European Agency for Safety and Health at Work

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Green jobs and occupational safety and health:

Foresight on new and emerging risks associated with new technologies by 2020

Report

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Safety and health at work is everyone's concern. It's good for you. It's good for business.

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Foresight on new and emerging risks associated with new technologies by 2020

Report

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Introduction

This report describes the project 'Foresight of new and emerging risks to occupational safety and health associated with new technologies in green jobs by 2020', carried out for the European Agency for Safety and Health at Work (EU-OSHA).

The outcome of the exercise is a set of scenarios covering a range of new technologies in green jobs and the impact they could have on workers' health and safety. They are intended to inform EU policymakers, Member States' governments, and trade unions and employers, so that they can take decisions to shape the future of occupational safety and health (OSH) in green jobs towards safer and healthier workplaces.

The project was conducted by a consortium of the UK Health and Safety Laboratory, SAMI Consulting and the Technopolis Group.

Project phases and structure of the report

This project was conducted over three phases and the methodology for each of these is described in Chapter 2.

- The first phase was to select the **key contextual drivers** for new and emerging OSH risks associated with new technologies in green jobs by 2020. These drivers were used to define the base scenarios. The descriptions of the drivers and the results of the selection process are provided in Chapter 3.
- The second phase selected **key technologies** that could create new and emerging OSH risks in green jobs. The data and results of this phase are in Chapter 4.
- The third phase of the project developed the **scenarios**. Three base scenarios were developed and then used through a series of technology workshops to explore the respective development of the key technologies and the new and emerging OSH risks to which they could lead in each of the three base scenarios. The information gathered informed the production of the full scenarios. The scenario development and the results of the technology workshops are described in Chapter 5. The scenarios were tested and consolidated in a further workshop, which also served to demonstrate how the scenarios can be used to develop policy options addressing the emerging OSH challenges identified. The results of this workshop are set out in Chapter 6.

The **three scenarios** are presented in Chapter 7 together with guidance on their use.

The **conclusions** drawn from the process and findings are set out in Chapter 8.

Contextual drivers of change

Sixteen key drivers were identified as having the greatest importance for the creation of the green economy in Europe up to about 2020:

- environment: carbon emissions, effects of climate change (temperature rise, natural disasters), shortage of natural resources (e.g. fossil fuels and water);
- government incentives: policies, grants, loans, and subsidies for green activities;
- government controls: taxes, carbon pricing, duties, and legislation;
- public opinion: the public's views on climate change and its causes;
- public behaviour: demand for green products, support for recycling;
- economic growth: the state of European economies and availability of resources to tackle environmental issues;
- international issues: effect of globalisation on the EU and other economies, and its effect on competition for scarce natural resources, driving the need for green activities;
- energy security issues: need for energy security, desire to reduce the dependency on energy imports;
- renewable energy technologies: progress in their development and availability;
- fossil fuel technologies: development of technologies to allow continued use of fossil fuels (carbon capture and storage and clean coal technologies);
- nuclear energy: the extent of its use, and whether it is regarded as 'green';
- electricity distribution, storage and use: development of technology to allow increased decentralised renewable electricity generation;
- energy efficiency improvements: energy-efficient new buildings, retrofitting of old ones, promotion of energy-efficient public transport, less energy-demanding manufacturing, etc.;
- growth in waste and recycling driven by resource shortages, public opinion and legislation;
- other technologies: availability of non-energy technologies, such as nanotechnologies and biotechnologies; and

- demographics and the workforce: a growing, ageing population and changing lifestyles may drive the need for more energy demand and/or more energy efficiency; the ageing workforce may result in skill loss, and in different OSH needs but also benefits; the ageing workforce, as well as the impact of climate change may lead to more migrant workers.

Key new technologies

Phase 2 of the project was to identify and describe the key new technologies that may be introduced in green jobs by 2020, which may lead to new and emerging risks in the workplace.

Descriptions of all the key technologies, including preliminary information, the potential for development and health and safety aspects are presented in Chapter 4. The development of these key technologies in each scenario and the exploration of their impact on OSH was considered as part of the Phase 3 technology workshops (Chapter 5).

Some of the technologies initially identified were related to specific industries (e.g. carbon capture and storage) while others were cross-cutting technologies that impacted on many sectors and many of the other technologies identified (e.g. nanotechnologies or robotics automation and artificial intelligence).

The key technologies finally selected for exploration in the scenarios in Phase 3 are shown in Table 1.

Table 1: **Key technology innovations for Phase 3**

Technology	Subtopics
Wind energy (industrial scale)	Onshore and offshore
Green construction technologies (buildings)	Energy efficiency measures: new build and retrofit (insulation, heat retaining windows, ventilation with heat recovery, energy-efficient lighting); renewable energy (solar thermal and cooling, geothermal heating and cooling, advanced monitoring systems, photovoltaic, wind energy, feed-in to grid, combined heat and power); new techniques (off-site construction/prefabrication); new materials (low-carbon cements, nanomaterials); increasing use of information and communications technology (ICT) and robotics and automation
Bioenergy and the energy applications of biotechnology	Biofuels (diesel, ethanol, etc.), biomass combustion, biomass-co-firing (see also clean coal technologies), anaerobic digestion (biogas production), landfill gas utilisation, biomass gasification, pyrolysis Biocatalysts, engineered cell factories, plant biofactories, novel process conditions/industrial-scale-up, biorefining and very-large-scale bioprocessing (VLSB), meso-scale manufacture, agricultural technologies, synthetic biology, genetic modification
Waste processing	Collection, sorting and processing of waste for recycling or for energy production; recycling of materials and components
Green transport	Electric, hybrid and biofuel road vehicles, battery technology, hydrogen and fuel cells, electrification of railways, biofuels in aircraft, novel materials in aircraft, improved efficiency of internal combustion engines (ICE), intelligent transport systems (ITS), refuelling/recharging infrastructure
Green manufacturing technologies and processes, including robotics and automation	Advanced manufacturing techniques, distributed manufacture (personal fabrication — 3D printing and rapid manufacture/rapid prototyping), lean methods, biotechnologies, green chemistry, nanomaterials Use in manufacturing, agriculture, construction and other industries
Electricity transmission, distribution and storage, and domestic and small-scale renewable energy	Smart grid, smart metering, distributed generation, combined heat and power, smart appliances Batteries, flywheels, supercapacitors, superconducting magnetic energy storage (SMES), hydrogen, pumped hydro, compressed air energy storage (CAES), liquid nitrogen and liquid oxygen energy storage Battery types: lead-acid, lithium-ion, sodium sulphur (zebra), sodium nickel chloride Decentralised energy generation technologies: wind, solar thermal and solar photovoltaic, bioenergy, geothermal energy, combined heat and power, fuel cells
Nanotechnologies and nanomaterials	A very wide range of potential applications, including improved batteries, engine additives, new composite materials, materials used in construction (e.g. pavements/bricks/asphalts that capture environmental pollutants, nanocoatings/nanopaints transforming solar energy into electricity, 'green' antifouling nanocoatings), agriculture and forestry

Construction of the scenarios

Each of the 16 drivers was reviewed and the uncertainty inherent within that driver over the period to 2025 was identified. A period beyond 2020 was chosen so that risks, the early signs of which might emerge in 2020, could be identified.

Twelve of the 16 drivers and associated outcomes were seen to fall naturally into three broad clusters around the following themes:

- economic growth: this includes both the external impact of global growth and growth in Europe and determines the availability of funding for green activities;
- green values: this relates to the willingness of people and organisations to change their behaviour to achieve green outcomes and the willingness of governments to implement regulatory and fiscal policies to promote green activities; and
- innovation in green technology — the development and exploitation of green technologies, which will deliver reduced resource use, less pollution and fewer environmental impacts.

These clusters define the scenario axes that form the framework for generating the base scenarios. The remaining four drivers (nuclear energy, demographics and the workforce, energy security issues and international issues) were later incorporated into the scenarios.

Each cluster of drivers (economic growth, green values, innovation in green technology) was associated with a single axis defining its state, which could be combined to define a base scenario (Figure 1).

Figure 1: **The three scenario axes**

Axis	Scenarios		
	Win-Win	Bonus World	Deep Green
Economic growth	High	High	Low
Green values	Strong	Weak	Strong
Rate of innovation in green technologies	High	Medium –	Medium +

The first two axes (economic growth and green values) were treated as independent axes. The third axis, the rate of innovation in green technologies, depends to some extent on the values chosen for the first two. This axis is linked to economic growth, which will influence the total level of innovation, and to green culture and energy efficiency, which will influence the green proportion of the innovation. It was considered that the level of green innovation was likely to be slightly lower in the Bonus World scenario than in the Deep Green scenario. These levels were therefore specified as 'Medium –' and 'Medium +' respectively. Although these two scenarios have similar rates of innovation in green technology, the nature of this technology would be quite different. In Bonus World, it is driven by a profit motive, while in Deep Green, it is implemented to achieve a green outcome.

This was used to generate a set of base scenarios for the Phase 3 technology workshops, in which the potential developments of the key technologies and the associated new and emerging OSH risks were explored. This information was then added to the base scenarios to generate the final scenarios. This process and the results are described in Chapter 5.

A final workshop was held in order to test and refine the scenarios by presenting them to a range of policymakers as well as OSH and technology experts, and by using them in exercises aimed at demonstrating the potential value of scenarios in policymaking and strategic planning.

Workshop participants were allotted to a single scenario for the duration of the workshop. After a short initial exercise to familiarise them with their scenario, they were asked to undertake the following tasks:

1. select the key OSH challenges and opportunities from Phase 2 in each scenario;
2. develop specific policy options for each scenario to address the respective challenges and opportunities selected, and how they would be implemented in the specific scenario considered;
3. review these policies across the three scenarios, and test their relevance and robustness (so-called wind-tunnelling) as well as how they would be implemented in all scenarios.

These activities are described in Chapter 6.

The scenarios produced

Scenarios are tools to generate discussion and insight into different elements of the future, rather than predictions. The scenario narratives produced are not evidence-based conclusions, but rather are based on assumptions and their possible consequences. Other scenarios are equally possible and there is no right or wrong choice, since the future may contain elements of each scenario. The full scenarios are presented in Chapter 7. Shorter versions of the scenarios looking back from 2025 (the year 2025 was chosen in order to stretch thinking so that changes after 2020, the early signs of which might be evident by 2020, would be included) are now described.

Win-Win

High economic growth

Looking back from 2025, after a slow start in 2012, growth across the EU and OECD returned to the levels prior to the economic crash of 2008. Developing countries also experienced high growth similar to that in the first decade of the century.

High green values

Advances in climate science started to show how vulnerable we are becoming to climate change. Growing public concerns encouraged governments to introduce green policies, including those leading to deep and progressive cuts in carbon emissions.

There was strong approval for green behaviour by corporations and individuals. This was reinforced by concerns over resource shortages (food, commodities, minerals, water and energy.)

High level of innovation in green technologies

Green growth has increasingly been seen as vital for a sustainable future. Corporate profits and access to finance have supported high levels of investment in new business opportunities and infrastructure. The rate of technological developments has accelerated with high levels of innovation. A high proportion of the innovation has been aimed at achieving a green outcome and generating future profits.

Society and work

Most people in the EU now feel prosperous and place a higher value on the preservation of the environment, human life and well-being. The strong economy allows governments to address the increasing demands for welfare and to invest in education.

There is high employment and many new jobs and new products are now being created over ever-shorter timescales, which can lead to new hazards and risks if not designed with OSH taken into consideration.

Occupational safety and health

Overview

In a buoyant economy, funds are available for investment in safety, but the high pace of innovation and the rapid roll-out of new technologies and new products, and the creation of new jobs requiring new skills mean that a wider population faces new risks over shorter timescales. It is, therefore, important that OSH assessments are undertaken early in the development cycle of a technology or product so that the pace of development doesn't leave OSH behind.

Wind energy

The risks are multiplied manyfold in offshore wind farms, which have the potential to become very dangerous worksites. With so many large turbines in ever-deeper water, ever further from safe haven, access issues are the dominant OSH consideration. Working sites are more widely dispersed, with lower profit margins to pay for safety than in the oil and gas industries. Construction is hazardous and with the large numbers of turbines come skill shortages as wind competes with other technologies for qualified staff. Specialist vessels are required to handle large turbines in deep water, and there are still issues over foundation strategies (especially as the seabed is different for each turbine in a wind farm), transport of foundations from yards, and longer-term issues over removal of foundations. Novel turbine designs have brought engineering unknowns. In the hostile environment, maintenance is demanding, although more reliable electronic infrastructure monitoring devices help to minimise unpredicted maintenance and improved quality of equipment has helped reliability. The need for workers to live so far offshore is leading to work organisation issues and psychosocial problems. New composites and nanomaterials used for the manufacture of wind turbines have possibly introduced new health hazards for workers involved in manufacturing, maintenance, decommissioning and recycling.

Green construction and building retrofitting

Off-site automated construction of modular buildings has improved on-site safety as far fewer tasks are undertaken on site. However, as building moves into factories, new risks emerge as workers are exposed to novel substances increasingly used in construction material (e.g. phase change materials, heat storage chemicals, novel surface coatings, nanomaterials and fibrous composites).

On-site issues arise from mixing automated with traditional, manual activities. There are risks during the connection of services (e.g. water and electricity) to prefabricated modules but, with the correct design, these should be negligible. There are also electrical risks as old and new buildings have to be integrated into the smart grid, incorporating smart appliances, energy storage technologies, etc. In increasingly crowded cities, the trend of developing basements has led to increasing underground congestion with associated OSH implications due to working in confined spaces, the risk of collapsing structures or drilling into existing cabling.

Combinations of new energy sources in buildings (e.g. photovoltaics (PV), geothermal and biomass) bring new hazards and unexpected accidents — in particular as there are many new players entering the sector.

With a high level of new build, there is a large quantity of old building materials from demolition to deal with, exposing workers to hazards. Retrofitting of existing buildings exposes workers to increasing roof work as they install solar panels and small-scale wind turbines, with the risk of falls and exposure to lead and asbestos as they disturb old structures.

Bioenergy

The storage and handling of biomass expose workers to physical, chemical and biological risks and to risks from fire and explosion. High temperatures, and sometimes high pressures, are used in pyrolysis (350–550 °C) and gasification (over 700 °C). There is also a potential issue with the increased variability in the constitution of gas derived from biomass compared to fossil fuels. Third-generation biofuels have the potential to give rise to new biological risks. There may also be operational risks associated with the scaling-up of third-generation biofuel production from demonstration plant to commercial scale.

With the widespread adoption of bioenergy, many workers are potentially at risk. Agriculture increasingly turns to biomass production and work in forestry is likely to intensify. Waste products from biomass can be toxic (e.g. wood ash contains heavy metals and is strongly alkaline).

Waste management and recycling

The political pressure to recycle means that workers are potentially exposed to a very large range of materials: increasing volumes of waste result in difficulties in identifying the provenance and composition of waste. However, improvements in labelling, tracking and auditing of materials are helping in the identification process.

Workers have to deal with hazardous waste, not just valuable waste, including material from urban mining and recycling of industrial waste. Nanomaterials are also increasingly appearing in waste as their use in manufacturing becomes more widespread. However, the increasing use of robots to sort and handle waste helps improve workers' health and safety.

The zero-waste economy entails dealing with the most difficult tail end of the waste stream: such wastes in concentrated form are hazards that need special handling.

Green transport

Maintenance of complex networks coupled with skills shortages presents an important OSH challenge. Most new vehicles are electric or hybrid. Rapid recharging or battery swaps may present hazards, as will the maintenance of electrified vehicles (EV). As electric vehicles are increasingly maintained by independent garages rather than specialists, there are electrocution risks since workers are not familiar with the high voltages involved. Risks of fire or explosion are particularly high during quick charging of EV and after accidents. Driverless vehicles and platooning (the grouping of vehicles that behave effectively as one) have improved safety for those who travel as part of their work. However, there is a risk of over-reliance on the technology. Absolute reliability is therefore crucial, with fail-safe modes in the event of accidents, problems or failures.

Green manufacturing, robotics and automation

Increased automation has improved OSH, in some respects, by removing workers from some hazardous tasks but, at the same time, the growth in the use of collaborative uncaged robots has introduced other potential risks.

Growing complexity and increasing ICT in automated manufacturing has brought human-machine interface issues. Some types of robot malfunction may be difficult to detect until it is too late and may, therefore, put workers' safety at risk. Growth in 'just-in-time' and 'lean' approaches facilitated by flexible manufacturing systems have put additional pressure on workers, leading to psychological risks. Workers are resorting to enhancement technologies in order to keep pace with developments and with their colleagues as well as with robots. There are potential unknown long-term health effects of new green materials and nanocomposites with a lower carbon footprint.

Domestic and small-scale renewable energy

The speed and diversity of change has resulted in skill shortages and, therefore, competency issues for work in renewable energy technologies. There are many new energy technologies where specific knowledge is needed but has not yet been fully developed, and where 'old' OSH knowledge and safe working practices are not always directly transferable. New entrants to the industry are not always sufficiently familiar with the risks and new combinations thereof. Small and medium-sized enterprises (SMEs) are increasingly using their land to produce electricity as a sideline and may use their own workers, or subcontractors, to install or maintain their renewable energy systems ad hoc, although such workers are not skilled in this type of work. The increasing adoption of solar PV has introduced risks for emergency workers accessing roof spaces that remain live even after the mains supply has been cut.

Batteries and energy storage

Hydrogen has grown in popularity as an energy carrier, including its use as a fuel for vehicles, bringing transport and storage issues. Batteries are the main means of electricity storage, with potential risks of fire and explosion, exposure to hazardous chemicals and electrocution from high voltages. Based on their experience from lead-acid batteries, people generally have a false perception that new batteries are safe. As for large offshore installations, specific OSH regulation is in place for deep-sea energy storage, which, although a relatively low-tech concept, involves high voltages and power levels in a complex environment ,complicating installation and maintenance work.

Energy transmission and distribution

The complexity of the SuperSmart Grid (SSG) makes it difficult to maintain top-down control of the grid and, consequently, of related OSH issues. The key OSH risk arises from increased live working to cope with the rapid pace of change. The dangers from electric shock, burns, fire and explosion are well known, but now involve different people in different situations. The increase in electricity storage is an added dimension. The pressure of work can lead to the use of inexperienced staff.

Bonus World

High economic growth

Looking back from 2025, after a slow start in 2012, growth across the EU and OECD returned to the levels prior to the economic crash of 2008. Developing countries also experienced high growth similar to that of the first decade of the century. High growth has led to high prices for natural resources, including energy.

Weak green values

After 2012, economic growth was the priority and some environmental degradation was considered to be an unavoidable consequence of strengthening EU economies. When faced with the costs, people have not valued greenness sufficiently for governments or business to have an incentive to deliver it. Government support for green practices is limited to charging for the visible externalities of production (noise, pollution, landfill, traffic congestion, etc.).

Medium levels of innovation in green technologies (directed towards profits)

Most consumers and businesses choose green products and services only if they are better or cheaper than the alternatives. Innovations in green technologies are limited to those areas that show a positive financial return.

High total levels of innovation

There are continuing advances in technology that are adopted into new products and processes. High levels of capital investment mean that capital-intensive technologies can be rolled out quickly. Corporate profitability and access to finance have supported high levels of investment in infrastructure. The environmental consequences of increased use of resources are seen as acceptable and necessary.

Energy sciences continue to deliver improvements in efficiency and low-carbon energy, but it is now clear that serious and unacceptable compromises would be needed to achieve a zero-carbon future.

Society and work

Most people in the EU now feel more prosperous than in 2012. They value economic well-being more than the environment, but are prepared to pay for a pleasant environment in the vicinity where they live.

Businesses are focused on generating current and future profits. New jobs are being introduced at a relatively fast rate and there are high levels of employment. There is also high mobility of workers, while inequalities mean that low-skilled workers are readily exploited.

Higher income levels and corporate profits have provided the tax revenues that allow European governments to pay for sustainable welfare programmes.

Human performance-enhancing drugs are being routinely used in work settings.

Occupational safety and health

Overview

In a healthy economy, funds are available to invest in OSH and make infrastructure and business processes safe, but OSH is of relatively low importance to most governments. Employers see OSH as important in terms of its impact on profits.

New jobs and new products may bring new hazards and the rapid roll-out of new technologies means that a wide population is exposed to these with short timescales for determining their possible health and safety impacts.

OSH by regulation is more effective than OSH by education.

As in Win-Win, there are skills shortages associated with the high pace of innovation. This leads to a polarisation of the workforce with regard to skills, with less-skilled workers more readily found in jobs with poorer, more hazardous working conditions.

Wind energy

With smaller turbines, predominantly located onshore, construction and maintenance are not as hazardous as in the other two scenarios; however, the proximity to population centres brings potential risks to a larger population, including workers. Much of the maintenance work is contracted out, so it is more difficult to keep an eye on work organisation and there is a risk of passing of blame and no due diligence by the ultimate owner. Cost pressures may lead to increased risk-taking. Many of the workers are migrants with low skill levels and a poor OSH culture. The decommissioning of old wind farms that were not designed to enable safe dismantling puts workers at high risk. New composites and nanomaterials used in the manufacture of wind turbines have possibly introduced new health hazards for workers in manufacturing, maintenance, decommissioning and recycling. On the plus side, the use of standardised designs has reduced complexity and made maintenance more straightforward.

Green construction and building retrofitting

Off-site automated construction of modular buildings has improved on-site safety as far fewer tasks are undertaken on site. There are risks during the connection of services (e.g. water and electricity) to prefabricated modules but, with correct designs, these should be negligible. However, as building moves into factories, new risks emerge as workers are exposed to novel substances.

On site, there are electrical risks as old and new buildings have to be integrated into the smart grid, incorporating smart appliances, energy storage technologies, etc. In increasingly crowded cities, the trend of developing basements has led to increasing underground congestion.

With a high level of new build, there is a large quantity of building materials from demolition to deal with. Compared with Win-Win, newer buildings are being demolished – exposing workers to new hazards from modern materials. Demolition waste is sent to landfill rather than recycling. Retrofitting of existing buildings exposes workers to increasing roof work as they install solar panels after they became economically viable, with the risk of falls and exposure to lead and asbestos as they disturb old structures. The lack of adequate ventilation when retrofitting insulation has become an issue, as this type of work may attract construction workers who are used to outdoor work and, hence, not aware of the need for proper indoor ventilation.

Bioenergy

As with Win-Win, storage and handling of biomass exposes workers to physical risks, to chemical and biological risks, and risks from fire and explosion: these may be mitigated by automation. Even where biomass is handled automatically, the boilers it fuels are a source of smoke and dust. With small subcontractors working under price pressures, work has intensified with a resulting increase in risks. Third-generation biofuels produced from organisms created by synthetic biology are a potential source of biological risks.

Waste management and recycling

With a high level of innovation, but a lack of attention to recyclability, the waste-handling process can be dangerous. There is some use of automation for handling waste, but only where it is cheaper, rather than for OSH considerations. The rapid rate of innovation means that new materials appear and find their way into waste before OSH can be considered. This is a throwaway society, so a high number of workers are involved in handling waste and are, therefore, potentially exposed. In an increasingly complex world driven by profit, combined exposure can be an issue. High charges for waste disposal may lead to more in-house efforts by the waste producer to deal with waste, transferring risks from professional waste operators to the waste producer: for example, business owners (including microenterprises and SMEs, as well as private individuals) using small-scale digesters, waste compactors or incinerators.

Green transport

As with Win-Win, maintenance and recharging of electric vehicles have become important hazards as they have become increasingly widespread and work has moved away from specialist suppliers and maintainers to independents. The risks arising from the growth in electric vehicles is not confined to the vehicle itself. Vehicle batteries that have reached the end of their life for vehicle service are being used to store electricity in buildings. As well as the normal fire and explosion risks associated with batteries, there is, therefore, the added complication of batteries used for energy storage that are degraded, decaying, unlabelled and of unknown provenance and design. Automation of vehicles is proving to be positive for the OSH of drivers, although there is an issue of over-reliance on the technology. The technology needs to be absolutely reliable with fail-safe modes in case of incidents.

Green manufacturing, robotics and automation

As in Win-Win, increased automation has improved OSH by removing workers from some hazardous tasks. At the same time, the growth in the use of collaborative robots has introduced other potential risks. Increasing complexity and increasing use of ICT in automated manufacturing has brought human-machine interface issues. Safety (as opposed to health) is increasingly engineered into processes, driven by the desire to avoid lost production, while employers are less interested in longer-term health issues. Decentralised manufacturing systems such as 3D printing or other rapid manufacturing techniques can lead to new groups of workers being exposed to manufacturing hazards (e.g. harmful dusts, chemicals or laser light) yet not being adequately trained to deal with them. There may be new occupational diseases caused by exposure to new materials. Without exposure registers, diseases are difficult to trace back to jobs as no one stays on the same production line for their entire career any more.

Domestic and small-scale renewable energy

In the period before solar PV reached grid parity, the sudden withdrawal of subsidies led to panic in the rush to meet deadlines, resulting in work done in a hurry thus introducing OSH risks including work-related psychosocial risks. The use of cheaper imported products, sometimes of poorer quality or even counterfeit, has led to increased risks, especially when installation is carried out by new entrants to the sector or by householders themselves.

Batteries and energy storage

Novel battery designs continue to appear, bringing potential risks from chemicals, carcinogenic metals, dusts, fibres, nanomaterials and fire. The waste treatment of batteries raises issues around recycling, degradation and fire risk. It is challenging to determine the precise contents of any particular battery type as this information is often treated as a trade secret. Batteries used as building energy stores are a hazard as people don't recognise the risks of overcharging. Hydrogen is used as an energy carrier but it is difficult to handle and there are risks of fire and explosion and risks from its cryogenic liquid form.

Energy transmission and distribution

There are risks from power cuts as cost pressures have led to a reduction in spare generating capacity. The risks arise from sudden darkness and the loss of power, especially with moving machinery, and other safety-critical situations. The pressure to squeeze more capacity out of the system leads to novel solutions, but this reduces safety margins. Substitution of copper cabling with aluminium, again driven by cost as copper becomes increasingly expensive, has introduced an increased risk of sparking and joint failure.

Deep Green

Low economic growth

Since 2012, there has been little economic growth within the EU and some countries are still facing sovereign debt problems. The BRICs have not returned to the former high growth rates and are currently growing at about 5 % per annum. Other developing countries are growing at a rate broadly in line with the growth of their populations.

Strongly green values

Green values have strengthened over the last decade and there is widespread and strong approval for green behaviour by corporations and individuals. This has given governments a mandate to legislate for deep and progressive cuts in carbon emissions. Reduced growth is seen as a price worth paying for a green future.

Advances in climate science have shown just how vulnerable the human race will be to climate change. There are growing public concerns about the loss of ecosystems and resource shortages.

Medium innovation in green technologies (directed toward greenness)

The concerns about a green future have driven progress on improvements in efficiency and the target of a zero-carbon future. There are continuing advances in technology, but restricted levels of capital investment mean that capital-intensive technologies have been slow to be rolled out. Commercial success depends on having appropriately green products and services.

There have been significant local small-scale innovations to address green issues, many directed toward self-reliance.

Energy sciences continue to deliver improvements in efficiency and low-carbon energy, but it is clear that serious compromises will need to be made to achieve a zero-carbon future.

Medium total innovation

The priority has been to direct innovation towards achieving a green future.

Society and work

Over the last decade, the key priority has been to move towards a green future, at the expense of growth and other social objectives. As a result, there is now higher unemployment and lower corporate profits. The reduced tax base has restricted the ability of EU governments to pay for increasing welfare demands.

The greening of the economy and society has introduced many new processes and enterprises, creating new green jobs. Businesses are focused on survival and reducing costs, and workers are concerned about joining the significant number of the unemployed.

Innovation continues to deliver improvements in efficiency and reduced carbon outputs but it is clear that serious compromises need to be made to achieve a zero-carbon future. Despite the difficulties, a green future is generally seen as worth the sacrifices.

Occupational safety and health

Overview

Low economic growth has tempted employers to cut corners, making investment in safer and healthier infrastructure more difficult. A tendency towards decentralised, more local and smaller enterprises (in particular microenterprises and self-employment) makes it more difficult to reach workplaces to disseminate good OSH practices and to control OSH conditions. With emphasis on reduced consumption of energy and physical goods, most new jobs are in the service sector. Many new small businesses, often with skills deficits, are set up to meet these needs. A make-do-and-mend approach leads to refurbishment rather than replacement, so there are risks associated with the use of old equipment. In this scenario, there are more difficult 'dirty' manual jobs (in repair, maintenance, waste sorting, etc.) than in the other scenarios with more innovation and automation. But the relatively slow roll-out of some new technologies and products gives more time to assimilate new hazards and risks. There are many new green processes and enterprises, all of which require new OSH procedures and training.

Wind energy

End-of-life issues and maintenance are the key OSH considerations. The economy requires the upkeep of older installations and there is pressure to keep systems running whatever the weather. Older wind turbines have not been upgraded with safety or ergonomic features, such as lifts, because of cost pressures: as a result, the physical risks associated with climbing and working in towers has become significant, especially as increasing numbers of older workers are unable to retire.

Green construction and building retrofitting

With relatively little new build, the main risks to workers come from exposure to new materials during refurbishment and the handling of waste from refurbishment (including asbestos), and from the retrofitting of renewable energy technologies, involving work at height and electrical connections to the grid. Retrofitting also exposes workers to dust and hazardous chemicals. The lack of adequate ventilation may be an issue, in particular as this type of work may attract unskilled workers, including 'do-it-yourself' installers, unaware of the risks.

Bioenergy

The risks from fire and explosion and exposure to chemicals and biohazards are similar to those in the other scenarios, but the emphasis on local production and use — with many small-scale producers — creates risks that are more difficult to regulate. New players, less familiar with the risks of handling fuel (e.g. farmers producing low quantities, or companies starting to use their own waste as an energy source, for example in the textile or food industry) may be particularly at risk. There may also be problems with the quality of their products and, therefore, safety issues, as well as the impact on gas network pipelines from biogas or syngas not meeting the required gas specification.

Waste management and recycling

Overall, waste volumes are down as a result of strong green values and the economic situation, but there is still legacy waste to deal with and construction waste volumes from refurbishment are high. There is an emphasis on local handling of waste at the small-scale — meaning a potentially weaker culture of OSH and more difficulties in controlling OSH risks in a decentralised system — and there is a high manual component, with a relatively low level of automation. The quality of the waste stream has improved, but landfill mining is increasing as the costs of raw materials climb, so workers risk being exposed to safety hazards as well as unknown health hazards. Greater use of biomass in this scenario brings exposure to dust, allergens and other toxins. Reused items may compromise safety and health (e.g. steel made from recycled metals containing lead).

Green transport

As in Win-Win and Bonus World, the maintenance and charging of electric vehicles are key OSH concerns. However, driven by the need to economise and by strong green values, there has been an increase in two-wheeled vehicles for personal transport and goods as well as for service deliveries, exposing those who travel for their work to risk of injury and accidents. Many 'mobility self-entrepreneurs' have seen a job opportunity in this growing area of the transport sector. However, the self-employed tend to have less of a culture of OSH and less access to OSH services such as OSH medical surveillance, labour inspectorate services; in addition, they are generally not covered by worker protection legislation.

Green manufacturing, robotics and automation

There has been less adoption of automation than in the other scenarios, so old OSH issues may persist as manufacturers make do with ageing infrastructure and machinery. The increasing tendency to outsource maintenance services to small companies has increased risks to maintenance workers who have to deal with a wide range of equipment to extend its life. The intermittent nature of renewable energy (reliant as it is on wind and sunlight, for example) means that shift working has increased, resulting in increased health and psychosocial issues and other risks such as accidents. Exposure to new materials in SMEs and microenterprises involved in decentralised manufacture (e.g. 3D printing) has brought potential exposure risks to more workers. Process integration means that industrial processes previously performed in different locations (e.g. manufacturing and recycling) are brought together, increasing the range of risks on a single site. This requires new skills and technical knowledge. However, there is a lack of skills as manufacturing is brought back into the EU as a result of global changes, and the loss of corporate memory and experience is exposing new workers to risks.

Domestic and small-scale renewable energy

A diversity of distribution systems and non-standard installations is resulting in electrical risks to maintenance workers. The combination of technologies (e.g. combined heat and power (CHP) and solar thermal) is adding to the complexity and, therefore, the risk. Similarly, unsophisticated, perhaps do-it-yourself, domestic installations are also potentially hazardous. Small-scale bioenergy generation gives rise to risks of fire and explosion and exposure to toxic substances. Distributed supply, especially from small clusters of houses or small businesses, is difficult to regulate. The emergency services are at risk when they attend non-standard installations. Emerging technologies generally may be responsible for long-latency effects, yet to emerge.

Batteries and energy storage

Batteries give rise to electrical risks and risks from toxic chemicals and fire. Greener batteries may be more hazardous as environmental regulations limit the range of materials allowed. Interconnected mixtures of energy storage technologies devices, especially those assembled by do-it-yourself enthusiasts, bring unexpected risks in themselves, to maintenance workers and to the emergency services. Hydrogen is used for energy storage, introducing risks of fire and explosion and risks from its cryogenic liquid form.

Energy transmission and distribution

OSH issues include the difficulty in maintaining top-down control of the grid as distributed generating sources increase. Major work to upgrade the grid has been undertaken, introducing increased live working. Life-extended systems bring more risks than new systems. Biogas distribution has brought risks of intoxication, suffocation, explosion and quality issues.

Conclusions

The scenarios produced are descriptions of possible future 'worlds' for green jobs. It is important to recognise that they are not projections or forecasts, but a tool for exploring the future and the critical uncertainties — those factors that will be most important in shaping the future but whose direction of development is uncertain. The value comes not only from the scenarios themselves but also from the insights and discussions that they generate.

During this work, it became apparent that many of the current assumptions about future green jobs are based on an optimistic outcome, a Win-Win scenario. But the possibility that these targets are not met should be taken into account: for example by looking at the alternative scenarios produced in this project (and others). The scenarios produced could equally be applied to a broad range of other technologies and other aspects associated with green jobs, so long as the underlying assumptions remain valid. They should be used with care when considering OSH for jobs beyond the scope of this project; they may have to be extrapolated to do this, although much of the data on drivers and technologies could be applied to a broader range of jobs.

It also became clear that 'green jobs' encompass a broad range of workplaces in different sectors, with different working conditions, working processes and workers' groups involved. The scenarios also revealed the impact of the socio-economic context and the strategies and policies adopted on technology developments and working conditions, and how this may give rise to a variety of OSH issues. Therefore, when devising a prevention strategy for green jobs, the specificities of the different types of green jobs and the diversity of the workforce have to be taken into account. Still, as diverse as green jobs may be, a number of common challenges were highlighted:

- decentralised work processes: as workplaces are getting more dispersed and more difficult to reach, monitoring and enforcement of good OSH conditions and safe working practices is likely to become more challenging;

- a growing use of subcontracted work, as well as an increase in self-employment, micro and small enterprises: such structures may have less awareness of OSH and a less-developed culture of OSH, as well as fewer resources available for OSH and less access to OSH services;

- new skills and the need for adequate worker training: there are many new green technologies and working processes where specific knowledge is needed but has not yet been fully developed; there are also (new combinations of) 'old' risks but found in new situations equally requiring new (combinations of) specific skills; the job opportunities in green jobs may attract new entrants extending beyond their original skills areas and unaware of these new challenges;

- skill shortages and polarisation of the workforce, with low-skilled workers pushed to accept poorer working conditions and more difficult jobs;

- increased automation, which may improve OSH but also bring human-machine interface issues as well as issues of over-reliance on the technology;

- conflicts between green objectives and OSH, with the risk of OSH being overlooked; and

- novel, difficult-to-characterise and potentially hazardous materials that will need to be closely monitored over their entire life cycle for potential (unknown, long-latency) health hazards: this will be increasingly challenging as no one stays in the same job for life, making it difficult to link health effects to occupational exposure.

With regard to prevention, at the workplace level, risk assessment remains the key to devising adequate prevention measures that take into account the specificity of the green job considered and the workers involved. At the development stage of any new technology, product or process, well upstream of their introduction into workplaces, a systematic, prior assessment of OSH over the entire life cycle is needed. Thus, integrating prevention into design is more efficient than retrofitting OSH and needs to start now to ensure safe green jobs in the future. This requires the cooperation of various actors at the level of policy, research and development (R & D) and the workplace across several disciplines, including OSH, environmental protection and from the different sectors in which green jobs are developing. Technology developers, designers and architects should also be included in the process. The scenarios have proven to be a powerful tool to support such cooperation. This, together with the new insights on new and emerging OSH risks generated in the scenarios, allows more robust strategies and policies to be developed. This is key to the creation of green jobs offering decent, safe and healthy working conditions and, thus, assisting the development of a smart, sustainable and inclusive growth of the green economy in line with the EU 2020 strategy (European Commission, 2010).

1. Introduction

1.1. Context

This report describes a project undertaken for the European Agency for Safety and Health at Work (EU-OSHA) to develop scenarios of the future in order to anticipate new and emerging risks to occupational safety and health associated with a range of new technologies in green jobs. This foresight will be used by EU-OSHA to inform EU policymakers, Member States' governments, trade unions and employers, so that they can make better decisions in order to shape the future of occupational safety and health (OSH) in green jobs leading to safer and healthier workplaces.

Working environments are continuously changing with the introduction of new technologies, substances and work processes, changes in the structure of the workforce and the labour market, and new forms of employment and work organisation. New work situations bring new risks and challenges for workers and employers, which, in turn, demand political, administrative, technical and regulatory approaches to ensure high levels of safety and health at work.

In OSH policy and practice, attention has too often focused on reacting to existing risks and problems. Over the last 50 years, many OSH hazards have evolved relatively slowly. The combination of the accelerating pace of technology change and potential moves towards a green economy mean that it will be increasingly important to anticipate new and emerging risks. The need for forward-looking efforts to identify future risks was underlined in the Community strategy 2002–06, Commission of the European Communities, 2002, which called on EU-OSHA to 'set up a risk observatory' and to 'anticipate new and emerging risks' in order to tackle the continuously changing world of work and the associated new risks. The second Community strategy 2007–12 (Commission of the European Communities, 2007) has further identified a series of problems, which arise from the current changes in society and workplaces and, in particular, from the fact that 'the nature of occupational hazards is changing in tandem with the acceleration of innovation'. This strategy emphasises 'risks associated with new technologies' as an area where risk anticipation should be enhanced.

At the same time, the European Union is committed to a 20 % reduction in greenhouse gas emissions compared to 1990 levels (or by 30 %, 'if the conditions are right') ([1]), a 20 % increase in energy efficiency, and to increasing the market share of renewable energy by 20 % by 2020 (European Commission, 2010). In its meeting in March 2009, the Environment Council emphasised 'that the economic crisis and the policy measures in response to it provide an opportunity to achieve necessary economic reforms and, at the same time, to speed up reforms towards a safe and sustainable low-carbon and resource-efficient economy' and 'reaffirmed the importance of environmental technologies as one of the fastest growing markets and a means to both reduce pressure on the environment and improve energy and resource efficiency, as well as to strengthen competitiveness and support job creation' (Council of the European Union, 2009).

Green jobs were therefore selected as the priority area for this scenario development project because of their importance for *Europe 2020 — A strategy for smart, sustainable and inclusive growth* (European Commission, 2010). Indeed, meeting the EU's objective of a 20 % increase in renewable energy alone has the potential to create more than 600 000 jobs in the EU. Adding the 20 % target on energy efficiency, it is well over one million new jobs that are at stake. If green jobs are not decent, safe and healthy jobs, many workers will be affected in the future. The impetus to 'green' the economy, associated with a strong emphasis on innovation in this area, provides an opportunity to anticipate potential new risks in these developing green jobs and make sure their design integrates workers' safety and health.

The decision to use a scenario-building approach project arose out of the workshop 'Shaping the future of OSH — A workshop on foresight methodologies' hosted by EU-OSHA's European Risk Observatory (ERO) in October 2008 ([2]). The ERO wished to build on earlier forecast exercises, comprising Delphi studies in four different risk areas ([3]), which had produced useful summaries and prioritisation of key risks as assessed by experts. However, it was felt that in order to consider likely occupational health and safety risks further into the future, an alternative technique should be used. The scenario-building approach was selected as a suitable vehicle to provide a forward look.

1.2. New and emerging risks

EU-OSHA defines an 'emerging OSH risk' as any occupational risk that is both 'new' and 'increasing'.

'New' means that:

- the risk did not previously exist and is caused by new processes, new technologies, new types of workplace, or social or organisational change;
- a long-standing issue is newly considered as a risk due to a change in social or public perceptions; or
- new scientific knowledge allows a long-standing issue to be identified as a risk.

(1) 'Provided that other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities' (European Commission, 2010).

(2) More information is available online (http://osha.europa.eu/en/seminars/shaping-the-future-of-osh-a-workshop-on-foresight-methodologies).

(3) EU-OSHA's expert forecasts were carried out in the following four areas: Emerging physical risks to OSH (EU-OSHA, 2005); Emerging biological risks (EU-OSHA, 2007a); Emerging psychosocial risks (EU-OSHA, 2007b); and Emerging chemical risks (EU-OSHA, 2009).

The risk is 'increasing' if the following conditions are met:

- the number of hazards leading to the risk is growing;
- the likelihood of exposure to the hazard leading to the risk is increasing (the level of exposure is rising and/or the number of people exposed is increasing); or
- the effect of the hazard on workers' health is getting worse (the health effects are getting more serious and/or the number of people affected is rising).

1.3. Green jobs

There are many definitions of 'green jobs'. Green jobs used to be considered as those involved with protecting biodiversity and the natural environment, but they now include areas such as low-carbon jobs, energy efficiency, and carbon finance. They can also go beyond 'direct' green employment into the supply chain, even though they may not supply green industries. Nuclear energy might be green to some, in the context of its low-carbon credentials, but not to others (Bird and Lawton, 2009). Some commentators distinguish 'green jobs', which contribute to improving or preserving the environment, from 'green-collar jobs', which are green jobs that are also 'decent' jobs in that they are good for the worker as well as the environment. Others talk about 'greening the workplace'. The US Blue Green Alliance describes a green job as 'a blue-collar job with a green purpose' (Blue Green Alliance, 2009). Although this is the view of a particular group, when we come to consider our remit of new and emerging risks in green jobs, the blue-collar label might not be too far adrift.

Pollin et al. (2008), break green jobs into three categories:

- direct jobs: first round of job changes resulting from changing outputs in target industries;
- indirect jobs: subsequent job changes resulting from changing inputs required to accommodate the above; and
- income-induced jobs: additional jobs created by changes in household incomes and expenditures resulting from both above.

Pollin et al. present a list of typical jobs that might be associated with various green activity areas (Table 2: Green recovery in the US) (Pollin et al., 2008).

Different definitions or interpretations of these terms will suit the purposes of those using them. Politicians, for example, will be eager to take a broad approach to the definition in order to boost the numbers of those apparently in green jobs. In the OSH arena, we need to be more critical in our definition, focusing on potential risk and prevention rather than inflating numbers.

An often-quoted definition of green jobs is that used by the United Nations Environment Programme (UNEP, 2008):

'We define green jobs as work in agricultural, manufacturing, research and development (R & D), administrative, and service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency strategies; decarbonise the economy; and minimise or altogether avoid generation of all forms of waste and pollution'.

The European Commission (European Commission, 2012) 'understands "green jobs" as covering all jobs that depend on the environment or are created, substituted or redefined (in terms of skills sets, work methods, profiles greened, etc.) in the transition process towards a greener economy' and adds that 'this broad definition is complementary and not opposed to the one by UNEP' (quoted above).

For the purpose of collecting employment data, Eurostat defined the Environmental Goods and Services Sector (EGSS) (Eurostat, 2009) which is more limited than the previous definition. The sector consists of a 'heterogeneous set of producers of technologies, goods and services' that do the following:

- measure, control, restore, prevent, treat, minimise, research and sensitise environmental damages to air, water and soil as well as problems related to waste, noise, biodiversity and landscapes: this includes 'cleaner' technologies, goods and services that prevent or minimise pollution; and
- measure, control, restore, prevent, minimise, research and sensitise resource depletion: this results mainly in resource-efficient technologies, goods and services that minimise the use of natural resources.

Eurostat also stipulates that these technologies and products (i.e. goods and services) must satisfy the end-purpose criterion: they must have an environmental protection or resource management purpose as their prime objective.

These definitions usefully describe the areas of work potentially covered by the green label but, in terms of jobs, including as they do administrative jobs, they give huge scope to green jobs. At the kick-off meeting for this project, EU-OSHA's European Risk Observatory (ERO) clarified its requirements and interpretation of the above definitions in the context of this project. It advised that the aim was to investigate *new types* of risk related to *new* technologies within green jobs. So the primary interest was in those *working with* or *directly* affected by the new technologies, rather than those merely associated indirectly with the new technologies. 'White-collar' jobs in a green industry were not of interest. *New combinations* of risk were of interest: for example in the installation of solar panels, where electrical risks combine with the risk of working at height. Jobs in green industries where the risks are the same as other jobs, for example the transport of green goods, were not of interest. *Novelty* was of more interest than the increase or decrease in known risks. Focusing attention in this way made the task more manageable and, potentially, more useful.

Table 2: **Green recovery in the US**

Strategies for green economic investment	Representative jobs
Building retrofitting	Electricians, heating/air conditioning installers, carpenters, construction equipment operators, roofers, insulation workers, carpenters' assistants, industrial truck drivers, construction managers, building inspectors
Mass transit/freight rail	Civil engineers, railway track layers, electricians, welders, metal fabricators, engine assemblers, bus drivers, dispatchers, locomotive engineers, railroad conductors
Smart grid	Computer software engineers, electrical engineers, electrical equipment assemblers, electrical equipment technicians, machinists, team assemblers, construction labourers, operating engineers, electrical power line installers and repairers
Wind power	Environmental engineers, iron and steel workers, millwrights, sheet metal workers, machinists, electrical equipment assemblers, construction equipment operators, installation assistants, labourers, construction managers
Solar power	Electrical engineers, electricians, industrial machinery mechanics, welders, metal fabricators, electrical equipment assemblers, construction equipment operators, installation assistants, labourers, construction managers
Advanced biofuels	Chemical engineers, chemists, chemical equipment operators, chemical technicians, mixing and blending machine operators, agricultural workers, industrial truck drivers, farm product purchasers, agricultural and forestry supervisors, agricultural inspectors

Source: Pollin et al., 2008.

1.4. Introduction to scenarios

Michael Porter defined scenarios used in strategy as 'an internally consistent view of what the future might turn out to be — not a forecast, but one possible future outcome' (Porter, 1985). Scenarios are descriptions of how 'the world' or issues being considered might look in the future: they are not predictions or forecasts. They are based on an analysis of drivers of future change. The most important uncertainties about the future should have different outcomes in each scenario.

A good scenario is engaging and compelling, has an internal logic and consistency and describes a credible path to the future. The contents of the scenarios are not to be taken as conclusions, or statements that the future would, indeed, be as described in the scenarios, but merely as descriptions of how it *could* be. There are many more possibilities, and the future will most probably contain a part of some or of all of these. Envisaging these different situations is simply an instrument to trigger discussion on how to be prepared for these different elements and different possibilities of the future.

Scenarios are important because the future is uncertain and, largely, unknowable. While policies are often driven by an 'official' view of the future, scenarios integrate an analysis of drivers of change, critical uncertainties and predetermined elements. They can be used for detailed analysis of future issues in order to inform decisions to be made today. They also provide a space (the future) removed from the constraints of the present, to allow stakeholders to talk about the future together.

Scenarios can be more engaging than statistics or policy papers to describe strategic issues and they can be an important tool for organisational learning.

1.5. Project phases and structure of the report

This two-year project was conducted between 2010 and 2012 over three phases and the methodology for each of these is described in Chapter 2.

Phase 1 was to select the key contextual drivers for new and emerging OSH risks associated with new technologies in green jobs by 2020. These drivers are the major forces or trends that will shape the future environment for workers in green jobs. Those that will have the greatest impact on the range of different future environments were used to define the scenarios. The drivers and the results of the selection process are set out in Chapter 3.

Phase 2 was to identify key new technologies that could contribute to creating new and emerging risks in green jobs by 2020. These were reviewed to select the nine key technologies where there would be the most significant new and emerging OSH risks. The data and results of this are contained in Chapter 4.

Phase 3 saw the development of the base scenarios using the key contextual drivers of change from Phase 1. These base scenarios were then used through a series of workshops to explore the respective development of the key technologies from Phase 2 and their impact on OSH in each of the scenarios. The information generated through this process was then integrated into the base scenarios to produce the full scenarios. The descriptions of the base scenarios, the process of their development and the technology developments and their OSH implications are set out in Chapter 5.

The scenarios were tested and consolidated in a consolidation workshop during which it was also demonstrated how the scenarios can be used to support OSH policymaking: the conclusions and the results of the consolidation workshop are in Chapter 6.

The final set of scenarios and guidance on their use are in Chapter 7.

The conclusions are in Chapter 8.

1.6. Acknowledgements

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2. Methodology

This chapter outlines the methodology adopted for the project.

2.1. Project initiation

A project initiation meeting was held in Buxton, United Kingdom, in January 2010. This involved the project team, EU-OSHA and five invited experts (Annex 1). The purpose was to ensure that there was a common understanding of the requirements of the project and included clarifying the definitions of the terms 'new and emerging risks', 'new technologies' and 'green jobs'.

The overall scope of the project was discussed and the approach to be adopted for Phase 1 was agreed. This included the production of a one-page project brief that was used to inform those who were eventually involved in some way during the project.

There was also an initial review of potential contextual drivers of change, which helped to prioritise the literature reviews in Phase 1 — Contextual drivers of change.

2.2. Project Phase 1: Contextual drivers of change

Phase 1 of this project concerned the identification of contextual drivers of change that could contribute to creating new and emerging OSH risks associated with new technologies in green jobs. This phase comprised three Work Packages (WP).

- WP 1.1: Review of the literature on contextual drivers of change resulting in an initial list of drivers
- WP 1.2: Consultation exercise carried out by interviews with experts and by an Internet-based exercise to consolidate the list of drivers
- WP 1.3: Voting exercise to prioritise the drivers and produce a list of suitable key drivers to be used in generating a set of scenarios in Phase 3 of the project

The results of Phase 1 are presented in Chapter 3: more detailed information on Phase 1 is available in the report on Phase 1 of the project (EU-OSHA, 2011a).

2.2.1. WP 1.1: Review of existing information on contextual drivers of change

The aim of WP 1.1 was a review of existing information (foresight, forecasts, studies, surveys, scientific reviews, statistics, etc.) in order to identify contextual drivers of change.

Literature review methodology

An initial literature review was carried out by the Health and Safety Executive's Library and Information Service (LIS), which has access to a wide range of subscription databases. Searches were carried out on the following databases:

- Applied Social Sciences Index and Abstracts (ASSIA): a database covering social services, psychology, sociology and health information;
- EBSCO Host: a portal for e-journals published by numerous publishers — it includes the tables of contents of 26 000 journals;
- International Bibliography of the Social Sciences (IBSS): online source covering social science fields including economics, social policy and social services, political science, law, accounting and finance, health and psychology, international relations and sociology;
- OSH-ROM containing bibliographic databases including: CISDOC (International Labour Office); NIOSHTIC (United States National Institute for Occupational Safety and Health); HSELINE; MHIDAS (US Major Hazard Incident Data Service); RILOSH (Ryerson International Labour, Occupational Safety and Health Index, Canada); MEDLINE OEM; and
- other (charged) databases: *enviroline*; Environmental Engineering; Ei Compendex®; BIOSIS (Thomson Reuters); *The Economist*; Management Contents; Management and Marketing Abstracts; Wilson Applied Science & Technology Abstracts; *New Scientist*; NTIS (US National Technical Information Service); and CAB.

Searches that focused specifically on 'drivers' for green or environmental jobs produced little in the way of leads, presumably because drivers themselves are not the primary focus of most of the literature on green jobs and may not appear in keywords. Opening the search to green jobs generally increased the number of hits dramatically, but with less discrimination. There is a large amount of material available on green jobs, much of it fairly recent. Most of the references found to be most useful were published from 2007 onwards.

The formal searches carried out by LIS yielded over 350 hits. The project team sifted these on the basis of age, geographical coverage, accessibility of the material and relevance as indicated by the title or abstract, where available.

The formal searches were supplemented by independent searches by the project team, relying largely on the Internet and covering a range of sources and websites of relevant organisations. In addition, information on environmental drivers from earlier work by team members was made available. The academic press did not yield a lot of relevant information, perhaps because of the newness of the area and the long lead-in time typical for academic journals. The most useful sources proved to be reports by and for government departments and other bodies, written from global, European and national perspectives. These are listed in Annex 2.

The results from the searches were analysed and 69 drivers were selected and used to produce a short report, which was supplied as briefing material to participants in WP 1.2. The initial list of drivers is presented in Annex 3.

2.2.2. WP 1.2: Consolidation of the list of contextual drivers of change

The aim of WP 1.2 was to consolidate the findings of WP 1.1, using the expertise of key people who may be aware of contextual drivers of change not yet described in published material. The consolidation stage was based on two consultation exercises.

Interview programme

The first consultation exercise was a programme of telephone interviews with 25 experts. The selection of interviewees was intended, as far as possible, to identify people from a range of organisations, with a variety of backgrounds and experience in order to bring a range of views to the exercise. The interviewees are listed in Annex 4. In addition to the views obtained from the interviews, a written response was received from the European Trade Union Institute (ETUI).

Interviews were based on the 'SAMI 7-Questions' technique, which was developed by SAMI Consulting and is now widely used in scenario-building exercises (Ringland, 2006). The questions are designed to be 'open' so as to give interviewees the freedom to develop ideas in a relaxed setting.

Interviewees were advised that interviews would be non-attributable, so comments could not be linked to any individual. Therefore, they were invited to give their own views and not necessarily those of their organisation.

The following question set was used.

Question 1

Having read the literature review of contextual drivers of change, what do you see as the main drivers identified in the document and affecting new and emerging risks to occupational safety and health associated with new technologies in green jobs by 2020?

- Is there anything additional that was not in the literature review that you feel is a relevant driver?
- Are there any drivers that don't belong?
- Are there any drivers you disagree with?
- Which drivers are most likely to drive new technology?

Question 2

Clairvoyant

If you could spend some time with someone who knew the outcome, a clairvoyant or oracle if such existed, what would you want to know? What are the critical issues?

Question 3

An optimistic outcome

Optimistic but realistic — What would be a good outcome and what would be the signs?

Question 4

A pessimistic outcome

How could the environment change to make things more difficult? What could go wrong?

Question 5

Looking back

Looking back 10 years, what successes can we build on and what failures can we learn from?

Question 6

Looking forward

What decisions need to be made in the near term to achieve the desired long-term outcome?

Question 7

Epitaph

If you had a mandate, without constraints, what more would you need to do?

Interview transcripts were structured, where possible, in short paragraphs dealing with a single issue to allow coding and sorting to produce a workbook. Individual paragraphs were sorted into appropriate sections to allow key issues to emerge.

Internet questionnaire

The second consultation exercise, run alongside the interview programme, consisted of an Internet-based questionnaire. Participants were asked to select the drivers that in their views were most important from the 69 drivers listed in Annex 3.

A questionnaire was created in SNAP Survey software (4) which has been used by the Health and Safety Laboratory (HSL) for numerous surveys.

The questionnaire contained the 69 drivers and their descriptions. Participants were asked to use drop-down menus to select their top three drivers from each of the categories: Societal; Technological; Economic; Environmental; and Political. In addition, space was made available for free-text comments.

The questionnaire was publicised through articles in the Health and Safety Executive's (HSE) *Science and Research Outlook* newsletter (HSE, 2012) and in EU-OSHA's *OSHmail* newsletter (EU-OSHA, 2010). In addition, the existence of the questionnaire was picked up by independent websites such as Hazards (O'Neill, 2010), which gave further publicity to the questionnaire (O'Neill, 2010). Overall, about 50 000 people were potentially exposed to the questionnaire. Given the very large potential audience for the questionnaire, the number of replies received, at 49, could be considered rather surprising. However, it was not untypical for an unsolicited survey of this type and sufficient responses were obtained to provide useful information. Also, many recipients of the *OSHmail* newsletter receive it in a language other than English, so they might have been unwilling to undertake a questionnaire in English.

Responses were obtained from 17 countries, mostly in Europe, but also from Australia, Bangladesh, Cameroon and the United States. Respondents included health and safety professionals, directors, trade union representatives and others whose interests in green jobs ranged from professional to 'self-taught eco-warrior'. Of those who provided information, 19 were from the public sector/government; 18 from the private sector; 3 were academics; 2 came from trade unions; and 1 from the voluntary sector.

The free-text comments made by participants in this exercise were added to the workbook.

Following a review of the workbook and the results from the Internet questionnaire, 16 groups of drivers were identified.

2.2.3. WP 1.3: Selection of key contextual drivers

The aim of WP 1.3 was to select the key contextual drivers from the consolidated set of 16 groups of drivers produced in WP 1.2.

Selection of the key drivers was achieved through a simple voting exercise using the External Communities area of the HSE's website. Short versions of the driver descriptions were reproduced in the voting table, with the longer descriptions available if required. Participants were invited to give each driver from the consolidated list a score of between 1 and 7 in terms of its importance to the creation of a green economy in Europe by 2020 (1 = low importance, 7 = high importance). The drivers were ranked by taking the mean of the scores awarded to each driver.

Those invited to vote comprised the following:

- the 25 interviewees in WP 1.2;
- the five members of the project team;
- the Director of EU-OSHA and the two Project Managers from EU-OSHA's ERO;
- government, employer and trade union representatives from EU-OSHA's former ERO Advisory Group (EROAG) (5);
- a selection of 12 of those who responded to the Internet survey in WP 1.2.

Responses were received from 37 of the 50 invited to participate.

2.3. Project Phase 2: Key technologies

The aim of Phase 2 of the project was to identify and describe the key technological innovations that may be introduced in green jobs by 2020 and that may lead to new and emerging risks in the workplace. This phase comprised three Work Packages (WP).

- WP 2.1: Review of existing material on technological innovations that may be introduced in green jobs by 2020 and may impact, positively or negatively, on workers' safety and health
- WP 2.2: Consultation exercise using the expertise of key people who may be aware of important technological innovations not yet described in published material; this was carried out by interviews with experts and by an Internet-based survey to consolidate the list of technologies
- WP 2.3: Selection of the key technologies from the results of WP 2.2 to be studied in Phase 3; the selection was based on all the data from Phase 2 and informed by a workshop of invited experts

The results of Phase 2 are presented in Chapter 4: more detailed information on Phase 2 is available in the report on Phase 2 of the project (EU-OSHA, 2011b).

(4) More information about SNAP Survey software is available online (http://www.snapsurveys.com/).

(5) The ERO Advisory Group (EROAG) was replaced by the Prevention and Research Advisory Group (PRAG) in the course of the project.

2.3.1. WP 2.1: Review of existing information on technological innovations

The aim of WP 2.1 was to undertake a review of existing information in order to identify technological innovations that may be introduced into green jobs.

An initial literature review was carried out by the Health and Safety Executive's Library and Information Service (LIS), which has access to a wide range of subscription databases. Searches were carried out using the following database services:

- OSH-ROM containing bibliographic databases including: CISDOC (International Labour Office); NIOSHTIC (United States National Institute for Occupational Safety and Health); HSELINE; MHIDAS (US Major Hazard Incident Data Service); RILOSH (Ryerson International Labour, Occupational Safety and Health Index, Canada); and MEDLINE OEM;

- Web of Science® (Thomson Reuters) — a bibliographic database containing Science Citation Index, Social Sciences Citation Index and Arts and Humanities Citation Index;

- Dialogue, of which the databases searched were CAB Abstracts; Biosis Previews; NTIS (US National Technical Information Service); Wilson Applied Science & Technology Abstracts; Ei Compendex®; *New Scientist*; and

- STN (online database service), the following databases searched were: Healsafe; Environmental Engineering Abstracts; Abstracts in New Technologies and Engineering.

Given the emphasis on new technologies, searches were limited to the period after 2005.

Searches specifically for new technologies in green jobs were not particularly fruitful. Searches for 'new technologies' tended to be dominated by nanotechnologies. Overall, the searches listed above provided 108 hits, of which 47 related to nanotechnologies.

In addition to using database services, LIS carried out Internet searches using a range of keywords derived from earlier results. Roadmaps were targeted in particular as it was expected that these might provide a guide to the potential for development of technologies; health and safety impacts of technologies were also targeted.

The searches carried out by LIS were supplemented by independent searches by the project team, relying largely on the Internet, covering a range of sources and websites of relevant organisations. In addition, information on technologies from earlier work by team members was included.

The Internet searches by LIS and the project team yielded a further 205 hits.

The project team sifted the hits on the basis of relevance as indicated by the title or — where available — the abstract, to identify those most likely to provide relevant information.

The results from the searches were analysed and used to produce a short report describing 26 technologies or technology areas, which was supplied as briefing material to participants in WP 2.2.

2.3.2. WP 2.2: Consolidation of the list of technological innovations

The aim of WP 2.2 was to consolidate the results of WP 2.1 using the expertise of key people who might also be aware of additional technological innovations not yet described in published material.

The consolidation stage was based on two consultation exercises.

Interview programme

The first consultation exercise comprised telephone interviews with 26 selected individuals. The selection of interviewees was designed to provide a mixture of OSH experts and technology experts. In addition, a mixture of those experts consulted in Phase 1 (to provide some continuity) and of new consultees was selected. It was not practicable to consult experts for each of the technologies and, in any case, our view was that technology experts with a broader background would be better capable of comparing and contrasting the different technologies. Those interviewed are listed in Annex 5.

Interviewees were advised that interviews would be non-attributable, so comments could not be linked to any individual. Interviewees were also advised that we were seeking their views as experts, rather than the official views of their organisation.

The following question set was used.

Question 1

Having read the report, are there any technologies, particularly new and emerging technologies that are missing from the report that are relevant, or could be relevant in the next 10 years, to green jobs? (The technology itself need not necessarily be green, if it contributes to green jobs.)

Question 2

Are there any technologies/sectors in the report that you think don't belong — that are not relevant to green jobs?

Question 3

Of the technologies/sectors that are in the report or that we have discussed, which do you think will develop most quickly over the next 10 years and how?

Question 4

Which technologies/sectors do you think have the most significance, either positive or negative for OSH? What are the hazards to workers? Do you have any views on the size of the impact (numbers of people affected, severity of harm, exposure situations)?

Question 5

How do you think that those technologies/sectors (if not already covered in Question 4) will develop and what are the uncertainties that might affect that development?

Question 6

Thinking outside the areas we have already discussed, in what circumstances (e.g. jobs or sectors not yet in existence) do you think we might encounter new technologies in green jobs? Be as speculative or outrageous as you like.

Question 7

If you had to choose just one of the technologies we have talked about for inclusion in the scenarios, which one would you choose?

Question 8

Closing discussion: How did you find the report/the interview experience? Do you have any comments on the findings? Are there any other points you would like to make?

Internet questionnaire

The second consultation exercise was run alongside the interview programme. It consisted of an Internet-based questionnaire in the External Communities area of the HSE website, to which 42 responses were received.

Participants were asked to score each technology on a scale of 1 to 7 (where 7 is high) for their potential for technical development and for their potential impact on OSH. In addition, a free-text comments box was available for each technology. At the end of the questionnaire, participants were asked for any further comments and whether they thought there were any other new technologies that could take place in green jobs by 2020 that should be added to the list. They were also asked, 'If you were to select one of the technologies described in this survey for our investigation into the risks to workers' safety and health caused by new technologies in green jobs, which one would you choose?'

The questionnaire was publicised through articles in the Health and Safety Executive's *Science and Research Outlook* newsletter (HSE, 2012) and in EU-OSHA's *OSHmail* newsletter (EU-OSHA, 2011c). Overall, about 50 000 people were potentially exposed to the questionnaire.

The results from the interview programme and the Internet consultation exercise were used to compile a report containing a consolidated list of 34 technologies or technology areas, which was used to inform participants in WP 2.3. The consolidated list is presented in Annex 6.

2.3.3. WP 2.3: Selection of key technologies

The aim of WP 2.3 was to select the key technologies to be explored in the workshops in the scenario work of Phase 3 of the project from the consolidated list of 34 technologies from WP 2.2.

The information gathered during the interview programme and the Internet consultation in WP 2.2 was supplemented by discussions and exercises at an expert workshop held in Manchester, United Kingdom, in May 2011. The experts invited covered a range of technology areas and OSH. All members of EU-OSHA's former ERO Advisory Group (EROAG) were also invited. Some of the attendees had earlier been interviewed in WP 2.2. The workshop participants are listed in Annex 7.

The workshop began with two introductory presentations: the first on the origins of the project and the second on its design. The remainder of the workshop was structured around three sessions. The first two sessions, in the same format, were aimed at producing a shortlist, based on the importance for OSH, of 18 main technologies (out of the 34 resulting from WP 2.2) to be considered for possible inclusion in Phase 3 of the project. Nine energy-related technologies and nine non-energy-related technologies were needed for the shortlist. The third session was devoted to selecting the top technologies, from those 18 preselected, to be explored in more depth in the workshops in Phase 3 of the project.

Energy technologies

The first session, on energy technologies, started with a presentation by Dr Lee Kenny of the UK HSE who called on her recent experience in the HSE's Emerging Energy Technologies programme to cover a wide range of energy-related topics and technologies from both technical and OSH angles.

Delegates were then asked, in groups of two or three, to arrange cards bearing descriptions of each of the energy technologies (Annex 6, 1–16) in order in terms of their potential impact on OSH in green jobs, while at the same time bearing in mind the aim of the exercise, which was to select technologies that would be relevant to explore in the scenarios in Phase 3. They were allowed to merge technologies if they wished, but not to disaggregate them. After the initial placement of the cards, there was discussion, aided by a facilitator, during which adjustments were made to the order of the cards until a final order was reached.

Delegates then worked in three groups to construct timelines showing expected developments in each of the nine selected technologies between 2010 and 2025, and to list what they thought would be the key dependencies (factors that might affect the direction or rate of development of the technology) and uncertainties (those factors that might affect the development of the technology whose influence or own progress is uncertain).

The year 2025 was chosen rather than 2020 as in the project title, in order to stretch thinking so that changes after 2020, the early signs of which might be evident by 2020, could be included. Each group worked on three technologies.

Non-energy technologies

This session started with a presentation from Dr Mike Pitts, Chemistry Innovations Ltd, who covered a wide range of topics suitably illustrated with many interesting examples.

The prioritisation exercise and the construction of timelines for the non-energy technologies (Annex 6, 17–34) followed the same methodology as for the energy technologies.

Voting

In the final session, delegates voted on the 18 topics selected from the energy and non-energy exercises. The timelines and sheets listing the uncertainties/dependencies for each technology were posted around the room. A spokesperson from each group summarised the main points of their discussion to the plenary session. Delegates then studied the outputs from all the groups and then voted for the eight technologies they would like to see go forward into Phase 3. Each delegate had to select their top technology (green vote) and seven others (red votes). Each delegate had to vote for at least two energy technologies and two non-energy technologies, and could not cast more than one vote for any single technology. This was followed by a plenary discussion of the results.

The final selection of the key technologies for the Phase 3 workshops was made by the project team in consultation with EU-OSHA.

2.4. Project Phase 3: Scenarios

2.4.1. WP 3.1: Scenario development

A set of base scenarios was developed by the project team for the Phase 3 technology workshops. They were based on an analysis of the 16 drivers of change from Phase 1 that were identified as having the greatest importance for the creation of a green economy in Europe by 2020. They were combined into three groups covering green values, the economy and innovation. These three groups of drivers were mapped on three axes to create the scenario framework, in which the base scenarios were then developed.

The process of scenario development and the three resulting scenarios (Win-Win, Bonus World and Deep Green) are described in more detail in Chapter 5.

2.4.2. Technology workshops

Seven workshops were held to consider the key technologies identified in Phase 2.

The objectives of the workshops were to explore the development pathways for each technology across the scenarios and the respective OSH implications. Invitees included a mixture of technical experts and OSH experts as well as members of EU-OSHA's Prevention and Research Advisory Group (PRAG). Details of technology workshop participants are given in Annex 8. The following workshops were held.

1. Wind energy — Manchester, 28 and 29 September 2011

2. Green construction (buildings) — Manchester, 29 and 30 September 2011

3. Bioenergy and the energy applications of biotechnology — Tallinn, 5 and 6 October 2011

4. Waste and recycling — Tallinn, 6 and 7 October 2011

5. Green transport — Brussels, 2 and 3 November 2011

6. Green manufacturing technologies and processes, and robotics and automation — Brussels, 3 and 4 November 2011

7. Domestic and small-scale renewable energy, energy storage and batteries, and energy transmission and distribution — Bilbao, 9–11 November 2011

Nanomaterials, also identified as a key technology in WP 2.2, were considered in all workshops, as a horizontal issue. The workshops began in the late afternoon with an introduction to the project. This was followed by a presentation on the technology and a plenary exercise to develop the most optimistic technology pathway, assuming high green values, high economic growth and a high level of innovation directed towards new technologies in green jobs. (This is the Win-Win scenario.) The final session on the first evening was a presentation and discussion of the three scenarios. More information on the scenarios is presented in Chapter 5.

At the start of the second day, participants were divided into two scenario groups (Bonus World and Deep Green). It was important to have a cross section of technology experts and OSH experts as well as representatives from industry, trade unions and government in each group, as a key objective was to use the scenarios to explore the relationship between technology developments and OSH.

After some time to enable each group to become familiar with their scenario and consider the key issues in it, each group generated a technology timeline for its scenario to 2025. The timelines were extended beyond 2020 so that issues that may start emerging in 2020 were also captured. The groups drew on their own knowledge and used the most optimistic timelines in the context of their scenario, as well as data provided on the technology, as sources of additional ideas. They also considered 'horizontal' technology issues, such as nanomaterials.

Following feedback on the two technology pathways, each group considered the possible OSH implications of each pathway. In addition to the technology development pathway, the groups kept in mind the context of the scenarios, including social conditions and industrial structure. Following broad discussion of the OSH issues in the scenario the groups considered those that had the following characteristics:

- highest impact (severity and number affected);
- highest uncertainty (wide range of outcomes); and
- most surprising (not currently anticipated)

The final exercise was to return to the most optimistic technology pathway (Win-Win) developed the previous evening. Following a review of the pathway, the OSH implications were considered, repeating the exercise previously carried out for the other two scenarios. In most cases, individual high impact, high uncertainty or most surprising OSH implications were considered by a technology expert and an OSH expert working as a pair.

Each workshop concluded with a plenary discussion of the three technology pathways and the most important OSH implications for green jobs in each of the three scenarios.

The combined workshop on energy technologies followed the same process, commencing late afternoon on the first day and ending at the start of the afternoon on the third day.

The data captured in these workshops is recorded in Section 5.4. These data were also integrated into the base scenarios to generate the full scenarios presented in Chapter 7.

2.4.3. WP 3.2: Testing and consolidating the scenarios

The full scenarios were tested and consolidated and their potential use for policymaking demonstrated at a workshop in London on 7 and 8 March 2012 (Chapter 6). This was attended by multidisciplinary representatives of employers, trade unions, representatives of EU Member States' governments, the European Commission and the OSH organisations listed in Annex 9. Prior to the workshop, participants were sent a copy of the base scenarios and the technology pathways, and resulting OSH issues identified in technology workshops.

The workshop started in the early evening of 7 March 2012 with presentations on the background to the project and the three scenarios. The participants were then divided into three representative groups, one for each scenario, for the exercises on the next day. On 8 March, the workshop started with a presentation of a selection of OSH issues from the technology workshops. Participants had also been given (the previous evening) a report on the technology and OSH detail from the technology workshops for the scenario they would be working with. In a preliminary exercise, each group was asked to review its scenario and consider potential OSH media headlines in about 2025. The purpose of this was to immerse the participants in their respective scenarios.

In the first main exercise, participants reviewed the key OSH issues and checked for any gaps or omissions, drawing on the report on the results of the technology workshops. They then prioritised the OSH issues in terms of which had the greatest impact and were most likely to occur.

The second exercise was to develop policies to address the key OSH issues in each scenario. These were required to include policies that related particularly to the conditions in each scenario. The implementation of the policy was also considered, including supply-side and demand-side measures, any obstacles to be overcome, the resources required and the timescale.

The third exercise involved 'wind-tunnelling' each policy against the other two scenarios. This was to test the robustness of a policy across the three scenarios, including their relevance and potential differences in implementation, and was conducted by each group presenting a policy and the other two groups considering them in their scenario. The policies were ranked in each scenario and the resource and implementation requirements recorded.

A cross-scenario matrix of the 'wind-tunnelling' results was built up during the exercise and was considered as part of the concluding plenary discussion.

The process and results of this workshop are described in Chapter 6.

3. Phase 1: Contextual drivers of change

The aim of project Phase 1 was to identify key contextual drivers of change that could contribute to creating new and emerging OSH risks associated with new technologies in green jobs within 10 years. The methodology applied in Phase 1 is described in Section 2.2: more detailed information is available in the report on Phase 1 of the project (EU-OSHA, 2011a).

3.1. Consolidated driver set

Following a literature review of global, European, and national studies (Annex 2), a consolidated list of contextual drivers of change was produced by means of interviews with 25 selected experts and an Internet questionnaire. The data from each of these stages are presented in the report on Phase 1 of the project (EU-OSHA, 2011a). Based on these analyses, the following consolidated set of 16 drivers of change was determined:

- environment;
- government incentives;
- government controls;
- public opinion;
- public behaviour;
- economic growth;
- international issues;
- energy security issues;
- renewable energy technologies;
- fossil fuel technologies;
- nuclear energy;
- electricity distribution, storage and use;
- energy efficiency improvements;
- growth in waste and recycling;
- other technologies; and
- demographics and the workforce.

Each of these drivers is now examined in detail.

Environment

The state of the environment is inevitably the key driver of green activities, either in terms of short-term issues such as pollution, or longer-term issues such as increasing carbon dioxide emissions and climate change, generally considered to be due to human activity.

Scientific and media reports on climate change and other environmental issues will drive public opinion, which may, in turn, influence politicians and industry to act. Increasingly extreme weather and other observable physical effects of climate change such as temperature rises and natural disasters that may be attributable to climate change will further drive public opinion, strengthening the position of pressure groups and potentially influencing government policies.

Climate change may lead to water shortages in parts of the world, such as southern Spain, so activities to store water and to use less will become increasingly important. Desalination might become more important. Climate change may drive the need for more efficient and/or more local food production. This could lead to an increase or decrease in jobs, depending on the solutions adopted. Increasing energy costs could lead to a decrease in the transport of food, resulting in more local food production.

Other environmental concerns including famine, pollution, man-made disasters (especially those related to the energy sector), the depletion of natural resources other than fossil fuels (e.g. the increasing demand for minerals and other commodities by emerging economies) will add to the issues previously described.

Government incentives

Government incentives for green activities are likely to have a strong influence on the creation of green jobs. Examples of government incentives, which can be financial or enabling, include the following.

- Governments having clear and stable energy policies and taking a long-term view to create a favourable climate for investment will make investment in new technologies more attractive.
- Government investment in research and development would likely boost the creation of green jobs; actions would include developing clear criteria to prioritise research in order to target funding towards environmentally friendly activities, developing energy-research capabilities and promoting the development of technology clusters.
- Many companies developing green technologies are SMEs that need capital to invest in green technologies and insurance cover for speculative ventures. Governments offering technical assistance or innovative financing for private investment (e.g. by underwriting) may encourage venture capitalist firms to recognise that green technology development can give significant business opportunities.
- Simplifying planning controls for green activities, implementation of waste collection and recycling schemes is another approach likely to boost green employment.

- Governments may also offer loans, subsidies, rewards or favourable tax regimes for the following:
  - retrofitting energy-efficiency measures in existing buildings;
  - car scrappage schemes that replace older, polluting vehicles with more carbon-efficient vehicles;
  - reduced tolls for energy-efficient vehicles;
  - recycling;
  - less energy-dependent, less material-dependent and less waste-generating manufacturing processes and products; and
  - locally generated electricity; for example, feed-in-tariffs for solar energy were very successful in Germany and Spain, and have had significant impact since their introduction in the United Kingdom in April 2010.
- Many observers fear that a shortage of skills will hamper the development of green activities and, therefore, green jobs. Action to encourage education in science, technology, engineering and mathematics, to identify the skills gaps and to provide relevant training will promote the creation of green jobs. Skill levels are important to health and safety.
- Where jobs in other sectors may be lost as a result of the creation of green jobs, action to retrain and redeploy displaced staff may reduce the risk of opposition to green job creation.

The key to the growth of the green sector is the extent to which incentives are successful in encouraging the creation of green jobs.

Government controls

As an alternative to incentives for undertaking green activities, governments can impose controls on polluting activities. These controls include regulation, taxing of high carbon and polluting activities (e.g. aviation and motoring) and, in some cases, the removal of 'perverse' subsidies on fossil fuel use.

Examples include:

- landfill taxes to encourage reduction in waste and an increase in recycling;
- carbon pricing and carbon trading, for example the EU's Emissions Trading Scheme (EU-ETS);
- extended producer responsibility laws (requiring companies to take back products at the end of their useful life) for all types of products;
- a requirement for eco-labelling of consumer products to ensure that consumers have access to the information they need to make responsible purchases; this will encourage manufacturers to design and market more eco-friendly products;
- emissions targets;
- developing green building regulations, such as the Directive on the Energy Performance of Buildings (2003), energy conservation standards, or other requirements for new green buildings or retrofits of existing buildings;
- higher levels of tax for the most polluting vehicles, developing energy-efficiency standards for appliances; vehicles, etc.;
- requirements for biofuel content of diesel fuel;
- proportionate health and safety legislation.

Public opinion

Public opinion on environmental issues — in particular climate change, and the extent to which the public believe that human activities contribute to climate change — will influence politicians and businesses. Pressure groups and campaigns will influence governments, while commercial pressures will have more impact on producers.

If people believe that CO_2 emissions play a major part in global warming, then they will be increasingly likely to support low-carbon energy sources. However, the general public's growing intolerance of risk, coupled with their inability to properly assess risk, may lead to reluctance to adopt new (green) technologies. A major accident involving new technologies such as carbon capture and storage (CCS) could seriously hold back development. On the other hand, the public may favour newer renewable and sustainable technologies over older, dirtier technology. Improved risk communication might affect people's attitudes.

Public opinion on other environmental issues and opposition to activities that damage the environment could drive the creation of green jobs in environmental protection. However, shortages of essential natural resources could eventually result in conflict between our material needs and protection of the environment.

Public opinion and competitiveness issues could drive corporate social responsibility programmes leading to companies making efforts to operate more efficiently and sustainably.

Public behaviour

Public opinion in favour of green activities will influence the creation of green jobs. But, unless consumers demonstrate their support for green activities through demand for green products (e.g. by their use of energy efficiency measures, changing their travelling patterns (using fuel-efficient vehicles, electric vehicles or choosing public transport), and supporting recycling schemes), the incentive for manufacturers to offer environmentally friendly products will be diminished.

Economic growth

European economic growth will be a significant factor in the creation of green jobs. The state of European economies will have a significant effect on the availability of resources with which to tackle environmental issues. On the one hand, a healthy economy and the availability of capital for investment could give business the confidence to invest in new technologies, driving the creation of green jobs. On the other hand, many governments may see the need to boost their economies in the wake of the global recession as an opportunity to green their economies by targeting environmentally sound activities. It may be that the costs involved in major engineering projects will be lower over the next few years as contractors compete for business in a reduced market.

Green activities may offer commercial opportunities outside Europe for European companies. The global market for environmental products and services (efficiency, recycling, water sanitation and efficiency and sustainable transport) is reported to be currently EUR 1 000 billion, and could reach EUR 2 200 billion by 2020. Any future growth of the EU could lead to potentially bigger markets for green technology. The availability of a sizeable domestic market for green products and services and a requirement for local content will make developments more attractive to potential investors.

International issues

Globalisation, itself driven in part by the availability of cheap transport, is now leading to ever-increasing demand for energy and natural resources as emerging economies, benefiting from global trade, increase their own use.

Increasing competition for natural resources from emerging economies and increasing use at home will lead to greater efforts in areas such as recycling, more efficient production and reduction of waste. In addition, competition from emerging economies in production drives cost-cutting in Europe, resulting in greater efficiency.

Emerging economies such as China and India are growing more quickly than OECD countries and their economic influence will increase accordingly. This is leading to increasing political influence as seen in, for example, China's ability to affect decisions on carbon targets at the Copenhagen Climate Change Conference in 2009.

The current global economy has been enabled by, among other factors, increasingly liberal trade conditions. Continuation or re-emergence of recession could drive a return to protectionism. This could affect prices and availability of natural resources, including energy.

The continuing instability of the Middle East, Russian control of gas pipelines, etc., gives rise to concerns about fossil fuel security. Continuing conflicts or acts of terrorism that increase instability will cause fears about oil supplies.

Energy security issues

The need or desire for energy security, in particular reduced dependency on imported oil and gas, is undoubtedly a major driver, alongside climate change, in the search for alternative energy sources and improved energy efficiency.

As easy-to-reach oil and gas resources decline and demand increases, there will be increasing pressure to improve fuel efficiency and to seek alternative, renewable fuel sources. In addition to its transport and heating uses, oil is a feedstock for many industrial processes and so shortage and increasing prices will drive efficiency improvements and use of alternative sources, such as biomass.

In addition to concerns about reserves of available oil and gas, the ongoing risks of conflict and unrest in some of the source countries is another factor in the desire for independence from imported energy.

Renewable energy technologies

The availability and affordability of renewable energy technologies (e.g. wind, wave and solar energy, and biofuels) leading to increasing uptake of these technologies will drive the creation of green jobs. As the cost of energy from renewable sources decreases, whether as a result of technological innovation or as a result of subsidies and incentives, its popularity and rate/extent of adoption will increase. As renewable technologies develop, they will introduce new OSH risks, some known and some, as yet, unknown.

Fossil fuel technologies

Reliance on fossil fuels will continue for some years. The development and availability of technologies, for example CCS (including geoengineering approaches such as ambient air carbon capture and ocean seeding) and clean coal technologies, to allow the continued use of fossil fuels, will become increasingly important.

Successful testing and development of CCS and clean coal technologies will result in increasing numbers of jobs in this sector, although numbers by 2020 may not be great. It is not universally agreed that such jobs qualify as green jobs. Since the technologies aim to reduce atmospheric carbon dioxide in order to combat climate change, their role is, indeed, environmental protection. However, it might also be argued that they are not sustainable, long-term solutions and that they may just be shifting risks or creating other environmental risks.

Nuclear energy

Nuclear energy was not considered to be environmentally friendly when originally introduced. However, in the face of increasing carbon emissions, a different view might be taken. One significant environmental group has changed its view on nuclear energy.

Whether or not nuclear energy is considered to be green itself, the extent of its use will affect the numbers of other green jobs.

Electricity distribution, storage and use

As distributed generation of electricity by renewable sources such as wind turbines, small-scale hydroelectricity and combined heat and power increases, ageing grids may be unable to handle two-way traffic or cope easily with the fluctuating output from renewable sources. A smart grid will need to be developed, alongside better ways of storing electricity (e.g. improved battery technology, hydrogen, electric vehicles).

Development of smart grid technology and other associated technologies, resulting in more efficient use of power, would lead to green jobs. The development of a smart grid will require a corresponding development in information and communication technology (ICT) to control the grid.

Introduction of these new technologies for distribution, storage and use of electricity may bring new risks.

Energy efficiency improvements

Opportunities for green jobs will be created in the construction of new energy-efficient buildings, in retrofitting energy-efficiency measures to older buildings, in less energy-demanding manufacturing and in the adoption of more efficient means of transport — either alternatives to fossil fuel or making more use of public transport.

These, in turn, will be driven by increased awareness of the benefits, reducing or subsidised prices, policies and standards on energy efficiency and public procurement policies.

Growth in waste and recycling

Continued growth in waste management and recycling, driven by environmental concerns and shortages and prices of natural resources, will lead to increasing employment in this sector. International pressures and public opinion could mean that it may no longer be acceptable to export waste to developing countries. Increasing transport and labour costs overseas will also contribute to this trend. Jobs in this sector are often low-quality jobs carried out by vulnerable workers. Risks can include manual handling during collection and sorting, potential exposure to dangerous objects, hazardous chemicals that may become concentrated during processing, biohazards, toxic or flammable gases, etc. What we are manufacturing now will become waste during the next 10 years. Examples include solar panels that contain toxic chemicals, low-energy light bulbs that contain mercury and nanomaterials. Landfill mining is now being carried out as a way of recovering valuable materials from previously discarded waste. Food waste is increasingly being directed to anaerobic digestion.

Other technologies

Developing technologies other than energy technologies may influence health and safety risks in green jobs, as indicated in the following.

- **Nanotechnologies:** It is likely that nanotechnologies will contribute to green issues in various ways (e.g. changes in manufacturing resulting in saving of natural resources, novel materials, desalination, changes in food production, and carbon nanotubes in new battery designs). New materials and nanoparticles may bring health and safety risks as well as environmental risks.

- **Biotechnologies:** The use of synthetic biology and genetic modification techniques to generate desired traits in crops and animals may have health and safety implications. Genetic testing could be used to identify those at particular risk from toxic substances.

- **Climate change mitigation technologies:** These include coastal defences, reinforcing of buildings, water management, harvesting, and adapting agriculture in the direction of agroforestry. Efforts to protect and make the most efficient use of land could lead to increased food production and green jobs and may bring new risks.

- **Sustainable manufacturing/green chemistry:** Manufacturing making use of low-carbon technologies, renewable and non-toxic materials, recycling and low waste has strong green credentials, but new manufacturing methods and new or substitute substances may bring changes in health and safety risks.

Demographics and the workforce

The increasing population, both worldwide and in Europe, is likely to increase the use of energy and natural resources, driving the need for ever-more energy efficiency, sustainable development, recycling and other steps to reduce and manage the environmental impact of human activity.

Changing lifestyles may also affect the use of energy and other resources: increasing urbanisation of populations and the growing number of single households are likely to increase energy use.

Increasing numbers of older people in the general population and in the workforce will have an impact on energy use and the potential for health and safety issues. Older people tend to use more energy in the home, but less on transport. Older workers may be more susceptible to specific risks in the workplace (e.g. from new technologies and substances, and to risks of musculoskeletal disorders). However, older workers also present some strengths: they are generally more dedicated to the workplace; have fewer sickness absences; stay in jobs longer; and have stronger skills and greater experience and maturity.

As many post-war baby boomers reach retirement, there may be a loss of essential skills in the workplace and a resulting threat to health and safety in work generally, including green jobs.

A shortage of the skills necessary in some green jobs means that migrant labour is used to fill vacancies: migrant workers can be at greater risk of accidents and work-related ill health than local staff owing to language and cultural issues. They are also typically more often employed in more risky jobs, in more precarious conditions, and may receive less training.

Climate change might modify migration patterns (e.g. owing to water shortages in some regions of the world) and new populations of migrant workers with different characteristics might be found in the EU, or the migration flow might also be modified.

3.2. Selection of key contextual drivers

The results of the voting on the key contextual drivers (from the survey described in Section 2.2.3) are shown in Table 3. A score of 1 means a low level of importance and 7 a high level of importance to the creation of green jobs. There were no 'runaway' winners. The following drivers were considered most important: the state of, and impact on, the environment; government interventions; the state of the economy; the availability of renewable energy and energy-efficiency technologies; and public opinion. At the other end of the scale, fossil fuel technologies and nuclear energy were considered the least important.

A number of key uncertainties surrounding the creation of green jobs also arose from Phase 1. They include the following.

- The pace and direction of a change to a low-carbon economy — Which technologies will succeed and what will be the energy mix by 2020?
- The effect that political and social attitudes will have — Will governments rise to the challenge and take the appropriate steps?
- What will the future market conditions and funding models be as the world climbs out of recession?
- How will the increasing influence of the emerging economies affect Europe?
- How will all the previous points affect working conditions, and will a truly sustainable economy be achieved, where decent, healthy and safe working conditions are provided for the diverse workforce?

The results of Phase 1 were taken forward to Phase 3 to generate the base scenarios (Chapter 5).

Table 3: **Ranking of drivers after voting exercise**

Ranking	Driver	Mean Score	Ranking	Driver	Mean Score
1=	Government controls	5.81	**9**	Other technologies	4.81
1=	Government incentives	5.81	**10**	Energy security issues	4.70
3	Environment	5.62	**11**	Electricity distribution, storage and use	4.62
4	Renewable energy technologies	5.54	**12**	Public behaviour	4.51
5	Economic growth	5.27	**13**	International issues	4.35
6=	Energy efficiency improvements	5.21	**14**	Demographics and the workforce	4.15
6=	Public opinion	5.21	**15**	Fossil fuel technologies	3.97
8	Growth in waste management and recycling	5.03	**16**	Nuclear energy	3.59

4. Phase 2: Key new technologies

This chapter describes the work carried out in Phase 2, the aim of which was to identify key new technologies that could contribute to creating new and emerging OSH risks in green jobs by 2020. The methodology used is described in Section 2.3: more detailed information about Phase 2 is available in the report on Phase 2 of the project (EU-OSHA, 2011b).

4.1. Results of the literature review

Information on emerging technologies, their potential health and safety implications, and their potential for development was extracted from approximately 40 selected references.

In deciding which technologies to include, it was important to remember that the aim of the project was 'new and emerging technologies in green jobs'. Thus, it is the jobs that are green, not necessarily the technologies. Therefore, the selection of emerging technologies was necessarily influenced by their relevance to work sectors in which green jobs are to be found. The focus was also on those areas that are large enough to be significant and with the potential for variability to lead to useful contributions to scenarios.

The following sectors were selected: energy; transport; manufacturing; construction; agriculture, forestry and food; waste, recycling and environmental remediation; and medicine and healthcare technologies.

In identifying technologies, it was important to classify them at the right level to take forward to scenarios — not so narrow as to limit possibilities for interesting technology development pathways, but not so broad as to be unmanageable. The result was that, for the most part, technological areas were identified, each of which may contain several related technologies.

In some cases, a sector was classified as a technology area. This was a pragmatic approach and is consistent with the approach taken by European Technology Platforms, which treat several industrial sectors as discrete technology areas (CORDIS, 2012). Inevitably, there was some duplication and some technologies appeared in more than one area. Table 4 provides a list of the 26 technology areas and sectors identified, and the links between them. Only significant links are indicated in Table 4. Thus, for example, while transport and construction have relevance in some way to all sectors and technologies, we have noted only links where new technologies contribute to transport or construction rather than the contribution of transport and construction to other sectors.

Unsurprisingly, in the context of this report, energy technologies made up a considerable proportion of the technologies identified.

This table includes only the initial 26 technologies identified by the literature search. After the interview programme and Internet survey (Section 4.2.1), 34 technologies were taken forward to the Phase 2 workshop (Annex 6).

4.2. Consolidation of the list of technological innovations

4.2.1. Interview programme

Twenty-six experts, listed in Annex 5, were interviewed by the project team (for the methodology, see Section 2.3.2).

In response to Question 1 on whether there are any technologies, particularly new and emerging technologies, missing from the report, interviewees made several suggestions. Some of these were additions or amendments to technologies already in the list, while others were potential candidates for addition to the list.

Two interviewees suggested that extraction technologies should feature in the list. A significant proportion of the world's energy goes into extracting minerals, some of which are essential to the other technologies in the list. Improved efficiency in extraction techniques would make a valuable contribution to reducing energy use. This suggestion was taken on board.

"Better mineral extraction technologies. Rare minerals are fundamental to many of the other technologies listed. It's a very energy-intensive industry. Some 3–5 % of the world's electricity goes into smashing up rocks so savings would be helpful. Despite recycling, we have to accept that we will still need to access natural resources."

The omission of the health sector was noted. Alongside that, the absence of the convergent technologies (sometimes known as NBIC — Nano, Bio, Information and Cognitive sciences) and their application to human performance enhancement attracted comment. In an earlier draft of the report, 'medicine and healthcare technologies' had been included, but then it was removed, as it would have an impact on a wider range of jobs than just green jobs. The same challenge could be levelled at robotics and ICT. For this reason, this category and NBIC were reinstated for discussion at the workshop. However, the related 'singularity' was not included — the 'point at which we see sudden technological change so rapid and profound it represents a rupture in the fabric of human history' — because this was seen as likely to occur well beyond 2020.

Photonics — the technology of transmission, control, and detection of light (photons), as in fibre optics and optoelectronics — was suggested as an additional technology. Like other 'new' technologies, it has been in existence for some years, but is now developing quickly and finding increasing applications. It contributes, for example, to ICT and to laser manufacturing. Like ICT,

Table 4: **Technologies (left hand column) and sectors (top line) resulting from the literature review show significant overlaps**

	Energy	Transport	Manufacturing	Construction	Agriculture, forestry and food	Waste, recycling and environmental remediation
1. Wind energy technologies	✓		✓	✓	✓	
2. Marine energy technologies	✓		✓	✓		
3. Solar energy technologies	✓		✓	✓	✓	✓
4. Bioenergy technologies	✓	✓		✓	✓	✓
5. Geothermal technologies	✓		✓	✓	✓	
6. Hydroelectricity technologies	✓			✓		
7. Carbon capture and storage technologies	✓			✓		
8. Clean coal technologies	✓					
9. Other fossil fuel technologies	✓					
10. Nuclear technology	✓					
11. Electricity transmission technologies	✓			✓	✓	✓
12. Electricity storage technologies	✓	✓				✓
13. Battery technology	✓	✓				✓
14. Hydrogen and fuel cell technologies	✓	✓		✓		
15. Domestic and small-scale energy applications	✓	✓		✓	✓	
16. Biotechnologies	✓		✓	✓	✓	✓
17. Green chemistry	✓		✓			✓
18. Novel materials	✓	✓	✓	✓		✓
19. Nanotechnologies and nanomaterials	✓		✓	✓	✓	✓
20. Robotics, automation and artificial intelligence	✓	✓	✓	✓	✓	✓
21. Information and communication technologies	✓	✓	✓	✓	✓	✓
22. Green transport technologies	✓					
23. Green manufacturing technologies	✓			✓		✓
24. Green construction technologies	✓	✓				
25. Agriculture, forestry and food technologies	✓					✓
26. Waste, recycling and environmental remediation technologies	✓		✓		✓	

its applications will be relevant to green jobs, but not limited to them. Again, this was included for discussion at the workshop.

Other comments included the following.

- "More should be included on the risks to the self-employed and the public from domestic and small-scale novel energy technologies." This was added to the description in the consolidated technology list.
- "Solar PV and concentrating solar power should be separated as they rely on different technology and present different risks." This was included in the consolidated technology list.
- "Waste and recycling could be separated. They are quite different and usually carried out by different people." Waste and recycling are often taken together, but the point was made that waste management and recycling are often carried out by different people with different skills. Furthermore, recycling is becoming increasingly sophisticated. Therefore, they were separated in the consolidated technology list and the reaction of the workshop to this was awaited. As a consequence, environmental remediation was given its own category and geoengineering was added.
- "The use of carbon dioxide as a new source for plastics." This was added to the description of green chemistry in the consolidated technology list.
- "Eco-tourism. This is not a technology, but will be a source of green jobs." This was not added to the list as it is not a technology.
- "Clean coal and CCS should be merged and CCS should include transport." Transport of CO_2 is identified in the list of technologies. CCS was not merged with clean coal, as CCS is not limited to coal and can be applied to other areas, such as cement manufacture.
- "Energy storage should include the use of molten salts and molten graphite." This was added to the description in the consolidated technology list.
- "What about the cloud?" This was made explicit in the ICT category.
- "Hydroelectricity could include micro-scale as well as large- and small-scales (i.e. at the level of individual households)." This was added to the description in the consolidated technology list.
- "In addition to the electricity grid, what about the pipeline grid for hydrogen, CO_2, liquefied natural gas, biofuels, biogas, etc.?" This was not added. Although there are issues (e.g. regarding the transport of hydrogen and the injection of biomethane into the existing gas pipeline systems), no generic information on pipelines was found. Perhaps, this is best dealt with under the individual substances.
- "Manufacturing should mention formulation technologies as well as fabrication. Formulation has its own different skill set." This was added to the description in the consolidated technology list.

Question 2 on whether any of the technologies listed did not belong attracted relatively few responses.

Two interviewees had reservations about the inclusion of nuclear power. While its low-carbon credentials were recognised, they felt its full life cycle aspect was inconsistent with green status.

Similarly, the inclusion of coal and other fossil fuel technologies was also called into question by two interviewees.

The responses to Question 3 on the technologies with the greatest potential for development by 2020 and Question 4 on the technologies with implications for occupational safety and health are presented graphically in Figure 6 and Figure 7 respectively in Annex 10.

The top eight technologies identified from the responses to Question 3 were: wind energy; solar energy; nanotechnologies; marine energy; battery technologies; bioenergy; biotechnologies; and ICT.

The top six technologies identified from the responses to Question 4 were: nanotechnologies; wind energy; biotechnologies; solar energy; robotics and automation; and ICT. Nuclear energy, marine energy, green chemistry, transport and construction shared sixth place.

Given the way the information was harvested from the interviews, the responses have limited statistical significance (these were not votes but citations extracted from the interview notes), but they are interesting nonetheless.

Question 5 was not applicable in most cases.

Interviewees found Question 6 challenging. This question asked how they think that those technologies/sectors not already covered in Question 4 will develop and what are the uncertainties that might affect that development. Some referred to existing jobs, but there were several novel suggestions. Three different uses of outer space were identified by three interviewees: the use of space to carry out hazardous processes, colonisation of the moon and space tourism.

> "One activity is space tourism. It is coming. There may be risks to the environment here. It might create some green jobs."

Moving in another direction, working in the deep oceans was suggested. However, it was decided not to include space and deep oceans as they are unlikely to represent significant numbers of jobs by 2020 and are not necessarily 'green'.

Other suggestions included employment in 'energy storage gardens'. Again, this was not considered likely to be significant by 2020 and was, therefore, not included.

The responses to Question 7 on the preferred technology for inclusion in Phase 3 are presented in Figure 2, combined with the responses from the Internet survey. The clear favourite was nanotechnologies, with wind energy, bioenergy, CCS, domestic and small-scale energy applications, and waste and recycling all equal second.

"Recycling. And, by that, I really mean advanced processes that preserve the performance qualities of materials. We're not talking about what they call 'downcycling' where you take materials into a lower grade application, where you reuse the material without preserving the value of it. We should design products in the first place with the end of life in mind, so they are easier to take apart and recover the valuable components."

4.2.2. Internet questionnaire

The purpose of the Internet questionnaire was to expose the above results to a wider audience than could be reached by the interview programme alone. Although the survey could not gather the depth of information offered by interviews, it provided a source of endorsement of the findings of the interviews and the opportunity to identify any omissions.

Completed responses were obtained from 38 people from 21 countries, mostly in Europe, but including the United States. This is a reasonable response for a survey of this type (OECD, 2012). Respondents included predominantly health, safety and environment professionals and R & D professionals. Of those who provided information: 10 were from the public sector/government; 11 from the private sector; 9 research or academics; 3 trade unions; and 5 others or not stated. Nearly all had a professional interest in green jobs, with: 14 working in health, safety and environment; 15 in research and development; 4 in management; 1 in policy; and 4 in other or undisclosed professions.

Not all respondents replied to all the questions on technologies, with the number of scores fluctuating between 31 and 38.

The mean scores given to each technology for its potential for development to 2020 and its potential impact on occupational safety and health are shown in Figure 8 and Figure 9 respectively in Annex 11.

The scores show much less separation between the technologies than was observed in the interviews, owing to the structure of the survey (each respondent could score all the technologies), but the top eight technologies for development potential were: waste and recycling; construction; solar energy technologies; ICT; wind energy; transport technologies; domestic and small-scale energy applications; and electricity transmission.

The top eight for potential impact on OSH were: nuclear energy; waste and recycling; nanotechnologies; bioenergy; biotechnologies; hydrogen and fuel cells; construction technologies; and clean coal technologies.

In response to the question 'If you could pick just one technology for Phase 3, which one would you choose?', nanotechnologies and wind energy came first and second, with waste and recycling and carbon capture and storage third and fourth respectively. Electricity transmission, nuclear energy and green chemistry were joint fifth. These results are shown in Figure 2.

In addition to the quantitative information, a considerable number of comments were added in the free-text boxes made available. These comments were added to the workbook prepared from the interview responses.

4.2.3. Comparison between the interview programme and Internet survey results

The quantitative results obtained from the interview programme and the Internet survey were not intended, in themselves, to determine the future of the project. Rather, they were intended to inform the participants in the workshop that would close Phase 2 of this project.

Comparison of the top eight technologies with potential for development showed three matches between the interviews and the Internet survey: wind energy, solar energy and ICT.

Comparison of the top eight technologies with potential for OSH impact showed four matches: nanotechnologies, biotechnologies, solar energy and nuclear energy.

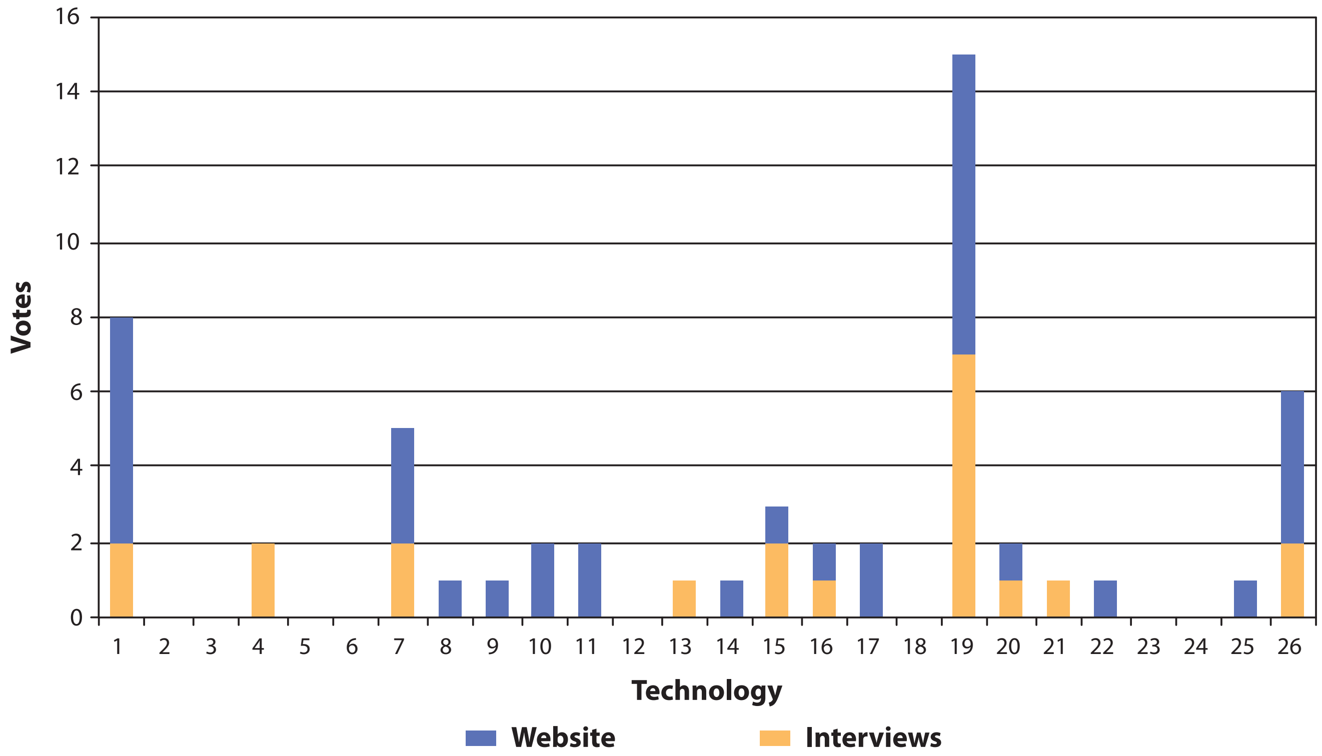
Perhaps the most informative result was that nanotechnologies and wind energy were first and second in both exercises as the respondents' top choice for inclusion in Phase 3. The combined responses are shown in Figure 2.

4.2.4. Consolidated list of technologies

Overall, the feedback from the interview programme and the Internet consultation, which exposed the technologies identified during the literature search carried out in WP 2.1 to a range of experts from varying disciplines and organisations, was that the list of technologies produced from the literature review was very comprehensive. However, some suggestions for additional technologies and changes to some of the entries were made and a consolidated list of 34 technologies was produced.

This is shown in Annex 6, which includes information on potential developments and typical health and safety hazards associated with the technologies listed.

Figure 2: **Combined responses from interviews and the Internet survey: preferred technology for Phase 3**



Key: 1. Wind energy; 2. Marine energy; 3. Solar energy; 4. Bioenergy; 5. Geothermal energy; 6. Hydroelectricity; 7. Carbon capture and storage; 8. Clean coal; 9. Other fossil fuel technologies; 10. Nuclear energy; 11. Electricity transmission; 12. Electricity storage; 13. Battery technology; 14. Hydrogen and fuel cells; 15. Domestic and small-scale energy; 16. Biotechnologies; 17. Green chemistry; 18. Novel materials; 19. Nanotechnologies and nanomaterials; 20. Robotics, automation and artificial intelligence; 21. ICT; 22. Transport technologies; 23. Manufacturing technologies; 24. Construction technologies; 25. Agriculture, forestry and food; 26. Waste, recycling and environmental remediation

4.3. Workshop on the selection of key technologies

4.3.1. Energy technologies

Using the methodology described in Section 2.3.3, delegates selected the top 9 of the 16 energy technologies. There were differing opinions about the placing of nuclear energy and clean coal technologies. Although it was agreed that they had significant impact on OSH, there was disagreement about the green credentials of these technologies and on the usefulness of having Phase 3 technology workshops focused on these. However, it was emphasised that not having a workshop dedicated to these technologies in Phase 3 does not mean that they are not important components of the future and should not be part of the 'landscape' of the scenarios produced, but simply that there would be no workshop specifically dedicated to them in Phase 3. Eventually, they were discarded for the Phase 3 workshops. The top nine energy-related technologies selected were (Annex 6, reference no. in brackets):

- wind energy (industrial scale) (1);
- solar energy (industrial scale) (3);
- bioenergy (industrial scale) (5);
- carbon capture and storage (7);
- electricity transmission (11);
- electricity storage (12);
- battery technology (14);
- hydrogen and fuel cells (15);
- domestic and small-scale applications of emerging energy technologies (16).

4.3.2. Non-energy technologies

In a similar prioritisation exercise for non-energy technologies, delegates merged nanotechnologies and nanomaterials with novel materials, extractive technologies with environmental remediation, and waste management with recycling.

The nine technologies judged to be the most important were the following (Annex 6, reference no. in brackets):

- biotechnologies (17);
- nanotechnologies and green nanomaterials/novel materials (20/23);
- robotics and artificial intelligence (21);
- green transport technologies (25);
- green manufacturing technologies (26);
- green construction technologies (27);
- extractive technologies/environmental remediation (28/32);
- agriculture, forestry and food (29); and
- waste management and recycling (30/31).

4.3.3. Voting on selected technologies

Feedback from Session 1 (selection of nine energy-related technologies) and Session 2 (selection of nine non-energy-related technologies) (Section 2.3.3) now follows.

Wind energy (industrial scale)

The current model of large-scale onshore and offshore wind farms is intended to continue over the decade, with wind supplying 20 % of electricity demand by 2020. There was some uncertainty as to whether the speed of the roll-out would meet this target. For example, in the United Kingdom, 32 000 offshore turbines will need to be built by 2020 to meet targets. This will require about 40 transfers of workers to offshore sites every day, with the risk of transport accidents. Offshore accommodation will need to be built. Dependencies for progress were political support, local acceptance (onshore), feed-in tariffs and funding and development of the grid. Big companies would be the major player. A comparison was drawn between OSH issues of offshore wind and those of offshore oil industries.

Solar PV (industrial scale)

The materials used are complex and expensive, so development was seen as fairly flat in the absence of a 'step change' technological development, with increasing uptake of existing technology. Uncertainties and dependencies included government incentives such as feed-in tariffs, availability of key elements and cost versus other renewables.

Bioenergy (industrial scale)

There is a diversity of producers and technologies, with companies struggling to identify the best. Performing risk assessments in this area is challenging. There are quality issues with biogas for injection into the grid. Biogas has low energy density, so large quantities are needed, leading to transport and storage issues. It is better for the plant to be near the source. Other issues include skills, incentives and the cost of energy. Many SMEs will be producing energy (e.g. biodiesel) in addition to their core activities, with consequent OSH challenges.

Carbon capture and storage

The demonstration of large-scale capture, large-scale storage and small-scale transport should occur towards 2020. Large-scale roll-out may possibly arrive in the early 2020s. Issues to be dealt with include cross-border matters, ownership of risk, maintenance, integrity and decommissioning.

Electricity transmission

Developments are expected in materials (e.g. cables), superconductors to reduce losses, high voltage to low voltage transformation, the introduction of direct current (DC) to the grid, increasing European interconnection and smart meters in most homes by 2020. Uncertainties discussed were standards for equipment, increasing microgeneration and the need for cooperation between countries. OSH issues included domestic and small-scale installation, including do-it-yourself installations, skills shortages, and the danger of working on live equipment as two-way grid connections may not be under the control of the installer, and the pressure of targets leading to a 'tail-end dash'.

Electricity storage technologies

There are many competing technologies with no clear winner. Progress will be evolutionary, not revolutionary. Political and economic support are needed to guarantee a financial return. How will storage be paid for? Competencies and skills will be important.

Battery technology

Government support and the EU Batteries Directive are driving development. New materials are leading to improved lifetimes, capacities and charge cycles. Electric cars will be the major application, with the need for replacement/recharging stations (car batteries may be leased and exchanged rather than recharged in the car). Cars could be used for energy storage. Large-scale recycling will be necessary. Disruption could be caused by lithium shortages.

Hydrogen and fuel cells

Hydrogen is a 'step change' technology, and there is investment from governments in hydrogen, but electric cars receive more, and are a major competitor. Increasing energy costs in the future could make a difference. Cheaper ways to make and store hydrogen are needed and government support for development of the infrastructure is unlikely without government funding. New materials are needed to improve the efficiency and lifetime of fuel cells.

Domestic and small-scale applications of emerging energy technologies

A range of technologies is involved — solar, hydrogen, wind, and geothermal. There is a major role for self-employed contractors/small companies and/or self-installation. Accreditation and control over installers will be important, as will the structure of the labour market. Other factors include skills, knowledge, incentives, payback time, the cost of oil and electricity and development of the grid.

Biotechnologies

Developments will include high-value niche products, further development of biorefining, more efficient yeasts and bacteria, combined plant with biotechnology, biomass CHP, nanotechnology and energy. Uncertainties surround 'traditional' industry adapting to new feed-stocks and new production processes, competition between food versus biofuels for land use, siting of infrastructure near the source of raw materials and the price of oil as a driver.

Nanotechnologies and green nanomaterials/novel materials

Increasing applications are being seen and more are expected, although these are constrained by limitations on bulk manufacture. Health implications are not well researched yet, and there is no legislation specifically on nanomaterials. Exposure will grow with increasing potential for OSH issues to arise.

Robotics and artificial intelligence

A move from industrial to service applications (agriculture, military, medical) and then domestic applications over the period to 2020 was discussed. Uncertainties were the availability of appropriate standards and legislation, economic aspects and the human-machine interface (e.g. how people interact safely with free-roaming and autonomous robots).

Green transport technologies

The major issues are alternative fuels and an increasing role for IT — flow control, congestion management, many-to-many freight journey bids, interactive cars, driverless cars, driver aids. Other factors are road pricing and ownership models.

Green manufacturing technologies

There is expected to be less mass manufacture but more mass customisation, using adaptable processes, flexible technologies and an adaptable skills base with a constant churning of skills. There will be more smart goods, IT-enabled goods, pervasive computing and smart packaging. The human-machine interface will be important. The effects of recycling legislation will see these costs internalised in the price of goods.

Green construction technologies

There will be growth in prefabrication, the use of new materials and new processes, varying across Europe. Retrofitting will be a growth area, covering insulation, energy generation and storage. Progress will be dependent on economic growth and political incentives. The potential role of migrant workers was mentioned.

Extractive technologies and environmental remediation

No clear view on developments in this area was expressed. Public opinion will be important, as will economic aspects. Who will undertake landfill mining? How will it be controlled? Workforce skills will be important.

Agriculture, forestry and food

Better yields of food will be needed. Increased introduction of robot technologies will be seen, which can identify and discriminate between weeds and crops and use accurate targeting of chemicals, thereby reducing use and exposure. There may be public fears, leading to bioenergy/fuel and GM debates. Traceability of produce will be important. There will be an increasing role for big companies.

Waste management and recycling

Increasing activity is expected as raw material costs rise and existing plants work below capacity. Legislation is also a driver. There is expected to be more food waste collection, more incineration, and more digesters. More items will be designed for recycling (i.e. easier to dismantle). Manufacturers will have the responsibility to recycle: there will be more closed-loop businesses. In addition, waste disposal is turning into a new branch of the energy sector. Associated hazards include impure gas production, explosion risks if the organisms used do not produce the gas intended, dangerous substances, confined spaces and musculoskeletal disorders (MSDs).

In the final session of the workshop, delegates were asked to select their top technology (green vote) and seven others (red votes) out of this list of 18. Each delegate had to vote for at least two energy technologies and two non-energy technologies, and could not cast more than one vote for any single technology.

The voting exercise was followed by a plenary discussion, which reviewed the outcome of the vote and considered the implications for Phase 3 of the project. The result of the voting exercise was intended to inform the decision on which technologies to take forward to Phase 3. It was not an election in the sense that the top scoring technologies would automatically proceed. With a relatively small number of participants, the green votes alone would be unlikely to give statistically significant results, but might be useful in a tiebreak situation. The final decision would be taken by the project team and EU-OSHA, taking into account the voting, the earlier interviews and Internet survey and the need to have a useful range of technologies with the potential to trigger useful discussions in Phase 3 and to provide adequate variation between outcomes in the different scenarios.

The results of the workshop vote and the outcome of the plenary discussion at the workshop, together with data from the interviews and the Internet survey, are shown in Table 5.

Results of workshop voting

The 10 highest scoring technologies (total of green and red votes) at the workshop were:

- waste and recycling 12
- construction technologies 11
- nanotechnologies and nanomaterials 10
- agriculture, forestry and food 9
- transport technologies 9
- biotechnologies 8
- manufacturing technologies 8
- energy transmission 8
- wind energy 7
- bioenergy 7

In the final workshop discussion, the following points were made.

- There was some surprise that energy topics did not feature as prominently as had been expected. This could be a consequence of the way energy technologies had been considered individually, whereas other areas had been treated as sectors or technology groupings. Thus, the energy vote had been split.
- The distinction between energy transmission (see Annex 6, No. 12 for more details of the aspects it includes) and energy storage (Annex 6, No. 13) was not helpful and these could be merged. If this were done, then domestic and small-scale applications of energy technologies (Annex 6, No. 16) should be included also. Battery technology (Annex 6, No. 14) had been introduced as a separate topic because it was felt that it was such an important topic, but it would, in any case, be part of energy storage. Thus, a combined energy topic comprising Nos 12, 13, 14 and 16 was proposed. However, it was felt that this combined topic would need a longer workshop than for the other technologies in Phase 3.
- Construction technologies should focus on buildings, rather than infrastructure in order to give greater emphasis to energy efficiency measures.
- Robotics, automation and artificial intelligence, while not a high scorer in its own right, could usefully be considered alongside manufacturing technologies.
- Wind energy and solar energy were judged to be of medium priority. The low score obtained by solar energy was surprising.
- Carbon capture and storage, hydrogen and fuel cells, and extractive technologies/environmental remediation obtained low scores in the workshop vote, the interviews and the Internet survey and were, therefore, not selected for Phase 3.

4.4. Selection of the key technologies for Phase 3

The final selection of the key technologies for the Phase 3 workshops was made by the project team in consultation with EU-OSHA. The following additional points were agreed.

- Wind energy had failed to make the top eight in the workshop but ranked among the top nine (equal with bioenergy) and had, in addition, been cited often as high priority in the Phase 1 interviews and scored well in the Phase 2 interviews and the Internet survey.
- Bioenergy had not made the top eight in its own right, but ranked among the top nine (equal with wind energy) and could be merged with biotechnologies in a single topic dealing with energy applications of biotechnologies.
- Nanotechnologies and nanomaterials scored highly at the workshop, in the interviews and in the Internet survey. However, it was felt that such a broad topic, featuring as it does in many of the other technologies and technology areas, and whose applications and OSH implications are already the subject of a large body of research and conferences, would not be well served in a single workshop of the format planned for Phase 3. In fact, it was felt it was such a major and transversal issue actually found in almost all other technologies/technological applications selected for the Phase 3 workshops, that it should be addressed in each of these workshops in relation to the specific sector and applications they will address. Indeed, as mentioned previously, not having a workshop on a specific technology does not mean that it is not an important component of the future and of the scenarios produced in this project.
- Agriculture, forestry and food, although scoring highly at the workshop, had hitherto attracted little interest. It would, therefore, not be the focus of a specific workshop in Phase 3.

Thus, a final list for the Phase 3 workshops was compiled:

- waste and recycling technologies;
- green construction technologies (buildings);
- green transport technologies;
- bioenergy and the energy applications of biotechnology;

- green manufacturing technologies and processes/robotics and automation;
- decentralised domestic and small-scale energy generation; energy storage, including batteries; and energy transmission and distribution (longer workshop);
- wind energy;
- nanomaterials as a horizontal issue to be considered in all workshops.

Table 5: **Results of the workshop votes, initial conclusions, interviews and Internet survey**

Technology*	First choice workshop votes (green votes)	Other workshop votes (red votes)	Workshop conclusions on inclusion for Phase 3 workshops	Interview votes	Internet survey votes
(1) Wind energy (Industrial scale)	0	7	Undecided	2	6
(3) Solar photovoltaic (Industrial scale)	1	1	Undecided	0	0
(5) Bioenergy (Industrial scale)	3	4	Yes	0	0
(8) Carbon capture and storage	0	2	No	3	2
(12) Energy transmission	0	8	Yes (combine with 13, 14 and 16)	0	2
(13) Energy storage and recovery	4	2	Yes (combine with 12, 14 and 16)	0	0
(14) Battery technology	0	4	Yes (combine with 12, 13 and 16)	1	0
(15) Hydrogen and fuel cells	0	4	No	0	1
(16) Domestic and small-scale energy	1	4	Yes (combine with 12, 13 and14); also linked to construction	2	1
(17) Biotechnologies	1	7	Yes	2	1
(20) Nanotechnologies and nanomaterials	2	8	Yes	7	8
(21) Robotics, automation and artificial intelligence	0	4	(Aspects to be considered with 26)	1	1
(25) Transport technologies	0	9	Yes	0	1
(26) Manufacturing technologies	1	7	Yes (to include aspects of 21)	0	0
(27) Construction technologies (buildings)	1	10	Yes	0	0
(28 and 32) Extractive technologies; environmental remediation	0	3	No	N/A	N/A
(29) Agriculture, forestry and food	0	9	Yes	0	1
(30 and 31) Waste management and recycling	1	11	Yes	2	4

NB: * Numbers in brackets refer to the technology description in Annex 6.

5. Phase 3: Scenarios

5.1. Introduction to the three scenarios

The following sections describe three scenarios for evaluating the OSH implications of new and emerging technologies in the context of the 'changing world', taking into account the scientific, societal and economic context. They have been developed specifically to explore green jobs in Europe.

Each full scenario consists of a base scenario (Section 5.3), supplemented with descriptions of how the nine technologies identified in Phase 2 might have developed within that scenario and what are the OSH implications (Section 5.4).

During the construction of the scenarios, the year 2025 was considered rather than 2020 as in the project title, in order to stretch thinking during the construction of the scenarios so that changes happening after 2020, the early signs of which could emerge in 2020, would be considered.

5.2. Constructing the base scenarios

The base scenarios were built on an analysis of the 16 key drivers of future change identified in Phase 1 as having the greatest importance to shaping the future of green jobs in Europe. They were developed in an iterative process as they were used and tested in the Phase 3 workshops, and the feedback from these workshops then served to refine the description of the base scenarios presented in Section 5.4.

5.2.1. Analysing the drivers of change

The first step in generating the base scenarios was to select the scenario axes, which define the framework for generating the scenarios.

To select the axes, each of the 16 drivers was taken in turn and the uncertainty inherent identified within that driver over the period to 2025. As an illustration, consider the driver of economic growth:

Economic growth — the state of European economies will affect the availability of resources with which to tackle environmental issues and to invest in new technologies

The pattern of economic growth over the time frame could vary significantly:

- there could be steady economic growth across the EU;
- there could be wild swings of activity with economic booms and busts; or
- Europe could grow strongly whilst the rest of the world stagnated, or vice versa.

The possible variations are large, and the scenario-generation process requires some simplification. Here, it was assumed that overall economic growth was more or less uniform across Europe, and that economic growth elsewhere in the world followed the same steady pattern as growth in Europe.

Under this simplified assumption, the main uncertainty is now whether overall economic growth (both in Europe and globally) would be high or low over that period (Table 6). These two outcomes are given as two possible end points to the economic growth driver.

We repeated this exercise and assigned two plausible 'High' and 'Low' outcomes for each of the 16 drivers.

5.2.2. Choosing scenario axes

On examination, 12 of the 16 drivers and associated outcomes were seen to fall naturally into three broad clusters centred on three themes;

- economic growth;
- green culture and energy efficiency; and
- innovation in green technology.

Each of the 12 drivers was therefore assigned two possible outcomes consistent with the following 'High' and 'Low' state for each cluster (Table 7):

- high economic growth, and low economic growth;
- strong green values (Green), and weak green values (Brown); and
- fast innovation in green technologies (High-tech) and slow innovation (Low-tech).

Each cluster was associated with a single axis, the extremities of which were defined by the 'Low' and 'High' states of the cluster. These axes could then be combined to define the base scenarios.

The other four drivers (nuclear energy, demographics, energy security, and international issues) did not fall into these three clusters but were later included in the scenarios by matching plausible outcomes with the emerging scenario stories (Section 5.2.5).

Table 6: **Plausible high and low outcomes for economic growth in Europe**

Low growth and sovereign debt problems	**Economic growth** — the state of European economies will affect the availability of resources with which to tackle environmental issues and to invest in new technologies	High growth

Table 7: **Clusters of drivers, and associated LOW and HIGH outcomes**

LOW outcome	Driver	HIGH outcome
Low growth	**Economic**	**High growth**
Low growth (in Europe and globally) sovereign debt problems	**Economic growth** — the state of European economies will affect the availability of resources with which to tackle environmental issues and to invest in new technologies	High growth (in Europe and globally)
'Brown' Weak green values	**Green culture/energy efficiency**	**'Green' Strong green values**
Indifference to climate change: seen as not man-made Public does not support energy-efficient practices	**Public opinion** — the public's awareness and views on climate change and the extent to which they believe human activity is responsible, views on other environmental matters and attitudes to risk	Panic over climate change: seen as man-made Public supports energy-efficient practices
Consumers do not demand green products	**Consumer behaviour** — whether consumers demonstrate their support for green activities through their demand for green products, by their use of energy efficiency measures, changing their travelling patterns, supporting recycling schemes, etc.	Consumers demand green products
Environmental degradation No one cares	**Environment** — carbon dioxide emissions and the physical effects of climate change, including natural disasters and the shortage of natural resources other than energy (e.g. water) and the need to manage them better, which may drive public opinion and influence government policies	Environmental recovery Public concern (activism)
Laissez-faire Ineffective, wasteful interventions	**Government incentives** — having clear and stable energy policies to encourage investment, promoting R & D, and offering grants, subsidies, loans, technical assistance and other inducements to promote green activities	Effective intervention Stable effective policies
Low-carbon taxes Lax pollution regulations and emissions taxes	**Government controls** — taxes, carbon pricing, removal of subsidies and increased duties on fossil fuels, legislation and other instruments to penalise polluting activities	High-carbon taxes Strict pollution regulations and emissions taxes
Increasing energy use and intensity Waste of energy	**Energy efficiency improvements** — the construction of energy-efficient buildings, the retrofitting of insulation in older buildings and the promotion of public transport and less energy-demanding manufacturing	Efficiency measures embraced Declining energy consumption Insulation
No increase in recycling activity	**Growth in waste management and recycling** — driven by declining natural resources, environmental legislation and public opinion, this sector is likely to continue to grow: this is a dangerous sector in which to work	More and more recycling Legislation Less landfill

LOW outcome	Driver	HIGH outcome
Low tech	**Innovation in green technology**	**High tech**
Little progress	**Renewable energy technologies** — progress in the development, and the availability, of renewable energy technologies	Substantial progress
No take-up Lack of investment Outside the EU	**Other technologies** — technologies other than energy technologies that may offer environmental advantages may also bring health and safety risks (e.g. nanotechnologies, biotechnologies, green chemistry, and sustainable manufacturing)	Investment Development Progress within EU
Low levels of investment Lack of storage Little flexibility to handle local generation	**Electricity distribution, storage and use** — the development and availability of technology to cope with increased use of electricity in buildings and vehicles, with distributed generation and with the variability of output from renewable sources	Transformed intelligent grid Energy storage Local generation
CCS doesn't work Clean coal doesn't work	**Fossil fuel technologies** — the development and availability of technologies to allow continued use of fossil fuels within carbon limits	CCS works Clean coal works

5.2.3. Defining the scenario space

Economic growth and green values axes

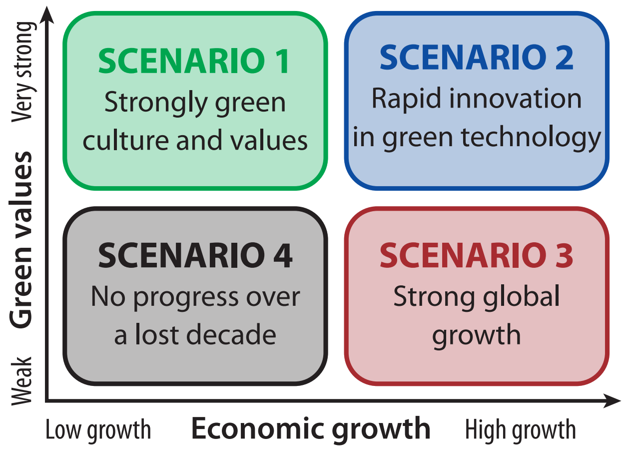
After much debate, the two axes of Economic growth and Green values were defined as starting points. Selecting 'Low' or 'High' values for each of these two axes generated four scenarios, shown in Table 8 with their eventual names.

This combination gives a classic 'scenario cross' layout with four scenarios that can be plotted graphically (Figure 3).

Table 8: **Summary of the base scenario definitions**

Axis	Scenarios			
	Win-Win	**Bonus World**	**Deep Green**	**Scenario 4**
Economic growth	High	High	Low	Low
Green values	Strong	Weak	Strong	Weak

Figure 3: **Four scenarios plotted by Economic growth v Green values axes**

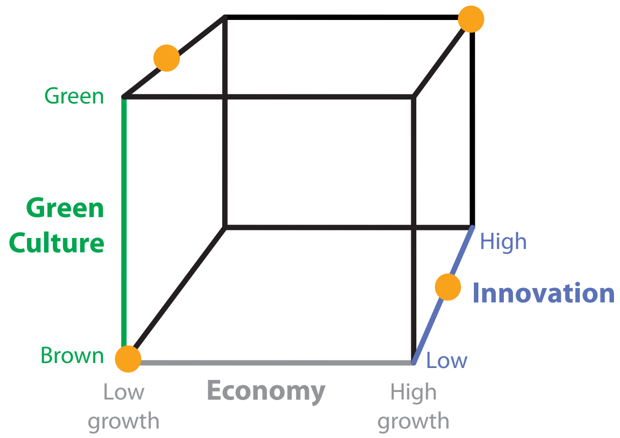


Adding the green technology/innovation axis

In theory, each of the four boxes in Figure 3 would be associated with two end points on the technology axis, giving eight scenarios in all, but some of these combinations were not consistent. For example, if the human race were both to achieve high economic growth and live by strong green values, then a step change in the rate of innovation in green technologies would be needed. Similarly, a world of low growth and uncaring green values is unlikely to be associated with a lot of new green technologies.

Plotting possible combinations of the three axes on a cube gave four potential and coherent scenarios, shown as orange dots in Figure 4. It was found that the Deep Green and Bonus World scenarios were more realistic if a medium level of innovation was assumed but, of course, the nature of that innovation would be very different in each world.

Figure 4: **Three-dimensional view of scenario axes**



These four potential scenarios were then considered jointly with EU-OSHA to determine their respective value in assessing the new and emerging risks to OSH associated with new technologies in green jobs by 2020. Based on this, it was decided not to use Scenario 4 (low growth, low green culture and low innovation), as there would have relatively few new and emerging risks from new technologies in green jobs as a result of low innovation and low green values. The development of Scenario 4 was therefore curtailed early in Phase 3 but, for completeness of the project, an early draft development is described in Annex 12.

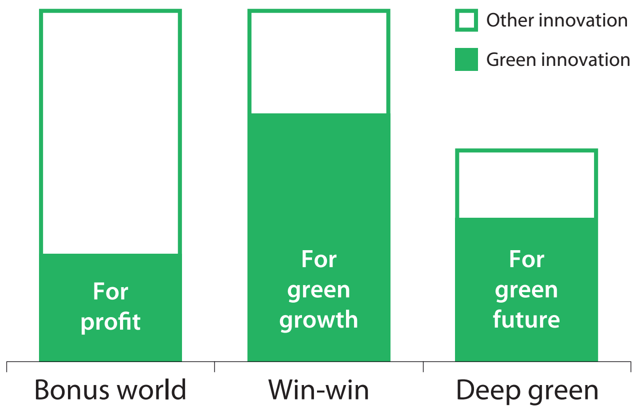
Additionally, it was discussed that the level of Green Innovation was likely to be slightly higher in Deep Green than in Bonus World. These levels were, therefore, specified as 'Medium +' and 'Medium –' respectively. (Note that these descriptions are subjective assessments, and not quantified measures.) This gave a final definition of the three remaining scenarios (Table 9).

Table 9: **Summary of remaining scenario definitions**

Axis	Win-Win	Bonus World	Deep Green
Economic growth	High	High	Low
Green values	Strong	Weak	Strong
Rate of innovation in green technologies	High	Medium –	Medium +

Figure 5 shows how, in three of the scenarios, the level of green innovation is a variable proportion of the total innovation. Overall, levels of innovation in society are related to long-term economic growth. Because each scenario is different, not only the level but also the focus of green innovation will be different.

Figure 5: **Green innovation shown as a proportion of total innovation**



NB: This is a purely diagrammatic representation.

5.2.4. Defining the Scenarios

At the end of this iterative process, the three axes, and the place that each scenario occupies on each axis, were defined. This was the starting point for creating the scenario storyline. But note that in developing the scenario narrative, the simple definitions for each axis were influenced by the effects of interactions with the other axes to create a different story in each case.

Note again that the scenario narratives presented are not evidence-based conclusions, but based on assumptions and their possible consequences. Other stories are equally possible. In the end, there is no right or wrong choice, since the future may contain elements of each scenario. Scenarios are tools to generate discussion and insight into different elements of the future, rather than predictions.

Economic growth

Economic growth includes the external impact of both global growth and growth in Europe.

High growth

Europe and other OECD states return to an average real growth rate of 3 % per year (OECD, 2012). India and China maintain their growth of 8–10 % per year, while the rest of the world maintains the high growth rates achieved in the first decade of the century of around 6 % per year.

There are high and growing levels of overall consumption and mobility. There are high levels of overall innovation (but not necessarily 'green' innovation).

High levels of investment in infrastructure mean that any new technologies are rolled out at a high rate.

Low growth

Europe and other OECD countries achieve little or zero economic growth in real terms. The BRIC countries (Brazil, Russia, India and China) suffer a retrenchment after the boom years of 2000–10, and revert to the more usual boom-bust cycles of emerging markets, averaging half their previous rates of growth at around 5 % per year. The rest of the world manages growth that more or less keeps pace with growing populations, so that incomes per capita are static in real terms.

Low levels of investment in infrastructure mean that even the technology that is available is not yet widely installed (e.g. in buildings and energy networks). There are low levels of overall innovation.

Unqualified workers cut back on spending and are more likely to stay put. If their skills are in demand, they are more likely to seek opportunities outside Europe.

Green values

Green values relate to attitudes, the willingness of people and organisations to change their behaviour to achieve green outcomes, and the willingness of governments to implement regulatory and fiscal policies to promote green activities.

Strong green values

Growing public panic over climate change and other environmental threats gives governments a mandate to legislate for deeply green measures. Green behaviour by corporations and individuals is strongly approved of by the general population.

Advances in science and improved environmental models show just how vulnerable the human race will be to climate change and the loss of ecosystems services.

Repeated resource shortages (e.g. food, commodities, minerals, water, energy) drive home the Green message.

Weak green values

Environmental degradation is seen as an unavoidable result of progress. Advances in science and improved environmental models show that climate change and the loss of ecosystems services will not have major consequences in the next 50 years anyway.

Fossil fuel energy and other resources remain available at a price that encourages investment in new sources of supply.

Innovation in green technologies

The third axis is the rate of innovation in green technologies, a measure of development and exploitation of green technologies that will deliver the following:

- reduced resource use, especially of non-renewable resources;
- less pollution; and
- fewer environmental impacts.

This axis is influenced by both green values and economic growth, so the interactions between them must be taken into account in the scenario storylines. Because each scenario is different, not only the level, but also the focus of green innovation will be different and, later, will be adapted case by case.

High rate of innovation in green technologies

The trajectories of green technologies accelerate as more and more young engineers and scientists qualify around the world, and developments in every field are published and propagated immediately.

Energy science continues to deliver, and the path to a zero-carbon future is now clear, even though the installed base is quite low so far.

Moore's Law continues at its previous rate, where the number of components on an integrated circuit doubles every 18 months, using ever-less energy and materials per unit of processing power. Biosciences continue to develop at an increasing rate, and start to deliver new green chemistries and processes, medical treatments, improved crop yields, and other unimagined benefits.

New buildings are smart, and energy grids have local generation and storage capabilities.

Medium rate of innovation in green technologies

Science continues to deliver advances in green technologies but, as always, it takes some time for new discoveries to be incorporated into new products and processes and yet more time for them to be implemented worldwide.

Energy sciences continue to deliver, but it is still not clear how or whether a zero-carbon future can be achieved without serious compromises.

Improvements in integrated circuits continue, but at a slower rate than Moore's Law. The number of components on an integrated circuit now doubles every 3 years. Biosciences continue to develop, and are starting to deliver new green chemistries and processes, some medical treatments, improved crops, and other benefits, but the time taken from concept to roll-out is still very long.

Some new buildings are smart, and energy grids are starting to get local generation and storage capabilities.

Low rate of innovation in green technologies (used in Annex 12: Scenario 4)

Green and other technology is taking longer and longer to deliver on its promises.

In energy sciences, new battery and PV technologies are developed, but only by using ever-rarer minerals that are not available in the necessary volumes. CCS and clean coal are not yet proven, and there are serious and growing doubts if they would ever work. After several disasters, the nuclear power industry is in a state of retrenchment.

Improvements in integrated circuits continue, but at a much slower rate than Moore's Law, as integrated circuits reach their physical limits. Chip components are now doubling only every 5 years. Biosciences continue to produce new findings and new organisms, but many products from living systems are self-limiting, in the same way that overuse of antibiotics provokes the development of resistance.

5.2.5. Allocating the remaining drivers

The remaining four drivers were allocated to the three scenarios in a similar manner. In an iterative process, we defined plausible alternative outcomes for each driver, as shown in Table 10.

The most plausible outcome was then allocated to each scenario, adjusting the outcome to best match the emerging scenario storyline (Table 11).

Table 10: **Outcomes of remaining drivers**

Outcome A	Other drivers not included in the scenario axes	Outcome B
No new nuclear	**Nuclear energy** — whether or not nuclear energy is regarded as green, the extent of its availability will affect the creation of green jobs	Big nuclear programme (With either traditional designs, or new designs that are inherently safer)
Static populations (in Europe)	**Demographics and the workforce** — increasing population and changing lifestyles (e.g. increasing urbanisation) will drive the need for energy and, therefore, the need for green activities: ageing of the population may result in a loss of skills with a resulting increase in risk	High migration
Ready supplies of energy (at a price)	**Energy security issues** — the need for energy security and the desire to reduce dependency on imported energy will drive energy efficiency and the growth of renewable energy sources	Concern over supply Incentives to diversify
Free trade	**International issues** — globalisation and the extent to which it grows or possibly recedes in the wake of the recession will affect competition for scarce natural resources, driving the need for green activities	Protectionism

Table 11: **Allocation of remaining drivers to scenarios**

DRIVER	Outcome in Win-Win	Outcome in Bonus World	Outcome in Deep Green
Nuclear energy — whether or not nuclear energy is regarded as green, the extent of its availability will affect the creation of green jobs	Big nuclear programme started (with new designs that are inherently safer)	Big nuclear programme started (with traditional designs)	No new nuclear
Demographics and the workforce — increasing population and changing lifestyles (e.g. increasing urbanisation) will drive the need for energy and therefore the need for green activities: ageing of the population may result in a loss of skills with a resulting increase in risk	Static populations (in Europe)	High migration (especially immigration of poorly qualified people into Europe)	Medium migration (especially 'brain drain' emigration out of Europe)
Energy Security Issues — the need for energy security and the desire to reduce dependency on imported energy will drive energy efficiency and the growth of renewable energy sources	Concern over supply Incentives to diversify	Ready supplies of energy (but at high prices reflecting competition for resources)	Concern over supply Incentives to diversify
International issues — globalisation and the extent to which it grows or possibly recedes in the wake of the recession will affect competition for scarce natural resources, driving the need for green activities	Free trade	Free trade	Protectionism

5.3. Base scenarios (6)

Summary of base scenarios

Win-Win

High economic growth — Strongly green values — High green innovation

Green growth is sustainable, by combining economic, social and environmental goals. Green activities are seen as a major contribution to economic growth rather than simply as a cost; and technology has delivered on its promise to make green growth affordable and achievable. A high proportion of jobs are green and they are valued for both their economic and green outcomes.

Bonus World

High economic growth — Low green values — Medium green innovation

Despite claims of green principles, people have, in general, preferred the route of short-term material affluence when faced with the cost of going green. Green jobs are in areas where they achieve the required financial returns. Technology has helped the world to be more efficient in its use of resources, but this efficiency has merely translated into increased levels of material consumption. Carbon emissions and resource use are still rising.

Deep Green

Low economic growth — Strongly green values — Medium green innovation

Green production and consumption are valued by the public sufficiently for governments to have an incentive to deliver them, even at the cost of short-term economic growth. Green investment and green activities are seen as costs that must be borne, and compromises in lifestyle are seen as necessary. A high proportion of jobs are green and the benefits they produce are valued. Technology is helping to deliver a green future.

5.3.1. Win-Win (Base scenario)

High growth — Strongly green values — High green innovation

Green growth is sustainable. Green activities are seen as a major contribution to economic growth rather than as a cost.

Description

Summary

Greenness is valued by people sufficiently for governments and business to have an incentive to deliver it; and technology has delivered on its promise to make green growth achievable. The path to a sustainable and low-carbon future is now clear.

High growth means that green investment is affordable and is being made. This necessary investment includes: new green infrastructure (buildings, energy systems, transport networks); green production methods (sustainable sourcing, whole life cycle design, low resource use, etc.); and green consumption patterns (valuing low impact products and services).

High economic growth

People in Europe are now about 50 % richer in real terms than they were in 2012. For 15 years, OECD states have enjoyed steady economic growth equal to the average in the decade before the 2008 economic crisis (i.e. 2.8 % real growth per year) (OECD, 2012). India and China have maintained historical growth rates (8–10 % per year); other developing countries have maintained the high growth rates achieved in the first decade of the century (of around 6 % per year).

Corporate profitability and access to finance have supported high levels of investment in infrastructure, so that much of the present infrastructure has been renewed relatively recently or is newly built.

New technologies are rapidly rolled-out and become widely available soon after they have been developed.

Strongly green values

People, in general, strongly approve of green behaviour by corporations and by individuals.

Advances in climate science have shown just how vulnerable the human race will be to climate change, and growing public concerns have given governments a mandate to legislate for deep and progressive cuts in carbon emissions.

Similarly, improvements to environmental models have highlighted the cost of losing other ecosystems services (fisheries, soil, etc.), reinforcing wider environmental concerns. Repeated concerns over resource shortages (e.g. food, commodities, minerals, water, energy) have driven home the Green message.

High innovation in green technologies

The trajectory of technology has accelerated as more and more young engineers and scientists qualify around the world. Developments in every field are published rapidly and propagated in minimal timescales.

(6) Picture credits: *Wikimedia Commons users:* Kirk, Licence CC BY-SA 2.5; Állatka; Ton1, Licence CC BY-SA 3.0.

Energy science has transformed energy efficiency and carbon footprints; and the path to a zero-carbon future is now clear, even though this has not yet been achieved.

Other drivers

Energy policy in Europe is driven by concerns over supply. As part of the urge to diversify energy sources, renewable energy systems are widespread and a nuclear programme has been started with new inherently safer designs, but no new reactors are yet operating.

Global trade is very easy and free from restrictions.

The population is highly mobile, but total overall immigration into Europe is roughly balanced by emigration out of Europe.

Implications

Development of new technology

In the Win-Win scenario, achieving both high economic growth and green outcomes requires extensive and high-quality innovation in green technologies.

Innovation is directed towards the profit motive, whilst still achieving green outcomes.

Scientific research and technological invention are driven mainly by the prospect of making money, with the expectation that commercial success will depend on offering green products and services. New products are green by design because they would not have a market if they were not green.

Technological developments are adopted into new products and services by companies who see a new market for them. Greenness and sustainability are designed into these from the start. Consumers buy them because they offer new functions and opportunities for consumption that they didn't have before and deliver lower costs and lower resource footprints.

Government support for innovation is driven by the promise of new green jobs and environmentally sound sustainable economic growth.

Implications for green jobs

There are many green jobs.

Governments assign a high economic value to externalities (e.g. pollution and carbon taxes, and by valuing ecosystem services), which supports green jobs.

Companies actively seek out, and achieve, the economic benefits of waste-free processes. They calculate a positive economic business case for environmentally sound activities and Corporate Social Responsibility (CSR). They apply project discount rates that give a higher value to the long-term sustainability of the enterprise.

The choices consumers make encourage green employment, and governments have a mandate to regulate in favour of green jobs and even to subsidise them.

The greening of economies has introduced many new processes and enterprises into what are now green jobs.

Implications for society and work

… of high economic growth:

- high and growing levels of overall economic activity but with increased efficiency and reduced resource footprints;
- high levels of employment and higher corporate profits provide the tax revenues that allow European governments to address the increasing demands for welfare;
- people feel prosperous; and
- businesses focus on investment to generate future profits.

… of strongly green values:

- people value the environment and nature;
- green attitudes are likely to coincide with preferences for self-reliance, holistic wellness and self-care; and
- the greening of society introduces many new processes and enterprises across the economic spectrum.

… of a high rate of green innovation:

- new jobs and new products are being introduced all the time, at a rapid rate.

Implications for OSH

… of high economic growth:

- as people are richer, cost-benefit analysis will assign a higher economic value to the preservation of human life and of well-being; and
- the economy can afford the investments needed to make infrastructure and business processes safer and more accessible.

… of strongly green values:

- environmental hazards are seen by society as of particular concern, especially if released into the general environment, rather than contained in the place of use;
- if preferences for self-reliance, holistic wellness and self-care are translated to the OSH arena, the most effective

OSH interventions may be self-regulation, education and cooperation; and

- new processes and enterprises across the economic spectrum, introduced by the greening of society, all require new OSH procedures and training.

… of a high rate of green innovation:

- the high pace of innovation is transforming the nature of work and of working lives in many ways that have an equally transformative effect on OSH;
- extensive new skills are needed to develop, produce, install, maintain and dispose of new innovations;
- rapid roll-out of new technologies, new products, and the new jobs linked to these, if not designed taking OSH into consideration, mean that a wider population may be exposed to potential new hazards and risks in shorter timescales; OSH assessments need to be done ever earlier in product development cycles in order to catch issues before they have been rolled out globally; there is an opportunity to improve OSH by designing in safety from the start.

5.3.2. Bonus World (Base scenario)

High growth — Weak green values — Medium green innovation (–)

Despite the green rhetoric, most people will prefer the route of short-term material affluence when faced with the unavoidable cost of going green.

Description

Summary

When faced with the costs, people do not value greenness sufficiently for governments or business to have an incentive to deliver it. People have always preferred economic growth, and new technology has, in general, not delivered ways to achieve growth in a sustainable manner.

Technology has helped the world to be more efficient in its use of resources, but this efficiency has merely translated into increased consumption. Carbon emissions are still rising everywhere, as is the use of resources.

Companies pursue profits. They undertake environmentally sound activities and implement green processes only when economically advantageous. Governments need corporate profits and a strong economy to deliver their social programmes.

High economic growth

People in Europe are now (in 2025) about 50 % richer in real terms than they were in 2012. For 15 years, OECD states have enjoyed steady economic growth equal to the average in the decade before the 2008 economic crisis (i.e. 2.8 % real growth per year) (OECD, 2012). India and China have maintained historical growth rates (8–10 % per year); other developing countries have maintained the high growth rates achieved in the first decade of the century (of around 6 % per year).

Corporate profitability and access to finance have supported high investment in infrastructure, so that much of the present infrastructure has been renewed relatively recently or is newly built.

There is a high level of investment in innovation and new technologies are rapidly rolled out and quickly become widespread.

Weak green values

Some environmental degradation is seen as less important than economic growth and an unavoidable consequence of progress.

Fossil fuel energy and other resources have remained available at prices high enough to have encouraged investment in new sources of supply. The environmental consequences of increased use of resources (minerals, food, energy, etc.) are seen as acceptable and necessary.

Green measures and environmentally sound business practices are still seen as desirable, but funds for green investment are limited to those areas that show a positive accounting return, such as reduced resource use in industrial processes and better insulation in new buildings.

Government support for green practices is limited to charging for the visible externalities of production (e.g. noise, pollution, landfill, congestion).

Most consumers choose green products and services only if they are better or cheaper than the alternatives.

Medium innovation in green technologies (directed towards profits)

Science continues to deliver advances in technology that are adopted into new products and processes. High levels of capital investment mean that capital-intensive technologies can be rolled out quickly.

Energy sciences continue to deliver improvements in efficiency and low-carbon energy, but it is now clear that serious and unacceptable compromises would be needed to achieve a zero-carbon future.

Other drivers

Energy policy in Europe is driven by high energy prices and the expected economic return from any investment. Large commercial nuclear power programmes have started, using proven designs, but no new reactors are yet operating.

Global trade is very easy and free from restrictions.

Migration is running at quite a high level, with high overall levels of immigration of poorly qualified people into Europe.

Implications

Development of new technologies

Innovation is directed towards the profit motive. Scientific research and technological invention are driven mainly by the prospect of making money.

Technological developments are adopted into new products and services by companies who see a profitable market for them. Consumers buy them because they offer new functions and opportunities for consumption that they didn't have before.

Government support for innovation is driven by the promise of new jobs and economic growth.

In Bonus World, there is a high level of overall innovation, but this is driven by a profit motive, so the level of innovation in green technologies is constrained.

Implications for green jobs

Governments have no mandate to regulate in favour of green jobs, let alone to subsidise them. They impose relatively low charges for proven externalities of production: and low charges for landfill and low-carbon taxes are seen as being appropriate and proportionate. These undermine the economics of some green jobs in recycling and alternative energy. However, this is counterbalanced by high prices of raw materials and of energy that support the economics of green jobs in recycling and in making efficient use of resources.

There are a limited number of green jobs, but there is a high volume of waste in Bonus World that needs to be dealt with. Green jobs only exist where they are self-financing — where they are economically profitable in their own right.

Green jobs cannot depend on consumers choosing products or services just because they are green.

Implications for society and work

… of high economic growth:

- high and growing levels of overall consumption and of travel;
- high levels of employment and higher corporate profits have provided the tax revenues that allow European governments to pay for sustainable welfare programmes;
- most people feel prosperous; and
- businesses focus on investing to generate future profits.

… of weak green values:

- people value progress and economic well-being; the environment and nature are important but less so than making money.

… from a medium rate of innovation:

- new jobs and new products are being introduced at a relatively fast rate.

… from combinations of factors:

- high inequalities mean that low-skilled workers (often immigrants) are readily exploited; and
- human performance-enhancing drugs are being used in work settings.

Implications for OSH

In a world based around the profit motive, employers will tend to assess OSH in terms of its return on investment and impact on profits.

Bonus World is less idealistic (less green) and more mindful of the financial liabilities of OSH failures. OSH interventions are more likely to be most effective through regulation (i.e. by raising the cost to the company of unsafe working practices).

Implications for OSH

… of high economic growth:

- the economy can afford the investments needed to make infrastructure and business processes safer and more accessible; and
- rapid roll-out of new technologies and new products means that a wide population is exposed to possible new hazards and risks in short timescales; there will be increased potential OSH risks and skills shortages associated with high rates of change.

… of weak green values:

- if weak green values are reflected in less voter concern for other people, OSH may be an area of relatively low priority for governments.

… of a medium rate of green innovation (but high rate of global innovation):

- new jobs and new products linked to general high rate of innovation may well bring new hazards and risks if not designed taking OSH into consideration: there is an opportunity to improve OSH by designing in safety and health from the start; and
- new technology and newer equipment may also be beneficial to OSH, in particular with regard to safety.

5.3.3. Deep Green (Base scenario)

Low growth — Strong green values — Medium green (+)

Sustainability and greenness are valued by people more than economic growth.

Description

Summary

Greenness is valued by people sufficiently for governments to have an incentive to deliver it, even at the cost of lower economic growth. Green activities are seen as a cost that must be borne. Technology is helping to deliver a green future.

Governments have introduced high taxes on pollution and carbon and other externalities that impact on corporate profits. They have chosen to prioritise the limited available funds towards green measures.

Overall, consumption is less than it would have been otherwise. Low economic growth implies reduced use of resources and reduces the growth of greenhouse gases and pollutants.

Funds for green investment are limited and green outcomes are achieved more by changes in behaviour by corporations and individuals leading to a reduced utilisation of resources.

Low economic growth

People in Europe are now only relatively as rich as they were in 2012. OECD countries have achieved little or zero economic growth in real terms, and many are still facing sovereign debt problems. The BRIC countries (Brazil, Russia, India and China) suffered a retrenchment after the boom years of 2000–10, and reverted to the more usual boom-bust cycles of emerging markets, averaging half their earlier rates of growth (at around 5 % per year). Other developing countries manage growth that more or less keeps pace with their growing populations, so that incomes per capita are static in real terms.

Strongly green values

People, in general, strongly approve of green behaviour by corporations and by other individuals.

Advances in climate science have shown just how vulnerable the human race will be to climate change. Growing public concerns have given governments a mandate to legislate for deep and progressive cuts in carbon emissions.

Similarly, improvements to environmental models have highlighted the cost of losing other ecosystem services (fisheries, soil, etc.), reinforcing wider environmental concerns. Repeated concerns over resource shortages (e.g. food, commodities, minerals, water, energy) have driven home the Green message.

Medium innovation in green technologies (directed towards Greenness)

Science continues to deliver advances in technology but restricted levels of capital investment mean that capital intensive technologies can be slow to roll-out.

Energy sciences continue to deliver improvements in efficiency and low-carbon energy, but it is clear that serious compromises will need to be made to achieve a zero-carbon future.

Other drivers

Energy policy in Europe is driven by concerns over supply as fossil fuel use is reduced, but the Green agenda means that no new nuclear reactors have been built in Europe.

Global trade is suffering from tit-for-tat trade sanctions and protectionism.

Migration is running at a moderate level, especially ‘brain drain’ emigration out of Europe.

Implications

Development of new technologies

In Deep Green, the overall level of investment in all new technologies is constrained by low economic growth. Of what investment there is, a high proportion is directed towards green technologies.

Innovation is directed towards green outcomes. The desire is still to make money but commercial success depends on having appropriately green products and services. New products are green by design because they would not have a market if they were not green.

Scientific research and technological invention are mainly driven by the prospect of saving money or resources; and of delivering green outcomes that satisfy market demands.

Technological developments are adopted into products and services by companies who see a market for them. Consumers buy them because they offer the same functionality at lower cost, or have a lower resource footprint. They also seek products with extended working lives and scope for repair and refurbishment during use.

Government support for innovation is driven by the promise of green jobs and a sustainable economy.

Implications for green jobs

There are many green jobs. Consumers make choices that encourage green employment and governments have a mandate to regulate and to subsidise green jobs.

The greening of the economy and society has introduced many new processes and enterprises into what are now green jobs.

Companies actively seek out, and achieve, the economic benefits of waste-free processes. They calculate a positive economic business case for environmentally sound activities and environmental aspects of CSR. They apply project discount rates that give a higher value to the long-term sustainability of the enterprise.

Implications for society and work

… of low economic growth:

- people are careful with their spending and are less inclined to travel;
- higher unemployment and lower corporate profits have undermined the tax base that used to allow European governments to pay for comprehensive welfare programmes;
- people fear for their jobs; and
- businesses focus on survival and reducing costs.

… of strong green values:

- people value the environment and nature;
- Green attitudes are likely to coincide with preferences for self-reliance, holistic wellness and self-care;
- the greening of the economy and society has introduced many new processes and enterprises across the economic spectrum; with the emphasis on reduced consumption of energy and physical goods, most new jobs are in the service sector.

… of a medium rate of green innovation:

- new jobs and new products are being steadily introduced.

Implications for OSH

… of low economic growth:

- in a world of low growth, businesses may be tempted to cut costs on OSH;
- lower growth limits the capacity to invest in new infrastructure and to make business processes safer and more accessible; and
- the slower roll-out of new technologies and new products means that there is more time to assimilate new hazards and new risks; but there may be less funding available for OSH research.

… of strongly green values:

- environmental hazards are seen by society as of particular concern, especially if released into the general environment, rather than contained in the place of use;
- environmental issues tend to be given priority over OSH;
- if preferences for self-reliance, holistic wellness and self-care are translated to the OSH arena, the most effective OSH interventions may be self-regulation, education and cooperation; and
- new processes and enterprises across the economic spectrum, introduced by the greening of society, all require new OSH procedures and training.

… of a medium rate of green innovation:

- new jobs and new products may well bring new hazards and risks if not designed taking OSH into consideration;
- new skills will be needed to develop, produce, install, maintain and dispose of new green products and systems;
- there is an opportunity to improve OSH by designing in safety and health protection from the start; and
- there are more difficult, 'dirty' manual jobs (in repair, maintenance, waste sorting, etc.) than in other scenarios with more innovation and automation.

5.3.4. Social context of work in the base scenarios

Table 12 summarises how the social context of work may vary between scenarios.

Note that these are general trends. These factors may vary widely between industries, or even in different sectors of the same industry, and will vary in time as an industry or a technology develops. These factors were tested and refined as part of the workshops in Phase 3.

Table 12: **Social context of work across the three scenarios**

Factor	Win-Win	Bonus World	Deep Green
Attitudes to risk (blame culture v responsibility)	Greenness suggests a greater sense of corporate and personal responsibility	Blame culture The motivation for good OSH practices is the risk of being sued or prosecuted	Greenness suggests a greater sense of corporate and personal responsibility
Attitudes to risk/ OSH (employers)	Caring for the environment suggests caring for staff too, and will fit with CSR	Pursuit of profit treats reducing risks as a cost	Low economic growth and high unemployment suggests some employers may be prepared to cut corners
Attitudes to risk/ OSH (workers)	Workers demand safe working: a priority of unions is to improve conditions	Skilled workers demand safe working: a priority of unions is to improve conditions Unskilled workers need jobs, even if they are risky	Workers need jobs, even if they are risky: a priority of unions is to protect employment
Size of firms Structure of companies Industrial structure	Lots of small start-ups, across the economy, doing new things in new green ways Tendency towards global business and markets	Lots of small start-ups, across the economy, doing new things in new ways Tendency towards global business and markets Non-green jobs could be 'exported' Businesses' interest in making profit could lead to worsened working conditions for workers	Smaller innovative start-ups within green industries, and in the greening of the rest of the economy Tendency towards localised business
Migration	High growth suggests high mobility Workers drawn to countries with high growth Total overall immigration into Europe is roughly balanced by emigration out of Europe	High growth suggests high mobility Workers drawn to countries with high growth High levels of immigration of poorly qualified people into Europe	Low growth suggests low mobility and low levels of migration; but prolonged recession will stimulate out-migration through a wish to find a better life elsewhere
Need for new skills	Need new skills to produce new things and operate new technologies and processes, in green ways, across the economy Potential exists for polarisation between skilled and unskilled workforce	New skills are needed to produce new things and operate new technologies and processes, across the economy Potential exists for polarisation between skilled and unskilled workforce	Need new skills to operate new processes, within green industries, and in green activities in other industries, but rate of innovation is slower than in other scenarios
Structure of the economy	Ever-increasing production and consumption, but with a reducing environmental footprint	Ever-increasing production and consumption, with growing environmental footprint	Production and consumption of services rather than making and consuming more and more physical goods
Labour market	Growth suggests fuller employment Workers can find alternative jobs more easily Balance of power with the workers	Growth suggests fuller employment Skilled workers can find alternative jobs easily Unskilled workers are exploited	Low growth suggests unemployment Balance of power lies with the employers
Government and regulation	Education, supported by funding, plays an important role in the enforcement of OSH	Enforcement of OSH primarily through regulations	Education plays an important role in enforcement of OSH The Green agenda is seen by governments as more important than OSH

5.4. Exploration of new and emerging OSH risks through the scenarios — Validating and extending the scenario tool

Section 5.4 reports on the results of the seven technology workshops, each addressing one of the nine key technology areas selected in Phase 2 (nanomaterials being addressed as a horizontal issue in all workshops). This Section covers both what was said in each workshop and the conclusions that were drawn from this discussion in post-workshop analysis.

The objective of the workshops was to develop the full scenarios by looking at the development of the technologies and the OSH implications in each base scenario. Each workshop lasted 2 half-days except the workshop dedicated to decentralised domestic and small-scale energy systems, batteries and energy storage, and energy distribution and transmission, which filled 2 entire days. A full OSH assessment for each technology in each base scenario in the time frame of a single workshop was outside the scope of the project: that would have required significantly more time and resources. However, important insights on possible future OSH challenges were obtained. The workshops also demonstrated the value of scenarios in promoting an OSH dialogue between different groups of stakeholders.

In each workshop, the programme included a plenary session to consider the development pathway for the focus technology in the Win-Win base scenario and group work to consider the same in the Bonus World and Deep Green base scenarios. The groups assessed the most important OSH implications in their scenario and then, together, did the same for Win-Win. The workshops finished with a review of the implications for OSH of the whole picture.

In post-workshop analysis, OSH implications identified in the workshop were compared with existing OSH source material reviewed by HSL included in the OSH briefing for workshop participants, to show where the scenario approach had led to new insights into new and emerging risks, and to ensure that other known issues not picked up in the workshops were included in the mix.

In each workshop, there was a mix of people with technology and/or OSH backgrounds from relevant industries and trade unions, national agencies and academics with expertise in each area. They were joined by representatives of EU-OSHA and its Prevention and Research Advisory Group (PRAG), as well as government representatives, various Directorates-General of the European Commission and the International Labour Organisation (ILO). Details of each workshop, including a list of participants, are given in Annex 8.

5.4.1. Wind energy

Comparison of technology developments across scenarios

Table 13: **Technology developments: Wind energy**

Technology developments	Win-Win	Bonus World	Deep Green
Amount of wind power	Extensive	Limited, depending on the price of energy	Lots of wind power but less than Win-Win
Locations	Deep water offshore, in addition to traditional sites	Onshore, closer to cities Planning rules relaxed	Mostly onshore Less ambition and less offshore pioneering than Win-Win
Turbines	Big turbines (up to 20 MW) Specialised marine designs	Standard turbine designs to minimise cost per unit output (5–7 MW)	Smaller turbines (3–5 MW)
Grid connection	Extensive interconnectors Continental supergrid	Direct connections to areas of greatest consumption	Storage buffers rather than the supergrid
Existing wind farms	Sites are repowered	Decommissioning issues, as uneconomic sites are abandoned	Old turbines kept going as long as possible
Wind farm operators	Continued government subsidies	Firms can go bust Consolidation of industry participants and subcontracting of maintenance and operations	Continued government subsidies

Wind energy in Win-Win

Technology and societal context

In Win-Win in 2025, continued political support and funding have contributed to explosive growth in wind energy. There are many wind farms in Europe. More and more installations are coming on stream. Offshore wind farms are being constructed in ever-deeper water, with designs specific to the marine environment.

Installed capacity in 2020 comfortably met the European Wind Energy Association (EWEA) targets (dating from 2009) of 230 GW wind power capacity (EWEA, 2012), including 40 GW offshore wind. In 2025, the industry is now well on course to beat its 2009 target for 2030 of 400 GW of installed capacity in Europe, of which 150 GW will be located offshore, producing a substantial proportion of Europe's electricity.

Economies of scale have been realised on several dimensions. Growing numbers of turbines have cut manufacturing costs: there is now considerably more experience in construction and ever-larger turbines have become possible.

Managing the flow of energy from these systems has been made easier through a continental-scale supergrid, with a variety of energy storage capabilities, and better localised wind forecasts to predict power output levels.

In 2025, the very largest turbines now have 20 MW of capacity. These have become possible through better manufacturing techniques and new monitoring and control processes to ensure safe operation. Most of these are destined for offshore sites, with better foundations in shallower water, and floating installations allowing wind farms to be installed in much deeper locations.

Workshop discussion on OSH — Wind energy in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Deep-water offshore sites Here, the main issues are the scale of operations and the distance from safe haven. The situation is similar to the oil and gas industries, but with more widely dispersed working sites and lower profit margins to pay for safety. Workers need accommodation vessels and feeder boats. Mother vessels need facilities on board for emergencies and methods for safely disembarking feeder vessels. Turbine worksites need welfare facilities for the staff. Specialist vessels are required to handle such large turbines in deep water, and there are still issues over foundation strategies (especially as the seabed is different for each turbine in a wind farm), transport of foundations from yards, and longer-term issues over removal of foundations.	Greatest volumes and deepest waters in Win-Win	New challenging wind farm locations, especially in Win-Win
Availability of skilled manpower New technologies will need people with skills, and long timescales are needed to achieve competence. For a university student to become a qualified engineer, and for them to gain relevant experience and training, will, typically, take 10 years. And cross-border transfers bring risks around skills equivalence, varying attitudes to OSH culture, and language difficulties. The high economic growth and innovation of Win-Win makes increased competition for skills particularly important for this scenario.	Applies to all scenarios, but greatest in Win-Win with the fastest innovation in green industries	Growing issue with implications for OSH (Section 5.4.10 OSH factors common across technologies)
New access technologies (e.g. airships) As offshore wind farms move to deeper water and more distant locations, operators will still need to access them in an economically efficient way. They will adopt procedures and knowledge from offshore oil and gas industries (and specialised personnel) and develop their own unique procedures, all of which will require specialist OSH supervisions.	Greatest numbers and deepest waters in Win-Win	New access routes (e.g. helicopter or airship platforms)
Better reliability Over time, maintenance will get smarter with more reliable electronic devices. The aim will be to minimise unpredicted maintenance.	Especially Win-Win and Bonus World	Positive for OSH
Size of turbines The scale of the lifting operation needed to raise towers and turbines is a significant hazard. Also, the higher the turbine, the more challenging it is to rescue workers in case of emergency (e.g. fire or medical). This is relevant to all scenarios, but the biggest turbines feature in Win-Win, with its high level of government support for wind energy and innovation.	Biggest turbines in Win-Win	New turbine designs and assembly processes

Wind energy in Bonus World

Technology and societal context

In Bonus World in 2025, high economic growth and resource scarcity have pushed up energy prices to the point where the cheaper forms of wind energy in favourable locations can generate electricity for a cost that is comparable with other sources of supply.

In this scenario, there is no funding or green tariff to support the development of more expensive wind farms. Only the lowest cost sites have been developed, as these are the only ones to be economically viable, with sufficient profits to cover their cost of capital.

These sites are nearly all onshore, and many are located nearer to cities and other communities, which are the areas of highest demand. Luckily for the wind energy industry, the low green values of Bonus World mean that planning rules and environmental impact assessments have been relaxed somewhat, which permits more wind farm locations near habitation and in areas of outstanding natural beauty.

Because of the need to be price competitive, designs of turbines have focused on cost-efficiency and low-cost maintenance. The very largest turbines envisaged in 2012 were never built, and the industry has effectively standardised on 5–7 MW turbines. Standard designs based on common platforms (like some models of car) have helped to keep costs down, and innovative maintenance regimes, such as new access methods, have been introduced — again, to keep costs down.

In Bonus World, wind farms are owned by large companies, but they tend to outsource maintenance to the lowest bidder.

In the early years of the decade, there was a rush to develop wind farms and install turbines before the deadlines were reached for the reduction and withdrawal of subsidies.

Workshop discussion on OSH — Wind energy in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Government deadlines The imperative to install and commission as many turbines as possible ahead of government deadlines for subsidy withdrawal is likely to be a big underlying driver of risk as it may be associated with OSH being overlooked.	Most immediate in Bonus World, but applies to all scenarios	Relevant to OSH policymaking (Section 5.4.10 OSH factors common across technologies)
Cost pressures In this scenario, there is always the risk of cutting corners to save costs, especially with regard to foundations, which are difficult to inspect after installation and may never be tested by extreme weather events.	Bonus World	Not new
Subcontracting of maintenance Together with cost-cutting, this has led to increased risk-taking and the use of migrant workers with low skills and a poor safety culture. There is a passing of blame and no due diligence by the ultimate owners.	Applies most particularly to Bonus World	Growing cost pressures as subsidy regime moves to price competition (Section 5.4.10 OSH factors common across technologies)
Standardised designs These are likely to converge on the lowest cost option and may have fewer health and safety features installed (e.g. lifts eliminating the physical work associated with climbing up the tower), to save costs. Standard designs will, however, have great benefits in improved familiarity and applicability of OSH lessons to other sites.	All scenarios, but especially Bonus World	Standardisation is likely to be positive overall for OSH
Legacy issues As subsidies for wind power are withdrawn in Bonus World, old wind farms are not repowered as it would not be economic to do so. Design action is needed now to enable eventual safe dismantling at end of life.	All scenarios, but most urgent in Bonus World	Design action needed now to enable eventual safe dismantling or refurbishment (Section 5.4.10 OSH factors common across technologies)

Workshop discussion on OSH — Wind energy in Bonus World		
OSH implications within the scenario as identified in the workshop	Applicability	Scope for new and emerging risks
Manufacturing risks There is uncertainty over where the turbines would be manufactured. Manufacturing within the EU brings all the associated OSH risks back into the jurisdiction of EU Member States.	Depends on supply chain configuration, but local manufacturing of wind mills is most likely in Deep Green	Not new, but may grow in EU Member States, as more turbines are manufactured in Europe
Politics/funding Targets need to be coordinated across Europe and reviewed after a time to check that they are realistic and achievable. OSH depends on funding and political support. OSH should be a part of the licensing programme, and should be a factor in who wins the funding.	Using the lever of licensing conditions will be much easier in Win-Win and Deep Green with their high subsidies than it would be in Bonus World with lower subsidies and reduced profit margins	Growing issue if subsidies are reduced
Knowledge of new materials New materials are increasingly being used for new applications. They have the potential for major unexpected impacts on health and environment. Understanding of the materials is required at all stages of the product life cycle: production; construction; operation, maintenance; prolonging operational life; decommissioning; and disposal. New composites will be used for the manufacture of wind turbine blades and will eventually need to be disposed of. Nanomaterials are being used in applications including anticorrosive and antifouling coatings for offshore and onshore use. Maintenance access to offshore wind turbines means that workers climb turbines and clamber onto them from boats. Antifouling paints and similar materials on wind turbines may, therefore, carry a much higher risk of contact exposure than for other applications such as oil platforms and ships´ hulls, where there are other routes of access.	Greatest use of new materials and least care for health and environment in Bonus World, but applies most in Win-Win with its greater growth and fast innovation in the wind industry	New risks (Section 5.4.10 OSH factors common across technologies)
Novel access mechanisms Novel access mechanisms such as helicopters are used to access the turbines (especially offshore).	Most relevant to the high innovation scenarios such as Bonus World and, most especially, Win-Win with its fast growth and innovation in the wind industry	New access routes (e.g. helicopter or airship platforms)
Ice throw There are risks of ice throw, which could injure workers and the public, especially where turbines are located near population centres. This is a well-recognised risk.	Relevant in all three scenarios, but may affect a larger population in Bonus World due to the proximity of wind farms to population centres	Not new, but a new siting policy in Bonus World
Metal theft The risks to the workforce from the consequences of metal theft could be a big issue. Live cables left exposed are an obvious hazard and thefts of cable could result in power cuts leading to safety risks as industrial processes are interrupted. Theft could also damage the (electrical) installations and result in risks to workers, in particular maintenance workers. Theft of other metal items could similarly cause safety risks.	Greatest in Bonus World, with high prices and profit motives: risks occur in many green jobs	Not new, but a growing risk across many technologies including wind, batteries, domestic energy, etc. (Section 5.4.10 OSH factors common across technologies)

Wind energy in Deep Green

Technology and societal context

In Deep Green in 2025, the lack of capital constrains the development of wind energy, despite the strong green values and political support. The installed base of wind energy in Europe (110 GW) is modest compared to Win-Win, but more extensive than in Bonus World. Projects tend to be smaller, with infill developments. There are cost hurdles to offshore developments, so that fewer of the deeper offshore sites that had been envisaged in 2012 have been built.

The usual turbine size is relatively small at 3–5 MW. The latest designs have converged on direct drive generators and transformers in the nacelle rather than the base.

Rather than investing in a full electrical supergrid to support wind power, wind farms typically use storage buffers (e.g. nearby upgraded hydroelectric schemes) to cope with fluctuations in power.

Make-do-and-mend attitudes encourage owners to refurbish older wind farms rather than rebuilding, though, in some places, 1 MW turbines have been replaced with 3 MW on the same towers as the technology has improved.

The wind energy industry has been beset by corporate failures and consolidation. The priority of the remaining big players is to drive down costs and minimise the investment needed to deliver wind energy.

With high unemployment, people are more likely to accept personal risks.

Workshop discussion on OSH — Wind energy in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Pressures to maintain equipment The drive to maintain equipment, even in extreme weather conditions, could expose maintenance workers to hostile and dangerous conditions.	More extreme sites in Win-Win; greater cost pressures in Deep Green and Bonus World	May affect an increasing number of workers in the sector
High voltages With transformers in the nacelle, high-voltage electrical connections running down the tower at typically 32 kV are a clear risk to safety and require safe systems of work using keys and tokens.	All scenarios, depending on turbine design	Hazards from new turbine designs need full OSH assessment
End-of-life issues The OSH uncertainties revolve around the long term as wind farms reach the end of their design life. Life-extension would require more maintenance, which is the most dangerous activity. There has been very little experience of long-lasting wind farms, especially as older farms have, in the past, usually been repowered first. There will be a need for inspection regimes including, for example, non-destructive testing of the towers, to ensure the continued safe operation of old wind farms.	All scenarios, but refurbishment most likely in Deep Green	Design action needed now to enable eventual safe dismantling or refurbishment (Section 5.4.10 OSH factors common across technologies)
Physical risks Climbing high towers always brings a risk of falling as well as a high physical load on the body linked to musculoskeletal disorders. This might be an increasing challenge to address as the workforce is ageing but needs to be kept at work for longer with retiring age being postponed. It also makes recovery difficult in the event of emergency. The risks are made worse as features such as lifts have become less common, due to cost pressures.	All scenarios, but more maintenance activity and fewer access technologies to the wind tower nacelle in Deep Green	Not a new issue, but growing number of installations and workers involved

Complementary information from desk research and Phase 2 technology workshop on OSH issues for wind energy

Workshop briefing on OSH issues

The briefing material for the wind energy workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors.

General

Diverse range of duty holders: the industry will involve many new entrants as the market expands rapidly. There is the potential for gaps in knowledge and the availability of appropriate standards and guidance as OSH tries to keep up with developments.

Engineering unknowns: as novel designs appear, and ever more challenging locations are developed, construction, access, maintenance, and life cycle issues may appear.

Anomalies in the regulatory regime resulting in inconsistencies across the energy sector: there may be issues surrounding the interfaces across regulatory boundaries (e.g. licensing, OSH, environment). In the case of offshore wind, there could be major regulatory gaps outside territorial waters.

There could be technical issues surrounding the interface problems with infrastructure still to be resolved, with regard to the transmission network, for example.

Competency and skills: if target levels of new installations are reached, there are likely to be massive shortages of skilled personnel (industry and regulators). New and inexperienced workers could be at risk.

Access issues, with boats and helicopter, especially in bad weather: evacuation from tower platforms in the event of fire.

Psychosocial risks from isolated working, especially offshore.

Chemical and biological

Exposure to chemicals and dust could occur, for example:

- during the manufacture of turbine blades — (epoxy) resins, styrene, solvents;
- while sanding components (e.g. when maintaining installations); and
- during decommissioning and recycling.

In addition, there is evidence of the growth of microorganisms in the nacelles.

Construction and maintenance related

Building of wind turbines is complex. Offshore wind arrays are the world's largest construction projects, up to 200 km offshore. They have major infrastructure needs: subsea cables, ports, substations and accommodation platforms.

Risks include:

- structural failure, such as blade throw if blades fracture, or tower collapse; risks to workers and the public if near buildings;
- working at height;
- working over water, risks from jack-up barge stability; diving risks;
- electrocution during installation, maintenance; connection to the transmission network;
- heavy lifts — dropped or swung loads — crane, derrick and hoist safety;
- risks during eventual decommissioning; and
- working in confined spaces, as when undertaking maintenance, for example.

Source: UK Health and Safety Laboratory Futures Team and additional sources (HSE, 2010b; RenewableUK, 2010; O'Neill, 2009; Seifert et al., 2003; Bradbrook et al., 2010).

OSH discussion for wind energy

Working on wind turbines is potentially dangerous at the best of times, and the widely distributed nature of the work means that the monitoring and enforcement of safe working practices are difficult for both operators and regulators.

The risks are multiplied manyfold in offshore wind farms, which have the potential to become highly dangerous worksites. It will be necessary to closely monitor processes for installing and maintaining ever-larger turbines in deep-water offshore wind farms.

The potential for OSH risks will continue to grow whatever the subsidy regime. If generous subsidies continue, ever-larger turbines will be installed in ever-greater depths of water, ever further from safe haven. If subsidies are reduced, then price competition will bring pressures to cut corners. Deadlines to qualify for subsidies will bring urgency to installation work that will bring unnecessary and avoidable risks.

Developments in the following areas of new technology should be monitored.

- New turbine designs may bring new risks (electrical or ergonomic).
- New materials and coatings may be an issue. New composites will be used for the manufacture of wind turbine blades and will eventually need to be disposed of. Offshore wind turbines need maintenance access, so workers climb the towers and clamber onto them from boats. The risk of contact exposure to antifouling paints and other materials on wind turbines may, therefore, be much higher than for other offshore applications like oil platforms and ships´ hulls, where there are other routes for access.
- There may be possible new access mechanisms, such as helicopters and airships.

The following areas of growing risks should be reviewed.

- Physical security is an issue, especially if continued high metal prices increase the risks of theft, which may damage the structure and put the safety of the installation in question.
- Ice throw from turbines may put workers at risk in the wind farm grounds or in the surroundings (7), especially if planning regulations allow installations closer to human habitation; ice throw is also an issue for the general population.
- Though not likely to lead to major hazards in the 2020 time frame, turbines designed today should have provision for safe disposal at end of life. They should also allow for major maintenance and exchange processes in case governments in the future require wind turbines to be refurbished and life-extended instead of simply being demolished.

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single day's workshop with experts in technology and/or OSH expertise as well as policymakers, with the HSL desk research as briefing. The intention was to illustrate the power of the scenario method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.2. Green construction

Comparison of technology developments across scenarios

Table 14: **Technology developments: Construction**

Technology developments	Win-Win	Bonus World	Deep Green
Energy focus	High energy efficiency (innovative PV and insulation) Retrofit of public buildings Extending underground for thermal mass	High insulation (at optimum economic efficiency with high energy prices)	Monitoring and control of household behaviours
Heating and ventilation	Low air circulation	Air conditioning	Low air circulation
Exposure risks	Exposure to novel materials	Exposure to new materials through demolition processes	Exposure from retrofitting and recycling
Building waste	Recycled	Landfill	Recycled
Government regulation	High standards	Relaxed planning	Mandatory retrofitting for energy efficiency (at owners' expense)
Construction activity	High levels of new build Prefabricated modular buildings, and automated construction Hyperinsulating materials	High levels of new build (with grandiose but well-insulated designs) Hyperinsulating materials	Little new build Lots of retrofit of energy-saving measures

(7) According to some accident reports, ice throw has been reported up to 140 m (Caithness Windfarm Information Forum, 2012).

Construction in Win-Win

Technology and societal context

In Win-Win in 2025, new buildings are zero-carbon, designed with heat stores, and built to at least *Passivhaus* standards (Passive House Institute, 2012) with comprehensive instrumentation and monitoring. Provision for electric cars (for recharging and as energy stores) is part of building design, and roofs include built-in PV (BIPV). Energy consumption of new buildings has reached very low levels.

The aim is to have buildings free from hazardous chemicals: finishes with ever-lower levels of formaldehyde and other volatile organic compounds (VOCs) are now necessary with the reduced levels of ventilation that are now standard.

Retrofitting of the building stock is common. Public buildings are being retrofitted to high energy and resource standards, tending towards a zero carbon footprint. Energy usage is controlled by re-engineering building structures and external insulation, enabled by advances in spray foam insulation.

Hyperinsulating materials (e.g. aerogels and nano-lattice structures) have been developed, and are in common use in new builds and retrofits.

Modular prefabricated buildings have become mainstream in new builds, with modules already fitted with heating, ventilation, and air conditioning (HVAC) and other services. There is less waste and super-insulation is cheaper. Automation (originally in new building assembly, and now in maintenance and retrofitting) has moved workers away from many hazardous activities.

Every part is designed to be disassembled and recycled. Recycled materials are used in new construction.

Buildings interact among themselves and with the smart grid.

Workshop discussion on OSH — Construction in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Highly skilled workforce New demanding high-level technologies will need a highly skilled workforce, well trained in OSH procedures for the new processes. With competition for skills between technologies, there is an increasing shortage of skilled workers. Unskilled, poorly trained workers are more at risk, including for work-related stress. Is there a need for incentives for companies to train staff?	High overall innovation in Bonus World, but Win-Win has the greatest innovation and most skills needs within green jobs	Growing issue with implications for OSH (Section 5.4.10 OSH factors common across technologies)
Prefabrication of modular buildings and automation Prefabrication can lead to a significant reduction in risks (particularly on site). Automation will be applied first to the prefabrication of modules in factories, but it will soon migrate to the building site itself. Installing prefabricated modules does, however, mean handling large loads on site, with all the associated risks, and does not eliminate all on-site work such as the preparation of foundations and provision of services to the site. Issues will arise when mixing automated and traditional manual activities on construction sites. New accidents will occur due to these innovative techniques, but will tail off as people get used to them and the work processes become better coordinated. There are theoretical risks (electrocution, gas, drowning, etc.) during connection of services but, with correct design, these should be minimal.	Most likely in Win-Win and Bonus World with the highest pace of change	Very positive for OSH as exposure to risks on site is reduced, but new risks could emerge in the factory
New energy sources (PV, geothermal, biomass) bring new hazards and unexpected accidents. PV leads to risks of electrocution, burns, working at height, and may incorporate new chemical exposure risks. Geothermal energy hazards include: exposure to emissions, such as sulphur, from activities such as trenching; excavation; welding and cutting; falls; steam/hot water from boreholes.	Greatest in Win-Win and Deep Green	Growing exposure

Workshop discussion on OSH — Construction in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Underground construction/congestion In densely populated cities, many homes will be extended downwards into and beyond basements, for living space and thermal storage. This brings risk of collapse including during (underground) construction, through instability of structure or ground, and risks from drilling into gas pockets or existing underground services. There are specific OSH implications due to underground working in confined spaces (including MSDs and toxic gases).	Win-Win and Bonus World	Not new, but growing in these scenarios
Building energy nodes Buildings will become integrated into smart grids, mainly by retrofitting. This brings complexity and combinations of risks (e.g. leakages close to electric storage systems). Innovative storage technologies (e.g. thermochemical effects) may lead to new risks in manufacturing, installation and maintenance. With combined risks, OSH will need to be considered in designs even more. Workers will need training in the hazards, in particular in installation and maintenance, as these are where the workers involved may have a lower OSH awareness.	Mostly Win-Win	Growing issue as smart grids develop
Novel materials Potential hazards used in construction or surface coatings at the installation stage include nanomaterials, aerogels, water treatment agents, plastic/concrete combinations, phase-change materials, fibrous composites, active surfaces, heat storage chemicals, novel surface coatings, and prefabricated structures. All of these will need careful assessment for OSH risks before introduction, including provision for maintenance activity and eventual safe disposal.	Greatest exposure in Bonus World, with its lower investment in occupational health (research)	New chemicals with unknown (long-latency) health hazards (Section 5.4.10 OSH factors common across technologies)

Construction in Bonus World

Technology and societal context

In Bonus World in 2025, there are new construction materials (e.g. hyperinsulation) and new building technologies. There is a high turnover of building stock, with ostentatious designs common.

Most new houses are prefabricated modular designs. Modules come already fitted with HVAC and other services. Automation (originally in new building assembly, and now in maintenance and retrofitting) has removed workers from many hazards.

Bonus World has high energy prices and, as the most cost-effective energy saving measure, very high levels of insulation have become the norm. Uninsulated houses are difficult to sell. As PV has now become economically viable without subsidy, new buildings have built-in PV (BIPV) to produce energy, and PV tiles (incorporating new PV technologies) are being retrofitted to older buildings.

Bonus World is an uncaring world, with its focus on the profit motive and cutting costs:

- subcontracting, used to drive down costs, leads to pressure on subcontractors to cut corners;
- cities sprawl and planning restrictions are less onerous;
- buildings (and products) are not designed for recycling;
- building waste goes to landfill;
- contaminated waste is exported, or is mixed with clean waste streams.

There are many home offices. Global warming, an ageing population, and increased teleworking lead to increased complexity in climate control systems in residential buildings (e.g. more air conditioning).

Workshop discussion on OSH — Construction in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Prefabrication of **modular buildings** Prefabrication can lead to a significant reduction in risks. Installing prefabricated modules does, however, mean handling large loads on site, with all the associated risks, and does not eliminate on-site works such as the preparation of foundations and provision of services to the site. Issues will arise when mixing automated and traditional manual activities on construction sites. There are theoretical risks (electrocution, gas, drowning, etc.) during connection of services, but with correct design these should be negligible.	Most likely in Win-Win and Bonus World with the highest pace of change	Very positive for OSH as exposure to risks on site is reduced, but new risks could emerge in the factory
New demanding high-level technologies New technologies will need a well-trained workforce.	Bonus World and Win-Win	High (Section 5.4.10 OSH factors common across technologies)
Retrofitting of insulation This leads to exposure to dust and dangerous substances such as lead and asbestos. The lack of adequate ventilation may be an issue, in particular as this type of work may attract construction workers used to outdoor work and not aware of the need of proper indoor ventilation.	Greatest exposure in Deep Green, with its emphasis on refurbishment and make-do-and-mend philosophy (also see Section 5.4.7 Domestic and small-scale energy systems)	Not new, but potential for growing exposure
New construction materials New construction materials such as phase-changing materials, hyperinsulation, nanomaterials, give rise to new exposure risks to dangerous substances.	Greatest exposure in Bonus World, with its lower concern for occupational health and with high innovation	New chemicals with unknown (long-latency) health hazards New risks continually emerging (Section 5.4.10 OSH factors common across technologies)
Demolition of recent buildings Demolition will also lead to exposure to new materials (e.g. nanomaterials and polychlorinated biphenyls (PCBs)).	Greatest exposure in Bonus World with high turnover rate	Exposure to new chemicals (Section 5.4.10 OSH factors common across technologies)
Polarisation within the construction industry More polarisation is expected, with well-run large firms, and poor SME subcontractors, with OSH issues over migrant workers and self-employed workers at the end of the subcontractor chain.	Greatest in Bonus World	Not new, but growing scope in Bonus World
Work-related stress Work-related stress and impacts on mental health issues seem likely in Bonus World from living with employment uncertainty and intensification of work.	Greatest in Bonus World	Potentially growing issue (Section 5.4.10 OSH factors common across technologies)

Construction in Deep Green

Technology and societal context

In Deep Green in 2025, the regulation and control of household behaviour is invasive, backed up by pervasive ICT. This monitors and enforces home temperature limits and ensures that some appliances run only at night. Householders are being forced to retrofit homes to new standards (with some subsidies, but mostly at their own expense). In addition to regulation, there is social pressure on householders to be green.

Retrofitting is common. There is less new building in total, but what there is, is deeply green.

There is widespread use of intelligent networks and ICT to optimise conditions.

With changes of legislation, a high percentage of materials in new building is recycled.

Workshop discussion on OSH — Construction in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Refurbishment The introduction of novel materials into existing buildings will bring risks of accidents from unfamiliar procedures and unexpected properties of the material, and may also bring exposure to chemical risks. Refurbishment will also bring exposure to familiar hazardous materials such as asbestos, lead and dust. The extended lifetime of products, buildings and infrastructures may mean emerging risks for workers linked to: dealing with product maintenance; using (old) products with extended life; recycling and reuse; and waste management (including exposure to unknown materials). There is scope to research and develop new approaches to reusing existing buildings and infrastructure, to reduce the risks and hazards associated with refurbishment, and the opportunity to create greener and healthier living spaces and offices.	Greatest exposure in Deep Green with high refurbishment rate	Exposure to new chemicals
Air circulation Low energy use entails low settings on air circulation and air extraction. There is a risk of build-up of VOCs, stale air, and sick building syndrome as green building means minimal fresh air.	Most relevant in Deep Green and Win-Win	Increasing problem, especially in office buildings as well as houses and, therefore, a growing OSH risk to home-based workers
Retrofitting renewables Retrofitting existing buildings for a low energy green world brings a host of occupational hazards. Roof work involves risks of falls; installing insulation brings exposure to dust and hazardous chemicals. The lack of adequate ventilation may be an issue, in particular as this type of work may attract unskilled workers not aware of the need of proper indoor ventilation. There are always electrical risks, made worse by the do-it-yourself mentality of the Deep Green Scenario.	Greatest exposure in Deep Green (Also see Section 5.4.7 Domestic and small-scale energy systems)	Not new, but potential for growing exposure
Waste handling Demolition and the separation of waste for recycling leads to MSDs, physical risks and chemical hazards. Hazardous construction materials need to be properly labelled to allow adequate waste treatment and minimise workers' exposure to dangerous substances. When buildings are demolished, all construction waste is mixed together and it is, therefore, challenging to recognise and separate construction material containing hazardous material from the rest.	All scenarios, but mainly Bonus World with high turnover of building stock and less environmental concern regarding material and waste labelling	High

Complementary information from desk research and Phase 2 technology workshop on OSH issues for green construction

Workshop briefing on OSH issues

The briefing material for the construction workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors.

Risks

- A range of physical hazards — in particular, the combination of known risks in new situations, such as installation of renewable energy equipment at heights, electric shock or electrocution from the installation of new technology such as feed-in to smart grids. There is a risk of fire from fuel cells or battery storage systems.
- Exposure to hazardous materials used for insulation. For example, aerogel insulation blankets are made mostly of synthetic amorphous silica embedded in a fabric blanket and the handling of these blankets will produce dust, exposure to which can cause irritation to eyes, skin and respiratory tract.
- Risk of exposure to dangerous substances (e.g. asbestos, lead, dust) during retrofitting activities.
- Use of nanomaterials and new materials and potential risks from dangerous substances used in new construction materials (e.g. when polishing or grinding nano-containing bricks/paints), including in maintenance and demolition activities.
- OSH conditions worsening as OSH is not visible enough or emphasised in 'green building' (e.g. 'green building' certification).

Benefits

- Off-site construction has the potential to reduce accidents on site, although lifting prefabricated sections or modules may be hazardous. Moving work off-site into the factory could cause additional risks there to replace on-site risks.
- Robotics and automation can improve safety through developing and deploying machines for dangerous jobs, such as excavation and construction in hazardous environments, although there may be new risks from increasing use of robots.
- The use of Radio Frequency Identification Tags (RFIDs) in construction workers' shoes can help avoid collisions with moving plant.

Source: UK Health and Safety Laboratory Futures Team and additional sources (RI Committee on Occupational Safety and Health, 2009; Kanth, 2010; Schulte and Heidel, 2009; Taylor, 2009).

OSH discussion for green construction

Construction makes up a significant proportion of all CO_2 emissions (e.g. in the United Kingdom, 47 % of emissions are estimated to result from the manufacture, distribution, building, occupation, refurbishment and demolition of buildings), so any reduction in emissions from the building/occupation life cycle has the potential to make a significant impact on overall emissions.

Impact on the building stock can be made either through energy-efficient new build or retrofitting existing buildings. Given the relatively slow rate at which the building stock is replaced, retrofitting is likely to be significant for years to come, in any of the scenarios, but is greatest in Deep Green where new build is at its lowest.

The increasing use of off-site building techniques will, while reducing the use and wastage of materials, also offer health and safety benefits.

Specific examples of OSH issues include the following.

- Off-site and modular construction moves many elements of construction into a factory environment where work is more controlled. This reduces the amount of time workers spend on site and so limits the risk of site-based accidents and ill-health, although there will be new challenges on site (e.g. increased transport and lifting of large components). But off-site construction could transfer some risks into the factory (e.g. handling of large components and exposure to new materials such as composites).

- Increasing use of robotics and automation could improve safety during manufacturing and construction, but the human-machine interface needs to be monitored in the light of increasing flexibility and autonomy of robots.

- There is a risk associated with exposure to new materials and substances in construction — including composites, phenolics and nanomaterials (e.g. aerogels).

- Retrofitting of insulating materials and small-scale renewable energy devices could expose workers to a range of dust and hazardous materials, including asbestos.

- Retrofitting could increase the incidence of existing hazards (e.g. falls from height, slips, MSDs) but, in some cases, in new situations (e.g. retrofitting of renewable energy systems on house roofs by relatively inexperienced workers), these could expose workers to electrical risks also. If retrofitting becomes mandatory, there could be substandard work by unqualified tradesmen trying to offer low-cost installations.

A significant shift towards off-site and modular building will mean that traditional construction activities will start to be replaced by what is essentially manufacturing. This will require different skills and there may be significant training needs as existing construction workers adapt to the change, especially if an ageing workforce finds the change to be challenging. At the same time, automation in construction could be an opportunity for the increasing ageing workforce who may be more vulnerable to the repetitive manual handling of (heavy) loads in traditional construction activities. However, it should be monitored to ensure that the OSH benefits from off-site construction are not countered by a corresponding rise in risks in the factory setting, either because new substances are used or because existing activities that were previously carried out in the open air are now undertaken indoors.

The risks linked to many new players entering the sector alongside the introduction of novel energy systems should be considered.

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single day's workshop with experts in technology and/or OSH expertise as well as policymakers, with the HSL desk research as briefing. The intention was to illustrate the power of the scenario method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.3. Bioenergy and energy aspects of biotechnology

Comparison of technology developments across scenarios

Table 15: **Technology developments: Bioenergy**

Technology developments	Win-Win	Bonus World	Deep Green
Production	Biomass production across EU	High volumes of diverse biomass waste streams to mine for their energy content	Local supplies preferred Waste recycling and energy recovery
Energy utilisation	Combined Heat and Power (CHP) to extract maximum energy	Small local CHP	Reduced consumption of energy
Biogas	Widespread, fed into the national gas supply	Methane digesters and pyrolysis	Widespread, fed into the local gas supply
Biofuels	Second and third generation	Second and third generation through advanced genetically modified organisms (GMOs)	Energy intensive biomass
Volume of bioenergy use	High	Medium	Medium

Biofuel definitions

First-generation biofuels are based on starches and sugars, and other food crops, which are fermented to produce alcohols.

Second-generation biofuels use other bacteria to produce usable fuels from cellulose, lignin, and other non-food agricultural waste.

Third-generation biofuels is a term used loosely to describe the use of genetically modified algae or bacteria to produce enhanced volumes of biofuels from non-food agricultural waste, or directly photosynthesised from sunlight.

Bioenergy in Win-Win

Technology and societal context

In Win-Win in 2025, biomass is grown across the EU. Legislation supports the maximum extraction of energy from biomass sources, including its heat content. The objective becomes a zero-waste economy.

Rural biomass is shipped to cities after torrefaction (heat treatment to dry the material and increase its energy density) so that the heat can be used in CHP systems. Garden material is used for heating homes and all the energy embedded in municipal waste and from manufacturing processes is recovered.

Biogas production has developed so that 20 % of gas in the mains is now biogas. Most agricultural waste is biodigested anaerobically to product methane. Waste water is used for its nutrient content to fertilise biogas production.

Biomass power generation uses a mixture of very large (400 MW) and efficient small-scale CHP plants in towns where the heat can be used. Some existing coal-fired plants have been converted to run on biogas. Where these plants have also been enabled for CCS, they now run with negative carbon emissions.

Second-generation biofuels, produced efficiently with genetically modified bacteria, are common in transport, and third-generation fuels have been developed.

Workshop discussion on OSH — Bioenergy in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Biohazards There may be unknown biohazards from biotechnology, especially from new third-generation biofuel organisms operating at room temperature.	Most important in Win-Win and Bonus World	New
Agricultural handling and storage risks There are new and emerging 'agricultural risks' as agriculture turns to bioproducts. Work in forestry is likely to intensify.	All scenarios, but especially Win-Win and Deep Green	Not new, but growing in importance
Third-generation biofuels Algal fuels may give rise to new hazards: new organisms, fuel compounds, and the by-products of production.	Most important in Win-Win and Bonus World	High (Section 5.4.10 OSH factors common across technologies)
Zero-waste economy The zero-waste economy entails dealing with the most difficult tail end of the waste stream (e.g. a completely closed cycle means bringing wood ashes back to the forest, but these contain heavy metals). Such wastes in concentrated form are hazards that need special handling before it is spread out and diluted to safe levels. Even wood ash is strongly alkaline.	Most applicable to Win-Win	Rapidly increasing risk of diminishing ecological return
Bioenergy processing Risks exist from the operation and maintenance of bioenergy technologies. Temperatures can range up to 370 °C, pressures up to 5 bar. Chemicals can pose exposure risks. Digesters give rise to methane risks of explosion and suffocation. With smaller recycling and bioenergy plants, the associated hazards are diverse and distributed, and, therefore, more difficult to monitor and regulate.	Most applicable to Deep Green and Win-Win	Not new, but growing in importance

Bioenergy in Bonus World

Technology and societal context

In Bonus World in 2025, second-generation biofuels (liquid fuels and chemical feedstocks from lignin and cellulose) have become common, aided by rapid innovations in genetic modification and synthetic biology.

Techniques from advanced medical biotechnology have been applied to bioenergy. Even without green incentives, this technology has become available to develop life forms that produce third-generation biofuels, though their widespread adoption has been dependent in this world on continuing high oil and energy prices.

This world focuses on energy-efficient technologies and resource efficiency, with a whole life cycle approach. Biomass sources — forestry and agriculture, and agricultural waste — get used through the most cost-efficient route. There is plenty of biomass waste to harvest for its energy potential, and it is incinerated where necessary or profitable to do so, and is left in the field (or goes to landfill) where not.

Coal, natural gas and oil power stations persist, supplemented by lots of small-scale biofuels and biomass CHP generating plants. Methane digesters and pyrolysis are used to generate biogas. In this world, there are many energy-containing waste streams to harvest and exploit, usually in lots of small, localised CHP systems.

There are plenty of jobs in producing and harvesting biomass for energy and chemical feedstock.

The biomass industry separates into big agribusinesses with many small subcontractors.

Workshop discussion on OSH — Bioenergy in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Storage and handling of biomass Storage and handling of biomass products is not risk free. There are physical risks in handling, storage and harvesting, and exposure risks from leakage, chemical and biological emissions from the decay process, and moulds, which vary with the biomass type. These are mitigated by automation.	All scenarios	Not new, but growing in importance
Work design Good design of work processes and machinery is needed to minimise ergonomic risk factors and associated risks. Indoor air quality and ventilation are important when processing biomass, given the likelihood of airborne irritants.	All scenarios, but especially Deep Green, with its low-tech, less automated approach	Not new, but growing in importance
Intensification of work With small subcontractors under price pressure, work is likely to intensify.	Greatest in Bonus World	Potentially growing issue (Section 5.4.10 OSH factors common across technologies)
Risks from waste Waste streams can contain toxic chemicals, heavy metals, biohazards, vermin infestations, and radioactivity (e.g. caesium in ash). These are not new, but will increase in a bioenergy-based economy.	All scenarios, but especially in Deep Green	Not new, but growing in importance
Nature of third-generation biofuels Questions arise over the safety of the main fuel product (e.g. ethanol, biopropanol, and biodiesel) and any by-products (e.g. methanol) and contaminants that may be generated in the production process.	Most important in Win-Win and Bonus World	High and new
Behaviour of new organisms/synthetic biology These could pose unknown biohazards, especially third-generation biofuel organisms operating at room temperature.	Most important in Win-Win and Bonus World	New
Biomass boilers Even with automatic handling of biomass, there are hazards associated with biomass boilers. There are respiratory hazards from smoke and dust, requiring boilers to be closed and the area to have proper ventilation. Exposure to dust may also put maintenance workers at risk. In addition, (wood) ash is strongly alkaline, with associated dermal hazards when maintaining and cleaning the boiler. There may be other risks during maintenance and cleaning.	Applicable to all scenarios	Not new, but increasing use

Bioenergy in Deep Green

Technology and societal context

Deep Green is characterised by an industrial paradigm shift towards symbiosis: 'Your waste is my resource'. This leads to big changes in ways of sourcing energy and managing waste. Local waste is recycled or, at least, its energy content is recovered locally.

Energy conservation reduces demand for energy, but biomass production has increased, with consequences for both spatial planning and land use.

Local procurement becomes important with local biogas from landfill, and local community biodiesel. The focus is on local installations in small towns and rural areas and there is plenty of labour in this scenario to collect energy crops. There is rising use of biofuels and biodiesel. Animal fats and food waste are used as heavy fuel oils.

There has been little spillover from high-value biotechnology, but green biotech is still cutting costs and increasing the energy intensity of bioenergy crops. Non-food energy crops become viable in Europe and production rises.

In 2025, there is a very diversified energy system. There are some big biomass power stations, for economies of scale, and small plants for heat in district and community heating systems. Existing coal-fired electricity plants are being retrofitted to burn biomass.

Workshop discussion on OSH — Bioenergy in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Unpleasant working conditions Unpleasant working conditions result from handling biomass (even with better ventilation and personal protection equipment).	All scenarios	Not new, but growing in importance (Section 5.4.10 OSH factors common across technologies)
Respiratory problems Respiratory problems resulting from exposure to dust during cleaning and internal operations of biofuel boilers etc.	Especially in Deep Green, with its low-tech, less automated approach	Not new
Diverse risks Diverse risks exist that are difficult to monitor and regulate from decentralised installations, including micro-CHP and biogas, with risks of leaks and explosion.	All scenarios, but greatest in Win-Win and possibly Deep Green	Growing issue (Section 5.4.10 OSH factors common across technologies)
Long-term health implications There are uncertain OSH impacts from the use of biofuels and new biomass, because of exposure to dangerous substances and/or biohazards.	Greatest in Deep Green	Not new
Biohazards Biohazards linked to work with new bacteria developed in bioengineering.	Most important in Win-Win and Bonus World	New
Biomass storage Biomass storage brings risks from high temperatures, fire, explosions, and exposure to biohazards.	All scenarios, but most applicable to Deep Green	Not new, but increasing occurrence
Risk from handling biomass Asphyxiation in confined spaces or exposure to carbon monoxide and aldehydes when feedstocks are imported to docks, transported and stored. Respiratory allergies may result from handling degraded biomass fuel. Risks also exist of exposure to VOCs, dusts, moulds and endotoxins during handling/storage.	All scenarios, but most applicable to Deep Green	Not new, but increasing occurrence

Complementary information from desk research and Phase 2 technology workshop on OSH issues for bioenergy

Workshop briefing on OSH issues

The briefing material for the bioenergy workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors:

- storing dry biomass presents a fire risk;
- small biomass particle sizes, particularly after size reduction prior to combustion or pyrolysis/gasification, when dispersed in air can give rise to a risk of explosion;
- biomass material may not store well and may produce hazardous VOCs, dusts, moulds and endotoxins, which can be a risk to health;
- there is a risk of biomass self-heating, due to microbiological processes, which can also be a fire risk;
- biomass processes can involve the production or use of flammable gases and liquids being handled at high temperatures and, sometimes, moderate pressures: other gases that can be produced, such as CO_2 and CO, have the potential to harm health;
- there is increased collection and distribution of biomass;
- collection of biomass material from woodland involves forestry occupations, which have a high injury and fatal accident rate;
- increasing numbers of new entrants come into the bioenergy sector, particularly from the waste and agriculture sectors and other sectors producing organic waste: many will be SMEs and they may lack expertise in constructing and operating biomass equipment;
- the variable quality of biofuels (e.g. methane from biomass) may produce hazards if injected into the gas grid.

Source: UK Health and Safety Laboratory Futures Team and additional sources (HSE, 2010b; Bradbrook et al., 2010; Christiansen et al., 2009; Bradbrook, 2009a; Nicol et al., 2011).

OSH discussion for bioenergy

The volume of biofuel production and use could be scenario-dependent, with varying degrees of emphasis on local production and use: for example, biofuel production is higher in Deep Green. Third-generation (algal) biofuels are likely to become of increasing importance as the technology develops and is introduced closer to 2020.

OSH organisations may need to consider the following hazards.

Major hazards

Risks from biogas, biodiesel and bioethanol production include:

- explosion and fire risk from large-scale biofuel production;
- fire and explosion caused by electrical equipment sparking in an explosive atmosphere, such as one filled with methane;
- pressure vessel explosion;
- impact on gas network pipelines from biogas or syngas not meeting the required gas specification; and
- the potential for large-scale accidents caused by the 'domino effect', where a minor initial incident can lead to a catastrophic situation.

Risks from biomass used in co-firing with coal include:

- large-scale stores of biomass feedstock can self-heat and combust spontaneously;
- exposure to dusts, moulds, endotoxins and VOCs;
- the co-milling of coal and biomass can lead to explosion and rapid, intense combustion;
- worker exposure to acidic gases during removal (H_2S, CO_2 and COS are typical gas impurities);
- exposure to microorganisms and metal residues; and

- possible longer-term health risks from exposure to chemicals in feedstock and those used in biofuel production and chemicals from waste streams.

Smaller-scale occupational and workplace hazards

Hazards may be primarily due to the fact that bioenergy is being used in a more decentralised and innovative way, with a large number of small-scale projects within communities and schools.

Risks in biogas, biodiesel and bioethanol production include the following:

- risks of asphyxiation in confined spaces (e.g. anaerobic digesters);
- exposure to chemicals and solvents, such as methanol used in the production of fuel, and plant clean-up;
- exposure to CO_2 generated during the fermentation process and volatile by-products from microbiological processes;
- fire, burn and explosion risk from the manufacture of biofuels; and
- operational risks associated with the scaling-up of third-generation biofuel production from demonstration plant to commercial scale.

Risks in biomass combustion include the following:

- impaired functioning and, ultimately, asphyxiation as a result of inhalation of CO and aldehydes produced during storage and transportation of feedstocks;
- respiratory allergies resulting from degraded biomass feedstock; and
- hazards common to importing, transporting and storage of biomass feedstocks — exposure to VOCs, lack of oxygen in confined spaces, exposure to dusts, moulds and endotoxins.

A risk common to both biofuel production and biomass combustion is that new players, less familiar with the risks of handling fuel, may be particularly at risk. Such new players may be farmers producing low quantities, or companies starting to use their own waste as an energy source, for example in the textile or food industry. There may also be problems with the quality of their products and, therefore, safety issues.

Hazards common to major hazards and smaller-scale production of biofuels and biomass combustion include the following:

- increased collection of wood from woodlands (forestry activities have a very high rate of injury and fatal accidents);
- the high temperatures and, sometimes, high pressures used in pyrolysis (350–550 °C) and gasification (over 700 °C) — there is also a potential issue with the increased variability in the constitution of gas derived from biomass compared with fossil fuels;
- potential land-use planning issues from the use of biogas, for example landfill generators; and
- increased collection, transport and use of large amounts of animal waste for energy production, giving rise to potential risks of slips and trips, falls into slurries/manures, exposure to fumes, microbiological exposure, methane explosions and fires.

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single day's workshop with experts in technology and/or OSH expertise as well as policymakers, with the HSL desk research as a briefing. The intention was to illustrate the power of the scenario method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.4. Waste management and recycling

Comparison of technology developments across scenarios

Definition of 'waste'

In the workshop, usage of the word 'waste' varied. It was sometimes used to mean only material that cannot be reused or recycled. But, in some cases, 'waste' was being recycled, so, strictly speaking, it was not waste at all, though of course it did come out of a waste stream. This report uses the terms *intractable waste* and *waste stream* when necessary to distinguish between the two.

Table 16: Technology developments: Waste management and recycling

Technology developments	Win-Win	Bonus World	Deep Green
Volumes of waste streams	Low, through recycling	Higher	Low, through generating less
Waste stream handling	Robots/automation	Low-cost workers	Local workers
Industrial symbiosis	Widespread	Only where profitable	Widespread
Philosophy	Recycle	Don't bother	Reduce and reuse
Value capture	High, through technology	Throwaway society	Low-tech recycling

Waste management and recycling in Win-Win

Technology and societal context

In Win-Win in 2025, recycling has become a political necessity. Regulations require the use of recycled materials rather than new materials wherever possible and forbid the destruction of waste at the end of its use. The aim of government disposal policy is zero waste, and landfill is greatly reduced.

A philosophy of industrial symbiosis (Your waste is my feedstock) means that a market is created for by-products that would otherwise be treated as waste. Society adopts a whole life cycle (cradle to cradle) approach to production that minimises waste, and punitively high gate fees for landfill reinforce this message. There is a high level of knowledge in society about how to deal with waste, and extended producer responsibility (e.g. in terms of materials used) forces manufacturers to minimise the life cycle costs of their activities.

Building codes encourage new construction materials and concretes from waste. New materials and products (e.g. plastic-bamboo composites and high-pressure pressed plastics) are only introduced if there is a system available to treat them at the end of the life cycle.

Techniques such as gasification and pyrolysis are used to extract energy from waste streams, and even aerobic composting is discouraged because it dissipates embodied energy; it should be replaced by anaerobic digestion.

All metals are recycled and rare earth elements are recovered from devices at the end of their life. Automated sensing of waste items improves to the point that robotic disassembly of discarded items becomes common. By 2025, 70 % of industrial waste is recycled.

Businesses proactively seek out resources in waste streams and earlier landfill sites are widely mined to recover useful materials. By 2025, the use of raw materials per unit of GDP is many times lower than it was in 2012.

Workshop discussion on OSH — Waste and recycling in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Nanomaterial release The release of new materials such as nanomaterials during mechanical operations in waste treatment is possible. There is a lack of knowledge of the health and safety effects of these nanomaterials and how they change during the life cycle (e.g. graphene). OSH research is needed in this area, as it is on the whole area of waste management.	All scenarios, but mainly Win-Win and Bonus World, with their higher innovation rates	New risks continually emerging (Section 5.4.10 OSH factors common across technologies)
Certification and standardisation There is a need for control mechanisms for the waste operator for the entire process from accepting inputs, through processing and the production of (waste and non-waste) by-products. These control mechanisms need to be both voluntarily audited and legally enforced. The system of certification and audit should be reviewed and re-evaluated periodically. And a long-term study is required of the whole waste system including waste management.	More of an issue in Bonus World with its lower environmental values	Not new
Labelling and identifying hazardous substances after use There appears to be a gap in the legislation concerning the traceability and marking or labelling of hazardous substances after they have been used. The problem stems from hazard labelling becoming lost. For example, some hazardous products have warning notices on the outer packaging only. Under the current system, houses being demolished have unlabelled and unknown materials in them. It is important to have better mechanisms for workers to recognise dangerous substances and new labelling standards such as special colours or RFID (Radio Frequency Identification) chips to help recycling workers to recognise hazardous materials. Better labelling would help everybody to understand risks more easily.	All scenarios, but mainly Bonus World with high innovation and less environmental concern	High

Workshop discussion on OSH — Waste and recycling in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Urban mining and recycling of industrial waste Because more industrial waste has to be recycled in this scenario, more hazardous waste will have to be treated. Depending on the nature of the waste, this can include persistent organic pollutants (POPs), Polychlorinated biphenyls (PCBs), dioxins, heavy metals, asbestos and nanomaterials. It is difficult to determine the precise content of hazardous substances in the waste, and the implementation of adequate prevention measures as well as provision of OSH training of recycling workers is made more difficult due to lack of information. In the short-term, new ways of detecting and sorting waste streams are needed so that hazardous waste is handled correctly. It is important that recycled material is not more hazardous than virgin material. In the longer term, better equipment is needed for urban mining, including robots, and more OSH education all along the value chain from design to recycling.	All scenarios on principle in Win-Win and Deep Green, and through economic returns in Bonus World	Growing activity and, therefore, exposure
Robotic disassembly The use of robots in waste processing and recycling would be highly beneficial in OSH terms as it means that workers will be less exposed to manual handling and exposure to dangerous substances from waste. The technology would need to be developed to ensure at least the same efficiency as manual work in terms of recognition and separation of waste. There will still be risks from activities such as maintenance (until the longer-term development of maintenance and self-cleaning robots).	Win-Win and Bonus World	Beneficial to OSH (Section 5.4.10 OSH factors common across technologies)

Waste management and recycling in Bonus World

Technology and societal context

Bonus World in 2025 is a high-consumption world producing lots of waste that could be avoided. It is a throwaway society. Products are not necessarily designed for recycling, and metals are only recycled where valuable. There are lots of innovative new products and, consequently, new waste problems.

Firms respond to incentives. Waste processing, where it happens, is driven by the high prices of raw materials and the high cost of space for landfill. Industrial symbiosis (heat and waste reused by others) is only used where profitable. Recycling is practised only where it makes money, but all waste streams are seen as a potential resource that could be sold to someone.

Waste streams are separated, and the energy in dry waste is recovered. Much waste is sorted automatically (but only where this is cheaper than manual labour). High-value waste is recycled in the EU; lower-value waste is exported. Everything else goes to landfill, where it is treated as a future resource for mining and/or a biogas energy store. This includes incinerator ash, digester residue, and hazardous wastes.

Households pay for waste disposal by volume, leading to the installation of domestic compactors, incinerators and digesters, all to save waste charges.

In construction, most demolition waste goes to landfill (except where it is cost-effective to use it in new construction). Previously installed house insulation has become an intractable waste in itself.

Workshop discussion on OSH — Waste and recycling in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Rapid innovation Rapid innovation leads to new materials and new processes with the increased risk of not taking the time to integrate OSH into R & D and design, or to gain expertise on how to safely use them. In this scenario, high levels of innovation involve new products that are not designed for recycling, so adding to the risks faced by the workers who have to handle them in the waste.	Bonus World	New products (Section 5.4.10 OSH factors common across technologies)
Long-latency hazards There is a real risk of unrecognised long-latency hazards, such as carcinogens, from new materials when at the waste treatment stage of their life cycle.	Greatest use of new materials with less investment in research on health hazards on Bonus World	New risks (Section 5.4.10 OSH factors common across technologies)
Throwaway society In Bonus World, a rich society with high economic growth becomes a throwaway society with high volumes of waste to deal with. The sheer volume of waste and the number of jobs needed to deal with it increases exposure to OSH risks (e.g. chemical exposure, MSDs, and accidents) if no adequate work organisation and prevention measures are in place. The risk of leachate from landfill is also increasing.	Bonus World	High
Complex world Combined exposure to hazardous substances will become more common in an increasingly complex world. The growing number of existing and used substances and complex working processes, generating diverse by-products that are difficult to identify, leads to more a complex exposure situation.	Greatest in Bonus World	New combinations of hazards
Charges for disposal High charges for disposal of waste in this scenario will lead to domestic action to cut costs. Domestic digesters bring gas and explosion risks; compactors, the risk of crush injury; incineration, issues over air quality and soot. These diverse sources will be very difficult to control. Homeworkers and workers in SMEs will be exposed to similar hazards.	All scenarios, but with differing motivations in each	Not new, but growing usage May affect growing numbers of homeworkers and workers in SMEs

Waste management and recycling in Deep Green

Technology and societal context

The deep green values of Deep Green, coupled with low economic activity, longer product life cycles and products designed for ease of repair and recycling mean that waste volumes are much reduced and the waste is less hazardous. There are much lower volumes of intractable waste, so the OSH risk is reduced.

Waste streams are dealt with locally. A systems view is taken of waste, with integrated waste systems, and integrated waste treatment value chains. Industrial symbiosis is the prevailing philosophy (Your waste is my input). Plastics, metals, and textiles are recycled, with jobs in collecting, sorting and recycling waste. Laws mandate the full recirculation of nutrients and energy recovery, and landfill sites are mined for their resources.

In the longer term, biological waste streams are used to generate biogas, and biomass, energy.

All biomass waste is used productively — but hazardous waste still has to be incinerated (e.g. hospital waste and glass fibres).

The reduced volumes of waste mean that, overall, there are fewer green jobs in the waste sector. But there are still green jobs in the waste sector, in engineering and design and testing, and in working to prevent waste and waste issues. There are also green jobs in such fields as mining landfill sites and recycling, as well as in handling intractable waste.

Workshop discussion on OSH — Waste and recycling in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Systems The main issue is the importance of the design of systems, not just the design of products.	All scenarios, but most lacking in Bonus World	High
Reducing volumes With a focus on the waste hierarchy, the quality of waste streams has improved over time. But there is the inheritance of previous waste still to be dealt with, and hazardous waste still has to be handled and incinerated (hospital waste, glass fibres, etc.). With much lower volumes, the OSH risk is reduced.	Deep Green	Positive for OSH
Landfill mining There is a trend to recover materials from previously dumped waste — there is a great need for information on what these materials may contain. Landfill mining could be very messy and hazardous.	All scenarios on principle in Win-Win and Deep Green, and through economic returns in Bonus World	Growing activity and, therefore, exposure
Construction jobs In construction, there will be high volumes of recycled construction materials, and risks from retrieving electrical cables and metals on site.	All scenarios Greatest in Win-Win, with its combination of high growth and green practices, but also high in Bonus World with high turnover rate of building stock and high metal prices Most construction waste in Deep Green is from retrofitting and refurbishment	Growing risks
Small companies separating and sorting their own waste With small companies (e.g. in construction) processing their own waste, there are greater OSH risks because of a lower level of awareness of those risks, fewer resources to dedicate to OSH risk management and worker training, etc.	All scenarios, but greatest in Deep Green	Growing risks
Biomass Greater use of biomass in this scenario brings greater risk of exposure to dust, allergens, moulds and other toxins, as does more composting of organic waste streams.	Especially Deep Green	Not new, but growing in importance
Greenery creates waste problems Green values and green activities create their own waste problems. Reused materials may be of variable quality and be contaminated. New light composite materials to reduce energy use may not be recyclable and, therefore, add to the volume of waste to be incinerated or sent to landfill. Biomass brings its own biohazards such as moulds and respiratory issues.	Win-Win and Deep Green	New products and materials
Dealing with the dirtiest waste streams Dealing with the dirtiest waste streams brings OSH issues as people process the most difficult tail end of the waste stream in concentrated form.	Win-Win and Deep Green	Growing risk in these scenarios

Complementary information from desk research and Phase 2 technology workshop on OSH issues for waste and recycling

Workshop briefing on OSH issues

The briefing material for the waste and recycling workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors:

- increased collection and separation of organic waste in Europe, such as food and nappies, which may lead to increased exposure to bacteria and fungi as well as sensitising agents;
- risks from novel waste treatments, which are under development, such as the separation of brominated fire retardants from waste electrical equipment;
- risks from novel energy-generating processes, which are under development, such as arc plasma power;
- health risks from chemical exposure in 'downstream' processes for recycling batteries, fluorescent lighting, cathode ray tubes (e.g. mercury exposure or fire risks);
- exposure to nanomaterials and other novel materials in waste;
- the impact of increasing segregation of waste, which could lead to greater concentration of potentially harmful materials;
- the increasing economic value of extracting precious or potentially rare earth metals from waste electronic material (especially after the implementation of WEEE recycling regulations) means increased levels of recycling in Europe and increased risk of chemical exposure: for example, there are plans to open up landfill to extract valuable materials in Belgium;
- potential chemical exposure from recycling of devices that have previously been sent to landfill, such as LCD TVs, lithium-ion batteries and low-energy light bulbs;
- high risk of human-large vehicle collisions during collection or on-site handling of waste or recyclable material;
- MSDs — for example from repetitive manual handling (of heavy loads), carpal tunnel syndrome, injuries from collection and sorting/picking activities, or hearing damage from very noisy recycling activities (e.g. from equipment use or recycling of glass); and
- handling of construction waste: volumes may change as efforts to reduce construction waste are implemented.

Another key issue is the nature of the waste-handling workforce. Work in the recycling and waste management sector may require only low levels of skills and be poorly paid and so be likely to employ migrant workers. Migrant language and literacy barriers could lead to communication problems and, along with differing attitudes to health and safety, could lead to increased risk in the sector. With society ageing, older workers will naturally be present in this sector, as in most others. Some jobs in the waste and recycling sector will be physically demanding, and this will exert a greater physical toll on the older worker. Additionally, in some roles in this sector, there will be exposure to dust, microbiological agents and chemicals, and little is known about the effect of this exposure on ageing workers.

Source: UK Health and Safety Laboratory Futures Team and additional sources (Schulte and Heidel, 2009; HSE, 2007; HSE, 2009b; O'Neill, 2009; Brentnall, 2006).

OSH discussion for waste and recycling

The volumes of waste and the way it is handled may be scenario-dependent. Issues that OSH organisations need to be aware of include the following.

- The **increasing diversity and growth of the recycling and waste management sector** will increase in the hazards and risks in the sector. There are many examples of expansion in the recycling of plastics, paper, glass, aggregates and other materials for the construction industry.
- Waste management and the recycling of older waste could lead to **worker exposure to unknown hazardous substances because of poor traceability.** Landfill mining may be particularly hazardous in this respect. There may also be a fire and explosion risk from methane generated from the breakdown of biological material underground in the landfill area being mined.
- There will potentially be risks from **workplace exposure to new materials**, including nanomaterials, in new products, but they may be better documented and controlled. However, increasing segregation of waste could lead to greater concentrations of hazardous materials.

- The **increasing use of automation** for waste sorting and handling has the potential to reduce risks to workers. As products are increasingly designed with eventual dismantling and recycling in mind, risks to workers may reduce.

- **Well-known risks from waste and recycling will continue to be significant** and will grow, along with the corresponding increase and diversity of the sector. These risks include, for example, risks of being run over by a large vehicle, physical injuries, MSDs from handling waste products and risks from the interaction with large-scale processing equipment such as balers, boilers, crushers, chippers, compactors and shredders.

- Other well-known risks that will increase along with the expansion of the sector **include exposure to biohazards** (e.g. when handling putrescible waste, sorting textiles or dismantling cars and **exposure to toxic materials** such as mercury and lead (e.g. while breaking up items such as computers and televisions).

- Due to the increasing worldwide shortage of raw materials and the rising cost of energy, there will be a **large expansion in the recovery of metals, polymers and glass**. This may lead to a corresponding increase in workplace exposure to the chemical processes used in these recovery processes.

- A significant number of new **companies are entering the waste management sector** as well as existing waste management companies diversifying into other areas of the sector (e.g. waste metal processing companies are expanding into the recycling of end-of-life vehicles and lithium-ion battery recycling plants have started to appear).

- The impact of **increasing segregation of** waste could lead to a greater concentration of potentially harmful microbes, chemicals and dust (e.g. the increasing separation of food waste in Europe will lead to more collection and handling of putrescible waste coupled with an increase in worker exposure to these harmful materials).

- Due to the increased complexity of the recycling and waste sector across Europe, there will be greater **reliance on multiple contractors and multiple contractor interfaces**. This is likely to increase the risk of accidents due to poor communication.

- **Novel processes** are being developed, commercially introduced, or becoming widespread in Europe. Each of these will have specific hazards associated with them. Examples include the anaerobic digestion of organics with fire/explosion risk due to the methane produced and the separation of brominated fire retardants from waste electrical equipment, with potential exposure to toxic or carcinogenic substances.

- The expansion or introduction of processes have been driven by the introduction of **European legislation on recycling**, some of which will have increasing targets in the next 5–10 years, such as the European Battery Directive and the Waste Electrical and Electronic Equipment Directive (WEEE). Additionally, the increase in recycling has been driven by the increasing cost of landfill in Europe. Now, a large number of companies are recycling waste electronics and batteries.

- Household items and electronics that are currently used will become waste that is likely to be recycled in the near future This means there will be **changes in the waste stream**, which could lead to an increase in hazards (e.g. the switch from incandescent bulbs to low-energy light bulbs has increased the risk to workers from exposure to mercury). OSH organisations will need to be aware of changes in the waste stream and associated changes in workplace hazards.

- The priority should be to **integrate OSH into the conception of the entire waste treatment process** and work organisation.

- Certification and standards (for the waste operator for the entire waste process) could help improve safety, but it is important that standards **promote the principle of designed-in safety**.

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single day's workshop with experts in technology and/or OSH expertise as well as policymakers, with the HSL desk research as briefing. The intention was to illustrate the power of the scenario method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.5. Green transport

Vehicle engine nomenclature

EV: electric vehicle

PHEV: plug-in hybrid electric vehicle

ICE: internal combustion engine

PV: photovoltaic

V2G: vehicle to grid (energy transfer)

Platooning: Vehicles travelling closely together under automatic control

Comparison of technology developments across scenarios

Table 17: **Technology developments: Transport**

Technology developments	Win-Win	Bonus World	Deep Green
Cars	Most new cars are EV or PHEV	Many new cars are electric Some use gas fuel cell power	Widespread use of bicycles and electric bicycles
Engines	Fuel cells	Highly efficient petrol and diesel, for PHEV	Mix of electric and life-extended internal combustion models
Self-driving vehicles	Some self-driving autonomous vehicles Self-driving vehicles can form themselves into **platoons** (8) on motorways and highways to save energy	Motorway platooning led by professional driver In emergencies, platooning cars can stop and park themselves	Human drivers (but reduced distances driven)
Road infrastructure	Major change — electric recharging and grid; support for automation	Road infrastructure to support automation	Very limited or no infrastructure investments
Public transport	Electric land transport Biofuelled aircraft	Automated trains High speed rail	Growing rail use Public transport plays a key role: heavily subsidised and, sometimes, free Multimodal city transport
Private transport	Reduced demand for business travel	Overall growth in travel Growing air travel and sea transport	Severely curtailed transport demand
Teleworking	Increased levels (primarily to save energy)	Increased levels (primarily to avoid congestion)	Increased levels (primarily to reduce overall consumption)
Freight	Electric for short runs (50 km) Road-rail for long distances	Electrified or biodiesel trucks Electrified or biodiesel rail Hybrid diesel vans	Wide role for green two-wheeled deliveries in cities Trucks retain internal combustion technology

Transport in Win-Win

Technology and societal context

In Win-Win in 2025, new cars are mostly electrified with fully electric city runabouts and, for long-distance use, plug-in electric hybrids with highly efficient biopetrol and biodiesel engines. The few remaining non-electric vehicles use biofuels or gas, though some use hydrogen.

Over time, technology has made the running of an electric car more convenient and energy efficient:

- rapid recharging (at a rate of 50–100 kW) has become widespread;
- intelligent congestion charging manages the road space to reduce the time and energy costs of congestion;
- control technology allows platooning (closely-spaced vehicles following each other automatically) on motorways;
- new materials keep the weight and energy consumption low; and

(8) Platooning is where a convoy of automated vehicles follow a driven lead vehicle.

Workshop discussion on OSH — Transport in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Maintenance in high capacity environments The Win-Win scenario requires complex and sophisticated transportation networks. The complex mixture of novel materials (e.g. composites, alloys and polymer-based materials) and novel systems may have OSH implications. Construction and rapid upgrade of infrastructure will have an impact on OSH, especially with a possibly less skilled workforce early on in the contractor supply chain. Attention and resources will be needed to provide safe maintenance capacity.	Greatest in Win-Win and Bonus World	Not new, but growing as sophistication of transport infrastructure grows
Self-driving cars and other vehicles In the context of people driving for their work or commuting, this development is potentially very positive for OSH, though it brings a risk of over-reliance on the technology. Absolute reliability will be essential, with fail-safe modes in the event of accidents, problems, incidents and failures.	Mostly Win-Win and Bonus World	New risks
Electric vehicles and quick charging of electric vehicles With such high energy densities, there may be an increasing risk of explosion or fire. This will be particularly high during rapid recharging, and after accidents. In the short term, the key consideration will be lack of training and familiarity with maintenance workers and in the emergency services to deal with these new situations. Over time, the number of people exposed will increase, but experience in safer design and level of skills in safe use will increase also. Charging infrastructure may be a prime source of electrical risk for maintenance workers especially if damaged or vandalised.	All scenarios, but greatest in Win-Win	Rapidly growing exposure
Teleworking and teleconferencing This has positive implications in reduced travel stress and time, and may give workers more control over their working day. But it may also lead to more difficulties for employers in ensuring good working environments (e.g. in employees' homes), isolation from colleagues, and less separation of private home and working life. Organisations will need to get used to new working practices and learn how to manage staff appropriately and flexibly.	Likely in all scenarios: in Win-Win (to save energy), in Bonus World (to avoid congestion), and Deep Green (to reduce overall consumption)	Growing strongly Domestic hazards will become an OSH concern

- ICT systems allow people to make informed choices about when and how to travel with maximum convenience and minimum energy consumption.

Finally, self-driving vehicles have become available. Driverless transport has evolved through the sequence of subway trains (before 2012); suburban trains (2015); trams (2020); buses (2020); cars on motorways (2020); and cars in towns (2025). Cars have been automated to the level of motorway platooning: self-driving autonomous cars should be able to extricate themselves from a platoon and stop and park themselves, in particular in case of emergency.

Elsewhere, small city delivery trucks, and public transport (including buses) have been electrified; long-distance freight transport has shifted to multimodal road-rail transport; and the development of effective video-conferencing systems has reduced the need for business travel.

Transport in Bonus World

Technology and societal context

In Bonus World in 2025, consistently high oil prices have led to a big new nuclear power programme (which is only just coming on stream after many years), and continued use of fossil fuels for electricity generation and transport. Concern for energy use is driven by the high cost. The focus is on lighter more efficient transport solutions.

EVs are sometimes used as city runabouts, but PHEVs have quickly become a large share of all new cars sold, powered by highly efficient, clean and economical diesel and petrol engines.

The demand for transport continues to grow, across all modes, and congestion in the air and on the roads gets ever worse, countered to some extent by congestion pricing and road charging.

Urban trains and, finally, trams have been automated. Cars have been automated to the level of motorway platooning led by a professional driver. The requirement for motorway automation was for the car to drive along the motorway and be able to stop and park itself safely if the driver does not take control again at the end of the automated section.

Workshop discussion on OSH — Transport in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Electric vehicle maintenance New and unfamiliar systems in electric vehicles will initially be maintained by specialist repairers, but these will migrate to general repairers over time, requiring extensive training in safe procedures.	Mostly Win-Win and Deep Green	Growing risks (Section 5.4.10 OSH factors common across technologies)
Automation Automation in transport leads to a reduced role for humans and will be very positive for safety in the long term, although it brings the issue of over-reliance on the technology and of its absolute reliability. Self-driving vehicles need to ensure safety for workers in the roadway.	Greatest in Win-Win and Bonus World	New processes bring risk, but automation is likely to be positive for OSH (Section 5.4.10 OSH factors common across technologies)
Reuse of EV batteries The biggest OSH impact from EVs may not be in vehicles at all. Batteries degrade over time, so old batteries that no longer perform adequately in EVs will be replaced. But they will still have electrical storage capability (perhaps 50 % of new capacity). This means that they will be used in static energy storage. So, in an EV world, the main risks from degraded and decaying and unlabelled EV batteries will be in energy storage applications for grid boosting or even home electricity demand management. Risks will be made worse by users not knowing the history of the EV battery and, maybe, not even knowing the full details of its construction.	All scenarios, but greatest in Win-Win and Bonus World	High

Transport in Deep Green

Technology and societal context

In Deep Green in 2025, the focus on transport is efficiency. People only travel when necessary, and use virtual meeting places whenever they can. This is a world of conflicting priorities, where painful choices have had to be made. The deep green philosophy pushes against major changes in infrastructure: the aim has become to better use what exists. Infrastructure cannot change quickly; therefore, changes in behaviour were needed to achieve green goals.

There is no new nuclear power: society sticks, through necessity, to shifting the generating mix towards renewable energy systems (RES). There is a growing role for renewables, but funds for investment in these are limited.

There has been no substantial shift in the transport mix. There are some electric cars, but the majority are still internal combustion engines (ICE). The Green way is to make better use of existing cars — to prolong their working life. Retrofitting of efficiency measures such as stop-start ignition and low-resistance tyres are widespread.

Road freight is still ICE, as there have been no great advances in battery technology that would power more than the smallest runabouts, or public transport vehicles that can recharge regularly. For long-distance freight, of which there is less, road-rail intermodal transport is favoured.

But, there are new solutions to the issue of urban mobility, with many electric bikes and electric buses. Walking or cycling jobs for the transportation of goods and delivery of services in urban areas are the norm. Plumbers, electricians and certain maintenance services, for example, now use cargo bikes to deliver their services (WHO, 2011). People make their own decisions about transport: in some remote areas, the norm is also electric for local travel, as renewable energy to recharge EVs is available locally at less cost than transporting refined fossil fuels.

Public transport is heavily subsidised and, sometimes, free.

In the context of Deep Green and low growth, there has been growth in self-entrepreneurship as more people try to make a living by finding new 'green' methods for delivery services.

Workshop discussion on OSH — Transport in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Two-wheeled vehicles Increased use of bicycles may lead to more accidents. Two-wheeled vehicles (e.g. cargo bikes) are used for the transport of people and goods, including mail and other deliveries, takeaway food, parcels and bigger items, as well as for delivery of services. 'Mobility entrepreneurs' may bring a reduced OSH culture and have lower access to OSH services.	Deep green	Growing risk
Human-ICT interfaces Human-ICT interfaces can give rise to complex risks. There are greater risks if the ICT system fails, and the over-reliance on ICT can lead to loss of skills that would be necessary in the event of such a failure.	Greatest in Bonus World	Growing risks (Section 5.4.10 OSH factors common across technologies)
EV electrical risks Higher voltages in EVs lead to high maintenance risks if the safe working procedures described by the manufacturers in the user guide are not followed. Electrical risks also arise from charging stations. Risks are also linked to the combination of electricity and water (in the case of rain or flooding) and there are technological challenges linked to energy storage. The risks are predominantly to technicians and service workers working at service stations, but possible risks to wider groups if charging stations are not well maintained.	All scenarios, but greatest in Win-Win	Rapidly growing exposure
Growth of self-entrepreneurs in green transport and deliveries The self-employed tend to have a lower awareness of OSH risks, less access to OSH services such as OSH medical surveillance, and poorer links to labour inspectorate services. They are generally not covered by worker protection legislation.	Deep Green	Increasing occurrence

Complementary information from desk research and Phase 2 technology workshop on OSH issues for transport

Workshop briefing on OSH issues

The briefing material for the transport workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors.

- The **electrification of road transport** is occurring over the next 10 years in Europe. The risks associated with this include electrocution and fire risk from vehicles and necessary infrastructure, such as charging points, battery swap depots and smart grid connections. Batteries used in vehicles have a high voltage and amperage. There will be additional electrical risks during battery removal, car maintenance, and to emergency services after a road accident. Safety may not be a priority when designing these systems: Will there be sufficient knowledge of technology and its safe use? There will be a need for provision of robust training in the refuelling, and maintenance, of electric vehicles.

- **Electrified rail networks** across Europe have been, and will continue to be, introduced in order to reduce carbon emissions. The risks associated with this will come from construction activities, electrocution and fire risks during building of infrastructure as well as risks from trains during track preparation and maintenance.

- **New vehicle fuels** such as Liquified Petroleum Gas (LPG), or natural gas may be introduced in the EU Member States to reduce carbon and particulate emissions. There may be risks associated with the use of unfamiliar new fuels in vehicles: LPG, for example, has different properties to petrol, and a different refuelling procedure. There will also be risks from fire and explosion due to increased distribution of these fuels. The aviation industry is aiming for biofuel to make up 10 % of fuel by 2017: there may be risks associated with this change.

- There will be increasing numbers of **hydrogen vehicle pilots and demonstrations**, such as the over 150 hydrogen vehicles used at the London 2012 Olympics. There will be fire and explosion risks from all stages of the hydrogen process from distribution through to refuelling and its use. In the future, it is possible that major infrastructure developments will be needed to distribute hydrogen for transport either alone or mixed with natural gas (as 'Hythane'), through existing or new pipeline networks. If so, the risks and hazards associated with this approach will need to be considered. In the nearer future, for transport applications, there will be a need to distribute hydrogen in some form direct to the end-user, analogous to the operation of petrol stations at present. Hydrogen has also been suggested as a possible (although not very likely) fuel for aircraft as well as road vehicles.

- **Use of 'intelligent' vehicle aids** that have been, and are being, developed include automatic braking, fatigue monitoring and vehicle-to-vehicle communication. 'Road trains' or platooning is being developed by Volvo as part of the Safe Road Trains for the Environment (Sartre) project. The technology allows a car to automatically monitor the car in front and mimic its actions during long-haul drives on pre-planned routes. The platoon will be led by a professional driver. These technologies should make workplace driving safer. However, there may be risks from over-reliance on vehicle technology (e.g. not enough attention being paid to the road, or a driver following a satellite navigation system regardless of where it leads him — even into a river!). These technologies could also fail, which may lead to accidents.

- **'Intelligent' transport infrastructure** in cities can be used as a more efficient way to control traffic, thus reducing the time that vehicles are stationary and reducing energy use. Process-safety software to run such systems needs to be robust and reliable, to avoid accidents.

- **Internet shopping** is increasing further and means that organisations can reduce their carbon footprint, as fewer people have to drive to the store. This will lead to more delivery vehicles on the road, many on tight schedules (aiming for 'just-in-time' delivery), which can increase the risk of an accident. Additionally, there are likely to be increased levels of MSDs from drivers having to lift heavy items on their own.

- There will be an increase in European **Liquefied Natural Gas (LNG) imports**. LNG vessels and terminals are increasing in size and number. There are hazards from fire, explosion, fireball and late ignition of a vapour cloud. The scale of the hazard from a large LNG deep-water port spill is around 3 km for fire and about 5 km for a vapour dispersion explosion risk.

- Use of **novel materials and substances**, including nanomaterials, in all kinds of vehicles may bring the risk of worker exposure in manufacturing and use, or risks from the performance of such materials and substances.

Source: UK Health and Safety Laboratory Futures Team and additional sources (HSE, 2010b; Grant, 2010; Umair, 2011).

OSH discussion for transport

Although there is a lot of potential for change in transport, including rail, air and shipping, the workshop tended to focus on electric and hybrid road vehicles, perhaps reflecting those areas where there is currently most activity. This, in turn, focused primarily on cars and vans, as trucks were considered unlikely to be suitable for electrification in the near to medium term.

Issues that may be of concern to OSH organisations include emissions targets and the price of oil, which are likely to drive an increase in the number of electric and hybrid vehicles. Electric vehicles are likely to present significant electrical risks to workers and the wider public from the high voltages involved. Drivers and workers involved in maintenance will initially be unfamiliar with the high voltages (approximately 360–500 V), instead being used to the 12 V batteries associated with current internal combustion engines. Hence, there may be electrical risks in:

- maintenance, as electrical vehicle maintenance moves away from specialist providers to smaller independent garages as EVs become more widespread;
- recharging, either by cable or through battery replacement; and
- rescue after accidents.

This means that there is a need to raise awareness of the potential hazards of high-voltage batteries in vehicles and the associated infrastructure. Groups of workers most at risk are independent mechanics and rescue workers. There also needs to be suitable accredited training for the mechanics who will service and maintain hybrids and EVs, and for personnel involved in battery recharge or swap systems.

A rise in the number of EVs or hybrid vehicles due to government incentives or cheaper prices is likely to lead to a corresponding increase in the number of vehicles being scrapped (as was seen across Europe with the scrappage scheme to stimulate the European car market). European end-of-life legislation for vehicles means that more vehicles will be dismantled and recycled with a corresponding increase in the number of potential workplace exposures to hazardous chemicals, materials and microbes.

There may be risks from exposure to new materials in manufacture and refinishing as lighter, more efficient vehicles are designed and manufactured. For example, the increasing use of carbon fibre may pose a health risk to workers manufacturing these vehicles.

Use of intelligent computer systems in cars will increase and become mainstream, initially to provide driver assistance, such as lane departure or blind spot warning system. This technology will lead to semi-automated driving, initially with platooning on motorway systems and, maybe by 2020, eventually to fully automated driving in city centres.

The volume of travel may be scenario-dependent: the cost to travel to work versus the advances in telecommunication technology and its quality for telecommuting and meetings and the environmental benefits this will bring will be important.

The increasing cost of fuel and European legislation on city air quality will increase the number of bicycles and motorised two-wheeled vehicles on city roads (e.g. motor scooter sales have increased in the United Kingdom recently). There will be increased accident and injury risks to workers using two-wheeled travel to commute or for business, rather than four-wheeled vehicles, but there will be fewer cars and large vehicles in city centres, so this may mitigate the risk. There are likely to be more electrical tram systems installed in European cities as a result of legislation and high fuel prices. There are likely to be safety risks (mostly collision-related) to people not familiar with trams and their movements.

There will be explosion, fire and burn hazards associated with the greater storage and distribution of hydrogen if hydrogen vehicle uptake becomes significant over the next 10 years, particularly as individuals are not familiar with the differences in refuelling, operation and hazards associated with this technology. Again, fire, ambulance and police personnel are unlikely to know that a vehicle involved in an accident is hydrogen fuelled, or how to deal with it. There may also be OSH hazards associated with hydrogen if land-use planning is not carried out (e.g. placing a hydrogen refuelling station or storage facility close to residential, business premises or in some other inappropriate location).

Increasing imports of LPG and LNG for vehicles will increase the risk of fire and explosions at associated offshore, port and storage facilities. Additionally, any switch to greater use of LPG and LNG in vehicles is likely to lead to unfamiliarity with the new refuelling systems, infrastructure and operations, which may increase the risk to individuals from fire, burns and explosions.

Sophisticated transportation networks, with a complex mixture of multiple systems and modes of transport, may have increased risks. This increased risk will be due to the combination of OSH risks from all the forms of transport within the multimodal system — trains, cars and road freight.

Construction and the rapid upgrade of infrastructure to support the electrification of rail and road transport will have implications for OSH, due to the combinations of risk. These include the hazards associated with construction activities along with electrical hazards. This work may be carried out by a less-skilled, possibly migrant, workforce used early on in the contractor supply chain. Poor communication, language issues and, potentially, different OSH cultures could lead to increased risks. Attention by OSH professionals and stakeholders along with monitoring, training and resources will be needed to provide a safe maintenance capacity for this extensive work.

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single day's workshop with experts in technology and/or OSH expertise as well as policymakers, with the HSL desk research as briefing. The intention was to illustrate the power of the scenario method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.6. Green manufacturing, robotics and automation

Comparison of technology developments across scenarios

Manufacturing is one of the key drivers in the future of green jobs. New manufacturing techniques (including robotics) will allow new products to be made and old products to be produced with less energy and less waste of material inputs.

Similarly, new techniques such as 3D printing and small-scale production will reduce transport costs to the place of use, and may be more energy efficient. Novel enzymes and other biotechnology production methods will allow manufacturing of many products at lower temperatures and with less energy than today.

Table 18: **Technology developments: Manufacturing**

Technology developments	Win-Win	Bonus World	Deep Green
Demand for manufactured goods	High	High	Reduced levels of manufacturing
Level of automation	High	Very high	Low
Configuration	Distributed local production	Automated self-assembling plants	Nearer point of use
Attitudes to safety	Automate away the risks to humans	Only where lack of safety has a financial cost	Unemployed workers more ready to accept risky jobs because of high unemployment rates
Design philosophy	Whole life cycle Design for dismantling	Built-in obsolescence Fashion driven	Reduced energy and material reliance Repair and reuse
Attitudes to chemicals used in manufacturing	Low impact chemicals More care with chemicals and materials	Don't care	Less use of chemicals
Process philosophy	'Green tech'	High tech More innovation and advanced robotics	'Slow tech'

Manufacturing in Win-Win

Technology and societal context

In Win-Win in 2025, mass customisation and flexible manufacturing systems, such as 3D printing, have changed the industrial ecology, with distributed local production within integrated supply chains.

High levels of automation mean that many processes are performed within autonomous manufacturing cells. Much of the manufacturing industry is roboticised. Intelligent robots collaborate between themselves and work closely with humans. But even with self-diagnosing equipment, high levels of skills are needed for maintenance. These skills are in short supply, even with continuous training on the job. There is always work for highly skilled personnel.

Work layouts are redesigned towards smart working environments (using modelling or simulation techniques).

Bioautomation combines humans and robots and materials and structures. This ranges from artificial limbs to electronic implants: initially, these were used in healthcare to address disabilities (e.g. replacing limbs or supplementing damaged neural pathways).

Sustainable design has become the prevailing design philosophy, with whole life cycle assessment of products and processes. Products are designed for eventual dismantling.

Many new materials and nanocomposites that are used are lighter, have higher performance, and a lower carbon footprint.

Workshop discussion on OSH — Manufacturing in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Smart robots Intelligent robots working closely with humans make the safety of the interaction paramount. Some types of robot malfunctions may be difficult to detect until it is too late and may put workers' safety at risk. The same technology will make it possible for protective equipment, for humans, to adapt itself to the needs and dangers of each situation.	High in Win-Win and greatest in Bonus World	Rapidly growing hazard (Section 5.4.10 OSH factors common across technologies)
New materials Many new materials and nanocomposites are lighter, have higher performance, and a lower CO_2 footprint. There is strong pressure to use them in Win-Win, despite the unknown (long-term) potential health risks both in manufacturing and in downstream uses. And, if they are recyclable, as they should be, then there will also be possible health risks in the waste treatment sector. Regulators should develop an appropriate legislative framework, and invest more in research and health assessments of new materials and new processes. These should be piloted before going full scale. On the other hand, new materials may be safer substitutes for hazardous substances.	Greatest use of new materials overall in Bonus World Greatest innovation in green jobs (including use of new materials) in Win-Win	New risks (Section 5.4.10 OSH factors common across technologies)

Workshop discussion on OSH — Manufacturing in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Reduction of batch sizes to one As economic batch sizes are reduced from the millions typical of 'mass production' to one, manufacturing supply chains will reconfigure, with manufacturing much closer to the point of use. This will lead to the decentralisation and reduction in size of manufacturing systems, and wider distribution of chemicals amongst possibly untrained workers. More distributed small-scale production equipment may give rise to lower severity but higher frequency of exposure, and risks may be more difficult to control. All novel technologies and procedures may cause OSH issues, and need careful OSH assessment. Risks associated with reconfiguration of equipment will increase.	High in Win-Win and greatest in Bonus World	Rapidly growing hazard
Disassembly of manufactured goods The dismantling of manufactured goods, especially when driven by WEEE directives, brings MSDs, eye strain, and exposure to dangerous substances, along with other risks, if work processes are not well designed, and control measures not put in place. In Win-Win, there is the greatest demand for safe, green and profitable systems for disassembling electronic goods. Eventually, disassembly should be fully roboticised, avoiding human contact with the dangers of discarded manufactured goods.	Worst manual handling in Deep Green Automation in Win-Win and Bonus World	Automation would be beneficial to OSH
Non-ionising radiation There are potential health risks from radiation from increased use of microwaves, lasers, etc., and exposure to electromagnetic fields (EMF) from use of Wi-Fi connections between humans and machines.	Most applicable in high-innovation scenarios	Low

Manufacturing in Bonus World

Technology and societal context

In Bonus World in 2025, there are high levels of overall innovation (not necessarily 'green'). Many new materials and processes have been invented and used in production. Moore's Law has continued to operate: ICT offers ever-higher processing power. Many processes have been computerised and automated. The evolution of the 'Internet of Things' continues. Human workers and robots work in close proximity and often collaboratively.

Production lines have become flexible and self-adapting. Materials are moved around automatically: even the machinery is moved automatically as plants are designed to self-assemble.

Mass customisation and flexible manufacturing systems, such as 3D printing, have changed the industrial ecology, with distributed local production within integrated supply chains. Localised plants mean distributed hazards (e.g. a wider distribution of chemicals amongst possibly untrained workers).

The economies of scale of mass production are preserved even with batch sizes of one. There is customised local production and even manufacturing while delivering.

Biotechnology is being used in many manufacturing processes.

Manufacturing needs very skilled workers and technicians, with no jobs for the unskilled. Most 'manufacturing' jobs are in knowledge-based marketing, design, etc., as other jobs are automated. Adaptable workers need a wider education, not just focused training. Poor education is the cause of an economic bottleneck.

Human performance-enhancing drugs are being used in work settings, including manufacturing, because of the highly competitive work environments and job intensity.

Subcontracting is an integral part of a managed process, so attitudes to OSH within subcontractors reflect those of the main manufacturer: reduction of risks is seen as a cost.

Workshop discussion on OSH — Manufacturing in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Safety Safety is engineered into manufacturing systems because of the otherwise high cost of accidents in terms of lost production. Short-term safety will be high, even in smaller local production sites but, without legislation, there will be less focus on long-term health issues that do not disturb production.	Bonus World	Not new
Long-term health Employers in this world will only care about long-term health issues (as opposed to production-costing accidents) if they are legally liable. Legislation or government mandate is needed for OSH organisations or labour inspectorates to impose such liabilities. Such organisations will need to demonstrate the economic case for ensuring protection from long-term health risks, so that employers accept liability. Health surveillance programmes should be more comprehensive, and records are needed of exposure in the past (i.e. from 2012), supplemented by longitudinal studies. But flexibility and diversity of production leads to difficulty in linking effects to processes: nobody spends 30 years on the same production line any more.	Greatest in Bonus World	Scenario-dependent: in Deep Green, the focus will be on long-term environmental health; in Win-Win, more efforts will be made for the early assessment of health effects of new materials
Bioautomation and human implants With an ageing population working later in life, OSH risk assessments may have to accommodate developments in human performance-enhancing technologies such as implants in the body to operate bionic limbs. These may lead to issues with biocompatibility, and issues with privacy and personal life. As functionality and person-machine interconnections increase, it will be necessary to monitor for initial signs of unrecognised OSH issues and new physical and mental health conditions from this highly artificial situation.	Greatest in Bonus World, possibly high as well in Win-Win	New (Section 5.4.10 OSH factors common across technologies)
Human-Machine Interfaces (HMIs) Machines, materials and people will need to interact. It is not known how humans will react to the continuous high cognitive load of HMIs. Chips in humans allow inputs directly into the brain (e.g. to allow the control of machinery, IT equipment or bionic limbs, or to treat depression). These may lead to health or safety issues as yet unknown (e.g. biocompatibility, but also susceptibility to magnetic or electric fields, as well as blurred boundaries between professional and private life).	Greatest in Bonus World, possible as well in Win-Win	Uncertain risk that needs research (Section 5.4.10 OSH factors common across technologies)
Uncaged robots Uncaged robots will be an issue as boundaries between robot space and human space become blurred in the industrial environment (and outside it). It may bring safety issues. It will, therefore, be essential to integrate OSH during development. Robots will have sensors to detect humans. Chips on people proving their level, past training and current state of awareness will be used as ‘authority to operate’. Unchipped persons will be sensed and cause the machinery to shut down.	Greatest in Bonus World, also possibly high in Win-Win	Rapidly growing hazard
Robot maintenance Procedures will be needed for the safe maintenance of robots, and there will also be issues of cyber security and privacy, potentially contributing to stress	Greatest in Bonus World, also possibly high in Win-Win	Rapidly growing hazard
New occupational diseases What exposure will there be to chemicals and new materials, and to new processes and procedures in the future? Without exposure registers, diseases are difficult to trace back to jobs as no one stays on the same production line for their entire career any more.	Greatest in the high innovation Bonus World	Scope for new physical risks (e.g. new MSDs), as well as exposure to chemicals (Section 5.4.10 OSH factors common across technologies)

Workshop discussion on OSH — Manufacturing in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Exposure to new chemicals and potentially harmful substances Exposure to new chemicals and potentially harmful substances (e.g. composites, nanomaterials, smart materials, polymer gels, intelligent polymers) where OSH information about these may be lacking, and exposure poorly controlled, may make dissemination of information on risks and prevention difficult in SMEs.	Greatest use of new materials overall in Bonus World Greatest innovation in green jobs (including use of new materials) in Win-Win	New risks (Section 5.4.10 OSH factors common across technologies)

Manufacturing in Deep Green

Technology and societal context

In Deep Green in 2025, there is lower consumption of mass-produced goods and, consequently, a manufacturing sector of reduced size. Some offshore production has returned to Europe, with more point-of-need manufacturing. Manufacturing focuses on reducing energy and materials use. The target is zero-landfill, zero-emission factories.

Highly automated working environments are generally safer by design, but in Deep Green there is less new automation than in other scenarios, and more ageing plants and industrial infrastructure (including ageing robots and assembly lines). The march of technology slows, except for green technologies (green products and green processes). Green public procurement supports innovation in this area.

But legacy bottlenecks still exist, as new systems take time to be adopted (e.g. in 2012, laser welding was faster, but many manufacturers still used spot welding, as they had invested in the equipment and skills.)

There are more decentralised, low-investment, low-margin manufacturing sectors, which need maintenance and servicing. Decentralised repair and maintenance services have become common again as there is a strong focus on reuse. These are negative influences on OSH in manufacturing.

With heavily subsidised or free public transport, fewer cars are used or sold, and there is an increase in deliveries to home addresses. New vehicles are not the mainstay of manufacturing industry that they once were.

Workshop discussion on OSH — Manufacturing in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Process integration Process integration may bring new OSH risks due to the bringing together of industrial processes previously performed in different locations, such as manufacturing and recycling. This requires new skills and technical knowledge in the workforce that now has to undertake this work.	Greatest in Win-Win and Deep Green	Not new processes, but unfamiliar
Lack of skills in the manufacturing sector Bringing back manufacturing to the EU may mean demand for manufacturing jobs, but OSH is often tacit knowledge passed on in a master-apprentice relationship, so this might be in short supply following the decline of manufacturing in recent years.	Skills shortages may be a feature of all scenarios, but in the context of manufacturing returning to the EU will be significant in Deep Green	Growing issue with implications for OSH (Section 5.4.10 OSH factors common across technologies)
Ageing manufacturing infrastructure In absence of new investments, ageing manufacturing infrastructure may have significant OSH implications (e.g. due to corrosion or material fatigue).	Greatest in Deep Green	Not new

Workshop discussion on OSH — Manufacturing in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Low OSH culture New small service companies that supply the greater maintenance load in Deep Green may have a low OSH culture, and find it difficult to access OSH information and expertise.	Greatest in Deep Green	Not new
Less automation Less automation in Deep Green may influence OSH. The time lag in the adoption of new technologies may mean that old OSH issues persist.	Greatest in Deep Green	Automation is very positive for OSH (Section 5.4.10 OSH factors common across technologies)
Unpredictable night shifts There could be an increasing move towards such shifts as the pattern of electricity prices change. Electricity from renewable energy sources (e.g. wind energy) will bring lower energy costs during the night for many nights in the year. Night shift work is commonly associated with an increased accident rate. Shift work that involves circadian disruption is classified as probably carcinogenic to humans by the International Agency for Research on Cancer (IARC, 2010).	Applicable to Win-Win but greatest in Deep Green	Emerging issue (Section 5.4.10 OSH factors common across technologies)
Maintenance and recycling of imported equipment and products Unknown or unlabelled imported materials mean that the appropriate prevention measures to ensure their safe maintenance and recycling may not be in place as a result of a lack of information.	More imported products in the more globalised worlds of Bonus World in particular, and Win-Win, but higher maintenance and recycling in Deep Green and Win-Win	Not new

Complementary information from desk research and Phase 2 technology workshop on OSH issues for manufacturing, robotics and automation

Workshop briefing on OSH issues

The briefing material for the manufacturing, robotics, and automation workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors.

- **More sophisticated pre-programmed robots** have been developed that have greater dexterity and flexibility and are able to perform more complex tasks than earlier models. These robots are entering workplaces that have not previously contained robots (e.g. autonomous forklift trucks in warehouses). These have obvious OSH implications if workers get in the way or uncaged autonomous machinery develops a fault.
- These robots are **increasingly operating in much closer proximity to workers** acting as assistants when previously they would have been behind gates or fences. This has the potential to lead to an increased risk of human injury from robot collision/strike. These robot assistants have been described as 'cobots', which can be defined as 'A robot for direct physical interaction with a human operator, within a shared workspace.' Vision-based protective devices to distinguish the worker from a cobot and from the products being manufactured are currently being developed in order to ensure a good teaming of the human-machine system and, therefore, the operators' safety. Additionally, the rapidly decreasing cost of 3D vision systems, such as the Microsoft Kinect system, means low-cost robots with vision systems are being developed.

(9) Immediate or anaphylactic hypersensitivity.

- **Robots are becoming more 'intelligent' and, hence, more complex**, and the more complex a device becomes, the more difficult it might be to achieve a safe design. Crucially, researchers developing robots might not always have safety as a priority, so safety may not have been adequately considered by the time the robot is available commercially.
- **Advanced materials and processes used, especially in high-tech electronics, may be harmful to human health or be carcinogenic** (e.g. novel metal compounds and polymers such as cadmium telluride used in thin-film solar panel manufacture). There is a potential exposure risk during manufacture and disposal. There may be greater concern for the integrity of the high-tech product than the worker's health (e.g. in semiconductor manufacture where a number of hazardous chemicals are used). Other risks may include exposure to harmful fibres or resins, such as epoxy resins during the manufacture of composites, the use of which is increasing.
- **There is increasing use of carbon nanotubes in manufacturing**; recent data have shown that if certain carbon nanotubes are inhaled they can cause inflammation and fibrosis in the lungs. It is also not clear if inhaled carbon nanotubes cause adverse health effects in other parts of the body.
- **There is a potential for dangerous wastes**, produced from new processes, which may present chemical or biological hazards.
- **Rapid manufacturing or 3D printing** has been described as being at a 'tipping point'. This can lead to new groups of workers being exposed to manufacturing risks though increasing use of such machines for manufacture in SMEs, retail and education as rapid manufacturing is introduced into courses. There is the potential for operator exposure to harmful dusts, chemicals or laser light.
- There are **risks associated with increasing numbers of industrial biotech and green chemistry plants**. There are potential health and safety risks from breaches in reaction vessels in chemical or biological processes, including potential explosion, fire and electrical risks. There are risks during the collection and distribution of feedstocks for the plant (e.g. risks related to the release of harmful dust, explosion, and fire from wood chips). Chemical plants will need to be altered in order to accommodate biological feedstocks; there may be risks associated with plant construction and alteration. There may also be processing changes (e.g. temperature and pressure) which could pose additional risks.
- **Novel enzymes are being increasingly manufactured** which can act as sensitising agents (e.g. cleaning products). Potential routes of exposure are inhalation, skin, eye, and by mouth, during manufacture and at point of use. The potential hazards include type 1 hypersensitivity ([9]) or irritation of the respiratory tract from inhalation; in certain individuals, allergic contact dermatitis can also occur after contact with some enzymes.
- **More powerful portable laser systems** are being produced at lower costs and so becoming increasingly more accessible. Potential operator risks in using photonics equipment include electrical and fire risks, substances hazardous to health (laser marking fumes, grinding coolant mist) and lasers, which can damage eyes and skin.
- **Shift work has increased in Europe for economic reasons**. Shift work enables employers to make the maximum use of plant, which can reduce production costs and increase output. Shift work has also increased for social reasons: changes in living and working patterns have created a demand for goods and services outside traditional working hours. Shift work is often introduced in organisations with manufacturing processes, which — for technical or economic reasons — must operate for long periods or even continuously. According to the International Agency for Research on Cancer (IARC), their current evaluation is that, on the basis of 'limited evidence in humans for the carcinogenicity of shift work that involves night work' and of evidence from experimental animal data, 'shift work that involves circadian disruption is probably carcinogenic to humans.' The IARC also concluded that there is evidence for an association with breast cancer and shift work that involves night work. Increasing numbers of women are performing shift work. There are other health effects associated with shift work, including gastrointestinal tract disorders, cardiovascular disorders and metabolic disturbances.
- **Increasing numbers of migrant workers and workers subcontracted in manufacturing** may mean that health and safety messages are not adequately communicated due to language barriers in an international workforce. Workers from a different country may adopt their home culture of health and safety, which may be inadequate for the work being performed.

Source: UK Health and Safety Laboratory Futures Team and additional sources (Bradbrook, 2007; HSE, 2010a; Bömer, 2003; HSE, 2009a; Brentnall, 2007; SDA, 2005).

OSH discussion for manufacturing, robotics and automation

Parts of the manufacturing sector are likely to undergo significant change over the next few years as advanced manufacturing techniques offer greater flexibility, allowing small production runs and mass customisation to become economically viable. Advanced materials will enable the design of properties to suit individual applications. These developments, which offer increased efficiency, lower energy use and reduced waste, will also change the OSH landscape for workers in the sector.

The following OSH issues in particular need to be considered:

- new processes and materials leading to potential exposure to new (green) substances, including nanomaterials, or substances used or emitted (including dust) from new (green) manufacturing processes;
- the extent of chemical use and the potential for exposure as manufacturing is distributed to smaller units as a result of rapid manufacturing techniques (3D printing);
- the difficulty in monitoring OSH in distributed manufacturing taking place in smaller businesses;
- the increasing use of lasers in techniques such as rapid manufacturing; the potential physical risks from human-robot interaction as robots gain increasing autonomy and become free-roaming;
- potential psychosocial risks:
  - the high cognitive load of the HMI, 'lean' production and just-in-time principles all have the potential to contribute to job intensity and pressure and to result in psychosocial problems;
  - the potential effect of renewable energy, with its intermittent nature currently, on shift work in those companies that take interruptible supplies, resulting in more unpredictable working hours;
- workers possibly resorting to human performance-enhancing technologies as they feel the need to keep up with co-workers, and maybe even with robots (this could also be a feature of other sectors); and
- a focus on safety as opposed to health in competitive scenarios owing to the greater impact of accidents on productivity (this could also be a feature of other sectors).

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single day's workshop with experts in technology and/or OSH expertise as well as policymakers, with the HSL desk research as briefing. The intention was to illustrate the power of the scenario method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.7. Domestic and small-scale energy systems

Comparison of technology developments across scenarios

Table 19: **Technology developments: Domestic and small-scale energy**

Technology developments	Win-Win	Bonus World	Deep Green
Feed-in tariffs	High	Low	High
Domestic heating focus	CHP gas and heat pumps	Insulation	Biofuels/incineration
PV	Subsidised and widespread	Not viable until 2020–25	Subsidised
Smart meters	In all homes	Backlash against smart meters	Slow roll-out
Energy production	Medium From alternative sources	High From coal and gas	Low

Domestic and small-scale energy in Win-Win

Technology and societal context

In Win-Win in 2025, taxes on fossil fuel energy are high enough to change the behaviour of the population. Government incentives reduce payback time for renewable energy to the extent that companies and individuals invest heavily in alternative energy technologies.

Domestic gas installations rapidly standardise on highly efficient fuel cell micro-CHP systems, backed up by small ground-sourced and air-sourced heat pumps.

New forms of PV (both paint and nano-based) have sharply reduced the cost of PV systems. Already widespread through subsidy, PV had achieved grid parity in the south of the EU by 2020, and now, in 2025, this is being achieved in the north. This is leading to even higher demand for further domestic installations.

In the north of the EU, large-scale wind energy had achieved grid parity by roughly 2020, leading to more and more generation of intermittent wind energy from proliferating wind farms.

Domestic, commercial and public buildings have solar panels. Companies with roof space for PV and yard space for turbines generate energy as a secondary business, as farms already generate wind, solar, biogas, and biodiesel.

Smart meters are installed in nearly all homes and small business premises. They are used to monitor and manage smart appliances and electricity demand in response to the requirements of the grid and availability of electricity generation capacity.

Workshop discussion on OSH — Domestic and small-scale energy in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Competence of renewables workers The design, installation, operation, maintenance and removal of renewable energy installations (PV, micro-CHP, etc.), requires training and experience to recognise risks and to take the appropriate safety measures. These activities may attract workers not adequately trained in the new combinations of skills necessary to perform these jobs (e.g. electricians working at height and roofers who have to work as electricians). The owners of the buildings where such renewable energy systems are installed may not be competent to select contractors to install and maintain equipment, or might choose the cheapest ones, who may cut corners on OSH.	All scenarios	Growing issue (Section 5.4.10 OSH factors common across technologies)
Risks for emergency workers There will be risks for emergency workers accessing roof spaces with live electrical systems even after the power to a building has been cut.	Common to all scenarios	Very high (Section 5.4.10 OSH factors common across technologies)
Speed and diversity of change The speed and diversity of change in Win-Win is a challenge for OSH. There are many new technologies, where specific knowledge is needed and standards have not yet been fully developed. 'Old' OSH knowledge may not be directly transferable to these new technologies and, therefore, not very helpful, and applying 'old' procedures may even be risky.	Greatest innovation in green jobs in Win-Win	New risks
Efficient and cheap PV Efficient and cheap PV technology leads to widespread adoption of PV systems: this brings physical and electrical hazards, and problems with sustainability of components and panels.	Greatest in Win-Win and Deep Green	Not new, but extensive growth
Decentralised systems Old risks will acquire a new nature with decentralised systems and the risks associated with the complexity of grid, maintenance, decommissioning and retrofitting.	All scenarios, but greatest in Win-Win and Deep Green	Growing
SMEs become energy producers Short-term risks may derive from SMEs using their own workers, or subcontracted workers, to install or maintain their renewables installations (when these workers are unskilled or partly skilled). With such installations often near other houses or other businesses, it may also put these at risk.	Win-Win and Deep Green	Not new, but growing occurrence

Domestic and small-scale energy in Bonus World

Technology and societal context

In Bonus World in 2025, there were strong reactions against new energy technologies when the costs become apparent to the public. Feed-in tariffs had been cut back sharply in 2013 and horror stories about poor people being forced to upgrade their domestic wiring after the old meter had been taken out led to strong reactions against smart meters.

Power still comes from coal and gas, with less green energy over the course of this scenario, but alternative energy became competitive with fossil fuels by around 2020–25. PV reached grid parity in southern Europe by 2020.

Network operators encourage some distributed generation, but only in particular areas as a means of saving on the costs of upgrading the network. Blackouts are common as governments balk at the cost of investing in smart grids and storage facilities. PV and CHP became popular for their energy security: domestic systems are now designed to provide some electricity even if there is a power cut.

In Bonus World, increased consumption has led to resource shortages and high oil prices. Fuel prices have increased more quickly than wealth. Poor people have to cut back on domestic heating to save money, and fuel poverty has become an election issue.

With the cost of energy rising, house insulation (the most cost-efficient energy measure) is important. Well-insulated homes command higher prices.

Many teleworkers work from home in Bonus World to avoid congestion on the roads, and there is a need for housing with adequate temperature control and energy systems to reflect this occupational usage.

Workshop discussion on OSH — Domestic and small-scale energy in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
PV energy reaches grid parity There is widespread adoption of PV after PV systems eventually achieve economic viability without subsidy. PV installations (high in 2012) effectively ceased after feed-in tariffs were slashed. A great deal of knowledge about safe practice was lost and had to be relearned when the attainment of grid parity led to renewed widespread installation.	The use of PV is greatest in Win-Win and Deep Green, but the loss of experience linked to change in feed-in tariffs is specific to Bonus World	Not new, but extensive growth in exposure to hazards, especially after PV systems eventually achieve economic viability
Sudden withdrawal of subsidies In Bonus World, 2012 levels of government support for alternative energy were withdrawn, often at short notice. This led to high levels of preventable OSH risk in the short term as installers rushed to complete the backlog of orders before the deadline.	Bonus World	High levels of unnecessary and preventable OSH risk (Section 5.4.10 OSH factors common across technologies)
Psychosocial risks A world of profit motive and high competition can lead to psychological pressures at work and work-related stress. This OSH factor applies generally within Bonus World.	Bonus World	Not new, but growing, particularly under Bonus World scenario (Section 5.4.10 OSH factors common across technologies)
Imports of products Imports of (cheaper) components and whole systems for the domestic and small-scale renewable energy market give rise to higher risk of counterfeit, unsafe products. Examples include cables with adulterated copper and with ineffective flame-retardant properties. Even if components sourced from the Internet are certified, the system they are used in may not be safe.	All scenarios, but more likely in Bonus World	Not new, but may grow and become more widespread

Domestic and small-scale energy in Deep Green

Technology and societal context

In Deep Green in 2025, taxes and charges on classic nuclear and fossil fuels have been increased, and renewable energy sources have reached grid parity. Renewable energy has become competitive. New energy capacity is mainly decentralised, but smart meters have been rolled out relatively slowly.

Low-carbon buildings are seen as more desirable and are valued more than older 'business as usual' buildings.

There is more use of biogenerated energy resources (biofuels), and many more small-scale energy schemes (e.g. biogas digesters, local hydroelectricity, waste incineration and domestic CHP). Do-it-yourself approaches to energy systems are common. Many non-standard do-it-yourself systems have been built with diverse parts from various sources.

There is an urge to use existing equipment: a 'make-do-and-mend' mentality, with less emphasis on high-tech to achieve results.

With emphasis on reduced consumption of energy and physical goods, most new jobs are in the service sector (e.g. repairing services to extend the life of goods). Many new small businesses, often with skills deficits, arise to meet these needs.

Workshop discussion on OSH — Domestic and small-scale energy in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Electrical risks Distributed generation gives rise to electrical risks, as many more sources of voltage can give rise to electric shock even when the mains current is disconnected.	All scenarios, but greatest in Win-Win and Deep Green	Not new, but growing
Solar PV There is potential exposure to chemicals from PV systems during manufacture, installation, repair, accidental damage, and during disposal or recycling. Risks of electrocution and falls from height are always present when installing and maintaining. Firefighters may be at risk from PV, which continues to produce electricity even when the mains supply is turned off.	Greatest in Win-Win and Deep Green	Not new, but extensive growth in exposure to hazards
Non-standard installations Diversity of systems and non-standard installations, including do-it-yourself systems, give rise to risks to maintenance workers. A strong regulatory framework is needed to address these risks.	Deep Green	Not new, but growing in this scenario
Bioenergy The generation of bioenergy gives rise to risks of fire, explosion, toxic substances, and biological hazards (in small-scale/domestic settings and elsewhere).	Deep Green and Win-Win	Not new, but growing
Mixing of risks Combining and mixing technologies such as CHP, solar, thermal, may bring as yet unknown risks from novel combinations.	All scenarios, but greatest in Win-Win and possibly Deep Green	Growing issue (Section 5.4.10 OSH factors common across technologies)
Decentralised systems Old risks will acquire a new nature with decentralised systems and the risks associated with the complexity of grid, maintenance, decommissioning, retrofitting, etc.	All scenarios, but greatest in Win-Win and Deep Green	Growing
Emerging technologies New technologies may bring new risks. Long-latency effects may take years to appear and it will be a challenge to monitor such OSH situations and link health effects to exposure. Many new areas of green technologies will be established by innovators and entrepreneurs who may not assign the same priority to OSH as large, established corporations.	Greatest use of new materials in Bonus World, but Win-Win has the greatest innovation and most use of new technology within green jobs	New risks

Workshop discussion on OSH — Domestic and small-scale energy in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Emergency services Emergency services will be confronted with different unknown risks due to differing combinations of energy sources, devices and systems.	All scenarios, but greatest in Win-Win and Deep Green	Not new, but growing (Section 5.4.10 OSH factors common across technologies)
Distribution of risk Alternative energy systems are distributed in nature, in small business premises and on houses, with much wider exposure to risk (including to the general public). This distribution makes it much more difficult to control the quality of installation work and therefore to control the risks, and more difficult to enforce good OSH practices.	Deep Green and Win-Win	Not new
Unsophisticated domestic installations Early domestic installations are likely to be installed by enthusiasts and be assembled to their own designs. Examples include domestic production of first-generation biodiesel with potential exposure to fire, explosions and burns from corrosive leaks. Such unsafe installations may put maintenance workers at risk. Also, the transfer of building ownership brings particular exposure as people may be unaware of the risks they inherit with a building and, therefore, the necessary information for its safe maintenance is lost. Over time, these risks should reduce as people become more used to these new systems.	Most likely in Deep Green scenario	Growing risk
Local battery energy stores It is possible that building occupiers will be tempted to use expired EV battery packs (typically 5 kWh, weighing 50–60 kg) in their garages or basements as energy buffers to store PV output and/or avoid peak-time electricity. There would be risks of short circuiting, fire, explosion, and hazardous fumes. Systems may not be professionally connected, potentially putting maintenance and electricity workers at risk, and people don't currently recognise the risks of using big batteries. Over time, it is expected that the risks from leakage and degradation and the risk of internal short circuits will increase. Bulk local electricity storage may need to be restricted to locations outside the home where fires would be less dangerous.	All scenarios	New; the risks are to the building occupiers and any workers or contractors that they employ
Small local initiatives In Deep Green, small clusters of householders or occupiers of other buildings might build their own ecosystems (e.g. mini-CHP, biodigesters, or PV systems). A small cluster of households is probably the least safe size for this sort of activity, with no central authority or 'keyholder' responsible for safe operation. With a single building, there is a clear responsibility, even if the building owner has no training. Larger schemes at community scale would have a central point of control.	Most likely in Deep Green scenario May not be strictly applicable to occupational safety and health	Emerging risk

Complementary information from desk research and Phase 2 technology workshop on OSH issues for domestic and small-scale energy

Workshop briefing on OSH issues

The briefing material for the domestic and small-scale energy workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors:

- shortage of sufficient skilled workers for installation and maintenance of distributed generation systems;
- electrical risks, falls from height and manual handling issues during the installation, connection, maintenance and dismantling of roof-mounted micro-wind turbines or solar panels;
- burns from cryogenic hydrogen storage, electrical risks from fuel cells, explosion/fire risk from handling and using hydrogen or methane;
- 'flashover' burns, falls and electrocution during installation, connection and maintenance of new power sources;
- exposure to toxic chemicals and metals (e.g. cadmium — a known carcinogen) during solar panel manufacture, disposal and recycling, and possibly installation and maintenance in case of leakage;
- potential exposure to epoxy resins, styrene and other hazardous chemicals/solvents during micro-wind turbine manufacture;
- risk of exposure to asbestos during retrofitting activities;
- risks to fire fighters from roof-mounted solar cells: limited access to the property, cells remaining live, and exposure to chemicals if leakage occurs; and
- possibly poorer quality and attendant safety risks of cheaper components bought online.

Source: UK Health and Safety Laboratory Futures Team and additional sources (Bradbrook et al., 2010; Bradbrook, 2009b; Bradbrook, 2009c).

OSH discussion for domestic and small-scale energy

The uptake of renewable energy technologies will be affected by the extent of government subsidies and will, therefore, be scenario-dependent until, and unless, actual costs become competitive with other sources. The role of solar energy and other renewable sources versus insulation will also be scenario-dependent and dependent on location. There may be new players, such as SMEs and farmers, selling energy.

OSH issues could include the following.

- The risk of poor quality installations as new players enter the market, people undertake do-it-yourself installations (perhaps sourcing parts on the Internet), and as systems are put in quickly to meet deadlines, could lead to electrical and fire risks, maintenance issues, perhaps at heights, and risks from gas. There could be particular risks where installers extend beyond their original skills areas. For example, someone who previously installed gas boilers might also install solar thermal systems, working at heights on roofs, extending their boundaries to new technologies in new situations.
- There are risks to the emergency services in dealing with such installations. For example, solar panels remain live as long as there is daylight, but fire crews often break through the roofs of houses to gain access. Various sprays are on the market, claiming to 'switch off' the panels, but this remains an area of concern.
- Connection to the grid is an issue, as electricians have to cope with two-way flows in cables and smart metering.
- Particular risks adhere to clusters of buildings combining renewable technologies but with no clear responsibility for safe operation.

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single day's workshop with experts in technology and/or OSH expertise as well as policymakers, with the HSL desk research as briefing. The intention was to illustrate the power of the scenario method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.8. Batteries and energy storage

Comparison of technology developments across scenarios

Table 20: **Technology developments: Batteries and energy storage**

Technology developments	Win-Win	Bonus World	Deep Green
Bulk energy storage	LNG tankers and biomass at CCS power stations	Coal heaps	Harvested biomass Local wood stores
Bulk electricity storage (transmission network scale)	Many technologies prove practical Supergrid connects European hydroelectric capacity	Little need for bulk storage (except pumped hydro)	'Virtual storage' (i.e. load balancing by behaviour change at national scale) Little investment in bulk electricity storage
Local electricity storage	Many technologies prove practical Local heat stores	Specialised applications to save grid upgrade costs	'Virtual storage' (i.e. load balancing by behaviour change at local scale)
Batteries	Lots of new battery technologies Widespread availability of used EV batteries Vehicle to Grid (V2G) applications (e.g. where vehicle batteries are used to store surplus electricity from the grid overnight)	Fewer new battery technologies Limited spread of EV, in favour of PHEV	Slower development of battery technology Designed on green principles

Batteries and energy storage in Win-Win

Technology and societal context

In Win-Win in 2025, several bulk energy storage solutions for transmission grids have proved practical, and are being progressively implemented. These include: large-scale molten salt storage systems (50 MW); hydrogen; wind twinning (10); and 'virtual storage' by demand-side management in intelligent domestic and industrial buildings. Experiments are continuing with deep-sea energy storage. Static battery technologies for energy storage include sodium-sulphur, fluorine and vanadium flow batteries.

On the smaller distribution network scale, micro compressed air energy storage (CAES), battery storage, compact thermochemical storage, and flywheels are used.

Domestic-scale battery energy storage is common as older EV batteries are used as static energy stores: more than 90 % of retired EV batteries are used in this way.

(10) Matching demand to supply by making electricity prices high when there is little wind and low when it is windy.

In the longer term, the problem of intermittency of wind generation is being addressed as buildings are designed to include high thermal mass, five-day domestic heat stores (for hot water), and limited seasonal energy storage.

Connections across Europe and upgrades to capacity mean that European hydroelectric systems are able to supply all of the European electricity demand for several days at a time.

Batteries and energy storage in Bonus World

Technology and societal context

In Bonus World in 2025, the grid has maintained its substantially one-way architecture with electricity generation mostly through coal, nuclear, gas (fuel cells, CHP), and combined cycle gas turbine (CCGT). PV has only recently grown strongly after grid parity was achieved.

With less intermittent and distributed generation, there is much less need for bulk energy storage (except for pumped hydro facilities for load balancing).

Workshop discussion on OSH — Batteries and energy storage in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Hydrogen as an energy carrier In the future, the promise is that hydrogen can be used as an energy store and converted back to electricity as needed. Hydrogen is difficult to handle, difficult to access, and expensive to produce. In 2012, work is mostly centralised in large companies with chemical engineering expertise, so OSH is controlled. But in the future, as hydrogen becomes more widely used, risks arising from its transport and storage and use by less experienced workers and even the public, in the case of vehicles, may increase.	All scenarios, depending on means of generating hydrogen	Not new, but possibly much wider use if hydrogen economy developed
New battery technology Each new battery technology will bring its own specific risks of exposure to chemicals and fire/explosion during manufacture, use, degradation, and disposal. Based on their experience from lead-acid batteries, people generally have a false perception that new batteries are safe.	All scenarios, but greatest in Win-Win	New battery designs bring new specific chemical and degradation characteristics
Deep-sea energy storage This works by pumping water out of a large solid chamber on or below the seabed to store energy. This is a relatively low-tech concept, with no new technology involved. It would need specialist OSH regulation like any other large offshore installation, but with the added complication of high voltages and power levels, which adds risks to installation and maintenance work.	Most likely first in Win-Win	OSH should be considered even in the early design stage of this technology

Storage applications tend to be specialised and limited. Energy storage is used in distribution networks for load balancing to avoid the cost of upgrading the network, and flywheels and supercapacitors limited to specialised public transport applications. Electric vehicle development has favoured PHEVs, with their lower energy storage requirements and therefore limited V2G capability.

Workshop discussion on OSH — Batteries and energy storage in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Fire risks of EV batteries There is a fire risk related to EV batteries in vehicles (and in buildings if charging is undertaken indoors). The industry hopes that a solution will be found to this problem, but no resolution is foreseen in the short term.	All scenarios, but greatest in Win-Win, with greater use of EVs	New, depending on battery design
Waste treatment of batteries Dealing with life-expired batteries raises a number of OSH issues (e.g. exposure to toxic or caustic chemicals) mostly around recycling, degradation and fire risk. It can be difficult to determine the contents of any particular battery type: the precise contents are often treated as trade secrets.	All scenarios, but mainly Win-Win and Bonus World with their higher innovation rates	New risks continually emerging (Section 5.4.10 OSH factors common across technologies)
Battery composition New battery technologies are continually being developed. Potentially, there is exposure to hazardous chemicals, carcinogenic metals, dangerous dusts, fibres, nanoparticles, and noxious fumes.	Greatest use of new battery materials in Bonus World, but Win-Win has the greatest use of batteries, especially within green jobs	New risks

Workshop discussion on OSH — Batteries and energy storage in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Local energy stores Householders or small business owners may start to keep large batteries as energy stores. These are different from the batteries to which they are accustomed; they hold much more charge — perhaps 5 kWh stores of energy. People don't recognise the risks from overcharging, or accidental discharge. Decentralised systems are harder to monitor for OSH.	All scenarios	New; the risks are to the owner of the building and any workers or contractors that they employ
Hydrogen as an energy carrier In the future, the promise is that hydrogen can be used as an energy store and converted back to electricity as needed. Hydrogen is difficult to handle, difficult to access, and expensive to produce. In 2012, work is mostly centralised in large companies with chemical engineering expertise, so OSH is controlled, but in the future, as hydrogen becomes more widely used, risks arising from its transport and storage and use by less experienced workers and even the public, in the case of vehicles, may increase.	All scenarios, depending on means of generating hydrogen	Not new, but possibly much wider use if hydrogen economy developed

Batteries and energy storage in Deep Green

Technology and societal context

In Deep Green in 2025, there is lower energy use, less acceptance of environmentally invasive technologies, and less demand for novel battery technologies. There is a surge in biomass and biogas energy production, with harvested biomass used as energy store.

There has been slower progress in batteries. The need to use fewer toxic materials and to produce items that are more easily recycled is a constraint on battery development. EV batteries are reused for static energy storage as performance degrades.

Behaviour changes drive many energy requirements, with more use of (electric) public transport rather than private transport, and with people trying to use energy when it is available so energy demand more closely matches supply (so-called virtual storage).

There is less emphasis on major engineering solutions, and more on progress by incremental developments, with more of a life cycle approach taken, using fewer toxic materials.

Workshop discussion on OSH — Batteries and energy storage in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Battery technology Batteries bring well-known risks including electrical risks, toxic chemicals and fire. There are severe risks to the emergency services. Greener batteries may be more hazardous, as manufacturers are constrained in their choice of materials that can be used in them. This is exacerbated by the habit of reusing and extending the working life of equipment.	All scenarios, but greatest in Deep Green with more use of old equipment	New battery designs bring new specific chemical and degradation characteristics
Device combinations Combinations of different devices bring risks to maintenance workers and emergency services. Do-it-yourself systems by enthusiasts would be a particular hazard.	Greatest in Deep Green	Not new, but scope for growing importance
Hydrogen The use of hydrogen as a long-term energy store in vehicles and buildings or domestic settings, bring risks of fire and explosion. There are issues in transport and distribution, with possibly cryogenic storage temperatures and possibly high pressures. In 2012, work is mostly centralised in large companies with chemical engineering expertise, so OSH is controlled, but in the future, as hydrogen becomes more widely used, risks arising from its transport and storage and use by less experienced workers and even the public, in the case of vehicles, may increase.	All scenarios, depending on means of generating hydrogen	Not new, but possibly much wider use if hydrogen economy developed.

Complementary information from desk research and Phase 2 technology workshop on OSH issues for batteries and energy storage

Workshop briefing on OSH issues

The briefing material for the batteries and energy storage workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors.

- The primary concern with high-voltage electrical storage technologies is electrocution risk. In the near to medium term, there is likely to be increasing use of electrical storage technologies in the distributed generation and microgeneration areas. The concern will be electrical safety for installers and other workers in households, communities and SMEs, which will be generating electricity.
- Fire risks exist with batteries.
- Health and safety risks could arise from inexperienced tradesmen installing, maintaining or operating electricity storage technologies that export electricity into the grid or for use locally. There may be issues surrounding the protection of these individuals from the electricity being generated on site for storage or that is to be exported to the grid.
- There are potential issues around, skills, competence and accreditation, particularly in relation to electrical safety.
- Health and safety risks may come from the high-temperature operation of sulphur and zebra batteries, and high temperature and gas pressure in gravel batteries. On one occasion, a large sodium-sulphur battery installed at a wind farm in Japan caught fire.
- Risks arise from compressed and liquefied gases.
- Compressed air energy storage (CAES) will have risks related to the integrity of pipelines and storage structures, and to the associated mechanical equipment. Flywheel technology may also have risks associated with rotating mechanical equipment, which — if released — could cause significant damage.
- Hydrogen gas is flammable and easily forms an explosive mixture in air. There is a very wide range of hydrogen-air concentrations that will explode. Additionally, very low ignition energy is needed to ignite a hydrogen-air mix. Methanol, which can be used directly by fuel cells, is highly flammable and toxic. LPG and methane, which can be converted into hydrogen using a high temperature catalytic reformer, often adjacent to the fuel cell, are also highly flammable.
- There are implications for safety from all elements of the hydrogen fuel chain from conversion of the primary energy source, through to possible transport, storage and delivery stages, to use of the hydrogen for power generation.
- In terms of CHP, currently, there is no accreditation scheme for the installation of CHP devices: this may cause a problem if electricity is exported back to the national grid, as this is likely to be beyond the training of most electricians. Additionally, as hydrogen is prone to leak from systems, those working on CHP hydrogen systems will need to be retrained.
- In addition to the hazards associated with hydrogen itself, the electrical safety implications of its use in fuel cells need to be considered. Electrical hazards within fuel cell installations are from the 240 V mains supply and the electrical output of the fuel cell stack: this can be between 100 V and 400 V, and 500 A.
- Exposure to potentially toxic nanomaterials and other chemicals during the manufacture, maintenance, disposal and recycling of hydrogen fuel cells, hydrogen storage systems, batteries and supercapacitors is a risk.

Source: UK Health and Safety Laboratory Futures Team and additional sources (HSE, 2010b; Bradbrook et al., 2010; HSE, 2003; Littelfuse®, 2005; NGK Insulators, 2011; Nearing, 2011).

OSH discussion for batteries and energy storage

The main thrust of the workshop was on batteries, with only limited interest in other forms of storage. Development of battery technology was scenario-dependent, ranging from significant advances, through emphasis on specialist applications driven by the need to cut costs, to reliance on behavioural change to reduce the need for storage.

OSH risks from batteries include:

- exposure to chemicals, including nanomaterials, during manufacture, use and recycling of batteries;
- electrical risks to emergency services in EV accidents;
- fire and explosion risk from batteries in vehicles and in buildings — in particular, the possible reuse of aged vehicle batteries in buildings; and

- use by untrained workers, or building occupiers in the case of batteries used as building energy storage, without adequate knowledge of the risks of large batteries.

Other forms of energy storage include hydrogen (considered in Section 5.4.5); flywheels, where a risk is that of fracture of the flywheel; and compressed-air energy storage, where risks may come from the integrity of pipelines. Electrical risks are, of course, common to all these. There may be as yet unknown risks from the interconnection of diverse combinations of energy storage equipment.

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single-day workshop with experts in technology and/or OSH expertise as well as policymakers, with the HSL desk research as briefing. The intention was to illustrate the power of the scenarios method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.9. Energy transmission and distribution

Comparison of technology developments across scenarios

Table 21: **Technology developments: Energy transmission and distribution**

Technology developments	Win-Win	Bonus World	Deep Green
Transmission	Capacity constraints as energy use grows SuperSmart Grid across Europe to balance supply and demand	Capacity constraints as energy use grows	Capacity growth limited by lack of funds for investment Local focus for networks
Grid architecture	Two-way	One-way from central generators to distributed users	Two-way: local demand better matched to local generation
Distribution network	Local storage and smart meters used to relieve local capacity issues	Overloaded network at risk of blackouts Aluminium cables common	Local distribution of locally generated power Active local demand management Biogas distributed via gas network

Energy transmission and distribution in Win-Win

Technology and societal context

In Win-Win in 2025, there is a new two-way electricity grid architecture. Supply is much more diverse with more renewables instead of centralised fossil fuels to meet demand. This is backed up with flexible tariffs, incentives to use EV batteries as local storage, and smart meters to control it all.

The pattern of supply is highly complex, with changing generation and demand at multiple levels (transmission, distribution, use) in the network.

Smart meters controlling interruptible loads and local storage are also used as a stopgap measure to reduce the need to reinforce the distribution network.

A SuperSmart Grid (SSG) using high voltage direct current (HVDC) technology is now transmitting renewably generated electricity over vast distances between points in North Africa, the Mediterranean, and northern Europe.

Workshop discussion on OSH — Energy transmission and distribution in Win-Win		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Live working in distribution networks Live working in distribution networks (240 V to 50 kV) will grow with the repowering of distribution networks and increased use of renewables and of storage. The dangers of electric shock, burns, fire and explosion are well understood, but will involve different people, in different applications. The storage of electricity is a new dimension. Safe working requires robust procedures (e.g. lock off, tag out, notices, and lock out), all of which require training and experience. The issue is the speed of change, with new applications with more services and, consequently, the employment of new and inexperienced workers and trainees. There will always be pressure to cut corners on OSH and to use inexperienced staff.	All scenarios, but most acute in Win-Win and Deep Green	Growing issue
Blackouts In Bonus World in 2025, the profit motive and the need to keep costs down leads to a reduced margin of spare capacity, making blackouts more common. The risks arise from sudden darkness and loss of power, especially with moving machinery, in hospitals, and other life-critical situations. These are a self-evident OSH issue.	Growing risk in Bonus World and Deep Green	Growing risks in many areas of work

Energy transmission and distribution in Bonus World

Technology and societal context

Energy use has grown. There is pressure on distribution networks, and an urgent need for innovative smart solutions to avoid the cost of wholesale upgrades. Interconnectors are still being built but only where there is a good business case.

Copper prices have doubled since 2012 because of grid upgrades, and the use of aluminium cables has become widespread. The risk of blackouts is rising, but the political imperative is to keep the lights on. National nuclear power programmes (cut back after the Fukushima incident in 2011) have been reinstated.

Distribution monopolies have been broken up to promote competition.

Workshop discussion on OSH — Energy transmission and distribution in Bonus World		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Aluminium cabling As copper prices rise, other metals like aluminium are used for cables instead. In reaction with the air, aluminium forms an insulating layer of aluminium oxide: these have a greater risk of joint failure and sparking than copper does and this can result in fire. This is a particular risk, as seen in the United States in the 1970s when aluminium cables were used for house wiring. This is likely to be a growing problem in the long term in Bonus World as copper reserves are used up and prices rise.	All scenarios, but greatest in Bonus World	Growing risk
Novel solutions to capacity issues There will be strong economic incentives to develop new 'smart' solutions to improve the capacity of the distribution network without the huge investment of a wholesale upgrade. Squeezing more capacity out of the system means that there will inevitably be less safety margin in the event of control system failure.	Bonus World	Possibility of new systemic hazards emerging
Electrical connection in wind farms between the towers and grid connection points In a wind farm, responsibility for the towers is fairly well defined, as is the premises of the distribution network operator (DNO) where grid connection is made. The HV distribution system outside the footprint of the tower that connects these is more accessible, and responsibility is often less clear between the various subcontractors.	All scenarios	Not new, but growing in scale

Energy transmission and distribution in Deep Green

Technology and societal context

The emphasis is on local distribution systems and localised production. There is increased demand for small-scale storage, with increased flow in both directions.

The pattern of supply is highly complex, with changing generation and demand at multiple levels (e.g. transmission, distribution, use) in the network. With lack of investment, these have led to an unreliable electricity supply with frequent brownouts and blackouts.

In times of energy surplus, electricity is used to generate gas (methane and hydrogen) as a store of energy and as a medium to transport energy through the existing gas network.

The capacity of the transmission grid and the distribution grid are being increased, to accommodate localised production, but low levels of funds for investment is an obstacle to this.

Workshop discussion on OSH — Energy transmission and distribution in Deep Green		
OSH implications within the scenario as identified in the workshop	**Applicability**	**Scope for new and emerging risks**
Control of the grid It is difficult to maintain top-down control of the grid as a result of the new distributed generation sources.	Greatest in Win-Win and Deep Green	Growing issue
Upgrading the grid Major work will be needed to upgrade the existing grid, bringing electrical risks and live working, and access issues. Highly trained workers will be needed. Life-extended systems will have more risks than new ones.	All scenarios	Not new
Biogas Storage and distribution of biogas brings risks of intoxication (e.g. from H_2S) or of suffocation, and of explosion. Quality issues, such as impurities, militate against injection into the gas main.	Greatest in Win-Win and Deep Green	Emerging risk

Complementary information from desk research and Phase 2 technology workshop on OSH issues for energy transmission and distribution

Workshop briefing on OSH issues

The briefing material for the energy transmission and distribution workshop, based on desk research by HSL, as well as the discussions in the Phase 2 technology workshop (Section 4.3), highlighted the following OSH factors:

- 'flashover' burns, falls and electrocution during the installation, connection and maintenance of new power sources;
- risk of 'flashover' burns and electrocution owing to the increased need to work on 'live' systems as systems become more complex;
- construction and excavation risks during cable laying, substation construction and other activities (onshore and offshore);
- risks from the installation, maintenance and use of smart meters: the estimated 200 million smart meters (Williamson, 2012) to be installed in homes in Europe to 2020 will see an enormous increase in meter installers who may not all have electrical installer qualifications to the level of qualified domestic or light industry electricians; they may, therefore, put themselves and occupiers at risk; they may not be able to certify the connections between the householder system and the new meter; there are obvious areas of safety concern in blocks of flats sharing a common smart meter, both in terms of access controls, and also the connection of a smart meter to a number of different electrical installations with different maintenance contractors;
- electrical risks from self-built installations using cheap components: each component may be CE marked but there may be safety issues when they are combined by unqualified people;
- cyber security — risks from accidental or malicious interference with ICT control of networks; and
- risks from interruption of supply to users with interrupted supply contracts.

Source: UK Health and Safety Laboratory Futures Team and additional sources (HSE, 2010b; Bradbrook et al., 2010; HSE, 2003; Littelfuse®, 2005).

OSH discussion for energy transmission and distribution

The rate of development of the grid and its nature will be scenario-dependent, ranging from a fully functional two-way Europe-wide system to a more locally focused set-up.

The main hazards from the construction of a SuperSmart Grid (SSG) and infrastructure are electrocution, 'flashover' burns and falls. These hazards will be present in activities such as the connection and maintenance of new power sources; these hazards will be more likely to occur as the SSG will be hugely complex, so there will be much more 'live' electrical working.

There may be time pressures to build a new SSG and associated infrastructure to accommodate the huge future increase in European renewables, both large-scale and distributed. Time pressures from governments or electric company deadlines, such as cut-off dates for feed-in tariffs, may lead to installation work being done in a hurry with a resulting risk of accidents or poor quality installation. Owing to the huge engineering task of building a European SSG, there will be large amounts of construction and excavation carried out both on and offshore, along with the hazards and risks associated with cable laying, substation construction and other activities. These construction OSH risks include blasting/explosion hazards, entrapment by tunnel or structure collapse, being struck by heavy equipment and plant, working at height and in confined (or hot) conditions, and MSDs. Tight deadlines, physically strenuous work and long working hours may lead to psychosocial risks to the workforce.

Large construction projects typically make extensive use of subcontractors. Given the huge scale of the task needed to construct an SSG, multiple subcontractors are likely to be required. There may be problems with maintaining OSH throughout the work chain. With a huge international project such as this, there is the potential for language barriers and different cultural attitudes to OSH, which could lead to an increased risk of accidents. Given the number of people required to build an SSG, there is likely to be a shortage of skilled workers (particularly electrical engineers and electricians). Hence, less-experienced or skilled individuals may be used and this may lead to safety issues. There is also the issue of confusion over which of the many contractors involved with the SSG will be responsible for the maintenance of any given grid interface in the system.

The sheer diversity and number of energy providers connected to the grid and the complexity of the system will give rise to a greater number and wider range of OSH risks. For example, offshore wind farms will deliver their electricity to shore by direct current (DC), rather than the alternating current (AC) used by electricity grids. DC current activities are more dangerous than AC activities and there may also be electrical and flashover burn risks at the DC/AC interface. A diverse range of microgeneration technologies and local or community electricity generators, spread over huge areas of land with millions of two-way connections to the grid, means that a vast number of people will be exposed to electrical hazards, including local electrical engineers, maintenance workers and the general public. Given the lack of experienced personnel in the future, these individuals are likely to be overstretched and required to work long hours: this will increase the risk to their health as well as the risk of an accident, and may affect the safety of the installation and grid connection. Psychosocial risks are likely too.

The domestic and business end of the grid will be controlled by smart meters; currently, there are few meters of this type in Europe, so vast numbers will need to be installed across Europe in the near future. For example, in the United Kingdom alone, an estimated 48 million new meters will be installed over the next 5 years. It is very likely that there will be a shortage of skilled electricians to install smart meters and meter installers may not have the required competence or accreditation to install them. It is unlikely that all installers will be qualified to the level of domestic or light industry electricians and will, therefore, not be able to certify the connections between the building system and the new meter. There may also be a corresponding increase in the number of unqualified 'cowboy' meter installers over the next decade. This will expose both the worker and the public to the risk of electrocution, burns and fire. There are also safety concerns over blocks of flats and multiple occupancy work buildings sharing a common smart meter, both in terms of access controls, and also the connection of the meter to a number of different electrical installations with different maintenance contractors.

Note on limitations of OSH analysis

This is a futures-based view of this technology. The issues considered above were based on a single day's workshop with experts in technology and/or OSH expertise as well as policymakers, and with the HSL desk research as briefing. The intention was to illustrate the power of the scenario method to broaden the discussion and generate insights. This is not intended to be a comprehensive list of OSH issues.

5.4.10. OSH factors common across technologies

This section covers OSH factors that appeared in two or more workshops, or were otherwise assessed as being applicable across the technologies (Table 22).

OSH discussion of cross-technology issues

Cross-cutting issues are inevitably more general than those concerning specific technologies, but they are important, often more so.

Skills and training

EU Member States have ambitious targets for environmental improvement and the use of low-carbon energy sources. Therefore, in any scenario, we are likely to see rapid growth in the use of renewable energy technologies. It is established that workers are more vulnerable in the early days in a job. When we have large numbers of people new to sectors, or people already in a particular sector who must encounter changes, then risks may be increased. The classic example is the case of gas fitters who find themselves working on roofs fitting solar thermal systems. Alongside this, we are seeing growth in the numbers of new entrants, such as small companies and sole proprietors who may be subcontractors, inexperienced in the new technologies, and for whom OSH issues may be more challenging. An example is in the growth of biogas generation in methane digesters.

Economic and time pressures

While poor economic conditions exist, there may be pressure to do things cheaply and an increasing tendency to subcontract work. Additional factors such as feed-in-tariff deadlines or EU targets can add urgency to the installation of renewable energy technologies. Cost-cutting and time pressures may have an adverse effect on OSH, which tends not to be seen as a priority in these conditions.

Work-related psychosocial risks

Factors such as rapid innovation, the increasing complexity of systems, the rising use of robots (especially those that interact with humans), increasing automation, growing reliance on IT and human-machine interface issues, increased shift working, and increased remote working, possibly in a context of economic growth and increased job security, or of high competition depending on the scenario, all have the potential to have psychosocial impacts on workers.

If the pressures lead to increases in the use of performance-enhancing technologies, such as drugs, then other health impacts may follow.

Health and safety risks from exposure to and use of new materials

A wide range of novel materials, including nanomaterials, are likely to be introduced and the health risks related to them may not yet be fully known or understood. Increasingly, materials will be customised for particular applications. An increase in the range of these could mean that there is no such thing as a standard material, so setting standards will be difficult. Where materials are designed for a particular application, it could be dangerous if they are wrongly used for another.

Examples of new materials include: composites; ceramics; new nanomaterials; smart materials (e.g. piezoelectric, shape memory, thermochromic, photochromic and magnetorheological). These will appear in a range of sectors, such as construction, manufacturing and waste processing. Also, new biological materials will appear as a result of developments in biotechnologies. We are currently seeing genuinely novel materials being developed that bring genuinely new risks. The biggest impacts may be exposure at end-of-life through product degradation or waste processing.

In a world where people change jobs more often and a job for life is rare, there could be difficulties in tracking exposure histories without exposure registers or health surveillance in place, adding to the risk of long-latency effects.

There is a need for:

- research on long-term effects of material use on health, thorough risk assessment and initial testing before introducing materials on the market;
- exposure monitoring; and
- making better use of existing information (e.g. there is already a lot of information on biohazards of new materials).

Waste and recycling

Although this has been treated as a technology in its own right in this report, it cuts across a range of industrial sectors. While technological advances, such as robots that sort waste, could make jobs in this sector safer by distancing workers from hazardous materials, at the same time, technological developments in other areas will constantly increase the range of materials and devices and, therefore, hazards that have to be dealt with. This could include a wide range of customised materials or 'one-offs' with unknown properties that, therefore, present potential risks to workers in waste management and recycling.

The extent to which any of the above issues are present and the impact they have is likely to depend on the scenario, but it is likely that they will all appear to some extent in any scenario.

Table 22: **Summary of OSH issues identified as 'cross-technology'**

OSH factor: Title and short description	Applicability	Scope for new and emerging risks
New materials have the potential for major unexpected impacts on health and environment: • nanomaterials • new insulating materials • new composites • smart materials • new organisms • biofuels and by-products. There is a real risk of **long-latency hazards** (e.g. carcinogens): without exposure registers, diseases are difficult to trace back to jobs, as no one stays in the same job until retirement any more.	Greatest use of new materials in Bonus World, but Win-Win has the greatest innovation and use of new materials within green jobs	New risks
New occupational diseases What will the health risks be from new materials, processes and procedures in a couple of decades' time?	All scenarios, but greatest in the high-innovation Bonus World	Scope for new physical risks (e.g. new MSDs), as well as chemical and biological exposure
Diverse risks Diverse risks that are difficult to monitor and regulate from decentralised renewable energy installations, including PV, micro-CHP and biogas will emerge.	All scenarios, but greatest in Win-Win and possibly Deep Green	Not new, but possibly growing occurrence
Rapid innovation Rapid innovation may lead to a variety of OSH risks, with new materials and new processes, and little time to learn how to use them safely.	Rapid innovation in general in Bonus World, but greatest innovation in green jobs in Win-Win	New risks
Automation Automation is most likely to be very positive for safety in the long term, but absolute reliability is essential.	Greatest in Win-Win and Bonus World	New processes bring risk, but automation is likely to be positive for OSH
Human-machine and human-ICT interfaces Human-machine and human-ICT interfaces can give rise to complex risks (e.g. ergonomics and high cognitive load) and over-reliance on ICT.	Greatest in Bonus World but also relevant in Win-Win	Growing risks
Human performance-enhancing technologies (e.g. drugs, implants, bionic limbs) Evidence exists now of the increasing use of drugs by people who are well, as a means of enhancing concentration and performance at work; dramatic developments in bionics and implants.	High in Win-Win and greatest in Bonus World	High, across many sectors and types of jobs
Stress and mental health Stress and mental health issues seem likely, given job uncertainties, increasing complexity and intensification of work.	Greatest in Bonus World	Potentially growing issue
Unpredictable shift working More unpredictable shift working owing to the intermittent nature of renewable energy: unpredictable working hours and shift working are known to have an impact on health and safety. This depends on development of the grid and electricity storage technologies.	Applicable to Win-Win but greatest in Deep Green	High

OSH factor: Title and short description	Applicability	Scope for new and emerging risks
End-of-life issues Refurbishment, demolition, disposal, waste and recycling (e.g. old wind farms not being repowered; it is required that wind turbines be refurbished rather than replaced; demolition of recent buildings with modern new materials in them; robotic disassembly of manufactured goods; decay of PV panels and ex-EV batteries).	All scenarios Refurbishment greatest in Deep Green	High
Emergency services The emergency services will be confronted with various unknown risks due to differing combinations of energy sources, devices, and systems.	Common to all scenarios	Very high
Metal theft Metal theft brings OSH risks to a world where valuable components are kept on the outside of buildings. Thefts of cable could result in power cuts leading to safety risks as industrial processes are interrupted and could leave live cables exposed. This also brings risks to maintenance workers. Theft of other metal items could similarly cause safety risks.	Greatest in Bonus World, with high prices and profit motives. Risks occur in many green jobs	Not new, but growing risk across many technologies including wind, batteries, and domestic energy
Government deadlines Government deadlines give rise to unnecessary pressures to cut corners resulting in less emphasis on OSH.	Most immediate in Bonus World, but applies to all scenarios	Relevant to OSH policymaking
Subcontracting Subcontracting can lead to cost-cutting, which, in turn, may result in less emphasis on OSH issues.	Greatest in Bonus World	Not new, but growing scope in Bonus World
Availability of skilled manpower New technologies will need people with skills, and long timescales are needed to achieve competence. In areas where expansion is rapid (e.g. renewable energy), there could be a skills gap. Workers without sufficient skills and training may be at risk.	Greatest in Bonus World with the highest pace of change Most relevant to green jobs in Win-Win	Growing issue with implications for OSH
Ageing workforce People are working longer so the average age of the workforce is increasing and more people are working beyond state pension age. This could be in response to the recession, reduced pension benefits or because they want to. Previously 'older workers' have been considered to be those over 50. Relatively little research has been done on workers over 65, so OSH risks particular to this group are not well documented.	Common to all scenarios	Growing potential for OSH risks as workers age, but there may be as yet unknown consequences

6. Consolidation and testing of the scenarios

The scenarios described in Chapter 5 were tested in a consolidation workshop held in London, 7 and 8 March 2012. The workshop was attended by the project team and a range of policymakers, technical and OSH experts invited by EU-OSHA.

The aims of the workshop were to: present the scenarios (in their nearly final form); use the scenarios to test their coherency and utility; revise and consolidate the scenarios with the feedback received; demonstrate their use in supporting policymaking. Imagery was used to present the scenarios and to help facilitate the workshop discussion. This can be a powerful tool to help people 'live' the scenarios and explore elements within them.

Participants were allotted to a single scenario for the duration of the workshop. After a short initial exercise to familiarise them with their scenario, they were asked to undertake the following tasks:

1. identify the key OSH challenges and opportunities in each scenario;

2. develop specific policy options for each scenario to address the respective challenges and opportunities, and explore how they would be implemented; and

3. review the policies across the three scenarios and test their relevance and robustness in each scenario (wind-tunnelling) and how they would be implemented in each scenario.

6.1. OSH challenges and opportunities

In order to provide the workshop participants with a manageable quantity of information given the time constraints of the workshop, 40 of the OSH issues identified during the Phase 3 technology workshops were selected as source material for the exercises. They were selected by the team as being most suitable in order to give a spread of issues judged to be significant across the technologies and sectors and to stimulate discussion with this workshop audience of policymakers.

This selection suited the purposes of the workshop to test the scenarios developed and demonstrate their use for policy development but, for 'real' policymaking, all issues would need to be taken into account. For other audiences or other purposes, it may be appropriate to prioritise some other of the OSH issues described in Chapter 5, or to use the scenarios to generate further OSH issues as the technologies used in green jobs evolve over time, and new risks emerge.

The 40 new and emerging OSH risks, challenges and opportunities selected are now summarised. Some of these could be expected in all futures; some will occur only in certain possible scenarios. More detail on these issues is contained in the descriptions in Chapter 5.

Wind energy

1. **Deep-water offshore sites**

   Here, the main issues are the scale of operations and the distance from safe haven. This will get worse as wind farms are developed in new and challenging locations open to the ocean. Safe access for maintenance will also be an issue.

2. **Size of the turbines**

   The biggest turbines (much bigger than anything installed in 2012) will have very high towers; installation involves lifting very heavy loads with high aerodynamic resistance in some of the windiest locations on Earth. The largest turbines will need new turbine designs and assembly processes.

3. **End-of-life and legacy issues**

   The OSH uncertainties revolve around the long term as wind farms reach the end of their design life. Design action is needed now to enable eventual safe dismantling or refurbishment.

Construction

4. **Automation of construction**

   The automation of construction through the prefabrication of modules in factories and machine handling on site is an opportunity that potentially could be very positive for OSH. However, while this could reduce the physically demanding manual construction work, it would increase heavy crane-lifting tasks. There are risks during the connection of services (water and electricity) to the prefabricated modules but, with correct designs, these should be negligible. Furthermore, there is a possibility that risks could be transferred from the construction site to the factory by way of new processes or new materials.

5. **Retrofitting**

   Retrofitting of renewable energy technologies to old buildings leads to exposure to dust, lead, asbestos, and work at heights. The lack of adequate ventilation in the case of retrofitting indoor insulation may be an issue, in particular as this type of work may attract unskilled workers (or construction workers used to outdoor work, not aware of the need of proper indoor ventilation). These are not new risks, but known risks in new situations.

6. **New construction materials**

   New construction materials (e.g. phase changing materials, active surfaces, heat storage chemicals and new insulation) could result in construction workers, installers and future refurbishers being exposed to potentially harmful new substances.

Bioenergy

7. **Third-generation biofuels**

   The safety of third-generation biofuels and any by-products and contaminants is a potential issue. The variability of by-products (like methanol in fermentation) will be a particular potential hazard.

8. **Synthetic biology**

   Biohazards from new organisms and synthetic biology are a new risk.

Waste and recycling

9. **Zero-waste economy**

   Delivering a zero-waste economy means dealing with the most difficult tail end of the waste stream in concentrated form.

10. **New materials**

   The release of **new materials** such as nanomaterials during mechanical operations in waste treatment is a significant future hazard. New risks are continually emerging in this area.

11. **Robots in waste processing**

   The use of robots in waste processing, disassembly and recycling would be highly beneficial in OSH terms.

12. **Growth in landfill mining**

   As raw material costs increase, it will become economically viable to recover material from landfill sites, with potential exposure to unknown materials.

Transport

13. **Self-driving vehicles**

   Self-driving vehicles are potentially very positive for OSH, although they bring the issue of their absolute reliability as well as of the danger of over-reliance on the technology.

14. **Electrical risks from EVs**

   High voltages in EVs lead to new risks for maintenance and emergency workers. EVs and charging points bring risks of electrocution, explosion or fire.

15. **Two-wheeled vehicles**

   Increased use of **two-wheeled vehicles** with their green credentials for the transport of goods and people may lead to more accidents.

Manufacturing and robotics

16. **Uncaged robots**

   Intelligent uncaged robots working closely with humans are a growing hazard.

17. **Human performance enhancement**

   The health and safety implications of human performance enhancement through robotics (bioautomation and implants) is an area that may need active consideration by OSH organisations.

18. **Decentralised manufacturing**

   It will be more difficult to enforce OSH in a decentralised manufacturing ecosystem (using flexible systems, 3D printing, etc.). Decentralised production may also mean smaller companies, which may have a weaker OSH culture.

Domestic and small-scale energy

19. **Shared eco systems**

   Small clusters of households with their own shared eco systems (e.g. mini-CHP, biodigesters, and PV systems) are probably the least safe size for this sort of activity, with no central authority or 'keyholder' responsible for safe operation.

20. **PV**

   The widespread adoption of PV, when PV eventually reaches economic viability, will bring growing hazards. Risks of electrocution and falls from height during installation, maintenance and decommissioning are always present, as is potential exposure to chemicals.

21. **Distributed generation**

   Distributed generation gives rise to electrical risks as many more sources of voltage can give rise to electric shock even when the mains current is disconnected.

Batteries and energy storage

22. **Hydrogen**

   As an energy store, hydrogen brings risks of explosion, leakage, cryogenic hazards. The use of hydrogen in homes is particularly risky (though this may not be a strictly OSH issue).

23. **New battery technologies**

New battery technologies bring well-known risks including electrical risks, toxic chemicals and fire. There are severe risks to the emergency services. The worst hazards may arise in secondary uses after batteries have degraded and are no longer suitable for vehicles, for example, but still have a value as fixed energy stores.

24. **Bulk energy storage**

In addition to hydrogen, a range of potential storage methods exists (e.g. compressed air, flywheels, and supercapacitors). Any complex mixture of these technologies may present particular risks.

Energy transmission and distribution

25. **Blackouts**

It seems likely that, in the future, there will be an increasing risk of blackouts. Blackouts lead to dangerous situations in the workplace.

26. **Complex grid**

There will be difficulties controlling a complex grid (e.g. two-way transmission, intelligent machines and appliances and electricity storage issues). It is also expected that there will be an increase in live electrical working.

Cross-technology (generic) issues

27. **Metal theft**

Metal theft brings OSH risks (e.g. because of the resulting interruption in industrial processes or risks during repair operations) to operatives or to maintenance workers. This risk will grow in a world where valuable components are increasingly kept on the outside of buildings. This is not new, but is a growing risk across many technologies including wind, batteries and domestic energy.

28. **Availability of skilled manpower**

New technologies will need people with skills, and long timescales are needed to achieve competence. There is an increased likelihood of polarisation of the workforce between skilled and unskilled workers.

29. **New materials**

New materials have the potential for major unexpected impacts on health and environment. Nanomaterials, new insulation, new composites, new organisms, biofuels and by-products potentially bring new risks. There is the risk of long-latency hazards (e.g. with carcinogens) and diseases are difficult to trace back to jobs: no one stays in the same job until retirement any more.

30. **Subcontracting**

Subcontracting in industry leads to cost-cutting, which may result in less emphasis on OSH.

31. **Government deadlines**

Government deadlines (especially to qualify for green subsidies with an installation deadline) give rise to unnecessary pressures to cut corners, with a risk of negative impact on OSH.

32. **Work-related stress**

Work-related stress resulting in impacts on health seems likely in some cases, as a consequence of intensification of work and job insecurity.

33. **Older workers**

Demographic trends mean we must expect to see a growing proportion of older workers in the workforce. This is an increasingly important issue that will need to be addressed across all OSH activities and is relevant to all technologies and scenarios.

34. **Decentralised installations**

Diverse risks from decentralised installations will be difficult to monitor and regulate. These include, for example, decentralised local manufacturing, electricity generation, micro-CHP and biogas.

35. **Innovation**

Rapid innovation may lead to a variety of OSH risks, with new materials and new processes, with little time to learn how to use them safely.

36. **Automation**

Automation and robotics are likely to be positive for safety in the long term, but absolute reliability is essential and new processes may bring new risks.

37. **Human-ICT and human-machine interfaces**

Human-ICT and human-machine interfaces can give rise to complex risks (e.g. high cognitive load in monitoring and surveillance work, and ergonomic load), and over-reliance on ICT.

38. **End-of-life issues**

End-of-life issues are a recurring theme. They can arise during refurbishment, demolition, degradation, disposal, waste and recycling. Worker health and safety during future end-of-life processing needs to be designed into products at their design and development stage.

39. **More unpredictable shift working**

More unpredictable shift working owing to the intermittent nature of renewable energy will bring risks as workers have to adapt their circadian rhythms. Unpredictable working hours and shift working are known to have an impact on health. The size of this problem depends on the future development of the grid and on electricity generation and storage technologies.

40. **Human performance-enhancing technologies**

This includes principally pharmaceuticals, and there is evidence now of increasing use of drugs by people who are well, in order to, for example, boost concentration at work. In the future, this will also include implants and bionic limbs as the dramatic developments in these areas bear fruit. These will bring a whole new dimension to issues of liability and blame for workers' actions and behaviour.

6.2. Consolidation workshop exercises

Exercise 1: OSH issues in each scenario

Delegates were asked to consider the list of 40 OSH issues for green jobs. Working in scenario groups, they were asked to identify the five most important issues for their scenario ([11]) and to prioritise them according to which had the greatest impact and which were most likely to occur. The prioritised OSH issues were to cover both technology-related and generic risks, plus at least one opportunity. At the start of the exercise, a check was made for any gaps or omissions in the above, drawing on participants' knowledge and the OSH data provided from the technology workshops.

Table 23 shows which OSH issues were considered to be of high priority in each scenario. The '**H**' symbol denotes which issues were seen as high priority in each scenario. The pattern of **H**s shows that the high-priority issues varied greatly by scenario (however, some issues might have been selected here in scenarios other than the one where they were first identified in the technology workshops as the participants were different, and they had very limited time to become familiar with the differences between the scenarios and select the issues). This variability is clear evidence to support the strength of the scenario method. A foresight study that used a single view of the future — effectively a single scenario — would only pick up on a limited number of these key OSH issues. The fact that different scenarios lead to different choices of priority issues, as in this workshop, demonstrates their value in considering what the key OSH issues might be in a range of possible futures.

Comments generated in the workshop on the selected OSH issues were fed back into the OSH analysis of each technology and thereby used to consolidate the scenarios into their final form.

Exercises 2 and 3: Use and testing of scenarios by developing priority OSH policies

In order to test the use of the scenarios produced and demonstrate their value, the second and third exercises took the priority OSH challenges and opportunities from Table 23. Exercises 2

Table 23: **Priority OSH challenges and opportunities by scenario**

OSH issue (*)		Win-Win	Bonus World	Deep Green
Wind energy				
3.	End-of-life and legacy issues as wind farms reach the end of their design life; design action needed now			**H**
Construction				
5.	Retrofitting of renewable energy technologies to old buildings leads to exposure to dust, lead, asbestos, and work at heights			**H**
Waste and recycling				
9.	Zero-waste economy means dealing with the most difficult tail end of the waste stream in concentrated form		**H**	

(11) In practice, two groups exceeded this number.

OSH issue (*)		Win-Win	Bonus World	Deep Green
10.	The release of new materials during mechanical operations in waste treatment; new risks continually emerging		H	H
12.	Growth in landfill mining, with potential exposure to unknown materials		H	
Transport				
13.	Self-driving vehicles are potentially very positive for OSH		H	
14.	Electrical risks in EVs and charging points			H
Manufacturing, robotics and automation				
16.	Intelligent uncaged robots working closely with humans		H	
18.	OSH may be more difficult to enforce in a decentralised manufacturing ecosystem	H		
Batteries and energy storage				
21.	Distributed generation gives rise to electrical risks even when the mains current is disconnected			H
24.	Bulk energy storage, especially in complex mixtures		H	
Cross-technology (generic) issues				
28.	Availability of skilled manpower	H		
29.	New materials have the potential for major unexpected impacts on health and environment; risk of long-latency hazards	H	H	H
32.	Work-related stress resulting in impact on health	H	H	
34.	Diverse risks from decentralised installations that are difficult to monitor and regulate (e.g. decentralised local manufacturing, electricity generation, micro-CHP and biogas)	H		
38.	End-of-life issues: refurbishment, demolition, disposal, waste and recycling			H

(*) Numbers refer to the listing in Section 6.1. Only those selected by workshop participants are shown in Table 23.

and 3 used them to develop policies to achieve the best possible outcome for OSH in green jobs in each scenario in 2020. Novel policies that related to the conditions in each scenario were encouraged. The expected benefits and implementation of the policies were also considered, including supply and demand side measures, any obstacles to be overcome, the resources required and the timescale.

Exercises 2 and 3 also used the priority OSH challenges and opportunities to review the policies across the three scenarios to explore their relevance and robustness in each scenario (wind-tunnelling) and consider how the policies could be implemented in each scenario.

Policy development is a complex process that requires sound evidence and significant analysis of options. In the time available, it was only practical to give initial consideration to a limited number of policies in order to demonstrate the value of scenarios.

Though OSH policy generation is beyond the scope of the project, the results were of interest and are, therefore, included. The ensuing OSH policy initiatives can be divided into two groups: those that appear to have support in each scenario, and those that are scenario-dependent.

The text in italic at the end of each of the following boxes (Tables 24 and 25) indicates the discussion from the wind-tunnelling exercise.

Table 24: **Potential OSH policies supported within each scenario**

Workshop discussion on potential OSH policies
Incentivise companies to research future OSH risks Adopt measures to enable companies to better understand future OSH risks. Areas that need to be better understood include: new materials; decentralised manufacturing; decentralised energy generation; and how to identify hazards in R & D related to green jobs. This should be implemented by means of incentives for large companies to conduct research to understand OSH risks across the life cycle of products, technologies and jobs and thereby to promote 'OSH by design'. Incentives should include tax breaks. Penalties for non-compliance would include naming and shaming, and loss of corporate OSH accreditation. *This policy was developed by taking a Win-Win perspective of the future. It was supported by the Deep Green team, where it was seen as a potentially useful idea to incentivise companies; however, it was seen as too business-oriented and with not enough focus on citizens for the Deep Green world. It was supported to a lesser extent within the Bonus World view, even though there was a risk that it was to some extent based on wishful thinking.*
Better OSH training in green jobs This would encourage an OSH culture in green jobs, and lead to stakeholders being better informed and better protected against emerging risks. This policy can be implemented by: • making OSH a mainstream element in education for all ages, with OSH apps, OSH games, and OSH on the curriculum; • developing, delivering and monitoring green OSH vocational-training schemes; and • providing information in a timely manner (perhaps with a green OSH database), tailoring information intelligently for the recipient and ensuring that information can be accessed at all levels of hierarchies and across media technologies. *This policy was developed by taking a Win-Win perspective of the future. It was supported strongly within the Bonus World view. It was also supported by the Deep Green team, where some elements of the policy were seen as relevant, but the top-down approach and absence of bottom-up information collection makes it incomplete and one-sided, with insufficient focus on the societal dimension.*
Life long education in OSH Introduce a programme of lifelong education and training in health and safety. This would include schoolchildren, university students, workers, etc. For example, schoolchildren could be taught to do their own risk assessments for school trips. This should be made part of the learning experience and preparation for adult life, rather than a chore for the teacher. The intention is that good OSH becomes second nature. *This policy was developed by taking a Bonus World perspective of the future. It was supported strongly within the Win-Win view, but was only weakly supported by the Deep Green team. In the Deep Green perspective, although seen as valid, it seemed to shift too much of the OSH responsibility from companies to education, and the absence of the involvement of societal and business stakeholders makes it a one-sided, traditional approach to education.*

Table 25: **Potential OSH policies that are scenario-dependent**

Workshop discussion on OSH policies
Green OSH standards for industry Develop a set of clear green OSH standards for industry (so that 'green' also means safe and healthy, being compatible with good OSH). Relate these standards to technologies, work processes, and new materials. Implement with a mix of legislation, industry-led good practice, and awareness-raising campaigns everywhere. Promote the idea that green OSH standards are part of good corporate social responsibility (CSR). *This policy was developed by taking a Win-Win perspective of the future, but was seen as difficult to implement in Deep Green. Green standards are not a big issue in Bonus World.*

Workshop discussion on OSH policies

Globalise OSH

This would bring about worldwide improvements in OSH practice. Additionally, the World Trade Organisation (WTO) would need to recognise poor OSH practices as a legitimate factor in claiming unfair competition. This would mean that companies outside Europe would not be able to gain competitive advantage by neglecting health and safety at work.

This policy was developed by taking a Bonus World perspective of the future. It was seen as unfeasible in Win-Win where OSH standards in Europe would drop from a high current standard to average global level. It was similarly seen as unfeasible in Deep Green, where any global dimension would be realised by pursuing a global OSH culture and where global collaboration would be bottom-up and based on voluntary agreements.

Internalise the costs of bad OSH practice

Introduce charges and financial penalties so that employers cannot externalise the costs of bad OSH practice. This would bring recognition that good OSH pays for itself, and mean that taxpayers do not end up paying for the consequences of bad OSH.
The policy can be implemented by:

- imposing strict liability on employers for work-related diseases and accidents (backed up by mandatory insurance in all EU Member States) and making employers pay workers' hospital bills for work-related injuries or ill health;
- creating a lifelong logbook or 'passport' recording workers' personal exposure — in particular, to chemicals to ensure traceability;
- ensuring that OSH and environmental agencies work together; and
- supporting the dissemination of good OSH practice that provides positive economic returns.

This policy was developed by taking a Bonus World perspective of the future. It was seen as reasonably supported in a Win-Win world, but incompatible with a Deep Green culture where economics is not the main argument for companies to implement good OSH: the proposed approach did not take into account a systemic view of the problem.

Holistic OSH policy

Institute one holistic policy to promote OSH through the following three aspects.

1. A bottom-up collaborative approach is required to create an OSH culture, through education and awareness-raising activities.
2. An integrated two-way approach (bottom-up and top-down) is needed to develop OSH intelligence. This includes research on new and old risks, collecting and monitoring relevant problem-related data, as well as exploring new ways of transferring OSH knowledge. This would contribute to developing a better needs-targeted OSH agenda.
3. OSH can be brought more into the mainstream with a strategy to support an OSH culture by applying OSH intelligence across different sectors and professions.

The first aspect, a bottom-up collaborative approach, can be implemented by means of the following:

- making OSH fun to learn — innovative OSH education based on 'edutainment', using video games, for example;
- raising awareness of OSH through participative approaches, such as TV/radio programmes that encourage the public to report OSH issues and propose solutions, or reality shows that feature employers and workers solving OSH problems together (this would both raise public awareness and generate public pressure on companies and authorities for the OSH case); and
- introducing OSH awards with high-visibility media, and an official label for recognition of good OSH performance.

The second aspect, an integrated two-way approach, can be implemented by means of the following:

- coordinating issues requiring joint, large-scale responses; and
- creating a key role for national OSH strategies.

This policy was developed by taking a Deep Green perspective of the future. It was seen as unfeasible in Bonus World (except, perhaps, for some aspects of OSH intelligence) and either too slow or ineffective in Win-Win (except for the OSH-mainstreaming element, which is similar to a Win-Win policy initiative, although successful implementation of this element in Deep Green would be bottom-up while it would need to be top-down in Win-Win.)

Note that the workshop was intended to validate the scenarios and illustrate the strength of the method. We do not advocate the adoption of any of the above OSH policies on the strength of a single day's workshop, but they do highlight areas that could, and should, be explored further.

Even the policies that applied to just one scenario should be explored further. Indeed, in some circumstances, it may be appropriate to implement a policy that is only relevant to one scenario, owing to the need to manage a particular OSH risk. This is an appropriate policy decision if it is important to avoid the risk in question. It is also important to note the different implementation issues across the scenario. This could also lead to adjustments in the proposed implementation, or noting scenario dependence and the associated risks.

6.3. Conclusions from the consolidation workshop

The workshop aimed to: present the scenarios (in their nearly final form); use the scenarios to test their coherency and utility; revise and consolidate the scenarios with the feedback received; demonstrate their use in supporting policymaking. The conclusions drawn, therefore, concern these aims.

Policies

The objective of this policy workshop was to test the scenarios for assessing OSH risks and policies. It would not be appropriate to set policies on the basis of the discussion of the workshop as more time would be needed to develop proper policy proposals. More evidence would also need to be gathered (e.g. on the OSH risks associated with any particular technology).

There were common policies across the scenarios, such as those on education and training. However, it is important that the differences in implementation in the different scenarios are noted. OSH policies were also proposed that would only be appropriate in one scenario, as shown by the 'wind-tunnelling' exercise.

In interpreting the 'wind-tunnelling', it is important not to assume that the policy that seems to best apply to all scenarios should be implemented. There may be good reasons why a policy that seems valid in one scenario only should be implemented. In this case, the options for amending the policy to make it more broadly applicable may be appropriate. Where policies are not adopted, the information can be used to inform the future scanning for risk and help inform risk registers.

The scenarios

The workshop demonstrated how scenarios can lead to a broader range of strategic discussions that will ensure more robust analysis of future OSH issues. The workshop confirmed the value of scenarios as part of the toolkit for OSH policymaking. However, it is important to remember that the value of scenarios comes particularly from the discussion and insights generated.

7. Scenario presentation

7.1. Introduction to scenarios

The scenarios following combine the base scenarios (Section 5.3) and the technology developments from the technology workshops (Section 5.4). Their use for the identification of emerging OSH risks and development of policy options to address these was tested at the policy workshop, which is reported in Chapter 6. Comments from the policy workshops were used to consolidate the scenarios into their final form. The pictures illustrate some OSH issues identified in the technology workshops for each of the key technologies.

This version of the scenarios is intended for use in future workshops or further exploration of emerging OSH risks. They all look back from 2025 on the development of the scenarios. (The year 2025 was chosen rather than 2020 as in the project title, in order to stretch thinking so that changes after 2020, the early signs of which might be evident by 2020, would be included.)

7.2. Win-Win

High economic growth

Looking back from 2025, after a slow start in 2012, growth across the EU and OECD returned to the levels prior to the economic crash of 2008. Developing countries also experienced high levels of growth similar to the first decade of the century.

Strong green values

Advances in climate science started to show how vulnerable we are becoming to climate change. Growing public concerns encouraged governments to introduce green policies, including policies leading to deep and progressive cuts in carbon emissions.

There was strong approval for green behaviour by corporations and individuals. This was reinforced by concerns over resource shortages (e.g. food, commodities, minerals, water and energy).

High levels of innovation in green technologies

Green growth has increasingly been seen as vital for a sustainable future. Corporate profits and access to finance have supported high levels of investment in new business opportunities and infrastructure. The rate of technological developments has accelerated with high levels of innovation. A high proportion of the innovation has been aimed at achieving a green outcome and generating future profits.

Society and work

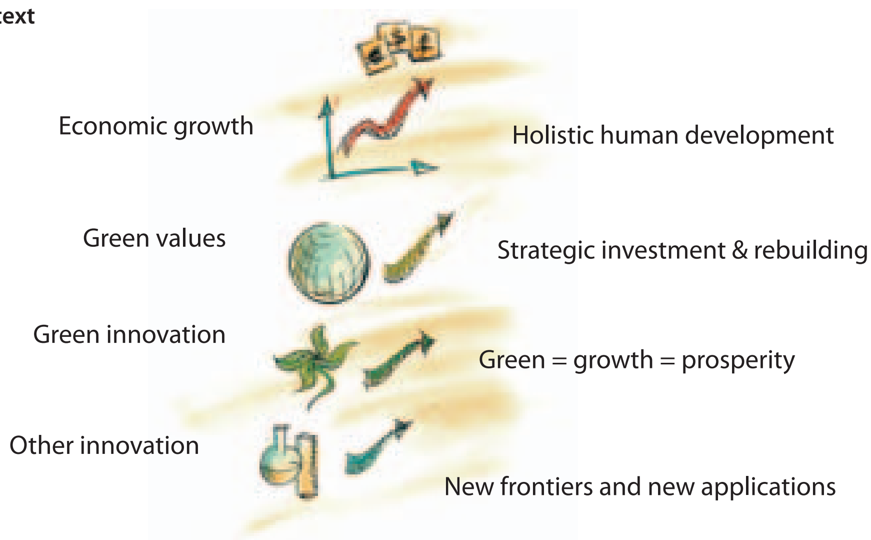
Most people in the EU now feel prosperous and place a higher value on the preservation of the environment, human life and well-being. The strong economy allows governments to address the increasing demands for welfare and to invest in education.

There is high employment and many new jobs and new products are now being created in ever-shorter timescales, which can lead to new hazards and risks if they are not designed with OSH taken into consideration.

Win-Win OSH general

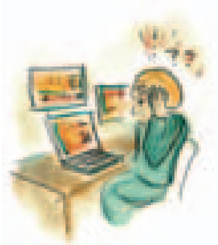
In a buoyant economy, funds are available for investments in OSH, but the high pace of innovation and the rapid roll-out of new technologies and new products, and the creation of new jobs requiring new skills mean that a wider population may face new risks over shorter timescales. It is, therefore, important that OSH assessments are undertaken early in the development cycle of a technology or product so that the pace of development doesn't leave OSH behind. If preferences for self-reliance, holistic wellness and self-care are translated to the OSH arena, the most effective OSH interventions may be self-regulation, education and cooperation. The high pace of innovation results in skills shortages and in a sectoral competition for qualified staff, eventually leading to a polarisation of the workforce with regard to skills.

Cartoon 1: **'Win-win' - context**



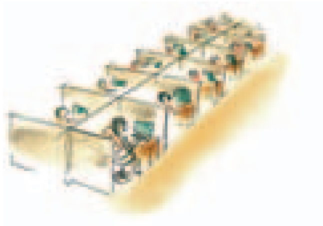
Cartoon 2: **'Win-win' - human systems**

'Every day we continue to re-design the human-machine interface...'



'We scored 8 out of 10 in the last green audit… how can we do even better next time?'

'Welcome to the L.Z.C. Safety & Health @ Work training module. Today we look at everyday hazards...'



'I guess every smart grid needs a call centre but it's still pretty stressful'

Wind energy

The target of 230 GW of installed capacity in 2020 (EWEA, 2012) was met. Now, in 2025, good progress is being made toward the target (for 2030) of 400 GW of installed capacity.

Improved manufacturing techniques and new monitoring and control processes have helped to contribute to safer operations.

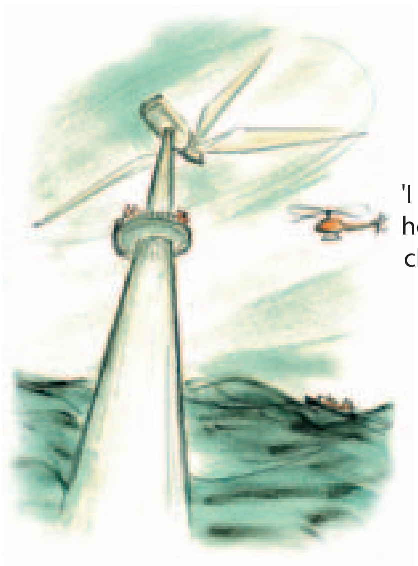
There are now large turbines of up to 20 MW. Large turbines have been designed specifically for the marine environment, including for installation in deeper offshore locations.

The foundations in shallower water have improved and the innovations in deeper water have included floating installations. Accommodation platforms have also started to appear in wind farms further offshore.

The risks are multiplied manyfold in offshore wind farms, which have the potential to become highly dangerous worksites. With so many large turbines in ever-deeper water, ever further from safe haven, access issues are the dominant OSH consideration. Working sites are more widely dispersed, with lower profit margins to pay for safety than in the oil and gas industries. Construction is hazardous and with the large numbers of turbines come skill shortages as wind competes with other technologies for qualified staff. Specialist vessels are required to handle large turbines in deep water, and there are still issues over foundation strategies (especially as the seabed is different for each turbine in a wind farm), transport of foundations from yards, and longer-term issues over removal of foundations.

Cartoon 3: **'Win-win' - wind energy**

'Delta Charlie to Base... I repeat... Storm force winds are forecast... Returning to the accommodation platform...'



'I wish the Green Job Policy Team was here. They would then appreciate the challenges of working on these large turbines in this environment'

Novel turbine designs have brought engineering unknowns. In the hostile environment, maintenance is demanding, although more reliable electronic infrastructure monitoring devices help to minimise unpredicted maintenance and improved quality of equipment has helped reliability. The need for workers to live so far offshore is leading to work organisation issues and psychosocial problems. New composites and nanomaterials used for the manufacture of wind turbines have possibly introduced new health hazards for workers in manufacturing, maintenance, decommissioning and recycling.

Green construction and building retrofitting

New buildings are zero-carbon, with heat stores, and built to at least *Passivhaus* standards (Passive House Institute, 2012), with low levels of energy consumption, and comprehensive instrumentation and monitoring. Hyperinsulating materials (e.g. aerogels and nano-lattice structures) have been developed, and are in increasing use. Every part is designed to be disassembled and recycled.

Modular prefabricated buildings, with modules pre-fitted with services, are now the norm.

There is a high level of activity to reduce the carbon footprint of the existing building stock. This includes external insulation, facilitated by advances in spray foam insulation.

Buildings interact amongst themselves and the smart grid. PV is integrated into buildings or painted on and provision is made for charging electric cars and using them for energy storage.

The off-site and automated construction of modular buildings has improved on-site safety as far fewer tasks are now undertaken on site. However, as building moves into factories, new risks emerge as workers are exposed to novel substances increasingly used in construction material (e.g. phase change materials, heat storage chemicals, novel surface coatings, nanomaterials and fibrous composites).

On-site issues arise from mixing automated with traditional, manual activities. There are risks during the connection of services (e.g. water and electricity) to the prefabricated modules but, with the correct designs, these should be negligible. There are also electrical risks as old and new buildings have to be integrated into the smart grid, incorporating smart appliances, energy storage technologies, etc. In increasingly crowded cities, the trend of developing basements has led to increasing underground congestion with associated OSH implications due to working in confined spaces, risk of collapsing structures or drilling into existing cabling.

Combinations of new energy sources in buildings (e.g. photovoltaics, geothermal and biomass) bring new hazards and unexpected accidents — in particular as there are many new players entering the sector.

With a high level of new build, there is a large quantity of old building materials from demolition to deal with, exposing workers to hazards. Retrofitting of existing buildings exposes workers to increasing roof work as they install solar panels and small-scale wind turbines, with the risk of falls and exposure to lead and asbestos as they disturb old structures.

Cartoon 4: **'Win-win' - construction**

Cartoon 5: **'Win-win' - bioenergy**

Bioenergy

Legislation has been passed to support the objective of a zero-waste economy.

Biogas production has developed over the last decade and 20 % of gas in the mains is now biogas.

Most agricultural waste is biodigested anaerobically to produce methane. Waste water is used for its nutrient content to fertilise biogas production.

Bioenergy is produced in large facilities (of 400 MW) and small CHP plants in towns.

In most cases, biomass is heat treated to dry it and increase its energy density before transport. The energy embedded in municipal waste and manufacturing processes is now recovered.

Second-generation biofuels, produced with genetically modified bacteria, are now common in transport; and third-generation fuels have been developed.

The storage and handling of biomass expose workers to physical, chemical and biological risks and to risks from fire and explosion. High temperatures, and sometimes high pressures, are used in pyrolysis (350–550 °C) and gasification (over 700 °C). There is also a potential issue with the increased variability in the composition of gas derived from biomass compared to fossil fuels. Third-generation biofuels have the potential to give rise to new biological risks. There may also be operational risks associated with the scaling-up of third-generation biofuel production from demonstration plant to commercial scale.

With widespread adoption of bioenergy, many workers are potentially at risk. Agriculture increasingly turns to biomass production and work in forestry is likely to intensify. Waste products from biomass can be toxic (e.g. wood ash contains heavy metals and is strongly alkaline).

Waste management and recycling

The objective is zero waste and 70 % of industrial waste is now recycled. There is a market for by-products that would otherwise be treated as waste: 'Your waste is my feedstock'. Society adopts a whole life cycle 'cradle to cradle' approach to production that minimises waste.

Regulations require the use of recycled materials over new materials wherever possible. New types of material and products (e.g. plastic bamboo composites and high-pressure pressed plastics) are only introduced if there is a system available to treat them at the end of the life cycle. Building codes encourage new construction materials and the manufacture of concretes from waste.

Landfill is expensive and greatly reduced, and existing sites are now mined to recover useful material.

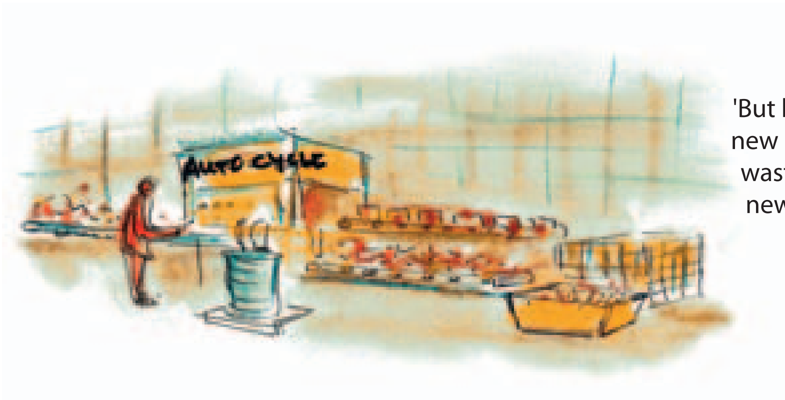
All metals are recycled and rare earth elements are recovered. Automated sensing of waste items improves to the point that robotic disassembly of discarded items is becoming the norm.

Techniques such as gasification and pyrolysis are used to extract energy from waste streams. Aerobic composting is replaced by anaerobic digestion, as it reduces the loss of embodied energy.

As a result of these measures, the use of raw materials per unit of GDP is now many times lower than it was in 2012.

Cartoon 6: **'Win-win' - waste**

'Our automated waste recovery extraction and intelligent re-use technology is the best available...'



'But how do we know if new kinds of hazardous waste are getting into new kinds of places?'

The political pressure to recycle means that workers are potentially exposed to a very large range of materials: increasing volumes of waste result in difficulties in identifying the provenance and composition of waste. However, improvements in labelling, tracking and auditing materials are helping in the identification process.

Workers have to deal with hazardous waste, not just valuable waste, including material from urban mining and recycling of industrial waste. Nanomaterials are also increasingly appearing in waste as their use in manufacturing becomes more widespread. However, the increasing use of robots to sort and handle waste helps to improve workers' health and safety.

The zero-waste economy entails dealing with the most difficult tail end of the waste stream: such wastes in concentrated form are hazards that need special handling.

Green transport

New cars have become mostly electrified with fully electric city runabouts. For long-distance use, plug-in electric hybrids with efficient biopetrol and biodiesel engines have become the norm. This has been supported by the development of:

- rapid recharging (at a rate of 50–100 kW);
- intelligent congestion charging;
- control technology for platooning on motorways (closely-spaced vehicles following each other automatically); and
- new materials to keep the weight and energy consumption low.

The few remaining non-electric vehicles use biofuels or gas, though some use hydrogen.

The self-driving ability of vehicles has become progressively more widely available. This evolved through subway trains to suburban trains to trams to buses and, finally, to cars on motorways. There is now increasing acceptance of cars in towns. The minimum requirement for motorway automation was for the vehicles to drive along the motorway and be able to stop and park safely if the driver did not take control again at the end of the automated section.

Elsewhere, small city delivery trucks, and public transport (including buses) are electrified. Multimodal road-rail freight transport is now used for long distances.

ICT systems allow people to make informed choices about when and how to travel with maximum convenience and minimum energy consumption and effective video-conferencing systems have reduced the need for business travel.

Maintenance of complex networks coupled with skills shortages presents an important OSH challenge. Most new vehicles are electric or hybrid. Rapid recharging or battery swaps may present hazards, as will maintenance of electrified vehicles. As electric vehicles are increasingly maintained by independent garages rather than specialists, there are electrocution risks since workers are not familiar with the high voltages involved. Risks of fire or explosion are particularly high during quick charging of EV and after accidents. Driverless vehicles and platooning (the grouping of vehicles that behave effectively as one) have improved safety for those who travel as part of their work. However, there is a risk of over-reliance on the technology. Absolute reliability is therefore absolutely crucial, with fail-safe modes in the event of accidents, problems or failures.

Cartoon 7: **'Win-win' - transport**

Green manufacturing and robotics

Manufacturing has been transformed by the high levels of innovation, mass customisation and flexible manufacturing systems, such as 3D printing. High levels of automation mean that many processes are performed within autonomous manufacturing cells.

Intelligent robots now collaborate between themselves and work closely alongside humans. Bioautomation, which combines humans with robotics and materials, has started to move from healthcare applications (e.g. addressing disabilities) to the workplace with a view to boosting workers' performance.

Sustainable design has become the prevailing philosophy, with whole life cycle assessment of products and processes. Many new materials and nanocomposites used are lighter, with better performance, and with a lower carbon footprint. Products are designed for eventual dismantling.

There is now more distributed local production within integrated supply chains. Even with the high levels of automation and self-diagnosing equipment, high levels of skills are still required. There are always opportunities for highly skilled personnel.

Increased automation has improved OSH in some respects, by removing workers from some hazardous tasks. At the same time, however, the growth in the use of collaborative uncaged robots has introduced other potential risks. Increasing complexity and increased use of ICT in automated manufacturing has brought human-machine interface issues. Some types of robot malfunction may be difficult to detect until it is too late and may, therefore, put workers' safety at risk. Growth in 'just-in-time' and 'lean' approaches facilitated by flexible manufacturing systems have put additional pressure on workers, leading to psychological risks. Workers are resorting to enhancement technologies in order to keep pace with developments and with their colleagues as well as with robots. There are potential unknown long-term health effects of new green materials and nanocomposites with a lower carbon footprint.

Cartoon 8: **'Win-win' - manufacturing**

Domestic and small-scale renewable energy

Companies and individuals have invested heavily in alternative energy technologies in response to high energy prices. Government incentives also encouraged these investments.

Smart meters are now installed in all homes and small business premises. They are used to monitor and manage smart appliances and electricity demand in response to the requirements of the grid and the price of electricity.

Companies with roof space for PV and yard space for turbines generate energy as a secondary business. Farms and companies working with organic materials (e.g. leather and foodstuffs) generate wind, solar, biogas, and biodiesel.

Domestic buildings and offices have solar panels and highly efficient fuel-cell combined heat and power systems. Many also have small ground-sourced and air-sourced heat pumps. New buildings are being built with a high thermal mass to store heat for typically five days of hot water.

The speed and diversity of change has resulted in skills shortages and, therefore, competency issues regarding renewable energy technologies. There are many new energy technologies where specific knowledge is needed but has not yet been fully developed, and where 'old' OSH knowledge and safe working practices are not always directly transferable. New entrants to the industry are not always sufficiently familiar with the risks and new combinations thereof. SMEs are increasingly using their land to produce electricity as a sideline and may use their own workers, or subcontractors, to install or maintain their renewable energy systems ad hoc, although they are not skilled in this type of work. Increasing adoption of solar PV has introduced risks for emergency workers accessing roof spaces that remain live even after the mains supply has been cut.

Batteries and energy storage

The increase in renewable energy generation has led to the need for high-capacity energy storage. For transmission networks, several bulk energy storage solutions have proved practical, and are being progressively implemented: large-scale molten salt storage systems, such as sodium sulphur batteries (50 MW). Other battery technologies for energy storage include fluorine and vanadium flow batteries. Experiments are continuing with deep-sea energy storage.

Connections across Europe and upgrades in capacity mean that European hydroelectric systems are able to supply all of the European electricity demand for several days at a time.

On the smaller distribution network scale, micro-compressed air energy storage, battery storage, compact thermochemical storage, and flywheels are used.

Domestic-scale battery energy storage is also now common as 'retired' electric vehicle batteries are used as static energy stores.

Hydrogen has grown in popularity as an energy carrier, including its use as a fuel for vehicles, bringing transport and storage issues. Batteries are the main means of electricity storage, with potential risks of fire and explosion, exposure to hazardous chemicals and electrocution from high voltages. Based on their experience from lead-acid batteries, people generally have a false perception that new batteries are safe. As for large offshore installations, specific OSH regulation is in place for deep-sea energy storage, which, although a relatively low-tech concept, involves high voltages and power levels in a complex environment complicating installation and maintenance work.

Cartoon 9: **'Win-win' - energy systems**

Energy transmission and distribution

Following all the changes to energy generation and managing demand at transmission and distribution levels, energy supply is now highly complex. There are two-way grid architectures with flexible tariffs, incentives to use storage, and smart meters to control it all.

A SuperSmart Grid (SSG) using high-voltage direct current (HVDC) technology is now transmitting renewably generated electricity over vast distances between points in North Africa, the Mediterranean, and northern Europe.

> The complexity of the SSG makes it difficult to maintain top-down control of the grid and, consequently, of related OSH issues. The key OSH risk arises from increased live working to cope with the rapid pace of change. The dangers from electric shock, burns, fire and explosion are well known, but now involve different people in different situations. The increase in electricity storage is an added dimension. The pressure to get work done can lead to the use of inexperienced staff.

7.3. Bonus World

High economic growth

Looking back from 2025, after a slow start in 2012, growth across the EU and OECD returned to the levels prior to the economic crash of 2008. Developing countries also experienced high growth similar to that of the first decade of the century. High growth has led to high prices for natural resources, including energy.

Weak green values

After 2012, economic growth was the priority and some environmental degradation was considered to be an unavoidable consequence of strengthening EU economies. When faced with the costs, people have not valued greenness sufficiently for governments or business to have an incentive to deliver it. Government support for green practices is limited to charging for the visible externalities of production (noise, pollution, landfill, traffic congestion, etc.).

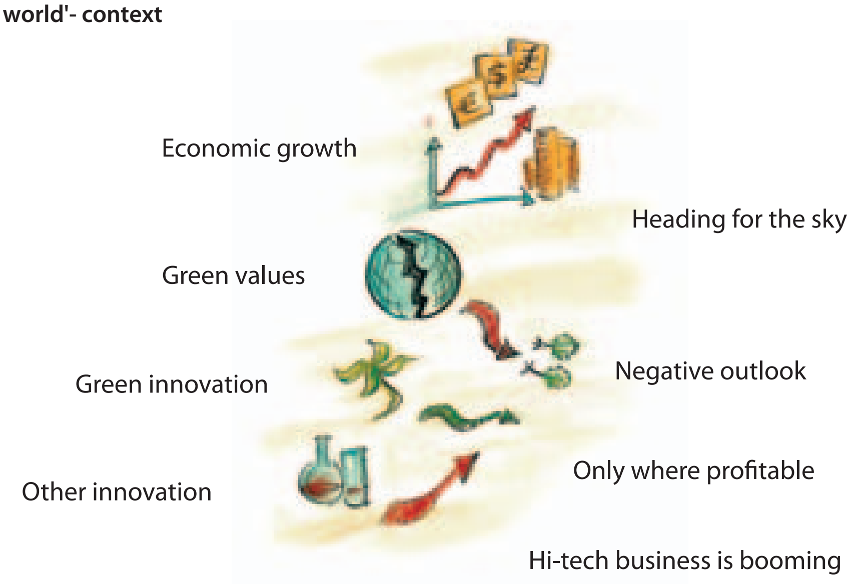
Medium innovation in green technologies (directed towards profits)

Most consumers and businesses choose green products and services only if they are better or cheaper than the alternatives. Innovations in green technologies are limited to those areas that show a positive financial return.

High total innovation

There are continuing advances in technology that are adopted into new products and processes. High levels of capital investment mean that capital-intensive technologies can be rolled out quickly. Corporate profitability and access to finance have supported high levels of investment in infrastructure. The environmental consequences of increased use of resources are seen as acceptable and necessary.

Cartoon 10: **'Bonus world'- context**



Cartoon 11: **'Bonus world'- human systems**

Energy sciences continue to deliver improvements in efficiency and low-carbon energy, but it is now clear that serious and unacceptable compromises would be needed to achieve a zero-carbon future.

Society and work

Most people in the EU now feel more prosperous than in 2012. They value economic well-being more than the environment; but are prepared to pay for a pleasant environment around where they live.

Businesses are focused on generating current and future profits. New jobs are being introduced at a relatively fast rate and there are high levels of employment. There is also high mobility of workers and inequalities mean that low-skilled workers are readily exploited.

Higher income levels and corporate profits have provided the tax revenues that allow European governments to pay for sustainable welfare programmes.

Human performance-enhancing drugs are being routinely used in work settings.

Bonus World OSH Overview

In a healthy economy, funds are available to invest in OSH and make infrastructure and business processes safe, but OSH is of relatively low importance to most governments. Employers see OSH as important in terms of its impact on profits.

New jobs and new products are bringing new hazards, and the rapid roll-out of new technologies means that a wide population is exposed to them with short timescales for determining their possible health and safety impacts.

OSH by regulation is more effective than OSH by education.

As in Win-Win, there are skills shortages associated with the high pace of innovation. This leads to a polarisation of the workforce with regard to skills, with less-skilled workers more readily found in jobs with poorer, more hazardous working conditions.

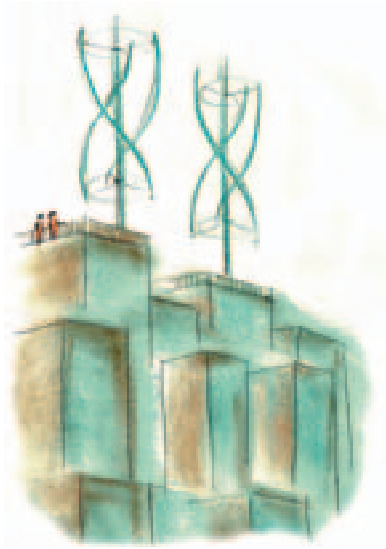
Wind energy

High economic growth and resource scarcity have pushed up energy prices to the point that, in favourable locations, wind energy can generate electricity at a cost that is comparable with other sources of supply.

Most new wind farms are onshore and many are located nearer to the areas of highest demand. Planning rules and environmental impact assessments have been relaxed permitting more wind farm locations in built up areas.

There are no subsidies or green tariffs to support the development of more expensive wind farms. When this support was withdrawn, Cartoon 12: **'Bonus world'- wind energy**

'… relaxed planning rules allow large energy companies to put turbines on apartment blocks...'



'Think about the profit we will make with these… they could not be more cost effective'

there was a rush to develop wind farms before the deadline. Old wind farms are decommissioned, as repowering would not be economically viable.

Turbine design has focused on cost-efficiency, including low-cost maintenance. The very largest turbines envisaged in 2012 were never built, and the industry is now mainly installing turbines of between 5 MW and 7 MW. Standard designs based on common design platforms (like some models of car) and innovative maintenance regimes have helped to reduce costs.

With smaller turbines, predominantly onshore, construction and maintenance are not as hazardous as in the other two scenarios, although the proximity to population centres brings potential risks to a larger population, including workers. Much of the maintenance work is contracted out, so it is more difficult to keep an eye on work organisation and there is a risk of passing of blame and no due diligence by the ultimate owner. Cost pressures may lead to increased risk-taking. Many of the workers are migrants with low skills and a poor OSH culture.

The decommissioning of old wind farms that were not designed to enable safe dismantling puts workers at high risk. New composites and nanomaterials used in the manufacture of wind turbines have possibly introduced new health hazards for workers in manufacturing, maintenance, decommissioning and recycling. On the plus side, the use of standardised designs has reduced complexity and made maintenance more straightforward.

Green construction

There is a high turnover of building stock, and ostentatious designs are common. Most new buildings are prefabricated modular designs with services pre-installed. There is increasing automation in new building, assembly, and retrofitting.

In response to high energy prices, high levels of insulation have become the norm. New buildings now have built-in PV to produce energy, with PV tiles (incorporating new PV technologies) for retrofits.

Buildings are not designed for recycling and waste goes to landfill. Contaminated waste is exported, or mixed with clean waste streams.

Subcontracting is used to drive down costs, leading to pressures on subcontractors to cut corners.

The off-site and automated construction of modular buildings has improved on-site safety as far fewer tasks are undertaken on site. However, as building moves into factories, new risks emerge as workers are exposed to novel substances.

On site, there are electrical risks as old and new buildings have to be integrated into the smart grid, incorporating smart appliances, energy storage technologies, etc. In increasingly crowded cities, the trend of developing basements has led to increasing underground congestion.

With a high level of new build, there is a large quantity of building materials from demolition to deal with. Compared with Win-Win, newer buildings are being demolished exposing workers to new hazards from modern materials. Demolition waste is sent to landfill rather than recycling. Retrofitting of existing buildings exposes workers to increasing roof work as they install solar panels, with the risk of falls and exposure to lead and asbestos as they disturb old structures. The lack of adequate ventilation when retrofitting insulation has become an issue, as this type of work may attract construction workers who are used to outdoor work and, hence, not aware of the need for proper indoor ventilation.

Cartoon 13: **'Bonus world'- construction**

'Hey, this tube of sealant says “extremely toxic and hazardous”... So why are we not using a safer one?'

'You better keep quiet if you want to keep your bonus...'

Bioenergy

There is plenty of waste to harvest for its energy content, and it is incinerated where it is profitable.

Biomass sources (e.g. forest and agriculture, and agricultural waste) are used through the most cost-efficient route. Coal, natural gas and oil-powered stations persist, supplemented by many small-scale localised biofuel and biomass CHP generating plants.

Second-generation biofuels (liquid fuels and chemical feedstocks from lignin and cellulose) became common, aided by rapid innovations in genetic modification (GM) and synthetic biology.

High energy prices encourage third-generation biofuels, including technology transferred from medical biotechnology.

Methane digesters and pyrolysis are used to generate biogas.

As with Win-Win, storage and handling of biomass exposes workers to physical risks, to chemical and biological risks, and risks from fire and explosion: these may be mitigated by automation. Even where biomass is handled automatically, the boilers it fuels are a source of smoke and dust. With small subcontractors working under cost pressures, work has intensified with a resulting increase in risks. Third-generation biofuels produced from organisms created by synthetic biology are a potential source of biological risks.

Cartoon 14: **'Bonus world'- bioenergy**

'So, any idea what’s in silo number 2 today?'

'No idea... But we got to get it out of here before the morning shift'

Waste management and recycling

The EU is a high-consumption, throwaway society. There are lots of innovative new products, which are not generally designed for recycling. Waste streams are only seen as a resource if they can be sold to someone.

Waste processing is driven by the high prices of energy and raw materials and the lack of space for landfill. Some waste is sorted automatically, but only where automation is cheaper than manual labour. High-value waste is recycled and the energy in dry waste is recovered.

Large volumes of waste go to landfill, where it is treated as a future resource for mining and biogas. Households pay for waste by volume, leading to the use of domestic compactors, incinerators and digesters, to save waste charges.

With a high level of innovation, but a lack of attention to recyclability, the waste-handling process can be dangerous. There is some use of automation for handling waste, but only when it is cheaper, rather than for OSH considerations. The rapid rate of innovation means that new materials appear and find their way into waste before OSH can be considered. This is a throwaway society, so a high number of workers are involved in handling waste and are, therefore, potentially exposed. In an increasingly complex world driven by profit, combined exposure can be an issue. High charges for waste disposal may lead to more in-house efforts by the waste producer to deal with waste, transferring risks from professional waste operators to the waste producer: for example, business owners (including microenterprises and SMEs, as well as private individuals) may use small-scale digesters, waste compactors or incinerators.

Green transport

Over the last decade, the demand for transport has continued to grow across all modes. Congestion in the air and on the roads has increased, despite congestion pricing and road charging.

EVs are sometimes used as city runabouts, but hybrids comprise the largest proportion of new vehicles sold. There is a significant demand for fossil fuels for transport and the high cost is an incentive for more efficient transport solutions.

A market has developed for batteries removed from EVs and hybrids: they are used for energy storage in buildings.

Urban trains and trams are now mostly fully automated.

As with Win-Win, maintenance and recharging of electric vehicles have become important hazards as these activities have become increasingly widespread and work has moved away from specialist suppliers and maintainers to independents. The risks arising from the growth in electric vehicles is not confined to the vehicle itself. Vehicle batteries that have reached the end of their life for vehicle service are being used to store electricity in buildings. As well as the normal fire and explosion risks associated with batteries, there is, therefore, the added complication of batteries used for energy storage that are degraded, decaying, unlabelled and of unknown provenance and design. Automation of vehicles is proving to be positive for OSH of drivers, although there is an issue of over-reliance on the technology. The technology needs to be absolutely reliable with fail-safe modes in case of incidents.

Cartoon 15: **'Bonus world'- waste**

'Have you thought about investing in automated landfill resource extraction and recovery?'

'Who needs to invest in automation when you've got all these cheap workers?'

Cartoon 16: **'Bonus world'- transport**

Green manufacturing and robotics

There are high levels of overall innovation and many new materials (including nanomaterials); in addition, automated and robotic processes are being used in production. Biotechnology is increasingly used in manufacturing.

Over the last decade, mass customisation and flexible manufacturing systems (e.g. 3D printing) have changed the industrial landscape, with distributed local production within integrated supply chains. The economies of scale of mass production have been preserved, even with batch sizes of one.

Most jobs are knowledge-based and subcontracting is an integral part of the process.

As in Win-Win, increased automation has improved OSH by removing workers from some hazardous tasks, but with efficiency — rather than safety — as the goal. At the same time, the growth in the use of collaborative robots has introduced other potential risks. Increasing complexity and increasing use of ICT in automated manufacturing has brought human-machine interface issues, but in the high-pressure environment of Bonus World, workers are turning to performance-enhancing drugs and technologies in order to keep up.

Safety (as opposed to health) is increasingly engineered into processes, driven by the desire to avoid lost production time, while employers are less interested in longer-term health issues. Decentralised manufacturing systems such as 3D printing or other rapid manufacturing techniques can lead to new groups of workers being exposed to manufacturing hazards (e.g. harmful dusts, chemicals or laser light) yet not being adequately trained to deal with them. There may be new occupational diseases caused by exposure to new materials. Without exposure registers, diseases are difficult to trace back to jobs as no one stays on the same production line for their entire career any more.

Domestic and small-scale renewable energy

After 2012, there was increasing public opposition to the costs of renewable energy. Feed-in tariffs were cut back, so there has been limited investment in domestic and small-scale energy over the last decade. 'Horror stories' of poor people being forced to upgrade their domestic wiring after the electricity meter was taken out also led to strong reactions against smart meters. With increasing energy costs, insulation has become increasingly important.

Network operators encourage some distributed generation, but only in particular areas as a means of saving on the costs of upgrading the network.

In the period before solar PV reached grid parity, the sudden withdrawal of subsidies led to panic in the rush to meet deadlines, resulting in work done in a hurry thus introducing OSH risks including work-related psychosocial risks. The use of cheaper imported products, sometimes of poorer quality or even counterfeit products, has led to increased risks, especially when installation is carried out by new entrants to the sector or by householders themselves.

Cartoon 17: **'Bonus world'- manufacturing**

Batteries and energy storage

The grid has maintained its substantially one-way architecture, with most electricity still provided by large generators. Due to the limited level of intermittent and distributed generation, there has been limited investment in bulk energy storage on the transmission networks. The exception has been pumped hydro facilities for load balancing, to avoid the cost of upgrading the networks.

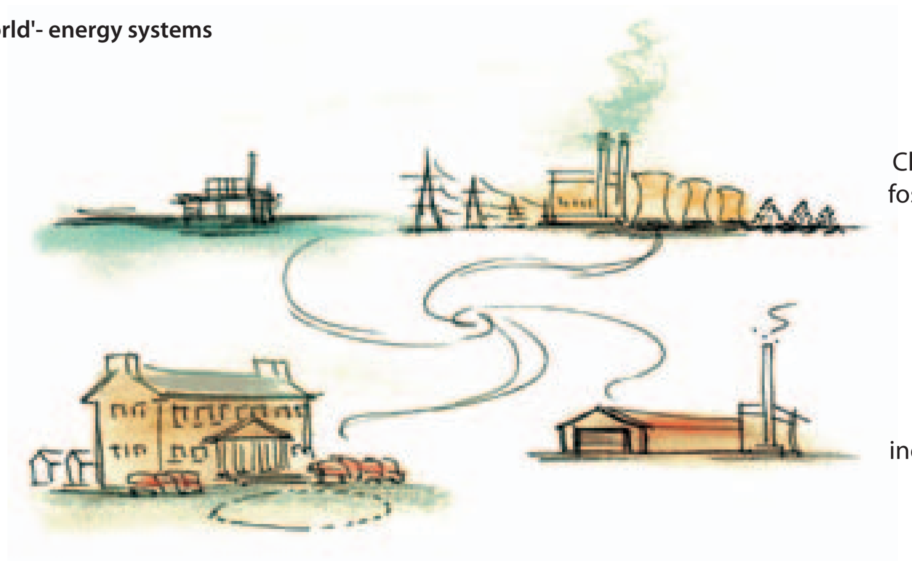
Storage applications on the distribution networks are specialised and limited. Some energy storage (e.g. flywheels, ultra capacitors, batteries, compressed air and hydro) is used in the network for load balancing and to avoid the cost of upgrading the network. There are also flywheels and supercapacitors for specialised public transport applications.

Power cuts are a greater risk due to limited investments in smart grids and storage facilities. Small capacity storage, such as banks of former EV batteries, are therefore of increasing interest. Domestic PV systems are also designed to provide some electricity if there is a power cut.

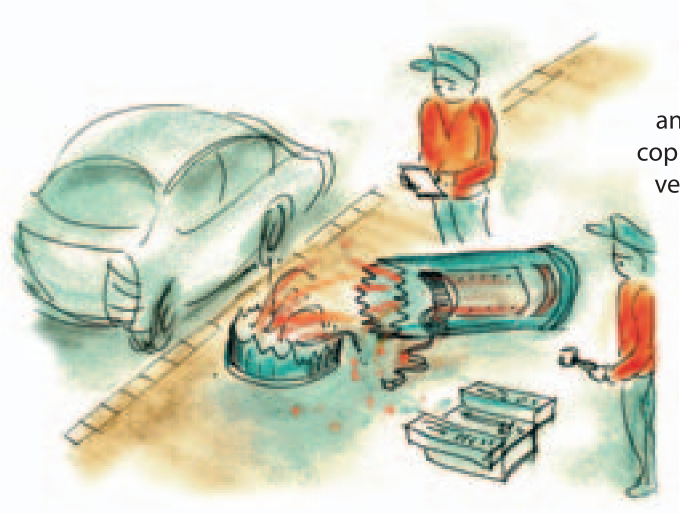
Vehicle development has favoured hybrids, so their energy storage requirements are limited.

Novel battery designs continue to appear, bringing potential risks from chemicals, carcinogenic metals, dusts, fibres, nanomaterials and fire. The waste treatment of batteries raises issues around recycling, degradation and fire risk. It is difficult to determine the precise contents of any particular battery type as this information is often treated as a trade secret. Batteries used as energy stores in buildings are a hazard as people don't recognise the risks of overcharging. Hydrogen is used as an energy carrier but it is difficult to handle and there are risks of fire and explosion and risks from its cryogenic liquid form.

Cartoon 18: **'Bonus world'- energy systems**



Cartoon 19: **'Bonus world'- resource limits**



Energy transmission and distribution

There continues to be significant growth in the demand for energy. There has been insufficient investment in the transmission and distribution networks and smart grid infrastructure: the need for investment is now a major issue.

There has been investment in interconnectors, where there is a strong business case.

Since 2012, copper prices have doubled and the use of aluminium cables has increased. Metal theft has become an important concern in the energy sector and more broadly.

There are risks from power cuts as cost pressures have led to a reduction in spare generating capacity. The risks arise from sudden darkness and loss of power, especially with moving machinery, and other safety-critical situations. The pressure to squeeze more capacity out of the system leads to novel solutions, but this reduces safety margins. Substitution of copper cabling with aluminium, again driven by cost as copper becomes increasingly expensive, has introduced an increased risk of sparking and joint failure.

7.4. Deep Green

Low economic growth

Since 2012, there has been little economic growth within the EU and some countries are still facing sovereign debt problems. The BRIC countries have not returned to their former high growth rates and are currently growing at about 5 % per annum. Other developing counties are growing at a rate broadly in line with the growth in their populations.

Strongly green values

Green values have strengthened over the last decade and there is widespread and strong approval for green behaviour by corporations and individuals. This has given governments a mandate to legislate for deep and progressive cuts in carbon emissions. Reduced growth is seen as a price worth paying for a green future.

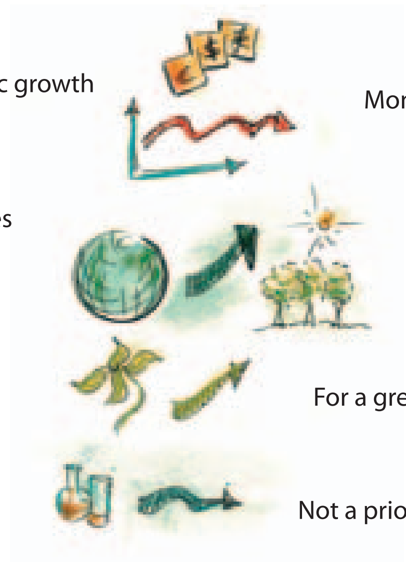
Advances in climate science have shown just how vulnerable the human race will be to climate change. There are growing public concerns about the loss of ecosystems and resource shortages.

Medium innovation in green technologies (directed toward greenness)

The concerns about a green future have driven progress on improvements in efficiency and the target of a zero-carbon future. There are continuing advances in technology, but restricted levels of capital investment mean that capital-intensive technologies have been slow to be rolled out. Commercial success depends on having appropriately green products and services.

There have been significant local small-scale innovations to address green issues, many directed toward self-reliance.

Cartoon 20: **'Deep green'- context**



Energy sciences continue to deliver improvements in efficiency and low-carbon energy, but it is clear that serious compromises will need to be made to achieve a zero-carbon future.

Medium levels of total innovation

The priority has been to direct innovation towards achieving a green future.

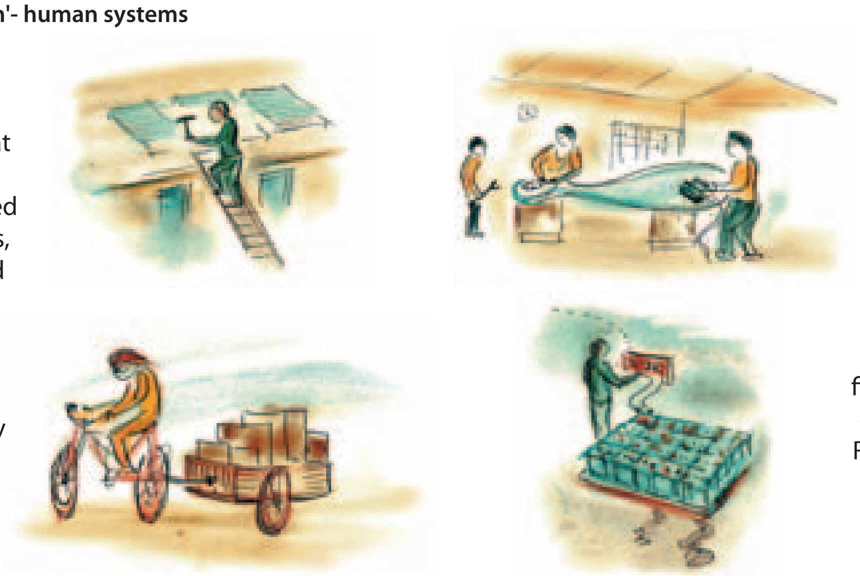
Society and work

Over the last decade, the key priority has been to move towards a green future, at the expense of growth and other social objectives. As a result, there is now higher unemployment and lower corporate profits. The reduced tax base has restricted the ability of EU governments to pay for increasing welfare demands.

The greening of the economy and society has introduced many new processes and enterprises, creating new green jobs. Businesses are focused on survival and reducing costs, and workers are concerned about joining the significant number of the unemployed.

Innovation continues to deliver improvements in efficiency and reduced carbon outputs but it is clear that serious compromises need to be made to achieve a zero-carbon future. Despite the difficulties, a green future is generally seen as worth the sacrifices.

Cartoon 21: **'Deep green'- human systems**



Deep Green OSH general

Low economic growth has tempted employers to cut corners, making investment in safer and healthier infrastructure more difficult. A tendency towards decentralised, more local and smaller enterprises (in particular micro-enterprises and self-employment) makes it more difficult to reach workplaces to disseminate good OSH practices and to control OSH conditions. With the emphasis on the reduced consumption of energy and physical goods, most new jobs are in the service sector. Many new small businesses, often with skills deficits, are set up to meet these needs.

A make-do-and-mend approach leads to refurbishment rather than replacement, so there are risks associated with the use of old equipment. There are more difficult, 'dirty' manual jobs (in repair, maintenance, waste sorting, etc.) than in the other scenarios with more innovation and automation. But the relatively slow roll-out of some new technologies and products gives more time to assimilate new hazards and risks. There are many new green processes and enterprises, all of which require new OSH procedures and training.

Wind energy

Despite the strong green values and political support, the lack of capital has constrained the development of wind energy. The total installed base in the EU has recently passed 100 GW. Few of the deeper offshore sites that were envisaged in 2012 have been built.

Over the last decade, projects have tended to be smaller, with infill developments. Most turbines are relatively small: between 3 MW and 5 MW. The latest designs have converged on direct drive generators and transformers in the nacelle.

The priority of the remaining big wind energy players is to drive down costs and minimise the investment needed to deliver wind energy. 'Make-do-and-mend' attitudes have encouraged owners to refurbish older wind farms rather than rebuilding them. Furthermore, as the technology has improved, 1 MW turbines have been replaced with 3 MW installations on the same towers.

End-of-life issues and maintenance are the key OSH considerations. The economy requires the upkeep of older installations and there is pressure to keep systems running whatever the weather. Older wind turbines have not been upgraded with safety or ergonomic features, such as lifts, because of cost pressures: as a result, the physical risks associated with climbing and working in towers have become significant, especially as increasing numbers of older workers are unable to retire.

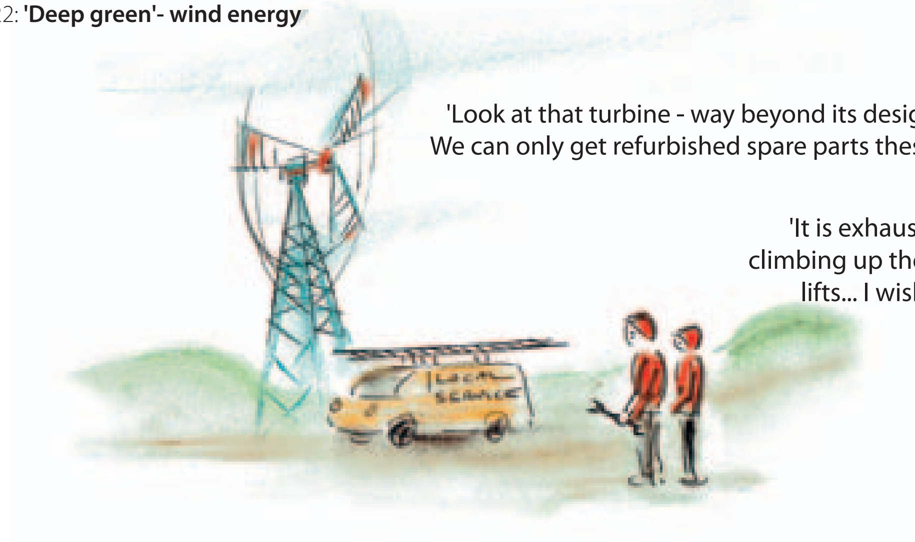
Green construction

There has been limited construction and the building stock has changed little since 2012. Any construction has been deeply green and uses a high proportion of recycled materials.

Householders have been forced to retrofit homes to new standards, with some subsidies, but mostly at their own expense.

Government regulations and controls enforce energy consumption limits, including heating and cooling, in buildings.

Cartoon 22: **'Deep green'- wind energy**



Cartoon 23: **'Deep green'- construction**

'This "retro-fit photo-voltaic" programme is a job for life!'

'Just mind out for the unknown substances and fibres in your lungs... Or else you could just slip in the rain & fall off the ladder first.'

With relatively little new build, the main risks to workers come from exposure to new materials during refurbishment and the handling of waste from refurbishment (including asbestos), and from the retrofitting of renewable energy technologies, involving work at height and electrical connections to the grid. Retrofitting will also expose workers to dust and hazardous chemicals. The lack of adequate ventilation may be an issue, in particular as this type of work may attract unskilled workers, including 'do-it-yourself' installers, unaware of the risks.

Bioenergy

There have been big changes in the ways in which energy is sourced and waste is managed. The energy content is recovered from all local waste that is not recycled.

Local procurement is important, with local biogas from landfill. There is increased use of local community biofuels and biodiesel. Animal fats and food waste are used as heavy fuel oils.

Biomass production and the associated land use has increased over the last decade. There has been little spillover from high-value biotechnology but green biotech has cut costs and increased the energy intensity of crops. Some former coal power stations have been converted to burn biomass.

The risks from fire and explosion and exposure to chemicals and biohazards are similar to those in the other scenarios, but the emphasis on local production and use — with many small-scale producers — creates risks that are more difficult to regulate. New players, less familiar with the risks of handling fuel (e.g. farmers producing low quantities, or companies starting to use their own waste as an energy source, for example in the textile or food industry) may be particularly at risk. There may also be problems with the quality of their products and therefore safety issues, as well as the impact on gas network pipelines from biogas or syngas not meeting the required gas specification.

Waste management and recycling

Waste volumes have significantly reduced and are less hazardous as products have longer life cycles and are designed for sustainability and recycling. Waste is also seen as having value: 'Your waste is my resource'.

Waste streams are dealt with locally, with very limited use of landfill. Plastics, metals, and textiles are recycled, with jobs available in collecting, sorting and recycling waste. Laws now mandate the full recirculation of nutrients and energy recovery, and landfill sites are mined for their resources. Hazardous waste is still incinerated.

Overall, waste volumes are down as a result of strong green values and the economic situation, but there is still legacy waste to deal with and levels of construction waste from refurbishment are high. There is an emphasis on local handling of waste at the small-scale — meaning a potentially

Cartoon 24: **'Deep green'- bioenergy and waste**

lower OSH culture and more difficulties in controlling OSH risks in a decentralised system — and there is a high manual component, with a relatively low level of automation. The quality of the waste stream has improved, but landfill mining is increasing as the costs of raw materials climb, so workers risk being exposed to safety hazards as well as unknown health hazards. Greater use of biomass in this scenario brings exposure to dust, allergens and other toxins. Reused items may compromise safety and health (e.g. steel made from recycled metals containing lead).

Green transport

Over the last decade, the growth in travel has slowed and, in some cases, travel has reduced. People only travel when necessary, and use virtual meeting places whenever they can. There is increased use of subsidised public transport.

There are some electric cars, but the majority of vehicles still use internal combustion engines. The Green way is to make better use of existing vehicles and prolong their working life. Retrofitting of efficiency measures, such as stop/start ignition and low-resistance tyres, is widespread.

Road-rail intermodal transport has become the norm for the reduced levels of long-distance freight.

For urban travel and delivery, there are increasing numbers of electric bikes and vehicles, recharged from local renewable energy sources.

As in Win-Win and Bonus World, the maintenance and charging of electric vehicles are key OSH concerns. However, driven by the need to economise and by strong green values, there has been an increase in two-wheeled vehicles for personal transport and goods as well as for service deliveries, exposing those who travel for their work to the risk of injury and accidents. Many 'mobility self-entrepreneurs' have seen a job opportunity in this growing area of the transport sector. The downside of this is that the self-employed tend to have a weaker OSH culture and less access to OSH services, such as OSH medical surveillance, labour inspectorate services. Furthermore, they are generally not covered by worker protection legislation.

Cartoon 25: **'Deep green'- transport**

Cartoon 26: **'Deep green'- manufacturing**

'Today it's plasma TVs – very hi-tech.... Tomorrow, washing machines and hoovers. Day after... Radios and alarm clocks.'

'Yeah right – who needs the latest model when you can fix anything you want?'

Green manufacturing

Over the last decade, there has been an increasing level of ageing manufacturing plants and industrial infrastructure, coupled with limited investment in automation.

Longer product life cycles and less consumption of mass-produced goods have reduced the demand for manufacturing. Some offshore production has returned to the EU.

There is more decentralised point-of-need manufacturing, much of which has low financial margins. There are innovations to reduce the use of energy and materials in ways that only require low levels of investment.

There is a strong focus on decentralised maintenance and repair and reuse: 'make-do-and-mend.'

There has been less adoption of automation than in the other scenarios, so old OSH issues may persist as manufacturers make do with ageing infrastructure and machinery. The increasing tendency to outsource maintenance services to small companies has increased risks to maintenance workers who have to deal with a wide range of equipment when extending the life of these items. The intermittent nature of renewable energy means that shift working has increased, resulting in increased health and psychosocial issues and other risks such as accidents. Exposure to new materials in SMEs and microenterprises involved in decentralised point-of-use manufacture has brought potential exposure risks to more workers in less well-controlled OSH conditions. Process integration means that industrial processes previously performed in different locations (e.g. manufacturing and recycling) are brought together, increasing the range of risks on a single site. This requires new skills and technical knowledge. However, there is a lack of skills as manufacturing is brought back into the EU as a result of global changes, and the loss of corporate memory and experience is exposing new workers to risks.

Domestic and small-scale renewable energy

Over the last decade, there has been a significant increase in local small-scale energy generation: increased taxes on large generating companies using nuclear power and fossil fuels have made this cost-competitive.

There is significant use of biogenerated energy resources. There is also a wide mix of technologies including biogas digesters, local hydroelectricity, waste incineration and domestic CHP.

There has been a trend for both businesses and local communities to generate energy, often using non-standard 'do-it-yourself' systems, built with parts from various sources.

A diversity of distribution systems and non-standard installations is resulting in electrical risks to maintenance workers. The combination of technologies (e.g. combined heat and power (CHP) and solar thermal) is adding to the complexity and, therefore, the risk. Similarly, unsophisticated, perhaps do-it-yourself, domestic installations are also potentially hazardous. Small-scale bioenergy generation gives rise to risks of fire and explosion and exposure to toxic substances. Distributed supply, especially from small clusters of houses or small businesses, is difficult to regulate. The emergency services are at risk when they attend non-standard installations. Emerging technologies generally may be responsible for long-latency effects, yet to emerge.

Batteries and energy storage

The surge in biogas and biomass energy production has led to high levels of storage of harvested biomass as an energy reserve.

Battery developments have been constrained by concerns about the use of toxic materials and the need for them to be recycled. The growth in electric vehicles has also been slower than anticipated in 2012. Vehicle batteries are used for static storage after their peak performance has degraded.

Cartoon 27: **'Deep green'- energy systems**

In times of energy surplus, electricity is used to generate gas (methane and hydrogen) as a store of energy and as a medium to transport energy through the existing gas network.

'Virtual storage' has been implemented through measures being taken to match energy supply and demand. However, this has been made difficult by the diverse, localised energy providers and the relatively slow roll-out of smart meters.

Batteries give rise to electrical risks and risks from toxic chemicals and fire. Greener batteries may be more hazardous as environmental regulations limit the range of materials allowed. The variety of interconnected systems of technologies and devices for energy storage, especially those assembled by do-it-yourself enthusiasts, bring unexpected risks in themselves, and to maintenance workers as well as emergency services. Hydrogen is used for energy storage, introducing fire and explosion risks and risks from its cryogenic liquid form.

Energy transmission and distribution

There has been a lack of funds for investment in the electricity transmission network, which has become less reliable.

There has been greater emphasis on distribution systems. The complex network of localised energy production has led to increased bidirectional flows. The diverse range of energy suppliers at multiple levels has made control of the network increasingly difficult.

As a result of restricted levels of investment and increasing levels of localised energy product, the reliability of the electricity supply has reduced.

OSH issues include the difficulty in maintaining top-down control of the grid as distributed generating sources increase. Major work to upgrade the grid has been undertaken, introducing increased live working. Life-extended systems bring more risks than new systems. Biogas distribution has brought risks of intoxication, suffocation, explosion and quality issues.

7.5. Using the scenarios

Michael Porter defined scenarios used in strategy as 'an internally consistent view of what the future might turn out to be — not a forecast, but one possible future outcome' (Porter, 1985). It is important that these scenarios are not treated as forecasts, as it is likely that in 2020 the EU will not be entirely like any of these scenarios as such; however, there will be elements of all three scenarios across the EU in 2020. It is not possible to predict which elements of each scenario will be dominant at that time.

The scenarios are a tool to help people think about a broader range of futures and manage the associated uncertainties. This can lead to a better understanding of potential future OSH risks and strategies to ensure the best possible future outcomes for OSH. Scenarios can also be used to challenge the 'official' view of the future that often includes significant assumptions on issues that are uncertain but is generally the viewpoint on which policy development is based. Scenarios provide a 'neutral' space (the future) removed from the constraints of the present for strategic discussion, including reviewing existing plans and policies.

The scenarios produced in this project are principally intended to be used in a workshop setting as was the case in this project. There are many types of scenario workshop processes that can be used. The value of using scenarios comes from the strategic discussions and the insights generated, so it is important that these are captured, whatever workshop process is used. Imagery in the form of 'visual thinking' was used to present the scenarios (Sections 7.2, 7.3 and 7.4) and to help facilitate the workshop discussions. Visual thinking can be a powerful tool to help people 'live' or immerse themselves in scenarios and explore the possibilities that lie beyond normal boundaries and assumptions.

Using the scenarios outside the focal question of this project

The three scenarios developed in this project are designed to explore future OSH challenges and opportunities associated with new technologies in green jobs by 2020.The scenarios produced may also have a potential value for assessing new and emerging OSH risks for a broader range of jobs than green jobs, but care needs to be exercised in doing so. The area that would need to be changed most in this case would be the drivers of change specific to green issues.

There are other technologies alongside those finally selected in Phase 2 that may have a significant impact on OSH in green jobs: these scenarios can be used without adaptation to analyse these. One approach would be to follow the process adopted for the Phase 3 technology workshops. The results of this could then be added to each base scenario.

Note that the technologies used in green jobs will evolve over time, and new risks may emerge from these. After some years, it may be more appropriate to use the base scenarios produced in this project to generate another set of pathways of technology development, and identify associated potential new OSH issues that will be more current and more relevant to the audience of that time.

Use for future risk analysis

It is important that foresight is used to determine new and emerging OSH risks. If the risk assessment is just based on current data and trends, important future risks will almost certainly be overlooked. The advantage of using scenarios is that they challenge people's perceptions of the future and enable a more robust assessment of the full range of risks, particularly if the risks are new ones. A common concern when using scenarios (and other foresight techniques) is how to compare insights from them with risks for which there are objective current data. The tendency is to assign a higher priority to risks for which there are current data, and a lower priority to risks anticipated through foresight. Looking backwards at how the risks have evolved over a similar or longer period can help to inform the judgement required for such an assessment. High-quality scientific advice is also an important requirement for assessing the respective risks.

These scenarios can be used in workshop settings similar to those described in Section 5.4 to explore the future OSH risks associated with green jobs.

Use for policy development

These scenarios can also be used to determine how risks can best be managed against an uncertain future, including exploration of the best policies to be adopted. Policy is frequently driven by an accepted 'official' view of the future. This is based around the things that are known now and assumptions about the future. Policy development often begins with analysis of the current issues and a review of options to deliver agreed targets of business plans. By using scenarios to develop policy, the changing environment in which the policies will be implemented and the associated uncertainties over the period in question can be addressed. A common approach for scenario-based policy development is to consider the respective challenges and opportunities in each scenario. Since the mechanisms for achieving good OSH outcomes are different across the three scenarios, this can encourage greater policy innovation and will generally result in a broader range of policy options than a more traditional policy review will provide.

Using scenarios to develop policies should, therefore, result in a wider range of more robust policies with lower associated risks. It is very common for organisations to have blind spots on policy opportunities, or a resistance towards certain policy directions. In our experience, using scenarios is an effective means of overcoming these obstacles, which in most cases organisations are not aware that they have.

Use for policy analysis

The three scenarios can be used to test both existing and potential policies, including those developed within the scenarios. A common approach is 'wind-tunnelling', where policies are tested against each scenario, both to see if they achieve the desired benefits and to test the implementation plans. This enables the robustness of policies to be tested against different scenarios and different routes to the best future outcome to be explored. It can also create an environment for an open debate on the policy options in which assumptions about the future can be tested and challenged. The 'wind-tunnelling' process was used in this project at the policy workshop to test and refine the scenarios, as described in Chapter 6.

Use for stakeholder engagement

This project has considered the implications of the scenarios for the EU and national governments, trade unions, employer associations, employers and workers. The OSH implications for these and other stakeholders will be different across the three scenarios. There will be different winners and losers in each scenario and there are also wide variations within stakeholder groups. For example, in Bonus World, there are good opportunities for skilled workers, while the least skilled are liable to be exploited.

The scenarios can be used for stakeholder impact analysis, which considers how the different scenarios will impact on each relevant group of stakeholders. These can be groups, or individuals, who are likely to be affected by the scenarios. This process helps to understand the perspectives and possible responses to different circumstances or policies.

Scenarios can also be a valuable tool for engaging stakeholders. This can lead to stakeholders having a greater recognition of the issues and a shared understanding of the options for addressing the issues. It is often easier for stakeholders with different viewpoints to discuss issues and to understand each other's positions within the relatively safe, neutral environment of a future scenario, than in the present as part of their normal business interaction. Scenarios can, therefore, also assist in reaching a consensus. This process is similar to the application of scenarios to conflict resolution, such as the Mont Fleur scenarios developed in South Africa during 1991–92 in the midst of a deep conflict (GBN, undated). Given the potentially very different perspectives of OSH across the different stakeholder groups, the three scenarios produced in this project can be used to assist with consensus building.

Use for organisational strategy

Like stakeholders, different organisations will face different opportunities and challenges across the three scenarios. Strategies to maximise success can be developed for each scenario and tested against the other two scenarios. Current business plans can also be tested against all three scenarios to determine how robust they are in a range of different futures. Then, either the plans can be modified to make them more resilient to different futures or the risks in the plan can be better understood so that they can be monitored and managed. This approach is similar to that for policies described above. In many cases, scenario analysis of an organisation's strategy results in a significant change in direction for the organisation, or reallocation of its resources. A case study and further description of the use of scenarios in organisational strategy can be found in Ringland et al. (2012).

8. Conclusions

8.1. New and emerging challenges for OSH in green jobs

'Green jobs' is a generic term encompassing a broad range of jobs in different sectors, with different working conditions and working processes and involving a diverse workforce. The scenarios developed in this project have shown that these aspects also vary with the socio-economic context and the strategies and policies adopted, and give rise to a variety of OSH issues. Therefore, when devising a prevention strategy for green jobs, the specificities of the different types of green jobs have to be taken into account. A sectoral approach may be appropriate, although, even within one sector, there will be different types of green jobs with specific conditions to consider. Still, as diverse as green jobs may be, this project has revealed that they are characterised by a number of common challenges.

The first of these challenges is an increasing trend towards decentralised work processes and the widely distributed nature of work. Thus, as workplaces become more dispersed and more difficult to reach, monitoring and enforcing good OSH conditions and safe working practices is likely to become more challenging. For example, such decentralisation is exactly the case in the generation of renewable energy with a diversity of distributed, small-scale installations. Such energy systems, especially when installed by new, unskilled entrants in the sector (or by do-it-yourself enthusiasts) are likely to be non-standard installations, which may be dangerous — in particular to maintenance workers. With the large diversity and number of energy providers connected to the grid, there may also be difficulties in controlling a complex grid linked to a two-way transmission.

The manufacturing sector is also likely to undergo significant changes as advanced manufacturing techniques, such as 3D printing, offer greater flexibility allowing mass customisation to become economically viable, possibly resulting in decentralised, local manufacturing. Increasingly, local manufacturing plants could mean widely distributed hazards in small units, with new groups of workers exposed to manufacturing risks. Mass customisation with batch sizes of one could also lead to product safety and OSH issues, where items are one-offs and OSH standards are difficult to define or enforce.

Partly linked to decentralisation, a growth in the use of subcontracted work (as well as an increase in self-employment, micro and small enterprises) may be expected, and not only in the energy and manufacturing sectors. The growing area of green transport, for example, may be seen as a job opportunity by 'mobility self-entrepreneurs', using new types of green vehicles such as 'cargo bikes' to deliver people, goods and services. The downside of these economic structures is that they may have less OSH awareness, a weaker OSH culture, fewer resources available for OSH, and less access to OSH services.

Greening the economy, therefore, means a fundamental transformation in terms of business processes and skills sets. There are many new technologies and working processes where 'old' OSH knowledge is not always directly transferable, and where specific knowledge is needed but has not yet been fully developed. There are also a number of 'old' risks found in different situations and combinations requiring new specific skills. The installation of PV elements on roofs, for example, brings together traditional construction risks and electrical risks: workers, therefore, need specific training to perform this job. However, the job opportunities associated with the rapid greening of the economy may attract new entrants possibly extending themselves beyond their original skills areas and unaware of these new challenges and risks.

A further issue related to skills is the shortage of skilled workers resulting from the speed of change and the new technologies competing with each other for highly-qualified staff. This could result in a greater polarisation of the workforce, with low-skilled workers pushed into accepting poorer working conditions in more difficult and manual jobs (e.g. in waste collection and sorting, maintenance or repair). Such jobs are likely to increase with the green 'make-do-and-mend' attitude of extending the life of products — in particular, in the context of low economic growth.

Another challenge is linked to the potential conflicts between the pursuit of green objectives and OSH, with achieving green outcomes taking priority. For example, indoor finishing construction work in energy-efficient, tightly sealed buildings may expose workers to higher concentrations of dangerous substances. Time pressures to take green actions generated by economic and political factors, such as subsidies and their withdrawal, may additionally contribute to OSH being overlooked.

Besides risks shifting from the environment to workers, there may also be an increasing level of transfer of OSH risk between jobs. For example, high waste-disposal charges may lead to more in-house efforts by the waste producer to deal with waste, thus transferring risks linked to waste management from professional waste operators to waste producers. The political pressure to recycle also means that the range of materials and, therefore, of risks to which workers are potentially exposed, will be increasingly large.

In general, there could be increasing potential for the release of novel, difficult-to-identify and potentially hazardous materials throughout the life cycle of green technologies and products and, in particular, during end-of-life processing. The rapidly evolving technologies of PVs, batteries, new construction materials and new materials such as biomaterials and nanomaterials, will need to be closely monitored over their entire life cycle for potential (unknown) health and safety risks — in particular, long-latency health hazards. This will be increasingly challenging as no one stays in the same job for life, making it difficult to trace health effects back to jobs.

High levels of innovation and increased automation may improve OSH by removing workers from some hazardous tasks: for example, the off-site automated construction of modular buildings is likely to improve on-site safety as building moves into factories where good OSH conditions are easier to ensure. However, this development may also bring human-machine interface issues as well as issues of over-reliance on the technology, as in the case of driverless vehicles and platooning in transport, or collaborative robots in manufacturing.

It is fair to say that many of the risks highlighted in the scenarios are not new: in many cases, it is the new, different settings and conditions in which the risks are found, as well as the new combinations of 'old' risks, and the different groups of workers, possibly without the adequate OSH training, that bring new OSH challenges. Measures are, therefore, needed to raise awareness and train employers and workers in green jobs for these new and emerging challenges. In any case, whether new or 'old' risks, the workplace risk assessment remains key to devising adequate prevention measures that take into account the specificity of the green job considered and the workers involved.

Finally, all three scenarios highlight the need for a systematic, prior OSH assessment of any new technology, product and process at a very early development stage that considers the entire life cycle, from 'cradle to cradle' (i.e. including design, manufacture, transport, installation, operation and maintenance, decommissioning, treatment of waste and later reuse). Integrating prevention into the design is more efficient, as well as cheaper, than retrofitting OSH; this needs to start now for safe future green jobs.

However, this approach requires the intensive cooperation of various disciplines and actors at the levels of policymaking, R & D, and the workplace, including (sectoral) social partners. In addition to the OSH community, this should include the key actors in environmental protection as well as technology developers, designers and architects. Throughout this project, the scenarios have proven to be a powerful tool to support such cooperation, by encouraging people to think outside their 'usual box' in a neutral context (the future, removed from the constraints of the present) thereby facilitating discussion. This has also had the result of efficiently mainstreaming OSH into the various disciplines and sectors represented in the project (environmental protection, public health, transport, energy, manufacturing and construction). This, together with the new insights into new and emerging OSH risks generated in this process, is key to the creation of green jobs offering decent, safe and healthy working conditions and, thus, contributing to the smart, sustainable and inclusive growth of the green economy in line with the EU 2020 strategy (European Commission, 2010).

8.2. The foresight and scenario-building process

This foresight project was designed to develop scenarios that could be used to consider the potential future impact that a number of key new technologies may have on workers' safety and health in green jobs. It is important to recognise that the three scenarios developed during this project are not projections or forecasts but describe possible future 'worlds' for green jobs. They constitute a tool for exploring the future and the critical uncertainties, thereby allowing the anticipation of potential future challenges and supporting the development of more robust strategies to address them.

The scope of the project was challenging, owing to the difficulty in defining green jobs and the associated breadth of the potential jobs involved. It is also a sector where there are high levels of interdependence between areas of technology, with energy cutting across nearly all other areas. There is also a range of 'horizontal' technology issues, such as the application of nanomaterials. As a result, the project was a particularly robust test of the foresight process and the scenarios.

The scenarios produced could equally be applied to a broad range of technologies associated with green jobs other than those selected in Phase 2. It may also be possible to extend their application to other aspects of green jobs, so long as the underlying assumptions remain valid. But they should not be used as such for considering OSH for jobs outside the scope of green jobs. For such a purpose, the greatest area that would need to be changed would be that of the drivers of change specific to green issues. However, a significant amount of the data on drivers of change and technologies could be applied to a broader range of jobs.

The fourth scenario (one of low growth, weak green values and low levels of innovation in green technologies) was not developed as part of this project since it was not relevant for exploring OSH risks from new technologies (because of low innovation) in green jobs (because of weak green values). However, it could be used to explore existing or emerging OSH risks in a context of low growth; furthermore, aspects of the fourth scenario are present to varying degrees in parts of Europe.

The workshops in Phase 3 of the project were a critical element in achieving the objective of the project. They created opportunities for experts in OSH and technology to engage in a valuable dialogue and to gain knowledge of each other's disciplines, thus enabling OSH to be mainstreamed into innovation and technology development as well as to generate new insights on the impact of new technologies on OSH. This is essential in order to better identify future OSH challenges and needs and so better target actions and allocate resources available for OSH.

At the same time, these workshops showed the value of the scenarios in engaging with different groups of stakeholders and in generating strategic discussions between them. As participants shared their respective insights, many current assumptions were tested. It was, for example, apparent that many of the assumptions about future green jobs currently being made by governments, as indicated, for example, by their targets for renewable energy, are currently based on an optimistic outcome — a Win-Win scenario. The possibility that these targets may not be met should be taken into account by, for example, looking at the alternative scenarios produced (and others).

Policy generation and analysis is a difficult process that requires significant evidence and detailed evaluation. It was not the objective of this project to rigorously produce and evaluate policies during the final workshop (Section 6). However, it was possible to demonstrate the potential and value of using the scenarios to support the process of developing and evaluating policies needed to achieve the best future OSH outcome, and to give participants experience of this application.

In conclusion, the project demonstrated the value of the three scenarios produced to generate a strategic discussion and new insights. The scenarios have proven to be a robust tool for supporting the anticipation and analysis of future OSH challenges and opportunities in green jobs as well as the development of more robust 'future-proofed' strategies and policies tested against different assumptions. We hope that they will be used by organisations to support the ongoing work in this area.

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Annexes

Annex 1: Participants at project kick-off meeting

Name	Affiliation
Sam Bradbrook	Health and Safety Laboratory (HSL), United Kingdom
Emmanuelle Brun	European Agency for Safety and Health at Work (EU-OSHA)
Øle Busck	Aalborg University, Denmark
Kären Clayton	Health and Safety Executive (HSE), United Kingdom
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Peter Ellwood	Health and Safety Laboratory, United Kingdom
Xabier Irastorza	European Agency for Safety and Health at Work (EU-OSHA)
Ian McCluskey	Shell Gas Ltd, United Kingdom
Michal Miedzinski	Technopolis Group, Belgium
Andrea Okun	National Institute for Occupational Safety and Health (NIOSH), United States
John Reynolds	SAMI Consulting, United Kingdom
Olivier Salvi	French National Institute for Industrial Environment and Risks (INERIS), France

Annex 2: Literature sources for contextual drivers of change

	Organisation	Title	Page	Author(s)	Date	URL, publication details	Notes	Region
1.	Institute for Public Policy Research (IPPR)	*The Future's Green: Jobs and the UK low-carbon transition plan*	71	Jenny Bird and Kayte Lawton	Oct 2009	http://www.ippr.org.uk/publicationsandreports/publication.asp?id=712	Identifies 'smart government intervention' as crucial. Prioritising in low carbon, incentives — supply-side 'push' and demand-side 'pull', develop the workforce — STEM (Science, Technology, Engineering and Mathematics) education, skills. Useful discussion on 'What are green jobs?' Chapters 4 and 5 give more detail on incentives and skills measures.	United Kingdom
2.	Institute for Public Policy Research (IPPR) (with Greenpeace)	*Green Jobs: Prospects for creating jobs from offshore wind in the UK*	58	Jenny Bird	Apr 2009	http://www.ippr.org.uk/publicationsandreports/publication.asp?id=658	Considers prospects for offshore wind in the United Kingdom. Considers drivers as: stable and sizeable domestic market; industrial activism — tax incentives, feed-in tariffs, favourable duties, R & D; skills base; job creation opportunities.	United Kingdom
3.	Universidad Rey Juan Carlos	*Study of the effects on employment of public aid to renewable energy sources*	53	Raquel Merino Jara and Juan Ramón Rallo Julián	Mar 2009	http://www.juandemariana.org/pdf/090327-employment-public-aid-renewable.pdf	Analysis of heavy government investment in renewables jobs. Claims that for every green megawatt, between 4.27 and 8.99 jobs lost in other areas. Identified cheap credit as a driver. Spanish 'photovoltaic bubble'.	Spain
4.	House of Commons Environmental Audit Committee	*Pre-Budget Report 2008: Green fiscal policy in a recession*	111		Mar 2009	http://www.publications.parliament.uk/pa/cm200809/cmselect/cmenvaud/202/202.pdf	Identifies the following drivers: green fiscal stimulus — opportunity afforded by recession, treasury influence on banks — investigate environmental criteria for investment strategies, green tax — shift from 'goods' to 'bads', aviation taxes — regrets backtrack from per passenger to per plane duty, motoring taxes and scrappage (since done).	United Kingdom
5.	Institute for Energy Research (IER)	*Green Jobs — Fact or Fiction? An Assessment of the Literature*	21	Robert Michaels and Robert Murphy	Jan 2009	http://www.instituteforenergyresearch.org/wp-content/uploads/2009/01/IER Study — Green Jobs.pdf	US report dismissive of green jobs initiatives saying many reports based on incomplete economic analysis and overstate benefits. Some good points on definition of green jobs.	United States
6.	University of Illinois	*Green Jobs Myths*	97	Andrew P. Morriss, William T. Bogart, Andrew Dorchak and Roger E. Meiners	2009	http://www.instituteforenergyresearch.org/wp-content/uploads/2009/03/morriss-green-jobs-myths.pdf	Report critical of green jobs movement. Subsidies could lead to description of jobs as green when they aren't. Green jobs include clerical and administration jobs — shouldn't. Examines seven 'myths'.	United States

	Organisation	Title	Page	Author(s)	Date	URL, publication details	Notes	Region
7.	United Nations Environment Programme (UNEP)	*Green Jobs: Towards decent work in a sustainable, low-carbon world*	376	Michael Renner, Sean Sweeney and Jill Kubit	Sep 2008	www.unep.org/PDF/NEPGreenjobs_report08.pdf	Comprehensive study with worldwide scope. Looks at the definition of green jobs and measurement of them. Section on Green Policies and Business Practices, including Policy Toolbox. The Policy Toolbox includes: Financial and Fiscal Shifts — Subsidy Shifts (i.e. between fossil and renewable energy sources, removal of 'perverse subsidies'); Rethinking R & D Priorities (Stern recommends doubling efforts on energy R & D); International Development Assistance (away from hydropower); Carbon Trading and Finance; Ecological Tax Reform; Mandates — Extended Producer Responsibility; Eco-labelling; Energy Targets and Mandates; Promotion of Energy Alternatives. The bulk of the report looks at the main sectors for green jobs in some detail. Likely to be useful in Phase 2.	Global
8.	United Nations Environment Programme (UNEP)	*Green Jobs: Towards decent work in a sustainable, low-carbon world*	36		2008	http://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_158733.pdf	Summary of full UNEP report.	Global
9.	United Nations Environment Programme (UNEP)	*Global Green New Deal — Policy Brief*	40		2009	http://www.unep.org/pdf/A_Global_Green_New_Deal_Policy_Brief.pdf	Study based on the premise that the financial crisis is an opportunity to green the world. Use 1 % of GDP to achieve Millennium Development Goals.	Global
10.	United Nations Environment Programme (UNEP)	*UNEP Background Paper on Green Jobs*	20		2008	http://www.unep.org/labour_environment/PDFs/Green-Jobs-Background-paper-18-01-08.pdf	A short summary of the main UN Report but without the sectoral summaries. One page on drivers of green jobs — growth in investment, business benefits, employment benefits. Policies for green jobs — the need for government action; green investment strategy; green R & D and technology transfer; international cooperation and aid; job training.	Global
11.	World Wildlife Fund (WWF)	*Low Carbon Jobs for Europe — Current Opportunities and Future Prospects — Executive Summary*	8	Meera Ghani-Eneland	2009	http://assets.panda.org/downloads/low_carbon_jobs_summary_final.pdf	Recession offers opportunity to use stimulus packages to green economies. Disappointing that only 9 % of EU money going to climate change goals. Includes statistics and projections to 2020 for jobs in various sectors in EU.	EU
12.	World Wildlife Fund (WWF)	*Low Carbon Jobs for Europe — Current Opportunities and Future Prospects*	36	Meera Ghani-Eneland	2009	http://assets.panda.org/downloads/low_carbon_jobs_final.pdf	Recession offers opportunity to use stimulus packages to green economies. Disappointing that only 9 % of EU money going to climate change goals. Includes statistics and projections to 2020 for jobs in various sectors in EU.	EU

	Organisation	Title	Page	Author(s)	Date	URL, publication details	Notes	Region
13.	European Trade Union Confederation (ETUC)	Speeches and slides from Climate Change and Employment meeting 20 and 21 February 2007	—		2007	http://www.etuc.org/a/3161	Speeches and slides from Climate Change (CC) and Employment meeting on 20 and 21 February 2007. Sessions covering impact of CC on employment, links between employment and CC policy in energy, transport, building and industry. Slides alone not very easy to follow.	EU
14.	Global Climate Network	*Low-Carbon Jobs in an Inter-Connected World*, Global Climate Network discussion paper No 3	6		2010	http://www.globalclimatenetwork.info/ecomm/files/GCN%20low%20carbon%20jobs%20summary%20update%20March%202010.pdf	Looks at low-carbon job creation in a range of countries, focusing on targets as a key driver. In summary offers the following conclusions: Clear, consistent and targeted government policy will help boost jobs numbers; Finance is critical to the creation of low-carbon economic opportunities; Training is critical to the development of low-carbon sectors; Adjustment policies should also form part of the strategy.	Global
15.	Pew Centre for Global Climate Change	*Review of Green Jobs*	8		2009	http://www.pewclimate.org/review-greenjobs	Set of literature references with short summaries, mostly US.	United States
16.	Economic Policy Institute	*Green Investments and the Labor Market — How many jobs could be generated and what type?*	12	Josh Bivens, John Irons and Ethan Pollack	2009	http://epi.3cdn.net/3ede40f054b5406d66_q6m6b9ne5.pdf	Calls for government stimulus to counter the recession as an opportunity to boost green jobs, over and above Obama's cap-and-trade policy. Contains analysis of the numbers of jobs that could be created by sector (US).	United States
17.	Commision of the European Communities	Commission Staff Working Document — *Summary report on the analysis of the debate on the green paper 'A European Strategy for Sustainable, Competitive and Secure Energy'*	60		2006	http://ec.europa.eu/energy/strategies/2006/doc/sec_2006_1500.pdf	Identifies six priority areas to meet policy objectives of energy sustainability, security of supply and competitiveness. Not specifically dealing with green jobs. Includes results of online poll on favoured energy sources. Results perhaps surprising in that carbon capture and storage came only seventh.	EU
18.	International Labour Organisation (ILO)	*The social and decent work dimensions of a new Agreement on Climate Change — A Technical Brief*	40	Ana Belén Sanchez and Peter Poschen	2009	http://www.ilo.org/wcmsp5/groups/public/---dgreports/---integration/documents/briefingnote/wcms_107814.pdf	Looks at impacts of CC on work, but focusing more on adaptation rather than mitigation. Drivers/areas for action — skills developments, climate change investment, special needs of SMEs, enabling technology transfer, mapping skill requirements.	Global

	Organisation	Title	Page	Author(s)	Date	URL, publication details	Notes	Region
19.	International Labour Organisation (ILO)	*Green jobs: Facts and Figures*	2		2008	http://www.ilo.org/wcmsp5/groups/public/—-dgreports/—-dcomm/documents/publication/wcms_098484.pdf	Short leaflet with key worldwide figures. Green jobs will be in at least four types — additional jobs — as in the manufacturing of pollution controlled devices added to existing production equipment; substitution — as in shifting from fossil to renewable energy, from landfill to recycling; elimination without direct replacement — as in reduction or banning of packaging materials and their production; many existing professions such as plumbers, electricians, metalworkers and construction workers will be transformed and redefined as day-to-day skills sets, work methods and profiles are greened.	Global
20.	Directorate-General for the Environment	*Links between the environment, economy and jobs*	132	GHK, Cambridge Econometrics, and the Institute for European Environmental Policy	2007	http://ec.europa.eu/environment/enveco/industry_employment/pdf/ghk_study_wider_links_report.pdf	Considers three categories of environmental jobs — where the environment is a primary natural resource, activities concerned with protection and management of environment, activities dependent on environmental quality. Subdivides these into 10 second-level environment-economy linkages. Useful five top-level drivers for environment-related economic activities. Very useful paper. Also looks at future drivers (Chapter 8). See also related annexes following.	EU
21.	Directorate-General for the Environment	Links between the environment, economy and jobs: Annexes	125	GHK, Cambridge Econometrics, and Institute for European Environmental Policy	2007	Unpublished. Obtained from the Directorate-General for the Environment's Library	Annexes to previous document. Excellent Annex B linking five high-level drivers to environmental activity areas.	EU
22.	European Commission	*The Impacts of Climate Change on European Employment and Skills in the Short to Medium-Term: Company Case Studies Final Report (Volume 1)*	156	Adarsh Varma (GHK)	2009	http://ec.europa.eu/social/main.jsp?catId=88&langId=en&eventsId=172	Set of 15 case studies of company responses to climate change. Chapter 2 is a very useful synthesis of the overall findings. The main drivers to date relate to policies rather than the physical effects of CC or immediate competitive pressures. Regulation has been more important than corporate social responsibility policies except for airlines. The main drivers were: CSR and reputation; competitiveness; regulation; physical (e.g. water shortages). Dominant drivers for particular sectors also identified.	EU

	Organisation	Title	Page	Author(s)	Date	URL, publication details	Notes	Region
23.	European Commission	*The Impacts of Climate Change on European Employment and Skills in the Short to Medium-Term: A Review of the Literature Final Report (Volume 2)*	48	James Medhurst (GHK)	2009	http://ec.europa.eu/social/main.jsp?catId=88&langId=en&eventsId=172	Literature review linked to above report. Identifies three main forms of climate change regulation — 'traditional' (standards etc.), carbon pricing, innovation policy. Future policy drivers — three main types continue. Quotes McKinsey — four types of regulation required — traditional, carbon pricing, innovation support, measures to ensure potential of forestry and agriculture is addressed (mainly developing countries). Table 32 in the report lists 32 references and employment estimates extracted from them.	EU
24.	European Commission	Commission Working Document — Consultation on the Future EU 2020 strategy	12		2009	http://ec.europa.eu/eu2020/pdf/eu2020_en.pdf	Conserving energy, natural resources and raw materials, using them more efficiently and increasing productivity will be a key driver for the future competitiveness of industry and economies. The EC aims for Europe to lead, compete and prosper as a knowledge-based, connected, greener and more inclusive economy. Key drivers of the EU 2020 strategy should be: Creating value by basing growth on knowledge; Empowering people in inclusive societies — skills innovation, entrepreneurship, etc.; Creating a competitive, connected and greener economy — lower and efficient energy consumption etc. Targeted regulation, emission trading, tax reform, grants, subsidies and loans, public investment and procurement policies, targeting research and innovation budgets.	EU
25.	European Commission	*Facts and Figures — the links between EU's economy and environment*	14		2007	http://ec.europa.eu/environment/enveco/pdf/facts.pdf	Short pamphlet with various numbers and charts — EU eco-industry, employment, polluter pays, cost of inaction, environmental policy, international competitiveness and eco-innovation.	EU
26.	International Labour Organisation (ILO)	Green Economy and Green Jobs: Myth or Reality?	28	David Kucera (presentation at EC Sustainable development meeting)	2009	http://ec.europa.eu/research/sd/conference/2009/presentations/13/david_kucera_-_green_economy_and_green_jobs_-_myth_or_reality.ppt	A good summary of the prospects for green economies in four regions/countries — United States, EU27, Germany and the United Kingdom. Conclusions — a reality for all except the United Kingdom. References to four 'high-quality' studies — US Green Recovery — PERI; EU — Links between environment, economy and jobs (GHK); Germany — Renewable Energy: Employment Effects; United Kingdom — Building a Low Carbon Economy. EU27 core definition of environment-related jobs: organic farming, sustainable forestry, renewable energy, water supply and environment-related tourism.	EU

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27.	American Council for an Energy-Efficient Economy	*The Size of the US Energy Efficiency Market: Generating a More Complete Picture*	58	Karen Ehrhardt-Martinez and John A. 'Skip' Laitner	2008	http://www.aceee.org/pubs/e083.htm	Facts and figures on the potential for energy savings and the number of related jobs in the United States.	United States
28.	American Solar Energy Society and Management Information Services Inc.	*Defining, estimating and forecasting the renewable energy and energy efficiency industries in the US and in Colorado*	207		2008	http://www.greenbiz.com/sites/default/files/document/CO_Jobs_Final_Report_December2008.pdf_	Discusses definitions of green jobs and green industries with examples. Statistics on US markets. Three 'scenarios' to 2030, a base case and two others — the 'moderate' and 'advanced' scenarios — based on assumptions that could be translated into drivers.	United States
29.	Apollo Alliance	*Green-Collar Jobs in America's Cities — Building pathways out of poverty and careers in the clean energy economy*	24		2008	http://www.americanprogress.org/issues/green/report/2008/03/13/4170/green-collar-jobs-in-americas-cities/	A report aimed at communities, talks of 'green collar jobs' (i.e. decent green jobs). Create demand by: public sector investment policies — energy efficiency in buildings, renewable energy in public buildings, green standards in public buildings, build transit infrastructure, convert official vehicles to alternative fuels, plant trees, create green space. Incentives or requirements to drive private sector investment — tax incentives, rebates, streamlined permissions for energy efficiency, renewable energy or green building, technical assistance or innovative financing; green building codes; land use and infrastructure policies to support green manufacturing.	United States
30.	European Parliament Policy Department Economic and Scientific Policy	*Burden Sharing — Impact of Climate Change mitigation policies on growth and jobs*	44	Samuela Bassi and Jason Anderson, IEEP, and Onno Kuik, IVM	2008	http://www.europarl.europa.eu/activities/committees/studies/download.do?file=20894	Literature search plus sector-by-sector analysis of current situation and trends. Good reference section with summaries.	EU
31.	Commission of the European Communities	Commission Staff Working Document accompanying the Communication on Investing in the Development of Low Carbon Technologies (SET-Plan) — A Technology Roadmap (SEC(2009) 1295)	56		2009	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2009:1295:FIN:EN:PDF	Lists main sectoral targets for EU and roadmaps for each. Relevant targets recorded.	EU

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32.	Institution of Environmental Sciences	'The uptake of emerging science into strategic planning', *Environmental Scientist*	52	Martin Duckworth, Mark Everard, Joe Ravetz, John Reynolds, Sarah Bardsley, Jennifer de Lurio, Sarah Webb, John Seager and Kathryn Monk	Jul 2009	http://www.ies-uk.org.uk/resources/uptake_emerging_science_strategic_planning	Global drivers of change for the future, some related to green jobs and new technologies. Relevant ones recorded.	United Kingdom
33.	United Kingdom Commission for Employment and Skills (UKCES)	*Scenarios for Skills in 2020, Drivers*	24	SAMI	2009		List of drivers of change, some relevant to green jobs, recorded.	United Kingdom
34.	Natural England	*Global Drivers of Change to 2060*, Natural England Commissioned Report NECR030	49		2009	http://www.jmt.org/assets/john muir award/global drivers of change to 2060.pdf	List of global drivers of change to 2060, relevant drivers to project recorded.	United Kingdom
35.	Political Economy Research Institute (PERI)	*Green Recovery: A Program to Create Good Jobs and Start Building a Low-Carbon Economy*	38	Robert Pollin, Heidi Garrett-Peltier, James Heintz and Helen Scharber	2008	http://www.peri.umass.edu/green_recovery/	Report describes benefits of a low-carbon economy — widespread employment gains, lower unemployment, renewed construction and manufacturing work, more stable oil prices, self-financing energy efficiency. Defines green jobs as Direct, Indirect and Induced. Gives estimates of job creation figures. Annexes describe the methodology used for estimation.	United States

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36.	Ecofys, Fraunhofer ISI, Energy Economics Group, Lithuanian Energy Institute and Seven	Renewable Energy Country Profiles	168	Rogier Coenraads, Gemma Reece, Corinna Kleβmann (Ecofys); Mario Resch, Anne Held (Fraunhofer ISI); Gustav Resch, Christian Panzer (EEG); Inga Konstantinaviciute (Lithuanian Energy Institute); Tomas Chadim (SEVEN)	2008	http://ec.europa.eu/energy/renewables/studies/doc/renewables/2008_03_progress_country_profiles.pdf	A detailed EC paper describing the renewable energy profiles of a number of EC countries. Includes national commitments, government investments and incentives and a breakdown of the technologies used in each country.	EU
37.	Commission of the European Communities	Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Investing in the Development of Low Carbon Technologies* (SET-Plan), COM(2009) 519 final of 7 October 2009	14		2009	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0519:FIN:EN:PDF	See 31.	EU
38.	Technology Review	*New Technologies in Spain — Solar Energy*	8		2007	http://icex.technologyreview.com/articles/2009/01/solar-energy-in-spain/solar-energy-in-spain.pdf	Article on the history and future of all forms of solar energy in Spain, includes solar concentrators.	Spain
39.	Technology Review	*New Technologies in Spain — Desalination*	8		2007	http://icex.technologyreview.com/articles/2009/01/desalination-in-spain/desalination-in-spain.pdf	Article on the history, technology and future of desalination in Spain.	Spain

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40.	Technology Review	*New Technologies in Spain — Wind Power*	8		2008	http://icex.technologyreview.com/articles/2008/12/wind-power-in-spain/wind-power-in-spain.pdf	Article on the history and futures of wind energy technology in Spain. A good example of how government incentives can stimulate a rapid expansion in renewables — in this case, by government decrees.	Spain
41.	Commission of the European Communities	White Paper *Adapting to climate change: Towards a European framework for action*, COM(2009) 147 final of 1 April 2009	16		2009	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52009DC0147:EN:NOT	Strategy paper on coping with climate change. Section on instruments focuses mainly on financing and insurance but not specifically related to job creation. Reference to European Economic Recovery Plan (EERP).	EU
42.	Journal of the American Medical Association (JAMA)	'Expansion of Renewable Energy Industries and Implications for Occupational Health'	3	Steven A. Sumner and Peter M. Layde	2009	JAMA, 19 August 2009, Vol. 302, No 7, pp. 797–789	A large number of renewable energy technologies are safer in fact that they reduce or remove the fuel extraction phase. This is not the case with biomass. Electrical issues are likely to provide the greatest risk. Other health and safety risks of renewables are discussed.	United States
43.	United Federation of Danish Workers and the Ecological Council	*Green Jobs: Examples of energy and climate initiatives that generate employment*	48	Christian Ege, Trine Bang Hansen, Jeppe Juul and Vibeke Ero Hansen	2009	http://www.ecocouncil.dk/front-page	Paper outlines a number of proposals to combat the economic and environmental crisis in Denmark. It describes renewable technologies to be embraced, how to change the transport system and energy savings that can be made.	Denmark
44.	Energy Policy	'Renewable Energy and Employment in Germany'	8	Ulrike Lehr, Joachim Nitsch, Marlene Kratzat, Christian Lutz and Dietmar Edler	2008	*Energy Policy*, Vol. 36, 2008, pp. 108–117	Paper outlines the results of a study that models the impact of policies for an increasing share of renewable energy on the labour market in Germany. The net effects of two policy scenarios for Germany were calculated to 2030.	Germany
45.	Journal of Cleaner Production	*The Quantitative and Qualitative Impacts of Clean Technologies on Employment*	24	Getzner, M.	2002	*Journal of Cleaner Production*, Vol. 10, 2002, pp. 305–319	An Austrian paper describing the results of a survey of companies in five European countries on the impact of clean technologies on all aspects of employment.	EU
46.	International Journal of Technology Management	'Cleaner Production, Employment Effects and Socio-economic Development'	21	Michael Getzner	1999	*International Journal of Technology Management*, Vol. 17, No 5, 1999, pp. 522–543	An Austrian study on the employment effects of clean technologies	

	Organisation	Title	Page	Author(s)	Date	URL, publication details	Notes	Region
47.	Trade Unions as Environmental Actors: The United Kingdom Transport and Workers' Union	'Capitalism Nature Socialism'	31	Michael Mason and Nigel Morter	1998	*Capitalism Nature Socialism*, Vol. 9, Issue 2, 1998, pp. 3–34	Essay that aims to establish the role of British trade unionism in extending ecological regulation and in expanding the public discourse of ecological politics. Britain's second largest union, the Transport and General Worker's Union, is studied closely in relation to its involvement in environmental issues.	United Kingdom
48.	Global Climate Network	*Low-carbon Jobs in an Interconnected World: Literature Review*	14		2009	http://www.globalclimatenetwork.info/uploadedFiles/globalclimatenetwork/low_carbon_jobs_lit_review.pdf	See 14.	Global
49.	European Commission, Directorate-General for the Environment	*Environment and labour force skills — Overview of the links between the skills profile of the labour force and environmental factors — Final report*	77	Allister Slingenberger et al., ECORYS	2008	http://ec.europa.eu/social/main.jsp?catId=370&langId=en&featuresId=63&furtherFeatures=yes	Report on the potential for environment-related employment in the EU25, looking at skills requirements and how they will change as jobs change. Identifies the risk of a shift to low skills work associated with new jobs favoured by climate policies.	EU

Annex 3: Drivers of change for green jobs and potential health and safety risks in green jobs

SOCIETAL		
Demographics		
1.	Increasing population	Increasing population, worldwide as well as in Europe, is likely to increase the use of energy and natural resources. Thus, population increase drives the need for ever-more efforts to improve energy efficiency, sustainable development, recycling and the environmental impact of human activity.
2.	Ageing population and workforce	Increasing numbers of older people in the general population and in the workforce will have an impact on energy use and the potential for health and safety issues. Older people tend to use more energy in the home, but less on transport. Older workers may be more susceptible to new technologies and substances in the workplace.
3.	Baby boomer retirement bulge 2010–20	As many post-war baby boomers reach retirement, there may be a loss of essential skills in the workplace and a resulting threat to health and safety in work generally, including green jobs.
4.	More women in the workforce	There may be gender issues associated with new substances and new work processes in green jobs.
5.	Increasing urbanisation	Increasing urbanisation of populations may impact on energy use, use of natural resources, pollution, etc., driving the need for mitigation measures such as energy efficiency, renewable energy and recycling.
6.	Increasing single living, driven by family breakdown, lifestyle choices, increasing longevity	Single households are likely to be less energy efficient than multiple occupancy houses, driving the need for mitigation measures such as energy efficiency and renewable energy.
7.	Increasing levels of obesity	Health and safety risks attributable to obesity in general will apply to green jobs and may be particularly relevant in certain jobs (e.g. in susceptibility to the effects of new or substitute chemicals).
8.	Migration	Shortage of the skills necessary in some green jobs means that migrant labour is being used to fill vacancies. Migrant workers can be at greater risk of accidents and work-related ill health than local staff owing to language and cultural issues. They are also typically more often employed in more risky jobs and in more precarious conditions and benefit less from training and are, therefore, more at risk. Climate change might modify migration patterns (e.g. owing to the scarcity of water in some regions of the world) and new populations of migrant workers with different characteristics might be found in the EU; the migration flow might also be modified.
Public opinion		
9.	Increasing consumer and investor concerns about energy and other industry sectors' responsibility	Public opinion and competitiveness issues could drive corporate social responsibility programmes leading to companies making efforts to operate more efficiently and sustainably. Public opinion, pressure groups and campaigns will influence governments.
10.	Growing intolerance of risk	The general public's growing intolerance of risk, coupled with their inability to properly assess risk, may lead to reluctance to adopt new (green) technologies. On the other hand, the general public may favour newer, renewable and sustainable technologies over older, dirtier technology. Improved risk communication might affect people's attitudes.

11.	People's reaction to climate change and the extent to which they regard human activity as responsible	If people believe that CO_2 emissions play a major part in global warming, they will be increasingly likely to support low-carbon energy sources. Climate change deniers will take a different view. Companies and government will be influenced by these views.
12.	Public opinion on environmental protection generally	Public opinion on environmental protection and opposition to activities that damage the environment could drive green jobs in protection. However, shortages of essential natural resources could eventually result in conflict between society's material needs and the protection of the environment.
13.	Generational attitudes	Social scientists define different cohorts in society (e.g. baby boomers and Generations X, Y and Z); each group has different attitudes and approaches to communication ('digital migrants' compared with 'digital natives'), learning, engagement with politics, etc. Younger groups may be more questioning and challenging; they will have different attitudes to environmental issues.
14.	Increasing demand for organic food	Increasing demand for organic food is likely to generate more jobs in the production of organic food.
15.	Increasing demand for low-carbon and environmentally friendly products and services	Increasing demand for such items and services will drive increases in jobs involved in their production and delivery.
TECHNOLOGICAL		
Technologies for climate change mitigation		
16.	Carbon capture and storage (CCS)	Successful testing and development of this technology will result in increasing numbers of jobs in this sector, although numbers by 2020 may not be great. Although this qualifies as green in that it reduces carbon emissions to the atmosphere, it could be argued that it is not a long-term sustainable solution.
17.	Clean coal technologies	Successful testing and development of this technology will result in increasing numbers of jobs in this sector, although numbers by 2020 may not be great. Although this qualifies as green in that it reduces pollutant emissions to the atmosphere, it could be argued that it is not a long-term sustainable solution.
18.	Renewable energy technologies	Developments in renewable energy technologies and/or expansion in these areas would create jobs. The technologies include: wind, wave, solar PV, solar heating, geothermal energy, air exchange methods, small-scale hydroelectricity, biofuels and biomass.
19.	Other emerging energy technologies	Developments and expansion in novel energy solutions will lead to jobs in those areas (e.g. combined heat and power, microgeneration, hydrogen and energy storage technologies, including batteries).
20.	Nuclear energy	The extent to which nuclear energy contributes to the future energy supplies will affect the demand for energy from other sources, including green energy sources.
21.	Smart grid technologies	Development of smart grid technology, resulting in more efficient use of power, would lead to green jobs. The development of a smart grid will require the corresponding development of information and communications technology (ICT) (see below) to control the grid.
22.	Development of energy-efficient transport	Increasing development and production of greener transport technologies (e.g. electric, hybrid and hydrogen — fuel cell or internal combustion — vehicles).

Technologies for climate change adaptation		
23.	Coastal defences; reinforcing buildings; water management; harvesting; adaptation in agriculture — agroforestry	Efforts to make the most efficient use of land could lead to increased food production and green jobs.
24.	Geoengineering	Developments in technologies such as ambient air CCS and ocean seeding, designed to remove carbon from the wider atmosphere as opposed to capture at source, or management or exploitation of methane gas hydrates, would create jobs in these areas. Unlikely to be large numbers by 2020. Although these qualify as green in that they reduce CO_2 levels in the atmosphere, it could be argued that they are not long-term sustainable solutions.
Other environmentally relevant technologies		
25.	Growth in waste management and recycling	Growth in waste management and recycling activities, driven by declining natural resources, environmental legislation and public opinion. Recycling is a dangerous sector in which to work.
26.	Developments in information and communications technology (ICT)	Increasing use of computers will require more energy. A lot of software contains redundant code thus reducing the efficiency of the computers; more energy-efficient computers, in terms of both hardware and better software, will reduce the inevitable increase in energy use in this area. Computers will be essential for the control of, for example, smart-grid technology and smart appliances, optimisation of energy use in buildings, and for transport.
27.	Development of smart appliances	Alongside a smart grid, society will need smart appliances (appliances that can communicate with energy suppliers and take their own decisions about when to switch on and off in order to use electricity at the best price). In an industrial situation, there could be risks associated with autonomous machines switching themselves on and off.
28.	Developments in robotics and automation	Robots will increasingly be used to replace humans in dangerous jobs. They may also replace humans in green jobs. For example, the use of computerised tractors in farming already exists. 'Precision farming' uses global positioning technology and satellite images to make the best use of land.
29.	Nanotechnologies	It is likely that nanotechnologies will contribute to green issues in various ways (e.g. changes in manufacturing resulting in saving of natural resources, novel materials, desalination, changes in food production, and carbon nanotubes in new battery designs). New materials and nanoparticles may bring health and safety risks as well as environmental risks.
30.	Biotechnologies	Use of synthetic biology and genetic modification techniques to generate desired traits in crops and animals may have health and safety implications. Genetic testing could be used to identify those at particular risk from toxic substances.
31.	Green chemistry	Substitution of chemicals for environmental purposes may inadvertently result in changes in health and safety risks.
32.	Sustainable manufacturing	Manufacturing making use of low-carbon technologies (renewable and non-toxic materials, recycling, low waste) has strong green credentials, but new methods and new or substitute substances may bring changes in health and safety risks.
Wild card ([12]): Major incident involving renewable technology.		

(12) Wild cards are low frequency, high-impact events.

ECONOMIC		
33.	European economic growth to 2020	The state of European economies will have a significant effect on the availability of resources with which to tackle environmental issues. Will the European economy grow? Has the recession ended? Will another global financial crisis occur? Will the European economy be favourable to investment in green technologies?
34.	Decreasing oil availability and increasing and more volatile oil prices	As easy-to-reach oil resources decline and demand increases, there will be increasing pressure to improve fuel efficiency and to seek alternative, renewable fuel sources. In addition to its transport and heating uses, oil is a feedstock for many industrial processes and so shortages and increasing prices will drive efficiency improvements and use of alternative sources (e.g. biomass).
35.	Decreasing availability of gas and increasing and more volatile gas prices	As easy-to-reach gas resources decline and demand increases, there will be increasing pressure to improve fuel efficiency, energy efficiency in buildings and to seek alternative, renewable fuel sources. In addition, methane from biomass and novel natural sources (e.g. gas hydrates) may be introduced.
36.	Decreasing price of renewable energy	As the cost of energy from renewable sources decreases, whether as a result of technological innovation or as a result of subsidies and incentives, its popularity and rate/extent of adoption will increase.
37.	Shortages and increasing prices of natural resources (other than energy)	Increasing competition for natural resources from emerging economies and increasing use at home will lead to increased efforts in areas such as recycling, more efficient production and reduction of waste. Companies adopting more sustainable business practices to hold down costs by reducing waste.
38.	Global recession	Governments are seeing the need for financial stimulus to deal with the recession as an ideal opportunity to green their economies.
39.	Globalisation	Globalisation leads to increasing movement of goods and people, contributing to global energy use and, therefore, driving the need for efficiency. In addition, competition from emerging economies drives cost-cutting in Europe resulting in greater efficiency. Increasingly demanding climate-change regulations affecting multinational businesses could also drive efficiency gains.
40.	Trade liberalism versus protectionism	The current global economy has been enabled by, among other factors, increasingly liberal trade conditions. The continuation or re-emergence of recession could drive a return to protectionism; this could affect prices and availability of natural resources, including energy.
41.	Shifts in world economic power	Emerging economies such as China and India are growing more quickly than OECD countries and their economic influence will increase accordingly. This could lead to increasing political influence (e.g. China's ability to affect decisions on carbon targets at the Copenhagen Climate Change Conference in 2009).
42.	Employment — need to create jobs	Green jobs tend to be more labour intensive. However, some argue that green policies cause a net loss of jobs overall. Others argue that the environmental crisis that could occur as a result of climate change will threaten more jobs than environmental policies. Every green job contributes to greening of jobs in other parts of the economy.
43.	The attitudes of insurance companies to developing green technologies	Businesses need to be able to get cover for speculative ventures.
44.	Creation of a suitable financial climate to enable investment in green technologies	Businesses need to be able to raise capital to invest in green technologies. Many companies involved in this area are SMEs. Legislation to remove investment uncertainty and the availability of credit are essential drivers. Recognition by venture capital firms that green technology development can give significant business opportunities. Many companies driving renewable energy solutions are SMEs. More established companies can use green technologies to stay at the cutting edge, expand sales and exploit new export markets.
45.	Availability of capital for investment	Government action to encourage banks and venture capitalists to back green projects: government to underwrite borrowing.

46.	Market opportunities offered by environmental products	Global market for environmental products and services (efficiency, recycling, water sanitation and efficiency and sustainable transport) is currently EUR 1 000 billion, and could reach EUR 2 200 billion by 2020.
47.	Growth of the EU	The growth of the EU will see potentially larger markets for green technology.
48.	The need for food security	Increasing energy costs could drive decreasing transport of food and increasing local food production.
49.	The need to replace ageing infrastructure	Ageing infrastructure and networks (e.g. electricity grids) need replacement over the coming decade. New forms of energy generation require new infrastructure. The massive amount of activity required will affect the size and shape of EU workforce: 'Smart' infrastructure requires manufacture, installation and maintenance.
50.	Availability of a sizeable domestic market for green products and services and a requirement for local content	A ready domestic market and a need for local input will make developments more attractive to potential investors.
Wild card: New global financial crisis.		
ENVIRONMENTAL		
51.	Global climate change initiatives	UN initiatives — Kyoto, Copenhagen, etc.
52.	EU initiatives	European directives and regulations, including: Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources; Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport; Directive 2002/91 of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings; Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles; Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast).
53.	National initiatives	The extent to which individual Member States comply with EU initiatives.
54.	Increasing responsibility on producers	Extended producer responsibility laws (requiring companies to take back products at the end of their useful life) for all types of products, and the requirement for eco-labels on all consumer products to ensure that consumers have access to the information they need to make responsible purchases, will encourage manufacturers to design and market more eco-friendly products.
Physical effects of climate change		
55.	Increasing frequency of natural disasters and/or freak weather	Increasingly extreme weather will drive public opinion on climate change, strengthening the position of pressure groups and potentially influencing government policies.
56.	Increasing need to manage water supplies	Climate change may lead to water shortages in parts of the world such as southern Spain. Activities to store water and to use less water will become increasingly important. Desalination might become more important.
57.	Food security	Climate change may drive the need for more efficient and/or more local food production. This could lead to an increase or decrease in jobs, depending on the solutions adopted.
58.	Increasing importance of 'uplands'	As climate change affects lower-lying areas, higher ground might become more important in farming and forestry, possibly bringing new challenges.
Wild cards: Release of climate change e-mails; increase in natural disasters/freak weather.		

POLITICAL		
Government interventions		
59.	Actions to encourage research and development	Develop clear criteria to prioritise research and development needs in order to target research and innovation budgets towards environmentally friendly activities. Strengthen, optimise and expand energy research capabilities. Promote the development of technology clusters.
60.	Actions to develop education and training to develop the necessary skills	Many observers fear that a shortage of skills will hamper the development of green activities and therefore green jobs. Actions to encourage education in science, technology, engineering and mathematics, to identify the skills gaps and to provide relevant training will promote the creation of green jobs. Skill levels are important to health and safety.
61.	Action to ensure that regulation enables rather than stifles the development of green jobs: removal of the barriers to the creation of green jobs	Ensuring that the regulatory regime is used in the drive to develop greener technologies, products, and services and, thus, green jobs: for example, faster and easier planning procedures for green projects, including land-use policies and planning permission, building codes, energy efficiency standards (for appliances, vehicles, etc.), targets for producing renewable energy, and proportionate health and safety legislation
62.	A favourable tax regime for environmental activities	Tax incentives for green activities: favourable customs duties; taxation of high carbon and polluting activities (e.g. aviation and motoring); removal of 'perverse' subsidies on fossil fuel activities in some cases; shifting of tax from 'goods' to 'bads'
63.	Financial incentives	Grants, subsidies and loans, for renewable and low-carbon energy projects, car scrappage schemes, feed-in tariffs, etc.
64.	Governments to target recession busting financial stimulus	Many governments are seeing the need to boost their economies in the wake of the global recession as an opportunity to green their economies by targeting environmentally sound activities. In addition to the availability of finance, it may be that costs of major engineering projects will be lower over the next few years as contractors compete for business in a reduced market.
65.	Carbon markets	Fixing the current shortcomings inherent in carbon trading and Kyoto Protocol-related innovations such as the Clean Development Mechanism (CDM) so that they can become reliable and adequate sources of funding for green projects and employment; carbon pricing via EU's Emissions Trading Scheme (EU-ETS) (Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve the greenhouse gas emission allowance trading scheme of the Community).
66.	Public sector investment policies	The public sector should lead on energy efficiency by retrofitting energy efficiency measures to public buildings, using renewable energy systems on public buildings and ensuring that new public buildings are built to green standards. The public sector should undertake initiatives to boost public transport and energy-efficient vehicles to convert local government fleets to alternative vehicles or fuels. Procurement policies should favour green products and services from local providers.
67.	Tax incentives, rebates, reduced fees or streamlined planning for private building owners who invest in energy efficiency, renewable energy, or green building	Technical assistance or innovative financing for private investment in renewable energy, efficiency, green building, alternative vehicles or green space; green building codes, energy conservation ordinances, or other requirements for new green buildings or retrofits of existing buildings; land use and infrastructure policies to support green manufacturing companies.
68.	Existence of adjustment policies	Where jobs may be lost as a result of the creation of green jobs, action to retrain and redeploy displaced staff may reduce the risk of opposition to green job creation.
69.	Increased housebuilding to cope with demand	Requirements for new housing to be energy efficient or even 'carbon-neutral' will increase the number of green jobs in construction.
Wild cards: Global instability disrupts supplies of energy and other resources; terrorism.		

Annex 4: Participants in Phase 1 Interview programme

Name	Affiliation
Francisco Jesús Alvarez	European Commission, Directorate-General EMPL.B.3, Employment, Social Affairs and Equal Opportunities, Health, Safety and Hygiene at Work Member of EU-OSHA's former European Risk Observatory Advisory Group (EROAG) ([13])
Janet Asherson	International Organisation of Employers, representing the employers' representatives of EU-OSHA's former European Risk Observatory Advisory Group (EROAG)
Edward Barbier	University of Wyoming, United States
Øle Busck	Aalborg University, Denmark
Stefano Carosio	D'Appolonia S.p.A., Italy
Kären Clayton	Health and Safety Executive (HSE), United Kingdom
Bo Diczfalusy	International Energy Agency (IEA)
Fruzsina Kemenes ([14])	RenewableUK, United Kingdom
Sergio Iavicoli	National Institute for Occupational Safety and Prevention (ISPESL), Italy
Ivan Ivanov	World Health Organisation (WHO)
Totti Könnölä	European Commission, Joint Research Centre — Institute for Prospective Technological Studies (IPTS)
Ian McCluskey	Shell Gas Ltd, United Kingdom
Steven Marshall	Scottish Power, United Kingdom
Andrea Okun	National Institute for Occupational Safety and Health (NIOSH), United States
Ian Pearson	Futurizon, United Kingdom
Aïda Ponce	European Trade Union Institute (ETUI), representing the workers' representatives of EU-OSHA's former European Risk Observatory Advisory Group (EROAG)
Jorma Rantanen	Formerly Finnish Institute of Occupational Health (FIOSH), Finland
Dietmar Reinert	Institute of Occupational Safety and Health of the German Social Accident Insurance (IFA), Germany
Michael Renner	Worldwatch Institute, United States
Anabella Rosemberg	International Trade Union Confederation (ITUC)
Olivier Salvi	French National Institute for Industrial Environment and Risks (INERIS), France
Ana Belén Sánchez	International Labour Organisation (ILO)
Klass Soens	Federation of Enterprises, Belgium
Jennifer Stack	Tecnalia, Spain
Michael Sturm	E.ON Climate and Renewables GmbH, Germany

(13) The ERO Advisory Group (EROAG) was replaced by the Prevention and Research Advisory Group (PRAG) in the course of the project.
(14) Chris Streatfeild responded for RenewableUK in the WP 1.3 voting exercise.

Annex 5: Participants in Phase 2 Interview programme

Name	Affiliation
Francisco Jesús Alvarez	European Commission, Directorate-General EMPL.B.3, Employment, Social Affairs and Equal Opportunities Health, Safety and Hygiene at Work Unit Member of EU-OSHA's former European Risk Observatory Advisory Group (EROAG) ([15])
Camille Burel	Europabio, Belgium
Øle Busck	Aalborg University, Denmark
David Campbell	Scottish Power, United Kingdom
Stefano Carosio	D'Appolonia S.p.A., Italy
Kären Clayton	Health and Safety Executive (HSE), United Kingdom
Tiina Delmonte and Barrie Shepherd	Doosan Babcock, United Kingdom
Richard Gowland	European Process Safety Centre (EPSC)
Christian Jochum	European Process Safety Centre (EPSC)
Lee Kenny	Health and Safety Executive (HSE), United Kingdom
Jesús López de Ipiña	Tecnalia, Spain
Ian McCluskey	Shell Gas Ltd, United Kingdom
Massimo Mattucci	COMAU, Italy
Andrea Okun	National Institute for Occupational Safety and Health (NIOSH), United States
Geoff Pegman	RuRobots, United Kingdom
Mike Pitts	Chemistry Innovation Ltd, United Kingdom
Daniel Podgórski	Central Institute for Labour Protection — National Research Institute, Poland Member of EU-OSHA's former European Risk Observatory Advisory Group (EROAG), representing the governments' group
Aida Ponce	European Trade Union Institute (ETUI), representing the workers' representatives of EU-OSHA's former European Risk Observatory Advisory Group (EROAG)
Olivier Salvi	French National Institute for Industrial Environment and Risks (INERIS), France
Reto Schneider	Swiss Re, Switzerland
Rebekah Smith	Business Europe Member of EU-OSHA's former European Risk Observatory Advisory Group (EROAG)
Jennifer Stack	Tecnalia, Spain
Chris Streatfeild	RenewableUK, United Kingdom
Michael Sturm	E.ON Climate and Renewables GmbH, Germany
Evangelos Tzimas	European Commission, Joint Research Centre, JRC.F.6, Institute for Energy and Transport, Energy systems evaluation Unit

(15) The ERO Advisory Group (EROAG) was replaced by the Prevention and Research Advisory Group (PRAG) in the course of the project.

Annex 6: Consolidated list of technologies

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
Renewable energy technologies					
1. Wind energy (industrial scale — see domestic applications)	Onshore, offshore	Renewable energy source	Physical hazards: falls from height, manual handling, working in confined spaces (exposure to dust, MSDs owing to awkward postures), physical load from climbing towers, electrocution during construction and maintenance; offshore hazards: lifting, boats, weather, stability of platforms; machine safety: ice throw, blade fracture; chemical risks: exposure to resins, styrene, etc., during blade manufacture and maintenance.	Large increase in use already under way and likely to accelerate. Development of larger turbines, especially offshore. Integration with smart grids. New stackable, replicable and standardised substructures for large-scale offshore turbines such as tripods, quadrupods, jackets and gravity-based structures. Floating structures with platforms, floating tripods or single anchored turbine. Manufacturing processes for mass production of substructures. Improved reliability and lifetime through new materials and designs. Further automation and optimisation of manufacturing. Innovative logistics for transport and erection.	A1, A2, A3, A4, A5, A6, A7, A8
2. Marine energy	Wave, tidal and in-stream devices, salinity gradients, temperature gradients (ocean thermal energy conversion, OETC)	Renewable energy source	Physical hazards: falls from height, manual handling, working in confined spaces (exposure to dust, MSDs owing to awkward postures), electrocution during construction and maintenance; offshore hazards: lifting, boats, weather, stability of platforms; chemical risks: exposure during manufacture and maintenance of components.	Currently, no leading commercial technology. Many devices at advanced R & D stage, some large-scale prototypes at pre-market stage. Further development of technologies needed alongside grid connection issues, integration with other developing technologies to make hybrid systems. New designs have to overcome large technical challenges in a harsh marine environment.	A1, A2, A9, A10, A11
3. Solar photovoltaic (industrial scale — see domestic applications)	Direct conversion of the sun's rays to electricity using semiconductors	Renewable energy source	Physical hazards: falls from height, manual handling, confined spaces, electrocution during construction and maintenance; exposure to toxic chemicals and nanomaterials during manufacture and disposal/recycling.	Improvements in solar panel design to improve energy yield and reduce costs. Emerging technologies include: advanced inorganic thin-film technologies; organic solar cells; thermo-photovoltaic cells and systems. Development of solar desalination.	A1, A9, A10, A12, A13

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
4. Concentrating solar power (CSP) (industrial scale — see domestic applications)	Use of the sun's rays to heat a receiver to create mechanical energy to generate electricity, as opposed to PV, which uses direct conversion with semiconductors	Renewable energy source	Construction and maintenance of industrial-scale installations, electrical hazards, hazards from concentrated sunlight. High temperatures in concentrating sites.	Growth in CSP is anticipated. The International Energy Agency (IEA) *Technology Roadmap — Concentrating Solar Power* postulates that CSP could provide approximately 10 % of global electricity by 2050. New collector designs for medium temperatures being developed for industrial heat demand.	A47
5. Bioenergy (industrial scale — see domestic applications)	Biofuels (diesel, ethanol, etc.), biomass combustion, biomass-co-firing (see also clean coal technologies), anaerobic digestion (biogas production), landfill gas utilisation, biomass gasification, pyrolysis	Renewable energy source	Fire and explosion during production and use; biogas quality for injection into the grid; exposure to biological hazards; exposure to carcinogens, heavy metals and gases during thermal processing; asphyxiation; risks from small-scale manufacture by inexperienced people; dock-related hazards during biomass importation, such as oxygen depletion in confined spaces, exposure to hazardous volatile organic compounds (VOC), dusts, moulds and endotoxins; integration of biofuels into the European refinery network.	Develop and optimise feedstock-flexible thermochemical pathways and biochemical pathways to promote large-scale sustainable production and efficient use. Technological development of biofuels to 2020 includes: a wider range of bioethanol feedstocks (cereal straws, industrial/municipal/commercial wastes); a wider range of biodiesel feedstocks — algae, jatropha and curcas (monocrops) and used cooking oil/animal fats. Conversion technologies will improve: biomass enzymatic conversion (release of sugars in cellulose and hemicellulose for fermentation) better, cheaper enzymes, along with the development of enzymes to ferment pentose and hexose sugars to ethanol (not currently possible) to increase yield. Increased efficiency of biomass combustion and anaerobic digestion. Development of plasma arc gasification (heating biomass in high-voltage electric current).	A2, A4, A8, A9, A14, A15, A16
6. Geothermal energy (industrial scale — see domestic applications)	Ground and air heat pumps, hot fluid, hot rocks; current use in Europe is hot water from deep aquifers for district heating and small/medium shallow geothermal plants (which can also be used for thermal energy storage); recent new technology is the exploitation of low temperature geothermal sources	Renewable energy source	Emissions (e.g. sulphur, silica), hazards from activities such as: trenching, excavation, electrical issues, welding and cutting, falls; hazards associated with borehole drilling, piping steam/hot water, construction and operational activities; potential for earthquake/tremor risk from drilling, pumping activities into deep rock.	Main future developments are seen to be enabling technologies, such as innovative drilling technologies, resource assessment, utilising low temperature sources and exploiting supercritical zones. Increased efficiency in geothermal combined heat and power (CHP) technologies and components. Improved site assessment, exploration and installation. New geothermal applications: de-icing/snow melting on roads, runways, seawater desalination and absorption cooling. Current transition into new areas, southern Europe and the Mediterranean (cooling and heating), eastern and south-eastern Europe, the United Kingdom and Ireland growing interest. Leading countries currently Austria, Germany, Sweden and Switzerland.	A1, A4, A10, A17

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
7. Hydroelectricity	Large-scale, small-scale, micro-scale	Renewable energy source	Hazards associated with construction, operation and maintenance; electrical hazards, water hazards, moving machinery, etc.	Small hydropower is seen as having real potential in the new Member States, estimated around 7.7 TWh by 2020. Technological innovations by 2020 will concentrate on turbine design looking at low and very low head turbines, and to make simple, reliable, efficient turbines with a guaranteed performance. Also, improve environmental integration (submersible turbo generators); increased cost-efficiency and use of new materials. New generator designs, including high pole synchronous generators, have recently been introduced; new concepts are under development in the areas of prediction of energy output, scheduled production and condition monitoring. Integration with other renewable technologies.	A9, A10
Fossil fuel technologies					
8. Carbon capture and storage	End of pipe — precombustion/ post-combustion	Reduces CO_2 emissions/ removes ambient CO_2	Presence of large volumes of CO_2 requiring compression, transportation and underground injection; handling CO_2 in its dense (liquid) or supercritical phase; CO_2 escape due to loss of plant integrity or embrittlement of equipment caused by the gas; potential impact injuries and asphyxiation risk; acute and chronic health problems caused by exposure to high CO_2 concentrations (e.g. inhalation may affect respiratory, cardiovascular and central nervous system); burns/frostbite from liquid CO_2 exposure; exposure to chemicals and solvents used in carbon capture (e.g. amines, methanol) which can cause irritation to eyes, skin and respiratory tract; presence of toxic, flammable and explosive substances (e.g. amines, ammonia, oxygen) in coal combustion plant as part of CC process; not conclusive, but may be the potential for seismic activity as a result of burying CO_2 underground.	Proving technical and economic feasibility using existing technology; develop more efficient and cost-effective technologies; develop new capture concepts; transfer CCS to other carbon-intensive sectors (e.g. cement, refineries and iron and steel); develop alternative transport and storage technologies to allow broadening of geographical deployment; zero-emissions platform (ZEP) plant technology (up to 12 EU demonstrators by 2015), commercial by 2020.	A2, A8, A9

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
9. Clean coal technologies	Oxyfuel combustion, integrated gasification combined cycle (IGCC), coal bed methane extraction, co-firing with biomass (see also 5. Bioenergy), supercritical coal power plant, underground coal gasification)	Reduces pollution	Fire and explosion risk from flammable gases, failure of pressure vessels and pipes, spontaneous combustion of biomass (for co-firing); exposure to toxic substances during syngas or flue gas processing.	Continued development and testing of the technologies listed left under 'Subtopics' heading.	A8, A9
10. Other fossil fuel technologies	Natural gas, oil	Natural gas (with CCS) reduces pollution (compared to coal).	Fire and explosion risk from flammable gases, failure of pressure vessels and pipes. Dockside issues associated with the transport of liquefied natural gas (LNG); risks from offshore regassing.	Increased LNG imports. Greater gas storage capacity underground and potentially undersea. Increased efficiency in use of oil. Conventional power plant life extension — work on modelling and assessment tools.	A8, A12
Other energy technologies					
11. Nuclear energy	Nuclear fission, nuclear fusion	Low-carbon energy source	Hazards associated with construction, operation and maintenance;radiation, containment issues, waste disposal, decommissioning; avoidance of nuclear accident.	Fission: life extension of current generation II plants, mostly by material performance. Development of generation III designs, which are standardised designs to decrease costs, construction times, etc. There are four main types: Light-Water Reactors (advanced boiling water and advanced pressurised water reactors (PWR)), Heavy Water Reactors, High-Temperature Gas-Cooled Reactors (HTRs) and Fast Neutron Reactors (FNRs). Generation IV Reactors are under development — six technologies are being considered by the Generation IV International Forum (GIF): Gas-Cooled and Lead-Cooled Fast Reactors, two types of Molten Salt Reactors (MSRs), Sodium-Cooled Fast Reactors, Supercritical Water-Cooled Reactors and Very High-Temperature Gas Reactors (which can co-generate heat/electricity). Small (under 500 MWe) systems are being developed and can be independent from large-grid systems; a range of technologies are being developed outside Europe based on PWR, HTR, Liquid-metal Reactors and MSR Technology.	A1, A2, A9
				Fusion — first commercial plant unlikely before 2040, although there is talk of a demonstrator in five years. Cold fusion (Low energy nuclear reactions) is yet to be proven, although the US Navy appears to be having success in this area.	A2, A9

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
12. Electricity transmission	Smart grid, smart metering, distributed generation, combined heat and power, smart appliances	Enables use of renewable energy sources	Electrical safety; construction; working at height; skills issues; risks in all sectors consequent on power cuts during installation: flashover burns, falls and electrocution during installation, connection and maintenance of new power sources; electrocution owing to more work on live systems as systems become more complex; falls when installing, connecting or repairing roof-mounted micro wind turbines or solar panels; construction and excavation risks during cable-laying, substation construction and other activities (onshore and offshore); smart appliances, those that interact with the grid to make most use of lower cost electricity, may be prone to unexpected starting and stopping; companies with interrupted supply contracts may be prone to the same risks.	Grid integration techniques for turbine output — High-Voltage Alternating Current (HVAC), High-Voltage Direct Current (HVDC). PV grid integration and storage technologies. Develop advanced network technologies to improve security and flexibility; preparing long-term evolution of grids. Work on protection, fault detection and voltage sag algorithms. Inclusion of storage devices into centralised control systems. European Supergrid, HVDC, Flexible AC Transmission Systems (FACTS), new conductors — Gas Insulated Lines (GIL) High Temperature Superconduction (HTS) wires. HVDC and FACTS only viable with suitable ICT control. North African solar power grid (DESERTEC). Smart meter roll-out programme.	A1, A2, A8, A9, A11, A18
13. Electricity storage and energy recovery technologies	Batteries (see also separate category), flywheels, supercapacitors, Superconducting Magnetic Energy Storage (SMES), hydrogen (see also separate category), pumped hydro, Compressed Air Energy Storage (CAES), liquid nitrogen and liquid oxygen energy storage	Enables use of renewable energy sources	Electrical hazards; hazards associated with feed-in technologies (wind, wave, solar); hazards from batteries, hydrogen, fuel cells (see separate categories); hazards from compressed and liquefied gases; hazards from the use of molten materials for storage.	Continuous improvements in efficiency and cost reduction of these technologies. Increasing use of these technologies. Establishment of specialised energy storage 'gardens'?	A8, A12

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
14. Battery Technology	Lead-acid, lithium ion, sodium sulphur (zebra), sodium nickel chloride	Enables use of renewable energy sources	Some batteries operate at high temperatures; there are also electrical risks from the high voltage/currents of large batteries; some batteries may catch fire or explode; exposure to toxic substances during manufacture; hazards in the recycling of batteries: chemical, electrical and fire risk (lithium ion battery fires in the United Kingdom).	For large-scale systems, energy companies are looking at sodium sulphur (NaS) batteries — long-life, large (room-sized) batteries, recently deployed at 1.2 MW. Other potential battery technologies are all-liquid batteries (long-life, high current) and gravel batteries (use spare electricity to heat/pressurise argon, which heats/cools gravel; energy is stored as a temperature difference between two gravel silos). A range of smaller-scale batteries are being developed, such as thin-film batteries (solid state and long storage), lithium manganese oxide batteries (charge/discharge in 10 minutes), lithium phosphate-coated lithium ion batteries (shorter charge/discharge). Nanotechnology will have a big impact on battery technology. Developments include: silicon nanowire electrodes in lithium ion batteries (triples their capacity), lithium air batteries (large storage potential, useful for cars); in addition, novel catalysts are being developed. World market growth rate of batteries predicted at 7–30 % a year. It is thought that many emerging battery technologies could revolutionise battery use, with a step change in recharge time and capacity.	A2, A38, A39
15. Hydrogen and fuel cells	Hydrogen in fuel cells, heating boilers and internal combustion engines; generation methods: thermochemical electrolytic splitting of water using renewable electricity and waste heat; biomass biological processes, algae; other fuel cells (ethanol, methanol, methane, diesel, biogas, LPG)	Enables use of renewable energy sources	Fire and explosion hazards during manufacture, distribution, storage and use; electrical hazards from fuel cells; if hydrogen use in vehicles is widespread, the issue of hydrogen handling by the general public and workers could present risks.	Significant developments anticipated to improve storage of hydrogen, especially in vehicles. Developments to improve efficiency of fuel cells and to reduce costs. Development of domestic hydrogen CHP systems. If hydrogen is to be successful in vehicles, a network of refuelling stations will need to be developed. Domestic generation of hydrogen and vehicle refuelling is already under development.	A2, A8, A10, A12

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
16. Domestic and small-scale applications of emerging energy technologies	Wind, solar thermal and solar photovoltaic, bioenergy, geothermal energy, combined heat and power, fuel cells	Renewable energy sources	Domestic and small-scale (e.g. community buildings) applications of these technologies may bring a different mix of risks from those encountered on the industrial scale; installers will need new skill mixes (e.g. those who previously worked only on gas systems who move into solar thermal installation will have increased exposure to electrical work and work at heights); many installers may be self-employed; risks to householders; farmers who produce their own biofuel may be at risk of fire/explosion; risks to recycling workers on disposal.	Domestic solar and wind applications are seeing a rapid increase in uptake. Small-scale biofuels manufacture is increasing. Domestic use of geothermal systems is relatively low at present. Extension of solar thermal from water to space heating. Combi+ systems (heating in winter, cooling in summer) will have a large market share by 2020–30.	A30, A40
Non-energy technologies					
17. Biotechnologies	Biocatalysts, engineered cell factories, plant biofactories, novel process conditions/ industrial- scale-up, biorefining and very-large-scale bioprocessing (VLSB), meso-scale manufacture, agricultural technologies (see also separate category), synthetic biology, genetic modification	Contributes to green chemistry, biofuels, and improved agricultural yields	Potential for exposure to unknown hazards from new processes and materials; distributed manufacture could increase the potential hazards; risks to workers from biological agents at the manufacturing stage, when these materials are further used down the user chain, and at the recycling stage.	An area in which considerable development is under way across a range of individual technologies with a wide range of applications.	A2, A14
18. Green chemistry	Reaction and process design, novel solvents, novel catalysis, separation technology, renewable feedstocks replace non-renewable (e.g. CO_2 as a possible new source for plastics), industrial biotechnology, materials technology	Greater efficiency, low carbon, reduces pollution	Potential for exposure to unknown hazards from new processes and materials; substitution of chemicals for environmental reasons could result in greater risks to workers; chemicals obtained from renewable sources can still be toxic; potential risks at the recycling stage.	Development of novel catalysts, novel solvents, substitution of environmentally harmful chemicals.	A1, A2, A19, A20, A22

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
19. Novel materials	Smart (multifunctional) and biomimetic materials (e.g. metamaterials), intelligent polymers (plastic electronics), electroactive polymers (EAPs), shape memory polymers (SMPs), smart interactive textiles, nanomaterials (see also separate category), organic light-emitting diodes (LEDs), organic light-emitting polymers (OLEPs)	Lighter, stronger materials contribute to energy efficiency.	Potential for toxic or irritant effects of new materials; risks from potentially dangerous substances involved with these novel materials in manufacturing, and when these materials are used, processed, or handled further down the user chain, and in waste-recycling activities.	Developments in a wide range of classes of new materials with applications in a wide range of sectors.	A2, A21
20. Nanotechnologies and nanomaterials	A very wide range of potential applications, including improved batteries, engine additives, new composite materials, materials used in construction (e.g. pavements/bricks/asphalt). 'Capturing' environmental pollutants, nanocoatings/nanopaints transforming solar energy into electricity, 'green' antifouling nanocoatings), agriculture and forestry.	Contribution to green sectors	The particle size of nanomaterials may affect their toxicity and explosive properties when compared to the bulk materials; these properties of nanomaterials are still under investigation and potentially pose risks to workers at all stages of their life cycle.	The applications of nanotechnology are expected to grow very rapidly. There are predictions that worldwide production could reach 50 000 tonnes a year during the period 2011 to 2020, with 20 % of manufactured goods involving nanomaterials.	A2, A41, A42, A43
21. Robotics, automation and artificial intelligence	Use in manufacturing, agriculture, construction and other industries	Facilitate introduction, control and monitoring of green technologies	Risks are mainly those related to the potential for automated devices to injure workers, especially during malfunction and when free-roaming.	The use of robots is likely to grow. Increasingly, robots will be free-roaming and autonomous.	A31

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
22. Information and communication technologies	In green jobs terms, use in monitoring and control of energy production and distribution (e.g. the smart grid) in modelling and optimisation of systems; increasing use of networks in applications such as intelligent traffic systems, smart grids, and smart cities; many wider applications	Facilitate introduction, control and monitoring of green technologies; reduce the need for travel	Networks may be susceptible to interference or hacking (potential to create major disruption); damage to safety critical applications could occur, such as the Stuxnet virus; increasing use of wireless systems could increase workers' exposure to electromagnetic radiation; there may be over-reliance on computers in safety-critical situations; monitoring systems such as radio frequency identification (RFID) offer safety benefits such as protection for lone workers, traceability of components, process control, etc.; the potential for stress from monitoring and surveillance; any risks from 'cloud computing' (non-localised software).	Continued expansion of computer applications is inevitable, with growing potential for the safety benefits and risks described left. The introduction of quantum computing could see a step change in computer power, but this is likely to be some way off.	A32
23. Convergent technologies	This term can be applied to a range of technologies, but is most commonly used to describe the co-development of nanotechnologies, biotechnologies, information technologies and cognitive sciences (NBIC).	Enhancement of human performance leading to greater efficiency; tailored materials offering environmentally friendly energy efficiency	Unknown effects of enhancement technologies (e.g. performance-enhancing drugs, implants, bionic limbs, exoskeletons); unknown hazards in the workplace presented by such technologies.	Developments in these technologies continue to be made. There is evidence of a change in public opinion such that enhancement technologies will become more accepted. Potential developments include: · direct human brain-machine connections, transforming work, sports and art; · computers and environmental sensors worn as part of everyday attire; · more robust, healthy, energetic human body, easier to repair when necessary; · practically any structure made of tailored materials, able to adapt to changing situations, offering energy efficiency while remaining environmentally friendly; · treatments for many physical and mental disabilities, perhaps completely eradicating some handicaps such as paralysis or blindness.	Interview programme, A53, A54

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
24. Photonics	Operations including emission, transmission, modulation, signal processing, switching, amplification and detection and sensing of light; more recently, photonics describes the use of light to perform functions that traditionally fell within the typical domain of electronics (telecommunications, information processing, etc.)	Improved efficiency of processes, Photonics and Plastic Electronics Knowledge Centre claims 'massively reduced energy consumption'	Laser safety, electrical hazards	Increasing range of applications, including merging with nanotechnologies. In the European roadmap for photonics and nanotechnologies (Merging Optics and Nanotechnologies or MONA), over 50 devices involving nanophotonics are listed in areas such as datacoms/telecoms, optical interconnects, displays.	Interview programme, A44, A45, A46, A59
25. Transport technologies	Electric, hybrid and biofuelled road vehicles; battery technology; hydrogen and fuel cells; electrification of railways; biofuels in aircraft; novel materials in aircraft; improved efficiency of internal combustion engines (ICE); intelligent transport systems, refuelling/recharging infrastructure	Greater efficiency, low carbon, enables use of renewable energy sources, reduces pollution	Health and safety issues associated with contributing technologies: energy sources, materials, vehicles, etc.; fire and explosion from fuels; novel electrical risks from electric and hybrid vehicles during maintenance and operation; risks to rescue crews after accidents; distribution and use of hydrogen; recharging/battery exchange hazards.	A great deal of work is already under way to improve the range and performance of electric and plug-in hybrid road vehicles. If they are to succeed, a network of charging points and/or battery exchange facilities will need to be built. Use of novel materials to reduce weight. Increasing use of ICT in vehicles, increasing automation. Driverless cars, buses and trains with potential for collision risks.	A7, A23, A24

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
26. Manufacturing technologies	Advanced manufacturing techniques, distributed manufacture (e.g. personal fabrication, 3D printing and rapid manufacture/ rapid prototyping); lean methods; biotechnologies (see also separate category); green chemistry (see separate category), nanomaterials (see separate category).	Greater efficiency, low carbon, reduced pollution	Very wide range of applications; potential for exposure to unknown hazards from new processes and materials; while many established manufacturing processes have robust safety systems, distributed manufacture could increase the potential hazards; skills issues including exposure to chemicals for unskilled workers; potential for dangerous waste generated by new manufacturing technologies/ processes.	Significant progress anticipated in sustainable manufacturing, products and services; energy-efficient manufacturing; key technologies (e.g. digital technologies, micro and nanoelectronics, nanotechnologies, plastic electronics, silicon electronics, industrial biotechnology, photonics, advanced materials; standardisation; and innovation, competence development and education). Progress in rapid manufacturing leading to increasing customisation — product safety issues. Novel formulation technologies.	A21, A28, A29
27. Construction technologies	Energy efficiency measures — new build and retrofit (insulation, heat-retaining windows, ventilation with heat recovery, energy-efficient lighting); renewable energy (solar thermal and cooling, geothermal heating and cooling, advanced monitoring systems, photovoltaic, wind energy, feed-in to grid, combined heat and power); new techniques (off-site construction/ prefabrication); new materials (low-carbon cements, nanomaterials), increasing use of ICT and robotics and automation	Utilise low-carbon energy sources, greater energy efficiency, reduced carbon emissions	A range of hazards. In particular, the combination of known risks in new situations (e.g. the installation of renewable energy equipment at heights), the installation of new technology (e.g. feed-in to smart grids); use of new materials and potential risks from dangerous substances used in new construction materials (e.g. when polishing, grinding nano-containing bricks and paints, including in maintenance and demolishing activities); off-site construction could reduce risks on site but transfer the risks to other groups of workers; risk of exposure to asbestos during retrofitting activities.	Considerable potential for increased volumes as requirement for carbon-neutral buildings are introduced alongside incentives such as feed-in-tariffs and renewable heat subsidies. Novel technologies such as algaetecture (biological generation of hydrogen on buildings). Application of carbon capture and storage to cement production. New insulation and building materials, including based on nanomaterials such as aerogel nanofoams.	A33

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
28. Extractive technologies	Quarries, underground mines, opencast mines, mining of metals, minerals and aggregates	This sector is very energy intensive; improvements in efficiency could make a significant difference to carbon emissions	Hazards associated with mining and excavation activities; use of plant and explosives; working underground; exposure to chemicals and heat; greater automation may bring health and safety benefits to the industry; there may be an increase in mining activities in Europe driven by shortages of rare earth metals, minerals, metals and coal; old mines may be reopened in order to extract more products or as they are now economical to operate.	Metal mining, recovery and reuse of waste heat from metallurgical slags, use of biomass derived charcoal instead of coal in the iron and steel industry and use of by-product slag as 'green cement'. Reconstruction of old mines, construction of new automatic mines, system and unit integration and system automation. Use of solar power air conditioners to cool mining structures, reclamation and treatment of waste water and fuel additives to minimise carbon emissions from mining equipment engines. Aggregates: substitution of primary aggregate for recycled and secondary aggregate. Developments in crushing technology (e.g. high productivity with lower cost, 'just-in-time' supply, improved reliability and availability of plant, crusher automation with increased throughput, and in-pit crushing).	A55, A56
29. Agriculture, forestry and food technologies	Biotechnology (e.g. genetic modification, see separate category); decarbonisation, precision farming; robotics and automation (see also separate category); water conservation; nanotechnology (see also separate category)	More efficient production, reduced environmental impact, reduced use of fuels	A range of hazards: machinery; electrical; exposure to chemicals; biological hazards; exposure to GMOs.	Increasing use of automation (e.g. robotic dairy farming); novel chemicals for pest controls; new pests resulting from climate change, changing weather, increasing size of farms.	A34, A35, A36
30. Waste management	Collection, sorting and processing of waste for recycling or for energy production	Reduced environmental pollution; provides material for recycling	Manual handling risks during collection and sorting; exposure to chemicals and microorganisms during collection, sorting and processing; fire and explosion risks from processing; new materials, when being collected as waste, may present a variety of unknown risks linked to (new) dangerous substances they may contain; landfill mining will increase exposure to harmful materials.	Waste management activities will increase, driven by government targets to reduce landfill and to meet increasing requirements to recycle. Landfill mining is likely to increase.	A51, A52

Technology	Subtopics	Green credentials	Health and safety aspects	Potential for development	References (next section)
31. Recycling technologies	Recycling of materials and components	Recycling reduces energy use, conserves natural resources	New recycling technologies may introduce new risks; new materials, when being recycled, may present a variety of unknown risks linked to (new) dangerous substances they may contain.	New technologies will be developed to improve recycling. Greater emphasis on advanced processes that preserve the performance qualities of materials. Recycling of novel materials and devices may present new hazards.	A37, A51, A52
32. Environmental Remediation Technologies	Excavation or dredging, surface enhance aquifer remediation (SEAR), pump and treat, solidification and stabilisation, in situ oxidation, solar vapour extraction, bioremediation, phytoremediation	Restores polluted areas	Environmental remediation can involve the handling of large quantities of chemicals used in the process or potential exposure to pollutants or microorganisms.	Novel techniques, introduction of nanotechnology-based methods.	A60
33. Geoengineering (other than industrial CCS)	Solar radiation management (cool roof, sulphur clouds); ambient CO_2 capture (e.g. ocean seeding); artificial trees (resin towers that absorb CO_2 from the atmosphere); heat transport (ocean pipes)	Aims to reduce global warming	Unintended consequences for the environment; OSH hazards likely to be associated with construction or exposure to chemicals involved.	Only limited activity to date, with controversy around, for example, ocean seeding.	A48, A49, A50
34. Medicine, healthcare and related technologies	A range of techniques to aid monitoring of health indicators; personalised treatment; Improved sensors for exposure monitoring; 'lab-on-a-chip' applications	Increased efficiency, improved worker health; telemedicine could reduce the need for travel; applicability to green/non-green jobs alike	Developments in personal medicine, improved techniques generally, will lead to improved health and safety; genetic testing could identify those workers most at risk from certain substances; developments such as performance-enhancing drugs could either improve or impair health and safety performance.	Continuing rapid developments in detection and treatment. Personalised treatments. Targeted drug delivery using nanotechnology. Developments in bionics, human computer interface leading to thought controlled prostheses, robotic exoskeletons, all of which will allow people with disabilities back into the workplace. Performance-enhancing drugs.	A57, A58, A59

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Annex 7: Phase 2 Workshop participants

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Sam Bradbrook	Health and Safety Laboratory (HSL), United Kingdom
Emmanuelle Brun	European Agency for Safety and Health at Work (EU-OSHA)
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Viktor Kempa	European Trade Union Institute (ETUI) Member of EU-OSHA's former European Risk Observatory Advisory Group (EROAG) ([16]), representing the workers' group
Lee Kenny	Health and Safety Executive (HSE), United Kingdom
Ian McCluskey	Shell Gas Ltd, United Kingdom
Geoff Pegman	RuRobots, United Kingdom
Mike Pitts	Chemistry Innovation Ltd, United Kingdom
Aïda Ponce	European Trade Union Institute (ETUI) Member of EU-OSHA's former European Risk Observatory Advisory Group (EROAG), representing the workers' representatives
John Reynolds	SAMI Consulting, United Kingdom
Olivier Salvi	French National Institute for Industrial Environment and Risks (INERIS), France
Jennifer Stack	Tecnalia, Spain
Chris Streatfeild	RenewableUK, United Kingdom
Erkki Yrjänheikki	Ministry of Social Affairs and Health, Finland Member of EU-OSHA's former European Risk Observatory Advisory Group (EROAG), representing the government group

(16) The ERO Advisory Group was replaced by the Prevention and Research Advisory Group (PRAG) in the course of the project.

Annex 8: Attendance at Phase 3 Technology workshops

Wind energy workshop

EU-OSHA Wind energy workshop

Manchester (United Kingdom), 28 and 29 September 2011

Name	Affiliation
Emmanuelle Brun	European Agency for Safety and Health at Work (EU-OSHA)
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Martin Duckworth	SAMI Consulting, United Kingdom
Peter Ellwood	Health and Safety Laboratory (HSL), United Kingdom
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Donna Heidel	National Institute for Occupational Safety and Health (NIOSH), United States
Paul Helm	DONG Energy, United Kingdom
Julian Hubbard	RES Ltd, United Kingdom
Xabi Irastorza	European Agency for Safety and Health at Work (EU-OSHA)
Lee Kenny	Health and Safety Executive (HSE), United Kingdom
Angeliki Koulouri	European Wind Energy Association (EWEA)
Stephane Pouffary	ENERGIES 2050, France
John Reynolds	SAMI Consulting, United Kingdom
Martin Röhrich	Consultant, Czech Republic Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the employers' group
Chris Streatfeild	RenewableUK, United Kingdom
Steve Window	Nordex, United Kingdom

Construction workshop

EU-OSHA Construction workshop

Manchester (United Kingdom), 29 and 30 September 2011

Name	Affiliation
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Brian Cody	Graz University of Technology, Austria
Emiliya Dimitrova	Confederation of Independent Trade Unions of Bulgaria (KNSB/CITUB), Bulgaria Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the workers' representatives
Martin Duckworth	SAMI Consulting, United Kingdom
Peter Ellwood	Health and Safety Laboratory (HSL), United Kingdom
Rolf Gehring	EFBH (European Federation of Building and Woodworkers)
Donna Heidel	National Institute for Occupational Safety and Health (NIOSH), United States
Xabier Irastorza	European Agency for Safety and Health at Work (EU-OSHA)
Carmine Pascale	STRESS S.c. a r.l., Spain
Stephane Pouffary	Energy 2050, France
John Reynolds	SAMI Consulting, United Kingdom
Martin Röhrich	Consultant, Czech Republic Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the employers' group
Maria Zalbide	Tecnalia, Spain

Bioenergy workshop

EU-OSHA Bioenergy workshop

Tallinn (Estonia), 5 and 6 October 2011

Name	Affiliation
Jan Van den Auweele	Laborelec Electrabel, GDF, Belgium
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Martin Duckworth	SAMI Consulting, United Kingdom
François Engels	Fédération des Artisans (FDA), Luxembourg Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the employers' group
Ann Hedlund	Dalarna University, Sweden
Meeli Hüüs	The Estonian Biomass Association, Estonia
Xabier Irastorza	European Agency for Safety and Health at Work (EU-OSHA)
Veronika Kaidis	Estonian Social Ministry, Estonia
Ülo Kask	Tallinn University of Technology, Estonia
Antti Leinonen	Bioste Ltd, Finland
Eckhard Metze	Commission for Occupational Health and Safety and Standardisation, Germany Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the employers' group
Michal Miedzinski	Technopolis Group, Belgium
John Reynolds	SAMI Consulting, United Kingdom
Martin Röhrich	Consultant, Czech Republic Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the employers' group

Waste and recycling workshop

EU-OSHA Waste and recycling workshop

Tallinn (Estonia), 6 and 7 October 2011

Name	Affiliation
Emmanuelle Brun	European Agency for Safety and Health at Work (EU-OSHA)
Stefano Carosio	D'Appolonia S.p.A., Italy
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Martin Duckworth	SAMI Consulting, United Kingdom
François Engels	Fédération des Artisans (FDA), Luxembourg Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the employers' group
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Antti Leinonen	Bioste Ltd, Finland
Jaromir Manhart	Czech Government Waste Department, Czech Republic
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Michal Miedzinski	Technopolis Group, Belgium
Milos Milunov	Bipro, Germany
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John Reynolds	SAMI Consulting, United Kingdom
Martin Röhrich	Consultant, Czech Republic Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the employers' group
Peter Segers	European Federation of Waste Management and Environmental Services (FEAD)
Carlo Vandecasteele	University of Leuven, Belgium

Transport workshop

EU-OSHA Transport workshop

Brussels (Belgium), 2 and 3 November 2011

Name	Affiliation
John Batterbee	Energy Technologies Institute (ETI), United Kingdom
Tom Breen	Transport for London (TfL), United Kingdom
Emmanuelle Brun	European Agency for Safety and Health at Work (EU-OSHA)
Eduardo Chagas (partial attendance)	European Transport Workers' Federation (ETF)
Martin Duckworth	SAMI Consulting, United Kingdom
Peter Ellwood	Health and Safety Laboratory (HSL), United Kingdom
Xabier Irastorza	European Agency for Safety and Health at Work (EU-OSHA)
Viktor Kempa	European Trade Union Institute (ETUI) Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the workers' representatives
Uwe Likar	Mitsubishsi, Germany
Arne Lindeberg	Swedish Transport Administration, Sweden
Maria-Cristina Marolda (partial attendance)	European Commission Directorate-General for Mobility and Transport, MOVE C.2, Maritime Transport, Ports and Inland Waterways
Martine Meyer	Renault, France
Michal Miedzinski	Technopolis Group, Belgium
Neal Parton	Health and Safety Laboratory (HSL), United Kingdom
Christer Persson	WSP Group, Sweden
Aïda Ponce	European Trade Union Institute (ETUI) Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the workers' representatives
John Reynolds	SAMI Consulting, United Kingdom
Irene Wintermayr	International Labour Organisation (ILO)

Manufacturing, robotics and automation workshop

EU-OSHA Manufacturing, robotics and automation workshop

Brussels (Belgium), 2 and 3 November 2011

Name	Affiliation
Richard Brook	Health and Safety Laboratory (HSL), United Kingdom
Emmanuelle Brun	European Agency for Safety and Health at Work (EU-OSHA)
Stefano Carosio	D'Appolonia S.p.A., Italy
Martin Duckworth	SAMI Consulting, United Kingdom
Peter Ellwood	Health and Safety Laboratory (HSL), United Kingdom
Xabier Irastorza	European Agency for Safety and Health at Work (EU-OSHA)
Viktor Kempa	European Trade Union Institute (ETUI) Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the workers' representatives
Vasileios Lakkas	Health and Safety Executive (HSE), United Kingdom
Javier Larraneta	Tecnalia, Spain
Massimo Mattucci	Comau, Italy
Michal Miedzinski	Technopolis Group, Belgium
Björn Ostermann	German Social Accident Insurance (DGUV), Germany
Aïda Ponce	European Trade Union Institute (ETUI) Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the workers' representatives
John Reynolds	SAMI Consulting, United Kingdom
Reijo Tuokko	Technical University of Tampere, Finland

Energy workshops — combined attendance

EU-OSHA Energy workshops

Bilbao (Spain), 9–11 November 2011

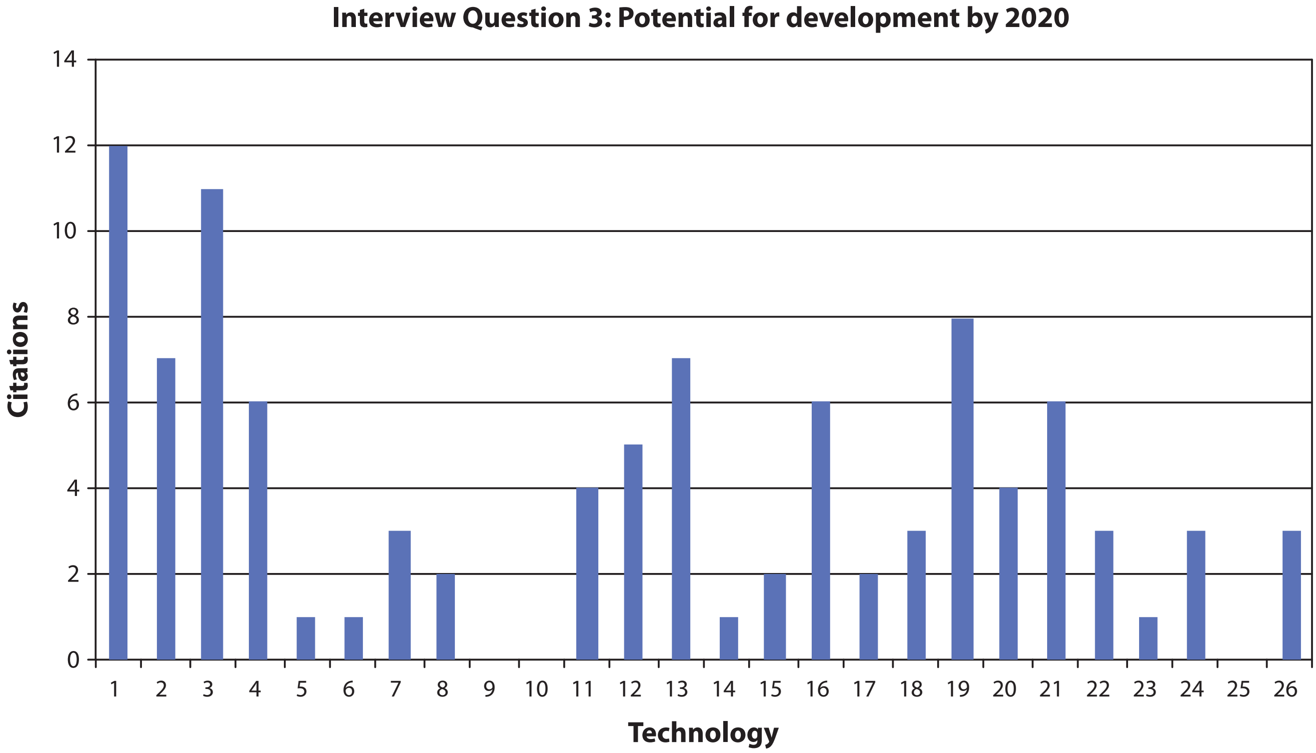
Name	Affiliation
Francisco Jesús Alvarez	European Commission, Directorate-General EMPL.B.3., Employment, Social Affairs and Equal Opportunities Health, Safety and Hygiene at Work Unit Member of EU-OSHA's Prevention and Research Advisory Group (PRAG)
Bill Bates	Health and Safety Executive (HSE), United Kingdom
Emmanuelle Brun	European Agency for Safety and Health at Work (EU-OSHA)
Øle Busck	Aalborg University, Denmark
Stefano Carosio	D'Appolonia S.p.A., Italy
Martin Duckworth	SAMI Consulting, United Kingdom
Peter Ellwood	Health and Safety Laboratory (HSL), United Kingdom
Sebastian Gallehr	Desertec, Germany
Eusebio Rial González	European Agency for Safety and Health at Work (EU-OSHA)
Xabier Irastorza	European Agency for Safety and Health at Work (EU-OSHA)
Viktor Kempa	European Trade Union Institute (ETUI) Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the workers' representatives
Guy Marlair	French National Institute for Industrial Environment and Risks (INERIS), France
Aïda Ponce	European Trade Union Institute (ETUI) Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the workers' representatives
Ningling Rao	DONG Energy, Denmark
John Reynolds	SAMI Consulting, United Kingdom
Katalin Sas	European Agency for Safety and Health at Work (EU-OSHA)
Elke Schneider	European Agency for Safety and Health at Work (EU-OSHA)

Annex 9: Participants at Phase 3 Policy workshop

Name	Affiliation
Francisco Jesús Alvarez	European Commission, Directorate-General EMPL.B.3, Employment, Social Affairs and Equal Opportunities Health, Safety and Hygiene at Work Unit Member of EU-OSHA's Prevention and Research Advisory Group (PRAG)
Carita Aschan	Finnish Institute of Occupational Health (FIOH), Finland
Pavan Baichoo	International Labour Organisation (ILO)
Laurent Bontoux	European Commission, Directorate-General for Health and Consumers
Sam Bradbrook	Health and Safety Laboratory (HSL), United Kingdom
Emmanuelle Brun	European Agency for Safety and Health at Work (EU-OSHA)
Stefano Carosio	D'Appolonia S.p.A., Italy
Eduardo Chagas	European Transport Workers' Federation (ETF)
Colin Connor	Health and Safety Executive (HSE), United Kingdom
Martin Duckworth	SAMI Consulting, United Kingdom
Peter Ellwood	Health and Safety Laboratory (HSL), United Kingdom
Stephen Freeland	European Federation of Waste Management and Environmental Services (FEAD)
Jan Kahr Frederiksen	Confederation of Professionals in Denmark (FTF), Denmark Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the government group
David Gee	European Environment Agency
Mikko Härmä	Finnish Institute of Occupational Health (FIOH), Finland
Xabier Irastorza	European Agency for Safety and Health at Work (EU-OSHA)
Viktor Kempa	European Trade Union Institute (ETUI) Member of EU-OSHA's Prevention and Research Advisory Group (PRAG), representing the workers' group
Angeliki Koulouri	European Wind Energy Association (EWEA)
Michal Miedzinski	Technopolis Group, Belgium
Ina Neitzner	Institute of Occupational Safety and Health of the German Social Accident Insurance (IFA), Germany
Brenda O'Brien	European Agency for Safety and Health at Work (EU-OSHA)
Palle Ørbæk	National Research Centre for the Working Environment (NRCWE), Denmark
Willem Penning	European Commission, Directorate-General for Health and Consumers
Joe Ravetz	SAMI Consulting, United Kingdom
Dietmar Reinert	Institute of Occupational Safety and Health of the German Social Accident Insurance (IFA), Germany
John Reynolds	SAMI Consulting, United Kingdom
Katalin Sas	European Agency for Safety and Health at Work (EU-OSHA)
Christa Sedlatschek	European Agency for Safety and Health at Work (EU-OSHA)

Annex 10: Phase 2 Interview results

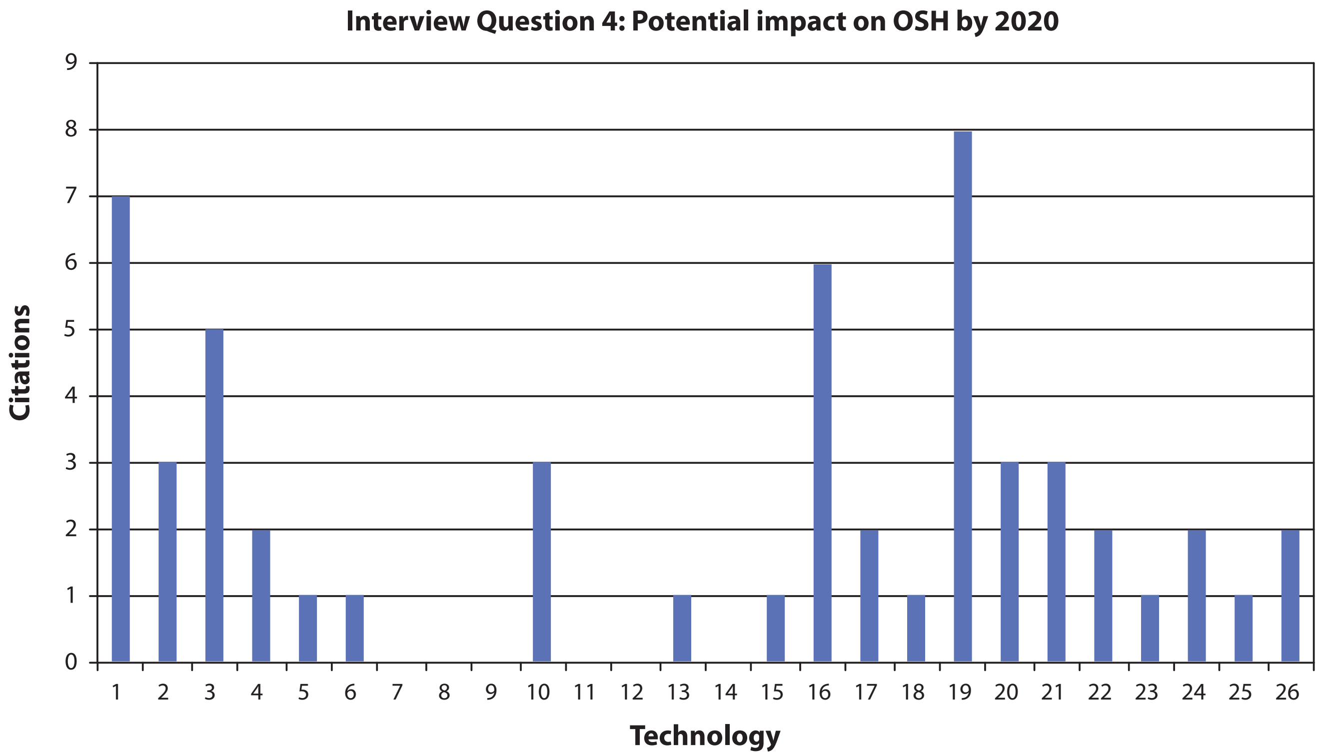
Figure 6: Results from Phase 2, Interview Question 3: Potential for development by 2020



Key to Technologies

1. Wind energy
2. Marine energy
3. Solar energy
4. Bioenergy
5. Geothermal energy
6. Hydroelectricity
7. Carbon capture and storage
8. Clean coal
9. Other fossil fuel technologies
10. Nuclear energy
11. Electricity transmission
12. Electricity storage
13. Battery technology
14. Hydrogen and fuel cells
15. Domestic and small-scale energy
16. Biotechnologies
17. Green chemistry
18. Novel materials
19. Nanotechnologies and nanomaterials
20. Robotics, automation and artificial intelligence
21. ICT
22. Transport technologies
23. Manufacturing technologies
24. Construction technologies
25. Agriculture, forestry and food
26. Waste, recycling and environmental remediation

Figure 7: Results from Phase 2, Interview Question 4: Potential impact on OSH by 2020



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Annex 11: Phase 2 Internet survey results

Figure 8: Results of potential for development scoring

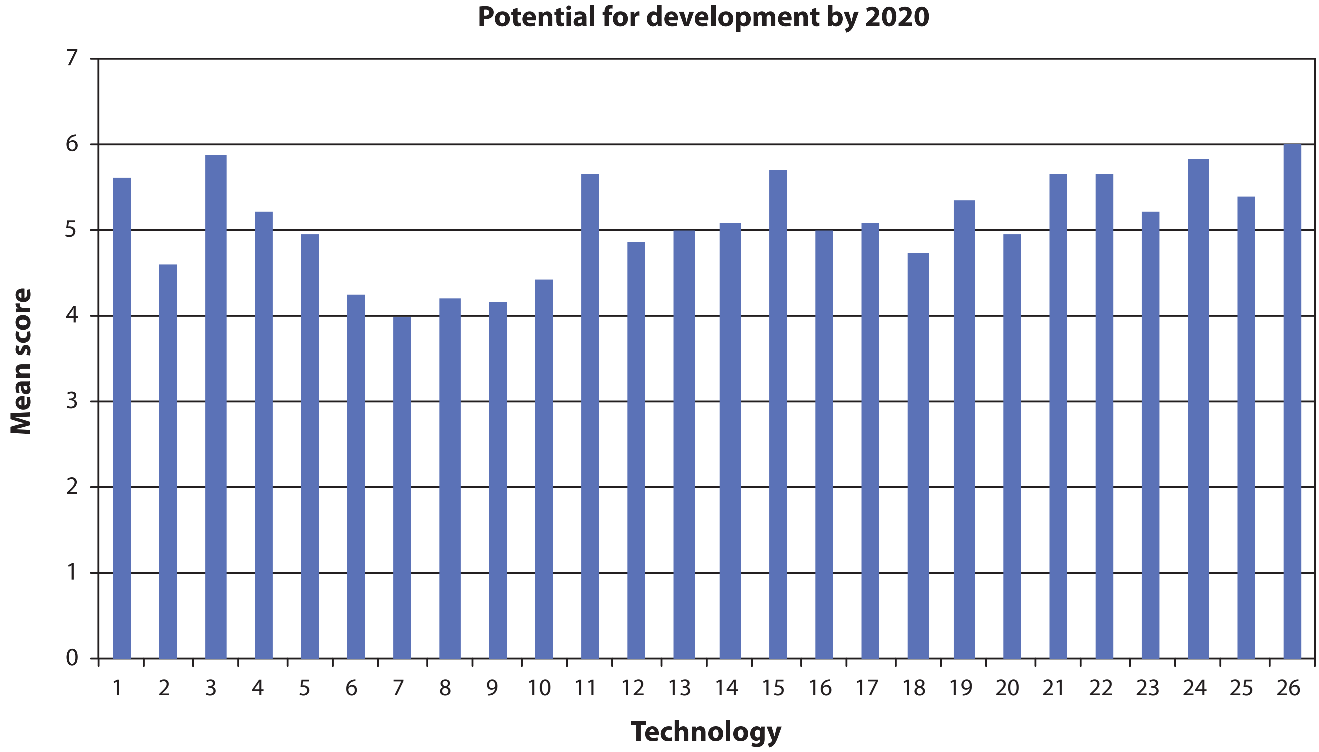

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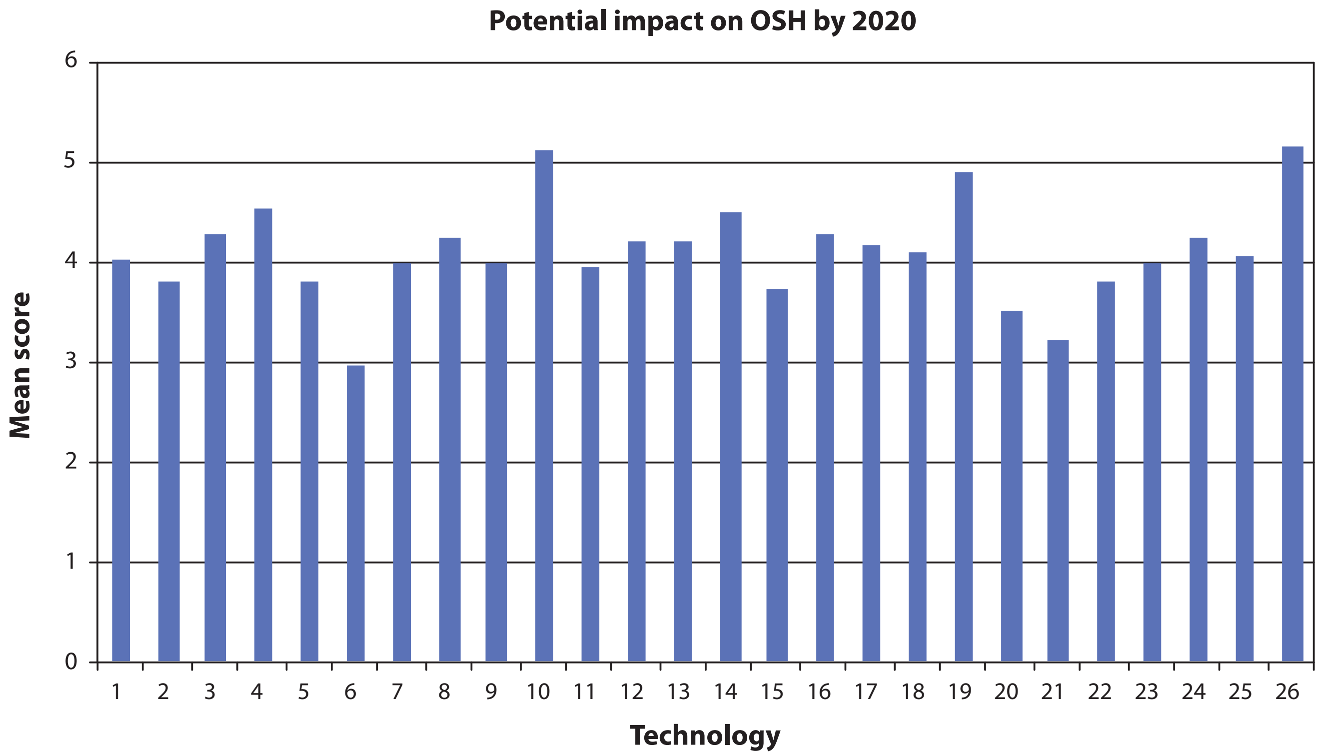
Figure 9: Results of potential for OSH impact scoring



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Annex 12: Scenario 4

Introduction

The scenario development process generated a fourth scenario not further used in Phase 3. This scenario was characterised by low economic growth, weak green values and low levels of innovation. With few green jobs and fewer new technologies, it was considered that this scenario would have little value in exploring the focal question of the project (new and emerging OSH risks from new technologies in green jobs) and was not considered further.

The development of this scenario was therefore curtailed early in Phase 3 and the description following is not at the same stage of completeness as the other three that were retained.

Scenario 4 Definition

Low economic growth
Low 'Greenness'
Low levels of innovation

Despite the green rhetoric, low economic growth means that governments do not impose the costs of green policies on electorates who are focused more on jobs and feeding their families.

Resource use and carbon emissions are rising slowly in line with slow economic growth.

Low economic growth

Europe and OECD countries have achieved little or zero economic growth in real terms, and are plagued by sovereign debt problems. The BRIC countries suffered a retrenchment after the boom years of 2000–10, and reverted to the more usual boom-bust cycles of emerging markets, averaging half their earlier rates of growth (at around 5 % per year) Other developing countries manage growth that more or less keeps pace with their growing populations, so that incomes per capita are static in real terms.

Social and work aspects

People cut back on spending, and are less inclined to travel.

High unemployment and lower corporate profits has undermined the tax base that used to allow European governments to pay for generous welfare programmes.

People fear for their jobs.

Businesses focus on survival and reducing costs.

OSH aspects

Lower economic value assigned to human life, making it more difficult to justify higher investments in health and safety.

Investments needed to make infrastructure and business processes safer and more accessible are a cost to the economy.

Slower roll-out of new technologies and new products means that there is more time to assimilate potential new hazards and new risks.

Low greenness

Environmental degradation is seen as an unavoidable consequence of progress.

Advances in the science and improved environmental models show that vulnerabilities to climate change and the loss of ecosystems services will not happen for decades anyway.

Fossil fuel energy and other resources have remained available at prices high enough to have encouraged investment in new sources of supply. The environmental consequences of increased use of resources (minerals, food, energy) are seen as acceptable and necessary.

Lip service is still paid to green measures and environmentally sound business practices, but funds for green investment are limited to those areas that show a positive accounting return, particularly reducing resource use in some industrial processes and better insulation in new buildings.

Social and work aspects

People value progress and economic well-being. They tend not to value the environment and nature.

There are a limited number of green jobs. Green jobs that do exist are self-financing in that they are economically profitable activities.

Consumers tend not to choose green products and services, and this does not encourage green employment. Governments have no mandate to regulate in favour of green jobs, let alone subsidise them.

Picture credit: US Environmental Protection Agency, Public domain.

OSH aspects

OSH is seen by employers as most important in terms of its impact on profits.

OSH is an area of low priority for governments.

Low levels of innovation

Technology is taking longer and longer to deliver on its promises.

In energy sciences, there have been few really new breakthroughs in recent years.

Moore's Law is breaking down as integrated circuits reach their physical limits; biosciences continue to produce new findings and new organisms, but many products from living systems are self-limiting in the way that overuse of antibiotics provoked the development of resistance.

Many scientific breakthroughs that were 10 years away in 2012 are still 10 years away.

Reinforcing mechanisms

The promise that new technologies would underpin sustainable green growth has not materialised, and faced with the choice between long-term green outcomes and short-term economic benefits, the short-term view always wins.

High prices for resources (oil, energy, water, minerals, food), driven by scarcity, and high costs of extraction, act as a brake on economic growth.

To reduce budget deficits over the past decade, governments have cut research budgets, stopped subsidising green industries, and have systematically attacked excessive profits in industries from pharmaceuticals to financial services.

European Commission

Green jobs and occupational safety and health:
Foresight on new and emerging risks associated with new technologies by 2020
Report

Luxembourg: Publications Office of the European Union

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