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

Summary

European Agency for Safety and Health at Work

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

Summary

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1. Introduction

The European Union (EU) is committed to a 20 % reduction in greenhouse gas emissions [1], a 20 % increase in energy efficiency and a 20 % increase in the market share of renewable energy by 2020 (European Commission, 2010). Meeting these targets on renewable energy and energy efficiency alone has the potential to create over 1 million new jobs. If not enough consideration is given to occupational safety and health (OSH) in these new 'green' jobs, the health and safety of many workers will be compromised.

However, in the area of OSH, policy and practice focus too often on reacting to existing risks and problems. The need for forward-looking efforts to 'anticipate new and emerging risks' was already underlined in the Community strategy 2002–06 (European Commission, 2002); the second Community strategy 2007–12 (European Commission, 2007) particularly emphasised 'risks associated with new technologies' as an area where risk anticipation should be enhanced.

With the impetus to green the economy, associated with a strong emphasis on innovation, it is therefore important to anticipate new and emerging OSH risks in these developing green jobs in order to ensure decent, safe and healthy working conditions. Green jobs should indeed not only benefit the environment but also workers. This is the key to the smart, sustainable and inclusive growth of the green economy, meeting the objectives of the EU 2020 strategy (European Commission, 2010).

This document summarises 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) by a consortium of the United Kingdom's Health and Safety Laboratory, SAMI Consulting and Technopolis Group. It synopsises a longer report (EU-OSHA 2013) that gives more detail on the methodology and findings. Available at: http://osha.europa.eu/en/publications/reports/green-jobs-foresight-new-emerging-risks-technologies/view

A scenario-building method was used for this foresight. The outcome of the project 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, trade unions and employers, so that they can take decisions to shape the future of OSH in green jobs towards safer and healthier workplaces.

(1) Compared to 1990 levels. The target is a 30 % reduction in greenhouse emissions 'if the conditions are right', that is, '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).

What are green jobs?

There are many definitions of 'green jobs'. An often-quoted one is that used by the United Nations Environment Programme (UNEP, 2008). This defines

> *… 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; de-carbonise 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 mentioned above.

'Green jobs' may also extend beyond 'direct' green employment into the supply chain. 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.

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 a huge scope. At the kick-off meeting for this project, EU-OSHA's European Risk Observatory (ERO) clarified its requirements and its 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 for other jobs, for example the transport of green goods done in the same conditions as for other types of goods, were not of interest. Novelty was of more interest than the increase or decrease of known risks. The focusing of attention in this way made the task more manageable and potentially more useful.

Introduction to scenarios

Scenarios are tools used for strategy development. They are internally consistent descriptions of how 'the world' or issues being considered might look like in the future; they are not predictions or forecasts, but describe possible future outcomes (Porter, 1985), based on an analysis of drivers of future change and of uncertainties. Each scenario considers a different possible outcome for each driver of change and for the most important uncertainties.

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 events will indeed happen, unfold or be interlinked as described in the scenarios. There are many more possibilities, and the future will most probably contain some elements of all these. Envisaging these different situations is simply an instrument to trigger discussions on how to be prepared for these different elements and possibilities of the future.

Scenarios are important because the future is uncertain and largely unknown and they provide a tool to help to understand and manage an uncertain future. While policies are often driven by an 'official' view of the future, scenarios integrate an analysis of drivers of change, critical uncertainties and pre-determined elements. They also provide a space (the future) removed from the constraints of the present and therefore facilitate discussion between different groups of stakeholders about the future. They can therefore be used for detailed analysis of future issues in order to inform decisions to be made today, and to support the development of more robust 'future-proofed' strategies and policies tested against different assumptions (see Figure 1). They can be more engaging than statistics or policy papers to describe strategic issues and they can be an important tool for organisational learning.

Project phases

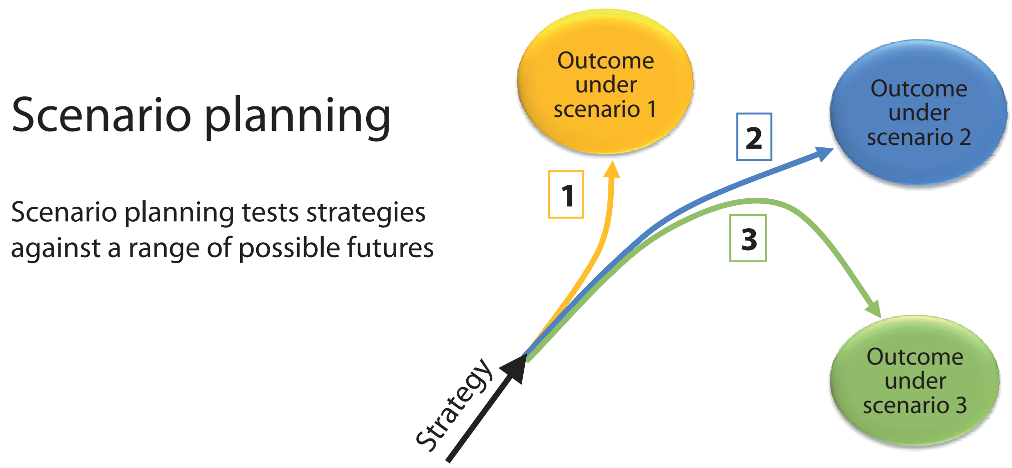
This project was conducted over three phases.

Phase 1: The first phase was to select the **key contextual drivers** (such as socioeconomic and demographic factors, and European and international political agendas) that could shape green jobs and workplaces by 2020 and contribute to creating new and emerging OSH risks associated with new technologies. These drivers were then used to define the 'base' scenarios in phase 3.

Phase 2: The second phase selected **key new technologies** that may be introduced in green jobs by 2020 and may lead to new and emerging risks in the workplace.

Phase 3: The third phase of the project developed the **scenarios**. This phase started with the production of three 'base' scenarios with the key drivers of change identified in phase 1. The 'base' scenarios were then used through a series of technology workshops to explore the development of the key technologies selected in phase 2 and the new and emerging OSH risks to which they could lead. The information gathered in these workshops informed the production of the 'full' scenarios. These scenarios were finally tested and consolidated in a final workshop, which also served to demonstrate how the scenarios can be used to develop policy options addressing the emerging OSH challenges identified.

Figure 1: **Use of scenarios for strategy planning**



2. 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 involved three aspects:

- a review of the literature on contextual drivers of change, resulting in an initial list of 69 drivers;
- a consultation exercise carried out by means of interviews with 25 key people covering a variety of backgrounds and experience in order to bring a range of views to the exercise, and a web-based survey (49 replies) to consolidate the list of drivers; and
- a voting exercise (with 37 participants) to prioritise the drivers and produce a list of suitable key drivers to be used in phase 3 of the project.

As a result of this process, 16 drivers of change were identified as having the greatest importance:

1. environment: carbon emissions, effects of climate change (temperature rise, natural disaster), shortage of natural resources (fossil fuels, water);
2. government incentives: policies, grants, loans, subsidies for green activities;
3. government controls: taxes, carbon pricing, duties, legislation;
4. public opinion: the public's views on climate change and its causes;
5. public behaviour: demand for green products, support for recycling;
6. economic growth: the state of European economies and availability of resources to tackle environmental issues;
7. international issues: the effect of globalisation on the EU and other economies, and its effect on competition for scarce natural resources, driving the need for green activities;
8. energy security issues: the need for energy security, the desire to reduce the dependency on energy imports;
9. renewable energy technologies: progress in their development and availability;
10. fossil fuel technologies: the development of technologies to allow continued use of fossil fuels (such as carbon capture and storage, and clean coal technologies);
11. nuclear energy: the extent of its use, and whether it is regarded as 'green';
12. electricity distribution, storage and use: the development of technology to allow increased decentralised renewable electricity generation;
13. energy-efficiency improvements: energy-efficient new buildings, retrofit for old ones, promotion of energy-efficient public transport, less energy-demanding manufacturing, and so on;
14. growth in waste and recycling: driven by resource shortages, public opinion and legislation;
15. other technologies: the availability of non-energy technologies, such as nanotechnologies, biotechnologies; and
16. 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.

3. Phase 2 – Key new technologies

The aim of phase 2 of the project was to identify and describe the key new technologies that may be introduced in green jobs by 2020, and which may lead to new and emerging risks in the workplace. It involved three aspects:

- a review of existing material on technological innovations that may be introduced in green jobs by 2020, which resulted in a list of 26 technologies or technology areas;
- a consultation exercise with interviews with 26 OSH and technology experts in order to consolidate the findings from the literature review and to capture technological innovations that may not yet be described in published material; this was followed by a web-based survey (38 respondents) and led to a consolidated list of 34 technologies or technological areas; and
- the selection of the key technologies to be explored in phase 3 of the project, based on all the information gathered through the above, and informed by a workshop of 14 invited OSH and technology experts.

The technologies first considered in this phase related to a range of sectors such as energy; transport; manufacturing; construction; agriculture, forestry and food; waste, recycling and environmental remediation; biotechnologies; green chemistry; novel materials, including nanotechnologies; convergent technologies; photonics and geo-engineering. 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 one of the phase 3 technology workshops focused on these. Some of the technologies initially identified were related to specific industries, and others were cross-cutting technologies that impacted on many sectors and many of the other technologies identified (such as 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.

'Nanotechnologies and nanomaterials' were felt to be a major issue but transversal to all other technologies/technological applications selected. Rather than having a workshop dedicated to nanomaterials in phase 3, it was therefore decided to address these transversally in all other technology workshops.

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 (offsite construction/prefabrication), new materials (low-carbon cements, nanomaterials), increasing use of ICT and robotics and automation
Bioenergy and the energy applications of biotechnology	Biofuels (diesel, ethanol and so on), 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

Technology	Subtopics
Green transport	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 (with ICT applications), refuelling/ recharging infrastructure
Green manufacturing technologies and processes, including robotics and automation	Advanced manufacturing techniques, distributed manufacture (such as personal fabrication, 3D printing and rapid manufacture/rapid prototyping), lean methods, biotechnologies, green chemistry, nanomaterials Used 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 (for instance, pavements/bricks/asphalts 'capturing' environmental pollutants, nanocoatings/nanopaints transforming solar energy into electricity, 'green' anti-fouling nanocoatings), agriculture and forestry

4. Phase 3 – Constructing the scenarios

Each of the 16 drivers of change selected in phase 1 was reviewed and the uncertainty inherent within that driver over the period to 2025 (instead of 2020) was identified. A period beyond 2020 was used so that risks of which early signs might emerge in 2020 could be identified.

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

- economic growth: includes both the external impact of global growth and growth in Europe, and determines the availability of funding for green activities;
- green values: 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: development and exploitation of green technologies that 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, and innovation in green technology) was associated with a single axis defining its state. The scenario-building process started with the two axes of economic growth and green values. Selecting 'low' or 'high' values for each of these two axes generated four scenarios (see Figure 2).

Scenario 4 with low economic growth and weak green values was considered as irrelevant for this project as it would result in few new and emerging OSH risks from new technologies (as a result of a low innovation rate in the context of low economic growth) in green jobs (as a result of weak green values). It was therefore decided not to further explore this fourth scenario in the context of this project.

The third axis is the rate of innovation in green technologies. This is linked to the two previous axes: economic growth, which will influence the total level of innovation; and green values, which will influence the green proportion of the innovation. Combining the three axes therefore resulted in the three scenarios described in Table 2. Although the overall level of innovation was likely to be higher in the 'bonus world' scenario than in the 'deep green' scenario, it was argued that the level of green innovation was likely to be slightly higher in deep green (as a result of the strong green values) than in bonus world (assumed to be more driven by a profit motive). These two scenarios would therefore have similar rates of innovation in green technology, but the nature of this technology would be quite different. These levels were therefore specified as 'medium +' and 'medium –' respectively. The relationship between the rates of green innovation in the three scenarios is shown in Figure 3. (Note that these descriptions are subjective assessments, and not quantified measures).

Figure 2: **Four scenarios plotted by economic growth against green values**

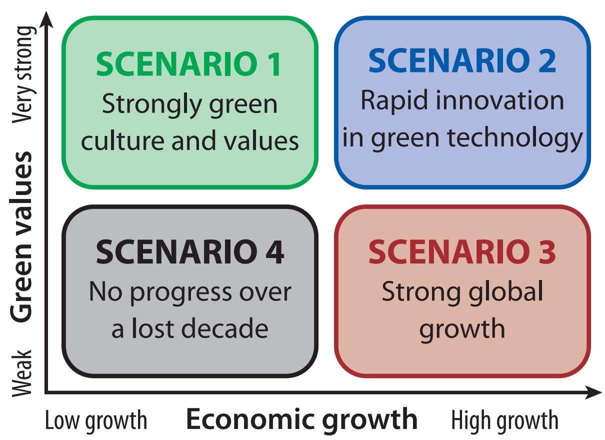
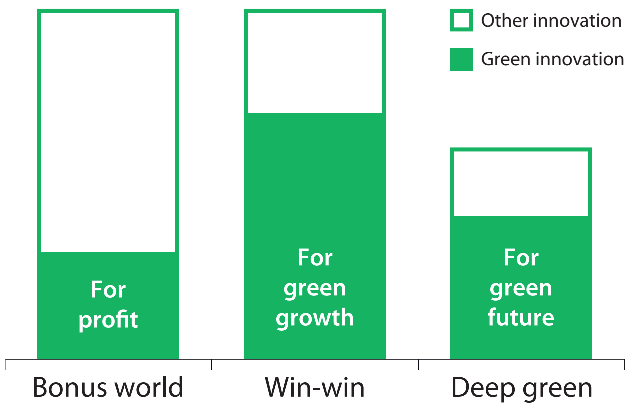


Table 2: **Three base scenarios defined**

Axes	Scenarios: Win-win	Bonus world	Deep green
Economic growth	high	high	low
Green values	strong	weak	strong
Innovation in green technologies	high	medium –	medium +

Figure 3: **Qualitative representation of the level of green innovation shown as a proportion of total innovation**



It is important to note that the names given to the three base scenarios reflect their respective characteristics with regard to the three axes defined but do not reflect the state of OSH in these worlds.

Bonus world: This reflects people's choice of the route of increased prosperity when faced with the cost of going green. Technology continues to help more efficient use of resources but this translates into continuing increases in consumption.

Win-win: The respective wins are that green activities are seen as a major contribution to economic growth, rather than simply a cost; and that technology is delivering on its promise to make green growth achievable. It does not imply that it is all 'win' on OSH.

Deep green: This reflects the strong green values, with green activities being seen as a cost that needs to be borne, even at the cost of economic growth.

The three base scenarios were then used as a basis for the phase 3 technology workshops. In these workshops, the potential developments of the key technologies from phase 2 and the potentially associated new and emerging OSH risks were explored in the context of each base scenario. This generated the full scenarios.

A final workshop was held in order to test and refine the scenarios produced with policymakers as well as OSH and technology experts. During this workshop, the scenarios were also used in exercises aimed at demonstrating the potential value of scenarios in policymaking and strategic planning. Participants were asked to develop specific policy options for each scenario, addressing the respective OSH challenges and opportunities identified, and to review these policies across the three scenarios in order to test their relevance and robustness as well as how they would be implemented in each scenario.

The scenarios generated through this process are presented in the next section.

5. Scenarios and overview of new and emerging OSH risks

The version of the scenarios presented below is a tool for further exploration of emerging OSH risks in green jobs or for use in policymaking workshops. The scenarios all look back from 2025. (The year 2025 was chosen rather than the 2020 of the project title, in order to stretch thinking so that changes after 2020 the early signs of which might only be evident by 2020 would be included). More extensive information on the OSH issues identified in relation with the key technologies in each scenario is available in the full report of the project. It synopsises a longer report (EU-OSHA, 2013) that gives more detail on the methodology and findings. Available at: http://osha.europa.eu/en/publications/reports/green-jobs-foresight-new-emerging-risks-technologies/view

5.1. 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 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 ones 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 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 taking OSH into consideration.

Win-win OSH general

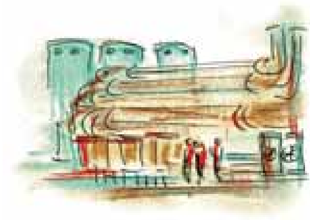
In a buoyant economy, funds are available for investments in OSH, but the high pace of innovation and the rapid roll-out of new technologies and new products and the creation of new jobs requiring new skills mean that a wider population may face new risks over shorter timescales. It is therefore important 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.

Cartoon 1: **'Win-win' - context**

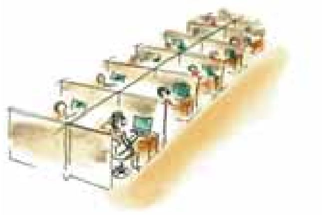
Cartoon 2: **'Win-win' - human systems**

'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'

The high pace of innovation results in skill shortage and in a sectoral competition for qualified staff, eventually leading to a polarisation of the workforce with regard to skills.

Wind energy

The target of 230 gigawatts (GW) of installed capacity in 2020 (EWEA, 2012) was met. Now in 2025, good progress is being made towards 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 megawatts (MW). Large turbines have been designed specifically for the marine environment, including for installation in deeper offshore locations.

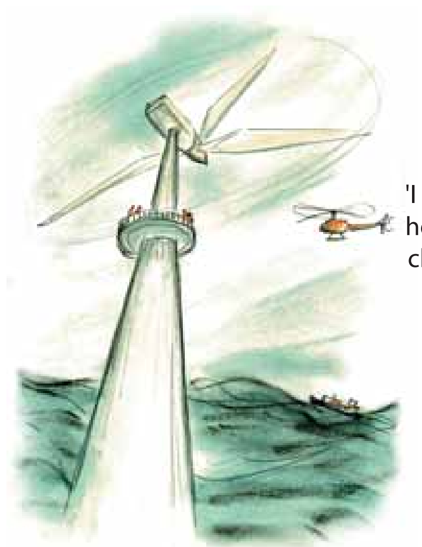
The foundations in shallower water have improved and the innovations in deeper water have included floating installations. Accommodation platforms have also started to appear in wind farms further offshore.

The risks are multiplied many-fold in offshore wind farms, which have the potential to become highly dangerous work-sites. With so many large turbines in ever-deeper water, ever further from a 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.

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'

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 the 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 in minimising unpredicted maintenance, and the 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 (such as 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. Photovoltaics (PV) are integrated into buildings or painted on; and provision is made for charging electric cars and using them for energy storage.

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

Onsite issues arise from mixing automated activities with traditional, manual ones. There are risks during connection of services (water and electricity) with the pre-fabricated modules, but with 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 and so on. 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 structure or drilling into existing cabling.

Combinations of new energy sources in buildings (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 or exposure to lead and asbestos as they disturb old structures.

Cartoon 4: **'Win-win' - construction**

Cartoon 5: **'Win-win' - bioenergy**

'Well, according to the diagnostics, there should be no problem. The automatic risk assessment shows 99.99% safe... But something isn't right...'

'So .... Have you thought about:
• Shortage of skilled labour,
• Non-zeroed instruments,
• Outsourced consultants,
• New maintenance schedule,
• Out-of-date specifications,
• Cost-cutting management,
• Obsolete safety & health regulations ....
• Unknown unknowns?'

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 the 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 combined heat and power (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 GM bacteria, are now common in transport. And third-generation fuels have been developed.

The storage and handling of biomass exposes workers to physical risks, to 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 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 (for example, 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 lifecycle 'cradle to cradle' approach to production, which minimises waste.

Regulations require the use of recycled materials over new materials wherever possible. New types of material and products (such as 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 lifecycle. Building codes encourage new construction materials and 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 the range of materials to which workers are potentially exposed is very large. Increasing volumes of waste result in difficulties in identifying the provenance and composition of waste. However, improvements in the labelling, tracking and audit 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 serves to improve workers' health and safety.

The zero waste economy entails dealing with the most difficult tail-end of the waste stream, as 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 (closely-spaced vehicles following each other automatically) on motorways; 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 the sequence of subway trains, suburban trains, trams, buses, cars on motorways. And there is now increasing acceptance for 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

Cartoon 7: **'Win-win' - transport**

'Do you think this new “platoon” technology is going to be totally safe?'

'How safe is safe? ... At least I can catch up on my e-mails whenever I want' if the driver does not take control again at the end of the automated chapter.

Elsewhere, small city delivery trucks, and public transport (including buses) are electrified. Multi-modal road–rail freight transport is now used for long distances.

Information and communications technology (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 the 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 electric vehicles (EVs) and after accidents.

Driverless vehicles and platooning 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 key, with fail-safe modes in the event of accidents, problems or failures.

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 (such as addressing disabilities) to the workplace to increase workers' performance.

Sustainable design has become the prevailing philosophy, with whole-lifecycle assessment of products and processes. Many new materials and nanocomposites that are used are lighter, with higher 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 skill 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, but at the same time the growth in the use of collaborative uncaged robots has introduced other potential risks.

Increasing complexity and increasing ICT in automated manufacturing has brought human–machine interface issues. Some types of robot malfunctions 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**

'Now that robots or "co-bots" do most of the work.... What's there to worry about ???'

'Boredom ... insecurity ... Keeping up with innovation ... And, what if they do not keep out of our way...'

+++ THIS HUMAN HAS A POOR TRAINING RECORD+++ KEEP HER UNDER ACTIVE SURVEILLANCE +++

Domestic and small-scale renewable energy

Companies and individuals have invested heavily in alternative energy technologies in response to high energy prices. Government incentives have 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 (such as 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 to give, typically, five days of hot water.

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. 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 for 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

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, such as large-scale molten salt storage systems (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 to 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.

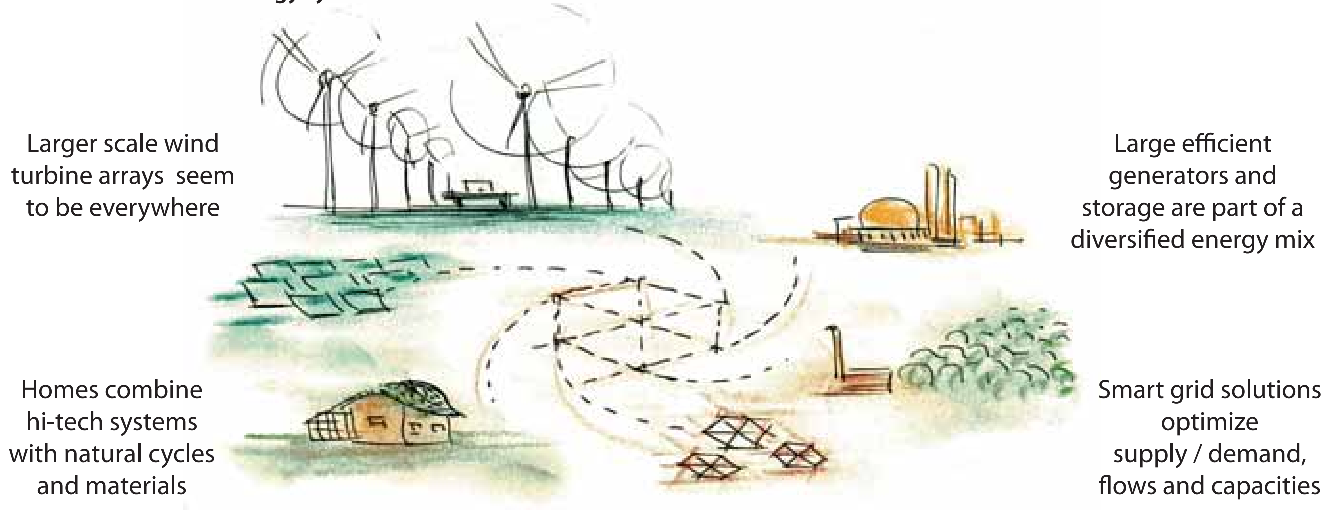
Domestic-scale battery energy storage is also now common as 'retired' electric vehicle batteries are used as static energy stores.

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 demanding 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 of work can lead to the use of inexperienced staff.

5.2. 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 (such as noise, pollution, landfill and traffic congestion).

Medium innovation in green technologies (directed towards profits)

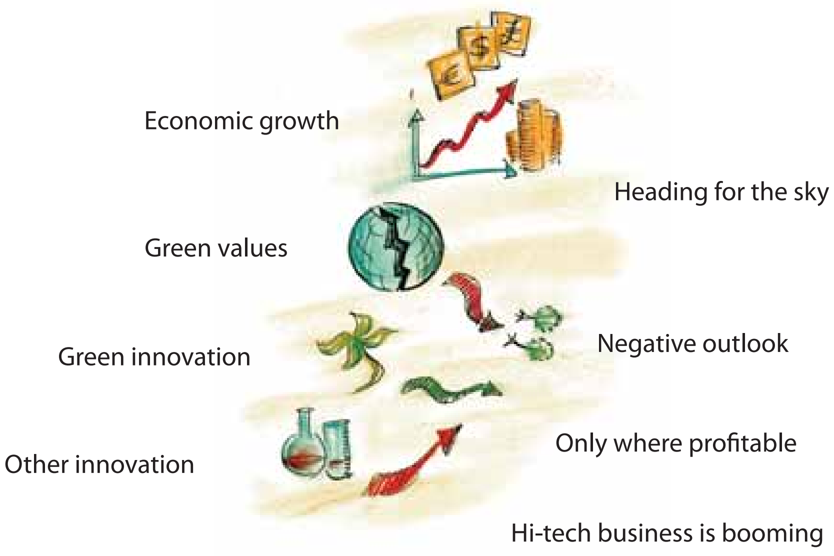
Most consumers and businesses choose green products and services only if they are better or cheaper than the alternatives. Innovations in green technologies are limited to those areas that show a positive financial return.

High total innovation

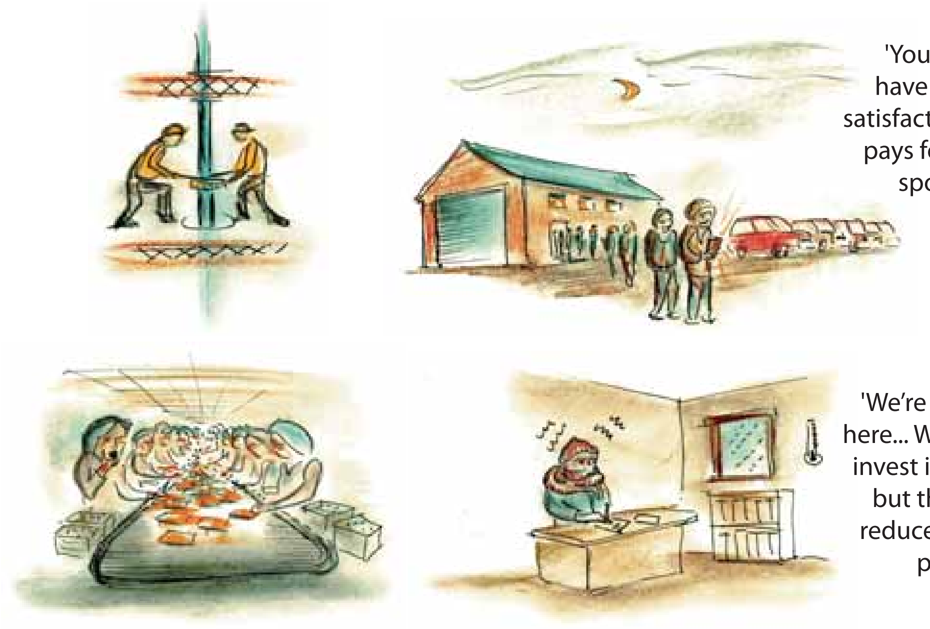
There are continuing advances in technology that get adopted into new products and processes. High levels of capital investment mean that capital-intensive technologies can be rolled out quickly. Corporate profitability and access to finance have supported high investment in infrastructure. The environmental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

Cartoon 10: **'Bonus world'- context**



Cartoon 11: **'Bonus world'- human systems**



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 for 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 at short timescales.

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.

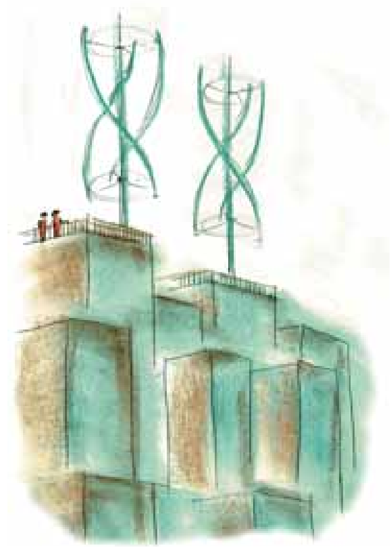
Most new wind farms are onshore and many are located nearer to the areas of highest demand. Planning rules and environmental impact assessments have been relaxed permitting more wind farm locations in built-up areas.

There are no subsidies or green tariffs to support the development of more expensive wind farms. When this support was withdrawn, 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.

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'

With smaller turbines, predominantly onshore, construction and maintenance are not so 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 pressure 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 so as to enable safe dismantling puts workers at high risks.

New composites and nanomaterials used for the manufacture of wind turbines have possibly introduced new health hazards for manufacturing, maintenance, decommissioning and recycling workers.

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, with ostentatious designs 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 pro-

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...'

duce energy, with PV tiles (incorporating new PV technologies) for retrofits.

Buildings are not designed for recycling and waste goes to landfill. Contaminated waste gets exported, or mixed with clean waste streams.

Subcontracting is used to drive down costs, leading to pressures on subcontractors to cut corners.

Offsite automated construction of modular buildings has improved onsite safety as far fewer tasks are undertaken there. However, as building moves into factories, new risks emerge as workers are exposed to novel substances.

Onsite there are electrical risks as old and new buildings have to be integrated into the smart grid, incorporating smart appliances, energy storage technologies and so on. 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 roofwork 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 attracts construction workers used to outdoor work, unaware of the need for proper indoor ventilation.

Bioenergy

There is plenty of waste to harvest for its energy content, and it is incinerated where it is profitable.

Biomass sources (forest and agriculture, and agricultural waste) get used by means of the most cost-efficient route. Coal, natural gas and oil power stations persist, supplemented by lots of small-scale localised biofuel and biomass CHP generating plants.

Second-generation biofuels (liquid fuels and chemical feed stocks from lignin and cellulose) became common, aided by rapid innovations in genetic modification 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, the 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.

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 this is cheaper than manual labour. High-value waste is recycled and the energy in dry waste is recovered.

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'

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?'

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 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 waste handling, but only where this 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 waste handling and are therefore potentially exposed.

In an increasingly complex world driven by profit, combined exposures can be an issue.

High waste disposal charges may lead to more in-house efforts by the waste producer to deal with waste, transferring risks from the professional waste operator to the waste producer, for instance business owners (including micro-enterprises and SMEs, as well as private individuals) using 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.

Electric vehicles (EVs) are sometimes used as city runabouts, but hybrids form the largest share 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.

Cartoon 16: **'Bonus world'- transport**

'Yes these ex-car batteries should be fine, no service record but never had any problem...'

'No need for guarantees... I just need 20 units for the home system'

A market has developed for selling batteries removed from EVs and hybrids to be used for energy storage in buildings.

Urban trains and trams are now mostly fully automated.

As with win-win, maintenance and the recharging of electric vehicles have become important hazards as they have become increasingly widespread and work has moved out from specialist suppliers and maintainers to independents.

The risks arising from the growth in EVs 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 and robotics

There are high levels of overall innovation and many new materials (including nanomaterials) and 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, such as 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, the goal. At the same time the growth in the use of collaborative robots has introduced other potential risks.

Increasing complexity and increasing 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, 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 risks (harmful dusts, chemicals or laser light) but not being adequately trained to deal with these.

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 at the same productionline 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

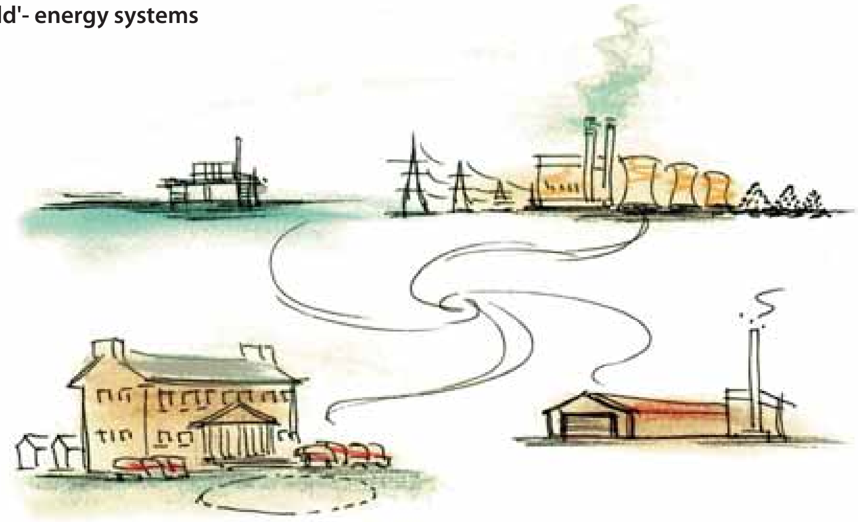
Cartoon 17: **'Bonus world'- manufacturing**

'I'll have a Zpad 4.2 ... in lime green and purple ... and a cup of coffee while I wait please'

'Hello - how may I help you??'

(....I used to work just in retail... Now I am expected to be a manufacturer as well. I just press the buttons and hope it is OK!)

Cartoon 18: **'Bonus world'- energy systems**



the last decade. 'Horror stories' of poor people being forced to upgrade their domestic wiring after the electricity meter has been 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, 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

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 (such as flywheels, ultra capacitors, batteries, compressed air and hydro) is used in the network

Cartoon 19: **'Bonus world'- resource limits**

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 batteries designs continue to appear, bringing potential risks from chemicals, carcinogenic metals, dusts, fibres, nanomaterials and risks from fire. Waste treatment of batteries raises issues around recycling, degradation and fire risk. It is challenging to determine the precise content of any particular battery type as this 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 continues to be significant growth in the demand for energy. There has been under-investment in the transmission and distribution networks and a smart grid infrastructure. The need for investment is now a major issue.

There have been investments 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 are 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.

5.3. Deep green

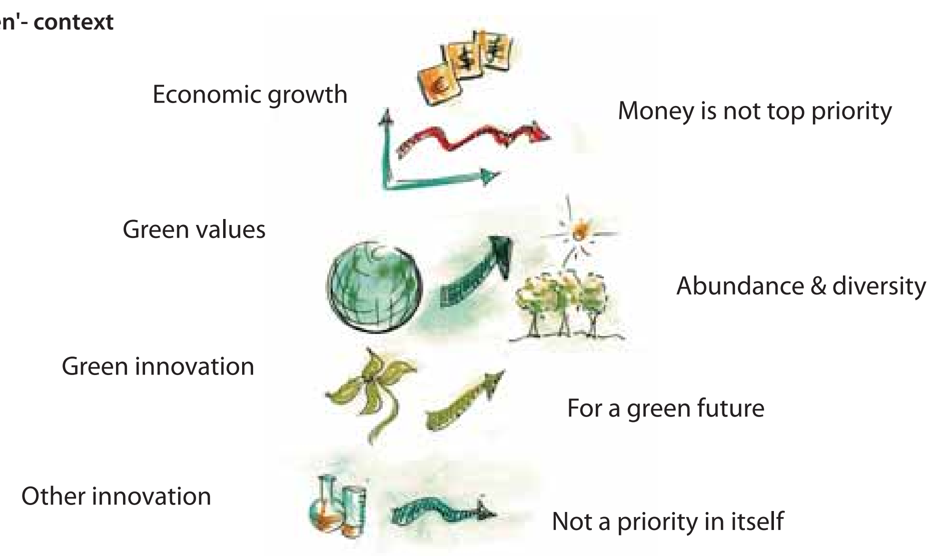
Low economic growth

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 the former high-growth rates and are currently growing at about 5 % per annum [2] . Other developing counties are growing at a rate broadly in line with their population growths.

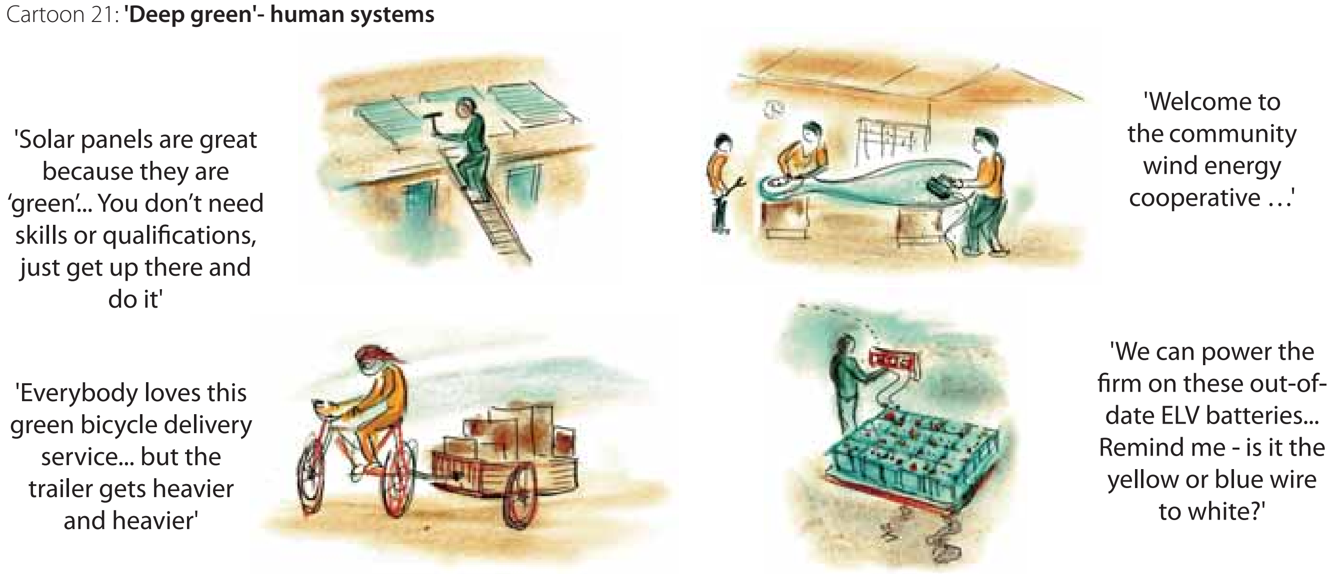
Strongly green values

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.

Cartoon 20: **'Deep green'- context**



Cartoon 21: **'Deep green'- human systems**



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 appropriate 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 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.

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 reduced consumption of energy and physical goods, most new jobs are in the service sector. Many new small businesses, often with skills deficits, arise 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, and so on) than in 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.

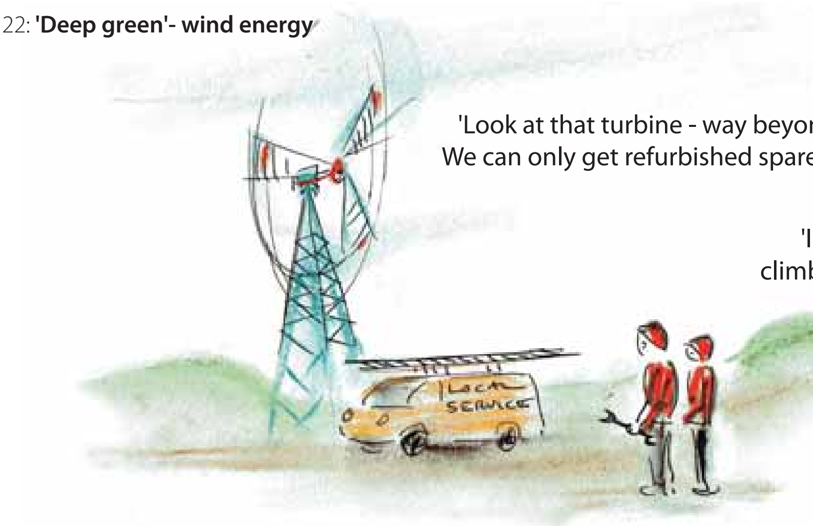
There are many new green processes and enterprises, all of which require new OSH procedures and training.

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

(1) The BRIC countries are: Brazil, Russia, India and China.

Cartoon 22: **'Deep green'- wind energy**



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 rebuild them. Also, as technology has improved, 1 MW turbines have been replaced by 3 MW installations on the same towers.

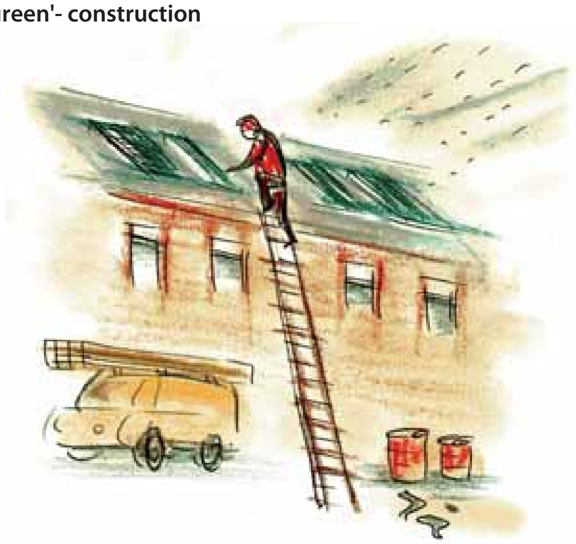
End-of-life issues and maintenance are the key OSH considerations. The economy requires the upkeep of older installations and there is pressure to keep systems running whatever the weather. Older wind turbines have not been upgraded with safety or ergonomic features, such as lifts, because of cost pressures; the physical risks associated with climbing and working in towers 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 used 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.

Cartoon 23: **'Deep green'- construction**



Cartoon 24: **'Deep green'- bioenergy and waste**

Government regulations and controls enforce buildings' energy consumption, including heating and cooling limits.

With relatively little new build, the main risks to workers come from exposure to new materials during refurbishment and 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 of sourcing energy and managing waste. 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 its associated land use have 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 creates risks that are more difficult to regulate, with many small-scale producers. New players, less familiar with the risks of handling fuel, such as 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 lifecycles 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 in collecting, sorting and recycling waste. Laws now mandate 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 high 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 on a small scale, meaning a potentially weaker OSH culture and more difficulties in controlling OSH risks in a decentralised system. In addition, there is a high component of manual work, 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 (for example, steel made from recycled metals containing lead).

Cartoon 25: **'Deep green'- transport**

'There's no vehicle that can't be repaired... That is, if you give it enough love...'

'If you can't get the spare parts, you can always bend some metal into shape...'

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 wherever 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, maintenance and charging of electric vehicles are key OSH concerns.

However, driven by the need to economise and by strong green values, an increase in two-wheeled vehicles for the transport of people and goods as well as for service deliveries has occurred, 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.

The counterpart is that the self-employed tend to have a weaker OSH culture and less access to OSH services, such as OSH medical surveillance and labour inspectorate services. Furthermore, they are generally not covered by the worker protection legislation

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 lifecycle and less consumption of mass-produced goods has reduced the demand for manufacturing. Some offshore production has come back to the EU.

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?'

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, repair and reuse: so-called '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 to extend their life. 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 micro-enterprises 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, for example 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. These have been made cost competitive by increased taxes on large nuclear and fossil fuel generators.

There is significant use of biogenerated energy resources. There is also a wide mix of technologies: biogas digesters; local hydro-electricity; waste incineration; and domestic combined heat and power.

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 distributed systems and non-standard installations is resulting in electrical risks to maintenance workers. The combination of technologies, for example 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.

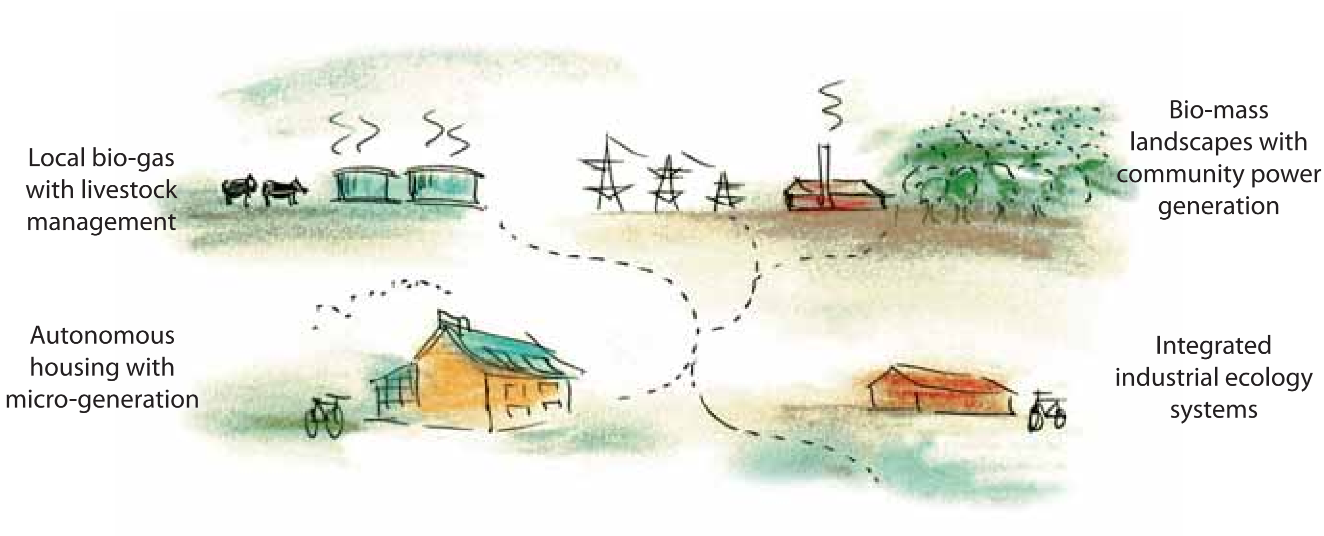
Small-scale bioenergy generation gives rise to risks of fire and explosion and exposure to toxic substances.

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.

Cartoon 27: **'Deep green'- energy systems**



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 of electric vehicles has also been slower than anticipated in 2012. Vehicle batteries are used for static storage after their peak performance has degraded.

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.

There is 'virtual storage' through measures being taken to match energy supply and demands. 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 place a limit on the range of materials allowed.

Interconnected mixtures of energy storage technologies devices, especially those assembled by do-it-yourself enthusiasts, bring unexpected risks to 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 been 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.

6. Conclusions

6.1. 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 raise to a variety of OSH issues, extensively described in the full report of this project (EU-OSHA, 2013). 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 a widely distributed nature of the work. As workplaces are therefore getting more dispersed and more difficult to reach, monitoring and enforcing good OSH conditions and safe working practices is likely to become more challenging. Decentralisation is the case, for example, 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 to control a complex grid linked to a two-way transmission.

The manufacturing sector is, for example, 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. An increase of 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 sub-contracted work as well as an increase in self-employment and 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' for the delivery of people, goods and services. The counterpart is that these economic structures may have a lower OSH awareness and 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 skill sets. There are indeed 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 equally requiring new specific skills. The installation of PV elements on roofs, for example, combines traditional construction risks together with 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 who are 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 new technologies competing with each other for highly qualified staff. This could result in a greater polarisation of the workforce, with low-skilled workers forced to accept poorer working conditions in more difficult and manual jobs, for example in waste collection and sorting, maintenance or repair, which are likely to increase with the green 'make-do-and-mend' attitude to increasing the lifecycle 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 pressure to take green actions generated by economic and political factors, such as subsidies and their withdrawals, may additionally contribute to OSH being overlooked. Besides risk 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 increase.

In general, there could be increasing potential for the release of novel, difficult-to-identify and potentially hazardous materials all along the lifecycle of green technologies and products, and in particular during end-of-life processing. The rapidly evolving technologies of PV, batteries, new construction material and new materials such as biomaterials and nanomaterials will need to be closely monitored over their entire lifecycle 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 offsite, automated construction of modular buildings is likely to improve onsite safety as construction moves into factories where good OSH conditions are easier to ensure. However, it 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.

If 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 to these new and emerging challenges. In any case, whether new or 'old' risks, the workplace risk assessment remains key to devising adequate prevention, with measures taking into account the specificity of the green job considered and of the workers involved.

Finally, all three scenarios highlight the need for a systematic, prior OSH assessment of any new technology, product and process at the development stage and for considering its entire lifecycle, from 'cradle to cradle' (meaning from the design, including manufacture, transport, installation, operation and maintenance, and into decommissioning, waste treatment and later reuse). Integrating prevention into the design is more efficient, as well as cheaper, than retrofitting OSH and needs to start now for safe future green jobs.

But this requires the thorough 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, architects and so on. Through 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 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 on 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).

6.2. 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 associated breadth of green jobs. 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 area that would need greatest adaptation would be 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 (corresponding to low growth, weak green values and low levels of innovation in green technologies) was not developed as part of this project, as it was not relevant to explore 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; and 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, which is both to mainstream OSH into innovation and technology development as well as to generate new insight in order to better identify future OSH challenges and needs, thus enabling a better targeting of actions and allocation of 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 are not met should be taken into account, for example, by 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 testing workshop. 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. They have proven to be a robust tool to support 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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