

**Foresight of New and Emerging Risks
to Occupational Safety and Health
Associated with New Technologies
in Green Jobs by 2020**

PHASE II – KEY TECHNOLOGIES



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Foresight of New and Emerging Risks to Occupational Safety and Health
Associated with New Technologies in Green Jobs by 2020

1. Introduction

This report describes the work carried out in Phase 2 of the project 'Foresight of New and Emerging Risks to Occupational Safety and Health Associated with New Technologies in Green Jobs by 2020' commissioned by the European Risk Observatory (ERO) of the European Agency for Safety and Health at Work (EU-OSHA). The aim of Phase 2 was to identify key new technologies that could contribute to creating new and emerging risks in green jobs by 2020. This report serves as an interim report to the whole project, which has three phases, described below.

2. Background

Over the last fifty years many of the occupational safety and health (OSH) hazards have evolved relatively slowly. The combination of the accelerating pace of technology change and the potential moves towards a green economy mean that it will be increasingly important to anticipate new and emerging risks.

The purpose of the project is to produce sets of scenarios for 2020, covering a range of new technologies in green jobs and the impact they could have on workers' health and safety. The aim is to inform EU decision makers, Member States' governments, trade unions and employers, so that they can take decisions in order to shape the future of occupational safety and health in green jobs towards safer and healthier workplaces.

The decision to pursue a scenario-building project arose out of a workshop hosted by the ERO in October 2008. The ERO wished to build on earlier forecast exercises, comprising Delphi studies in four different risk areas. These had produced useful summaries and the prioritisation of key risks as assessed by experts, but it was felt that in order to consider likely health and safety risks further into the future, an alternative technique should be used. The scenario-building approach was selected as a suitable vehicle to provide a forward look. In order to limit the scope to manageable proportions, new technologies in green jobs were selected as the target area. The rationale behind this choice was twofold. First, new technologies is an area where we are most likely to be confronted with new risks and the Community strategy on health and safety at work 2007-2012 emphasises 'risks associated with new technologies' as an area where risk anticipation should be enhanced. [1] Secondly, the impetus to 'green' the economy, associated with a strong emphasis on innovation in this sector, gives an opportunity to anticipate potential new risks in these developing green jobs and make sure their design integrates workers' safety and health.

The definitions of 'new and emerging risks' and 'green jobs' were discussed in the report on Phase 1. [2]

3. Project Structure

The project has three distinct phases:

- **Phase 1** involved the identification of key contextual drivers of change that could contribute to creating new and emerging risks associated with new technologies in green jobs by 2020. The drivers identified will be used in the generation of a set of scenarios. The results of Phase 1 have been published on the EU-OSHA website. [2]
- **Phase 2**, the subject of this report, was the identification of the key technological innovations that may be introduced in green jobs over the next ten years that may lead to new and emerging risks in the workplace or have a positive impact on workers' safety and health.
- **Phase 3** will comprise a series of workshops to be held across Europe to generate the scenarios, based on the findings of Phases 1 and 2.

4. Phase 2 – Key Technologies

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

- WP 2.1 – a review of existing material on technological innovations that may be introduced in green jobs by 2020 and may impact, positively or negatively, on workers' safety and health. [3]
- WP 2.2 – a consultation exercise using the expertise of key people who may be aware of important technological innovations not yet described in published material. This was carried out by interviews with experts and by a web-based survey to consolidate the list of technologies. [4]
- WP 2.3 – selection of the key technologies from the results of WP 2.2 that will be studied in Phase 3. The selection was based on all the data from Phase 2 and informed by a workshop of invited experts.

4.1 Work Package 2.1 – Review of existing information on technological innovations

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

4.1.1 Literature Review Methodology

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

OSH ROM: This contains bibliographic databases including: CISDOC (International Labour Office); NIOSHTIC (United States National Institute for Occupational Safety and Health); HSELINE; MHIDAS; RILOSH (Canada); MEDLINE OEM.

Web of Science: A bibliographic database containing Science Citation Index, Social Sciences Citation Index and Arts and Humanities Citation Index.

Dialogue: Databases searched - CAB Abstracts, Biosis Previews, NTIS, Wilson Applied Science & Technology Abstracts, Ei Compendex, New Scientist

STN: Databases searched - Healsafe, Environmental Engineering Abstracts, Abstracts in New Technologies and Engineering

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

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

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

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

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

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

4.1.2 Literature Review Results

Information on emerging technologies, their potential health and safety implications and their potential for development was extracted from approximately 40 selected references (see Annex 4 and section 6).

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

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

In identifying technologies it was important to pitch our classification at the right level to take forward into scenarios - not so narrow as to limit possibilities for interesting development pathways, but not too broad as to be unmanageable. The result is that for the most part we have identified technological areas, each of which may contain several related technologies.

In some cases a sector was classified as a technology area. This is a pragmatic approach and is consistent with the approach taken by European Technology Platforms, which treat several industrial sectors as discrete technology areas. [5] Inevitably, there is some duplication and some technologies appeared in more than one area. Table 1 gives a list of 26 technology areas and sectors and the links between them. Only significant links are indicated in Table 1. Thus, for example, while transport and construction have relevance in some way to all sectors and technologies, we have only noted links where new technologies contribute to transport or construction rather than the contribution of transport and construction to other sectors.

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

The technology areas identified are described in Annex 4 where, in addition to identifying technology areas, some information is given on potential developments and typical health and safety hazards associated with those technologies.

Table 1: Technology and sector list showing significant overlaps

	Energy	Transport	Manufact'ing	Construction	Agriculture, Forestry and Food	Waste, Recycling and Environm'tal Remediation
1. Wind	✓		✓	✓	✓	
2. Marine	✓		✓	✓		
3. Solar	✓		✓	✓	✓	✓
4. Bioenergy	✓	✓		✓	✓	✓
5. Geothermal	✓		✓	✓	✓	
6. Hydroelectricity	✓			✓		
7. Carbon Capture and Storage	✓			✓		
8. Clean Coal	✓					
9. Other Fossil Fuel Technologies	✓					
10. Nuclear	✓					
11. Electricity Transmission	✓			✓	✓	✓
12. Electricity Storage	✓	✓				✓
13. Battery Technology	✓	✓				✓
14. Hydrogen and fuel cells	✓	✓		✓		
15. Domestic and Small-scale Energy Applications	✓	✓		✓	✓	
16. Biotechnologies	✓		✓	✓	✓	✓

	Energy	Transport	Manufact'ing	Construction	Agriculture, Forestry and Food	Waste, Recycling and Environm'tal Remediation
17. Green Chemistry	✓		✓			✓
18. Novel Materials	✓	✓	✓	✓		✓
19. Nanotechnologies and Nanomaterials	✓		✓	✓	✓	✓
20. Robotics, Automation and Artificial Intelligence	✓	✓	✓	✓	✓	✓
21. Information and Communication Technologies	✓	✓	✓	✓	✓	✓
22. Transport Technologies	✓					
23. Manufacturing Technologies	✓			✓		✓
24. Construction Technologies	✓	✓				
25. Agriculture, Forestry and Food Technologies	✓					✓
26. Waste, Recycling and /Environmental Remediation Technologies	✓		✓		✓	

4.2 Work Package 2.2 - Consolidation of the list of technological innovations

The aim of Work Package 2.2 was to consolidate the results from WP1.1 using the expertise of key people who might be aware of additional technological innovations not yet described in published material.

4.2.1 Methodology

The consolidation stage was based on two consultation exercises.

In the first consultation exercise, twenty-five telephone interviews involving twenty-six selected individuals were carried out. The selection of interviewees was designed to provide a mixture of OSH experts and technology experts. In addition, we aimed to have a mixture of those consulted in Phase 1, to provide some continuity, and new consultees. It was not practicable to consult experts for each of the technologies, but in any case our view was that technology experts with a broader background would be better capable of comparing and contrasting the different technologies.

The second consultation exercise, run alongside the interview programme, consisted of a web-based questionnaire, to which forty-two responses were received. Participants were asked to score each of the technologies identified in WP 2.1 for their potential for development by 2020 and for their potential impact on OSH by 2020. In addition, each participant was invited to select his/her top technology for Phase 3.

4.2.1.1 Interview Programme

The twenty-six experts interviewed by the project team are listed in Annex 1.

Interviews were conducted by telephone and in most cases recorded, with the interviewee's permission, in order to facilitate accurate reporting. Interviewees were advised that interviews would be non-attributable, so comments could not be linked to any individual. Interviewees were advised that we were seeking their views as experts, rather than the official views of their organisation.

The question set used is given below:

Question 1

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

Question 2

Are there any technologies/sectors in the report that you think don't belong – i.e. they are not relevant to green jobs?

Question 3

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

Question 4

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

Question 5

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

Question 6

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

Question 7

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

Question 8

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

4.2.1.2 Internet Questionnaire

A questionnaire was created in the External Communities area of the HSE website.

The questionnaire contained the twenty-six technologies identified by the WP 2.1 literature review and their descriptions as shown in report D4. [3]

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

The questionnaire was publicised via articles in the Health and Safety Executive's Science and Research Outlook newsletter [6] and in EU-OSHA's OSHmail newsletter. [7] Overall, about 50,000 people were potentially exposed to the questionnaire.

4.2.2 Results

4.2.2.1 Interview Programme

The duration of interviews ranged from about 15 minutes up to a maximum of 55 minutes. The responses were combined in a workbook in which they were sorted by question and by topic. This provided a rich source of information and opinion, which was used to consolidate the list of technologies (Annex 4).

In general, interviewees were complimentary about the report on the literature review and felt it presented a comprehensive summary of the technologies relevant to green jobs. One interviewee noted that more information on the rate of development of the technologies listed would have been helpful. Some other general points came out in the discussions.

The first concerned application of the definition of 'new' as applied to technologies. It could be said, for example, that wind turbines are not strictly new. Certainly wind turbines have existed for many years. However, it could be argued also, that in the context of energy technologies, they are (relatively) new, and within the broad description 'wind turbines' there will be modifications and developments that are new within the discipline. Similarly, the component parts of carbon capture and storage are well established, but their combination on the scale envisaged in future is arguably a new technology. So we have to take a pragmatic view of what is generally perceived as 'new'. The use of interviews and the web consultation in addition to the literature search, as well as potentially identifying technologies not found by the literature review, assisted in the interpretation of what is regarded as 'new'.

Secondly, there was a mixture of views on the presentation of the technologies. At one extreme, was the view that some of the topics on our list are not technologies, but applications of other technologies, of which there are relatively few in a pure sense.

Some questioned the mixture of single technologies with technology groupings or sectors.

Others were quite happy with the way that single technologies and technology groupings or sectors appeared together in our list. Another wanted to roll up the technologies further.

Quotes

'For me there are only three basic technologies – bio, nano and ICT and the rest are applications.'

'I had difficulty with the way the information was presented. There is a mix between technologies and sectors and industries.'

'Some are singular and some are so broad. Energy is split up into little pieces.'

'Need to narrow these technologies down. For example, wind can be a windmill on a canal barge (not grid connected) to a giant 10 MW turbine. Need some form of breakdown of these technologies or we will lose some of our intended audience.'

'Novel materials is too broad for me. Nano should be in there.'

'I wondered about some of the groupings. I'd like to combine some of them. I wish we could put the energy ones together. Have the report think about energy technologies.'

'Biotech – I would group that with agriculture.'

'Under manufacturing I think you've done a sensible thing in bringing together advanced fabricating techniques, lean methods and separated out biotechnology and green chemistry and nanomaterials.'

If we define 'technology' as 'the mechanical arts or applied sciences collectively; the application of these' or 'a particular mechanical art or applied science' (New Shorter Oxford Dictionary), then a looser interpretation seems reasonable. So, for example, a grouping such as construction technologies is as valid in this project as, say solar PV. 'Biotechnologies' is an accepted term, but it describes a range of technologies. Again, we need a pragmatic approach. We need to have descriptions that are useful and manageable.

Lastly, the interpretation of the meaning of 'green' also came up. In the report we took the view that jobs that reduce the environmental impact of activities would qualify as 'green'. However, one view expressed in the context of cradle-to-cradle design was that *'It's no longer good enough if we just do less harm. Processes should not have undesirable outputs. We should change processes so they only produce good products and side products. Green should be about good only.'* Another view was

that we have to accept that we need to use natural resources and that to do so most efficiently is a green approach.

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

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

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

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

Photonics – the technology of transmission, control, and detection of light (photons), e.g. fibre optics and optoelectronics – was suggested as an additional technology. Like other 'new' technologies, it has been in existence for some years, but is now developing quickly and finding increasing applications. It contributes, for example, to ICT and to laser manufacturing. Like ICT, its applications will be relevant to green jobs, but not limited to them. Again, we included this for discussion at the workshop.

Other comments included:

- *'More should be included on the risks to the self-employed and the public from domestic and small-scale novel energy technologies.'* We added this to the description in the consolidated technology list (Annex 4).
- *'Solar PV and concentrating solar power should be separated as they rely on different technology and present different risks.'* We did this in the consolidated technology list.
- *'Waste and recycling could be separated.'* They are quite different and usually carried out by different people. Waste and recycling are often taken together, but the point was made that waste management and recycling are often carried out by different people with different skills. Also, recycling is becoming increasingly sophisticated. Therefore we tried separating them in the consolidated technology list and awaited the reaction of the workshop to this. As a consequence we also gave environmental remediation its own category and added geoengineering.
- *'The use of carbon dioxide as a new source for plastics.'* We added this to the description of green chemistry in the consolidated technology list.
- *'Eco-tourism. This is not a technology, but will be a source of green jobs.'* We did not add this to the list, as it is not a technology.
- *'Clean coal and CCS should be merged and CCS should include transport.'* Transport of CO₂ is identified in Annex 4. We did not merge CCS with clean coal as CCS is not limited to coal and can be applied to other areas, e.g. cement manufacture.

- *'Energy storage should include the use of molten salts and molten graphite.'* We added this to the description in the consolidated technology list.
- *'What about the cloud?'* We made this explicit in our ICT category.
- *'Hydroelectricity could include micro-scale as well as large and small scales, i.e. at the level of individual households.'* We added this to the description in the consolidated technology list.
- *'In addition to the electricity grid – what about the pipeline grid for hydrogen, CO₂, liquefied natural gas, biofuels, biogas etc.?'* We did not add this. Although there are issues, for example regarding the transport of hydrogen, or the injection of biomethane into the existing gas pipeline systems, we found no generic information on pipelines. Perhaps this is best dealt with under the individual substances.
- *'Manufacturing should mention formulation technologies as well as fabrication. Formulation has its own different skill set.'* We added this to the description in the consolidated technology list.

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

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

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

The responses to **Question 3** – on the technologies with the greatest potential for development by 2020 and **Question 4** – the technologies with implications for occupational safety and health are presented graphically in Figures 2 and 3 respectively in Annex 2.

The top eight technologies identified from the responses to Question 3 were: Wind Energy, Solar Energy, Nanotechnologies, Marine Energy, Battery Technologies, Bioenergy, Biotechnologies and ICT.

The top six technologies identified from the responses to Question 4 were: Nanotechnologies, Wind Energy, Biotechnologies, Solar Energy, Robotics and Automation and ICT. Nuclear Energy, Marine Energy, Green Chemistry, Transport and Construction shared sixth place.

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

Question 5 was not applicable in most cases.

Interviewees found **Question 6** challenging. Some referred to existing jobs, but there were several novel suggestions. Three different uses of outer space were identified by three interviewees – the use of space to carry out hazardous processes, colonisation of the moon and space tourism.

Quote 'One activity is Space Tourism. It is coming. There may be risks to the environment here. It might create some green jobs.'

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

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

The responses to **Question 7** – the preferred technology for inclusion in Phase 3 – are presented in Figure 4 in Annex 2. The clear favourite was nanotechnologies, with wind energy, bioenergy, CCS, domestic and small-scale energy applications, and waste and recycling all at equal second.

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

4.2.2.2 Internet Questionnaire

The purpose of the Internet questionnaire was to expose the results of WP2.1 to a wider audience than could be achieved by the interview programme alone. Although the survey could not gather the depth of information offered by interviews, it provided a source of endorsement of the findings of the interviews and the opportunity to identify any omissions.

Completed responses were obtained from 38 people from 21 countries, mostly in Europe, but also including the USA. This is a reasonable response for a survey of this type. [8] Respondents included predominantly health, safety and environment professionals and R&D professionals. Of those who gave the information, 10 were from public sector/government, 11 private sector, 9 research or academic, 3 trade unions and 5 others or not stated. Nearly all had a professional interest in green jobs, with 14 working in health, safety and environment, 15 in research and development, 4 in management, 1 in policy and 4 in other or undisclosed professions.

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

The mean scores given to each technology for its potential for development to 2020 and its potential impact on occupational safety and health are shown in Figures 5 and 6 respectively in Annex 3.

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

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

Figure 7 shows the technologies selected in response to the question 'If you could pick just one technology for Phase 3, which one would you choose? Nanotechnologies and wind energy came first and second, with waste and recycling and carbon capture and storage third and fourth respectively. Electricity transmission, nuclear energy and green chemistry were joint fifth.

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

4.2.3 Comparison between Interview and Web Survey Results

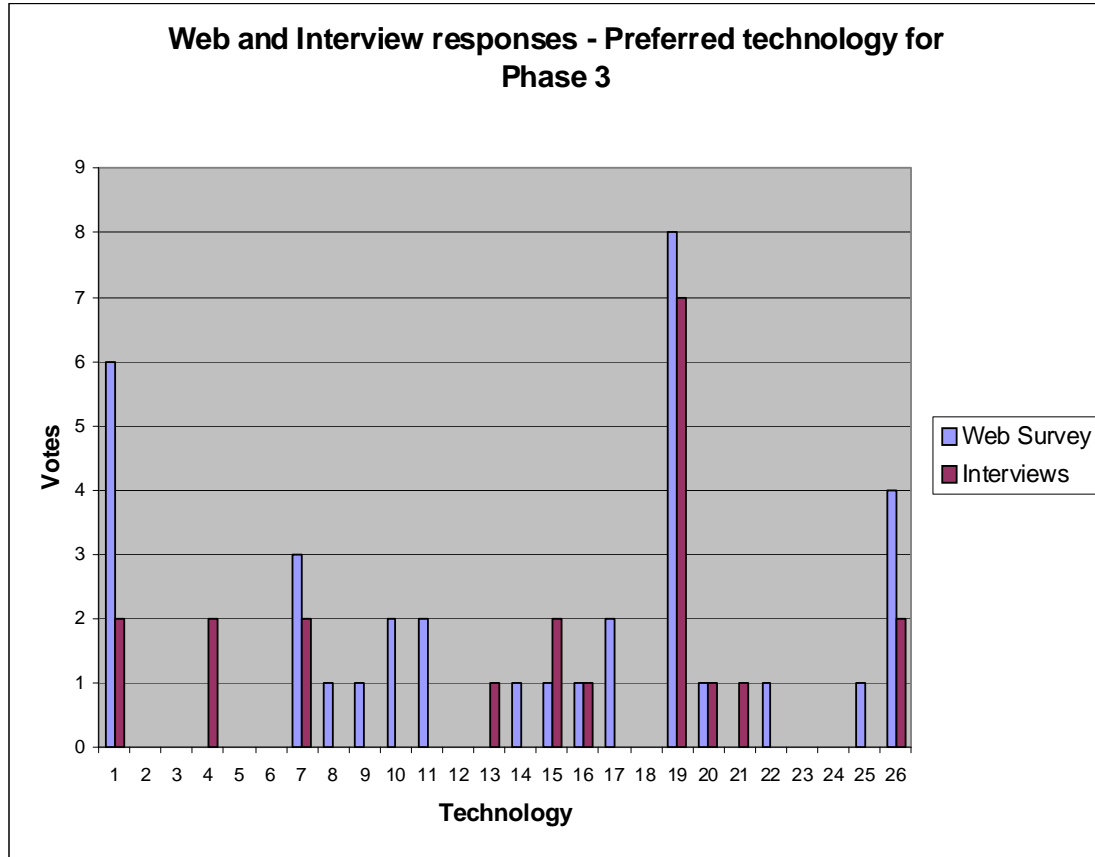
The quantitative results obtained from the interview programme and the web survey were not intended in themselves to determine the future of the project. Rather, they were intended to inform the participants in the workshop that will close Phase 2 of this project.

Comparison of the top eight technologies with potential for development show three matches between the interviews and the web survey – wind energy, solar energy and ICT.

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

Perhaps the most informative result was that nanotechnologies and wind energy were first and second in both exercises as respondents' top choice for inclusion in Phase 3. The combined responses are shown in Figure 1 below.

Figure 1: Combined responses – Preferred technology for Phase 3



Key to Technologies in Figure 1					
No	Technology	No	Technology	No	Technology
1	Wind Energy	10	Nuclear Energy	19	Nanotechnologies and Nanomaterials
2	Marine Energy	11	Electricity Transmission	20	Robotics, Automation and AI
3	Solar Energy	12	Electricity Storage	21	ICT
4	Bioenergy	13	Battery Technology	22	Transport Technologies
5	Geothermal energy	14	Hydrogen and Fuel Cells	23	Manufacturing Technologies
6	Hydroelectricity	15	Domestic and Small-Scale Energy	24	Construction Technologies
7	Carbon Capture and Storage	16	Biotechnologies	25	Agriculture, Forestry and Food
8	Clean Coal	17	Green Chemistry	26	Waste, Recycling and Environmental Remediation
9	Other Fossil Fuel Technologies	18	Novel Materials		

4.2.4 The Consolidated list of technologies

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

This is shown in Annex 4, which includes information on potential developments and typical health and safety hazards associated with the technologies listed.

In addition to the revised technology list, WP 2.2 also produced a great deal of information which has been recorded and will be carried forward for use later in the project.

4.3 Work Package 2.3 - Selection of Key Technologies

The aim of Work Package 2.3 was to select eight key technologies from the consolidated list of WP 2.2 for further study in dedicated workshops in the scenario work of Phase 3 of the project. The information gathered during the interview programme and the web consultation of WP 2.2 was supplemented by the discussions held and exercises carried out at an expert workshop held in Manchester, UK on 4 and 5 May 2011. The experts invited covered a range of technology areas and OSH; all members of EU-OSHA's European Risk Observatory Advisory Group were also invited. Some of the attendees had earlier been interviewed in WP 2.2. The workshop participants are listed in Annex 5.

4.3.1 Methodology

The agenda for the workshop is shown in Annex 6. The workshop began with two introductory presentations, one on the origins of the project and one on its design. The remainder of the workshop was structured around three sessions. The first two sessions had the same format and were aimed at producing a short-list, based on importance for OSH, of 18 main technologies (out of the 34 resulting from WP 2.2) to consider for possible inclusion in Phase 3 of the project – nine energy topics and nine non-energy topics. The third session was devoted to selecting the top eight technologies - out these 18 pre-selected - to be explored in more depth in workshops in Phase 3 of the project.

Each of the first two sessions started with a keynote presentation designed to review the relevant topics in order to refresh delegates' memories and to expand on the descriptions given in Annex 4 to bring the topics alive and put them in context.

Session 1 Energy Technologies

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

Her introduction covered:

- EU Energy demand to 2030 by broad sectors,
- Contributions to the energy supply from renewables, natural gas, oil, solid fuels and nuclear energy;
- Contributions to electricity generation from renewables, natural gas, oil, solid fuels and nuclear energy;

In both the last two of these the most notable feature was the increasing contribution from renewable sources.

Dr. Kenny then discussed trends under three headings.

Trends in energy sources showed:

- huge increases in renewables, particularly wind, solar, biomass and refuse derived fuel;
- some petroleum replaced by biofuels;
- increasing imports of gas, including liquefied natural gas (LNG);(*)

* In the past, regassing was done – onshore. This will increasingly be done offshore, but the Seveso Directive does not apply there. Also, storage will be needed for the increasing quantities of gas.

- a reduction in coal mining; and
- life extensions of ageing plant.

Trends in power/fuel generation showed:

- on and offshore wind, energy from waste and biomass, combined heat and power, ground/air source heat pumps, geothermal, wave and tidal;
- 1st, 2nd, 3rd and 4th generation biofuels;
- landfill gas, anaerobic digestion;
- carbon capture from large combustion plant; and
- new, safer and more efficient power plant.

Trends in distribution and storage included:

- one-to-many systems replaced by many-to-many;
- supergrids manage regional fluctuations in supply and demand across borders;
- smart meters and smart grids enable local supply and demand management;
- hydrogen, batteries and supercapacitors for local distribution and storage;
- relaxed gas quality standards to enable diversification of supply, which may have negative consequences on OSH, and
- pipeline transport and sequestration of CO₂.

Common challenges across the emerging energy sector are:

- engineering unknowns as technologies are upscaled to major industrial output (the potential for mechanical failure, risks from machinery);(+)
- availability of appropriate standards/guidance resulting in a lack of control of risks;
- anomalies in the regulatory regime resulting in inconsistencies across the sector; (#)
- a diverse range of duty holders, many new entrants with a lack of experience of medium and high hazard activities – applies to SME's and large organisations alike
- competency and skills shortages with consequent OSH risks (industry and regulators);
- interfaces across regulatory boundaries – licensing, OSH, environment with the potential for omissions at the margins;
- challenges with public acceptance at a local level; and
- infrastructure deficits as existing plant is relifed or put to new uses.

Dr. Kenny then described four key areas identified as being of interest to the UK – Carbon Capture and Storage (CCS), Wind, Liquefied Natural Gas (LNG) and Energy from waste, followed by a summary of infrastructure OSH challenges;

- Fragmented, ageing energy infrastructure needs updating and integrating;

⁺ Between now and 2020 many pilots that are now being tested to demonstrate the viability of green technologies/applications will be taken from the small-scale to the large-scale, which will present major OSH challenges. Once this is done, the technologies/green jobs might be safer as the hazardous ones will have fallen before that.

[#] For example, the applicability of existing OSH regulations to wind farms or LNG terminals outside national territorial limits or the applicability of existing regulations to the large scale transport and storage of carbon dioxide.

- Smart grids and smart meters are needed (47 m smart meters by 2020 in the UK alone) to support distributed generation and system balancing. OSH concerns include electrical risks and shortage of workers with the skills to undertake installation;
- Price pressures could drive outsourcing, i.e. less manufacturing, more installation;
- Green jobs may be concentrated in sectors with poor OSH performance; and
- Major skills shortages across all sectors.

Delegates were then asked, in small groups of two or three, to arrange cards bearing descriptions of each of the energy technologies (1-16 in Annex 4) in order in terms of their potential impact on OSH, while at the same time bearing in mind the aim of the exercise, which was to select technologies with the potential to give variation between the scenarios in Phase 3. They were allowed to merge technologies if they wished, but not to disaggregate them. After initial placement of the cards, there was discussion, aided by a facilitator, during which adjustments were made to the order of the cards until a final order was reached. There were differing opinions about the placing of nuclear energy and clean coal technologies. Although it was agreed that they had significant impact on OSH, there was disagreement about the green credentials of these technologies and on the usefulness of having Phase 3 technology workshops focused on these. However, it was emphasised that not having a workshop dedicated to these technologies in Phase 3 does not mean that they are not important components of the future and should not be part of the “landscape” of the scenarios produced, but simply that there would be no workshop specifically dedicated to them in Phase 3. Eventually they were discarded for the Phase 3 workshops. The top nine technologies were taken through to the third session.

The nine technologies selected were (Annex 4 numbers in brackets):

- Wind Energy (1)
- Solar Energy (3)
- Bioenergy (5)
- CCS (7)
- Electricity Transmission (11)
- Electricity Storage (12)
- Battery Technology (14)
- H2/Fuel Cells (15)
- Domestic and Small Scale Applications of Emerging Energy Technologies (16)

Delegates, working in three groups of five, each with a facilitator, were then asked to attempt to construct timelines showing expected developments in each the nine selected technologies between 2010 and 2025, and to list what they thought would be the key dependencies (factors that might affect the direction or rate of development of the technology) and uncertainties (those factors that might affect the development of the technology whose influence or own progress is uncertain). 2025 was chosen rather than the 2020 of the project title, in order to stretch thinking so that changes post 2020 whose early signs might be evident by 2020 would be included. Each group worked on three technologies. Feedback from this exercise was given in Session 3 (below).

Session 2 Non-energy Technologies

This session started with a presentation from Dr. Mike Pitts, of Chemistry Innovations Ltd, who covered a wide range of topics suitably illustrated with many interesting examples. The following is only a brief summary of a very comprehensive presentation.

He started with an overview of population growth, increasing consumption and an ageing population, global water stress and greenhouse gas emissions as significant drivers of the need for progress.

He then presented descriptions of the following technologies, covering key features benefits and likely development:

Biotechnologies/biomass

One of the challenges is the uncertainty over how to carry out risk analyses for synthetic biology organisms. Biotechnology benefits include energy saving, cleaner and shorter manufacturing routes, less waste and reduced greenhouse gas emissions. There is huge potential for growth.

Green chemistry

Green chemistry aims to reduce the use or generation of hazardous substances. The EU is a leader in this field.

Novel materials/nanotechnologies and nanomaterials

Novel materials, including nanomaterials have many useful properties and can offer a wide range of possibilities. However, the presence of nanomaterials in some products, for example foods and cosmetics, may not always be acknowledged in product descriptions, so users may not be aware of potential exposure and we do not yet understand the risks of nanotechnologies.

Robotics, Automation and Artificial Intelligence/ICT

These technologies offer many useful applications across all sectors, including communications, manufacturing, transport and agriculture. Robotics can help upskilling of jobs. Some of the ICT issues include the effect on privacy of a highly connected world, identity theft and proving your own identity, cyber-terrorism and network security. This opens up the potential for risks to key services, including safety critical applications.

Transport Technologies

Approximately 20% of greenhouse gases are generated by transport. Improved efficiency would offer savings. Electric vehicles, hydrogen, biofuels, and higher efficiency internal combustion engines have a role to play. Novel materials and additives can contribute to lighter and more efficient vehicles.

Manufacturing technologies

Manufacturing business models are changing, with increasing specialisation leading to outsourcing of non-core activities. New processes offer increased customisation. Products are being designed with end-of-life in mind – i.e. designed to be taken apart easily for reuse. An example is 'leased flooring' that can easily be taken up at the end of the hire period. Presently, for every tonne of household waste that is disposed of, there is a further 5 tonnes of materials that have been used in the manufacturing of the products consumed.

Construction technologies

Increasing city dwelling will see two thirds of the world's population living in cities by 2050. Currently 45% of carbon emissions are from buildings and 32% of landfill waste is from the construction industry (UK). Lower carbon construction and lower carbon buildings will be needed. Retrofitting of energy efficiency measures will be very important.

Agriculture, Forestry and Food

The food industry will need to increase yields, reduce waste and deal with phosphorus and nitrogen pollution challenges. Robotics can help farms to reduce waste of chemicals, and reduce exposure to chemicals by effective targeting of weeds.

Waste, Recycling and Environmental Remediation

Waste electronic equipment was used as an example in the presentation and the high toxicity of the waste was highlighted. Many items contain high value materials, which are worth recovering. However, dismantling of the equipment can be difficult because of its complex structure, and the work may be outsourced to countries where OSH issues are not controlled.

In the prioritisation exercise, which followed the same methodology as the Session 1 exercise, delegates merged: nanotechnologies and nanomaterials with novel materials; extractive technologies with environmental remediation; and waste management with recycling.

The nine technologies judged to be the most important were (Annex 4 numbers in brackets):

- Biotechnologies (17)
- Nanotechnologies and Nanomaterials/Novel Materials (20/23)
- Robotics and Artificial Intelligence (21)
- Transport Technologies (25)
- Manufacturing Technologies (26)
- Construction Technologies (27)
- Extractive Technologies/Environmental Remediation (28/32)
- Agriculture, Forestry and Food (29)
- Waste Management and Recycling (30/31)

As before, delegates working in three groups were asked to draw up timelines and dependency/uncertainty sheets for each of these topics

Session 3 Voting

In the final session delegates were asked to vote on the eighteen topics selected from the first two exercises. The timelines and uncertainties/dependencies sheets for each technology were posted around the room. A spokesperson from each group was asked to summarise the main points of their discussion to the plenary session. Delegates were then asked to study the outputs from all the groups and then to vote for the eight technologies they would like to see go forward into Phase 3. Each delegate had to select their top technology (green vote) and seven others (red votes). Each delegate had to vote for at least two energy topics and two non-energy topics, and could not cast more than one vote for any single topic. The feedback from Sessions 1 and 2 is given below.

Wind Energy (Industrial scale)

The current model of large scale onshore and offshore wind farms is intended to continue over the decade, with wind supplying 20% of electricity demand by 2020. There was some uncertainty whether the speed of the roll-out would meet this target. For example, in the UK 700,000 offshore turbines will need to be built by 2020 to meet targets. This will require about 40 transfers of workers to offshore sites every day, with the risk of transport accidents. Offshore accommodation will need to be built. Dependencies for progress were political support, local acceptance (onshore), feed-in tariffs and funding and development of the grid. Big companies would be the major player. A comparison was drawn between OSH issues of offshore wind and those of offshore oil industries.

Solar PV (Industrial scale)

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

Bioenergy

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

Carbon Capture and Storage

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

Electricity Transmission

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

Electricity Storage Technologies

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

Battery Technology

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

Hydrogen and Fuel Cells

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

Domestic and Small Scale Energy Applications

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

Biotechnologies

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

Nanotechnologies and nanomaterials

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

Robotics and Artificial Intelligence

Moving from industrial to service applications (agriculture, military, medical) and then domestic applications over the period to 2020. Uncertainties were the availability of appropriate standards and legislation, economic aspects and the human/machine interface, for example how people interact safely with free roaming and autonomous robots.

Transport Technologies

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

Manufacturing Technologies

There is expected to be less mass manufacture but more mass customisation, using adaptable processes, flexible technologies and an adaptable skills base with a constant churn of skills. There will be more smart goods, IT enabled goods, pervasive computing and smart packaging. The human/machine interface will be important.

The effects of recycling legislation will see these costs internalised in the price of goods.

Construction Technologies

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

Extractive Technologies and Environmental Remediation

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

Agriculture, Forestry and Food

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

Waste and Recycling

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

4.3.2 Results

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

It should be remembered that all the technologies that made it to the final stage are important, and it is clear that many of them will be important components of the future, but resources do not permit the inclusion of them all in the eight workshops planned for Phase 3.

The results of the workshop vote and the outcome of the plenary discussion at the workshop, together with data from the interviews and the web survey are shown in Table 2.

Table 2: Results of Workshop Vote, Initial Conclusions, Interviews and Web Survey

Technology	1 st Choice votes (green votes)	Other Workshop votes (red votes)	Workshop conclusions re. focus of Phase 3 workshops	Interview votes	Web survey votes
1 Wind energy (Industrial scale)	0	7	?	2	6
3 Solar photovoltaic (Industrial scale)	1	1	?	0	0
5 Bioenergy (Industrial scale)	3	4	✓	0	0
8 Carbon capture and storage	0	2	X	3	2
12 Energy transmission	0	8	✓ (Combine with 13,14 & 16)	0	2
13 Energy storage and recovery	4	2	✓ (Combine with 12, 14 & 16)	0	0
14 Battery technology	0	4	✓ (Combine with 12, 13 & 16)	1	0
15 Hydrogen and fuel cells	0	4	X	0	1
16 Domestic and small scale energy	1	4	✓ (Combine with 12, 13 & 14) Also linked to construction	2	1
17 Biotechnologies	1	7	✓	2	1
20 Nanotechnologies and nanomaterials	2	8	✓	7	8
21 Robotics, automation and artificial intelligence	0	4	(Aspects to be considered with 26)	1	1
25. Transport technologies	0	9	✓	0	1
26 Manufacturing technologies	1	7	✓ (To include aspects of 21)	0	0
27 Construction technologies (buildings)	1	10	✓	0	0
28 & 32 Extractive technologies; and environmental remediation	0	3	X	N/A*	N/A*
29 Agriculture, forestry and food	0	9	✓	0	1
30 & 31 Waste management and recycling	1	11	✓	2*	4*

4.3.3 Selection of technologies

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

Waste and Recycling	12 votes
Construction technologies	11 votes
Nanotechnologies and nanomaterials	10 votes
Agriculture, forestry and food	9 votes
Transport technologies	9 votes
Biotechnologies	8 votes
Manufacturing technologies	8 votes
Energy transmission	8 votes
Wind energy	7 votes
Bioenergy	7 votes

In the discussion the following points were made:

- There was some surprise that energy topics did not feature as prominently as had been expected. This could be a consequence of the way energy technologies had been considered individually, whereas other areas had been treated as sectors or technology groupings. Thus the energy vote had been split.
- The distinction between energy transmission (see Annex 4 number 11 for more details of the aspects it includes) and energy storage (Annex 4 number 12) was not helpful and these could be merged. If this were done, then domestic and small scale applications of energy technologies (Annex 4 number 16) should be included also. Battery technology (Annex 4 number 14) had been introduced as a separate topic because it was felt it was such an important topic, but it would in any case be part of energy storage. Thus a combined energy topic comprising numbers 12, 13, 14 and 16 was proposed. However, it was felt that this combined topic would need two workshops in Phase 3.
- Construction technologies should focus on buildings, rather than infrastructure in order to give greater emphasis to energy efficiency measures.
- Robotics, automation and artificial intelligence, while not a high scorer in its own right, could usefully be considered alongside manufacturing technologies.
- Wind energy and solar energy were judged to be of medium priority. The low score obtained by solar energy was surprising.
- Carbon capture and storage; hydrogen and fuel cells; and extractive technologies/environmental remediation obtained low scores in the workshop vote, the interviews and the web survey and were therefore not selected for Phase 3:

In subsequent analysis of the results by the project team in consultation with EU-OSHA, the following additional points were made.

- Wind energy had failed to make the top eight in the workshop but ranked among the top 9 (equal with bioenergy) and had in addition been cited often as high priority in the Phase 1 interviews and scored well in the Phase 2 interviews and web survey.
- Bioenergy had not made the top eight in its own right, but ranked among the top 9 (equal with wind energy) and could be merged with biotechnologies in a single topic dealing with energy applications of biotechnologies.
- Nanotechnologies and nanomaterials scored highly at the workshop, in the interviews and in the web survey. However, it was felt that such a broad topic, featuring as it does in many of the other technologies and technology areas, and whose applications and OSH implications

are already the subject of a large body of research and conferences, would not be well served in a single workshop of the format planned for Phase 3. In fact, it was felt it was such a major and transversal issue actually found in almost all other technologies/technological applications selected for the Phase 3 workshops, that it should be addressed in each of these workshops in relation to the specific sector and applications they will address. Indeed, as already mentioned previously, not having a workshop on a specific technology does not mean that it is not an important component of the future and of the scenarios produced in this project.

- Agriculture, forestry and food, although scoring highly at the workshop, had hitherto attracted little interest. It would therefore not be the focus of a specific workshop in Phase 3.

This gave a final list for the Phase 3 workshops of:

Waste and Recycling Technologies
Green construction Technologies (Buildings)
Green transport Technologies
Bioenergy and the energy applications of biotechnology
Green manufacturing Technologies and processes/Robotics and Automation
Electricity Transmission and Storage 1
Electricity Transmission and Storage 2
Wind Energy

5. Conclusions

Phase 2 of the project has reviewed the literature on emerging technologies associated with green jobs, initially identifying 26 different technologies. A programme of interviews with experts and a web consultation exercise increased this list to 34. Further consultation with technical and occupational safety and health experts in a workshop environment, and a review of the data and comments collected has resulted in a final list of 8 technologies/technological applications to be taken forward into a series of workshops in Phase 3 of the project. The aim of these workshops will be to explore in more depth the developments of these technologies and how they may create emerging risks to workers' safety and health by 2020 in the context of the key drivers of change identified in Phase 1.

A challenging aspect of Phase 2 was the considerable overlap between the different technologies and the sectors in which green jobs will occur. A constant dilemma was the right level at which to consider technologies. Should they be considered as individual technologies such as solar photovoltaic, for example, or as groupings of technologies or even industrial sectors? On the one hand, too tight a specification of an individual technology might limit the scope for differentiation between development in different scenarios, while too broad a topic might be too complex.

In the event, the broader technology areas have been selected over the individual topics by those consulted. There has perhaps been a reluctance to exclude technologies and aggregation into larger topics reduces the need for this.

There have been some surprises. At the start of the project we thought it likely that, for example, solar energy and carbon capture and storage would appear in the final list of technologies, but they did not. We should remember, however, that we have asked consultees to take into account potential for development by 2020, potential impact on OSH and the degree of uncertainty. If they consider that a particular technology is unlikely to progress significantly by 2020, or that its development and hazards are predictable, then they need not choose it.

We have arrived at an interesting mix of technologies and technology areas and collected first hand information on surrounding issues with potential impact on OSH, advised by a range of experts from different disciplines and different countries; this shows how enriching and successful multidisciplinary cooperation can be.

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7. Annexes

7.1 Annex 1: Participants in the Interview Programme

Øle Busck	Aarlborg University, Denmark
F Jesus Alvarez	European Commission, DG EMPL.F.4, EU Member of EU-OSHA's European Risk Observatory Advisory Group (EROAG)
Andrea Okun	NIOSH, USA
Olivier Salvi	Ineris, France
Kären Clayton	Health and Safety Executive, UK
Ian McCluskey	Shell Gas Ltd, UK
David Campbell	Scottish Power, UK
Chris Streatfeild	Renewable-UK, UK
Michael Sturm	E.ON Climate and Renewables GmbH, Germany
Stefano Carosio	D'Appolonia S.p.A., Italy
Jennifer Stack	Inasmet-Tecnalia, Spain
Aida Ponce	European Trade Union Institute, EU Nominated by EU-OSHA's EROAG workers' representatives
Jesús López de Ipiña	Tecnalia, Spain
Daniel Podgórski	Central Institute for Labour Protection – National Research Institute, Poland Member of EU-OSHA's EROAG
Rebekah Smith	Business Europe, EU Member of EROAG
Evangelos Tzimas	EC Joint Research Centre – Institute for Energy, Netherlands
Geoff Pegman	RuRobots, UK
Christian Jochum	European Process Safety Centre, UK
Massimo Mattucci	COMAU, Italy
Camille Burel	Europabio, Belgium
Reto Schneider	Swiss re, Switzerland
Richard Gowland	European Process Safety Centre, UK
Mike Pitts	Chemistry Innovation Ltd, UK
Tiina Delmonte and Barrie Shepherd	Doosan Babcock, UK
Lee Kenny	Health and Safety Executive, UK

7.2 Annex 2: Results of Interview Questions

Figure 2: Results from Interview Question 3

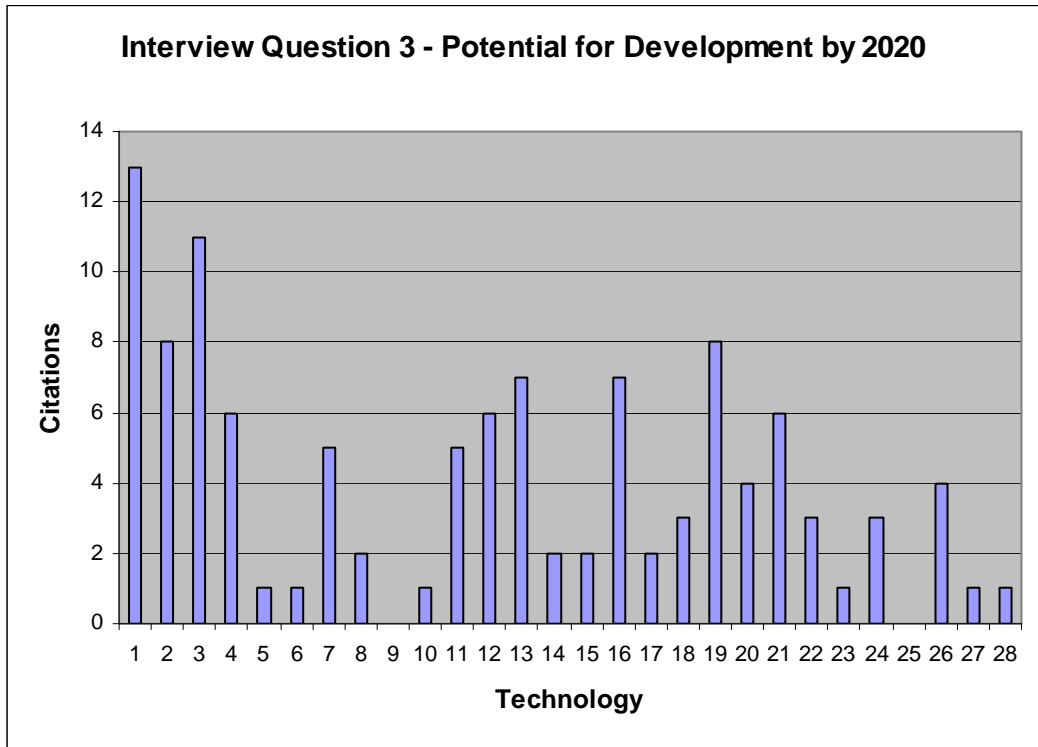


Figure 3: Results from Interview Question 4

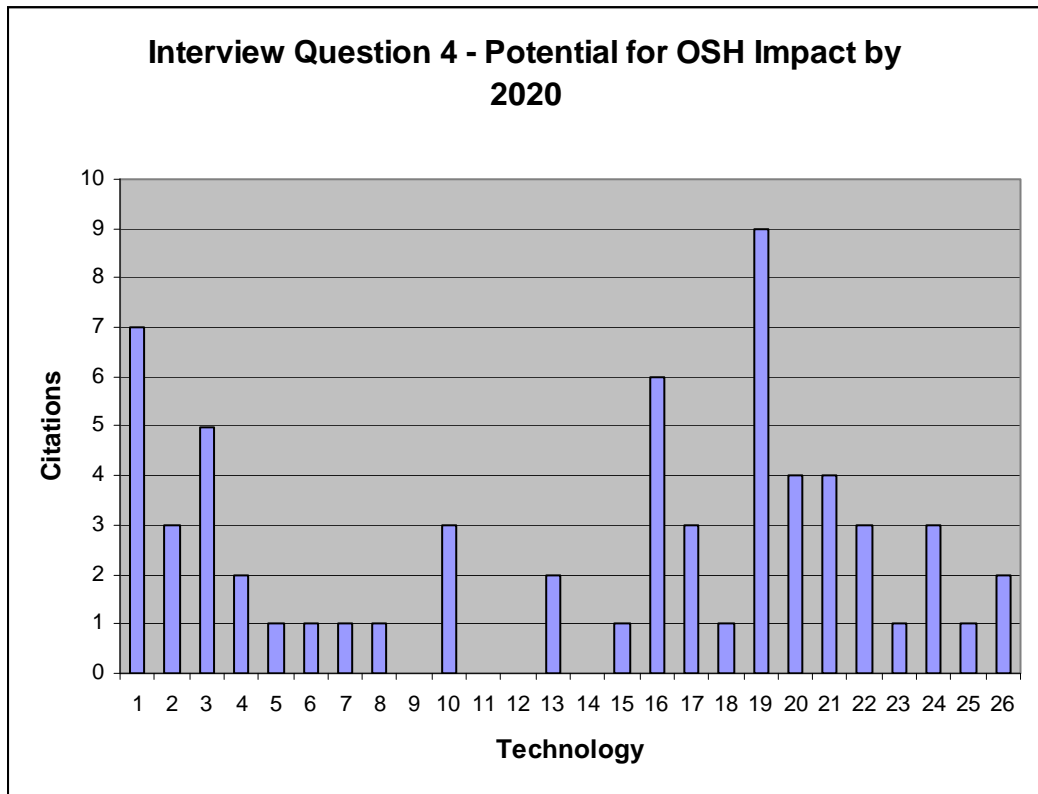
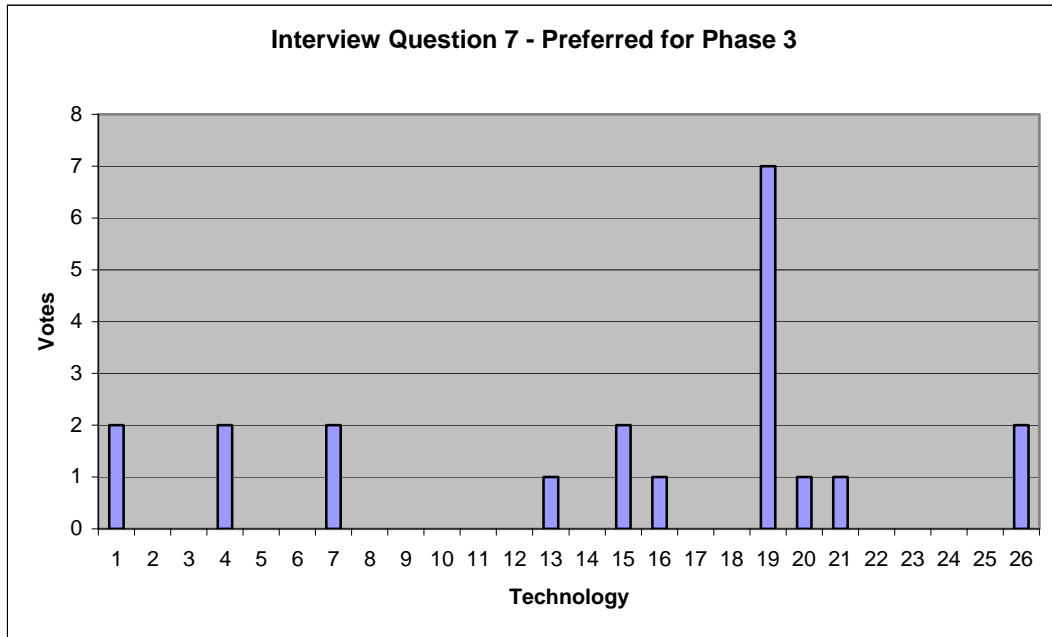


Figure 4: Results from Interview Question 7



Key to Technologies in Figures			
No	Technology	No	Technology
1	Wind Energy	14	Hydrogen and Fuel Cells
2	Marine Energy	15	Domestic and Small-Scale Energy
3	Solar Energy	16	Biotechnologies
4	Bioenergy	17	Green Chemistry
5	Geothermal energy	18	Novel Materials
6	Hydroelectricity	19	Nanotechnologies and Nanomaterials
7	Carbon Capture and Storage	20	Robotics, Automation and AI
8	Clean Coal	21	ICT
9	Other Fossil Fuel Technologies	22	Transport Technologies
10	Nuclear Energy	23	Manufacturing Technologies
11	Electricity Transmission	24	Construction Technologies
12	Electricity Storage	25	Agriculture, Forestry and Food
13	Battery Technology	26	Waste, Recycling and Environmental Remediation

7.3 Annex 3: Web Survey Results

Figure 5: Results of Potential for Development Scoring

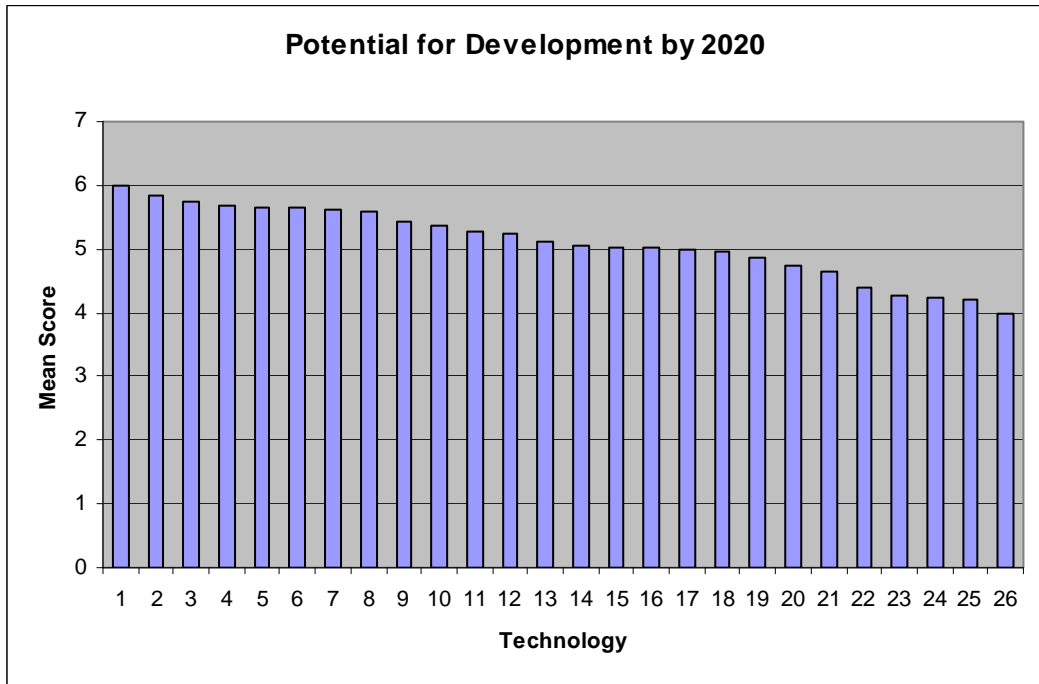


Figure 6: Results of Potential for OSH Impact Scoring

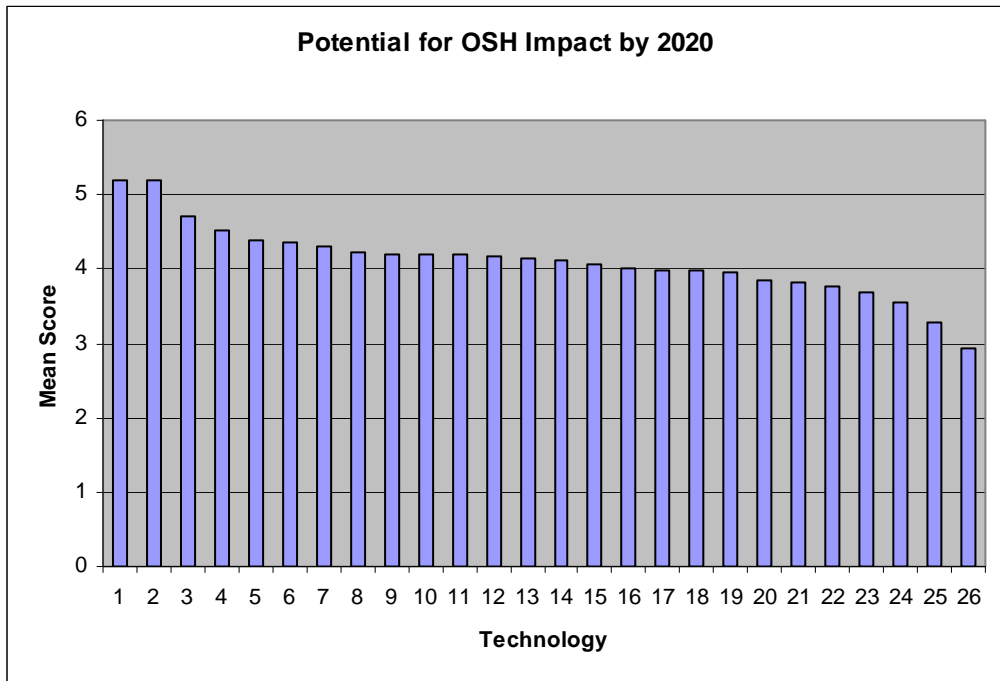
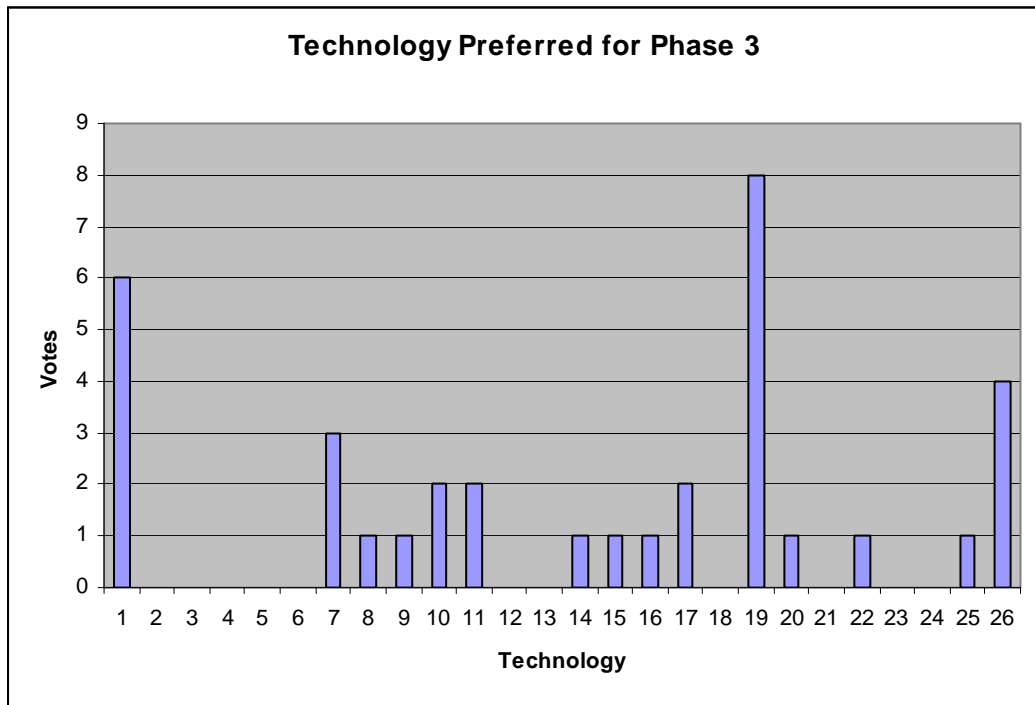


Figure 7: Results of Preferred Technology for Phase 3 Scoring (Web Survey)



Key to Technologies in Figures			
No	Technology	No	Technology
1	Wind Energy	14	Hydrogen and Fuel Cells
2	Marine Energy	15	Domestic and Small-Scale Energy
3	Solar Energy	16	Biotechnologies
4	Bioenergy	17	Green Chemistry
5	Geothermal energy	18	Novel Materials
6	Hydroelectricity	19	Nanotechnologies and Nanomaterials
7	Carbon Capture and Storage	20	Robotics, Automation and AI
8	Clean Coal	21	ICT
9	Other Fossil Fuel Technologies	22	Transport Technologies
10	Nuclear Energy	23	Manufacturing Technologies
11	Electricity Transmission	24	Construction Technologies
12	Electricity Storage	25	Agriculture, Forestry and Food
13	Battery Technology	26	Waste, Recycling and Environmental Remediation

Analysis of Respondents to Web Survey

Country	Number
Austria	2
Belgium	2
Croatia	1
Cyprus	2
Czech Republic	1
Denmark	2
France	1
Germany	1
Ireland	2
Italy	2
Lithuania	1
Malta	1
Netherlands	1
Norway	4
Portugal	3
Romania	1
Spain	2
Sweden	1
Switzerland	1
United Kingdom	5
USA	2
Total	38

Sector	Number
Government/Public	10
Private	11
Research/Academic	9
Trades Union	3
Voluntary	0
Not Stated	5
Total	38

Interest	Number
Health, Safety & Environment	14
R&D	15
Manager	4
Policy	1
Other/Not Stated	4
Total	38

7.4 Annex 4: Consolidated Technology List

Technology	Subtopics	Green Credentials	Health and Safety Aspects	Potential for Development	References
Renewable Energy Technologies					
1. Wind Energy (Industrial scale – see domestic applications below).	Onshore, offshore	Renewable energy source	Physical hazards - falls from heights, manual handling, working in confined spaces (exposure to e.g. dusts, musculoskeletal disorders (MSDs) owing to awkward postures), physical load from climbing towers, electrocution during construction and maintenance. Offshore hazards - lifting, boats, weather, stability of platforms. Machine safety - ice throw, blade fracture. Chemical risks - exposure to resins, styrene and others during blade manufacture and maintenance.	Large increase in use already underway and likely to accelerate. Development of larger turbines, especially offshore. Integration with smart grids. New stackable, replicable and standardised substructures for large-scale offshore turbines such as tripods, quadrupods, jackets and gravity based structures. Floating structures with platforms, floating tripods or single anchored turbine. Manufacturing processes for mass production of substructures. Improved reliability and lifetime through new materials, designs. Further automation and optimisation of manufacturing. Innovative logistics for transport and erection.	9, 10, 11, 12, 13, 14, 15, 16
2. Marine Energy	Wave, tidal and in-stream devices, salinity gradients, temperature gradients (ocean thermal energy conversion OETC).	Renewable energy source	Physical hazards - falls from heights, manual handling, working in confined spaces (exposure to e.g. dusts, MSDs owing to awkward postures), electrocution during construction and maintenance. Offshore hazards - lifting, boats, weather, stability of platforms. Chemical risks - exposure during manufacture and maintenance of components.	Currently no leading commercial technology. Many devices at advanced R&D stage, some large-scale prototypes at pre-market stage. Further development of technologies needed alongside grid connection issues, integration with other developing technologies to make hybrid systems. New designs have to overcome large technical challenges in a harsh marine environment.	9, 10, 17, 18, 19
3. Solar Photovoltaic (Industrial scale – see domestic applications below).	Direct conversion of the sun's rays to electricity using semi-conductors.	Renewable energy source	Physical hazards - falls from heights, manual handling, confined spaces, electrocution during construction and maintenance. Exposure to toxic chemicals and nanomaterials during manufacture and disposal/recycling.	Improvements in solar panel design to improve energy yield and reduce costs. Emerging technologies include: advanced inorganic thin-film technologies; organic solar cells; thermo-photovoltaic cells and systems. Development of solar desalination.	9, 17, 18, 20, 21

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<p>4. Concentrating Solar Power (Industrial scale – see domestic applications below).</p>	<p>Use of the sun's rays to heat a receiver to create mechanical energy to generate electricity, as opposed to PV, which uses direct conversion with semi-conductors.</p>	<p>Renewable energy source</p>	<p>Construction and maintenance of industrial scale installations, electrical hazards, hazards from concentrated sunlight. High temperatures in concentrating sites.</p>	<p>Growth in CSP is anticipated. The International Energy agency (IEA) Technology Roadmap – Concentrating Solar Power postulates that CSP could provide approximately 10% of global electricity by 2050. New collector designs for medium temperatures being developed for industrial heat demand.</p>	<p>55</p>
<p>5. Bioenergy (Industrial scale – see domestic applications below).</p>	<p>Biofuels (diesel, ethanol etc), biomass combustion, biomass-co-firing (see also Clean Coal Technologies), anaerobic digestion (biogas production), landfill gas utilisation, biomass gasification, pyrolysis.</p>	<p>Renewable energy source</p>	<p>Fire and explosion during production and use. Biogas quality for injection into the grid. Exposure to biological hazards. Exposure to carcinogens, heavy metals and gases during thermal processing. Asphyxiation. Risks from small scale manufacture by inexperienced people. Dock related hazards during biomass importation, e.g. oxygen depletion in confined spaces, exposure to hazardous volatile organic compounds (VOC), dusts, moulds and endotoxins. Integration of biofuels into the European refinery network.</p>	<p>Develop and optimise feedstock-flexible thermochemical pathways and biochemical pathways to promote large-scale sustainable production and efficient use. Technological development of biofuels to 2020 includes: a wider range of bioethanol feedstocks (e.g. cereal straws, industrial/municipal/commercial wastes); a wider range of biodiesel feedstocks - algae, jatropha and curcas (monocrops) and used cooking oil/animal fats. Conversion technologies will improve: biomass enzymatic conversion (release of sugars in cellulose and hemicellulose for fermentation) better, cheaper enzymes, along with the development of enzymes to ferment pentose and hexose sugars to ethanol (not currently possible) to increase yield. Increased efficiency of biomass combustion and anaerobic digestion. Development of plasma arc gasification (heating biomass in high voltage electric current).</p>	<p>10, 12, 16, 17, 22, 23, 24</p>
<p>6. Geothermal Energy (Industrial scale – see domestic applications below).</p>	<p>Ground and air heat pumps, hot fluid, hot rocks. Current use in Europe is hot water from deep aquifers for district heating and small/medium shallow geothermal plants (which can also be used for thermal energy storage). Recent new technology is the exploitation of low temperature geothermal</p>	<p>Renewable energy source</p>	<p>Emissions, (e.g. sulphur, silica), hazards from activities such as: trenching, excavation, electrical issues, welding and cutting, falls. Hazards associated with borehole drilling, piping steam/hot water, construction and operational activities.</p>	<p>Main future developments are seen to be enabling technologies, such as innovative drilling technologies, resource assessment, utilising low temperature sources and exploiting supercritical zones. Increased efficiency in geothermal combined heat and power (CHP) technologies and components. Improved site assessment, exploration and installation.</p>	<p>9, 12, 18, 25</p>

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	sources.		Potential for earthquake/tremor risk from drilling, pumping activities into deep rock.	New geothermal applications: de-icing/snow melting on roads, runways, seawater desalination and absorption cooling. Current transition into new areas, South Europe and the Med (cooling and heating), Eastern and SE Europe, UK and Ireland growing interest. Leading countries currently Sweden, Switzerland, Germany and Austria.	
7. Hydroelectricity	Large-scale, small-scale, micro-scale.	Renewable energy source	Hazards associated with construction, operation and maintenance. Electrical hazards, water hazards, moving machinery etc.	Small hydropower is seen as having real potential in New Member States, estimated around 7.7 Twh by 2020. Technological innovations by 2020 will concentrate on turbine design looking at low and very low head turbines, and to make simple, reliable, efficient turbines with a guaranteed performance. Also improve environmental integration (Submersible Turbo Generators); increase cost efficiency and use of new materials. New Generator designs include High pole Synchronous Generators, have recently been introduced, new concepts are under development in the areas of prediction of energy output, scheduled production and condition monitoring. Integration with other renewable technologies.	17, 18
Fossil Fuel Technologies					
8. Carbon Capture and Storage	End of pipe - precombustion/post combustion.	Reduces CO ₂ emissions/removes ambient CO ₂ .	Presence of large volumes of CO ₂ requiring compression, transportation and underground injection; handling CO ₂ in its dense (i.e. liquid) or supercritical phase; CO ₂ escape due to loss of plant integrity or embrittlement of equipment caused by the gas; potential impact injuries and asphyxiation risk.	Proving technical and economic feasibility using existing technology; develop more efficient and cost effective technologies; develop new capture concepts; transfer CCS capture to other carbon-intensive sectors - cement, refineries and iron and steel; develop alternative transport and storage technologies to allow broadening of geographical deployment. Zero emissions platform (ZEP) plant technology - up to 12 EU demonstrators by 2015. Commercial by 2020.	9, 16, 17

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			<p>Acute and chronic health problems caused by exposure to high CO₂ concentrations (e.g. inhalation may affect respiratory, cardiovascular and central nervous system). Burns/frostbite from liquid CO₂ exposure.</p> <p>Exposure to chemicals and solvents used in carbon capture (amines, methanol etc) which can cause irritation to eyes, skin and respiratory tract.</p> <p>Presence of toxic, flammable and explosive substances (e.g. amines, ammonia, oxygen) in coal combustion plant as part of CC process. Not conclusive, but may be the potential for seismic activity as a result of burying CO₂ underground.</p>		
9. Clean Coal Technologies	Oxyfuel combustion, Integrated Gasification Combined Cycle (IGCC), coal bed methane extraction, co-firing with biomass (see also Bioenergy), supercritical coal power plant, underground coal gasification).	Reduces pollution	Fire and explosion risk from flammable gases, failure of pressure vessels and pipes, spontaneous combustion of biomass (for co-firing). Exposure to toxic substances during syngas or flue gas processing.	Continued development and testing of the technologies listed left under 'Subtopics' heading.	16, 17
10. Other Fossil Fuel Technologies	Natural gas, oil.	Natural gas (with CCS) reduces pollution (compared to coal).	Fire and explosion risk from flammable gases, failure of pressure vessels and pipes. Dockside issues associated with transport of liquefied natural gas (LNG). Risks from offshore regassing.	Increased LNG imports. Greater gas storage capacity underground and potentially undersea. Increased efficiency in use of oil. Conventional power plant life extension - work on modelling and assessment tools.	16, 20

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Other Energy Technologies					
11. Nuclear Energy	Nuclear fission, nuclear fusion	Low carbon energy source	Hazards associated with construction, operation and maintenance. Radiation, containment issues, waste disposal, decommissioning. Avoidance of nuclear accident.	<p>Fission: Life-extension of current Generation II plants, mostly by material performance. Development of Generation III designs, which are standardised designs to decrease costs, construction times, etc. There are 4 main types: Light-Water Reactors (Advanced boiling water and Advanced pressurised water reactors (PWR), Heavy Water Reactors, High-Temperature Gas-Cooled Reactors (HTRs) and Fast Neutron Reactors (FNRs).</p> <p>Generation IV Reactors are under development - 6 technologies are being looked at by the Generation IV International Forum (GIF): Gas-Cooled and Lead-Cooled Fast Reactors, 2 types of Molten Salt Reactors (MSRs), Sodium-Cooled Fast Reactors, Supercritical Water-Cooled Reactors and Very High-Temperature Gas Reactors (which can co-generate heat/electricity).</p> <p>Small under 500Mwe systems are being developed and can be independent from large-grid systems; a range of technologies are being developed outside Europe based on PWR, HTR, Liquid-metal Reactors and MSR Technology.</p>	9, 10, 17
				<p>Fusion - first commercial plant unlikely before 2040, although there is talk of a demonstrator in five years. Cold Fusion (Low energy Nuclear Reactions) is yet to be proven, although the US Navy appears to be having success in this area.</p>	10, 17
12. Electricity Transmission	Smart Grid, Smart metering, distributed generation, combined heat and power, smart appliances.	Enables use of renewable energy sources	Electrical safety, construction, working at heights, skills issues. Risks in all sectors consequent on power cuts during installation.	Grid integration techniques for turbine output – high voltage alternating current (HVAC), high voltage direct current (HVDC). PV grid integration and storage technologies.	9, 10, 16, 17, 19, 26

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			Flashover burns, falls and electrocution during installation, connection and maintenance of new power sources. Electrocution owing to more work on live systems as systems become more complex. Falls when installing, connecting or repairing roof-mounted micro wind turbines or solar panels. Construction and excavation risks during cable laying, substation construction and other activities (onshore and offshore). Smart appliances, i.e. those that interact with the grid to make most use of lower cost electricity, may be prone to unexpected starting and stopping. Companies with interrupted supply contracts may be prone to the same risks.	Develop advanced network technologies to improve security and flexibility; preparing long-term evolution of grids. Work on protection, fault detection and voltage sag algorithms. Inclusion of storage devices into centralised control systems. European Supergrid, HVDC, FACTS (Flexible AC Transmission Systems), new conductors - gas insulated lines (GIL) high temp superconduction (HTS) wires. HVDC and FACTS only viable with suitable ICT control. North African Solar Power Grid (DESERTEC). Smart meter roll-out programme.	
13. Electricity Storage and Energy Recovery Technologies.	Batteries (see also separate category), flywheels, super-capacitors, superconducting magnetic energy storage (SMES), hydrogen (see also separate category), pumped hydro, compressed air energy storage (CAES), liquid nitrogen and liquid oxygen energy storage.	Enables use of renewable energy sources	Electrical hazards. Hazards associated with feed-in technologies, e.g. wind, wave, solar. Hazards from batteries, hydrogen, fuel cells (see separate categories). Hazards from compressed and liquefied gases. Hazards from the use of molten materials for storage.	Continuous improvements in efficiency and cost reduction of these technologies. Increasing use of these technologies. Establishment of specialized energy storage 'gardens'?	16, 20
14. Battery Technology	Lead-acid, lithium ion, sodium sulphur (zebra), sodium nickel chloride.	Enables use of renewable energy sources	Some batteries operate at high temperatures. There are also electrical risks from the high voltage/currents of large batteries. Some batteries may catch fire or explode. Exposure to toxic substances during manufacture.	For large-scale systems energy companies are looking at Sodium Sulphur (NaS) batteries - long-life, large (room-sized) batteries, recently deployed at 1.2MW.	10, 46, 47

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			There are also hazards in the recycling of batteries, e.g. chemical, electrical and fire risk (lithium ion battery fires in UK).	Other potential battery technologies are all-liquid batteries (long-life, high current) and gravel batteries (use spare electricity to heat/pressurise argon, which heats/cool gravel; energy is stored as a temperature difference between two gravel silos). A range of smaller scale batteries are being developed, e.g. Thin-Film batteries (solid state and long storage), lithium manganese oxide batteries (charge/discharge in 10 mins), lithium phosphate coated lithium ion batteries (shorter charge/discharge). Nanotechnology will have a big impact on battery technology. Developments include: silicon nanowire electrodes in lithium ion batteries (triple their capacity), lithium air batteries (large storage potential, useful for cars) and novel catalysts are being developed. World market growth rate of batteries predicted at 7-30% a year. It is thought that many emerging battery technologies could revolutionise battery use, with a step-change in recharge time and capacity.	
15. Hydrogen and Fuel Cells	Hydrogen in fuel cells, heating boilers and internal combustion engines. Generation methods - thermochemical electrolytic splitting of water using renewable electricity and waste heat; biomass biological processes, algae. Other fuel cells (e.g. ethanol, methanol, methane, diesel, biogas, LPG etc).	Enables use of renewable energy sources	Fire and explosion hazards during manufacture, distribution, storage and use. Electrical hazards from fuel cells. If hydrogen use in vehicles is widespread the issue of hydrogen handling by the general public and workers could present risks.	Significant developments anticipated to improve storage of hydrogen, especially in vehicles. Developments to improve efficiency of fuel cells and to reduce costs. Development of domestic hydrogen combined heat and power (CHP) systems. If hydrogen is to be successful in vehicles a network of refuelling stations will need to be developed. Domestic generation of hydrogen and vehicle refueling is already under development.	10, 16, 18, 20
16. Domestic and small scale applications of emerging energy technologies	Wind, solar thermal and solar photovoltaic, bioenergy, geothermal energy, combined heat and power, fuel cells.	Renewable energy sources	Domestic and small-scale (e.g. community buildings) applications of these technologies may bring a different mix of risks from those encountered on the industrial scale.	Domestic solar and wind applications are seeing a rapid increase in uptake. Small-scale biofuels manufacture is increasing. Domestic use of geothermal systems is relatively low at present.	38, 48

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			<p>Installers will need new skill mixes. For example, those who previously worked only on gas systems who move into solar thermal installation will have increased exposure to electrical work and work at heights. Many installers may be self-employed. Risks to householders. Farmers who produce their own biofuel may be at risk of fire/explosion. Risks to recycling workers on disposal.</p>	<p>Extension of solar thermal from water to space heating. Combi+ systems (heating in winter, cooling in summer) will have a large market share by 2020-30.</p>	
Non-energy Technologies					
17. Biotechnologies	<p>Biocatalysts, engineered cell factories, plant biofactories, novel process conditions/industrial scale-up, biorefining and very large scale bioprocessing (VLSB), meso-scale manufacture, agricultural technologies (see also separate category), synthetic biology, genetic modification.</p>	<p>Contributes to green chemistry, biofuels, and improved agricultural yields.</p>	<p>Potential for exposure to unknown hazards from new processes and materials. Distributed manufacture could increase the potential hazards. Risks to workers from biological agents at the manufacturing stage, when these are further used down the user chain, or at the recycling stage.</p>	<p>An area in which considerable development is underway across a range of individual technologies with a wide range of applications.</p>	10, 22
18. Green Chemistry	<p>Reaction and process design, novel solvents, novel catalysis, separation technology, renewable feedstocks replace non-renewable (e.g. carbon dioxide as a possible new source for plastics), industrial biotechnology, materials technology.</p>	<p>Greater efficiency, low carbon, reduces pollution.</p>	<p>Potential for exposure to unknown hazards from new processes and materials. Substitution of chemicals for environmental reasons could result in greater risks to workers. Chemicals obtained from renewable sources can still be toxic. Potential risks at the recycling stage.</p>	<p>Development of novel catalysts, novel solvents, substitution of environmentally harmful chemicals.</p>	9, 10, 27, 28, 30

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19. Novel Materials	Smart (multifunctional) and biomimetic materials, (e.g. metamaterials, intelligent polymers (plastic electronics), electroactive polymers (EAPs), shape memory polymers (SMPs), smart interactive textiles, nanomaterials (see also separate category), Organic light-emitting diodes (LEDs), organic light-emitting polymers (OLEPs).	Lighter, stronger materials contribute to energy efficiency.	Potential for toxic or irritant effects of new materials. Risks from potential dangerous substances involved with these novel materials in manufacturing, when these materials are further used, processed, handled down the user chain, and in waste-recycling activities.	Developments in a wide range of classes of new materials with applications in a wide range of sectors.	10, 29
20. Nanotechnologies and Nanomaterials	A very wide range of potential applications, including improved batteries, engine additives, new composite materials, materials used in construction (e.g. pavements/bricks/asphalts “capturing” environmental pollutants, nanocoatings/nanopaints transforming solar energy into electricity, “green” anti-fouling nano-coatings), agriculture and forestry.	Contribution to green sectors.	The particle size of nanomaterials may affect their toxicity and explosive properties when compared to the bulk materials. These properties are of nanomaterials are still under investigation and potentially pose risks to workers at all stages of their life cycle.	The applications of nanotechnology are expected to grow very rapidly. There are predictions that worldwide production could reach 50,000 tonnes a year during the period 2011 to 2020, with 20% of manufactured goods involving nanomaterials.	10, 49, 50, 51
21. Robotics, Automation and Artificial Intelligence	Use in manufacturing, agriculture, construction and other industries.	Facilitate introduction, control and monitoring of green technologies.	Risks are mainly those of the potential for automated devices to injure workers, especially during malfunction and when free-roaming.	The use of robots is likely to grow. Increasingly robots will be free roaming and autonomous.	39
22. Information and Communication Technologies	In green jobs terms - use in monitoring and control of energy production and distribution (e.g. the smart grid), in modelling and optimisation of systems.	Facilitate introduction, control and monitoring of green technologies	Networks may be susceptible to interference or hacking, which have the potential to create major disruption. Damage to safety critical applications could occur, e.g. the Stuxnet virus.	Continued expansion of computer applications is inevitable, with growing potential for the safety benefits and risks described adjacent. The introduction of quantum computing could see a step-change in computer power, but this is likely to be some way off.	40

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	Increasing use of networks in applications such as intelligent traffic systems, smart grids, and smart cities. Many wider applications.	Reduce the need for travel	Increasing use of wireless systems could increase workers' exposure to EM radiation. There may be over-reliance on computers in safety critical situations. Monitoring systems such as radio frequency identification (RFID) offer safety benefits such as protection of lone workers, traceability of components, process control etc. The potential for stress from monitoring and surveillance. Any risks from 'cloud computing', i.e. non-localised software.		
23. Convergent Technologies	This term can be applied to a range of technologies, but is most commonly used to describe the co-development of nanotechnologies, biotechnologies, information technologies and cognitive sciences (NBIC).	Enhancement of human performance leading to greater efficiency. Tailored materials offering environmentally friendly energy efficiency.	Unknown effects of enhancement technologies such as performance enhancing drugs, implants, bionic limbs, exoskeletons etc. Unknown hazards in the workplace presented by such technologies.	Developments in these technologies continue to be made. There is evidence of a change in public opinion such that enhancement technologies will become more accepted. Potential developments include: 'Direct human brain/machine connections, transforming work, sports and art; Computers and environmental sensors worn as part of everyday attire; More robust, healthy, energetic human body, easier to repair when necessary; Practically any structure made of tailored materials, able to adapt to changing situations, offer energy efficiency while remaining environmentally friendly; Treatments for many physical and mental disabilities, perhaps completely eradicating some handicaps such as paralysis or blindness.'	Interview Programme, 61, 62

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24. Photonics	Operations including emission, transmission, modulation, signal processing, switching, amplification and detection and sensing of light. More recently, photonics describes the use of light to perform functions that traditionally fell within the typical domain of electronics, such as telecommunications, information processing, etc.	Improved efficiency of processes, Photonics and Plastic Electronics Knowledge Centre claims 'massively reduced energy consumption'	Laser safety, electrical hazards.	Increasing range of applications, including merging with nanotechnologies. In the European roadmap for photonics and nanotechnologies, (Merging Optics and Nanotechnologies or MONA) over 50 devices involving nanophotonics are listed in areas such as datacoms/telecoms, optical interconnects, displays etc.	Interview Programme, 52, 53, 54, 68
25. Transport Technologies	Electric, hybrid and biofuelled road vehicles, battery technology, hydrogen and fuel cells, electrification of railways, biofuels in aircraft, novel materials in aircraft, improved efficiency of internal combustion engines (ICE), intelligent transport systems (ICT), refuelling/recharging infrastructure.	Greater efficiency, low carbon, enables use of renewable energy sources, reduces pollution.	Health and safety issues associated with contributing technologies - energy sources, materials, vehicles etc. Fire and explosion from fuels, novel electrical risks from electric and hybrid vehicles during maintenance and operation. Risks to rescue-crews after accidents. Distribution and use of hydrogen etc. Recharging/battery exchange hazards.	A great deal of work already under way to improve the range and performance of electric and plug-in hybrid road vehicles. If they are to succeed a network of charging points and/or battery exchange facilities will need to be built. Use of novel materials to reduce weight. Increasing use of ICT in vehicles, increasing automation. Driverless cars, buses and trains with potential for collision risks.	15, 31, 32
26. Manufacturing Technologies	Advanced manufacturing techniques, distributed manufacture (e.g. personal fabrication - 3D printing and rapid manufacture/rapid prototyping), lean methods, biotechnologies (see also separate category), green chemistry (see separate category), nanomaterials (see separate category).	Greater efficiency, low carbon, reduced pollution.	Very wide range of applications. Potential for exposure to unknown hazards from new processes and materials. While many established manufacturing processes have robust safety systems, distributed manufacture could increase the potential hazards – skills issues, exposure to chemicals for unskilled workers. Potential for dangerous waste generated by new manufacturing technologies/processes.	Significant progress anticipated in sustainable manufacturing, products and services; energy efficient manufacturing; key technologies, for example digital technologies, micro and nano-electronics, nanotechnologies, plastic electronics, silicon electronics, industrial biotechnology, photonics, advanced materials; standardisation; and innovation, competence development and education. Progress in rapid manufacturing leading to increasing customisation - product safety issues. Novel formulation technologies.	29, 36, 37

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<p>27. Construction Technologies</p>	<p>Energy efficiency measures - new build and retrofit, (e.g. insulation, heat retaining windows, ventilation with heat recovery, energy efficient lighting), renewable energy, (e.g. solar thermal and cooling, geothermal heating and cooling, advanced monitoring systems, photovoltaic, wind energy, feed-in to grid, combined heat and power), new techniques,</p> <p>(e.g. offsite construction/prefabrication), new materials, (e.g. low carbon cements, nanomaterials), increasing use of ICT and robotics and automation.</p>	<p>Utilise low carbon energy sources, greater energy efficiency, reduced carbon emissions.</p>	<p>A range of hazards. In particular, the combination of known risks in new situations, e.g. installation of renewable energy equipment at heights, the installation of new technology such as feed-in to smart grids. Use of new materials and potential risks from dangerous substances used in new construction materials (e.g. when polishing, grinding nano-containing bricks/paints, etc., including in maintenance and demolishing activities.</p> <p>Off-site construction could reduce risks on site but transfer of risks to other groups of workers. Risk of exposure to asbestos during retrofitting activities.</p>	<p>Considerable potential for increased volumes as requirement for carbon neutral buildings are introduced alongside incentives such as feed-in-tariffs and renewable heat subsidies. Novel technologies such as algaetecture (biological generation of hydrogen on buildings). Application of carbon capture and storage to cement production. New insulation and building materials, including nanomaterials based, e.g. aerogel nanofoams.</p>	<p>41</p>
<p>28. Extractive Technologies</p>	<p>Quarries, underground mines, opencast mines, mining of metals, minerals and aggregates.</p>	<p>This sector is very energy intensive. Improvements in efficiency could make a significant difference to carbon emissions.</p>	<p>Hazards associated with mining and excavation activities, use of plant and explosives, working underground. Exposure to chemicals and heat.</p> <p>Greater automation may lead to health and safety benefits to the industry.</p> <p>There may be an increase in mining activities in Europe driven by shortages of rare earth metals, minerals, metals and coal. Old mines may be reopened in order to extract more products or as they are now economical to operate.</p>	<p>Metal Mining: recovery and re-use of waste heat from metallurgical slags, use of biomass derived charcoal instead of coal in the iron and steel industry and use of by-product slag as 'green cement'.</p> <p>Reconstruction of old mines, construction of new automatic mines, system and unit integration and system automatisation. Use of solar power air conditioners to cool mining structures, reclamation and treatment of waste water and fuel additives to minimise carbon emissions from mining equipment engines.</p> <p>Aggregates: Substitution of primary aggregate for recycled and secondary aggregate. Developments in crushing technology such as; high productivity with lower cost, 'just in time' supply, improved reliability and availability of plant, crusher automation with increased throughput, and in-pit crushing.</p>	<p>63, 64</p>

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29. Agriculture, Forestry and Food Technologies	Biotechnology (e.g. genetic modification) (see separate category), decarbonisation, precision farming, robotics and automation (see also separate category), water conservation, nanotechnology (see also separate category).	More efficient production, reduce environmental impact, reduced use of fuels etc.	A range of hazards. Machinery, electrical, exposure to chemicals, biological hazards, exposure to GMOs.	Increasing use of automation, e.g. robotic dairy farming, novel chemicals, e.g. for pest controls, new pests resulting from climate change, changing weather, increasing size of farms.	42, 43, 44
30. Waste Management	Collection, sorting and processing of waste for recycling or for energy production.	Reduced environmental pollution. Provides material for recycling.	Manual handling risks during collection and sorting. Exposure to chemical and micro-organisms during collection, sorting and processing. Fire and explosion risks from processing. New materials, when being collected as waste, may present a variety of unknown risks linked to (new) dangerous substances they may contain. Landfill mining will increase exposures to harmful materials.	Waste management activities will increase, driven by government targets to reduce landfill and to meet increasing requirements to recycle. Landfill mining is likely to increase.	59, 60
31. Recycling Technologies	Recycling of materials and components.	Recycling reduces energy use, conserves natural resources.	New recycling technologies may introduce new risks. New materials, when being recycled, may present a variety of unknown risks linked to (new) dangerous substances they may contain.	New technologies will be developed to improve recycling. Greater emphasis on advanced processes that preserve the performance qualities of materials. Recycling of novel materials and devices may present new hazards.	45, 59, 60
32. Environmental Remediation Technologies	Excavation or dredging, surface enhance aquifer remediation (SEAR), pump and treat, solidification and stabilization, in situ oxidation, solar vapour extraction, bioremediation, phytoremediation.	Restores polluted areas.	Environmental remediation can involve handling of large quantities of chemicals used in the process or potential exposure to pollutants or micro-organisms.	Novel techniques, introduction of nanotechnology based methods.	69

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33. Geo-engineering (other than industrial CCS)	Solar radiation management, eg cool roof, sulphur clouds. Ambient CO ₂ capture, eg ocean seeding, artificial trees (resin towers that absorb CO ₂ from the atmosphere), Heat transport (ocean pipes).	Aims to reduce global warming.	Unintended consequences for the environment. OSH hazards likely to be associated with construction or exposure to chemicals involved.	Only limited activity to date, with controversy about, for example, ocean seeding.	56. 57, 58
34. Medicine, Healthcare and Related Technologies.	A range of techniques to aid monitoring of health indicators. Personalised treatment. Improved sensors for exposure monitoring. 'Lab-on-a-chip' applications.	Increased efficiency, improved worker health. Telemedicine could reduce the need for travel. Applicability to green/non-green jobs alike.	Developments in personal medicine, improved techniques generally, will lead to improved health and safety. Genetic testing could identify those workers most at risk from certain substances. Developments such as performance enhancing drugs could either improve or impair health and safety performance.	Continuing rapid developments in detection and treatment. Personalised treatments. Targeted drug delivery using nanotechnology. Developments in bionics, human computer interface leading to thought controlled prostheses, robotic exoskeletons, all of which will allow people with disabilities back into the workplace. Performance enhancing drugs.	65, 66, 67, 68

7.5 Annex 5: Phase 2 Workshop Participants

Sam Bradbrook	Health and Safety Laboratory, UK
Emmanuelle Brun	EU-OSHA
Stefano Carosio	D'Appolonia S.p.A., Italy
Kären Clayton	Health and Safety Executive, UK
Martin Duckworth	SAMI Consulting, UK
Peter Ellwood	Health and Safety Laboratory, UK
Pål Evensen	Booregaard, Norway
Xabier Irastorza	EU-OSHA
Viktor Kempa	European Trade Union Institute, EU Member of EU-OSHA's European Risk Observatory Advisory Group (EROAG)
Lee Kenny	Health and Safety Executive, UK
Ian McCluskey	Shell Gas Ltd, UK
Geoff Pegman	RuRobots, UK
Dr. Mike Pitts	Chemistry Innovation Ltd, UK
Aida Ponce	European Trade Union Institute, EU Nominated by EU-OSHA's EROAG workers' representatives
John Reynolds	SAMI Consulting, UK
Olivier Salvi	Ineris, France
Jennifer Stack	Tecnalia, Spain
Chris Streatfeild	Renewable-UK, UK
Erkki Yrjänheikki	Ministry of Social Affairs and Health, Finland Member of EU-OSHA's EROAG

7.6 Phase 2 Workshop Agenda (Manchester, UK, 4-5 May 2011)

4 May

- 14:00 Welcome and introduction (HSL/Project team)
- 14:10 Presentation by EU-OSHA - Background information to the project
- 14:30 HSL Presentation – Process and D5 Report + Questions
- 15:15 Energy Topics Keynote Presentation + Questions
- 16:00 Coffee
- 16:15 Breakout Exercise - Impact/Timeline/Uncertainty Exercises
- 17:45 Report Back and discussion on results of the exercise
- 18:15 Close of Day 1

5 May

- 09:00 Welcome
- 09:05 Other Technologies Keynote Presentation + Questions
- 10:00 Breakout Exercise - Impact/Timeline/Uncertainty Exercises
- 11:30 Coffee
- 11:45 Report back and discussion on the results of the exercise
- 12:15 Plenary conclusions and final discussion
- 13:00 Next steps and close