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INNOPATHS

Innovation pathways, strategies and policies for the Low-Carbon Transition in Europe

H2020-SC5-2016-2017/H2020-SC5-2016-OneStageB

D3.3 Report on first participatory co-design workshop

Work Package: 3

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1. Introduction

The INNOPATHS project is using an intensive process of stakeholder engagement and co-design in order to inform the development of technologically-detailed decarbonisation pathways for Europe to 2050. An important stage in that process is the co-design workshop, which brought together teams from the INNOPATHS consortium involved in WP3, along with 10 co-designers with policy, industry and scenario experience.

This document provides a report on the workshop, which was held in Florence on February 6th 2018. In doing so, it first provides some background to the scenario and co-design process. It then sets out the workshop design, and the key insights derived from the workshop. Finally, it draws together some conclusions and highlights next steps. The workshop agenda, a list of participants, and the briefing notes for workshop facilitators are included as appendices.

2. Workshop design and preparation

The workshop was hosted by the European University Institute in Florence, and was prepared by UCL. The aim of the workshop was to enable the project to draw out from co-designers the possibilities and issues they believe to be important in shaping Europe's energy future. In particular, we aimed to explore the inter-dependency of large scale trends, technology pathways, and policy options.

1.1 Identifying and inviting participants

In identifying potential participants, the aim was to secure involvement of people involved in public policy (ideally those developing or informing policy development in government bodies), those with expert knowledge of policy and technology issues confronting the sectors that are the principal focus of the INNOPATHS project, and those with expertise in long-term energy scenarios. A first round of invitations was sent to a selected group of INNOPATHS co-designers (a group of people recruited to the project during the proposal). This was then extended, based on suggestions from co-designers, the extensive network of contacts of INNOPATHS consortium members, and targeted searching for representatives of specific sectors (such as industry groups and non-governmental organisations). Particular efforts were made to ensure a balance of genders and geographic origins.

1.2 Workshop structure

The workshop was designed to facilitate a rich discussion of the possible developments of Europe's energy system. The overall structure was straightforward:

- **Scene-setting presentations.** The workshop was introduced with an overview of the INNOPATHS project, and a discussion of the role of the INNOPATHS scenarios. The findings of the INNOPATHS stakeholder survey (see

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INNOPATHS D3.2) were presented. Presentations were then provided by the International Energy Agency and the SET-NAV project, each of which develop scenarios of possible future energy systems and configurations.

- **Structured workshop sessions**, which involved structured discussions around the perceived likelihood and importance of a set of possible future developments. The three sessions were themed as follows:
    1. Big picture trends.
    2. Technologies and systems.
    3. Policies.

A full agenda is provided in Appendix 1, along with participants list (Appendix 2), and the briefing notes for discussion group facilitators (Appendix 3).

Figure 1. Some participants of the workshop. Missing are: Elena Verdolini, Laura Diaz Anadon; Lara Aleluia Reis; Florie Gonsolin,

Figure 2. Professor Paul Ekins opening the workshop in the grand surroundings of the European University Institute

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3. Session 1: big picture trends

In this session, participants were asked to consider a series of statements about possible future conditions for Europe. They were then asked to 'map' these statements to two dimensions: likelihood, and importance in shaping Europe's decarbonisation pathway (see Box 1). Participants were also invited to suggest additional issues or themes.

- **Politics—and especially populist nationalism—will mean that some regions and countries can be expected to lag and resist strong policy action**; while others will go through cycles of leadership and retrenchment. The implication is that policy measures and technological system advances may be regionally and temporally patchy.

- **Actively interventionist state:** As the energy transition unfolds, governments are increasingly interventionist: slow-moving sectors will be increasingly targeted by regulatory and technology-specific measures.

- **Digitisation and automation will drive pervasive change in energy systems**: this will enable integration of energy systems, with greater efficiency and optimisation of processes. But it could also enable new energy demands and exacerbate inequalities.

- **A settled political consensus on climate change will remain elusive.** Public support for transition policies will remain politically vulnerable: a plausible political pathway requires a focus on co-benefits and equity, rather than pursuit of least-cost, and suggests stop-start dynamics and challenges with co-ordination and long-term planning

- **Europe will aim for 95% rather than 80% by 2050.**

Box 1. Big picture trends

Participants expressed strong interest in the issue of populist nationalism, and the potential for divergent political ambition and fragmented action on climate policy within Europe. It was noted that this was a concern within countries, as well as between them, with regional disparities and tensions creating risks for smooth implementation of optimal climate policies and technology trajectories. Economic dimensions of populism have strong implications for trade policies, and for attempts to achieve industrial leadership in emerging technologies. It was widely agreed that fragmentation of the EU's approach to decarbonisation was both likely and potentially very important in shaping policy options and technology pathways.

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Some participants felt that populism was likely to deliver a focus on energy security and affordability, and arguing that climate change policy was an easy target for nationalist politics. Others suggested the possibility of new political and advocacy coalitions for climate action emerging in response to populist nationalism, resulting in a more networked and flexible climate governance regime in Europe.

Several participants discussed the potential for increasingly obvious climate impacts to shore-up political support for decarbonisation policies; but it was widely agreed that a stable political consensus on climate action is likely to be elusive. The role of business in advocating for climate policy was also discussed. Increased concerns about the potential for climate-related litigation to threaten business operations can drive business advocacy for moderate climate policies, including carbon pricing. As the transition unfolds, it is also clear that different constellations of political interests will intersect: as low-carbon energy firms grow in economic importance, they will increasingly advocate for supportive policies. Current political advocacy coalitions may splinter as technology options emerge that enable decarbonisation of some economic activities faster than others.

Much greater levels of digitisation and automation were seen as a near certainty, though participants disagreed about the potential importance of this trend for energy pathways. It was widely suggested that digitisation and automation could facilitate efficiency savings and reduce the costs of integrating variable renewables into energy systems.

Issues of information security and privacy were seen as potentially very important: both are seen as potentially delaying the rate at which digitisation might be expected to play a significant role; or limiting the extent to which data is available to enable system optimisation, or the extent of automation.

There was a sense that the widespread diffusion of digitisation/automation into the European economy can be expected to create new modes of consumption that will require energy. It was seen as plausible that digitisation could enable greater efficiency of various systems, but could also drive overall growth in energy service demands. More broadly, participants expressed the view that the digital revolution would not, by itself, be expected to generate carbon savings – this will only occur where strong policies exist.

Participants saw a shift to more actively interventionist states as plausible, but less likely than the other big trends. One participant said it was difficult to imagine the emergence of clear motivations for strongly interventionist policies: while climate impacts might provide such a motivation, this might be expected to direct action towards adaption or geo-engineering, rather than carbon abatement. Others suggested that a switch to a more interventionist mode would be high impact, but was also unlikely; while it was also noted that a more interventionist approach risked pursuing mitigation objectives but raising costs and overlooking co-benefits (the ‘big picture’).

There was disagreement among participants about the extent to which they saw an increased ambition level—to a 95% target—as plausible. Some argued that a 95% reduction target is likely. Most felt it was rather unlikely, and participants disagreed about how much this mattered. Some felt that a 95% target would be highly important

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in advancing the decarbonisation objective, as this sets the long-term expectations about the policy initiatives required, and would drive actors across the economy to prepare for such a future. If packaged as part of a broad vision with a high quality of life and economic resilience, such a target could be politically feasible, and could act to stretch the debate such that an 80% target is less politically difficult. Others argued that establishing more stretching targets would be counter-productive, as it could be seen as a detachment of rhetoric from reality, since even existing targets are very ambitious and difficult to meet. It was also suggested that including such an objective in narratives, scenarios and projections, helps inform the political debate and raises the likelihood of establishing such a target.

4. Session 2. Technologies, sectors and systems

This session addressed the innovation dynamics of specific groups of technologies. Participants were asked to discuss a series of technology outcome statements, each of which was posed as a pessimistic and optimistic view. The aim of this session was to generate insights into not only the possibilities for the technologies, but to link those technological possibilities to big-picture trends. This section provides an overview of the discussion around each of the technology statements in turn. As a general point, it was observed that the optimistic views were premised on the assumption that innovation success would be forthcoming, and that appropriate support structures were in place to facilitate this.

- Solar and wind run into increasing resistance. The tipping-point takes longer to emerge than many hope **vs.** *Costs fall, driven by scale and ongoing innovation, and diffusion accelerates*

There was general consensus that costs for solar and wind technologies are likely to continue to fall, and there was general optimism about the prospects for these technologies. Some participants suggested that the 'tipping point' referred to in the statement above has already been reached in parts of the EU, at least in the sense that new renewables can be cheaper than new fossil fuel plant – the later tipping point (where new renewables are cheaper than the marginal costs of fossil fuel plant) is still to come. It was also recognised that there is social and political opposition to the deployment of renewables which may impact diffusion rates, but this was thought to be generally minor and often localised – perhaps suggesting that this is a factor that might slow, but not prevent, further deployment. It was suggested that deployment will largely depend on the broader system configuration, including balancing and storage costs.

Despite general optimism, some threats to renewables were also seen as plausible factors that could slow or stall developments. The cost of deployment subsidies was recognised to be a potentially significant source of political contestation that could threaten progress in driving renewables adoption. While some participants suggested this political risk could be balanced by highlighting subsidies still granted to fossil fuels, it is clear that public political debate does not always accurately weigh competing arguments in this way. Participants noted that recent moves to shift renewables support to auction-based approaches appeared to be successfully driving down the costs of

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renewables projects, and that this might alleviate such concerns. Finally, there was discussion about the political imperatives of demonstrating domestic economic benefits from investments in renewable energy, and the resulting challenges this places both in terms of extra-EU trade relations (with protectionism an issue) and state-aid concerns within the EU.

- Application of ICTs to energy responsive demand is inhibited by privacy and security concerns, and is slower to make a difference than anticipated **vs.** *Smart energy systems and dynamic pricing enable flexible demand and smart charging, facilitating integration of variable renewables and EVs.*

There was general agreement that smart energy systems will advance to some degree, but a number of potential challenges were also raised. This included: the potential resistance to monopoly power if certain companies were to become the dominant actor in a range of different but increasingly interconnected fields (e.g. Google); concerns surrounding national security and the potential for hacking to lead to ever wider and more pervasive consequences; increasing inequality as new technologies are adopted by the wealthy in society but remain out of reach of others; and concerns around personal privacy. There was debate around the importance of this final point, as it was pointed out that at present there is little concern around surrendering privacy in order to use smartphones and 'home assistants' (e.g. Amazon Dot, Google Home, etc.), amongst other technologies and applications. Smart systems were seen as potentially important enablers of penetration of variable renewables, through vehicle-to-grid, responsive demand in domestic appliances, and more efficient system operation.

- Energy efficiency in domestic buildings progresses much more slowly than analysts expect, as people remain conservative in their behaviour, **vs.** *new business models and policies enable sustained upgrading of the built environment*

There was general consensus that energy efficiency in domestic buildings is likely to progress slowly for a range of reasons (hassle factor, long payback periods, high capital costs, etc.). It was suggested that current levels of investment in energy efficiency are 10x too low. However, one participant raised the possibility of new business models arising as smart meters and systems allow a 'big data' approach to energy services, potentially reducing transaction costs for ESCOs in the residential sector. Virtual Power Plants are a rapidly growing business model within the utility sector. It was noted that facilitating the emergence of such business models depends on market design: consumers are currently insulated from minute-to-minute fluctuations in power prices, and this inhibits the potential for new business models to emerge in this area.

One major issue for this sector is the small size of projects. While the return-on-investment is often good, the transaction costs associated with managing many very small projects make it an unattractive sector for investors. There is potential here for digitisation to help, through greater predictability of energy savings. The institutional set-up of the finance sector is also relevant here, and helps explain regional divergence in performance within Europe: the local nature of many German banks facilitates

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relatively small-scale loans, whereas (mostly very large) UK banks are not interested in many small loans unless they are (like mortgages) very standardised.

The role of state investment banks was also considered to be important here, with Germany's KfW the leading example of good practice. Another policy suggestion was the idea of requiring an increase in the energy efficiency of a building when a certain value is spent on other amendments to the building, as has been implemented in some countries.

Several participants highlighted current interest—particularly in the UK—around the potential for hydrogen to play a significant role in heating, by making use of existing gas distribution infrastructure.

Slow progress with building retrofit measures was seen as more likely under a 'fragmented' scenario, in which climate policy is less stable.

- Continued exploration and innovation in the gas sector facilitates relatively low costs of gas in the 2040s, diminishing the incentives to shift to alternative fuels **vs.** *European gas costs fall in the 2020s, facilitating a shift away from coal*

There was general agreement around the uncertainty of the future of gas (and whether or not it might be a 'transition fuel'), and recognition that it is likely to vary by country and sector. For example the UK has already transitioned to gas from coal in its power sector, whilst Poland has not. It may also have a longer lifetime in residential heating than in the power sector. The availability of other energy resources within a given country is also a crucial factor. Gas could be seen as the underpinning alternative fuel of a relatively low carbon (compared to today) system; but this is an alternative to a greener scenario with very limited fossil fuels and reliance on renewables, nuclear, efficiency and CCS.

- Electric vehicle deployment: mainstream adoption is delayed by grid constraints and charging network **vs.** *EVs and PHEVs quickly reach tipping point and become dominant in sales terms by 2035*

There was general agreement that electric vehicles will continue to become more prevalent, driven by cost reductions and air quality policy, as well as climate change. However, whether this would be a positive thing from a broader environmental perspective will depend on progress in decarbonising electricity grids and managing increased demand, and lifecycle issues. Vehicle-to-grid technologies were seen as potentially a strong enabler of wider diffusion of variable renewables.

- Aviation and shipping remain stubbornly hard to decarbonise beyond incremental efficiency gains **vs.** *biofuels and hybrid-electric technologies increasingly adopted in both*

There was substantial uncertainty surrounding the future of decarbonisation in these sectors, with one participant suggesting it depended on the development of incremental

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or revolutionary new technologies. Another participant stated that when CO_2 emissions from these sectors are determined as follows:

CO_2 emissions =
personkms*(vehiclekms/personkm)*(energy/vehiclekms)*(CO_2/energy),

improvements to the middle two elements are likely only to be incremental at this stage. The majority of improvements must therefore be sourced from reducing the CO_2 intensity of fuel (or reducing personkms). Another participant stated that air quality concerns may drive innovation to low-pollution fuels or electrification, although the lack of economic incentives and lack of policy ownership by a given country due to the international nature of these industries inhibit progress. On balance, there is greater optimism around aviation, as this sector appears to be subject to greater public and policy attention than shipping at present.

- Nuclear energy projects continue to experience cost escalations and delays, **vs.** *a new generation of reactors facilitates new round of nuclear build*

There was strong disagreement around the general future of nuclear energy, although general pessimism surrounding its future in the EU.

- Pan-European power systems integration and supergrids fail to materialise; result is requirement for higher levels of domestic balancing **vs.** *Growing opportunities for trans-European energy trading facilitate investment in interconnection and a 'supergrid', which further enable variable renewables*

There was 'weak pessimism' surrounding the development of a European 'supergrid'. Other approaches to facilitating integration were also discussed, and seen as promising, including vehicle-to-grid, flexible demand response, and power-to-gas.

- Bioenergy is hampered by continued contestation over sustainability, this limits its potential **vs.** *supply chain standards become accepted for bioenergy, enabling its widespread use in European energy systems*

Participants expressed pessimism about the future of bioenergy. The political challenges associated with bioenergy were seen as being particularly difficult. Several participants expressed the view that the challenges of certification and supply-chain management would mean bioenergy would only be desirable in relatively narrow application areas (such as aviation fuel), and if so, the overall importance of bioenergy would be relatively minor. Others noted that bioenergy was potentially very important, particularly because of Bio-CCS enabling negative emissions, and the potential roles in aviation and freight. The concern was raised that the EU would be 'left behind' – losing out on first-mover advantages in technology.

- CCS fails to attract significant near-term development investment, and becomes available only in 2040 **vs.** *CCS demonstrations facilitate renewed focus on the*

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technology: driven by need to tackle mitigation in hard-to-reach sectors; or regions that are heavily economically (and hence politically) carbon-intensive

A mix of views was expressed around CCS. It was highlighted that CCU was gaining significant interest and attention in some sectors, particularly in the chemicals sector where CCU plus low-carbon electricity could provide a viable feedstock in a wide range of core chemical products. This has the clear benefit of creating market demand for CO_2, facilitating investments in capture technologies.

However, participants expressed gloom concerning the near-term prospects of CCS adoption in the power sector. There was a sense that no-one wants to take on the first-mover risks; that the co-ordination challenges are very challenging (many actors with divergent interests); and that the large sizes limit the potential for rapid learning (each plant slow to build, and resulting learning is limited). While it is clear that governments still see CCS as a long term priority, particularly for facilitating decarbonisation of heat and industry, there was some general pessimism about future developments. A further concern is the risk of local 'not-in-my-backyard' objections to carbon pipelines and geological storage.

CCS was seen as requiring both public support for demonstrations, and strong stable carbon prices (€100/tCO_2). There was disagreement about the role of the state in delivering CCS. Some participants felt that only an interventionist, active state could drive CCS development.

- Crop yield growth inhibited by public concerns about crop protection products and climate change impacts **vs.** *R&D in agricultural systems enables continued yield growth, facilitating biomass production for food, energy and materials*

The group expressed optimism about future crop yield growth, with further adoption of precision agriculture, automation, and reduced waste. There was also discussion about the possibilities for increased used of insect protein in animal feed. However, participants generally thought that these developments were not critically important. There was some debate about whether yield growth could, or could not, keep pace with expected future demand for food, with divergent opinions about the potential for land availability for bioenergy.

In discussions about bioenergy and crop production, doubt was also raised about the potential for non-CO_2 gases in the agricultural sector to be reduced. Since many of these are related to fundamental biological processes, there was pessimism about the scope to significantly reduce these.

- Many industrial processes using natural gas resist change to assure product quality and contain costs **vs.** *R&D enables adoption of low-carbon fuels in many industrial heating applications: electric kilns, hydrogen and bioenergy*

There was widespread optimism for the potential for emissions reductions in industrial sectors, but complexities were noted. Electrification may result in net increases in total

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energy demand, but could also deliver emissions reductions – yet current policies are oriented towards energy reduction. CCU was seen as very important, and 'already happening', at least to some degree, because of the existing business case. The issue of competitiveness and carbon leakage is critical here.

- Material substitution and the circular economy progresses slowly and don't meaningfully affect primary industrial demands **vs.** *Energy demands in industry fall as value shifts to design and services (maintenance, cleaning, repair) for longer-lived products; some shifting towards wood-based construction, reducing demand for cement and steel*

There was considerable optimism around circular economy business models, though disagreements about how much of an impact this could make on industrial and commercial energy demand and emissions. There were disagreements on both the magnitude of emissions impacts, and also on their direction, with some suggesting that circular economy models could generate additional manufacturing activity within the EU, resulting in a re-shoring of emissions.

5. Session 3. Policies

There was a clear consensus on the need for a policy mix to drive the technological transformation for decarbonisation. Two examples raised were the development and deployment of wind and solar technologies and electric vehicles; success here was and is due to technology specific support and R&D working in tandem. Another example is improving energy efficiency in buildings; it was suggested that efficiency regulations, technology-specific subsidies and exposure of end users to dynamic energy pricing are all important, with carbon pricing likely to be largely secondary to these.

It was highlighted that regardless of the specific design of the policy mix, it must be mindful of 'losers' from the low-carbon transition, such how to replace employment from coal mining with other employment opportunities, and how to design carbon pricing mechanisms so they are not regressive. It is also important to consider mechanisms to allow access to finance for those that require it.

As the previous sections have illustrated, policy options for Europe were discussed in the context of both big picture trends and specific technology pathways. The policy discussion highlighted:

- Widespread agreement about the value of carbon pricing, but diverse opinions about whether the ETS could deliver the carbon price required to support investment in significant decarbonisation. While some sectors keen to see higher carbon prices – and a carbon price floor – others (particularly trade-exposed, emissions-intensive sectors) are happy with the status quo and low price level of the ETS. The prospect of different emissions prices across Europe (multi-speed decarbonisation) was suggested as a plausible near-term development, with France and Germany potentially committing to higher prices. The fear is that this will further diminish signals for abatement investments elsewhere in

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Europe, particularly in Poland and Greece. Trade and protectionism issues were raised as important, given the need to prevent emissions leakage. There was debate about the sectors that are not part of the ETS, such as waste and agriculture; and the potential for carbon pricing to play a role here. A further issue around carbon prices was the potential for renewables support policies to interfere with, and undermine, carbon prices, thus reducing the price incentives for other forms of low-carbon innovation in the sector.

- Electricity market structure and regulation were discussed. What is the extent to which consumers should be exposed to dynamic pricing? There is a need for lots of good data and transparency to enable business models for flexible demand. Market access requirements also important here.

- Subsidies for fossil fuel consumption and production were widely considered to be an important issue – their removal was considered by stakeholders to be an important enabler of decarbonisation.

- There was extensive discussion of the challenges for policy in driving energy efficiency in buildings. Financing and transaction cost barriers were seen as key. Long-termism and stability in policy was seen as being particularly important here, given strong dependency of technology diffusion on a suitable institutional context (i.e. appropriate financial institutional structure; adequate skills base in the construction sector).

6. Conclusions and next steps

The workshop in Florence represented a second step in the process of co-designing scenarios for Europe's technology pathway to deep decarbonisation, following on from the stakeholder survey reported in D3.2. A key next step for the INNOPATHS scenarios is the generation of draft narratives (Milestone 7), which will be circulated both internally among project partners and to co-designers for feedback. This set of draft narratives will then be used in the development of modelled scenarios (Milestone 8).

The process, as set out in the Description of Work, involves an iterative 'dialogue' process between the narrative scenarios and the models: some aspects of the scenarios, seen as plausible possibilities by stakeholders, may turn out to be difficult or impossible to represent in model runs; other aspects may be shown by modelling to be implausible. The development of narratives and modelled scenarios will be considered in a further co-design workshop, to be reported in D3.5.

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7. Appendix 1: Workshop agenda

Pathways to European decarbonisation: the INNOPATHS scenarios workshop

6th February 2018

Badia Fiesolana, European University Institute, Florence

9.00 Welcome & introductory presentation: the INNOPATHS project and scenario process
Professor Paul Ekins, UCL

9. 15 Presentation: Insights from existing European scenarios - What do we think we know?
Will McDowall & Robert Pietzcker

9.45 Presentation: Insights from the Innopaths Scenarios Questionnaire
Will McDowall

10.00 Brief presentations: perspectives on energy futures

- Hannah Daly, International Energy Agency (presenting on the World Energy Outlook)
- Charlie Wilson, University of East Anglia (presenting on the SET-NAV scenarios)

10.30 Coffee break

11.00 Morning workshop session - The big picture: politics, macro-trends and context

12.30 Lunch

13.30 Afternoon workshop session 1: Sectors, systems and technologies

15.00 Coffee break

15.20 Afternoon workshop session 2: Policies for decarbonisation and technological transformation

16.15 Summary and next steps for the scenarios
Will McDowall and Robert Pietzcker

16.30 – 17.00 Innopaths Policy Evaluation tool
Laura Diaz Anadon

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8. Appendix 2: List of participants

1. Jeff Hardy, BEIS/Imperial College London
2. Aldo Ravazzi, Italian Ministry of Environment
3. Martin Haigh, Shell
4. Krzysztof Laskowski, Eurelectric
5. Jonathan Scurlock, National Farmers' Union (UK)
6. Hannah Daly, International Energy Agency
7. Sarah Livermore, Head of Modelling, UK Committee on Climate Change
8. Florie Gonsolin, European Chemical Industries Council
9. Charlie Wilson, University of East Anglia
10. Carlo Orecchia, Italian Ministry of Environment – TA Sogesid
11. Paul Ekins, UCL
12. Will McDowall, UCL
13. Paul Drummond, UCL
14. Robert Pietzcker, Potsdam Institute for Climate Impact Research
15. Lara Aleluia Reis, Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
16. Elena Verdolini, Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
17. Panagiotis Fragkos, E3 Modelling
18. Laura Diaz Anadon, University of Cambridge
19. Cristina Penasco, University of Cambridge
20. Isabella Aloisio, European University Institute
21. Francesco Nicolli, European University Institute
22. Stefano Verde, European University Institute

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9. Appendix 3: Briefing document for workshop facilitators

Pathways to European decarbonisation: the INNOPATHS scenarios workshop

Morning workshop session - The big picture: politics, macro-trends and context

Task: Discuss the statements in the bullet point list, and map them to a matrix of likelihood vs. impact on Europe's decarbonisation pathway. Participants consider their own judgements silently (for 3-5 minutes), and add any additional big picture issues. They are then invited one-by-one to put a statement on a post-it, map them to the impact/likelihood matrix on the flipchart, and explain their choices.

Which are most likely? Which might have the biggest impact on the decarbonisation pathway Europe takes?

During lunch: please add dots to "vote" on which are most important for INNOPATHS scenarios to explore?

- **Politics—and especially populist nationalism—will mean that some regions and countries can be expected to lag and resist strong policy action**; while others will go through cycles of leadership and retrenchment. The implication is that policy measures and technological system advances may be regionally and temporally patchy.

- **Actively interventionist state:** As the energy transition unfolds, governments are increasingly interventionist: slow-moving sectors will be increasingly targeted by regulatory and technology-specific measures.

- **Digitisation and automation will drive pervasive change in energy systems**: this will enable integration of energy systems, with greater efficiency and optimisation of processes. But it could also enable new energy demands and exacerbate inequalities.

- **A settled political consensus on climate change will remain elusive.** Public support for transition policies will remain politically vulnerable: a plausible political pathway requires a focus on co-benefits and equity, rather than pursuit of least-cost, and suggests stop-start dynamics and challenges with co-ordination and long-term planning

- **Europe will aim for 95% rather than 80% by 2050.**

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Afternoon workshop session 1: Sectors, systems and technologies

1.5 hours

This session addresses the innovation dynamics of specific groups of technologies. The task is to discuss the following technology outcome statements, each of which is posed as a pessimistic and optimistic view.

Task 1 (first hour). Map each technology outcome against the following axes: Are you optimistic or pessimistic about this? How important is this for Europe's decarbonisation pathway?
Each participant first takes a few minutes to think about prioritising these, then you can go round and invite people to explain their choices and map their statements.

Task 2 (final 30 minutes). Mapping technology outcomes to the most closely associated big picture trends.
Invite participants to write technology outcomes onto a post-it, and then:

a. Suggest how/why this technology outcome might occur
b. Associate the outcome with a big-picture trend (invite participants to stick them onto the associated trend on the flipchart)

During the break: please add dots to "vote" on which are most important for INNOPATHS scenarios to explore?

Group 1

- Solar and wind run into increasing resistance. The tipping-point takes longer to emerge than many hope **vs.** *Costs fall, driven by scale and ongoing innovation, and diffusion accelerates*

- Application of ICTs to energy responsive demand is inhibited by privacy and security concerns, and is slower to make a difference than anticipated **vs.** *Smart energy systems and dynamic pricing enable flexible demand and smart charging, facilitating integration of variable renewables and EVs.*

- Energy efficiency in domestic buildings progresses much more slowly than analysts expect, as people remain conservative in their behaviour, **vs.** *new business models and policies enable sustained upgrading of the built environment*

- Continued exploration and innovation in the gas sector facilitates relatively low costs of gas in the 2040s, diminishing the incentives to shift to alternative fuels **vs.** *European gas costs fall in the 2020s, facilitating a shift away from coal*

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- Electric vehicle deployment: mainstream adoption is delayed by grid constraints and charging network **vs.** *EVs and PHEVs quickly reach tipping point and become dominant in sales terms by 2035*

- Aviation and shipping remain stubbornly hard to decarbonise beyond incremental efficiency gains **vs.** *biofuels and hybrid-electric technologies increasingly adopted in both*

- Nuclear energy projects continue to experience cost escalations and delays, **vs.** *a new generation of reactors facilitates new round of nuclear build*

- Pan-European power systems integration and supergrids fail to materialise; result is requirement for higher levels of domestic balancing **vs.** *Growing opportunities for trans-European energy trading facilitate investment in interconnection and a 'supergrid', which further enable variable renewables*

Group 2

- Bioenergy is hampered by continued contestation over sustainability, this limits its potential **vs.** *supply chain standards become accepted for bioenergy, enabling its widespread use in European energy systems*

- CCS fails to attract significant near-term development investment, and becomes available only in 2040 **vs.** *CCS demonstrations facilitate renewed focus on the technology: driven by need to tackle mitigation in hard-to-reach sectors; or regions that are heavily economically (and hence politically) carbon-intensive*

- Crop yield growth inhibited by public concerns about crop protection products and climate change impacts **vs.** *R&D in agricultural systems enables continued yield growth, facilitating biomass production for food, energy and materials*

- Self-driving cars diffuse widely by 2050. They enable increasing vehicle-based mobility, driving up passenger km demand and undermining mode-shifting to public transport **vs.** *Self-driving cars have limited impacts on demand, and enable higher per-vehicle usage*

- Many industrial processes using natural gas resist change to assure product quality and contain costs **vs.** *R&D enables adoption of low-carbon fuels in many industrial heating applications: electric kilns, hydrogen and bioenergy*

- Material substitution and the circular economy progresses slowly and don't meaningfully affect primary industrial demands **vs.** *Energy demands in industry fall as value shifts to design and services (maintenance, cleaning, repair) for longer-lived products; some shifting towards wood-based construction, reducing demand for cement and steel*

*"This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No **730403**"*

Afternoon workshop session 2: Policies for decarbonisation and technological transformation

This final session explores policy options and responses. The task is to suggest policies, mapping them to the big picture conditions and/or the technological options.

Mapping policies to big picture conditions and technological options

- What policies are required to bring about the optimistic technology outcomes?
- What policies are required to mitigate the impacts of the pessimistic technology outcomes?
- To what extent are policies related to the big picture trends?

Ask participants to write down policies and relate them to optimistic or pessimistic technology outcomes, or to big picture trends (or to both)

Broad policy areas:

- Sector-specific regulatory policies (emissions performance standards, BAT requirements, etc.)
- Technology specific subsidies: feed-in tariffs vs. auctions; EV deployment subsidies
- Big strategic investment programmes in infrastructure (supergrid; hydrogen conversion of gas grids; CCS networks; vehicle charging infrastructure)
- Carbon pricing will drive much abatement and remains a cornerstone of decarbonisation policy *(vs. Carbon pricing is good policy but bad politics: patchier pricing schemes required)*
- R&D and Innovation policies
- Market structure: exposing consumers to dynamic pricing
- Regional development policies: dealing with potential losers
- Environmental regulations: preventing environmental downsides

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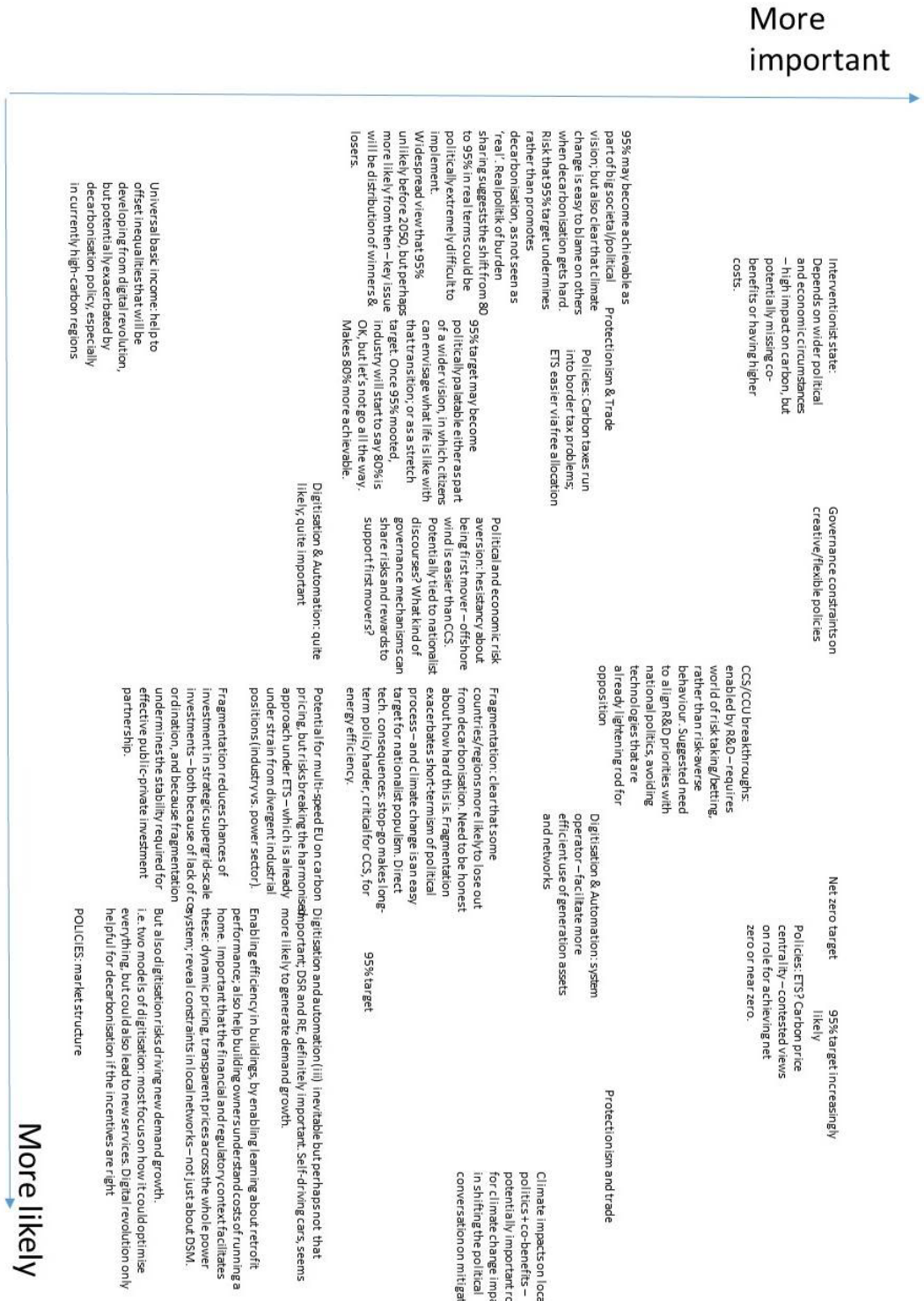
10. Appendix 4: Copies of flipcharts

The notes taken on flipcharts have been transcribed and elaborated here to reflect the discussion.



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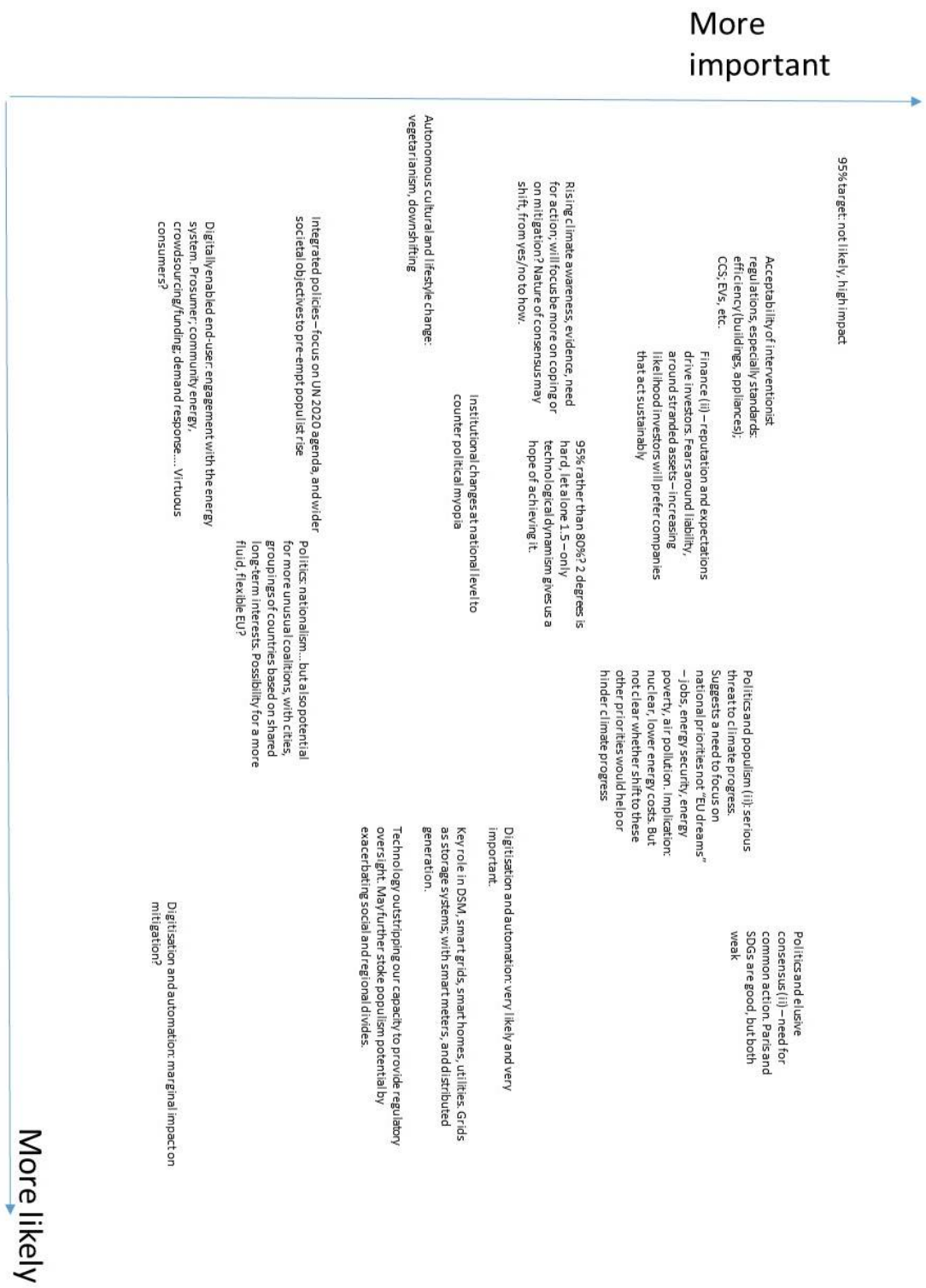

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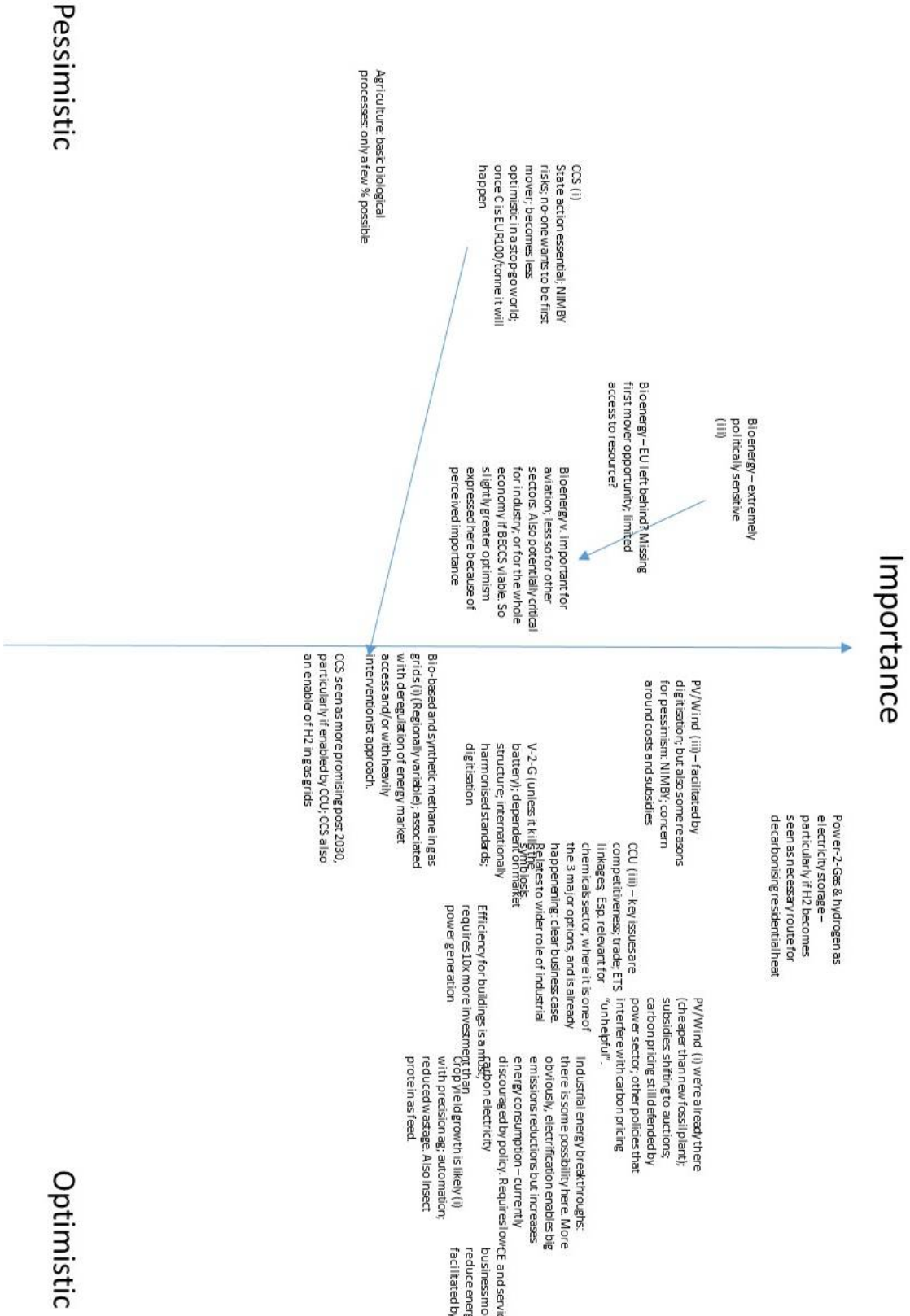

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