PROJECT FINAL REPORT

Grant Agreement number: 603942

Project acronym: PATHWAYS

Project title: Exploring transitions pathways to sustainable, low carbon societies

Funding Scheme: Collaborative project

Period covered: from 01-12-2013 to 30-11-2016

Name of the scientific representative of the project's co-ordinator, Title and Organisation:

Prof.dr. D.P. van Vuuren, PBL Netherlands Environmental Assessment Agency

Tel: +31 6 11956484

E-mail: Detlef.vanvuuren@pbl.nl

Project website address: http://www.pathways-project.eu/

Executive Summary

Different scientific approaches offer insight into transitions towards low-carbon, biodiversity-rich societies, among which integrated assessment modelling, socio-technical transition analysis, and case studies and participative action research. Integrated assessment modelling provides a macro perspective, linking future goals to the concrete implementation of technologies and the related policies and costs and benefits to achieve them and the linkages across different issues. Socio-technical transition studies seek to explain long-term shifts, taking account of a broad set of institutional, economic, social and cultural factors including those enabling behaviour change and adoption of new technologies. Finally, participative action research engages with concrete projects at the local and regional scale involving diverse social actors. Unfortunately, interaction between these approaches has so far been limited. The PATHWAYS project (http://www.pathways-project.eu/) aimed to advance the understanding of transition pathways towards European sustainability goals by better coupling methods and tools from quantitative systems modelling, socio-technical transition studies, and participative action research.

The PATHWAYS project analysed five different sectors: energy sector, buildings, transport, food production and nature/biodiversity. For each sector, several case studies were analysed in different countries to better understand the role of different actors and institutions in transitions. Moreover, country-level studies looked at the possible niche options, the existing regime and the momentum for change. Finally, model studies looked at the changes in each sector to meet 2050 climate and biodiversity goals.

The information generated in these studies was used to formulate two alternative pathways that are consistent with achieving the long-term goals for climate and biodiversity. In Pathway A the current regime remains strong, and incumbent actors mainly search technology substitution responses to the current challenges. In pathway B, new actors come in creating a total regime shift with more radical response strategies. These pathways have been elaborated in quantitative and qualitative transition scenarios. The qualitative narratives are consistent with the quantitative modelling analyses, the findings from socio-technical transition analyses, and the findings from participative action research. The storylines focus on the notion of branching points: where in the system is a deviation from business-as-usual required to achieve the transition? Is there momentum to achieve this deviation, and can policies help to increase such momentum? These storylines can support policy-making on mainly EU level, as they provide a comprehensive analysis of possible transition pathways in which the challenges with regard to technologies, policies, and behavioural changes are made clear.

The main policy messages were summarized in policy briefs for each of the domains analyzed in the PATHWAYS project (electricity, heating, mobility, agro-food, and land use & biodiversity). Some key messages emerge in all domains: 1) socio-political analysis and techno-economic modelling can complement each other, 2) social acceptance is a crucial success factor for decarbonization strategies, 3) demand side changes are essential for sustainability transitions, 4) the combined analysis in PATHWAYS can identify key barriers to change and 5) a transition to a low-carbon society requires a consistent and coherent strategy/vision.

Table of Contents

Summary description of project context and objectives

In order to prevent dangerous climate change and to avoid further loss of biodiversity, the EU has set ambitious policy goals. Achieving these sustainability goals will require fundamental societal transitions and coordinated policy action. For instance, reducing European greenhouse gas emissions to a level consistent with the 2 °C target requires a decarbonisation rate 2-3 times higher than observed over the last decades, leading to a radically transformed energy system. Similarly, to prevent a further loss of biodiversity, fundamental changes are needed in agricultural systems and, potentially, food consumption. Deepening (scientific) understanding of how to promote these fundamental and interrelated transitions is crucial for meeting sustainability goals.

Different scientific approaches offer insight into these transitions, quantitative systems modelling (among which integrated assessment models (IAMs)), socio-technical transition studies, and participative action research. Quantitative systems modelling provides a macro perspective, linking future goals to the concrete implementation of technologies and the related policies and costs and benefits to achieve them. It also allows linking the different policy issues, such as biodiversity protection and climate change. Socio-technical transition studies seek to explain long-term shifts, taking account of a broad set of institutional, economic, social and cultural factors including those enabling behaviour change and adoption of new technologies. Finally, participative action research engages with concrete projects at the local and regional scale ('transitions in the making') involving diverse social actors such as citizens, businesses, civil society organisations and (local) government, with the aim of fostering innovation and upscaling innovative sustainability solutions. Unfortunately, interaction between these approaches has so far been limited. While each of them has strengths, none alone can give a full picture. This fragmentation of research weakens the understanding of transitions and thus limits the value of transition analysis to European, Member State and local policy-makers. For instance, the focus of modelling studies on least-costs pathways implies that little attention is paid to institutional constraints and opportunities. Better understanding of realistic transition pathways is also of interest to other key stakeholders in the EU, such as businesses and civil society.

The overall objective of the PATHWAYS project (http://www.pathways-project.eu/) is to *provide policy-makers and other key stakeholders with better insight in on-going and necessary transition pathways for key domains relevant for EU policy*. Our approach is to do this by *better coupling methods and tools from quantitative systems modelling, transition studies and participative action research approaches*, generating an integrated, multi-scale and transdisciplinary chain of analysis (Figure 1). The project aimed to achieve the overall objective by means of the following specific objectives:

1. Provide a detailed mapping of key alternative transition pathways in terms of its technical, economic, political and social dynamics characteristics.
2. Better understand the conditions needed for the development of socio-technical systems in a way that is consistent with rapid transitions towards sustainable development goals (the conditions include descriptions of regimes, niches and landscape related to these transitions).
3. Explore how insights and activities of key actors can be harnessed, specifically by analysing how the limitations of current policies can be overcome by a stronger focus on the involvement of different stakeholders.
4. Link integrated assessment modelling, transition studies and participative action research in order to create an integrated, interdisciplinary chain of analysis which allows to deepen the understanding of transitions towards sustainable, low carbon societal systems.
5. Use the findings to inform 'transition policies' in the EU, amongst others in the form of well elaborated scenarios that are based on more realistic descriptions of policies and their impacts.

Studying transitions has been a major component of the different disciplines described above and several large-scale projects. In PATHWAYS we not only aimed to contribute further to this, but to go beyond existing work in integrated assessment modelling, transition and innovation sciences and participative action research by relating these research areas in order to find out whether "bridges" can be build that can increase the insights from each discipline. Important activities to achieve this were to i) create model-based scenarios building on insights from sociotechnical transition analysis and participative action research, and ii) create socio-technical scenarios providing the narrative for the model-based scenarios. In the second type of scenarios, more focus has been given on the challenges, non-linearities, and role of actors of sustainable transition scenarios.

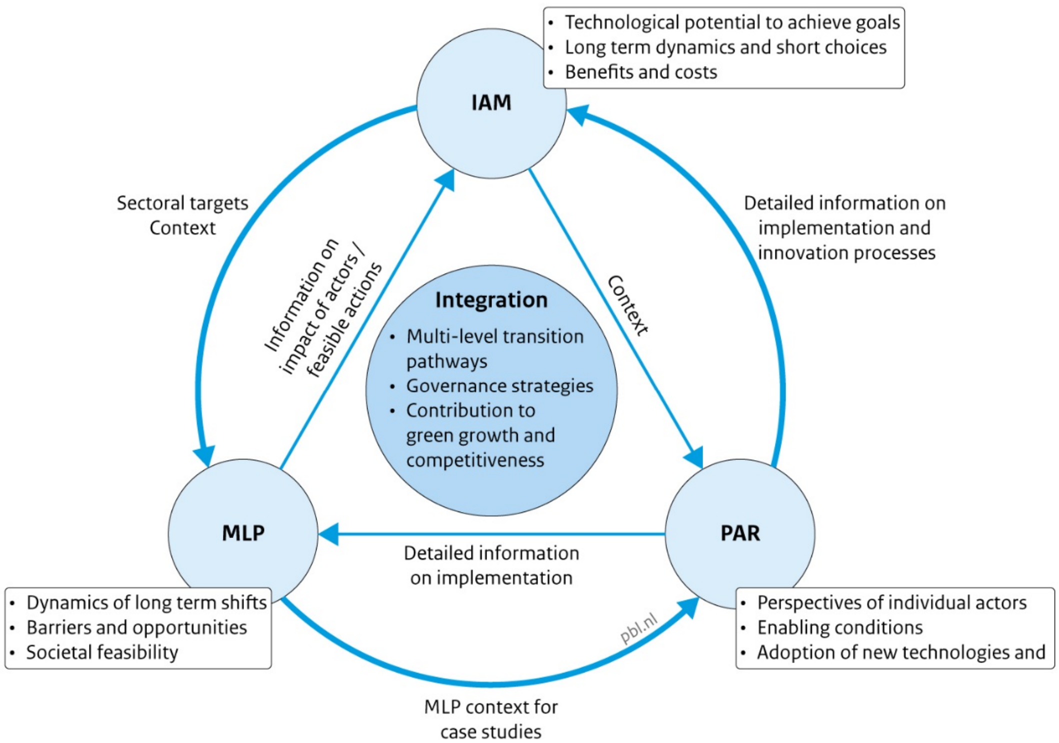

Figure 1. The PATHWAYS approach of linking IAM (integrated assessment or quantitative systems modelling), MLP (multi-level perspective of socio-technical transition studies) and PAR (participative action research) and the information flows in the project

Table 1. Defining elements of Pathway A and Pathway B

	Pathway A: Technical component substitution	Pathway B: Broader regime transformation
Departure from existing system performance	Substantial	Substantial
Lead actors	Incumbent actors (often established industry and policy actors)	New entrants, including new firms, social movements, civil society actors.
Depth of change	Radical technical change (substitution), but leaving other system elements mostly intact	Radical transformative change in entire system (fundamentally new ways of doing, new system architectures, new technologies)
Scope of change	1-2 dimensions: technical component and/or market change, with socio-cultural and consumer practices unchanged	Multi-dimensional change (technical base, markets, organisational, policy, social, cultural, consumer preferences, user practices)

The PATHWAYS project focuses on the domains electricity, heating/cooling, mobility, agro-food, and land use and biodiversity. Central in the PATHWAYS project are two alternative transition pathways storylines (Table 1). In ***Pathway A*** the technical component of substitution dominates. Sustainability objectives are achieved by adjusting the existing regime but without fully reordering of the existing societal structures. While in this pathway the technical components of the socio-technical regime change, many other elements (e.g. user practices, lifestyles, governance arrangements) remain close to the existing regime. This pathway tends to be advocated and enacted by incumbent actors. In ***Pathway B*** a broader transformation of the existing regime takes place. This leads to a shift to a new socio-technical system, based on the breakthrough of radical niche-innovations that entails not only technical changes, but also wider behavioural and cultural changes, new user practices and institutions (reconfiguration of preferences, infrastructure, and actors). Incumbent industry actors may be overthrown by new entrants, or enter into new alliances with them.

Description of the main S&T results/foregrounds

Collaboration between approaches

The work package structure was organized in such a way to enhance collaboration between approaches (Figure 2). Apart from a separate work package for integration and governance, we have assigned domain leaders within the project who were responsible for analyzing transitions in their domain based on all three approaches.

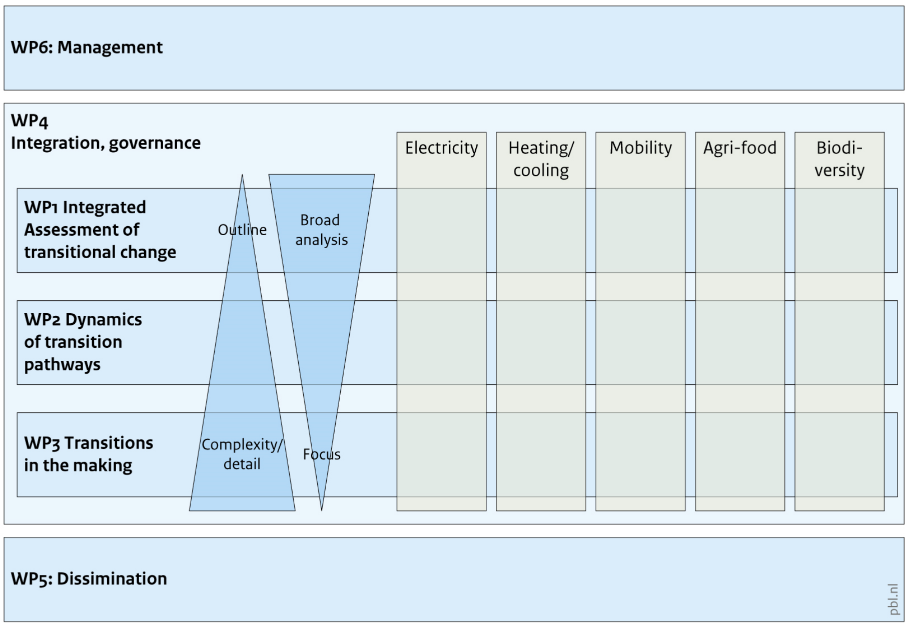

Figure 2. PATHWAYS work package structure

The integration work package developed the means for connecting and linking the three approaches that together constitute the PATHWAYS framework, with developing ways of characterizing the *state* of transition pathways, with assessing the role of policy and governance in transitions and with drawing scientific conclusions about the nature and dynamics of transitions (given that there are different types of transitions) and their governability.

Two papers have been published (in Nature Climate Change and Global Environmental Change, see Table A1) which clarify the purpose and strategy for integration between approaches. By integration we mean a research strategy of aligning, bridging between largely separate analytical approaches, and iterations of such interactions. Integration is a procedure based on shared concepts, information and targets. The first aligning step is to adopt a broadly shared problem formulation and framing that can act as channels for dialogue between the three approaches for evaluating sustainability transitions pathways. To generate potential linkages, it is important that research activities across WPs share common concepts and agree a common problem frame for integration. In practice, the common problem frame enabling integration is defined by: 1) a common research problem or shared normative policy goal, 2) shared or spanning concepts, 3) commonly defined empirical domains, and 4) agreed parameters, metrics, indicators and data.

A second bridging step is to orient analysis towards specific governance problems, explicitly mobilising different kinds of information in the assessment of transition strategies, to specify the empirical domains of the analysis to be carried out (setting clear boundaries, scales and temporalities), to establish the common metrics and data that will be transferred (and enable the consolidation of operational linkages) between analytical approaches, and to specify the type of assessment sought. Figure 3 gives a schematic representation of how we mobilized transfers between approaches in an interlinked chain of analysis in PATHWAYS.

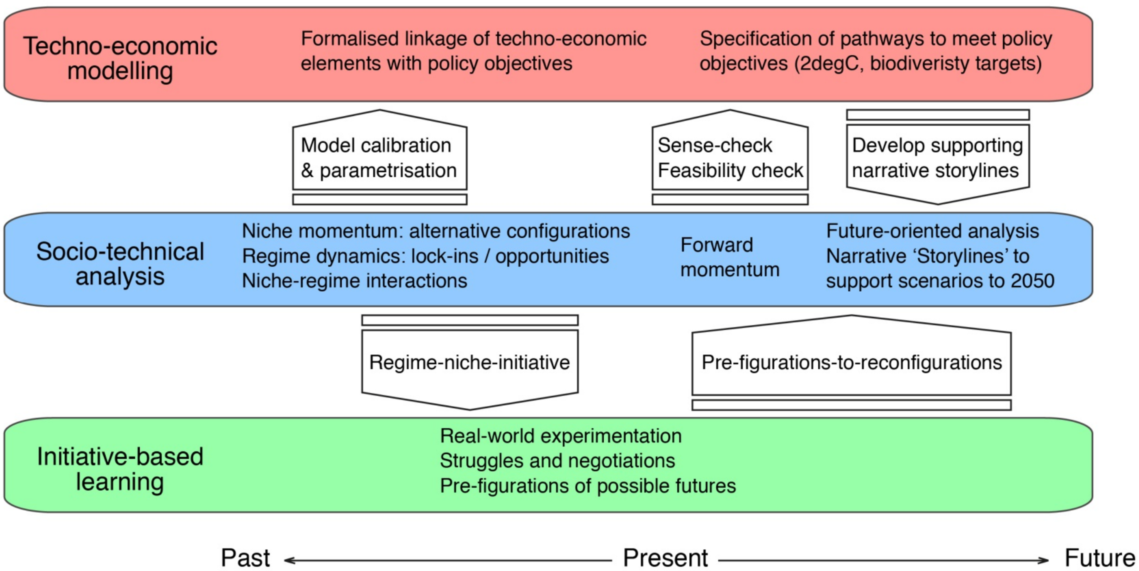

Figure 3. Schematic representation of steps in an interlinked chain of analysis of future-oriented transition pathways.

Later in the project, continued interaction between approaches and active mobilization of the empirical material produced in WP1-3 enabled the comparative analysis of transition pathways in the five empirical domains across different countries, as well as the analysis of governance opportunities and desirable arrangements to support sustainability transitions.

The final deliverable D4.4 brings together the findings from all PATHWAYS work packages in a comparative frame, thus mobilising findings generated by three analytical approaches in five domains and five EU countries. It focuses on presenting those findings that are most salient in revealing the opportunities, obstacles, and resulting lessons for governance that emerge from the collaborative and comparative work of the PATHWAYS project. Some major lessons include:

- The PATHWAYS frame attends to transitions governance challenges by spelling out a plurality of possible directions that can inform intervention strategies, and exploring their implications for a number of strategic actors;
- The PATHWAYS approach recognises the varied governance contributions of different analytical approaches, and their inherent limitations. Rather than seeking to overcome these limitations by 'fitting' all approaches into one (full-scale integration, a strategy long-pursued in 'sustainability science'), a multi-approach analytical strategy to governance challenges is to structure a dialogue between alternative approaches, that cannot otherwise be integrated,

through methods we have termed 'bridging', to articulate alternative perspectives on these challenges;

- Linkages between domains is an understudied aspect of transitions research but critical for a number of sustainable transitions visions (e.g. electrification vision) and can be supported by the more systematic approach suggested by PATHWAYS. We would advocate not only a multi-approach, but also a multi-domain evaluation of sustainability pathways;
- Systematically analysing cases in different countries enables the generation of insights about the role of local (national) circumstances and their influence on transitions pathways. Most salient aspects concern: 1) governance styles, 2) conditions for pathway realisation, 3) opportunities for learning, 4) cross-evaluation of transitions strategies and expectations.

Main results from Integrated Assessment Modelling

WP1 has developed a set of low-carbon and biodiversity-rich scenarios, based on insights from WP2 and WP3 (Figure 3). In Pathway A, the current regime remains strong, and incumbent actors mainly search technology substitution responses to the current challenges. In Pathway B, new actors come in creating a total regime shift with more radical response strategies (including behavioural changes). In Pathway A, the ***low-carbon transition*** is accomplished by deploying large-scale, centralised technologies, such as offshore wind, nuclear power, and carbon capture and storage (CCS) with most of the investments coming from incumbent actors. In contrast, the second pathway B achieves decarbonisation of the electricity system with a greater focus on behavioural changes and the deployment of decentralised technologies such as rooftop PV, onshore wind, small-scale biomass, integrated into smarter grids by new entrants, including a larger role for citizens. Regarding the ***land use and biodiversity transition***, Pathway A consists of a future with highly efficient agriculture, separation of nature and agriculture, precision farming, genetically modified crops and live-stock, and enclosed environments for animal husbandry. In Pathway B, land-use and biodiversity goals might be met by lower meat and dairy consumption and reduction of waste. Moreover, in this scenario agriculture and nature protection could be combined creating mosaic landscapes, with ecological reserves in high-production areas.

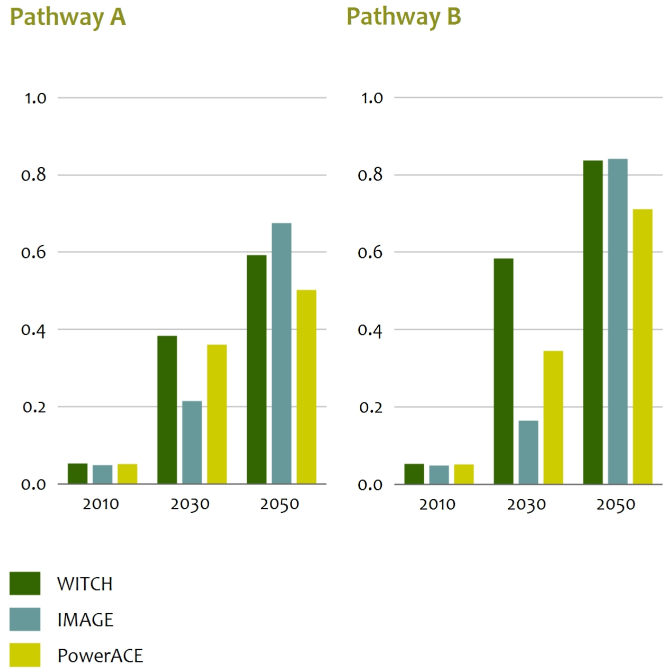

Figure 4. Share of solar and wind energy in total EU power generation in alternative transition pathways according to three different models.

The scenarios show that ***a major acceleration of the energy transition is needed*** to achieve a carbon neutral electricity system by 2050. The power sector has an important role in this transition, which is challenging: not only would the electricity system need to be carbon neutral around 2050, but in addition, electricity demand is expected to increase rapidly as a result of electrification processes in end-use sectors such as transport and heating. Different scenarios exist that achieve carbon neutrality, but all of them face significant challenges, for instance with respect to the rapid introduction of renewable, intermittent options (Figure 4). During the last decade, in many countries the electricity sector has been a prominent example that policy-driven change towards cleaner technologies and practices can lead to results. Wind farms and rooftop solar-PV, decreasing electricity prices and the development of new business models are very visible indicators of the ongoing, sometimes even disruptive, changes in the sector. However, the current speed and scope of the decarbonization of the electricity sector need to be significantly increased at the European scale if a carbon neutral electricity sector is to be achieved by 2050.

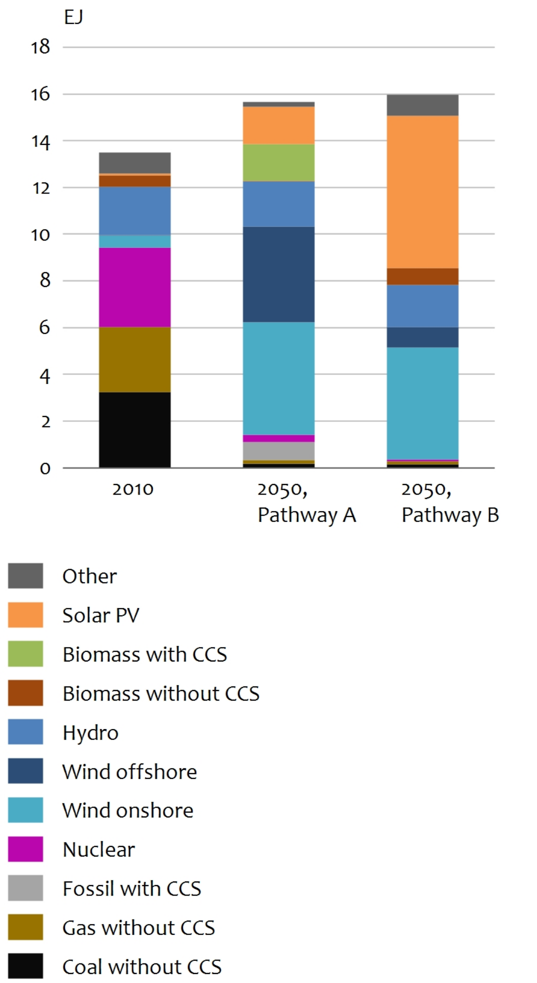

Figure 5. Share of energy carriers in total EU power generation in alternative transition pathways according to the IMAGE model

There are fundamentally different and in some ways opposing decarbonization pathways to reach the EU climate targets for 2050 (Figure 5). At one end of the spectrum, policy makers can focus on large-scale centralised technologies like offshore wind, nuclear energy or carbon capture and storage (CCS). Some of such strategies are heavily built upon so-called negative emission technologies, for example from bioenergy combined with CCS (BECCS). At the other end of the spectrum, policy makers can focus on small-scale renewable energy technologies with decentralized, flexible system designs. Policy-makers can also reduce demand via efficiency and building on larger behavioural changes. Of course, combinations of these extremes are possible, and each strategy has its own advantages and challenges. For instance, in several countries strategies based on large-scale technologies and incumbent actors currently have a high momentum. However, more fundamental changes could possibly find less opposition further in the transition. However, ***all decarbonization strategies have in common the need to phase out the use of unabated coal as soon as possible***.

Another important conclusion from WP1 is that ***if CCS or negative emissions should be part of the strategy, new policies are needed to prepare for the large-scale implementation of CCS technologies***. Currently, societal support for these technologies is extremely low. This leaves the choice of either taking immediate decisions to radically change energy systems at a much higher pace to avoid the need for negative emissions, or to make the conscious decision to become dependent on carbon removal technologies that are currently not available on the scales necessary. Postponing the decision for or against the usage of negative emissions will irrefutably lead to either greater dependence on said technologies, or require adjustments in global commitments and acceptable implications in the long run.

The model scenarios show that ***energy efficiency and demand side changes are essential for decarbonizing the electricity system***. Strategies that reduce and change energy demand are important to meeting long-term climate objectives, whether it be through efficiency gains or behavioural change. In the absence of negative emission technologies, the reduction of energy demand becomes even more important and requires much greater policy attention. Government policy can fruitfully consolidate and strengthen efforts to stimulate further efficiency innovations in electricity-using appliances. More ambitiously, governments can facilitate changes in the lifestyles of citizens through more specific demand-side innovations such as smart meters, peak load shifts, dynamic tariffs, and smart appliances. Often incorrectly deemed a low-hanging fruit, reaching and maintaining smarter energy behaviour can be challenging, but for a successful decarbonization this has to be pursued nonetheless.

With regard to personal land-based mobility, decarbonization strategies can be considered through different policy approaches, including 1) improving and changing car mobility, 2) reducing the need to travel, 3) encouraging modal shift, and 4) reducing trip length. Each of these approaches requires a range of changes in strategy and mobility choices.

One 'greening' scenario may consist of a strong early prioritization of electric mobility choice. Transitional innovations, such as hybrids, may serve as stepping-stones that allow further electrification of mobility in a gradual way. They may also serve as buffers, as is partly the case for car-sharing which may allow a more gradual phase out of car ownership. In other cases, specific innovations support a combination of technologies, such as battery-electric vehicles and a culture of slow modes to produce light weight electric vehicles as an option for the mass diffusion of electric mobility. In another scenario, lifestyle and behavioural change may have a greater tendency for nurturing and supporting a combination of travel reduction, modal shift and reduced trip lengths (Figure 6). However, ***all pathways towards a low-carbon mobility sector require a rapid and almost complete phase-out of the petrol car in the next 2-3 decades***.

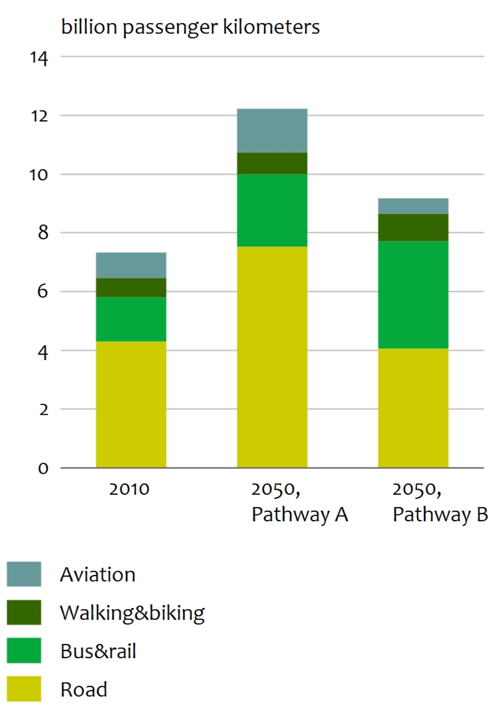

Figure 6. Total EU passenger travel demand per mode according to the IMAGE model.

The main environmental challenges for agro-food are the reduction of greenhouse gas emissions, halting biodiversity loss (both inside and outside Europe), preserving the natural capital needed for food production (fertile soils, water, biodiversity), reduction of emissions of nutrients (mainly nitrogen and phosphorus) and pesticides, while producing enough healthy food for reasonable prices for consumers and generate a reasonable income for farmers. The environmental impact of livestock is the largest: it accounts for about 80% of total of total agricultural greenhouse gas emissions, more than 75% of total agricultural nitrogen emissions, and about 70% of total agricultural land use. Other than in the energy-related domains, where a complete shift is required from fossil fuels to renewable energy, the ***changes in the agro-food domain are likely to be more gradual***. Several conditions such as the need for crop production and the requirement of land, water, and nutrients are given. Other factors, however, can change – and still have important impacts. For instance, major ***changes in size or nature of animal***

production will have a large impact. These changes can be driven by changes in diet and behaviour (less meat and dairy and less food waste) or by technological breakthroughs as plant-based meat replacers or cultured meat. Both require cultural acceptance, which takes time to develop. Therefore, in the short term, progress is more likely to come from improving current production methods (higher efficiencies in the form of higher crop yields, higher feed efficiencies), and conserving natural capital and decreasing emissions.

Finally, biodiversity has been declining steadily over the last decade primarily due to land use change, land degradation and fragmentation, disturbance, climate change, and pollution. Factors that could influence future biodiversity include the increase in urban areas and infrastructure (e.g. roads), changes in forest cover (substitution of native forest); farmland abandonment, and intensification of the agricultural sector. To ***deal with current and future pressures of land use, and its impacts on biodiversity, different strategies can be pursued. a diverse set of measures are required***. For instance, investing in intensive farming to fulfill increasing food demand will reduce the amount of land needed for food, opening up opportunities for land to be used for other purposes. Species associated with "natural areas" (e.g., forest species and other non-farmland species) will expand as more habitat becomes available, mostly due to farmland abandonment. Farmland species will see their range constricted to the more intensively used areas, and those more sensitive to change will disappear. In other words, changing to a more intensive farming system will cause loss of farmland species and gain in forest and other non-farmland species. In contrast, a strategy aimed at extensive agriculture and integrating farming with biodiversity functions will favour farmland species, while forest species might decline (Figure 7). In the end, different strategies will favor distinct species groups; therefore, it is a political/societal choice where the focus should be.

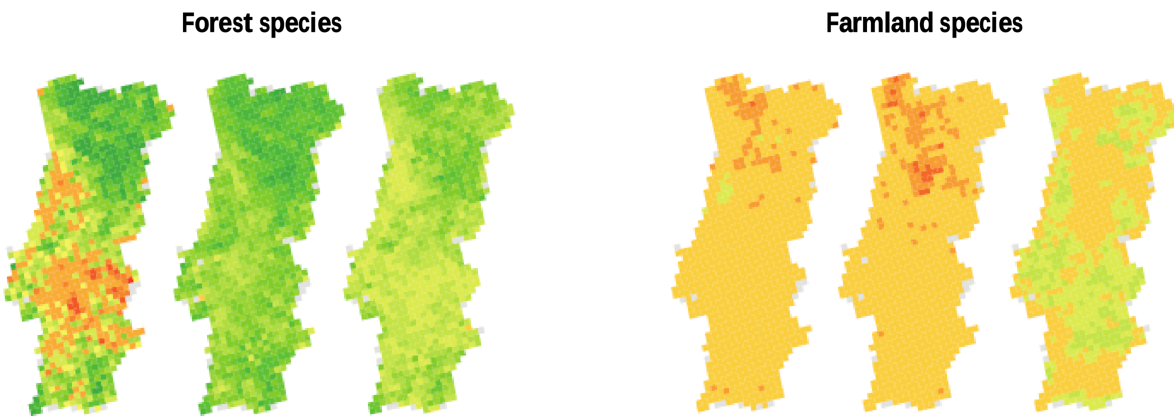

Figure 7. Maps of change in species richness by 2050 in Portugal. The maps on the left represent a scenario where current trends of land use remain as they are (leading to further decline); the maps in the center represent Pathway A; the maps on the right represent Pathway B. Red colored cells indicate a mean loss of species relative to 2010, and green-colored cells an increase.

Deliverable 1.2 discussed the possibilities of improving the representation of actors in models. Several types of models are used to provide insight into transition pathways to sustainable low-carbon societies, including Integrated Assessment Models (IAMs), energy system models, and simulation models, such as Agent-Based Models (ABMs). These models all differ with regard to their representation of institutions and actors. D1.2 maps the different representations of institutions and actors in models applied in the PATWHAYS project. It focuses on two IAMs, one energy system model, and one ABM. The objective was to outline opportunities to introduce more realism in models with respect to actor heterogeneity and the role of institutions. The report concludes that ***opportunities to improve the behavioral realism, the degree of heterogeneity, and the representation of institutional and governance factors within models can be created by fostering***

collaboration across different disciplines, between modelers, empirical economists, and policy analysts.

Apart from developing the above scenarios, WP1 has systematically compared the European and national policy goals on (1) greenhouse gas emission reductions, (2) gross primary energy consumption, and (3) the share of renewable energy sources in electricity (D1.4). For the comparison, we have relied on representative European and national modelling studies that align to the EU 2050 ambition to reduce greenhouse gas emissions by 80%-95% relative to 1990 levels. Based on this comparative analysis we draw conclusions on the translation process and the considered future pathways for Denmark, France, Germany, The Netherlands and the United Kingdom until 2030 and 2050. We find a ***high diversity in developments for national roadmaps towards 2050*** – ranging in institutional embedding of creating such visions (e.g. by the presence or lack thereof of climate regulations and auditing organisations) as well as in the distribution and utilization of modelling and scenario design competences. ***National scenarios that predominantly focus on technological cost-optimal solutions show that Member States do not necessarily reflect similar ambitions as described in EU policy.*** Furthermore, national scenarios show clear differences with scenarios explored by other (inter)national modelling teams as a result of different normative and technological assumptions.

Main results from Socio-technical transition analysis

The socio-technical transition analyses for the five empirical domains electricity, heat/buildings, mobility, agro-food and biodiversity used the Multi-Level Perspective (MLP), which focuses on interactions between radical niche-innovations, incumbent regimes, and exogenous secular 'landscape' developments. Table 2 reports the main findings on the green niche-innovations: it allocates the various niche-innovations to transition pathway A and B, and it provides an assessment of the momentum of niche-innovations on a five-point scale (very high, high, medium, low, very low).

Table 2. Momentum of niche-innovations

	Pathway A	Pathway B
German electricity	CFL and LED lighting: High Offshore wind: Medium Smart meters: Low Power-to-gas: Very low Vehicle-to-grid: Very low	Onshore wind: Very high Solar-PV: High Bio-power: Low
UK electricity	CFL and LED lighting: Very high Offshore wind: High Bio-power: Medium Onshore wind: Medium	Smart meters: High Solar-PV: Low
Swedish heat/buildings	Heat pumps: Medium Waste heat recovery: Medium Small-scale biomass: Low Individual metering and billing: Very low	District heating: Medium Low-energy housing: Low Individual metering and billing: Very low
German heat/buildings	Heat pumps: Medium/high Small-scale biomass: Medium District heating: Medium Solar thermal: Low	District heating: Medium Low-energy/passive house: Medium Behaviour change/smart metering: Low
UK heat/buildings	Smart heating controls and meters: Medium Low energy retrofits: Very low	Solar thermal: Low Small biomass: Very low

		District heating: Very low Heat pumps: Very low
UK mobility	(Plug-in-)Hybrid Electric Vehicles: Medium Battery Electric Vehicles: Medium Inter-modal Ticketing (Smart Cards): Low Biofuels: Low Hydrogen Fuel Cell Vehicles: Low	Inter-modal Ticketing (Smart Cards): Low Car-sharing: Low Urban Cycling/Sharing Schemes: Very low Compact Cities: Very low
Dutch mobility	(plug-in) Hybrid electric vehicles: High Battery electric vehicles: Medium Biofuels: Medium Compact cities; Medium Hydrogen fuel cell vehicles: Very low	Car sharing: High
Dutch agro-food	Algae production for fish feed: Medium Hybrid meat: Low Cultured meat: Very low	Sustainable fishing, Marine Stewardship Council: Medium Dairy alternatives/ Soy drinks: Medium Vegetarianism, flexitarians: Medium Local and regional food: Medium Organic food: Medium
Portuguese agro-food	Sustainable fishing: Low	Organic farming: Medium Shifts towards local food: Medium Local breeds: Low Sustainable fishing: Low Eating less meat vegetarianism: Very low Algae production for fish feed: Very low
Hungarian agro-food		Localized food chains: Medium Community-supported agriculture:Medium Organic agriculture: Low Vegetarianism/less meat: Low
Portuguese multi-functional land-use	Multi-functional landscapes for energy: Low	Biodiverse cities: Medium/low Land sharing: Medium/low Business and Biodiversity: Medium/low Biodiverse pastures: Medium/low Fire Resilient landscapes: Low Land sparing-rewilding: Low Multi-functional landscapes for energy: Low
Dutch multi-functional land-use		Agro-food business/biodiversity: Medium Agricultural nature conservation: Medium Water/environmental management: Medium Local renewable energy: Medium Urban Farming: Low Agro-tourism: Low

Significant results from this comprehensive analysis are the following:

1. Most green niche-innovations have medium, low or very low momentum. This means that a transition does not appear to the imminent in most domains without further policy support.
2. Only a few niche-innovations are assessed as having high or very high momentum:
    a. Energy-efficiency light bulbs (both in UK and Germany), driven by a European ban in incandescent light bulbs
    b. German onshore wind, mainly enacted by new entrants (citizens, farmers, city authorities, NGOs) and civil society enthusiasm
    c. German solar-PV, mainly enacted by new entrants (citizens, farmers, city authorities, NGOs) and civil society enthusiasm

   d. UK offshore wind, stimulated by strong government support and private sector interest in attractive subsidies
   e. UK smart meters, with a 100% roll-out being mandated by the government by 2020.
   f. Dutch car sharing, with rapid increase in *urban* customers, positive cultural meanings and acceptance by policymakers as part of future mobility systems
   g. Dutch (plug-in) hybrid electric vehicles, with sales exceeding 5% of total car sales in 2012, high socio-cultural acceptance and moderate policy support
   h. Most of these niche-innovations relate to new technologies, with only one option (Dutch car sharing) relating to a more prominent social innovation.
3. For three domains (electricity, heat/buildings and mobility), the niche-innovations seem more or less equally distributed over pathway A and B. For two domains (agro-food and land-use), most niche-innovations relate to pathway B. The suggested explanation for the latter is that regime actors in these domains mainly focus their attention on incremental improvements in the existing regime. Regime actors in these domains mostly perceive green niche-innovations as uninteresting or unviable, leaving them to smaller peripheral actors, who develop more radical (pathway B) innovations, but have limited resources to achieve high momentum.
4. Some niche-innovations are differentially deployed and socially embedded in different countries, leading to Pathway A in one country and pathway B in another country. Onshore wind, for instance, is ranked as Pathway B in Germany (implemented by new entrants) and as pathway A in the UK (implemented by incumbent utilities). So, the character and meaning of niche-innovations may not be intrinsic, but related to actor strategies and perceptions.

Next, the degree of stability and tensions in existing regimes was analysed. Table 3 reports the main findings on degrees of lock in (due to stabilizing forces) and degree of regime cracks (due to tensions and problems) in terms of a three point-scale (strong, moderate, weak).

Significant results from this comprehensive regime analysis are the following:
1. Most empirical domains are not characterized by a single regime, but by multiple regimes. This observation is an interesting challenge for transitions theory, which mostly focuses on single regimes.
2. For most regimes the stabilising lock-in forces are 'strong' or 'moderate', which means that incumbent actors are still committed to them and are not reorienting themselves towards a major transition.
3. There are only few domains where existing regimes are weakly locked-in:
   a. German electricity generation which was assessed to have destabilised because of major tensions (due to nuclear phase-out, increase in renewable electricity technologies, ambitious greenhouse gas reduction targets in the Energiewende, financial and business model problems)
   b. UK cycling (despite small increases in recent years, UK cycling remains marginal and is mostly seen as an 'abnormal' activity)
   c. Dutch fishing (the regime is assesses as becoming less locked-in, because over-fishing problems and policies such as fish quota are leading to shrinking numbers of Dutch fishermen)
   d. In most regimes, the cracks, tensions and endogenous problems are assessed to be 'moderate' or 'weak', which leads incumbent actors to think that they can continue with business as usual or with incremental change.

Table 3. Degree of lock in and cracks of existing regimes

	Lock-in, stabilizing forces	Cracks, tensions, problems
German electricity generation regime	Weak	Strong
German electricity networks regime	Moderate/strong	Moderate
German electricity consumption regime	Moderate	High
UK electricity generation regime	Strong	Weak/moderate
UK electricity networks regime	Strong	Weak
UK electricity consumption regime	Strong	Weak/moderate
Swedish heat generation regime	Strong	Moderate
Swedish housing regime	Moderate/strong	Weak
German heat supply regime	Strong/Moderate	Weak/moderate
German heat demand/building regime	Strong	Weak
UK heating regime	Strong/moderate	Moderate
UK building regime	Strong	Weak/moderate
UK auto-mobility regime	Strong	Weak/moderate
UK railway regime	Moderate	Moderate
UK bus regime	Moderate	Weak
UK cycling regime	Weak/moderate	Weak
Dutch auto-mobility regime	Strong	Moderate
Dutch public transport regime	Strong	Weak
Dutch cycling regime	Strong	Weak
Dutch meat regime	Strong	Moderate
Dutch fish regime	Weak	Moderate
Dutch dairy regime	Strong	Moderate
Dutch vegetable farming regime	Strong	Moderate
Dutch retail regime	Strong	Moderate
Hungarian pork regime	Strong	Strong
Hungarian beef regime	Strong	Weak
Hungarian retail regime	Strong	Weak
Portuguese agriculture regime	Moderate/strong	Strong
Portuguese forestry regime	Strong	Weak/moderate
Portuguese nature regime	Moderate	Moderate
Portuguese urban regime	Moderate	Weak/moderate
Dutch agricultural regime	Strong	Weak/moderate
Dutch nature regime	Moderate	Strong
Dutch water regime	Strong	Weak
Dutch urban regime	Strong	Moderate

4. There are a few regimes where tensions/cracks are assessed as ‘strong’, which in most cases (except German electricity) is due to economic problems:
    a. German electricity generation (major tensions because of nuclear phase-out, increase in renewable electricity technologies, greenhouse gas reduction targets in the Energiewende, financial and business model problems)
    b. Hungarian pork regime (tensions are mainly economic, related to price squeezes, competition and struggles for economic survival by Hungarian pig farmers)
    c. Portuguese agriculture regime (tensions mainly arise from economic problems, decreasing farmer income’s and decreasing interest in farming from young people)
    d. Dutch nature regime: the old regime of nature protection (excluding humans from nature areas) is under pressure from new ideas and policies with more permeable boundaries between nature and society.

The combined conclusions **suggest that a transition is not imminent in most domains**, with the momentum of most-innovations assessed as medium, low or very low and most existing regimes assessed as relatively stable. A clear exception is German electricity generation, where a transition towards renewable energy appears to be underway. In the UK electricity domain, the transition is more mixed. Finally, although the Swedish heat generation regime is assessed as locked-in and niche-innovations having moderate momentum, it is worth pointing out that a low-carbon transition has already largely occurred there, with 65-70% of heat coming from renewables.

Deliverable 2.4 compared the empirical transition pathways in different domains and countries to the ideal-type transition pathways, distinguished in the PATHWAYS project. For electricity, Germany and the UK have equally ambitious long-term decarbonization targets. However, they differ significantly in terms of the status of their electricity generation regime: while the UK regime remains strongly locked-in and evidences only moderate cracks so far, the German regime is already in flux and shows very strong cracks. With regard to heating, the transition potential in both Germany and the UK is low and both countries face a stable regime with heavy lock-ins into assets both in infrastructure and buildings. Moreover, lack of political commitment in the UK up to now and difficult positions of interest groups in Germany together with an inconsistent mix of policies further complicate the situation. Sweden, on the other hand, is posed very differently and mostly concerned with stabilizing and manifesting the low-carbon regime's state. In the mobility domain, both UK and The Netherlands show a dominant national pathway promoting the defence of auto-mobility. Though there are significant differences in the development of alternative mobility pathways between the UK and the Netherlands this should not be over-stated. The report highlights the ***strength of seeing the national of mediating generic transitions possibilities***, and also highlights a second ***role for the national as a co-constitutor of contingent socio-technical mobility experiments***. In the agro-food domain, most niche innovations in The Netherlands and Hungary demonstrate a low to medium momentum and the likelihood of breaking through is in general limited. Most of the niche innovations are considered to be consistent with Pathway B, meaning that they are broader regime transformations. The niche innovations in Hungary have a lower momentum, mainly because the initiatives are preoccupied by maintaining financial sustainability and focus on an economically viable pathway. However, recently the attention for environmental issues in Hungary is growing as well. Finally, the land-use regimes are stable in the Netherlands and in Portugal. There are opportunities to break through the regime established patterns, but these are limited and will most likely happen as small incremental changes.

In Deliverable 2.5, finally, ***qualitative storylines*** that describe plausible socio-technical transition pathways were developed for the revised quantitative scenarios described in D1.3. In other words, this report sets out what needs to change (in a socio-technical sense) to make two alternative transition scenarios happen. It addresses changes in the various dimensions of socio-technical systems, including technology as well as societal and behavioural aspects such as institutional change, different types of actors, their goals, strategies and resources. The main policy lessons from these storylines are outlined below per domain.

Regarding **electricity**, ***social acceptance*** will be the most crucial success factor for decarbonization strategies. Many measures taken today focus on keeping the costs of the transition as low as possible. As the willingness to pay for clean electricity varies and is not limitless, this is indeed an important aspect, but not the only one. The best strategy to deep decarbonization is not always the one that offers the solutions at the lowest price, but the one that offers solutions with the best overall public acceptance. Even in the power sector, some system changes in electricity supply and transmission require the support of those whose local livelihoods are affected. Without the careful consideration of the interests of the stakeholders involved, large-scale implementation of any technology may not be feasible. Related to this, ***policy approaches need to be developed to overcome barriers to change.*** Given that nearly all decarbonisation strategies also have unwanted side-effects, any transition faces barriers to change, whether commercial, legal, social, or otherwise. Therefore, policy makers need to design policies that can over-come such barriers. One option is to work with new entrants, thereby generating momentum and creating new (and increasingly powerful) interests for low-carbon transitions. Germany pursued this option with the feed-in law, stimulating investments from actors other than large utilities. Another option to overcome barriers is compensating the ones suffering from the downsides of the transition, thereby reducing their resistance to change. A third recommendation is that ***ideally, policies are adaptive and flexible, but at the same time maintain stability of long-term targets***. The low-carbon transition of the electricity system is a largely uncertain process that is hard to predict. Therefore, policy makers need to prepare for surprises, nonlinearities and controversies. New technologies and options may arise, while some pursued options might not be feasible because of resistance or technical difficulties. These large uncertainties and complex interdependencies call for a combination of stable long-term targets and adaptive policymaking. Adaptiveness includes regular monitoring and evaluation of the progress made and the challenges faced, as well as the evidence-based adjustment of specific policy instruments or their mix.

Regarding **mobility**, D2.5 concluded ***that strategies towards sustainability can be more successful implemented if they have support of several societal groups***, including policy-makers, manu-facturers, business, citizens and the financial sector. Transitions in mobility are associated with enormous consequences in infrastructure (spatial planning, urban planning, fuel strate-gies). This means that, despite the short life time of cars themselves, a long-term vision will be required. Recent experience from historical case studies has shown the importance of actor alliances around shared normative goals in transport, both in positive and negative ways. In order for new, ambitious, visions towards sustainable transport to become effective these visions need to gain legitimacy and generate trust. In this context, it is very unlikely that a single instrument that will be sufficient to support a transition towards sustainable transition on its own. Instead, ***a combination of policy instruments could be successful***, focused at integrating the various relevant policy areas, including energy policy, land use and infrastructure planning, innovation support, industrial stimulus, and consumer incentives. Examples of such arrangements might be market rules to restrict petrol cars in urban centers, new public service mobility providers that sell intermodal journeys via smart phones and the internet, or combined electricity supply and service packages for battery-electric vehicles. ***National governments can champion the role of local authorities in promoting slow modes in local areas.*** This includes the promotion of walking to work and walking to school schemes. It also involves promotion of cycling and cycling infrastructure.

Regarding **heating**, important policies include ***monetary incentives and providing supply-chains and maintenance networks for low-carbon heating technologies***. The technological options to reduce carbon emissions from heating are known, available, and mature. The main challenges are changing existing structures and behaviour as well as introducing the low-carbon technologies. Monetary incentives could support this, as shown by the successful switch in Swedish heating from oil to electricity, district heating, and biomass, which was supported by policies that increased the cost of carbon and incentivised structural change. Another important conclusion is that ***electrification of heat is a promising strategy, but important challenges have to be addressed***.

For countries with electric heating, heat pumps could be an important efficiency measure. Also in other countries, an "electrification of heat" could be expected. Indeed, the potential of heat pumps for decarbonisation is large, but 'outsourcing' decarbonisation of heat to the electricity sector also presents significant challenges and adds to existing ones: It elevates the demands on the power sector for decarbonised and renewable energy production. Specifically, addressing power intermittency of sources such as solar and wind will become even more important. Another example is the development of heat networks, which offers huge potential but only if primary energy sources are renewable. Finally, as for the other domains electricity and mobility, ***a transition to low-carbon heating requires a consistent and coherent strategy***. Most European countries lack coherent and consistent strategies for low-carbon transitions in heating and the building sector. Such a strategy should include a spectrum of interventions, starting with cost-effective behaviour-oriented solutions that can also reduce energy poverty, all the way through more challenging and costly structural options involving substantial changes to the building stock and energy infrastructure. Only a well-planned approach, with consistency and coherence in measures over time is likely to be successful. It takes time to build knowledge, to transform infrastructure, and to gradually replace fossil-fuel dependent technologies. These strategies may differ between countries, and a European political strategy should balance European overarching measures with subsidiary strategies and intervention schemes.

Regarding **agro-food**, there are ***many challenges to be addressed simultaneously***, such as improving human health (related to food consumption patterns), reducing greenhouse gas emissions and biodiversity loss (both within and outside the EU) and safeguarding the viability of rural areas. ***A clear vision with related goals*** would be helpful to mobilize actors to deal with these challenges and stimulate them to take steps in reducing environmental impacts. A useful vision would need to consider that agro-food consists of many sectors and actors, both at the production side (farmers, fishermen, feed companies, food processing industry), as well as on the consumption side (consumers, but also many small and medium enterprises such as bakeries and restaurants). This vision is of vital importance, since ***despite the important role of the agro-food sector in several environmental problems, there is little sense of urgency to reform***. Increasing the awareness of the current problems can help to increase the urgency to act and take measures in the entire agro-food chain. As the different actors in the chain are so strongly connected, and because improvements are possible within the whole food chain, it is important to take measures in the whole chain: from production to consumption. Other than in the energy-related domains, where a complete shift is required from fossil fuels to renewable energy, the ***changes in the agro-food domain are likely to be more gradual in nature***. Food production will continue to rely on crop production, which in turn needs large quantities of land, water, and nutrients. Other important aspects could change more drastically. For instance, ***major changes in size or nature of animal production will have a large environmental impact***. These changes can be driven by changes in diet and behaviour (less meat and dairy and less food waste) or by technological breakthroughs as plant-based meat replacers or cultured meat. Finally, ***reforming of the CAP can be a lever for change.*** The CAP beyond 2020 provides an opportunity to change the agro-food system, for example by encouraging farmers (especially beef and dairy producers) to reduce on-farm greenhouse gas emissions and nutrient losses and improve feed efficiency. A more drastic option is to promote more spatial segregation between farmland and more natural areas, which would implicate a rewilding of certain areas - especially the "less-favoured areas" which now receive additional payments. Alternatively, mosaic type landscapes could be strived for, implying more funding to create a "green veining, as well as other agro-environmental measures. If meat and dairy consumption would decrease (for health and environmental reasons), less meat and dairy production in Europa would be needed, which in turn would lead to lower greenhouse gas emissions.

Regarding **land use and biodiversity**, it is important to consider that ***optimal biodiversity strategies depend on the local situation.*** As indicated above, there are different strategies in preventing further loss of biodiversity. It is clearly not preferable or even possible to implement the same measures everywhere in Europe: the national and sub-national landscape context needs to be taken into account in the development of policies promoting a given conservation measure. For example, in the Netherlands, a land-sharing strategy seems to produce strong biodiversity benefits, as the agricultural landscape is already very intensive. In contrast, in Portugal, land-sparing strategies present interesting opportunities, as there is enough margin for intensification on existing agriculture areas. In any case, ***biodiversity strategies are more likely to be successfully implemented if they also contribute to other societal goals.*** Land use is related to a large number of different functions, and thus the interest of many actors (including farming, tourism, housing, nature protection, water management). While strategies may look optimal from a biodiversity perspective alone, it will be hard to implement them if they are not combined with other functions. This is for instance shown by the "Room for rivers" program in The Netherlands, where biodiversity benefits are combined with the need to protect the country against river flooding. Greening of cities to improve livability and health is another good example of a strategy that combines several functions.

Main results from Participative Action Research

In a first step, WP3 has developed its theoretical framework, research protocols and procedures for the work package tasks. These resemble the fundamental documents for empirical research and are being applied in the respective tasks. Two real-world experiments were developed and applied: A LivingLab approach for smart home systems in the heat domain and a participatory action research approach ("real-world-laboratory") in a city quarter of Wuppertal in the agri-food domain. Furthermore, a number of case studies have been conducted (Table 4).

Table 4. Summary of WP3 case studies

Domain	Type and Affiliation	Case study
Land use	Case study FFUL	**Peneda-Gerês National Park**: This case study illustrates the ways in which innovative forms of land management were developed and implemented in Castro Laboreiro Parish. The innovation addressed throughout this case study relates to the ways in which local communities in coordination with regional institutions (e.g. Peneda Geres National Park) organized themselves in order to use public funds (national and European) for reconciling biodiversity and rural livelihoods. This case study therefore reports a social innovation.
Land use	Case study PBL	**Low Holland:** Development of Green-Blue services in a National Landscape in a metropolitan region in the Northwestern part of the Netherlands. It studies WLD, a collective that has started as an agricultural nature conservation organisation. Because the organisation was able to get funding for projects, they improve their knowledge and negotiate with the national government on the new Common Agricultural Policy. Together with 3 other regions they performed a pilot with money from the government. In this pilot they practiced being an 'implementation organisation' and developed different new services based on farming and nature conservation.
Land use	Meta analysis	**Food from the sky**: Operation of Rooftop farms in London (UK). It is an initiative pursuing a special form of urban gardening called zero-acreage farming (Zfarming). This innovative form of farming is located in and on buildings in urban areas such as rooftop gardens, rooftop greenhouses or indoor farms. "Food from the sky" is a rooftop farm operating on the rooftop of a London supermarket, selling its products downstairs in the shop. This way, unproductive space is purposefully used; vegetation and thus a habitat for e.g. insects is brought into the inner city and emissions from transportation are reduced. Due to community involvement and an educational mission of the farm the local social spirit is also improved.
Land use	Meta analysis	**Kristianstads Vattenrike Biosphere Reserve**: Is an innovative approach for biosphere management (Sweden). This initiative is an example for how the effort and advocacy of a

		single person at the right time and place can lead to the transformation of governance structures and therewith to new approaches of nature preservation. By establishing a network of important stakeholders from different institutions on different scales (national, regional, local) and with different aims, the general perception of society and all stakeholders on the importance for landscape preservation and protection increased and biodiversity was promoted.
Agri-food	Case study Wuppertal Institute	**Biond**: Presents the development of an initiative for organic farming that eventually develops into a business case for organic catering in schools. The business undergoes several phases of development through growth and investment with a period discovering its market niche. The case particularly highlights the messiness of business development with a new niche and the importance of agency and governance therein.
Agri-food	Case study KCL	**Capital Growth**: Capital Growth, an urban farming network initiative spearheaded by Sustain (the alliance for better food and farming) is an initiative that seeks to develop urban farming in the Greater London area. Capital Growth is a partnership initiative between London Food Link (within Sustain), the Mayor of London, and the Big Lottery's Local Food Programme. The initiative provides a generic structure for the development of highly localised farming projects, which are mainly based on reclaiming urban spaces and developing them into food-growing spaces but also on raising awareness about food and its provenance, education and training, etc. The initiative has a strong local and community component, generating substantial local enthusiasm. The initiative has been highly successful, with around 3,000 urban food-growing spaces developed since 2008. These spaces are all unique. After a period aimed at multiplication and awareness, it seems that the new strategy (Grow to Sell) seeks greater emphasis on productivity and developing achievable targets in terms of harvest/yield/impact for each growing space.
Agri-food	Meta analysis	**Buschberghof**: Set in Germany the initiative operates organic farming, establishing a local food system and organising a farm following the concept of "community-supported agriculture". The initiative promotes biodiversity not only through cultivating without artificial fertilizers and pesticides but as well through the cultivation of ancient types of vegetable. Furthermore, the reconsideration of value of food, seasonal and regional vegetables minimises foot waste and reduces CO_2 emissions from storage and transportation.
Agri-food	Meta analysis	**Original Unverpackt**: Establishing a shop for unpackaged bulk shopping (Germany), this initiative illustrates a more sustainable business model in selling unpackaged groceries and detergents. In 2010, 2.7 Mio tonnes of plastic packaging have been used in Germany alone. Reducing this amount to a minimum at the point of sale can save a lot of CO_2 taking production chains into account (reduced plastic production, reduced need for crude oil extraction, etc.). Besides, the ecosystem will profit from fewer plastics spreads into the environment (e.g. fewer animals die because of plastic in their digestion). Moreover, Original Unverpackt sells organic and locally produced products.
Mobility	Case study KCL	**Amsterdam Metropolitan Area Electric (MRA-E)**: Amsterdam Metropolitan Area Electric (MetropoolregioAmsterdam (MRA) Elektrisch) is a project set up by MRA in 2011 to stimulate the development of electric mobility in the region. The main focus is the collaboration across communes for the rollout of a charging network to further the attractiveness and acceptability of electric mobility. MRA-E also provides centralised support to regions and municipalities (e.g. tendering, advice, etc.). The main interest of the case study concerns the cooperation between local and regional actors towards long-term objectives and commitments to overcome typical infrastructure barriers in socio-technical transitions.
Agri-food	Case study Manchester University	**Transport projects and transport governance** arrangements in greater Manchester (UK). This case study addresses two interrelated issues: (1) the building of a suite of Greater Manchester transport projects funded by the national Local Sustainable Transport Fund and other forms of funding.

		(2) The background to these projects, the way they have been framed and efforts to implement them cannot be understood without appreciating their interrelationships with the construction of transport governance arrangements in Greater Manchester. Transport governance – and indeed the wider governance of low carbon – in Greater Manchester is a messy and historically rooted story. This can be understood as a forty-year process of governing experimentation which has intensified and become more formalised in recent years. It is key to understanding the transport projects set out above to also understand these governance arrangements, the key actors in this process, how this has changed over time and what agendas this has resulted in. The important aspect of this case are not only are the projects in the making but also the governance context.
Agri-food	Meta analysis	**Cargo Hopper**: This initiative aims to introduce an environmentally friendly cargo delivery system for cities based on special electric vehicles (Netherlands). This innovation seeks to achieve the goal of an environmental friendly cargo delivery in inner cities through electric cargo vehicles and the reorganisation of delivery schemes. The electric vehicles, powered with regenerative energy, reduce the use of fossil fuels, therewith reduce emissions and counteract air pollution problems due to high traffic volume and the resulting street congestion.
Electricity	Case study KCL	**Brixton Energy**: This case looks at local community renewable energy projects. It focuses specifically on Brixton Energy, a not-for-profit cooperative, which creates "cooperatively owned renewable energy projects". It has completed its 3rd solar community rooftop installation (BES3) by September 2013. BS4 is currently in planning. The funding is innovative, it relies on: - Community investors for initial investments (a form of crowd funding) - Feed-in tariffs and local electricity supply contracts as a revenue stream - Re-invest revenues to shareholders and in community It is strongly normatively driven, the main motor being local community actors (residents). It is inscribed within a parent initiative: Repowering London. This could be described as a community-driven movement, with links with activists, local authorities, celebrity support, etc.
Electricity	Case Study FCUL	**Coopérnico**: Coopérnico is a Portuguese cooperative of renewable energy with the mission to involve citizens and companies in creation of the new energy paradigm (renewable and decentralized) for the benefit of society and the environment. The Coopérnico was founded by a group of 16 citizens from different professional areas and with different backgrounds, but who share a common concern: sustainable development. It defends a renewable energy and responsibility model contributing to social, environmental and sustainable energy future.
Electricity	Meta analysis	**EWS Schönau**: Energy cooperative working towards decentralization of energy generation and supply (Germany). This initiative addresses several issues immanent in the current national regime. EWS Schönau is an energy supplier that evolved out of a citizens´ movement against nuclear power and offers advice on reducing energy consumption, advocates the decentralization of energy generation and supply and offers electricity from renewable sources. Since the liberalization of the energy market, it supplies to customers all over Germany.
Heat	Meta analysis	**SolabCool**: Development of an air-conditioning technology using sorption cooling technology (Netherlands). It addresses the heat generation as well as heat consumption side: through the technology "SolabCool" offers a possibility to transform unused heating energy from the district heating system or industrial production sites into cold for air conditioning. Thus, significant amounts of energy are saved when cooling residential and commercial buildings.
Heat	Case study SEI	**Sustainable community Hökarängen**: initiative aiming to create inspiring and repeatable examples for how resource efficiency can be achieved within a neighbourhood by involving and activating the people who live and/or work there (Sweden). The project

		aims, through interdisciplinary action research[1], to develop, test and demonstrate ways in which various forms of cooperation between property owners, residents and others can work together to reduce energy and other resource use in a residential area.
Heat	Meta analysis	**BedZed ("Beddington Zero Energy Development"):** Is a housing initiative concerned with reducing the environmental footprint of its residents that combines innovative solutions for energy savings, on-site energy production, waste management, water management, etc. (UK) BedZed is a housing initiative which is related to more sustainably lifestyles in general, but focuses on heat energy in specific. BedZed is UK´s first large scale mixed use sustainable community, which was designed and build to minimise emissions. It shows how diverse living arrangements can be made sustainable on a larger scale.

The single and cross-case analysis have identified several findings: The influence of governance and governmental interference on initiative development, the importance of processes of social and institutional learning, and the role of acceptance for success as well as (potential) replication or up-scaling.

Potential points of contact and common analyses between work packages 2 and 3 regard discoveries from initiatives that may shed a light on factors for acceptance of certain niches, or initiative-level perspectives on ongoing transitions. Through these findings inferences for a transition's future development may be derived in later stages of cross-work package analysis. In this, the initiatives resemble small-scale applications and patterns for what is currently happening and/or is yet to come. They may therefore be used as exemplary/ideal, contrasting or explanatory cases that reveal "real-life" insights not available from less fine-grained analyses. Promising topics that have already emerged here, e.g. in the area of governance, are the role of co-operatives for transitory developments and the orchestration of transitions in urban contexts through citizen initiatives.

Two experiments - a real-world experiment on food waste reduction in a city quarter, and a LivingLab approach on heating behaviour in households – showed that ***Participative Action Research is able to connect to transitions very directly and very deeply***.

Deliverable 3.4 explored the opportunities of integration between Initiative Based Learning (IBL) and Integrated Assessment Models (IAMs) to improve the understanding of learning in the context of transition towards cleaner energy technologies. Our analysis shows major structural differences with respect to the geographical as well as temporal scale of analysis caused by the different goals the two methodologies have. IAMs develop possible alternative energy and technology pathways for the next fifty to eighty years, whereas IBL deals with understanding the configuration of actors in specific institutional settings that legitimize and support specific technologies. We therefore conclude that ***ambitious forms of integration of IAMs and IBL are not feasible as of today. Yet, collaboration between the two approaches can lead to significant mutual enrichment***.

Deliverable 3.5 summarizes findings on the nature, role and potential of initiative-based learning for and in transitions. Coming from the hypothesis that transitions are complex with emergent patterns and continuous dynamics in and between technological, economic, social and ecological dimensions, the processes behind the initiatives "on the ground" were analysed with a specific focus on learning, scaling and governance. The analysis of the cases helped to understand the strengths and limitations of local experimentation. They exhibited the expected uncertainties that come with experimental environments. The cases contribute to understanding sustainability transitions by exploring their

[1] This case hence relates to research undertaken in work package task 3.2. At present, however, investigations related to this case within the PATHWAYS project, will not conduct interventionist actions, but analyse them "from the outside".

evolution and governance, the relationships and interdependencies between local initiatives, larger-scale network, as well as by demonstrating sustainable practices and business models, reached for example by an open innovative development process with Living Labs. The variety of the cases enabled us to explore the diversity that can be found in real-life transitions dynamics but also enabled us to tentatively identify overarching patterns with regard to attitudes and values that drive initiatives. Interesting results concern for example the ***importance of the social dimensions of sustainability transitions and the significance of observing and acknowledging processes rather than outcomes when transitions and transition governance is concerned***.

Main overall conclusions

Socio-political analysis and techno-economic modelling can complement each other

High-level policy making often focuses on techno-economic dimensions such as investments, carbon price, costs and price performance improvements, at high levels of aggregation. Any policy maker needs to take note that techno-economic scenarios may not suffice, as other aspects to the deployment of low-carbon solutions may be just as important to take into consideration, such as innovation dynamics and social acceptance. The PATHWAYS project has pioneered methodologies to mobilise both socio-technical as well as techno-economic assessment approaches. Combining these allows for a better understanding of future system change in a carbon-constrained Europe. We therefore find it highly recommendable to integrate different methodological approaches for analyzing low-carbon transitions.

Social acceptance is a crucial success factor for decarbonization strategies

Many measures taken today focus on keeping the costs of the transition as low as possible. As the willingness to pay for clean energy varies and is not limitless, this is indeed an important aspect, but not the only one. The best strategy to deep decarbonization is not always the one that offers the solutions at the lowest price, but the one that offers solutions with the best overall public acceptance. Even in the power sector, some system changes in electricity supply and transmission require the support of those whose local livelihoods are affected. Without the careful consideration of the interests of the stakeholders involved, large-scale implementation of any technology may not be feasible.

Demand side changes are essential for sustainability transitions

Strategies that reduce and change energy demand are important to meeting long-term climate objectives, whether it be through efficiency gains or behavioural change. In the absence of negative emission technologies, the reduction of energy demand becomes even more important and requires much greater policy attention. Government policy can fruitfully consolidate and strengthen efforts to stimulate further efficiency innovations in electricity-using appliances. More ambitiously, governments can facilitate changes in the lifestyles of citizens through more specific demand-side innovations such as smart meters, peak load shifts, dynamic tariffs, and smart appliances. Often incorrectly deemed a low-hanging fruit, reaching and maintaining smarter energy behaviour can be challenging, but for a successful decarbonization, this has to be pursued nonetheless. This could be achieved via active intervention strategies including consumer education, awareness raising, altering the structure of incentives, and improved billing. Such measures can induce energy saving cheaply and relatively quickly. They can also help to alleviate energy poverty, as they do not require major investments but rather changes in habit, which could help reducing people's energy bill. In the agro-food sector, reducing the maximum amount of meat in one package could probably help to reduce meat consumption. This type of choice editing can help to fasten changes towards a more sustainable agro-food system. These changes can be initiated by government, but also by industry or retail. A good example is sustainable fishery (MSC) in the Netherlands, where the sales of MSC-certified fish strongly increased after supermarkets decided only to sell fish with a MSC label. This happened under pressure of NGOs.

The PATHWAYS approach allows to identify barriers to change

Given that nearly all decarbonization strategies also have unwanted side-effects, any transition faces barriers to change, whether commercial, legal, social, or otherwise. Therefore, policy makers need to design policies that can overcome such barriers. One option is to work with new entrants, thereby generating momentum and creating new (and increasingly powerful) interests for low-carbon transitions. Germany pursued this option with the feed-in law, stimulating investments from actors other than large utilities. Another option to overcome barriers is compensating the ones suffering from the downsides of the transition, thereby reducing their resistance to change. In doing so, it is important to recognize the existence of national differences, for instance regarding policy styles, technological preferences, and actors involved. These can best be taken into account at the national level, thereby following the subsidiarity principle. For example, the strategies for decarbonizing electricity are very different between the United Kingdom and Germany: The UK largely works with incumbents and large-scale renewables, such as offshore wind, while Germany largely unleashes new entrants and smaller scale technologies, such as onshore wind and solar PV. Our findings indicate that “one-size-fits-all” policies neglecting these differences need to be avoided in order to have a chance to promote a successful transition. In the buildings sector specifically, solving actor-specific barriers is of utter importance as it is very difficult to reduce demand through retrofitting buildings – which is needed to reach deep demand reductions. Here, the split-incentive dilemma between owners and tenants is one of the main decelerators of change as both groups are not willing to bear the costs of refurbishment and therefore are united in hindering effective energy saving measures.

A transition to a low-carbon society requires a consistent and coherent strategy/vision

Finally, and perhaps most importantly, most European countries lack coherent and consistent strategies for low-carbon transitions. Such a strategy should include a spectrum of interventions, starting with cost-effective behaviour-oriented solutions that can also reduce energy poverty, all the way through more challenging and costly structural options involving substantial changes to e.g. the building stock and energy infrastructure. Visions towards sustainable societies need to gain legitimacy and generate trust, based on 1) coherence and long-term thinking, 2) involvement of the general public in some form, and 3) connection to long-term policy commitments. Only a well-planned approach, with consistency and coherence in measures over time is likely to be successful. It takes time to build knowledge, to transform infrastructure, and to gradually replace fossil-fuel dependent technologies. These strategies may differ between countries, and a European political strategy should balance European overarching measures with subsidiary strategies and intervention schemes.

Potential impact and main dissemination activities and exploitation of results

Throughout the project, we have used several different routes to maximize the impact and exploitation of results:

i) Establishing contacts with the European Environment Agency (EEA);
ii) Via scientific papers and the Intergovernmental Panel on Climate Change (IPCC);
iii) Via (co-)organization of several workshops throughout the project;
iv) Via numerous talks and presentations at conferences and workshops;
v) Via the website, for which we have established a transition case study database;
vi) Via the final policy briefs.

Collaboration with the EEA

During the project, we have established close contacts with the EEA. The EEA is planning to use insights from the PATHWAYS approach for their next State Of the Environment Report (SOER-2020). The PATHWAYS project collaboration with the EEA consisted of the following:

- Organisation of a PATHWAYS workshop at the EEA (February 5, 2016), with an introduction of Hans Bruyninckx. The workshop consisted of two main sessions. In the first session, the tools and approaches to evaluate sustainability transitions pathways were discussed, with the aim to achieve a common understanding of the analytical and governance challenges of sustainability transitions and to explore options to handle these challenges.
- Frank Geels and Andries Hof were invited speakers at the EEA's Scientific Committee seminar on knowledge for transitions (May 18, 2016). Geels spoke about the role of innovation and technology in transitions in socio-technical systems; Hof about the role of quantitative systems modelling in sustainability transitions. Both presentations were based on insights from the PATHWAYS project. The report of the seminar is available at the EEA (http://www.eea.europa.eu/about-us/governance/scientific-committee/reports);
- Frank Geels, Detlef van Vuuren, and Andries Hof have written background papers for the EEA, which will be input for a EEA publication explaining the 'transformations' and 'transitions' concepts and setting out the transdisciplinary knowledge, governance approaches and competencies that are needed to effect systemic change. These background papers discuss the socio-technical and the modelling approach for analysing transitions.
- PBL has organised an expert workshop with Hans Bruyninckx and André Jol on 17 February 2017, with the topic "the roles of knowledge institutes PBL and EEA for transitions in an European perspective". At this workshop, Detlef van Vuuren presented insights from the PATHWAYS project.
- The PATHWAYS final workshop was co-organized with the EEA at the premises of the EEA (21-22 November 2017). The overarching objective of the workshop was to explore how PATHWAYS and related projects can support the development of knowledge for transitions at the European scale, focusing in particular on how they can contribute to the planned SOER 2020 systems assessment. The workshop was a continuation of the two previous EEA-hosted events (the PATHWAYS workshop in February 2016 and the Scientific Committee seminar on knowledge for transitions in May 2016). This workshop focused on the knowledge needs for a specific report (SOER 2020). Next to EEA staff and PATHWAYS members, the OECD, European Commission (DG-ENER, DG-ENV, and DG-RTD), JRC, the EEA Scientific Committee, and related European projects (ARTS, TESS, CARISMA) were present.

Scientific papers and the IPCC

More than 20 scientific papers have been published throughout the project, another 10 are in review, and several others in preparation (see Table A1). All papers are published in high-quality journals, including *Nature Climate Change, Global Environmental Change, Technological Forecasting and Social Change, and Environment Research Letters*. These papers will contribute to next IPCC reports – both the report about 1.5 degrees and the next Assessment Reports. Furthermore, Frank Geels was present at the scoping meeting for the 1.5 degrees IPCC report. Some key results of the project will be published in a Special Issue of PATHWAYS in Technology Forecasting and Social Change.

Workshops

Apart from the final workshop co-organized with the EEA (see Section Collaboration with the EEA), we have (co-)organized 11 other workshops, of which 4 internal partner workshops (see Table A2). The workshops were targeted both at the scientific community as well as at policy-makers.

Talks and presentations

Close to 80 presentations at conferences and workshops were given during the course of the project, not including presentations at workshops which we have (co-)organized (see Table A2). Most presentations were targeted at the scientific community. For instance, several presentations of PATHWAYS researchers were given at the scientific conference summer 2015 in Paris. Several presentations of PATHWAYS research were also given at transition science conferences. Other presentations were targeted at policy-makers, industry, and the media especially in the final year.

Website

The website (http://www.pathways-project.eu/) serves as a portal to several other social media outreach activities that the project is engaging in. The project has established its twitter account – and tweets are reported as well at the portal immediately on the home page.

- Currently, the PATHWAYS project has 236 followers. The portal also captures news items on the project, the newsletters and policy briefs, and provides links to the various project outputs in terms of scientific articles and deliverables. The portal also includes links to our sister project TESS and ARTS.
- In addition, we have established a case study database, which allows for sharing information of previously done European case studies in order to foster reuse of the knowledge gained in previous studies. The case studies of the European projects PATHWAYS, TESS, CD-Links, ClimPol, and CARISMA are currently included in the database (http://www.pathways-project.eu/Database). The database is open for researchers to submit new studies. PBL will continue to host the database beyond the PATHWAYS project.

Final policy briefs

One of the most important activities of the PATHWAYS project was to combine the results of the quantitative systems modelling, socio-technical transition analyses, and participative action research to create two alternative quantitative and qualitative transition scenarios. The qualitative narratives are consistent with the quantitative modelling analyses, the findings from socio-technical transition analyses, and the findings from participative action research. The storylines focus on the notion of branching points: where in the system is a deviation from business-as-usual required to achieve the transition? Is there momentum to achieve this deviation, and can policies help to increase such momentum? These storylines can support policy-making on mainly EU level, as they provide a comprehensive analysis of possible transition pathways in which the challenges with regard to technologies, policies, and behavioural changes are made clear. The main policy messages were summarized in policy briefs for each domain (electricity, heating, mobility, agro-food, and land use & biodiversity). The most important conclusions of these policy briefs are summarized below per domain.

Electricity

A major acceleration of the energy transition and a rapid phase out of unabated coal is required

Scenario analysis shows that the electricity system needs to be carbon neutral before 2050 to meet the ambitious target of the EU to reduce domestic greenhouse gas (GHG) emissions by 80% by 2050. There are different pathways towards a carbon neutral power system, both in terms of technologies and the transition processes towards a decarbonized electricity system. However, any such pathway requires a major acceleration of the energy transition and a rapid phase out of unabated coal . During the last decade, in many countries the electricity sector has been a prominent example that policy-driven change towards cleaner technologies and practices can lead to results. Wind farms and rooftop solar-PV, decreasing electricity prices and the development of new business models are very visible indicators of the ongoing, sometimes even disruptive, changes in the sector. However, the current speed and scope of the decarbonization of the electricity sector need to be significantly increased at the European scale if a carbon neutral electricity sector is to be achieved by 2050.

If CCS or negative emissions should be part of the strategy, new policies are needed to prepare for the large-scale implementation of CCS technologies

CCS technologies could play an important role, as combined with bioenergy it can lead to negative CO_2 emissions. However, societal support for these technologies is currently extremely low. This leaves the choice of either taking immediate decisions to change energy systems radically at a much higher pace to avoid the need for negative emissions, or to make the conscious decision to become dependent on carbon removal technologies that are currently not available on the scales necessary. Postponing the decision for or against the usage of negative emissions will irrefutably lead to either greater dependence on said technologies, or require adjustments in global commitments and acceptable implications in the long run.

Ideal policies are adaptive and flexible, but at the same time maintain stability of long-term targets

The low-carbon transition of the electricity system is a largely uncertain process that is hard to predict. Therefore, policy makers need to prepare for surprises, nonlinearities and controversies. New technologies and options may arise, while some pursued options might not be feasible because of resistance or technical difficulties. These large uncertainties and complex interdependencies call for a combination of stable long-term targets and adaptive policymaking. Adaptiveness includes regular monitoring and evaluation of the progress made and the challenges faced, as well as the evidence-based adjustment of specific policy instruments or their mix. One example would be the unexpectedly rapid cost reductions of solar PV, which in many countries required extraordinary adjustments of feed-in-tariffs. At the same time, however, investments in the power system are meant to last. Formulation of long-term targets in more aggregated terms is therefore necessary to give all involved actors security and to ensure that decisions taken today can be evaluated against these targets. A combination of stability and flexibility is necessary to create new systems in which investments are made (something that is currently lacking).

Share experiences with decarbonization strategies across Member States

In the context of the Energy Union governance framework, all EU Member States are required to formulate national climate and energy policy plans with a detailed outlook towards 2030 and some indication towards 2050. The approaches to setting long-term national climate and energy agendas vary a lot among the Member States, but have in common to predominantly focus on the domestic market. National strategies, as well as the research providing the analytical underpinning for these strategies, are therefore based on assumptions on, for example, energy imports and exports without attuning this with parties beyond the national borders. Given the increasing importance of fluctuating resources in future electricity sectors, it is vital for Member States to expand their collaboration as to assure one functional system. The EU could steer towards a better coordination of cross-border issues (such as electricity grid expansion) by intensifying the collaboration of Member States to formulate national - but regionally informed - climate and energy policy plans.

Heating

Decarbonizing heating is both urgent and challenging

In the PATHWAYS scenarios that achieve a long-term EU greenhouse gas emission reduction target of 80% by 2050 relative to 1990 levels, CO_2 emissions from residential heating are reduced by 35% to 50% by 2050 relative to 1990. Since existing infrastructure and the built environment are difficult to change, this task is far from easy and requires a rapid introduction of new policies.

Important policies include monetary incentives and providing supply-chains and maintenance networks for low-carbon heating technologies

The technological options to reduce carbon emissions from heating are known, available, and mature. The main challenges are changing existing structures and behaviour as well as introducing the low-carbon technologies. Monetary incentives could support this, as shown by the successful switch in Swedish heating from oil to electricity, district heating, and biomass, which was supported by policies that increased the cost of carbon and incentivised structural change. Furthermore, supply-chains and maintenance networks for low-carbon heating appliances such as heat pumps need to be developed. Such an infrastructure is largely lacking in many European countries. For successful deployment of capital-intensive options like district heating, several conditions need to be in place, including policy and legal as well as business frameworks that can support long-term investments.

Electrification of heat is a promising strategy, but important challenges have to be addressed

For countries with electric heating, heat pumps could be an important efficiency measure. Also in other countries, an “electrification of heat” could be expected. Indeed, the potential of heat pumps for decarbonisation is large, but ‘outsourcing’ decarbonisation of heat to the electricity sector also presents significant challenges and adds to existing ones: It elevates the demands on the power sector for decarbonised and renewable energy production. Specifically, addressing power intermittency of sources such as solar and wind will become even more important. Another example is the development of heat networks, which offers huge potential but only if primary energy sources are renewable. In Sweden, there is an on-going discussion related to the import of waste for combined heat power plants. Complementarily, more attention needs to be given to the development of effective energy storage infrastructure. Moreover, there will be an increased need for developing more and smarter grids and incentivising consumers to shift demand to off-peak hours.

Smart meters require careful installation measures including programming and schooling

The roll out of smart meters has been a major part of many national strategies towards energy saving. However, research shows that smart meters perform well below aspired targets due to rebound effects and wrong application in houses. To yield positive results, the diffusion of smart meters requires careful installation measures including programming as well as education for installers and users. In this regard, smart metering has been shown to profit from feedback-giving devices that complement “smart” capabilities with tuning behaviour towards more conscious heating, ventilating etc. It is of vital importance to include such devices into strategies for smart metering and enabling correct use by installers and users. Otherwise, positive effects from smart metering are not likely to occur.

There are important co-benefits of residential sector efficiency programs

Measures associated with low-carbon heating have important co-benefits. Next to providing help in the face of energy poverty, issues such as indoor air quality and protection from harmful threats to health such as mould are clear advantages. Moreover, they can increase living comfort while at the same time decrease energy use. Effectively addressing and communicating these co-benefits can therefore increase societal acceptance for heat-efficient housing and motivate investments and behavioural change.

Mobility

An almost complete decarbonization of land-based passenger transport by 2050 is needed

Scenarios that achieve an EU 80% greenhouse gas emission reduction target relative to 1990 by 2050 tend to also show an 80% reduction in transport CO2 emissions (freight and passenger combined). This translates into an almost complete decarbonization of land-based passenger transport by 2050, as freight and air travel are more difficult to decarbonize. In the past, however, we have seen an increasing demand for mobility. Decarbonization of land-based passenger transport requires substantial changes in mobility behavior, which is complex as it involves not only changes in transport systems, but also in lifestyles and culture and in the structure of the built environment.

Strategies to decarbonize personal land-based mobility can be considered through different policy approaches

These policy approaches include 1) improving and changing car mobility, 2) reducing the need to travel, 3) encouraging modal shift, and 4) reducing trip length. Each of these approaches requires a range of changes in strategy and mobility choices. One ‘greening’ scenario may consist of a strong early prioritization of electric mobility choice. Transitional innovations, such as hybrids, may serve as stepping-stones that allow further electrification of mobility in a gradual way. They may also serve as buffers, as is partly the case for car-sharing which may allow a more gradual phase out of car ownership. In other cases, specific innovations support a combination of technologies, such as battery-electric vehicles and a culture of slow modes to produce light weight electric vehicles as an option for the mass diffusion of electric mobility. In another scenario, lifestyle and behavioural change may have a greater tendency for nurturing and supporting a combination of travel reduction, modal shift and reduced trip lengths.

A rapid phase out of the petrol car seems required

All pathways towards a low-carbon mobility sector require a rapid and almost complete phase-out of the petrol car in the next 2-3 decades. A phase out of petrol cars will require dedicated policies. This could include a gradual ban on the sale of petrol cars, providing infrastructure for alternative cars or transport modes, pricing mechanisms, tighte-ning emission controls and call-back procedures. Interestingly, the current direction and speed of technology development of electric cars and hybrid vehicles (e.g. with respect to batteries) could make a transition easier than often included in the scenarios. At the same time, it can be questioned whether these scenarios provide enough attention to the associated infrastructural changes. All-in-all, phasing out petrol cars seems possible, but requires daring and ambitious policy-making for the collective interest. There are positive signs that the resurgence of interest in issues such as air pollution can contribute to reinforcing support for such a phase out. Moreover, also changing cultural attachments to automobility may help.

Experimentation can play an important role in enabling future transitions

Experimentation allows local coalitions of activists and policymakers to become aligned to jointly deliver on community and policy goals, and eventually address the environmental challenges linked to mobility. In some instances, specific governance strategies need to be crafted to alleviate resistance, such as in the case of 'special status' concessions for a fraction of car owners, or attractive rates for car-sharing and public transport to support 'modal conversions' of specific users.

A diverse set of policy interventions are required

Given the considerations above, there is no single instrument that will be sufficient to support a transition towards sustainable transition on its own. Instead, a combination of policy instruments could be successful, focused at integrating the various relevant policy areas, including energy policy, land use and infrastructure planning, innovation support, industrial stimulus, and consumer incentives. Examples of such arrangements might be market rules to restrict petrol cars in urban centers, new public service mobility providers that sell intermodal journeys via smart phones and the internet, or combined electricity supply and service packages for battery-electric vehicles. National governments can champion the role of local authorities in promoting slow modes in local areas. This includes the promotion of walking to work and walking to school schemes. It also involves promotion of cycling and cycling infrastructure. Much of this can be done in a preparatory way to change mobility habits and provide realistic alternatives to cars for a future transition to a slow modes system of transport provision.

Agro-food

There is currently no sense of urgency for a transition to more sustainable agriculture

There are many challenges to be addressed simultaneously in the agro-food sector, such as improving human health (related to food consumption patterns), reducing greenhouse gas emissions and biodiversity loss (both within and outside the EU) and safeguarding the viability of rural areas. Despite the important role of the agro-food sector in these challenges, there is little sense of urgency to reform. Increasing the awareness of the current problems can help to increase the urgency to act and take measures in the entire agro-food chain. As the different actors in the chain are so strongly connected, and because improvements are possible within the whole food chain, it is important to take measures in the whole chain: from production to consumption.

Progress in agro-food will be gradual in nature

Other than in the energy-related domains, where a complete shift is required from fossil fuels to renewable energy, the changes in the agro-food domain are likely to be more gradual in nature. Food production will continue to rely on crop production, which in turn needs large quantities of land, water, and nutrients. Other important aspects could change more drastically. For instance, major changes in size or nature of animal production will have a large environmental impact. These changes can be driven by changes in diet and behaviour (less meat and dairy and less food waste) or by technological breakthroughs as plant-based meat replacers or cultured meat. Both require cultural acceptance, which takes time to develop. Therefore, in the short term, progress is more likely to come from improving current production methods (higher efficiencies in the form of higher crop yields, higher feed efficiencies), and conserving natural capital and decreasing emissions. To achieve results in the next decades, it is important to start implementing sustainability measures early and develop them quickly.

European policy plays an important role in setting the scene

National policy needs to be formulated within the boundaries set by European policies. As food can be freely transported within the EU, farmers have to compete at a European playing field. This makes the CAP (Common Agriculture Policy) an important EU wide policy instrument. At the same time, each country has its own specific opportunities and challenges, indicating the importance of national policies.

Reforming of the CAP can be a lever for change

The CAP beyond 2020 provides an opportunity to change the agro-food system, for example by encouraging farmers (especially beef and dairy producers) to reduce on-farm greenhouse gas emissions and nutrient losses and improve feed efficiency. A more drastic option is to promote more spatial segregation between farmland and more natural areas, which would implicate a rewilding of certain areas - especially the “less-favoured areas” which now receive additional payments. Alternatively, mosaic type landscapes could be strived for, implying more funding to create a “green veining”, as well as other agro-environmental measures. If meat and dairy consumption would decrease (for health and environmental reasons), less meat and dairy production in Europa would be needed, which in turn would lead to lower greenhouse gas emissions. The CAP could play a role in facilitating livestock farmers to end their livestock operation in a socially acceptable manner: without having large debts, and with a reasonable pension for older farmers. The shift of focus from agriculture (and fisheries) to ‘food’ could be reflected in widening the CAP to a Common Agriculture and Food policy

Not all bottom-up incentives to change the agro-food system are effective in reducing environmental pressure

Not all public initiatives and changes in behavior related to food are directly connected to environmental goals. Urban farming and local products, for instance, get a lot of attention from the public, but the actual impact on reducing greenhouse gas emissions is limited. Society is mainly paying attention to issues like human health, local production, animal welfare, and pesticides, while other aspects get less public attention. A shift in attention for the developments that have environmental benefits (such as higher crop yields or technical mitigation efforts) could be more effective.

Land use and biodiversity

A diverse set of measures is required to deal with current and future pressures of land use and its impacts on biodiversity

Biodiversity has been declining steadily over the last decade. Habitat loss due to land use change is often considered to be a primary driver for biodiversity decline (Pereira et al. 2012), next to land degradation and fragmentation, disturbance, climate change and pollution. The pressure on land use will increase, as global population is expected to increase from around 7 billion in 2010 to 9.2 billion by 2050, increasing food consumption by 1.7 times and wood consumption by 1.3 times (Vuuren van & Kok 2012). These developments will lead to further habitat and biodiversity loss. In Europe, other factors that could influence future biodiversity include the increase in urban areas and infrastructure (e.g. roads), changes in forest cover (substitution of native forest), farmland abandonment, and intensification of the agricultural sector. To deal with current and future pressures of land use, and its impacts on biodiversity, a diverse set of measures is required.

Different strategies can be pursued to preserve biodiversity

One strategy to preserve biodiversity could be to invest in intensive farming to fulfill increasing food demand, which will reduce the amount of land needed for food, opening up opportunities for land to be used for other purposes. Species associated with "natural areas" (e.g., forest species and other non-farmland species) will expand as more habitat becomes available, mostly due to farmland abandonment. Farmland species will see their range constricted to the more intensively used areas, and those more sensitive to change will disappear. In short, changing to a more intensive farming system will cause a loss of farmland and a gain in forest and other non-farmland species. In contrast, a strategy aimed at extensive agriculture and integrating farming with biodiversity functions will favour farmland species, while forest species might decline. In the end, it is a political/societal choice on which strategy the focus will be.

It is important to focus on a wide range of different functions and indicators

Species diversity is key for a rich and diverse set of ecosystem services, therefore it is essential to aim for a diversity of habitats in order to sustain higher levels of biodiversity. Although it is unavoidable that there will be some loser species independently of the chosen plan of action, conservation efforts should be implemented to safeguard these species and/or strategies to maintain their habitats requirements within the landscape, thus minimizing losses. For instance, the impact on farmland species could be mitigated by maintaining patches of extensive agriculture, or by reintroducing large herbivores to limit secondary succession.

Optimal biodiversity strategies depend on the local situation

As indicated above, there are different strategies in preventing further loss of biodiver-sity. It is clearly not preferable or even possible to implement the same measures everywhere in Europe: the national and sub-national landscape context needs to be taken into account in the development of policies promoting a given conservation measure. For example, in the Netherlands, a land-sharing strategy seems to produce strong biodiversity benefits, as the agricultural landscape is already very intensive. In contrast, in Portugal, land-sparing strategies present interesting opportunities, as there is enough margin for intensification on existing agriculture areas. However, even here further details need to be looked at. For instance, a sparing strategy is likely to only benefit biodiversity in the centre and north of Portugal, regions currently under large-scale farmland abandonment pressure. In contrast, most of the south of Portugal is characterized by a well-established agro-forestry system (i.e. land sharing). This multifunctional landscape not only supports high levels of biodiversity and ecosystem services, but plays a very important role in the Portuguese economy. Therefore, it is important to select the preferable measure in terms of improving the state of biodiversity, considering not only the biodiversity outcomes but also the existing social-economic context of the region. The latter implies that for successful implementation, both stakeholders and practi-tioners should be engaged to improve social acceptance of land use and biodiversity measures.

Biodiversity strategies are more likely to be successfully implemented if they also contribute to other societal goals

Biodiversity futures critically depend on policies with respect to agriculture, spatial planning, energy use, mobility, housing, recreation, water management, and climate change. While strategies may look optimal from a biodiversity perspective alone, it will be hard to implement them if they are not combined with other functions. This is for instance shown by the “Room for rivers” program in The Netherlands, where biodiversity benefits are combined with the need to protect the country against river flooding. Greening of cities to improve livability and health is another good example of a strategy that combines several functions. This indicates that broad strategies are needed to reach biodiversity goals.

EU policies on land-use activities such as agriculture have large impacts on national policies

While each country has its own specific opportunities and challenges, indicating the importance of national policies, national policies need to be formulated within the boundaries set by European policies. The CAP (Common Agriculture Policy) is an important EU wide policy instrument. To allow more biodiversity friendly land-use decisions, European policies should account for the diversity of landscapes. As biodiversity is not bounded by national borders, it is important to have a European approach towards biodiversity. A European approach can also take account of cross-border issues (for example, if one country decides to quit production of animals, it is likely that another country will produce more). When looking at biodiversity and land use from a European perspective, decisions can be taken in which areas the focus will be on agricultural production and which areas are more suitable for developing nature.

A successful biodiversity strategy will require strong commitments from policy-makers

Depending on the local situation and policy choices, biodiversity policies might require deep transformations. These could include reform of agro-environmental subsidies, changes in dietary patterns, further agricultural intensification, and changes in current demographic patterns in rural areas (increasing attractiveness of rural areas by e.g. public infrastructure, tax benefits). These considerations highlight the crucial role of actors, at every level of society. One of the major drivers as well as locked-in forces is society. Ultimately, transitions can be operated if relevant actors change their commitments, strategies, investments, and behaviors. It is essential to observe a joint effort of society, government, NGOs and other institutions for change to result in a more sustainable use of the land, and lowering the impact on biodiversity.

Project website and contact details

Project website: http://www.pathways-project.eu/

Contact details: pathways@pbl.nl

Use and dissemination of foreground

Section A (public)

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
1	*Bridging analytical approaches for low-carbon transitions*	*Geels, FW*	*Nature Climate Change*	*6*	*Nature Research*		*2016*	*576-583*	http://www.nature.com/nclimate/journal/v6/n6/full/nclimate2980.html	*Yes*
2	*Evaluating sustainability transitions pathways: bridging analytical approaches to address governance challenges*	*Turnheim, B*	*Global Environmental Change*	*35*	*Elsevier*		*2015*	*239-253*	http://www.sciencedirect.com/science/article/pii/S0959378015300315	*Yes*
3	*Comparing future patterns of energy system change in 2°C scenarios with historically observed rates of change*	*Van Sluisveld, MAE*	*Global Environmental Change*	*35*	*Elsevier*		*2015*	*436-449*	http://www.sciencedirect.com/science/article/pii/S095937801530056X	*Yes*
4	*Exploring the implications of lifestyle change in 2 °C mitigation scenarios using the IMAGE integrated assessment model*	*Van Sluisveld, MAE*	*Technological Forecasting and Social Change*	*102*	*Elsevier*		*2016*	*303-319*	http://www.sciencedirect.com/science/article/pii/S0040162515002607	*Yes*
5	*Rapidly falling costs of battery packs for electric vehicles*	*Nykvist, B*	*Nature Climate Change*	*5(4)*	*Nature Research*		*2015*	*329-332*	http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2564.html	*Yes*
6	*Pathways to achieve a set of ambitious global sustainability objectives by 2050: Explorations using the IMAGE integrated assessment model*	*Van Vuuren, DP*	*Technological Forecasting and Social Change*	*98*	*Elsevier*		*2015*	*303-323*	http://www.sciencedirect.com/science/article/pii/S0040162515000645	*Yes*
7	*A critical appraisal of*	*Geels,*	*Global*	*34*	*Elsevier*		*2015*	*1-12*	http://www.sciencedirect	*Yes*

[2] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[3] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

	Sustainable Consumption and Production research: The reformist, revolutionary and reconfiguration positions	*FW*	*Environmental Change*						.com/science/article/pii/ S0959378015000813	
8	*Governing the electric vehicle transition – Near term interventions to support a green energy economy*	*Nilsson, M*	*Applied Energy*	*179*	*Elsevier*		*2016*	*1360-1371*	http://www.sciencedirect.com/science/article/pii/ S0306261916303762	*Yes*
9	*The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014)*	*Geels, FW*	*Research Policy*	*45*	*Elsevier*		*2016*	*896-913*	http://www.sciencedirect.com/science/article/pii/ S0048733316300087	*Yes*
10	*Carbon budgets and energy transition pathways*	*Van Vuuren, DP*	*Environmental Research Letters*	*11(7)*	*IOP Publishing*		*2016*	*075002*	http://iopscience.iop.org/ article/10.1088/1748-9326/11/7/075002	*Yes*
14	*The EU 40% greenhouse gas emission reduction target by 2030 in perspective*	*Hof, AF*	*International Environmental Agreements: Politics, Law and Economics*	*16(3)*	*Springer*		*2016*	*375-392*	http://link.springer.com/ article/10.1007/s10784-016-9317-x	*Yes*
12	*Horses for courses: Analytical tools to explore planetary boundaries*	*Van Vuuren, DP*	*Earth System Dynamics*	*7*	*Copernicus Publications*		*2016*	*267-279*	http://www.earth-syst-dynam.net/7/267/2016/esd-7-267-2016.html	*Yes*
13	*Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective*	*Geels, FW*	*Theory, Culture & Society*	*31(5)*	*SAGE journals*		*2014*		http://journals.sagepub.com/doi/full/10.1177/0263276414531627	*Yes*
14	*Alleviating inequality in climate policy costs: an integrated perspective on mitigation, damage and adaptation*	*De Cian, E*	*Environmental Research Letters*	*11(7)*	*IOP Publishing*		*2016*	*074015*	http://iopscience.iop.org/ article/10.1088/1748-9326/11/7/074015	*Yes*
15	*Costs and benefits of differences in the timing of greenhouse gas emission reductions*	*Admiraal, A*	*Mitigation and Adaptation Strategies for Global Change*	*21(8)*	*Springer*		*2016*	*1165-1179*	http://link.springer.com/ article/10.1007/s11027-015-9641-4#	*Yes*
16	*Indirect Effects from Resource Sufficiency Behaviour in*	*Buhl, J*	*Rethinking Climate and*		*Springer*		*2016*	*37-55*	http://link.springer.com/chapter/10.1007%2F978-	*Yes*

	Germany		Energy Policies. New Perspectives on the Rebound Phenomenon						3-319-38807-6_3	
17	The political economy of energy innovation	Dasgupta, S	WIDER Working Paper	17/2016	UNU-WIDER	Helsinki	2016		https://www.wider.unu.edu/publication/political-economy-energy-innovation	Yes
18	Research priorities for negative emissions	Fuss, S	Environmental Research Letters	11(11)	IOP Publishing		2016	115007	http://iopscience.iop.org/article/10.1088/1748-9326/11/11/115007	Yes
19	Knowledge Creation between Integrated Assessment Models and Initiative-Based Learning - An Interdisciplinary Approach	De Cian, E	FEEM Working Paper	2016.066	Fondazione Eni Enrico Mattei	Milan	2016		http://www.feem.it/getpage.aspx?id=8787&sez=Publications&padre=73	Yes
20	Institutions and the Environment: Existing Evidence and Future Directions	Dasgupta, S	FEEM Working Paper	2016.041	Fondazione Eni Enrico Mattei	Milan	2016		http://www.feem.it/getpage.aspx?id=8470&sez=Publications&padre=73	Yes
21	Including system integration of variable renewable energies in a constant elasticity of substitution framework: The case of the WITCH model	Carrara, S	Energy Economics	In press	Elsevier		2017		http://www.sciencedirect.com/science/article/pii/S0140988316302171	Yes
21bis	Including System Integration of Variable Renewable Energies in a Constant Elasticity of Substitution Framework: the Case of the WITCH Model	Carrara, S	FEEM Working Paper	2015.109	Fondazione Eni Enrico Mattei	Milan	2015		http://www.feem.it/getpage.aspx?id=8187&sez=Publications&padre=73	Yes

Papers submitted (in review)

22	Global and regional abatement costs of INDCs and of enhanced action to levels well below 2°C and 1.5°C	Hof, AF	Environmental Science & Policy	Second revision	Elsevier					Yes
23	A new regime and then what? Cracks and tensions in the	Dzebo, A	Energy Research and	Second revision	Elsevier					Yes

	socio-technical regime of the Swedish heat energy system		*Social Science*							
24	*Reconfiguring urban sustainability transitions, analysing multiplicity*	*Hodson, M*	*Sustainability*	*submitted*	*MDPI*					*Yes*
25	*Socio-technical scenarios as a methodological tool to explore social and political feasibility in low-carbon transitions: Bridging computer models and transition theory in UK electricity generation (2010-2050)*	*Geels, FW*	*Technological Forecasting and Social Change*	*submitted*	*Elsevier*					*Yes*
26	*Automating behaviour? An experimental Living Lab study on the effect of smart home systems and traffic light feedback on heating energy consumption*	*Buhl, J*	*Energy Efficiency*	*submitted*	*Springer*					*Yes*
27	*Comparing future patterns of energy system change in 2°C scenarios to expert projections*	*Van Sluisveld, MAE*	*Global Environmental Change*	*submitted*	*Elsevier*					*Yes*
28	*Knowledge Creation between Integrated Assessment Models and Initiative-Based Learning - An Interdisciplinary Approach*	*De Cian, E*	*Technological Forecasting and Social Change*	*submitted*	*Elsevier*					*Yes*
29	*Agricultural nature conservation in the Netherlands: three lenses on transition pathways*	*Zwartkruis, J*	*Technological Forecasting and Social Change*	*submitted*	*Elsevier*					*Yes*
30	*Enriching Integrated Assessment Modeling with socio-technical transition insights: an application to low-carbon energy scenario analysis in Europe*	*Van Sluisveld, MAE*	*Technological Forecasting and Social Change*	*submitted*	*Elsevier*					*Yes*
31	*Multi-Scale Scenarios for Nature and Nature's Benefits to People*	*Pereira, HM*	*Science*	*submitted*	*AAAS*					*No*

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/ Period	Place	Type of audience[5]	Size of audience	Countries addressed
	(Co-)organisation of workshops/conferences							
1	*Partner workshop 1 (M4.1)*	*Turnheim, B.*	*Assessing linking tools and procedures, and pathways representations*	*18 July 2014*	*Manchester*	*Scientific Community*	*30*	
2	*Partner workshop 2 (M4.1)*	*Turnheim, B.*	*Aligning research methodology: operational progress with integration and outlook*	*25 Feb 2015*	*Leipzig*	*Scientific Community*	*30*	
3	*Stakeholder workshop (M4.2)*	*Berkhout, F*	*Scenario modelling and socio-technical analysis: opening up a timely debate about integration and linking strategies to address the governance challenges of sustainability transitions*	*27 Aug 2015*	*Brighton*	*Scientific Community*	*80*	
4	*Partner workshop 3 (M4.3)*	*Turnheim, B.*	*Assessing the role of governance and method for comparative analysis of pathways (scoping)*	*23 Nov 2015*	*Wuppertal*	*Scientific Community*	*30*	
5	*Stakeholder workshop (M2.2 & M4.4)*	*Geels, FW Berkhout, F*	*Exploring the scope for collaboration at the science-policy interface - PATHWAYS/SOER2020*	*5 Feb 2016*	*Copenhagen (EEA)*	*Scientific Community, Policy makers*		
6	*International workshop (M3.5)*	*Berg, H*	*SOS! Charting a safe operating space for humanity – lessons from different scientific approaches*	*20 Apr 2016*	*Vienna*	*Scientific Community*	*30*	
7	*Partner workshop 4 (M4.3)*	*Turnheim, B.*	*Assessing the role of governance and method for comparative analysis of pathways (implementing)*	*9 May 2016*	*Venice*	*Scientific Community*	*30*	
8	*Session at the Green Week*	*Berg, H*	*Social Innovation for Accelerating Transitions to Sustainable Cities*	*30 May 2016*	*Brussels*	*Scientific Community, Policy makers*	*40*	
9	*Regional stakeholder workshop (M3.3)*	*Berg, H*	*Knowledge Co-production for Initiative-based Sustainability Transitions: Emerging Patterns and Pathways for Governing Sustainability Transitions*	*8 Sep 2016*	*Wuppertal*	*Scientific Community*	*25*	
10	*Session at the European Week of Regions and Cities*	*Berg, H*	*Cities as actors of open innovation: Accelerating Transition towards Sustainable and Low-carbon Societies*	*11 Oct 2016*	*Brussels*	*Policy makers*	*100*	

[4] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[5] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

11	*Final conference (jointly organised with other projects ARTS and TESS)*	*Hof, AF*	*Sustainability transitions towards low-carbon societies*	*13-14 Oct 2016*	*Rotterdam*	*Scientific Community*	*50*	
12	*Final PATHWAYS workshop*	*Van Vuuren, DP*	*Towards systematic comparative analysis of pathways, PATHWAYS/SOER2020 links*	*21-22 Nov 2016*	*Copenhagen (EEA)*	*Scientific Community, Policy makers*	*60*	
	Presentations and media briefings							
1	*Presentation at conference*	*Geels, FW*	*National Economy: Challenges and Ambitions*	*24/04/2014*	*Jedda*	*Scientific Community*		
2	*Presentation at workshop*	*Geels, FW*	*Innovation 4 Sustainability workshop*	*07/05/2014*	*Manchester*	*Scientific Community*		
3	*Presentation at worshop*	*Geels, FW*	*Policy support for energy transitions: Where is public money best spent?*	*12/05/2014*	*London*	*Scientific Community*		
4	*Presentation at workshop*	*Geels, FW*	*Expert workshop on energy transitions, Karlsruhe*	*29/07/2014*	*Karlsruhe*	*Scientific Community*		
5	*Presentation at conference*	*Geels, FW*	*Innovation & Sustainability*	*22/08/2014*	*Curitiba*	*Scientific Community*		
6	*Presentation at conference*	*Geels, FW*	*IST 2014*	*27/08/2014*	*Utrecht*	*Scientific Community*		
7	*Presentation at conference*	*Geels, FW*	*IST 2014*	*27/08/2014*	*Utrecht*	*Scientific Community*		
8	*Presentation at conference*	*Geels, FW*	*CIRCLE 10th anniversary conference*	*27/11/2014*	*Lund*	*Scientific Community*		
9	*Presentation at conference*	*Geels, FW*	*Incumbent-challenger interactions in energy transitions*	*22/09/2014*	*Stuttgart*	*Scientific Community*		
10	*Presentation at conference*	*Geels, FW*	*Lessons from the shale gas revolution*	*29/01/2015*	*San Francisco*	*Scientific Community*		
11	*Presentation at workshop*	*Håkansson, I*	*Stadtkolloquium Annual Workshop*	*31/03/2015*	*London*	*Scientific Community*		
12	*Presentation at workshop*	*Van Sluisveld, M*	*BE4 workshop*	*20/04/2015*	*London*	*Scientific Community*		
13	*Presentation at conference*	*Håkansson, I*	*DPhil Day 2015*	*06/05/2015*	*Brighton*	*Scientific Community*		
14	*Presentation*	*Van Vuuren, DP*	*Inaugural lecture*	*11/05/2015*	*Utrecht*	*Scientific Community*		
15	*Presentation at conference*	*Hof, AF*	*ECCA2015*	*13/05/2015*	*Copenhagen*	*Scientific Community*		
16	*Presentation at conference*	*Carrara, S*	*34th International Energy Workshop (IEW).*	*03/06/2015*	*Abu Dhabi*	*Scientific Community, policy makers*	*150*	*Worldwide*
17	*Presentation at conference*	*Van Vuuren, DP*	*CFCC 2015*	*08/07/2015*	*Paris*	*Scientific Community*		
18	*Presentation at conference*	*Van Vuuren, DP*	*CFCC 2015*	*09/07/2015*	*Paris*	*Scientific Community*		
19	*Presentation at conference*	*Geels, FW*	*CFCC 2015*	*09/07/2015*	*Paris*	*Scientific Community*		

20	*Presentation at conference*	*Hof, AF*	*CFCC 2015*	*09/07/2015*	*Paris*	*Scientific Community*		
21	*Presentation at conference*	*Van Vuuren, DP*	*CFCC 2015*	*09/07/2015*	*Paris*	*Scientific Community*		
22	*Presentation at conference*	*Van Vuuren, DP*	*CFCC 2015*	*09/07/2015*	*Paris*	*Scientific Community*		
23	*Presentation at conference*	*Echternacht, L*	*IST2015*	*26/08/2015*	*Brighton*	*Scientific Community*		
24	*Presentation at conference*	*Geels, FW*	*IST2015*	*26/08/2015*	*Brighton*	*Scientific Community*		
25	*Presentation at conference*	*Geels, FW*	*IST2015*	*26/08/2015*	*Brighton*	*Scientific Community*		
26	*Presentation at conference*	*Berkhout, F*	*IST2015*	*26/08/2015*	*Brighton*	*Scientific Community*		
27	*Presentation at conference*	*Zwartkruis, J*	*IST2015*	*26/08/2015*	*Brighton*	*Scientific Community*		
28	*Presentation at conference*	*Nykvist, B*	*IST2015*	*27/08/2015*	*Brighton*	*Scientific Community*		
29	*Presentation at conference*	*Geels, FW*	*IST2015*	*27/08/2015*	*Brighton*	*Scientific Community*		
30	*Presentation at conference*	*Köhler, J*	*IST2015*	*27/08/2015*	*Brighton*	*Scientific Community*		
31	*Presentation at conference*	*Hof, AF*	*IST2015*	*28/08/2015*	*Brighton*	*Scientific Community*		
32	*Presentation at conference*	*Van Sluisveld, M*	*IST2015*	*28/08/2015*	*Brighton*	*Scientific Community*		
33	*Presentation at conference*	*Rogge, K*	*IST2015*	*28/08/2015*	*Brighton*	*Scientific Community*		
34	*Presentation at conference*	*Turnheim, B*	*IST2015*	*28/08/2015*	*Brighton*	*Scientific Community*		
35	*Presentation at conference*	*Dzebo, A*	*IST2015*	*28/08/2015*	*Brighton*	*Scientific Community*		
36	*Presentation at conference*	*Lukas, M*	*IST2015*	*28/08/2015*	*Brighton*	*Scientific Community*		
37	*Presentation at workshop*	*De Cian, E*	*UNU-Wider workshop, NREL*	*28/08/2015*	*Colorado, USA*	*Scientific Community*	*40*	*USA and beyond*
38	*Presentation at workshop*	*Dasgupta, S*	*UNU-Wider workshop, NREL*	*28/08/2015*	*Colorado, USA*	*Scientific Community*	*40*	*USA and beyond*
39	*Presentation at conference*	*Turnheim, B*	*Royal Geographical Society Annual International Conference*	*01/09/2015*	*London*	*Scientific Community*		

40	*Presentation at workshop*	*Berg, H*	*Theories of change in sustainability transitions*	*11/09/2015*	*A Coruna*	*Scientific Community*		
41	*Presentation and poster at workshop*	*Zwartkruis, J*	*Theories of change in sustainability transitions*	*10/09/2015*	*A Coruna*	*Scientific Community*		
42	*Presentation at conference*	*Håkansson, I*	*Transformations 2015, Stockholm*	*05/10/2015*	*Stockholm*	*Scientific Community*		
43	*Presentation at conference*	*Zwartkruis, J*	*Transformations 2015, Stockholm*	*05/10/2015*	*Stockholm*	*Scientific Community*		
44	*Presentation*	*Geels, FW*	*ABIS Annual Colloquium on 'Global Sustainability Strategy: New models and approaches to achieve sustainable living'*	*19/10/2015*	*Milan*	*Scientific Community*		
45	*Media briefing*	*Nykvist, B*	*Stationary Storage and BEV*	*27/10/2015*	*Berlin*	*Medias*		
46	*Presentation*	*Nykvist, B*	*Annual meeting in the Danish EV alliance*	*25/11/2015*	*Copenhagen*	*Industry, policy makers*		
47	*Presentation at workshop*	*Zwartkruis, J*	*Eionet Improvement and Innovation Initiative (E3I) workshop*	*09/12/2015*	*Berlin*	*Scientific Community, policy makers*		
48	*Presentation*	*Geels, FW*	*OECD Green Growth and Sustainable Development Forum*	*14/12/2015*	*Paris*	*Scientific Community, policy makers*		
49	*Presentation*	*Geels, FW*	*World Congress on Sustainable Technologies (WCST-2015)*	*16/12/2015*	*London*	*Scientific Community*		
50	*Presentation at workshop*	*Geels, FW*	*Research Workshop on the Social and Historical Dimensions of a Vehicle-to-Grid Transition*	*15/01/2016*	*Copenhagen*	*Scientific Community*		
51	*Presentation at conference*	*Carrara, S*	*4th IAERE conference (Italian Association of Environmental and Resource Economists)*	*11/02/2016*	*Bologna*	*Scientific Community*	*120*	*EU and beyond*
52	*Presentation at workshop*	*Geels, FW*	*Expert working meeting on 'Transformation to sustainability', organized by Future Earth*	*19/02/2016*	*Oslo*	*Scientific Community*		
53	*Presentation at workshop*	*Geels, FW*	*Energy systems challenges in a world in transition organised by UK Energy Research Centre*	*22/04/2016*	*Oxford*	*Scientific Community*		
54	*Presentation at conference*	*Berg, H*	*European Geosciences Union General Assembly 2016*	*20/04/2016*	*Vienna*	*Scientific Community*		
55	*Presentation at conference*	*De Cian, E*	*European Geosciences Union General Assembly 2016*	*20/04/2016*	*Vienna*	*Scientific Community*		*Worldwide*
56	*Presentation at conference*	*Geels, FW*	*Global Transformative Climate Governance après Paris*	*23/05/2016*	*Berlin*	*Scientific Community*		
57	*Presentation*	*Hof, AF*	*EEA Scientific Committee meeting*	*18/05/2016*	*Copenhagen*	*Scientific Community, policy makers*		
58	*Presentation*	*Geels, FW*	*EEA Scientific Committee meeting*	*18/05/2016*	*Copenhagen*	*Scientific Community, policy makers*		
59	*Presentation at conference*	*Dasgupta, S*	*International Energy Workshop (IEW2016)*	*01/06/2016*	*Cork*	*Scientific community*		*EU and beyond*

60	*Presentation at conference*	*Carrara, S*	*22nd EAERE conference (European Association of Environmental and Resource Economists)*	*24/06/2016*	*Zurich*	*Scientific Community, policy makers*		*EU and beyond*
61	*Presentation at conference*	*Dasgupta, S*	*22nd EAERE conference (European Association of Environmental and Resource Economists)*	*25/06/2016*	*Zurich*	*Scientific Community, policy makers*		*EU and beyond*
62	*Presentation at conference*	*Geels, FW*	*28th Annual Conference of the Academia Europaea*	*27/06/2016*	*Cardiff*	*Scientific Community*		
63	*Presentation at conference*	*Dasgupta, S*	*FEEM-IEFE Joint Seminar*	*21/07/2016*	*Venice*	*Scientific Community*	*50*	*Italy and beyond*
64	*Presentation*	*Geels, FW*	*IPCC Scoping Meeting for the Special Report on 1.5 °C global warming*	*15/08/2016*	*Geneva*	*Scientific Community*		
65	*Presentation at conference*	*Zwartkruis, J*	*4S/EASST*	*31/08/2016*	*Barcelona*	*Scientific Community*		
66	*Presentation at conference*	*Geels, FW*	*4S/EASST*	*31/08/2016*	*Barcelona*	*Scientific Community*		
67	*Presentation at conference*	*Hof, AF*	*RGS-IBG Annual International Conference 2016*	*31/08/2016*	*London*	*Scientific Community*	*40*	
68	*Presentation at conference*	*Geels, FW*	*IST 2016 Wuppertal*	*06/09/2016*	*Wuppertal*	*Scientific Community*		
69	*Presentation at conference*	*Köhler, J*	*IST 2016 Wuppertal*	*09/09/2016*	*Wuppertal*	*Scientific Community*		
70	*Presentation at conference*	*Geels, FW*	*SPRU's 50th anniversary conference*	*09/09/2016*	*Brighton*	*Scientific Community*		
71	*Presentation at conference*	*Dasgupta, S*	*Responding to Crises Conference*	*23/09/2016*	*Helsinki*	*Scientific Community, policy makers*	*200*	*Worldwide*
72	*Presentation at workshop*	*Pereira, HM*	*Worskhop on future scenarios development for the Intergovernmental Platform on Biodiversity and Ecosystem Services*	*3/10/2016*	*Leipzig*	*Scientific Community, Policy-makers*	*50*	*Worldwide*
73	*Presentation*	*Geels, FW*	*Invited talk at BP head office about Incumbent actors in energy transitions*	*20/10/2016*	*London*	*Industry*		*UK*
74	*Presentation at conference*	*Dasgupta, S*	*ECOCEP – Energy and Climate Economic Modeling 2016 Conference, 03-04/11/2016, Prague (Czech Republic)*	*04/11/2016*	*Prague*	*Scientific community*	*50*	*EU and beyond*
75	*Presentation at conference*	*Martins, IS*	*iDiv Annual Conference 2016*	*7/11/2016*	*Leipzig*	*Scientific Community*	*100*	*EU*
76	*Presentation at conference*	*Verdolini, E*	*1st AIEE Energy Symposium on Current and Future Challenges to Energy Security*	*02/12/2016*	*Milan*	*Scientific community, policy makers*	*100*	*EU and beyond*
77	*Presentation at workshop*	*Geels, FW*	*Expert workshop on rapid transitions, organized by Tyndall Centre*	*12/12/2016*	*Manchester*	*Scientific Community*		*EU and beyond*
78								

Section B (Confidential[6] or public: confidential information to be marked clearly)
Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[7]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)

[6] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

[7] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
-	-	-	-	-	-	-	-	-

Report on societal implications

A **General Information** *(completed automatically when* ***Grant Agreement number*** *is entered.*	
Grant Agreement Number:	603942
Title of Project:	Exploring transitions pathways to sustainable, low carbon societies
Name and Title of Coordinator:	Prof. Dr. Detlef van Vuuren

B **Ethics**	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports?	***No***
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	0	1
Work package leaders	1	5
Experienced researchers (i.e. PhD holders)	15	19
PhD Students	16	12
Other	4	4

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**10**
Of which, indicate the number of men:	4

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	● ○	Yes No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective … Very effective
■	Design and implement an equal opportunity policy	○ ○ ○ ● ○
❑	Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○
❑	Organise conferences and workshops on gender	○ ○ ○ ○ ○
❑	Actions to improve work-life balance	○ ○ ○ ○ ○
○	Other:	

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

- ○ Yes- please specify
- ● No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

- ○ Yes- please specify
- ● No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- ○ Yes- please specify
- ● No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

- ● Main discipline[8]: 1.4
- ● Associated discipline[8]: 5.4
- ○ Associated discipline[8]:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	● ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ● No
- ○ Yes- in determining what research should be performed
- ○ Yes - in implementing the research
- ○ Yes, in communicating /disseminating / using the results of the project

[8] Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ●	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ● Yes- in framing the research agenda
- ● Yes - in implementing the research agenda
- ● Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ● Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture		Energy	X	Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment	X	Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and		Food Safety		Research and Innovation	
Monetary Affairs		Foreign and Security Policy		Space	
Education, Training, Youth		Fraud		Taxation	
Employment and Social Affairs		Humanitarian aid		Transport	X

13c If Yes, at which level? ○ Local / regional levels ● National level ● European level ○ International level	

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**21**
To how many of these is open access[9] provided?	**17**
How many of these are published in open access journals?	**12**
How many of these are published in open repositories?	**5**
To how many of these is open access not provided?	**4**
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ■ no funds available to publish in an open access journal ■ lack of time and resources ❑ lack of information on open access ❑ other[10]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**None**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**None**
	Registered design	**None**
	Other	**None**

17. How many spin-off companies were created / are planned as a direct result of the project?	**None**
Indicate the approximate number of additional jobs in these companies:	**-**

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑ Increase in employment, or	❑ In small & medium-sized enterprises
❑ Safeguard employment, or	❑ In large companies
❑ Decrease in employment,	■ None of the above / not relevant to the project
❑ Difficult to estimate / not possible to quantify	

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*

[9] Open Access is defined as free of charge access for anyone via Internet.
[10] For instance: classification for security project.

Difficult to estimate / not possible to quantify	■

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ● No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ● No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☐	Press Release	☐	Coverage in specialist press
■	Media briefing	☐	Coverage in general (non-specialist) press
☐	TV coverage / report	☐	Coverage in national press
☐	Radio coverage / report	☐	Coverage in international press
■	Brochures /posters / flyers	■	Website for the general public / internet
■	DVD /Film /Multimedia	■	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

☐	Language of the coordinator	■	English
☐	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):
1.4; 5.4

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES
1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]
1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)
1.3 Chemical sciences (chemistry, other allied subjects)
1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)
1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY
2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]