



## TRANSITIONS PATHWAYS AND RISK ANALYSIS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES

### D2.2 - Complementarity of qualitative and quantitative analytical tools

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# TRANSrisk

## Transitions pathways and risk analysis for climate change mitigation and adaptation strategies

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## Preface

Both the models concerning the future climate evolution and its impacts, as well as the models assessing the costs and benefits associated with different mitigation pathways face a high degree of uncertainty. There is an urgent need to not only understand the *costs and benefits* associated with *climate change* but also the *risks, uncertainties and co-effects* related to different *mitigation pathways* as well as *public acceptance* (or lack of) of low-carbon (technology) options. The main aims and objectives of TRANSrisk therefore are to create a novel assessment framework for analysing costs and benefits of transition pathways that will integrate well-established approaches to modelling the costs of resilient, low-carbon pathways with a wider interdisciplinary approach including risk assessments. In addition, *TRANSrisk* aims to design a decision support tool that should help policy makers to better understand uncertainties and risks and enable them to include risk assessments into more robust policy design.

## PROJECT PARTNERS

No	Participant name	Short Name	Country code	Partners' logos
1	Science Policy Research Unit, University of Sussex	SPRU	UK	
2	Basque Centre for Climate Change	BC3	ES	
3	Cambridge Econometrics	CE	UK	
4	Energy Research Centre of the Netherlands	ECN	NL	
5	Swiss Federal Institute of Technology (funded by Swiss Gov't)	ETH Zurich	CH	
6	Institute for Structural Research	IBS	PL	
7	Joint Implementation Network	JIN	NL	
8	National Technical University of Athens	NTUA	GR	
9	Stockholm Environment Institute	SEI	SE, KE	
10	University of Graz	UniGraz	AT	
11	University of Piraeus Research Centre	UPRC	GR	
12	Pontifical Catholic University of Chile	CLAPESUC	CL	

## Executive Summary

In TRANSrisk, case studies focus on how pathways towards a low-emission future can be achieved within the domestic contexts of countries. For such analyses, the project can use both quantitative and qualitative analytical tools. Models are an example of the first type of tools which help to assess the positive and negative impacts of a low-emission pathway for the country, thereby assuming implementation of low-emission options (such as technologies) at a certain scale. Qualitative tools help to assess aspects that are more difficult to quantify, and therefore often not covered by models, while still being important for the eventual success of a decision. An objective of TRANSrisk is to integrate quantitative tools with qualitative tools for improved analysis.

In order to practice with an integrated approach with qualitative and quantitative tools, the TRANSrisk team organised a training workshop in March 2016. At this workshop, TRANSrisk partners took part in a roleplay session in which they acted as stakeholders in a decision-making process and were asked to respond to a research question, using H-diagram as qualitative and the MEMO model as quantitative tool. Based on stakeholders' response, which reflected their positions, interests and preferences, additional research questions were formulated. For example, should energy efficiency be stimulated at a larger scale, what would be implications for employment in energy-intensive and other sectors? These additional research questions were discussed with the modeller, after which the model simulations could begin to explore answers to the questions raised. Answers were presented at the same workshop. While this was very helpful, it also became clear that for the case study analysis in TRANSrisk this may be more difficult, especially if the H-Form-derived questions require a calibration of the model. In that case, more time is needed between the H-Form discussion and presentation of the model results.

A next example of integrating stakeholder consultation with modelling has been applied by partners BC3 and JIN to explore how stakeholder engagement can support scenario development and pathway design for a low-emission and climate resilient future. For that, stakeholder preferences have been collected through an international stakeholder consultation (mostly representing international organisations) and which are used for modelling mitigation option portfolios in Work Package 4 of TRANSrisk. The stakeholder consultation took place via an online survey to elicit preferences of experts that are often excluded from decision making and to translate them across different levels of policy. Stakeholders' views as expressed via the survey have subsequently been used as an input for model-based scenarios. These scenarios will, in a next stage of the project, be communicated with stakeholders to see whether stakeholder opinions change after the results of the scenarios have been presented to them.

Another area in TRANSrisk where integration of qualitative and quantitative tools can produce enhanced insights is that of risk and uncertainty determination. In the case study

analysis two categories are considered: risk that a low-emission pathway will not be (successfully) implemented (implementation risk); and the risk that a pathway may have negative impacts to the rest of society (consequential risks). Implementation risks could be assessed, for example, by using the qualitative, participatory tool of system mapping, which would help to identify potential system barriers and assess to what extent these barriers could imply a risk of unsuccessful implementation of the pathway. Models could also be used for assessing implementation risks, especially when these can be quantified, such as implementation costs. Consequential risks could be quantified using a model, thereby assuming a certain implementation scale of the pathways, after which qualitative tools can be used to assess the risks and their acceptability or not.

The potential complementarity of quantitative and qualitative tools for low-emission pathway development will be tested and evaluated in the TRANSrisk case study analysis. Quantitative tools are used, among others, for making business-as-usual scenarios and scenarios which assume achieving a longer-term climate and/or sustainable development goal, and assessing implementation of low-emission options as part of these scenarios. Qualitative tools are used for identifying stakeholder preferences, public acceptance of low-emission options and analysing systems and required system improvement for successful implementation of low-emission pathways.

Insights gained from TRANSrisk and its case studies can be helpful input for developing methodologies for Nationally Determined Contributions (NDCs), which are national climate plans that countries must communicate as part of the Paris Agreement. The method used in TRANSrisk for case study analysis has several similar similarities with the type of analysis that is required for formulating NDCs, as TRANSrisk takes the domestic context of a country as a starting point, considers desired socio-economic futures as a basis for low-emission pathways and conducts this analysis in a participatory manner with stakeholder engagement. Therefore, the TRANSrisk methods reflect the bottom-up approach taken by the Paris Agreement for formulating country climate actions towards the 2°C target.

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## 1 *EC SUMMARY REQUIREMENTS*

### 1.1 Changes with respect to the DoA

This deliverable is prepared in accordance with the DoA.

### 1.2 Dissemination and uptake

This deliverable will support the work in the TRANSrisk case studies, in particular the participatory consultations with stakeholders, to mobilise tacit knowledge of stakeholders in the case study countries and help integrate qualitative and quantitative analysis in TRANSrisk. Project partners are primary users of the deliverable.

More generally, beyond TRANSrisk, the deliverable can be used by any kind of environmental and/or climate change decision making process as the tools help to consider and integrate stakeholder knowledge and preferences in such processes.

### 1.3 Short Summary of results

This deliverable has shown that application of quantitative and qualitative tools in an assessment of low-emission pathways in a country can have the following benefits:

- (i) It can combine insights on aspects that are difficult to quantify with aspects that can be quantified, such as with models, for a better understanding of social preferences and system inefficiencies related to pathways that contribute to a country's climate and development goals.
- (ii) Modelled scenarios can improve stakeholders' knowledge of positive and negative impacts of a low-emission pathway to other areas of society, assuming a larger-scale implementation of low-emission options under the pathway.
- (iii) While some risks related to implementation of low-emission pathways can be quantified, other can only be assessed through stakeholder consultation. Combining both approaches supporting a better-informed risk assessment.
- (iv) The combined quantitative-qualitative tools application in TRANSrisk case studies form a useful testing ground for formulating Nationally Determined Contributions (NDCs) under the Paris Agreement.

## 1.4 Evidence of accomplishment

This Deliverable.

## 2 INTRODUCTION

Deliverable 2.1 introduced a set of tools for engaging stakeholders in participatory processes during TRANSrisk case studies. It supports the objective of TRANSrisk to integrate quantitative tools with qualitative tools. Integrating these tools means that the output of an analysis is not only based on aspects that can be quantified, but also include aspects (e.g. stakeholder viewpoints and knowledge) that are more difficult to quantify while still being important for the eventual success of a decision. With qualitative tools, stakeholders' tacit knowledge can be codified to support development of low-emission pathways.

In this report, we explain, and illustrate, how qualitative, participatory tools can complement analysis done with quantitative tools, such as models. To explore the need for such complementarity, we refer to the rationale for the TRANSrisk project that fundamental transformations are required to move towards low-emission, sustainable, and climate-resilient economies. This implies making choices about low-emission (technology) options by balancing their benefits and costs, and considering these at a required scale to enable a transformation. With models, application scenarios of low-emission solutions at an assumed scale can be formulated, thereby considering multiple possible futures. This type of analysis can, for example, show that, while a country can meet half of its electricity demand through domestic hydropower sources, it is wise, for grid stability reasons, to maximise application of this technology option to a certain limit. A weakness of models is that they usually do not say anything about how people perceive the costs and benefits of options and what this means for social acceptability.

Participatory, qualitative analysis, on the other hand, can facilitate a much more detailed discussion on benefits and costs as perceived by stakeholders and to what extent people are willing to accept energy installations near their home environment. A weakness of this type of analysis is that stakeholders may find it difficult to assess options at a larger scale, as this increases the complexity of their decision context. A local stakeholder consultation on a nearby wind power park requires knowledge of the local context and how the technology fits in there. Taking a decision on deployment and diffusion of a technology at the scale of a sector or country requires detailed knowledge of relevant systems and positive and negative 'knock on' or consequential effects of the technology for the rest of the sector or country.

Two examples demonstrating the limitations of applying quantitative and qualitative tools on their own are the following. In 2011, the European Commission published the EU Roadmap for moving to a low-emission economy by 2050 (European Commission, 2011). It sets out how the main sectors responsible for Europe's greenhouse gas emissions (namely power generation, industry, transport, buildings, construction and agriculture) could make low-emission transitions in a cost-effective manner, whilst boosting Europe's economy through innovation and investment in clean technologies. However, among the key technology options identified for reducing greenhouse gas emissions are carbon capture and storage,

and wind power. The first option, while technically representing a large emission reduction potential, has not yet passed through the stage of technology R&D and demonstration. Important reasons for that are of techno-economic nature (IPCC, Summary for Policymakers, 2014a) as well strong public resistance to pilot projects. The second option has been successfully deployed in the market, but its further diffusion on a larger scale is prevented in several EU areas by public concerns around visual impact, noise and disturbing bird migration (Hofman, van der Gaast, & Fujiwara, 2014). In other words, while technically and economically feasible and viable, low-emission pathways may be hampered by lack of social acceptance. Relying only on quantitative tools such as models in this context implies the risk that other crucial aspects, such as public acceptance, are insufficiently addressed in the scenario analysis.

While the above example illustrates the limitation of relying only on models when designing low-emission pathways, the example of the Global Technology Needs Assessment (TNA) Project<sup>1</sup> shows how relying only on participatory tools implies the risk that stakeholders have insufficient knowledge of costs, benefits and implementation aspects related to larger-scale diffusion of low-emission technologies. Typically, a TNA starts with identification of national development priorities, including strategic sectors for climate and development. These priorities are then used as criteria for assessing, via multi-criteria decision analysis, possible technologies in terms of contribution to reaching development goals and reducing GHG emissions or enhancing climate resilience. The resulting portfolio of technology options should then enable the country to achieve its development goals with low emissions and/or with strong climate resilience.

A complication when assessing technology options in a TNA with stakeholders is the need to consider costs and benefits of an option at a larger scale, in the short, medium and long term. For example, stakeholders may have good knowledge of potential benefits of a technology option, but may be insufficiently aware of possible ‘knock-on’ effects for the rest of the economy over time. In terms of employment the technology can be perceived to be a job-creating option, but for a fuller picture, job losses also need to be considered when the technology replaces another technology within the sector or elsewhere in the economy. Moreover, job losses may occur in the short term, whilst generation of new jobs may take place in the longer term. For example, in Work Package 4 of TRANSrisk an analysis was done of direct and indirect employment impacts of energy transition processes during 1995-2009 in 27 EU Member States which showed, among other cases, that in Poland there were net employment benefits due to energy efficiency measures, which offset the job losses in the coal sector (Markandya, Arto, Gonzáles-Equino, & Román, 2016). Without tools to assess technologies at different scales, at different times and under different assumptions to see what are possible outcomes of technology diffusion at a larger scale in the longer term,

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<sup>1</sup> <http://tech-action.org>

stakeholders cannot do much more than making assessments (if not ‘guestimates’) based on their best professional judgement.

Should a TNA-type of assessment be combined with a model, then different scenarios can be constructed under different assumptions. By doing this a sense can be obtained of the possible risks of diffusing a technology at a large scale, such as grid stability, employment loss, lower international competitiveness. With these scenarios, stakeholders can take better informed decisions about costs, benefits and implementation issues related to technology options.

Within TRANSrisk the importance of quantitative modelling exercises is acknowledged, such as carried out for the EU Roadmap. At the same time, it is realised that models concerning the future climate evolution and its impacts, as well as models assessing the costs and benefits associated with different mitigation scenarios, face a high degree of uncertainty, and have difficulty in accounting for the issue of public acceptance (or lack thereof) of low-emission (technology) options. These risks and co-effects of mitigation pathways related to technological innovation are often not sufficiently understood and quantified, and therefore are not appropriately included into the policy design. Stakeholder input is therefore essential for scenario development. For instance, stakeholders, as practitioners, can give a better indication of how a market, supply chain, etc., may respond to policies.

Stakeholders also represent the institutional and social-economic innovations essential for driving technological innovations, including public acceptance of low-emission options. Innovation for a low-emission future often takes place along complex pathways with involvement of multiple actors and consideration of existing policies, cultures, habits, etc. With the help of stakeholders and the models, TRANSrisk will explore such system dynamics in the case study countries. For that, the project will consider how different approaches towards climate and energy policy, as well as related policies across multiple sectors, can affect the process of innovation. Such approaches include the most commonly modelled ones, such as the imposition of a carbon price, alongside others, including specific technology support policies, or measures to achieve other objectives (e.g., air pollution targets) that are in line with climate mitigation.

Given the large uncertainties of model-based results, there are blurred boundaries between quantitative and qualitative methods. Additional examination is therefore required for:

- (i) Policy risks, which concern the possibility that a policy approach may not succeed in reducing emissions, which is determined by making the conditions for success of the different approaches explicit;
- (ii) Social and political risks, such as impacts of climate policy approaches on health, safety, food supply, security, employment and displacement of social groups, and which partly determine their public acceptance;

- (iii) Economic risks: the issue of the risk that climate policy approaches may incur or alleviate, determined by running the models under multiple scenarios with respect to many of the core assumptions; and
- (iv) Environmental risks of climate policy approaches that are not necessarily related to carbon emissions.

In this report, an overview is presented of how qualitative and quantitative tools can complement each other in preparing low-emissions pathways, thereby taking the TRANSrisk work packages as a framework. Firstly, we explain the example of a training workshop with the TRANSrisk team at which a stakeholder consultation was simulated based on a research question about a possible low-emission pathway. The consultation resulted in several positive and negative statements which were, in a dialogue with the modeller, formulated as research questions to be answered by the model. Model outcomes were then communicated with the stakeholders, for their further consideration. Secondly, we describe the process of incorporating views of a selected group of international stakeholders on longer term climate change development, and possible solutions for that in scenario building with help of an Integrated Assessment model (Work Package 4, Task 2). Thirdly, the report demonstrates how models can help identify the range of uncertainties related to low-emission pathway and the possible risk implications for other sectors or groups in society. Finally, it is shown how models and participatory processes are being applied in consecutive steps of the case study analysis.

With these insights, the report will conclude with an identification of how complementary application of qualitative and quantitative tools, as investigated under TRANSrisk, could support formulation of Nationally Determined Contributions (NDCs) as required under the Paris Agreement. Countries are committed to communicating NDCs under the Agreement, but since communicated climate measures are identified considering domestic circumstances, countries are relatively free to choose their desired pathways, both for realising national development goals and international climate targets.

## 3 PRACTICAL EXAMPLE: MODEL RUNS BASED ON STAKEHOLDER QUESTIONS

### 3.1 Introduction

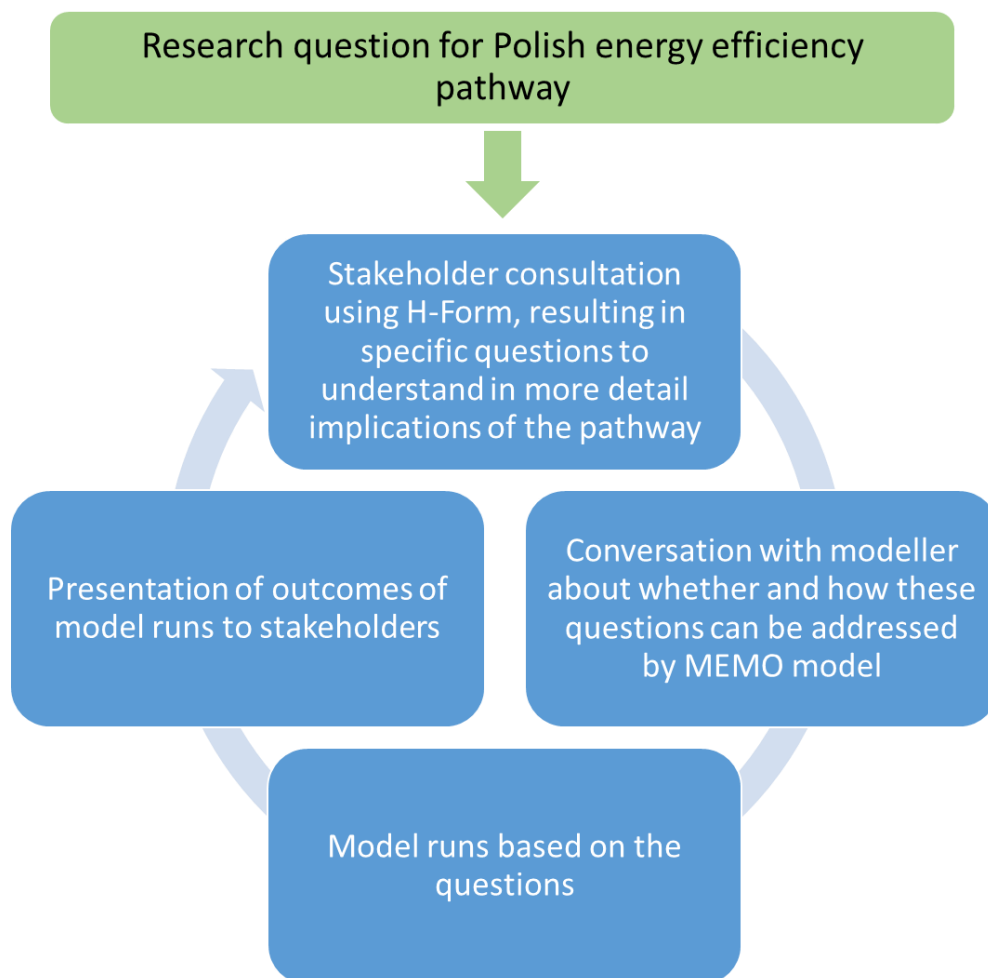
To practice with the qualitative tools, the TRANSrisk project team organised a mock stakeholder workshop in Athens on 9-10 March 2016. One of the goals of the mock workshop was to practice with an analytical approach to address a research question by using stakeholder consultation tools in combination with a modelling tool. The workshop tested how inputs, views and questions formulated by stakeholders based on the research question could be formulated as subsequent research questions for a modeller to address in several model runs. For example, a stakeholder may express concern that a low-emission solution leads to job losses in a certain sector of the economy and argue that that effect is unacceptable. A model run could analyse the estimated employment impact of the solution, which is then communicated with the stakeholder to better inform their decisions. Moreover, the mock workshop aimed to test whether such a combined stakeholder consultation and modelling approach could be done within the timespan of a one, or two, day workshop, or whether more time would be needed between the stakeholder consultation and the results of the model run(s).

To illustrate the approach, the case of an energy efficiency enhancement pathway in Poland was taken, using H-Form as qualitative tool<sup>2</sup> and the MEMO model<sup>3</sup> as quantitative tool (see Appendix 1 - Summary of MEMO model). For the sake of illustration and practice, TRANSRISK partners were given roles of Polish stakeholders. Each stakeholder role was described in a profile in terms of policy preferences and position on climate change. As described in further detail below, using the H-Form and starting from a general research question about the pathway, several specific questions were formulated. These questions formed the basis for a series of model runs to obtain a better understanding of the implications of the energy efficiency pathway in Poland. The model outcomes were presented to 'stakeholders'. The workflow is summarised in the diagram below.

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<sup>2</sup> H-form is a stakeholder consultation tool to organise a discussion around a research or policy question or statement. Stakeholders are then asked to respond to this, whereby negative answers are collected to the left of the question/statement (e.g. on a flip-over paper) and positive answers to the right, which results in an H-form. Based on the answers additional research or policy questions can be formulated for further discussions. A detailed description of H-form can be found in TRANSrisk deliverable D2.1 (van der Gaast, et al., 2016).

<sup>3</sup> MEMO is a large scale, multisector, dynamic stochastic general equilibrium model that was constructed in IBS for climate policy assessment.



**Figure 1. Workflow training workshop with application of qualitative and quantitative tools**

The outcomes of each step are discussed below. Please note that the set-up of the workshop and viewpoints expressed were only for the sake of illustration, and do not necessarily represent formal positions of Polish public and private sector stakeholders.

## 3.2 Stakeholder involvement during the workshop

During the first session of the workshop, TRANSrisk partners, in their role of Polish Stakeholders, were presented with the context of the Polish case study. Subsequently, participants were asked to play the role of Polish stakeholders representing various ministries, NGOs, trade unions, employers' organisations and banks. Stakeholder profiles were presented, including positions on energy efficiency and climate change and specific issues that individual stakeholders find important, such as employment, balanced budgets and (international) competitiveness (see Table 1).

**Table 1. Stakeholder profiles for Polish case study at training workshop**

Type of stakeholder and their position on climate change	Stakeholders	Stakeholder characterisation
<b>Trade unions</b> (240 trade unions of miners) There is no proof of human impact on climate change. Reducing use of coal is a waste of domestic resources, undermines economic growth and leads to unemployment. The government must rescue the sector.	NSZZ Solidarność	The largest trade unions federation in Poland. Consistently opposed to the climate-energy package and any attempts to make it more impactful (Back-loading, <b>market stability reserve</b> , etc.). To protect mining sector, it can mobilise protests of energy sector, farmers and railwaymen.
	OPZZ	The second largest trade unions federation, cooperating with the largest mining trade union. Opposes climate and energy policy in all aspects.
<b>Employers organisations</b> Climate change policy is a megatrend which needs to be considered. Polish coal based economy needs faster modernization. It requires less control of the state.	Confederation Lewiatan	Progressive organisation of Polish and foreign SME interested in modernisation of the Polish energy system.
	Business Centre Club	Mostly large enterprises, support the effort towards energy efficiency and lower emissions yet assess the climate policy as having a negative impact on Poland. RES disfavour the coal which essentially should remain an important fuel.
	Pracodawcy RP	The third biggest organisation of employers having the largest number of mining companies; interested in support for this industry. At the same time defends the prosumer support in the form of feed-in tariffs, and promote energy efficiency in buildings.
<b>Chamber of commerce and industry</b> For large stakeholders - there is no proof of human impact on climate change / at least Polish economy should not be burdened with counteracting. In a short run efficiency measures on demand side and RES have a negative impact on the energy system as they lead to reduction of (coal based) energy production.	KIG	The largest federation of sectoral and regional chambers of commerce. Sceptical towards the idea of human impact on climate. Most chambers and experts support a coal based energy system, some however see the potential in prosumers.
	PKEE (electricity)	Poland needs investments in energy infrastructure. Climate-energy policy negatively affects Poland in many aspects, especially by crowding out the coal. Prosumer based energy is economically not justified as it increases the instability of the system, is expensive and remains such for at least another 5 years. PKEE favours conventional wind and biomass as the most efficient RES in Poland.
	SIB (retrofitting)	Producers of retrofitting materials in favour of growing market for their products

<p><b>Public administration</b> There is no proof of human impact on climate change. There is no fast way to overcome the strength of unions. Energy security requires to use own resources (no switch to gas as it is expensive for Poland and comes mainly from Russia).</p>	PIGEOR (renewable)	Conventional wind and biomass as the two strongest groups. Very low potential for solar and hydro.
	ZAE (energy auditors)	Struggle for state support for retrofitting programmes.
	KIGEiT (ICT)	Interested in development of innovative grid system management and smart grids
	Ministry of Energy	Willing to further modernise the coal and energy sector, reduce the state subsidies but also considering a lesser tax burden for coal.
	Ministry of Environment	Doubt in human impact on climate. Positive towards climate policy however if it includes special preference for Poland.
	National Energy Conservation Agency	Scientific body under the ministry of Environment involved in projects aiming at retrofitting and increasing the share of prosumers (Ceglarz, 2015).
	NFOŚiGW	Support the energy efficiency and RES programmes.
	BGK and BOŚ (2 Banks)	Both national banks offer loan and credits for retrofitting and renewables including prosumer installation.
	Ministry of Development / Ministry of Finance	Defending incomes from coal sector, fragile to demands of the unions. Sceptical about additional cost for the budget.
	<p><b>Climate friendly NGO</b> Poland can reduce emissions in a more ambitious way but a fundamental behavioural /mind-set change is needed. Local governments are potential partners for cooperation</p>	Institute for Sustainable Development
Climate coalition		Support for coal till 2050 to avoid nuclear. Support for RES and prosumers. Opposed to new lignite mines which in long run could replace hard coal.
Więcej niż energia (More than energy)		A social movement/campaign supporting prosumer based electricity system.
<p><b>Opposition parties -</b> play minor role as the parliament itself has become in recent years a “voting machine” for the subsequent governments. The two new parties (Kukiz 15, Nowoczesn) did not have a chance to act in this field. The two parties which created the previous government (Civic Platform, PSL) have largely</p>		Civic Platform, the largest opposition party (previously leading coalition partner)
	Kukiz 15 a new party based on nationalistic anti-systemic movement	Opposed to foreign investments. Protects the mining sector, close to trade unions.
	Nowoczesna	Liberal party, opposed to vertical integration. Proposes further privatisation

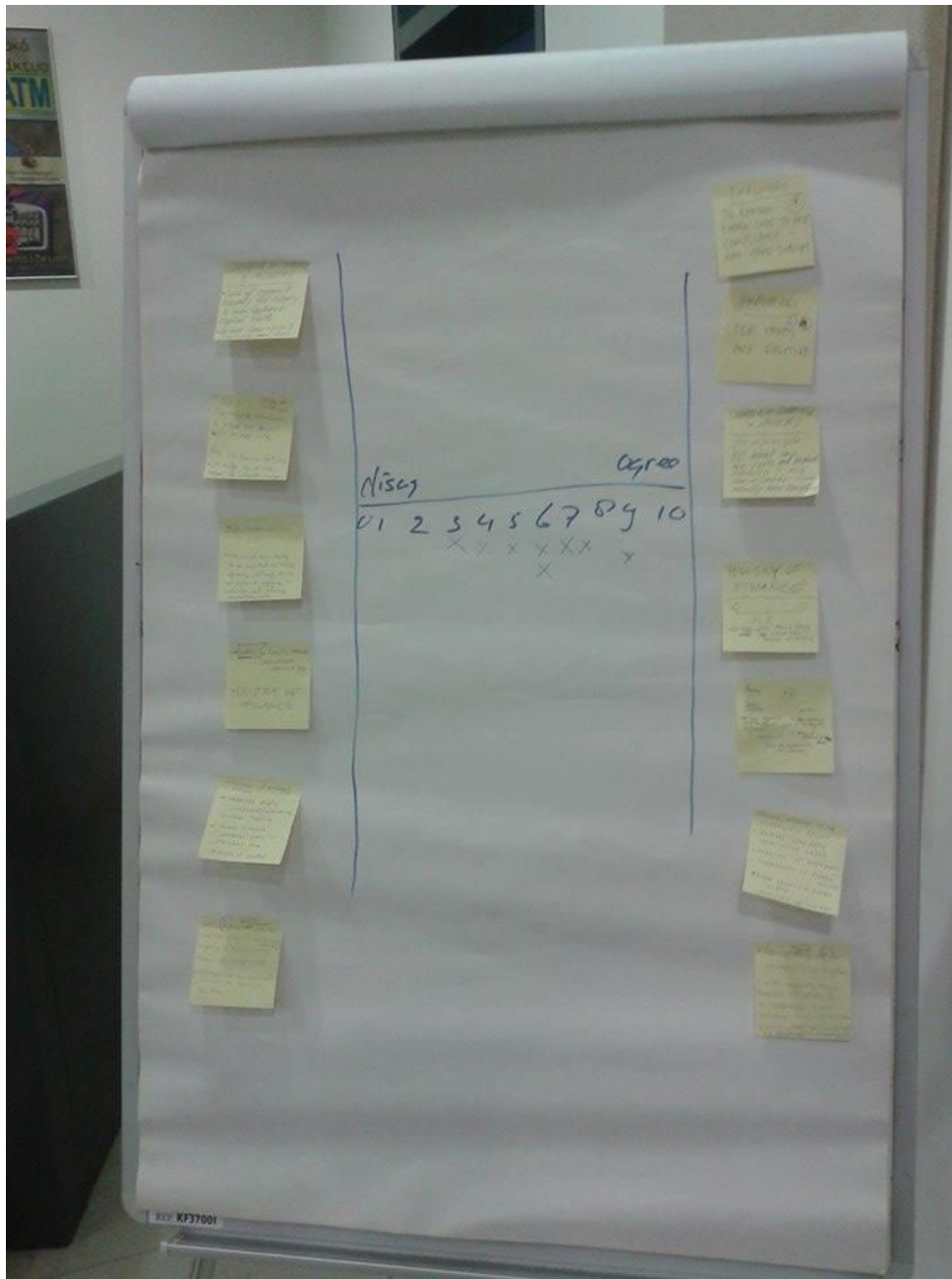
similar view on the sector as the current government		of the sector, removing the privileges for miners and limiting the rights of trade unions
	PSL	Previously the second coalition partner, involved in promotion of wind and biomass renewables yet protective towards the mining sector.

TRANSrisk partners, acting as stakeholders, were then asked to evaluate one transition pathway for Poland which focused on energy efficiency. Specifically, the participants were asked the following question:

*“Should energy efficiency (in buildings, industry, grid infrastructure) be promoted and a priority within the national (energy) agenda in Poland?”*

This question was deliberately formulated in a relatively broad sense to invite a wider range of views, which could then be narrowed down into more specific questions to be addressed by the model. Additionally, the term ‘low carbon’ was avoided in the question, as there was an acknowledgement that pushing the climate change agenda would alienate some stakeholders; thus more ‘neutral’ terms were used in order to initiate a more constructive discussion.

The answers were taken through the H-form using a simple flip-over chart (see Figure 1). The participants were asked to answer the research question by indicating on a scale of 1 to 10 whether and to what extent they (dis)agreed with a further promotion and prioritisation of energy efficiency in the national energy policy agenda in Poland. In addition, they were asked to give a rationale for their answer. Positive answers (‘agree with energy efficiency promotion’, 6 through 10 on the scale) were posted on the right-hand side of the flip-over paper and negative answers (‘disagree with energy efficiency promotion’, 0 through 4 on the scale) were posted on the left-hand side. The resulting H-Form is shown in Figure 2. One stakeholder felt indifferent about the question (which was marked as a 5). Some stakeholders, while they disagreed or agreed with energy efficiency promotion in Poland, provided both positive and negative rationales for their final answer (‘for reason A, we agree, but we realise that there could be a problem with B’).



**Figure 2. H-form result of training workshop**

The comments in favour (‘positive rationales’) of promotion of energy efficiency investment in Poland included:

- The investment can give a positive economic stimulus, particularly in the construction sector
- It creates jobs
- Energy efficiency enables conservation of energy sources

- It improves security of energy supply
- Reduces energy costs for consumers in the long run
- The investment can trigger R&D activity
- Lowers energy demand and thus limits coal extraction

The concerns ('negative rationales') about the investment included:

- If the scope of investment is large, it could be difficult to finance
- The investment will involve substantial costs
- Lack of support schemes for industry to cover upfront investment
- The energy is relatively cheap and therefore no energy efficiency improvement is needed
- The investment may lower the competitiveness of the economy
- The investment might have negative impact on energy prices

Based on the answers provided in the H-Form and the rationales for these, a discussion took place between stakeholders and the modeller, supported by the facilitator who had distilled a first set of specific questions from the answers. For example, when stakeholders in their rationales expressed concerns that an energy efficiency programme, which is financed from a tax on energy, would lead to higher energy bills and long payback times for households and buildings, a question for the modeller could be: what would be the impact of an energy efficiency promotion programme in Poland on energy bills; or: what would be an increase in energy efficiency by the programme that involves an acceptable energy bill increase? Obviously, stakeholders may disagree on the questions ('we don't accept any energy bill increase'; 'for us a 10% energy bill increase is acceptable') and then the question can be formulated as a request for a sensitivity analysis ('what would be the impacts of a 0 or 10% energy bill increase and how much difference does that make for the energy efficiency programme').

Eventually, based on the H-Form discussion, the following modelling questions were formulated:

- (i) What would be the desired size of an energy efficiency promotion programme in the Polish built environment?
- (ii) What would be the effect of investments in insulation of buildings on energy prices?
- (iii) What would be the effect of investments in insulation of buildings on energy expenditure by households and enterprises?

- (iv) What would be the impact of an energy efficiency programme on employment, including possible employment impacts in the coal sector?
- (v) What would be the impact of an energy efficiency programme on GDP?

### 3.3 MEMO model simulation

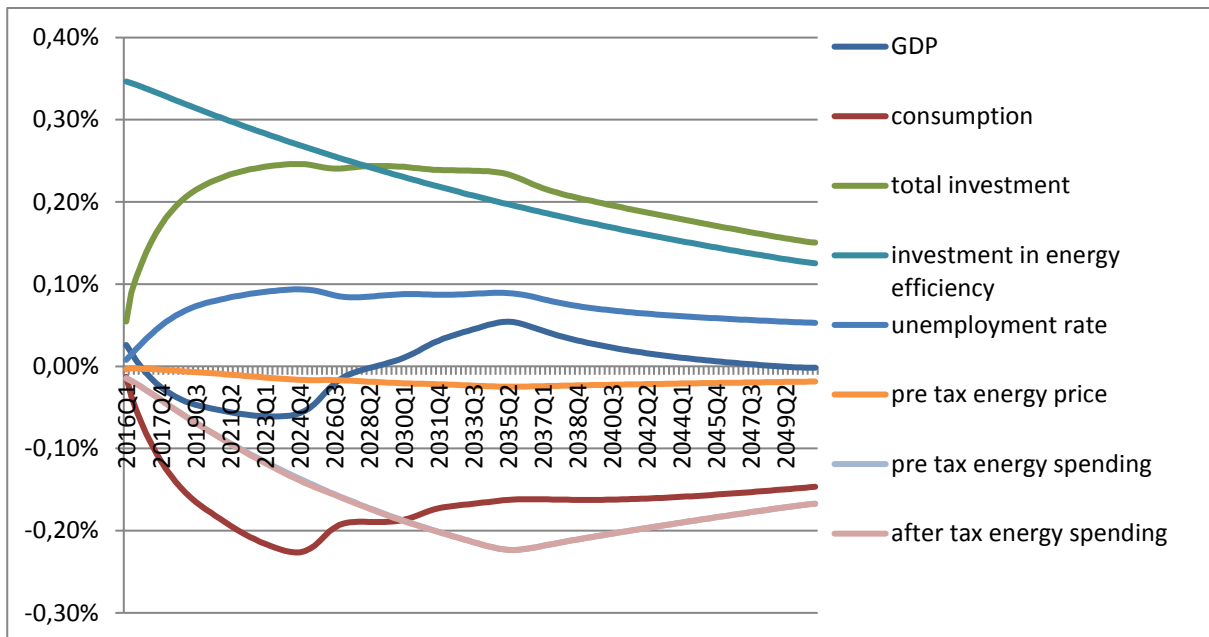
The goal of the model run was to shed light on the macroeconomic impacts of investment in energy efficiency in Poland in the built environment. Based on the questions derived from the H-Form discussion, the model was set up to examine the effect of investment in insulation of buildings on GDP, employment, energy prices and energy expenditures (questions 2-5 from H-Form).

For the simulation, we used the technology option of building insulation, which was proposed by Polish experts from the Polish National Energy Conservation Agency (KAPE) prior to the workshop. The experts specified the size of desired investment, resulting in energy savings and the level of subsidy which is required to incentivise the investment (question 1 from H-form discussion).

The outcomes of the first simulation are depicted in Figure 3 and Figure 4. The results are presented as deviations from the baseline (business as usual) scenario. Deviations of GDP, consumption, investments and energy spending are expressed in terms of baseline GDP (Figure 3). Deviations of employment in each sector (Figure 4) are expressed in terms of the total size of the population. The simulations were performed for the period 2016-2050 (for each quarter of a year).

The results were presented to the participants of the workshop together with a narrative describing some key causal mechanisms driving the macroeconomic outcomes.

In addition, a simple sensitivity analysis was presented: we considered a scenario in which labour is not able to freely flow between sectors (this exercise involved changing the value of the parameters of the model). Such a scenario is motivated by recent studies in labour economics which show that the major structural changes (such as globalisation) cause a surprisingly sluggish movement of labour between sectors (Autor, Dorn, & Hanson, 2016) (Tyrowicz & van der Velde, 2014). The results of the simulation under this scenario are presented in Figure 5.



**Figure 3. Macroeconomic changes caused by the building insulation programme.**

The results are presented as deviations from the baseline (business as usual) scenario. Deviations of GDP, consumption, investments and energy spending are expressed in terms of baseline GDP

As can be seen in Figure 3, an immediate impact of the building insulation programme is that, in addition to a logically much higher energy efficiency investment and total investment levels, spending money on building insulation clearly goes at the expense of consumption. Energy spending becomes clearly lower than without a building insulation programme, to only partly recover in the longer run. The programme will in the short run lead to a lower growth rate of gross domestic product (GDP), compared to business-as-usual, to be followed by an acceleration of growth in the longer run. The size of the macroeconomic impact of the programme is small: for instance, GDP never falls below 99.95% of GDP in the reference scenario.

Zooming in on the employment, as is done in Figure 4, it can be seen that a large-scale building insulation programme in Poland leads to extra job creation in construction work. Figure 4 also shows that employment levels in all other sectors of the economy will be lower than without the insulation programme.

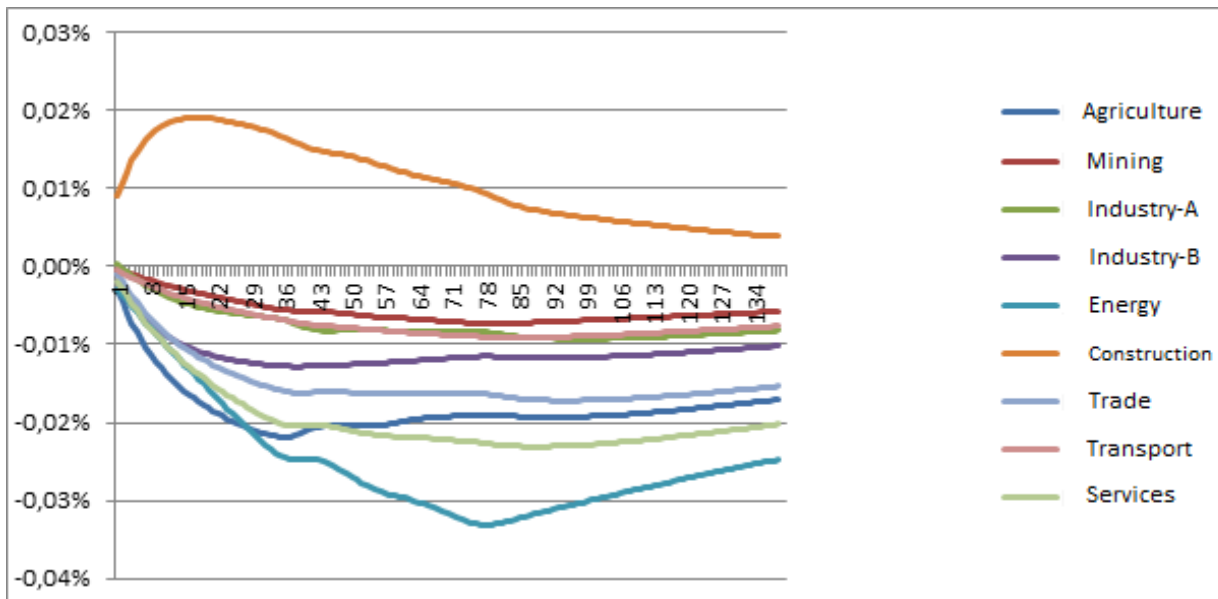
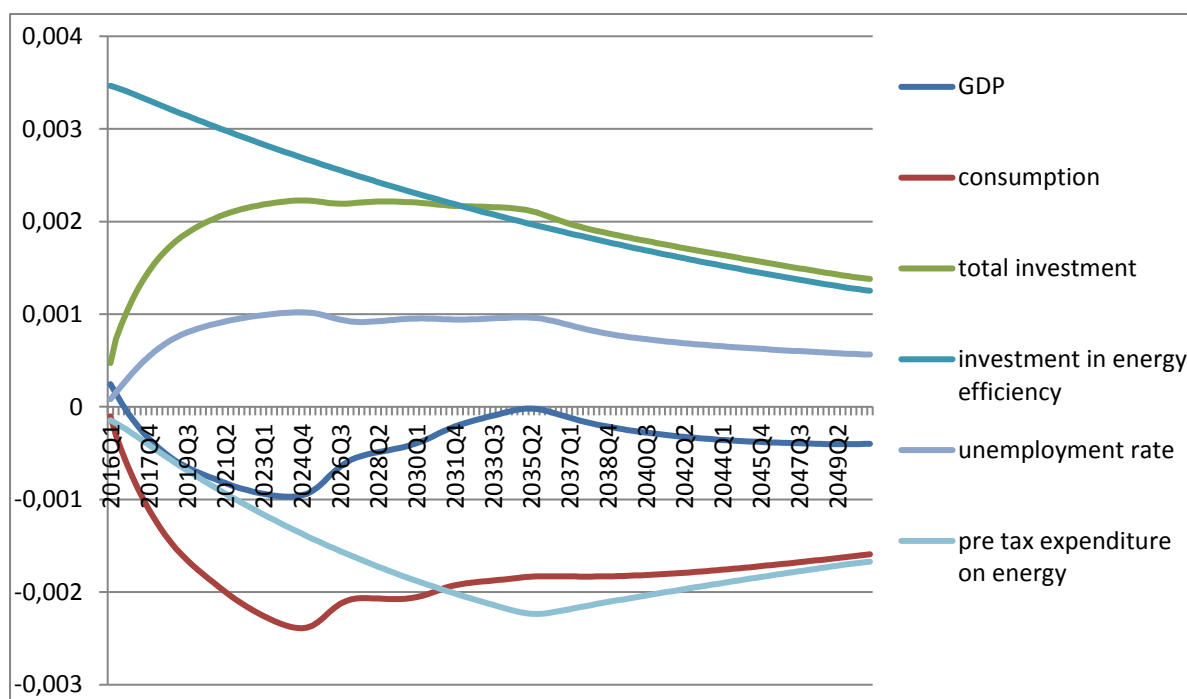


Figure 4. Changes in employment in 11 sectors (agriculture, mining, heavy industry (A), light industry (B), energy, construction, trade, transport and services) caused by the building insulation programme.

The results are presented as deviations from the baseline (business as usual) scenario. The deviations are expressed in terms of the total size of the population.

In Figure 5, the analysis done in Figure 3 has been repeated with the additional assumption of limited labour mobility between sectors. The main finding is that, when workers cannot smoothly flow between sectors, GDP growth rates will be lower than in the scenario with higher labour mobility. In the long-run, GDP will not accelerate above business-as-usual rates, as is expected to happen with higher labour mobility. The intuition for this result is that when the increase in demand for construction is not accompanied by a flow of workers into construction sector, investment in energy efficiency will crowd-out other types of investment. This reduces the amount of capital and limits the growth of the economy in the long run.



**Figure 5. Macroeconomic changes caused by the building insulation programme in the scenario with limited labour flow between sectors.**

The results are presented as deviations from the baseline (business as usual) scenario. Deviations of GDP, consumption, investments and energy spending are expressed in terms of baseline GDP.

### 3.4 Evaluation

The combined application of H-Form and the MEMO model worked well in the sense that specific modelling questions could be derived from the stakeholder consultation. An important intermediate step was the dialogue between the stakeholders and modeller, because stakeholders' rationales may not be directly suitable as modelling question. It is therefore of key importance that the modeller is present at the stakeholder workshop. A facilitator with basic knowledge of the model can help distil several specific questions that are suitable for the model, which the modeller can support. It is, however, important that stakeholders agree on how their rationales will be addressed by the model.

The approach of keeping the H-Form question relatively broad was successful, as it helped to collect a broader set of stakeholder views which could then be narrowed down into more specific questions for the model.

At the training workshop, it was possible to present the model results to the stakeholders during the second day of the workshop. Partners, in their role of stakeholders, took note of the results and asked questions for clarification. At the workshop, due to a lack of time, no

session was organised to ask ‘stakeholders’ to revisit their position based on the model outcomes. While the feedback from the modeller to the partners, in their role of stakeholders, was very helpful, it also became clear that for the case study analysis in TRANSrisk this may be more difficult to organise, especially if the H-Form-derived questions require a calibration of the model. In that case, more time is needed between the H-Form discussion and presentation of the model results; for example, two workshops may be needed with H-Form discussion taking place at the first and the model results presented at the second.

## 4 IMPLICATIONS OF LOW-EMISSION PATHWAYS BASED ON STAKEHOLDER PREFERENCES

### 4.1 Introduction

This task, included in Work Package 4 (Task 4.2), aims to explore how stakeholder engagement can support scenario development and pathway design for a low-emission and climate resilient future. In this section, we focus on stakeholder preferences that have been collected through a stakeholder consultation and which will be used for modelling mitigation option portfolios in Work Package 4.<sup>4</sup> In this case, stakeholder participation (qualitative approach) is aimed at formulating better-informed scenarios based on a model (quantitative approach), so that more accurate policy recommendations could be addressed than those based solely on theoretical scenarios that are produced with quantitative tools only. A goal of this task is to elicit preferences of experts that are often excluded from decision making and to translate them across different levels of policy.

The most consistent scientific assessment currently influencing climate policy making is based on model projections (i.e. IPCC reports and explained further in TRANSrisk deliverable D3.2, Global and Regional Case Study), which rely on scenarios and are thus strongly dependent on the robustness of the underlying assumptions and availability of databases. The results arising from these simulations could be attractive from a theoretical standpoint (e.g., large-scale diffusion of wind turbines can contribute strongly to achieving the 1.5-degree Celsius target), but unfeasible from a more practical angle (e.g., there can be societal resistance against large-scale application of wind energy in the landscape). In this sense, the role of stakeholders is to provide information to adjust the likely scenarios for policy analysis and make them more realistic.

As Figure 6 shows, the integration of qualitative stakeholder engagement (Work Package 2) with quantitative modelling (Work Package 4) is made in four steps and pursues a twofold goal. Firstly, stakeholder opinion, collected through an online survey, is used as an input for model-based scenario implementation, since their domain knowledge offers more detailed insights on barriers, acceptance, technical, legal and financial aspects which may have an impact on costs (Steps 1 and 2 in Figure 6). Secondly, model outcomes (scenarios) based on stakeholder preferences are used as an input to see whether stakeholder opinions change after the results have been presented to them, including synergies and trade-offs (Steps 3 and 4 in Figure 6). The rationale is that this not only improves the quality of analysis by

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<sup>4</sup> D4.3: Implications of different mitigation portfolios based on stakeholder preferences.

integrating stakeholders' practical experience and preferences, but it also enhances 'buy-in' to options that are eventually negotiated and could become important decision support tools for policy making.

Please note that the analysis in Task 4.2 is not part of, and thus differs from, the case study analysis in Work Package 3. The aim of the task is to illustrate how views of international stakeholders can be incorporated in modelling of scenarios for low-emission pathways. Contrary to stakeholder identification in the country case studies in Work Package 3, which was mainly limited to stakeholders from the case study countries, stakeholders in Task 4.2 were identified from international organisations, including research, multilateral development and business-related institutes (see section 4.2 for a further specification). For stakeholder consultation, both a survey and interviews were used; the survey in round 1 to collect stakeholder views and a series of interviews in Step 3 to present model outcomes to stakeholders (stakeholders in Step 3 are those who have indicated during the survey that they would be interested in taking part in a following round of interviews).

This document presents the implementation and results of Steps 1 and 2, whereas Steps 3 and 4 will be further developed in D4.3. The rest of this chapter is structured as follows. Section 4.2 includes a description of the first survey, aimed at gathering stakeholders' initial preferences. Afterwards, Section 4.3 compiles the scenario implementation resulting from the survey results. Section 4.4 presents some preliminary results of the model implementation based on the stakeholder preferences, which will be used to develop the second survey. Finally, conclusions and next steps are presented in Section 4.5.

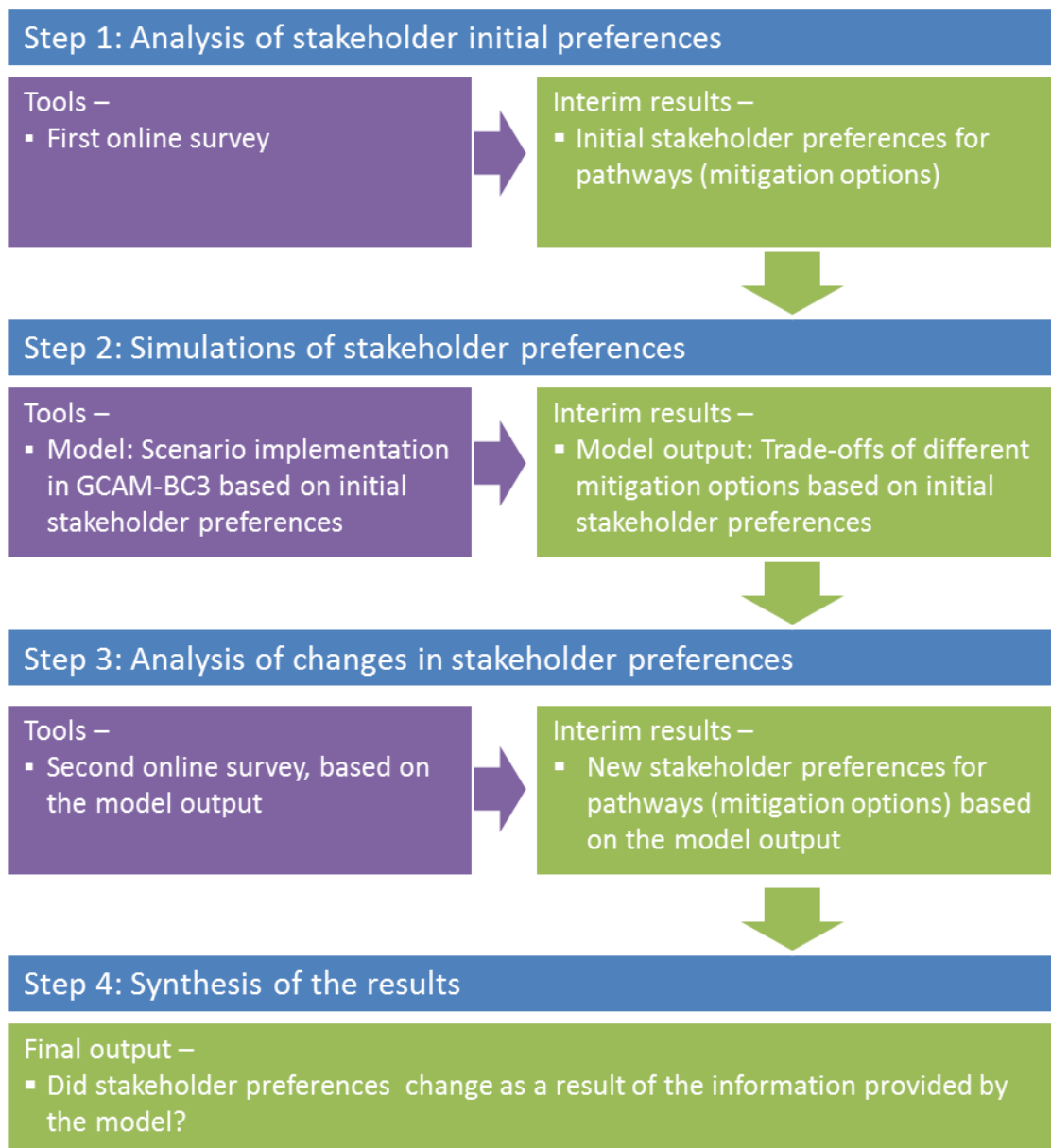


Figure 6: Steps for integrating qualitative stakeholder engagement tools with quantitative modelling tools: Interactions between WP2 and WP4

## 4.2 The survey

A survey was used to analyse stakeholders' initial mitigation preferences (considering a regional or global level) presented in the Step 1 of Figure 6. The stakeholder approach was carried out through an online questionnaire to experts in energy and climate change. It was answered by 28 stakeholders (161 representatives from 102 international institutions were invited to complete the survey) from the following categories: policy makers, private and

public sector industries, scientists and researchers, international associations, NGOs and the finance community. While the invitation to the survey was sent globally, 80% of the respondents were from Europe. From these, 71% were in the age range 30-49, 18% over 50 and 7% under 30 (1 stakeholder did not provide this information). Concerning the gender of the stakeholders, 64% were males and 32% females (1 stakeholder did not provide this information). Due to the large share of European stakeholders in the survey, the views resulting from it may differ from non-European stakeholder views. While this has been a limitation of the geographical scope of the analysis, the approach remains useful to illustrate how stakeholder views on socioeconomic factors and climate change can be incorporated in modelled scenarios.

The survey consisted of 11 technical questions reflecting key themes in the international debate on climate change, and which were categorised in four content blocks: (i) target to limit global temperature increase, (ii) mitigation and adaptation, (iii) socio-economic factors to consider for mitigation and adaptation measures, and (iv) technology options and preferences. These four categories are further explained below while the questions addressed in the survey are listed in Appendix 2 - Online survey for Stakeholders, 1st Round.

**Temperature target (Q1):** There are multiple mitigation pathways that could limit global warming to below 2 °C (RCP2.6<sup>5</sup>) and avoid the worst consequences of climate change. These pathways would require substantial emissions reductions over the next few decades and near zero emissions of CO<sub>2</sub> and other long-lived greenhouse gases by the end of the century. Implementing such reductions poses substantial technological, economic, social and institutional challenges, which increase with delays in additional mitigation and if key technologies are not available. Limiting warming to lower or higher levels involves similar challenges but on different timescales.

**Mitigation and adaptation (Q2):** Adaptation (i.e. coping with climatic changes) can reduce the risks of climate change impacts, but there are limits to its effectiveness, especially with greater magnitudes and rates of climate change. In the long term, there is an increasing likelihood that immediate adaptation actions will support realising sustainable development goals, as these are less likely to be affected by climatic change. However, adaptation alone will be insufficient to overcome all climate change effects, which implies that mitigation (i.e. reduction of greenhouse gas emissions to avoid climate change) remains essential to avoid damages due to climate change.

**Socio-economic factors (Q3):** Socio-economic factors are important to consider when exploring low-emission futures as reaching a long-term climate goal may contradict with

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<sup>5</sup> RCP stands for Representative Concentration Pathways which are scenarios described the development of greenhouse gas emissions under different policy ambition level assumptions (IPCC, 2013).

domestic socio-economic preferences or affect economic behaviour, lifestyles, policies, etc. (Moss, et al., 2010). For example, addressing climate change could take place at the expense of economic growth, especially when no or only a few low-emission technology options are available in a country context. If this were the case, it would raise the debate about whether economic growth should prevail over climate change mitigation/adaptation measures or the other way around.

**Technology options and preferences (Q4-Q11):** The IPCC has stressed in its reports that there is no “magic bullet” or technology that can deliver all the mitigation that is needed. Instead, portfolios of technologies and measures will need to be compiled and it is very likely that these portfolios depend on the context of each country and sector (IPCC, 2007). The choice of these technologies will be determined, for example, by their cost (which can be different for each country), their public acceptability, which can also change due to its perceived negative or positive side-effects, and how the technologies may contribute to achieving socio-economic goals. In the survey, the focus was on the following technologies: Carbon Capture and Storage (CCS), nuclear energy, intermittent renewables (i.e. wind, solar), biomass, other renewables, energy efficiency, natural gas, coal and oil.

Finally, 20 stakeholders (71%) agreed to take part in the second online survey that will be conducted in the Step 3 of Figure 6, and used for the final results of the WP4 in the Step 4 of Figure 6.

### 4.3 Simulation of scenarios

In Step 2 of Figure 6, scenarios based on stakeholder preferences were simulated using the GCAM-BC3 model.<sup>6</sup> The aim of these simulations was to find feasible global pathways for the transition towards a low-emission future in the next century. Therefore, two scenarios were simulated for the set of technology options: one reference scenario, with assumptions on the availability of the technologies; and another restrictive scenario, with assumptions on the unavailability of the technologies. For this purpose, the survey responses were aggregated, so that the stakeholder choices were translated into suitable variables for the model. Detailed responses are presented in Appendix 2 - Online survey for Stakeholders, 1st Round.

When stakeholders were asked about their preferred combination of mitigation and adaptation options, 43% of them valued mitigation over adaptation and another 50% gave them the same value. It should be noted that, as mentioned above, 80% of the respondents

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<sup>6</sup> The model is described in Appendix 3 - Overview of GCAM model.

were from Europe, so that this outcome may reflect European stakeholder views. Therefore, all the simulated scenarios pursued a mitigation goal, specifically a temperature target. In this sense, 93% of the stakeholders claimed that the temperature target to limit global warming should be below 2°C (54% below 1.5°C and 39% below 2°C). According to these responses, both 1.5°C and 2°C targets were implemented for the simulations.

Another important aspect considered in the survey was the relationship between climate change and economic growth. In this respect, 64% of the stakeholders pointed out that there is no need for one to prevail over the other, since the Green Growth<sup>7</sup> concept enables us to decouple economic growth from increased greenhouse gas emissions. Another 32% reported that climate change mitigation investments should prevail over economic growth for different reasons: 18% considered that further delay of climate change mitigation could not be afforded, whereas 14% reasoned that economic growth is the main reason why we face climate change.

Two different growth paths are modelled: the model default and an SSP2 scenario<sup>8</sup>. The default scenario of the GCAM model assumes a global population peak in 2065 at roughly 9 billion people and a long-term labour productivity growth of approximately 1.5 percent per year in the developed world. Economic growth rates are generally higher in developing countries, with countries undergoing initially rapid growth which then gradually slows towards the growth levels of developed countries (Calvin, et al., 2015). The SSP2 scenario is modelled using data provided by the International Institute for Applied Systems Analysis (IIASA, 2016) under middle of the road assumptions about population growth, technological change, and economic growth.

Concerning the technology portfolio for the next 50 years, stakeholders agreed that the two most important technology options in the energy sector (see Figure 7) should also receive the most public support (see Figure 8). These technologies are intermittent renewables (i.e. wind and solar) and energy efficiency. Other renewables (e.g. geothermal) are regarded as less important options in terms of climate change mitigation investments, but are in third place regarding the level of economic support needed. Similarly, CCS importance is also lower compared to its required support level to make it feasible. On the other hand, biomass and nuclear energy will receive less public support relative to their importance for

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<sup>7</sup> According to the OECD, “Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies” (OECD, 2011).

<sup>8</sup> Shared Socioeconomic Pathways (SSPs) are storylines to analyse the interactions between socioeconomic factors (related to population, economy and technology) and climate change. SSP2 is a pathway which assumes that recent trends will continue and is also called ‘middle of the road’ or ‘current trends continue’ (O’Neill, et al., 2012).

mitigation. According to these answers, the technologies explored in the simulations were CCS, nuclear, intermittent renewables and biomass.<sup>9</sup>

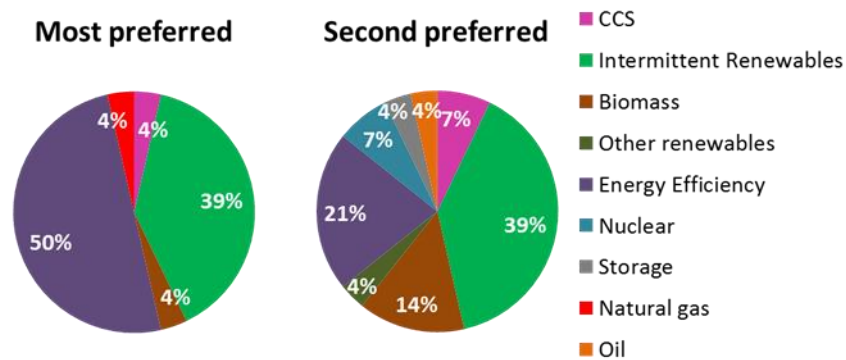


Figure 7: Two most important technology options in the next 50 years

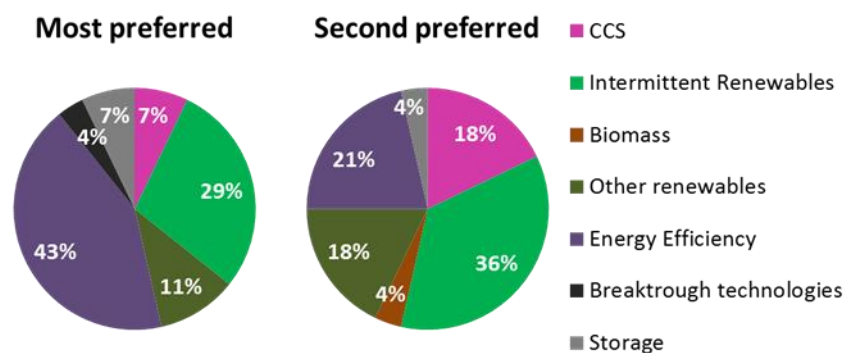


Figure 8: Two most preferred technology options for receiving public support in the next 50 years

Examining the technology options in depth, there was no agreement among stakeholders on the future for CCS. Half of the respondents expected a global CCS expansion in the future, but 88% of them agreed that it will not occur within the next two or three decades. The other half thought that CCS will not be deployed globally for different reasons: 45% of them expected that this will be due to limited public acceptance and safety concerns; 36% of them based their opinion on economic reasons and the remaining 18% argued technological reasons. Given that there is consensus on the delayed introduction of CCS, the simulations

<sup>9</sup> Energy efficiency has not been considered in the simulations for TRANSrisk deliverable D4.3, since its implementation depends on consumption preferences rather than technological characteristics. These behavioural demand changes have been explored in deliverable D4.2 Implications of different “heterodox” mitigation policies: the role of behavioural changes.

considered a reference scenario with CCS available from 2030 onwards and a restrictive scenario with CCS not available in the whole century.

In the case of nuclear energy, only 12% of the stakeholders foresaw a global expansion of nuclear energy production, which supports the consensus of low acceptability of nuclear energy, even among experts. On the contrary, 24% claimed that there will be a nuclear phase-out and 64% argued that nuclear energy levels would remain constant at most. Therefore, in the reference scenario the nuclear power sector was not allowed to expand beyond present-day deployment (consistent with the nuclear remains constant statement), whereas in the restrictive scenario a nuclear phase-out was assumed.

The highest consensus among stakeholders was reached for intermittent renewables. In this case, 96% of the respondents agreed that the share of these sources will increase in the future global energy mix and none of them foresaw a decrease. For this reason, an advance renewables scenario was considered as reference (i.e. it considers lower costs for wind and solar compared to the business as usual case). However, recalling the responses concerning the level of public support that these technologies should receive in the future (see Figure 8), their development would not be possible without this kind of support. Furthermore, the potential for renewable deployment varies across countries, which could have an important impact at a global scale. Therefore, a restrictive scenario with a limited participation of wind and solar has also been simulated, including a maximum of 20% global electricity generation in any year from 2020 to 2100.<sup>10</sup>

Concerning bioenergy, 11% of the stakeholders thought that there will be limited bioenergy deployment globally in the future, 33% that current global levels will remain and 56% that there will be a bioenergy expansion. Given these results, in the reference scenario total biomass consumption is assumed to grow (remaining above 400 EJ in 2100), whereas in the restrictive scenario a limit of 100 EJ is set for the whole period (which is four times higher than total global biomass consumption in 2015, according to the model).

Finally, stakeholders were also asked about the importance of other sectors, apart from the energy sector, for climate change mitigation. In this case, transport and agriculture were the most mentioned options, and therefore, in the next steps of the analysis the interactions of the mitigation portfolios with these two sectors will also be explored.

A summary of the scenarios developed with the model is presented in Table 2. Scenario 0 is modelled with all the technologies available and no climate policy; in this case, global average temperature increase reaches 3.81°C by 2100. Concerning scenarios with climate policy, Scenario 1 represents the reference scenario with all low-emission technologies

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<sup>10</sup> Actual shares grew from 1.3% in 1990 to 6.7% in 2015 (IEA, 2016).

available, whereas Scenarios 2-5 are the restrictive scenarios including the limited technology options resulting from the interaction with stakeholders. In these restrictive scenarios, the share of technologies with the highest mitigation potential is limited. Therefore, the analysis of the resulting model outcomes in WP4 (synergies, trade-offs and co-benefits) will draw conclusions that could help drive decision-making. Furthermore, a second online survey will also be conducted, to see if stakeholder preferences change considering these results. Finally, it is noteworthy that this scenario selection based on stakeholder preferences is in line with the scenario reporting from IPCC (2014b, p. 60), a fact that will be further discussed in the deliverable D4.3 of the WP4.

**Table 2. Scenario implementation in GCAM-BC3 based on stakeholder preferences**

Technology options:	Temperature target	
	2°C	1.5°C
0. No climate policy	N/A	N/A
1. All technologies available (Reference)	✓	✓
2. No CCS	✓	
3. Nuclear phase-out	✓	✓
4. Limited intermittent renewables	✓	
5. Limited bioenergy	✓	✓

*Note: Options marked with ✓ indicate feasible scenarios with GCAM-BC3.*

## 4.4 Preliminary model results

The results of the simulations based on stakeholder preferences will be explored in detail in TRANSrisk WP4 (D4.3). Nevertheless, some trade-offs are presented in this document, since they serve as a starting point for the second approach to stakeholders.

Figure 9 presents the effect of each technology in terms of climate change mitigation costs towards a 2°C temperature target. These costs are computed as the cost increment in percentage terms of each restrictive scenario with respect to the reference scenario (all technologies available and a climate policy consisting of a temperature target). The most relevant conclusion is that the scenarios where biomass and CCS are restricted impose the greatest cost, since these are the only existing technologies able to achieve negative emissions (i.e. BECCS: bio-energy with CCS) and without them other more expensive options need to be used to meet the climate goals.

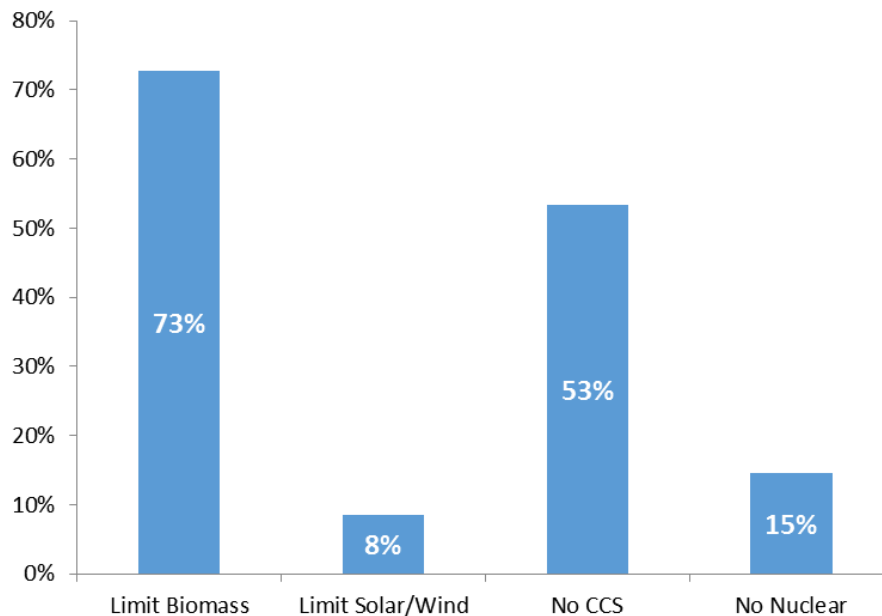


Figure 9: Mitigation cost increment with respect to reference scenario (%)

In fact, according to Figure 10, fossil-fuel based technologies such as coal or oil are substituted by renewable sources when carbon capture is not available. This is precisely what increases the policy costs, since renewables are more expensive than conventional technologies in terms of public support (as stakeholders already pointed out), especially if the costs of the network infrastructures and the back-up systems needed to cover for renewables' intermittency are considered in the cost calculation (IPCC, 2012). Moreover, a scenario without CCS and a temperature target of 1.5°C is not feasible in the GCAM-BC3 model, which raises questions about what kind of changes would be needed to achieve that more restrictive target, or even if it could be achieved at all with the current technologies.

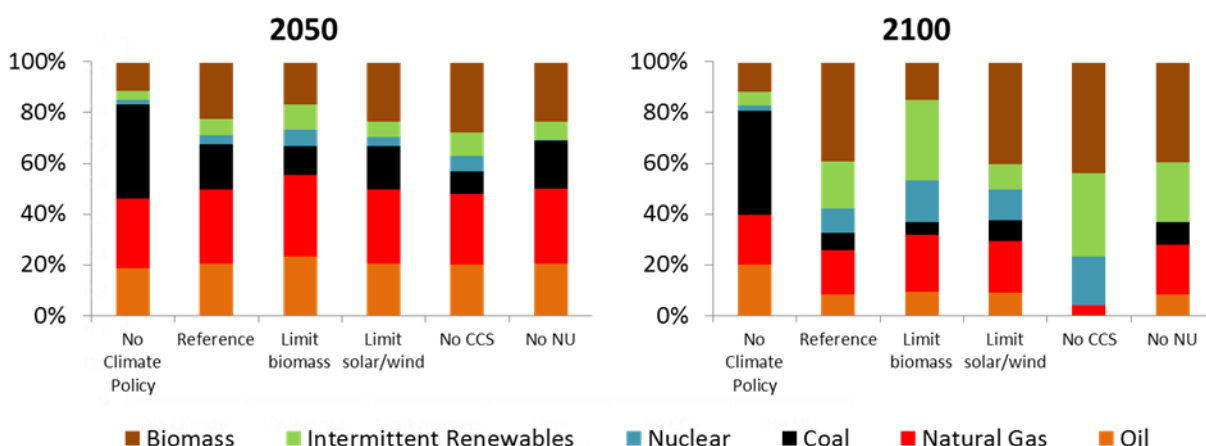


Figure 10: Global primary energy mix for a 2°C temperature target (%)

Figure 10 also shows important differences in the technology mix for 2050 and 2100. The role of fossil fuels is reduced significantly in all the scenarios, in favour of non-emitting technologies, including nuclear power, and it is subject to the availability of CCS (especially, compared to the scenario without climate policy). This will be another issue to discuss with stakeholders, since most stakeholders thought that there will not be a nuclear expansion.

These results will be included in the second survey with a twofold aim: firstly, to answer additional questions about the possible mitigation pathways; and secondly, to see if stakeholders change their preferences after they are provided with more information based on scenarios with their preferences and views considered.

## 4.5 Conclusions and next steps

This chapter has described the interactions between qualitative (WP2) and quantitative (WP4) approaches with the specific aim of integrating stakeholder preferences into modelled scenarios. By including stakeholder views and preference on technology options and policies in the design of the scenarios that are modelled, more realistic assumptions could be made about mitigation portfolios for a low-emission future.

One of the main conclusions of this analysis is that stakeholders value ambitious temperature targets for climate change mitigation (i.e. 2°C and even 1.5°C). However, they do not believe that technologies necessary for achieving these goals will be ready soon (e.g. CCS) and they claim that renewable energy still requires important levels of support, that might not be so easy to achieve at a global scale. These inconsistencies make the combination of stakeholders and models a highly valuable tool to continue improving the analysis.

Finally, this is still a work in progress. A second round of surveys is planned in the course of TRANSrisk to see whether stakeholder preferences change when they are provided with the results of the first set of simulations. This could change some of the initial assumptions for the scenarios and thus improve the final conclusions. All in all, these contacts with stakeholders will help to develop better informed scenarios that could provide valuable material for policy advice.

## 5 COMPLEMENTARITY OF QUANTITATIVE AND QUALITATIVE TOOLS IN ASSESSING UNCERTAINTIES AND RISKS

### 5.1 Introduction to risk and uncertainties in relation to low-emission pathways

When formulating low-emission pathways, especially when they cover a longer time period, decision makers face a range of possible uncertainties and risks<sup>11</sup>. In a pathway, uncertainty may, for example, refer to possible economic growth rates for the short to medium term. These rates depend on a range of national and international political, context-specific, technological, environmental and societal factors which can be assessed in terms of possible outcomes but never be predicted with full certainty. By putting together a set of possible outcomes for these factors and what this means for economic growth, a range of growth rates is obtained. A small range, i.e. most predictions of growth rates are in the similar direction, implies relatively low uncertainty about economic growth, while a large range implies greater uncertainty.

Whether high uncertainty implies that a desired outcome, such as a low-emission pathway, will not be achieved depends on the likelihood of each possible outcome becoming reality. For example, if a country considers hydropower for its low-emission pathway but is confronted with a possible outcome that in twenty years' time, due to climate change, hydro resources will be smaller, then it needs to know how likely this situation is. In case of a high probability of hydro resources drying up, the country runs the risk that this pathway will become unviable.

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<sup>11</sup> *Uncertainty* is an expression of the degree to which a value is unknown, which can, for example, result from a lack of information or from disagreement about what is known. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgement of a team of experts (Moss & Schneider, 2000) (Manning, et al., 2004).

*Risk* refers to the potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk can also be defined as the set of threats to life, health and safety, the environment, economic well-being, and other things of value. Risks are often evaluated in terms of how likely they are to occur (probability) and the damages that would result if they did happen (consequences).

This example shows how uncertainties and risks are related and how both concepts need to be considered together in decision making on low-emission pathways. Table 3 shows examples of how different levels of uncertainty can result in high or low risk profiles. However, this does not imply that the sequence of analysis should always go from uncertainty to risk. Risk items may as well be identified first as potential factors that negatively impact realisation of a low-emission pathway, which is then followed by uncertainty analysis to see how likely these factors are. The resulting probability of the factors, in combination with the size of the impact, then determines the risk. Moreover, while Table 3 shows examples of individual risk items, risks can also occur in combination with other risks, e.g. risk accumulation in a system. As this will be addressed in Work Package 5 of TRANSrisk, it will not be further considered in this chapter.

In TRANSrisk, uncertainties and risks are covered by Work Package 5, which looks at these from two main perspectives:

- ▲ Uncertainties and risks related to the *consequences* of a low-emission pathway for the rest of society, such as: balancing issues on the electricity grid related to upscaling renewable energy options, cost implications for end users and employment impacts in other sectors.
- ▲ Uncertainties and risks related to the *implementation* of a low-emission pathway, such as: insufficient capacity to deploy and diffuse a technology on a larger scale, lack of social acceptance of a technology option, vested interest in the market chain not to pursue with the low-emission technology, etc.

In Table 3 examples of both consequential and implementation risks are shown.

**Table 3. Examples of possible combinations of uncertainties and implementation or consequential risks**

	High uncertainty	Low uncertainty
<b>High risk</b>	A low-emission pathway relies fully on one new technology, which is still in at R&D stage and which has not been tested and demonstrated yet (e.g. Carbon dioxide capture and storage). Whether the technology will make it through the ‘valley of death’ towards deployment in the market and diffusion towards commercial application is highly uncertain, as it depends on capacities, which implies a high implementation risk that the low-emission pathway will not materialise.	As a consequence of a pathway making a transition from coal-based to renewable resources-based energy production, it is very likely (low uncertainty) that there will be fewer jobs in coal-mining. Because of the pathway there is a high risk of employment loss.
<b>Low risk</b>	A low-emission pathway takes solar PV as key technology option and the government supports this by providing households that invest in solar PV with energy tax exemptions. The scale of solar PV take-up, and the associated take-up of the tax exemption, is highly uncertain. The fiscal budget risk for the government, as a consequence of the pathway, is relatively low though as the strong diffusion of the technology will result in higher tax revenues based on construction of panels.	Most scenarios predict that, for a region, precipitation levels will become substantially lower during the next two decades, but at the same time it is very likely that the region will have more sun hours. A low-emission pathway that includes both small hydro and solar PV technology options, will face a lower risk of failed implementation.

## 5.2 Consequential risks

Work Package 5 lists tools for evaluating uncertainties and risks related to consequences of a low-emission pathway for the rest of society. Based on the case studies in TRANSrisk Work Package 3, a set of the most important consequential risks associated with climate policies will be identified. These can be risks that pursuing a low-emission pathway leads to, for example, job losses in carbon-intensive sectors. Throughout the case studies, this can be identified as a general observation, but in some case studies, the job losses may have been offset by job creation in other, low-emission sectors, so that the net effect may be few or no job losses. These observations from the case studies will then be compared with a review of literature sources which have identified similar risks in specific contexts and tried to quantify the impact of these. Where quantitative data for identified risk items in the case studies is not available in the literature, qualitative assessments will be done via expert interviews. This approach aims for a supplemental application of qualitative tools next to a

method to quantify risk implications for the rest of society, in case quantitative data is not available.

The above example of job losses in one sector being offset by job creation in other sectors clearly demonstrates that for assessment of consequential risks (a possible negative impact of a pathway) it is important to also consider possible positive impacts. For example, stakeholders may be willing to accept the risk of job losses if they know that elsewhere in the economy new jobs will be created because of the pathway. In case the pathway only results in job losses, with no new jobs in other sectors, stakeholders may consider the pathway too risky from a socio-economic perspective. For the scoring and weighing of consequential risks and benefits of a pathway, which could be both qualitatively and quantitatively determined, as explained above, qualitative tools such as multi-criteria decision analysis (MCDA) can be used (see D2.1 for a detailed explanation of MCDA).

In addition to elaborating on consequential risks identified from the low-emission pathway case studies, Work Package 5 will also apply quantitative and qualitative tools to assess climate policy risks. The quantitative approach in this respect is a large-scale survey of the general public (at least 1,500 people), whose answers will then be quantitatively analysed with a goal to understand the attitudes and perceptions of the general public. The weighing of the risks ('many people see a risk, but how important is it actually?') is intended to be done by interviewing climate policy experts, using a 'semi-structure' technique.

## 5.3 Implementation risks

Whether a low-emission pathway will be successfully implemented or not can depend on many factors. For example, increasing the economic viability of low-emission options identified in the pathway, may require that use of fossil fuels becomes more expensive. For that, a CO<sub>2</sub>-pricing mechanism can be introduced which adds a cost to fossil fuel combustion. However, the CO<sub>2</sub> price level may be uncertain, so that the risk remains that fossil fuels will be competitive for another few decades and the low-emission pathway not materialise. Another uncertainty could be the extent to which the Paris Agreement will lead to ambitious nationally determined contributions (NDCs). A possible risk of other countries not formulating an ambitious NDC (in terms of GHG emission reductions) could be that CO<sub>2</sub> pricing mechanisms will not lead to high costs for using fossil fuels and a lower economic viability of low-emission pathways. Quantitative tools, such as models, can assess those uncertainties by considering several scenarios (e.g. high or low CO<sub>2</sub> price, high or low NDC ambition level, stronger or weaker international GDP growth, etc.), compare the possible outcomes of each scenario, and conclude to what extent the outcome ranges reflect uncertainty. With help of qualitative tools such as expert consultation or literature review these uncertainty profiles can be translated into risk profiles, within the specific country or sector context for the low-emission pathway. As illustrated in Table 3, high uncertainties do

not necessarily imply high risks, as this depends on the context and, for example, how stakeholders consider the varying outcomes as risky for a low-emission future.

In addition, risks that a low-emission pathway may not be implemented could also be qualitatively assessed with help of the system mapping tool applied in the TRANSrisk case studies. System mapping is a qualitative tool that is used to describe the relevant system for a low-emission pathway in a country or sector. A system can, for example, be a market, when the pathway is centred around a technology or commodity. It could also be a sector, when the pathway is focussed on a sector policy. An important objective of system mapping is to identify opportunities and barriers that could potentially make or break successful implementation of the pathway. For that, together with stakeholders, three main questions are asked:

- ▲ What does the enabling environment for the pathway look like in terms of: policy environment, culture, habits, values, corruption, bureaucracy, etc.?
- ▲ What does the value chain for the system look like in term of: who are the actors that play a role, e.g., in the implementation of the technology and how do they compete or collaborate?
- ▲ What are the supporting services to the system and how supportive are they?

From the mapping, it may be concluded that, for example, the financial services in the country are insufficiently capable of providing investment capital for individual plant (a barrier). At the same time, stakeholders may indicate that technical knowledge for operating the technology is sufficiently available in the country and that local communities appreciate the technology as it enhances their energy security (opportunities).

System mapping therefore results in a snapshot of what the current system situation looks like, including the identification of opportunities and barriers. To answer the question of how the current system may accelerate, block or slow-down development along a prioritised low-emission pathway, it is required to transform the current snapshot into a more dynamic picture: how likely is it that current barriers and opportunities will continue to exist in the future; and what risks do these barriers imply to the success of the low-emission pathway?

To make that transformation from static to dynamic system analysis, the following steps can be made (focussing on barriers as direct concern for risk):

- (i) Identify barriers and decompose them: e.g. financial barrier -> cost of capital -> high interest rate -> an interest rate of 15% per year for households.
- (ii) Assess for each barrier whether and how it could slow down or block the development and implementation of the pathway, if the barrier will continue to exist.

- (iii) Assess the likelihood of this happening: how certain are we that the current barrier continues to exist?
- a. For some barriers, qualitative expert/stakeholder judgements can be sufficient for that: what are possible outcomes due to this barrier and how likely do we consider each outcome?
  - b. For other barriers, modelling can help determine a range of possible outcomes for the barrier, which provides an indication of uncertainty (which could be a similar analysis as the modelling analysis described above with ranges of possible outcomes as indications of uncertainties).
- (iv) What does this mean in terms of risks for the low-emission pathways? For this assessment, Table 4 below identifies (for a hypothetical situation) possible outcomes.

**Table 4. Possible assessment of barriers, uncertainty and related risks**

Stakeholder consultation and/or modelling		Expert judgement (stakeholders)
Potential barrier	Uncertainty assessment	Risk implications for pathway implementation
Financial barrier	Model run shows wide range of possible outcomes, so high uncertainty	Potential high risk  One end of the range would mean ‘no low-emission pathway’ while the other end of the range means a ‘successful pathway’. Which value of the range can be considered most likely (and therefore whether the risk is high or low) can be assessed using WP5 literature review on generic risk assessments or country/sector stakeholder consultation.
Knowledge gap on new low-emission technology	Stakeholders identify this barrier (low uncertainty).	Low risk  Expert judgement is that it can be addressed within envisaged programmes
Lack of rural development policy	This barrier currently exists (low uncertainty)	Low risk  Stakeholders conclude that the planned National Development Strategy 2030 contains a detailed chapter addressing this issue
Lack of future natural resources for the pathway	Due to climate change, this barrier is very likely to happen; low uncertainty	High risk  In the future, it is likely that insufficient natural resources exist for successful implementation of the pathway

## 5.4 Conclusions

When designing strategies for a low-emission future it is important to consider, next to the benefits and opportunities, what could the risks of a low-emission pathway to the rest of the economy (e.g., job losses, energy system instability or higher energy costs). Models can help identify such consequential risks, as they can, under different assumptions, sketch potential impacts of a pathway. For example, a country can formulate a climate target which it considers a necessary contribution to the 1.5 or 2 degree target of the Paris Agreement. Achieving that target implies application of low-emission technologies at a certain larger scale, and the model can estimate the impacts (i.e. risks) of such a climate target to the rest of the economy. Whether these risks are acceptable within the country context could then be assessed by stakeholders using qualitative tools such as multi-criteria decision analysis. This example shows that quantitative and qualitative tools can be truly complementary when it comes to characterising and assessing risks of pursuing a low-emission strategy within a country.

A second type of risk considered in TRANSrisk is the risk that a desired low-emission pathway will not be successfully implemented due to system blockages. Such risks can be assessed, for example, with the qualitative tool of system mapping thereby using inputs from stakeholders who operate in the relevant system(s) for the pathway. Possible synergies with quantitative tools could be established when some risks require quantification, such as costs of pathway implementation at a larger scale.

This chapter has also shown possible relations between risks and uncertainties. Identifying a risk element means that a potentially negative effect can occur due to a low-emission pathway, but the actual risk is determined by the impact (e.g. job losses) combined with the likelihood of the impact to take place. This likelihood can both be assessed, depending on the decision context, with help of qualitative tools (e.g. asking stakeholders how likely they think something will happen) or quantitative tools (e.g. a model to formulate different scenarios around the risk element, thereby using different assumptions, and to determine a range of possible impact values). Uncertainty analysis can therefore be used for determining such likelihoods and the actual risk of a low-emission pathway for the rest of the economy or society.

## 6 COMPLEMENTARITY OF QUANTITATIVE AND QUALITATIVE TOOLS IN TRANSRISK CASE STUDIES

Several research elements in TRANSrisk, such as stakeholder consultation, scenario development with the help of models, and assessment of uncertainties and risks, are all applied in the case study analysis (in 14 case studies) to explore how quantitative and qualitative tools can enhance each other’s effectiveness and result in a better understanding of where a country or sector would like to go in terms of low-emission development, what (drastic) change it is willing to undertake and how it perceives associated risks (for further information about the case studies, see deliverables 3.1 and 3.2).

The workflow for the case study analysis, as shown in Figure 11, contains steps for taking analysis based on stakeholder consultation and other qualitative analysis tools and integrating it with analysis using quantitative tools (such as modelling). For the entire process, research questions are formulated which may be modified or refined during the case study analysis based on new insights from earlier steps.

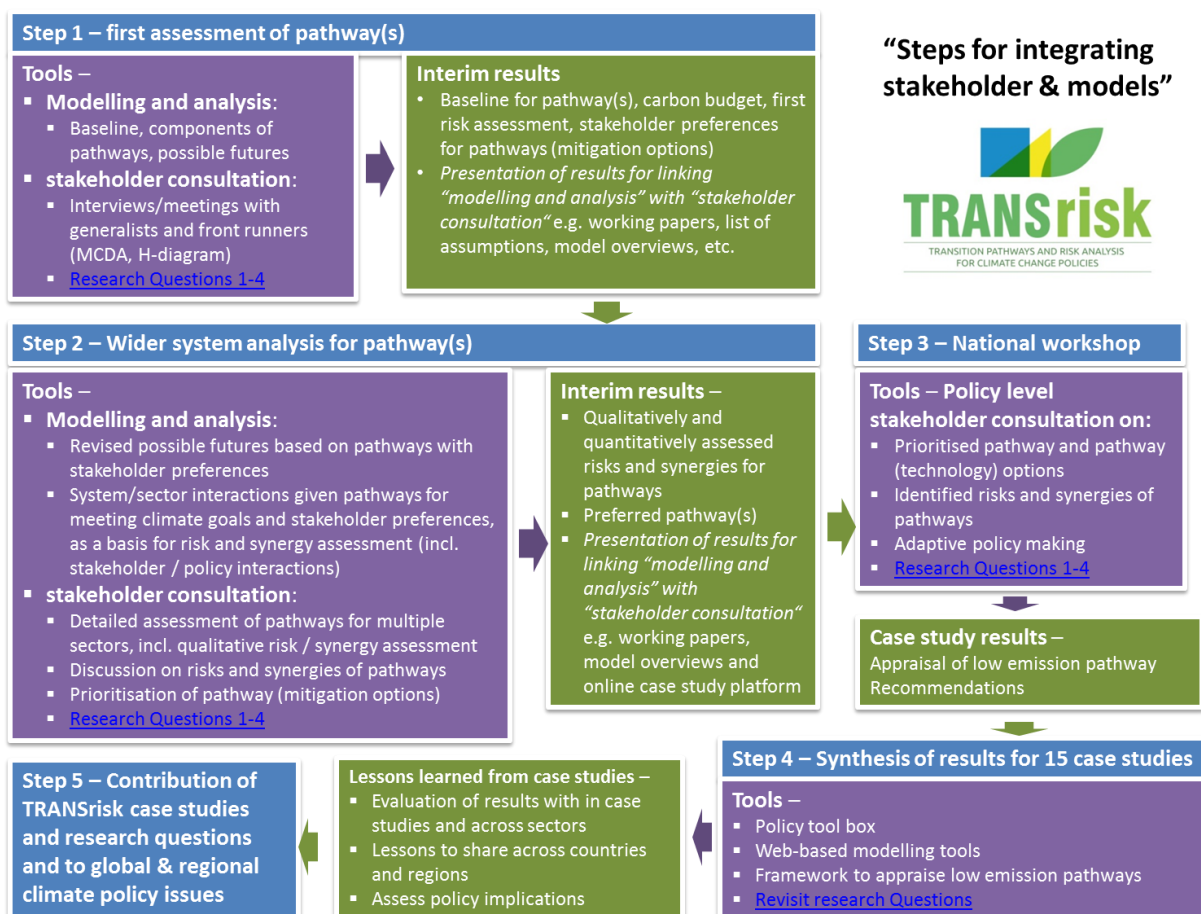


Figure 11. Workflow for case study analysis in TRANSrisk

In the first step, the case study context is assessed to understand the past, describe the present context (social, economic, political, policy and environment - see D3.2 Context of 14 country case studies) and formulate a business-as-usual scenario for the country and/or sector into the future. There is a broad focus on all research questions to provide the initial settings and context for transition pathways to test and develop with stakeholders in later steps. For that, modelling as well as qualitative tools can be used. With a selected group of stakeholders, descriptions are discussed of the past and present situations in the country or sector and what could be possible futures from there, and which future is desired from a socio-economic development and climate perspective. This forms the basis for discussing a possible pathway: given a desired future(s), what are preferred ways to get there? Interim results are presented as working papers and overviews, in order to outline the approach and initial findings for further development in Step 2.

In this first step, quantitative tools can be used for describing a baseline scenario: given the past and the present situation (including implemented and planned investments and policies), what would be a likely future development for the country or sector? Quantitative tools can, based on the baseline, also help identify possible risks related to investing in low-emission options in terms of climate change damage (e.g. models can help estimate carbon leakage effects which may happen when some countries invest in low emission measures and others not). With qualitative tools, present stakeholder preferences and perceptions, as well as system barriers (e.g. insufficient government policies for low-emission action, insufficiently stable banking system to fund low-emission technologies and vested interests among market actors to pursue with fossil-based options) can be identified as possible obstacles to achieving a desired future.

In the second step, a wider, more detailed analysis is done for reaching the desired future(s). At this stage, stakeholder preferences can be included in model-based scenarios in order to support formulation of pathways that, next to technologically feasible, are also economically feasible and socially acceptable. This can be done by modelling possible impacts of a low-emission pathway to the rest of the economy in a country, such as employment effects, costs and productivity, when implemented at a larger scale for realising climate benefits, and sharing these impacts with country stakeholders. For them, a potentially negative impact of a pathway (which could be considered a risk) may, for example, be offset by a potentially positive impact and therefore become acceptable. Modelling can also help assess the likelihood of these impacts by making different assumptions of parameter values and see how these lead to different scenario outcomes with different impacts of low-emission pathways (see also Chapter 5). The range of outcomes can be considered as an indicator of uncertainty (i.e. a wide range could mean a higher uncertainty). Using stakeholder (including policy experts) knowledge, these uncertainties can then be interpreted in terms of how risky an investment in a low-emission option or pursuing a low-emission pathway can be.

In step 3, the preferred (i.e. shortlisted) pathways identified are presented at a national workshop, with a wide group of stakeholders, to discuss policy implications of pathways. The outcome of the national workshop would then be agreement, subject to certain revisions. Limited case studies may not necessarily have national workshops, so the shortlisted pathways can be presented to stakeholders bi-laterally (e.g. interviews) or in smaller focus groups.

As explained above, steps 1, 2 and 3 use a similar set of research questions as a basis, to ensure that at all stages qualitative and quantitative methods consider similar questions and that there is a consolidated effort to feedback information from qualitative and quantitative outputs. However, depending on interim results, questions for consecutive steps may need to be modified, extended, etc. The envisaged result of step 3 is an appraised low-emission pathway for the country/sector.

All case study results are then synthesised in step 4 to identify commonalities and differences between them; such as which quantitative and qualitative tools and approaches have worked well or not so well under which circumstances. The aim is to arrive at a framework which applies quantitative and qualitative tools for achieving a desired socio-economic future with the lowest emissions possible, which can be used for addressing multiple global and regional climate policy issues (step 5).

## 7 INTEGRATING QUALITATIVE AND QUANTITATIVE TOOLS FOR NATIONALLY DETERMINED CONTRIBUTIONS

One of the core elements of the Paris Agreement of December 2015 (UNFCCC, 2016) is the requirement for countries to communicate Nationally Determined Contributions (NDCs). Contrary to the Kyoto Protocol, which contained legally-binding quantitative emission reduction commitments for industrialised countries, the NDCs are country-driven national climate plans enabling countries to embed climate measures in their national socio-economic and development planning. At the same time, the Paris Agreement does not specify how NDCs need to be formulated, which leaves countries with a high degree of freedom in terms of determining greenhouse gas emission reduction goals, selecting suitable options for that and formulating policies to support implementation of these options.

A complexity in this respect is that while the Paris Agreement contains a global target to limit global average temperature increase to well below 2°C (compared to pre-industrial times levels), this target is not directly linked to individual countries' NDC goals. In other words, all NDCs together may not add up to a status in which the 'well below 2°C' target is reached (see, for example, IEA (2015)). To address this, the Paris Agreement contains a Global Stocktake, which is a process of reviewing NDCs every five years to see how all communicated NDCs together contribute to the below 2°C target. In case the overall NDC progress is inadequate, the Global Stocktake can lead to a recommendation to make NDCs more ambitious.

In addition to the above issue that a high degree of freedom in formulating NDCs may lead to insufficient ambition, another issue is that the Paris Agreement has not provided methodological guidance on NDCs. Therefore, the challenge is how countries can identify GHG emission reduction measures that are ambitious from a climate perspective and feasible from a domestic socio-economic perspective. Earlier under the Convention (United Nations Framework Convention on Climate Change, UNFCCC), experience has been built with developing methodologies for identifying options for mitigation (as well as for adaptation) and calculating the resulting GHG emissions below business-as-usual practice.

For example, for the Clean Development Mechanism (CDM), which facilitates international trade in carbon credits, the number of methodologies approved by the CDM Executive Board to account for GHG emission reductions in large-scale and small-scale projects are 89 and 95 respectively<sup>12</sup>. However, these methodologies only address GHG accounting issues and do not support identification of options for mitigation considering countries' development

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<sup>12</sup> <http://cdm.unfccc.int/methodologies/index.html>

goals. Although supporting developing countries' sustainable development is one of the CDM's main objectives, how projects fit in CDM host country development plans is left to the countries themselves, without methodological guidance.

Another example of a process under the Convention, whereby actions for mitigation and country development are recommended to go together, are the nationally appropriate mitigation actions (NAMAs). NAMAs became particularly important after the failed UNFCCC climate negotiations in Copenhagen in 2009 when countries and their negotiators started to realise that a top-down negotiated international treaty such as the Kyoto Protocol was no longer feasible and that the focus should be on climate measures identified from the bottom-up, considering countries' domestic circumstances. NAMAs reflected this as they called for mitigation actions that were nationally appropriate, which was especially important for developing countries. Since 2010, when NAMAs were given a prominent place in the Cancún Agreements (UNFCCC, 2010), a wide range of NAMA programmes and initiatives have been set up and funded.<sup>13</sup> However, for NAMAs no internationally adopted methodology exists under the Convention, which, therefore, has become the prerogative of the individual NAMA programmes.

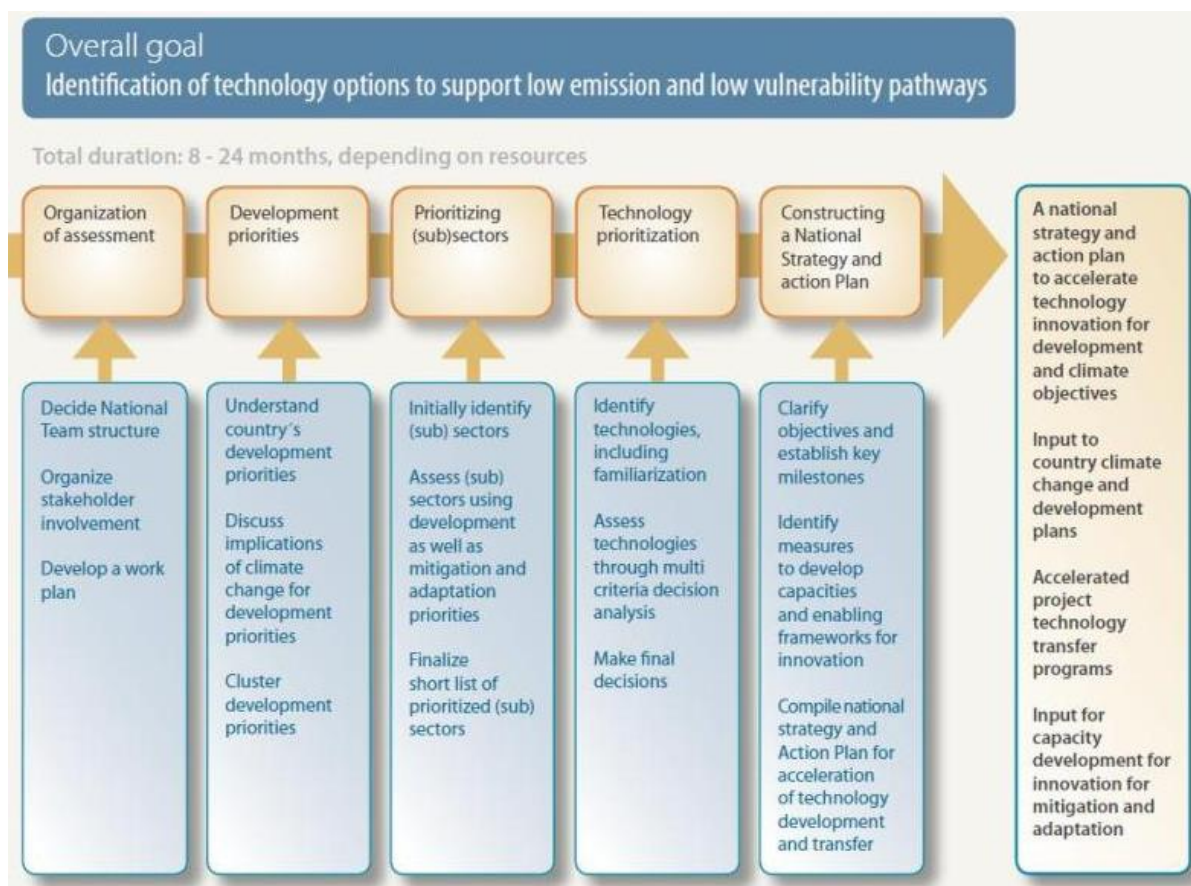
A third example of a country-driven process under the Convention is that of Technology Needs Assessment (TNA), which are aimed at supporting developing countries in identifying low-emission and/or climate-resilient technologies that are in line with their national development plans. Contrary to NAMAs, for TNAs specific guidance has been prepared under the Convention - Handbook for Technology Needs Assessment for Climate Change - which was done at the request of developing countries and mandated by COP-17 (UNDP, 2010). The TNA process is shown in Figure 12. It starts with an identification of national development priorities, followed by selection of strategic sectors for climate and development (e.g., sectors with high GHG emissions or vulnerable for a changing climate and which are important for realising development goals). Within the selected strategic sectors, technology options are considered and assessed against multiple climate and socio-economic criteria. For the prioritised technology options, actions plans are formulated for their implementation. As the TNA process usually contains multiple strategic sectors, its combined results can form inputs for a national strategy for climate and development.

Since 2009, the TNA methodology, as shown in Figure 12, has been applied by 36 developing countries in a first round of the Global TNA Project (funded by the Global Environment Facility), followed by 26 countries in the second round (which started in November 2014).<sup>14</sup>

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<sup>13</sup> [http://unfccc.int/cooperation\\_support/nama/items/7476.php](http://unfccc.int/cooperation_support/nama/items/7476.php)

<sup>14</sup> <http://www.tech-action.org/participating-countries>



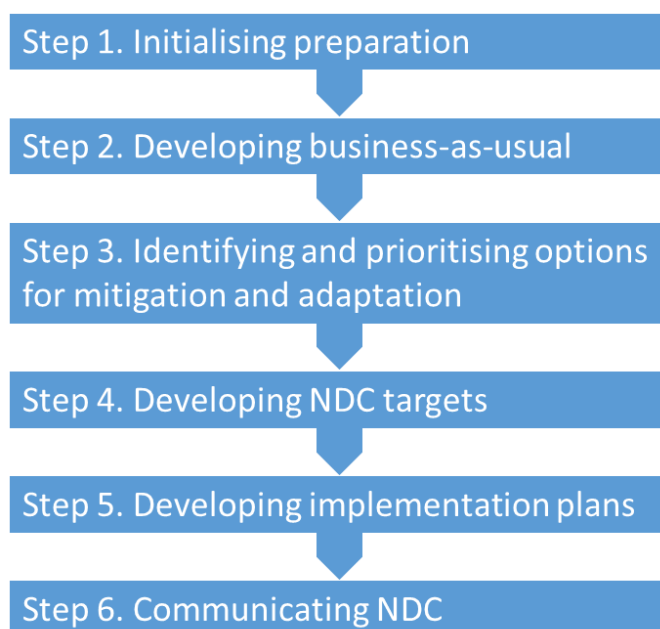
**Figure 12. Steps in a Technology Needs Assessment for climate change**

To explore how the TNA methodology can be used for NDC formulation, the UN Technology Executive Committee (TEC), prepared a paper on “Linkages between the Technology Needs Assessment Process and the Nationally Determined Contribution Process” for its meeting in August 2016 (Technology Executive Committee, 2016). This paper took as a starting point that TNAs have their own role under the Convention, based on the Decision on Development and Transfer of Technologies at COP7 in 2001 (UNFCCC, 2002), but that several outputs from TNA steps can be used as inputs for NDCs and that harmonising both processes is therefore recommended (Technology Executive Committee, 2016). As a matter of fact, some countries decided to use their already completed TNA reports for the intended NDCs which they communicated before the Paris Climate Conference of 2015 (JIN Climate and Sustainability, 2016).

A specific characteristic of the TNA process is that it is largely based on participatory processes, with the objective to mobilise stakeholders’ tacit knowledge, learn about objections that society may have against some technology options and stimulate stakeholders’ co-ownership of prioritised technology options. The linking of TNAs to a higher, more aggregate level of policy making, such as an NDC, could take place by amalgamating technology action plans for sector-level or even national-level plans (including a

rationalisation of plans to prevent overlaps and inconsistencies between technology action plans).

A limitation of the TNA process is that it does not contain the use of models to create future scenarios under different assumptions, for example, to find out what are the consequences of larger scale deployment and diffusion of a technology. TNA processes usually call upon the help of a wide range of stakeholders to assess consequences (risks) of implementing a technology at a certain scale, but generally no models are used to present stakeholders with a range of possible outcomes with their likelihoods. This makes TNAs less suitable for formulating business as usual (baseline or reference) scenarios, deriving possible futures for a sector or country and learning how each possible future could reduce greenhouse gas emissions below the baseline.



**Figure 13. Possible NDC development process (Technology Executive Committee, 2016)**

In Figure 13 a possible workflow is shown for preparing NDCs under the Paris Agreement, based on an elaboration by the Technology Executive Committee (2016). This in turn was based on an observation made by UNEP DTU in supporting development of intended NDCs (which were to be communicated as input for the Paris Climate Conference of 2015) in 31 countries through a UNEP-GEF INDC support project.<sup>15</sup> Comparing Figure 12 and Figure 13, it can be concluded that the TNA analysis, using *qualitative* tools for participatory processes with stakeholders, can contribute to the analytical steps 2-5 as follows:

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<sup>15</sup> <http://www.indcsupport.org>

- Step 2: By revisiting a country's current policies and strategic plans for climate and development, stakeholders can assume a possible future based on these existing policies and plans.
- Step 3: Through multi-criteria decision analysis, options for climate change mitigation (and adaptation) are assessed by stakeholders against multiple criteria derived from national social, economic and environmental priorities.
- Step 4: In a bottom-up process such as TNAs, aggregating across prioritised technologies could lead to sector or country level plans, including potential overall greenhouse gas emission reductions and costs.
- Step 5: Based on a mandate to the TEC by the COP-20, guidance has been prepared on how the results of TNAs can be implemented. COP-21 in Paris welcomed the work on the guidance and noted that the guidance will be available in 2016 to developing countries and TNA stakeholders for their use.<sup>16</sup>

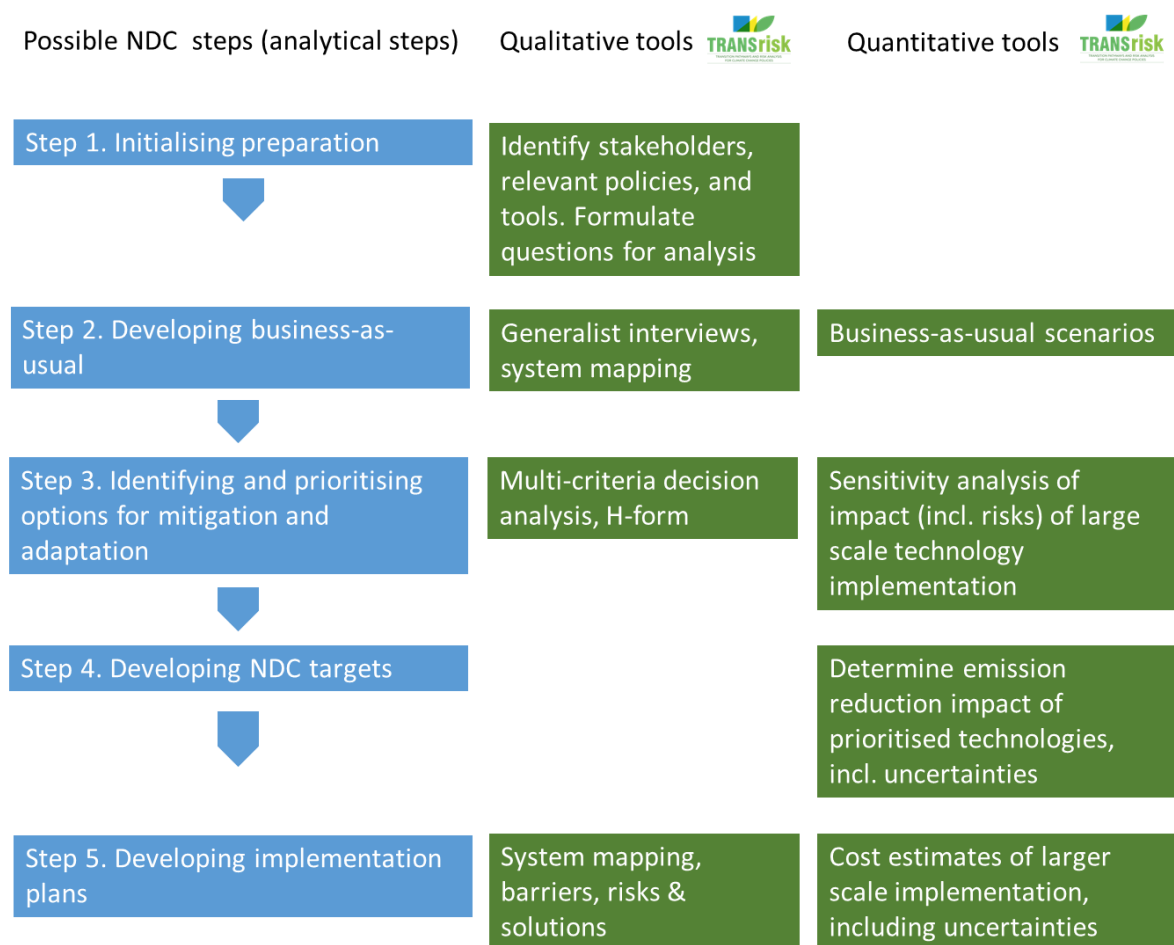
For Step 2, the NDC process could benefit from *quantitative* tools such as a model that calculates scenarios for possible futures, based on the present portfolio of climate policies. In Step 3, stakeholders' work on prioritising technologies can be enhanced if they know the consequences of implementing technologies on a larger scale (e.g. grid stability impact, employment losses and gains in the rest of the economy). With help of quantitative tools, such consequences or risks, as well as the positive impacts of technologies can be better assessed, including sensitivity for variation in parameter values. In Step 4, based on the prioritised technology options for climate change mitigation, quantitative tools can calculate the overall climate impact of these technologies within the country, when implemented at an assumed scale. This then determines the targeted GHG emission reduction under the NDC for compliance with the Paris Agreement target. In Step 5, based on TNA experiences, proven qualitative participatory tools such as system mapping, barrier root cause analysis, identification of solutions to clear these barriers and a planning protocol for implementing these solutions are available. However, an important aspect of Step 5 is estimating the costs of implementing a technology at a desired scale for realising climate and development benefits, which are difficult to make with qualitative tools only and for which modelled scenarios could provide a broader picture.<sup>17</sup>

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<sup>16</sup> [http://www.tech-action.org/-/media/Sites/TNA\\_project/TNA%20Guidebooks/Guidance-for-Preparing-a-Technology-Action-Plan\\_Upload.ashx?la=da](http://www.tech-action.org/-/media/Sites/TNA_project/TNA%20Guidebooks/Guidance-for-Preparing-a-Technology-Action-Plan_Upload.ashx?la=da)

<sup>17</sup> The [guidebook for Enhancing Implementation of Technology Needs Assessments](#) recommends making relatively rough calculations, based on standardised data for similar investments, which can be further detailed at later stages. The reason for this approach is that TNA technology action plans are first-step feasibility studies which inform potential funders or investors about cost items to be covered, order of magnitude of costs for each item and possible (types of) funders for each item. TAPs

An overview is presented in Figure 14 of how the *qualitative and quantitative* tools collected within the TRANSrisk project, and applied in the case study analysis in Work Package 3, could support the analytical steps of formulating NDCs, going beyond harmonisation of TNAs and NDCs. This is based on the above observation of how, in the view of the Technology Executive Committee (2016), a process with mainly qualitative tools, such as the TNA process, could support formulating NDCs.



**Figure 14. NDC steps and possible contributions of qualitative and quantitative tools in TRANSrisk**

In the case study analysis, as explained in Chapter 6, a first step is to identify stakeholders and describe their roles, and to identify tools and (research) questions for analysis. In the next step, generalist interviews and business-as-usual scenarios describe the context for the case study country or sector, based on what is known from the past and the present, and what this information, together with the current state-of-play with climate and energy policies, may imply for the future. In the next stages of the case studies, possible futures are explored with help of the models. While the case studies from the start already focus on pathways with predetermined technology options (for reasons of limited resources within the TRANSrisk project), the Work Package 2 toolbox, and partners' expertise, enables

assessment of multiple mitigation options to prioritise among these. Alternatively, stakeholders can be asked for their views, for example by using H-form, about whether large-scale diffusion of the technology option is desirable with a view to possible risks. As shown in Chapter 3, such an H-form participatory discussion could be combined with a few model runs to answer stakeholder questions emerging from the H-form.

The aspect of climate target setting (step 4 in Figure 14) in TRANSrisk case studies is not a goal as such, rather it is a focus on what a low-emission pathway looks like, including risk mitigation measures, given a climate goal. Alternatively, given a low-emission technology, the focus can rest on the best way to develop it in a country at a desired scale for climate and development benefits. Nevertheless, the quantitative tools in TRANSrisk enable making calculations of the climate change mitigation impact of deployment of a low-emission technology in a market and its diffusion at a large scale in a country, and could therefore contribute to step 4 of an NDC.

With respect to preparing for implementation of the priority technology options, an NDC could benefit from the qualitative system mapping tool that has been developed under TRANSrisk and the also risk and uncertainty assessments which are both qualitatively and quantitatively assessed within the TRANSrisk case studies.

This chapter has illustrated how the complementarity of qualitative and quantitative tools, as operationalised in TRANSrisk case studies, could contribute to possible steps of developing an NDC. In this chapter, the focus was mainly on bottom-up derived NDCs, as this was the main observation of the above-mentioned UNEP-GEF INDC Support Project for 31 countries. In such a process, the climate goal follows from prioritised technology options, based on stakeholder consultation and supported by inputs from models. Other NDCs may follow a top-down approach, starting with GHG emission reduction goals for which technology options need to be chosen and implemented at a required scale. While this would require a different analytical approach, it seems reasonable to assume that similar qualitative and quantitative tools will be required, as top-down derived NDCs also need assessments of costs, benefits, risks and robustness (in terms of societal feasibility and acceptance). All tools that are available in the TRANSrisk toolbox could be developed as an NDC-support methodology, once application experience in the thirteen cases studies has been gathered, reviewed and implemented.

## 8 CONCLUSIONS

In this document, examples have been presented, from the TRANSrisk project, of using both qualitative and quantitative tools for identifying preferences, options, impacts, costs and uncertainties with respect to the design of low-emission transition pathways. It has been concluded from these examples that qualitative and quantitative tools can be complementary as each type of tools helps to collect and analyse information that cannot be collected and analysed by the other type of tools. The examples in this document have illustrated that while models can assess large-scale application of solutions for low-emission transitions in detail, they are less suitable for understanding public perceptions and balancing positive or negative impacts of such transitions. On the other hand, while qualitative tools can support participatory processes for generating stakeholders' tacit knowledge or other information that is difficult to quantify, they are less suitable for assessing in detail what are implications of larger scale transitions for a country as a whole.

The combined application of H-Form and the MEMO model in a TRANSrisk training workshop showed how a stakeholder consultation (using the H-form) can result in specific research questions for a modeller (e.g. 'what will be the implications for employment if labour mobility between sectors is low?'). From the training workshop, it has become clear that it is important to have a discussion between stakeholders and modellers as some questions cannot be answered by the model directly, but need modification. Subsequently, skills are required to communicate different modelled scenarios with stakeholders for them to be better able to see the implications, including risks, of large-scale implementation of a low-emission transition pathway.

Another example of a complementary application of qualitative and quantitative tools in TRANSrisk is the process of combining an online survey with modelling of impacts of the answers. Including stakeholder views and preference in the design of the scenarios that are modelled leads to more realistic assumptions about portfolios with technology options for a low-emission future. For example, while the survey has shown that stakeholders generally support ambitious climate actions (i.e. realising the goal of 2°C and even 1.5°C), they also express concerned about required technology development for that.

TRANSrisk identifies two broad categories of risks related to low-emission transition pathways. First, consequential risks are those that relate to negative impacts of such transitions for the rest of society. Models can help identify such consequential risks, as they can, under different assumptions, sketch potential impacts of pathways (next to the climate benefits). Whether these risks are acceptable within the country context could then be assessed by stakeholders using qualitative tools such as multi-criteria decision analysis. Second, TRANSrisk considers the risk that a desired low-emission pathway will not be successfully implemented due to system blockages. For assessing these risks, qualitative tools can be used, such as system mapping with engagement of stakeholders (for example,

in their capacity as system actors). Some aspects of implementation risks may also be addressed by quantitative tools, such as when exploring the risk that a pathway may become too costly.

Finally, as the TRANSrisk case studies all start from a context description of the case study countries, including understanding the past, describing the present and looking forward towards the future, including how future developments can be climate-friendly, a link has been established in this document to the process of communicating Nationally Determined Contributions (NDCs) by countries under the Paris Agreement. It has been illustrated how a complementary application of qualitative and quantitative tools, as operationalised in TRANSrisk case studies, could support developing NDCs. It has been suggested, based on the lessons learned from the early stages of case study analysis, that the quantitative and qualitative tools that are available in the TRANSrisk toolbox could be developed as an NDC-support methodology, once application experience in the thirteen cases studies has been gathered, reviewed and implemented.

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## Appendix 1 - Summary of MEMO model

MEMO is a macroeconomic, multi-sector model. It examines the effect of policies on unemployment, wages in different sectors, GDP, sectoral composition, demand for energy etc. MEMO is particularly suitable for studying dynamics of economic systems after introduction of a policy. For example, it considers, that upon change in sectoral composition, not all workers can smoothly move from heavy industry to services. Thus, a policy, which leads to changes in sectoral composition produces a temporary increase in unemployment rate.

The model consists of a series of optimization problems: each firm chooses quantities which maximize its profit subject to the specified production functions. Consumers make decisions on consumption, savings and labour input to maximize their utility. Each optimization has an infinite horizon, e.g. firms consider future consequences of their current actions. The solver of the model generates a set of equations which must be satisfied in equilibrium if firms take optimal decision (the set of first order conditions). Solving this system gives equilibrium quantities and prices.

Questions that the model can address are:

1. What is the effect of carbon tax on unemployment and wages in different sectors?
2. How does a reduction in the PV installation cost affect energy prices, energy demand and GDP?
3. (When combined with a bottom up analysis) what is the effect of feed-in tariffs for PV on industrial output?

The type of answers that the model can provide are:

1. Upon introduction of carbon tax, unemployment increases in the first (financial) quarters due to a contraction in heavy industry. In the following quarters, workers find employment in other sectors and unemployment gradually returns to its long-run level.
2. A reduction in the cost of PV installation results in a reduction in electricity price and increase in energy demand. However, since firms have limited possibilities to adjust their production to lower energy prices in the short term, in the first quarters the increase in energy demand is small. In the long run, firms have a possibility to increase their energy consumption and thus in the long run, energy demand grows more significantly.
3. Manufacturing of PV increases the demand for output of the industrial sector. In short run, the industrial sector cannot significantly increase output and thus the price of industrial goods raises significantly. This leads to a drop in investment in other sectors

(crowding out of investment by the PV). However, in the long run, the industrial sector is capable of increasing employment and accumulating capital and thus, of increasing its production capabilities. This reduces the price of industrial goods and brings the investment in other sectors back to their initial levels.

Stakeholder inputs can be needed in the model to:

- Identify the most interesting and most relevant research questions to be answered by the model,
- Identify the objectives (socio-economic priorities) of different stakeholders (zero emissions, wages, unemployment, GDP etc.),
- Judge the plausibility of the mechanisms modelled in MEMO II and its predictions
- Identify additional mechanisms which could affect the model predictions.

(Nearly all parameters of the model are calibrated using input-output tables or using the results of econometric studies.)

Examples of MEMO model outputs are the following:

- **MAPS project for Chile:** MAPS ([www.mapsprogramme.org](http://www.mapsprogramme.org)) was a network of projects conducted in several Latin American countries with the aim to identify scenarios which would help these countries make a transition to robust, carbon efficient and climate resilient economies. IBS was responsible for developing a macroeconomic model (MEMO), which was used to assess general equilibrium effects of various mitigation actions. The mitigation actions were developed for each sector of the economy by sector experts using expert analysis and microeconomic models and then quantified as time series of required capital expenditures (CAPEX) and savings resulting from carrying out particular investment (OPEX).
- **FP7 DYNAMIX project:** Dynamic is a project funded by the European Union seventh framework programme with a goal to identify policy mixes that would potentially lead to decoupling of the environmental impact of EU resource use from economic growth. Within this project, IBS used the MEMO model to analyse the macroeconomic effects of various tax policies, thereby concentrating on two particular aspects of these policies: their potential to induce technological change that would increase resource efficiency, and their impact on the labour market.

Figure 15 presents an overview of MEMO components and their underlying structure.

Example of Research Question:  
**How support for renewables affect the employment opportunities in Poland**

# MEMO II

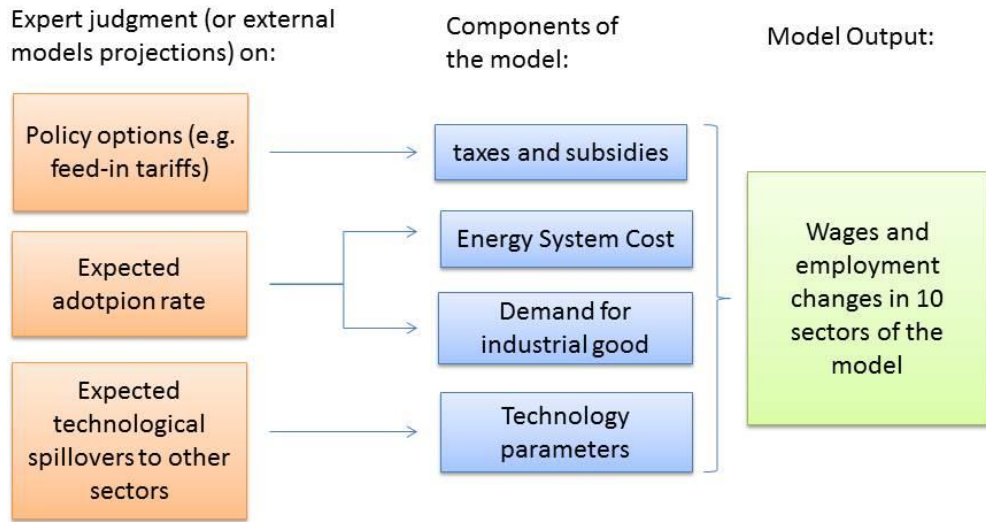


Figure 15. Overview of the components of the Memo II model

## Appendix 2 - Online survey for Stakeholders, 1st Round

**Q1. In your opinion, what is the optimal temperature target that we should aim for to limit global warming? Please select one of the following options:**

Answer Options	Response Percent	Response Count
Below 1.5 °C	53.6%	15
Below 2 °C	39.3%	11
Below 3 °C	7.1%	2
<i>answered question</i>		28
<i>skipped question</i>		0

**Q2. From a global perspective, if you had to allocate funds for climate change (e.g. via the Green Climate Fund), which combination of mitigation and adaptation measures would you choose? Please select one of the following options:**

Answer Options	Response Percent	Response Count
100% Mitigation	0.0%	0
75% Mitigation and 25% Adaptation	42.9%	12
50% Mitigation and 50% Adaptation	50.0%	14
25% Mitigation and 75% Adaptation	3.6%	1
100% Adaptation	3.6%	1
<i>answered question</i>		28
<i>skipped question</i>		0

**Q3. Addressing climate change could go at the expense of economic growth, especially when no or only a few low-emission (technology) options are available in a country context. What is your view on the debate about whether economic growth should prevail over climate change mitigation/adaptation measures or the other way around? Please select one of the following statements:**

Answer Options	Response Percent	Response Count
Economic growth should prevail over climate change mitigation investments - economic growth is needed to accelerate low-emission technology development.	0.0%	0
Economic growth should prevail over climate change mitigation investments - climate change is not the only problem to solve.	3.6%	1
Climate change mitigation investments should prevail over economic growth - we cannot afford further delay of climate change mitigation.	17.9%	5
Climate change investments should prevail over economic growth - Economic growth is the main reason why we face climate change.	14.3%	4
There is no need to prevail one over the other - the Green Growth concept enables us to decouple economic growth from increased greenhouse gas emissions.	64.3%	18
<i>answered question</i>		28
<i>skipped question</i>		0

**Q4. With a view to climate change mitigation investments in the global energy sector, which technologies, do you think, will be most important during the next 50 years? Please rank the following options from 1 (most preferred) to 9 (least preferred); (Or from 1 to 10, in case you wish to provide other options in the section 'other'):**

Answer Options	1	2	3	4	5	6	7	8	9	10	Rating Average	Response Count
CCS (Carbon capture and storage)	1	2	0	3	6	5	2	2	4	1	5.88	26
Nuclear	0	2	2	3	3	5	2	2	5	2	6.23	26
Intermittent renewables (solar, wind, hydro)	11	11	3	1	0	1	0	0	0	0	1.93	27
Biomass	1	4	5	12	1	3	2	0	0	0	3.89	28
Other renewables (geothermal...)	0	1	11	5	5	1	1	2	0	0	4.19	26
Energy Efficiency	14	6	5	1	2	0	0	0	0	0	1.96	28
Natural gas	1	0	2	2	5	8	8	1	0	0	5.63	27
Coal	0	0	0	0	1	1	4	6	8	5	8.36	25
Oil	0	1	0	0	1	0	5	12	7	0	7.73	26
Other	0	1	0	0	2	1	1	1	0	2	6.63	8
<i>answered question</i>												28
<i>skipped question</i>												0

**Q5. The technologies listed in Question 4 are in different stages of development in terms of market readiness. Considering development support, technologies that are still in a research, development and demonstration phase, require more public (governmental) support than technologies that are close to commercial applications in the market. Which of the following options, do you think, should receive more public support in the next 50 years in the global energy sector? Please select the two most preferred options, indicating their importance with using number 1 (most preferred) and number 2 (second preferred):**

Answer Options	1	2	3	4	5	6	7	8	9	10	Rating Average	Response Count
CCS (Carbon capture and storage)	2	5	0	0	3	2	0	0	0	0	3.25	12
Nuclear	0	0	0	1	1	1	2	2	1	0	6.75	8
Intermittent renewables (solar, wind)	8	10	1	0	1	0	0	0	0	0	1.80	20
Biomass	0	1	2	2	1	1	0	0	0	0	3.86	7
Other renewables (geothermal...)	3	5	4	4	1	0	0	0	0	0	2.71	17
Energy Efficiency	12	6	3	2	0	0	0	0	0	0	1.78	23
Natural gas	0	0	0	0	0	0	3	3	0	0	7.50	6
Coal	0	0	0	0	0	1	0	1	1	3	8.83	6
Oil	0	0	0	0	0	0	1	0	4	1	8.83	6
Other	3	1	0	0	0	1	0	0	0	1	3.50	6
<i>answered question</i>												28
<i>skipped question</i>												0

**Q6. In a transition to a low-emission future, there could still be considerable scope for fossil fuels in the global energy mix. With which of the following statements do you agree most?**

Answer Options	Response Percent	Response Count
Fossil fuels will remain the most important energy sources because of their widespread availability, relatively low costs and energy reliability.	3.7%	1
The share of fossil fuels in global energy mixes will decrease during the next two decades, except for natural gas, which will remain important as back up for intermittent renewables.	51.9%	14
Globally, energy systems will increasingly become decentralized, which implies that fossil fuels will be marginalized by 2050.	44.4%	12
There is no urgent need to reduce fossil fuel use, as technologies are or will be available to capture and store emitted greenhouse gases.	0.0%	0
<i>answered question</i>		27
<i>skipped question</i>		1

**Q7. Many energy-economic models assume a worldwide exploitation of CCS during the first half of this century. Considering a global perspective, how would you respond to this assumption? Multiple answers are possible.**

Answer Options	Response Percent	Response Count
Yes, there will be a global CCS expansion soon	7.1%	2
Yes, there will be a global CCS expansion but not within the next 2 or 3 decades	50.0%	14
No, CCS will not be deployed globally for technological reasons	14.3%	4
No, CCS will not be deployed globally for economic reasons	28.6%	8
No, CCS will not be deployed globally due to limited public acceptance and safety concerns	35.7%	10
<i>answered question</i>		28
<i>skipped question</i>		0

**Q8. From your personal/professional perspective, what is the most likely (feasible) future of nuclear power at a global scale?**

Answer Options	Response Percent	Response Count
Nuclear energy phase-out: there will be no additional nuclear power plants in the future.	24.0%	6
Nuclear energy remains constant: current levels of nuclear power production in the world remain the same in the future.	64.0%	16
Global expansion of nuclear energy production: nuclear power becomes increasingly important in future energy mixes in the world.	12.0%	3
<i>answered question</i>		25
<i>skipped question</i>		3

**Q9. From your personal/professional perspective, what is the most likely (feasible) future of solar, hydro and wind based renewable energy from a global perspective?**

Answer Options	Response Percent	Response Count
The share of solar, hydro and wind power technologies in the global energy mix will decrease.	0.0%	0
The share of solar, hydro and wind power technologies in the global energy mix will remain constant at current levels.	3.7%	1
The share of solar, hydro and wind power technologies in the global energy mix will increase.	96.3%	26
<i>answered question</i>		27
<i>skipped question</i>		1

**Q10. From your personal/professional perspective, what is the most likely (feasible) future of bioenergy in the global energy mix?**

Answer Options	Response Percent	Response Count
Limited bioenergy: limited bioenergy deployment globally in the future	11.1%	3
Bioenergy constant: current global levels of bioenergy applications remain the same in the future	33.3%	9
Bioenergy expansion: bioenergy deployment in the world will utilize its maximum potential in the future	55.6%	15
<i>answered question</i>		27
<i>skipped question</i>		1

**Q11. Next to low-emission options and measures in the energy sector, which other sectors do you consider important, from a global perspective, for climate change mitigation? Multiple answers are possible.**

Answer Options	Response Percent	Response Count
Industry	53.6%	15
Transport	85.7%	24
Agriculture	82.1%	23
Waste	39.3%	11
Forestry	53.6%	15
Other (Please specify this at the end of the survey in the provided comment box.)	7.1%	2
<i>answered question</i>		28
<i>skipped question</i>		0

## Appendix 3 - Overview of GCAM model

The model used in the integrated qualitative-quantitative analysis (WP2 - WP4), as described in Chapter 4 in this report, is the Global Change Assessment Model (GCAM)<sup>18</sup>, developed by the University of Maryland and the Pacific Northwest National Laboratory (PNNL)<sup>19</sup>. GCAM is an integrated assessment model that links economic, energy, land use and climate systems. It has been one of the four models chosen to develop the Representative Concentration Pathways (RCPs) of the IPCC's 5th Assessment Report<sup>20</sup>. The model is available under the terms of the ECL open source license version 2.0. In this study, we use the standard release of GCAM 4.2.

GCAM is a global dynamic-recursive partial equilibrium disaggregated in 32 geopolitical regions and operating in 5-year time steps from 1990 to 2100. The GCAM energy system includes primary energy resource production, energy transformation to final fuels, and the use of final energy forms to deliver energy services. The model distinguishes between two different types of resources: depletable and renewable. Depletable resources include fossil fuels and uranium; renewable resources include biomass, wind, geothermal energy, municipal and industrial waste (for waste-to-energy), and rooftop areas for solar photovoltaic equipment. All resources are characterised by cumulative supply curves, i.e. upward-sloping supply-cost curves that represent the idea that the marginal monetary cost of resource utilisation increases with deployment. Competition between technologies is modelled by a logit probabilistic model that provides a share weight to each technology and each of the levels. Complete documentation on all the technologies in the energy system is provided in Clarke et al. (2009).<sup>21</sup>

GCAM tracks all GHG emissions from the energy and the land-use systems. GCAM provides the mitigation cost of different energy and climate policies for each specific region. The mitigation costs are calculated by the model as the area below the marginal abatement cost curve calculated by the model.<sup>22</sup> GCAM also reports the emissions of main air pollutants (including NO<sub>x</sub>, VOCs, CO or SO<sub>2</sub>) and can be used to analyse the co-benefits / trade-offs of mitigation in terms of air pollution. Emissions of air pollutants depend on activity levels in

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<sup>18</sup> <http://www.globalchange.umd.edu/models/gcam/>

<sup>19</sup> <http://www.pnnl.gov/>

<sup>20</sup> IPCC, 2014a. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

<sup>21</sup> Clarke, L., Kyle, P., Wise, M., Calvin, K., Edmons, J., Kim, S., Placet M. and Smith, S., 2009. CO<sub>2</sub> Emissions Mitigation and Technological Advance: An Updated Analysis of Advanced Technology Scenarios. (Scenarios Updated January 2009). Preparer for the U.S. Department of Energy. PNNL-18075.

<sup>22</sup> Kyle, 2015. Global Change Assessment Model (GCAM) Tutorial.

each region, such as fuel consumption, and the level of pollution controls, which are assumed to increase over time (Smith et al., 2005; Smith and Wigley, 2006).<sup>23</sup>

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<sup>23</sup> Smith, S.J., H. Pitcher, T.M.L. Wigley, 2005. Future sulfur dioxide emissions. *Climate Change* 73(3):267-318.  
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