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Scaling up Mitigation Technologies in Integrated National Energy and Climate Plans

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The CARISMA Project started in February 2015 and received funding from the European Horizon 2020 programme of the EU under the Grant Agreement No. 642242. CARISMA intends, through effective stakeholder consultation and communication, to ensure a continuous coordination and assessment of climate change mitigation options and to benefit research and innovation efficiency, as well as international cooperation on research and innovation and technology transfer.

Executive Summary

Within the EU, the 'Winter Package' focusses on clean energy for all Europeans. It contains specific goals for energy and climate and calls upon Member States to formulate Integrated National Energy and Climate Plans (INECPs). While the energy and climate goals of the EU require scaling up of climate change mitigation technologies, integrating such options in existing economic and social structures is not always easy. As the case studies in this paper show, it requires careful planning and acknowledgement that some options are less suitable within the country context, but also that solutions exist to mitigate negative impacts and build local support among citizens for expanding mitigation options.

Building further on the insights from the CARISMA project, this report analyses issues that Member State policy makers may face when formulating INECPs and scaling up technology options for mitigation. These issues are then analysed as case studies for three EU Member States: Greece, Austria and the Netherlands.

Case study findings in support of INECP formulation are assessed in this report based on the following questions:

1. *How can we characterise benefits and drawbacks of mitigation technologies if they are scaled up and implemented over the longer term, in terms of system- and macro-level impacts?*

When formulating INCEPs, among the factors to consider are possible job and sector activity losses and gains because of energy policy and deep decarbonisation. The cases of Greece and Austria illustrate how these impacts may arise in countries with wholly separate starting conditions: Greece with little renewable electricity source penetration and high costs of capital, and Austria with ample renewables and cheap capital.

The results found for Austria, Greece, as well as for the Netherlands, illustrate the importance of understanding country contexts and differences between these. For instance, the limited capital availability in Greece causes investments in capital-intensive renewable energy technologies, such as wind turbines, to become relatively costly. In Austria, with its existing large share of (relatively low-cost) hydroelectricity, almost any investment in non-hydro mitigation technologies will cause electricity prices to go up.

Expanding technologies for mitigation does not mean ‘simply’ implementing a single technology project multiple times within the country. Scaling up may require grid stability investments and economy-wide costs, including large government expenditures on subsidising renewables (or reduced tax revenue due to tax exemptions) which are an important determinant for the technical or economic potential of a mitigation technology in a Member State.

2. *How much do location-specific carbon payback times of climate mitigation technologies affect their climate benefits?*

Using the concept of Carbon Payback Time (CPT), the effectiveness of scaling up a mitigation technology is determined by: which technology and accompanying GHG emissions it replaces, and the GHG emissions throughout its own lifecycle of production, construction, operation and dismantling. In the Netherlands, due to the large wind energy resources and relatively large share of fossil fuels in the energy mix, the CPT for wind energy is relatively short, while for solar PV it is considerably longer. In Austria, CPTs for renewable energy technologies are relatively long. Due to the already low carbon footprint in the country, it takes relatively long time for a renewable energy technology to compensate its lifecycle emissions.

3. *What are viable approaches to opening up public discussions that would be needed for wider social adoption and acceptance of mitigation options?*

The European Commission acknowledges the important role of stakeholders in INECP formulation, as actors in value chains and consumers of energy. The three case studies in this paper highlight a range of aspects related to social adoption and acceptance of technologies for mitigation in the Member States.

Technologies’ social implications can be broad, ranging from impacts on employment to changes in the landscape nearby residential cores. With respect to the latter, the case studies show examples of how gaining public acceptance of scaled up technologies can be a challenge under INCEP development. The case studies also demonstrate that including stakeholders in planning and development stages of expanding a technology for mitigation in their country or region within the country has a positive impact on their acceptance of technology expansion. A feeling that a technology project or programme has been imposed on them could easily give rise to feelings of discomfort and protest. At the same time, engaging people in a project, including its design, contributes to enhanced social acceptance.

In this respect, among the first things to explore are how a technology deployment plan fits within or competes/conflicts with other activities in the area or region concerned and who will be impacted by that. This ‘area-based’ innovation, preferably carried out at municipal and provincial levels, would focus on addressing a combination of problems/issues at the same time to balance multiple individual preferences within an energy transition package. Such inclusive processes may also imply more flexibility in terms of zone planning and choosing locations for project activities.

Table of Contents

Executive Summary **1**

Part I - Taking mitigation technology decisions under the 'Winter Package' **4**

1 Introduction **5**
2 Integrating Energy and Climate Planning in the EU **7**
2.1 The Winter Package 7
2.2 INECPs: state of the play 8
2.3 Aspects to consider when designing INECPs 9
3 Main findings: scaling up mitigation technologies in INECPs **12**

Part II - Case study analysis – Greece, Austria, the Netherlands **14**

4 Introduction to case study analysis **15**
5 Case study 1: Greece **18**
5.1 Introduction 18
5.2 Economic effects of large-scale renewable energy technology deployment 18
5.3 Climate-effectiveness of mitigation technologies: carbon payback times 21
5.4 Social aspects of upscaling renewables in Greece 21
5.5 Conclusions 22
6 Case study 2: Austria **24**
6.1 Introduction 24
6.2 Economic effects of large-scale renewable energy deployment 24
6.3 Climate-effectiveness of mitigation technologies: carbon payback times 26
6.4 Social implications of renewables options in Austria 27
6.5 Conclusions 28
7 Case study 3: Expanding Solar PV in the Netherlands **29**
7.1 Introduction 29
7.2 The case of solar renewable electricity in the Netherlands 31
7.3 Economic effects of solar PV expansion in the Netherlands 32
7.4 Social implications and spatial planning issues related to expanding solar PV in the Netherlands 38
7.5 Conclusions 40
8 Discussion – Lessons for scaling up mitigation options in INECPs **41**
8.1 How can we characterise benefits and drawbacks of scaling up mitigation technologies in terms of system- and macro-level impacts? 41
8.2 How much do location-specific carbon payback times of climate mitigation technologies affect their climate benefits? 43
8.3 What are viable approaches to opening up public discussions that would be needed for wider social adoption and acceptance of mitigation options? 44
9 References **46**

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Part I - Taking mitigation technology decisions under the 'Winter Package'

1 Introduction

In November 2016, the European Commission presented its package 'Clean Energy for All Europeans' with measures for a clean energy transition in Europe over the next decades (European Commission, 2016). The package, dubbed 'Winter package', contains steps towards increased energy efficiency, growth of renewable energy, as well as measures to reorganise electricity markets in Europe and reduce energy poverty. The package is aimed to be a substantial step in the direction of reducing greenhouse gas (GHG) emissions in Europe by 40% before 2030, which the EU pledged at COP-21 (held in Paris, December 2015), and by 80 to 95% by 2050. As part of the Winter Package, Member States are required to develop Integrated National Energy and Climate Plans (INECPs), in accordance with the EU's Energy Union Strategy for 2030 (European Commission, no date), and national long-term low emission strategies for 2050.

It is planned to enhance energy efficiency by 30% by 2030, in comparison to projected energy efficiency levels by then. To achieve that, energy suppliers and distributers need to save energy by around 1.5% per year, while also measures for limiting energy use in existing and new buildings have been proposed. The Commission particularly points out the issue of energy poverty by stating that in 2014, lowest-income households spent 9% of their budgets on energy costs, which is 50% higher than ten years before (European Commission, 2016, p. 11). Enhancing investments in renovation of low-income housing could help reduce this energy poverty.

Regarding renewable energy the goal is that by 2030, 27% of the overall energy mix should be based on renewable energy sources, although a higher target is currently (i.e. early 2018) under discussion between the European Parliament and the European Council. This target is binding at the EU-level and Member States are to contribute to that via pledges identified through their INECPs. To make a larger share of renewables technically feasible, investments in the European electricity grid are anticipated, including enhanced interconnectedness of the grid network. With the expansion of renewable energy, also measures will be needed to deal with the variability of renewable energy supply, with increased flexibility in the market for generation, demand or storage of energy.

Understanding impacts of scaling up mitigation options

Developing long-term national low-emission strategies requires an understanding of how options for mitigation fit in a Member State's long-term socio-economic planning and priorities. This requires knowledge of impacts of a low-emission option when implemented on a larger scale on the medium to longer term, as needed for achieving climate goals for 2030 and 2050. In the CARISMA project, issues related to making technology options market-ready (for large-scale implementation) are discussed in workpackage 3 (*Research and Innovation*, task "From research and innovation to market implementation"). Issues related to understanding the policy and implementation contexts for technology deployment and diffusion are discussed in workpackage 6 (*Roles of policy implementation and contextual factors in realising climate change mitigation*). How this can be supported through international collaboration on research and innovation has been the focus of workpackage 7. While decision-makers may have a good understanding of the possibilities, maturity, cost and potentials of a mitigation option, the consequences of implementation on a larger scale and longer timeframes, and in a societal context, are often less clear. It is in these areas where implementation problems may arise, and which could result in reduced compliance with the EU's energy and climate goals and eventually not meeting the goals of the Paris Agreement. These aspects have been addressed in workpackage 4.

Aim of this paper

The aim of this paper is to synthesise the work carried out in workpackage 4 in such a way that it produces relevant knowledge for EU member state decision-makers for use in INECPs. For that, we will first identify several aspects for policy makers to consider when formulating INECPs. The main overall challenge will be that a range of technology options for mitigation will have to be scaled up for complying with European climate and energy goals and that this requires knowledge that goes far beyond what are impacts, costs and benefits of single projects. Scaling up renewable energy technologies next to or instead of conventional technologies may require additional investments in energy grids to guarantee secure supply of energy. It may, however, also have social and economic impacts, which may, or may not be offset by socio-economic benefits. The outcome of such an analysis of impacts versus benefits may eventually determine the public acceptance of scaled up options.

2 Integrating Energy and Climate Planning in the EU

2.1 The Winter Package

Integrated National Energy and Climate Plans (INECPS) need to cover the key dimensions of the EU's Energy Union Strategy: decarbonisation, energy efficiency, energy security, internal energy market and innovation and competitiveness (European Commission, 2016). Moreover, INECPs need to be in line with Member States' strategies towards low-emission economies by 2050. The plans are compiled via iterative processes between Member States and the Commission containing planning, reporting and monitoring steps. Progress with INECP implementation will be reviewed through an annual 'high-level' progress monitoring. In the proposed package it is also foreseen that revision of the INECPs falls together with the 5-yearly Global Stocktake of Nationally Determined Contributions (NDCs) under the Paris Agreement (UNFCCC, 2015).

In its communication about the Winter Package, the Commission highlights the economic importance of the energy sector for the European economy with close to 2.2 million people employed, spread over 90,000 enterprises (European Commission, 2016, p. 2). According to the Commission, the measures foreseen in the package would create almost 1 million additional jobs. Most of these (700,000) are in construction, followed by 230,000 additional jobs in engineering and 27,000 in iron and steel production. For meeting the EU's 2030 energy and climate targets, the Commission estimates that an investment of €379 billion per year will be needed in energy efficiency, renewable energy and infrastructure.

Active role of stakeholders

Important in the Winter Package is the envisaged role of stakeholders as actors in energy efficiency and renewable energy value chains and consumers of energy. One aspect is that the Package recommends that (negative) societal impacts of the clean energy transition are minimised. Moreover, next to Member State authorities, also local and city authorities and businesses, social partners and investors should be involved in the preparation and implementation of the INECPs. Both aspects would support policy makers in considering a stakeholder- and end-users perspective for stronger social acceptance of the eventual energy efficiency and renewable energy support activities.

Renewable energy target(s)

While there is an overall, legally binding minimum target for renewable energy (27% share in the energy mix by 2030), Member States must determine for themselves how they will contribute to this overall target. This contribution will be specified in the INECPs and is subject to review and possibly recommendations by the Commission for improvements to higher ambition levels (as part of the iterative process between Member States and the Commission). Renewable energy will be a key element of the INECPs, especially with a view to scaling up renewable electricity production.

The Commission considers this larger scale implementation of renewable electricity technologies as beneficial for Europe's manufacturing and installation activities (such as via a well-interconnected European electricity network), with job increases and value added. However, it also highlights required system-level improvements, and changes in market rules to cope with the intermittent nature or renewable energy supply, such as rewarding market actors that offer more flexible energy supply services or having priority dispatch rules for low-emission electricity technologies.

Energy consumers in control of their energy choices

A key role in the INECPs is envisaged for energy consumers. Through the Winter Package, the Commission proposes an energy market reform to enable energy consumers to be more in control of their energy choices. This implies provision of better information and increased transparency about low-emission energy sources, related costs, impacts and benefits. For example, despite the recent trend of decreasing international oil and gas prices (60 and 50% price reduction since 2013 and 2014, respectively) and a corresponding reduction in the EU's energy import expenses of 35%, retail prices for electricity and natural gas have increased for households since 2008 (by 3% and 2% per year, respectively). The latter prices increases are mainly due to rising network costs and governments' taxes and levies.

Investments in decentralised grid systems

Scaling up renewable energy technologies is likely to change the role of energy consumers into 'prosumers', as households and small and medium-sized enterprises will increasingly use their rooftops for electricity production, consume part of it and feed the remaining electricity into a grid. To enable this trend from centralised to decentralised generation, with smart and interconnected grids, physical investments will be needed in the grids and electricity networks. It will also require that the caps on wholesale and retail prices are removed. The latter enables households and businesses to become more actively involved in the energy system and respond to price signals.

The latest adopted text regarding the Package by the EU Parliament in January 2018 provides an improved and more consistent proposal requesting more dialogues with stakeholders and more assessments of (EU and national) policy impacts. The recent Parliamentary text also contains a reference to achieving carbon neutrality within the EU by 2050. INECPs are to be submitted by Member States by 1 January 2019 (European Parliament, 2018).

2.2 INECPs: state of the play

In November 2017, as part of its Energy Union progress report, the European Commission reported on progress by individual Member States towards INECPs (European Commission, 2017a, pp. 1-13, Annex 3). It concludes that a few countries are in an advanced stage regarding establishing INECPs, while several Member States have made important preparations including updates of existing climate strategies. Some examples of Member States' progress are listed below:

- **Croatia** has a draft *Strategy for Low Emissions Development by 2030* with an outlook towards 2050. Next to that, the country is in the process of revising its Energy Strategy. Both strategies will be used for preparing Croatia's INECP.
- **France** is in the process of designing its energy-climate policies packages for 2030 with an update of its *Low-Carbon National Strategy*. It considers steps towards carbon neutrality by 2050 for contributing to the Paris Agreement's goal.
- **Austria** is in an advanced stage of developing its INECP for the years 2021 to 2030, thereby building further on a Green Paper that was published in June 2016. The new government of Austria plans to have a draft INECP ready in March 2018 and strives for its adoption by the summer of 2018.

Other Member States that, according to the Commission's progress report, are among the more advanced ones in terms of developing INECPs are: Italy, Finland, Germany and the Netherlands. A few Member States are only in the initial stages regarding the development of their INECPs. Some of them, such as Slovenia and Greece, have now started with stakeholder consultations about the plan. In 2018, Greece will carry out a comprehensive modelling exercise supporting the drafting of their INECP (Vougiouklakis, 2017).

2.3 Aspects to consider when designing INECPs

Determining the scale of deployment and diffusion of technology options for reaching the country's and the EU's energy and climate targets is an overarching challenge for policy makers. Partly, the scale depends on the technology's 'technical potential' for which, for instance, the availability of renewable energy resources, such as biomass, wind, hydro and solar energy in the country is an important factor. In their INECPs, Member States may realise the **strongest climate effectiveness** (e.g., realising emission reductions within the shortest possible time frame, see Box 1) when renewable energy technologies are in areas or regions where most of the resources are, such as high wind speeds or high solar radiation.[1]

Next to climate effectiveness, the scales for individual technologies within Member State may furthermore depend on:

- **economic and social drawbacks and benefit** per technology option for mitigation, and
- whether and to what extent a technology will have **social implications** and how these determine public acceptance of a technology option.

Determining economic and social drawbacks deals with impacts of scaled up technology options on a Member State's gross domestic product, electricity prices, employment, wages and capital, *etc*. Deployment and diffusion of technologies for mitigation are expected to result in a range of positive impacts, such as newly created jobs and increased added value

[1] The scale of technology deployment and diffusion for mitigation in EU Member States can also be politically determined based on target setting at the level of the EU, which was, for example, the practice under the EU's contribution to complying with the goals of the Kyoto Protocol during 2008-2012. However, the Winter Package does not contain such individual Member State level targets; Member States must jointly comply with overall EU-level targets for energy and climate.

in renewable technology installation, as explained in Section 2.1. However, there may also be negative impacts, such as:

- **Job losses** and/or **lower wages** in sectors not benefiting from the deployment and diffusion of renewable technologies;
- **Higher energy costs** for consumers due to increased energy demand in combination with required system-level improvements; and
- **Higher capital costs** since technologies for mitigation are usually more capital-intensive than conventional energy technologies, so that an increase in clean technologies requires larger capital investments (Bachner, Tuerk, Williges, & Steiniger, 2017).

Therefore, the challenge is how to scale up technologies for mitigation in an INECP to a level that is 'affordable' from the perspective of socio-economic impacts

With respect to climate effectiveness, it is important to consider that technologies for mitigation not only contribute to GHG emission reductions and bringing climate targets within reach, but their production, construction, operation, and eventual dismantling also cause GHG emissions. Hence, the net mitigation impact of a technology for mitigation is the difference between the emission reduction effect of replacing fossil fuel-based technologies and the life-cycle emissions.

This net mitigation impact can be important to consider as several mitigation technologies are produced in Europe (note from the former section that 43% of all wind turbines installed in the world are produced by European manufacturers). Also, other technology life-cycle phases may take place in Europe. This means that from a European perspective, not only the emission reduction gains of mitigation technologies are accounted for in climate inventories of Member States, but also the life-cycle emissions (albeit possibly in different Member States).

For the overall EU climate change mitigation effectiveness, it thus makes sense that Member States include in their INECPs technologies with the shortest carbon payback time (CPT).[2] Moreover, while lifecycle emissions are currently not included in GHG accounting systems, these may be included at a later stage, and an early awareness and consideration of these emissions can thus be important.

Finally, as mentioned above, the importance of **engaging with stakeholders** in the Winter Package has been highlighted. This enables 'opening up' of public discussions for wider social acceptance of mitigation options. From analysis in the CARISMA project on social implications of technologies for mitigation, examples can be taken of situations where lack of public engagement in climate-related decision-making resulted in social resistance (Hagens, Koretsky, & Toemen, forthcoming). Understanding what causes public resistance to a mitigation option and how to act for increased public acceptance thus determines what is a realistic scale for deployment and diffusion of the option in the Member State and the ambition level of its INECP.

[2] CPT is the time needed before a technology's emission reduction gains outweighs it life-cycle emissions, see Box 1.

Based on the discussion in this section about the Communication by the European Commission on 'Clean Energy for all Europeans' (European Commission, 2016), it can be concluded that Member State policy makers need to consider a range of aspects in an integrated energy and climate planning. Of these, scale of implementation of mitigation options, cost elements related to that, how effective an option is from a climate change mitigation perspective with respect to (renewable) energy resources, and consideration of the roles and opinions of stakeholders, have been identified and assessed by the CARISMA project as being of key importance for the likelihood of mitigation options to deliver effective, affordable and realistic contributions to integrated climate and energy planning in countries. In Part II of this paper, based on three EU Member State case studies, consideration of these aspects will be further assessed. The main findings of the case study analysis are presented in the next section.

3 Main findings: scaling up mitigation technologies in INECPs

Impacts of scaling up options for mitigation, for consideration in INECPs, have been assessed in further detail through case study analysis in three EU Member States: Austria, Greece and the Netherlands. These Member States have different characteristics in terms of, for instance, capacity and uptake of renewable energy, existing energy mix, as well as availability of capital for scaling up technology options, and therefore different 'starting points' for formulating INECPs. This enables identification of commonalities and differences between Member States, which can be instructive for other Member States when preparing their INECPs. This chapter contains the main findings from the case studies as recommendations for policy makers in the formulation of INECPs. Detailed case study descriptions, followed by a discussion of the case study findings, are presented in Part II in this report.

A crucial strategic element of the EU's energy policy is decarbonisation of the electricity sector through policies that target innovation and foster technological change. The EU 'Winter Package' includes an ambitious set of policy measures that aim to better align and integrate climate change mitigation goals into the energy and electricity sectors at the level of the EU. Under this plan, the share of renewable energy sources in final energy demand is targeted to grow to at least 50% by 2030, with more decentralised production and self-consumption taking place, and liberalisation of the grid and power networks, allowing for trans-national electricity trade within the EU. Such policy goals require an optimal allocation of newly installed electricity generation capacities among Member States according to countries' demand needs, cost factors, natural resource availability, grid requirements, and technological availability.

The case study analysis in this paper has highlighted a range of aspects to be considered for integrated energy and climate planning, such as in the INECP context, all of which go far beyond evaluating a technology solely based on their production-based emissions. Instead, for finding optimal and cost-effective solutions for electricity grid expansion under climate change policy in the EU, the **apparent 'simple' solutions may not necessarily be the best for reducing emissions**. In this paper, it has been indicated that expansion of renewable technologies is bound and constrained by factors to which policy makers may have traditionally paid less attention to.

With **costs assessments**, for different technology options it can be calculated what cost items need to be considered when scaling up a technology within a country, such as additional system and overarching (meso and macro) level costs. **System and macro-level cost aspects are an important determinant for the technical or economic potential of a technology option in a country.** The case studies in this paper have illustrated how cost impacts can differ between countries, due to factors such as costs of capital, whether the country already has a large share of low-cost renewable energy, etc.

Life-cycle GHG emissions are significant contributors to overall emissions of a country or of other countries if the technology in question is scaled up. Even though current GHG accounting procedures do not require that life-cycle emissions are accounted for by a country if these take place elsewhere, for assessing the overall contribution of a scaled-up technology to overall climate change mitigation (and having a clearer understanding of the consequences of making technology choices) an option's carbon payback time (CPT) is an important parameter. **Based on CPT insights per technology, policy makers can consider choosing technologies with lower life-cycle emissions and/or technologies for which the country has larger energy resources**.

Finally, the case studies have, focussing on renewable energy options such as wind power and solar photovoltaics (PV), highlighted aspects related to social implications of technology options for mitigation and how these could lead to public resistance. The case studies have shown examples of how climate technologies can both support and hinder sustainable societies, become sources of expected and unexpected opportunities, and obvious and hidden risks. Therefore, **implementation of technology options that are promising in terms of emission reduction potential, can be blocked for reasons related to social resistance against these options.**

A common observation is that public resistance becomes stronger, the closer upscaling of a mitigation option is located to people's living environments. While it may not clear public resistance in all cases, the examples discussed have demonstrated that **early involvement of people as stakeholders in a decision-making process generally has a positive effect on public acceptance of an option.** For instance, by opening up public discussions, people's preferences can be considered in the planning and implementation. Moreover, as local contexts and priorities are of key importance for social impacts of technology options and since these can strongly differ, even within countries, avoiding 'one-size-fits-all' policy approaches is recommended. Contextualised approaches to enhance people's awareness of a technology option, include people in the process, provide clarity about costs and benefits and accompanying risks are recommended for greater public acceptance of mitigation options and unlocking their physically possible and economically feasible GHG emission reduction contribution within a country.

Part II - Case study analysis: Greece, Austria, the Netherlands

4 Introduction to case study analysis

The aspects identified in the discussion of INECPs in Part I of this paper will have to be assessed in combination, as a favourable assessment of a technology on one aspect (e.g., low costs) may be counteracted by a negative assessment on another aspect (e.g., low public assessment or limited renewable energy resources). For example, a country may have large solar energy resources, but when it is also densely populated, public resistance to ground mounted solar parks can be high, as the ground used for solar energy production can no longer be used for other applications. Therefore, policy makers in the country need to balance carbon-effectiveness of solar energy investments against public acceptance issues, which can result in, either, a smaller share in the electricity mix for solar energy due to public resistance or trying to address public resistance by opening discussions with stakeholders and finding a common ground for acceptance of the option.

This example also shows the **importance of understanding country contexts**: how large is the country, what are its energy resources, what is the population density, what is the share of renewable energy, what are the capital costs, how climate-supportive or sceptic are key stakeholders, etc.? Such contextual factors, each in their own turn, have an impact on the potential for scaling up of mitigation technologies and therefore a country's ability to achieve a low-emission transition.

The importance of considering these aspects in conjunction, keeping in minde the country contexts, will be illustrated with help of three case studies of EU Member States for which the effects of expanding mature renewable energy technologies, specifically wind and solar PV, will be analysed. In the vein of country contexts, the selected cases represent different starting points regarding EU energy policy and the upcoming INECPs, namely in terms of the costs of capital, and current share of renewables in the energy mix. This broad categorisation allows for a representative country case to highlight issues which may arise due to one or both factors and may serve as examples for other countries with similar starting points. To span the potential national situations in the EU, the selected cases are:

1. Greece (low renewable electricity share and high costs of capital);
2. Austria (high renewable electricity share, little difficulty to meet EU renewable energy targets, and a low cost of capital); and
3. the Netherlands (low renewable energy share, low costs of capital and densely populated).

It is important to underline though that despite the broad categorisation of the countries and their characteristics, the case studies will not result in blueprints for policy making on how to scale up technology options. Rather, the case studies demonstrate the impact of different country contexts and INECP 'starting points' on decision-making about mitigation technologies. Based on the case study analysis, recommendations will be presented for policy makers for consideration during INECP establishment (see Section 8).

The case study descriptions are organised according to the following three questions. These have been derived from the discussion in Section 2 of aspects that determine an affordable and acceptable implementation scale of technology options in a Member State, for consideration in an INECP, and insights on these aspects from the CARISMA project

(Bachner, Tuerk, Williges, & Steiniger, 2017) (Loriaux, et al., forthcoming) (Hagens, Koretsky, & Toemen, forthcoming):

1. What are economic and social drawbacks and benefits of scaling up technologies for mitigation?
2. What is the 'climate effectiveness' of a technology in a Member State given the (renewable) energy resources, existing energy mix in the Member State and the technology's life-cycle emissions (the carbon payback time, CPT)?
3. What are social implications of scaled up technologies and how can these be dealt with for wider public acceptance of the technologies?

In Box 1, background information for these questions is presented based on Deliverables in CARISMA workpackage 4.

The case studies focus mainly on the renewable energy technologies wind and solar PV power, whereas the Greek case study also briefly addresses issues related to energy efficiency measures under the INECP for Greece. While the case studies follow a similar structure, it is noted that for the case studies for Greece and Austria modelling capacity has been available (as part of other CARISMA work) so that system- and macro-level economic and welfare impacts of technology scaling up could be quantified. Life-cycle emissions and social impact analysis for the technology options in these case studies have been done through literature review. The Dutch case study has been based largely on qualitative analysis with active consultation of stakeholders in the solar PV sector. For some quantitative impacts of technology diffusion, a simpler modelling exercise was carried out. For the Dutch case study, collaboration has been sought with the Horizon 2020 project TRANSrisk, in terms of stakeholder consultation and data gathering.

Box 1. Explanations of factors analysed in the case studies in this paper

System- and economy-wide implications of scaling up technologies for mitigation

When discussing the costs of electricity, and particularly when comparing different types of electricity generation to each other for planning or projection purposes, the direct costs of investment, operations and maintenance, and fuel are typically used as a starting point by policy makers. These are the so-called levelized cost of electricity. This indicator represents a relatively easy way for stakeholders to assess what each unit of electricity would need to cost to repay investments, maintain the plant, and if needed, pay for fuel. Scaling up a technology to *n* applications within a country implies that these costs will have to be borne *n* times. However, that is not the full picture. Multiple applications of, for example, a renewable energy intermittent technology will require additional investments in, e.g., grid balancing and system integration activities.

System integration costs arise after production of electricity at a generation site, when that power is supplied to the larger grid. Often these costs are not sufficiently considered in economic assessment of renewables. They include for example:

- balancing costs which accrue due to deviation from day-ahead planned generation schedules or
- grid-related costs that are the reduction in market value due to the location of generation in the power grid, essentially, the marginal costs of transmission losses or limitations.

Bachner, Tuerk, Williges & Steiniger (2017) included these cost items in their macroeconomic assessment of economy-wide implications of scaling up renewable energy technologies, done in the CARISMA project.

For policy makers, it is important to have a comprehensive picture of cost impacts of scaling up mitigation technologies within a country. The direct costs of generating electricity are not sufficient to compare renewables with fossil fuel options. An economy-wide perspective must be used to capture the economic challenges of power sector transformation since the introduction or expansion of certain technologies can lead to unexpected consequences for other economic agents and sectors, expressed as changes of macroeconomic indicators such as regional gross domestic product (GDP), welfare, or employment.

Climate effectiveness of mitigation technologies in different Member States

With help of the indicator Carbon Payback Time (CPT), it can be determined how soon a technology's life-cycle emissions are offset by its contribution to GHG emission reduction (Loriaux, et al., forthcoming). For example, the lowest CPTs have been found for wind farms located offshore and near the coast, while it takes more time for wind power plants to recover their own life-cycle emissions when built onshore (Abeliotis, 2014). The large difference between on- and offshore sites is caused by offshore wind turbines being taller (than onshore turbines) so that they can endure stronger wind speeds. In Europe, lowest CPTs for wind power are found in the UK, north of Germany and other countries along the coast of the North Sea. Highest CPTs for wind power are found further inland, in southern Germany, parts of Austria and France in regions with low average annual wind speed.

Social implications of scaling up technologies for mitigation

For scaling up technologies options for mitigation, it is important that these are suitable with existing social structures and can thus be accepted by the public. This can be an important aspect for determining the scale at which a technology option can be realistically implemented in the country (Hagens, Koretsky, & Toemen, forthcoming).

Public acceptance is generally complex as there are many different actors who may have different preferences and behaviour in different countries and different circumstance (Hagens, Koretsky, & Toemen, forthcoming). There have been attempts to monetize public acceptance by asking actors, for example, how much they would be willing to pay for preservation of a certain piece of land (e.g., IPCC (2007), Atkinson et al. (1997), Baumgärtner (2015)). However, in many cases such social implications (or performance) are not easily captured by quantified assessments (by, e.g., financial gain/loss). Additionally, social implications (or performance) are context-specific and difficult to translate into standardised (monetized) overviews or manuals.

Nevertheless, understanding the extent to which people (and their elected representatives) accept a technology option (or resist to it) is an important step for determining the practically feasible scale of technology implementation within a country. For example, should, based on economically feasible system- and macro-level costs and technically favourable CPTs, areas within a country be identified for economically and technically feasible implementation of the technology, public resistance to the technology would reduce this potential to what is realistic, given people's acceptance of the technology.

5 Case study 1: Greece

5.1 Introduction

Greece was selected as a case study due to its economic situation and energy mix. For several years, Greece has been in recession and under credit crunch conditions, with high interest rates and high costs of capital. It additionally is characterized by a high share of fossil fuels (over 80%) in its electricity mix, with most of total primary energy supply consisting of oil and coal production. Over 12% of primary energy supply (31% of electricity generation) was derived from renewables in 2016, due to mainly wind and solar PV. In terms of energy efficiency, While the country has seen a drop in energy consumption, due mainly to the economic and financial crises beginning in 2008, it is not projected to meet the goals of the EU Energy Efficiency Directive by 2020 (IEA, 2017). Greece would likely encounter similar roadblocks to meeting the Winter Package goal of increasing energy efficiency as well.

In line with the issues that countries face relating to the INECPs, as discussed in Section 2, we discuss below how increasing the share of renewables in electricity generation would affect the larger economy, focusing on the impacts to other sectors and changes in the labour market and capital rents, emphasizing the effect of system costs on projected results. We then discuss the challenge of choosing locations and types of renewable energy sources to scale up in terms of life-cycle accounting and carbon payback times. Finally, we discuss issues of public acceptance or resistance to such possible policies, followed by an assessment of possible trade-offs, conflicts, and synergies which arise for each technology, given the different strands of analysis presented, as well as synergies or trade-offs between technologies.

5.2 Economic effects of large-scale renewable energy technology deployment

As described in greater detail in Bachner, Tuerk, Williges & Steiniger (2017), large-scale renewable electricity deployment in Greece was analysed in an EU-wide Computable General Equilibrium (CGE) modelling framework, assessing large-scale wind and solar PV deployment. For wind power expansion, Bachner, Tuerk, Williges & Steiniger (2017) assumed Greece would see an additional renewable energy capacity of 9.83 GW by 2030, leading to an overall share of 35% of total electricity generation. The weighted average cost of capital (WACC), comprised of the costs of debt and equity, is assumed to be higher for Greece than for other EU regions, at 12% in a high scenario, and 5.23% (equal WACC for all regions) in a low scenario.

In comparison to the wind power deployment scenario, the new solar PV capacity scenario would add 36.4 GW of capacity. This would result in 54.06 TWh of additional supply, and a solar PV share of 91% of total electricity generation by 2030. This work provides insights into effects on the electricity market, other sectors, and the broader economy in terms of:

- the costs of labour and capital,
- potential changes in employment, and
- overall welfare.

Of note is the inclusion of system costs. This is an attempt to better quantify the effects of large-scale renewable energy source build up by estimating:

- the additional costs incurred to the larger energy grid due to uncertainty of supply,
- lack of dispatchability, and
- the mismatch between supply and demand requirements, particularly in case of renewable sources.

Electricity sector effects

Results show that while **wind generation** would be competitive by 2030 for most of Europe under a large-expansion scenario, the high WACC for Greece, combined with the inclusion of system costs, would lead to wind being non-competitive for the country. The cost of the current electricity mix is estimated to be just over 0.08€/kWh, while the price of wind power in a 2030 scenario with system costs would be over 0.09€/kWh. This high cost is due not only to high WACC, but also to a relatively low capacity factor of 24%, compared to, e.g., Northern and Western Europe with 30 and 29% respectively. The latter means that capacity is used less efficiently, thus the cost for one kW is higher.

With system costs included, the market price for electricity in 2030 would rise by 1 cent, to 0.09€/kWh. This is driven by the high costs of capital in Greece and the 'utilisation effect'.[3] However, a low-WACC scenario (representing a potential de-risking of investment) could result in generation costs falling to competitive levels.

The results change for the **solar PV expansion scenario**, which is much larger in terms of final share of the total electricity supply. Even with Greece still assumed to have a high WACC, solar PV is estimated to be highly competitive. In a high WACC scenario and including system costs, electricity from PV would still be over 0.015€/kWh cheaper than in the current situation. It should be noted here that the scenario assumptions are more indicative of large-scale installations, and costs may increase if, as discussed in the section on social implications below, a more rooftop-solar-oriented build-up of PV is undertaken.

In terms of impacts on the resulting electricity prices when wind is expanded, the market price of electricity is pushed up, since the levelized costs of electricity (LCOE, see Box 1) are higher compared to those of the conventional regional mix. In this case, renewables are hamstrung by a high WACC leading to a high LCOE and a generation cost disadvantage (a cost ratio of wind/conventional of 1.12). However, this cost disadvantage disappears in the PV scenario, with the estimated market price falling by an estimated 10% compared to the original.

Effects of high renewable energy build-up on other sectors

As can be imagined, large increases in renewable energy could have follow-on effects to the activity and prices of other sectors' goods, even beyond closely related sectors such as mining and fuel production. For the **wind scenario** in Greece, the sectors concerned with extraction of natural gas and mining of coal would be most drastically affected, with activity

[3] The utilisation effect is the portion of system costs that arise due to the lower rate of use of existing generation capacity (e.g., oil and coal required as a backup), leading to higher costs of generation.

in those sectors dropping an estimated 28 and 35 percent, respectively. The increasing cost of electricity would also lead to reduced consumption of electricity goods, reducing electricity sector output by just over 1%. Impacts on other sectors (e.g., technology industries, food and textiles, services) are minimal (i.e. far below 1%) except for the iron and steel sector, which would face a reduction in domestic production of 2%.

For a build-up of **solar PV**, effects on the previously listed sectors are more severe, as PV replaces more of the original energy mix. Gas and coal sector activity levels would fall 39 and 55% respectively, with only a very slight impact (-0.9%) on the production of electricity. As the price of electricity falls in this scenario, effects on other sectors mainly switch sign (i.e. they increase output) but the size of such an effect is consistently less than half a percent. The exception is the technology industry sector which would benefit from lower electricity prices and increase domestic production by 2.5%.

Macro-economic impacts

In terms of effects on the rest of the Greek economy, market effects can be seen in the form of **prices of labour and capital**. With the expansion of renewables, the demand for capital increases, raising prices, while the labour price decreases, as there is less demand (see Figure 1). While higher capital rents and lower wages are seen in all regions, the strongest effects emerge in Greece, with up to +9% capital rent increases and reductions in wages for unskilled labour of up to -7%.

The relatively strong magnitude of effects in Greece is because of a higher capital cost share (due to high WACC) and due to ambitious renewable technology penetration targets. When comparing across technologies, we see that PV triggers stronger effects since it is even more capital intensive than wind:

- In the PV expansion case, capital rents increase by up to +9% and wages decline by up to -7%;
- In the wind expansion case, the maximum increase in capital rent is +3% and the strongest decline in wage is -3%.

We also observe that when system integration costs are included, the effects on factor prices are slightly stronger, since the utilization effect additionally drives up capital prices. Also, grid-related costs are associated with higher capital demand and thus higher prices.

While Bachner, Tuerk, Williges & Steiniger (2017) estimate that economy-wide effects (in terms of gross domestic production, GDP) would be positive for Greece for both technology expansion scenarios, **welfare** would only see a positive change in the PV scenario. This is because the inclusion of integration costs results in a negative effect on welfare in the wind scenario. However, if Greece could lower its WACC, this would result in an eventual positive welfare effect for both the PV and wind expansion scenarios.

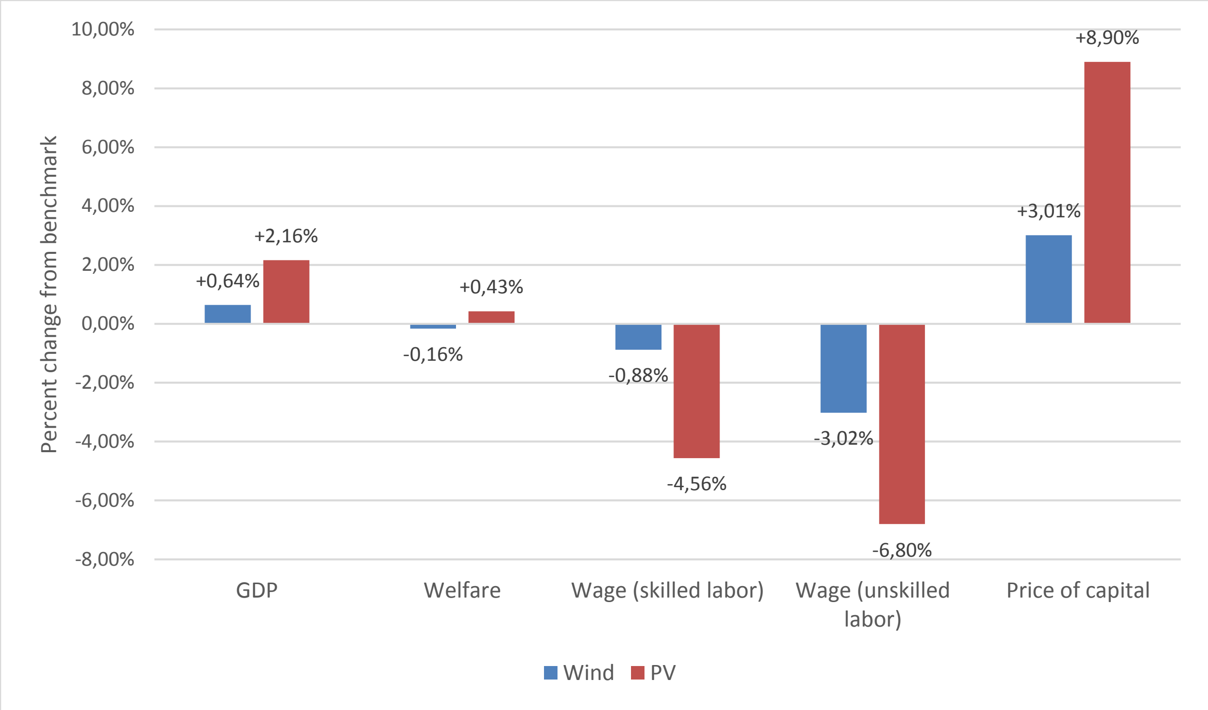

Figure 1. Macroeconomic effects of large-scale expansion of renewables (wind or solar PV) for Greece

5.3 Climate-effectiveness of mitigation technologies: carbon payback times

Loriaux et al. (forthcoming) do not provide country-specific carbon payback times (CPT) estimates for Greece for wind power. However, other attempts have been made in the literature, with an estimated CPT of seven months for Greece from Abeliotis and Pactiti (2014). This falls well within the range of estimates for wind turbines in Northwest Europe as described in Loriaux et al. (forthcoming) and other estimates from the literature.

The potential CPT for solar PV is estimated in Loriaux et al. (forthcoming). As Greece has relatively high solar insolation, PV capacity factors are higher than elsewhere in Europe. This leads to relatively short payback times: 1.62 years for Greece, compared to, e.g., Austria (9.64), Germany (3.54) and progressively higher CPTs as latitude increases. However, there are some caveats to this analysis. First, it pertains mainly to larger installations, with a reference plant of 570 kW, employing over 4,000 square meters of panels. Second, it has been shown that high PV module temperatures in warmer climates limit their efficiency somewhat, with a comparative study between Germany and Cyprus showing a performance decrease of 4% in the southern country. Thus, any estimate of CPT for smaller-scale PV generation in Greece (e.g., rooftop solar) may be higher than the results in Loriaux et al. (forthcoming), and might rather be a lower bound or first-order estimate awaiting further investigation.

5.4 Social aspects of upscaling renewables in Greece

While Greece was not mentioned explicitly in Hagens, Koretsky & Toemen (forthcoming) pertaining to social issues, there is an ample literature particularly dealing with social acceptance and public opinion of wind power in the country. Previous work has shown that the public is by and large familiar with wind energy and the potential benefits: 78% of the population perceives wind energy as beneficial; almost two-thirds of the population supports existing wind infrastructure (Kaldellis, Kapsali, Kaldelli, & Katsanou, 2013).

Nevertheless, a huge gap appears in terms of support of *future* wind development, with only 35% of the population in favour, and 21% finding them aesthetically displeasing. Further work highlighted that residents in areas with wind turbines generally supported expansion of wind energy capacity, but not in their own region (Kontogianni, Tourkolias, Skourtos, & Damigos, 2014), possibly due to fears of negative impacts on tourism (Dimitropoulos & Kontoleon, 2009) or just a Not-In-My-Backyard (NIMBY) response to wind power.

Comparatively, public opinion for expansion of solar PV installation is generally seen as more positive than for wind (Smardon & Pasqualetti, 2017). A survey showed that 94% of respondents in the country were in favour of PV parks. Over half of respondents indicated that there were no visual impacts from such installations, and 22% stating that they were an annoyance (Kaldellis, Kapsali, & Katsanou, 2012).

Social aspects also play a role in the winter package objective to increase energy efficiency. As mentioned, Greece is likely to fail to meet its energy efficiency target for 2020, unless drastic changes are made. The country has put forward initiatives to address efficiency, particularly in buildings (Fujiwara, Williges, & Tuerk, 2017), but several contextual factors relating to public support, awareness, and capacity inhibit policy success. In general, energy services and construction sectors are ill-equipped to participate in initiatives to reduce energy consumption via, e.g., smart technologies. The existing workforce for promoting and installing such smart tech is viewed as low by Greek stakeholders, necessitating increased training and certification. A lack of incentives for funding household investment in energy efficiency, as well as a lack of awareness at a local level regarding funding opportunities, further limits the success of such policies.

5.5 Conclusions

The Greek case study illustrates some of the challenges discussed for the upcoming INECPs, and the need to perform broader assessments which consider how changes to the energy system could affect the country more broadly, from economic to social aspects. It also highlights the complementarity of results from the various strands of research.

When considering the economic effects, wind power expansion, under pessimistic assumptions (high interest rates), would not be competitive by 2030 compared to other energy technologies. Moreover, it would raise the market price for electricity, increase capital rents, lower wages and lower welfare by almost 0.2%. The economic potential for solar PV, however, is very high as the option is highly competitive, at over 1.5 €cents cheaper than current electricity. Effects of scaling up solar PV on capital rents and wages would be much larger than for wind (e.g., +9% and -7% respectively) and could produce positive welfare effects between 0.4% and 1.8%.

Finally, while majorities of survey respondents from multiple studies support existing wind installations, a significant NIMBY effect exists in the country in relation to new installations, pertaining to worries about effects on tourism. With respect to solar PV, a clear majority of survey respondents (94%) are in favour of solar PV and have less negative feelings towards solar PV parks as compared to wind power farms.

In other words, the potential net contribution of large-scale wind power implementation in Greece to GHG emission reduction (which, in terms of CPT, is comparable to elsewhere in Europe) is significantly reduced because of unfavourable economic impacts (such as negative economy-wide effects) and public resistance to building wind farms by local communities. Solar PV, on the other hand, has a potentially strong contribution to net GHG emission reduction (given the relatively low CPT), which is supported by positive economy-wide effects of scaling up the technology, and a generally positive public attitude towards large-scale solar PV. The main reason for this is that Solar PV investments are viewed as having a strong local involvement, while wind turbine parks have always been regarded as investments of big companies with no ties to the local communities

This would then appear to be a beneficial alignment of social opinion and economic projection, favouring solar PV rather than wind. Due to its southern, coastal locale, the country would likely benefit from some of the shortest CPTs in the EU in either case, although results may change slightly if policy aims for rooftop PV instead of larger-scale installations. However, as the Greek case of energy efficiency has demonstrated, social contextual factors outside of public opinion on wind versus solar PV, such as the ability and knowledge of private actors, communication of policies and incentive mechanisms, etc., all play a large role in policy success or failures and should be considered in the planning process.

6 Case study 2: Austria

6.1 Introduction

In comparison to the Greek case study described above, Austria was selected to provide an example of a country with:

- a high renewable share of total electricity generation, which as a result
- has enabled the country to be on track to meet or exceed its EU energy and climate mitigation targets.

Hydropower has long held the lion's share in terms of electricity production. In 2013, 67% of all domestic production originated from hydropower plants, with a further 7% from biofuel plants, 5% from wind, and less than 1% from solar PV. In total, the renewables share of electricity production stood at 79% (Energie-Control Austria, 2014). The residual is produced by fossil fuel sources, e.g., natural gas and coal.

Beyond the electricity sector, Austria has low interest rates, which again is a juxtaposition to the Greek case, with weighted average costs of capital (WACC) estimated at 6.5%. However, while Austria and Greece differ in terms of finances and electricity generation, they have similarly struggled to meet energy efficiency targets. Austria implemented legislation which, while successful, did not substantially contribute to meeting goals.

The Austrian case is meant to highlight how a country which, at the outset, would appear to be well on its way to meeting energy and climate goals, may encounter issues related to designing and implementing an INECP, as discussed in Section 2. We again begin with a similar economic assessment as was carried out for Greece and follow with a discussion on carbon payback time and social implications of scaling up technology options for mitigation.

6.2 Economic effects of large-scale renewable energy deployment

As part of the CARISMA project, Bachner, Tuerk, Williges & Steiniger (2017) assessed large-scale wind and solar PV deployment in the EU, thereby singling out Austria. They highlighted the different economic effects of such deployment with different renewables targets. For the **wind power scenario**, developed based on projections to 2030 by the European Wind Energy Association (EWEA, 2015), Austria would deploy an additional 6.29 GW of wind power (added to the current estimated 2.1 GW). This corresponds to an additional electricity supply of 13.22 TWh, leading to a final share in total electricity generation of 20%. This increase would require an estimated €6.98 billion in investment costs, including grid-related costs. For an **expansion of solar PV** with a target of 38% of the total electricity generation (an additional 21.71 GW, leading to 25.03 TWh of electricity supply), €9.84 billion would be required.

Electricity market effects

Similar to the Greek case, the inclusion of system integration costs related to **wind power expansion** would result in a cost increase of almost 0.0075€/kWh compared to the current electricity mix. This would result in an increase in the market price for electricity in Austria. However, the reasons for the price increase are different than in the Greek case. While Greece suffers from a high weighted average cost of capital (WACC), Austria currently has a rather low levelized cost of electricity (LCOE) for its electricity mix in absolute terms (0.06€/kWh). This is because of a very high share of hydropower in Austria, making it difficult for wind to compete (the cost ratio for wind/conventional is 1.11). However, sufficiently lowering WACC due to de-risking of investments would (as was the case in Greece) again lead to wind LCOE being lower than the conventional mix, but only if system integration costs are not factored into the analysis.

In comparison to wind power, the **solar PV expansion** scenario would result in competitive PV in the country, with an LCOE of about one tenth of a cent lower than the current electricity mix. However, in terms of economy-wide effects and the market price of electricity, the eventual price would still be higher in 2030 than the current benchmark estimate, by about 1%. This is again due to the current LCOE being relatively low, again producing an unfavourable cost ratio between PV and conventional generation.

Effects on other sectors in Austria

The effects of drastic increases in **wind power** production in the country are predicted to be much less pronounced than in Greece. Having no extensive domestic coal mining or natural gas extraction, immediate effects on this sector are non-existent. However, sectors are affected by a decrease in the production of electricity (sector activity falls 7%) and corresponding increase in price (rising 2.2%).

This price effect does not lead to any significant shift in sector outputs or prices, with the largest effect being foreseen on the iron and steel sector, reducing its output by a mere 0.7%. All other sectoral effects are below this in magnitude. Some effects can be seen on international trade, with the activity level of coal and natural gas imports falling 6.5 and 4.3%, with prices that fall by 7.4 and 2.3% respectively. This is likely due to decreased use of coal and natural gas both domestically and abroad, as the study scenarios were carried out for the entire EU.

The outlook is similar for a case of **solar PV expansion**: electricity sector activity falls (by 6.8%) and the price of electricity rises (by 2.5%). Sectoral effects, again, are insignificant, with the iron and steel sector experiencing the largest decrease in activity, at 0.95%. The activity levels of imports of coal and natural gas both fall (9.7 and 6.6% respectively) and at lower prices, with sector prices dropping 10% (coal) and 2.3% (gas).

Macroeconomic effects in Austria

While both the wind power and solar PV scenarios would increase capital rents (by 0.75 and 2.2% respectively) and reduce labour wages (~0.5 and ~1.25% respectively), the eventual effects on GDP are again positive for the country (see Figure 2). However, with a scenario of high WACC and system integration costs, overall welfare is projected to decrease, albeit minimally (~0.1%) in both scenarios, as neither technology can compete with the conventional mix. Even lowering WACC via de-risking would not produce positive welfare effects. Only when the assumption of a boom economy is relaxed (e.g., assuming a recession economy), positive welfare effects may occur, mainly for solar PV, which could hypothetically see a 0.175% increase in welfare.

This is due to two effects:

1. The utilisation effect, as described in Bachner, Tuerk, Williges & Steiniger (2017), drives up generation costs for conventional power plants in the system, thus increasing the overall price of electricity.
2. The relatively high capital intensity of the new technologies being expanded (particularly solar PV), which leads to higher capital prices and thus higher generation costs.

The Austrian case demonstrates that at high penetration rates of renewables, the macroeconomic feedback effects can significantly increase electricity generation costs.

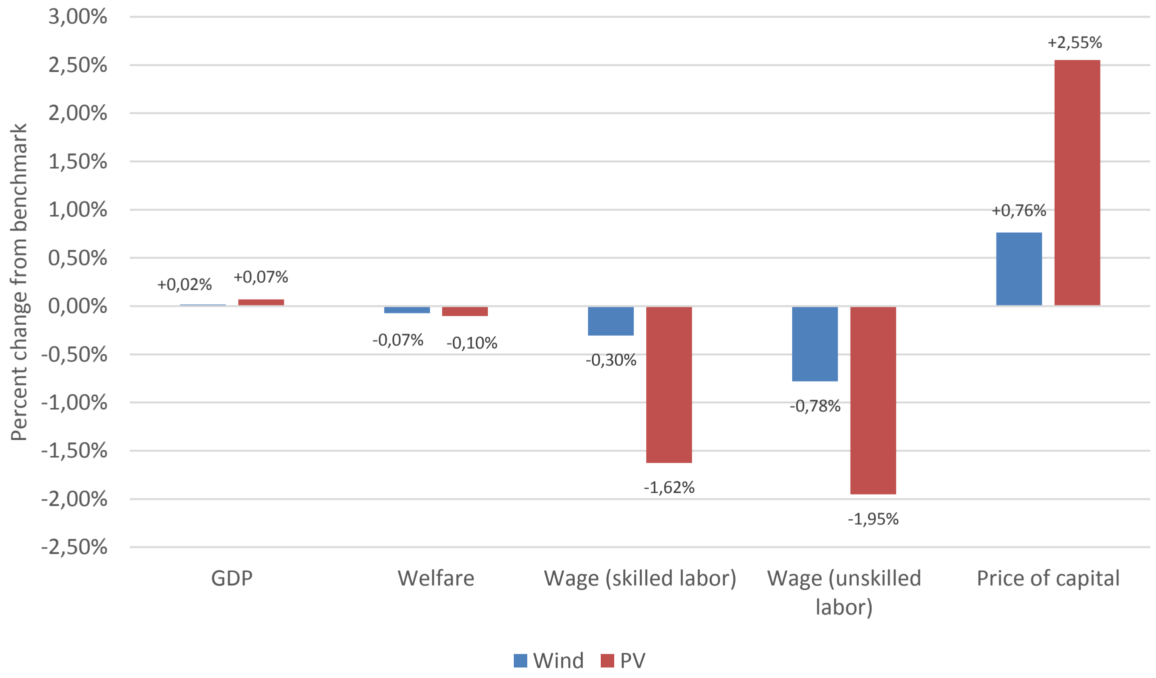

Figure 2. Macroeconomic effects of large-scale expansion of renewables (wind power or solar PV) for Austria

6.3 Climate-effectiveness of mitigation technologies: carbon payback times

As the work in CARISMA on carbon payback times (CPT) for **wind power** was on North-western Europe, Austria was not part of the study (Loriaux, et al., forthcoming). Additionally, literature review of relevant life cycle assessments did not find any contemporary studies of country- or region-specific CPTs for Austria. However, comparing wind climatology for Austria versus the study area of Loriaux et al. (forthcoming), using the Global Wind Atlas (DTU Wind Energy, 2017), indicates less favourable wind conditions for most of the country.

While the regions in Loriaux et al. (forthcoming) consistently see mean wind speeds of 6 m/s and above (especially offshore wind, with averages of mainly 9 m/s or higher), Austria is comparatively wind-poor, with:

- average wind speeds of 6 m/s and below, especially in the more mountainous regions of the country, and
- a power density (depicted as W/m^2) of 350 W/m^2 or less.[4]

While no concrete estimates can be derived as to the actual CPT for the country, wind turbines in Austria can be assumed to have substantially higher CPTs than those found for the region of North-western Europe (Loriaux, et al., forthcoming).[5]

In the CARISMA project, for Austria a CPT for **solar PV** was estimated of 9.64 years. Austria's very high hydropower capacity results in its electricity grid's carbon footprint being relatively low (0.21 kg CO_2/kWh), which raises the country-specific CPT.[6] Additionally, Austria is situated in a more northerly latitude than Greece, thus high temperatures possibly limiting PV module efficiency are not anticipated as a concern. In Greece this may contribute to a (albeit small) lengthening of CPTs for solar PV.

6.4 Social implications of renewables options in Austria

Austria by-and-large did not experience great difficulty in terms of social acceptance of renewables in the past. The country has an extremely high portion of electricity from hydropower (76% in 2015) and has already met its goal of 34% renewables in the energy system set via the EU Renewable Energy Directive (Nachmany, et al., 2015). However, further expansion of hydropower has started to target ecologically sensitive areas with increasing public resistance (Fruhmann, Tuerk, Kulmer, & Gubina, 2018). Walter & Gutscher (2010) carried out stakeholder interviews with renewable energy operators and developers and highlighted frequent and early public interaction as a key factor in dealing with and solving public opposition to renewables development. This, in addition to political support at all levels of government, is viewed as the reason for Austria's success in diffusion of renewable energy resources.

A counter example to the successful development of renewable energy sources as discussed above is Austria's relative lack of success at introducing demand-side measures to reduce emissions, namely in the building sector. While renewable energy sources enjoy broad support across all political levels, the structure and division of responsibilities of Austria's national and state-level authorities (building policies are decentralized, with

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[4] In most of the country the power density is below 200 W/m^2, dropping further in mountain areas. for the study area in Loriaux et al. (forthcoming), with estimates for the region being predominately 350 W/m^2 and above

[5] This assumption can be made because wind speed is of vastly greater importance for the CPT than other factors (Loriaux, et al., forthcoming).

[6] Due to the low carbon intensity of Austria's energy market (large hydro-power share), more time is needed in Austria for Solar PV's emission reduction to be large enough to outweigh the technology's life-cycle emissions, see also Box 1.

responsibilities mostly falling to regional governments) led to provinces failing to meet EU requirements on building energy performance (Steurer, Casado-Asensio, & Clar, 2016).

6.5 Conclusions

While sectoral effects would be minimal, expanding wind power would raise market prices for electricity, increase capital rents, and reduce wages, unless weighted costs of capital could be sufficiently lowered. Welfare would be expected to decrease under a wide range of assumptions. Solar PV expansion could achieve lower costs than current electricity LCOE, but eventual market prices for electricity in 2030 would still be increased, compared to today's prices. The high current renewables share, plus the utilisation effect, makes it unlikely that build-up of PV has a positive effect on prices of electricity or welfare.

In terms of net contribution to GHG emission reduction, scaling up wind power in Austria is expected to have a relatively small potential. The CPT for solar is 9.64 years, which is relatively high due to the quite low carbon footprint of the Austrian electricity sector. Thus, scaling up wind power and solar PV has a relatively low net additional GHG emission reduction potential in Austria.

Finally, from a social perspective, there is little mention of opposition to further renewables deployment, based on the broad support for renewable energy sources in government and given the early involvement of the community in planning processes.

As presented, the Austrian case highlights that while country starting-points may be vastly different in terms of costs of capital and renewables generation, macroeconomic effects can be of the same sign and magnitude as in a country like Greece (see Section 5), with both countries expected to experience:

- rising costs of capital,
- falling price of labour (e.g., skilled and unskilled labour), and
- likely minimal positive or even negative projected welfare impacts.

Again, similarly to Greece, Austria has encountered problems enacting energy efficiency legislation and meeting energy efficiency targets, due to blocking by contextual factors.

In a juxtaposition to the previous case (of Greece), one approach does not emerge as a front-runner in terms of likely positive welfare effects, public support, and beneficial GPT, as was the case of PV in Greece. The potential in Austria for further expansion of renewable energy is mainly limited to the already existing large share of hydropower in the electricity mix.[7] Social resistance is less important in terms of restricting wind and solar power potentials, but of key interest to the challenges faced when producing the INECP is the issue of energy efficiency. The broader contextual factors potentially influencing efforts to reduce energy use require further investigation to support the development and success of new energy efficiency policies.

[7] Which reduces the scope for further net GHG emission reduction and increases higher-level economic costs, such as electricity price increases and negative welfare effects.

7 Case study 3: Expanding Solar PV in the Netherlands

7.1 Introduction

In this case study, aspects related to the upscaling of renewable energy technologies in the Netherlands are discussed. By 2020, as included in the EU Energy and Climate Package of 2008 (European Commission, 2008), 14% of all energy consumed in the country must be produced from renewable energy sources. According to the 'Renewable Energy Progress Report' (European Commission, 2017b), however, in 2015 only 5.8% of energy consumption was based on renewable energy production. During 2016, the share of renewable energy in overall energy sources used hardly grew, to only 5.9% (CBS, 2017). Most Dutch energy is produced from oil, natural gas and coal. Figure 3 shows the Dutch renewable energy share from 2014 through the first quarter of 2017 (EnTranCe, April 2017).

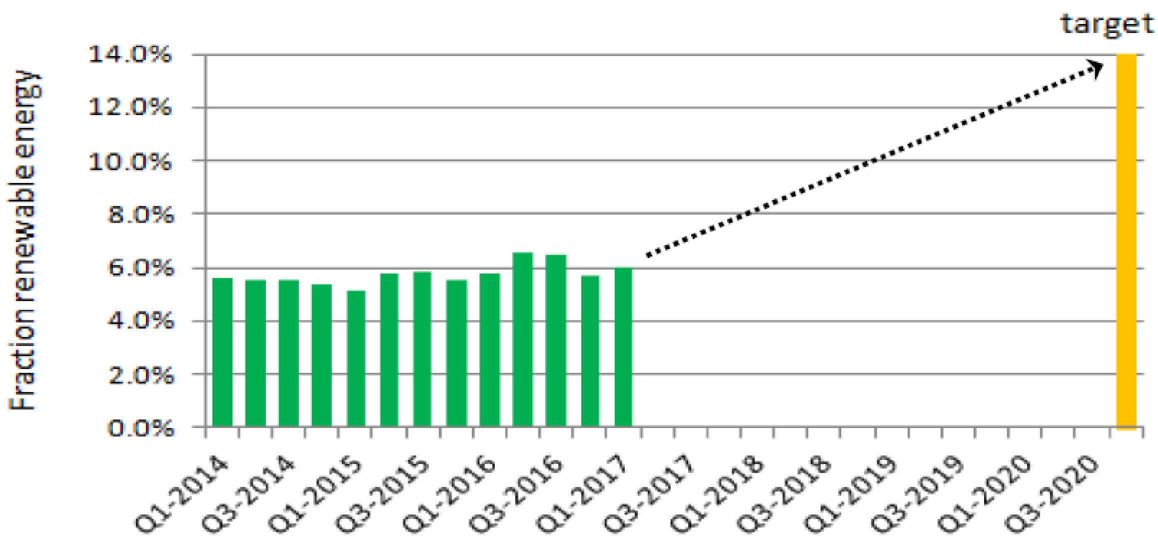

Figure 3. Share of renewable energy in overall energy production (EnTranCe, April 2017)

Considering the gap between the realised and required renewable energy share, the Netherlands Court of Audit has concluded that compliance with the 14% commitment in 2020 (as well as with renewable energy goals in 2023) is getting out of sight (Netherlands Court of Audit, 2015). In the national energy report of 2015 (Schoots & Hammingh, 2015), it is estimated that the realised renewable energy share in 2020 will amount to 11.9%, which is 2.1%-pts below the 14% commitment. The European Commission has estimated, based on 2014-2015 data and keeping in mind current and planned policies, the renewable energy share in the Netherlands for 2020 at 13% (European Commission, 2017b).[8]

[8] An explanation for the difference between both findings is that the European Commission's analysis includes the estimated effects of an additional package of measures to accelerate renewable energy

Most of the current renewable energy produced in the Netherlands originates from biomass (63%), followed by wind energy (24%, of which 17.4% onshore wind plants), solar energy (5.4%, both electricity and heat), geothermal energy (5.4%) and outside air energy (2.1%). The share of hydro energy in the Netherlands is very small (0.3%) (CBS, 2017).

In October 2017, the new Cabinet of Ministers (Rutte III) announced that the new energy and climate plan of the Netherlands (forming the basis for the INECP) should be based on a goal to reduce GHG emissions by 49% by 2030 (compared to 1990 emission levels). This goal forms an intermediary target towards a 95% GHG emission reduction by 2050. The 49% goal implies a reduction below baseline emissions of 26% by 2030 (44 Mt CO_2-eq.) (PBL, with ECN, 2017). Most of the additional emission reduction below the baseline is expected to be realised by carbon capture and storage (CCS) (18 Mt), followed by closure of all existing coal plants by 2030 (8Mt), and energy efficiency improvements in the built environment sector (5 Mt).

Additional emission reductions from wind and solar energy are not foreseen in the new Cabinet's energy and climate plan, as these are already covered by existing policies, such as policies to comply with the energy and climate package for 2020 and the 'intensiveringspakket' for increased renewable energy by 2023 (Netherlands Ministry of Economic Affairs, 2016). Nevertheless, the challenges to scale up the production of these two sources in the Netherlands, for reaching the goals for 2020 and 2023 remain large (PBL, 2017).

An important factor in the Netherlands for slowing down onshore wind power capacity growth has been local resistance to wind farms. In a survey by De Boer and Zuidema (2013), the needs of citizens, local initiatives, stakeholder interests and other local economic functions have often been overlooked in the planning.[9] No direct revenues from the wind farms accrued to the local population, so that they felt being left with the negative effects, such as "visibility, noise and the intermittent shade of the wind turbines" (De Boer & Zuidema, 2013, p. 5). As initially only land owners were involved in the planning process, resistance to the plans evolved from the wider local community during public hearings. From the survey, it became clear that the local population did not resist wind energy per se, but some respondents indicated that it is not fair that farmers receive financial compensation for the solar projects, while other people do not get compensation while they must live with the change in their environment.

Nevertheless, wind energy has received a lot of attention in Dutch policies and has been included in the Dutch sustainable energy support programme (SDE+). This is largely due to the relatively large wind energy resources in the Netherlands, onshore, but especially offshore.

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uptake ('intensiveringspakket') (Netherlands Ministry of Economic Affairs, 2016). At the same time, the Commission's estimate was done before publications by the Netherlands Enterprise Agency (RVO) in June 2017 showing that it will be unlikely that the Netherlands will reach the target of 6,000 MW of installed wind power capacity onshore, which had been set for 2020. Around 1,000 MW of planned capacity is in 'critical state' (Netherlands Enterprise Agency, 2017a, p. 7).

[9] The survey was held among the population in the *Veenkoloniën* area of Groningen and Drenthe provinces in the Netherlands, where the government had planned 700 MW of installed onshore wind power capacity, over 10% of the country's total planned onshore capacity.

For solar PV, energy resources in the Netherlands are (much) less than for wind, yet it cannot be ignored given the country's struggle with reaching renewable energy and climate goals. Therefore, in this case study, the focus will be on impacts of scaling up solar electricity in the Netherlands both via small-scale rooftop solar PV and larger-scale solar parks. While rooftop application has been growing in the recent past, solar parks, especially ground-mounted projects, are still rare in the country. Through this case study, insights will be gained on cost implications of scaling up solar PV and potential social implications of that and how this could lead to public resistance to, mainly, ground-mounted parks.

7.2 The case of solar renewable electricity in the Netherlands

In 2015, solar-based electricity contributed 1%-point to Dutch electricity production (CBS, 2016). About 70% of the solar power is generated through rooftop panels by households,[10] 28% by businesses and only 2% by large-scale projects (e.g., ground-mounted solar PV). The National Solar Power Action Plan for 2016 (DNV GL, 2016) sets a goal of 4 GW_p installed solar PV capacity by 2020 (currently, this amounts to 2 GW_p). With a view to the longer term, two pathways have been estimated by the Action Plan:

- A slow-growth pathway that is mainly based on utilising rooftop potential of households and businesses, but also based on ground-mounted solar PV, could lead to an installed capacity of solar PV of 15 GW_p by 2030.
- A fast-growth pathway with intensive utilisation of ground-mounted solar PV capacity in the Netherlands (next to the use of rooftop PV capacity), could lead to an installed capacity of 30 GW_p by 2030.

In other words, more intensive utilisation of ground-mounted solar PV doubles the country's solar electricity capacity (DNV GL, 2016). As mentioned above, ground-mounted solar parks have been scarce in the Netherlands.[11] In order to stimulate development of this technology option, ground-mounted solar projects[12] have become eligible for funding under the Dutch sustainable energy feed-in tariff scheme SDE+.[13]

For this case study, an extensive stakeholder consultation has been carried out by interviewing 20 stakeholders from different professional backgrounds. This consultation has taken place in the context of the EU-funded project TRANSrisk[14], which contains a set of case studies on risks and uncertainties related to low-emission pathways. For this report, stakeholder interview transcripts as prepared by TRANSrisk, have been consulted. In addition, a wider stakeholder survey, through an online questionnaire, has been carried out by TRANSrisk in different regions where ground-mounted solar parks could be in the Netherlands. The results of this survey are also discussed in this case study.

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[10] In 2015, 450,000 residential dwellings in the Netherlands were equipped with solar panels, out of 4 million potentially suitable dwellings (which is around half of all dwellings) (CBS, 2016).
[11] The largest solar park, Sunport Delfzijl, launched in 2017 is situated in the north of the Netherlands with an installed capacity of 30 MWp.
[12] Within the category of large-scale solar PV projects with a capacity equal or larger than 15 kWp; also large-scale rooftop solar PV projects could belong to this category.
[13] SDE+ is a feed-in subsidy scheme to stimulate the production of energy in the Netherlands by compensating the difference between the cost prices of renewable and fossil energy.
[14] www.TRANSrisk.eu funded under the EU Horizon 2020 programme.

7.3 Economic effects of solar PV expansion in the Netherlands

Expanding solar PV technology for electricity will have several cost implications. At the level of a household, these costs relate to the purchase of rooftop solar PV panels, including the installation. At the level of a ground-mounted solar park, next to the purchase and installation of the panels, also costs need to be made for establishing connection to the grid. In Table 1, these costs are summarised for an installed capacity of 3000 kWh (= one house with twelve panels) and compared with the costs of a larger solar park.

Table 1. key figures small and large-scale PV projects*

	Rooftop panels (3000 kWh/year)	**Large-scale solar project[15] (10 MW installed capacity)**
Investment (€/kWh) (EPC)**	1.5	0.79
Land costs (€/ha)		5,000
Operation and maintenance costs (€/kWh)	0.042	0.008
Grid connection costs fixed (€) (assuming a 10 MW solar park), excl. VAT		260,000
Grid connection costs based on distance (€/meter, assuming a 10 MW solar park), excl. value-added tax (VAT)***		182
Financial incentive	Net-metering	SDE+ subsidy
VAT refund (€)	750	
SDE+ subsidy (€/kWh)		0.125

* normalised for 1 household with 12 panels
** EPC costs = engineering, procurement and construction
*** In this table, possibly required grid expansion or enhancement costs are not included, as these are usually not included in the business cases for solar PV projects. Should such investments be required, these costs usually accrue to grid operators.

The table shows that per unit engineering, procurement and construction (EPC) costs for large scale solar parks are around half of those for rooftop panels, which can be explained by economies of scale effects. In the EPC costs for solar parks are not included the costs related to land purchase and grid connection, which depend on the size of the park and the produced electricity per year. Based on stakeholders' feedback, fixed connection costs could amount to €260,000 (depending on the required capacity of the transmission) and variable cost at €182 per meter of the connection.

In the case of small scale solar PV applications, electricity producers (households and small businesses) are also the consumers of the electricity produced. If they produce enough solar electricity to meet their own demand, the costs of the panel investment can be compared with the costs related to consumption of grey electricity, which is approximately 0.19€/kWh and which includes energy taxes, value-added tax (VAT) and add-on for sustainable energy. Assuming a production/consumption of 3000 kWh per year, and refund

[15] 'large-scale projects' refer to ground mounted parks, but also to larger-scale projects on rooftops, near traintracks, roads and even on water.

of VAT and a general tax reduction, the financial payback period of rooftop solar PV amounts to between 6 and 7 years.

Box 2. Incentives for small and large scale solar PV in the Netherlands

Both rooftop panel and ground-mounted solar parks are financially supported by fiscal policies. Rooftop solar PV is supported by a net-metering policy (in Dutch: 'salderingsregeling'), which enables households and businesses to feed solar-produced electricity that they don't need, into the electricity grid (net-metering is then the difference between what is taken from and given to the grid). Small businesses can take also benefit from the Energy Investment Allowance (EIA) (Netherlands Enterprise Agency, 2017b) and a separate subsidy is available for sporting facilities using rooftop PV, called EDS (Energy saving and sustainable energy for sporting facilities) (Netherlands Enterprise Agency, 2017c).

Large-scale solar PV is not eligible for net-metering. Instead, the option has become eligible for stimulation through the SDE+ feed-in programme (supporting sustainable energy) (Netherlands Enterprise Agency, 2017d).[16] For large-scale projects, the SDE+ contribution could amount to 0.125 €/kWh for 15 years (the size of SDE+ contributions depend on the difference between the actual project costs and the electricity price).

System level modifications

Further deployment and diffusion of rooftop-based and ground-mounted solar PV may have consequences for the stability of the grid. Interviewed stakeholders, however, explained that current power grids in the Netherlands will be able to handle expansion of rooftop solar PV. One reason for that is that the load hours and volumes of generated power for rooftop installations are much fewer than those of a power plant or an average wind farm. Second, should all suitable homes be equipped with solar panels, about 16 GW of solar power could be generated at peak level (which is 50% of total private sector electricity consumption). However, such an electricity influx can still be managed by grid operators with current grid technology (PBL, 2014). The only possibly required investment would be a set of large neighbourhood batteries to temporarily store generated electricity that cannot be used momentarily.[17]

For large-scale ground-mounted solar projects, however, grid balancing might be a bigger challenge as network operators need to cope with a larger influx of electricity near the sites where the plants are located. Interviewed stakeholders have explained that grid balance can be maintained, among others, by using smart grid technology or placing solar panels in areas where required grid infrastructure already exists (e.g., near wind parks, industrial areas or railways), so that energy demand can be modulated depending on the available supply of electricity. PBL (2014) suggests similar solutions. In contrast to household-scale

[16] This has also been done for offshore wind power in the Netherlands.
[17] For example, an interview with a Dutch electricity transport operator revealed the example of the Province of Groningen, where households invested on a large-scale compensation money received as compensation for earthquake damage (due to natural gas production in the region), in solar panels. This resulted in a grid balancing issue which the operator solved by investing in smart transformers.

solar projects, grid operators are usually involved in the development of ground-mounted solar projects as they need to arrange the necessary infrastructure (connections, cables, etc.). Moreover, grid operators are obliged to connect the park to the grid, although it is often uncertain whether a planned park will materialise or when, which complicates the planning for operators.

Impact on employment

In general, expansion of the solar energy sector leads to increase in employment in the sector. For example, in the USA, the growth of solar energy-related jobs is twelve times as strong as average employment growth in the country (Business insider Nederland, 2017). Moreover, the US solar power sector employs more people (374 000) than the coal, oil and gas-based energy sectors in the country combined (187 117 people) (Bulman, 2017).

For the Netherlands, labour market impact analyses of increased shares of renewable energy in the energy market were carried out in the framework of the Dutch Energy Agreement of 2013 (Koning, Smit, & Dril, 2016) (Ligtvoet, Pickles, & Barneveld, 2016). It was concluded that most jobs in the solar PV sector in the Netherlands are generated during the construction phase involving installation companies, construction workers and planners for both rooftop and large-scale projects. Therefore, these assignments are short term and flexible. After panels are installed on rooftops, only minimal maintenance is required.

Moreover, interviewed stakeholders have pointed out that the building of ground-mounted solar park is mainly done by foreign employees with large experience in solar park construction elsewhere in Europe. Jobs for operation and maintenance of ground-mounted solar parks are more long-term, but their number is relatively small. After all, outputs and heat curves of the panels can be measured remotely or with drones, while cleaning of the panels is mainly done by rain. According to Koning, Smit & Dril (2016), in the framework of the Netherlands Energy Agreement, around 9165 work years of employment will be generated in the period of 2014-2020. This corresponds to the installation of 985 MW of solar panels and therefore to 9165/985 = 9.3 FTE/MW.

At the same time, job losses in the traditional energy production sector due to the growth of the renewable sector is expected to occur. These people will not necessarily be redirected to the renewable sector but are more likely be employed in other sectors (chemical, manufacture, etc.). Therefore, a one on one replacement of jobs lost in fossil fuel-based energy by jobs gained in renewable energy activities by cannot be assumed.

Impact on the fiscal balance of the Dutch Treasury

Due to net-metering for rooftop solar panels, the Dutch Treasury misses potential tax revenues because households and businesses with solar PV panels on their rooftop do not pay energy tax, value-added tax (VAT) and sustainable energy tax add-on over the self-generated and used electricity. To learn what could be the impact of further diffusion of solar electricity on the Dutch fiscal budget, for this case study three scenarios have been identified:

1. In one scenario (the baseline) fossil fuel-based and nuclear energy capacity will continue to operate until the end of their technical lifetime.
2. The second scenario assumes that coal plants will be phased out somewhat quicker (10 years) than in the baseline scenario.
3. The third scenario is most ambitious with coal plants phased out much earlier than their technical lifetime; recently started coal plants stop by 2030 and older ones by 2025.

For scenarios 2 and 3 in this section the National Solar Power Action Plan (DNV GL, 2016) has been taken as a starting point (see elsewhere in this section). The goal formulated in the plan of 4 GWp installed solar PV capacity by 2020 corresponds with the second scenario. The 'phase out coal fast' scenario builds further on that by assuming earlier closing of coal plants and solar electricity capacity reaching 6 GW at peak level in 2020. The latter scenario resembles the Netherlands' government intention to work towards closing coal plants by 2030. As an illustration, the resulting electricity mixes for the baseline and most ambitious scenarios are shown in Figure 4 and Figure 5, respectively.

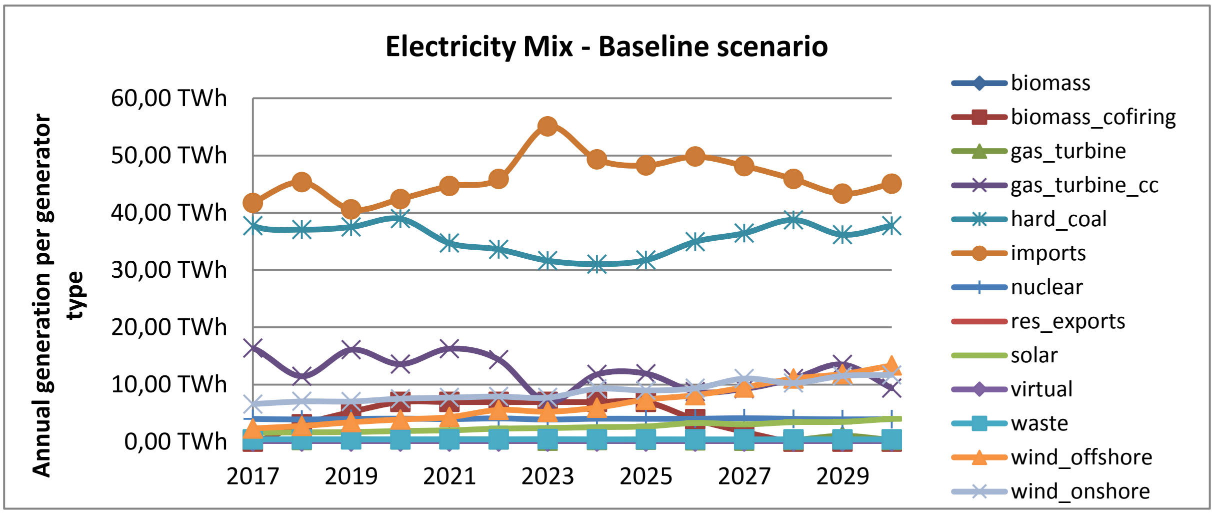

Figure 4. The Dutch electricity mix in the baseline scenario (1)

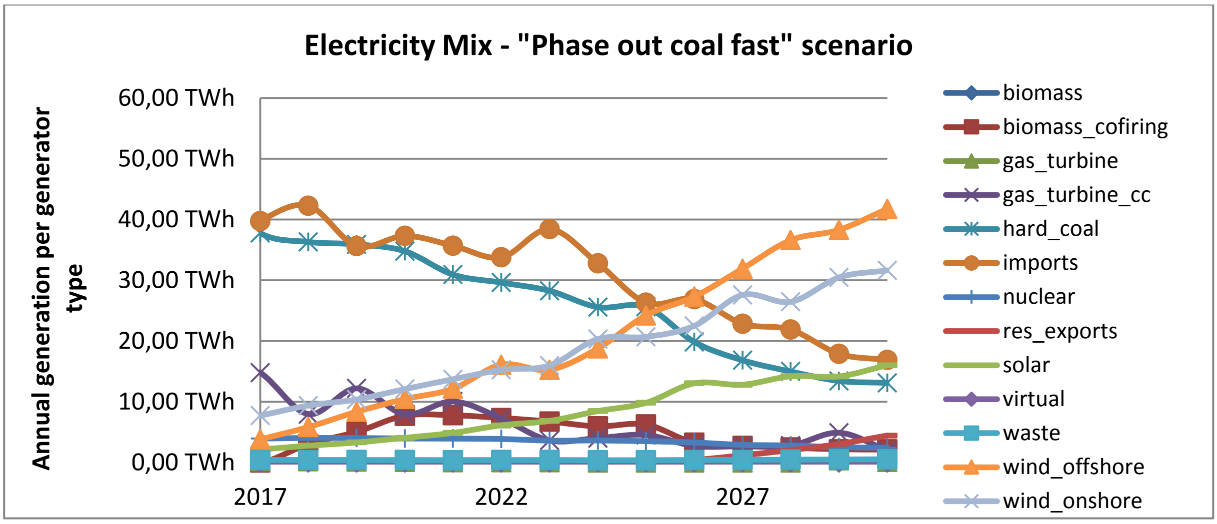

Figure 5. Illustration of the Dutch electricity mix in the ambitious (2) scenario

Using these scenarios and if current fiscal stimulation regimes will continue to exist, it has been estimated, with help of the BSAM model[18], what could be the amount of tax income loss for the Netherlands government (i.e. Ministry of Finance) due to tax exemptions[19] for households and businesses with solar PV panels on their rooftops. As shown in Figure 6, these losses in the ambitious 'phase out coal fast' scenario are significant because solar PV installed capacities increase more rapidly than in the other two scenarios: around €800 million per year in this ambitious scenario, compared to around €500 million per year in the second scenario of 'phase out coal slowly' and €200 million per year in the baseline scenario by 2030.

[18] BSAM = Business Strategy Assessment Model (Papadelis, Flamos, A, & Androulaki, 2012). It is an agent-based model that is used in the TRANSrisk project.
[19] Exemptions from energy tax, VAT and sustainable energy add-on over the self-generated and used electricity.

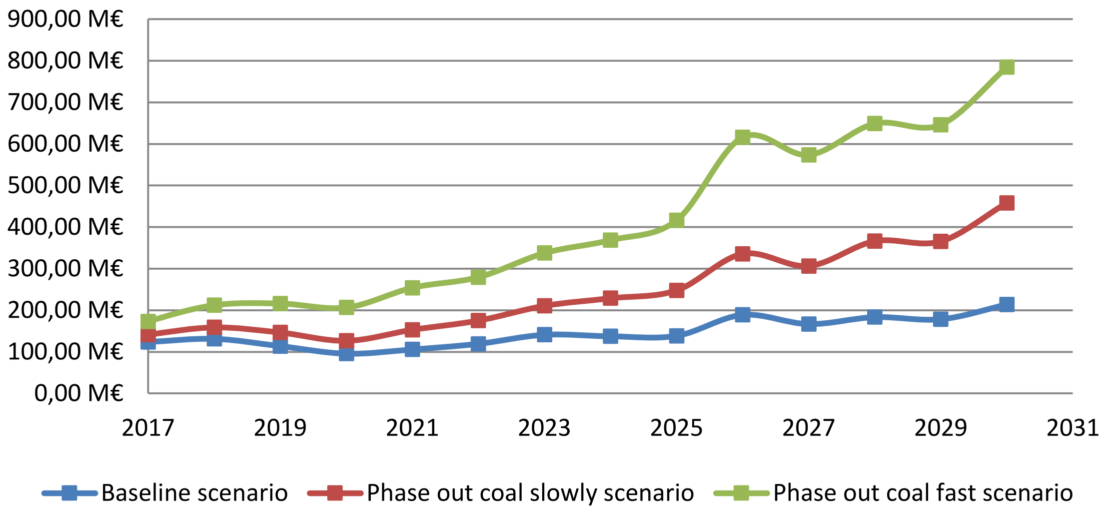

Figure 6. The taxation losses due to self-consumption of solar PV electricity by households under the three scenarios

However, under the scenarios of phasing out coal plants, the impact on the fiscal budget of subsidising large-scale solar plants becomes much bigger than the impact of offering tax exemptions for small-scale solar PV investment (see Figure 7). For example, while in the most ambitious scenario ('phase out coal fast') tax revenue reduction amounts to €800 million per year, the subsidies for large-scale solar may amount to over €4.5 billion per year. In Figure 7, after 2030 the subsidy costs are assumed to decrease, which is mainly based on the assumption that current subsidy schemes will expire around 2025-2030 (e.g., in 2025 for biomass co-firing, 2030 for solar PV).

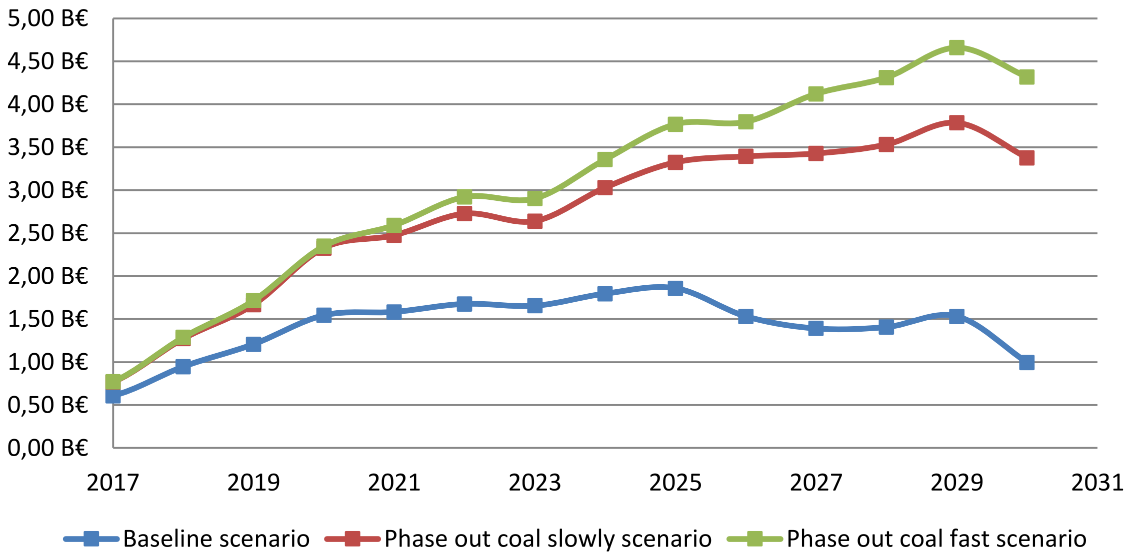

Figure 7. The subsidy costs under the three scenarios discussed in this section

7.4 Social implications and spatial planning issues related to expanding solar PV in the Netherlands

Scaling up solar PV technology in the Netherlands may have physical or spatial limitations. Rooftop PV panels are not suitable on every roof, for reasons of insufficient direction to the sun, insufficient carrying capacity of some roofs (especially at commercial buildings), or regularly required rooftop maintenance. Ground-mounted solar PV projects are spatially constrained in the Netherlands as the country is small, densely populated and most of the lands have their designated purpose, such as agriculture.

With respect to the latter, an important role is played by the provinces and municipalities as they develop spatial visions for their regions. For example, in the Provence of Fryslân ground-mounted solar parks can only be installed near cities/villages and not in open land (Gemeente Súdwest-Fryslân, 2015). The size of the park should also be proportional to the size of the town or city. Smaller projects (up to 3 ha) are managed by the municipality while larger ones require the involvement of the province as well. In the development of ground mounted solar PV projects, also the government agency Rijkswaterstaat[20] is often involved as it manages large areas of land and has the responsibility to make sure that lands are only exploited without harming the environment (water supplies, infrastructure, etc.).

Competition with other purposes of the area?

Stakeholders interviewed for the case study assume that public acceptance for ground-mounted solar PV projects is relatively high when these are located near (existing) infrastructural systems (e.g., along railways, roads and highways, sound barriers, bike routes) and industrial development zones. Projects located at agricultural land and nature reserves could be less acceptable, especially since parks use land for at least 25 years, which cannot be used for agricultural production anymore. Generally, 1 MW of solar installation requires 1 hectare of land. For comparison, one wind turbine of 3MW only takes up a small amount of space, while the same amount of MW in solar energy would mean the installation of panels on at least 3 hectares of land (or 6 football fields).[21]

Stakeholder responses were divided on this topic though. On the one hand, a stakeholder from the agri- and horticultural organisation (LTO, representing farmers) argued that ground-mounted solar parks should be limited to avoid competition with agricultural production. Other stakeholders argued that there are sufficient land areas and water surfaces available in the Netherlands for ground-mounted solar projects to prevent competition with agricultural production. Currently, there are two large parks in the northern part of the country: one on the island of Ameland and one near the harbour of Eemshaven (Province of Groningen). Both locations have a low population density and a low risk of competition with alternative economic activities.

[20] Government agency for infrastructure and waterworks.
[21] This could be even more if we consider that wind turbines are able to make more full load hours.

Involvement of local citizens and cooperatives for larger public acceptance

According to interviewed stakeholders for the case study, an important step to increase public acceptance is to involve local people and cooperatives in all stages of project development. For example, stakeholders explained the example of a solar park planned in Wirdum, also in the north of the Netherlands, which was developed without consulting the local population during project development. This resulted in local resistance to the park. In principle it would be easier to mount solar panels on the countryside, because developers only need to agree with the land owner (e.g., a farmer) and it is also easier to 'hide' and fit the park in the existing landscape, leading to lower public resistance risks. This, however, contradicts with regional regulations in Fryslân that prefer installing solar parks near cities and towns (Gemeente Súdwest-Fryslân, 2015). As a result, there is an ongoing political discussion on how to deal with land-use issues and different point of views between the public and (local) governments.

In some cases, the local population is also able to invest in and benefit from nearby solar parks via crowd funding or due to the postal code 'rose' regulation, through which citizens are able to invest in a solar park nearby and get tax benefits on their electricity received from their energy company (DNV GL, 2016).[22] The stakeholders consulted were not certain about whether citizens mainly take part in such projects for financial reasons, or also because of the environmental benefits. It could be a motivating factor for people to be part of a decision-making process and feel that they contribute to societal and environmental improvements. According to stakeholders, this may become stronger, the more people become familiar with the climate change problem and required solutions. In addition, stakeholders argued that people's feedback might improve the project design (aesthetics, location, etc.), which would also increase overall acceptance.

Rooftop solar panels as status symbol

With respect to acceptance of rooftop solar PV, several aspects have been mentioned by interviewed stakeholders. One aspect is that of rooftop panels as status symbol, showing that the owner of the panels invested money (cost signalling) and cares about the environment. Another aspect is that of communication of all benefits of renewable energy technologies to households, i.e. environmental and social next to financial benefits. Financial incentives generally provide only a short-term solution, and should this incentive be taken away, interest in renewables may decline as households are insufficiently familiar with other environmental motivations.[23]

Related to that, stakeholders explained that while the issue of climate change is often difficult to comprehend by people in its entirety, investing in rooftop solar PV panels enables people to contribute personally to climate change mitigation. This can be enhanced by another psychological aspect which is that people often do not want to be seen as someone who only cares about money. Obviously, the latter aspects are only feasible when

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[22] In some cases, citizens can also buy obligations or certificates for a solar park.

[23] The net-metering policy, see elsewhere in this section, was reviewed by the Netherlands government in 2017. As a result, it was decided to keep the policy in place until 2023. After that, it would be replaced by a subsidy scheme. However, the new government's coalition agreement of October 2017 contained an announced closure of the net-metering policy already in 2020.

financially affordable, and this is, according to interviewed stakeholders, where a balance needs to be found between financial (taxation) incentives and emotional motivations.

7.5 Conclusions

Considering European commitments, the Netherlands needs to increase its share of renewable energy sources to 14% of total energy consumption by 2020. Currently, due to a range of factors, there is a gap between this goal and the actual renewable energy share. As a result, even though solar radiation levels in the Netherlands are lower than, for instance, in Southern regions in Europe (i.e. the carbon payback time for solar PV in the Netherlands is relatively long), scaling up solar PV is needed for reaching renewable energy goals.

This chapter has analysed two options for that: rooftop solar PV panels and larger-scale, often ground-mounted, solar parks. In terms of costs, the case study has identified a range of system-level costs for both options, in terms of balancing, grid-connection, maintenance, etc., and concluded that due to economies of scale larger-scale solar PV generally has lower costs per kWh. Also, based on literature review and stakeholder consultation, potential employment impacts were analysed.

It was concluded that construction of solar PV installations will create jobs (which are not necessarily filled by employees from traditional fossil fuel-based energy sectors), but domestic employment is mainly needed for rooftop solar panels. Large-scale projects are usually built by specialised, foreign teams, who only temporarily stay in the country. Maintenance employment effects from large scale solar parks are little as cleaning of panels is mainly done by rainfall. With help of a modelling analysis, impacts on the Netherlands government budget were estimated should scaling up of solar PV continue to be supported with subsidy schemes. Among the estimates was that subsidy costs in a 'fast coal phase-out' scenario (assuming closing coal plants) could climb to nearly €5 billion per year by 2030.

In terms of social implications, stakeholder interviews resulted in views that large-scale solar PV may meet social resistance if parks are in areas where competition with agriculture takes place or if parks are very much visible, close to urban areas. These findings seem to contradict with current planning practice in some analysed cases in the North of the Netherlands where local governments prefer solar parks relatively close to urban areas. An important recommendation from consulted stakeholders is that social acceptance of a large-scale solar park is more likely if citizens and other stakeholders are actively engaged in the decision-making and planning process for a park. This enables adding design aspects that stakeholders appreciate and makes them 'co-owner' of a project.

8 Discussion – Lessons for scaling up mitigation options in INECPs

In Part I of this paper we identified aspects for policy makers to consider when formulating Integrated National Energy and Climate Plans (INECPs) at the level of Member States. These aspects have been identified based on the communication by the European Commission on the Winter Package, 'Clean Energy for all Europeans" and work done on technology assessments by the CARISMA project. '

The European Commission has identified several potential benefits of pursuing development and diffusion of low-emission technologies, such as employment and economic competitiveness gains. However, large-scale use of intermittent renewable energy technologies may require investments in electricity distribution systems and large areas for installing, e.g., wind turbines and solar panels. The latter may also conflict with other economic use of land and may have (perceived) social impacts on the well-being of the (local) population.

Therefore, while the energy and climate goals of the EU require scaling up of climate change mitigation technologies, integrating such options in existing economic and social structures is not always a panacea. As the case studies in this paper have shown, it requires careful planning and acknowledgement that some options are less suitable within the country context, but also that solutions exist to mitigate negative impacts so that scaling up of mitigation options can be realised.

In this section, we assess case study findings in support of INECP formulation by asking the questions which have been introduced in Section 4:

4. How can we characterise benefits and drawbacks of mitigation technologies if they are scaled up and implemented over the longer term, in terms of system- and macro-level impacts?
5. How much do location-specific carbon payback times of climate mitigation technologies affect their climate benefits?
6. What are viable approaches to opening up public discussions that would be needed for wider social adoption and acceptance of mitigation options?

8.1 How can we characterise benefits and drawbacks of scaling up mitigation technologies in terms of system- and macro-level impacts?

As put forward earlier, when formulating INCEPs, factors to consider are possible job and sector activity losses and gains because of energy policy and deep decarbonisation. The cases of Greece and Austria illustrate how these impacts may arise in countries with wholly separate starting conditions: Greece with little renewable electricity source penetration and high costs of capital, and Austria with ample renewables and cheap capital. Furthermore, the literature on system costs is still developing, and quantification of the effects are not yet perfectly defined. However, the cases indicate orders of magnitude of these impacts for policy makers and planners to keep in mind when designing long-term energy and climate policies in EU Member States.

Economically, scaling up of technologies for mitigation has the advantage that **learning effects** can be generated, resulting in economies of scale and lower per unit costs. Moreover, **employment benefits** can be generated, although the case studies have also highlighted observations of large-scale ground-mounted solar PV parks, such as in the Netherlands, which are constructed by specialised teams with employees from different EU countries. While the latter is beneficial from an overall European employment perspective, it has limited local or national employment impacts in the Member State concerned. Operation and maintenance could be a source for additional employment, but the size of that impact depends on the technology. Solar PV, for instance, generates relatively few maintenance jobs.

With respect to **required government financial support** for further deployment and diffusion of mitigation technologies, the Dutch case study showed that fiscal budgets impacts can be strong: in the order to magnitude of €2.5 to nearly €5 billion of required subsidy for solar PV in case of a fast phase out of coal-based technology by 2030.

Interestingly, the results found for Austria, Greece as well as for the Netherlands, illustrate the importance of **understanding country contexts** and differences between these. For instance, the limited capital availability in Greece, due the conditions of the economic recession, causes investments in capital-intensive renewable energy technologies such as wind turbines, to become relatively costly. The Greek case study shows that these costs are eventually passed on to end users in the form of higher electricity prices. Another example is the **existing electricity context** of Austria with its large share of hydroelectricity. As hydropower generally has relatively low operational costs, almost any investment in non-hydro low-emission technologies will cause electricity prices to go up.

Another aspect that the case studies have made clear is that scaling up a technology for mitigation does not mean 'simply' implementing a single technology project multiple times within the country. While a single renewable energy project can be relatively easily connected to the grid without causing grid stability issues, scaling up the technology to multiple projects may require **grid stability investments**. This adds to the cost aspects to be considered in an INECP (see Table 1 in the Dutch case study for an example of different cost items between a small-scale application of solar PV on rooftops and large-scale solar PV investments). Scaling up a technology implies additional system and overarching (meso- and macro-) level costs and these costs are an important determinant for the technical or economic potential of a mitigation technology in a Member State.

In terms of **additional economic investments**, the Commission estimates that €379 billion per year will be needed in the EU in energy efficiency, renewable energy and infrastructure improvement measures under the Winter Package (European Commission, 2016). As a large share of the required installations of renewable energy technologies is expected to be produced by European industry (see also Section 2), these additional investments are expected to largely accrue to the European economies. For instance, the European Commission foresees that, because of the Winter Package 1 million additional jobs will be generated in renewable energy production (700,000 in construction, 230,000 in engineering and 27,000 in iron and steel production for, e.g., wind turbines).

From an environmental perspective, scaling up low-emission energy technologies will contribute to achieving medium- to long-term climate goals and reaching the temperature limitation targets of the Paris Agreement. Moreover, replacing fossil fuel-based technologies with renewable energy or other low-emission technology options will contribute to **cleaner living environments** in European cities and improved health conditions due to cleaner air in cities and other areas.

From the Dutch case study, it could be learned that expanding solar PV through large-scale projects contributes to reaching the Dutch **renewable energy targets** for 2020 (and the domestically sharpened goals for 2023). While nowadays biomass and wind energy form the strongest resources for renewable energy in the Netherlands, partly through fiscal stimulation targets, large-scale solar PV deployment and diffusion will be needed to reach national energy and climate targets. This diversification will furthermore contribute to a more robust energy supply system.

8.2 How much do location-specific carbon payback times of climate mitigation technologies affect their climate benefits?

When planning a technology for climate change mitigation in a country, among the first questions to be asked is whether sufficient resources are available for it. For example, in a country with limited wind energy resources, scaling up wind power technology is not an effective approach for meeting renewable energy and climate goals. The Dutch case study showed that **wind energy resources** are among the highest in Europe and the country has set up programmes to utilise these through on- and offshore wind power projects. For solar energy, resources are relatively low in the country, especially when compared to southern European states. At the same time, as argued above, despite relatively low solar insolation, the country needs solar energy for meeting its renewable energy targets.

In Greece, solar PV has a strong potential for renewable energy production as the country has among the **highest insolation levels** in Europe. Therefore, it is logical to further expand solar energy technology in the country. Similar to the Netherlands, for meeting renewable energy goals, also wind power will be needed in Greece, although the country is less ‘endowed’ with wind resources than it is with solar insolation. Austria has large **hydropower resources** and has utilised these to such an extent that it has already reached its renewable energy goals for 2020. Wind and solar technologies may be needed though for achieving future energy and climate targets for the country, although particularly wind energy resources in Austria are relatively scarce.

Large availability of resources is not the only aspect though to consider when determining **climate effectiveness of a mitigation technology** in a country. Using the concept of Carbon Payback Time (CPT), as explained in Box 1, the effectiveness of scaling up a technology for mitigation is determined by:

- Which technology and accompanying GHG emissions it replaces, and
- The GHG emissions throughout its own lifecycle of production, construction, operation and dismantling.

In the Netherlands, due to the large wind energy resources and relatively large share of fossil fuels in the energy mix, the CPT for wind energy is relatively short, while for solar PV it is considerably longer. In Austria, CPTs for renewable energy technologies are relatively long, which is largely due to the already low carbon footprint in the country due to the large share of hydropower. It takes relatively long before a renewable energy technology has reduced enough emissions in Austria before its lifecycle emissions are compensated for.

Strictly speaking, due to current international GHG accounting procedures under the UNFCCC, when life cycle emissions of a technology partly take place abroad, the country only reports on the emissions and emission reductions taking place within its own borders. Life-cycle emissions taking place elsewhere will be accounted for in the countries concerned. Nevertheless, a country can, as part of its INECP, consider new energy supply chain procurement policies, using CPT as a parameter, to add **incentives to buy from 'greener' suppliers and thus hence decarbonize supply chains**. Policy makers could also, for reducing global climate impacts, re-integrate displacement of life cycle emission in a production-based emissions accounting scheme.

An interesting insight from the Commission's communication on the Winter Package is that a large share of the installed renewable energy technologies is produced in Europe. In CPT terms, this implies that GHG emissions caused by producing, e.g., a wind turbine will be accounted for in the GHG inventory of the Member State where the production takes place, whereas the emission reductions related to operating the turbine will accrue to the Member States which operate it. In other words, the CPT for this wind turbine is an indicator of how long it takes to offset life-cycle emissions by emission reductions caused by the same technology within Europe, even though these emission impacts appear in different Member States' INECPs and GHG inventories. Therefore, in these cases, the CPT indicator may not directly be determined at the level of individual Member States, but rather for the EU as a whole, and thus function as an indicator of climate effectiveness of mitigation options at the EU level.

8.3 What are viable approaches to opening up public discussions that would be needed for wider social adoption and acceptance of mitigation options?

The three case studies in this paper have highlighted a range of aspects related to social adoption and acceptance of technologies for mitigation in the Member States. Technologies' social implications can be broad, ranging from impacts on employment to changes in the landscape nearby residential cores. With respect to the latter, the case studies have illustrated examples of how gaining public acceptance of scaled up technologies can be a challenge under INCEP development. The cases strongly point to issues with contextual factors; from Greek 'NIMBY' attitudes on wind parks to the lack of public knowledge and skills for energy efficiency, to other issues such as the structure of national- and state-level authorities, and the powers and responsibilities delegated to them.

The European Commission acknowledges the important role of stakeholders within the context of the Winter Package, as actors in energy efficiency and renewable energy value chains and consumers of energy. As explained in Section 2, the Commission recommends that next to Member State authorities, also local and city authorities and businesses, social partners and investors should be involved in the preparation and implementation of the INECPs.

The examples studied in Hagens, Koretsky & Toemen (forthcoming) and the case studies in this paper showed that including stakeholders in planning and development stages of has a **positive impact on social acceptance** of expanding mitigation technologies. The feeling that a project has been imposed on them could easily give rise to feelings of discomfort and protest, especially when the project is clearly visible and considered a disruption of the landscape. On the other hand, once people have the possibility to actively become engaged in a project, and can co-design the project, this can enhance acceptance levels. After all, active involvement can result in financial benefits for them or the local society or support the feeling of being able to contribute to an environmentally beneficial investment (e.g., rooftop panels as status symbol to show that a house owner cares about the environment, as mentioned in the Dutch case study).

Building further on that observation, stakeholders interviewed for the Dutch case study highlighted that not engaging stakeholders in the decision making on energy transition processes implies the risk that people feel surprised or overwhelmed by a project. Interviewed stakeholders therefore recommend that energy transition processes are accompanied with an 'institutional innovation'. This enables **active involvement of local or regional stakeholders in designing and planning** the transition, as it affects their wellbeing and living environment.

As part of this innovation, among the first things to explore are how the plan fits within or competes/conflicts with other activities in the area or region concerned and who will be impacted by that. This 'area-based' innovation, preferably carried out at municipal and provincial levels, would focus on addressing a combination of problems/issues at the same time (e.g., not only energy generation but also improving air quality, generate jobs, etc.), to **balance multiple individual preferences** within an energy transition package. Such inclusive processes may also imply more flexibility in terms of zone planning and choosing locations for project activities.

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