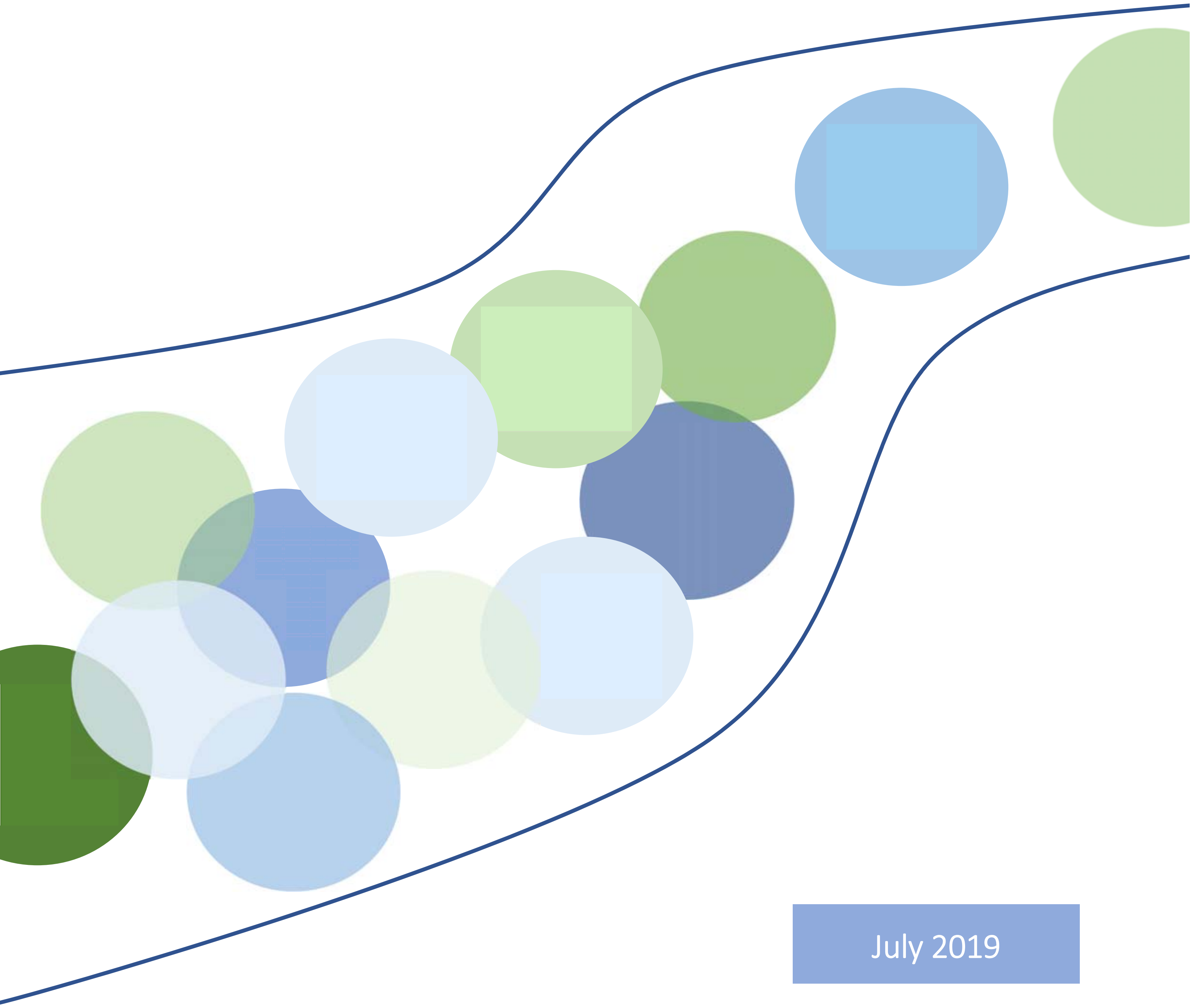
Deliverable 5.5b

Work Package 5 Policy Briefs



July 2019

About this report

These Policy Briefs constitute the Deliverable 5.5b of the REEEM Project, which analyses economic, social and environmental impacts of pathways towards a low-carbon EU energy system. The deliverable provides policy recommendations based on detailed reports produced in Work Package 5 “Environment, Health and Resources”

Authors

European Energy System Transition: Air Quality and Health Impacts
- Dorothea Schmid (USTUTT) and Ulas Im (AU)

Life Cycle Assessment and Demand for Critical Materials
- Pernille K. Ohms, Jette L. Marcher, Serena Fabbri, Florence Bohnes and Alexis Laurent (DTU)
- Francis Li, Pei-Hao Li, Seyed Mehdi Mohaghegh and Ilkka Keppo (UCL)

Accounting for Ecosystem Services in Energy Planning
- Olexandr Balyk (DTU), Ulla Mörtberg and Xi Pang (KTH)

Reviewers

Anna Darmani, Louise Coffineau (KIC InnoEnergy), Francesco Gardumi (KTH) and Steve Pye (UCL)

REEEM partners

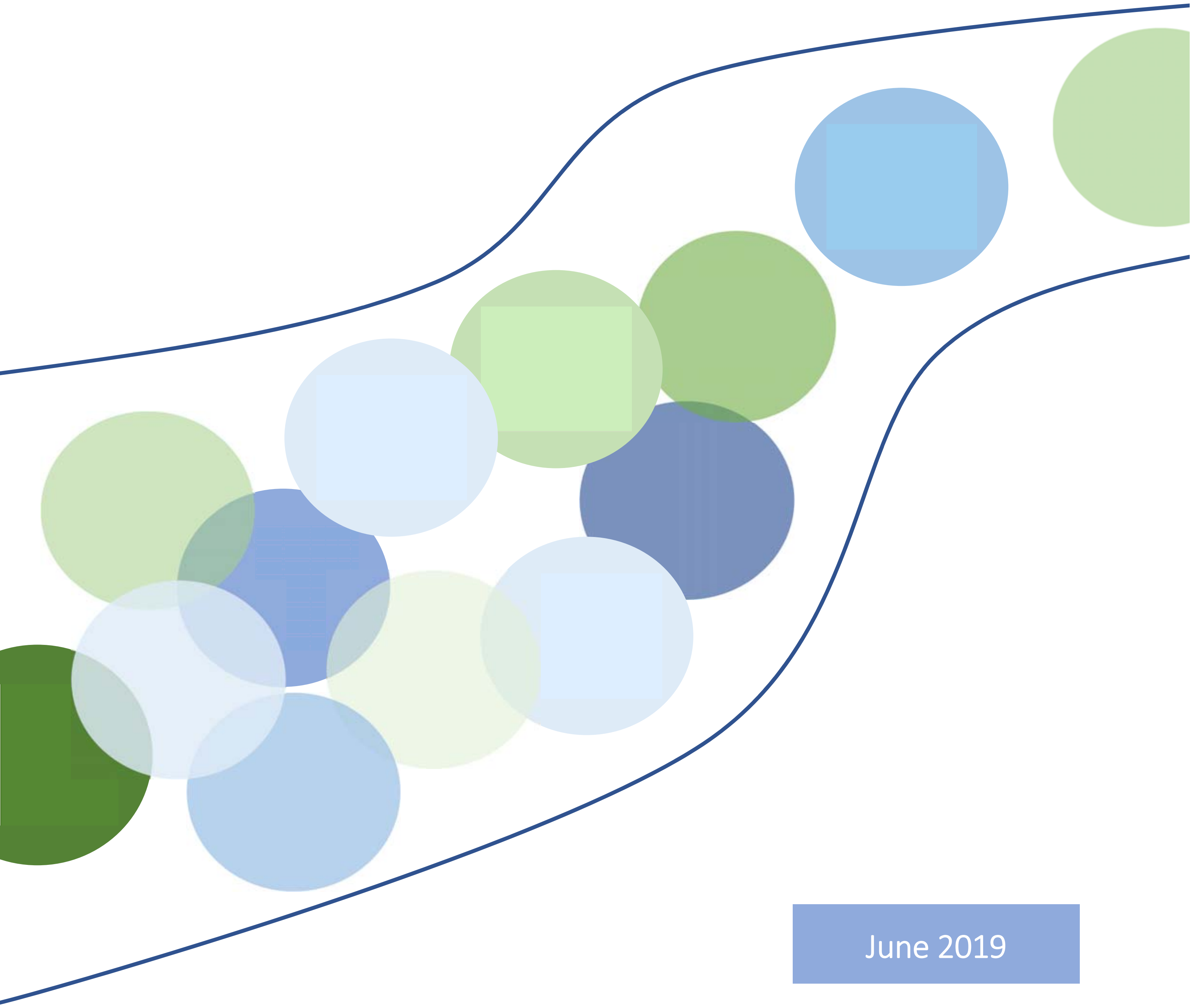
About REEEM

REEEM aims to gain a clear and comprehensive understanding of the system-wide implications of energy strategies in support of transitions to a competitive low-carbon EU energy society. This project is developed to address four main objectives: (1) to develop an integrated assessment framework (2) to define pathways towards a low-carbon society and assess their potential implications (3) to bridge the science-policy gap through a clear communication using decision support tools and (4) to ensure transparency in the process.

The REEEM project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691739. This publication reflects only the views of its authors, and the European Commission cannot be held responsible for its content.

European Energy System Transition: Air Quality and Health Impacts

Policy Brief



June 2019

Air quality and a sustainable European energy system

On its way to a low-carbon European society, a sustainable energy system does not only have to follow ambitious decarbonisation pathways, but do so while minimizing other adverse impacts on society. This includes reducing air pollution and its related impacts. Since both GHG and air pollutants are released by the same processes, climate change mitigation often results in better air quality, providing attributable co-benefits to the society. Air pollution control, on the other hand, may also facilitate changes in the energy system partly compensating for GHG mitigation or interfering with it. Thus, **the implications of climate change mitigation and air pollution control need to be considered simultaneously in an integrated assessment to achieve both goals, clean air and a low-carbon society.** The aim of this study is therefore to assess the impact of possible pathways towards a sustainable European energy system on air pollution and associated health impacts as wells as the impact of mitigating air pollution on the energy system and its transformation. For the latter purpose, internalizing health costs associated with air pollution serves as a proxy for additional air pollution control actions.

Policy Implications & Recommendations

- **Climate change mitigation** and **air pollution control** interact with and **may profit from each other**
- an **integrated perspective** may result in **earlier actions**, additional benefits and welfare savings
- **Pure decarbonisation policies may not** inevitably **reduce air pollution across all sectors**
- **Process-related emissions** form industry and abrasion processes in road transport **remain challenging** asking for **new innovative technological processes and changes in behaviour**
- **Conflicts between national and EU-wide targets** may arise as **not all countries will profit equally** from better air quality
- A **pan-European, integrated strategy is needed,** tackling climate change mitigation and air pollution simultaneously
- **Further research** is needed with regard **to quantifying the magnitude** of possible societal benefits and **its uncertainty**

Model Framework & Scenarios

To enable an integrated analysis of possible transformation pathways and air pollution control, **external effects of air pollution** need to be part of an energy system analysis. By definition, external effects arise as soon as economic transactions have negative impacts on an uninvolved third party. In the case of air pollution, these external effects can be estimated as adverse health impacts following the Impact Pathway Approach [1], and monetized as **damage costs, reflecting a monetary loss in welfare**. If these costs are considered in the optimization of an energy system model, external effects are efficiently avoided as long as their avoidance costs do not exceed their damage costs.

To study the interplay of decarbonisation targets and air pollution control, the European energy system model *TIMES PanEU* is linked with the health impact assessment model *EcoSense*. *EcoSense* implements a parametrized atmospheric dispersion model that simulates changes in air quality by linking changes of emissions in a specific country to changes in concentration levels of ozone, NO_2 and particulate matter at a spatial resolution of 0.5 ° × 0.25 °. By combining these changes with detailed population data, exposure and associated health impacts are estimated. For this purpose, *EcoSense* is applied using emissions of air pollutants as estimated by *TIMES PanEU* for two purposes:

- To estimate **marginal damages costs** that are **fed back to *TIMES PanEU*** as additional cost parameters on emissions of air pollutants in order **to study the impact of air pollution control on the energy system transformation**
- To **estimate health impacts and associated costs** on country level **to study the impact of GHG reduction targets on air quality**

The link between the models is described in detail in [2] and [3]. In this study, two scenarios are compared. The **Base Pathway** constitutes the **"coalitions for a low-carbon path"** narrative as defined within this project [4]. This scenario is characterized by an 83 % decarbonisation target for ETS sectors in 2050 compared to 2005 levels. For non-ETS sectors, reduction targets are set by country groups, aiming at 75 % reduction of these emissions across the EU-28. Here, **health impacts** are also **considered in the optimization from 2020 on**. The **Reference Scenario** follows the **same assumptions**, but in this case, **health impacts are not part of the optimization at all**. This allows an assessment of how much air pollution control in form of internalized damage costs impact air quality, health and GHG reductions, when considered in combination with already ambitious decarbonisation targets.

Results

The **ambitious GHG reduction targets** as set in the **Reference Scenario** seem to be a driving force in reducing air pollution (Figure 1). On EU-28 level, most air pollutants are **reduced between 30 % and 55 %** in 2050 compared to 2015 levels. Only SO_2 is not reduced in the long term due to increasing industrial demand and associated process emissions, originating, for example, from coke use in steel production. By **including health related costs** of air pollution in the optimization, **additional reductions of up to 15 %** in 2050 are achieved in the **Base Pathway** (Figure 1).

Box 1: Future unit cost factors and their uncertainty

Within in this project, unit cost factors for SO_2 and NO_X emissions from energy production only (high release heights) are also estimated by a second impact assessment model – *EVA* [5]. A detailed comparison of both models is given in [2]. As a result of their varying assumptions and method, the unit cost factors vary significantly between the two models. On average, *EVA* shows lower unit cost factors than *EcoSense* for current years; this can be explained by the transport and chemical reactivity of the considered emissions due to their release height, effectively reducing exposure and impacts. For future years (2030), however, *EVA* estimates much higher unit costs. *EcoSense* considers changes in exposure by including population projections for future years, but keeps the levels and balance of background concentrations constant. In contrast, *EVA* only accounts for changes in background concentration levels based on emission projections, resulting in drastically increasing unit cost factors for most countries. It seems that savings in associated health costs in *EVA* are not proportional to the amount of emissions reduced. *EcoSense*, on the other hand, builds on the assumption of proportional cost reductions with no radical changes regarding the balance of different species in background concentrations.

This comparison highlights the uncertainty that is still associated with unit cost factors and the need to further identify the main determinants of future exposure. This should include population data, emission projections and changing background concentrations as well as the possible influence of climate change for years after 2050.

The most striking difference is the **sharp increase of SO_2 in the Reference Scenario** (w/o damage costs) between 2030 and 2045.The main reasons for this are **conversion processes** such as gasification and synthetic fuel production using sulphur-heavy fuels (e.g. coal or refinery oil), which are **not utilized in the Base Pathway**, because of their relatively high damage costs. As a result of **banning coal in the residential sector** and replacing **bunker fuel with diesel** in maritime transport, the **Base Pathway** (w/ damage costs) also shows a **sharper initial decrease of all air pollutants**, especially of particulate matter and SO_2, though the latter later almost reaches 2015 levels again as process-realted emissions increase.

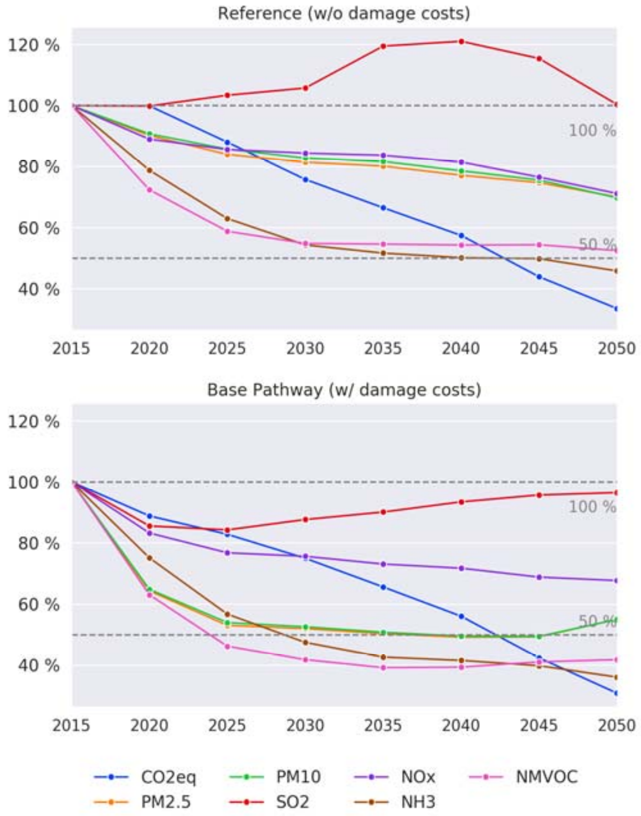


Figure 1: Changes in emissions of air pollutants and GHG relative to 2015 levels in EU-28.

These differences are also visible on sector level in 2050 as depicted in Figure 2, where $PM_{2.5}$, as the most hazardous substance to human health, is representative of air pollution. Both the conversion as well as the transport sector show lower $PM_{2.5}$ and GHG emissions in the Base Pathway compared to the Reference Scenario (w/o damage costs). As a result of **less biomass utilization**, **air pollution from the residential sector** is also **lower** in the **Base Pathway** (w/ damage costs), but **GHG emission reductions are not as high** as in the Reference Scenario (w/o damage costs). Similarly, **a high share of biomass** also results in **increased $PM_{2.5}$ emissions from industry, agriculture and the commercial sector** in the **Reference Scenario**. For industry, $PM_{2.5}$ emissions even increase in the Base Pathway (w/ damage costs) due to the high share of process emissions and increasing demand. Internalizing costs of air pollution mainly affects conversion and electricity supply, the residential and commercial sector as well as agriculture. Industry and transport are both characterized by comparatively high air pollution control standards and also by non-exhaust emissions (abrasion processes in road transport and process-related emissions), which may further limit reduction potentials.

With regard to **climate change mitigation**, both scenarios result in **almost the same GHG emission levels in 2050**, mostly driven by the same ambitious reduction targets. The **Base Pathway** (w/ damage costs) still achieves **higher emission reductions in the years before 2030,** partly for the same reasons that cause the sharp decrease in air pollutants, as well as **slightly lower CO_2 levels in 2050**. This indicates **that decarbonisation can benefit from air pollution control**, particularly in the near future, which is also reflected in **CO_2 prices on ETS emissions**, which are **on average 44 % lower** compared to the Reference Scenario in these years.

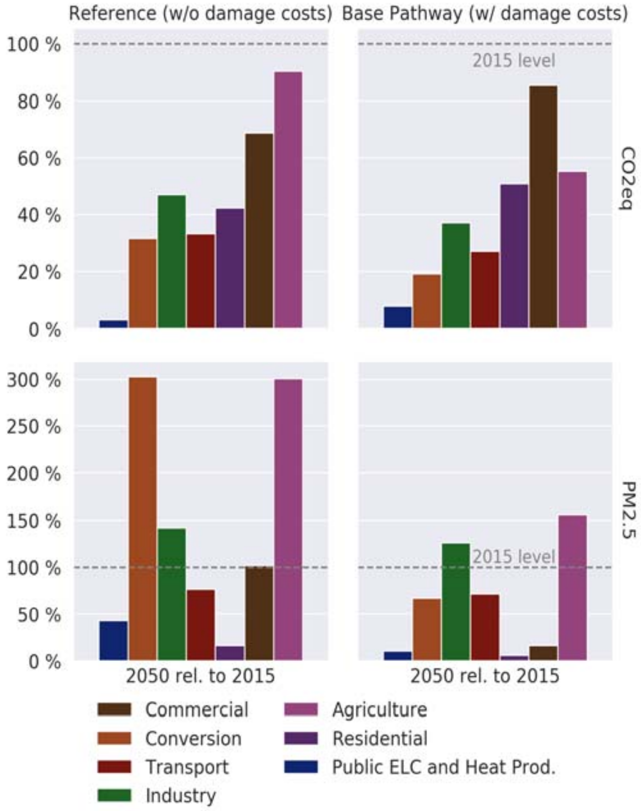


Figure 2: Sector-specific levels of CO_2-eq. and $PM_{2.5}$ for EU-28 in 2050 relative to 2015 (100 %).

When analysing the distribution of health impacts caused by air pollution form EU28, CH and NO, **not all countries profit equally from better air quality and health**. While some countries, such as Germany and Poland, show high reductions in exposure and attributable external costs in both scenarios (Figure 3 and Figure 4), exposure to air pollution, related health impacts and attributable costs actually increase for other countries. Greece and Cyprus, for example, are showing an increase of impacts over time that is even higher in the Base Pathway (w/ damage costs). Note that associated costs in Figure 4 are allocated following the “Polluter Pays” principle including health costs in neighbouring countries whereas health impacts in Figure 3 relate to their own exposed population, which is also affected by emissions from other countries.

Box 2: Disability Adjusted Life Years

To assess the combination of different health impacts, the common indicator ‘Disability Adjusted Life Years’ (DALY) can be used [1]. DALY reflect the impact of a specific health outcome on both the quality and quantity of a life lived by providing scores for each health outcome according to its severity between 1 (death) and 0 (perfect health). When this is combined with the typical duration of an illness, it is possible to calculate a weighted sum of mortality and morbidity as a combined indicator for health impacts due to air pollution. Impacts on chronic mortality are usually better assessed in terms of “Years of Life Lost” (YOLL), rather reflecting the average loss in life expectancy based on life table calculations then actual cases of death. In this case, one YOLL equals one DALY as the most severe health outcome possible.

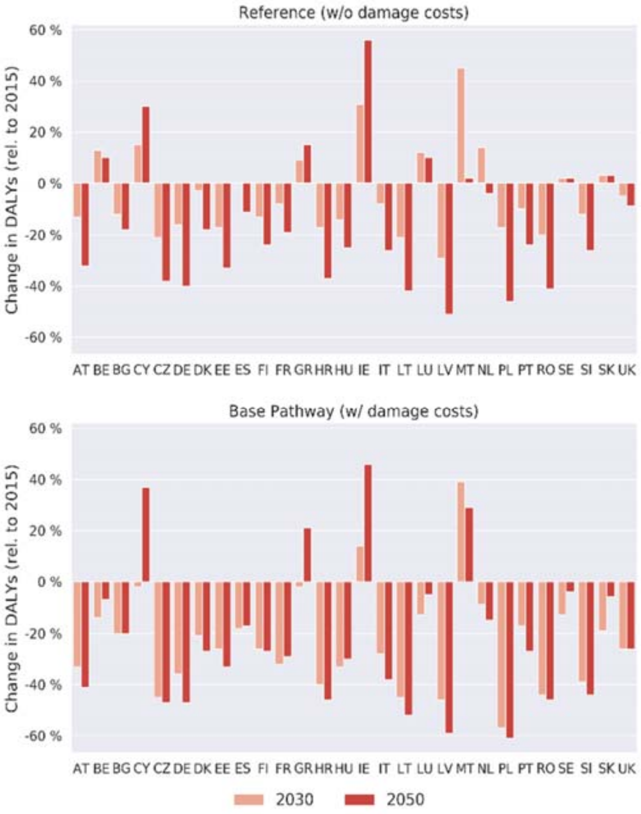


Figure 3: Changes in health impacts attributable to air pollution from EU-28, CH and NO for selected years rel. to 2015.

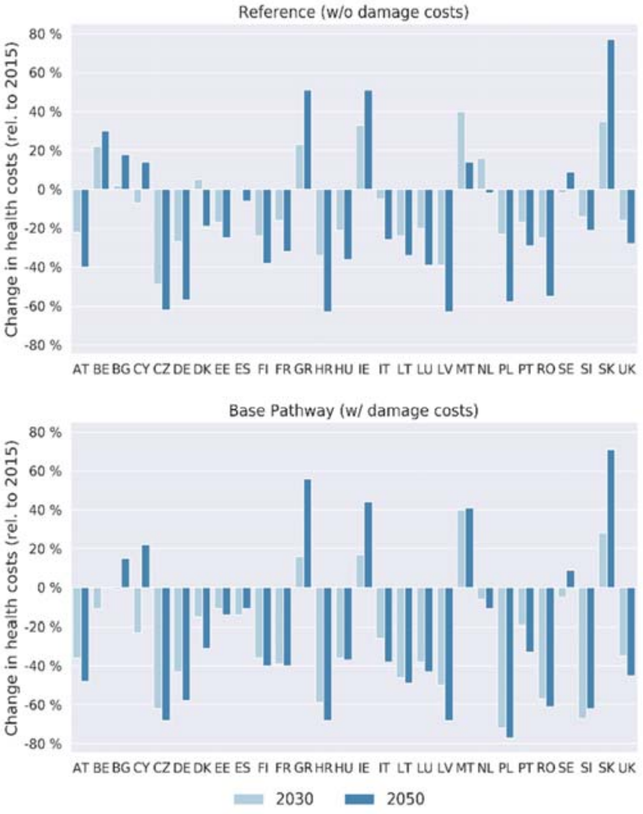


Figure 4: Changes in country-specific costs of air pollution due to health impacts for 2030 and 2050, relative to 2015. Allocated following the “polluter pays” principle.

Central European countries like Germany, Poland, and France can actually **cut their attributional costs** by a **third or even more than half** (Figure 4) – clearly **identifying them as beneficiaries of climate change mitigation efforts** and air pollution control within the European energy system. As depicted in Figure 3 their health impacts, however, are not reduced as much. With the burden sharing in GHG reductions in ETS sectors in combination with the specified national targets, **reductions in emissions** of air pollutants **in central Europe** are at least partly achieved by **shifting activities and related emissions to south-eastern Europe, resulting in increased attributable costs in Greece, Cyprus, Bulgaria and Slovakia**. These findings highlight that, similar to climate change mitigation policies, **reducing air pollution and its impacts requires a joined up, collaborative approach**. In the **Base Pathway**, internalizing costs of air pollution results in an **even more decisive decrease in associated costs in Germany and Poland.** This also indicates that **most of the potential, additional welfare savings** can be attributed to **further reducing emissions and impacts in only few countries**. Across the EU28, **associated costs** of air pollution for the Reference Scenario (w/o damage costs) are **21 % lower** in 2050 than in 2015, which corresponds to 54 bn. € in cost savings[1]. In the **Base Pathways** (w/ damage costs), these savings are even higher, resulting in **additional welfare benefits of 879.5 bn. €[2] over the years**.

Summarizing conclusion

By comparing two pathways towards a low-carbon European energy system situated within the same future narrative, **this study analysed possible interactions of air pollution control and climate change mitigation policies** and **their impact on the energy system transformation as well as air quality**. Ambitious **GHG reduction targets** lead to reduced emissions of air pollutants and **improved air quality in most EU-28 countries** (Reference Scenario, w/o damage costs). **Introducing costs of air pollution** and its implications on human health into the model (Base Pathway), results in even higher reductions in emissions of air pollutants and GHG and thus **additional benefits for the society**. This indicates that **air pollution control and climate change mitigation can be favourable for each other**. As both climate change and air pollution mostly relate to the same emission sources, **climate change mitigation and air pollution control policies should thus be developed and assessed in an integrated manner** to benefit from each other. Results of this study indicate, for example, that **additional air pollution control may lead to earlier action in reducing GHG emissions**, especially in non-ETS sectors, and by that may foster climate change mitigation. On the contrary, **biomass utilization** as a result of ambitious decarbonisation targets **may increase emissions of air pollutants if their adverse impacts are not considered** simultaneously. Because of these complex interactions, **decarbonisation policies alone do not inevitably lead to reductions of air pollution across all sectors**. As indicated by the Reference Scenario (w/o damage costs), emissions of air pollutants may even increase in conversion, industry and agriculture. While **considering associated health costs** as a proxy for actions to further improve air quality**, effectively reduces emissions further**, their **impact is also limited**. Even under a low carbon system, **process-related emissions**, such as particles from steel production in the industrial sector or **from abrasion processes in road transport, remain challenging**. These emissions can often only be mitigated by a change in behaviour (e.g. shifts in transport modes) or new, innovative process technologies. Such changes may, in turn, also result in lower GHG emissions.

The **uneven distribution of health benefits across countries**, with some countries even showing higher exposure in 2050 compared to 2015, **may lead to conflicts between pan-European climate change mitigation policy** and **national or even local air**

---

[1] Undiscounted savings in 2050, assuming constant 2015 costs as a reference.

[2] Net present value 2015. 5 % discount rate applied.

quality plans. Additionally, the role of **trans-national impacts**, i.e. impacts occurring in one country caused by emissions of another country, should not be underestimated. **This highlights the necessity for a pan-European strategy to address climate change and air pollution simultaneously**. With burden-sharing schemes and national targets aiming to achieve a common target across the EU, integrated policies are even more important.

While this study indicated that **air pollution control and climate change mitigation interact with and may profit from each other**, **the magnitude of societal benefits** of an integrated policy approach in this area is **still subject to uncertainty** as estimating **marginal damage costs for future years is highly influenced by assumptions** regarding the determinants of and their influence on exposure assessments, such as population and emission projections. To better estimate future impacts, especially relating to distributional effects across Europe**, further research is needed regarding the influence and uncertainty of different data and realistic projections on actual exposure** and related marginal damage costs.

References

[1] P. Bickel und R. Friedrich, Hrsg., Externalities of Energy: Methodology 2005 Update, Luxembourg: Office for Official Publications of the European Communities, 2005.

[2] D. Schmid und U. Im, „Focus Report on Health Impacts and External Costs due to Air Pollution, REEEM D5.2,“ 2019.

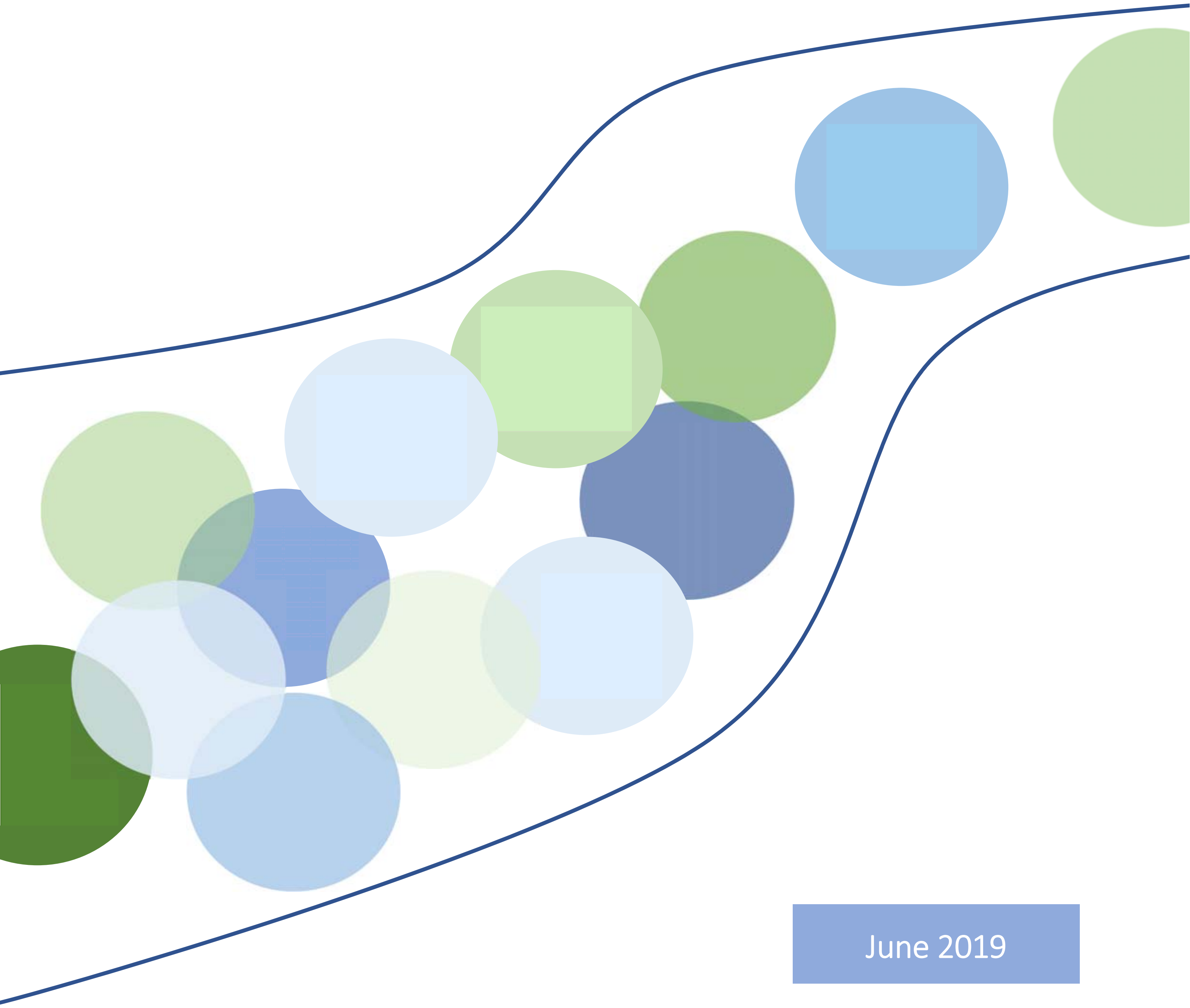
[3] P. Korkmaz, M. Blesl, U. Fahl, O. Balyk, S. Petrović, M. B. Simonsen und H. Henke, „Integrated Energy System Model, REEEM D6.1,“ 2019.

[4] G. Avgerinopoulos, F. Gardumi, U. Fahl, P. Korkmaz, R. Montenegro, J. Welsch, S. Pye, X. Pan, U. Mörtberg, S. Syri, A. Hast, A. Darmani, B. Normak und A. Salem, „First Integrated Impact Report, REEEM D1.2,“ 2018.

[5] U. Im, J. Brandt, C. Geels, K. M. Hansen, J. H. Christensen, M. S. Andersen, E. Solazzo, I. Kioutsioukis, U. Alyuz, A. Balzarini, R. Baro, R. Bellasio, R. Bianconi, J. Bieser, A. Colette, G. Curci, A. Farrow, J. Flemming, A. Fraser, P. Jimenez-Guerrero, N. Kitwiroon, C.-K. Liang, U. Nopmongcol, G. Pirovano, L. Pozzoli, M. Prank, R. Rose, R. Sokhi, P. Tuccella, A. Unal, M. G. Vivanco, J. West, G. Yarwood, C. Hofgrefe und S. Galmarini, „Assessment and economic valuation of air pollution impacts on human health over Europe and the United States as calculated by a multi-model ensemble in the framework of AQMEII3,“ *Atmospheric Chemistry and Physics,* pp. 5967-5989, 2018.

Life Cycle Assessment and Demand for Critical Materials

Policy Brief



June 2019

Summary

Deliverable 5.3 “Life Cycle Assessment and Demand for Critical Materials” assessed pathways towards a low-carbon energy system for the European Union developed in the REEEM project for environmental impacts in a life cycle perspective and risks with regards to material availability. Based on the results of the Deliverable we came up with the following recommendations:

- Holistic perspectives should be integrated into assessments of future pathways for a low-carbon EU28 and be considered in energy policy making to ensure actual transition to more environmentally sustainable energy systems.
- Material efficiency, recycling and substitution should be considered as policy imperatives for mitigating critical material supply risk under all three pathways considered in REEEM.

Introduction

Energy system investment decisions can significantly impact the environment and the transition to a more environmentally sustainable society. “Environment” here should be understood in a broad sense, not just addressing climate change impacts from emissions of greenhouse gases (which can be reflected by the change in radiative forcing expressed by the Global Warming Potential – expressed in kg-CO2eq – or by metrics that model further the cause-effect chain and capture the potential damages to human health and ecosystems) but other types of environmental problems like chemical pollution, resource depletion, etc. To ensure environmental sustainability, it is important to quantify to what extent the anticipated pathways towards a low-carbon EU society contribute to all those environmental problems, and whether they lead to actual impact reductions.

Deliverable 5.3 of the REEEM project addressed this need by performing life cycle assessment and by evaluating the demand in critical materials associated with the pathways to a low-carbon Europe defined in the project. This Policy Brief presents main findings of the two assessments and provides policy recommendations based on the results of the assessment.

Three pathways are considered in REEEM: “Coalitions for a low carbon path”, “Local solutions”, and “Paris Agreement”. The first, in this report referred to as the Base Pathway, achieves an 80% reduction in energy-related emissions by 2050 as compared to 1990 levels. The second also achieves an 80% reduction, but with a significant fraction of the climate mitigation efforts driven by communities and individuals. The third achieves a 95% reduction corresponding to the obligations agreed upon in the Paris Agreement.

How was the assessment performed?

Life cycle assessment

Life cycle assessment (LCA) is an ISO-standardised methodology that enables us to quantify a large variety of environmental impacts in a life cycle perspective, i.e. from extraction of raw materials, through production and use, up to end-of-life and potential recycling or disposal (Laurent et al. 2018). Thanks to its holistic nature, LCA is widely used to address eco-efficiency questions in comparative studies; for example addressing whether a specific technology is better than another, providing the same service. The inclusion of the full life cycle perspective and the broad variety of environmental problems is essential to identify potential hotspots, which are places in the energy system life cycle that are associated with large environment impacts, and potential burden-shifting across life cycle stages or environmental problems. An example of environmental burden-shifting could occur if a particular strategy leads to decreasing of some environmental impacts, while increasing others at the same time, e.g. chemical pollution (Laurent and Espinosa 2015).

Critical material demand

The critical material analysis focused on understanding what the implications of the three REEEM pathways could be for the critical material demand related to energy technologies within the EU. As definitions of criticality are wide ranging, the initial step in the analysis was to carry out a literature review on material criticality as it pertains to the broader REEEM project, in order to establish the specific materials that will be considered in the analysis. These materials were then mapped to energy technologies that require them and further to the REEEM results reflecting the development of the energy system, in order to project the critical material demand reflected by the three pathways. Finally, a bottleneck assessment was carried out to determine whether and which materials could provide challenges to the transitions depicted in the REEEM scenarios.

What tools were used in the assessment?

Life cycle assessment

An LCA model was developed to enable the assessment of the entire energy systems of EU with a full life cycle coverage and with a coverage of several environmental impact categories. For time constraints reasons, only the Base and Paris Agreement pathways out of the three pathways considered in REEEM were assessed.

TIMES is an energy system model generator using a bottom-up linear optimization model (REEEM, 2019), and its outputs are used as inputs for constructing the LCA model that strongly relies on life cycle inventories. Life cycle inventories (LCI) are building bricks for the model that compiles all inputs (energy, intermediate materials or products, resources) and outputs (energy, waste, emissions, intermediate products) of a given process or activity (e.g. rolled steel production, high-voltage electricity from a specific technology of coal-fired power plant in a given country, etc.). Using the ecoinvent database (v. 3.3; Wernet et al. 2016), which is currently the largest LCI database with more than 20,000 process LCIs, as starting point, the LCA model was built with the addition of 7,275 created or edited processes, which were parameterized and linked to an Excel interface allowing for differentiating between technologies, time and countries, and allow for assessing different pathways (connection via 33,112 links between the LCI processes and the Excel interface).

The LCA model was applied to all energy systems. Only assessment at full EU-28 scale was assessed since the TIMES model in REEEM was developed to fit EU-wide narratives and it therefore does not bring full consistency at national level. For example, national energy policies are not factored in the TIMES model, meaning that potentially major discrepancies exist between national pathways framed in existing and planned policies and national trends resulting from the TIMES model.

Critical material demand

Based on the literature review, a database mapping critical material inputs to energy technologies was first constructed. As with the LCA model, results from TIMES Pan-EU were used to reflect the development of the energy system and thus the database was further mapped to the technologies explicitly represented in TIMES Pan-EU. Python scripts were then used to automate the production of critical material projections from the TIMES Pan-EU outputs.

What were the main results?

Life cycle assessment

Reductions of climate change impacts (expressed as change in radiative forcing, in kg-CO2 equivalent) by 32% and 49% between 2015 and 2050 are obtained for the Base and Paris Agreement pathways, respectively. These decreases are much lower than the reduction of GHG emissions. For example, in the Paris Agreement pathway, a reduction of 95% GHG emissions in 2050 compared to 1990 level is modeled in TIMES PanEU model, which roughly corresponds to a decrease of 93% between 2015 and 2050. This is different from the decrease of 49% obtained with the LCA model. An explanation for such differences may stem from the inclusion of the full life cycle in the LCA study, as opposed to the main focus on greenhouse gas emissions occurring within the EU28 geographical boundaries in the TIMES PanEU model. The climate change impacts of fossil fuel-based energy technologies are driven by the combustion processes, while those of renewables sources like wind turbines or photovoltaics are stemming from their production stage. As a consequence, the switch from fossil fuels to renewables tend to shift the climate change impacts outside EU28, if renewable energy technologies are produced outside Europe and imported thereafter. This may therefore limit the actual decrease in anticipated greenhouse gas emissions.

However, it should be noted that potential reductions of GHG emissions in regions outside Europe are not considered in the LCA model, which may then tend to overestimate the GHG emissions in these regions (because of no time differentiation factoring in the decreases in emission intensities), and lead to underestimate the overall decrease in the global GHG emissions associated with the two pathways. An estimate of the true decrease in GHG emissions should therefore expected to range between the reduction values used in the pathway modelling (in TIMES model) and the reduction values reported above.

When assessing the total human health damages, none of the Paris Agreement or the Base pathways seem to perform better than the other –see Figure 1. Results show that both pathways lead to the same level of decrease between 2015 and 2050 (i.e. decrease of ca. 30%). However, it must be noted that environmental trade-offs occur, with some environmental impact categories tending to decrease more in one pathway over another, e.g. climate change decreasing more in Paris Agreement than in Base pathways, and vice versa, e.g. cancer effects from released chemicals aka “human toxicity, cancer effects (HH canc)” (Fig. 1). Particulate matter formation, climate change and toxicity of chemical releases are found to be the three main contributors to human health damages from energy systems in EU28. These impacts are caused by emissions of particulate matter (and its precursors, like SOx, NOx, NH3), greenhouse gases and metal and organic substances.

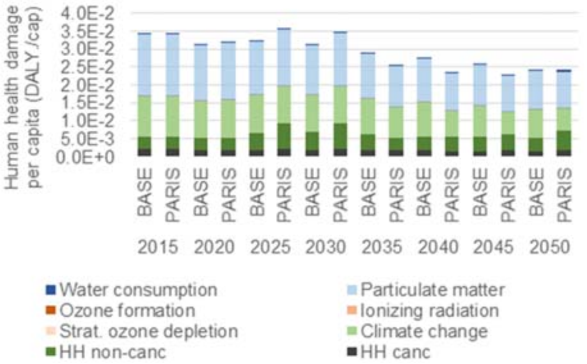


Figure 1. Total human health damage assessment results in EU28 over 2015-2050 for both Base and Paris Agreement pathways, with contribution of different environmental impact categories. HH: human health.

It can be observed that the total damages from the LCA study are equivalent to approx. 17 million DALYs in 2015 and decrease to 12 million DALYs in

2050 for both Base and Paris Agreement Pathways (Fig. 1), although as indicated previously, overestimations are expected in these estimates, particularly in future years due to the modelling of regions outside Europe using the same technology efficiencies – and hence emission intensities – as today (no time differentiation). Yet, factoring in this overestimation, the obtained results would still remain higher than the results reported when using the ECOSENSE model, where approximately 2.8, 2.0 and 1.9 million DALY were found to stem from the energy systems in EU28 in 2015 for both pathways, in 2050 for the Base Pathway and in 2050 for the Paris Agreement Pathway (see D.5.2, Schmid et al).

The different scoping between the two assessments explains part of this difference since the ECOSENSE model focuses on the emissions during the operation stage of the energy system, while the LCA study includes the entire life cycle of the energy systems, from extraction of raw materials through production and installation and operations up to end-of-life. The difference in impact contributors to the total human health damages is another cause for the discrepancies. The assessment from the ECOSENSE model considers emissions of few air pollutants, while the LCA study encompasses all environmental stressors contributing to human health damages, hence including contributions from climate change, water stress and carcinogenic and non-carcinogenic effects induced by chemical releases like metals and organic substances.

Critical material demand

The analysis suggests that a number of potential supply bottlenecks exist across the three risk dimensions considered, geological, economic and geopolitical dimensions. In table 1 below summarise supply risks for each of the selected materials. Cobalt and tellurium are at risk across all three assessed dimensions. Platinum and the rare earths are not at risk from a geological perspective but are exposed to economic risks due to rapid demand growth and geopolitical risks as a result of high supply concentrations in single countries. Gallium and indium are also clearly exposed to economic and geopolitical risks but the overall geological risk level could not be determined due to a lack of quantitative data on reserves. Lithium is at risk from the economic dimension but is not likely to be affected by geological constraints or geopolitical crises. Finally, hafnium does not appear to be at risk in any of the assessed dimensions.

Table 1 – Overview of Supply Risks for Selected Materials

Material	**Risk**		
	Geological	**Economic**	**Geopolitical**
Cobalt (Co)	Yes	Yes	Yes
Gallium (Ga)	-	Yes	Yes
Indium (In)	-	Yes	Yes
Hafnium (Hf)	No	No	No
Lithium (Li)	No	Yes	No
Platinum (Pt)	No	Yes	Yes
Rare Earths	No	Yes	Yes
Tellurium (Te)	Yes	Yes	Yes

Our analysis further suggests that in absolute terms, the Local Solutions pathway has the highest cumulative total materials demand and is at the greatest risk of being affected by supply bottlenecks, while material demands for the Coalitions for a Low Carbon Path and Paris Agreement pathways are much lower. Both of the latter pathways represent similar levels of material demand at 7169 kt and 7710 kt respectively, whereas the Local Solutions pathway has material demand of 9483 kt, owing to the significantly larger role that a transition to low carbon end-use demand technologies has in this case. Electro-mobility is a key driver of increased critical material demand in all three scenarios.

Implications and Recommendations

Implications and main recommendations from Task 5.3 are summarised below:

- From the LCA study, the findings demonstrate that, in addition to a systemic and holistic perspective, including all life cycle stages (and not just the operations within EU), a broad spectrum of environmental problems, covering all relevant impacts of energy systems, must be included in environmental sustainability assessments. Only such broad and all-encompassing scoping can provide a complete overview of which environmental problems are predominant in the total environmental burden, where potential environmental trade-offs occur, where burden shifting from one life cycle stage to another or from one impact to another arise, and what to prioritize in decision-making processes. Such holistic perspectives should be integrated into assessments of future pathways for a low-carbon EU28 and be considered in energy policy making to ensure actual transition to more environmentally sustainable energy systems.
- The assessment suggests that material availability does pose some risks for the three transition pathways and mitigation measures for these risks should be considered. A large fraction of the critical material demand assessed in this analysis arises from the transition to electro-mobility, so per unit estimates of material demand for vehicles are a key driver of the findings. It is worth reflecting that research into material efficiency and component substation has found that rare earth content in vehicle magnets could be reduced through efficient design by up to 40% and that options for electric motors are under development that are free of rare earths entirely. This suggests that material efficiency, recycling and substitution should be considered as policy imperatives for mitigating critical material supply risk under all three pathways.

References

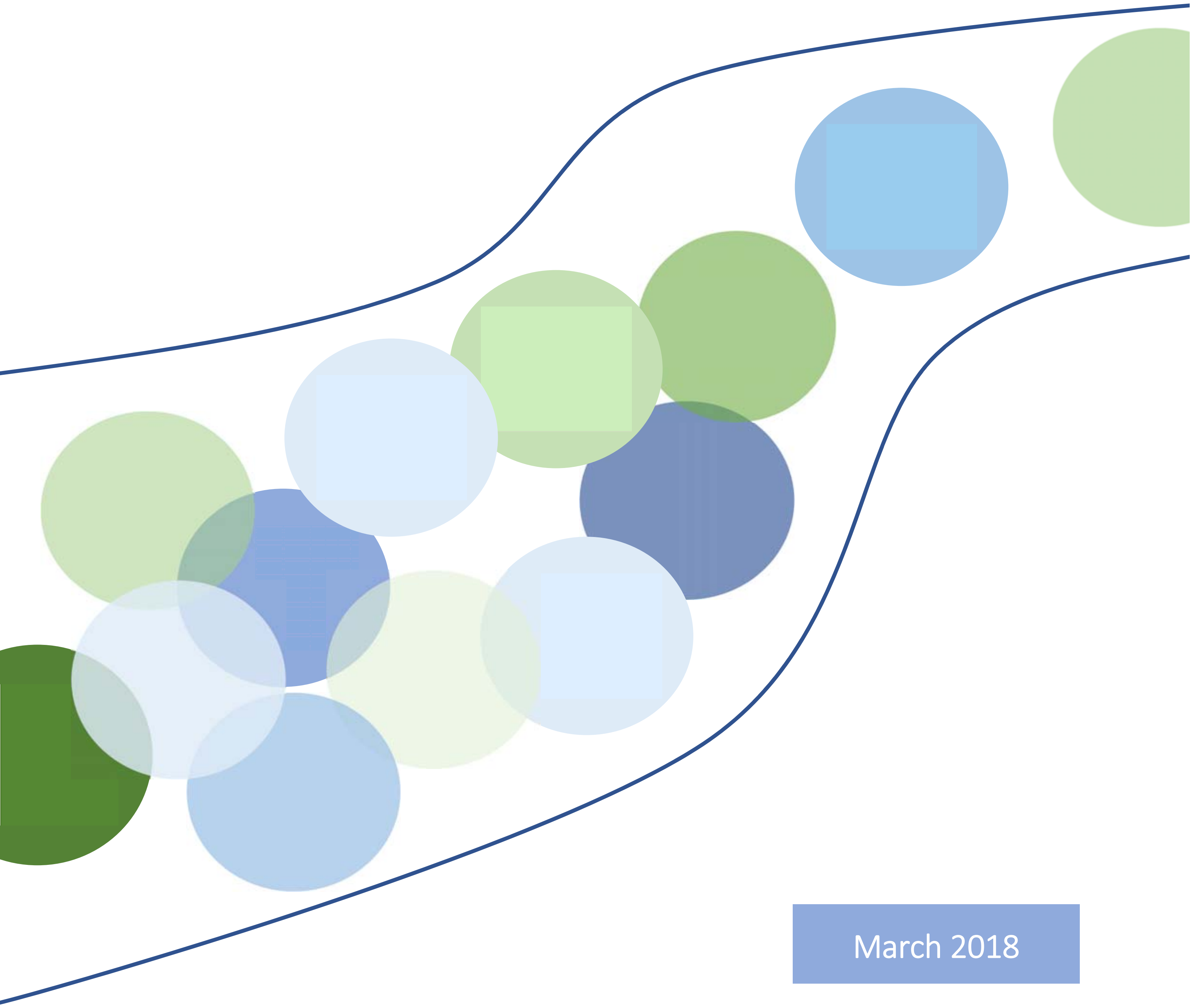
Laurent A, Espinosa N (2015) Environmental impacts of electricity generation at global, regional and national scales in 1980–2011: what can we learn for future energy planning? Energy Environ Sci 8:689–701. doi: 10.1039/C4EE03832K

Laurent A, Espinosa N, Hauschild MZ (2018) LCA of Energy Systems. In: Hauschild MZ, Rosenbaum RK, Olsen SI (eds) Life Cycle Assessment: Theory and Practice. Springer International Publishing, pp 633–668

Wernet G, Bauer C, Steubing B, et al (2016) The ecoinvent database version 3 (part I): overview and methodology. Int J Life Cycle Assess 21:1218–1230. doi: 10.1007/s11367-016-1087-8

Accounting for Ecosystem Services in Energy Planning

Policy Brief



March 2018

Summary

We expect that the use of biomass will increase significantly as the world is focusing on increasing the share of renewable energy to mitigate climate change. The unchecked increase in use of forest biomass can have negative environmental effects. In the EU significant focus is given to ensuring that the energy derived from biomass is sustainable. Based on the Ecosystem Services Case Study focusing on Lithuania that was carried out in the REEEM Project, we came up with the following recommendations:

- Apply a bi-directional and iterative process when formulating National Energy and Climate strategies, so that local constraints and availability of resources are taken into account;
- Support the process by applying the tools that can bring ecosystem services consideration in energy planning;
- Give sufficient focus to forest management strategy as this is a crucial linkage between forest biomass extraction and other ecosystem services.

Introduction

Forests are important for climate change mitigation: they provide bioenergy feedstock to substitute fossil fuels and they store carbon. Forests are also important for other ecosystem services (benefits people obtain from ecosystems). They include **provisioning services** such as food, water, timber, and fibre; **regulating services** that affect climate, floods, disease, waste, and water quality; **cultural services** that provide recreational, aesthetic, and spiritual benefits; and **supporting services** such as soil formation, photosynthesis, and nutrient cycling. Increasing use of renewable energy sources (RES), such as forest bioenergy feedstock, could potentially conflict with environmental goals, affecting the sustainability of the delivered energy, which is one of the three overarching policy challenges mentioned in SET-Plan Roadmap [1]. The EU Renewable Energy Directive (2009/28/EC) aims to promote RES and to reduce greenhouse gas emissions in a sustainable way, ensuring that negative effects on ecosystem services are avoided [2,3]. Therefore, it is essential to integrate multiple ecosystem services in assessments of energy policies and plans for increasing use of forest biomass. However, energy policy assessments seldom take landscape-level ecosystem services into account [4]. Moreover, development of methods and tools for sustainability assessment of renewable energy options is needed, that can link energy models with ecosystem services assessment tools for integrated analyses and allow for balancing various ecosystem services and analysing implications of forest bioenergy options.

Deliverable 5.4 of the REEEM Project – Ecosystem Services Case Study Report – assessed the implications of the use of forestry biomass to meet the decarbonisation targets included in the Lithuanian National Energy Strategy [5]. This Policy Brief presents main findings of the assessment and provides policy recommendations based on the results of the assessment.

How was the assessment performed?

The analysis considered two pathways for the development of biomass demand in Lithuania. In one pathway, Biomass Low, the biomass potential was limited according to assumptions on its availability on the domestic market [5]. The other pathway, Biomass High, assumed a higher availability of biomass and a lower price, resulting in a higher biomass demand. Both pathways represented the same energy policy conditions for the renewable energy share in the final energy demand.

The impact of these pathways on ecosystem services was analysed across the following categories: industrial wood production and bioenergy feedstock representing provisioning services; carbon storage representing regulating service that affects climate change; forest recreation evaluation representing cultural services; and habitat indicators of essential biodiversity components. Different intensity of forest management was considered.

What tools were used in the assessment?

A bottom up energy system model for Lithuania formulated in the MESSAGE [6] framework was used to estimate the cost optimal forest biomass use for bioenergy purposes in Lithuania for the two pathways Biomass Low and Biomass High. The model covers a wide variety of energy technologies including different types of heat plants and CHPs, technologies for electricity production, storage, etc. The model reflects existing and prospective policy measures [5], as well as electricity exchange with other countries.

The Landscape simulation and Ecological Assessment (LEcA) tool [7] was used to assess impact on ecosystem services. The LEcA tool allows assessing several ecosystem services together, including sustainable production of forest bioenergy feedstock. The integrated assessment of forest ecosystem services is aided by three modules embedded in a GIS framework: 1) LandSim simulates forest growth and management; 2) Storage and yield estimator uses spatially-distributed output of LandSim to aggregate and estimate the storage of carbon and the yield of industrial wood and bioenergy feedstock; and 3) Habitat assessment tool localises and quantifies habitat with high value for forest biodiversity as well as for recreation. The LEcA tool uses land use data and data from the Lithuanian State forest cadastre [8,9].

What were the main results?

The case study focusing on Lithuania assessed implications of the use of forestry biomass to meet the decarbonisation targets included in the Lithuanian National Energy Strategy [5]. When low prices and high availability of biomass were assumed (Biomass High pathway), biomass was found to have a considerable share in the energy supply mix of Lithuania. However, when applying an intensive forest management strategy to meet this demand, the use of biomass would exceed the country's resource base. This would cause damage to the ecosystem in the long run. This was found to be less probable under Biomass Low pathway and following a business-as-usual forest management strategy.

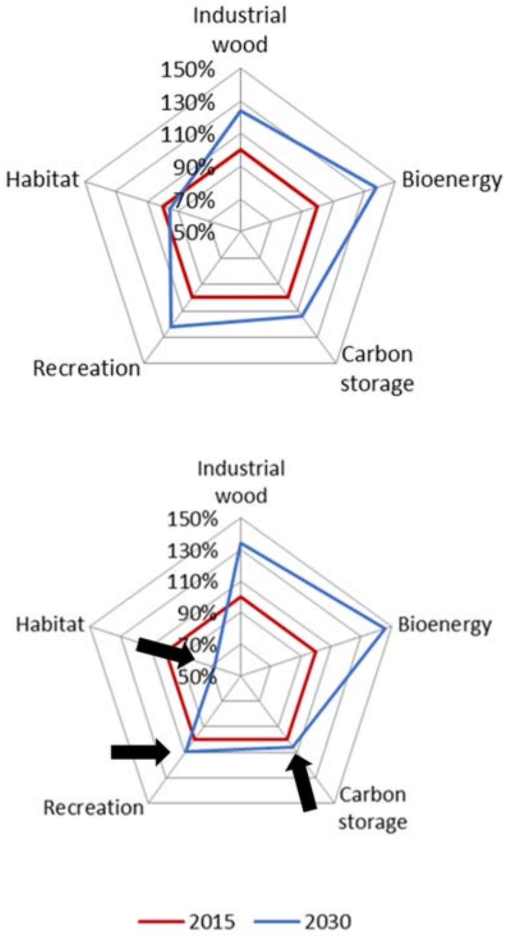


Figure 1. Impacts of the use of biomass for bioenergy on other ecosystem services in case of less intensive (top) or more intensive (bottom) use of biomass.

Intensive harvesting of forest biomass for energy use may be detrimental in the long term for ecosystem services such as habitat, recreation and carbon storage (Figure 1). Generally, when applying a more intensive management strategy, the biomass yields were considerably higher in the earlier simulation periods, but by the end of the modelling period (around 2050) the yields were on the same or declining level while the biomass demand in Biomass Low and Biomass High pathways increased. A similar effect was observed with regards to the yields of **industrial wood**: an intensive management strategy gave a much higher yield in the beginning of the simulation period, but after around 2040, the resources would be somewhat exhausted, and a decrease would follow. The management strategy also influenced **carbon storage**. A shorter rotation period i.e., the trees were harvested on average at a younger age, resulted in a lower carbon stock under a more intensive management strategy. The resulting smaller area of old and mature forest also led to smaller **recreational area**, as well as **habitat area** supporting biodiversity. The **habitat network area** was also higher under a less intensive forest management strategy.

Implications and Recommendations

As the case study focusing on Lithuania shows, the national decarbonisation targets can have substantial impacts on the ecosystem services. These impacts are not evident unless an assessment taking local conditions into account is performed. Under favourable conditions, biomass could constitute a considerable share in the energy supply mix of Lithuania. However, the high use of biomass could exceed the country's resource base, causing damage to the ecosystem in the long run. Even when the resource base is not exceeded, the impact of biomass use on the ecosystem depends on how intensive the forest management is. These results suggest the following:

- When developing the National Energy and Climate strategies, a bi-directional and iterative process could be appropriate, where local constraints and availability of resources are taken into account in the national policy making.
- This process can be supported by applying toolboxes integrating models such as MESSAGE and the LEcA tool (demonstrated in the case study) which can bring ecosystem services consideration in energy planning.
- Substantial focus should be given to developing management strategies that keep the desired level of ecosystem services while supporting fulfilment of national decarbonisation targets. The same level of biomass supply can often be obtained using a multitude of different forest management configurations, both with regard to the character of activities and their geographic allocation. Forest management strategy is a crucial linkage between forest biomass extraction and other ecosystem services.

References

[1] European Commission, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - A European strategic energy technology plan (SET-plan) - "Towards a low carbon future," 2007.

[2] European Commission, A sustainable Europe for a better world: A European Union strategy for sustainable development, 2001.

[3] European Commission, REPORT FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling, 2010. doi:SEC(2010) 65; SEC(2010) 66.

[4] X. Pang, U. Mörtberg, N. Brown, Energy models from a strategic environmental assessment perspective in an EU context - What is missing concerning renewables?, Renew. Sustain. Energy Rev. 33 (2014) 353–362. doi:10.1016/j.rser.2014.02.005.

[5] A. Galinis, Technine Ekonomine Energetikos Sektoriaus Pletros Analize, Kaunas, Lithuania, 2015.

[6] International Atomic Energy Agency, Model for Energy Supply Strategy Alternatives and their General Environmental Impacts - User Manual, 2007.

[7] X. Pang, E.-M. Nordström, H. Böttcher, R. Trubins, U. Mörtberg, Trade-offs and synergies among ecosystem services under different forest management scenarios – The LEcA tool, Ecosyst. Serv. 28 (2017) 67–79. doi:10.1016/j.ecoser.2017.10.006.

[8] GIS-Centras, Spatial data set of (geo) reference based cadastre. National Center for Remote Sensing and Geoinformatics., (n.d.).

[9] State Forest Survey Service, Lithuanian State forest cadastre., Kaunas, 2016.