EUCALC

Explore sustainable European futures

Expert consultation workshop on electricity and fossil fuels

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Short Description

This deliverable describes presentations, discussions and lessons learnt during EU Calculator Expert consultation workshop on electricity and fossil fuels. Electricity generation is the main CO_2 emitting sector in Europe which needs to be fully decarbonized in the next decades. Thus, the focus of the workshop was the electricity generation (in comparison oil refinery is responsible for 3% of the European emissions). Hence the understanding and expert insight into the dynamics, as well as recent and future trends with their impacts on possible future emissions trajectories are critical.

The workshop started with the general introduction of the European Calculator project and the co-design process which is a key step in stakeholder involvement and, in particular, guiding element of the actual workshop. In order to put the European Calculator and its electricity supply module into context, a presentation from the representative of UK BEIS described the history and uniqueness of the Calculator approach. Followed by short introduction of the IMAGE integrated assessment model by expert of PBL Netherlands Environmental Assessment Agency who also involved in the sister project REINVENT.

Pannon, responsible for the module development, described then the current progress in sectoral modelling development and the main discussion items as focus for group work with focus on levers choice, calculation method, input data sources and definition of ambition levels. The report includes the most important findings that has been and will be used to fine tune data, calculation and levers for the module programming.

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Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

EUCalc policy of personal data protection in regard to the workshop:

EUCalc defined the procedures in order to reply to ethical requirements in Deliverable 12.1 (Ethics requirements – procedures and criteria to identify research participants in EUCalc – H – Requirements No. 1). All procedures in relation to the co-design process, in particular the stakeholder mapping, the implementation of the workshops and the follow-up of the workshops, follow these procedures. The informed consent procedure in relation to the workshops is based on D9.2 "Stakeholder mapping" and D9.4 "Method for implementation of EUCalc co-design process". The originals of the signed consent forms are stored at the coordinators' premises without possibility of access of externals. Scans of the informed consent forms are stored on the internal EUCalc file storing system.

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Abbreviations

BAU – Business As Usual

CCS – Carbon Capture and Storage

CHP – Combined Heat and Power

CSO – Civil Society Organization

CSP – Concentrated Soler Power technology

DSM – Demand Side Measures

EUCalc – European Calculator project or model

EV – Electric Vehicles

GHG – Greenhouse Gas

NREAP – National Renewable Energy Action Plan

PV – Photovoltaic technology

UK BEIS – Department for Business, Energy & Industrial Strategy within the UK Government

UK DECC – Department of Energy & Climate Change within the UK Government (former organization, followed by UK BEIS)

VRE – Variable Renewable Electricity

1 Executive Summary

The ultimate goal of European Calculator project is to create proficient decarbonisation model for EU member states and Switzerland. The model is mainly for policy makers on EU level and stakeholders from civil society. While meeting the scientific rigour is a requirement, the EUCalc model, as final output of the project, has to reflect the inputs and meet the needs of stakeholders.

In order to involve stakeholders, the project has introduced a co-design methodology. In this framework, every module of the European Calculator is discussed and presented to stakeholders within a co-design expert workshop. For the electricity supply and fossil fuel module, the respective workshop was held in 26th of October 2017 in Budapest as side event of the SUSCO Budapest 2017.

The main focus of the co-design workshop was to discuss scenarios and assumptions of the future electricity supply of Europe, and how those assumptions can be integrated into the model. This deliverable repots on the main outcomes of this stakeholder workshop. Before the workshop, Pannon circulated a brief description of the modelling setup, calculation method and lever settings, complemented by a set of discussion items and questions.

During the half-day workshop first, we introduced the context of modelling also by involving external speakers, followed by a session on the modelling of the electricity supply and finally discussion with stakeholders to validate assumptions and discuss open issues.

The inputs of the workshop and the questions made have influenced the development of the module significantly. Main areas of improvement have been lock-in resolution with decommission schedules, better definition of ambition levels and integration calculation mechanism for balancing strategies and technologies.

In agreement with the workshop, the EUCalc tool can fill a gap in the modelling landscape by offering a tool to policy makers since not all the tools are adequate and relevant for this stakeholder group. We are aiming to keep the balance between reliability and simplicity of the final modelling layout, as emphasized by many experts. This is needed, as the complexity of most tools risks the possibility of contribution to the policy development process.

2 Introduction

The European Calculator[1] aims to provide decision makers with an accessible modelling solution on EU plus Switzerland level. The novel and pragmatic modelling approach is between complex society-energy systems and integrated impact assessment tools. It introduces an intermediate level of complexity and a multi-sector approach that is based on co-design with stakeholders.

The model relates emission reduction with human lifestyles, the exploitation and/or conservation of natural resources, job creation, energy production, agriculture, costs, and so on, in one highly integrative tool which enables decision makers to get real-time policy support. Consequently, the approach will satisfy practical needs of decision makers.

In order to involve stakeholders, the project has introduced a co-design methodology. In this framework, every module of the European Calculator is discussed and presented to stakeholders within a co-design expert workshop. For the electricity supply and fossil fuel module, the respective workshop was held in 26th of October 2017 in Budapest as side event of the SUSCO Budapest 2017.

SUSCO Budapest is an international conference on sustainable development, organised by the Antall József Knowledge Centre. SUSCO Budapest 2017: The Global Energy Landscape focused on global energy supply and security topics. The plenary session held after the expert workshop involved Prof. Jürgen Kropp, coordinator of the project in a panel discussion. SUSCO Budapest 2017 focused on the shifting global energy market as one of the main challenges of the coming decades, aligned well with the objectives of the European Calculator project.

The electricity supply sector involves generation, transmission, and distribution of electricity. CO_2 emissions from electricity and heat production is the largest key category in the EU-28 plus Iceland accounting for 24% of total greenhouse gas emissions in 2016. Between 1990 and 2016, CO_2 emissions from electricity and heat production decreased by 29% [1]. The reason for this decrease is threefold; first improvement of thermal efficiency; secondly changes in the fossil fuel mix used to produce electricity, and thirdly the higher combined share of renewable energy and nuclear in 2016 compared to 1990 [1]. Therefore, the composition of the electricity generation mix is highly relevant for projections and modelling.

Before the workshop Pannon circulated a brief description of the modelling setup, calculation method and lever settings, complemented by a set of discussion items and questions. This deliverable reports on the main outcomes of the stakeholder workshop and how those impact the modelling process.

A total of 29 participants attended a workshop representing a good balance of public sector, companies, academic and CSOs, a list of participants can be found in annex.

[1] for more information on the project please visit http://www.european-calculator.eu/

3 Note on fossil fuels

The workshop reported in this deliverable focused on the electricity supply of EU plus Switzerland and not discussing fossil fuels apart the portion used to generate electricity.

The focus of the working package in which framework the reported workshop took place in energy supply in the context of EU plus Switzerland. While electricity generation produced 24% of the total greenhouse gas emissions in 2016, oil refinery is only responsible for 3% [1]. More importantly, from the view of the co-design process, there are multiple and highly debated ways to decarbonize the electricity supply, the volume and emissions from other uses of fossil fuels highly depend on the pathways chosen by demand sectors, as main consumers – for example transport for refined oil products, and buildings and industry for natural gas. Therefore, experts of Pannon attended the expert workshops of transport, buildings and industry, as the main sectors using fossil fuels, to learn about stakeholders' position on the supply. As a conclusion, demand measures, such as building refurbishment, were mentioned as actions to cut back emissions. Hence, unlike electricity supply, there are no levers associated to fossil fuel supply for purposes different than electricity generation.

Noteworthy, no participants of this workshop mentioned supply issues of fossil fuels destined for electricity generation which indicates the potential difference between group of experts knowledgeable in electricity generation and fossil fuel exploitation and trade.

Fossil fuels though are not omitted from the calculations, an oil refinery calculation module is implemented to turn oil products demand from all sectors into crude oil demand. Moreover, we aim to express how energy self-sufficiency of the EU would change with implementing different pathways. It is of crucial importance, as in 2016, near 90% of EU crude oil, 70% of natural gas and 40% of solid fuel demands were covered by imports[2]. In cooperation with other partners working on the rest of the world – EU trade, it is aimed to address this issue.

Nevertheless, as all parts of the model the calculations related to fossil fuel supply will be subject of the call for evidence process and transparent for the stakeholders to comment.

[2] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Energy_dependency_rate,_EU-28,_2006-2016_(%25_of_net_imports_in_gross_inland_consumption_and_bunkers,_based_on_tonnes_of_oil_equivalent).png

4 Workshop- introductory part

The introductory part was a set of plenary presentations aimed to introduce the project, the wider context of modelling, as well as the current status of the module development with the introduction of discussion item and questions as basis for co-design dialogue. This was complemented by two presentation of external experts, plus learning the participants in an interactive session. Here, all participants were asked to add their attitudes towards the subject.

A key element of the development is the involvement of stakeholders and integrating their inputs (referred as co-design process) by getting their feedback on modelling assumptions and creating of scenarios (4 pre-defined ambition levels for each lever). The aim of the co-design workshop is to discuss scenarios and assumptions of the future electricity supply of Europe, and how those assumptions can be integrated into the model. The format of the second part of the workshop was a facilitated discussion.

4.1 Background and expectations from the workshop

The 29 participants had different backgrounds and come from different sectors: CSOs, academia, private sector and governmental organizations/public sector but in a balanced distribution. Their visions of the workshop included learning about the model and contributing to the process of development of the calculator, but some participants had already more specific expectations: to help in defining of the ambition levels. Others had preliminary expectations towards the workshop to find out where is the exact border between assumptions and strategies, or how can governmental fact-based developed strategies and policies also include expectations of other sectors – mainly CSO and private sector.

4.2 Attitude towards need for models as policy tools

In order to define the place of EUCalc in the modelling landscape and the expected features, participants were asked on the purpose and adequacy of policy tools developed so far, as well as the position of EUCalc in comparison to other modelling tools. Although, part of the participants believed there are enough tools with similar content and purpose of emission modelling to 2050 and beyond, others did not agree to the statement. After a brief discussion, the conclusions brought them to the same side, stating that there are a lot of tools developed, but that there is still a gap in the following:

- There is a need to transfer more information to policy makers, since not all the tools are adequate for this stakeholder group.
- There are a lot of tools, but not all are relevant for the purpose due to their complexity that risks the possibility of contribution to the policy development process.
- Policy makers need simple tool useful for achieving consensus to see the political question and intervention possibilities.

- There is lack in transferring knowledge and using of the tools, due to inadequate communication between different stakeholder groups.
- There is a need for transparency and communication between policy makers and researchers (modellers).

Most important aspect of the model is a consensus around it and acceptance from the stakeholders. Stakeholders need to recognize it as result of co-development and co-design, seeing it as "their own", which will surely influence their will to use it for policy making, decision making and discussions on relevant topics.

4.3 European Calculator context

The team of the European Calculator project will create an online tool for analysing trade-offs and pathways towards sustainable and low-carbon Europe. With this tool, the partners aim to help decisionmakers and the general public to understand the links between our lifestyles, the energy system and the consequences for the environment. In the online tool, the users will be able to design own scenarios by setting the most important drivers of GHG emissions to one of four different ambition levels, and thus to better understand the different pathways towards a low carbon society and their associated sustainability impacts.

The calculator has a module-based operation whereas each module represents a sector, see Figure 1. A principle of building the EUCalc model is transparency, hence all the modules will be created by co-design process including a respective workshop and a call for evidence.

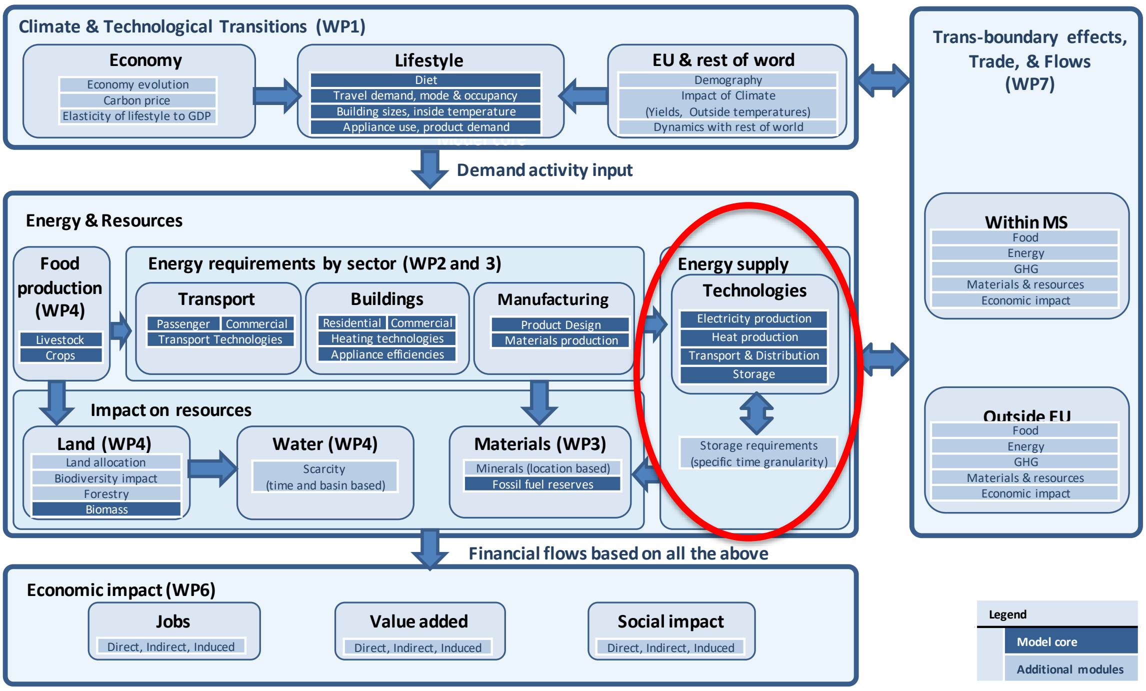

Figure 1 – Structure of the EUCalc model

Figure 1 shows the structure of the EUCalc project and the modular structure of the modelling itself. The interactions of WP5, Energy supply are related to the demand sides module in order to gather the need for energy carriers and electricity, and develop supply side scenarios. In this sense, demand is coming from the modules: WP1 (lifestyles), WP2 (transport and buildings), WP3 (industry), WP4 (agriculture), whereas input on technology parameters (including specific costs) is coming from the technology module. Output is used to calculate different impacts, mainly jobs and materials need in other modules.

The role and uniqueness of European Calculator were presented during the introductory part of the workshop. One key feature of the EUCalc model is transparency, however, in the challenging setup with need for both scientific rigour and simple, pragmatic use at the same time. This is of importance, as the process of investigating sectoral drivers, trends, game-changing practices, social and environmental impacts, is directly correlated with the depth of understanding of various stakeholders and also with the use of knowledge to generate action and change. In the EU picture of climate change and energy policy, including "Clean energy for All Europeans" legislation package [3], there is a need for transparent, yet scientifically rigorous tool, and EUCalc can fill this gap.

Therefore, the cooperation of scientific and societal actors in order to mobilize co-design knowledge is critical in the light of the EUCalc's mission to integrate and translate existing knowledge, both fundamental and applied, through to decision making and further to action, as shown in Figure 2 below.

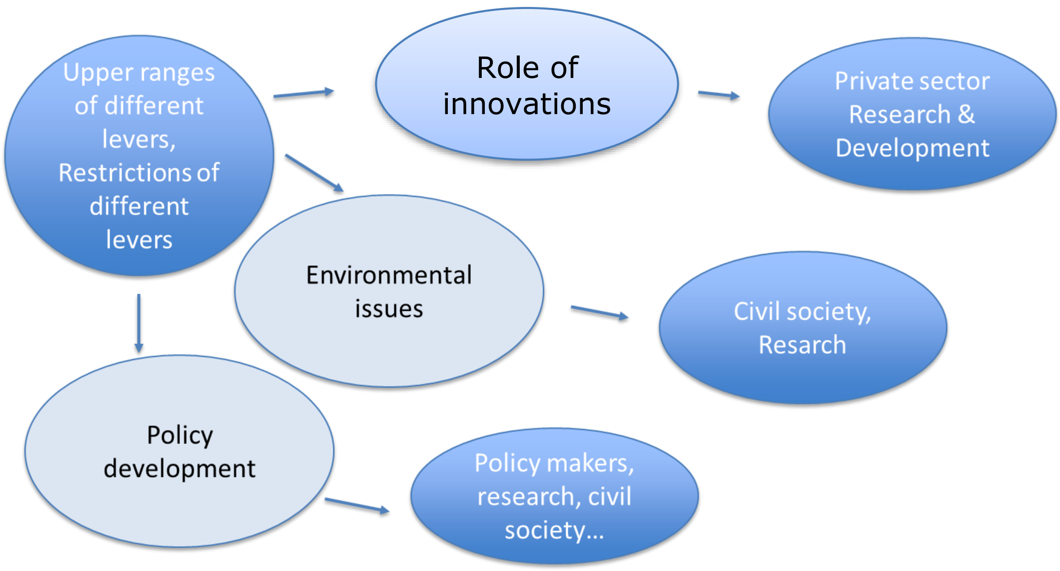

Figure 2 – Stakeholders' roles in the process

The key topic discussed here was whether or where is the balance (or even compromise) between reliability and simplicity of the model that create the wished balance between usefulness and transparency.

4.4 Contributions from invited speakers

4.4.1 History of the calculators and co-design

Stuart Younger, from UK BEIS introduced the original Carbon Calculator initiated by UK DECC. The focus was on the co-design process and transparency. UK Calculator, shown in Figure 3, was built for the UK long term climate strategy from 2008, and to answer many open questions. The model gives options and enough information for fact-based discussion and decision making.

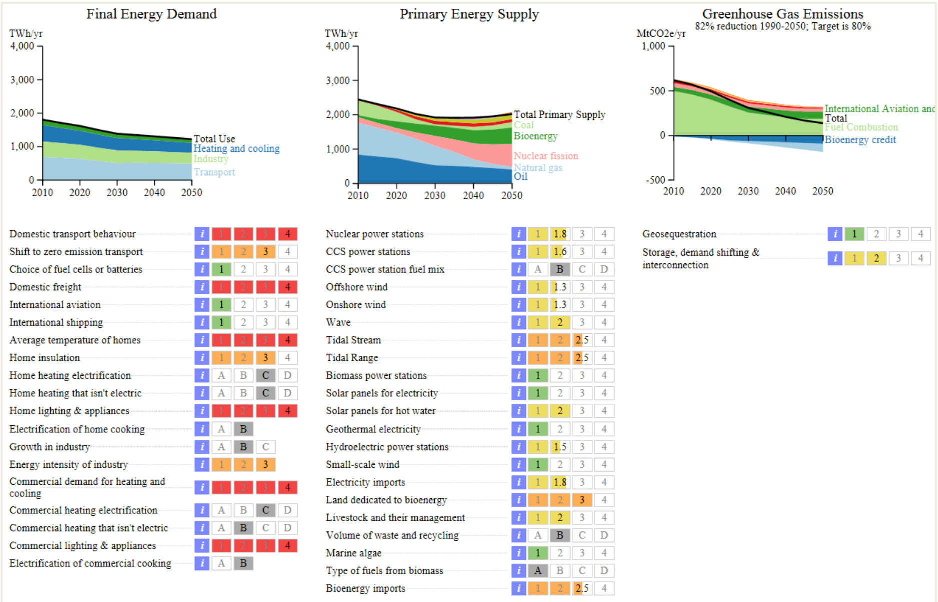

Figure 3 – UK Carbon Calculator, presentation from UK BEIS

Although time consuming, transparent and co-designed work made it useful for not only policy makers but everyone. The tool has been transferred and used in other countries around the world. The UK Calculator including the calculation method, inputs and assumptions was reinforced by a call for evidence event to create the common ground. Call for evidence phase, allowing stakeholders to review and comment the model, is also planned for EUCalc.

4.4.2 Electricity sector in IMAGE

Harmen Sytze de Boer of PBL Netherlands Environmental Assessment Agency introduced shortly the IMAGE model, as well as the focus of the REINVENT project. IMAGE is an integrated assessment framework that considers interactions between society, biosphere and climate system with coverage of 26 world regions and modelling period between 1970-2100. The outputs of the modelling are parameters related to land, water, energy, resources, emissions and climate change indicators [4]. In relation to power generation VRE (solar CSP, solar PV, wind onshore, wind offshore), Hydropower, Nuclear, Biomass (CCS, CHP) and Fossils (CCS, CHP) are included. Objectives of PBL in REINVENT is incorporating new knowledge in IMAGE and use IMAGE to show impact of new knowledge on energy system and climate targets.

5 Energy (electricity) supply module

In the next part of the workshop, Miklós Gyalai-Korpos on behalf of Pannon, as project partner introduced the general modelling environment, and specifically the status of the energy supply module with main focus on the electricity generation. In order to allow the participants to arrive prepared the essence of modelling and the discussion items were provided in advance to the workshop, too.

The description here reflects the situation of the module as of October 2017, at the time of the workshop. Changes introduced since then, partly as result of this event, are described in a later section.

5.1 Calculation mechanism and general assumptions

As the concept of transparency and open source is central in the development of the calculator, the choice of environments has been made in order to keep the code easy to understand by everyone. The KNIME Analytics Platform [3] was therefore chosen for the development layer and Python for the production layer.

EUCalc, similar to other members of the carbon calculator family[4], has a lever based operation. A lever is an important driver for change, where intervention can impact decarbonisation pathways. Four possible ambition levels are defined for each lever, the first (1) involving minimal effort, the fourth (4) underpinned by maximum physical or technical potential. The user has the opportunity to play with the level of the levers. By doing so, the user is able to build different low carbon scenarios for Europe and to compare their impacts. The user-friendliness is one of the key features of the calculators. This means a tool that allows immediate calculation without having to wait multiple hours or days for the results.

As for the electricity supply, the logic of the calculation is illustrated in Figure 4., based on the actual (2015, as base year) working generation capacities as primary input. Within each calculation period between 2015 and 2100, the actual capacities of the selected technologies are considered based on new capacity additions (as lever) corrected with the decommissioned capacities, as illustrated in the figure below. The decommissioning of generation capacities is based on the life span or policy phase-out intention for different technologies.

[3] https://www.knime.com/knime-software/knime-analytics-platform
[4] https://www.2050.org.uk/calculators

Input data			Output (per country and aggregated)
Name	Spatial detail	Source (2015)	
Installed capacity	Country	ENTSO-E	Annual electricity production, GWh Co-gen heat produced, GWh Emission generated, million tonne CO_2 Production cost of electricity, €/MWh
Capacity factor	Country	calculated from the production data of ENTSO-E	
Technology efficiency	Aggregated	IEA	
Co-gen heat ratio	Aggregated	IEA	
Decommission schedule for existing power plant stock	Country	not decided yet	
Lifespan of technologies	Technology data	not decided yet	
LCOE	Technology data	not decided yet	
Emission factors	Technology data	IPCC	

Figure 4 – Input and output of electricity supply module

This calculation considers the following technologies (as levers) in the electricity mix and aggregates their output on country and EU level.

1. Wind energy generation capacity
2. Solar energy generation capacity
3. Nuclear energy generation capacity
4. Fossil fuels generation capacity (note: new additions of natural gas based capacities excluded as level, but different emission factors are considered)
5. Ratio of CCS in the power plant stock
6. Biomass-based electricity[5]
7. Other renewables (as composite indicator)

In order to create a realistic energy mix and account for balancing capacities, a control mechanism will be implemented in the model. Though the modelling focuses on long-term period of emissions, it should propose such energy mixes that provide safe supply of electricity all-day every day. The module will provide two level mechanism for balancing.

1. Supply side fluctuations: the essence of this mechanism is the difference between the maximum and the minimum production (i.e. sunny and windy vs cloudy winter day), to understand the gap to be filled. This will consider rather a period of time (a few weeks) than daily peaks.

[5] this lever has been removed since then, but this chapter aims to report about the workshop, thus the situation at the time of the workshop

2. Supply demand matching: in cooperation with partners responsible for the demand of electricity (buildings, transport, industry), the volume of those capacities will be adjusted according to the demand. As on supply side the demand side will not consider daily peaks of consumption, but seasonal highs and lows in consumption pattern. Transmission losses will be accounted for a difference between production and demand.

The 2 levels will be cross-checked to see if fluctuations on the supply side meets the variable demand. In order to secure supply, an 8th lever will be introduced describing the variations how the gap is filled by different technology options, mainly by:

- Export – import: trade within EU limited by physical interconnector capacities and determined by cost differences in the participating countries (based on LCOE)
- Storage including hydro and batteries (links to be considered to demand modules too for inclusion of smart networks)
- Natural gas capacities (here are the new natural gas based capacities included)

5.2 Scenarios for Electricity supply: ambitions & trends

This calculation approach will be performed for each 5-year period modelling, using 8 levers (drivers) to describe the electricity generation: the 7 generation technology capacities above plus the composite indicator describing a strategy for balancing. Each lever will have 4 ambition levels (i.e. scenarios) that can be combined:

1. BAU
2. Ambitious but realistic renewable energy trajectory considering also different aspects in energy policy and avoidance of stranded assets
3. Ambitious but realistic renewable energy trajectory considering also different aspects in energy policy and avoidance of stranded assets, with significant advances and wide spread storage and DSM
4. Technologically exploitable renewable energy potential: fully but sustainably exploited which probably possible only with a not-realistic trajectory and conflicts in land use /resource supply

The main difference in the four levels will be the composition of the electricity generation mix. Energy policies and potential analysis for renewable energies will be used to define the values for each level of technology levers. From BAU to ambition level 4, the exploitation of the renewable energy potential will gradually increase expressed as percentage of the full potential. The concrete capacities used will depend on the demand in order to avoid oversized capacities, thus the value of the level for a country will be an interval depending on the demand.

5.3 Discussion items

The workshop concluded with a facilitated discussion on the levers, ambitions and assumptions for the electricity supply modelling, and how the different assumptions and data can be integrated into the model.

The basis for this was the discussion items introduced herein but also shared with the participants in advance. Thus, the main objective of the session was to have expert input on the below topics and questions that determine the further development process.

The questions shared in advance with the participants were as follows here:

1. Input data and calculation mechanism
    a. do you think the input data and their sources for electricity supply (as shown in Figure 4) describe well the actual situation and are suitable for modelling purposes?
    b. from the input data what should be kept constant and is improving over time?
    c. do you know a source for the decommission schedule of the existing plants per country or if not based on actual data what approach could be useful for the existing power plant stock?
    d. what factors are necessary to be included in the balancing strategy?
2. Future scenarios
    a. do you agree with the choice of the levers (technologies) and the definition of levels (ambitions)?
    b. how could we define the renewable energies potential per country? (you may suggest analyses we could use as input)
    c. how to express that the electricity network is becoming smarter (i.e. connectivity and complexity)?
3. Changes in external factors:
    a. how the joint energy market and implementation of the Winter Package could actually impact the future pathways of electricity supply?
    b. how the role of the grid in balancing can change and how to account this in the module?
    c. what are the largest uncertainties in technology development pathways?
    d. what role new technologies (nuclear fusion, tide, smart/autonomous homes) could play on the time horizon of 2100?
    e. how do you see the development of prices of energy carriers?

6 Discussion and recommendations

This chapter introduces the feedback received by participants during the discussion session and how it was considered in the development process.

6.1 Input data and calculation mechanisms

Main focus of the discussion was the basic calculation mechanism of the core electricity supply calculation method, as well as the input data used in these equations regarding both their sources and future developments.

The basic mathematical equations, as presented below on Figure 5., were confirmed by stakeholders as appropriate to calculate the amount of electricity supplied and associated emissions.

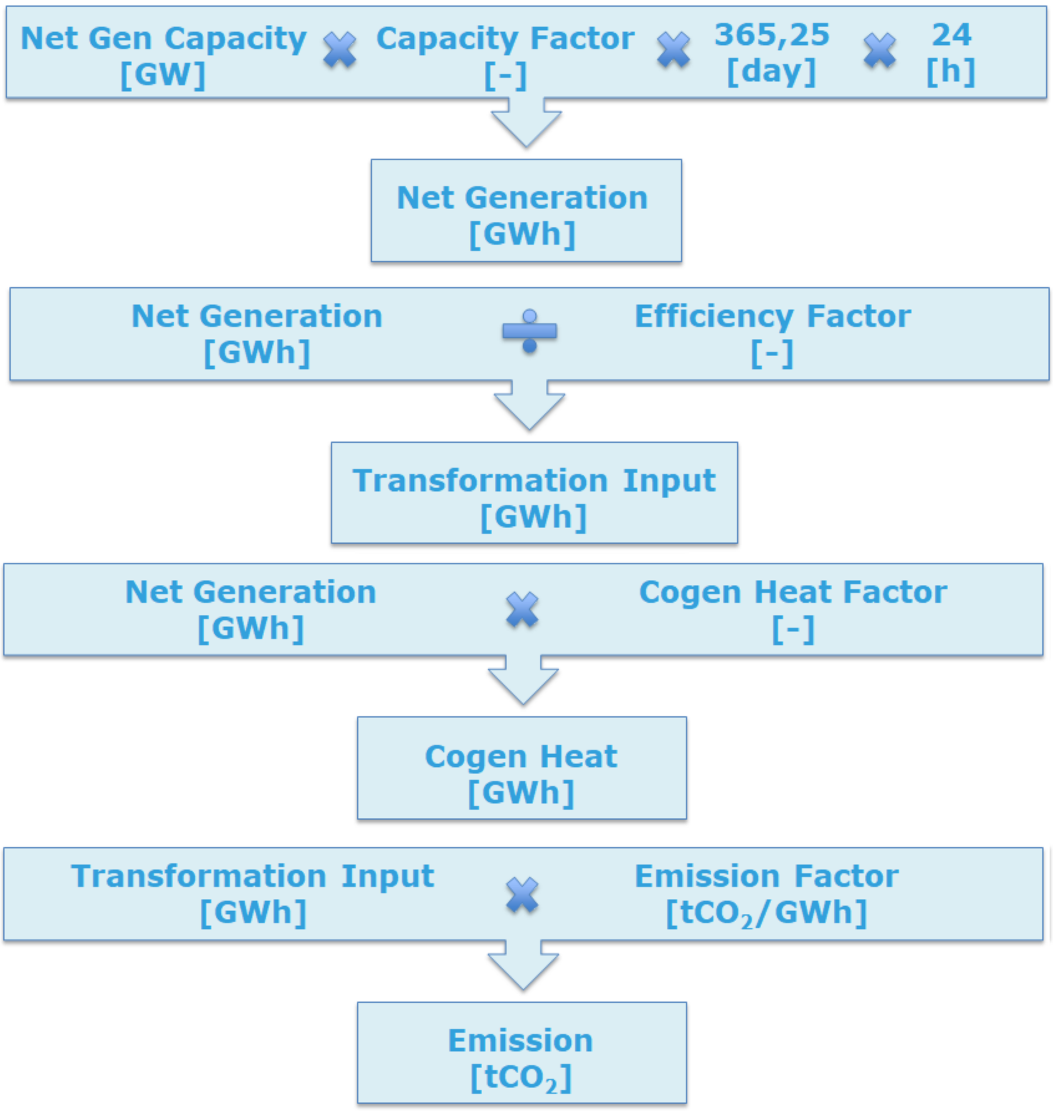

Figure 5 – Mathematical equations used in the core electricity supply module

In the calculation mechanism, the net generation capacities are levers (discussed in next chapter), i.e. the intervention points for stakeholders where they can influence the composition of the electricity generation mix, and thus emissions. The other parameters shown on Figure 5 are not directly influenced by the user, but there was a debate on the future development of those values. Basically, as concluded from the discussion, those parameters can be grouped into three categories:

- constant: the value is not changing in time but for all calculations same value is used from a credible and referred source,
- fixed trajectory: the value of the parameter is changing along a fixed trajectory,
- flexible trajectory: the value of the parameter is linked to a development track, i.e. depending on the choice of other levers.

Based on the discussion, the current calculation mechanism uses the parameter setting as in Table 1.

	Constant	Fixed trajectory	Flexible trajectory
Capacity factor		x	x
Efficiency factor		x	
Cogen heat factor	?	?	
Emission factor	x		

Table 1 – Categories of parameters

Capacity factor expresses the ratio of actual production to a continuous, full capacity production during a period, practically a year. In case of renewable based electricity generation, the capacity factor depends on the climatic conditions (such as solar radiation or wind speed) assuming no curtailment and guaranteed network access. Thus, climate change influences the renewable based electricity production through the changes of the capacity factor. In order to draw the trajectories of capacity factor of renewable based electricity generation technologies, impact of climate change needs to be assessed on the electricity generation by using input from respective partners or relying on external sources, such as Tobin et al. [4]. On the other hand, capacity factor of fossil fuel based electricity generation technologies largely depends on the operation of the electricity network which most significant is in the case of natural gas based technologies with quick ramp up time used for balancing. For this reason, capacity factor of those technologies will be linked to their role in balancing and ratio of renewables in the mix.

Efficiency factor is the output-input ratio of a power generation technology calculated from the energy content of the input material. As suggested by stakeholders, changes in this parameter reflect well the technology progress as fossil fuel based technologies are becoming more efficient. Thus, the progress in technology development can be well represented through the improvement of this factor. This is true to the non-thermo power generation technologies, i.e. where the electricity is not generated via incineration and thus the output-input ratio cannot be perceived as the physical quantity of the energy carrier. In this case through the development of the efficiency factor, other impacts can be shown, such as area need of solar panels (that decreases as efficiency factor increases). Efficiency factors are provided through the technology module, during the model development close cooperation is necessary to adjust the trajectories of the parameters to reflect progress in technology development. Moreover, technology module will provide specific capital and operational costs to calculate system level costs which will also follow a trajectory.

Cogen heat factor expresses the amount of heat produced by CHP units and used in district heating networks. The amount of heating energy largely depends on the actual situation of the building stock; thus, involvement of the demand module is necessary to decide on the cogen heat factor and its evolution. The calculation mechanism of heating is still under elaboration in cooperation with other partners working on the building module, thus it is not yet decided how to integrate this factor.

Emission factor is the amount of GHG produced via the burning of a unit energy carrier. As it is a physical quantity, specific to the type of energy carrier it was agreed to keep it constant.

As next, the sources for the above parameters were discussed, and stakeholders agreed to use credible and well documented sources for those parameters, such as the portals of the International Energy Agency[6], ENTSO-E[7] and other services of the European Commission, such as the NREAPs and Progress Reports DATA PORTAL operated by the Joint Research Center[8]. Emission factors are from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2 Energy[9] using the tier 1 method, i.e. constant values for energy carriers.

Though, the main calculation scheme and data sources were accepted by stakeholders, there were unclarity about the method to match electricity demand with supply. On one hand, the EUCalc should provide the flexibility for users to trial, challenge and play with any combinations of the levers (even if it results in highly unrealistic outputs). Building in a mechanism to match demand with supply would strongly limit those possibilities and flexibility, as well as make the levers interlinked. On the other hand, not considering balancing power and the capacity

[6] https://www.iea.org/statistics/
[7] https://www.entsoe.eu/publications/statistics-and-data/
[8] https://iet.jrc.ec.europa.eu/remea/nreaps-and-progress-reports-data-portal
[9] https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

needs for delivering the needed electricity can lead to unrealistic electricity generation mixes, biased investment needs and false conclusions.

Noteworthy, this approach is also valid on the issue of wholesale market prices raised by a participant. Though, wholesale prices have significant impact in the modelling of the entire European power system as influencing flows between countries, but the EUCalc is not a market equilibrium model and not considering market processes, but it is a "playground" for future scenarios consisting wide range of possibilities.

These inputs from stakeholders prompted us, to integrate the storage/balancing module more into the power generation module (both developed by Pannon, though in different working packages), see Figure 6.

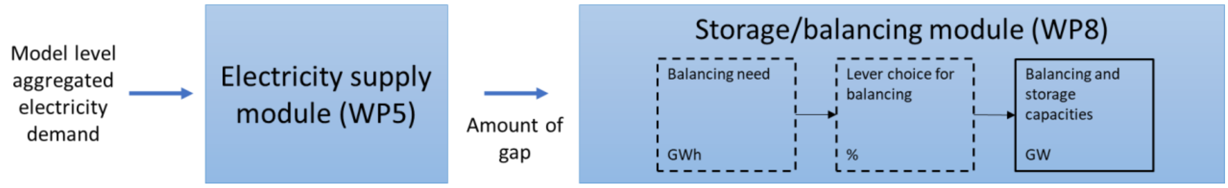

Figure 6 – Link between the electricity supply and storage/balancing modules

This way, the calculation will provide the EU level aggregated gap between electricity demand and supply, and depending on that, the next measures will be implemented:

- significant gap (exact value to be decided later), i.e. large difference between demand and supply: warning sign to user to adjust levers,
- more supply than demand: export assumed
- more demand than supply: natural gas based gap filler capacities added

A very important input by the stakeholders to this decision is that there is no physical bottleneck between the EU countries in the electricity infrastructure, thus we can assume a joint electricity market which allow us to aggregate the demand and supply on EU level for calculating the balancing power.

The amount of gap and the ratio of VRE will be the basis to calculate the balancing/storage power, whereas the user will choose the technology mix to deliver that flexible power. The exact calculation mechanism and implementation of this non-core module is in progress.

Nevertheless, in order to define the link between demand and supply, and consider fluctuations on both sides, profiles with enhanced granularity are needed as part of the balancing/storage module. As raised by participants, this will consider DSMs and other tools the consumer may have to influence consumption patterns (such as charging of electric vehicles). In cooperation with the developers of the demand side modules, most likely the impact of DSM and they spread will be captured through the demand displaced in time (%, percentage of demand).

6.2 Levers and definition of ambition levels

At the time of the workshop, the trajectories representing the different ambition levels were not defined, thus the main points of the discussion were about the lever setting, data sources and definition of levels without debating the trajectories. At the time of the workshop the next levers were suggested:

1. Wind energy generation capacity
2. Solar energy generation capacity
3. Nuclear energy generation capacity
4. Fossil fuels generation capacity (note: new additions of natural gas based capacities excluded as level, but different emission factors are considered)
5. Ratio of CCS in the power plant stock
6. Biomass based electricity
7. Other renewables (as composite indicator)
8. Balancing strategies

Since then, the biomass-based electricity lever has been removed from the list, as allocated to the working package 4 studying the biomass supply in its complexity considering completing uses and priorities. Therefore, it is excluded from the discussion herein.

In general, the above list of levers was agreed. However, a few clarification and inclusion of sub-technologies are necessary. Including a separate lever for hydro power was challenged, as it is presented in two levers only as sub technologies. Pumped hydro power plants will be used in balancing strategy with main focus of project developers[10], while run-of-river hydro power plants are considered in the other renewables lever. In 2016, hydropower was Europe's largest renewable energy resource accounting for more than 14% of total primary energy production of renewable energy in the EU-28[11].

Adding sub technologies, not separate levers are necessary to include important technologies but keep the complexity and speed of calculation on reasonable level. Thus, the following technologies are considered in levers (for levers not listed there are no sub-technologies):

1. Wind energy generation capacity: on- and off-shore wind
2. Solar energy generation capacity: PV and CSP
3. Fossil fuels generation capacity: existing capacities of natural gas and oil, and trajectories for coal based power

[10] https://www.worldenergy.org/data/resources/region/europe/hydropower/
[11] https://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/natural-resources/energy-resources/hydropower

4. Other renewables (as composite indicator): geo, marine and hydro

Due to the early stage of modelling, at the time of the workshop no exact trajectories for ambition levels were presented, the participants agreed that the current definition of ambition levels as presented in chapter 4.2 is not sufficient and not exact enough. Based on the finding of the workshop about the insufficiency of current terminology, as well as the importance of lock-in and exploitation of renewables potential, the levels were set in the following way.

In level settings two different patterns can be distinguished, as approved by participants. For fossil fuel and nuclear based power generation, energy policies define the future of those technologies, mostly specific phase-out policies in certain countries. Thus, a possible direction to set the trajectories for levels is consideration of phase-out policies and different timings aligned to ambition levels. Emphasized by stakeholders, lock-in situation caused by the power plant stock in operation can be a main bottleneck in timely decarbonization, thus input sources for setting levels for the decommission of current power plants is an important topic, as discussed in next chapter. In case of renewables, as the second pattern, a well-defined potential that consider different factors and its gradual exploitation can be basis of level setting.

6.3 Future scenarios

The level setting for phase-out and decommissioning should consider actual age of power plant, political wills per country and possibly other, such as economic, factors.

Participants suggested the following potential sources for creating decommissioning schedule:

- National authorities if no data for specific country is found in joint EU databases which is the preferred method to overcome methodological and linguistics challenges.
- Member companies of ENTSO-E, i.e. national transmission system operators usually have ten-year network development plan which contains data on decommission of existing power plants.
- ENTSO-E has its own Ten-year Network Development plan which includes data on net generating capacities and transmission capacities across Europe[12].
- Useful data on decommission could also be plans regarding EU coal phase-out[13], as well as nuclear phase out in several European countries.
- PLATTS database[14] (historic decommissioning time).

[12] http://tyndp.entsoe.eu/

[13] http://climateanalytics.org/hot-topics/eu-coal-phase-out/eu-coal-phase-out-detailed-information.html

[14] https://www.platts.com.es/products/world-electric-power-plants-database

After consideration of the above alternatives and complemented with thorough literate review, in the actual model the levels are defined by using the next sources:

- Coal based generation and phase out scenarios are based on the European Coal Map[15], the coal phase-out database of Climate Analytics[16] and Global Coal Plant Tracker database[17]. Scenarios consider age of power plants and phase-out policies, whereas the primer sources for input were made by considering economic factors too, of which importance was pointed out by the participants. Ambition levels mainly differ in the pace of phase out where level 1 is a quick, before policy action while for certain countries (such as Poland) level 4 includes new coal based capacities too.
- For nuclear power generation capacities, the country profiles of World Nuclear Association[18] are used considering also phase-out policies and intentions for new builds. Regardless the nuclear policies of countries, level 1 is defined as maintenance or slow phase-out, while level 4 is the quick closure. At the moment the modeling of waste management is an open and cross-sectorial issue which leaves open the concern of integration of nuclear waste management.

Each trajectory is defined by a bottom-up method defining the closure for each existing coal and nuclear based power plant, and of course the planned opening date for new one coal and nuclear, based on the input sources of the above list.

New oil and natural gas based capacities are not considered as part of this lever (new natural gas based capacities are part of the balancing strategies lever), and decommission of existing oil and natural gas based capacities are considered not on power plant level but based on the equation suggested by Farfan and Breyer [5], and shown on Figure 7.

[15] http://www.coalmap.eu/downloads/European-coal-map-complete.pdf
[16] http://climateanalytics.org/briefings/eu-coal-phase-out/eu-coal-phase-out-detailed-information.html
[17] https://endcoal.org/tracker/
[18] http://www.world-nuclear.org/information-library.aspx

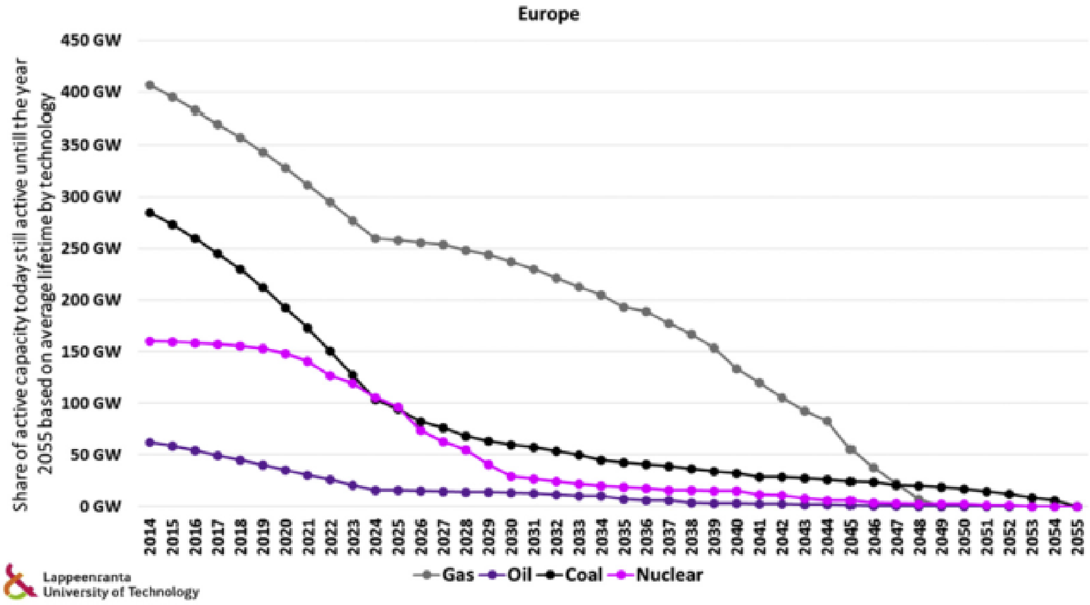

Figure 7 – Projected decommissioning of non-renewable capacities in Europe, from Farfan and Breyer

Nevertheless, as emphasized by Farfan and Breyer [5], ageing power plant is not only a risk but an opportunity, too, to replace them by low carbon technologies. Here the question is how to define the maximal potential contribution by renewables per country that could be a basis for lever setting. While participants approved this method based on potential, they expressed concerns about the multiple definition of potential and the factors they may consider.

After a thorough literature search, for the highest ambition level the potential values by Scholz [7] were used which are based on detailed assessment of potentials considering geographical constrains and technology development, as detailed in the resource work. Ambition levels differ mostly in the timing of reaching the potential.

7 Summary of the workshop

7.1 Conclusion

In agreement with the workshop, the EUCalc tool can fill a gap in the modelling landscape by offering a tool to policy makers with the balance between reliability and simplicity, as emphasized by many experts. This is needed, as the complexity of most tools risks the possibility of contribution to the policy development process.

In the EU picture of climate change and energy policy, there is a need for transparent, yet scientifically rigorous tool, and EUCalc has a possibility to fill the gap. To live with this chance, stakeholders need to recognize the model as result of co-development and co-design process, seeing it as "their own", which will surely influence their will to use it for policy making, decision making and consensus/ discussions on relevant topics. A process we have started for the electricity supply module with the workshop.

Levers are most important part of the module, as this is the way users can intervene and test different scenarios and their impacts. Electricity supply and its emissions are defined by the composition of the electricity generation mix, i.e. the capacity of different technologies. Technologies in the mix are also topic of policies (i.e. phase-outs and renewable targets), thus levers defining the capacities are good indicators for scenarios. Based on the discussions, levers will include separately sub-technologies differentiated, as shown below in the final list of levers:

1. Wind energy generation capacity: on- and off-shore
2. Solar energy generation capacity: PV and CSP
3. Nuclear energy generation capacity
4. Fossil fuels generation capacity: coal, oil and natural gas
5. Ratio of CCS in the power plant stock
6. Other renewables (as composite indicator): geothermal, marine and hydropower
7. Balancing/storage strategies

As the main aim of EU policies is to decarbonize the economy, the fossil fuel lever will focus on the decommission schedules of coal based power plants with timing as the main difference in the ambition levels. Same approach is taken in case of nuclear, however, with Member States having different position. Levers for renewables are set to gradually increased until fully using the potential. Additionally, based on discussion with other modules, biomass-based electricity has been removed as module and biomass available for electricity generation will be included considering other priorities in biomass use and land availability.

7.2 Further development of energy supply module

In line with the above and considering the inputs of the workshop, the following features of the module can add up to this approach with value in policy making:

- Focus on lock-in resolution: how policy makers can facilitate decommission of existing power plant stock has great importance. Decommission rate of existing power plant stock will happen at diverse rates depending on the level of ambition chosen.
- Balancing strategies: while most of the renewable electricity production technologies are gaining market parity, the next big question for a fully decarbonized power sector is how it can organize as a 0-24 hours and reliable system. Thus, the importance of balancing, the breakthrough of storage technologies, namely batteries, as well as DSM (including smart homes and EV) can make this happen and create a new system. Policy influence is reflected in the balancing strategies lever that will consist a portfolio of technologies on 4 levels on how balancing can be added to the system. For instance, depending on the choice of ambition, batteries and DSM will spread faster against natural gas or import.

Other important inputs that considered during the process:

1. Better definition of ambition levels with using figures not subjective description, as well as defining the term potential better. Levels are now associated mostly with schedule of changes in different generation capacities, for example phase-out of coal or exploiting the potential of renewables.
2. Attachment of trajectories of parameters in calculations with keeping the levers independent of each other, for example attaching the changes of capacity factor to climate change and utilisation rate, as well as describing technology development with parameters.
3. Approach and source for the decommission schedule of existing power plant stock is selected as input for level definition based on multiple sources investigated.

8 References

[1] European Environment Agency, "Annual European Union greenhouse gasinventory 1990–2016and inventory report 2018," European Environment Agency, Brussels, Belgium, 2018.

[2] European Commission, "Clean Energy for All Europeans – unlocking Europe's growth potential," 30 November 2016. [Online]. Available: http://europa.eu/rapid/press-release_IP-16-4009_en.htm.

[3] E. Stehfest and T. Kram, "Integrated Assessment of Global Environmental Change with IMAGE 3.0 - Model description and policy applications," PBL Netherlands Environmental Assessment Agency, The Hague, Netherlands, 2014.

[4] I. Tobin, W. Greuell, S. Jerez, F. Ludwig, R. Vautard, M. van Vliet and F.-M. Bréon, "Vulnerabilities and resilience of European power generation to 1.5 °C, 2 °C and 3 °C warming," *Environmental Research Letters,* vol. 13, no. 4, p. 044024, 2018.

[5] J. Farfan and C. Breyer, "Aging of European power plant infrastructure as an opportunity to evolve towards sustainability," *International Journal of Hydrogen Energy,* vol. 42, no. 28, pp. 18081-18091, 2017.

[6] Y. Scholz, "Renewable energy based electricity supply at low costs: development of the REMix model and application for Europe.," PhD Thesis, University of Stuttgart, 2012.

9 Appendix documents

9.1 Annex 1: List of participants

Bastian Hoffmann	European Institute for Energy Research
Felician Gergely	Pannon Green Power Ltd.
Francesco Gattiglio	Eurobat
Zanna Vanrenterghem	CAN
Stuart Younger	Department for Business, Energy & Industrial Strategy - GOV.UK
Fanni Sáfián	Energiaklub
Richard Uchrin	Consultant
Tamás Heigl	FI NTP Smart City Forum
Laszlo Zentko	Pannon
Hannes Warmuth	OGUT
James Atkins	Vertis Environmental Finance
Helena Teschner	German Energy Storage Association
Csaba Hegyfalvi	PPIS
Ivana Milinković Turalija	Energy Institute Hrvoje Požar
Lucija Krstanović	Energy Institute Hrvoje Požar
Nolan Theisen	Globsec Policy Institute
Boris Thurm	EPFL
Judit Kockat	BPIE
Garret Tankosic-Kelly	SEE Change Net
Janos Laszlo	Endo IT
Attila Holoda	Aurora Energy ltd
Csilla Hegyfalvi	not provided
Daniel Scholten	TUDelft
Harmen Sytze de Boer	PBL Netherlands Environmental Assessment Agency
Emily Taylor	Climact
Pál Ságvári	Ministry of Foreign Affairs and Trade of Hungary
Ákos Varga	Századvég Gazdaságkutató Zrt.
Gergely Toth	MOL
Janos Hidi	MOL

9.2 Annex 2: Invitation

Dear XXXX,

Europe needs your expertise - as key person in the energy sector, we want your guidance and input in shaping the future electricity supply scenarios for Europe!

We are working on setup of an online tool, similar to Global Calculator, to aid decisions in the low carbon transformation of Europe. A principle of building this model is transparency - no black boxes - hence all the modules in European Calculator, will be created by co-design process, starting with a respective sectorial workshop.

To achieve this we kindly invite you to be part of the debate on the options for low carbon transformation of Europe electricity supply, with participating at the European Calculator expert workshop for "Electricity supply: modelling challenges and solutions for a low carbon Europe" to be held on

Thursday, October 26, 2017 from 9:00 AM to 2:30 PM

Aranytíz Cultural Center
10 Arany János utca
1051 Budapest
Hungary

For registration and more details please click here.

What can you expect from the workshop?

PANNON Pro Innovations Ltd. is responsible for the development of the electricity supply module of the calculator. The workshop will include a joint discussion on ambitious prospects for the European energy system, the scenarios and assumptions for electricity supply, as well as debate how those assumptions can be integrated into the calculator tool. The calculator has a module based operation - modules represent different sectors of the economy, each with a set of levers, a pre-defined route for transition with four levels of ambitions to choose.The format will be professionally facilitated discussion, for a joint discussion, we are going to circulate a preparatory material for registered participants.The event will also result in documented outcomes and establishment of a network to continue the discussion on model assumptions and development.

This is a personal invitation! The workshop has a limited capacity to host 20 key experts, registered on first come, first served basis, so don't be late to secure your place at this event. In case you cannot make the event, but a colleague of yours would be interested, please contact the organizers.

Workshop participants are also welcome at the main SUSCO 2017 conference to be held in the afternoon at the same venue, however, with separate registration process.

Looking forward to seeing you at this workshop!

Kind regards,

Prof. Dr. Jürgen P. Kropp, Potsdam Institute for Climate Impact Research (PIK), Coordinator of the European Calculator Project

Dr. Miklos Gyalai-Korpos, PANNON Pro Innovations Ltd., In charge of the Electricity supply module, and the Expert Workshop

Ivana Rogulj, SEE Change Net (SEECN), Co-Organizer of the Expert Workshop

9.3 Annex 3: Agenda

EUCALC

Agenda

Date: 9:00 – 14:00, 26th of October 2017

Venue: Aranytíz Cultural Center, Budapest

8:30-9:00	Registration
9:00-9:15	Welcome to the EUCalc project (PIK Potsdam)
9:15-9:30	The co-design methodology: what's going to happen today? (SEE Change NET)
9:30-9:45	Introduction of Participants (tour de table)
9:45-10:05	Guide and expectations to the workshop (SEE Change NET)
10:05-10:15	Spark talk I: History of the calculators and importance of co-design (UK BEIS)
10:15-10:30	Introduction to the electricity supply module (PANNON Pro Innovations Ltd.)
10:30-10:45	Coffee break
10:45-10:55	Spark talk II: The integrated assessment model (IMAGE) and the role of the electricity sector (PBL Netherlands Environmental Assessment Agency)
10:55-11:30	Interactive session: assumptions, drivers and trends
11:30-11:45	Scenarios for the Future of Electricity: ambitions and trends (PANNON Pro Innovations Ltd.)
11:45-12:45	Interactive session on the scenarios and level/ambition definition
12:45-13:30	Lunch
13:30-13:50	Conclusions and follow-up

The format of the workshop will be professionally facilitated discussion. The basis for the debate is this document, as well as the presentations at the workshop. The event will also result in documented outcomes and establishment of a network to continue the discussion on model assumptions and development.

9.4 Annex 4: Written feedbacks received from participants following the workshop

Hereby, we added the comments received by email from some participants after the workshop without any changes but removing their names.

Thank you for contacting us! The workshop was very interesting and useful, especially due to the fact that main activities of our department are related to modelling and simulation of electricity markets, including different generation technologies. Also, our projects are mostly related to different countries, and we are often confronted with similar modelling problems (for example sources of input data or data harmonization by countries). So, our questions during the discussion were basically formed according to our modelling experiences and we will gladly share those questions with Miklos again. The questions were related to definition of technologies (levers): How come hydro power was not mentioned in the list of technologies in the energy mix? It was mentioned later that pumped hydro power plants will be used in balancing strategy, but what about large run-of-river hydro power plants, existing and committed? Will there be a differentiation between onshore and offshore wind power plants? Is electricity price on the wholesale market taken into consideration? In our experience, it has significant impact and should not be ignored in the modelling of the entire European power system. Is the cost of nuclear waste disposal included in the lever for nuclear energy? Regarding the sources for the decommission schedule of the existing plants per country, here are few tips that could be useful. Member companies of ENTSO_E, i.e. national transmission system operators usually have ten-year network development plan which contains data on decommission of existing power plants. ENTSO_E has its own Ten-year Network Development plan which includes data on net generating capacities and transmission capacities across Europe (http://tyndp.entsoe.eu/). Of course, the question is if the modelling approach is based on EU clean energy policy or on real technical conditions and decommission plans according to lifespan of certain technology. Useful data on decommission could also be plans regarding EU coal phase out (http://climateanalytics.org/hot-topics/eu-coal-phase-out/eu-coal-phase-out-detailed-information.html), as well as nuclear phase out in several European countries. We hope that our comments will be useful in further development of EU Calculator. Finally, thanks for the opportunity to participate in the workshop!
Many thanks again for the invitation to the EUCalc workshop.

Your approach is very interesting and I appreciated the openness, the dynamic interactions as well as the high quality of exchanges among the participants. Moreover, both the workshop and the conference were very well organised. Kudos to you and all the other organisers and speakers. I would be interested in the slides of the EUCalc workshop and the afternoon conference. Do you know if this is feasible and whom to contact?
Thanks again for having me at the workshop. I think it was very interesting and well organized! Below you can find my personal notes with regard the questions discussed. ☐Input data and calculation mechanism o Input data ☐ Is it possible to add specific cost data and calculate the LCOE yourself? In that way you might be able to endogenously determine capital cost learning of technologies ☐ Curtailment, capacity credit and storage use data could be added. The RLDC data source I showed yesterday is freely available at: http://www.fp7-advance.eu/content/variable-renewable-energy-integration-module. There were dataset for strict, normal and loose VRE integration available (different assumptions on grid integration, storage costs; you might have to contact the authors in order to get these). These might be interesting for the balancing lever. The advantage of this dataset is that you will be able to use hourly information on VRE deployment in a rather simply way. Constant variable ☐ Constant: ☐ Lifetimes (although an early retirement option is key) ☐ Potential load factor conventional plants ☐ Variable: ☐ Fuel/investment costs, ☐ Capacity credits renewables, ☐ Renewable load factors (maybe use cost supply curves for renewable potentials and load factors) ☐ Curtailments renewables ☐ Efficiencies

☐ I would expect a relationship between lever setting and input variables (so, fossil focus => more efficient fossil plants, VRE focus => cheaper VRE)

o Data source decommissioning data

☐ We use Platts for historic and planned capacity. Platts has construction year info and historic decommissioning info. This is not a free dataset. Early retirement option essential (especially for mitigation scenarios)

o Balancing strategy

☐ Take into account less capital intensive if more VRE (lower residual load factors)

☐ Storage

☐ Curtailments

☐ Capacity credits

☐ ADVANCE dataset mentioned before might be interesting

☐ Future scenarios

o Levers

☐ I do wonder what happens when you put all levers at level 4. Is this different from all levers at level 2?

o Potential

☐ You could have a look at cost supply curves. At PBL we have them for PV, CSP, onshore wind, offshore wind and hydropower. However they are based on 0.5x0.5 grid maps. This might not be detailed enough for an EU analysis. Also, in the ADVANCE project a country dataset has been made which is publicly available at: http://www.fp7-advance.eu/content/variable-renewable-energy-resource-module

☐ Be careful for overlapping potential between technologies

o Smartness

☐ higher price elasticity of demand? Only works in hourly simulation

☐ Have a look at the ADVANCE RLDC dataset. It is designed at different levels of VRE integration

☐ External factors:

o Winter package

☐ I don't have enough experience with the winter package to answer this questions

o Grid balancing

☐See earlier comments on the RLDC dataset developed in ADVANCE

o Uncertainties

☐ Cost of storage

☐ Cost development of newer technologies (like solar and wind)

☐ New technologies

o New technologies

☐ That's almost impossible to answer. You could ask experts on these topics, although they tend to be a bit optimistic

o Price development

☐ I would expect fossil fuels prices to increase due to depletion effects and VRE capital costs to decrease due to learning. However, integration costs for VRE (load factor depletion, backup requirements, curtailments, etc.) are expected to increase at larger shares of VRE.

Before all, please accept my truly congratularions for the workshop of last week at the SUSCO summit. I think it was one of the most time-efficient and intensive workshops I ever participated. Also, I was glad to see you again in Budapest - I hope you had a nice time there.

I did not really had the possibility to ask you about your See change project in details. Are there any current activities about that? Did you manage to benefit from our conference in Budapest? As I remember, Benedek Jávor started an interesting discussion about a possible future collaboration about regional energy modelling in the Balkans - did anything happened in this direction since that?

By the way, actually I am now in Wuppertal at Wuppertal Institute, where we are working on learning and adapting a new, modular, potentially GIS-based model to simulate and optimize regional energy models. Wuppertal Institute plans to use this with to model a South-East-European regional energy model to see how their cooperation could foster emission reduction via more intensive renewable utilization. Energiaklub is one of the potential project partners. I think this model could be an efficient second (and more detailed) step attached to your EUCalc model. Do you think that this could be an interesting idea?

Thanks a lot for this well-organized workshop in Budapest, I really enjoyed the discussions. My only regret is that it was too short, there were many topics to discuss and 4 hours were not sufficient to first explain the project and then have fruitful discussions. Still, I hope you had useful inputs.
Here are some feedbacks from discussions I had in smaller groups:

About the choice of levers:

We might want to have different levels of complexity: the current one for the public, and then the possibility to have more details for "experts", for example:

1. onshore/offshore wind for wind,

2. PV/Concentrated solar power for solar,

4. different types of cogeneration in fossil fuel,

6. different types of bioenergy,

7. run-of-river hydro/large hydro/tidal energy/deep geothermal... in other renewables,

That would also allow three sub-levers for the balancing lever.

About CCS, not sure it should be in WP5, but there is also carbon reuse technologies (you capture CO2 to produce something with it).

About the ambition levels:

People in the group didn't understand the description of the levels, specially what we meant by"ambitious". Here are some thoughts to improve it:

Maybe the first level shouldn't be BAU. For example for wind, let's say there is currently 10% wind in one country, then maybe first level should be 0% in 2050, and level 4 should be the maximum potential. Level 2 and 3 defined in % of maximum potential. If we let the possibility of 0%, then people could also see the negative effects of not having RES in the mix. I had a look at the Swiss calculator, they separate between RES and non-RES, for RES, you can choose between 0GW and maximum potential, except for hydro where it's between 8.1 and 8.2GW (based on the Swiss current system), for non-RES, you can choose between 0GW and 10GW, and if you exceed the demand, it goes to export. (http://calculateur.energyscope.ch/) I think in EUCalc we could use a similar strategy for RES, while for non-RES it could be in % of the demand for example. In case of overcapacity, we could have a signal to tell the users that the production is too large.

About the decommission, since it seems it depends on political choices, economics (profitability), and technology (lifespan), Here is what we could do:

1. We construct a "technology decommission scenario" based on lifespan of plants. We would need to know for each country when the plants were built. If the data are not available, we will need to make some assumption about it. Based on lifespan, we know when they should be decommissioned.

2. The actual decommissioning is based on the user choice: If the user decides on a 2050 mix close to the current mix, we use the "technology decommission scenario". If the user adds lots of RES in the mix, we decommission "earlier" nuclear and fossil power plants (strong preference for RES). The more RES in the mix, the fastest the decomissioning. If the user adds nuclear/fossil compared to current mix, we decommission "late" nuclear and fossil power plants (preference for non-RES).

Else, we need a lever for the "speed" of decomissioning (maybe a sublever of nuclear and fossil fuel?), or we only consider technology decommissioning...

Finally, it is important to have an "updating process" for input data. For example, if technology efficiencies or capacity factors change, it should be easy to modify our input data with the new ones.

I hope it is clear and that the comments help,