June 19

Unbundling the Energy Union

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Candidate Number: 4036

Number of Words: 32 358

Applying the decision quality framework to understand the challenges and opportunities for the planning and implementation phase of energy union policy, directives and regulations. With specific focus on energy systems assessment, grid design and market reforms to support the energy transition – to answer the research question: "What are the challenges and opportunities for the Energy Union Policy Planning and implementation phase? Do we have "Commitment to action and Will we take Action?"

University of Stavanger, Master of Energy Environment & Society Thesis: MEEMAS

UNIVERSITY OF STAVANGER

MASTER DEGREE IN
Energy, Environment and Society

MASTER THESIS

CANDIDATE NUMBER: 4036

SEMESTER: Spring 2019

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MASTER THESIS TITLE: Unbundling the Energy Union

SUBJECT WORDS/KEY WORDS: energy union, energy systems, decision quality

PAGE NUMBERS: 126

STAVANGER 

…Andrew Kilmartin…15 June 2019…….
DATE/YEAR

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Abbreviations

ACER	Agency for the cooperation of Energy Regulators
CAPEX	Capital Expenditure
CBA	Cost Benefit Assessment
CCS	Carbon Capture and Storage
CEA	Cost Effectiveness Assessment
CEER	Council of European Energy Regulators
CO2	Carbon Dioxide
DCF	Discounted Cash Flow
DS	Degree Scenario
DG	Directorate General
DISCO	Distribution Company
EC	European Commission
EIB	European Investment Bank
EFI	European Fund for Innovation
ENTSO-E	European Networks of Transmission System Operators for Electricity
ENTSO-G	European Networks of Transmission System Operators for Gas
ENPV	Expected Net Present Value
EPSC	European Political Strategy Centre
EP	European Parliament
EU	European Union
ETS	Emissions Trading System
FF	Fossil Fuels
GDP	Gross Domestic Product
GENCO	Generation Company
GHG	Green House Gases
H2	Hydrogen
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Providers
ISO	Independent Service Operators
IRENA	International Renewable Energy Agency
LNG	Liquefied Natural Gas
MS	Member States
NDC	Nationally Determined Contributions
NPV	Net Present Value
OPEX	Operating Expenditure
P2X	Power to (some type of gas)
PCI	Projects of Common Interest
QMV	Qualified Majority Voting
R&D	Research and Development
RACI	Responsible Accountable Consulted Informed
RES	Renewable Energy Sources
SDG	Sustainable Development Goals
TEN-E	Trans-European Networks for Energy
TRL	Technical Readiness Level

Abstract

The Energy Union is the culmination of over 10 years work by the European Union. The energy union vision became a reality in 2019 and will come into effect in January 2020.

However there are still concerns over the policy development process or more specifically the energy system design and market reforms that are considered. It remains unclear how the energy mix options and selection decisions were made and subsequently covered in the energy policy. More importantly it is necessary to understand how energy modelling was used to form system design and market reforms to support the Energy Transition. Therefore we need to research how the policy was developed, what analytical and assessment criteria or methodology was used and what analysis was completed before the policy was released. This is important to know in order to effectively plan and implement the energy policy.

This thesis will answer the Research Question: **What are the challenges and opportunities for the Energy Union Policy Planning and implementation phase?**

This was achieved and derived from the analysis and application of the Decision Quality appraisal to review the policy to confirm**: "Are we committed?" and "Will we really take action?"**

To undertake the work the researcher was fully immersed into the Energy Union policy development process and through attendance at several workshops, seminars and roll out events. By review of the abundant EU documentation and communications it was possible to deconstruct the process and through observation and abduction methods understand the mechanisms in play. After Unbundling the Energy Union – the researcher then applied the "Decision Quality" framework (Spetzler, Winter, & Meyer, 2016) to assess the policy process and determine what supporting analytical tools to screen energy mix alternatives were used and if this could be improved.

This process is necessary to understand the challenges and opportunities for the planning and implementation phase of energy union policy, directives and regulations. The results will focus on the "EU's Commitment to action" and through the application of the Decision Quality Framework determine if we are taking the right action and prioritizing the correct infrastructure developments needed to support the energy union transition to a zero carbon energy future.

An outstanding amount of work and effort was undertaken by the EU to deliver the energy policy, and they should be applauded for these efforts. However in the spirit of continuous improvement at this critical planning, approval and implementation juncture, it was found that by applying the decision quality framework several opportunities and challenges were identified. These could be leveraged or mitigated from benefit and value approach to make good decisions through improved decision and risk analysis assessment processes. That way decisions can be optimized, verified and validated with respect to policy and infrastructure decisions pertaining to energy grid design and market reform changes to support the energy transition.

Acknowledgements

A special word of thanks to my supervisor Professor Reidar B. Bratvold for introducing me to Decision Making and Decision Quality, his willingness to share his extensive experience and passion to help us make good decisions is contagious.

Big thank-you to Professor Oluf Langhelle, for the timely design, delivery of the Energy, Environment and Society master programme and your support throughout.

To Associate Professor Thomas Sattich who managed to get "an engineer" to understand and appreciate Energy & Environmental: Politics, Policy and Geopolitics.

Thank you to Doctor Harry van der Weijde, my supervisor on the Energy Systems in Transition Research Project who allowed me to work on this thesis as part of my investigation into Market Designs to support the Energy Transition.

And to my family: to my wife, Anna, thank-you for believing in me and supporting my mid-life "student" crisis and career change. To our 7-year old twins, Alexander Thomas and Sophia Elizabeth, you are my motivation. You provided me with some welcome distractions and made me a master of time management and opportunity. I love your curiosity and the way you already care for the world more than most. I hope we can fix it for you!

Introduction

In 2019 the European Union delivered the 4th Energy Status and then the Energy Union became a reality after it launched a series of policies, directives and regulations in support. The Energy Union – A cleaner energy for all Europeans was launched (April 2019)[1]

Whilst the implementation of the EU 3rd Energy Package[2] is still the foundation of the Energy Union and is still in final stages of implementation, the new Energy Union policy, regulation and directives have been approved by the EC & will be approved by the EP in July 2019 to compliment and replace earlier versions. These new policies, regulations and directives need to be ratified by the member states within the next 9-18 months, but plans to implement them have already started. The Market Design still needs to be finalized but will soon to be ready for approval, but draft proposals were released Dec 2018 and it is anticipated that the new Market Reforms will be in place by Oct 2019.

By following this process the EU has boldly and readily adopted the challenges and changes associated with climate change and acting on this developed the concept of the Energy Union in response to the changes needed to support the transition. The focus of the Energy Union through Energy transition is to deliver "clean energy for all Europeans". This is further aligned with the sustainable development goals and designed to deliver: clean, safe and secure energy at affordable prices.

One of the main drivers in this transition is the need to reform the energy market to support this transition. This market reforms are across the energy sector but regulations and directives are mainly focused on the Gas and Electricity sectors (to reflect changes to a hybrid grid and focus on electricity in the future to absorb heating and transport energy demands).

These hybrid sector coupling of electricity and gas are the main mode of energy supply and distribution in the European Union which are is set for expansion due to ambitious interconnectivity and optimal energy mix to deliver a reliable, low carbon and energy efficient product to meet growing demand and satisfy the sustainable target of the UNIPCC and to comply with the COP21 Paris Agreement and the committed Nationally Determined Contributions[3].

The European Union's Energy Union vision is ground breaking with respect to changes anticipated in the transition and corresponding market reforms but this is not without significant challenges to implement and govern. There is a general consensus that the benefits and opportunities that it will deliver outweigh the risks and uncertainties that we face.

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[1] EU A clean energy for all Europeans https://publications.europa.eu/portal2012-portlet/html/downloadHandler.jsp?identifier=b4e46873-7528-11e9-9f05-01aa75ed71a1&format=pdf&language=en&productionSystem=cellar&part=
[2] EU 3rd Energy Package https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/third-energy-package
[3] Paris Agreement COP 21 http://www.cop21paris.org/about/cop21

Problem Statement:

The majority of the energy union policies regulations and directives were issued in the first half of 2019 and now the planning and implementation phase will start in earnest, so this is "hot off the press" so to speak. Therefore there is very little research and formal analysis to compare current alternatives at this stage but we need to understand what preceded the final stage so we can execute and comply accordingly.

It remains unclear how the options and decisions covered in the energy policy were determined or more importantly what analysis was completed before the policy was released. This is important to know before we implement and act on the policy.

On first impressions of the policy proposals[4] it is difficult to find any real measures, routines or obvious application of decision analysis, option screening and selection criteria that was applied. Did we make the right decisions? Can we implement it? Will we focus on the policy that will support energy transition and market reformations required?

If we can't document, measure, compare and justify the selection, how can we implement and monitor the impact and progress and therefore evaluate the policies that are introduced (Peters, 2015).

This is of concern, as it is necessary part of the informed decision process. The real test for any change or reform is in the implementation and realization of the said benefits and without any decision analysis evidence it may indicate that the reasoning and rationale behind the decisions are flawed (Bratvold, 2010). This could make the implementation phase very difficult or delay progress on this critical and urgent task. If it is not sufficient it will affect the project selection and approvals that we need to undertake.

We need to investigate the decision analysis adopted to support the decision making process pertaining to the Energy Union policy and to assess the process with respect to the market reforms and changes proposed in the Energy Union. To do this we need to understudy and understand the decision process that was adopted. This will be done by analyzing the decision making process used in developing Energy Union policy, regulations and directives by following their development and communications from the EU using the Decision Quality Framework (Spetzler et al., 2016). To enable this study it is necessary to understand how the Energy system and market works and what changes or reforms are needed or proposed.

Fortunately there is an abundance of material on the EU websites (see References) concerning Energy systems and Energy Markets and the EU has made this publically available including all data and proceeds from public consultations, impact

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[4] EU 2050 vision and strategy https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN

assessments and documented policy processes which allow for analysis[5]. It also lists the respective history and revisions of policy so you can see the changes and impact that the decision makers use to approve. In addition Eurostat has databases and reports on progress, status and measurement of all indices and metrics associated with the EU Energy policy. However it is difficult to navigate and follow the threads of some of the development efforts. This thesis will attempt to trace and link these threads to answer the research questions posed.

By the bureaucratic nature of the EU, it prides itself on the ability to produce policy. However from the EU websites the process used to make decisions is not as transparent or obvious at first. But this is well documented in books and papers so an understanding of the decision process and systems is possible (Peterson & Bomberg, 1999; Wallace, Young, & Pollack, 2010). While there is a frenzy of workshops and seminars surrounding the topic, there is little research and comment regarding the recent deliveries from the Energy Union policy and processes, especially since the majority of the governing documents and policies were released between Dec 2018 and May 2019. Therefore it is important that we immerse ourselves as a stakeholder into the process in order to research and understand this process at this point in time when the policy, regulations and directives derived from the EU decision process are entering the ratification and implementation phase to ensure that it was sufficiently well controlled and that due process was followed (see Research Methods for more details).

It is the aim of this thesis to review the policy and decision process adopted by the EU in the formation of the Energy Union – A cleaner Energy for all by applying a decision quality control framework to the process and highlighting challenges and opportunities that may present themselves in the planning and implementation phase and to confirm commitment to action and if the appropriate actions will be taken as planned (Spetzler et al., 2016).

Research Question

This leads us to consider the following Research Question in consideration of the Energy Union Policy:

This thesis will answer the Research Question:

1. **What are the challenges and opportunities for the Energy Union Policy Planning and implementation phase?**

2. **Subsequently we will see if we are prepared for the Energy Union policy planning and implementation phase to answer the question– "are we committed" and "will we take action"[6]?**

[5] Models, policy and impact assessment https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0410&from=EN

[6] Adopted from Making Good Decisions (Bratvold, 2010) and Decision Quality (Spetzler et al., 2016)

To answer these research questions the EU policy developed to date will be reviewed with specific focus on the decision-making and assessment processes specifically focusing on Energy Union Policies and Market Reforms that need to be realized.

These will be assessed against a Decision Quality framework in order to see if the process is sufficient to ratify and implement and thereby support the correct energy transition project portfolio and associated market design.

The focus of this thesis is to consider the strategic decision and policy development to delivered in the form of the Energy Union through energy policy and subsequent efforts to deliver a reformed market approaches to support the energy transition and associated regulation and directive for the delivery of clean, secure and affordable energy in the context of the European Union - Energy Union "Clean Energy for all Europeans" programme[7].

Background and Motivation

Following a rebranding of Energy Policy as the Energy Union in 2014 (a term coined by Donald Tusk) the European Commission issued a press release to highlight changes to the Energy Union and to deliver a Market Design with a focus on Consumers[8]. This market design was intended to transform Europe's Energy system and the press release detailed on how the system actors involved in "generation, trade, supply and consume electricity" would be regulated and governed. It hinted at new technology integration and changes in energy mix to meet the objectives of clean, safe and secure energy.

"Energy and Climate Action" is one of the Top 10 EC priorities for 2014-2019[9]. What started as Energy policy in the millennium (2008) was rebranded as Energy Union in 2014 and then efforts to produce policy merged with Climate and Environment in 2015. In addition the Energy Union is integrated with the Internal Market. The EU Strategic objectives are captured as follows[10]:

Strategy, Objectives and Policy Areas of the Energy Union is stated as follows:

- Securing energy supplies
- Expanding the internal energy market
- Increasing energy efficiency
- Reducing emissions and decarbonizing the economy
- Supporting research and innovation

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[7] EU A clean energy for all Europeans https://publications.europa.eu/portal2012-portlet/html/downloadHandler.jsp?identifier=b4e46873-7528-11e9-9f05-01aa75ed71a1&format=pdf&language=en&productionSystem=cellar&part=
[8] EU Market Reforms https://europa.eu/rapid/press-release_MEMO-15-5351_en.pdf
[9] EU Top 10 Priorities https://ec.europa.eu/commission/priorities_en
[10] EU Strategic Objectives https://ec.europa.eu/commission/priorities/energy-union-and-climate_en

To achieve a market reforms and enable a fully integrated grid and expanding the market as mentioned above the following actions are identified and prioritized[11]:

- New energy market design – to transform Europe's electricity system and market
- Empowering energy consumers – placing consumers at the core of the system and markets and power to supply and demand energy
- Helping energy cross borders – interconnectors to allow energy to flow

To achieve this sector coupling (gas and electricity) and market coupling (cross-border transmission and trading) reforms were intended and proposed to reorganize how investments and operations within the power and energy system would be decided and how to integrate new services and technology into these systems. It also positioned a new regulatory approach to oversee the internal market through maximized efficiency, minimized emissions and ensure competition and renewable energy sources through increased cross border trade[12].

The reasons for the changes were justified by the imminent growth in the electricity market due to changes in requirements for cross border capacity caused, but also in order to accommodate the shift to renewable energy sources, coupled with anticipated growth of the electricity services as it absorbed supply and demand volatility across the union through storage and strategic reserves or spare capacity. The further increase in energy demand is also anticipated from the transport, heat and buildings/facilities sector as these systems electrify. All of this is compounded by anticipation of the future disruption caused by the phasing out of fossil fuel plants with high emissions[13].

To facilitate this the market needs to be more[14]: flexible, by offering consumers (industry and households) opportunity to participate actively in the market, triggering generation investment opportunities, increasing efficiency and upgrading and expanding infrastructure. Most importantly it wants to make the market more flexible by integrating renewables more efficiently by pursuing near or real time trading, eliminating regulation on prices and get to real energy price and cost by removal of subsidies and energy incentives for polluting energy sources (i.e. coal and oil) and better coordination and ease of integration of renewables. This is needed to establish accurate investment opportunities and reduce consumer uncertainty or exposure around energy prices[15].

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[11] EU Market Design https://ec.europa.eu/commission/priorities/energy-union-and-climate_en

[12] EU long term strategy 2050 https://ec.europa.eu/clima/sites/clima/files/long_term_strategy_brochure_en.pdf

[13] EU 2050 vision and strategy https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN

[14] EU New Market Rules https://ec.europa.eu/energy/sites/ener/files/documents/electricity_market_factsheet.pdf

[15] Markets and Consumers https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/electricity-market-design

To achieve this the Energy Union was supported by a market reform campaign to put consumers and hence demand, efficiency and reduction management at the center of the new model [15]. Illustrating how it would leverage new technology specifically through the introduction of SMART Grids, SMART metering, SMART Homes, dynamic contracts and increase in self-generation and renewed focus on self-sustaining communities couple to storage and grid (MUSE Energy Euronews 21 May 2019). It puts the consumers at the center of the proposal to take control of their energy use (efficiency, reduction and type). By giving them access to actual energy costs they could change their behaviour, routines and manage their energy use and reduce exposure in periods of high-energy spikes or periods of price volatility.

The progress has been rapid and revolutionary as far as policy process is considered: from the initial launch of the 3rd Energy package to birth of the Energy Union in 2014, the market reform proposal in 2015 and following a public consultations, new legislation proposals were developed in 2016 and delivered in 2018. And market reform, renewables, energy efficiency directives followed in Nov and Dec 2018. These have been finalized by the EC forwarded to the EP in May 2019 ready for approval by Oct 2019. Ready to be enforced as of 01 Jan 2020. A list of the policies and legislative progress is listed below[16]. What is interesting to note is how long from the process is from proposal, through negotiations, adoption and publication (approx. 2,5 years). Furthermore the legislation process in each member state needs to be considered, which is anticipated to take a further 9-18 months).

	European Commission Proposal	EU Inter-institutional Negotiations	European Parliament Adoption	Council Adoption	Official Journal Publication
Energy Performance in Buildings	30/11/2016	Political Agreement	17/04/2018	14/05/2018	19/06/2018 - Directive (EU) 2018/844
Renewable Energy	30/11/2016	Political Agreement	13/11/2018	04/12/2008	21/12/2018 - Directive (EU) 2018/2001
Energy Efficiency	30/11/2016	Political Agreement	13/11/2018	04/12/2018	21/12/2018 - Directive (EU) 2018/2002
Governance of the Energy Union	30/11/2016	Political Agreement	13/11/2018	04/12/2018	21/12/2018 - Regulation (EU) 2018/1999
Electricity Regulation	30/11/2016	Political Agreement	26/03/2019	22/05/2019	14/06/2019 - Regulation (EU) 2019/943
Electricity Directive	30/11/2016	Political Agreement	26/03/2019	22/05/2019	14/06/2019 - Directive (EU) 2019/944
Risk Preparedness	30/11/2016	Political Agreement	26/03/2019	22/05/2019	14/06/2019 - Regulation (EU) 2019/941
ACER	30/11/2016	Political Agreement	26/03/2019	22/05/2019	14/06/2019 - Regulation (EU) 2019/942

Fig 1. Clean energy for all Europeans Legislative Progress (https://euobserver.com/energy/144633)

[16] https://euobserver.com/energy/144633

The EU's two highest-ranking energy and climate officials boldly declared in April 2019 that the Energy Union had become "a reality"[17][18]

> "I am proud to stand here today, to present this package with one simple message – the Energy Union has become reality," said Maros Sefcovic, European Commission vice-president for the Energy Union, at a press conference in Brussels.
>
> "Four years after the October 2014 European Council [EU leaders' summit], we can now say that we have completed the Energy Union," added his colleague Miguel Arias Canete, EU commissioner for climate action.

So the EC Energy Union was as formally declared a reality. The directives, regulations and reforms were put to vote early 2019 and rolled out within 3 months (ca. July 2019)[19]. Then ready for ratification by member states, the policies are drafted to come into effect on the 01 Jan 2020 and to be ratified by the member states as soon as possible.

Through compliance and governance with the policies, rules and regulations above, investment and support to realize the infrastructure necessary to meet the national energy and climate action plans of the different member states. This support is in the form of Projects of Common Interest, Research and Design and Innovation efforts to meet the energy system transition and climate actions.

The preliminary plans have been reviewed and approved by the EU subject to change and comments as directed. The final national energy and climate plans are due in Dec 2019 and it is estimated that a budget and approval process based on these plans will be completed within 9 – 18 months (coinciding with the new commissions EU budget announcement).

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[17] EU Energy Policy https://eur-lex.europa.eu/summary/chapter/energy/1801.html?root=1801
[18] EU State of the Union Speech 09 April 2019 http://europa.eu/rapid/press-release_SPEECH-19-2073_en.htm
EU Energy and Climate Speech 09 April 2019 http://europa.eu/rapid/press-release_SPEECH-19-2072_en.htm
[19] Clean energy for all https://ec.europa.eu/info/news/clean-energy-all-europeans-package-completed-good-consumers-good-growth-and-jobs-and-good-planet-2019-may-22_en

Fig 2. EU State of the Union Facts https://ec.europa.eu/commission/sites/beta-political/files/factsheet-energy-union-priority_april2019.pdf

To support this activity a set energy and climate policies with corresponding directives, regulations and targets to deliver secure, sustainable, competitive and affordable energy have been issued and budgets to support activity up until 2021 has been approved.

Some of the achievements and ambitions of the Energy Union are listed below[20] but new budgets and project approvals based on the energy transition and climate action plans for the period 2021 – 2025 and beyond are still to be approved and confirmed (which will be the responsibility and focus of the new commission when they take office 01 Nov 2019). To do this the EU will first need to collate and consolidate all member states energy and climate action plans.

[20] EU State of the Union Factsheet https://ec.europa.eu/commission/sites/beta-political/files/factsheet-energy-union-priority_april2019.pdf

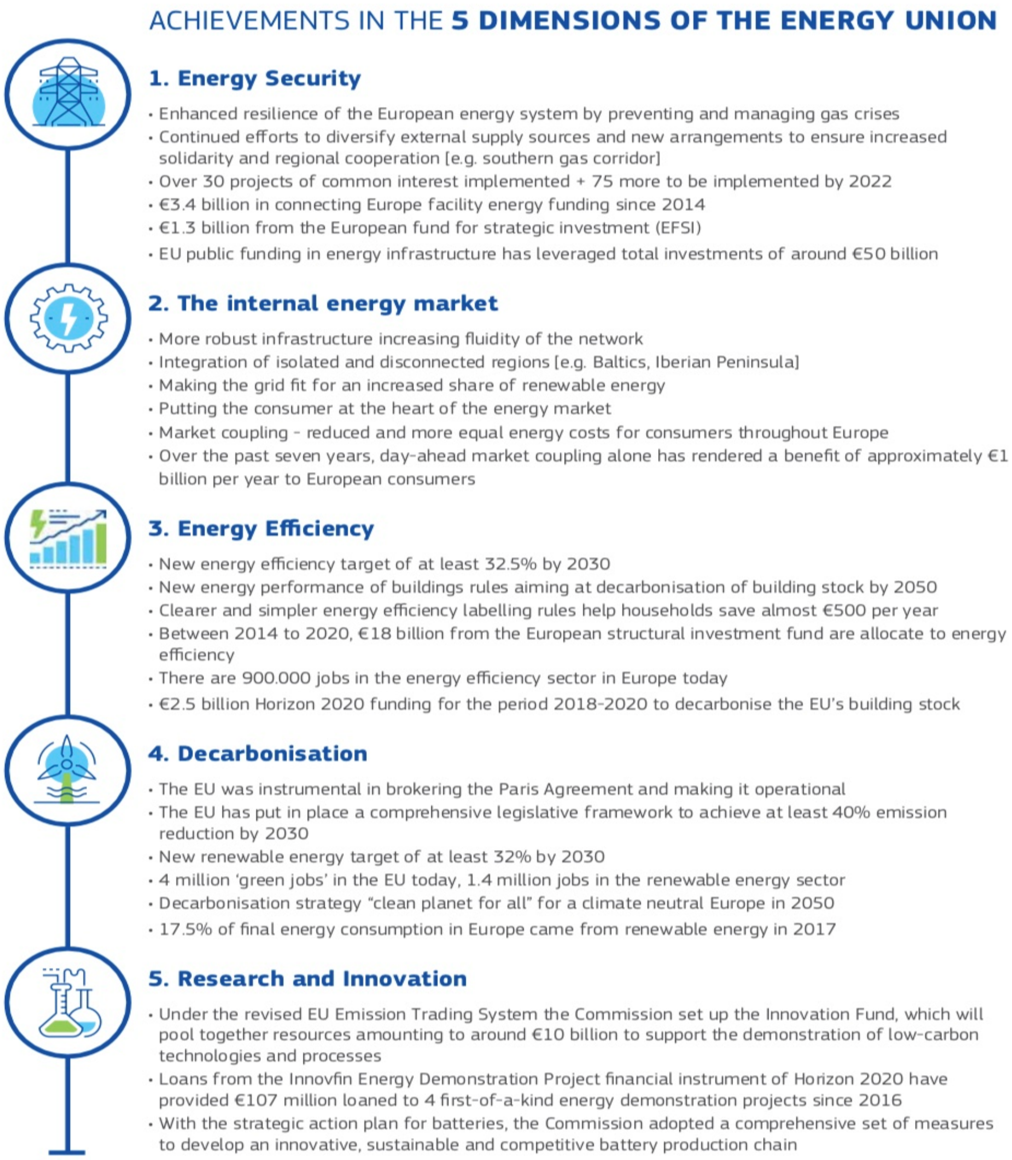

Fig 3. EU State of the Union Facts https://ec.europa.eu/commission/sites/beta-political/files/factsheet-energy-union-priority_april2019.pdf

To arrive at this point an energy policy and applicable regulations and directives have been proposed by the EC and already approved by the EP, now the ratification phase will commence with significant infrastructure development projects already approved which are required to deliver the Energy Union vision(Wallace et al., 2010). Whilst we can celebrate arriving at this stage, the ratification and implementation phase is still in progress and consolidation of approved projects of common interest to be confirmed[21]. This will be undertaken to better understand the methods used to arrive at and embark on the Planning and Implementation phase and how the infrastructure projects will be selected based on the policies outlined by the EU.

It is also essential to address what needs to be done to finance and execute the projects. This study will focus primarily on the Energy Union and energy market

[21] EU PCI Project http://europa.eu/rapid/press-release_IP-19-561_en.htm

design, we will need to review preparations up to the planning and implementation phase i.e. PCI projects for infrastructure to facilitate the Energy Market Design and Energy Union vision, this is the most difficult step in order to secure success if decisions and assessment analysis is not effective.

To do this we will complete a decision quality review of the decision process that was followed and focusing on challenges or opportunities in the planning and implementation phase. To facilitate this investigation a decision quality framework will be used to analyze the decision process (Spetzler et al., 2016).

Fig 4. Decision Quality Framework (Spetzler et al., 2016)

The reason that this framework was selected as it can deal with complex and difficult transition processes and review the decisions and changes that are required in order to comply with the new legislation, regulations and directives. By considering the elements of the Decision Quality Process, will allow us to focus on the history and considerations taken into account and subsequent opportunities and challenges to plan and implement the policy and also allow an opportunity to measure its effectiveness.

From a strategic point of view we need to understand the status of the energy system now (Where are we?). What the vision is (Where are we going!), and how we are going to get there! Through this approach we can appreciate what changes are planned to realize this vision and through implementation of the energy policy we can understand what it will take to get there (i.e. decide on a pathway, breakdown into manageable tasks and design a phased approach or strategic route to suit. Therefore we need to understand the scope and context of the planning process to compliment the implementation phase.

To achieve this objective we need to understand how energy systems work and how they are modeled, we need to know how a power grid is designed, how it will change to meet future requirements and how it works and how it will be controlled, specifically regarding market reforms we need to understand how the energy market works today and what reforms are planned, and in addition we need an outline of how policy in the EU is made and most importantly how policy is implemented and monitored. For readers who are not familiar with the grid and development a more detailed description in the next chapter.

Energy Systems & Energy Grid Design Overview

Energy Systems and Models represent a simplification and overview of the Energy system supply and demand: supplied, converted, consumed, drivers. They also give an overview of external and internal factors. The IEA gives a good overview of the process (IEA World Energy Outlook, Klaus Mohn, 2016):

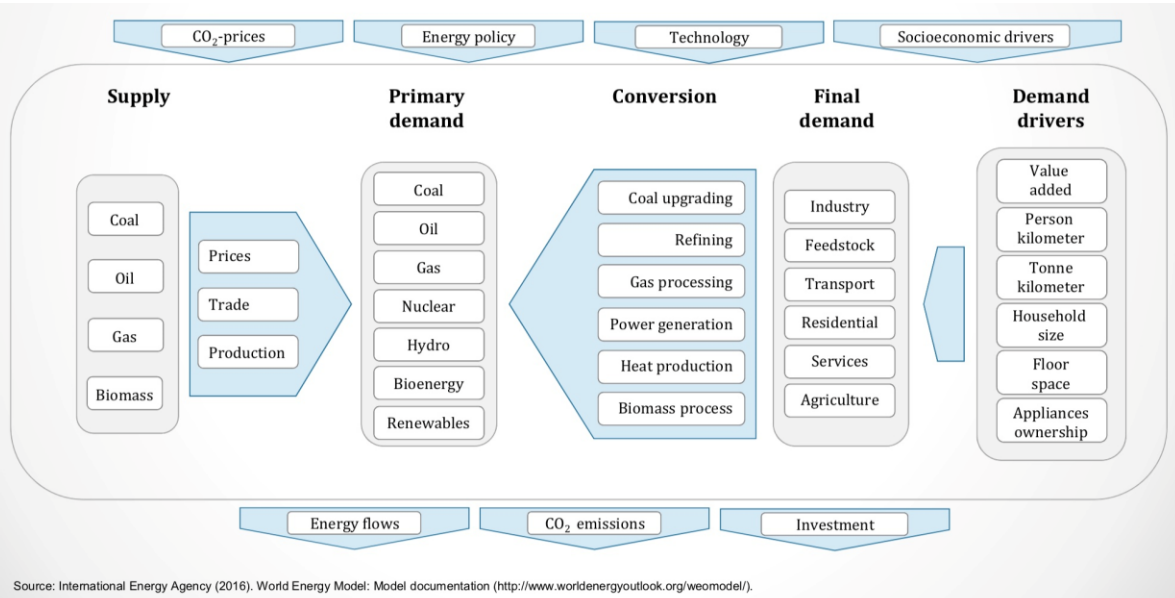

Fig 5. World Energy Model (IEA adapted from Energy Economics, Klaus Mohn)

This model is also modeled using three typical scenarios to reflect policy trends: New Policy (adopted or proposed commitments e.g. Energy Union), Current Policy (Business as Usual, 3rd Energy Package) and a sustainable development scenarios which offer more aggressive low carbon pathway solutions to achieve zero carbon as soon as possible (i.e. to address climate change, clean air and ease of energy access).

According to (Herbst, Toro, Reitze, & Jochem, 2012) energy model pathways and scenarios allow the models to build on energy flows and adapt to reflect on exogenous assumptions (energy prices, economic growth, population and demographics, energy prices, climate policies). These models can often develop representative strategic pathways and possible solutions to achieve clean, secure and affordable energy objectives and the abatement costs associated or indeed used to highlight consequences if steps to limit carbon are not taken (i.e. climate damage and projected loss or incidents and possible events).

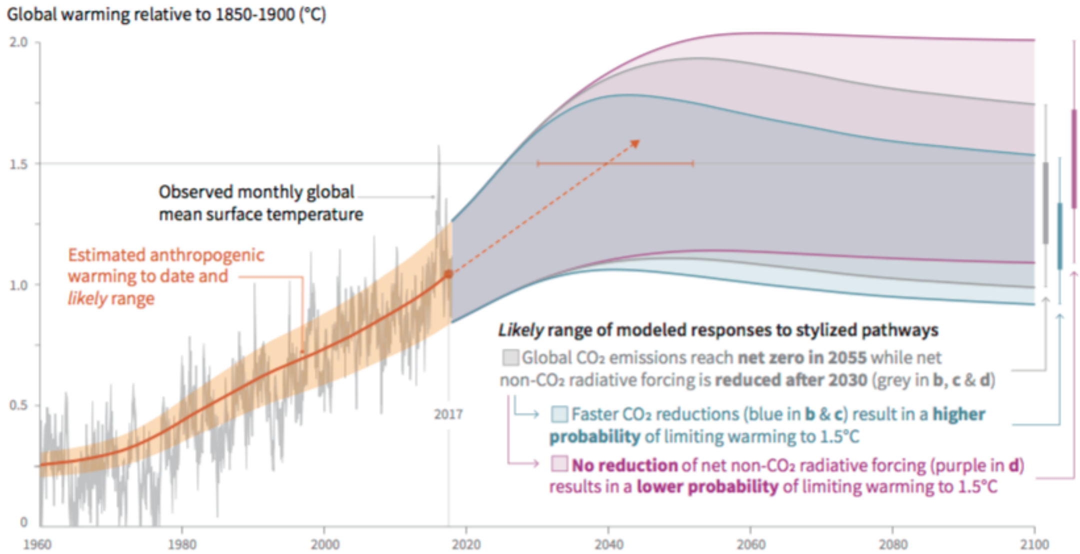

Fig 6. Relative Global Warming & Model Pathways (IPCC SR15 Climate Change[22])

Note the scales of the likely responses on the right hand side of the diagram[22]. This gives us a spread of possible outcomes. It must also be noted that the model itself only represents a 66% chance of remaining within the 2DS, so already we are not confident of achieving this, i.e. 33% chance we will not. This is significant and must be communicated more readily to the public and be reflected by all researchers, analysts and modelers alike[23]. These probabilities of remaining within the temperature affect the carbon budget remaining – this is very important to consider when distinguishing between the temperatures, urgency to act and energy mix to achieve zero or net zero. Below is the carbon tracker model for 2018[24]:

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22 https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

23 https://cicero.oslo.no/no/posts/klima/well-below-2c

24 https://www.vox.com/energy-and-environment/2018/1/19/16908402/global-warming-2-degrees-climate-change

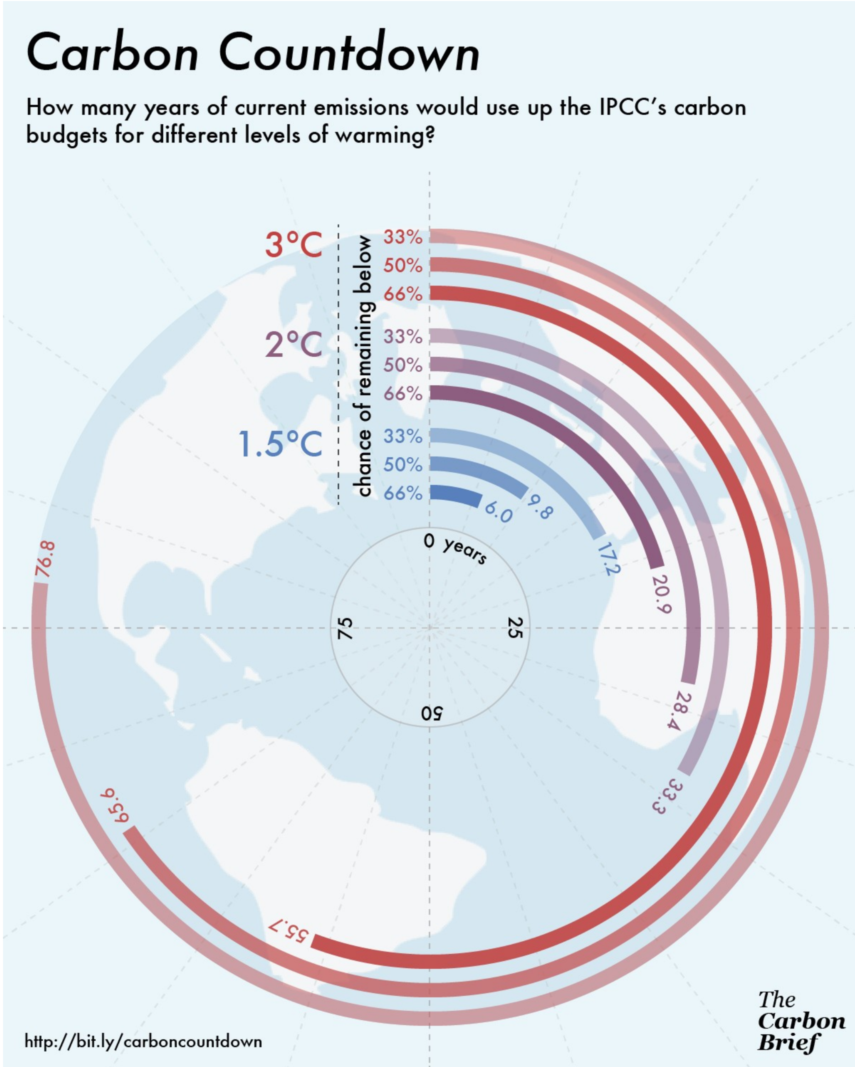


Fig 7. Carbon Countdown (Carbon Tracker retrieved from VOX[25])

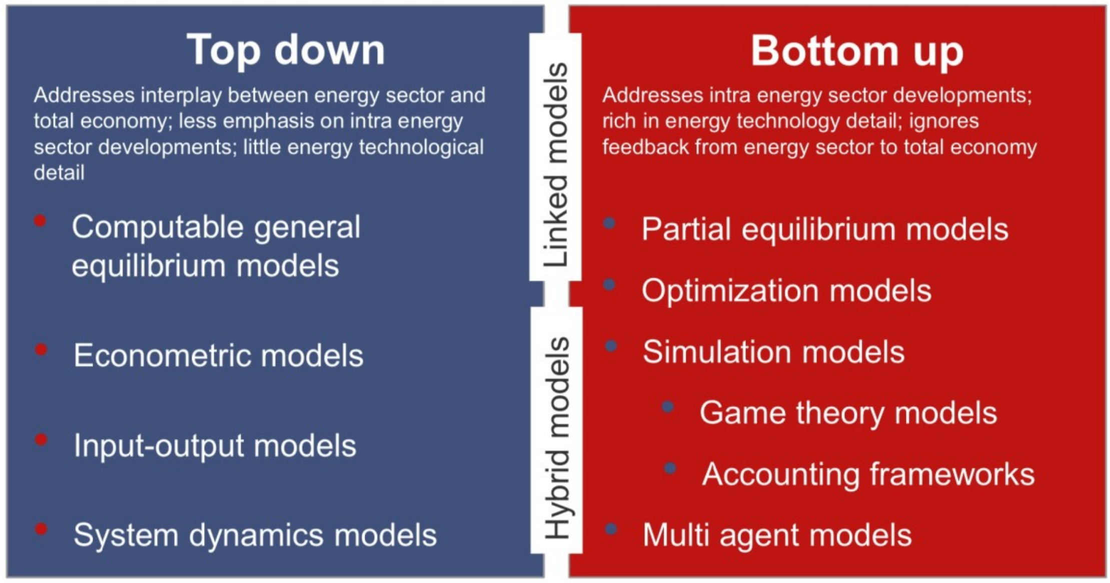
As stated in research (Herbst et al., 2012) these factors are considered in the Energy System Models to develop insight and overview of trends and changes. They are not accurate and contain error. They are complex in nature and may also be used to establish perspectives and support opinions whereby parameters are modified or changed to suit stakeholder bias and heuristics. Often the data used in the models is closed source and not accessible so it is difficult to replicate, reconstruct or probe. Quite often used for projections and to analyze behaviour of the different energy mix and used to understand energy system behaviour if restrictions to any of the factors are modified or targets or limits applied.

Models are used in energy policy groups to establish "perspectives, feasibility and impact of future energy demand and supply" [26]Typical models are classified as top down, bottom up or combinations thereof (Hybrid or linked models). Linked models can be soft or hard wired (which allows for transfer of data and results between

[25] https://www.vox.com/energy-and-environment/2018/1/19/16908402/global-warming-2-degrees-climate-change

[26] Equinor Energy Models and Market Lecture March 2018

models either automatically or manually). Hybrids are built with both Top Down and Bottom Up and are extremely complex and difficult to run.



Herbst et.al.: Introduction to Energy Systems Modelling http://www.sjes.ch/papers/2012-II-2.pdf

Fig 8. Energy System Models (Equinor 2018, adapted from (Herbst et al., 2012))

Top down models as described in the literature (Herbst et al., 2012) are normally classified as macroeconomic models which are predominately used by Policy makers to simulate sector specific future energy demands and address and capture interplay between economy and energy sector economic growth but do not capture intraenergy sector development. They also rely on exogenous drivers or external factors such as energy prices and financial policies. They "do not adequately address the development of technology or considered sufficiently detailed to address specific sector policy". For example model used to evaluate economic costs of CO2 taxes or Emission Trading System or Feed-In-Tariffs for Renewable Energy Sources. Popular examples are: MERGE, E3ME to calculate GDP for EU (mainly used for investment).

Bottom up models (Herbst et al., 2012) are categorized as techno-economic, process-orientated models that look at market penetration or cost of changes. There can accommodate technical detail and design configuration and controls but cannot "project economic, social or net impact for society". That said these models could consider feasibility of major changes to the energy system but ignore feedback from the energy sector or economy. For example the POLES (Prospective Outlook on Long Term Energy System) model used by Enerdata, MARKAL or TIMES optimization models for international world markets or PRIMES Energy System Models with macroeconomic modules as used by the EU.

From the energy systems and models it is possible to introduce different scenarios and transition options to arrive at or derive changes and opportunities to reconfigure the system or the energy mix to ensure that supply meets demand and restrictions on emissions, efficiency and decarburization can be met.

Energy Systems

Before we can understand the energy market and models, we need an overview of the energy system and to understand the design and role of the grid in this context if we are going to look at market reforms.

If we look at the Sankey diagram for the EU below (Eurostat 2017) we can consider the energy flows in the System. Imports/Exports to Final Demand and consumption. This is an accumulated flow of energy from source, through conversion to

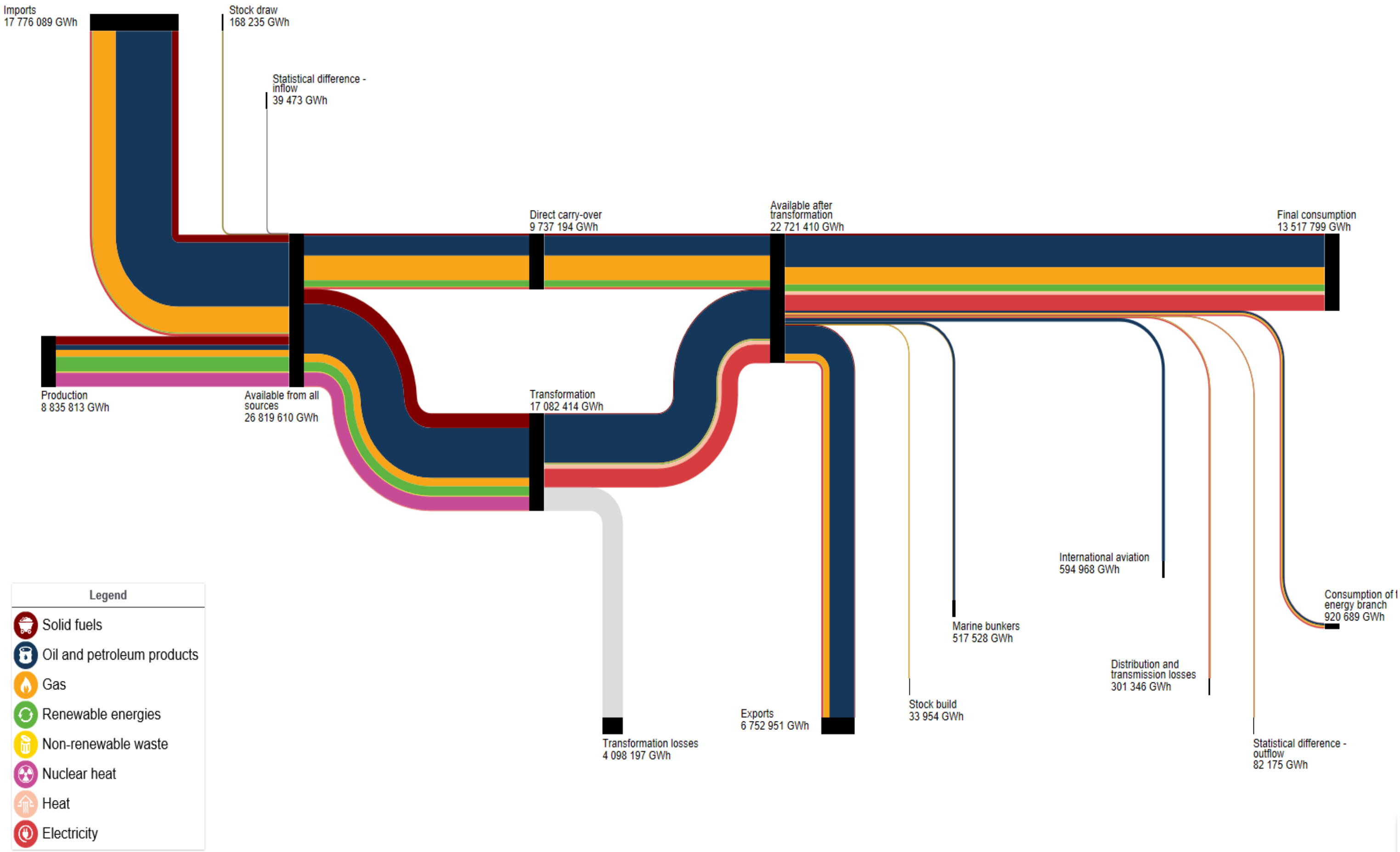


Fig 9. Sankey Energy Flow diagram for EU28 (Eurostat 2018)

From Total Supply on the Left Hand Side, we can then see visually the energy mix. Using the legend colours scheme we can then see the energy mix and by considering the transformation we can see the portion used for electricity and the subsequent losses in grey (this is an area to consider for efficiency improvement and capture for as storage in another form of energy such as heat or gas or used for some other alternative, application or use). As we can see from the blue and orange lines the energy flow is predominately fossil fuel (ca 80 %), the transformation is equivalent to the conversion to final demand through refining and processing facilities. This is used for transport, industry and exports.

In the lower part of the diagram we can see on the transmission to electricity significant losses and the red line is the electrical power we produce for transmission and distribution that also exhibits some losses until it reaches final consumption.

Hence the policy focuses on integration to renewables, decarbonization and energy efficiency. Electricity is also one of the sectors which is easier to decarbonize compared to agriculture, aviation or shipping, or some aspects of heavy road transport or facilities (buildings) and industry (steel and cement), however as this power system of the future may absorb transport and heating sectors and the fact that it may be combined with gas grid in future makes it worthy of our focus on decarbonization efforts.

Electrical Grids

So how does a typical grid look for electrical system? (Coley, 2008). We need to consider supply fuels that enter the power plants and are converted into electricity. How this high voltage ac and dc electricity is carried and fed to consumers. It is also important to not where renewable energy sources actually connect to the grid as this affects grid design and operation and control. What is also important to note is the boundary between Transmission and Distribution as these are separate entities and assets in the system, which play an important part in the market design, and show which subsequent energy transactions are possible.

Furthermore interconnectors need to be considered at the transmission networks (and not in the distribution networks). This also affects the grid design and operation depending on how we wish to design and operate. All of this needs to be considered while maintain stability in the grid (i.e. maintaining the frequency at 50 Hz +/- 10%, this is known as grid inertia and is affected when changes in load or demand require more or less supply and the frequency changes that occur during this process need to be strictly controlled to maintain the frequency at prescribed levels).

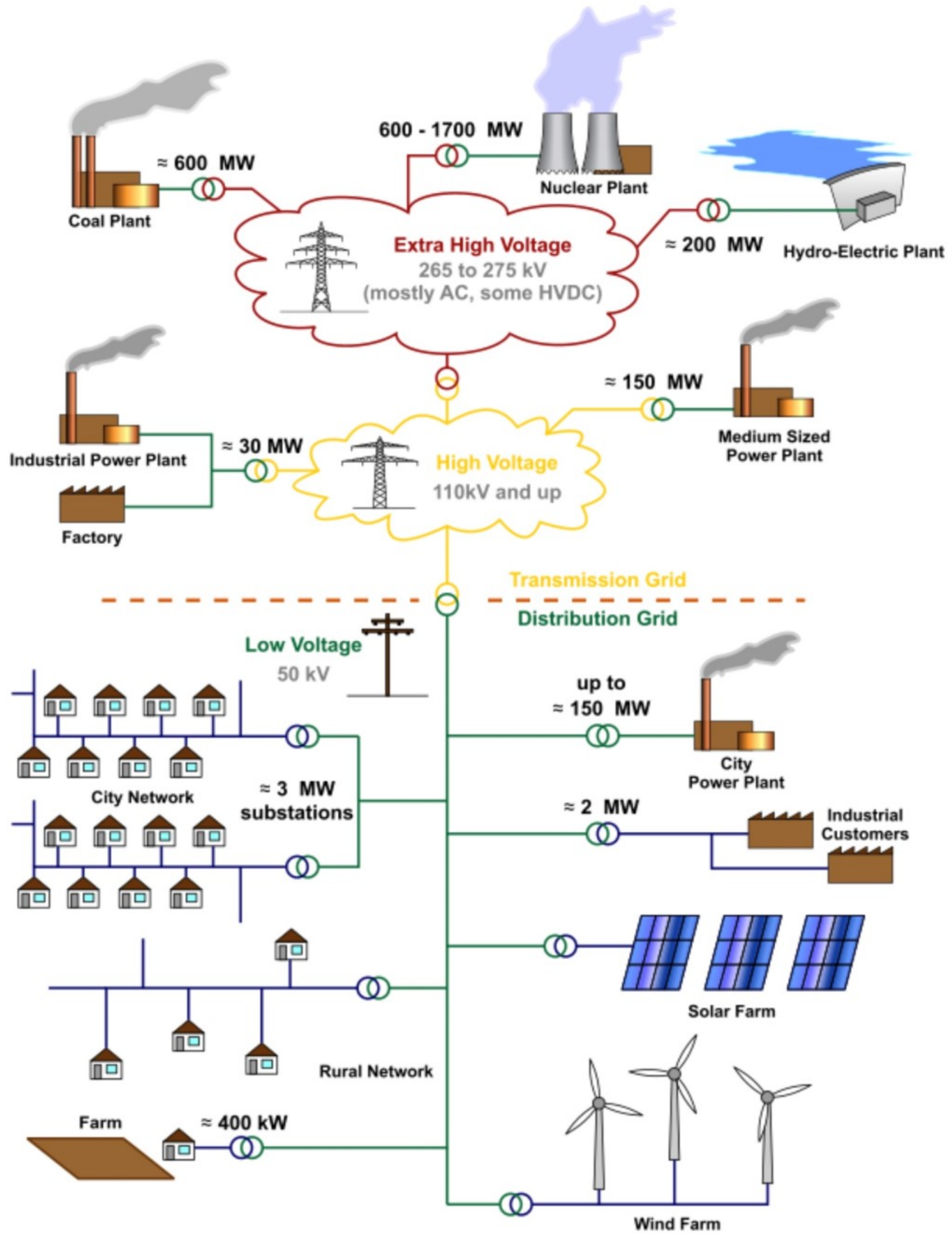


Fig 10. Typical Current EU Grid (Wikipedia)

From the diagram the grid is structured to facilitate production and delivery of electricity through several stages (Harris, 2006):

1. Energy sourcing (fuel supply or renewable)
2. Power generation (transformation) Generation Companies
3. Network transportation (HV) Transmission System Operators
4. Energy distribution (LV) Distribution System Operators
5. Supply Management (supply vs. demand) Wholesale and Retail Markets
6. Consumption (used) by customers and industry
7. Demand management (to enable correct supply to meet demand)

Additionally to facilitate this flow we need to consider (Harris, 2006)

8. System Operation and Independent System Operators

9. Market Operation Trading, Energy and Capacity Markets (*trading and contracts, this will be discussed in more detail in the next section)
10. Metering
11. Disposal & Decommissioning
12. Environmental Impact

Gas Grids

The gas grid is similar to the electricity grid and forms part of the energy grid; we need to consider the gas grid (currently a natural gas grid reaching over most member states).

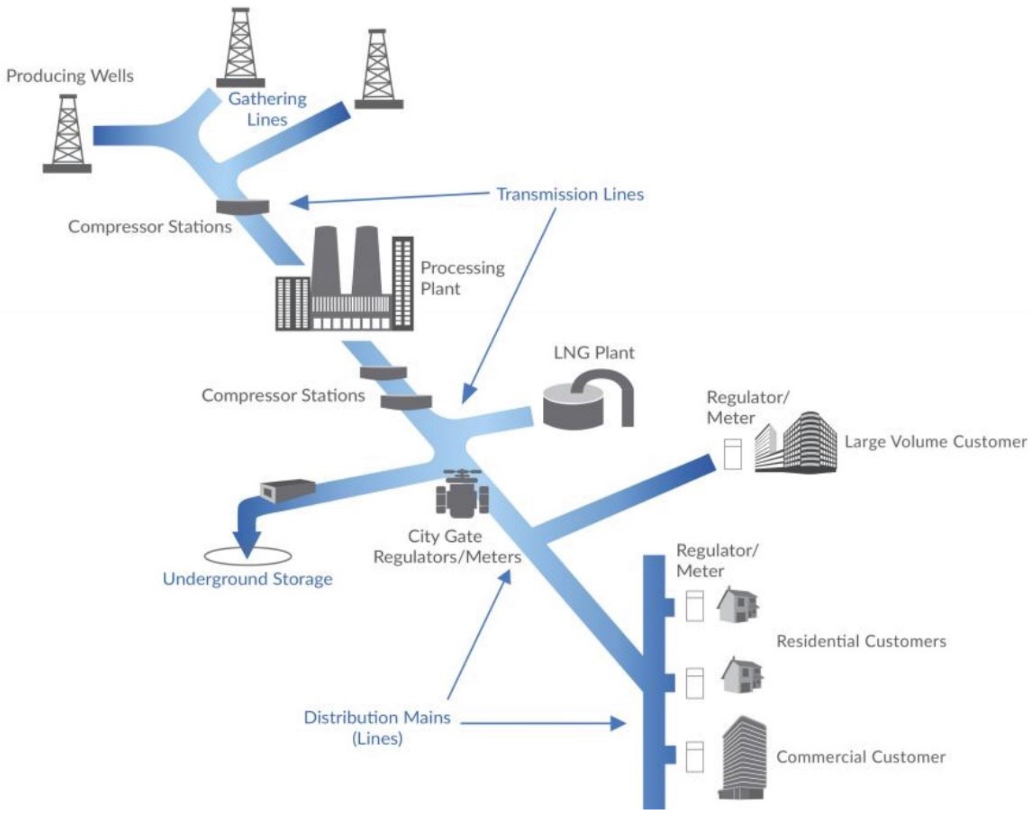


Fig 11. Typical Gas Grid (Google)

But looking to the future grid we also need to consider the heating and transport energy requirements that will be absorbed into electricity service and alternative energy sources, therefore we need to introduce the move to develop a hybrid grid complete with conversion and storage facilities and new products envisaged including: blue and green gas, batteries and Power 2 various gas and energy carriers such as Hydrogen. In addition we need to consider new fuel source entrants and energy technologies. This is best summarized in the following diagram.

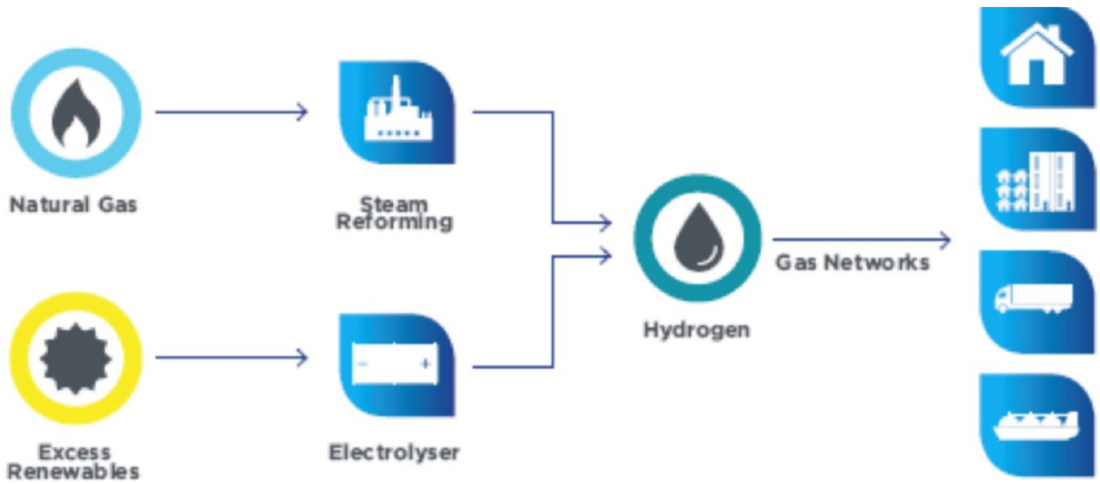


Fig 12 Gas Hybrid System (Google Images)

So combing the systems into a hybrid grid and combining electrical, heating and transport requirements and addressing storage facilities we have the following system. Which will become the basis of future grid design.

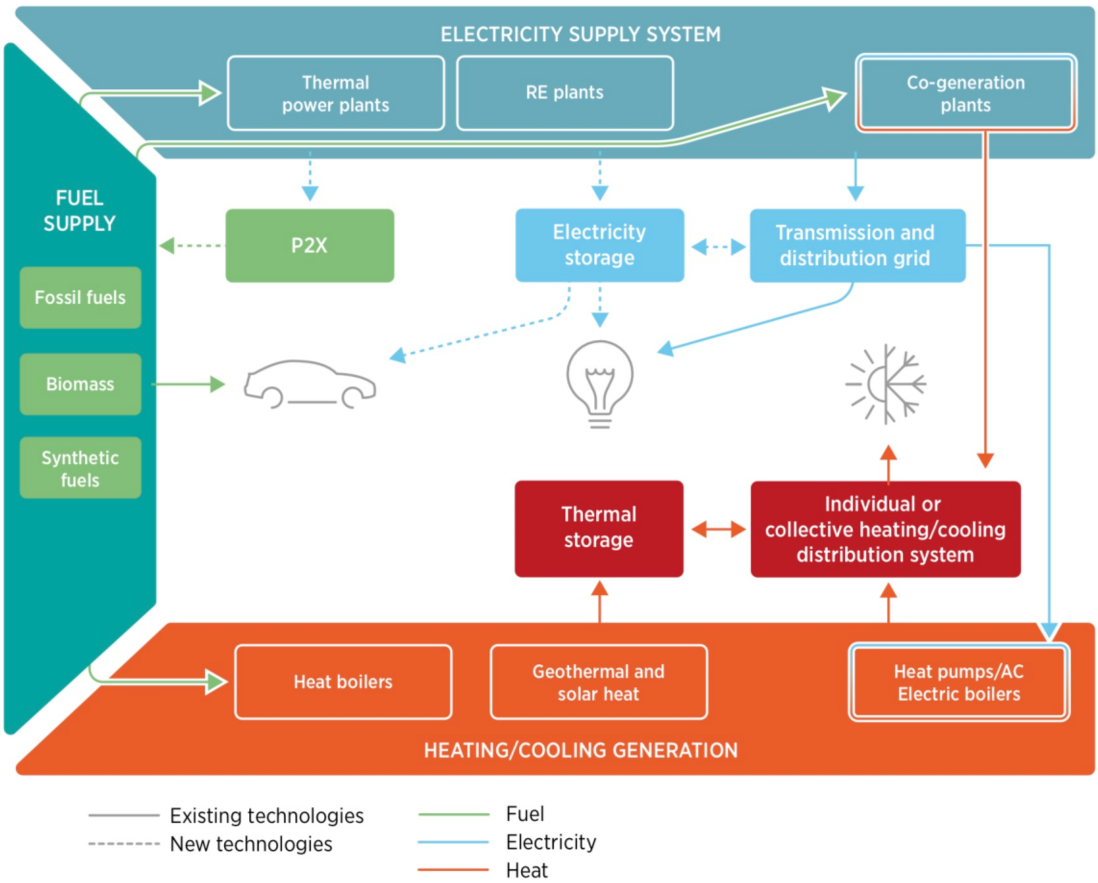


Fig 13. Hybrid Grid (Google Images)

Future Hybrid Grids and Energy Systems

Now we have a better understanding of the current grids and opportunities we can look to the layout of the future grid (Heinberg & Fridley, 2016) in its entirety to better understand the complexities and opportunities that are envisaged. It is very important to use the energy system and grid design outlined above and builds on the changes and innovations below to be able to look into the future concepts and changes that will need to be accommodated (and realized through policy compliance). Special attention to the colours coding is necessary to understand the system boundaries of the various energy supply, conversion and consumption patterns and how the energy sources interact with one another in the market.

The concepts below introduce a sustainable and clean concept – from renewable integration in the form of generation, storage, alternative fuels, storage of energy and the concept of carbon capture and storage is built into the system which will further reduce the carbon footprint of the system and help drive to net zero or neutral operation when this technology and transport and storage issues are resolved.

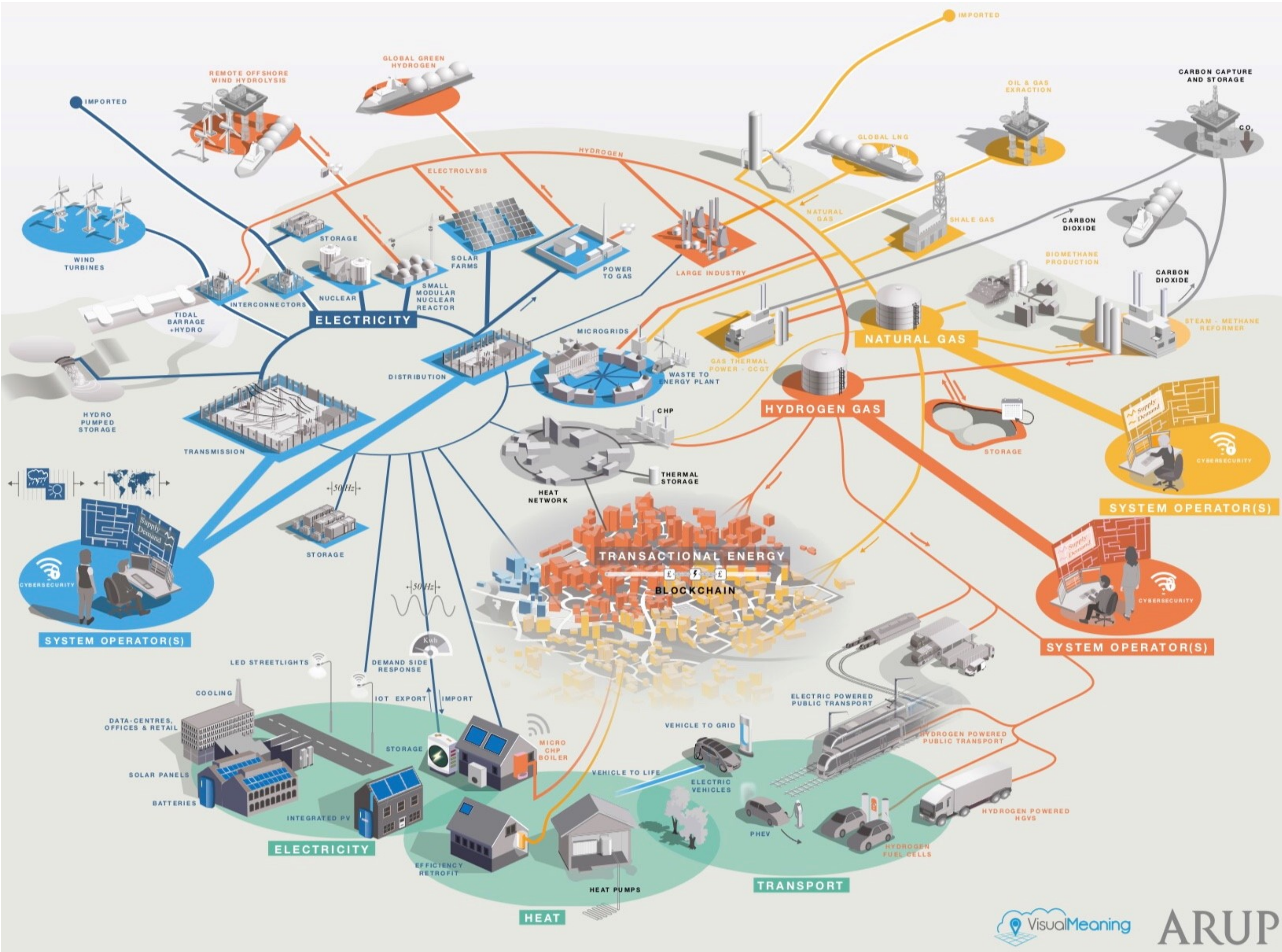


Fig 14. Future Grid (retrieved from ARUP website)

Although the above sketch is considered on a local regional level for a country in Europe this is a simplification and many of the power sources and conversion, storage and application supporting Energy Transition. It could be depicted as interconnected regions and links to neighbouring countries. This will require cross border transmission and markets that will be covered in the Energy Market theory later.

This can also be better explained if we consider the advent of interconnectors between the different countries which constitutes market coupling which will lend to the formation of a super grid or electrical reticulation in the future where generated capacity surplus to local requirement can be transmitted and distributed by neighbouring local distribution grid.

The accommodation of intermittent renewables will also benefit from this arrangement until storage issues are resolved. The future grid also introduces gas market coupling which looks beyond natural gas as a fuel for power production but also addresses heating and services supplied directly by gas and in future scenarios where power will be used to create gas as an energy form and also a storage. Notwithstanding these opportunities it will require a complex control and operating system that is more dynamic and responsive than the grids we operate at the moment.

The future electrical interconnection will look like this in 2030 (i.e. 15% interconnectivity where electrical power can flow both ways – i.e. bi-directional flows, this adds to the flexibility of the power system response and storage or capacity). Also at the end of this section is a diagram of the gas network. This may be expanded or converted for alternative gas use in the future.

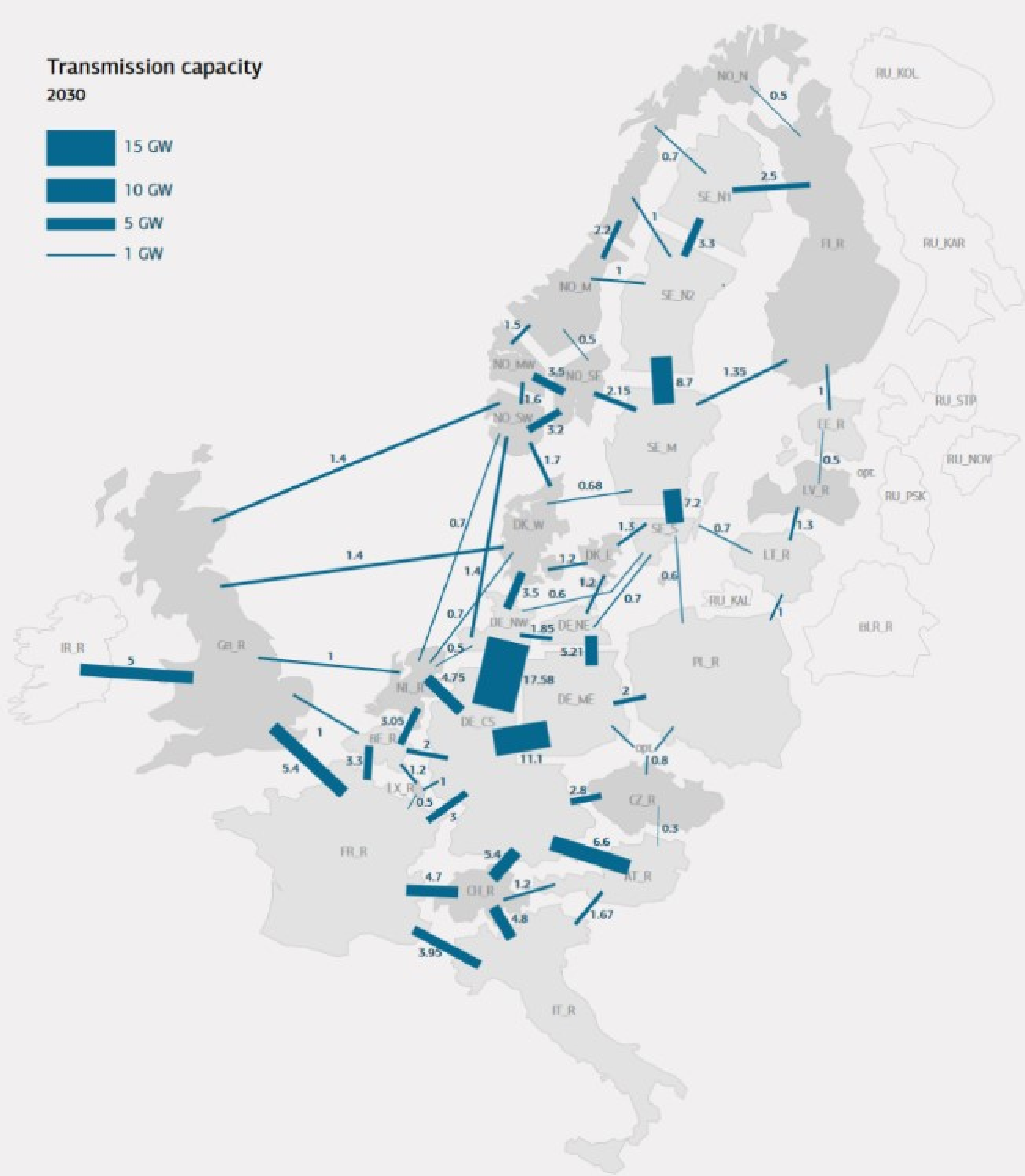


Fig 15. EU 2030 Electrical Transmission Interconnectors (ENTSO-E 10 year network development plan[27])

Similarly the current gas grid can be adapted or lines superimposed to create a gas grid network on top of the existing gas grid in Europe. Again some lines and storage facilities or infrastructure will be modified for P2X or new systems or gas interconnectors installed. Also interconnection between electrical and gas grids is envisaged.

27 www.iea.org/etp/nordic

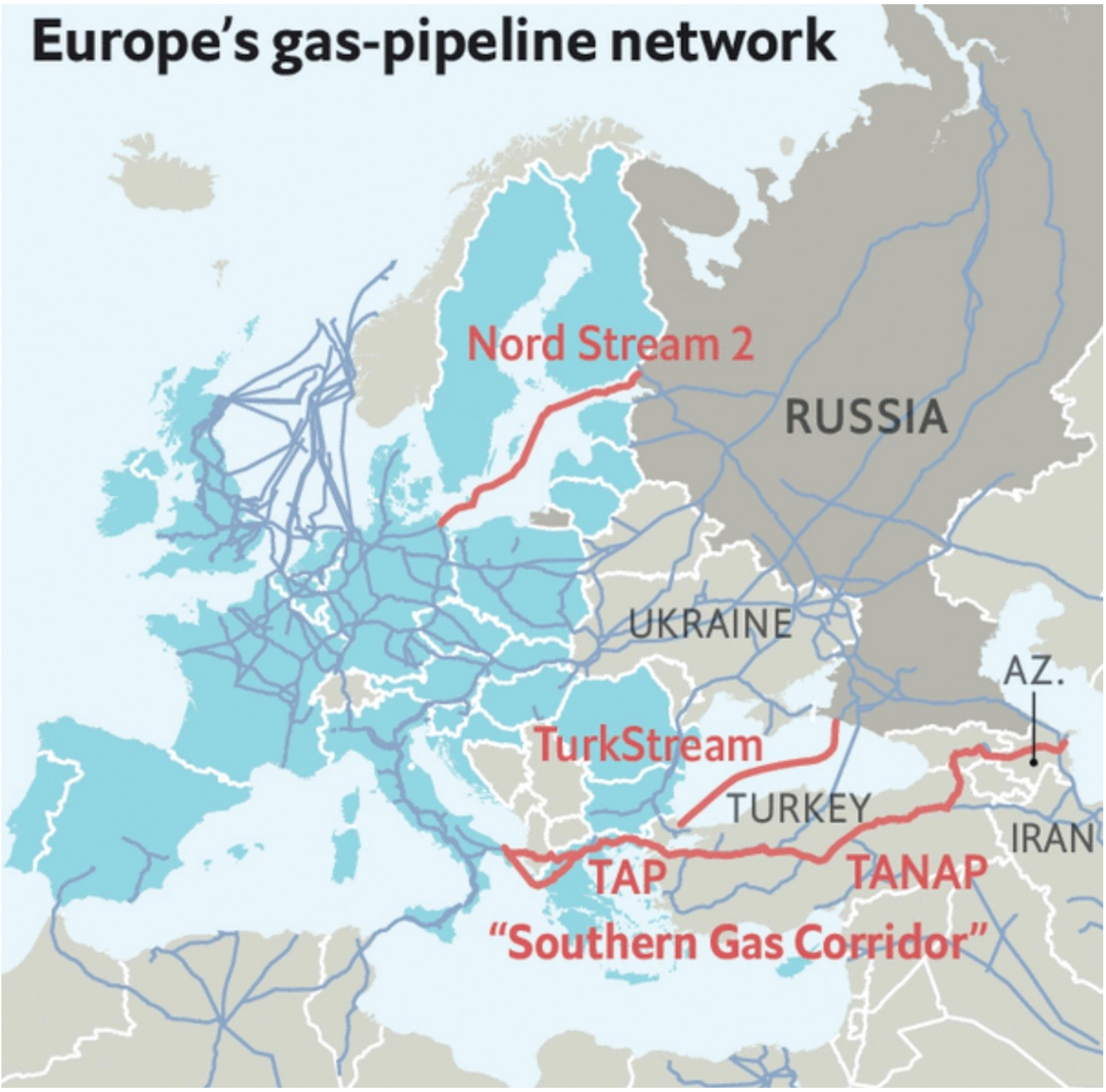


Fig 16.Planned EU Gas Grid and New Projects (Retrieved from Google)

Energy Power Economics and Markets

Following on from the previous section it is important to understand the electricity market and competition models in play from such a system and design. There are various configurations reflecting the generating, wholesale, transmission, distribution, retail and customers or consumers (Kirschen & Strbac, 2004)

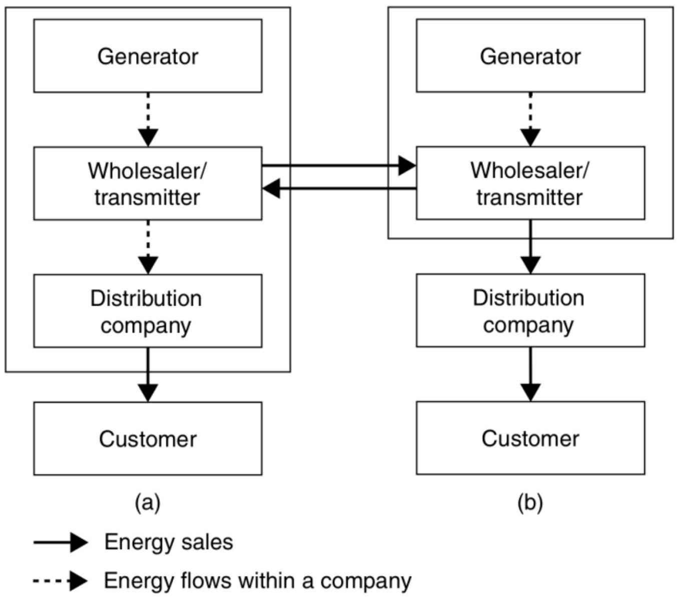


Fig 17. Monopoly Electricity markets (Kirschen & Strbac, 2004)

Which through market liberalization was unbundled to avoid monopolies in accordance with their internal market rules. But some countries do allow introduction of Independent Power Producers (IPP) to operate alongside generator companies especially when trying to integrate new renewable energy sources (RES).

Furthermore if we consider wholesale and retail between the actors in the system this can be adapted to reflect as follows (Kirschen & Strbac, 2004). Where consumers buy direct from distribution companies (disco) who purchase wholesale from the generator companies. Or where consumers can choose their suppliers, this latter approach is the type of model that the EU would like to implement across Europe.

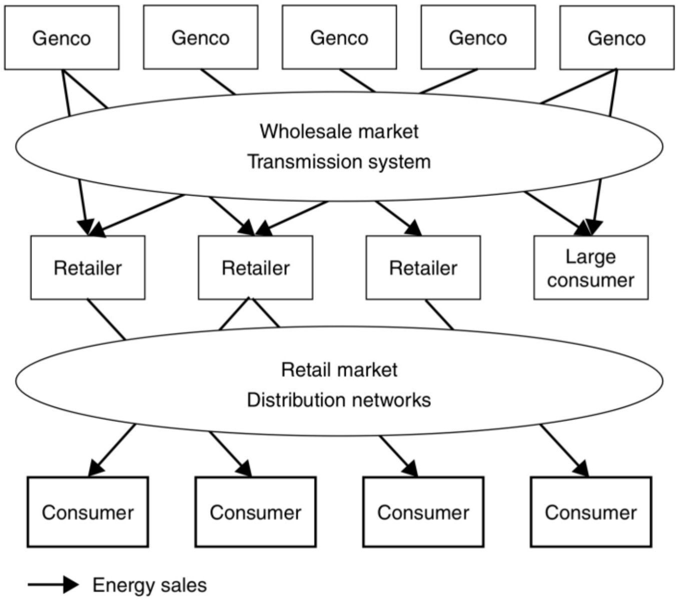


Fig 18. Retail Competition Model (Kirschen & Strbac, 2004)

From a fundamental point of view Energy Economics (Kirschen & Strbac, 2004)we can see it is based on the intersection of supply and demand curves, but adopted to factor in supply based on generation, capacity and distribution of energy to meet the variable and timely demand represented by the consumer. By using volumes of quantity of energy against price and plotting the supply and demand curves and considering the intersection of the S&D we can set a market price (Kirschen & Strbac, 2004). The plan is for excess supply to be used to produce energy carrier fuels (H2) and or transferred to other parts of the grid where there is unsatisfied demand (through interconnectors).

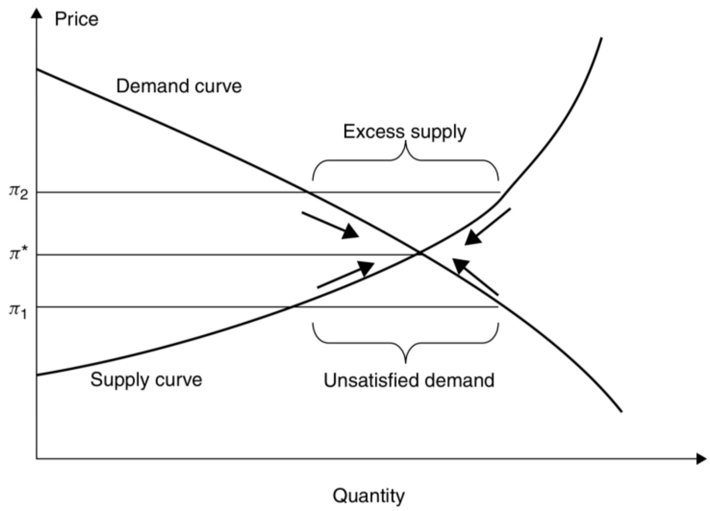


Fig 19. Standard Energy Supply and Demand Curve (Kirschen & Strbac, 2004)

However with changes in demand and load profiles and multiple configurations of grid design, operation and factoring in resilience and robustness of the supply grid to meet the variable and fluid and changing on the demand side requires significant management, putting the two together to determine price we can start to appreciate that this picture becomes complex (Harris, 2006).

Furthermore by considering policy and by introducing the subsidies and state aid instruments for various energy sources, the use of long and short run production and contractual arrangements market trading and accommodating changes in the market lead to a very complex arrangement (Harris, 2006).

All of this whilst simultaneously balancing the endogenous intricacies and then considering the external fuel prices and geopolitical externalities (exogenous) to deal with i.e. the introduction of carbon tax and emission trading schemes and we can see that we need tools and coordination to control (Wallace et al., 2010). This will need a series of models, technologies and dispatch and control tools and systems to help solve this phenomenon. The electrification and development of a hybrid gas and electric grid with storage is key to this.

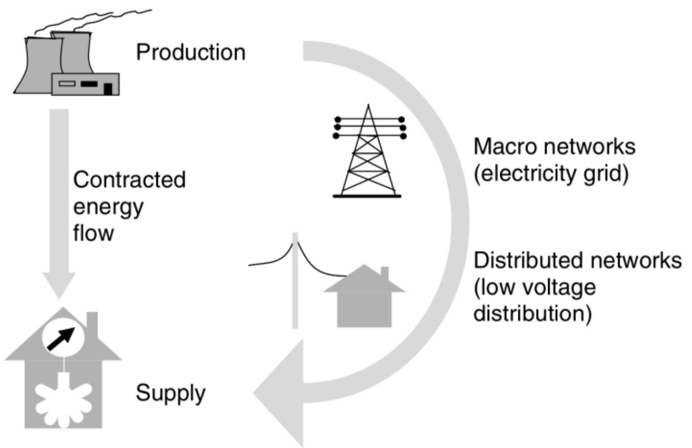


Fig 20. Energy Flows, markets and transmission (Harris, 2006)

While Natural Gas will continue to be traded as a commodity, due to the electrification of the hybrid grid with introduction of Hydrogen as an energy carrier. The grid will mainly continue to trade on the basis of the energy only market system. (Electricity Markets) and a similar model will be in use for sector coupling (gas & electric – whereby electricity will be used to produce gas for ancillary services, stored as strategic reserve or used to generate electricity. Note the time line across the trading and position of the various market systems (Harris, 2006).

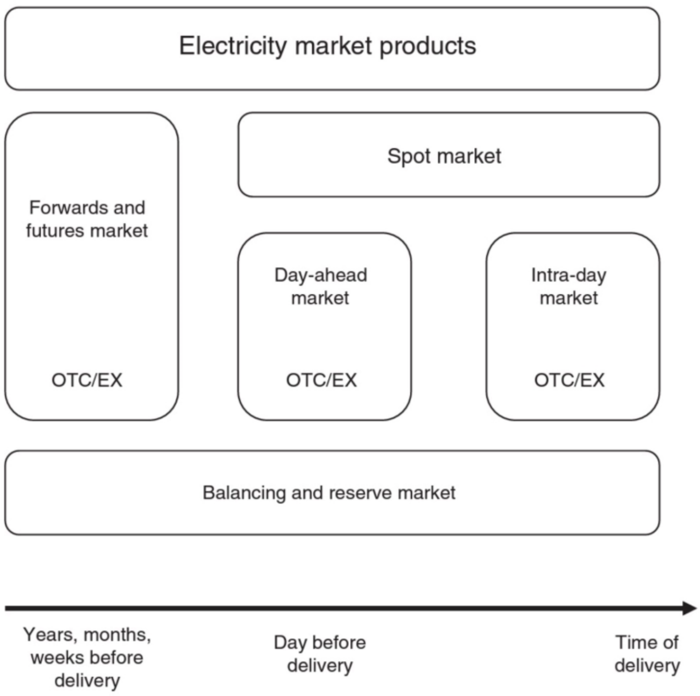


Fig 21. Electricity Markets and Trading Options (Harris, 2014)

While many market designs exist. Energy has predominately been settled by a combination of market designs which reflect the complexities of the design, operation and control of the grid to manage supply to match demand. The EU have given directives, proposals and regulation to unbundle the energy market[28]. To appreciate total overview of the market is best captured in the following diagram. It is important to consider how energy will be traded with respect to asset and grid operation (lower part of the diagram) against the market functions (top half of the programme). This is to highlight the energy flows and capacity or strategic market functions.

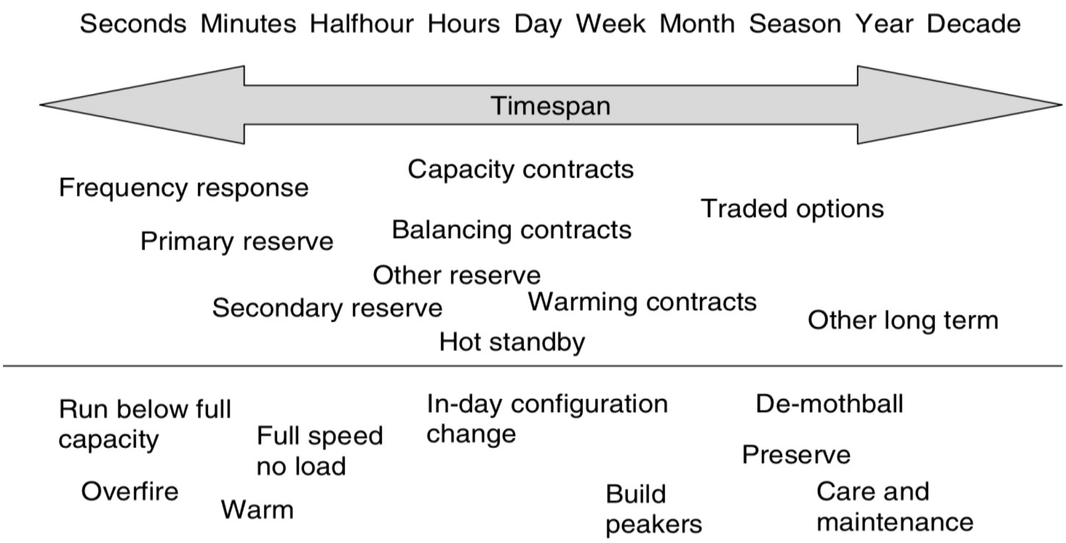


Fig 22. Electricity Market Designs and Asset Management (Harris, 2006)

[28] EU 3rd Energy Package https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/third-energy-package

To break down the monopolies and ensure competition in the market a series of steps were taken to reform the market these are described as: Unbundling, Liberalization and integration of Electricity and Gas Grids to address Heat, Transport, and Electricity expansion requirements including efforts to introduce Storage. This will increase electricity demand that currently makes up approximately 20% of the energy system today but will rise to approximately 50% in 2050 of the total internal energy market in the EU. The products could be traded as follows (Harris, 2006)

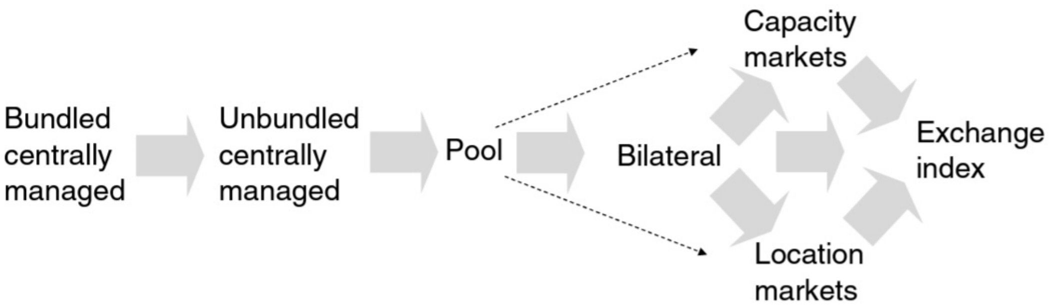


Fig 23. Unbundling the Energy Market and Trading Systems (Harris, 2006)

But with the focus on consumers and SMART technology and the introduction of demand side management to coordinate fluctuations there are steps to develop the market to trade in near real time response. So supply will also need to be flexible to match the demand[29]. This requires grid and market reforms to managing existing assets and building new facilities and interconnecting infrastructure.

[29] Market Retail http://europa.eu/rapid/attachment/MEMO-15-5351/en/Retail%20Market.pdf

Theoretical Basis

To support the research we need to understand the Theory to be used for Policy development and for the purposes of the research objectives focus on decision-making rational choices and decision and risk analysis and how to accommodate uncertainty

We also need to introduce the decision making analysis that was used by using the quality appraisal approach (Spetzler et al., 2016) so we can analyze the policy to arrive at challenges and opportunities in the planning and implementation phase.

Public policy, decision-making and rational choices

Given the focus on Energy Policy, Regulation and Directives it is equally important that we address this process as it is instrumental in the decision making process to ratify and implement the policy (Peterson & Bomberg, 1999).

The public policy framework lends itself to a policy cycle which is related to the applied to problem solving such as design of an integrated market which meets climate change requirements (Howlett, Ramesh, & Perl, 2009).

The policymaking cycle consists of 5 distinct stages (Howlett et al., 2009) supported by considerations where we are addressing energy or dynamic issues (Peters, 2015):

1. Agenda Setting – importance and problem recognition
2. Policy Formulation – forecasting, solutions and recommendations
3. Decision Making – choice of solution by advocacy/approval
4. Policy Implementation – putting policy into effect
5. Policy Evaluation – monitoring and evaluation the policy impacts

Why have energy public policy? As stated by (Wallace et al., 2010) this allows for intervention in failing markets where instruments such as subsidy, investment, emission targets or trading and taxes need to be introduced to rectify or correct the market[30]. This is readily applied to socio-economic nature energy markets with external environmental constraints to enable the market to function more effectively and efficiently to address sustainable objectives i.e. access to clean, secure and affordable energy (Wallace et al., 2010).

Policy can also assist with highly technical and complex political (geopolitical) issues where energy and environmental policy is positioned. Specifically when trying to deal with climate change this could be categorized as “wicked” or “super wicked” problems (Peters, 2015):

- Problem is difficult to define
- Problem multi causal/attributes and interconnected
- Sensitive to change and impact
- No clear choice or consensus on approach

[30] Directive market electricity https://data.consilium.europa.eu/doc/document/PE-10-2019-INIT/en/pdf

- Intervention consequences
- Multiple actors and socially complex

Super wicked problems (associated with climate change or CO2), which can be considered the most serious Market Failure ever and it could lead to Government Failure scenarios if we do not deal with it as described by the Stern Review 2006 and 2016 [31]. These problems and efforts to avoid political failure can be associated with climate change and abatement efforts are compounded by (Peters, 2015):

- Time running out
- No central or weak authority (no authority to manage problem)
- Same actors causing the problem seem to solve it
- Future discounted radically so contemporary solutions less valuable.

In addition these policies can assist where certainty and risk prevails, whereby policy can mitigate or reduce investment risk, ensure security and help manage uncertainty (through support mechanisms to meet targets and objectives) (Peters, 2015).

It is equally important to assess the alternatives or solutions available in developing policy. This will help with the selection and development of policy and adoption by analyzing the policy proposals set out by the EU Energy Union. The policy development within the EU for Energy normally follows the policy cycle as follows (Howlett et al., 2009).

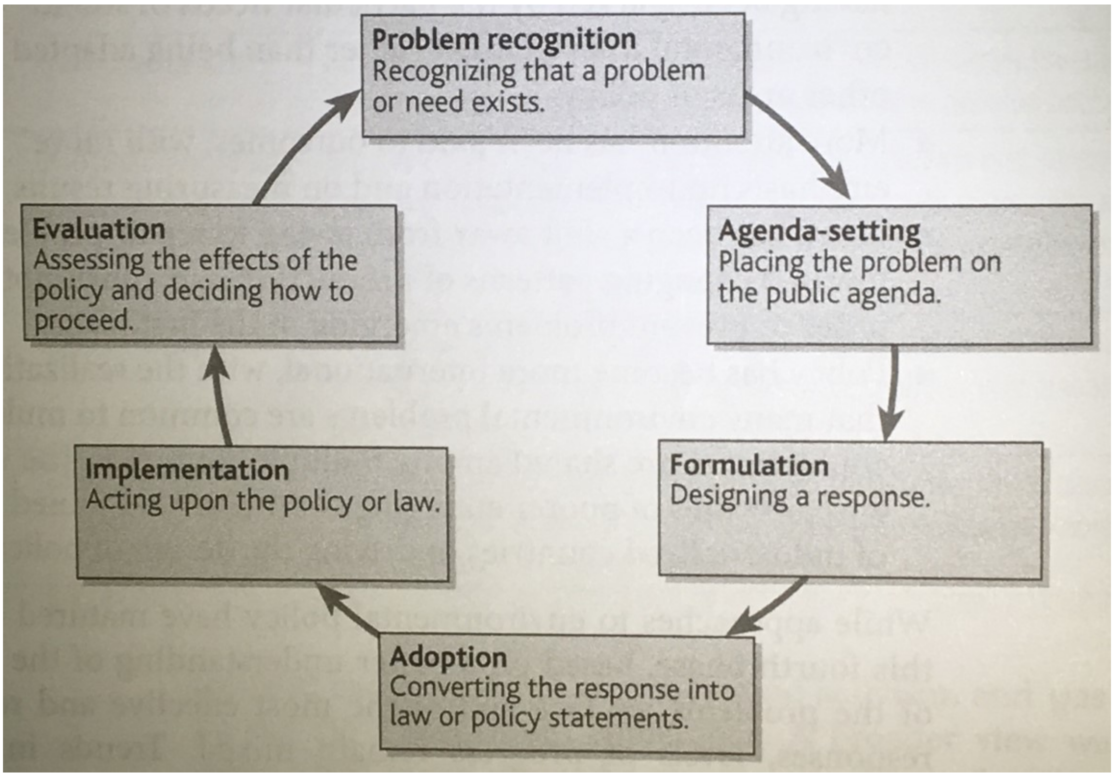


Fig 24. The Policy Cycle (McCormick, 2017)

[31] Stern Review http://www.lse.ac.uk/GranthamInstitute/publication/the-economics-of-climate-change-the-stern-review/

Decisions regarding the energy policy are normally governed by rationality, maximizing utility with known preferences and ability to make rational choices between options and that the consequences and impact of the decisions are understood. The application of rationality can be supported by decision science whereby able to quantify the payoffs and accommodate uncertainty or establish likely costs and associated benefits for any set of probabilities or order of events. This will be discussed in more detail in the next section (Peters, 2015).

Decision Analysis and Risk Analysis under Uncertainty

Decision making under uncertainty:

Decision-making regarding the adoption and implementation of policy for change and the proposed solutions needs to be understood. The effect of how we handle decisions regarding policy and market design, which trigger investments with high risk (investment analysis, market design and environmental impact) and large uncertainties (scope, emissions control, scope and scalability, policy, technical readiness, legislation and changes in grid or energy system design etc.). It is a challenge as outcomes and consequences are difficult to predict.

But decision making, decision analysis and risk analysis constitute a tool and methodology to be employed when confronted with alternatives or need to analyse a scenario against a series of options. What is important is to consider the stakeholders and values, strategy, targets, preferences and performance measures combined with analysis including cost benefit analysis and cost effectiveness (where metrics cannot be monetize) (Aven, 2015).

This analysis needs to be used by the decision maker so that various alternatives can be considered and the strength, weaknesses or limitations of the analysis understood so that the decision maker can perform a review and judgement accordingly. This involves difficult considerations when considering weighting of factors and deliverables subject to uncertainty and risk (Aven, 2015). The information required and developed here is typically the type of information that can be included in a Business case (and refined as you move beyond feasibility, concept selection, development and project execution).

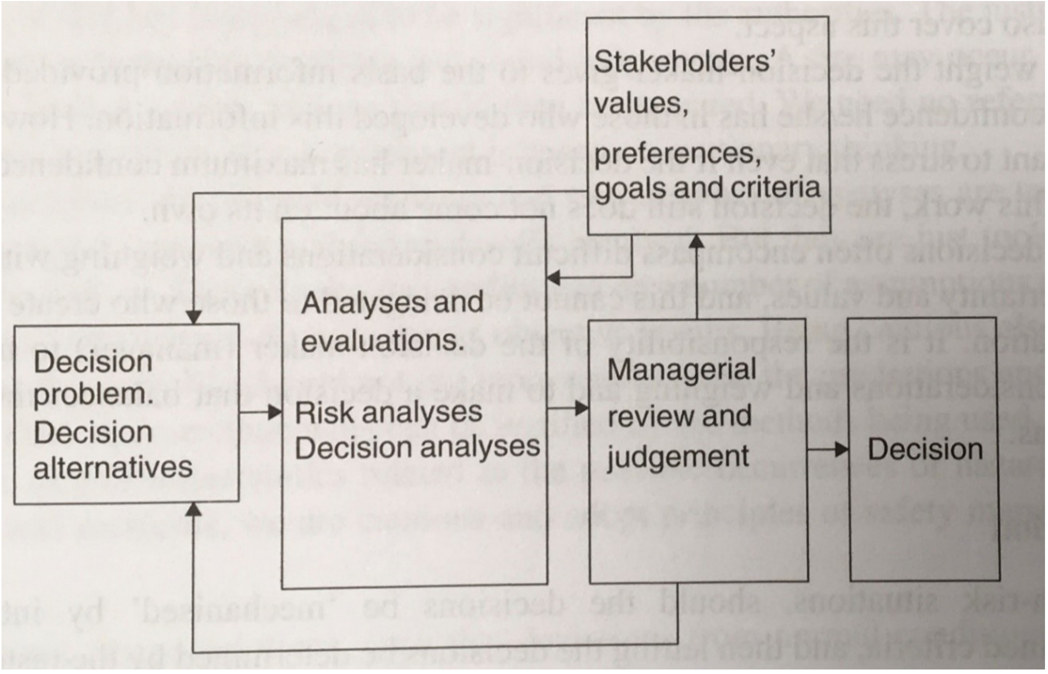


Fig 25. Model for Decision Making under Uncertainty (Aven, 2015)

Where risk and decision analysis need to be carried out so an informed decision regarding policy can be made (Aven, 2015):

- Values, Goals Preferences or Criteria
- Decision or Problem
- Analysis and Evaluations
- Management Review
- Decision (including plan for implementation!!)

Decision Making Methodology:

As (Bratvold, 2010) points out we need to consider a process or methodology to facilitate the aim to make good decisions to capture the decision analysis referred to in the above diagram is a methodology that captures all of the considerations above to meet the analysis and information requirements of the decision maker. Thus a thorough and logical decision making methodology is required this is especially necessary when we are considering hard and complex decisions (Clemen & Reilly, 2013).

Through this decision making methodology the analysis to support the necessary calculations and weighting of objectives can be considered and the alternatives compared. It will be possible to quantify the uncertainty and update probabilities or consider a range of values and probabilities through model simulation and analysis (Bratvold, 2010)

The methodology is captured in the diagram below and represents a much more structured and analytical approach to decision making (Bratvold, 2010).

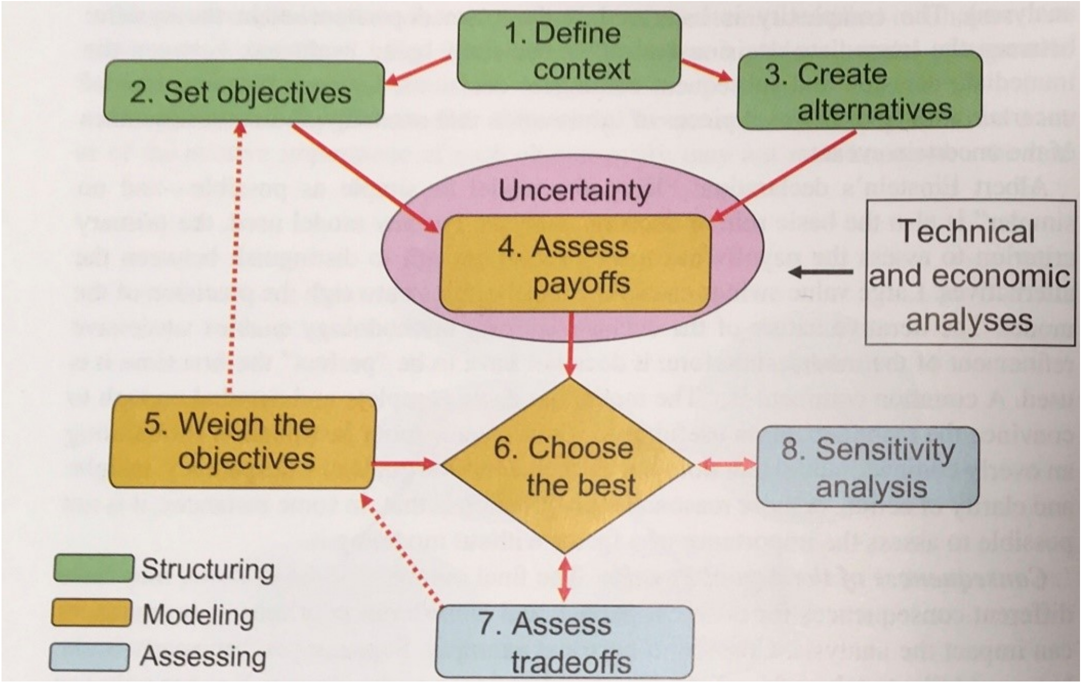


Fig 26. Decision Making Methodology (Bratvold, 2010)

Good Decision Framework can be described as follows (Bratvold, 2010):

Phase 1 Structuring – Framing:

1. *Define the decision context (decision, decision maker and feasibility)*
2. *Set objectives/criteria – by which each alternative can be evaluated and identify any conflicts between objectives*
3. *Create/identify the alternatives (choices)*

Phase 2 Modeling – Evaluating:

4. *Calculate expected payoff of each alternative based on how well it meets objectives (as measured on their attributed scales)*
5. *Weigh the objectives according to their relative importance in distinguishing between the alternatives*
6. *Calculate an overall weighted value for each alternative and provisionally select the best - the one that provides the highest value (including Real Option Evaluations)*

Phase 3 Assessing and deciding:

7. *Assess tradeoffs between competing objectives (e.g. Cost Benefit or Cost Effectiveness or Expected Net Present Values)*
8. *Perform a sensitivity analysis to test the robustness of the decision to the information that produced it.*

It is important to consider the methodology above as this represents the phases and building blocks for any decision-making and introduces the tools and techniques required to support good decisions. This is the type of analysis and applications we need to see if a thorough and systematic decision making process has been followed (Clemen & Reilly, 2013). If we consider the decision we need to consider what is a good decision (Bratvold, 2010). This could be better understood if we consider the Decision Quality (Spetzler et al., 2016).

Decision Quality

Most people refer to the outcome of a decision making process as a measure of how good a decision is. But we can't control or know the outcome at the time of decision making (Bratvold, 2010)but we can control or appraise the decision quality(Spetzler et al., 2016). Therefore an appropriate framework for this thesis will be to use the decision quality appraisal.

But first lets understand what constitutes a good decision (Bratvold, 2010): It can be summarized as the best decision given the information and strength of knowledge to hand (Aven, 2015). We need to consider that a good decision is logically consistent with maximizing the value of the decision given that (Bratvold, 2010):

- Alternatives have been created or identified
- Decision Maker's objectives and associated weights are assigned
- Forecast payoffs based on information we have
- Decision Makers preferences for payoffs, as specified by the value functions.

By keeping the above methodology and definitions in mind we can consider the quality of our decisions by considering if the decision has (Bratvold, 2010): been framed correctly, do we have alternatives, have we got relevant and reliable information, have we established clear values and tradeoffs, has sound reasoning been applied, but most importantly is there a commitment to action have we realized all the value on offer through the alternative selected (Bratvold, 2010).This decision quality framework will be discussed in more detail below.

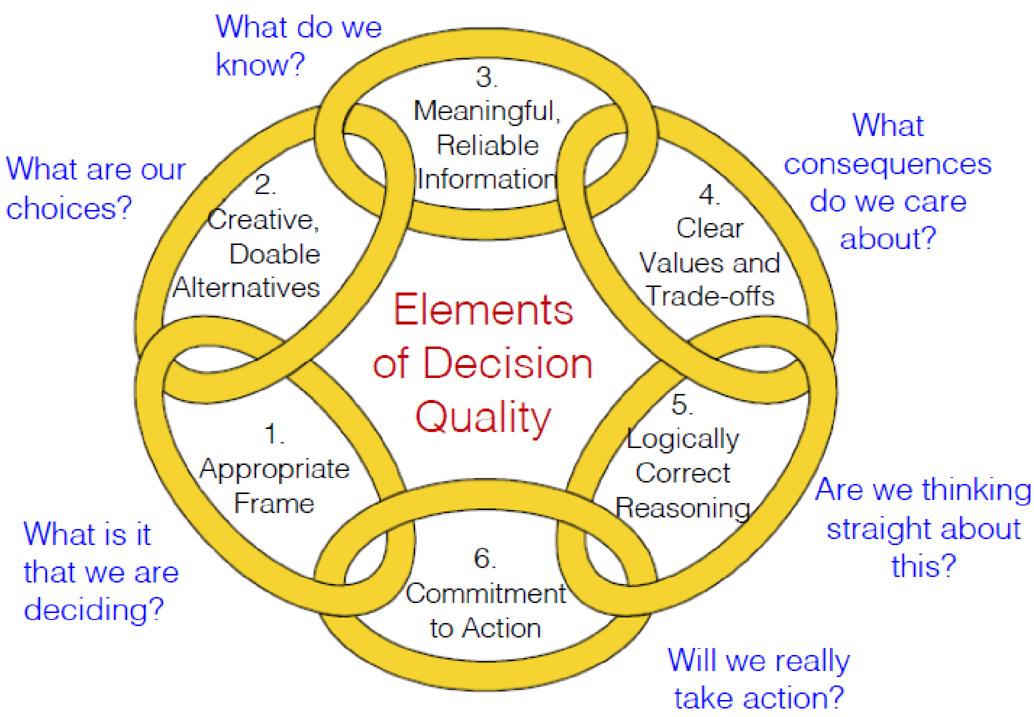


Fig 27. Decision Quality Framework and Elements (Bratvold, 2010)

Decision Quality Appraisal Outline (Bratvold, 2010):

1. Helpful and Appropriate Frame (What is it that we are deciding? And equally what are we not deciding?)
2. Creative Alternatives (What are our choices?)
3. Useful Information (What do we know?)
4. Clear Values and Tradeoffs (What do we care about?)
5. Sound Reasoning (Are we thinking straight about this?)
6. Commitment to follow through (Will we really take action?)

6 Dimensions of High Quality Decision is central to the chain of decision model which evaluates the quality of decision making through the following dimensions (Bratvold, 2010) and the descriptions were summarized from descriptions given by the same author and promulgated by the Strategic Decision Group (SDG) and reiterated in the book Decision Quality "Value Creation from Better Business Decisions" (Spetzler et al., 2016):

1. Helpful and Appropriate Frame: Context as to what needs to be decided, and equally important what is not being decided. At this step it is also important to frame what will be taken as given and are the assumptions clearly specified. This will help solve the correct problem.

2. Creative Alternatives: These are necessary to ensure that high quality decisions are made. Here we need to consider what the choices are, are alternatives feasible (doable), do the alternatives solve the problem, how broad are the alternatives. If there are no alternatives there is no decision (note: do nothing is an alternative but needs to be justified and consequences need to be quantified and this approach must also be assessed for quality).

3. Useful Information: Here we need reliable and relevant information where it is important to consider: what do we know, is all the important information available, is the information unbiased, how accurate other similar assessments have been, what information we would need if more time, finance and resources were available. Given what we know, it is equally important to understand what we do not know, information can be wrong, incomplete or unknown (or implications if consensus not reached).

4. Clear Values: Here we need to be able to define and measure the criteria and value of the alternatives i.e. NPV, DCF, payback and lifecycle against compliance and regulation and balance investment against returns. Essential to address consequences we care about, tradeoffs made and if these are measurable (considering similar scenarios). Ranking and sensitivity of criteria will aid this process while alignment with strategy and governance or assurance requirements. Reducing uncertainty and increasing confidence surrounding the decision enable this. These values may not have an economic value and there may be a tendency to ignore intangible indicators (such as: global, national, government or corporate reputation, health or safety).

5. Sound Reasoning: This is how to combine: alternatives, information and values to arrive at a decision. Justifies the reason (and business case). Look at all dimensions to decide which one brings most value. Requires more that instinct and intuition. Requires modelling. Important to reflect: Are we thinking straight about this? Need clarity and transparency. Not sufficient to use a deterministic model which ignores uncertainty and key dependencies. Also deterministic approach may lead to a false belief in accuracy and impact or relevance. Goal is to create a clear, transparent and understandable recommendation that maximizes value of the decision maker.

6. Commitment to follow through: This dimension moves the decisions into execution or implementation phase, Best decision must be implemented. If not committed the follow through is not undertaken, put on hold, deferred and as a result will not achieve best result (it is also important to quantify the "no action" or "do nothing" scenarios). We need to consider objectively: is the recommendation appropriate and feasible, how will the decision be communicated, how can the organization support the decision and is there an implementation plan (this comes back to strategy alignment). Success at this stage requires: resource allocation and tenacity to see it through and flexibility to overcome obstacles and change.

Once we have reviewed the EU Energy policy development and understand the needs and challenges of the implementation phase we can also see if the decision quality framework and methods above could help improve the process this will be undertaken later in the Analysis section.

Research Methods and Methodology

Unbundling the Energy Union - applying the decision quality framework and supporting analytical tools to understand the challenges and opportunities for the planning and implementation phase of energy union policy, directives and regulations. "Commitment to action – Will we take Action?"

To answer the Research Question:

What are the implementation challenges and opportunities for the Energy Union Policy Planning and implementation phase – as derived from the analysis and application of the Decision Quality appraisal to confirm: "Are we committed?" and "Will we really take action?"

Research Strategy ((Blaikie, 2000): Mixture of Inductive, Deductive, Retroductive and Abductive but mainly achieved through observation and participation as a "Stakeholder" in the policy planning and implementation phase and applying Project and Portfolio experience to quality control the process.

- Review Energy System and Market design Stakeholder Requirements – Inductive through Observation (Secondary Data and documentation analysis and observation through participation at seminars and workshops). Review of the European Energy Union Policy development.
- Review and compare Energy System Models, configurations and results or alternatives. Also consider assessment quality to support the Decision Makers in order to make correct choices to effectively implement the Energy Union proposals – Deductive through Observation (assess model, model results and combinations thereof and quality assessment checks to support robust decision making for policy planning and implementation)
- Apply the Decision Making Methodology or Frame work – Retroductive Analysis through application of framework (and check project assessment and decision analysis processes and to check to see if analysis accommodates Uncertainty and Risk/Opportunity into models and subsequent analysis thereof)
- Throughout the research analyze Decision Quality of the above with specific focus on implementation of energy union measures – Abductive through observation (to understand the mechanisms and workings of the decisions regarding policy to support grid design and market reforms to help create framework for hybrid grids select correct market design to support energy transition)

Research Methods:

Qualitative approach. Stakeholder, Risk and Decision Analysis review in a Qualitative approach by applying Decision Quality Framework and see if modelling, analysis and decision making when developing energy policy includes appraisal of the Decision Assessment and Risk/Uncertainty management in a Qualitative manner.

By considering the decision making methodology we can review the decision process by applying the decision quality framework, from this we can derive the various grid design and market design options and understand the modelling, technical and economic analysis through energy system modelling (types and scenarios) we can consider the options or alternatives and how the best option was selected.

Through the decision quality framework we can critique the policy cycle focusing on readiness for the planning and implementation phase. This will enable us to retrospectively understand the context and structuring of the problem, appraise the modelling methods and review the assessment processes. Simultaneously checking to see if the risk and uncertainty management and analysis that will be needed has been addressed and considered in implementation phase.

To do this the research activity plan is to:

1. Further to the literature review and information gathering focusing on EC and EP Energy Union Policy Development and Decision Making efforts: including review of communications and publically available documents from concept through to launch and to review just how effective policy and processes are (also to understand the merging the energy, environment and climate policies)
2. Attendance at a series of Energy Workshops and Seminars focusing on Energy Markets to support transition following the EU Policy, Regulations and Directives
3. Attendance at EU arranged Infrastructure and Project Proposal and Grid configuration gatherings and events that are working to implement the policy.
4. Complimented by Detailed Risk and Decision Making training and understudy of Decision Quality and Strategic Decision making guidelines and application of Risk and Decision Analysis appreciation.

As part of Information gathering and understanding of challenges and opportunities and the opportunity to ask questions and network, attended a series of seminars and workshops geared for the stakeholders across the energy policy spectrum:

1. Risk and Decision Making Analysis online training and webinars 2018 (including @Risk, SIPMath, SDG Webinars and review of Society of Decision Professional Conference proceeds)
2. Attend the Ensystra Energy Transition Business Economics and Market Design Workshop, Edinburgh UK, Jan 2019
3. Attend the Infrastructure Workshop Scottish & Southern Energy SHE Transmission Upgrade Workshop Feb 2019, Edinburgh, UK
4. Energy Transition Week Attend Capacity Markets Workshop and follow the Energy Transition Conference Trondheim Mar 2019
5. Webinar Strategic Decision Making Workshop and Decision Quality presentation (SDQ Climate Change presentation) April 2019
6. Attend and present at the Carbon Intensive economies and sustainability workshop, Is CCS coming to the rescue? UiS, Stavanger Norway 11 April 2019

7. Follow the EU Energy Union Announcement and Draft Regulation and Directive Review Launch and Communications review Dec 2018 - May 2019
8. Energy Policy Research Group Capacity Market and Market Disruption Seminar Cambridge, UK, 9-10 May 2019
9. Follow Live Feed from the EC 2019 Infrastructure Forum, Copenhagen, Denmark 23-24 May 2019 (Implementation Workshop)

Results

By following the process for energy policy development and the launch of the clean energy for all Europeans package and subsequent release of regulation, directives and framework for energy it is necessary to review the policy development process including all decision points and approval processes together with the grid design and market reforms used by the EU. This will assist to capture all the planning and implementation challenges and opportunities, which will later be derived from review Decision Quality Framework stages applied to EU Energy Union, to enable this analysis it was necessary to review the following to develop research results for analysis:

- Decision Making and Governance in the EU and Energy Union
- Policy Making in the EU focusing on Energy Policy in particular
- Energy System Modelling used by the EU and R&D groups supporting the EU
- Technical & Economic Assessment Techniques used by the EU to support decision making and assess model outputs and how alternatives for projects and energy mix are assessed against grid design and market design
- Market Designs – Internal Market Design and Energy Market Reforms in the EU and assess selection and application effectiveness.

Decision Making and Governance in the EU

To understand how policy is developed it is important to review how the EU makes decisions selects alternatives and develops policy, this is particularly important if we are to use the decision dialogue frame work in combination with the decision quality framework in the analysis section as described earlier:

As described by (Nugent, 2010) the EU operates under the authority described by the EU Treaty of Lisbon, signed up by member states of the EU in 2009, and through the treaty the voting systems and policy and governance responsibilities for the various sectors, including energy, environment and climate, are established. The normal pattern for policy making and decision making follows the format: the Commission proposes a policy on behalf on the European Council (designed by the commission to meet their objectives and mandates issued by the European executive council), the parliament advises on the member state or various party requirements and once the commission has developed the policy via the various directorate general bodies it is sent on to the council for approval before release (Wallace et al., 2010). After the council approves it the commission on behalf of the council forwards this to the European parliament and Council of ministers (normally agreed by co-decision) for vote and if successful will be legislated after consultation with the council and the budgets agreed accordingly, this is captured in the schematic below.

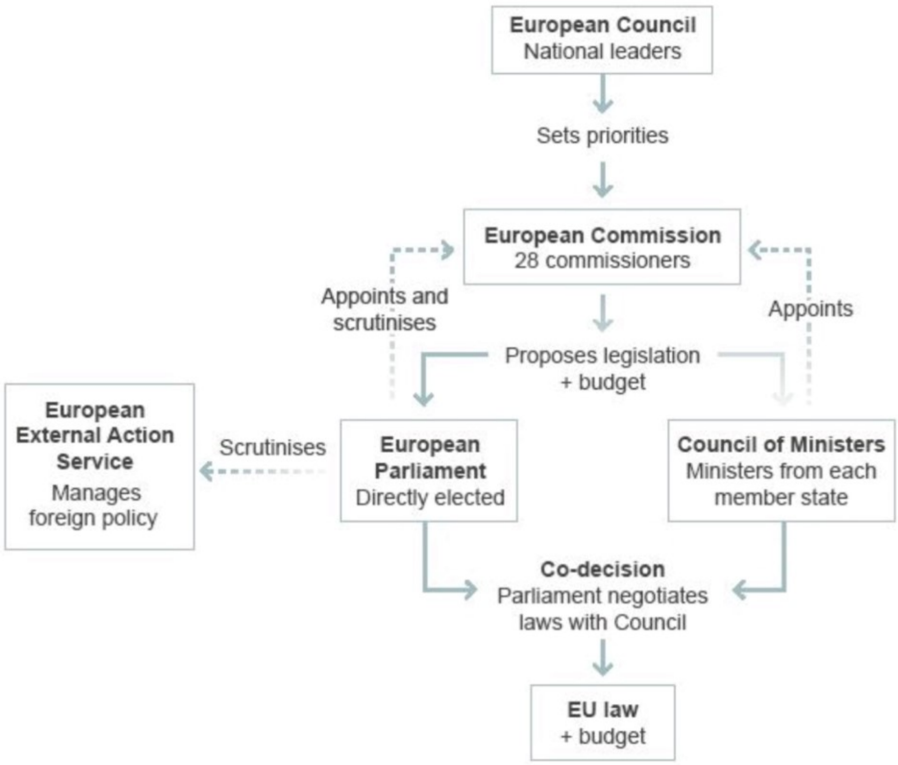


Fig 28. European Organizational RACI Chart (ec.europe.eu)

But due to the integration and expansion of the EU and following the signing of the Lisbon Treaty, a more cohesive policy approach to Energy was found necessary and as a result the voting by “Unanimity” (all agree). This was later changed to a “Qualified Majority Voting” (keep a 2/3rds majority in favour) regarding issues concerning energy and associated policy instruments. This voting mechanism for energy was introduced in 2014. It tends to favour the larger member states or those holding larger quota of votes (representative quotas) – this step was seen as necessary after serious setbacks to the introduction of taxes concerning and market instruments struggled to win the vote and subsequently these proposals were withdrawn. However they will be approved now that the voting mechanism has changed to QMV (Wallace et al., 2010)

But overall with respect to Energy and Climate Action the move to Qualified Majority Voting will make it easier to facilitate Decision Making in the EU and in addition overcome the resistance to Energy taxes and Carbon Taxes in the future which is an essential part of the decarbonization strategy. As a result it may be more difficult to get member states to ratify and implement the energy system transition and climate actions but that may be why the EU is pushing for a bigger regulatory and governance role in the future and also to introduce investment and financing incentives for member states who comply with the policy and align to the strategy of the Energy Union.

Previously policy development responsibilities regarding Energy was normally a combined and collective effort between the EU and the member states, but due to climate action and decarbonization of the energy system this has moved up the agenda for the EU and is currently receiving a lot more of attention (Wallace et al., 2010). As a result a much bigger resource group has been created and the EU has took the lead through the commission to develop the policy and that has developed the proposal to create an integrated energy system and also opted to build up a more formidable regulatory body to govern the cross border nature of the system. Thus new energy policy, directives and regulations have been developed with specific focus on an energy union including grid and market regulation responsibilities[32].

Correspondingly regarding the nature of the policy involvement, there will be a move from the regulatory, governance and inter-state cooperation to one of considerable reliance on legal regulation and EU Energy, Environment and Climate Action groups concerning compliance and governance. This will also enable the ability to coordinate the development, infrastructure and budgets that are needed to facilitate the transition.

The policy processes adopted by the EU are based on the treaty conditions, although the energy policy is mainly designed to comply with the principles of the integrated internal market, there is need to address external trade with respect to fuel (e.g. LNG supplies) and technology resources or services (Solar, Wind and Hardware) to support the transition phase and in to meet energy security requirements (diversification due to geopolitical issues).

Policy Development in the EU

The EU, through the commission's activities, has adopted the policy cycle as its main framework for policy development where Energy, Environment and Climate issues are concerned. (Wallace et al., 2010). To date the EU have completed the policy proposals based on an Energy Union and these are ready for the planning and implementation stage of the cycle.

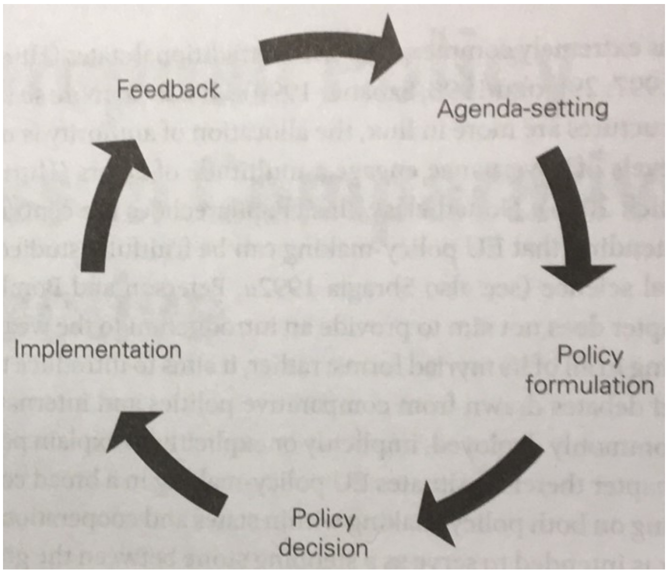


Fig 29. The EU Policy Cycle (Wallace et al., 2010)

[32] https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/electricity-market-design

However this cycle has received criticism if it is not sufficiently populated and the sequence is not followed, this can affect the quality of the problem to be addressed and scoping of the issue and agenda setting, the policy formulation in response may be lacking where development and comparison of feasible alternatives and selection criteria against objectives set out earlier in the policy process are not applied (which in turn affects the policy and issues to be addressed). This in turn affects the implementation and effectiveness of the policy. In addition during the implementation phase further negotiation and bargaining with respect to strategy and measures to be taken to comply with the policy are required between internal members, the commission representative bodies (DG Climate and DG Energy) and the European executive (European Commission and European Parliament) before it is legislated. These support assessment negotiations are required to help support the policy compliance through capital projects and operational research and systems support (Nugent, 2010).

In addition the policy process helps with: experience transfer, interface management, standardization, codes, regulations and knowledge transfer is key to the energy transition. This will become important in the implementation of the policy (where competence and technology readiness, adaptability and security and handling of sensitive system information and vulnerabilities or resilience or robustness is considered or required). While they follow the policy cycle they employ four types of EU frameworks for policy process, the energy union makes use of all four depending on the application (Nugent, 2010):

- Community method – awareness and climate issues, shared competences
- Intensive transgovernmentalism – emissions control, market and sector coupling, trading and contracts. Also standardized system design and controls.
- Open Coordination – research and innovation, open source collaboration
- Centralized Decision Making - After the initial use of community, open and transgovernmentalism the EU resorts to centralized decision making with respect to energy policy and implementation by, by collating plans and proposals a selection of common interest projects are considered and awarded support, this is especially important when we consider the policy planning, implementation and associated CAPEX budgets and approvals are to be determined and considered (e.g. Projects of Common Interest) the European Central Bank or European Investment Fund that will partially finance these[33].

The policy process may seem diverse in its approach but it also needs to take into consideration the various maturity levels of the different member states (based on current energy and system status) [34]; these will be complimented by imminent delivery of member states Energy and Climate action plans which will be reviewed and consolidated by the EU, this affects the decisions with respect to energy mix alternatives and the need to upgrade and modify grid or readiness to interconnect (synchronizing and balancing issues). In addition the policy needs to accommodate domestic choices regarding energy mix and different priorities with respect to Energy (safety, security, competence and current upgrade plans and strategies). Therefore the

[33] CBA EU https://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf
[34] EU Maturity Mapping EU Member States

although the targets are set, the method each member state uses to contribute to collective achievement (portfolio approach) leaves some flexibility and options for timing projects and long term strategy decisions (or deferrals or application of real options in cases where technology readiness/affordability or return on investment or value of benefits, information or flexibility needs to be considered) (Bratvold, 2010).

Energy Policy in the EU

With respect to Energy Union the EU Energy policy is aimed at (Wallace et al., 2010):

- Ensuring the functioning of the energy market
- Ensuring security of energy supply in the Union
- Promoting Energy efficiency and energy saving and development of new and renewable forms of Energy
- Promoting the interconnection of energy networks

To achieve these aims requires decision-making. This is normally based on Rational choice of the alternatives on offer as long as they are aligned with strategic direction of the EU and offer good value (Wallace et al., 2010). Thereafter the appropriate policy, directives and regulations are drafted, proposed and approved based on a vote held by the European Parliament in co-decision with the Council of Ministers.

The introduction of taxes, cap and trade schemes and carbon price (with carbon floor price) are planned. This is specifically geared to enable energy taxes, carbon taxes and penalties that will be enacted and applied in the future. Non-compliance to the Energy Policy including state aid and internal subsidies will result in investigations fines, warnings and withholding of finance or investment – hence the regulatory arm of the EU Energy Union known as ACER has been strengthened (i.e. stick instruments) (Wallace et al., 2010).

As described by (Peterson & Bomberg, 1999)energy policy, legislation and regulation, the European Council first raises priorities and sets the agenda for issues to be addressed. These issues are then delegated to the respective Commission entity responsible to resolve during the appointed period of council tenure currently operating in 2014-2019 (e.g. delegated by the EU president to Council Commissioners of Energy and Commissioner of Energy and Climate Action, further these orders or objectives are delegated to the respective Directorate General and their teams to resolve and collaborate. This organization is responsible to develop policy and legislation for adoption by the Parliament (if successful) this is best described by the diagram below[35]

[35] Master Thesis L D'hont https://lib.ugent.be/fulltxt/RUG01/002/480/358/RUG01-002480358_2018_0001_AC.pdf

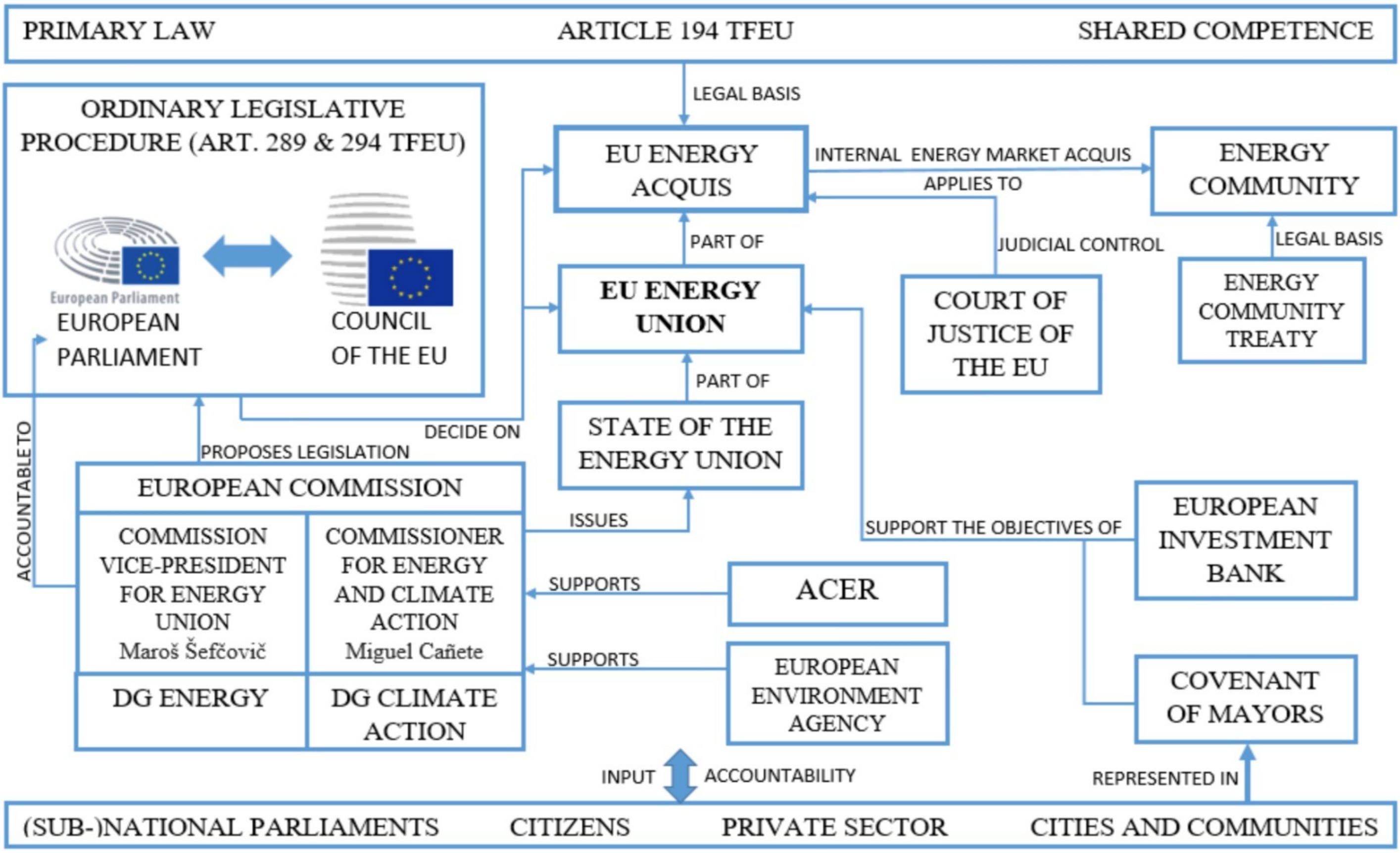


Fig 30. The Energy Union: Interfaces and Organization (MSc RUG L. D'hont 2018) https://lib.ugent.be/fulltxt/RUG01/002/480/358/RUG01-002480358_2018_0001_AC.pdf

In addition as described by (Wallace et al., 2010), while the energy mix and exploitation of natural resources is left to the decision of member states, they will find that they still need to comply to restrictions in emissions and meet specific pre requisites of compliance or evidence of transition, this is very important if they are to be awarded: subsidies, grants or concessions and access to investment funds or support for the development of national energy plans and strategy (i.e. carrot instruments).

Further explained by (Wallace et al., 2010), if the issues are of a significant complex, multi-attribute and diverse nature (e.g. Energy Transition and Environmental impact or mitigation) a member state stakeholder representative team is established (e.g. Energy Union) in addition supported by dedicated specialist groups or competent cells e.g. Energy Network Transmission Operators for Electricity and Gas, ENTSO –E and ENTSO-G[36] and in addition the appointment of various expert organizations or personnel to advise and develop

[36] Regulation market electricity https://data.consilium.europa.eu/doc/document/PE-9-2019-INIT/en/pdf
15 ACER governance https://data.consilium.europa.eu/doc/document/PE-83-2018-INIT/en/pdf

policy proposals (e.g. Energy Transition and Climate Action support teams). To promote governance compliance arm of the various commissions is established (Agency for the Cooperation of Energy Regulators).

Once policy becomes legislation is ratified and it becomes law and then it needs to be legislated by the member states, in parallel plans for infrastructure development have been reviewed and approved the European Investment Bank can support projects that can further economic and social cohesion which contribute to the economic development. Normally with respect to Energy this is reserved for capital spending on innovation and infrastructure developments. The projects must support innovation and contribute to competitiveness, introduce advanced technology and integrate at a European level. More specifically Projects of Common Interest (PCI Projects) should be of interest to several member states. The energy transition and infrastructure plans are well suited to these conditions and are high priority and constitute 100% finance of capital projects or enter a Joint Public Private Partnership where possible. In addition the EU under a separate scheme known as the European Invest Fund - this fund can finance development projects on a smaller scale by attracting up to 40% of the required funds from the EIB and supplement addition to this source of funding, can allocate EU budget by way of the Cohesion Fund in the form of a grant to supply up to 30% of the support required. The remainder is obtained from public and private investment (up to 30%) (Nugent, 2010)

To facilitate research and innovation the H2020[37] fund has been established by the European Commission, specifically focused on Energy transition and innovation in technology required to support these efforts. This constitutes a majority of the funds for Research and Innovation in the European Union. Plans are already underway to allocate a second fund to cover the 2021-2027 implementation phases (where it is not used for capital investment)

What is interesting to note is that it seems that options and alternatives are only analyzed after a selection has been made and for project approval purposes, although the Impact Assessment does include analysis of cost of damage against cost of abatement it does not apply any rigorous assessment of alternatives or various energy system configurations. Thus we may have policies that do not capture the best representation for value or meet objectives, preferences or priorities based on analysis. While we have reviewed Impact Assessments and Model results from the EU, there is no comparison or assessment of alternatives, or project approval routines with respect to Energy, however there is a Regional Development framework that addresses project appraisal that captures this depicted below[38].

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[37] H2020 http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/climate-sustainable-development_en.htm

[38] Funding https://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf

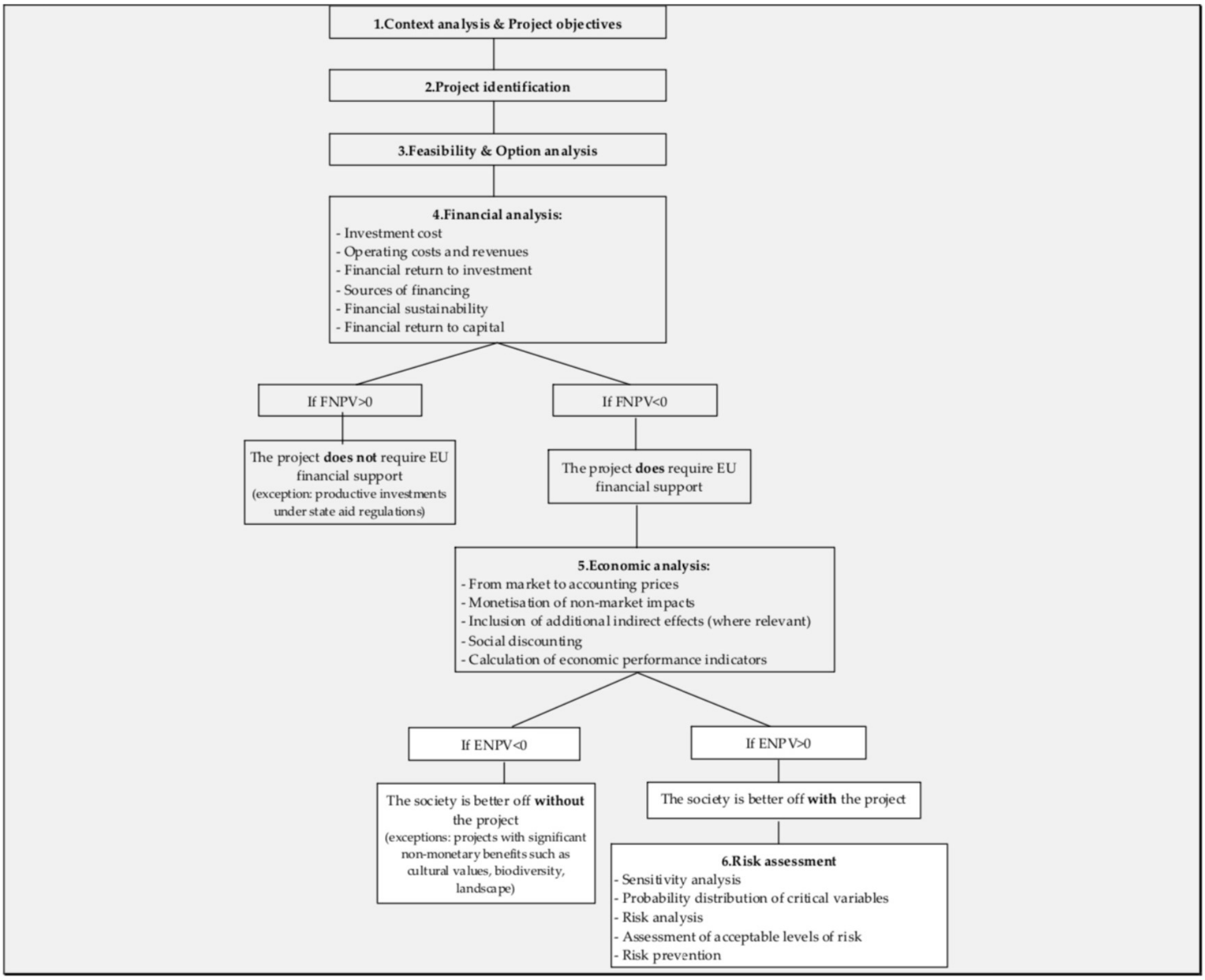

Fig 30. European Regional Policy Project Appraisal
https://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf

EU Project Approval form used for financing and support of infrastructure projects. But this is done after the policy process is complete i.e. in the implementation phase, so begs the question, do we have the right policy? This approach may have ruled out or neglected many of the alternatives, or alternatively combined too many without filtering the options that we should be assessing early in the process.

This process is also tied into the budget allocation or financing phase. €180 billion has been budgeted until 2021 (mainly for R&D and Infrastructure Projects and administration), new budgets will be developed when the new commission is in office, but it is projected that[39] 2% of GDP is required for infrastructure (€480 billion) per annum 2022 – 2035 and increased to 2, 8% (€550 billion) 2035 onwards to achieve net zero carbon in 2050 (Please Note: These figures do not include transport

[39] 4th State of the Energy Union https://ec.europa.eu/commission/sites/beta-political/files/fourth-report-state-of-energy-union-april2019_en_0.pdf

replacement costs)[40]. What is not known is what projects or scopes are included within this budget. And it seems low compared to the estimates of individual member states (e.g. net zero decarb estimated at £1 trillion for the UK)[41].

Energy Union Policy and Decision Making Policy Analysis

Energy Policy was created to provide: affordable, secure and sustainable energy for all citizens initially started via the 3rd Energy Package This package was especially significant regarding the unbundling of monopolies and the infrastructural needs of a new systems and focus on connectivity efforts, towards the end of 2014 and the formation of a new Commission the Energy Union was proposed with the need to review energy regulation and directives pertaining to market design, security and integration of renewables. The targets for 2020 were set in 2008 and a plan to achieve these set in motion[42]. This was summarized in the 4th state of the Energy Union:

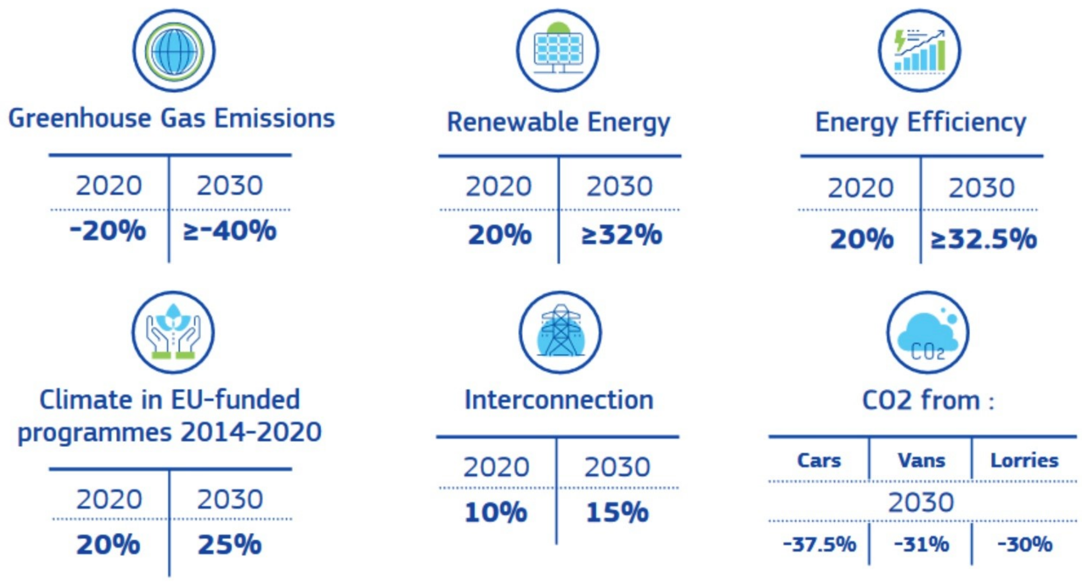

Fig 31. Energy Union Targets (4th state of the Energy Union[39])

But the scope has been further widened and supported by objectives agreed at COP21 in 2015 culminating in the signature of the Paris Agreement that the EU supported and presided over. To that end the original 3rd energy package introduced in 2009 was expanded and enlarged and now the focus is on implementation to accommodate environmental impact, emission targets and climate objectives.

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[40] Energy Infrastructure Forum 23 & 24 May 2019 Copenhagen, Denmark, streamed live and available through link on YouTube https://www.youtube.com/watch?v=-myqMqXncKs

[41] UK Government leaked announcement before committing UK to Net Zero by 2050

[42] EU Energy Union https://ec.europa.eu/commission/sites/beta-political/files/euco-sibiu-energy_union_and_climate_change_policy.pdf

The result, following a public consultation[43], the launch of a new market proposal in 2016, involved a dramatic push for low carbon energy transition. This was quickly followed by the introduction of a "clean energy package for all Europeans"[44] with updated stretch targets for 2030 were established in 2016. It was around this time that a unified approach between the Energy Union and Climate Action was formally formed. Thereafter this was also expanded to include internal market and competitiveness into the policy development[45].

Nearly 2 years later in the release of new directives for electrical and gas systems were published with a huge public consultation campaign to rally support and awareness. In addition the European Commission called for measures and efforts to attain a climate neutral economy and energy system by 2050 and this was branded "A Clean Planet for All"[46].

In the background to these developments Horizon 2020 (2014 – 2020)[47] continues to address the research and innovation requirements campaign to enable solutions to meet infrastructure and technology needs. As a result of these efforts and results the Energy Union was able to put forward proposals and scenarios to deliver an integrated energy market directive in 2018[48]. This culminated in the delivery of the 4th State of the Energy Union[49] and subsequent claim that the Energy Union of the EU has been achieved in 2019. (NB Targets, Main Objectives and removal of subsidies for energy

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[43] Consultation new market design https://ec.europa.eu/energy/en/consultations/public-consultation-new-energy-market-design
& Consultation energy security https://ec.europa.eu/energy/en/consultations/public-consultation-risk-preparedness-area-security-electricity-supply

[44] EU Energy Union https://ec.europa.eu/commission/sites/beta-political/files/euco-sibiu-energy_union_and_climate_change_policy.pdf

[45] EU Clean energy for all Europeans https://publications.europa.eu/portal2012-portlet/html/downloadHandler.jsp?identifier=b4e46873-7528-11e9-9f05-01aa75ed71a1&format=pdf&language=en&productionSystem=cellar&part=

[46] EU A clean planet for all https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf

[47] H2020 http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/climate-sustainable-development_en.htm and EU H2020 https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/system-modelling

[48] Market Reform https://europa.eu/rapid/press-release_MEMO-15-5351_en.pdf
& Market Retail http://europa.eu/rapid/attachment/MEMO-15-5351/en/Retail%20Market.pdf

[49] EU State of the Union Facts http://europa.eu/rapid/press-release_MEMO-19-1875_en.htm
EU 4th State of the Energy Union https://ec.europa.eu/commission/sites/beta-political/files/fourth-report-state-of-energy-union-april2019_en_0.pdf
EU State of the Union Speech 09 April 2019 http://europa.eu/rapid/press-release_SPEECH-19-2073_en.htm
EU Energy and Climate Speech 09 April 2019 http://europa.eu/rapid/press-release_SPEECH-19-2072_en.htm

production with CO_2 exceeding 550 g/KWh – which is approximately half the emissions of a thermal coal plant). Carrots and Sticks Instruments!

However despite the developments and guidance this is still to be ratified by member states and the implementation phase is the next major focus (to join up all the changes and development so the benefits of an integrated market can be realized. That said the Market Directives proposed in May 2019[50] only address the electrical markets rules and regulations. In addition the scope to include transport and heating into the energy union and the framework governing the hybrid grid does not feature (an idea which had not previously been addressed but now raised in infrastructure forums)[51].

That said, there are significant technological and infrastructure gaps to be addressed, optimized solutions and utility issues to be considered despite significant modelling and analysis[52]. In addition a revised gas directive and regulation was required and complementarity ideas pertaining to the energy mix on the grid to be introduced, in addition a combined or coupled gas and electricity grid is now touted as the preferred option to achieve a pathway or approach to become carbon neutral (EU Energy Strategy)[53]. This has received much attention at infrastructure and projects of common interest workshops, these models that are developed to integrate the energy market and optimize the energy mix and storage requirements to achieve the 2050 targets[54]. However the integrated grid design and smart operation requirements to achieve the sector coupled and market coupled objective across the EU still needs to be determined or developed, this will be discussed in more detail in the next section.

Energy System Modelling, Technical and Economic Analysis

The technical and economic analysis supporting decision making for energy systems with constraints and restrictions with respect to capacity, order of dispatch, supply and demand fluctuations, demand management feedback and GHG emissions, and the consideration of global warming scenarios further implies that the systems are

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[50] New market rules https://ec.europa.eu/energy/sites/ener/files/documents/electricity_market_factsheet.pdf and Energy Market Observations https://ec.europa.eu/energy/sites/ener/files/documents/emos_june2018_final.pdf
[51] 56 PCI Infrastructure https://ec.europa.eu/info/news/come-and-discover-benefits-interconnected-energy-grid-2019-mar-01_en
57 PCI Energy Days https://ec.europa.eu/info/news/come-and-discover-benefits-interconnected-energy-grid-2019-mar-01_en
[52] EU Modelling https://ec.europa.eu/energy/en/content/metis-1-dissemination-event-20022019-brussels-ccab
[53] EU Energy Long Term Strategy https://ec.europa.eu/energy/sites/ener/files/documents/final_draft_asset_study_12.05.pdf
[54] EU 2050 vision and strategy https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN

complex and integrated[55]. Therefore models are constructed to capture dependencies and inferences or affects in a dynamic and volatile environment.

The European Commission for research, development and reporting purposes has readily used H2020 Energy System models[56]. They favour PRIMES for most of their modelling and reporting requirements. But for comparative purposes the EU have used other models available on the market such as WEM and NEMS[57]. More interestingly they have financed and supported the development of new models or alternatives within the Energy Union by several research groups in Europe such as REEEM, REN21, SET-Nav, MEDEAS, REFLEX and POTEnCIA[58]. These have allowed the capability to develop several pathways or configurations in order to meet the decarbonization and integration of renewable energy into the energy systems. All of the models can produce results which reflect the various scenarios of the UNIPCC i.e. 1,5 DS, 2 DS and 3 DS, which enable analysis with respect to how effective energy system changes are positioned against the criteria and behaviour over time[59].

Typical modelling parameters (Equinor, 2018):

- Energy Balances, process and CO2 emissions
- Energy System costs and prices
- Installed Equipment Capabilities and rate of use
- Activity Indicators and changes over time
- Dynamic Technology changes and improvements demand side

Model Types

Various mathematical, economical tools and needs or solving preferences are selected to build the models depending on the application, this is an important consideration as they make certain assumptions and are selected depending on what or how we want to

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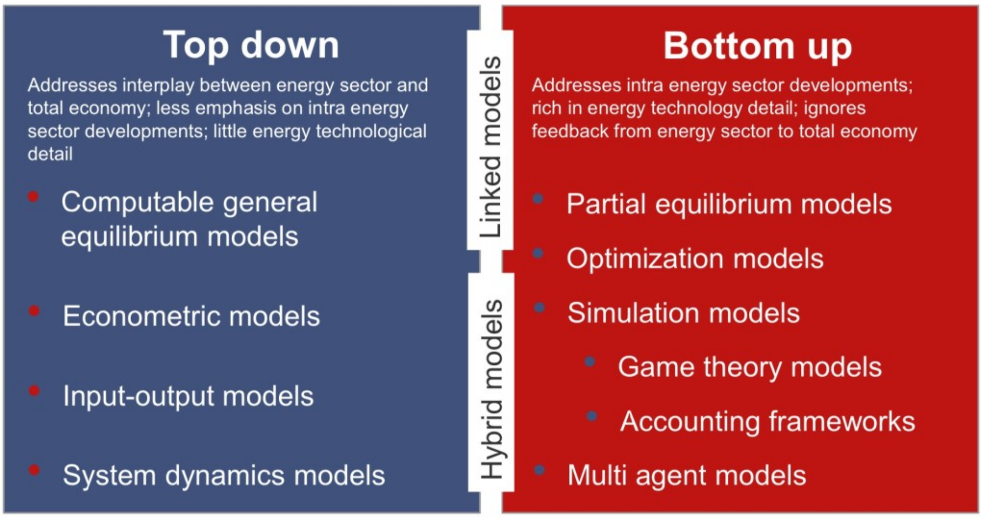
[55] EU Modelling https://ec.europa.eu/energy/en/content/metis-1-dissemination-event-20022019-brussels-ccab
[56] EU Energy Reference 2016
https://ec.europa.eu/energy/sites/ener/files/documents/20160712_Summary_Ref_scenario_MAIN_RESULTS%20%282%29-web.pdf
EU. Modelling POLES
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC113757/kjna29454enn.pdf
SET NAV Website https://data.ene.iiasa.ac.at/set-nav/#/about
[57] Models and impact assessment https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0410&from=EN
[58] 29 EU MÉTIS https://ec.europa.eu/energy/en/data-analysis/energy-modelling/metis/metis-studies
30 EU METIs PRIMES Model Markets
https://ec.europa.eu/energy/sites/ener/files/documents/ntua_publication_mdi.pdf
31 E3M Modelling Markets
https://ec.europa.eu/energy/sites/ener/files/documents/ntua_publication_mdi.pdf
[59] (Equinor, 2018 adopted and developed from (Herbst et al., 2012)).

model to gain insight (simulations, system dynamics, optimization, equilibrium or partial equilibrium). Thus the results need to be analyzed keeping these assumptions and model selection in mind. The models cannot be compared like for like as such, but the various results and outputs could help give perspective or insight to underlying features and mechanisms of the Energy systems and combinations of the various Top Down and Bottom Up models (i.e. Hybrid, Linked or Integrated Assessment Models) could strengthen the confidence and application of the results to support decision or policy making. Or a comparative analysis or analysis of the range of results and assessment of these could help the decision making process where alternatives and result distribution can be quantitatively assessed to improve support to decision makers. A summary of the different model types is below these can be independent, combined by hard or soft linking or integrated (Equinor, 2018 adopted and developed from (Herbst et al., 2012)).



Herbst et.al.: Introduction to Energy Systems Modelling http://www.sjes.ch/papers/2012-II-2.pdf

Fig 32. Energy System Model Types (Equinor, 2018 adopted and developed from (Herbst et al., 2012)).

Energy System Modelling Challenges.

Combining the various models above offers different challenges when we consider the spatial and temporal nature of the different applications. The models could operate on different levels (international, national, regional). This is compounded by how we manage uncertainty that may be more in social context compared to technological, economic or technical disciplines. Therefore there may be integration or linking issues when we try to address social, economic and technical issues simultaneously and we need to configure the interfaces between the modules and synchronize the data sets of the models if we do wish to combine or gain insight into the integrated effects. So there will be compromise in the accuracy and error in the models but if this is understood it can be addressed when we interpret and analyze or assess the results (Pfenning, 2014).

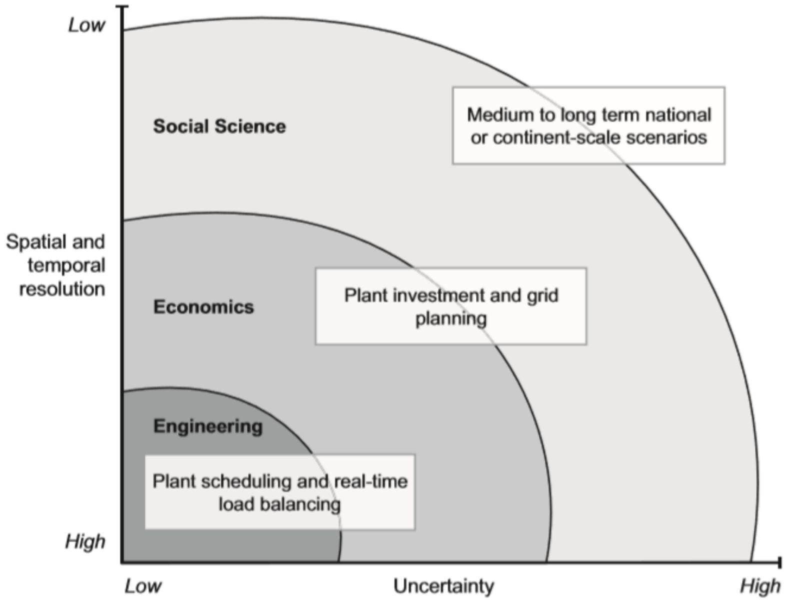


Fig 33. Stylized scales across energy modelling (Pfenning, 2014)

EU Energy System Model Types and models used:

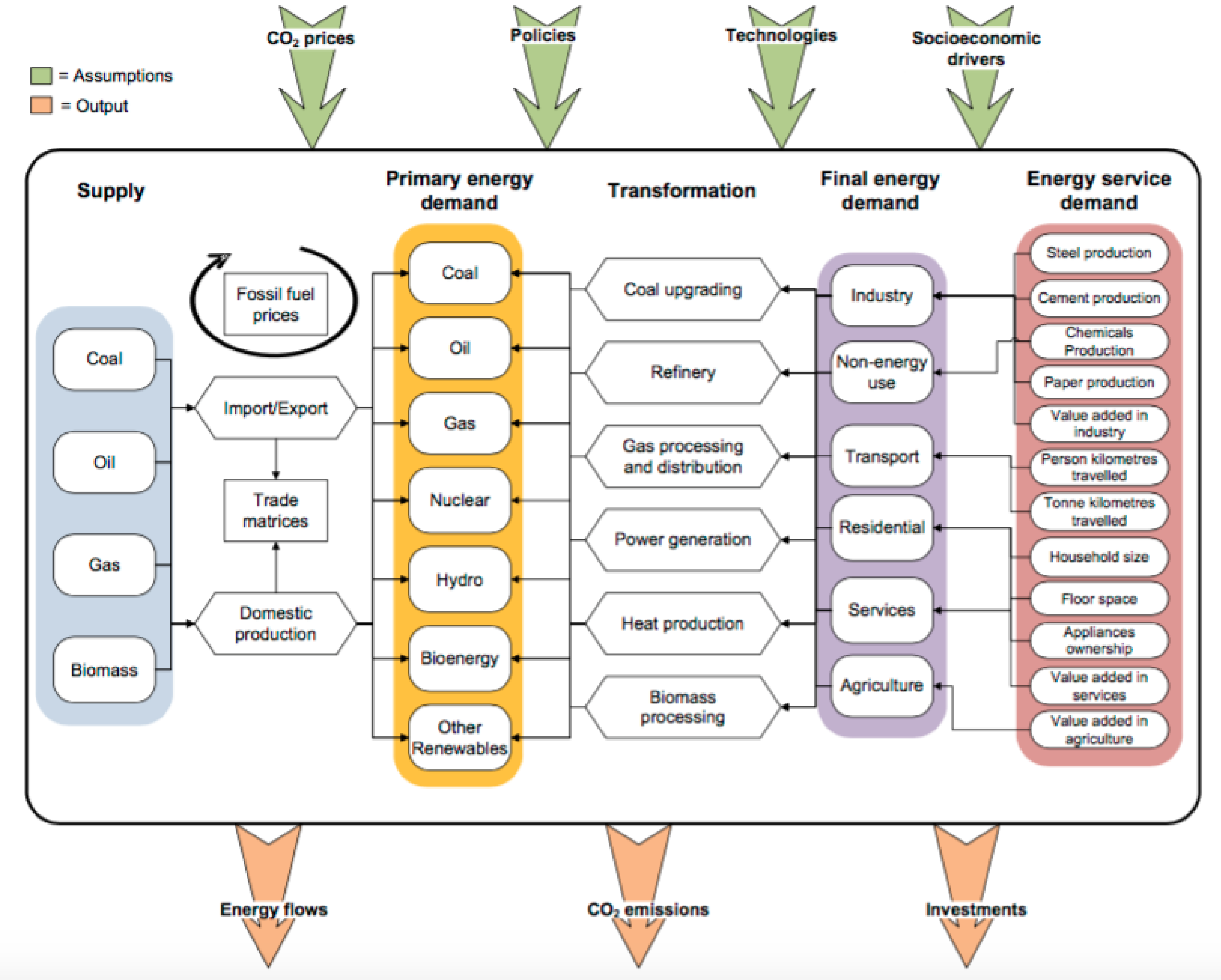
Below are examples of the models commonly employed[60]. While the EU does not use all the models they do quote and use the results from the various models especially international arena (WEM, IEA, PRIMES, POLES and NEMS) and the outputs or insight used in model assumptions and parameters or the techniques are adopted and tailored to EU requirements. That said there is a big drive by the EU to develop the competency in model building to address all of the insights required to support the Energy Transition in order to compliment and support the Energy Union policy and this will be very necessary to support the planning, implementation and market design including establishing instruments, so that effective control and monitoring can be achieved.

The EU has started a campaign through Horizon 2020[61] energy research & innovation programme to raise competencies of modelling in the European Union. This allows member states to participate in modelling development and by modelling various

[60] EU Modelling https://ec.europa.eu/energy/en/content/metis-1-dissemination-event-20022019-brussels-ccab,
EU MÉTIS https://ec.europa.eu/energy/en/data-analysis/energy-modelling/metis/metis-studies
EU METIs PRIMES Model Markets
https://ec.europa.eu/energy/sites/ener/files/documents/ntua_publication_mdi.pdf
EU Energy Reference 2016
https://ec.europa.eu/energy/sites/ener/files/documents/20160712_Summary_Ref_scenario_MAIN_RESULTS%20%282%29-web.pdf
EU. Modelling POLES
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC113757/kjna29454enn.pdf
[61] Energy Modelling for Europe Implementing Clean Energy for All
http://www.energymodellingplatform.eu/home-emp-e-2019.html

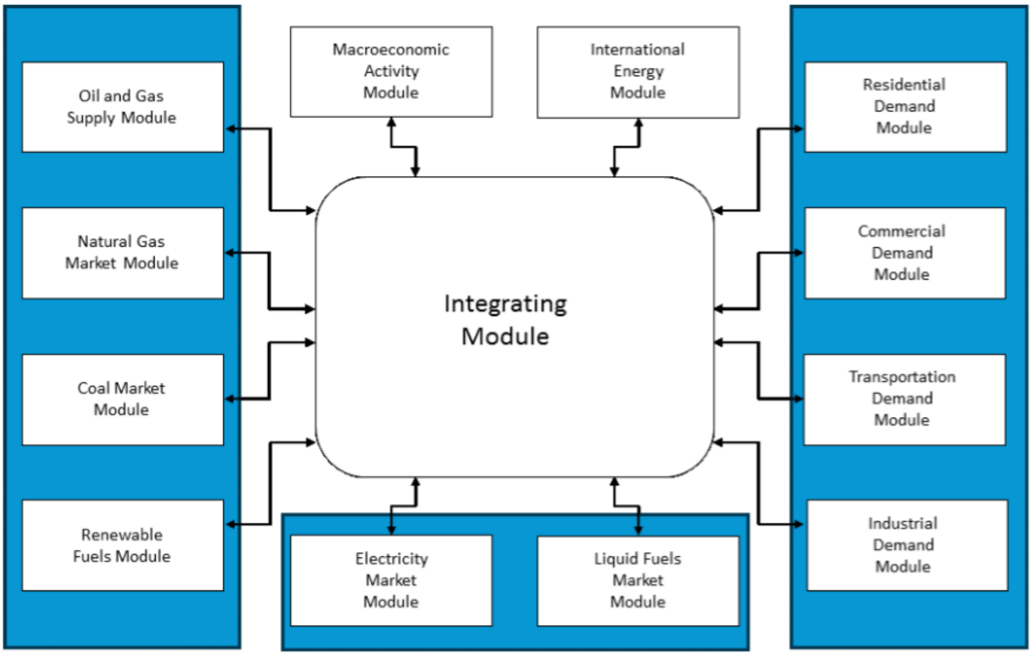
socio, economic and environmental aspects with respect to the energy system they can develop pathways for Energy Transition and compare these to the temperature scenarios to see which configurations are viable and how the model or system responds to changes. Below are examples of the models that the EU uses or is adapting and additional sites for EU models are included in the footnotes but a summary of the 8 Pathways that the EU uses will follow at the end of this section.

WEM IEA Model[62]:

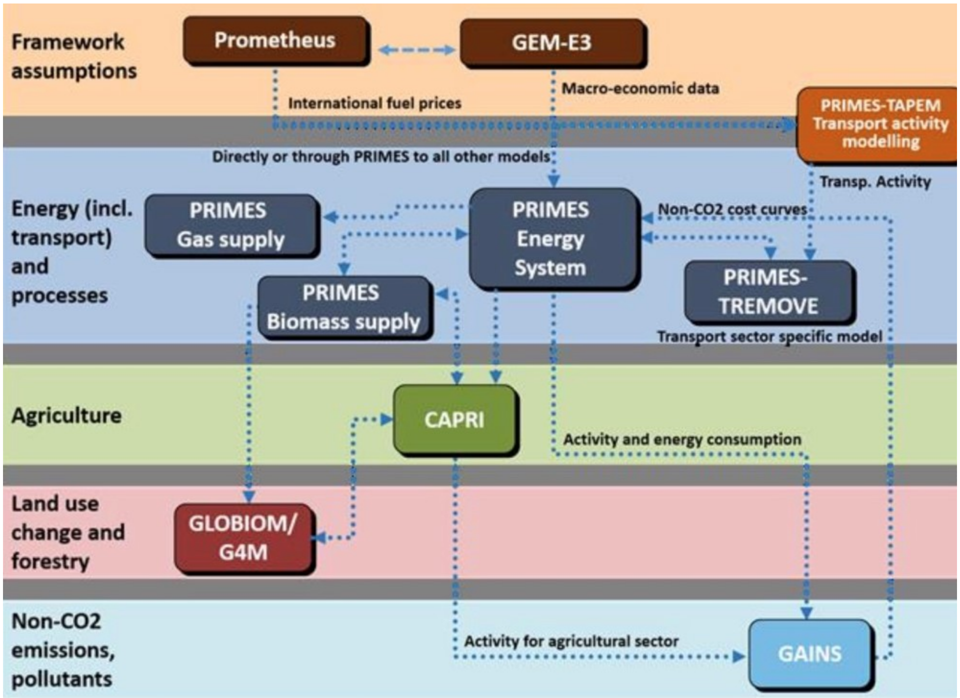


[62] https://www.iea.org/media/weowebsite/energymodel/WEM2018.pdf

NEMS DoE EIA (USA)[63]:



PRIMES E3M EU[64]



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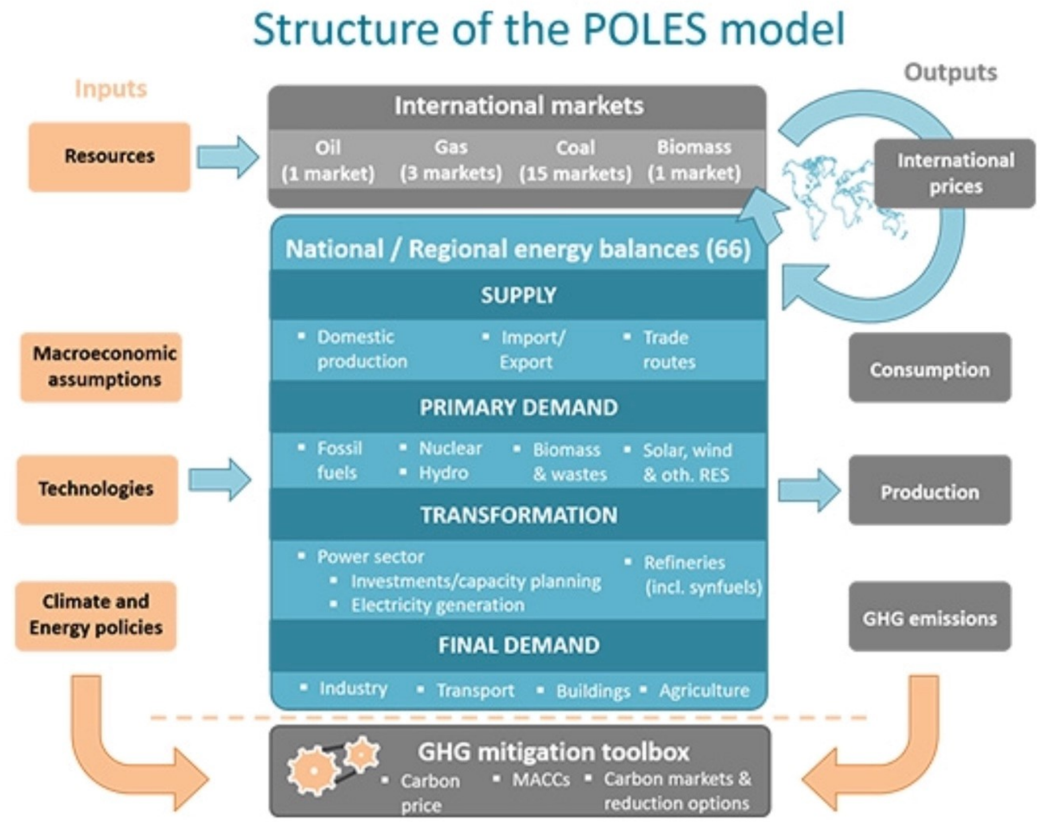
63 https://www.eia.gov/outlooks/aeo/nems/overview/pdf/0581(2018).pdf

64 EU METIs PRIMES Model Markets
https://ec.europa.eu/clima/policies/strategies/analysis/models_en#PRIMES
https://ec.europa.eu/energy/sites/ener/files/documents/ntua_publication_mdi.pdf
http://www.e3mlab.eu/e3mlab/PRIMES%20Manual/The%20PRIMES%20MODEL%202018.pdf

POLES[65] Enerdata France



H2020 Modelling efforts started in 2014 were necessary to support the Energy Union Policy development; many projects have been established and supported. The EU uses these models to establish the scenarios and pathways that the Energy Transition and associated grid changes and market reforms will take. The models below represent a significant part of the R&D and Innovation projects sponsored by the EC: Clean planet for all and Clean Energy for all Europeans) [66]The original efforts from earlier attempts at energy system modelling proposed in 2008 for 2020 and 2030 included a reformed EU ETS, GHG reduction targets, carbon sinks, energy efficiency and renewable energy capacity and integration requirements. The scenarios were also developed to reduce CO2 in the transport sector. But it was discovered that the targets set out earlier were not sufficient to meet the collective Nationally Determined Contributions (NDC) set by the EU (i.e. meet the COP 21 Paris Agreement requirements collectively).

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[65] EU. Modelling POLES https://www.enerdata.net/solutions/poles-model.html http://publications.jrc.ec.europa.eu/repository/bitstream/JRC113757/kjna29454enn.pdf

[66] EU A clean planet for all https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf

EU A clean energy for all Europeans https://publications.europa.eu/portal2012-portlet/html/downloadHandler.jsp?identifier=b4e46873-7528-11e9-9f05-01aa75ed71a1&format=pdf&language=en&productSystem=cellar&part=

Outputs from Energy System Models

The scenarios developed from the energy system models used by the EU in policy development (derived from these or similar/earlier versions of the models) [67]were adapted and developed to produce revised targets for 2030 and beyond and also to meet Energy Union and Climate action requirements.

Scenarios were built based on “no regret” policy (i.e. avoid current trend and do nothing and probably positioned between new policy and SDG policy depending on amount of abatement or impact reduction). These models required increased renewable energy sources and stronger focus on energy efficiency and energy reduction.

Five of the models/scenarios allow comparison of various features and impacts of different technologies in the energy system to arrive at net zero GHG. These gave rise to the hybrid energy grids: electrification combined with hydrogen and e-fuels (P2X), energy efficiency, circular economy and emission reduction[68].

For the models focusing on electrification supply side to absorb heat and transport energy loads into the model consumption increases, but waste decreases due to the advent of increased storage capability and requirements (enabled through the introduction of hybrid grids). Storage helps cope with variable demand. That said electricity generation increases by 150% by 2050 (to give sufficient capability to absorb heat and transport load and simultaneously producing sufficient hydrogen to meet requirements). This puts a tremendous pressure on renewable capacity or low carbon technology to reduce CO2.

Alternative models which are associated with a larger portion of H2 to meet energy needs in the transport and heating sector, produce less electricity enabled by higher efficiency at the consumer/demand side or circular economy only require 35% increase in electrical energy by 2050, limited storage and best price for consumers.

Both approaches need infrastructure investment to enable sector coupling, market coupling (grid conversions and interconnectors). But there are distinct differences between those models that focus on supply side (producers) and those that focus on demand side (consumers).

All the scenarios, on an individual basis, achieve between 80% - 85% GHG reductions in 2050 compared to 1990 levels. Combining scenarios delivers maximum 90% GHG reduction (the remainder to be achieved is required in the Agriculture sector). To that end sustainable Biomass, improving carbon sinks and carbon capture and storage are introduced into the mix while food in form of crops and livestock need to be addressed (but this is outside of the Energy Policy).

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[67] Models and impact assessment https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0410&from=EN
[68] Models and impact assessment https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0410&from=EN

The introduction of biomass, CCS and sinks are then modeled with targets to achieve CO2 neutrality by 2050 and then continue to provide net negative emissions by using zero carbon energy carriers and vastly improved efficiencies. But it requires negative emission technology in the form of bioenergy combined with CCS.

One final scenario follows similar structure to the model above but uses circular economy and prosumer low carbon choices in combination with carbon sinks (that way there is no need for negative emission technology).

EU Energy Union Policy & Market Design Reforms

After taking in the considerations and results above we can now review the Energy Union Policy and Market reforms in more detail. The first thing that you notice about the Energy Union is a combined Energy, Environment and Climate Action approach. This is evident in the strategic intent of the policy and market reform objectives built into the Energy Union Policy based on secure, clean and affordable foundations – the EU strategy included[69]:

- Ensuring the functioning of the energy market
- Ensuring security of energy supply in the Union
- Promoting Energy efficiency and energy saving and development of new and renewable forms of Energy
- Promoting the interconnection of energy networks

As discussed in the introduction the Energy Union vision was to be achieved through policy implementation by realizing the following objectives[70].

- Securing energy supplies
- Expanding the internal energy market
- Increasing energy efficiency
- Reducing emissions and decarbonizing the economy
- Supporting research and innovation

Criteria for Energy Policy in the Energy /Power sector includes reference to: Sustainability (Economic, Environment & Societal Benefits), Adaptability (Changes and Solutions through Technological Solutions, integrating Renewables and linking supply to managed demand through Digitalization and SMART Grids), Affordability (Breakdown of Monopolies, Open Competiveness and Markets, driving Research and Innovation and placing the Prosumer at the center of the model), Secure Supply and Economic Benefits (Geopolitical and Societal issues concerning Transition, Employment, Research and Innovation Willingness to Pay and Control of Volatile Prices).

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[69] EU 2050 vision and strategy https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN
[70] EU Energy Union https://ec.europa.eu/commission/sites/beta-political/files/euco-sibiu-energy_union_and_climate_change_policy.pdf

The Energy Union – A clean planet for all

EC Communication, Dec 2018[71] stated that it will achieve these objectives by using the scenarios developed from the energy system models and scenarios outlined above. But to achieve net zero GHG further options must be considered[72]:

- Maximize benefits from Energy Efficiency
- Maximize deployment of renewables and use of electricity to decarbonize EU energy supply
- Clean safe and connected transport
- Competitive EU industry and circular economy
- Deliver SMART network infrastructure and interconnections
- Realize the benefits from bio-economy and create carbon sinks
- Deploy CCS

Furthermore based on the 8 scenarios and pathways the EC showcased a number of options to achieve climate neutral GHG. These were deemed feasible from a PESTLE (political, economic, social, technological, legislative and environmental) point of view. The changes require societal and economic transformations and that is why many models include society and economic modules or exogenous factors. The EU employed multi-lateral approach with overriding priorities consistent with the SDGs namely[73]:

- Accelerating the energy transition, increasing and integrating renewables, increase energy efficiency, improve security of supply, reduce cyber threats, ensure competiveness of energy prices and support the modernization of the economy
- Recognize and strengthen the role of the citizens and consumers in the energy transition, support individuals' climate change choices, reduce environmental impact, enjoy societal benefits and improved quality of life.
- Deliver carbon free, connected and automated transport and necessary links, structure charges and taxes to reflect emissions, reduce emissions through technology and alternative fuels, invest in mobility infrastructure and improve urban planning.
- Improve EU industrial competiveness through R&D and application of digitalized and circular economy that limits material dependencies. Introduce new low carbon technology solutions.
- Promote sustainable bio-economy, diversified farming and aquaculture and forestry by adapting to climate change and restoring ecosystems whilst also ensuring sustainable use and management of these resources.
- Strengthen and climate proof infrastructure, adapt smart and cyber secure systems to meet future electricity, gas heating and other grids. Allow for sector coupling and integration at local level and industrial energy clusters.

[71] EU Climate Neutral 2050 http://europa.eu/rapid/press-release_IP-18-6543_en.htm
[72] EU A clean planet for all https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf
[73] EU A clean planet for all https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf

- Accelerate research, innovation and entrepreneurship into a zero carbon portfolio to reinforce EU global leadership.
- Provide finance and investment and attract long-term venture capital, invest in green infrastructure and minimize stranded assets, whilst using internal market potential.
- Human capital investment and training to meet future job requirements (Digitalization, Sustainability and Green Technology).
- Align growth and support policies: competition, labour market, cohesion, taxation and structural policies aligned with climate action and energy policy.
- Implement socially fair transition policy (no worker, region or community or citizen left behind).
- International efforts to encourage other actors and economies to join in and embrace above to support their own transition and transformation. Open and shared knowledge and experience to develop long-term strategies to meet Paris Agreement objectives.
- Anticipate and prepare for geopolitical shifts, migratory issues, strengthen bilateral and multilateral investment partnerships.

Also following the above proposals the EU developed a COP 24 proposal for EU Long term zero emissions by mid-century strategy and a after a debate on 09 May 2019 an announcement regarding the "deep economic transformations and profound societal changes" to achieve the Energy Union will follow![74]

In tandem the DG Energy developed the Energy perspective based on the above and launched in May 2019. A clean energy for all Europeans launch coincided with the announcement that the Energy Union is now a reality. But the planning and implementation phase has not been achieved as yet. That said it does supply a framework that has been so desperately sought.

The Energy Union provides a framework

The Energy Union framework was developed to ensure a consistent approach in all policy areas.

- Accelerating the clean energy transition in the EU: increasing energy efficiency to a minimum 32,5% in 2030, new renewable target of 32% by 2030, minimum 40% GHG emission reduction by 2030, drafting a national energy and climate action plan (2021-2030) and a long term strategy for 2050, putting consumers at the heart of the transition and presenting strategy on how to decarbonize the economy.
- Modernizing the economy: growth in jobs and competitiveness, allocating €180 billion funding up until 2021 (then new budgets to be determined), becoming a technology and industry leader by supporting R&D, 1% increase in growth over 10 years, 900 000 new jobs in the clean energy sector investing

[74] EU Climate Neutral 2050 http://europa.eu/rapid/press-release_IP-18-6543_en.htm and EU A clean planet for all https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf

in digitalization, CCS, storage, hydrogen and nuclear fusion?? , Just and ethical transition for all.

- Increasing energy security: diversification, reduce dependency on imports (especially FF), increase renewable capacity and integration, increase energy efficiency, more flexible and efficient electricity market to support the energy transition (real time trading, better forecasts from renewable generation, transmission from where sourced to where needed depending on local capacity for clean energy, reduced environmental impact, reduce capacity markets (standby) and thereby reduce cost to consumers, strengthen interconnections and market coupling (through PCI Projects), reconciling security of supply and decarbonization, risk preparedness and event prevention, union through solidarity.
- Bringing people and countries closer: standardized rules, regulations and directives for all in the Energy Union, governance and compliance agencies, Energy and Climate Action 10 year plans, interconnections and infrastructure to improve market design and strengthen collaboration between energy regulators and transmission system operators (ENTSOs) by ACER (Agency for cooperation of the Energy Regulators)
- Putting Consumers at the heart of the energy transition: SMART Technology and information on costs, proactive role with choice and flexibility, improve appliance and equipment efficiency and rating, consumers to drive renewable revolution locally and regionally or by preference, reaching energy poor or connection to grid for all.
- Europe as energy and climate leader in the world: fulfill and exceed Paris agreement requirements, fulfill commitments to the international energy cooperation, EU – Africa Alliance, strengthen European Sovereignty and currency.
- Moving towards a clean planet for all: going beyond 2030 towards 2050 by pursuing efforts to keep global warming well below 2DS and aim for 1,5DS.creating a dynamic economy with reduced emissions, improving air quality,

But it does not provide the time line and grid development in the interim period, but it does have a supporting document and framework that addresses the market reforms

To achieve a market reforms and enable a fully integrated and expanding the market the following actions required are[75]:

1. New energy market design
2. Helping energy cross borders
3. Empowering energy consumers

[75] EU Energy Union https://ec.europa.eu/commission/sites/beta-political/files/euco-sibiu-energy_union_and_climate_change_policy.pdf

Public Consultations and stakeholder input was undertaken in 2015[76], these were set against draft policy and regulations regarding energy market design were undertaken. These were considered in Market design and Grid Security or Risk Assessment issues proposals were addressed. Summary of the preliminary results are summarized below:

Market Design and Helping energy cross borders

Market Adaptations concerns or proposals[77]:

- Scarcity pricing (supply and demand based on dispatch and real time bids)
- Move to Regional and Zonal Pricing (over Local and Nodal models)
- Congestion Management (interconnections)
- Cross Border Capacity Markets and Strategic Reserves
- Renewable integration through Balancing Markets and removing priority dispatch mechanisms
- Phase out subsidies for Fossil Fuels and for plans generating more than 550 g CO2/KWh (which is approximately half the emissions from a coal plant)
- Introduction of regional support schemes (Investment support) Subsidies and State Aid
- Instruments for Energy Transition: Emissions Trading Scheme, Carbon Price with Floor (with future increases planned), Energy Taxes and Carbon Taxes.

Generation Adequacy:

- Energy Only Markets (paid for the energy you actually produce and supply) combined with a Strategic Reserve (to ensure resilience and robustness)
- Generation Adequacy assessment (in each state and for interconnected grid)
- Capacity Markets to support cross border trading and transmission

Retail Issues:

- Introduce dynamic pricing (flexible prices for supply to meet variable demand)
- Market Rules and Framework to remove current regulatory barriers for demand response management through SMART interconnected grids
- DSO neutral market and data protection rules (Digital market and SMART Grids)
- Distribution Tariff national regulations to be standardized

Regulatory Framework and Governance:

- Strengthen ACERs organization, jurisdiction and powers for interconnected SMART grid
- ENTSO E and ENTSO G collaboration on Hybrid Grid for future Sector and Market Coupling

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[76] Market consultation proposal https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v11.pdf and https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v11.pdf

[77] Public consultation new market design https://ec.europa.eu/energy/en/consultations/public-consultation-new-energy-market-design

- Governance from ACER and CEER
- Regulatory oversight of Power Exchanges and market coupling rules to be strengthened (especially to facilitate trans-border capacity markets)

Regionalization:

- Zonal approach supported by cooperation between TSOs including decision-making, accountability and security. However this may be in conflict with Member state security and current cross border cooperation.

A separate Security and Risk Preparedness Assessment public survey was completed to compliment the Market Reform Survey. The summaries of the results are as follows[78]:

Obligation for Risk and Security Plans:

- This was seen as obligatory and a national responsibility
- However there is a need for a standardized framework and template
- Energy Security and maintaining the grid in times of crisis or sequence of events is essential and despite national obligations coordination between the networked system is essential

A framework for international security and risk is required for transparency and coordination of recovery. The content and timing of risk and security review needs to be confirmed and regulated [79] a summary of the main issues raised can be found below.

Content of plans:

- Definitions of risk to be established and risks to be identified
- In light of SMART grid Cybersecurity to be a priority
- Standard Risk assessment to be established (but standards to be agreed first)
- Preventative measures and security or energy grid and restoration should an event occur to be developed for both supply and demand side. Import capacity and geopolitical issues to be addressed (vulnerabilities and exposure documented and managed). Network codes to be developed.
- Roles and responsibilities to be determined.
- Emergency situations and specific actions must be done in cooperation between member states.

Risk preparedness plans:

- National governments should draw up and be responsible but TSOs instrumental to process (especially where interconnectivity and open markets exist and envisaged). DSO involvement also required at retail and consumer interface.

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[78] Public consultation energy security https://ec.europa.eu/energy/en/consultations/public-consultation-risk-preparedness-area-security-electricity-supply

[79] Public consultation energy security https://ec.europa.eu/energy/en/consultations/public-consultation-risk-preparedness-area-security-electricity-supply

- One competent authority to coordinate these activities suggested, but plans and responsibility to be maintained at national level.
- Risk preparedness developed at national level but cross border cooperation required and move to develop regional cohesion necessary.
- Risk preparedness to be peer reviewed or ECG to verify. ACER and ENTSO to be involved regarding technical aspects but not keen for commission to take decision and responsibility roll.

Empowering the consumers

Several issues to be addressed[80], which the European Parliament put forward in a review of the developments of the strategic framework and raised some concerns or suggestions regarding the final directives and regulations pertaining to the customer at the center of the market design (adapted from original communication from the EU Parliament communication): summarized from 5 documents Eur Lex EU Parliament documents[81]

- Ensure that the citizens as the core of the Energy Union can take ownership of the transition and benefit from technologies to reduce bills, to participate actively and protect vulnerable consumers or those energy poor sectors.
- To improve the transparency regarding costs, consumption and range of products
- The changes in network charges, taxes and levies on households
- Improve competition in the energy markets, reward participation and ease ability to switch suppliers
- To further develop markets for residential energy services and demand response
- Remove obstacles for self-generation and self-consumption
- Give equal access to information and reduce barriers to entry for new competitors and improve access to adoption of and opportunity to take advantage of technological developments (including smart metering, smart appliances, distributed energy sources and energy efficiency improvements).
- The new market design to make use of: new technologies, innovative energy service companies, enable consumers to manage their consumption through energy efficient solutions to reduce bills and overall energy consumption.

After the Public Consultation and working with the comments from the European Parliament a full impact assessment (IA) of policy, objectives and implementation was undertaken was undertaken by the EU Commission which is delegated to the expert DG Energy Team and ENTSO E and ENTSO G with collaboration of TNE-E

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[80] Development of Markets in Europe http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf and EU Energy Consumers Focus https://ec.europa.eu/energy/en/topics/markets-and-consumers/consumer-rights-and-protection

[81] Models and impact assessment https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0410&from=EN

(Transmissions Network Energy – Europe)[82]. This impact assessment was reviewed the concerns and market design proposals and developed a shortlist of priorities to be addressed. The use if impact assessment is used by the DG teams to justify particular policy choice or legislation proposal, and are an integral part of the policy planning process, these plans contain input from expert groups and publically made available which allows some form of transparency, but it is difficult to see how the IA are integrated into the policy, also the IAs are mainly qualitative and do not disclose any quantitative analysis (this is discussed in extensive detail in "The role of experts in International and European decision making", (Monmbrus, Karts, & Ellen Hnd Helena, 2014)). Due to lack of transparency it is difficult to see why some alternatives are disregarded or options neglected while other options are included or pursued. In addition the list of experts involved is a relatively small group from only a few member states, which may contribute to an unintentional bias (despite the Impact Assessment Board reviews which are established to ensure neutrality and good value). After the EC reviewed the IA to approve the policy development to proceed, it was found that are still significant shortcomings that the EC raised to be addressed. These include[83]:

- Internal Markets not adaptable to energy exchanges even when interconnectors in place.
- Current Market design still not fit to integrate variable, decentralized and renewable sources or associated technologies.
- Uncertainty regarding future generation investments and uncoordinated capacity mechanisms.
- Member states not sufficiently aware of cross border organization and developments, especially with respect to risk and crisis preparedness and restoration.
- Retail markets slow to develop and low level of service and poor market performance in the EU.

Here the research links to policy development and decision making seem to be disconnected. No response or detail in the policy can be found to resolve the above - but they do need to be resolved and therefore included in this report. Also at no stage is it evident how the Impact Assessments are distributed and considered by those who will eventually vote on this matter (Monmbrus et al., 2014). This is a problem as the impact assessment forms the basis for energy mix and scenario and pathway selection proposals and recommendations that need to be considered in the policy and grid and market designs.

Further to the market reforms and security issues raised above, the EC decided to embark on a Union wide network development plan, which was to be developed and built upon the national plans and regional investment plans. These plans will be aligned to the EU EC and EP network planning practices and is subject to a cost benefit analysis but again this is not subject to a selection or comparative process to

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[82] Impact Assessment https://eur-lex.europa.eu/resource.html?uri=cellar:e4c834ae-b7b8-11e6-9e3c-01aa75ed71a1.0001.02/DOC_5&format=PDF#page210

[83] EU Decision Making and policy in the energy and climate change https://ec.europa.eu/commission/sites/beta-political/files/communication-efficient-democratic-decision-making-eu-energy-climate-april2019_en.pdf

determine which options are best. The main focus of the EU is the focus on cross border connections and the need integrate renewables into the plans to meet long-term strategic commitments. Any gaps in cross border capacities still need to be identified. In addition any barriers to increase in cross border capacities need to be documented.

For consumers (at the core of the energy union: market and grid model), an active awareness campaign at EU level has started, training and development programs have started. SMART meters are currently under implementation phase, several pilot programmes and national campaigns[84].

To meet energy system and climate action information requests to address the issues identified above all member states were requested to build upon the energy systems status plans (which were delivered in 2016) and in alignment with the proposed changes to the Energy Union Policy and Market reform proposals in 2018[85], and now all member states have been instructed to provide a new detailed 10 year investment plans to summarize strategic development of their climate and energy plans reflecting specifically on projects of common interest which may require funding (due Dec 2018 but delayed) covering the period 2021 – 2030 (and some long-term considerations beyond up to 2050). These will then be collated and analyzed as a complete Energy Union in 2019 in conjunction with the formal publishing of the Energy Union Policy and Market Reform Regulations and Directives) to be effective from 01 Jan 2020.

Energy Markets

There are currently two market options in play: energy only market and capacity markets. While many member states are in a transition from energy only to capacity markets or rely on using capacity mechanisms it is important to understand both so we can appreciate how the market design may evolve[86].

Liberalization of the internal market and efforts to include smaller producers and more importantly to integrate renewable energy sources led to establishment of energy only markets. But the majority of countries are still designed to run using capacity markets and this is used for majority of exchange activity, including interconnector activity i.e. market coupling (but the model is mainly based on electricity energy exchanges and the expansion of this market through future Sector coupling is not discussed, this would be reflected in the hybrid model i.e. electricity,

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[84] EU State of the Union Facts http://europa.eu/rapid/press-release_MEMO-19-1875_en.htm and EU State of the Union Factsheet EU Energy Consumers Focus https://ec.europa.eu/energy/en/topics/markets-and-consumers/consumer-rights-and-protection https://ec.europa.eu/commission/sites/beta-political/files/factsheet-energy-union-priority_april2019.pdf

[85] New market rules https://ec.europa.eu/energy/sites/ener/files/documents/electricity_market_factsheet.pdf

[86] Market Reform https://europa.eu/rapid/press-release_MEMO-15-5351_en.pdf Market Retail http://europa.eu/rapid/attachment/MEMO-15-5351/en/Retail%20Market.pdf

natural gas and future gas (hydrogen and methane) as introduced earlier in this thesis[87].

Further to the market design introduction at the beginning of the thesis, we need to appreciate the short term and long term trading aspects of the energy market, how the energy market will evolve to operate and trade on a near real time basis in the future, This will accommodate long term energy security requirements that will form the basis for infrastructure development whilst simultaneously addressing the short term intraday and clearing requirements to balance the grid.

In addition we need to appreciate the differences on how member states will trade in the future, i.e. when markets evolve from a national and independent model with fixed production, energy exchange and strategic reserves which is predominately centered on an interconnected electrical grid (with import and export features for fuel supply and power exchange), to an integrated and interdependent model with drivers from market coupling and sector coupling (where bilateral and multilateral trading is further enhanced by the proposed Hybrid Grid).

That is the market design should be looking beyond electricity markets to an energy market that is integrated and expanded across gas and electrical grids, designed to meet total energy demand and introduce a production, conversion, transmission and storage mechanisms to meet low carbon requirements whilst avoiding congestion. This could be achieved through improved integrated energy transmission networks which allows for the introduction of new and future forms of energy and hybrid grid systems (e.g. production and distribution of hydrogen gas: grey (from Natural Gas), blue (from Natural Gas with CCUS) and green (using electrolysis and renewable energy sources), power to gas processes (P2X) to avoid waste and inclusion of other electrical storage opportunities so curtailment of renewables can be avoided and ramp up times are reduced i.e. batteries and compressed air or use of non-fossil fuels such as biomass and synthetic fuels.

Although these energy alternatives are discussed as part of the future energy system, the grid and system to realize this is not covered in detail in the policy and specifically with respect to grid design and as a consequence the market design that needs to evolve to accommodate the alternative options are not considered or highlighted but this will be addressed in more detail below.

Market Designs

The energy market is evolving to support Energy Transition. As the Power Grid and Market Designs unfold various options and configurations are evolving to support the objectives and requirements of the transition. What started as energy trading coordinated a centralized, inflexible predominately fixed base model to an energy model flexible production to meet peak demand. To ensure reliability and resilience a strategic reserve or capacity was integrated into the market models. To address

[87] Markets and Consumers https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/electricity-market-design

security concerns some energy only markets opted for strategic reserves while other counties have resorted to capacity markets and mechanisms (Harris, 2006).

Now there are plans to move towards an energy only model in the future[88], but in the interim and to meet investment and facilitate interconnection and ensure capacity and spare capacity is enabled, and to develop an interconnected market hence the market design is currently a blend of an energy only and capacity market currently exists (even though this is at odds with the EU internal market philosophy). Thus this combination needs to be managed and controlled and continuous evolvement will be necessary until the Energy Union is fully implemented.

An energy only market is a product of the liberalized and unbundled markets and is the opposite of a capacity market. In an EOM we pay for the energy produced at Power exchanges or trading facilities, whereas capacity markets are remunerated for readiness and capacity for power production[89].

Energy Only Markets

Energy Only Markets (EOM) – where energy is procured/compensated on demand seem a much more efficient way to produce and trade energy, but these markets still need to be more flexible when generation and capacity adequacy are considered, especially in when interruptions to supply or significant disruptions occur, thus strategic capacity reserves or control of these reserves are required to support this market which are traded as long term futures whereby agreement for production of power at a certain time in the future are agreed. EOM supply is much better matched to demand and therefore focuses on demand side management and shorter trading cycles (which can approach real time in the future)[90]. A main feature of this market is that a certain amount of power must be delivered by a certain deadline, this may have implications for certain intermittent renewable energy sources (such as solar and wind). There are also concerns that the current grid design and operations can cope with this in real time, but free markets, as introduced in Germany seem to overcome this issue. That said long term capacity reserves are still required to meet reliability and resilience requirements. But from an investment point of view, these additional reserves or capacities can suffer from a "Where's my Money?" dilemma as facilities, despite being ready and bidding for supply to meet demand may not be required to produce and therefore not remunerated[91]. This may affect future investment decisions or guaranteed retainers or payment for standby modes and readiness levels may need to be considered and careful planning and control to reduce over-capacity and to adjust for imperfect markets (i.e. production withheld until prices increase due to scarcity).

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[88] Markets and Consumers https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/electricity-market-design
[89&90] Energy Markets Kraftwerk https://www.next-kraftwerke.be/en/knowledge-hub/energy-only-market/

[91] Understanding electricity Markets Europe http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf

In addition they may only be required to produce for a few hours, fortunately at peak prices, but even these prices will not be sufficient to cover the costs to run the plant let alone recover the investment or guarantee returns. However to overcome this problem, assets are now smaller and more flexible and as a result of decentralization and interconnectivity can be called upon to produce more frequently, but this market is still in its infancy and resilience and robustness challenges have not been fully addressed. This has consequences for the grid design, whereby transmission capacity may change and we could experience congestion through interconnectors.

Larger, traditionally base load, generation assets, using Fossil Fuels may lose out in reforms to this flexible market design where more renewable energy sources are integrated and storage realized. This is further compounded by loss of subsidy or state-aid cuts, new restrictions on emissions and loss of financial support for development and upgrade (i.e. if they emit more that 550 g CO2 /KWh where most coal plants are nearly twice this factor). Whilst nuclear plants may exhibit higher costs in future due to more stringent safety and requirements to be flexible are incorporated into design and operational requirements.

It must also be noted that EOM market prices are much more volatile and can be significantly high due to the nature of the market design (known as scarcity pricing) but on the other hand energy waste is significantly reduced and this market is much more suited to competition, internal market and renewable integration. This model seems better suited to support the retail market where consumer demand side management is key and is more related to the distribution. The main question is can an EOM provide sufficient spare capacity to cover changes in demand i.e. do they offer generation adequacy. This could be resolved by storage and hence is a huge focus at the moment. But this will increase costs that are ultimately passed onto consumers[92].

Capacity Markets and Capacity mechanisms.

Capacity markets and mechanisms[93] are popular and used throughout the majority of Europe to maintain grid stability and security of supply. Capacity contracted on longer term capacity guarantees, and favour a more rigid base load model (continuous production) but have spare capacity that can be pooled or steadily ramp up to absorb additional loads if required, but there are no guarantees that this future contract option

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[92] Energy Markets Kraftwerk https://www.next-kraftwerke.be/en/knowledge-hub/energy-only-market/

[93] Capacity Mechanisms for Europe electricity
http://www.europarl.europa.eu/RegData/etudes/BRIE/2017/603949/EPRS_BRI(2017)603949_EN.pdf
Understanding electricity Markets Europe
http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf
Development of Markets in Europe
http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf

for spare or additional may not be required, and even the base load may be substituted by alternative power production where priority feed in for cleaner energy is preferred. But nonetheless the generator will be paid to be ready to supply if required, even if they do not supply power they will be compensated. There is a concern that this can distort the market (Harris, 2006).

A more recent approach was to pool spare capacity on a regional basis and use bids or auctions to secure contracts to supply other countries, but this has come under scrutiny as it may hinder competitive rules of the internal market as well as conflict with state aid support mechanisms [94](especially if renewables are crowded out or emissions or power capacity restrictions form a barrier for some potential market entrants). However this model is better suited to investment and returns for development of plants and interconnecting infrastructure especially in the wholesale markets on an intra-national level where supply capacity dominates to ensure capacity to meet demand.

That said, challenges in low marginal costs offered by renewables squeeze the feasibility of larger plants (especially where fuel supply prices are in play). There is also a threat to lock in fossil fuel capacity players and that will affect transition. In addition due to relatively low interconnection and transmission capacity, congestion will result which will cause different prices in different regions as energy at lower prices cannot be transmitted to areas experiencing higher prices (this is a problem when different markets cannot take advantage of renewable supply) this also prevents an EU wide Capacity Mechanism being applied.

EU Energy Union Market Design Position:

Ideally the Energy Union would like to aim for an interconnected Energy Only Market reflecting a free, integrated and perfect internal market, but during transition a combination of Energy Only, Capacity markets and Capacity Mechanisms prevails (however Capacity Markets and Mechanism regulations have been proposed to ensure no conflict with the EU internal market but imperfect markets have still not received sufficient attention)[95]. As a result the EU has focused on meeting internal market design principles to specify generation, capacity and resource adequacy with special rules for capacity mechanisms (i.e. subsidies, state aid, anti-competitive noncompliance, emission controls and market governance have been introduced).

The investment into infrastructure to interconnect the markets, integrate renewables and development of the hybrid grid with storage is prioritized (sector coupling), but the EU understands it will need to combine Energy Only and Capacity Markets and Mechanisms during the initial transition phase, strict regulation will be required

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[94] Development of Markets in Europe
http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf
http://www.ewea.org/uploads/tx_err/Internal_energy_market.pdf
[95] Briefing Understanding Electricity Markets in the EU
http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf

especially when cross border market capacity becomes more prevalent and as intra state interconnectivity increases (market coupling) hence increased use of strategic reserves – all the while ensuring the consumer is protected from price volatility and reliable service and that benefits of the SMART grid are realized (i.e. demand side management focus).

So at the moment it seems like a blended approach is adopted and focus is on how cross border trading will be resolved instead of prescribing a market design for each member state – but a choice will need to be made in the future or an evolving market design to cope with transition phases to meet transformation ambitions (i.e. controlled and phased market design evolving after transition starts to deliver benefits and opportunities for renewable integration and interconnectivity and cross border exchanges).

Analysis

After covering the grid format, market design and policy developments to date and considering the results of the reviews of the EU communication and documentation, it was possible to apply the Decision Quality Framework to determine if the correct policy development and selection was achieved to support decision making quality achieved during policy implementation.

To do this all references and material in the results section above were used, together with the workshops and seminars attended as described in the research methodology section. This would facilitate a decision quality appraisal of this process and was complimented and continuously updated to accommodate the feedback, questions and discussions that were tabled at the seminars and workshops attended (see Research Plan under methods).

By assuming an observer role in the process and by participating in the numerous network events it was possible to follow strategic development, understand the various stakeholder positions and statements that followed the events and develop material and a logical thread throughout the Decision quality appraisal framework as introduced in the theory section (Spetzler et al., 2016).

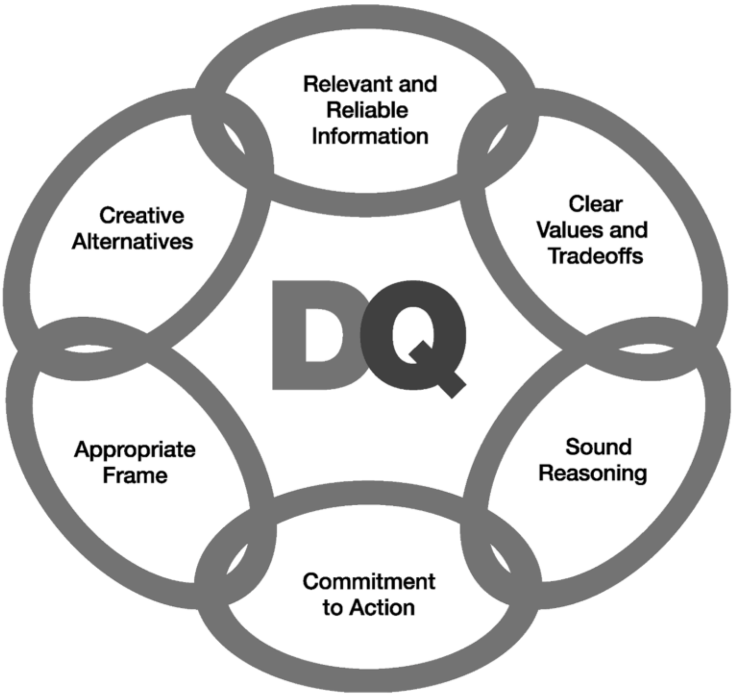

Fig 34 Decision Quality Framework (Spetzler et al., 2016)

During the analysis, careful consideration and focus on the real issues and challenges and opportunities were consolidated. Thus it was possible to include these in the analysis with respect to planning and implementation and execution of projects to support the policy selection and proposals. It was also possible to recognize issues and concerns surrounding grid design and market reforms. The research plans and decision quality framework allowed the researcher to revisit the theory and results and iteratively populate the analysis throughout the research work. A summary of the analysis follows.

Appropriate Framing

The Energy union is the policy for the European Union, to facilitate transition to a Low Carbon system and requires a market design to support this transition. It is firmly entrenched in the sustainability model reference economic, society and environmental considerations.

Hence the amalgamation of the Energy System and Climate Action with the Consumer as the focal point of the integrated market is welcomed and no surprise. Energy Union and Climate Action is a top 10 priorities for 2015-2019 under the Energy union and climate initiatives, but is closely linked to the internal market initiatives regarding:

- Securing, solidarity and trust energy supplies
- Fully integrated internal energy market
- Increasing energy efficiency
- Climate action and decarbonizing the economy
- Supporting research and innovation and competitiveness

It is underpinned by targets set in 2014 for the 2020 & 2030 and in 2018 it made a call to become carbon neutral by 2050 which is ambitious but welcomed. But this affects the decisions and methods on how and when we need to reach certain milestones in planning and implementation of the policy. An enabling support framework developed by the EU supports the objectives:

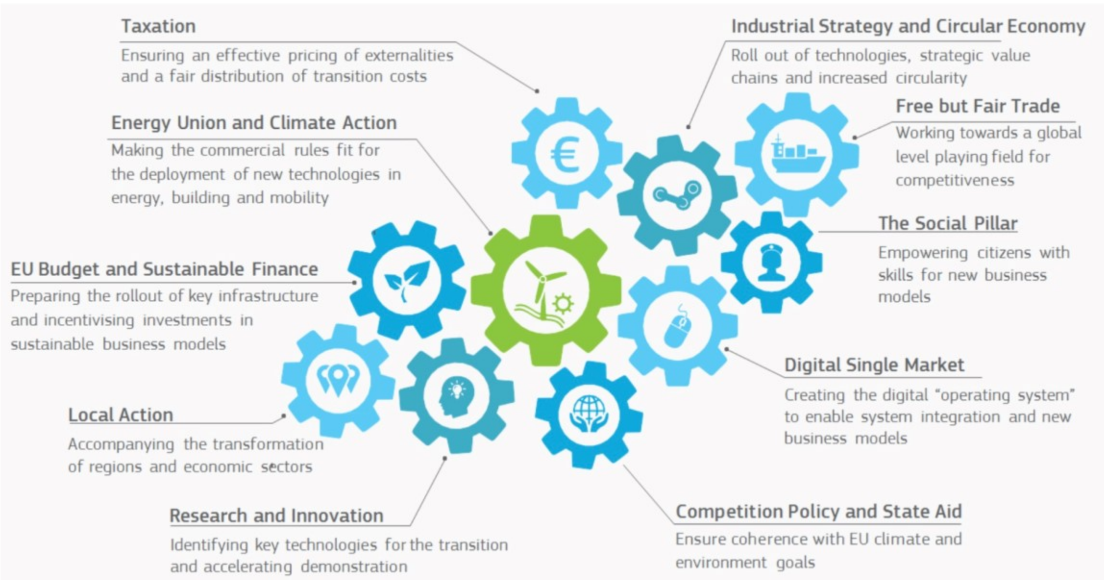

Fig 35. Enabling Framework (EPSC)[96]

Furthermore to achieve the energy union vision, market reforms to support transition and enable a fully integrated and expanding the market the following actions required are populated as follows:

[96] A clean planet for all https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf

- New energy market design – energy only or capacity markets
- Empowering energy consumers – SMART prosumer
- Helping energy cross borders – interconnections and auction of spare capacity or setting up strategic reserves internally or through grid interconnection so that other member states can access this on a market basis as necessary (e.g. Hydropower in Norway).

To facilitate these actions proposals were made in 2014 were made but parts of this were voted down and subsequently withdrawn in 2015 with respect to energy tax, subsidies and state aid for grid development[97]. New proposals for market reforms were tabled in 2016 following the public consultation and additional survey on energy security.

This ultimately led to the creation or affirmation of market alternatives (i.e. further Liberalization of markets but with significant infrastructure gaps!). During implementation of the 3rd Energy Package[98] there was an attempt to move to energy only markets, the results was a combination of energy only for internal market and setting up strategic reserves and a move to capacity markets and capacity mechanisms was established across the EU member states. But with rekindled voting mechanisms and the compliance to the COP21 Paris Agreement these have re-emerged. To further develop this all member states have delivered their Energy System and Climate Action plans for 2021-2030 and beyond to include long-term strategy to achieve carbon neutral by 2050 (by July 2019). Now these need to be consolidated and the priority projects of common interest agreed and financed or supported as necessary[99].

So in terms of framing, collectively this may be possible i.e. to meet decarbonization and transition efforts to a low carbon system can be achieved but it needs modelling and analytical assessment and selection. The pathways and efforts of independent countries/member states have not been sufficiently coordinated, compared, assessed or established as yet and this may lead to uncertainty or delays in infrastructure projects.

While decisions on how to meet targets requirements were historically left to the individual countries, this can now be combined under the Energy Union (and supported or facilitated through the fact that all countries in the EU have adopted the IPCC and COP21 Paris agreement objectives). But at the moment it seems that regions have developed their own energy system models or embarked on regional development of models and market designs to support the transition, and despite the Energy Unions plan to establish a collective energy system design or market design this is still in the review, planning and implementation phase so as yet no specific

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[97] Energy taxes withdrawn http://www.europarl.europa.eu/legislative-train/theme-deeper-and-fairer-internal-market-with-a-strengthened-industrial-base-taxation/file-taxation-of-energy-products-and-electricity
[98] Third energy package https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation
[99] Energy Infrastructure Forum Copenhagen May 2019 documents summary https://ec.europa.eu/info/sites/info/files/20190524_conclusions_of_the_2019_energy_infrastructure_forum_final.pdf

framework on how or when this will be achieved is available. Thus, if not careful, we could end up with a two-tier energy union.

To overcome this we need to consider the accuracy and integration assumptions of the collective modelling and assessment and analysis of the models in use, we also need to consider the databases and coding and assumptions used in the models. There are no criteria governing this at the moment. Suggestions to make information, data and models open source have been made but given reluctance to do so at a national level and the variety of models in use, it seems that efforts to consolidate this into a pan European Model will prove to be challenging[100]. Transparency regarding assumptions and restrictions or limitations applied to the models is also crucial.

In addition accuracy and changes to the energy system models and subsequent use of outputs for analysis may be difficult and affect pan European market design applications due to distortions at national levels (e.g. Capacity and Strategic Reserves). In addition some countries have not embraced the hybrid model and if we are to consider the interconnectivity, storage and changes required for future systems this needs to be addressed now to understand the timing and energy mix and instruments that will come into play and regarding the energy union the capacity and volumes or energy flows required (this is necessary to set parameters and scope for projects of common interest otherwise these cannot be estimated and financed correctly and the value and utility addressed if these are to be connected into a supra-grid at a later stage.

The member states also need to understand the EUs position on energy tax, subsidies, state aid, financing and regulation of the Energy Union. The Energy Union policy and market design needs to be ratified, however questions regarding instruments to decarbonize and regulate energy systems need to be fully understood, especially the timing and consequences of these instruments. They should already be reflected in the national models and plans regarding energy systems and climate action. The cost of these actions vs. abatement need to be addressed and the value or impact considered so that the decision makers are fully informed when it comes to considering the options and alternatives.

So while there is significant focus on decisions by the EU to decarbonize and interconnect the grid which were supported by energy system models proposals on markets and sector coupling there is no one agreement on future grid design and market design to support this transition[101]. Nor is there sufficient guidance on how the market will trigger infrastructure and grid development (hence the combined energy only and regulated capacity market approach currently in place in most countries or regions). Whilst it is convincing that the EU Energy Union and Market Designs are trying to collectively address the Decarbonization and Climate Action problem and the policy, regulations and directives are being developed accordingly, there are

[100] EU Modelling https://ec.europa.eu/energy/en/content/metis-1-dissemination-event-20022019-brussels-ccab
[101] Market Design Evaluation https://ec.europa.eu/energy/sites/ener/files/documents/1_en_autre_document_travail_service_part1_v2.pdf

serious gaps in the framework to facilitate the changes and the scale of the infrastructure development required to achieve this may be underestimated.

Energy Transition proposals and Energy Market Reforms were framed to capture[102]: Consumer central to model enabled by Decentralizing, Decarbonizing and Interconnecting grids, Introducing emission restrictions, market intervention by introducing finance to promote renewables while simultaneously removing subsidies for Fossil Fuels and promote integration of renewable energy sources. Furthermore they are discussions on introducing storage and use of green and blue gas but it seems that these are not sufficiently covered in the policy or framework. SMART Grids to manage energy demand, reduce consumption and optimize choice/behaviors are recommended but not rolled out yet.

Sector coupling which will lead to further energy exchanges through: Electrifying the Heating, Transport and Facilities sectors are also not sufficiently addressed in the policy framing to accommodate these. Interconnection of countries (gas and electricity) will increase exchange in energy markets between countries but Market Coupling is not addressed in any great detail.

Market reforms through: capacity and energy only markets are not mature and subsequently the triggering of investment in infrastructure to allow sector and market coupling requires state or European intervention. But most importantly the timelines to achieve and introduce the various measures and proposals were not defined hence it is difficult to frame the transition proposals effectively and this has led to more uncertainty. That said a series of scenarios and pathways were developed and considered as will be discussed in the next section.

Creative Alternatives

When we consider the choices for the Energy Union and Market Design to support the transition we need to look towards the vision of the Energy Union and the Climate Actions and the requirements and tools to achieve this accomplished through Energy Union focus to deliver:

- Policy, Regulations and Directives
- Scenarios and Pathways
- Options and grid configurations
- Infrastructure and technology development
- Market Design to support the transition

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[102] 2016 market consultation proposal
https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v11.pdf and
https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v11.pdf
Directive market electricity https://data.consilium.europa.eu/doc/document/PE-10-2019-INIT/en/pdf
Regulation market electricity https://data.consilium.europa.eu/doc/document/PE-9-2019-INIT/en/pdf

But we need to understand the choices that are available to support these endeavors. We have the focus on remaining within the various temperature limits (Degree Scenarios – DS): i.e. the 1,5DS, 2DS and 3DS scenarios and control that the various pathways derived from the models achieve this, but more importantly how and when changes occur in the transition. But there is confusion regarding the effort to “keep within” 2DS, probability that we can achieve this, what abatement costs we would need versus climate damage risks and events and what climate change we are able to adapt to. It is crucial that we need to communicate and understand the efforts and limits on CO2 or carbon budget to be considered to keep within these restrictions. This is often overlooked and thus introduces errors, biases or heuristics when considering the alternatives.

We also need to understand the models and pathways that have been developed to accommodate these scenarios[103]. As discussed earlier, the models need to be transparent, understood and communicated. We need to appreciate that the different approaches cannot be compared like for like, and are developed to address different challenges and scenarios, but the various results and outputs from the models could help give perspective or insight to underlying features and mechanisms of the Energy systems and combinations of the various Top Down and Bottom Up models (i.e. Hybrid, Linked or Integrated Assessment Models) if the results are analyzed correctly. This could strengthen the confidence and application of the results to support decision or policy making.

We should also not rely on one model and approach to support decisions nor rely on sensitivity analysis with respect to one model only as a way to develop a range of results. The error, accuracy and assumptions need to be known including the data sources. If a common data pool and assumptions during the framing phase is used then a more useful comparative analysis or analysis of the range of results could be achieved. That is assessment of the array or results could help the decision making process where alternatives and result distribution can be quantitatively assessed to improve support to the decision or policy makers. This needs to be done at a local, regional and national level, aggregated at an Energy Union level to ensure all contributions by the member states can collectively meet our obligations to the Paris Agreement when assessed together where common policy is decided and decisions need to be made unilaterally across the union for the welfare and benefit of all. This is especially important when we consider the development, infrastructure and connectivity of the future energy grids.

When we look at the spread of results the EU is considering, i.e. PRIMES, POLES and WEM energy models or the various models recently developed by the EU such as REEEM, REN21, SET-Nav, MEDEAS, REFLEX and POTEnCIA with various energy mix and results. We need to understand their top down, bottom up, hybrid, linked or integrated attributes. Appreciate their inherent biases to politics, social, technical or economic aspects of the modelling and associated pathways/scenarios that were used. For if we consider the outputs individually, all the results and

[103] Modelling comparison http://www.set-nav.eu/sites/default/files/common_files/deliverables/WP10/Issue%20Paper%20on%20Hybrid%20Modelling%20Linking%20and%20Integrating%20Top-Down%20and%20Bottom-Up%20Models.pdf

proposals seem doable, but these are often read without proper decision assessment and crucially risk and uncertainty are not fully addressed in the decision assessment phase. This is true and necessary for all the: social, economic, political, and technological aspects of the transition models. To correct this, it is important that the information and considerations in the framing phase are sufficient and aligned to. Including all the parameters contributing to the uncertainty and risk for all socio-economic and socio-technical or techno-economic perspectives and no one dimension can be ignored it is a multifaceted problem which requires multidimensional and combined sectoral analysis. But to correctly quantify this we need to understand the assumptions and interdependency between costs, risks or consequences for the stakeholders when we apply these alternatives (Khodakarami & Abdi, 2014). This means we all need to revisit the first step and ensure that we have framed the problem appropriately and disseminated correctly. This will help with the modelling transparency, assessment and communication of the results.

A transition will mean change and we need to be aware of the change implications. This always needs to be compared to the scenario where we do nothing or suffer consequences of global warming or climate change where insufficient action or steps are taken. This will help with the approval or decision process. Most importantly for the Market Design options we need to understand how much impact the new grid design and energy mix and energy flows will have as the transition gains momentum and more critically when will they benefits be realized. If not on track or if we suffer any setbacks and delays we need to remodel this in order to determine the additional intervention or policy changes that are required.

While it can be accepted that the EU and member states have taken considerable steps and deliberate decisions to embark on this transformational journey, the impressive spread of creative solutions and broad range of proposals to achieve future Energy Union and Climate Action vision will need to be consolidated or aggregated through analysis (addressing risk and uncertainty and introduce decision tools to help with this process) (Bratvold, 2010).

The scenarios, models and pathways will require further refinement especially in the implementation phase where grid design, operational, development and interconnection infrastructure investment decisions are made which must be delivered in time and aligned with the strategic objectives of the framing above. To that end we really need to embark on a Portfolio analysis (Project Management, 2006) of the options to ensure that collectively the approval and development process is aligned with the strategy to decarbonize the Energy system and the Market design supports this process. We also need to start developing the distribution of the solutions and start to address the probability of the extreme events i.e. fat tails exacerbated if the distribution moves (Taleb, 2010)(which will help make decisions on how much abatement or which configuration best limits the warming and meets the EU energy and climate targets).

Despite focus on research and development and introduction of new technology and steps to take advantage of new technology and systems, detailed versions of the proposed system have yet to be delivered and rolled out (e.g. CCS, SMART metering, Hybrid Grids). Innovation, scale up and roll out takes time (Schilling, 2013) and could critically affect the timing of the benefits or needs to be considered as this affects the models and pathways feasibility. This must be updated and communicated as new information becomes available to ensure that we develop the solutions representing to best utility and value in order to meet our targets. This way critical and viable pathways can be established with more confidence.

Finance and funding for these developments needs to be checked against the member states energy system and climate action plans and priorities on these projects need to be confirmed. The EU has set aside that €200 bn is to be made available for projects of common interest for all member states, and further financing from EIB and EFB will be made available, but if we look at the costs to truly decarbonize (UK estimate £1 trillion by 2050) we have to ask if the budgets set out by the EU are sufficient. Also before national governments baulk at these costs they need to understand the consequences and costs if we delay or do not take sufficient action now. Perhaps if we addressed this as an investment opportunity as opposed to focusing on costs it would help justify and ease the process.

Maturity mapping and interface management between the grids needs to be considered when interconnection and transmission of energy between the member states is considered. Although projects of common interest have started to address these, these were on a small scale and local regional level (Sync, Gas line, Hybrid systems and Europe wide SMART Metering). Therefore we need to be realistic about the timing and effectiveness of the projects delivered to date and over the next 10 years as these will affect if we can follow the pathways and ensure that CO2 levels are sufficiently low to keep global warming well within the 2DS as promulgated.

At this stage we do not know collectively which options: scenario, energy mix or pathway is best, despite having information on hand which could be ranked and weighted according to priority, preference and confirm technical readiness and viability. This is tightly connected with establishing a more stringent timeline and development, operation and regulation of the Energy System and the application of the Market Design that can best support this endeavor[104].

We do not have to specifically choose one standardized model or pathway but can use these models with anticipated energy mix we can develop some initial grid design parameter based on the spread of results and volume or flows to develop a range of capacity for the various energy and technology options so that we can start to refine grid planning and estimate the associated implementation and operational costs (CAPEX and OPEX) set against abatement and value or benefits achieved in order to justify and support the selection and decision process. We should also anticipate a glut in capacity as we move through the transition phase until storage and market interfaces have been resolved, also as new renewable and low carbon technologies come on line. We also need to allow sufficient time to integrate these into the grid and have confidence in how to manage and control the grid before we can remove or carbon intensive systems or we could mitigate their effect before phasing out (e.g. CCS).

[104] Market Design Evaluation Framework Internal Steering Group for Pathways http://ec.europa.eu/smart-regulation/roadmaps/docs/2015_ener_061_evaluation_eu_electricity_market_en.pdf

If we develop an overview of the interconnected grid design of the future, we can then break it down into manageable phases (Kaplan & Norton, 2004)so that all efforts can be strategically aligned and that these all contribute to the Energy Union vision and deliver according to the end state of a carbon neutral economy in 2050. This will enable us to meet the targets in the interim years while building up the infrastructure to deliver in the future as opposed to attempting to solve the end state upfront[105] with options that are not viable yet and where in early phases where significant uncertainty and risk is prevalent. If we don't assess and analyze this properly it may lead to suboptimal selection of energy mix configurations, poor combination of alternatives and utility issues on the infrastructure. Thus we could not meet the energy demands and introduce market design instruments that actually hinder the transition process or do not reflect value or benefits envisaged.

Relevant and Reliable information

We know we need to decarbonize the energy system and act to mitigate or abate climate change impact and understand what we can adapt to. But we still do not know ultimately how we will address this collectively and resolve all the issues and concerns simultaneously in an affordable and timely manner. That said we must also make it very evident the impact of delay or consequences if we do not support the transition and achieve the objectives agreed in the Paris Agreement.

There can be no debate in the EU that we have generated a copious amount of information that has enabled us to develop high-level policy, regulation and directives pertaining to the Energy Union. As a result we have identified several options, alternatives and pathways to achieve the scenarios required to decarbonize the energy system. But the information used is disjointed, not sufficiently transparent and plagued by assumptions that cannot be justified. In addition the information has not been managed to facilitate assessment and analysis that can distinguish which pathways are feasible or show value and benefits for the member states and the EU collectively. For example the multitude of models address various perspectives and could be biased to certain interest groups or larger member states. Confidence that technology will be available and operate as envisaged might not materialize, be sufficient or be rolled out in time. Market Design and Instruments may not work to meet the priorities and concerns of individual member states. That said it is better to have a series of models and data so that we can combine viable features and dilute any biases or uncertainty through decision analysis – but it is imperative that we verify and check these models and not accept the results at face value.

We are at the stage now where we need to implement and deliver on the Energy Union and to do so we need to start drilling down to the specifics of the grid design and execute a significant portfolio of infrastructure and transition projects to realize this vision. Whilst we have focused on Research and Development and changes that are required on a national or regional basis, we have not aggregated this at an EU

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[105] Impact Assessment https://eur-lex.europa.eu/resource.html?uri=cellar:e4c834ae-b7b8-11e6-9e3c-01aa75ed71a1.0001.02/DOC_5&format=PDF#page210

level. We need to establish this high level overview first before we start to identify priorities and select options to facilitate the transition actions.

So if any more time, money or resources are available to work on the Energy Union and Climate Action plan it should be used to consolidate and verify the information we already have. We also need to implement a decision analysis framework to help structure the process of determining the best options and priorities that offer the most value to meet the climate change actions and transition efforts and requirements of the Energy Systems. To do this we first need to verify all of the methods and proposals used to date (including validation of the data, structure and results of all models used). We then need to establish the collective status of capacity and systems as per today and then based on a collective energy system plan for the future, develop the shortlist of critical and prioritized projects at EU, national, regional level. We also need to take into account local and individual member state efforts to ensure that the overview is accurate and that we have the correct information to start the analysis process to compare and select options to meet the objectives. This process has just started and is critical for the future milestones of the Energy Union to meet or exceed targets.

Whilst there is an overwhelming consensus amongst the EU and member states to develop an Energy Union and reform the Energy Market Design, there are differences in opinion of how to achieve this (e.g. grid design and market types). Or this could be an apprehension to commit to certain transition objectives and aspects given uncertainty regarding future taxes, subsidies and rules for state aid. But we can still recover this situation if we consolidate the information available and through a more thorough and professional Decision Analysis(Bratvold, 2010) process whereby we can approximate or deal with a spread of data to help simulate for a combination of eventualities based on value analysis from the model results. By addressing this we can assess the sensitivity and dependency of the various outcomes against the low energy transition objectives. Thereby selecting the correct options and projects to be prioritized or those that require urgent or additional support to achieve the objectives and deliver the value and benefits envisaged.

To support this we need to understand the concept of probability in achieving certain targets and the additional costs to improve success i.e. decision trees and degree of confidence. We also need to apply decision options and associated probabilities and options to get an overview of viable pathways and measure the expected values. We need to consider moving beyond traditional ENPV or CBA business model approaches to arrive at a method that can accommodate value of the environment and impact on the environment in order to compare and compute perceived value and alignment with strategic objectives. Perhaps if we convert CBA into an investment benefit appraisal we could see more value created (Perman, 2011).

If we follow the Decision Analysis (Bratvold, 2010)process we will have more analytical tools to help deal with information inaccuracies, uncertainties or know where we may require more information if necessary. We will be able to identify the most critical and important issues to focus on (instead of trying to deal with all issues and options simultaneously). By ranking and weighting objectives and options we can also determine which options and projects offer best value and benefits required to sustain the process and which options can be deferred or addressed at a later stage, it will also assist on where critical infrastructure projects are required most i.e. when the technologies are required or level of readiness or maturity to assist.

This is coupled to the market needs for these products exist e.g. H2 for transport, or grid expansion for electric vehicles and heating – which should specify when we need this and in what capacities. If we know our energy demands and when and where these occur on a pan European level, we start to plan the interconnection and transmission grids to ensure that energy can flow to these areas. To do this we need to know where we have capacity surplus, adequacy and where deficiencies and potential congestion spots are. This also needs to be balanced against energy system transition plans and urgency to decarbonize (which is more prevalent in some of the member states compared to others who have started on this journey).

Clear Values and Tradeoffs

If we consider the European Energy Union Goals and Objectives:

- Securing energy supplies
- Expanding the internal energy market
- Increasing energy efficiency
- Reducing emissions and decarbonizing the economy
- Supporting research and innovation

We can start to consider the grid design and market design reforms and priorities. We also need to ensure that these are governed by the principles of the internal market, and in doing so take the appropriate steps that need to be taken to facilitate:

- Competitive and liberalized market – ease of access to a hybrid coupled grid
- Helping energy cross borders – capacity and trading through market coupling
- Empowering energy consumers – through SMART Grids and technology

The values of the alternatives are measured and underpinned by the strategic intent of the Energy Union to provide: clean, secure and affordable energy to consumers. The only tradeoff is that the EU has accepted that the transition will carry a significant price tag (that has not been clearly formulated or communicated), but it can be balanced and justified by benefits of opportunity to prevent global warming or detrimental impact of climate change on society and the environment.

The EU clearly cares about the impact on the environment, decarbonizing the energy supply, ensuring access to energy poor and underdeveloped areas whilst helping communities with transition from fossil fuel dominated power sectors into clean renewable sectors[106]. This is also supported by the awareness that we need to transfer of skills knowledge and experience from sectors that will phase out under the transition plans to support the new energy industry, innovation and opportunities that it presents. All of this emphasizes the Sustainability of the Energy Union. However

[106] A clean energy for all Europeans https://publications.europa.eu/portal2012-portlet/html/downloadHandler.jsp?identifier=b4e46873-7528-11e9-9f05-01aa75ed71a1&format=pdf&language=en&productionSystem=cellar&part=

due to the amount of uncertainty surrounding the plans and implementation phase and lack of clarity regarding grid and market designs, are further compounded by fear that communities may be left behind or neglected in the transition (e.g. steel, power and heavy industry declining) or bear the brunt of increased costs in Energy incurred in this transition (e.g. Energiwende).

Tradeoff to achieve this is increases in cost of energy but by reducing waste, increase in energy reductions and market efficiency that should offset some of the impact. The increase in cost is balanced by the consumer's willingness to pay for clean and secure energy, but it is envisaged that the SMART technology will help reduce energy use and change consumer behaviour so that they can take advantage of lower priced energy in off-peak times – but this requires a significant socio-economic paradigm shift that does not manifest itself in the Energy Union policies and will require significant efforts to deliver. In addition from the current liberalized market model, where monopolies have been unbundled so we can introduce more competition and integrate renewables to reduce costs to the consumer– it is still difficult to see how businesses will be sustainable without accepting increased costs in energy supply to the consumers (e.g. Energiwende).

Although we can anticipate a cost reduction in power production where marginal costs for renewable energy services are lower, due to the intermittent nature of renewables we will still experience price uncertainty and risk due to volatile nature of energy prices, especially in the absence of sufficient storage i.e. we will experience price spikes(Harris, 2006). So the original aims of the transition to reduce costs to consumer maybe lost as the costs for infrastructure development to provide storage, alternative fuels and transmission and distribution requirements to integrate renewables will result in additional costs will be passed onto the consumers – however through SMART technology and providing options to change suppliers within 24 hours it is hoped to reduce the impact of this (Bessis, Dobre, & SpringerLink, 2014) – but from the EU communication and policy material reviewed this is a very ambitious recovery mechanism to avoid high prices to consumers but on a positive note it may help to reduce demand.

On the other hand, if costs are significantly lower (due to market intervention, state aid and smooth transition) we need to be sensitive about the possible rebound effect whereby consumers use more energy to offset cost or efficiency savings (Dobbs, 2000). This too has received little attention in the Energy Union policy. Notwithstanding both issues need to be addressed if we are to decarbonize the energy system.

Regarding grid design, the abatement value is on decarbonizing, integrating renewables and ensuring that there is sufficient and adequate capacity to meet a managed demand needs to be calculated and justified against the climate damage or global warming impacts if the actions set out in the transition are not undertaken. This will help support the transition decision-making process. Furthermore the steps to ensure that the grid is balanced and stable (i.e. through storage and system inertia need to be communicated to reduce uncertainty and mitigate risks. Resilience and Reliability are also values that are measured and the energy security is an important value that can also support the transition decision-making needs to be addressed and communicated.

The European market design is currently split between a combination of Energy Only Markets with Strategic Reserves and Capacity Markets with Capacity Mechanisms. Most producers, transmission and distributors prefer that scarcity-pricing method is the overall economic model i.e. to set the energy price through trading) (Harris, 2006). That way the business model is sustainable; however there is a threat that the tradeoffs created by capacity mechanisms and strategic reserves could distort the market and affect scarcity (or strike price). Therefore this needs to be carefully monitored and regulated (see Enron for example where they shut down plants for "maintenance" to increase energy prices due to supply shortfalls to meet demand).

We have been through an energy transitions before and we should look at the lessons learned and knowledge gained. Some transitions lasted between 30 – 50 years (wood to coal, coal to oil) but these transitions were normally on a national or local or regional level and not on coordinated combined effort as proposed by the EU Energy Union. The third transition was anticipated to be from coal and oil to natural gas with CCS, but given climate change and environmental concerns and the urgency to decarbonize, supported by the advent of renewable technology and political will, it is understood from the Energy Union policy that the EU may try to leapfrog natural gas as a major energy source or at least a flexible source as required. CCS (Bui et al., 2018) could have also assisted other parts of the world in their transition process so it is difficult to understand why this does not feature more prominently in the EU Energy Models at least during the transition phase.

We also have some recent Energy Transition examples on a national European level: Germany (namely the Energiwende), UK, Sweden and Denmark to name a few. But we have also discounted France in much of the discussion and their Energy preferences, i.e. to use Nuclear as a base load power which is a carbon free source to support the energy mix, this could assist in the transition until it could be substituted by a cleaner and safer energy source at a later stage. We have also ignored Europe's dependency on Natural Gas and investment in a series of pipelines and LNG contracts. Are these tradeoffs regarding gas with CCS and nuclear assessed against renewables and the consequences of the former deemed incompatible with the Energy Union values? If so where does Nuclear Energy stand in the transition – will it play a role? And will Europe forego its dependence on Natural Gas and LNG to avoid geopolitical issues to improve its energy security (Kuzemko, Keating, & Goldthau, 2015) (i.e. avoid dependency on Russia for gas or will the EU look to the USA for its LNG needs (which is ironic since USA opted out of the Paris Agreement and now will supply gas to Europe).

That said some countries already have spare capacity in Renewable energy resources that can be shared (e.g. Hydropower from Norway or excess wind from the North Sea Region). And if infrastructure interconnectivity is realized some countries could fast track or leap frog transition from fossil fuel reliance (Heinberg & Fridley, 2016)i.e. coal and oil to gas or alternatively jump straight to clean renewable energy via the interconnectivity of the union. All of these efforts are enabled and underpinned by the Sustainability Development Goals and supported by efforts to contribute to COP21 Paris Agreement targets.

But given the increases in energy demand and population growth and coupled energy intensity and economic growth and GDP this may not be possible and tradeoffs may be required e.g. interconnectivity, transmission, wind vs. hydro and expansion new renewable industrial sector, introduction of mini Nuclear fission reactors using spent fuel from fusion processes or full scale roll out of CCS (initially through EOR with associated revenue streams) and the push for P2X and Storage. But as with any energy mix in transition we need to determine when and where these options will come into play. So these tradeoffs could also help realize new opportunities but they need a strategic decision framework with analysis tools and dialogue to choose most valued options.

Previously the benefits were increased mechanization, increased energy efficiency, cleaner air and environmental sensitivity. But despite best intentions of the Energy Union to reduce waste, decarbonize the system and improve market efficiency we will have to contend with this problem on a multi-national level, where energy mix and transition maturities and willingness to transition differ. Even though we have begun to show successfully that we can decouple energy from GDP and reduce energy intensity in Europe, we may find that we will need to sacrifice growth in certain sectors to build up more needy sectors in order to satisfy collective energy transition objectives.

So despite advancement and confidence in technology opportunities and advance in technical readiness levels (TRL), there is still uncertainty about the scale and rollout of technology and infrastructure to meet sector and market coupling objectives. This is particularly evident in concerns surrounding timing and delivery of the technologies to enable and facilitate this vision. In addition the volume and flow of energy, compounded by the standardization and scaling up of technologies and integrating renewables present issues and concerns surrounding the capacity and interconnectivity to a hybrid system to help meet transition requirements (e.g. CCS and P2X).

Consequently market design extremes need to be merged and evolve to a model that supports the grid technology and energy mix. The triggers for development should come from the market design but state intervention and support will be required during the initial phase to enable the investment signals and opportunities to come through. Normally this was measured by utilization and generation adequacy, but given the complexity of the network integration and interconnection we will introduce congestion and energy transmission and distribution issues that will need to be monitored and resolved. This is especially pertinent if we move to a Decentralized and Unbundled Energy Only Market and reduced reliance on Capacity markets in the future (and rid ourselves of reliance on strategic reserves and capacity mechanisms at a later stage if we are to follow the Energy Union's vision).

That said we still need to address the storage dilemma (Heinberg & Fridley, 2016) to ensure reduced waste and sufficient robustness to meet plausible events or security issues (i.e. down time due to accidents or external threats including reliance on imports of natural gas and LNG in the future). At the moment this is left to individual member states but due to the interconnected markets and sectors in the future this will require significant coordination and cooperation between the member states – especially if consumers demand clean and renewable energy sources at point of delivery (even if that means paying extra for carbon credits or pay for carbon neutrality of supply to finance carbon capture to offset impact). More analysis and study of consumer behaviour will be required here e.g. Willingness to Pay (Perman, 2011).

Sound Reasoning

The extensive modeling activity by the EU highlights our need to combine our energy alternatives into an energy mix that supports the transition. However solutions cannot be determined by choosing one the various energy system models only and the results and assumptions of these models including restrictions or market parameters need to be understood– but before we choose an option we need to compare or group complementary solutions to develop a strategic combination to reflect doable choices during the transition. These are governed by the need to comply with the required decarbonization levels of the energy system to keep temperature increase within specified scenario levels (i.e. well within 2DS and aiming for 1,5DS)[107]. This forms the base of the analysis that is used to make decisions regarding various grid designs and regulation thereof. Beyond the grid design and operation we look toward the market design and associated instruments that are used to keep within these limits and monitor their effectiveness on carbon reduction while noting consumer satisfaction.

As we saw from the various Energy System Models used by the EU, they are normally built up of interconnected modules that use various databases to develop responses and trends to the various externalities (prices and taxes). The models are designed to take inputs and give insight into the workings and mechanisms, system responses and energy delivery outputs or projections that are used meet energy union objectives. But what is missing is a comparison or assessment of the various solutions. A decision framework can bring these ideas and alternatives together. They can through an optimization or comparison process arrive at the best configurations for the alternatives under a variety of circumstances and variable parameters.

As we can see we are dealing with an extremely complex and multi-faceted issue with many attributes, which can only be resolved by using models, but we cannot make decisions based on these models alone as we need to consider the results as a spread of ideas to scope the changes required (i.e. Low, Most Likely and High or a distribution of possible values to be considered). This way different operational parameters are considered and assumptions can be applied. By looking at the various models we can choose the best combinations and set volumes and performance criteria ranges to help ease the design and investment decisions. This is particularly essential for grid design and operational considerations.

We should also consider how to break down the options into a time series of manageable chunks to understand how system changes will evolve and thereby focus on the required infrastructure capabilities and capacities in a certain period and look to build on these in subsequent periods. More importantly we can address the "when

[107] CICERO What does well below 2D mean https://cicero.oslo.no/no/posts/klima/well-below-2c

and where" issues that the options will be required in order to achieve the desired targets and objectives. But the true value of the decision process is that it can accommodate the risk and uncertainty into the decision process whilst accommodating variability and dynamic nature of the energy system models to assist in achieving the multiple objectives associated with the energy system and operational challenges (which may be too difficult to include in the models themselves).

If we consider the approach above we can move from a more rigid deterministic approach to an analytical and comparable based assessment which would benefit the current decision making processes within the EU by learning to manage uncertainties and risk associated with the models and decision methodology. This will then enable us to turn these into opportunities and informed impact assessments that will create the most value for the stakeholders. By doing so we can create a better process to make informed decisions that consider all the options, sensitivities and tradeoffs that may be required. We can achieve this if we set up advanced methods on how to compare the various alternative pathways against the scenarios, looking for the best energy and technology mix that can achieve the desired results. This step must use the advanced tools and techniques that can prevent bias and overcome advocacy or approval myths and ensure competition between the alternatives not relying on the model owners and their pitch or preferences or being caught up in trends or negative connotations regarding certain solutions (i.e. avoiding nuclear power or not supporting CCS even with EOR revenue stream and support from industry (Harrison & Falcone, 2014) because we may very well need these if they are shown to be a viable alternative and outperform others in the analysis). Let the decision analysis and assessment inform and give insight on this.

By employing Decision Making Methodology, Quality and structured processes the process can be better controlled and focus on the value of the investment in Climate Change abatement measured against Climate Change risks or damage and sustainability of the future, but these can only be truly measured if we change the way we can improve funding and financing arrangements to suit. We need to move away from the decision making and rational choice based on the deterministic Cost Benefit Assessment approach to allow more advanced and unbiased selection through analysis and more analytical project appraisal routines (Jaffe, Westerfield, Ross, & Jordan, 2011). This is necessary to assist in the selection of projects and ultimately the management of a project investment portfolio where by initiatives meet the requirements. This could be applied to the planned grid designs and enabled through optimized sector and market coupling assessment to deliver an overall decarbonization benefit to all member states in the Energy Union. Decision Analysis and Decision making models can further support this, where risk, opportunities, uncertainties and options can be assessed and the best decision made on the information we have aligned to the strategic intent of the Energy Union and Climate Action cohort.

The modelling and analysis will help confirm if we are thinking straight about the decarbonization requirements and the market reforms that will be introduced, again it could help stagger or sequence the decisions and investments that may need to be taken, it allows the decision maker to defer some decisions where more value can be realized (but when such decisions are made models need to be updated and rerun to see the impact and analyze the consequences), similarly it may bring forward some options and proposals that were not considered in early stages. Or alternatively help the stakeholders focus on the critical technologies and infrastructures that are required at the various stages to achieve the targets laid out in the framework and mobilize resources and effort to achieve this. Even though the Energy Union is at a European Union level it can assist member states to redefine developments that have a mutual benefit and value. Thereby, collectively configuring the deliveries and benefits to be realized and the phases that are to be planned and implemented. This can also address the order of priority that the energy system development needs to move through before finally achieving full sector and market coupling which will deliver the energy system decarbonization and climate actions as set up in the framing of the decision.

To compliment this process the models must be baselined and updated with current energy system status and utility in order to give an indication of how best we can use current assets to meet demand or alternatively how these are modified to support the transition before they are phased out i.e. while we integrate renewable technologies and storage to replace them. Therefor at all stages we need to verify that there is sufficient capacity, generation adequacy (Kirschen & Strbac, 2004)and resilience in the system to recover from undesired events or match dynamic demand as a quality check before we take action.

Ideally the transition should be assessed and analyzed to give insight to the various stages and phases of the grid design. In addition we need to consider how change is managed (i.e. bring new energy sources on line, substitute or store and how we can select or priorities energy supplies and control the system to respond in a timely manner. All of this while we continue "business as usual" i.e. ensure supply meets demand and the grid is balanced and contains sufficient inertia so that frequency is maintained (+/- 10 % of 50 Hz). There may be solutions in the future to help synchronize and overcome these issues, but these issues cannot be neglected (including the need to enable black start and employ grid recovery methods if a failure or event were to occur).

What cannot be underestimated is the requirement for transparency at this stage, from the data, through design, to preferred options and configurations. The models too need to be user friendly and shared so that all of the modelling and analysis can be verified, updated as new knowledge comes to light or benefits of current developments and infrastructure come into play. This will also help address the uncertainties and update associated probabilities as necessary (i.e. Bayesian updates) (Hand, 2012) in subsequent decision analysis. This may change the preference or priority of the configurations and make new options more viable or feasible, or it could prove that alternatives options or design specifications need to be changed (updates on accuracy or relevance to improve objective in making good decisions and addressing decision makers' behavioral challenges in this process). This flexibility allows us to achieve the full value and realization of the benefits in a timely, transparent and unbiased manner.

Further to the above we need to ensure that we are considering the correct choices and application of the market design reforms and alignment with the EU internal market principles[108]. That is choice of energy over capacity markets, interim use of strategic reserves and storage vs. capacity mechanisms and instruments. Specifically we need a firm control over any carbon intensive strategic reserves and capacity mechanisms if they are used or deemed essential to maintain grid resilience and robustness, i.e. we need to ensure that these are not traded as spare capacity or competitive energy sources as they could distort the market. In addition subsidies, investment support, state aid needs to be thoroughly planned to suit, especially where we consider introduction of energy taxes, emissions trading schemes and carbon tax or prices in the future. The timing of these initiatives is crucial to the decision makers, as it will affect the value and budgeting or approval processes that follow in the future.

Of crucial importance here is the current process of project selection and funding process. Currently infrastructure development through Project of Common Interest with selection criteria and regulation is lacking the ability to distinguish between the alternatives, no analysis of the model outputs is evident with respect to decision-making. It relies on CBA based on review of the projects put forward by member states. The Energy Union by way of grid design or vision should be able to pin point requirements and by portfolio management (strategic whole overview concept) be able to rank projects according to priority and criticality. They should be feeding this information into the Energy System and Climate Action plans as options to pursue (not the other way around as is the case now). The incentives on offer form part of the finance and support instruments to realize these projects. This will also help address key interdependencies of the Energy Union (i.e. interconnection of a hybrid grid design which reflects the market and sector coupling mechanisms to ensure that the transition is supported collectively). This approach will also put pressure to verify and analyze output from the energy system models to see that solutions, proposals and configurations are accurate, relevant and timely. Volumes of energy flow and supply links to meet demand can be derived from the member states current and planned grid designs. This work is still to be completed and once consolidated will give a better overview of energy status and grid design and market reforms required to make it a reality.

The short-term and long-term aspects of trading (Kirschen & Strbac, 2004)aligned with the evolvement of the grid design also needs to be addressed. Short term trading and change impact on prices, must be balanced against longer-term infrastructure development. This is particularly necessary when we plan for or implement the integration of new technology and alternative energy sources and storage facilities or services as this affects the value of other actors in the energy mix (e.g. feed in tariffs or strategic reserve capacity).

The macroeconomic and microeconomic[109] analysis needs to be considered when we are considering the modelling of energy systems and the triggering of infrastructure developments. i.e. the application of macro: societal, welfare and economy aspects and how these need to be considered in the micro aspects of capital allocation for assets and project financing through state aid or funding. This is further complicated

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[108] EU Internal Market Design http://www.ewea.org/uploads/tx_err/Internal_energy_market.pdf

[109] Macro-economy EU overview https://ec.europa.eu/energy/en/data-analysis/energy-modelling/macroeconomic-modelling-and-other-modelling-activities

by the need to assess: where we are now, where we want to be in the future and how existing assets can help us in the interim until upgrades and new infrastructure or hybrid grids effectively take over (there is a threat that many assets may be left stranded in the transition instead of contributing or offering alternative utility (i.e. fossil fuel plants with some modification i.e. CCS or control i.e. use as strategic reserve or mothballed in standby to ensure security and support in transition period – complete with appropriate CAPEX or OPEX requirements).

In a similar vein it is necessary to consider the transfer the skills and workforce from decommissioned assets to the new sectors (and balance the costs and benefits thereof). This is often neglected and results in resistance to change or dis-benefit (unemployment or loss of experience or knowledge). In addition if this is not controlled properly we will have a communication or compliance issues or resistance to change affecting how all the parties can contribute collectively to help support the transition. This also applies to the need to communicate the changes envisaged and interpretation of the energy union vision, especially to the stakeholders, so that all can understand where they can contribute (i.e. avoid market failure by efficient allocation of resources and address benefits).

If there is any uncertainty or delay in a decision, there may be a need for precautionary steps or emergency interim measures if we are in danger of not recovering the pathway to decarbonization (i.e. design new gas plants with option for CCS in future if they are required to support base load, introduction of smaller nuclear stations in interim to help achieve low carbon targets or emergency energy rationing if necessary – or load shedding as it is more commonly known). In addition the countries that intend to leap frog certain energy sources (e.g. Germanys reluctance to make gas central to their energy transition) need to do so diplomatically and sensitively as they currently import ca. 40 % of Europe's gas needs from Russia, which is distributed throughout Europe.

In addition the fact that EU has been in trade talks with the USA for LNG supply, whilst ignoring the local gas resources and finds in the North Sea (which could be developed in conjunction with the CCS issues by employing EOR methods to reduce the impact and scale up the CCS efforts). This has further repercussions when embarking on long term trade deals and then announcing intention weaning off gas in near future sends the wrong signals for technology and market investment and could harm our energy security (Kuzemko et al., 2015) or costs in the future (despite best efforts to diversify).

Thus it is imperative that the Energy Union and Climate Acton policy based on the analysis of the energy system models is transparent and not determined on base case deterministic models as there must be room to accommodate uncertainty, risk and opportunities (and hence realize value and utility in their fullness). Whenever we have undertaken an energy transition Wood to Coal, or Coal to Oil. The transition has initially started with an over demand and limited supply, which artificially raised prices of the new energy source (Grin, Rotmans, & Schot, 2010). In response and through competition, opportunities to supply these new sources of energy were then exploited with vigor and systems and infrastructure to use this new source of energy put in place (i.e. create markets). However the transition was normally quickly followed by a flood of the supply product to the market to meet growing demand, but because this was not controlled the prices crashed and many suppliers were forced to close as they could not cover operational costs or repay the loans (CAPEX). Thus we must be very careful that supply (capacity) matches demand and if necessary during the transition period intervene to stabilize.

We also need to think straight about the management and regulation of the Energy Union, track-record regarding Political Union and Monetary Union have been fraught with implementation challenges (Howlett et al., 2009) and in some cases the transition and compliance has taken years and concessions, compromises and market failures. Although the energy union makes sense, we cannot ignore that some countries require substantial investment and aid to join and participate in the union, that said many countries are dependent on the fossil fuel (Oil, Gas and Coal) industry for fuel supply that secures employment and export revenues. Energy aside, the loss of this revenue and socio-economic security in the short term needs to be considered carefully (despite the benefits of clean, secure and affordable energy on offer).

This argument goes two ways as we must be careful what markets we trade in, we may achieve utopia by transitioning to clean, secure and affordable energy, but the increase in price due to system transition costs and compounded or closure of industry and digitalization or automation threats (and opportunities) will mean that we may stagnate growth in some sectors, or end up in a vulnerable service sector economy where skills are not transferrable without significant re-training or relocation (i.e. no manufacturing, production or agriculture and then rely on import of goods and products (which ironically could originate from countries that have not embarked on the energy transition and flout the very targets and objectives we are trying to achieve).

Despite the concerns noted above, we need to maintain the collective urgency (Geels & Frank, 2014) to undertake the transition and encourage others to join us. We need establish how fast we can transition whilst maintaining social and economic stability and if possible avoid recession and reiterate what benefits society, industry and the economy could enjoy (i.e. export green energy, development and export of technology that could assist other regions on their transition or the sharing of transition experience (i.e. opportunity to relocate to other sectors or address new challenges identified in the transition process to avoid mass unemployment or worst case be uncompetitive in trade and power in the international markets).

So to that end does the reasoning here develop a clear, transparent and understandable recommendation that maximizes the values of the decision maker? Yes, but we need more analysis and assessment of the options and strategy to understand the magnitude and impact of the changes and the resources, efforts and designs that are required and continuously compare this to the scenarios where we do not take the appropriate corrective steps. But we should always be mindful of what is being proposed, down to the design, resource and material constraints or limitations, e.g. in order to electrify the energy sector will require extensive development of infrastructure which will use up copious amounts of copper and rare minerals (Perman, 2011). Have we budgeted or planned for this? If the whole world embarks on such ambitious transition plans, will we have enough raw materials or by being "first mover" and capitalizing on these markets will we create a whole new crisis and security concern in the future. Or will we be able to take this opportunity to help find alternative materials, solutions and technologies that are sustainable in order to help other parts of the world with their transition in the future to correct the damage we created during the industrial revolution and by doing so enable other countries to enjoy the benefits of a social and economic development that they deserve. Question is how do we put a price on this?

Commitment to action

There can be no doubt that the EU will take action as per the vision to interconnect the energy system and regulate through market reforms. Budges have been allocated and a proposal for the next commission is underway. But we need to ask ourselves if the correct actions are being taken. Whilst the benefits of the current PCI projects are under way (gas lines in the north and south of Europe, synchronization projects with the Baltic states and interconnectors on the mainland in Norway, UK, Denmark and Germany), it must be said that these were approved prior to sufficient knowledge or understanding of the energy mix and transmission requirements that would be required and before the grid design and markets were formally established (i.e. before volumes and flows and import/export ambitions were confirmed, or generation capacity and adequacy issues have been resolved which are detrimental to grid design and market functions to support these are finalized).

As mentioned in the Sound Reasoning section above, one of the most crucial activities is to process the results of the technical and economic analysis derived from the energy system model results, these too need to be updated with recent feedback from the member states regarding energy system plans and climate action initiatives. In combination with inclusion of risks, uncertainties and opportunities identified by accommodating proposals on energy mix; a complete European wide framework can be developed complete with grid design and steps to be taken to achieve this to build on the transition efforts and ensure that this remains on track and represent best value.

This cannot be achieved by applying the EU PCI project approval process as it stands[110]. It needs to be done by undertaking professional decision analysis and risk analysis which will take the values from the energy system models presented earlier. This in turn needs to be analyzed according to Decision Making, Risk and Uncertainty frameworks and the spread of results and options presented to the Decision makers so that they can take informed decisions and not rely on a few shortlisted proposals that meet individual CBA requirements. This will help stagger and develop the investment and grid development apace and also provide clarity to current suppliers and retailers while the transition is underway. The current approach has resulted in lack of visibility with respect to capacity, adequacy and reserve requirements and thus has instilled a degree of uncertainty in many of the stakeholders and benefactors of the Energy Union. Already as a result of this oversight the grid is could have an energy shortfall in the near future as investment is withheld. But this offers an opportunity to an energy provider who is new to or already established in the market to provide energy to cover this shortfall should the infrastructure be made available. This could easily be resolved through communication and transparency of the process.

[110] PCI Energy Days https://ec.europa.eu/info/news/come-and-discover-benefits-interconnected-energy-grid-2019-mar-01_en

What may require some additional training is how to manage the implementation phase through decision analysis and project selection and execution. This cannot be left to short-term quick win or best pitch/advocacy or approval methods as currently applied in policy implementation methods. Indeed it cannot be determined by voting or rational choice alone if the analysis, assessment and comparisons of options and selection processes to inform the decision makers is not in place and the decision makers are not fully versed in the concepts or confident in the proposed benefits to be achieved (e.g. hybrid design, or interconnected grid capacities). Also there needs to be an understanding between Energy and Climate sector regarding what is feasible or essential in the transition phase and how we can achieve this i.e. how to deliver clean, secure and affordable energy while continuing to manage the grid (supply & demand, grid balance and stability) whilst accommodating the integration of renewable and smart technologies.

Without a grid design designed to meet the targets at said milestones, we cannot justify or verify the recommendations or proposals. Indeed we cannot begin to solve the problem in a timely and effective manner if this is not in place. It is noted that the stakeholders have repeatedly asked for this, and requested clarification beyond the policy, regulations and directives that have been delivered to date. Due to lack of transparency regarding market reforms and introduction of transition instruments (carbon tax, energy tax, emissions trading etc.) many actors have delayed changes or innovative projects until grid issues and project policy frameworks have been established. This delay is not helpful as renewables are not able to absorb all energy demands in the near future and we need to allow for interim measures in capacity to support the transition process until new technologies and services are available and proven.

If we change the decision process it will be much easier to communicate and understand how the decisions are made and indeed what decisions are necessary. It will also trigger the correct signals for future development and opportunities. Member states will be able to offer to support the process by building it into strategic plans. This includes policy framework on how to collectively manage security and events. It will also make it easier for the EU and National governments to support the transition process, reduce resistance to ratify and thereby ensure that the implementation phase is effective and sustainable. Maybe initially we have benefitted through some quick wins (e.g. efficiency and energy intensity reduction) and have benefited from some obvious high impact projects (e.g. interconnector upgrades by countries already mature in the transition process like Germany, Denmark and UK). But if we consolidate the Energy Union plan and implementation phase more benefits of energy system changes, energy union and climate actions will be more clearly understood, supported but more importantly justified and accepted. This will ensure that the PCI projects are designated correctly and backed up by unbiased assessment and analysis.

Whilst the EC and EP may support the decisions politically through qualified majority voting and rational choice, the detail to support these decisions is not available. It is interesting that the policy, regulation and directives were drawn up before the grid design is finalized or agreed (this may be due to fact that current commission ends its term in office on 31 Oct 2019). Despite the combined DG Energy & DG Climate efforts and election of ENTSO E, ENTSO G and TNE-E and ACER [111]groups working alongside DG Climate and Environment, it must be understood that these competent bodies do not have a full overview themselves yet and as such it is difficult to give steer and feedback to the stakeholders.

In my opinion the recent generation of policy, regulations and directives may have been a little premature and that until we have reviewed and consolidate the big picture this should not have proceeded so quickly to legislation, when serious decisions regarding design and market reforms are still to be made. But it is also understandable that a version did need to be submitted before a new commission is nominated in order to ensure closure and continuity. That said many members of the DG, ENT and TNE should remain in position when the new commission is in place so there is further confidence for continuity as the EU have ensured that and that there is now a good degree of energy system and modelling competence in the various member states to ensure that the plans can progress and if we manage to integrate formal decision analysis, assessment and selection of the various options we will be able to manage the PCI and Implementation phase.

But for the moment we can deduce that there is no formal implementation plan as such, but as stated earlier there is sufficient budget to start the implementation phase over the next 2 years while the plan is developed. In addition the ECB and EFI are ready to support the implementation phase (but if the PCI process was improved i.e. to follow a decision making framework, this would result in much better value on the investment for the stakeholders and meet the objectives of the exercise). It is also ironic that the transition requires market signals to invest, yet the market cannot trigger the correct signals now as the grid system changes and energy trading mechanisms are not defined or known in detail therefore state intervention is required and it may be required throughout the transition period. In addition the grid should be designed to take advantage of the interconnected market and sector coupling which is not described in any great detail in the policy issued, as current market reforms focus on the electricity market only and are applied regionally where bilateral agreements are already in pace. However this can be addressed if future design is communicated more readily.

Until this is achieved we will not know the precise budgets, financing, resource allocation and coordination or regulation requirements (but there are currently sufficient funds these cover all eventualities in the interim until resolved). More importantly we will not know if we made the correct choice to reflect priority or value – and this will materialize through the decision analysis and associated budget setting process. Whilst we are on track to deliver and even exceed the 2020 Nationally Determined Contributions and targets collectively as the EU, but if we don't get this next project selection and implementation phase correct we may jeopardize the 2030 targets and if there is an incorrect strategic choice or delay in execution in the some of the 7-10 year implementation phase for some of the projects envisaged we will definitely not achieve the 2040 interim or the 2050 targets.

[111] Governance https://data.consilium.europa.eu/doc/document/PE-83-2018-INIT/en/pdf

To compound this, barriers to trade (internal market rules), jurisdiction issues and regional issues may present additional unforeseen issues, we need to select the correct grid design and energy market designs to overcome or accommodate these. That said if it is necessary to have a market hybrid design until (i.e. combination of pro-risk Energy Only Markets and a mixture of risk averse Capacity Markets, including associated strategic reserves and capacity mechanisms, until the grid is developed sufficiently then we must communicate this strategy to all. This is necessary in order to reduce confusion and hesitation to participate in the market and reduce the need to introduce national or regional measures to protect member states). In addition we are vulnerable to external events disrupting the grid and may be exposed geopolitically when dealing with energy imports regarding suppliers of fossil fuels[112] (mainly Natural Gas or LNG in the interim).

Responsibility and accountability needs to be more readily defined with regard to the Energy Union and as the EU wishes to take a more prominent role in regulation and intervention, these responsibilities and accountabilities need to be more effectively communicated. Thus the EU may need to prepare and organize itself to absorb more responsibility, especially regarding security and trade functions, where currently nations are left with the responsibility to organize their own internal markets, grid recovery and security arrangements – the EU may need to perform a more active coordinating and governing role in the future.

In addition to the implementation phase and project of common interest infrastructure portfolio, the issues concerning subsidies, taxes and state aid need to be addressed as a priority; otherwise these issues will affect investment and returns in the long run. These issues coupled with potential for some regions to trade strategic reserves or spare capacity may distort the market (as opposed to regulated auctions and bids which can be monitored and controlled much more effectively). In addition the reliance on imports from countries where trade deals are fragile, geopolitical tensions are evident and uncertainty surrounding long term contracts and source need to be addressed as soon as possible before energy supply security of the energy union is affected, including the use of strategic reserves that rely on transfer or flow of energy sources through or from other countries (Hughes, 2009)(e.g. Ukraine transit lines and Germany which acts as a gas hub to Russia or alternatively the EUs agreement to import LNG form USA despite their withdrawal from the Paris Agreement, which both will have effects on local gas and LNG markets and could be considered missed opportunities in the context of EU internal market and more seriously affect the EU energy security in the future).

[112] Grid Security https://data.consilium.europa.eu/doc/document/PE-73-2018-INIT/en/pdf

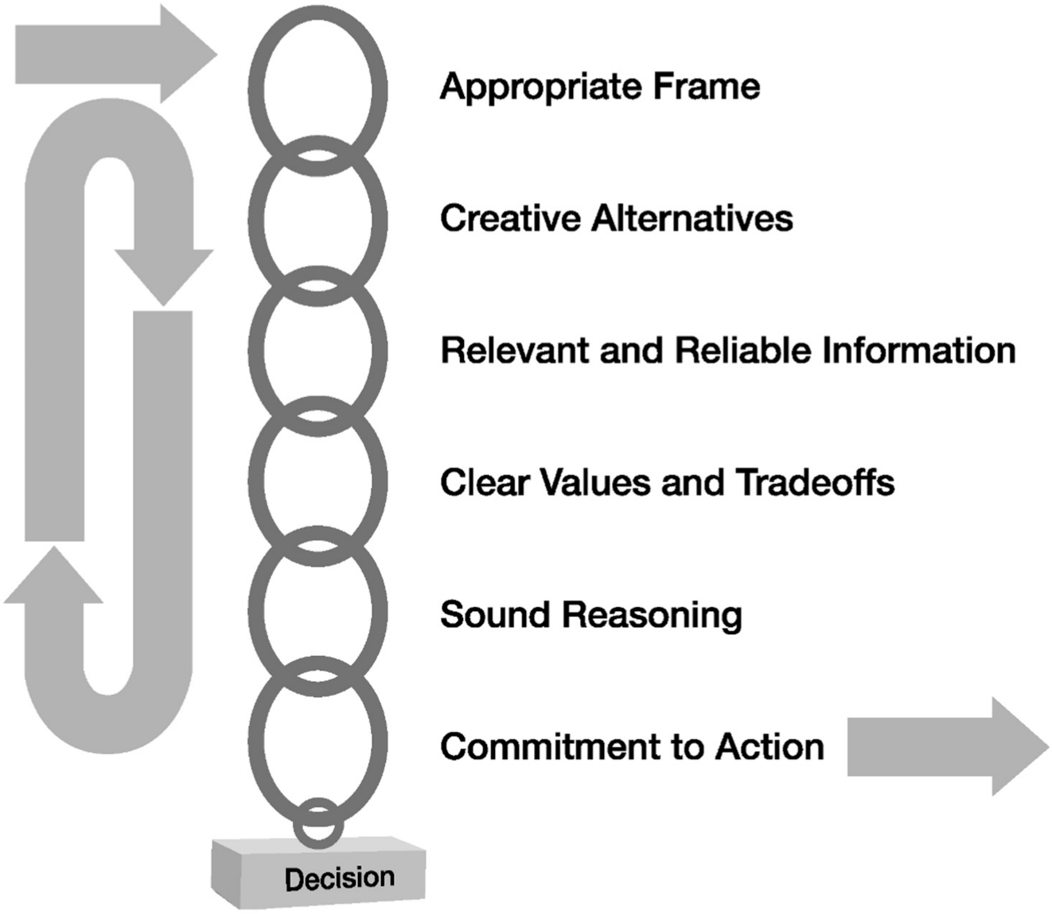

Fig 36. Decision Quality – commitment to action (Spetzler et al., 2016)

In summary, we can see that the application of the decision quality framework above and subsequent analysis has raised some interesting issues and concerns, challenges and opportunities. But the true values and benefits described above, applied to the current decision process, will need to be assessed more thoroughly. This is necessary to improve the overall decision quality and ensure commitment to implement the changes to enable us to meet the strategic objectives in a more formal and structured way. It may attract some additional cost and overheads, but then the decisions will be the best we can achieve based on the information we have and we can have confidence that due diligence with respect to decision making has been performed.

Discussion

As we can see a significant effort has been made to grapple to issues surrounding energy system changes and a market reform to address environmental concerns and support climate action requirements is evident. The culmination of 10 years work to deliver energy policy, regulation and directive is backed by strategic research and development that deserves recognition. It is no easy task to deal with such a complex issue and as such it is relief to see that so many issues have been included and assimilated into the studies and proposals. The ability to deliver an energy union focused on decarbonization and integration of alternative energy sources whilst addressing security and reliability requirements is impressive, however it is obvious from the decision quality analysis in the preceding section, that there are still areas of uncertainty and conflict. Many of these issues will not be resolved by application of the normal and established routines in decision making and deterministic rational choices or voting mechanisms with in the EC and EU. Maybe energy system design and cohesion is beyond these traditional tools and therefore a new approach needs to be employed especially where serious amounts of investment capital and operational costs are at stake to deliver a clean, secure and affordable energy to consumers. On reflection it may also be deduced that there are many processes or issues pertaining to current energy modelling and analysis that require clarification, validation and verification before the implementation phase begins in earnest.

From the analysis it can be seen that a form of decision and risk analysis and project selection, comparison and selection is required. The actors and stakeholders still need guidance with respect to future grid design (sector coupling) and market reforms (market coupling) in order to proceed with confidence. Given the copious amount of work completed it would make sense to consolidate this through strategic decision making framework that meets the decision quality issues raised in the framework above.

This will help confirm that stakeholder requirements have been addressed and that a formal process is in place to help frame the problem (communicating what will be decided and what will not be decided). Furthermore it can set the tone for how the many alternatives and solutions can be grouped ranked and compared to the objectives that are set by the EC. This then allows for a controlled and unbiased selection of the options and choices available to be followed through in order to address the scenarios and energy mix configurations that are available to tackle the problem.

To this end given the vast support for energy system models and research, with some additional decision analysis they could start to develop flexible grid proposals built on electrification, decentralization and using digitalization and design criteria (limits, types, volumes, and optimal mix) it would be much more appropriate and convenient if the EC could develop an outline of the hybrid grid design proposals based on their vision and demonstrate that the market reforms are viable and to suitable instead of the member states trying to resolve at a local level and missing opportunities in market coupling and possibilities. That is that the envisioned market design is realistic and the EC can demonstrate the opportunities of the hybrid model and transmission expansion to satisfy supply and demand needs (currently focused on demand side management and consumers). That included addressing the sector coupling and market coupling issues that are to be realized in order to satisfy the energy union and climate actions can be demonstrated. Most models and forecasts rely on long-term energy scenarios to resolve the challenges and support decisions. However the transition period and short-term operation and changes are neglected. This may contribute to the uncertainty and risk on how to proceed. It is therefore important that we address this. At the moment there seems to be a mixture of alternatives, which may all play a role in the transition, but ultimately we need to decide on the options that will best support the future energy system (e.g. capacity or energy only markets, flexibility over strategic reserves or capacity reserves).

This will assist the member states with their own grid planning and climate action objectives. It will turn allow any gaps in information or knowledge will be highlighted and decisions can be made to further develop this or make a decision based on optimal analysis (e.g. wind versus hydro development, or Power to Gas preferences, transmission line expansion and interconnection vs. decentralized local hybrid heating and transport grids to reduce grid load.

In addition we can explore that the decisions offer the best value in addressing the consequences we care about. Tradeoffs between different configurations and opportunities can be better assimilated and we will be able to confirm that the choices are logical and have considered all the factors and issues at hand to deliver the best value at that time i.e. using natural gas to produce hydrogen or determining the storage capacity and battery capacity we need. If we ensure that we have a formal selection and approval process, it will avoid any sub-optimal investments or go ahead for infrastructure that otherwise will not be fully utilized or effectively help resolve the decarburization challenges we face.

The problem is when researching the Energy Union Policy and Decisions supported by the Energy System Modelling is that all of the options look viable and doable and it is hoped that in some way the invisible hand of the market will help decide which way the grid design will develop or indeed which market reforms are required for intervention. But by state intervention and discussion of various new or resuscitated market instruments will be introduced to intervene as necessary (e.g. Emission Trading Schemes, Carbon Tax, Carbon Prices and Subsidies and State Aid). But we have already constrained or forced the markets hand by embarking on the transition.

That said it is also apparent that not all energy system plans and climate actions are aligned with the EU internal market rules and that there is insufficient analysis or assessment of the various alternatives. We have already seen a series of investigations whereby the EU has approved capacity markets and state aid allocation only to retract or investigate areas of concern (e.g. UK capacity auctions over 100 kWh which discounted renewable energy companies or Germany's state aid for renewable transition and investigation into internal subsidy of lignite coal plants which prolonged operation in 2019). This raises another important point the only restriction listed in the policy is that there will be no more subsidies for any power plants with emissions over 550 g CO2 /kWh. This rules out most coal and lignite plants, but instead of investigating or pursuing CCS options (which is a solution required world over) the priority is to shut these plants down and fast track renewable services from neighbouring countries to fill this void. For many of these countries the transition support programme to help the individual countries transition their work force from fossil fuel to renewable energy services has come too late and the countries have already lost the market opportunity to become self-sufficient or developed in renewable energy (e.g. Poland where coal is still predominate, gas is preferred alternative and wind is struggling to penetrate or get approval (Equinor, NTNU, 2019).

It is also apparent that a number of member states are at various system maturity positions regarding the development of their power systems and that the first wave of projects and investments may be directed at suboptimal investment projects as a result (which may not offer the best value or strategic choice) and result in hindering the desired impact on decarbonization targets. Misplaced investments could also result in a lack of access to the grid or markets for renewable integration sources, in addition if there are restrictions in transmission or congestion levels and no storage solutions or CCS options are available, as currently experienced, this may exacerbate the situation and if the correct power capacity and generation adequacy levels are not maintained (or strategic reserves are not planned) this could leave certain countries vulnerable and even subject to load shedding or blackouts (Engie Tractable report Energy Shortage 2023-2025, EPRG Cambridge, May 2019). If transmission, distribution and storage issues are not resolved we may end up with a capacity glut in some regions and power shortage in others, which will also affect how we balance and manage the grid (North South Germany dilemma). This need still be addressed in the grid design and market reforms and there are many issues like this that have not been resolved to date (wind and solar flexible grid and hydro capacity and pumped storage via Norway debate or decision! NTNU Energy Transition Week 2019)

Despite best efforts to assimilate an extensive topic exacerbated by the analytical and organizational complexities of the Energy Union, the study was limited to publically available information, this was deliberate in order to understand the decision process and climate actions based on information that was readily available, therefore the study was not privy to any behind the scenes discussions or thoughts as such. That said it was able to participate as a stakeholder in the process and also position the researcher as the “consumer or customer” which is central to the new energy union system and market model and therefore supplied with all the information and transparency afforded to all consumers worldwide.

By doing so it was possible to pick up on contradictions and concerns from following the policy roll out real time and participate in the many public and special interest workshops and seminars that were available to the consumer as the energy union policy and process unfolded. This provided a significant volume of information and communications, especially as the commission neared the end of its term and finalized the process to be in a position to ensure “closure” for the outgoing commission and some form of “continuity” when the new commission picks this up later in the year.

However it is recommended that given the changes regarding Decision Making at policy level shifting from unanimity to qualified majority voting as highlighted in this study, it is essential that we follow up to see when (not if) the energy union and market reforms are approved, how well and how soon the energy taxes and carbon taxes are introduces, how well subsidies and state aid is regulated and the reaction by the member states, how quickly these issues are implemented and if there are any objections to the policy reforms or resistance to ratify (as experienced with the 3rd energy package previously). It would also be interesting to know if any clarifications or policy amendments or dispensations are requested.

More importantly it will be interesting to see if the EU Energy Union releases or is pushed by the member states to provide a template and framework for the new hybrid grid and gives an indication of which market design will prevail and in the interim how well the EU coordinates the regulatory and governance of infrastructure and projects of common interests over the next two years and if the EU will reform the CBA methodology used to make energy system decisions for selection and approve projects (Infrastructure Forum, 23 May 2019) and replace it with a process which focuses on decision analysis and employs a decision quality approach to improve decision making as this will represent the make or break for optimal investment choices and financing decisions.

Conclusion

During the course of this research we have managed to gain an improved overview of the Energy Union and appreciate the efforts and process involved in delivering energy policies. By reviewing this policy we have established. Through application of the Decision Quality framework numerous points and issues, challenges and opportunities in the EU's Energy Union policy process were highlighted and identified.

We were able to critique if the: appropriate framing, assessment of alternatives, communication of information, consequences or values, logical reasoning and analytical assessment were sufficiently developed and analyzed to support the policy development and implementation. Furthermore we could quality appraise the efforts required or in place to support the project selection and financing of activities to ensure effective commitment to energy transition and climate actions.

The issues and points raised in the analysis need to be revisited as they will have a detrimental effect or bearing on the decision makers ability to make good decisions. It is also essential that some decisions regarding grid design and market reforms are revisited to verify and validate the decision by application of a more structured decision and risk analysis methodology. If not we may be left with poor decisions, sub optimal investments, low value, loss of benefits or a waste of resources. A more analytical and assessment methodology will better support the decisions made and hence improve the sustainability of the policy to embark on a more effective planning and implementation phase.

To directly answer the research question regarding opportunities and challenges associated with the energy union strategy and delivery, we can see that we are "committed to action" through the policy planning, implementation, but through the decision quality appraisal and the application of better alternative analysis we can verify and validate that we are taking the right actions. Hence we need to apply improved decision analytical tools and assessment criteria to support the decision makers and ensure they make an informed decisions – this can be derived from the decision-making methodology. It is also imperative that we create a transparent and structured approach so that decision makers are informed with all the assessment and analysis to compare the alternatives, that this is transparent. This should also be available to all stakeholders so that they are informed and actively encouraged to participate in the Energy Union.

Decision analysis and assessment quality needs to be enhanced, supported by the tools and techniques that facilitates informed decision-making – regarding grid design and market reforms there are many opportunities to be realized or leveraged but there are equally many alternatives that can be discounted. Decision and Risk analysis through quality controlled decision-making methodology can achieve this. This must be done so that we do not waste resources and efforts pursuing alternatives that are not required now, focus on the critical deliveries and projects and defer projects that offer more value to a point as and when required or resolve technical confidence and uncertainty so that they are viable and feasible at point of requirement – in doing so we will ensure that we take the appropriate response and timely actions!

Recommendations

After the decision quality framework was applied and on researching the subject in more detail, it was interesting to discover that decision quality could be further extended to include a decision dialogue to compliment complex decisions, it is recommended that is followed up this was deemed important to consider and the dialogue and structure required to support the decision quality theory and framework in this thesis was updated to include this concept so it could be assessed for its potential to resolve some of the analytical and organizational complexity that was witnessed in applying the decision quality framework to the EU Energy Union. This should be followed up and some theory and application of this concept can be found in Appendix A.

Furthermore it is recommended that a Quantitative assessment be undertaken to compliment the qualitative work in this thesis. By putting so it can gather or use the data available to run calculations and apply analytical techniques to investigate several issues noted in the decision quality analysis i.e. verify the Cost Benefit Assessments to see if these can be converted to an Investment Benefit Assessments. Model Capacity Market performance against Energy Only Markets approach to assess which design best suits the future grid and supports energy transition. To enable that we need a much better insight into: Generation Capacity and Adequacy, use and management of Capacity Reserves. Strategic Energy Reserves, enhancement requirements to facilitate Cross Border Market arrangements that can overcome Regional or Zonal Barriers and Jurisdiction issues,

In addition we need to start addressing potential design constraints and limitations or determine future grid energy parameters, volumes and functionality, controls and requirements. This needs to be undertaken for the energy mix and Hybrid Grid Design so that we can start working on design proposals and options to meet market needs to support the transition. Many stakeholders have requested that framework to support this needs to be made available by the EU so we can ensure that it complies with Energy Union requirements and all stakeholders are strategically aligned.

References

(Accessed between January 2019 – June 2019)

1. UN IPCC Report 1,5 https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf
2. EU A clean planet for all https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf
3. WEO 2018 Reporthttps://webstore.iea.org/download/summary/190?fileName=English-WEO-2018-ES.pdf
4. EU 3rd Energy Package https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/third-energy-package
5. Paris Agreement COP 21 http://www.cop21paris.org/about/cop21
6. IRENA IEA REN 21 Renewable policies https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_IEA_REN21_Policies_2018.pdf
7. DNV GL Energy Transition Outlook 2018 https://eto.dnvgl.com/2018/download
8. CICERO What does well below 2D mean https://cicero.oslo.no/no/posts/klima/well-below-2c
9. EU Energy Figures 2018 https://europa.eu/european-union/topics/energy_en
10. EU climate change adaptation https://ec.europa.eu/info/sites/info/files/climate_change_adaptation_booklet_2018.pdf
11. EU 2050 vision and strategy https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN
12. EU graphics 2050 https://ec.europa.eu/clima/sites/clima/files/strategies/2050/docs/long-term_analysis_in_depth_analysis_figures_en.pdf
13. EU long-term strategy 2050 https://ec.europa.eu/clima/sites/clima/files/long_term_strategy_brochure_en.pdf
14. EU Priorities https://ec.europa.eu/commission/priorities_en
15. EU Regulation at the heart of DM http://europa.eu/rapid/press-release_IP-19-2117_en.htm
16. EU Energy Union https://ec.europa.eu/commission/sites/beta-political/files/euco-sibiu-energy_union_and_climate_change_policy.pdf
17. EU Energy Long Term Strategy https://ec.europa.eu/energy/sites/ener/files/documents/final_draft_asset_study_12.05.pdf
18. EU State of the Union Facts http://europa.eu/rapid/press-release_MEMO-19-1875_en.htm
19. EU State of the Union Speech 09 April 2019 http://europa.eu/rapid/press-release_SPEECH-19-2073_en.htm
20. EU Energy and Climate Speech 09 April 2019 http://europa.eu/rapid/press-release_SPEECH-19-2072_en.htm
21. EU Set Plan https://ec.europa.eu/info/news/making-energy-transition-happen-locally-interest-growing-12th-set-plan-conference-2019-may-29_en
22. EU Climate Neutral 2050 http://europa.eu/rapid/press-release_IP-18-6543_en.htm

23. EU A clean planet for all https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf
24. EU A clean energy for all Europeans https://publications.europa.eu/portal2012-portlet/html/downloadHandler.jsp?identifier=b4e46873-7528-11e9-9f05-01aa75ed71a1&format=pdf&language=en&productionSystem=cellar&part=
25. EU State of the Union Facts https://ec.europa.eu/commission/sites/beta-political/files/factsheet-energy-union-priority_april2019.pdf
26. EU 4th State of the Energy Union https://ec.europa.eu/commission/sites/beta-political/files/fourth-report-state-of-energy-union-april2019_en_0.pdf
27. EU Energy Consumers Focus https://ec.europa.eu/energy/en/topics/markets-and-consumers/consumer-rights-and-protection
28. Markets & Electricity https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/electricity-market-design
29. Master Thesis L D'hont https://lib.ugent.be/fulltxt/RUG01/002/480/358/RUG01-002480358_2018_0001_AC.pdf
30. Impact Assessment https://eur-lex.europa.eu/resource.html?uri=cellar:e4c834ae-b7b8-11e6-9e3c-01aa75ed71a1.0001.02/DOC_5&format=PDF#page210
31. H2020 Modelling R&I programme http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/climate-sustainable-development_en.htm
32. Markets and Consumers https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/electricity-market-design
33. Market Reform https://europa.eu/rapid/press-release_MEMO-15-5351_en.pdf
34. Market Retail http://europa.eu/rapid/attachment/MEMO-15-5351/en/Retail%20Market.pdf
35. IEA MEM Model Klaus https://www.researchgate.net/figure/Overview-of-IEAs-World-Energy-Model_fig1_322951643
36. Electrical grid https://en.m.wikipedia.org/wiki/Electrical_grid
37. New market rules https://ec.europa.eu/energy/sites/ener/files/documents/electricity_market_factsheet.pdf
38. Energy Market Observations https://ec.europa.eu/energy/sites/ener/files/documents/emos_june2018_final.pdf
39. Macro econ EU overview https://ec.europa.eu/energy/en/data-analysis/energy-modelling/macroeconomic-modelling-and-other-modelling-activities
40. Public consultation new market design https://ec.europa.eu/energy/en/consultations/public-consultation-new-energy-market-design
41. Public consultation energy security https://ec.europa.eu/energy/en/consultations/public-consultation-risk-preparedness-area-security-electricity-supply
42. Clean energy for all https://ec.europa.eu/info/news/clean-energy-all-europeans-package-completed-good-consumers-good-growth-and-jobs-and-good-planet-2019-may-22_en
43. Energy Infrastructure Forum 23 & 24 May 2019 Copenhagen YouTube https://www.youtube.com/watch?v=-myqMqXncKs

44. 2016 market consultation proposal https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v11.pdf and https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v11.pdf
45. Directive market electricity https://data.consilium.europa.eu/doc/document/PE-10-2019-INIT/en/pdf
46. Regulation market electricity https://data.consilium.europa.eu/doc/document/PE-9-2019-INIT/en/pdf
47. ACER governance https://data.consilium.europa.eu/doc/document/PE-83-2018-INIT/en/pdf
48. Grid Security https://data.consilium.europa.eu/doc/document/PE-73-2018-INIT/en/pdf
49. ECT https://ec.europa.eu/info/news/energy-charter-treaty-commission-asks-mandate-negotiate-modernisation-investment-provisions-2019-may-14_en
50. Energy Infrastructure Forum Copenhagen May 2019 documents summary https://ec.europa.eu/info/sites/info/files/20190524_conclusions_of_the_2019_energy_infrastructure_forum_final.pdf webpage https://ec.europa.eu/info/events/energy-infrastructure-forum-2019-2019-may-23_en agenda https://ec.europa.eu/info/sites/info/files/final_energyinfrastructure2019_programme.pdf
51. Models and impact assessment https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0410&from=EN
52. Third energy package https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation
53. Market design https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation
54. Energy Only Markets vs. Capacity Markets https://www.next-kraftwerke.be/en/knowledge-hub/energy-only-market/
55. Market Design Evaluation Framework Internal Steering Group for Pathways http://ec.europa.eu/smart-regulation/roadmaps/docs/2015_ener_061_evaluation_eu_electricity_market_en.pdf
56. Market Design Evaluation https://ec.europa.eu/energy/sites/ener/files/documents/1_en_autre_document_travail_service_part1_v2.pdf
57. EU Modelling https://ec.europa.eu/energy/en/content/metis-1-dissemination-event-20022019-brussels-ccab
58. Energy taxes withdrawn http://www.europarl.europa.eu/legislative-train/theme-deeper-and-fairer-internal-market-with-a-strengthened-industrial-base-taxation/file-taxation-of-energy-products-and-electricity
59. EU energy tax proposal https://ec.europa.eu/taxation_customs/business/excise-duties-alcohol-tobacco-energy/excise-duties-energy/excise-duties-energy-tax-proposal_en
60. EU energy taxation presentation https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/review_of_regulation_en.pdf
61. EU MÉTIS https://ec.europa.eu/energy/en/data-analysis/energy-modelling/metis/metis-studies

62. EU METIs PRIMES Model Markets https://ec.europa.eu/energy/sites/ener/files/documents/ntua_publication_mdi.pdf
63. E3M Modelling Markets https://ec.europa.eu/energy/sites/ener/files/documents/ntua_publication_mdi.pdf
64. EU Energy Reference 2016 https://ec.europa.eu/energy/sites/ener/files/documents/20160712_Summary_Ref_scenario_MAIN_RESULTS%20%282%29-web.pdf
65. EU. Modelling POLES http://publications.jrc.ec.europa.eu/repository/bitstream/JRC113757/kjna29454enn.pdf
66. Model POTEnCIA https://ec.europa.eu/jrc/en/potencia
67. Model Set NAV https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/system-modelling/set-nav and website http://www.set-nav.eu/content/set-nav-modelling-workshop-24%C2%A0-%C2%A025-november-2016-trondheim-norway and Modelling comparison http://www.set-nav.eu/sites/default/files/common_files/deliverables/WP10/Issue%20Paper%20on%20Hybrid%20Modelling%20Linking%20and%20Integrating%20Top-Down%20and%20Bottom-Up%20Models.pdf
68. SET NAV Website https://data.ene.iiasa.ac.at/set-nav/#/about
69. REEEM Energy System Modelling http://www.reeem.org and EU H2020 https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/system-modelling/reeem
70. REFLEX EU http://reflex-project.eu and https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/system-modelling/reflex
71. MEDEAS https://www.medeas.eu/news/medeas-organises-third-energy-modelling-platform-europe-emp-e-2019 and website MDEAS https://www.medeas.eu/#block-views-model-block
72. Energy Modelling for Europe Implementing Clean Energy for All http://www.energymodellingplatform.eu/home-emp-e-2019.html
73. EU Energy Law https://eur-lex.europa.eu/summary/chapter/energy/1802.html?root=1802
74. EU Energy Policy https://eur-lex.europa.eu/summary/chapter/energy/1801.html?root=1801
75. Energy, environment and climate https://europa.eu/european-union/topics/environment_en (interesting that agriculture not here too)
76. Implementation of Policy https://s3.amazonaws.com/academia.edu.documents/33366842/Implementation.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1559238400&Signature=gWqICHIBW5dCENldkWmq0t3nvv0%3D&response-content-disposition=inline%3B%20filename%3DCONCEPTUAL_FRAMEWORK_THE_IMPLEMENTATION.pdf
77. CBA EU https://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf
78. State Aid Poland http://europa.eu/rapid/press-release_IP-19-2150_en.htm
79. State Aid Lithuania http://europa.eu/rapid/press-release_IP-19-2230_en.htm

80. State Aid Slovakia http://europa.eu/rapid/press-release_IP-19-2469_en.htm
81. State Aid Germany http://europa.eu/rapid/press-release_IP-18-3966_en.htm
82. EU PCI Project http://europa.eu/rapid/press-release_IP-19-561_en.htm
83. EU RES Innovative Investment http://europa.eu/rapid/press-release_IP-19-1381_en.htm
84. EU Qol investmenthttp://europa.eu/rapid/press-release_IP-19-1128_en.htm
85. EU Tab change in voting for DM http://europa.eu/rapid/press-release_IP-19-225_en.htm
86. EU Tax savings http://europa.eu/rapid/attachment/IP-19-225/en/Moving%20to%20QMV.pdf
87. EU in USA https://ec.europa.eu/info/news/vice-president-sefcovic-joins-us-president-trump-opening-lng-export-terminal-2019-may-14_en
88. ECT Modernization https://ec.europa.eu/info/news/energy-charter-treaty-commission-asks-mandate-negotiate-modernisation-investment-provisions-2019-may-14_en
89. PCI Infrastructure https://ec.europa.eu/info/news/come-and-discover-benefits-interconnected-energy-grid-2019-mar-01_en
90. PCI Energy Days https://ec.europa.eu/info/news/come-and-discover-benefits-interconnected-energy-grid-2019-mar-01_en
91. EIB Project Appraisal https://www.eib.org/attachments/thematic/economic_appraisal_of_investment_projects_en.pdf
92. EU investigate UK Capacity Market http://europa.eu/rapid/press-release_IP-19-1348_en.htm
93. EU progress to an internal energy market https://ec.europa.eu/energy/sites/ener/files/documents/2014_iem_communication_1.pdf
94. EU DM and policy in the energy and climate change https://ec.europa.eu/commission/sites/beta-political/files/communication-efficient-democratic-decision-making-eu-energy-climate-april2019_en.pdf
95. Energy Markets Kraftwerk https://www.next-kraftwerke.be/en/knowledge-hub/energy-only-market/
96. Energy Markets Statnett Analysis https://www.statnett.no/globalassets/for-aktorer-i-kraftsystemet/planer-og-analyser/2015-A-European-Energy-Only-Market-in-2030
97. Capacity Mechanisms for Europe electricity http://www.europarl.europa.eu/RegData/etudes/BRIE/2017/603949/EPRS_BRI(2017)603949_EN.pdf
98. Understanding electricity Markets Europe http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf
99. Development of Markets in Europe http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf
100. Internal Market Design http://www.ewea.org/uploads/tx_err/Internal_energy_market.pdf
101. Trans Euro Energy Structure https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0347&from=en

102. UKERC Issues, Opportunities and Challenges http://www.ukerc.ac.uk/asset/6E6348E9%2D26B3%2D4E6F%2DAEADEE86AF14E5D9/
103. UKERC programme http://www.ukerc.ac.uk/asset/D4B77761%2D9378%2D4AEE%2D8856472BC0E7C9C2/
104. SDG Thought Leadership https://sdg.com/thought-leadership/webinars/
105. NTNU energy Transition https://www.ntnu.edu/energytransition-conference
106. Temperature Shift Bell Curve https://www.exploratorium.edu/climate/atmosphere

Bibliography

Aven. (2015). *Risk Analysis* (2nd ed. ed.). Hoboken: Wiley.

Bessis, N., Dobre, C., & SpringerLink. (2014). *Big Data and Internet of Things: A Roadmap for Smart Environments* (Vol. 546): Springer International Publishing.

Blaikie, N. (2000). *Designing social research : the logic of anticipation*. Cambridge: Polity Press.

Bratvold, R. B. (2010). *Making good decisions*. Richardson, Tex: Society of Petroleum Engineers.

Bui, M., Adjiman, C. S., Bardow, A., Anthony, E. J., Boston, A., Brown, S. F., . . . Mac Dowell, N. (2018). Carbon capture and storage (CCS): the way forward.

Clemen, R. T., & Reilly, T. (2013). *Making hard decisions with DecisionTools* (3rd rev. ed. ed.). South Western.

Coley, D. A. (2008). *Energy and climate change : creating a sustainable future*. Chichester: Wiley.

Dobbs, I. M. (2000). *Managerial economics : firms, markets, and business decisions*. Oxford: Oxford University Press.

Geels, & Frank, W. (2014). Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society, 31*(5), 21-40. doi:10.1177/0263276414531627

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*. London: London : Taylor and Francis.

Hand, D. J. (2012). Modeling and Reasoning with Bayesian Networks by Adnan Darwiche (Vol. 80, pp. 191-191). Oxford, UK.

Harris, C. (2006). *Electricity markets : pricing, structures and economics*. Chichester: Wiley.

Harrison, B., & Falcone, G. (2014). Carbon capture and sequestration versus carbon capture utilisation and storage for enhanced oil recovery. *Acta Geotechnica, 9*(1), 29--38.

Heinberg, R., & Fridley, D. (2016). *Our Renewable Future: Laying the Path for One Hundred PercClean Energy*: Island Press.

Herbst, A., Toro, F., Reitze, F., & Jochem, E. (2012). Introduction to Energy Systems Modelling. *Swiss Journal of Economics and Statistics, 148*(2), 111-135. doi:10.1007/BF03399363

Howlett, M., Ramesh, M., & Perl, A. (2009). *Studying public policy : policy cycles & policy subsystems* (3rd ed. ed.). Don Mills, Ont: Oxford University Press.

Hughes, L. (2009). The four 'R's of energy security. *Energy Policy, 37*(6), 2459-2461. doi:10.1016/j.enpol.2009.02.038

Jaffe, J. F., Westerfield, R. W., Ross, S. A., & Jordan, B. D. (2011). *Core principles and applications of corporate finance* (3rd ed., Global ed. ed.). New York: McGraw-Hill.

Kahneman, D. (2011). *Thinking, fast and slow*. New York: Farrar, Straus and Giroux.

Kaplan, R. S., & Norton, D. P. (2004). *Strategy maps : converting intangible assets into tangible outcomes*. Boston, Mass: Harvard Business School Press.

Khodakarami, V., & Abdi, A. (2014). Project cost risk analysis: A Bayesian networks approach for modeling dependencies between cost items. *International*

Journal of Project Management, 32(7), 1233-1245. doi:10.1016/j.ijproman.2014.01.001
Kirschen, D. S., & Strbac, G. (2004). *Fundamentals of power system economics*
Kuzemko, C., Keating, M. F., & Goldthau, A. (2015). *The Global Energy Challenge: Environment, Development and Security*: Palgrave Macmillan.
McCormick, J. (2017). *Environmental Politics and Policy*: Macmillan Education UK.
Monmbrus, Karts, & Ellen Hnd Helena, R. (2014). *The Role of `Experts' in International and European Decision-Making Processes*: Cambridge University Press.
Nugent, N. (2010). *The government and politics of the European Union* (7th ed. ed.). Basingstoke: Palgrave Macmillan.
Perman, R. (2011). *Natural resource and environmental economics* (4th ed. ed.). Harlow: Pearson.
Peters, B. G. (2015). *Advanced introduction to public policy*. Cheltenham: Edward Elgar Publishing.
Peterson, J., & Bomberg, E. (1999). *Decision-Making in the European Union* The European Union Series,
Project Management, I. (2006). *The Standard for portfolio management*. Newtown Square, Pa: The Institute.
Schilling, M. A. (2013). *Strategic management of technological innovation* (4th ed. ed.). New York, N.Y: McGraw-Hill/Irwin.
Spetzler, C. S., Winter, H., & Meyer, J. (2016). *Decision quality : value creation from better business decisions*
Taleb, N. N. (2010). *The black swan : the impact of the highly improbable* (Rev. ed. ed.). New York: Random House Trade Paperbacks.
Wallace, H., Young, A. R., & Pollack, M. A. (2010). *Policy-making in the European Union* (6th ed. ed.). Oxford: Oxford University Press.

Appendix Decision Dialogue

Decision Dialogue Theory

Given that we are working on policy with strategic and significant impact and with an inherent technical and organizational complexity we need to consider additional tools that Decision Quality approach suggests (Spetzler et al., 2016), this is also necessary to understand and address the magnitude of the decisions to be made, this is required to ensure that the correct approach and tools to support the decision are used, this would identify Decision Quality appraisal cycle (Spetzler et al., 2016):

Magnitude of the Decision	Number and Duration	What's Needed?
STRATEGIC: Of great importance and highly complex	FEW: Decided in days, weeks, or months	RIGOROUS DELIBERATIVE EFFORT: Apply formal processes and analysis tools to achieve DQ
SIGNIFICANT: Important but "easy," or complex but not especially important	SEVERAL: Decided in hours	MODERATE DELIBERATIVE EFFORT: Use pencil and paper with DQ requirements as a checklist; avoid decision traps along the way
QUICK: Frequent or small everyday choices; emergencies	MANY: Decided in the moment	AUTOMATIC: Develop decision fitness and good habits

Fig 37. Decision Magnitude and Support Needed (Spetzler et al., 2016)

The tools and processes to be applied according to the complexity of the situation pertaining to analytical and organizational complexity that it is immersed in.

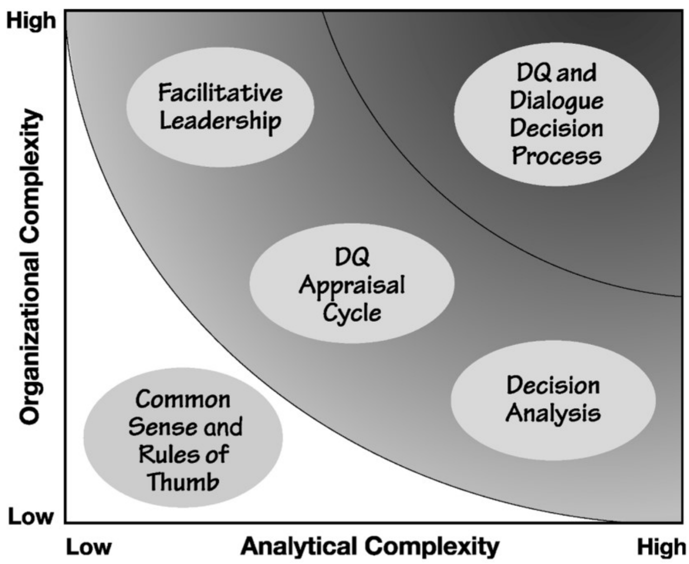

Fig 38. Analytical and Organizational Complexity (Spetzler et al., 2016)

It is also necessary to use tools processes, data, experts and analysis when dealing with highly complex scenarios, this goes beyond the intuitive “thinking fast and slow” model proposed by (Kahneman, 2011), but is extended to accommodate models and analytical tools (Spetzler et al., 2016). But we still need to understand system 1 (Fast) and system 2 (Slow) and that these are complimented by system 3 (models and analytics), however on reviewing the analytical results it is equally important that we use system 2 to digest and react, and not rely on system 1 (fast-intuition) alone as this may result in poor decision or acceptance bias (this is my own observation of a decision team when reviewing analysis). A simplified diagram below captures the systems.

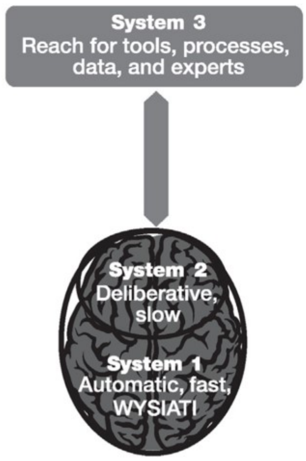

Fig 39. System Thinking Fast, Slow and Reaching for support (Spetzler et al., 2016)

Furthermore we need to understand our predicament and where we sit relative to the need to implement decision quality and decision dialogue. To select the position on the graph we need to weigh up 5 dimensions for diagnosing the mature of the decision (Spetzler et al., 2016):

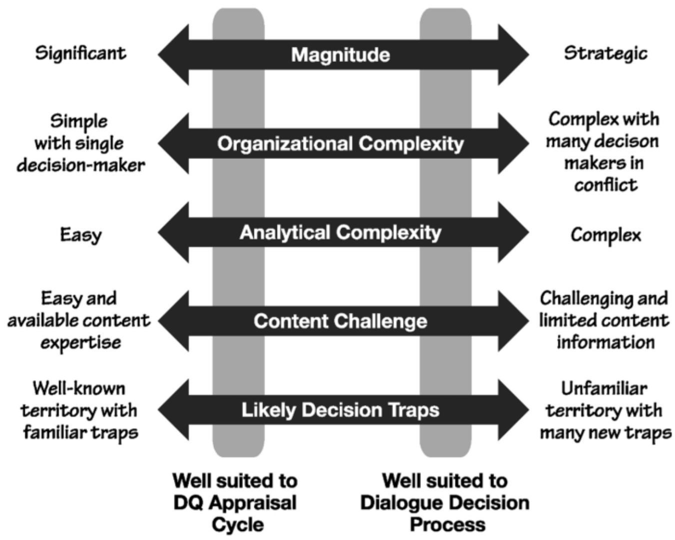

Fig 40. Selecting the right decision quality and dialogue approach (Spetzler et al., 2016)

Whereas the option to undertake a decision quality appraisal and introduce decision dialogue (which I first encountered in an SDG Webinar [113]). This can be applied to highly analytically and organizational complexity (Spetzler et al., 2016) which could be adapted to be used for policy development and implementation as well as a development or quality check for the policy planning and implementation phase. This model could help with the development team and decision maker barriers that exist in organization, it also encourages a phased and structured application for decision dialogue and is presented below (Spetzler et al., 2016):

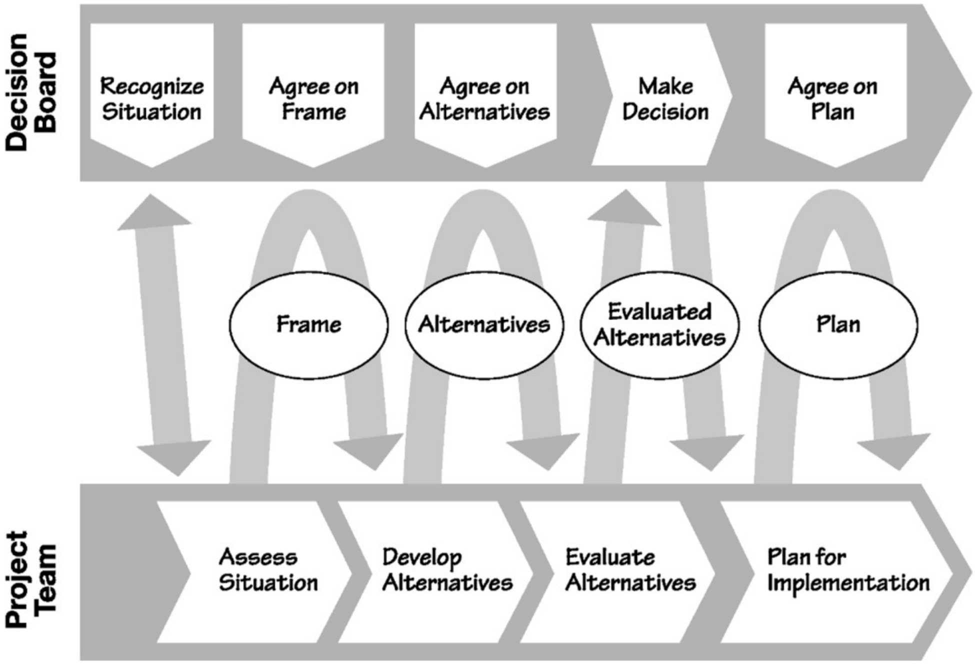

Fig 41. The Decision Dialogue Model (Spetzler et al., 2016)

A very important feature of the decision dialogue is the framing but through this framing we can scope alternatives but the most important step in this process regarding decision process is evaluation of the alternatives. This may be quite new to many in the decision making as many decisions we relied on advocacy or approver processes in the past (Spetzler et al., 2016) it does not focus on comparing the alternatives or competition between alternatives, but rather competition between policy advocates based on pitch or justification by people (as we often see in politics and boardrooms) (Peterson & Bomberg, 1999). This requires tools, systems, data and experts and analysis and transparent processes to remove biases, preferences and heuristics, and therefore we need to use system 3 as described earlier. (*NB! Notice that the model has a break in the path where alternatives are evaluated – this is to allow for unbiased selection and verification at a formal review by the decision makers when the decision will be made (i.e. not rely on the presentation pitch or advocacy by the project team which is a common pitfall in decision making quality[114]).

[113] SDG Thought Leadership https://sdg.com/thought-leadership/webinars/
[114] SDG Decision Quality https://www.youtube.com/watch?v=dFV-lzIqfRA

After the decision is made we need to plan for the implementation, this plan needs to be agreed and then executed. This still requires decision makers to approve and therefore take responsibility and be held accountable for the plan; this is often overlooked to detriment of the decision and associated action.

Decision Dialogue Preliminary Analysis

On reflecting on the Decision Quality appraisal used in the Analysis section in the thesis above, focusing on policy decision for energy system design and market reforms a framework to capture and improve the whole policy process the Decision Dialogue methodology was discovered. .

It was felt that this might help address some of the decision quality issues raised in the analysis section and could help to deal with more analytical and organizational or operational complex issues at the dialogue level whilst taking pressure off the decision analysis process which could then be decoupled from the organizational complexity of the EU. We need to identify where we are and by considering the complexity of the situation, decide where we need to be. From consideration of the decision quality exercise undertaken in this thesis, I think we are in a Facilitative Leadership sector (due to the organizational complexity of the EU) and we have not sufficiently addressed the analytical complexity of the task at hand. This also gives us an opportunity to address risk and uncertainty in more detail. This is necessary if we intend to introduce more analytical and assessment tools and coordinate this between multiple stakeholders and assist the policy development team to coordinate between the representatives and stakeholders.

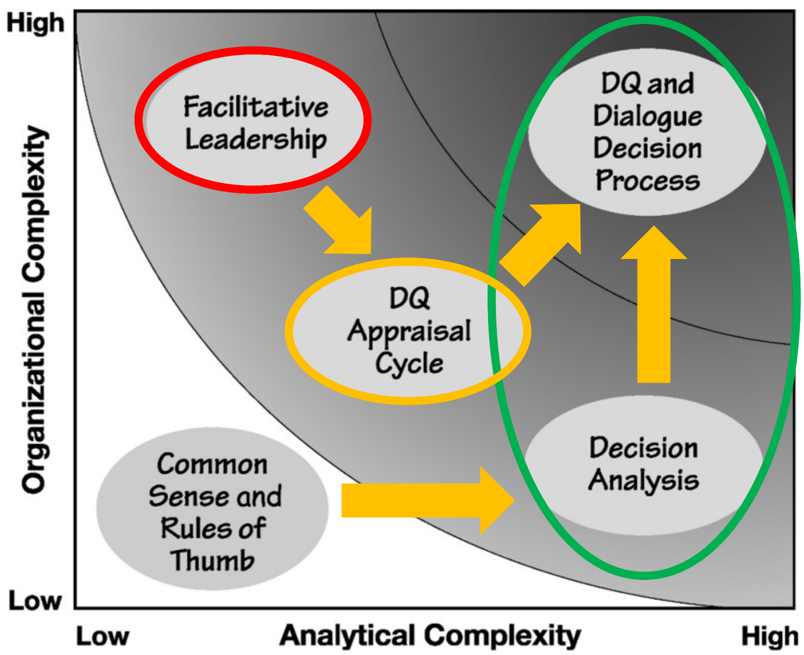

Fig 42. Analytical and Organizational Complexity (Spetzler et al, 2016)

It is therefore recommended that we need to move beyond the facilitative, decision quality and decision analysis performed by the respective DG cohorts appointed by the Commission based on a mandate from the Council. We need to ensure that there is sufficient dialogue between the commission and parliament throughout the process. The Commission could be represented by the Decision Board and the DG Energy, Environment and Climate Action groups who are represented by the Project Policy Group to ensure that the decision which we are making regarding policy development and implementation can be improved.

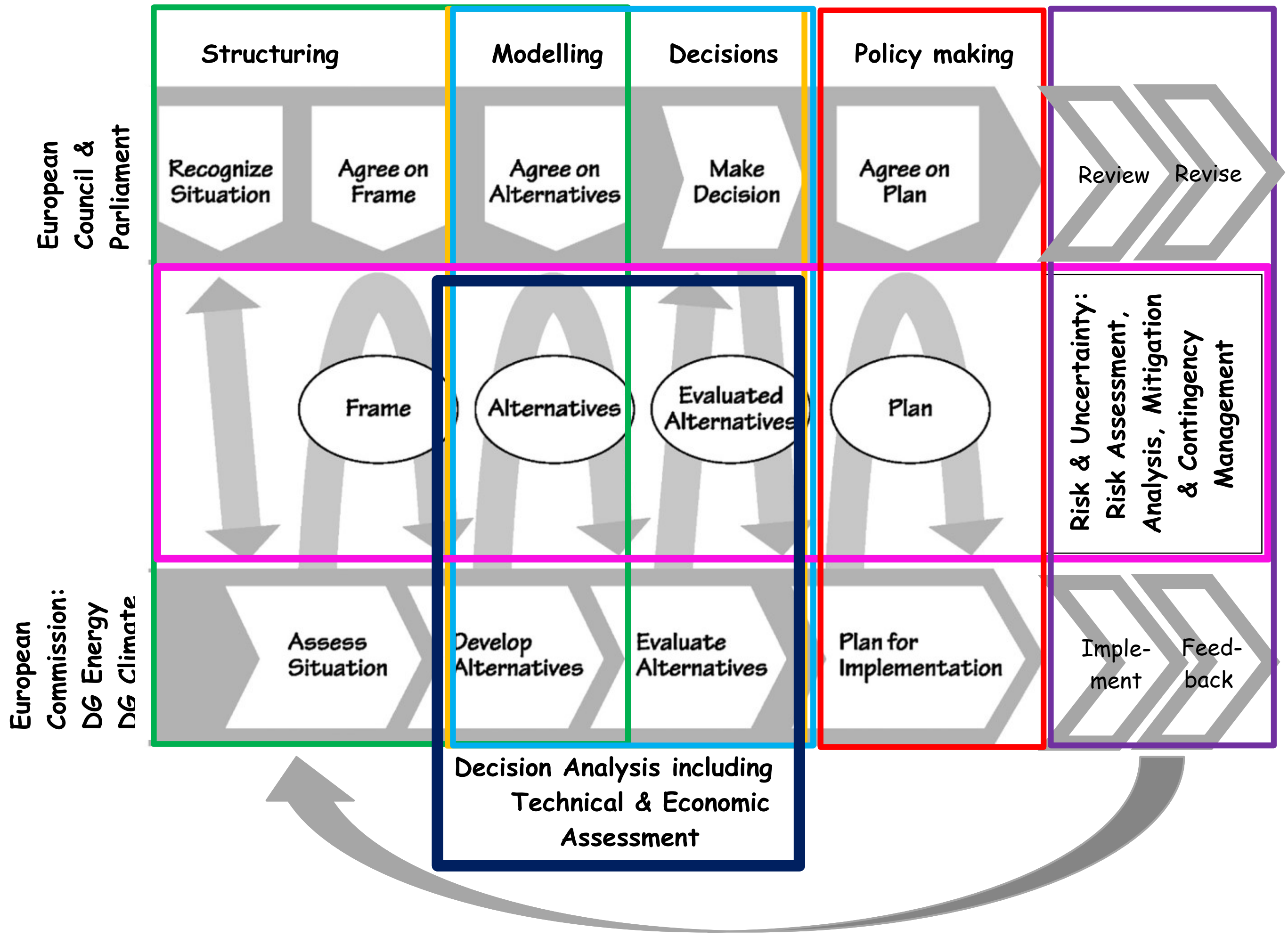

Fig 43. Modified Decision Dialogue Model (Spetzler et al., 2016)

This is necessary to ensure that the mandates and stakeholder analysis and impact assessments of policy change are capture in the framing stage – and that the decisions to be made (and decisions not to be made or delegated or to be resolved at national and intra-national level) can be categorically stated and aligned to strategy. But it also allows for early stage review and approval or agreement (acts as a type of Decision Gate) to set objectives, priorities and attributes or metrics. We can also summarize the information we have used to set these parameters (which can be improved and strengthened throughout the process as more information or knowledge developed and uncertainties reduced where possible).

Once framed correctly and established that all stakeholder requirements and concerns are addressed, it is possible to start developing alternatives which we can derive from EU modelling and the combined efforts of the research institutions and H2020 results can deliver a spread of alternatives, here it is also possible to rerun models based on new information, parameters or align to focus areas. This will help focus the design and selection process and put some detail towards grid design plans and energy trading and mechanisms. Again the Parliament and Commission can agree on the alternatives and assign preferences and priorities to be addressed and required in order to meet policy objectives so we can start to develop strategic path to be agreed and followed by all and this will also set the baseline requirements for further analysis.

But now the essential part, analyzing the alternatives. This is a dedicated and bespoke yep in the decision dialogue. While it is appreciated that some alternatives are analyzed on a provisional deterministic level we need to apply more complex tools and methods to analyze low, most likely and high attributes of the models which will allow us to go beyond the mean deterministic values and start addressing the tails of the distributions, also how the probabilities of temperature change start to affect these distributions and the costs to avoid or abate these. This is essential to start filtering out some options that are not feasible or viable or will not have the desired impact or present value. It is also important that we are not prone to faulty reasoning by misunderstanding the complexity or having any confusion about the uncertainties involved. Further to the energy system modelling we need to start analyzing against weighted criteria to ensure that we can analyze against the objectives established in the framing phase. This is essential if we are to develop the correct policy, regulations and directives to give guidance to the project team to develop policy that meets objectives and covers the prioritized and favoured options presented in the framework. It will require that we select the correct configurations and mechanisms and consider the timing and sequence of the decisions and how these will contribute to achieve the milestones and targets in the interim whilst culminating in an overall design that meets future vision.

This includes setting realistic model parameters and limits so we can rerun the energy system models and analyze the outcomes. This includes the establishment of impact of climate change against abatement or mitigation that the energy system design and market design can help to support the energy transition (i.e. combined efforts of low, zero and net zero carbon approach to meet objectives). It is at this stage that we should see a transparent policy alternative analysis, as this will help to understand what is included and what is excluded, what is treat as externality and what is endogenous to the policy choice. This is important as it has bearing on the decision and affects the implementation phase where we are addressing Market and Government failures and challenges or opportunities in the adoption of the policy (this was not evident or available in the review of the development of the Energy Union Policy)

At this stage and if the policy alternatives analysis is deemed sufficient we can proceed with the policy decisions i.e. state preferred options and policy changes to support the transition where we have taken account of all policy assessment impacts and sufficient regulation requirements and issue of directives that will be steer the transition after ratified on a national level. These need to be in place to support the planning phase and feed through to the project selection and implementation phase to support the energy system transition. This is a unique process to the EU whereby it will actively be involved in reviewing and collating the member states energy transition and climate action plans – to regulate that they reflect the policy, regulation and directives issued, but more importantly starts the process whereby the EU will select projects of common interest and award funding.

This should be based on a fair and unbiased review of the proposed portfolio and the projects supported should represent the priorities, values and objectives of the Energy Union. At this stage when the plan is agreed it should be possible to ensure that the combined approaches can be interfaced to realize the interconnected and hybrid grid visions supported by a market design which enables cross border trading, integrates renewables and delivers the vision of: clean, secure and affordable energy to the consumers. It must also be transparent through the implementation plan how the transition will be managed (timing of deliverables and benefits). This will also tie into the policy monitoring and control part of the policy cycle whereby changes and impacts can be evaluated and decisions on how to proceed can be made in future (if required).

Reflections on the Analysis using Decision Dialogue

If we address the decision quality issues and compliment it using decision dialogue the raised we can address the analytical and organizational complexity and therefore improve the speed, effectiveness and timeframe of the transition, although there seems to be a consensus regards what needs to be done, the implementation urgency or actions on what will be done do not reflect this. While we may have hit targets or are on track for 2020, this could be due to quick wins and exploitation of easy options (energy reduction, energy efficiency and initial renewable breakthrough in wind and solar). The real challenges lie ahead.

It seems that the responsibility is placed with the lack of Political will and support. So we need to confirm this and rectify it through better decision structures used to form the energy policy, directives and regulation but we need to ensure that the message and communication reaches the consumers. So in that light it could be said that the current drafts are not sufficient and we have not introduced the timing for the measures and actions to be taken. In addition we have not exhausted the emergency measures and systems that could assist the current system with a series of easy conversions to speed up the transition especially in the interim (i.e. CCS or use of Natural Gas or Mini Nuclear plants). These solutions could also help the rest of the world transition but we seem to have traded these for other energy sources and reliance on new technology some of which has not been proven or tested yet (H2, batteries and hybrid smart grids). Or we have lost a viable source to support the transition and meet targets in the interim.

Whilst the speed that the EU has introduced the policy is remarkable, and the boldness of the policy admirable, there seems to be a coordination or communication gap between the commission and parliament regarding options, assessment and selection of solutions (i.e. policy makers and voters and implementers) it seems that the policy made is impartial to some central concerns or decisions surrounding the energy grid design and we have embarked on a process of rational choice or bounded rationality based on little analysis or awareness of the unique situations in other countries (or parts of the world) again decision dialogue could support this and focus decisions on essential and valued activities that make use of opportunities and information available (i.e. developments across the complete value chain to achieve a hybrid grid or market design).

Another change, which must be noted, is the move from unanimity to qualified majority voting, as this will change the ability to resist or repeal proposals. This means that the transition will become much more bureaucratic and prescriptive and not debated or agreed by all member states. This means that the rate of energy taxes and carbon prices or emission levels will be set and qualified by the majority which will put some countries at a disadvantage and while this will speed up transition or actions to comply, it also means that the economy will be detrimentally affected and it will detract from other sectors and societal development should have been prioritized.

The decision dialogue can assist to structure these debates, make them more transparent and by the nature of the model promote more accountability and responsibilities to the stakeholders and decision making executive and the policy development teams to promote better decision planning and implementation results.

We may have fallen into a trap of satisficing, i.e. making decisions and selecting options that we perceive to resolve the problem, but they actually do not reflect value. We may also be a little premature in finalizing this policy where understanding of current system and what changes are required have been tabled before we have selected the best option or path to achieve the decentralized flexible grid and associated market reforms, we need to absorb the impact assessment and perform a gap analysis on a national basis of what needs to be done and the should be reflected in the policy, directives and regulations to give the correct steer and disruptive signals we require (NTNU, 2019).

This may delay or hinder the transition, especially as a new commission will be responsible to select and execute the series of projects required where the budget will run into € trillions to achieve a net zero carbon result in 2050. This has been proposed without any discussion or debate of the material availability, technology readiness or the energy requirements of the new system and we need to start addressing this as it affects the feasibility of the options and the strategic decisions.

The system design is centered on the consumer side, which have not really been engaged in the development of policy or indeed consulted on their requirements. We need a much bigger awareness campaign and onboarding process. Also we need to communicate the proposals and changes that are coming. But we need to expose the upsides and downsides (secure clean energy, but volatile pricing which can be resolved using smart technology or algorithms or a change in our behaviour). There is a tendency to believe that through SMART technology coupled with systems to manage demand to optimize use or service at the lowest market price.

If we are focusing on SMART systems we need to ensure that the consumer is an informed and active participant in the process and if we are not careful rebound effects could increase energy demands, therefore we must continue to push for everyone to use less energy and change behaviour if the transition is to be a success. Also we need to establish if citizens are willing to pay for these changes, as often the acid test is that the change will introduce increases in energy prices. But to counter this citizens and consumers need to be made aware of the consequences to them if we do nothing or impact miss our targets (Stern Review 2006 and 2016 follow up).

It is also important to include a do nothing pathway in the modelling so everyone is aware of how the energy system will change, i.e. demand increases and costs to provide conventional power and additional impact on environments. In addition we need to consider the social aspects in the modelling as especially if behaviour change, demand management and consumers are focal point of the energy union – all solutions need to point towards benefits for the consumer to help with communication of changes and how SMART technology will help us achieve this.

The modelling has to include all of the instruments and mechanisms (energy tax, carbon tax and carbon prices) so we can understand when these will come into effect and the aggregated effect on the consumer. We also need to simulate and understand how the new system and smart demand management will help us avoid high energy prices, this includes visualization of how we can switch energy types, take advantage of new technology or alternative energy sources, how we can produce energy and feed into the grid and be rewarded for this (and the need for bidirectional, bottom up decentralized design to achieve this).

We also need to start disseminating EU metrics and indices and setting and communicating these for local industrial and household targets to reflect the collective aggregation of efforts to reach the targets. i.e. energy reduction, carbon footprints and options to select and achieve this but more importantly monitor and report progress (to ensure on track and so decisions can be made to choose alternative energy sources and even pay more for cleaner energy and avoid the need for expensive and carbon intensive activity or carbon intensity including all aspects we are involved in: heating, transport, food, waste and the carbon footprint of all of these). This could be achieved through SMART technology, the EU plans to roll out 200 Million of these by 2020, using this we can build the data base that we can then analyze and through real time algorithms and artificial intelligence we could start to manage the demand and through market design engage clean, affordable supply to match.

Decision Analysis, Technical and Economic Analysis will come to the forefront if we apply the decision dialogue model as analytical and organizational complexity is identified and accommodated. To support this energy system modelling and experience is required but we need to change the way we approach this. We need to accept that we are dealing with complex situations that we cannot resolve without the use of models and analysis. This includes the use of open source data and share results from the models. We need to understand how they can be interpreted and analyzed to translate them into information that we can use to support and make decisions. The decision makers need to be able to understand how the analysis is undertaken and how to interpret and use the results.

An example from the SDG is that we can take a standard energy system model and then apply decision analysis whereby we could produce pathways that can then be plotted against the various temperature scenarios to see how the model performs against these, so we can see and develop with the outputs of the models, new designs and market reforms need new tools or application and understanding of the analysis that is required to make the decisions. This is also necessary if we are then to use the decision process to assess projects for funding and finance. We need to move beyond the traditional deterministic approach to CBA NPV IRR CAPM and project approval processes to accommodate environmental impacts and investment to mitigate/abate these impacts reduce the impact (i.e. reduce climate change impact by CO2 abatement) SDG, April 2019. Again additional tools, assessment, communicating alternative results and options are possible in this process.

We need to ensure that the best options representing value are targeted and that we do not end up with a series of stranded assets from poor investment decisions in the future (this includes new infrastructure such as pipelines and transmission networks whereby in the future we are much more decentralized and self-sufficient). We also need to agree what measures are required to support the transition and what is required in the interim vs. infrastructure requirements for long term.

It is essential that all the decisions that are made can fully reflect the changes and realistic configurations, meaning we only include viable technologies and energy mixes that are designed in the grid and where a market is viable (i.e. will we move to a green or blue hydrogen grid, what type of conversion technology will we use). This will help with resource allocation and focus the development and speed up the efforts as we all pull in the same direction and help standardize some technologies for deployment (and not split our loyalties and spread our efforts so thin that they are not effective or representative of values and objectives associated with the Energy Union objectives).