Master's thesis

Mapping the~~the~~ legal map between power system flexibility in synergy with ~~renewal~~ renewable energy

Master's thesis of 30 ECTS credits

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Resume:

Dette resume har til formål at undersøge det administrative barriere der findes indenfor PTX og sector-coupling.

PTX er en technologi med banebrydende mulighederne indenfor transformationen af den europæiske energi sektor.

Baggrunden for at undersøge PTX og sector-coupling i led med den europæiske er for at finde forståelse på hvor stor en betydning teknologien har for fremtiden af den europæiske energisektor både nu men også fremadrettet.

Europa har nogle klimamål igennem dens lovgivning der gør at der skal tages nogle drastiske beslutninger om hvilken retning unionen on de medlemsstater har tænkt sig og gå.

Specialet anvender europæiske direktiver, love og strategier til at finde frem til de forskellige barrierer.

Specialet anvender den rets dogmatigtiske metode til at analysere den påfundet lovgivning samt bruge den comparative metode til at sammenligne strategier

Specialet går derefter så til en problemløsene tilgang for at svare på de barriere der nu skulle blive identificeret.

Introduction:

This thesis will research the different aspects of the legal perspectives that revolves around energy law and climate change. The objective is to identify different legal barriers that challenges the transition from a carbon-based energy production into a green renewable energy production and research the solutions that could enable the current framework to overcome these barriers. The thesis will take a case-based approach revolving around "sector-coupling".

Background:

The energy sector is the root of all production, because energy is essential in everything and therefor the biggest contributor of greenhouse gas (GHG) emissions and combined with the additional processes~~, and~~ it is the biggest (GHG) emitter word wide.[1]

Climate change is a result of human interactions with natural resources that affects the planets ecosystem. CO_2 – emissions is a result of overuse of resources that can be categories as fossil-fuels that contains carbon which have a huge impact and acceleration on climate change because of the thermic effects that creates a rise in global temperature. Therefore, the goal is to halt and in best case reversing climate change effects, and this is achieved by reducing the consumption of carbon-based resources with the purpose of reducing GHG emissions to a level where the ecosystem can adapt naturally.

The EU have a consumption percentage of carbon-based fuels at an alarming 72% and where renewable energy only amount to 15% of our electricity coverage. Not only does the EU have a carbon dominant energy sector, but the EU also imports around 55% of the fuel used in electricity production, which states that the EU is not self-sufficient in regards of producing electricity, and there for the EU must rely on other countries to supply the resources needed.[2]

[1] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#electricity

[2] https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-2a.html

According to a paper written by *"Gioietta Kuo"*[3] fossil fuel consumption is increasing, and this has an impact on our reserves, with the current rates we will exhaust our oil reserves in the year 2050 and our gas reserves in 2060. With the increasing global temperature caused by the increasing GHG and our carbon reserves being exhausted, in the near future, a substitute for our carbon-based energy structure is due.

In 1997, 192 parties agreed to the Kyoto protocol[4], which is a treaty that had the goal of reducing the GHG emissions and the treaty was implemented in 2005 and was replaced by the Paris agreement[5] agreed upon in 2016 entered into force at the end of 2020[6]. With the Paris agreement in place, targets have been set to lessen climate change affects and the EU has ~~have~~ taken on these targets and incorporated them into their own legislation. One of the key tools to combative climate change is~~are~~ mitigation and this is achieved by reducing emissions for the sake of keeping the global average temperature below 2° compared to preindustrial times. Another agreed goal is adaptation which overall is the capabilities of dealing with the impacts and damages that is caused by climate change.[7] Based on the Paris agreement, a set of key targets for 2030 have been agreed upon and these consist of 40% cuts in GHG – preindustrial time, 32% share of renewable energy and 32,5% improvement in energy efficiency[8]. As of now the EU's energy share from renewable energy consist only of 15% and therefor needs to see a double in size over the next 10 years.

Kommenterede [SC1]: when you cite legal sources Do not use web sites it is not academic and low quality. Check Veronika's thesis to learn how to cite correctly

Kommenterede [KS2]: Should I also mention that the PAG was aggreed on in 2015?

Kommenterede [SC3R2]: Rather the date when the PA entered into force (2016).

Kommenterede [SC4]: Has been replaced by…

Kommenterede [SC5]: Idem as previous comment on the Kyoto Protocol

Kommenterede [KS6]:

Renewable energy

Renewable energy is a category of different technologies that generates electricity without the need of limited natural resources, whereas the sources are unlimited. In Denmark wind and photovoltaic energy is the two most common sources of renewable energy and this kind of energy have a potential which carbon-based fuels do not have, but the other way around renewable energy also has limitations.

[3] https://mahb.stanford.edu/library-item/fossil-fuels-run/
[4] https://unfccc.int/kyoto_protocol
[5] https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[6] https://unfccc.int/kyoto_protocol
[7] https://ec.europa.eu/clima/policies/international/negotiations/paris_en#tab-0-0
[8] https://ec.europa.eu/clima/policies/strategies/2030_en

Firstly, as previously stated renewable energy production does not deprive of the planet's natural limited resources, thus renewable and climate friendly. Secondly, Renewable energy consist of many different technologies, therefor it´s multiple sourced and is not bound to one specific climate because some renewable technologies perform better with E.g., a place with a lot of sun for photovoltaic electricity or energy produced by waves. Thirdly, Renewable energy is in a developing stage, where some technologies are in its infancy others are further ahead, but what this clarify is that while as of now renewable energy only supports 15% of our current electricity production, but in relation to carbon-based fuels, renewal energy has the potential to grow vertical and horizontal because of the endless possibilities of new technologies but also in the amount of output that the different sources can produce, this growth can be directly affected by the amount of investments that are put into development and research of the renewable energy field, and this can be further helped by policies and governments by focusing their resources into the green transition.

Renewable energy has a lot of strong key factors for why the world should consider transitioning from a carbon-based energy structure into a green energy structure, but before renewable energy can support our electricity demand, several problems need to be addressed and solved.

First problem is that the current renewable energy production is too low and for this to be increased a lot of spatial planning for both the land and maritime areas needs to be reserved for photovoltaic fields and windmill parks, this issue is more complex than just buying up lands because setting up these renewable energy plants can affect the surrounding areas in a negative manner, which the acting government needs to take into consideration. One of such complications can be noise from windmills or decrease in market prices, but the thesis will not go into those specific problems.

Second problem is, wind and solar energy can produce a lot of electricity, this electricity needs to be used directly after its produced, since it's not possible to store the energy yet, there for the produced electricity at night from e.g., windmills is not effectively being used because the electricity demands at night are minimal. Renewable energy can be quite

inefficient because of the waste electricity that is produced. Third problem with renewable energy is that it requires a lot of upfront investment compared to carbon-based fuels, but still in the long run renewable energy a lot less manpower and maintenance.

Power-to-x in synergy with energy & climate law.

The ideal energy structure society can strive for is a self-sufficient, efficient and climate friendly energy sector, but as mentioned previously, is also characterized by difficult flaws, and looking at it from a broad perspective these flaws can be solved with the support of other areas. One of the key strengths of carbon-based fuels is that it is storable and if spikes of energy usage happen, the electricity demand can be met by using the stores to comply with the consumption need. This key strength is one of the big disadvantages that renewable energy has because it is impossible to predict the weather and it's impossible to make the weather comply with energy demand.

Power-to-x (PTX) is a flagship-project that can solve the issue of inefficiency within the green energy sector, by enabling the usage of excess or "wasted" electricity. The excess electricity produced from renewable energy can be used in a process called electrolysis, this process separates elements of water to create synthetic materials like hydrogen, methane, liquid fuels and ammonia[9]. PTX should be viewed as a dynamic building block that when coupled together with a renewable energy source it enables the two different technologies to support one another, by covering each technologies disadvantage, this will be reviewed later in the thesis.

PTX have~~ve~~ the potential to decarbonize not only the energy sector but also sectors within society like the transport, housing and the production industry, this is why PTX is related to sector-coupling, because of the potential of bringing these and other sectors together. Being a flagship project PTX have yet to impact the legal system in such a way that It can be

[9] ENERGINET – PTX IN DENMARK BEFORE 2030 – Page 5, section 1,3

effectively integrated and this is a very delicate process, because it's not only about PTX, but also all the sectors affected by the changes that PTX or sector-coupling revolves around.

PTX with the backing of renewal energy and a proper legal framework, have~~ve~~ the potential to strengthen the weak areas of the green energy sector and with the pressing matter of reaching a share of 32% renewal energy before 2030[10] this project could stimulate and catalyse ~~initiate~~ an interest in investing~~ments~~ into renewable energy.

The energy framework as is today, is not optimized therefor it would be most effective having a structure with the potential of having a legal system that can be regulate the sectors for effective use of the production but also regulating the other sectors to create harmony between the sectors. This legal system should be designed to be versatile, so that I can carry over from etc. Danish domestic law into the European legal framework, therefor structuring the legislation with supranational level in mind. The argumentation for designing the framework to be versatile, is to increase the potential of vertical integration from etc. Denmark or Germany into the rest of Europe.

Kommenterede [SC7]: Difficult to understand. Please reformulate What do you want to say? That the legal framework integrating the power system in synergy with renewable energy could improve in terms of effectiveness by using the Danish legal example as a model to improve the EU level?

Kommenterede [KS8R7]:

The thesis will focus on the case-based approach with power-to-x in synergy with renewable energy as its core "Sector-coupling" with a main focus on Denmark and Europe.

PTX is as earlier stated a new field, that is in its infancy, like wise with wind energy in the early nineties. Denmark was the leading country within the field and have had a lot of influence on the structure of its legal field, in a parallel view Denmark can take its experience with creating a new legal field and stimulate a bottom-up reaction that can spark a chain reaction for the European law to create a harmonized legal package for PTX and Sector-coupling.

The multiregulatory approach.

Climate change is a problem on a global scale with a multilateral system ranging from international global scale all the way down to the regional plane. At the top of the international level, we have the UNFCCC and other groups like the G20. The UNFCCC is the leading organization and will be gone through later in the thesis. Other groups and forums like the G20 discuss the main topics of climate change. The supranational level is a

[10] [10] https://ec.europa.eu/clima/policies/strategies/2030_en

multinational union which is best described with European union, at the lower levels we have the domestic and regional level.

In the times of the Kyoto protocol this structure was a top-down, but with the Paris agreement this has changed into a bottom-up structure and again this will be further discussed later in the thesis.

In accordance with sector-coupling, the multi-regulatory structure is important because of its vertical and horizontal structure, this legal framework is effective and enables for vertical integration between the different levels and in a holistic perspective the need for adopting the best parts of climate development within the levels is crucial.

Research question:

Kommenterede [SC9]: You still have to work of the right formulation of your research question. It is not clear. I have tried to reformulate.

Based on the flagship project PTX and taking into account the challenges and opportunities when integrating power system flexibility with renewal energy (sector-coupling) the
research question examined in this thesis is the following:

> *What are the regulatory barriers of implementation "power system flexibility" with the implementation of EU Law when structuring power system flexibility in synergy with renewable energy?*
>
> *The hypothesis is a multi-regulatory approach is useful in identifying the legal barriers at the supranational level in the case of the Power-to-X in synergy with renewal energy.*

In order to answer the research question, the following research and analysis needs to be done. Firstly, the different sectors that is intertwined with PTX and sector-coupling needs to be identified and thereafter the legislation that is relevant within the different sectors. Secondly, to understand the different synergies the sectors have and what regulatory barriers that could prevent the transition.

Methodology:

The objective of this thesis is to identify and get an overview of the current situation of the case-study that the thesis revolves around. Since the PTX case is a newer project and the legal barriers is yet to be identified or explored, it is important to map the current legislation and policies that involved with the case.

The Case-study will be carried out with focus on a qualitative analysis but will have a fraction of quantitative data in its argumentation. The qualitative data is important because the thesis strive to build a legal framework, that can be expanded upon and therefore the current status of the legal field needs to be identified and analyzed. The quantitative data within the thesis will be in complementation of the qualitative data as a strengthening factor for argumentations.

The research question will be explored by conducting legal analysis and with the use of the legal-dogmatic approach, because of the nature of the case-study. Sector-coupling is one of the main aspects of the case, with PTX at its heart. Therefore, the thesis needs an approach that can analyze the different interactions, synergies and gaps within the different legal fields revolving around the subject.

The legal-dogmatic approach is the perfect doctrine/method for exploring and identifying the different legal aspects of sector-coupling because of its descriptive, prescriptive, and systematic way of internally identifying law and how it touches, regulates and form the outcome of the law[11]. It is also important to note that the dogmatic approach, with its descriptive nature have an excellent approach on being creative with the building of a new legal field[12].

The case-study on the Power-to-X project in accordance with sector-coupling is a project with a high profile within the climate change regime, not only in because of it's a none emitting technology but also because of its potential to transform energy structure completely. Firstly, the PTX project strengthen and solve, the storing issue that is the major

[11] Jan M. Smits – WHAT IS LEGAL DOCTRINE? ON AIMS AND METODS OF LEGAL-DOGMATIC RESEARCH. Page 8-12: Introducing the aims of the doctrine.

[12] Jan M. Smits – WHAT IS LEGAL DOCTRINE? ON AIMS AND METODS OF LEGAL-DOGMATIC RESEARCH. Page 10: Top section, first 3 lines.

problem with renewable energy and bring together the different sectors that are intertwined with the energy sector. Secondly, the case has a lot of international focus and therefor rich in discussion and data especially in western Europe, mainly Denmark and Germany.

Scope:

The scope of the thesis is to identify the law and policies interacting with the case in synergy to renewable energy with the focus on EU law, Danish law, climate change law and policies.

Power-to-X and renewable energy is in an area that is evolving at a high pace and already has roots in Denmark and other European countries like Germany, because of the already existing interest for advancement of the technology in Europe, mostly Denmark and Germany the study will be conducted with a focus on Danish law and a mix of German policies with EU law at the supranational level, since EU-law has an impact on all parties that the EU consist of.

Delimitations:

The delimitation of the thesis is not to build a full structured model for the case-study but an insight on how the framework could be and to see what lays ahead for the case, also the thesis will have a lot of different sectors involved and there will not be an in-depth focus on each sector, but more of an overview of the interface, to identify why this sector is affecting or connected to the case. The reason for not exhausting the layout of all the sectors that is affected and connected in sector-coupling, is because the number of sectors is just too broad and some of the sectors do not have that much of an impact on the case-study, for example, the agriculture will be a part of the new structure in the future, but the impact is unilateral, PTX will affect the agriculture, but not the other way around.

The thesis will focus on the European model because of the language barrier there is on the German model but will not fully avoid the German literature and model, because Germany and Denmark are the leading countries on electrolysis as an actual incorporated technology. The legislation and policies will be a dualistic approach between Denmark and the EU

because of the relationship of the two but also because the EU have a top-down dualistic structure and a focus on these two subjects can take a bottom-up approach from Denmark to the EU, but also for a horizontal integration and Top-down from the EU to other membership countries for a vertical integration.

The case-study will include a focus on what is essential for the establishment of PTX and sector-coupling in a the present and near future but exclude problems that may arise further in the future. The reason for not incorporating the obstacles in the future is the limited information on the variables that may arise with the integration of a new energy structure.

Research Outline:

The thesis will be built in a chapter structure with each chapter going onto the next step in detailing the data and information on the subject.

The first chapter will have the purpose of identifying and explaining what PTX and sector-coupling is, but also clarifying what the fundamentals of climate change law is and how it is structed.

The second chapter will analyze the legal and economic landscape, identify the barriers that is accompanied by PTX and sector coupling and how the barriers are affecting the case-study.

The third chapter have the purpose of taking the identified and analyzed data from the second chapter and comment on where the field is lacking, but also give an opinion and formulate different strategies on building policies, legislation and structures that in the future could further the development on the case-study and the transition of transforming the current energy- sector into a green energy-sector.

At the conclusion a combination of all material, will be directly applied and commented to answer the research question.,

Chapter 1: Introducing sector-coupling and the law

1. Introduction:

The objective of this chapter is to structure the interface of sector-coupling and what revolves around it, and how to integrate the technology it into the framework for optimal effectiveness, but also to explain the foundation of what the climate change law and how it applies to sector-coupling.

Within the introduction, of the renewable energy section, its confirmed that, the data points in a direction that calls out for drastic measure, because of the 2030 and 2050 targets adopted by the EU and its parties[13]. The targets will not be reached by working in a linear progressive way, why an exponential strategy is necessary, pre-COP26 it was confirmed that with the amount of effort forwarded towards climate change globally as of now, we would reach a global temperature of 2,6°C.

The project name "power-to-X" means that it has a multipurposed meaning because the X can stand for anything and therefor reach a lot of different variants uses of the technology, for example can the X stand for Gas or Liquid ext. Since PTX is a multipurpose technology, a lot of different sectors apply to it because of the many different applications of the X.

When taking the energy sector into account, we must picture PTX as a building block for connecting all the different sectors and combining them into a structured system that works like a supply-chain.

1.1 Sector-coupling

Sector-coupling is as its named, the coupling of different sectors, when describing the term in its simplest form.

The structure of Sector-coupling can be divided into 3 different categories, the supply, storage, and end-use category[14].

The supply category is the foundation of sector coupling and it is here, the electricity originates from. In the supply category we have all forms of energy generating sectors like

[13] The European climate law – article 3 and directive 2018/2001

[14] Sector coupling: How can it be enhanced in the EU to foster grid stability and decarbonise?
Source: Based on Imperial College London (2018)

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wind, photovoltaic, nuclear, or fossil fuel, which is also found in this category, but it is being faced out because of its polluting properties. The importance of interconnection between the different energy supply area's is that they each have their strength, like photovoltaic being most effective in the summer and wind energy on a day with a lot of wind. In the introduction about renewable energy, I comment on that the different RES have fluctuations in their energy output and therefor it's important for the supply category to have a wide variety of technologies that complement each other, so that the electricity demand can be achieved even on a cloudy or wind still day.

The storage category is one of the areas lacking in development and it is also here PTX will play a major role, within the storage category there are liquid fuel, thermal energy, and raw power as in products that can be stored and then consumed for electricity when needed. In the future the storage category is going to be the core of sector coupling because it will act as a connection between the supply and end-use.

When PTX is properly integrated, it will be possible to produce green hydrogen, that can be further processed into E-products which can be used in both the transport and energy sector but also in the production of fertilizer and therefore also reaching the agriculture sector. With the combination of hydrogen and green carbon, a variety of other E-products such as diesel, methanol, kerosene, and methane can be produced, and this enables the transport sector to become decarbonized[15].

The end-use category is where we have the consumers of the products produced, here we see the transport, Industry, household, services, and the agriculture sector. The end-use category is an important part of the chain because it is in this area where our consumption levels are identified, and therefore have a high interconnection on supply and storage, because without data from the end-users, governments and companies would not be able to produce the right amount of electricity and E-products, but also know how much to invest into the transition.[16]

[15] Anbefalinger til en dansk strategi for power-to-x
Dansk energi, Bain & Company analyse

[16] Sector coupling: How can it be enhanced in the EU to foster grid stability and decarbonise?
Source: Based on Imperial College London (2018)

1.1.1 The sectors

With a holistic view, it is possible to further divide the 3 categories into subcategories, such as the Renewable energy sector (RE-Sector), which is the most important sector in developing of PTX, without the green energy supplied by the renewable energy sector the projects value in the aspect of climate change deflates because without green energy the produced products will not be emission free produced and it becomes irrelevant, so the RE-sector is the fundamental building block in the PTX project.

1.1.2 The renewable-energy Sector

Renewable energy is the important benefactor for PTX because it makes the produced hydrogen emission free and it is also an important realization for building the PTX framework because PTX needs to be regulated in such a way that its capabilities do not exceed the output produced by the RE-sector, so the advancement of these two sectors needs to be in synergy, so when capabilities of the RE-sector grow, PTX product production should grow accordingly. This may seem simple, but already now taking this information into account the investments needed for PTX can already be calculated by taking the current output available in the RE-sector and match it accordingly too the production of e-products with PTX.

The RE-sector is already becoming a valid competitor within the supply sector with a rapidly dropping electricity price and there are some important variables that are decreasing the distance from today's carbon produced electricity and the renewable energy prices, firstly the renewable energy prices are high compared to carbon based electricity, renewable energy have a high investment price that originates from the need to produce windmills, solar panels etc., but over time the RE-sector will pay itself off and become cheaper in the long run. Another benefactor in this price "war" according to Dansk energi's study from 2017 is the carbon energy price is based on the coal price[17] which they hope will increase, with the reduction of coal-based energy and therefor have the gap between RE and Carbon energy decrease.

To shortly summarize in the long run the RE-sector will overtake the carbon-based electricity and with the help of politics and policies, this process can be furthered by

[17] Dansk energi: Elprisscenarier 2020-2035 (2017) – Page 7

implementing harder quotas on carbon-based fuels, like coal. Early investments into the RE-sector will also give a larger and faster return in the future, and this is supported by a law in Danish legislation that supports the furtherment of RE[18] and in 2020 this law was changed to increase the pool of funding for green projects, but also gave the government the authorization to govern finance of the windmill park known as "Thor"[19] The windmill park will be further discussed in chapter 2 – Webinar with Dansk energi.

The RE-sector is in a rapid development within the EU and there have been put forward great deal of legislation towards promoting renewable energy that can be found in different directives as Article 194(1) in the TEUF[20] with four functions (a) a functioning market, (b) security of the supply, (c) "*Promote energy efficiency and energy saving and the development of new and renewable forms of energy;*[21]" This part of the directive supports not only the promotion of renewable energy but also saving and efficiency, therefor this directive have a major role, because it supports three of the pillars in the PTX project and sector-coupling. Firstly, efficiency is the whole concept of sector-coupling, by having a system that is connected from start of the supply-chain and to the end of it, so each sector can be regulated if inefficiency should occur, and this is also applicable to the energy saving. Secondly, the directive promotes and supports development of renewable energy, and this should be interpreted further than just the renewable energy technology, but also the technology that is directly connected to it as PTX and not least the framework that supports it. In the last part of TEUF article 194 (1) is the last part (d) "*promote the interconnection of energy networks"*[22] This part of the article, may be more important than article 194(1)(C), because it directly promotes the development of sector-coupling, with one of the core aspects of sector-coupling being the connection of the different energy networks and combining it into an extensive energy network.

1.1.3 The role of the Renewable energy-sector.

This sector has one main role and that is the production of green electricity, this objective is thus only at the end development of sector-coupling, as of now the role is to produce and

[18] LOV nr 2065 af 21/12/2020 - Lov om ændring af lov om fremme af vedvarende energi og lov om elforsyning
[19] LOV nr 2065 af 21/12/2020 -
[20] TEUF Article 194(1)
[21] TEUF Article 914(1) (C,)
[22] TEUF article 194(1) (d)

increasing the flexibility of electricity output accordingly with the energy demand. Thereafter further the research on advancement of the current technology, but also creating new technologies for increasing the multithreaded streamline of electricity. The third role of the sector is “Interconnecting communication” with the storage sector and with the government for regulation pricewise, but also for creating a system with synergy between the different technologies and forward planning for new technologies.

1.1.4 The carbon-based fuel sector.

The carbon-based fuel sector (CB-sector) is worth discussing, though it is being faced out of the supply sector because of the polluting properties of carbon fuel, the CB- sector still has its role to play within sector-coupling, as mention before[23] this sector will act as a security measure if something were to happen and the energy demand could not be met by RE-sector, then the CB-sector would take over, but only as a last viable option.

The last viable option role will not be without its price, this option will need a lot of regulation and restrictions, so it really can be viewed as a critical last option, and not something parties can pull on if needed without consequences. My recommendation for this mechanism is that a government body will have the authorization to commence the operation, but also have sufficient high prices on the carbon-based fuel with the objective of only being used if absolutely necessary.

Another role of this sector will be carbon extraction from the air to use with the hydrogen created from electrolysis[24] this is another important aspect of the sector-coupling case-study, because carbon is needed for the manufacturing of the e-products, but by taking the already existing carbon in the air the emission would be neutral and therefor a green solution.

Recap: The role of the CB-Sector:

Act as a last viable option to comply with energy demands, store carbon extracted from the air and use it to supply the supply-sector with C_o^2 to create e-products.

[23] Find references.
[24] Find products.

1.1.5 The gas-sector.

The gas-sector is one of the major components like the RE-sector it is vital for the system to work. The gas-sectors objective is storage and production, PTX uses renewables to produce hydrogen and hydrogen is the key component because of its multiple uses. Firstly, hydrogen from PTX "Power-to-Hydrogen" can be used in its original form for hydrogen-technology that produces electricity by splitting the molecules but one of largest issues with hydrogen is the storage aspect, hydrogen is gas and for it to be viable it needs to be stored in large quantities and that requires high-pressure tanks. Secondly, hydrogen can be used to produce E-products by combining hydrogen with either carbon or nitrogen which enables the technology to influence all the other sectors especially the transport-sector and the agriculture-sector.

Recap: The role of the gas-sector.

The main role of the gas-sector is production of hydrogen, where the sector branches out with the end-product of e-fuels and ammonia synthesis[25].

1.1.6 The household-sector and transport-sector

The household-sector is a consumption sector without any technological objective but is a regulatory sector where the main objective is being observatory on the consumption data and integrating of smart technologies within the end-use for minimizing consumption on energy. Like the household-sector, the transport-sector is in the end-use category, but this sector's objective is to transform the transport-sector into a sector run on electricity and E-fuels, so its compatible with PTX and sector-coupling

Recap: The household-sector and the transport-sector

Regulate the household sector by influence the consumption and statistically observation. Transform the transport-sector from being mainly carbon based into a electrical and e-fuel based.

[25] Benoit Decourt: Weaknesses and drivers for power-to-X diffusion in Europe. Insights from technological innovation system analysis – On the different uses of hydrogen.

1.1.7Comments & thoughts on Sector-coupling

After an interface explanation and coverage of PTX and sector-coupling, the reader should now have an understanding on what sectors are involved, but also an idea of the synergies that are needed for sector-coupling to work.

PTX and sector-coupling is transformative technology with a huge potential to decarbonise our society with electrification and electrolysis but faces major problems, when looking at it realistically. Firstly, the transition from the carbon-based structure into a RE structure is the main criteria for PTX to be carbon neutral, therefore massive investments are needed not only into RE but also into developing and industrialize PTX. Secondly, where should the investments come from and who will take charge of the developing of the PTX plants? Thirdly, is there enough legislation that supports the development of sector-coupling, with Denmark as an example, the government changes every fourth year, so the political view can change with each change of power, and this can have a dynamic effect on climate change policy making and therefor also affect the sector-coupling system.

1.2 The fundamental of climate change law.

Climate change is a result of human interaction and execs use of natural resources, with the acknowledgement of climate change a union was formed to confront the problems and find solutions to battle climate change.

The United Nations Framework Convention on Climate Change (UNFCCC) was founded in 1994 and consist of 194 countries, the ultimate goal of the convention is “Preventing “dangerous” human interference with the climate system”[26]

The UNFCCC is one of the origin points of climate change law, because of its backing but also because likewise with the Vienna convention and Montreal protocol that was implemented to protect the ozone layer[27] it is one of the first times where the world has come together and acknowledged that an internal crisis was before them.

[26] https://unfccc.int/process-and-meetings/the-convention/what-is-the-united-nations-framework-convention-on-climate-change - 2nd and 3rd line.
[27]https://ozone.unep.org/treaties/vienna-convention#nolink
https://ozone.unep.org/treaties/montreal-protocol

The UNFCCC's websites convention summary refers to the objectives of the convention and generally what it stands for, like what I have firstly gone through is, accepting that there is a problem and borrowed from the Montreal convention, binds the member states to act for the sake human safety. Other focuses are to set high goals of reducing the GHG that society are polluting the atmosphere with, other than settings target for our emissions the UNFCCC also finance and support developing countries with their financial mechanisms.[28]

1.2.1 Kyoto protocol & the Paris agreement

The Kyoto protocol was adopted in 1997 and had the objective of goalsetting of creating targets for the different parties, also the Kyoto protocol had a top-down structure by setting a 5 percent reduction target in GHG emissions compared to 1990 levels[29].

The Kyoto protocol had two different commitment periods the first period started in 2008 and ended in 2013 and in Doha, Qatar 8th of December 2012 a second commitment period was accepted known as the Doha amendment and lasted until 31st December of 2020[30].

Other than setting goals and timelines, the Kyoto protocol also categorizes its parties into an annex system where developed countries had a considerable higher responsibility than developing countries and this also makes sense with developed countries having emitted more GHG than their counter part.

The Paris Agreement was adopted in 2015 on the 12 of December and entered into force on 4th of November 2016. Compared to the Kyoto protocol is the Paris agreement legally binding to its 196 parties and have the objective of stopping the rise in temperature before 2 Celsius and preferred before 1,5 °C [31].

The Paris agreement is structured different than the Kyoto protocol, because its legal approach changed from a top-down approach to a bottom-up approach. Nationally determined contributions[32] (NDC) are what gives the Paris agreement its bottom-up and enables countries domestic control over how they plan to contribute to the GHG reduction

[28] Y. Yamineva and K. Kulovesi – page 191 line 9.
[29] UNFCCC – the Kyoto protocol
[30]UNFCCC – the Kyoto protoco - 6th paragraph
[31] The Paris agreement – Article 2.1(a): below 2°C and efforts to limit it to 1,5 °C
[32] The Paris agreement – Article 4.2: Nationally determined contributions

and how they will introduce adaptation into their NDCs. Adaption is how governments prepare or adapt to climate change, like how Holland have created cities that can adapt to the sea-level because of the risk of being swallowed up by the sea[33] adaptation will be further discussed in context to PTX later in the thesis.

Every five years the parties will have to submit their NDC´s to the UNFCCC and the reason for this is that the parties have the possibility to change their ambitions or regulate, so their contributions match their capabilities. E.g., if advancement in the RE technology were made countries would find it easier to reach their goals and therefore could increase their contribution but vice versa downscale the contribution if a negative event would affect the party. This is one of the aspects of the Paris agreement that makes it bottom-up but also does so that developing countries can match their contribution to their capabilities.

1.2.2 Why the UNFCCC is important in accordance with PTX.

The Paris agreement changed the structural hierarchy for climate change policy and law because of the NDC mechanism and moving the stimulus on combating climate change from the top-down to, the bottom-up and allocating the legal responsibility into the domestic level, so now parties are formulating and structuring new laws and policies, in accordance with the parties own NDC goals.

PTX is one of these stimulus points that actually originates from the current active Paris agreement, and this can be argued by creating a chain connection from the UNFCCC to PTX. UNFCCC is as earlier stated the origin point of the value chain, from the UNFCCC we get the Kyoto, and Montreal protocols. The Paris agreement comes as the next step of the value chain and with the agreement being the reason for the targets set to 2030 and 2050, which was adopted by the EU “The European green deal”[34], these targets are the reasoning for the legal and technical stimuli to create opportunities to comply with the goals.

The PTX project is product of this stimuli as a bridge to meet the targets, but PTX is still in its infancy and stand at a “point of no return” which can cost the project its life, this will be discussed in chapter 2 under Webinar with Energinet.

[33] Article by Pacific Standard: Adaptive housing in the Netherlands.
[34] European commission: A European Green deal

To conclude PTX can be linked all the way back to the UNFCCC and its climate policies and especially connected to the NDC mechanism and the EU green deal goals. The reason to clarify this connection between UNFCCC and PTX is because it is important when creating a framework to establish why it is important, and what factors create the movement and need for developing this technology, and the UNFCCC's policies can be viewed as a climate change constitution that supports this need for innovation and policy making.

1.3 What role can law play in the transition into a climate friendly society.

Law is a multipurposed tool for society to regulate and create standards for the people to follow and create a structure, within law there is a lot of fields like contract law that regulates the boundaries for contracts and so on.

Climate change law is as its stated, law that interconnects with climate change, that implies that every aspect of climate change touched by policies and law is climate change law. Climate change law is multipurposed because it creates a variety of policies and standards to follow, like how it is illegal to drop waste and toxins into the nature or directly damaging the environment, but also creates restriction for preventing long term damage.

The purpose of climate change law is in a very holistic view a tool to preserve or reverse damage to nature[35], but by being a protective measure for nature, this law area will be a dynamic and fluid area that could in the future change drastically, but this depends on the circumstances of the world. The easiest way to explain this is with the current state of the world. In today's earth we face a climate crisis because of human interaction on multiple fronts like, plastic in the oceans, deforestation, overfishing, greenhouse gasses and so on, therefore as of now climate change law is at its peak in the manner of importance because there is such a need for law and policies for preserving and protecting nature. In the future this may not be the case, if we look at it hypothetically and the problems that are endangering and damaging the environment Is solved there will no longer be need for extensive climate change law and this area of law would probably change into a new regime that could be argued to be Climate preservation or protection law. This area of law would

act as an instrument of judging new technologies, products and markets to ensure that the specific subject is not a benefactor in damaging the climate.

With a short introduction on what climate change law is and its nature, the thesis will now go into the instruments and elements within climate change law.

1.3.1 Elements of climate law

Elements of climate change law in the aspect of GHG emission can be divided into two rough categories, adaptation, and mitigation. Adaptation is the primary aspect of adapting to climate change and creating laws that ensure that society is adapted to the dangers of climate change[36] e.g., Sea walls. Mitigation is the reduction of something harmful to the environment.

Targets is one of the most known and popular elements of climate change law, because it is good to have established a timetable and a goal to reach, this can impel governments to find solutions that agrees with the target. The Kyoto protocol was based on a target and timetable mindset by trying to achieve a 5% reduction in GHG by 1990 pre-industrial levels within a five-year period[37]. Targets is an aspect or a category of mitigation because of its nature to reduce the emission of GHG.

Stated by Barry Barton "*Long-term targets are essential, but as we have noted the difficulty is in ensuring that early action is taken. With far-off target dates, political processes may put short-term considerations first and defer action"*[38] Therefor it is important to have other instruments that can ensure that the targets are met, not just by proactive action on the political front, but also in a passive manor, so early action is ensured.

Instruments are important in terms of reaching the targets, the instruments within the climate change can be found deeply integrated within the policies of the UNFCCC. The Paris agreements NDC[39], is an instrument that can work as a political reminder each five years.

[36] Find fodnote - Bog
[37] UNFCCC Kyoto protocol- 4th paragraph & also found in the Kyoto protocol Article 3 section 2.
[38] Barton & Champion 2018: page 8 – paragraph 2
[39] The Paris agreement – Article 4.2: Nationally determined contributions

Carbon budget is also an effective instrument that can work as a reminder in terms of how much carbon we need to mitigate and thus gives a realization for what is needed to comply with the targets. Budgets are very understandable since it is an instrument used firstly all over the world but also heavily used in the private and financial sector[40] and it gives just like money encouragement to use the set amount of (X) efficiently and promote innovation to get around the limit with other means.

Other instruments parties can take into action is education, educating the public in climate change and the consequences if nothing is done, this kind of action can bear fruit in the manner of that on the end-use level the people have a subconscious influence on choices that can have a small effect on the climate.

Measures to comply with targets other than budgets and education can be regulatory actions and this works in harmony according with the PTX case, because if we view the GHG problem as a pipeline, we have a certain amount of C_0^2 coming from the start of the pipe to end of the pipe, but the pipe is not linear, it is more like a knot with multiple entrances and exits, therefor the theory is we can either switch to entrances that contains less GHG or regulate the entrances so it's in take is lesser than before. This is generally what sector-coupling is, a complex system that innovates the supply chain of energy to the end-use with flexibility to regulate the system with efficiency and effectiveness.

The fundamental needs for climate change policies are flexibility, awareness and a fundamental change in the political regime, politics are complex because of the short amount of time that politicians actually are in power and to create an impact on society that is positive but also will get them re-elected and this is a general problem within the climate regime, because that the targets are set for 2030 and 2050, therefor it is not easy to make green politics that impacts society today because if the reward for complying with climate change is so fare into the future.

Comments on climate change law and how it can help transitioning can be simplified by taking the origin point of climate change policies and the targets. Firstly, the origin says, "preserve and reverse damage to nature[41]" and the targets implies how the output of GHG

[40] Barton & Champion 2018: Page 8 – paragraph 4
[41] Find den fodnote!!

should be in the future, so the start and end is clear, but the fundamental problem is the roadmap from A to B how do the parties reach the target and the Partis agreement try to stimulate the parties to figure this out with the mechanism in article 4.2[42] the NDC's as explained earlier, forces the parties to act on climate change and give their solutions to the problem in accordance with their resources. The NDC's also gives a horizontal aspect because with all parties reporting their solutions it is possible to analyze and horizontally integrate the best strategies.

1.4 The European legal structure & climate action

The EU is the establishment of European countries and consist of 27 member states. The EU is at the supranational level and its legal foundation is structured trough the treaties, The Treaty on European Union (TEU) and The Functioning of The European Union (TFEU)[43] The difference on the TEU and the TFEU, is TEU defines the principles and objective of the EU, where TFEU is defined in functions and regulations[44].

Defined earlier the EU is a supranational entity governing and regulating between 27 member states. The legal procedure for the member states is to integrate the law or directives by incorporating the law into their respective legal areas.

The EU and climate legislation

In the TFEU the basis for the European environmental law is in the environmental section that ranges from article 191 to 193,[45].

Article 191(1): defines the different areas the union contributes too, this entails preserving and improving the environment, protecting human health, rational use of natural resources and promotion measures of combating climate change on all levels. 191(2): clarifies that the union aims high for environmental protection, and it's based on the precautionary principle and the polluters pay principle, lastly it defines environmental protection requirements. 191(3): Is the analytical requirements for policy making on the environment. 191(4): This section of the article supports the cooperation between member states and third countries but also third parties related to the union.

[42] The Paris agreement – Article 4: National determined contribution
[43]
[44] Find fodnote or skriv mere.
[45] The Treaty of the Functioning of the European Union: Section on Environment + energy art.191-194

Article 192(1) defines that the union in accordance with different procedures, decides the action that shall be taken on the objectives defined in article 191. 192(2) is a counter article for article 191, so that the union can take measures of fiscal nature[46] and measures affection e.g., spatial planning, water resources and energy supply[47]. 192(3-4) part 3 and 4 defines that action programs shall be adopted with a normal legal procedure and that the member states are financially responsible for the implementation of the policy. 192(5) is protective measure for the member states, that if the actions taken by the union in accordance with paragraph 1 is disproportionate the member state can get support from the union.

Article 193 is short article defining that member states can maintain or enforce the protective measures as long they are compatible with the treaties.

Article 194 is in the energy section of the TFEU and was examined briefly in the section on sector-coupling and renewables, this article can be argued to be partly part of the environmental section because 194(c) promotes renewable energy.

This is the legal basis for environmental protection within TFEU, The EU has also created different legislation, polices and strategies, with importance of brining the EU from A to B in transforming the union towards a society that is decoupled from resource use in regards of the economic and energy.

1.4.1The clean energy package

Clean energy for all Europeans package (the clean energy package) (CEP) published in 2016 and completed in May 2019, the CEP is an updated energy policy framework, the package contains 8 new laws and is the EU's way of presenting its commitments on the Paris agreement. The CEP's 8 new laws ranges from energy performance in buildings[48] to internal market on electricity[49], in relation the case-study the most affecting laws contained in the CEB is the renewable energy directive 2018/2001[50] and the governance of the energy union and climate action regulation 2019/1999 because these two laws have articles that can be

[46] The Treaty of the Functioning of the European Union: 192(2)(a)
[47] The Treaty of the Functioning of the European Union: 192(2)(b)+(c)
[48] DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018
[49] DIRECTIVE (EU) 2019/944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019
[50] DIRECTIVE (EU) 2018/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018

argued to support the development of PTX and sector-coupling and therefor will be examined to see what articles relates to the case-study and how.

1.4.2 The European green deal

the European green deal (EGD), sets out a roadmap for transforming the EU in various areas, especially two sections of EGD is applicable to the case-study on PTX. Section 2.1.2[51] is the roadmap for the energy sector and envisions the commission picture of how the energy sector should be and a large part of this picture is renewable energy in synergy with regional cooperation between the member states, In the last section of 2.1.2 the commission proposes a review of the regulatory framework of the energy sector and quote:

> ” This framework should foster the deployment of innovative technologies and infrastructure, such as smart grids, hydrogen networks or carbon capture, storage and utilisation, energy storage, also enabling sector integration”[52]

This line from the EGD indirectly advocates sector-coupling by proposing that the essential products and technologies of sector-coupling, as stated earlier the EGD is not a legal directive, but a roadmap therefor this is not an indirect legal support for sector-coupling but a political one and this supports that the commission plans on integrating it into the future energy infrastructure. Section 2.1.3[53] of the EGD also forwards claims that support PTX and sector-coupling, 2.1.3 is about a clean circular economy and in the 12th section of 2.1.3 its promoted that the EU Industry needs the top of the industry to develop technology in the most important sectors by 2030[54], in the section it is also mentioned that the priority areas should be clean hydrogen[55], alternative fuels and carbon capture.

The EDG is a roadmap for the EUs, and it clearly supports PTX and sector-coupling, by incorporating key technologies into the future energy framework, but also states that the main technologies of sector-coupling should be a priority and in the first chapter in sixth

[51] The European Green Deal. Section 2.1.2: Supplying clean, affordable, and secure energy
[52] The European Green Deal. Section 2.1.2: Supplying clean, affordable, and secure energy (5th section)
[53] The European Green Deal. Section 2.1.3: Mobilising industry for a clean circular economy
[54] The European Green Deal. Section 2.1.3: Mobilising industry for a clean circular economy (12th section)
[55] Also, what is referred as “green hydrogen”

section it declares that the available policy synergies need to be exploited which is a direct parallel for sector-coupling.

The EDG also reveals the commissions "climate law" which is the where the objectives and goals in the EDG are forwarded into law.

1.4.3The European climate law

The European climate law (ECL), is the first law that sets the climate situation into legislation and does not like the EDG go into detail about the roadmap, but sets the objectives and targets[56] in law and combines this by adopting key fragments of the Paris agreement into the ECL by e.g., incorporating adaptation[57] and extending the assessment of the contribution on the supranational level and the national level in article 6 and 7 every 5th year after 2023[58], this is an extension of the regulation 2018/1999[59] article 29, the difference of ECL article 6-7 and 2018/1999 article 29 is that 2018/1999 mainly focus on progress made each second year from the 31 of October, whereas the ECL article 6-7 also assesses the measures, this is also in accordance with article 5 on adaption[60], so the union can keep track on the measures on adaptation which is an important part of the ECL because it enables the EU to analyze the development of measures but also improve the possibility of horizontal integration by being able to pin point the technologies and strategies with the most potential.

The case-study in context of the ECL is not that important because the ECL do not promote or support renewables and technologies of green nature, but article 6 can be an effective way of promoting PTX and sector-coupling by having the union assessing the measures and progress the advancements made will be noticed by the union and if it's a success the union can focus its resources on this strategy.

[56] REGULATION (EU) 2021/1119 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 June 2021: The European climate law. Article 4 targets.
[57] REGULATION (EU) 2021/1119 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 June 2021: The European climate law. Article 5 on adaptation
[58] REGULATION (EU) 2021/1119 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 June 2021: The European climate law. Article 6-7 assessment on the supra and national level.
[59] REGULATION 2018/1999 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018
[60] REGULATION (EU) 2021/1119 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 June 2021: The European climate law. Article 6-7 (1)(b)

1.4.4 3rd RES directive 2018/2001

Directive 2018/2001 is the directive on the promotion of the use of renewable sources, the 3rd RES setouts the target of the renewable energy share and the 3rd RES is directly connected to the 2nd RES directive, which is very similar, but with some differences. The 3rd RES originates from the CEB, which is as earlier mentioned the overhaul of the energy framework to comply with the Paris agreement commitment, The 3rd RES also differs from the 2nd RES by having its legal foundation in TFEU 194(2) by being an instrument in achieving its goal[61]which the 2nd RES doesn't.

The first and the second article of the 3rd RES defines the subject of the directive and define its content, The third article lay out a minimum[62] target of the gross consumption of renewable energy at a share of at least 32%[63] this minimum target will be changed in the near future with the new proposal by the commission completed 14/7/2021, with an amending of the 3rd RES directive, Regulation 2018/1999, Directive 98/70/EC and Directive 2015/652, the proposal explains that 32% gross share is not enough and it needs to be increased by 5 to 7%, the proposal will be reviewed later in the thesis with its plan on introducing hydrogen into the energy system[64] which is the main product of PTX, along with the targets the member states shall also set national contributions in accordance[65] with regulation (EU) 2018/1999. This element points out that the nature of the 3rd RES is a bottom-up structure, where the member states individually can develop their own strategies within the framework from regulation (EU) 2018/1999 article 3 to 5 and 9 to 14.

Article 4 on supports schemes enables member states to directly support the promotion of renewable energy source, article 4(2) states that the schemes is a way of getting the energy into the market without affecting the electricity market, article 4(2) follows up with a statement on that the support schemes that the integration shall be designed in a manner that maximizes the competitiveness of renewable energy on the electricity market this is

[61] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018: (2) second line.
[62] Minimum as in the lowest share of renewable to be able to reach the 2030 goal.
[63] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018: Article 3(1).
[64] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2018/2001: Page 2 – Context of the proposal.
[65] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018: Article 3(2)

done by market premium. An important part of article 4 is 4(4) which dictates that the support is given in an open, transparent, competitive, none-discriminatory, and cost-effective manner[66] this compliments the ways of the EU with its fair trade and inform that the EU renewable energy within the EU is supported but in a fair way. The last 3 parts of article 4 consists of limiting tendering procedures to specific technologies for 5(a) to 5(e) that lists the reasons and the securing of the quality of tendering procedures along with support for outer regions and small islands, lasty a performance reporting by the commission to the European parliament.

Article 9 to 13 enables member states along with third countries to join up and make a join support scheme, with this some of the produced energy can count toward one of the supporting states followed with a statistical transfer[67].

The support schemes is a great way for member states to directly support the furtherment of renewable energy and projects with financial support and tendering, this feature of the 3rd RES directive can in the future be vital for the implementation of PTX and sector-coupling, firstly because any support legal or financial designated towards renewable energy is vital because the gross share of renewable energy dictates the size of PTX, secondly with minor changes the support schemes can be altered towards supporting second link technologies[68] enabling the article support PTX and incentives the implementation of the technology.

PTX and sector-coupling in context with the current reviewed articles of the 3rd RES directive, are the most impacting legal features of the 3rd RES legislation on the case-study. The 3rd RES offer a lot of legal support and some economical support considering the support scheme feature but the directives main focus is the proportion of renewable energy the union strives to achieve before 2030 and offers ways of forwarding the process through the features. The 3rd RES directives scope is very narrow in context of the problems that follows alongside renewable energy e.g., its storage and efficiency issues, where the

[66] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018: Article 4(4)
[67] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018: See article 8 for more on statistical transfers.
[68] Second link technology is PTX, which is the second link in the supply chain of sector-coupling (Renewable energy -> PTX -> hydrogen and on) Reference appendix 1

promotion of grid optimization and second link technology[69] easily could fit into the directive for a more balanced transition into a renewable dominant energy sector.

1.4.5 Comments and thoughts on the European energy and climate law.

After a review of the European energy and climate legislation, some structural keys points have identified within the framework. Firstly, the way the EU structures its climate law is like a core (article 191-194 of the TFEU) and then having directives that sets out to fulfill the objectives of the core e.g., the 3rd RES has its basis in TFEU 194(1) on the promotion of renewable energy and the European climate law having its basis in TFEU 192(1), which refers to TFEU 191 on preserving the environment, therefor it can be said that TFEU 191-194 is the European environmental protection constitution.

The 3rd RES directive shall be viewed as single directive with none-binding targets but as a legal tool to achieve a renewable dominant energy sector, whereas the European climate law have binding targets for climate neutrality before 2050 and milestone target with a domestic reduction in emissions by least 55% compared to 1990 levels by 2030[70]. This gives a synergy between the two pieces of legislation with one setting the goal and the other functioning as an instrument to achieve the goal, also introducing a combination of both the top-down and bottom-up approach because the ECL sets an order for all the member states and the 3rd RES having the flexibility of the member states choosing their strategies.

[69] See reference 67
[70] The European climate law: article 4

2. Chapter 2: The legal and economic challenges of sector-coupling

2.1 introduction

With the integration of PTX and sector-coupling into our current framework challenges will arise, and these challenges will come in form of legal and economic barriers but as opportunities as well.

In the second chapter of the thesis, the focus will switch from the basis of sector-coupling and climate change law, into identifying the legal barriers and economic challenges of the case-study. The major focus is the legal aspect of sector-coupling, but the economic challenges are deeply intertwined with case and the legal part of it.

The chapter will follow a redline trough the identified problems with an interface view of the legislation and thereafter go into the policies, proposals, and political aspects of the case-study with a focus on the Danish and European integration of system power flexibility.

2.2 the future of the European energy framework.

2.2.1 The amendment of the renewable and energy directive.

On the 7th of July 2021 a proposal[71] for changing the renewable and energy directives was released. The proposal circles back to the objective of becoming climate natural in 2050 in a way that contributes to creating of jobs and economic growth defined in the EGD[72], the proposal concludes that the current efforts and goals are indeed not sufficient to reach the 55% emission reduction by 2050.

The propels calls out for changes such as increase in renewable energy gross share from 33% to 38-40%[73] and the amendment also calls out for a variety of new measures within many different sectors, the measures mentioned is energy system integration which has its core concept around effective heat use and heat pumps[74], "The hydrogen" which is directly how its stated in the proposal and therefore it must be a broad definition on all use and technologies revolving around hydrogen, the offshore renewable energy and lastly biodiversity strategies.

[71] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2018/2001:
[72] The European green deal – see also page 26 of the thesis
[73] Also mentioned in review of the 3rd RES
[74] https://eurovent.eu/?q=articles/eu-strategy-energy-system-integration-gen-113800 - explanation on energy system integration.

The amendment of REDII is only one of many to come with the commissions “fit for 55 package” where they initiates an overhaul of the whole energy framework by amending and revising eight different directives and regulations to meet the new 2030 goals.

This is the introduction of the amendment and with hydrogen being one of the aspects of the amendment yields great relevance for the case-study.

The current 3rd RES directive is lacking in technologies and strategies that is closely related to renewable energy sources, but with the new amendment these changes, and the thesis will go through the amendment to see where the proposal supports and further the advancement of hydrogen technology.

Firstly, the commission proposes a revision of 8 directives and regulations, one of the directives that is being changed is the Alternative fuel infrastructure directive[75] (AFID) this directive defines what is an alternative fuel and hydrogen falls under the definition of an alternative fuel within the definition article. Article 5 in the AFID gives the member states the possibility to choose hydrogen fuel and if they chose to include hydrogen as a fuel the member state have until 2025 to make hydrogen filling point. Article 5 of the AFID is a barrier for the development of hydrogen technologies because of its bottom-up approach that gives the member states the opportunity to deselect hydrogen as a fuel. Hydrogen as a fuel is not the important part of this article, but by selecting to have hydrogen as an alternative fuel binds the member state to construct hydrogen filling points, the fuel stations could act as a booster for the development of hydrogen technologies but also the filling points can be used with a fuel cell to create electricity for electric vehicles directly at the filling point and lessen the burden on the energy grit. By adopting a top-down approach on the amendment of AFID, the union can bind the member states to develop hydrogen filling points, with this change the union can in the amendment of the REDII combine it with fuel cells and strengthen the electrification of the transport-sector.

Secondly, the amendment goes directly into the 3rd RES directive and describes the changes proposed in the legal text, this is e.g., the changes in article 3 the commission propose a

[75] DIRECTIVE 2014/94/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014

change in renewable share from least 32%[76] to 40%[77] which is a response to that 32% as minimum target isn't enough to comply with 2030 target. The first amendment with change in accordance with PTX and hydrogen is to be found in the amendments article 22a, this new article is on "mainstreaming renewable energy in industry"[78] and promotes renewable fuels of none-biological nature and in the third section of the first paragraph it defines that member states shall ensure a decrease in hydrogen[79] but this can be replaced by green-hydrogen produced from renewable energy through electrolysis and promote investments into the PTX project through the industry and this sums up the introduction of hydrogen into the legal text of 3rd RES directive in the amendment.

Thirdly, in the assessment report of the amendment the commission describes in detail and envisions what role renewable hydrogen will partake in the new energy framework. The impact assessment report is structed from an introduction into a problem assessment of directive 2018/2001 and thereafter the report goes into the policy options available to the commission. The first mention of hydrogen is in the second problem definition and here the commission explains that the directive does not properly reflect the hydrogen strategies one of such strategies is the "A hydrogen strategy for a climate-natural Europe"[80] which will be revied later in the thesis.

Second mention of hydrogen is in the section on problem drivers, within this section the commission explains that the electrified transport sector is underdeveloped, and this is driven by the few options of vehicle models and the lack of an infrastructure for fillings points but also reward to risk ratio is too low for operators is unknown because the lack of information on the progress of electrification, an important identification of the problem is the main market barrier[81] the commission explains the barrier as a gab created by price difference of carbon-based fuels and that hydrogen technologies are in its infancy. This barrier is a valid point and this can be tackled from two different perspectives, the first can

[76] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018: article 3
[77] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2018/2001: article 3
[78] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2018/2001: article 22a
[79] Hydrogen that is not carbon free.
[80] Communication from the commission to the European parliament on A hydrogen strategy for a climate-natural Europe
[81] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2018/2001: Section on problem drivers – On the barriers of hydrogen technology.

help tackle both problems and that is the amendment of the 2018/2001 directive, the directive supports renewable energy and this is only empowered with the amendment, by increasing the renewable energy share amount this gives electricity produced by renewable a better competitive standpoint and this drives the price down and reducing the gap between the two sources of electricity, the second is the implementation of hydrogen strategies in the amendment but also in the changes to come in the "fit for 55 package" to promote the development of hydrogen through other directives such as the AFID[82], like pointed out earlier in the thesis this directive can promote the furtherment of the hydrogen infrastructure. The second perspective is on the development of hydrogen technologies in similar manner with the changes made in the amendment by promoting it through the industries, this will take regulation and market analysis to figure out every aspect to market hydrogen.

Rest of the amendment has its focus primarily on synthetic fuels or as earlier described in the thesis (e-fuels), the commission sees innovative renewable fuels especially fuels from hydrogen technology as an essential for achieving climate neutrality[83] the commission argues that the technology is not ready deployment and the argument is valid, the production of e-fuels haven't been industrialized and the transport sector needs transformation, so that its ready for e-fuels when its production rate is high enough to start competing with other fuels on the market.

Comments and thoughts on the proposal on the 2018/2001 directive

The proposal on the 2018/2001 directives sets out a high and ambitious change of the directive on promoting renewable energy, but also fills in the blanks around the directive and by doing that the commission strengthen the opportunities the union have on reaching the climate neutrality goal in 2050[84] this is done by introducing second link technology complimenting renewable energy technologies and supporting its issues.

The impact assessment of the amendment focuses on a variety of different technologies within the hydrogen regime and the commission points out both barriers and opportunities,

[82] DIRECTIVE 2014/94/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014
[83] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2018/2001: The commission on advanced fuels and its current situation.
[84] REGULATION (EU) 2021/1119 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 June 2021: article 2(1) net zero emission 2050.

the barriers are mainly technological development based and market based with PTX and sector-coupling the development aspect of the barriers can be solved by slowly introducing sector-coupling into the member states and creating foundation for investment and advancing the production of synthetic fuels.

2.1.2 Review of "A hydrogen strategy for climate-neutral Europe"

The hydrogen strategy communicated by the commission on the 8th of July 2020, is well formulated hydrogen strategy which defines the different hydrogen products and what products the strategy plans to use and how it plans to incorporate it into the new hydrogen framework. The mentioned hydrogen products is hydrogen from electrolysis with no regards to the energy source, hydrogen produced from electrolysis based on renewable energy "clean hydrogen", fossil-based hydrogen from feedstock or gasification of coal[85].

The roadmap for the hydrogen strategy prioritizes the use of renewables that originates from wind and photovoltaic energy, this is because these are the two dominant technologies within the renewable energy sector and by focusing on only two different sources, the EU therefor narrows its scope.

The strategy proposed by the commission is structured in three different phases. The first phase stretches from 2020 to 2024, the main objective of phase one is to establish a foundation on the production of clean hydrogen by installing at least 6 Gigawatt (GW) clean hydrogen electrolyze [86]In the EU. The commission plans un achieving the 6 GW by installing electrolysis plants and proposes to install them near the industry that uses or can use the products, this can help reduced the price on green hydrogen which is 3-5 times higher than carbon hydrogen and 1-2 times higher of low-carbon based on carbon capture storage. This is one the barriers of green hydrogen and this is a main area to be solved so that the price difference of green hydrogen and fossil-based hydrogen does not impede the interest of buying green hydrogen.

The second phase of the implementation of green hydrogen is from 2025 to 2030 and in this time period, the commission plans to make this industry an inner part of the energy sector. From the first phase the target was an increase from 6 GW to 40 GW an increase by 666,7%.

[85] Communication from the commission: A hydrogen strategy for a climate-neutral Europe – on hydrogen based on carbon.
[86] Communication from the commission: A hydrogen strategy for a climate-neutral Europe – Phase 1

The phase is based on green hydrogen becoming price competitive, this will be ensured by using energy from renewable energy when the price is high and in the night where the energy demand is low, this optimizes the effectiveness of renewables and lowers the price of green hydrogen. The hydrogen industry will need policies to ensure new industrial uses e.g., within the transport sector in synergy with synthetic fuels. The rapid increase of this sector will require heavy investments into the sector, and this needs support from all levels, supranational, national, and regional but also the private sector.

The third phase of the hydrogen strategy synchronizes with the climate targets by following the 2030 to 2050 structure, at this phase the green hydrogen technology will be deemed to be mature and have an impact on all hard-to-decarbonize[87] sectors, the 2050 goal is to have 25% of the renewable energy share allocated into the production of green hydrogen.

For the hydrogen strategy to be realized market policies needs to be incorporated and heavy investments into different areas impacting the development of the hydrogen sector. The roadmap for investments is focused on phase two and phase three, whereas the investments needed in phase two to sums up to a 24-42 billion euro, but this is only the investment needed in electrolysis development for the cost of connecting photovoltaic and wind energy to electrolysis in scale will cost another 220-340 billion euros, another 11 billion is needed to develop carbon capture storage technology, so to sum it up to around 324 billion euros[88]. Another 65 billion euro will be needed for infrastructure purposes, and this will increase to 180-470 billion euro towards 2050[89]. The strategy also explains the investment requirements for the end-use sector to adapt and clarifies that a single steel instillation can cost up to 200 million euros.

The investment needed in both the second and third phase are high, the commission have different proposals to comply with the investment need and the first is a European clean hydrogen alliance with the objective of promoting investments and implement the strategies of the hydrogen strategy. The commission plans to use the emission trading scheme (ETS) as an instrument to support the finances of hydrogen with a fourth phase

[87] Sectors hard to decarbonize are sectors that heavily rely on carbon-fuels
[88] The investment estimates are very broad the sum is taken from the median of the lowest and highest number.
[89]Communication from the commission: A hydrogen strategy for a climate-neutral Europe – page 8 on investments required

revision of the ETS directive, another strategy by the commission is a support scheme that support the implementation of a green hydrogen sector. This was proposed in the thesis[90] and in the hydrogen strategy this should act as a reward for electrolysers through price signals[91].

Comments and thoughts on "A hydrogen strategy for climate-neutral Europe"

The hydrogen strategy is a core move for implementing PTX and sector-coupling into the energy framework, the strategy is a long-needed roadmap for a plan to roll out the hydrogen regime into the EU. Renewable energy and electrolysis is the foundation of sector-coupling, because without these two components the overhaul of the energy sector will not be possible, so having the union support the core components of the case-study, the strategy sums up how profitable the hydrogen sector is going to be with an estimate of annual sales of 630 billion euro[92].

With high opportunities on profits from the hydrogen sector in mind, the commission needs to broaden the reach of support for the advancement of low-carbon and green hydrogen, and this will be proposed in the third chapter of the thesis.

2.1.3 Wishes and recommendation from Danish Energy Agency & the EU on sector-coupling

The previously legislation and strategies have been primarily focused on electrolysis and hydrogen, but now the thesis will dive into sector coupling. the EU under the gas infrastructure Europe (GIE)[93], the European commission[94] have published recommendations, strategies, and policies directly on the sector-coupling subject this will be viewed alongside a study on enhancing sector-coupling[95] and lastly a paper published by the Danish Energy Agency with their recommendation on developing[96].

[90] First chapter on the EU legislation: 3rd RES DIRECTIVE
[91] Communication from the commission: A hydrogen strategy for a climate-neutral Europe: page 14 (support-schemes)
[92] Communication from the commission: A hydrogen strategy for a climate-neutral Europe: page 2
[93] Gas infrastructure Europe: Position paper – Sector coupling and policy recommendations
[94] Report Potentials of sector coupling for decarbonisation – Assessing regulatory barriers in linking the gas and electricity sectors in the EU
[95] EU STUDY – Sector-coupling: how can it be enhanced in the EU to foster grid stability and decarbonize?
[96] Danish Energy Agency - Development and Role of Flexibility in the Danish Power System Solutions for integrating 50% wind and solar, and potential, future solutions for the remaining 50%

Firstly, the published papers from the commission will be reviewed and thereafter compared to the paper by Danish Energy agency[97]. This will give an overview perspective on how the EU visions on the establishment of sector-coupling on the supranational level and thereafter a review of a paper on the national level, to see if the barriers and recommendations identified at the supranational level and at the national level is matching.

2.1.3.1 Potentials of sector coupling for decarbonisation – Assessing regulatory barriers in linking the gas and electricity sectors in the EU

First part of the report focuses on the role of gas in will not be revied because the role of gas has been identified through the amendment of the 2018/2001 Directive and the hydrogen roadmap.

The report divides identified barriers into five different categories. First immature technology, second uneven playing fields due to tariffs and levies, third focus on natural gas in infrastructure regulations, fourth uncoupled and uncoordinated infrastructure planning and the fifth risk for interoperability across markets and boarders[98].

The immature technology category is a barrier the thesis has encountered before especially with the hydrogen strategy, where immature technologies like electrolysis needs promotion and support. the report explains that stakeholders have called out a need of a binding target within the gas-sector to indirectly drive policies to increase investment and financial support, this was directly call upon in the hydrogen strategy with large amount of investment needed to transform the gas sector[99].

A barrier mentioned in the report which is the risk to ratio reward the industrial sector faces when switching to technologies such as PTX and renewable energy, an argument could be offered that the industry can just wait until the framework and technology is ready to implement, but this won't happen if stakeholders and private investors won't risk investing

[97] Danish Energy Agency - Development and Role of Flexibility in the Danish Power System Solutions for integrating 50% wind and solar, and potential, future solutions for the remaining 50%
[98] Report on - Potentials of sector coupling for decarbonisation – Assessing regulatory barriers in linking the gas and electricity sectors in the EU: page 40
[99] Report on - Potentials of sector coupling for decarbonisation – Assessing regulatory barriers in linking the gas and electricity sectors in the EU: page 46

in the early stages, therefore like with the support-schemes the EU should meet the private industry sector and help carrying the risk[100].

In the second barrier category on uneven playing field due to tariffs and levies a tax problem is defined because of high taxation in the end-use sector and with the PTX products produced by the electrolysis process and its key ingredient electricity, therefore the products price is highly define by the energy tax and this is because 2/3 of the energy price is tariffs and levies, this is especially relevant for the production of green hydrogen, because it does not require any external ingredients and therefor only defined by the electricity price[101]. The solution to this problem can be solved in different ways, one of the solutions could be a joint plant combination with both renewable energy sources and PTX technology to avoid taking renewable from to grid and therefor avoid taxations on the PTX products, another solution could be a law that exempts climate friendly products from tariffs and levies to bring down the price to help the products become more market competitive.

The last barrier to be revied of the report is a harmonization barrier with future support schemes applied to the gas sector and domestic integrated support on hydrogen development, with different ways to support the clean gas prices the important can be distorted[102]. This barrier is a difficult one and is mainly and issue if the EU approaches the financial support for gas at a bottom-up approach, where a top-down approach would be easier to manage, because the support features will be determined at the supranational level.

2.1.3.2 Sector coupling: how can it be enhanced in the EU to foster grid stability and decarbonise?

This study calls out for other strategies than electrification within the industry sector, because of a potential electrification percentage that is around 38-50%. Rest of the 50-62% can be achieved through synthetic fuels, which have been touched upon by the thesis more than once.

[100] Report on - Potentials of sector coupling for decarbonisation – Assessing regulatory barriers in linking the gas and electricity sectors in the EU: page 53
[101] Report on - Potentials of sector coupling for decarbonisation – Assessing regulatory barriers in linking the gas and electricity sectors in the EU: page 58.
[102] Report on - Potentials of sector coupling for decarbonisation – Assessing regulatory barriers in linking the gas and electricity sectors in the EU: page 87

The study goes into detail about the transport sector and how it can be electrified, but also points out that servals studies shows that the charging of electrical vehicles is done in a none coordinated way, the study circles back to the tariff/tax problem on electricity and proposes a coordinated flexible tariff that changes accordingly with the time, this will both have a positive impact of electrical vehicles but also on PTX and the production on hydrogen and other e-products, this could promote the competitiveness of PTX products. The study also points out local grid problems with the charging of electric vehicles and proposes to make a system that make electric cars work as a unified battery which is a solution that create more problems than solved, by needing high end IT-solutions and a very strict framework on pricing and compensation for the car owners.

The study compared to the report structures barriers in two different categories instead of five. The first category is techno-economic barriers, which entails technology, markets, and infrastructure, the second category is policy and regulatory barriers which entails integrated planning and operation, climate and energy policies and market designs included tariffs.

The first category is the techno-economic barriers, and it starts off with a barrier on competitive prices, where carbon low/free products as they are now can't compete with its counterpart, fossil-based fuels. Rest of the section is on subjects that has already been reviewed in other papers and laws, such a hydrogen competitiveness.

The second category is the policy and regulatory barriers, first part focuses on the lack of synergies and the integration on effective measures to reduce lag within the sectors[103].

The study calls out for a carbon-price, a reformed ETS[104] and lastly for drastic measures a carbon-tax to level the playing field on carbon products and clean energy products. Another barrier is the tariffs on grid connections and access and is viewed as one of the main barriers of electrification in Netherlands and therefor it propose a new tariff structure that promotes renewable energy and products created from it[105].

[103] Sector coupling: how can it be enhanced in the EU to foster grid stability and decarbonise?: page 48
[104] Emission trading scheme
[105] Sector coupling: how can it be enhanced in the EU to foster grid stability and decarbonise? Page 50

2.1.3.3 GIE Position paper Sector Coupling and policy recommendations

The paper continues on the grid optimization for fair grid charges, and this is because of the impact it has on power 2 gas which is the core of sector-coupling and goes into detail on e-fuels which is not properly covered by legislation, but the paper is before the proposal on changes in the 3rd RES directive and the Hydrogen strategy. The paper supports investment support for pilot projects on power to gas[106] and clarifies that it is not yet profitable to invest into PTX, this will subject will be approached in the webinar with energinet.

The GIE paper categories barriers in third way, with four different categories, market design barriers, regulatory barriers, technical barriers, and governance barriers. The categories shall be viewed as a checklist and the paper takes the subject and measures it to each category.

First subject to be crosschecked is gas to power starting at the regulatory section, the paper details a problem with gas power plants not having the sufficient network to transport or store gas, the suggestion on a solution is an increase in short-term products with a more volatile influx[107]. The paper also remarks a tax barrier that doesn't comply with the nature of gas-to-power, with some EU countries not taxing the end-use but the procedure, the suggested solution for this problem is tax exemption and reductions to even out the tax burden[108].

On the subject on power-to-gas the paper identifies an important barrier stands in the way of harmonization of gas in the EU. The barrier is in the inconsistent use of Guarantees of Origin (GoO) certificates for gases which not all member states is a part of. The problem lies in the definition of gasses where green hydrogen is treated as neutral gas in Switzerland and biogas in Germany, where this can act as a barrier for the trade of clean hydrogen. Proposed solution is adopting a supranational wide definition on the different gasses especially the different varieties of hydrogen[109].

The paper focuses on another tax barrier, which is like the barriers identified in the other papers. The barrier in this problem lies with producers in some member states being taxed

[106] Power-to-gas is one of the branches of PTX
[107] GIE Position paper Sector Coupling and policy recommendations: page 8
[108] GIE Position paper Sector Coupling and policy recommendations: page10
[109] GIE Position paper Sector Coupling and policy recommendations: page 14

as an end-use of the gas and in Germany this kind of tax barrier is problematic because storage is seen as an end-use and therefor taxed. The solution can be found in Denmark here PTX products is viewed as a process energy and therefore not taxed.

2.1.3.4 Danish Energy Agency - Development and Role of Flexibility in the Danish Power System Solutions for integrating 50% wind and solar, and potential, future solutions for the remaining 50%

The paper is structured different than the other three papers on the EU, where this paper is structured as a roadmap with solutions and suggestions on sector-coupling in Denmark.
The paper suggests a couple of solutions for Denmark, such as a pricing scheme which is reminiscent of support schemes, this is aligned with the suggestion of the other papers with the objective of ensuring an attractive business model for investors[110], but the paper also suggests an open balance of the utilization of energy generating timing for different sources for effective use of different technologies[111].
The paper doesn't offer much new information compared to the EU papers and is generally focusing on the integration of renewables which also an important factor for reaching the climate targets, but also implementing sector-coupling

2.1.3.5 a comment on the papers

The papers are structured very differently but their content is very similar. Key points of the papers are that they all outline a need for change in the tax area, this involves changes in tariff and the tax structure within the energy sector, this is an important benefactor for more reasons. Firstly, the exemption I taxes on electricity, which is the key ingredient in PTX products, secondly a harmonized tax structure within the EU can further the development of gas trade of member states by having a unified way of taxing PTX products. Thirdly the technological advancement of immature technologies which is a major driver for increasing the progress of implementing clean hydrogen into Europe.

[110] Danish Energy Agency - Development and Role of Flexibility in the Danish Power System Solutions for integrating 50% wind and solar, and potential, future solutions for the remaining 50%

2.2 Web interview with Dansk energi.

Dansk energi is a Danish interest organization for energy firms which is a promoter on the PTX project and wishes to kickstart the implementation of PTX in Denmark.

Dansk energi also have a paper on PTX in Denmark but it is very technological and is based on what PTX is the recommendations on how it can be implemented into Denmark.

Dansk energi made in 19/11/2020 a webinar[112] about this integration together with the industry leaders of Denmark, the webinar is important in accordance with thesis because of the nature of the webinar, because it dives into the relation between the public and the private sector and what barriers that exist in this relationship in context of PTX.

2.2.1 Commentary on the webinar with Dansk energy.

The webinar starts with an introduction on what is PTX, what can it do and how its appliances can be used, thereafter Lars Aagaard the current director of Dansk energi talks about a barrier that the government and private sector needs to come together to achieve the establishment of PTX and then invites the current climate, energy, and supply minister Dan Jannik Jørgens on stage, Dan Jørgens ensures that Denmark is going towards a green future, but again explains that all hands are required.

Later companies are invited to the scene, these companies are Topsøs, shell and Vattenfall, the companies explains that they already are ready to invest into the technology and shell already have a plant coming in May 2022[113] with the company "everfuel[114]" the companies also explains that the price is not good enough overall and therefor they cannot start by themselves, and they need political enticement to start.

After Topsøs, Shell and Vattenfall have been on the representatives of Mærsk, and SAS joins the stage and Mærks claims that they want their first climate-natural ship in 2030[115]. SAS expects to increase their use of biofuels on airplanes to 10% in 2025[116], SAS also explains that e-kerosene is four times as expensive as fossil fuels and says that 25% of their expenses is fuels and therefor the price is not acceptable and both SAS and mærks explains the need

[112] Webinar on PTX - https://www.youtube.com/watch?v=DpEG08_g-Jg
[113] Webinar on PTX - https://www.youtube.com/watch?v=DpEG08_g-Jg (minute 42)
[114] A company on green hydrogen in Denmark
[115] Webinar on PTX - https://www.youtube.com/watch?v=DpEG08_g-Jg (minute 58)
[116] Webinar on PTX - https://www.youtube.com/watch?v=DpEG08_g-Jg (minute 64)

for political intervention in the PTX flagship project, especially mærks argued that the government need to ensure regulations on the subject to make it attractive for the private-sector.

The webinar invites Lars Aagaard back with Tommy Ahlers climate politician, Ulrik Stridbæk VP of Ørsted and Maria Hansen from CPH airport to the scene. Tommy argues that the government should let the private investors take the lead on the PTX project because with too much political involvement the process can slow down which is not good for the climate[117].

2.2.2 final comments on webinar with Dansk energi.

The webinar shows a great dynamic between the actors within the development of PTX, where you have the government and politicians on one side and the private sector on the other. In the webinar the private sector shows the interest and sees the possibilities that PTX offers to their respective firms, but PTX is an immature technology with no real infrastructure and high prices, this drives away the private sector because their objective is to make a profit and therefor, they need the government to reach out and reduce the risk there is to invest into PTX at its infancy. The government on the other hand need the insurance of the private sector so that if they set up an infrastructure of PTX, there actors to invest but also take the produced products of their hand.

PTX on the domestic level is crucial for the advancement of the technology firstly, because it can create a legal stimulus and promote horizontal integration. Secondly, because it's a vital aspect of reaching the climate neutrality target of 2050, which is a binding target and without advancements in impactful technologies like PTX the target will never be reached.

[117] Webinar on PTX - https://www.youtube.com/watch?v=DpEG08_g-Jg (minute 78)

3. Chapter 3: Legal barriers of sector-coupling and its solutions

With the sector-coupling, international and European supranational climate law explained in chapter 1, the fundamental of sector-coupling and the law was established. In the second chapter legislation, policies and political was reviewed to identify the barriers of the case-study. At the third the chapter the thesis will take identified barriers within chapter two and give solutions based already existing ideas, but also ideas created by the author of the thesis.

3.1 List of barriers within sector-coupling and PTX.

Before addressing the identified barriers, the barrier will be listed and summarized to create a catalog of the barriers, that can be used to orientate and navigate.

- **First barrier:**
  Technological immaturity in vital technologies that dictates the future of PTX and sector-coupling.
- **Second barrier:**
  Risk to reward ratio for private investors, the area is not developed enough and carries a big risk for the investor.
- **Third barrier:**
  The gap between the prices on carbon-based fuels and PTX products mainly green and low carbon hydrogen.
- **Fourth barrier:**
  no flexibility in tariff and levies on PTX products
- **Fifth barrier:**
  lack of harmonization on taxes from PTX products,
- **Sixth barrier:**
  lack of harmonization on the definition on hydrogen-products on a supranational level.
- **Seventh barrier**
  Lack of finance mechanisms to support the transition into a green energy sector.

This sums up the rough list of barriers identified through the thesis on PTX and sector coupling. Some of the barriers will now be tried with a solution-based perspective.

3.2 Financial support

In chapter two on the hydrogen strategy, it has been realized how much funding the hydrogen strategy needs and therefor mechanisms and support schemes needs to be instated to help the EU to fund, the project.

The thesis will propose solutions on the economic barriers of PTX and sector-coupling

3.2.1 Emission trading scheme

The emission trading scheme (ETS) is a European mechanism to reduce emission within the union that set up a cap-and-trade system with the objective of putting a price on carbon.

The ETS works by creating an allowance/right to emitting GHG and this allowance is capped this means there's a maximum and the allowances is decreased annually from 2013 by 1,74%, with the goal of having companies reduce their overall emission.

The allowances is worth 1 ton of Co2, and the participants needs to return allowances accordioning to every ton of Co2 they emit and if they do not have sufficient allowances the party will need to buy allowances from others or auctions. The penalty the party faces if they can't comply with allowances and released Co2 is 100-euro pr. ton Co2.

3.2.2 A European carbon tax

With the European green deal and new carbon free products a regulation is due to help the transition into a union with a dominant clean energy sector. In the barriers section of the third chapter, third barrier identifies a gap in competitiveness which is price based, the studies have offered solutions on exempting or regulating the taxes applied on PTX products and this can help closing the gap, but it leaves out the need investment demand for industrializing and upscaling of PTX, therefor the thesis proposes a carbon-tax that shall ensure to raise the prices on carbon based fuels and closing the gap between the two alternatives even more.

The carbon tax is a difficult measure to implement into to society because our structure as it is now carbon dominant and therefor the tax will impact a lot of areas, but the tax will be implemented with a very small percentage and annually increase, and this will be done in synergy with renewable energy and PTX to comply with market prices. The collected carbon tax will be allocated to a green energy transition fund that member states can use invest in the green energy transition.

For the carbon tax to be effective it need to be a tax that is mandatory for all member states (top-down) approach, this is done because if the tax is not harmonized through out the countries prices on products will differ and then the harmonization of the market will be disrupted.

Realistically a carbon tax will be hard to implement on the supranational level, because of the disadvantage it puts the European member states in relation to USA or China, because our products will be more expensive, but even the Danish climate council propose a carbon tax in their status outlook of 2021[118]. The outlook points towards the ETS being to dynamic cross all sectors, where they propose a unified tax have set in motion to create a model that envisions the roadmap for the tax.

3.4 a proposal for a joint PTX plant.

The second barrier identified that the risk to reward ratio of investing in the immature technologies is problem for the advancement of the project, therefor the thesis propose a public-private hybrid partnership[119]. The initiative is a public owned company where the government owns 50% and the remaining 50% will be owned by the private sector and the public. The idea is to create a plant that is supported by the government ensuring that its funded and then with the rest of the 50% being open for the public and the private to invest in.

According to the revied papers in chapter 2, the immature technology sure be mature in 2030 therefor after 2030 the government will sell 12,5% of the company every fifth year and in 2050, the plant should be independent from the government.

[118] Klimarådet: Status outlook 2021 – Denmark's national and global climate efforts: Page 12
[119] Hollo, Kulovesi, Mehiling – Climate change and the law 2013: Page 55.

This suggestion diminishes the risk factor for the private sector and should then promote the investment into PTX and deal with one of the barriers that PTX and sector-coupling faces

Conclusion

The thesis research question is: What are the regulatory barriers of implementation "power system flexibility" with the implementation of EU Law when structuring power system flexibility in synergy with renewable energy?

The thesis gives a respond to the research question by going through the basis of the legislation connected to the case-study's core and thereafter going deeper into what legal aspects of the European law and policies that drives the case-study forward.

The regulatory barriers identified in the thesis originates with the case-study being a project in its infancy. The case-study as it is now does not even have a foundation within the EU and its legislation, but the thesis proved that the EU is making legal and policy changes that can kickstart the project and establish the foundation.

The barrier that proved to be the bottleneck of the case-study is the lack of harmonization on the area, with definitions of hydrogen varying from member-state to member-state confusing the cross-boarder trade by not having a unified label kind of gas that its traded and the uneven playing field on taxation area, whereas some electrolysers are better off than others.

The case-study was found to have both advantages and disadvantages from both the bottom-up approach and the top-down approach. The bottom-up approach promotes different PTX and sector-coupling strategies that proves to be great for horizontal integration, but also harming the harmonization on the price. The top-down approach offers a strong unification on the hydrogen strategy by communicating too all member states that hydrogen is the future of the EU.

The case-study also proved to have opportunities that enables the union and the member states to reach the targets of the Paris agreement and the binding targets of the EU. This is achieved by electrification of the sectors and replacing carbon-based fuels with synthetic fuels produces from clean hydrogen.

Abbreviations

CB-S - Carbon-based sector

EGD - European green deal

UNFCCC - The United Nations Framework Convention on Climate Change

GHG - Green House Gasses

NDC - National determined contribution

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Report, proposals, and policies

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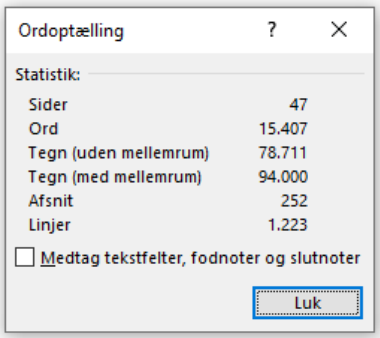
Ordoptælling
?
Statistik:
Sider 47
Ord 15.407
Tegn (uden mellemrum) 78.711
Tegn (med mellemrum) 94.000
Afsnit 252
Linjer 1.223
Medtag tekstfelter, fodnoter og slutnoter
Luk