The European Green Deal - a chance to foster the further integration of renewable energies into the European energy system ?

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The European Green Deal – a chance to foster the further integration of renewable energies into the European energy system?

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Abstract

This master thesis investigates whether the systemic approach of the European Green Deal (EGD) is beneficial to address the different challenges for the further integration of renewable energies (RE) into the European energy system. To prepare the terrain, the thesis gives an overview of the situation of RE in the EU and the development of European RE policies. The analysis is based on two steps: firstly, the thesis identifies the most important challenges for an increase in RE based on an academic literature review, on 12 interviews with officials of the European Commission, and on the attendance of six webinars, where Commission members, interest groups as well as experts discussed the energy transition. This working methodology has allowed identifying 22 challenges for the increase of RE in the European energy system. In a second step, the EGD and all its sub-initiatives adopted by the European Commission up to 31st of July 2020, and the proposed recovery instrument addressing the Covid-19 crisis are evaluated with respect to the question whether the identified challenges are addressed. Information gathered during the interviews have a supportive function. In both steps of the analysis, 'energy system integration' and 'renewable hydrogen' are treated in more detail, because the integration of the energy system and the deployment of renewable hydrogen are generally considered crucial for the increase of RE, and because the European Commission adopted an 'energy system integration strategy' and a 'hydrogen strategy' in July 2020. As a result of this analysis, it appears that most challenges are addressed by the EGD, or if not addressed by initiatives the European Commission is conscious of possible risks. Nevertheless, land use competition and the supply of critical raw materials might become limiting factors for RE in the future, if not tackled more thoroughly. Nonetheless, the systemic approach of the EGD has demonstrated to be beneficial to address challenges that would be difficult to overcome through mere RE policies and the recovery measures are designed to support the energy transition.

Résumé

Ce mémoire évalue la capacité de l'approche systémique du Pacte Vert pour l'Europe (PVE) à relever des défis menant à la croissance des énergies renouvelables (ER) au sein de l'Union européenne. Le mémoire présente dans un premier temps l'évolution de la politique européenne des ER et leur situation actuelle. L'analyse est réalisée en deux étapes : Premièrement, les principaux défis liés aux ER sont identifiés en se basant sur 12 entretiens avec des fonctionnaires de la Commission européenne, une revue de la littérature académique ainsi que six webinaires au cours desquels des membres du personnel de la Commission européenne, des experts, des groupes d'intérêt et acteurs du secteur ont discuté de l'avenir énergétique européen. Grâce à cette analyse, 22 défis sont ainsi identifiés. Ensuite, les réponses que propose le PVE aux défis identifiés sont évaluées sur base d'une analyse des initiatives adoptées par la Commission européenne jusqu'au 31.07.2020 dans le cadre du PVE et de l'instrument de relance suite à la crise de la Covid-19. Des informations tirées des entretiens complètent cette analyse. Au cours des deux étapes de ce travail, l'intégration du système énergétique et l'utilisation d'hydrogène renouvelable font plus spécifiquement l'objet d'une analyse approfondie, étant donné que ces deux facteurs sont considérés comme étant primordiaux pour la croissance des ER par la communauté scientifique. De plus, la Commission européenne a adopté une « stratégie pour l'intégration du système énergétique » et « une stratégie d'hydrogène » en juillet 2020. La thèse conclut que le PVE propose des initiatives pour la plupart des défis ou en reconnait du moins la pertinence. Néanmoins, les défis « conflit d'usage des territoires » et «approvisionnement en matières premières critiques » risquent de devenir des facteurs limitants à l'avenir s'ils ne font pas l'objet d'un traitement plus spécifique. En conclusion, l'approche systémique du PVE est utile pour traiter un grand nombre de défis, ce qui serait difficilement envisageable avec des politiques ER isolées, et les mesures de relance proposées ont été conçues pour soutenir la transition énergétique.

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List of abbreviations

ASSET	Advanced System Studies for Energy Transition
BDEW	German Association of Energy and Water Industries (BDEW)
CEAP	Circular Economy Action Plan
DG	Directorate-General
DG Growth	Directorate-General for Internal Market, Industry, Entrepreneurship and small and medium-sized enterprises
DG REGIO	Directorate-General for Regional and Urban Policy
EEA	European Environmental Agency
EGD	European Green Deal
EIB	European Investment Bank
EPBD	Energy Performance of Buildings Directive (Directive 2018/844/EU)
ETS	Emission trade scheme
EU	European Union
FCCC	Framework of Convention on Climate Change
GHG	Greenhouse gas
GW	Gigawatt
GWh	Gigawatt hour
IAS	Internal Audit Service
MS	Member State
NECP	National energy and climate plans
P2G	Power to gas
PV	Photovoltaic
RE	Renewable energies
RED	Renewable energies directive (Directive 2009/28/EC)
RED II	Recast of the renewable energies directive (Directive 2018/2001/EU)
RES	Renewable energy sources
TEN-E	Trans European Network for Energy Regulation (EU) 347/2013
TEN-T	Trans-European Transport Network Regulation (EU) No 1315/2013
TJ	Tera joule
W^e	Electric Watt

1 Outline of the context and the research question

1.1 The European Green Deal as a new policy approach in an age of environmental crises

In 2020, humanity is facing environmental challenges "of unprecedented scale and urgency" according to the European Environmental Agency (EEA).[1] Humans' lifestyle puts natural balances of our planet at risk, which affects biodiversity, the climate, and also our well-being. The EEA states that the transformation of natural environments is very much related to the quick development of humans' standard of living since the 18th century with a "quick acceleration since 1950".[2] Important factors are our vast energy use (since 1950 the primary energy use increased five-fold) and our consumption patterns.[3] Projections for the future expect resource use might double by 2060, water use have increased by 55% in 2050 and energy demand is also expected to grow further.[4] As a consequence, scientists warn about a number of environmental crises: a sixth human-induced mass extinction is already under way ("anthrophocene defaunation"), which is also named as one of the reasons for the recent step-over of an animal virus to humans and the following Covid-19 crisis.[5]

A second crisis is climate change which might cause a sea-level rise between 0.3 to 2.5 meters by 2100 and induce many harmful side effects like extreme weather events, the transformation of local climates and refugee streams of people that need to find new habitable territories.[6] In the planetary boundary approach, which identifies "levels of anthropogenic perturbations below which the risk of destabilization of the Earth System is likely to remain low", climate change and "biosphere integrity" are identified as core planetary boundaries, having individually the potential to "drive the Earth system into a new state should they be substantially and persistently overshot".[7] [8]

Other planetary boundaries at high risk are biochemical flows, mainly the nitrogen and the phosphorus cycle, and land-system.[9] Resource use is probably at core for these problems.

The EEA calls for "systemic solutions" to tackle these sustainability challenges and transition is needed in the food system, the energy system, housing and mobility.[10] Indeed, the EEA outlines the very systemic character of current environmental crises, which means that many factors influence

[1] European Environmental Agency, *The European environment - state and outlook 2020*, 9.
[2] European Environmental Agency, 35.
[3] European Environmental Agency, 10.
[4] European Environmental Agency, 10.
[5] European Environmental Agency, 38.
[6] Lindsey, "Climate Change: Global Sea Level".
[7] Steffen et al., "Sustainability. Planetary boundaries: guiding human development on a changing planet".
[8] European Environmental Agency, *The European environment - state and outlook 2020*, 43.
[9] Steffen et al., "Sustainability. Planetary boundaries: guiding human development on a changing planet".
[10] European Environmental Agency, *The European environment - state and outlook 2020*, 1-2.

each other and one crisis cannot be seen apart from the others. Therefore, established environmental governance approaches are limited in delivering the necessary change. As a consequence, the EEA calls for a "systemic change", where the role of a government shifts from a "pilot" to an "enabler of society-wide innovation and transformation".[11] In 2019, the EEA recommended a bottom-up systemic governance approach, in order to tackle the sustainability challenges of biodiversity loss, climate change, resource use and pollution. These warnings of the EEA and academia describe well the context, in which the European Commission launched a new initiative aiming to "mitigate" the impacts of the environmental and climate crises for future generations.[12]

The **European Green Deal** (EGD) seems to take up this recommendation in proposing a policy agenda for the European Union (EU) to become climate neutral in 2050 and to transform intrinsically the society and the economy towards more sustainability. In December 2019, the new European Commission took office under the presidency of Ursula von der Leyen, who announced shortly after taking office that the EGD would become guiding priority for the period from 2019 to 2024. The EGD outlines 48 policy initiatives (legislative and non-legislative) in all policy sectors for the period until 2022.[13] Although, the objective of a climate-neutral European continent was already stated in the Paris Agreement[14], many Commission officials regard the EGD an unprecedented change in European policies, because most sectors are covered and all policy areas are aligned under one objective. In fact, most Commission officials interviewed for this thesis regard specifically the **systemic approach of the EGD as revolutionary** and responding to the call for systemic change of the EEA. In the context of the Covid-19 crisis, the EGD was designated the "growth strategy" for the recovery after the crisis and for the future of Europe. The President of the European Commission Ursula von der Leyen emphasised that the importance of the EGD even increased during the crisis and that the huge investments by public authorities into the economy needed to serve the EGD for "the future generations".[15] The EGD has a high importance on the European agenda and aims as responding to the environmental crisis in a systemic way. Recovery from the Covid-19 crisis should be conforming to the climate-neutrality objective, so that significant progress in the domain or renewable energies (RE) may be expected in the future.

Climate and energy policy have been naturally linked and although the approach of the EGD is new, the content can be regarded as a continuation of former EU policies, especially in the area of climate and energy policy. The EU regards climate and RE policies important topics since many years. The "20-20-20 targets" of the 2020 climate and energy package are one example: Greenhouse

[11] European Environmental Agency, 14.
[12] Leyen, "Exchange of views with the German Trainees at the European Commission, 29.07.2020".
[13] *The European Green Deal*, COM(2019) 640 final (Brussels, December 11, 2019), 2.
[14] This is the final agreement of COP21(2015) within the United Nations Framework Convention on Climate Change. It is considered an important step in global action to combat climate change.
[15] Leyen, "Exchange of views with the German Trainees at the European Commission, 29.07.2020".

gas (GHG) emissions should be reduced by 20% with respect to 1990 levels, 20% of energy should be produced by renewable energy sources (RES) and energy efficiency should be increased by 20% by 2020.[16] The target for 2030 is to increase the share of RE to 32 %, while GHG emissions should be reduced by 40% with respect to 1990 levels.[17] The targets for GHG emission reductions and for the RE share in the overall energy mix have been strengthened already a few times and under the EGD the reduction targets for 2030 should be reinforces to either 50% or 55%. In 2015, during the Paris negotiations and the Paris Agreement, the EU committed itself for the first time to the target to become climate-neutral in 2050. In November 2018, the European Commission presented its long-term strategy for 2050 in the Communication "A clean planet for all", in which the target of climate neutrality in 2050 was repeated. This Communication was accompanied by a very detailed analysis, where 8 different scenarios were explored that could lead to net emission reductions between 80% and 100% in 2050. In all the scenarios, the share of RES in the gross final energy consumption had to increase to at least 67% in 2050, to up to 100%.[18] The EGD thus repeats the target of Europe becoming climate neutral in 2050 but, for the first time, all policy areas are subordinated to this objective and climate neutrality should also become embedded into European law, hence becoming obligatory.

RE policy has to play a crucial role in the achievement of the carbon neutrality target of the EGD, as about 80% of GHG emissions in the EU stems from the energy sector.[19] The EGD proposes a number of initiatives to ensure the supply of "clean, affordable and secure energy". The most important initiatives in this domain that have already been adopted by the European Commission are the "energy system integration strategy" and the "hydrogen strategy". The integration of the energy system is regarded as crucial by many experts in order to increase the supply of RES and to balance differences in demand and supply of energy. Other initiatives aim at multiplying off-shore wind capacity, transforming the energy infrastructure, fostering housing renovation and motivating sustainable transport. The EGD aims to foster the further integration of RE into the European energy system and, for the first time, the RE policies are integrated into a systemic policy strategy addressing all policy areas simultaneously. This is a novelty with respect to the former policy approach, where RE and climate policies were seen as being separate from other policy domains. It is worthwhile to analyse whether this systemic approach of the EGD can address the multiple challenges for the RE in Europe, which might need a systemic approach. After clarifying key terms and concepts, this master thesis analyses this question.

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[16] European Commission, "2020 climate & energy package".
[17] European Commission, "2030 climate & energy framework".
[18] *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy* (Brussels, November 28, 2018), 73.
[19] *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy*, 57.

1.2 Definition of important concepts for the master thesis

Initiative

The term "initiative" will be used often in the thesis and refers to all key actions the Commission identifies in its "Communications" as proposals for the next years. An initiative can be legislative (the Commission proposes a draft directive or draft regulation on a specific topic, which then has to be adopted by the European parliament and by the Council), or non-legislative (the European Commission publishes a Communication, strategy or action plan that mainly presents a political agenda). An initiative may also represent some broader actions such as an "assessment of legislative options", which will in a further step result in a legislative proposal or a diplomatic objective (e.g. "EU to continue to lead the international climate and biodiversity negotiations, further strengthening the international policy framework"). The announcement of an initiative in a Communication is an important step in the agenda-setting process of the European Commission. Only afterwards the Directorate-General (DG)[20] identified as "lead service" will start the drafting and consultation process which precedes every proposal.

The "Communications" of the Commission are therefore documents that express policy guidelines or views on necessary policy actions. They are one of the instruments of the Commission to interact with the other European institutions and to initiate legislation. The EGD is a Communication, expressing the need for increased climate and environmental action and affirming the goal of climate neutrality in 2050. The Communication includes an annex, which outlines 48 "initiatives", to achieve this goal. Other Communications of the European Commission also included annexes with "action plans" or "key actions". This is thus the normal process to put initiatives on the European agenda and initiate action. Since the Commission alone can only initiate legislation and actions can be very broad in itself, the term "initiative" has been considered suitable and preferred to "action". Furthermore, any initiative is in its nature a policy initiative, which is clear through the context, so that the term "initiative" will be preferred to policy initiative.

Adoption

The term "adoption" needs some clarification, because an initiative can be adopted at the level of the European Commission and at the level of the EU institutions mainly involved with the legislative approval process.[21] To represent an official statement by the Commission, an initiative

[20] Directorate-Generals are services within the European Commission with one thematic specialisation (e.g. environment, transport, budget…) that do all analytic and drafting work in the preparation of an initiative.
[21] EU institutions mainly involved with the legislative approval process :European Commission, Council and Parliament

needs to be adopted by the College of Commissioners, which is the steering body of the Commission.[22] Every legislative proposal and every Communication are voted by "the College". However, the Commission alone cannot adopt European legislation. The European Parliament and the European Council need to adopt a proposal to transform it into European legislation in the form of a Regulation or a Directive.[23] Hence, the institution, which "adopts" a proposal, is crucial for the status of an initiative. In the context of this master thesis, "adoption" mainly means the approval by the College of Commissioners and focuses on the level of the Commission. Since this master thesis examines a Commission's priority, namely the EGD, all initiatives analysed represent Commission's affirmations or proposals. 'Adoption' is thus used hereafter for the approval of an initiative at Commission level.

Renewable energies and renewable energy sources

Renewable energy sources (RES) refers to the energy sources that are defined as renewable by the recast of the Renewable Energies Directive (RED II).[24] These are "wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas".[25] Gas generated from landfills will be of marginal relevance for the present master thesis. Renewable energies are used to generate electricity, to fuel transport and to produce heat. All three energy usages will be treated in the master thesis.

Challenge

A challenge for the further integration of RE is a factor the might limit the progress of RE in the EU or represent a barrier. Challenges need to be overcome in order to enhance RE supply in the EU.

Sector coupling, sector integration and energy system integration

The terms *sector coupling*, *sector integration* and *energy system integration* are all closely interlinked and refer to similar concepts where the exact definition of one term always depends on the

[22] « The Commission is composed of the College of Commissioners from 27 EU countries. Together, the 27 Members of the College are the Commission's political leadership during a 5-year term. They are assigned responsibility for specific policy areas by the President. »
See https://ec.europa.eu/commission/commissioners/2019-2024_en

[23] The "ordinary legislative procedure" is applied to the majority of areas of EU action. The Commission proposes a Directive or a Regulation and adoption is jointly and on an equal footing by the European Parliament and the European Council in up to three readings.

[24] Directive 2018/2001/EU

[25] *DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources*, DIRECTIVE (EU) 2018/2001 (Official Journal of the European Union, December 21, 2018), 21.

author. The concept of "sector coupling" and "sector integration" generally refers to increasing links of the electricity system with other energy usages like heating, cooling, transport and industry, in order to decarbonise the energy system and to respond to supply variations that are inherent to solar and wind energy.[26] The concept of sector coupling was developed in Germany, where the increasing share of RES made new approaches necessary to tackle fluctuating power supply. The "German Association of Energy and Water Industries (BDEW)" defines sector coupling as "the energy engineering and energy economy of the connection of electricity, heat, mobility and industrial processes, as well as their infrastructures, with the aim of decarbonization, while simultaneously increasing the flexibility of energy use in the sectors of industry and commercial/trade, households and transport under the premises of profitability, sustainability and security of supply".[27] In its narrowest application, sector coupling refers to the coupling of heating and transport with the electricity sector.[28]

In wider concepts, the terms of "energy system integration" or "integrated energy system" are preferred, because buildings, industry and possibly the market are integrated and coordinated with each other.[29] The term "multi energy systems" is also used and sometimes equivalent to sector coupling.[30] When balancing the variability of RES, the question of energy storage necessarily comes into play. In all three concepts, different storage options are explored like batteries or the usage of superfluous electricity for the generation of synthetic gases and fuels from renewable sources (Power-to-X technologies), which act as energy carriers and can be stored. Renewable hydrogen plays and important role in many sector integration scenarios. Renewable hydrogen is produced through an electrolysis process, based on renewable electricity. It is not polluting and can be stored contrary to electricity. Although the efficiency of the electrolysis process is only about 50% (research might increase this number), hydrogen is seen as solution for energy storage, and for decarbonising energy-intense sectors like steel production or heavy transport.[31] Consequently, the gas and the electricity systems are no longer considered as separate entities and the production of electricity does not have to coincide at every moment with demand.[32] It becomes evident that the concept is broad and different aspects are emphasized by different stakeholders.

The European Commission states in their assessment for the long-term strategy: "Sector coupling refers to linking the energy (electricity, gas and heat), transport and industrial infrastructures

[26] Münster et al., "Sector Coupling: Concepts, State-of-the-art and Perspectives," 7.
[27] Robinius et al., "Linking the Power and Transport Sectors—Part 1: The Principle of Sector Coupling," 2.
[28] Deutsche Umwelthilfe e.V. – Environmental Action Germany, "Sector coupling: Using electricity for heating and transport to protect the climate," 3.
[29] Bründlinger et al., "dena-Leitstudie: Integrierte Energiewende," 12.
[30] Münster et al., "Sector Coupling: Concepts, State-of-the-art and Perspectives," 14.
[31] Lottin, "Fuel cells," 107.
[32] Olczak and Piebalgs, *Sector coupling*.

with a view to increase the penetration of renewable energy sources and decarbonise the economy."[33] The same Communication underlines that sector integration and energy storage would make the energy transition more cost-effective and that decarbonisation can be optimized best. The "Commission Expert Group on electricity interconnection targets" expresses in a meeting in 2019 that " 'Sector Coupling' and 'Sectorial Integration'[…] are very close to each other" and that distinctive definitions might not necessarily be helpful. The group further states:

> "Both concepts refer to interlinking different energy sectors and identifying interactions between energy carriers, on the generation, transmission and demand side. They thus cover electrification of additional end-use sectors, but also technologies that allow the coupling of i.a. electricity and gas, such as power-to-gas (P2G). In addition, a limitation of sector coupling to the electricity and gas sectors is too restrictive and the concept should cover other energy carriers (liquid fuels and heat) as well."[34]

The European Commission uses all three terms, but through its *Energy System Integration Strategy*, the Commission finally decided for this term. In the strategy, **energy system integration** is defined as "the coordinated planning and operation of the energy system 'as a whole', across multiple energy carriers, infrastructures, and consumption sectors".[35] The strategy also emphasises that current energy systems are "built on parallel and vertical energy value chains, chains, which rigidly link specific energy resources with specific end-use sectors".[36] Energy system integration represents the possibility to deliver "low-carbon, reliable and resource-efficient energy services, at the least possible cost for society".[37] In the factsheet on the energy system integration strategy, this shift is visualised as follows[38]:

[33] *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy* (Brussels, November 28, 2018), 65.
[34] Minutes of the Meeting 15 - 16 May 2019, page 2.
[35] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration,* COM(2020) 299 final (Brussels, July 8, 2020), 1.
[36] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*.
[37] European Commission, "Questions and answers: An EU Strategy for Energy System Integration".
[38] European Commission, "Factsheet on the Energy System Integration Strategy".

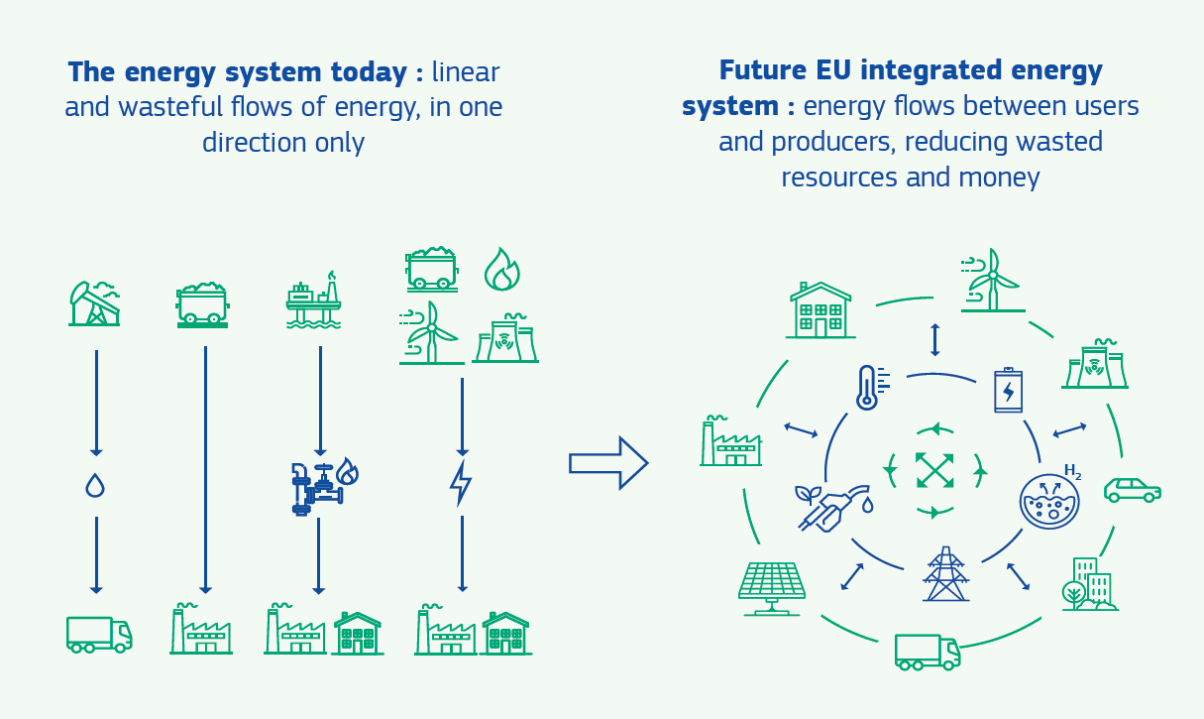

Figure 1: Energy system integration

Sector coupling, sector integration and energy system integration are very interlinked and a differentiation of the three terms is difficult. In this thesis, the term "sector integration" will be preferred to sector coupling and defines the process to achieve an integrated energy system as defined by the European Commission.

1.3 Research question and scope of the research

This master thesis examines the question whether the systemic approach of the EGD can address various challenges for the further integration of RE into the European energy system and thus whether the systemic approach may be evaluated as supporting the further integration of RE into the European energy system. The analysis will regard all relevant initiatives under the EGD that have been adopted by the Commission by the 31st of July 2020 and use information publicly available for the initiatives outlined under the EGD, but not yet adopted. The energy system integration strategy and the hydrogen strategy (both adopted the 8th of July 2020) will be analysed in more detail, since they are the most relevant initiatives in the energy domain that are already adopted.

In a first step, this analysis will cover the most important challenges for the further integration of RE in Europe. This will be done through a literature review, through the extraction of information from relevant webinars, and though interviews with Commission's officials. Subsequently, the initiatives under the EGD will be scrutinized, in order to see, whether the identified challenges are addressed. A special focus will lie on the energy system integration strategy and the hydrogen strategy.

This master thesis will thus proceed as follows:

- First of all, a literature review will present the state of the art of the renewable energy policies in the EU and relevant scientific literature on European RE policies, and on policy-mixes in sustainability transitions.
- Secondly, the methods used in order to examine the research question will be presented.
- Thirdly, the analysis and results section will identify challenges for the further integration of RES and sector integration itself and afterwards examine relevant initiatives under the EGD evaluating them in regard to whether they address the challenges.
- Lastly, the results will be discussed and finally a conclusion will be drawn.

2 The history of RE policies in the EU and academic studies on RE

In the following, the evolution of European renewable energy policies and the state of the art of RE in the EU will be presented. Afterwards, the state of the art in scientific literature on RE policies and on policy mixes for sustainability transitions will be presented.

2.1 The evolution of renewable energy policies in the EU

In order to understand the today's European renewable energy policies and the role of sector integration, it is important to trace its evolution in history. According to Solorio and Bocquillon, European RE policies were always marked by a tension between European initiatives to centralize governance and Member States' (MS) preference for flexible measures.[39] The evolution can be divided into four phases, where this tension becomes evident. According to Solorio et al., only the Renewable Energy Directive of 2009[40] achieved a partial centralisation.[41]

In the first phase of RE policies in the EU, RE arrived on the European agenda and first RE objectives were adopted in the late 1990s. The first steps in promoting RE in the EU started in the 1970s with an enhancement of research and development on "new sources of energy" seeking to diminish dependence on oil imports from other countries and to foster European energy independence.[42] This was also a reaction to the oil crises in 1973 and 1979.[43] During the 1980s, RE were targeted by some regional policies (e.g. VALOREN programme) but generally research and development mostly took place in some ambitious MS until the 1990 (Germany, Denmark, Netherlands). In 1986, the European Commission defined RES as "policy priority" and thus, RES became officially part of the Commission's agenda.[44] From the 1990s onwards, climate change became a key issue on the global agenda and the international climate negations started with the Rio summit (1992) under the Framework of Convention on Climate Change (FCCC). Thus, climate change also gained importance on the European agenda and RE were seen as a measure to reduce carbon dioxide emissions.[45] The ATENER programme, adopted in 1993, set indicative targets of 8% of RES of EU energy consumption by 2005, 5% use of biofuels as market share by 2005 and a tripling

[39] Solorio and Bocquillon, "EU renewable energy policy: a brief overview of its history and evolution," in *A Guide to Renewable Energy Policy in the EU*, 23.
[40] Directive 2009/28/EC
[41] Solorio and Bocquillon, 23.
[42] Hildingsson, Stripple, and Jordan, "Governing Renewable Energy in the EU: Confronting a Governance Dilemma," 19.
[43] Hildingsson, Stripple, and Jordan, 20.
[44] Solorio and Bocquillon, "EU renewable energy policy: a brief overview of its history and evolution".
[45] Solorio and Bocquillon, 25.

of RES-electricity generation.[46] Between 1986 and 1996, MS developed different market schemes to foster RES (feed-in tariffs, tendering schemes). On European level, a harmonization did not exist, but RES had become an important point on the EU agenda.

The second phase of RE policies was marked by the establishment of a "loose regulatory framework" on RE a European level, namely first legislative acts.[47] In 1997, the European Commission published the white paper "Energy for the future: renewable sources of energy" which formulated a new RES target of 12 % of primary energy consumption by 2010.[48] Moreover, the paper listed measures in order to overcome hurdles towards RE employment in the electricity sector, in transport, in cooling and in heating.[49] Both Solorio et al. and Hildingsson identify this white paper as "turning point" and as "birth of EU RES policy".[50] The first proposals for a directive to promote RES and biofuels were launched by the Commission in the 2000 and 2001 influenced by the climate negotiations and the need to implement the Kyoto Protocol. The Directive on Electricity Production from Renewable Energy Sources[51] was adopted by the Council and the Parliament in 2001, the Directive on biofuels in 2003 (indicative target of 5.75% by 2010). The Directive on Electricity Production from Renewable Energy Sources was thus the first European legislation act in the domain of RE and introduced as definition of RES: "non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases)".[52]

Furthermore, the Directive set an indicative goal of 22.1% of total European electricity produced form RES by 2010 and defined specific targets for the MS in the annex.[53] Yet, these targets were non-binding due to the pressure by the MS during the legislative process.[54] Although, the Commission had called for a harmonization of national support schemes for renewable electricity sources, this proposal was opposed by Spain and Germany within the Council, so that this point did not appear in the final directive. The Directive also required MS to take initiative "to ensure that transmission system operators and distribution system operators in their territory guarantee the transmission and distribution of electricity produced from renewable energy sources", for example by

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[46] Solorio and Bocquillon, 25.
[47] Solorio and Bocquillon, 25.
[48] *Energy for the future: Renewable sources of energy.,* COM(97) 599 final (1997).
[49] Solorio and Bocquillon, "EU renewable energy policy: a brief overview of its history and evolution," in *A Guide to Renewable Energy Policy in the EU*, 26.
[50] Hildingsson, Stripple, and Jordan, "Governing Renewable Energy in the EU: Confronting a Governance Dilemma," 21.
[51] Directive 2001/77/EC
[52] *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market,* 2001/77/EC (September 27, 2001), article 2.
[53] *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market*, article 3.
[54] Solorio and Bocquillon, "EU renewable energy policy: a brief overview of its history and evolution," in *A Guide to Renewable Energy Policy in the EU*, 27.

priority access.[55] By the mid of 2000, a Directive on renewable electricity and a Directive on Biofuels were adopted and represent first European legislation in this field. Nevertheless, according to Solorio et al., this framework is "loose" since no binding targets on European or MS level existed.[56]

In a third phase, from the mid of the 2000s onwards, a shift from a policy framework to a regulatory framework took place.[57] Existing policy was reviewed, binding targets were introduced and a decentralised policy framework was adopted. A few events favoured the focus on RES on the European agenda. After a review of the Directive on Electricity Production from Renewable Energy Sources, it became clear that neither the EU as a whole nor MS were on track to achieve their 2010 targets. Furthermore, energy imports increased and the gas crisis between Russia and the Ukraine in 2006 underlined the risk of energy imports towards supply security. Climate change mitigation again gained importance after a publication on the cost of climate change.[58] In this context, in 2007, the European Commission proposed a trans-sectorial climate and energy package which included five legislative proposals and the prominent 20-20-20 targets. This meant a share of RES of 20% by 2020, an increase of energy efficiency by 20%, and a reduction of GHG by 20%. Moreover, the Commission launched the debate about second generation biofuels which are not based on food crops but on wood, algae or residues due to stainability concerns about first generation biofuels. In 2008, a study of the World Bank concluded that biofuel production had caused a rise in food prices at about 75%.[59] Amongst the legislative proposals was a draft for a new renewable energies directive which included binding national targets for RE and the introduction of sustainability criteria for second generation biofuels. As a consequence, the legislative process in both institutions was complicated since "basic disagreements over the harmonisation of national policies were still not resolved".[60]

Finally, a compromise was reached by the introduction of flexible cooperation and joint implementation and the Directive 2009/28/EC on the promotion of the Use of Energy from Renewable Sources (RED) was adopted in 2009. It amends both the Directive on Electricity Production from Renewable Energy Sources and the Biofuels Directive. For the first time, binding national targets for the share of RES existed but the flexibility mechanisms permitted a "statistical

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[55] *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market*, 2001/77/EC (September 27, 2001), article 7.

[56] Solorio and Bocquillon, "EU renewable energy policy: a brief overview of its history and evolution," in *A Guide to Renewable Energy Policy in the EU*, 28.

[57] Hildingsson, Stripple, and Jordan, "Governing Renewable Energy in the EU: Confronting a Governance Dilemma," 21.

[58] Solorio and Bocquillon, "EU renewable energy policy: a brief overview of its history and evolution," in *A Guide to Renewable Energy Policy in the EU*, 29.

[59] Mitchell, "A Note on Rising Food Prices".

[60] Hildingsson, Stripple, and Jordan, "Governing Renewable Energy in the EU: Confronting a Governance Dilemma," 22.

transfer" of MS exceeding their targets to MS lagging behind.[61] Especially in the area of electricity, these mechanisms should enforce cooperation between MS. National support schemes were still not harmonised. RE were promoted in the electricity sector, in transport, in heating and in cooling. Besides the general objective of achieving 20% of renewable energy consumption by 2020, a 10% goal of RE in transport (electric cars, and biofuels) was included (Article 3). MS were obliged to develop national action plans in order to assure the achievement of the measures, which are then evaluated by the Commission (article 4). The RED similarly fostered the prevalence of RE over other energy forms by introducing priority access or guaranteed access to national energy systems of RES. Thanks to the international climate negations and a the EU's ambition to act as leader in this area, the 2020 objectives and the corresponding legislation were adopted rather quickly.[62] The other legislative proposals concerned the review of the Emission Trading Scheme (ETS), which had been introduced in 2001; national emission reduction targets; energy efficiency; the effort sharing regulation and carbon capture and storage. As a result an "Europeanised structure of governance" with binding RES targets and a review process was created even though the implementation remained the responsibility of MS.[63]

As a fourth phase the process for the adoption of the 2030 targets can be identified as, which is influenced by the tension between MS striving for flexibility and Europeanisation and the urgent need to step up measures for climate change. Although targets for 2030 were already adopted in 2014, the targets will be adjusted as part of the European Green Deal. The first adoption process of the 2030 targets was influenced by a number of factors: the rising critique in RES support schemes which were blamed to cause the rise in electricity prices that could be observed in some MS, the economic and financial crisis in 2009 and the failed climate negotiations in 2009, where a final agreement could not be achieved during the COP15.[64]

Consequently, the climate was not favourable for new ambitious targets. MS were striving for re-nationalisation of RE policies and the European Commission and the Council were divided upon the question whether new ambitious national RE targets should be adopted. Parts of the European Commission and the Council preferred a common GHG emissions reduction target without new RE targets which should be achieved by a strengthening of the ETS. The legislative proposals presented by the European Commission in 2014 followed this second approach: binding national targets were removed and a European objective of 27% RES in 2030, a GHG emission reduction target of 40% and an indicative target of 28% increase in energy efficiency were adopted.[65] According to Solorio et al.,

[61] Hildingsson, Stripple, and Jordan, 22.
[62] Solorio and Bocquillon, "EU renewable energy policy: a brief overview of its history and evolution," in *A Guide to Renewable Energy Policy in the EU*, 33.
[63] Solorio and Bocquillon, 33.
[64] Solorio and Bocquillon, 24.
[65] Solorio and Bocquillon, 35.

the 27% target of RE is representing only a slight difference to the "business-as-usual-scenario".[66] The targets were, however, already adapted in the context of the creation of the Energy Union in 2015.[67] These initiatives wanted to ensure "secure, sustainable, competitive and affordable energy" for consumers, households and businesses.[68] The Energy Union aims at decarbonising the economy, energy efficiency and a fully integrated internal energy market. The link to RE is thus only indirect. In 2015, the adoption of the Directive to reduce indirect land use change for biofuels and bio-liquids limited the use of first generation biofuels to 7% and introduced an indicative target of 0,5% for advanced biofuels (second generation).[69]

As a follow up of the "Energy Union", a "clean energy for all Europeans package" was initiated and implemented in the following years. It consisted of eight legislative acts of which the last one was adopted in 2019.[70] Important for the present paper is the Regulation on the Governance of the Energy Union and Climate Action (EU) 2018/1999, which obliges MS to report every five years on their plans and measures regarding climate and energy (national climate and energy plans NCEP) to the Commission. The Commission evaluates the plans, can issue recommendations and verifies whether the Union is on track with its targets. Currently, the Commission is evaluating the NCEPs of 2019. A second important legislative act is the review of the Renewable Energy Directive in 2018 (RED II), which updated the RE targets on a European level to 32% in 2030.[71] The review of the Energy Efficiency Directive increased the EU target for energy efficiency to 32.5%.[72] The target to reduce GHG by 40% by 2030 was also introduced and a target of 15 % electricity interconnection by 2030 was established. Furthermore, RED II reinforced the sustainability criteria for biofuels and targets on RE in transport were increased: by 2030 14%, energy consumption in the transport sector should be covered by RE. The share of final energy consumption in transport of advanced biofuels was increased to 3.5%.[73]

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[66] Solorio and Bocquillon, 28.
[67] *A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy,* COM/2015/080 final (Brussels, February 25, 2015).
[68] European Commission, "Energy union".
[69] *Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources,* 2015/1513 (Luxembourg: Official Journal of the European Union, September 15, 2015).
[70] European Commission, "Clean energy for all Europeans package".
[71] *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources,* 2018/2001 (Luxembourg: Official Journal of the European Union, December 21, 2018), article 3.
[72] *Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency,* 2018/2002 (Luxembourg: Official Journal of the European Union, December 21, 2018), article 1.
[73] *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources,* 2018/2001 (Luxembourg: Official Journal of the European Union, December 21, 2018).

Still, this process is not terminated yet. With the establishment of the new Commission under Ursula von der Leyen in December 2019, the priorities and agenda changed, the EGD being on the top of the agenda. As a consequence, on the 4th of March, the European Commission presented a new climate law, which will turn (after adoption by Council and European Parliament) the target of climate neutrality in 2050 into a binding EU law.[74] Although the EU had already committed to this target in the Paris agreement, the law constitutes a political and strategic sign, leading to a number of other legislative initiatives. It is part of the EGD to update the targets for 2030, in order to better reflect the trajectory which is necessary for the 2050 target. The Commission will propose a 50% or 55% reduction target of GHG emissions after the evaluation of the NCEPs in the end of 2020. It can thus be expected that climate targets will increase up to 55%. The EGD also includes strategies in order to "decarbonize energy", e.g. initiatives to foster sector integration, to promote offshore wind energy or to enhance energy efficiency renovation of buildings. To resume, the adoption of the 2030 goals is and was a vivid process with various revisions. The main influencing factors are preferences of MS to re-nationalise RE policies and the increasing pressure to act in order to prevent climate change. It is still unclear how easy the process will be for the review of the 2030 goals. Although both the European Parliament and the Council[75] already expressed their support for the carbon neutrality target in 2050 and the European Parliament also for the reduction target of 55% by 2030[76], experts expect to face resistance for the 55% goal in the Council. According to the head of cabinet of Vice-President Timmermans, a well prepared impact assessment for every MS will be the basis for fruitful negotiations.[77]

A summarising table of the process is provided below:

[74] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law),* COM(2020) 80 final (March 4, 2020).
[75] *European Council Meeting - conclusions,* EUCO 29/19 (Brussels, December 12, 2019).
[76] European Parliament, "Parliament supports European Green Deal and pushes for even higher ambitions".
[77] Diederik Samsom, "European Green Deal: Discussion with Diederik Samsom, 24.03.2020".

Phases of RE policies in the EU			
Phase?	**What?**	**Indicative targets?**	**Obligatory targets?**
1	RE arrive on European agenda	**1993**: 8% of RE consumption by 2005, 5% biofuels of transport energy consumption by 2005, tripling of RES-electricity generation	none
2	"Loose regulatory framework"	**2001:** indicative goal of 22.1 % of total European electricity by 2010, indicative target of 5.75% of biofuels by 2010	none
3	Regulatory framework		**2009:** RED sets targets for 2020: 20% of RE consumption, increase of energy efficiency by 20%, reduction of GHG emissions by 20%, 10% goal of RE in transport (electric cars, and biofuels) **2015:** limit of first generation biofuels of 7%, target for second generation biofuels of 0.5%
4	Clean energy for all European package and update of 2030 targets		**2018:** REDII sets targets for 2030: 32% of RE by 2030, increase of energy efficiency of 32.5%, reduction of GHG by 40%, 15 % electricity interconnection 14% of RE in transport of that 3.5% advanced biofuels
5	EGD, 2050 targets (indicative targets because not yet adopted by Council and Parliament)	Climate neutrality by 2050, GHG reductions of 55% or 55% by 2030	*As soon as the climate law will be adopted by Council and Parliament, the targets will become obligatory*

Table 1: Phases of RE policies in the EU

2.2 Sector coupling and energy system integration rising on the European Agenda

With the increased employment of RE in the EU, the role of sector integration will increase since it is a cost-effective solution to face the natural fluctuations in RES[78] and is regarded as necessary to decarbonise remaining energy intensive sectors.[79] Sector integration seems to have an increasing place on the European Commission's agenda since 2018 and advice and research in this area is requested. In April 2018, the Commission Expert Group on electricity interconnection targets

[78] van Nuffel et al., *Sector coupling*, 1.
[79] Vita et al., "Sectoral integration- long-term perspective in the EU Energy System," 106.

was requested to prepare a report on ”sector coupling and its possible implications for electricity network development”.[80] In the same year, sector integration appeared for the first time in a Communication of the European Commission which outlines a long-term vision for a “prosperous, modern, competitive and climate neutral economy”.[81] This Communication regards “further sector integration” as supportive of the transition to a carbon neutral economy referring also to a possible necessity for hydrogen pipelines.[82]

In January 2019, two calls for tenders were published under the European research and innovation programme “Horizon 2020”. Both supported the development and research on hydrogen infrastructures as a possibility for sector coupling (development of a hydrogen valley and a “validation of the ability to inject hydrogen […] into high-pressure gas networks”.[83] Hydrogen as energy vector seems to play an important role in sector integration for the European Commission.

In June 2019, the roadmap for the evaluation of the Trans European Network for Energy Regulation[84] (TEN-E) expressed the need to include “smart electricity, hydrogen and sector coupling”[85] and, in a Communication on the Energy Union in June 2019, the Commission emphasized the importance of interconnections between national energy markets which is also said to be necessary for “reaping the full potential of renewable energy sources, and facilitating sector coupling and integration”.[86] In its long-term vision, the European Commission stated that in 2050, at least 80% of electricity “will be coming from renewable sources.[87] The strategy envisaged the electrification of the heating transport and industry and in this context of the “interconnectivity” of the power system. In the context of the European transport and energy networks, the long-term vision clearly formulated a need for “digitalisation and further integration of relevant sectors”.[88] Sector coupling and sector integration were thus already named various times as goals, but no concrete action had been taken.

In the EGD-Communication, the European Commission announced for the first time the preparation of a “smart sector integration strategy” by June 2020 and highlighted the importance of this topic in other initiatives.[89] The EGD-Communication stated that the review of the energy

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[80] “11th meeting of the Commission Expert Group on electricity interconnection targets”.
[81] *A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy,* 28.11.2018 (Brussels, COM(2018) 773 final).
[82] *A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*, 13.
[83] European Commission, “H2 Valley”.
[84] Regulation (EU) 347/2013
[85] European Commission, “Evaluation of the guidelines for Trans-European Energy (TEN-E) infrastructure”.
[86] *United in delivering the Energy Union and Climate Action - Setting the foundations for a successful clean energy transition*, COM(2019) 285 final (Brussels, June 18, 2019), 7.
[87] *A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy,* 28.11.2018 (Brussels, COM(2018) 773 final), 9.
[88] *A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*, 10–13.
[89] *The European Green Deal,* COM(2019) 640 final (Brussels, December 11, 2019), 6.

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". The European Industrial Strategy also named the smart sector integration strategy as a means for the European Commission to set out its vision on "clean hydrogen". Furthermore, "all carriers of energy, including electricity, gas and liquid fuels will need to be used more effectively by linking different sectors".[90] In July 2020, the European Commission finally presented an "**Energy System Integration Strategy" and a "Hydrogen Strategy"**. Sector integration and renewable hydrogen seem thus to be closely interlinked for the European Commission and both topics have already been part of the European agenda for two.

The adoption of both strategies can be seen as a result of a longer preparation process, whereby the European Commission **commanded and issued a number of studies**. The DG Energy started working on sector coupling and sector integration around 2017/2018. The European Commission funds the ASSET project (Advanced System Studies for Energy Transition) which drafts studies on different topics of the energy transition to support European policy and decision-making. In 2018, the study "Sectoral integration- long-term perspective in the EU Energy System" was published on the request of DG Energy. This study focuses on the role hydrogen could play in a future energy system. Different scenarios are explored, where hydrogen serves as provider for electricity storage, as feedstock for the production of carbon-free gas and liquid hydrocarbons and as energy carrier for different consumption sectors.[91]

Moreover, DG Energy commanded a study on "regulatory barriers in linking the gas and electricity sectors in the EU" which examines possible barriers and regulation gaps that might inhibit the coupling of the electricity and the gas sector.[92] In 2019, the Joint Research Centre of the European Commission published the report "decarbonising the EU heating sector" which proposes as main solutions the electrification of heating and the installation of district heating, summarized under the term "integration of the power and heating sector".[93] This demonstrates that the preparation of the two strategies started one or two years ago. A European Commission senior official confirmed that sector integration was already discussed in the previous Commission mandate when Miguel Arias Cañete was Commissioner for Energy and Climate (2014 – 2019).

The **European Parliament has also been gathering expertise** on sector integration: already in 2018, the European Parliament requested a study on "Sector coupling: how can it be enhanced in the EU to foster grid stability and decarbonise?". This study evaluated a number of topics, namely the electrification of heating and passengers' transport and the deployment of advanced biofuels,

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[90] *A New Industrial Strategy for Europe*, COM(2020) 102 final (Brussels, March 10, 2020), 8.
[91] Vita et al., "Sectoral integration- long-term perspective in the EU Energy System".
[92] Riechmann et al., *Potentials of sector coupling for decarbonisation*, 8.
[93] Kavvadias, Jiménez-Navarro, and Thomassen, *Decarbonising the EU heating sector*.

synthetic fuels and gases.[94] In June 2019, the parliamentary research service issued a briefing on "Energy storage and sector coupling" for the creation of an "integrated, decarbonised energy system".[95] These examples show that the topic of sector coupling and sector integration has gained importance in the European agenda which ultimately led to the recent adoption of the first initiatives in the field: the energy system integration strategy and the hydrogen strategy are the first initiatives to put the results of research into practice.

Prior to the literature review, the state of RE in the EU shall be presented since it is an important starting point and can be regarded the result of the described European RE policies.

2.3 The state of renewable energies in the EU

The EU has as target that in 2020, 20% of European energy consumption are produced by RE.[96] This is generally considered achieved, although data is not yet available for the present year. In 2018, Eurostat amounted 18,9 % of the gross final energy consumption to renewable sources which include in EU definitions hydropower; tide, wave, ocean energy, geothermal energy, wind energy, solar energy, ambient heat (heat pumps), biofuels and renewable municipal waste.[97] However, energy consumption does not equal energy production. In 2018, the EU had an energy dependence of 58%, which means that only 42% of energy demand could be covered by EU production and 58% were covered by net imports. The huge majority of energy imports are non-renewable since they consist of petroleum products (about 66%), natural gas (24%) and solid fossil fuels (8%).[98] Imports account mostly for heat production, transport, and production of electricity by gas plants. Only 0.4% of electricity demand is covered by net-imports.[99] The consumed renewable energy is thus produced "domestically". Imports are mainly important for the production of heat or transport fuels.

The **different usages of energy** (electricity, heat production and transport) have to be considered separately to evaluate the role of RES. The gross **electricity production** of the EU-28 in 2017[100] accounted for 3 294 TWh. 30.5% was produced by renewable power plants, followed by nuclear power plants (25.2 %), gas fired plants (21.1 %) and coal fired power plants (20.1 %).[101] The renewable electricity production is composed by a number of techniques with wind energy and hydropower in the lead. Details are represented in the table 2:

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[94] van Nuffel et al., *Sector coupling*.
[95] Erbach, "Energy storage and sector coupling: Towards an integrated, decarbonised energy system".
[96] European Commission, "2020 climate & energy package".
[97] *DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources*, DIRECTIVE (EU) 2018/2001 (Official Journal of the European Union, December 21, 2018), 21.
[98] Eurostat, "2.3 From where do we import energy and how dependent are we?".
[99] Eurostat, "Electricity and heat statistics".
[100] Newer data were available.
[101] Eurostat.

Renewable electricity production EU-28 (2017)	TWh	share
Wind energy	1185.84	36.00%
Hydro energy	1083.726	32.90%
Solar photovoltaic	372.222	11.30%
Primary solid biofuels	309.636	9.40%
Biogases	207.522	6.30%
Others	135.054	4.10%
Total	3294	100.00%

Table 2: Renewable electricty production EU-28 (2017)

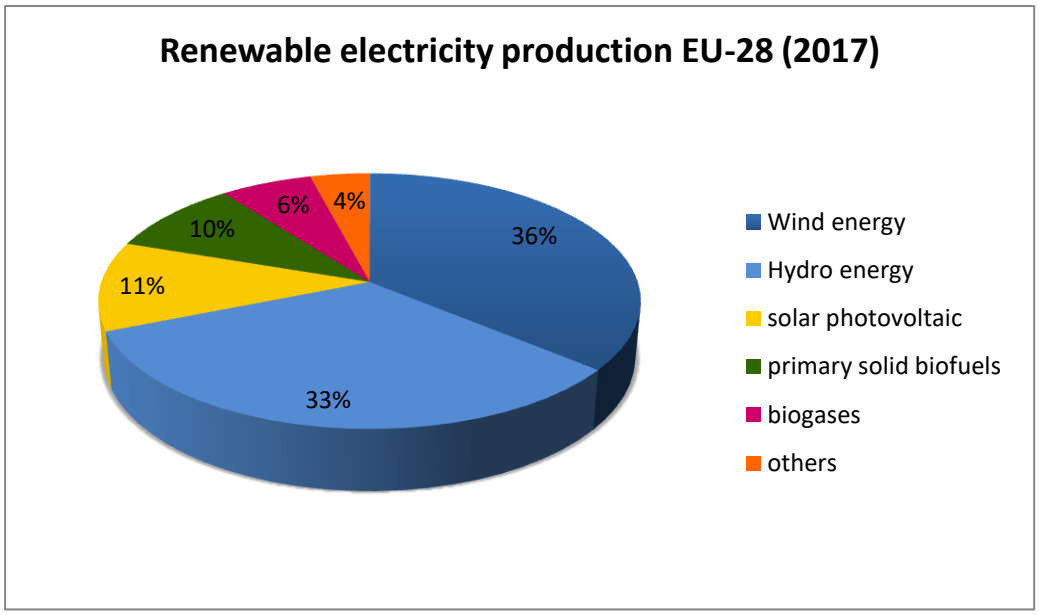

Figure 2: Renewable electricity production EU-28 (2017)

Looking at the **heat production** for the EU-28 for the year 2017, total gross heat production in the EU accounted for 670.2 TWh. Almost 70% of the heat production was based on natural gas and oil products. Only 26.5% constitute "renewable sources", whereby the overarching share of renewable heat is based on bioenergy, thus the burning of biomass and biofuels (77% of renewable heat). The second important share of renewable heat is based on renewable municipal waste (19% of total renewable heat) and only a small share is based on ambient heat, solar heat and geothermal heat (1% of total heat production and 3.8% of renewable heat).[102] The detailed data are presented in table 3 below:

[102] Eurostat.

Gross derived heat generation EU-28 (2017)	TWh	Share
Solid fossil fuels and oil products	191.8	28.6%
Natural gas and manufactured gases	262.9	39.2%
Nuclear	1.3	0.2%
Renewables other than biofuels	6.8	1.0%
Biofuels (also counted as RE)	137.1	20.5%
Renewable municipal waste	33.8	5.0%
Non-renewable waste	36.1	5.4%
Electricity	0.5	0.1%
Total	670.2	100.0%

Table 3: Gross derived heat generation EU-28 (2017)

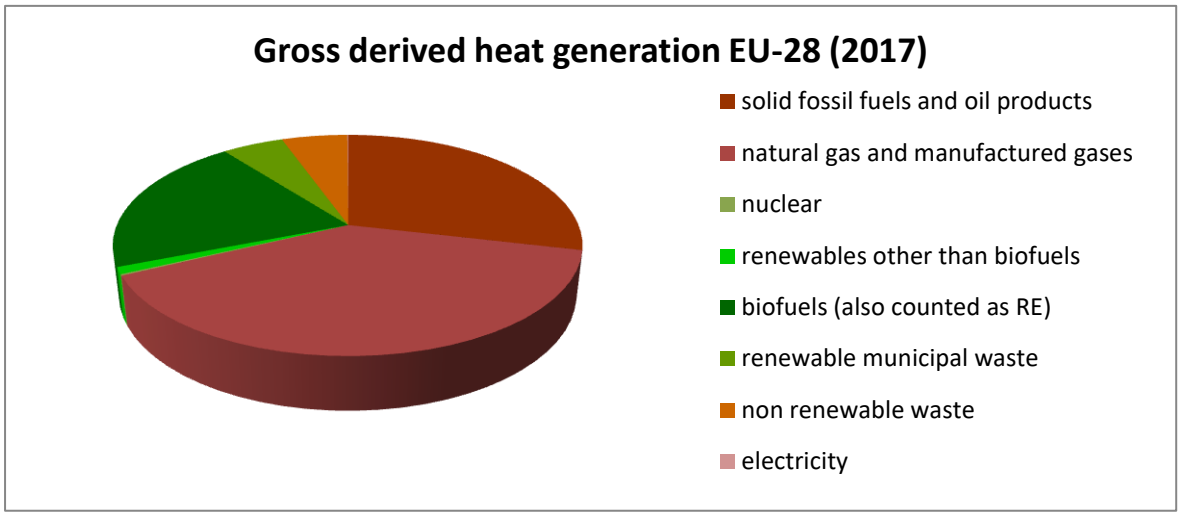

Figure 3: Gross derived heat generation EU-28 (2017)

With respect to **transport**, the share of RE is even smaller. The target for RE in transport is 10% for 2020.[103] According to Eurostat, in 2018 the share of RE in transport accounted for 8.3%.[104] Renewable electricity plays only a small role in RE in transport (more in railway transport than road transport). "The bulk" of RE in transport comes from biofuels.[105] Generally, one can thus conclude that bioenergy accounts for a large part of RE used in heating and in transport. Even in electricity production, bioenergy plays a reasonable role with a share of about 10%. In 2019, the Joint Research Center of the European Commission stated in a report that 59.2% of renewable energy production in the EU were based on bioenergy in 2016.[106] This is also visualised in figure 4.[107] Bioenergy plays thus

[103] European Commission, "Biofuels".
[104] Eurostat, "Energy from renewable sources".
[105] European Environmental Agency, "Share of renewable energy in gross final energy consumption in Europe".
[106] European Commission, *Brief on biomass for energy in the European Union*.
[107] European Commission.

a tremendous role for renewable energy production in the EU. This has to be considered when analysing opportunities of RE in the future.

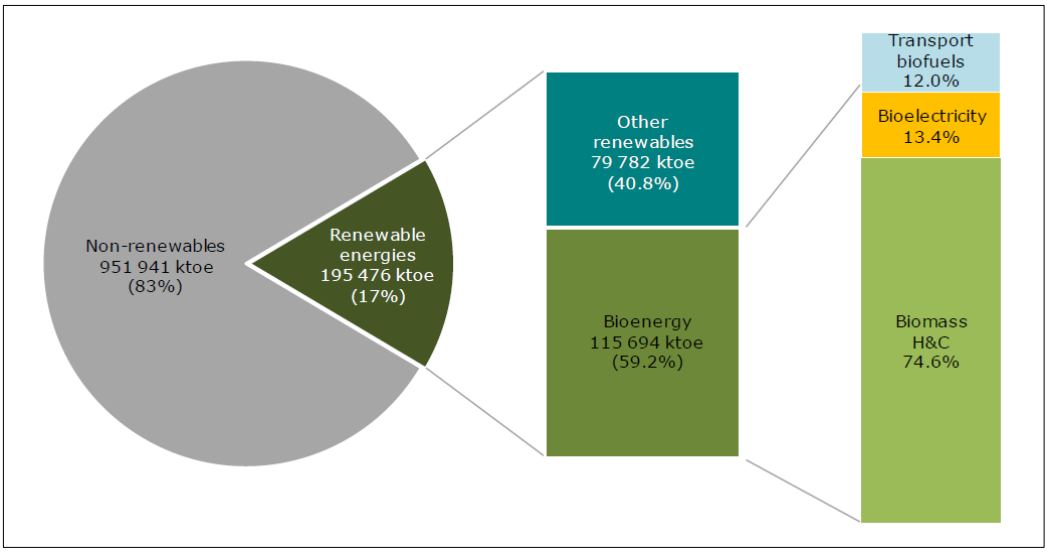

Figure 4: Bioenergy in the EU according to the European Commission

An overview of the evolution of RE policies and the state of RE in the EU have been established. As a next step, the state of the art of scientific literature on European RE policies and policy mixes shall be introduced.

2.4 Studies on European renewable energy policies and policy-mixes

Apart from studies that describe the evolution of renewable energy policies[108] [109] [110], scientific research focuses on many other aspects of European renewable energy policies: subjects of analysis are for example the relation between environmental pollution, economic growth and the deployment of RES.[111] [112] [113] Other studies investigate on the motivations for RE policies [114] [115] [116] or

[108] Hildingsson, Stripple, and Jordan, "Governing Renewable Energy in the EU: Confronting a Governance Dilemma".
[109] Solorio and Bocquillon, "EU renewable energy policy: a brief overview of its history and evolution".
[110] Solorio Sandoval, *A guide to renewable energy policy in the EU*.
[111] Saint Akadiri et al., "Renewable energy consumption in EU-28 countries: Policy toward pollution mitigation and economic sustainability".
[112] Dogan and Aslan, "Exploring the relationship among CO 2 emissions, real GDP, energy consumption and tourism in the EU and candidate countries: Evidence from panel models robust to heterogeneity and cross-sectional dependence".
[113] Menegaki, "Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis".

examine the effectiveness of RE policies.[117] [118] [119] [120] [121] Some studies try to understand better the adoption process of RE policy in Europe.[122] [123] Many studies focus on economic support schemes as a mean to foster RE integration.[124] [125] [126] [127] [128] All these studies focus on specific sub-topics of RE policies or on one specific policy. They are important with respect to the scientific body about RE policies but for the present analysis, a more holistic approach of policy analysis is necessary.

There is an increasing number of studies that investigate on "policy-mixes" in the context of achieving so called "sustainability transitions". Schmidt and Sewerin state that especially for such "sustainability transitions", analyses need to focus on a policy mix rather than individual policies, since only a combination of policy instruments can address the multiple challenges of such a transition (market or system failures, bottlenecks, risks and actors involved).[129] The literature on sustainability transitions is of high relevance for the present analysis since the EGD is also a strategy that aims at transforming the European society and economy towards more sustainability through a set of policy initiatives. It is thus useful to learn from the methods used in this scientific literature field. Schmidt and Sewerin focus on the evolution of policy mixes through an investigation on the balances between the numbers of policies in different domains. The number of policies per policy domain is analysed in a retrospective way. Such a retrospective study is not possible for the present analysis, as the EGD represents a policy strategy and agenda for proposed legislative projects.

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[114] Marques, Fuinhas, and Pires Manso, "Motivations driving renewable energy in European countries: A panel data approach".
[115] Bauwens, "Explaining the diversity of motivations behind community renewable energy".
[116] Schaffer and Bernauer, "Explaining government choices for promoting renewable energy".
[117] Kilinc-Ata, "The evaluation of renewable energy policies across EU countries and US states: An econometric approach".
[118] Hafeznia et al., "Analysis of the effectiveness of national renewable energy policies: A case of photovoltaic policies".
[119] Harmelink, Voogt, and Cremer, "Analysing the effectiveness of renewable energy supporting policies in the European Union".
[120] Abdmouleh, Alammari, and Gastli, "Review of policies encouraging renewable energy integration & best practices".
[121] Zhou and Brown, "Smart meter deployment in Europe: A comparative case study on the impacts of national policy schemes".
[122] Zhou et al., "Understanding renewable energy policy adoption and evolution in Europe: The impact of coercion, normative emulation, competition, and learning".
[123] Bromley-Trujillo et al., "The Spreading of Innovation: State Adoptions of Energy and Climate Change Policy".
[124] Lauber and Schenner, "The struggle over support schemes for renewable electricity in the European Union: a discursive-institutionalist analysis".
[125] del Río, "On evaluating success in complex policy mixes: the case of renewable energy support schemes".
[126] Mezősi, Szabó, and Szabó, "Cost-efficiency benchmarking of European renewable electricity support schemes".
[127] Dressler, "Support schemes for renewable electricity in the European Union: Producer strategies and competition".
[128] Ramírez et al., "Combining feed-in tariffs and net-metering schemes to balance development in adoption of photovoltaic energy: Comparative economic assessment and policy implications for European countries".
[129] Schmidt and Sewerin, "Measuring the temporal dynamics of policy mixes – An empirical analysis of renewable energy policy mixes' balance and design features in nine countries," 1.

Rogge and Reichardt develop an analytical concept describing a policy-mix which aims at driving technological change.[130] Although this thematic is too narrow for the analysis of the EGD, some **helpful concepts** can be drawn from this study. According to Rogge and Reichardt, a policy-mix encompasses three elements, namely a policy strategy, instruments and an instrument mix. A policy strategy is a "combination of policy objectives and the principal plans for achieving them" and puts the emphasis to a specific output.[131] Instruments "constitute the concrete tools to achieve overarching objectives" and can be seen as techniques of governance. The study identifies three primary instrument types, namely an economic instrument, a regulation and information:[132] for example, the EU Emission Trade Scheme (ETS) can be regarded as an economic instrument, the phasing-out of energy intense bulbs is an example for a regulation and examples of information are information campaigns on any topics. Lastly, an instrument mix is a combination of different instruments that interact one with the other resulting in the fact "that the influence of one policy instrument is modified by the co-existence of other [instruments]".[133] The instruments mix' outcome also depends on the overarching context. Furthermore, one policy mix may encompass various instrument mixes. Therefore, the terms "instrument mix" and "policy mix" are defined separately.[134]

Applying this terminology to the EGD, the EGD and its target of climate neutrality in 2050 represent a policy strategy. Many initiatives under the EGD are instrument mixes with their own specific objectives. For instance, the biodiversity strategy[135] wants to hold biodiversity loss by 2030, which will also help to achieve climate neutrality in 2050, as any living being constitutes a carbon sink. Other important instrument mixes are the Circular Economy Action Plan[136] (a reduced resource use will diminish emissions form land use change etc.) or the Energy System Integration Strategy (fostering of RE integration and thus less polluting fossil fuels). Within each of the named instrument mixes, multiple instruments are proposed. The terminology introduced by Rogge and Reichardt can thus help to understand the interrelations of the different elements of the EGD. Table 4 visualises these concepts in the context of the EGD:

[130] Rogge and Reichardt, "Policy mixes for sustainability transitions: An extended concept and framework for analysis".
[131] Rogge and Reichardt, 4.
[132] Rogge and Reichardt, 5.
[133] Rogge and Reichardt, 6.
[134] Rogge and Reichardt, 6.
[135] COM(2020) 380 final
[136] COM(2020) 98 final

Concepts according to Rogge and Reichardt	Applied to the EGD	Objective
Policy strategy	European Green Deal	Climate neutrality in 2050
Instrument mix	Energy System Integration Strategy	Decarbonise the energy sector and enhance RE
Instrument	Review of the Renewable Energy Directive	Increase the electrification of end-use sectors.

Table 4: Concepts of policy mixes according to Rogge and Reichardt

Lindberg et al. also undertake a policy mix analysis, investigating how actors' preferences and actual policies are inter-related in European energy policy. In order to do so, they introduce two generic dimensions (i.e. degree of ambition and degree of centralised policy approach) to determine different sustainability pathways.[137] Afterwards, they analyse the position of different stakeholders (environmental NGOs, firms, and industry associations) on the basis of the public consultations, and the adopted European energy policies between 2009 and 2015.[138] From that they follow that "by and large, there are similar priorities when comparing the policy mix and the preferences of key industry actors".[139] This study has to be named in the context of scientific literature on sustainability transitions, though a similar approach cannot be applied to the analysis of the EGD. The EGD represents a policy strategy without any adopted policies beyond the Commission yet so that mainly the Commission's targets and the envisioned instrument mixes can be analysed.

Falcone et al. use a sophisticated methodology in order to identify according to them the "most effective policy combinations to steer a sustainable energy transition under alternative crisis scenarios" with a focus on the Italian biofuels sector.[140] This is an meaningful analysis, because it does not analyse a policy mix retrospectively but recommendations are made on the basis of the analysis of interactions between elements characterising the Italian biofuels sector. They use the methodology of a "Fuzzy cognitive mapping", where interrelations between elements are depicted through arrows, that indicate reinforcing or inhibitory relationships between factors and the intensity of this relationship. The identification of important variables and the strength of interrelations was done by expert interviews and by an analysis of relevant legislation. Variables were defined in the categories crisis issues, sector outcomes, sector structure, community perceptions and policy drivers.[141] The results were combined to develop one fuzzy cognitive map where factors were varied

[137] Lindberg, Markard, and Andersen, "Policies, actors and sustainability transition pathways: A study of the EU's energy policy mix," 3.
[138] Lindberg, Markard, and Andersen, 7.
[139] Lindberg, Markard, and Andersen, 12.
[140] Falcone, Lopolito, and Sica, "Policy mixes towards sustainability transition in the Italian biofuel sector: Dealing with alternative crisis scenarios," 2.
[141] Falcone, Lopolito, and Sica, 6.

with a computational procedure. They conclude that the optimal policy mix depends on the chosen objective goal (jobs, profits, EU targets) and the crisis scenario. Their main argument is that feedback loops and rebound effects play an important role in the outcomes of a policy mix and that policy makers need to be sensitive to these tendencies.[142] The proposed method cannot be applied in the current thesis due to the limited circumstances of this master thesis and the rather informal nature of interviews pursued.

Another study, which aims at recommending specific policies, although in the area of circular economy, applies a descriptive methodology. It mostly consists of a mapping and an analysis through categorization of existing EU policy in the domain of circular economy and resource efficiency, which serves as a basis to identify gaps.[143] Consequently, three policy areas are identified that are considered as promising for increasing the EU targets in resource efficiency.[144] The article also quotes principles from the scientific literature that should be taken into account for designing an optimal policy mix. Thereafter, a policy mix needs to incorporate clear targets, an inventory of measures and a dynamic packaging and appraisal even before implementation.[145] This approach demonstrates the importance of understanding the policy mix in place, in order to design or evaluate new measures. This also applies for the analysis of the EGD.

Many other studies in the domain of sustainability analysis exist which have been evaluated as less relevant for the present analysis: Edmondson et al. investigate on the interrelations between the evolution of policy mixes and socio-technical systems[146], Flanagan et al. pursue a critical review of scientific literature of policy mixes in the field of innovation policy with a special focus on the influence of actors, instruments, institutions and interactions[147], Hennicke discusses the reported outcomes of the Commission on "Sustainable Energy Supplies in View of Globalisation and Liberalisation" for a German energy policy mix up to 2050[148] and finally, Kern and Howlett research the drivers for changes in policy mixes on the example of the Dutch energy sector.[149]

Through this literature review, it has become clear that most studies investigating policy mixes are based on a **retrospective** analysis of policies. Notwithstanding, **this approach is not possible for the present master thesis** for the analysis of the EGD because the EGD is a policy strategy with a number of instrument mixes and instruments proposed but implementation is still

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[142] Falcone, Lopolito, and Sica, 8.
[143] Milios, "Advancing to a Circular Economy: three essential ingredients for a comprehensive policy mix," 867.
[144] Milios, 874.
[145] Milios, 874.
[146] Edmondson, Kern, and Rogge, "The co-evolution of policy mixes and socio-technical systems: Towards a conceptual framework of policy mix feedback in sustainability transitions".
[147] Flanagan, Uyarra, and Laranja, "Reconceptualising the 'policy mix' for innovation," 702.
[148] Hennicke, "Scenarios for a robust policy mix: the final report of the German study commission on sustainable energy supply".
[149] Kern and Howlett, "Implementing transition management as policy reforms: a case study of the Dutch energy sector".

awaiting and results cannot be measured yet. Only the studies of Falcone et al. and Milos focus on future policy mixes so that they can serve as inspiration for the methodology of this master thesis. Due to the specific circumstances of the drafting of this thesis and limited possibilities, an own approach to analyse the policy mix “EGD” was developed.

3 Methods

The analysis of the research question whether the systemic approach of the EGD can address important challenges for the further integration of RES into European energy system is conducted in two steps: First of all, important challenges for the integration of RE will be identified by a literature review, by the evaluation of information from relevant webinars on the energy transition and by informal interviews with members of the European Commission, who are experienced in energy topics. Secondly, the EGD-Communication and its sub-initiatives will be analysed, in order to see whether solutions are proposed to the identified challenges. The interviews with Commission members support this analysis.

In order to identify the **most important challenges towards a further integration of RE into the European energy mix,** a combination of literature review, interviews with Commission officials working with energy topics and information extracted from relevant webinars has been chosen. The **literature review** served as starting point to identify challenges for the further use of RE as mentioned and analysed in scientific literature. However, scientific studies are often focused on one specific theme and require to be complemented by additional methods to get a better understanding of the overall picture.

Thanks to **interviews** with officials of the European Commission, the "overall picture" could be better addressed. The European Commission as political organisation needs to capture the broader picture in order to propose adequate policy measures. In reality, this means that Commission officials in respective DGs need to be informed about their topic of expertise and exchange with other officials that work on similar topics. The internal procedures of the European Commission aim at ensuring the best possible interaction and exchange between officials of different DGs and proposals of one DG have to be consulted and reviewed by many others before being proposed to the College of Commissioners for adoption. As a consequence, officials are well-informed not only about the topics they are working on but also on related topics. Furthermore, officials often switch services and policy fields during their carreer at the Commission which also enhances their "broad understanding" of topics. By the very nature of their work, Commission officials have to be in contact with a various stakeholders involved in the field they cover, from within and even outside of Europe as well as with academia or experts researching in the fields which also contributes to enhancing their overall knowledge and understanding of the broader picture. Therefore, the views of officials are valuable information to identify important challenges for RE integration in the European context.

Additional, seven **webinars** were attended, with high officials of the European Commission as guests and interest groups, academia and RE industry expressing their views. Due to the Covid-19 crisis, the vast majority of the exchanges between Commission officials and interest groups were

organised in an online form. In the webinars, representatives of DGs, members of the cabinets of the President, the Vice-Presidents and/or Commissioners replied to questions of the audience. This gave the opportunity to **interrogate stakeholders** on their views on important challenges for RE that would be difficult to obtain through interviews. Furthermore, in webinars, experts or representatives of interest groups and industry were present. As a result, their views on the further integration of RE could be evaluated. The webinars thus opened the opportunity to integrate even more opinions of Commission officials and of related interest groups on challenges with respect to the further integration of RE in Europe. One important event was the "sustainable energy week 2020" during which many speakers from the Commission and industry exchanged on various aspects of the energy transition in a three-day online event.[150] Table 5 details all attended webinars:

Date	Title	Organiser
10.06.2020	Decentralised, smarter greener: the 2030 European grid	Solar Europe
17.06.2020	Energy transition and EGD	European Institutions' trainees networking week
23.06.20	Energy transition towards climate neutrality: the EU's support for the clean energy transition	Sustainable Energy Week, European Commission
23.06.2020	Opening session of the sustainable energy week	Sustainable Energy Week, European Commission
23.06.2020	Smart sector integration of gas and electricity infrastructure – opportunities and challenges in the context of the EGD	Sustainable Energy Week, European Commission
25.06.2020	A robust solar & wind industrial base underpinning the EGD	Sustainable Energy Week, European Commission
14.07.2020	European green deal in the context of post covid-19 recovery: implications for EU energy policy	European School of Administration, European Commission

Table 5: Attended webinars on the energy transition

To conclude, important challenges for the further integration of RE into the European energy system were thus identified through scientific literature review, interviews with Commission officials and attendance of webinars on energy topics.

The **interviews** were pursued during a traineeship at the European Commission which opened the opportunity to conduct interviews with officials in a trustful and informal setting. Representing a trainee and a student "working on her master thesis" proved effective to be received with openness. This very specific context gave the opportunity to contact and speak with officials of the European Commission which otherwise might be hesitant to talk about their work and their views. It became also clear that the context of the European Commission work at the time of the Covid-19 crisis was

[150] European Commission, "EU Sustainable Energy Week, 22-26 June 2020".

specific (home-office) and I was advised to contact an official only on the basis of the recommendation of another one in order to facilitate contacts. As a consequence, the interview partners have been identified with the "snowball principle" where one contact most of the time proposed one or two other contacts. Starting points were the recommendations of the supervisor of the traineeship. From there, the contacts were widened, so that 12 interviews have been conducted in total. All interviews were conducted by the internal communication tool "skype for business" via video or phone call. Due to the teleworking conditions from the third week of the traineeship onwards, no interview was pursued in person. The interview language was either English or German, depending on the native language of the interviewee. Interviewees were working in the DGs for Environment, Climate Action, Research and Development, Agriculture and Energy and six persons were in middle management or senior management positions. This is important because officials in management positions need to direct a large number of people and topics and thus need to have a good overview of all aspects that come into play for their department's work. Eight persons were already directly working on energy topics in their current or former position at the European Commission. Table number 6 gives an overview of the affiliation and position of interview partners.

	unit	position	Part of management
1	DG Agriculture	Advisor	senior management
2	DG Climate Action	Assistant to the Deputy Director-General	no
3	DG Environment	Team Leader	no
4	DG Environment	Advisor	Follow-up from management position
5	DG Environment	Deputy Head of Unit	middle management
6	DG Research and Development	Deputy Head of Unit	middle management
7	DG Agriculture	Director	senior management
8	DG Agriculture	Policy Officer	no
9	DG Agriculture	Head of Unit	middle management
10	DG Energy	Policy Officer	no
11	DG Energy	Policy Officer	no
12	DG Environment	Policy Officer	no

Table 6: interview partners

Due to the **confidentiality** guidelines of the European Commission and the preference of the interviewees, all information has been anonymised and only adherent departments (Directorate-Generals) will be named. The same applies for speakers form webinars in accordance to the Chatham

House Rule[151]. Only Commissioner Kadri Simson is named personally since she is in a political position.

Each person was interviewed once so that the identification of the most important challenges according to the interviewee and the potential of the EGD to respond to these challenges was covered in the same interview. The interviews had a length of 30 to 60 minutes depending on the availability of the interviewee. For each interview partner, an individual set of questions was developed in accordance to his or her experience and field of expertise, however, some "core questions" have been asked in every interview. Hence, the interviews were semi-structured. An exemplary set of questions is attached in the annex with the core questions marked in bold. The topic of the interviews was the EGD, the relevance of different initiatives under the EGD, the role of RE in the EGD and their opinions on other related topics.

The analysis whether the EGD proposes answers to these challenges has been pursued by a **thorough analysis of the EGD-Communication and relevant public documents on sub-initiatives of the EGD (instrument-mixes and instruments)**. Questions during the interviews with people that were part of the drafting process reinforced the analysis and the information gathering. The analysis builds on public available documents, on the interviews and on background information gained during the webinars which also helped to gain a broader perspective.

Although the EGD proposes policy initiatives within the horizon to 2022, only initiatives that were adopted by the European Commission by the end of July 2020 were analysed in depth. The date of the 31st of July as deadline for initiatives to be analysed has been chosen due to various practical reasons. First of all, the traineeship terminated at the end of July so that no further interviews or deeper information research was possible. Secondly, the due date for this master thesis made a limit at this point necessary. Thirdly, no important initiative is expected to be adopted in August, since the Commission also diminished its activity during the summer.

Initiatives of the EGD that are relevant for the RE but will be adopted only after the end of July (e.g. offshore wind strategy, scheduled for October 2020, renovation wave of buildings, scheduled for October 2020, review of the Trans European Network Directive – Energy, scheduled for December 2020) will be presented and their impact for the identified challenges will be evaluated, on the basis of information available. No in depth-analysis is possible. The analysis of the responses to the identified challenges through the systemic approach of the EGD will thus mainly be based on officially released documents and on publicly available statements of Commission's officials and affirmations during interviews.

[151]The Chatham House Rule is a journalistic principle that should encourage openness. It says that participants are free to use the information received, however the speaker must not be disclosed.

A difficulty in the analysis of the EGD lies in the fact that it is a political agenda with many sub-initiatives and a complex structure. The scheduled adoption of initiatives by the European Commission can be regarded as "indicative targets" but as a political institution, the European Commission needs to adjust to the circumstances and scheduled initiatives can be postponed. The master thesis thus analyses an agenda, although the implementation can be influenced by many external factors.

The analysis is based on two steps: first of all, the most important challenges for a further integration of RE into the European energy system are identified by a combination of literature review, interviews and webinars; secondly, the EGD and its sub-initiatives are analysed with respect to the identified challenges. In the following parts, the analysis and the results are presented.

4 Analysis and Results

In the following chapter, the challenges for RE identified through a literature review, through interviews with staff members of the European Commission and through the attendance of webinars will be presented. Afterwards, the potential of EGD initiatives to give answers to these challenges will be evaluated.

4.1 Challenges for the further integration of RE in the European energy system according to literature

In literature, five main challenges for the further integration of RE sources are discerned: the increased land use, especially for wind and solar energy, the increased demand for rare raw materials, the water footprint, the variability of RE sources, which makes energy storage necessary and the necessary transformation of the energy infrastructure. Land use of RE refers to the occupied territory for energy plants and the transmission infrastructure.

Land use with respect to energy output is very low for fossil fuel plants (200–11 000 W^e/m^2), whilst the surface occupied for solar panels, wind turbines and biomass plantations is considerably higher. According to Capellán-Pérez et al., typical ranges of net power density in the literature are 2–10 W^e/m^2 for solar power plants, 0.5–7 W^e/m^2 for large hydroelectric, 0.5–2 W^e/m^2 for wind and ~0.1 W^e/m^2 for biomass.[152] With the energy transition, this intensity in land use will provide "a new form of competition for land", since other pressures like urbanisation, agriculture and increased afforestation will persist or intensify.[153] Van Vuren et al. estimate that natural land cover might increase under a scenario where RE accounts of 65% of worldwide energy demand in 2100. The land use for energy plants is very small compared to pasture and crops, nevertheless, in total, artificial land use decreases. This scenario assumes a stabilizing world population in 2050, a change in life style of wealthy societal layers (decrease in meat consumption) and increased energy efficiency. Under other (less favourable) scenarios, the worldwide natural land cover will decrease, due to increased land use by all named purposes.[154] Capellán-Perrez et al. evaluate 100% RE scenarios through solar energy and conclude that "the transition to domestically produced RES maintaining the current levels of energy consumption could be physically unfeasible for many countries: in particular, the Netherlands, Luxembourg, Belgium, the UK, Denmark, Germany, Ireland, Czech Republic, Sweden, Poland,

[152] Capellán-Pérez, Castro, and Arto, "Assessing vulnerabilities and limits in the transition to renewable energies: Land requirements under 100% solar energy scenarios," 760.
[153] Poggi, Firmino, and Amado, "Planning renewable energy in rural areas: Impacts on occupation and land use," 639.
[154] van Vuuren et al., "Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm," 246.

Estonia […] and Italy would require over 30% of their total land area". They estimate that the EU-27 would require using 50% of their total area for energy use.[155] Nevertheless, they also state that most studies do not identify a "compelling constraint for transition" for 100% RE scenarios through additional land requirements.[156] The risk of land use depends thus very much on the location and additional factors like the population's habits.

The intensified use of wind turbines, photovoltaic panels, batteries and transmission infrastructure will increase the demand for **critical raw materials** which might lead to shortages. Electric power transmission infrastructure depends on the availability of copper (Co), aluminium (Al), zinc (Zn), steel, ferroalloy metals and other construction materials. The permanent magnets in wind turbines require "rare earth elements" such as neodymium (Nd), dysprosium (Dy), praseodymium (Pr) and Terbium (Tb); batteries use lithium (Li), cobalt (Co), nickel (Ni), manganese (Mn), carbon (C) and vanadium (V); and solar panels require silicon (Si), indium (In), gallium (Ga), tellurium (Te) and other base and minor metals.[157] A detailed overview can be found in table 7 below:

Renewable energy relevant raw materials (among others)	
Solar photovoltaic energy	In, Ga, Se, Cd, Te, Si, Ag, Sn, Ge, Mo
Wind energy	Cu, REE (Dy, Nd, Pr, Y, Tb), Co, Mn, Cr, Mo, Ni, Fe, B, Ba
Energy storage facilities	Li, Co, Ni, C, Mn (lithium-ion batteries) V, Zn, Fe, Cr (vanadium redox batteries)
Electric grids and transmission	Al, Cu, Ge, steel, Zn, Sn

Table 7: Renewable energy relevant raw materials after Buchholz et Brandenburg (2018)

These raw materials need to be imported to European countries or recovered through the recycling of technologies. According to Buchholz et Brandenburg, there exists for most of these elements and processed products a "moderate" or a "relatively high" risk for global supply and price due to a market concentration of mineral raw material production. Only the production of copper (mine and refined production) is faced with a "rather low risk". For bauxite production (necessary for the production of aluminium), selenium (Se), cadmium (Cd) and cobalt (Co) refined production the risk is "moderate". For aluminium (al) smelter production, silicon (Si), indium (In), gallium (Ga), rare earth elements, lithium (Li), cobalt (Co) mine production and vanadium (Va) the price and supply risk is evaluated "relatively high", mainly due to the market concentration on few countries. China is the

[155] Capellán-Pérez, Castro, and Arto, "Assessing vulnerabilities and limits in the transition to renewable energies: Land requirements under 100% solar energy scenarios," 774.
[156] Capellán-Pérez, Castro, and Arto, 761.
[157] Buchholz and Brandenburg, "Demand, Supply, and Price Trends for Mineral Raw Materials Relevant to the Renewable Energy Transition Wind Energy, Solar Photovoltaic Energy, and Energy Storage," 141.

first producer of seven of these elements with market shares between 55% and 95%.[158] China's dominance and "unpredictable political measures in the rare earth sector (e.g., consolidation, export quotas, production limitations, market power on pricing)" justify these ratings according to the authors.[159]

In a study by Wellmer et al. (2019), neither lithium (Li) nor copper (Co) are regarded critical, as they expect new resources to be discovered. Furthermore, both materials can be recycled with Copper even having the same quality in recycled form.[160]

Gonzalez et al. examine to which degree the "dependency on critical resources" might constitute a risk for the implementation for more wind power, solar thermal power and solar photovoltaic (PV) in a time frame until 2050.[161] In a baseline scenario, almost all studied resources (silver (Ag), aluminium (Al), cadmium (Cd), chromium (Cr), copper (Cu), dysprosium (Dy), gallium (Ga), germanium (Ge), indium (In), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), neodymium (Nd), tin (Sn), tellurium (Te), titanium (Ti), vanadium (V), zinc (Zn)) seem to suffice in reserves and resources. Only the demand of tellurium (Te) exceeds availability. Silver, cadium, indium and nickel almost reach available resources and many others are also close. With respect to the technologies, wind energy is the least affected by these possible supply difficulties.[162] In a second scenario, a common growth in annual recycling rates of 2% per material has been assumed. This would moderately reduce the observed limits, but nonetheless tellerium would not be available in sufficient manner.[163] The article evaluates the dependence on China for the supply in rare earth elements as risk.[164] These studies imply that the availability and the supply of raw materials might constitute a serious risk for the increase in RE and propose a dependency on China. Precise predictions are however difficult to make, since new resources can be discovered and calculation methods vary from study to study. When assuming carbon-neutrality in 2050, the Joint Research Center of the European Commission estimates that for wind turbines, the raw material demand in the EU will increase by 5 to 12 times for the structural materials and by 3.5 to 15 times for technology-specific materials.[165]

One possible challenge which needs to be considered according to an open letter by scientists of the Joint Research Center of the European Commission, is the **water footprint of the energy**

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[158] Buchholz and Brandenburg, 147.
[159] Buchholz and Brandenburg, 148.
[160] Wellmer et al., "The Raw Material Requirements for Energy Systems," in *Raw Materials for Future Energy Supply*, 164–65.
[161] Gonzalez et al., "Is the future development of wind energy compromised by the availability of raw materials?," 1.
[162] Gonzalez et al., 5.
[163] Gonzalez et al., 6.
[164] Gonzalez et al., 5.
[165] Carrara et al., *Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system*, 45.

system.[166] This is especially relevant since water scarcity is likely to increase due to climate change. Furthermore, water is crucial in the energy sector for cooling, storage, biofuels and hydropower.[167] One differentiates between the blue water footprint (water used form river, lakes and aquifiers) and the green water footprint (water in the soil, formed by precipitation and available to plants).[168] Both footprints are calculated by the authors for a number of energy production methods, which results in the following footprints, considering operation, construction and fuel supply[169]:

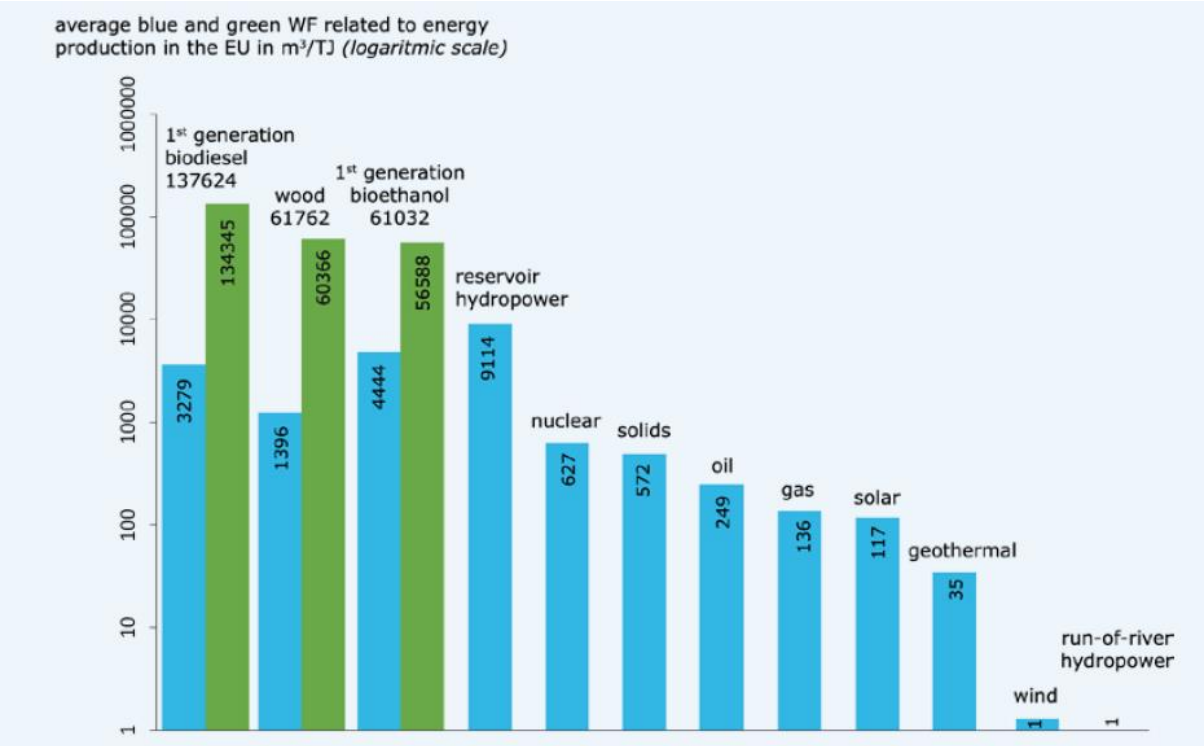

Figure 5: blue and green water footprint of RE

The water footprint of bioenergy is the highest, where the growth of the plants and thus the green water footprint play the most important role (137624 – 61032 m^3 TJ^{-1}). Reservoir hydropower has a higher footprint than fossil fuel plants and nuclear energy. Renewable plants in solar, geothermal wind and run-of-river hydropower have the lowest water footprint (117 - 1 m^3 TJ^{-1}). In total, the European energy system requires 74 billion m^3 of freshwater per year.[170] The water footprint of the energy system could however be reduced through the energy transition by 38% by 2050.[171]

[166] Vanham et al., "The consumptive water footprint of the European Union energy sector".
[167] Magagna et al., "WATER - ENERGY NEXUS IN EUROPE," 5.
[168] Vanham et al., "The consumptive water footprint of the European Union energy sector," 2.
[169] Magagna et al., "WATER - ENERGY NEXUS IN EUROPE," 21.
[170] Magagna et al., 5.
[171] Magagna et al., 5.

Good freshwater management and the inclusion of water questions into RE policies is crucial according to the Joint Research Center.

Another commonly acknowledges challenge is the **variability of RES which makes storage facilities necessary**, in order to balance energy demand and energy supply. Energy systems, mainly based on fossil energies like gas, oil and coal can easily offset demand fluctuations because the energy production can be activated or reduced easily. This is crucial for the stability of the electricity grid since electricity use and electricity generation need to be balanced at every moment to ensure the frequency of the grid and to avoid the overloading of transformers and feeders.[172] In the case of heat, stability is not a big problem because heat is mostly produced where it is used and in accordance to necessities. This makes a large-scale heat infrastructure and storage facilities redundant at the current moment in time, although their significance will increase in the future. In energy systems where most energy is produced from intermittent solar and wind energy, short-term (daily) and long-term (seasonal) storage systems will be important to balance periods of low energy production.

Many studies examine the difference of consumption patterns and the production of solar and wind energy in Europe. Graabag and Korpås give an overview of literature that examines the "Variability Characteristics of European Wind and Solar Power Resources".[173] Collins et al. examine the inter-annual variability in the EU and result that variations might increase five-fold by 2030.[174] Jerez et al. examine how the expected weather changes due to climate change will impact this temporal variability of RES and conclude that overall changes in wind-plus-solar production will be below 5% in Europe. A smart planning of the energy system might decrease daily variability in combined solar and wind production by up to 15% at a European level.[175] Studies suggest that a higher variation in RES and the integration of storage facilities can decrease the risk of "energy droughts".[176] In reviewing three different energy storage technologies (pumped hydroelectricity storage, batteries and fuel cells), Yekini Suberu et al. conclude that batteries and pumped hydroelectricity storage are already mature technologies. All technologies have advantages and caveats and no single energy storage system is qualified "to meet the entire requirements for use as an ideal energy storage system for either RE integration or mitigation of intermittency in the power utility sector".[177] Generally, storage capacity has to increase tremendously in a future energy system and storage facilities will probably be integrated in a decentralised way. Scenarios for Belgium in

[172] Münster et al., "Sector Coupling: Concepts, State-of-the-art and Perspectives," 31.
[173] Graabak and Korpås, "Variability Characteristics of European Wind and Solar Power Resources—A Review".
[174] Collins et al., "Impacts of Inter-annual Wind and Solar Variations on the European Power System".
[175] Jerez et al., "Future changes, or lack thereof, in the temporal variability of the combined wind-plus-solar power production in Europe," 257.
[176] Raynaud et al., "Energy droughts from variable renewable energy sources in European climates".
[177] Yekini Suberu, Wazir Mustafa, and Bashir, "Energy storage systems for renewable energy power sector integration and mitigation of intermittency," 512.

2040 with a supply of 100% green electricity foresee a need of 1700 GWh stored energy in case of a week with low wind and sun conditions. However, current existing pumped storage account only for 6 GWh. One million home batteries and 2 million electric vehicles might provide further 115 GWh but this still represents only 7% of the potential need. A representative of Elia said that current existing technology cannot provide such amounts of stored energy.[178]

In the EU, more than 90% of the energy storage capacity is currently provided by pumped hydro storage. Electrochemical energy storage is on the second place (batteries), however, more than 90% of current capacity is provided by the United Kingdom, which is no longer member of the EU.[179] Total electrochemical and pumped hydro storage capacity in the EU-28 is currently 40 GW, of which 20% are situated in the United Kingdom.[180] The European Commission estimates that by 2030, home batteries will need to provide for about 108GW storage capacity in the EU-28; by 2050 this capacity will decrease to 50GW since power-to-X (mainly hydrogen) in different applications will provide more flexibility and other storage options.[181] To summarise, the increasing use of RES requires an enhanced capacity of energy storage in different time intervals (daily, weekly, seasonal) and for different energy usages (heat, electricity, transport) in order to balance variability in energy production. This requires a combination of solutions from pumped hydro storage, to batteries and power-to-X solutions. Sector integration is often proposed as solution to decrease the necessary energy storage capacities.

Apart from the tremendous increase in storage capacities, an increased supply by RES will necessitate more **flexibility of the energy system and an adjusted energy infrastructure**. The balancing of energy demand will not merely be achieved through the adjustment of energy generation, but through the adjustment of consumption.[182] Verzijbergh et al. identified four forms of flexibility: flexible generation, storage, demand response and interconnection.[183] Already these factors imply a transformation of the energy system. Other studies go even further in advocating the management of energy system through "smart grids", which are defined as "electricity network[s] that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supply".[184] In contrast to traditional energy systems, smart grids use communication tools and digital technology to

[178] Lambin, "Elia grid Impact of renewable energies, 06.11.2019".
[179] Andrey et al., *Study on energy storage – Contribution to the security of the electricity supply in Europe*, 21.
[180] Andrey et al., 117.
[181] Andrey et al., 117.
[182] Ourahou et al., "Review on smart grid control and reliability in presence of renewable energies: Challenges and prospects," 19.
[183] Verzijlbergh et al., "Institutional challenges caused by the integration of renewable energy sources in the European electricity sector," 660.
[184] Ourahou et al., "Review on smart grid control and reliability in presence of renewable energies: Challenges and prospects," 20, after Smart Grids European Technology Platform.

process information of different grid points. In taking into consideration the behaviours of consumers, the balancing of supply and demand can be optimised though a non-linear but interactive way.[185] This grid structure can optimize grid efficiency and is necessary to accommodate the decentralised energy production patterns that can be expected by increased decentralized electricity production through small power plants (roof top solar panels and wind parks).[186]

The European Commission identifies electrolysis, methanisation and gas turbines with carbon capture (capture rate of about 90%) as flexibility mechanisms.[187] In scenarios for 2050, electrolysis and net imports and electric vehicles would provide most flexibility services, flexibility service being defined as the difference between supply and demand that can be transferred into another energy form by the given technology.[188] If an excess of RES is used to produce renewable hydrogen, methane, or other synthetic gases or fuels, the interrelations between the current gas and the electricity system have to be increased and established; both sectors need to be coupled. Although small percentages of hydrogen can be blended into the gas network, infrastructure to transport important products and by-products of Power-to-X technologies (pure hydrogen, carbon dioxide) do not exist yet in many regions and it is unclear whether existing infrastructure can be retrofit to these purposes.[189] It can be summarised that important adjustments to the energy system are necessary for the increased integration of RES: The grid structure must be transformed from linear to multidirectional, the management has to evolve to the described "smart grids", more interconnections between MS' electricity systems are necessary, and interconnections between gas and electricity systems have to be enhanced.

Up to now, five challenges have been identified for the increase in RE: land use, critical raw materials, the water footprint, necessary storage solutions and a necessary flexibility of the energy infrastructure. For the last two points, generally sector integration is regarded the most cost-effective solution. Still, many challenges exist for sector integration. Through a literature review a number of **specific challenges for sector integration** and for the **integration of renewable hydrogen** have been identified. A study commanded by the European Commission on "regulatory barriers in linking the gas and electricity sectors in the EU" for a full decarbonisation of the EU energy system by 2050 comes to the findings that sector coupling technologies and low-carbon renewable gas technologies are not yet mature, which makes investment into innovation necessary.[190] Synthetic gases which are based on power-to-gas technologies might not be competitive with biogases, since taxes and levies on electricity increase the final costs. As a solution, the study recommends that levies and taxes should

[185] Ourahou et al., 20.
[186] Ourahou et al., 23.
[187] Andrey et al., *Study on energy storage – Contribution to the security of the electricity supply in Europe*, 53.
[188] Andrey et al., 55–56.
[189] Münster et al., "Sector Coupling: Concepts, State-of-the-art and Perspectives," 41.
[190] Riechmann et al., *Potentials of sector coupling for decarbonisation*, 14.

be based only on final electricity consumption.[191] The study also identifies a problem in the missing regulatory framework for hydrogen and other gases than natural gas. The current regulatory framework is focused on natural gas and it is unclear whether it applies to other gases.[192] The study concludes that a combined planning of the gas and the electricity infrastructure is necessary.[193]

A study on sectoral integration of the EU energy system (also procured by the European Commission) highlights the indispensability of a maximum of energy efficiency in all sectors, high shares of RE, electrification of mobility and stationary energy end-uses (like heat pumps), and the production of advanced biofuels for aviation and shipping.[194] Decision-makers will have to decide between a centralised or decentralised hydrogen production approach but the electricity price needs to be low to make renewable hydrogen competitive.[195] The study also emphasises that hydrogen can fulfil the purpose of inter-seasonal storage, for that natural caverns and a large scale distribution system would be necessary.[196] A successful business model for hydrogen would also need a coordination of all users of the chain, namely infrastructure developers, technology and research providers, hydrogen producers and end-use consumers to avoid a market failure. Since all actors follow different targets, "long-term anticipation and regulatory certainty are of utmost importance for market coordination".[197]

A study issued by the European Commission stresses the importance of a flexible energy system and the coupling of the power sector, heating, industry and mobility which can offer solutions for flexibility also with respect to energy storage solutions.[198] According to the study, about 550 GW of electrolysers would be necessary in 2050. To enable this, "cost-reflective network charges and appropriate taxation rules" should value environmental benefits, system flexibility and stability.[199] Double charging tariffs during storage charge and storage discharge should be eliminated.[200] Additionally, action is needed to ensure that MS foster dynamic electricity prices and time-of-use grid tariffs, and that MS out-phase net metering. Finally, the energy taxation needs to be revised, in order to reflect correctly GHG emissions and eliminate double taxation on stored energy.[201]

A study by Verzijlbergh et al. states that the electricity markets need to be adjusted for a higher share of RES. In order to prevent negative electricity prices (caused by too inflexible energy providers in low demand periods), which would also damage RE suppliers, renewable electricity

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[191] Riechmann et al., 15.
[192] Riechmann et al., 16.
[193] Riechmann et al., 16.
[194] Vita et al., "Sectoral integration- long-term perspective in the EU Energy System," 2–3.
[195] Vita et al., 3–5.
[196] Vita et al., 4.
[197] Vita et al., 5.
[198] Andrey et al., *Study on energy storage – Contribution to the security of the electricity supply in Europe*, 7.
[199] Andrey et al., 11.
[200] Andrey et al., 11.
[201] Andrey et al., 12.

markets should cover areas as large as possible, which would reduce the fluctuating amounts of traded electricity, since geographical differences have a balancing effect. Secondly, the interval of trading should be reduced from one hour to intervals of five minutes, so that the flexibility of energy supply can be reflected by the market. The markets also need to incentivise investment into flexibility services.[202] Moreover, a reinforcement of electricity infrastructure would be necessary, since high loads are likely to appear in peaks, for example if an off-shore wind park produces much electricity in a short amount of time. This needs to be accompanied by a "congestion management", which aligns "the network capacity, RES production and demand volumes and location by market signals".[203] Lastly, carbon policies and RE support schemes have to be better planned and coordinated across European MS. A higher CO_2-price could make polluting energy sources with very low marginal costs (coal) less attractive so that they are shut down earlier in energy poor situations than it is currently the case, e.g. in Germany. If electricity is traded more on a European than a national level, electricity markets need to be better coordinated so that national support schemes do not deter the market. German feed-in tariffs for RE can for example have a negative effect on the RE industry in the Netherlands that need to trade their electricity on the markets.[204] An integrated energy system and the extension of the use of renewable hydrogen face thus important challenges which need to be addressed in European initiatives to foster sector integration and renewable hydrogen. A summary of the identified challenges and proposed solutions is presented in table 8:

Challenge for sector integration	Proposed solution
Immature technology	Investment into innovation
Synthetic poser to gas uncompetitive with biogas	Taxes and levies only on final electricity consumption
Separate planning of the gas and the electricity infrastructure	Combined planning of the gas and the electricity infrastructure
Necessary electrification of mobility and stationary energy end-uses (like heat pumps)	Scale-up the electrification of these sectors.
Decarbonising aviation and shipping	Production of advanced biofuels for aviation and shipping
Double charging of stored energy	No double charging tariffs during storage charge and storage discharge
Adaptation of energy consumption to	Dynamic electricity prices and time-of-use grid tariffs

[202] Verzijlbergh et al., "Institutional challenges caused by the integration of renewable energy sources in the European electricity sector," 664.
[203] Verzijlbergh et al., 665.
[204] Verzijlbergh et al., 665.

load	
motivate the development of storage solutions	Out-phasing net metering
Adaptation of electricity markets	Short trading intervals; coverage of large areas to balance fluctuating energy; incentivise investment into flexibility services
Very high peak loads	Reinforcement of electricity infrastructure; congestion management
National support schemes can deter the European electricity market	Better coordination of national support schemes
Challenges for hydrogen extension	**Proposed solution**
Transmission of hydrogen	Adaptation of gas infrastructure & blending options
Storage of hydrogen	Natural caverns & large scale distribution networks
High electricity price makes hydrogen uncompetitive	More RE, out-phasing of fossil fuel subsidies, higher CO_2 price
Missing regulatory framework for hydrogen and other gases than natural gas	Adaption of regulatory framework
Up-scale electrolysers	Cost-reflective network charges and appropriate taxation rules
Coordination of all users of the chain, namely infrastructure developers, technology and research providers, hydrogen producers and end-use consumers market failure for hydrogen	Long-term anticipation and regulatory certainty are of utmost importance for market coordination

Table 8: challenges for sector integration and proposed solutions

In this section, important challenges for the integration of more RES into the European energy system identified by literature have been presented. First of all, RE will increase the land use for energy purposes which might increase the competition with other land uses. The use of critical raw materials and their supply might pose a risk for the increase in RES, since resources are limited and most of the materials are extracted and processed in China. The water footprint of RES needs to be considered in RE policies. Furthermore, RE are intrinsically intermittent energy sources which makes energy storages necessary and an evolution of the energy system towards more flexibility, more decentralisation and a coupling with the gas sector necessary. The integration of the energy system and a broader use of renewable hydrogen face many challenges. Other challenges named in literature are the social acceptance of RE, the cost of innovation, market integration of RES and policy

uncertainty. Although these factors might play a role, they have been identified as less meaningful, since they are less subject to scientific research.

4.2 Challenges for the further integration of renewable energies identified through interviews

Apart from the challenges that have been identified through a scientific literature review, 12 interviews with Commission staff members have been conducted and 7 webinars on energy topics have been followed with representatives of interest groups, academia and European institutions (Commission, Parliament).

During the interviews, every interviewee was asked the question what he/she considers important challenges for the further integration of RE. In later interviews, the interviewees were also asked whether they considered factors that had been named by previous interviewees as challenges. Some interview partners regarded certain specific factors as possible challenge but were not entirely sure and made statements like "if not managed correctly, that will become a challenge" or "on a local level this might be challenging". For every interview, the number of *challenges* and *possible challenges* have been identified and summing up all named challenges, one can get an impression of the importance of the different named challenges. The following figure 6 demonstrates the results of the interviews:

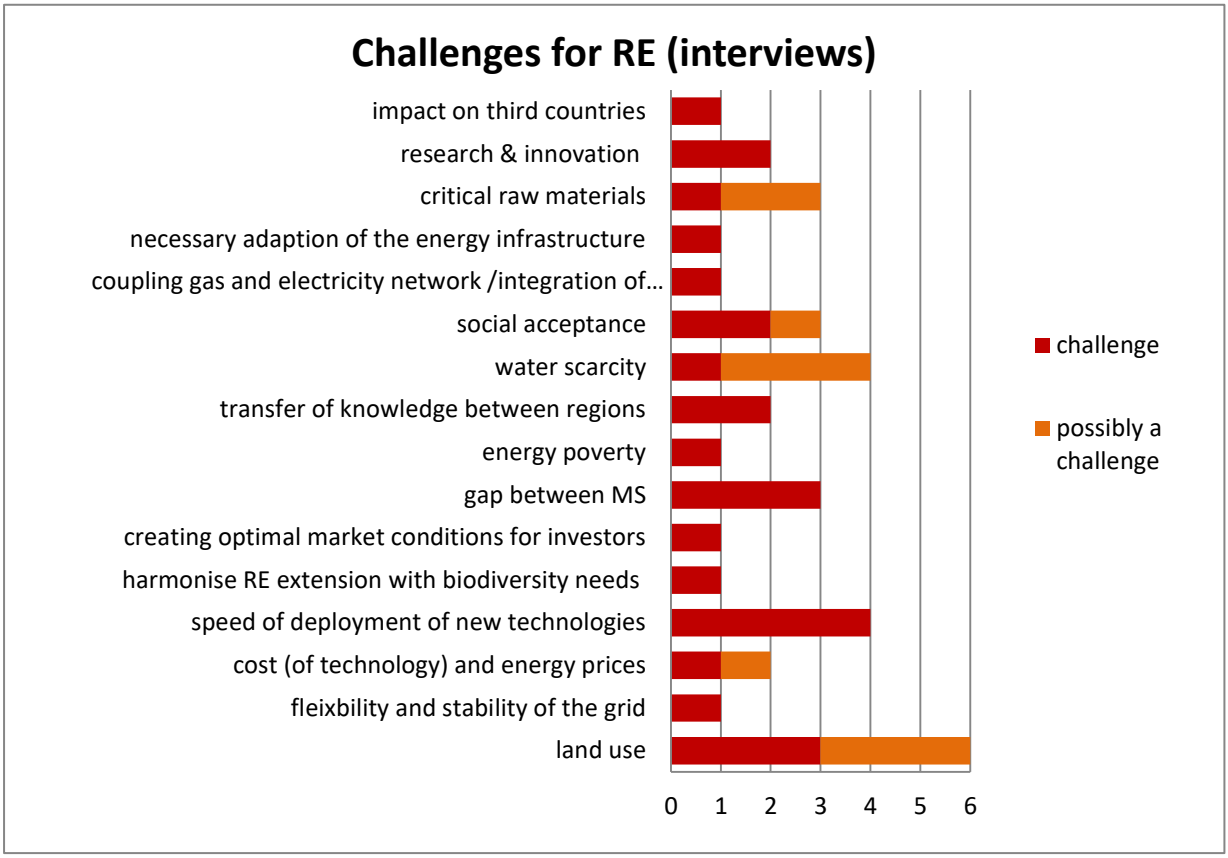

Figure 6: Challenges for RE identified by interviews

Interestingly, the **land use** is identified by three people as a challenge and by three people as a possible challenge. Factors named are that solar panels and wind turbines need much space, but at the same time protected areas under the EGD should increase for the sake of biodiversity; areas are necessary for construction with increasing urbanisation and the land used for agriculture might increase with increased organic farming targets. Furthermore, much arable land is used for the growth of energy crops. For two interview partners (DG Agriculture, DG Environment) this is a clear contradiction in the EGD. Other interview partners (DG Agriculture) do not see a problem in land use, since there seems to be a tendency that farmers abandon land due to decreased yield. Furthermore, the competition for land use due to the growth of energy crops should be mitigated by European sustainability criteria for biofuels. One interviewee (DG Environment) states that potential areas for RE may not be calculated in a fully correct way, since according to this person, the calculations only differentiate between protected areas, arable land and "the rest" and all the rest is considered potential land to explore for RE. When interviewees (DG Agriculture, DG Energy) are asked about this calculation approach, no one confirms the named methodology. According to them, potential land for RE is based on different models that are developed by the Joint Research Center, which uses amongst others satellite images. It can thus not be established, whether there are weaknesses in the calculations of RE potential. An interviewee from DG Energy says that for PV panels, the potential on roofs needs to be exploited, because this space is already there. Furthermore, there exist models where PV and agriculture are combined, whereby PV panels protect sensitive crops against sun radiation. According to this person, land use competition may be prevented with similar models and good management. Still, land use and potential land use competition is regarded as a challenge or possible challenge by many interview partners.

A second challenge named frequently is the **speed of deployment of new technologies**. Four interview partners name this factor as an important challenge; one interviewee (DG Research and Development) says the time between the development of a technology and the deployment was in the past "tremendous", giving the example of wind energy and wind turbines. An adaptation of the market and the framework conditions would be necessary to respond to this issue. Another interviewee (DG Agriculture) states that there is much research and development in the EU, but the commercialisation is lagging behind. As an example, this person names the price of bio-methane which is much more expensive than natural gas per MWh. An interviewee (DG Energy) used the word "death valleys": although the technology is tested, it never arrives on the market. Another interviewee (DG Energy) confirms that currently progress is very slow. This person says that in electrification some progress is made, but everything is still "way to slow". There is little progress in renovation and cooling and the situation in transport is even worse, with an almost flat curve.

Another challenge emphasised by three interview partners **is the development gap between MS**. They say that currently strong differences in the deployment of RE between MS of the EU exist

and this development might be reinforced with an acceleration in the energy transition. As reasons, different political and social developments in MS are named. In Germany for example, new regulations for the minimum distance between wind turbines and a minimum distance to small villages inhibits the extension of wind energy. In Greece, social resistance against wind turbines is also present. Linked with this is the challenge "transfer of knowledge between regions". Two interviewees (DG Agriculture, DG Environment) indicate a missing **transfer of knowledge** between regions. This exacerbates differences in MS development and uptake of RE.

Social acceptance is named by two interviewees as challenge and by one interviewee as possible challenge. An interviewee (DG Energy) considers social acceptance as the main challenge for RE. The calculations through models of the necessary installed RE capacity in the future will mean a complete transformation of the landscape. According to this person, a smart way needs to be found to put this on the European agenda and people need to be convinced through personal benefits from RE. Support schemes need to give the right incentives. Two other interviews (DG Agriculture, DG Climate Action) mention situations where people were opposed to wind turbines at specific places. Other interviewees (DG Energy) see social acceptance as a question of management. Wind farms can be constructed offshore to be less visible. In sum, amongst interviewees, social acceptance is regarded as an issue, but less than the land use competition and the deployment speed of mature technology.

Research and innovation is considered a challenge by two interview partners. An interviewee (DG Energy) says "an extra step is necessary" in this area. This person also says that massive investment is necessary into research and innovation of which usually only 20% comes from public sources. Another interviewee (DG Agriculture) sees the problem in the access to finance for research and innovation. Research and innovation needs to be incentivised according to both interview partners.

The **availability of sufficient critical raw materials** is indicated only by one person as challenge (DG Agriculture). This person sees the dependency on China for the supply of these critical raw materials critical. When interrogated on the question, two other interviewees (DG Energy) reply that this might possibly become a challenge or is likely to become a challenge. However, Commission experts on this topic do not think critical raw materials will become an issue. On the one hand, research and innovation is necessary to find materials that can replace the critical ones (coming from China). On the other hand, critical raw materials in use need to be better recycled. One interviewee (DG Energy) has the impression that that climate change is currently prioritised over the question of critical raw materials, because climate change is the more urgent issue. This approach is reasonable according to the interviewee. There is awareness about the potential risk of supply of critical raw materials, but this risk is accepted in order to propose mitigating actions to combat climate change.

The **cost of technology** for the energy transition is named by one person as the most important challenge (DG Environment). This person says that prices for RE and for the energy produced need to decline more.

The question of **water scarcity** is not named by any of the interviewees unless they are specifically asked. One interviewee (DG Agriculture) expresses that there is already a challenge with water scarcity in some MS. In Greece, the shortage in water is linked with the agricultural practices and could be addressed by cultivating less water-intense crops. Three other interviewees reply that water scarcity can be a problem at local level if inadequately managed. One interviewee (DG Agriculture) states that the cultivation of energy crops may cause water scarcity. An interviewee (DG Energy) sees a potential risk with the large-scale use of electrolysers for the production of green hydrogen. If a 1MW plant would be constructed in a region with limited fresh water, this might lead to water scarcity. In order to prevent this, good management and project planning is necessary.

The challenge of the **flexibility of RE**, the necessary **adaptation of the energy network**, and the **coupling of energy sectors** are named by few interviewees as most important challenge. One interviewee (DG Climate Action) names the variability of RE, which makes much flexibility of the energy grid necessary as main challenge. Another interviewee (DG Energy) identifies as most important challenge the need not to waste the energy produced. In order to do so, the transmission and distribution grids need to be adapted, the energy grid needs to be expanded, and possibilities for energy storage need to be created through conversion processes. Hydrogen will play an important role, smart sector integration is necessary and a circular energy system. The same person also states that the gas network and the electricity network need to be planned in a combined way, which is only starting. Another interviewee (DG Energy) states that many people regard the energy system integration as the most important challenge. This interviewee's stance is however, that this is achievable through a gradual transition and that social acceptance will be a more challenging issue.

A number of factors were named by single interviewees as challenges: one interviewee (DG Environment) regards deforestation in third countries as an important challenge, caused by the import of energy crops and biomass for the production of bioenergy. This person refers to the British bioenergy power plant "Drax power station", which imports pellets form the US, where old forests are cut. This issue has already been improved by the introduction of sustainability criteria in the review of the Renewable Energy Directive (RED II)[205], according to this interviewee. One interviewee (DG Agriculture) sees a risk for energy poverty, since the EU depends on oil and on gas. Furthermore, there is the willingness to move out of nuclear energy, although this can guarantee energy security. One interviewee (DG Research and Development) identifies as challenge the creation of optimal market conditions for RE and appropriate channels for private investment, as most investment should

[205] Directive 2018/2001/EU

come from the private sector. Fossil-fuel subsidies are for example a wrong signal. One interviewee (DG Environment) emphasises the need to harmonise RE needs with biodiversity needs. Possible risks for fishes arise from flooded areas for hydro power plants. These risks can be offset though smaller hydro plants. Risks and issues for biodiversity with respect to RE need to be made explicit so that they can be tackled and incorporated into the planning process.

Additional to the general challenges for RE, in some more specialised interviews, the **specific challenges for sector integration** were raised. This question was asked in five out of the 12 interviews. **Five challenges** are named: the **linking of the gas and the electricity sectors and networks**, which makes some adaptation necessary, especially for hydrogen (three interviewees); the current **lack of a legal supportive framework for that and for power-to-X conversion processes** (two interviewees); the **slow electrification of many sectors**, the **slow renovation of buildings**; and **a lack of clarity internally in the concept of "sector coupling" and "sector integration"** (one interviewee (DG Climate Action)[206].

The main challenges for the energy system integration are thus according to the interviewees the necessary connection of the electricity and the gas network, which makes a combined planning necessary and an adaptation of the gas network, so that it can be used for hydrogen and blended options. Furthermore, the lack of legal framework, slow progress in electrification and slow progress in housing renovation are important challenges. These challenges match the challenges identified in the academic literature review.

4.3 Challenges for RE identified by webinars

Seven webinars have been followed with guests from different interest groups and members of the European Commission. In particular, the Commissioner for Energy Ms Kadri Simson and the Director-General for DG Energy Ms Ditte Juul Jørgensen were amongst the guests in the webinars. The webinars were thus helpful to get insights from Commission members and senior officials, other institutions and bodies (for example the European Investment Bank (EIB)), other Commission services[207] and to hear the opinion from some industry representatives, scientists and other key stakeholders.

Industry stakeholders came from Bloomberg New Energy Finance, Gate Ventures, Vestas, Meyer Burger, and Wind Europe. Some of the invited people mentioned challenges during their

[206] This last statement was made in April. Meanwhile, the energy system integration strategy was adopted by the European Commission, so that the interviewee might reply differently at a present moment in time.
[207] For example, representatives from DG Internal Market, Industry, Entrepreneurship and Small and Middle-sized Enterprises, DG Climate Action, DG Regional and Urban Policy, and the Secretariat-General were present in some/most of the webinars attended.

presentations. In some cases the question about challenges could be posted during the question and answer sessions. As a result, the following challenges have been identified:

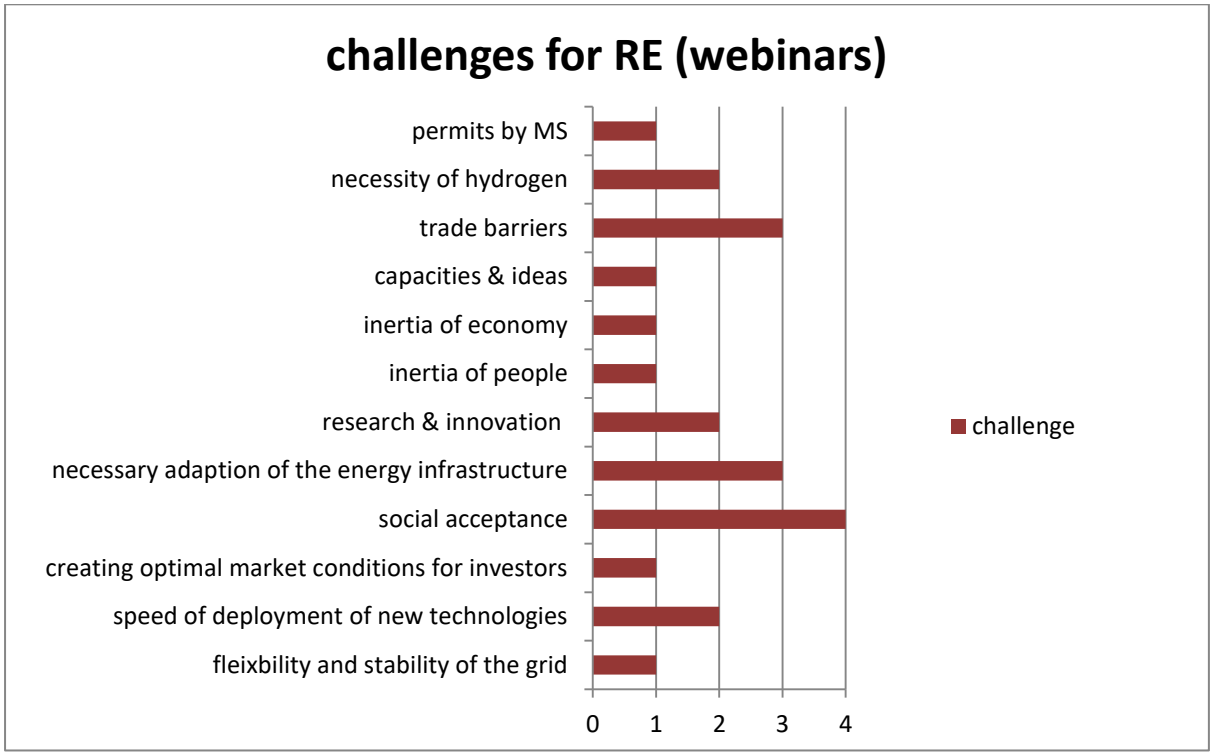

Figure 7: Challenges for RE identified by webinars

Some of the challenges correspond to former identified challenges, but some new challenges are also identified.

Social acceptance is regarded a challenge by four people (Commission officials DG Growth[208], DG Energy) and stakeholders form the wind industry (Vestas, Wind Europe). A representative of DG Growth emphasises that consumers play an extremely important role, so that legislation and policies should enable an increased consumption and acceptance. The Director-General of DG Energy regards social acceptance to be the main challenge for RE.[209] The **adaptation of the energy infrastructure** is mentioned three times and has thus a higher importance with respect to the interviewees. Representatives of DG Growth, DG Energy and of Wind Europe make statements in this direction. A representative of DG Growth emphasizes the electricity grid needs to be reinforced, and one from DG Energy and representatives of Wind Europe regard investments for the reinforcement of the power infrastructure as necessary. **Research and innovation** is specifically highlighted by the Commissioner for Energy Kadri Simson and a representative of DG Energy. Kadri Simson regards innovation as crucial for the recovery from the Covid-19 economic crisis. Investment

[208] Directorate-General for Internal Market, Industry, Entrepreneurship and Small and Middle-Sized Enterprises
[209] Juul Jørgensen, "The european green deal in the context of post covid-19 recovery: implications for eu energy policy".

into the energy transition should foster the recovery. A representative of DG Energy refers to the necessity for more progress in technology development. Interestingly, the **speed of deployment of new technologies** is also mentioned in the webinars by Gates Ventures and a representative of DG Growth. The representative of DG Growth stresses that currently technology is developed in Europe, however it is not quickly enough placed on the market, so that China "grabs" the technology for commercialisation. A "role-up" is necessary according to this person. Bloomberg New Finance sees high risks in the **necessary flexibility of the energy system** for the integration of RE, specifically in the over-sensitivity of the grid with decentralised embedded generation by solar panels and wind turbines. This increases the risk for blackouts. Finally, a representative of the EIB stresses the importance of motivating **private investment into RE** and thus to create good market conditions for investors. For that an ambitious and robust regulatory framework is necessary and innovative finance strategies are necessary to tackle climate change on a local level. Nevertheless, representatives of DG Growth and the enterprise Meyer Burger stated that the EIB is not financing disruptive innovation, meaning innovation that does not yet have an established market. This is considered a hindrance for some new RE technologies by these stakeholders.

To conclude, in the webinars the five challenges that had also been identified in interviews were confirmed: **research and innovation**, the **necessary adaptation of the energy infrastructure**, **social acceptance**, the **speed of deployment of new technologies**, and the **flexibility and stability of the electricity grid**.

Apart from the named challenges, thanks to the webinars **six further challenges** could be identified: Industry stakeholders from Vestas, Meyer Burger, and Wind Europe are all concerned about possible **trade barriers** that might increase the price on imported materials (e.g. steel, glass, glass fibre) or components and thus decrease the competitiveness of European products. Kadri Simson and a Commission staff member (DG Growth) highlight the importance of **green hydrogen** in the future. A third challenge is named by Wind Europe, who expresses that MS do not award sufficient **permits for PV and for wind turbines** to deliver the objectives of the EGD. A representation of DG Regional and Urban Policy (DG REGIO) expresses a **lack of ideas and capacities** for new solution in the domain of RE in the EU and the need for a revolution in terms of skills and capacity. The skills and capacities that are necessary to deliver on the targets for 2030 are not there yet. A representative of the Secretariat-General mentions that there will be naturally winners and losers and there is **inertia of people** that have much to lose. The solution for this issue lies in finance. Furthermore, the awareness of people is fluctuating. Currently, landlords are not sufficiently motivated to renovate property for rent. Finally, a representative of DG Climate Action sees a challenge in the **inertia of the economy**: according to this person it is difficult to achieve a quick change in the economy, though the Covid-19-crisis demonstrated that the behaviour of people can change quickly. To sum up, some stakeholders form the renewables industry and Commission members see additional challenges in

permits for solar panels and wind turbines, in a **large increase of renewable hydrogen**, in **possible trade barriers**, in **capacities and ideas** and in the **inertia of people and the economy**.

The challenges identified through the literature review, interviews and webinars are summarised in the following figure 8 in a combined way:

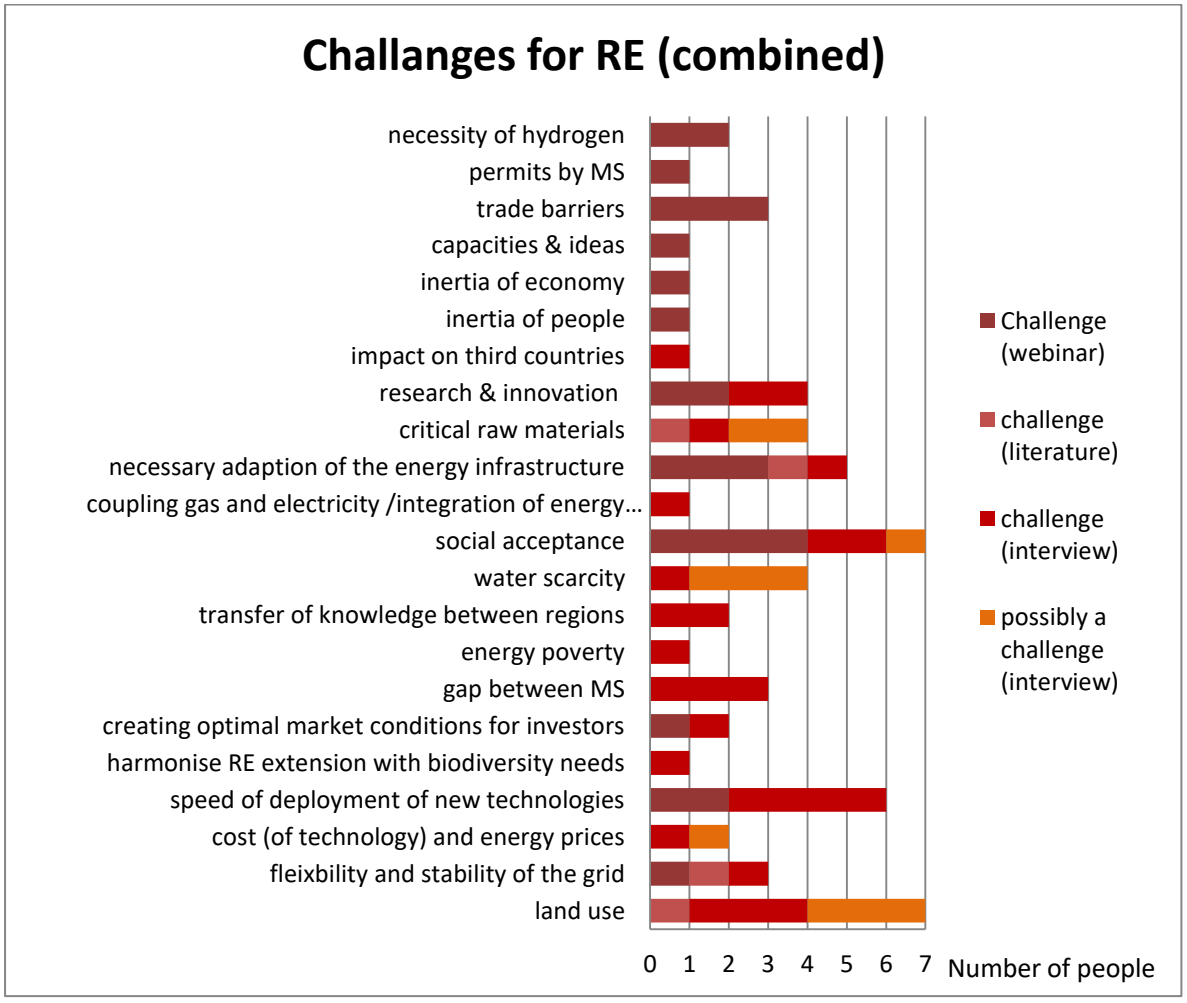

Figure 8: Challenges for RE identified through combined methods

In total, 22 challenges have been identified, whereby some are very much related with each other. With respect to figure 8, social acceptance, land use, the speed of deployment of new technologies and the necessary adaptation of the energy infrastructures seem to be main challenges that are identified by many stakeholders. In the following section, the European Green Deal will be analysed with respect to these challenges.

4.4 What does the EGD offer?

The European Green Deal is a Communication of the European Commission that outlines the target of climate neutrality in 2050. In order to achieve this very ambitious objective, the economy and the society should be transformed through a "transformative set of policies" that touch upon all policy areas: agriculture, energy, biodiversity, finance, industry, social policy, etc. It is thus a very all-

encompassing approach subordinating all policy areas to one common objective, which was regarded as new and revolutionary by almost all interview partners. The structure of the EGD and the initiated policies is however rather complicated. The Communication "A European Green Deal for Europe" includes an Annex with 48 initiatives for the years 2020 and 2021.[210] These 48 initiatives include instrument mixes and instruments. The instrument mixes define sub-objectives and include in themselves an outline with initiatives (e.g. Biodiversity Strategy, Energy System Integration Strategy, Circular Economy Action Plan…). The instruments consist of concrete legislative proposals or revisions (e.g. revision of the ETS, revision of the Energy Efficiency Directive etc.). Since one instrument mix includes about 30 to 50 new initiatives and the EGD in itself included 13 instrument mixes and 29 concrete initiatives, one can say that the EGD should give rise to at least about 400 initiatives. Figure 9 tries to represent the complex structure of the EGD:

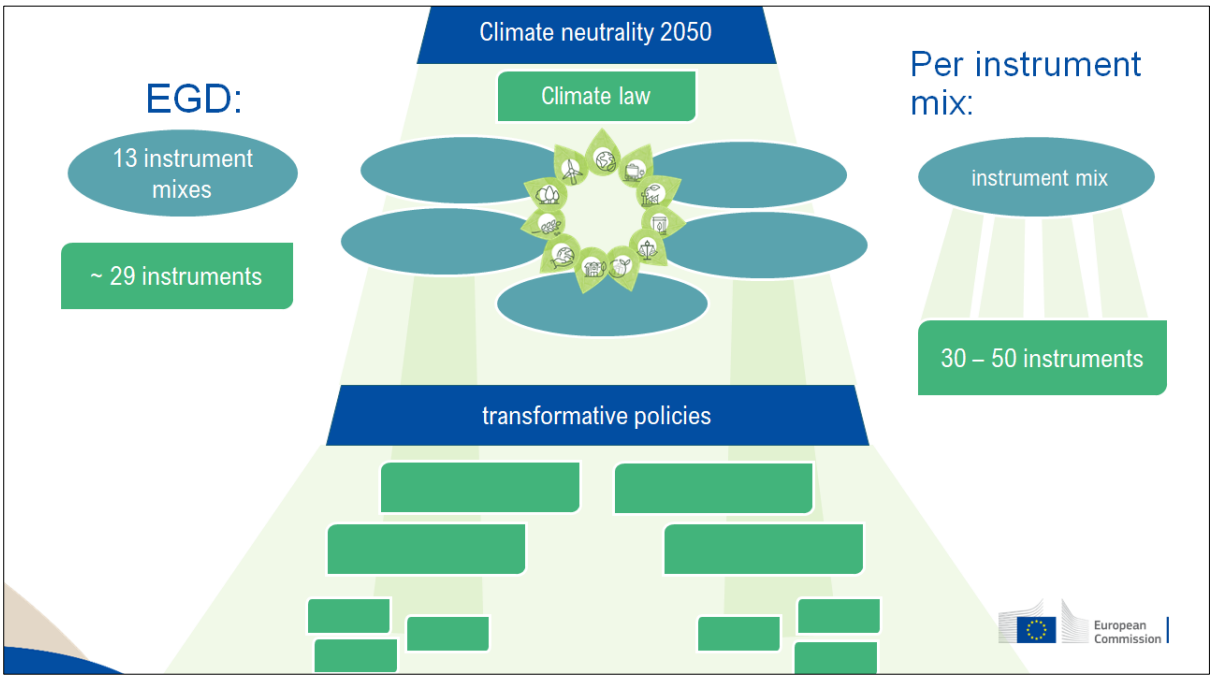

Figure 9: structure of the EGD

The EGD is thus extremely broad and complex, also due to the fact that initiatives make reference to each other and are closely interlinked. The Farm to Fork strategy introduces for example an objective of 25% of organic agriculture in 2030, whilst the biodiversity strategy initiatives in its annex an "organic-farming-action plan".[211]

In order to analyse whether the EGD addresses the multi-fold challenges for the further integration of RE, one thus needs to analyse the content of the Communication "a European Green

[210] *The European Green Deal*, COM(2019) 640 final (Brussels, December 11, 2019).
[211] *A Farm to Fork Strategy*, COM(2020) 381 final (Brussels, May 20, 2020).

Deal for Europe" and the information that are publicly available on the initiatives that are foreseen under the EGD. At the moment of the finalisation of this master thesis, nine actions had already officially been adopted by the European Commission and had thus been presented to the EP and the Council for further formal adoption or feedback. A list of all adopted actions and the relevance for the identified challenges is presented below in table 9. The Conclusions of the last European Council and the proposals for a recovery package are also taken into consideration.

What?	Adoption date	Relevance for RE and challenges
Just Transition Mechanism	14.1.2020, update 28.05.2020	medium
European Green Deal Investment Plan	14.1.2020	medium
Climate law	04.03.2020	medium
Industrial strategy	10.03.2020	medium
Circular economy action plan	11.03.2020	medium
Biodiversity strategy	20.05.2020	low
Farm to Fork Strategy	20.05.2020	low
Smart sector integration strategy	08.07.2020	high
Hydrogen strategy	08.07.2020	high
Recovery package	27.5.2020, conclusions of the European Council[212]	high

Table 9: Adopted initiatives under the EGD by the 31.07.2020

In the Communication "a European Green Deal for Europe", energy is mentioned several times. As introduction the Communication states "to deliver the European Green Deal, there is a need to rethink policies for clean energy supply across the economy, industry, production and consumption, large-scale infrastructure, transport, food and agriculture, construction, taxation and social benefits".[213] A revision of the Energy Taxation Directive is proposed in order to ensure effective carbon pricing.[214] In the chapter "supplying clean, affordable and secure energy" a number of points are highlighted with respect to RE. As the production and use of energy across economic sectors accounts for 75% of GHG emissions, "a power sector must be developed that is based largely on renewable sources, complemented by the rapid phasing out of coal and decarbonising gas".[215] The principle "energy efficiency first" is stressed which says that an efficient use of energy is to be preferred to all other measures. The Communication also outlines that the Commission will propose

[212] *Special Meeting of the European Council - Conclusions*, EUCO 10/20 (Brussels, July 21, 2020).
[213] *The European Green Deal*, COM(2019) 640 final (Brussels, December 11, 2019), 4.
[214] *The European Green Deal*, 5.
[215] *The European Green Deal*, 6.

increased climate targets for 2030 with the new objective to reduce GHG emissions by either 50% or 55%.[216] The Commission will propose the increased target based on an evaluation of the MS' national climate and energy plans (NECPs), in which MS report regularly on their progress towards climate and energy targets as part of the regulation on the governance of the energy union and climate action[217]. MS were supposed to send their reports to the Commission by the end of 2019, although in the end of July 2020, not all MS had submitted their reports.[218] The assessment of these plans is highlighted in this EGD-Communication, since the resulting increased target for 2030 will be the basis for the revision of relevant energy legislation in June 2021. The Communiation highlights furthermore the importance of benefits for the consumers through the energy transition. Energy poverty or high energy prices should be prevented. Offshore wind energy will play an increasing role in the future and measures for the smart integration of RE into the energy system will be proposed by the Commission. Finally, the Communication emphasises a necessary extension and adaptation of the energy infrastructure. As approaches, a revision of the TEN-E Regulation with the integration of "innovative technologies and infrastructure, such as smart grids, hydrogen networks or carbon capture, storage and utilisation, energy storage" is envisioned.[219] In total, this chapter outlines the initiatives that are included in the annex in the category "Clean, affordable and secure energy": The assessment of the national climate and energy plans, a strategy for smart sector integration, a renovation wave, a review of the Trans-European Network – Energy Regulation, and a strategy on offshore wind.[220]

Most of these initiatives were however scheduled for dates after the deadline of the present master thesis, so that only the smart sector integration strategy (originally scheduled for June 2020) can be analysed more closely. Table 10 presents an overview of all directly energy-related initiatives in the EGD. To come to a first conclusion, the European Green Deal Communication makes clear that much action is foreseen for the next few years in the areas of RE and most energy should be generated by renewable sources until 2050. In the long-term analysis of the European Commission evaluating different scenarios for GHG reductions of 80% to 100% by 2050, the RE covers up to 100% of the energy mix, with electricity representing 60% of all energy carriers.[221] In the following, the already adopted initiatives under the EGD will be analysed.

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[216] *The European Green Deal*, 4.
[217] Regulation EU/2018/1999
[218] European Commission, "National energy and climate plans (NECPs)".
[219] *The European Green Deal,* COM(2019) 640 final (Brussels, December 11, 2019), 6.
[220] *The European Green Deal,* COM(2019) 640 final (Brussels, December 11, 2019), 2.
[221] *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy* (Brussels, November 28, 2018), 72–73.

Energy related initiatives of the EGD as announced in December 2019 (some names changed meanwhile)
Assessment of the final National Energy and Climate Plans
Strategy for smart sector integration
'Renovation wave' initiative for the building sector
Evaluation and review of the Trans-European Network – Energy Regulation
Strategy on offshore wind
Initiatives to stimulate lead markets for climate neutral and circular products in energy intensive industrial sectors
Proposal to support zero carbon steel-making processes
Legislation on batteries in support of the Strategic Action Plan on Batteries and the circular economy
Strategy for sustainable and smart mobility
Funding call to support the deployment of public recharging and refuelling points as part of alternative fuel infrastructure
Assessment of legislative options to boost the production and supply of sustainable alternative fuels for the different transport modes
Revised proposal for a Directive on Combined Transport
Review of the Alternative Fuels Infrastructure Directive and the Trans European Network – Transport Regulation
Initiatives to increase and better manage the capacity of railways and inland waterways
Proposal for more stringent air pollutant emissions standards for combustion-engine vehicles

Table 10: energy-related initiatives of the EGD

4.4.1 The European Green Deal Investment Plan

The European Green Deal Investment Plan is a document dating from January 2020 that outlines how EU funding should support the achievement of the necessary investment for the implementation of the EGD initiatives. It was adopted shortly after the publication of the EGD-Communication and can be regarded as a supporting document. Still, the EGD Investment Plan is in some points already outdated, since the recovery measures for the Covid-19 crisis and the conclusions of the last European Council propose and decided upon increased amounts of investment.[222] Nevertheless, in the following paragraphs the most important points, especially with respect to the energy transition should be presented.

The EGD Investment Plan states that during the next decade (2020-2030) more than a trillion Euros of private and public investment should be mobilised for sustainability.[223] This is done by some

[222] *Special Meeting of the European Council - Conclusions*, EUCO 10/20 (Brussels, July 21, 2020).
[223] *Sustainable Europe Investment Plan European Green Deal Investment Plan,* COM(2020) 21 final (Brussels, January 14, 2020), 1.

advanced financial mechanisms, where MS can apply for funding of the European Commission, but need to contribute specific shares of national funding (e.g. under the InvestEU programme).

A quarter of the EU long-term budget (which is always decided for a 7-years period) will be dedicated to climate-related purposes. In a first draft of the budget for the period from 2021 to 2027, a total budget of 1 279 billion Euros was proposed. A quarter of this would already constitute 319 billion Euros. On the ten years interval an amount of 503 billion Euros is estimated. Further investment of 280 billion Euros should be motivated by the InvestEU programme, which combines EU funding with MS' funding and blending of loans or equities with grants. The national co-financing under the European sustainable and investment funds should leverage further 114 billion Euros, and the Innovation and Modernisation Fund should contribute about 25 billion Euros. The two latter funds are not part of the EU budget as such and thus count as separate.[224] Both funds are financed by the allowances of the ETS. In total, it is expected that 922 billion Euros would be invested over the 10-years period.

Furthermore, the EIB should dedicate more and more of their financing activities to climate purposes. By 2025, 50% of its financing actions should promote environmental sustainability and climate action (the current share being about 30%).[225] This would leverage another 600 billion Euros over the 10-years period according to the EGD investment plan. This can be explained by the fact, that the EIB does not entirely finance projects (usually up to 50% of the investment costs), but can motivate further investment into a project thanks to the EIB's good reputation and high standards.[226]

Apart from this concrete investment targets, the EGD investment plan announces a shift in the financial system, which should facilitate private investment into projects that respect environmental and sustainability targets. The plan makes reference to the taxonomy regulation[227], which was recently adopted by the European Council and the European Parliament. It is no initiative under the EGD, but it fully supports the targets of the EGD, since it established criteria for sustainable investment. The EGD Investment Plan refers also to the Sustainable Finance Strategy that is foreseen under the EGD and will be adopted later in 2020.[228] A great number of other initiatives are named in the EGD Investment Plan, that all aim at integrating sustainability and climate concerns closer into the financial system. This is an important step to create favourable market conditions for RE as mentioned by one interviewee (DG Research and Innovation). This person says that one of the most important contributions of the EGD is to set a financial environment that motivates private investment for sustainability. The same person emphasized that the mobilising of so much public money is also an

[224] *Sustainable Europe Investment Plan European Green Deal Investment Plan*, 6.
[225] *Sustainable Europe Investment Plan European Green Deal Investment Plan*, 9.
[226] Stanic, "Policy Assessment and Evaluation of Energy projects".
[227] Regulation (EU) 2020/852
[228] *Sustainable Europe Investment Plan European Green Deal Investment Plan,* COM(2020) 21 final (Brussels, January 14, 2020), 10.

important signal for investors. The EGD Investment Plan and its consequent actions seems thus to be a crucial step to address the challenge of **setting the right incentives to investors**. Since investments into the energy transition are generally considered respecting climate and sustainability principles, the EGD Investment Plan will most likely motivate more investment into the energy transition.

4.4.2 The climate law

The **climate law** can be considered the most important initiative under the EGD, because its sets the basis for all reinforced or new legislation and all other actions. The EU objective is to be climate neutral in 2050 in its total, however different MS can balance each other's differences, so that not every MS needs to be climate neutral in itself, if others decrease the amount of GHG present in the atmosphere (e.g. through carbon capture and storage). However, the climate law enshrines the climate neutrality objective into European legislation and make it obligatory.[229] Already before the Commission's proposal of 4 March 2020[230], there was a strong political commitment to the climate-neutrality target. The Paris agreement set this target for the EU, the European Parliament had already adopted a resolution expressing its support for this target[231] and the European Council had enshrined the target into its conclusions in December 2019.[232]

The law fulfils two functions: it gives a strong political signal for climate negotiations, and it gives a strategic signal to industry and investors in setting a clear objective. This can enhance the investment into transition projects and make the financing of carbon-intensive projects unattractive. The climate law represents consequently an important step to address the challenge of **creating market conditions in favour for RE**.

The climate law will also incorporate the increased climate targets for 2030, as soon as it is adopted. It will be then up to the Commission to propose a trajectory for the periods between 2030 and 2050, based on an analysis of possible scenarios. The climate law was one of the first proposals of the new Commission under the EGD and was part of its very ambitious work program during the first 100 days. The climate law is now discussed in the European Parliament and in the Council and an adoption in both institutions is planned before the end of 2020, which is also a signal of its importance. With respect to the named challenges, it is an important **signal for investors** and can be regarded as part of the solution to create a favourable environment for the investment into RE.

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[229] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law)*, COM(2020) 80 final (March 4, 2020).
[230] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law)*.
[231] European Parliament, "The European Parliament declares climate emergency".
[232] *European Council Meeting - conclusions*, EUCO 29/19 (Brussels, December 12, 2019).

4.4.3 The Circular Economy Action Plan and the Industrial Strategy

The **Circular Economy Action Plan (CEAP)** and the Industrial Strategy were both adopted in March 2020 and propose strategies to foster a more circular economy and a more sustainable industry. According to a representative from DG Environment, who was much involved into the drafting of the CEAP, both initiatives go hand in hand whilst they address different target groups. The CEAP aims at accelerating the "transformational change required by the European Green Deal, while building on circular economy actions" through a set of actions.[233] The Industrial Strategy outlines the general context and addresses those stakeholders that adhere to the "old system". According to the same person, both initiatives are necessary and complement each other. The CEAP-Communication highlights the importance of decoupling resource use from economic growth to scale up circular economy and states that this transition to a "sustainable economic system is an indispensable part of the new EU industrial strategy".[234] The CEAP constitutes an instrument-mix, with the objective of accelerating progress towards a more circular economic system and it provides an agenda of instruments/initiatives in the action plan in its Annex.

The CEAP is not directly referring to RE, but to energy efficiency and raw materials. One core initiative under the CEAP is for example a review and extension of the Ecodesign Directive[235], which already regulates energy efficiency aspects and should, in the future, address more product groups and circularity aspects.[236] A more circular economy might offer solutions for the challenges of a **sufficient supply in critical raw materials**. The Communication states that measures will be put in place to ensure "that the EU has a well-functioning internal market for high quality secondary raw materials".[237] As measures for this purpose, the Communication proposes standardisation, "EU-wide end-of-waste criteria for certain waste streams", a "market observatory for key secondary materials", and restrictions on the use of substances in high quantities are introduced.[238] These or similar actions are also announced in the annex action plan.[239] Furthermore, a new regulatory framework for batteries is announced, "taking account of, for instance, the carbon footprint of battery manufacturing, ethical sourcing of raw materials and security of supply, and facilitating reuse, repurposing and recycling".[240] Finally, a regulatory framework for the certification of carbon removals should be proposed in 2023. This can be relevant for carbon removal technologies which offer also solutions for renewable fuels.

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[233] *A new Circular Economy Action Plan For a cleaner and more competitive Europe,* COM(2020) 98 final (Brussels, March 11, 2020), 3.
[234] *A new Circular Economy Action Plan For a cleaner and more competitive Europe*, 2.
[235] Directive 2009/125/EC
[236] *A new Circular Economy Action Plan For a cleaner and more competitive Europe*, 4.
[237] *A new Circular Economy Action Plan For a cleaner and more competitive Europe*, 3.
[238] *A new Circular Economy Action Plan For a cleaner and more competitive Europe*, 14.
[239] *A new Circular Economy Action Plan For a cleaner and more competitive Europe - Annex,* COM(2020) 98 final Annex (Brussels, March 11, 2020).
[240] *A new Circular Economy Action Plan For a cleaner and more competitive Europe,* COM(2020) 98 final (Brussels, March 11, 2020), 8.

There is no direct reference made to *critical* raw materials. According to the representative of DG Environment, the CEAP *does* respond to the challenge of critical raw materials, also in the context of RE. The flow of materials will be monitored, and thanks to actions taken under the CEAP, the need for the import of critical raw materials will decrease. The quality and the quantity need to be monitored, which is already done through the coding of waste[241] and a regular publication of a list of critical raw materials.[242] The CEAP seems thus to encourage actions towards a **more circular use of (critical) raw materials**.

The I**ndustrial Strategy** touches upon a few topics with reference to RE and also alludes to critical raw materials. The Industrial Strategy emphasizes the importance of European industry to contribute to climate neutrality and digitalisation. It also stresses the European social economy and the high environmental standards applied in the EU. In order to contribute to the climate-neutrality target, European industry is called to decarbonise with a special focus on energy-intensive sectors. The Communication states: "to become more competitive as it becomes greener and more circular, industry will need a secure supply of clean and affordable energy and raw materials". Therefore, investment into research, innovation, deployment and infrastructure is necessary and will create jobs.[243] The EU should develop "lead markets in clean technologies" and become a global frontrunner in this field. The Communication supports moreover a "more strategic approach to renewable energy industries", which makes investment into low-carbon generation technologies, capacity and infrastructure necessary.

A number of actions are listed as core initiatives:

- a strategy on clean steel, the support for the development of carbon-free products by the innovation fund,
- a strategy for smart sector integration, a vision on clean hydrogen with the creating of a Clean Hydrogen Alliance,
- the strategy for sustainable and smart mobility,
- the offshore wind strategy,
- the review of the Trans-European Network for energy regulation, and a common European Energy data space.[244]

Most of these initiatives mirror the original EGD-Communication. The Industrial Strategy makes however clear that the energy transition will be one of the main drivers for economic growth and job creating and should be supported on all levels. Innovation in relevant industries should be also supported by European investment programmes (such as Horizon Europe) and an industrial

[241] Eurostat, "Circular economy indicators".
[242] *the 2017 list of Critical Raw Materials for the EU,* COM/2017/0490 final (Brussels, September 13, 2017).
[243] *A New Industrial Strategy for Europe,* COM(2020) 102 final (Brussels, March 10, 2020), 3.
[244] *A New Industrial Strategy for Europe,* 8–9.

renovation strategy.[245] Hence, the strategy supports **investment into the RE sector** and can be regarded partly as a reply to this challenge.

A further point named in the strategy is the necessary "re-skilling" or "up-skilling" of workforce in carbon-intense industries. The European Commission proposes support to a "skills agenda for Europe", a "European pact for skills", and a "Communication on a European Education Area Strategic Framework".[246] Action in this area can be considered as an important reply to the challenge of **social acceptance and inertia of people** that have the most to lose, especially when working in carbon-intense industry. Action for upskilling and reskilling the most affected workforce is thus crucial to respond to this challenge.

Finally, the Industrial Strategy makes reference to raw materials and **critical raw materials**. It states that the demand for raw materials is projected to double by 2050 and that critical raw materials are "crucial for markets such as e-mobility, batteries, renewable energies, pharmaceuticals, aerospace, defence and digital applications".[247] As a consequence, the European Commission should present an "Action Plan on Critical Raw Materials, including efforts to broaden international partnerships on access to raw materials". Hence, the European Commission acknowledges the issue with critical raw materials and plans to undertake action in this area in the future.

In total, the Industrial Strategy stresses the role of the energy transition as an opportunity for the European economy and a trigger for growth; it also addresses part of the challenges of **social acceptance and inertia of people** identified through webinars. Finally, it also acknowledges that action needs to be taken in the area of **critical raw materials** and it offers **streams of investments**.

4.4.4 The Just Transition Mechanism

The **Just Transition Mechanism** is a financial tool that is supposed to support the regions in Europe "most affected by the transition towards climate neutrality and avoid regional disparities growing".[248] A first proposal for this tool was made by the European Commission in January 2020, an updated version was adopted in the end of May 2020 in the context of the recovery package form the Covid-19 crisis. The Just Transition Mechanism consists of three pillars, the first being the most important one, namely the "**Just Transition Fund**". The investments under the Just Transition Fund should alleviate social and economic cost caused by the green transition in specifically affected regions, e.g. places with strong coal and lignite mining or the production of peat and oil shale. All MS can receive money from the fund on the basis of territorial just transition plans developed by

[245] *A New Industrial Strategy for Europe*, 11.
[246] *A New Industrial Strategy for Europe*, 12.
[247] *A New Industrial Strategy for Europe*, 14.
[248] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the Just Transition Fund*, COM(2020) 22 final (Brussels, January 14, 2020), 2.

MS and approved by the European Commission.[249] The Just Transition Fund itself also consists of three parts: direct commitments of the European Commission's budget, co-financing by MS, and a transfer of budget form European Structural and Investment Funds (ERDF and ESF+) to the Just Transition Fund. In the first proposal of January, the European Commission's commitment for the next seven years (2021 – 2027) amounted to 7.5 billion Euros.[250] The total financial volume of the fund was announced to be 100 billion in January.[251] In the updated proposal of May, the European Commission's commitment is increased to 11.3 billion Euros. The total financial volume of the fund is increased to 135.6 billion Euros with the help of the European recovery instrument "Next Generation EU".[252] In the European Council conclusions the Commission's commitment for the Just Transition Fund was amounted to 10 billion Euros.[253]

The second pillar of the Just Transition Mechanism is a scheme under the investment programme of the EU "**InvestEU**". This means that a specific amount of EU budget is reserved for financial guarantees that facilitate investment into energy and transport infrastructure decarbonisation projects, economic diversification of the regions and social infrastructure. In the first proposal, 45 billion Euros should be mobilised. In the context of the recovery this amount will be increased. The Commission's budgetary commitments increase from 1.8 billion to 12 billion Euros.

The third pillar of the Just Transition Mechanism is the creation of a **Public Sector Loan Facility**, which will combine commitments of the EU budget and the EIB, in order to support public investments for the named purposes through favourable lending conditions.[254] The estimated investment triggered is estimated to be between 25 and 30 billion Euros.[255] The Just Transition Mechanism combines various financial EU instruments and will mobilise much money for energy infrastructure. Funding needs to comply with specific purposes, one being "investments in the deployment of technology and infrastructures for affordable clean energy, in

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[249] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the Just Transition Fund*, 3.
[250] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the Just Transition Fund*, 8.
[251] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the Just Transition Fund*, 2.
[252] *Amended proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the Just Transition Fund*, COM(2020) 460 final (Brussels, May 28, 2020), 1.
[253] *Special Meeting of the European Council - Conclusions*, EUCO 10/20 (Brussels, July 21, 2020), 66.
[254] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the public sector loan facility under the Just Transition Mechanism*, COM(2020) 453 final (Brussels, May 28, 2020), 2.
[255] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the public sector loan facility under the Just Transition Mechanism*, 2.

greenhouse gas emission reduction, energy efficiency and renewable energy".[256] Investment into fossil fuel related energy services or nuclear energy are specifically excluded from funding under the Just Transition Fund.[257] Investments under all three pillars of the Just Transition Fund need to favour the green transition. The Just Transition Mechanism thus constitutes an initiative which mobilises huge amounts of EU budget and MS budget for investments into the energy transition and it is an important instrument to reduce social resistance against the transition and the inertia of people, since regions suffering the most from the energy transition are targeted. The Just Transition Mechanism proposes answers to three identified challenges for RE**: inertia of people, social acceptance and the cost of transition**.

4.4.5 The Energy System Integration Strategy and the Hydrogen Strategy

The Energy System Integration Strategy[258] and the hydrogen strategy[259] are the main initiatives under the EGD in the area of RE that have already been adopted. The Energy System Integration Strategy had been announced as "smart sector integration strategy", but the final title had been changed to "Energy System Integration Strategy", since this reflects better what should be achieved by the strategy according to the Director-General of DG Energy.[260] The hydrogen strategy was not announced under the EGD, because it was considered a part of the Energy System Integration Strategy. In March 2020, the head of cabinet of the Vice-President Timmermans still said the Energy System Integration Strategy would mainly be a hydrogen strategy.[261] According to a representative of DG Energy, during the drafting process of the strategy, it became clear that there are so many aspects on hydrogen that the European Commission decided to adopt two separate strategies, one on energy system integration and one specifically on hydrogen. Both strategies are closely interlinked and will be analysed in the following paragraphs.

The **Energy System Integration Strategy** stresses the importance of due action in order to foster energy system integration, to achieve the climate target of 2050 and also the necessary investment to recover from the economic crisis caused by the Covid-19 pandemic. The strategy describes itself as "vision on how to accelerate the transition towards a more integrated energy system" with concrete policy and legislative proposals on a European level.[262] The strategy highlights

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[256] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the Just Transition Fund*, COM(2020) 22 final (Brussels, January 14, 2020), 14.
[257] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the Just Transition Fund*, 15.
[258] Communication COM(2020) 299 final
[259] Communication COM(2020) 301 final
[260] Juul Jørgensen, "The european green deal in the context of post covid-19 recovery: implications for eu energy policy".
[261] Diederik Samsom, "European Green Deal: Discussion with Diederik Samsom, 24.03.2020".
[262] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, COM(2020) 299 final (Brussels, July 8, 2020), 2.

three concepts as principles for the transformation of the energy system. The energy system should become as "circular" as possible, which means that high degrees of energy efficiency and the reuse of waste heat or the production of biogas from bio-waste and waste water will ensure the least "loss" possible of energy. Secondly, end-use sectors should be electrified (heat pumps, electric vehicle, electrified low-temperature industrial processes). Thirdly, renewable and low-carbon fuels should be used for processes, where a high energy density of the fuel is necessary, like aviation and shipping or high-temperature industrial processes. Renewable hydrogen and the Hydrogen Strategy play an important role in this sector.[263]

According to the strategy the energy system integration will reduce GHG emissions, will reduce air pollution, will motivate a reduced energy water footprint, will increase competitiveness of the European economy, the energy system will become more flexible and a boost of storage technologies will be achieved. This is substantiated by the examples of home batteries, electric vehicles and pumped hydro-power. Furthermore, electrified end-use appliances can react to real time electricity prices and charge when the electricity prices is low, which would also reinforce the grid stability (if the price is low, this means there is high load). In peak electricity situations, electrolysers can transform the electricity into hydrogen, which can serve as seasonal storage. A closer connection of the gas and the electricity networks would be the consequence. These points are consistent with the advantages of sector integration outlined in literature. The Communication also stresses the reinforced role of consumers and the increased resilience and energy security through a decentralised energy production. In order to motivate the described transformation in the energy system, a number of actions are described and initiated through the strategy.

Many announced initiatives **echo the EGD-Communication**, although they are put into context in the Energy System Integration Strategy. The review of the Trans-European Network for Energy Regulation (TEN-E)[264] and the Energy Efficiency Directive[265] (June 2021) should help to better apply the energy efficiency first principle in the EU. The Offshore Wind Strategy and the review of the Renewable Energies Directive (RED II) [266] should help to up-scale the production of renewable electricity, which is necessary to keep electricity prices low. The review of the RED II should subsequently accelerate the electrification of end-use sectors. The Renovation Wave strategy will also play an important role for the electrification of heating and cooling appliances.[267] To accelerate the integration of electric vehicle and electric vehicle infrastructure in the EU transport system, the objective of 1 million charging points by 2025 is repeated and the review of the Trans-

[263] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 3.
[264] (EU) 347/2013
[265] 2012/27/EU
[266] 2018/2001/EU
[267] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 10.

European Network for Transport[268] and TEN-E Regulation are alluded. A revision of the Alternative Fuels Infrastructure Directive[269] is also announced under the EGD, which is repeated in the Energy System Integration Strategy.[270] The revision of the RED II will also support the development of low carbon and renewable fuels together with an assessment of legislative options to foster alternative fuels for shipping and aviation. The revision of the Energy Taxation Directive[271] and the ETS[272] are named in order to levelise the taxes and levies of different energy carriers and eliminate barriers for the increase in RE. A number of actions announced thus are a repetition of initiatives already proclaimed in the EGD-Communication. The Communication also proposes a number of new actions.

The Communication identifies a number of challenges for energy system integration, which overlap with the challenges identified earlier in this thesis. The following overview will present challenges identified for RE and sector integration through a literature review, interviews and webinars are addressed in the energy system integration strategy.

Increased energy efficiency is said to decrease the overall **land use, the water use and the biodiversity** loss related to the RE sector. These three challenges are thus recognised, although the "solution" is rather limited, with respect to the fact that general renewable electricity consumption is estimated to increase by 50% in 2050. If this demand will be covered through domestic production, much new generation capacities and transmission infrastructure will be necessary, which raises new questions of land use, water use and harmful effects on biodiversity.[273]

The Communication also states the necessity of "large amounts" of raw materials and **critical raw materials** for the technologies necessary for energy system integration. The reply to this issue by the Communication is however:

> "replacing imported natural gas and petroleum products with locally produced renewable electricity, gases and liquids, combined with the greater implementation of circular models, will first and foremost reduce the import bill and lessen dependency on external fossil fuel supplies, creating a more resilient European economy".[274]

The challenge is thus recognised but not tackled as such. Although the energy system integration might reduce dependency from energy imports, the dependence on imports of critical raw materials is likely to increase. According to a member of DG Energy, who was part of the drafting process of the Energy System Integration Strategy, the European Commission is aware of the issue of critical raw materials supply, but currently combatting climate change is prioritized. Furthermore,

[268] Regulation (EU) No 1315/2013
[269] Directive 2014/94/EU
[270] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 11.
[271] Directive 2003/96/EC
[272] Directive (EU) 2018/410
[273] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 5–7.
[274] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 4.

experts on the topic within the Commission seem to think that there will not be an issue thanks to technology development and circular materials use. The energy system integration strategy does not propose a solution, though the challenge is acknowledged.

The Energy System Integration Strategy makes one direct reference to **energy poverty**, in saying that no one must be left behind and energy poverty must be avoided. If heating and transport are increasingly electrified and run by domestically produced RE, current energy imports can be reduced. It seems to be a premise of the Communication that a shift towards more RES must not endanger energy security.

The need for **investment into RE** and its infrastructure is also recognised by the Communication. The EU recovery instrument of the Covid-19 crisis "Next Generation EU" is named as supportive financial instrument and an EU renewable energy financing mechanism might channel EU funding into RE.[275] With respect to more specific actions, other financing opportunities through EU funds are named. A representative of DG Energy, working on the innovation part of the strategy said that the strategy would support innovation. There will be funding for pilot projects and the EU programme "Horizon Europe". This thus seems to offer part of a solution for **necessary investment**, **high costs** and **creating optimal market conditions for investors**.

According to the Communication, the **electrification of end-use sectors** needs to be tackled per sector. The review of the RED II (June 2021) with increased sectoral standards can generally foster motivation for more electrification. In the transport sector the review of CO_2 standards for vehicles, the review of the Alternative Fuel Infrastructure Directive[276], the smart and sustainable mobility strategy planned under the EGD, and the review of the Clean Vehicles Directive[277] will constitute important steps to foster electrification. In the building sector, the renovation wave is named as main initiative to support electrification of heating, besides its objective to increase energy efficiency of buildings.[278] Details on the renovation wave are presented later in this thesis. Electrification of end-use sectors plays a very important role in the energy system integration strategy; this challenge is thus clearly and thoroughly addressed.

The Communication mentions "Regional Coordination Centres", in order to tackle challenges of grid management with increasing electrification. The centres will ensure regional cross-border coordination between MS, common infrastructure planning, and the deployment of storage and other flexibility options. This can be regarded as an approach to address the challenge **for peak loads** through a form of **"congestion management**", and the challenge of **coordinating national support schemes**.

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[275] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 7–8.
[276] Directive 2014/94/EU
[277] Directive (EU) 2019/1161 on the promotion of clean and energy-efficient road transport vehicles
[278] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 8.

The Communication states that an approach to motivate an **uptake in energy storage** lies in the complete implementation of the Clean Energy Package and a review of the TEN-E Regulation.[279] Since energy system integration is expected to decrease the necessity for energy storage in long-term and the initiative wants to increase storage capacities in short-term, the challenge of energy storage due to intermittent RE is clearly addressed.

The Communication also aims to **increase the renewable electricity supply** through the Offshore Wind Strategy, the review of the RED II and financial support through EU funding programmes (LIFE). This increase is necessary to keep electricity prices competitive while the demand will rise, due to electrification and the large-scale use of electrolysers for renewable hydrogen. The challenge of electricity prices is thus at least partly addressed.

The strategy makes reference to the development of a carbon removal certification mechanism, which was announced under the CEAP and announces a European system of certification for GHG savings for renewable and low-carbon fuels. Both initiatives can enhance **carbon pricing and foster low-carbon and renewable fuels.**[280] Additionally, renewable and low-carbon technologies should be promoted through a number of actions: the review of the RED II, the proposition of a comprehensive terminology for all renewable and low-carbon fuels and the financing of flagship projects under EU financing programmes (LIFE, Horizon Europe, InvestEU).[281] There is thus also a clear support for the further development of low-carbon and renewable fuels.

The Communication clearly recognises that current energy taxes and levies deter the market and do not reflect sufficiently environmental costs and carbon emissions. In order to tackle these issues, a number of actions are (re-)announced. The revision of the Energy Taxation Directive should ensure the harmonisation of electricity gas and oil taxation, as well as eliminate double taxation. A guidance to MS should enhance the consistency of non-energy price components across energy carriers; the review of the European ETS might extend the scheme to new sectors, namely aviation and maritime transport; direct fossil fuel subsidies should be out-phased; and a revision of the state aid framework should ensure consequent decarbonisation though public support.[282] These steps address thus the challenges of **double charging** of energy and the fact that **synthetic gas is currently uncompetitive with biogas**, due to the energy taxation and levies. A well-set carbon price will also **shift investment towards low-carbon technologies**.

The Communication also identifies the need for a **coupled planning of the gas and the electricity network**. First steps in this direction seem to have started, but future progress should be ensured by the revision of the scope and governance of the 10-Year Network Development Plans (for

[279] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 9.
[280] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 14.
[281] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 14.
[282] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 17.

electricity and gas) and the review of the TEN-E Regulation.[283] The planning of hydrogen infrastructure should be integrated into this planning process.[284] This challenge is thus identified and addressed.

Finally, the Communication sees the need for more **research and innovation** in many aspects of the energy system. The Communication recognises the need to place "lower maturity technologies" on the market, which acknowledges the need to **speed up the process between technology development and technology deployment**.[285] In order to respond to this challenge, the Communication proposes investment through EU funding programs and it announces an "impact-oriented clean energy research and innovation outlook", which will ensure that research and development is favouring the energy integration.[286]

This overview demonstrates that the Energy System Integration Strategy indeed proposes actions to address many of the identified challenges. In other areas, the strategy acknowledges the challenge, but does not yet propose a solution. The Communication realises for example "lengthy permitting" processes as administrative barriers for more RE.[287] The adaptation of the electricity market is mentioned and the Communication states that flexible electricity prices can help to balance consumption and load. Still, no action is proposed for that target.

One challenge for sector integration is not mentioned, namely the phasing-out of net-metering. This might, however, be addressed in the review of energy taxation and levies. In total the strategy seems to propose a good framework and first vision for energy system integration in Europe, which recognises almost all identified challenges for sector integration and addresses the majority of them. The energy system integration also responds to the general challenges for RE, namely the flexible energy systems, necessary storage capacities, the cost and energy prices and the necessary upscale in deployment of mature technology.

The **hydrogen strategy** is much more specific than the Energy System Integration Strategy, and aims at building a "dynamic hydrogen ecosystem in Europe".[288] The strategy emphasises the role of hydrogen as vector for energy storage, as feedstock for industry, as fuel for different purposes and as energy carrier without emitting CO_2 or polluting the environment. Clean hydrogen (produced from electrolysis of water with RE) will thus have a crucial role in the energy transition. Currently, less than 2% of the European energy mix is covered by hydrogen, which is moreover based on fossil fuels ("grey hydrogen"). By 2050, the hydrogen's share in Europe's energy mix is projected to be 13-14%,

[283] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 18.
[284] *A hydrogen strategy for a climate-neutral Europe*, COM(2020) 301 final (Brussels, July 8, 2020), 15.
[285] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, COM(2020) 299 final (Brussels, July 8, 2020), 19.
[286] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 19–20.
[287] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 7.
[288] *A hydrogen strategy for a climate-neutral Europe*, COM(2020) 301 final (Brussels, July 8, 2020), 3.

ideally clean hydrogen.[289] As intermediate step, the EU formulated the objective to install 40GW of electrolysers within the EU (6GW should be installed already by 2024) and 40GW of electrolysers in neighbouring countries with export to the EU by 2030. Decreasing electricity prices in recent years and increased interest by MS and industry should foster this development. The hydrogen strategy acknowledges that a number of challenges for this development and tackles prevailing barriers. In the following paragraph will be analysed, whether the hydrogen strategy offers replies to the former identified challenges specifically for hydrogen.

The strategy acknowledges that currently **renewable hydrogen is not cost-competitive** with fossil-based hydrogen and fossil-based hydrogen with consequent carbon capture and storage. The price for renewable hydrogen is estimated at 2.5-5.5 €/kg, fossil-based hydrogen at 1.5€/kg and fossil-based hydrogen with carbon capture and storage at 2€/kg. The strategy estimates however that renewable hydrogen will be cost-competitive with fossil-based hydrogen by 2030 due to an increase of electrolysers and decreased costs for electrolysis and renewable energies. A much higher carbon price would be also necessary.[290] In the first half of 2020, the carbon price under the ETS fluctuated between 20 and 25€ per tonne CO_2.[291] An analysis by the European Commission says that the carbon price will rise to 350€ per tonne CO_2 in 2050, if the climate neutrality target will be reached.[292] This is thus a significant increase, which cannot be achieved without the out-phasing of fossil-fuel subsidies. According to a staff member of DG Energy, renewable hydrogen will not become competitive under current carbon prices. Then, much management would be necessary and in the end the tax payer would pay for the costs. The hydrogen strategy thus addresses the challenge of not yet competitive renewable hydrogen, but it assumes that the general developments will cause such a rise in the carbon price, so that renewable hydrogen will be competitive in 2030. This however depends on a number of factors that cannot be addressed by one single strategy.

The strategy also addresses the challenge of **infrastructure for hydrogen**. On the one hand, the strategy emphasises that hydrogen should be produced decentralised close to the site where it is used. Then, large scale hydrogen infrastructure is not necessary in a first phase. Furthermore, hydrogen can be blended with natural gas in small amounts and can thus be transported in the gas network.[293] This option should however be avoided since the quality of gas changes and usage becomes less efficient.[294] Only at a later stage, the logistical distribution of hydrogen will be necessary. For that purpose, the existing gas network should be retro-fitted, so that only a limited new

[289] *A hydrogen strategy for a climate-neutral Europe*, 1.
[290] *A hydrogen strategy for a climate-neutral Europe*, 3–4.
[291] EMBER, "EUA Price".
[292] *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy* (Brussels, November 28, 2018), 210.
[293] *A hydrogen strategy for a climate-neutral Europe*, COM(2020) 301 final (Brussels, July 8, 2020), 5–6.
[294] *A hydrogen strategy for a climate-neutral Europe*, 16.

infrastructure for hydrogen needs to be constructed.[295] Guidance for these steps will be given by the review of the TEN-E Regulation and the review of the internal gas market legislation for competitive decarbonised gas markets.[296] The planning of a hydrogen infrastructure should start soon and be combined with the Ten-Year Network Development Plans for Energy and Transport. The revision of the Alternative Fuels Infrastructure Directive should include plans for hydrogen refuelling stations. The challenge of a hydrogen infrastructure is thus clearly addressed by the strategy.

Closely interlinked with the question of hydrogen infrastructure is the question of **hydrogen storage**. According to the strategy, in the second or third phase of the development of hydrogen, large-scale hydrogen storage facilities will be necessary.[297] Investment into hydrogen storage, hydrogen production, hydrogen transmission and hydrogen distribution is enabled by a Clean Hydrogen Partnership. Apart from that, no concrete action in this area is mentioned. Although the Communication states that hydrogen can provide seasonal storage of energy in salt caverns, no approach is outlined, how this possibility should be further explored or established. Still it can be expected that huge amounts will need to be stored to balance seasonal differences in RE production. The challenge of hydrogen storage facilities is thus addressed to a limited extend.

The missing **regulatory framework for hydrogen** and other power-to-X technologies is probably one of the main motivations for the hydrogen strategy. An enabling regulatory framework is identified as challenge by the strategy, which is also important for creating new lead markets of renewable hydrogen.[298] The strategy announces that the European Commission will swiftly propose EU-wide instruments for a policy framework of renewable hydrogen. Part of this will be the introduction of a low-carbon standard for renewable hydrogen production facilities that reflects GHG emission over the whole life-cycle. Furthermore, European-wide criteria for the certification of renewable and low-carbon hydrogen (with carbon capture and storage) will be introduced. This can be realised in the context of the revision of the RED II and the revision of the European ETS.[299] This will guarantee the most cost-effective production and ease European trading with renewable hydrogen. A framework of market rules for renewable hydrogen will be also developed on the context of the revision of the Trans-European Networks for Energy and the review of the internal gas market legislation for competitive decarbonised gas markets. The challenge of a missing regulatory framework for hydrogen is thus addressed through a future certification system of clean hydrogen, standards for renewable hydrogen production plants and the foreseen market rules.

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[295] *A hydrogen strategy for a climate-neutral Europe*, 7.
[296] Review of Directive 2009/73/EC concerning common rules for the internal market in natural gas and Regulation (EC) 715/2009 on conditions for access to the natural gas transmission networks.
[297] *A hydrogen strategy for a climate-neutral Europe*, 7.
[298] *A hydrogen strategy for a climate-neutral Europe*, 2.
[299] *A hydrogen strategy for a climate-neutral Europe*, 12.

The **up-scale of electrolysers** is also an important challenge addressed by the hydrogen strategy. The respective targets for the scale-up of electrolysers have already been outlined. Decreased production costs of renewable hydrogen are the main tool to increase demand. In the first phase this can only be achieved by much investment, which will be outlined in the next paragraph. To boost the demand in industry and transport for renewable hydrogen, funding of flagship projects (Horizon Europe) and increased emission standards play an important role.[300] Hydrogen in transport will be covered by the upcoming sustainable and smart mobility strategy. The common standard or threshold for GHG emissions in the whole lifecycle of electrolyser installations and the certification system of renewable hydrogen aim at increasing the attractiveness of renewable hydrogen and thus boost the demand. This is closely interlinked with a consumers' conscience and increasing carbon price. The carbon price is supposed to increase further, thanks to the European ETS. The upcoming revision of the ETS might include incentives for renewable hydrogen. The challenge of up-scaling the production of renewable hydrogen, is thus addressed by multiple actions announced in the hydrogen strategy. Further support is challenged through investment.

The hydrogen strategy states to be part of the recovery measures form the Covid-19 crisis and much investment will also be channelled to the development of hydrogen and smart sector integration under the recovery instrument "Next Generation EU". One action, to promote **investment** into renewable hydrogen is the establishment of a European Clean Hydrogen Alliance, which unites public authorities, industry and civil society and should help to develop an investment agenda and facilitate cooperation between stakeholders.[301] Available funding will come from different EU programmes (InvestEU, Innovation Fund, Just Transition Fund) and was increased by the recovery package. In total, the hydrogen strategy estimates a necessary investment into renewable hydrogen in Europe of 180-470 billion Euros by 2050.[302] It is difficult to estimate whether such amounts will be mobilised, but at least much investment is announced by the strategy. Other initiatives under the EGD will also motivate investment into the energy transition.

The last challenge which had been identified for sector integration by a literature review is the **coordination of all users of the chain, namely infrastructure developers, technology and research providers, hydrogen producers and end-use consumers**. Initiative in this direction is also provided through the European Clean Hydrogen Alliance, which pursues exactly the target to connect all stakeholders of the supply chain. This challenge is thus also addressed by the hydrogen strategy.

Furthermore, the strategy wants to motivate much **research and development** in the hydrogen field. Pilot projects will be funded by different EU programs and carbon intensive regions will be supported in the decarbonisation, which can also be achieved through the use of renewable

[300] *A hydrogen strategy for a climate-neutral Europe*, 10.
[301] *A hydrogen strategy for a climate-neutral Europe*, 3.
[302] *A hydrogen strategy for a climate-neutral Europe*, 2.

hydrogen.[303] In total, the hydrogen strategy seems to deliver a well-developed vision for renewable hydrogen in Europe that addresses almost all identified challenges for hydrogen. Only storage possibilities are addressed in a limited way, but possibly this is also due to the fact that the hydrogen production needs to be massively up-scaled before the question of storage becomes very relevant.

The hydrogen strategy mentions the issue of large amounts of **critical raw materials** that will be necessary for the related technologies. The hydrogen strategy refers to the Critical Raw Material Action Plan that should be developed under the CEAP and its implementation. The issue of critical raw materials is thus addressed and for a solution another EGD-initiative is mentioned.

Both the hydrogen strategy and the energy system integration strategy are part of the measures that are proposed by the European Commission for the recovery from the Covis-19-crisis. Increased action and investment in both areas can thus be expected.

4.4.6 The recovery mechanism: "Next Generation EU" and the Council conclusions of the EU summit

The Covid-19 crisis represents a huge impact on the European society and economy (as on other parts of the world). In order to tackle the resulting economic crisis on a European level, the European Commission developed a recovery instrument, named "Next Generation EU", which was discussed with European heads of states during the last European Council (17th to 21st July). The European recovery instruments is important in the context of RE in Europe, because the EGD is the "growth strategy for Europe" according to the President of the Commission Ursula von der Leyen and Vice-President Frans Timmermans. Both stressed on many occasions that the EGD must not be forgotten in the Covid-19 crisis, but becomes even more important than before, since huge amount of investment will be mobilised to re-launch the economy, which will define the future of Europe. These aspects are also highlighted in the Communication announcing the recovery package: "The EU's recovery plan must guide and build a more sustainable, resilient and fairer Europe for the next generation" and it "will press fast-forward on the twin green and digital transitions".[304] Much money will thus be mobilised for the energy transition and digitalisation.

The recovery instrument represents an unprecedented novelty in EU politics, because for the first time, the EU will borrow money on the financial markets as a union, in order to support the MS in the recovery from the crisis. The recovery foresees an amount of 750 billion Euros that will be borrowed from the financial markets and an increase of the next EU-budget by 1 100 billion for the

[303] *A hydrogen strategy for a climate-neutral Europe*, 22–23.
[304] *Europe's moment: Repair and Prepare for the Next Generation*, COM(2020) 456 final (Brussels, May 27, 2020), 2.

period from 2021 to 2027.[305] Both parts of the recovery instrument will thus mobilise 1 850 billions of additional funding, which will be challenged through different financial EU instruments, so that democratic standards and accountability are ensured.[306] All public investments under the recovery should respect the principals of the EGD.[307] According to the President Ursula von der Leyen, it is very important that no investment will be invested against the EGD.[308] This should be guaranteed by guiding investment through the National Climate and Energy Plans and through the Just Transition Plans.[309] A number of programs that target the energy transition will be enforced by the additional funding. As already mentioned, the budget dedicated to the Just Transition Mechanism is increased. Furthermore, additional funding is assigned to InvestEU, which amongst other finances RE related investments. The scheme under InvestEU for sustainable infrastructure should be doubled.[310] In the Communication, a number of initiatives were named as being specifically important for the recovery, amongst them the renovation wave, the Hydrogen Strategy, the Energy System Integration Strategy, sustainable vehicles, alternative fuels, the financing of one million charging points for electric vehicles, and generally sustainable transport.[311]

On the whole, the European Council agreed to the idea of the recovery programme, including the novelty to borrow money on the financial market, although the distribution of the money was much reason for discussion. The Council conclusions also indicate the agreement of investment into the "green and digital transition". Investment should be conditioned to recovery and resilience plans drafted by MS that need to incorporate this criterion.[312] Moreover, climate action is further inscribed as a target for financing under all EU programmes: 30% of all expenditures made under the new EU-budget (2021-2027) and under the recovery should serve climate targets. This is thus an increase of 5%, with respect to the target that was inscribed into the EGD Investment Plan. Considering the tremendous amounts of money that will be mobilised to address the economic crisis and the increased climate target of 30%, the recovery should mobilise much investments into the energy transition and into RE. This will thus present another chance for RE and addresses the **challenge of costs**. Nevertheless, one must not omit that, at the current moment, all agreements are provisional and that the final adoption needs the consent of the European Parliament, and in the case of Multiannual Financial Framework[313], also ratification by all national parliaments. The inter-institutional adoption

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[305] *Europe's moment: Repair and Prepare for the Next Generation*, 4.
[306] *Europe's moment: Repair and Prepare for the Next Generation*, 4.
[307] *Europe's moment: Repair and Prepare for the Next Generation*, 6.
[308] Leyen, "Exchange of views with the German Trainees at the European Commission, 29.07.2020".
[309] *Europe's moment: Repair and Prepare for the Next Generation*, COM(2020) 456 final (Brussels, May 27, 2020), 6.
[310] *Europe's moment: Repair and Prepare for the Next Generation*, 7.
[311] *Europe's moment: Repair and Prepare for the Next Generation*, 7.
[312] *Special Meeting of the European Council - Conclusions*, EUCO 10/20 (Brussels, July 21, 2020), 6.
[313] The Multiannual financial framework is the long term budget of the EU always decided for a 7-years period. The decision for the budget for 2021- 2027 is in process.

is scheduled for December this year; only then will be clear how much money is likely to enhance the further integration of RE in the European energy system.[314]

4.4.7 Future relevant actions under the EGD

After all relevant and already adopted proposals by the European Commission have been discussed, a number of initiatives under the EGD that are still in preparation shall be presented with respect to the challenges identified for RE.

The **European Climate Pact** is one important initiative to address social acceptance towards the green transition. The initiative is scheduled for later this year and should create a societal movement, including businesses, public administration, youth, civil society, citizens, schools, academia and media, in order to raise awareness and motivate a behavioural change for climate action. Citizen-dialogues, voluntary pledges by enterprises or communities, and climate ambassadors are amongst the tools that should motivate the movement. Ideally, the climate pact wants to outreach to the general European public through a bottom-up approach.[315] Although, this is a difficult task, given that the European Commission is a centralised European institution, the Climate Pact is promising to increase public awareness for the urgency to combat climate change and thus to increase the public acceptance for RE. The initiative of the Climate Pact clearly demonstrates that the challenge of public acceptance is recognised by the European Commission and that targeted action is prepared. Whether the implementation of the pact can target all societal layers and will increase the **acceptance for RE** is a question that stays open at the current moment in time.

A number of energy-related initiatives have already been mentioned earlier. **A Renovation Wave Communication** will outline strategies and targets to speed up renovation for energy efficiency, with a special focus on social housing, schools, and hospitals. The reduced expenditures on energy can decrease energy poverty of affected societal layers and the saved money can be made available for public health and education. The renovation wave also wants to reinforce the use of heat pumps, solar thermal panels and photovoltaic panels. The consumer should be put into the centre and buildings could become the "petrol stations of the future". A reinforcement of the Energy Performance of Buildings Directive (EPBD)[316] might be also part of the strategy.[317] The exact content of the renovation wave will be developed after a "gap analysis" based on the national long term renovation strategies, which MS were demanded to send by March 2020 under the EPBD. The renovation wave will thus be important to **increase energy efficiency in buildings**, to increase the supply in **decentralised embedded RE, and to electrify end-use sectors**.

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[314] European Commission, "Factsheet: The EU Budget powering the recovery plan for Europe," 5.
[315] *The European Green Deal,* COM(2019) 640 final (Brussels, December 11, 2019), 22.
[316] Directive 2010/31/EU
[317] *The European Green Deal,* 9.

Another energy related strategy scheduled for this year is the **Offshore Wind Strategy**. The objective of the strategy will be to scale-up offshore wind energy in Europe from the current 20 GW to about 240-440 GW in 2050. According to a member of DG Energy working on the strategy, the offshore wind strategy will create massive potential for economic growth all over Europe, since new value chains will be created. Questions of land use and biodiversity are very present in the drafting of the strategy through the involvement of DG Maritime Affairs and Fisheries and the invitation of stakeholders like World Wide Fund. A mapping of all European sea areas is the basis for the strategy. The strategy will thus increase the supply in renewable electricity in Europe, which will **decrease the energy prices** and it seems to **incorporate land use and biodiversity issues**. It is interesting that the EGD encompasses a strategy on wind energy, but not on other RES like solar, biofuels or hydro energy. According to the sources cited in the literature review, wind energy seems to be favourable with respect to land use, water use and the critical raw materials needed. In promoting wind energy specifically, the Commission seems to have made a strategic decision in favour of this renewable energy source.

The review of the **Trans-European Network – Energy Regulation (TEN-E)**[318] is another energy-relevant initiative scheduled for this year. The regulation should be revised to adapt it to the climate neutrality objective and to 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".[319] This initiative is thus a further step to respond to **many challenges related to sector integration and hydrogen usage**.

For 2021, a review of the **Alternative Fuels Infrastructure Directive**[320] and the **Trans European Network – Transport Regulation** (TEN-T)[321] are announced.[322] Both revisions aim at improving the definitions of sustainable alternative fuels and their infrastructure. The legislative framework covering alternative fuels infrastructure should be also reinforced. Furthermore, permit granting and public procurement procedures should be accelerated and simplified. Quantitative objectives are 1 million public recharging and refuelling points for zero and low-emission vehicles by 2025 and the completion of TEN-T core network by 2030. Both reviews will thus also address important challenges for sector integration and will support the deployment of **electric vehicles** in Europe on a large scale.

Another important initiative to transform the transport sector is the S**trategy for Sustainable and Smart Mobility**, which is also scheduled for the end of this year. Objectives of the strategy will

[318] (EU) 347/2013
[319] *The European Green Deal*, 6.
[320] Directive 2014/94/EU
[321] Regulation (EU) No 1315/2013
[322] *The European Green Deal,* COM(2019) 640 final (Brussels, December 11, 2019).

be to reduce transport emissions by 90% by 2050 and to shift 75% of inland freight carried today by road onto rail and inland waterways.

As already mentioned, the **Energy Taxation Directive**[323] will be revised in June 2021. Important topics addressed will be the tax exemption for aviation and maritime transport, the taxation of Power-to-X products, and different level-playing fields of electricity and oil or gas taxation. The review will be important to out-phase fossil fuel subsidies and to make real prices more representative of environmental costs related with the use of fossil fuels. The review can expected to be difficult, since many former attempts to out-phase fossil fuel subsides did not obtain agreement in the European Council and the aviation industry is deeply hit by the Covis-19 crisis. It is however an important initiative to make RE and **alternative fuels more attractive** and competitive with traditional fossil fuel usages.

Related to energy taxation is also the planned **review of the European ETS**. The scheme should be extended to the transport and shipping sector and possibly to aviation and buildings. This is a centrepiece of carbon policy and will be important to **increase the carbon price**. As a consequence, RE should become more competitive.

Two other important initiatives in 2021 will be the **review of the Energy Efficiency Directive**[324] and the **RED II**[325]. The review of both Directives will be based on the new climate targets for 2030 that will be proposed by the Commission this autumn. Many aspects in the proposals will reinforce the implementation of the hydrogen and the Energy System Integration Strategy. The review of the Energy efficiency Directive is an important initiative to "apply the energy-efficiency-first principle consistently across the whole energy system".[326] A review of the "Primary Energy Factor"[327] should enhance the comparison of energy savings of different energy sectors.[328] According to a member of DG Energy, the review of the Renewable Energy Directive (RED II) will be challenging, because the Directive had been reviewed recently (2018) and the transposition in national law by MS is still on-going. A balance will need to be found between addressing what needs to be addressed and not "re-opening" everything, in order to guarantee stability and visibility. This aspect is also criticized by a staff member of DG Agriculture, who thinks that the so timely second review of the Directive will introduce much insecurity for investors and promoters. Nevertheless, the review is

[323] Directive 2003/96/EC
[324] Directive 2012/27/EU
[325] Directive 2009/28/EC and Directive 2018/2001/EU
[326] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration,* COM(2020) 299 final (Brussels, July 8, 2020), 5.
[327] The primary energy factor indicates the amount of primary energy used to generate a unit of final energy (electrical or thermal), allowing a comparison of the primary energy consumption of products with the same functionality using different energy carriers. It shall be revised periodically according to Annex IV of the Energy Efficiency Directive.
[328] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*, 5.

necessary according to a staff member of DG Energy, otherwise it would not be proposed. What exactly will be the content of both reviews is still under development.

The recovery package, the climate law and the EGD Investment Plan give already many signals to investors and pursue the aim to challenge private investment into clean energy technologies and the energy transition. A further step in this direction will be the **Sustainable Finance Strategy** later this year. The strategy should direct financial and capital flows into sustainable investment. This will thus further address the challenge of creating **the optimal market conditions for investors**.

A last initiative under the EGD which should be mentioned is the proposal for a **Carbon Border Adjustment Mechanism**. This mechanism should implement a new approach to prevent carbon leakage, which means that enterprises decide to produce outside the EU, due to high environmental or climate standards in the EU. Currently, carbon leakage is prevented through free allowances under the European ETS, where specific sectors receive free allocations and thus do not "pay" for the carbon emissions of their industry. The level playing field for these sectors within the EU is lowered to the standards outside the EU. The new approach wants to invert this logic, where all enterprises which want to sell their products on European markets need to comply with European climate and environmental standards and no European sectors will exempted.[329] How exactly this mechanism will be designed is not clear yet. It might be possible in the form of a tax. This might possibly increase the costs of products and materials necessary for RE technologies that are imported into the EU and decrease the competitiveness of European products. The RE industry might this see as additional "trade barrier", although the European Commission does not want to create an additional barrier and emphasises that the mechanism will comply with rules of the World Trade Organisation. Many initiatives under the EGD hence still await adoption by the Commission and have the potential to address many further challenges for RE, although the Carbon Border Adjustment Mechanism might increase the cost for some materials imported (with the hope that other parts of the world will also increase their carbon standards).

4.4.8 Summary of how the EGD addresses the challenges

In this thesis, 22 challenges for the further integration of RE have been identified through a literature review, the attendance of webinars with officials of EU institutions and bodies representatives of interest groups and academia, and through interviews with Commission staff members. Amongst the identified challenges, many are addressed in some form by initiatives under the EGD. The necessity for renewable hydrogen is addressed by the hydrogen strategy and the energy system integration strategy. The inertia of the economy is targeted by a number of measures: measures to increase the carbon price in the future (revision of the ETS, out-phasing of fossil fuel

[329] Diederik Samsom, "European Green Deal: Discussion with Diederik Samsom, 24.03.2020".

subsidies, revision of energy taxation), large investments under the recovery instrument and specific funding programs for pilot projects. The inertia of people and social acceptance is addressed by the Just Transition Mechanism that wants to support regions in the transition that are the most affected by the energy transition and the climate pact that will initiate a societal movement for more climate action and awareness. The Just Transition Mechanism and the investment under the recovery should also decrease the gaps in development between different MS. Research and innovation is part of a number of programs: the Energy System Integration Strategy proposes much action in this domain, the Hydrogen Strategy and a number of European funding programmes will support progress through financial support. The necessary speed-up in placing mature technology on the market is also mentioned in some strategies and the investment innovation and research programs should enhance this. The adaption of the energy infrastructure and energy system integration is targeted by the Energy System Integration Strategy and the upcoming review of the TEN-E Regulation. The same initiatives also tackle the challenge of the necessary flexibility of the energy grid and problems related to grid stability. Creating optimal market conditions for investors is the objective of a number of initiatives, the first one being the climate law that creates security about in which direction the EU wants to develop. Furthermore, the EGD Investment Plan, the upcoming sustainable finance strategy and the recovery instrument will give many signals to investors to prioritize "green investments". The huge amounts of investment planned also reply to the challenge of "costs". Although it is difficult to evaluate whether investment will suffice, there seems to be a consensus that investment into the recovery needs to benefit the EGD. The planned action will probably also increase the costs for polluting energy forms and make RE more competitive. All these challenges were thus addressed in the EGD.

While a number of other challenges are recognised, still no clear solution is presented yet. Lengthy processes in MS to issue permits for the construction of RE installations are named in the Energy System Integration Strategy, but no clear initiative is proposed apart from the review of a number of RE legislation pieces. The issue of critical raw materials is also stated in different Communications and a solution is awaited from the Critical Raw Material Action Plan that will be drafted as follow up initiative of the CEAP. One needs to await, if this will offer solutions in the extend necessary with a tremendous planned increase of installed RE capacity. The questions of RE increase without harmful effects on biodiversity, is touched upon by a number of initiatives. The main initiative in this area is the biodiversity-strategy[330], yet synergies between this strategy and RE increase are not obvious. The question of land use is only addressed in the way that increased energy efficiency will reduce the land use. This is however very limited, since much new RE installations and infrastructure will be necessary. The same is the case for water scarcity.

[330] COM/2020/380 final

Finally, the challenge of trade barriers is not addressed by the EGD; on the contrary, the Carbon Border Adjustment Mechanism might increase costs for imported products. The challenge of missing capacities and ideas and transfer of knowledge are not addressed in the EGD. Table 11 summaries these outcomes:

	challenges for RE	what initiatives addresses the challenge?
1	land use	not addressed
2	flexibility and stability of the grid	revision TEN-E; energy system integration strategy; hydrogen strategy
3	cost (of technology) and energy prices	revision energy taxation directive; revision ETS; Just Transition Mechanism; offshore wind strategy, review of RED II
4	speed of deployment of new technologies	energy system integration strategy; Next Generation EU
5	harmonise RE extension with biodiversity needs	only acknowledged
6	creating optimal market conditions for investors	climate law; EGD invetsment plan; sustainable finance strategy; Next Generation EU, review ETS, review of the energy efficiency directive will also enhance action
7	gap between MS	Just Transition Mechanism
8	energy poverty	basis for all action; renovation wave and review of energy efficiency directive will increase energy efficiency
9	transfer of knowledge between regions	not addressed
10	water scarcity	only acknowledged
11	social acceptance	Just Transition Mechanism; European Climate Pact; upskilling under the industrial strategy
12	coupling gas and electricity /integration of energy system	energy system integration strategy; hydrogen strategy
13	necessary adaption of the energy infrastructure	Revision TEN-E; energy system integration strategy; hydrogen strategy; review RED II
14	critical raw materials	the industrial strategy announces a critical raw materials action plan, the date is unclear, the issue is acknowledged
15	research & innovation	energy system integration strategy, hydrogen strategy
16	impact on third countries	not addressed
17	inertia of people	Just Transition Mechanism; European Climate Pact, upskilling under the industrial strategy
18	inertia of economy	revision of the ETS, out-phasing of fossil fuel subsidies, revision of energy taxation, Next Generation EU
19	capacities & ideas	not addressed
20	trade barriers	carbon border adjustment mechanism might worsen the situation
21	permits by MS	only acknowledged
22	necessity of hydrogen	hydrogen strategy; energy system integration strategy

Table 11: overview of the challenges for RE addressed under the EGD

5 Discussion of the results

This master thesis analysed whether the systemic approach of the EGD has the potential to address the many challenges existing for the increase of RE in the European energy system. Important challenges were identified by a combination of a literature review, interviews with officials of the European Commission, and webinars on related topics. Amongst the 22 identified challenges, almost all were addressed by initiatives under the EGD, which were already adopted by the Commission or are scheduled in the future. The EGD and the recovery instrument in the context of the Covis-19 crisis are specifically promising for channelling large amounts of public investment into the energy transition and motivating even further private investment. Challenges for the transformation of the energy system through sector integration and the use of renewable hydrogen are also addressed and progress is motivated. Initiatives to increase public acceptance, to transform the economy into a more circular model and to support poor or carbon-intense regions support the achievement and consent to the EGD objectives. Research and Innovation is also highlighted and supported in a number of initiatives and is expected to favour the implementation of the EGD. In all these aspects, the systemic approach of the EGD seems thus to reinforce the capacity of sub-initiatives to go hand in hand and foster the overall implementation. The challenge of social acceptance and gaps between MS could not be addressed by policy only focused on RE. The systemic approach is very beneficial for these different challenges. Furthermore, the systemic approach can encourage a larger buy-in of various stakeholders for the EGD, which is a crucial aspect for the smooth implementation.

Notwithstanding, not all objectives under the EGD can easily be aligned with each other and for some interview partners there exist clear **contradictions**. The EGD aims for example at increasing the share of arable land cultivated in organic way in the EU to 25% in 2030.[331] According to a representative of DG Agriculture, the yield of organic farming decreases significantly (up to 40%) if cultivated in organic way. The decrease in yield of cereals is the highest, whilst vegetables can be grown in organic way without much loss. As a consequence more land would need to be used for the cultivation of cereals to uphold the same yield. The EGD also aims at planting more trees for the sake of biodiversity and increasing protected areas. At the same time, more biofuels should be used. These targets might be incompatible and the issue of land competition becomes even more pronounced, if land is used for the installation of solar panels or wind turbines. According to this interviewee, the organic farming target will increase the land use competition. The question of land use seems to be crucial under the EGD and is not addressed by any initiative.

[331] *A Farm to Fork Strategy*, COM(2020) 381 final (Brussels, May 20, 2020), 9.

Still, it might be very difficult or impossible to tackle the **question of land use** on a European level. According to the same interview partner from DG Agriculture, the context of land use is unique in every MS. On the one hand, national taxation and state aid on land differ much. In some MS (Romania, Bulgaria), land ownership is a precondition for the pension schemes. Finally, the legislation for buying or inheritance of land is very different depending on the MS. All these factors make it mostly impossible to address land use at European level. Land use competition constitutes thus an important challenge for RE, which is not directly tackled in the EGD, possibly due to the limited possibilities of the EU in this area.

The question of **critical raw materials** seems to be recognised by the European Commission and by academic literature as important, still so far, no clear solution is proposed. Moreover, to combat climate change the quick energy transition seems to be prioritised at EU level over an assurance in the availability of critical raw materials. This approach bears some risks, if a sufficient supply in critical raw materials cannot be maintained to the necessary level for the energy transition. Nevertheless, an interviewee proposes that experts analyse the issue and do not perceive an immediate danger. As a result, an evaluation of the actual risks is difficult. A systemic approach should tackle this issue, which may be the case with the Critical Raw Material Action Plan to be proposed.[332]

A further challenge, possibly severed by the EGD is the question of **trade barriers**. Representatives of the RE industry fear trade barriers, which might increase the cost of materials necessary for RE technologies. As a consequence, the competitiveness of their industries would decrease. Still, the EGD aims at the establishment of a Carbon Border Adjustment Mechanism to increase the price of carbon-intense products imported to the EU. Although such a mechanism makes sense in the logic of the EGD, it might create an additional barrier for RE.

The present master thesis cannot be compared to former studies in the field of sustainability transitions, because it addresses mainly a political agenda, but cannot evaluate the success of a policy. Other studies on policy-mixes and sustainability transitions analyse in retrospectively whether the sustainability change was achieved. The EGD is currently mainly an ambitious policy strategy by the European Commission.

All analysis in this master thesis also needs to be seen on the context of the **decision-making processes in the EU**. The European Commission initiates legislation, but legislation is adopted by the European Council and the European Parliament. Communications of the Commission (most already adopted initiatives under the EGD), can be mainly understood as expressions of the strategic vision or agenda for the EU by the European Commission, but it does not mean that the other institutions share all these objectives in details. The EGD is a priority of the von der Leyen European Commission and

[332] No date is scheduled yet for this plan.

will shape the future of Europe, but the role of the co-legislators and MS must not be underestimated. A coherent implementation of the EGD will need the collaboration of all institutions and European citizens. A coherent approach within the EGD is still an important prerequisite for convincing all actors, which makes the present analysis meaningful.

The **methods** of this master thesis have proven to be useful to identify a variety of challenges that could not have been identified by one single source. A mere literature review would not have indicated a number of challenges e.g. the slow deployment of mature technology. This challenge was however identified through interviews and through the webinars. The question of critical raw materials supply seems to be more pronounced in literature than in the interviews and webinars. And the webinars gave the opportunity to hear the opinions of interest groups and industry, which informed for example about the difficulties with permits for RE and trade barriers. The mix to identify challenges was thus useful to get a broader picture and to identify challenges for different target groups.

Still, methods used might not be adequate to equally weight well the importance of different challenges. The number of interviewees was rather small (12 interview partners) and replies were naturally to a certain degree biased by the fields of expertise and working fields of the interviewees. As a consequence, it is important to interview people with different backgrounds. If one person did not name a challenge, that does not mean the person thinks the challenge does not exist. Furthermore, the named challenges are subjective perceptions. Again, this can be balanced by interviewing different people and combining different methods. Furthermore, for the analysed research question the degree of the challenges is less important than the fact that it might be a challenge. Under the given circumstances, namely a traineeship at the European Commission during the Covid-19 crisis, the used methods constituted the best possible option.

One might also argue that the methods of this master thesis are “circular” since many studies commanded or published by the European Commission have been used to identify challenges and staff members of the European Commission, who probably read these studies, were interviewed. Although this might be the case, it should not diminish the quality of the results. On the one hand, further scientific literature has been consulted and on the other hand, it is an advantage of the European Commission to base their work on scientific analysis, either through own studies or studies performed by external stakeholders. After all, the Commission has its also own department only for scientific analysis and preparatory studies, namely the Joint Research Center. Studies edited or commanded by the European Commission are generally well-targeted on the needs of the Commission, so that it is sensible to use them. The use of other scientific literature and the attendance of webinars with representatives of academia and interest groups ensure that additional perspectives are taken into consideration for this master thesis. A “circularity” of methods might thus exit, but it is

not entirely the case and it is useful to analyse whether points identified by EU studies were addressed in the proposals.

The question of increasing **energy efficiency** is intrinsically linked with RE and energy security and is present in the EGD in various initiatives. Although the role of energy efficiency in the EGD is not focus of this master thesis, it should be highlighted that increasing energy efficiency in all sectors is crucial for achieving the climate-neutrality objective in 2050. In an analysis of the European Commission with eight possible scenarios until 2050 of which two assume a reduction of GHG emission up to climate neutrality, all scenarios are based on reduced primary energy consumption in 2050 in comparison to today's level. The baseline scenario[333] assumes a reduction or 26% with respect to 2005.[334] This decrease in primary energy consumption is only feasible with increased energy efficiency. In all other scenarios, primary energy consumption decreases even more. Figure 10[335] demonstrates projected reduction in primary energy consumption. Scenario "1.5 Tech" and "1.5 Life" are aligned with the climate-neutrality objective. Both achieve reductions of primary energy consumption of at least 30%. The scenario, which evaluates possible effects of energy efficiency (EE) with projected GHG reductions of 80%, projects a decrease of primary energy consumption of 50%.

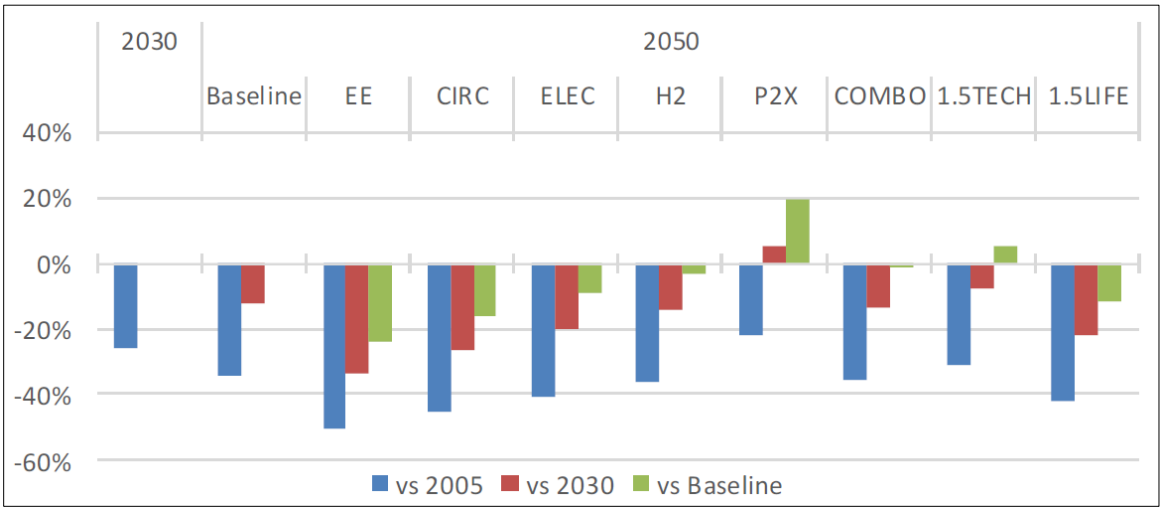

Figure 10: Changes in primary energy consumption in 2050 (% change)

It is thus clear that energy efficiency plays a crucial role for the climate-neutrality objective which is present in a number of initiatives of the EGD. Generally, the EU pursues the principle of

[333] The baseline scenario assumes no increased ambition with respect to policies in place or proposed. It projects GHG reductions of the EU of 65% compared to 1990.
[334] *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy* (Brussels, November 28, 2018), 48.
[335] *A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy*, 68.

"energy efficiency first" which means that all efforts to reduce GHG emissions firstly aim at enhancing the efficient use of energy, so that primary energy consumption can be reduced. This principle is also highlighted by the Energy System Integration Strategy which underlines the importance of a circular energy system where energy efficiency is increased and the least possible energy is wasted.[336] The renovation wave will increase energy efficiency in buildings and the review of the Energy Efficiency Directive will address the issue generally in all spheres. Increased energy efficiency is thus crucial for the achievement of the climate-neutrality objective and the EGD will enhance progress. This is a complementary aspect of RE, which was not treated in depth by this thesis, merits however attention in the future.

[336] *Powering a climate-neutral economy: An EU Strategy for Energy System Integration,* COM(2020) 299 final (Brussels, July 8, 2020), 5.

6 Conclusion

This master thesis analyses whether the systemic approach of the EGD has the potential to address the multiple challenges for the further integration of RE into the European energy system. The majority of identified challenges are addressed by the EGD and the systemic approach reinforces the potential effect of the various strategies, since multiple challenges are addressed simultaneously. This is very important for the achievement of the EGD goal of climate neutrality in 2050 and the buy-in of stakeholders.

Still, land use competition is likely to increase in the EU under the targets of the EGD and might become serious limiting factor for RE. Land use competition is probably reinforced through the increased use of RES, since these are generally more land intensive than fossil fuel plants. The EGD proposes no clear solution to the issue of land use competition apart from increased energy efficiency. At the same time, land use is difficult to tackle on a European level, because legislation in place differs much from one MS to the other and is MS competency.

For the increase of RE, the supply of critical raw materials might also become a limiting factor in the future, as RE technologies need many critical raw materials that are currently dominantly imported from China. Although European Commission experts in this domain do not seem to perceive a danger in that, solutions seem to be based on replacing critical raw materials through others thanks to more research and development, on trade agreements with China, and on a more circular use of critical raw materials. Whether this will suffice to cover the large demand, remains open at the current moment in time. Up to now, the problem of critical raw materials is acknowledged by the EGD, and a Critical Raw Materials Action Plan is foreseen as a consequent initiative of the Industrial Strategy.

The recovery measures for the Covid-19 crisis will mobilize vast amounts of money for the investment into RE services. The Covis-19 crisis might thus develop as a chance for RE and the EGD. One will need to await the Commission proposals on scheduled sub-initiatives of the EGD, the co-legislative process and the concrete implementation of those proposals on the ground to draw a clearer conclusion on the final impacts of the EGD on RE. Generally, the systemic apoach of the EGD is evaluated supportive for the increase in RE in the EU.

Further research could evaluate the developments of the EGD adoption in the European Parliament and the European Council, or classify the importance of identified challenges with a fuzzy cognitive map as suggested by Falcone et al.[337].

[337] Falcone, Lopolito, and Sica, “Policy mixes towards sustainability transition in the Italian biofuel sector: Dealing with alternative crisis scenarios”.

Appendix

Example of a questionnaire for the interviews:

- **Do you see the EGD as a revolution with respect to former environmental and climate policy? What makes the EGD revolutionary? / Why is it not a revolution?**
- Do you think the EGD will have an effect on other parts of the world to increase global climate ambition?
- **What do you consider the most important initiative under the EGD? Why?**
- Do you think the new structure of the Commission acts in favour for the implementation of the EGD? How?
- **What are the most important challenges for the implementation of the EGD according to you?**
- How will the systemic approach affect implementation? Advantages / disadvantages?
- Will the Corona crisis endanger the implementation of the EGD?
- **Do you think the EGD will favour a boost of renewable energies? If yes, more than former European energy policy?**
- **Where do you see the biggest challenges for an increase in Renewable Energy supply?**
- **Do you think the EGD offers responses to these challenges?**
- **Is the systemic approach of the EGD favouring the development of RE?**
- **What is necessary to promote sector integration? Where are challenges?**
- The Commission want to increase Europe's offshore capacity at least 20 times by 2050. Does the EU have enough critical raw materials at disposal for that?
- What do you think of the recently adopted hydrogen and sector integration strategy? How was the drafting process?
- Low carbon and renewable hydrogen is not yet competitive (as stated in the Communication). What would be the result for the hydrogen strategy, if MS oppose themselves (again) against the out-phasing of fossil fuel subsidies?
- In the hydrogen strategy huge amounts of necessary investment are named and a number of possible sources. Did the Commission calculate whether these sources will suffice?
- Do you generally think the investment for the energy transition will suffice?
- Will there be a competition in land use change in the future? (agriculture, RE, protected areas)
- Will there be a problem with water scarcity?
- Do you see a problem with the speed of commercialisation of new technologies?

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