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The Environmental Governance System Around the Implementation of Sustainable Aviation Fuels in Norway.

A Case Study on e-Fuels and Carbon Capture and Utilization Value Chain.

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Abstract

Over the last years Sustainable Aviation Fuels (SAFs) have gained attention as a solution to lower CO_2 emissions from aviation, a sector difficult to electrify that contributes to a large extent to global CO_2 emissions, and is expected to grow in the future years. A new European consortium based in Norway, Norsk e-Fuel, presented its project on sustainable fuels. The project aims to industrialize a hydrogen based e-fuel, generated from CO_2 and water, using Carbon Capture and Utilization (CCU), electrolysis, and Norwegian renewable energy. CCU, as well as many new technological solutions, comes with challenges and uncertainties that hinder their deployment and governance, constantly pushing for institutional changes. This thesis uses Norsk e-Fuel as a case study, and Institutional economics theory to analyze the environmental governance system framework around the implementation of CCU and e-fuels in Norway. Additionally, it looks to identify the uncertainties and challenges for their development and how these and actors from the governance structure push the dynamics of institutional change and influence their implementation.

Results showed Norway has a robust environmental governance structure that, together with an international framework, has a lot of influence on the implementation of e-fuels and the CCU value chain. The research identified several challenges and uncertainties for their development and implementation. These challenges have been actively discussed by the main actors involved. The discussions have shown a dynamic action within the national and international governance structure to have clearer policy instruments to implement or refute CCU and e-fuels. Today, a new regulatory framework from the EU that contains relevant instruments for implementing CCU and e-fuels is about to be adopted. However, the results identified some limitations in Norway to adopt new EU regulations, like slow processes and apprehensiveness from the institutions setting the rules to implement new regulations. Regardless of these limitations, institutional change is constantly happening within the actors in the governance structure, and the findings show that the influence they have to implement new solutions has a lot of weight.

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Abbreviations

AWE	Alkanie water electrolisis
CCS	Carbon, Capture and Storage
CCU	Carbon, Capture and Utilization
CCUS	Carbon, Capture, Utilization and Storage
CO2	Carbon dioxide
COP	Conference of the Parties
DAC	Direct Air Capture
DACSS	Direct Air Capture with Carbon Storage
EEA	European Economic Area
EFTA	European Free Trade Association
EGS	Environmental Governance System
ETD	Energy Taxation Directive
EU	European Union
EU ETS	European Union Emission Trading System
GHG	Green House Gases
IATA	International Air Transport Association
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
NDC	National determined contribution
NEA	Norwegian Environmental Agency
NGO	Non-governmental organization
NOU	Norges Offentlige Utredninger/ Norwegian Official Commissions
PEM	Proton exchange membranes
PGP	Provider gets principle
PPP	Polluter pays principle
PtL	Power to Liquid
R&D	Research and Development
RED	Renewable Energy Directive
RFNBO	Renewable fuels from non-biological origin
SAF	Sustainable Aviation Fuel
SOEC	Solid oxide water electrolysis cells
SPM	Summaries for policymakers
SRQ	Sub research question
T&E	Transport & Environment
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WTA	Willingness to accept
WTP	Willingness to pay

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1. Introduction.

Global warming has been escalating since the start of the Industrial Revolution (IPCC, 2014). The Intergovernmental Panel on Climate Change (IPCC) has estimated that CO_2 emissions from fossil fuels and industrial activities contribute to a 78% of the total increase of greenhouse gases (GHG) emissions from 1970 to 2010. In response, pathways for limiting global warming to 1.5 °C above pre-industrial levels rely on different mitigation strategies as sustainable development and an energy transition (IPCC, 2014). Sustainable development looks to meet present needs without compromising the future generation needs (WCED, 1987). Energy transition is often defined as *the changing composition (structure) of primary energy supply* (Smil, 2016,p.ix). One example of energy transition is the change of biomass fuels to fossil fuels that marked the shift from the pre-industrial era to a modern civilization. Since recent decades, fossil fuels have been transitioning to more efficient and environmentally friendly sources of energy (Smil, 2016). Several combinations of technologies as Carbon Capture, Utilization and Storage (CCUS) and sustainable fuels, have been crucial for this transition (IPCC, 2018).

Sustainable fuels have gained attention since the transport industry is one of the highest emitters, just in 2018 it contributed with approximately 24% of the total CO_2 emissions globally (IEA, 2021a). This attention has focused on aviation for the difficulties of electrifying it, the lengthy aircraft certification processes of new engine technologies, the build-up of new fueling infrastructure, and the growing expectations of the industry (European Commission, 2021a). Even though hydrogen and electrification of aviation are considered efficient and promising solutions with substantial development progress, many technical challenges remain yet. Some experts recognize both technologies will not account for a significant role in the decarbonization of aviation before 2050 (Cell & Undertaking, 2020; European Commission, 2021a).

Norway has established ambitious goals to reduce its CO_2 emissions and contribute to the energy transition as part of the Paris agreement and aligned with the European Union (EU) (KLD, 2020). To reach these goals, the Norwegian government has implemented several policies to promote the development of technologies as Carbon Capture and Storage (CCS), wind power, electrification of transport, and renewable fuels. They launched The Norwegian Climate Plan with ambitious goals and defined instruments like the green tax fix of CO_2, the increased support for R&D, and biofuels mandates (Regjeringen, 2021a). This plan is backed-

up by “Klimakur 2030”, an extensive report that analyzes several potential measures to reduce GHG emissions and represents the basis for Norway’s Climate plans (Norwegian Environment Agency et al., 2020).

On June 2020, a new European consortium based in Norway, Norsk e-Fuel, presented its project on renewable fuels. The project aims to industrialize what they call *e-fuel*, generated from CO_2 and water, using Carbon Capture and Utilization (CCU), electrolysis, and renewable energy (Norsk e-Fuel, 2020a). CCU, as well as many new technological solutions, comes with challenges and uncertainties that difficulties its deployment and the governance around it, constantly pushing for institutional changes.

The aim of this research is to analyze the current Norwegian environmental governance system towards an energy transition, as well as its strategies to manage challenges and the implementation of new technologies. Reducing dependence on fossil fuels is highly desired but not easy to achieve. It requires time, persistence, patience, large economic investments and coordinated governance systems (Vatn, 2015; Smil, 2016). Some of the new technologies needed for an energy transition face different hindrances of development and large capital investments. CCU is a good example of immature technology that require a coordinated governance to ensure implementation with effective results (European Union, 2019). Vatn (2015) developed the Environmental Governance System (EGS) framework to study human-environmental interactions based on institution influences to evaluate governance systems. The framework can help to map the most relevant actors and institutions involved, and how they interact and influence to institutional change and the implementation of new solutions. The study will use Vatn’s theory to analyze the current governance structure, the challenges of the implementation of CCU and e-fuels, and the possible institutional changes for their implementation or rejection in Norway.

1.1 Research Questions.

The main research question is:

How does the Environmental Governance System impacts the implementation of e-fuels and the CCU value chains in Norway?

The following sub-research questions will help to answer the main research question:

SRQ 1: Who are the main actors of the current governance structures influencing the implementation of CCU and e-fuels in Norway?

SRQ 2: Which are the institutions and policy instruments at play in implementing CCU and e-fuels in Norway?

SRQ 3: What are the main challenges and uncertainties for the adoption of e-fuels in Norway, and how are these challenges managed by the institutions and actors from the environmental governance structure?

SRQ 4: How are the dynamics of institutional change in the governance structure for CCU and e-fuels?

SRQ 1 to 3 will be addressed in chapter 5, Analysis. SRQ 4 will be addressed in chapter 6, Discussion when answering the main RQ.

2. Background

2.1 Carbon Capture Utilization (CCU) and Carbon Capture and Storage (CCS)

Given the challenge of reducing reliance on fossil fuels for energy demands, and the increasing demand of energy supply for a constant population growth, the development of new technologies is very important (Al-Mamoori et al., 2017). Besides renewable energy, CCU and CCS are considered important mitigation strategies to achieve climate and sustainable development goals by the IEA (2021b). CCS could be functional to a linear economy, while the CCU principle goes in line with a circular economy future (Nocito & Dibenedetto, 2020). The linear economy follows a "*take-make-use-dispose*" principle (Andrews, 2015), while a circular economy focus on reuse, re-manufacture and recycle materials to close material loops and create secondary products (Zink & Geyer, 2017).

CCU is a set of technologies that involve several steps in its value chain. It starts with the capture of CO_2 directly from the air, power stations or industrial facilities, a purification process, the compression and transportation to other facilities; and the transformation to useful products (Pieri et al., 2018; IEA, 2021b). When captured the CO_2, it can be used in several ways without chemical transformations. Some examples are, as solvents, as heat transfer fluids, to produce fertilizers, for medical uses, and for food and beverage production. It also can have a chemical or biological transformation to be used as fuels, chemical intermediates and building materials (IEA, 2021b).

CCS is a fast and large-scale solution for a linear economy (Nocito & Dibenedetto, 2020). It focuses on the removal of CO_2 from gas streams or industrial activities, along with its compression, transportation and storage in geologic formations (Al-Mamoori et al., 2017). This option promises large volumes of CO_2 mitigation. However, its costly development has affected its large-scale deployment. CCU has been seen as a more attractive alternative since it looks to turn CO_2 into renewable, valuable products (Al-Mamoori et al., 2017).

Norway has mainly opted for research and development (R&D) of CCS technologies, starting in 1987 with their first CCS R&D project by SINTEF, one of Europe's largest research organizations (Van Alphen et al., 2009). Since then, the development of projects related to CCS has increased considerably. In 2020, the Norwegian Government launched the full-scale CO_2 capture, transport and storage project called "Longship", with a total cost of NOK 25.1 billion of which the state is contributing to NOK 16.8 billion (Regjeringen, 2021b). Even though CCS offers a permanent mitigation solution by storing CO_2, the development and implementation

of CCU is also important in order to meet global climate targets regarding the urgency of the problem.

2.2 Sustainable aviation fuels (SAFs)

SAFs are low-carbon alternative fuels to replace fossil kerosene (Bauen et al., 2020). Based on recent European policy proposals, SAFs are certified liquid and drop-in fuels that can be blended with conventional aviation fuel and are compatible with existing aircraft engines (European Commission, 2021a). For the purpose of the study, two types of SAFs are considered, synthetic fuels and advanced biofuels. The latter are made from a limited list of wastes and residues like animal manure, used cooking oil, some types of algae, or specific biomass fraction of municipal waste. Synthetic fuels are made with renewable sources different from biomass (European Parliament & Council of the European Union, 2018). They are also called renewable fuels from non-biological origin (RFNBO) and e-fuels are part of this classification (European Commission, 2021a). Different certified production pathways of SAFs are ready to play an important role in reducing emission from aviation. However, there are different technological readiness, and many of these processes still require development to become fully industrialized (Chiaramonti, 2019; European Commission, 2021a).

2.3 Hydrogen, electrolysis and e-fuels

Hydrogen is an important energy carrier and a key element for the achievement of climate goals. Its production is more expensive than electricity because it must be produced by an energy source that requires energy and involves energy losses (Regjeringen, 2020a). In 2020, the Norwegian Government launched *The Norwegian Government's hydrogen strategy towards a low emission society,* which focuses on the development of new low emission hydrogen-based solutions (Regjeringen, 2020a). These solutions can create important emission cuts and contribute to value creation. Besides the development of technologies, the costs, energy system, and financial and political framework conditions are crucial for hydrogen to be successfully produced and used. Today, electricity to produce hydrogen in Norway is free from the consumer tax on electricity to help to reduce its costs (Regjeringen, 2020a).

Some of the most developed ways to produce hydrogen comes from natural gas or coal, resulting in a blue hydrogen, and electrolysis of water to produce the green hydrogen. For hydrogen to be "clean", as a low or zero emission energy carrier, the production process needs electrolysis of water using renewable electricity or steam from fossil fuel processes, combined with CCS (Regjeringen, 2020a). Hydrogen from water electrolysis has high purity (99.9%) and

can be used as an energy carrier and as a reactant for several industrial processes (Chi & Yu, 2018). There are several technologies for water electrolysis like alkaline water electrolysis (AWE), proton exchange membranes (PEM) and solid oxide water electrolysis cells (SOEC) (Chi & Yu, 2018). For its high efficiency levels and the purpose of this research, SOEC will be further analyzed.

SOEC is a relatively new technology that uses high temperature solid oxide cells. It has high energy efficiency since water electrolysis at high temperature requires lower energy consumption, but is also less mature than other electrolysis options like AWE (Schmidt et al., 2017; Chi & Yu, 2018). The German company Sunfire GmbH is currently the leader of the technology (Sunfire GmbH, 2020a). The SOEC simultaneously processes CO_2 and water to syngas in one step. Syngas is a gas fuel composed of hydrogen, carbon monoxide and carbon dioxide (Rostrup-Nielsen & Christiansen, 2011). It is also an essential feedstock that can be synthesized and refined to produce e-fuels (Sunfire GmbH, 2020a), see fig 1. Compared to low-temperature electrolysis technology, SOEC uses smart integration of waste heat from industrial processes to reduce renewable electricity demand and cut operation costs (Sunfire GmbH, 2020a).

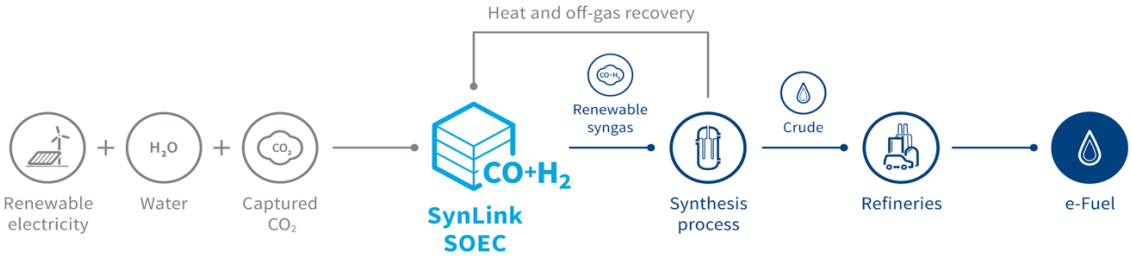

Figure 1: Power-to-Liquid (PtL) process Source: sunfire.de/e-fuel.

2.4 Norwegian renewable energy

Norway produces almost 100% of the electricity in the country with renewable energy sources. Hydropower is the primary source of renewable energy, with thermal and wind power also contributing to smaller percentages (Regjeringen, 2016). Even though wind power is not as strong as hydropower in Norway, it is a cost-effective climate initiative and a key renewable energy technology for Europe to achieve its climate goals (Inderberg et al., 2019). Since Norway has climate commitments with the EU, and it has excellent wind resources, wind power production has increased considerably in the last years. Increasing from 1TWh by the

end of 2010 to a projected 15 TWh by the end of 2021, equivalent to approximately 10% of annual electricity production (Gulbrandsen et al., 2021).

2.5 Norsk e-Fuel

Norsk e-Fuel is an industry consortium that plans to industrialize a Power to Liquid (PtL) hydrogen-based fuel for the transportation industry, starting the project focusing on aviation (Norsk e-Fuel, 2020a). They create the fuel from captured CO_2 and water, using 100% renewable electricity. To achieve this, four partners are contributing to the project with different technologies. First, the Swiss company Climeworks, that are the pioneers of direct air capture (DAC) of CO_2. Second, Sunfire GmbH from Germany, leading in technology of PtL with SOEC that enables the conversion of renewable energy to fuel. Third, Paul Wurth (SMS group) from Luxemburg, specialized in plant building and engineering technologies, primarily to the steel industry. And fourth, the largest private wind power developer in Norway, Valinor. The project promises a lurch potential and aims for a radical change for climate-neutral transportation by closing the carbon cycle, especially for hard-to-electrify sectors as aviation (Norsk e-Fuel, 2020a).

The e-fuel production comprises a single step co-electrolysis process from SOEC technology that converts water, CO_2 captured from air, and renewable electricity into syngas (Norsk e-Fuel, 2020a). After the syngas is produced, it is then processed into a renewable synthetic crude as substitute for crude oil (Sunfire GmbH, 2020b). This crude can be refined into different e-fuels as jet fuel, diesel or gasoline that can be used in existing infrastructures (Norsk e-Fuel, 2020a). According to Karl Hauptmeier, the managing director of Norsk e-fuel, once this fuel is burned, CO_2 is again released to the atmosphere and recollected with carbon capture technology to re-use it again and produce more e-fuels closing the carbon cycle (Norsk e-Fuel, 2020b).

The consortium is planning to build a first plant at Herøya Industry Park in Porsgrunn with a production capacity of 10 million liters annually, starting operations in 2023. This plant will be upscaled to a full-scale size plant, producing 100 million liters before 2026, saving 250,000 tones of CO_2 emissions. Finally, the upscaled industrialized plant will serve as a base for national replications (Norsk e-Fuel, 2020a).

2.6 International climate regime

Climate change issues was first discussed in the international political arena in the 1980s, with the consequences of the use of fossil fuels for the climate (Vatn, 2015). In 1979 the

first World Climate Conference was held, attracting mainly scientists and non-governmental organizations (NGOs). Since then, different international organizations and negotiations about climate change has been stablished. Some of the most relevant for this study are explained next.

2.6.1 IPCC

The IPCC is an organization created by the United Nations (UN) and the World Meteorological Organization (WMO) in 1988 with currently 195 governments as members (IPCC, 2013a). Its purpose is to provide scientific information to guide governments in developing climate policies, and to guide international climate change negotiations. The IPCC reports comprise a summary of drivers of climate change, its impacts and risks, and options for adaptation and mitigation. The summary comes from voluntary scientists doing an assessment of thousands of published scientific papers, identifying the strength of scientific agreement and further research needed. All the panel is divided into three working groups and two task forces. Group I is in charge of the physical science basis of climate change. Group II works with impacts, adaptation, and vulnerability. Group III suggests and defines strategies for mitigation of climate change. One task force is in charge of the development of methodology to calculate and report national greenhouse gas emissions and removals. And finally, a second task force that can be established for determined periods of time, for specific topics or questions (IPCC, 2013a; IPCC, 2021).

The drafts and final reports have to be approved by the government representatives and the scientists. Every final report and Summaries for Policymakers (SPM), goes through an endorsement process based on dialog between the governments and the scientists that happens in a Plenary Session (IPCC, 2013b). Even though the panel does not provide own research or instructions on what to do, it provides advice and guidance, and represents a big influence for policy makers and global perceptions on climate change.

2.6.2 UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC) was created in 1992 as part of the UN. Its major responsibility is to support the global response to climate change, and to keep global temperature rise at 1.5 C above pre-industrial levels (UNFCCC, 2021a). The Convention is formed by 197 parties and it was focused on facilitating the negotiations of the IPCC, but today, it supports a complex set of bodies that coordinates the implementation of the convention and international agreements. It follows a central principle

of *Common but Differentiated Responsibilities and Respective Capabilities,* which acknowledge the responsibility of all countries to climate change, but in different levels of responsibility and capabilities to address the problem (Andresen et al., 2012). Members are divided in two groups, Annex I formed by developed countries, and non-Annex I formed by developing countries (Kuyper et al., 2018). The UNFCCC is not legally binding, its normative gives a set for cooperation but does not establish quantifiable targets and formal rules. Instead, it requires all parties to report on their climate change mitigation and adaptation actions (Andresen et al., 2012).

Every year, the UNFCCC organizes two to four negotiation meetings, with a main session called the Conference of the Parties (COP) where decisions and agreements are adopted (Kuyper et al., 2018). In the first COP meeting in 1995, it was decided that the Annex I countries were the ones to start reducing GHG emissions, and the non-Annex countries were to follow in a later stage. This decision was undermined by the United States (Bauen et al., 2020) by demanding flexibility in emission reduction strategies, and the participation of developing countries in reducing emissions as well. This demand lead the convention to make some changes on future agreements (Kuyper et al., 2018).

2.6.3 The Kyoto Protocol and The Paris Agreement

The Kyoto Protocol and the Paris Agreement are international environmental agreements that were established during some UNFCCC COPs. They specify formal rules to climate cooperation based on the normative UNFCCC objectives (Andresen et al., 2012). The Kyoto Protocol was established in 1997 and entered into force in 2005, with 192 parties currently ratified in the Protocol (UNFCCC, 2021b). As the Kyoto Protocol followed the UNFCCC objectives, it only set specific emission reducing targets to Annex I countries. The Kyoto Protocol had two periods, from 2008 to 2012 and from 2013 to 2020, with legally binding targets for each period. For the first period, Annex I countries were required to reduce their emissions in average to 5.2% less than their emissions levels in 1990. By the second period the target increased to 18% below 1990 emissions levels, however, not all the countries ratified the agreement by the second period. To help countries meet their targets, the Kyoto Protocol established market-based mechanism like the International Emission Trading. It commodifies GHG emissions to sell them from countries with emission units to spare, to countries with exceeded capacities over their emission targets (UNFCCC, 2021b; UNFCCC, 2021c). .

Norway's first obligation under the Kyoto Protocol was an average annual emissions under 1% above emissions in 1990 for the period of 2008-2012. With help of climate quotas and emission cuts, Norway over-fulfilled the emissions obligations (Regjeringen, 2015a). For the second period, Norway's target was to reduce emissions by 30% compared to emissions in 1990 for the period of 2013-2020 (Norwegian Ministry of Climate and Environment, 2014).

The Paris Agreement was established in 2015 with 195 ratified parties and replaces the Kyoto Protocol from 2021 (Falkner, 2016). It acknowledges the primacy of domestic policies and allows countries to set their own targets for climate change mitigation. The distributional conflicts from the Kyoto Protocol are sidestep by discontinuing the Annex I and non-Annex I group separation, and establishing a more realistic approach for international cooperation. The national targets must be submitted as nationally determined contributions (NDC) every 5 years, exceeding the ambitions each time. These progressions are needed to meet the main target of keeping temperature rise below 2°C above pre-industrial levels. To raise the ambitions of progressions, a regular review of progress takes place every 5 years, starting in 2018 (Falkner, 2016). In 2020, Norway submitted its NDC under the Paris Agreement, compromising to reduce emissions by 2030 to at least 50% compared to 1990 levels (Regjeringen, 2021c).

2.6.4 EEA and EU ETS

The European Economic Area (EEA) agreement was established in 1992 with the purpose of promoting trade and economic relations with equal conditions of competition to all the parties involved. These parties are the EU and the European Free Trade Association (EFTA) states, Norway, Liechtenstein and Iceland (Cyndecka, 2020). The EEA agreement purpose deals with four freedoms: goods, services, capital, and persons. In addition, it calls for cooperation in areas that can affect the functioning of the internal market, and the environment is one of them (Regjeringen, 2015b). Even though the EEA does not include climate issues, it provides an efficient legal framework for climate change mitigation action (Cyndecka, 2020). The EU's climate and environment policies derived from the EEA agreement have much influenced the Norwegian law. Some of these influences can be seen as Norway being part of the European Union Emission Trading Scheme (EU ETS), and by sharing targets with EU regarding renewable energy, energy efficiency and energy savings (Regjeringen, 2015b). Under the EEA, Norway is committed to reduce non-ETS emissions by 2030 to at least 40% compared to 1990 levels (Cyndecka, 2020).

The EU ETS is the first and biggest carbon market, it is based on a 'cap and trade' principle where a cap is set on the total amount of certain GHG that a member installation can emit (European Commission, 2021b). The cap is reduced over time to reduce the total emissions. There is a limited total amount of allowances available to allocate or that installations can buy. At the end of a year, the installations must surrender allowances to fully cover its emissions. In case of spare allowances for a reduction of emissions during the year, the installations can save them for future needs, or sell them to another installations that went short of allowances. All the countries in the EU and the EEA are part of the system, and the included sectors are: electricity and heat generation, energy-intensive industry as oil refineries, and the production of steel, iron, cement, aluminum, lime, glass, acids, etc. Commercial aviation is also included within the EEA. The system was established in 2005, and it operates in trading phases. At the moment, it is on its fourth trading phase (2021-2030) and its framework is currently under revision to be updated according to the actual European climate goals. (European Commission, 2021b).

2.6.5 Norwegian Climate regime

International climate agreements have influenced Norway's national climate policies in order to achieve its goals. Emission reduction under the Paris Agreement is, until today, the most significant climate commitment Norway ever has. Norway presented a detailed plan for cutting emissions in every sector, ensuring that its strategy will pay with green growth (Regjeringen, 2021a). For this strategy, Norway's main emphasis is on domestic emission cuts, and not on non-ETS emissions, even though it also deals with them. The plan supports several policy instruments as: "*taxation of greenhouse gas emissions, regulatory measures, climate-related requirements in public procurement processes, information on climate-friendly options, financial support for the development of new technology, and initiatives to promote research and innovation"* (Regjeringen, 2021a).

Taxation of GHG emissions consists on gradually increasing the carbon tax rate from the current level of NOK 590 to NOK 2000 per ton in 2030 (Regjeringen, 2021a). The increase of overall taxes should not be affected, therefore, other taxes should be reduced. The tax raise will apply to non-ETS emissions and to emissions from petroleum and aviation activities that are covered by the EU ETS. In regards the climate-related requirements for public processes, zero-emissions solutions will be introduced for passenger cars, small vans, local buses, ferry services and high-speed passenger vessel services. Biofuels are planned to continue for fossil

fuel vehicles still in use, and vehicle taxes will be implemented to increase incentives to choose zero-emissions vehicles. The plan seeks to replace fossil fuels for road transport, off-road diesel, aviation and shipping with sustainable biofuels. For this purpose, the biofuel quota obligation will be increased for road traffic, and introduced for off-road diesel and shipping. This measure aims to maintain the current volume of biofuel sales while electrification or other measures replace liquid fuels. For aviation, the plan underlines that the government will gain experience from the new advanced biofuel quota of 0.5% established on 2020, before considering to increase the advanced biofuel proportion required (Norwegian Environment Agency, 2021a; Regjeringen, 2021a).

In the case of financial support and initiatives for development of new technology and innovation, the plan mentions Enova as a key element, giving it a "*clearer climate profile"* (Regjeringen, 2021a). Enova is a state enterprise owned by the Ministry of Climate and Environment. It is in charge of financial contributions for innovation and technology development to find the solutions to achieve a low emission society (Enova, 2018). The plan promotes CCS as a key technology and mitigation tool with the future implementation of the Longship project that encompasses capture, transport and storage of CO_2 (Regjeringen, 2021a).

The plan also cover points related to the EU climate legislation Norway is also part of (Regjeringen, 2021a). It consist of three pieces, the one relevant for this research is related to the EU ETS. Under the current legislation, the goal is to reduce emissions by 43% by 2030 (Regjeringen, 2021a). However, as already mentioned, the legislation framework is currently under revision to be updated.

3. Theory

This chapter explains the EGS framework theory of Vatn (2015), that includes a governance structure with actors, institutions, resource regimes and policy instruments. Different theories related to institutional change, will be also explained to help finding answers for the research questions.

3.1 Governance, Institutions and human motivations.

Governance is about the process and structures involved to shape social priorities and formulate goals (Vatn, 2015). With the process comes also the acknowledgement of conflicts, how can be possibly resolved and how coordination is facilitated. The organization and administration of this process refer to the structures. Governance can cover different spheres and levels of society, and institutions are very important in every governance system (Vatn, 2015).

Vatn (2015) defines Institutions as: "*conventions, norms and formally sanctioned rules of a society*" p.78. They are human constructs to regulate, provide stability and give meaning to social behavior, and also to shape behavior and construct the human. Institutions can be formal, as legal rules, or informal as norms and conventions. Conventions combine certain situations with certain practical solutions to simplify complexity, e.g., language, money or scales. When there is conflict, norms combine certain situation with a required solution which supports an underlined value and certain interests, e.g., you should not pollute to protect the environment. Finally, institutions as formally sanctioned rules combine a certain situation with a prescribed or forbidden act that is formally sanctioned by a third party as a system, or the law (Vatn, 2015).

In governance, institutions influence aspects of power distribution, interactions, coordination and motivations within and between the actors involved (Vatn, 2015). In addition, institutions are influenced by types of rationality that will shape motivation for certain actions. For example, an individual rationality that will look for the maximization of an individual utility, or a social rationality that focus on what is best for the group or the others. Social rationality can also be explained as the "we" rationality that refers to actions on behalf of the best for a group or a community, and the "they" rationality that refers to what is best for others, i.e., altruism (Vatn, 2015).

3.2 Environmental Governance System Framework

A framework is a set of variables with interactions that can be used to apply different theories and facilitates communication between disciplines (Vatn, 2015). The EGS framework was created to facilitate the analysis of the governance of environmental resources and identify if it is successful or not, see fig 2. It includes a governance structure formed by: the political, economic and civil society actors, each with their goals, motivations, rights and responsibilities; and the institutions that include rules for political processes, rules for economic processes and the resource regimes, along with the rules of civil society (normative basis). Besides the governance structure, the EGS includes environmental resources, processes and attributes, technologies and infrastructures, patterns of interaction of the economic actors, and outcomes of the resource. The patterns of interaction of the economic actors are a separate variable since it is also influenced by the attributes and outcomes of the resources (Vatn, 2015).

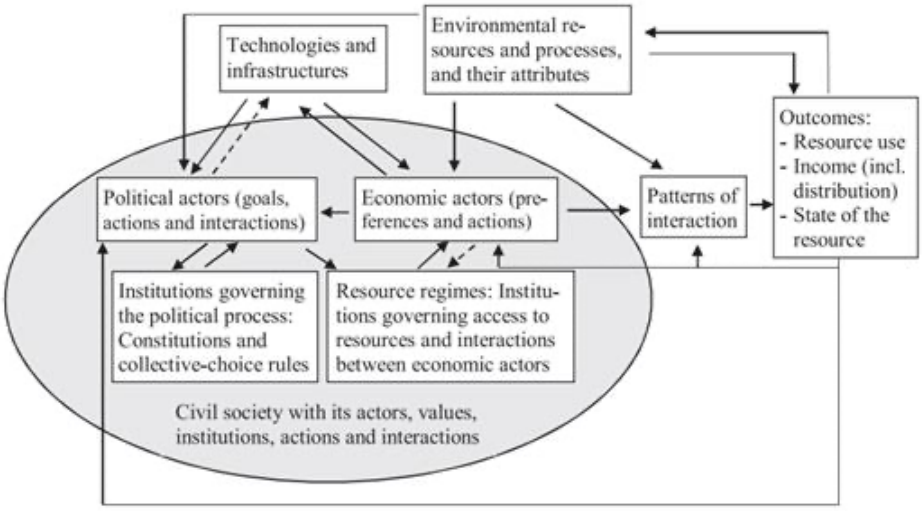

Figure 2: The EGS Framework. Source: Vatn, 2015, p.154

Civil society actors are the ones in charge to define normative basis and ensure legitimate democracy to political action (Vatn, 2015). They can be individuals, families, NGOs, political parties, mass media, business representatives, etc. Economic actors are the ones holding the right to use and own productive resources. They can be producers and consumers and can have different property rights. Political actors are the ones with the power to define resource regimes, property rights and rules of political processes. They can be public authorities or International Governmental Organizations (IGO). Public authorities are in charge of matters of constitutional and collective-choice rules and act as a third party when conflict appears.

IGOs are in charge to address global conflicts and co-operation for development, production, trade and environment (Vatn, 2015).

3.3 Resource regimes and Policy Instruments

Resource regimes are basis for environmental governance (Vatn, 2015). These are institutions governing access, use and protection of productive resources, including use and property rights. The access to resources defined by property rights may be *private, state, common* or *open access*. These are legally defined by a third party, that can be the state or a traditional authority. Having a state law and a customary law can in many cases overlap, having what is called as legal pluralism. The rules of interaction of actors who have access to the resources are also an important part of the resource regimes. These include coordination of use and side-effects. The interactions can present in different forms as *trade, command, community rules,* or *no rules.* When combining types of property rights and forms of interaction, we can get several resource regimes, while the dominant are: trade – private property, command – state/public property, community rules – common property, and no rules – open access (Vatn, 2015).

Vatn (2015) defines policy instruments as "(*re)formulations of the resource regime*" p. 287. This definition includes changes in property rights and interaction rules; and changes or introduction of environmental regulations, like legal regulations and economic incentives linked to environmental degradation activities. Policy instruments can have distributional effects depending on who gets the right, the polluter or the victim. They also influence the level of transaction costs, and people motivations, values and preferences. The main policy instruments can be economic, legal and informational (Vatn, 2015).

Economic instruments appeal to individual rationality, and self-interest. If something is cheaper we will consume more, if it is more costly, we will consume less (Vatn, 2015). The main principle is simple, however, several aspects need to be considered. Since it is based on an individual rationality the actors act for what is best for themselves, if people involve actions with a social rationality, the instrument may fail. The rights are defined with the type of instrument that can be economic, as taxes and subsidies, or market based as tradable quotas. For example, with taxes, the right is with the victim, since they operate with a polluter pays principle (PPP) and a willingness to accept (WTA) compensation. In the case of subsidies, the payment is for the polluter to reduce the damage for producing, hence, the right is with the

polluter and uses a provider gets principle (PGP) and a willingness to pay (WTP) the compensation (Vatn, 2015).

Legal instruments are based on the law, which is the legitimate role of the state to command its citizens (Vatn, 2015). The mechanism of legal instruments it to create publicly sanctioned rights, prohibitions or prescriptions. Citizens will follow the law, from an individual rationality perspective, if the cost of punishment is higher than the gains of breaking the law. From a social rationality perspective, the law is followed because it is the right thing to do. This is the normative content and effect of the law, bringing it as more than an external punishment structure. The law is strongly dependent on its legitimacy in society. It will be more effective if the process is fair, transparent and if it is internalized in people, with a significative value that one should follow. If the law is not accepted by society, it will have less impacts and effects (Vatn, 2015).

Informational instruments are important to help people to figure out what to do (Vatn, 2015). Information can be facilitated in forms of labeling or certification. They can help to create or activate norms since they include explicit normative elements, e.g., campaigns focused on emphasizing behaviors as good, like a sorting waste campaign. Pedagogical instruments can help to break or create habits at the individual and community level since typically habits are social constructs. Moreover, they have an important role to form preferences and values at individual and community levels (Vatn, 2015).

3.4 Changes in the Governance Structure

Considering that we are facing an energy transition trying to develop and implement new solutions to stop depending on fossil fuels, changings in the governance structure are very important. Vatn (2015) explains that inside the governance structure, changes in the institutions directly creates an effect of changes in actors, and the other way around, actors can also create changes in the institutions. Focusing on institutional change, he explains that it can be spontaneous or designed. The spontaneous change is often related with bottom-up and unintentional change (Sened, 1997), however this is not always the case since some types of spontaneous change can start with an intentional act, and the spontaneity of it is the way it penetrate and actually creates a change (Vatn, 2015). On the other hand, designed change is often related with top-down and intentional change (Sened, 1997), as for example a new law created by a third party. Design change has been questioned by the limits of the already existing

institution to rearrange and accept change, going beyond formal rules and consider the informal power structures and the willingness to accept new external rules (Cleaver, 2017).

According to Bromley (2006) institutional change can happen in three steps. First, to recognize that something is wrong, by identifying particular behaviors with consequences that are no longer "acceptable or reasonable" (p. 73). Second, to create new alternatives, and third to evaluate the alternatives and create change with new policies.

Vatn (2015) makes emphasis on the importance of power when recognizing what is wrong and for whom, since it is different to push for change when it concerns to the powerful, than pushing for change when it concerns to the powerless. With Vatn's EGS framework as a base, the negative outcomes can be caused by 3 reasons. First by natural causes. Second, by problems with the function of institutional structures, as high transaction cost, or opposite motivations and rationalities. And third, after some technological change that have unexpected effects (Vatn, 2015).

Going back to Bromley (2006) and the three steps of institutional change, the creation of new alternatives in the second step, helps to reduce uncertainties and set the conditions for action, to delegitimize or destroy authority of existing institutions to legitimize new solutions (Blyth, 2003; Vatn, 2015). In the third step, power and uncertainties are emphasized again. The emphasis on power relates to forming other people's visions, and to the power to decide what issues have priority and whose interests to protect (Vatn, 2015). Uncertainty is related to the causes of the problem and the effects of institutional changes to fix the problem. It can lead to action to fix the problem, it can create inaction, or it can be used to create the inaction to protect the interests of some (Vatn, 2015).

A lack of capacity to change can also cause inaction, and in order to increase the capacity to change, new actors might need to be created, i.e., a new political body. Cleaver (2017) explains that institutional changes can occur by self-structure or "bricolage" to cover new functions, as an influence of changes on another institution, and by copying existing rules.

3.5 Application of theory

Vatn's theory will be used to map the EGS framework and identify the main actors, institutions, and policy instruments within the governance structure. Since the research and the case study are focused on the implementation of new technologies and not on the governance of natural resources, the study does not investigate resource regimes.

The theories of institutional change will be a base to identify the dynamics of current institutional change. The different theories will help to analyze how institutional change happens, and which could be possible future changes inside the governance structure for or against the implementation of CCU and e-fuels.

4. Methodology

This chapter explains the methodological framework used for the research. The chapter is divided into five sections, starting with an overview of the methodology and a description of the methods applied to collect and analyze data. Following with a description of the research design and the data analysis. And finally, with two more sections that include the research challenges and limitations, and the ethical considerations.

4.1 Methodology overview

The research design of this study is oriented towards a qualitative research since, inspired by Vatn (2015) theory, it looks to analyze a governance framework where different actors, institutions and policy instruments are involved. The data for the research is based on actors' perceptions and policies. As Bryman (2016) explains, a qualitative research emphasizes words and could be inductivist, constructionist and/or interpretivist. The study has an inductive approach since it looks to generate new theories from the analyzed data and follows the six main steps of qualitative research; 1) *General research questions*, 2) *Selection of relevant sites and subjects*, 3) *Collection of relevant data*, 4) *Interpretation of data,* 5) *Conceptual and theoretical work*, and 6) *Writing up findings/conclusions* (Bryman, 2016, p.374-379). This process was not linear and involved several rounds of data collection and interpretation.

4.1.1 Epistemological and ontological considerations.

The epistemological considerations refer to what can we know and how can we gain the knowledge (Bryman, 2016). Interpretivism is one central epistemological position, it embraces the subjectivity of all the participants and the researcher, acknowledging that the researcher has a perspective that may influence the research. Interpretivism's' knowledge comes from descriptions and interpretations of social phenomena, and it looks to generate theories through inductive research. Positivism is the opposite stance of interpretivism. It recognizes empirical experience by observation and measurements as the only acceptable knowledge, and emphasize that this knowledge can be conducted without bias or perspectives of the participants or the researcher. Positivism is usually related to hypotheses testing or deductive approaches, however, it also covers inductive approaches since the testing hypotheses are based on inductively gathered knowledge (Bryman, 2016). Since the study is based in a qualitative research, analyzing texts and different perspectives of participants, the epistemological position of the research could be easily related with an interpretivist approach.

However, the analysis of the research does not make a thorough interpretation of the different perceptions and observations of the data collected. The results of the research explain the observations and perceptions collected in the documents and the interviews, leaning more towards a positivism epistemological position.

Ontology refer to the nature of being, the existence, and the reality (Bryman, 2016). There is a debate between two ontological positions, objectivism and constructivism. Objectivism explains reality as something definitive and outside the human understanding, while constructivism explains reality as created by social understanding and experiences (Bryman, 2016). Despite the positivism and objective position with the results of the data collected, the research has a constructivism approach since it recognize the important role of people on the construction of the reality. The different perceptions and participations of the actors involved in the governance structure, are an important part of the creation of the conditions for the implementation of new technologies like CCU and e-fuels.

4.2 Research design

The study design starts with a text analysis. First, stablishing a background and a theoretical framework as preparation of knowledge with relevant available data. The theoretical framework is based on scientific articles and textbooks in regards environmental governance, with special emphasis in institutions, resource regimes, policy instruments and the EGS framework from Vatn (2015). Data collection started in the background part of the study and comes from relevant scientific articles, and official documents from the state and private sources, i.e., reports, policies, and official news and press-release. Additionally, a pre-recorded webinar from Norsk e-fuel was also part of the data. All the collected data covers general context of national and international climate policies, and mitigation strategies, along with specific data for the case study. The case study is Norsk e-Fuel and the governance structure and policy-making processes around CCU, and SAFs in Norway. Using a case study allows to have a deep analysis for the specific setting, however, it limits the generalization and applicability to other cases with different settings and timing (Bryman, 2016).

After the first round of data collection via document and pre-recorded webinar analysis, semi-structured interviews were done for triangulation and to increase the credibility of the study. Based on Lune and Berg (2017), triangulation happens when more than one method, source of data, investigator and/or theories are used, and it helps to have more confidence in

findings and cross-check the data. A second round of text-based data collection were done after the data collected by the interviews.

4.2.1 Text-based data

Since part of the data collection was based on document analysis and not produced as part of the research, it was very important to assess the quality of the sources. The use of state and private sources documents can question the credibility of the study because the source can be in some way biased or have an agenda (Bryman, 2016). To assess the quality of documents, four criteria was used: 1) *Authenticity*: based on its genuineness and origin. 2) *Credibility*: based on lacking of error and distortion, 3) *Representativeness*: based on the evidence and if it is typical of its kind, and 4) *Meaning*: based on clearness and comprehension (Scott,1990,p.6, cited in Bryman, 2016,p.546).

Following the assessment of the documents, the authenticity was clearly confirmed by its origins since only official and published documents were used. The credibility and representativeness of some documents were not that simple, since several of the sources have a pre-established agenda. For example, information published in ENGOs organizations have been written based on their missions, perspectives and specific supporting causes. This was considered to ensure an appropriate use of the data.

4.2.2 Semi-structured interviews

The semi-structured interviews give an open space to have better insights into the participants' opinions, with rich and detailed content. They are based on an interview guide with specific topics to be covered but it gives the researcher the opportunity to improvise if interesting information comes from the interviewee's answers (Bryman, 2016). The interview guide (Appendix A) was designed following the initial text data collected. It followed logical order of topics and recommendations of Bryman (2016), as simplify language, formulate open-ended questions and avoid leading questions. It constitutes only a guide that was adapted according to the special characteristics of each participant.

4.2.3 Sampling

The purpose of the research required a certain type of interviewees, ideally one relevant figure from the involved actors in the governance structure and the developers of Norsk e-Fuel. Purposive sampling, in specific a criterion sampling, was used to select the participants for the

semi-structured interviews. Bryman (2016) explains that a purposive sampling looks to select strategic participants that can give relevant information for the research questions. The criterion sampling approach is suitable for the research since each participant meet a particular criterion (Bryman, 2016). Findings from initial document reviews served as a base to select the first participants.

The first participants selected were representatives of ENGOs with relevant positions to the development of climate solutions for aviation. Part of the interview guide included a question to reference to another relevant actor that could participate in the interviews, creating a snowball sampling that Bryman (2016) categorize as a type of purposive sampling. Lune and Berg (2017) define snowballing as a nonprobability sampling that involves a first identified group of people with certain characteristics that will refer to other people with same or similar characteristics. They claim that it is very useful to identify subjects that are usually difficult to reach.

4.2.4 Conduction of interviews

After a previous pilot interview to test interview skills, interview guide and recording devices, ten semi-structured interviews were carried out between September and October 2021, (Table 1). Two of the ten interviews were conducted in person at locations selected by the participants. Because of Covid-19 restrictions, the rest of the interviewees chose to have the interviews through online phone calls on Zoom or Teams. Each interview lasted between 30 to 60 minutes. Before starting each interview, all the interviewees were asked to read and sign an informed consent (Appendix B and C) with information about the study and confidentiality issues. The confidentiality section included a specification of the recording of the interview. Lastly, before submission the participants received a copy of chapter 5, and 6 to check the results and used quotes.

Table 1: Interview participants, the institution they represent, and reference.

Type of actor	Institution represented	Reference
Civil society actors	ZERO	ZERO1
	ZERO	ZERO2
	Bellona	Bellona1
	Bellona	Bellona2
	Anonymous	Anon ENGO
Political actors	Enova	ENOVA
	Green Party	GP
	Gassnova	Gassnova
	Norwegian Environment Agency	NEA
Economic actor	Norsk e-Fuel	Norsk e-fuel

All the participants agreed to be recorded. Nine of the ten participants asked to remain anonymous and only use the name of the institution they were representing. Only one participant asked to remain completely anonymous, even without mentioning the name of the institution. A different informed consent with an specification of this anonymity was used in this case (Appendix C).

4.3 Data analysis

After the first round of text data collected a background, and the main actors, institutions and policy instruments within the governance framework were identified. These where classified following Vatn (2015) EGS framework. Additionally, several uncertainties and challenges for the implementation of CCU and e-fuels in Norway where identified, along with possible institutional changes around them. Afterwards, the ten interviews were conducted for triangulation.

To facilitate coding of the vast amount of data collected in the interviews, Bryman (2016) recommendations were followed: coding was done immediately, the data was read on repeated occasions and the codes were revised several times. Table 2 bellow shows an example of the coding process, where condensed codes were extracted from initial codes to finally have an essence category.

Table 2: Example of coding process

Initial codes	Condensed codes	Essence category
Overal positive to use CO2 to produce new products if it meets some environmental criteria like renewable energy, use of CO2 from air or biogenic souces	Positive position to certain sectors and with certain sustainability criteria	Overall positive
We see e-fuels as one sustainable solution for aviation. We want to promote it as a sustainable fuel and we want to promote the production of this fuels		
Positive for hard to decarbonize sectors like aviation		
We are positive, we see e-fuels as a solution for difficult to decarbonize sectors.		
We see overall problems with e-fuels for several reasons	Negative position to introduce e-fuels but not necessary to CCU	Overal negative
The emission reductions are not big enough to justify the electricity consumption. Its very unlikely that its a solution for large scale fuel production		
We are positive towards CCU, but very skeptical towards the use of e-fuels.		
We do not have a clear position	Not a clear position yet	Neutral
We do not have a position		
We do not have a position yet, we are waiting for the definite EU regulatory framework		

4.4 Research challenges and limitations

The criterion sample approach presented some limitations to reach some participants, resulting in an uneven number of participants from each category, political, civil society, and economic actors. The participants gave an excellent base for triangulation with the text data collected, however, an extended time to reach and interview more actors would have been beneficial to increase the credibility of the results.

Most of the participants were male, and only two were female. It was difficult to find a balanced number in the gender of the participants, however, the level of knowledge and expertise in the topic were mostly similar for all the participants. All the interviews were uncomplicated to conduct since all the participants had a good level of knowledge of the topic. However, COVID-19 constituted a challenge because most of the interviews had to be done through online video calls on Zoom or Teams, when the initial plan was to conduct the most of them person. In turn, this become more time-efficient, and a less stress environment for the respondents.

A language barrier was a limitation. Even though most of the data is presented in English language, many of the official documents and interviews participants' primary language is Norwegian, which the researcher does not understand fluently.

4.5 Ethical considerations

Ethical considerations include issues of harm, privacy, confidentiality, consent, honesty, integrity, and responsible reporting (Lune & Berg, 2017). Several precautionary actions were taken to ensure all the ethical considerations in this research.

All the subjects who took part in this research were, to my knowledge, not vulnerable or at any level of physical risk by participating in this study. As explained in section 4.2.2 Semi-structured interviews, an informed consent (Appendix B & C) was presented before the interview. This informed consent was also explained during the interview, followed by a designated time for questions and answers on the document. It included several sections. Starting with general information about the study, and the potential risks and benefits of participating. The potential risks were identified as low and the only risk identified was a possible challenging feeling by the questions or ideas they had not before considered.

A confidentiality section was also part of the document. It explained that the information shared was going to be used in the study, specifying that no personal data was going to be stored or used. As also explained in section 4.2.2, only the name of the institutions the participants represented was used in the research, with exception of one case that asked for complete anonymity. There was no need to notify to the Norwegian Centre for Research Data, since the study do not use any personal data about the participants. The confidentiality section also included a specification about the recording of the interview, the secure online storage of the data on a NMBU facility, and the commitment to destroy it after submission and presentation of the study.

Two more sections were part of the informed consent, a clarification of a voluntary participation, and the right to withdraw from the study. Along with these last two sections, the informed consent covers the issues of harm, privacy, confidentiality, and consent. Regarding the issues of honesty, integrity and responsible reporting, neutrality in the interpretation of the data was key. The representativeness of the participants and the data collected from documents was carefully respected with a high level of neutrality to avoid bias in the analysis and findings of the research.

5. Analysis

The purpose of this chapter is to find the answers to the three first sub-research question of the study with the results of the data collected. By answering the sub-research questions, the EGS framework will be applied for analysis, identifying the main actors, institutions, resource regimes and policy instruments involved in the development and implementation of e-fuels in Norway. Fig, 3 and Fig. 4 show the broad picture of the international and national EGS of e-fuels. SRQ 1 in section 5.1 is focused on the main political, economic and civil society actors involved at different levels. Institutions and policy instruments are analyzed in section 5.2 to answer SRQ 2. Finally, section 5.3 answers SRQ 3, identifying the challenges and uncertainties for the adoption of e-fuels, and how are they being managed.

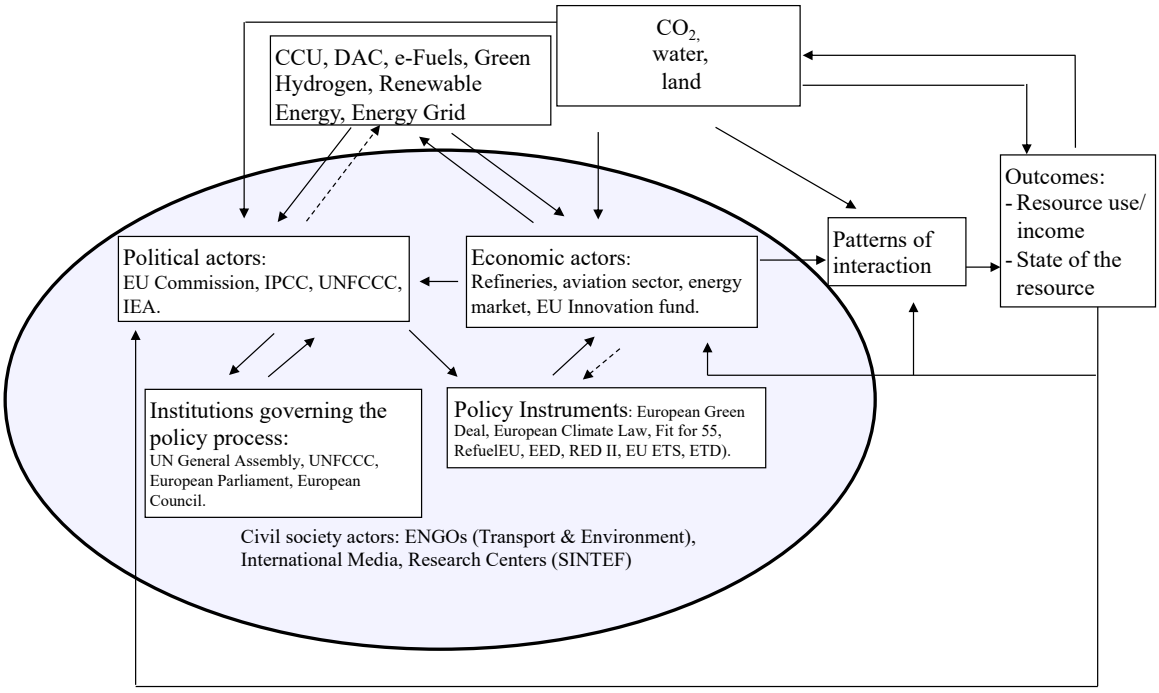

Figure 3: International EGS framework based on Vatn's EGS framework.

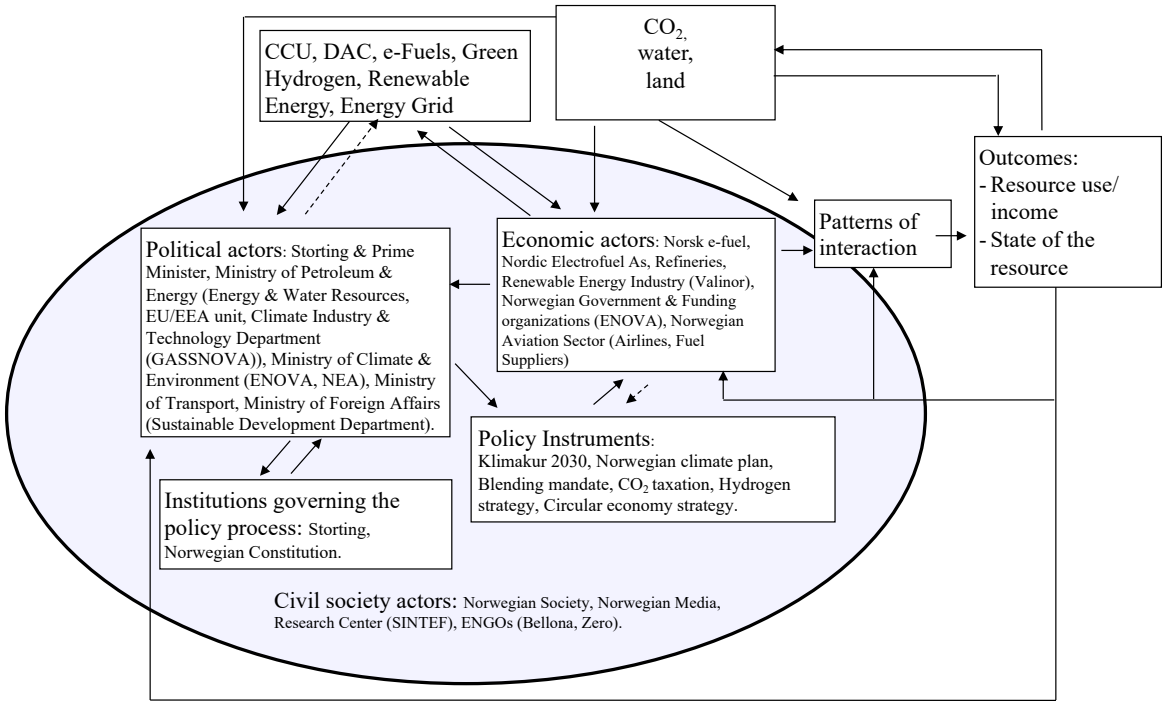

Figure 4: National EGS framework based on Vatn's EGS framework.

5.1 Main actors influencing the implementation of e-fuels

Since climate change is a global problem in need of global solutions as an energy transition, strategies to achieve this encompasses the action of actors from all levels. Implementing e-fuels in Norway, as part of an energy transition strategy, involves different actors from several levels and with different perspectives.

5.1.1 Political actors

The main political actors involved in implementing e-fuels in Norway are at international and national levels. The IPCC, the UNFCCC, the European Commission and the International Energy Agency (IEA) are important intergovernmental political actors. As a member of the IPCC and, and as part of the Paris Agreement through the UNFCCC, Norway's climate commitments and environmental policies take the recommendations of the Panel. For example, in its climate action plan published in January 2021, the Norwegian government establish new policy instruments as taxation of GHG emissions and financial support for new technology development as CCS (Regjeringen, 2021a).

The results from the semi-structured interviews show that the EU, or specifically the European Commission, is the most important international political actor since it was the only one mentioned by most of the participants. This result might be related to the current agreements with the EU, and the recent publication of the "Fit for 55" package by the European Commission, which will be further explained in section 5.2.2.

As part of the EEA agreement, explained in section 2.6.4, Norway is also part of the EU climate legislation. Because of this, the European Commission is an important international political actor influencing the implementation of e-fuels in Norway. The EU Commission works to create, evaluate and introduce the EU's policies and strategies (European Commission, 2021c). The Commission, bases its work on six priorities: the European Green Deal, a digital future for Europe, a stronger Europe, an economy that works for people, the promotion of European way of life, and the protection of democracy (European Commission, 2021d). The European Green Deal is relevant for the implementation of e-fuels because it aims to transform the EU into a modern economy with net zero emissions of GHG by 2050 (European Commission, 2019). In April 2021, Norway published its perspectives and contributions with the European Green Deal, where they declare their willingness to partner with the EU and contribute to its implementation (Regjeringen, 2021d). The Deal will be further explained in section 5.2.2 as a policy instrument.

The IEA is a global energy authority, in charge of providing data, and policy recommendations to help its members to have a secure and sustainable energy for all (IEA, 2021c). Its policy recommendations promote solutions as renewable energy, and new technologies like CCUS and sustainable fuels to advance a secure and clean energy transition. There are 30 member countries, including Norway, who have been receiving the IEA advice for its energy transition policies since 1974 (IEA, 2021c). As part of the recommendations for Norway to achieve its climate goals by 2030 and 2050, the IEA sees major potential in the transportation and in the oil and gas industries. Additionally, they recommend high investments in energy research, design and development (RD&D) like CCS (IEA, 2021d). Despite the importance of the IEA and all the collaborations with international political actors, Norway is not legally obligated to follow them. The recommendations are analyzed and approved by the main national political actors.

Norway's political framework develops in a parliamentary, democratic and constitutional monarchy with 3 branches of power. An executive power exercised by the

Government and lead by a Prime Minister; a legislative branch with an unicameral parliament, the Storting: and the judicial power in the courts (Regjeringen, 2021e). From all the political actors involved in the policy making and the development of technologies in Norway the most relevant for implementing e-fuels include the Prime Minister, the Storting, political parties, several Ministries from the Government, and derivate entities involved in environmental protection, climate change issues, energy transition, and RD&D.

Most of the decision-making and political debates takes part in the Storting by the elected representatives of the Norwegian people. Their main tasks are to introduce legislation, allocate public spending, impose taxes, and control the Governments work (Stortinget, 2021a). It is formed by 169 elected members from several political parties with different purposes that focuses towards left, central, or right wing politics (Nikel, 2021). During the research period of this study, parliamentary elections were held in September 2021, and by October 2021, the 166th Storting and the new Government 2021 to 2025, was opened and appointed by The King (Stortinget, 2021b; Stortinget, 2021c). The majority is for the left-wing Labor Party and the right-leaning Conservative Party, with 48 and 36 members each. Followed by the Centre Party with 28 representatives, and the farthest right-wing, the Progress Party, with 21 (Valgdirektoratet, 2021a).

The party with fewer seats in the Storting is the Green Party. However, two of the interviewees mentioned it as an important political actor with relevant opinions regarding the implementation of e-fuels, because of its special interest in the environment and climate policy. One of its representatives was a participant in the interviews and clearly explained their position towards CCU and e-fuels:

"We are positive towards CCU, but we are very skeptical towards the use of e-fuels, and the main reason is that this is a bad way of using the energy." [1] *(Interview, GP, 2021)*

The now leading Labor Party was the largest opposition party in the Parliament since 2013. It has a social democracy based ideology that looks for freedom, equality and solidarity (Arbeiderpartiet, 2021a). In regards climate policies, the party supports initiatives that look for 55% cut of GHG emissions by 2030. Increasing CO_2 tax, support investment for initiatives about offshore wind, and cross-sectoral investments for CCUS and hydrogen production, are

[1] Quote 1

some of its climate policies (Arbeiderpartiet, 2021b). On the other hand, the Conservative party defines itself as pursuing *"... a conservative progressive policy based on Christian cultural values, constitutional government and democracy..."* (Høyre, 2021a). Regarding climate and environment, it makes special emphasis on a green shift with more renewable energy according to the increasing demand and the need to replace fossil fuels (Høyre, 2021a). It has an ambitious desire to cut 90% of GHG emissions by 2050 based on circular economy strategies and a recycling culture. The party has also a 2021-2025 program that makes emphasis on investment and support for green and blue hydrogen production and offshore wind projects (Høyre, 2021b). After the last elections, the Conservative party lost its majority of seats in the Parliament, therefore, as of October 2021, the new Government is a coalition between the Labor Party and the Centre Party, led by a Prime Minister from the Labor Party (Stortinget, 2021b). The new government has not express a clear position towards e-fuels on these initiatives or on The Hurdal Platform, that sets the basis for the new coalition government (Arbeiderpartiet, 2021b; Arbeiderpartiet & Senterpartiet, 2021).

The Prime Minister is responsible of coordinate and lead all the work of the Government (Regjeringen, 2021f). The Ministries, as part of the Government, work in specified areas of concern. All the Ministries represent an important political actor with relevant insights to policy development. For the implementation of e-fuels, the Ministry of Petroleum and Energy, the Ministry of Climate and Environment, the Ministry of Transport, and the Ministry of Foreign Affairs have a relevant participation.

The Ministry of Petroleum and Energy is in charge of the energy policy, that must ensure an efficient and environmental-friendly management of the energy resources (Regjeringen, 2021g). Under this Ministry, there are 3 relevant actors: 1) the Energy and Water Resources Department, in charge of economic and environmental management of domestic energy sources and use; 2) the EU/EEA unit, that manages coordination between concerning directives; and 3) the Climate, Industry and Technology Department, that focus on the promotion of innovation, development and internationalization of the energy industry (Regjeringen, 2021g). This department is also responsible for projects for CCS and the ownership of Gassnova SF, which is in charge of the development of technologies and knowledge for CCS, and the coordination of the "Longship" project mentioned in section 3.1 (Gassnova, 2021). The interviewed representative of Norsk e-fuel mentioned Gassnova as an important political actor for the development of CCU, and Gassnova was also one of the

participant actors in the interviews. The participant explained they do not have a position since the Ministry has sent no instruction to develop this type of technologies and added some personal opinions:

"For Norway, CCS makes sense because we have oil and gas. We could continue producing oil and gas without the climate effects if we use CCS. (...) Synthetic fuel is a direct competitor for natural gas (...) Fossil fuels had made Norway rich, why should develop a technology that competes with the technology that makes it rich? (...) This is the reason why I think Gassnova has not received any tasks or missions from the ministry in order to develop this type of technology." [2] (Interview, Gassnova, 2021)

The Ministry of Climate and Environment is in charge of environmental policies (Regjeringen, 2021h). Among its several departments, the Department for Climate Change is a relevant actor. It focuses on international work and the creation of national policy relating to climate issues, the environment, and development. Under its management is the state-owned enterprise ENOVA, previously mentioned in section 3.7, that promotes the shift to a clean energy production and consumption, as well as the development of new technologies by funding innovation projects. Also under its management is The Norwegian Environment Agency (NEA), another important actor that implement and gives policy advice based on reducing GHG emissions, and protect Norwegian nature. Among its functions are to review and communicate national and international environmental information, as well as to implement, regulate, supervise, and guide regional and local government levels (Norwegian Environment Agency, 2021b). Both ENOVA and the NEA were interviewed. Its representatives explained they do not have a clear position towards e-fuels yet:

"In ENOVA, we have many different state aids support programs with different technologies and different levels of maturity (...). In addition to these national schemes, we also have the national role of supporting what is called the EU Innovation Fund (...) Within the EU Innovation Fund there is a special track for CCU and also for products that we placed common fossil based products. Which means that e-fuels and technologies for e-fuels have their home in the EU Innovation Fund. One role of Enova is to be what is called like a

[2] Quote 2

national contact point for the EU innovation fund, so we help Norwegian applicants to use that fund and also to follow up within the funds administration to look after Norwegian interests there." [3] (Interview, ENOVA, 2021)

Enova have not funded any e-fuels projects because of the base of their processes, the interviewee explained that Enova have two tracks of support. One is the Pilot scheme, that support the technology elements in any operations that could be improved. For these, Enova do not care on the climate result of particular projects, just on improve the technology. Secondly there is the full scale track, to provide support to full industrial deployment, the requirement for those investments is to have a clear climate contribution compared to a standard investment.

"For an e-fuel project, at the pilot level, that would be to improve the DAC process for example (...) E-fuels is not something that we had supported or we find that we can support as on now, within the full scale track (...) because how can you tell that one e-fuel factory can be better than other e-fuel factory? (...) the regulatory conditions for e-fuels at the moment are a bit unclear still." [4] (Interview, ENOVA, 2021).

As for the NEA, the interviewee explained they were still waiting to define a position:

"We have not taken a specific position yet, we are still waiting on the definite regulatory framework from the EU (...) we have not made an official position yet (...) we are keeping an open mind and trying to learn more" [5] (Interview, NEA, 2021)

Continuing with the Ministries, the conditions within the framework of postal activities, civil aviation, public roads, rail transport and ferry services, are responsibility of the Ministry of Transport. Some of its relevant responsibilities, are the civil aviation's legislative and regulatory work, and the coordination with the EEA work (Regjeringen, 2021i). Last, the Ministry of Foreign Affairs is in charge of securing and promoting Norway's interests at the international level. Among its extensive responsibilities, the management of Norway's relations with the EU, its policies analysis and coordination of work are important for the development

[3] Quote 3
[4] Quote 4
[5] Quote 5

of e-fuels. Its Department for Sustainable Development takes special attention to promoting Norway's energy interest and matters of climate change and the environment.

Many other underlying organizations under different Ministries have also an important influence as political actors. For example, the Research Council of Norway, under the Ministry of Education and the Ministry of Trade and Industry, is the most important research policy adviser (Regjeringen, 2021j; Regjeringen, 2021k). It is in charge of funding for research and innovation through different portfolios, including Energy, transport and low emissions (The Research Council of Norway, 2021). Within this portfolio, research to improve efficiency of technologies for the creation of e-fuels could be very relevant.

The Norwegian Government has a robust organization working on environmental and energy issues that impact the implementation of e-fuels. However, considering the results of the conducted interviews, the most relevant political actors in the National levels are the Norwegian Environment Agency, the Ministry of Petroleum and Energy, and the Ministry of Climate and Environment.

The result of the semi-structured interviews showed that the most mentioned political actor was the European Union, followed by the national political actors the Norwegian Environment Agency, the Ministry of Petroleum and Energy and governmental organization for R&D like Enova, Gassnova and Innovation Norway.

All the mentioned political actors influence in different ways to the creation of policies that can help or complicate the development and implementation of e-fuels. The Storting develops the policies with the advice of several bureaucracies, and many of this bureaucracies are also the ones in charge of implement and regulate them. Coordination between them seems fundamental for successful creation and implementation of policies. For example, in 2019, the Norwegian Government commissioned some of the bureaucracies a study with measures and instruments that can help cutting 50 % of non-quota emissions by 2030, the Klimakur 2030 report (further explained in section 6.2). The report was coordinated by The Norwegian Environment Agency and works as a guide for the Norwegian climate policies (Norwegian Environment Agency et al., 2020; Regjeringen, 2020b).

5.1.2 Economic actors.

Some of the main economic actors involved in the development of e-fuels in Norway are the associates of Norsk e-Fuel project: Climeworks, Sunfire, Valinor and Paul Wurth (see section 3.4). Before constituting Norsk e-Fuel, Sunfire was partner with Nordic Electrofuel AS,

which had recently change its name from Nordic Blue Crude AS (Nordic Electrofuel AS, 2021). The company constitute the direct competitor of Norsk e-Fuel and began its plant construction also at Herøya Industry Park in Porsgrunn in May 2021 (Viseth, 2020; NRK TV, 2021). They intend to become the first plant in operation to produce e-fuels for sale to aircraft worldwide. For this, they will use captured CO_2 , water and renewable energy (NRK TV, 2021). The main differences with Norsk e-Fuel is on the CO_2 capture source and the electrolysis technology (Viseth, 2020). Norsk e-Fuel wants the exclusivity to direct air capture and Sunfire's electrolysis technology, while Nordic Electrofuel will use captured CO_2 from neighboring industrial plants, and high-pressure alkaline electrolysis. This technology has longer been tested, and they claim it to be better in the short run reducing financial risks. Both companies agree that the aviation market for e-fuels is big enough for both to succeed (Viseth, 2020). Because of this, the development of both economic actors constitute a big influence to the implementation of e-fuels.

The product created by the technologies of Norsk e-Fuel is a renewable crude oil substitute that can be used to a variety of applications. After this phase, the e-crude must be refined to create certified products (Norsk e-Fuel, 2020b). The synthesis process they use to produce the e-crude, is a chemical process called Fischer-Tropsch, which is already certified and used by some refineries (Norsk e-Fuel, 2020b). The refineries who do this, represent an important economic actor to actually have the final product. Karl Hauptmeier, the Managing Director of Norsk e-Fuel, explained that they intend to add refinery partners to the project. The already existing refineries will receive the "raw product" produced in several locations around Norway, and transform it to specified applications (Norsk e-Fuel, 2020b).

The companies within the renewable energy industry and the energy market are also relevant economic actors. The availability and reasonable prices of renewable energy are very important for the profitability and sustainability of e-fuels. For Norsk e-Fuel, Valinor is the most important economic actor in this sector, however, the rest of the industry are also important since they could impact the renewable energy market. Norway is part of an integrated energy market with interconnections with Sweden, Denmark, Finland, Netherlands, Germany, the Baltic states, Poland, Russia, and most recently with the UK. These interconnections makes it part of the wide European power market (Enery Facts Norway, 2021). The energy market has some instruments to ensure competitive prices like the market coupling. However, it is important to address that changes in the energy demand and the fluctuating conditions for

renewable energy production, like dry summers for hydropower, could generate changes in the market.

With a an equal number of mentions as e-fuel producers in the semi-structured interviews, the aviation sector, including airlines and fuel suppliers, is another important economic actor as it will be the consumer of the product. Domestic and foreign air traffic in Norway contributes to 5.5% of the total national emissions (Larsen et al., 2020). With important commitments to reduce this emissions, the aviation industry in Norway is working with several strategies. The introduction of SAFs is one of them. Since the Norwegian government introduced a blending mandate for advanced biofuels from 2020, the aviation market has already started with similar sustainable practices (Larsen et al., 2020).

The financing of the project also brings another important economic actors. First, national and international investors from the private sector, and second, international governmental organizations and the Norwegian Government. Through some of its dependencies, the Norwegian Government can destinate founds to research and development of the technologies involved, and also it could participate with economic investment. Since e-fuels projects represent a new business industry, and are innovating solutions that could help with the Norwegian climate commitments, economic investments to support this projects may be convenient. Carl Berninghausen, as a representative of Sunfire GmbH for Norsk e-Fuel, mentioned that the project will need investment from the private sector and from the Norwegian Government (Norsk e-Fuel, 2020b).

The EU Innovation fund, mentioned previously by the Enova representative, looks for large and small-scale innovative low-carbon technologies in energy-intensive industries, CCUS, renewable energy, and energy storage. The fund is funded by the EU ETS from the auction of 2020 to 2030 allowances and unspent funds from previous funding program NER300 program (European Commission, 2021e). The fund already published the winners of the first call for large-scale proposals in 2020. Norsk e-Fuel is part of the list of 15 winner projects around the EU, Norway and Iceland, to receive funds for project development assistance (European Commission, 2021f).

5.1.3 Civil society actors.

Among the civil society actors that define the normative basis and ensure the legitimacy of political action, the study identified several relevant actors to the implementation of e-fuels. First, the Norwegian society. As a democratic country, the Norwegian society takes an

important part on the policy making process by choosing its representatives, and manifesting to the government initiatives. Norwegian society has an important percentage of participation in the election of its representatives, for example, the elections of the Storting in 2021 had 77.2% of voters turnout (Valgdirektoratet, 2021b). Additionally, an ongoing research project from the Center for International Climate Research (CICERO), showed that the majority of the Norwegian population believes in climate change as a negative effect caused by human activity (Aasen et al., 2019). Also a large majority believes that changes to cut emissions must be done in every sector, as well as in the individual level. Finally, regarding policy instruments for emissions reductions, young people under 30 are the most positive, and there is an increasing resistance in all the other age groups (Aasen et al., 2019).

The second relevant civil society actor is the media since its one of the factors that influence the most to attitudes and perceptions of climate change (Aasen, 2017). Studies reveal that Climate Change issues attention from the Norwegian media has been increasing steadily since 2000 (Ryghaug & Skjølsvold, 2016). Data recollected from retriever.no shows that in all the Norwegian press, 7,641 articles related to Energy and Climate were published in 2020. Additionally, according to the 2020 Norwegian Media Barometer, 77% of the total population read printed and online newspaper combined (Statistics Norway, 2021). The data presented can show how much influence media could have for climate and energy related issues. The information published clearly reaches the majority of the Norwegian population, who will use this information to shape its attitudes and motivations, which in turn, will also influence in its participation in political decisions.

Scientific results, are also an important influence for attitudes and perceptions of climate change (Aasen, 2017). Because of this, research centers and communities are the third important civil society actors selected for this analysis. SINTEF as one of the independent biggest research centers in Europe, have work in several multi-disciplinary researches in many relevant topics, among them, related to climate and environment, and zero-emission transport (SINTEF, 2021a; SINTEF, 2021b). The organization income comes mainly from won contracts in open competitions, having 48% of its total income from Norwegian and international business and industry, and 30% of grants from The Research Council of Norway (SINTEF, 2021a). As already explained in section 6.1.1, The Research Council of Norway is the most important research policy adviser for the Norwegian Government. Because of this, SINTEF

becomes a relevant actor with huge potential to influence the Norwegian policy if participating with research related to e-fuels and the CCU value chain.

The fourth relevant civil society actors for the analysis are environmental NGOs (ENGOs). ENGOs have pushed governments of industrialized countries to implement measures to reduce its GHG emissions since 1980s (Tjernshaugen & Lee, 2007). In the semi-structured interviews, Zero Emission Resource Organization (ZERO), Bellona, Transport & Environment (T&E), and Friends of the Earth Norway, are the most mentioned civil society actors that can influence in matters of e-fuels implementation in Norway. Three ENGO's where selected to participate in semi-structured interviews, ZERO, Bellona, and a 3rd participant that preferred to remain anonymous because some of the information discussed during the interview was on the sideways of the organization position. The anonymous ENGO expressed a positive position towards the implementation of e-fuels, specifically for aviation, including some considerations regards the CO_2 source and the regulatory framework.

ZERO is a Norwegian ENGO that works on solutions for climate crisis, focusing on the development and promotion of solutions for the business community and the political instruments (ZERO, 2021). The creation of a market for new zero-emission technologies with help of business and the political system is part of its ideology to achieve a global change. Among the several work topics of ZERO are transportation, energy and industry. They support initiatives for CCS, hydrogen, national and international renewable energy, and emission-free transportation (ZERO, 2021). In May 2020, they released a report about circular carbon economy and the reuse of CO_2 emissions as a climate solution (Post-Melbye & Stub, 2020). In the report, they analyze the potential of reuse CO_2 as a climate solution and gives some suggestions of policy instruments to the Norwegian Government to incentivize initiatives of CCU like e-fuel production. Some of the important suggestions are about driving the technology development towards having a major source of CO_2 from the atmosphere, and related to the CO_2 emission taxes in different industries (Post-Melbye & Stub, 2020). The interviewed representatives of ZERO expressed the positive position of the institution towards implementing e-fuels in Norway.

"We see e-fuels as one of the sustainable solutions for aviation. (...) We want to promote it as a sustainable fuel and we want to have political incentives for sustainable production of this fuel." [6] (Interview, ZERO2, 2021)

However, they specified that the production of new CO_2 based products should meet several environmental criteria, like the use of renewable energy, DAC or CO_2 from biogenic sources. They made emphasis on having special care to avoid double counting of CO_2 emissions cuts. These two specifications are equally important for Bellona,

Bellona is an independent, non-profit organization based in Norway and working in national and international environmental issues (Bellona, 2021). It works to fight climate challenges and implement sustainable solutions. Among its working topics are renewable energy, CCS, energy efficiency, climate change and fossil fuels (Bellona, 2021). Bellona has been called a policy entrepreneur for its influence in the CCS political debate in Norway (Tjernshaugen, 2011). It has positioned as a key influential actor after its work on CCS by attracting media attention and establishing relevant dialogue with influential actors in politics and business (Tjernshaugen, 2011). In the semi-structured interviews, the Bellona representatives expressed a clear negative position towards the implementation of e-fuels with very punctual points.

"We mostly see problems with e-fuels for a number of reasons." [7] (Interview, Bellona1, 2021)

"T*he emission reductions is not big enough to justify the electricity consumption (...) It is very easy to get into highly energy demanding processes with very low efficiency when it comes to how much electricity you put in and how much fuel you get out (...) It is very unlikely that it is a solution for large-scale fuel production, so we don't really see a way forward for e-fuels in general"* [8] (Interview, Bellona2, 2021)

In July 2021, Bellona launched "The net-zero compatibility test: a simple guide for GHG accounting of CO_2 use" (Wiriskey, 2021). The report explains what are e-fuels, how to

[6] Quote 6
[7] Quote 7
[8] Quote 8

count its environmental impacts, and the importance of the electricity and CO_2 source to understand the real value as a mitigation tool. The report made some policy recommendations to ensure regulation and monitoring of CO_2 sources for e-fuels. To the EU ETS, the recommendation is related to the surrender of allowances for all the emissions of GHG that will not be released directly to the atmosphere. If CO_2 from an ETS installation will be reused and not permanently stored, the ETS installation must surrender allowances for it, as if it were a regular emission directly to the air. The emission reduction resulted from the reused CO2 must be allocated to the CO_2 user, the airlines in this case. To the EU, Bellona suggests the enforcement of differentiation between CO_2 sources. To incentivize atmospheric CO_2, and to include fossil CO_2 in the system for counting. The same recommendation is referred to the ReFuelEU initiative that is part of the "Fit for 55" package, further explained in section 6.2.3.

ReFuelEU has been also analyzed by T&E, which has helped on shaping some European Environmental Laws like the EU ETS. The organization has 30 years working for a mobility system with zero emissions and lower environmental impacts (Transport & Environment, 2021a). They support the implementation of e-fuels for aviation that meets certain conditions as the use of DAC and additional renewable energy (Transport & Environment, 2021b). Some of its recent publications have important relevance in the development of e-fuels and CCU. For example several analysis and recommendations for the "Fit for 55" package (Transport & Environment, 2021b; Transport & Environment, 2021c), a study about the relevance of DAC for e-fuels (E4tech (UK) Ltd, 2021), and a study about DAC for aviation e-fuels versus DACCS and why should CO_2 be reused for e-fuels (Cames et al., 2021).

Friends of the Earth Norway, is part of the worldwide organization Friends of the Earth, and its main work is for conservation of nature and the environment with a focus in transportation, climate change, energy and conservation (Naturvernforbundet, 2021). The organization does not have an official position towards e-fuels. However, on its publication of their position about aviation and climate change, they welcome the development of innovation as synthetic fuels without reducing other mitigation action as encouraging to limit the use of aviation (Friends of the Earth Policy, 2021).

5.2 Institutions and policy instruments at play in implementing e-fuels.

This section analyze the relevant institutions for CCU and e-fuels within the governance structure. First, the institutions deciding how the decision-making process takes place and who

participates. Second, which are the policy instruments that influence in different ways to the implementation of CCU and e-fuels.

5.2.1 Institutions governing the political process.

As explained in section 4.2 the Institutions governing the political process can be "*constitutional rules and collective-choice rules*" (Vatn, 2015,p.144) that determine the policy-making bodies and who participates on the policy-making process. At the international level, Vatn (2015) explains, there is no third party or major rule with legal consequences for countries if withdrawing a negotiation. However, there are several institutions to ensure legitimacy of IGOs. In the case of the IPCC, as an UN body, it was approved by the UN General Assembly (UNGA), which is the main international policy-making organ that comprise all the 193 country members of the UN, each with an equal vote (IPCC, 2021; United Nations, 2021). In the IPCC, the 195 representatives of its governments are the ones who decide on the organization's budget, the working program, the IPCC Chair, the Working Groups and Task Forces, and the approval of the reports (IPCC, 2021). The members have annual plenary sessions to discuss and decide on each topic. These sessions are also attended by several experts, research centers and Observer Organizations (IPCC, 2021). As explained in section 3.5.2, the UNFCCC facilitates the negotiations of the IPCC and sets the normative for international coordination in climate matters. With the scientific explanations and recommendations of the IPCC, the members of the UNFCCC adopt agreements during the COPs. These agreements, like the Paris Agreement, set the rules and normative to work for adaptation and mitigation of climate change. The UNFCCC secretariat is in charge of the implementation of these agreements (UNFCCC, 2021a).

At the EU international arena, the law process starts with pre-assessed initiatives from the EU Commission which has to be approved by an elected European Parliament, and the Council formed by the governments of the EU countries (European Union, 2021). The pre-assessment of initiatives consists on an impact assessment with advantages, disadvantages and possible policies, as well as consultations to local authorities, industry representatives and civil society actors. In case any of the member countries thinks they could work better with the problem at a national level, they are free to express their reservations (European Union, 2021).

The Norwegian political process is ruled by the constitution and the Storting (Stortinget, 2021a). The new policies are proposed by the ministries as bills, which in turn are debated and decided by the Storting *(NORDRUM, 2020)*. For the proposal of new laws or policies, the

Government often uses the *Norwegian Official Commissions*, or what in Norwegian is called as *Norges Offentlige Utredninger* (NOU) (Christensen & Hesstvedt, 2019; Melby, 2019). These commissions are defined by the terms of the Government, they appoint specific actors or committees to take part, when are they using them, and which policies will be investigated. The participants of the commissions are usually academics, politicians and interest groups from civil society. Its main purpose is to bring together the different perspectives of expertise and stakeholders into public policy. Once the commission is done, the recommendations are published in the NOU reports submitted to the correspondent ministry (Christensen & Hesstvedt, 2019; Melby, 2019). After the NOU is submitted, the ministry conducts public consultations or, in Norwegian, *Høyringar.* In this consultations, invited actors and public in general can manifest their positions and recommendations about the proposal *(NORDRUM, 2020)*. A recent example is the consultation for the EU-EEA proposal for regulation on sustainable fuel for aviation (RefuelEU Aviation) (Regjeringen, 2021l). This is part of the EU Commission's "Fit for 55" regulatory proposal (further explained in section 6.2.2), that is now being discussed in the Council and the European Parliament. The consultation was requested by The Ministry of Transport and Communications to approximately 130 invited actors to comment on the RefuelEU Aviation proposal and how Norway should work with it. Among the 130 participants are the ENGO's Bellona and ZERO, The Ministry of Climate and Environment, the NEA, Avinor, and national airlines like Norwegian Air Shuttle ASA (Regjeringen, 2021l).

5.2.2 Policy Instruments

This section analyses the relevant policy instruments currently ruling the access and patterns of interaction to resources for e-fuels in the international and national levels. In 2019, the European Commission launched the European Green Deal, previously mentioned in section 6.1.1 (European Commission, S.-G., 2019). The deal describes a plan to change EU's economy into a sustainable economy where economic growth is decoupled from resource use, and climate change challenges could be turn into opportunities for all. The main goal of the deal is to reach climate neutrality by 2050 (European Commission, S.-G., 2019). As part of the plan, in March 2020, the European Climate Law was proposed, and in June 2021 the law entered into force (European Comission, 2021). The law writes into binding legislation the goals of the European Green Deal, including the updated NDC reduction of 55% GHG emissions by 2030 (European Commission, 2021g). In order to reach these goals, the Commission presented the

“Fit for 55”, a set of proposals to align legislation with the European Green Deal (Council of the EU and the European Council, 2021).

The “Fit for 55 package” propose and integrated set of solutions to work together for a green transition that can ensure the accomplishment of 2030 and 2050 climate goals (European Commission, S.-G., 2021). Some of these solutions are new, and some others are extensions from existing legislation. All of them cover a different range of sectors, including climate, energy and fuels, and transportation, among others. The design of the proposals was backed up by an impact assessment analysis that showed that a balanced and interconnected package of policies could bring the better results (European Commission, S.-G., 2021). Given the interconnectivity of the proposals in the package, all the points are relevant and important to achieve an energy transition and the EU climate goals. However, this study looks closer to the ones influencing directly the development of e-fuels for aviation.

Among the “Fit 55” proposals the package looks for a socially fair transformation with new sectors that can offer a competitive transition with a better regulatory framework, and more support for innovation that could bring predictability to investors (European Commission, S.-G., 2021). Instruments like carbon taxation and the expansion of the EU ETS, including the and phase out of free emission allowances for aviation, are some of its proposals (European Commission, S.-G., 2021).

For the transport sector, the package has four proposals for cleaner vehicles and fuels (European Commission, S.-G., 2021). The proposals cover infrastructure regulation for alternative fuels, price carbon for road transports, the RefuelEU initiative to promote SAFs, and the FuelEU Maritime to promote sustainable fuels for all ships coming to Europe regardless nationality origin (European Commission, S.-G., 2021).

The RefuelEU proposes a regulatory framework that increases the offer and demand of SAF by implementing a mandatory blending to existing jet-fuels that will be gradually increasing over time (European Commission, 2021a). Starting with a share of 2% from 2025, to a 63% in 2050 to all flight departures from EU. The proposal makes a clear differentiation of different types of SAFs, considering RFNBOs with very high potential of sustainability, being able to reach 100% emissions savings with renewable energy and DAC technologies. For this reason, the proposal of blending share percentages requires from the total SAF share a minimum percentage of synthetic aviation fuels starting with 0.7% from 2030 to 28% in 2050. The proposal requires policy obligations for suppliers and users, as well as flanking measures

to steer financial support to the development of SAF, and measures to raise ambitions on SAF use, like the facilitation of certifications (European Commission, 2021a).

For the energy sector, "Fit 55" proposes changes on the Renewable Energy Directive (RED), the Energy Efficiency Directive, and the Energy Taxation Directive (ETD) (European Commission, S.-G., 2021). The revision of the RED looks to increase the binding target of renewable energy production from 32 to 40% (European Commission, 2021h). The promotion of renewable fuels such as low-carbon fuels and RFNBOs are mentioned as crucial for sectors like industry and transport that are difficult to electrify. Renewable fuels are already mentioned in the current RED II instrument with a current target of 3.5% for advanced biofuels in transport. However, the new recommendation explains how the current framework offers limited incentives for innovative fuels like RFNBO, and the importance of a certification system to differentiate its energy sources. With the Energy Efficiency Directive proposal, the main objective is to reduce 9% of energy consumption by 2030 by increasing energy efficiency targets and make them binding (European Commission, 2021h).

Finally, the changes for ETD aims to support green transition by aligning minimum tax rates for heating and transport and removing outdated exemptions, like in aviation and maritime transport sectors (European Commission, 2021i). The proposal clearly mentions that the Directive is currently outdated with the EU's legal climate commitments for 2030 and 2050, and makes specific mention of the failure to keep pace with the development of alternative fuels. Because of this, they propose to restructure the tax rates based on the real energy content and environmental performance of the source. By doing this, they aim to have the highest tax to the most polluting fuels. For example, in aviation and maritime transport sectors, the use of kerosene and heavy oil are proposed to have the highest minimum tax rate of €10.75/GJ, that will increase gradually over ten years, while sustainable fuels will benefit with a fixed lowest minimum rate of €0.15/GJ for ten years (European Commission, 2021i).

The "Fit for 55" was acknowledged by all the participants of the semi-structured interviews as a regulatory framework that Norway must adapt because of its legal agreements with the EU. Their opinions of the package varied from neutral to positive, however, all of them had important observations or recommendations for improvement. Some of the most relevant opinions were:

"It is clearly a quite large package (...) with more ambitious approach, especially for transport and renewable fuel (...) It might have some impact on the Norwegian policy, especially regarding the fuel volume mandate for biofuels." [9] (Interview, NEA, 2021)

"Norwegians will have to follow at some point. Fit for 55 is very positive for us. It will be good to have specification on the source of CO2 in the future, since there is some lobbying for example from Bellona that CO2 sources should come from DAC or biogenic sources." [10] (Interview, Norsk e-fuel, 2021)

"The taxation is lower than we have in Norway today, and the mandate is lower than we have in Norway today, (...) Avinor read it as a way that is not allowed to go over the mandate, if that is the case, it will be harder for Norway to have sustainable aviation and then, we will need more tools like the carbon funding. (...) It is interesting the differentiation of RFNBO and I hope that Norway take that into its mandates." [11] (Interview, ZERO2, 2021).

"I think Norway will adopt it, (...) e.-fuels will be permitted and you will also have sustainability criteria that in praxis will make very difficult to produce e-fuels. That's at least what we see in the RED as it is today." [12] *(Interview, Bellona2, 2021)*

"Find surprise that the EU wants to implement a blending mandate of e-fuels. Norway will have to adopt it due to the EEA agreement. It does not make sense at all to mandate e-fuels at this point." [13] (Interview, GP, 2021)

The Minister of Climate and Environment talked about the "Fit for 55" packages and the interest in implementing Norwegian climate goal together with the EU (Regjeringen, 2021m). In July 2021, the Ministry of Climate and Environment with the Ministry of Transport and Communications, the Ministry of Finance, and the Ministry of Petroleum and Energy, did evaluations and consultation of the different proposals of the package (Regjeringen, 2021m). Regarding the proposed regulations for SAF, the Ministry of Transport expressed the

[9] Quote 9
[10] Quote 10
[11] Quote 11
[12] Quote 12
[13] Quote 13

importance of international cooperation and the positive contributions of having common rules and requirements (Regjeringen, 2021n). Considering that Norway is a pioneer in biofuels requirement in aviation, besides the new EU ETS regulations, large parts of the package will be relevant for it (Regjeringen, 2021n).

In the text-based data collected, no public law, plan or specification for CCU or e-fuels by the Norwegian government was found. The results of the semi-structured interviews confirmed that, at a national level, Norway lacks of a clear regulatory framework for CCU and e-fuels.

"There is not a framework for e-fuels and there is not even a classification of these fuels." [14] (Interview, ZERO2, 2021)

"There is no framework for CCU and e-fuels. There is a need of a clearer framework, especially because the CO2 will mainly come from emissions of industries part of the ETS. Those emissions will still go to the air. There is no rules of saying that you avoid emissions by making a CCU product, and since our supports are based on the processes and not the products, it is difficult to say that we can provide support." [15] (Interview, ENOVA, 2021)

"For biofuels it certainly has a framework but not for CCU or e-fuels (...) There are no incentives, except maybe some incentives for R&D," [16] (Interview, NEA, 2021)

"No real relevant framework for CCU. Gassnova is one of the most important tools for findings. There are some important CCS projects founded by them that also have clear intentions on CCU as well. This could be an indicator that Gassnova is open to CCU but there is still no CCU project founded by Gassnova." [17] (Interview, Norsk e-Fuel, 2021)

"There is not a clear strategy even to CCS." [18] (Interview, Gassnova, 2021)

[14] Quote 14
[15] Quote 15
[16] Quote 16
[17] Quote 17
[18] Quote 18

Even with a lacking regulatory framework for CCU and e-fuels, Norway has several instruments that could be relevant for the future implementation of e-fuels. The Norwegian Climate Plan explained in section 2.6.5 with its ambitious goals and defined instruments like the green tax fix of CO_2, the increased support for R&D, and the biofuels mandates could be a good starting point. This plan is backed-up by "Klimakur 2030", an extensive report made by the NEA together with the Norwegian Public Roads Administration, the Norwegian Coastal Administration, the Norwegian Directorate of Agriculture, the Norwegian Water Resources and Energy Directorate, and Enova. The report analyzes several potential measures to reduce GHG emissions and represents the basis for Norway's Climate plans (Norwegian Environment Agency et al., 2020). CCU or e-fuels are not mentioned at any part of the extensive report, however, the Norwegian Environment Agency representative explained that this could change very soon:

"Part of our general assignment is to have updated the current knowledge in both climate mitigation options as well as possible policy. And I think the new government wants to do a new climate mitigation plan very rapidly (...) the climate cure was only for 2030 and its definitely needed to look further ahead, so I think that it is something that will be working on very shortly (...) then you have to also look at e-fuels, for example, it will be very relevant to look at them as a mitigation option" [19] (Interview, NEA, 2021)

The new government launched the Hurdalsplataform, that forms the basis of the new strategy of the coalition Government with the Labor party and Center party. The plan does not include e-fuels specifically, but it talks about the need of additional policy instruments to drive a more environmental friendly aviation with biofuels and new technology. For this, there is a need for additional government instruments that drive more environmentally friendly aviation, with biofuels and new technology. It also points that they will look to facilitate CCS and CCU for industrial purposes (The Labour Party & The Center Party, 2021).

Previous Norwegian governments had been quite reserved about CCU until the summer of 2021 at their National strategy for a green and circular economy. The document does a short mention of CCU as a possible solution to produce certain type of products like food, plastics and some fuels. And clearly specify that further analysis and documentation of how much CO_2

[19] Quote 19

is permanently maintained out of the atmosphere is needed to guarantee real climate effects (Ministry of Climate and Environment, 2021). With this starting point for CCU, the new European regulatory framework, and the new Norwegian Government, it will be interesting how further policy instruments towards an energy transition, will be implemented in Norway.

5.3 Challenges and uncertainties for the adoption of e-fuels.

This section analyses the main challenges and uncertainties for the implementation of e-fuels, and how these are being managed by the actors involved. The results of the semi-structured interviews showed seven important challenges and uncertainties to consider, see table 1. The seven challenges will be further analyzed. However, it is important to note that along with the text-based data collected, it is clear that the most mentioned challenges are: 1) the availability of electricity from renewable sources; 2) competition with more effective climate solutions and; 3) the policy framework conditions and the sustainability criteria. With regards the management of the challenges, data collected showed important actions from the European Union, ENGOs and e-fuel producers.

Table 3: Challenges for the implementation of e-fuels mentioned in the semi-structured interviews.

CHALLENGES	Civil Society					Political Actors				Economic Actor
	Zero 1	Zero 2	Bellona 1	Bellona 2	Anonymous	Enova	Green Party	Gassnova	NEA	Norsk e-Fuels
Availability of electricity from renewable sources		●	●	●	●	●	●	●	●	●
Competition with more effective climate solutions			●	●	●	●	●			●
Policy framework conditions and the sustainability criteria	●	●				●			●	
Avoiding double CO2 counting	●	●				●	●			
High price / incentives to purchase		●	●	●	●					
Development of DAC					●					●
Civil society perceptions	●	●								

5.3.1 Availability of electricity from renewable sources.

According to the text-based data collected and the semi-structured interviews results the most relevant challenge for e-fuels is the energy intensity of its processes and the availability of enough electricity from renewable sources. From the perspective of all the actors who participated in the interviews, energy requirements are an important concern:

"It needs a lot of energy (...) that will be a debate, and how to put a frame for this will be so important for it to survive as a solution." [20] (Interview, ZERO2, 2021)

"We are facing a situation over the next 10 -15 to 20 years maybe, where there will be a high demand in connectivity to the power grid in Norway, and we should not promote the use of power in this situation for processes which are inherently inefficient." [21] (Interview, GP, 2021)

(...) electro fuels are very energy-intensive (...) If we are going to use renewable energy for water electrolysis (...) you are going to need much, much more renewable power than we have today, and we already need more sectors, including direct electrification of the transport via batteries, (...) It is irresponsible to incentivize the production of these fuels with help of electricity because there is not enough renewable electricity and fossil fuels still occupy a significant share in the European electricity mix (...), so by incentivizing production of electro fuels you are indirectly incentivizing fossil power, coal, and gas." [22] (Interview, Bellona1,2021)

"We choose Norway because of its percentage of renewable energy on the grid. We acknowledge the problems we can have in the future, that is why Valinor is our Norwegian partner, and we know that we probably will have to produce more renewable energy in other areas." [23] (Interview, Norsk e-Fuel, 2021)

The views of the participants can be summarized in three concerns: 1) Will there be enough electricity from renewable sources available to cover all the production? 2) Will the use of all this energy compromise the development of other solutions like direct electrification? 3) Will the use of all this energy indirectly incentivize the use of fossil fuel energy?

During a webinar of Norsk e-Fuel last June 2020, Pål Selboe Valseth, Board of Directors of Valinor, the renewable energy expert partner of Norsk e-Fuel, spoke about the renewable energy needs for their projected production. He explained that the renewable electricity needs

[20] Quote 20
[21] Quote 21
[22] Quote 22
[23] Quote 23

should not be a challenge in Norway for the 20 MWh capacity needed for the pilot at Herøya, and 200 MWh for the 100 mio litres full-scale plant. Considering that Norway produces ca. 150 TWh and uses 130 TWh, there should be plenty of room for Norsk e-Fuel production and more developments to further help the pricing (Norsk e-Fuel, 2020b). Specifically, about the electricity availability problems in Norway, Valseth explained:

> *"Norway holds a long tradition of power demanding industry, that's not necessarily longer in full operation, we are currently looking at locations that have these large energy capacities inherent, but where the power is sort of locked due to lack of grid capacity and where we can take a role as a large off taker to use this energy in the current environment. (...) We are into now, to select both, these first 100 million liter plant coming after the Herøya pilot, but also a forward roading program to further increase the capacity*" (Norsk e-Fuel, 2020b).

Even with a secure availability of electricity from renewable sources for a pilot and first industrial plants, raised concerns go beyond initial production, and focuses on future overall production along Europe. For example, published reports from Bellona ask for clearer specifications with regards the renewable energy requirements, specifically with the new proposals for the REDII in the "Fit for 55" package. They ask the European Commission to clarify if the renewable electricity to produce e-fuels will be additional to the RED target or not, since the 40% target will not be enough (Bellona Europa, 2021). The proposed modifications to the REDII includes one article amend that could cover this concern:

> *Article 1(3) amends Article 7 REDII with the updated calculation method of the share of energy from renewable energy sources so that (i) energy from renewable fuels of non-biological origin must be accounted in the sector in which it is consumed (electricity, heating and cooling or transport), and (ii) the renewable electricity used to produce renewable fuels of non-biological origin is not included in the calculation of the gross final consumption of electricity from renewable sources in the Member State.* (European Commission, 2021h,p. 10)

Point (ii) of the amendment could be interpretated as excluding electricity from renewable sources for RFNBO production, from the EU target of renewable energy by 2030. The RED II mentions that RFNBO production should ensure the use of electricity from renewable sources in order to meet a sustainability criteria (European Parliament & Council of the European Union, 2018). However, when the electricity used comes from the grid this could be a problem, especially in many countries from the EU where their renewable shares is not as high as need (Transport & Environment, 2021d). The development of an "*additionality framework*" for the transport sector is mentioned in the RED II (European Parliament & Council of the European Union, 2018). It will look to "*ensure that the expected increase in demand for electricity in the transport sector beyond the current baseline is met with additional renewable energy generation capacity"* (ibid, article 27.3) In the 2021 amending proposal for the RED II, it is mentioned that the Commission is currently working with a delegated act to set the rules for additionality (European Commission, 2021h).

Additionally, it will be important to address the capacity of renewable energy production of each country. Considering Norway's capacity of renewable energy production, makes sense the interest of investors to produce e-fuels in this country. However, Bellona points out the importance to consider the overall renewable energy production of the connected energy grid. They made a report explaining that green hydrogen and hydrogen-based fuels production under the REDII proposal, will not be entirely green since the European electricity grid is still carbon-intensive (Lovisolo & Whiriskey, 2021). Even considering Norway's electricity consumption could be 100% renewable according with its renewable energy production, it is important to consider that it is still connected to the European electricity grid, and that it is an active member of the energy market. Hence, a future increased demand of energy for the production of e-fuels, along with other future electricity needs in Norway, could increase the purchases of fossil-based energy from the European energy market.

Norway already has climate plans and projections of electricity needs for 2030 according to Klimakur 2030. The representative of the NEA, expressed its concerns about the availability of renewable energy including e-fuels production in its plans:

"The Norwegian green plans in general, needs a lot of renewable energy, if e-fuels will be added to this, energy plans must be reconsidered and the energy needs will be even bigger." [24] (Interview, NEA, 2021).

The NVE estimates a use of electricity in Norway of 153 TWh, and for the measures proposed by Klimakur 2030 electricity consumption can increase to 159 TWh with a power surplus of 15 TWh (Norwegian Environment Agency et al., 2020,p.377). If a blending mandate for e-fuels is implemented in Norway, future climate plans will need to make several considerations regarding renewable energy and e-fuels production. For example, to consider additional renewable energy production and strategic locations of e-fuel production facilities in order to employ surplus electricity and avoid the increase of energy purchase from the European energy market.

5.3.2 Competition with more effective climate solution

According to the actors interviews, in order to have an energy transition, several solutions must be developed and implemented, not only CCU and e-fuels. As already explained, climate plans for Norway and Europe consists on the development of several strategies. However, to develop these solutions we need time, investments, funds, policy instruments and change of motivations of civil society to actually be part of the transition. The development of other climate solutions, that in most of the cases can be more effective, is the second most mentioned concern (Table 1). From the perspective of Bellona and political actors, the concern focuses on how the development of e-fuels could lead to discourage or slow-down the development of other solutions:

"All the efforts on producing e-fuels can be prolonging the development of more effective solutions" [25] *(Interview, ENOVA, 2021)*

"All the new renewable energy we have to build the next 10-15 years, must be used for other sectors that do not emit carbon, like electrification through batteries and hydrogen for the industry." [26] (Interview, Bellona1, 2021)

[24] Quote 24
[25] Quote 25
[26] Quote 26

"We will have periods of excess energy production from many sources in many areas locally but we don't know exactly where we will have this bottle necks in the power production where you can sort of cut this bottle necks with different types of valuable production, it can be hydrogen, it can be ammonia, it can be large-scale utility batteries, but e-fuels should be quite low on that list because of the inherent inefficiency." [27] (Interview, GP, 2021)

It is possible that too much incentives to promote one solution could lead to an unbalanced framework for other solutions. Also, actors that promote the development of e-fuels, acknowledge that e-fuels are not the most energy efficient solution because of the thermodynamic conversion loses happening during its production. However it is a solution that can be deployed immediately without major changes in engines and infrastructure. In comparison, other more efficient solutions, like direct electrification and hydrogen, face several challenges that turn them into long-term solutions (Yugo & Soler, 2019; Bauen et al., 2020). Additionally, according to the text data collected and the opinions of some of the interviewed actors, e-fuels have the potential under certain sustainability criteria, to reduce significant amounts of CO_2 and have positive impacts on environmental air quality (Yugo & Soler, 2019; Bauen et al., 2020). The anonymous participant in the interviews and Gassnova gave important opinions related to this:

"CCU as synthetic fuels (...), makes only sense, in combination with DAC, and possibly with biogenic CO_2 (...) and with renewable hydrogen." [28] (Interview, Gassnova, 2021)

"The combustion of e-fuels, and that is a scientific fact, produces 50 to 70% less persistent contrails, which is the main non-co2 effect from aviation, you wouldn't get that with the combustion of fossil fuel, that's super important to bear in, there is a win-win thing with e-fuels being CO_2 and non-CO2 at the same time." [29] (Interview, Anon ENGO, 2021)

[27] Quote 27
[28] Quote 28
[29] Quote 29

"For now, given the inability or the impossibility of fueling long-haul flights with hydrogen, not even with electricity, I think e-fuels have a very long lifetime ahead. (...) It does give you maybe 50 years of safety, which I think is a long time." [30] (Interview, Anon ENGO, 2021)

Another perspective for this challenge comes from the e-fuel producers and the competition for funding with other solutions. Norsk e-Fuel representative shared that the general funding is one of the biggest challenges they face. The reason behind this is that they compete with other projects that can have bigger total CO_2 reductions, and that even with the advantage of their possible immediate deployment, they are still in a very young stage. Norsk e-Fuel representative also shared its thoughts about Gassnova as a funding institution:

"Gassnova is one of the most important tools for funding. There are some important CCS projects founded by them that also have clear intentions on CCU as well. This could be an indicator that GASSNOVA is open to CCU but there is still no CCU project founded by Gassnova." [31] (Interview, Norsk e-Fuel, 2021)

As mentioned in section 5.1.1 Political actors, Gassnova representative explained they are not working with CCU, and share some thoughts about the reasons behind not having received any instruction to do it:

"Norway has a business case to produce Hydrogen and use CCS for that (...) From Norwegian perspective it has been very hard to argue for CCU, because they don't understand the narrative of green hydrogen." [32] (Interview, Gassnova, 2021)

So far, the only funding program that has been granted to Norsk e-Fuel through Norwegian institutions is the European Innovation Fund that is coordinated by Enova. Specifically about hydrogen development, Norway has a clear interest in its development. The Norwegian Government's hydrogen strategy published in 2020, expresses a special interest on ensuring that natural gas-based hydrogen combined with CCS, can compete equally with green

[30] Quote 30
[31] Quote 31
[32] Quote 32

hydrogen in the European market. However, they also mention the interest on developing technologies for green hydrogen production (Regjeringen, 2020a). In the recently updated government budget for 2022, they increased the support for hydrogen R&D, and established a separate research center that will take place under the Research Council of Norway. They also allocated funds for the development of market and infrastructure for hydrogen (Regjeringen, 2021o). Additionally, in June 2021, Enova and the Research Council of Norway launched *HEILO,* a program to support hydrogen projects (Regjeringen, 2021p).

The development of hydrogen technologies is favorable for e-fuels, however, the specific processes of the CCU value chain to produce e-fuels are still not a relevant solution in the Norwegian climate plan, or in its R&D strategies.

5.3.3 Policy framework conditions and the sustainability criteria.

Several studies and publications underline the importance of a clear and complete policy framework, and give several policy recommendations to an effective development and implementation of e-fuels (Ausfelder & Wagemann, 2020; Transport & Environment, 2021b; Transport & Environment, 2021c; Ueckerdt et al., 2021). As explained in section 5.2 Institutions and policy instruments, the policy framework for CCU and e-fuels is apparently starting to be stronger at the international level, specifically in Europe. However, Norway lacks of a clear policy framework to introduce and further develop CCU and e-fuels. During the interviews, Enova, ZERO, and NEA representatives expressed a concern for the establishment of a policy framework for e-fuels (see table 1). Since Norway will mostly have to adapt to the European Commission policy framework around e-fuels, the NEA explained that the sustainability criteria established by the framework will be a big challenge for them:

> *"The sustainability. Will the criteria from the EU be good enough?, considering what type of conditions will be take in place regarding the use of electricity, additionality requirements, the CO_2 source, as DAC, biogenic sources, or if you should allow fossil CO_2 for specific projects with conditionalities, etc. Basically we are apprehensive and want to wait and see."* [33] (Interview, NEA, 2021)

[33] Quote 33

In July 2021 Bellona launched "The net-zero compatibility test: a simple guide for GHG accounting of CO_2 use" (Wiriskey, 2021). The report explain what are e-fuels, how to count its environmental impacts, and the importance of the electricity and CO_2 source to understand the real value as a mitigation tool. The report made some policy recommendations to ensure regulation and monitoring of CO_2 sources for e-fuels. Bellona suggest the enforcement of differentiation between CO_2 sources. To incentivize atmospheric CO_2, and to include fossil CO_2 in the system counting. The same recommendation is referred to the ReFuelEU initiative that is part of the "Fit for 55" package.

Transport and Environment had also express their concern about the sustainability criteria established in the European policy framework. For example, in its analysis of the ReFuelEU, they recommended a mandate of DAC share from the start of the mandate that should increase to 100% as soon as possible (Transport & Environment, 2021b).

The sustainability criteria established in the policy framework should cover all of the identified challenges for the implementation of CCU and e-fuels by establishing the proper policy instruments. These policy instruments should ensure the availability of renewable energy and a planned and balanced promotion of other effective solutions. Additionally it should have considerations on the definition of sectors who should have the CO_2 cuts, support for the development of DAC, the civil society perceptions, and a creation of a market to ensure competitive prices of e-fuels.

5.3.4 Avoiding double counting of CO2 cuts

The accounting of CO_2 use and cuts for e-fuels has been publicly mentioned as a concern, especially about avoiding double counting and on how to allocate the correct accounting and surrender or allowances (Transport & Environment, 2020a; E4tech (UK) Ltd, 2021; Wiriskey, 2021). Additionally, ZERO, Enova and the Green Party representatives talked about the importance of avoiding double CO_2 counting during the interviews (see table 1):

> *"(...) the double counting of ETS emissions. Why will you get paid for capturing co2 that will be released again?"* [34] (Interview, GP, 2021)

[34] Quote 34

"There is a need of a clearer framework, especially because the CO2 will mainly come from emissions of industries that are part of the ETS. Those emissions will still go to the air. There are no rules of saying that you avoid emissions by making a CCU product." [35] (Interview, ENOVA, 2021)

"To avoid double cuts. Aviation sector should count the cuts, and should have incentives to pay the more expensive fuels, and the industry should have the incentive to still cut their emissions." [36] (Interview, ZERO2, 2021)

In "The net-zero compatibility test: a simple guide for GHG accounting of CO_2 use" (Wiriskey, 2021), Bellona made some recommendation related to the surrender of allowances for all the emissions of GHG that will not be released directly to the atmosphere. If CO_2 from an ETS installation will be reused and not permanently stored, the ETS installation must surrender allowances for it, as if it were a regular emission directly to the air. The emission reduction resulted from the reused CO_2, must be allocated to the CO_2 user, the airlines or fuel suppliers in this case (Wiriskey, 2021). The EU ETS already offers incentives for the use of SAFs, like for airlines to avoid the surrender of allowances according to the percentage of SAF used (European Commission, 2021j). However, according to the actors interviews, CO_2 counting from the emitter ETS installation is still not clear.

Efforts have been done by civil society actors in order to avoid double counting of CO_2 emissions cuts. The reaction of the political actors to clarify this aspect on the regulatory framework, is crucial in order to have real positive climate effects with the implementation of e-fuels.

5.3.5 High price and incentives to purchase

Having competitive prices and the proper conditions to develop a market where e-fuels could actually be bought by the airlines, is one crucial aspect in order to be an effective solution. Participants from the civil society actors showed its concern about the current high prices of e-fuels in comparison with fossil fuels and the incentives that purchasers will need to pay for them.

[35] Quote 35
[36] Quote 36

"The 5-10 high cost of e-fuels compared to conventional fuels, this means that they will need incentives to buy it (...)" [37] (Interview, Bellona2, 2021)

"Supporting customers, because if the customers are supported in the purchase it saves you against the risk of them wanting to strap the mandate (...) because e-fuels are so expensive, airlines could say: we can't afford it, let's remove the mandate." [38] (Interview, Anon ENGO, 2021)

There are two perspectives regarding the high price of e-fuels. On one hand, the actors with a negative position about e-fuels implementation, explained that the use of incentives to buy them is giving an inappropriate use of funds to promote a solution that is not effective. On the other hand, actors supporting the implementation of e-fuels are more concern on which instruments could help to develop a market, to incentivize the production and the purchase of a more expensive fuel, and to gradually lower the prices to be fully implemented.

Norsk e-Fuel has not showed a specific concern about the high prices of e-fuels during the interview. However, last June 2020, during the Norsk e-Fuel webinar, Karl Hauptmeier talked about this, comparing e-fuel prices with advanced biofuel prices:

> *"In the first demonstration unit, specific prices will be higher than those for example first generation biofuel alternatives, but in the longer run this is not all we face, if we are looking at industrialized plants, and we´re looking at cheap electricity resources, we can push prices down or production prices to anywhere in the range to 1 euro to 1.50 euro, depending on electricity prices mainly (...) we expect actually when the first industrialized plants are ready, to be in the cost corridor where we are cost competitive to advanced biofuels, but this is specifically not saying that we are competing against them, we will need both solutions, we only offer the same solutions to those prices or lower with the unlimited growth factor"* (Norsk e-Fuel, 2020b)

Some studies showed that lower e-fuels prices will depend on several factors besides electricity prices. These factors can be CO_2 prices, the optimization of the production processes

[37] Quote 37
[38] Quote 38

as electrolysis and DAC, and the development of a market to increase the demand for e-fuels (Hombach et al., 2019; Cames et al., 2021; Ueckerdt et al., 2021). According to actors interviews, all of them could highly depend on governmental support. Because of this, implementing the "Fit for 55" package and the recommendations of civil society actors and economic actors about it, will be crucial. This could determine the regulatory framework to have competitive prices of e-fuels and reach an effective implementation.

5.3.6 Development of DAC

In 2020 Transport & Environment suggested that CO2 source should be only from DAC, or DAC plus biogenic sources, in order to avoid double counting of emission reductions. However, according to new commissioned report from E4tech assesses, exclusively ask for DAC CO_2 will not help with pricing and the creation of a market for e-fuels. Because of this, they now recognize other sources of CO_2 at initial phases, but still ask for a mandated percentage of DAC since the beginning of the mandate that will gradually increase to 100%. The development of DAC is the last challenge mentioned by the interviewed actors, see table 1.

DAC is necessary to have 100% climate neutral e-fuels (Cames et al., 2021). However, given the stage of development, the energy intensity needs because of the lower concentrations of CO_2, and the general costs of DAC process, it is not feasible to use the technology in higher percentages since the beginning (E4tech (UK) Ltd, 2021). Norsk e-Fuel representative shared during the interview, that they plan to develop DAC and increase considerably the percentage of CO2 from DAC by 2030. As an example of the most recent development and improvement of the technology, Norsk e-Fuel representative talked about "ORCA", the first industrial scale DAC plant in Iceland by Climeworks. However, the development of the technology is still seen as a big challenge:

"The development of the DAC technology since it's still a very young and costly technology but we want it to be a big component in our future plants." [39] (Interview, Norsk e-Fuel, 2021)

[39] Quote 39

"When I speak to DAC producers, they always tell me that is very difficult to raise capital since it is still seen as a risky business given the lack of opportunities, at least on the CCU side (...) I think it will be very interesting to know to what extent a mandate like the RefuelEU, if it apply to DAC, would provide more certainty for investors, and how much changes their interpretation of what is a risky investment." [40] (Interview, Anon ENGO, 2021)

So far, the only actions for the challenges and uncertainties of DAC technologies in Norway, has been done by civil society actors as ENGOs and the economic actors involved. As the anonymous participant said, it will be very important for the development of DAC to have an instrument like a DAC CO_2 source mandate in order to give higher certainty to the investors.

5.3.7 Civil society perceptions

Civil society perceptions is the last challenge mentioned by the actors interviews (see table 1). As seen so far, civil society general perceptions of e-fuels can be positive, neutral or negative. For example, the results of the semi-structured interviews, show almost equal numbers of opinions for each position, however, the positive position was the most prevalent, see figure 5. Political and economic actors are also included in the figure, since according to Vatn (2015), political and economic actors are "embedded within civil society" (p.145), and have an important influence within each other.

[40] Quote 40

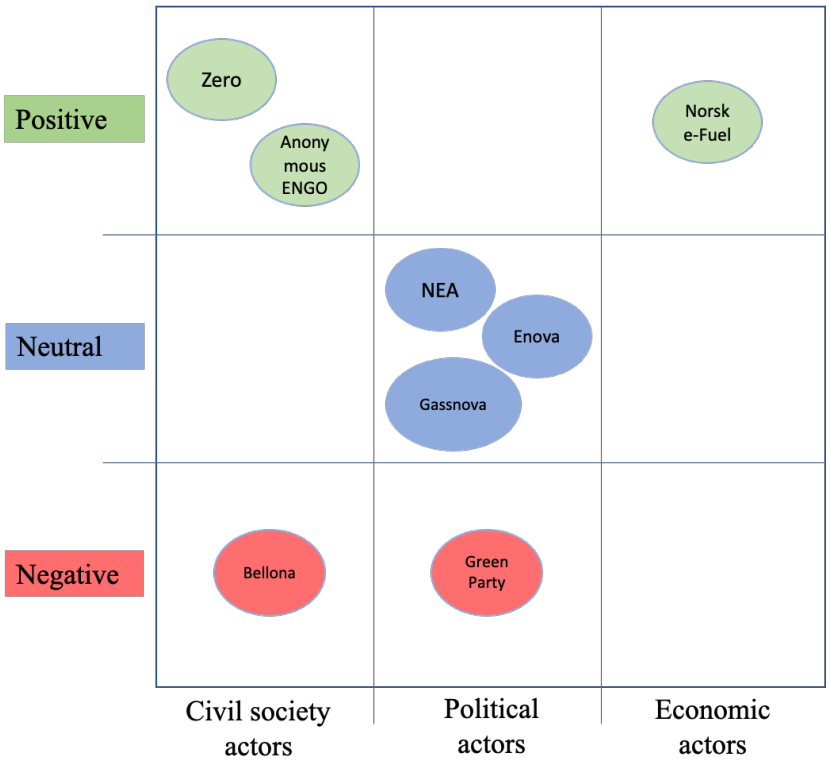

Figure 5: Semi-structured interviews results regarding position towards the implementation of e-fuels, including civil society, political and economic actors.

Civil society perceptions can include the position of ENGOs or some economic actors that are lobbying for, or against the implementation of e-fuels. The most relevant are the ones who have an important amount of power in the decision-making process. The representatives of ZERO mentioned civil society perceptions as a main challenge:

> *"How to manage the image and acceptance of e-fuels as a solution among people will be very important."* [41] (Interview, ZERO2, 2021)

General perceptions of society are very important. The acceptance of buying a more expensive plane ticket, or to reduce and change travel habits, is crucial in order to have effective climate results. Gassnova representative reflect on consumption habits, and how the change of motivations is also very important to have the best results.

[41] Quote 41

"It is also important to change the system, to change motivations and consumption patterns as part of the strategy. Just with technology changes will not be enough." [42]

(Interview, Gassnova, 2021)

According to the data collected, there are several publications from ENGOs and media coverage of new e-fuel projects in Norway. These publications are so far, the ones reaching society and shaping their perceptions. One example are two publications from NRK, the largest media organization in Norway. First an article that covered the launching of Norsk e-Fuel project, with positive and negative opinions of representatives of ZERO and Friends of the Earth Norway (Knudsen & Samuelsen, 2020). Second, the coverage on NRK TV about the beginning of the construction of Nordic Electrofuel's plant, where also a representative from ZERO share some thoughts (NRK TV, 2021).

As explained in section 5.1.3 Civil society actors, media has important influence in civil society perceptions, and following Vatn (2015) regarding how all the actors are embedded within civil society, influences within media and the political agenda are also very relevant. Media has an important influence on political agenda and vice versa (Brandenburg, 2002; Nicolas Hopmann et al., 2009; Van Dalen & Van Aelst, 2014). According to Van Dalen and Van Aelst (2014) study, the Norwegian mass-media has more influential power in the political agenda-setting than politicians, due to a weak general control of politicians over the political agenda. Because of this, media coverage and lobbying from ENGOs is very relevant for the development of new technologies and a policy framework for CCU and e-fuels in Norway.

[42] Quote 42

6. Discussion

This chapter looks to understand the dynamics of institutional change, and how the governance structure influences the implementation of CCU value chains and e-fuels in Norway. The analysis chapter identified the environmental governance structure around CCU and e-fuels, and the challenges to implement them. According to the results of the research, the implementation of new technologies needs the support of a policy framework. In Norway, there is a clear lack of specific policy framework for the implementation of CCU and e-fuels, but there is a robust national and international governance structure with different actors and institutions influencing its implementation.

The main actors influencing the implementation of CCU and e-fuels in Norway are at national and international levels. At the international level, the main political actors identified are the European Commission and organisms like the IPCC and the UNFCCC. Whereas at the national level, the Norwegian Government has a Parliament and a robust set of ministries and organisms like the Ministry of Petroleum and Energy, the Ministry of Climate and Environment, the NEA, ENOVA, and Gassnova. Political parties are also very relevant among the national political actors. The main economic actors at international and national levels are the aviation sector, including airlines and fuel suppliers, refineries, funding programs and organizations, and the renewable energy industry. Also, developers of the technologies for the CCU value-chain, like Norsk e-Fuel, Nordic Electrofuel, Climeworks and Sunfire, are very relevant. With regards the civil society actors, media, ENGOs, and research centers where identified as the most relevant in both national and international levels.

The main actors identified in the governance structure have shown different perspectives and actions towards or against the implementation of CCU and e-fuels. National and international actors interact with their different perspectives to influence the decision-making process. As explained in section 5.3.7 Civil society perceptions, media has an important influence in politics. Media publications with participation of ENGOs and economic actors are very relevant. ENGOs like ZERO and Bellona have an active participation with several publications and communication with political, economic and civil society actors. An example of this is the seminar by the Federation of Norwegian Aviation Industries (NHO Luftfart) about e-fuels during "*Arendalsuka".* Arendal's week, in English, is a Norwegian event of political gathering that looks to strengthen the democracy with open debates (Arendalsuka, 2021). In August 2021, several economic and civil society actors took part in the seminar with their

different perspectives, e.g., Norsk e-Fuel, Nordic Electrofuels, SINTEF, Bellona, ZERO, SAS, and Norwegian Air. "*Arendalsuka"* is an interesting platform for research and an important arena for lobbying (Raknes & Wollebæk, 2018; Ihlen & Raknes, 2020), This makes the seminar a relevant space to influence national decision-making process, and a clear example on how the actors interact and push for institutional change.

The main institutions and policy instruments identified within the governance structure are also at national and international levels. At the national level, the institution regulating access to the resources are the Storting and the Norwegian Constitution. The Storting has approved the relevant policy instruments for the implementation of e-fuels, Klimakur 2030, and the Norwegian Climate Plan that looks to reach ambitious national climate goals that had been set according with international agreements like the Paris Agreement and the European Green Deal. International agreements open the door to international actors like the EU, as critical elements to establish the "rules of the game". For example, carbon markets that are set by international agreements and must be followed by international and national levels. Another example is the implementation of the new EU regulatory framework, the "Fit for 55" package, that once adopted and converted into law, must be implemented in Norway. Apart from the identified institutions and policy instruments, the research results found a lack of a specific regulatory framework, which constitutes an important challenge to implement CCU and e-fuels in Norway.

Besides the lack of regulatory framework, other challenges for CCU, and specifically for e-fuels where identified. The most important challenge found is the availability of electricity from renewable sources. Despite the large applications of captured CO_2, they are not enough compared with global CO_2 emissions, and large number of conversion can only be achieved using a lot of renewable energy sources (Nocito & Dibenedetto, 2020). For e-fuels, results shown that it till be important to first, clarify the amount of surplus production of electricity from renewable sources needed to cover the projected production. And second, to clarify how this new renewable electricity will count in the general goals of renewable energy production. This will be crucial to ensure the availability of renewable energy to cover all the projected needs, including the development of other climate solutions that are also energy intensive.

The availability of electricity from renewable sources along with the avoidance of double counting of CO_2 cuts, and the development of DAC technologies where mentioned during the interviews as important points for e-fuels to meet a sustainability criteria. There is

also a challenge to implement a market for e-fuels to ensure a competitive price and support the airlines to buy them. Clear policy instruments could help to overcome these challenges, ensure real CO_2 emissions cuts, and diminish the uncertainties about e-fuel costs and its mitigation potential. The enforcement of current economic policy instruments like the EU ETS, and the creation of new ones like subsidies for the aviation sector to buy more expensive fuels, were some of the recommendations by the participants to overcome these challenges. On the other hand, there were also participants who expressed a negative position to create new economic instruments to support the implementation of e-fuels. In this case, the civil society perceptions are also an important challenge. Either to support or to refute the implementation of e-fuels, clear and accurate informational instruments are crucial to manage the mitigation potential and costs uncertainties of e-fuels. This is also crucial for the design of a proper and complete regulatory framework like the "Fit for 55" package.

Before and after the presentation of the new regulatory package from the EU, political, economic and civil society actors have been working to define a normative basis, and influence the policy making process in favor or against the implementation of CCU and e-fuels. Bellona, ZERO and Transport & Environment, for example, have been working on what Vatn (2015) calls informational instruments, presenting relevant arguments to influence the formulation of the regulatory framework. According to interviews results, the debate for e-fuels started as a solution for the transport sector, and after some research and interactions between the involved actors, the solution now is mostly focused on hard to electrify sectors as aviation. Today, different actors within the governance structure participate on a debate with regards the challenges and uncertainties of e-fuels, and which aspects should be included in the regulatory framework. The analysis suggests a highly dynamic and constantly changing governance structure around e-fuels.

To understand how governance structures around e-fuels may change, Bromley (2006) describes how institutions may address environmental issues in three steps: 1) the recognition of the problem, 2) the design of alternatives, and 3) the evaluation and implementation of alternatives. First, there has been a recognition from several actors that GHG emissions from aviation is something not acceptable and needs urgent action. An example of this is the International Air Transport Association (IATA) who's 290 member airlines recognize the need to address the climate change problems and adopted several targets from 2009 to reduce its GHG emissions (IATA, 2021). Another example is the recently created International Aviation

Climate Ambition Coalition (IACAC) during the COP26, where 23 states recognize the urgency of the climate related problems from aviation, and agreed to work for a sustainable international aviation (GOV.UK, 2021). With regards the second step "design of alternatives", R&D of new solutions for aviation has been ongoing from several years ago, SAFs in particular, has been researched since 1970s (Hemighaus et al., 2006). The final step, "evaluation and implementation" can be identified with the evaluation of alternatives from several actors as ENGOs or research centers, and the creation of new policies like the biofuels blending mandate in Norway, and the new regulatory framework from the EU. The implementation of new policies are designed, intentional and top-down institutional change, based on Sened (1997) theory explained in section 3.4 Changes in the Governance Structure .

The three steps of Bromley (2006) and the designed international change of Sened (1997), seems relevant for public sector actors since they are based on prescriptive change that needs a certain level of power to finally design and create new policies. However, the research results show that actors involved have different levels of power and influence, and that institutional change is happening in many directions. Most of the changes are across scales, occurring at an international level, and recently starting to happen in Norway. Part of these changes are R&D from economic and civil society actors, e.g. publications from ENGOs (Transport & Environment, 2020b; Lovisolo & Whiriskey, 2021), academic research publications (Chiaramonti, 2019; Ausfelder & Wagemann, 2020; Bauen et al., 2020), and the development of new projects like Norsk e-Fuel and Nordic Electrofuel. These actions have been an important influence at different levels for the creation of new policies like the EU regulatory framework.

One example of the different position and level of influence that an actor could have, can be explained with the case of CCS and ENGOs in Norway. Bellona has been a key actor promoting the technology since 1995, working closely with relevant actors from governments, industry, and media (Tjernshaugen, 2011). They gained an influential position as pioneers among "*clean fossil activists*" (p. 241), with values strongly connected to the political strategies in Norway (Simon, 2011). During this period, Bellona influenced the creation of ZERO, which also started supporting CCS (Tjernshaugen, 2011). Their engagement has been influential: today CCS has been a key element in the Norwegian climate strategy since 2014 (Regjeringen, 2021q). In the case of e-fuels, the two ENGO's have opposite positions that could lead to some problems with regards to the new EU regulatory framework. There are other ENGOs that also

have some level of influence to the Norwegian or EU government and still participate in the debate. For example, at the international level, T&E claims to have shaped important Europe's environmental law, and today they are working for the implementation of new solutions for the transport sector, like e-kerosene for aviation (Transport & Environment, 2021a).

Blyth (2003) and Vatn (2015) emphasize that new solutions can reduce uncertainties, set conditions for action, and delegitimize or destroy the authority of existing institutions. E-fuels as alternative solution with their correspondent evaluations, are still in the process of gaining legitimacy and there is still uncertainty with regards to impact. However, this pathway does contribute to delegitimize or diminish the use of fossil fuels, and has some degree of institutional support. Legitimization can come through new regulatory frameworks, but also because of the urgent need for SAF without viable alternatives. Some actors are concerned that the implementation of incentives for e-fuels, could be competing with the development of more effective solutions as direct electrification. There is a negotiation for legitimacy of new solutions where actors become polarized, in part, due to lack of data and actual viable technologies. Despite this, the advocates of e-fuels that participated in the interviews, emphasize that the development of other solutions should not be stopped or delayed. Norsk e-Fuel, made clear that they do not consider themselves as competition for advanced biofuels (Norsk e-Fuel, 2020b), which is the only other sustainable solution for aviation currently available in the market.

Norway has already started to implement biofuels, however, as part of the third step that Bromley (2006) suggested, the evaluations of this alternative have shown that feedstocks are limited (World Economic Forum, 2020). This national biofuel policy could be delegitimized by the new EU regulatory framework. International and national policy instruments and institutions like the "Fit for 55" package and Klimakur 2030, have interactive and interlinked effects that are very relevant for the implementation of CCU and e-fuels. The position of apprehensiveness from the participant of NEA (see quote 33), with regards the introduction of the new regulatory framework by the EU, is a clear example of this. The introduction of the new EU regulatory framework will influence national policy instruments like Klimakur 2030. An optimal implementation of CCU and e-fuels depends in a great part on a clear and designed regulatory framework at different scales.

Cleaver (2017) questioned the designed institutional change and how it can have some limits or be done in a messy and self-structured way called "*bricolage*". These limits can be

related to the capacity to change of an institution because of the nature of its processes, and/or their current practices and interests. Some examples of this were shared during the interviews. First, the apprehensiveness to the new EU regulatory framework, expressed by the participant of NEA. Second, ZERO and Bellona representatives mentioned that Norway is very slow on implementing EU policy. Finally, Gassnova representative shared that they are not working with CCU R&D projects, possibly because it does not make sense with Norwegian climate and business plans (see quote 2). The results shown that some actors are concerned, and other are less so, and it appears that with increasing responsibility, comes an increasing apprehension. This apprehensiveness could be justified considering the implications of establishing a new regulatory framework and the uncertainties accompanying it. On the other hand, a previous study by Ruud and Knudsen (2009) found that Norway is limited when engaging in new EU legislative issues that are relevant within the EEA agreement.

The concerns of the interviewed actors showed that Norway has limitations to implement new policies, and that it is not in the same pace as the EU when implementing them. This problem can be seen even with technologies that are an important part of the Norwegian climate plan, like CCS. Previous study found that the deployment of CCS in Norway has been delayed by institutional inaction (Karimi, 2017). Also, Weber (2021) explained that the implementation of the EU CCS regulatory framework in Norway was controversial and slow. Additionally, he mentioned that today, this legal framework is considered to be troublesome. If we take CCS case as an example, Norway has been developing it since 1996, the journey has been long, but today, the first full-scale and full-chain CCS project is already approved by the government (Weber, 2021). CCS technologies have been strongly financed by the government and the industry (Martin-Roberts et al., 2021), and strongly supported by NGOs like Bellona and ZERO (Tjernshaugen, 2011). The perceived lack of a proper regulatory framework for CCS can bring some challenges for its future expansion (Weber, 2021). However, the support of civil society, economic and political actors had shown important advance in its development. It is clear that CCS has different challenges and development process than CCU and e-fuels. Hence the comparison above could have some differences. Nevertheless, it shows a clear example on how the implementation of a legal framework in Norway could be limited, and how strong the influence of the governance structure to develop and implement new technologies could be.

According to these possible limitations, Norway could follow different pathways on its institutional change after the "Fit for 55" package. Vatn (2015) makes emphasis on power and uncertainties when creating change by implementing new policies. Power could define the pathway by, for example, limiting institutional change to protect certain interests. These interests could be the development of climate solutions that goes in line with the Norwegian climate and business plans, as Gassnova representative mentioned (see section 5.3.2 Competition with more effective climate solution). On the other hand, emphasis on uncertainty is related to the effects of implementing new policies. This uncertainty could lead to action to fix the problem, or could lead to inaction because of the possible effects of the institutional change, like Bellona's concerns with the possible diminishment of the development of more effective solutions. Also this uncertainty could be used to create the inaction to protect other interests. Inaction could also be caused by a limited capacity of the current institutions (Vatn, 2015). In this case, is possible that institutional change happens in a "bricolage" way as Cleaver (2017) explains. A messy and self-structured way, evolving to cover new functions or copying existing solutions that have already being tested.

One of the participants from ZERO shared that we need to agree on the end goal and what kind of solutions we need as an end game. Today, Norway shares climate goals with the EU. What is needed now, is to agree on which solutions and policy instruments will be the best to achieve them. However, individual interests and strategies could be a problem when choosing which solutions to promote. The Gassnova representative shared some important points about the best route to reach the climate goals:

"It has always been difficult, it's hard to choose which is the best route to reach the goal. We have different technologies to achieve it, choosing one or few is a strategy. We will have overinvestment in some areas in some cases, but we need to choose, and we will always have the risks. It is also important to change the system, to change motivations and consumption patterns as part of the strategy. Just with technology changes will not be enough." [43]

(Interview, Gassnova, 2021)

After choosing a pathway and policy instruments to reach the climate goals, institutional change will continue happening, and many current Norwegian regulations will

[43] Quote 43

have to be adapted. The implementation of CCU and e-fuels in Norway will depend on how institutional change happens, the pace of the change, the limitations that they will face, and how powerful actors and technological challenges influence the process. The management of uncertainties and challenges will be crucial to determine the look of the chosen pathway.

The uncertainties of CCU and e-fuels, and the management and governance of an emerging sub-sector, seems to evolve and be solved in an open and dynamic fashion, with actors positioning themselves, communicating and negotiating new knowledge. What we see seems to be an almost evolutionary process, where actors and solutions struggle to be part of the future energy system. Resulting in an extremely dynamic EGS around CCU and e-fuels, with institutions, actors and policies that are always changing. Although some actors may be perceived as more apprehensive, and others more proactive, the extent to which it is perceived as such, depends on time scale and position in the governance framework. The current institutional change and the future definition and implementation of the EU regulatory framework will have a big influence in the development of CCU and e-fuels, as well as in the future Norwegian climate plans.

7. Conclusion

Results showed that Norway has a robust environmental governance structure that together with a international agendas and regulatory frameworks has a lot of influence on the implementation of e-fuels and the CCU value chain. Norway is member of several international political agreements, and has a national political structure with at least four ministries involved in its energy transition plans. Also, it has several institutions and policy instruments governing the plans to achieve its climate goals, however, it lacks of specific instruments for CCU and e-fuels. The civil society actors, including research centers, Norwegian media and ENGOs, appear very active and informed about the development and implementation of new technologies. Specifically, ZERO and Bellona, two ENGOs that are doing some research work to support their arguments for and against the implementation of e-fuels. Finally, there are some relevant economic actors in Norway, like e-fuel producers that are pushing for a regulatory framework and funding, and the aviation sector that is already working with advanced biofuels.

Norway has several environmental policy instruments based on an extensive analysis for its climate strategy, the Klimakur 2030. Some of its most relevant policy instruments are the CO_2 taxation, a blending mandate of advanced biofuels for aviation, and a good structure and resources to support R&D. It also has strategies for hydrogen and moving towards a Circular Economy, and a climate plan, that according to political actors and plans of the new government, it will soon be updated. Despite this, Norway lacks a clear regulatory framework for CCU and e-fuels. According to the agreements with the EU, Norway has to adapt to the European Climate Law, including the new EU regulatory framework, "Fit for 55" that has several relevant elements for the implementation of e-fuels and CCU, as the ReFuelEU and the RED II.

The data collected, showed that e-fuels faces several challenges for its implementation. The most relevant are: 1) availability of electricity from renewable sources, 2) competition with more effective climate solutions, 3) high prices and incentives to purchase, 4) avoiding double counting of CO_2 cuts, 5) civil society perceptions, 6) policy framework conditions and the sustainability criteria, and 7) the development of DAC. These challenges have been identified by actors within the governance structure, who have also been working to develop solutions to overcome them, or have used them to argument against the implementation of e-fuels.

Results showed a clear and dynamic action within the EGS framework about CCU and e-fuels. However limitations within institutional change in Norway to adopt new regulations

have been identified, specifically with the implementation of new EU regulations. Power of actors in the decision-making process, and uncertainties of implementing new policies, could be the reason behind inaction or slow action of institutional change to implement e-fuels. Uncertainties are related with the results of implementing new policies, and how could this affect current interests and business plans. Regardless of these limitations, institutional change is constantly happening within the actors in the governance structure, and the findings shown that the influence they have to implement new solutions has a lot of weight. After the implementation and definition of the EU regulatory framework, Norway could follow different paths on its institutional change that will be crucial to future deployment of CCU and e-fuels.

Next step in the research of CCU and e-fuels in Norway could be focused on the viability of the implementation of e-fuels in Norway. Specifically, regarding the renewable energy resources considering future energy requirements for other climate solutions in the Norwegian climate plan. Furthermore, research on the development and implementation of DAC technologies to complement the actual CCS projects is important to address. And finally, a focused research on how to address the limitations of institutional change in Norway.

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Appendix A

Interview guide

1. What is your position in regards the implementation of e-fuels in Norway?

ACTORS

There are several actors involved in the EGS Framework, classifying them in political, economic and civil society actors, can you tell me:

2. Which political actors (as organizations, parties or individuals in both, the national and international levels) do you consider are relevant in the EGS for the implementation of e-fuels and why?
3. Which economic actors do you consider important in the implementation of e-fuels in Norway, and why?
4. Which civil society actors (besides your institution, as other institutions or individuals) do you consider relevant to the implementation of e-fuels, and why?

POLICY FRAMEWORK

5. What do you think about the current policy framework in Norway in relation to e-fuels?
6. Which policy instruments do you think are the most related to the implementation of e-fuels in Norway.
7. What do you think about the "Fit for 55" package from the European Commission? What should be Norway's position towards it?

CHALLENGES AND UNCERTAINTIES

8. Which do you think are the challenges and uncertainties that the implementation of e-fuels face in Norway?
9. How do you think these challenges and uncertainties are being managed by the main actors involved.
10. There are several new technologies developing as climate solutions. These technologies often comes with uncertainties (as is the case for e-fuels). What do you think it could be a good strategy to handle these uncertainties in the governance framework?
11. From the relevant political actors you mentioned before, could you suggest someone I could contact for an interview?

Appendix B

Informed Consent A

Please read this consent document carefully before you decide to participate in this study. The researcher will answer any questions before you sign this form.

Study Title: The Norwegian Environmental Governance System Towards an Energy Transition. A case study on Sustainable Fuels and Carbon Capture and Utilization Value Chain.
Purpose of the Study: The aim of this study is to evaluate the current Norwegian Environmental Governance System framework towards an energy transition, as well as its strategies to manage challenges and the implementation of new technologies. Norsk e-Fuel with its sustainable fuel and the CCU value chain involved in its production, is used as a case study for a specific analysis.
Potential Risks of Participating: Risk to those who will participate in this study is low. Participants may feel challenged by questions or ideas they had not before considered.
Potential Benefits of Participating: Participants will have the opportunity to share knowledge and experience to a research that can result with relevant findings to policy-making processes and the development and introduction of new technologies as climate solutions.
Confidentiality: All the information you supply during the interview will be held in confidence and, unless you specifically indicate your consent, your name will not appear in any report or publication of the research. Only the name of the Institution you represent can appear in reports or publications of the research. However, you can refrain from having the name of the Institution mentioned. The data will be collected via an audio recording of the interview and will be safely stored in an online locked facility from NMBU. Only the researcher will have access to this information, and it will be destroyed after the submission and presentation of the study.
Voluntary Participation: Your participation in the study is completely voluntary and you may choose to stop participating at any time.
Right to withdraw from the study: You can stop participating in the study or refuse at any time, and for any reason, if you so decide. You can also refuse to answer particular questions or ask to remove some information from the interview after this has been finished. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.
Contact information: If there is any doubts or you want to inform some changes of your consents, you can contact the researcher:
Ana Cristina Romo Martínez
ana.cristina.romo.martinez@nmbu.no
+47 92288889

Agreement
I have read the procedure described above. I voluntary agree to participate in the procedure and I have received a copy of this description.

Participant: _____ Date: _____

Researcher: _____ Date: _____

Appendix C

Informed Consent B

Please read this consent document carefully before you decide to participate in this study. The researcher will answer any questions before you sign this form.

Study Title: The Norwegian Environmental Governance System Towards an Energy Transition. A case study on Sustainable Fuels and Carbon Capture and Utilization Value Chain.
Purpose of the Study: The aim of this study is to evaluate the current Norwegian Environmental Governance System framework towards an energy transition, as well as its strategies to manage challenges and the implementation of new technologies. Norsk e-Fuel with its sustainable fuel and the CCU value chain involved in its production, is used as a case study for a specific analysis.
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Confidentiality: All the information you supply during the interview will be held in confidence and, unless you specifically indicate your consent, neither your name nor the name of the Institution you represent will appear in any report or publication of the research. The data will be collected via an audio recording of the interview and will be safely stored in an online locked facility from NMBU. Only the researcher will have access to this information, and it will be destroyed after the submission and presentation of the study.
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Participant: _____ Date: _____

Researcher: _____ Date: _____

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