University of Reading

ENERGY SUBSTITUTION AND THE INSTITUTIONAL ENVIRONMENT

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List of abbreviations

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GHG: greenhouse gas

IPCC: Intergovernmental Panel on Climate Change

WDI: World Development Indicators

IEA: International Energy Agency

solar PV: solar photovoltaics

TES: total energy supply

TFC: total final consumption

CES: community-based energy system

ICA: International Co-Operative Alliance

EROI: energy return of investment

UK: United Kingdom

VECM: vector error correction model

NEA: Nuclear Energy Agency

WGI: Worldwide Governance Indicators

NIMBY: not in my backyard

NIE: new institutional economics

OIE: original institutional economics

SES: social-ecological system

IAD: institutional analysis and development

GDP: gross domestic product

FE: fixed effects

RE: random effects

FGLS: feasible generalised least squares

AR(1): autoregressive process of order one

PPP: power purchasing parity

m/s: metres per second

kWh: kilowatt-hour

EUR: euros

USD: US dollars

UNSD: United Nations Statistics Division

ERA5: ECMWF Re-analysis (fifth)

ECMWF: European Centre for Medium-Range Weather Forecasts

OECD: Organisation for Economic Co-Operation and Development

MS Teams: Microsoft Teams

SME: small and medium enterprise

RED II: European Renewable Energy Directive Recast

ktoe: kilotonnes of oil equivalent

kWh/m^2: kWh per metres squared

sq. m.: square metres

Abstract

This thesis contributes insights on the role of institutions on the substitution for fossil fuels across countries. Using panel data econometric methods, the research focusses on 19 European countries from years 2011-2018, and finds evidence that (a) higher industrialisation levels in the economy positively affects energy substitution; that (b) changes in industrialisation levels, not the levels themselves, negatively affects energy substitution, but state-related institutions in support of green energy policy weaken this effect; and that (c) higher degrees of state participation of the electricity sector negatively affects energy substitution, but state-related institutions in support of green energy policy likewise weaken this effect.

Furthermore, qualitative research methods were used to investigate how community-based approaches to renewable energy help in the substituting renewables for fossil fuels in Europe. This feature online interviews focussing on 14 REScoop.eu member cooperatives and organisations and 4 non-REScoop.eu organisations, and a complementary online survey of 32 respondents. This part of the research finds that (a) cooperatives' legal form is not seen to generate the perceived advantages to cooperatives in renewable energy proliferation and (b) in addressing associated land use issues; that (c) there is the perception that renewable energy cooperatives directly help in renewable energy proliferation through localising energy production and stimulating the local economy, (d) by making renewables more acceptable at the local level, and (e) by building trust-based relationships with the communities; and that (f) such cooperatives are hampered by the general lack of corresponding professional and technical expertise, by being mostly run by volunteer work, and by the democratic decision-making process.

Declaration of original authorship

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.
Emmanuel Genesis T. Andal

Chapter 1. Introduction: climate change and energy transitions

Much of the issue of climate change is hinged on the fact that harmful anthropogenic emissions are the most immediate cause of the change in the climate. These emissions accumulate in the atmosphere and add to the naturally occurring greenhouse gasses, which makes the planet's surface warmer than it would be otherwise, leading to a rise in the global average temperature. In 2018, the largest causes of greenhouse gas (GHG hereafter) emissions are fossil fuel combustion, accounting for more than three quarters of GHG emissions[1]. Net GHG emissions have continued to rise from 2010 – 2019, in which the average annual GHG emissions in 2019 were higher than all preceding decades, though the growth rate slowed down compared to immediate previous one (IPCC, 2022). There are three main ways through which reducing GHG emissions can generally be done, namely through improvements in energy efficiency, through decarbonisation of overall energy exploitation, and through the reduction of fossil fuel use (Bradshaw, 2013). Whilst improvements in energy efficiency improve energy intensity, Herring (2000; 2006) challenges the perspective that energy efficiency reduces carbon dioxide emissions, contending that more efficient use of energy leads to lower energy prices that increases energy demand. In relation to this, there can be a decrease in resource savings because of increased consumption following increased efficiency, hence has what is called in the literature as a *rebound effect*[2]. This argument can be traced back to William Stanley Jevons (Jevons, 1865), hence the widely known "Jevons Paradox". Sorrell (2009) states that evidence consistent with the Jevons Paradox suggest that the rebound effect is larger than what is typically assumed, but also points out that the arguments supporting the Jevons Paradox are largely theoretical and illustrative, and do not include empirically backed evidence.

The Intergovernmental Panel on Climate Change states that global energy intensity has decreased by 2% from 2010 – 2019 (IPCC, 2022). This means that energy demand must be more directly addressed through reducing fossil fuel consumption, implying a lower share of fossil fuels in the energy mix in general. Attempts at reducing GHG emissions therefore requires an energy transition, which can be defined as a series of significant changes to the pattern that defines the way an economy is dependent

[1]https://www.climatewatchdata.org/ghg-emissions?breakBy=sector&chartType=percentage&source=CAIT Accessed 14 April 2022.

[2]More specifically, there is the *direct* rebound effect, i.e., the increase in energy demand caused by the fall in energy services prices; and the *indirect* rebound effect, i.e., the increase in energy demand caused by higher relative incomes as a result the decrease in energy services prices. Higher relative incomes are used to consume other goods and services that consumes energy, hence an overall increase in energy demand.

on one or a group of energy resources and technologies[3] (O'Connor, 2010; Fouquet and Pearson, 2012). To address climate change, the nature of this required energy transition needs to be towards more application of energy resources and technologies associated with lower GHG emissions.

One aspect of this energy transition therefore is the substitution of alternative energy resources for fossil fuels, leading to a cleaner energy mix. Regarding this, it appears that countries differ in rates at which they substitute for fossil fuels. Figure 1 for instance shows how the top ten carbon dioxide emitters (in kilotonnes) perform in substituting renewables from the consumption side as of 2019. It may be the case that renewables have increased in absolute terms in supply, demand, and electricity generation (IEA, 2021), but fossil fuels have done the same, as shown by the decreasing shares of renewables in energy consumption. This is not consistent with the goal of limiting both the global average temperature rise to below 2°C above pre-industrial levels and the increase in temperature to 1.5°C above pre-industrial levels, as specified by the Paris Agreement.

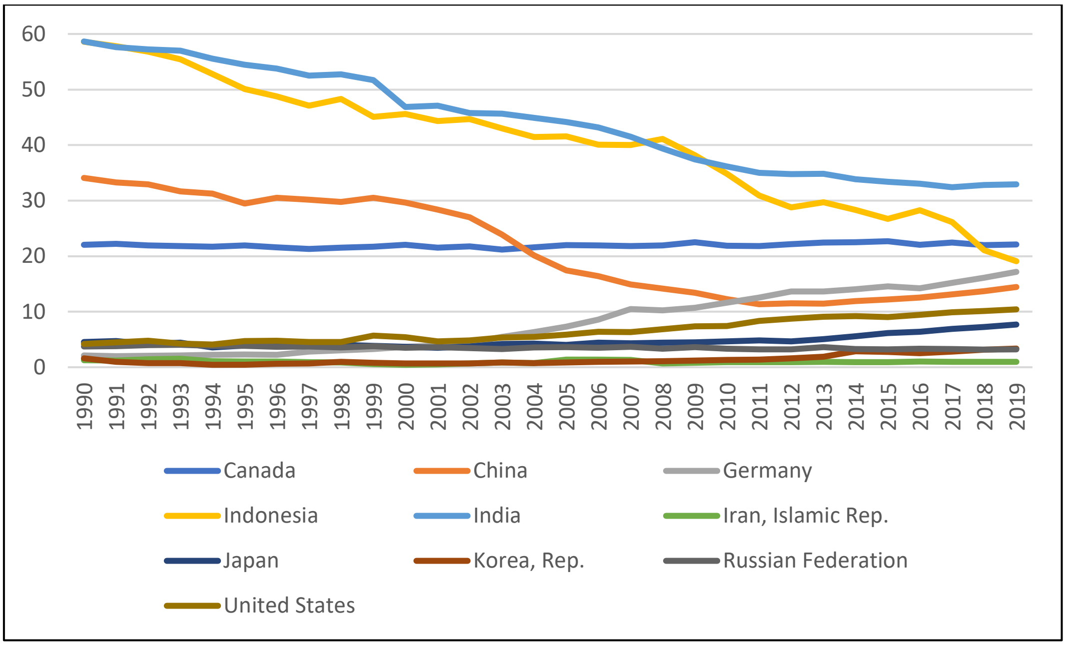

Figure 1. Share of renewables in the total final energy consumption (%) of the top carbon dioxide emitters. Source: Author using data from the World Development Indicators (WDI hereafter).

This thesis then contributes insights on the differences in observed rates of energy substitution towards a cleaner energy mix across countries as measured by changes in the latter. This is important

[3]Relative to the extant related literature, this definition can be seen as a more general one because some definitions in the literature tend to focus only on either energy consumption or production and tend to describe only an abrupt change instead of a trend, and the term "transition" allude to the former. It also can be seen as a more specific one because some definitions in the literature tend to focus on the society or the energy system as a whole. An energy system is a collection of energy flows, conversion processes, and services coordinated through energy markets (Cherp et al, 2018).

because if some countries have relatively lower rates of substitution towards a cleaner energy mix, the world is less able to reduce emissions, and may eventually fail in achieving the goal of the Paris Agreement. The thesis investigates the drivers of substitution towards a cleaner energy mix at the country level, in which both quantitative and qualitative methods were used in the investigation.

Using quantitative methods, more specifically panel data econometric methods, the research focusses on 19 European countries from years 2011-2018. At least three research gaps are quantitatively addressed by this thesis: the (a) effect of the industry sector's prominence in the substitution for fossil fuels in a given country, the (b) role of institutions in such substitution, specifically if strong institutions can influence the latter, and the (c) effect of state participation in the energy sector on such substitution.

In the first place, fossil fuels are the dominant source of energy in modern times, and this slows down an energy transition to alternative energy resources. In 2019, fossil fuels accounted for nearly 81% of the world's total energy supply (TES hereafter), and about two thirds of the world's total final consumption (TFC hereafter) of energy. The industry and transport sectors had the highest shares in energy consumption at almost 29% apiece (IEA, 2021). The industry sector consumes more than 72% of the world's coal and more than 37% of natural gas, the largest consumer of both. It is similarly the largest electricity consumer, consuming almost 42% of all the electricity. The latter, which makes up nearly a fifth of the world's TFC, is also primarily generated using fossil fuels; almost 63% of electricity being generated from fossil fuels, coal being the principal resource for electricity, generating about a third (IEA, 2021). More details on are in Section 2.1.

The industry sector then is highly dependent on fossil fuels. An economy in which the industry sector has a relatively lower share will therefore also be relatively less dependent on fossil fuels. This means lower costs in substituting towards a cleaner energy mix in the short run. Therefore, it will be easier for countries in which the industry sector has lower shares in the economy to substitute for fossil fuels. One hypothesis is then the following: *lower shares of the industry sector in the economy of a given country positively affects substitution towards a cleaner energy mix in that country*.

Furthermore, as is discussed in detail in Section 2.2, given the attractiveness of fossil fuels as an energy resource, a dedicated energy policy must be in place to incentivise the production and consumption of alternatives to substitute towards a cleaner energy mix, as the respective energy policy must satisfactorily be implemented. Strong institutions can help in the satisfactory implementation of an energy policy by supporting the latter's implementation, and thus can lead to a satisfactory implementation of energy policy geared towards substituting towards a cleaner energy mix to generate an energy transition to address climate change. Therefore, strong institutions are necessary to positively influence substituting towards a cleaner energy mix. A second hypothesis is then the following: *stronger institutions in support of energy policy designed to incentivise energy output from alternatives in a given country positively affects substitution towards a cleaner energy mix in a given country*. Here, the relevant institutional constraints as far as support for energy policy is concerned are those rules and regulations that are implemented and enforced by the government. This is not to say that these are the only institutional constraints that are important; the thesis just limits the scope of analysis on state-related institutions for the reason just provided.

Lastly, given that the government is willing to intervene with energy policy supported by strong institutions in the energy sector, the higher the degree of state participation in the energy sector positively affects the substitution towards a cleaner energy. The higher the level of participation the state has in the energy sector, the less difficult for the former to influence the latter. Therefore, a higher degree of state participation in the energy sector positively affects energy substitution because of a higher degree of influence in the energy sector. A third hypothesis is then the following: *given that the government is willing to intervene with energy policy in the energy sector and there are strong institutions in support of the latter, higher degree of state participation in the energy sector in a given country positively affects substitution towards a cleaner energy mix in that country*.

The quantitative part of the research addresses the question of what causes the differences in rates across countries in substituting towards a cleaner energy mix. *The quantitative part of the thesis has the general aim of investigating what makes other countries slower than others in substituting towards a cleaner energy mix.*

To achieve this general aim, the quantitative part of the thesis has the following ***objectives*:**

1. *To determine if countries with relatively stronger state-related institutions that support green energy policies at given shares of the industry sector in their economy experience higher rates of change in the share of non-fossil fuel resources in energy production*.
2. *To determine if countries with relatively high degree of state participation in the energy sector, more specifically electricity, given the existence of green energy policies supported by state-related institutions experience higher rates of change in the share of non-fossil fuel resources in energy production*.

The first quantitative research objective combines the first two hypotheses. This objective is essentially on finding out if strong state-related institutions in support of energy policy weakens the effect of high industry shares in a country in slowing down an alternative energy substitution. This also implies that this objective is on finding out if high industry shares slow down the energy substitution given that countries have strong state-related institutions in support of energy policy. The second quantitative research objective meanwhile is essentially on finding out if high degrees of state participation in the energy sector improve the extent to which the state-related institutions support energy green energy policies.

Qualitative research methods were meanwhile used to investigate how a bottom-up approach that lack the directive of an overarching public policy can come into play to propagate an energy substitution, and hence an energy transition: community-based energy system (CES hereafter). More particularly, to maintain a consistent theme across the thesis, the research also zero in on Europe like the econometrics part of the thesis this qualitative part of thesis investigates how renewable energy cooperatives help in the proliferation of renewable energy in Europe, particularly focussing on REScoop.eu, a federation of renewable energy cooperatives in Europe with a membership of about 1,900. This is for the following reasons. *First*, as implied in Bauwens et al (2016), focussing on cooperatives would considerably simplify the analysis. *Second*, cooperatives tend to be more comparable across countries than other CESs. REScoop.eu itself is a sectoral organisation of Cooperatives Europe, the European branch of the International Co-Operative Alliance (ICA hereafter), which means that REScoop.eu complies with a common set of principles upon which their members' organisational forms are based on. These make cooperatives more comparable across countries than those CESs that have more informal approaches. *Third*, cooperatives are likewise relatively strong forms of CESs in Europe, making them exemplary models for an approach to a CES in the continent.

As is discussed in detail in Sections 2.4 and 2.5, the cooperative organisational form can incentivise renewable energy adoption through the following. First, community-based approaches generally tend to be favourable to renewables, as the latter tend to be more distributed in nature than its alternatives hence are more readily available. These properties of renewables make them suitable for production at the community level. Second is through the democratisation of the energy sector, where communities here produce their own energy, hence less dependent on energy firms for energy supply. Third, renewable energy cooperatives can help achieve a more equitable distribution of benefits from resulting renewable energy projects through more open and participatory development and management schemes, being more local in terms of the extent, and more collective in terms of benefit accrual. A fourth hypothesis is then the following: *renewable energy cooperatives can directly help in the proliferation of renewable energy in Europe (a) by having a suitable organisational form to develop and manage energy systems at the community level, (b) through the desire to democratise the energy sector, and (c) by making distribution of the associated benefits more equitable*.

Renewable energy cooperatives can also help in renewable energy adoption by addressing the associated transaction costs. This is done through the increased likelihood of trust within cooperatives, reducing the associated transaction costs, i.e., the bargaining and enforcement costs. Moreover, cooperatives are more acquainted with the specific circumstances of the communities from which they arise, hence can come up with specialised arrangements based on such specific circumstances to specifically deal with the related transactions. These specialised arrangements require addressing less aspects of a transaction, reducing the respective transaction costs. A fifth hypothesis is therefore the following: *renewable energy cooperatives help in the proliferation of renewable energy by addressing transaction costs associated with renewable energy production*.

The qualitative part of the thesis features online interviews focussing on 14 REScoop.eu member cooperatives and organisations and 4 non-REScoop.eu organisations, and a complementary online survey of 32 respondents. *The qualitative part of the thesis has the general aim of investigating how renewable energy cooperatives help in the proliferation of renewable energy*.

To achieve its general aim, the qualitative part of the thesis has the following ***objectives*****:**

1. *To determine if renewable energy cooperatives directly help in renewable energy proliferation in Europe (a) by being a suitable organisational form to develop and manage renewable energy systems at the community level, (b) through the desire to democratise the energy sector, and (c) by making distribution of benefits more equitable in the context of REScoop.eu.*
2. *To determine if renewable energy cooperatives also do this by addressing transaction costs associated with renewable energy production in the context of REScoop.eu.*

These last two qualitative research objectives directly correspond to the last two hypotheses identified.

The thesis contributes insights on the role institutions on the substitution for fossil fuels across countries. To reiterate, climate change will be addressed more successfully if more countries in the world are more able in reducing GHG emissions, i.e., more able in substituting towards a cleaner energy mix. Regarding this, the thesis is on investigating how institutions might influence such energy substitution. More specifically, as indicated by the quantitative research objectives, *the thesis contributes insights on how state-related institutions might affect how the industry sector's prominence in the economy and the degree of state participation in the energy sector in turn influence energy substitution*. In addition, this time as indicated by the qualitative research objectives, *the thesis likewise contributes insights on how the cooperative organisation form in and of itself and by addressing transaction costs help in renewable energy proliferation*. The thesis therefore contributes to the related literature on energy substitution by investigating the role of institutions in how it unfolds.

The details are discussed in the next chapters. Chapter 2 goes over the related literature and related research gaps. Chapter 3 describes the theoretical frameworks used to address the quantitative and qualitative research gaps, Chapter 4 describes the respective methods, and Chapter 5 contains the respective results and discussion. Chapter 6 concludes.

Chapter 2. Literature review and research gaps: institutions, industrialisation, energy policy, community-based energy systems, and transaction costs

This chapter expounds on the emerging trends in the strands of literature related to the thesis topic. In particular, these are the notions that energy transitions are slowed down by the dominance of fossil fuels as energy resources (Section 2.1), the role of the levels of industrialisation, policy, and strong institutions in energy substitution (Section 2.2). Likewise discussed here is how renewable energy cooperatives help in the proliferation of renewable energy, i.e., the concept of the CES (Section 2.3), the cooperative organisational form (Section 2.4), and the associated transaction costs (Section 2.5). These trends in the related literature give a picture on the current direction of research on energy transitions and energy substitution, hence provide clues on what the current research gaps are, also discussed in this chapter.

It is important to initially note that some studies have been done in efforts to shed light on alternative energy substitution. A study by Bloch et al (2015) on China's aggregate production and consumption of oil, coal, and renewables of using autoregressive distributed lag and vector error correction model (VECM hereafter) models, finds a positive cross-price elasticity for all energy resources just mentioned, suggesting a purely market-based incentive for energy substitution by lowering the price of fossil fuels. Apergis and Payne (2014) meanwhile used a non-linear VECM in a panel data study on Central America on the determinants of renewables consumption and got similar results. An investigation directly related to energy transition, that of Guidolin and Guseo (2016) on Germany's Energiewende, delved into the social effects on both competition and substitution dimensions of an energy transition, particularly between nuclear and renewable energy. Using non-linear least squares to statistically implement an Unbalanced Competition and Regime Change Diachronic model, it finds that renewables have a significant effect on the decrease of nuclear power consumption in Germany through word-of-mouth.

It seems important as well to give attention to some studies on the technical aspect of energy substitution. In a study on Taiwan, Wang et al (2016) used an energy supply mix model to determine certain carbon tax thresholds that when breached, offshore wind will replace fossil fuels. In looking into hourly demand of electricity in Central North Texas, Leonard et al (2018) meanwhile finds a necessary daily and seasonal storage capacity for a complete solar and wind substitution of coal. In analysing the incentives Canada faces in introducing wind and solar to lower GHG emissions using life cycle assessments, Granovskii et al (2007) finds that the cost of GHG emissions reduction by substituting electricity from natural gas with that from such renewables is less than that in substituting hydrogen from natural gas with that from renewables. The paper also finds that an internal combustion vehicle substituting renewable hydrogen for gasoline will decrease the cost of GHG emissions.

Section 2.1. The dominance of fossil fuels as energy resources and industrialisation levels

The literature seems to point to four main reasons why fossil fuels continue to dominate world energy supply and demand, which hampers an energy transition: *first* is geographical availability; *second* is their efficiency in use; *third* are the significant innovations in the end-use technologies; and *fourth* are the large costs associated with shifting away from fossil fuels. These four are discussed in the following paragraphs.

First is geographical availability. The discovery and development of major petroleum (oil and natural gas) resources in Europe, namely the Groningen natural gas field in the Netherlands and the North Sea petroleum fields, and Siberian gas imports beginning in the early 1980s sped up Western Europe's transition to petroleum, leading to huge declines in coal mining, e.g., in France, the UK, and Germany, and a complete halt in the case of the Netherlands (Smil, 2006). Coal meanwhile is one of the most abundant fossil fuels on the planet, having reserves that are generally larger than those of petroleum. Also, even though Russia has tremendous potential for hydropower, the sheer size of Russia's fossil fuel endowments stunted growth of hydroelectricity (Smil, 2010). Pfeiffer and Mulder (2013) also finds that the abundance of fossil fuel appears to have a negative effect on the decision to adopt non-hydropower renewables. Shi (2016) also maintains that the relative fossil fuel dominance in Southeast Asia leads to lower diversity in the respective energy mix.

Second is the efficiency of fossil fuel in use. For instance, oil can be directed to the point of consumption without much difficulty, can be put in storage until use, and the energy contained in it can be produced at will. Crude oil can also be burned directly to generate electricity. Furthermore, coal is generally cheaper and easier to explore and produce than petroleum, currently one of the cheapest energy resources (Narbel et al, 2014). In relation to this, coal is an attractive energy resource because of its high energy return of investment[4]. It has been observed that historically, petroleum is second to none in history as an energy resource in terms of being extractable, transportable, versatile, and cost-effective (Divi, 2009). Add to this the fact that fossil fuels tend to have high power densities. Power density is the amount of energy produced per unit time per unit of volume or per unit of mass, a relatively straightforward way to measure productivity of an energy resource. Solar and wind power both tend to have relatively low power densities compared to fossil fuels, meaning that larger land

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[4]Energy return of investment, or EROI, is the amount of usable energy that is extracted from an energy resource divided by the amount of energy it takes to access the energy resource (Braun and Glidden, 2014).

areas are necessary for the same levels of energy to be harnessed to achieve the same rate of energy output.

Third are the significant innovations in the fossil fuel end-use technologies. As was pointed out in Grübler (2012), technology can commence a self-reinforcing positive feedback loop between energy supply and demand. Grübler et al (1999) observes that highly interdependent technologies, say oil refineries and pipelines, tend to coevolve. This coevolution arises from the high costs of one type of technology being incompatible with all others; hence coevolution of interdependent technologies arises from what can be called as "incompatibility costs". This coevolution brought about the dominance of petroleum in the energy mix, replacing coal over time. Furthermore, although oil eventually took over coal in many markets the latter served, such as electricity generation and commercial heating, it became more vital as an energy resource through the rise of internal combustion engines (Smil, 2006). Internal combustion engines paved the way for a new market for vehicles, eventually replacing steam engines. This made oil almost the only preferred fuel for transportation. More recent examples of such end-use innovations consistent with substituting towards a cleaner energy mix are the retrofitting of coal and natural gas-fired power plants to enable co-firing with biomass and vehicle models that run entirely on ethanol (Narbel et al, 2014). *Lastly*, there are large costs associated with shifting away from fossil fuels. There are at least two ways this can be demonstrated. One is that there are large sunk costs that inhibit an energy transition, especially given the existing size of its infrastructure. Another is that opportunity costs of substituting alternative energy resources are relatively higher compared to those for fossil fuels. The next paragraphs discuss these two.

Large sunk costs associated with fossil fuels mainly come from the size of the installed infrastructure. Fossil fuels are extracted in more than a hundred countries, with facilities ranging from exploration rigs to refineries, including thousands of large tankers and hundreds of thousands of kilometres of pipelines. According to Smil (2016), even if it is assumed that the cumulative capital investment is only 2% of the global economy, it would mean that establishing the entire fossil fuelled energy system has amounted to at least $25 trillion (in 1990 international dollars) in the 20th century. This can be illustrated with the collapse of the Soviet Union. Networks of pipelines, key oil terminals, and refineries were suddenly located in different independent states. The co-dependent Soviet republics experienced severe electricity and petroleum shortages when the respective infrastructure abruptly changed political boundaries (Campaner and Gubaidullin, 2013). This shows the enormous costs associated with adjustments made relative to installed infrastructure. Even if immediate alternative energy sources were available, shifting to such an alternative would mean discarding a huge amount of investment to putting in place a related immense infrastructure.

In addition, there are high opportunity costs in substituting towards a cleaner energy mix. Costs of using alternatives are overall relatively larger compared to those for using fossil fuels and the latter are also relatively more reliable compared to alternatives as energy resources. For instance, the intermittency of solar and wind as energy resources entails additional costs particularly for backup power plants and interconnectivity among systems. In addition, river-connected hydroelectric systems can only produce electricity when there is sufficient water and strong enough water flow (Narbel et al, 2014). Moreover, whilst fossil fuels can easily be brought to power plants through traditional transport or pipelines, this cannot be done for solar and wind. Also, some renewables, like hydropower and biomass, do not preclude environmental issues. For example, if a rainforest is flooded during the construction of a hydroelectric reservoir, the decomposition of extant biomass will release substantial amounts of methane into the atmosphere. Tropical reservoirs are also often invaded by aquatic weeds, another major source of GHGs (Narbel et al, 2014). Also, biofuel production from peatland conversion leads to increased carbon dioxide emissions (Fargione et al, 2008). All of these will worsen GHG levels in the atmosphere. Likewise, capital costs generally remain high for nuclear power, due to concerns on delays and risks related to technology, safety, and regulation (Khatib and Difiglio, 2016). Furthermore, strong public opinion against nuclear prevents it from becoming mainstream in the energy scene (Kidd, 2013; Zaleski, 2013), and fossil fuels are simply more socially accepted to some extent. This negative view of nuclear power comes from the risks of future nuclear accidents and delays and on harnessing technology that contribute to high capital costs (Narbel et al, 2014), and from issues on nuclear waste disposal (Zaleski, 2013). From a country-level perspective and short-term outlook, fossil fuels therefore cannot be easily replaced as energy resources because they are relatively cheaper and relatively more reliable.

Smith and Urpelainen (2013) states that industrialised countries have the tendency to reduce public investment in research and development on fossil fuel alternatives, and there are also studies that find that industrialisation increases energy intensity (Sadorsky, 2013) and energy consumption (Sadorsky, 2014) in emerging economies. This implies that, as Sadorsky (2014) puts it, since the industry sector is highly dependent in fossil fuels, and the latter account for most of the world's energy consumption, policies crafted to improve industrialisation levels are not consistent with sustainable[5] development,

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[5]Sustainability involves taking into consideration the wellbeing of future generations (Kibert et al, 2011), allowing the latter to experience the same living standards as the current one.

something that must be pursued to satisfactorily address climate change. Higher industrialisation levels can therefore hamper an economy's rate in substituting towards a cleaner energy mix to address climate change.

In relation to the discussion of the first hypothesis brought up in Chapter 1, *the first research gap that the thesis addresses is the effect of the industry sector's prominence on energy substitution towards a cleaner energy mix in a given country*. This thesis deals with this research gap in two ways. First is that the thesis specifically deals with the role of industry share in energy substitution per se. Second is that the thesis does a cross-country investigation using panel data on the matter. Regarding the first, whilst it is acknowledged in the literature that the structure of the economy is relevant in issues related to the energy sector (e.g., in Bradshaw, 2013), such literature focussed only on emissions (e.g., Suh, 2006; Baiocchi and Minx, 2010) or on energy intensity (e.g., Wing, 2008; Henriques and Kander, 2010) and not on energy substitution per se, which to reiterate entails an investigation on the changes in the energy mix in general. There is one study, Salim et al (2014), that deals directly with the relationship between economic structure and energy consumption. Using panel Granger causality methods, it finds a long-run bidirectional relationship between industry value added and both renewable and non-renewable consumption. To clarify, whilst this indeed overlaps with the thesis topics being tackled, this thesis is asking a different question: Salim et al (2014) is essentially on the relationship of industry output and energy use, whilst this thesis investigates the relationship between the relative importance of the industry sector in the economy and energy substitution. Regarding the second, to the best of the author's knowledge, there appears to be no study using cross-country panel data on the influence of economic structure on energy substitution per se. Much of the existing literature just focusses on one or few countries (e.g., Krausmann et al, 2008; Nansai, 2009). Henriques and Kander (2010) contain thirteen countries and did not run regressions on panel data. It must be acknowledged however that there are studies on the energy sector using panel data (e.g., Filippini and Hunt, 2011).

Section 2.2. Policy and strong institutional support

Whilst there are instances of diffusion of alternatives with a bottom-up directive to support the exploitation of the former as was discussed in Chapter 1 and given details in Section 2.3, e.g., the community-based wind energy system in Denmark (Mey and Diesendorf, 2018), energy policy must be implemented to hasten substituting towards a cleaner energy mix; as long as fossil fuels are more economically practical than alternatives, there will be a gradual growth in importance of such alternatives (Smil, 2017), as demonstrated by fossil fuel dominance in the global energy mix. Public policy is supposed to have been crafted to specify the framework upon which resource allocation is based and allows governments to guide behaviour in pursuit of a societal objective (Nersesian, 2016).

Energy policy then provides guidance in determining what resources to use to produce energy and how the resulting energy is used. As implied in Sorrell (2015), the aspect of energy policy set aside to address climate change must likewise be implemented such that it enables energy substitution to address it. It should be noted however that governments may not necessarily act in the interest of the public. According to theories on the nature of the state presented in Hall (1993), energy policy can be seen either (a) as determined by general societal interests, e.g., ensuring reliable energy access or increasing employment; or (b) as reflective of competing interests of various groups within a society, e.g., voters, industrial lobbies, or social movements, which can be manifested as public values (Correlje and Groenewegen, 2009) (governments may for example maximise votes from constituencies with preferences for specific energy resources); or (c) both. Diverse groups and individuals having conflicting interests therefore imply that energy policy that incentivises the substitution towards a cleaner energy mix may involve political struggles as well (Geels et al, 2018).

Energy policy instruments are necessary if there are not enough incentives to produce or consume an energy resource, such as if energy prices are not sufficiently high such that there is effectively no supply, or if there are barriers to entry and exit that prevent the realisation of such incentives, like when the perceived risk for producers are high enough to prevent them from even entering the market (Wüstenhagen and Menichetti, 2013). The literature points out that energy policy instruments, such as tradable green certificates (Johnstone et al, 2010), feed-in tariffs (Marques and Fuinhas, 2012; Kilinc-Ata, 2016), carbon taxes (Bruvoll and Larsen, 2004; Elliott et al, 2010), public financing (Mazzucato and Semieniuk, 2017), imposition of standards (Pfeiffer and Mulder, 2013), direct control (NEA, 2012) are necessary to incentivise renewables. Notwithstanding, energy policy can still be at the mercy of prevailing economic incentives. Associated costs with an energy resource may be so large that policy still does not make it worthwhile to support such an energy resource. For instance, according to Khatib and Difiglio (2016), subsidies on renewables, except on hydropower, are increasingly hard to maintain given certain economic circumstances. These policy problems may further make it even more costly to substitute towards a cleaner energy mix. The literature also suggests that problems can arise when implementing energy policy, like volatility in subsidy schemes and regulations (Negro et al, 2012), uncertainty associated and likelihood of termination (Aguirre and Ibikunle, 2014), a relatively short-term agenda in renewables (Hillman and Sandén, 2008), the lack of related technical knowledge that can have a positive effect on renewables investments (Popp et al, 2011) and can lower the associated costs (Huenteler et al, 2016), and policy misalignment across different administrative levels and across different sectors (Markard et al, 2009). Geels et al (2018) notes that it is necessary to examine the ecology of policy instruments to identify positive and negative interactions between them and likewise to investigate how to incentivise the rise of and impacts of low-carbon innovations.

Thus, strong institutions, i.e., those that can facilitate high-quality implementation of energy policy, are necessary for the latter to hasten the substitution towards a cleaner energy mix. Institutions are arrangements that determine how individuals interact by imposing constraints on behaviour, devised to establish order and reduce conflict associated with relations formed from such interactions (North, 1991; Woods, 2004). North (1984) remarks that the constraints on interactions which institutions impose include ethical, behavioural norms (e.g., traditions and values) and the rules and regulations (e.g., laws and policies) that arise from the former, along with corresponding procedures dealing with non-conformity with these rules and regulations. Institutions can help in the satisfactory implementation of an energy policy by supporting the latter's implementation and ensuring that this implementation is satisfactory. This also implies that there should be interactions between strong institutions and energy policy in a country. In a study on the United States, Germany, and the UK using a dynamic stochastic general equilibrium model, Atalla et al (2017) finds that market-oriented reforms in the 1990s for Germany and the UK influenced the respective primary fossil fuel mix. Moreover, the results in Marques et al (2018) in a study on ten European countries suggest that renewables cannot meet electricity demand without fossil fuel-based electricity generation, which encumbers shifting away from fossil fuels in electricity generation. The article then recommends that policies guiding electricity demand must be formulated. In a study on countries from East Asia and the Pacific, Hanif (2018), finds that public policies crafted specifically for shifting to renewables were insignificant. As of 2014, fossil fuels make up more than 85% of the region's TFC[6].

In relation to the discussion of the second hypothesis brought up in Chapter 1, *the second research gap that the quantitative part of thesis addresses is the role of institutions in energy substitution towards a cleaner energy mix, specifically if strong institutions can influence such energy substitution in a given country.* The way this thesis deals with this research gap is likewise twofold. First is that the thesis specifically deals with the role of the strength of institutions in energy substitution per se. Second is this thesis provides quantitative empirical methods in its analysis. Regarding the first, whilst there are studies on the role of institutions, specifically the governance structure and policy in the energy sector (e.g., Teece, 1990; Joskow, 1991; Ruester and Neumann, 2009), these studies focussed on the structure of the energy sector only, and not on energy substitution per se, as the latter call for an examination of changes in the energy mix in general. It must be noted that the literature does

[6]The only high-income country included in Hanif (2018) is South Korea.

underline the effects of political institutions on how policy is shaped. In a study on 26 European countries, Schaffer and Bernauer (2014) finds that federal governments are more likely to engage in intervention to support renewables. Cadoret and Padovano (2016), in a similar study on Europe, finds that industrial lobbying negatively affects the deployment of renewables. Both the previously mentioned studies likewise find that even positions in the political spectrum can be a factor: countries with left-leaning governments tend to use intervention to support the use of renewables. The thesis has a similar approach to that in Cadoret and Padovano (2016), in that a governance variable from Worldwide Governance Indicators (WGI hereafter) from the World Bank is also used here. Cadoret and Padovano (2016) however is tackling a different issue, i.e., how political factors affect the deployment of renewables in Europe. Regarding the second, there indeed is a strand of literature that tackle the use institutional theories to research on energy transitions, and how might institutional theories, like new institutional economics (Andrews-Speed, 2016[7]) or the association of historical institutionalism (Lockwood et al, 2017) and new institutionalism (Kuzemko et al, 2016) to the socio-technical pathways framework, to enrich the analysis of energy transitions at the national level. This strand of literature however only presents theoretical frameworks or qualitative approaches (e.g., Kuzemko et al, 2017), lacking quantitative empirical methods in its analysis.

By extension, as was brought up in the discussion of the third hypothesis brought up in Chapter 1, it can similarly be argued that given that the government is willing to intervene with energy policy in energy markets and there are strong institutions in support of the latter, the higher the degree of state participation in the energy sector, the higher the rate of change of the energy mix towards a cleaner one will be. *Therefore, the third research gap that the thesis addresses is the effect of state participation in the energy sector on energy substitution towards a cleaner energy mix in a given country.* This thesis deals with this research gap in two ways as well. The thesis deals with the role of state participation in the energy sector in energy substitution per se and does an actual econometric cross-country investigation using panel data on the matter. Regarding the first, there are indeed studies on state ownership in the energy sector. Szarzec and Nowara (2017) is a study on state-owned enterprises in the energy sector, featuring 13 Central and Eastern European countries over the years 2007-2013. The study however is on the economic performance of state-owned enterprises themselves and not on the countries wherein they operate, not in relation to energy substitution, and did not do a rigorous quantitative empirical analysis. A more extensive work is Wolf (2009), which did panel data regressions in comparing the performances of 1,001 state-owned and privately-owned oil

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[7]The article referred to new institutional economics (NIE hereafter) as “rational choice institutionalism”.

companies from years 1987-2006, and finds that in general, greater efficiency is encouraged by private ownership. This study, similar to Szarzec and Nowara (2017), is on firms themselves and has nothing to do with energy substitution. Regarding the second, the related literature seems to focus only on case studies on one or few countries, either directly tackling state participation (e.g., Laes et al, 2014; Fontaine et al, 2019) or indirectly (e.g., Moss et al, 2015; Mey and Diesendorf, 2018; Hvelplund and Djørup, 2019).

Section 2.3. Community-based energy systems

The literature on community-based approaches to energy seems to highlight several related concepts, the common seems to be "community energy" (e.g., Nolden, 2013; Kalkbrenner and Roosen, 2016; Bauwens et al, 2016), "community-based" actions (e.g., Khan et al, 2007; Rogers et al, 2008; Dóci and Vasileiadou, 2015), "community ownership" (e.g., Macdonald et al, 2017; Akinyele and Ryadu, 2016) "citizen ownership" (e.g., Moss et al, 2015; Gorroño-Albizu et al, 2019), "grassroots" actions (e.g., Hargreaves et al, 2013; Hoffman and High-Pippert, 2010), "distributed energy" (e.g., van der Vleuten and Raven, 2006; Koirala et al, 2018), "decentralised" actions (e.g., Boon and Dieperink, 2014; McLellan et al, 2016) and "consumer ownership" (e.g., Hvelplund and Djørup, 2019).

Walker and Devine-Wright (2008) provides a framework through which a CES may be conceptualised, which identifies two dimensions that characterise the perspectives of various stakeholders particularly in renewable energy projects. *First* is the *process* dimension, which is on who develops and runs an energy system. *Second* is the *outcome* dimension, which is on who will benefit from the outcomes of the energy system. These are summarised in Figure 2. The process dimension has a spectrum that goes from being open and participatory on one end and being closed and institutional on the other.

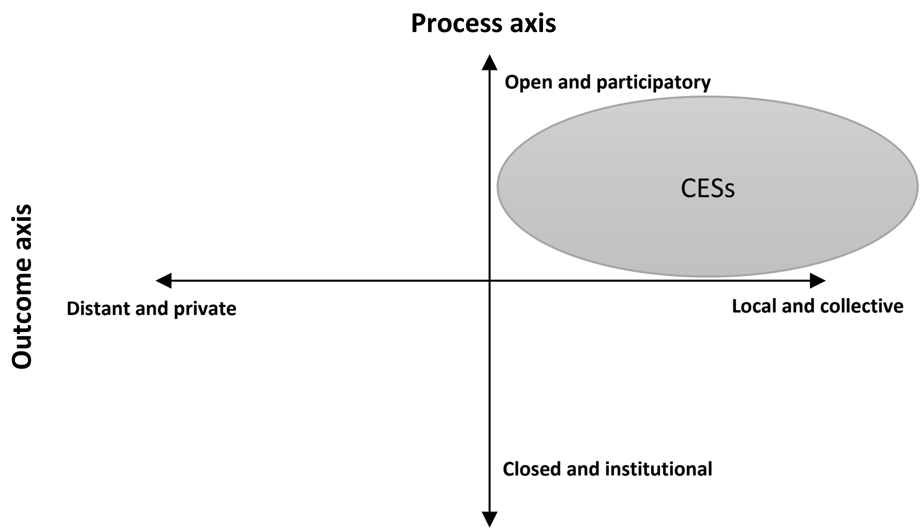

Figure 2. Perspectives on community renewable energy. Source: Walker and Devine-Wright (2008).

The outcome dimension meanwhile has a spectrum that goes from distant and private to local and collective. Being distant, as opposed to being local, means that the energy project is producing energy for a corresponding grid instead of for the local community. The "ideal" CES typically falls on the first quadrant, characterised by elevated levels of community participation both in involvement and benefits from the initiative (Walker and Devine-Wright, 2008; Bauwens, 2016).

There are variations of this model presented in Walker and Devine-Wright (2008) in the literature. Hoffman and High-Pippert (2010) specifies a "community energy initiative" to be characterised by the following dimensions: (a) the extent to which a community is participating in such an initiative; (b) the nature of the corresponding governance; (c) the extent to which local energy production and consumption are linked; (d) the nature of ownership under the initiative; (e) and/or the nature of the technology used in the resulting system[8]. Here, Dimensions (a) and (b) seem to correspond to the process dimension in Walker and Devine-Wright (2008): the extent of community involvement and the subsequent governance structure are associated with the manner of development and management of a CES. Dimensions (c) and (d) meanwhile appear to correspond to the outcome dimension: the link between energy production and consumption, and the nature of the ownership are associated with the extent and the distribution of benefits from the CES.

Furthermore, in its investigation on Danish wind turbines and district heating systems, Gorroño-Albizu et al (2019) also presents a model in which diverse types of community ownership models can be pinpointed based on different institutional designs. It describes such community ownership models in three dimensions: (a) geography (spectrum from local to distant); (b) type of ownership (spectrum from inclusive to exclusive); and (c) type of profits (spectrum from communal to private). The geography dimension is on the owners' distance from the area where the energy system is located, hence regarding geography as integral to the notion of CES as well; the ownership dimension is on the extent to which participants can be excluded from ownership; and the profit dimension is on the extent to which profits accruing to the participants are limited. The study does point out that these dimensions all relate only to the outcome dimension, as they determine the distribution of the benefits from a CES, and not the governance structure in running the CES that is relevant in determining the nature and extent of regulations.

Participants of CESs can satisfy their energy demand through local transactions, where communities can themselves be engaged in energy generation, storage, and trade. In summary, consistent with the

[8]Hoffman and High-Pippert (2010) maintains that the first three items in this list of community energy initiative determinants it identified comes from a paper published by California Energy Commission in 2001. This paper however cannot be found online in the respective website (https://www.energy.ca.gov/).

insights from the related literature just presented, this thesis conceptualises and defines a CES as *an energy system in which the respective development, management, and benefits structure involves high levels of participation from communities sharing a relatively small geography through their institutional features, done in a collective manner*. In a CES, the communities have high levels of control over the energy system, in that they own, run, and benefit from the energy system. Of note is that there are instances of top-down approaches to incentivise a CES, e.g., China's policies involving linking energy resources near the consumers with small installed capacity and incentivising the populace to use own assets and labour (Zhang et al, 2019) and decentralised electrification efforts in Morocco (Chevalier and Ouédraogo, 2013).

Section 2.4. The cooperative organisational form

According to Hansmann (1999), cooperatives are firms that are owned by the consumers or by the direct producers of goods and services themselves. In cooperatives therefore, ownership is directly tied to the goods and services produced, either through sales (consumer cooperatives) or purchases (producer cooperatives). Consumers as owners are the ones in charge of governance and the ones who decide on prices and profits, blurring the line between producers and consumers: here, the producers are also the consumers, hence prosumers. Cooperative members as prosumers have access to information on the nature of management and the quality of production, reducing information asymmetry and facilitating transparency.

ICA defines a cooperative as "an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly owned and democratically controlled enterprise" (Rodgers, 2015). This according to Henrÿ (2005) is the "universally recognised" definition of cooperatives, which gives the impression that a cooperative is a type of a collective effort to accomplish some common goal. In fact, Ostrom (1990) notes that cooperatives are instances of collective action where groups of individuals voluntarily organise themselves to reap the benefits from their own efforts and cites empirical examples of cooperatives being involved in managing common pool resources. This definition of ICA also appears to introduce another essential feature of cooperatives: *direct ownership by consumers or producers must be collective and democratic*. Relating this to Hansmann (1999), the ownership structure in cooperatives is the means towards collective action to accomplish some goal. In Rodgers (2015), ICA further specifies the following principles through which cooperatives operate: (a) voluntary and open membership; (b) democratic member control; (c) equitable economic participation by members; (d) autonomy and independence; (e) provision of education, training, and information; (f) cooperation among cooperatives; and (g) concern for the respective community.

Cooperatives therefore have an organisational model in which an association of persons jointly own a socio-economic venture from which they themselves benefit. Profit maximisation does not appear to be the main objective for cooperatives, as the meeting of needs and aspirations of a group of people is the primary reason cooperatives are organised. Whilst it may be the case that cooperatives are not necessarily community-based enterprises, as the respective membership is defined by a shared interest in the activities of the cooperative rather than of community itself (Peredo and Chrisman, 2006), there are many instances wherein a cooperative is created to realise the collective action of the community, as in the case of REScoop.eu and its member cooperatives. In summary, cooperatives can be defined as *firms that are collectively owned and democratically controlled directly by consumers or producers to accomplish some goal.*

From the perspective of institutional economics, cooperatives maintain common ownership of some resources, which should be tightly coordinated through some degree of integration, e.g., the profits proceeding from renewable energy project, something that cannot be adequately provided by a price system in purely market arrangements. At the same time, they involve some degree of separate and autonomous property rights on most assets, e.g., members on their owned shares (Ménard, 2007; Šahović and da Silva, 2016). The separate property rights cooperatives maintained on most assets distinguish cooperatives from regular private businesses, i.e., firms owned by capital investors. It is in this way that cooperatives can realise a community-based approach to renewable energy systems, something between predominantly private and state ownership. Here, the residual claims, or the rights to receive the differences between organisation's gains and supposed payments to actors under a fixed claim contract (Fama and Jensen, 1983), are restricted to the group that supplies patronage under the organisation's contracts, where the presiding authority is elected by the same group (Vitaliano, 1983). Patrons are those that transact with the firm, i.e., the firm's customers or suppliers (Hansmann, 1999). The organisation on which the thesis focusses, REScoop.eu, has the main objectives of (a) providing representation for renewable energy cooperatives in European policymaking, (b) providing a support network for new renewable energy cooperatives, (c) providing the corresponding necessary services for members, (d) and promoting the cooperative organisational model throughout Europe. REScoop.eu members subscribe to the seven principles specified in Rodgers (2015) described earlier. In REScoop.eu, the most fundamental decisions are made through a general assembly, which includes all members. There can either be full or associate members in REScoop.eu: full members can either be individual cooperatives or national cooperative federations, and associate members are those related organisations like non-governmental organisations or local authorities, not having voting rights. Votes of full members have equal weight, each having one vote, and decisions are always made on a simple majority, one-member-one-vote basis[9]. Individuals can be members of cooperatives through purchasing one cooperative share. Membership implies co-ownership, i.e., members have shares in the profits. To clarify, owning a share is required for membership, which means that it does not give voting rights to individual; membership does. Members participate in the decision-making process on investments and pricing. Members then can generally consume electricity at a mutually agreed-upon price[10]. The general assembly elects the federation's board of directors in four-year terms with re-election, which decides on the operational aspects of REScoop.eu. The board decides on strategy, planning, and budget issues, and supervises the federation's coordinator. Its decisions are similarly taken by simple majority.

To give details to the initial related discussion in Chapter 1, note that the literature cites several ways renewable energy cooperatives can incentivise renewable energy adoption. *First*, community-based approaches generally tend to be favourable to renewables. Renewables tend to be more distributed in nature than its alternatives like fossil fuels, hence are more readily available, and with some exceptions, are reasonably scalable. These properties of renewables make them suitable for production at the community level in locally owned and managed energy systems, where communities have more control. For instance, China gave control to local units in determining their own preferred source of electricity, and they chose the energy technologies that made the most sense locally. The local units then came up with their own energy systems, and this contributed to China's process of energy diversification (Bhattacharyya, 2013).

Second, renewable energy cooperatives can incentivise renewable energy adoption through the desire to democratise the energy sector. As communities are more in charge of the production of their own energy through their own energy system, they will be less dependent on energy firms for energy supply. Huybrechts and Mertens (2014) claims that one factor that led to the emergence of renewable energy cooperatives in Europe is the desire of energy consumers to gain better control of energy production and prices to get around an oligopolistic energy market. Goddard et al (2002) also highlights that cooperatives typically start from dissatisfaction with the structure of the terms of trade that prevail in the respective market, usually in relatively homogenous and geographically centralised communities. The literature also asserts that some incentives associated with establishing or participating in a CES are democratisation-related, like independence from domestic energy firms (Koirala et al, 2018), independence from energy imports (Boon and Dieperink, 2014), and prospect of

[9] https://www.rescoop.eu/federation Accessed 10 August 2020.
[10] https://www.rescoop.eu/the-rescoop-model Accessed 10 August 2020.

co-ownership gaining profit (Dóci and Vasileiadou, 2015). This democratisation can likewise lead to the development of rural or isolated regions (Cruciani, 2013), since more control of energy production for communities enables them to have more control of the respective development and management of the resulting systems (Khan et al, 2007; Koirala et al, 2018).

Third, renewables having low power densities result in negative externalities arising from massive land use requirements. Production of energy carriers from renewables then is tied to land use, making renewables rivalrous goods. This gives renewables some properties of a common pool resource, as land can be overexploited, i.e., in relation to its alternative uses like its amenity value, and this requires collective action to solve. Hardin (1968) argues that to prevent overexploitation and solve this collective action problem, common pool resources should either be privatised or be put under top-down regulation. Under private ownership of land, conflicts can arise because of inequitable distribution of benefits, e.g., in an oligopolistic energy market or that those who benefit from land's other amenity value like pleasant views hardly benefit from a renewable energy system in the same location. Top-down regulation by the government may be administratively costly and leads to inefficiencies from additional price distortions from higher tax levies.

The literature points out that equity considerations matter as far as energy transition policy is concerned (e.g., Bartiaux et al, 2018; Chapman et al, 2018). For instance, Wolsink (2007) asserts that equity perceptions appear to be determinant of nimbyism[11] in wind power. Meyer (2007) points out that because most wind turbines in Denmark are owned by local households through local cooperatives, wind power became acceptable at the local level despite negative externalities like noise and obstructive views. Also, ownership models in which benefits accrue privately and are exclusive potentially will more likely be rejected and can become more locally contentious (Walker and Devine-Wright, 2008; Gorroño-Albizu et al, 2019). Thus, more equitable distribution of benefits from the land upon which a renewable energy project is located indeed should be expected to make renewables more acceptable at least at the community level.

It can then be argued that cooperatives can offer solutions to such common pool resource problem. Cooperatives can help achieve a more equitable distribution of benefits from resulting renewable energy projects through more open and participatory development and management schemes, being more local in terms of the extent, and more collective in terms of benefit accrual. Therefore, cooperatives then can solve common pool resource problem related to land use by making distribution

[11]The term "nimbyism" comes from the acronym NIMBY, which means "not-in-my-backyard". Wolsink (2007) defines nimbyism as positive attitude towards a project, coupled with opposition when the project is in one's own neighbourhood.

of the associated benefits more equitable. In relation to the discussion of the fourth hypothesis brought up in Chapter 1, *the fourth research gap that the thesis addresses is on how renewable energy cooperatives can directly help in the proliferation of renewable energy (a) by having a suitable organisational form to develop and manage energy systems at the community level, (b) through the desire to democratise the energy sector, and (c) by making distribution of the associated benefits more equitable*. The thesis deals with this research gap by investigating the extent to which these apply to REScoop.eu using qualitative research methods. There are studies relating to REScoop.eu itself and the cooperative organisational forms within it (e.g., Rijpens et al, 2013; Bauwens, 2017; Huybrechts and Haugh, 2018; Huybrechts et al, 2018), but these are not specifically on renewable energy proliferation. Vansintjan (2015) is one study on REScoop.eu that did tackle energy transition, but not directly on the role the cooperative organisational form in how it unfolds.

Section 2.5. Transaction costs

Moreover, the thesis seeks to contribute to the literature by investigating the role of transaction costs in relation to land use in renewable proliferation in Europe. Given the aforesaid large land use requirements due to low power densities of renewables and that renewable energy production tends to be long-term affair, organisations may want to acquire land use rights for renewable energy production. Furthermore, transactions related to renewable energy production depend on the features of the location involved, e.g., the respective geography of the location of a wind energy project in addition to the latter's related infrastructure. A location might have high value for wind energy production, but otherwise will be unusable or have low market value. This is further exacerbated by the scarcity of sites suitable for renewable energy projects. Now, it could be argued that transaction costs related to land use for renewable energy production may be related to the need to maintain relationships with the respective communities. For instance, the cooperatives' relationship with the community they operate in may influence the nature of their ownership of rights to use land, e.g., onshore windfarms may first need to be allowed by the community to operate. If not allowed, organisations that own such windfarms end up having infrastructure and equipment that are costly for the cooperative to move around outside the location. The location to which such infrastructure and equipment may be moved also often requires to be prepared to host the latter. There are therefore assets that are specific to the transactions related to renewable energy systems[12]. The latter are

[12]This specificity can vary based on whether these assets (a) are relatively more flexible in terms of production, like energy systems that have multiple suppliers of energy, or (b) are already owned by producers or retailers, and the latter also have the technical skills and knowledge in relation to such assets (Altman et al, 2007; Altman et al, 2008).

perceived to tend to have high levels of asset specificity compared to those in fossil fuels (Signorini, 2015; Hvelplund et al, 2019), which tends to limit the extent of renewable energy deployment (Kerr et al, 2014; Kim and Park, 2016).

In cooperatives, as implied in Ollila (2009), owners are also the customers, which increase the likelihood that trust is developed. If cooperative members then are from the community the cooperative operates in, or if the community owns the cooperative, trust is more likely to develop between the community and the cooperative. This strengthens the respective relationship between the cooperative and the community, which can help the cooperative gain the property rights in using land for renewable energy production. Relationships being more based on trust should be able to reduce the bargaining costs associated with the respective transactions, and policing and enforcement costs after the resulting agreement is drafted. Additionally, cooperatives tend to arise more naturally from grassroot efforts, making them more acquainted with the specific circumstances of the communities from which they arise, in turn making them more suited to such circumstances (Mancino and Thomas, 2005; Bauwens, 2017). Furthermore, specialised arrangements based on such specific circumstances can then be built to specifically deal with the specific governance and coordination requirements of the related transactions. These specialised arrangements are expected to be better in handling such transactions than those that are not. Because of their specialised nature, these arrangements would require addressing less aspects of a transaction, which will reduce the respective transaction costs, particularly the associated information costs. In relation to the discussion of the fifth hypothesis brought up in Chapter 1, *the fifth research gap that the thesis addresses is on how renewable energy cooperatives help in the proliferation of renewable energy by addressing transaction costs associated with renewable energy production*. Similar to the fourth research gap identified in Section 2.4, this research gap is addressed in the context of REScoop.eu. As demonstrated in this section, there are studies on the role transaction costs in cooperatives, and how they are addressed by the latter’s organisational form, but none of these are in the context of REScoop.eu.

The first three research gaps identified therefore are then addressed using quantitative research methods, and the last two are addressed using qualitative research methods.

Chapter 3. Theoretical framework: social metabolism and Ostrom's social-ecological framework

A theoretical framework is developed to describe and analyse how energy substitution in an economy may happen. The framework is benchmarked based on the transition pathway literature to explain an energy substitution process and represent it using the social metabolism framework as used in ecological economics (Sections 3.1 and 3.2). This benchmark is extended by drawing insights from institutional economics to incorporate the role of institutions in energy substitution in this theoretical framework (Section 3.3). Incorporating institutions in the analysis leads to a discussion on the social-ecological system framework (SES hereafter), through which renewable energy proliferation towards a cleaner energy mix through renewable energy cooperatives can be understood and specific propositions derived from the literature may be described (Section 3.4).

Section 3.1. Transition pathways and social metabolism

Transition pathways are constructs that denote specific modelling scenarios to understand transition processes (Turnheim et al, 2015). The theoretical framework has the economic aspects of the energy substitution as its central focus. It can nevertheless be argued that the economic processes involving technological changes that characterise an energy substitution are likewise embedded in social structures. This is taken into account in Section 3.4, wherein institutions are introduced in the theoretical framework to describe an energy substitution.

Taking influences from the technology assessment literature, the techno-economic perspective frames an energy transition pathway as an economic phenomenon that involves technological changes (Rosenbloom, 2017; Cherp et al, 2018). Furthermore, as Romer (1990) puts it, technological change emerges primarily because actors respond to incentives, e.g., the depletion of an energy resource may incentivise either the adoption of more efficient technologies for production or consumption, or to shift to an alternative energy resource altogether. Energy substitution then can be characterised as involving economic processes happening alongside technological changes. Consequently, energy substitution can be explained using the lens of economics, for instance in terms of market dynamics and trade. Given these features, the techno-economic perspective seems to be the one that lends itself the most to be analysed using the tools of economics. Geels et al (2017) nonetheless remarks that techno-economic approaches tend to identify optimal pathways based on limited number of constraints, like social surplus or costs, and recommends that one way this shortcoming can be addressed is to consider a wider set of dimensions, which the thesis does to a certain degree by the incorporating institutions in the respective analysis.

The techno-economic perspective regards energy markets as connected to both the populace that values energy-related services, e.g., heating or transport, and to natural resources, e.g., petroleum deposits or falling water (Cherp et al, 2018). Energy markets can be seen as coordinating energy-related flows and energy-related processes performed by energy-related funds. *Funds* are those components of the economy and the biophysical environment that perform the necessary socio-biophysical processes on materials and energy flows, or simply *metabolic* flows. Examples can be human workers and production infrastructure like farms or factories. Specifically, such socio-biophysical processes convert flows into other forms that allow the economy to maintain itself and grow. Such conversion processes are described here as "socio-biophysical" because the conversion of flows involves both the society through its economic structure itself and the biophysical environment. *Flows* then are the inputs which are converted to outputs by funds, like a baker converting flour into bread, or a car converting potential energy from petrol to kinetic energy. Energy is produced and consumed in markets, which characterises energy supply and demand. This feature of the techno-economic approach lends its analysis of energy transitions to fit with the fundamental tenets of ecological economics. Ecological economics can be differentiated from mainstream economics by being more reliant on the natural sciences in analysing the economy in relation to the biophysical environment. It has the main premise of the economy being embedded in the biophysical environment, the latter being finite and therefore having limits (Klitgaard and Krall, 2012). The biophysical environment is ultimately dependent on the sun to sustain itself. The economy interacts with the natural environment, and a social metabolism framework can be used to describe and analyse this interaction between the two.

The social metabolism framework conceptualises the economy, and hence the society, as being part of a system defined by certain socio-biophysical processes that link the economy to the biophysical environment. As was mentioned earlier, the latter depends on solar energy to exist and continue. The second law of thermodynamics implies production at conversion losses, which results in higher entropy, the economy giving off waste and low-grade thermal energy. Mainstream economics does not take entropy into account, typically describing the economy as being in perpetual motion and growing indefinitely. Economic growth is presented as achievable through more capital accumulation, population growth, and technological progress, but does not consider that the energy and resources necessary for these economic growth factors, extricated from the biophysical environment, are finite and hence impose limits to economic growth. Furthermore, the law of conservation of mass implies serious limitations in the substitutability *across* factors of production. This may indeed be the case between the same factors, but across them, it could be argued that complementarity is the one that most likely holds, e.g., no more bread without more flour, even if there is another oven. Examples of such socio-biophysical processes can be resource extraction and manufacturing. Factors of production likewise consume energy, which limits their substitutability with energy inputs themselves. This implies a more difficult decoupling of energy consumption from economic growth (Sorrell, 2010). The economy grows by exchanging materials and energy with the natural environment (Fischer-Kowalski and Haberl, 2015) characterised by these socio-biophysical processes, hence a "social metabolism". This metabolism is propelled by the funds and flows.

Section 3.2. A benchmark

The techno-economic perspective can then be used in appropriating the social metabolism framework to describe and analyse an energy substitution. Whilst the techno-economic approach describes energy-related flows and funds being coordinated in energy markets, the framework presented here describes such occurrences as happening in the *energy sector*. This gives a more general view of the respective economic system, taking into account scenarios in which energy-related flows and funds are directed in non-market economies instead of being coordinated in markets. Such coordination in markets involves quite a strong assumption that markets clear. Ecological economics and the social metabolism framework indeed make no assumption, another way the latter can be differentiated from mainstream economics. The energy sector then is connected to both energy resources and energy resource users, where energy-related flows and funds are directed. The energy sector is conceived as being embedded in an exogenous environment, which can be referred to as the *energy landscape*, based on the work of Geels and Schot (2007). The energy landscape can be seen as the interface where the economy interacts with the biophysical environment through certain socio-biophysical processes. In the first place, the transition pathway that characterises an energy substitution can be said to unfold as the economy takes up certain energy-related metabolic flows (e.g., hydraulic resources or petroleum materials) from the natural environment through the energy sector. Take note that energy production, especially from renewables, is tied to land use, renewable energy resources being the flows and land being the fund. Renewable energy production is location dependent, and there is reallocation of land between fossil fuels and alternatives, where power density plays a key role. As was brought up in Section 2.1, renewables meanwhile require more land because of its relatively lower power density, whilst the opposite is true for fossil fuels. This leads to land being substituted away from other industries instead from the fossil fuel sector. Hence, even if fossil fuel exploitation is at maximum, it is possible to increase the production of renewables without reducing fossil fuel output.

Energy-related metabolic flows go to the energy sector, where they undergo certain socio-biophysical processes performed by energy-related funds (e.g., dams or oil refineries) for the economy to maintain its activity. Specifically, energy-related metabolic flows are converted to some forms through energy-related funds that allows the economy to use such energy to support its activity. These forms are called energy *carriers*, like refined oil and electricity. In Figure 3, this process is depicted as energy-related inputs finding their way to the energy sector to produce such energy carriers. The latter is likewise consumed in the energy sector themselves, as energy is its own input, and in the rest of the economy. As was previously remarked, the biophysical environment, hence all the socio-biophysical processes, are ultimately dependent on the sun to exist and continue.

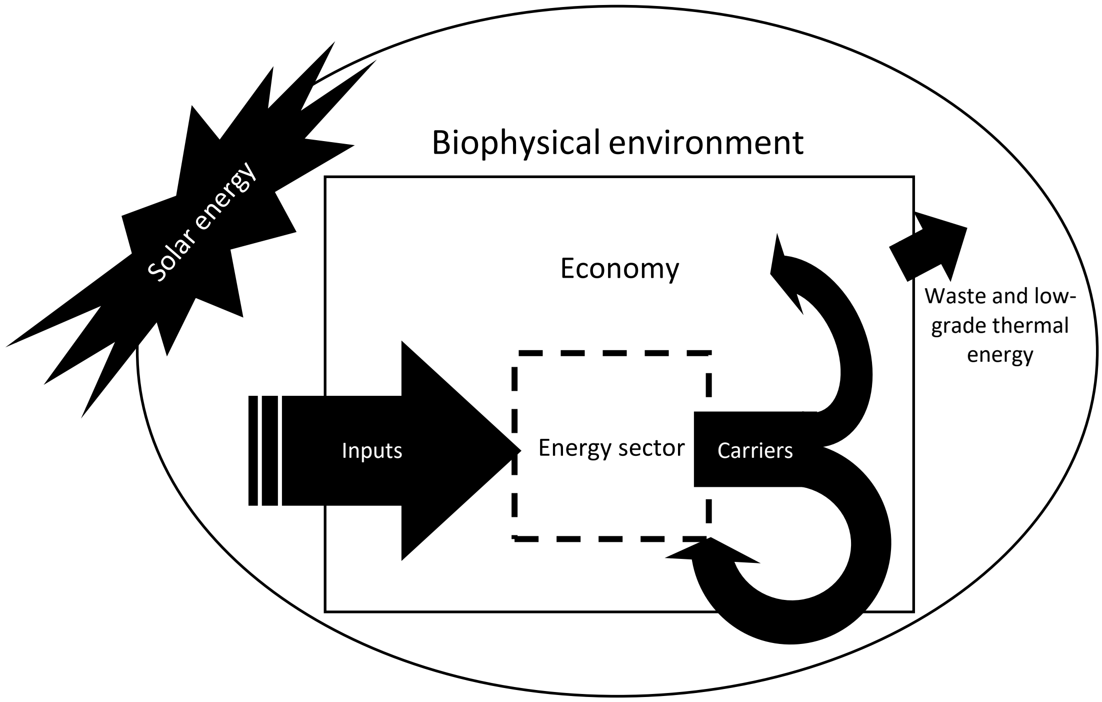

Figure 3. Social metabolism framework. Source: Author.

Section 3.3. Incorporating institutions

Economic processes involving technological changes that characterise an energy substitution can be argued to be embedded in social structures. Cherp et al (2018) specifically distinguishes the socio-technical and political perspectives on pathways from their techno-economic counterpart. The socio-technical perspective on pathways frames an energy transition pathway in terms of dynamics within what Schot et al (2016) calls "socio-technical systems". Here, technology is seen as part of social structures, hence itself a social phenomenon. Technology is likewise seen as to include related knowledge and practices circulating in the society and shared among members of this society. The political perspective meanwhile frames an energy transition as taking place because of policy changes on energy systems, with the state as the main focus of analysis, as the latter is regarded as adopter and implementer of energy policies. Governments may not necessarily act in public interest, formulating policies as reflective of competing interests of various groups within a society, e.g., voters, industrial lobbies, or social movements, as governments may for example maximise votes from constituencies with preferences for specific energy resources. In considering energy issues as intertwined with political considerations, Bressand (2013) presents a framework in which markets are construed to coexist, operate alongside, and influenced by power relations, and takes into consideration the structure of such power relations. The power relations structure identifies actors in the position to impose control over energy resources and influence the institutional environment for energy-related interactions. Such power may manifest itself, for instance, through the creation, design, and operation of energy markets. These actors usually include states, political organisations, other independent actors like civil society groups, and even energy enterprises themselves.

In addition, in analysing the prominent debate in the energy transition literature on the speed of the current energy transition[13], Sovacool and Geels (2016) distinguishes between the tendency to focus on the "tangible" elements of an energy transition, like markets, infrastructure, and technologies and the tendency to focus on the "intangible" elements, like norms, belief systems, and social practices. According to Sovacool and Geels (2016), the two camps of this conversation originate in part from two different perspectives on energy transitions: those that argue that energy transitions progress in a slow pace tend to focus on the tangible elements, and those that argue that energy transitions can be quick tend to focus on the intangible elements. Those that view the current energy transition to be a gradual affair do so because of techno-economic considerations, and those that view otherwise do so because of the socio-political sense of urgency that may lead to policies that override market forces and technology. It is with these "intangible" elements that institutions structure interactions in an economy.

To incorporate institutions into the analysis, insights are drawn from the institutional economics literature to highlight the role of institutions in energy substitution. In the first place, as already touched on in Section 2.2, constraints in behaviour that institutions impose include rules and regulations (e.g., laws and policies) and the set of societal ethical, behavioural norms (e.g., traditions and values) from which rules and regulations arise. The latter determine how these rules and regulations are to be defined and enforced. Taken together, these constitute the "rules of the game" according to which economic interactions are made (Williamson, 2000). Additionally, technology also includes related knowledge and practices circulating in the society and shared among its members. For

[13]A prominent theme in the energy transition literature is the debate on the speed of the current energy transition, on whether this will tend to be relatively slow like those that happened before it (e.g., Grübler et al, 2016; Smil, 2016), or will tend to be relatively faster than what historically transpired (e.g., Bromley, 2016; Kern and Rogge, 2016).

instance, the rise of technological innovations can be seen as knowledge being created or shared. Knowledge creation, in at least one sector, can reduce the costs of adopting further technological innovations in that sector (Comin et al, 2010).

Williamson (2000) discusses levels of social analysis in its attempt to explain the origin of institutions. The ethical and behavioural norms like traditions and values lie in the *social embeddedness* level, from where formal rules like laws and policies arise, as North (1984) puts it. Such formal rules are in the *institutional environment* level[14]. Williamson (2000) makes it clear that the social embeddedness level imposes constraints on the institutional environment level, consistent with how North (1984) characterises the formal rules, in that the latter (in institutional environment level) are understood as derivatives of ethical and behavioural norms (in the social embeddedness level). The institutional environment level similarly affects the social embeddedness level through some feedback link. This feedback link, along with how North (1984; 1991) defined institutions, can be interpreted as downplaying the "methodological individualism" approach in NIE. Here, the rise of institutions is attributed to individuals behaving and interacting rationally, where an initial state without institutions is assumed. Individuals then are treated as exogenous variables, and institutions as the endogenous ones (Hodgson, 2001). It is also the case that institutions influence individuals' thoughts, behaviour, and values. Institutions then likewise explain individual interactions (Dequech, 2015). This suggests that, as put forward by the original institutional economics (OIE hereafter), neither institutions nor individuals are more fundamental as a unit of analysis than the other and claims to require exploring the processes leading to the rise of both. These imply explaining the rise of institutions as an evolutionary process, and a research project towards a more open-ended approach (Hodgson, 2001). NIE does connect back to OIE, especially on transactions and bounded rationality (Rutherford, 2001).

The socio-economic interactions just pointed out are known in the literature as *transactions*. Perceived by Commons (1932) as the "ultimate unit of activity", a transaction is the series of transfers or trade of a good or service across a technologically separable interface (Williamson, 1996), e.g., a person buying an insurance package. Institutions influence the incentive structure of an economy through their influence on transactions, specifically on the costs associated with such transactions, i.e., *transaction costs*. According to Coase (1960), carrying out transactions requires determining the parties involved, the terms of trade of goods and services, the stipulations of the respective contract that embodies the terms of trade, setting up negotiations in writing the contract, setting up measures

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[14]To avoid confusion, North (1984; 1991) treat institutions to be constituted of both such ethical and behavioural norms from the social embeddedness level and formal rules from the institutional environment level.

to enforce the terms of trade, and so on. Based on this, Dahlman (1979) identifies three main types of transaction costs: (a) search and information costs, i.e., those incurred when economic actors search transaction partners and inform each other accordingly, e.g., telephone or internet subscription charges; (b) bargaining and decision costs, i.e., those incurred when negotiations are made to specify the terms of transfer and deciding on which, e.g., payments made to hired consultants when drafting a contract; (c) and enforcement and policing costs, i.e., those incurred when enforcing the contract and inspecting whether respective obligations are met, e.g., legal services fees involved in dispute settlements. Institutions influence the incentives associated with engaging in transactions, and therefore influence the incentives in engaging in economic activity; thus, institutions influence overall economic performance (North, 1991; 1994) and by extension the trajectory of economic change (Coase, 1992; Olson, 1996). Institutions hence influence the series of economic processes involving technological changes, which is how the techno-economic approach frames the transition pathway characterising an energy substitution.

Institutions as incorporated in the social metabolism framework is depicted in Figure 4. To begin with, a "domestic biophysical environment" is introduced. This is done to show that the extent to which the natural environment can be exploited by the economy for metabolic flows is limited by institutional constraints in place, e.g., national borders, exclusive economic zones, etc. Institutions likewise define the property rights over available resources, along with a framework that enforce such property rights, e.g., the spatial planning regime in relation to renewable energy systems. Land for energy production for instance can be subjected to private ownership through some property rights. Negative externalities arise from the enormous land use requirements because of low power densities of renewables. This specifically ties to the value associated with alternative uses of land, e.g., the amenity value associated with land like the location of a renewable energy project, that gives renewables some aspects that are rivalrous: whilst it can be the case that renewables themselves are non-rivalrous because they are not depletable and cannot be overharvested like in the case of wind and solar, land used to produce energy carriers from them are rivalrous in relation to its alternative uses. Hence in this case, whilst the flows themselves are not depletable, the funds in relation to its alternative uses are finite.

This then gives renewables some properties of a common pool resource in relation to their land use requirements, hence lends itself to overexploitation that in turn requires collective action to solve. The domestic biophysical environment therefore represents the only parts of the natural environment accessible to the economy as determined by the respective property rights. This implies taking into account of parts of the natural environment that are accessible only through transactions outside the

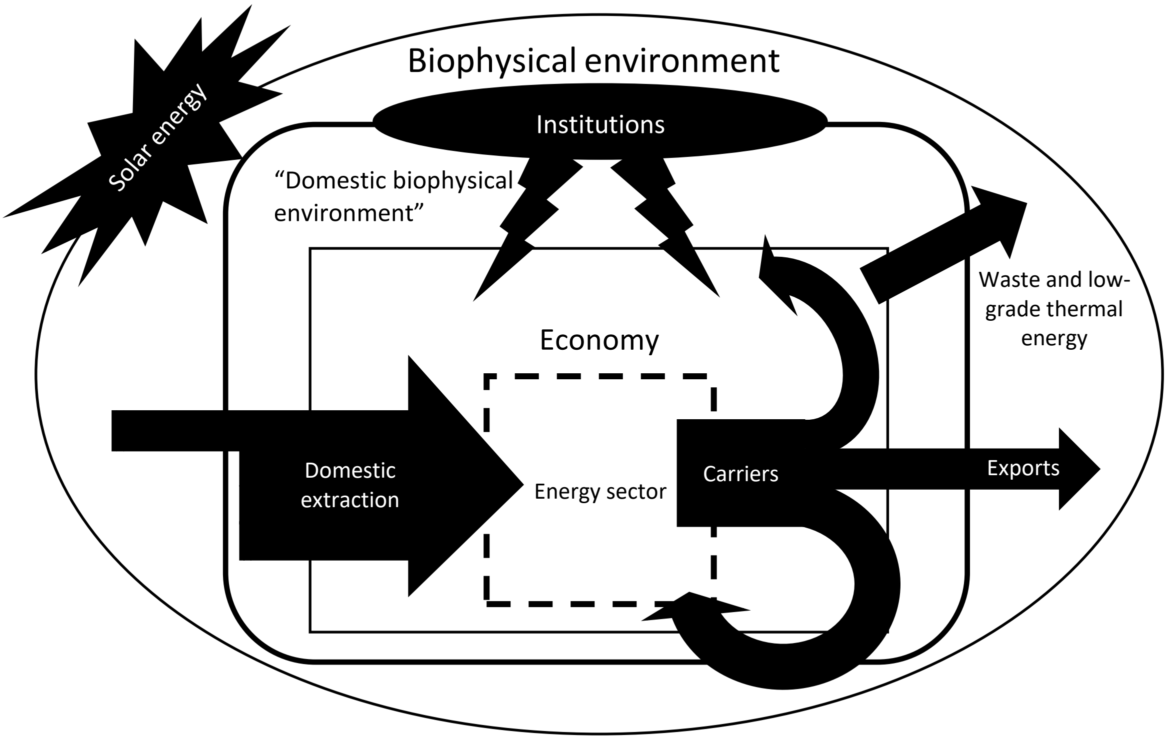

Figure 4. Social metabolism framework with institutions. Source: Author.

bounds of the respective property rights, say through international trade. Energy-related metabolic flows therefore reach the energy sector both from extraction from the domestic biophysical environment and from imports. The economy also exports energy resources from the domestic biophysical environment and energy carriers to other economies, latter having no direct access to the economy's domestic biophysical environment. Energy carriers therefore enter the economy also as part of its imports. Hence, institutions become part of the energy landscape in this extended framework. Consistent with the work of Van Driel and Schot (2005) on the macro-level factors that make up the backdrop for technological change, the components of the energy landscape then are (a) the available and accessible natural endowments, which for instance are determined by geography and trade relations; (b) the size and structure of the economy; and (c) the institutional environment, including cultural values and legal structure.

The modified social metabolism framework discussed here is used as basis for the nature of the data collected and the specifications of the panel econometric model to address the objectives of the quantitative part of the thesis. More details are in Section 4.2.

Section 3.4. Ostrom's social-ecological framework

One will notice that the modified social metabolism framework that incorporates institutions just presented has conceptual similarities to the SES framework in McGinnis and Ostrom (2014), specifically crafted within the context of analysing common pool resource structures, summarised in Table 1. Here, a *resource system* characterises a biophysical system (e.g., waterfalls or petroleum pits) from which *resource units* (e.g., natural resources like hydraulic resources or petroleum materials) can be extracted, afterwards can either be directly consumed, used as inputs for production, or traded (McGinnis, 2011). These resource units are extracted by *resource users* (e.g., the populace that values energy-related services). Such resource users are regarded as to likewise manage the resource system according to rules that impose constraints in behaviour determined by a *governance system* (e.g., the government along with a prevailing energy policy) and in the context of the broader *related ecosystems* (e.g., the whole planet) and *socio-politico-economic settings* (e.g., the greater world economy). The italicised words here denote the major components of the SES framework, the "first-level" variables in Ostrom (2009), referred to as *core subsystems*. The core subsystems themselves are composed of some "second-level" variables, which can be seen as dimensions that characterise them. These are either types, components that make up the core subsystem, attributes that describe them, or some related factor or category. The aforementioned social and biophysical context influence the decisions of individuals, from which *action situations* emerge. Action situations are patterns of *interactions* (e.g., monitoring, evaluative activities) among individuals that generate observable *outcomes* (e.g., sustainability, equity). Ostrom (2009) claims that these components were identified from related empirical studies, those that influence action situations, or types of them.

The SES framework is an extension of the institutional analysis and development (IAD hereafter) framework, described in Ostrom (2005) as a multidisciplinary effort to understand how institutions affect individuals' incentives and their respective behaviour, summarised in Figure 5. Like the modified social metabolism framework described earlier, the IAD framework focusses on the social and biophysical context within which individuals make decisions, i.e., on (a) the rules that prevail instead of only on those that were formally written; on (b) the underlying biophysical environment of the relevant resources; and on (c) the nature of the community, like the extent of trust and reciprocity. There are evaluative criteria used by individuals or other observers to assess these outcomes, and the latter in turn influence the individuals, creating a feedback loop (Ostrom, 2005). This concept of feedback was extended by the SES framework to all core subsystems, wherein generally, outcomes in all the core subsystems influence them back. In the SES framework, action situations are the set of interactions and outcomes among resource users, as well as between such resource users and units,

	Core subsystems	
Dimensions	**Resource systems**	
	Sector (e.g., energy, aquaculture, forests)	Equilibrium properties
	Clarity of system boundaries	Predictability of system dynamics
	Size of resource system	Storage characteristics
	Human-constructed facilities	Location
	Productivity of system	
	Resource units	
	Resource unit mobility	Distinctive markings
	Growth or replacement rate	Spatial and temporal distribution
	Interaction among resource units	
	Economic value	
	Number of units	
	Resource users	
	Number of users	Norms/social capital
	Socioeconomic attributes of users	Knowledge of SES/mental models
	History of use	Importance of resource
	Location	Technology available/used
	Leadership/entrepreneurship	
	Governance systems	
	Government organisations	Collective-choice rules
	Non-government organisations	Constitutional rules
	Network structure	Monitoring and sanctioning rules
	Property-rights systems	
	Operational rules	
	Action situations	
	Interactions	**Outcomes**
	Harvesting	Social performance measures (e.g., equity, accountability)
	Information sharing	Ecological performance measures (e.g., resilience, sustainability)
	Deliberation processes	Externalities to other SESs
	Conflicts	
	Investment activities	
	Lobbying activities	
	Self-organising activities	
	Networking activities	
	Monitoring activities	
	Evaluative activities	
	Related ecosystems	
	Climate patterns	
	Pollution patterns	
	Flows into and out of focal SES	
	Socio-politico-economic settings	
	Economic development	Media organisations
	Demographic trends	Technology
	Political stability	
	Government resource policies	
	Market incentives	

Table 1. The SES framework core subsystems and respective components. Source: Ostrom (2009); McGinnis and Ostrom (2014).

e.g., the extraction of such resource units and the management of the resource system that transforms inputs into outputs. According to Bauwens et al (2016), the advantage of the SES framework is its ability to integrate agency-based approaches, where individuals and their actions are the main unit of analysis, and structure-based approaches, where the institutions and social context are the main unit of analysis. This makes it more in line with the tenets of OIE.

It could be argued that on the global level, the natural environment is generally a common pool resource. It is rivalrous, and only practically excludable on the national level; no country can be prohibited to exploit natural resources in an absolute sense. Indeed, countries do have complete control of natural resources within their land borders, and can even have access to those outside land borders, e.g., maritime resources for which access is granted under the United Nations Convention on the Law of the Sea, but countries cannot be deterred from extraction of natural resources that do not fall under national or international institutional constraints that grant property rights on certain resources, as long as such country has the capability of extraction[15], as countries can even disregard national borders and international agreements in relation to such natural resource property rights if

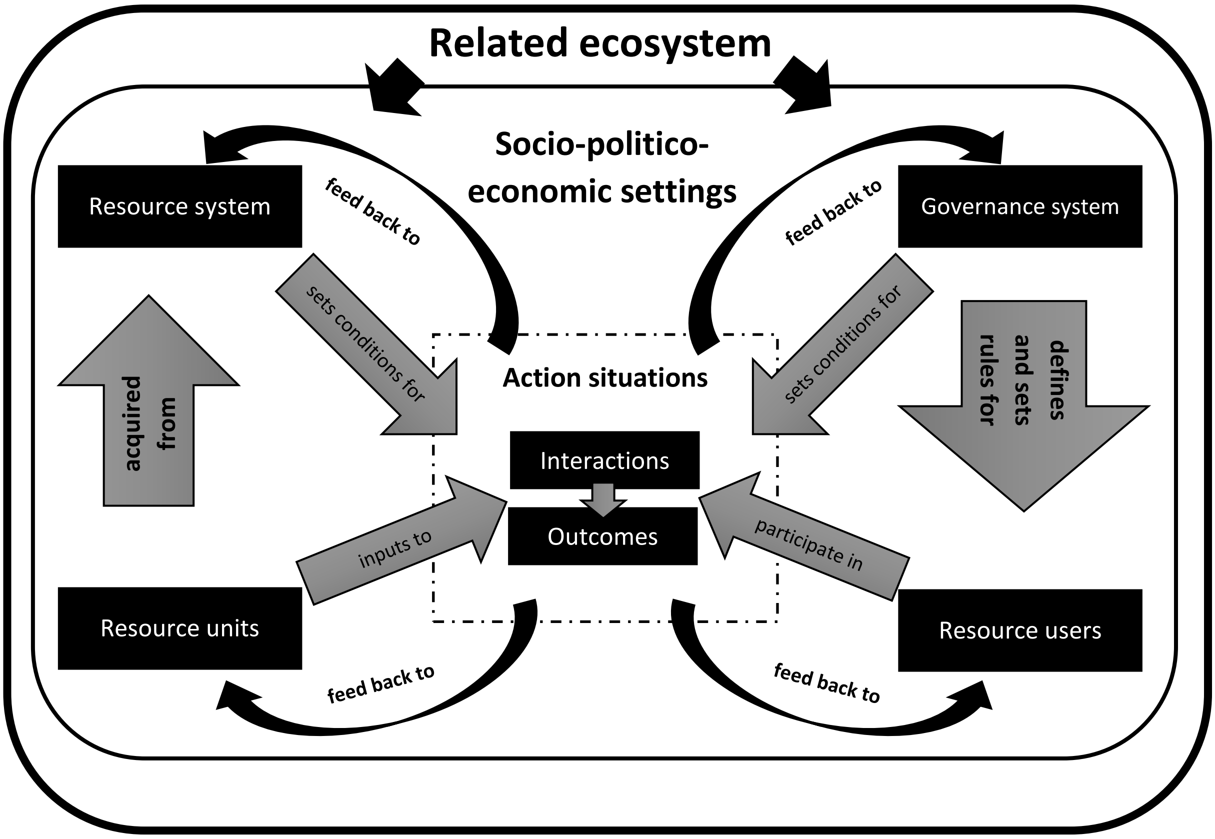

Figure 5. Social-ecological framework. Source: McGinnis and Ostrom (2014)

[15]The nature of a transnational resource complicates the issue. Take note for instance the issue of China damming their internal river flows in Tibet of international rivers like the Brahmaputra and Mekong. Here, the downstream countries will be excluded from benefitting from such river flows.

they have the capability, say political and military, to do so. The same can be said for energy resources. They are similarly non-excludable for the same reason just given for natural resources in general. As mentioned earlier, some energy resources are non-rivalrous, like sunlight or wind, but how such energy resources are converted into more usable forms makes them rivalrous: the low power densities they have are associated with greater land use requirements, which are indeed rivalrous.

Now the energy sector works based on the incentive structures faced by producers and consumers. These incentive structures define how energy-related metabolic flows are processed through energy-related funds within the energy sector. Institutions and their strength, which can be measured by the quality of enforcement of laws and policies, influence the incentive structures of an economy. Institutions can incentivise or disincentivise certain ways energy-related funds can process energy-related flows, and it is this through which energy policy can facilitate substitution towards a cleaner energy mix.

Renewable energy having some properties of a common pool resource due to its production being tied to land use makes it appear helpful to derive insights from the SES framework and from the work of Ostrom (1990; 2005) to analyse institutional and organisational forms of CESs. Ostrom (1990) lists eight principles common among successful common pool resources systems institutional designs based on case studies of enduring self-organised and self-governing common pool resources systems it featured. In the later work (Ostrom, 2005), these institutional design principles were ascribed to SESs and further evidence were similarly provided for such design principles since they were initially conceptualised in Ostrom (1990). Whilst the SES framework has been constructed in the context of common pool resource structures analysis, McGinnis and Ostrom (2014) has extended its use to also analyse man-made infrastructures, like a renewable energy system. According to Ostrom (2005), robust SES institutions have the following institutional designs principles:

1. The spatial boundaries of the SES itself and the participants that have rights to extract resources are clearly defined.
2. Rules on resource extraction (e.g., on the scale of exploitation and technology allowed) correspond to those on input requirements (e.g., on labour and capital requirements) and the actual attributes of resources along with their respective prevailing conditions.
3. Rules can be modified in a participatory and collective manner.
4. SES conditions and participants are monitored, with monitors themselves being participants and are accountable to all participants.

5. Penalties associated with breach of rules are based on the context and gravity of the offense, and imposed by participants themselves, and sometimes also by those assigned in position of accountable officials.
6. There are conflict resolution mechanisms and platforms. This is necessary given that rules tend to be rather ambiguous.
7. Participants have rights to devise own rules, independent from an external authority.
8. Among larger systems, extraction processes, rules enforcement, monitoring activities, and conflict resolution are done in many layers of polycentric governance structures.

Clearly defined boundaries are from where collective action can properly commence, as this properly defines what is being run and for whom. This is important considering that, as remarked in Section 2.4, renewable energy cooperatives may want to own land or rights to use land for renewable energy production. A participatory and collective way of modifying rules makes it easier to fit the extraction and input rules to the conditions relevant to the SES and the participants, given the direct interaction of participants with each other and with the SES itself.

The fourth and the fifth institutional designs mentioned were intended to address uncertainties associated with the lack of guarantee that participants will commit to comply with the rules. In relation to these, Ostrom (1990) posits that participants who are included in the development process of the set of rules tend to be willing to commit to such rules. Such commitments motivate participants to monitor others because, Ostrom (1990) writes, they want to assure themselves that others likewise follow the rules which they themselves help make. Hence, being committed to comply with the rules and mutual monitoring reinforce one another, solving the commitment and monitoring problem. Lastly, polycentric governance structures involve multiple, formally independent, self-organised decision-making nodes arranged in some hierarchy, functioning under certain rules (Ostrom et al 1961; Bauwens, 2017). Bauwens (2017) lists the perceived advantages of such polycentric structures: (a) enhanced flexibility for adapting to shocks (fosters conditions for experimentation and creativity needed to explore novel and potentially superior combinations of rule systems); (b) information, as it encourages the use of local knowledge to devise rules that are better adapted to each local situation than any general set of rules (akin to the specialised arrangements described in Section 2.5), better than a one-size-fits-all nature of centrally determined rules; (c) enabling quick feedback on the performance of rules; (d) higher likelihood in fostering trust (as local participants tend to know each other well); and (e) lower enforcement costs from less costly monitoring. Take note that cooperatives may not necessarily have all the institutional designs mentioned in Ostrom (1990) explicitly. For instance, renewable energy cooperatives may simply have market-based transactions governed by hierarchies, hence the fifth institutional design may come in the form of being denied access to renewable energy supply at a given agreed-upon price.

The following discussion uses the SES framework to further explain the qualitative research gaps identified in Chapter 1 and show why it matters for countries to have a thriving renewable energy cooperative sector. More particularly, the following is a discussion on how a CES might with a cooperative organisational form as its most immediate governance system specifically help in the proliferation of renewable energy through its expected outcomes. This is summarised in Figure 6. Here, a cooperative develops and manages a renewable energy system, in which both the renewable resource system and units are included; the renewable energy system is composed of the renewable energy infrastructure (e.g., a solar or wind farm), located in sites within the community's clearly defined spatial boundaries that is conducive for renewable energy production, harnesses renewable energy resources (e.g., sunlight or highspeed wind) to produce energy carriers like heat and electricity. The renewable energy infrastructure and its site constitute the resource system, with the renewable

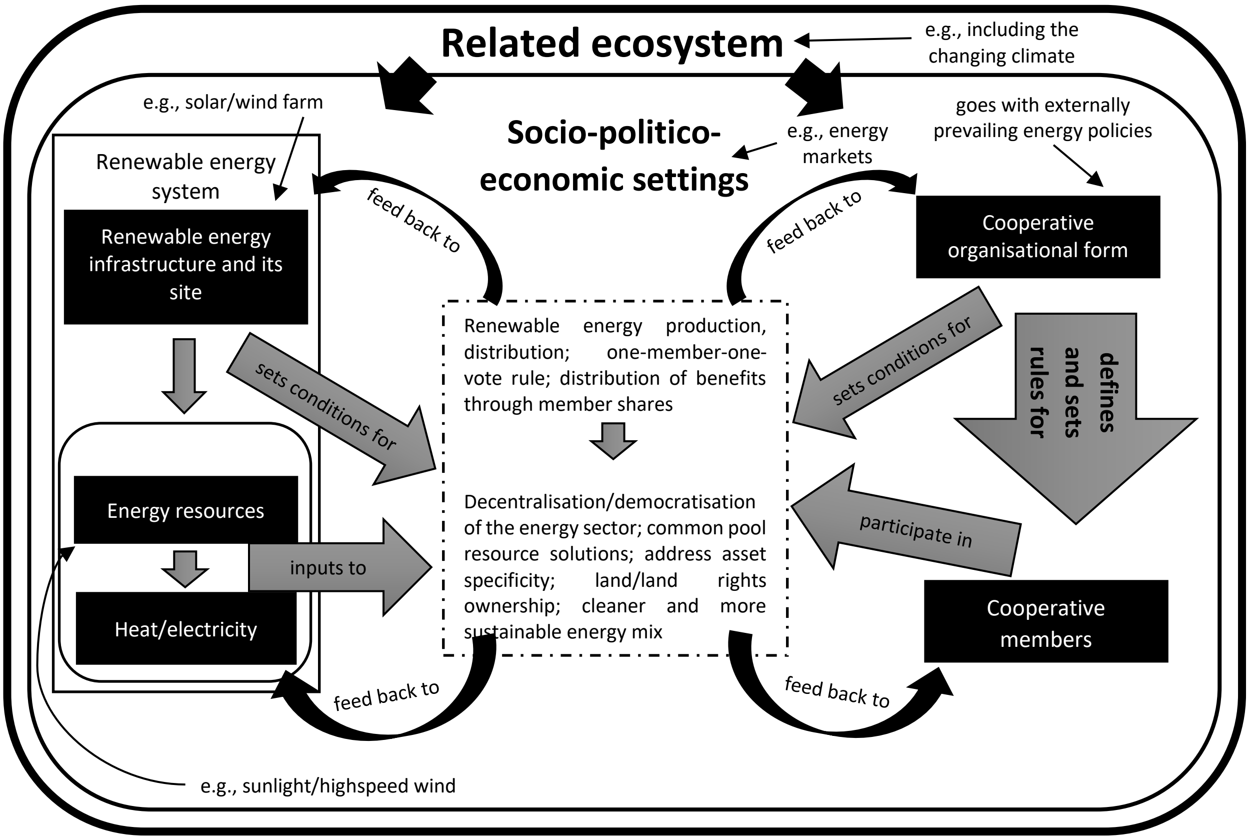

Figure 6. The cooperative organisational form explained through a SES framework. Source: Author using McGinnis and Ostrom (2014).

energy resources and the energy carriers being the resource units. These are then distributed to the cooperative members, the resource users, along with other benefits from the renewable energy project like profits. Cooperative members run and manage the renewable energy project through the cooperative organisational form, complete with rules on managing the energy system determined and modified in participatory and collective manner, say through the one-member-one-vote structure. These go along with the related energy policies prevailing in the country, the region, and communities to constitute the relevant governance system. The renewable energy system is run and managed in the context of related ecosystems (e.g., the energy project site's locational features), and of at least the most relevant socio-politico-economic settings (e.g., energy markets of the country the community where the cooperative operates is located). The action situations include the set of interactions which are the activities or services the cooperative is engaged in (e.g., renewable energy production, retailing, distribution, consumption, and other related services), the determination of how benefits accrue to members (e.g., through the cooperative's general assembly), and the actual mechanisms through which benefits accrue to the members (e.g., through membership shares).

The expected observable outcomes then are as follows. As influenced by the related ecosystems, renewable energy being suitable to be produced locally makes them the best energy resources to be harnessed using community-based cooperatives. Also, the socio-politico-economic settings may conjure the desire to democratise the energy sector, which can lead to other benefits mentioned earlier. Here, communities having ownership and more control of energy production gives rise to more local-level ways of managing a renewable energy system. Equity itself is an outcome in the SES framework as shown in Table 1, more specifically a social performance measure that can be used as a criterion in evaluating other outcomes (Ostrom, 2005). It is under which the notions that renewable energy cooperatives can incentivise adoption of renewables through desire to democratise the energy sector and a more equitable distribution of benefits both fall under. Take note also that action situations and expected outcomes likewise influence the core subsystems in the SES.

As implied in Bauwens (2017), the more local the level in which the renewable energy system is owned and managed, the better the governance system, i.e., the cooperative organisational form, can address the specific situation of the respective communities through grassroot-based information. The likelihood that trust is developed is also better, which facilitates a participatory and collective way of developing and managing a renewable energy system in determining and modifying the governance system. This should lead to the specialised arrangements that deal with the governance and coordination requirements to reduce transaction costs. Cooperatives, through a more open and participatory development and management schemes, through being more local in terms of the extent, and through more collective in terms of benefit accrual can solve the associated common pool resource problem. This comes from, and likewise leads to, a better relationship between the cooperative and the community themselves, which can aid in the former's pursuit of land or land rights ownership. It is thus argued here that the qualitative research gaps derived from the literature review can be seen in terms of outcomes of the SES framework, in which the cooperative organisational form is the most immediate governance system. The outcomes of this SES framework depict specifically how renewable energy cooperatives aid the substitution for fossil fuels towards a cleaner energy mix, which justify a thriving renewable energy cooperative sector for countries in Europe.

Aside from describing the qualitative research gaps as was just demonstrated, the SES framework discussed here guides the construction of the narrative arising from the qualitative research, and is the lens through which the narrative is understood and explained to address the objectives of the quantitative part of the thesis. The details on how this was done are in Section 5.2.

Chapter 4. Methods: panel data econometric models of social metabolism and the qualitative research design

The quantitative and qualitative methods used in addressing the research gaps are described in this chapter. In particular, this chapter provides a discussion on panel data econometric modelling (Section 4.1), the corresponding estimation strategy to address the quantitative research gaps (Section 4.2), an introduction to qualitative research methods (Section 4.3), and the qualitative research design to address the quantitative research gaps (Section 4.4).

Section 4.1. Panel data econometric modelling

The discussion on panel data modelling in this section relies heavily on Wooldridge (2010; 2020) and the panel data reference manual of Stata (Statacorp, 2015). The next three subsections discuss the panel data econometric modelling the thesis uses to address research objectives, i.e., panel data structures, fixed and random effects, and unit roots and structural breaks.

Subsection 4.1.1. Panel data structures

In the first place, there are several types of data structures used in econometrics. A *cross-sectional* dataset is one that contains a sample of *individual* units (or *cross sections*) within a specific time period, e.g., people, firms, or countries. A cross-sectional dataset is assumed to have been assembled using random sampling, i.e., the units were randomly selected from a population. The observations on the variables that pertain to the cross sections, e.g., average temperature of countries in a specific year, then are treated as random outcomes. Here, there are two other implicit assumptions, namely (a) the population model has been specified to begin with, and (b) an independently and identically distributed sample can be obtained from this population. The sample is independently distributed if the observations do not contain information about each other. An instance of this is when the probability of a coin toss result is not influenced by the information on the other coin toss results, e.g., knowing that the coin toss results in Tails. The sample being identically distributed means that the observations come from the same distribution, e.g., results of coin tosses having the same probabilities of occurring.

The assumption of an independent and identical distribution may not hold in some data structures. A *pooled* cross-sectional dataset for example is most likely not identically distributed. Here, samples of individuals are obtained from the population at *different* time periods. A different time period, say a different year, would provide a different random sample of individual units. This can be reflected in the actual econometric model by including dummy variables for the time periods, which allows the intercept to vary across these time periods. The different random samples are then pooled from the same population but from different time periods. For instance, a random sample on average temperature of countries can be acquired at two different years, and these samples at these two years contain different countries. Hence, the distribution of average temperature varies across these two years. Pooled cross sections are done to increase the sample size, under the assumption that the relationships amongst variables are of the same nature across the time periods. Pooled cross-sectional datasets hence are often used when investigating how the relationship between variables has changed over time. Pooled cross sections can be analysed as straightforward standard cross sections, though it is necessary to consider the differences in the variables across time.

This issue is also highlighted in a *time series* dataset. A time series dataset contains a sample of observations on the same variables across several time periods, say across several months or years. Some examples of such variables are GDP and consumer price index. Previous time periods influence next time periods; thus, time becomes a relevant dimension. Therefore, the chronological order of observations may also contain crucial information. Another implication of this is that observations in a time series dataset most likely are not independent across time. An observation on a variable in a time period can be influenced by the more recent previous observations on that variable. For example, GDP data tend to be relatively stable at least in short durations, which suggests that knowing the GDP in a quarter can be informative as far as knowing at least the range of the GDP in the next quarter.

A *panel* dataset contains time series data for each cross section. The structure of a panel dataset follows the *same* cross section across time; a panel dataset then contains repeated observations on the same cross section over a given time period, giving it both a cross-sectional dimension and a time dimension. The most basic panel data methods assume independent and identical distribution only in cross sections. According to Wooldridge (2010), this approach is justified in panel data structures in which the number of cross sections is relatively larger compared to the number of time periods. Panel datasets contain time series data for the same individual unit, and consequently, the respective observations cannot be assumed to be independently distributed across time.

There are at least two advantages of using panel data in empirical research. *First*, panel data structures can be used to analyse the role of lags in certain outcomes or the result of a certain policy. This is important because for instance, energy policy may have significant impacts to an economy or the environment only after the passing of some time. *Second*, the main motivation for using panel data to begin with is that it allows for taking into account certain unobservable variables, e.g., the philosophical underpinnings of a country's citizens' value system. If such unobservable variables are not taken into account, they become omitted variables that become part of the error term in the regression equation. If these variables are correlated with the other explanatory variables, the latter then is correlated with the error term. Such variables then become *endogenous variables*, and results in biased and inconsistent regression results. Whilst using proxies or finding instrumental variables[16] can remedy this issue, panel data can give way to other solutions, especially if good proxies or instrumental variables are not available. More specifically, in a panel dataset, if the unobservable variable is assumed to not vary over time, i.e., a constant, it can then be interpreted as an unobserved effect that captures time-invariant features of a cross sections, like a country's potential for geothermal power production. This unobserved effect captures unobserved heterogeneities across cross sections, say the heterogeneities across countries. This is important because for instance, certain unobserved effects, like a country's citizen's preference rankings that influences a country's desire for renewable energy in time t, can influence that country's desire for renewable energy in time $t + 1$.

A basic econometric model with unobserved effects is

$$y_{it} = \beta_0 + \beta_1 x_{it} + c_i + u_{it}, t = 1,2, \dots T \quad (1)$$

where c_i is the *constant* unobserved effect, say some feature specific to country i. c_i accounts for unobserved heterogeneities across cross sections, in the initial time period.

As already noted, a panel dataset consists of time series data per cross section. If the time series in all the cross sections have the same length, i.e., all the cross sections have the same number of time periods, then the panel dataset is *balanced*; otherwise, the panel dataset is *unbalanced*. The latter case, i.e., when there are cases wherein years are missing for some cross sections in a panel dataset, should not be an issue at all if the reasons why data for some years are missing in some cross sections is not correlated with the error term. This becomes a problem otherwise, like if there is attrition in state-owned power plants because of some time-varying unobserved factors that affect incentives to enter the market, like profitability (Wooldridge, 2020).

The way in which the unobserved effects in panel data models are taken into account depends on whether they are assumed to be correlated with the explanatory variables across time or not, hence there are two ways of dealing with these unobserved effects: ***fixed effects*** models (FE hereafter) assume that the unobserved effects are correlated with the explanatory variables across time, whilst ***random effects*** models (RE hereafter) assume otherwise. The next subsection gives more detailed explanations on these.

Subsection 4.1.2. Fixed effects and random effects

FE assumes that the unobserved effects are *correlated* with the explanatory variables across time. $t = 1,2, \dots T$. c_i as "fixed effect" does not mean that it is treated as non-random; it means that in FE, it is

[16]An instrumental variable is a variable that is uncorrelated with the error term in the regression equation and is also correlated with the endogenous explanatory variable.

allowed to have an arbitrary dependence on the observed explanatory variables. FE involves the transformation that eliminate c_i in (1). For each cross section i, obtain the average over time, which gives

$$\bar{y}_i = \beta_0 + \beta_1 \bar{x}_i + c_i + \bar{u}_i \tag{2}$$

Subtracting this from (1) yields

$$y_{it} - \bar{y}_i = \beta_1 (x_{it} - \bar{x}_i) + u_{it} - \bar{u}_i$$
$$\Rightarrow \ddot{y}_{it} = \beta_1 \ddot{x}_{it} + \ddot{u}_{it}, t = 1,2, \ldots T \tag{3}$$

where $\ddot{y}_{it} = y_{it} - \bar{y}_i$, $\ddot{x}_{it} = x_{it} - \bar{x}_i$, and $\ddot{u}_{it} = u_{it} - \bar{u}_i$. These are referred to as *time-demeaned data* on y, x, and u. The regression that follows uses the time variation in y and x within each cross-sectional observation, hence is called a within transformation, the respective resulting estimator being the *within* estimator. As a side note, there is also the *between* estimator, the one obtained from running a regression on cross sections using the averages over time for both the dependent and explanatory variables. If the panel dataset is unbalanced, with the number of time periods for cross section i being T_i, then use these T_i observations to calculate the time demeaned data.

Another way of looking at this is that c_i is essentially an intercept for the cross section i. Hence, a way to estimate c_i is the inclusion of a dummies for each cross section, say for each country i, in addition to the x_{it}. This however results in many additional explanatory variables, which may eat up too many degrees of freedom. The estimates c_i, i.e., $\widehat{c_i}$, may also be of interest in some cases, like when investigating how a particular country is doing relative to the rest of the sample. Whilst doing a within transformation and including cross-sectional dummies yield exactly the same estimates, these two approaches are not similar. As Wooldridge (2020) puts it, the unobserved heterogeneities, as taken into account by the dummies, being statistically significant does not imply that such unobserved heterogeneities are correlated with the explanatory variables.

Variables that do not vary across time cannot be included in FE, though such variables can certainly be interacted with variables that change over time, like year dummies. For example, longitude and latitude of a city is time-invariant and can be interacted with year dummies to estimate how the effects of the city's location coordinates on its renewable consumption has changed over time. Similarly, when time period dummies are included, variables that have time-invariant temporal change*s* also cannot be included, like a person's years of experience in the fossil fuel industry, which increases by one every year.

Meanwhile, RE assumes that unobserved effects c_i are *not correlated* with the explanatory variables x_{it}: $cov(x_{it}, c_i) = 0, t = 1,2, \ldots T$. A transformation to remove c_i results in inefficient estimators. RE then includes c_i in the error term, resulting in a *composite error*, defined as $v_{it} = c_i + u_{it}$, which is correlated across time; in RE, if heterogeneity across cross sections is not taken into account, serial correlation will be present in the composite errors; on the other hand, this does not cause correlation between the composite errors and the explanatory variables. One way of addressing this serial correlation is through using a feasible generalised least squares (FGLS hereafter) transformation. Based on the calculation for random effects estimator using an FGLS procedure that involves mathematical derivations that are beyond the scope of this text, define

$$\lambda = 1 - \sqrt{\frac{\sigma_u^2}{\sigma_u^2 + T\sigma_c^2}} \quad (4)$$

where σ_u^2 and σ_c^2, are the variances of u_{it} and c_i, respectively, and T is the number of time periods in the time series per cross section. $1 > \lambda > 0$ so long as $\sigma_u^2, \sigma_c^2, T > 0$. λ is used to transform (2) to

$$y_{it} - \lambda\bar{y}_i = \beta_0(1-\lambda) + \beta_1(x_{it} - \lambda\bar{x}_i) + v_{it} - \lambda\bar{v}_i \quad (5)$$

Since λ is a ratio, only proportions of the time averages are subtracted from the corresponding variables, as opposed to whole time averages in FE. RE allows for the inclusion of time-invariant variables, since RE assumes that c_i is uncorrelated with all x_{it}, whether the latter varies with time or not. The estimator for λ has the general form of

$$\hat{\lambda} = 1 - \sqrt{\frac{1}{1 + T\left(\frac{\hat{\sigma}_c^2}{\hat{\sigma}_u^2}\right)}} \quad (6)$$

where $\hat{\sigma}_u^2$ and $\hat{\sigma}_c^2$ are consistent estimators of σ_u^2 and σ_c^2, respectively. It can be seen from (6) that as T increases, $\hat{\lambda}$ approaches one, which implies that FE is just a special case of RE.

There is a trade-off when determining which between FE and RE is the more appropriate model to be used in a particular panel dataset. FE has the advantage of being able to allow for the correlation between c_i and x_{it}; if this is the case, FE produces consistent estimates. FE however has the limitation of not being able to allow for the inclusion of time-invariant variables. Regarding this, a test was proposed by Hausman (1978) based on comparing the FE and RE estimates to determine which of the two is more appropriate. The null hypothesis of this test is essentially that c_i and x_{it} are not correlated. As noted earlier, when c_i and x_{it} are correlated, RE is inconsistent, which means that its rejection implies that FE should be used.

Subsection 4.1.3. Unit roots and structural breaks

One issue with panel data models that needs to be addressed is the presence of unit roots. Consider an unobserved effects model

$$y_{it} = \rho_i y_{it-1} + c_i + u_{it}, t = 1,2, \dots T \quad (7)$$

where u_{it} is independently and identically distributed, having zero mean and variance σ_u^2. (7) has an autoregressive process of order one, or AR(1). y_{i0} then is the observed initial value. AR(1) is *stable* if

$|\rho_i| < 1$. If this is the case, this AR(1) is *weakly dependent*, in which the correlation between y_t and y_{it+h} decreases as their temporal distance, measured by h, increases without bound, i.e., $corr(y_{it}, y_{it+h}) \to 0$ "quick enough" as $h \to \infty$. This time series then is *asymptotically uncorrelated*. It can easily be shown that $corr(y_{it}, y_{it+h}) = \rho_i^h$, which indeed approaches zero as $h \to \infty$ when $|\rho_i| < 1$. This is important because it essentially is the equivalent of random sampling across time in a time series process.

Now when $\rho_i = 1$, the AR(1) is called a *unit root process*, where y_t is said to have a unit root. This is a case of a *highly persistent* time series, wherein observations far ahead in future time periods are highly correlated with more recent observations. The variance of this process increases with time, in which case the process is deemed as being not *stationary*. A time series process is stationary if the distribution of variable x_{it} do not change across time, i.e., the distribution of $(y_{i1}, y_{i2}, \dots y_{im})$ is the same as $(y_{i1+h}, y_{i2+h}, \dots y_{im+h}), h \geq 1$. This is important because this implies that the process is identically distributed across time. Furthermore, unit root processes are said to be *integrated of order one*, or I(1), which means that the *first differences* this process is weakly dependent; thus, an I(1) process is transformed into a weakly dependent one when it is first differenced. A weakly dependent time series then is said to be *integrated of order zero*, or I(0), which just means that nothing else needs to be done for it to be weakly dependent.

A formal unit root test has the null hypothesis $H_0\colon \rho_i = 1$ for all i, which is tested against the alternative $H_a\colon \rho_i < 1$[17]. A simple way of writing down an unobserved effects model with an autoregressive component is

$$y_{it} = \rho_i y_{it-1} + c_i + u_{it}, t = 1,2, \dots T \tag{8}$$

(8) can be written as

$$\Delta y_{it} = \phi_i y_{it-1} + c_i + u_{it}, t = 1,2, \dots T \tag{9}$$

where $\Delta y_{it} = y_{it} - y_{it-1}$ and $\phi_i = \rho_i - 1$. Here, y_{it-1} was subtracted from both sides of (8). The null hypothesis then becomes $H_0\colon \phi_i = 0$, tested against the alternative $H_a\colon \phi_i < 0$. This test is known as the *Dickey-Fuller test*. The test statistic is constructed in the form of a t-distribution, but under the null hypothesis, it has a non-standard distribution, known as the Dickey-Fuller distribution. Δy_{it} can also be allowed to follow an AR(k) process by adding lags. Hence

$$\Delta y_{it} = \phi_i y_{it-1} + \sum_{j=1}^{k} \theta_{ij} \Delta y_{it-j} + c_i + u_{it}, t = 1,2, \dots T, |\theta_i| < 1 \tag{10}$$

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[17]The alternative hypothesis practically means $0 < \rho_i < 1$, as negative ρ_i rarely occurs. The alternative that $\rho_i > 1$ is usually not considered, as this implies that y_{it} has an exponential trend.

where k is the number of lags Δy_{it}. The respective test then has been augmented by including the lags of Δy_{it}, thus is called the *augmented Dickey-Fuller test*.

There are several ways to specify unit root tests in panel data structures. There are tests specifications, e.g., in Harris and Tzavalis (1999), Breitung (2001), and Levin et al (2002), that assumes a common autoregressive coefficient for all cross sections in panel datasets, i.e., $\rho_i = \rho$. Such tests then require balanced panel datasets. There are also those that allows for specific coefficients for each cross section i, e.g., in Maddala and Wu (1999), Choi (2001), and Im et al (2003). Here, a unit root test is done for each individual cross section, and the resulting p-values are used to formulate one test for the entire panel data. Consequently, these tests can be done even if the panel datasets are unbalanced. That in Hadri (2000) meanwhile has a fundamentally different approach: it has the null hypothesis that all cross sections do not have unit roots, and an alternative that some of the cross sections have.

This issue however is further complicated by the presence of structural breaks per time series. Structural breaks are sudden changes in the time series because of some event, happening at $T_b, 1 < T_b < T$. Not taking structural breaks into account leads to a standard unit root test having lower power; the latter becomes biased towards less ability to reject the null hypothesis that there is a unit root (Perron, 1989; Glynn et al, 2007). Perron (1989) argues that it can be the case that time series deemed as being highly persistent do not arise from them having unit roots, but from rare, large shocks (e.g., the 1973 oil price shock), which eventually stabilises after more frequent and smaller shocks. To address this, Perron (1989) proposes to use a Dickey-Fuller test with dummy variables to account for a known, exogenous structural break. This was extended in Perron and Vogelsang (1992), where a method to endogenously find a structural break was developed. The test here has two types, one based on calculating the *innovative outliers* of the variable of interest, and another based on calculating the corresponding *additive outliers*. Innovative outliers reflect more gradual changes in the time series, showing changes in the time series even after time T_b. Additive outliers meanwhile capture what essentially are spikes in the time series, showing that the latter changes only at T_b (Magazzino, 2017).

Following Perron (1989)[18], Perron and Vogelsang (1992) specifies the tests based on innovative and additive outliers. For a specific cross section i the test based on innovative outliers is given by

$$y_{it} = \mu_i + \alpha y_{it-1} + \delta_{1i} D_{1i} + \delta_{2i} D_{2it} + \sum_{j=1}^{k} \omega_{ji} \Delta y_{it-j} + v_{it} \tag{11}$$

[18]Perron (1989) presents other three versions of the null hypothesis in (11): *one* allowing breaks in the intercept, *another* allowing breaks in the trend, and *lastly*, one allowing both. (11) is a variation of the first version mentioned, one without a trend; all the versions in Perron (1989) have trends.

Take note that the unobserved effect c_i was not included here, as this test is done only on a single cross section within the panel dataset. Here, $D_{1it} = 1$ if $t = T_b + 1$ and zero otherwise; $D_{2it} = 1$ if $t > T_b$ and zero otherwise. (11) has the null hypothesis $H_0: \alpha = 1$, tested against the alternative $H_a: \alpha < 1$ using the test statistic t_α, which has a modified Dickey-Fuller distribution. Meanwhile, in the test based on additive outliers, the null hypothesis of the existence of a unit root is given by $H_0: y_{it} = y_{it-1} + \mu_i + \delta_{1i} D_{1it} + u_{it}$. This is tested against the alternative of the absence of unit roots $H_a: y_{it} = \mu_i + \delta_{1i} D_{2it} + v_{it}$. The procedure here involves two steps. The first step is to detrend y_{it} by fitting it using ordinary least squares regression. The second step involves carrying out the test using resulting residuals $\widetilde{y_{it}}$ (Perron, 1994) in the regression

$$\widetilde{y_{it}} = \sum_{j=1}^{k} \psi_{ji} D_{1it-j} + \alpha \tilde{y}_{it-1} + \sum_{j=1}^{k} \omega_{ji} \Delta \tilde{y}_{it-j} + \epsilon_{it} \quad (12)$$

In (12), the lags of D_{1it} were included to ensure t_α in the innovative and additive outlier models are asymptotically similar, and for it to be invariant relative to j. (12) also has the null hypothesis $H_0: \alpha = 1$, tested against the alternative $H_a: \alpha < 1$, also using the test statistic t_α. For both the innovative and additional outliers models, the structural break T_b is found by minimising t_α, where the idea is to find the "strongest evidence" against the null hypothesis $H_0: \alpha = 1$. The time period that minimises t_α is selected as that in which the break occurs. The subsequent Dickey-Fuller test for a unit root test has a distribution that takes into account of the fact that the optimal break point has been chosen. Take note that the test specified in Perron and Vogelsang (1992) just described is for time series for a particular cross section i within a panel dataset. This means that for panel data, this test is done for each of the cross sections. The procedure used by the thesis to deal with the issue of structural breaks in unit root tests for panel data is specified in Subsection 4.2.2.

Section 4.2. Empirical estimation and data

The corresponding estimation strategy is described in this section. Described here are the baseline panel econometric model used in the study, the details on the calculations and transformations done on the raw data to acquire the variables necessary in the empirical analysis, and the the data sources for the construction of the dataset.

Subsection 4.2.1. The econometric model

The modified social metabolism framework that incorporates institutions described in Section 3.3 provides basis for the fundamental econometric model specification used in this thesis. Following the argument behind this modified social metabolism framework, the baseline panel data econometric model is specified as

$$DR_{it} = \beta_0 + \beta_1 NFE_i + \beta_2 B_{it} + \beta_3 LA_i + \beta_4 AP_{it} + \beta_5 EI_{it} + \beta_6 ED_{it}, + \beta_7 ln(GPC_{it}) + \beta_8 IS_{it} + \beta_9 CT_{it} + \beta_{10} EP_{it} + \beta_{11} SI_{it} + \beta_{12} SO_{it} + \beta_{13}(SI_{it} * EP_{it}) + \beta_{14}(IS_{it} * SI_{it} * EP_{it}) + \beta_{15}(SO_{it} * SI_{it} * EP_{it}) + u_{it} \quad (13)$$

where:

DR_{it} – the change in the share of non-fossil fuel resources (i.e., solar, wind, hydropower, biomass, geothermal, and nuclear) in energy production in country i at time t

NFE_i – an index for non-fossil fuel resource endowments

B_{it} – carbon stock in living biomass

LA_i – land area

AP_{it} – price of agricultural land

EI_{it} – imports of non-fossil fuel energy resources

ED_{it} – energy depletion

$ln(GPC_{it})$ – natural logarithm of GDP per capita in PPP

IS_{it} – share of the industrial sector[19] in the GDP

CT_{it} – carbon tax

EP_{it} – energy policy

SI_{it} – WGI Government Effectiveness Index

SO_{it} – share of state-owned or -operated power plants in the total

DR_{it} measures the change non-fossil fuel resources share over time. The share of non-fossil fuel resources are ratios between zero and one, and thus bounded outcomes. To address this issue, logistic transformations were done in constructing DR_{it}, hence,

$$DR_{it} = ln\left(\frac{R_{it}}{1-R_{it}}\right) - ln\left(\frac{R_{it-1}}{1-R_{it-1}}\right) \quad (14)$$

where R_{it} is the non-fossil fuel resources share in energy production in country i at time t. Here, the shares were mapped to odds ratio logarithms, which are unbounded. The estimates of the coefficients of the explanatory variables from the respective regressions then are to be interpreted as measures of the effects of the explanatory variables on the changes in the odds ratio logarithms of the non-fossil fuel resources shares over time. Thus here, energy substitution is represented by the changes in the odds ratio logarithms of the non-fossil fuel resources shares over time. Logistic transformations are monotonic, which means that they change in the same direction as the ratios from which they were derived, i.e., as the non-fossil fuel resources shares increase or decrease, their respective logistic transformations likewise increase or decrease. DR_{it} measures energy substitution only from the

[19]Include mining, manufacturing, construction, electricity, water, and gas.

production side because energy imports are an explanatory variable in the model, hence measuring energy substitution using TES would result in double counting, as imports are already included here.

The explanatory variables included in (13) are based on the components of the energy landscape in the social metabolism model. NFE_i, B_{it}, LA_i, AP_{it} represent available endowments for non-fossil fuel energy production, and EI_{it} meanwhile represent accessible endowments. NFE_i was calculated as follows. *First*, the world average for each of the variables that proxy for non-fossil fuel endowments was obtained. The non-fossil fuel endowment variables used to calculate NFE_i are (a) wind speed (in m/s, from the top 10% of windiest areas; proxy for wind) and (b) global tilted irradiance per day (in kWh per square metre; proxy for solar). *Next*, the ratio of country-level figures to the world average was obtained. This normalises the values, which gives a common measure for all non-fossil fuel endowment variables, making the resulting values comparable across all variables. *Finally*, the average of these ratios included per country were obtained, and NFE_{it} is the resulting ratio average. The same procedure for normalisation was done to the carbon stock in living biomass (in million tonnes per square metre; proxy for biomass) to calculate B_{it}, except that averages were calculated both per country and year, as the variable also varies across time. Carbon stock in living biomass was not included in the calculation of NFE_i; it is not substitutable with solar and wind, as it can be depleted. Only these three non-fossil fuel resources were included as explanatory variables as these three have relatively wide acceptance in the literature (e.g., Aguirre and Ibikunle, 2014; Gosens, 2017; Maekawa et al, 2018). DR_{it} could have been adjusted to this so that it would match NFE_i, but doing this presented another problem: some countries do not have data on energy production from some non-fossil fuel resources included in NFE_i, which further decreases the number of countries included in the analysis. NFE_i and B_{it} are expected to have positive signs.

LA_i (land area in square kilometre) and AP_{it} (agricultural prices initially in EUR, converted to USD) were included to take into account the fact that non-fossil fuel energy production, especially from renewables, is tied to land use. *First*, renewable energy production is location dependent. The larger the land area of a country is, the more locations suitable for non-fossil fuel production will be. LA_i therefore is expected to have a positive sign. *Second*, the fact that renewables tend to require more land because of its relatively low power density leads to land being substituted away from other uses. AP_{it} is meant to proxy for this substitution in terms of land use and is expected to have a negative sign. Eurostat, the source of the raw data for AP_{it}, calculates agricultural prices in absolute terms. Eurostat remarks that absolute prices are helpful when assessing the relationship between agricultural land values and respective incomes properly, i.e., the viability of agriculture given changes in land prices[20]. Since LA_i and AP_{it} are in units that are large relative to the dependent variable, both were scaled down, to thousand square kilometres and thousand USD, respectively. Otherwise, the respective coefficients become so small that they can only be shown using an unreasonably immense number of decimal places. EI_{it} was calculated simply as non-fossil fuels share in total energy imports and is expected to have a negative sign.

ED_{it} takes into account the dynamic aspect of an energy substitution. This variable was added to control for geological considerations, i.e., the quality of the remaining resource decreases over time due to declining pressure in oilfields. It was specifically constructed as a peak oil dummy, equal to one from the year a country has reached the peak of its resource-limited[21] conventional oil production and onwards, equal to zero otherwise, or simply:

$$ED_{it} = \begin{cases} 1 \text{ if } t \geq t_{PO} \\ 0, \text{if } t < t_{PO} \end{cases} \quad (15)$$

where t is the year and t_{PO} is the peak oil year. Energy depletion in a country is then proxied here by such country peaking in its oil conventional production. This is yet another research gap addressed by this thesis, i.e., the effect of energy depletion, i.e., reaching conventional oil production, on substituting towards a cleaner energy mix in a given country. ED_{it} is then expected to have a positive sign. $ln(GPC_{it})$ and IS_{it} represent the affluence and structure of the economy, respectively. GDP per capita is used here to measure the size of the economy in relative terms, to make the latter comparable across countries. GDP per capita nevertheless measures affluence and not size. It is in logarithmic form because it makes sense to conceive (13) as originating from a function linking R_{it} to the independent variables having a multiplicative form. If GDP were zero, it is quite unreasonable that R_{it} could be positive, even if compensated by other variables. $ln(GPC_{it})$ expected to have a positive sign and IS_{it} is expected to have a negative sign.

The next variables represent the institutional environment in the extended social metabolism model. CT_{it} is calculated as the share of annual global GHG emissions covered by the country's carbon pricing initiative and is expected to have a positive sign. CT_{it} therefore is in proportions, hence has no units and not in monetary terms. EP_{it} capture a government's willingness to intervene with energy policy, hence represent the institutional environment. The raw data necessary to construct EP_{it} were

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[20] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural_land_prices_and_rents_-_statistics&oldid=586826#Agricultural_land_prices_in_the_EU (Accessed 17 May 2023)

[21] This happens when the decline in production from larger, earlier conventional oil fields becomes greater than the increase in production from the smaller, more recently drilled ones (Bentley et al, 2020).

qualitative in nature, i.e., the actual energy policy instruments at the country level listed in the sources mentioned in Subsection 4.2.3, and the years for which such energy policy instruments are in force. The only energy policy measures used in creating this energy policy variable are those that incentivise renewables use. EP_{it} was constructed as a trend to take into account the long-term effects of energy policy, which takes positive integer values from the year at least one energy policy instrument incentivising energy output from renewables was in place in a country and onwards, and zero otherwise:

$$EP_{it} = \begin{cases} t - t_{PI} + 1 \text{ if } t \geq t_{PI} \\ 0 \text{ if } t < t_{PI} \end{cases} \quad (16)$$

where, t_{PI} is the year when the policy was implemented. Constructing EP_{it} as a dummy variable may only be capturing the immediate effects of the enforcement of the energy policy, hence was constructed as a trend. On a more practical note, all countries included in the analysis have at least one policy in force before 2011, which is the year the time series per country starts (more details on why this is the case are given in Subsection 4.2.3), which means that if EP_{it} is constructed as a dummy, it will take the value of one for the entire time series in the dataset, hence will have no variations over the respective time series. EP_{it} as a dummy therefore cannot be used as an explanatory variable. Take note that EP_{it} was constructed to specifically convey the effects of the government's willingness to intervene with energy policy, hence capturing only one policy in a year is enough. In all the countries included in the analysis, none has years in which no policy is in force, hence non-zero values are taken by EP_{it} in all years included in the time series. EP_{it} is expected to have a positive sign. More details on the respective calculations are in Table A in Appendix A.

SI_{it} measures strength of institutions. The Government Effectiveness Index from WGI was used as proxy. This variable is described as reflecting "perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies[22]". Cadoret and Padovano (2016) meanwhile used the Corruption Perception Index from Transparency International and Control of Corruption Index from WGI. The Government Effectiveness Index looks to be more in line with the objective of this paper, which is to investigate the strength of institutions in support of energy policy. The sign of SI_{it} seems to matter less than the previously discussed variables, because SI_{it} is not directly related to energy substitution per se, as it only captures the nature of prevailing institutions in a country. The time series of SI_{it} was produced in the following

[22]http://info.worldbank.org/governance/wgi/Home/FAQ Accessed 25 October 2019.

way. WGI data goes from 1996-2018 but were only collected annually from 2002 onward. Prior to 2002, the data were collected once every two years, hence data is missing for years 1997, 1999, and 2001. The data for these years then must be interpolated, and the following was done to interpolate the missing data. First, for 1997, a pseudo-random number was drawn from a normal distribution. Here, the 1996 value was used as the mean to restrict the draw for 1997 to some neighbourhood of values around the 1996 value, and the standard deviation of the whole series was used as that for the normal distribution. Next, the resulting three-year series was then used to forecast the value for 1999. After calculating the forecasted values for 1999, the resulting five-year series was used to forecast the value for 2001.

SO_{it} is the share of state-owned or -operated power plants in the total, which proxies for state participation in the electricity sector. Attention is given to the electricity sector because this is what the available data permit, as discussed in Subsection 4.2.3. This variable is not directly related to any of the components of the energy landscape, and was only included to address the second research objective. This can nonetheless be interpreted as reflecting how big the state relative to markets and society, hence reflect the country's institutional environment as well. Like SI_{it}, it has nothing to do with energy substitution at least directly. Its effect on energy substitution is nonetheless more obvious given that the country has green energy policy in place. SO_{it} was constructed based on the records from IndustryAbout.com and the Global Energy Observatory. For each power plant for which information is available, the respective data sources indicate the following: (a) the power plant owner and/or operator, (b) the year in which the power plant was commissioned, (c) the year in which the power plant was shut down, and (d) the year in which the power plant changed ownership. This information is not always available for all power plants (information on ownership change is available only in the Global Energy Observatory), and in such cases, further search would be done to look for information elsewhere, e.g., in the owner's or operator's websites. So, only those power plants for which the information is complete are included in the calculations, which of course would be very different if all power plants are included in the calculations. In some cases, the owner is not identified in the respective power plant webpage, for which the operator information is used. Further search was done to determine if the respective power plant is state-owned or -operated (if information on the owner is not available), or otherwise. The power plant is identified as state-owned or -operated if the respective information available implies that the owner or operator are the national or federal governments, or local governments like the provincial, state, or city governments. Additionally, the power plant is identified as state-owned if at least 50% of the shares are owned by national, federal, or local governments. Once the power plant is identified as state-owned or -operated, the share of which to the total would be calculated for each year included in the time series. Table A in Appendix A summarises the variables used in the study, along with the details on how they were calculated.

To accomplish the quantitative objectives, the thesis includes on the right-hand side an interaction term between an institutional variable and a policy variable, i.e., $(SI_{it} * EP_{it})$. This proxies for institutional support of energy policy: its respective coefficient measures the effect of the strength of institutions on non-fossil fuel share in the energy production given existing energy policy that support renewables, therefore expected to have a positive sign. $(SI_{it} * EP_{it})$ is interacted with the proxy for industrialisation, IS_{it}, resulting in the interaction of three variables, $(IS_{it} * SI_{it} * EP_{it})$. The coefficient of this variable is to be interpreted as the effect of strong institutions in support of energy policy on non-fossil fuel share given certain levels of industrial share in the economy, thus addressing the paper's first objective. $(IS_{it} * SI_{it} * EP_{it})$ is expected to have a positive sign, which means that strong state-related institutions in support of energy policy weaken the effect of high industrial shares in a country in slowing down an alternative energy substitution. To accomplish the second objective, $(SI_{it} * EP_{it})$ is likewise interacted with SO_{it}, the proxy for state participation, producing $(SO_{it} * SI_{it} * EP_{it})$. The respective coefficient is to be interpreted as the effect of state participation in the energy sector on energy substitution given existing energy policy supported by strong institutions. $(SO_{it} * SI_{it} * EP_{it})$ is expected to have a positive sign; state participation in the energy sector is expected to positively affect energy substitution given strong institutional support of existing energy policy, for reasons provided in Section 2.5.

Subsection 4.2.2. Addressing related issues

In the first place, FE cannot be used when there are variables that do not change over time, i.e., NFE_i and LA_i in the baseline econometric model presented in Subsection 4.2.1. There are ways of getting around this problem, like the using fixed effects vector decomposition procedure as proposed in Plümper and Troeger (2007)[23]. Notwithstanding, the Hausman test was performed to determine whether to use FE or RE, and shows that the estimation procedure in all models discussed should include random effects (details in Appendix B). Robust standard errors were used in all these models so that z-values are still valid in the presence of heteroskedasticity.

A panel unit root test was conducted to determine whether indeed there are unit roots. In Stata, there are two tests that allow for an unbalanced panel, the Im-Pesaran-Shin test (Im et al, 2003), and the Fisher test (Maddala and Wu, 1999; Choi, 2001). The latter was chosen as it is the only one that allows for missing data. The code for implementing the Fisher test does four different tests, all of which

[23]The extent to which this procedure is appropriate to address the presence of time-invariant variables using fixed effects is at least disputed (e.g., Greene, 2011).

implement an augmented Dickey-Fuller unit root test on each panel. The null hypothesis in the Fisher panel data unit root tests in Stata, i.e., that all panels contain unit roots, is tested against the alternative that at least one panel is stationary (StataCorp, 2015). These four tests then display four different test statistics and corresponding p-values, i.e., the inverse chi-squared, inverse-normal, inverse-logit, and modified inverse chi-squared tests.

Structural breaks then were taken into account. Structural breaks were determined by using the Clemente-Montañés-Reyes unit root tests per cross section (Clemente et al, 1998). Stata uses modified versions of the tests based on additive and innovative outliers, allowing for one structural break. Regarding this, the critical values were from the test described in Perron and Vogelsang (1992), as the test described in the former is an extension of that described in the latter. The test identified the years where the structural breaks occur. Dummy variables were then constructed based on these years identified by the Clemente-Montañés-Reyes test, i.e., dummy variables according to what year the structural break occurs, which vary across countries. These dummy variables are equal to one at the year the break occurs, and zero otherwise. The variables included in the econometric model were then regressed on the resulting dummy variables that take into account the structural breaks per country. The idea here is that each of these variables is interpreted as some latent variable with structural breaks included. The resulting residuals therefore can be seen as estimates of the latent variable with the structural breaks removed. These residuals were the ones subjected to the Fisher panel unit root tests. To clarify, the Clemente-Montañés-Reyes test was only used to determine the year of the possible structural break, from which a respective dummy variable is created; the Fisher tests for panel data were the ones used to test for the presence of unit roots.

The results are summarised in Tables C.1 – C.4 in Appendix C. Tables C.1 – C.2 show the Fisher tests that take into account the structural breaks determined using additive outliers, whilst Tables C.3 – C.4 show the same but using innovative outliers. Take note that in the latter, there are instances where structural breaks cannot be identified. This happens when there is not much variation in a time series, like in SO_{it}. Innovative outliers assumes that the effects of the outlier linger across time, which may make it difficult to detect if the time series is short. Since the cross-sectional sample space, i.e., the set of European countries, is finite, the inverse chi-squared test can be used (Choi, 2001; StataCorp, 2015). Here, the null hypothesis is rejected (e.g., the second column of Table B.1 shows that for DR_{it}, the null hypothesis for the inverse chi-squared test is rejected at the 1% level of significance) for all variables, except for CT_{it} and $ln(GPC_{it})$ in the model that uses additive outliers, as shown in fifth and eighth columns of Table C.1, signifying the corresponding presence of unit roots. Demeaning both variables solves this problem as shown in the sixth and ninth columns of Table C.1.

Subsection 4.2.3. Data and data sources

The dataset has nineteen European countries, as only for these countries are all variables specified in (13) available[24]. The data sources are as follows. Available and accessible endowment variables data were from the IEA through the UK Data Service, from the World Bank WDI, from the United Nations Statistics Division (UNSD hereafter), from the Global Wind Atlas, and from the Global Solar Atlas. The respective data from these sources are time-invariant (see Appendix A for the respective calculation methodology). Data that varies across time was in fact available from ERA5[25] of the European Centre for Medium-Range Weather Forecasts or ECMWF, but such has a very fine level of disaggregation; data was hourly and was precise down to the map coordinate level. This would have made the aggregation to years and country levels prohibitively impractical. This also includes energy imports data since these determine the access to endowments. Land use data were from WDI (land area) and Eurostat (agricultural land prices). The reason this thesis is limited to European countries is that only Eurostat provides reliable data on agricultural land prices, having a unified methodology in obtaining such data across all reporting countries, making the respective data more comparable across countries. Carbon tax data were from the World Bank's Carbon Pricing Dashboard. Socioeconomic data to provide measures for economic activity, like GDP and industrialisation levels were from WDI. The peak oil data used to construct the energy depletion variable were from the methodology used by Globalshift Ltd[26]. Proxies for institutional variables were from WGI, and data used to construct the energy policy variable were from the Policies and Measures Databases from the IEA and Climatescope from Bloomberg New Energy Finance. Data used to construct the variable for state participation in the electricity sector, specifically the share of state-owned or -operated power plants in the total, were from the records from IndustryAbout.com, the Global Energy Observatory, and from the owner's or operator's websites. Data available from IEA stretch from 1971 – 2018 (as far back as 1960 for OECD countries), and data from WDI in general go from 1960-2018. Carbon tax data from the Carbon Pricing Dashboard go from 1990 until the present. IMF data generally go from 1972 – 2018, and WGI goes from 1996 – 2018. Data from Climatescope were from a list of green energy policy instruments in force from 2018 and earlier. Power plant data from the Global Energy Observatory goes as far back as 1896, with the latest data being as of 2018. Eurostat agricultural land price data used in this paper goes only from 2011 – 2018.

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[24]The countries included in the study are the following: Bulgaria, Czechia, Denmark, Estonia, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Romania, Slovakia, Spain, Sweden, and the UK.

[25]https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5

[26]Table A in Appendix A provides a brief description of this methodology. More details are available in Smith (2015) and through the following link: http://www.globalshift.co.uk/mode.html

The Eurostat data go as far back as 1985, but were gathered without a unified methodology, hence the comparability of the data across reporting countries is severely limited. Consequently, time series per cross section would have to be from 2011 – 2018. Regarding this, Ireland and Spain have missing data for some years. This was taken into consideration when deciding how many lags should be included in the Fisher unit root tests to improve the fit of the respective regression. From a mostly practical perspective, given the length of the time series per cross section, a decision was made that that only one lag is to be included in the Fisher unit root tests. Including more lags makes the test more stringent, as it increases the critical values for the corresponding test statistics. This will reduce the power of the test, making it more difficult to reject the corresponding null hypothesis even if the latter is false. For the same reason, one lag was also included in the Clemente-Montañés-Reyes test.

Figure 7 summarises the procedure in the quantitative study. The quantitative research gaps identified

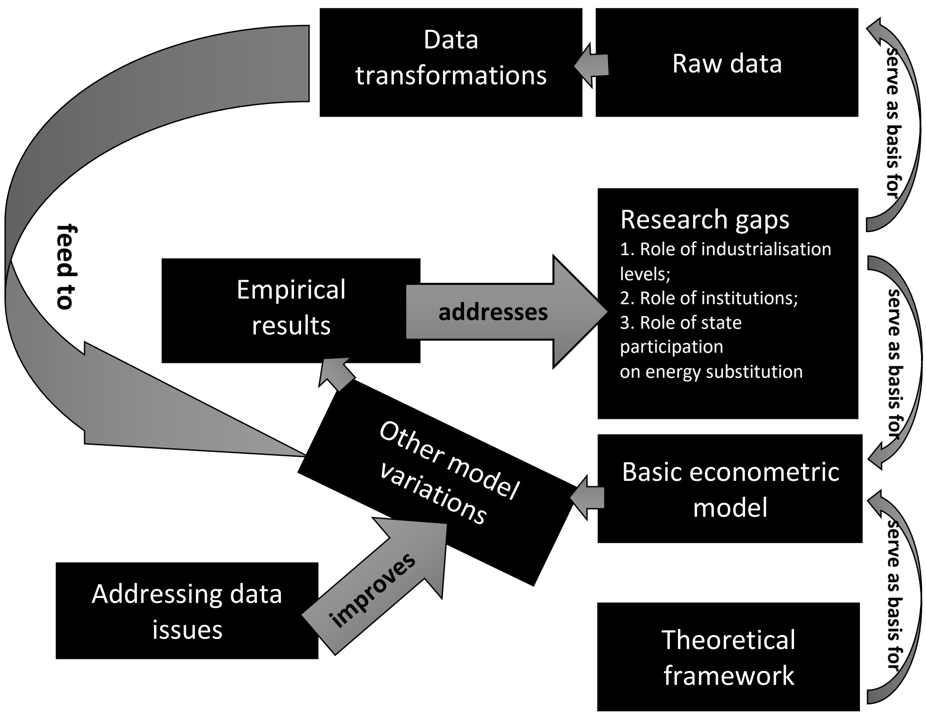

Figure 7. Summary of the quantitative research procedure. Source: Author.

by the literature review and the theoretical framework, i.e., the modified social metabolism framework, developed using insights from ecological and institutional economics serves as basis for the panel econometric model specifications. The raw data is then transformed as necessary to be useful to the analysis and are fed to the several variations of the econometric model. The issues with the data identified then are addressed to improve such models. From here are the empirical results derived, which then address the quantitative research gaps, In Figure 7, arrows are drawn from the empirical results to the quantitative research gaps they specifically address.

Section 4.3. Qualitative research

The analysis on how renewable energy cooperatives help in the substitution for fossil fuels towards a cleaner energy mix from the lens of institutional economics was undertaken using qualitative research methods. This analysis would benefit from a qualitative approach for the following reasons. *First*, institutional forms tend to be complex systems. Neoclassical quantitative microeconomic models tend to disregard such complexity to arrive at results given oversimplifying assumptions about economic behaviour, leaving out details and complexities that when dealt with, can lead to better understanding of economic phenomena. This is exemplified in the treatment of the firm as a "black box", the epitome of non-institutional analysis according to Williamson (1985). Qualitative research can address this limitation and flesh out these crucial details about institutions by exploring the latter more to extract more in-depth information (Sovacool et al, 2018). *Second*, there are certain aspects of the complexity of institutional forms that are difficult to quantify, like for instance the notions of trust, power, or equity. Such cannot be taken into account by neoclassical quantitative microeconomic models, as demonstrated by the results of public goods game experiments (Bardsley, 2000). Recall the idea of "intangible" elements of an energy transition in Sovacool and Geels (2016) discussed in Section 3.3, like norms, belief systems, and social practices, with which institutions determine interactions in an economy by imposing constraints on behaviour, as discussed in North (1991) and Woods (2004). *Third*, phenomena and context can be difficult to distinguish in real-world settings (Yin, 2018), and a qualitative approach is useful when investigating the contextual conditions to be considered under which a real-world phenomenon should be understood. There are indeed many instances wherein studies that involve institutional forms analysis resort to qualitative methods (e.g., Ostrom 1990; 2005; Walker and Devine-Wright, 2008; Hoffman and High-Pippert, 2010; Bauwens, 2016; Gorroño-Albizu et al, 2019).

Take note that the qualitative part of the thesis is essentially a *case study* on REScoop.eu member cooperatives. The related qualitative research gaps are all addressed in the context of REScoop.eu, hence all results and respective discussion of the qualitative research done here must all be understood in the context of REScoop.eu.

Section 4.4. Interviews, thematic analysis, and survey

The following describes the research design to tackle the qualitative research gaps. The ***first stage*** of the qualitative approach of the research involves semi-structured online interviews. Interviews can provide more detailed understanding of the topic through follow up questions. Interviews may however be biased both by the interviewer and interviewee; the former through the questions asked, and the latter through responding to questions based on what is socially desirable (Sovacool et al, 2018). Online interviews function almost the same as face-to-face interviews, with the advantage of allowing to save time and money, albeit limited by the quality of the equipment and internet connection. The main reason for the interviews is *to obtain data from which themes can be derived to construct a narrative that addresses the qualitative research gaps*. The interviewees, hence, the key actors in these interviews, were chosen based on two main considerations. These two considerations essentially represent the sampling approach used determine which types of actors were included in the interviews. One consideration is the extent of involvement in the actual development of renewable energy cooperatives within REScoop.eu. Regarding this, the REScoop.eu member cooperatives with which the prospective interviewees are affiliated were first selected at random, after which emails containing the interview invites were sent to those that were selected, i.e., to the relevant contact persons within the member cooperative. These emails also give basic information on the nature of the research, along with a participant information sheet that explains how the responses would be recorded and used. These emails ask for consent and for the interviewees' preferred time for the interview. The respective interviewees are those chosen by the respondent REScoop.eu member cooperatives that agreed to participate to represent them, e.g., presidents, directors, board members, etc.

It must be clarified that in participating in the interviews conducted, these interviewees expressed their personal views, and not necessarily those of the cooperative they are from. These interviewees are from two main types REScoop.eu member cooperatives, i.e., the smaller, county- or municipal-level cooperatives, and the larger, national-level cooperatives. Moreover, there were also interviewees from cooperative federations or intermediary organisations within REScoop.eu. These organisations are involved in the development of community-based cooperatives. Here, a representative from REScoop.eu itself was included. As was raised earlier, phenomena and context can be difficult to distinguish in real-world settings. The respective interviews then situate the qualitative research gaps in the context of REScoop.eu by obtaining data from the real-world experiences of REScoop.eu. These interviews thus help identify some important contextual conditions under which renewable energy proliferation in Europe towards a cleaner energy mix through renewable energy cooperatives could be understood.

The other consideration is the extent to which a more external and broader perspective on community-based renewable energy cooperatives can be obtained. The respective interviews are for extracting data that provide perspective from outside REScoop.eu, i.e., those are not REScoop.eu members. These interviews act as additional lines of sight to further improve the insights to be derived from the online interviews. Another set of interviewees were thus chosen from outside REScoop.eu. The sets of interviews were done to bring to bear the experiences of REScoop.eu actors, and relevant others from the broader context. These interviews thus help identify important contextual conditions under which renewable energy proliferation in Europe towards a cleaner energy mix through renewable energy cooperatives could be understood. The research was given ethical clearance by the Ethics Committee of the School of Agriculture, Policy, and Development of the University of Reading, after which emails were sent to the selected REScoop.eu member cooperatives.

The interviews were semi-structured to allow for relatively more freedom as to how the conversation progresses, as to not limit the way insights on a topic are brought up. The interviews were done via the virtual meeting platform MS Teams and were recorded upon being granted the permission to do so by the interviewees. Interview transcripts were also produced using MS Teams through the latter's transcription function (see Appendix G). The transcripts produced using MS Teams were not always accurate, and erroneous text must be corrected manually. More details on the characteristics of the interviewees are in Section 5.2. The online interview schedule is in Appendix D.

The ***second stage*** involves using the thematic analysis method outlined in Braun and Clarke (2006). The latter conceives thematic analysis to mainly involve identifying themes, or repeated patterns of meaning in a qualitative dataset, which involves six main phases:

1. *Familiarisation phase*, where the data is read and reread to immerse oneself in them. Preliminary ideas on the data collected and generated are then listed down.
2. *Coding phase*, where labels, or *codes*, on the salient features of the data are generated, and collate the data based on these codes. The coding procedure may be based on the dataset itself or may be based on some theoretical framework, around which codes are generated.
3. *Theme search phase*, where the codes are collated to find the potential general themes and subthemes. Here, the codes are analysed as to how they may point to some overarching themes. The data then is further collated based on these themes. A preliminary thematic map that organises and connects the themes and subthemes is drawn here.
4. *Review phase*, where the themes are checked if consistent with the codes and actual data generated. In this phase, the initial thematic map is refined, e.g., some initial themes may not really be supported by the data, or some themes must be broken down into separate subthemes or be combined into a broader one.
5. *Identification phase*, where the preliminary themes are more thoroughly analysed, refined, and organised into a coherent and internally consistent narrative that indeed reflects the data based on the smaller narratives that surround them. The definitions and nomenclature of such themes are clarified in this stage as well.

6. *Finalisation phase*, where the write-up of the thematic analysis is done. The write-up is expected to be on the overall narrative that best represents the data and addresses the research gaps.

This thematic analysis method is reflexive in that the phases are not necessarily implemented in a linear fashion. This method is more of a recursive process, where one can go back and forth across these phases as deemed necessary. The themes identified were then used to describe and organise the dataset, as well as to interpret the latter in relation to the qualitative research gaps. The interviews were done to construct a narrative to understand renewable energy proliferation in Europe towards a cleaner energy mix through renewable energy cooperatives in the context of REScoop.eu and the prevailing policy environment. Addressing the qualitative research gaps through thematic analysis then likewise involves testing whether the theoretical bases for this proposition hold in the context of REScoop.eu. The narrative themes arising from the interviews are compared to patterns predicted by the respective theoretical bases, akin to the technique of pattern matching in linking data to propositions (Villamayor-Tomas, 2016; Yin, 2018).

The ***third stage*** involves an online survey based on the narrative constructed from the thematic analysis. The main reason for this survey is *to obtain data that complement those from the interviews and allow having data from a larger sample size and for more standardised questions to be asked*. The latter make the corresponding responses relatively more comparable, both of which allows the qualitative research gaps to be addressed in a more general way within the context of REScoop.eu. In addition, the survey allows for anonymity and privacy for the respondents for topics the latter may deem sensitive and embarrassing. Some limitations of the survey however are the biases arising from low response rates because responding to the survey is voluntary, and that the corresponding questionnaire may be too closed, which can constrain on corresponding responses, limiting the ability of the respondents to address the qualitative research gaps.

The online interviews then relate to the online survey in that the former was used as basis for the latter through the results of the thematic analysis. The interviewees then also act as the key informants for this online survey. The latter provide the data necessary to craft the corresponding questionnaire, which helps the survey better complement the interviews in addressing the qualitative research gaps. Therefore, relative to the survey, the interviews through the results of the thematic analysis can also be seen as a preliminary data gathering stage to identify what questions are to be included in the respective questionnaire, hence serves as guide in the latter's construction. The online survey was expected to confirm the results of the thematic analysis, i.e., confirm the main themes identified therein. The main themes identified from the thematic analysis comprise the central perspective around which the survey is organised. The online survey hence has the main expected result of demonstrating that the responses in the interviews from which the main themes were identified indeed do generalise within REScoop.eu.

The online survey questionnaire is in Appendix E. All questions involving specific responses, including the respective response options, were based on the interview results, i.e., the main themes identified from the interviews through the thematic analysis. The response options in these questions reflect the narrative provided in Section 5.2, where the interviews' main themes were discussed. "Other" was included as an option to make such questions more open, which allows the questionnaire to go beyond the interview results. To wit, this allows the questionnaire to obtain data other than those used to identify the main themes through the thematic analysis, which can further enrich the narrative constructed from the interviews. A box provided at the end of the questionnaire further improves the openness of the survey, in which the survey respondent can write additional comments or any other issue the respondent wants to raise. There are questions wherein the respondents are allowed to choose more than one answer, like in Question 11. The respective number of responses therefore in these types of questions were expected to exceed the actual number of survey respondents. In some of these questions, the responses are conditional to a preceding related question, i.e., Questions 12, 23, 27, 29, 32, 34, and 36. These questions were constructed in this manner to reflect the main themes identified from the interviews. Boxes were also provided after these questions for clearer and more detailed responses, hence more open responses. In addition, the survey questionnaire has questions in which the responses are in a 6-level Likert scale, for which the questionnaire also contains the respective explicit definitions.

The online survey questionnaire was crafted using Qualtrics and was sent via email or contact form to REScoop.eu member cooperatives as of 6 July 2022. Consistent with how the interviews were conducted, the survey was presented as seeking the personal views of the respondents and responding to the survey was entirely on a voluntary basis. Lastly, the online survey was constructed in Qualtrics to allow multiple responses to allow the survey to be sent to as many people as possible within a respondent cooperative.

There were further criteria used to identify the general themes presented over the course of using the last four phases in the method discussed in Braun and Clarke (2006). *First* is how such themes relate to and address the qualitative research gaps in the context of REScoop.eu. Such themes were then discussed in a way that revolves around how they relate to the qualitative research gaps the interviews are attempting to address to begin with. *Second* is how prevalent they were brought up in the interviews. Their prevalence indicates how important such themes are from the perspective of the interviewees (who act as key informants), and likewise gives an idea of how consistent such themes are across the interviews conducted. *Third* is how a perspective provide details in the issues that arise and are related to the qualitative research gaps, in turn providing corresponding novel insights. *Fourth* is how appropriately they fit with an internally consistent overarching narrative that best reflect the qualitative data obtained from the interviews in relation to addressing the qualitative research gaps. This is criterion is a result of the recursive nature of the method specified in Braun and Clarke (2006); the narrative could have already been constructed from the general themes, but in turn could also be used to determine which ones are to be included based on what would make the narrative internally consistent. The survey results are shown in a way that serves how these four criteria are used to identify the main themes.

Figure 8 summarises the qualitative research design. The qualitative research gaps serve as basis for the online interviews, which in turn are described by the theoretical framework, i.e., the SES framework. The latter then guides the construction of the narrative that addresses the qualitative research gaps through the main themes arising from the interviews using thematic analysis. In dealing with these research gaps, the interviews are complemented by the online survey by extracting data from a larger sample size and asking more standardised questions. The interviews also serve as basis for the survey through the thematic analysis and provide the data necessary for the construction of the questionnaire.

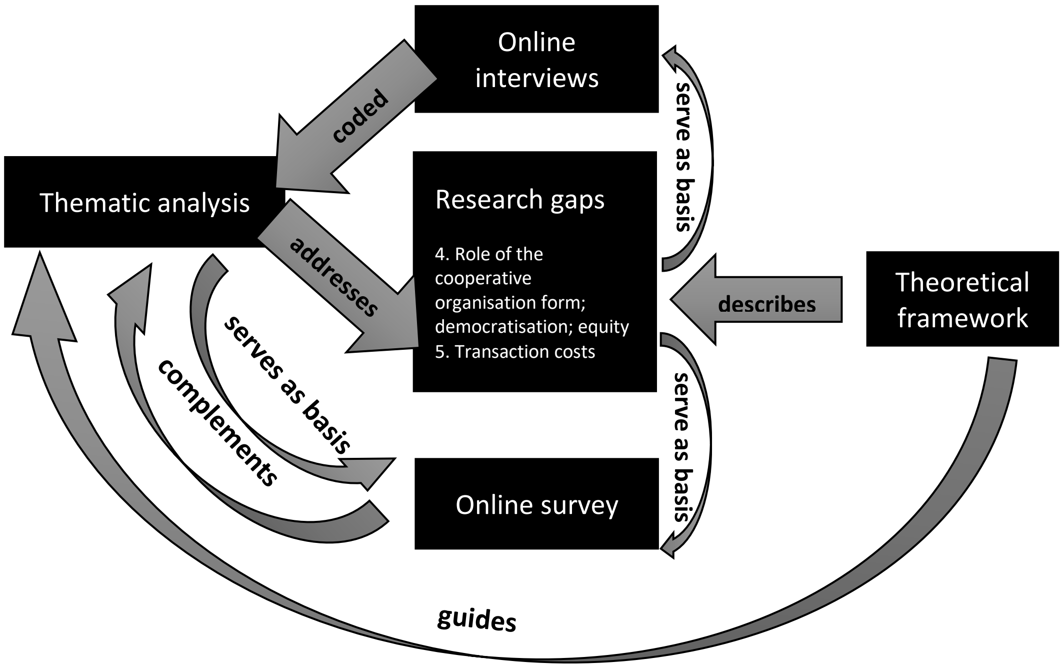

Figure 8. Summary of the qualitative research procedure. Source: Author.

Chapter 5. Results and discussion

This chapter contains the results of the quantitative and qualitative research and the respective discussions. More specifically, this chapter contains the econometric results and discussion (Section 5.1), and a narrative using the main themes extracted from the interviews using thematic analysis, along with a discussion of the survey results (Section 5.2).

Section 5.1. Econometric results and discussion

This section contains the results and the respective discussion of the econometric analysis. It discusses the model specifications arising from the baseline econometric model for a sensitivity analysis, then presents and discusses the actual coefficient estimates, along with their implications. A version of the econometric part of this thesis, i.e., one that includes Sections 4.2 and 5.1, has been published as an article in Volume 239 of the journal Energy, entitled "Industrialisation, state-related institutions, and the speed of energy substitution: The case in Europe" (Andal, 2022).

Subsection 5.1.1. Sensitivity analysis

Nine model specifications were used in this thesis, summarised in Tables 2 – 4. Model 1 is the most basic, a straightforward rendition of the baseline model presented in Subsection 4.2.1, hence a fundamental econometric model specification based on the modified social metabolism framework. The next two models are variations of this baseline model to account for certain nuances in the components of the energy landscape, and hence of the social metabolism framework. Model 2 is the result of making two modifications for Model 1, both on functional forms. First, NFE_i was interacted with LA_i. Taking note that renewable energy production is tied to land use, it could be argued that an interaction between these two variables is warranted. This interaction term captures how NFE_i affects DR_{it} at varied sizes of LA_i. Second, the squared terms of IS_{it} were included, as it could be argued that there may be non-linear relationships between IS_{it} and DR_{it}. Model 3 is a variation of Model 2, where the differences of IS_{it} instead of its levels were included along with their respective squared terms. This modification was made because it could be argued that *changes* in industrialisation levels are the ones that actually influence energy substitution towards a cleaner energy mix.

These three models, Models 1 – 3, were likewise estimated using an alternative form of ED_{it}, resulting into Models 4 – 6. The latter was constructed as the number of years that passed since the country reached peak oil:

$$ED_{it} = t - t_{PO} \tag{17}$$

For instance, Bulgaria reached peak oil in 1967, which means that ED_{it} takes the value of 44 in 2011, 45 in 2012, and so on. Constructed this way, ED_{it} takes on the value of zero in the year peak oil was reached, positive values in the years after peal oil, and negative values in years before peak oil. In the case of Bulgaria for example, ED_{it} is zero in 1967, has positive values from 1968 onwards, and has negative values in 1966 and earlier. A dummy variable will not capture the effect of proximity to the peak oil year on renewable production, as it only provides information on whether a country has reached peak oil or not. Models 4 – 6 were then modified using an alternative form of EP_{it} to produce Models 7 – 9. In these models, EP_{it} was constructed instead as a staggered trend, which changes in value only every 3 years, hence:

$$EP_{it} = \begin{cases} n+1 \text{ if } t_{PI}+3n+2 \geq t \geq t_{PI}+3n \\ 0 \text{ if } t < t_{PI} \end{cases}$$
$$n = 0,1,2,\ldots \tag{18}$$

A total of nine models seems appropriate for sensitivity analysis to show how the estimates change given changes in the fundamental specification of the econometric model based on the modified social metabolism framework, i.e., changes in Model 1, and changes in how some variables are measured. Models 1 – 3 could have been run using the alternative measure for EP_{it}, but the degree to which there are variations in these additional runs seems negligible, hence adding further models do not seem to add any further value to the sensitivity analysis done here.

Subsection 5.1.2. Coefficient estimates, their implications, and quantitative results summary

The coefficient estimates are summarised Tables 2 – 4 and plotted in Figures 9 – 11. Take note once again that these estimates are to be interpreted as measures of the effects of the explanatory variables on the changes in the odds ratio logarithms of the non-fossil fuel resources shares over time, to which the non-fossil fuel resources shares were mapped by the logistic transformations done to DR_{it}. The most important variables to examine are ($IS_{it} * SI_{it} * EP_{itj}$) and ($SO_{it} * SI_{it} * EP_{itj}$), $j = a, b$, which address the first and second objectives of this paper, respectively. The eleventh row of Tables 2 – 4 shows that in Models 2, 5, and 8, where IS_{it} is in levels, IS_{it} is positive and significant. This may imply

	Model 1		Model 2		Model 3	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
NFE_i	2.494	1.35	5.814***	2.60	2.764	1.56
B_{it}	-0.208	- 1.52	-0.011	-0.09	-0.112	-0.96
LA_i	-7.93e-5	-0.27	0.013**	2.00	0.012*	1.78
$NFE_i * LA_i$		-0.34	-0.014**	-2.08	-0.013*	-1.78
AP_{it}	-0.001	-0.84	-0.006	-1.32	-0.005	-1.04
EI_{it}	-8.951	1.23	-10.527**	-2.12	-8.785	-1.6
$ED_{ita}{}^{+}$	0.253	-0.74	0.286	1.61	0.363	1.38
$ln(\widetilde{GPC}_{it})$	-0.199	1.59	0.182	0.57	0.223	0.82
IS_{it}	6.648	1.35	14.766***	2.45		
$(IS_{it})^2$			-17.900	-1.47		
$IS_{it} - IS_{it-1}$					-7.494	-1.54
$(IS_{it} - IS_{it-1})^2$					-160.948	-1.44
$\widetilde{CT}_{it}$	-0.782	-1.58	-1.216	-1.00	-1.385	-0.97
$EP_{ita}{}^{++}$	0.022	0.78	0.019	0.65	-0.008	-0.58
SI_{it}	0.408	0.81	0.201	0.37	0.008	0.02
SO_{it}	-1.007**	-2.29	-0.997**	-2.40	-1.211***	-2.77
$(SI_{it} * EP_{ita})$	0.023	1.12	0.039**	2.38	-0.009	-0.48
$(IS_{it} * SI_{it} * EP_{ita})$	-0.262*	-1.62	-0.275**	-2.06		
$[(IS_{it} - IS_{it-1}) * SI_{it} * EP_{ita}]$					1.180*	1.65
$(SO_{it} * SI_{it} * EP_{ita})$	0.074**	2.32	0.058**	2.10	0.053**	2.36
Constant	-3.800	-1.28	-7.543***	-2.48	-1.998	-1.18
Criteria for model selection: AIC	527.726		531.306		531.296	
Criteria for model selection: BIC	579.063		588.347		588.337	

Obs.: 128; $^{+}ED_{it}$ as a peak oil dummy; $^{++}EP_{it}$ as a regular trend.
***Significant at 1% level; **Significant at 5% level; *Significant at 10% level.

Table 2. Summary of coefficient estimates (Models 1 – 3). Source: Author.

that higher industrial shares require more energy production across the board, and this happens in greater magnitudes for non-fossil fuel resources. For instance, Salim et al (2014) finds a positive relationship between industrial output (proxied by the industry sector's value added, the same raw data used to calculate IS_{it}) and renewable energy use, albeit from the consumption side, and finds the same for non-renewable energy use. Energy substitution therefore similarly has to do with the industry sector requiring more energy production in absolute terms. This gives credence to policies that further diversify energy portfolios to satisfy its economy's demand when attempting to substitute towards a cleaner energy mix.

In none of the models are the EP_{itj} significant. This implies that the willingness of government to intervene with energy policy alone is not enough to influence the country's energy mix. This may be because of the relatively short time series per cross section in the dataset; effects of energy policy may

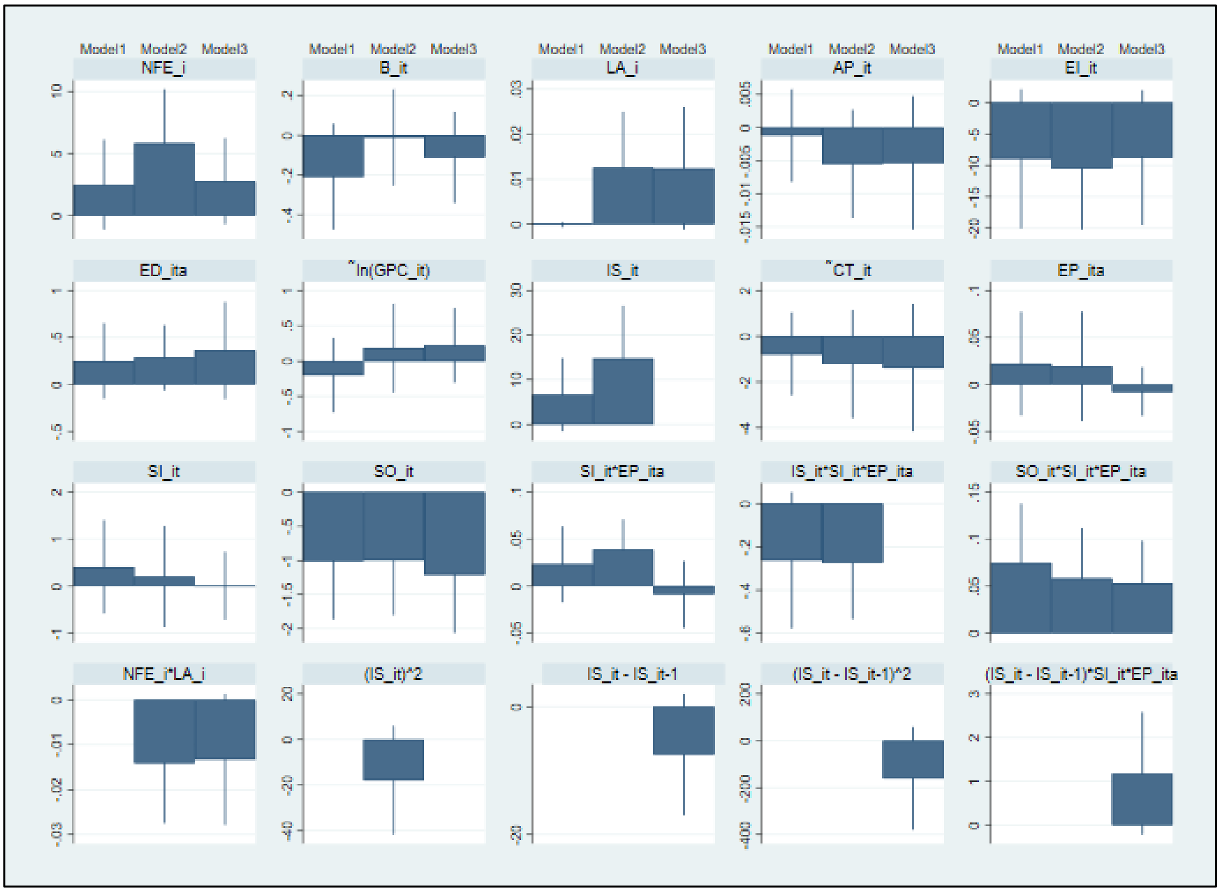

Figure 9. Coefficient plots of variables used (Models 1 – 3). Source: Author.

only be noticeable after a significant number of years have passed. The dataset therefore may just not be able to capture such effects which may just be felt in the long run. However, in Models 2 and 5, where EP_{it} is constructed as a simple trend (EP_{ita} in Tables 2 and 3), and in Model 8, where EP_{it} is constructed as a staggered trend (EP_{itb} in Table 4), the $\left(SI_{it} * EP_{itj}\right)$ (in the 19^{th} row of Tables 2 –4) are positive and significant. These provide evidence that state-related institutions in support of green energy policy positively affects energy substitution on their own; energy policy supported by effective governments are successful in inducing positive changes on non-fossil fuel resources shares in energy production. These also provide evidence that state-related institutions in support of green energy policy will help the effects of energy policy on a country's energy mix to be relatively significant in a relatively shorter period. In Models 1, 2, and 5 as depicted by the 20^{th} row of Tables 2 and 3, $(IS_{it} * SI_{it} * EP_{ita})$ is negative and significant, which implies that higher industrialisation levels can hamper state-related institutions in support of green energy policy in positively affecting energy substitution.

		Model 4		Model 5		Model 6	
		Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
$\boldsymbol{NFE_i}$		2.611	1.34	6.006**	2.36	2.978	1.46
$\boldsymbol{B_{it}}$		-0.218	-1.44	-1.83e-4	0.00	-0.086	-0.57
$\boldsymbol{LA_i}$		-2.55e-4	-0.93	0.013*	1.90	0.013	1.59
$\boldsymbol{NFE_i * LA_i}$				-0.015**	-1.97	-0.014	-1.60
$\boldsymbol{AP_{it}}$		4.92e-4	0.14	-0.004	-1.00	-0.003	-0.62
$\boldsymbol{EI_{it}}$		-7.654	-1.51	-8.374*	-1.87	-6.333	-1.34
$\boldsymbol{ED_{itb}}^{+}$		-0.001	-0.29	0.003	0.66	0.004	0.66
$\boldsymbol{ln(\widehat{GPC}_{it})}$		-0.343	-1.11	0.063	0.20	0.110	0.33
$\boldsymbol{IS_{it}}$		6.315	1.45	13.713**	2.21		
$\boldsymbol{(IS_{it})^2}$				-15.485	-1.48		
$\boldsymbol{IS_{it} - IS_{it-1}}$						-8.567	-1.59
$\boldsymbol{(IS_{it} - IS_{it-1})^2}$						-151.180	-1.39
$\boldsymbol{\widetilde{CT}_{it}}$		-0.317	-0.43	-0.908	-0.83	-0.936	-0.79
$\boldsymbol{EP_{ita}}^{++}$		0.022	0.69	0.029	0.79	0.002	0.11
$\boldsymbol{SI_{it}}$		0.126	0.23	0.153	0.24	-0.121	-0.29
$\boldsymbol{SO_{it}}$		-1.393***	-3.05	-1.317***	-2.94	-1.594***	-3.61
$\boldsymbol{(SI_{it} * EP_{ita})}$		0.035	1.39	0.041*	1.91	-0.007	-0.29
$\boldsymbol{(IS_{it} * SI_{it} * EP_{ita})}$		-0.270	-1.60	-0.292**	-1.98		
$\boldsymbol{[(IS_{it} - IS_{it-1}) * SI_{it} * EP_{ita}]}$						1.149	1.58
$\boldsymbol{(SO_{it} * SI_{it} * EP_{ita})}$		0.073**	2.32	0.056**	2.13	0.052**	2.35
Constant		-3.420	-1.11	-7.495**	-2.07	-2.007	-1.02
Criteria for model selection	AIC	527.891		531.490		531.609	
	BIC	579.228		588.531		588.650	
Obs.: 128; $^{+}\boldsymbol{ED_{it}}$ as the number of years since peak oil; $^{++}\boldsymbol{EP_{it}}$ as a regular trend. ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level.							

Table 3. Summary of coefficient estimates (Models 4 – 6). Source: Author.

In Model 9, $IS_{it} - IS_{it-1}$ (IS_{it} in its differenced form; in the 13th row of Table 4) is also significant but has a negative sign. This implies that it is indeed the case that changes in industrialisation levels negatively affect substituting towards a cleaner energy mix. Hence changes in industrialisation levels, and not the actual levels themselves, negatively affect energy substitution. In Models 3 and 9, where EP_{ita} in Table 2 and EP_{itb} in Table 4 were used respectively, the $[(IS_{it} - IS_{it-1}) * SI_{it} * EP_{itj}]$, as shown in the 21st row of Tables 2 and 4, (the form using the differences of IS_{it} and the staggered version of EP_{it}) is positive and significant. This confirms that state-related institutions in support of green energy policy increase the rates of substitution towards a cleaner energy mix, given changes in the industry sector in the GDP. This implies that state-related institutions in support green energy policy indeed weaken the slowing down effect of high industrial shares in a country on energy substitution.

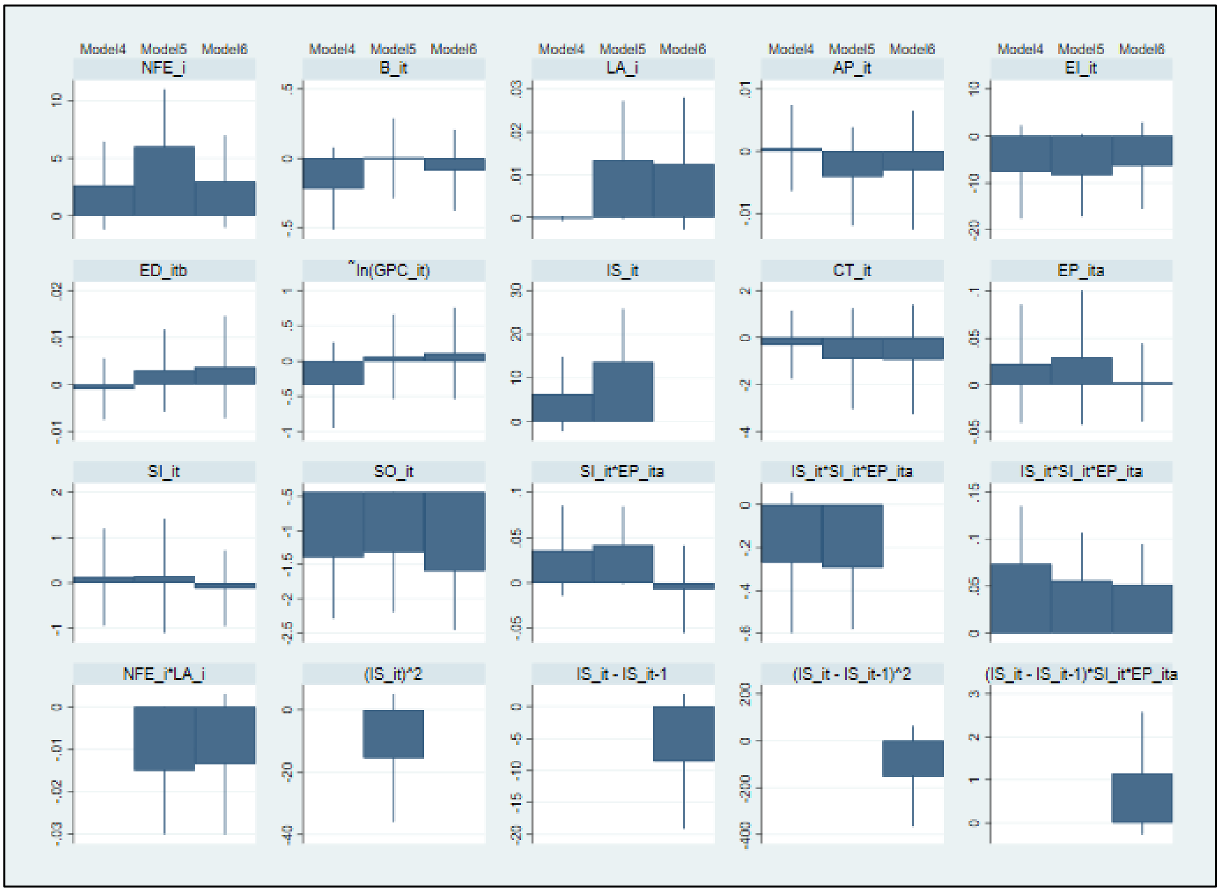

Figure 10. Coefficient plots of variables used (Models 4 – 6). Source: Author.

The 18th row of Tables 2 – 4 meanwhile indicates that SO_{it} is negative and significant in all models presented, implying that more state participation in the electricity sector, specifically in terms of ownership or operation of power plants, on its own negatively affects energy substitution. This may imply that decentralising the electricity sector by incentivising more local-level ownership of power plants managed by communities can be expected to have a positive effect on energy substitution towards a cleaner energy mix. The $(SO_{it} * SI_{it} * EP_{itj})$ meanwhile are positive and significant in all models presented, as can be seen in the 22nd row of Tables 2 – 4. This variable should be interpreted as state participation in the electricity sector having a positive effect on energy substitution given existing energy policy supported by strong institutions. However, given SO_{it} is negative and significant, it seems that the right interpretation of this result is that state-related institutions in support of green energy policy weaken the negative effect of state participation in the electricity sector. This shows that an increased rate of change in the share of non-fossil fuel resources in energy production can result from efforts to further liberalise the energy sector, specifically to limit the market power of state-owned enterprises at least in electricity. Nevertheless, as noted in Prag et al (2018), market power and state ownership are still two separate concepts, and the analysis of their effects must likewise be

	Model 7		Model 8		Model 9	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
$\boldsymbol{NFE_i}$	4.008	1.14	7.383*	1.75	3.487	1.47
$\boldsymbol{B_{it}}$	-0.143	-0.79	0.077	0.36	-0.033	-0.17
$\boldsymbol{LA_i}$	-0.001	-1.02	0.012**	2.36	0.012*	1.71
$\boldsymbol{NFE_i * LA_i}$			-0.014**	-2.42	-0.013*	-1.7
$\boldsymbol{AP_{it}}$	0.004	0.75	-0.001	-0.17	7.52e-5	0.02
$\boldsymbol{EI_{it}}$	-10.587	-1.34	-11.681	-1.54	-8.675	-1.33
$\boldsymbol{ED_{itb}}^{+}$	-0.002	-0.62	0.002	0.43	0.001	0.32
$\boldsymbol{ln(\widetilde{GPC}_{it})}$	-0.694	-1.02	-0.278	-0.43	-0.194	-0.45
$\boldsymbol{IS_{it}}$	8.686	1.13	17.980*	1.78		
$(\boldsymbol{IS_{it}})^2$			-18.589*	-1.75		
$\boldsymbol{IS_{it} - IS_{it-1}}$					-10.357*	-1.72
$(\boldsymbol{IS_{it} - IS_{it-1}})^2$					-134.579	-1.56
$\boldsymbol{\widetilde{CT}_{it}}$	-0.346	-0.44	-0.874	-0.86	-0.888	-0.79
$\boldsymbol{EP_{itb}}^{++}$	0.096	0.63	0.119	0.72	6.69e-6	0.00
$\boldsymbol{SI_{it}}$	0.084	0.12	0.108	0.14	-0.438	-1.31
$\boldsymbol{SO_{it}}$	-1.602***	-2.92	-1.474***	-2.9	-1.962***	-2.74
$(\boldsymbol{SI_{it} * EP_{itb}})$	0.158	1.30	0.181*	1.67	0.019	0.31
$(\boldsymbol{IS_{it} * SI_{it} * EP_{itb}})$	-1.016	-1.22	-1.108	-1.36		
$[(\boldsymbol{IS_{it} - IS_{it-1}}) * \boldsymbol{SI_{it} * EP_{itb}}]$					3.254*	1.73
$(\boldsymbol{SO_{it} * SI_{it} * EP_{itb}})$	0.279*	1.82	0.232*	1.72	0.215*	1.84
Constant	-5.463	-0.93	-9.804	-1.44	-2.348	-1.03
Criteria for model selection AIC	526.952		530.590		530.953	
BIC	578.288		587.631		587.993	

Obs.: 128; $^{+}\boldsymbol{ED_{it}}$ as the number of years since peak oil; $^{++}\boldsymbol{EP_{it}}$ as staggered trend.
***Significant at 1% level; **Significant at 5% level; *Significant at 10% level.

Table 4. Summary of coefficient estimates (Models 7 – 9). Source: Author

separated.

It is interesting to note that in Models 2, 5, and 8, the available and accessible endowments are significant, and took their expected signs. NFE_i and LA_i were both positive, whilst their interaction term is negative. This implies that at larger values both variables, their effect on the change in the share of non-fossil fuel resources in energy production; both positively affects energy substitution at a diminishing rate. EI_{it} meanwhile is negative, also its expected sign (it is nonetheless insignificant in Model 8 though). Moreover, the ED_{itj} are insignificant in all the models presented. This case may be similar to that of EP_{itj}, as the effect of peak oil may only be considerable over long periods of time.

In summary, the main findings of the quantitative part of the thesis are as follows. First, contrary to the first hypothesis brought up in Chapter 1, higher industrialisation levels positively affect energy substitution. This implies that higher industrialisation levels require more energy across the board, which implies that energy substitution also has to do with the industry sector requiring more energy production in absolute terms. Second, changes in industrialisation levels can hamper the rate at which an economy substitutes for fossil fuels, and thus negatively affect energy substitution, which implies that structural transformation in the economy itself can have negative effects on energy substitution.

State-related institutions in support of green energy policy nonetheless weaken this effect. Third, more state participation in the electricity sector on its own negatively affects energy substitution, contrary to the third hypothesis raised in Chapter 1. However, like the case of industrialisation, green energy

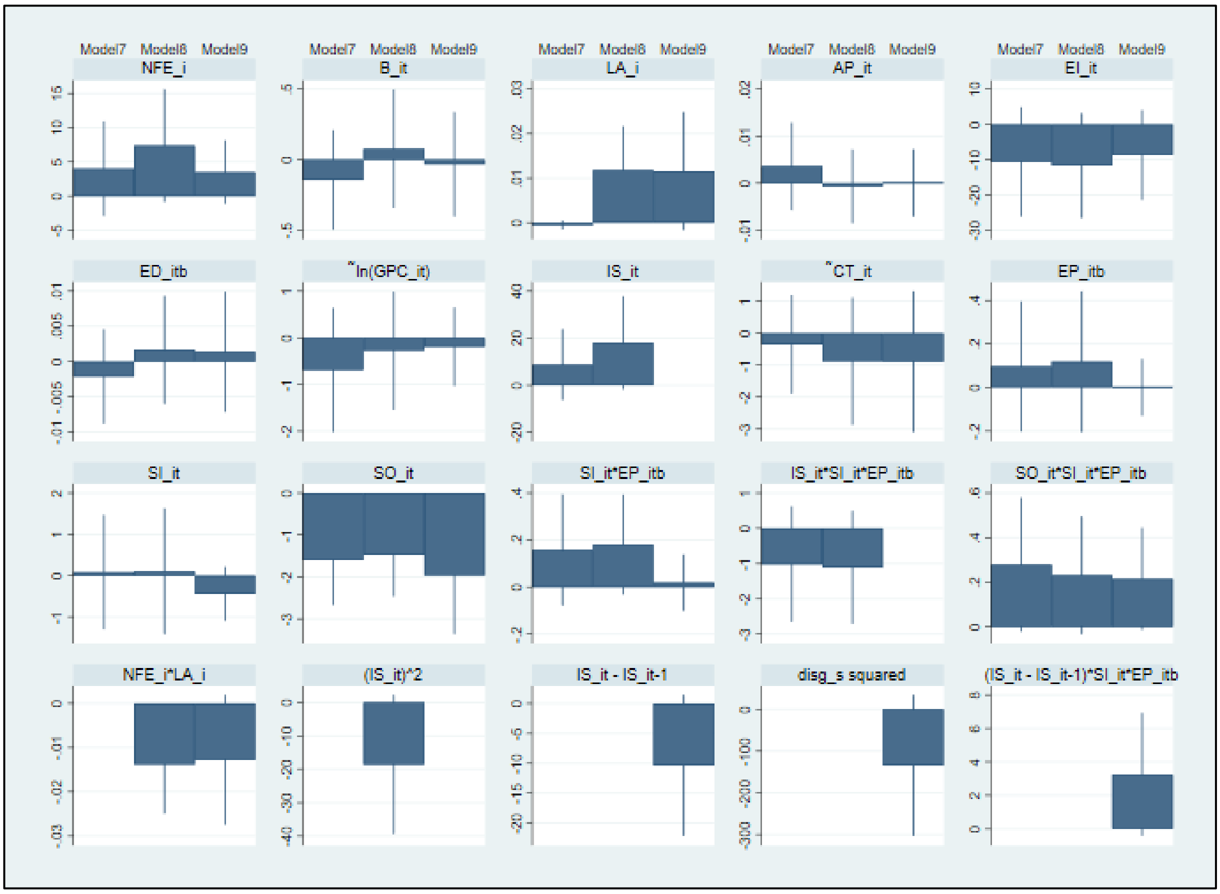

Figure 11. Coefficient plots of variables used (Models 7 – 9). Source: Author

policy supported by state-related institutions likewise weaken this effect. These last two findings nonetheless are both consistent with the second hypothesis, and in fact enriches the perspective on how exactly state-related institutions indeed are relevant as far as energy substitution in Europe is concerned.

Now when calculating for the proxy for state participation in the energy sector as discussed in Subsection 4.2.1, the available data reveal that power plants cannot simply be categorised as either owned, controlled, or operated by the state or by private enterprises. There are power plants, particularly renewable power plants, that are owned by the *communities* where such power plants stand. Such community-based approaches can commence in a grassroot, bottom-up fashion, where such power plants are developed and managed by the members of communities in a participatory and collective manner. Moreover, one main result of the empirical analysis is that more state participation in terms of ownership or operation of power plants in the electricity sector slows down energy substitution towards a cleaner energy mix, implying advantages to reduced state ownership of power plants. A way to do this is to decentralise the electricity and the energy sector through more local and community-level ownership and management of power plants through CESs, and more specifically through renewable energy cooperatives. In fact, it is the nature of the available data and the aforementioned result of the empirical analysis is what led to the interest in doing an investigation on cooperatives to begin with. The next section then sheds light on how renewable energy cooperatives help in the substituting renewables for fossil fuels towards a cleaner energy mix.

Section 5.2. Qualitative results and discussion

This section outlines the most important general themes arising from the REScoop.eu online interviews as revealed by collating the codes generated, along with the results of the online survey in relation to the online interviews. Such codes were directly generated from the dataset constructed from the interviews itself. Some direct quotes from the interviewees are included in the discussions to substantiate and provide more details to the claims made. The alphanumeric identifiers used to group the interviews are in parentheses after the direct quotes to indicate their corresponding specific interviews of origin. The main themes are as follows. The *first theme* is the set of issues relating to politics, history, and geography. The *second theme* is social cohesion. The *third theme* is lack of efficiency. The *fourth theme* is democratisation and equity. The *fifth theme* is local acceptance of renewables. The *sixth theme* is the set of issues relating to the cooperative organisational form. The *seventh theme* is the set of issues relating to land use. The *eighth theme* is support mechanisms.

Subsection 5.2.1. Respondent characteristics

The interviewees were from four main types of organisations: (a) county- or municipal-level cooperatives, (b) national-level cooperatives, (c) cooperative federations and intermediary organisations, and (d) non-cooperative, non-REScoop.eu member organisations. The interviews were anonymised using alphanumeric identifiers based on the four main types of organisations included in the online interviews. The interviews were grouped together based on the type of organisation the interviewee is from and were each assigned Roman letters as identifiers. More specifically:

A – County/municipal-level cooperatives

B – National-level cooperatives

C – Cooperative federations/intermediary organisations

D – Non-REScoop.eu member organisations

Hence, all interviews from county- or municipal-level cooperatives were assigned the letter A, national-level cooperatives were assigned the letter B, and so on. Within each of these groups, the interviews were also assigned Hindu-Arabic numerals based on the chronological order the interviews were taken. For instance, the first interview to occur chronologically in the group composed of county- or municipal-level cooperatives was labelled A1, the second A2, and so on. The first interview to occur chronologically in the group composed of national-level cooperatives was labelled B1, the second B2, and so on. Table 5 provides more details on the participant organisations.

Participant code	Code type	Remarks
A1	County/municipal-level cooperative	Municipal-level cooperative in Italy
A2	County/municipal-level cooperative	Subcounty-level (barony) cooperative in Ireland
A3	County/municipal-level cooperative	A town-level mobility cooperative in the UK
A4	County/municipal-level cooperative	County-level cooperative in the UK
A5	County/municipal-level cooperative	Municipal-level cooperative in the Netherlands
B1	National-level cooperative	Located in Portugal
B2	National-level cooperative	Located in Luxembourg
B3	National-level cooperative	Located in Belgium
B4	National-level cooperative	Located in Spain
B5	National-level cooperative	Located in Germany
C1	Cooperative federation/intermediary organisation	REScoop.eu
C2	Cooperative federation/intermediary organisation	A cooperative federation and intermediary organisation in France
C3	Cooperative federation/intermediary organisation	An intermediary organisation in Switzerland
C4	Cooperative federation/intermediary organisation	A cooperative federation the Netherlands
D1	Non-REScoop.eu member organisation	A non-government organization
D2	Non-REScoop.eu member organisation	A policy-making body
D3	Non-REScoop.eu member organisation	A Europe-wide mobility cooperative federation
D4	Non-REScoop.eu member organisation	An intermediary organisation in the UK

Table 5. Interviewees. Source: Author

The average duration of the interviews was 39.7 minutes, and the median duration is 39 minutes. There were 18 interviews conducted in total: 5 interviewees each are from the county- or municipal-level and national-level cooperatives, and 4 each are from the cooperative federations/intermediary organisations and non-cooperative, non-REScoop.eu member organisations.

The online survey had a low response rate, only having 32 respondents despite allowing for multiple responses in Qualtrics. This limited the extent to which statistical analysis can be done. The respective results are then treated as qualitative data, indeed as complements to the online interview results. Figure 12 shows some information on the respondents. The bulk of the respondents are from Spain, i.e., 9 respondents. Most respondents, i.e., 26 respondents, are from individual cooperatives. Meanwhile 22 respondents are from regional- or national- level cooperatives. More information is in Figure 13. Most respondents, i.e., 25 respondents, are from cooperatives that produce solar energy. There are also those that come from cooperatives that produce wind, hydro, and bioenergy. Energy production and support services, e.g., consultancy or research and are the two most frequently cited

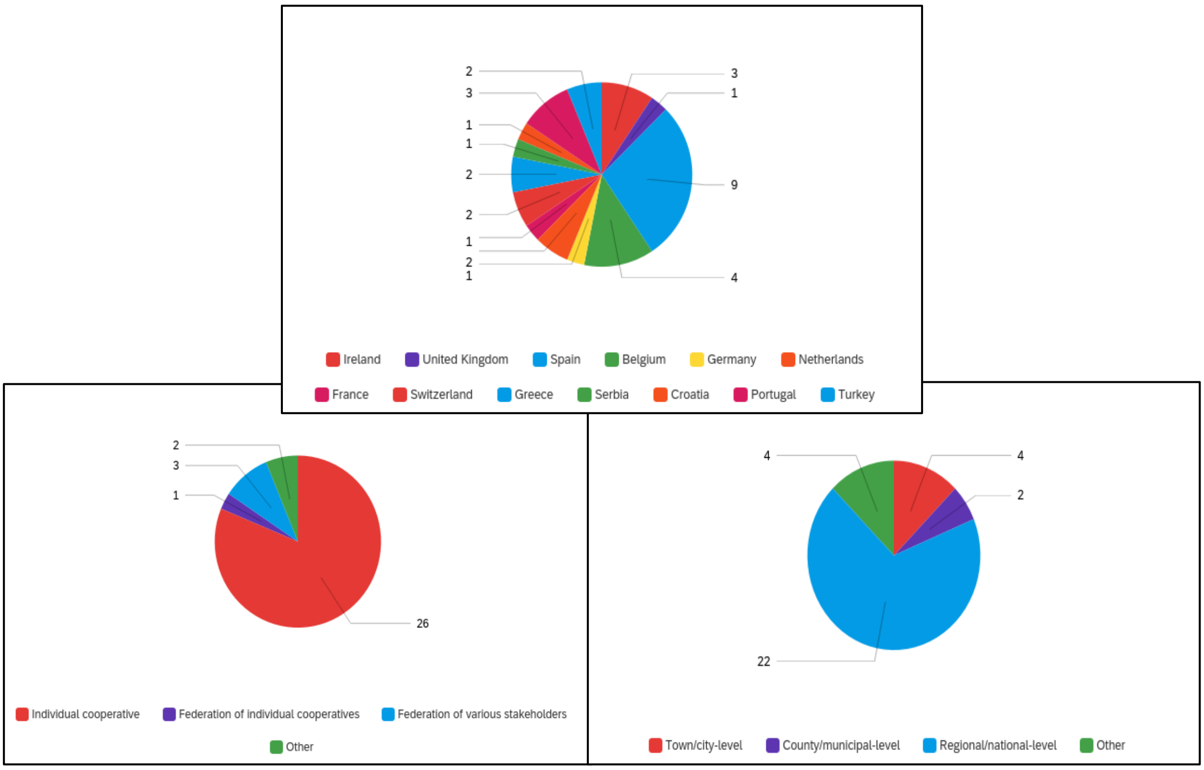

Figure 12. Selected information on respondents. Source: Author using Qualtrics.

activities of the cooperatives where respondents are from. Furthermore, 31 respondents come from cooperatives where members are individual citizens.

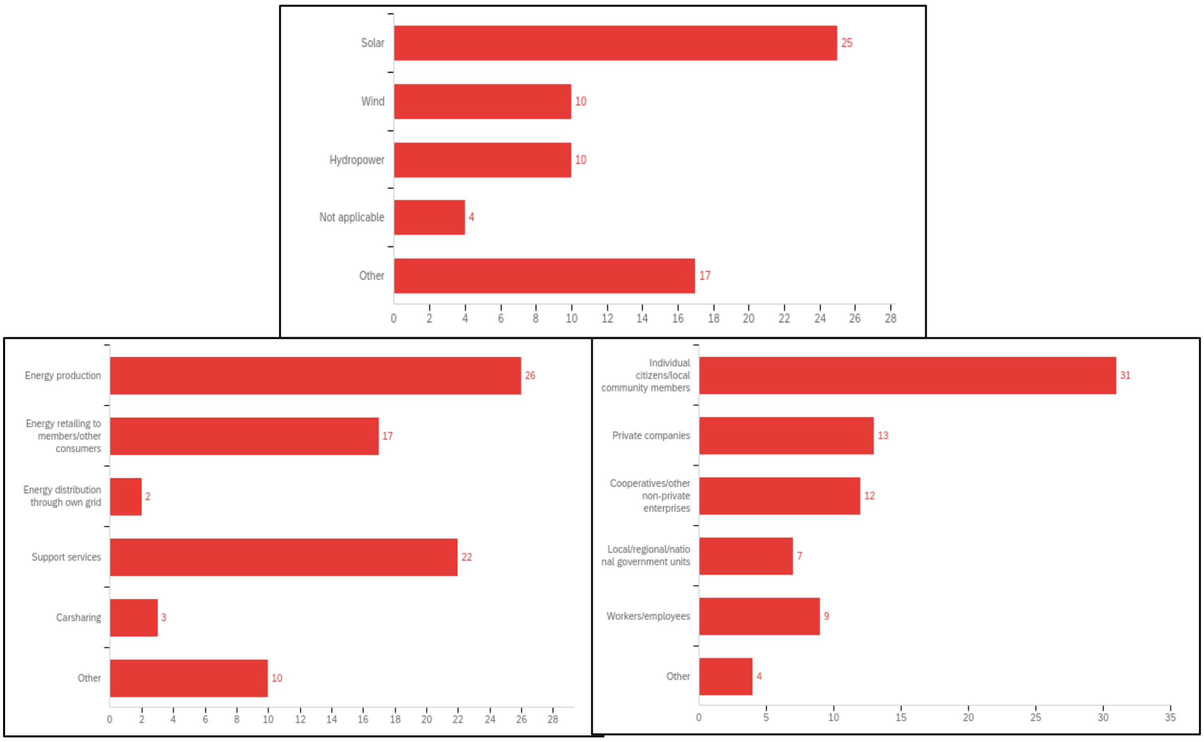

Figure 13. Selected information on respondents (cont.). Source: Author using Qualtrics.

Subsection 5.2.2. Theme 1: politics, history, and geography

The REScoop.eu interviews pointed to the prevailing politics in a country, along with history and geography, as factors that affect how renewable energy cooperatives influence renewable proliferation in Europe. These are the ones that make up the exogenous environment upon which the ability of renewable energy cooperatives to influence the proliferation of renewable energy in Europe is embedded, which is why it makes sense to start the discussion of the main themes here. These largely represent the social embeddedness level of social analysis in Williamson (2000) as discussed in Section 3.3. The following discussion provides more details. *First*, the level of politicisation of environmental issues matters, as political support for renewable energy cooperatives can be obtained from political parties or movements that advocate for renewable energy to address climate change. One interviewee points to a perceived *"political dissatisfaction that the energy transition is not going fast enough"* **(C4)**, which suggests the politicised nature of the issue. This blurs the lines between environmental and political motivations of joining cooperatives. Three quarters of the online survey respondents agreed with this claim with varying degrees of intensity in Question 20 in Appendix E.

Second, there is a mixed perception on renewable energy projects owned by the government, i.e., those owned by municipalities. There is a perception that the interests of the people can somehow be considered here, making them better than private companies, but this is much more indirect compared to cooperatives. The interests of the people are considered even less at higher administrative levels. As an interviewee puts it: *"And with government, with public service, you have this as the citizens…but it's much more indirect. It goes…really far away from your vote to the actual action being taken. So, it's also nearly non-existent. Perhaps on municipal level, yes. But everything which is above municipal level, it's very difficult to influence"* **(D3)**. In addition, municipalities are seen not to be democratic at all to begin with, and just represent the interest of a few individuals. One interviewee maintains that *"I think a municipal company is not really democratic thing. It's not because you have elections once every four years and that you have a few people who will represent the elected people in the municipal company that you can say that…the citizens* [are] *actually represented there"* **(C1)**. The survey respondents gave an almost unanimous support for the respective 6-level Likert scale statement in Question 22 in Appendix E, with only one respondent choosing to disagree. In connection with this, government owned companies are perceived to have the tendency to be driven by political interests that do not necessarily coincide with the interests of the people. Therefore, cooperatives owned by municipalities are seen not to represent the voice of the respective citizens and are vehicles to further the political interests of a few. This means that even for the more developed countries like in Europe, as per the levels of social analysis in Williamson (2000), the formal rules in the institutional environment may not work the way they are intended to be because of some problems in the social embeddedness level. The prevailing institutional environment therefore are only as good as the ethical and behavioural norms from which such institutions arise.

Third, there is also a perception that bigger market players influence the actions of the government regarding decarbonisation of energy. For instance, it has been pointed out in the interviews that politicians will tend to consider only their personal interests, not addressing the needs of the people, e.g., privatising government owned companies for profits, leading to monopolistic markets and lack of focus on green energy production. An interviewee states:

> *"After the liberalisation of the of the market, the energy market in Europe, a lot of these public companies were privatised. And so, you can't trust politicians, that they will keep the public companies public. You can't even trust them that they keep public companies because they make profits with it. So, take the example of Belgium, Flanders. So, our distribution system operators, they were fifty percent public, fifty percent the private monopolist. Liberalisation made the private monopolist to leave the distribution companies. But they could have been replaced by another private player. It was not. Europe didn't say to the countries that distribution system operators and the transmission system operators should be public. No, they didn't"* **(B3)**.

Moreover, renewable energy cooperatives lose customers to bigger market players, especially those that are subsidised by the government, as they can always offer lower prices.

Fourth, cooperatives can be used as political pieces. For instance, renewable energy cooperatives that allow communities to produce energy locally makes the respective countries less dependent on energy imports from countries that have political views that oppose their countries, e.g., Russia or Saudi Arabia. As per the SES framework, this is a case wherein the socio-politico-economic settings indeed created the desire to democratise the energy sector. *Fifth*, the incentives for the rise of cooperatives are seen to have been also influenced by the respective historical and geographical context. There are renewable energy cooperatives that came about amid energy crises like that in 1973. Some were started to oppose the use of some energy resources, e.g., some renewable energy cooperatives rose as a reaction against nuclear power following the Chernobyl disaster and against gas from fracking, as shown in Figure 14. In Belgium, some renewable energy cooperatives were formed in areas with difficult terrain, which for big private companies offer insufficient incentives to make profits off. The

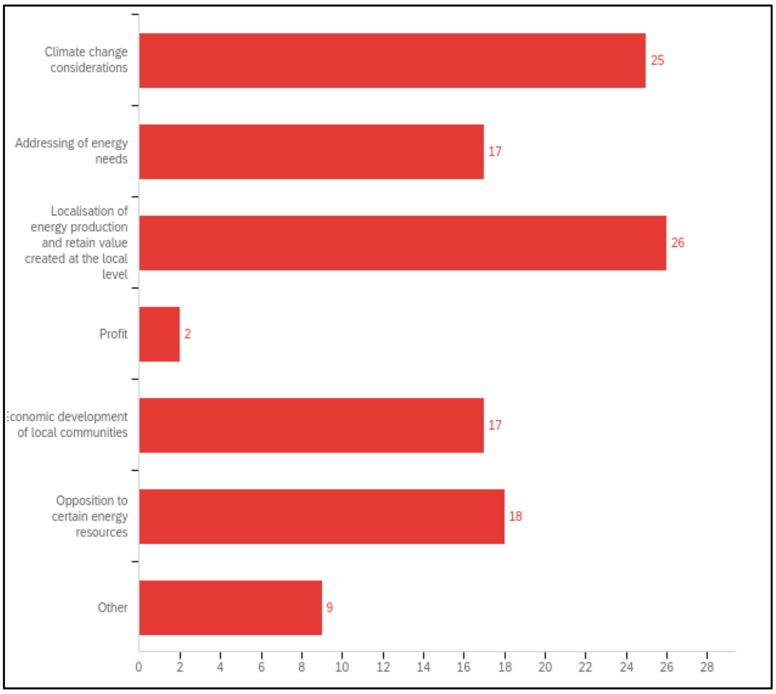

Figure 14. Reasons for starting the cooperative[27]. Source: Author using Qualtrics.

same applies to areas that have limited grid connectivity, like in islands in the case of the UK. Referring to the SES framework, this is a case where the related ecosystem indeed influenced the local production of renewable energy through cooperatives. *Last*, the historical context of a country could also have affected the current perception on cooperatives. For instance, in Portugal, the cooperatives' historical bad reputation contributed to a more positive view of cooperatives among the younger generations compared to the older ones, as the latter still remember cooperatives' historical bad reputation. Likewise, in Eastern Europe, the word "cooperative" is still easily associated with communism, hence the use of the term "energy community" is preferred.

Subsection 5.2.3. Theme 2: social cohesion

Within REScoop.eu, cooperatives are perceived to be good ways to build better relationships with communities where the renewable energy projects are located. As was discussed in the SES framework, this strengthens the relationship between cooperatives and the communities they operate in, which can help renewable energy cooperatives gain the property rights in using land for renewable energy production. Cooperatives are generally seen as more trustworthy than other business models in the interviews. In the survey, all 32 respondents save one agreed with this statement in Question 12 in Appendix E. One main reason for this is that cooperatives are not seen as distant, anonymous organisations that only profit from energy the respective contracts or investments, having little to no

[27]Survey question: **"**What have been the main reasons for the formation and development of your cooperative?" (Question 9 in Appendix E).

regard for the community. Other business models are seen to care less about the communities they operate in because earning profit is the priority. As shown in Figure 15, this was identified relatively

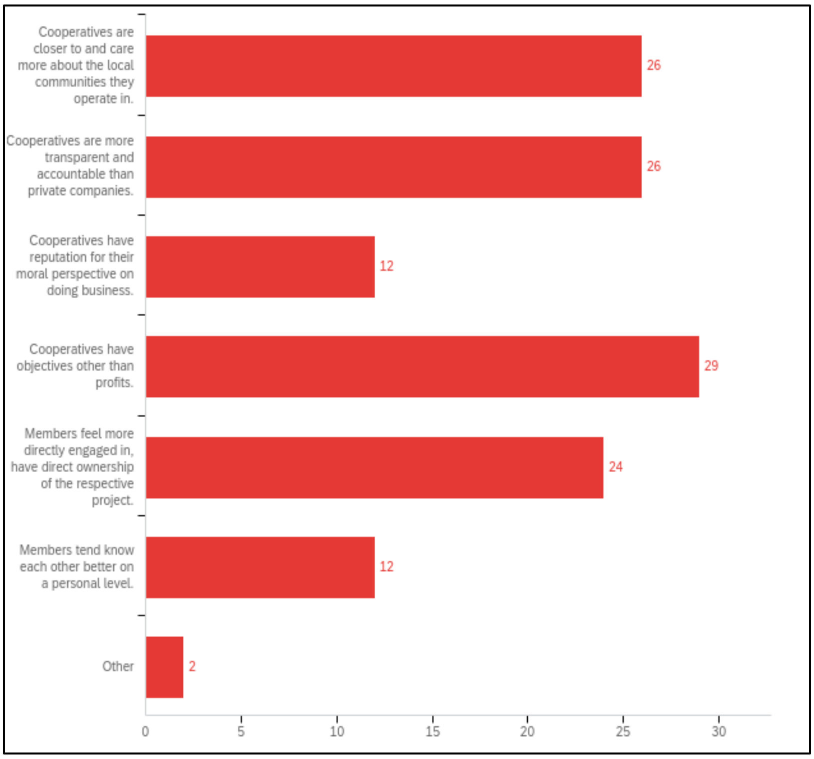

Figure 15. Why cooperatives are more trustworthy than private businesses[28]. Source: Author using Qualtrics.

frequently in the survey as a reason why cooperatives are deemed more trustworthy than private companies. It has been brought up in the interviews that the people willing to form a cooperative, in doing so, agree to be open, transparent, and accountable. Cooperatives are structurally participatory and democratic, allowing for open discussions, for public scrutiny especially from the communities where cooperatives operate in, and for decisions to be made collectively. Cooperatives have the reputation for their moral perspectives, one reason people tend to be more accepting of them. For example, one interviewee avers that *"people who choose Enercoop[29]…I think because they know how a cooperative work. They might have known it from other experience of cooperative, but they might know it because they are part of an energy cooperative. So, I would say it does have an influence for some people"* **(C2)**. Cooperatives are also perceived to be transparent on the nature of the energy produced, where one can be certain on whether its green energy than is being produced, to which also 26 of the 32 respondents concurred. There was a claim made in the interviews that large energy

[28]Survey question: "You agreed that cooperatives are more trustworthy than private companies. For what reasons are cooperatives more trustworthy?" (Question 13 in Appendix E)
[29]The only cooperative that supplies renewable energy in France.

companies tend to engage in greenwashing: the latter project the image of producing green energy, which has been noted to be at best dubious.

It was noted in the interviews that people in these communities also tend to know each other better on a personal level, enhancing the sense of belonging to the renewable energy project. Such personal acquaintance with people is likewise seen as the main basis of trust given to cooperatives, which 12 of the 32 survey respondents also claimed. Having a local focus, it is easier for cooperatives to reach out to and have better communication lines with the people involved, hence making it easier to address their specific needs. Cooperatives then are closer to people, hence have better grassroot knowledge to better address their needs. This grassroot knowledge also extends to the wider local economy, hence cooperatives are more equipped in dealing with it. Energy project developers outside the communities generally do not have this knowledge, which may lead to the failure of their communication lines with the community. Nonetheless, the specialised arrangements remarked in Section 2.5 that are based on better grassroot knowledge to specifically deal with transactions to reduce the associated transaction costs, more specifically the associated information costs, were never brought up in the REScoop.eu interviews. It may just be the case that the interviewees did not think of dealing with specific needs of the community members this way, but this still leaves no evidence that such transaction costs are reduced through specialised arrangements that by hypothesis rise because of higher likelihood of trust that is expected to facilitate a participatory and collective way of developing and managing an energy system and the presence of better grassroot knowledge, as described in the SES framework. In fact, 18 of the 32 survey respondents reported their cooperative experiencing difficulties dealing with their respective local communities (top-left panel in Figure 16). It is interesting to note that of the 14 respondents who did not report having such difficulties, 11 are from larger scale, regional- or national-level cooperatives. Regarding this, a Fisher's exact test was performed, which has a null hypothesis that experiencing difficulties dealing with local communities has no association with operational scale. Here, the degrees of intensity in agreement and disagreement were combined into one category each, resulting to two categories, i.e., "Agree" and "Disagree". The cooperatives' scales of operation were also reduced to only two categories, i.e., "Large", consisting of regional- and national-level cooperatives, and "Small", in which the rest of the scale categories were combined, due to the respective cell frequency is less than 5 (details in Appendix F). The Fisher's exact test gives a two-tailed p-value of 0.45, which indicates the lack of association. These may imply that specialised arrangements based on grassroot knowledge has little to do with how local the scale of a cooperative is, or that regional- or national-level cooperatives just have access to better resources to deal the specific needs of their respective local community, or both.

Cooperatives similarly are more likely to be trusted than other business models because people involved feel more directly engaged and have direct ownership. One interviewee says that *"[W]hen you take a share in a cooperative, you automatically feel ownership, and you feel like part of a community, engaged"* **(D2)**. Three quarters of the survey respondents have the same opinion. This is seen to encourage more people to support renewable energy cooperatives, hence one way cooperatives can be suitable in developing and managing renewable energy systems. Cooperatives give communities the opportunity to own a renewable energy project themselves, hence better represent and respond to the interests of the people there compared to other business models like private companies. The survey respondents unanimously agreed with this claim in the respective question in the survey (Question 14 in Appendix E). This is accomplished mainly through the local focus of cooperatives and their participatory and democratic nature. This is the case if they were set up by the communities themselves, operating in a bottom-up fashion in which people's opinions are reckoned. These imply reduced transaction costs. Cooperatives being more trustworthy than other business models means reduced policing and enforcement costs in relation to the respective transactions. According to the REScoop.eu interviews nonetheless, trust given to cooperatives depends on the people behind it, which themselves can also be driven by personal interests. As one interviewee puts it: *"[C]ooperatives, that's a group of people, and people can go wrong. Sometimes we see that people who set up cooperative[s], they try to protect the original idea of the founders. But then all these people come in, and…their idea is different from the founders…and so we tend to say to…our members…that we have a sort of golden standard"* **(B3)**. In addition, relationship with the community may not always be smooth, e.g., as cited by an interviewee, when there is animosity among the people and when the cooperative is not seen as being representative of the community.

Cooperatives then help build solidarity and social cohesion for people to come and work together to achieve a common goal, including renewable energy proliferation in the case of REScoop.eu. Cooperatives provide incentives for people to learn how to act as a group and make collective decisions to see the needs of the immediate community more clearly and engage in other activities that directly benefit it, something that is unlikely to happen in profit-driven business models. For example, one group of cooperatives in Belgium reinvested their earnings to refurbish an old bar. The people then have a completely new bar in their town, where they go for concerts and for all kinds of social activities. This ultimately can be extended for the society at large, like addressing people's energy needs and pull people out of energy poverty. One survey respondent indeed raised this as one key activity of their cooperative. Such social cohesion likewise facilitates people to build empathy towards each other and

Figure 16. Selected statements to which respondents agree or disagree[30]. Source: Author using Qualtrics.

help each other. This also help in creating networks of stakeholders, which can include private operators and local governments. Creating such networks can help address the lack of human capital to some degree, as is discussed in the next subsection.

[30]The following are the survey questions (all in Appendix E). **Top-left panel:** “Your cooperative has experienced difficulties dealing with the local community it operates in.” (Question 15); **top-right panel:** “Renewable energy cooperatives have difficulty securing enough of the professional and technical expertise necessary for their operations.” (Question 19); **middle-left panel:** “There are instances in which cooperatives can be seen as ‘private investors’ club’, where the shares are so expensive that only wealthy people can participate.” (Question 31); **middle-right panel:** “Private companies would have a difficult time adopting the principles of the International Cooperative Alliance in doing business.” (Question 23); **bottom-left panel:** “If cooperatives receive significant external funding, they become beholden to the institutions providing the funding.” (Question 25); **bottom-right panel:** “In your cooperative, the democratic decision-making process is valued more than efficiency.” (Question 18).

Subsection 5.2.4. Theme 3: lack of efficiency

The REScoop.eu interviews also reveal the lack of efficiency in cooperatives, in the sense that internal transaction costs pervade cooperatives. This is how the term "efficiency" is used in this subsection only. Whilst the sense of direct ownership seems to encourage more engagement in energy cooperatives, such perceived lack of efficiency also leads to cooperatives being perceived as less suitable in developing and managing energy systems at the community level than other business models. This is explained in detail in the next paragraphs.

Whilst a few renewable energy cooperatives have their own research and development capabilities, they generally have difficulty securing enough of the professional and technical expertise needed for their operations, especially the smaller ones. Responding to Question 13 in Appendix D, one interviewee states: *"No, it doesn't. It's quite challenging for community groups to do that because they don't have the professional expertise, they don't have perhaps an engineer and their employment or other skilled people who can help with all the technical details, the planning applications, environmental studies. All that sort of thing, so it's much more challenging for our local community to do this than for bigger organisations or for specialist developer or developer organisations"* **(A2)**. Another interviewee responding to the same question says: *"I don't think so, not more than the others…we need the knowledge, and the knowledge are with the private companies"* **(B1)**. Still another interviewee identifies this as a major difficulty, remarking that *"the cooperative buyers are not professional. So, people are citizens who are doing this after the job, and it can be difficult on the time to have the same members"* **(C3)**. Of the 32 survey respondents, 20 concur with this statement (Question 19 in Appendix E), as shown in Figure 16 (top-right panel). This even includes 13 of the 22 respondents from the larger scale, regional- and national-level cooperatives. The respective Fisher's exact test also indicates no evidence of association between lack of expertise and cooperative size (two-tailed p-value of 0.7), as detailed in Appendix F. In the table where the full Likert scales were tabulated, also in Appendix F, the respective two-tailed p-value is 0.63.

Thus, there is the perception of having difficulties with professional and technical expertise makes renewable energy cooperatives less suitable in developing and managing energy systems at the community level. Cooperatives often have the reputation of being unprofessional and not very well-organised, perceived to be less efficient than other business models in developing and managing renewable energy projects. Add to this the perception from the online survey that the cooperative organisational form is complicated for people to understand, as remarked in the online survey. This lack of human capital in cooperatives leads to higher transaction costs: the technical knowledge vital for their operations, especially in handling infrastructure and equipment, need to be outsourced. The respective transactions have their own risks and difficulties, like expensive energy project materials and the presence of maintenance costs therein. This is further exacerbated by cooperatives' lack of networks with the relevant industries.

Aside from these, there are other difficulties cooperatives have in relation to human capital, which include the lack of people engaged in full time work, quick personnel turnover, and being purely based on volunteer work. Volunteers then have jobs outside the cooperative for their living, which put time constraints on them, slowing down the progress of the cooperative. One interviewee notes that *"many people decide that they do not have enough time to participate in the yearly general assembly because it [is] just impossible for them to invest one whole day discussing topics…there is compromise of your time, time to the cooperative and family time, or time for our topics"* **(B4)**. One interviewee describes this as being *"time poor"* **(A3)**. This also makes it difficult to reach out people from lower income groups, in turn leading to cooperatives being less inclusive. One interviewee remarked: *"[I]f you worry if you can feed your kids at the end of the month, then starting up an energy cooperative in your free time, it's not on top of mind"* **(C4)**. The survey results support this claim from the interviews to some degree; of the 32 survey respondents, 21 agreed with this statement, though only 11 of these 21 agreed that this is indeed because activities within cooperatives leave less time to work for a living (Questions 32 and 33 in Appendix E). It has also been widely acknowledged in the REScoop.eu interviews that cooperatives are considered time-consuming, as people must devote time when involved, which decrease the time for personal matters. Most of the survey respondents gave support for this statement, with 18 of the 32 agreeing in the respective question (Question 17 in Appendix E).

The democratic decision-making process in cooperatives also contributes to this lack of efficiency, as it takes longer to make decisions and actions compared to other business models, also implying higher transaction costs in making decisions, i.e., higher bargaining costs internal to the cooperative. Cooperatives are expected to represent the perspectives of the members, which need to be incorporated in the terms of contract when transacting with external partners. One interviewee states that *"it needs a little bit more internal communication work, because, you are not alone to take decisions. You take it alone, but you have to defend it. You have to always think [that] it's not for you, but it's for our cooperators…if you are doing it for the cooperators, it's even more important…because you don't want that you do something in their name which is not in line with their personal convictions"* **(B2)**. Most survey respondents attested to this, with 20 of the 32 respondents agreeing with this claim in Question 16 in Appendix E. The latter are also expected to have their own perspectives; it has been noted in the interviews that it is indeed difficult to engage with external partners if they do not hold the same views as the ones represented by the cooperative. Both of which further contribute to the transaction costs associated with outsourcing, i.e., the bargaining costs of negotiations and costs associated with enforcing the resulting contracts. There is therefore a perceived trade-off between a participatory and democratic process integral to the cooperative organisational form on one hand, and efficiency on the other. However, REScoop.eu members seem to value the fact that communities can be more directly and actively involved, i.e., have more agency in transactions, hence the perception that a more democratic and participatory decision-making process, along with representing the concerns of the people, is deemed more important than efficiency. As one interviewee puts it: *"I wouldn't say it's more or less suitable…it's not a question of efficiency…I would say it's more about ethics"* **(C2)**. Not all survey respondents agree with this claim however, with as many as 11 of the 32 respondents disagreeing in the respective question, i.e., Question 18 in Appendix E. Nevertheless, 14 of the 20 respondents that agreed that cooperatives are slowed down by the democratic process also agreed in Question 18. This result shows the same trend as in the interviews; whilst the democratic process is viewed to hamper the cooperative's efficiency, it is valued more than the latter by most of the survey respondents. Hence here, the level of democratic control has developed as a social performance measure that can be used as a criterion in evaluating other outcomes as described in the SES framework.

Subsection 5.2.5. Theme 4: democratisation and equity

The REScoop.eu interviews and survey results indeed provide evidence for the perception that renewable energy cooperatives help in the proliferation of renewable energy in Europe through the democratisation of the energy sector. In the online survey, only one respondent disagreed with the statement that renewable energy cooperatives contribute to the economic development of the local communities they operate in (Question 26 in Appendix E). One important incentive for the existence of renewable energy cooperatives, as noted in the interviews, are the set of associated economic advantages, i.e., reduction of electricity prices and costs of related services. This was seen by the survey respondents as significant way cooperatives improve their respective local economies, as shown in Figure 17. Individual members can also benefit economically in terms of dividends earned that are distributed fairly. One added benefit from cooperatives, as raised in the online survey, were collective

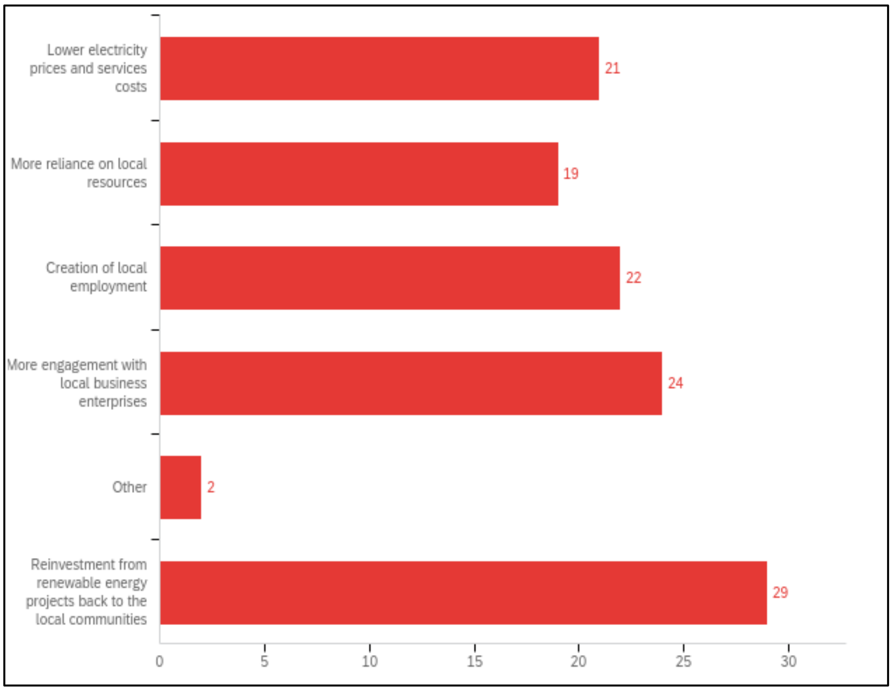

Figure 17. How cooperatives contribute to economic development[31]. Source: Author using Qualtrics.

installation purchases, noted as an important activity of cooperatives by some respondents. This essentially pools investment risks among the members, as the latter make investments collectively (Ollila, 2009). The survey respondents almost unanimously agreed with the claim that renewable energy cooperatives make the distribution of benefits from renewable energy exploitation more equitable (Question 28 in Appendix E), with only one respondent disagreeing with the statement. One survey respondent identified the promotion of women entrepreneurship as a reason for their cooperative's existence. There are however some related intricacies regarding equity in renewable energy cooperatives, as discussed in Subsection 5.2.7.

Building relationships with the community even becomes easier because of sharp rise in energy prices was brought up in one of the interviews. Once there is already an existing project, tangible results can be seen and directly benefit from, the economic incentives in forming or joining cooperatives are further enhanced. Moreover, as was previously remarked, cooperatives' reputation also matters: economic incentives for cooperatives are perceived to be bolstered when the cooperative already has a good track record, the latter incentivising cooperative membership. In addition, a good crowdfunding campaign to raise sufficient funds likewise helps. Also brought up was the notion of *"cooperative porosity"*, which was explained as *"things come in from community and things go out to community"*

[31]Survey question: "In what ways can then renewable energy cooperatives contribute to the economic development of the local communities they operate in?" (Question 27 in Appendix E).

(A4), or in other words, there are reciprocal returns that move between the cooperative and the community. Therefore, there is indeed evidence that, in the context of the SES framework, cooperatives having a more local extent and having a more collective accrual can solve common pool resource problem associated with renewable energy production, one result of a good relationship between them and their communities.

Renewable energy cooperatives democratise the energy sector mainly by stimulating the local economy and localising energy production. An interviewee mentions that one main driver for the rise of renewable energy cooperatives is that people *"just want to have a sustainable income for local development"* **(D4)**. The direct ownership mentioned in Subsection 5.2.3 gives the people some degree of influence on how the respective energy project is developed and managed, along with making them directly benefit from it. In the first place, localising energy production reduces the associated transmission costs, as electricity needs to be transmitted over shorter distances. It was also brought up in the interviews that when local communities having access to their own energy through cooperatives, the returns to their own investment can stay with the community, e.g., if wind turbines in rural areas belong to the people living there instead of to big private energy companies. This is seen to lead to the economic development of such areas. This can be achieved by reinvesting such returns in other projects that directly help the community. This was identified in the survey as a way cooperatives can contribute to the economic development of their local economies most frequently, as seen in Figure 16. This is expected to create or boost a local supply chain, which in turn emphasise the use local resources for the local energy project, generate local employment (though may not always be permanent), and engage in business more with local enterprises. One interviewee narrates: *"If we need electrical person, we don't go to France, or to Poland…and often…some cooperatives have also some people of the electric parts are coming in the cooperatives"* [sic] **(C3)**. Generation of local employment and more engagement with local enterprises were also identified in the survey relatively frequently as seen in Figure 17, and further magnified by renewable energy cooperatives reducing electricity costs in the local community. Through the cooperatives' participatory and democratic nature, the people involved can collectively decide on what prices to pay, leading to cheaper electricity. Regarding this, the profitability of the energy project is still a major consideration, as the existence of cooperatives are incentivised by profit gains as previously discussed. Cooperatives then are seen as a "middle ground" between democratic and entrepreneurial governance. The value created is then retained at the local level, to which one interviewee referred to as *"energy democracy"* **(B3)**. As can be seen in Figure 14, the desire to localise energy production and retain value created at the local level was identified in the survey most frequently as one main reason for the formation and development of REScoop.eu cooperatives. It was also explicitly mentioned by some survey respondents that one reason for their cooperative's existence was to gain energy independence from big energy firms as mentioned in Koirala et al (2018), along with getting around oligopolistic markets as raised in Huybrechts and Mertens (2014). Figure 14 also shows that profit was identified the least by the respondents as one of their cooperatives' raisons d'être. The energy transition to address climate change is seen to only succeed if it leads to such energy democracy, wherein the benefits from the energy project *"stay as local as possible"* **(B3)**, such that there is connection *"between the goals of energy transition and the local community"* **(A5)**. As a sidenote, it was likewise remarked in the survey that there is a trade-off between growth and maintaining a local scale. Lastly, it was raised in the online survey that giving lower administrative governance levels like regional governments more important roles in relation to cooperatives would also assist in the development of renewable energy projects.

Renewable energy cooperatives nonetheless are not currently seen to provide total localisation of energy production; grid connection is still necessary for stable energy supply. Better grid connectivity makes such energy production localisation less of an issue. Here however, grid saturation can be a problem, along with severe backlogs in installing new capacity in the infrastructure, the latter being insufficient to support local renewable energy initiatives, and technical difficulties associated with connectivity. One survey respondent also raised economies of scale concerning grid connection costs as a problem. Grid saturation was indeed identified in the survey as a problem that hounds grid connectivity (identified by 13 of the 32 respondents). The most pressing concern however was the set of regulations and the infrastructure setup that makes self-consumption more difficult (identified by 22 of the 32 respondents). More specifically, it is more difficult for communities to provide themselves with the electricity they themselves generate, as it is less costly to transmit electricity generated back to the grid directly and sell such electricity through the grid. In Turkey, as brought up in the survey, cooperatives are required by law to sell electricity to members only through the grid. Also brought up in the survey is that in Spain, grid distribution is monopolised. As one interviewee explained, *"that's partly because of, in the UK anyway…of how the regulations and the infrastructure is set up that it's hard for communities to…provide themselves with the electricity they generate. It's easier for them to transmit that, to sell that back to the grid directly"* **(D4)**. It must be noted here however that not all survey respondents agreed that grid connection indeed lingers as a problem for renewable energy cooperatives in Question 36 in Appendix E; only 25 of the 32 respondents did. One of those that disagreed noted that their cooperative has a virtual power plant run through a system that models prices, energy flows, and weather conditions, which solves grid problems[32].

Additionally, the REScoop.eu interviews do show that renewable energy cooperatives also arise because of environmental concerns, i.e., addressing climate change through substituting renewables for fossil fuels. People form or join cooperatives because of the legitimate desire for an energy substitution away from fossil fuels to address climate change, as shown in Figure 13. People participate in cooperatives also because of the desire to contribute to and be an actor in it, and not just because of dissatisfaction with energy markets; in fact, when asked the related question (Question 5 in Appendix D), the interviewees generally answered negatively; renewable energy cooperatives are perceived to provide opportunities to invest resources to address climate change in a more equitable and inclusive way, even at the personal level (e.g., promoting ecofeminism was cited by a respondent as a rationale for their cooperative in the survey). As was already remarked, people involved are more willing to participate in addressing climate change because they feel that they are doing something tangible about climate change, that their perspectives are represented in climate change action mainly because they have ownership of the project, where people involved are said to feel more personally connected to and directly involved in the energy project and to the overall energy substitution. This claim from the interviews was unanimously agreed upon by the survey respondents in Question 30 in Appendix E. Renewable energy cooperatives then are seen as being able to engage people in the energy substitution required to address climate change and help in the proliferation of renewable energy in Europe by making distribution of the associated benefits more equitable. Here, the expected outcome of equity as described in the SES framework indeed was perceived to have been achieved. The associated complexities here are discussed in Subsection 5.2.7.

Subsection 5.2.6. Theme 5: local acceptance of renewables

Renewable energy cooperatives are seen to influence renewable energy proliferation mainly positively in Europe through improving the local acceptance of renewables. An interviewee states that *"It's that energy cooperatives… it eases local acceptance of…renewable energy. I mean, it…eases the way for developing…renewable energies in general."* **(C2)** Another interviewee mentions that *"energy communities present a very important characteristic. So, they increase the local acceptance of renewables. So, for this reason, they have the potential to further enhance the deployment of renewables in EU…"* **(D1)**. Almost all the survey respondents agreed with this, with only two choosing to disagree in Question 34 in Appendix E. As mentioned in Subsections 5.2.3 and 5.2.5, the local

[32]https://www.nweurope.eu/projects/project-search/cvpp-community-based-virtual-power-plant/ Accessed 2 August 2022.

communities themselves own the renewable energy projects and are engaged in the latter's development and management. The local community then benefits directly from the renewable energy projects installed in its location, where people benefit from their own investment through directly netting consumption from own production. Such direct benefits for the community make local acceptance of renewable energy more likely to happen compared to other business models. Because the local people directly benefit, they are incentivised to invest on such projects. The 30 respondents who agreed in Question 34 in Appendix E unanimously agree with this claim from the interviews (Question 35 in Appendix E). Therefore, there are incentives for a land use property rights regime in favour of renewable energy production that address transaction costs associated with land use. More details on this are given in the next subsection. In addition, the community members are more encouraged to address the larger climate change issues because they have the perception that they can do something directly and personally about it, that their perspectives are represented in climate change action. In REScoop.eu, people involved in cooperatives get a sense of pride and empowerment that they are directly and personally participating in the energy substitution to address climate change, seeing themselves as doing something concrete about climate change. Because renewable energy cooperatives increase the local acceptance of renewables, they do help in enhancing the deployment of renewables in Europe.

Direct benefits from and involvement in renewable energy projects of the local people seem are the reasons why cooperatives improve renewables local acceptance of renewables. Here, local communities indeed can take advantage of renewables as the best energy resources to be harnessed using community-based approaches, as an outcome described in the SES framework. It noteworthy that direct local benefits and involvement are more relevant than the higher likelihood of trust and better grassroot information when it comes to addressing transaction costs, as direct local benefits and involvement themselves incentivise a land use property rights regime in favour of renewable energy production.

Subsection 5.2.7. Theme 6: the cooperative organisational form

The discussions in Subsection 5.2.5 show that the interviews and survey results suggest that within REScoop.eu, there is a perception that renewable energy cooperatives help in renewable energy proliferation in Europe by democratising the energy sector and making the distribution of the associated benefits more equitable. More specifically, this happens through localising energy production and stimulating the local economy. However, there are nuances as far as the degree to which the cooperative organisational form is necessary when it comes to achieving these goals. In the first place, there is a perception is that what defines an organisation as a cooperative is the way it does business, not the legal form. One interviewee states that a cooperative is a group of citizens who set up a legal form to organise or to structure activities around doing something beneficial for the society where earning profits is not prioritised. As this interviewee states,

> *"But what truly makes you a cooperative is the way you do business, regardless of the legal form. You can be a limited company and still work according to your cooperative principles. And so, for us, the way you do business is represented in…what we call ICA principles. So, it's the seven principles that make a cooperative a real cooperative. And that includes open and voluntary membership. That means the independent character of the cooperatives…that we maintain or autonomy, somehow that there's democratic governance. So, the one person, one vote principle, those are the typical kind of principles that make a cooperative a real cooperative, regardless of the legal form that you have"* **(C1)**

There are countries where the legal form of a cooperative does not even exist. For example, Denmark technically does not technically have the cooperative as a legal form. The country has the "non-profit association" as a legal form, which works exactly as a cooperative. Also, an interviewee brought up that smaller private companies would also want fairer distribution and would want to distribute profits. This is because it is the only way for them to make projects, hence share projects with renewable energy cooperatives. Private companies are themselves members of cooperatives, as depicted in Figure 13. Small and medium enterprises, or SMEs, on numerous occasions in the interviews were identified to have crucial roles in the proliferation of renewable energy in Europe. There were two respondents who are from a cooperative that has SMEs as members, and giving the latter, along with citizens and other social entities, opportunities to participate in the energy sector and the renewable energy transition was also one of the reasons cited in the survey for starting the cooperative they are from. In the survey however, three quarters of the respondents agreed with the statement that private companies would have a difficult time adopting the aforementioned ICA principles in doing business (Question 23 in Appendix E). When asked which of the ICA principles private companies would have a difficult time adopting (Question 24 in Appendix E), the survey respondents identified democratic control and equitable economic participation most frequently (identified by 22 and 19 of the 32 respondents, respectively). In relation to this, one respondent raised that because of its organisational form and the way it works, cooperatives are considered as "outsiders", i.e., that cooperatives are still not mainstream actors as far as renewable proliferation in Europe is concerned.

In addition, it was noted in the REScoop.eu interviews that cooperatives can create and fully own other organisational forms like foundations and limited liability companies to make generating funds easier and for spreading risk. In fact, it was remarked in one interview that non-cooperative business models can work with renewable energy cooperatives to resolve land use issues, bringing them closer to the communities to work with them as well, as the former are perceived to have a harder time gaining the trust of the community. Lastly, cooperatives are seen to bring about a *"social economy"* where profits are not prioritised, *"not in the usual way that companies have investors, and these investors want…in the end want to earn money to make bigger the investments"* **(B4)**. Cooperatives not prioritising profits was identified in the survey as one reason why cooperatives are considered more trustworthy than private companies most frequently, as shown in Figure 15. This shows that in the interviews, the cooperative organisational form in and of itself is viewed as less important in renewable energy proliferation in Europe than the economic and social incentives provided by the cooperative. Moreover, the cooperative organisational form is itself not perceived as a factor that drives the democratisation of the energy sector and making the distribution of the associated benefits more equitable. One interviewee even goes on to say that the cooperative organisational form is a result of the desire to achieve this democratisation: *"I think the form is more a result of that need... it's not a driver, but it's a result. So, you want to organise with your community, you want to be autonomous. You want to be democratic. And then if you feel those like seven cooperative principles, if you put that into an organisational form, then you end up with the cooperative form"* **(C4)**. In SES framework, this can be seen as the socio-politico-economic settings influencing the most immediate governance system. This to a degree verifies the survey result earlier presented in Figure 14, i.e., that one main reason for their cooperative's existence was energy production localisation.

It was also brought up in the interviews that there are cooperatives in legal form that are undemocratic and non-inclusive, like those set up by private and government-owned companies that only allows for limited participation. It has been claimed that such cooperatives were meant to hinder the cooperative movement and has no real desire to share benefits equitably. Cooperatives have also been seen as "private investors' clubs", where the shares are expensive and hence only relatively wealthy people can participate, limiting cooperative activity in relatively wealthy communities. It is noteworthy that most survey respondents disagreed with this statement in the respective question (Question 31 in Appendix E), i.e., 17 of the 32 respondents. Of these disagreeing 17 respondents, 10 agreed in Question 23 in Appendix E described earlier (see Item 3 in Appendix F for the tabulation). Both can be seen in Figure 16 (two middle panels). A respective Fisher's exact test was performed to see if there is an association between seeing that private companies will have a difficult time adopting the ICA principles on one hand (Question 23) and not seeing cooperatives as private business clubs (Question 31) on the other, where again, the degrees of intensity in agreement and disagreement were combined two categories. The Fisher's exact test gives a two-tailed p-value of 0.04, implying a statistically significant association. The Spearman's rho and Kendall's tau-b coefficients are 0.4 and 0.4, respectively (also in Appendix F), having p-values of 0.02 and 0.02, respectively. This may imply that respondents generally hold cooperatives to high standards, that truly complying to cooperative principles is generally difficult to achieve. Of note here is that in the same table where the complete scales were tabulated, the Fisher's exact test gives a two-tailed p-value of 0.72. To reiterate, this is important as both Questions 23 and 31 probe how important really the cooperative organisational form with respect to renewable proliferation in Europe is. It is also worth mentioning that one online survey respondent pointed out that there can be companies that just identifies as a cooperative, but without the characteristics that makes the latter trustworthy. The online interviews and survey therefore provide mixed results as far as inclusivity in cooperatives is concerned.

It could be argued that whilst cooperatives are viewed quite distinctively from other organisations in the REScoop.eu interviews, there seems to be a lack of attribution of this perceived uniqueness of cooperatives to the legal form. It seems that whilst advantages to cooperatives were brought up in the interviews, even those that are directly related to renewable proliferation in Europe, the interviewees do not seem to view these advantages as being generated by the legal form. At least judging from the responses of the interviewees, there seems to be a disconnect between the perceived beneficial characteristics of cooperatives and the legal form itself. In the SES framework therefore, the advantages to the specific form of the most immediate governance system are not seen as consequential as to how the renewable energy system is developed and managed. There seems to be therefore a puzzle in these interviews, in that the perceived uniqueness of cooperatives in the interviews contrasts with what was said about the legal form, at least in the context of REScoop.eu.

Subsection 5.2.8. Theme 7: land use

The cooperative legal form seems to be seen as of minor importance when addressing land use issues. To begin with, the main points brought up in the interviews against renewables were their negative impacts on the landscape, conflicts with agricultural land use, and biodiversity issues. The last one seems to be the one where renewable energy cooperatives are having the most trouble with, getting into conflicts with environmental groups more than other issues. Dealing with such land use issues are enshrined in countries' spatial planning regime and procedures, something to which the REScoop.eu interviewees largely alluded to. Thus, to participants from REScoop.eu cooperatives, addressing land use issues depends on what has been specified in the law more than on the legal form of cooperatives.

On obtaining land use rights, one interviewee even remarked that *"I never thought in that question to be honest. We never faced that problem"* **(B1)**.

According to the interviews, the land use planning regime largely determines the property rights in using land. Given this, the land use planning regime must consider the interests of the local and regional communities to mitigate the rise of conflicts. As mentioned by one interviewee: *"The problem starts when this kind of spatial planning does not take into account, during the planning, the voice of local and regional communities. So, in the absence of their participation and designing an adequate…framework, landscape on where or where not to put…renewables, would create conflicts"* **(D1)**. Land use issues also seems to be solved by prevailing technology and good land use designs and practices, e.g., agrivoltaics (say by putting solar PVs over crops that have are less tolerant of heat to shield them sunlight), installing solar PVs on roofs instead of on the agriculturally active pieces of land, or permaculture practices. With such technologies and land use practices, land use property rights need not be adjusted when land use conflicts arise. It must nonetheless be noted that without the necessary professional and technical expertise to adopt such technologies and practices, higher transaction costs may be incurred. In REScoop.eu, there is a claim made by one interviewee that *"working in a cooperative mind frame can actually increase the potential yield of any area of land if it can be used more creatively and not one piece of land for one project for profit"* **(A3)**.

The respective survey provides nuances. As seen in Figure 18, the online survey the land use planning regime, technological advancements, and land use designs and practices were not the most frequently identified ways to address land issues. Improving the local acceptance of renewables was the most frequently identified, i.e., by 20 of the 32 respondents, which is nonetheless consistent with the interviews. All these 20 respondents agreed with the related statement in Question 34 in Appendix E. As renewable energy cooperatives make renewables more locally acceptable, the land use property rights regime should be expected to be more in favour of renewable energy projects, the latter being allowed to operate by the communities in the respective locations, like in a particular case in the Netherlands where there is a perceived fierce competition over land ownership as raised by an interviewee. One corresponding implication is that the value of the related infrastructure and equipment in that specific location then become realised, which would have been significantly less valuable elsewhere because their high asset specificity. This should reduce the transaction costs related to land use for renewable energy production.

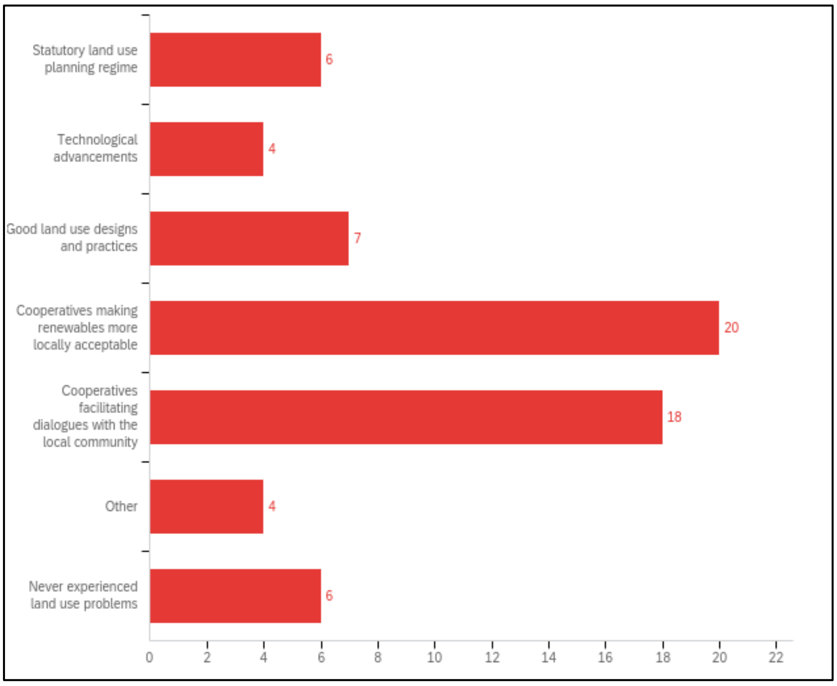

Figure 18. Addressing land use issues[33]. Source: Author using Qualtrics.

Furthermore, cooperatives help address land use issues by building social cohesion that facilitates dialogues with the local community through having better relationships with it to bring its interests to the forefront of the spatial planning regime. This was the second most frequently identified way cooperatives help deal with land use issues in Question 10. Such dialogues can lead to the creation of a land use property rights regime in favour of renewable energy production, or to adjustments in the property rights as defined by the existing spatial planning regime. This can happen if citizens are involved in public consultations, which is not always the case. Take note further that such dialogues incur additional transactions costs, particularly bargaining costs during the dialogues. These transaction costs can be mitigated by cooperatives being more trustworthy than other business models, and by the former having more direct communication lines with the communities than the latter. As mentioned in the previous subsection, other business models can work with cooperatives for them to reach to communities better to resolve such land use issues. It was further noted that the community can even gain the technical expertise in developing and managing renewable energy projects from these partnerships for free, which lessen transaction costs associated with outsourcing such expertise, and make renewable energy cooperatives more efficient in managing and developing renewable energy systems. Since cooperatives are seen as grassroot, local initiatives, they are

[33]Survey question: “How are land use issues (such as conflict between renewable energy production and agricultural production, enjoyment of the landscape, biodiversity) in areas where your cooperative has its renewable energy infrastructure primarily addressed?” (Question 10 in Appendix E)

expected to assist bringing up dialogues at the grassroots regarding the renewable energy installations through their participatory and democratic nature. This also makes the people involved to feel more attached to the cooperative and to its respective renewable energy projects.

More local acceptance of renewables and facilitation of dialogues by cooperatives are viewed as advantages to cooperatives in relation to renewable energy proliferation in Europe. However, as was raised in Subsection 5.2.7, these are not seen as derivatives of the respective legal form. This corroborates the claim made in Subsection 5.2.7, i.e., that in the context of REScoop.eu, the perceived beneficial characteristics of cooperatives has nothing to do with the legal form itself; the perceived distinctiveness of cooperatives contrasts with claims made on the legal form. In the case of land issues therefore, the specific form of the most immediate governance system is also perceived as inconsequential as to how the renewable energy system is developed and managed.

Subsection 5.2.9. Theme 8: support mechanisms

Finally, the REScoop.eu interviews show that there is a perception that renewable energy cooperatives still have quite small impact in renewable energy proliferation in Europe, and given this, it has been consistently brought up in the interviews that adequate legal and policy frameworks are crucial for enabling renewable energy cooperatives to be successful in aiding the renewable energy proliferation in Europe, aiding renewable energy cooperatives to be suitable to develop and manage renewable energy systems at the community level, democratise the energy sector, and make distribution of benefits more equitable. One interviewee asserts that *"in the absence of the state, for instance, to have the adequate policies in order to move ahead with this problem that is getting bigger and bigger so energy communities can actually cover those kind[s] of needs and demands"* **(D1)**. There are cases wherein renewable energy cooperatives rose directly because of supportive policy measures, like subsidies and feed-in tariffs, hence seen as respective major instigators. This was indeed mentioned in the online survey as another reason for the formation and development of cooperatives, the latter being a legal entity that makes the respective community eligible for subsidies from the European level of governance. This nonetheless is the case only given that renewable energy cooperatives are started by people who deem environmental issues of prime importance, where the supportive legal and policy frameworks are seen to give the opportunity to engage in climate action through setting up renewable energy cooperatives.

In the first place, the interviews allude to the necessity of adopting the European Renewable Energy Directive Recast, or RED II, by all Member States, for which the adequate legal and policy frameworks are necessary. Only 10 of the 32 survey respondents perceived their country to have largely adopted RED II, with varying degrees of extent. It must be noted that 11 of the 32 respondents did not know whether this has happened in their country. Given this, the next challenge is to make sure that these Member States adopts these the respective provisions in a way that are aligned with the actual intent of such provisions as envisioned by its drafters. Then, the Member States create the enabling legal and policy frameworks at the national level that allows cooperatives to compete on equal grounds with bigger players. One policy recommendation is what is termed as cooperative "bike lane", wherein protection is given to cooperatives when competing with bigger market players. Here, there are specific rules and measures put in place to allow cooperatives to compete with bigger players according to their principles. This was indeed seen in the survey as important, being identified by half of the survey respondents as shown in Figure 19, and was even directly pointed out by one respondent. It was however noted that given enough scale, cooperatives can exert competitive pressures against larger players. One interviewee explains this in the following way:

> *"I think at a European level this I mean the definitions as they stand or quite good and quite supportive. The next challenge for us will be making sure that…all different Member States transpose these definitions in a way that they are still aligned with what the European decision-makers had in mind. [T]hen as a second step, it's important that every Member State makes a favourable legislative framework at the national level that allows these energy communities to compete on equal grounds with big utilities. So, they have to design what we call a 'bike lane'. They have to make a bike lane just like we have with specific rules or with specific measures that they can put in place to allow them to compete on equal grounds. It's one of the things that…we don't want them to push energy communities on the 'main roads'. We want a separate bike lane for energy communities that allows them to work according to their principles and that allows them to do projects and we're not against the big utilities, not at all. I think if we want to make the energy transition succeed, we will need all forces and we will need all actors at all different levels. So, we also need the big roads, don't get me wrong. I think we need to big road too, but I think it's hard to push community energy projects onto the big road, we need a specific bike lane with specific rules that allow us to do those projects that we think are important and needed and what we need to put in place to achieve that is favourable legislative framework at the national level, that allows these communities to compete on equal grounds, and that can mean a whole lot of things, and it really depends on the local context"* **(C1)**.

Regarding this, the REScoop.eu interviews also pointed out that these legal and policy frameworks must consider the interests of the local and regional communities; otherwise, conflicts indeed will arise, as was explained in the last section in the case of land use issues. Other perceived necessary policy measures include setting energy production targets at the hands of local actors and the facilitation of power supply sharing among members or customers. The latter was the one identified by the survey respondents most frequently as Figure 18 shows. In relation to this, respondents in the survey voiced out that a more efficient bureaucracy is necessary to facilitate the development of renewable energy projects, where red tape is eliminated to make the participation of smaller actors easier.

Generating funds for projects is a major difficulty for cooperatives cited in the REScoop.eu interviews, hence policy measures on financing were deemed significant, e.g., grant programmes for cooperatives, the aforementioned subsidies, and having a one-stop shop where cooperatives can reach out to in cases where they need support and financing to get projects off the ground. The communities where the cooperatives operate are likewise seen to benefit from such financing provided. Regarding this however, it was noted that cooperatives may not be the best choice for an organisational form in the presence of external funding, say via external investors. This is because investors provide funding to

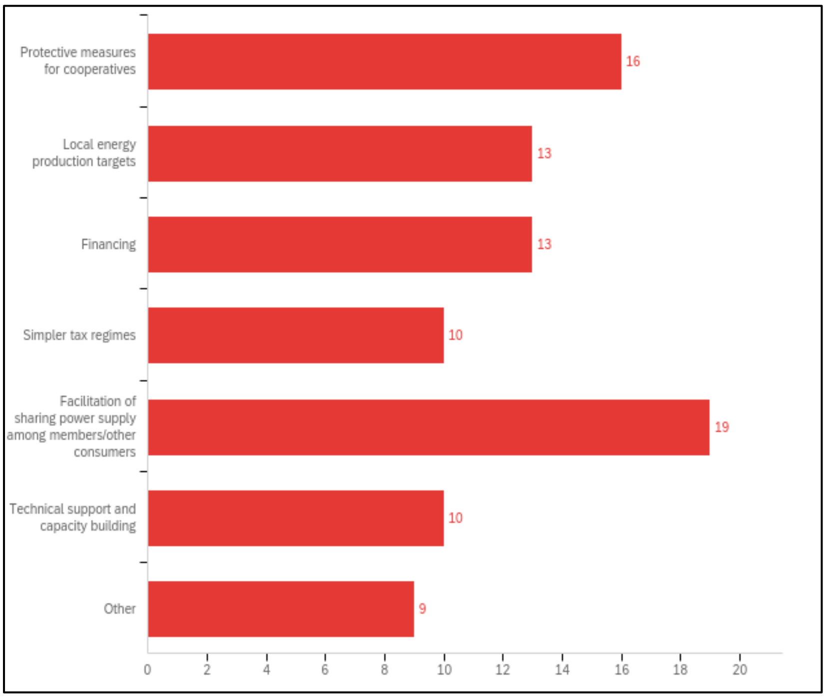

Figure 19. Necessary legislation on renewable energy cooperatives [34]. Source: Author using Qualtrics.

earn profits back, and investors providing large sums of money in a project would not want to share equal bargaining power in the decision-making process. As explained by an interviewee: *"In case*

[34]Survey question: "In the country where your cooperative operates, what legislation on renewable energy cooperatives would assist the development of renewable energy projects?" (Question 11 in Appendix E).

external funding is made available, a cooperative may not be the ideal model. So, other company framework can be used because clearly the investors want to get its money back, with a profit margin" **(A1)**. Here, 21 of the 32 respondents agreed with the corresponding claim in Question 25 in Appendix D (bottom-left panel in Figure 16). Here, a chi-square test was performed to see if there is an association between this claim specified in Question 25 and the tendency to value democratic decision-making more than profits (Question 18 in Appendix E, bottom-right panel in Figure 16). The chi-square test gives a p-value of 0.08 (shown in Appendix F), weak evidence of association. A noteworthy result is that the chi-square test however gives a p-value of 0.14 in tabulations that involved the full scales. The Spearman's rho and the Kendall's tau-b coefficients, 0.43 and 0.38 respectively, with p-values of 0.01 and 0.01 respectively. Profit-driven motives then impede the democratic structure of cooperatives. Renewable energy cooperatives also help in renewable energy proliferation by disseminating related information, raising awareness in public consciousness, and launching campaigns. There were survey respondents who raised that cooperatives are still not well-known ways to address climate change, energy prices, and energy dependence.

These occurrences, along with the social cohesion and solidarity cooperatives help build is seen as *"outweigh[ing] at the moment the actual level of renewable capacity"* **(A4)**. All these contribute to what one interviewee referred to as the *"sensibilisation"* of the general public **(B5)**. In connection with this, technical support and capacity building is necessary for local community citizens, where they are educated and guided when forming their own energy cooperatives. People involved in cooperatives learn more how the latter work to begin with, as they are transparent, which contribute further to the trustworthiness of cooperatives. This goes in full circle, as cooperatives likewise tend to trust its members more than external investors if any, as the former are more involved in the decision-making process, hence has a more open and transparent relationship with them. On deciding the rules in using the services in carsharing cooperatives, one interviewee narrates: *"The cooperative trusts more its users…we made the voting, and everybody contribute these ideas. So, the sanctions are somehow agreed upon from the members and that's a completely different way of doing things. And we see it also translated to accidents and damages on the car. The people take much more care of these cooperative in cars, whereas a normal carsharing has a very bad reputation for damages and things like this"* **(D3)**.

It has also been pointed out that information dissemination being received well by the people requires trust from such people. This is grounded on having good communication lines with the stakeholders and other people involved and considering their perspective in respective energy projects. Also, research should be conducted to further enhance knowledge and raise awareness to better explain what is needed in the necessary legal and policy frameworks and communicate such to the relevant policymakers. Cooperatives are also seen to raise this respective awareness by themselves engaging in lobbying, legal battles, and political discourse. Engaging in political activities was even remarked by survey respondents as one of the reasons for starting their respective cooperative and as its focal activity. Cooperatives here are perceived to have the result of people with the same political inclinations, especially in more local communities, having the feeling that they are being supported, which allows for building good relationships with them. One interviewee maintained that *"if you're talking about the local ones…it's important that you are being backed, politically speaking, in your region as well. So especially like smaller communities, they approach us as well and say, 'Hey, we would like to launch a cooperative in this area,' because they see that is very important; energy is a critical point if you talk about… environmental politics"* **(B5)**. This claim was overwhelmingly supported in the survey, with only two respondents choosing to disagree with the respective statement in Question 21 in Appendix E. These two respondents also disagreed with the related statement in Question 20 in Appendix E, i.e., that politicised climate change issues help renewable energy cooperatives get more support. This is important when building networks to further reach out to the general public. Indeed, the prevailing politics in a country significantly impacts the way renewable energy cooperatives incentivise the adoption of renewable energy.

Subsection 5.2.10. Qualitative results summary

The qualitative study of REScoop.eu reveal that the organisational form of cooperatives in and of itself is not perceived to be important in its suitability in developing and managing renewable energy systems at the community level to influence renewable energy proliferation in Europe. The REScoop.eu interviews in fact raised a puzzle, in that whilst cooperatives are viewed distinctly from other organisations, such distinctiveness is virtually not attributed to the respective legal form. This perceived distinctiveness, including the advantageous characteristics of cooperatives as far as renewable proliferation in Europe is concerned even apparently contrasts with claims made about the legal form. The prevailing legal and policy framework, along with political, historical, and geographical context in a country that are the ones perceived to be as important factors when it comes to renewable energy proliferation than the organisational form of cooperatives itself. Some nuances were revealed by the complementary online survey, i.e., that principles in doing business cooperatives adopt, more specifically the ICA principles, are perceived to be difficult to adopt for private companies, hence a mixed perception on the cooperative organisational form as a necessary means to equitably renewable energy proliferation in Europe, particularly in the extent of its inclusivity. The discussions in

Subsections 5.2.2 and 5.2.9 means that, as per the SES framework, the external governance system (legal and policy frameworks), the socio-politico-economic settings (political and historical context), and the related ecosystem (geographical context) are more important than the internal, most immediate governance system (the cooperative organisational form) used to manage renewable energy system as far as renewable energy proliferation in Europe is concerned.

The cooperatives' legal form also is not seen as important when addressing land use issues. The interviews and the survey results pointed out that more acceptance of renewables at the local level and facilitation of dialogues by cooperatives, along with the existing available technology, good land use designs and practices, and the prevailing related legal and policy framework, are the ones that matter when dealing with land use issues. Consistent with this and what was claimed in Subsection 5.2.7, more local acceptance of renewables and facilitation of dialogues by cooperatives, both viewed as beneficial characteristics of cooperatives in relation to renewable energy proliferation in Europe, were not seen as products of the respective legal form; the perceived advantages to cooperatives in land use issues likewise contrasts with claims made on the legal form. As per the SES framework, the specific form of the most immediate governance system is seen as inconsequential as to how the renewable energy system is developed and managed.

Furthermore, whilst renewable energy cooperatives are generally still seen as having quite small impact in renewable energy proliferation in Europe, there is indeed the perception that renewable energy cooperatives do directly help in the proliferation of renewable energy in Europe through the democratisation of the energy sector and making distribution of the associated benefits more equitable. This is done by stimulating the local economy and localising energy production. In the SES framework, cooperatives having a more local extent and having a more collective accrual can solve common pool resource problem associated with renewable energy production. In addition, equity as an expected outcome in the SES framework was perceived to have been achieved. Cooperatives also help in renewable energy proliferation in Europe mainly by making renewables more acceptable at the local level. The awareness raising activities of cooperatives in relation to renewable energy helps as well in this regard. Renewable energy cooperatives also help deal with land use issues also through making renewables more locally acceptable. Overall, there is mixed evidence in relation to the fourth hypothesis raised in Chapter 1.

In addition, the evidence in relation to the fifth hypothesis in Chapter 1 is likewise mixed. In the first place, renewable energy cooperatives do address transaction costs in renewable energy production by building relationships with the communities based on trust. Cooperatives also tend to have better grassroot knowledge, complemented with good communication lines with community members.

Whilst this is the case, these do not seem to lead to the rise of specialised arrangements to specifically deal with transactions to reduce the associated transaction costs, and there is no evidence that such transaction costs are reduced through better grassroot knowledge. Finally, cooperatives are hampered by the general lack of the corresponding professional and technical expertise, and of the inefficiencies associated with the democratic decision-making process. All these further entail internal additional transaction costs to cooperatives. The necessary professional and technical expertise must be outsourced, requiring contracts to be drafted. The democratic decision-making process incurs higher bargaining costs within the cooperative, and at the same time makes renewable energy cooperatives less suitable to develop and manage renewable energy systems than other business models.

Chapter 6. Conclusion: summary of findings and reflections on the research exercises

This chapter concludes the thesis. This chapter is on a summary of the main findings of the quantitative and qualitative research, along with some policy implications with respect to such findings (Section 6.1), and a reflection on the research process, specifying its limitations and exploring ideas for future study (Section 6.2).

Section 6.1. Summary of main findings

The thesis sought to quantitatively investigate what factors causes the differences in rates across countries in substituting towards a cleaner energy mix. More specifically, the quantitative part of the research sought to determine if countries with relatively stronger state-related institutions that support green energy policies at given shares of the industry sector in their economy experience higher rates of change in the share of non-fossil fuel resources in energy production, and if countries with relatively high degree of state participation in the energy sector given the existence of green energy policies supported by state-related institutions experience higher rates of change in the share of non-fossil fuel resources in energy production. This was done using econometric methods on panel data structures.

The main findings with respect to the quantitative work are as follows. *The first quantitative finding* is that higher industrialisation levels increase the rates of change in the share of non-fossil fuel resources in energy production, contrary to the first hypothesis brought up in Chapter 1. This supports the claim that higher industrialisation levels require more energy across the board, which implies that energy substitution also has to do with the industry sector requiring more energy production in absolute terms. From a policy standpoint, this points to putting further emphasis on policies involving greater further diversification of energy portfolios to satisfy its economy's demand when attempting to substitute for fossil fuels. *This finding contributes insights to address the first research gap identified in Section 2.1, i.e., a cross-country study on the effect of the industry sector's prominence on energy substitution per se*.

The second quantitative finding is that changes in industrialisation levels, can hamper the rate of which an economy's is substituting for fossil fuels; it is the changes in the levels of industry share in output, not the respective levels, that negatively affects energy substitution. This implies that structural transformation of the economy also matters when it comes to a country's attempts to substitute towards a cleaner energy mix. State-related institutions in support of green energy policy nonetheless weaken this effect. *This finding meanwhile contributes insights to address the first research gap just described, and likewise the second research gap identified in Section 2.2., i.e., an econometric study on the role of institutions in energy substitution per se*.

The third quantitative finding is that contrary to the third hypothesis raised in Chapter 1, more state participation in the electricity sector on its own negatively affects energy substitution. However, like the case of industrialisation, green energy policy supported by state-related institutions likewise weaken this effect. This provides evidence that a less liberalised electricity sector can impede energy substitution. Hence, an increased rate of change in the share of non-fossil fuel resources in energy production can be another benefit from liberalising the energy sector with the specific goal of reducing the market power of state-owned enterprises in the electricity sector. *This finding contributes insights to address the third research gap also identified in Section 2.2, i.e., an econometric cross-country investigation using panel data study on the effect of state participation in the energy sector on energy substitution per se.* The last two econometric findings brought up are nevertheless both consistent with the second hypothesis. In fact, these two findings reveal a more detailed picture of how state-related institutions in support of green energy policy indeed are relevant as far as energy substitution in Europe is concerned.

Another implication of the third econometric finding is that an electricity sector that is more decentralised in terms of more community-level ownership of power plants can be expected to increase the rates of substitution towards a cleaner energy mix. In addition, the available data for the calculation for the proxy for energy sector state participation reveal that power plants cannot be categorised as either owned, controlled, or operated by the state or by private enterprises, but by the communities where such power plants stand. This can be done through an alternative way bottom-up approach can come into play to propagate an energy substitution, the CES. The thesis specifically focussed on REScoop.eu member cooperatives, seeking to address how renewable energy cooperatives help in renewable energy proliferation in Europe. More specifically, an investigation was made on how renewable energy cooperatives directly help in renewable energy proliferation in Europe (a) by being a suitable organisational form to develop and manage renewable energy systems at the community level, (b) through the desire to democratise the energy sector, and (c) by making distribution of benefits more equitable in the context of REScoop.eu; and how renewable energy cooperatives also do this by addressing transaction costs associated with renewable energy production in the context of REScoop.eu. This investigation was done through qualitative research methods, i.e., through online interviews and survey.

The main findings with respect to this qualitative study are as follows. *The first qualitative finding* is that judging by the interviewees' responses, whilst cooperatives are viewed rather distinctly from other organisations, there is a lack of attribution of this distinctiveness to the respective legal form. The perceived advantages to cooperatives were not seen as arising from the respective legal form. The perceived uniqueness of cooperatives contrasts with claims made the legal form. Moreover, the prevailing legal and policy framework, along with political, historical, and geographical context in a country are the ones perceived to be more important factors when it comes to renewable energy proliferation than the legal form of cooperatives itself. Regarding this, the principles in doing business cooperatives adopt are perceived to be difficult to adopt for private companies, and that there is a mixed perception on the inclusivity of cooperatives. *The second qualitative finding* is that the cooperatives' legal form is also not viewed to be important when addressing land use issues. More acceptance of renewables at the local level and facilitation of dialogues, along with the existing available technology, good land use designs and practices, and the prevailing related legal and policy framework, are the ones that matter more when dealing with land use issues. More local acceptance of renewables and facilitation of dialogues by cooperatives, both viewed as beneficial characteristics of cooperatives in relation to renewable energy proliferation in Europe, were not seen as causes of the respective legal form; the perceived advantages to cooperatives in land use issues likewise contrasts with claims made on the legal form. *Both these findings contribute insights to address the fourth research gap identified in Section 2.4, i.e., an investigation on the role of a suitable cooperative organisational form develop and manage energy systems at the community level in REScoop.eu to directly help in renewable energy proliferation using qualitative research methods*.

The third qualitative finding is there is indeed the perception that renewable energy cooperatives directly help in the proliferation of renewable energy in Europe through the democratisation of the energy sector, done by localising energy production and stimulating the local economy. This implies renewable energy cooperatives can lead to healthier local economies. Renewable energy cooperatives also help in this regard with their awareness raising activities in relation to renewable energy. All these warrant the support mechanisms discussed in Subsection 5.2.8 to incentivise the existence of renewable energy cooperatives in local areas, namely financing in the form of grant programmes, subsidies, support one-stop shops. *This finding also contributes insights to address the fourth research gap, i.e., an investigation on the role of cooperatives in REScoop.eu to directly help in renewable energy proliferation through the desire to democratise the energy sector using qualitative research methods*.

The fourth qualitative finding is that renewable energy cooperatives indeed help in renewable energy proliferation in Europe mainly by making renewables more acceptable at the local level, which is also how cooperatives help deal with land use issues. *This finding is another one that contributes insights to address the fourth research gap, i.e., an investigation on the role of cooperatives in REScoop.eu to directly help in renewable energy proliferation by making distribution of the associated benefits more equitable using qualitative research methods*. Therefore, there is indeed the perception that renewable energy cooperatives do directly help in the proliferation of renewable energy in Europe through the democratisation of the energy sector and making distribution of the associated benefits more equitable.

The fifth qualitative finding is that renewable energy cooperatives help in the proliferation of renewable energy in Europe by building relationships with the communities based on trust. Cooperatives also tend to have better grassroot knowledge, complemented with good communication lines with community members. Whilst this is the case, these do not seem to lead to the rise of specialised arrangements to specifically deal with transactions to reduce the associated transaction costs, and there is no evidence that such transaction costs are reduced through better grassroot knowledge. *The last qualitative finding* is that cooperatives are hampered by the general lack of the corresponding professional and technical expertise. The necessary professional and technical expertise must be outsourced, requiring contracts to be written. To address this and help renewable energy cooperatives obtain the necessary professional and technical expertise to incentivise their formation, necessary policy measures must then be in place, which can be of similar nature to those discussed in Subsection 5.2.9. Another related issue is that cooperatives are mostly run by volunteers, which leads to the problems discussed in detail in Subsection 5.2.4. It would then be helpful to have mechanisms that would make it cooperative membership financially more viable; more specifically, mechanisms that circumvent expensive cooperative shares. This is to encourage the cooperative membership, including those in lower income levels. Furthermore, certain legal and policy measures should also be in place to see to it that cooperatives indeed are functioning in a democratic and inclusive way. The democratic decision-making process incurs higher bargaining costs within the cooperative, and at the same time makes renewable energy cooperatives less suitable to develop and manage renewable energy systems than other business models. All these entail internal additional transaction costs to cooperatives. Therefore, the evidence on renewable energy cooperatives helping in renewable energy proliferation in Europe by addressing transaction costs associated with renewable energy production is likewise mixed. *Both these findings contribute insights to address the fifth research gap identified in Section 2.5, i.e., an investigation on the role of cooperatives' organisational form in REScoop.eu to directly help in the renewable energy proliferation by addressing transaction costs associated with renewable energy production using qualitative research methods*.

As a last point on the main findings with respect to the qualitative work, the corresponding third, fourth, and fifth main findings here imply that localisation is key for renewable energy cooperatives to be significant drivers of renewable energy in Europe. It is likewise noteworthy that this qualitative part of the research highlights the failure of governments to represent the interests of their people, at least at the local level, and be independent from the influence of big players in the energy market. This means that the prevailing institutions are only as good as the ethical and behavioural norms from which they arise. Another set of issues related to localisation of renewable energy production is that related to the grid. Technological innovations are necessary to address grid saturation. The most pressing concern however was the set of regulations and the infrastructure setup that makes self-consumption more difficult, and policy adjustments are meanwhile necessary for this to be facilitated for communities that produce their own energy. All these findings imply that there is mixed and nuanced evidence both for the fourth and fifth hypotheses raised in Chapter 1.

Section 6.2. Reflections on the research exercises

Some limitations of the quantitative and qualitative part of this thesis must be raised. Regarding the quantitative work, two limitations come from the fact that, one, only Eurostat provides reliable data on agricultural land prices, as discussed in Subsection 4.2.3. The other is that because of the latter, the time series per cross section in the panel dataset were relatively short. At the same time, the thesis was limited to include only European countries due to this. Future study with respect to the quantitative work can therefore address the issues raised to conduct econometric work that uses fixed effects and longer time series.

These limitations are essentially data-related, not because of the lack thereof, but because of the (a) appropriateness of using such data and the (b) practicality of doing the transformations necessary to make them usable in the econometric work. Addressing these issues can likewise enable future study to have a more global scope by including more countries. Developing countries can be included to provide insights on how they address climate change on the energy substitution front, and hence insights to better address climate change in general. The econometric results would have been, at least in the author's opinion, more relevant and helpful, because it would have been able to directly deal with climate change issues being confronted by developing countries, which are more vulnerable to the harmful effects of climate change than the more developed countries in Europe.

It could be argued nonetheless that these data limitations reasonably reined in scope of the study. This seemed to have paved the way, perhaps accidentally, for a relatively coherent narrative of energy substitution with a clear focus. More specifically, the thesis focussed entirely on Europe. The quantitative work mainly dealt with the more macrolevel issues in energy substitution, whilst qualitative work zoomed in on the corresponding intricacies, particularly focussing on the role of renewable energy cooperatives in renewable energy proliferation in the continent. The focus on cooperatives was brought about by one arguably noteworthy discovery in the dataset constructed, i.e., that the power plant ownership data reveal that power plants are likewise owned by the communities where such power plants are located. This led to an investigation on CESs, which in turn turned the direction of the thesis towards studying cooperatives, still within a European context.

Another crucial limitation of the quantitative part of the thesis is that an energy price or cost variable was not included in the econometric model discussed in Subsection 4.2.1. An energy price or cost variable is not a direct component of the social metabolism framework that was used as basis for the econometric model; the model then was not meant to estimate an expenditure or cost function. Nevertheless, the cost of production has already been indirectly captured by the carbon tax variable. At any rate, this indeed is one limitation of the econometric model and thus of the quantitative work.

The future study with respect to the quantitative part of the thesis may also delve in how other types of institutional constraints are important as far as energy substitution is concerned, as one should take note that the thesis limits the scope of analysis on state-related institutions. Future study may for instance focus on how cultural norms or perhaps religious beliefs of countries influence how they determine their energy mix. Admittedly, the corresponding investigation may be more challenging, given the issues on how the respective data may be quantified. Primary data may have to collected, and a whole procedure to adequately quantify such data may have to be invented, which itself is a significant contribution to the respective literature.

Meanwhile, some limitations of the qualitative work include the respective scope. The thesis limits the scope of qualitative work to cooperatives. In addition, the thesis only had 18 respondents in the online interviews and only 32 in the online survey. Hence, future study with respect to the qualitative work may investigate other types of CESs. One may take inspiration from the case studies presented in Ostrom (1990) on self-governed common pool resources, e.g., mountain and fishery societies, or perchance a study on present-day Stone Age tribes. These types of studies can be far more difficult given the respective geographical and even perhaps cultural context of the case study. Future study will likewise benefit from doing more interviews and higher survey response rates, which can be achieved is having a longer time period for qualitative research.

One important outcome in the qualitative work is that the respective investigation made on cooperatives seems have led to a puzzle to be solved. The inquiry made into cooperatives revealed that there seems to be, at least in the context of REScoop.eu, a lack of attribution of the advantages to cooperatives as far as renewable energy proliferation is concerned to the cooperatives' respective legal form. This appears to imply that the distinct characteristics of cooperatives, let alone those directly related to renewable energy proliferation, are perceived to have little connection to the legal form. If this is the case, why then do other organisations, say private companies, behave differently? Why are the latter profit-oriented and cooperatives are not? If such advantages to cooperatives are not being attributed to its legal form, then an explanation of the differences in behaviour of different organisations must be found. Future study in relation to cooperatives can be driven by such puzzle. The qualitative work then exemplifies a typical occurrence in a research process in which trying to answer questions led to another set of questions.

Aside from the reasons provided in Chapter 1 for the focussing on community-based approaches to energy and more particularly on renewable energy cooperatives, there is a purposive intent on the part of the author for this focus. The author is in search for a nexus between practical ways of contributing to energy substitution away from fossil fuels and a more equitable distribution of access to resources through a common ownership of the latter. The author is convinced that climate change needs to be addressed immediately using all means efficient and effective. At the same time, the author is also convinced income and wealth distribution in the world must be improved by making them more equitable, and one way the author is convinced this can be done is through common ownership of resources. Studying renewable energy cooperatives seems to be one such nexus, as this both tackle climate change and common resource ownership relatively directly. Ostrom (1990) already focussed on common-pool resources, and the author learned some concepts that can be useful in doing research on political schools of thought that espouse common ownership, like anarcho-syndicalism or socialism (e.g., Bardhan and Roemer, 1992; Heying, 1999; Fuller, 2019; Hodgson, 2019). The jury is still out regarding the extent to which such concepts from the work of Ostrom are indeed applicable to research on these political schools of thought, and the author is committed to follow a corresponding research path. Thus, aside from contributing to the related literature on energy substitution, this thesis is also expected to encourage further research on political schools of thought in support of common ownership of resources.

This thesis contributes to the ecological economics literature, more specifically in the social metabolism literature strand. It is of the author's estimation that ecological economics has better tools compared to neoclassical economics to study and explain economic phenomena, as it recognises that the economy is embedded in the biophysical environment, the latter being finite and therefore having limits. More specifically, the thesis extended the standard social metabolism framework by incorporating institutions, as was done in Section 3.3. Perhaps one noteworthy outcome of this exercise is the revelation that this extended model is similar to the SES framework as presented in the works of Ostrom (1990; 2005; 2009) and respective collaborators. The extended social metabolism framework developed in this thesis seems to be a more macrolevel version of the SES framework, which also seems to adequately fit the earlier described narrative of energy substitution in this thesis.

The main topic of this thesis is energy substitution, which directly tackles one main point ecological economics is making, i.e., that every aspect of the world economy requires energy inputs. Energy then is the most basic component of the world economy, the very foundation upon which the latter is standing on (Hagens and White, 2021). All economic activity requires energy inputs; energy is necessary for the creation and transformation of all material inputs, and can only be substituted by other energy (Hagens, 2020). Without energy therefore, the world economic system will simply not exist. Neoclassical economics ignores this and treats energy on equal footing as any other input, one of its major flaws. This is one reason why it makes sense to conceive the economy as being embedded in a biophysical system. The latter, the processes therein, all life it contains, etc., will not exist without energy, more specifically energy from the sun. All energy inputs to keep economic activity going comes from the biophysical environment, which in turn requires energy to keep going as well. As mentioned earlier, ecological economics recognises the limits of the biophysical environment. Therefore, there are also limits as far as the extent to which the economy can grow. Hagens (2020) notes that if the world continues at its most recent levels of economic activity, run by 17 terawatts of energy, approximately one kilogramme of minerals and materials is needed for every $2 of global GDP even if carbon neutrality is achieved, which is physically impossible. This implies that the only solutions to carbon emissions involve economic contraction, hence the pursuit of economic growth should be abandoned. Whilst not a direct contribution, the thesis also relates to the degrowth literature (e.g., Kallis et al 2012; Victor, 2012; Jackson, 2016). It is the author's opinion that degrowth should be seriously considered to address climate change from an energy standpoint in particular, and to ensure a sustainable future in general.

The overarching theme of the research exercises in the thesis is the role of institutions far as energy substitution towards a cleaner energy mix is concerned, and has demonstrated that some useful insights on energy transitions can be drawn from engaging in this strand of study. The quantitative part of the research suggests that both changes in levels of industrialisation of state participation in the energy sector, more specifically in electricity, both decrease the rates of change in the share of non-fossil fuel resources in energy production, but state-related institutions weaken both such negative effects. A more theoretical approach on institutions meanwhile was done in the qualitative part of the research, where energy substitution was viewed in the context of the associated transaction costs, more specifically in the context of land use. Both the quantitative and qualitative part of the research were guided by the works of Ostrom (1990; 2005; 2009) and respective collaborators, i.e., by the SES framework and insights from the respective research on common pool resources systems institutional designs.

The thesis contributes insights on the role institutions on the substitution for fossil fuels across countries. More specifically, to recapitulate from Chapter 1, *the thesis contributes insights on (a) how state-related institutions might affect how the industry sector's prominence in the economy and the degree of state participation in the energy sector in turn influence energy substitution, and on (b) how the cooperative's organisation form in and of itself and by addressing transaction costs help in renewable energy proliferation.* The thesis therefore contributes to the related literature on energy substitution by analysing it using the tools of institutional economics, specifically investigating the role of institutions in how it unfolds.

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Appendix A: summary of variables used

Variable	Raw data	Source	Years available	Transformation	Further remarks
$\boldsymbol{DR_{it}}$ (absolute change in the share of non-fossil fuel resources in energy production from the previous year)	Non-fossil fuel (i.e., solar, wind, hydropower, biomass, geothermal, and nuclear) energy production in ktoe	IEA	1971-2018	Logistic transformation is done on the shares of non-fossil fuels in energy production	1. The dependent variable 2. Energy production from solar, wind, hydropower, biomass, geothermal, and nuclear were summed up and was divided by the total. 3. Energy substitution using TES would result in double counting, as imports are already included when TES is calculated 4. There are sometimes discrepancies in the raw data, i.e., the summing up energy production from all energy resources at times does not equal the total. Because of this, the research calculates the total based on the summed-up energy production from all energy resources. 5. The logistic transformation was done to make DR_{it} unbounded to get around the problem of it being truncated data.

$\boldsymbol{NFE_{it}}$ (non-fossil fuel endowment index)	1. Wind speed (m/s, from the top 10% of windiest areas) 2. Global tilted irradiance (kWh/m^2) per day	Global Wind Atlas Global Solar Atlas	Do not vary across time	The following are the steps in calculating NFE_i: 1. The world average for both variables and the ratio of country-level figures to this world average were obtained. 2. The ratios of country-level figures to the world average normalise the values. 3. The average of these ratios for both variables per country were obtained.	1. Wind speed data: a. Based on ERA5 dataset from 2008-2017. Methodology for calculation is available through the following link: https://globalwindatlas.info/about/method b. Generation capacity increases with the cube of wind speed, which implies that wind will only be useful at a certain threshold. 2. Global tilted irradiance data calculated based on 2019 Solargis data. Methodology for calculation is available through the following link: https://globalsolaratlas.info/support/methodology 3. Only includes solar and wind because only these have proxies that are widely accepted in the literature. 4. The ratios of country-level figures to the world average mentioned in Column 4 show how endowed each country is in non-fossil fuel energy resources relative to the rest of the world. 5. DR_{it} could have been adjusted to match NFE_{it}, but some countries do not have energy production data from some non-fossil fuel resources, meaning that such countries have to be dropped from the analysis.
$\boldsymbol{B_{it}}$ (carbon stock in living biomass)	In million tonnes per sq. m.)	UNSD Energy Statistics database	1990-2017	The same procedure for normalisation done to calculate to NFE_i was also done to calculate B_{it} except that averages were calculated both per country and year.	2017 data were used for 2018

$\boldsymbol{LA_i}$ (land area)	In sq. km.	World Bank WDI	Does not vary across time		1. Along with AP_{it}, was included to take into account the fact that non-fossil fuel energy production especially from renewables is tied to land use. 2. Along with AP_{it}, was scaled down due to being in units that are large relative to the dependent variable (will result in ridiculously small coefficients, only possible to be shown using an unreasonably immense number of decimal places) LA_i was scaled down to thousand square kilometres, whilst AP_{it} was scaled down to thousand USD.
$\boldsymbol{AP_{it}}$ (price of agricultural land)	In USD	Eurostat	2011-2018	The raw data from Eurostat is in EUR, hence was converted in USD	1. The Eurostat data go as far back as 1985 but were gathered without a unified methodology leading to the data having low comparability across reporting countries. 2. Only Eurostat provides reliable data on agricultural prices, having a unified methodology in obtaining such data across all reporting countries, making the respective data more comparable across countries. This is the reason the study is limited to European countries. 3. According to Eurostat, absolute prices are helpful when assessing the relationship between agricultural land values and respective incomes, i.e., the viability of agriculture given changes in land prices
$\boldsymbol{EI_{it}}$ (non-fossil fuels share in total energy imports)	Non-fossil fuel imports in ktoe	IEA	1971-2018		
$\boldsymbol{ED_{it}}$ (energy depletion)	Conventional oil (crude oil and	Globalshift Ltd.		Constructed in two ways:	1. Included to take into account the dynamic aspect of energy substitution

	lease condensate) production forecasts			1. As a peak oil dummy: =1 from the year a country has reached peak oil and onwards, =0 otherwise. 2. As the number of years that passed since the country reached peak oil: $$ED_{it} = t - t_{PO}$$ For instance, Bulgaria reached peak oil in 1967, which means that ED_{it} takes the value of 44 in 2011, 45 in 2012, and so on. Done because a simple dummy variable will not capture the effect of proximity to the peak oil year on renewable production.	2. A brief description of the process by which Globalshift Ltd. did the forecasts based on which peak oil production per country was determined a. Historic annual oil output was initially collected. Future output was estimated using reported reserves and field resources, whilst total output was based on reported annual production, estimated using data from fields, field complexes, and sedimentary basins. In cases of limited available data, interpolation or extrapolation using any other data that can be acquired was done. b. Included in the calculations are data from all field discoveries which have not yet entered production but will eventually be developed, based on which a “speculative undeveloped” component is added to the production forecast based on such data using a model to craft a production profile wherein the undeveloped fields are sequentially developed. c. There is also a “speculative undiscovered” component, estimated by examining the exploration history and geological potential of each area using the same model. The corresponding volumes and maximum output were determined through subjective evaluation of: (i) how much exploration acreage remains to be explored; (ii) how successful exploration has been in the past; (iii) how new

					technology is allowing access to new resources; and (iv) how historic exploration and development has been restricted due to political factors. d. Updates are made when new data come out. Data are reviewed every January and July to ensure that global interpretations are consistent and match prevailing economic circumstances. e. The model is primarily constructed around supply, with demand and prices allowed to change to match supply, subject to external geological, political, and economic factors. Data are compared graphically with actual consumption figures to ensure global supply and demand match. More details on this methodology are available in Smith (2015) and through the following link: http://www.globalshift.co.uk/mode.html
$\boldsymbol{ln}(\boldsymbol{GPC_{it}})$ (natural logarithm of GDP per capita in PPP)	GDP per capita in PPP in USD	World Bank WDI	1960-2018		If GDP were zero, it is quite unreasonable that the dependent variable could be positive, even if compensated by other variables; this necessitates to specify a log-linear model
$\boldsymbol{IS_{it}}$ (share of the industry sector in GDP	Share of the industry sector in GDP	World Bank WDI	1960-2018		Include mining, manufacturing, construction, electricity, water, and gas
$\boldsymbol{CT_{it}}$ (carbon tax)	Share of annual global GHG emissions covered by the country's	Carbon Pricing Dashboard	1990-2021		1. The data for the annual global GHG emissions were from the Emission Database for Global Atmospheric Research. From 1990-2015, this data includes biofuels emissions.

	carbon pricing initiative				2. In cases where GHG emissions are covered by multiple carbon pricing initiatives, such are attributed to the one that was introduced first.
$\boldsymbol{EP_{it}}$ (energy policy)	Policies listed in sources specified in Column 3	Climatescope (Bloomberg), Policies and Measures Databases (IEA)	Policies listed are as of 2018	Constructed in two ways: 1. As a trend: =1 in the year at least one energy policy became effective, and thereafter takes positive integers onwards: $EP_{it} = \{ t - t^{*} + 1 \; if \;\; t \geq t^{*} \; 0 \; if \; t < t^{*}$ 2. As a staggered trend: similar to the second way EP_{it} is constructed, but changes in value only after 3 years: $EP_{it} = \{ n + 1 \; if \; t^{*} + 3n + 2 \geq t \; + 3n \geq t^{*} \; 0 \; if \; t < t^{*}$ $n = 0,1,2, \ldots$	The way the EP_{itj} were constructed as described in Column 4 was to take into account the long-term effects of the energy policy
$\boldsymbol{SI_{it}}$ (strength of institutions)	Government Effectiveness index	World Bank WGI	1996-2018	Missing data for years 1997, 1999, 2001 were interpolated: 1. For 1997, a pseudo-random number was drawn from a normal distribution where the 1996 value was used as the mean to restrict the draw for 1997 to some neighbourhood of values around the 1996 value, and the standard deviation of the whole series was used as that for the normal distribution. 2. The resulting three-year series was then used to forecast the value for 1999.	

				3. After obtaining the forecasted values for 1999, the resulting five-year series was used to forecast the value for 2001.	
SO_{it} (share of state-owned/controlled power plants)	Share of state-owned or -operated power plants in the total	IndustryAbout.com, Global Energy Observatory, and the individual owner's or operator's websites	Varies; earliest records go back as far as 1896	Based on the records from the cited sources in Column 3, the number of power plants were counted for years to be included in the time series: 1. For each power plant for which information is available, the respective data sources indicate the following: a. the power plant owner or operator; b. the year in which the power plant was commissioned; c. the year in which the power plant was shut down; d. the year in which the power plant changed ownership. 2. Only those power plants for which the information is complete are included in the calculations. 3. In some cases, the owner is not identified in the respective power plant webpage, for which the operator information is used. 4. The power plant is identified as state-owned or -operated if information available implies that: a. the owner or operator are the national or federal governments,	

				or local governments like the provincial, state, or city governments; b. the owner or operator is at least 50% of the shares are owned by national or federal or local governments.	

Table A. Summary of variables used in the research. Source: Author.

Appendix B: Hausman test results

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE
B_{it}	23.687	-0.208	22.890	-0.011	23.645	-0.112	23.725	-0.218	23.008	-1.83e-4	23.704	-0.086
AP_{it}	-0.007	-0.001	-0.007	-0.006	-0.009	-0.005	-0.008	4.92e-4	-0.007	-0.004	-0.009	-0.003
EI_{it}	-29.121	-8.951	-28.197	-10.527	-27.901	-8.785	-28.515	-7.654	-27.791	-8.374	-27.291	-6.333
$ED_{itb}{}^{+}$							-0.051	-0.001	-0.042	0.003	-0.047	0.004
$ln(\widetilde{GPC}_{it})$	-2.416	-0.199	-2.602	0.182	-1.609	0.223	-2.708	-0.343	-2.826	0.063	-1.897	0.110
IS_{it}	1.953	6.648	-23.654	14.766			1.712	6.315	-21.088	13.713		
$(IS_{it})^2$			43.903	-17.900					39.160	-15.485		
$IS_{it} - IS_{it-1}$					7.595	-7.494					6.877	-8.567
$(IS_{it} - IS_{it-1})^2$					-170.787	-160.948					-166.546	-151.180
$\widetilde{CT}_{it}$	-2.125	-0.782	-2.138	-1.216	-1.591	-1.385	-2.063	-0.317	-2.085	-0.908	-1.550	-0.936
$EP_{ita}{}^{+}$	-0.138	0.022	-0.127	0.019	-0.129	-0.008	-0.091	0.022	-0.089	0.029	-0.085	0.002
SI_{it}	-0.817	0.408	-0.642	0.201	-0.825	0.008	-0.704	0.126	-0.567	0.153	-0.708	-0.121
SO_{it}	14.736	-1.007	14.188	-0.997	17.997	-1.211	14.514	-1.393	14.062	-1.317	17.620	-1.594
$(SI_{it} * EP_{ita})$	0.013	0.023	-0.001	0.039	0.018	-0.009	0.015	0.035	0.002	0.041	0.021	-0.007
$(IS_{it} * SI_{it} * EP_{ita})$	0.049	-0.262	0.031	-0.275			0.054	-0.270	0.037	-0.292	0.689	1.149
$[(IS_{it} - IS_{it-1}) * SI_{it} * EP_{ita}]$					0.669	1.180					0.106	0.052
$(SO_{it} * SI_{it} * EP_{ita})$	0.179	0.074	0.194	0.058	0.149	0.053	0.133	0.073	0.154	0.06		
Chi-sq.	4.08		4.01		4.19		4.29		4.15		4.45	
p-value	0.98		0.98		0.98		0.99		0.99		0.99	
Obs.: 128; $^{+}ED_{it}$ as the number of years since peak oil; $^{++}EP_{it}$ as a regular trend.												

Table B.1. Hausman test (Models 1 – 6). Source: Author.

	Model 7		Model 8		Model 9	
	FE	RE	FE	RE	FE	RE
$\boldsymbol{B_{it}}$	20.413	-0.143	19.622	0.077	20.936	-0.033
$\boldsymbol{AP_{it}}$	-0.007	0.004	-0.007	-0.001	-0.009	7.52e-5
$\boldsymbol{EI_{it}}$	-55.643	-10.587	-54.585	-11.681	-53.461	-8.675
$\boldsymbol{ED_{itb}}^{+}$	-0.081	-0.002	-0.078	0.002	-0.080	0.001
$\boldsymbol{ln(\widetilde{GPC}_{it})}$	-2.631	-0.694	-2.811	-0.278		-0.194
$\boldsymbol{IS_{it}}$	-4.763	8.686	-27.702	17.980		
$(\boldsymbol{IS_{it}})^2$			38.760	-18.589		
$\boldsymbol{IS_{it} - IS_{it-1}}$					8.971	-10.357
$(\boldsymbol{IS_{it} - IS_{it-1}})^2$					-84.719	-134.579
$\boldsymbol{\widetilde{CT}_{it}}$	-1.643	-0.346	-1.633	-0.874	-1.475	-0.888
$\boldsymbol{EP_{itb}}^{++}$	-0.089	0.096	-0.069	0.119	-0.043	6.69e-6
$\boldsymbol{SI_{it}}$	-1.483	0.084	-1.328	0.108	-1.398	-0.438
$\boldsymbol{SO_{it}}$	14.087	-1.602	13.546	-1.474	16.520	-1.962
$(\boldsymbol{SI_{it} * EP_{itb}})$	-0.269	0.158	-0.310	0.181		0.019
$(\boldsymbol{IS_{it} * SI_{it} * EP_{itb}})$	1.061	-1.016	1.053	-1.108		
$[(\boldsymbol{IS_{it} - IS_{it-1}}) * \boldsymbol{SI_{it} * EP_{itb}}]$					0.584	3.254
$(\boldsymbol{SO_{it} * SI_{it} * EP_{itb}})$	1.230	0.279	1.268	0.232	1.104	0.215
Chi-sq.	5.66		5.54		5.78	
p-value	0.96		0.98		0.97	
Obs.: 128; $^{+}\boldsymbol{ED_{it}}$ as the number of years since peak oil; $^{++}\boldsymbol{EP_{it}}$ as staggered trend.						

Table B.2. Hausman test (Models 7 – 9). Source: Author.

Appendix C: Fisher unit-root test results

Tables C.1 – C.4 summarise the types of Fisher tests based on which test statistics were calculated. Tables C.2 – C.3 show the Fisher tests that takes into account the structural breaks determined using additive outliers, whilst Tables C.4 – C.5 show the same but using innovative outliers. The null hypothesis is that all panels contain unit roots is tested against the alternative that at least one panel is stationary. In these unit root tests, only one lag was included.

	DR_{it}	B_{it}	AP_{it}	EI_{it}	$ln(GPC_{it})$	$ln(\widetilde{GPC}_{it})^{+}$	IS_{it}	CT_{it}	$\widetilde{CT}_{it}$
Inverse chi-squared transformation	134.729***	1281.858***	59.592**	98.662***	39.750	67.082***	159.022***	3.907	103.616***
Inverse-normal transformation	-4.042***	-33.740***	-0.409	-1.488*	3.119	-1.041	-2.356***	1.253	-1.950**
Inverse-logit transformation	-6.255***	-81.483***	-0.946	-3.231***	3.126	-1.099	-6.214***	1.176	-4.526***
Modified inverse chi-squared transformation	10.118***	135.280***	2.190**	6.182***	-0.246	2.737***	12.768***	-4.156	6.723***

+Demeaned CT_{it}; ++Demeaned GPC_{it}
***Significant at 1% level; **Significant at 5% level; *Significant at 10% level

Table C.1. Fisher unit-root test based on augmented Dickey-Fuller tests with structural breaks calculated from additive outliers. Source: Author.

	SI_{it}	SO_{it}	$(IS_{it})^2$	$IS_{it} - IS_{it-1}$	$(IS_{it} - IS_{it-1})^2$	$\widetilde{SO}_{it}^{+}$
Inverse chi-squared transformation	66.797***	314.223***	166.193***	141.983***	972.075***	604.997***
Inverse-normal transformation	-1.935**	-6.635***	-2.560***	-3.645***	-24.996***	-16.148***
Inverse-logit transformation	-2.146**	-18.107***	-6.640***	-6.844***	-59.593***	-35.891***
Modified inverse chi-squared transformation	2.706***	29.702***	13.551***	10.909***	101.480***	61.428***

+Demeaned SO_{it}
***Significant at 1% level; **Significant at 5% level; *Significant at 10% level

Table C.2. Fisher unit-root test based on augmented Dickey-Fuller tests with structural breaks calculated from additive outliers (cont.). Source: Author.

	DR_{it}	B_{it}	AP_{it}	EI_{it}	$ln(GPC_{it})$	$ln(\widetilde{GPC}_{it})^{+}$	IS_{it}	CT_{it}	$\widetilde{CT}_{it}$
Inverse chi-squared transformation	264.743***	1270.676***	80.727***	60.992**	149.924***	122.774***	132.793***	2.206	113.093***
Inverse-normal transformation	-7.294***	-33.549***	-2.977***	0.2504	-4.486***	-1.041	-1.761**	-0.435	-2.615***
Inverse-logit transformation	-14.383***	-80.773***	-3.584***	-0.321	-7.433***	-1.099	-4.761***	-0.413	-5.476***
Modified inverse chi-squared transformation	24.303***	134.060***	4.553**	2.072**	11.775***	2.737***	9.906***	-4.342	7.757***

+Demeaned GPC_{it}
***Significant at 1% level; **Significant at 5% level; *Significant at 10% level

Table C.3. Fisher unit-root test based on augmented Dickey-Fuller tests with structural breaks calculated from innovative outliers. Source: Author.

	SI_{it}	SO_{it}	$(IS_{it})^2$	$IS_{it} - IS_{it-1}$	$(IS_{it} - IS_{it-1})^2$	$\widetilde{SO}_{it}^{+}$
Inverse chi-squared transformation	253.358***	352.227***	130.723***	167.478***	57.956*	571.948***
Inverse-normal transformation	-7.159***	-11.005***	-1.774**	-4.623***	0.042	-15.059***
Inverse-logit transformation	-13.650***	-24.834***	-4.851***	-8.385***	-0.138	-33.540***
Modified inverse chi-squared transformation	23.061***	33.849***	9.680***	13.691***	1.741**	57.822***

$^{+}$Demeaned SO_{it}
***Significant at 1% level; **Significant at 5% level; *Significant at 10% level

Table C.4. Fisher unit-root test based on augmented Dickey-Fuller tests with structural breaks calculated from innovative outliers (cont.). Source: Author.

Appendix D: online interview schedule

A. General questions. These will be asked to all interviewees.

1. Do cooperatives increase the rate of renewable energy use in your country? Please expand on your reasoning.

2. Is it important for countries to have a thriving renewable energy cooperative sector? Please expand on your reasoning.

Questions specifically related to individual benefits from cooperatives

3. What are the advantages and disadvantages of being a member of a cooperative to a person?

4. How can a person be encouraged to be a cooperative member?

5. Do cooperatives usually start from a dissatisfaction with energy markets? Please expand on your reasoning.

[Follow-ups: (a.i.) Aside from cooperative membership, are there other ways for individuals to address such dissatisfaction? Please expand on that. (a.ii.) If so, what are these ways?]

6. In your country, are people in communities that have renewable energy systems more independent from other energy suppliers? Please expand on your reasoning.

[Follow-ups: (a) Does the organisational form of cooperatives influence such independence (or the lack thereof)? Please expand on your reasoning. (b.i.) Aside from cooperative membership, are there other ways for individuals to be independent of energy suppliers? Please expand on that. (b.ii.) If so, what are these ways? (c.i.) Does such independence differ for privately-owned companies? Please expand on your reasoning. (c.ii.) Does such independence differ for public sector enterprises? Please expand on your reasoning.]

7. Do cooperatives help achieve a fairer distribution of benefits from renewable energy projects, like in terms of profits or access to electricity for example? Please expand on your reasoning.

[Follow-ups: (a) Does the organisational form of cooperatives influence the achievement of this fairer distribution? Please expand on your reasoning. (b.i.) Does achieving this fairer distribution differ for privately-owned companies? Please expand on your reasoning. (b.ii.) Does achieving this fairer distribution differ for public sector enterprises? Please expand on your reasoning.]

Questions specifically related to social benefits from cooperatives

8. What legislation on cooperatives in your country [for non-policy interviewees] would make development of renewable energy projects faster?

9. Do cooperatives contribute to the economic development of the communities they belong to? Please expand on your reasoning.

10. Are cooperatives more likely to be trusted than other business models? Please expand on your reasoning.

11. Do cooperatives have a better relationship with communities than other business models do? Please expand on your reasoning.

Questions specifically related to organisational benefits from cooperatives

12. Using land for renewable energy production may conflict with alternative uses of land. For example, renewable energy production may conflict with agricultural land use or enjoyment of the landscape. Do cooperatives help to resolve this issue? Please expand on your reasoning. [Follow-ups: (a.i.) Do privately-owned companies help to resolve this issue? Please expand on your reasoning. (a.ii.) If so, does the manner they do it differ? Please expand on your reasoning. (b.i.) Do public sector enterprises help to resolve this issue? Please expand on your reasoning. (b.ii.) If so, does the manner they do it differ? Please expand on your reasoning.]

13. Does the organisational form of cooperatives make them particularly suitable for developing and managing renewable energy systems? Please expand on your reasoning.

[Follow-up: (a) Does this suitability differ for privately-owned companies? Please expand on your reasoning. (b) Does this suitability differ for public sector enterprises? Please expand on your reasoning.]

B. Questions specific to industry players, i.e., to REScoop.eu members.

Questions specifically related to social benefits from cooperatives

1. Is the community involved in the cooperative's operations? Please expand on that.

[Follow-up: If so, in what ways?]

2. Is obtaining the rights to use land important to the cooperative? Please expand on that.

[Follow-ups: (a) If so, how important? (b.i.) Is the community involved here? Please expand on that. (b.ii.) If so, in what ways?]

Questions specifically related to organisational benefits from cooperatives

3. What would be the main barriers to operating in another area, for example if you had to relocate or were setting up additional operations elsewhere?

[Follow-ups: (a.i.) How difficult would it be to address these? (a.ii.) Do these barriers, along the difficulty of addressing them, differ for privately-owned companies? Please expand on your reasoning. (a.iii.) Do these barriers, along the difficulty of addressing them, differ for public sector enterprises? Please expand on your reasoning. (b.i.) What would be the main barriers to handling infrastructure and equipment? (b.ii.) How difficult would it be to address these? (b.iii.) Do these barriers, along the difficulty of addressing them, differ for privately-owned companies? Please expand on your reasoning. (b.iv.) Do these barriers, along the difficulty of addressing them, differ for public sector enterprises? Please expand on your reasoning. (c.i.) Does your cooperative's relationship with the community influence the nature of these barriers, and the difficulty of addressing them? Please expand on your reasoning. (c.ii.) How would this compare for privately-owned companies? Please expand on your reasoning. (c.iii.) How would this compare for public sector enterprises? Please expand on your reasoning. (c.iv.) Was building such relationships an issue for the cooperative? Please expand on that. (c.v.) If so, how difficult was it? (c.vi.) Does building such relationships, along its difficulty, differ for privately-owned companies? Please expand on your reasoning. (c.vii.) Does building such relationships, along its difficulty, differ for public sector enterprises? Please expand on your reasoning.]

4. When your organisation was set up, it could be assumed that there were different business models that might have been selected. If so, could you identify the main alternatives?

[Follow-ups: (a.i.) What are the advantages and disadvantages of the cooperative as a business model? (a.ii.) Why was it selected for your organisation? (b.i.) It could also be assumed that there were different specific organisational forms that might have been selected for your cooperative. If so, could you identify the main alternatives? (b.ii.) What are the advantages and disadvantages of your cooperative's specific organisational form? (b.iii.) Why was it selected for your organisation?

Appendix E: online survey questionnaire

Online survey for a study on REScoop.eu member cooperatives

Q1 Hello! My name is Emmanuel Genesis Andal, a Ph.D. student at the University of Reading, UK. This survey forms part of my thesis.

About my research

I am conducting research on the substitution of alternative energy resources for fossil fuels, and I am interested in the role of cooperatives in the renewable energy sector.

What is involved?

You will be given a series of questions in this online survey, which will take around 15 minutes to complete. Here, you are asked to complete the survey in a personal capacity drawing on your experience in the sector. You may stop completing the questions at any time if you do not wish to proceed. Once you have completed the survey, you or your cooperative will not be required to do anything else.

Confidentiality, storage, and disposal of information

I will not collect any name, email address, or any other details of a respondent, and no information identifying the cooperative will be published.

Do participants have to take part?

Your participation is entirely voluntary, and you are free to exit the survey at any point. Once you finish, the responses will be entered into the survey, and you will no longer be able to withdraw your responses.

Consent

If you decide to take part in the survey, you are acknowledging that you understand the terms of participation and that you consent to these terms.

Further Information and contact details

You can contact me by email before 3 August 2022 if you wish to receive further information about the research at any stage. My contact details are below. Many thanks in advance for your help with this.

Emmanuel Genesis T. Andal

Email e.t.andal@pgr.reading.ac.uk

School of Agriculture Policy and Development

Alternatively, you can contact my supervisor:

Dr. Nicholas O. Bardsley

Email n.o.bardsley@reading.ac.uk

Address: School of Agriculture, Policy, and Development, University of Reading, Whiteknights, PO Box 237, Reading, United Kingdom, RG6 6AR

This online survey has been reviewed according to the procedures specified by the University of Reading Research Ethics Committee and has been granted ethical clearance.

Q2 **Section I. In this section, you will be asked to provide information on your cooperative.**

In which country does your cooperative operate?

▼ Austria ... United Kingdom

(The choices are: Austria, Belgium, Croatia, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Romania, the Netherlands, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, and United Kingdom)

Q3 What is the scale of your cooperative?

- [ ] Town/city-level
- [ ] County/municipal-level
- [ ] Regional/national-level
- [ ] Other (Please specify) ____

Q4 Which of the following best describes the organisational form of your cooperative?

- [ ] Individual cooperative
- [ ] Federation of individual cooperatives
- [ ] Federation of various stakeholders
- [ ] Other (Please specify) ____

Q5 What are the types of members in your cooperative? (Please tick all that apply)

- [ ] Individual citizens/local community members
- [ ] Private companies
- [ ] Cooperatives/other non-private enterprises
- [ ] Local/regional/national government units
- [ ] Workers/employees
- [ ] Other (Please specify) ____

Q6 What type/s of renewable energy is your cooperative producing? (Please tick all that apply)

- [ ] Solar
- [ ] Wind
- [ ] Hydropower
- [ ] Not applicable

- [ ] Other (Please specify) ____

Q7 What activities/services is your cooperative engaged in? (Please tick all that apply)

- [ ] Energy production
- [ ] Energy retailing to members/other consumers
- [ ] Energy distribution through own grid
- [ ] Support services (e.g., consultancy, R&D, bringing risk-capital, etc.)
- [ ] Carsharing
- [ ] Other (Please specify) ____

Q8 For how long have you been working for your cooperative? (Please enter the number of years in the space provided)

____

Q9 What have been the main reasons for the formation and development of your cooperative? (Please tick all that apply)

- ☐ Climate change considerations
- ☐ Addressing of energy needs
- ☐ The desire to localise energy production and retain value created at the local level
- ☐ Profit
- ☐ Economic development of local communities
- ☐ Opposition to certain energy resources (e.g., nuclear power or gas from fracking)
- ☐ Other (Please specify) ____

Q10 How are land use issues (such as conflict between renewable energy production and agricultural production, enjoyment of the landscape, biodiversity) in areas where your cooperative has its renewable energy infrastructure primarily addressed? (Please tick all that apply)

- ☐ Statutory land use planning regime
- ☐ Technological advancements
- ☐ Good land use designs and practices
- ☐ Cooperatives making renewables more locally acceptable
- ☐ Cooperatives facilitating dialogues with the local community
- ☐ Other (Please specify) ____
- ☐ Our cooperative has never experienced these problems.

Q11 In the country where your cooperative operates, what legislation on renewable energy cooperatives would assist the development of renewable energy projects? (Please tick all that apply)

- ☐ Protective measures for cooperatives
- ☐ Local energy production targets
- ☐ Financing (e.g., grant programmes, subsidies, a one-stop shop for support)
- ☐ Simpler tax regimes
- ☐ Facilitation of sharing power supply among members/other consumers
- ☐ Technical support and capacity building
- ☐ Other (Please specify) ____

Q12 **Section II. In this section, you will be asked to respond to a statement, to say whether you agree or disagree, and how strongly.**

Cooperatives are more trustworthy than private companies.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

Q13 (You agreed that cooperatives are more trustworthy than private companies.)

For what reasons are cooperatives more trustworthy? (Please tick all that apply)

- ☐ Cooperatives are closer to and care more about the local communities they operate in.
- ☐ Cooperatives are more transparent, open, and accountable than private companies.
- ☐ Cooperatives have the reputation for their moral perspective on doing business.
- ☐ Cooperatives have objectives other than making profits.
- ☐ The members feel more directly engaged in and have direct ownership of the respective project.
- ☐ The members tend know each other better on a personal level.
- ☐ Other (Please specify) ____

Q14 Cooperatives better represent and respond to the interests of the members, employees, and other consumers than private companies do.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

Q15 Your cooperative has experienced difficulties dealing with the local community it operates in.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q16 The democratic process in cooperatives makes them slower in making decisions than private companies.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q17 Involvement in cooperatives is time-consuming, leaving members with less time for other activities outside cooperatives.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q18 In your cooperative, the democratic decision-making process is valued more than efficiency.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q19 Renewable energy cooperatives have difficulty securing enough of the professional and technical expertise necessary for their operations.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q20 Politicisation of climate change issues helps renewable energy cooperatives get more support.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q21 Shared political goals regarding the energy sector between renewable energy cooperatives and the local communities in which they operate encourages better relationships between them.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q22 Cooperatives better represent and respond to the interests of the members, employees, and other consumers than government agencies and political institutions do.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q23 Private companies would have a difficult time adopting the principles of the International Cooperative Alliance (click here to check these principles) in doing business.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q24 (You agreed that private companies would have a difficult time adopting the principles of the International Cooperative Alliance in doing business.)

Which of these principles would private companies have a difficult time adopting?

- ☐ Voluntary and open membership
- ☐ Democratic control
- ☐ Equitable economic participation
- ☐ Autonomy and independence
- ☐ Provision of education, training, and information
- ☐ Cooperation with cooperatives
- ☐ Concern for the respective community

Q25 If cooperatives receive significant external funding, they become beholden to the institutions providing the funding.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q26 Renewable energy cooperatives contribute to the economic development of the local communities they operate in.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q27 (You agreed that renewable energy cooperatives contribute to the economic development of the local communities they operate in.)

In what ways can then renewable energy cooperatives contribute to the economic development of the local communities they operate in? (Please tick all that apply)

- ☐ Lower electricity prices and services costs
- ☐ Reinvestment of returns from renewable energy projects back to the local communities
- ☐ More reliance on local resources
- ☐ Creation of local employment
- ☐ More engagement with local business enterprises
- ☐ Other (Please specify) ____

Q28 Renewable energy cooperatives make the distribution of benefits from renewable energy exploitation more equitable.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

Q29 Members of renewable energy cooperatives are more willing to participate in addressing climate change than non-members.

- Strongly disagree
- Disagree
- Somewhat disagree
- Somewhat agree
- Agree
- Strongly agree

Q30 (You agreed that members of renewable energy cooperatives are more willing to participate in addressing climate change than non-members.)

They are more likely to participate because they feel more personally connected to and directly involved in climate change action.

- Strongly disagree
- Disagree
- Somewhat disagree
- Somewhat agree
- Agree
- Strongly agree

Q31 There are instances in which cooperatives can be seen as “private investors’ club”, where the shares are so expensive that only wealthy people can participate.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q32 People with lower incomes are harder to get to join cooperatives.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q33 (You agreed that people with lower incomes are harder to get to join cooperatives.)

They are harder to encourage because activities within cooperatives leave less time to work for a living.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

Q34 Renewable energy cooperatives improve the local acceptance of renewables in the communities they operate in.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

Q35 (You agreed that renewable energy cooperatives improve the local acceptance of renewables.)

This is because the respective communities benefit directly from the cooperatives' renewable energy projects.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q36 Grid connection can be a problem for renewable energy cooperatives.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree

Q37 (You agreed that grid connection can be a problem for renewable energy cooperatives.)

In what specific ways may grid connection be a problem for renewable energy cooperatives? (Please tick all that apply)

- ☐ Grids can be saturated.
- ☐ There are backlogs in installing new infrastructure capacity.
- ☐ The infrastructure setup makes it difficult to sell electricity.
- ☐ Unfavourable regulations make it difficult to share power generated among members/other consumers.
- ☐ The geography makes grid connection difficult.
- ☐ Other (Please specify) ____

Q38 The country where your cooperative operates in has largely adopted the Renewable Energy Directive Recast (RED II).

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Agree
- ◯ Strongly agree
- ◯ Don't know
- ◯ The country where my cooperative operates in is not an EU Member State.

Q39 **Section III. Please use the space provided to express your other views, comments, things you want to clarify, or any other issue you might want to raise concerning renewable energy cooperatives.**

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Appendix F: Fisher's exact and chi-square tests

1. Fisher's exact test on Questions 15 and 3 in Appendix E.

		Q15: Your cooperative has experienced difficulties dealing with the local community it operates in.						
		Total	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
Q3: What is the scale of your cooperative?	Total	32	3	8	3	12	6	0
	Town/city-level	4	0	1	0	1	2	0
	County/municipal-level	2	1	0	0	1	0	0
	Regional/national-level	22	2	7	2	8	3	0
	Other	4	0	0	1	2	1	0

Two-tailed p-value: **0.63**

Observed values			
	Disagree	Agree	Total
Small	3	7	10
Large	11	11	22
Total	14	18	32

One-tailed p-value: **0.25**
Two-tailed p-value: **0.45**

2. Fisher's exact test on Questions 19 and 3 in Appendix E.

		Q19: Renewable energy cooperatives have difficulty securing enough of the professional and technical expertise necessary for their operations.						
		Total	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
Q3: What is the scale of your cooperative?	Total	32	2	5	5	8	6	6
	Town/city-level	4	0	0	0	1	1	2
	County/municipal-level	2	0	1	1	0	0	0
	Regional/national-level	22	2	4	3	7	5	1
	Other	4	0	0	1	0	0	3

Two-tailed p-value: **0.06**

Observed values			
	Disagree	Agree	Total
Small	3	7	22
Large	9	13	10
Total	12	20	32

One-tailed p-value: **0.43**
Two-tailed p-value: **0.70**

3. Fisher's exact test on Questions 31 and 23 in Appendix E.

		Q31: There are instances in which cooperatives can be seen as "private investors' club", where the shares are so expensive that only wealthy people can participate.						
		Total	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
Q23: Private companies would have a difficult time adopting the principles of the ICA in doing business.	Total	32	4	9	4	8	6	1
	Strongly disagree	0	0	0	0	0	0	0
	Disagree	1	1	0	0	0	0	0
	Somewhat disagree	7	1	4	1	1	0	0
	Somewhat agree	6	1	1	1	2	1	0
	Agree	12	0	2	2	4	3	1
	Strongly agree	6	1	2	0	1	2	0

Two-tailed p-value: **0.72**

Spearman's rho: **0.35**
Spearman's rho p-value: **0.04**
Kendall's tau-b: **0.30**
Kendall's tau-b p-value: **0.04**

Observed values			
	Disagree	Agree	Total
Not Difficult	7	1	8
Difficult	10	14	24
Total	17	15	32

One-tailed p-value: **0.03**
Two-tailed p-value: **0.04**

4. Chi-square test on Questions 25 and 18 in Appendix E.

		Q25: If cooperatives receive significant external funding, they become beholden to the institutions providing the funding.						
		Total	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
Q18: In your cooperative, the democratic decision-making process is valued more than efficiency.	Total	32	2	5	4	17	4	0
	Strongly disagree	0	0	0	0	0	0	0
	Disagree	4	1	2	0	1	0	0
	Somewhat disagree	7	1	0	2	4	0	0
	Somewhat agree	7	0	1	2	3	1	0
	Agree	12	0	1	0	9	2	0
	Strongly agree	2	0	1	0	0	1	0

Chi-square test statistic: **22.18**
p-value: **0.137**

Spearman's rho: **0.43**
Spearman's rho p-value: **0.01**
Kendall's tau-b: **0.38**
Kendall's tau-b p-value: **0.01**

Observed values				Expected values	
	Disagree	Agree	Total	Disagree	Agree
Not more valued	6	5	11	3.78	7.22
More valued	5	16	21	7.22	13.78
Total	11	21	32		

Ratio of squared differences		
	Disagree	Agree
Not more valued	1.302	0.682
More valued	0.682	0.357

Chi-square test statistic: **3.02**

p-value: **0.08**

Appendix G: selected interview transcripts

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