Perspective

How could Finland promote renewable-energy technology innovation and implementation?

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Abstract

Several major market failures are hindering renewable energy production. Probably the most significant one of these are negative externalities. Another issue hindering renewable energy production is low technological and commercial maturity. These technologies might not become commercially viable in the near future without state intervention. This study aims to analyse Finnish energy policy based on current legislation related to renewable energy production and budget policy related to renewable-energy subsidies. This study shows that the polluter-pays principle is implemented quite well in Finland due to the emissions trading scheme and taxation. Still, this principle is not entirely implemented in electricity production as electricity tax is not based on the carbon intensity of the fuel used, but rather on who uses the electricity. National subsidy policies focus on a short-term increase in renewable energy production as most subsidies are production subsidies granted through a bidding process, making these subsidy policies partly technology-neutral. These policies do not take into account long-term needs for energy policy as much as they could.
Introduction

Finland has set a target for a 39% reduction in greenhouse-gas emissions by 2030 and an 80–95% reduction by 2050 [1]. The European Parliament has also made a resolution that the EU should lead the way to climate neutrality and achieve that by reaching net-zero greenhouse-gas emissions by 2050 [2]. This can be seen as an opportunity, as the transition will bring significant opportunities for new businesses and technological development [3]. Technological development is seen as key to reducing greenhouse-gas emissions and therefore technology-specific strategies are needed to achieve these climate-neutrality targets [4]. Achieving net carbon neutrality requires significant net investments annually in the EU for several decades [5]. These climate-neutrality goals are strongly tied to technological development: annual cost-reduction goals are set to be higher during years closer to 2050 as a broader set of cost-effective technologies are anticipated to become available [6].

If technological development is not as fast as expected, the socio-economic burden of greenhouse-gas emissions will be much more significant. This burden is often referred to as greenhouse-gas emissions’ social cost or the ‘social cost of carbon’ [7]. This social cost is difficult to calculate as there are several factors to be taken into account, which makes the models extremely complex [8]. Still, traditionally, the definition includes damage that global warming causes, like agricultural damage and damage from sea-level rise, but also includes positive effects from warming, like increased agricultural output [9]. There are several models that can be used to estimate costs but, as all these models have several restrictions, they are only indicative for policy advice [7]. Therefore, national and EU-level technology policies are in a key position for reaching greenhouse-gas targets and reaching them cost-efficiently. At the national level, carbon-neutrality strategies keenly follow technological development and are adjusted based on the level of the current technology [10].
Economic efforts to achieve carbon neutrality are strongly linked to the cost-effectiveness of several renewable-energy technologies [11]. This requires the innovation and implementation of new technologies, as well as these technologies becoming commercially viable. In Finland, the development of new energy-efficient technologies, renewable-energy technologies and business models is seen as a way to promote the national economy and increase welfare nationally [12]. This is based on the assumption made by the European Commission that current investments for reducing greenhouse-gas investments will determine the future competitiveness of an economy in the following decades [13]. In Finland, investments in climate technology and low-carbon production are seen as being key to a sustainable economy in Finland, sustainability covering in this case an ecologically, socially and financially sustainable economy [14].

This article focuses on several renewable-energy-production technologies and policies that can promote those technologies. At least from the policymaker’s viewpoint, other benefits might be regional effects or increased employment [10]. One of these renewable-energy-production technologies is offshore wind power. Offshore wind power has higher investment costs than land-based wind power. Still, offshore wind power installations generate more electricity due to better wind conditions and, more importantly, create less conflict with interest groups, e.g. neighbours, than land-based wind power installations [15]. Other major renewable-energy technologies that have potential in Finland are solar and biomass energy production [16]. This study does not compare the regulative or economic contexts of different energy policies unless otherwise specified. This means that policies used in different kinds of market-oriented economic systems will be included in this study. However, their usability will be evaluated in the ‘Conclusions’ section if recommendations are based on them.

This article does not cover technology-specific research unless specifically mentioned. Instead, this article focuses on issues that come from energy markets and low technological maturity in general. Obstacles constraining renewable-energy technologies from entering the energy market can be viewed from three perspectives: (i) the research, development and deployment perspective, (ii) the market-barrier perspective and (iii) the market-transformation perspective [17]. This article focuses on all those perspectives. The third perspective will be covered by viewing the market and policy incentives for energy and how to promote market transformation.

This article focuses only on the phase in which new technology is already developed. Several developed technologies might still require test sites to increase technological maturity or increase production to scale up to become commercially viable due to economics of scale or technological maturity issues. To clarify, this study does cover inventions that have not been tested and thus have not become innovations, but not new inventions [18]. Therefore, research and development (R&D) issues, such as innovation environment cases and R&D subsidies, are not covered in this study. This article focuses on possible actions taken at the national level, covering legislation and using the national budget. The use of the budget covers both taxation and subsidies. Therefore, this article does not cover cases in which companies or other organizations could improve their technological development by changing their policies. This article does not cover general economic measures aimed at boosting the economy as a whole, such as cutting taxes or general fiscal measures. This article covers only measures that could be implemented in Finland. Technological and commercial issues that are universal are assumed to occur in Finland, and policy solutions chosen in other countries are assumed to have a similar effect in Finland unless otherwise stated. One central viewpoint that is not deeply covered in this article is that countries compete on renewable-energy investments, which reduces policy effectiveness [19]. This has partially led to the subsidy race as state-aid rules have been relieved to increase renewable energy production and investments [20].

This study aims to provide information on how policymakers could change current policies, legislation and budgets to promote new renewable-energy technologies so that they become commercially viable more quickly. This study answers two research questions:

(i) Which are the key policies to promote new renewable-energy-production technologies?
(ii) How could Finland promote new renewable-energy technologies so that they become commercially viable?

Research question (i) is answered in Section 1. The answer is based on a literature review. The literature review is focused on previous research on market failures of new technologies, especially in renewable-energy technologies and renewable energy production. The other part of the literature review focuses on previous research on how different policies will affect technologies and businesses that are not yet commercially viable due to low technological maturity. Research questions are linked so that the answer to the first research question will give several base assumptions that the solutions of the second research question will be based on. Research question (ii) will be answered in Section 2 based on several methods. A law and economics method will be used to determine how current policies affect the commercial viability of new renewable-energy technologies in Finland. To be specific, the used method is a normative theory of regulation, focusing on analysing how particular regulation affects achieving specific goals [21]. The practical legal dogmatic method is used to analyse current legislation and restrictions set by it without further systemizing it [22]. The last section of this study includes conclusions and discussion.
There exists relatively recent literature by Pilpola and Lund [23] on how different energy-development scenarios would affect energy markets in Finland. Their research implies that there are several risks in the case of dominance of a few energy sources. However, their paper does not address the impact of national energy policies. There are other studies from Finland addressing issues in Finnish energy policy [24] or risks that development in energy markets poses without policy intervention [25]. However, these studies are from the early 2010s, which means that the energy system has drastically changed since the EU emissions trading scheme (ETS) is forming energy markets even more. Several renewable-energy technologies have become more commercially viable and the structure of energy markets is changing. A study about Finnish national energy policy in the current era in energy policy would therefore add to the existing literature.

There are several studies on how technology-neutral energy policies can generate undesired outcomes: Carton [26] has studied how the principle of technology neutrality has led to biomass combustion in the Netherlands, but otherwise technology-neutral energy policies and their impacts in specific market areas have not been discussed extensively lately. Technology neutrality itself has gained much attention in the literature. For example, Verbruggen and Lauber [27] have assessed how renewable-electricity support instruments affect the energy markets, and they have assessed how different policy instruments affect different technologies with different technological and commercial maturity. In the case of negative externalities and energy policies, there is an excessive number of previous studies. It has been recently proposed by Paukku [28] that in the EU and Finland, the primary tool to prevent climate change is not removing externalities from fossil energy production, but giving incentives to produce more renewable energy via subsidies and other promoting policies. This study aims to extend the literature that assesses whether removing externalities has actually lost popularity in energy policy.

There are three further sections in this study. The Section 1 contains a literature review on energy-policy issues. Four issues are addressed: externalities, energy subsidies, technology neutrality and uncertainty. Externalities, technology neutrality and uncertainty are addressed as they have a crucial role when designing energy policy. Literature on energy subsidies is also addressed as its effects are widely analysed in the literature and it can be used to address several challenges in energy policy. Based on this literature, two aspects of Finnish energy policies will be discussed in Section 2: energy taxation and energy subsidies. In Section 2, the Finnish energy policy is evaluated through its ‘hard’ tools, meaning practically laws and the national budget, as they are the main tools for how the policymaker can affect energy markets. Policy documents and other official sources will be used to determine the goal of a certain policy as well as to determine the general goals of the Finnish energy policy.

1 Energy policy and new energy technologies

1.1 Externalities

The invisible hand of the market might not make environmentally friendly innovations succeed commercially. Several market failures force a state to make market interventions to promote technologies and businesses that generate more welfare, taking into account market effectiveness, environmental issues, sustainability and even social issues [29]. The market failure that is mostly ‘responsible’ for climate change is externalities [30]. Externalities have been the main barrier in preventing technologically mature renewable-energy technologies from entering the energy market [17]. In EU policy, the existence of market failure is agreed to be so obvious that market failure in the renewable-energy market is presumed to exist until otherwise proven [31]. Sometimes externalities are divided into positive and negative externalities. Positive externalities mean that one actor’s actions positively affect other actors’ positions [32]. A negative externality is one feature of the ‘tragedy of commons’ [33]. In this study, the term ‘externality’ refers to a negative externality unless otherwise stated.

Externalities mean that certain environmental costs of production are not reflected in the market cost of the commodity, which means that a customer does not have to pay the full price for the commodity. Still, the price is subsidized by others that bear the cost of external impact [17]. On a more theoretical point, externalities can be defined in the following way: external effects are present whenever a firm’s production function depends in some way on the amounts of the inputs or outputs of another firm [34].

The commercial viability of renewable-energy technologies has been heavily linked to market distortions in the energy sector, mainly externalities, but also including subsidies for fossil fuels [35]. Economic efficiency prescribes that externality costs should be apportioned to their causes [36]. This internalization must be done by the government, as private actors have no incentives to do so [37]. This can be done using the so-called Pigouvian tax, which means tax set at the level at which all pollution costs are assigned to the goods or product produced [38]. There are also other possible ways to internalize externalities, but their advantages and disadvantages in energy production are partly unclear [37]. Internalizing externalities is not alone sufficient policy to achieve energy transition as there are energy users who undervalue energy costs and therefore are less likely to react to rising energy prices [39]. This suggests that a combination of policies is required to achieve an energy transition.

The role of externalities in policies has been stated quite often and at relatively high levels; e.g. the EU climate...
policy has been based on the idea of dealing with externalities. The European Parliament has given a resolution which states that externalities that distort competition are major factors preventing investments for areas beneficial for the environment and climate policy, others being public subsidies for environmentally harmful action [40]. The basis of EU policies has been that, despite taxation and ETS, a residual market failure remains in the energy markets due to externalities [31].

Due to the need to assign the costs of pollution to polluters, the so-called polluter-pays principle has been the main principle in environmental law and policy for several decades [41]. This policy has been acknowledged in several high-level policy documents, like the Rio declaration and Article 191 of the Treaty on the Functioning of the European Union (TFEU) [42]. This principle is also mentioned as the main principle in several recent policy papers [43]. If the polluter-pays principle is applied to fossil fuels, it means that their use is taxed based on harmful environmental effects, mostly CO₂ emissions. This could lead to two things compared to a baseline scenario in which tax is not applied: an increase in demand for energy sources where tax is not applied and a medium-term decrease in overall energy demand [44]. The latter would also be beneficial for achieving climate targets, and it could also mean more energy-efficient technologies and processes. Both effects combined lead to reduced CO₂ emissions when the price of fossil fuels increases due to markets or taxation or other means [45].

There is a relatively strong consensus that the price elasticity of energy demand exists, and it is negative, meaning that when energy prices rise, energy consumption decreases. However, the magnitude of elasticity varies greatly depending on the assumptions and models used [46].

Several energy-intensive sectors are quite vulnerable to the cost increase that ETS causes due to international competition and high energy share in total costs [47]. The European Commission has estimated which sectors could suffer heavy damages and listed them as energy-intensive sectors [48]. Previous studies show that the increase in energy prices does not affect the price of end products on a larger scale. This was argued to be due to a small energy share in the total cost [49]. In the EU, the Commission has estimated that it is impossible to pass increasing energy costs onto product prices in a few sectors without significant market-share loss [50]. Therefore, there are political needs to compensate energy-intensive sectors. This is economically justified by the carbon-leakage reasoning. The Commission uses the term 'carbon leakage', meaning 'an increase in global greenhouse-gas emissions when companies shift production outside the Union because they cannot pass on customers' cost without significant market share loss' [50]. There are several estimations about how large this carbon leakage is in different carbon prices. Still, it is evident that increasing carbon pricing and the carbon footprint of imports are likely to increase [51]. Based on the draft for new guidelines, this EU policy will not change in the near future [52].

Previous literature suggests that it is an economically effective energy policy to refund part of funds collected from increased energy taxes or ETS for industries that suffer most from increased energy prices [53]. In Finland, the sectors that are evaluated to be at risk of losing market shares due to the effect of the ETS on electricity prices are defined by the energy cost of unit value added. According to the tax act for electricity and other fuels 8 a §, ’laki sähkön ja eräiden poltroaineiden valmisteverosta (1260/1996)’, from now on Act (1260/1996) 8 a §, if the energy taxes that the company pays or that are included on energy goods that they bought are >0.5% of the company’s unit value added, the company is eligible to have these taxes partly refunded. The estimated yearly cost of this energy subsidy is 235 M€ [54]. This subsidy is based on combining the polluter-pays principle with competitiveness concerns [55]. These taxes and refunding part of taxes back are coming to an end in Finland in upcoming years. These subsidies for energy-intensive industries are harmful to the environment. Therefore, they are abolished, but the electricity tax is simultaneously cut down to compensate for the same amount of money to all industries using electricity [56].

Several economists view a carbon tax as the best tool to effectively decrease CO₂ emissions [57]. However, the role of the polluter-pays principle compared to other policy tools in EU policy has been declining for two decades as it has not been seen as the best solution for current environmental issues due to the harm it causes to international competitiveness without other complementary policy instruments [28]. Although the EU ETS promotes polluter-pays and carbon pricing, Member States are allowed to promote renewable energy production and energy transition with state aids, which is not traditionally compatible with the polluter-pays policy [28]. The decline of the principle started late in the 1990s in order to implement measures for protecting the environment going beyond existing mandatory requirements or preserving the competitiveness of the industries when imposing new environmental requirements [58]. A carbon tax, which represents the polluter-pays principle, is not considered a viable solution to be implemented nationally, as it strongly affects international competition and is politically unpopular [59]. The EU Commission has based several policies based on this view; e.g. the ETS scheme has been restricted for several energy-intensive sectors. In addition, the EU has set minimum energy tax levels for certain energy products, like coal and natural gas, to reduce CO₂ emissions [60]. However, even if the Commission proposed so, the energy taxation in the EU is not linked to CO₂ emissions as some Member States strongly opposed it based on their worries about their competitiveness [61].

Externalities can also be solved without meddling with pricing. It is quite common that states have adopted a
regulatory framework that forces some market players to buy some renewable energy. In Europe, such systems have been implemented in Germany, where network operators are required to purchase a certain amount of renewable energy and the producers are chosen by an auctioning process [62]. Probably the largest purchase quota system has been adopted in China, which has been increasing renewable-energy supply and demand rapidly [63]. Although this policy is efficient for increasing renewable energy production, it is not alone sufficient for decreasing greenhouse-gas emissions [64].

Taxation is not the only way to address externalities; they can also be addressed with subsidies [65]. The national decision margin for the taxation of carbon emissions in energy production might be relatively small as EU policies are more focused on subsidizing than increasing costs with taxation, the ETS or other tools [66]. Due to differences between several Member States, it is unlikely that energy taxation will be harmonized to be more CO₂-based in the future. As the polluter-pays principle has been partly forgotten due to its adverse effects on competitiveness [28], other means to promote renewable energy production need to be analysed. Renewable energy production will increase when renewable-energy-production profits are higher than profits from fossil energy production. If the price for producing fossil energy cannot be raised higher than renewable energy production in a politically acceptable way, the price for producing renewable energy needs to be lowered. This can be achieved through a subsidy policy.

1.2 Energy subsidies

Internalizing the negative externalities might not be a sufficient tool to achieve energy transition, and so complementary tools are often used. As increasing fossil-fuel costs is politically unpopular due to its adverse effects on international competitiveness, politicians might be willing to focus more on subsidy policies. Another reason that might affect implementing the polluter-pays principle is the lobbying power of fossil-fuel industries. However, this is likely to change when the economic significance of renewable energy production increases [67]. Previous studies also suggest that price increases are not an effective way to develop new technology and markets, but subsidies are also needed [68]. It has also been stated that price increases are not an effective tool alone, but they need other supportive policies to achieve energy transition effectively [39]. Due to the nature of EU state-aid rules, the subsidies in Finland can be divided into investment subsidies, production subsidies and other subsidies [69]. The ‘other subsidies’ group covers subsidies without long-term operational significance, such as subsidies for labour costs in one-time projects and small de minimis subsidies. State aid is a widely used and accepted tool to correct market failures, especially negative externalities [70]. In the previous literature, state aid is seen as an effective tool to correct market failures [71]. In the EU, the economic justification for granting aid is correcting market failures [72], although the role of this reasoning had been diminishing during the 2010s [73]. State aid is seen as an acceptable policy solution against market failure in energy markets as taxation and the ETS have not fully internalized all greenhouse-gas-emission costs for energy prices [31].

The effects of renewable-energy subsidies are widely analysed in the literature [57]. An important note is that subsidies are not alone a satisfactory permanent solution: as long as the costs of greenhouse-gas emissions are not included in the fossil-fuel prices, renewable-energy subsidies will generate significant welfare losses due to their high price [74]. A subcategory of energy subsidies, namely tax incentives, has not been an effective way to increase renewable energy production, being a rather expensive and unfocused tool [57]. Tax subsidies are hard to design to effectively increase environmental protection due to their effectiveness depending on the cost structure and cost-effectiveness of produced goods [75]. Poorly designed energy subsidies can cause excessive competition, overcapacity and state financial stress [76]. However, renewable-energy subsidies are a cost-efficient tool when addressing market failures related to technology [74]. Renewable-energy subsidies might, in some cases, be the only tool to avoid high social costs when the price of fossil energy rises [77]. Policy recommendations for energy subsidies recommend subsidies to be decreasing over time, competitive and reasonable [76]. These points from previous literature can be synthesized as: renewable-energy subsidies should be grants rather than tax advantages. They should be designed to promote energy technology development. They should be decreasing over time, and they should encourage competitiveness and effectiveness.

The profitability of renewable energy had been long dependent on public subsidies like feed-in tariffs, tax credits and power purchase agreements [59]. Even now, renewable energy production in Finland requires production subsidies to become more common [78]. Significant attention had been given to production subsidies, although the role of investment subsidies could be substantial for some technologies. From a theoretical viewpoint, compared to taxation and operating subsidies, investment subsidies are not a cost-efficient tool to assess problems where costs and prices are continuously changing. They cannot be efficiently adjusted to the equilibrium level when prices and costs vary [79]. However, previous studies from Finland suggest that operators prefer investment subsidies over production subsidies and tax relief, as investment subsidies are seen as more stable and reliable for long-term investments as production subsidies, and tax levels can be easily changed when policymakers change. However, these results are partly controversial to findings in other EU countries [80].

Energy-consumption subsidies are an effective tool for changing energy-consumption patterns [81].
Energy-consumption subsidies are often used in order to improve the situation of those consumers with low purchasing power [82]. Consumption subsidies might not be effective in promoting technological change in renewable energy production [83]. Nevertheless, consumer subsidies do still play a significant role in the energy transition. First of all, there are several consumption subsidies for fossil fuels, which increase their consumption. Due to this, removing those subsidies would decrease their consumption at least locally, although possibly affecting the global market price of those fuels and thus increasing their consumption somewhere else [84]. The second reason is that they can help consumers with lower purchasing power to overcome energy transition and thus increase the political acceptability of those subsidies [82].

1.3 Technology neutrality

One viewpoint for energy policy is that policymakers cannot pick a technology that will generate the most welfare to society, but they have to promote all technologies aiming for similar goals [15]. A technology-neutral policy can be defined as a policy that sets goals but does not specify the exact means of how to achieve them [85]. A technology-neutral-policy approach is stated to be more effective than policies promoting one technology in some instances, such as vehicles using alternative fuels [86]. There are two goals for technology neutrality. The first one is cost-effectiveness, as the most effective technology should be the one delivering the results [87]. This goal is based on the assumption that different technologies can be unproblematically equated under a single market mechanism, leading to cost-effective equilibrium [26]. The other one is that the technology-neutral approach promotes technological development and creates positive externalities [85].

Due to its cost-effectiveness, it has been stated in Finnish national energy strategies that financial-steering instruments should be based on technology neutrality and the ranking of economic priorities [88]. There are, however, high risks related to technology neutrality. If a few energy sources gain dominance, the energy transition will become much more costly and harder to achieve [23].

Despite its name, technology neutrality does always affect different technologies in different ways, and therefore true neutrality might not be achievable in any policy [89]. As technology-neutral policies aim to favour some set of technologies put on the level playing field, some technologies in this set might be more advantageous than others and therefore create excess profits [90]. Even if the maturity levels of the technologies are the same, technology neutrality tends to favour different products or services over others. In addition to this, technology neutrality tends to favour lower-quality solutions that might have less long-term potential but high market readiness [27]. When a lock-in effect might occur, the regulator should be careful when adopting a technology-neutral approach [91].

In most cases, the reason for giving up a technology-neutral-policy approach is promoting technologies that are seen to have the greatest long-term potential [27]. Due to this, EU policies are, in principle, technology-neutral but, in some instances, designed to favour certain technologies due to their greater long-term potential [92]. On the other hand, giving up a technology-neutral approach even partly has significant disadvantages. If a policy focuses on a particular technology or technologies, this will hinder and create uncertainty for developing all other related technologies [93]. Different technologies have different sustainability issues, advantages and disadvantages, making it undesirable to promote one technology over others, regardless of how technologically neutral the policy favouring this particular technology is [67]. One practical example of this is wind power, which has extremely fluctuating energy production and requires other energy sources or energy storage to balance production and demand.

A technology-neutral approach for promoting renewable energy might not lead to the best results. Regulatory actions needed to encourage technology depend highly on technological maturity [94]. There is a risk in all technology-neutral policies that technology with the greatest short-term potential will emerge victorious at the cost of technology with greater long-term potential [26]. If all renewable-energy-production technologies are promoted in the same way, there is no guarantee that technology or technologies that will emerge victoriously will generate the most welfare to society. In addition to this, a poorly designed technology-neutral policy might lead to a case in which, more generally, more harmful technology emerges victorious [26]. One reason for this is that technology neutrality tends to favour more mature technologies [27].

1.4 Uncertainty

Another issue for renewable-energy development is uncertainty. The role of uncertainty in the regulatory environment has been recognized as one factor that significantly affects the investment decisions of all economic actors [95]. As renewable-energy investments for developing technologies are high-risk investments, governmental support is often needed to speed up these investments [77]. Higher uncertainty affects investment decisions more, and there are several factors increasing the uncertainty of renewable energy production. To promote renewable energy efficiently, policies need to be stable and long-term [77]. If investment would have substantially less value under an alternative regulatory scheme, investments are greatly hindered [96]. Due to this, several subsidy programmes are set for a long and fixed time to ensure investment profitability [97]. In addition to policy-related uncertainty, the policymaker can affect how other uncertainties, like market-demand uncertainty, affect the investment decision. This can be done using policy tools to increase the profitability of an
investment or to reduce uncertainty from demand, such as increasing the market demand [98]. Stability in renewable-energy policy boosts the technological development and viability of renewable-energy-production technologies [99]. Even if economists often prefer adjusting measures based on the market situation, empirical evidence shows that even too frequent subsidy or tax-evaluation processes effectively hinder new investments [100].

Uncertainty can be linked to a policy or policymaker. Previous studies suggest that in regions with a history of substantial policy changes, introducing long-term policies does not boost investment in regions with more stable policies [96]. This might be one major explanatory factor for why several investors in Finland prefer investment subsidies over production subsidies.

One key tool to reduce risks related to renewable-energy investments and increasing technological development is public financing. As public actors can take risks independently of the business cycle and take into account the public-good viewpoint, the role of public finance for developing new technology further can be significant [59]. Public finance has previously played an important role in mobilizing private cash flows for renewable energy, and the role is not diminishing [101]. In addition to large energy-production sites, the role of public finance can also be remarkable in small-scale on-site production, which would not be effectively financed through credit markets [102]. Furthermore, potential greenhouse-gas-emission reduction from publicly funded alternative-energy projects is seen as relatively high [103]. Thus, public finance can significantly boost technological development with high risk but also high technological, environmental and social relevance [104].

One other issue affecting renewable-energy development is the administrative process, especially the environmental permit system. The goal of the traditional environmental regulation has been to minimize the harm caused to the environment and people, not to promote different projects [15]. In other countries, environmental regulation demands are even considered to prevent change in the energy system due to hindering renewable-energy projects [105]. In Finland, these administrative issues are considered to be greater in low-maturity technologies developing quickly because technology might develop further during the administrative process or during the operation of the site, and the permit process is too stiff to adapt to these technological changes [15]. In recent history, the permit process has been developed to make it faster and cheaper to obtain different permits while still maintaining a high level of environmental protection [106]. However, previous studies from Finland also suggest that local environmental permit officers’ lack of knowledge about new renewable-energy technologies and lack of guidance from officials hinder especially small-scale renewable-energy projects governed by municipal environmental permit officials [107]. Furthermore, other studies from Finland suggest that the permit process might create unexpected results when permit requirements for a particular type of action are not yet established at a national level [108].

2 Current policies and legislation

2.1 Energy taxation

Current renewable-energy-promotion policies can be divided into two groups: energy taxation and subsidy policy. The EU regulation highly affects both policies, but although Europeanization has highly influenced environmental and energy policy, national policymakers still make the final decision when it comes to renewable-energy promotion [109]. Europeanization means that national policies and legislation become more similar to EU policies and regulation [69]. As taxation cannot be addressed without also covering subsidy issues due to the EU state-aid regulation [110], this section begins with tax policy and then moves forward to subsidy policies. At the end of this section, a brief note about administrative policies and issues is discussed.

It is possible to implement the polluter-pays principle to energy taxation in the EU countries, which means that externalities can be taken into account in energy taxation. The EU energy tax directive sets only minimum tax levels for specific fuels, which are loosely based on the carbon content of the fuel [111]. These minimum levels are barely applicable in Finland as national taxes are much higher; e.g. the minimum tax required by the energy directive for gas oil used for heating is 2.1 cent/l in EU [112] and Finland has set the correspondent tax level for fuels under CN code 2710 for 75.28 cent/l [113].

Energy taxation in Finland has been primarily based on environmental viewpoints since 1989 when the scope of energy taxation was widened to reduce environmental damage caused by certain energy sources [114]. In addition to this, energy taxation has been based on the CO₂ intensity of the energy source since 1990 [115], long before such policies were suggested and abolished due to political reality [61]. Since 2018, carbon taxation has not been based on how much CO₂ is released while burning hydrocarbon fuels, but on life-cycle greenhouse-gas emissions of energy sources. According to the European Commission, the previous taxation system gave an unfair advantage to certain fuels, and therefore it had to be altered [116]. This means that externalities are taken into account in the taxation, but the extent to which this is done needs to be further evaluated.

In Finland, the general act for excise taxation is ‘valmisteverotuslaki (182/2010)’; however, this act covers mostly administrative issues, and the actual tax rules for energy taxation are in special laws. There are two of these particular laws governing renewable-energy taxation in Finland. One act is for liquid fuels, ‘laki nestemäisten polttoaineiden valmisteverosta (1472/1994)’, from now on Act (1472/1994), and Act (1260/1996) is for electricity and other fuels. The base principle for taxing fuels is similar
to those for liquid and other fuels. Three different taxes are carried from these fuels: (i) energy tax based on the energy content of the fuel—the more energy gained by using the fuel, the higher the tax is; (ii) carbon tax based on the life cycle of the CO₂ emissions of the fuel; and (iii) strategic stockpile fee to cover costs from funding strategic stockpiles of these fuels [117]. This energy taxation system, which is partly based on taxing carbon content and partly energy usage, is similar to the one that Sweden has adopted, which is stated to be a compromise between environmental and fiscal goals [118].

A carbon tax is one implementation of the polluter-pays principle. For other than liquid fuels, the carbon tax is the largest tax component [119]. The carbon tax is around one-third of the overall tax from liquid fuels, while the energy tax is the largest tax component [119]. The only hydrocarbon fuels that are free from carbon taxes are biofuels that meet sustainability criteria set in the RES Directive [120] according to the ‘Laki biopolttoaineista ja bionesteistä (393/2013)’ act and that are made from waste according to Act 1472/1994 2 § paragraph 27 b. This is due to the fact that biowaste would decompose and produce greenhouse-gas emissions in any case, and using this waste for energy production does not increase overall greenhouse-gas emissions [121].

This taxation system means that using CO₂-intensive fuels is more expensive, which is a straightforward implementation of the polluter-pays principle. As taxation is also based on the life-cycle emissions of fuels, the CO₂ emissions and overall damage by fuels are taken into account sufficiently. Of course, taxation also has fiscal needs and therefore part of the taxation is based on the energy content of the fuel. Also, a sufficient level of a carbon tax could be discussed. The Organisation for Economic Co-operation and Development (OECD) has estimated that a sufficient carbon-price level could be between 30 and 60 €/t [122]. The current CO₂ tax for heating fuels used in energy production is 53 €/t in Finland [116]. The tax for CO₂ from traffic fuels is currently 77 €/t [123]. According to the OECD estimation, the Finnish carbon tax for fuels is close to the social costs of carbon. It needs to be noted that this is not a country-specific estimation, and there are no estimations about the social costs of greenhouse-gas emissions in Finland. Therefore, there currently exists no better measure to be used in policy analysis of carbon pricing. As all carbon-pricing tools are quite sensitive to uncertainty related to climate-change models, their usage in policy advising is limited [7].

On the other hand, the polluter-pays taxation has been implemented only partly in the Finnish energy policy. The carbon tax is not carried from fuels used for electricity production [124]. This is due to avoiding overlapping policy with the EU ETS [125]. It is also required in the EU energy directive [126]. A similar policy has been implemented in Sweden [127]. Norway has also adopted a similar energy taxation structure where a carbon tax is carried from all mineral products, except those subject to the EU ETS [128]. One-quarter of the energy consumed in Finland is consumed in the form of electricity [129]. This means that a significant part of electricity consumption is under the EU ETS and not under energy taxation. Instead, electricity taxation is based on how electricity is used: industrial use has a significantly lower tax rate—0.703 cents/kWh versus 2.253 cents/kWh of other uses [130]. The level of tax for industrial users will be lowered in the near future due to the goal to abolish energy subsidies for energy-intensive industries [56]. This is stated to increase the role of the polluter-pays principle in energy production [131].

Even if electricity production is not carbon taxed, it is included in the EU ETS [132]. This means that all energy-production installations that exceed certain rated thermal input must have greenhouse-gas-emission permits, and they must surrender allowances equal to the total emissions of the installation yearly [133]. The EU ETS is a cap-and-trade system. ‘Cap-and-trade’ means that the maximum number of emission allowances decreases each year and firms can trade allowances with each other [134]. Due to the ETS directive, it is forbidden to allocate free allowances for electricity production, which means that the industry must pay for all CO₂ emissions produced. Thus, the polluter-pays principle is applied in the whole EU [135]. However, the price level of emission allowance is relatively low, at between 20 and 35 €/t in 2020, which is quite a lot below the OECD recommendation. Even though the OECD recommendation can be criticized, several studies and official sources state that the emission-allocation price might be too low, especially compared to the target of 30 €/t anticipated when the system was adopted in 2008 [136].

### 2.2 Energy subsidies

Energy subsidies can be used to compensate that part of the energy policy that compensating externalities do not cover. Energy subsidies have a crucial role in Finnish energy policy. Energy subsidies are mentioned in the government programme, just after tax measures. According to the programme, subsidy programmes will transfer from operating aids to investment and research aids for new energy technologies [137]. State-aid regulation is heavily Europeanized, as a general prohibition of state aid is included in the founding treaties of the EU [69]. TFEU article 107(1) states that state aids are forbidden unless otherwise stated later on in the same article. Most of the environmental aids are granted based on the exception set in article 107(3)(c) in the TFEU [138]. This article states that aid to facilitate the development of certain economic activities or certain economic areas, where such aid does not adversely affect trading conditions to an extent contrary to the common interest, may be compatible with the internal market. The Commission guidelines on state aid for environmental protection and energy define which aids the Commission agrees to be compatible with the internal market and therefore does not prevent granting them. Section 3.3 of these guidelines includes requirements for
investment and operating aids for renewable energy production. In addition to this, the Commission has given block exemption regulation, which enables granting aids fulfilling certain criteria without notifying the Commission first [139]. National subsidy programmes for renewable energy are based on these guidelines and block exemption regulation [69].

According to paragraph 119 of the guidelines, investment aid for renewable energy production can be granted if the general requirements stated in Section 3.2 for investment aid are met. One major requirement for investment aid is the maximum aid intensity stated in paragraphs 77–80 of the guidelines and annex 1 of the guidelines. The maximum aid intensity for renewable energy production is 45–65% of investment costs, based on how big the receiving company is. Therefore, the maximum intensity for aid granted through the bidding process is 100%.

The general act for granting state aid in Finland is 'Valtionavustuslaki (688/2001)'. Two governmental decrees were given to specify this law. The decrees are 'Valtioneuvoston asetus energiatuotteen myyntimäiseen yleisistä ehdosta vuosina 2018–2022 (1098/2017)' and 'Valtioneuvoston asetus uusiutuvan energian ja uuden energiateknologian investointituen myyntimäiseen yleisistä ehdosta (145/2016)'. In 2020, 60.75 M€ could be granted for investment aids, while the maximum intensity was 30/40% of the total investment depending on the maturity of the technology. The aid had almost doubled from 2018 [140]. According to the decree (145/2016) §5, investment aid for projects that cost >5 M€ can only be granted for renewable-energy technologies that are novel or for renewable-energy projects with new technology that have a higher risk than normal investment projects. However, for projects that cost <5 M€, investment aid is granted according to decree 1098/2017 and requirements are lower. Investment aid can be granted for projects that promote renewable energy and that have some new technology, or a new site is built. Therefore, technology does not have to be new, and it is still possible to receive investment subsidies. These requirements are set in block exemption regulation and aids exceeding these amounts or not meeting these requirements need to gain the approval of the Commission. Significant investment subsidies are, therefore, currently focused on projects on an experimental scale.

The government’s programme states that in energy aids, the goal is ‘shifting the focus from production aid to grants supporting investments in new energy technologies and product demonstrations’ [137]. However, most of this aid was not used; only 27.5 M€ out of 60.75 M€ was used in 2019 [141]. As the aid was granted for all projects fulfilling the requirements to get aid, the reason for the underuse of these funds was that there were not enough suitable investment projects. This might be harmful to the government’s goal to grant more aid for new energy technology and technological development. Underuse means that state resources were saved, but there were fewer private investments, assuming that private investors with investment projects eligible for aid would apply for aid when investing. This does also mean that technology development might be hindered due to the lack of development, which might make energy transition more difficult due to the lack of mature technology. As these subsidies were targeted for developing technology and not for energy production, there were no short-term environmental effects.

These investment subsidies have only a limited impact on project financing. According to decree 1098/2017 §13 and decree 145/2016 §11, subsidies can be paid after at least a certain part of the cost of the project has been paid by its own financing. This creates a need to finance a larger portion of the project without support, as the costs must be paid before subsidies are received. The subsidy decision with binding effect for officials might help to receive funding from external sources, but making it easier to finance projects is one thing to consider when developing subsidy programmes in the future. Especially projects with higher risks and lower technological maturity might need additional support to get financing.

Production subsidies for renewable energy production were initially granted as feed-in-tariff. Feed-in-tariff means that a state sets a target price for renewable energy and pays the difference between the market price and the producer’s target price [142]. However, this system became rather expensive and was abolished. New wind power installations have not been accepted for the feed-in-tariff system since 2017, when a total cap of 2500 MWA wind power in the tariff was fulfilled. Other renewable energy productions since 2019 have been subsidized according to the act ‘Laki uusiutuvilla energialähteillä tuotetun sähkön tuotantotuesta (1396/2010)’ §17 b § and §14. However, installations accepted for the feed-in-tariff system get production subsidies 12 years from the acceptance decision, which greatly reduces uncertainty about market prices and cash flow from investment [143].

The current system for production subsidies for renewable energy production is called the premium system. The premium system aims to divide the market-price risk between the producer and the state. This is done by paying a specific premium to the electricity producer when the electricity price is under the target price. The premium does not cover the whole difference between the market price and the target price, which means that the producer partly carries the risk [143]. It is common that the maximum premium and the maximum amount of electricity in the premium system are limited [15]. Electricity installations accepted into the premium system are chosen based on a competitive bidding process [144]. The premium system is partially technology-neutral for renewable energy, meaning that only some renewable-energy installations can be accepted into the system: wind power, solar power, biogas plants and certain wood-based energy installations can be accepted into the system according to Act (1396/2010) §7. In the first, and currently the only, bidding in 2019, 1.4 TWh worth of power was taken into the subsidy programme. In that bidding, all installations accepted into the subsidy programme were onshore wind
power installations [78]. This is ~2% of all energy production in Finland [145]. According to 12 § of Act (1996/2010), the premium is paid for 12 years, decreasing uncertainty due to being a long enough time period. This system might be cost-efficient as it is competitive and, therefore, an effective way to increase renewable energy production. It does also provide information about the production costs of energy.

However, the system can be criticized for two issues. First, subsidies might be paid to installations that would have been built even without subsidies. Of course, state-aid requirements apply for these aids and, according to the EU regulation, state aid should not be granted for projects that would have been done without state aid [139]. However, evaluating whether state aid is necessary or only cosmetic is complicated in many cases, and the necessity for the aid is based on some assumptions stated in the guidelines. Therefore, some projects that would have been completed in any case might receive aid [146]. There are no estimates on how large a portion of aid could go to projects that would be completed in any case, as it would require knowing the investor’s profitability calculations and assumptions, and there are no previous studies on the subject.

The main criticism is based on the technology neutrality of the policy. The current policy view on technology neutrality only promotes the most mature technology, namely onshore wind power. This policy might hinder the development of less mature renewable-energy technology, and it might also fail to account for the long-term potential of different technologies. Sweden has adopted different strategies to give subsidies for specific energy sectors, namely solar and biogas [147]. From 2021, Sweden is not granting any production subsidies for onshore wind power [148]. Norway adopted the same strategy earlier [149].

The current strategy in Finland is likely to promote short-term renewable-energy capacity relatively cost-effectively. This has led to a situation in which production subsidies are granted by tendering to the most cost-effective renewable-energy production [16]. As all production subsidies go to onshore wind power, there are fewer incentives to invest in renewable energy production other than wind power as less mature technology makes it harder to make profits. This hinders technological development as investments in other technologies are reduced. Even if the current goal is to shift the focus of aid to technological development and new installations, this might not help technologies to become commercially viable as long-term support for business operations is not provided. The EU state-aid regulation would not prevent focusing on the production subsidies for less mature technologies and therefore speed up their development to commercially viable energy-production options [150]. There are even country-specific studies from Finland, suggesting that the high dominance of a few energy sources would be a costly scenario and endanger achieving 2030 and 2050 climate goals [23].

Administrative processes have been developed in recent years. In 2019, a new act was given about combining certain environmental processes: ‘laki eräiden ympäristöllisten lupamenettelyjen yhteensovittamisesta (764/2019)’. The impacts of the act were difficult to predict, and it remains to be seen how it will affect permit processes for new installations [151]. There are some suggestions stating that permit processes should be more adaptive for technologies that are developing during the administrative processes [15]. As permit processes have undergone significant changes in the near past, new recommendations for permit processes cannot be made before impact assessment of the new legislation.

3 Conclusions and policy implications

Increasing the market viability of renewable energy can be examined from two major viewpoints. The first one is how externalities are taken into account in energy production. This means practically how the costs of CO₂ and other greenhouse gases are considered in energy costs. The goal of several policies is to follow the polluter-pays principle, which means that the actor who causes the pollution should also bear its costs. In the case of greenhouse-gas emissions, this is often done with carbon taxes or the ETS.

However, there are also externalities in renewable-energy technologies. For example, some technologies burden the energy system more due to the variation in their energy production. Other technologies cause significant conflicts with neighbours or other stakeholders, and others are required to solve the greenhouse-gas-emission problems and profitability issues that a specific industry, like biogas plants, could do for agriculture, but alone they are not enough to make a significant change in energy production. Due to this, it is not likely possible to choose one technology that could solve climate change and energy transition alone, and it is necessary to promote the development and commercial maturity of several renewable-energy technologies.

The other issue is how technology neutrality affects policies aimed to increase renewable energy production and technological development. Technology neutrality tends to favour more mature technologies. Therefore, policies aimed to be technology-neutral for some renewable-energy-production forms might promote only one technology, which in the worst case might be commercially mature enough to prosper without policies aimed to promote it. On the other hand, policies that aim to promote technologies that are not yet commercially mature must also create enough certainty in order to encourage investment. Certainty can be achieved with long-term policies that ensure at least some profitability level for investments made for this technology.

Research question (i) was: Which are the key policies to promote new renewable-energy-production technologies? Key policies are policies that account for externalities and follow the polluter-pays principle to raise greenhouse-gas-emission prices high enough to correspond to the societal costs of such emissions. The most important of these policies are carbon taxes and the ETS. The EU ETS is an
EU-level policy. However, national governments can implement policies on greenhouse-gas emissions that comply with the polluter-pays principle through carbon-based taxation in sectors not covered by the EU ETS.

There are some political difficulties in implementing the polluter-pays principle. Energy transition creates social tensions due to changing economic and social frameworks [152]. Some relevant issues are energy poverty and affordability, which might be increased due to increasing electricity prices via carbon pricing [153]. This might be a politically challenging option due to the importance of carbon-based economic actions on regional economies and employment in several areas [154]. The EU Just Transition Fund aims to alleviate the economic, environmental and social costs of the transition to climate neutrality, especially in territories suffering the heaviest impacts of transition [155]. In 2021, Finland will spend 1.5 billion euros for just transition and get 1.5 billion euros from the Just Transition Fund, which might soothe the impact of climate transition [156]. Other key policies are policies that increase the technological development of several renewable-energy technologies to improve their commercial maturity and create a sustainable energy system based on several energy sources.

Research question (ii) was: How could Finland promote new renewable-energy technologies so that they become commercially viable? The first part was implementing the polluter-pays principle more broadly than it is currently implemented. Increasing greenhouse-gas-emission taxation is an effective long-term policy, but it is not politically popular in the EU or Finland due to competitive issues. Currently, the price that the ETS sets for greenhouse-gas emissions is close to the OECD recommendation, as the price has risen in 2021.

Finland is using carbon-based taxation of energy production, which can be seen as an effective tool for decreasing greenhouse-gas emissions. National taxes for fuels are based on the energy content and carbon intensity of the fuel. These greenhouse-gas-emission taxes for these fuels are low compared to the OECD recommendations. Therefore, usage of these fuels follows the polluter-pays principle as greenhouse-gas-emission costs are transferred to the user. One-quarter of energy production is outside of this polluter-pays taxation, as electricity production is not based on the carbon intensity of the fuels used. However, these fuels are under the EU ETS, which is based on the carbon intensity of fuels and the market price of carbon, which has fluctuated in previous years.

These policies are similar to those adopted in other Nordic countries. This policy choice gives significant advantages for fossil fuels due to externalities and, due to this, some policy measures are needed to correct this advantage. One effective policy for promoting renewable energy production would be a tax policy that taxes electricity production partially or entirely based on greenhouse-gas emissions. This policy could even be cost-neutral if the carbon tax would be adjusted over time to compensate for the increasing share of renewable energy production and rising of the EU ETS prices.

Tax incentives for greener energy production are quite common all over the world. In Finland, the current national policy is to tax energy production based on the carbon intensity of the fuel used, leaving renewable energy sources outside this tax. These carbon-based tax incentives for renewable energy production also promote technologies with higher maturity and lower subsidy needs and, therefore, might become expensive if not actively assessed when technological maturity develops. This active assessment does not comply well with the need for long-term policies to increase high-risk renewable-energy investments.

However, these polluter-pays policies have limits due to their adverse effects on competitiveness and political unpopularity. Therefore, other means are needed to promote renewable energy. There are market failures related to the maturity of some renewable-energy technologies. The long-term policy recommendation is to address these issues with subsidy policy. Subsidies are an effective policy when addressing market failures related to the market or technology, but they are an expensive permanent solution. Therefore, using subsidies to enable technology development or a short-term increase in renewable energy production is an effective policy instead of permanent production subsidies. However, subsidy programmes need to be long enough to reduce uncertainty and to promote high-risk investments and technology, and commercial maturity development.

It is quite clear that policymakers cannot choose winning technology. Therefore, the most cost-efficient policy is likely a policy that only specifies the goal and incentives but does not specify the means to get there. This is called a technology-neutral policy. However, technology-neutral policies require a more sophisticated approach to avoid other policy failures. As technology-neutral policies more effectively promote more mature technologies, a technology-neutral policy might promote technologies that are overall less beneficial for society. For example, the current production subsidy policy in Finland is partly technology-neutral. Certain renewable-energy technologies can participate in bidding processes in which subsidies are granted to installations that require the fewest subsidies. However, this bidding process does not promote less mature technologies; all subsidies were granted to onshore wind power when addressing market failures related to the market or technology, but they are an expensive permanent solution. Therefore, using subsidies to enable technology development or a short-term increase in renewable energy production is an effective policy instead of permanent production subsidies. However, subsidy programmes need to be long enough to reduce uncertainty and to promote high-risk investments and technology, and commercial maturity development.
technology, but subsidies could be focused on less mature technologies, such as excluding onshore wind production from energy subsidy programmes.

The other Nordic countries have abolished production subsidies for onshore wind power, as onshore wind power is becoming more and more commercially viable. They are focusing on production subsidies for energy technologies that are not that commercially viable. It needs to be noted that these other Nordic countries have significant energy surpluses, while Finland is consuming significantly more energy than it produces [157]. This makes comparing energy policies a bit more difficult, and similar policies might not be viable in Finland. The majority of renewable-energy subsidies granted are these production subsidies, which are mostly granted for onshore wind power. A small minority of subsidies are investment and technology subsidies. The current government aims to change the weight of subsidies, which would be beneficial in the long run. However, using only technology-neutral policies is not viable in the long term, as technological maturities are very different. Therefore, using several other policies to promote several goals simultaneously would most likely lead to better results.

Production subsidies are not that effective for several renewable-energy technologies with high uncertainty. Investment subsidies are probably a preferable solution for less mature technologies as they reduce uncertainty much more effectively. For more mature and commercially viable technologies, production subsidies granted in the bidding process are probably the most cost-efficient way to increase renewable energy production. Both policies are most likely needed to achieve renewable-energy and climate targets in the long and short term.

Current energy policies in Finland can be summarized in the following way: the current policies are focused on the short-term increase for cost-effective renewable energy production. Long-term development for experimental technologies is also subsidized, but the permit system is not designed for these small-scale projects. For the mid-term, the policies are primarily absent as already developed technologies that currently lack technological maturity to become commercially viable are not promoted much in subsidy policy or by other means.

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Conflict of Interest
None declared.

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