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Citizens' images of a sustainable energy transition

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ABSTRACT

Achieving a sustainable energy transition is crucial for mitigating climate change. Citizens' acceptance of the transition is important for it to succeed. We explored citizens' images of the future energy forms and energy system in Finland, and the drivers of a sustainable energy transition. The data gathered with an online questionnaire targeting an adult population 17–75 years of age (N = 1012) were analysed with exploratory factor analysis and multiple linear regression. Four dimensions of future energy forms were identified: next-generation renewables, fossil energy, bioenergy, and established renewable vs. nuclear energy. Four dimensions of the future energy system were also identified: renewing the energy market, domestic power, small-scale producers, and consumer awareness. Five transition drivers were likewise identified: mainstreaming renewable energy, international actors, individual actions, changing values and economy, and emancipatory change. Mainstreaming renewable energy emerged as the key driver of transition, followed by individual actions. Generally, the sustainable energy transition was strongly supported by citizens' images, but different socio-economic groups preferred somewhat different images. Thus, the diversity of consumers' and citizens' roles in the transition needs to be acknowledged and encouraged in legitimate national energy policies.

1. Introduction

The current energy production and consumption system is unsustainable, and is increasingly contributing to global environmental problems, such as climate change. A reduction in carbon emissions requires a profound transition in the socio-technical energy system. A core objective of the energy transition is to replace fossil energy with renewable energy. While there are significant economic and technological challenges to be resolved, societal and structural obstacles may be more serious. The energy innovations literature has identified a broad set of structural lock-ins developed over time [1]. These act as incentives for incremental improvements in existing systems, instead of fostering new approaches, conventions and technologies [2]. Socio-technical transitions are co-evolutionary processes between actors and social groups [3], but the public understanding of transitions is still under-researched.

The multi-level perspective (MLP) on socio-technological transitions developed by Geels [4] has become a prominent framework for conceptualizing energy transitions. MLP identifies trends occurring at three levels: niche, regime and landscape [5]. A transition is defined as a medium-to long-term process involving a structural change of production and consumption. Niches form the micro level of new innovations attempting to gain greater prominence, and are typically developed by small networks of dedicated actors. The regime level presents a stable configuration of existing practices, technologies, institutionalised networks and habits that often act as a deterrent for novel innovations. The socio-technological landscape represents the exogenous environment beyond the direct influence of actors. It includes megatrends that influence societies extensively, such as international climate policy and energy market regulation, increasing environmental awareness, or availability of energy resources. Changes at the landscape level usually take place rather slowly [5].

In order to realise a socio-technological transition, the existing regime has to be challenged by new ideas, innovations and

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practices emerging at the niche level. Innovation processes are organised around niche-regime interactions. When a certain number of successful innovations has become available, the dominant regime is challenged and a process towards a new regime gets underway. MLP represents a bottom-up view of transition [6]. However, while MLP assigns an active role to niche actors, empirical studies have mainly treated the public as consumers and technology users [7,8]. Since a socio-technological transition can occur only if citizens support and participate in it, we need to better understand the public understanding of energy transitions. In order to fill this research gap, we explored how the Finnish adult population approaches the ongoing energy transition and its future.

Finland is an example of an industrialised country, with its own distinctive mix of energy sources and uses. Energy decisions are influenced by national policies, companies and consumers, but as a member of the European Union, Finland is also involved in international energy markets and influenced by international policies.

We focused on the following research questions:

1. How desirable do citizens perceive the development of various energy production forms up to the year 2030?
2. What kinds of dimensions can be identified in citizens' images of the future energy system?
3. To what extent do citizens perceive different drivers as being relevant to the environmentally sustainable energy transition?
4. How are the perceived drivers and respondents' socio-economic characteristics associated with futures images?

We have defined futures images as flash-like descriptions of a future state of the topic at hand. They provide an opportunity for dealing with the uncertain future by looking at where current developments would lead us, and by providing alternative futures for decision-making [9,10]. Futures images differ from scenarios in that they do not typically describe a path to the end state, but rather the end state itself [11]. Moreover, scenarios are usually related to societal dynamics and societal systems, whereas futures images are typically described as individuals' personal perceptions. Earlier studies on laypeople's futures images have not focused on a specific socio-technical system in an in-depth manner. An exception is the study by Höjer et al. [12]; who analysed futures images of the energy system on a city scale. The present study brings individuals' futures images closer to systemic scenario studies. However, the purpose is not to compete with modelling in creating systemic scenarios, but rather to provide an empirical description of alternative human perceptions of the transition. Futures images portray citizens' preferences and perceptions, which in turn may transform into individual or political action that will drive the transition and change the future.

2. The Finnish energy system

Up to the first energy crisis in 1973–1974, the Finnish energy system relied heavily on oil, coal, hydropower and domestic wood. Since then, a diversification policy has been adopted: Nuclear energy and natural gas have been added to the system, along with renewable energy such as bioenergy, wind power and ground source heat pumps. Peat, a domestic semi-fossil fuel, stands out as a national peculiarity. The common Nordic electricity market has had an effect on electricity imports from Norway and Sweden, in addition to power imported from Russia. The total energy consumption reached a peak in 2006 and has since steadily declined for a decade (Fig. 1). Arguably, there are three reasons for this: 1) due to globalisation, energy-intensive industry has been outsourced; 2) the financial crisis and trade restrictions between the EU and Russia have reduced export; and 3) energy efficiency is increasingly appreciated by the wider public and private actors, partly due to the international climate agreements.

Due to its northern location, the number of heating days in Finland is usually the highest among the EU27 [14]. The share of space heating has been roughly 20–25% of total energy consumption since 1980 (Fig. 2). In 2016, for example, 72% of energy consumed in housing was allocated to space heating and 15% to heating domestic water. Lighting, cooking and other electrical appliances accounted for the remaining 13% [15]. The heat demand has had an effect on the efficient use of combined heat and power (CHP) plants and the market-driven trend of heat pumps [16].

There are over a hundred companies operating in the Finnish electricity sector, but three companies own about half of the production capacity [17]. Off-grid electricity is mainly produced at summer cottages. Heating is more decentralised, as in addition to numerous district heating systems, individual houses often have their own heating solutions.

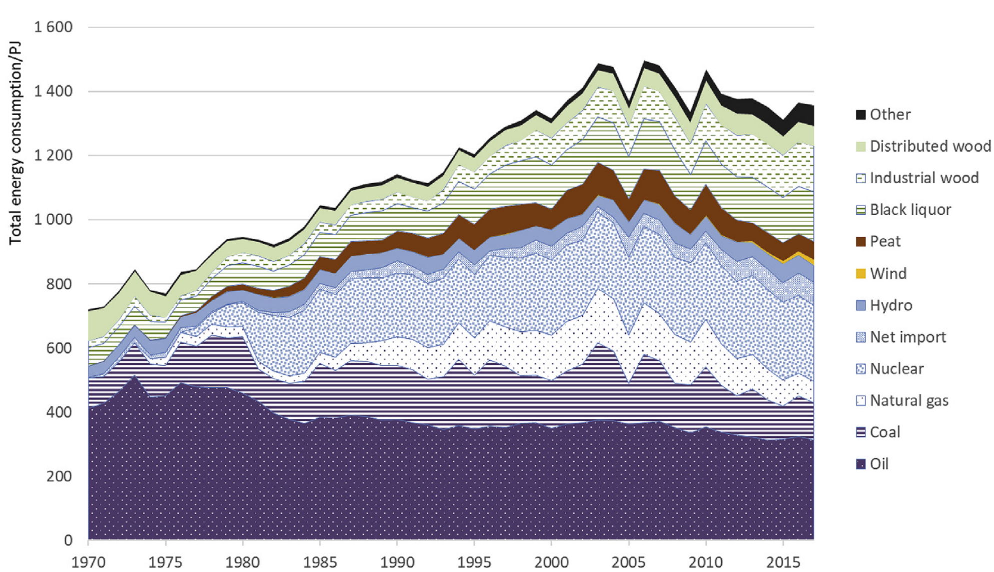

Fig. 1. Total energy consumption in Finland by energy source 1970–2017 [13].

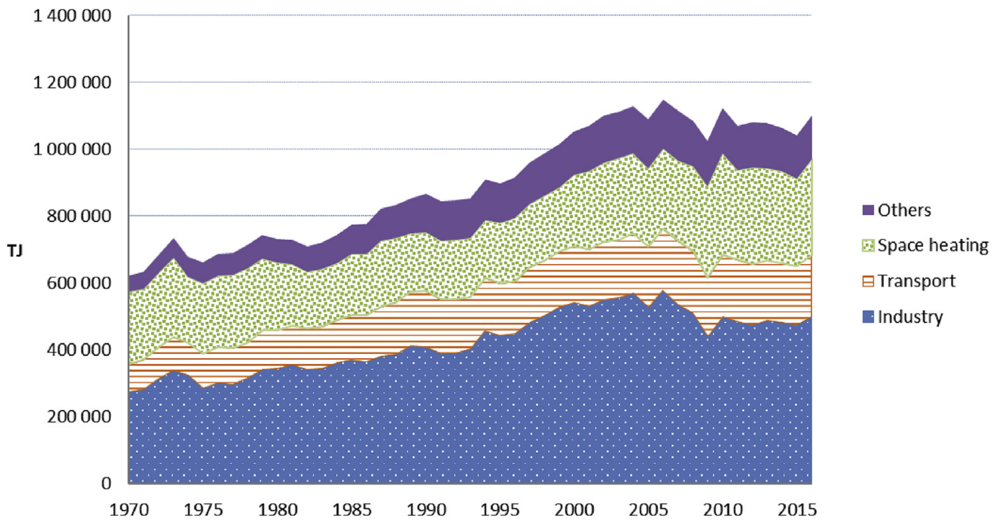

Fig. 2. Total energy consumption in Finland by sector 1970–2016 [15].

Renewable energy is increasing its share and there is budding prosumerism in Finland. For example, installed photovoltaic capacity almost doubled in 2017 to 80 MWp, and 13 MW of the growth came from grid-connected residential instalments [18]. Increasing decentralisation, decarbonisation and digitalisation are expected to change power transmission and distribution systems Europe-wide [19], and the integration of renewable energy is considered a key challenge for decarbonisation in Nordic countries [20]. However, large-scale changes increasing the flexibility of the energy system have not yet taken place [21].

Citizens' acceptance of energy forms and technologies is usually associated with risk-benefit perceptions [22], which in turn are associated with general environmental concern [23]. Finns strongly prefer renewable energy as opposed to other energy forms [24]. They are less supportive of wind, solar and hydropower than citizens of most EU countries, being more supportive of combusting biomass instead [25–27]. Moreover, Finns (27%) and Swedes (32%) have been found to be more supportive of nuclear energy than other EU citizens [28].

3. Material and methods

3.1. Participants

The data were collected in 2017 through an online questionnaire using the consumer panel of a commercial marketing research company, representative of the 17- to 75- year-old internet users living in Finland (N = 1012). The response rate was 15.3%, which is quite typical for online surveys. In order to achieve a representative sample, targeted reminders were sent to subgroups with low response rates. As compared to the adult population living in Finland, the participants in the sample were more likely to be men and to have a high level of education (Table 1).

Table 1
Distribution of age, gender, highest education level, and area of residence in the Finnish population and the data sample.

	Finnish population (%)	Data sample (%)
Gender (among 17–75 years of age) [a]		
women	49.8	44.0
men	50.2	56.0
Age groups [a]		
17–35	31.8	28.1
36–55	34.3	37.4
56–75	33.9	34.6
Highest education (among 20–74 years of age) [b]		
basic level	19.9	5.7
secondary level	45.6	11.7
lowest level, tertiary	10.5	29.6
lower-degree level, tertiary	12.5	30.5
academic	11.5	24.0
Region (among 17–75 years of age) [a]		
Helsinki-Uusimaa	30.7	34.2
Southern Finland	21.2	22.6
Western Finland	24.9	19.7
Northern and Eastern Finland	23.2	23.5

[a] Source: [29].
[b] Source [30].

3.2. Survey

Standard survey methods were used to explore citizens' images of the future energy system in Finland. The survey items analysed in this study were part of a longer questionnaire. The focus of this article is on three sets of items: images of preferred energy forms to be used in Finland in 2030, images of the energy system in 2030, and drivers reducing the environmental and climate impacts of energy use. The year 2030 was chosen as it is far enough in the future to allow changes to occur even in the established energy regime, and yet close enough for the respondents to be able to imagine it. The items were drawn from national policy documents [31–33], media discussions [34], and existing academic literature to present the most relevant aspects in the current national energy policy discourse.

The three levels of the MLP framework – regime, niche and landscape – were operationalised into questionnaire statements (see Appendix) as follows. More specifically, the socio-technical regime included stabilised conventions, rules and norms that guide the use of technologies and everyday practices, and it embraced seven dimensions: policy, technology, user practices, science, cultural meanings, infrastructure, and industry [35]. The niche included innovations and networks that aim to bring sustainable alternatives to the regime level, whereas the landscape was defined as the external context affecting the energy system transition [4].

Images of energy forms in Finland in 2030. The participants indicated in which direction (1 = reduce significantly to 5 = increase significantly) the production of fourteen different energy production forms ought to be developed in Finland up to the year 2030. The energy forms represented the current regime (e.g. oil), and the niche (e.g. wave energy).

Images of the energy system in Finland in 2030. The participants were requested to imagine Finland in the year 2030, and to indicate how the energy system will change, by evaluating changes occurring in the current regime (e.g. municipalities), as well as the current niche (e.g. innovations) (1 = reduce significantly to 5 = increase significantly).

Drivers of the reduction in environmental and climate impacts of energy production in Finland. The participants were requested to indicate how important different drivers were in reducing the environmental and climate impacts of the energy production in Finland (1 = unimportant to 5 = extremely important). The items represented landscape (e.g. climate change), regime (e.g. policies), and niche-level drivers (e.g. small-scale energy production).

The following socio-economic variables were used in the analyses: age (years), gender (male = 0, female = 1), perceived economic status of household (1 = serious economic problems to 5 = manages very well), residential area (1 = urban, 0 = other), level of education (1 = academic, 0 = other), and political orientation. In order to measure the political orientation, the respondents were asked which party they would vote for if the parliamentary elections were held right now. Political parties were then allocated on a left-right continuum using the Finnish Election Study Portal index, ranging from 0 to 10 [36].

3.3. Analysis

The questionnaire items were analysed with exploratory factor analysis (EFA) using maximum likelihood and Varimax rotation for each of the three sets separately. The purpose of EFA is to group the items into a limited set of clusters based on shared variance. Factors with an eigenvalue of 1 or greater were selected for further analysis [37] and factor loadings of ±0.40 or greater (the absolute value) in the rotated solutions were used as a cut-off for selecting items for each factor [38].

The association between the factors and socio-economic variables was analysed with multiple linear regression. For this purpose, the mean scores including the items with factor loadings of 0.40 or greater in each factor were calculated.

4. Results

4.1. Energy forms

The EFA of citizens' images of the future energy production and consumption in Finland yielded four factors with an eigenvalue ≥1, explaining 59% of total variance (Goodness of fit test: $\chi^2 = 275.90$, df = 41, $p < .001$; KMO Measure of Sampling Adequacy .751; Bartlett's test of sphericity: $\chi^2 = 3214$; df = 91, $p < .001$) (Table 2).

Factor 1: Next generation renewables. This factor represents the next generation of renewables. As such, it conveys technological optimism and the desire for new, additional innovative energy forms.

Factor 2: Fossil energy. The energy forms in this factor include coal and oil, but peat is also loaded rather strongly here.

Factor 3: Biomass. The energy forms in this factor include wood, biogas, energy plants, and also peat, which is a very slowly renewing fuel.

Factor 4: Established renewables vs. nuclear. Wind power and solar power loaded positively, while nuclear power loaded negatively in this factor. This factor therefore represents a future where the more established renewable (non-biomass) energy forms rise, combined with a decrease in nuclear energy use.

4.2. The energy system in 2030

The EFA of the respondents' future visions of energy forms yielded four factors with an eigenvalue ≥1, explaining 57% of total variance (Goodness of fit test: $\chi^2 = 1462.58$, df = 347, $p < .001$; KMO Measure of Sampling Adequacy .964; Bartlett's test of sphericity: $\chi^2 = 16{,}355$; df = 465, $p < .001$) (Table 3).

Factor 1: Renewing the energy market represents a change in the *energy production regime:* renewable energy is increasing, new energy producers and prosumers have emerged alongside new business models, and smart technologies ranging from household scale to smart grids are enabling it all.

Factor 2: Domestic power emphasises the *national policy regime and national actors*, where local energy companies, citizens and state policies and subsidies all have a significant role in building energy in the future.

Factor 3: Small-scale production represents *a growing niche:* it focuses on small-scale production characterised by an increase in self-reliance, the adoption of new innovations, and the role of prosumers in sharing energy in the grids.

Factor 4: Consumer awareness depicts an increase in consumer

Table 2
Images of the change in energy forms in Finland by 2030. The results of EFA (maximum likelihood, Varimax rotation).

	Factors			
	1. Next generation renewables	2. Fossil energy	3. Bioenergy	4. Established renewable vs. nuclear energy
Wave energy	**.70**	-.10	.11	.21
A technology that is not yet in use	**.70**	-.18	.01	.03
Ground source heat and other geothermal energy	**.61**	-.18	.22	.02
Coal	-.25	**.91**	.00	.03
Oil	-.22	**.64**	.16	-.20
Wood	.03	.07	**.58**	-.05
Biogas	.26	-.07	**.53**	.04
Arable energy plants	.34	-.02	**.52**	.19
Peat	-.20	**.41**	**.48**	.02
Natural gas	.04	.24	.32	-.10
Wind power	.21	-.09	-.05	**.71**
Nuclear power	-.01	.08	.10	*-.55*
Solar power	.35	-.24	.08	**.48**
Hydropower	-.04	.12	.20	.33

Note: The items in bold were included in the mean scores. Nuclear energy (italics) was used as a separate variable in subsequent analyses.

Table 3
Images of the energy system in Finland in 2030. The results of EFA (maximum likelihood, Varimax rotation).

	Factors			
	1. Renewing the energy market	2. Domestic power	3. Small-scale producers	4. Consumer awareness
Utilisation of smart grids in the transmission of renewable energy	**.72**	.17	.22	.18
Smart energy systems in households	**.71**	.09	.19	.20
Business activities based on renewable energy	**.66**	.25	.22	.23
Renewable energy produced by farms	**.64**	.15	.36	.12
Renewable energy produced by citizens	**.62**	.16	**.45**	.10
Acceptance of small-scale renewable energy production among consumers	**.59**	.24	.26	.20
Share of renewable energy of all energy produced in Finland	**.59**	.37	.23	.23
Citizens' joint investments in renewable energy	**.56**	.33	.30	.10
Number of small-scale energy producers	**.55**	.31	.39	.09
Number of distributed renewable energy production facilities in urban areas	**.54**	.28	.26	.14
Energy efficiency of buildings	**.51**	.34	.09	.24
Cooperatives and similar associations involved in energy production	**.50**	.22	**.49**	.14
Service companies that sell energy but do not own the energy production equipment	**.49**	.24	.30	.14
Variety of energy production forms	**.44**	.25	.39	.28
Services offered by large companies to small-scale energy producers	**.40**	.34	.30	.18
Share of local companies of the energy companies in Finland	.22	**.63**	.17	.09
Citizens' power in defining national energy policy	.07	**.60**	.29	.10
Share of domestic energy of the energy consumed in Finland	.39	**.54**	.22	.13
The importance given to climate impacts in energy policy decisions	**.44**	**.48**	.07	.24
State subsidies for small-scale renewable energy producers	.30	**.48**	.13	.15
State responsibility for national electricity production	.01	**.46**	.04	.06
The skills of housing condominiums to negotiate competitive energy solutions	.23	**.44**	.32	.35
The profitability of centralised energy production facilities in urban areas	.20	**.42**	.10	.11
The carbon neutrality of energy used in Finland	.39	**.41**	.10	.12
Energy bought by households from small-scale producers	.34	.22	**.66**	.20
Economic benefits received by small-scale producers from distributing extra electricity or heat into a public grid	.30	.32	**.60**	.18
The spreading of different energy production innovations among small-scale producers	**.45**	.21	**.51**	.26
The number of housing condominiums that produce all or nearly all of their own energy	**.48**	.19	**.51**	.12
Consumers' awareness of the environmental impacts of energy production forms	.27	.32	.20	**.79**
Consumers' awareness of different energy production forms	.32	.22	.24	**.78**

Note: Items in bold were included in the mean scores.

awareness of energy production alternatives and their environmental impacts.

The majority of respondents preferred the production and consumption of the established ($M = 4.23$, $SD = 0.76$; response scale 1–5) and next generation renewables ($M = 4.09$, $SD = 0.70$) to increase in Finland by 2030 (Fig. 3). Around 50% of respondents preferred the production of bioenergy to remain at the present level ($M = 3.30$, $SD = 0.68$). Views on nuclear energy were strongly divided ($M = 2.81$, $SD = 1.31$). A majority of respondents preferred the production of fossil energy to decrease ($M = 1.91$, $SD = 0.74$). Respondents' views on the established and next generation renewables correlated positively, as did bioenergy and fossil energy, whereas nuclear energy correlated negatively with established renewables and positively with fossil energy (Table 4).

The majority of respondents expected all four energy system changes to increase by 2030. Consumer awareness ($M = 4.09$, $SD = 0.72$; response scale 1–5) and renewing the energy market ($M = 3.93$, $SD = 0.53$) were expected to show an increase by the largest proportion of respondents, followed by the role of small-scale producers ($M = 3.80$, $SD = 0.57$) and the role of domestic power ($M = 3.53$, $SD = 0.55$). Moreover, perceptions of all four types of energy system changes correlated positively with each other (Table 4), suggesting that the same people were likely to have similar views on all of them.

4.3. Drivers of transition

The EFA of the survey responses measuring the perceived importance of drivers of the environmentally sustainable energy transition yielded five factors with an eigenvalue ≥1, explaining 62% of total variance (Goodness of fit test: $\chi^2 = 3251.39$, $df = 523$, $p < .001$; KMO Measure of Sampling Adequacy .953; Bartlett's test of sphericity: $\chi^2 = 23{,}645$; $df = 703$, $p < .001$) (Table 5).

Factor 1: Mainstreaming renewable energy describes a situation where various obstacles are removed from the path of renewable energy. It becomes more affordable, information gaps are removed, funding is available and companies take action. The energy regime participates in transition. Barriers are perceived as problems that can be resolved within the system. Power resides mainly in the market: if renewable energy is affordable, it will be taken into use.

Factor 2: International actors refers to actors such as other states, environmental agreements, and international corporations. It reflects the assumption that large-scale actors also determine the national energy system: they affect markets, and encourage national policy-makers and energy producers to embrace environmental sustainability.

Factor 3: Individual actions describes individual and social action, and public acknowledgement of prosumerism. Responsibly behaving individuals take action and the small-scale production of energy becomes popular as a form of self-expression.

Factor 4: Changing values and economy represents large-scale changes in the economic system, including a controlled or uncontrolled decrease in economic growth and change in societal values. It signifies changes at the landscape level.

Factor 5: Emancipatory change focuses on a change in citizenship behaviours. New actors representing currently underprivileged groups are included in decision-making. Citizens are seen as more enlightened or environmentally friendly than the existing regimes. People engage in behaviours as groups.

The respondents perceived international actors ($M = 4.01$, $SD = 0.89$; response scale 1–5) and mainstreaming renewable energy ($M = 3.96$, $SD = 0.66$) as the most important drivers of energy

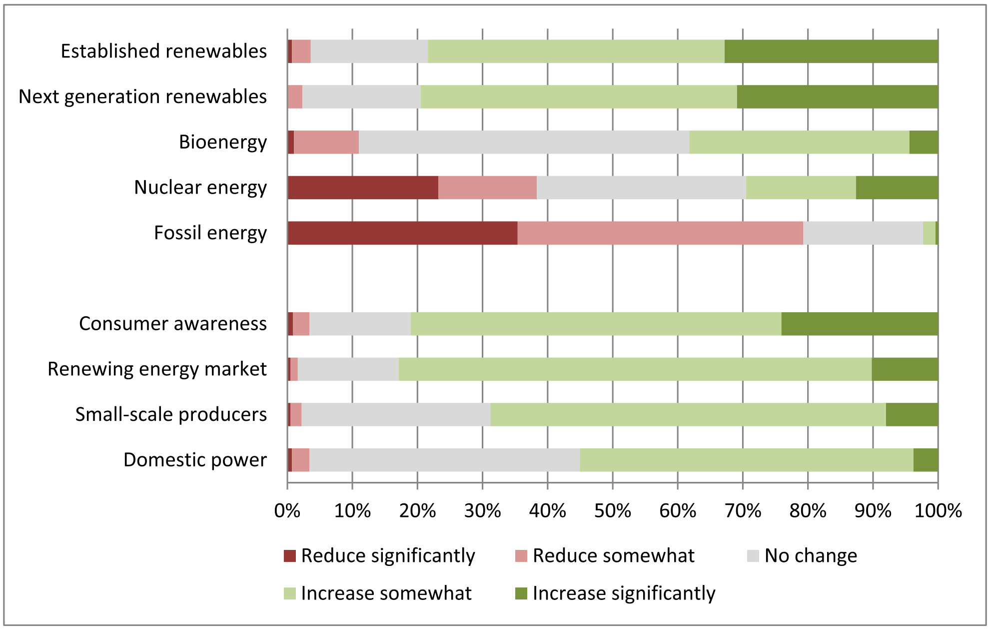

Fig. 3. Images of the energy production and the energy system in Finland in 2030: percentages of the responses indicating reduction, no change, and increase.

Table 4
Associations between images of the energy production forms and images of the Finnish energy system in 2030 (mean scores). Bivariate correlations.

	Established renewables	Next generation renewables	Bioenergy	Nuclear energy	Fossil energy	Consumer awareness	Renewing the energy market	Small-scale producers
Next generation renewables	.36***							
Bioenergy	.07*	.19***						
Nuclear energy	-.39***	-.04	-.01					
Fossil energy	-.27***	-.34***	.48***	.12***				
Consumer awareness	.35***	.30***	.12***	-.16***	-.20***			
Renewing the energy market	.38***	.46***	.09**	-.11***	-.32***	.64***		
Small-scale producers	.36***	.41***	.08**	-.13***	-.24***	.59***	.81***	
Domestic power	.35***	.29***	.06*	-.20***	-.20***	.60***	.72***	.64***

Note. $^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$.

transition (Fig. 4); the majority of respondents perceived them as either important or extremely important drivers. The perception of other drivers was more ambiguous: changing values and economy ($M = 3.35$, $SD = 0.78$), individual actions ($M = 3.24$, $SD = 0.87$), and emancipatory change ($M = 2.85$, $SD = 0.86$). All five drivers correlated positively ($r = 0.27–0.68$, $p < .001$).

The perception of mainstreaming renewable energy as an important driver was positively associated with all futures images apart from nuclear energy and fossil energy (Table 6). The perception of individual actions as an important driver was associated with the expectation that the role of domestic power, renewing the energy market and small-scale production will increase, as well as the preference for established renewables instead of nuclear and fossil energy. The perception of international actors as an important driver was associated with the expectation that the role of domestic power and consumer awareness will increase, and the use of fossil energy will decrease. The perception of a change in values and the economic system was weakly associated with the expectation that the role of domestic power will increase, as well as the preference for a decrease in fossil energy, bioenergy and established renewable energy. The perception of emancipatory change was weakly associated with the expectation that the role of domestic power will increase, and the preference for fossil energy production instead of nuclear energy.

There was a weak positive association between age, the expectation that the role of domestic power and consumer awareness will increase, and the preference for a decrease in nuclear and fossil energy production. Being female was weakly associated with an expectation that the role of domestic power and consumer awareness will increase. Moreover, females preferred fossil energy and established renewables slightly more than males, whereas males preferred next generation renewables and nuclear energy. Moreover, there was a weak association between a high perceived financial status and an expectation that the renewing energy market, small-scale production and consumer awareness will increase. Having an academic degree was weakly associated with a perception that small-scale production will increase and strongly associated with a preference for the use of new renewables instead of fossil energy. A right-wing political orientation was associated with a preference for bioenergy, nuclear energy and fossil energy instead of established renewable energy. Urban residents preferred a decrease in the use of fossil and bioenergy.

5. Conclusions

This study explored citizens' futures images of the energy

Table 5
Drivers of environmentally sustainable energy transition. The results of EFA (maximum likelihood, Varimax rotation).

	Factors				
	1. Mainstreaming renewable energy	2. International actors	3. Individual actions	4. Changing values and economy	5. Emancipatory change
Production of renewable energy becoming easier	**.79**	.19	.13	.04	.13
Production of renewable energy being economically profitable	**.73**	.24	.00	.03	.03
Consumption of renewable energy becoming cheaper	**.72**	.16	.08	.01	.17
Societal experiments with distributed renewable energy	**.63**	.11	.26	.25	.17
Those commissioning new housing emphasise distributed renewable energy	**.61**	.13	.31	.23	.17
Evaluating economic profitability on a longer time scale than nowadays	**.61**	.20	.11	.24	.11
Developing renewable energy business models	**.60**	.37	.22	.18	.12
Research and other knowledge production	**.58**	.33	.20	.22	.12
Energy is seen as a key cost and people are ready to invest in it	**.58**	.21	.24	.24	.06
New technological innovations	**.56**	**.40**	.11	.15	.06
The predictability of state taxes and subsidies concerning electricity and heat produced by citizens themselves	**.55**	.12	.14	.36	.10
Banks offer affordable loans for renewable energy solutions in homes	**.52**	.02	.21	.26	.23
Information and education	**.49**	.32	.38	.19	.19
Valuing energy policy in the construction of the future	**.49**	.32	.26	**.44**	.07
Actions by companies and markets	**.47**	.30	.22	**.40**	.02
Small-scale production of energy as a part of a transition of work	**.44**	.04	.23	.39	.24
Decisions and climate policy of the USA	.22	**.83**	.08	.19	.07
Decisions of large developing countries	.24	**.83**	.02	.19	.06
Actions by large international corporations	.34	**.68**	.26	.21	.08
Wide-ranging binding international environmental agreements	.31	**.62**	.35	.21	.05
Decisions and climate policy of the EU	.35	**.59**	.34	.21	.05
Actions by individual citizens	.18	.19	**.71**	.04	.28
Actions by NGOs or popular movements	.16	.30	**.62**	.12	.40
Energy production by individuals is socially respected	.32	.07	**.53**	.41	.20
Different ways to produce renewable energy by oneself is discussed in the media	.40	.11	**.53**	.40	.19
Energy decisions are a way to communicate one's own identity as a consumer	.29	.10	**.49**	.40	.27
National actions and political decision of Finland	.30	.29	**.46**	.14	.18
Change of the economic system	.12	.11	.06	**.58**	.22
Controlled slowing down of economic growth	.16	.19	.11	**.57**	.18
Change of values in society	.32	.28	.27	**.55**	.11
Lengthening the time period of policy impact analyses	.36	.28	.21	**.45**	.05
Uncontrolled slowing down of economic growth	.06	.13	.03	**.42**	.12
Increase in citizens' decision-making power in Finnish energy policy	.18	.03	.02	.15	**.84**
Referendums on energy policy	.15	.05	.07	.15	**.79**
Influence possibilities of low-income population	.10	.06	.23	.13	**.69**
Increasing decision-making power of citizens	.20	.16	.33	.11	**.66**
Lowering the legal voting age	.03	.00	.16	.17	**.45**

Note: Items in bold were included in the mean scores.

system and energy production in Finland. According to the results, Finns strongly support a sustainable energy transition by 2030 through increased production of renewable energy, which would replace fossil energy. Hence, our study corroborates the findings of previous studies reporting that Finnish citizens support renewable energies and are against fossil energy [39].

However, the views regarding bioenergy were more ambiguous, suggesting that the tension associated with bioenergy may shape the direction of energy transition [40]. Peat, in particular, loaded highly both in fossil energy and bioenergy factors. The ambivalence towards bioenergy stems in part from its positive significance for the rural economy, and more broadly for the Finnish economy [41], and from the way it threatens to increase overall greenhouse gas emissions from Finland [42].

Renewing the energy market, domestic power, small-scale producers, and *consumer awareness* were the four identified dimensions of the future energy system. They correspond to some important actors identified in the MLP literature, namely the market, political actors, (small-scale) private actors, and citizens [4]. Respondents expected an increase in all four dimensions, with the greatest change occurring in consumer awareness and renewing the energy market. The respondents perceived these dimensions as being aligned with each other without significant tensions. Further, over two-thirds perceived the number of distributed small-scale producers as increasing, suggesting that these niche actors are anticipated to enter the Finnish energy regime in the future. As citizens' values and attitudes towards change are important for the transition to occur, this finding is highly promising because it indicates a psychological readiness to engage in the transition and accept new actor roles in the energy system.

International actors, mainstreaming renewable energy, changing values and economy, individual actions, and emancipatory change were the five identified drivers of a sustainable energy transition. International actors and mainstreaming renewable energy were perceived as the most important drivers, whereas the importance of other drivers was more ambiguous. A strong positive correlation suggests that there was no tension between the drivers. It also explains, for example, why regarding international actors as important was associated with the expectation that domestic power and consumer awareness will increase. Many changes can take place simultaneously.

Previously, Finns have been found to perceive new technology and inventions as the most important driver of environmentally

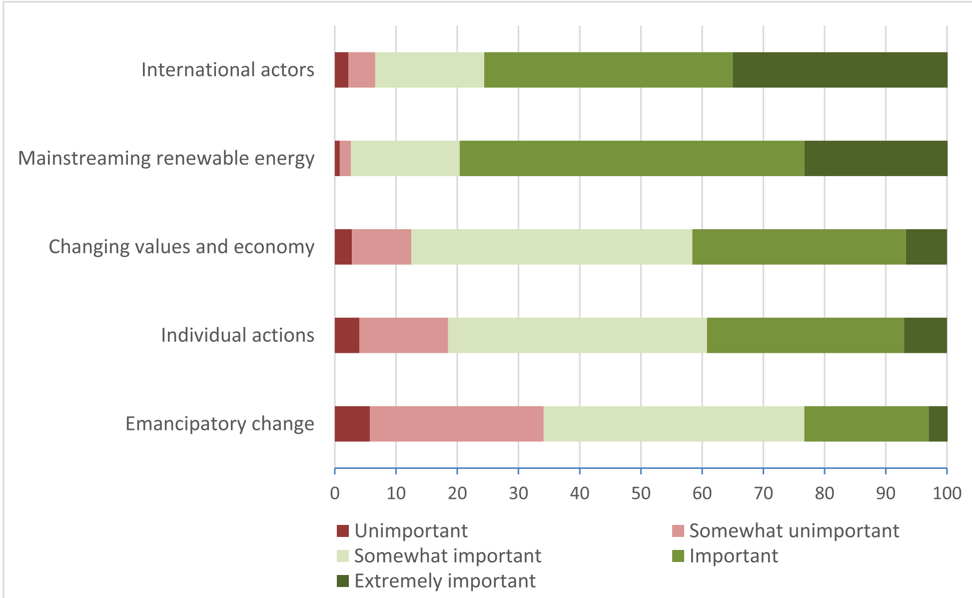

Fig. 4. Drivers of environmentally sustainable energy transition. Percentages of responses (mean scores).

Table 6
Associations between futures images of energy production-form changes and the future energy system (dependent variables), and drivers reducing energy-related environmental impacts and socio-economic variables (explanatory variables). The results of linear regression: standardised coefficients and standard errors.

Dependent variables	Preferred change in energy production in Finland by 2030								Probable future of energy system in Finland by 2030									
	Established renewables		Next generation renewables		Bioenergy		Nuclear energy		Fossil energy		Consumer awareness		Renewing the energy market		Small-scale producers		Domestic power	
	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Drivers of the reduction in energy-related environmental impacts:																		
International actors	.07	.06	.08	.04	-.03	.04	-.02	.07	-.24***	.04	.11*	.04	.07	.03	.02	.03	.12**	.03
Mainstreaming renewable energy	.33***	.06	.47***	06	.22***	.07	.00	.11	-.02	.06	.34***	.06	.49***	.04	.46***	.05	.21***	.04
Changing values and economy	-.13**	.04	-.04	.04	-.10*	.04	.02	.07	-.10*	.04	.01	.04	.01	.03	-.02	.03	.10*	.03
Individual actions	.15**	.04	-.03	.04	-.11	.05	-.21***	.08	-.15**	.04	.06	.04	.15***	.03	.12*	.03	.16***	.03
Emancipatory change	.07	.04	.04	.03	.09	.04	-.12**	.06	.12**	.04	.06	.03	.00	.02	.10*	.03	.11**	.03
Socio-economic variables:																		
Age	-.01	.00	.04	.00	.04	.00	-.10**	.00	-.07*	.00	.09**	.00	.02	.00	-.04	.00	.10**	.00
Gender (female)	.12***	.05	-.11**	.05	.00	.05	-.35***	.09	.07*	.05	.05	.05	-.04	.03	-.05	.04	.08*	.04
A high perceived household financial status	.05	.04	-.06	-.03	-.01	.03	-.04	.05	.03	.03	.10**	-.03	.09**	-.02	.08*	-.02	.05	-.02
Degree: academic	.05	.05	.17***	.05	-.05	.05	.00	.09	-.15***	.05	-.02	.05	.05	.03	.08*	.04	.02	.04
Political orientation (right-wing)	-.12***	.02	-.06	.02	.15***	.02	.21***	.03	.12**	.02	-.03	.02	.01	.01	.00	.01	.06	.01
Residential area: city	.07	.06	.03	.05	-.17***	.06	-.02	.10	-.10**	.06	.03	.06	-.12	.04	-.01	.04	.05	.04
Adjusted R^2	.28***		.27***		.09***		.34***		.22***		.28***		.42***		.35***		.33***	

Note. ***p < .001, **p < .01, *p < .05.

sustainable energy production and consumption, followed by international actors such as China or India, international companies, and international environmental agreements [43]. The majority of citizens have been found to expect the public sector and the government to take the initiative in increasing the production of renewable energy in Finland [44]. Our results seem to indicate that market actors are also considered important, as well as the roles of citizens and consumers. The mounting concern regarding climate change in Finland may have increased the perceived relevance of different types of actors in tackling climate change [48].

Of the five drivers identified, mainstreaming renewable energy was associated with all images of the Finnish energy future, apart from the image concerning fossil energy use, highlighting the key role of this driver among respondents. Other drivers were also associated with futures images, suggesting a positive alignment with them and respondents' futures images. In particular, all five drivers were associated with the perception that domestic power will increase. Moreover, individual actions were seen as being part of the energy transition. This observation somewhat contests the common theory that people's images of the future regarding society and their own individual life are not coherent [10]. Another interesting finding is that the respondents in this study seemed to envisage the future rather optimistically, which has not been very common [45,46]. Although this could be a positive sign for the perceived agency to participate in the energy transition, a recent study suggests that people possessing overly optimistic views about the future do not see themselves as very active citizens [46].

In addition, different socio-economic groups preferred somewhat different futures images. Energy transition management needs to take into account differences in individuals' preferences, which in part are associated with their socio-economic backgrounds.

Limitations. The demographic differences between the sample and the Finnish population need to be taken into account when interpreting the results. The respondents were slightly more likely to be men and to be more highly educated than the average Finnish population. Gender and the level of education were found to be associated with preferences for energy forms and the perceived role of domestic power. This means that the preference for established renewables and fossil energy is likely to be higher, and the support for next generation renewables and nuclear energy lower in the Finnish population than in the sample. The perception of those believing that the role of domestic power will increase by 2030 is likely to be higher in the Finnish population than in the data sample. Further, there may be some socio-demographic biases in certain subgroups due to recruitment difficulties: for example, female respondents (45.2 years) were slightly younger than male respondents (48.8 years). We took this issue into account in the analyses by using multiple linear regressions, which controlled for the effect of differences in the socio-demographic characteristics of respondents.

Despite these limitations, we believe that these findings contribute to the scientific literature on sustainable energy transitions and the MLP framework, adding a detailed analysis of the citizens' perspective on the sustainability transition. Previously, it has been acknowledged that actors can engage in transition at several levels [47]. Citizens can engage in regime- or niche-level activities, and their values, attitudes and practices can support either the status quo or change. The majority of the respondents supported the transition away from the current system. The findings of this study suggest that citizens – not only early adopters [49] – may show even greater readiness for transition than the current political, economic and technological systems do. Therefore, citizens' future-oriented values and attitudes have an important role in driving transition, but only when they have the possibility to actively engage in the transition [50]. On the one hand, it is extremely important that the development of policies and technologies sufficiently engages citizens, both in creating visions and policies for more sustainable transitions and in actively implementing them. On the other hand, it is important that transition theories fully conceptualize the role of citizens as a driver of transition. In a democratic society, institutions, innovations and policies should reflect the values and preferences of its citizens, which should be an inseparable part of the social, material and technological aspects of the socio-technological systems.

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Appendix. Questionnaire

A. In your opinion, which direction the energy production should be developed in Finland by 2030?

Response scale:

1 = Reduce significantly
2 = Reduce somewhat
3 = Maintain at the current level
4 = Increase somewhat
5 = Increase significantly
6 = I don't know

- Nuclear power
- Natural gas
- Biogas
- Oil
- Coal
- Peat
- Hydropower
- Wind power
- Solar power
- Wood
- Arable energy plants
- Ground source heat and other geothermal energy
- Wave energy
- A technology that is not yet in use, you can specify it here if you want__________

B. Please imagine Finland in 2030. In your opinion, how the following issues related to the consumption and production of energy will change by 2030?

Response scale:

1 = will reduce significantly
2 = will reduce somewhat
3 = no change
4 = will increase somewhat
5 = will increase significantly
6 = I don't know

- Consumers' awareness of different energy production forms
- Consumers' awareness of the environmental impacts of energy production forms
  - The skills of housing condominiums to negotiate competitive energy solutions
  - Energy bought by households from small-scale producers
  - Economic benefits received by small-scale producers from distributing extra electricity or heat into a public grid
  - The spreading of different energy production innovations among the small scale producers
  - Variety of energy production forms
- Citizens' power in defining national energy policy
  - State responsibility of national electricity production
  - The number of carbon-neutral municipalities
  - The number of housing condominiums that produce all or nearly all of their own energy
- Cooperatives and similar associations involved in energy production
- Electricity transmission and guidance services offered by large companies to small-scale energy producers
  - State subsidies to small-scale renewable energy producers
  - Service companies that sell energy but do not own the energy production equipment
  - Renewable energy produced by farms
  - Kansalaisten itse tuottama energia
  - Smart energy systems in households that guide electric appliances, own energy production, its storage and sales and purchase of electricity
  - Utilisation of smart grids in the transmission of renewable energy
  - The profitability of centralised energy production facilities in urban areas
  - Number of distributed renewable energy production facilities in urban areas
  - Energy efficiency of buildings
  - Business activities based on renewable energy
  - Citizens' joint investments in renewable energy

- Acceptance of small-scale renewable energy production among consumers
- The importance given to climate impacts in energy policy decisions
- Share of renewable energy of all energy produced in Finland
- Share of local companies of the energy companies in Finland
- Number of small-scale energy producers
- Share of domestic energy of the energy consumed in Finland
- The carbon neutrality of energy used in Finland

C. Arvioikaa seuraavia mahdollisesti tapahtuvia asioita sen mukaan, kuinka keskeisiä ne olisivat Suomen energiantuotannon ympäristö-ja ilmastovaikutusten vähentämiseksi

Vastausasteikko:

1 = Unimportant
2 = Somewhat important
3 = Somewhat important
4 = Important
5 = Extremely important
6 = I don't know

- Actions by individual citizens
- Actions by NGOs or popular movements
- Increasing decision making power of citizens
- Referendums on energy policy
- Lowering the legal voting age
- Increase of citizens' decision-making power in Finnish energy policy
- Influence possibilities of low-income population
- National actions and political decision of Finland
- Decisions and climate policy of the EU
- Decisions and climate policy of the USA
- Decisions of large developing countries
- Wide-ranging binding international environmental agreements
- Actions by international large corporations
- New technological innovations
- Developing renewable energy business models
- Research and other knowledge production
- Consumption of renewable energy becoming cheaper
- Production of renewable energy becoming easier
- Production of renewable energy being economically profitable
- Evaluating economic profitability on a longer time scale than nowadays
- Societal experiments of distributed renewable energy
- Energy is seen as a key cost and people are ready to invest in it
- Those commissioning new housing emphasise distributed renewable energy
- Banks offer affordable loans for renewable energy solutions at homes
- Energy decisions are a way to communicate one's own identity as a consumer
- Energy production by individuals is socially respected
- Different ways to produce renewable energy by oneself is discussed in the media
- Climate change impacts becoming apparent
- Uncontrolled slowing down of economic growth
- Controlled slowing down of the economic growth
- Change of the economic system
- Change of values in the society
- The predictability of state taxes and subsidies concerning electricity and heat produced by citizens themselves
- Small scale production of energy as a part of a transition of work
- Actions by companies and markets
- Valuing energy policy in the construction of the future
- Lengthening the time period of policy impact analyses

Appendix D. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.energy.2019.06.134.

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