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Visions for small-scale renewable energy production on Finnish farms – A Delphi study on the opportunities for new business

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ABSTRACT

The future of the energy system in many countries is characterised by a balance between centralised and distributed systems. Besides producing food, farms possess biomass and open space suitable for renewable energy (RE) production. This paper presents the agricultural, farm-level opportunities for fostering RE business in Finland. The timeframe for this scrutiny is until 2030, and the Delphi method is used to analyse the possibilities, barriers and solutions for growth. The results show that among national renewable energy and agricultural experts the most preferred energy sources for increasing RE business on farms were wood (including wood chips), biogas and solar photovoltaics (PV). When asked about the most likely development, wood and biogas remained, but solar PV was changed to 'other farm-based biomass for burning'. The expert panel recognised the potential for RE business growth in agriculture, but easy access to the energy grid and refining incentives (both in the investment and production phases) for small-scale RE production were called for. Forerunners, pilots and new innovations were considered to foster the use of small-scale energy technologies. There was a clear hope that small-scale RE production on farms would not be based on heavy subsidies, but would grow as a market-based business.

1. Signs of energy transition towards distributed renewables

The future of the energy system in many countries is characterised by a balance between centralised and distributed energy systems. This paper sheds light on this discussion by presenting the agricultural, farm-level possibilities of developing renewable energy capacity in Finland. Distributed energy production and markets for renewable energy (RE) technologies are currently expanding (Sipilä et al., 2015). This is due to the greener policy goals within the European Union and global sustainability concerns. All EU countries have agreed an energy and climate package to increase energy efficiency by 20%, the utilisation of renewable energy sources by 20% and the reduction of CO_2 emissions by 20% by 2020 from the 1990 level (EU Commission, 2014). Targets for 2030 have been set as a 40% cut in greenhouse gas emissions compared with 1990 levels, at least a 27% share of renewable energy consumption and energy savings of at least 27% compared with the business-as-usual scenario (EU Commission, 2014).

International climate policy means that decentralised energy production and markets for renewable energy technologies are continually growing. This market growth is ensured, for example, by international and EU policies for renewable energy generation, the EU directives for increasing competition within the electricity industry and rising fossil fuel prices. Local energy production increases energy efficiency because of lower transport or transfer losses. Local energy production also increases local business, and energy production from local waste reduces waste management costs, thus enabling other local business and local employment. Local energy production also increases energy, electricity and fuel security by reducing import dependency (Sipilä et al., 2015).

The state of the total consumption of energy in Finland amounted to 1.36 million terajoules (TJ) in 2017 of which agriculture uses three percent (Official Statistics of Finland, 2017). The use of renewable energy sources continued to grow, and their share was a record high: 36 percent of total energy consumption. The share of renewable energy in total consumption has risen by nearly 10 percentage points in the 2010s. According to Official Statistics of Finland (2017), fossil fuel and peat use decreased by five percent, and correspondingly, carbon dioxide emissions from energy production decreased by five percent in 2017. The consumption of wood fuels grew by 3.5 percent, and they remained the most important individual energy source in Finland, with a share of 27 percent. This growth was due to an increase in the burning of by-products and waste wood from the forest industry. Of renewable energy sources, wind power grew relatively the most: its production rose by as

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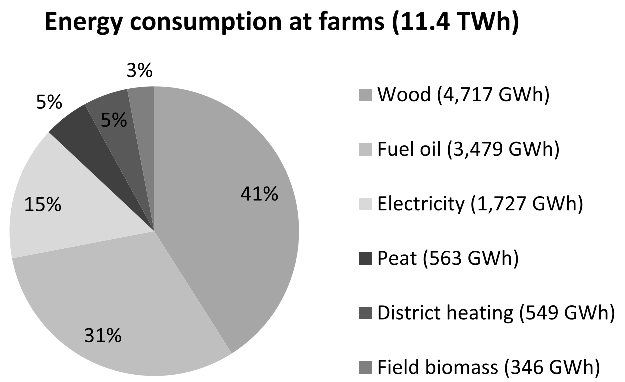

Fig. 1. The composition of total energy consumption on farms (Official Statistics of Finland, 2018).

much as 57 percent within one year. In total energy consumption, the share of wind power remains low at 1.3 percent. The use of biofuels in road transport started to rise again after a fall in the preceding year (Official Statistics of Finland, 2017). Biogas and solar power were still marginal, but growing overall.

The energy use in agriculture has heavily relied on external energy sources; especially fossil fuels and electricity bought outside of the farm from the national energy grid (see Fig. 1). Due to the scarcity of conventional energies and the environmental load they cause, a trend towards self-sufficient production within agriculture has emerged. The question is how the transition to a new energy system can occur. Various tools and techniques have been developed which seek to better anticipate and shape future technological developments. Some of these approaches, particularly in the early stages, tended to be techno-determinist in their outlook, but more recently a greater acknowledgement of the co-evolution of technology and society has led to the adoption of necessarily more complex perspectives (Geels and Schot, 2007). Some approaches have been purely quantitative, others purely qualitative, whilst a mix is often preferred. Some have involved only 'experts', whilst others have sought to initiate a societal dialogue (Cagnin and Keenan, 2008).

In the diffusion of new technologies, policies play a major role, as growth is supported by, e.g. EU policies for renewable energy and subsidy systems introduced in all EU member states (Ruggiero et al., 2015). The allocation of support systems varies. For example, in Finland the feed-in-tariffs are allocated only to large-scale plants, while in Germany small-scale energy production has been more extensively supported (Fulton and Capalino, 2012; Koistinen et al., 2014). The German *Energiewende* is one example of a strong turnaround in long-term energy policy with the enormous subsidies put into the energy market. (Agora Energiewende, 2017; Renn and Marshall, 2016). As a result of the German *Energiewende*, consumer electricity prices have risen, but at the same time the capacities of distributed renewable energy technologies have increased considerably (Trendresearch, 2011). This has meant new business opportunities and a need for new networks and concepts to emerge at the local level (Wassermann et al., 2012).

The growth of small-scale energy production has been mainly market-based in Finland. Before business opportunities in markets become solid businesses, an overview of the growing business field should be studied. As has been said, the role of policy is vital, but there is also a need to scrutinise the whole picture in renewable energy development, including e.g. technological solutions, market functionality, the value creation chain and emerging business concepts. In creating an overall picture, futures studies can contribute greatly. According to Cagnin et al. (2013), future-oriented technology analysis (FTA) has a potentially useful role to play in enabling a better understanding of complex situations and in defining effective policy responses by 1) improving the quality and robustness of anticipatory intelligence and preparedness for disruptive transformations through the use of systematic approaches and the development of shared insights and perceptions; 2) creating spaces for dialogue between key players from different domains with diverging views and experiences; 3) vision-building and consensus-building for considering and inducing 'guided' transformation processes; 4) shaping and defining dialogues on transformations and policy discussions on tackling these major changes; and 5) defining research and innovation agendas to support these dialogues and policy discussions. It is noteworthy that none of these benefits promise nor aim for prediction of the actually realised, 'terminally true' future (see Bell, 1997, 227–232).

The study bases itself to the socio-technical transition theory (Rotmans et al., 2001). Geels (2002, 2011) introduced a transition theory, which has also been used as a framework for analysing the development of distributed renewable energy production (Ruggiero et al., 2015). The process of social learning and acceleration can be stimulated by monitoring the transition process, where the rate of progress, including motivating drivers, the barriers, and the points of improvements are recognised (Rotmans and Loorbach, 2009). A transition to more sustainable energy system can occur when the local operational environment and the functioning of markets stimulate the local energy supply, the former being the special interests of our study. The term socio-technical transition is being increasingly used to denote a major transformation not only in terms of technological solutions but also with regard to wider societal change, including regulation, user practices, infrastructure, industrial networks and culture (Geels, 2002, 2011). Geels (2002, 2011) also adopts a multilevel perspective (MLP) to look at socio-technical transformation, proposing three analytical levels: landscape (macro), socio-technical regime (meso) and niche (micro). According to Mathijs et al. (2012), regimes (meso) are the stable backbone of socio-technical systems and have a characteristic rigidity that often prevents innovations from impacting or fundamentally changing existing structures. The dominant regime is challenged by niches (micro), the small-scale segments of society, where radical innovations can emerge and be tested on the periphery of existing regimes. They are the outcome of the co-evolutionary process of an entrepreneurial impulse within heterogeneous social and technological networks.

In recent studies (Ruggiero et al., 2015) small-scale energy production seems to have taken a step forward in light of volumes and used technologies. Farms and households have invested in e.g. bioenergy, solar and geothermal solutions. However, barriers ranging from high initial costs to a lack of loan opportunities and an underdeveloped rural enterprise sector to diffuse the technology can prevent small off-grid renewable energy applications from reaching their potential (Byrne et al., 2007).

Ge et al. (2017) have found that especially diversified farms are more likely to adopt renewable energy, especially wind, solar and biomass energy. Farms are also more likely to adopt renewable energy if they have high local demand for energy, or suitable conditions for renewable energy production. In Finnish context taken into account the long distances and sparsely located farms, the location of e.g. biogas plants are more likely nearby settlements or other enterprises utilizing energy. In addition to bioenergy based energy, in solar and wind energy there is a need to accelerate electricity system reforms to expand the transregional access to renewable electricity generation (Wakiyama and Kuriyama, 2018). It is also highlighted that in order to maximise the use of these potentials, a combination of technologies and policies are required to promote flexible grid operation, and strengthen transmission capacity and renewable priority dispatch order, as well as to introduce technology for stabilizing electricity systems supplied by renewable electricity (Wakiyama and Kuriyama, 2018). Also micro-grids, even off-grids using locally available energy sources, such as solar and wind power, are seen as an important option rather than waiting for the investment in large-scale generation and centralised transmission systems, but this ambition costs (Stram, 2016).

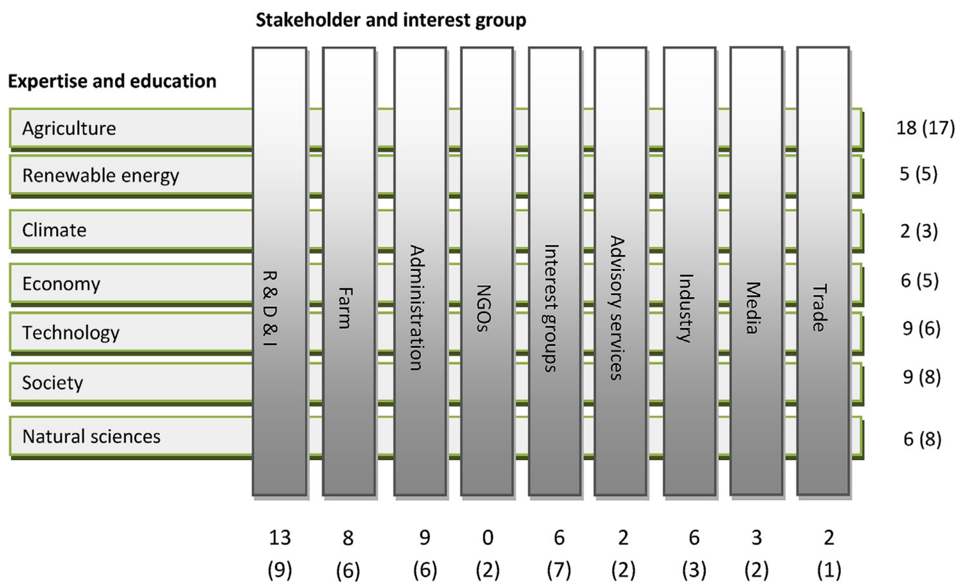

Fig. 2. The criteria and composition of the Delphi expert panel (numbers refer to the number of panellists possessing certain expertise; second-round figures in parentheses).

With these starting points in mind, we conducted a Delphi study within the agricultural sector from the perspective of small-scale RE production. The selected Delphi panel experts anticipated the business opportunities as well as the obstacles in the growth of farm-based energy production in Finland. The expert panel also envisioned what kind of energy business Finnish farms could run in the future. Scrutiny was undertaken through a process in which the preferred and probable future views of the expert panel were sought. The timeframe was set until 2030, which was long enough to allow the experts to consider large transitions but short enough to attain realistic envisioning.

The paper is constructed as follows: first, the background of the study is presented; second, the method and data used are presented; third, the results from two Delphi rounds are analysed and special attention is paid to the differences and emerging topics between rounds and scrutinising the results in the light of the multilevel perspective (MLP) to examine socio-technical transformation opportunities; fourth, conclusions are drawn and discussed from a more general perspective. The development of different energy technologies is interpreted by a socio-technical transition approach.

2. Delphi as a method in exploring future trends

2.1. Why Delphi?

In this study, a two-round Delphi process was used to evaluate the future potential of different energy technologies. Delphi as a research method has been widely used in futures studies. The users of the Delphi technique aim to predict and explore alternative future images, possibilities, their probabilities of occurrence, and their desirability by tapping the expertise of respondents (Linstone and Turoff, 2002). It is relevant that with this technique issues under scrutiny are dealt with more than once. This means that the iteration of future views is undertaken in several rounds, and feedback is given from previous survey and/or interview rounds. Every respondent on the expert panel is able to re-evaluate his/her answers anonymously (Linstone and Turoff, 2002). The traditional Delphi method was based on questionnaires, but it is increasingly common that at least one round is undertaken with face-to-face interviews to attain more in-depth arguments (Rikkonen, 2005; Rikkonen and Tapio, 2009; Varho et al., 2016).

According to the twenty-year experience of the authors and literature, the Delphi method is a suitable method to anticipate the future of a system when

- Significant change in the system under study is anticipated or viewed as strongly favourable
- It is unclear whether and how the significant change will (or should) happen
- The relationships between parts of the system are expected to change
- The system is an object of strong political debate
- Some persons and organisations dominate the debate on the future of the system.

All these points apply in this study. Renewable energy use has grown in recent decades, starting from the 1990s, and it has more than doubled in that time (Statistics Finland, 2017). Furthermore, significant future growth would be beneficial because of climate policy goals. This energy transition requires clear structural changes in the energy production system and an active role for development. Energy and agriculture are at the heart of the political debates of our time and in our case country, Finland, strong players dominate the discussion.

In this study, the first Delphi round was conducted with interviews in which a pre-tested questionnaire was completed. The second round was conducted using an online Webropol survey tool. The overall Delphi study consisted of four parts, taking agriculture's role in climate and energy strategy into account: 1) commenting on pre-prepared alternative agricultural climate and energy scenario narratives (Rintamäki et al., 2016); 2) evaluating agricultural climate change mitigation measures (Rikkonen et al., 2015); 3) anticipating the energy change scenarios of self-sufficient farm-based RE energy production (Tapio et al., 2017); and 4) anticipating the business opportunities as well as the obstacles and solutions in the growth of farm-based energy production in Finland. This paper is based on the Delphi results in part 4.

2.2. How was Delphi used?

According to Kuusi (1999), choosing the expert panel is one crucial phase of a Delphi study. The Delphi facilitator should consider in his/her actor analysis the most important stakeholders and interest groups, most important substance (the competence of experts) as well as the terms of delivering information in a Delphi process (information policy). The selection process of an expert panel should be done as overtly as possible. It is usual that selection criteria are established before the individual experts are listed. The goal is to have sufficient expertise coverage in the phenomena under scrutiny (Kuusi, 1999). In this study, the following expert panel was established (Fig. 2).

First, the areas of the needed competences were defined to ensure a comprehensive picture of the topic: agriculture; renewable energy; climate policy; economy; technology; social and natural sciences. Then the different actors and stakeholders of the value chain were defined to ensure a variety of viewpoints: research; development and innovation (RD&I); farms; administration; non-governmental organisations (NGOs); interest groups; advisory services; industry; media; and trade. It is notable that this expert panel consisted of agricultural expertise and expertise closely related to renewable energy within agricultural sector. For example (Fig. 2) there were five out of 28 experts specialized directly in different renewable energy technologies. Also several experts in other categories were chosen in such a way that they were supposed to have some background in renewable energy in addition to agricultural competences. During the Delphi rounds background questions were asked to confirm this. Twelve out of 28 considered themselves as experts especially in renewable energy.

After selection, the experts were first approached by email and then personally by phone to schedule a first round interview meeting. The structured questionnaire in the interviews was sent by email beforehand. The experts were asked to return them electronically before the interview. This technique has proven efficient timewise and includes an additional iteration to the first round, because the interviewer can ask for arguments for the first round answers immediately (Varho and Tapio, 2005). Interviews were conducted face-to-face in all except two cases, in which video calls were used. The experts were asked to focus on the research issues using their own expertise, not as representatives of their background organisation.

The first round (interview) questionnaire was sent to 36 experts, of whom 28 returned it. The second Delphi round was conducted through an online tool (Webropol survey) with an additional three experts on the same expert panel because a gap was identified in the expertise matrix during the first round. The survey was open for a month and several reminders were sent. Altogether 23 experts answered the second-round questionnaire. This is a rather typical number of participants in a Delphi study – in their systematic review de Loë et al. (2016) found that more than a third of policy Delphi studies in academic journals had 30 or fewer participants, and more than two thirds of the studies had 50 or fewer participants. Diversity and in-depth knowledge of the panel is more important than probabilistic sampling.

In the first round, the panellists were asked about the desirable and probable future development of individual energy forms. The respondents rated each nine energy sources according to whether the farm was a buyer or seller of a specific energy form, and stated how probable and preferable this would be on Finnish farms by 2030. The scale was a seven-step Likert (1 = buys a lot; 7 = sells a lot).

The second round consisted of 1) first round feedback results and 2) seven selected arguments derived from the first round interviews, including typical arguments and measures for increasing RE production as a business opportunity for farms. The five most popular arguments were selected, as well as two of the arguments that divided opinions but would be indicators of disruptive transformation. As the second Delphi questionnaire consisted of several sections and was quite laborious, we did not include more than seven arguments to ensure a reasonable response rate.

2.3. Consensus or dissensus Delphi?

The classical Delphi method aimed to achieve an expert consensus based on the assumption that experts are rational people who, after sharing and discussing arguments, eventually agree on the most probable future, and this agreement would be a reasonably accurate estimate of what would really happen. This could be attained by removing the psychological bias of group behaviour with an anonymous process and sharing knowledge on the topic. However, the basic assumption has been criticised for being unrealistic or undesirable: unrealistic, because experts often disagree about the future course of events or trends; undesirable, because helping decision making requires producing pluralistically alternative desirable futures for decision makers rather than single estimates of the most probable future. Indeed, there are clearly two types of Delphi study: the classical Delphi aims for consensus concerning the future; the policy Delphi tradition aims to explore the variety of views of the future (Tapio, 2013; Rikkonen and Tapio, 2009; Steinert, 2009; Van de Linde and Van der Duin, 2011). In this paper, the two approaches are combined.

How is the combination of the consensus and dissensus Delphis possible? Are they not based on completely different schools of thought in futures studies, where the first aims to accurately predict the most probable future and the latter aims to open alternative possible futures? They are – but they do not need to be. In the data gathering phase, where views of the future of a given topic are sought, there is barely any difference. Questions to the panel are asked in the same manner, but only the framing of questions and the purpose of the study may differ. The data analysis phase is typically different – in consensus Delphi, the measures of central tendency (means, medians, most common arguments) in reporting the data are much more important, whereas in dissensus Delphi the variation is examined more closely. However, means, medians and variation are important aspects of the data in both approaches. The main difference is the interpretation phase, because in consensus Delphi, small or decreasing variation in successive rounds is called success, whereas dissensus Delphi continues to report a diversity of views in a more qualitative manner and the arguments supporting them, and the researchers tend to emphasise their impressions of the most common views less within the panel.

In this paper, the consensus and dissensus approaches are combined because we are interested in both the most promising renewable energy technologies and the arguments supporting the common views and the relevant counter-arguments overshadowing them. We report

- both probable future and desirable future estimates,
- the means but also standard deviations of the growth of energy forms
- the overall direction based on the answers, but also diverging arguments and alternative directions

Importantly, we attempt to avoid overly deterministic expressions when indicating probable futures and overly relativistic 'anything goes' expressions when discussing variation.

3. Results

3.1. Biogas, wood and solar power will probably rule in farm-based RE production

Contrary to the assumptions of the research team, the expert panel saw that the time frame until 2030 was too short for any radical change to happen. However, the panel regarded bioenergy as an asset for Finland because there was significant potential biomass available. The panel hoped for more self-sufficient energy production in distributed energy systems and through new business models. New business was anticipated because of the extra income for farms in addition to revenues from food products.

Biogas was considered the most desired energy form in building new business. The supporting argument was that biogas production utilised biomass in an efficient and circular manner by producing energy and nutrients. Firewood (including wood chips) was also seen as a growing source, and the panel considered that it offered increasing income opportunities. The potential of solar energy in its various forms was also

Table 1
Future views of renewable energy on farms and arguments for change proposed by the 28 panellists (round I) and 23 panellists (round II).

Biogas	1. round	2. round	Difference between rounds	Future direction	Key arguments (+ positives and - negatives)
Probable (average)	5.00	4.71	−0.29	↑↑	+ Available field area for biomass production
SD	0.80	1.38	+0.58		+ Increases self-sufficiency of nutrients and energy
Desirable (average)	5.80	6.05	+0.25		+ Cooperation between crop and livestock production increases sustainability -
SD	1.00	1.33	+0.33		Farm-scale profitability is questioned - Land should be used for food production
Solar PV	**1. round**	**2. round**			**Key arguments**
Probable (average)	4.38	4.14	−0.24	↑	+ Available field area for installations
SD	1.13	1.15	+0.02		+ Existing number of buildings on farms offers potential
Desirable (average)	5.40	5.33	−0.07		+ Easy to use, low maintanence costs, easy access to grid - Still relatively costly
SD	1.32	1.35	+0.03		
Solar heat	**1. round**	**2. round**			**Key arguments**
Probable (average)	4.32	4.42	+0.10	↑	+ Fits well with the need for heat energy on farms
SD	0.80	1.26	+0.46		+ Easy to use, low maintanance costs, cost-effective
Desirable (average)	5.00	5.00	0.00		+ Existing number of buildings on farms creates potential - The heat production
SD	1.18	1.41	+0.23		volume is hard to match to the need
Wind power	**1. round**	**2. round**			**Key arguments**
Probable (average)	4.42	3.63	−0.79	↑	+ Income from renting windmill sites
SD	1.17	1.30	+0.13		+ Available field area for own small scale production purposes
Desirable (average)	5.20	4.27	−0.93		+ Farm clusters constitute larger investment potential - Small-scale wind turbines
SD	1.32	1.72	+0.40		are an expensive way to produce energy
Hydropower	**1. round**	**2. round**			**Key arguments**
Probable (average)	3.42	2.83	−0.59	↔	+ Potential sites already used - Impacts on wild fisheries negative
SD	1.17	1.20	+0.03		
Desirable (average)	4.16	3.35	−0.81		
SD	1.57	1.79	+0.21		
Wood (incl. wood chips)	**1. round**	**2. round**			**Key arguments**
Probable (average)	5.31	5.71	+0.41	↑↑	+ Synergies with forestry
SD	1.16	1.27	+0.11		+ Traditional source for heating, existing technology
Desirable (average)	5.60	6.00	+0.40		+ Strong support from energy policy (no negative arguments)
SD	1.15	1.02	−0.13		
Heat pumps	**1. round**	**2. round**			**Key arguments**
Probable (average)	4.42	4.45	+0.03	↑	+ Cost efficient especially in farms (need for heating can be extensive)
SD	0.81	1.36	+0.55		+ Available sources for heat exist, and they are unused in ground, in buildings, in
Desirable (average)	4.76	4.64	−0.12		production processes
SD	1.01	1.50	+0.49		
Biofuels	**1. round**	**2. round**			**Key arguments**
Probable (average)	4.04	3.85	−0.19	↔	+ Farms are the raw material supplier for biofuels, not producers - Producing
SD	1.49	1.57	+0.08		biofuels is not energy-efficient - The reduction to GHG is modest compared to
Desirable (average)	4.54	4.62	+0.08		other measures
SD	1.77	1.28	−0.49		
Other biomass for burning	**1. round**	**2. round**			**Key arguments**
Probable (average)	4.67	4.58	−0.09	↑	+ Farms possess different biomass sources for utilisation
SD	1.24	1.39	+0.15		+ Combustion technologies are traditionally extensively used (no negative
Desirable (average)	4.96	4.95	−0.01		arguments)
SD	1.40	1.50	+0.10		

considered because of its relatively low investment price and ease of use.

The largest obstacles for small-scale RE growth were seen in legislation and in current energy policy that favoured a centralised energy system. Smart grids, free entrance to grids and net metering were seen as crucial preconditions for making RE production economically feasible and thus enabling growth in farm-level energy systems.

3.2. Arguments for business opportunities from different energy sources

Table 1 summarises the different potential in RE technologies according to the expert panel. The first and second round quantitative answers are presented with an equal emphasis on averages and standard deviations. Next, the differences between rounds are presented to describe the effect of the iteration. The most plausible future direction is then indicated with arrows and, finally, the key arguments concerning the evaluated future change are presented.

3.2.1. Biogas is clearly favoured

Biogas production was considered to have the most potential for farm-based energy production, especially on dairy farms. In addition to available manure, farms possess cultivated field areas that produce a large amount of biomass, some of which forms unused residues that should be rationally utilised. Simultaneously, manure from livestock farms can be utilised. Some experts highlighted that due to rising prices in fertilisers (especially phosphorus), biogas production was an increasingly rational option. At the same time, it decreased the costs of petrochemical fertilisers. Some experts doubted the cost efficiency of biogas production. It was argued that it would not be wise to utilise crops for biogas by taking field areas out of food production. However, there was a strong opinion that biogas would be an increasing business for farms if the right sales channels were found. The sale of biogas for traffic fuel was considered one such channel. Increasing production would require the dismissal of administrative barriers and increasing information about best practice. Some experts considered that larger biogas plants (e.g. multi-farm entities) would improve profitability.

Practices that would bring livestock and crop production farms together were seen as desirable.

3.2.2. Solar PV has potential, but caution is needed

The experts considered that certain areas of farms might be suitable for enlarged PV production because there was plenty of space. However, solar PV was still considered an expensive and subsidy-driven technology for farms, even if technology prices had decreased recently. It was seen as probable that solar PV would increase on farms in the future, and it was hoped that Finland would learn from Germany's experience in using existing buildings as platforms for new PV installations. Solar PV was seen as easy to use, and maintenance costs in labour and equipment were considered minor. When prices further decreased and the energy price increased, demand might also increase on farms. Solar electricity was also seen as easy to produce and sell to the grid compared to e.g. biogas, which is used for combined power and heat in areas where the demand for heat is limited.

3.2.3. Solar heat fits well with farm production processes

Some experts considered that solar heat production was more reasonable for farms than solar electricity production, especially in livestock production where the buildings and water used could be heated, and the surface area of buildings was extensive. However, solar heat was criticised because the heating it offered did not correspond to the time in winter when it was mostly needed. Like solar PV, solar heat was considered easy to use, and maintenance costs were considered minor. As the technology becomes cheaper and the energy price increases, the demand for solar heat may also increase.

3.2.4. Wind power on farms means renting sites

Wind power was seen as having the potential to bring income to farms from the rental of agricultural areas for them. Some experts considered that farms' own small-scale windmills offered no potential due to their relatively high price. However, larger wind farms were seen as having some potential. Some experts regarded wind power as a centralised energy form due to its positive treatment in energy policy (e.g. it is an energy form that belongs to the production support system). Therefore, they saw no role for wind power on primary production farms. To promote wind power in agriculture, some experts suggested shared wind farms run by farm clusters.

3.2.5. Hydropower will probably not increase

Increasing hydropower was not considered relevant for Finland because the optimal resources are already in use and the development of harvesting water power is instead turning to restoring rivers to their natural state. It is also possible that some panellists misunderstood the question relating only to harnessing on-farm hydropower, which was considered to have low potential. Hydropower is in use on a farm-scale especially in horticultural enterprises. It would of course be possible for farms to buy more hydropower outside the farm with a hydropower contract available in Finland. However, even this capacity is already much in use.

3.2.6. Firewood (incl. wood chips) business will probably increase strongly

Firewood was considered a traditional heat source and its relationship with forestry solid. It is still evident that the extensive number of forests in Finland owned by agricultural farms enables their use in energy production. The utilisation of forests in farm-based energy business was considered likely to grow steadily. Some experts referred to the structural change in forestry (e.g. the decreasing number of paper mills) which could lead to a situation where more wood was available for energy production. The potential for farm business was seen in selling firewood outside, not in producing energy for grids by e.g. small-scale CHP plants. It was thought the use of wood chips would increase due to the support of Finnish energy policy. However, the utilisation of forest-based energy should be based on overall sustainability. Fostering and maintaining biodiversity was seen as essential in forestry when energy wood was collected.

3.2.7. Heat pumps are cost-effective

Heat pumps were considered a cost-effective alternative. Heat pumps were seen mainly as a farm-level solution in bringing self-sufficiency, but not as bringing extra income. Some experts saw that piping systems could be developed even further through heat pump technology to gather the heat from different production processes (e.g. cattle houses). The future views did not change in the second, the feedback round. However, it is notable that the standard deviation of probable future increased. The reason for this could not be tracked because the second round was organised as a structured questionnaire.

3.2.8. Finnish farms will probably not produce biofuels

Farm-based biofuels were not seen as very effective in climate change mitigation, and their production was considered a process that wasted energy. Farm machinery could utilise them, but they were not seen as something that farms would produce for sales. However, if the small-scale production technology developed quickly, there might be a business opportunity for farms to produce e.g. biodiesel. The main role of farms was still considered to be to produce raw material instead of biofuels. Some respondents also stated that fields were for food production, which was simply considered more important than producing fuels.

3.2.9. Other biomass for burning is always relevant on farms

Using biomass other than firewood for burning was considered feasible on farms because they possessed different biomass stocks for utilisation. Biomass from e.g. set-aside areas could be utilised more extensively than currently. The less fertile fields could especially be used to produce biomass in combustion. Combustible algae production was also mentioned as a weak signal.

3.3. The differences between rounds

The desirable development of biogas was considered clearly stronger than the probable future development in bringing business for farms. This observation also strengthened during the two rounds. Solar PV and heat were also more desired than what was considered probable. Business from firewood was thought likely to increase more strongly in round two. Views of the probability and desirability of future wind power decreased the most between rounds. The most stable future views between rounds concerned heat pumps and other biomass for burning. Hydropower was the only renewable energy source that seemed to decrease in energy production on farms.

3.4. Societal impacts and prerequisites for growth in distributed rural RE in the Finnish context

In general, the expert panel estimated that the potential to produce RE from agriculture was huge. Therefore, the future role of agriculture as an energy supplier for its society could be significant. This was also supported by the fact that farms possessed extensive field and forest areas: they could introduce new mitigation measures to minimise climate change and increase the self-sufficiency of energy supply in Finland. One of the experts stated, 'If there are opportunities to strengthen self-sufficiency, agriculture has the most potential to start with.'

The expert panel also stated that Finnish society should examine more closely how agriculture could serve society better in energy supply. The combined agriculture and forestry farms typical of Finland could build a new business branch from RE production. Impacts were also seen from a wider perspective in rural areas. The distributed energy business could revitalise abandoned and uninhabited rural areas. It was also considered that new energy business would increase cooperation between different actors in agricultural and other rural areas. Despite the fact that Finland is rather subject to continued urbanization than revitalising rural areas, some of the panellists encouraged new emergence of regional policy to plan how to employ as much as possible in agricultural and energy business, and increase recolonisation. The rise of distributed RE can also play a strong role in building a distributed societal structure as a whole that many Finns already appreciate e.g. through their summer cottages and seasonal visits to their original residences.

The importance of cooperation between all the actors involved was highlighted. Without it, the common goal of a distributed system would not become a reality. The sharing of material and immaterial resources was also considered important. The expert panel felt no radical development was probable, but a step-by-step process was more likely. The pioneers in the field were considered important as role models and in making changing energy technology visible and concrete.

Self-sufficiency was the most mentioned argument and it was hoped it could be achieved quickly. This requires strong energy and agricultural policy support in piloting and demonstrating new solutions. If they succeed, export opportunities are also opened. To affect a radical energy change on farms, an agricultural emission trade scheme was proposed by some experts. Furthermore, some respondents proposed that a change in energy taxation would be desirable measure at this point.

A fear was expressed concerning enterprises seeking economies of scale in distributed, small-scale RE production. When the business became attractive, the big players might take over the bioenergy markets from smaller enterprises. Agriculture's lack of profitability was also mentioned as a threat to RE business. In order to be able to invest in new technologies and build new business, capital was needed. If the economic situation was already challenging, no desire to invest would arise. This might mean that only a few frontrunner farms would proceed with RE business, and the majority would remain traditional fossil fuel utilisers.

It was hoped the RE business would develop as local and small-scale production that served nearby homes. It was argued that Finland was already a sparsely populated country, and it was wise to use local heat and electricity production from nearby plants.

The biggest driver influencing the rise of distributed, small-scale energy was considered to be the price of energy. When relatively affordable fossil fuels are available, there are no incentives to innovate new technologies even if they are more environmentally friendly. Energy sources like solar and wind energy that do not take agricultural land away from food production were also seen as likely to increase more than biomass-based bioenergy. The utilisation of agricultural biomass was thus seen as an interphase in transition from fossil to renewable energy.

3.5. Measures for RE growth in the face of the multi-level perspective

In the first Delphi round, opinions of energy source-specific solutions were also sought in interviews, and in Table 2 the main solutions are presented. The expert panel discussed biogas and wood-based energy most. In these cases, the proposed solutions included research, development and innovation (RD&I), marketing and administrative actions. Table 2 also presents different energy forms according to the Multi-Level Perspective (MLP) approach, which asks whether the technology is a niche or at a mature level in society (Geels, 2002, 2011).

In the second round, some of the measures proposed by the experts were defined as statements and it was asked again whether the respondents disagreed or agreed with the statement (Fig. 3). The strongest agreement concerned the ease of connection to the grid with sufficient compensation. This should be the starting point to build really smart grids for distributed, small-scale RE production. The promotion of pilots and demonstrations to diffuse RE technologies on farms were considered almost as important. These could provide information for new investors about the most feasible, efficient and profitable solutions. However, the experts hoped that such demonstrations would not be based on strong subsidies. The statements most disagreed with concerned case-by-case evaluation of subsidies and the need to recognise energy sales revenue as an agricultural income source.

4. Discussion

The study's results demonstrate that at the farm level there are two potential and growing small-scale energy business opportunities, namely biogas and traditional wood (incl. wood chips). These were evaluated as both desirable and probable. The potential for biogas was seen in refining it for e.g. traffic fuel and investing in the nutrient cycle as a circular solution. Profitability was considered a concern and, especially, it was argued that farm-scale plants should move to a larger scale and base themselves strongly on cooperative models. Wood (incl. wood chips) already has a strong position, but farm-scale technology development is preferred. To achieve a level of growth in line with the preferred future views, stronger policy measures are needed, and cooperation and networks between businesses need to be developed.

From the socio-technical transition path perspective, energy technologies differ greatly from each other. Biogas is still a niche technology in Finland, especially in agriculture. Volumes of biogas production are still modest, and it is not institutionalised at regime level. Solar PV and heat are also still at a niche level in Finland, though households and farms have invested strongly in Solar PV systems in recent years. Heat pumps are moving from niche to regime level due to rapidly increasing market demand and supply in Finland, especially in detached houses. It has potential for farms, and investments have been made. However, due to their market-driven small-scale character and modest regulation, strong institutionalisation at the regime level cannot yet be seen. Wind power is also moving from niche to regime level due to a strong support policy. According to the study, it has some potential for farms, and some individual investments have been made. However, due to energy policy, large-scale offshore windmill parks are the future direction, even if open spaces can be found in the rural environment and farms can achieve rental income as landowners by providing sites for windmill operators (see also Sokołowski, 2017).

Hydropower is already institutionalised at regime level in Finland due to the historic use of suitable sites for hydropower. It offers stability in energy generation, but growth is not foreseen. Indeed development is in reverse, with the restoration of white waters for fish stocks. However, small-scale hydropower has its significance for energy production e.g. in greenhouses. Woodchip burning is also already institutionalised at the regime level in Finland due to the historic use of firewood in households, energy generated from forest industry side-streams, and powerful national mental models of forests. Many farms have their own forests, making this a lucrative alternative. Woodchips are suitable for combined heat and power production. Other biomass for burning has strong traditions due to the historic use of biomass combustion technologies. Biofuels have emerged at regime level due to a strongly supportive EU energy policy. The EU aims to see 10% of the transport fuel of every EU country coming from renewable sources such as biofuels by 2020. Fuel suppliers are also required to reduce the greenhouse gas intensity of the EU fuel mix by 6% by 2020 compared with 2010 (EU commission, 2014).

Much recent work exploring food system energy use has been motivated by increased awareness of the role of food systems in anthropogenic GHG emissions (Pelletier et al., 2011). The traditional agriculture can be challenged in the future if the food systems change drastically through the tightening GHG mitigation policy and novel food production technologies. Currently urban populations are fundamentally dependent on the resource provisioning and waste assimilatory capacities of geographically remote ecosystems (Rees, 2008). This can change in a long run. Conventional food systems are constantly argued with other possible food alternatives such as insects or mini-

Table 2
Solutions for growth proposed by the panellists and interpreted from the Multi-Level Perspective (MLP) approach and socio-technical readiness.

Energy form	Socio-technical readiness	Solutions for growth proposed by the panellists
Biogas Niche level	Biogas is still a niche technology in Finland, especially in agriculture. Biogas technology has been demonstrated in farm-level installations and has a promising future based on the international landscape. Biogas can be used as a transport fuel and it enables a sustainable nutrient cycle on farms. Volumes of biogas production are still modest, and it is not institutionalised at regime level.	- Selling biogas as traffic fuel - Introducing forerunners to foster use - Dismissal of administrative barriers and costs - Investing in bigger biogas plants - Investing in cooperation models between crop and livestock production
Solar PV	Solar PV is still at a niche level in Finland, though households and farms have invested strongly in Solar PV systems in recent years. Volumes of Solar PV are still modest, and it is not institutionalised at regime level.	- Using more existing buildings in installations - Marketing efforts (ease in use, low maintenance cost, easy to sell to the grid)
Solar heat	Solar heat is still at a niche level in Finland, though households and farms have invested somewhat in solar heating systems in recent years. Volumes of solar heat are modest, and it is not institutionalised at regime level.	- Marketing efforts (ease in use, low maintenance cost)
Heat pumps	Heat pumps are currently emerging from niche to regime level due to rapidly increasing market demand and supply in Finland, especially in detached houses. It has potential for farms, and investments have been made. However, due to their market-driven small-scale character and modest regulation, strong institutionalisation at the regime level cannot yet be seen.	- RD in piping systems that gather heat in various farm production processes
Windpower	Wind power is emerging from niche to regime level due to a stronger support policy. It has some potential on farms, and some investments have been made. However, due to the energy policy, large-scale windmill parks are the future direction, even if open spaces can be found in the rural environment.	- Optimising the tariff system - Shared windmills in farm clusters - RD in small-scale windmills
Hydropower	Hydropower is already institutionalised at regime level in Finland due to the historic use of suitable sites for hydropower. It has stability in energy generation, but growth is not foreseen. Small-scale applications are usually integrated in greenhouses and grain mills.	- No solutions proposed
Wood (incl. wood chips)	Woodchip burning is already institutionalised at regime level in Finland due to the historic use of firewood in households, energy generated from forest industry side-streams and powerful national mental models of forests. Many farms have their own forests, making this a lucrative alternative. Woodchips are suitable for combined heat and power production.	- Continuing strong energy policy support - Specialisation in raw material production - RD efforts in the chemical and wood construction industries; also increases raw material for energy - Marketing the synergies between sustainable forestry and RE production
Biofuels	Biofuels have emerged at regime level due to a strongly supportive EU energy policy. The EU aims to see 10% of transport fuel in every EU country coming from renewable sources such as biofuels by 2020. Fuel suppliers are also required to reduce the greenhouse gas intensity of the EU fuel mix by 6% by 2020 compared with 2010.	- Specialisation in raw material production from farms - Several sources of biomass (plants, trees) available
Other biomass for burning	Other biomass for burning has strong traditions due to the historic use of biomass combustion technologies (on farms, from forest industry side-streams, waste management etc.)	- Integration with other raw materials using combustion technologies (wood-based) - Several sources of biomass (plants, trees) available

livestock, cultured food and shifting food production to urban locations. If these novel systems are realised to the regime level in the future, it has also impacts on society's energy system.

4.1. Methodological and paradigmatic considerations for Delphi users

In this study, the consensus and dissensus approaches were combined. First round face-to-face interviews with a semi-structured questionnaire gave us an opportunity to present relevant arguments for discussion in the following round. We were therefore able to detect the arguments supporting the common views and counter-arguments overshadowing the common views on farm-level RE generation.

We also used future images and their arguments in interpreting the MLP approach (niche, regime and landscape levels) in each of the technologies. Based on this study's experience, experts were more active in arguing for niche technologies than for already mature technologies. This may be considered valuable because it guided experts to carefully consider in-depth solutions for growth, and the barriers and supporting factors for development.

To widen up the debate between consensus and dissensus Delphi paradigmatic views of the criteria for good futures studies and academic research in general should be discussed. First, as the future does not exist we cannot observe nor measure the future and are always dependent on past and current trends and views of the future. Second, as humans have an effect on the very future that will finally occur, uttering a vision or a prediction of the future may itself have an effect on the future, either by increasing the probability of occurrence (self-fulfilling prophecies) or decreasing it (self-destructing prophecies). Third, it follows that there are several alternative possible futures that need to be addressed. For these reasons futures studies do differ from standard academic endeavors (See e.g. de Jouvenel, 1967; Amara, 1981).

In order to deal with this ontological dilemma about the future, Delphi studies provide a platform facilitating expert and/or stakeholder discussion of the future. That is, the call for objective truth is displaced by intersubjective truth. The consensus Delphi is in line with the Habermasian ideal of continuing the discussion as long as agreement occurs, since it considers truth as the limit value of discussion conducted under the criterion of ideal speech situation (see Yetim and Turoff, 2004). Thus the level of agreement is considered as the level of accuracy. However, dissensus Delphi is more in line with the discussions of deliberative democracy (e.g. Dryzek, 2005). Here truths, especially truths about the societal future are seen as a constant battle of various interests and values. Consensus of a single agreed-on future is not the goal, instead the goal is consensus on dissensus, i.e. 'meta-consensus' (Dryzek, 2010). In a futures study, meta-consensus would mean that the participants 'vote' for different futures in terms of their probability and preferability, but agree on that other participants' views are relevant. Therefore, listening to (or, here reading) the arguments of other participants increase understanding and respect for others rather than produce agreement. Table 3 illustrates the four basic ways panelists can agree and disagree and how these cases can be interpreted form the consensus and dissensus Delphi point of views.

The methodological aim of this study was to combine the approaches of consensus and dissensus Delphi (see Section 2). We conclude that the combination can be made by accepting that:

- The aim of the study is to find out possible, strategically relevant

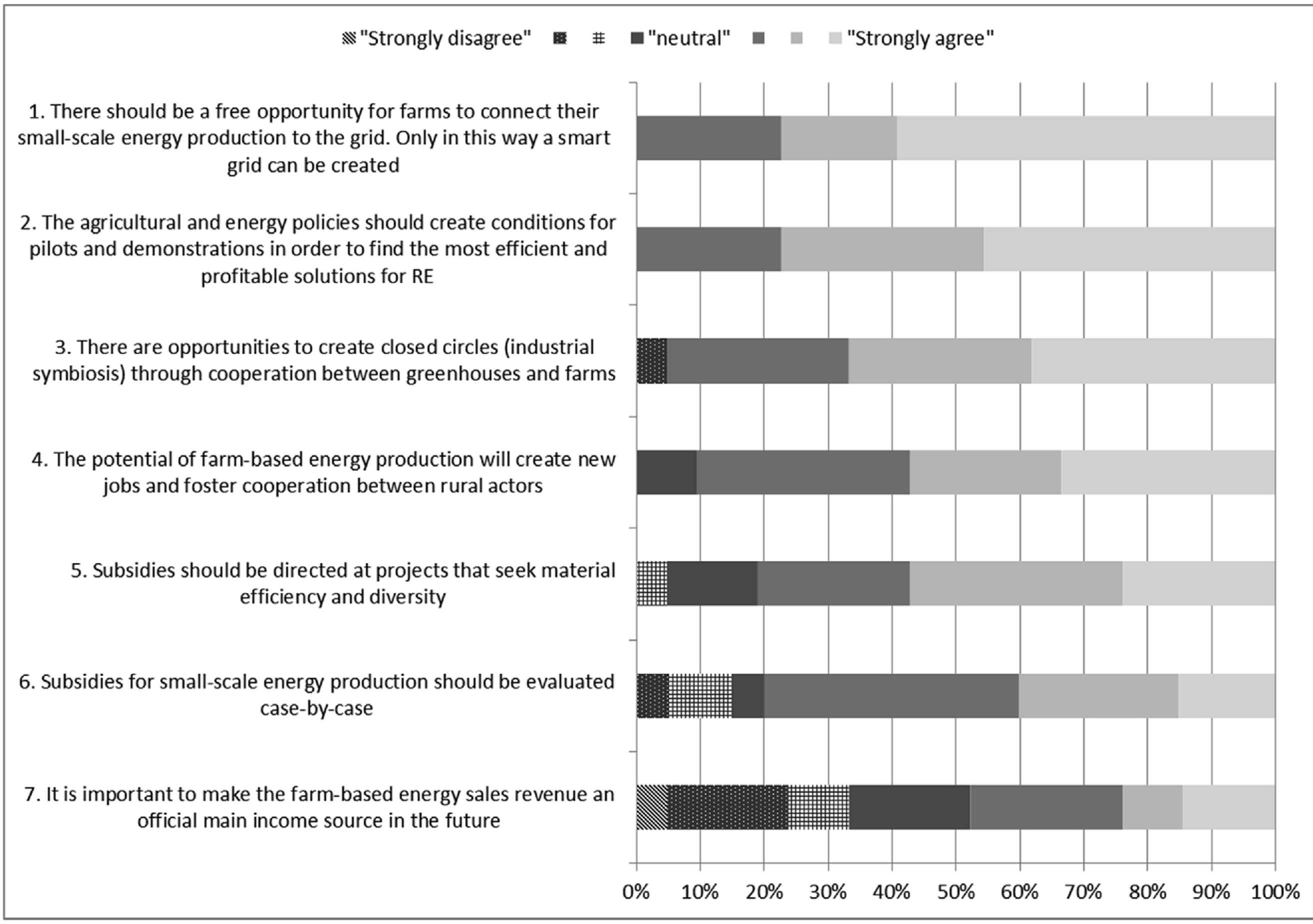

Fig. 3. The expert panel second-round responses to the statements arising from the first Delphi round (N = 20 … 22).

futures, rather than probable futures.

- The results on probability are intersubjective, relevant expert views rather than predictions. Since perceptions of probabilities have an effect on human decision-making, studying them is relevant.
- Delphi is not a random-sample two-round survey but a facilitated, iterative and secure forum for experts to share ideas and learn from each other.

5. Conclusions and policy implications

This paper has attempted to shed light on the discussions of growth opportunities in distributed energy systems by presenting the agricultural, farm-level possibilities of fostering the renewable energy (RE) business in Finland. It has to be kept in mind that these results represent only the chosen panel's view on future of RE potential. The results tell us how the Finnish expert community within the agriculture and agri-based small scale renewable energy production sees the future of RE possibilities in the Finnish national context. The main goal in this paper has been to analyse whether there are opportunities to increase production and sales of energy products on farms, or whether farms are mostly energy buyers.

The expert panel recognised the potential for RE business growth in agriculture, but easy access to the energy grid and further incentives (both in the investment and production phases) for small-scale RE production were called for. Forerunners, pilots and new innovations were considered to foster the use of small-scale energy technologies on farms. There was a clear hope that small-scale RE production on farms would not be based on heavy subsidies, but would grow as a market-based business. To achieve a level of growth in line with the preferred future views, stronger policy measures need to be improved, and co-operation and networks between businesses need to be developed.

Four main conclusions can be drawn if significant growth is to be achieved. First, investments in grids for small-scale distributed electricity should be supported (even off-grid solutions when relevant in a

Table 3
Four logical ways participants can agree or disagree about the future and four interpretations from the Consensus and Dissensus Delphi viewpoints.

Outcome	Approach to the outcome	
	Agreement	Disagreement
Single future	Agreed single future, 'Consensus' *Classical Delphi: small variation, high accuracy* *Dissensus Delphi: unexpected surprise*	Disagreement on a single future, 'Dissensus on consensus' *Classical Delphi: small variation, low certainty, moderate accuracy* *Dissensus Delphi: process failure*
Multiple futures	Agreement on the relevance of alternative futures, 'Consensus on dissensus' *Classical Delphi: large variation, low certainty, moderate accuracy* *Dissensus Delphi: increased understanding*	Disagreement concerning which are the relevant alternative futures, 'Ontological dissensus' *Classical Delphi: inaccurate prediction* *Dissensus Delphi: genuine discord*

sparsely populated area). Second, market functionality for RE small-scale prosumers should be more encouraging than is now the case. The price the small-scale producer gets is somewhat modest at the moment. Third, there is still a need for different demonstrations and piloting of RE small-scale solutions. They have their value in making e.g. farm or household hybrid systems concrete for those who are on the threshold of making an investment decision. As the renewal of an energy system is quite expensive, functional examples ought to be easily familiarised. Forerunners are important in this respect. Fourth, even if heavy long-term subsidies were not seen as desired, there is a need to plan and introduce novel policy measures for small-scale energy generation. Easing taxation, investment subsidies for sites with an industrial symbiosis approach, free and easy connection with the grid, and reserving seed money for demonstrations are examples of such measures.

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