

Two sides of biogas: Review of ten dichotomous argumentation lines of sustainable energy systems

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ABSTRACT

Societal debates are often constructed through dichotomies influenced by various factors such as cognitive capabilities of individuals, culturally shaped valuation processes, underlying societal struggles for power and prestige, economic competition, technological changes or lock-ins and operation logic of the media and social media. Debates over emerging technologies of renewable energy provide an illustrative example of this polarisation. Based on national-level studies focusing on the development of the biogas sector in Finland, we identify ten pertinent dichotomies of renewable energy and discuss their implications for the transition towards a more sustainable energy system. The dichotomies include: producer vs. consumer, urban vs. rural, local vs. national, domestic vs. foreign, centralised vs. distributed, food vs. energy, environment vs. economy, traditional vs. innovative, long-term vs. short-term, and private vs. public. These diverse and deeply rooted dichotomies structure societal debate. In some cases they may encourage and guide critical thinking, but they may also hinder the renewing of the current energy behaviour and energy system. Societal capabilities that enable the bridging of different but inherently linked dichotomies are a key precondition of sustainable energy transition.

1. Introduction: Dichotomies and their multiple forms and functions

“The world is divided into two groups of people: those who divide the world into two groups of people, and those who don’t.” [1], p. 875].

Human action in real-life decision-making situations is strongly influenced by simple heuristics and dichotomies such as good and evil, certain and uncertain, dark and light, or matter and energy. Dichotomies are partly based on the physical realities surrounding the individual, and partly they originate from socio-cultural and mental processes. As Hukkinen and Huutoniemi [2], p. 177] note, “human beings make distinctions about the world according to their biological cognitive structure, the cultural networks they are part of, and their positions in those networks.” These distinctions are subject to biological and cultural evolution, and thus are in a state of flux [3].

In current societies, dichotomies are highlighted due to the ongoing polarisation of perceptions and opinions, the questioning and blurring of scientific facts, and the social movements fuelled in part by the dynamics of social media [4]. Dichotomies are necessary simplifications also in energy debates. They are needed to make sense of the complex world and to make various dimensions of phenomena, their characteristics and their associated uncertainties and ambiguities comprehensible and manageable. They thereby often function as didactic and communication tools. Dichotomies can provide useful guidance, but they can also misguide by drawing highly distorted pictures and strengthening false stereotypes [5–7]. Unjustified dichotomies can also reinforce or create societal lock-ins and path dependencies that are hard to break even when the situation at hand radically differs from the situation that originally produced the perception of the dichotomy [8]. Perceptions of the system do not always correspond with the actual changes in the system. As the concept of shifting baseline syndrome suggests, self-reinforcing feedback loops may effectively maintain societal

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non-knowledge related to continuous environmental change [9].

Dichotomies can sometimes be binary constructions with clear-cut borders, but usually they involve a variety of shades between the opposing ends [1,10]. The key issue is the simplified representation of the often multifaceted and graded reality through one-dimensional and dichotomous continua narrowly representing a multitude of conceivable dimensions. This may allow certain value positions, interests or fact claims fitting to this particular continuum to dominate the debate and to exclude other possible framings, interpretations and explanation models.

Dichotomies related to the structures and dynamics of an energy system are a case in point. Here we define the energy system as the interconnected network of production, distribution and use of energy. Energy debates include various dichotomies that help energy professionals, decision-makers, stakeholders and the public to understand and communicate about selected features of the functioning of the complex system. For example, a dichotomy between renewable and non-renewable energy sources is often used – in an uncritical manner assuming a self-evident division line – to organise energy discussion in relation to climate and environmental policies [11]. The starting point for this review is that identifying such perceived divisions and critically examining their nature can illuminate key factors enhancing or inhibiting sustainable energy transitions.

Transitions of energy systems are fundamentally a societal question [12,13]. In societal debates concerning sustainable energy transitions, dichotomies can be employed by various actors opposing or favouring certain proposed solutions such as nuclear power [14], forest-based bioenergy [15] or wind power [16]. Emerging energy technologies provide a particularly interesting case, since debates around them often become loaded with opposing views and expectations about economic and employment potentials, environmental effects or societal consequences. This article takes biogas as an example of promising renewable energy technology [17–19]. The article aims to answer the following research questions:

- What kind of dichotomies characterise the societal debate over biogas? In particular, how is biogas positioned as part of the current and future national energy palette?
- How do these dichotomies influence sustainable energy transitions? In particular, what kind of lock-ins and ignorance is created or maintained by the energy dichotomies?

First, the context of the study is briefly presented and the materials and methods are described. Second, the key dichotomies identified are introduced. Third, the relevance of these dichotomies to sustainable energy transition is discussed. Finally, conclusions are presented.

2. Context, materials and methods

2.1. The Northern European context

This study is focused on the Northern European context of an affluent, energy-intensive society with a relatively cold climate, extensive energy infrastructure covering the whole country, and a welfare state providing for the basic needs of the people, a high education level, a democratic policy system and a liberal media system respecting freedom of expression. More specifically, the focus is on national-level debates in Finland. The Finnish energy system is characterised by high per capita energy use and a high share of forest-based bioenergy in energy production [20]. Finland is a northern country with a large area and only 5.5 million people, who are increasingly concentrated on the metropolitan area of the capital Helsinki and a few other cities. About 6% of the population lives in sparsely populated rural areas comprising nearly 70% of the country's total area [21].

In the context of the Finnish energy system, biogas production can be characterised as an emerging energy technology with several

environmental benefits [18,22–24]. Most of the biogas in Finland originates from organic municipal waste in landfills or wastewater treatment sludge, but biogas plants designed to utilise organic wastes and side streams of industry and agriculture, such as crop residues and manure, have been increasingly built. There are about 48,000 active farms in Finland [25], but the number of farm-level biogas facilities has been very low. Only about 20 plants were operational in 2018 and over a hundred were planned [26]. The share of energy produced from biogas remains low in comparison with other sources of renewable energy (Fig. 1). Most of the biogas is used for combined heat and power production. Compared to Finland's neighbouring country Sweden, the use of biogas in the transport sector has been limited even though the number of vehicles and gas stations has increased during recent years [27,28]. The number of biogas or natural gas fuelled vehicles almost doubled between 2017 and 2018 to over 5,100, yet reached only 1.6% of all registered vehicles [29].

2.2. Materials

This review is based on material from national-level newspapers, social media discussion, key policy documents, public and expert surveys and interviews as well as domestic and international scientific literature and selected reports (Table 1). The newspapers mainly illustrate the development of public biogas agendas, while the surveys and interviews give insights of perceptions of key actors within the biogas sector and related areas of energy production and natural resources management. The policy documents illustrate policy agendas and the knowledge base of national-level decision-making.

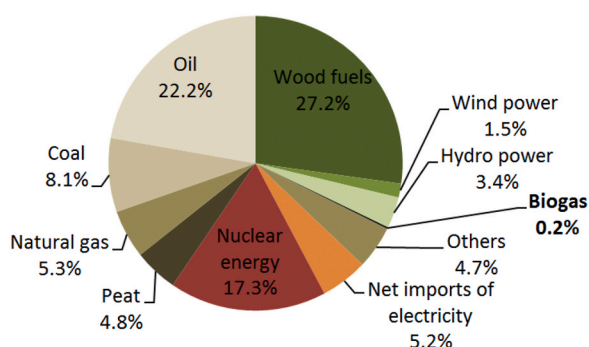
Most of the empirical material was collected under the project FutWend (Towards a future-oriented “Energiewende”: An anticipatory multi-level approach to the decentralised renewable energy transition). The selection of material was guided by the assumption that professional, public and policy debates provide different but interacting arenas of action with high importance for energy policy and sustainability transition [30,31]. It was further assumed that framings highlighting or omitting certain economic, social or environmental impacts, risks and future opportunities can considerably affect the knowledge base and motivation of actors to advance new energy technologies and practices.

2.3. Methods and theoretical background

The analysis employed a mixed methods approach and combined results based on several data sources with different qualities. Both quantitative and qualitative research methods were employed. The methods ranged from qualitative studies to statistical analyses as detailed in the references given in Table 1. The results presented here are mostly based on established content analysis methods in the social sciences that allow for dealing with different types of written and verbal materials (including open-ended survey responses, interviews, newspapers, social media postings and policy documents) and are particularly helpful in finding ways of describing and structuring complex phenomena [40,41]. Because of the heterogeneity of data, the final integration of results from different cases relied on qualitative interpretations and expert assessment taking into account the socio-cultural context of the study [42,43]. The materials were screened for different representations of dichotomies related to biogas. In particular, characterisations advocating or opposing the development of biogas were searched for. Preliminary interpretations were contrasted with the insights from pertinent literature of the biogas sector and energy policy and further developed through multiple commenting rounds between the researchers involved.

The dichotomies defined in the analysis are discussed under the conceptual background of sustainability transition studies and the widely used framework of multi-level perspective (MLP) [44–46]. The MLP conceptualises non-linear dynamic processes of socio-technical transitions as results from the interplay of developments at three

Energy sources in Finland



Relative development of energy consumption

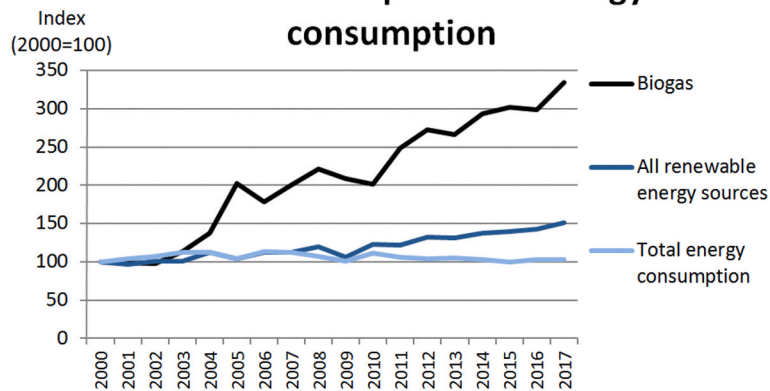


Fig. 1. Share of biogas in the current Finnish energy palette (left panel) and development of biogas used for heat and electricity production in relation to consumption of renewable and total energy in Finland (right panel) [20,28].

Table 1

Materials of the study.

Type of material	Description	Data units and references for more detailed descriptions
Media coverage	Newspaper “Maaseudun Tulevaisuus”. Professionally oriented newspaper focusing mainly on agriculture, forestry and rural issues. Newspaper “Helsingin Sanomat”. Leading national-level newspaper aimed at a wide audience.	318 items focusing on biogas, 2000–2017 [32,33]. 117 news items focusing on biogas, 2000–2017 [32].
Social media debate	Facebook group “New Energy Policy” (In Finnish: Uusi Energiapolitiikka). Discussion group of about 6000 members focusing on various energy topics.	Sample of online posts focusing on biogas (N = 301), November 2014–February 2017 [34].
National strategies	Selected key policy documents and reports focusing on energy and climate policies in Finland.	EU’s proposal for directive on promotion of the use of renewable energy; National energy and climate strategy 2030; Strategic Programme of the Finnish Government 2015; Finnish bioenergy strategy 2014; MoEE report Small-scale energy production 2014; MoEE report Renewable energy subsidies 2016 [35].
Expert views	Interviews within the biogas business branch and future views of experts in the Delphi panel.	Transcribed interviews (FutWend and Ilvemap-projects) [35–37].
Public perceptions	Nationwide representative survey on citizens’ perceptions on future of energy system in Finland and prerequisites for energy transition.	Survey responses (N = 1012) [38,39].

analytical levels: niches, socio-technical regimes, and an exogenous sociotechnical landscape [47]. Earlier studies have focused on the role of technology, institutions and action or non-action by niche-level actors in sustainability transitions [48]. The role of societal dichotomies in transition processes has not been specifically addressed, even though dichotomies are one factor setting the energy agenda and creating framings for contestation and negotiation and thereby for action or non-action.

Dichotomies operate at multiple levels: they are part of larger narratives that relate to the niche-level actor roles, policy frameworks and regulatory regimes as well as exogenous landscape level changes. Previous technologically or socio-economically oriented studies – and ecological research related to sustainability transitions – have largely omitted the roles of human perceptions and representations created and delivered by mass media and social media [31,33]. A key issue for this study is whether the dichotomies organising the societal debate can be employed to accelerate the transition towards a sustainable energy system.

3. Results: Key dichotomies of the Finnish biogas debate

Based on studies and materials presented in Table 1, the following key observations are taken as a starting point for the analysis:

- In citizen surveys, biogas was appreciated widely; a majority of citizens supported the increase of biogas (71% of the survey

respondents). Moreover, there was only little variation among the opinions.

- Samples of widely read popular and professional newspapers showed that the media frames biogas as an environmentally friendly energy solution, but mixed framings were presented on the economic performance of biogas. The Facebook discussion group focusing on energy transition also indicated highly positive expectations, with only about one per cent of posts having a critical stance towards biogas.
- Interviews of biogas experts indicate that biogas has benefits that improve its value beyond energy use (e.g. recycling of nutrients, biowaste treatment, biochemicals, climate change mitigation), and it can become more feasible as a part of the circular economy development. The role of biogas as a sustainability product was considered important by most of the experts.
- Policy documents indicated that Finnish policies do, to some extent, recognise the broader sustainability potentials of biogas in addition to its energy functions, but they fail to effectively promote such sustainability potentials in terms of concrete policy measures (e.g. as an element of a multifunctional circular economy). Instead, policies tend to treat biogas as an energy product in terms of economic profitability and competitiveness on the energy market. Promising opportunities for biogas use are expected to be found, e.g. in the transport sector and as fuel for machinery. While the promotion of more flexible and active participation of producers and consumers in the electricity market through the development of smart solutions is envisioned, policy measures for the promotion of energy

prosumerism remain vague and mainly limited to informing and clarification of regulations.

The key dichotomies identified are presented in Table 2. Most of the dichotomies were discerned from all of the materials but their relative importance varied considerably. Some of the variation can be explained by the different focus of the data or contextual factors. For example, the materials illustrating media debates included a mainstream newspaper and a newspaper focusing on rural issues. This variation was taken into account when making the interpretations. Generalisations based on the materials were also contrasted and complemented with insights from available earlier literature, as described below.

3.1. Energy producers vs. consumers

The dichotomy between energy producers and consumers is a key underlying categorisation organising the Finnish media coverage and

Table 2
Key dichotomies of biogas and their salience in the biogas debate in Finland.

Dichotomy	Salience within the biogas debate	Key topics illustrating the debate under the dichotomy
Producer vs. consumer	High	Main emphasis on traditional site-specific use of biogas in heat production (M, CS, PD, SM). Increasing attention to use as traffic fuel and consumer markets (DE).
Urban vs. rural	High	Rural aspects emphasised and perceived as separate from urban (M). Biogas offers new income sources and therefore business for rural areas (DE). The perception of biogas as a predominantly rural issue was seen as a handicap for wider adoption (SM).
Local vs. national	Medium	Local-level impacts emphasised (M), strong reliance on national-level infrastructures and consumer demand only occasionally brought up (SM, DE).
Domestic vs. foreign	Medium	Domestic setting emphasised and Finland perceived as laggard in biogas policy (M). Expectations of the strengthening domestic biogas sector (M, CS). Biogas emphasised as a domestic fuel for transport compared to imported fossil fuels (SM).
Centralised vs. distributed	Medium	Criticism directed at the dominance of traditional centralised energy production (M, CS). Biogas is understood as a distributed solution even though production is dominated by centralised co-digestion plants (DE, M, PD).
Traditional vs. innovative	Medium	Novelty of biogas technology highlighted, but also established solutions referred to (DE, M). Policies emphasise the criteria of technology neutrality and economic potential (PD).
Long-term vs. short-term	Low	Long timeframe of energy system transformation obscured by focus on current actions (M, CS).
Private vs. public	Low	Public support through stable policies and regulations called for; entrepreneurs prefer investment aids over production support (PD, DE).
Food vs. energy	Very low	Competition for agricultural land not a major issue in Finland. The potential of biomass (manure, grass residues) is still underused, does not endanger food production (DE)
Environment vs. economy	Very low	Biogas considered predominantly as environmentally beneficial solution (DE, PD, M). Experts pinpoint the renewability and locality as well as self-sufficiency (DE).

Note: citizen survey (CS); media coverage by newspapers (M); social media (Facebook) (SM); Delphi and other expert opinion (DE); policy documents (PD).

public debate of biogas [32,33]. In the public debates, biogas is predominantly addressed from the perspective of energy producers, leaving the potential roles of active consumers and demand-side measures largely out of the debate. An exception is the occasional attention given to the users of biogas-fuelled cars. However, the transport sector is also typically addressed from the perspective of infrastructure and energy policies, with the key issues being the number and availability of gas filling stations, taxation and legislation rather than the needs and choices of consumers.

The focus on energy production is typical for Finnish energy discourse, which has been traditionally dominated by the interests of large energy producers [49]. Most of the biogas is produced by private and public actors concentrating on other energy sources or completely other business such as waste or water treatment. The actors concentrating on biogas production are often small entrepreneurs with limited resources and low potential to disrupt the established actor constellations. However, the business environment has been changing since the state-owned Gasum Ltd entered the biogas business in 2016, with it being currently the largest biogas producer in the Nordic countries [50].

So-called energy prosumers (actors operating simultaneously as producers and consumers of energy) may challenge the lock-ins of the actor positions of energy policy [51,52]. Signs of emerging prosumerism were identified in the Finnish biogas field. The newspaper coverage is characterised by a relatively high salience of farmers building and operating small-scale biogas reactors. In practice, farmers themselves must use the energy produced in farm-based plants because of the requirements of current investment subsidies from the state. A lower investment aid is applied to biogas plants selling energy outside the farm, and instead of a farm a separate company must be involved as an operator. This can be labelled as forced prosumerism, limiting the opportunities of farmers to induce more large-scale energy transition.

This aspect is reflected also in the policy documents, where a dominant and rather uncontested narrative argues that biogas prosumerism is to be encouraged if it can be done cost-efficiently and as a response to on-site consumption needs. This typically means heat and electricity production to cover on-site consumption (e.g. in a farm context). Furthermore, while more flexible and active participation of producers and consumers in the future electricity markets are being envisioned through the development of smart solutions, concrete policy measures for the promotion of energy prosumerism in practice remain vague and mainly limited to informing and clarification of regulations.

3.2. Urban vs. rural areas

In the Finnish media and social media debate, biogas production is predominantly framed in the context of rural development, even though most of the biogas is produced in a rather urban and industrial setting as a part of the water treatment and waste management processes of cities [28]. The framing focusing on biogas as an opportunity for rural livelihoods and agri-environmental management pays little attention to questions related to urban areas. This framing strengthens the public impressions of urban and rural as something separate or even opposite. Such impressions are already strong because of the continuing urbanisation [21]. As urban areas gain more economic and policy influence, the urban framings are increasingly dominating also the public and policy agendas, despite attempts to amend this through policies and programmes supporting the regionally based bioeconomy of rural areas. Disagreements between rural and urban actors are likely to deepen. In the Facebook debates, the image of biogas as a predominantly rural issue was perceived to create political resistance or ignorance and hinder the scaling up of the technology. The expert interviews showed that biogas use as traffic fuel means entering consumer markets, which requires the understanding of consumer behaviour [37]. However, a successful launch of appealing local energy products can gain appreciation and added value over faceless energy distributors in the same way as local food products have done [53].

Policy documents and debates have provided major attention to connections between the urban and rural. In particular, the recently emerged concept of circular economy provides a framework for highlighting biogas as a potential solution capable of turning the nutrient flows from rural to urban areas into more closed material loops [18,54]. However, the debate on circular economy can either bridge or deepen the dividing lines between urban and rural. For example, some critical attention has already been directed at the risks of digestate potentially containing chemical pollutants or microplastics. Farmers have been generally reluctant to accept digestate originating from the human waste of city dwellers and other biomaterials from urban and industrial processes. Current legislation is also preventing the use of such material as a fertiliser. The public debate over such risks – and the possibilities of closing nutrient loops – has been scattered.

3.3. Local bottom-up action vs. top-down national policies

The dichotomy between locally based action and top-down governance manifested itself mainly through a critique of lacking or insufficient state support for biogas initiatives. Policy debates have treated biogas as a minor part of the national-level energy palette without outlining ambitious goals and concrete roadmaps for achieving these goals. The importance of bioenergy has been highlighted in national energy policy, but the attention given to forest-based bioenergy (both from wood chips and forest industry side streams) has marginalised biogas [15]. Few national-level policymakers have shown major interest in biogas. The lobbying power and public visibility of the biogas sector is weak, especially if compared with the strong forest sector that is closely coupled with the national energy elites [32,49]. Furthermore, convincing and widely discussed calculations of the economically and environmentally feasible national-level energy potential of biogas have been missing. Such debate was arising in early 2019 with a special supplement focusing on biogas potential by the newspaper “Maaseudun Tulevaisuus” (April 1, 2019).

The possibilities of biogas production have been emphasised more vigorously at the local level. Debates have been fuelled by concrete examples of biogas forerunners as well as some preliminary calculations and publicly presented assumptions about the local and regional level production capacity and economic potential of biogas production, including considerations of the economic cut-off size of local facilities. Recently, some local energy companies have been interested in investing in a local biogas plant. This activity is important, since farmers seldom have possibilities to make large investments, while other potential investors have been uninterested because of long payback times [37]. The local-level debate focuses mostly on short-term performance of individual facilities without reflections on the national level. The benefits and potentials as well as obstacles and resultant opportunity losses are not systematically summed up.

3.4. Domestic impacts vs. foreign influences

Biogas as a form of domestic energy was an underlying theme in all of the materials studied here. The development of biogas technologies and production of biogas were often described with national and even patriotic tones as possibilities to decrease the nation’s dependency on energy imports. However, the overall frame of national energy security was weak, despite the strong reliance of the Finnish energy sector on imports from the unpredictable neighbouring country of Russia. Most of the natural gas consumed in Finland is imported from Russia and therefore domestic biogas production would offer opportunities to improve energy self-sufficiency. The relationship between Finland and Russia has traditionally been complicated and sensitive. Russia’s military activities in Ukraine and the previous gas shutdowns, as well as sanctions against Russia by the EU since 2014, have created additional unpredictability. The critique against the Nord Stream pipelines across the Baltic Sea has been absent in the Finnish biogas debate. In Finland,

the lack of critical, open and public debate over energy security may partially reflect the legacy of “Finlandisation” – a national policy emphasising collaboration with an important economic partner but at the same time also with the greatest potential security threat to the country’s sovereignty [55]. However, the fact that the Finnish state in 2015 purchased all shares of the gas company Gasum Ltd owned by Russian actors indicates some concern over foreign influences [56].

The domestic biogas sector was only occasionally contrasted with experiences from other countries. News coverage repeatedly created impressions of Finland as a laggard if compared to more advanced countries, such as Finland’s neighbouring country Sweden or Germany, which can be considered the forerunner country of biogas [57]. For example, the newspaper “Maaseudun Tulevaisuus” (October 10, 2005) highlighted that Sweden already had the world record on the number of biogas-fuelled vehicles and ambitious plans to advance the use of biogas in the transport sector. The lack of systematic international comparisons considerably limited the opportunities for constructive public and policy debate and learning from other countries.

3.5. Centralised vs. distributed energy system

Biogas facilities can be classified as plants integrated with municipal or industrial wastewater treatment plants, centralised co-digestion plants and decentralised farm-scale plants. Most of the biogas plants integrated with municipal wastewater treatment plants were built in the 1980s, and almost all the larger wastewater treatment plants already have an integrated biogas plant. The currently unused biomass resources suitable for biogas production are mainly scattered agricultural biomasses [58]. Furthermore, the local raw materials form a basis for decentralised production. Biogas was typically framed as a form of small-scale decentralised energy production potentially challenging centralised solutions that dominate Finnish energy policies. However, as an emerging technology with very low production volumes, biogas was seen to be unable to seriously challenge the current centralised modes of energy production.

The ambivalence between framings emphasising the potentials associated with centralised vs. distributed systems is evident also in the policy documents. There, the general emphasis is on the facilitation and encouragement of investments in profitable and cost-efficient renewable energy technologies with business potential. Therefore, potentials of smaller-scale, geographically distributed renewable energy technology networks, such as geographically distributed and multifunctional biogas technology and business ecosystems, tend to receive only marginal policy support. Synergetic and cross-sectoral potentials are easily ignored. Since current policies related to investment subsidies restrict farms from selling biogas-based energy outside the farm, it has further inhibited the creation of, and incentives for, regionally distributed biogas business networks on the ground.

The popular public framing of biogas as decentralised energy overshadowed the fact that the consumption of biogas is strongly reliant on the centralised energy infrastructure and that most of the biogas is currently produced by relatively large facilities. Household-based micro-scale biogas production and use, often seen as a potential energy solution in many developing countries [59], is almost completely absent in Finland. This is largely because of the wide availability, high reliability and relatively low price of other energy sources and the lack of micro-scale technical solutions suitable to northern climates.

The images of biogas as a distributed energy form were strengthened by the high visibility of relatively small-scale farm-based biogas production. Farmers were represented disproportionately often as key actors, especially if compared with the minuscule share of biogas produced in farm-level facilities (3% of all biogas production) [35]. Even if the public debate has been around the farm-scale biogas, both centralised co-digestion plants and farm-scale plants have recently grown in number.

3.6. Traditional vs. innovative technologies and practices

Biogas was often represented as a novel niche-level technology complementing or challenging the traditional modes of energy production. The key players, such as large energy companies, ministries and the Parliament, were often considered as obstacles rather than supporters of rapid development of biogas innovations. The regulations and formal permit procedures as well as informal practices and power relations of actors in the energy sector were also typically seen as factors creating inertia against changes.

The importance of individual inventors and early adopters was highlighted, but technology diffusion in the biogas sector was represented as being highly dependent on the actions of a very low number of key actors. Technology choices and successes or failures of key innovators can strongly influence the development of the whole sector. Sometimes the influence of single actors was clearly exaggerated. For example, the municipal bus company of the largest city, Helsinki, decided not to use biogas in 2012. This led the most widely read national newspaper, "Helsingin Sanomat" (February 20, 2012), to conclude: "Biogas has no future as a fuel." An example of a more serious drawback was the bankruptcy of one of the leading biogas plant suppliers in 2018. Several biogas plant projects with €20 M in investment support were left unfinished [60]. The small and medium-sized companies do not necessarily have the skills, business competencies and resources to tackle the challenges with emerging technologies and markets under development.

Biogas technologies were recognised as being complex and involving several uncertainties, but this was not considered a major obstacle for technology diffusion. In particular, news coverage focusing on concrete domestic cases highlighted the novelty of biogas technologies with a positive tone. Technical difficulties typical for new solutions received only little critical public attention, perhaps reflecting the early phase of development and the low level of accumulation of experiences, as well as the low familiarity of the public with the technology. The failures typical for experimenting and early phase technologies, and the obstacles for upscaling and reaching commercial self-reliance, were not actively brought up by biogas entrepreneurs.

3.7. Long-term vs. short-term development

Time frames are a key issue of sustainable energy transition, especially regarding the urgency of meeting the targets of climate policy and other societal goals and the slow pace of large-scale changes in energy systems [61]. Long-term and short-term thinking divided citizen perceptions regarding their agency on the energy market. In the media coverage individual biogas projects were most often described under the terms of present-day activities and expected short-term future developments. The long-term future of the energy system was referred to only occasionally and rather vaguely, typically without clear scenarios, targets or estimations of future development. The newspaper coverage in particular did not provide readers with clear long-term visions of energy futures regarding biogas.

The perception of a slow pace of change for energy policy was emphasised. Strong frustration by the advocates of biogas development was voiced, highlighting the perceived discrepancy between general-level positive expectations and a lack of concrete policy decisions advancing the biogas sector. Rapid technological development was hereby taken as a self-evident boundary condition, but long-term technological changes impacting the use of biogas were discussed only rarely. An exception was the debate contrasting biogas vehicles with the relatively rapidly evolving technologies of electric cars. This debate has been shaped by arguments concerning changes in distribution systems, the car fleet, car and fuel pricing, taxation and subsidies.

3.8. Private vs. public actors as drivers of change

The role of niche-level actors as a driver of innovation and change

has been emphasised by research literature [47]. Despite the activity of a few individual entrepreneurs, the development of the biogas sector has been relatively slow in Finland. Although a few small-scale enterprises have arisen and tested the technologies, they have been unable to induce large-scale market change in an energy sector dominated by large companies and with an energy regime favourable to their activities.

In addition to a gradual increase of the activity of small-scale actors, there have been some clear signals of increasing activity of large-scale actors. In particular, the state-owned gas company Gasum has had a commercial interest to develop the traffic use of biogas since the company launched a network of natural gas and biogas filling stations in 2011. Environmentally friendly biogas is a key element of the company's image-building, as it has labelled itself as "a forerunner in sustainable Nordic energy solutions and circular economy" [50].

On a general level, the distinction between private vs. public actors is closely related to that of regulatory steering vs. market-driven development. Both expert and stakeholder debates have pointed out that both are needed, and over-reliance on markets may lead to dysfunctional and even harmful solutions. Intermediate solutions in policies such as public steering of markets and public-private partnerships have not been discussed much yet, with some exceptions such as the possibilities of rural cooperatives.

3.9. Food vs. energy production

Conflicting land use needs between food production and energy crops have been a central theme of public and policy debates in several countries [62,63]. In addition to competition between agriculture and energy, this affects the balance between wood-based bio-SNG (synthetic natural gas) and waste-based biogas, both of which are subject to EU regulatory policies [19]. In Finland the conflict frame related to the use of agricultural land was missing almost completely. This is explained by the fact that, instead of reserving large areas for growing energy crops, farm-based biogas production has so far utilised manure and other animal wastes and side-streams of agriculture. As emphasised by the expert views, in addition to manure, farms possess cultivated field areas that produce a large amount of biomass, some of which forms unused residues that should be rationally utilised [36]. If compared with more densely populated countries, Finland also has a relatively wide availability of agricultural land currently set aside from active farming. Furthermore, because of the small size of biogas plants and small volume of biogas production, there has not been a need for large-scale growing of energy crops.

The collaboration frame has so far also dominated the Finnish discussion over the food-energy nexus because biogas production has typically been framed as a potential solution to one of the key environmental problems of food processing and consumption, namely food waste. Thus, the focus of the biogas sector has been on utilising the side-streams and wastes of the food industry, catering services and households. The amount of biogas raw materials not competing with food production is estimated to be 10 TWh per year [58]. The total biogas production in 2017 was 0.7 TWh [28]. Thus, the production could grow more than tenfold without competition with food production. However, more large-scale biogas production may require monocultures of energy crops that are likely to induce more critical discussion. This has happened already in Germany with the establishment of biogas as a major player in the agricultural and rural economy [64]. These debates can be seen as part of the responses, also institutional, of existing systems to new challenges and regimes, where their boundaries, positions and trade-offs are negotiated.

3.10. Environmental effects vs. economic development

The dichotomy between economic growth and ecological degradation has been one of the basic features of modern environmental discourse. Environmental and economic aspects are strongly present in

biogas debates as well. However, in Finland the debate has predominantly focused on biogas production as a solution potentially benefitting both the environment and the economy. Contrary to several other countries [44,63], the potential adverse environmental impacts of biogas production have not been extensively discussed. One of the reasons is that current Finnish production relies on wastes and side-streams. In Finland, the John Nurminen Foundation [65] has recently criticised the risks with nutrient leakages from the European biogas plants, but this has not produced any major public or policy debate. This is partly explained by the positive and even uncritical overall public attitudes towards bioenergy in Finland [66] and partly by the genuine environmental benefits of the biogas as a renewable energy source. The synergies between environmental and economic benefits are also seen within the expert community [35]. Biogas can be seen as a sustainable product that produces many environmental benefits (e.g. recycling of nutrients, biowaste treatment, GHG mitigation) as well as new business opportunities and income for rural entrepreneurs [36].

The tension between environmental and economic aspects and objectives was clearly visible in the policy documents. While the policies do, to some extent, recognise the broader environmental benefits and sustainability potentials of biogas in addition to its energy functions, they lack concrete policy measures with which to effectively promote the adoption and mainstreaming of biogas technology in those (rather common) cases where biogas technologies fall short of reaching sufficient economic profitability and competitiveness on the energy market. The bias towards economic performance and development is further reinforced by the strong role that policies grant to the criterion of 'technology neutrality': in order to create a level playing field for various renewable energy technologies and businesses, the policies refrain from prioritising technologies on the basis of functions or criteria that are not recognised by the markets.

More generally, the economic narrative of Finnish biogas discussion is characterised by two partially incompatible storylines [33]. First, biogas is presented as an opportunity to improve the poor economic performance of agricultural farms especially because of the possibilities for savings in energy costs and also fertiliser costs. The potential for economic gains was emphasised especially during the early phase of the biogas debate. Second, the need for public subsidies because of relatively high investment costs and poor profitability of biogas production has been a key storyline. A metanarrative where environmental and economic aspects are not seen as mutually exclusive but complementary, on new paradigms of growth and welfare, may also recast the biogas storyline.

4. Discussion: Moving beyond binary thinking

The review showed that the dichotomies identifiable in policy and public debates and private perceptions over biogas range from issues that are already focal points of energy discussion to ones that are only occasionally or implicitly brought up. Overall, dichotomies were relatively easy to be discerned from the media representations. This reflects the nature of news production emphasising controversies and highlighting or even creating polarisation of views [67]. However, in the media debate novelty emerged as a more important news criterion than controversy. Public debate over biogas is a recent one in Finland, making it easy to find novel and therefore interesting issues to report. Media framings of biogas have been dominated by assumptions of positive environmental effects, and controversies typical for debates over other forms of renewable energy, such as forest bioenergy or wind energy, were largely missing [15,68,69]. Some topics were missing from the Finnish debate. The controversy over land use for food vs. energy production was not a key issue and risks related to potential greenwashing by energy industries or gas utilities were not debated. Criticism addressing the contradiction between increasing use of biogas containing carbon and attempts to decarbonise the energy system was missing from the Finnish debate as well. These issues have been debated in other

countries [63,70], highlighting the need for further studies identifying which types of dichotomies are relevant only for certain contexts and which are present in energy debates more generally.

Since the media, public and policy agendas are interconnected, the dichotomies present in media representations are reflected also in survey results and policy documents – but often less conspicuously. The results support earlier research that has noted the tendency of mainstream newspaper representations to contextualise energy issues through techno-economic topics and supply-side technologies [57]. The Finnish energy discussions centre on costs, jobs and energy needs of the industry as well as on climate change.

The dominant dichotomies organising the Finnish biogas debate include divisions between energy producers and consumers, rural and urban, local and national, domestic and foreign, and centralised and distributed energy systems. There are intersections between the dichotomies. For example, polarisation between centralised and distributed energy systems can be found as a sub-theme of several other dichotomies. The framing of debates in the biogas field inherently involves a preoccupation with the local level, where disruption and revision of constellations may take place by autonomous actors.

The transformative capacity of the biogas debate has so far been relatively weak. Overall, the Finnish legislation and energy taxation has been criticised as impediments for niche-level energy experiments and development of innovative solutions. The public subsidy schemes have also been criticised as unambitious and unfair for small-scale actors such as farms willing to produce and sell biogas to external customers. The results support earlier analysis claiming that the destabilisation of the energy sector requires the existence of regime outsiders with both a radical ideology and influence over economic factors [27,44,71,72]. However, renewal based on a 'self-selling' technology is also possible, and change can thus occur rapidly and in a self-sustained manner without radical ideology or game-changing support, as with heat pumps [73]. Biogas as an emerging energy technology has the potential to challenge, reorganise and ultimately bury or bridge the traditional dichotomies of the energy debate. In particular, it may challenge the deeply rooted dichotomy of centralised and distributed energy systems.

If compared with other energy debates, biogas is generally treated under less polarised framings. Furthermore, public and policy awareness over biogas remains relatively weak, despite the relative increase of media coverage in the past decade and interest shown by a few politicians. Because of wide availability of wood resources and strong position of forest industries, bioenergy dominates the Finnish discourse of renewable energy while wind and direct or photovoltaic solar energy dominate the debate over emerging energy production technologies, leaving biogas with lower public visibility [57].

The number of individuals and organisations interested in promoting the biogas sector is rather limited in Finland. Earlier research has suggested that networks between local projects that enable the sharing of experiences and learning between energy actors can play a crucial role in technology diffusion [74]. Some of the dichotomies discussed here create considerable obstacles for social learning and scaling-up processes by excluding other ways of thinking and limiting the debate to certain temporal or spatial scales. Some of them, properly utilised, may on the other hand be fruitful in social learning by opening up and guiding discussion, awareness-raising and collaboration.

Such issues include a lack of a clear joint vision for the sector by key actors and practitioners and of a clear sense of what the new types of energy production, such as biogas, could mean in the Finnish context. The renewable energy transition in Finland is expected to take place through investment-focused measures and other market-based approaches [75]. However, a significant growth is unlikely without other measures such as updated permit procedures (and hence also control-focused regulation), ease of grid connection, and new business concepts based on new ideas such as energy prosumerism.

The debate over prosumerism related to biogas has potential implications on other dichotomies between rural and urban, local and

national, and food and energy systems. In particular, prosumerism based on joint ownership of biogas facilities may lead to new types of actor constellations of energy systems. The traditional dichotomy between producers and consumers has already been challenged in photovoltaic energy systems [52], and the increasing popularity of heat pumps [73] can also be seen as a factor challenging or at least blurring the dividing line between energy production and consumption.

There are various possibilities to utilise dichotomies of biogas, and similarly of other areas and issues in the energy field, in a more constructive way to advance the transition towards more sustainable energy systems. The fundamental issue is to create understanding and better self-awareness of the existence of dichotomies guiding the debate. Dichotomies can even function, precisely through the simplifications they involve, as tools to start debates, tease out arguments and illustrate points. They thereby can offer ways to break loose from 'endless qualifications' and 'paralysis by (more intricate) analysis' – until such analysis again will be needed and is performed, as in the discussion above. Once identified, the dichotomies can thus in general be purposefully used to develop societal debates related to energy systems at least by:

- 1) Perceiving dichotomies as continua instead of binary constellations. Directing the debate towards the middle ground by combining insights from the opposing ends of dichotomy and providing stakeholders with learning possibilities.
- 2) Interpreting dichotomies not as final endpoints but as starting points of a dynamic and dialectic societal process potentially leading to new types of understanding.
- 3) Building unconventional combinations of current prominent dichotomies providing a richer picture and highlighting different perspectives.

5. Conclusions

Only limited scholarly attention has been paid to the socio-cultural dynamics related to biogas. In Finland, this is partly explained by the marginal role of biogas production in the national energy palette, but also by a lack of social controversies. Generally, biogas in Finland has been warmly welcomed as an environmentally benign domestic energy solution. However, this does not mean the absence of polarisations related to biogas, as shown by our review.

The results indicate that even when the dichotomies manifest themselves as clearly identifiable polarised binaries they often involve a graded continua of views. Furthermore, the dichotomies are not completely separate and isolated but have connections and overlaps. Collectively, they create a multi-dimensional landscape of knowledges, values and opinions emphasising certain aspects of the perceived reality and downplaying others.

The biogas debate is dynamic and it reflects, reproduces and also challenges several of the prevailing societal dichotomies, such as divisions between producers and consumers, rural and urban, local and national, centralised and distributed energy systems, and food and energy systems. Dichotomies often maintain the lock-ins, conventions and routines of the prevailing energy system, but the strengthening of those dichotomies that are currently weak can also challenge prevailing assumptions.

Dichotomies are a basic feature of human cognition and organisation of society. New ways to organise dichotomies are possible and sometimes desirable from the perspective of sustainable energy transition in other fields of application, as well as from a methodological point of view.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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