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Barriers and drivers for technology commercialization by SMEs in the Dutch sustainable energy sector

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ABSTRACT

To enable the transition to renewable and sustainable energy systems, Small and Medium-sized Enterprises (SMEs) can successfully commercialize new technologies, yet doing so is highly challenging. Moreover, governmental policy makers tend to support measures for early-stage ventures or university spin-offs, based on the assumption that sustainable energy technologies primarily arise from early-stage technology development. Attention has recently been shifting to SMEs, which can help accelerate the energy transition. By combining a literature review with an explorative multiple case study of 20 SMEs in the Dutch sustainable energy sector, this article identified barriers and drivers for technology commercialization by SMEs. A country-specific barrier is the large consumption of natural gas by Dutch households, which strongly inhibits the successful scale-up of new technologies. The study found several managerial, financial, technological and policy-related barriers and drivers which affect technology commercialization of sustainable energy technologies by SMEs. These barriers and drivers were further assessed in an actor-based analysis, which suggests that the various barriers and drivers arise from the interactions between policy makers, industry partners and end-users. The paper also discusses the policy implications of the barriers and drivers identified, and outlines several challenges for future research.

1. Introduction

Over the past decades, European citizens, governments, firms, and academics have become increasingly aware of the renewable and sustainable energy transition [1,2]. Firms offering renewable energy solutions tend to experience greater obstacles than other firms, and therefore governmental institutions often offer support. Although governmental bodies have been developing and implementing investment programs for research and development of sustainable energy technologies [3,4], there is little knowledge about which policies are suitable and effective. Policy makers tend to (unintentionally) favor a particular type of firms, such as early-stage ventures [5] or university spin-offs [6–9], based on the assumption that sustainable energy technologies arise from early-stage technology development only.

Recently, the attention has been shifting to small- and medium-sized enterprises (SMEs), since these can provide sustainable energy solutions that are already demonstrated by means of initial commercial successes [10]. SMEs are typically older than 3 years, have between 10 and 250 fte staff [11], and can sell (new) products to their existing customer base in local markets [12].

Despite the attention shift, governmental policy makers are still reluctant to support SMEs as these firms are often more prone to failure due to their small size and sensitivity to environmental change [13], with unexpected environmental fluctuations putting severe pressures on their low levels of slack resources [14]. However, many SMEs have demonstrated to be able to commercialize sustainable technologies [15], by developing new products in laboratories as well as creating new organizational forms and business models [16]. This capability means that SMEs are (largely overlooked) cradles for technology commercialization in the renewable energy market.

While previous studies have investigated technology commercialization by SMEs, further research is needed especially with regard to renewable energy [17]. This paper aims to revise the prevailing perspective on SMEs in the energy transition (cf. [18]), by investigating the inhibiting as well as facilitating factors (i.e. barriers and drivers) of SMEs’ technology commercialization efforts in the Netherlands, which provides an interesting context from the point of view of the ongoing sustainability transition [19,20]. Despite many efforts to push the sustainability transition in this country [21], this transition has remained rather slow, partly due to various policy changes and lack of

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governmental support [22–24]. So far, few policy makers turn to research evidence to better understand the role of SMEs in commercializing sustainable energy technology [25,26].

To investigate SMEs’ barriers and drivers, this study reviews the literature on barriers and drivers in the renewable energy market and extends these general insights with a study of twenty SMEs in the Netherlands. The results include a list of barriers and drivers for SMEs. Four barriers appear to be highly disadvantageous to an SME’s technology commercialization effort: limited financial resources, technological complexity of energy solutions, high market competition caused by incumbent players, and low legitimacy of renewable energy solutions. By contrast, several drivers may improve an SME’s position: external financial investment, management having strong entrepreneurial abilities, early-stage prototyping and piloting, and legitimizing sources such as an official ‘stamp’ for product quality. An actor-based analysis of SME barriers and drivers further highlights the role of policy makers, industry partners and end-users.

By investigating the barriers and drivers of SMEs in the renewable energy market, this study contributes to the growing literature in this area. More specifically, this study shows that government can help improve the contribution of SMEs to the energy transition, especially via policy measures such as performance audits and network access.

The next section provides a review of the Dutch energy landscape, including its energy mix and relevant stakeholders. The third section then explains the procedures for data collection and analysis, involving both a literature review and empirical data collection. The Results section describes the main barriers and drivers for technology commercialization by SMEs in the Dutch sustainable energy sector. Finally, the last section serves to discuss the main findings and outline several challenges for future work in this area.

2. The Dutch energy landscape

2.1. The Dutch energy mix

The Netherlands is (still) a significant producer of natural gas and serves as a major transit and trade hub for electricity from coal and gas – especially for neighboring countries [27,28]. In the coming years, natural gas extraction from soil needs to decrease substantially in compliance with regulations in the area of safety and risk mitigation, intended to prevent further earthquakes in the Northern regions of the Netherlands [29]. Yet, a huge potential to implement renewable energy technologies remains, as the share of renewable power was 10.5% in 2017, surprisingly lower than the 12.1% in 2016 [30,31]. The Netherlands is a densely populated country that already has 20% of its territory located below sea level, which tends to demotivate the implementation of renewable energy technologies on land [32].

2.2. Actors in the Dutch energy landscape

The Dutch power sector has an unbundled structure [33], with eight Distribution Services Operators (DSOs), a separate Transmission System Operator (TSO), more than 25 producers, and 35 electricity retailers. In 2011, this power system served about 8 million delivery points, with a total grid length of 2200 km distributed over 51 electrical high voltage substations [31].

The Dutch government and its various agencies are important actors in transitioning the Dutch power sector toward a more sustainable system of energy production and consumption. The overall responsibility for Dutch energy policy (including energy efficiency) lies with the Ministry of Economic Affairs, which develops policies for renewable energy, energy transition, research and development (R&D) programs, and demonstration projects. The Ministry is also involved in the planning of large scale energy projects. The Ministry of the Interior and Kingdom Relations regulates the energy efficiency of buildings. Several other organizations such as the Dutch Office of Energy Regulations and the Netherlands Independent Post and Telecommunication Authority have the authority to supervise electricity and natural gas markets as well as district heating markets [27].

Several centers are conducting research on the development of the Dutch energy market. Examples are Energy Research Centre of the Netherlands [34], Environmental Assessment Agency [35], and Statistics Netherlands [36]. To support the energy transition, the Netherlands Enterprise Agency implements R&D policies and funds programs for sustainability, innovation and international co-operation. It facilitates the set-up of training and certification facilities and supports public-private innovation contracts [37]. R&D is also supported by the Netherlands Organization for Scientific Research and many universities [38,39], and is stimulated by international collaboration initiatives like Horizon 2020, Euratom, and Strategic Energy Plan [27,40].

2.3. Governmental policies

The Dutch government has acknowledged the impact of the energy sector on greenhouse gas emissions [41] and has taken various policy measures. The Ministry of Economic Affairs created the so-called ‘Top Sector Energy’ to stimulate cooperation between industry, academia, government and society [42] in areas such as offshore wind, energy and industry, urban energy, and new gas [42]. A national climate agreement was enacted in 2017 to ensure a 55% emission reduction (from production and consumption) by 2030, which implies the closure of at least one coal plant by 2021 and all remaining coal plants by 2030, making more locations available for offshore windfarms, and prohibiting new homes to connect to the traditional gas infrastructure [27,43].

The Dutch government also supported private-public partnerships for renewable energy and aimed to reduce non-economic barriers for renewable energy technologies [27]. This was done by creating a number of investment and production subsidy programs to stimulate demand for sustainable energy technologies like solar and wind, which require high up-front investment [29,23,44]. Many subsidy arrangements have strongly fluctuated over time, leading to high levels of uncertainty. In this respect, the IEA recommends to grow the local supply and consumption of renewable energy, acknowledging the importance of SMEs [45].

Dutch SMEs account for 67% of Dutch import from other European countries and 66% of intra-European export [46] and are thus an essential part of the Dutch economic performance [19].

In this respect, the European Commission has argued that policy measures in The Netherlands and other European countries can grow the competitiveness and resilience of SMEs by supporting the difficult transition from R&D to the demonstration and commercialization stage [47,48]. From 2013 onwards, the Dutch government therefore has been taking initial steps to involve SMEs producing sustainable technologies in the Top Sector Energy [42]. However, the exact role of SMEs in commercializing energy technologies has remained rather unclear. This study aims to uncover the barriers and drivers during the commercialization of sustainable energy technologies by Dutch SMEs.

3. Method

3.1. Research design: case studies in the Dutch renewable energy market

This study draws on a multiple-case study approach, involving the collection and analysis of qualitative data [49]. The goal is to extend existing theories of barriers and drivers in the renewable energy market. Therefore, this study first draws on a literature review [49,50] and then proceeds with the case study.
According to WEA (2014), a large company consists on average of 50% studies observe that technological know-how is often lacking in the literature concerns the complexity of the technology, as several commercializing sustainable energy. The barrier most often discussed includes a number of literature reviews, mainly in the journal Partly subject to the European legal system. The set of selected studies three criteria: the selected study had to simultaneously address (1) Change, Entrepreneurship & Innovation Management, and Technology Journal of Cleaner Production, Technological Forecasting and Societal Renewable and Sustainable Energy Reviews, as well as empirical stu- part, flexible workers in this table draw on average 8-10 fte's in flexibility staff capacity [53]. and other studies with regard to the sustainable energy sector [55]. financial resources is another barrier com- petition [26,44,51,54,57,58]. The literature review also points out that financial investment can drive sustainable technology commercialization by SMEs [26,44,51-53] and firms in the sustainable energy sector in general [55-58].

3.2. Data collection

3.2.1. Literature review

For the literature review, several academic journals were consulted. The selection of articles was based on the combination of the following three criteria: the selected study had to simultaneously address (1) SMEs, (2) sustainable energy, and (3) one or more countries in Europe. The third criterion was formulated because Dutch energy policy is partly subject to the European legal system. The set of selected studies includes a number of literature reviews, mainly in the Journal Renewable and Sustainable Energy Reviews, as well as empirical studies in journals such as Energy Policy, Energy Procedia, Technovation, Journal of Cleaner Production, Technological Forecasting and Societal Change, Entrepreneurship & Innovation Management, and Technology & Innovation Management. Table 1 provides an overview.

The literature review suggests various barriers and drivers for commercializing sustainable energy. The barrier most often discussed in the literature concerns the complexity of the technology, as several studies observe that technological know-how is often lacking [26,44,51-55]. A lack of financial resources is another barrier commonly found in the literature. Some studies have addressed this barrier for SMEs [44,51-53] and other studies with regard to the sustainable energy sector [54-56]. Regarding SMEs, the literature review also reveals that SMEs struggle with a shortage of qualified personnel [51-53] and a lack of knowledge and experience in marketing and communication [44,51,52]. Moreover, SMEs have difficulties with registering patents, secrecy requirements and Intellectual Property related com- petition [26,44,51,54]. The most important driver for sustainable energy commercialization is the availability of complementary resources, such as knowledge or capital, which are needed for exchanging value in the commercialization process [51,52,54,55,57,58]. In addition, a showcase in the form of, for instance, a prototype serves to demonstrate the potential of the innovation and can contribute to the firm’s commercialization position [26,51,54,55,57,58]. The literature review also points out that financial investment can drive sustainable technology commercialization by SMEs [26,44,51-53] and firms in the sustainable energy sector in general [55-58].

3.2.2. Interviews

The interview sample consisted of 20 SMEs in the Dutch renewable energy sector, selected through the website of the Dutch Chamber of Commerce. Initially, a population of 12 SMEs from the solar industry (i.e. solar cells, solar panels, solar IPV, and solar thermic) was selected [20]. Because solar technologies may have specific R&D trajectories supported by technology-specific governmental subsidies, the sample was complemented with renewable and sustainable technologies other than solar–to obtain findings that can be better generalized. The original sample of 12 SMEs was thus extended with 8 SMEs in other fields of sustainable energy (especially biomass, smart grids, heating), resulting in a total sample of 20 SMEs. Half of this sample of SMEs had less than 15 employees, and the other half employed between 20 and 120 people. Table 2 provides an overview of the firms interviewed.

Data was collected between February 2017 and July 2017. All semi-structured interviews were tape-recorded and transcribed. To avoid bias, each interview started with an open query for the barriers and drivers for technology commercialization perceived by the interviewee. These perceptions refer to what actually (de)motivates entrepreneurs, and are largely ignored in public policies regarding innovation and technology commercialization. Moreover, prevailing theories of SME behavior primarily draw on perceptions, also in the literature on renewable energy commercialization [60-63]. Some additional questions, informed by the literature review, were subsequently raised about barriers and drivers during different phases of technology development (from R&D to commercialization). Appendix A contains the interview guide.

To ensure the internal validity of the results, a qualitative research method was adopted [49], following standard requirements for data triangulation to validate the findings across different data sources. The barriers and drivers identified in the literature review were triangulated with the interview data. Moreover, the interview data was triangulated with secondary data to ensure the validity of the claims made by respondents. Sources of secondary data included company websites, annual reports, newspaper articles, and (e.g. company) presentations [64]. Drafts of interview transcripts and reports were further validated by sending them to the interviewees, inviting their feedback to assure

<table>
<thead>
<tr>
<th>Themes</th>
<th>Barriers</th>
<th>Drivers</th>
</tr>
</thead>
</table>

Table 2

Overview of interviewed firms per sector.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Market</th>
<th>Founding year</th>
<th>Staff (fte)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 RBA</td>
<td>Solar Cells</td>
<td>Testing</td>
<td>2008</td>
</tr>
<tr>
<td>2 ITV</td>
<td>Solar Cells</td>
<td>Appliances</td>
<td>2003</td>
</tr>
<tr>
<td>3 SLC</td>
<td>Solar Cells</td>
<td>Layer technology</td>
<td>2011</td>
</tr>
<tr>
<td>4 STF</td>
<td>Solar IPV</td>
<td>Building Integrated PV</td>
<td>2002</td>
</tr>
<tr>
<td>5 HYS</td>
<td>Solar IPV</td>
<td>Building Integrated PV</td>
<td>2012</td>
</tr>
<tr>
<td>6 SCX</td>
<td>Solar Panels</td>
<td>Building Integrated PV</td>
<td>2003</td>
</tr>
<tr>
<td>7 TSS</td>
<td>Solar Panels</td>
<td>Offshore</td>
<td>2008</td>
</tr>
<tr>
<td>8 VDS</td>
<td>Solar Panels</td>
<td>Regular</td>
<td>2014</td>
</tr>
<tr>
<td>9 SLH</td>
<td>Solar PVT</td>
<td>BIPV – Thermic</td>
<td>2010</td>
</tr>
<tr>
<td>10 SLS</td>
<td>Solar PVT</td>
<td>Heat boiler</td>
<td>2006</td>
</tr>
<tr>
<td>11 SNC</td>
<td>Solar PVT</td>
<td>Concentrated PV</td>
<td>2005</td>
</tr>
<tr>
<td>12 TFS</td>
<td>Solar PVT</td>
<td>Heat Pump</td>
<td>2009</td>
</tr>
<tr>
<td>13 SHT</td>
<td>Smart Grids</td>
<td>Energy Services</td>
<td>2003</td>
</tr>
<tr>
<td>14 LCM</td>
<td>Smart Grids</td>
<td>Substation automation</td>
<td>1983</td>
</tr>
<tr>
<td>15 RNR</td>
<td>Heat</td>
<td>Heat Pump</td>
<td>1997</td>
</tr>
<tr>
<td>16 HMT</td>
<td>Heat</td>
<td>Heat Pump</td>
<td>2009</td>
</tr>
<tr>
<td>17 HST</td>
<td>Biofuels</td>
<td>B2B Biogas</td>
<td>1991</td>
</tr>
<tr>
<td>18 NDS</td>
<td>Biofuels</td>
<td>Fuel Cells</td>
<td>1995</td>
</tr>
<tr>
<td>19 INA</td>
<td>Smart Homes</td>
<td>Clean Air</td>
<td>1993</td>
</tr>
<tr>
<td>20 DCD</td>
<td>Smart Homes</td>
<td>Smart Products</td>
<td>1983</td>
</tr>
</tbody>
</table>

* F: The number stated, plus an additional number of flexible workers. According to WEA (2014), a large company consists on average of 50% flexible personnel. Smaller firms tend to have much more flexible staff capacity. The four SMEs with flexible workers in this table draw on average 8-10 fte’s in flexible staff capacity per company [59].
that the raw data was registered and interpreted correctly [49].

3.3. Data analysis

The interview data were analyzed using a procedure involving two coding cycles [65–67]. In the first coding cycle, the first author read the transcripts and formed codes based on the (barriers and drivers) and the themes observed in the literature review. To improve coding reliability, an independent researcher who did not participate in the interviews double-coded the interview transcripts [64,67]. The two coders subsequently discussed and resolved the differences between the coding results; in several instances, initial coding differences regarding a particular text phrase were resolved by comparing the interview data with secondary data on the issue at hand. This first coding cycle resulted in a preliminary list of barriers and drivers.

The second coding cycle focused on identifying relationships among codes. At this point, one of the authors proposed a number of axial relationships, while two others played the ‘devil’s advocate’ by questioning and further exploring the proposed connections [65]. This served to aggregate the list of barriers and drivers arising from the first cycle into higher-level labels, and thus enabled the construction of a final list of barriers and drivers. This final list is given in the first two columns of Tables 3 and 4. The keywords listed in both tables represent the second-order codes related to the first-order codes in the first column. As will be discussed in the Results section, the second-order codes identified in the coding procedure are, in turn, linked to the findings from the literature review. The coding procedure thus involved an iterative process of going back and forth from interview to literature data.

Finally, an actor-based analysis was conducted, following Kangas, Lazarevic and Kivimaa [61] who argued that an in-depth analysis of barriers should account for the different actors operating in the business ecosystem. Thus, the list of drivers and barriers arising from the coding procedure was analyzed in function of the various actors in the business ecosystem. This analysis served to identify four relevant actor groups: (1) the SME with its technology; (2) the market with its end-user; (3) industry partners; and (4) the government. The analysis also demonstrates how each of these four actors is key to understanding the connections between barriers and drivers [61].

4. Results

This study aims to analyze the barriers and drivers for technology commercialization experienced by SMEs in the renewable energy market. This section provides an overview of the drivers and barriers arising from the interviews, and relates each of them to findings from the literature review.

4.1. Barriers

Fig. 1 provides an overview of the barriers and reports their frequencies. For example, the barriers ‘limited financial resources’ and ‘high market competition’ were mentioned in 19 of the 20 interviews (95%). The remainder of this section explains and elaborates the barriers identified.

4.1.1. Limited financial resources

For SMEs to move beyond the R&D stage and successfully commercialize R&D outcomes, financial viability and fungible financial resources are important assets. Yet, some SMEs in the sample lacked the required financial resources for moving to mass production of the technology or for going through legal procedures, such as patent litigations, needed to secure their market position. For example, interviewee RRA (see Table 2) observed that when a competitor violated one of the firm’s patents ‘you can start a case and that costs a lot of money and the outcome is uncertain; and in the meantime, you’ll soon have two people at work to provide the judge with the required information.’

Although applying for and obtaining subsidies can help build a stronger financial portfolio, the interview data suggests that many SMEs experience barriers in accessing and managing subsidies for technology development. The subsidy process is often time-consuming, involving administrative activities that slow down the development of the focal technology, as interviewee ITV states:

‘(…) you become very grumpy when you see how long the journey takes. Very grumpy. In the end, we received all the subsidy we requested. It’s just that we started two years ago, applying for EFRO [European subsidy for innovation and research], but we got it half a year ago. And yes, the market opportunity then is gone, it’s too late.’

Moreover, some SMEs considered the subsidy process as rather unfair. Governmental agencies are perceived to favor early-stage technology development, rather than subsidizing technology projects of SMEs which tend to be more mature and beyond the proof-of-concept stage. So, deficient subsidy arrangements often constrain SMEs in growing and upscaling the technology, which often causes very promising offerings to be cut off. Prior research referred to this barrier as ‘bureaucratic hurdles’ [51], ‘policy barriers’ [68], ‘lack of funds’ [52], ‘financial barriers’ [51,53], and ‘high upfront investments’ [54].

4.1.2. Risk averseness

Some SMEs hesitate to push for technology commercialization, due to the high risks involved. When referring to these risks, interviewees did not only refer to financial risks, but also to technological, reputational and legal risks. As banks and investors tend to ask high interest rates for bank loans [51,52] and need evidence of the technological and economic feasibility of the project before approving funds [53], SMEs appear to be reluctant to engage in high-risk projects. In addition, since many (e.g. large) incumbent firms try to maintain the status quo [54],

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Barriers compared with literature (keywords represent the second order codes).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barriers</td>
<td>Keywords</td>
</tr>
<tr>
<td>1 Limited financial resources</td>
<td>Subsidy process: unfair, slow [44,51,53,56]</td>
</tr>
<tr>
<td>2 Complexity of technology</td>
<td>Liquidity, production, justice [44,52,56]</td>
</tr>
<tr>
<td>3 Short-term planning</td>
<td>Technological know-how [26,44,51-55]</td>
</tr>
<tr>
<td>4 Risk averseness</td>
<td>Investment [51,52,55]</td>
</tr>
<tr>
<td>5 Time-waste</td>
<td>Technology [56]</td>
</tr>
<tr>
<td>7 Limited attention to end users</td>
<td>Competition (patent) [26,51,54]</td>
</tr>
<tr>
<td>9 High market competition</td>
<td>Lack of time [44,52]</td>
</tr>
<tr>
<td>10 Deficient Legitimacy</td>
<td>Uncertainty [54]</td>
</tr>
<tr>
<td>1 Limited financial resources</td>
<td>Lack of personnel [51,53,55,57]</td>
</tr>
<tr>
<td>2 Complexity of technology</td>
<td>Lacking regulations [44,51,52]</td>
</tr>
<tr>
<td>3 Short-term planning</td>
<td>Unfairness, Market protection [26,44,53,56]</td>
</tr>
<tr>
<td>4 Risk averseness</td>
<td>Domain-specific value chain [44,51,52,54,55]</td>
</tr>
<tr>
<td>5 Time-waste</td>
<td>Communication differences [51,52,68]</td>
</tr>
<tr>
<td>6 Limited attention to end users</td>
<td>Involvement, customer focus [26,56]</td>
</tr>
<tr>
<td>7 Firm accountability</td>
<td>Product efficiency expectations [51,52]</td>
</tr>
<tr>
<td>9 High market competition</td>
<td>Gas-dominated market (no market fit) [26,54,56]</td>
</tr>
<tr>
<td>10 Deficient Legitimacy</td>
<td>Lack of market know-how [44,51,52,55]</td>
</tr>
<tr>
<td>1 Limited financial resources</td>
<td>Trust and understanding [44,55,56]</td>
</tr>
<tr>
<td>2 Complexity of technology</td>
<td>Acceptance by value chain [44,51]</td>
</tr>
<tr>
<td>3 Short-term planning</td>
<td>Cultural differences [56]</td>
</tr>
</tbody>
</table>

1 Customers of SMEs (i.e. the end-user) can also get financial aid for sustainable technologies, in the form of tax advantages or external support [53].
SMEs perceive the risk of failure to be quite high.

4.1.3. Short-term planning

Some SMEs in the interview sample missed a long-term plan or vision on how to commercialize the technology [54]. Technology development appears to be mostly managed in an adhoc project-based manner. Yet, interviewees indicated it is becoming increasingly difficult to work in a project-based manner when the number of employees grows. SMEs thus need to develop know-how on project management and integrate it in the SME’s long term planning [51]. According to interviewee SOL:

‘What is missing is a long-term strategy. That’s just the culture in the Netherlands. That is always missing here.’

4.1.4. Technological complexity

Most interviewees observed that technological innovation in the sustainability landscape is quite complex, which in turn is a major barrier in commercializing technology. Technological complexity requires SMEs to hire highly skilled engineers. Yet, SME-entrepreneurs themselves need to have a profound understanding of the technology, to be able to convince lead customers and other stakeholders about its commercial value. However, there are few business-oriented entrepreneurs with engineering expertise or engineers with entrepreneurial skills, which inhibits the upscaling of complex innovations [68].

Prior research has also identified the barrier of technological complexity, suggesting that firms suffer from a lack of technical know-how and experience cognitive constraints [52–54]. This barrier makes it hard to commercialize the technology, often causing SMEs to not move beyond the R&D phase [51].

4.1.5. Time-waste

Technological innovation in the renewable energy sector involves many long and uncertain development cycles [54], which make it time-consuming [52]. Some SMEs especially pointed out how
time is consumed by searching for qualified personnel such as mechanical and building engineers [51,53]. The SMEs were also suffering from time-consuming administrative work that their highly qualified staff needs to do. Both the search for new employees and the administrative workload appears to substantially slow down the process of developing and commercializing new technology, says interviewee STF:

‘Just the fact that you have to keep track of the hours spend on that process. That simply puts pressure on your agenda, which you need to keep up. You continuously think, ‘Have I written that down, what have I done?’ The weight is sometimes a bit too much on the administrative side.’

4.1.6. Institutional inertness

Many interviewees observed that the sustainable energy sector is still relatively young, despite decades of technology development. As a result, not all governmental regulations and support measures fit the needs of the sector at large (including SMEs). This lack of fit provides an institutional barrier for the development of SMEs' innovations. Several interviewees even reported how fiscal and legislative rules induce unintended discrimination. That is, while a certain policy measure appears to enable some sustainable energy solutions, it simultaneously restricts other solutions [53]. For example, one of the entrepreneurs mentioned that “netting regulations” (“salderen” in Dutch) are beneficial for the solar PV sector, but inhibits the development of solar thermal innovations, since solar thermal end-users do not receive the (netting) financial compensation [69]. In this respect, Polzin [68] noted that regulations for (fossil fuel) gas extraction, supply and consumption are not in favor of renewable energy innovation. These regulations thereby form a significant institutional barrier for SMEs and other firms pursuing this type of innovation:

‘In the case of energy storage systems, the barrier is that there is very little regulation at all.’ (Interviewee STC)

‘It's more about equality between [sic, solar panels and solar water heater] (...) People only have so many roof tiles, so many square meters of roof and when someone has to choose: “Do I put solar panels or a solar water heater on my roof”? People prefer to add two extra solar panels instead of a solar water heater. Now we're at a point where both products are more or less equivalent, so we can bring a better sales story for a solar water heater.’ (Interviewee SOL).

4.1.7. Firm accountability

Interviewees reported that legal accountability is a major issue for both the SME and its clients. This is particularly the case in the construction of energy efficient buildings, which is perceived as a ‘fuzzy’ market with a lack of contractual agreements. Technology projects in this area are often managed and executed by different parties, making it difficult to assess and predict legal accountability in case of damage or other legal risks such as those arising from secrecy requirements [52]. Additional factors are cultural and communication issues between firms, industrial partners and customers that operate in, for example, different time zones [51]. The SMEs believed that multi-stakeholder projects increase legal risks, and thus they rather preferred to avoid them. For example, RRA observed:

‘The tricky thing is doing that [fixing problems or selling products] through other parties, imagine if there is a malfunction and via four layers the report finally arrives. We do not like that, because then the customer is ultimately dissatisfied and the malfunction is a week old.’

4.1.8. Limited attention to end user

Half of the interviewed SMEs said they primarily focus on pushing their innovation to the market, rather than explicitly considering the end-user needs during technology development (cf. technology-push versus demand-pull). These entrepreneurs typically lacked any direct contact with end users. Consequently, they were only confronted with user needs after the technology development was completed. Then, the SME was often unable to adequately address specific end user needs. For example, several entrepreneurs explained that their technology turned out to be highly user-unfriendly or completely unfit for the market:

‘So, you also see a bit of the problem here for a company like this, that we never have contact with the end user in the first instance.’ (Interviewee DCD)

Attending too late to the needs of end users thus appears to inhibit successful technology commercialization. Limited attention to end user needs especially occurs when the value chain is rather long and many parties need to be involved in commercializing the innovation. These conditions complicate any effort to develop a strong end user orientation and engagement with end users. The data also demonstrates that technological solutions for renewable and sustainable energy are often not designed to meet locally varying requirements [54]. Previous work has largely neglected the barrier of limited attention to end users [70].

4.1.9. High market competition

This barrier involves deficiencies in marketing and commercialization capabilities [52] and the entrepreneurs' underdeveloped know-how of the market [51]. Almost all interviewees (19 out of 20) referred to high market competition as a strong barrier. Moreover, three specific underlying mechanisms were identified that apparently make market competition highly disadvantageous for the SME: (1) market preferences caused by a limited understanding of new technologies; (2) competitive pricing; and (3) current product efficiency expectations.

Market preferences. Some entrepreneurs argued that potential end users (e.g. families, households, farmers) are not yet ready to adopt a new technology. Several interviewees connected this to the observation that market infrastructure and conditions are still entirely focused on natural gas. Other referred to a prevailing emphasis on gas due to established monopolies and high-powered incumbent firms. They observed that the dominance of gas demotivates potential customers to search for sustainable alternatives; and SMEs are often unable to build substantial public exposure in the gas-dominated market [71,72]. According to TPS:

‘Ultimately, what we have to beat is gas. And gas is disproportionately cheap, compared to electricity.’

Competitive pricing. About 70% of the interviewees observed that the high costs arising from the development of sustainable energy technologies makes their firms unfit to face the price competition in and around established energy markets. Prior literature relates the SMEs' inability to develop a market-based pricing strategy to 'unavailable or too expensive technology' [52], ‘high innovation costs’ [51,54], and ‘economic barriers’ [68]. Reduced expenses for R&D and technology commercialization would result in lower price levels, which in turn would help increase the adoption rate of sustainable energy solutions. However, many SMEs indicated they were still facing high R&D costs and expensive production facilities, which makes it extremely difficult to sell their offerings at competitive price levels:

‘You think, that's a nice solution. But the sector is very price-driven. Price counts.’ (Interviewee SCX)

Product efficiency expectations. Product efficiency is another competitive mechanism driving established energy markets [52], often at the expense of other factors such as endurance, esthetics, or quality. In this respect, renewable sources of energy typically have a low energy density [54], which makes it even more critical that new technologies turn these sources into higher density levels. For this reason, several SMEs appear to spend a lot of effort in making their technologies as efficient as possible:
‘Now our efficiency is about 11–12 percent. That’s not bad at all, but you see that the market is already progressing toward 20 percent.’

(Interviewee SCX)

Unfortunately, the time and money spent on efficiency improvements often are at the expense of having a good business plan in place or focusing on the experience of end users. In other words, an SME’s current focus on high product efficiency may undermine the (equally important) effort to make its business commercially viable.

4.1.10. Deficient legitimacy

Approval by the SME’s stakeholders such as the government, suppliers and customers serves to create legitimacy. In turn, this legitimacy entails a trust relationship with supply chain partners, and acceptance from customers. It also refers to fair treatment by the government regarding subsidy requests and public exposure in comparison to the offerings of established fossil fuel firms. Some SMEs claimed they struggle with gaining legitimacy because stakeholders often lack knowledge and information [54]. For example, in the case of SLH:

‘It is also a bit of ignorance that there are installation firms that are still trying to talk people into buying a boiler.’

Similar struggles occur when SMEs search for new partners in their value chain or the public and financial sectors [51]. Table 3 provides an overview of the barriers outlined thus far, and connects each of them to the various studies identified in the literature review.

4.2. Drivers

This section highlights the drivers of an SME’s commercialization success. Fig. 2 suggests that a financial injection in the SME is vital (mentioned by 95% of the interviewees). Moreover, having an entrepreneur in-house during the commercialization phase apparently increases the chance of success (also 95%). Thirdly, a showcase in the form of a product prototype or a living lab pilot is important (80%). The remainder of this section explains each of the drivers. Table 4 provides a summary.

4.2.1. Financial investment

Investment by either private or public agents is a key driver of technology development [26,55–57,68]. These financial resources serve several purposes such as start capital, product development, liquidity, risk investment, commercialization, or patent protection. One of the interviewees explained a need for ‘tranches’ in the sustainable energy market. Tranches are classes of securities that are part of the same transaction [73]. On the one hand, this approach would allow the SME to deploy the acquired capital in different business activities (over time), on the other hand it mitigates the risk for the investor. The entrepreneur of SNC referred to one ‘tranche’ for scaling up production, whereas the other one would be for triggering sales:

‘Actually, you need money twice. Once to do the development and start production. The second time to start sales. Two tranches, the first two tranches as they usually call it.’ (Interviewee SNC)

Subsidies would need to be provided in tranches as well. For example, one of the Dutch subsidy programs for sustainable energy has been established to stimulate the production of sustainable energy and therefore only involves the commercialization phase. The compartmentalization of financial support mechanisms to specific venture stages has undermined the viability of many SMEs pursuing technology commercialization. Past research already stated that financial support throughout the entire project (provided in subsequent tranches), called ‘support perseverance’ [58], is a key driver of the ultimate success of these SMEs [74].

4.2.2. Staff

Many Dutch industries are currently facing a shortage in mechanics and engineers [75]. Not because there is not enough money to hire them, but simply because there is a lack of graduates in these professions. SMEs reported a significant demand for qualified, competent, and knowledgeable personnel that can handle complex technologies. The literature review supports this insight as well [57,58]. Facing the shortage, one of the entrepreneurs in the interview sample ingeniously revised the technology (developed in his company) in function of lower skill levels. By building on standard products and systems, his small business was able to effectively hire and operate with employees that are less technically skilled:

‘But what we are running into is that it is very difficult to get good technical people, so now I think more in standard products and standard systems [which requires less technical knowledge].’ (Interviewee RNR)

4.2.3. Knowledge

Many interviewees believe their enterprises are highly knowledge-driven, referring to both internal knowledge and knowledge obtained from external sources. The literature study suggested that to overcome a shortage in relevant knowledge, such as those needed to apply for a patent or subsidy, one thus needs to invest in knowledge and skills [55,58]. Interviewee STC:
‘We are not yet familiar with patents, a year ago we were not yet familiar with subsidies. This is really something you need to know more about.’

Moreover, the interview data suggest that SMEs in the sustainable energy sector appear to especially benefit from knowledge on operations, logistics and internationalization.

4.2.4. Technology focus

In the early stages of technology development, SMEs often motivate their engineers and product developers to build creative solutions, allowing a lot of experimentation. The SMEs often remained too long in the stage of early-stage experimentation, and therefore experienced difficulties in settling on a focal product and engaging in sales efforts. Yet, the literature study informs us that at some point the SME needs to decide on the product and market segment [26,55]. Although this moment cannot be precisely predicted, the entrepreneur of SNC reported that creating such a focus is an essential trigger for success:

‘Then you have to shut things out and just do that particular thing. And then you should not think, when you’re halfway there, that maybe we can still take this and we have so many options, and we still have this, and that, and there, we still have to think about this, and if we do this like that (…).’

4.2.5. Commercialization speed

Many of the SMEs claimed that it is critical to speed up R&D and enter the commercialization phase as quickly as possible. The literature also acknowledges the ‘speed’ driver, suggesting that SMEs are required to (1) set ambitious deadlines for themselves while providing solutions for operations management and logistics (e.g. just-in-time delivery) [34,46], and (2) set strict delivery deadlines for their suppliers and customers [55]. By setting deadlines, SMEs fulfill the expectations of all involved stakeholders, since the SME is more likely to meet deadlines. Adequate time management might also reduce costs and standardize performance factors [55,58]. For example, one interviewee observed:

‘If you say to them “we have announced that we are going to show something on 1st of March”, then those people will also start thinking and then we’ll also activate their time schedule.’ (Interviewee SNC)

4.2.6. Stamp of technology

SMEs actively search for ways to increase the validity and reliability of their technology and product [55,57,58]. More specifically, some interviewees suggested that a ‘stamp’ helps in proving their concept. Such a stamp could be a patent, certificate, partnership, or investment by another reliable SME. These external sources of legitimacy are, in turn, helpful in attracting other stakeholders. Several entrepreneurs appreciate the effect of official measurements by independent organizations, for example:

‘If you stamp that as OK, then that’s like a letter from the king, as you used to have with a wax stamp underneath, with which you would go to the sultan.’ (Interviewee STF)

4.2.7. Reputation of company

In a similar fashion, SMEs can benefit from reputation-building mechanisms at the firm level. A strong reputation makes the SME more attractive to potential partners or investors. Reputation can be realized by hiring experienced employees who have earned their “stars and stripes” in prior careers, or by staying in the market for such a long time that the company itself qualifies among customers as an ‘experienced’ supplier. For example, interviewee TPS reflected on his company’s reputation as follows:

‘In our team, we have architects for that reason, people with a lot of experience in this area.’

Reputation can also be realized by means of the SME’s branding efforts within their own network [57]. Here the SME’s network contributes to its value proposition by sharing an already established reputation [58].

4.2.8. Prototypes and pilots

Successful technology commercialization in the sustainable energy sector requires that customers understand the technology. According to SNC, many SMEs engage in R&D by (implicitly) targeting a mature product and, by doing so, unintendedly sequence technology and market development and thereby delay market entry. Some interviewees reported that they try to overcome such a sequential approach by building prototypes. A prototype helps potential customers to understand the SME’s value proposition and to preview product quality, which makes it easier to attract business partners.

The data demonstrates several forms of ‘prototyping’. First, the SME can produce a beta-version of its product and demonstrate it to the market. Potential customers and their stakeholders can then give feedback, leading to product improvements. By working closely with its stakeholders, the SME ensures that its innovation processes and outcomes more closely match the requirements of customers:

‘What I have probably learned over there [i.e. from potential customers in Asia] is simply setting a deadline and then get it finished. And if you do not get a specification point [documented product requirement] ready, then that will be a CR - a Change Request - for the next generation.’ (Interviewee SNC)

Second, rapid prototyping is another form of prototyping, in which the SME produces (a miniature version of) the product and distributes it among many partners, in order to test the product [57]. Rapid prototyping may also involve a quotation offered to potential customers, since a quotation is a prototype on paper which depicts the components and functionalities of the product [55].

Third, the SME can test its product by means of a pilot with lead customers and other stakeholders, possibly in a niche market. This pilot allows the SME to experience the competitive landscape, the regulations and institutions in place, and the desirability of the product among relevant stakeholders [26,54,55,57,58,68].

4.2.9. Networks

For any technology firm, obtaining access to complementary knowledge is often critical for successful commercialization [76]. Such knowledge is often obtained by means of established networks, for instance by hiring knowledgeable new staff members through the social networks of current employees. Yet, a network can also serve to exchange resources, for example, for acquiring investment capital or research facilities, obtaining IP protection, or applying for subsidies (see quote below). Moreover, regulatory or institutional changes [54,55,57,58,68] can be addressed by working together with powerful actors in the network [77]. Ten of the interviewees indeed reported how their network plays an important role during technology commercialization. For example:

‘Many subsidy projects work in a similar fashion: a few parties think about how their consortium needs to become a bit better (…) and we as a potential partner, we’re more often involved in these kinds of projects. We’re a good party. They know us through various channels.’ (Interviewee ITV)

4.3. Entrepreneur as pivotal figure

Almost all SMEs emphasized the importance of an ‘entrepreneurial figure’ in technology commercialization. Three specific reasons for the key role of an entrepreneurial figure can be inferred from the data.
First, a good entrepreneur is key to bridging the gap between technological complexity and market needs. Several interviewees claimed they needed clever engineers who can build complex products; yet, if these engineers cannot commercialize the technology into a saleable application or, vice versa, if the SME does not have an entrepreneur who can convince others, it has little chances of survival. Having a good entrepreneur or salesman in-house therefore is an important driver for commercializing sustainable energy solutions [55–58,68].

Second, entrepreneurs help to commercialize technology because they often function as a leader in building the network, coaching the team, and creating momentum [77]. One of the interviewees (SNC) defined himself as an entrepreneur as follows:

“So you need coaches as peculiar like me, who have already done some of those things and who therefore have a bit of expertise, a piece of knowledge. Have a bit of expertise but also acquaintances.”

(Interviewee SNC)

Third, entrepreneurs have often mastered long-term strategic and out-of-the-box thinking [55], are more creative with firm resources, and better able to construct a holistic vision [58]. In this respect, several interviewees acknowledged the importance of a vision that links the new technology to its broader business ecosystem. For example:

‘The ambition is that I’ll become the provider of energy systems.’

(Interviewee RNR)

“We are capable of providing, sort of, big Lego blocks in a box for customers to assemble.”

(Interviewee TSS)

5. Discussion and conclusion

This study aims to shed light on the role of SMEs in the energy transition, by identifying the inhibiting as well as facilitating factors for their technology commercialization efforts. The extant literature was reviewed, and the results from this review were extended by conducting a study of SMEs in the Dutch energy market.

By combining the insights from the review with empirical data, the study contributes to the existing literature that largely overlooked SMEs as agents, by providing new insights into barriers and drivers for commercializing sustainable energy technologies. Table 3 sheds new light on barriers identified in previous work by reporting that SMEs are confronted with risks arising from technological and competitive dynamics, uncertainty (about time), and deficient legitimacy due to cultural differences (e.g. toward German versus Asian technologies). Similarly, Table 4 adds to the existing literature by identifying drivers such as the ‘stamp of technology’, which can take the form of measurements, certificates, patents or investments. Also, prototyping and piloting while improving product features and providing building blocks to clients are drivers that were under-researched so far. These new insights are relevant for future business model choices by SMEs [54]. The business model perspective on barriers and drivers will be discussed in section 5.3.

Fig. 3 summarizes the results in an actor-based model. The data suggests that four actors are important [1]: the SME with its technology [2]; the market with its end-users [3]; industry partners; and [4] government. By accounting for different actors in the analysis of barriers and drivers, one can make more specific suggestions on how to improve public policy regarding SMEs as well as their management [61]. Below, various barriers and drivers for SMEs are discussed, followed by a description of the policy implications.

5.1. Barriers in the Dutch sustainable energy market

The analysis helped to identify important barriers that Dutch SMEs experience in the sustainable energy sector: (1) high market competition, (2) limited financial resources, (3) risk averseness, and (4) technological complexity. While Figs. 1 and 2 in the results section involve a ranking of barriers and drivers across cases, the interview data is perceptual in nature. This means that the results are likely to be prone to a self-serving attribution bias, arising from the human tendency to relate negative things such as barriers more to external factors [78]. It is, however, standard practice in the analysis of narrative data to let key patterns speak for themselves [61,79–82].

The SMEs in this study reported market competition to be outside their sphere of influence, also as a result of their relatively low impact compared to large incumbents such as gas and oil energy producers. SMEs’ vulnerability arising from limited financial resources complements this first barrier. Limited financial resources are intrinsic to SMEs [13,83–85] and give them little slack to invest in R&D and commercialization of renewable technologies. Hoogendoorn et al. thus argued that the smallest SMEs in terms of turnover are the least likely to be involved in greening their products and service offerings [83]. Wiklund and coauthors observed that market competition, measured as hostility increase, has a direct negative effect on innovativeness, risk-taking and pro-activeness of SMEs [13]. The technological complexity and the lack of know-how of the SMEs involved [26,44,51–53] is not necessarily unique for the SME setting. It is, however, an important barrier highlighted by the interviewed entrepreneurs, who were calling for more careful and tailored policies. Large firms can also suffer from long technology development cycles, although new ventures created by large firms can profit from the resources of the parent firm, which allow them to grow despite policy discontinuity [86].

5.2. Drivers in the Dutch sustainable energy market

This study also provides insights in the intrinsic qualities of SMEs which can enhance the commercialization of renewable energy technology. Their small size allows them to move more easily across functional domains as well as develop prototypes and pilot projects faster. SMEs typically have no more than 100 employees, which allows the entrepreneur to maintain an overview and act as a pivotal driver in renewable technology commercialization (see Table 4). This finding reflects a traditional notion of prior management studies that although large firms are favoured by the availability of internal funds, they are more bureaucratic than small and medium-sized enterprises with rigid rules and routines that may make innovation difficult [87]. Many SMEs participating in this study reported that renewable technologies often require them to enter a new market other than the one which they already serve and that entering a new emerging market such as the one of sustainable energy technology is associated with a liability of newness [88]. When entering the sustainable energy market, SMEs need to show the value of their new products and services. Therefore, most SMEs searched for ways to obtain an external quality assurance, claiming that some kind of quality stamp can help legitimize their offering toward customers and other stakeholders (see Table 4).

5.3. The interplay between barriers and drivers

In contrast to earlier research that suggests barriers and drivers for the commercialization of sustainable energy technology are separate entities [54], some barriers and drivers appear to operate as a kind of ‘mirror images’, meaning that a particular barrier can potentially be removed by a specific driver. Therefore, the dynamic interplay between barriers and drivers is very promising. For instance, the barrier of high level of market competition can be addressed by hiring someone with exceptional entrepreneurial skills (as driver). Or the barrier of technological complexity can be addressed by hiring more staff with advanced engineering competences. In some conditions, multiple drivers can be instrumental in removing one particular barrier, or vice versa, one driver can resolve several barriers simultaneously. For example, the barrier of deficient legitimacy can potentially be solved by obtaining a stamp (e.g. a patent or investor), but also by a pilot in which potential
customers learn about the product and its value. As various barriers and drivers differ substantially in their frequency in the interview sample (Figs. 1 and 2), it might well be that some barriers/drivers are more key to inhibiting or accelerating technology commercialization. For example, technological complexity appears to be a substantial barrier (85%), whereas obtaining a stamp of the technology (63%) is an important driver.

This study also explicitly explored the role of different actors in sustainable technology commercialization by SMEs, adding an extra dimension to the understanding of barriers and drivers. In this respect, previous work shows that business model designs define how SMEs and their partners create and capture value [89] and a deep understanding of the business model can support successful commercialization of sustainable technologies [89–91]. For example, one study in this area found that new business model designs for solar energy in the Netherlands remove financial barriers, since these business models allow for new financing mechanisms by third-party involvement of end-users [23]. Another study shows that new business models for car sharing appear to structure the actors in an innovative way, which serves to increase mobility with potential sustainability gains [77]. Both examples show how barrier and drivers are affected by the relationships between the actors involved in one single business model.

5.4. Policy implications and future research

The findings from this study imply that government can support SMEs in various ways in their efforts to commercialize technology. For example, governments could support SMEs by promoting the ‘stamp’ concept that enhances legitimacy, auditing of early-stage performance, supporting the independent testing of SMEs’ technologies, and providing specialized training for new staff. In addition, the government regulates energy markets by providing subsidies to different types of technologies as well as setting regulations to operate in energy markets. Local and national governments thereby both enable and restrict opportunities for SMEs [92]. In this respect, the institutional inertia of governmental policies appears to restrict the support for SMEs’ efforts to commercialize renewable technology. Policy arrangements such as ‘netting’ appear to be highly beneficial to solar PV providers in the Netherlands, but, at the same time rather disadvantageous to those commercializing heating solutions. This illustrates the high dependence of SMEs on public policy. The recent decision to discontinue gas extraction in The Netherlands by 2030 [93] can thus be an important and necessary market enabler for SMEs in this gas-dominated country.

Over time, regulations change (e.g. due to lobbying) which results in larger or smaller sets of opportunities for SMEs to enact. Other factors may also initiate changes in the set of barriers and drivers. For example, when the market for sustainable energy solutions grows, customers and other stakeholders may become more experienced with these solutions, thereby decreasing the barrier of technological complexity [94]. Future research in the form of a longitudinal study on some of these drivers and barriers would therefore be highly interesting.

The findings also suggest other avenues for further research. First, one can study the extent to which barriers and drivers are technology-
or SME-specific. This article has made some preliminary suggestions for solar technology in that direction, but more work is needed to fully capture the technological specificity of (some) barriers and drivers. Second, prior research on solar energy market development in the Netherlands has suggested that business model design can help SMEs in lifting or bypassing certain barriers [77,92], which calls for more research into the relationships between sustainable technology commercialization and business model design. The findings in this paper add to this stream of research, yet, suggest that future work can further explore how the relationships between all actors involved are best structured in a business model that elevates most, if not all, barriers. Finally, the results of this study pertain to the Dutch sustainable energy market only, and future research in this area thus needs to address other countries and continents.

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Appendix A. Interview guide

Introduction of interviewers, asking for permission to record the conversation.

Introduction

- Introduce myself: Who am I? Where is this interview for?
- Explain the goal of the research project and interview: with this interview we hope to find out the barriers and the needs of an innovative SMEs in the energy sector.
- Thank the interviewee for his/her time.
- Explain how data will be handled and published. Indicate option for 'off the record' answering (not taped or transcribed) and checking of transcripts and final report by the interviewee. Ask for permission to publish their name in the final report.

A. General questions

1. Who am I talking to, what is your position in the firm? How long are you working here?
2. How big is the firm? How many employees?
3. How many/what (innovative) products did you bring to the market? What is your customer segment and what do you offer them (value proposition)?

B. Open questions about necessities of the innovative firm

1. Did you experience barriers/trouble during the creation, development and launch of the (innovative) product/process? If yes, can you tell us more about it?
2. What does your firm need in order to be more successful in your innovation process and to bring innovative products to the market? What is still lacking?
3. How do the social, economic, environmental, technological, legal and political environments impact your business?

C. Innovation development questions to guide the interviewee

1. Research and development
   a. Are any of the innovations patented?
   b. Do you have an innovation strategy? How do you enlarge your business impact? Are you planning to become an international organization? What is your vision for the coming 5/10 years?
   c. Is there space for innovation provided through the whole firm?

(Where is there an innovation culture)

d. Where do you get the knowledge for innovation from?
   (Organizational, sharing)?

2. Demonstrations
   a. Can you describe the company’s network?
      i. Competitors, Partners, Government, Clients, KI, Universities
      (Do you have partners in your network that do not seem to fit in the same branch/are very different from your company?)
      ii. Value chain position
   b. What help/resources do you receive from your partners?
   c. Do you assess the competitors’ capabilities?
   d. Do you receive subsidy from the government or investment from other parties?

3. Commercialization
   a. How often do you do market research and what is your targeted customer segment does not like the product?
      i. Expectations, legitimacy, popularity (What are the expectations of your customers?)
   b. Do you involve your customer in the product development process?
   c. Do you have contact with firms that focus on product commercialization?
   d. Do you experience problems with (governmental) regulations?

Last questions:

- What is the difference in innovation processes between being an SME or a start-up? How is the transition?
- Where do you think innovation intermediaries can help you with?
- What is the added value compared to cold money from a bank?
- Is there anything you would like to add to this interview?
- Are there others we did not think about? (Snowballing)

References

[17] Gibson DV, Conceição P. Incubating and networking technology commercialization centers among Emerging, developing, and mature technopoleis worldwide. Int


[76] Miles MB, Huberman AM, Huberman MA, Huberman PM. Qualitative data analysis: an expanded sourcebook. SAGE; 1994. p. 358.


