BUSINESS MODEL INNOVATION FOR CIRCULARITY

– PERSPECTIVES FROM THE SWEDISH ENERGY SECTOR

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Preface and summary

This report provides an overview of the research financed by grant ref. nr 21-148 with the project title *Business model innovation in the Swedish energy sector – enabling a circular economy*. A circular economy is a novel production model that is based on circular flows of material and energy, thereby reducing waste generation, and minimizing the extraction of finite resources. This research was initiated due to the need to identify challenges associated with developing and implementing circular business models in the Swedish energy sector. The study aims to identify obstacles and coping strategies associated with the development of circular business models in the Swedish energy sector, and to explore how actors within the sector work with circular business model innovation. Due to the complex character of business model innovation and the rather recent emergence of the field of circular business models, the study was designed as an exploratory qualitative study. In total, 36 respondents were interviewed, and these respondents had mostly senior roles in their organization or were prominent advocates for aspects linked to their professional area within the Swedish energy sector. The interviews allowed for a comprehensive overview of how circularity and circular business models are developed within multiple subsets of the Swedish energy sector.

Based on the analysis of the data, three main groups of barriers to circular business model innovation were identified. The groups were *external, organizational*, and *collaborative* barriers. These main categories of barriers are made up by subcategories of barriers, with external barriers comprising *market and institutional, regulatory,* and *systemic* barriers; organizational barriers containing *perceptional,* and *knowledge and resource* barriers; and collaborative barriers containing *perceptional*, *financial*, *social*, and *regulatory* barriers.

In the report we have gathered multiple examples of how to counter these barriers. However, when it comes to strategies of key importance we see collaboration, long-term dedication, and collective iterative learning as important for successful circular business model innovation. We also point to other aspects which policy makers and others may act upon in order to accelerate the innovation speed in the energy sector. By identifying tensions between business model innovation within the linear consumption-driven innovation paradigm and those associated with the emerging trend of the circular economy, the project facilitates the realization of a circular economy.

While the results from the project are presented in a condensed way in this report, additional analysis is currently being conducted with the aim to further develop theory on the matter of circular business model innovation. Ongoing research is conducted within the framework of two academic papers that the project has facilitated. Furthermore, the project funding has allowed for the development of cases as well as general knowledge which the authors will include in their teaching.

The authors want to thank the Åforsk Foundation for the generous grant which has enabled us to further develop our research. We also thank all the respondents that despite the extreme circumstances that the Swedish energy sector faced during 2022, generously volunteered and offered their time to answer our questions.

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1. Introduction

In 2020, the Swedish government adopted a strategy for implementing a circular economy. The strategy envisions a society that uses resources and energy efficiently in non-toxic, and climate friendly circular flows (Regeringskansliet, 2020). Hence, the circular economy strategy was proposed as an important step toward transforming Sweden into a fossil-free welfare state. However, it has been estimated that the Swedish economy is only 3.4 percent circular, less than half the global average of 8.6 percent, indicating that the transition toward a circular economy is an uphill struggle even for a sustainability oriented country such as Sweden (Conde et al., 2022). While governments may establish strategies and ambitions it is the private sector that will develop and implement many of the innovative solutions that is believed to be needed for a transition to a fully circular economy. The circular economy is expected to act as a driving force, incentivizing the development of innovations and circular business models (Regeringskansliet, 2020).

The business model has become a central analytical concept when studying the alignment of business activities with the vision of a circular economy (Boons et al., 2013; Reim et al., 2019). A primary reason for this is that the business model explains how a company creates value while utilizing resources and balancing the needs of its stakeholders (Morris et al., 2005). The business model has therefore gained recognition as a useful tool to explore how to enable the introduction of sustainable innovations or change customer behaviour (Schaltegger et al., 2016). Moreover, with the rising interest in the circular economy, the literature on circular business models has expanded considerably during recent years (Hina et al. 2022). For societies that rely on the private sector for the production of goods and services it is thus necessary to spur innovation in circular business models to enable the shift towards a circular economy (Geissdoerfer et al., 2018).

The process of developing and implementing new business models is a considerable challenge, especially for actors with established models (Chesbrough & Rosenbloom, 2002). The difficulty of developing and implementing new business models has been studied extensively. However, with the introduction of the concept of circularity it has become apparent that there are challenges to innovation that are specific to circular business models. The barriers to innovation encountered by those wanting to develop and establish new circular business models are resource-related challenges (e.g. acquiring access to the physical and intellectual resources required for business model innovation), cultural and psychological challenges (e.g. failure to identify possible solutions due to cognitive dissonance), as well as challenges associated with communicating with key stakeholders (e.g. investors and customers with a negative attitude towards business model change) (Guldmann & Huulgaard, 2020). The importance of barriers related to stakeholder interaction has increased as business model innovation increasingly occurs through open and iterative processes where stakeholders provide feedback and influence the direction of business model development (Bogers et al., 2018; Saebi & Foss, 2015). Swedish corporate governance is strongly associated with the stakeholder model which postulates that it is the relationship between the focal organization and its stakeholders that drives business success (cf.Freeman et al., 2010).

When business models are developed through open innovation or interaction with external stakeholders that do not have formal influence over the company (e.g. customers or suppliers), these processes tend to be arranged in ways that minimize downside risks while maximizing organizational flexibility. This can be achieved by separating experimentation from standard business practices, e.g., through the establishment of subsidiaries or joint ventures (Chesbrough & Rosenbloom, 2002; Enkel & Gassmann, 2010). These separate organizations breed other types of opportunities compared to what would have been possible if development took place in-house. The reason is that within the organization it is the compatibility of an innovation with the existing business model that determines adoption (Chesbrough & Rosenbloom, 2002). This means that there is considerable resistance among incumbents to engage with business model innovation and once business model innovation processes are started, the results are likely to generate new organizations rather than changing the current organization. It can thus be

concluded that the Swedish energy sector is likely to face considerable challenges when attempting to innovate business models for the circular economy and would thus benefit from research that exemplifies how other industry actors work with and benefit from business model innovation.

1.1 Purpose and Research questions

This study has two aims. First it seeks to identify obstacles to the development of circular business models in the Swedish energy sector. Second, it aims to explore and portray the strategies that actors within the sector deploy to cope with such obstacles.

To fulfil the purpose, the study will answer the following research questions:

- How do actors in the energy sector work with circular business model innovation?
- What obstacles and coping strategies do actors in the energy sector associate with the development of circular business models?

By answering the research questions, the study highlights tensions between business model innovation within the linear innovation paradigm and business model innovation associated with the emerging circular economy. By making these tensions explicit and showing how actors handle them, the study will further the development of business strategies and policies that facilitate the transition to a circular economy. Since overcoming barriers may create competitive advantages (Galvao et al. 2022) our results have the potential to strengthen the competitiveness of the Swedish energy sector.

2. Previous research

Since its popularisation by the Ellen Macarthur foundation in 2013, circularity has been adopted in multiple industrial sectors and incorporated in many sustainability related research fields. The term circularity refers to the closing of resource loops and is associated with popularized strategies such as reduce, reuse, recycle and remanufacture (Stahel, 2016). Comparing research on circularity, it is apparent that, except for the bioenergy sector, the concept of circularity is not as firmly integrated into the energy sector as in the manufacturing sector. A plausible reason for this is that circularity is conceptually not adapted to the role of entropy in systems and the fact that energy cannot be created or destroyed but rather is transformed into other forms or transferred between bodies (Andersen, 2006; Winans et al., 2017).

Circularity forms the conceptual foundation of the circular economy which is built on ideas such as industrial symbiosis and systems theory (Winans et al., 2017). The term circular economy is contested and by some criticised for its potential misuse or lack of concern for other sustainability related aspects (Corvellec et al., 2021; Johansson & Henriksson, 2020; Murray et al., 2017). However, literature reviews have shown that the multiple definitions share a view of the circular economy as requiring a systemic shift towards actions such as reduce, reuse and recycle (Kirchherr et al., 2017). The circular economy is linked to the idea of circular business models in the sense that just as a linear economy relies on linear business models to generate value, frequently causing external costs, a circular economy will need circular business models for businesses to create value and internalize the costs that such value creation generates. Hence, despite research failing to acknowledge the role of business models in enabling a circular economy (Kirchherr et al., 2017), business model theory implies that a value chain that closes resource loops within an industrial ecosystem will require circular business models for those actors that want to collaborate within the loop (Geissdoerfer et al., 2018).

2.1 Circular business models

A taxonomy of circular business models has been suggested which bases classification on the degree of circularity along two business model dimensions, the *customer value proposition* and the *underlying value network* (Urbinati et al., 2017). This places circularity in the borderland between the organization and its stakeholders and presents the user with key modes of supporting the circular economy. Such modes address a dedication to the principles of circular economy both in the internal production and outward facing aspects of business models. Firstly, through the focus on internal and upstream aspects of circularity such as production and supplier relationship, and secondly through downstream approaches such as supporting customer utilization of spare resources, i.e. extracting value from goods and resources that otherwise would go to waste or be left underutilized (Urbinati et al., 2017). Similarly, a framework has been suggested for the integration of circular business models with the circular supply chain, resulting in five categories of circular loops: closing, slowing, intensifying, narrowing, and dematerialising (Geissdoerfer et al., 2018). Each of those categories then help the achievement of a circular economy. Multiple categorizations of circular business model archetypes have been proposed, but the archetypes can be categorized based on their focus on down- or upstream architecture and the type of value created, delivered or captured, e.g. reduction of virgin materials, waste and increased product/material use or lifespan (Pieroni et al., 2020) A review of key sources identified common traits of circular business models which in turn provides the definition as “business models that are cycling, extending, intensifying, and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organisational system” (Geissdoerfer et al., 2020, p. 7).

While circular business models incorporate circular economy principles in their value propositions, the systemic effect of that value is difficult to assess (Manninen et al., 2018); Yet if it affects multiple actors along a value chain, the systemic effect can be considerable (Piispanen et al., 2020). It is thus important to critically examine the assumptions that circular business models build upon and question if a specific circular business model will truly have a positive impact on sustainability, something which will require a systematic evaluation rather than a review limited to the business model in question (Hofmann, 2019;

Mattos et al., 2022). Viewing the development of business models from an outsider's perspective highlights the need for utilizing circular strategies such as narrowing (use less), slowing (use longer), closing (use again), regenerating (clean up) and informing (use data to support the development of the circular economy) with respect to material and energy flows targeted by the business model (Konietzko, Bocken, et al., 2020). It also puts emphasis on the need for assessment methods to account for how indicators of circularity translate between different levels found within the production system, or else circular business models may fall by the wayside unnecessarily (Harris et al., 2021).

2.2 Barriers to circular business model innovation

Business model innovation is a considerable challenge for existing organizations due to two main barriers: obstruction due to resource constraints, i.e. lacking the right resources to execute the business model, and confusion about which business model that is correct for a certain scenario, i.e. a difficulty to assess both the business setting and the suitability of business models in a specific business environment (Chesbrough, 2010). Being able to overcome barriers associated with the circular economy may create competitive advantages and working with barriers is thus an important task not only for the achievement of a circular economy but also for corporations' competitiveness (Galvão et al., 2022). However, the increased level of interconnectedness in the circular economy poses unique challenges to business model innovation. A literature review of research on circular business models found barriers and drivers linked to sustainability, supply chains, internal corporate factors, ICT, and lean production (Rosa et al., 2019). A more recent study similarly identified central categories of barriers and drivers (financial, legal, market, technical, organizational, and value chain) (Geissdoerfer et al., 2022). The mixed groups of factors indicate a widespread presence of obstacles and accentuates the complexity of business model innovation for the circular economy.

Due to its focus on material flows, circularity may clash with the much broader scope of sustainable development. The interaction between the fields impacts all phases of business model innovation (conceptually delineated through the lens of dynamic capabilities, i.e. sensing, seizing and transforming). Yet research tends to focus on single innovation stages, ignoring the long term challenge of iterative learning and development posed by the circular economy and sustainability (Pieroni et al., 2019). Hence, just as new circular business models can be developed for any stage of the life cycle of a product (Neligan et al., 2022), barriers to innovation for circular business models may occur at any stage of the development and implementation process. An empirical study of circular business model innovation in three consumer oriented multinational companies found that the process of innovation can be partitioned into four phases (visioning, sensing, seizing & transforming) and that those phases are characterized by practices and tools that are adapted to tasks typical for each stage of development (Bocken & Konietzko, 2022). Yet, since business model innovation is an iterative process, the barriers may be addressed repeatedly and organizations may learn from their failures (Chesbrough & Rosenbloom, 2002) and incorporate those learnings into both the business model design and the business strategy, ultimately achieving competitive advantages (Galvão et al., 2022). Circular business model innovation also emphasises the role of experimentation and stakeholder outreach in the innovation process (Konietzko, Baldassarre, et al., 2020). However, it is also suggested that the implementation of circular business models can be facilitated by adjacent innovations, especially digitalisation since it appears to support resource efficiency (Neligan et al., 2022).

Categorizing barriers to the implementation circular business models as either inside and outside the organization it has been suggested that stakeholder interaction poses a particularly difficult challenge and that strategies to overcome collaboration barriers need to be tailored based on traits specific to the business model in question – a result that serves as caution against generalization about barriers and strategies to circular business models (Vermunt et al., 2019). The internal/external dichotomy is commonly applied in studies of barriers and drivers of business model innovation for the circular economy and is useful for management that wants anticipate obstacles (Hina et al., 2022). A study of 12 Danish companies identified barriers to circular business model innovation at four socio-technical levels, i.e. for market development, in the development of institutions and value chains, for internal

organizational development and for development of employee engagement and competence (Guldmann & Huulgaard, 2020). Moreover, due to the unique characteristics of circular business model innovation, research is still needed on topics such as the influence of organizational culture, the interplay with business strategy, managerial influence, change management, and potential inertia (Santa-Maria et al., 2021).

3. Method, data collection and analysis

The study was initiated with a literature review (Hart, 2018) of publications in the fields of circular economy, circular business models, and business model innovation. The literature review provided an up-to-date frame of reference which formed the foundation for the interview study. In parallel with the literature review, key actors, and organizations in the Swedish energy sector with a presumed interest or current engagement in the circular economy were mapped. To be able to explore the meaning of circularity and approach to circular business model innovation from different perspectives, various types of organizations with experience from different forms of energy production were of interest. Furthermore, insights from industry associations and experts provide a valuable complement to the data collected from energy professionals. Based on this, a list of organizations of interest for data collection was compiled.

Subsequently, relevant representatives from these organizations were identified through websites, LinkedIn and personal contacts. These included CEOs, Senior Advisors in Energy and Strategy, and middle managers in sustainability, business development, environment, and communication, amongst others. Focal companies represented various types of energy production, such as electricity, district heating, wind and solar developments, as well as nuclear power. In addition, suitable experts and researchers from industry organizations, research institutes and universities were identified. This resulted in a list of potential respondents to be interviewed, to which further candidates were added later through snowballing technique (Parker et al., 2019).

Potential interview candidates were contacted by e-mail starting in December 2021. In the end, thirty-six gave a positive response and were interviewed during the period December 2021 to December 2022. Table 1 lists the organizations and the position of each respondent.

Table 1 List of organizations, organizational type and respondents' title and/or occupation

Organization	**Type**	**Title**
Borås Energi & Miljö	Energy Company	Head of Sustainability
Chalmers	University	PhD Student/Researcher – Nuclear Energy
Chalmers Industriteknik	Research Institute	Senior Researcher and project manager
Chalmers Industriteknik	Research Institute	Innovation manager and circular business advisor
COWI	Energy Consultant	Process Engineer
E.ON	Energy Company	Strategic Business Partner
E.ON	Energy Company	Strategic Partnerships and City Development
Energiföretagen	Industry organization	Senior Advisor Environment, Sustainability and Fuel Supply
Energiföretagen	Industry organization	Senior Advisor Nuclear Power
Energiföretagen	Industry organization	Senior Advisor Climate, Wind Power, Solar and Energy Storage
Eolus Vind	Project developer wind & solar power	Environmental Coordinator
Göteborg Energi	Energy Company	Head of Sustainability
Kraftringen	Energy Company	Business Development and Project Management

KTH - Royal Institute of Technology	University	PhD Student – Nuclear Energy
Lund University	University	Postdoc Researcher
Mälarenergi	Energy Company	Head of Strategy & Development
NiNa Innovation AB	Entrepreneurial company	Entrepreneur
Profu	Energy Consultant	Senior Consultant
Ragn-Sells	Recycling Company	Head of Sustainability Expert Circular Economy
Ragn-Sells	Recycling Company	CEO Ragn-Sells Treatment & Detox
Renova	Waste and Recycling Company	Strategic Development of Waste and Recycling and their Environmental Impact
RISE	Research Institute	Senior Researcher in Sustainable Business
Solkompaniet	Solar project developer	Head of Business EPC
Stockholm Exergi	Energy Company	Energy Policy Expert
Studsvik	Expert	Expert Nuclear Energy
Sundsvall Energi	Energy Company	CEO
Svebio	Industry organization	Program Director
Sysav	Waste and Recycling Company	Chief Commercial Officer
Sysav - Siptex	Waste and Recycling Company	Communication Manager
Söderenergi	Energy Company	Sustainability & Communication Manager
Södra	Forestry Cooperative	Head of Energy
Umeå Energi	Energy Company	Business Development and Project Management
Varberg Energi	Energy Company	Head of Development and Sustainability
Vattenfall	Energy Company	Senior Advisor
Vestas	Wind turbine producer	Head of Advanced Structures and Sustainability
Övik Energi	Energy Company	CFO/Strategic Business Development

The interviews were semi-structured and guided by a questionnaire that was adapted to the type of organization and means of energy production in focus. Questions investigated the respondents' perspectives on circularity and their approaches to and perceived barriers to circular business model innovation, amongst others. Follow-up questions allowed for exploring these topics more in depth. Most of the interviews were conducted jointly by two researchers and held over Microsoft Teams. Video interviews are a convenient and effective way to collect qualitative interview data while replicating the face-to-face experience (Archibald et al., 2019). They also allowed for a broader geographical coverage of the interviews.

One of the researchers took the lead in the interview whereas the other asked follow-up questions and took notes to catch the essence of the respondents' answers. Upon approval by the respondents, the interviews were recorded on Teams or through a voice recorder to allow for transcription and further data processing. Two interviews were not recorded, one on request by the respondent, the other due to technical problems. The interviews were between 35 and 75 minutes long with the was majority of the interviews lasting for about an hour or more. All recorded interviews were subsequently transcribed, either manually or by using the transcript function in Microsoft Teams or Word. For the latter two, the transcript was subsequently manually checked and adjusted.

Data analysis was based on both interview transcripts and notes taken. The data was analysed by using NVIVO and conducting a thematic analysis (Guest et al., 2011). In the first step, the researchers familiarized themselves with the data by re-reading or re-listening to the interviews, which allowed for generating initial codes and coding interesting sections in the data systematically. The codes were subsequently collated into themes, whereas all data belonging to a theme was gathered. This process was accompanied by regular meetings of the researchers to discuss the findings and their linkages with prior research.

4. Opportunities for circular business models

When developing an understanding of barriers and coping strategies it is helpful to first get a sense of what the general innovative landscape looks like when it comes to circular economy and the Swedish energy sector. In Figure 1 below a typology of circular economy opportunities in the Swedish Energy sector is presented. It is divided into four quadrants along the dimensions *Used* and *New* as well as *Material* and *Energy*.

As the literature review showed, there are multiple ways to categorise circular characteristics. There are thus opportunities that do not fit within the dimensions used in Figure 1. Especially important in this sense is the Reduce strategy which has been left out of the figure since it is an approach which can be used in combination with all the opportunities in the quadrants. Reduction is the basic principle behind improving energy efficiency which in turn is one of the most cost efficient measures available when aiming to cut greenhouse gas emissions (UN, 2023).

	Material	**Energy**
New	**Recycling of energy infrastructure**, e.g.: - Wind turbines - Solar panels - Energy infrastructure - Batteries	**Renewable energy production**, e.g.: - Biomass-based CHP - Wind power - Solar power - Hydroelectric power - Geothermal power
Used	**Regenerate**, e.g.: - Pre-sorting of waste, e.g. wood, plastic etc. - Extract metals from bottom ash - Extract salts from hazardous fly ash - Extract zinc from fly ash - Return ash fr. bioenergy to forests - Differentiated pricing model for plastic waste - Detoxify waste streams	**Reuse**, e.g.: - District heating from residues - Waste heat - Low-grade heat - Energy storage - Biogenic CO2

Figure 1 Circular economy opportunities in the Swedish energy sector

In the following, the different dimensions are explained and linked to examples of circular business models.

4.1 Circular economy opportunities from used material and energy

The two lower quadrants of the typology show circular economy opportunities from *used material* and *used energy*, whereas used material offers opportunities to be *regenerated* and used energy to be *reused*. These two quadrants and the opportunities they offer for circular business model innovation are the main interest of this study.

4.1.1 Regenerating used material

In the quadrant dealing with *regenerating used material*, predominantly a *single company circular business model* is at use.

Examples of well-established circular business models within this category are *returning ashes from biomass combustion back to forests* and the *extraction of metals from bottom ash*. An example of a circular business model requiring innovation and product development is *the extraction of zinc from fly ash*. Another circular business model identified relates to *the extraction of salts from hazardous fly ash*

(sodium chloride, calcium chloride & potassium chloride), a circular business model that requires collaboration (see Box A).

It should also be mentioned that improved pre-sorting of waste, especially when it comes to plastic, can open up for further circular business model innovation. According to this study, energy companies burning waste frequently use a differentiated pricing model depending on the plastic content of waste, which creates incentives for better pre-sorting of waste. Finally, it should be mentioned that by burning waste, hazardous substances are removed and taken care of, detoxifying society. It is important that these substances do not circulate, which respondents consider to be a further aspect of circularity in the Swedish energy sector. Waste incineration acts as a kidney that cleans society.

4.1.2 Reuse of Energy

The quadrant addressing the *reuse of energy* holds the largest potential for circular business model innovation and has therefore received most attention in this research. An important characteristic of circular business models located in this quadrant is that they require collaboration. Various types of circular business models have been identified, involving different degrees of complexity.

The least complex model refers to energy companies delivering some form of energy or substance that *enables a circular business model with an industrial actor*. An example of this is the planned investment in a production facility for E-methanol from hydrogen and biogenic CO2, whereas the energy company delivers the biogenic CO2, among other energy carriers (see Box B). This is an example of carbon capture and utilization (CCU) which can be thought of as more advantageous than storing carbon below the seabed.

Another circular business model relates to the *bi-lateral exchange of resources*. Waste heat from industrial processes is the most conventional resource that is commonly fed into district heating systems, making use of excess heat that would otherwise be lost. Such collaboration can result in further resources being exchanged, for instance delivering steam that enables replacing fossil fuel use at the industrial company. In another collaboration, the energy company not only uses surplus heat from a nearby paper and pulp mill, but also bark and wood chips, whereas the ashes from bioenergy combustion go back to the paper mill and are returned to the forest as fertilizer, closing the circle (see

Box A: Collaboration between RagnSells and Söderenergi, enabling a circular business model

The patented Ash2Salt method developed by Easy Mining, Ragn-Sells' innovation company, enables the extraction of salts from toxic fly ash (sodium chloride, potassium chloride and calcium chloride) that can be used as road salt and to produce fertilizer.

An additional benefit is that after salt recycling, the ash residues no longer need to be placed in special landfills for hazardous waste.

At the time of the study the completion of the extraction facility was in its final stages. Söderenergy and RagnSells signed an agreement for the circular disposal of 25,000 tons of fly ash yearly.

Box B: FlagshipONE – E-methanol plant to be co-located with Övik Energy's combined heat and power plant

In December 2022, the Danish energy company Ørsted took the decision to invest in Europe's first large-scale electro fuel production plant, co-located with Övik Energy's combined heat and power plant at High Coast Innovation Park in Örnsköldsvik.

Övik Energy will invest in the infrastructure linking the facilities and deliver the biogenic CO2 from flue gases, steam, cooling and electricity to FlagshipONE, enabling a circular business model for its customer.

The biogenic CO2 is combined with renewable hydrogen made from water and electricity from wind power. The E-methanol produced will primarily be used to decarbonize the shipping industry.

Box C: Use of waste heat from Södra Cell Värö in Varberg Energy's district heating system

Varberg Energy purchases the waste heat from Södra Cell Värö's pulp and paper mill, a resource that otherwise would be lost. The waste heat is fed into the local district heating system.

Varberg Energy's combustion plant, burning bark and wood chips, covers the need for heat during the winter season when the residual heat from Södra Cell is not sufficient.

The ash resulting from the combustion is later returned to the forest, feeding back nutrients to nature.

Box C). However, a challenge with this type of business model mentioned by respondents is to agree on a pricing model that is perceived as fair by all involved.

Furthermore, a *circular business model optimizing the resource use of multiple actors* has been identified which has higher complexity than the previous models. It builds on sharing, balancing, and storing energy in a decentralized energy system. All available energy flows are used efficiently before adding new energy to the closed network. This model increases efficiency and minimizes energy losses between buildings, in neighbourhoods or within whole areas (see Box D).

A further model discerned is *a circular business model with multiple companies sharing a resource* which seems to be most challenging to implement. In the studied example, devising a business model for sharing an underground storage (geothermal heating/cooling storage) was the core interest. For this purpose, three different business models were tested to evaluate both the optimal use of the shared resource and to determine the most favourable way to share the value created from the shared resource (see Box E). This business model also incorporates the use of energy efficiency which exemplifies the circular principle of reduction. Other forms of resource sharing models could be relevant to investigate in order to better understand the challenges that this circular business model entails.

Regarding geothermal energy storage as such, opportunities are explored by multiple corporations studied. The technology offers the benefit of cutting power peaks, providing flexibility, and enabling better utilization of existing production capacity. Thanks to energy storage capacity, the building of new production plants can at best be avoided.

Box D: E.ON ectogrid™ is a decentralized energy system that optimizes the resource use of multiple actors between buildings

E.ON ectogrid™ is a closed network with low temperatures where heat pumps and cooling machines in each building adjust the temperature as needed. By sharing, balancing and storing energy in a closed loop, E.ON ectogrid™ uses all available energy flows efficiently before adding new energy.

Variations in supply and demand are solved by storing energy in an accumulator tank. Thanks to low temperatures in the network, the system also has the possibility to maximize the use of waste energy.

Box E: Ruggedized – research project evaluating different business model enabling the sharing of geothermal energy storages

The RUGGEDISED smart city project focuses on the development of the Umeå University City area towards energy efficiency and fossil free energy supply by cutting power peaks and better utilization of production capacity.

The possibilities of sharing an existing geothermal heating/cooling storage between three parties were evaluated by testing three different business models: Business as usual, Joint Venture and Cooperative (a distributed solution with a local energy market).

The best solution that benefitted all parties was to use the geothermal storage for cooling, applying the Cooperative business model with a local energy market.

4.2 Circular economy opportunities from material recycling and renewable energy production

In the top half of *Figure 1 Circular economy opportunities in the Swedish energy sector*, a distinction is made between circular economy opportunities involving *new material* or opportunities related to *new renewable energy production*. These quadrants are not the focus of this study and will therefore only be reported upon at a conceptual level.

The use of new material for energy generation eventually will require the *recycling of the energy infrastructure* at the end of its useful life. This can refer to infrastructure such as wind turbines and solar panels, among others. According to our interviews, solar power installations have very good sustainability over time and, when it comes to Sweden, have not yet reached their end of life. At the global level, it is predicted that the first-generation solar power will be decommissioned in the early 2030s and by 2050, up to 78 million tonnes solar panels could be decommissioned per year (Weckend

et al., 2016). Opportunities for circular business model innovation, giving solar panels a second life have been studied in projects such as Circusol, financed by the Horizon 2020 program of the European Commission (Circusol, 2022).

Looking at wind farms in Sweden, very few have been decommissioned yet. The repowering of wind farms constitutes an opportunity, allowing for extending the life of some of the infrastructure. While between 85-95 percent of the materials making up wind turbines can be recycled (Vestas, 2023; Örsted, 2023) , it has been predicted that the amount of wind blade waste worldwide will be 43 million tonnes by 2050 with approx. 25 percent of the waste generated in Europe (Liu & Barlow, 2017). Wind turbine producers are addressing this issue, with Siemens Gamesa recently announcing the development of the first fully recyclable wind turbine blade (Siemens-Gamesa, 2023). In the future, large amounts of materials embedded in the energy infrastructure need to be taken care of in a circular fashion by either repurposing/reutilizing its components or material recycling.

The top right quadrant encompasses all forms of *renewable energy production*, e.g. biomass-based combined heat and power production (CHP), wind power, solar power, geothermal energy, and other zero-emission technologies. Renewable energy production facilitates electrification and the phasing out of emission intensive technologies, enabling fossil fuels to be eliminated. The circular economy and the energy transition to net-zero emissions by 2050 are tightly interlinked and reinforce each other. However, creating a truly sustainable energy transition means integrating circular economy principles already at the design stage. The circular economy can secure the sustainable supply of raw materials and reduce the dependence on mining new raw materials. Building renewable energy infrastructure from recycled materials will help the transition to net-zero emissions while aligning with the circular economy (Pennington, 2022).

To achieve this vision, manufacturers of energy infrastructure need to think ahead and work with a circular economy strategy to keep track of materials, set concrete targets for recycled content and implement tangible measurements (Pennington, 2022). Sustainable procurement practices of energy sector companies can speed up such development towards circular resource use in energy infrastructure. Further research in this area is necessary to elucidate current circular economy strategies with manufacturers of energy infrastructure and in the procurement process of energy sector companies.

5. Barriers to circular business model innovation

From the empirical material, three main categories of barriers were identified: external barriers, organizational barriers, and collaborative barriers. Each of the main categories contain subcategories as indicated below each subheading.

5.1 External barriers to circular business model innovation

External barriers to CBMI are divided into *market and institutional barriers*, *regulatory barriers*, and *systemic barriers*.

5.1.1 Market and institutional barriers

Companies producing electricity and heat from waste incineration highlighted multiple barriers when it comes to reducing the plastic content of waste. Their opportunities for creating circular business models are determined by actions taken earlier in the waste value chain. Instead of trying to solve the problem in the final stage through sorting, plastic waste should be avoided already in the design stage, for instance by abolishing single use plastics or drastically reducing the amount of plastic types. The lack of design for circularity earlier in the value chain is seen as a barrier for developing circular business models at later stages. Another barrier mentioned is the deficient pre-sorting of waste in general.

When it comes to the market for recycled material, there is a lack of willingness to pay for recycled material, leading to missing incentives to recycle. Several recycled materials, e.g., plastics and textiles, also face the problem of underdeveloped markets. In sum, there is very little market pull. At the same time, purchasers of recycled plastic have high requirement as to quality, which cannot be as high as for virgin plastic. An additional barrier is that proper recycling is very expensive as it requires several steps of sorting, cleaning and upgrading the material. This results in that recycled material frequently is more expensive than virgin raw material, plastic being a prominent example. Also, for other materials such as bottom ash, the interest in circular solutions from industrial actors tends to be low.

In relation to waste energy resources, a barrier for circular business models are the specific qualities that these resources must possess to be suitable for re-use, e.g., specific requirements as to temperature, continuity of flow and security of supply. As a result, many waste energy resources are unfit for re-use.

Respondents further address that current environmental policy instruments do not produce the desired effect, mentioning the waste incineration tax as a prominent example of this barrier. The tax neither directs waste streams in any other way, nor does it have the effect of diverting recyclables from waste streams. Moreover, it fails to send the right signals to the actors who cause the problem. In addition, there is also a lack of environmental policy instruments that favor collaboration for circularity.

5.1.2 Regulatory barriers

The political uncertainties about the future regulation of the energy sector are a large challenge for energy companies. This hampers innovation and investments. A prominent example is the EU's suggestion to no longer classify forest biomass as zero-carbon emission.

Respondents also address that existing regulations are not adapted to circular economy principles or do not cover all aspects. The absence of rules and standards for recycled products creates confusion and uncertainty, increasing risks. Risks are also perceived as high due to time consuming and uncertain assessment processes by for instance local municipalities (e.g., permit processes). Different municipalities or counties may even give differing assessments despite similar conditions. A further regulatory barrier raised is the difficulty for municipal actors to prioritize environmental and quality parameters over economic ones in public procurement.

5.1.3 Systemic barriers

The respondents addressed the lack of an overarching systems perspective in international frameworks as a barrier for (circular) business development. For instance, categorizing district heat as purchased

energy (Scope 2) according to the GHG Protocol results in a disadvantage for district heat as the associated climate impact is allocated to the energy buyer. Similarly, green building certifications systems such as BREEAM or LEED disfavor district heat as it is classified as purchased energy.

At a national level, the lack of common rules, norms and standards is perceived as a barrier. Many actors and industries want to contribute towards the circular economy, but each industry has their own system, rules and goals that are not always compatible. This makes coordinating interested actors a challenging task.

5.2 Organizational barriers to circular business model innovation

Two categories of barriers were identified at the organizational level, *perceptional barriers* and *knowledge and resource barriers*.

5.2.1 Perceptional barriers

In brief, perceptional barriers relate to the challenge for managers to take bold decision under uncertainty, act proactively, and accept that circular solutions may involve ways of working that go beyond the corporate comfort zone.

At the highest organizational level, bold investment decisions despite uncertainty may be required to change the course of organizational development. The lack of far-sighted decision making was seen as a barrier that might obstruct the development towards circular solutions. Once a decision to invest has been taken, it was considered important to be proactive in the permit process and interaction with legal authorities. Passive work may result in more time-consuming and cumbersome processes. A similar barrier addressed was the lack of responsiveness to stakeholder demands, which may result in a negative attitude towards a project by local stakeholders.

When it comes to seizing circular opportunities, respondents mentioned the reluctance to engage in collaboration with large industry actors as a potential barrier to circular business model innovation. Smaller energy companies may be hesitant to collaborate with actors that have a large international organization behind them.

It should also be acknowledged that circular business differs from the familiar patterns of doing business in the linear economy. These characteristics may act as barriers by deterring some actors. Firstly, the buyer-supplier relationship is more intense and requires more frequent interaction. The customer must get involved in the supplier and be willing to enter into a more collaborative relationship. Secondly, given the fact that commonly, existing residual flows are re-used, the buyer must be prepared to adapt to the conditions for supply and cannot make specific demands as to the quality of the resource. Thus, willingness to adapt to the existing conditions for supply is needed.

5.2.2 Knowledge and resource barriers

Respondents highlight the importance of possessing knowledge and having access to resources to innovate, but also emphasize that endurance is required. They address that much of what they would like to achieve cannot be implemented alone. Resources, skills, infrastructure, and raw materials are scattered among different actors. This fragmentation makes it clear that circular solutions are all about partnership. Additionally, it was stated that common budgeting tools fail to support circular value creation and long-term sustainability investments scenarios. Thus, both budgeting tools and performance measurements that reflect the true value potential of circular business models were requested. The lack of standards for these types of tools also means that organizations tend to create one-off solutions which in turn impacts the ability to communicate them both internally and to other organizations.

There is no doubt that the complexity and uniqueness of circular business models represents a significant barrier. Potential partners may be completely unfamiliar with circular solutions and may thus need considerable convincing before engaging with the idea. A lack of experience with putting a monetary value on the potential benefits that accrue to different actors involved in a collaborative

solution may present a significant barrier. Circular models thus require dedication and a capacity for intense communication and dialogue with external partners to establish a common understanding. Hence, companies need endurance in their efforts to engage potential partners.

A further barrier addressed is the lack of knowledge about neighboring industries and their residual resources, which may result in missed opportunities for collaboration. In addition, insufficient knowledge about waste regulations may hinder the re-use of waste streams as a basis for circular business models. Residual products must be declared as biproducts early on to prevent them from falling under the Swedish Waste Directive.

The fostering of circular innovation is a challenging and lengthy process which requires dedication and multiple forms of resources. Some circular business models hinge on development work that only can be conducted in collaboration, be it with local universities or in externally financed research projects. This can be demanding for smaller or less experienced actors that lack the resources and competences to collaborate efficiently. Furthermore, it was revealed that it was very uncommon to rely on structured innovation processes and even more uncommon to use innovation tools that were specifically designed for circular innovation. The lack of tools that support business model innovation throughout the entire process of development and implementation was also acknowledged as problematic by the respondents. Innovation was instead often handled on a project basis, resulting in challenges to address complex issues and maintain a long-term dedication to a topic.

The absence of a corporate culture that encourages experimentation may also be a barrier. Individuals that are ready to seize opportunities play an important role in collaborations. Setting up systems is not enough if committed individuals and intrapreneurs are lacking.

5.3 Cooperation barriers to circular business model innovation

The third category addresses barriers for cooperation that are grouped into *perceptional barriers*, *financial barriers*, *social barriers*, and *regulatory barriers*.

5.3.1 Perceptional barriers

Many respondents addressed the fact that creating collaborative models is much more demanding than doing things by oneself. Collaboration models are more complicated because it takes time for two commercially oriented partners to come to an agreement. This may be one of the reasons for poor interest in collaboration. As mentioned by one respondent: “If you have a large balance sheet and a lot of cash you don't have to consider others – then you can do it on your own.” A further barrier is that interdependencies create risks. Although contracts can create security, making yourself dependent on a third party involves multiple risks. The collaboration must be long term in order for investments in joint infrastructure or production processes to be valuable. If the flow disappears due to bankruptcy or other reasons, the investment will be worthless. The fact that collaborative circular solutions take more time to achieve may also make them less attractive than simpler solutions. Especially when authorities are involved and must take decisions, this can be time-consuming, requiring patience and endurance.

5.3.2 Financial barriers

Unclear financial benefits are a strong collaborative barrier. If there is no clear win-win situation, no obvious cost reductions or earnings, potential collaboration partners may want to reconsider or refrain from implementing the solution, especially if implementation is tedious. For a circular business opportunity to be attractive, all collaboration partners must clearly benefit from it. Lack of mutual benefits thus represents a further barrier. Yet another barrier mentioned are difficult price negotiations. These tend to become increasingly complex and time-consuming. It is important that the model for sharing costs or benefits is perceived as fair by all involved.

When making investment appraisals, differences between partners in how the investments costs for a circular solution are calculated create barriers to collaborating on a joint solution. This was particularly visible in the varying discount rates applied by collaboration partners in the calculations, which resulted

in diverse outcomes as to the attractiveness of the investment. Similarly, it was suggested that there is, at a national and even international level, a need for new budgeting and accounting tools that capture the true costs of linear value chains and elevate the benefits of circular business models. It was suggested that it is necessary to develop a standardized financial decision-making system that incorporates the future systemic effects of a robust and sustainable energy sector. Such a system could enable more long-term strategic and sustainable decision making. This is a necessary step if we expect a fragmented private sector to invest and run a sustainable energy system with a size that greatly surpasses the production and transmission systems that the Swedish government established during the last century.

5.3.3 Social barriers

Energy companies may identify interesting waste resources with another actor which could be harnessed through a collaborative circular business model. However, the company may lack access to the resource suitable for re-use. Bringing about collaboration with the aim to exploit this resource may be a challenge. In this context, the lack of social relational capital is mentioned as a barrier. It is vital to create a common understanding of what can be achieved together and the benefits this would bring. Openness and building trust can foster social relational capital that lies at the base of collaborative circular business models.

5.3.4 Regulatory barriers

During the study, the issue that the Swedish Local Government Act hampers collaboration for municipal companies was raised. Collaboration may be interpreted as unduly favoring a third party, which goes against the principle of equality stipulated by the law. Furthermore, respondents from municipal companies addressed the fact that the Swedish Public Procurement Act inhibits collaboration for municipal companies. The reason for this is that, although municipal companies are free to exchange ideas and collaborate on solutions and business models, once the solution is ready to be implemented, they must invite tenders from all contractors. This may disturb or jeopardize collaboration and business model development, although most private actors are aware of this obligation. There also seem to be legal barriers to cross-sector collaboration with the water and wastewater sector. This inhibits the circular use of different types of water flows, e.g., treated wastewater, which could have been interesting for energy companies. The regulatory barriers for cooperation require further investigation to understand the nuances before any significant conclusions can be drawn about the severity of these barriers.

6. Strategies for managing barriers to business model innovation

The interview data showed both implemented coping strategies and those that were hinted at as potential solutions. Moreover, comparisons between the cases found in the empirical data and in previous research indicated further potential solutions. The results indicates that due to the complexity of the barriers it is possible to address them in multiple ways. Hence, companies may for example successfully work with external barriers by developing inhouse competencies or by collaborating with actors that have the skills and resources necessary to move forward quickly in an innovation process. Yet, there are several potential lessons identified in the interview material. Besides the following text we have gathered key recommendations in Appendix 1. As in the chapter on barriers, the strategies are presented based on the tripartite structure: external, organizational, and collaborative.

6.1 Strategies addressing external barriers

Managerial ability to influence barriers that are external to the organization is limited in the short run. Yet, it is possible for both managers and regulators to address and lower barriers that impact the Swedish energy sector through the design of market and institutions, regulatory reform and an overhaul of systemic issues raised in the previous chapter. When it comes to market design, the low willingness to pay for recycled material can be addressed by establishing commonly acknowledged and cost-efficient ways to identify and separate valuable resources from waste flows. Since the potential for further circular use of material or energy flows diminishes with the degrading quality of information about

those flows, it is especially important to consider traceability already at an early stage in a value chain. Open and accessible data about origin, composition etc. thus offer opportunities for both quality management and the development of new uses in circular business models.

Targeting business models that build on circular principles in procurement is in line with current policy goals, but there is still potential for further improvement when it comes to the implementation of such practices. The added complexity that often comes with circular solutions raises the threshold in terms of involvement and thus lowers the interest among actors that lack experience with the circular economy. To address this problem, the public sector could further its support for the procurement of circular solutions and target creative uses of residual flows. This allows the public sector to move towards circularity without being hindered by the lack of regulatory adaptation to circular economy principles. Among industry actors it is suggested to avoid political risk that arises from the reliance on policies, to explore temporary workarounds of regulatory obstacles by for example moving critical activities to areas with more suitable regulation, and in the meantime identify legal long-term solutions. A particularly problematic obstacle are time-consuming evaluation processes with uncertain outcomes. These were suggested to be addressed through close and early communication with the authorities, as well as with other individuals or organizations that have knowledge and interest in promoting circular innovations. It is possible to pave the way for a fast-track by working proactively and identify potential obstacles even before the process is started. It is also possible to support the development of a better understanding of the qualities of the circular innovation by priming the decision makers with information and precedents or examples of beneficial administrative decisions made elsewhere or for similar cases.

6.2 Strategies addressing organizational barriers

If the respondents are seen as representative for the Swedish energy sector, we may argue that there is a high degree of diversity when it comes to the understanding of circularity. While respondents from waste processing, waste heat or the bioeconomy sectors readily used the concept, circularity was rarely used by representatives from other types of power generation. However, those respondents were aware that their suppliers of production machinery and buildings used circularity as a framework when discussing sustainability. Thus, even for those respondents the idea of circular business models for the energy sector was not entirely alien. Interestingly, measures such as peak shaving through the use of energy storage were associated with sustainability rather than with the circular economy, despite the fact that the measure enables increased resource utilization of fixed capacity.

The tendency of organizations to focus on short-term gains may lead to missed opportunities for establishing circular business models. Linking a long-term view to a circular perspective may imply revising the organization’s stance on value creation as well as supplier and investor relationships. Being committed to a continuous dialogue together with owners about circularity makes it easier to get acceptance for projects which generate types of circular value that go beyond established norms and are thus difficult to evaluate. Similarly, it is possible that other stakeholders fail to see the benefits of circular business models due to the inability of managers to anchor a vision and communicate the value that circularity produces. Especially internal stakeholders, i.e., employees, may have difficulties accepting new ideas which may be both radical and counterintuitive when viewed from a linear perspective. It is thus important to develop a corporate culture that encourages experimentation and infuses circular thinking into the company's core values. Linear industrial value chains seldom cross employees and organizations tend to benchmark themselves with a limited set of competitors. This results in a myopic view and a lack of knowledge about neighbouring industries which, considering the importance of collaboration for the circular economy, can be counteracted by starting conversations with neighbouring industries and compiling information about their residual streams of energy and resources. The organization should also approach innovation as an open and continuous process rather than a series of isolated projects. In general, there is a value in supporting the development of curiosity about alternative business models among staff working in the main production unit, while constantly

evaluating how switching to new business models will benefit stakeholders and support the development of a circular economy.

6.3 Strategies addressing cooperation barriers

Collaboration among actors that interact along or across value chains offers opportunities to overcome both internal and external barriers. Yet, as we have shown above, there are barriers that occur in cooperation itself. The complexity of circular business model innovation is suggested to be counteracted by a strong commitment to openness and transparency. Energy companies are reportedly quite accustomed to collaborating in complex structures and may therefore be well suited to engage other actors. By taking the lead in collaborations, these companies may facilitate the transition to a more circular energy system. Especially collaborations between multiple actors with complex energy or resource flows may benefit from a central actor that takes responsibility for the creation and upkeep of networks that support cooperation. Within local collaborating clusters it is possible to establish a common understanding of the value of residual flows, support the identification of potentially valuable flows, and find ways to use the flows in cost-effective ways. Moreover, communication between partners from different sectors can reveal tensions that arise from different systems perspectives, i.e. different ideas about where to draw boundaries between areas of activities. It may therefore be important to discuss fundamental principles and persistent worldviews associated with circularity and the flows of resources or energy prior to engaging in complex and detailed negotiations about the finer details of a circular solution.

Closer communication and cooperation can also be a solution to the challenge of finding financial value in existing resource or energy flows. Value is inherently subjective which makes it important to explore different approaches to value and find investors, suppliers and customers which have a view on value, and the financial benefits linked to that value, that is in line with a circular perspective. Moreover, by exposing internal value logics in meetings with external actors it is possible to support thinking outside the box and identify win-win scenarios where cooperation generates synergies. In business-to-business relationships value is also closely tied to price. When cooperating to extract value, negotiations about pricing can be tough and hamper the development of the business model. It is thus important to early on work together to identify the space for negotiation, for example through open book negotiations, and optimally divide the benefits/savings in fair shares. A fair pricing model should be supplemented with documentation that explains the background to the model, e.g., the different values that it creates and why those were important at the time of inception, and what the alternatives were at the time for each actor. In this way the circular business model will be less likely to fall out of favor with management if the company makes changes to the business strategy or raises the required rate of return.

The importance of cooperation stresses the need for diplomacy and social capital. Developing such competencies does however take considerable time. Among the studied companies external research projects were key to starting collaboration and gradually building social capital together with important stakeholders. Setting common goals to explore something together during several years strengthens the relationship and enables learning about each other's needs and capacities. While collaboration requires skills and resources, cooperation may generate long-term benefits that scale both with the reach and the number of collaborations. Developing capacities to lower both costs and risks of collaboration will make it more profitable and likely improve interest in collaboration both within the organization and among potential partners. Cooperations is thus a skill that in itself can enable circular business model innovation.

7. Discussion & Conclusion

In this report three groups of barriers to the creation and implementation of circular business model in the Swedish energy sector were identified. The external barriers consisted of *market and institutional, regulatory,* and *systemic* barriers. They reveal the complexity and uncertainty that managers encounter when engaging with the unchartered business and regulatory landscapes that exists beyond the well-established linear system that still characterizes much of the Swedish energy sector. The second group of barriers were organizational and consisted of two subgroups: *perceptional,* and *knowledge and resource barriers.* Together these barriers arise out of cognitive and resource related constraints. While circular business models may represent the best option not only for the environment but also for the company in question, the difficulty in envisioning and enduring a new type of investment is challenging to a degree that it might, as one respondent expressed it, be necessary to introduce a new generation of decision makers that are more accustomed to complex and more collaborative business models. This brings us to the third group, cooperation barriers, which contains four subtypes: *perceptional, financial, social,* and *regulatory* barriers. These barriers arise when businesses engage in collaboration, and they exemplify the difficulty in finding common ground in the four areas.

When it comes to strategies to overcome the barriers, we have found that there exists a broad spectrum of ideas about of how circularity should be incorporated in business models in the Swedish energy sector. An important explanatory factor behind this heterogeneity is the differences between energy types when it comes to engaging with circularity. Sectors such as biofuels, waste heat and waste incineration have been exposed to circular thinking through regulatory and stakeholder pressure, while actors in the wind and solar power sectors have a shorter history of such exposure. The nuclear sector was the one where respondents expressed least familiarity with circular business models and circularity. However, due to strict regulations the nuclear sector can be said to have the most rigorous circular fuel and waste management.

While barriers may be categorized neatly based on their relationship to some arbitrary point, it is less obvious how strategies that target them should be systematized. Similar challenges may be addressed very differently by different companies and still those approaches may all be successful. Despite this ambiguity we can point to the importance of collaboration, long-term dedication and collective iterative learning as important strategies for circular business model innovation. In Appendix 1 we present selected key lessons proposed by the respondents.

An important result is that the respondents in general do not link renewable energy to circularity in the same way as what is done elsewhere (cf. Lacy et al., 2020). Outside Sweden, circular business model innovation tends to focus on the switch to renewable energy while our data suggests that this is not even considered to be an aspect linked to circularity or circular business models. Instead, it is viewed as a simple switch of input source and something that to a large part already has been achieved. A potential reason for this view is the fact that the Swedish energy mix has been mainly generated through fossil free means of energy generation. As a result, we may draw the conclusion that the Swedish respondents have a stricter view on what classifies as a circular business model.

Furthermore, we see that while circularity in the manufacturing and consumption oriented sectors relies on variations of the three R:s (that is variations of the Reduce, Reuse and Recycle) to establishing circular business models, this is not enough for the energy sector. The nature of energy means that circularity and circular business models need to be reimagined and reinterpreted in order to make sense. Analysing our findings, we suggest that circularity in the energy sector could benefit from incorporating the idea of additionality as a central aspect when designing circular business models for energy producers and distributors. An additionality requirement would put pressure on actors to prove that the circular efforts generate positive effects that would not have occurred otherwise. While the introduction of additionality would bring some clarity to the conceptualization of a circular energy sector, it is important to be aware that, as has been shown in the debate about designing emissions trading schemes

(Haring, 2022), additionality in itself is a difficult and cumbersome concept which may need adaptation to the specific circumstances.

Another key aspect of circularity visible in the successful examples was a focus on transparency throughout the value chain. For this to work, business models need to help transmitting information between each stage of the value chain. This can be done by creating and maintaining incentives to share information, especially information that is important for product quality and cost efficiency. It is noteworthy that additionality also requires a high degree of transparency for it to work. There is thus a possibility that transparency and additionality may generate synergies and support circular business models, which would not work in settings characterized by poor information flows or lack of trust between actors.

The contextual dependencies of circular solutions mean that they at times are unique in their complexity. Additionally, local culture and ownership structures may offer unique opportunities for visionary work with low margin projects. Circular business models are thus difficult to copy-paste since they are deeply rooted in the local physical production system and culture. Therefore, to bolster the spread of circular solutions it is important to support the development of both circularity-oriented knowledge and mindset. Furthermore, since the complexity in circular solutions often is high it is important to be aware early on that there is a need for extensive testing and negotiation, and to accept that early attempts may fail or be less financially attractive in the short run than existing solutions.

The lack of suitable tools to use during different stages of the innovation process is a result that has implications both for policy and future studies. Since circular business models are inherently more complex than linear alternatives there is a need to address the systemic challenges associated with circular business model innovation. Policy makers need to rethink the many overlapping systems of standards, frameworks and regulations which create unintended consequences and a cascading degree of complexity which is difficult for industry actors to get a grip on. Together with a high degree of policy risk, this complexity stifles development, especially at an early stage. Moreover, even though several respondents emphasized the importance of industrial leadership, no single market actor can take the lead when it comes to establishing a long-term systemic approach to the transition of the energy system toward circularity. Hence, in a system where actors on the energy market are expected to act with the public interest in mind and with a long-term perspective, it is necessary to consider if there may be other ways to think about investments in energy and distribution. Otherwise, the transition to circularity in the energy sector will be heavily dependent on policy and political dealmaking, potentially creating an energy sector characterized by a permanently high level of policy risk.

Conceptually, the lack of processes might be counteracted by incorporating business model innovation in the organizational innovation culture, alternatively establishing positions and functions with the responsibility of reviewing current business models and developing new business models. We examined the data to see if there exists a distinction between a diffused, organizationally anchored cultural approach, and a more focused and specialized approach. We found that it is not necessary for businesses to choose between these two extremes. Instead, the interviews suggested in multiple instances that both ways of addressing circular business model innovation may co-exist under the same roof.

By identifying, analysing, and portraying both obstacles and coping strategies we hope that this study generates results that can help actors within the Swedish energy sector to manage the problems associated with the development of circular business models and in that way accelerate the transition towards the circular economy.

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Appendix 1 – Key takeaways

Identifying opportunities

- Curiosity and knowledge about neighbouring industries residual resources and energy flows is important for identifying **opportunities** for collaborative circular business models.

- **Arenas** such as industry networks or local innovation platforms that facilitate collaboration among broad groups of actors from multiple industries are crucial to identify circular solutions.

- **External research projects** that build on cross-industry collaboration are one example of an arena that facilitates knowledge accumulation, innovation and partnerships that support the development of collaborative circular business models.

- Companies that produce (sizable) residues/by-products should **actively seek partners** that potentially could reuse the resources and energies. Search for such partners in industries with considerable experience of extracting value from your specific type of waste flow.

- Get inspiration from industries that have institutionalized circular business models (e.g., chemical and pulp and paper) and explore possibilities for fruitful collaboration.

- To understand the direction of circular trends, **partake early in different societal processes** and keep a close dialogue with local stakeholders that have access to or influence the control over energy sources viable for circular use, preferably before detailed development plans have been established.

Enablers at the organizational level

- **Knowledge, mindset and relations** are key ingredients for identifying and bringing about collaborative circular business models.

- Bold managers and a forward-looking board of directors can **show leadership** and shape organizational culture towards an experimenting mindset, exploring new business and technical solutions, including circular business models.

- **Never be satisfied** with the waste resources and energies you generate. Rather task internal staff or specialists working with the specific waste components to investigate whether the waste can be re-used, re-purposed or recycled, and what type of values can be linked to the waste.

- Due to the cost of transmitting and converting energy, circular use of energy sources is facilitated by clustering or **co-locating industries**. The next step is to explore potential areas of collaboration - how can you make use of each other's resources and competences in the best possible way.

- Opportunities to use seasonal excess capacity or replace fossil fuels in industrial processes with waste heating represent a **low hanging fruit** with circular characteristics.

Take-aways for collaboration

- Identify the **joint value** that can be created from a collaborative circular business model by exploring what potential value different actors see in the energy source.

- Agree on **principles** how the value and costs should be distributed among the partners early on in collaborative processes but avoid giving up control over the energy source.

- **Be persistent** when trying to find solutions with your partner(s). Create mutual understanding through communication and dialogue. Designing circular business models is demanding.

- **Municipal companies** have more leeway to maximize environmental and social value and are often attractive collaboration partners.

Suggestions and observations

- Create a function in the company, municipality or region that acts as a **matchmaker** for bi-products, residual energy flows and other resources that could be shared.

- Map sources and flows of low-valued energy sources and compile a **publicly accessible inventory** of such information to support their use in circular business models. This can be done by encouraging partners and customers to **identify potential sources of waste energy.**

- Since the quality of waste flows impacts their circular potential, it is important to encourage customers and collaboration partners to work for **better sorting of waste**.

- Make concrete what property owners and municipalities need to do - influencing these actors helps the energy industry become more circular. The energy sector can be a **node for circularity** by collaborating with other industries.

- **Owner directives** are a strong instrument to steer municipal (energy) companies towards sustainability and potentially also towards circularity. As circularity becomes more institutionalized it becomes easier to include actionable circular goals.