University of Groningen

Designing viable multi-commodity energy business ecosystems

D'Souza, A.; Bouw, K.; Velthuijsen, H.; Huitema, G. B.; Wortmann, J. C.

Published in:
Journal of Cleaner Production

DOI:
[10.1016/j.jclepro.2018.01.256](https://doi.org/10.1016/j.jclepro.2018.01.256)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2018

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

D'Souza, A., Bouw, K., Velthuijsen, H., Huitema, G. B., & Wortmann, J. C. (2018). Designing viable multi-commodity energy business ecosystems: Corroborating the business model design framework for viability. *Journal of Cleaner Production*, 182, 124-138. <https://doi.org/10.1016/j.jclepro.2018.01.256>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Designing viable multi-commodity energy business ecosystems: Corroborating the business model design framework for viability

A. D'Souza ^{a, c, *}, K. Bouw ^b, H. Velthuisen ^a, G.B. Huitema ^c, J.C. Wortmann ^c

^a Centre of Expertise – Entrepreneurship, Hanze University of Applied Science, Zernikeplein 11, 9747 AS Groningen, The Netherlands

^b Centre of Expertise – Energy, Hanze University of Applied Science, Zernikeplein 17, 9747 AA Groningen, The Netherlands

^c Department of Operations, University of Groningen, Nettelbosje 2, 9747 AE Groningen, The Netherlands

ARTICLE INFO

Article history:

Available online 1 February 2018

Keywords:

Business model design
Business ecosystem
Flexibility
Multi-commodity energy systems
Business ecosystem design
Energy business model

ABSTRACT

In this paper, a multi-commodity energy business model for an industrial park is designed and evaluated using the extended “business model design framework for viability”. The framework has been validated earlier for mono-commodity energy systems. Our goal is to examine the application of the business model design framework for viability for multi-commodity energy systems as they are more complex. The framework was applied to an industrial park, where heat and electricity networks are integrated. The business model was designed iteratively to harvest and exploit the flexibility embedded in the industrial processes of the heat consumers. The first iteration showed that the business model design framework for viability was largely successful. However, adding two extensions to the framework helps to deal with the complexity of designing and evaluating viable business models for multi-commodity energy systems in a better way. First, the configuration techniques in the framework are extended to include reference business models. Second, the evaluation criteria in the framework are extended to include the capabilities of the stakeholders. The extended business model design framework for viability better enables the design of complex business models and allows to evaluate the capabilities of the stakeholders to implement the designed Business model. The extended business model design framework for viability successfully facilitated the design and evaluation of a viable multi-commodity energy business model and therefore is corroborated.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Increasingly, multi-commodity energy systems (MESs) are designed and implemented, among others to create and exploit flexibility in the energy infrastructure (Mancarella, 2014). Multi-commodity energy systems include several commodities (e.g. heat and electricity), and the corresponding production, conversion, transport, and storage technologies that are intelligently integrated. Depending on the supply and demand dynamics, multi-commodity energy systems allow energy to flow from one form to another, thus providing flexibility (Adhikari et al., 2012; Mancarella, 2014). Flexibility refers to the ability to increase and decrease energy production and or consumption on demand subject to certain conditions such as infeed and outfeed quantities, power provision

capability, time, and ramp up and ramp down rate (Ulbig and Andersson, 2015).

Obviously, the complexity of multi-commodity energy systems is greater than that of mono-commodity energy systems, and the corresponding business models are also more complex. This complexity stems from the competing interests of an increased number of stakeholders, dynamic interaction among the commodities and the underlying infrastructure, multiple markets, and multiple regulatory regimes and policies.

Correspondingly, the process of designing viable business model for multi-commodity energy systems are even more complex. Viable business models are crucial for the long-term survival of the organisations that implement and exploit multi-commodity energy systems. Existing frameworks that support the design of viable business models in mono-commodity energy systems are not necessarily valid for multi-commodity energy systems. D'Souza et al. (2015) developed the business model design framework for viability for designing and evaluating viable business models for mono-commodity energy systems. The framework was chosen

* Corresponding author. Centre of Expertise – Entrepreneurship, Hanze University of Applied Science, Zernikeplein 11, 9747 AS Groningen, The Netherlands.

E-mail address: a.d.souza@pl.hanze.nl (A. D'Souza).

Abbreviations

APX	Amsterdam power exchange
BM	Business model
BMDFV	Business model design framework for viability
BMO	Business model ontology
EDSN	Energy data services Netherlands
MES	Multi-commodity energy systems
PRP	Programme responsible party
USEF	Universal smart energy framework

because it is more comprehensive than its predecessors (for more information see section 2 and 3). The question addressed in this paper is, if and how the business model design framework for viability (BMDFV) is also a useful tool for designing viable business models (BMs) for multi-commodity energy systems (MESs)?

BMs offer a systemic viewpoint on how business is done (Zott et al., 2011). It details the logic and the architecture that enables the value creation, delivery, and capture from the service/product perspective, focal actors perspective, business ecosystem perspective, and the technology perspective (Al-Debei and Avison, 2010; Chesbrough et al., 2006; Kraussl, 2011). Additionally, they also describe the stakeholders and their roles (Timmers, 1998). A BM is viable when the stakeholders participating in the BM can capture sufficient value such that they are motivated to be a part of the BM. Also, the BM should be viable in terms of technology, that is the envisioned technology architecture can be reasonably acquired/developed and implemented. Moreover, the BM should be viable in terms of the service/product.

Value is a crucial component of viable business models (Al-Debei and Avison, 2010). The term value is discussed in a broad sense in management literature, and it is composed of use value and exchange value (Bowman and Ambrosini, 2000; Lepak et al., 2007; Priem, 2007). Use value refers to the utility that stakeholders derive by being a part of the business model such as maintain grid balance, reduce CO₂ emissions, etc. Exchange value refers to the monetary value that the stakeholders derive by being part of the business model such as profit in terms of Euros. Hence, in the context of this research, the term value refers to both use value and exchange value. Furthermore, for a business model to be viable in the long term, the stakeholders should be able to realise or capture sufficient use value and/or exchange value (i.e. revenue – cost = profit). Consequently, the stakeholders are motivated to be a part of the business model (Bowman and Ambrosini, 2000; Lepak et al., 2007).

This paper demonstrates the use of the extended BMDFV to design and evaluate a viable BM for an industrial park with an MES in the north of the Netherlands. The industrial park has one heat consumer, one potential new firm who is exploring the option to relocate to the industrial park, and a municipal solid waste incinerator. The industrial park wants to transition to an MES where flexibility is the key value driver. By doing so, they hope to create value for all the stakeholders involved in the BM and attract many more energy-intensive industries in the process. The first iteration showed that it is difficult to start designing BMs for MESs from scratch and examples ('reference models') of successful BMs that are similar are helpful. This paper introduces ways to configure new designs from reference models. Moreover, it turned out that capabilities of stakeholders are often not sufficient to implement and operate the BM as designed. Accordingly, evaluating such capabilities are included in the BMDFV, which results in the extended BMDFV.

The structure of this paper is as follows. Section 2 presents a literature review on existing methods and methodologies for designing and evaluating viable BMs. Section 3 presents a brief description of the extended BMDFV. The methodology is described in Section 4. Since the research contributes to the development of the BMDFV (i.e. an artefact) by corroborating it in a multi-commodity setting, the *design science* research approach is used. Section-5 provides an overview of the application of the extended BMDFV to the multi-commodity case. In Section 6 we reflect on the validity of the extended BMDFV for MESs. Finally, Section 7 presents the conclusion.

2. Literature review

BM is a relatively young concept and is being adopted in several domains including enterprise architecture, flexible manufacturing, and energy (Chavarria-Barrientos et al., 2016). Given the goal of this research this section reviews literature related to design and evaluation of BMs for energy systems. Section 2.1 provides an overview of the different approaches adopted to design BMs for mono-commodity energy systems and MESs. Section 2.2 examines the business model ontologies (BMOs) and frameworks for designing and evaluating viable BMs.

2.1. BMs for exploiting mono-commodity and multi-commodity energy systems

Much attention is paid to BMs of mono-commodity systems. Helms et al. (2016) identify four mono-commodity reference models that are used to exploit flexibility in electricity systems. Hall and Roelich (2016) position complex value propositions as an important source of business model innovation. To demonstrate the importance of complex value, the researchers have identified several mono-commodity reference business models in the electricity retail sector that rely on complex value propositions. Complex value propositions refer to value propositions that encompass financial, social, and environmental benefits. The reference models are best practice guides that can be used as an input for design BMs for individual firms/business ecosystems (D'Souza et al., 2015).

Scholars have also addressed the design of innovative BMs for mono-commodity energy systems. Kempton and Tomić (2005) have proposed three BMs that utilise electric vehicles to provide flexibility to the electricity grid operator. They do not make use of any BMO or framework to design the BMs. BMOs are formal, and semi-formal languages used to describe business models. Gordijn and Akkermans (2007), have used the e3-value BMO to design three BMs for decentralised electricity producers who supply electricity and flexibility related services to energy retailers, and to transmission system operators in a business ecosystem setting. D'Souza et al. (2015), have used the BMDFV to design and validate a BM for a community-owned solar farm in the Netherlands. However, the BMOs and frameworks that are valid in the mono-commodity context are not necessarily valid in the multi-commodity context.

Extant literature mainly focuses on designing and validating MESs using techno-economic models. Bachmaier et al. (2016) focus on choosing optimal locations for realising thermal storage capacity in district heating networks that utilise excess heat produced by combined heat and power units (CHPs). The CHPs, in turn, will focus on providing balancing services. They have developed a techno-economic model that optimises the location, size, and operation of the thermal storage. The techno-economic model optimises the location, size, and operation of the thermal storage by minimising CAPEX and OPEX and maximising revenue on the

electricity markets. A techno-economic model is an important part of a viable BM, but it does not necessarily lead to a viable BM. The techno-economic models ignore important aspects, such as the viability of the stakeholders in the BM, service concept, business rules, etc.

In summary, much attention is paid to BMs in the context of mono-commodity energy systems. Additionally, the focus is on designing MESs using techno-economic models with some attention to the business cases. Thus, the BM design approach has largely been ignored in the context of MESs.

2.2. Overview of business model ontologies and related frameworks

There are several BMOs and related frameworks for designing BMs, for instance, the business model canvas (Osterwalder et al., 2010), and the e3-value (Gordijn and Akkermans, 2003). Each of these BMOs helps to conceptualise BMs from a single perspective, and at different levels of granularity. For example, the business model canvas conceptualises the BM from the focal firm perspective, while the e3-value conceptualises the BM from a business ecosystem perspective (D'Souza et al., 2014). However, designing viable BMs – especially in complex situations requires the BM designer to adopt different perspectives to ensure the viability of the BM, such as service/product perspective, focal firm perspective, business ecosystem perspective, and technology perspective (D'Souza et al., 2015; Weiller and Neely, 2013).

The BMDFV was proposed to address the above deficiencies. The BMDFV is an umbrella framework that builds on top of well-established BMOs and modelling techniques to facilitate the design and evaluation of viable BMs from the above perspective; Fig. 1 further illustrates this point. The BMDFV bridges the above deficiencies by using well-established BMOs and modelling techniques to operationalise the service/product, focal actor, business ecosystem, and the technology perspective. Hence, the BMDFV leverages the strengths of the different BMOs and modelling techniques to create a more detailed description of the BMs when compared to the descriptions created by the current BMOs. The BMDFV also adds the much-needed design elements that facilitate the process of designing viable BMs, more specifically design principles, business rules, design choices, and configuration techniques that are widely ignored by BMOs. The BMDFV helps to create detailed descriptions of BMs which facilitates critical and realistic evaluation of the BMs (D'Souza et al., 2015).

Nevertheless, the first iteration showed that adopting a clean slate approach to designing viable BMs for complex systems such as the MESs is difficult. Additionally, the stakeholders lack the capabilities to implement and operate the business model as designed. It is crucial that the stakeholders possess the right capabilities to implement and operate the designed BM (Teece, 2010). The BMDFV

does not explicitly address the difficulty of adopting a clean slate approach for designing and evaluating MESs nor does it explicitly evaluate the capabilities of the stakeholders to implement and operate the designed BM.

3. The extended business model design framework for viability (BMDFV)

This section provides a brief overview of the extended BMDFV that bridges the deficiencies mentioned above. For more details on the theoretical underpinnings of the framework see (D'Souza et al., 2014; D'Souza et al., 2015).

3.1. Steps in the extended BMDFV

This section describes the subsequent steps of the extended BMDFV starting with the business idea that hopefully leads to a viable BM, see Fig. 2.

3.1.1. Step 1 the business idea

As shown in Fig. 2 the design process starts with a brief description of the business idea. After understanding the business idea, the BM designer then decides which BM design perspective to adopt to design the BM further.

3.1.2. Step 2 the BM design perspectives

The extended BMDFV explicitly defines four perspectives: the service/product perspective, the focal actor perspective, the business ecosystem perspective, and the technology perspective. The service/product perspective describes the benefits the service/product intends to deliver to its customers and how these benefits are delivered (Edvardsson and Olsson, 1996). The focal actor perspective defines how the focal actor intends to create, deliver, and capture value. It involves defining the key stakeholders (i.e. key partners, and customers), what is the value proposition for the customers, channels, relationship types, key value creation activities, etc. The business ecosystem perspective defines how the different stakeholders create and exchange value. It involves assigning roles and responsibilities as well as the value creation activities, defining the value exchange relationships while ensuring that the stakeholders capture sufficient value. The technology perspective describes the architecture of the physical technologies and the information services necessary to support the BM. This perspective is a prerequisite for synthesising the focal actor perspective and the business ecosystem perspective; especially in the case of technology-intensive industries. These perspectives are synthesised with the help of ontologies described in the following section.

3.1.2.1. The business model ontologies and the business model building blocks. The extended BMDFV allows the BM designer to use different formal and semi-formal BMOs and modelling tools to synthesise the perspectives above. In this paper, we use the system platform modelling technique to depict the service concept in Fig. 3 (Morelli and Tollestrup, 2006). We use the business model canvas to depict the focal actor perspective in Fig. 4 (Osterwalder et al., 2014). The business ecosystem is depicted using the e-3-value in Fig. 5 (Gordijn, 2002). The technology perspective is described using two methods: one, the physical technology architecture is depicted using the block diagram method in Fig. 6; two, the information systems architecture is depicted using information systems modelling technique defined by D'Souza et al., 2015 in Fig. 7.

3.1.2.2. Design choices and BM design elements. A BM designer makes design choices at the level of the BM building blocks that

Fig. 1. Use of business model ontologies and other modelling techniques in the BMDFV.

Fig. 2. Overview of the consequent steps in the extended Business model design framework for viability (BMDFV) modified from D'Souza et al. (2015).

lead to a viable BM. To guide the process of making design choices in a systematic and transparent manner, the extended BMDFV proposes four design elements, namely design principles, business rules, assumptions, and configuration techniques. These BM design elements systematically store the logic and motivation behind the design choices. Design principles are general guidelines that the designer should consider while designing the BM. For example, there should be a clear value proposition for all the stakeholders participating in the BM. Business rules affect the content, structure, and the functioning of the BMs. They internalise the requirements put on the BM. For example, regulatory requirements, and technological requirements. Assumptions are data or information believed to hold. For example, assumed cost structure. While

designing the BM, a designer makes several assumptions. It is important to systematically store, update, and manage the resulting *design decisions* as and when more information becomes available. Configuration techniques are actions that the BM designer can take to achieve viability. For example, deconstruction and reconstruction of the BM. The application of the BMDFV to design viable BMs for complex systems such as the MESS necessitates the extension of the configuration techniques. The configuration techniques are extended by adding the reference model technique. The reference model technique involves creating descriptions of relevant BMs. The descriptions are created to learn from other relevant BMs. The lessons learnt are then used as inputs in the first iteration of designing and evaluating viable BMs.

3.1.3. Step 3 is the BM viable?

3.1.3.1. Evaluation criteria. The application of the BMDFV leads to a BM design, which is then evaluated for viability. The viability of the BM is evaluated from the afore-mentioned four perspectives. Evaluating the service/product perspective involves assessing if the service creates value for the customer. Evaluating the focal actor perspective includes assessing whether the focal actor can capture sufficient value to be viable. Evaluating the business ecosystem perspective involves assessing if all of the stakeholders can capture sufficient value such that they are motivated to be a part of the BM. Evaluating the technology perspective includes assessing if the technology architecture is an acceptable solution that enables the provision of the service. The viability of the above-mentioned perspectives also depends on the alignment with the BM design elements and should be assessed while evaluating the BM for viability. For example, in the business ecosystem perspective, the assignment of roles and responsibilities should comply with business rules. Therefore, as per requirements laid down by the Dutch law, the role of the energy retailer cannot be assigned to a transmission system operator. The evaluation criteria are extended to include the capabilities necessary to implement the designed business models. While assessing the viability of the four-perspective explicit attention is paid to evaluating the capabilities to implement the business model.

If the BM is viable, it leads to an implementation or a selection process. If not, the designer proceeds to the next step.

3.1.4. Step 4 can the BM be adjusted to make it viable?

If the BM is not viable, the designer should critically assess whether to proceed to the next iteration. For more information on the framework see [D'Souza et al. \(2015\)](#). Designing a viable BM usually requires multiple iterations.

4. Methodology

The BMDFV is an artefact that facilitates the design and evaluation of viable BMs. Hence, design science research is an appropriate method for developing and improving the BMDFV with subsequent versions. Design science research is iterative by nature and requires rigorous validation to develop robust artefacts. One way to ensure robust artefacts is to increase the scope and/or complexity of the problem with each successive iteration ([Hevner et al., 2004](#)). Moreover, for the BMDFV to have a significant impact on solving a class of problems (i.e. facilitate the design and evaluation of viable BMs) and become increasingly relevant to practice, it has to be validated by applying it to real-life cases. Additionally, the design activity should lead to generalisation and formalisation of the learnings, for instance, an extension of the artefact to solve a class of problems ([Hevner, 2007](#)).

To carry out this research, the design science research approach proposed by [Peffer et al., 2007](#) is adopted. This approach consists of four possible research entry points and six phases. The following describes the research entry point relevant to this research and how the six phases are applied in the context of this research. The design and development centred entry point is adopted as the goal is to examine the extent to which the BMDFV is corroborated for designing and evaluating viable BMs for MESs. Phase 1 involves identifying the problem and describing the motivation for solving the problem. In this paper, the problem description and the motivation for solving the problem to create viable MES were presented in Section 1, the Introduction. In phase 2 the objectives of the solution should be defined. In this paper, the objective of the solution, viz. to facilitate the design and evaluation of MESs, was also presented in Section 1. Phase 3 focuses on designing and developing the artefact, viz. the extended BMDFV. The scientific rigour, i.e., the

related work on which the extended BMDFV is developed is presented in Section 2, and the extended BMDFV is presented in Section 3. Phase 4 involves demonstrating the artefact. Section 5 demonstrates the application of the artefact to design and evaluate a viable business model for an MES. Phase 5 focuses on evaluating the artefact, viz. the extended BMDFV. Section 6 evaluates this artefact by reflecting on the validity of the artefact. Phase 6 involves communicating the artefact to relevant groups. The results of this research, i.e., both the extended BMDFV and the BM for the industrial park are communicated to professionals and academics via presentations, a professional publication ([Bouw et al., 2016a](#)), a report ([Bouw et al., 2016b](#)), and this publication.

Given the objective of this paper, an industrial park located in the north of the Netherlands was chosen as a case study. The industrial park is a complex MES with an increased number of stakeholders with competing interests, dynamic interactions between the commodities and the underlying infrastructure, and multiple regulatory regimes (i.e. heat and electricity regimes). To add to the complexity, the stakeholders want to specifically change their BM in a way that flexibility becomes the key value driver.

For data collection purposes, two researchers conducted semi-structured interviews with four representatives from the energy sector to gain knowledge on energy markets, transport infrastructure, innovation in flexibility, aggregator services, technical architectures, etc. Additionally, the researchers also met relevant stakeholders at the industrial park five times for setting up scope, requirements gathering, data collection, and BM evaluation. The interviews and meetings lasted from about 45 min to 1:30 h. Additionally, several emails were exchanged on an ad hoc basis for information gathering, and necessary clarification. Secondary sources of data were also used, for example, academic literature, websites, reports, and online documents ([Agroenergy, 2016](#); [USEF Foundation, 2015](#); [Van der Veen, 2012](#)).

We use expert opinion to evaluate the output of the extended BMDFV, that is the business model for the industrial park. Expert opinion is a well-established method for evaluating BMs ([Bouwman et al., 2008](#)). Five experts and a senior manager from the MSW incinerator (henceforth referred to as business owner) evaluated the BM. Two experts have a background in developing techno-economic models for the energy sector. One expert has a background in developing services for flexibility in the energy sector. One expert is an enterprise architect in the smart grid domain, and one of them has a background in strategic innovations in the energy sector. The manager at the MSW-incinerator works in the business development division.

5. Application of the extended BMDFV to design and evaluate the BM

This section illustrates how the BMDFV is applied to design and evaluate the BM for the industrial park.

5.1. Step 1 introduction to the case study and the business idea

The case study involves an industrial park that includes a municipal solid waste (MSW) incineration plant producing energy and two heat consumers. One heat consumer is already located at the industrial park and consumes superheated steam (175 °C), and the other one is a potential new firm that is similar to the existing consumer. Processing solid waste is the core business of the MSW incineration plant. The resulting energy products include electricity, biogas, and heat (steam) of different qualities. It currently sells the electricity on the forward and day-ahead markets and retails the steam to the nearby industries. The MSW incinerator is confronted with changes in the MSW sector and the energy market

that triggers them to investigate alternate BMs. The amount of MSW to be incinerated is decreasing due to improving recycling technologies and the average price on the Dutch electricity markets is decreasing as well. Additionally, the increasing amount of renewables in the electricity system only increases the demand for flexibility to balance the supply and demand, resulting in volatile prices of electricity. This creates new business opportunities for market parties such as the MSW-incinerators provided these parties can flexibly react to the electricity market.

Hence, the incineration plant wants to change their BM so that flexibility becomes the key value driver. The MSW-incinerator wants to explore flexible operation by interlinking heat and electricity commodities. The flexibility stems from the heat consumer's ability to increase or decrease steam consumption and the MSW-incinerator's ability to change the ratio of steam that is converted to electricity and the steam that is supplied to the heat consumers. The *business idea* is that the electricity market prices determine the ratio between electricity and steam supplied on the day-ahead, intraday, and balancing markets and the availability of flexibility. When electricity prices increase beyond the threshold price, more electricity will be produced and less steam will be supplied to heat consumers and vice versa.

5.2. Step 2 the BM perspectives

Following the extended BMDFV the four perspectives are synthesised.

5.2.1. Service/product perspective

The extended BMDFV requires a clear conceptualisation of the service concept as it provides a description of what value is created for the consumer and how it is to be done. It also helps to create a common understanding of the service among the stakeholders who are going to be involved in providing this service. The service/product perspective also sets the stage for further designing the BM. The service concept as described below was developed in collaboration with the stakeholders who are involved in this BM.

The service targets three customer segments, namely the electricity buyer, the programme responsible parties¹ (PRPs), and the flexible heat consumers. The electricity buyers are traders who want to buy and sell electricity via the energy markets. The PRP buys flexible loads that they can control to increase or decrease the production of electricity and or consumption of electricity provided they meet certain conditions such as ramp-up and ramp-down capacity, response time, etc. Flexible loads refer to energy generation assets such as electricity generators that can increase or decrease electricity production and energy assets that can consume energy. The PRPs the flexibility to balance their portfolio of producers and consumers and to trade on the balancing market. The flexible heat consumers can earn additional revenue by trading their flexibility. The heat consumers located at the industrial park sign long-term contracts with the MSW-incineration plant for the supply of steam at a fixed price. Additionally, the consumers are flexible in their heat consumption and offer their flexibility to the MSW-incineration plant via an internal electronic trade platform. The internal trade platform allows for scalability and efficiency by introducing a trading system for flexibility. The MSW-incineration plant then sells the flexibility in terms of electricity on the

different commodity markets directly and to the balancing market via the external aggregator's trade platform. The external aggregator is an emerging role, and it is usually performed by the PRP. However, for conceptual clarity, we have modelled it as a separate entity. The external aggregator aggregates flexibility from several energy producers and consumers and offers it to the PRP (USEF Foundation, 2015). The PRP, in turn, uses this flexibility to trade on the balancing market. Table 1 presents an overview of the trading strategy that will be adopted by the MSW-incinerator.

5.2.1.1. Design choices and BM design elements. This section describes the *design choices* and the *BM design elements* that significantly affect the *service perspective*. The goal here is not to be exhaustive but to illustrate the importance of *design choices* and the *BM design elements* for a viable BM. For more details see Bouw et al. (2016b).

To synthesise the above *service perspective*, we made use of the *configuration techniques*; in particular, we made use of the deconstruction and reconstruction technique. This technique involves deconstructing the existing value chain into its key value creation activities, introducing innovations, and reconstructing the value chain in a novel combination such that it offers superior value and/or superior cost advantage (Timmers, 1998). We deconstructed the energy value chain at the industrial park into key value creation activities such as the production of steam and electricity. We then introduced the innovations, for example, the electronic trade platform, and transactions that trade flexibility and reconstructed the value chain in a way that it provides flexibility and additional revenue. The reference model (i.e., the BM of the Dutch greenhouses that collaborate to exploit energy) was benchmarked against the BM of the industrial park to perform the deconstruction and reconstruction activity. Hence, understanding similarities and differences between the industrial park and the Dutch greenhouses in the context of MESs, and distilling lessons learnt, provide invaluable input for the design activity. Following are the key lessons learned that are relevant to the design activity. First, the greenhouses actively manage their energy consumption. Second, the greenhouses also extensively use the internal aggregator's trade platform and the external aggregator's trade platform to trade flexibility among themselves as well as with the PRP. Finally, they also trade electricity on several markets, for instance, the forward, day ahead, and the intra-day markets.

Another *design choice* that affects the *service perspective* is how the balancing market is approached. The two main ways of accessing it are the active balancing approach and the passive balancing approach. In the active balancing approach, the Dutch TSO selects parties to participate in a single buyer market (the Dutch TSO is the only buyer) to provide balancing services. The parties are selected based on a set of criteria such as minimum install capacity. The passive balancing approach refers to the efforts of the PRPs to restore balance in the electricity grid by causing an imbalance in the opposite direction without being explicitly asked by the TSO. For example, if the PRP anticipates that there will be a shortage of electricity they put more electricity on the grid than they specified in their e-programme. The Dutch electricity balancing regime rewards the passive balancing approach that helps to restore the electricity grid balance. Analysis revealed that the *business rules* of the active balancing approach would render the service concept unviable for reasons such as minimum install capacity needed (60 MW or higher) and the necessary standby capacity they have to make available at all times to provide flexibility. Hence, we chose the passive balancing approach. Passive balancing in the context of this research involves offering the flexibility to the PRP's via an external aggregator. The PRP then uses the flexibility to restore the balance of the electricity system. For

¹ A programme responsible party is responsible for submitting e-programmes to the TSO on behalf of their customers. An e-programme specifies how much electricity the PRP's customers expect to put in or take out of the grid every day. At the end of the day the PRPs measure their customers' actual consumption and submit the data to the TSO (TenneT, 2016).

Fig. 3. Service concept for the industrial park.

Table 1
Trading strategy for electricity on energy markets.

Order →	APX day-ahead	APX intraday	Balancing (via PRP)
Method	Optimise energy production and consumption to day-ahead market	Upregulate (extra trade compared to APX position)	Up- or down-regulate (extra trade compared to APX position)
Closing time	24 h	5 Min	15 Min
Platform	APX trading platform	APX trading platform	External platform

more details on active and passive balancing approach see (Frontier Economics, 2011). Consequently, a *design choice* was made to access the balancing market via the PRP and the external aggregator's trade platform.

5.2.2. Focal actor perspective

It is important to design the BM from the focal actor's perspective because the focal actor plays a pivotal role in crafting the business ecosystem, and the BM is anchored on the focal actor. Designing the focal actor perspective is usually an easier step to perform before designing the business ecosystem. It also provides inputs for designing the business ecosystem by identifying the key partners, key value creation activities, and the value proposition. The rest of this section will focus on the key elements of the MSW-incinerator's BM perspective because this is the focal actor.

Fig. 4 presents the BM from the focal actor's perspective using the canvas business modelling method. The MSW-Incinerator targets three customer segments, namely the heat consumers, the PRPs, and the electricity buyers. On the one hand, the heat consumers valuable flexibility embedded in their industrial processes, but currently they have no feasible way of trading flexibility to earn additional revenue. On the other hand, the PRPs want affordable,

on-demand flexibility. The MSW-incinerator is in a unique position to harvest the flexibility embedded in the industrial process of the heat consumers and supply it to the PRPs in a way that creates value for all of the stakeholders. Additionally, it can also exploit this flexibility by selling more electricity to the electricity buyer on the day ahead and on the intraday markets when the prices are high and supply less steam to the heat consumers and vice versa. To deliver the above value propositions, the MSW-incinerator needs to perform value creation activities, attract partners and resources, establish and maintain relationships and channels, and define cost structure and revenue streams, as described in Fig. 4.

5.2.2.1. Design choices and BM design elements. The *design principles* influence the focal actor's perspective. In particular, the coherence *design principle* has led to *design choices* that have defined the building blocks that synthesise the focal actor perspective. The coherence principle states that all of the perspectives and the underlying BMO's and building blocks should align (D'Souza et al., 2015). For example, to offer the PRPs flexible production and to offer the heat customers additional revenue, the MSW incinerator should perform corresponding value creation activities that will facilitate the process of harvesting and

Fig. 4. BM from the MSW-incineration plant's perspective.

exploiting flexibility (for instance, internal aggregation, the sale of flexibility to the PRPs, etc.).

5.2.3. Business ecosystem perspective

The crux of the *business ecosystem perspective* is that the focal actor alone lacks the resources or the capacity to implement complex BMs such as that of the MESSs. Hence, those in charge of the MSW-incinerator need to work with other stakeholders in a business ecosystem setting cooperatively. For the ecosystem to be viable, each stakeholder should create, deliver, and capture value to render the ecosystem viable, as well as the BMs of the individual stakeholders. Therefore, it is crucial for the BM designer to synthesise the *business ecosystem perspective*.

The industrial park as a whole should be able to convert steam to electricity and adapt the steam consumption to exploit flexibility on the energy markets successfully. It achieves this in a business ecosystem setting where flexible heat consumers are connected to the energy markets via a complex interplay of stakeholders and value exchange relationships. In this business ecosystem, each stakeholder performs certain roles and assumes certain responsibilities, as well as the corresponding set of value creation activities. Furthermore, each of these stakeholders has to be viable. Fig. 5 depicts the business ecosystem perspective. It represents the BM that was found to be viable. It also provides an overview of the value creation activities performed by the actors and the value exchange relationships among them.

Table 2 presents a list of stakeholders, their goals, value propositions, and roles and responsibilities. The stakeholders were identified based on the service and the focal actor's perspective. Understanding the stakeholder's goals helps design value propositions for each of them. Additionally, it also helps design the business ecosystem with appropriate value exchange relationships

and assigned roles and responsibilities.

5.2.3.1. Design choice and BM design elements. The role of the internal aggregator was assigned to the MSW-incineration plant (*design choice*), because of two strategic reasons. The first, is their unique capabilities. The second, is the presence of only two customers at the industrial park does not justify costs related to creating a separate entity that performs the role of the internal aggregator. In addition to its existing relationships with PRPs, the unique capabilities that the MSW-incinerator possesses are the ability to regulate steam supply and electricity production, manage heat networks, and trade energy.

Another crucial *design choice* that is crucial for the viability of this BM ecosystem is that the heat consumers have the autonomy to plan their heat consumption and trade their flexibility on the internal trading platform. To make this *design choice*, it was assumed that the heat consumers had the capability to manage their heat consumption actively and to trade flexibility.

5.2.4. Technology perspective

The technology perspective describes the underlying technology architecture that supports the BM and how the technological components fit together in a multi-stakeholder environment. This perspective helps to assess if the envisioned technological solution is acceptable to the stakeholders and if it enables the provision of the service. In the context of the energy BMs, the extended BMDFV recommends describing technology architectures in terms of a physical technologies architecture and an information services architecture.

5.2.4.1. Physical technology architecture. Fig. 6 presents a high-level description of the physical technologies architecture. The process of

Fig. 5. Business ecosystem perspective of the industrial park.

producing steam and electricity starts by feeding waste into a boiler that produces steam. The steam is led through the high pressure (HP) and low pressure (LP) turbines. It is then converted to electricity at the generator. The remaining steam is condensed using a condenser and pumped back into the boiler using a feed water pump. The steam is extracted at different points in the steam cycle (1,2,3 in Fig. 6), which allows the MSW-incinerator to supply the steam at different temperatures and pressures. The industries require the steam at 175 °C/6–7 bar. The steam is therefore extracted at point 2 and led through a back pressure turbine that reduces the temperature and the pressure to required levels. When the demand for heat by the industries exceeds the supply capacity at point 2, additional steam is extracted from the high-pressure

point (point 1). Here, temperature and pressure are brought down from 400 °C/40 bar to 175 °C/6–7 bar by leading it through a pressure reducer. The steam is transported through a pipeline to the industries. The steam controller that controls the flow of steam at points 1 and 2 receives control signals to regulate the flow of steam from the information services architecture (see Fig. 7). For more details on the physical technology architecture see Bouw et al. (2016b).

5.2.4.2. Information services architecture. The information services architecture describes the information services necessary to support the BM, how the components are configured, and the information flows among the stakeholders. The objective here is not to

Table 2
Summarised stakeholder analysis.

Stakeholders	Goals	Value proposition	Roles and responsibilities
MSW-incineration plant	Attract new heat customers; increase energy efficiency; maximise profit by providing flexibility	Maximise revenue by exploiting the flexibility	Energy producer - optimise production and supply of steam and electricity; sale of energy Internal aggregator - setup and operate the necessary information services; accounting for energy supplied/ consumed and flexibility traded (clearing house services) Flexible consumers - actively manage heat consumption Trade flexibility on the internal trade platform PRP - balance portfolio Report E-programmes to the TSO Trade on imbalance market Internal balancing activities/acquire flexible assets that can be controlled via an external aggregator. External aggregator - collect flexibility on an electronic platform Trade available electricity optimally Send control signals based on trades executed.
Industrial customers	Minimise energy costs	Additional revenue by trading flexibility Flexible controllable load (≤ 4 s response time)	Transmission service System service Operate balance market mechanism
Programme responsible party (PRP)	Maximise profit; Balance portfolio; Collect flexibility to trade on the imbalance		Transmission service
Transmission grid operator (TSO)	Maintain grid balance (transmission grid)	Help maintain grid balance	
Distribution grid operator (DSO)	Maintain grid balance (distribution grid)	Help maintain grid balance

Fig. 6. Physical technology architecture of the industrial park.

be exhaustive but to highlight the most important aspects. The information services conceptualised below are based on the business processes specified by several actors. A discussion on these business processes is beyond the scope of this paper. For more information see (APX, 2016a, 2016b; EDSN, 2012; TenneT, 2016; USEF Foundation, 2015; Wismans et al., 2010).

Fig. 7 depicts the information services operated by different stakeholders. The key components of the service are the internal and external trade platforms. The internal trading platform aggregates the flexibility available at the industrial park and offers it to the MSW-incinerator, which in turn trades it on the energy markets and offers the flexibility to the PRP. The internal trade platform is

Fig. 7. Information services architecture.

Table 3
Stakeholders and corresponding information services.

Stakeholder	Description	Assigned to
Internal aggregator	The internal aggregator owns and operates three main information services: <ul style="list-style-type: none"> Internal trade platform (E-web) aggregates bids, executes trades, relays relevant information to relevant services; Metering services collects consumption data and relays information to clearinghouse/billing information service; Clearinghouse/billing information services generates appropriate bills and reconciles production, the flexibility offered/purchased, and consumption/supply. 	MSW-incineration plant
Energy producer	The flexible producer owns and operates the following information services <ul style="list-style-type: none"> Energy control system continuously monitors the prices on the trading platforms (such as the external aggregator's platform) and executes profitable trades. Steam controller regulates the flow of the steam to the turbine and heat extraction points. 	MSW-incineration plant
Flexible heat consumers	Register flexibility on the internal trade platform. The meters installed on the prosumers' premises transmit metering data to the internal aggregator.	Industries
External Aggregator	The external aggregator owns and operates two information services <ul style="list-style-type: none"> External trading platform collects flexibility from several actors and offers it to the PRP Energy generator management system sends control signals to the steam controller based on the trades executed on the trading platform. 	PRP
Programme responsible party (PRP)	The programme responsible party owns and operates two information services <ul style="list-style-type: none"> Balancing information service constantly monitors the imbalance market prices and the prices on external aggregator's trade platform Programme management service collects production and consumption schedules from producers and consumers 	Can be taken on by any licensed PRP
Transmission system operator (TSO)	The system operator owns and operates two relevant information services <ul style="list-style-type: none"> Balancing market Balance management system collects and manages e-programmes. The system also verifies the actual production and consumption against the submitted programmes. It calculates the fines accordingly and communicates them back to the PRPs. For more information see Wisnans et al. (2010). 	TenneT
Distribution system operator (DSO)	The DSO receives the meter data from the flexible producer. This is mainly read from a meter installed on energy producer's premises. The DSO stores this information in a CAR database which is then made available to the TSO and the energy supplier.	Enexis

operated by the internal aggregator (i.e., the MSW-incinerator). The internal aggregator controls the flow of energy based on the trades executed and provides clearing, billing, and metering services. The flexible consumers submit bids to the internal trade platform. The

MSW-incineration then chooses offers on a cost-based merit order up to the point that its plant has reached its maximum capacity. Additionally, it sends control signals to the steam controller that regulates the amount of steam based on the trades executed on the

Table 4

Best case, most likely case, and worst case scenarios.

Variables	Best case	Most likely case	Worst case
Net present value for the industrial park	€ 471,759	€ 20,456	€ -467,134
Lifetime (years)	10	10	10
Cost of capital/ year	6.72%	8%	10%
Capex/ year	€ 600,000	€600,000	€650,000
Opex/ year	€ 139,749	€ 157,776	
Total revenue/ year	€320,583		
Tax rate	25%		
Depreciation			

Table 5

Viability of actors involved in the business ecosystem.

Actor	NPV	Revenue
MSW-incinerator plant	6,819 €	87,201 €/year
Heat consumer-1	6,819 €	87,201 €/year
Heat consumer -2	6,819 €	87,201 €/year
PRP	NA	50,341 €/year
Intraday market	NA	
External aggregator	NA	
Day ahead market	NA	
TenneT		
DSO		

internal trade platform. The trading platform also sends necessary information internally to the clearinghouse/billing information service. Nevertheless, for the sake of simplicity, we have not modelled the internal information flows. On the external trading platform, the flexibility of several producers and consumers is aggregated and offered to the PRP. The producers offer their flexibility via the external aggregator's trade platform. The PRPs purchase the required flexibility at suitable price points on the trading platform. Table 3 presents a detailed overview of the different elements of the information services architecture and how they are configured.

5.2.4.3. Design choices and BM design elements. The technology architecture should be able to regulate the electricity production as per the *business rules* specified by the TSO and the PRP. The capability to regulate electricity production requires changes to the technology architecture of the industrial park such as the intelligent steam controllers that can control the flow of steam based on

control signals received from relevant stakeholders. Hence, it is assumed that the technology architecture can regulate the electricity production as necessary.

5.3. Step 3 Is the BM viable?

This section evaluates the viability of the designed BM from the four perspectives because if any one them is not viable, the BM will not be viable. The designed BM was presented to five experts and the business owner for evaluation; henceforth referred to as evaluators. During the evaluation process, the evaluators considered several aspects such as the following: How realistic are the perspectives? Are the design choices valid and logical? Are the BM design elements valid? Can the BM be viable?; do the stakeholders possess the capabilities to implement the business model?

The evaluators were given additional information related to the financial value that each stakeholder would potentially capture from this business ecosystem, see Table 5. A techno-economical

Table 6

Expert evaluation of the BM from the service perspective and technology perspective.

Evaluation criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Business owner
Viability of the Service concept	+	++	++	++	++	++
Viability of the focal firm	±	±	+	±	±	±
Viability of the business ecosystem	±	±	+	±	±	±
Viability of the technology architecture	++	+	±	±	±	±
Overall viability of the BM	±	±	±	±	±	±

++ very positive; + positive; ± neutral; –negative; – – very negative.

model was developed that simulates the trading strategies presented in Table 1. Such a model helps to estimate the potential financial value that can be captured from the business ecosystem. The prices of the day ahead, intraday, and balancing market for the year 2015 were used to estimate the earnings. The earnings were then extrapolated over the next ten years. To account for uncertainties and risks, a scenario analysis was performed that includes a best case, most likely case, and worst case scenarios (see Table 4). For more details on the simulation and scenarios see Bouw et al. (2016b).

The analysis shows that the viability of the BM is sensitive to the CAPEX and the OPEX. It is also sensitive to the price volatility on the electricity markets and the availability of the flexibility.

From Table 6 the evaluators believed the service concept was viable. Moreover, the service concept and information services as conceptualised above already exist for the greenhouses such as Agro energy's flex products (Agroenergy, 2016). However, the evaluators have a neutral position towards the viability of the focal firm and consequently the viability of the business ecosystem. The evaluators had doubts about the profitability of the focal actor because of the risks involved in trading energy and the uncertainties around the investment necessary in the physical technologies. Expert 3 believed that the volatility on the energy markets will only increase because of the increasing intermittent sources of energy and therefore positively evaluated the viability of the focal actor. Moreover, all the evaluators agreed that if the volatility and the quantity of flexibility sold on the markets increased, it would improve the viability of the BM. Expert 1 was very positive about the technology architecture and thought it was definitely viable. On the contrary, the other evaluators were neutral because they were not sure about the MSW-incinerator's technological capability to increase or decrease the production of electricity within the specified time constraints. The business owner was neutral about the viability of the technology architecture as the MSW-incinerator had little knowledge about their technological capabilities to increase or decrease electricity production within the specified constraints. It is not surprising that the MSW-incinerator does not possess the necessary knowledge as their current business model requires them to produce electricity at a steady rate and not increase or decrease their electricity production within certain time constraints. The evaluators believed it is an interesting BM especially considering the growing need for flexibility, and that the designed BM should be further investigated. Future investigations should focus on getting exact cost estimations from potential suppliers, and on getting a deeper understanding of the MSW-incinerator's technological capabilities to regulate the production of electricity within the specified time constraints.

The MSW-incineration plant and its partner firms are currently exploring how to implement the above designed BM. They are assessing their capabilities that we assumed the stakeholders already possessed such as their ability to regulate the amount of electricity produced within the time constraints. Besides, the BM was yet to be presented to higher management.

6. Reflection on the validity of the extended BMDFV

This section reflects on the validity of the extended BMDFV. For the extended BMDFV to be valid, it has to meet the objective (Hevner et al., 2004; Peffers et al., 2007), that is to successfully facilitate the design and evaluation of a viable BM for MESSs. Therefore, we reflect on the process of designing and evaluating the BM for MESSs using the extended BMDFV, the advantages of the extended BMDFV over existing business model ontologies in the context of MESSs, corroboration of the extended BMDFV, and limitations and future research.

6.1. The process of designing and evaluating the BM using the extended BMDFV

Applying the extended BMDFV to design and evaluate the BM for the MES was a complex, challenging, and an iterative process. The extended BMDFV provides several constructs such as BM design elements, design choices, perspectives, etc., to facilitate the design and evaluation of a viable BM in a structured and systematic way.

The extended BMDFV decomposed the complexity of designing the BM for the MESSs into four perspectives making it easier to approach the design process. Moreover, it systematically stored the design choices and the motivation behind the design choices in a transparent and traceable manner. Additionally, the design elements facilitated the process of making design choices. Hence, the BMDFV facilitated the process of designing BMs of MESSs in a systematic, transparent, and traceable manner.

Adopting a clean slate approach to design BMs for complex systems such as MESSs can be extremely difficult. Hence, using the extended BMDFV greatly facilitated the design process by facilitating learning from other successful MESSs. The reference model technique involves creating BM description of the MESSs to understand the value creation logic. This provided the BM designers with a good starting point to create the first iteration. As a deduction, the extension of the configuration techniques to include the activity of creating a description of reference models of similar BMs was useful. Creating reference models of successful MESSs is not a trivial task; it involves meticulous data collection and creating and validating description of BMs to ensure the correct understanding of the successful business models. It also involves reflecting on the lessons learnt and if and how they should be used in designing new BMs. Applying the reference model technique could have serious time and cost implications, this is especially true in the case of complex systems such as the MESSs.

The evaluation criteria of the BMDFV were extended to evaluate the capabilities of the stakeholders to implement the designed BM. Including the capabilities in the evaluation criteria clearly lead to a nuanced evaluation by the experts and the business owner (see section-6). Furthermore, the fact that the MSW-incinerator and its partners are assessing their capabilities to implement the newly designed BM, without which they will not be able to implement the BM, necessitates the inclusion of the capabilities in the evaluation

criteria. This seemingly simple extension to the framework can have serious consequences in terms of cost. Firstly, assessing the capabilities can be expensive, in the case of the MSW-incinerator it involves increasing and decreasing the production of electricity. Increasing and decreasing electricity production leads to additional operations costs and loss of revenue as a result of decreased electricity production. Secondly, acquisition of the necessary capabilities involves additional costs. The aforementioned costs could render the business model unviable.

As described above the extended BMDFV helped to systematically deal with the complexity of designing and evaluating viable business models for the MES.

6.2. Advantages of the extended BMDFV over existing BMOs and modelling techniques

The extended BMDFV is a comprehensive framework that facilitates the process of designing and evaluating viable BMs for MES. The framework facilitates the design and evaluation process from service, focal actor, business ecosystem, and the technology perspective with the help of well-established BMOs. Consequently, the BMDFV helps to create more complete descriptions of BMs when compared to the BMs designed with the help of a single BMO. The descriptions created using the BMDFV provide more insights into the designed BM thus facilitating critical evaluation of the business model. Hence, increasing the chances of designing and evaluating viable business models.

Furthermore, the BM design elements and the design choices help to approach the design process systematically. They also help to store the design choices and the motivation behind the design choices, which led to a transparent and traceable design process.

In addition to the above advantages, the extensions made to the BMDFV have the following advantages. Firstly, the reference model technique facilitates learning from successful business models this technique is a good first step in designing complex business models such as the MESs. Secondly, the extended BMDFV also helps to improve the evaluation process of the business models by explicitly focusing on evaluating the capabilities necessary to implement the business model. As demonstrated in Section 5.3 the inclusion of the capabilities criteria clearly leads to a realistic and nuanced evaluation of the BM. Therefore, the extended BMDFV is more comprehensive than the current BMOs. The framework enables the BM designer to address BM design issues which would have otherwise been ignored or overlooked when other BMOs are adopted. Thus, the extended BMDFV is in a better position to facilitate the design and evaluation of viable energy BMs for MESs.

6.3. Corroboration of the extended BMDFV

As demonstrated above, the extended BMDFV could successfully facilitate the design of a BM for MES and identify the conditions under which the BM could potentially be viable, for instance, the market conditions, and technological capabilities. From the following statement, the extended BMDFV can describe the business model in a clear and understandable manner, and it facilitates the design of realistic BM's in a transparent and traceable manner. *"I think this ... [is] a realistic [business] model ... We did some other analysis which showed something similar"* – Expert 1. *"The [BM] idea seems promising. The extent to which profits are made depends on the circumstances and agreements ..."* – Expert 2. *"it is a convincing business model that could work for us ... [but it needs further investigation]"* – the business owner. The experts also found the four perspectives that we synthesised using the extended BMDFV to be useful and believe it leads to a more complete description of the BM. They also thought that the *design choices* and the *BM design*

elements contributed to a realistic BM design.

Based on the analysis presented in Section 6.1., 6.2., and 6.3., the extended BMDFV successfully facilitated the design and evaluation of a viable BM for the MES. The experts and the business owner positively evaluated the viability of the MES business model. Therefore, the extended BMDFV is successfully corroborated for MESs.

6.4. Limitations and future research

The BM for the industrial park is theoretically evaluated for viability by six evaluators. Future research should focus on further validation and study if and how the BM was implemented.

The extended BMDFV was applied on only one MES to claim that the extended BMDFV is validated it should be successfully applied by a wider set of users in multiple cases. Nevertheless, it can be said that extended BMDFV is corroborated. The rote application of the extended BMDFV will not lead to a viable BM. The BM design process is inherently a creative and an iterative process, and like any other design tool, the result of applying the extended BMDFV largely depends on the creativity and skill of the BM designer. However, the extended BMDFV helps to approach the BM design process in a systematic, transparent, and traceable manner. The extended BMDFV is an extensive method that can grasp and deal with the complexity of MESs effectively. However, the use of all the four perspectives to design and evaluate BMs that are simple might be excessive.

Even though the extended BMDFV is a more comprehensive BM design and evaluation tool it is by no means complete. Sustained application to design and evaluate viable business models may require modifications to the BMDFV, such as the addition of new perspectives, new BM design elements, and extension of existing BM design elements, for example, the configuration techniques. Hence, future research should focus on further validating the extend the BMDFV to design and evaluate viable BMs.

7. Conclusion

MESs are rapidly emerging, among other reasons to create and exploit flexibility in the energy infrastructure. The process of designing viable BMs to exploit these MESs successfully is more complex than mono-commodity energy systems and therefore poses an additional challenge. Existing BMOs and frameworks that support the design and evaluation of mono-commodity energy systems are not necessarily valid for MESs. The BMDFV is one such framework that has been used to design and evaluate mono-commodity energy systems in the past (D'Souza et al., 2015). Therefore, our goal is to examine the extent to which the BMDFV is corroborated for designing and evaluating viable BMs for MESs.

An initial application of the BMDFV showed that it had to be extended to deal with the challenges of designing and evaluating viable business models of complex systems such as the MESs. The extension to the BMDFV involves extending the configuration techniques to include the reference model technique and extension of the evaluation criteria to include evaluation of the stakeholders' capabilities to implement the designed BM. The extended BMDFV was applied to design and evaluate a multi-commodity energy BM for an industrial park where the heat and the electricity networks are connected to harvest and exploit the flexibility embedded in the industrial processes of the heat consumers. The framework could deal with the complexity of designing and evaluating viable business models for the MESs. The extended BMDFV is better able to design complex BMs and to evaluate the capabilities of the stakeholders to implement the designed BM. The extended BMDFV successfully facilitated the design and evaluation of a potentially

viable multi-commodity energy BM and identified the conditions under which the BM could be viable and therefore is corroborated.

Acknowledgements

This research was financed by a grant of Transitie II & Pieken. Transitie II & Pieken was co-financed by SNN - The Northern Netherlands Provinces Alliance, the Municipality of Groningen, the Municipality of Eemshoofd, the Province of Drenthe, and the Ministry of Economic Affairs.

References

- Adhikari, R.S., Aste, N., Manfren, M., 2012. Multi-commodity network flow models for dynamic energy management – smart Grid applications. *Energy Procedia* 14, 1374–1379. <https://doi.org/10.1016/j.egypro.2011.12.1104>.
- Agroenergy, 2016. Products [WWW Document]. <http://www.agroenergy.nl/Producten.aspx>. (Accessed 10 April 2016).
- Al-Debei, M.M., Avison, D., 2010. Developing a unified framework of the business model concept. *Eur. J. Inf. Syst.* 19, 359–376. <https://doi.org/10.057/ejis.2010.21>.
- APX, 2016a. Continuous markets: intraday [WWW document]. <https://www.apxgroup.com/trading-clearing/continuous-markets-intraday/>. (Accessed 8 November 2016).
- APX, 2016b. Day-ahead auction [WWW document]. <https://www.apxgroup.com/trading-clearing/day-ahead-auction/>. (Accessed 8 November 2016).
- Bachmaier, A., Narmsara, S., Eggers, J.-B., Herkel, S., 2016. Spatial distribution of thermal energy storage systems in urban areas connected to district heating for grid balancing—A techno-economical optimization based on a case study. *J. Energy Storage* 8.
- Bouw, K., D'Souza, A., Van Someren, C., 2016a. Flexibele Warmtenetten zijn de toekomst. *Warmtenetw. Mag.* 18–20.
- Bouw, K., D'Souza, A., Van Someren, C., 2016b. A Flexible Business Model for the ETP Wijster. Groningen.
- Bouwman, H., De Vos, H., Haaker, T., 2008. *Mobile service Innovation and Business Models*. Springer.
- Bowman, C., Ambrosini, V., 2000. Value creation versus value capture: towards a coherent definition of value in strategy. *Br. J. Manag.* 11, 1–15.
- Chavarria-Barrientos, D., Batres, R., Perez, R., Wright, P.K., Molina, A., 2016. In: Afsarmanesh, H., Camarinha-Matos, L.M., Lucas Soares, A. (Eds.), *A Step towards Customized Product Realization: Methodology for Sensing, Smart and Sustainable Enterprise BT - Collaboration in a Hyperconnected World*. Springer International Publishing, Cham, pp. 327–339. https://doi.org/10.1007/978-3-319-45390-3_28.
- Chesbrough, H., Vanhaverbeke, W., West, J., 2006. *Open Innovation: Researching a New Paradigm*. Oxford University Press.
- D'Souza, A., Beest, N.R.T.P. Van, Huitema, G.B., Wortmann, J.C., Velthuisen, H., 2014. A Review and Evaluation of Business Model Ontologies: a Viability Perspective, *Lecture Notes in Business Information Processing*. Springer.
- D'Souza, A., Wortmann, J.C., Huitema, G., Velthuisen, H., 2015. A business model design framework for viability; a business ecosystem approach. *J. Bus. Model.* 3, 1–29.
- Economics, F., 2011. *Qualitative Assessment of Balancing Market Design for The Netherlands*. Frontier Economics, London, United Kingdom.
- EDSN, 2012. STROOMOPWAARTS.
- Edvardsson, B., Olsson, J., 1996. Key concepts for new service development. *Serv. Ind. J.* 16, 140–164.
- Gordijn, J., 2002. *Value-Based Requirements Engineering*. VU University Amsterdam, Amsterdam.
- Gordijn, J., Akkermans, J.M., 2003. Value-based requirements engineering: exploring innovative e-commerce ideas. *Requir. Eng.* 8, 114–134. <https://doi.org/10.1007/s00766-003-0169-x>.
- Gordijn, J., Akkermans, H., 2007. Business models for distributed generation in a liberalized market environment. *Electr. Power Syst. Res.* 77, 1178–1188.
- Hall, S., Roelich, K., 2016. Business model innovation in electricity supply markets: the role of complex value in the United Kingdom. *Energy Policy* 92, 286–298. <https://doi.org/10.1016/j.enpol.2016.02.019>.
- Helms, T., Loock, M., Bohnsack, R., 2016. Timing-based business models for flexibility creation in the electric power sector. *Energy Policy* 92, 348–358.
- Hevner, A.R., 2007. The three cycle view of design science research. *Scand. J. Inf. Syst.* 19, 87.
- Hevner, A.R., March, S.T., Park, J., Ram, S., 2004. Design science in information systems research. *MIS Q.* 28, 75–105.
- Kempton, W., Tomić, J., 2005. Vehicle-to-grid power implementation: from stabilizing the grid to supporting large-scale renewable energy. *J. Power Sources* 144, 280–294.
- Kraussl, Z., 2011. Operationalized ALignment: assessing Feasibility of Value Constellations Exploiting Innovative Services. *Fac. der Econ. Wet. en Bedrijfskd. Vrije Universiteit, Amsterdam*.
- Lepak, D.P., Smith, K.G., Taylor, M.S., 2007. Value creation and value capture: a multilevel perspective. *Acad. Manag. Rev.* 32, 180–194. <https://doi.org/10.5465/amr.2007.23464011>.
- Mancarella, P., 2014. MES (multi-energy systems): an overview of concepts and evaluation models. *Energy* 65, 1–17.
- Morelli, N., Tollestrup, C., 2006. *New Representation Techniques for Designing in a Systemic Perspective: Educating Designers*.
- Osterwalder, A., Pigneur, Y., Clark, T., 2010. *Business Model Generation*. John Wiley & Sons, Inc., Hoboken, New Jersey.
- Osterwalder, A., Pigneur, Y., Bernarda, G., Smith, A., 2014. *Value Proposition Design: How to Create Products and Services Customers Want*. John Wiley & Sons.
- Peffer, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S., 2007. A design science research methodology for information systems research. *J. Manag. Inf. Syst.* 24, 45–77.
- Priem, R.L., 2007. A consumer perspective on value creation. *Acad. Manag. Rev.* 32, 219–235. <https://doi.org/10.5465/amr.2007.23464055>.
- Teece, D.J., 2010. Business models, business strategy and innovation. *Long Range Plan.* 43, 172–194. <https://doi.org/10.1016/j.lrp.2009.07.003>.
- TenneT, 2016. Balance responsibility [WWW document]. <http://www.tennet.eu/electricity-market/dutch-market/balance-responsibility/>. (Accessed 8 April 2016).
- Timmers, P., 1998. Business models for electronic markets. *Electron. Mark.* 8, 3–8.
- Ullbig, A., Andersson, G., 2015. Analyzing operational flexibility of electric power systems. *Int. J. Electr. Power Energy Syst.* 72, 155–164.
- USEF Foundation, 2015. *USEF: the Framework Specifications 2015*.
- Van der Veen, R.A.C., 2012. *Diffusion of Combined Heat and Power in Dutch Greenhouses: a Case Study*.
- Weiller, C., Neely, A., 2013. *Business Model Design in an Ecosystem Context*. Univ. Cambridge, Cambridge Serv. Alliance.
- Wismans, B., Van Houten, C., Nobel, F., 2010. *Preparation of E-Programmes Instruction Manual*.
- Zott, C., Amit, R., Massa, L., 2011. The business model: recent developments and future research. *J. Manage.* 37, 1019–1042. <https://doi.org/10.1177/0149206311406265>.