Renewable and Sustainable Energy Reviews 53 (2016) 629–638

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

How is value created and captured in smart grids? A review of the literature and an analysis of pilot projects

Eva Niesten [a,*], Floortje Alkemade [b,1]

[a] Alliance Manchester Business School, The University of Manchester. Booth Street West, M15 6PB, Manchester, United Kingdom
[b] School of Innovation Sciences, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

ARTICLE INFO

Article history:
Received 29 July 2014
Received in revised form
11 March 2015
Accepted 30 August 2015

Keywords:
Smart grids
Business models
Value creation
Electric vehicles
Demand response
Renewable energy

ABSTRACT

Profitable business models for value creation and value capture with smart grid services are pivotal to realize the transition to smart and sustainable electricity grids. In addition to knowledge regarding the technical characteristics of smart grids, we need to know what drives companies and consumers to sell and purchase services in a smart grid. This paper reviews 45 scientific articles on business models for smart grid services and analyses information on value in 434 European and US smart grid pilot projects. Our review observes that the articles and pilots most often discuss three types of smart grid services: vehicle-to-grid and grid-to-vehicle services, demand response services, and services to integrate renewable energy (RE). We offer a classification of business models, value creation and capture for each of these services and for the different actors in the electricity value chain. Although business models have been developed for grid-to-vehicle services and for services that connect RE, knowledge regarding demand response services is restricted to different types of value creation and capture. Our results highlight that business models can be profitable when a new actor in the electricity industry, that is, the aggregator, can collect sufficiently large amounts of load. In addition, our analysis indicates that demand response services or vehicle-to-grid and grid-to-vehicle services will be offered in conjunction with the supply of RE.

Contents

* Corresponding author. Tel.: +44 161 3068433.
E-mail addresses: eva.niesten@mbs.ac.uk (E. Niesten), f.alkemade@tue.nl (F. Alkemade).
[1] Tel.: +31 40 247 7325.

http://dx.doi.org/10.1016/j.rser.2015.08.069
1364-0321/

1. Introduction

Increasing decentralized electricity production with renewable energy, more energy-efficient behavior by consumers, and the grid-connection of electric vehicles will severely affect electricity industries in the next decades [1, p. 344]. Although these changes will have positive effects on the environment and reduce CO_2 emissions, they will also fundamentally alter the peaks and valleys of electricity on the network and thereby negatively affect the reliability, quality and security of supply [2,3]. To cope with these changes and to guarantee the effective functioning of the network, electricity industries are implementing smart electricity grids, i.e., grids that integrate information and communication technologies (ICT) into the existing network to allow for a two-way flow of information and electricity between producers and consumers [4]. A variety of smart grid technologies, such as smart meters and advanced metering infrastructures, have been developed and are slowly being implemented, often stimulated by regulation. Although technologically feasible, the investments associated with the smart grid are high, and it is thus far unclear how the electricity industry will source those investments. That is, smart grid technologies are not yet accompanied by new business models on a large scale [5,6]. Companies need to develop new services that use smart grid functionalities, and they need to create value for consumers and capture value for themselves with these services. The successful transition to a smart grid will be compromised if companies cannot make money out of the smart grid or if consumers do not value the new services [7].

This paper offers a review of state-of-the-art business models, value creation and value capture with smart grid services. Business models describe what products and services a company offers to customers, which customer segments the company targets, and the company's distribution channels, core competences, cost structure, and revenue model [8]. They are defined as the means by which companies create value for consumers and capture value for themselves [9–11]. In this paper, value creation refers to the value created for consumers of a service and may include financial benefits, improved service quality but also environmental benefits. Value capture refers to value captured by the service provider and often includes financial benefits such as reduced costs, increased revenues and profits. The paper reviews 45 scientific articles on business models for smart grid services and analyses information on value in 434 European and US smart grid pilot projects. The paper combines a literature review with an analysis of pilot projects to obtain a richer set of data and, in particular, to include information on document analyses, interviews and simulation studies from the scientific literature and real-life experiments from smart grid pilots. Although services for smart grids have not been offered on a large scale, this review provides valuable insights into the direction of smart grid developments. Our review finds that the articles and pilots most often discuss three types of smart grid services. First, vehicle-to-grid and grid-to-vehicle services concern the transfer of electricity between electric vehicle (EV) batteries and the grid to charge and discharge the batteries but also concern profit from price differences on the electricity market and supplying power to the operator of the electricity system. Second, in demand response services, consumers increase or decrease their electricity consumption in response to signals from the energy companies or system operators. Third, energy companies provide services that increase the integration of renewable energy sources into the electricity system.

Our analysis of the literature and pilot projects results in a classification of business models, value creation and value capture for each of these services and for the different actors in the electricity value chain. Although earlier studies reviewed the literature on the state of technology of electric vehicles, the integration of renewable energy and smart grids [12], our paper is the first to review evidence on value creation and capture with smart grid services. The paper makes three important contributions to the literature on smart grids. First, it demonstrates that if companies are to capture value from offering smart grid services, they will need to operate on a large scale, meaning they will need to become aggregators. Companies need to aggregate a large number of EV batteries to offer V2G and G2V services, to aggregate a great deal of consumer load to offer demand response services and to have access to a large number of sites with renewable energy sources. Second, the paper shows that companies can capture value when they offer a combination of the three complementary services. Finally, the paper shows that the literature offers evidence of business models and value capture by companies, but the pilot projects primarily address value creation for system operators and consumers. We therefore propose that future pilot projects focus more on the ability of service providers to generate revenue with smart grid services to facilitate the transition to a smarter electricity grid.

The following section discusses characteristics of smart grids and defines business models. Section 3 describes the method that we used to select the literature and to collect data on the pilot projects. Sections 4 and 5 present the results. Section 6 offers future research suggestions based on our review of state-of-the-art value creation and capture in smart grids, and Section 7 presents the conclusions.

2. Smart grids and business models

Several scholars have argued that a common functional and technical definition of a smart grid has not yet emerged and that there is no consensus on what a smart grid is [13,1]. For this review, we identified the characteristics of a smart grid shared by most definitions in the literature; that is, a smart electricity grid integrates information and communication technologies into the existing electricity network to allow for a two-way flow of information and electricity between generators and consumers [14–16,13,1]. The related information and communication technologies include smart meters at the consumer site, communication networks between the consumer and a service provider, and data reception and management systems that make the information available to the service provider [17, p. 574]. These technologies can be considered enabling technologies because they are a prerequisite for firms to offer smart grid services to consumers [18, p. 461, 19, p. 4, 20, p. 947]. In addition to these enabling technologies, companies need to develop new business models that allow them to create and capture value on a large scale by offering new smart grid services to consumers [15]. Johnson and Suskewicz [6] have argued that the combination of a new technology and a new business model is especially important to stimulate a systemic change (e.g., a change from a fossil-fueled economy to a clean-tech economy with renewable energy, electric vehicles and smart