Energy Policy 115 (2018) 572–583

Contents lists available at ScienceDirect

Energy Policy

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

Energy policy regime change and advanced energy storage: A comparative analysis

Mark Winfield*, Shahab Shokrzadeh, Adam Jones

Sustainable Energy Initiative, Faculty of Environmental Studies, York University, 4700 Keele St., Toronto, Ontario, Canada M3J 1P3

ARTICLE INFO

Keywords:
Energy storage
Energy policy
Multi-level perspective
Socio-technical transitions
Sustainability

ABSTRACT

This paper employs a multi-level perspective approach to examine the development of policy frameworks around energy storage technologies. The paper focuses on the emerging encounter between existing social, technological, regulatory, and institutional regimes in electricity systems in Canada, the United States, and the European Union, and the niche level development of advanced energy storage technologies. The structure of electricity systems as vertically integrated monopolies, or liberalized or semi-liberalized markets, is found to provide different mechanisms for niche formation and niche to regime transition pathways for energy storage. Significant trade-offs among these pathways are identified. The overwhelming bulk of energy storage policy development activities are found to be taking place in liberalized or semi-liberalized markets. The key policy debates in these markets relate to technical barriers to market participation by storage resources, the ability of storage technologies to offer multiple services in markets simultaneously, the lack of clear rules related to the aggregation of distributed energy resources, and issues related to the meaning of "technological neutrality" in liberalized market systems. Landscape conditions, particularly jurisdictional commitments to pursue deliberate reconfigurations of their energy systems towards low-carbon energy sources, emerge as the most significant factor in the implementation of policy reforms in these areas.

1. Introduction

The large-scale electrification of transportation and other energy-based services are widely seen as important elements of efforts to reduce greenhouse gas (GHG) emissions from the combustion of fossil fuels (Bataille et al., 2015; Trottier Energy Futures Project, 2016). Major reductions in GHG emissions will be essential to meeting the requirements of the 2015 Paris climate change agreement.

The focus on electrification has emerged at a time of three major technological developments in the electricity industry. The past decade has seen declines in the costs of renewable energy technologies, particularly wind and photovoltaic (PV) and thermal solar systems, while the performance of these technologies has been improving (International Energy Agency, 2015; International Renewable Energy Agency, 2017). Secondly, the emergence of smart electricity grids, through the digitization of grid communications and control systems, has the potential to lead to more adaptive and resilient electricity systems. Such systems will be better able to coordinate intermittent, smaller-scale, and geographically distributed energy sources into reliable resources (Knight and Brownell, 2010; International Energy Agency, 2011; Navigant Research, 2012).

Finally, major developments have been occurring around energy storage technologies. Conventional energy storage technologies, including pumped or reservoir-based hydro-electric facilities, and lead-acid batteries, have existed for more than a century. The past decade has been marked by growing interest in both conventional and advanced energy storage technologies. Attention has been given to new mechanical systems based on compressed air and flywheels, advanced batteries (e.g. flow, lithium ion, NaS), and thermal and gas (i.e. hydrogen and methane) based storage technologies. These technologies are summarized in Fig. 1. They have become the focus of substantial government and private sector investments in technology development. These investments are expected to result in significant improvements in cost and performance (World Energy Council, 2016).

In addition to their potential role in managing the growing presence in electricity systems of intermittent renewable energy sources like wind and solar energy, energy storage technologies could also provide grid services as operating and ramping reserves, demand response resources, and ancillary service providers for frequency response and regulation. Storage resources may offer means of deferring transmission and distribution upgrades as well. Finally, storage technologies may facilitate the integration of distributed energy sources into grid-scale

---

* Corresponding author.
E-mail address: marksw@yorku.ca (M. Winfield).

https://doi.org/10.1016/j.enpol.2018.01.029
Received 26 July 2017; Received in revised form 10 January 2018; Accepted 12 January 2018

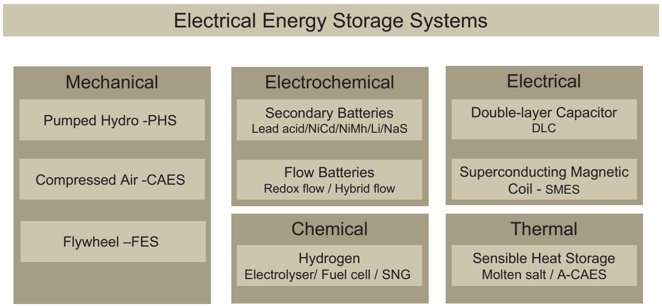

Fig. 1. Energy storage technologies classified based on their energy form. Figure adapted from (IEC, 2011).

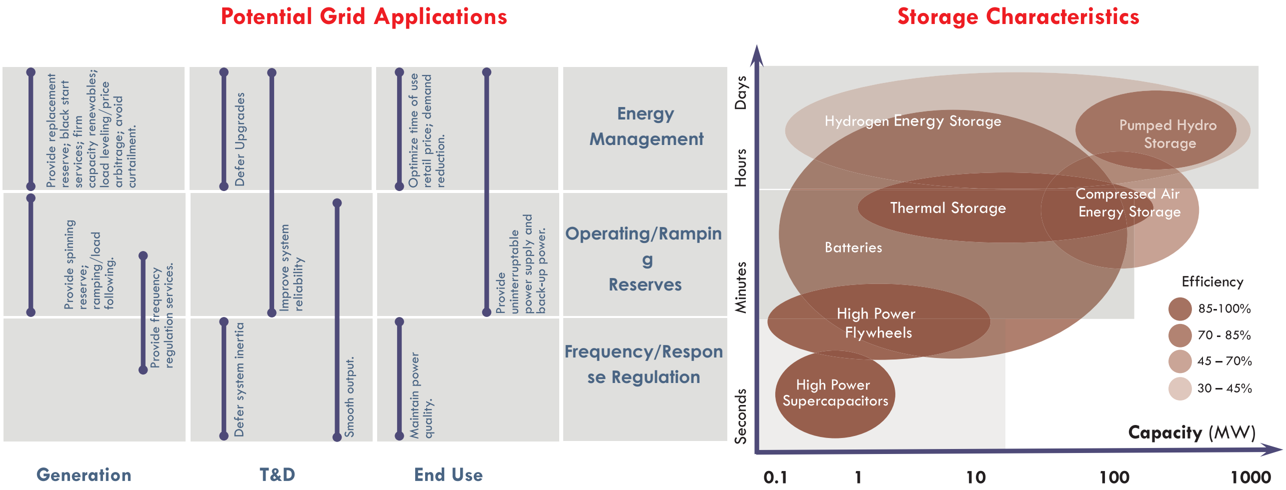

Fig. 2. Characteristics of energy storage technologies and the potential applications they can provide on the electric grid, adapted from (NREL, 2016).

resources. These applications are summarized in Fig. 2.

Taken together, the developments in renewable energy technologies, smart grids, and energy storage are seen to offer the potential to make energy systems more environmentally and economically sustainable than is currently the case. Specifically, they are expected to be able to:

- make better use of renewable low-carbon energy sources;
- be more reliable and resilient through expanded roles for distributed and technologically diverse energy sources;
- have improved ability to adapt to changing circumstances and needs; and
- have the potential to offer more control to consumers (Pepermans et al., 2005; US Department of Energy, 2007; Marsden, 2011).

This paper is focussed specifically on the new energy storage technology dimensions of these developments. Employing a multi-level perspective (MLP) approach (Geels et al., 2016), it examines the development of new energy storage technologies as an encounter between existing social, technological, regulatory, and institutional regimes in electricity systems in Canada, the United States, and European Union, and the niche level development of new energy storage technologies. The outcomes of these encounters are unknown at this stage. It is uncertain whether new energy storage technologies will remain relatively niche level developments, or if they will contribute to the transformation or even reconfiguration or realignment of energy systems in the direction of larger-scale deployment of intermittent renewable energy sources and significantly expanded roles for distributed generation.

Energy storage is not a substitute for existing energy generation technologies per se. Rather it is a potentially enabling technology for other new technologies, such as large-scale employment of distributed generation, and the expansion of behind-the-meter activity, which may disrupt conventional utility and generation models. These possibilities may prompt resistance from established actors within current regimes for these reasons. This may be especially the case in the current context of growing concerns about the stranding of conventional centralized generating, transmission and distribution assets in the reconfiguration or realignment of electricity systems (The Economist, 2013, 2017).

2. Methods and background materials

2.1. Theoretical approach

The MLP literature on socio-technical transitions is potentially helpful in understanding the processes of the development and adoption of new technologies and their impacts on existing institutional, regulatory, and technological systems. The MLP literature links three scales of analysis (Geels and Schot, 2007, 2010). The “socio-technical landscape” is defined as the exogenous environment of air quality, resource prices, lifestyles, and political, cultural and economic structures. The “socio-technical regime” consists of infrastructures, regulations, markets, and established technical knowledge. “Socio-technical niches” are smaller scale focal points of activity. The regimes are nested within and structured by landscapes, and niches are nested within and structured by regimes. The niche level is understood to be the key center for innovation in technology, practice, and policy. The MLP literature focuses on the transition processes that occur when landscape pressures on the regime create windows of opportunity for the adoption of niche-level innovations.

Three major variables are generally identified in socio-technical