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How 'transformative' is energy storage? Insights from stakeholder perceptions in Ontario

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ABSTRACT

'Energy storage' comprises a range of technologies of varying maturity and cost-effectiveness, which are increasingly considered to be an important part in building the electricity system of the future. As with any potentially transformative technology, there remain questions of how, and under what context, electricity system stakeholders (new and old) will perceive the technology. Our interest in this paper is to identify and assess the political and sociotechnical system factors that stand to shape the extent to which energy storage can be considered transformational. To do so, we investigate the transformative potential of storage in Ontario, Canada, based on interviews with key electricity system stakeholders. We find that the transformative potential of energy storage is by no means preordained, and is instead intimately intertwined with the complex interactions between actors and institutional factors in each and across three electricity system subsectors.

1. Introduction

'Energy storage" comprises a range of different technologies, ranging in their size and scalability, in their technical capabilities for storage capacity and discharge speed, and in their current availability or use within energy/electricity systems [1]. Because of these differences, energy storage in general can play many different roles, and at different levels or sectors within the system in question. Our focus in this paper is stakeholder perceptions of energy storage in electricity systems. Fig. 1 shows the variety of services that energy storage can play at 'grid scale' in such a system.

Though technologies such as pumped hydro storage have been in use for decades, interest in other, less-mature, innovative energy storage technologies has been growing rapidly – a dynamic that is influencing a range of supportive policy responses. For example, since 2012, the Independent Electricity System Operator (IESO) in Ontario has procured approximately 56 MW of storage capacity in several rounds of calls (some of which were targeted at energy storage specifically), though not all of that storage is yet operational [2]. In 2013, the California Public Utilities Commission set a target of 1.3 GW of energy storage to be brought onto the grid by 2020 [3], and, in 2015, the Government of Massachusetts launched an 'Energy Storage Initiative' with the aim of advancing energy storage and clean energy industry in the state. That state has since committed to introducing targets for energy storage [4].

Why all the interest in energy storage? The reasons, like energy storage technologies, are many. Fig. 1 above indicates several potential benefits of storage, including improving power quality, providing ancillary services for grid support (voltage support, regulation, black start capacity), load-shifting, and bulk power management [1, p. 2]. More broadly, the International Energy Agency (IEA) has identified several drivers of energy storage across different sectors of energy systems: improving energy system resource use efficiency; increasing use of variable renewable resources; rising self-consumption and self-production of energy; increasing energy access (e.g., off-grid electrification); improving electricity grid stability, reliability and resilience; and increasing end-use sector electrification (e.g., transport) [5, p. 6]. In California especially, interest in and public support of energy storage is closely connected to the dramatic growth in distributed energy resources in the state, and the challenges in maintaining system reliability in that context [6].

In short, growing interest in energy storage is due both to the range of potential services it can provide to electricity grids as they exist in the present, as well as for its potential role in facilitating a transition to an improved, future grid, particularly regarding concerns about climate change and the need to move toward low-carbon energy systems. The purpose of this study is to identify and assess the political and sociotechnical system factors, based on interviews with key electricity system stakeholders in Ontario, that stand to shape the extent to which storage can be considered transformational.

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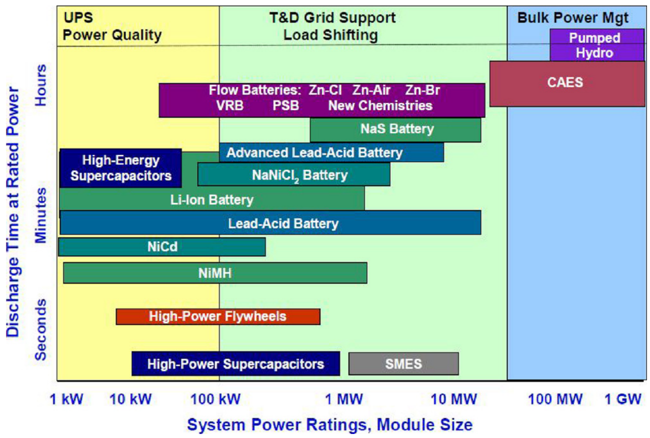

Fig. 1. Positioning of Energy Storage Technologies [1].

1.1. Transitions & energy storage

The notion of a multi-leveled, multi-faceted socio-technical system is a centrally-important concept in 'transitions studies', wherein the focus is – broadly speaking – on understanding how to reflexively guide the co-evolution of the material (institutional, technological) and immaterial (normative, behavioural) elements of such systems toward a desired future state (i.e., toward sustainability) [7].

The dynamics of change in a socio-technical system stem from developments in and interactions among three system 'levels' – niches (innovations), regimes (the incumbent status quo), and landscape (large, long-term trends) [7–9]. A transition is defined as a shift from one regime configuration to another, a process which can result – depending on the type of transition pathway followed, a consequence of the kind of interaction among niche, regime, and landscape - in the displacement of previously dominant actors and/or technologies by new ones emerging out of a niche [10]. A transition, or transformation, is thus sometimes termed "systems' innovation" – a process of change that involves more than just technological substitution, and extending to other facets of the sociotechnical system (e.g., behaviour, institutional configurations, new sets of actors, etc).

Unsurprisingly, this process can become highly politicized, the primary political fault-line running between the stabilizing and system 'constituting' forces of the regime and the destabilizing, 'destructive' tendencies of niche technologies and actors [11]. But, it is important to stress, nothing in the transitions framework suggests that the presence of a potentially disruptive niche innovation necessitates that a transition will take place, only that the presence of such innovations, and/or destabilizing landscape developments, is sufficient that systems innovation could occur. Furthermore, no transition pathway, once embarked upon, should be expected to follow a linear and standard pattern – it might continue on the pathway it evidently is following, or it could shift into an alternative developmental pathway, or reverse [7]. Suffice it to say that politics, not some innate characteristic of emerging technologies, is the critical, intervening factor, affecting the pace and direction of change.

Where does energy storage fit in this framework? A previous study by Grünewald et al. [12], utilized a transitions perspective to provide interesting insight into the "poor alignment" of storage with the existing socio-technical regime in the United Kingdom electricity system, based on a series of semi-structured interviews and focus groups they conducted with system stakeholders. Storage, they note, is not a "dominant design" contender, but rather a "facilitative technology, aimed at improving the effective working of the remaining system", and thus "inherently dependent on other system developments" to ascertain future potential [12]. Energy storage is also unique, they note, because it is applicable in several subsectors of the electricity system (generation, transmission, and end-use), and because its benefits can be diffuse (that is, benefiting actors other than the storage project operator, the value of which may be hard for the operator to capture). The poor alignment they observe is attributed to both existing market and commercial barriers (e.g., absence of storage licensing, inability to capture multiple value streams), as well as existing cultural norms and institutional inertia among incumbents.[1]

While Grünewald et al. [12] do note the need for future research to consider the potential "perverse incentives" or "unintended consequences" of policy to facilitate use of energy storage [12, p. 456], the authors do not elaborate more fully on its potential to transform electricity systems in the UK. The implication is that, because the technical potential of storage is constrained by institutional and sociotechnical system factors, system transformation involving storage must begin with institutional change to facilitate its use. There is no reason to assume this is a faulty conclusion. But, given that transitions are neither necessary nor linear in the presence of such innovations, the question of the factors that might shape this requisite process of institutional change – and with it, storage's transformative potential – remains open. In short, the sociotechnical question of storage's technical potential is one matter; the sociotechnical question of its potential to contribute to system transformation is another.

We would add that it is difficult to take a sociotechnical perspective on energy storage *sui generis*, as the available storage technologies have different levels of maturity, scalability, and potential services and use cases. Accordingly, it is important to consider the factors shaping the potential of storage in different sectors of the electricity system (as Grünewald et al. [12], did): namely, the bulk system (or transmission grid); distribution grids; and in the end-use or "behind-the-meter" sector (including residential, institutional and commercial, and industrial electricity consumption). The range of sociotechnical factors that might be pertinent to consider in this regard is thus quite wide, running from the market/economic barriers, norms and institutional inertia noted by Grünewald et al. [12], to properties of the sociotechnical system in question, like regime stability, niche competitiveness, and political-economic dynamics.

Our interest in this paper leans more to the latter than the former, to the set of broader perceived benefits and risks of energy storage that might be associated with likelihood and/or acceptability of policy interventions to facilitate further development of storage. We submit that this is fundamentally a political question, and thus will depend upon the perspectives held by key system stakeholders on the transformative potential of energy storage. This is an important question to ask - as noted by Devine-Wright et al. [13], there is value in understanding the unique socio-political circumstances that surround energy storage in different locales – in order to help "reveal the politics behind policies" [13, p. 30].

2. Methodology and data

To our knowledge, there is no existing literature that clearly and explicitly defines a concept of technological 'transformative potential'. The transitions literature is clear that innovations are not necessarily transformative, in recognition of the reality that developmental pathways depend to a large extent on the perceptions and actions of the actors involved. It also suggests that the tendency of a sociotechnical regime is toward stability (and therefore not transformation). Grünewald et al. [12], note that the technical potential of storage is limited by market and institutional barriers, as well as cultural norms and institutional inertia, therefore implying that actions must be taken to address these barriers for storage to play a larger role. The likelihood, kind and degree of those actions, we noted, are also subject to

[1] See Ref. [22] for further analysis of the barriers to energy storage in the United Kingdom.