# 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.

**Keywords**

socio-technical systems; transitions; energy storage; Canada

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# 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 (Akhil et al., 2013). 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. Figure 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 (IESO, 2016). 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 (California Public Utilities Commission, 2017), 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 (Department of Energy Resources, 2015).

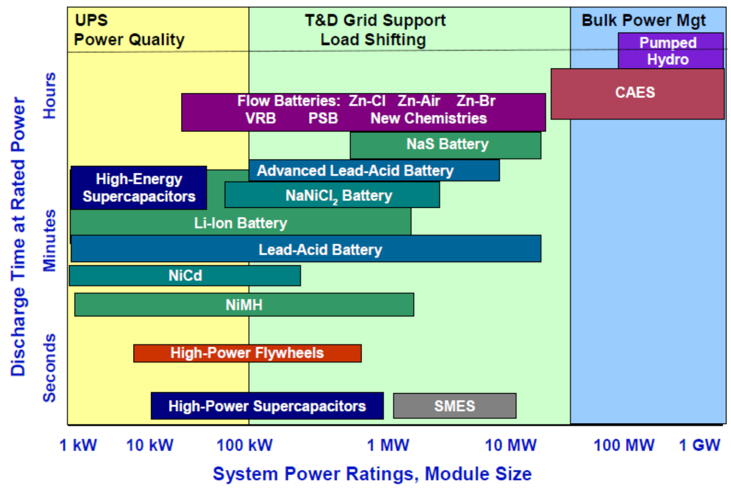


**FIGURE 1) POSITIONING OF ENERGY STORAGE TECHNOLOGIES (AKHIL ET AL., 2013)**

Why all the interest in energy storage? The reasons, like energy storage technologies, are many. Figure 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 (Akhil et al., 2013, 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) (International Energy Agency, 2014, 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 (Deal et al., 2010).

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.

## 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) (Grin et al., 2011).

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) (Geels, 2005, 2002; Grin et al., 2011). 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 (Geels and Schot, 2007). 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 (Avelino and Rotmans, 2009). 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 (Grin et al., 2011). 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. (2012), 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 (Grünewald et al., 2012, p. ___). 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. (2012) do note the need for future research to consider the potential "perverse incentives" or "unintended consequences" of policy to facilitate use of energy storage (Grünewald et al., 2012, 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. (2012), 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. (2012), 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. (2017), 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" (Devine-Wright et al., 2017, 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. (2012), 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

[1] See (Burlinson and Giulietti, 2017) for further analysis of the barriers to energy storage in the United Kingdom.

barriers for storage to play a larger role. Those likelihood, kind and degree of those actions, we noted, are also subject to sociotechnical system factors, including the perspectives of key stakeholders. Therefore, we propose that the transformative potential of an innovation is intertwined with how actors conceive of the transformative potential of the technology.

We thus interpret transformative potential as containing within it three separate but interrelated questions about energy storage: whether it is perceived as a *gateway* to the electricity system of the future, or a "*Swiss Army knife"* (providing multiple services, i.e., facilitative) to help with the operation of the current system; whether it is *here now* or "*on the horizon*" (as framed in a 2016 Ontario government discussion paper on the topic (Government of Ontario, 2016)); and, lastly, whether as an innovation, energy storage is primarily *adaptive* (i.e., helping established stakeholders adapt to change) or *disruptive* (i.e., threatening or challenging the positions of incumbent actors).[2] It is important to stress that, given the qualitative nature of the data we sought to collect, these questions were not intended to be binary and mutually exclusive options, but rather as spectrums along which perspectives on energy storage may be located.

Our choice of a single case study – the province of Ontario in Canada – reflects our intention for this study to serve as an early foray in the sociotechnical evaluation of energy storage, following in the footsteps of Grünewald et al. (2012), and thus as a template for future, comparative analysis among multiple jurisdictions (Eckstein, 1975; Yin, 2003). This choice was made in recognition of the value, when studying energy technology politics, in understanding and appreciating *local* or *regional-specific* considerations and narratives around the technology in question (Devine-Wright et al., 2017). Ontario also makes for an excellent case study as the province is one of the leading jurisdictions in North America in terms of procuring energy storage (as of 2017), having conducted two previous rounds of targeted procurement to acquire energy storage capacity at the bulk system level. Furthermore, Ontario was undertaking a long-term planning process to set a vision for the next five years of the Ontario energy system at the time of our research (called the "LTEP" – Long-Term Energy Plan), and had expressed an interest in preliminary documentation for that process in hearing from stakeholders as to the potential role that energy storage could play in that future (Government of Ontario, 2016).

Our process for gathering stakeholder perceptions on energy storage consisted of a series of semi-structured interviews with key stakeholders, exploring their perspectives on system benefits and risks of energy storage, on drivers and barriers to the deployment of energy storage, as well as on a set of conditions, trends, and/or present issues that are pertinent to the future potential of storage in the province. We sought to attain stakeholder perceptions from three broad actor groups: government (including Ontario government ministries, regulators, and agencies); non-government (including media, academic, research and/or think-tank organizations, and professional services (i.e., legal services, energy consultants)); and industry (including storage developers or proponents, local distribution utility companies (LDCs), and industry associations). Respondents were asked to express their own professional perspective on energy storage, and not necessarily that of the organization they were

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[2] Though the question of whether storage is adaptive or disruptive may at first glance seem identical to the question of whether it is a gateway or a Swiss Army knife, there is an important difference: adaptive/disruptive gets to the question of whether incumbent stakeholders can use storage to adapt to changing circumstances (and thus to maintain their privileged place in the system), or whether storage threatens to disrupt the status quo and, in doing so, create real and existential challenges for those stakeholders.

affiliated with. A total of 29 interviews were conducted on record (out of 63 invitations). Table 3 shows the breakdown of interviewees by actor group, and Appendix A lists interview participants (anonymized by a numeric code) by sector. Interviews are referenced by the anonymized code for each interview participant in the Results and Discussion sections below.

**TABLE 1) STAKEHOLDERS REPRESENTED AND INTERVIEWS CONDUCTED BY STAKEHOLDER GROUP**

| | Stakeholders (number of distinct organizations) | Interviews (number of distinct individuals) |
|---|---|---|
| Government | 4 | 8 |
| Non-government | 9 | 11 |
| Industry | 10 | 10 |
| Total | 23 | 29 |

The results and findings of these interviews are reported below in a narrative format, with positions and/or statements referenced with the associated interviewee by interview number. We recognize this is an unconventional way of presenting results, however we believe it is in line with our stated research objective. Our intention in this research was not to pit perspectives of different actor groups against each other, nor to associate certain actors with niches or regimes. Instead, we sought to identify and assess the range of factors that are present in stakeholders' minds when considering energy storage in Ontario and related issues and, where applicable, note potentially looming conflicts or political disputes that stakeholders themselves may not be fully aware of. Furthermore, though we include no direct quotations (partially because of the protocol agreed with our interviewees), we note that a draft of this paper was provided to all interviewees so that they could approve or ask for revisions to the way we referenced their interview. Two of the 29 took advantage of this opportunity, offering, in each case, one point of elaboration. Accordingly, we believe that our interpretation of stakeholders' perspectives is true to the actual beliefs and perspectives of the interviewees.

Finally, our objective in stakeholder selection was *not* to represent the most expansive "issue network" of actors with a stake in energy policy in Ontario, but instead to build a strong sample made up of a more restricted "policy community" of actors likely to have a direct interest in energy storage technology and policy (Fischer and Miller, 2017, chap. 10; Wolsink, 2010). We recognize that there are many such stakeholders in Ontario that may have an important perspective to add on energy storage, and that we have not captured all of them. This entails that our results and discussion are limited in how representative they are of stakeholder perceptions of energy storage in Ontario. Nevertheless, we do believe our research is useful in providing exploratory analysis and thereby insight into the factors influencing energy storage from a transitions perspective in the province.

# 3. RESULTS

As per previous research by Grünewald et al. (2012), we divide stakeholder perspectives along three sectoral lines, adapted slightly to reflect the Ontario electricity system structure: bulk system (i.e., large scale, centralized generation; transmission grids); distribution (e.g., local utilities, distribution grids), and end-use/behind-the-meter (residential, institutional/commercial, and industrial). We do not associate any individual stakeholder with these sectors however, as stakeholders often expressed perspectives on storage pertinent to more than one sector.

## 3.1. BULK SYSTEM

Stakeholders recognized several potential benefits and use cases for energy storage at the bulk system level, though perspectives on the degree to which energy storage specifically is required to provide them and which these benefits are needed in the short term, vary considerably. Here we can distinguish among three broad, yet interrelated classes of benefits: reliability, flexibility, and optimization. Generally speaking, reliability pertains to the provision of ancillary services, flexibility to balancing intermittency from renewables and providing capacity, and optimization to the use of storage to gain maximum value from existing assets.

The potential for energy storage to provide reliability to the grid through ancillary services (e.g., regulation, voltage support) at the bulk system level was widely recognized among stakeholders (2, 17, 22, 27, 33, 41, 43, 55, 57, 59, 61). Stakeholders pointed to single-service procurement of such services by the system operator to be a critical barrier to realizing this potential, followed by regulatory challenges that further reduce the competitiveness of storage resources. On the former issue, the reasoning was generally that energy storage can be most economical (indeed, more economical than existing assets providing services, e.g., natural gas plants) when used as a "Swiss Army knife", providing multiple different services at once (3, 6, 14, 21, 22, 40, 41, 43, 50). But, on procurements for single services, storage is not cost competitive with established assets. On the latter issue, the primary regulatory barriers are the various charges associated with being a load on the system (2, 6, 14, 21, 27, 41, 54, 59) which several proponents argued storage should be exempt from (21, 22, 27, 54) as well as the lack of a framework that would make it possible to capture the value of other, diffuse benefits provided elsewhere in the grid (2, 6, 33, 56, 58).

Consequently, some stakeholders were skeptical of storage's ancillary service potential in the near future. While agreeing that energy storage could play a role in providing ancillary services, some noted that it would be only in location-specific niches in the near-term (6, 19, 33, 40, 43, 59). Moreover, the desire for procurement practices that would allow 'stacking' of services amongst proponents is unlikely to be realized – operationally, future needs are not always easy to anticipate and there is some uncertainty as to how such an asset would be operated in practice (e.g., how to prioritize), or how it could be determined what it was providing when in operation (3, 6, 14, 35, 41, 50, 59). While stakeholders in each sector recognized the efforts of the government/IESO to procure storage through targeted programs to date, there was some dissatisfaction expressed that these projects were not yet operational, and thus that there is not enough knowledge to justify investing in energy storage for reliability purposes (27, 40, 41). Furthermore, on the 'role of government' in this regard, most stakeholders recognized and accepted the IESO's explicit goal of moving toward a more technologically-agnostic (or "outcomes-based") means of procurement, but some did express concerns about whether this would truly create a "level-playing field" (2, 14, 27, 35, 54). For instance, on the issue of consumption charges, non-industry stakeholders expressed a range of views, running from acceptance of the barrier created by double-taxing (6) storage to concern that storage proponents were looking for special treatment (41). In short, according to some (typically energy storage industry) stakeholders, a technologically-agnostic market for services without the exemption from consumption charges and without stacking services would not create a level-playing field, but for others (government, non-storage industry, non-governmental) doing so would be going too far to support storage in such a fashion.

Flexibility is a closely related potential benefit of energy storage on the bulk system grid, though one which some stakeholders perceived to be poorly defined in the existing system (14, 19, 61) and, consequently, one for which there is little near-term role for energy storage (19, 27, 61). There are several dimensions to this benefit, including balancing renewable generation (2, 3, 17, 19, 21, 27, 52, 55, 61), load following (22, 55, 56, 57), and capacity (22, 27, 57). Presently, load following and capacity are met largely by the natural gas fleet (and hydropower resources), contracts for most of which run to the mid-2020s leaving little role for energy storage to play in this regard. Regarding variable generation, curtailment clauses built into some contracts allow the IESO to forgo generation from wind, solar, and nuclear when necessary. Consequently, flexibility can be achieved without effectively being priced, according to one stakeholder, which further reduces the potential space for alternative flexible resources (19). While no stakeholders explicitly opposed the IESO's intention to address this exact issue through a market renewal process (e.g., through the creation of a capacity market), concerns were nevertheless raised about the possible impact on existing contract holders (55). Similarly, some stakeholders expressed concern about other government-led efforts to attain capacity outside of the market, for example through capacity agreements with neighbouring province, Québec (59).

Other interesting dynamics arose in relation to the interface among flexibility requirements, climate change planning, and the impending refurbishment of nuclear assets in the province – particularly concerning the place of natural gas in the Ontario energy system. While the long-term potential of storage vis-à-vis climate change (through its ability to balance and thus enable more renewable generation on the electricity grid) was widely recognized as a public benefit by stakeholders (2, 3, 17, 19, 21, 27, 43, 51, 52, 55, 61), some did *not* see this as a primary driver of interest in storage presently or over the near-term in Ontario, given that addition of new renewable capacity has been more or less halted and sufficient natural gas and hydropower capacity exist to provide flexibility at the moment (17, 33). The refurbishment of government-owned and private nuclear facilities, scheduled to take place over the course of several years before and after 2020, will necessitate greater reliance on natural gas generation to cover the capacity shortfall. Several stakeholders noted that this will increase emissions from the electricity sector, and that effort should be taken to ensure that capacity markets adequately align with public policy objectives vis-à-vis climate change (33, 58). Conversely, many stakeholders noted current costs of storage as a barrier to it playing a bigger role on such a short time frame (3, 6, 19, 40, 52, 57, 60). This coupled with stakeholder concerns about the impacts of market renewal on existing contract holders (noted above), the political salience of electricity prices (35, 55), but also the hostility toward government intervention among some industry and non-governmental stakeholders (19, 55, 59), all work against resolving this dilemma through targeted capacity procurement.

Thus, storage's potential to provide flexibility is constrained by past and present system arrangements. One stakeholder noted that, with nuclear refurbishment ending in the early-2020s and many long-term contracts with natural gas plants ending in the mid-2020s, the time could be serendipitous in a decade or so for renewables and storage to make significant gains (41). Yet, with the current dynamic appearing to work to cement the status quo, a significant flexibility role for storage in the near-term is unlikely.

The third potential benefit of storage on the bulk system – optimization – was often presented in concert with flexibility as a draw for storage. While the two are similar, it nevertheless makes sense to think of optimization as a distinct benefit from flexibility. Optimization, like flexibility, is often used to refer to the use of storage to even out troughs and peaks. However, it was typically positioned more as a *supplementary* benefit of storage (with regards to existing arrangements) by stakeholders who made note of it during interviews, rather than an alternative to current practices. Accordingly, optimization could be seen as a framing strategy (for proponents in particular) to counter the above dynamic that works against a near-term role for storage.

For example, several stakeholders noted that Ontario's occasional conditions of surplus baseload generation, arising from an inability to sufficiently curtail nuclear and renewables during periods of low demand and causing the province to dump surplus power at a loss (or even at negative rates) to neighbouring jurisdictions, is both economically *and* politically damaging (2, 14, 51, 60). Using storage to help absorb that surplus baseload generation is one way in which storage could help optimize the use of existing assets (2, 14, 21, 27, 30, 33, 52, 60). Optimization, as such, provides a service both to the grid and to political decision-makers (as it mitigates the image problems around bad contracts and poor decision-making). Stakeholders noted several other optimization benefits of storage, such as its ability to preclude "part-loading" and thus sub-optimal efficiencies of the natural gas fleet (e.g., by absorbing post-peak gas generation to allow the plant to run long enough to achieve its optimum efficiency) (14, 21), and to defer upgrades to existing distribution and transmission infrastructure (14, 17, 22, 41, 54, 57, 61).

Yet despite its ostensible 'win-win' nature, there was some skepticism about the potential for storage for optimization in the bulk system. One stakeholder noted that, given the size of Ontario's surplus baseload generation, any realistic amount of storage would never be able to absorb it all and even if it were, it would never be able to discharge (59). More broadly, technical and operational uncertainty (e.g., valuing such diffuse 'optimization' as public, services to the grid) remain as important barriers to the further development of energy storage in the province (noted above on regulatory barriers to reliability). The general support among industry and non-governmental stakeholders for technological agnosticism and markets enabling technologies to compete on a "level playing field" suggests that developing targeted means to address this problem (in addition to the past procurements) may not be a top priority in the province.

In summary, while recognition of the potential benefits of storage appears widespread among stakeholders, there is less consensus when it comes to acceptance of the conditions that could be associated with further storage deployment in the province, and exactly what a "level playing field" might entail. To the extent that flexibility is associated with system transition (i.e., more renewables, less natural gas), significant near-term prospects for storage seem low (arguments for optimization notwithstanding). From the perspective of the bulk system, storage seems constrained for the time-being to providing ancillary services, mainly in a "testing" context, and in niche, location-specific conditions (and only then through open procurements for the service in question).

## 3.2. DISTRIBUTION

While stakeholder perspectives on storage at the bulk system level were largely positive (if somewhat muted), storage in the distribution sector is both more uncertain and possibly disruptive. The main uncertainty is the customer; namely, how customer behaviour and preferences will evolve in the end-use / behind-the-meter sector, discussed in Section 3.3 below (41). The fact that distribution networks are caught between the centralizing tendencies of the bulk system and the decentralizing pressures of change in the end-use sector appears to be the main factor shaping perspectives of storage in this sector.

Stakeholders identified several different benefits of storage in distribution networks, though these were less associated with the "system-at-present" than the potential benefits of storage at the bulk system level. Perhaps the most facilitative role for storage in this sector was its potential to serve as a "non-wires alternative" allowing certain actors, namely local distribution utility companies (LDCs), to defer upgrades to other infrastructure assets (14, 17, 19, 22, 33, 41, 56, 57, 61). Similarly, storage could be beneficial in managing congestion, in certain regions and locations across the province (27, 57). Most of the discussion of storage in the distribution sector, however, centred around the growth of decentralized energy resources (DERs) in the province and the potential impact of that trend, if it continues as it had in recent years (see Section 3.3). In this context, distribution-level storage capacity is considered desirable for LDCs to maintain system reliability in the context of continued DER growth, and/or for meeting the evolving demands of their customers (for instance, in facilitating virtual net-metering among customers in a distribution network (2, 22, 33, 50); or for reliability in microgrids and remote communities (22, 30, 33)). The potential in aggregating storage resources in distribution networks to provide services to the bulk system was also noted, though not widely (56, 57, 61).

The evolving behind-the-meter storage question creates several risks for LDCs in Ontario, and it is these risks that are perhaps the main driving force behind interest in storage in the distribution sector. One commonly mentioned risk was the growing space for third-parties to provide and manage DERs and/or energy services for customers, which several stakeholders noted as a threat to the relationship between LDCs and consumers (17, 19, 33, 56). There are two primary components to this risk. On the one hand, if third-parties step in to provide cost-saving measures to customers this could disrupt this historic 'point-of-contact' relationship between LDCs and consumers, shift customer loyalty to the new parties, and do little to assuage consumers' negative perceptions of the management of the larger grid. On the other hand, is the question of the "death spiral" for utilities, wherein increased grid or load defection reduces utility income without reducing system costs. Of the stakeholders who spoke on this latter issue, however, all suggested that grid defection is not a concern in Ontario, though substantial load defection could create problems for LDCs (2, 17, 40, 59, 60), and political problems more generally if actions (or lack thereof) are taken to prohibit or slow down DER connection to the grid (17, 58). The recent shift to fixed-rate distribution charges in Ontario was intended to minimize the impact of load defection on customers who do not install DERs.

Stakeholders identified at least three possible avenues for addressing these challenges through the integration of storage in distribution networks in Ontario, distinguished by the degree and nature of involvement of LDCs in facilitating its development. The most restrictive case is that utility companies only act to connect behind-the-meter distributed resources installed by customers to the grid, but play little role in providing those resources, nor in coordinating or aggregating them to provide or attain a service or value to the distribution or bulk system grid more broadly (i.e., leaving this coordination to the IESO). Only one stakeholder explicitly discussed such a scenario, and as the "bare minimum" role of the LDC in the future (60). A more widely recognized scenario is where the utility company becomes, in effect, a mini-system operator, coordinating distributed resources and third-party storage projects on their network (though owning few or none themselves), facilitating market transactions among end-use consumers, and aggregating distributed resources to provide service to both the distribution grid and bulk system (e.g., energy, capacity) (17, 19, 30, 41, 60, 61, 63). A third pathway is also possible, in which utility companies (or, more likely, their unregulated affiliate businesses) invest in medium-sized energy storage projects designed to aid in the operation of their local network and/or get into the business of providing and managing distributed energy resources to their customers (e.g., renting rooftop solar systems to customers that are interested in them) (19, 41, 56, 63).

There were many barriers identified as prohibiting the more progressive scenarios from coming to pass. At the most general level, several stakeholders noted that the legacy of centralized planning and consequent amount of generation capacity and long-term bets on nuclear in the province limit the near-term need for new LDC business models (given the likely dampening effect these system features will have on the growth trend in DERs in Ontario) (6, 17, 35). Nevertheless, innovation is still considered desirable by most stakeholders, though many see it as “stifled” by the inherent conservatism of both the LDCs and the provincial regulator, the Ontario Energy Board (OEB) (3, 30, 54, 58). Several stakeholders noted that LDCs are most familiar and comfortable with their traditional “poles and wires” responsibility, and that adapting new business models would require a “shift in talent” (3, 17, 19, 30, 35, 41, 56, 59). As one stakeholder put it, the extent to which a true regulatory barrier exists to LDC innovation in this regard ultimately depends on the particular LDC and its Board of Directors (30).

Furthermore, several stakeholders noted that not all LDCs want to change, and that those that do tend to be larger, to have more resources at their disposal, and thus able to tolerate more risk around “non-wires” alternatives like energy storage (60, 63). Conversely, several stakeholders noted that though the OEB had expressed an interest in receiving proposals from LDCs for non-wires projects and that there were no concrete regulatory barriers to LDCs investing in or providing DERs or storage to their clients (through an unregulated affiliate), the lack of clarity on what specifically might be approved combined with the likely case that the LDC would have to absorb any losses from non-viable projects (i.e., not be able to “rate base” the cost), is sufficient enough a disincentive to prevent most LDCs from coming forward with such projects (3, 6, 17, 19, 21, 27, 54, 57, 63). Moreover, the lack of an institutional framework to allow LDCs (or any other party for that matter) to capture the value of additional benefits provided by storage to either their customers or to the transmission grid, and government intervention to reduce rates, further reduces the business case (3, 6, 33, 56, 58, 61, 63).

## 3.3. END-USE/BEHIND-THE-METER

The final electricity system sector examined here includes end-users and potential “behind the meter” applications for energy storage. Here, as noted above, the defining trend is the degree and speed of grid decentralization, spurred on by the installation of DERs (including storage) by residential, institutional/commercial, and industrial consumers.

With few exceptions (55), stakeholders perceive the long-run trend toward greater decentralization as likely to continue in Ontario, though the pace of the trend will depend on some key uncertainties moving forward. One of the main drivers of this decentralization, as perceived by stakeholders, is changing consumer preferences arising from the rise of engaged electricity consumers (2, 17, 19, 27, 33, 35, 43, 50, 54). As one stakeholder described it, the “customer indifference” that was once a function of the high complexity of electricity systems coupled with low rates was eroding in the face of increasing costs of the system and the decreasing costs of seemingly simple ‘alternatives’ (e.g., DERs) (35). However, several stakeholders noted that the recent growth in DERs in Ontario was largely a result of policy incentives stemming from a feed-in-tariff program that ended in 2017 (6, 19), and was replaced with revised net metering regulations thereafter. The policy uncertainty and potential impact on storage associated with this shift is discussed below.

Cost control and increased reliability were also consistently identified as potential benefits and thus drivers of storage in end-use applications, particularly for ICI consumers (2, 3, 6, 17, 22, 43, 50, 56, 60, 61). However, several stakeholders noted that action by the provincial government to reduce rates would reduce the business case for investment in energy storage by ICI consumers and potentially lead to stranded assets in this sector if investments had already been made (17, 19, 33). This is because, in Ontario, large consumers pay a global adjustment (GA) charge on top of the energy charge to help cover the costs of infrastructure and long-term contracts with generators (these costs are bundled into the regulated time-of-use prices for smaller and/or residential consumers). The largest consumers ('Class A') pay a GA cost that is multiplied by their consumption during the five system peaks throughout a predetermined base period. Effective use of storage by ICI consumers, particularly Class A consumers, could therefore potentially reduce GA costs significantly (by minimizing consumption during projected system peak periods). But, if the GA is reduced through government intervention, the case for storage dissipates.[3]

Of the stakeholders who spoke to it, most considered the economics of storage to be presently unviable in the residential sector (2, 19, 22, 27, 52) and what interest that does exist to be limited to early adopters and those driven by the "hype" around storage associated with figures like Elon Musk (14, 17). Consequently, many stakeholders associated the disruptive potential of storage in this sector to be a function of how fast costs (for storage and other DERs) come down (6, 19, 22, 27, 30, 40, 57, 59, 60).

Stakeholders identified several, interrelated, barriers and/or risks that could have a large bearing on the extent and pace of decentralization in Ontario. The first of those is the uncertainty stemming from the shift from feed-in-tariffs to net metering. In its final period, the feed-in-tariff program offered rates for wind and solar ranging from 12.5¢ / kWh for onshore wind greater than or equal to 500kW to 31.1¢ / kWh for rooftop solar less than or equal to 6 kW (all solar tariffs were above 19¢ / kWh) (IESO, 2017a); rates that are broadly considerably higher than the average per-kilowatt-hour rate paid by most consumers, including Class A and B (see Figure 1Figure 2).

[3] Notably, the provincial government did intervene to reduce rates in the summer of 2017, in part by expanding the class of consumers eligible for Class A status, and re-financing its leases on certain core capital components of the GA. It is unclear if the combination of lower system-wide GA costs coupled with ICI measures to minimize their own GA costs will cancel each other out, or lead to higher costs for non-Class A consumers.

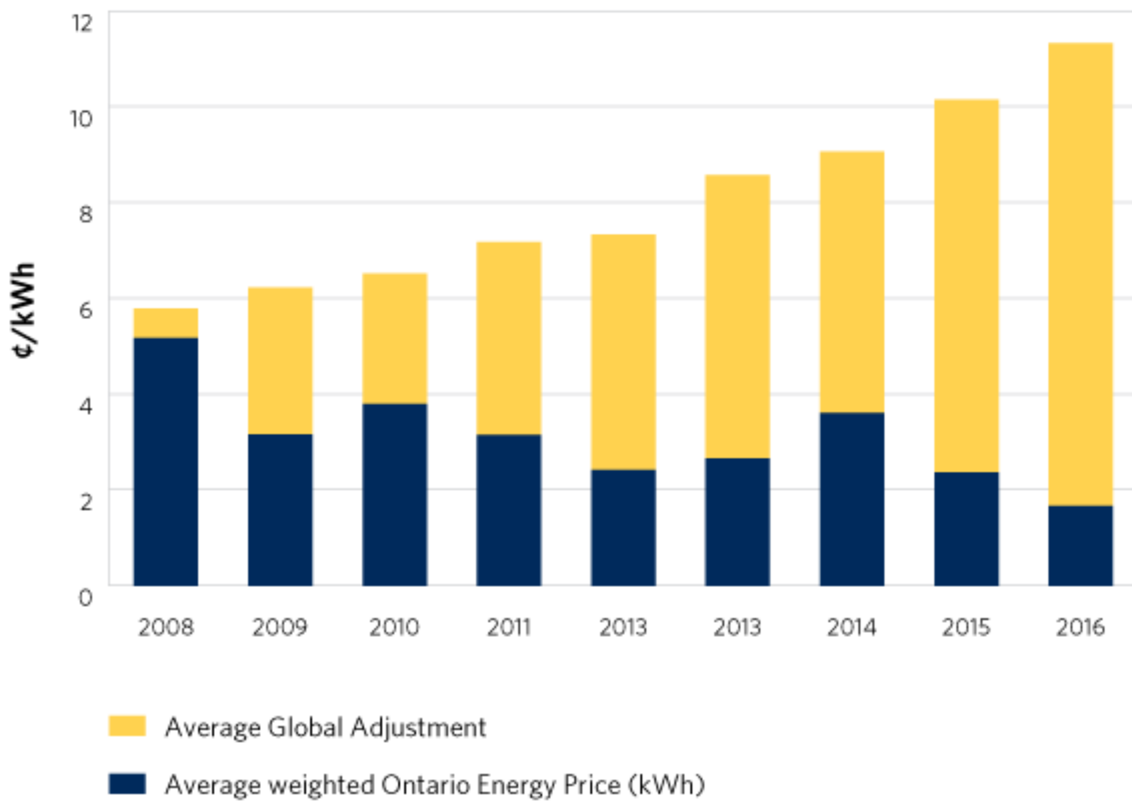


**FIGURE 2) AVERAGE ENERGY PRICE AND AVERAGE GLOBAL ADJUSTMENT IN ONTARIO (IESO, 2017B)**

There are lots of questions to be addressed (2, 22, 33, 41, 50, 52, 57, 61): Will small consumers receive payments at the scheduled time-of-use prices, an average rate, or at the hourly spot-market rate (the same question largely applies to larger consumers paying the GA as well)? Will the regulations allow for virtual net metering and/or market transactions between end-users? Will the combination of distributed generation and net metering increase the incentive for ICI consumers to use storage to minimize demand charges? How a transition to net metering will impact consumers' interest in DERs is thus quite complex and uncertain.

This uncertainty is complicated by a second risk – government intervention, either to reduce and/or manage rates (see Footnote 1); to prescribe certain technological or capacity solutions (55, 59); or to put in place measures to minimize potential disruption associated with DERs, e.g., a disconnection fee (30). As discussed above, several stakeholders noted that intervention to manage rates reduces the incentive of consumers to purchase DERs and storage, and to participate in net metering. However, perceived high cost is not the only political pressure that could influence government intervention. The commitment to further reducing emissions and meeting climate change action plan targets could also shape decentralization, either positively (if actions are taken to further electrification of end-use heating and transportation, thereby creating additional load that could justify more distributed generation) or negatively (if actions are taken to attain low-carbon generation, and potentially storage, capacity in the form of negotiated arrangements with neighbouring, predominantly hydroelectric provinces, thereby reducing the need for similar, distributed resources). The government could also intervene with the direct intent of slowing DER and end-use storage diffusion, if it perceives that trend to be detrimental to the system overall.

Accordingly, the last potential barrier to decentralization and end-use storage, and a key reason why stakeholders expressed concern about government intervention, was the degree of lock-in to the present system. This lock-in was perceived to be the consequence of two factors: the high degree of capital tied up in the present, centralized system (52) and, relatedly, the fact that Ontario has sufficient generation capacity to meet its projected needs at least until the mid-2020s (6, 19), most of which operates through long-term power purchase agreements with the system operator. Thus, while DER growth may itself increase the need for distributed or behind-the-meter storage, the low disruptive potential of decentralization proceeding outside centralized control before the mid-2020s, thereby stranding bulk-system generation and transmission assets, private and public, creates a countervailing incentive for regime actors (including, but not limited to, government) to minimize that risk.

# 4. DISCUSSION

Our intention in this paper was to identify and assess sociotechnical factors that may shape the transformative potential of energy storage. We asked whether storage is a gateway or a "Swiss Army knife"; whether is it here now, or on the horizon; and, lastly, whether is it primarily adaptive or disruptive. Below we will discuss the results of our research with reference to these three questions, highlighting the implications for our understanding of energy storage's transformative potential.

## 4.1.A GATEWAY OR A SWISS ARMY KNIFE?

Our findings suggest that storage is not perceived as a gateway to the electricity system of the future in Ontario, but rather as an important *feature* of the electricity system of the future. To the extent that 'gateway' implies a stepping stone, necessary to be put in place first before the system of the future can be constructed, storage does not qualify as such in either the bulk system, distribution networks, or the end-use sector. While many stakeholders did associate storage with expanded potential for reliably incorporating more variable generation into the grid, current institutional frameworks, storage costs and – more importantly - system conditions (i.e., adequate capacity under existing long-term contracts) appeared to have forestalled the need to start building the "system of the future" today. Accordingly, potential for energy storage, particularly in the bulk system, is relegated to niche, location-specific – facilitative - services for the medium term (~8-10 years). The fact that "optimization" is presented as a key benefit of the technology, particularly among industry proponents, suggests that niche actors are conscious of this and are explicitly positioning the technology as facilitative in the context of the present system.

An apparent consequence of the benign view of storage in this sector is that there appears to be less willingness on the part of regime actors to undertake strong actions to speed up (or slow down) energy storage diffusion. The limited potential of storage in the medium term necessitates only minor adjustments to ensure a "level enough" playing field for it to fill niche roles. This is mostly true of storage in the distribution sector as well, where stakeholder concerns about the technology itself are less salient than the more pressing question of institutional change. However, unlike the bulk system, distribution networks in Ontario are exposed to more pressures for change (competition from third-parties, evolving consumer preferences, grid/load defection, etc.,). Storage could be facilitative in some circumstances, a gateway to a more decentralized future in others, but institutional change will be necessary in either scenario. Accordingly, there is more room for contention (and alliance formation) here, around what changes should be made and whose responsibility it is to make them, than there is in the bulk system.

Stakeholders' perceptions of storage benefits and opportunities in end-use sector do not fit as easily into the gateway/Swiss Army knife category, since most stakeholders seemed to consider cost control as the main driving factor behind interest in storage in this sector, even in association with distributed renewable generation. Furthermore, the general agreement that storage is presently uneconomic for such purposes in most situations in Ontario suggests limited near-term integration. Nevertheless, decentralization was widely perceived as a system change that is unlikely to stop (though perspectives on speed differed), one which could create problems for the bulk system and distribution networks, and one for which storage would certainly be "facilitative". At the same time, several stakeholders – some of whom would not benefit from greater decentralization - expressed rather negative attitudes toward government efforts to mitigate or control rate increases in the system overall, or otherwise intervene in a non-market fashion in the electricity system. The combination of these factors creates a complex situation for storage (and associated enabling interventions) in the end-use sector, which we will discuss further in the adaptive/disruptive section below.

## 4.2. HERE NOW OR ON THE HORIZON?

From a technical / economic standpoint, our findings indicate that stakeholders in Ontario perceive energy storage to be closer to 'here now' in bulk system applications (albeit in niche circumstances) and more 'on the horizon' in distribution networks and behind-the-meter applications (though see 'Postscript' below). The barriers to energy storage playing a larger role in the latter sectors are more institutional and behavioural than in the former. A more interesting discussion is what stakeholders perceive to be the implications (e.g., consequences, risks) of storage development timelines in each sector. Here, the line of political debate is less about when storage will become 'feasible' (irrespective of institutional and/or policy adjustments to remove non-economic barriers to its use), and more about what is (or is not) *realistic* when it comes to envisaging storage's role in a future Ontario electricity system. There are a couple different senses of 'realism' in which this appears to be the case.

One is where being 'realistic' implies being reasonable about the potential of storage now and into the future. For example, stakeholders from all sectors agreed that, in certain, non-market bulk-system applications, storage is indeed "here now" (often pointing to the previous targeted procurements run by the system operator). In effect, this appears to be a 'realistic' statement of storage potential presently; one that few stakeholders appear to take issue with. However, this agreement breaks down somewhat in consideration of what could or should be done to enhance the role storage could play in the future. Proponents argued that storage could play a bigger role in optimizing use of existing assets were certain policy and institutional changes to be made to level the playing field (e.g., procuring for multiple services at once, and allowing storage to purchase electricity at or closer to wholesale rates), though other stakeholders disagreed that the playing field was biased. Instead, these stakeholders tended to argue, energy storage can play a bigger role if and when it is able to compete with existing assets in a technologically-agnostic, single-service procurement process. In other words, it is not realistic to propose a more expanded role for storage at present if it requires targeted institutional changes to realize it. Similarly, the perspective of several stakeholders that the adequate capacity on the grid already inhibits a larger role to be played by storage, or that any 'realistic' amount of storage at grid-scale wouldn't be able to discharge surplus baseload generation, also implies calls for a larger role in the medium-term are unrealistic.

A related connotation pertains to situations where interest or actions benefiting storage are perceived as non-rational. For instance, the perception held by several stakeholders that interest in storage in the end-use sector is hype because of the association with high-profile figures like Elon Musk, or when other stakeholders noted that a vocal industry lobby is an important factor driving interest in storage in the bulk system. A possible implication is that stakeholders holding such a perception will be inclined to be dismissive toward energy storage – holding a positive attitude overall, but nonetheless considering it to be a distraction from more important and pressing issues.

Continuing along that vein, a third sense of realism is prudence. Many stakeholders agreed that decentralization will continue, but that the pace may slow in the transition from feed-in-tariffs to net-metering (implying behind-the-meter storage is 'on the horizon'). Nevertheless, consumer preferences are changing. As noted by one stakeholder, if regulators and utility companies become perceived by consumers as inhibiting or blocking integration of DERs, the consequences could be dire (erosion of customer loyalty, increased third-party competition, etc.,). This could be particularly concerning if cost reductions in distributed storage and generation proceed quicker than expected (the disruptive potential of storage is discussed in the next section), which several stakeholders identified as a risk to distribution networks. The implication is that, even though storage may be on the horizon in such situations, prudence dictates that stakeholders take more immediate actions. However, countervailing pressures from the bulk system / regime-level (i.e., to reduce rates, to minimize the risk of stranding assets) versus those coming the bottom-up (more independence, more autonomy, more control over costs) suggest antagonistic if not oppositional understandings of what near-term actions are or would be prudent by different stakeholders.

## 4.3. ADAPTIVE OR DISRUPTIVE?

Our findings suggest that stakeholders in Ontario perceive storage to be largely adaptive at the bulk system level, and – potentially, depending on cost reductions – disruptive in the end-use, behind-the-meter sector.

The important point to note, however, is that the disruption that storage could create in the latter sector would reverberate throughout the entire electricity system, and thus be disruptive to the bulk system and possibly the disruption of network actors as well. Here the notion of regime/niche breaks down somewhat - not all incumbent (or regime) actors are equally threatened by storage; rather, it is stakeholders with a closer interest in the centralized system model that stand to lose the most to rapid and unmanaged DER growth in the end-use sector. Though incumbent stakeholders in the distribution sector do appear "caught between" the centralizing forces of path dependency at the bulk system level and the decentralizing pull of DERs in the end-use sector, with some actors being more amenable to innovation and change and others perhaps less so, decentralization creates opportunities for LDCs that it does not for some established actors at the bulk system level. Hence the interest in scenarios with more expanded roles for LDCs in acting as mini-system operators, or suppliers and managers of DERs for consumers.

The legacy of Ontario's electricity system evolution should not be overlooked as a contributing factor to this dynamic. Ontario attempted to privatize and deregulate its electricity system in the late 1990s and early 2000s but had to abort the process mid-way, leaving the "hybrid system" characteristic of the province today. The consequence has been that 44% of generation capacity is still owned by a public company (Ontario Power Generation), as well as approximately 49% of the utility that operates the transmission network (Hydro One). Furthermore, the substantial natural gas generation capacity on the grid (approximately 28% of total capacity), though privately owned, also stands to gain little from significant amounts of storage on the grid (arguments for optimization notwithstanding – though these may appeal to system operators and central, political decision-makers, whether they appeal to the private generators themselves is a different question). These stakeholders, along with the civil society organizations that represent them, have a common interest not only in mitigating any potential disruption from storage and decentralization, but also in prolonging Ontario's commitment to a centralized system. These interests suggest that stakeholder perspectives of storage, and particularly the conditions that might be associated with greater diffusion thereof, while benign and moderate now, could become more agnostic or dismissive if friction between centralizing and decentralizing forces increases in the future (Winfield et al., 2018; Winfield and Dolter, 2014).

# 5. CONCLUSION: THE TRANSFORMATIVE POTENTIAL OF ENERGY STORAGE

What can be said of the potential of energy storage in Ontario? Overall, we observe that similar market / institutional and normative barriers to storage as in the UK also exist in Ontario, but that it is not completely accurate to say storage is thus 'poorly aligned' with the existing system. Indeed, storage at the bulk system appears well-aligned, in the sense that there is a recognized need for more flexibility and only some relatively minor market and institutional barriers to storage playing a larger role in providing it. Rather, it may be more accurate to say that the electricity system itself is poorly aligned in Ontario, in that possible developmental pathways for different sub-sectors are diverging with potentially detrimental consequences for the grid as a whole. Storage plays a part in this, but is also constrained by it. Technological advances and cost reductions of storage make it more attractive in distribution and end-use applications, thus making decentralization a viable pathway, but in doing so reinforce the incentives for certain actors to try to limit or control that process, preventing it from stranding assets on the centralized grid.

Accordingly, we observe that interest in energy storage in Ontario is not presently closely associated with a desire to move further toward a low-carbon electricity grid (i.e., a gateway). Instead, storage is largely facilitative because Ontario is playing "catch-up". Institutional configurations and interventions from the past – efforts to exert control over the direction of change in the electricity system toward lower carbon sources of electricity – had consequences that were not so much unintended as they were unanticipated (e.g., consumers became very upset about costs). Present interest in storage in Ontario is thus to a large extent for its potential to mitigate those consequences, and not necessarily to go further down the path envisioned by those that originally designed the policies.

This brings us to a secondary observation – the actors involved here are not unreflexively self-interested. Narratives shift around innovative technologies, not because of shifting power balances between regime and niche, but rather because actors strategically reframe things they are interested in to align them with present plans, problems, and objectives. Energy storage used to be seen as a golden ticket to low-carbon grids, but now it is explicitly promoted (by the industry) as a 'Swiss Army knife' to help optimize existing resources. It isn't clear that this reframing is due to powerful incumbent actors reasserting control over the direction of electricity system policy in Ontario, but rather a recognition that present concerns about cost are the most salient issue on which to connect storage. Similarly, nearly all stakeholders interviewed here recognized that decentralization is likely to continue in the future, but none opposed it on grounds for the inherent benefits of centralized electricity systems. Instead, those more closely connected with the current 'regime' stressed only the importance of avoiding actions that could increase costs (i.e., the risk of stranding existing assets).

Overall, we find that while the technical potential of innovative technologies depends on the ability of actors to develop and implement policies and strategies to control their integration into the system, the transformative potential of innovative technologies appears inversely related to that ability to maintain control. Technology is most disruptive when it moves faster than the interested policy community believed it could and thus faster than they can move to 'contain' it – when assumptions about what is realistic to think about technology are proven faulty. For energy storage in Ontario, this is evidenced by the perceived facilitative aspects of storage at the bulk system (in that it is recognized to be 'here now', though mainly in niche applications that promise no drastic revision to the centralized electricity grid) in contrast to the transformative potential in distribution and end-use sectors (not 'here now' but difficult to predict when it will be, and coupled with a set of actors that are institutionally-designed to be conservative, i.e., the local utility companies and the regulator).

Therefore, when talking about transitions, systems innovation, and transformation, it is important to resist the temptation to abstraction. Electricity systems are not monolithic, and neither are the actors involved, or the available innovations. Our research shows that the situation for energy storage is different in each sub-sector of the electricity sector. Though certain actors may be formally and institutionally-bound toward stabilization and conservatism, this doesn't mean that the people involved are unaware of trends and opportunities, or opposed to doing more to capitalize on them (if only to minimize the potential for disruption associated with uncontrolled change). It is clear that storage promises no one thing – it may lead to decentralized, low-carbon electricity grids, owned and largely operated by smaller, local or community actors (or the users themselves), or large, foreign corporations may retain control of the assets and operate them in a way that does not necessarily work toward the public interest. Or it may simply end up playing a relatively niche, facilitative role in making the centralized grid work well.

Ultimately, transformation is not monolithic itself. This is not equivalent to the position of the transitions literature that transitions are neither necessary in the presence of innovation, nor linear and predictable once set upon a recognized transition pathway. In that sense, we observe that, at the present moment, storage in Ontario appears to be facilitating a 'reconfiguration pathway', wherein "symbiotic innovations, which developed in niches, are initially adopted in the regime to solve local problems[,] subsequently trigger[ing] further adjustments in the basic architecture of the regime" (Geels and Schot, 2007, p. 411). But, it is not apparent that that pathway is internally consistent across the entire system. What may be facilitative and beneficial to the operation in one part of the system may be completely disruptive and detrimental in other parts of the system. Cheaper storage at the bulk system level may help provide flexibility and support the integration of grid-scale renewables, but in doing so it may create a system incentive to block decentralized energy resources – or make them even more potentially disruptive. Therefore, we conclude, the transformative potential of energy storage in Ontario will be ultimately be determined by the interaction between intervention and unanticipated consequences in different sub-sectors in the electricity system, and the outcomes of the struggles of actors to exert control over them.

## 5.1. POSTSCRIPT

In the months following the completion of this research, the Ontario system operator (IESO) issued a request for proposals for the provision of a regulation services. Results were announced in November 2017. Two energy storage projects, both of which are 'new' projects (i.e., not existing storage projects operating under a previous procurement process) were awarded contracts, thus nearly doubling the total storage capacity contracted by the province (from 56MW to 111MW). The results of this process seem to indicate that storage is now capable of competing with existing grid assets on a single service procurement, without special treatment or provisions to allow for stacking of services.

The implications, specifically for whether provisions for stacking of services are necessary to 'level the playing field' for storage, are unclear, but perhaps inconsequential to the findings outlined here. Proponents may continue to argue that stacking services is still necessary to get the best value of energy storage assets, while those closer to the regime may continue to argue they are not. Indeed, it is possible that this development could further harden the difference of perspective between these two actor groups.

# 6. APPENDIX A

| **Interviewee Code** | **Sector** | **Detail** |
|---|---|---|
| 2 | Industry | Industry Association |
| 3 | Non-governmental | Academic |
| 6 | Governmental | Confidential |
| 14 | Industry | Industry association |
| 17 | Non-governmental | Research / Think-tank |
| 19 | Non-governmental | Research / Think-tank |
| 21 | Industry | Storage developer / provider |
| 22 | Industry | Storage developer / provider |
| 27 | Industry | Storage developer / provider |
| 30 | Non-governmental | Academic |
| 33 | Non-governmental | Consulting / Legal services |
| 34 | Non-governmental | Consulting / Legal services |
| 35 | Industry | Storage developer / provider |
| 40 | Governmental | Confidential |
| 41 | Governmental | Confidential |
| 43 | Governmental | Confidential |
| 46 | Governmental | Confidential |

| | | |
|---|---|---|
| 50 | Governmental | Confidential |
| 51 | Non-governmental | Academic |
| 52 | Governmental | Confidential |
| 54 | Non-governmental | Consulting / Legal services |
| 55 | Industry | Industry association |
| 56 | Industry | Utility company |
| 57 | Non-governmental | Research / Think-tank |
| 58 | Non-governmental | Media |
| 59 | Industry | Industry association |
| 60 | Industry | Industry association |
| 61 | Governmental | Confidential |
| 63 | Industry | Utility company |

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