WORLD ENERGY COUNCIL

FIVE STEPS TO ENERGY STORAGE

Innovation Insights Brief | 2020

In collaboration with the California Independent System Operator (CAISO)

ABOUT THE WORLD ENERGY COUNCIL

The World Energy Council is the principal impartial network of energy leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all.

Formed in 1923, the Council is the UN-accredited global energy body, representing the entire energy spectrum, with over 3,000 member organisations in over 90 countries, drawn from governments, private and state corporations, academia, NGOs and energy stakeholders. We inform global, regional and national energy strategies by hosting high-level events including the World Energy Congress and publishing authoritative studies, and work through our extensive member network to facilitate the world's energy policy dialogue.

Further details at www.worldenergy.org
and @WECouncil

Published by the World Energy Council 2020

World Energy Council
Registered in England and Wales
No. 4184478

VAT Reg. No. GB 123 3802 48

Registered Office
62–64 Cornhill
London
EC3V 3NH
United Kingdom

ABOUT THIS INSIGHTS BRIEF

This Innovation Insights brief on energy storage is part of a series of publications by the World Energy Council focused on Innovation. In a fast-paced era of disruptive changes, this brief aims at facilitating strategic sharing of knowledge between the Council's members and the other energy stakeholders and policy shapers.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

As the global electricity systems are shaped by decentralisation, digitalisation and decarbonisation, the World Energy Council's Innovation Insights Briefs explore the new frontiers in energy transitions and the challenges of keeping pace with fast moving developments. We use leadership interviews to map the state of play and case studies across the whole energy landscape and build a broader and deeper picture of new developments within and beyond the new energy technology value chain and business ecosystem.

The topic of this briefing is **energy storage**. We interviewed energy leaders from 17 countries, exploring recent progress in terms of technology, business models and enabling policies. We showcase these in 10 case studies. While the brief addresses energy storage as a whole, most insights are focused on electrical storage. **Our research highlighted that today's mainstream storage technologies are unlikely to be sufficient to meet future flexibility requirements resulting from further decentralisation and decarbonisation efforts.** Furthermore, a restricted focus on lithium-ion batteries is putting the development of other cost-effective alternative technologies at risk.

Our findings are based on interviews conducted with the following organizations:

- ACWA Power
- Avalon Battery
- BP
- Bright Source
- CAISO
- CPUC
- DBL Partners
- Delft University of Technology
- DNV GL
- Emerald Ventures
- Energy Storage Association
- Everoze
- Fluence
- HighView Power
- Hydrostor
- Iberdrola
- IERC
- IHS Markit
- Ion Venturest
- Kraftblock
- Noor Energy 1
- Nrstor
- ON Energy Storage
- Piller
- RTE
- Siemens
- Siemens Gamesa
- Stem, Inc
- Storengy
- SunRun
- The Energy Institute
- UC Berkeley
- Valhalla
- Verbund
- Vestas
- Zola Electric

A detailed list of the interviews with innovators, energy users and producers can be found at the end of this brief. Annex 4 provides a list of acronyms and abbreviations.

With major decarbonisation efforts and the scaling up of renewable base generation, the widespread adoption of energy storage continues to be described as the key game changer for electricity systems. Affordable storage systems are a critical missing link between intermittent renewable power and a 24/7 reliability for a net-zero carbon scenario. Beyond solving this salient challenge, energy storage is being increasingly considered to meet other needs such as relieving congestion or smoothing out the variations in power that occur independently of renewable-energy generation. **However, whilst there is plenty of visionary thinking, recent progress has focused on short-duration and battery-based energy storage for efficiency gains and ancillary services**; there is limited progress in developing daily, weekly and even seasonal cost-effective solutions which are indispensable for a global reliance on intermittent renewable energy sources.

The synthesis of thought leadership interviews and case studies with 36 companies and organizations from 17 countries helped derive the following key takeaways and also provide the impetus to the solution steps that we discuss in detail later in this brief:

KEY TAKE AWAYS

1 **SHARED ROADMAPS**
Energy storage is a well-researched flexibility solution. However, while the benefits of energy storage are clear to the energy community, there has been limited bridge-building with policy-makers and regulators to explore the behavioural and policy changes necessary to encourage implementation.

2 **MARKET DESIGN - ACCESS & STACKING**
Market access and the ability to stack different services simultaneously will enable cost-effective deployment of energy storage, regardless of the technology.

3 **MORE THAN BATTERIES**
Energy storage is too often reduced to battery technologies. Future-proofing our energy systems means considering alternative solutions and ensuring technologies have equal market opportunities. Demonstration projects of such technologies are necessary to disprove bias towards specific technologies.

4 **SECTOR COUPLING**
Energy storage presents a sector coupling opportunity between hard-to-abate sectors, such as mobility and industry and clean electricity. Different vectors of energy can be used, including heat, electricity and hydrogen.

5 **INVESTMENT**
Relying on investments by adjacent sectors such as the automotive sector is not enough. The energy sector must more aggresively adopt technologies aligned with the end-goal: affordable clean energy for all.

INTRODUCTION

Since 2009, the Council has been conducting a global survey of critical energy issues for its horizon scanning tool (Issues Monitor). This horizon scanning tool is a reality check of what energy leaders perceive as action priorities and what they perceive as uncertainties toward their respective energy transitions. It enables an understanding of the world energy agenda and the evolution of priorities on a historical and geographical basis. **Since 2015, the global perspective is that energy storage and renewables are action priorities, meaning that energy stakeholders from across the globe are working to incorporate these technologies into their energy transition portfolios**. In addition, World Energy Scenarios published in 2019, highlights that the pace of change is dependent on deployment and further development of energy storage.

As electricity systems evolve, there is an industry-wide recognition of the necessity to deploy additional new and flexible storage solutions. These flexible solutions are essential to meet new demand for diverse needs (including transport), to enable the reliable integration of intermittent renewables and to facilitate the cost-effective switching between supply and storage. Nonetheless, **significant progress remains to be achieved globally in terms of developing supportive policy and market frameworks for energy storage**. The interviews conducted as part of this brief very clearly show where and how deployments of energy storage are occurring.

Energy storage is a well recognised flexibility tool, both for electrical and thermal storage. However, as noted from the key takeaways drawn from the thought leadership interviews and case studies, there are missing elements that are preventing energy storage from providing their potential benefits. Industry, policy makers and regulators need common understanding derived from shared roadmaps. Market design needs to evolve to enable the access for new storage service opportunities and should be technology agnostic because energy storage needs to be more diversified than batteries. Adjacent sectors may provide new storage solutions beneficial for the energy system and investment should explore all potential storage technologies. Using these takeaways as foundational building blocks, we explore a set of helpful steps for energy storage developers and policymakers to consider while enabling energy storage. These steps are based on three principles:

1. encourage whole system thinking,
2. focus on energy storage as an "affordable and deeper" decarbonisation option, and;
3. advocate for technology-openness.

STEP 1: Enable a level playing field

- Clearly define how energy storage can be a resource for the energy system and remove any technology bias towards particular energy storage solutions
- Focus on how energy storage can contribute to a better energy transition

STEP 2: Engage stakeholders in a conversation

- Engage all relevant stakeholders to explore all potential energy storage needs
- Consider whether alternatives may be more suitable than energy storage

STEP 3: Capture the full potential value provided by energy storage

- Provide equitable access to ESS to all energy market services and products
- Stack revenues through the ability of storage technologies to offer multiple simultaneous market services
- Explore sector coupling opportunities with industry

STEP 4: Assess and adopt enabling mechanisms that best fit to your context

- Learn from & with others to identify those policies that best suit to your circumstances
- Ensure that there is no bias against or for behind-the-meter energy storage

STEP 5: Share information and promote research and development

- Maintain a long-term horizon in mind and promote R&D, especially for long duration storage
- Promote information sharing across the industry and beyond

In addition to the interview process to identify the enabling steps in the next section, we also prepared 10 case studies to showcase a variety of technologies at different stages of development which can provide daily, weekly and even seasonal solutions. These case studies can be found in the Annex I and focus on:

- Different energy storage applications
- The business models implemented
- The conditions for replicability of the different projects
- The value creation and cost-effectiveness of different case studies
- The lessons learned, whether they are technical, economic or regulatory

List of case studies (in alphabetical order by technology):

Project	Technology	Focus	Location
Angas A-CAES Project	A-CAES	Australia's first Advanced Compressed Air Energy Storage (A-CAES) facility	Australia
HighView Power	Cryogenic energy storage	Long-duration energy storage	United Kingdom
Siemens Gamesa Renewable Energy	Electric Thermal Energy Storage	Large-scale, long-duration solution	Germany
Project Centurion	Hydrogen	Feasibility study on storing 100% hydrogen in salt caverns	United Kingdom
ON Energy Storage	Lithium-ion battery	First industrial BESS to provide frequency regulation in Mexico	Mexico
Experion Energy Program	Lithium-ion battery	Large scale BTM deployment program	Canada & USA
IERC StoreNet	Lithium-ion battery	Residential storage to operate in the form of virtual power plant	Ireland
Kennedy Energy Park	Lithium-ion battery	Wind, solar and battery hybrid power plant solution	Australia
RINGO project	Lithium-ion batteries	Transmission congestions relief	France
Noor Energy 1	Molten Salt	Hybrid CSP and PV power station	United Arab Emirates
Espejo de Tarapaca	Pumped hydro	Seawater pumped hydro storage	Chile

Figure 1 – Sample overview of storage technologies

	ELECTRICAL		MECHANICAL			ELECTROMECHANICAL			CHEMICAL	THERMAL
	Superca-pacitors	**SMES**	**PHS**	**CAES**	**Flywheels**	**Sodium Sulfur**	**Lithium Ion**	**Redox Flow**	**Hydrogen**	**Molten Salt**
Maturity	Develop-ing	Develop-ing	Mature	Mature	Early commer-cialised	Commer-cialised	Commer-cialised	Early commer-cialised	Demon-stration	Mature
Efficiency	90-95%	95-98%	75-85%	70-89%	93-95%	80-90%	85-95%	60-85%	35-55%	80-90%
Response Time	ms	<100 ms	sec-mins	mins	ms-secs	ms	ms-secs	ms	secs	mins
Lifetime, Years	20+	20+	40-60	20-40	15+	10-15	5-15	5-10	5-30 years	30 years
Storage duration*	min - hr	ms - min	4 - 20hr	4 - 30hr	s - hr	min - 8hr	<8hr	<10hr	up to months	hr
Discharge time	ms - 60 min	ms - 8 s	1 - 24 hs+	1 - 24 hs+	ms - 15 min	s - hr	min - hr	s - hr	1 - 24 hs+	min - hr
Environmen-tal impact	None	Moderate	Large	Large	Almost none	Moderate	Moderate	Moderate	Depend-ent of H2 production method	Moderate
Possible applications by technologies										
Power quality	✓	✓			✓	✓	✓	🤞		
Energy arbitrage			✓	✓	🤞	✓	✓	✓	🤞	✓
RES integration		✓			✓	✓	✓	✓	✓	
Emergency back-up					✓	✓	✓	✓	🤞	
Peak shaving			✓	✓		✓	✓	🤞	🤞	🤞
Time shifting			✓	✓		✓	✓	🤞	🤞	🤞
Load leveling			✓	✓		✓	✓	🤞	🤞	🤞
Black start						✓	✓	✓	🤞	🤞
Seasonal storage			🤞	✧					🤞	🤞
Spinning reserve		🤞			🤞	✓	✓	🤞	🤞	
Network expansion			✓	🤞		✓	✓	🤞	🤞	🤞
Network stabilisation	🤞	✓			🤞	✓	✓	🤞		
Voltage regultation	🤞	🤞			🤞	✓	✓	✓		
End-user services	🤞	🤞			🤞	✓	✓	🤞		

Sources: Interviews, Schmidt et al. (2019), Das et al. (2018)
H2 = Hydrogen, RES = Renewable energy source, RE = Renewable energy, SMES = Superconducting magnetic energy storage, PHS = Pumped hydroelectric storage, CAES = Compressed-air energy storage
Note: The Council has reviewed available literature to build this table. In our review, technology specifications differ greatly based on the source.
*****: in practice

✓ for proven
🤞 for promising
✧ for possible