CICE

Powering the Future with Energy Storage

The role of energy storage in enabling electrification and grid decarbonization

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Territorial Land Acknowledgment

In the spirit of reconciliation, the BC Centre for Innovation and Clean Energy respectfully acknowledges that it operates on the traditional, ancestral and unceded territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish), and səlilwətaɬ (Tsleil-Waututh) Nations.

WHO IS CICE?

- **Independent not-for-profit organization**
- **Founded: Fall 2021**
- **$105M raised through public/private Member partnerships and grants:**
  - Government of British Columbia
  - Shell Canada
  - NRCan (Government of Canada)

WHY WE EXIST

- **Lead early-stage, catalytic seed investment into innovation** where the lack of validation and revenue metrics are often a barrier to funding
- **Drive market adoption and scale-up** to adopt cleantech faster and more cost effectively – at less risk
- **Enable a world-class clean energy sector** to leverage BC's natural resources and clean energy advantages and attract global investment, build IP, create good jobs and lead a prosperous economy

CICE PORTFOLIO SNAPSHOT

$145M
TOTAL PROJECT FUNDING

$23M
INVESTMENT BY CICE

1.02MT/YR
T/YR POTENTIAL GHG ABATEMENT

BATTERY & ENERGY STORAGE

CARBON MANAGEMENT

LOW CARBON BIO & SYNTHETIC FUELS

LOW CARBON HYDROGEN

CICE Supported Innovators

Agenda + objectives

AGENDA + OBJECTIVES

1. Context

How renewables and electrification change the grid

2. Applications

Energy storage provides many different services

3. Technologies + innovation

Current energy storage market, new technologies

4. What it all means for B.C.

BC needs, BC strengths

1. Context

VARIABLE RENEWABLE ENERGY (VRE) DYNAMICS

GROWING MARKET SHARE

FALLING COSTS

PV Module down 8X
Onshore wind down 2X
($/MW since 2010)[1]

INCREASING PENETRATION

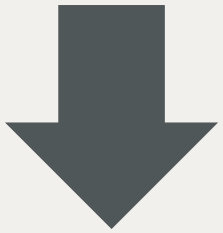
PV up 10X, Wind up 2X
share of worldwide capacity

California, Texas >25% of
energy in 2022[2]

[1] BloombergNEF 2023
[2] US Energy Information Administration

VARIABLE RENEWABLE ENERGY (VRE) DYNAMICS

…BUT DIFFERENT CHARACTERISTICS



VARIABLE SUPPLY

Capacity factor
~25% for solar,
~35% for wind[2]

COST PROFILE

VRE is higher capex,
near zero opex

DEPLOYMENT SCALE

Wind turbines <15 MW,
solar from rooftop
to utility-scale

[2] US Energy Information Administration

CONSEQUENCES OF INCREASING VRE PENETRATION

Displacement of traditional generators

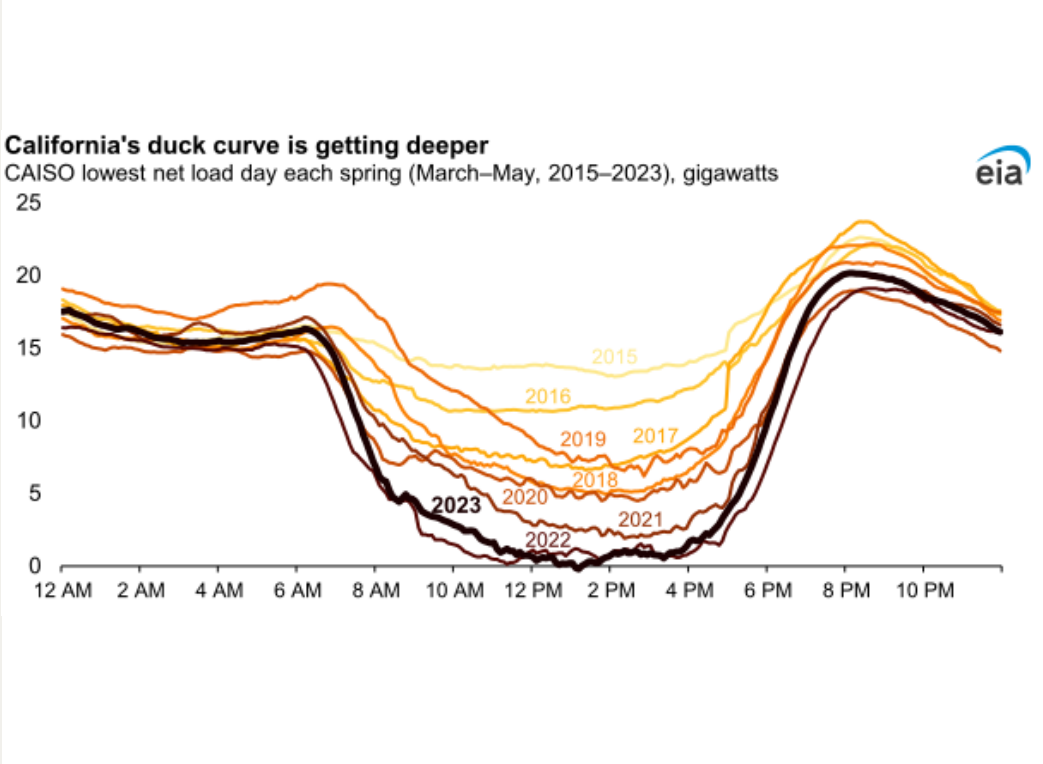
Curtailment (local and system-wide)

Greater cycling of dispatchable generation, especially natural gas

Mostly low wholesale prices, with price spikes

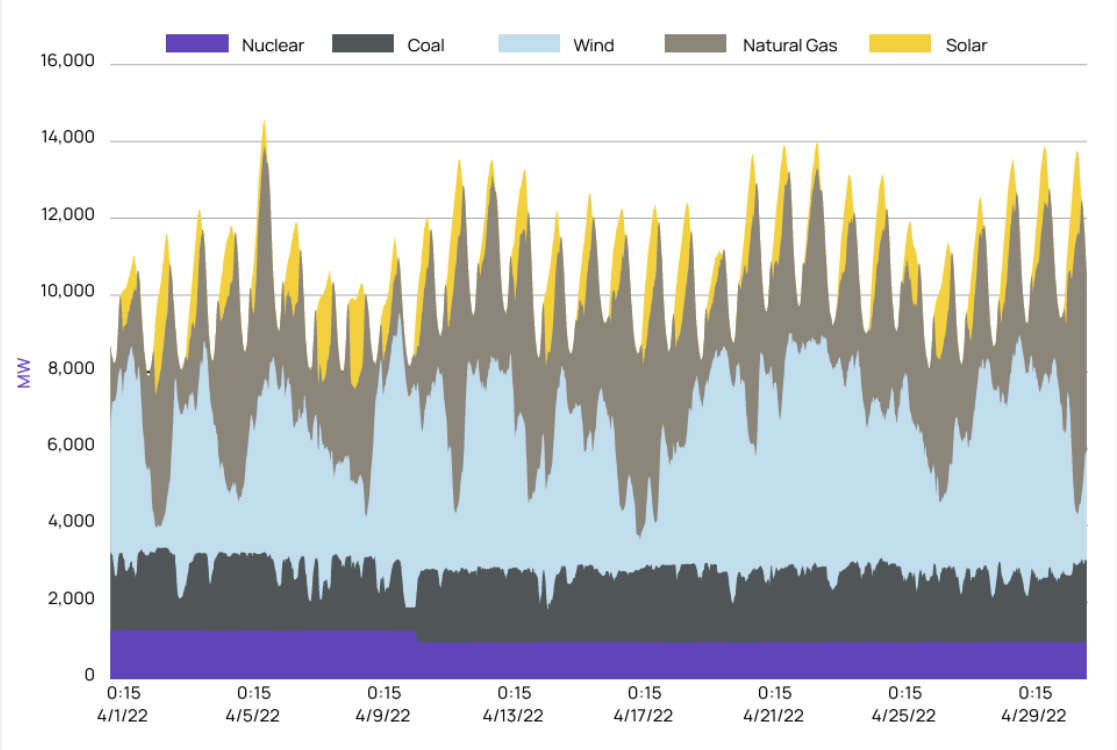
CONSEQUENCES OF INCREASING VRE PENETRATION

California - Solar dominant



EIA, 2023

Texas - Wind dominant



ERCOT, "Grid Information - Generation Fuel Mix Report 2022," 31 August 2023.

ELECTRIFICATION IMPACTS

INDUSTRY

Electricity use in industry doubles (+35 EJ) by 2050[1]

TRANSPORTATION

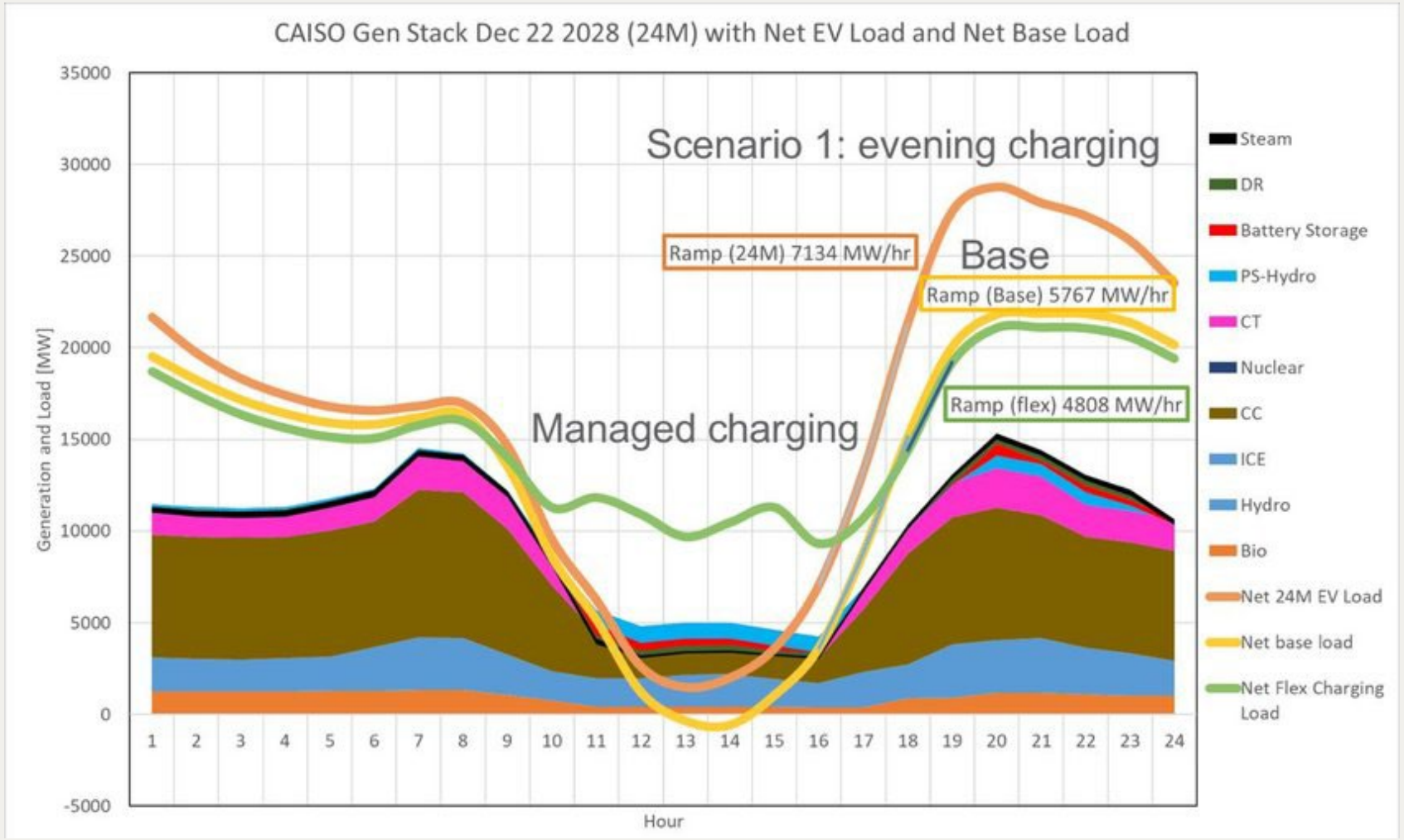
Another 35 EJ increase by 2050[1]
Large increase in daily peak

HEATING

Additional 25 EJ by 2050[1]
Shifts summer to winter peaks
Compounds daily peak demand, especially on the coldest days

[1] International Energy Agency Net Zero by 2050

ELECTRIFICATION IMPACTS



J. Zhu, H. Li, D. Bhatnagar, S. Davis, M. Kintner-Meyer, N. Samaan and S. Sridhar, "Integration of Electric Vehicles in a Highly Penetrated Renewable Energy Market," in CIGRE Session 48, Paris, 2020.

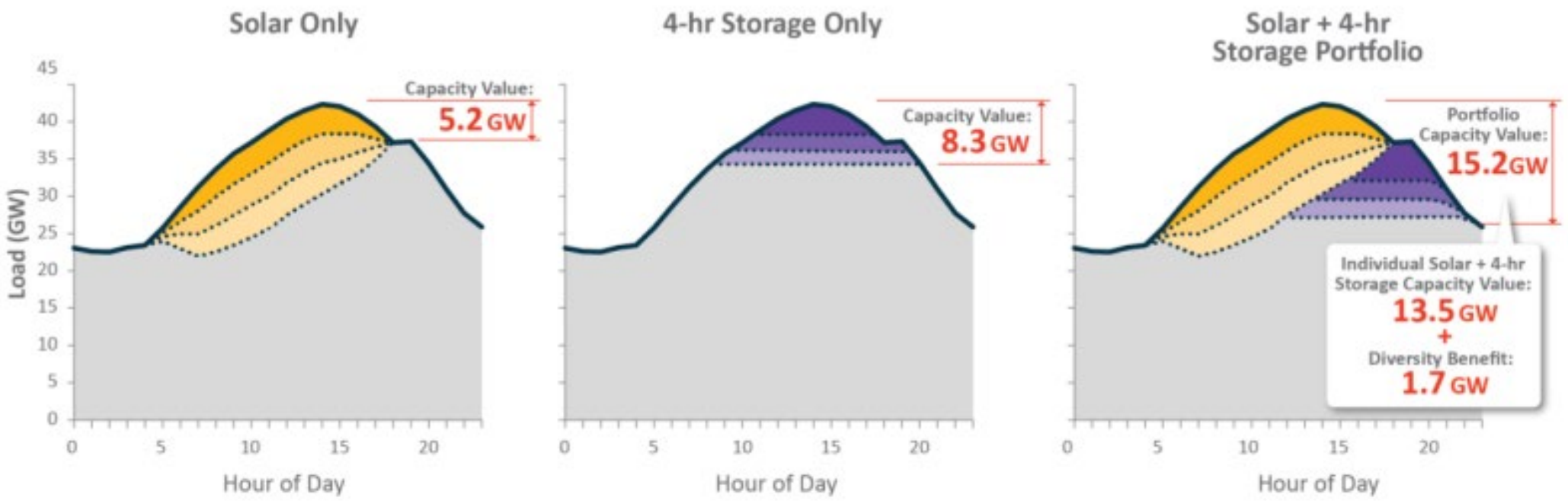
2. Applications

ENERGY STORAGE – PRIMARY APPLICATIONS

ENERGY ARBITRAGE
Buy low, sell high

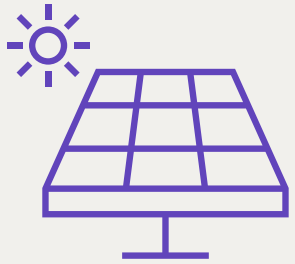
PEAKING CAPACITY
Displacing natural gas

ENABLING VRE PARTICIPATION IN CAPACITY MARKETS

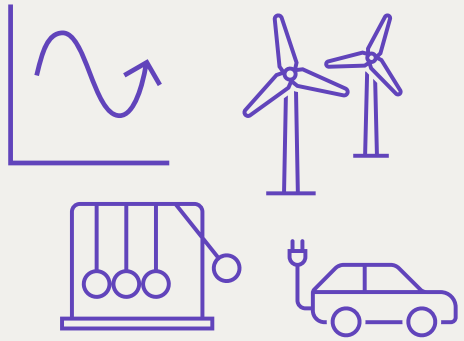


E3, "Capacity and Reliability Planning in the Era of Decarbonization: Practical Application of Effective Load Carrying Capacity in Resource Adequacy," Energy and Environmental Economics, 2020

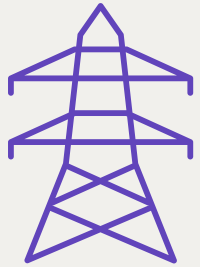
STORAGE DELIVERS MUCH MORE



BEHIND-THE-METER

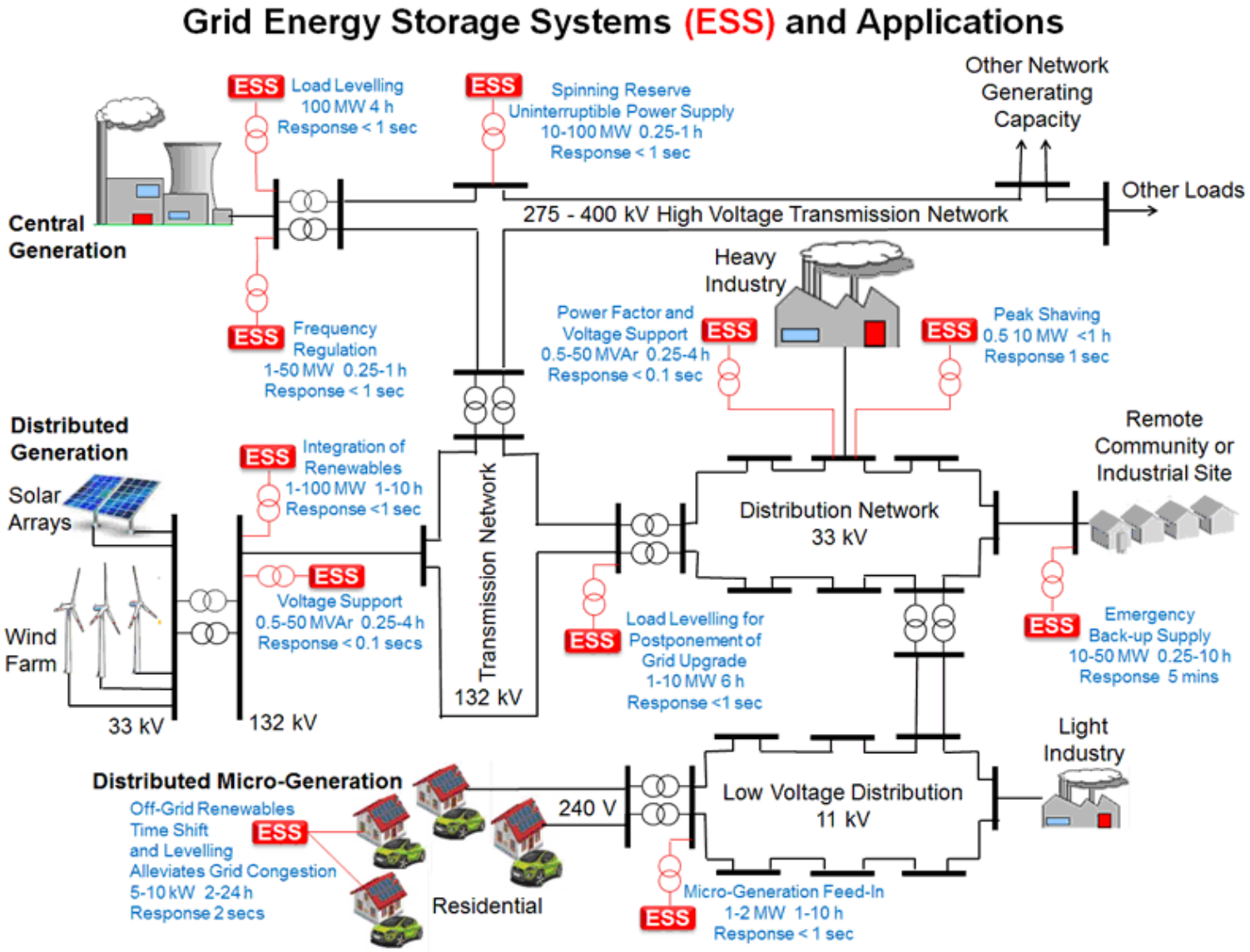


ANCILLARY SERVICES



TRANSMISSION + DISTRIBUTION NETWORK

GRID ENERGY STORAGE SYSTEMS (ESS) AND APPLICATIONS



Courtney Powell – Grid Level Energy Storage - https://xenogyre.com/2012/05/24/introduction-to-grid-energy-storage/

STORAGE CREATES VALUE DELIVERING MULTIPLE SERVICES

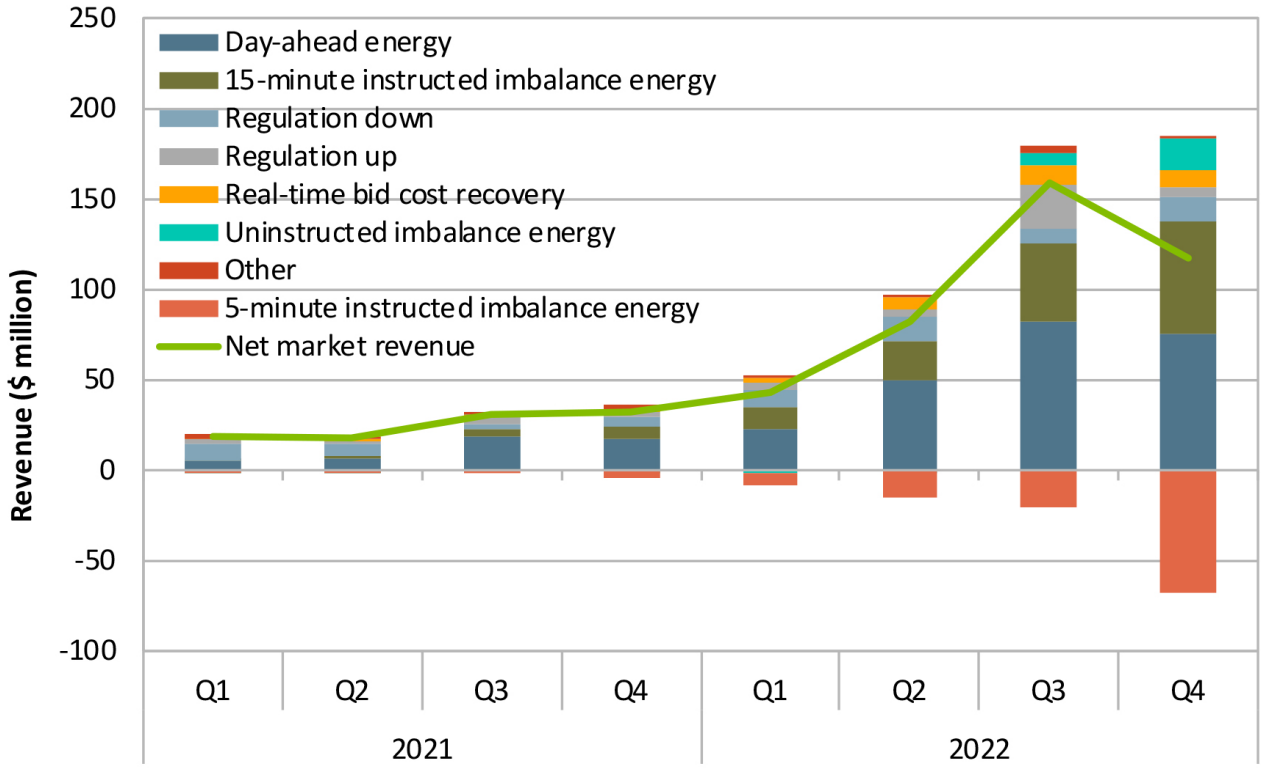
SERVICES CAN BE PROVIDED SIMULTANEOUSLY

Front-of-the-meter example

- Energy arbitrage
- Frequency response
- Reserve capacity
- Voltage support

Behind-the-meter example

- Energy arbitrage
- Bill management
- Backup power



Quarterly Revenues for Battery Resources in California, CAISO

CAISO, "Special Report on Battery Storage," California Independent System Operator, 2023.

ENERGY STORAGE SYSTEM MARKET

RAPID GROWTH

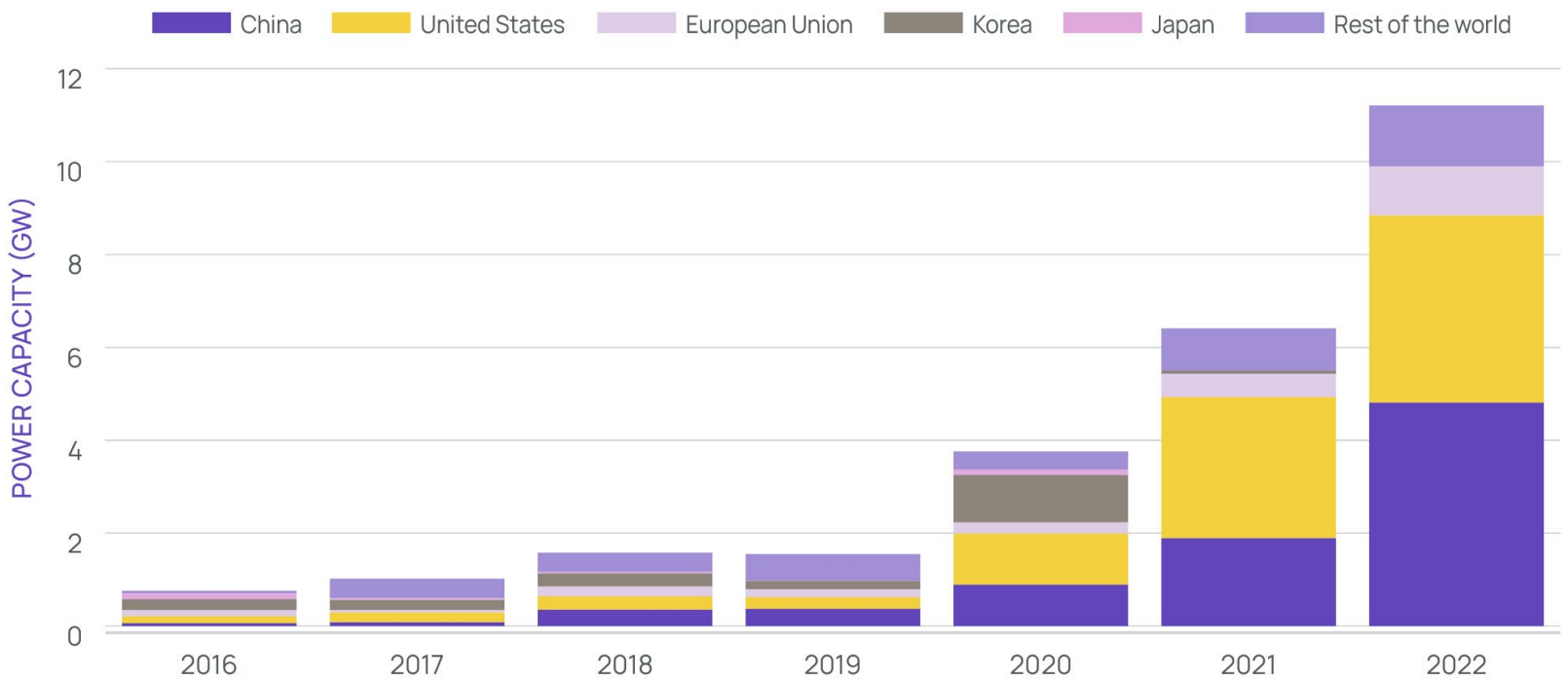
10X increase in annual deployments since 2016

SHORT DURATIONS

Average duration of US utility-scale energy storage systems 2020-2022 was **2.3 hours**[1]

LITHIUM BATTERIES

277 of 283 US utility-scale energy storage systems 2020-2022 used **lithium batteries**[1]

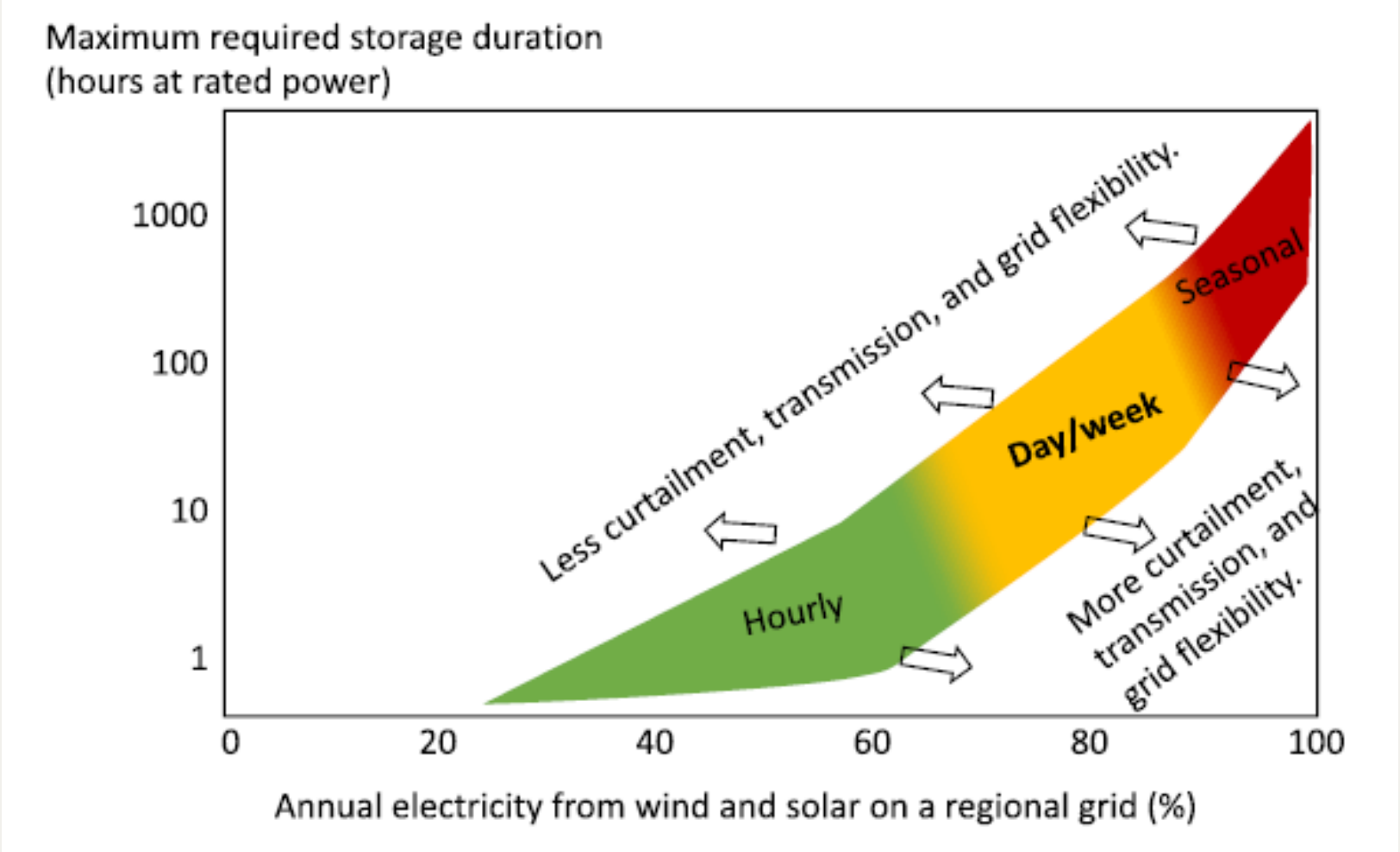


Annual Grid-Scale Battery Additions, International Energy Agency

IEA, "Annual Grid-Scale Battery Additions," 29 January 2024.

[1] US Energy Information Administration

STORAGE MARKET MUST EVOLVE WITH INCREASING VRE



J. S. M. S. L. Paul Albertus, "Long-Duration Electricity Storage Applications, Economics, and Technologies," Joule, pp. 21-32, 15 January 2020.

3. Technologies + innovation

TECHNOLOGIES – CURRENT LEADERS

PUMPED-STORAGE HYDRO

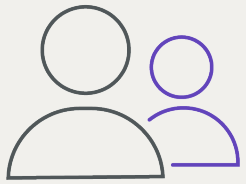
- **Largest installed capacity**
- **Scalability makes it the incumbent for long-duration applications**

Storage System	Number of plants and of generators	Power capacity (MW)	Energy capacity (MWh)	Gross generation (MWh)	Net generation (MWh)
Pumped-storage hydro	40-152	22,008	NA	22,459,700	-6,003,905
Batteries	403-429	8,842	11,105	2,913,805	-539,294
Solar-thermal	2-3	405	NA	NA	NA
Compressed-air	1-2	110	110	NA	57
Flywheels	4-5	47	17	NA	0

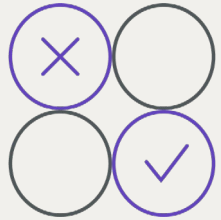
EIA, "Electricity explained - energy storage for electricity generation," 28 August 2023.

TECHNOLOGIES – CURRENT LEADERS

Lithium-ion dominates the market and is still improving rapidly

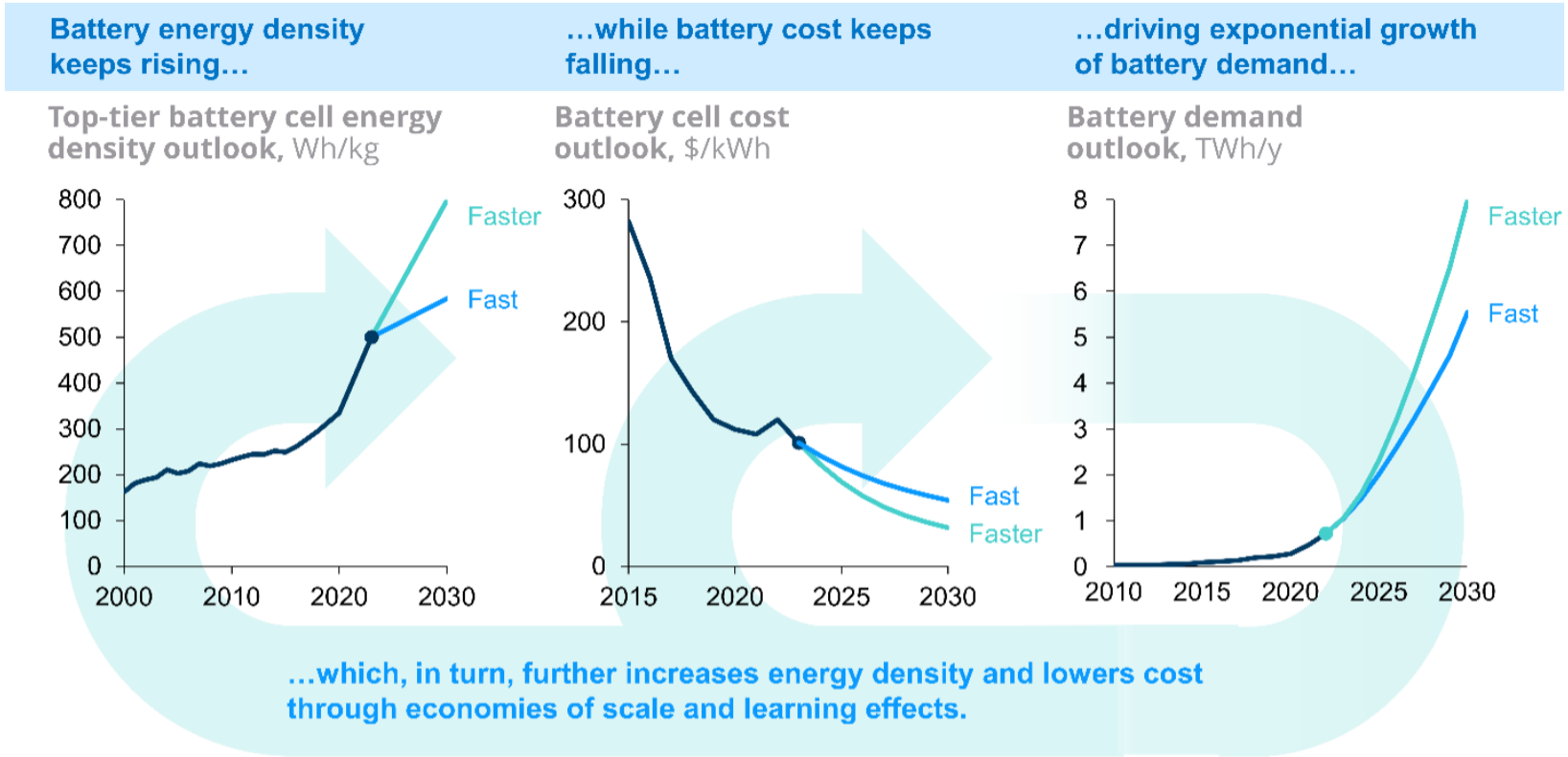


Competing with lithium-ion's scale and rate of improvement is a challenge for new entrants



BUT lithium-ion is highly unlikely to reduce costs sufficiently to make long-duration storage viable

TECHNOLOGIES – CURRENT LEADERS



RMI, "X-Change: Batteries - The Battery Domino Effect" 2023.

TECHNOLOGIES – OTHER ELECTROCHEMICAL

FLOW BATTERIES

Vanadium redox (Invinity), zinc-bromine most advanced.

Scalable, with independent power and energy.

Can bridge gap between short duration and very long duration.

METAL / AIR BATTERIES

Iron, zinc, aluminum.

Potential for very low cost (e.g. iron/air by Form Energy).

Low efficiency.

Best suited for long duration applications.

OTHER

Sodium-ion uses similar manufacturing tech but avoids the supply chain risks of Li.

Variations on zinc batteries (e.g. “alkaline”)

Nickel-hydrogen (EnerVenue).

Supercapacitors.

- Advantages for high power / fast response services (e.g. frequency response), most likely integrated with batteries.

Common themes: no/low fire risk, long cycle life, not dependent on critical minerals, early stages of development or deployment. Need project wins and manufacturing scale to advance learning curve and compete with Li-ion.

TECHNOLOGIES – NON-ELECTRIC

THERMAL

Wide range of latent, sensible, and some thermochemical technologies at different temperatures.

Generally, very low-cost storage medium.

Poor efficiency to convert back to electricity make applications that need heat a primary target (industry, space heating).

COMPRESSED AIR

Need to capture and reuse the heat of compression for reasonable efficiency, making this is a mixed mechanical/thermal storage tech.

Below ground reservoirs much lower cost but restricted by geography.

Early stage above ground tech (liquid air, compressed CO_2).

HYDROGEN

Low volumetric energy density makes above-ground storage and bulk transportation expensive.

Important for decarbonizing some industrial applications.

Early storage markets will be at locations which use hydrogen and have inexpensive electricity (surplus VRE).

OTHER Gravity storage can be efficient but has very low energy density.

Common themes: Low-cost storage media, long lifetimes, and independent scaling of power and energy make these all long-duration energy storage candidates. Generally low efficiency. LDES market still nascent.

OTHER COMPONENTS

Storage systems contain more technology than what is in the storage block (e.g. batteries)

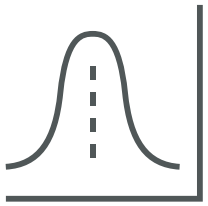
Balance of system (e.g. HVAC), power conversion equipment, communication and control are important

Grid-forming inverters are a particularly critical technology (and opportunity) as VRE penetration increases

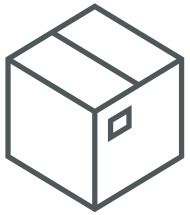
		1 MW		10 MW	
		Duration			
		2 hr	4 hr	4 hr	10 hr
Total Installed Cost (US$)		$1,037,160	$1,793,360	$16,428,500	$37,667,100
Component	Scales with	Fraction of Total Installed Cost			
DC Storage Block	Energy	36%	41%	42%	45%
DC Storage BOS	Energy	9%	9%	10%	10%
Power Equipment	Power	8%	5%	4%	2%
C&C	Power	4%	2%	0%	0%
Systems Integration	Energy	11%	11%	11%	11%
EPC	Energy	13%	14%	14%	14%
Project Development	Energy	16%	16%	16%	17%
Grid Integration	Power	3%	2%	2%	1%

DOE, "Storage Innovations 2030 - Technology Strategy Assessment - Flow Batteries," US Department of Energy, 2023.

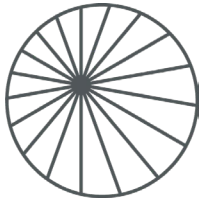
ALTERNATIVES WILL COMPETE WITH VRE + LDES AS SOLUTIONS FOR A NET-ZERO GRID



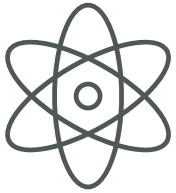
Demand response



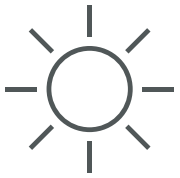
CCS



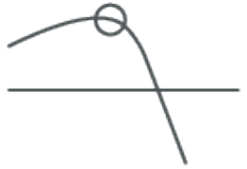
Renewable natural gas or Biofuels



Nuclear



Overbuild VRE

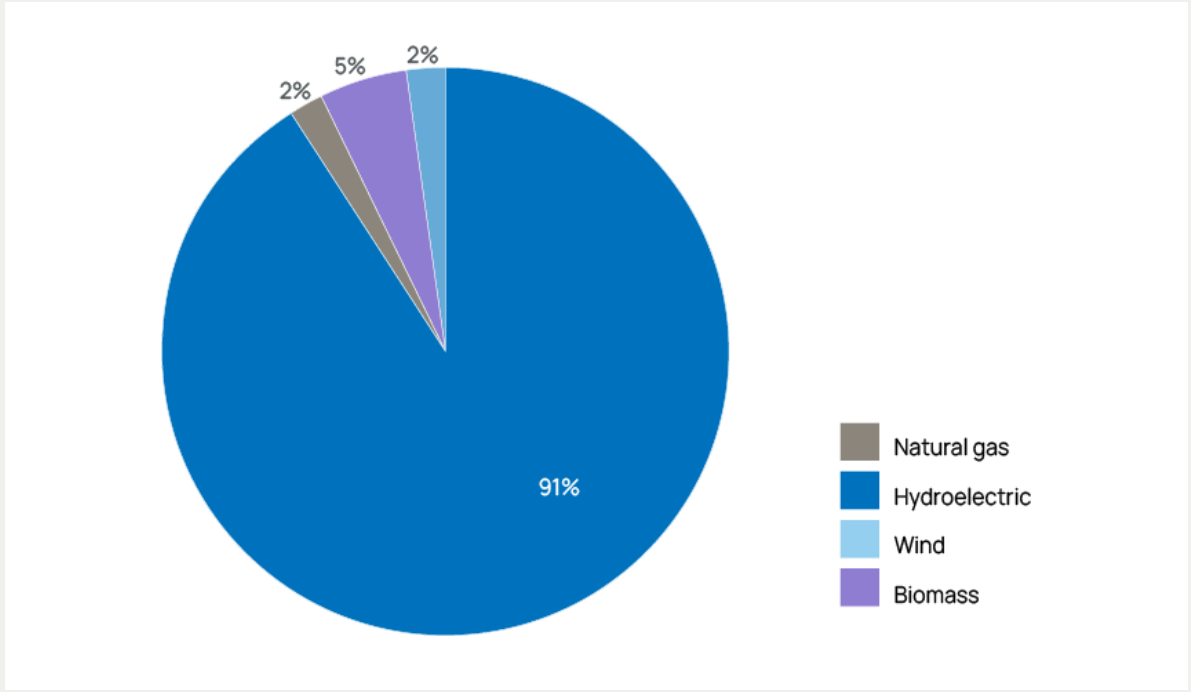


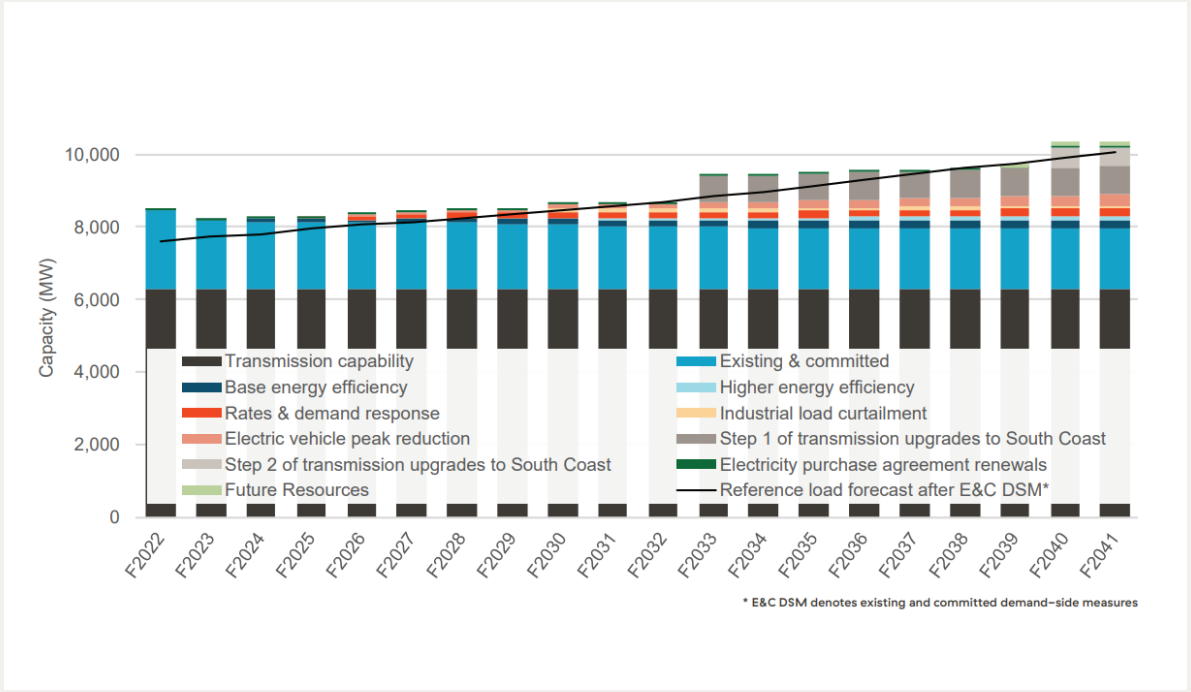
Transmission capacity

4. What it all means for B.C.

BC CONTEXT

HYDRO RESOURCE MEANS STORAGE APPLICATIONS ARE DIFFERENT





Statistics Canada, "Electric power generation, monthly generation by type of electricity," 17 October 2023.

BC Hydro, "2021 Integrated Resource Plan (2023 Update)," BC Hydro, 2023.

BC CONTEXT

- BC's large hydropower system allows for integrating VRE without additional storage.
- Most generation resources, however, are distant from the lower mainland (center of demand) and transmission lines are constrained.
- BCH planning 600 MW of storage to support transmission.
- Electrification will increase peak demand and stress on transmission and distribution systems leading to increased opportunities for storage.
- FortisBC leaning on RNG for peaking but have some smaller storage deployments planned.

LOCAL INNOVATORS HAVE STRENGTHS TO BUILD UPON

STRONG HISTORY IN BC IN ENERGY STORAGE TECHNOLOGIES:

Lithium-ion batteries and materials

E-One Moli
Nano One
Mangrove
Saltworks

Flow batteries

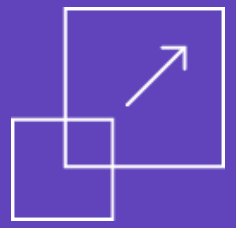
Invinity
Zinc8

Power electronics + integrated systems

Corvus
Xantrex
EnergyPlug
Moment

Hydrogen

Ballard
HTEC
Hexagon Purus
Powertech
Vessel Energy



SCALE, SCALE, SCALE.
Most BC technology innovators are pre-market or in early stages of deployment and need to scale to compete with Li-ion's learning curve.

Look at innovation in a broad sense to support this.

CICE

Any other questions?

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Download the report - https://cice.ca/