ENERGY

Grid-Connected Energy Storage – Project lessons learned

Electricity 2019, Eilat, Israel

Jos van der Burgt

06 November 2019

Grid-Connected Energy Storage – Project lessons learned

Outline

- DNV GL Energy Transition Outlook 2019
- Grid-connected energy storage
- Applications
- Projects
- Safety

But first …

The New York Times

https://www.nytimes.com/2019/10/09/science/nobel-prize-chemistry.html

Lithium-Ion Batteries Work Earns Nobel Prize in Chemistry for 3 Scientists

John B. Goodenough, M. Stanley Whittingham and Akira Yoshino were recognized for research that has "laid the foundation of a wireless, fossil fuel-free society."

(L-R): Akira Yoshino, Dr. M. Stanley Whittingham and Dr. John Goodenough.

These developments ultimately led to commercialization of the lithium-ion battery in 1991 by electronics company Sony Corporation.

DNV GL:
a quality assurance and risk management company

Industry consolidation

DNV

GL Group

KEMA

NOBLE DENTON

GARRAD HASSAN

ADVANTICA

DNV GL: a quality assurance and risk management company

12,000
employees

150+
years

100+
countries

100,000+
customers

5% R&D
of annual revenue

MARITIME

OIL & GAS

ENERGY

BUSINESS ASSURANCE

DIGITAL SOLUTIONS

Technology & Research

Global Shared Services

ENERGY

Energy Transition Outlook 2019

Power Supply & Use

Jos van der Burgt

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2019 HIGHLIGHTS

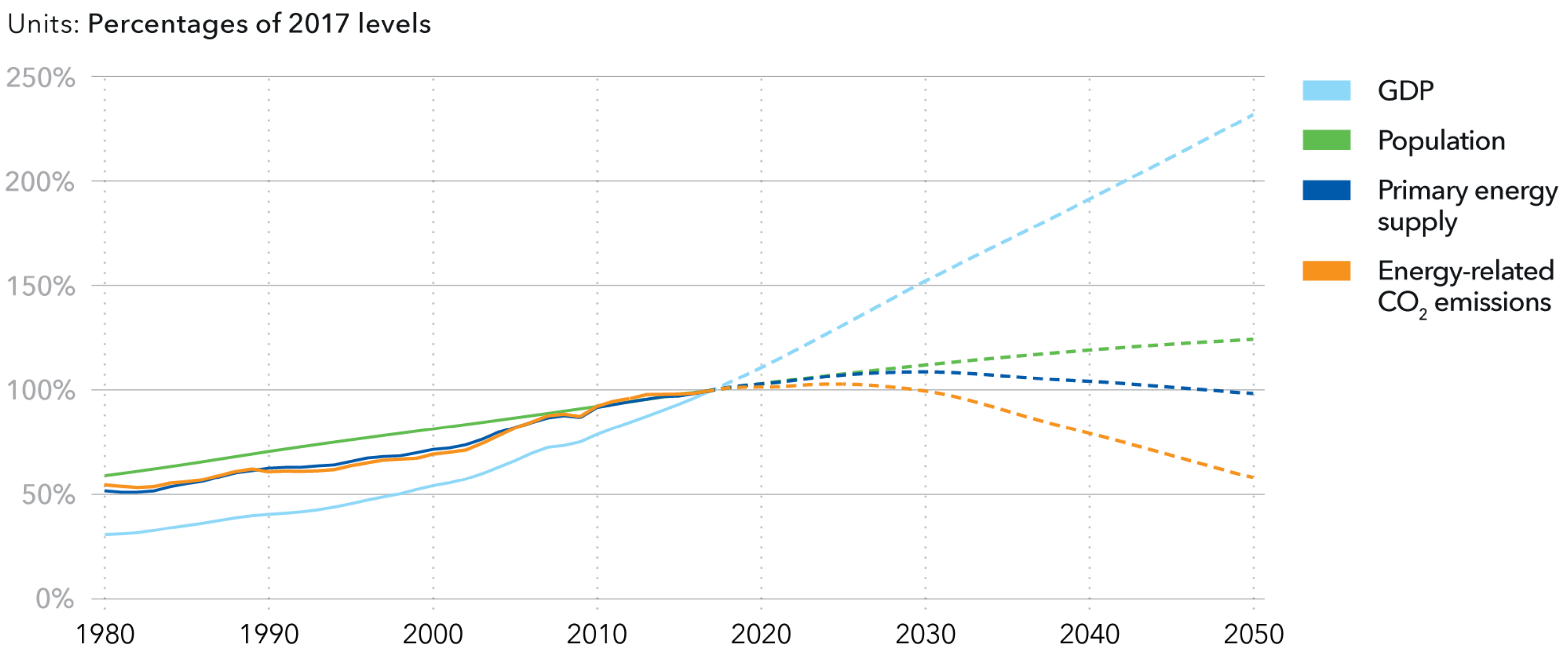
Rapid energy transition – but not fast enough

Existing technology can deliver the 1.5°C target

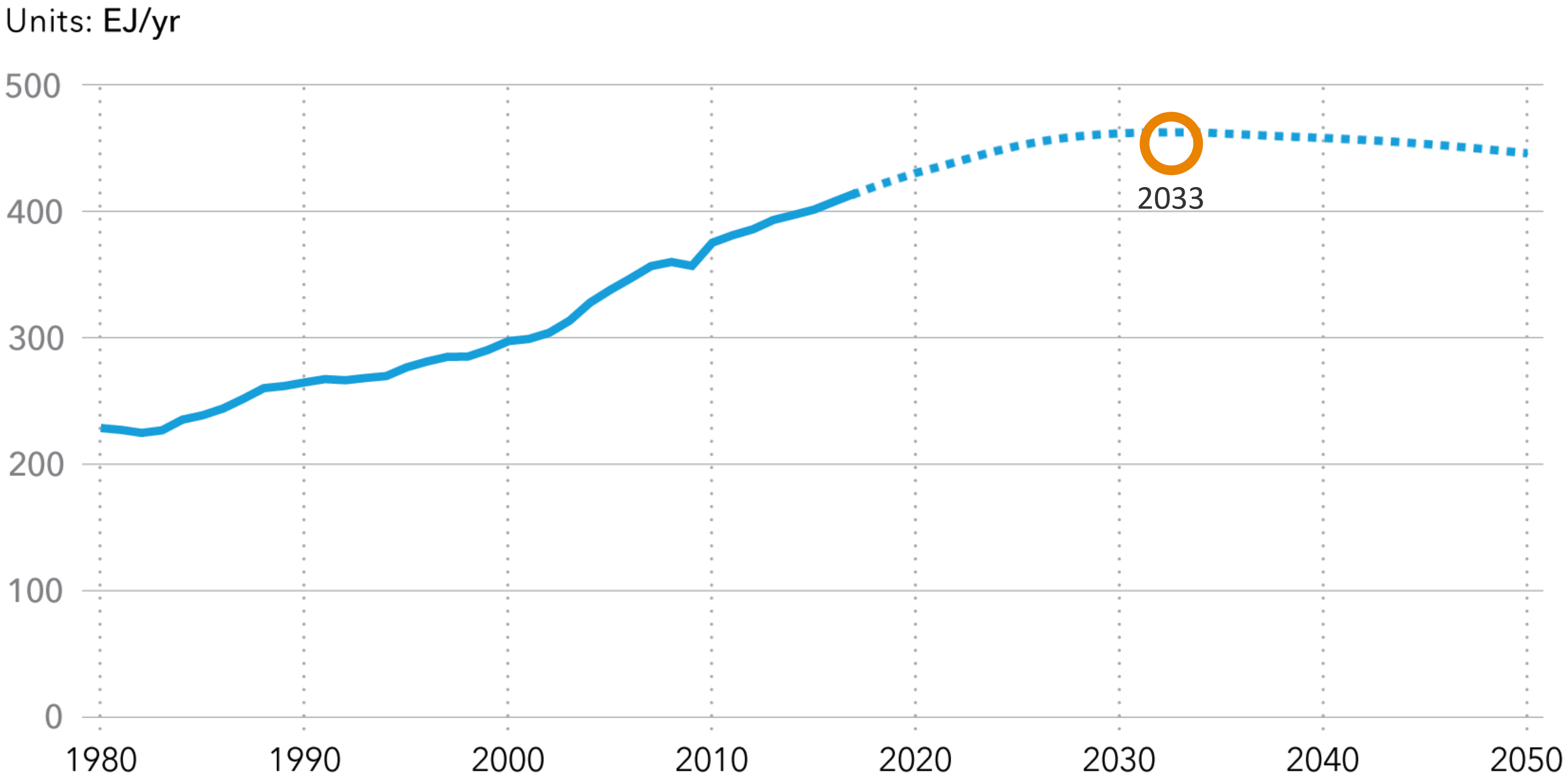
Global energy use peaks by 2030 due to energy efficiency

An affordable transition smaller share of GDP spent on energy

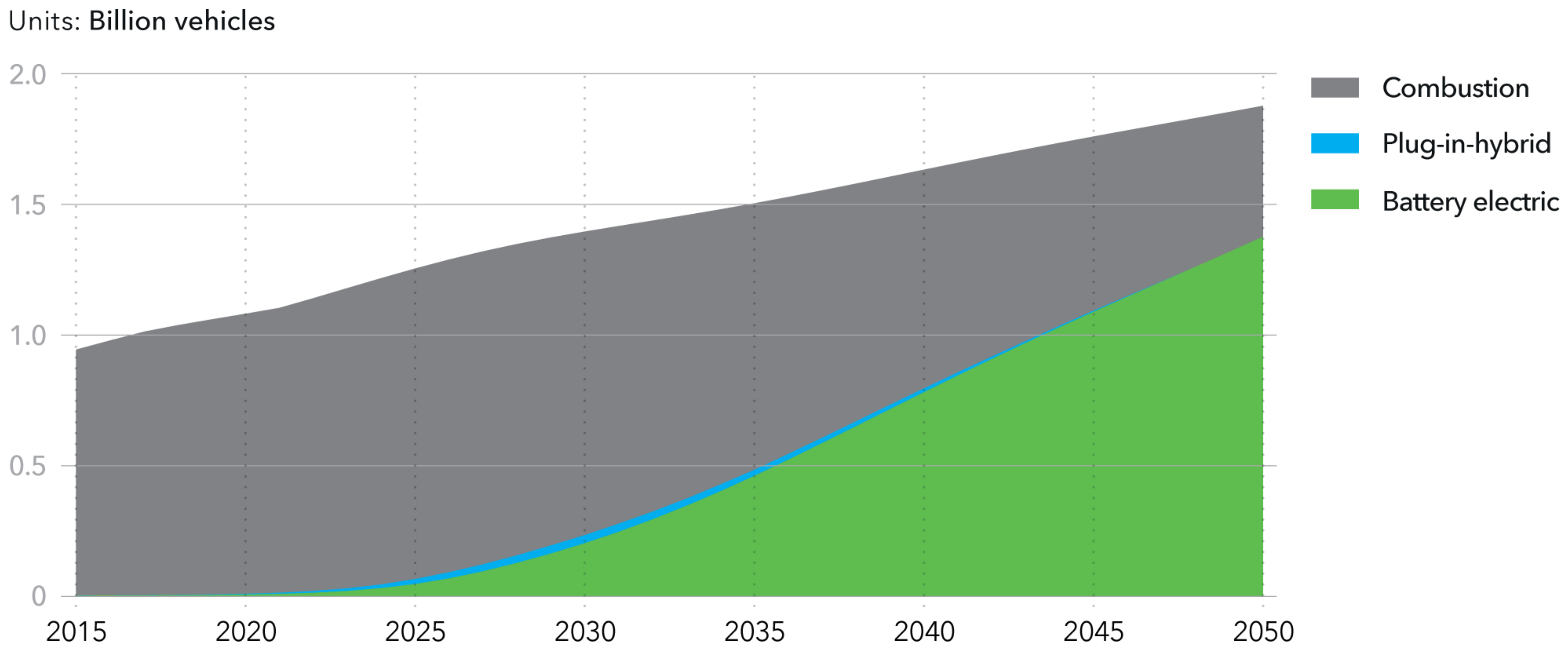
Decoupling of GDP



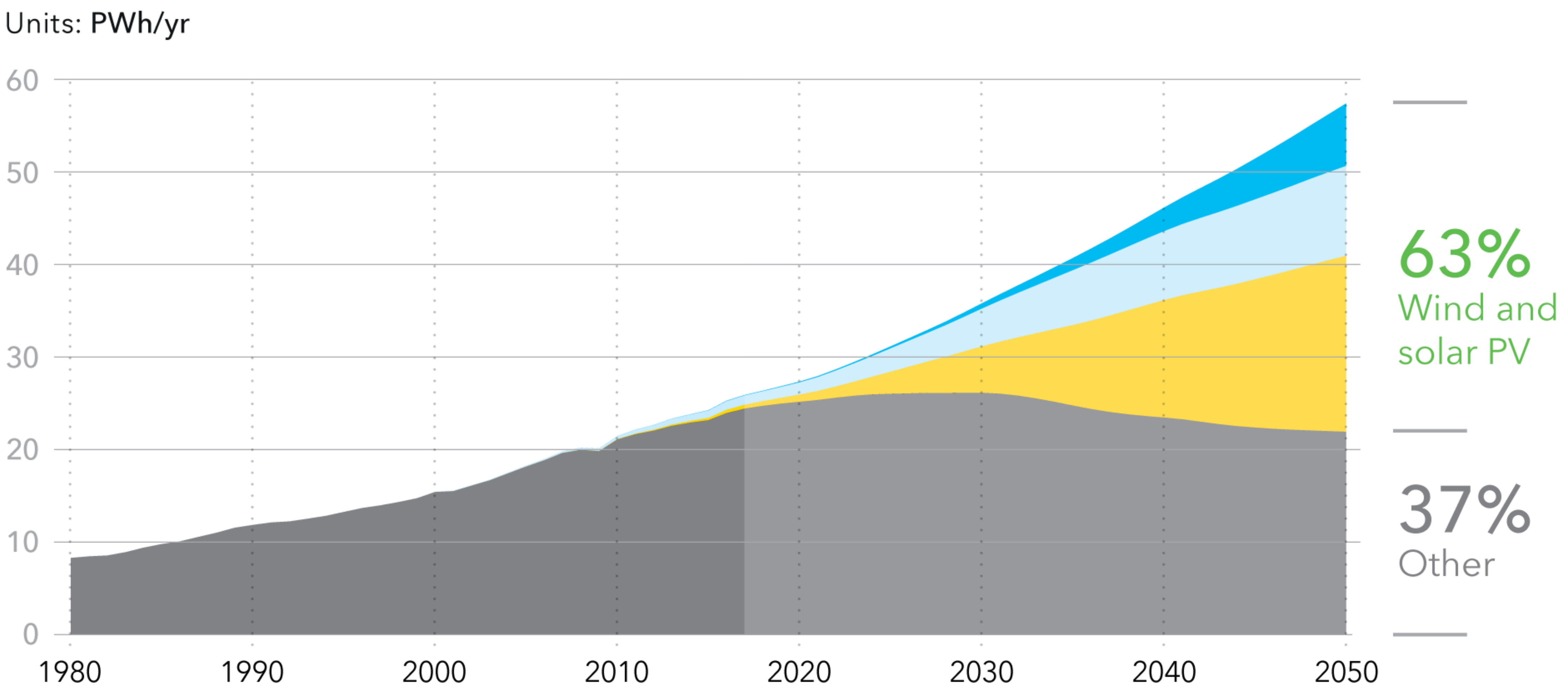
Energy demand will peak



Global passenger vehicles



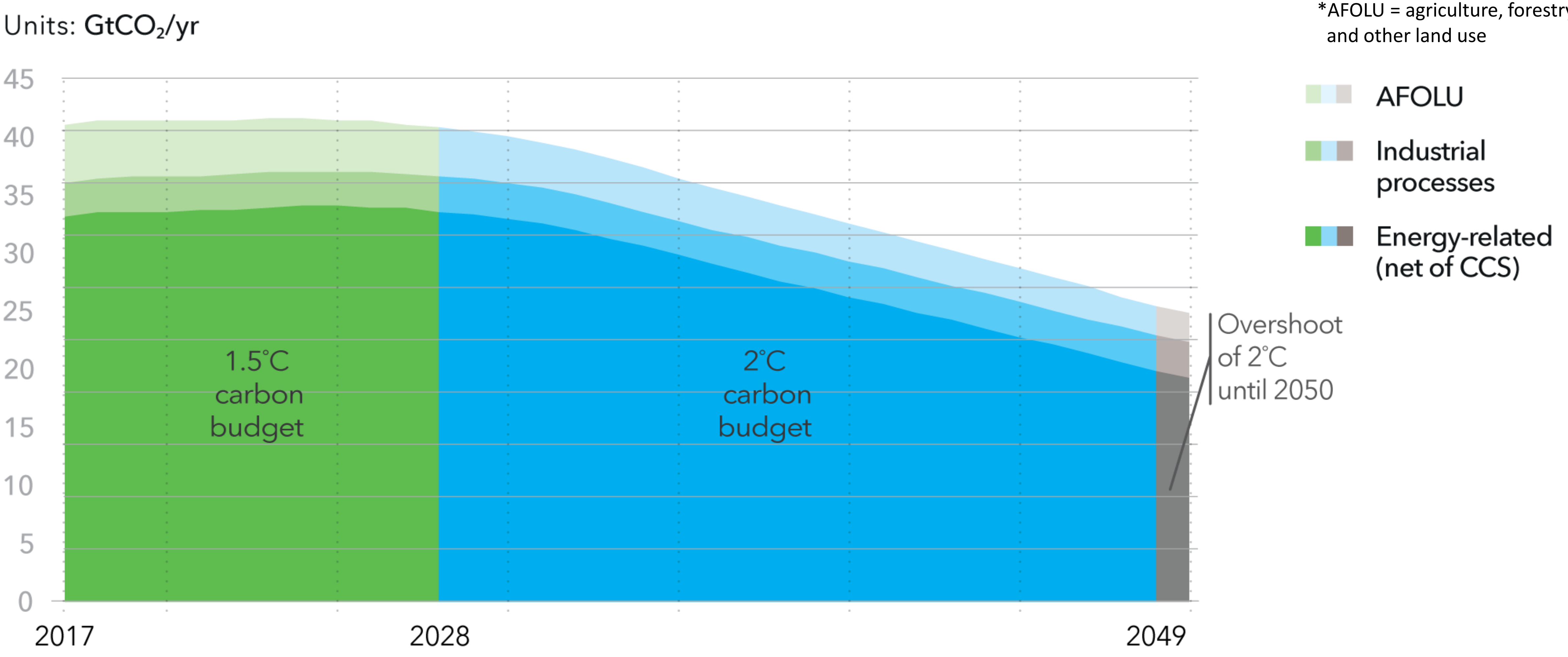
World electricity generation



FAST, BUT NOT FAST ENOUGH

Carbon emissions and carbon budget

*AFOLU = agriculture, forestry, and other land use



One such combination that could get us there includes:

Grow solar power by >10 times to 5 TW and wind by 5 times to 3 TW by 2030

50-fold increase in production of batteries for the 50 million electric vehicles needed per year by 2030

Invest more than $1.5 trillion annually in the expansion and reinforcement of power grids by 2030

Create new infrastructure for charging electric vehicles on a large scale

Increase global energy efficiency improvements by 3.5% per year within the next decade

One such combination that could get us there includes:

Improved and cheaper heat-pump technologies and improved insulation

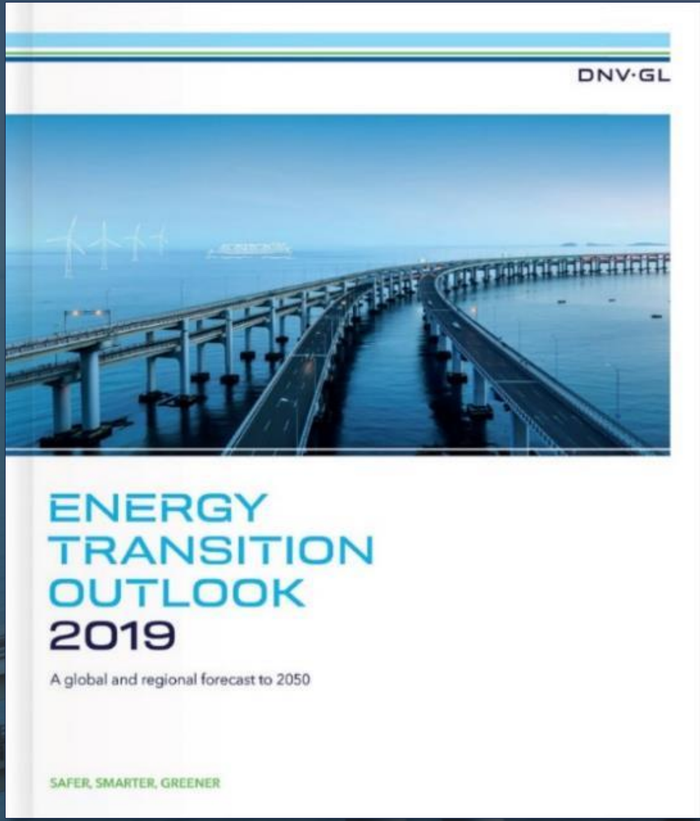
Green hydrogen to heat buildings and industry, fuel transport and make use of excess renewable energy in the power grid

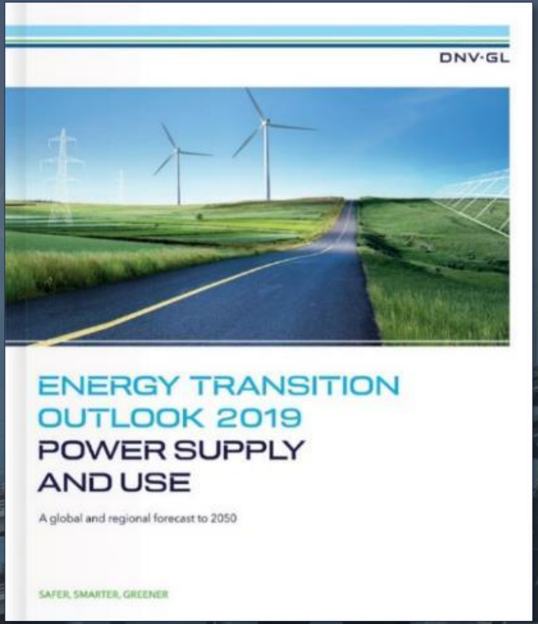
For the heavy industry sector: increased electrification of manufacturing processes, including electrical heating

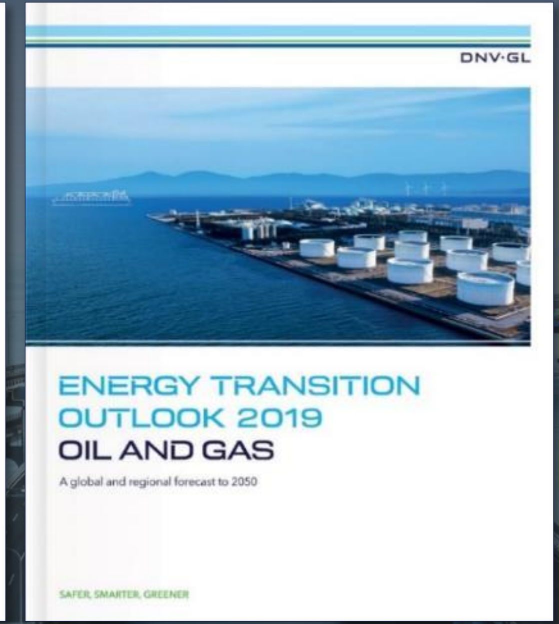
Massive rail expansion both for city commuting and long-distance passenger and cargo transport

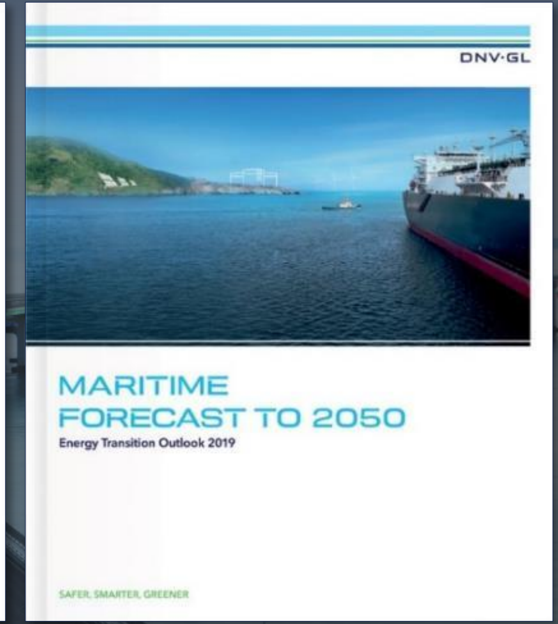
Rapid and wide deployment of carbon capture, utilization and storage installations

A SUITE OF REPORTS







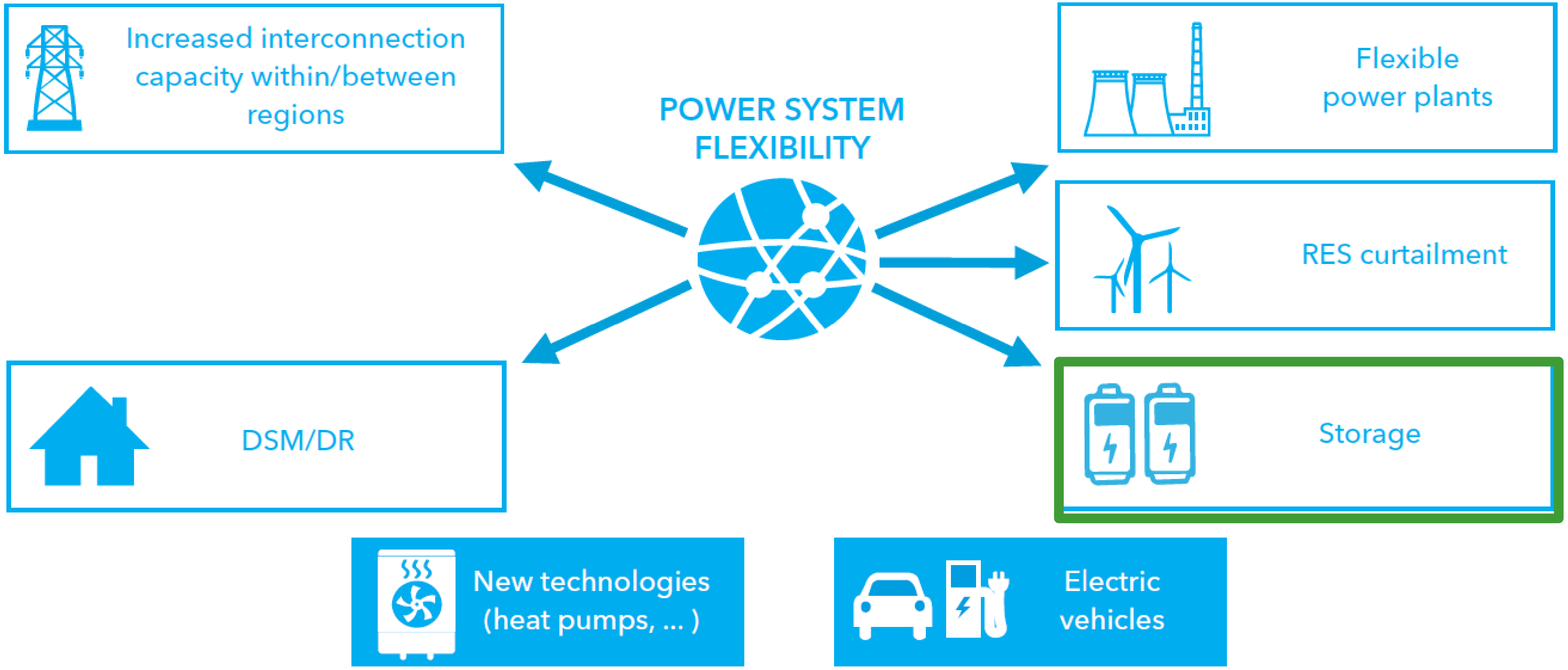


eto.dnvgl.com

Grid-connected energy storage

The energy transition and the need for flexibility

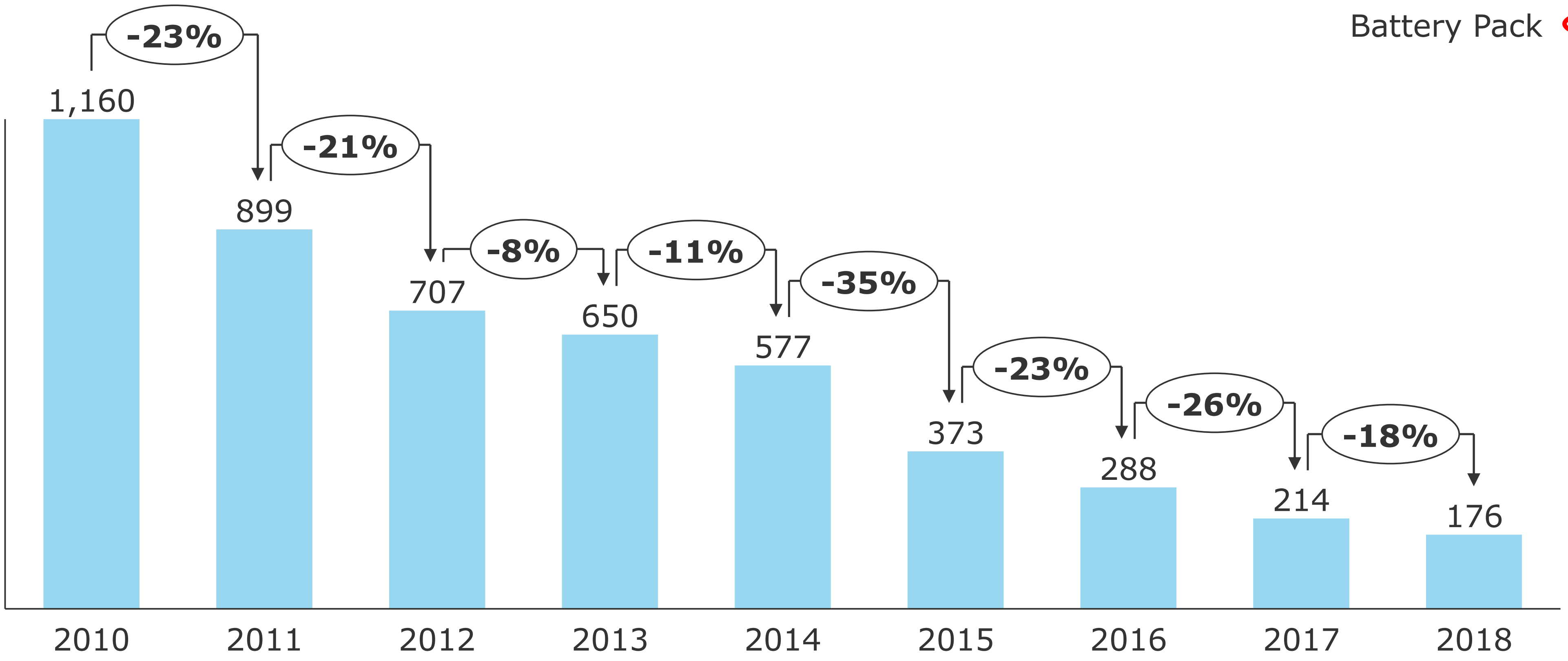
Power system flexibility options

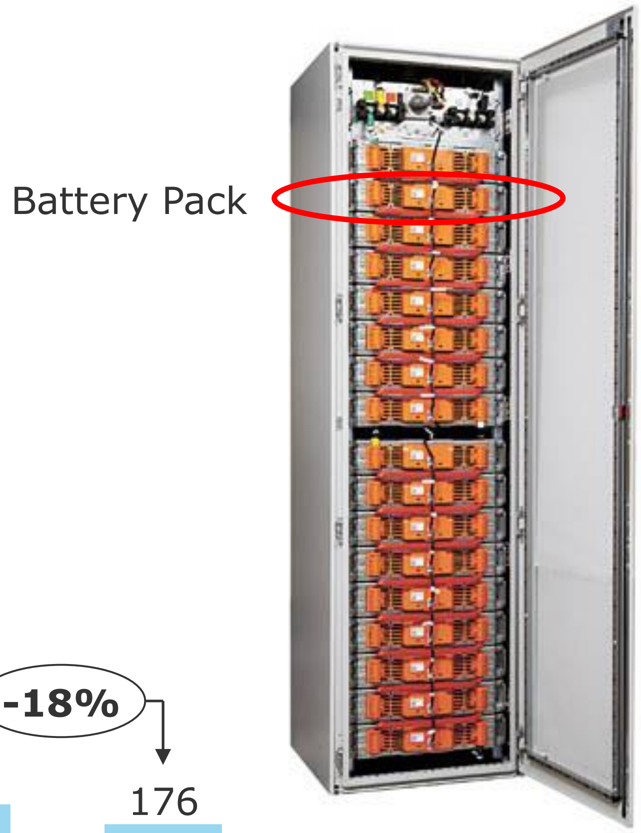


Energy storage trends & developments

Li-ion Battery pack price trend 2010-2018

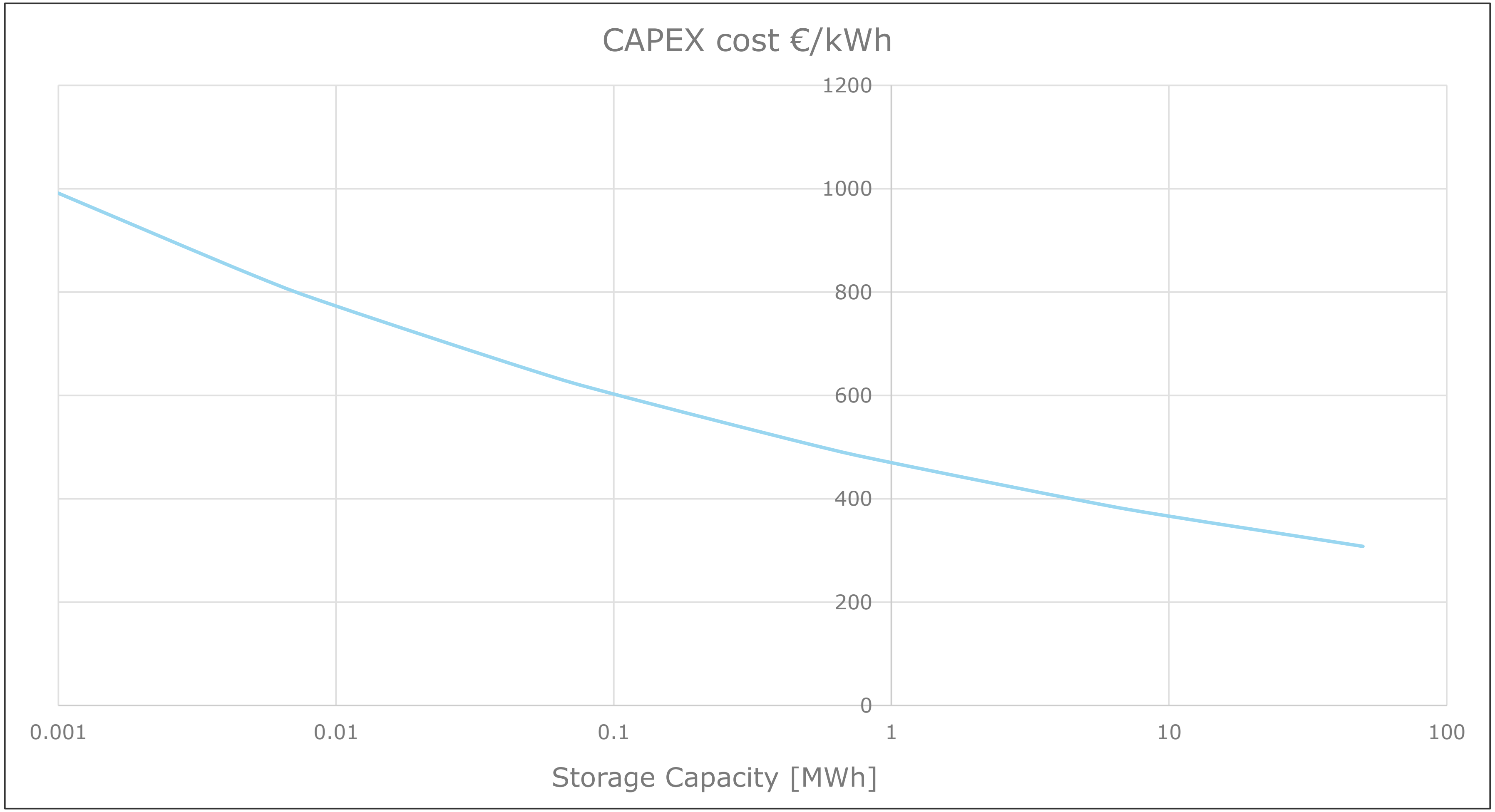
Battery pack price (real 2018 USD/kWh)





Based on BloombergNEF battery price survey 2018

Energy storage trends & developments
Turn key Li-ion ESS CAPEX prices in 2018 (DNV GL)

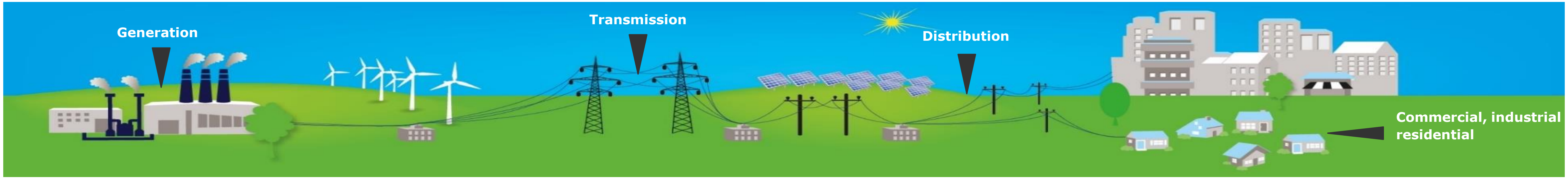


Applications for energy storage

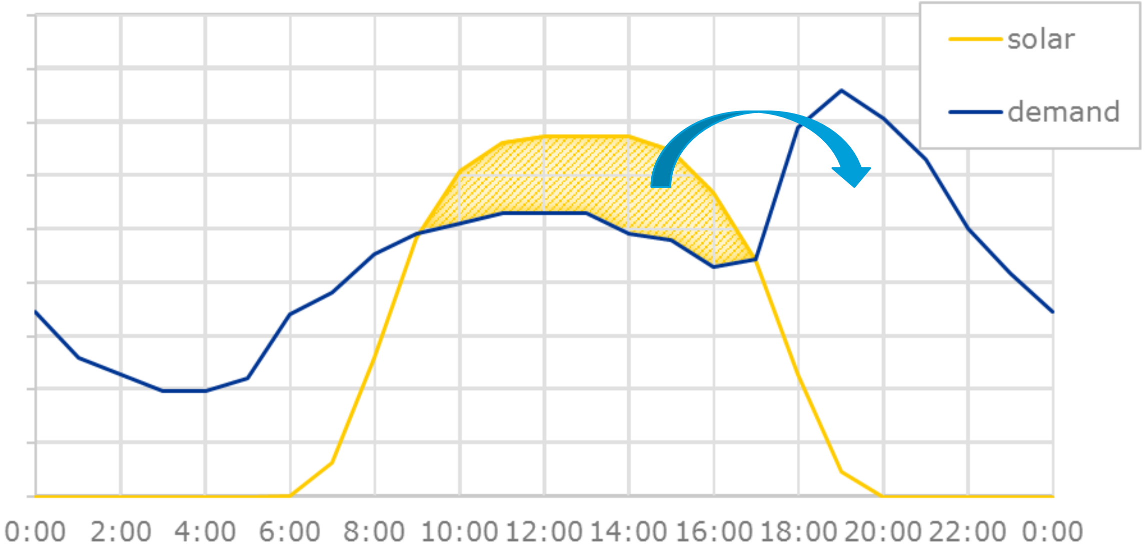
Energy storage applications
Service groups

- Bulk generation services (e.g. energy time shift)
- Renewables integration (e.g. capacity firming, ramp rate control)
- Ancillary services (e.g. frequency response, voltage support)
- Customer energy management and microgrid services (e.g. power reliability, power quality)
- T&D infrastructure services (e.g. upgrade deferral)

Energy storage applications
Bulk generation



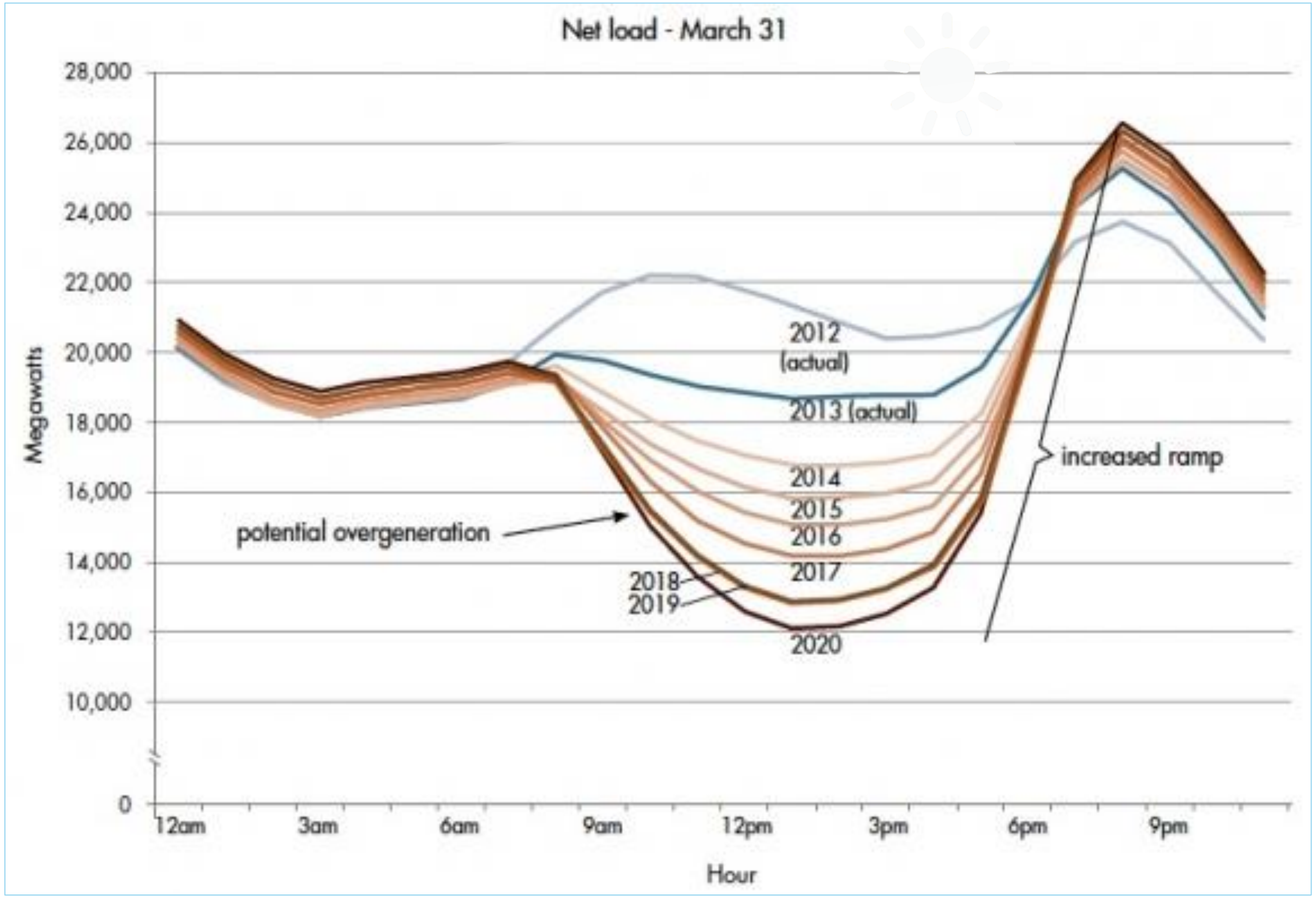
- Energy time-shift, e.g. solar + storage



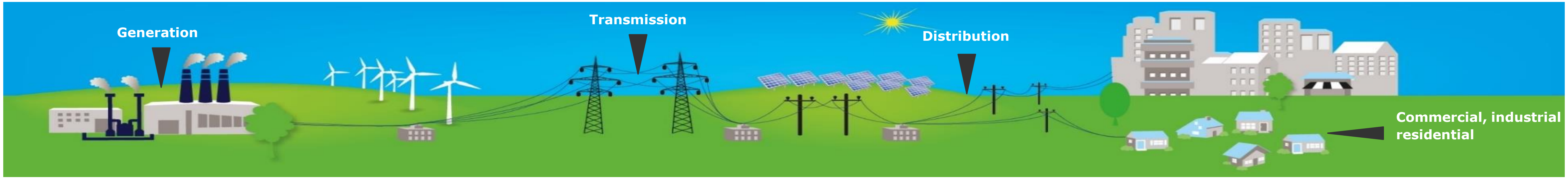
The energy transition and the need for flexibility

North America - What is driving interest in storage? Grid needs

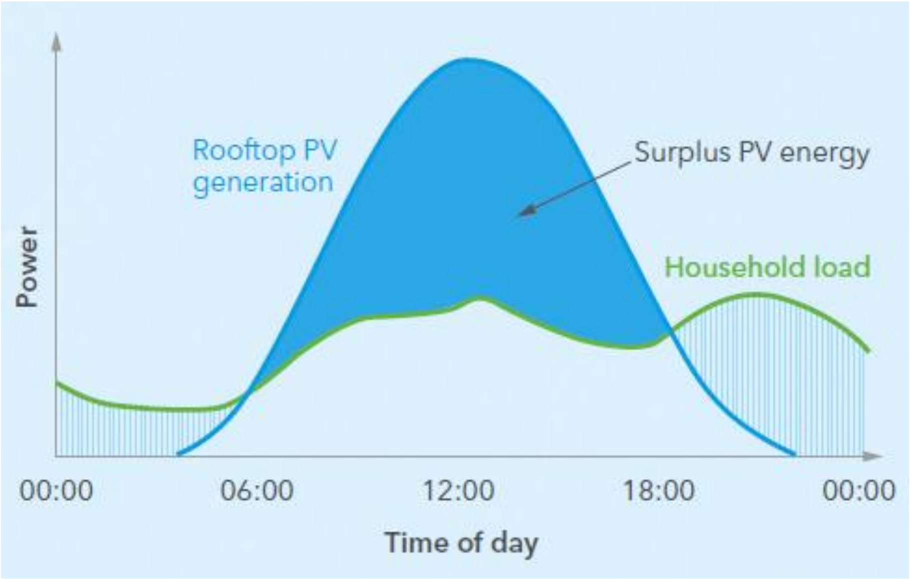
- One of the more pressing needs is due to the "Duck" Curve in California
- The combination of solar + storage has advantages that allow the application to be used as a tool to "flatten" the curve with smart charging/discharging of solar
- Beginning to see this trend elsewhere across the globe



Energy storage applications
Customer energy management



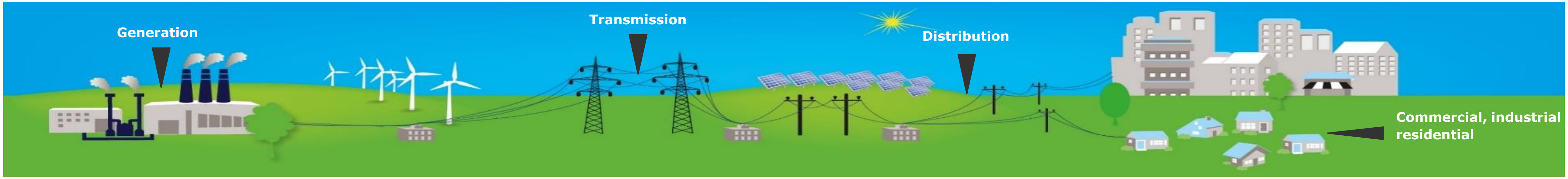
- PV self-consumption



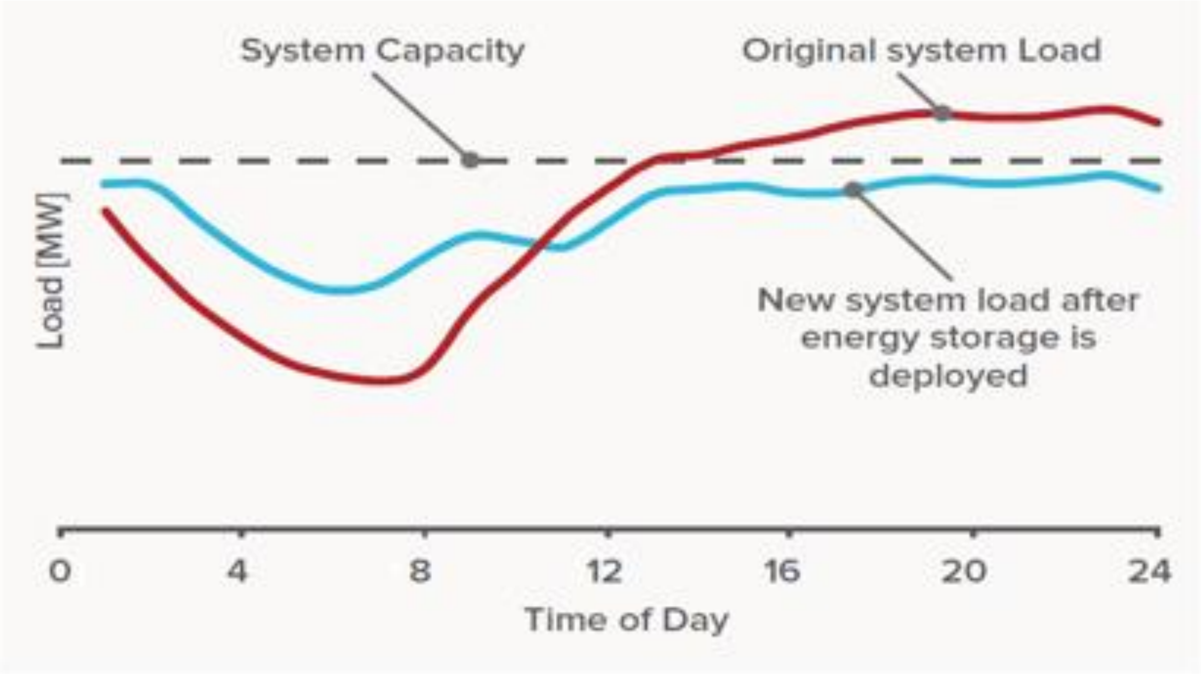
- C&I peak power reduction

- Reduce daily peak of power demand
- Save on *demand charges* (i.e. the fee that you pay for the maximum power during a month)

Energy storage applications
T&D infrastructure services



- Upgrade deferral, congestion relief



Projects

DNV·GL

Lithium ion batteries: Hawaii

US/Hawaii – AES - 20MW/100MWh - 2018

- 13,000 lithium-ion battery modules
- 28 MW Solar PV capacity
- Dispatch electricity at night
- Turn off peaker plants (running on import oil)
  → turn solar into 24/7 capacity
- $0.11 per kWh for 25 year

  (2019 Hawaii solar + storage projects underway
  for <$0.10/kWh)

Affordable renewable power for islands

DNV·GL

Tesla Battery at Hornsdale wind farm, AUS

Australia - Tesla - 100 MW/129 MWh - 2018

- Li-ion NMC/NCA chemistry
- Built within 100 days
- First 3 weeks of operation:
  - Smoothen out at least 2 imminent major energy outages
  - 0.14 sec response after sudden dropout of Australia's biggest power plant

Grid emergency support

A paid service for availability → strong business case

- CAPEX: $ 95m
- Annual reserve capacity: $ 4m
- Annual frequency support: $ 18m
- Annual energy arbitrage: $ 12m
- Pay back time ~3 years (!)

Stacked services

Lithium ion batteries: example projects

Germany - Eneco/Mitsubishi – 48 MW/50 MWh - 2017

- Ancillary services (primary reserve)
- Energy time-shift (wind energy vs grid congestion)

ENERGY STORAGE

Eneco and Mitsubishi Plan Europe's Largest Battery, Pitching Storage Against Coal and Gas

After the project had been under consideration for two years, lithium-ion battery costs finally hit the right price point to make it work.

by Jason Deign
April 24, 2017

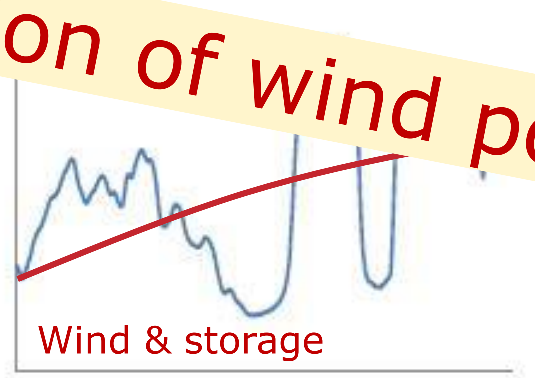
Grid support & renewables integration

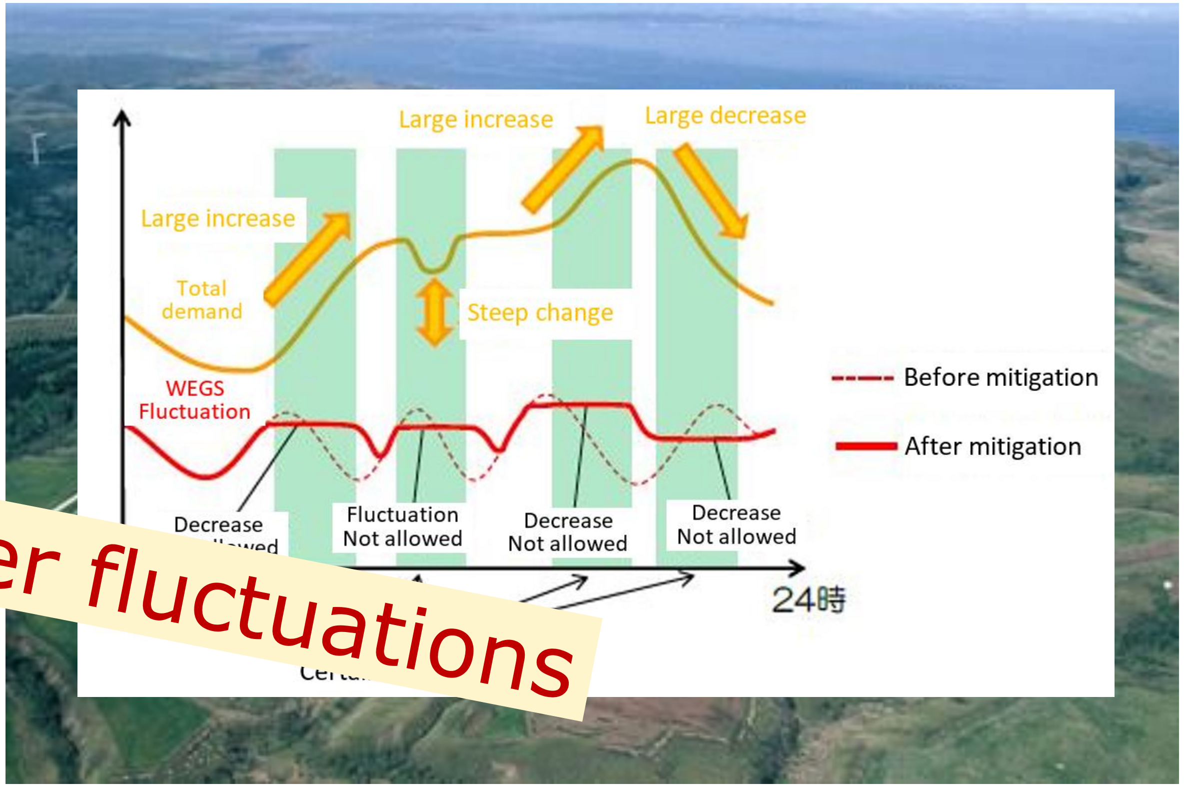
Source: https://www.greentechmedia.com/articles/read/eneco-and-mitsubishi-pitch-batteries-against-coal-and-gas

Li-ion battery of HWETC, Japan

- Hokkaido Wind Energy Transmission Corporation’s (HWETC’s) **240MW/720MWh** storage systems will be located on Hokkaido, the northern-most of Japan’s main islands
- BESS in co-location with 600MW of wind farms
- Construction was started in October 2018
- Applications:
  - Wind farm output smoothing
  - Wind farm output ramp rate control

Compensation of wind power fluctuations





Redox Flow Battery

Redox flow battery

Application

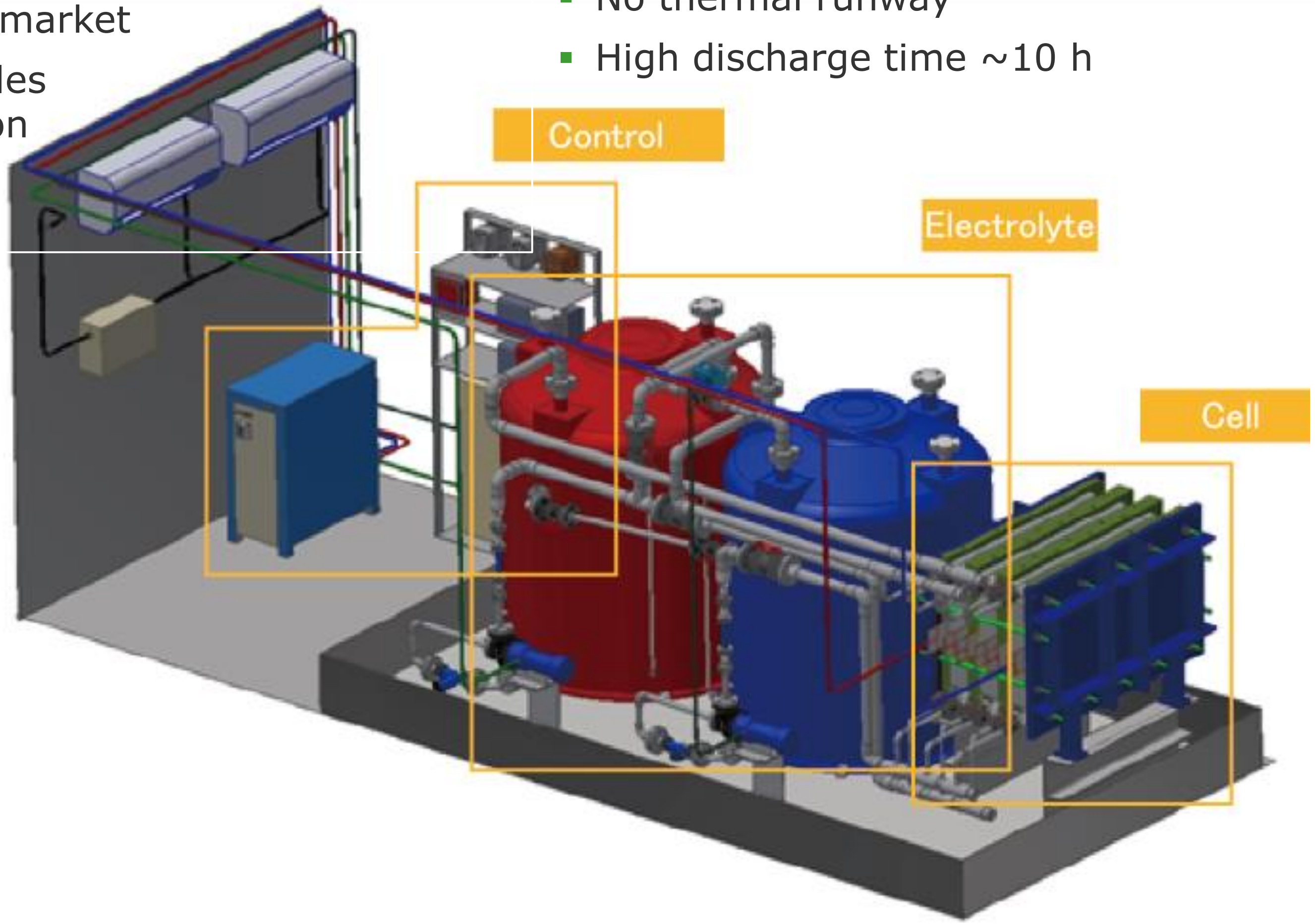
- Long storage of energy
- Capacity market
- Renewables integration

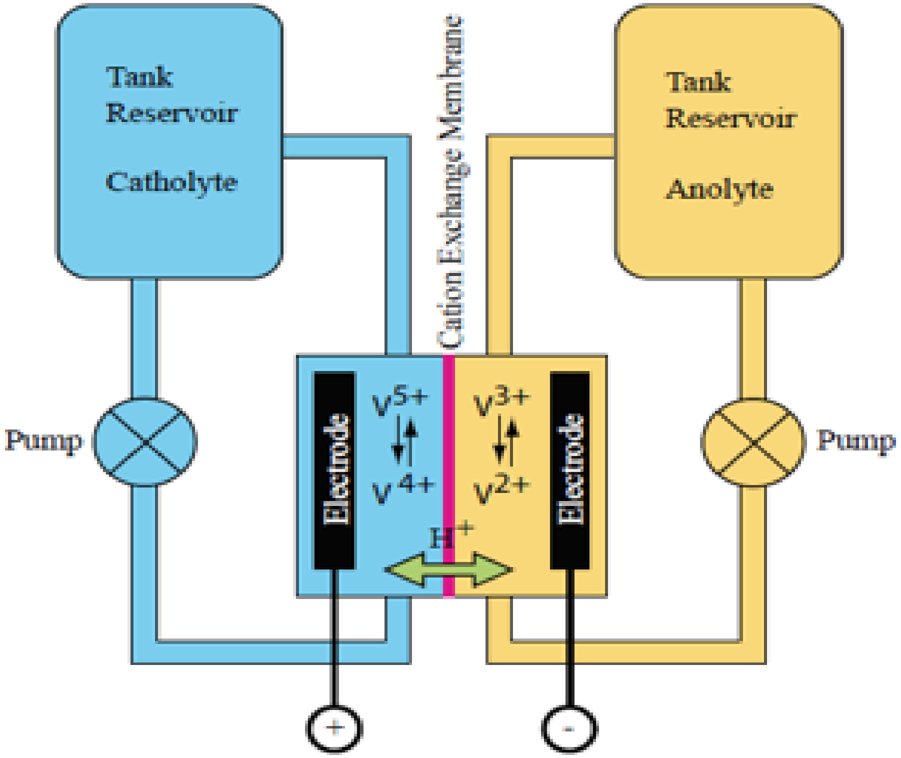
Pros

- No degradation, longer cycle life
- No thermal runway
- High discharge time ~10 h

Cons

- Low volumetric energy density
- Relatively high power unit price
- Low efficiency ~80%





DNV·GL

Redox flow battery: general outlook

- Runner op to Li-ion-based energy storage
- Potential for low LCOE costs, depending on cycling
- Government support from China
- Fragmented supply market

Redox flow battery is on its way

Recent projects/bids:

- Australia, 2019, 200 MWh
  (https://www.pv-magazine.com/2019/05/15/vanadium-flow-batteries-set-for-grid-scale-project-in-australia/)
- China, 2017-2019, 800 MWh
  (https://www.energy-storage.news/news/chinas-biggest-flow-battery-project-so-far-is-underway-with-hundreds-more-m)
- Europe, 2019-2020, 700 MWh, multiple deployments DE
  (https://redtenergy.com/redt-signs-exclusive-deal-for-700mwh-of-german-grid-projects/)

Flow battery: cost reduction

A New Path to Market for Flow Batteries: Rent an Electrolyte

The newfangled arrangement lowers the upfront price of vanadium flow batteries, potentially making them more competitive with lithium.

JULIAN SPECTOR | FEBRUARY 20, 2019

The Avalon flow batteries installed in a Santa Cruz microgrid contained a rented electrolyte to lower the project expense.

Photo Credit: Avalon Battery

When you're competing with mass-produced lithium-ion batteries, every bit of cost reduction counts.

The dominant energy storage technology benefits from massive economies of scale. Flow batteries, a major class of alternative storage technologies, lack that scale, and some require vanadium, a material whose price has shot up in the last three years.

A new business model innovation could lower the price for vanadium flow batteries, nudging them closer to competitiveness with lithium: rentable electrolytes.

Greentechmedia.com

Lessons learned – Li-ion Safety

Accidents with Li-ion batteries have attracted attention to battery safety

- In 2006, Dell recalled 4.1 million laptop batteries because they could erupt in flames.
- More recently, Samsung Electronics recalled and discontinued the Galaxy Note 7, its flagship smartphone, after several reports of the device exploding.

- Older events - - - - →

Current Affairs

Tesla Model S catches fire in California parking lot and reignites hours later at a tow yard

- A Tesla Model S car caught fire in a business parking lot in Los Gatos, California, on Tuesday, according to the Santa Clara County Fire Department.
- The fire department said the car reignited hours later at the tow yard.
- No injuries were reported in the incident.

Published 4:52 PM ET Wed, 19 Dec 2018 | Updated 5:36 PM ET Wed, 19 Dec 2018

NBC Bay Area

▲ On 21st, Shinchon-myeon, Gyeongnam-gun, Gyeongsangnam-do, was damaged by property damage of 4 billion won (estimated by the fire department) on the ESS, (Photo = Union)

South-Korea

Fire in Belgium raises questions about safety and costs of Li-Ion systems

A November 2017 fire at Belgium's first grid-connected lithium ion battery energy storage park raises important questions about the safety and costs of Li-Ion systems for high voltage grid ancillary systems.

South-Korea - when ambition seems to precede safety

- 23 fires in large-scale Li-ion systems (Aug 2017 – Feb 2019) in South-Korea
  >200MWh total, 4% of total installed capacity
- Investigation outcomes (11 June 2019):
  Eagerness to deploy at speed appears to have resulted in shortcuts
  - Lack of protective systems (grounding) for electrical shocks
  - Insufficient management of the environment (sea mist, sand dust)
  - Bad installation by sub-contractors
  - Insufficient control and protection systems
- Risk of overreaction from policy makers, regulators and other authorities
- Large-scale Li-ion systems can be safe, as long as safety is properly addressed

Switchgear and protection

- Uncleared short circuits cause major damage to equipment
- Switching functions
  - Isolation
  - Connect/disconnect
  - Fault Clearance
  - Circuit Earthing
- Sizing Considerations
  - Fault current rating
  - Load current rating
- Protection coordination needed between DC side and AC side and grid side
- Fuses
  - Are they really sensitive enough?
  - Specific DC fuses needed

Li-ion systems: dealing with fire

- **Risk**
  - Flammable components: organic electrolyte, anode/cathode, packaging
  - Several possible causes: overheating, internal shorts, external fire, …
  - Several effects: damage to / loss of system, external damage, toxic gases, …

- **Mitigation measures**
  - Containment (system design)
    - IEC 62619: “fire must be contained inside the system” *(not defined…)*
    - Industry, DNV GL: “fire should be contained to module”
  - Suppression systems
    - No adequate single extinguisher solution, no industry consensus; <u>compromise</u>
    - Issue: cool with water (stop spreading, emissions), or allow to burn
  - Ventilation: explosive/toxic gases (like burnt plastics)

See also: *Considerations for ESS Fire Safety*, public report for Consolidated Edison, DNV GL (2017)

Thank you

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