2-2. APEC Energy Demand and Supply Outlook 9th Edition: Power Sector

APERC Workshop

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Outline

- Power model improvements since the 8th edition
- Electricity demand, economic growth, and electrification
- Decarbonization technologies for the power sector:
  - Renewables
  - Hydrogen
  - Carbon capture and storage
- Conclusions

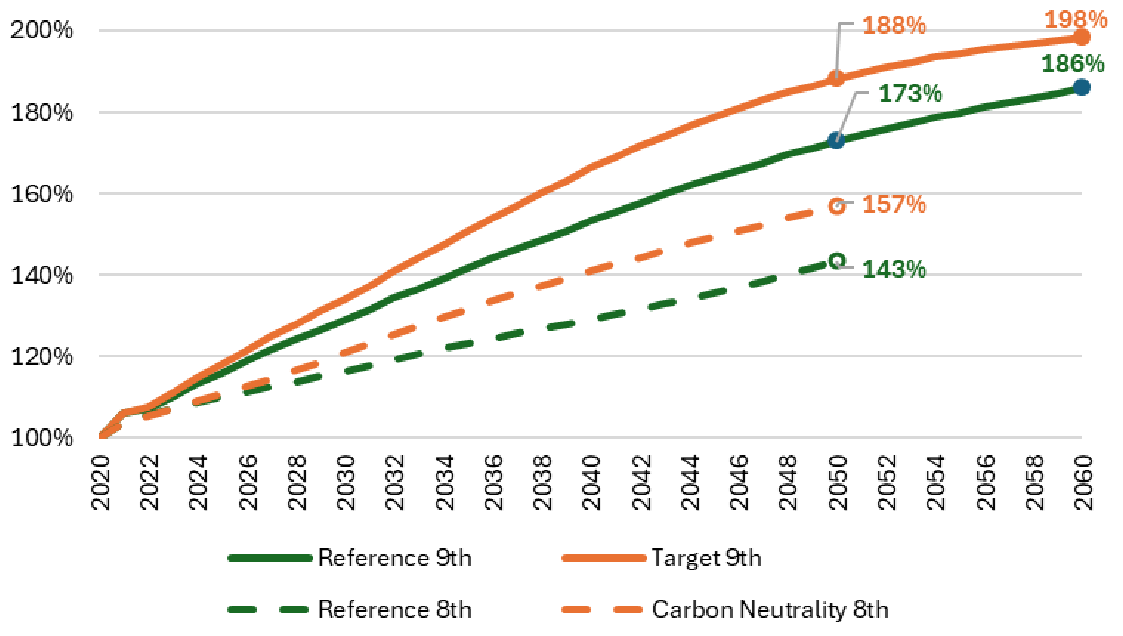
Power model improvements since the 8th edition

- Same open-source model for power generation
- OSeMOSYS: a least-cost linear optimisation model
- Economy-specific load profiles
- Expanded time representation:
  - 36 time slices (3 seasons, 2-day types, six 4-hour daily timebrackets)
  - improved understanding of the role of storage, including seasonal “storage”
- Two storage technologies (pumped hydro and batteries)
- Additional costs associated with variable renewables will be estimated outside the model

Electricity demand is a key inputs

- Preliminary electricity demand in the 9th is **30% higher** than in 8th **by 2050**
- Industry and Transport are the main contributors
- We haven't explicitly modeled the electricity consumption of **data centers**
- Estimation of the future peak load and demand profile is challenging
- Industrial consumers and data centers tend to consume electricity 24/7
- **When** will people charge their EVs?

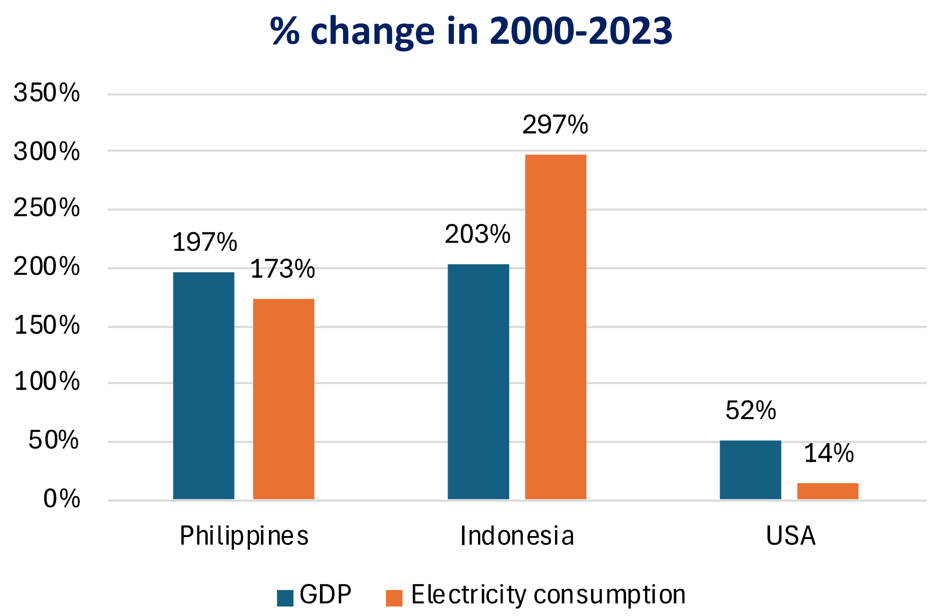
Electricity demand in APEC, 2020=100%

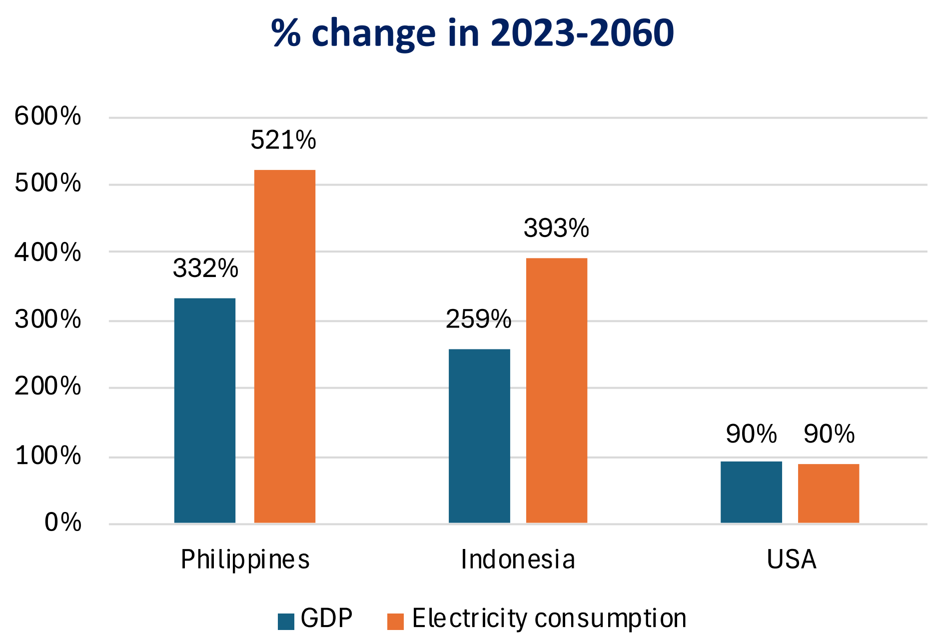


Jevons paradox (1865): "... technological improvements that increased the efficiency of coal use led to the increased consumption of coal".

Khazzoom-Brookes postulate (1980s): "... attempts to reduce energy consumption by increasing energy efficiency would simply raise demand for energy in the economy as a whole".

The relationship between GDP and electricity demand is changing





- Historically, the growth of electricity consumption was lower than GDP growth in many economies.
- Due to electrification, electricity consumption is likely to grow faster or at a comparable rate to GDP, even in advanced economies.
- The rapid growth in electricity demand will further increase the cost of power sector decarbonization.

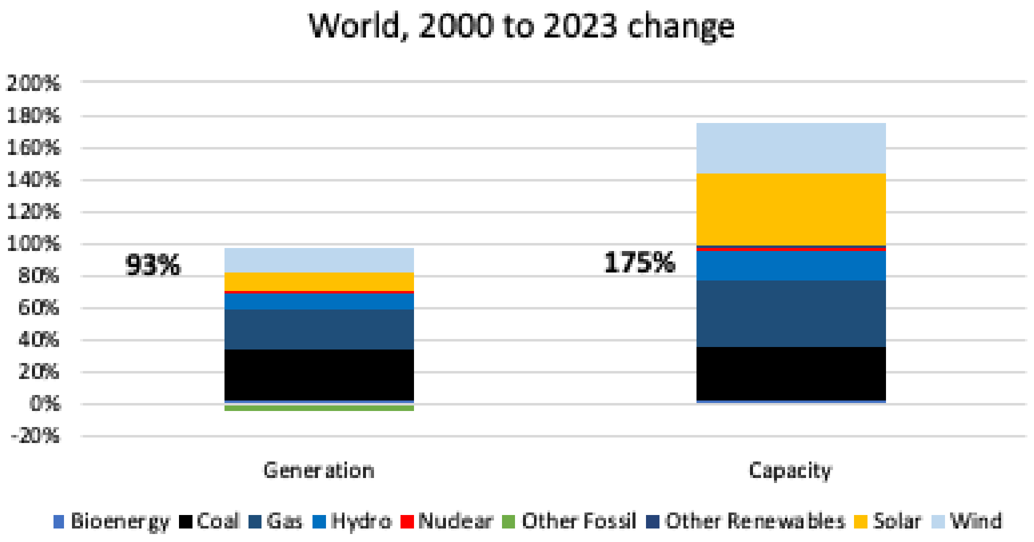
Decarbonization technologies for the Power sector

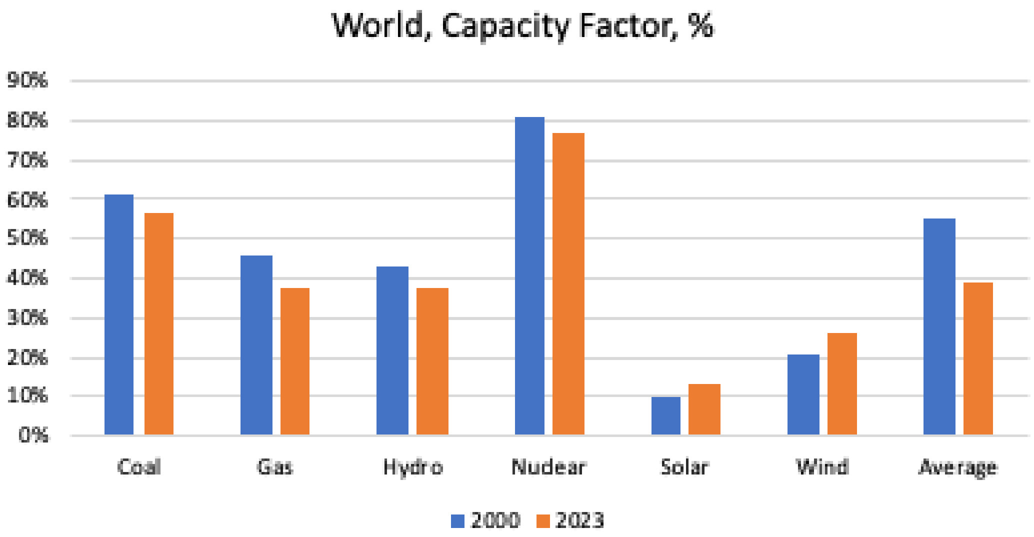
- The power sector is an integrated, complex system that is currently dominated by centralized power generation facilities.
- There is increased interest in distributed power generation, but its widespread adoption would require the resolution of many technical challenges.
- In the 9th edition, we aim to evaluate the role of 3 groups of technologies: solar and wind generation, hydrogen use in the power sector, and carbon capture and storage (CCS).

"Technology"	Challenges
Renewable generation	Integration, balancing the system, seasonal variations
Hydrogen use ("Green" H2)	Blending, co-firing for emission reduction, and possible way to serve as a seasonal storage of renewable generation
CCS	High hopes but many difficulties in pilot projects

Electricity generation and installed capacity in the world in 2000-2023

- Electricity generation almost doubled, while capacity almost tripled
- The contribution of wind and solar to that increase is 26%in generation and 76% in capacity
- The capacity factor of solar and wind has increased slightly over time
- Average capacity factor declined from 55% in 2000 to 39% in 2023 due to lower capacity factors of wind and solar generation and reduced capacity factors of conventional generation technologies
- The declining capacity factors raise the cost of maintaining electric grid reliability



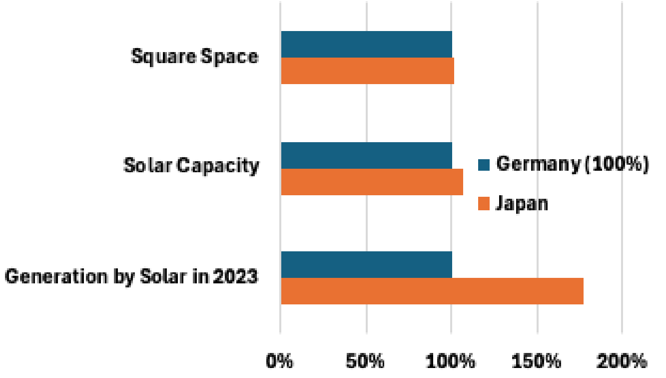


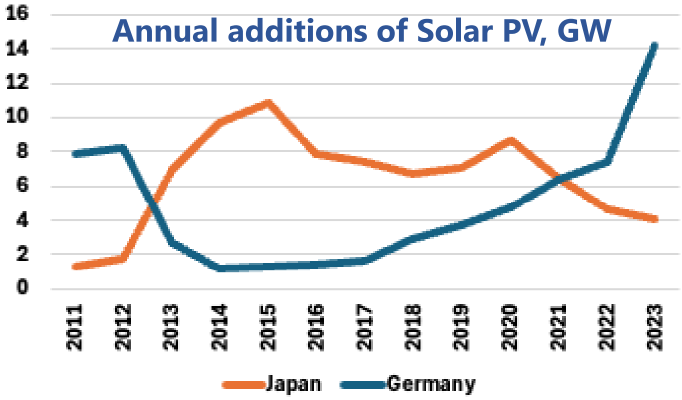
Ember data, Author's analysis

Geography does matter for grid-scale PV expansion

Japan

Source: [Reddit]() modified in accordance with APEC requirements





Source: Ember, 2023

Germany

Source: [Reddit]()

Some observations on renewables integration

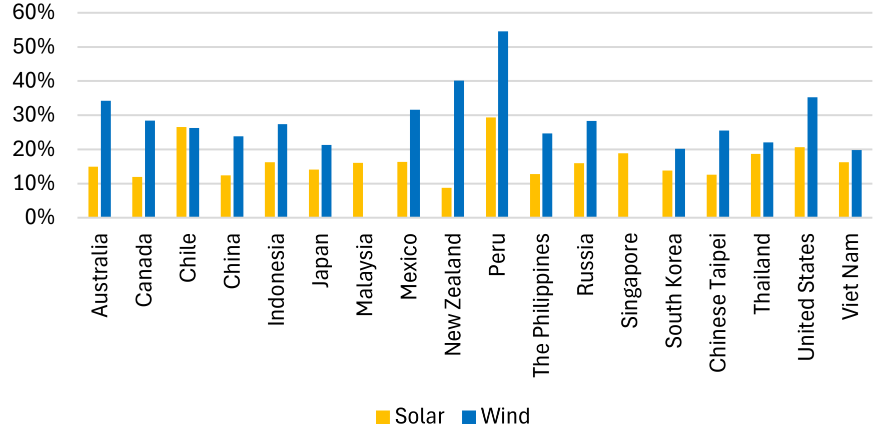
- For modeling, we need to know the constraints “on the ground”: geography, topography, and even public opinion.
- Existing and planned grid infrastructure strongly affects the development of any kind of generation, including solar and wind.
- Weather, geography, and topography are supply and capacity constraints for renewable electricity generation technologies.
- Solar irradiance and wind speed data are readily available; data on constraints in existing infrastructure are usually not.
- Batteries can serve well when there are small seasonal differences in electricity demand and renewable potential.
- Large seasonal differences in demand and renewable potential are difficult to overcome because seasonal storage is expensive.

“Green” hydrogen as seasonal storage

	Electrolyzer $\eta=0.7$	Compression $\eta=0.9$	Storage $\eta=0.99$	Gas turbine $\eta=0.4$
100 kWh	70 kWh	63 kWh	62 kWh	25 kWh

- Overall efficiency of using hydrogen as seasonal storage is very low – 25% is an optimistic estimate
- An electrolyser needs to run at a capacity factor of at least 60% to be commercial.
- Electrolysers that are co-located with renewables would benefit from additional power supply from the electric grid.
- However, power supply from the grid may introduce challenges related to emission compliance and zero-emission certification.

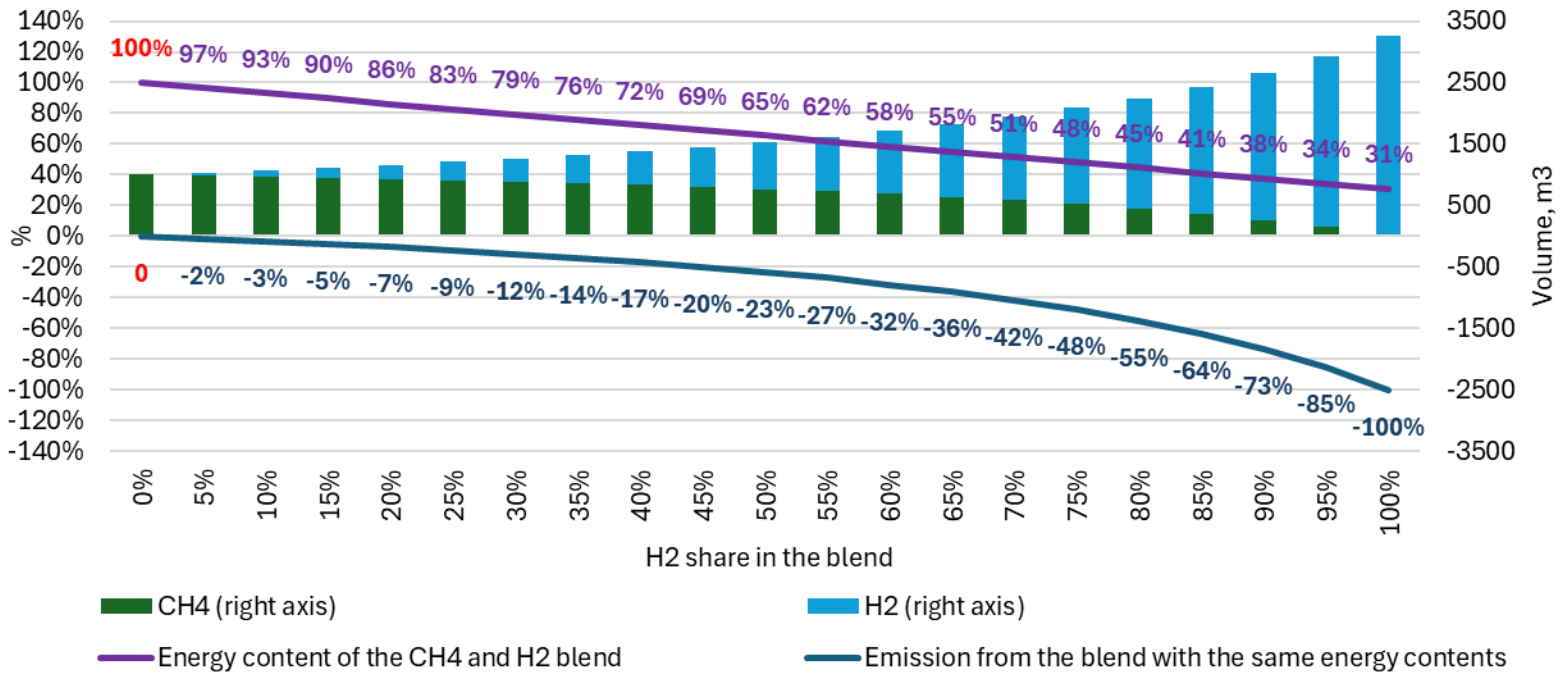
Capacity factor of solar PV and wind plants in APEC, 2022



Source: Ember (2024)

APERC
Asia Pacific Energy Research Centre

Hydrogen blending for emission reduction



- The energy density of hydrogen is lower than methane, therefore the energy contents of the blend is lower than pure methane.
- A 25% hydrogen blend (by volume) reduces CO_2 emissions by 9% for the same electricity output.

Some observations on the use of hydrogen

- In a broader context, green hydrogen can be used to transfer renewable electricity across time and space.
- The overall efficiency of using hydrogen as seasonal storage is small: 25% is an optimistic estimate.
- Blending hydrogen with methane reduces emissions by a smaller percentage than the share of hydrogen in the blend.
- Electrolysers need a higher capacity factor than stand-alone solar and wind facilities provide.
- Grid power could address the capacity factor issue but raises other issues.

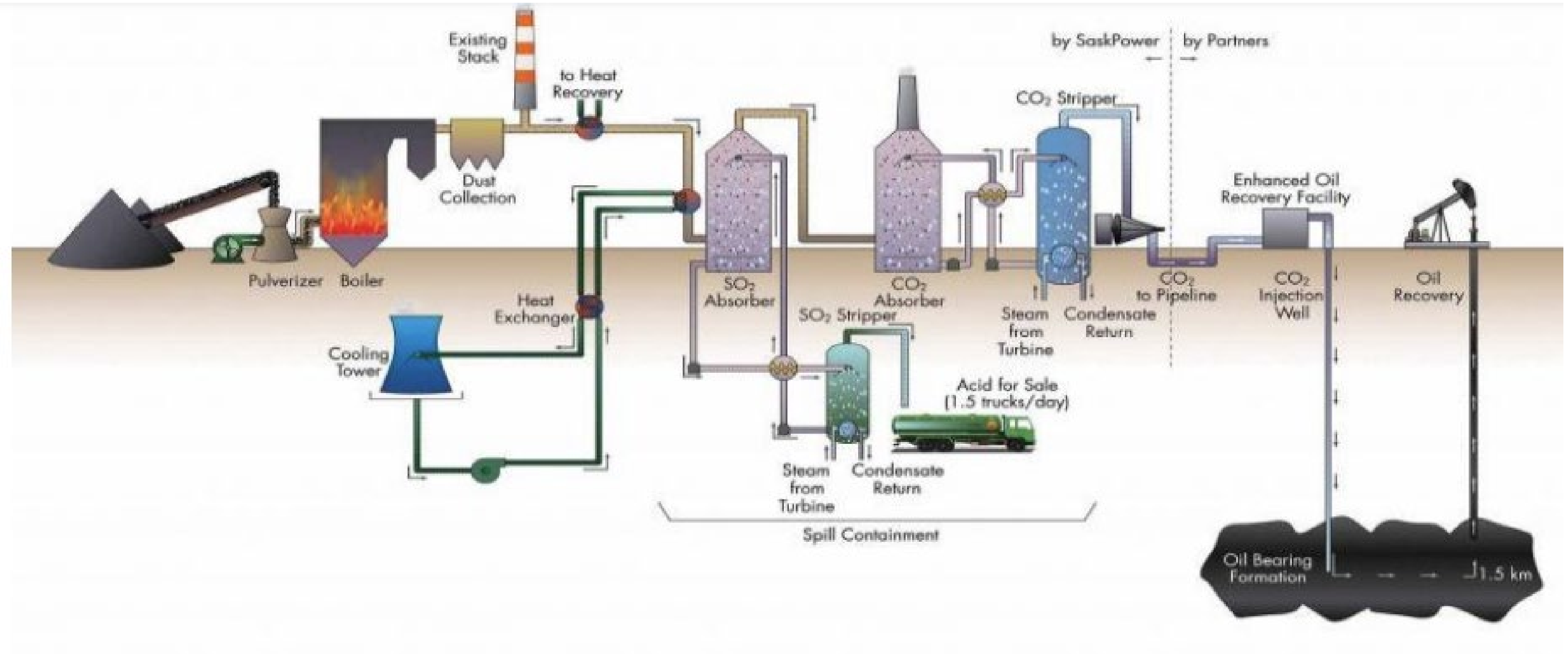
Carbon capture in the power sector: current status

- There are only two utility-scale carbon capture projects in the power sector worldwide: Petra Nova in the United States and Boundary Dam 3 in Canada.
- Both projects:
  - capture CO_2 from the flue gases of the coal-fired units;
  - designed to capture 1 million tons of CO_2 annually;
  - deliver CO_2 by pipeline to depleted oil fields to enhance oil recovery;
  - costs were about 1 billion USD for Petra Nova; 1 billion CAD for Boundary Dam 3.
- On April 30, IEEFA published an article about problems that Boundary Dam 3 is facing.
- Key findings from the article: Boundary Dam 3's long-term CO_2 capture rate through the end of 2023 was just 57%.

Full chain CCS process

Petra Nova:

- to capture CO_2 from a 240 MW coal-fired unit, CCS equipment consumes 35 MW -> own-use ratio 35/240 = 14.6%;
- 90 MW gas turbine with a heat recovery boiler was installed because pressure steam is used in the gas treatment process



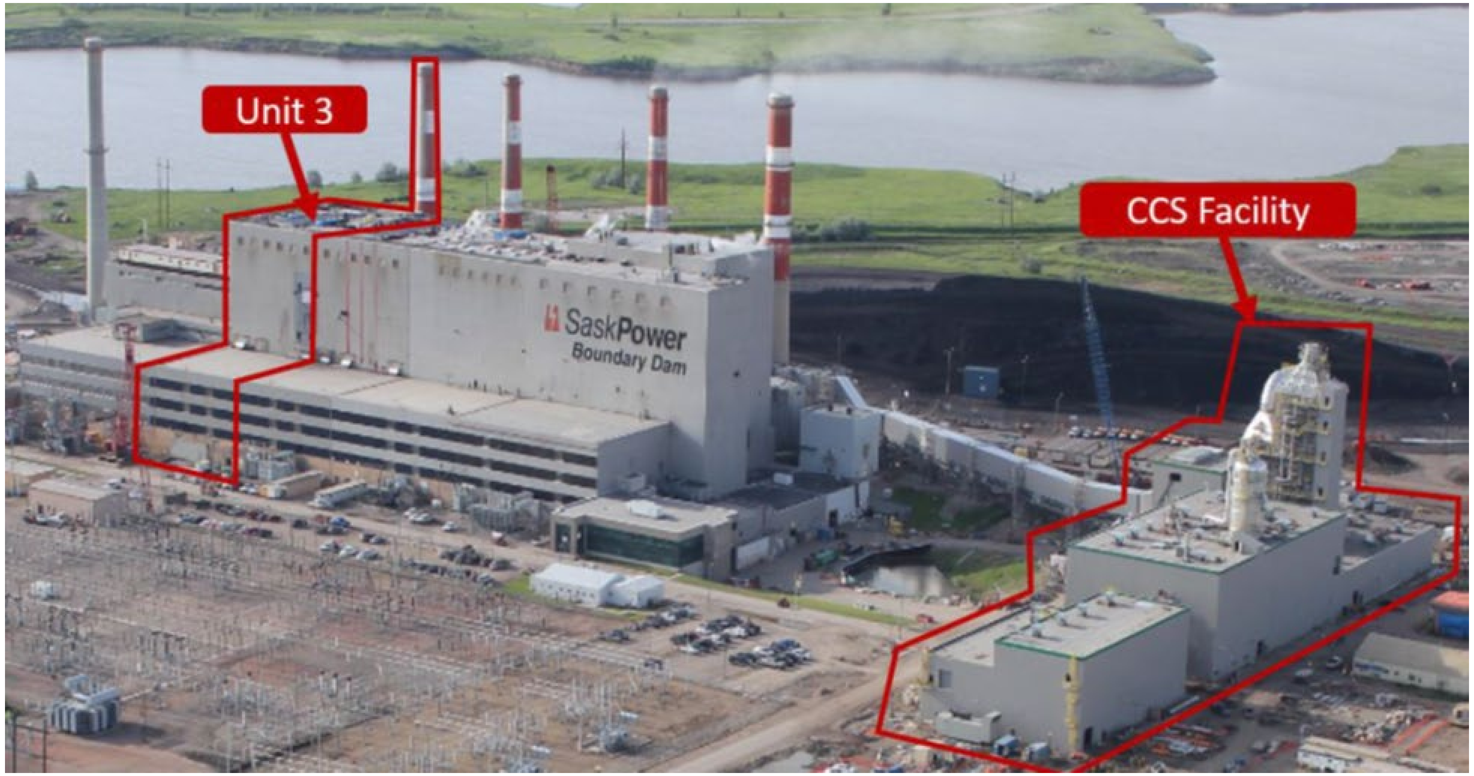
Boundary Dam 3 full chain CCS process: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4286430

Petra Nova carbon capture layout

https://netl.doe.gov/sites/default/files/netl-file/Anthony-Petra-Nova-Pittsburgh-Final.pdf
https://maps.app.goo.gl/t1NdEPdyBz7pc9tv7

Boundary Dam 3

- The size and the footprint of the carbon capture facility is comparable to the electricity generation unit



Some observations on the use of carbon capture

- Significant efforts are required to capture CO_2 in the power sector compared to other sectors (i.e. , natural gas processing), mainly due to lower CO2 concentrations in the flue gas and unstable gas flow.
- Petra Nova carbon capture facilities consume 15% of electricity generated.
- It is challenging for some power plants to provide the pressure steam necessary for the gas treatment process.
- CO_2 transport infrastructure is still very limited, especially long-distance CO_2 transport.

Conclusions

- Electricity demand is expected to grow despite energy savings and energy efficiency improvements.
- A key challenge is how to meet increased and more variable electricity demand with a growing share of intermittent generation from renewables.
- With current technology, it is very challenging and expensive to maintain grid stability and reliability during adverse weather events (cloudy days, windless days, and droughts) in power systems with a high share of variable renewable generation.
- We need to consider not only adding new capacity (especially renewable capacity) to existing power systems but also transforming them so that they can operate reliably despite fluctuations in renewable generation.
- In the 9th edition of Outlook, we aim to identify challenges for each APEC member economy in decarbonizing the power sector, considering the constraints and limitations of current technologies.

Thank you.

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