Path to 100% Renewables for California

What is Path to 100%?

Path to 100% is an objective community intended to bring together thought leaders and industry experts to discover solutions, raise awareness, and create a dialogue on how to achieve an operationally and financially realistic approach towards a 100% renewable energy future.

Path to 100% is made possible by Wärtsilä, a global leader in smart technologies and complete lifecycle solutions for marine and energy markets.

California Study and White Paper

California has set a target of 100% renewable electricity by 2045.

The study establishes a new path that enables California to meet it’s RPS target 5 years ahead of schedule (2040).

This new path provides a reliable, affordable and most importantly, environmentally friendly way to decarbonize the electricity generation.
Presenters

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Wärtsilä
Moderator

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Speaker

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General Manager, Utility Market Development, North America
Wärtsilä
Speaker
Decarbonizing Electricity in California by 2045

Content

1. California situation, plan & challenges
2. Modelling the Californian power system expansion until 2045
3. Scenario comparison & results
4. P2G
5. Summary
California Situation, Plan & Challenges

Situation
- Firm decarbonization targets
- Access to favorable solar and fair wind resources
- Need to stop using fossil fuels
- Rapidly growing installed base of solar power
- Strong dependency on imported power
- Increasing issues with
  - Solar curtailment
  - Duck curve & evening ramp
  - Security of supply – microgrids
  - Increasing cost of power

Decarbonization plan
- Keep adding solar power and storage
- Very limited repowering of gas plants
- Close down nuclear and OTC-plants
- Taxes on imported fossil fuel power

Challenges
- How to integrate renewables to the system?
- How to ensure
  - System reliability at all weather conditions?
  - Competitive electricity prices?
- Electricity available from neighboring states?
- Where to locate & how to connect new solar and wind power to the system?

“The report finds that limiting global warming to 1.5°C would require... ‘net zero’ around 2050.”
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Modelling the Californian power system expansion until 2045

Wärtsilä is a world leader in modelling power systems with high share of renewables

High-performance energy system simulation software

Wärtsilä model is based on the same model used by CAISO to support 2019 IRP

PLEXOS engineers the optimum Path to 100% decarbonized power system for California!

Modelling approach

PLEXOS (TM) Inputs

- All Western USA power plants (> 1200 units) with full parameterization
- Hourly solar and wind generation profiles for different regions
- Main transmission interconnectors
- Electricity load in 3 nodes
- Political decisions (RES % targets, OTC’s etc)
- Forecasts from BNEF:
  - Wind & solar price learning curves
- Fuel prices, new technology parameters and economic parameters from Californian IRP
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Path to 100 Scenarios

Current Plan*

- Power system development follows the 2019 state IRP (46 MMT Alternate Scenario) until 2030, and mirrors the IRP (High Electrification Scenario) until 2045
- OTC retirements delayed until 2026...
- Gas investments restricted to
  - Repowering of Intermountain
  - OTC replacements with CCGTs
- Full RPS compliance by 2045
  - ...but.... fossil fuels still in use after 2045!!

Optimal Path

- Full power system optimization until 2045 by Plexos
- No further delays on OTCs beyond 2023
- Flexible gas power available investment option
- Renewable fuels available for thermal assets
- Full RPS compliance by 2040
  - ...and.... fossil fuels fully phased out by 2045!!

* Current Plan emulates the current California state plan
Common Assumptions for Scenarios

Old gas power plants retire at the age of 35 years
- Average retirement age of CCGT’s in the USA 27 years

Neighboring states fully decarbonize their power systems by 2045
- Fossil balancing power will not be available from the neighbors in 2045

March 26, 2019
Idaho Power set a goal to provide 100-percent clean energy by 2045.
Current Plan*

- OTC retirements delayed until 2026 to maintain sufficient amount of capacity in the system
- "Generic Effective Capacity" as a “perfectly dispatchable peaker with zero emissions” replaces OTC’s 2026 to ensure system reliability
- Total installed new capacity 28 GW

Optimal Path

- Faster addition of solar and battery storage
- OTC repowering starts in 2022 enabling faster carbon reduction
- Flexible gas generation, additional storage and solar replace OTC’s and ensure system reliability
- Total installed new capacity 33 GW

Important characteristics of Flexible Gas Generation:
- Fast start and stop (in minutes)
- Multiple daily starts
- Fast ramping
- No restriction on up or down time
California System Expansion until 2045

**Current Plan**
- System capacity increases to 262 GW
- Overbuild of solar, wind and storage required to manage low wind and solar weather periods
- Maintain reliability → add new peakers
- Reach RPS by 2045
- Levelized cost of electricity 51 $/MWh in 2045

**Optimal Path**
- Smaller system capacity (237 GW) with 8 B$ less investments, grid connections and land use
- Security of supply provided by storage, flexible gas & some peakers (capacity margin)
- Meets RPS in 2040 & 100% de-carbon in 2045
- Levelized cost of electricity 50 USD/MWh in 2045
Emissions and Generation Costs

**Carbon Reduction**

- Optimal Path allows faster growth of renewables, without OTC extensions.
- Optimal Path avoids 124 MtCO₂ of Carbon compared to Current Path.
- Current Plan meets 60% RPS target at 2030, but Optimal Path exceeds it.
- Optimal Path is at 100% net-zero by 2045 while Current Path is not.

**Generation Costs**

- 8 B$ cost savings

FASTER CARBON REDUCTION WITH LOWER COSTS!
Third scenario for California?

**Current Plan without Thermal**

- Add only solar, wind & storage, no thermal
- Need to strongly overbuild storage for system reliability even during long unusual weather patterns

<table>
<thead>
<tr>
<th></th>
<th>Current plan</th>
<th>Optimal Path</th>
<th>Current Plan w/o thermal</th>
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<tr>
<td>System size GW</td>
<td>262</td>
<td>237</td>
<td>588</td>
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<tr>
<td>LCOE in 2045 $/MWh</td>
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<td>50</td>
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<td>Carbon 2045 MTon</td>
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### THE NUMBERS... Putting it all together (2045)

<table>
<thead>
<tr>
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<th>Optimal Path</th>
<th>Current Plan</th>
<th>Current plan w/o thermal</th>
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<td>GW Solar</td>
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<td>GW Hydro</td>
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<td><strong>Total GW (Capacity)</strong></td>
<td><strong>237</strong></td>
<td><strong>263</strong></td>
<td><strong>588</strong></td>
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<tr>
<td>P2G GW (load)</td>
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</table>

- **CAPACITY**
- **Affordable**
- **Reliable**
- **Sustainable**

- Only option with true long-duration seasonal storage!
- Significantly higher utilization of solar & wind!
- Lowest Cumulative Carbon!
- IPCC Compliant 2045!
- Lowest cost option!

- 26 to 351 GW less capacity!

- 213 to 295 sq. miles less land!
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Power to Gas Fuels Production Process

Excess Renewable Electricity

Direct Air Carbon Capture

Electrolyzer

Methanizer

Carbon Neutral Methane to natural gas network or to LNG
Power to Fuel – Synthetic Carbon Neutral Fuels

Driver = 100% Renewable targets for cities, states, nations, companies, utilities, airlines, etc.

Challenges
- Electrification domestic/industrial
- Shipping, Aviation, Automotive
- Reliability in electricity supply
- Limitations on Biofuel

P2X helps....
- Decarbonize via renewable fuels
- Decarbonize via renewable fuels
- Provide long-term energy storage, firm capacity
- Supplement renewable fuel supply

P2X Enablers
- Low cost or excess renewable MWh
- Policies to incent renewable fuels
- Increasing production volumes

Drives the Following
- Reduced P2X production cost
- Provide volume pricing
- Accelerate cost reductions
P2X Major Actions on the Market to Provide Supply

- Shell aims to become world’s largest electricity company (Financial Times 13.3.2019)
- Maersk carbon emissions to zero by 2050 via carbon-neutral fuels
- British Airways to offset carbon emissions from 2020, IAG invests in sustainable aviation fuels
- Rotterdam airport pilots direct air capture for aviation fuel
- Lufthansa pilots synthetic kerosene production
- Carbon Recycling International (CRI) - CO2-To-Methanol Plant in China to produce 180,000 tons of methanol and LNG annually
- Carbon Engineering - 1 million ton/day in Texas USA for Occidental Petroleum, start date 2021
- Shell, Neste, Wärtsilä, Finnair, St1, Kemira, Finnsementti and LUT university build an industrial pilot project for P2X fuels at Joutseno, Finland

German gas industry targets 5 GW of power-to-gas capacity in five years

"The only possible way to achieve the so much needed decarbonisation in our industry is by fully transforming to new carbon-neutral fuels and supply chains."

Søren Toft, Chief Operating Officer of Maersk
Renewable Fuels as Large Long Term Storage

**18 TWh_{fuel}**
Equivalent to “Full Charge” energy available to a battery (15% of current California storage capacity)

**4 % Capacity Factor**
Thermal Plants dispatch only when wind and solar not available

All renewable fuel produced in-state using renewable energy
Modern gas power plants can burn synthetic fuels efficiently today

7.7 TWh_{electric}

32 GW gas power in 2045
- 15 GW actively dispatched
- 17 GW in cold reserve
P2G - New Approach to Electricity Storage

Excess Renewable Electricity

Short Term Storage 158 GWh

Conversion Inverter

Balancing Power for the Grid

Long Term Storage 7650 GWh

Conversion Gas Power Plant

Fuel
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Meet RPS target by 2040, 5 years ahead of current schedule!

Reach full decarbonization by 2045, 5 years ahead of IPCC recommendation

Minimize total carbon emissions between now and 2045

Dramatically reduce land-use, grid connections & curtailment of solar and wind power

Provide security of supply with long-term energy storage using renewable fuel

Flexible gas power plants are an integral part of the 100% renewable system

All this for 8 B$ lower cost than Current Plan!
Full White Paper – PATHTO100.ORG

Please download the full study at www.wartsila.com/energy/optimising-power-systems