



Path_— to100%

Renewables for California

March 18th 2020

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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 its 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



Tyler Murphy
Marketing Manager, Americas
Wärtsilä
Moderator



Antti Alahäivälä
Manager, Business Development
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Speaker



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Wärtsilä
Speaker



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North America
Wärtsilä
Speaker



Decarbonizing Electricity in California by 2045

Content

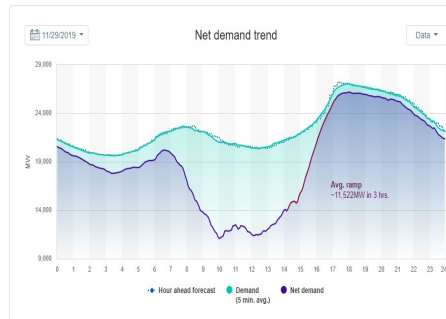
1. California situation, plan & challenges
2. Modelling the Californian power system expansion until 2045
3. Scenario comparison & results
4. P2G
5. Summary



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?

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Modelling the Californian power system expansion until 2045

Modelling approach

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



High-performance energy system simulation software



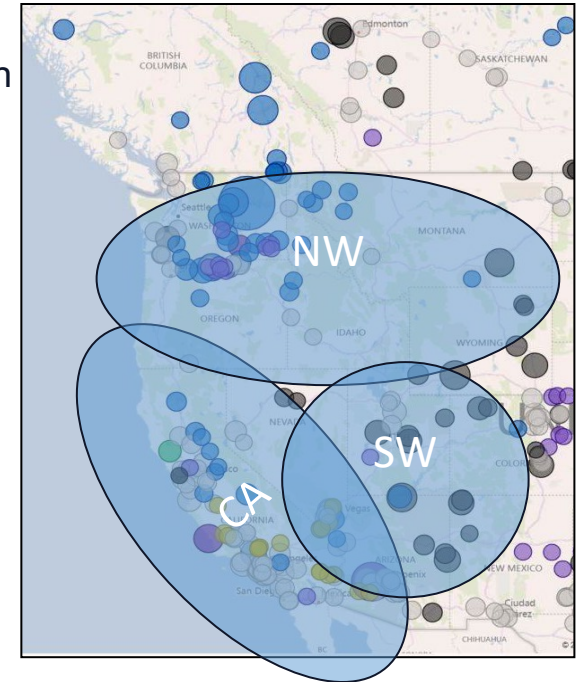
Wärtsilä model is based on the same model used by CAISO to support 2019 IRP

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



PLEXOSTM 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

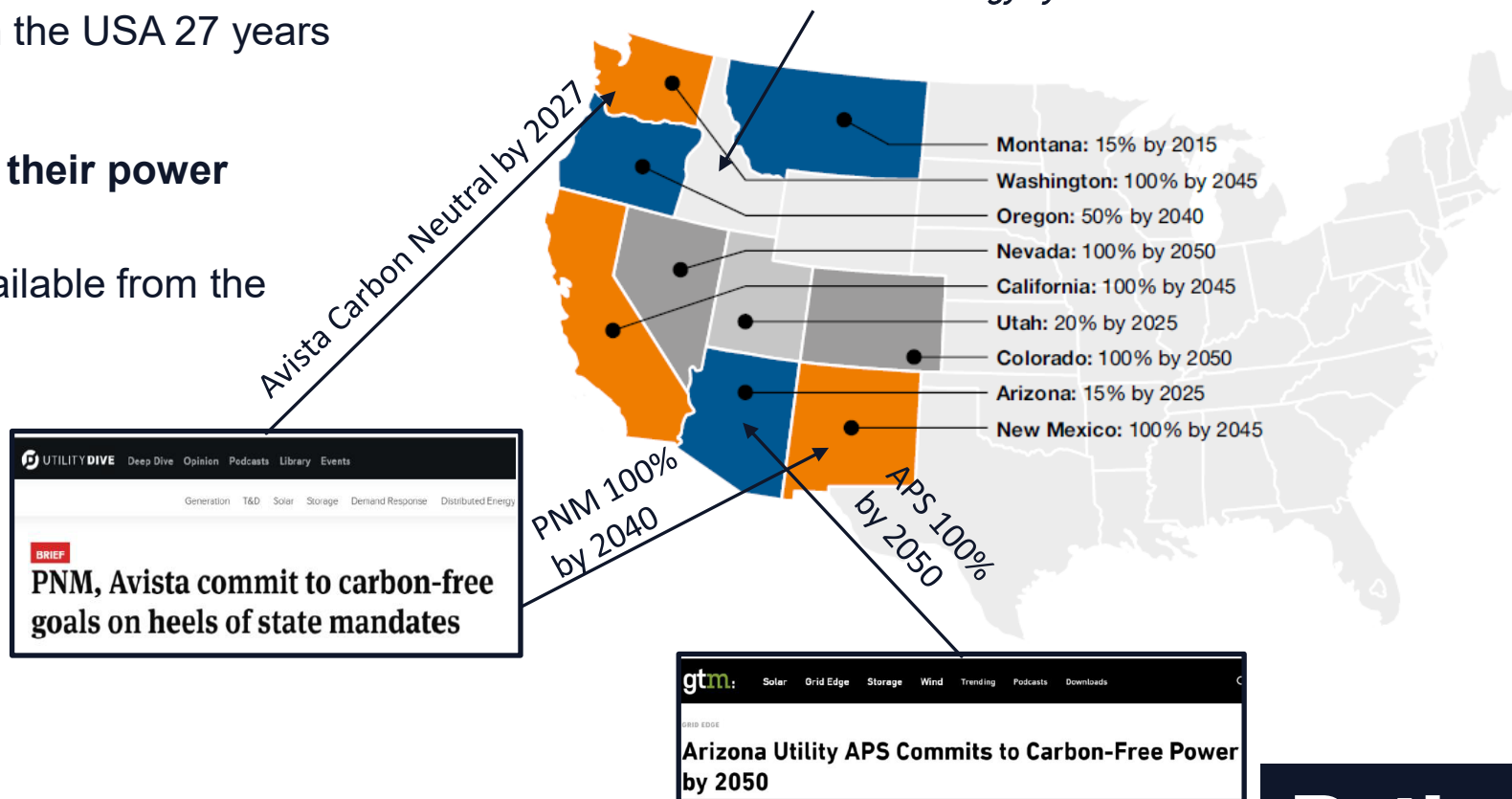
Neighboring states fully decarbonize their power systems by 2045

- 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.



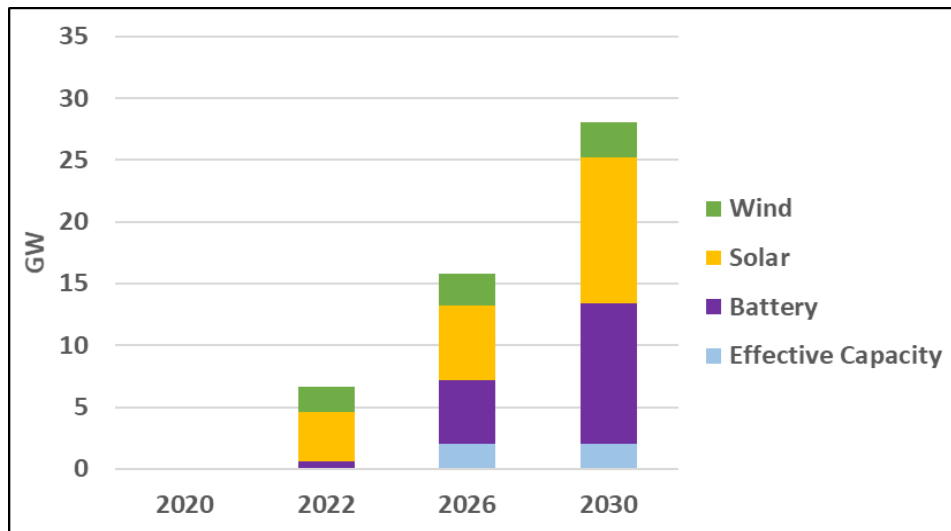
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Capacity Additions until 2030

Important characteristics of **Flexible Gas Generation**:

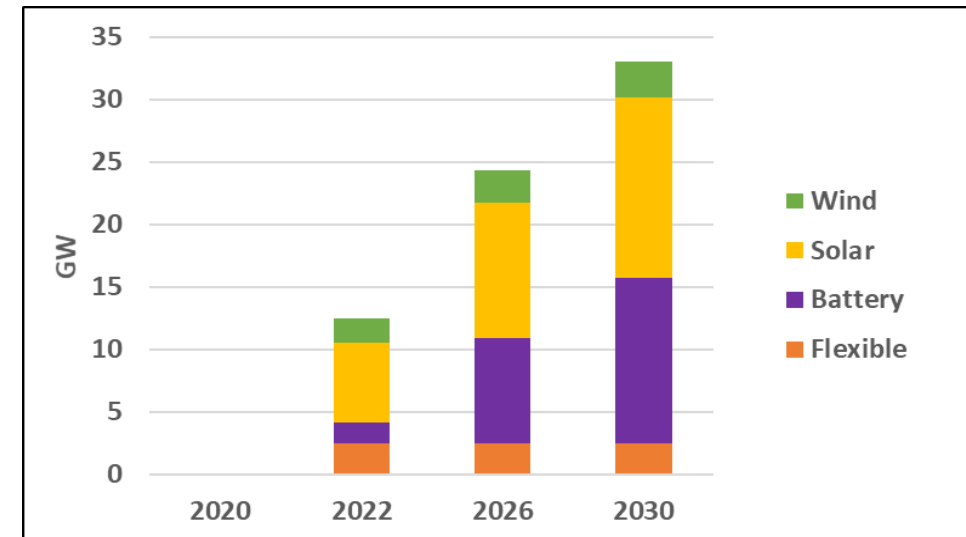
- Fast start and stop (in minutes)
- Multiple daily starts
- Fast ramping
- No restriction on up or down time

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

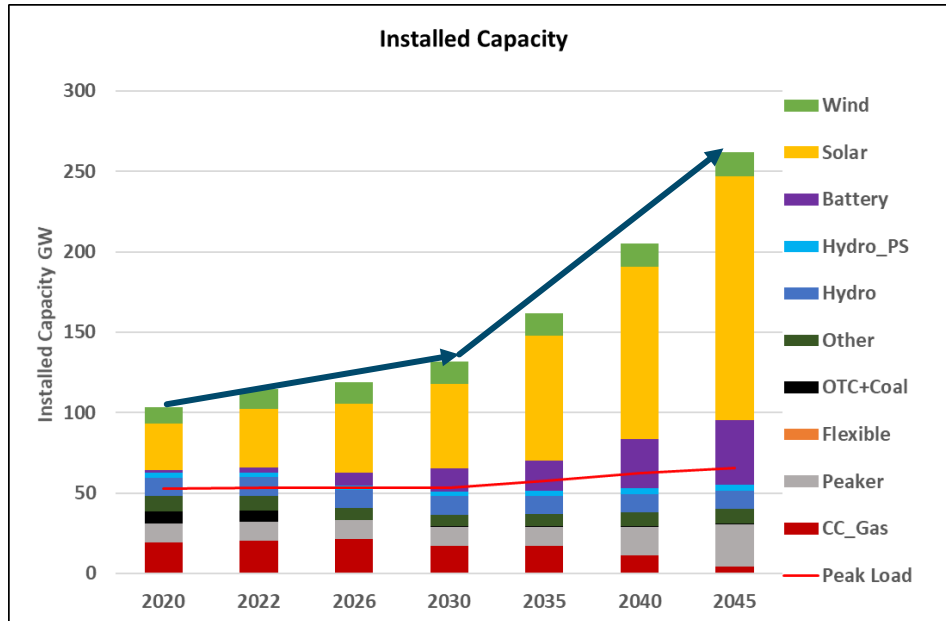


- Faster addition of solar and battery storage
- OTC repowering starts in 2022 enabling faster carbon reduction
- Flexible gas generation, additional storage and solar replace OTC's and ensure system reliability
- Total installed new capacity 33 GW

* Current Plan emulates the current state plan

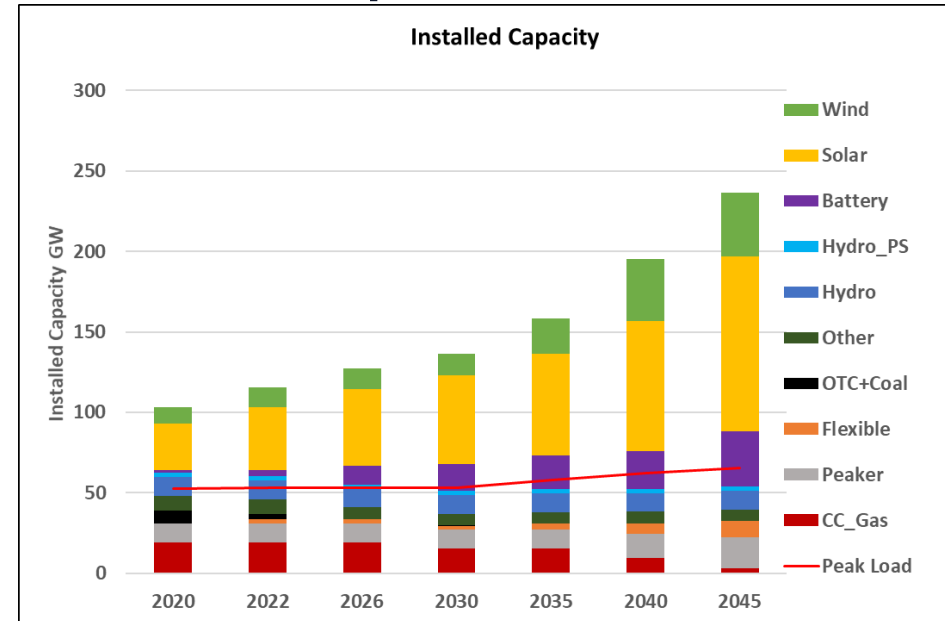
California System Expansion until 2045

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

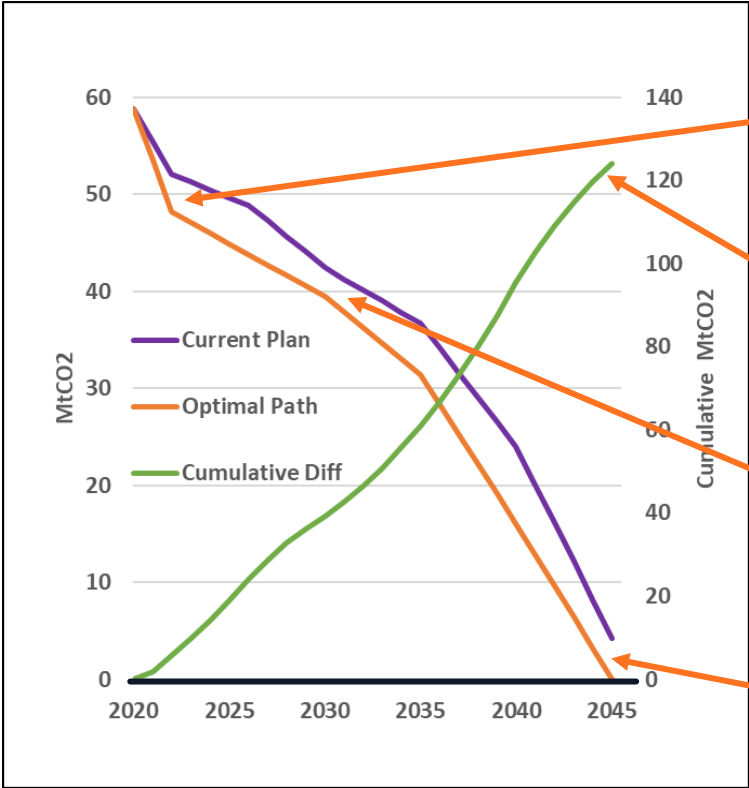


- Smaller system capacity (237 GW) with 8 B\$ less investments, grid connections and land use
- Security of supply provided by storage, flexible gas & some peakers (capacity margin)
- Meets RPS in 2040 & 100% de-carbon in 2045
- Levelized cost of electricity 50 USD/MWh in 2045

Emissions and Generation Costs



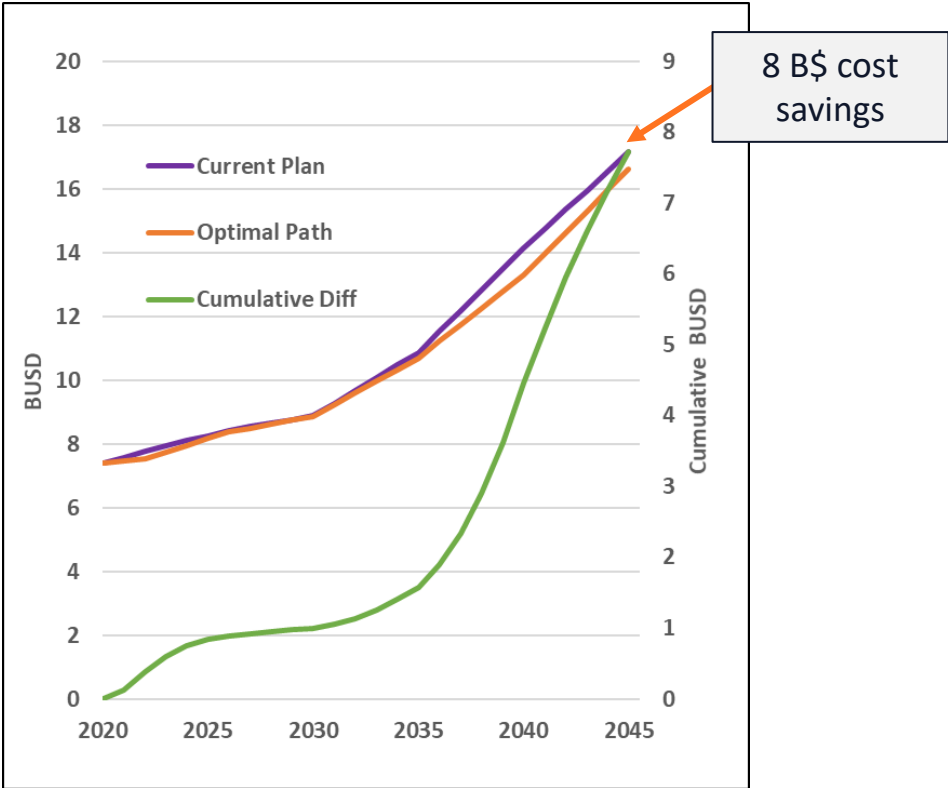
Carbon Reduction



- 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

FASTER CARBON REDUCTION
WITH LOWER COSTS!

Generation Costs



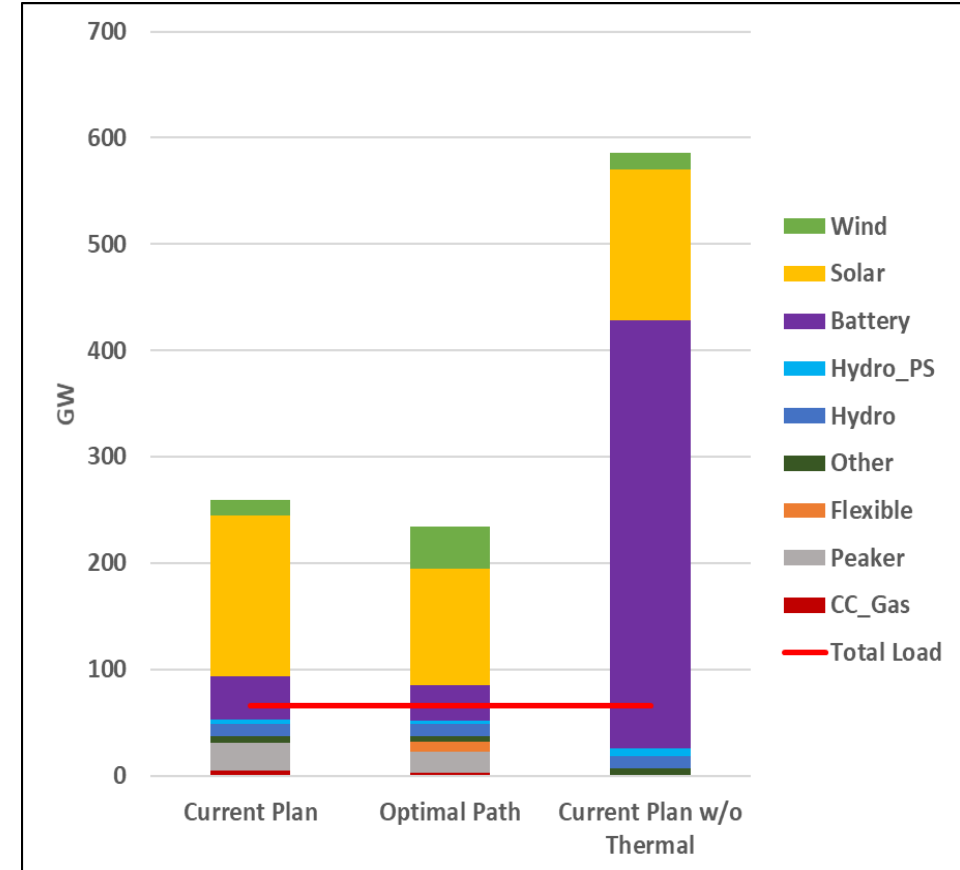
Third scenario for California?

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

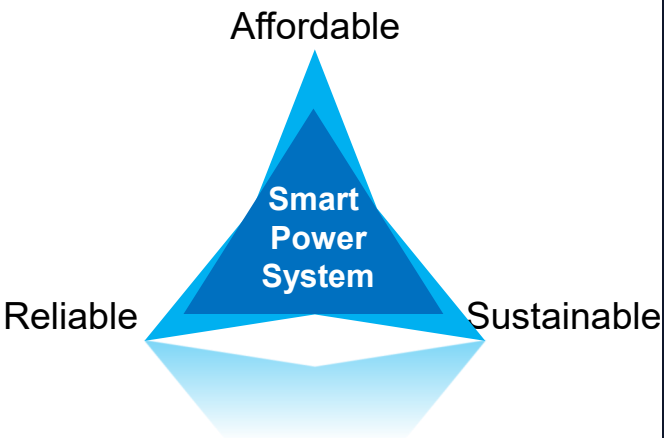
	Current plan	Optimal Path	Current Plan w/o thermal
System size GW	262	237	588
LCOE in 2045 \$/MWh	51	50	128
Carbon 2045 MTon	4	0	0

Installed Capacity in 2045



THE NUMBERS... Putting it all together (2045)

CAPACITY		Optimal Path	Current Plan	Current plan w/o thermal
	GW Solar	109	152	141
	GW Wind	40	15	16
	GW Storage	37	44	410
	GW Thermal Old	14	14	0
	GW Thermal New	18	17	0
	GW Other	7	9	9
	GW Hydro	12	12	12
	Total GW (Capacity)	237	263	588
	P2G GW (load)	10	0	0



26 to 351 GW less capacity!

Only option with true long-duration seasonal storage!

- Significantly higher utilization of solar & wind!
- Lowest Cumulative Carbon!
- IPCC Compliant 2045!
- Lowest cost option!

213 to 295 sq. miles less land!

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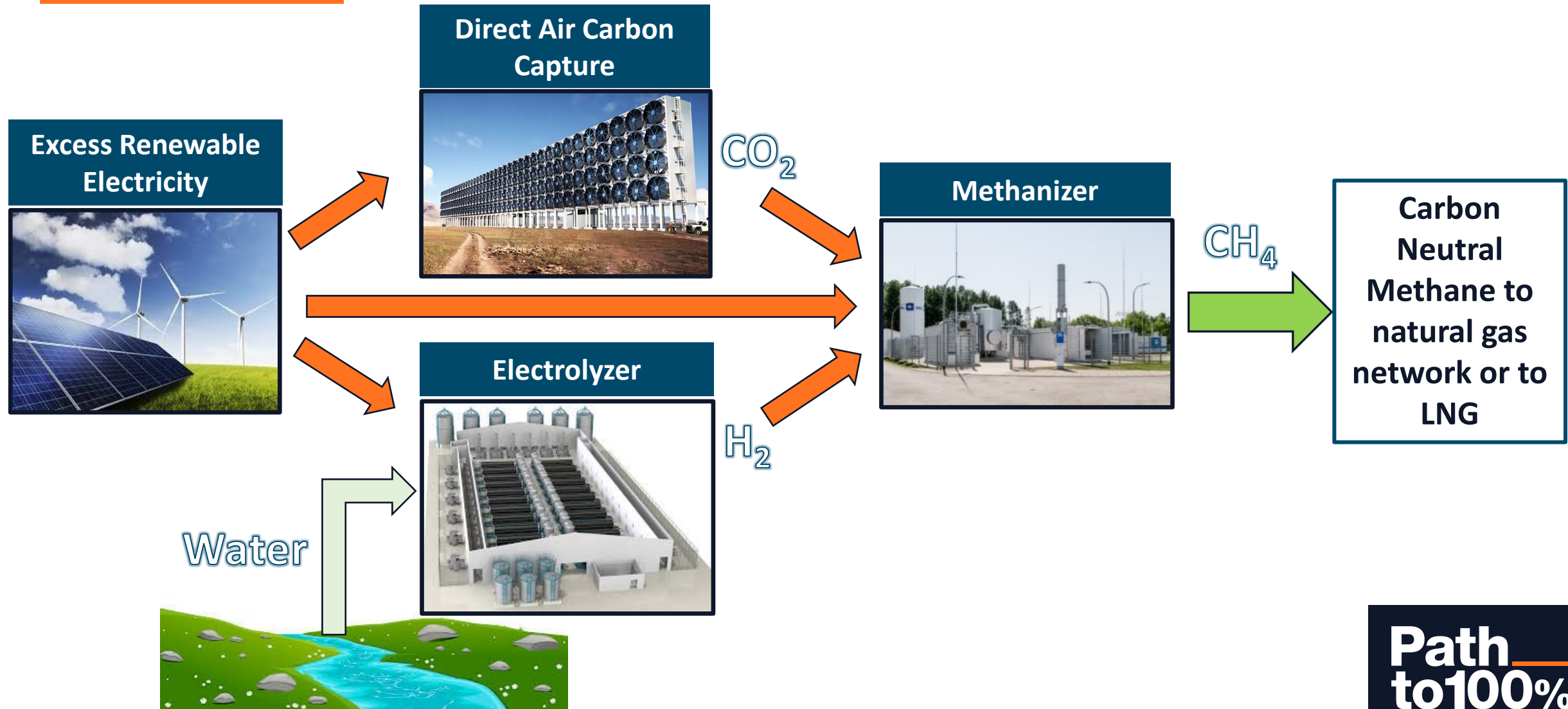
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Power to Gas Fuels Production Process



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 Enablers

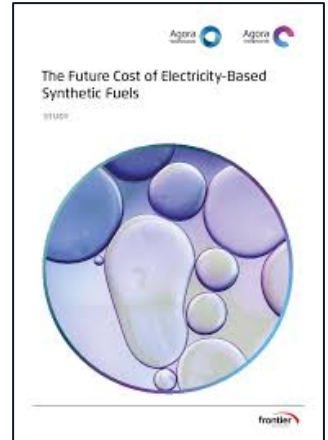
- Low cost or excess renewable MWh
- Policies to incent renewable fuels
- Increasing production volumes

P2X helps....

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

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 

MAY 22, 2019
AGREEMENT SIGNED FOR CRI'S FIRST CO₂-TO-METHANOL PLANT IN CHINA

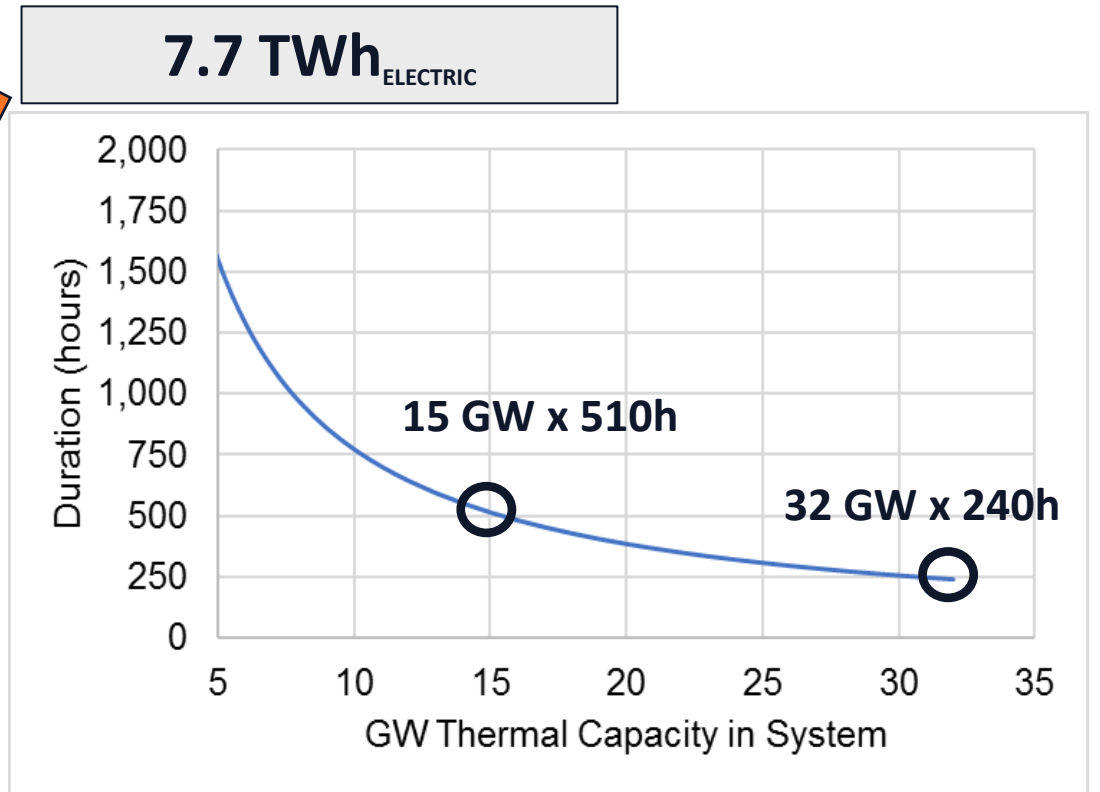
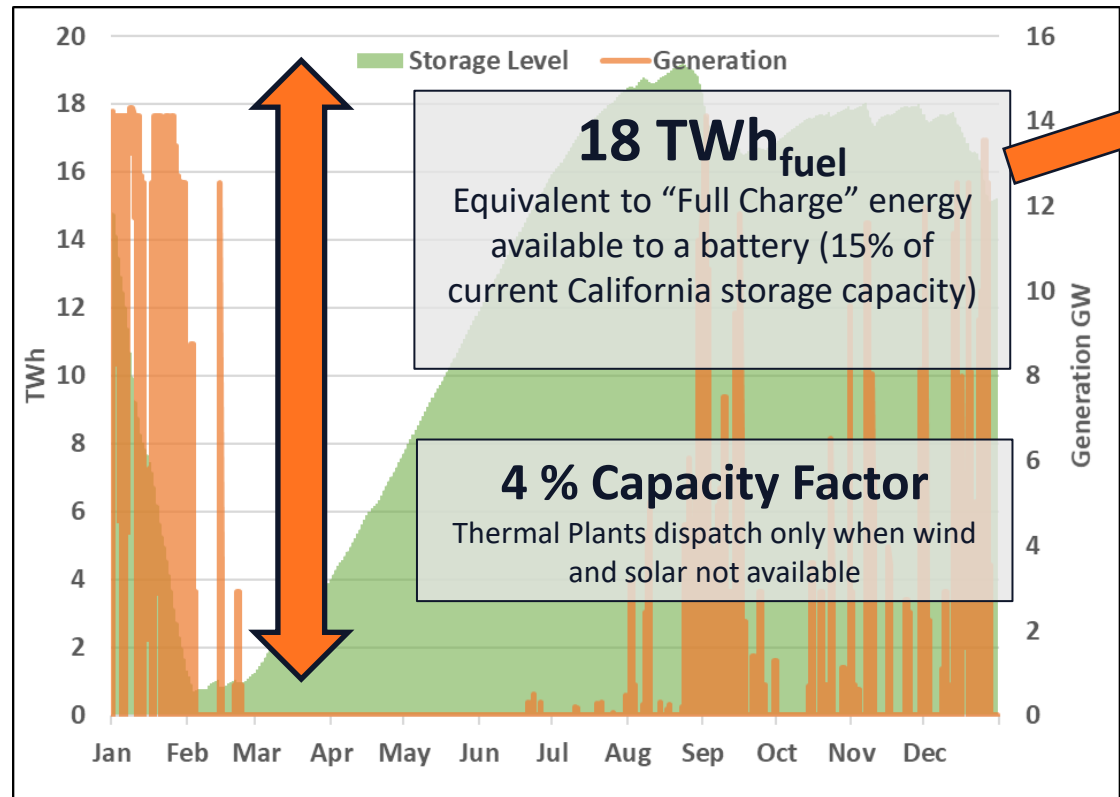
“ The only possible way to achieve the so much needed decarbonisation in our industry is by fully transforming to new carbon-neutral fuels and supply chains.



Søren Toft, Chief Operating Officer of Maersk

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Renewable Fuels as Large Long Term Storage

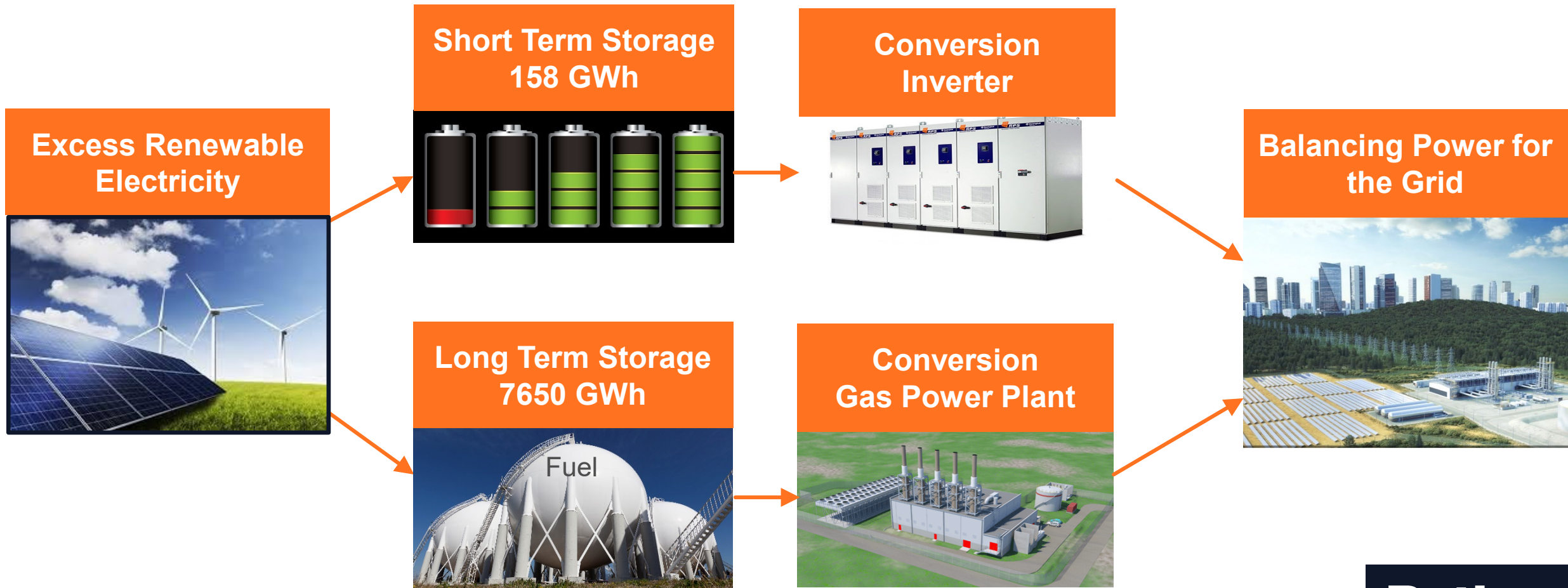


All renewable fuel produced in-state using renewable energy
Modern gas power plants can burn synthetic fuels efficiently today

32 GW gas power in 2045

- 15 GW actively dispatched
- 17 GW in cold reserve

P2G - New Approach to Electricity Storage



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Optimal Path to 100% Decarbonization for California


- 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





Path to 100% Renewables for California

WÄRTSILÄ WHITE PAPER




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Meeting California's goal of 100% renewable electricity by 2045 while also ensuring affordable and reliable power is a tremendous challenge. This white paper explores a new path that would enable California to meet its goal of 100% clean electricity by 2040 — five years ahead of schedule — slashing greenhouse gas emissions and air pollution along the way. Compared to current plans, this path optimizes the number of wind farms and solar installations built in the state, saving billions of dollars and alleviating land-use and grid construction pressures. The proposed pathway features flexible thermal generation that can run on carbon-neutral fuel produced from excess solar and wind energy. Together with energy storage, flexible generation can ensure affordable, reliable electricity and a net-zero-carbon future.	
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