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CESA ENERGY STORAGE VIRTUAL CONFERENCE

May 21, 2020

Advancing California's Faster, Cheaper Path to 100% Renewable Power

Joe Ferrari, Jussi Heikkinen, Tyler Murphy

May 21, 2020



Path to 100% Renewables for California



Tyler Murphy
Marketing Manager, Americas
Wärtsilä
Moderator

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



Jussi Heikkinen
Director
Growth & Development, Americas
Wärtsilä



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General Manager
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Wärtsilä

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Decarbonizing Electricity in California by 2045



Agenda


- Introduction
- Path to 100% Challenges & Opportunities
- California Path to 100% results
- Policy Recommendations
- Q&A




ENERGY

California Sets Goal Of 100 Percent Clean Electric Power By 2045

September 10, 2018 · 3:59 PM ET



CAMILA DOMONOSKE





BLOG

Inside Track

Xcel goal to provide 100 percent carbon-free electricity by 2050

BRIEF

By Cathy Roberts | DECEMBER 4, 2018 — 5:44PM

Xcel Energy made an ambitious announcement on Tuesday, pledging to provide 100 percent carbon-free electricity to customers by 2050.

By 2030, the Minneapolis-based utility pledges to reduce carbon emissions by 80 percent from the eight states it serves.



Credit: Wikimedia Commons

AUTHOR
Gavin Bade
@GavinBade

PUBLISHED
April 12, 2019

Dive Brief:

- Puerto Rico Gov. Ricardo Rosselló on Thursday signed into law a 100% renewable energy mandate that the hurricane-battered island must meet by 2050.

APS to go to 100% clean energy by 2050

APS, Arizona's largest utility, has released its first-ever decarbonization goal: 100% clean energy by 2050, with a 65% by 2030 landmark. The decision is being lauded as a big step forward for a utility that just a few short years ago opposed an Arizona RPS increase.

JANUARY 24, 2020 TIM SYLVIA

BUSINESS CONSUMER PROTECTION MARK



Umwelt Bundesamt

The UBA

Topics

Press

Publications

Data

Press > Press releases > Energy goal for 2050: 100% renewable electricity supply

Energy goal for 2050: 100% renewable electricity supply

New UBA study shows that electricity supplied entirely from renewable energies is realistic

Germany's electricity supply could make a complete switch to renewable energies by 2050. The technology already available on the market could make this possible even today, but it requires that electricity be used and produced very efficiently. These are the results of the Energieziel 2050: 100% Strom aus erneuerbaren Quellen [100% renewable electricity supply by 2050] study done by the Federal Environment Agency (UBA). In order to achieve this goal by 2050 UBA is calling for timely political support. "The earlier we take decisive action the more time there will be to make the necessary technological and social adaptation," says Jochen Flasbarth, President of the Federal Environment Agency. Moreover, Germany could drastically reduce its great dependence on imports of primary energy sources if electricity were produced with renewable energies only.

India's New 227 Gigawatt Renewable Energy Target Is Ambitious, Challenging, But Possible, Says IEEFA

 Twitter

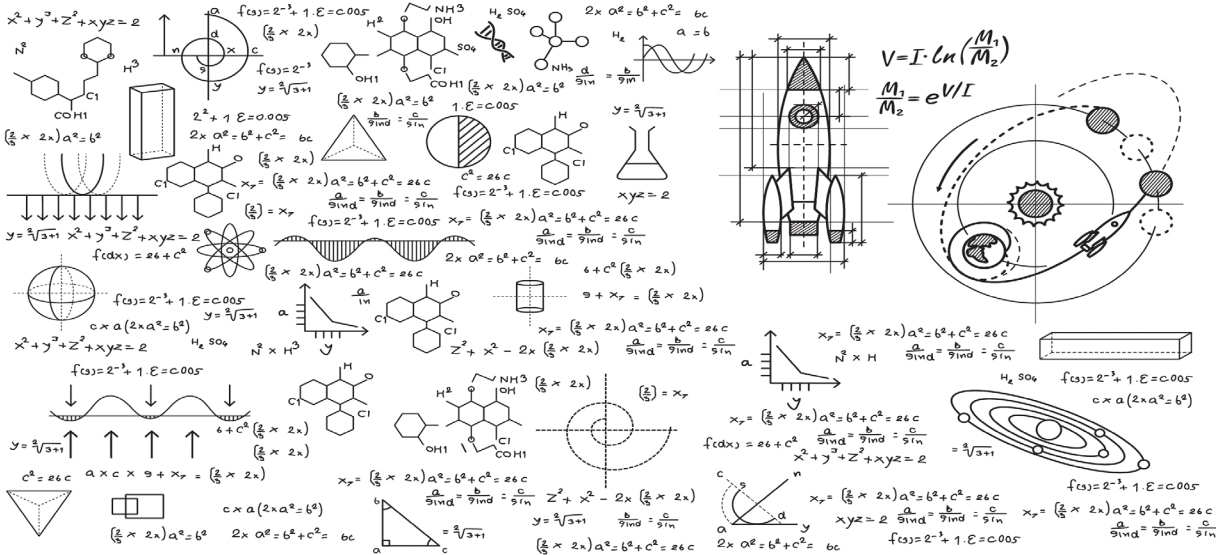
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 Facebook

Go for 100% renewables....



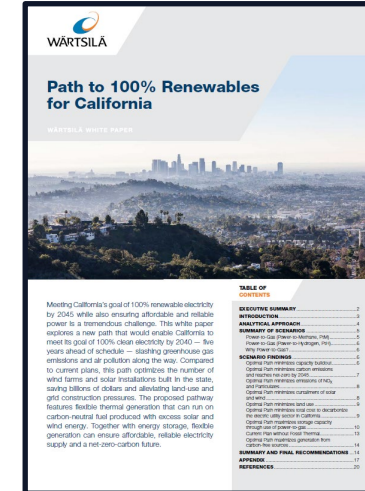
...but we will need some of this...

Wärtsilä in a nutshell

Our vision: We want to lead the world to the 100 % decarbonized energy future.

Leading power system Path-to-100 % expansion modeller (> 150)

Numerous national Path-to-100 % studies.



Wärtsilä

- Finnish company
- Turnover 5000 M€
- Personnel 19000
- 186 years young
- Engine OEM
- Flexible gas power plants and storage plants
- 75 GW of references

IEC 62443 Cyber Certification

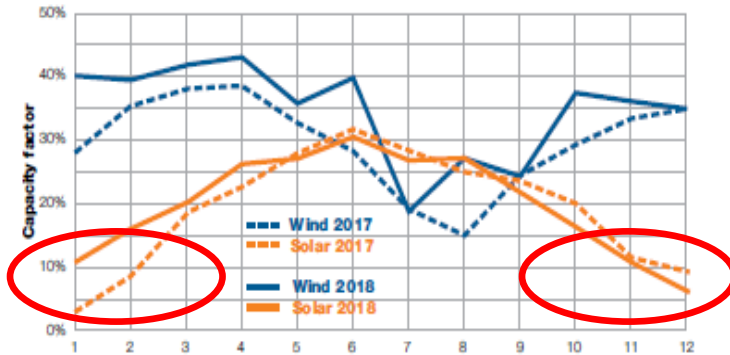
Cybersecurity has quickly become a serious issue for professionals in critical infrastructure industries. IEC62443 has answers.



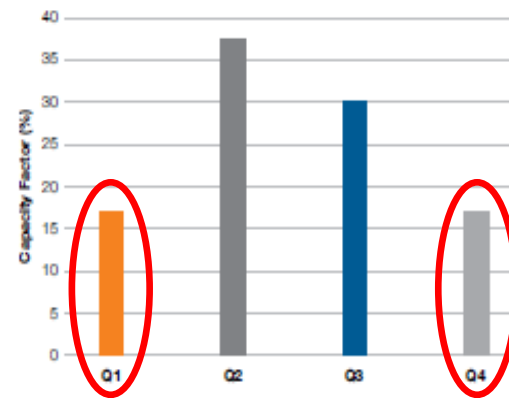
**Path
to100%**

Path to 100% reliant on Seasonal Solar, Wind, Hydro

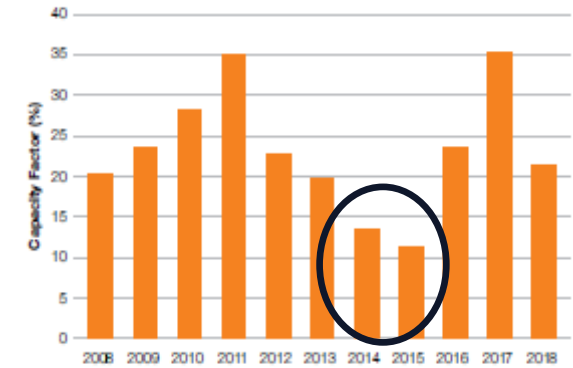
Energy production from Solar
Minimum in winter months



Energy production from Wind
Also minimum in winter months



Energy production from Hydro
Minimized in drought years



Power system must be designed for “worst case” overlay of Solar, Wind & Hydro.

Solar & Wind also impacted by short-term weather variations (1/3)

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF HAWAII

----- In The Matter Of -----)
PUBLIC UTILITIES COMMISSION) DOCKET NO. 2014-0183
Instituting a Proceeding to Review the)
Power Supply Improvement Plans for)
Hawaiian Electric Company, Inc., Hawaii)
Electric Light Company, Inc., and Maui)
Electric Company, Limited.)

Hawaiian Electric Companies'
PSIPs Update Report

Filed December 23, 2016

Book 1 of 4

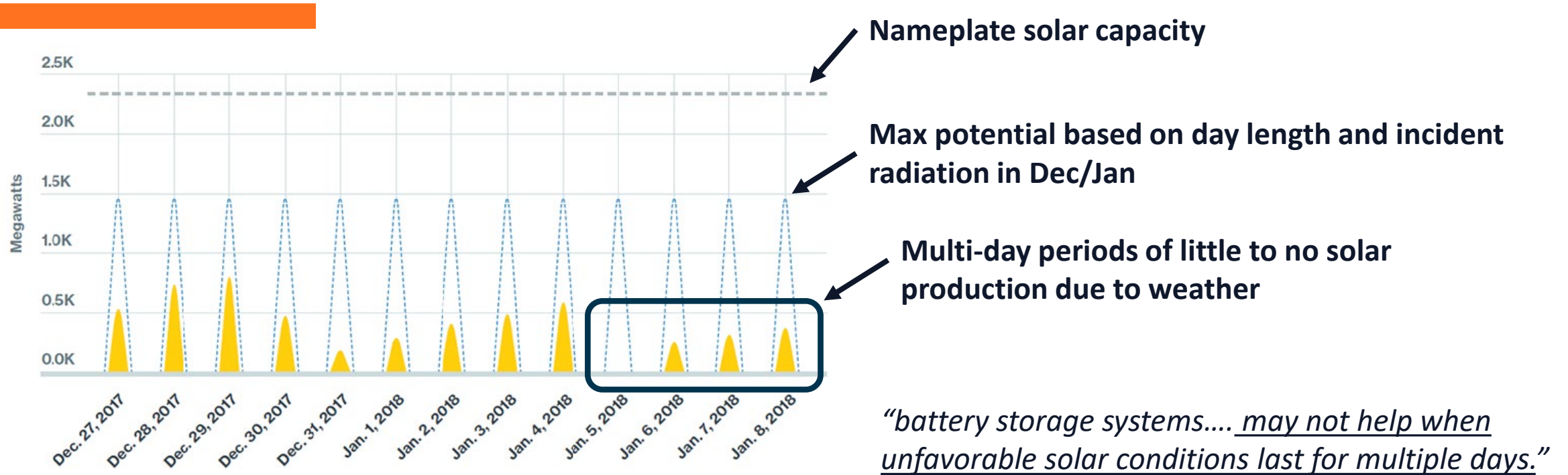
*“Load shifting energy storage with variable renewable energy such as wind and solar can have an important role in the 100% renewable energy future. **Conventional thermal generating resources will still be required to meet the load during seasonal low renewable energy production or unpredicted weather-related events (such as the 6 weeks of consecutive rainy days in 2006).**”*



Wind is not immune either.....

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Solar & Wind also impacted by short-term weather variations (2/3)



<https://www.iso-ne.com/about/what-we-do/in-depth/solar-power-in-new-england-locations-and-impact>



Solar & Wind also impacted by short-term weather variations (3/3)

Figure 4: Low Versus Typical Solar Production Days⁷

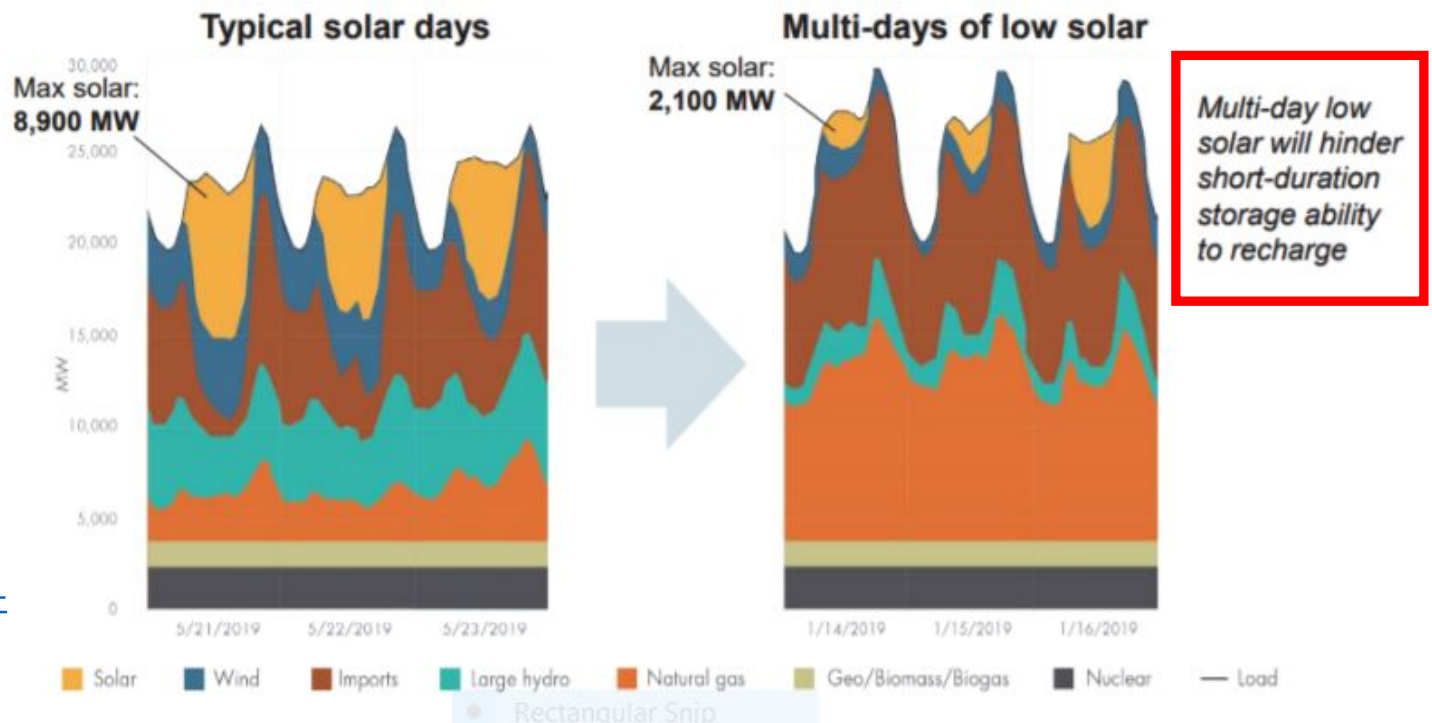
BEFORE THE PUBLIC UTILITIES COMMISSION OF THE
STATE OF CALIFORNIA

Order Instituting Rulemaking to Establish
Policies, Processes, and Rules to Ensure
Safe and Reliable Gas Systems in
California and perform Long-Term Gas
System Planning

Rulemaking 20-01-007
(Filed January 16, 2020)

COMMENTS OF THE
CALIFORNIA INDEPENDENT SYSTEM OPERATOR CORPORATION

<http://www.caiso.com/Documents/Feb26-2020-Comments-ScopeProceeding-SafeandReliableGasSystems-R20-01-007.pdf#search=solar%20output%20seasonal>



Need for long-term storage recognized

Getting to Zero
Carbon Emissions
in the Electric Power
Sector

Jesse D. Jenkins,^{1,*} Max Luke,²
and Samuel Thernstrom³

Joule 2, 2487-2510,
December 2018



**Reviewed 40 studies of what it
would take for “deep
decarbonization”, defined as 80-
100% decarbonized**



From the article...

- “Either ‘firm’ generation or ‘seasonal storage’ is needed to ensure reliability... “
- “prolonged periods of calm wind speeds lasting days to weeks during winter months... are too long to bridge with short-duration batteries or flexible demand.”
- “Power systems with high VRE penetration require sufficient capacity from reliable sources that can sustain output in any season and for long periods (weeks or longer).”

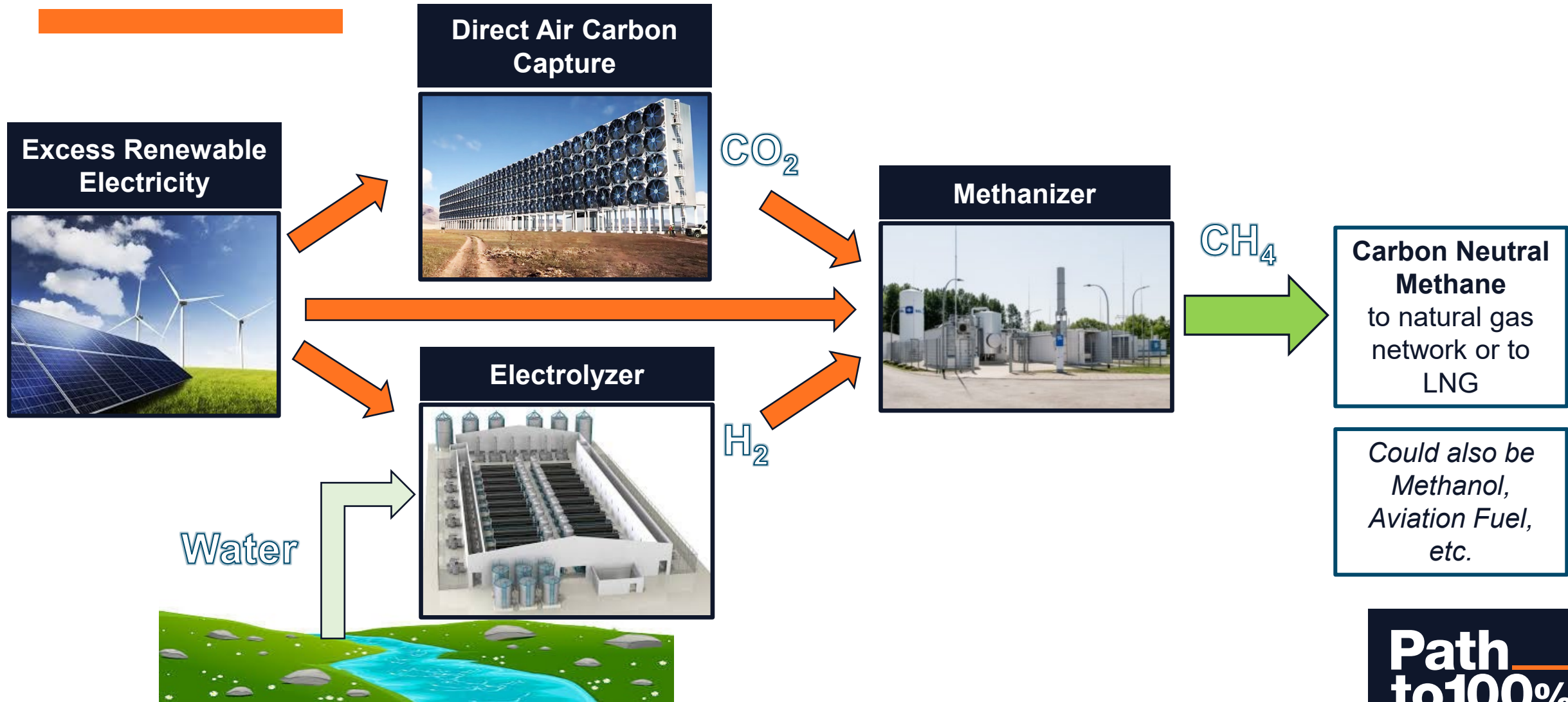
Power to X (X = Fuel) as Long Term Renewable Energy Storage



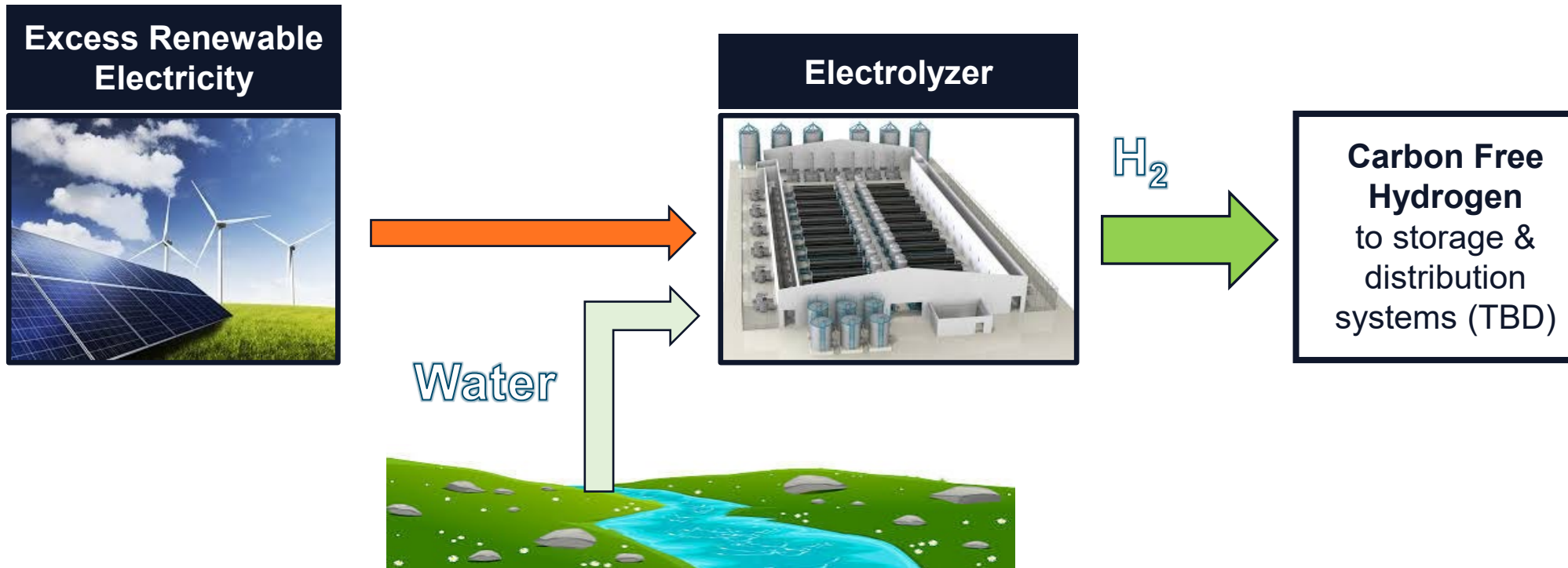
One of the most talked about forms of long-term energy storage is power-to-fuels

- Excess solar & wind stored as chemical potential in a fuel
- Considered necessary for industry sectors difficult to electrify/decarbonize
- Collectively referred to as “Power to X”, or PtX for short
 - X = methane → PtM
 - X = hydrogen → PtH

Power-to-Methane (PtM) fuel production process



Power-to-Hydrogen (PtH) fuel production process



P2X – Major action on the markets



- Maersk Carbon emissions to zero by 2050 via carbon-neutral fuels
- British Airways to offset Carbon emissions from 2020, IAG invests in sustainable aviation fuels¹⁾
- Rotterdam airport pilots direct air capture for aviation fuel
- Lufthansa pilots synthetic Kerosene production ²⁾
- Carbon Recycling International (CRI) first CO₂-To-Methanol Plant in China to produce 180,000 tons of Methanol and LNG annually
- Carbon Engineering building a 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

AGREEMENT SIGNED FOR CRI'S FIRST CO₂-TO-METHANOL PLANT IN CHINA

to 100%

Decarbonizing Electricity in California by 2045

Background....

- California's **Current Plan** by 2045 is highly reliant on renewables and storage
- Wartsila's White Paper outlines an ***Optimal Path*** for California to reach its RPS goals earlier than targeted, with lower costs and improved security of supply



California Power System Expansion Modelling 2020 - 2045

Modelling approach

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



High-performance energy system simulation software



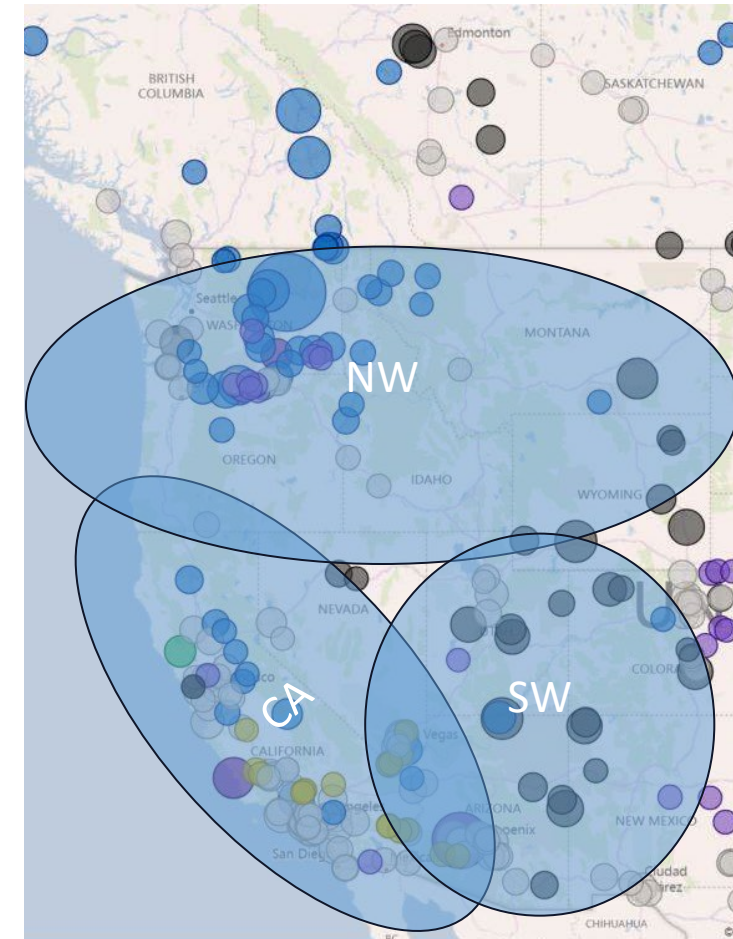
Wärtsilä model is based on the same model used by CAISO to support 2019 IRP

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 and solar price learning curves
- Fuel prices, new technology parameters and economic parameters from Californian IRP



Fuel ● Biomass ● Coal ● Cogeneration ● Gas ● Geothermal ● Hydro ● Nuclear ● Oil ● Petrock ● Solar ● Storage ● Waste ● Wind

Scenario assumptions

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

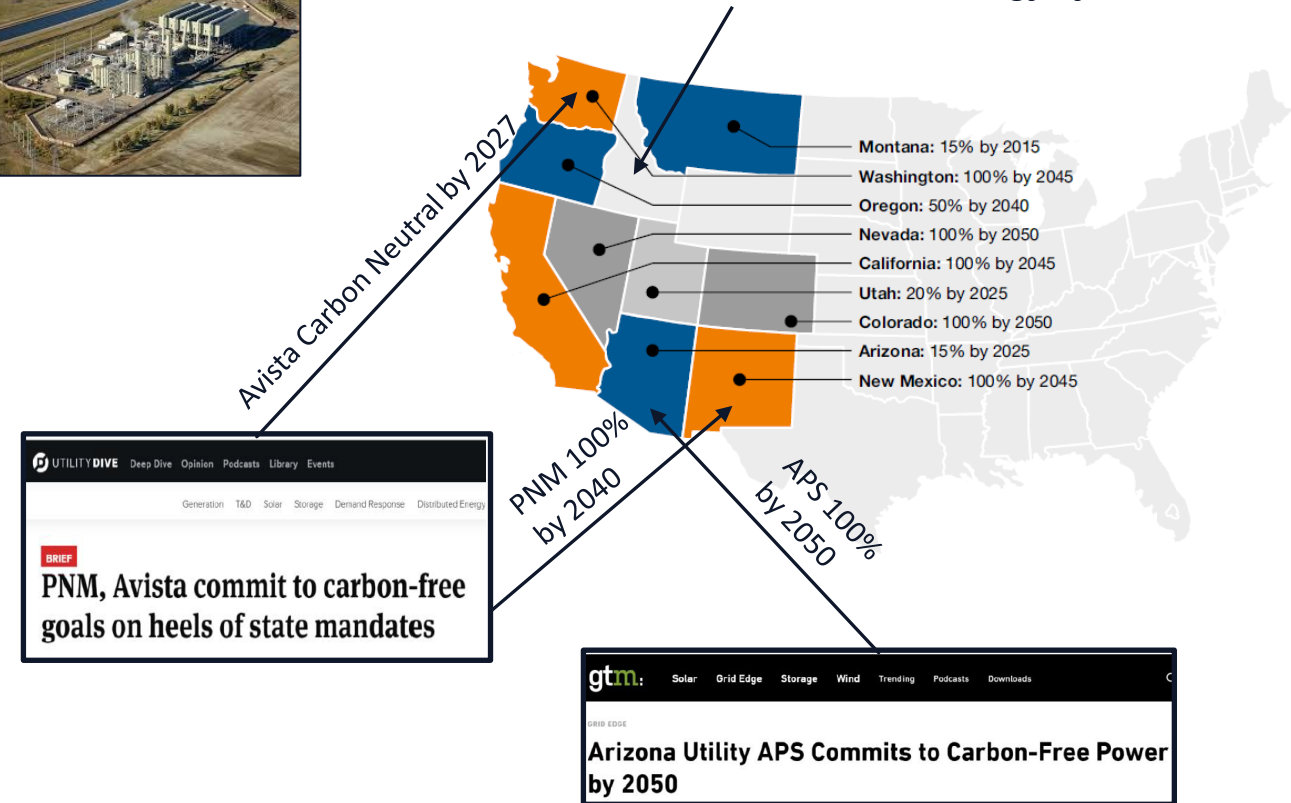
- Fossil balancing power will not be available from the neighbors in 2045

Hydrogen

- Hydrogen versions of thermal technologies available by the time renewable fuels become economically viable
- Power plant price levels (\$/kW) & performance similar as natural gas (methane) versions
- Hydrogen distribution & storage infrastructure costs not included



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



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Scenarios

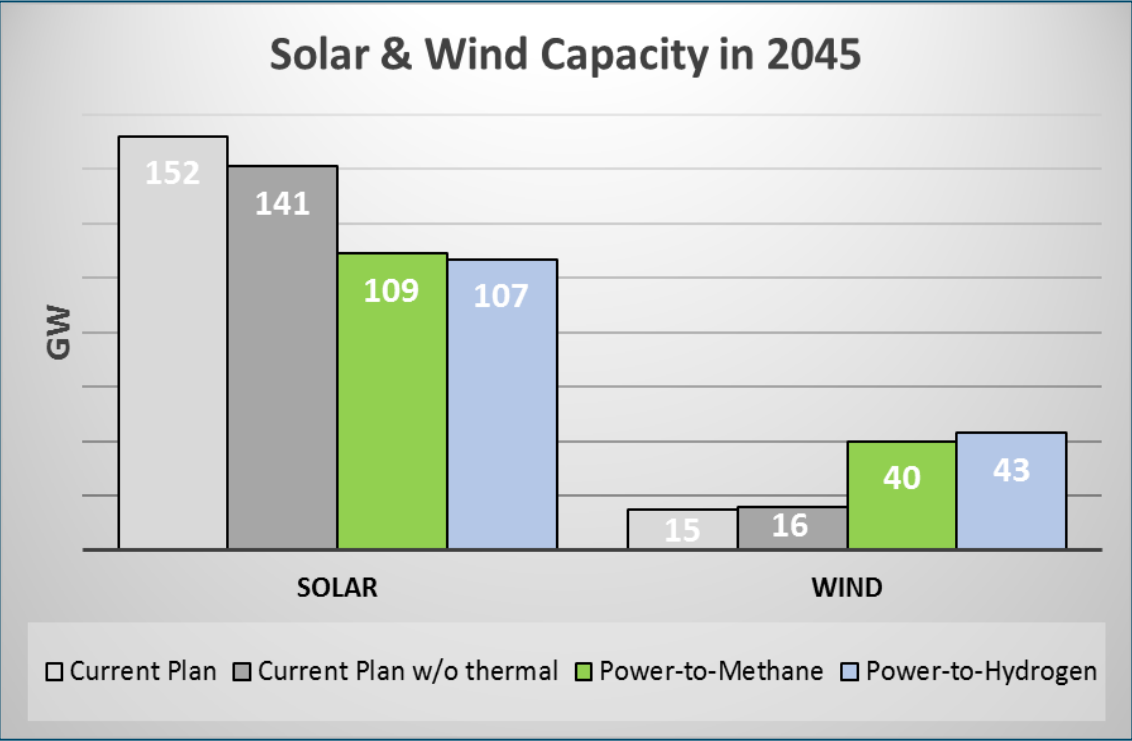
| Current Plan | Current Plan w/o thermal | Optimal Path (PtM) | Optimal Path (PtH) |
|---|--|--|---|
| <ul style="list-style-type: none">• OTC retirement delayed to 2026+• Limited repowering with thermal• 100% of retail sales carbon-neutral by 2045• ~ 8% of generation can still be fossil-thermal (to cover grid losses) | <ul style="list-style-type: none">• OTC retirement delayed to 2026+• NO repowering with thermal• Only solar, wind & traditional storage allowed• Carbon-neutral by 2045 | <ul style="list-style-type: none">• OTC retirement 2023• OTC's repowered with optimal capacity mix• RPS commitments met by 2040 (5 years early)• Carbon-neutral by 2045• Requires allowance of Power-to-Methane (PtM) | <ul style="list-style-type: none">• OTC retirement 2023• OTC's repowered with optimal capacity mix• RPS commitments met by 2040 (5 years early)• Carbon-neutral by 2045• Requires allowance of Power-to-Hydrogen (PtH) |

Long term capacity optimization, technology & capacity choices, costs etc. determined by PLEXOS software

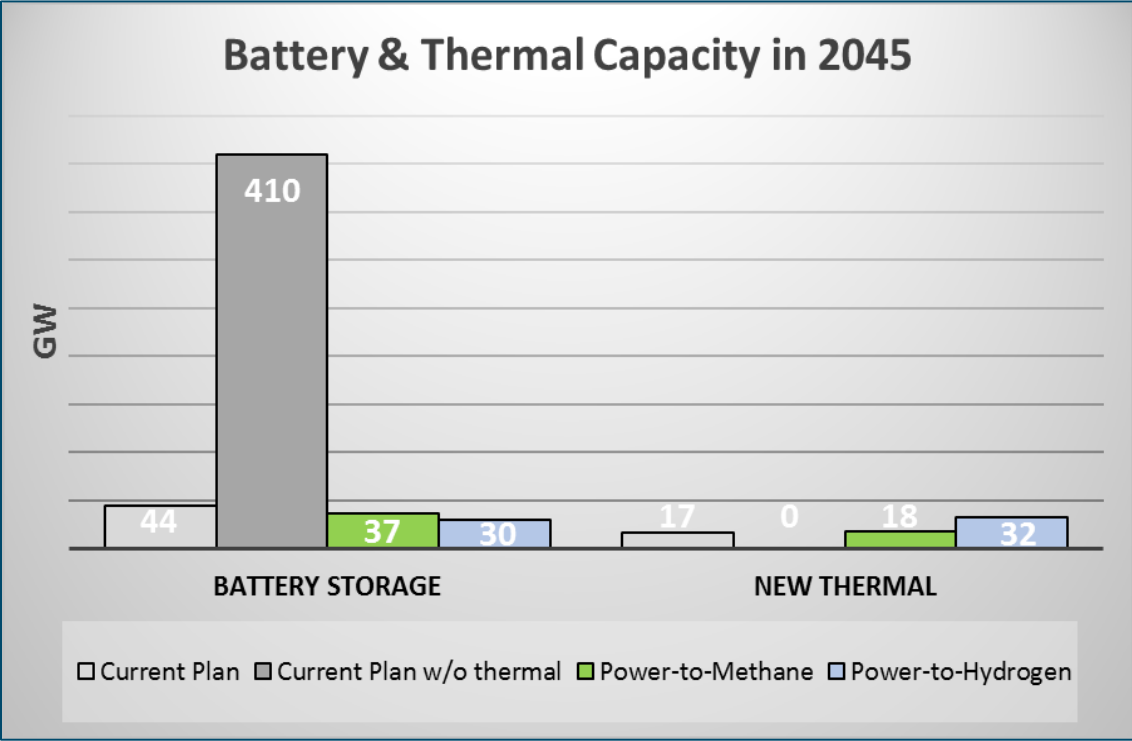
Study results - capacity additions by 2045



Optimal Path (PtM) contains 10 GW of PtM capacity
Optimal Path (PtH) contains 20 GW of PtH capacity

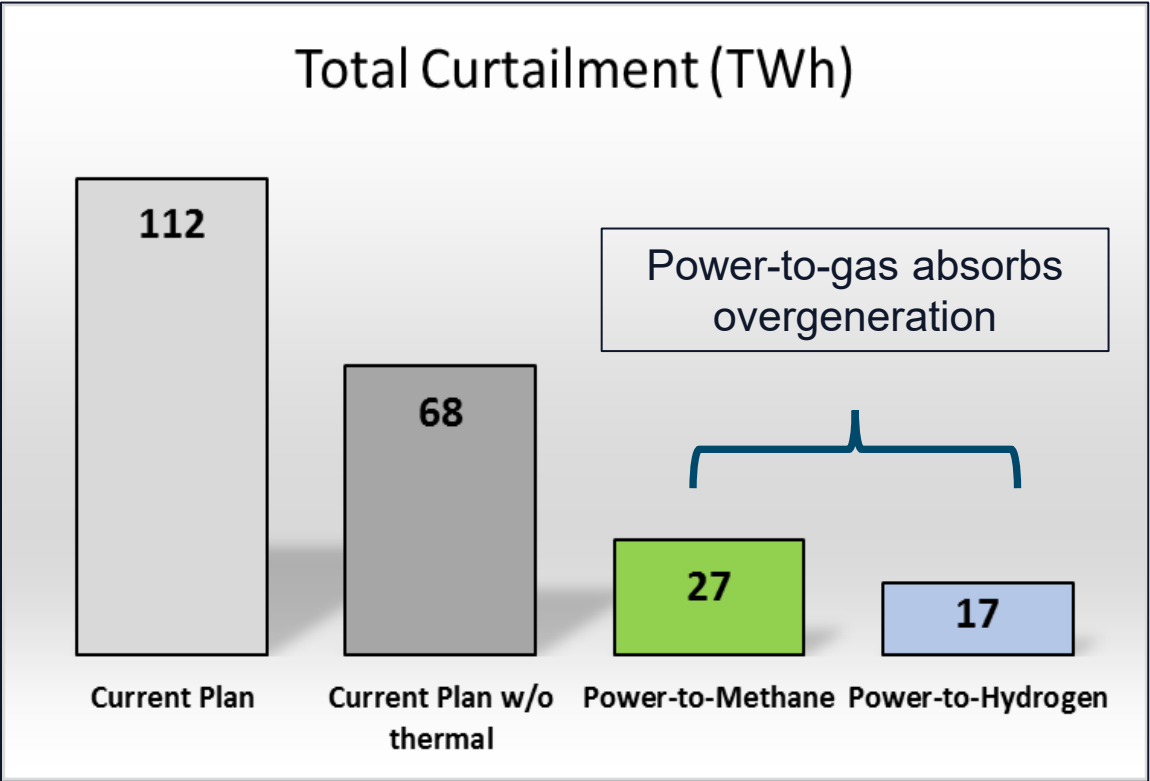
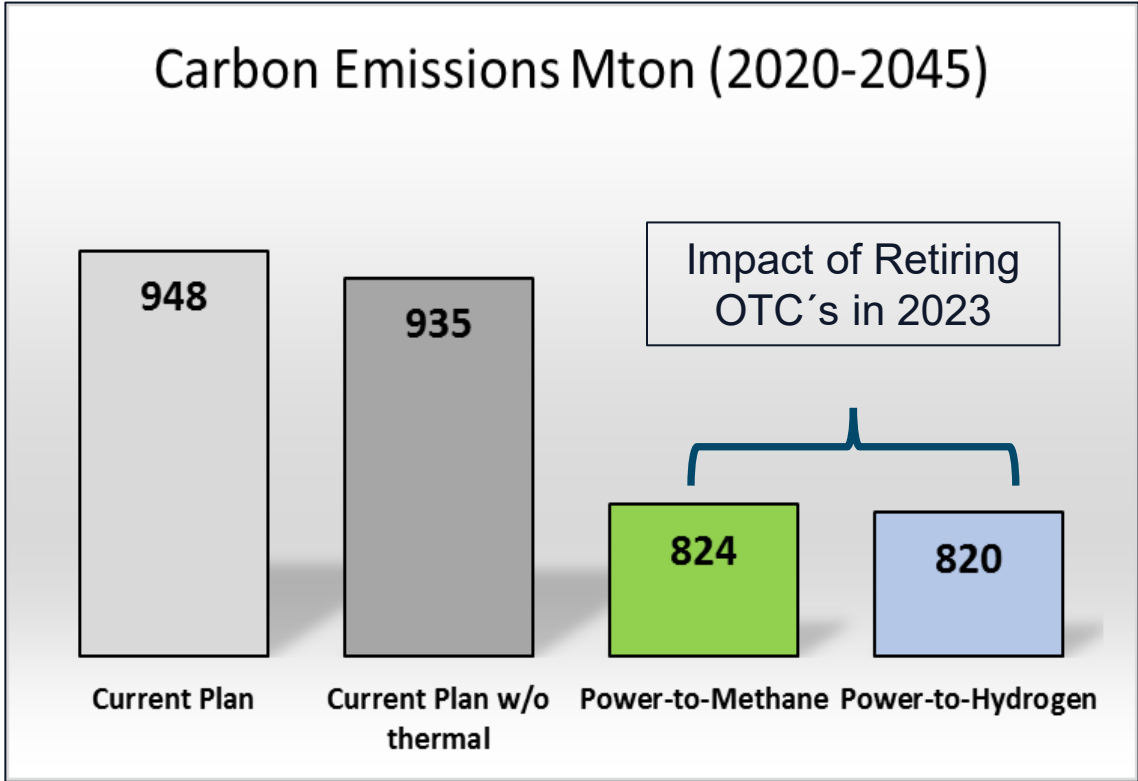


Optimal Path = less solar, more wind than current plan(s)

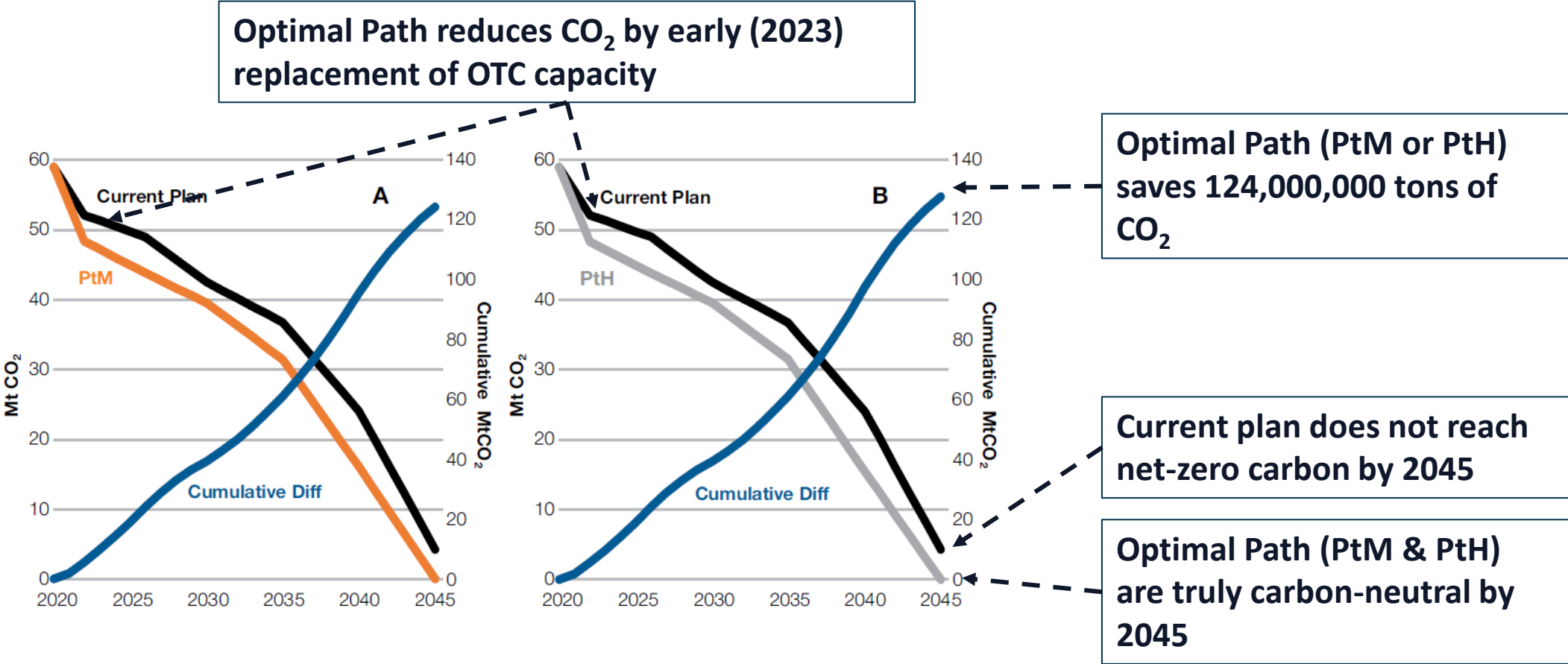


Current plan w/o thermal requires 10-fold larger Battery Storage capacity for system reliability (reserve margin)

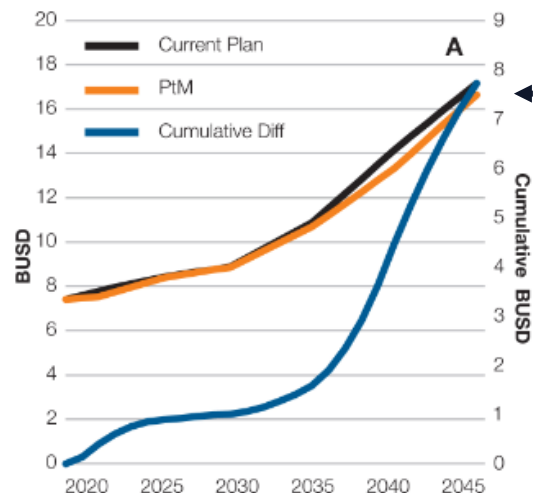
Cumulative carbon emissions and Solar & Wind curtailment (2045)



Carbon Reductions across Horizon (2020-2045)



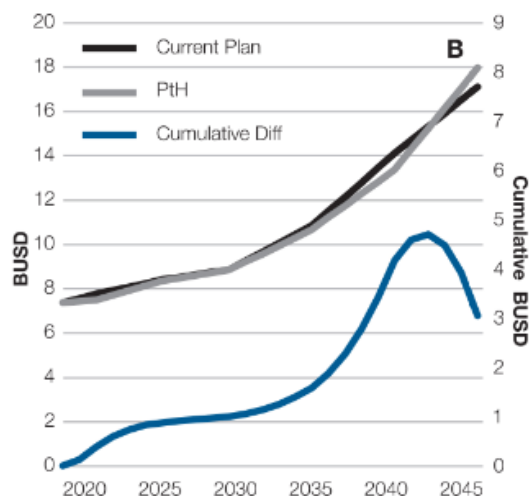
Cost Reductions across Horizon (2020-2045)



Optimal Path (PtM) saves 8 BUSD over Current Plan

Includes cost of

- 10 GW of Power-to-Methane equipment
- 18 GW of new thermal capacity (+ 14 GW existing)

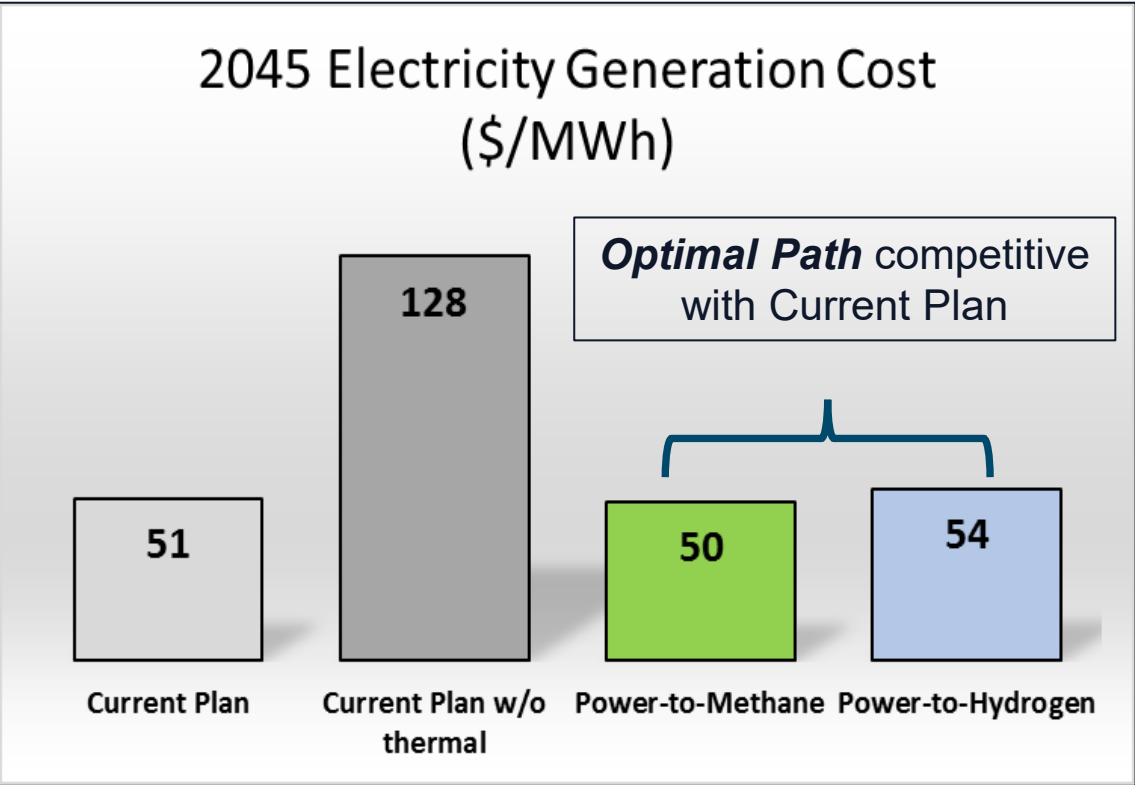


Optimal Path (PtH) saves 3 BUSD over Current Plan

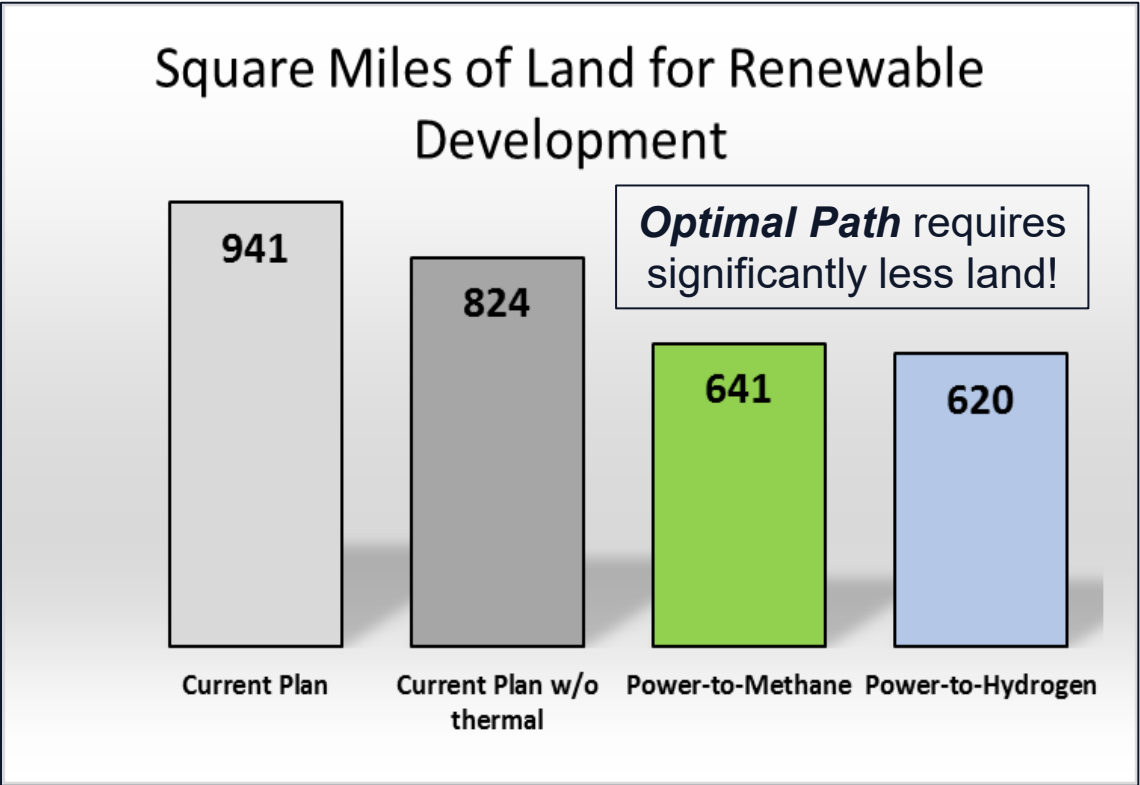
Includes cost of

- 20 GW of Power-to-Hydrogen equipment
- 32 GW of new thermal capacity
- Hydrogen infra costs excluded

Electricity generation cost and land use



Current Path does not provide carbon-free electricity in 2045
Current Path w/o thermal provides highly expensive power



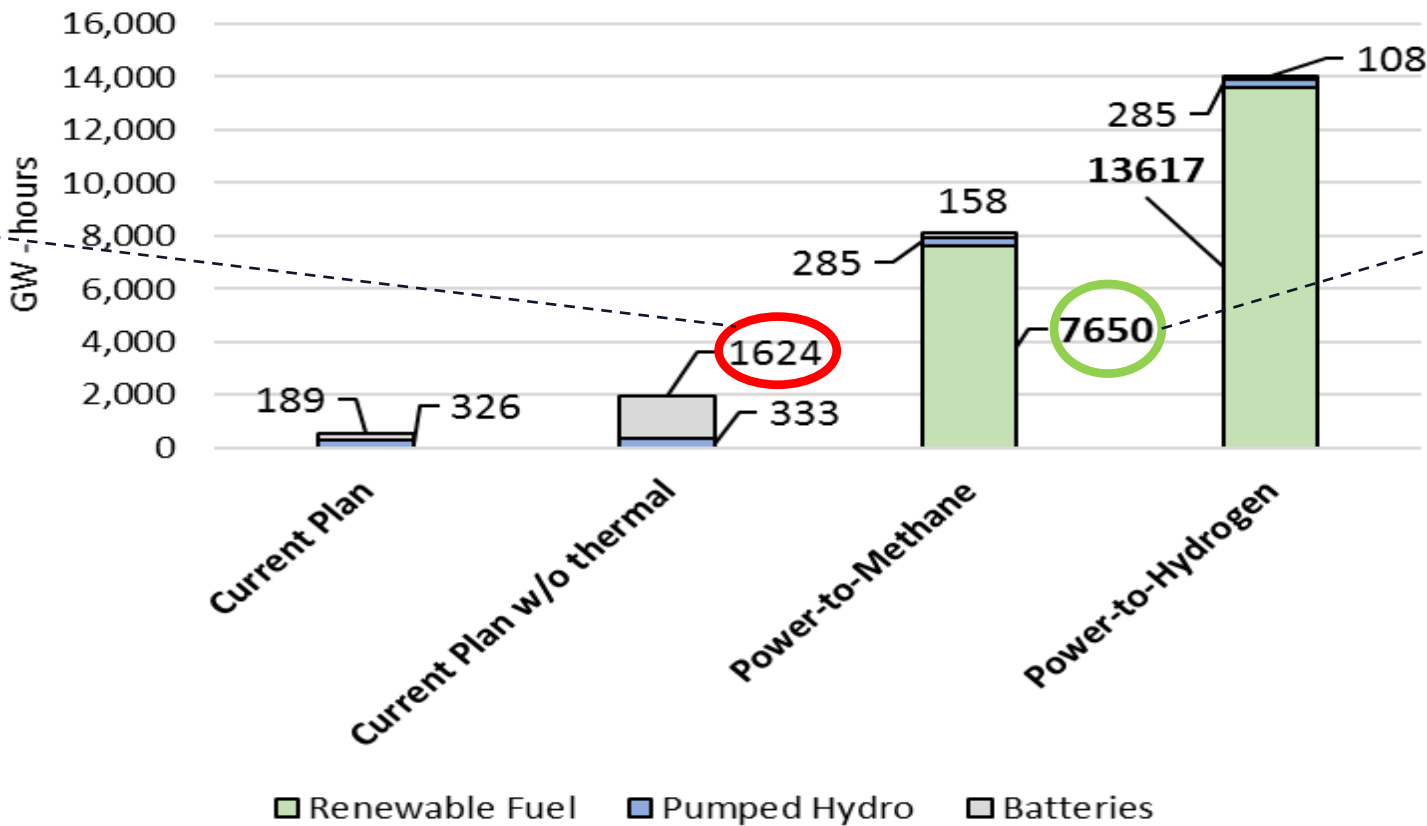
Land costs are excluded in this study

Energy Storage by scenario

Pumped hydro is in every scenario
serving same purposes as batteries
(<12 hr duration)

Energy Storage in 2045

As of 2018, the
USA had 1.24
GWh of battery
storage (EIA)

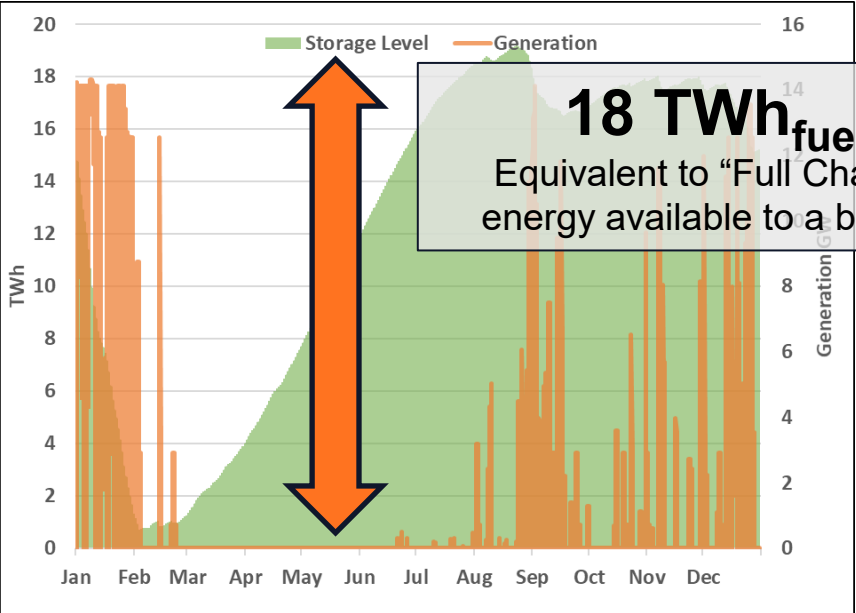


Optimal Path (PtM)
utilizes ~ 15% of
existing
underground gas
storage in California

Renewable Fuels turn the thermal fleet into a giant distributed "battery"



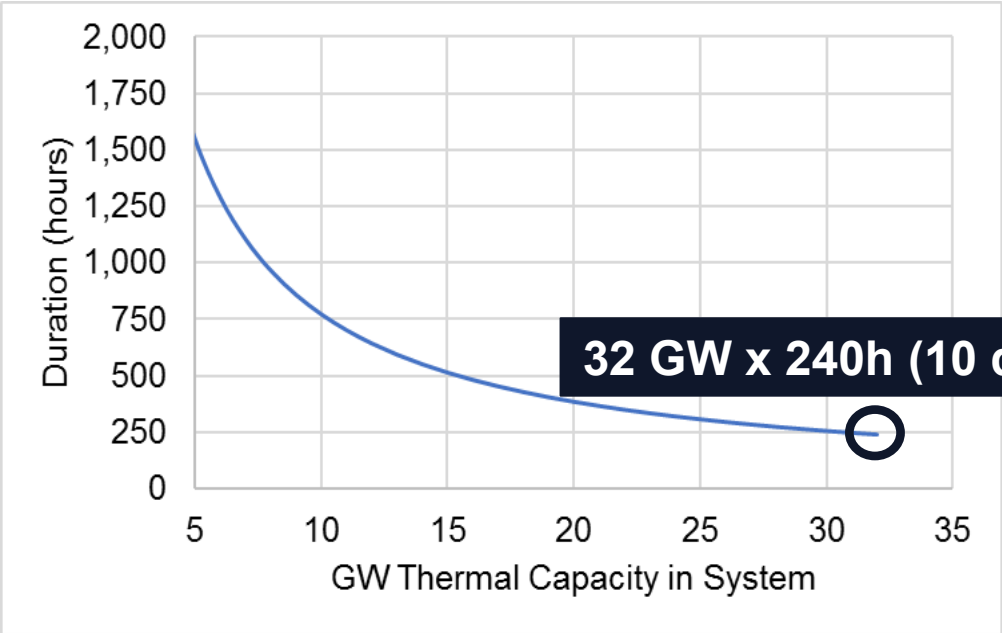
Power – to – Methane



~15% of CA underground gas storage volume



7.7 TWh_{ELECTRIC}

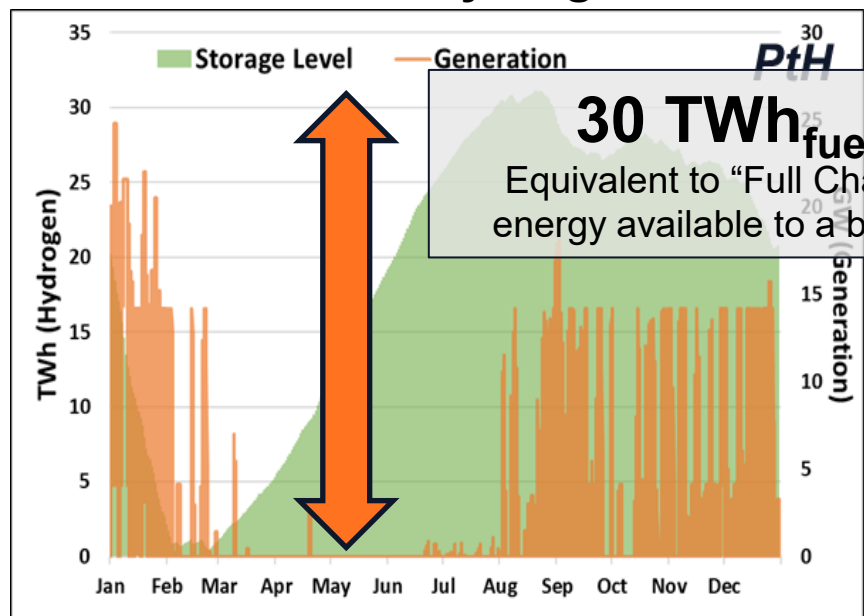


All renewable fuel produced in-state using renewable energy to serve CA load

Modern gas power plants can burn this synthetic fuel today

Renewable Fuels turn the thermal fleet into a giant distributed "battery"

Power – to – Hydrogen



30 TWh_{fuel}
Equivalent to “Full Charge”
energy available to a battery

~75% of CA underground gas storage volume (assuming hydrogen requires ~ 3x volume relative to methane for same energy content)

12.8 TWh_{ELECTRIC}
32 GW x 427 h (17 days)

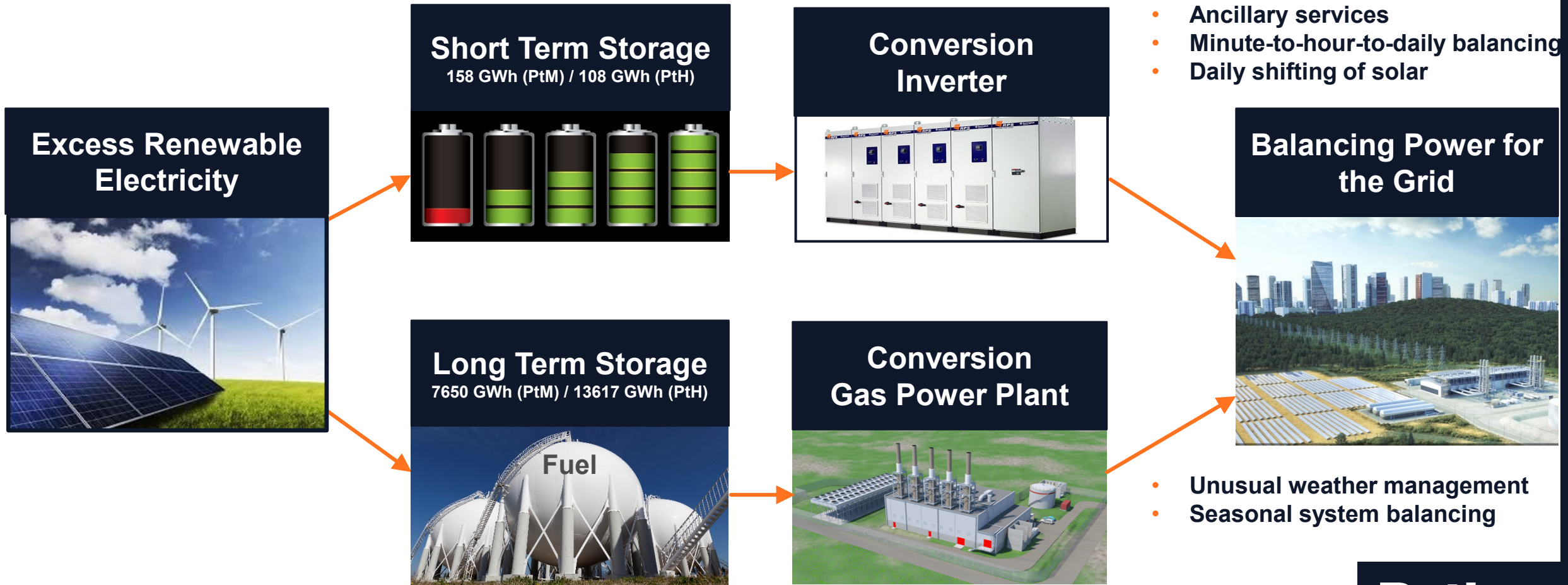
NOTE: Storage sizes for PtM (10 days) and PtH (17 days) are the economic optimum as determined by PLEXOS™ simulations and taking seasonality into account.

Longer durations may be needed pending weather analysis for CA to determine longest possible “weather event” compromising solar or wind.

All renewable fuel produced in-state using renewable energy to serve CA load

Modern gas fired generators can burn partial hydrogen today, all major OEMs committed to 100% hydrogen versions

P2G - New approach to electricity storage



Key takeaways



1. ***Optimal path* outlined in the study is the best path to 100 % for California**

- Faster, complete decarbonization
- More efficient use of solar, wind and battery storage
- Less land required for development
- Lower cost for ratepayers
- Maximized security of supply with dispatchable thermal fleet

2. **Power to Gas** (Methane or Hydrogen) **is a key ingredient of the optimal, clean power system**

- Enables construction of highly efficient, 100 % Carbon Neutral power system
- Optimal Path can be entered now as first year's actions are the same for PtM and PtH – renewable fuel choice can be made later!

3. **Policy recommendations for California**, to enter the *Optimal Path* to 100 %:

- Recognition of Renewable Fuels (including renewably sourced Methane and Hydrogen) as "renewable" for RPS compliance purposes
- Maintain OTC 2023 retirement dates; add necessary flexible gas generation to the power system to enable those retirements
- Add optimal proportions of Renewables, Traditional Storage and Flexible Thermal, to enable the transition to 100% clean energy

THANK YOU

Please contact us at: info@storagealliance.org | www.storagealliance.org