Energy Storage Association

StoragePLUS Natural Gas

March 27, 2019

www.energystorage.org

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All lines will be muted during the webinar.

To submit questions, please use the chat box on the left-hand side of your screen at any time throughout the presentation.

Energy Storage Association

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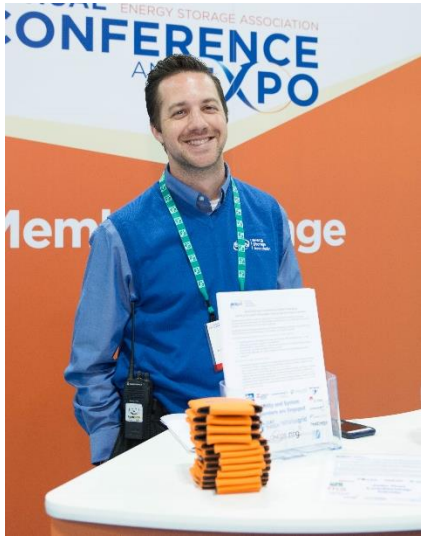
Energy Storage Association

Energy Storage Association

ESA Membership

ESA works to ACCELERATE markets, CONNECT members and EDUCATE all stakeholders.



Contact **Richie O'Neill**, Membership Director
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Energy Storage Association

Today's Speaker

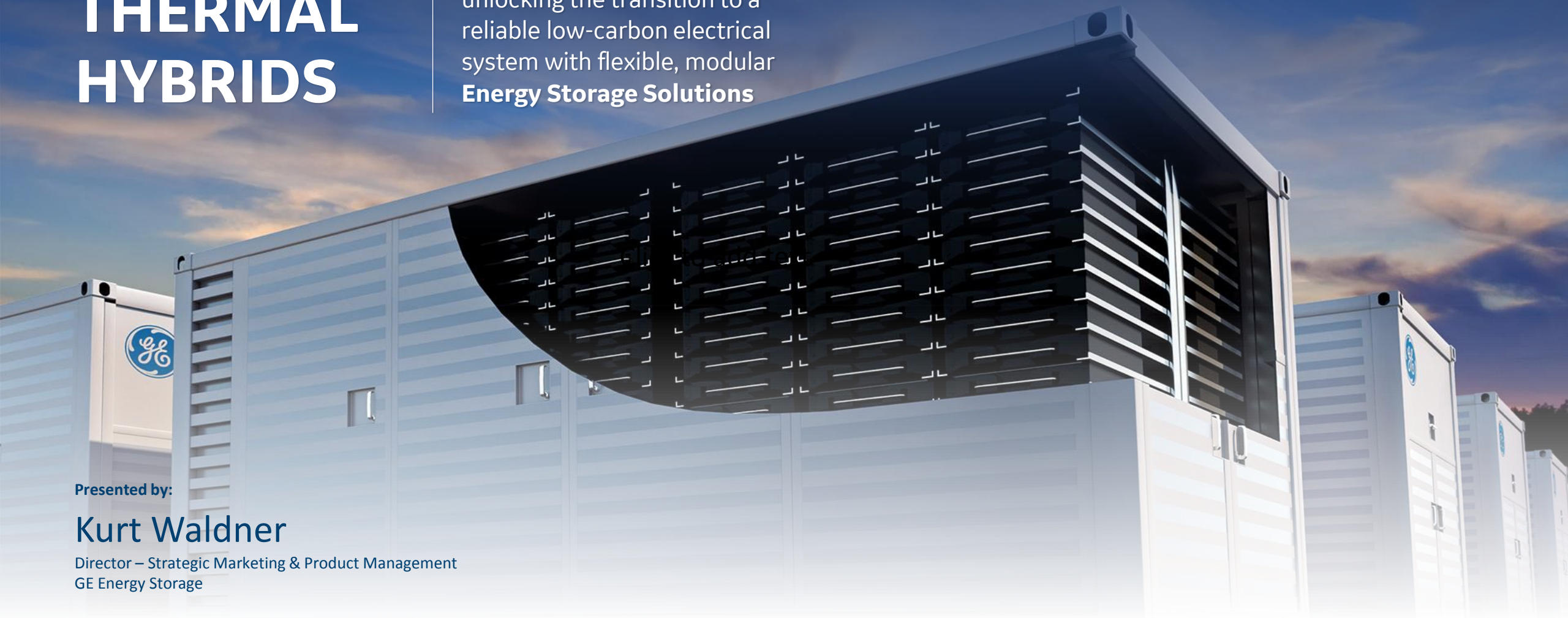
Kurt Waldner
Director, Strategic Marketing
and Project Management
GE Energy Storage

Energy Storage Association

GE Renewable Hybrids

THERMAL HYBRIDS

unlocking the transition to a reliable low-carbon electrical system with flexible, modular **Energy Storage Solutions**



Presented by:

Kurt Waldner

Director – Strategic Marketing & Product Management
GE Energy Storage

KURT WALDNER

Director – Strategic Marketing & Product Management
GE Energy Storage

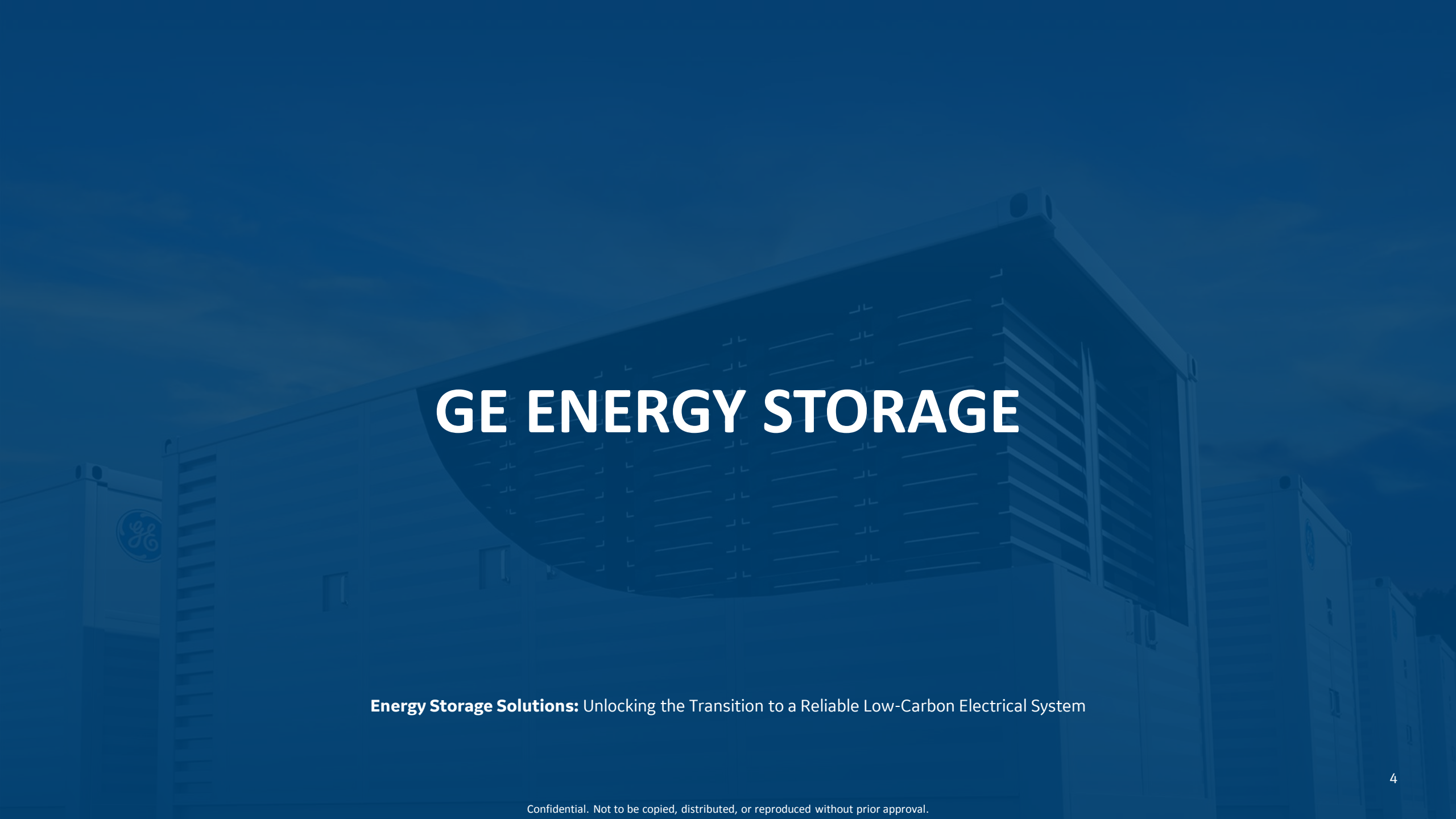
Director – Strategic Marketing and Product Management for GE Energy Storage

Responsible for overall lifecycle management of GE's Energy Storage and hybrid subsystem offerings

Multiple roles over a 22 year GE career including turbine design, Product Management, LTSA Productivity Leader and GM of the Aeroderivative LTSA business

AGENDA

- GE Energy Storage
- Today's Environment
- The Renewables Conundrum
- Thermal Hybrids: Macroeconomic Benefits
- What is a Thermal Hybrid?
- Thermal Hybrids: Case Studies
- Conclusions, Next Steps



GE ENERGY STORAGE

Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System

SERVING **GLOBAL CUSTOMERS** WITH **LOCAL EXPERTISE**

GE is globally recognized for designing and delivering customized energy storage solutions for diverse applications. With regionally located technical experts, our teams work directly with customers during the lifetime of the project. To date GE has more than 330 MWh of energy storage in operation or in construction globally.

INDUSTRY EXCELLENCE	PIONEERING	LOCAL EXPERTISE
10 years of storage experience **20 year** performance guarantee	**1st Hybrid EGT** storage + gas turbine peaker in operation **Black Start** first proven emergency start of CCGT	**40+ Countries** providing comprehensive consulting & services

Services

52+ service and repair centers
17 technical institutes

GE SOLUTION

GE's Reservoir is a flexible, compact energy storage solution for AC or DC coupled systems. The Reservoir solution combines GE's advanced technologies and expertise in plant controls, power electronics, battery management systems and electrical balance of plant – all backed by GE's performance guarantees.

GE APPROACH

GE's broad portfolio of Reservoir Solutions can be tailored to the operational needs enabling, efficient and cost-effective storage distribution and utilization of energy where and when it's needed most.

1	2	3	4	5
Consulting Services Customized solutions based on needs analysis	**Business Case** Cost-Benefit Analysis	**Project Planning & Financing** Value Engineering, Plan & Budgets, Financing	**Turnkey Service Project** Implementation & Production Roll Out	**Service Agreement** Training, Operations, Long Term Services

Our approach results in an investment grade business case that provides the basis of project planning and financing

TODAY'S ENVIRONMENT

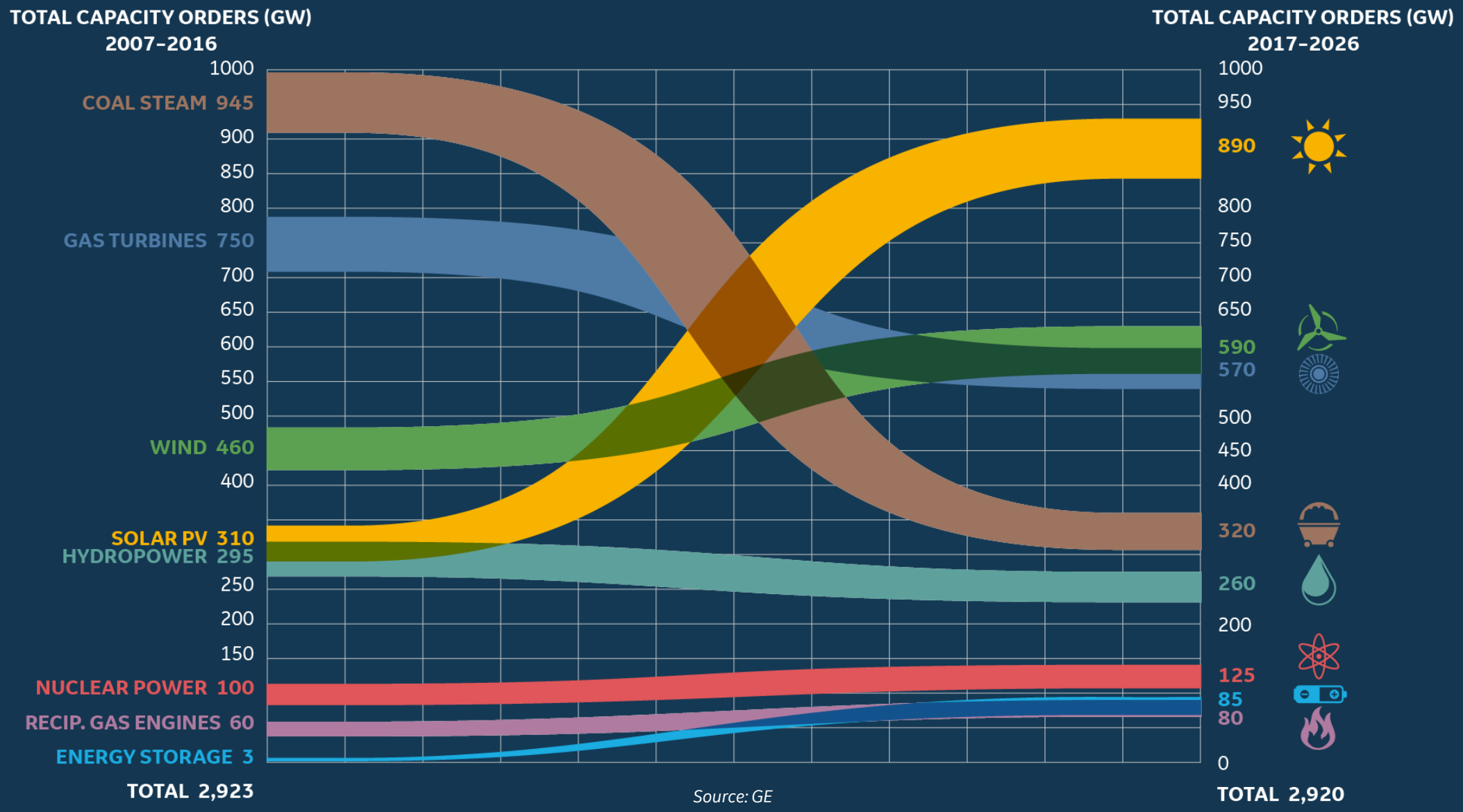
Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System

NYC 1903

NYC 1913

Difficult to predict the pace of change

A LOT CAN HAPPEN IN 10 YEARS



Source: GE

TRENDS DISRUPTING THE POWER SECTOR FROM GENERATION TO T&D

DECARBONIZATION

By 2040, **RENEWABLES will represent 30%** of global net electricity … **or more?**

IMPACT

- Generation is becoming difficult to forecast & variable
- Grid stability, Congestion Volatility on electricity markets

DIGITIZATION

GROWING THE NUMBER of **connected devices** & **smart sensors**

IMPACT

- Allowing decision making based on dynamic and nodal prices

DECENTRALIZATION

GROWING PENETRATION of **distributed resources** (renewable, storage, efficient devices)

IMPACT

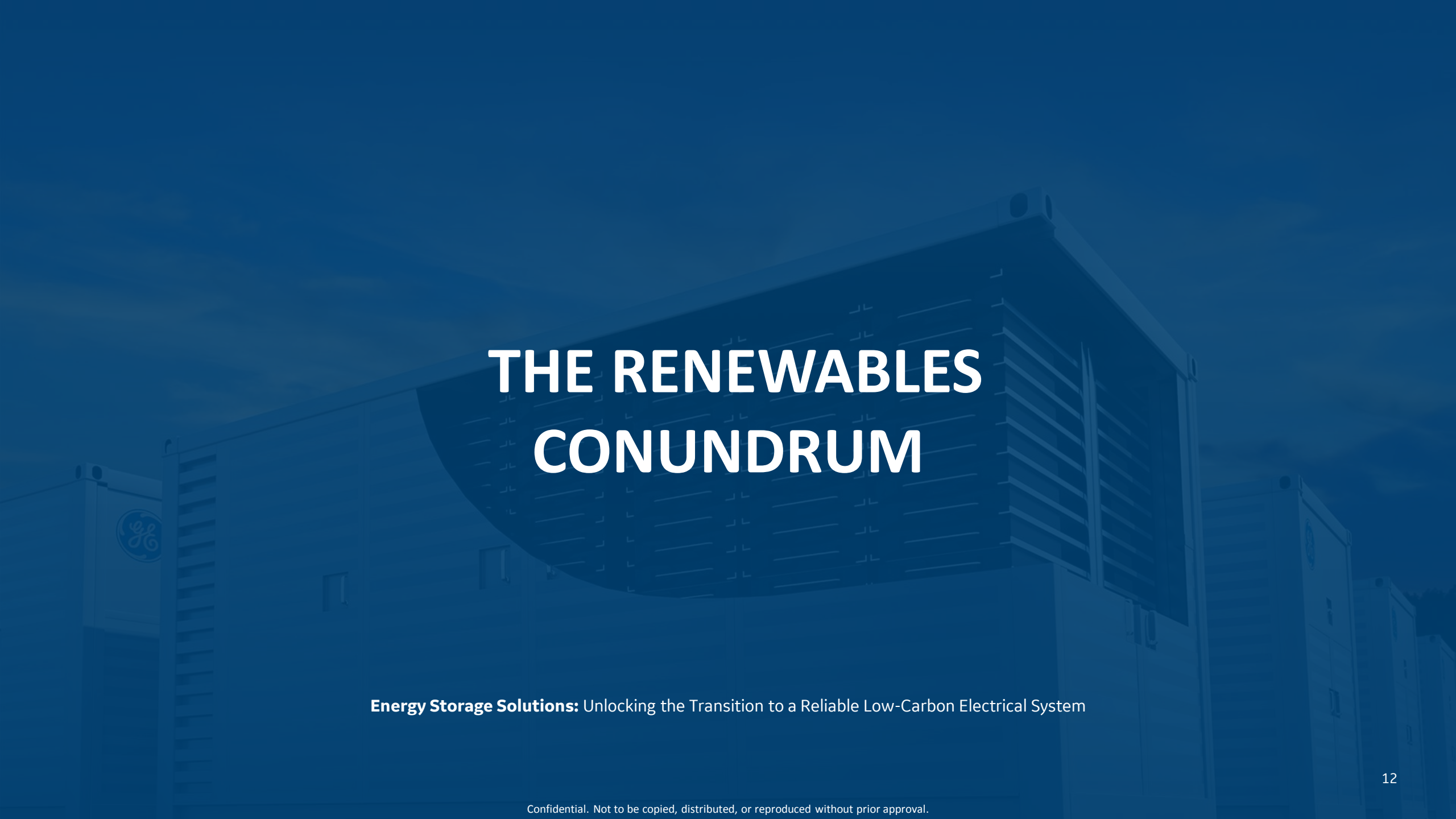
- End user becomes an active actor of the power system ('pro-sumer')
- Growing complexity of distribution grids

ELECTRIFICATION in energy ecosystem

ELECTRIFICATION OF ENERGY USES, transport (EVs) and heating

IMPACT

- Growth of Electricity demand, and an acceleration of decentralization of the power sector

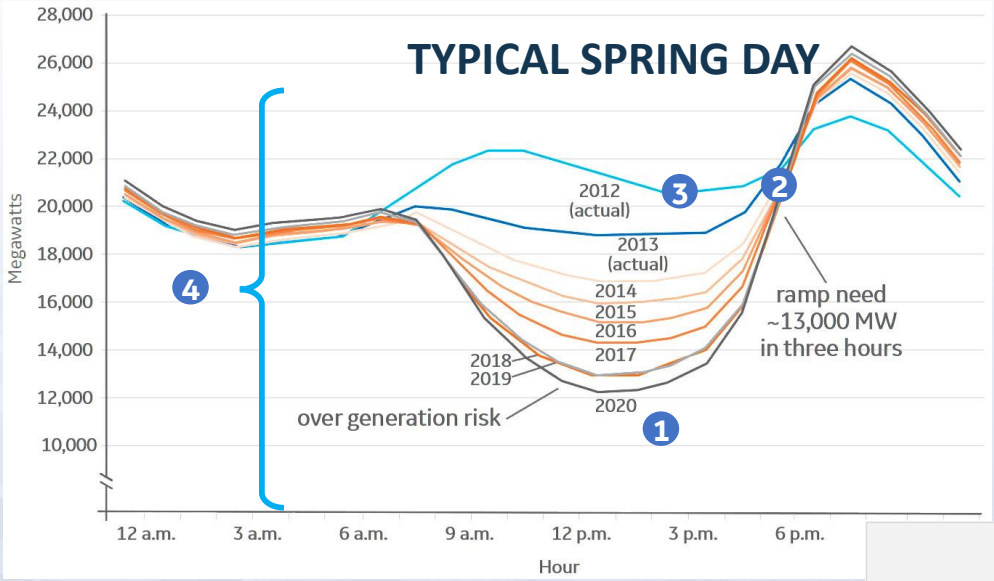


THE RENEWABLES CONUNDRUM

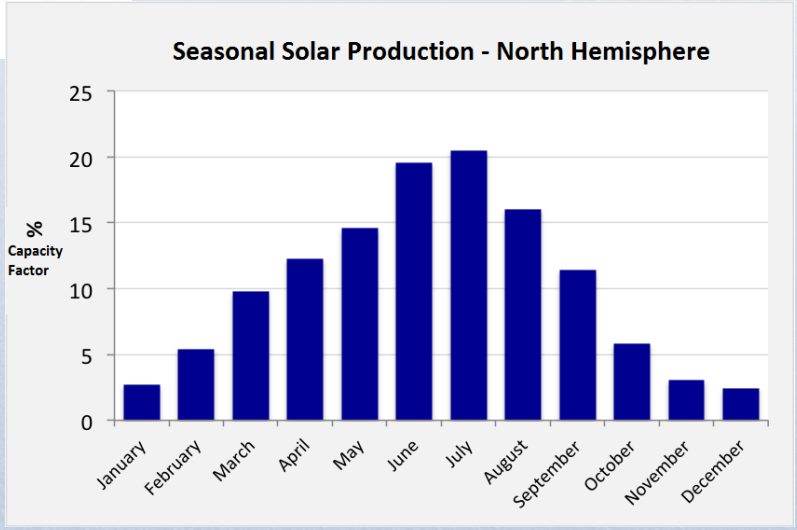
Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System

INCREASING RENEWABLES CREATE NEW PRESSURES ON THE GRID

1. Overgeneration from PV
2. Quick changes
3. Volatility
4. Variation in Time of Day prices



5. Seasonal loss in renewable sources
6. Extended negative weather events



Sources: CAISO; pv magazine

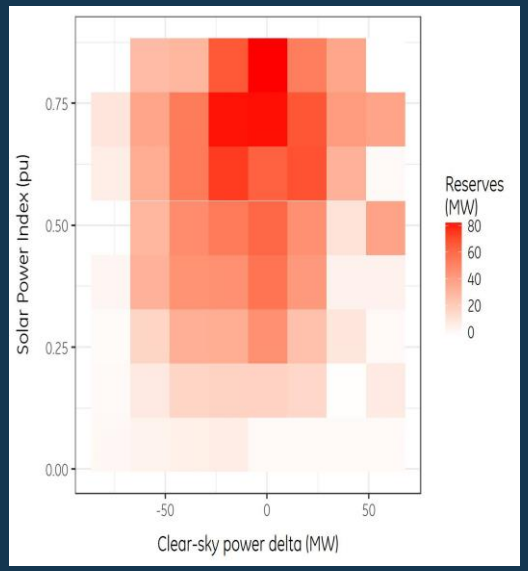
"Levelized" mindset inadequate for the future – time of day, seasonality, and extremes matter more than ever

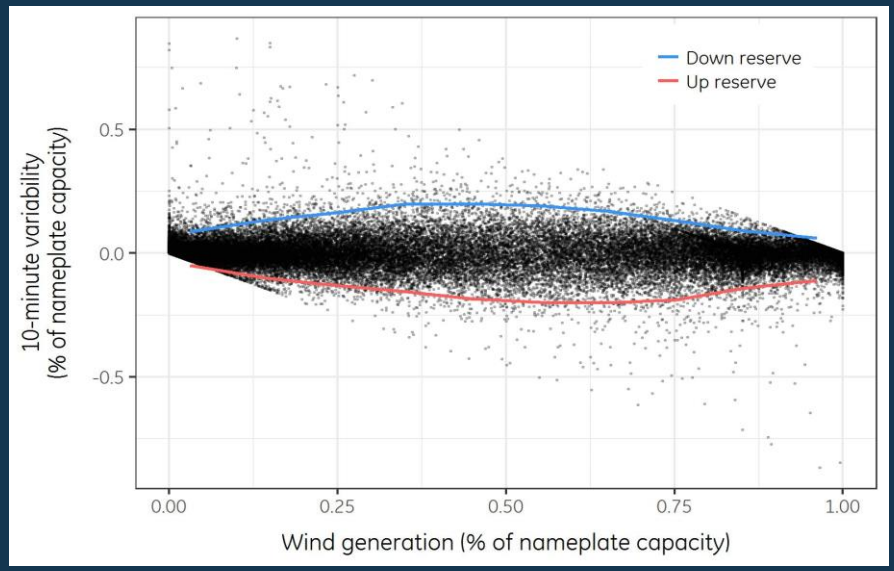
CHALLENGE: RELIABILITY IMPACTS OF AN EVOLVING FLEET

1	Unforced Capacity	Frequency Response Capability	Reactive Capability	Ramp Capability	Fuel Assurance Capability	Flexibility Capability	Unforced Capacity	Frequency Response Capability	Reactive Capability	Ramp Capability	Fuel Assurance Capability	Flexibility Capability
	Expected Near-Term Portfolio						Natural Gas Replacement of Moderate Coal & Nuclear Retirements					
Coal	34.2%	19.7%	35.5%	27.9%	32.9%	5.8%	17.1%	12.8%	18.9%	15.3%	25.1%	2.2%
Natural Gas	33.1%	31.2%	39.0%	47.9%	7.6%	50.4%	44.0%	38.1%	55.0%	61.2%	13.5%	51.5%
Oil	6.2%	15.5%	6.8%	5.6%	21.4%	15.9%	6.2%	14.7%	7.3%	5.5%	22.5%	12.3%
Nuclear	18.1%	9.7%	13.3%	0.0%	22.7%	0.0%	13.6%	7.7%	10.6%	0.0%	22.9%	0.0%
Solar	0.1%	1.5%	0.0%	0.0%	0.0%	0.1%	5.5%	2.8%	0.6%	0.0%	0.0%	3.9%
Wind	0.6%	3.0%	0.2%	0.1%	0.0%	1.3%	6.1%	5.6%	2.2%	0.6%	0.0%	9.4%
	Renewable Replacement of High Coal & Nuclear Retirements						Natural Gas Replacement of High Coal & Nuclear Retirements					
Coal	8.6%	10.0%	10.7%	7.6%	21.4%	0.9%	8.6%	9.0%	8.8%	6.4%	18.6%	1.0%
Natural Gas	43.0%	43.5%	61.1%	65.3%	20.3%	40.9%	59.2%	45.2%	69.3%	72.8%	21.6%	58.7%
Oil	6.2%	15.5%	8.3%	6.1%	24.8%	10.0%	6.2%	14.5%	6.8%	4.9%	23.3%	10.4%
Nuclear	4.5%	3.2%	4.1%	0.0%	16.1%	0.0%	9.0%	4.8%	6.7%	0.0%	20.0%	0.0%
Solar	9.9%	2.8%	1.2%	0.1%	0.0%	5.7%	0.1%	2.8%	0.0%	0.0%	0.0%	0.0%
Wind	20.3%	5.6%	8.4%	2.3%	0.0%	25.5%	9.3%	5.6%	3.2%	0.9%	0.0%	12.4%

NOTE: Hydro, battery/storage, demand response and other renewables are excluded from this graphic because their contribution to the total amount of reliability services is consistent in each example portfolio.

Load Following and Operating Reserves required to *firm* VERs is approximately 28% of wind and 20% of solar PV





US CCGT Fleet		MW	GWh	%	Btu/kWh
2017	Nation Total	249,460	1,019,019	47%	7,405
2016	Nation Total	243,669	1,107,389	52%	7,267

Sources: PJM Evolving Resource Mix 2017; NREL WWSIS-2; EVA Analysis of EIA-923, EIA-860 and EPA CEMS data

Gas fleet CF shrinks, reliability needs grow as RPS increases, placing an even higher burden on remaining gas fleet

CHALLENGE: ENVIRONMENTAL IMPACT (NEGATIVE EXTERNALITIES)

Adding renewables can require more operating reserves and ramping from existing gas plants, increasing local pollutants & causing diminishing returns on GHG reduction.

GHG target, RPS's

↓

Seasonality, volatility ↑

↓

Sub-optimization of gas fleet

↓

GHG reduction impact ↓

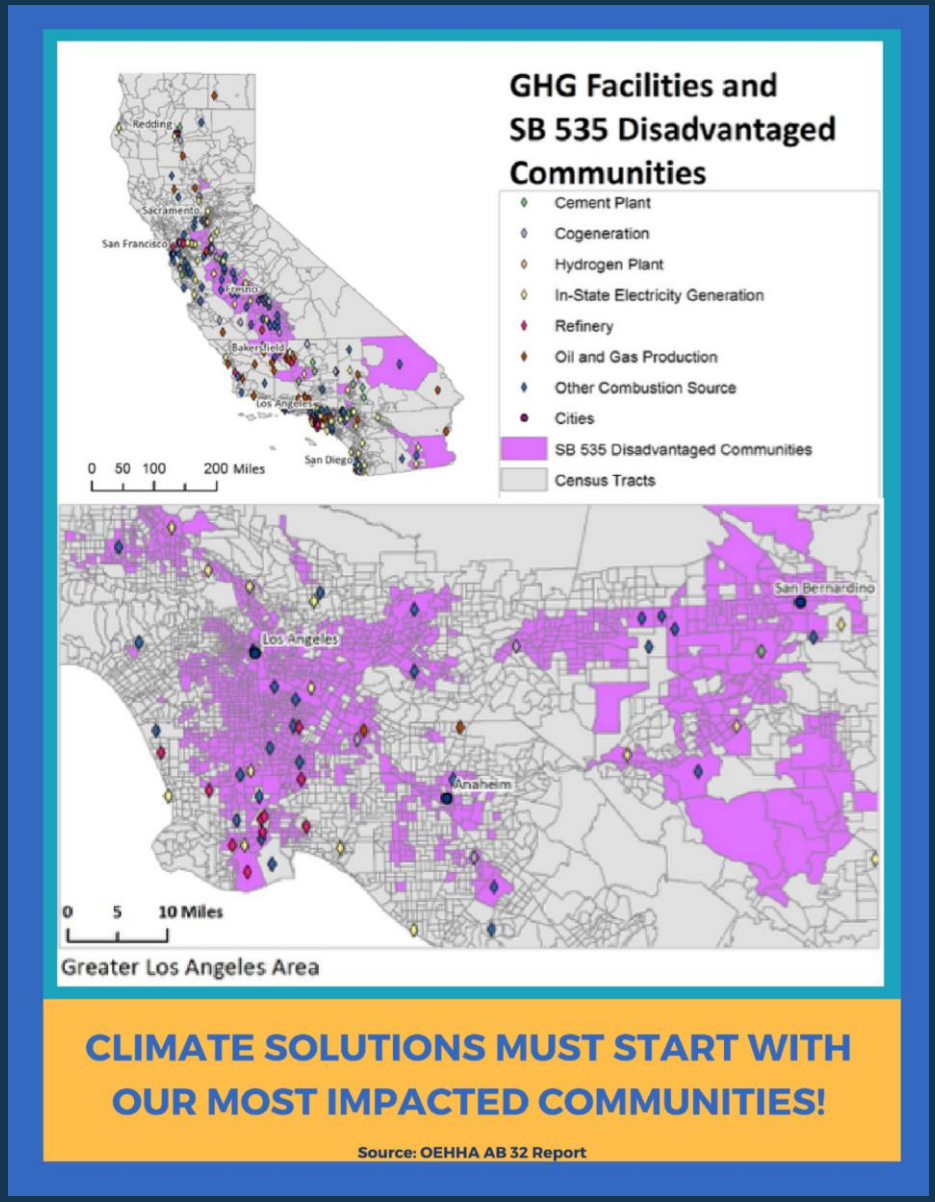
CAISO's assessment of early economic retirement of gas-fired resources show shortfalls in *load following* and *operating reserves* with only 1,000 – 2,800 MWs of retirement

CAISO's recent analysis of the CPUC's proposed preferred portfolio noted capacity insufficiencies with more than 2,150 MWs of thermal retirement due to the 40 year plant-life assumption

Source: CAISO Reliability Assessment of the IRP Hybrid Conforming Plan, 2019

CHALLENGE: GHG, CRITERIA EMISSIONS IN DISADVANTAGED COMMUNITIES

Increased cycling, ramping of thermal power plants will increase emissions, often located in sensitive areas …



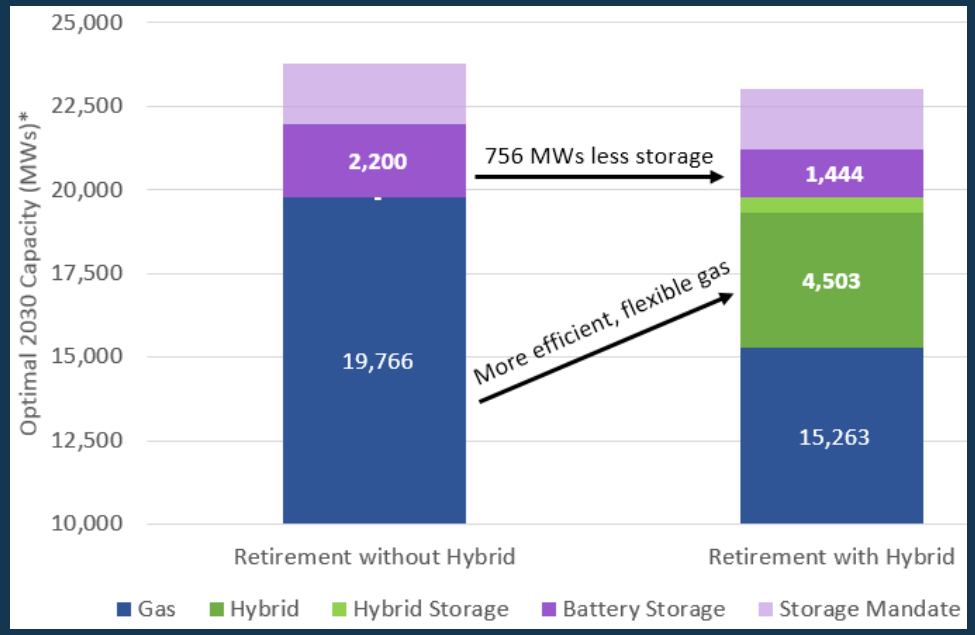
THERMAL HYBRIDS: MACROECONOMIC BENEFITS

Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System

THE PRAGMATIC SOLUTION: HYBRIDIZE A SUBSET OF GAS PLANTS

Example: California

TECHNOLOGY TYPE	2018 RETIREMENT	2018 HYBRIDIZATION (464 MWS, 30-MIN. STORAGE)
CCGT	2,974 MWs (11 units)	3,682 MWs (6 units)
Peaker	2,665 MWs (58 units)	821 MWs (16 units)
Steam Units	6,416 MWs (19 units)	-



Relative to retirement case w/o hybridization:

- ✓ Reduces **energy neutrality** concerns
- ✓ Reduces cycling of gas fleet by an average of **940 starts a year**
- ✓ Reduces GHG emissions from gas fleet by **350,000 metric tons a year**

** Modeling was validated using GridPath, another capacity expansion model, with directionally similar results*

**Other resource types omitted from chart for ease of discussion; shed DR increased by 384 MWs with hybridization

Source: Gridwell Consulting, Wellhead Electric Company, Inc.

Early procurement of hybrid facilitates ***immediate*** retirement of gas-fired resources w/o sacrificing reliability

QUANTITATIVE IMPACT OF HYBRIDIZING A SUBSET OF GAS PLANTS

- ✓ Hybridization of a subset of the existing Peakers in DACs can allow them to provide immediately responsive operating reserves without burning gas
- ✓ Hybridization of a subset of the current CCGTs can provide the same ramping capability (load following) from fewer resources without increasing GHG

Example: California

1 Hybrid Peaker
(e.g. 10 MW/5 MWh battery added to 50 MW existing gas peaker)

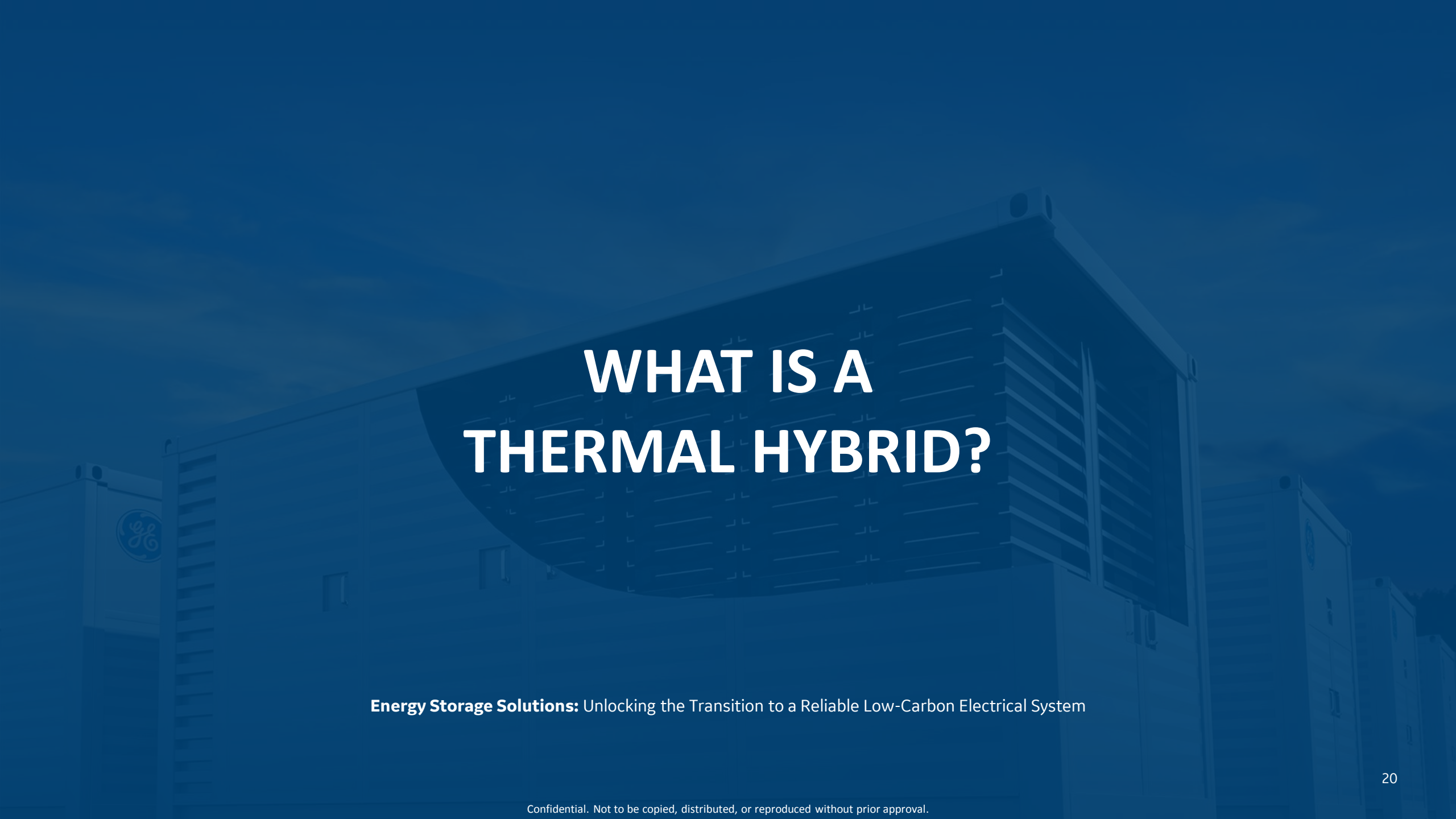
Gas free operating reserves …
-15,000 to -30,000 metric tons GHG
(annual reduction)

22 Hybrids
(e.g. 460 MW batteries installed on ~4,500 MW existing plants)

Gas free operating reserves AND additional load following can help create enough head room for **~5500 MW gas plants to retire**

Source: Wellhead Electric Company, Inc.

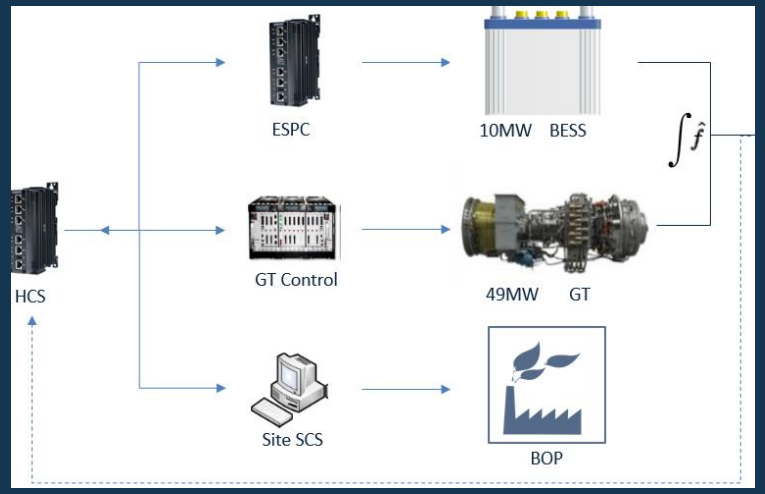
Hybridization of an existing gas plant also increases it speed, operating range and flexibility.



WHAT IS A THERMAL HYBRID?

THERMAL HYBRID: SIMPLE CYCLE

TYPICAL CONFIGURATION



USE CASES / APPLICATIONS

Spinning reserve

Regulation

Frequency response

Load following

Voltage support

CAPABILITIES (FULLY AUTOMATED POWER PLANT IN HYBRID MODE)

- *P_{min} = 0.00 MW*
- *P_{max} = GT P_{max} (47.00 to 49.90 MW)*
- *Commitment time = 0.00 minutes*
- *Commitment cost = $0.00*
- *GT start/stop managed by the Hybrid Control System (HCS)*
- *Battery SOC managed by the HCS*
- *Minimum Down Time = 0.00 minutes*
- *Minimum Up Time = 0.00 minutes*
- *Precise Net MW Control*
- *ISO AGC Control (25 to 30 MW of high quality regulation)*
- *Automated response to grid events*
- *Primary Frequency Response*
- *Will start GT only if required*
- *Voltage Regulation*
- *Adjustable Trickle Charge to maintain battery SOC when GT is not running*

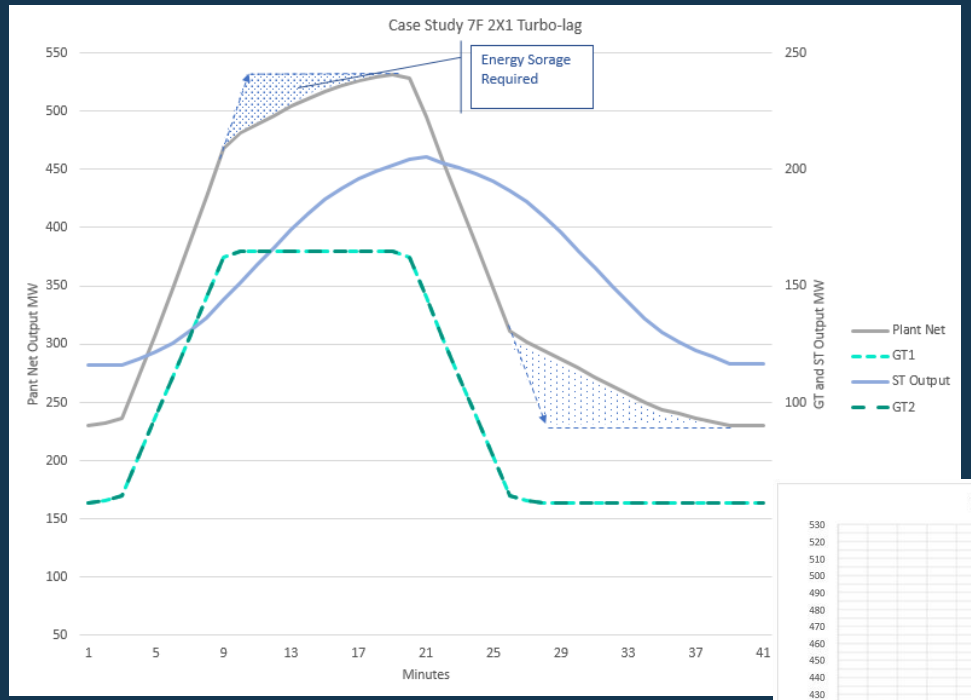
Source: Wellhead Electric Company, Inc.; GE

GE LM6000 HYBRID EGT VS. STANDALONE ASSET

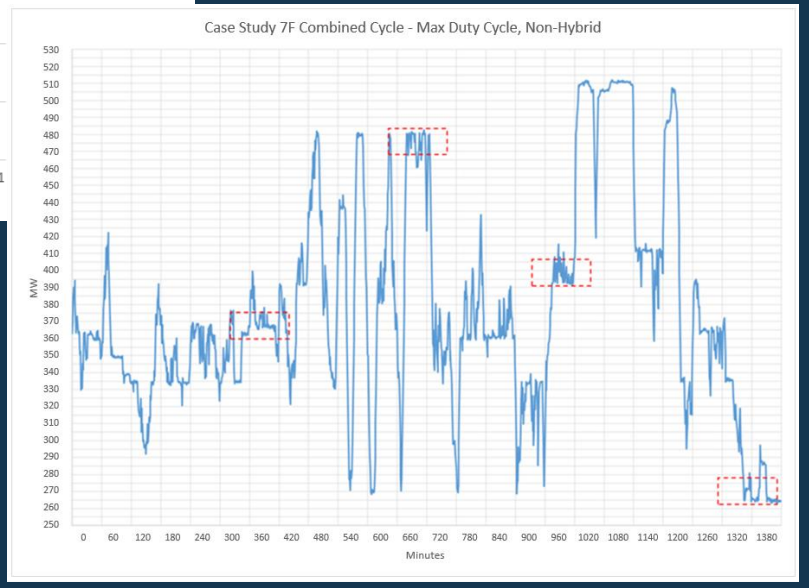
DIRECT PROJECT VALUE	EXISTING LM6000	10MW 4-HR. BESS ONLY	LM6000 EGT UPGRADE
Contingency reserve value no emissions	0	10 MWs	50 MW
Instant on	✗	✓	✓
RA value	50 MWs	10 MWs	50 MWs
Max power	50 MWs	10 MWs	50 MWs
Min power	>0	-10 MWs	-10 MWs
Spinning reserve value no emissions	0	10 MWs	50 MWs
Energy capacity	Unlimited	Very limited	Unlimited
High-speed frequency regulation	0	10 MWs	10-25MWs
Grid energy neutrality	✓	✗	✓
Blackstart with no emissions	✗	?	✓
Utilize existing interconnect	N/A	✗	✓
Utilize existing substation & GSU	N/A	✗	✓
Utilize existing communications and backhaul	N/A	✗	✓
Utilize existing land	N/A	✗	✓
Speed to install	N/A	Slower	Fast
Cost	0	$$	$

THERMAL HYBRID: COMBINED CYCLE

CAPABILITIES



1. Eliminate ST lag
2. Increase flexibility



1. Eliminate oscillations
2. Improve accuracy

BENEFITS

PERFORMANCE

- ✓ *Increased ramp rate*
- ✓ *Increased accuracy*
- ✓ *Less wear on turbo machinery*

GRID / MARKET

- ✓ *Increase in intra-hour, flexi-ramp/load following capability*
- ✓ *Primary frequency response available at P_{max}*
- ✓ *Fast, accurate generation*

Source: Wellhead Electric Company, Inc.; GE

OPTIMIZING GENERATION FLEETS

INDUSTRY CHALLENGES

Reserve dispatching favors low-cost providers and often requires assets to run at non-optimum, minimum loads.

SYSTEM CHALLENGES :

EFFICIENT INTEGRATION
of variable generation

FLAT LOAD GROWTH
but faster ramps & higher peaks

CONTINGENCY RESERVE
& Inertia Requirements

REDUCE EMISSIONS
& Increase renewable penetration

OPERATIONAL CHALLENGES :

MULTIPLE
Starts per day

INCREASED
need for spinning reserve

DISPATCH
to minimum loads

View GE's **SOLUTION**

RESERVOIR APPLICATIONS

HYBRID THERMAL

Optimize Generation Fleets

GE's solution combines steam and gas turbines with energy storage plus digital controls to reduce fuel costs and gas emissions, by optimizing the use of existing generation sources and enabling applications such as frequency response, black start, shifting and capacity markets.

SYNTHETIC INERTIA

Reliability
Dynamic Response

HIGH POWER

Discharge: **20 MIN**

LEARN **MORE**

FREQUENCY RESPONSE

Ancillary Service Revenue
Grid Code Compliance

HIGH POWER

LEARN **MORE**

CONTINGENCY RESERVE

Fuel Cost Reduction
Emission Reduction
Fast Ramp Rate

MID POWER

LEARN **MORE**

IMPROVED OPERATIONS

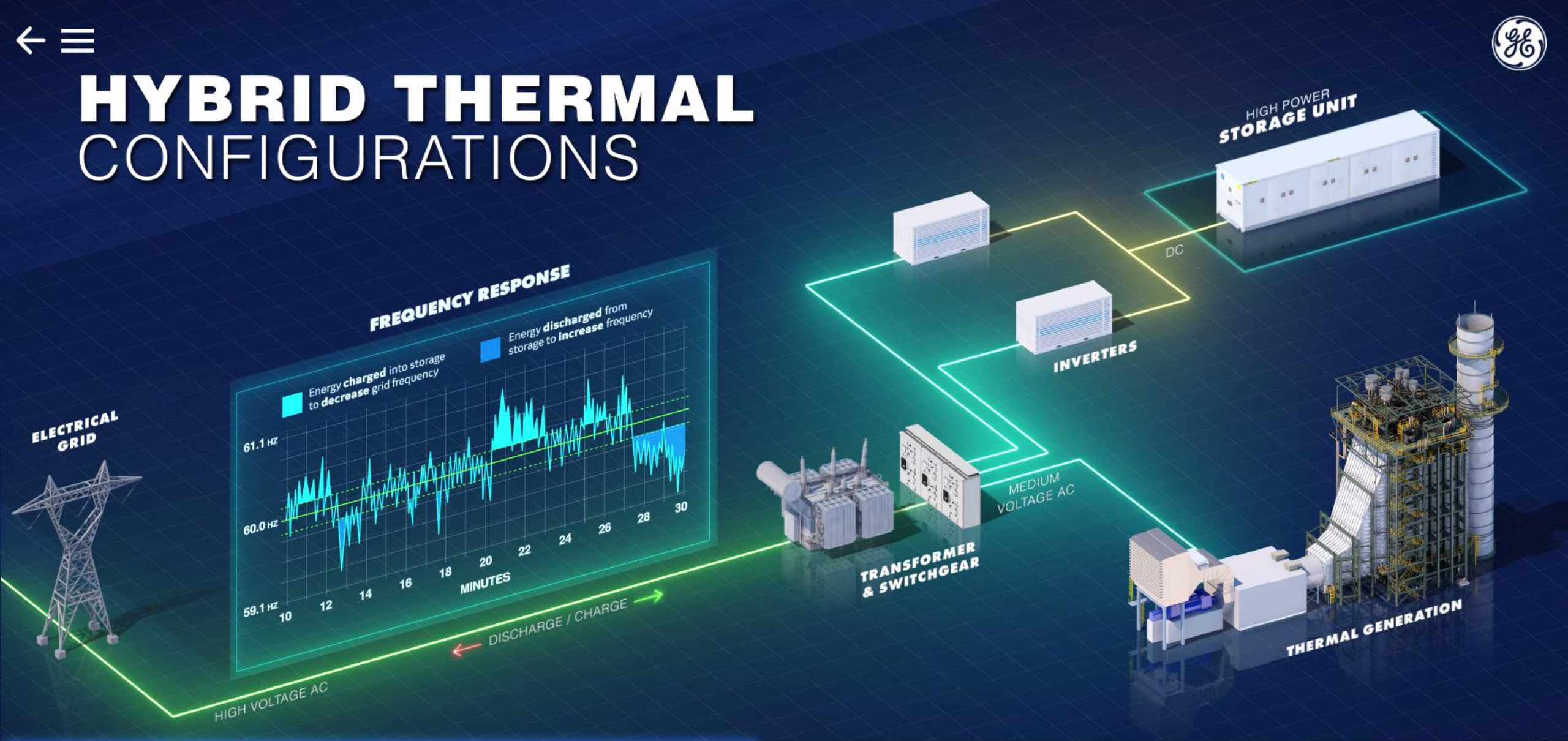
Reduced Fuel Consumption
Black Start Capability
Start/Stop Reduction

MID POWER

Discharge: **6+ HR**

LEARN **MORE**

HYBRID THERMAL CONFIGURATIONS



HIGH POWER
SYNTHETIC INERTIA

HIGH POWER
FREQUENCY RESPONSE

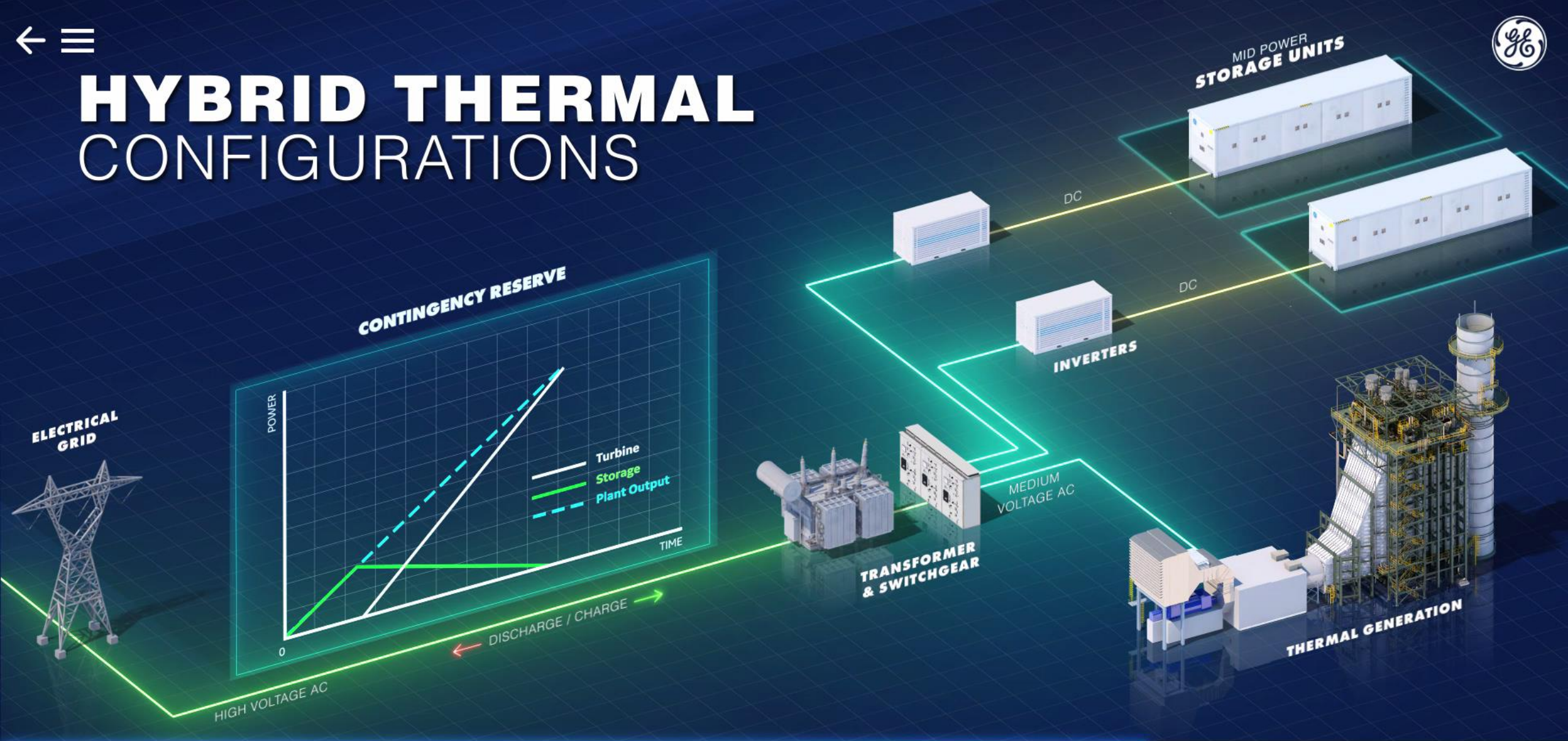
MID POWER
CONTINGENCY RESERVE

MID POWER
IMPROVED OPERATIONS

20 MINUTE DISCHARGE

6+ HOUR DISCHARGE

HYBRID THERMAL CONFIGURATIONS



HIGH POWER
SYNTHETIC INERTIA

HIGH POWER
FREQUENCY RESPONSE

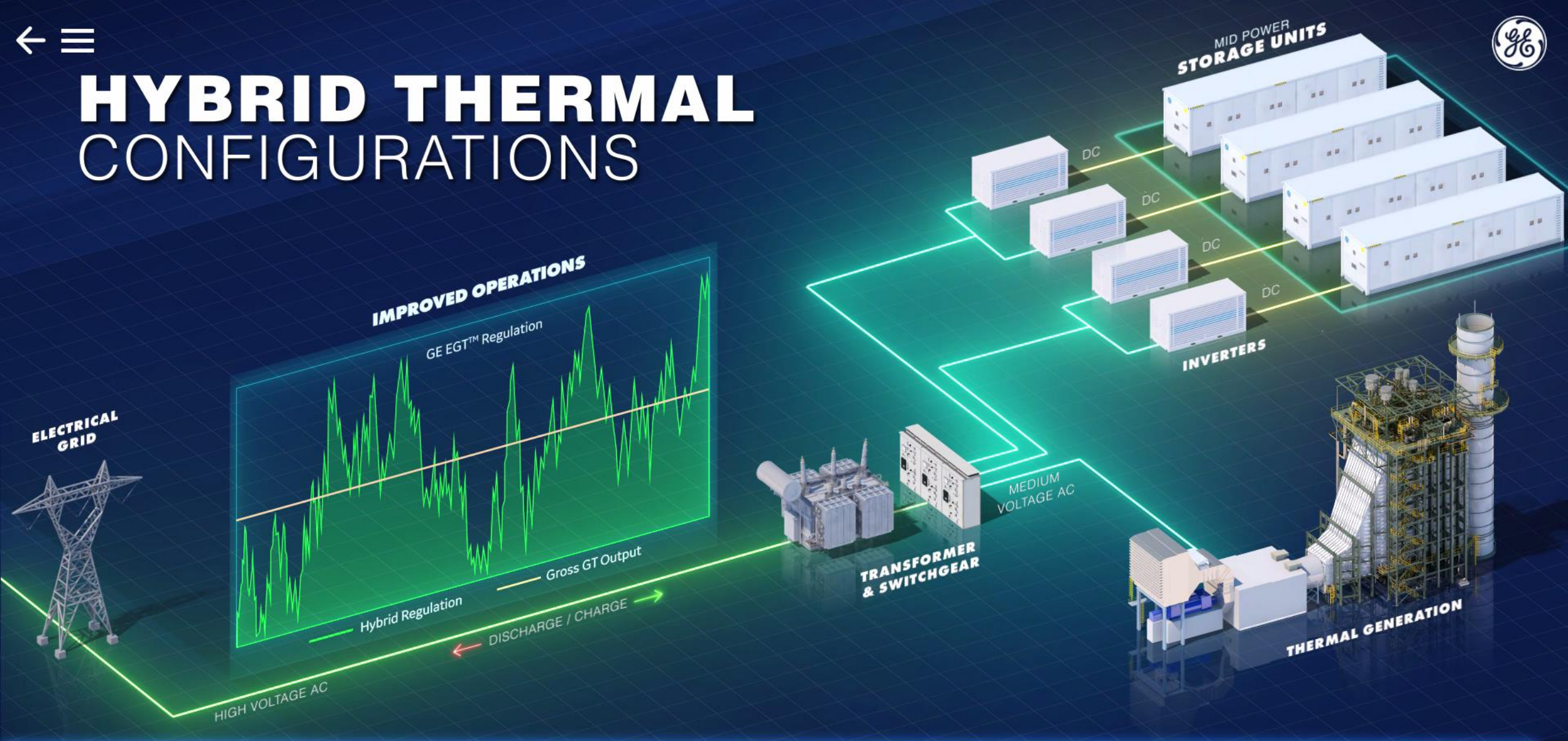
MID POWER
CONTINGENCY RESERVE

MID POWER
IMPROVED OPERATIONS

20 MINUTE DISCHARGE

6+ HOUR DISCHARGE

HYBRID THERMAL CONFIGURATIONS



HIGH POWER
SYNTHETIC INERTIA

HIGH POWER
FREQUENCY RESPONSE

MID POWER
CONTINGENCY RESERVE

MID POWER
IMPROVED OPERATIONS

20 MINUTE DISCHARGE — 6+ HOUR DISCHARGE

THERMAL HYBRIDS: CASE STUDIES

Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System

OPTIMIZING THE GENERATION MIX WITH THERMAL HYBRIDS

Introducing thermal hybrids on their system allowed SCE to change how and when its other assets were dispatched

- Saves 2 million gallons of water per year
- Reduces starts by half, GHG and other emissions by as much as 60%

CUSTOMER PUBLIC POWER UTILITY

CHALLENGE
Addressing local grid reliability concerns

APPLICATION
Hybrid - Thermal (EGT)
Spinning reserve

LOCATION
Southern California (US)

GE SOLUTION
10MW / 4.3MWh BESS, integrated controls

STATUS
In operation

This project consists of two 10 MW of battery energy storage systems, each paired with GE's proven 50 MW LM6000 aeroderivative gas turbines, capable of providing instantaneous response during a spinning reserve event.

OPTIMIZING
GENERATION FLEETS

GE's SOLUTION

Gas Turbine + Energy Storage + Digital Controls

INCREASED UTILIZATION :

50MW
of greenhouse gas-free peaking energy for local contingency

25MW
of high speed frequency regulation for improved response

-8/+5
MVAR Voltage support & primary frequency response when offline

INTEGRATED SYSTEM OPTIMIZATION
for both the turbine and the battery storage

REDUCED SYSTEM COSTS & EMISSIONS:

REDUCED
THERMAL STRESS
on turbine for extended asset life

ZERO
FUEL & EMISSIONS
between dispatch events while supporting ancillary services

Reduce costs by optimizing the use of existing generation sources and enabling contingency (spinning) reserve without fuel-burn

“As we navigate the transition to a 100% renewable future we need the gas fleet to become faster and more flexible (lower minimum load level, short start-ups). Like what Edison did with their EGT’s by adding batteries to their Peakers. We need more solutions like that.”

- Mark Rothleder, Vice President of Market Quality & Renewable Integration, CAISO

INTEGRATING MORE RENEWABLES

Imperial Irrigation District manages high levels of solar and wind generation, in and across their network. The energy storage system provides multiple services to increase grid reliability by managing dynamics events at multiple time scales.

CUSTOMER PUBLIC POWER UTILITY

CHALLENGE
Providing grid stability & smoothing renewable output

GE SOLUTION
33MW / 20MWh BESS

APPLICATION
Standalone - Transmission
Emergency power / black start capability, distribution management system integration, ramp rate control, frequency response, spinning reserve

LOCATION
Southern California (US)

STATUS
In operation

Located in California, which has some of the most aggressive renewable portfolio requirements in the US, this 33MW / 20MWh battery system complements the integration of renewable resources, such as solar and wind, by adding stability and improving power quality.

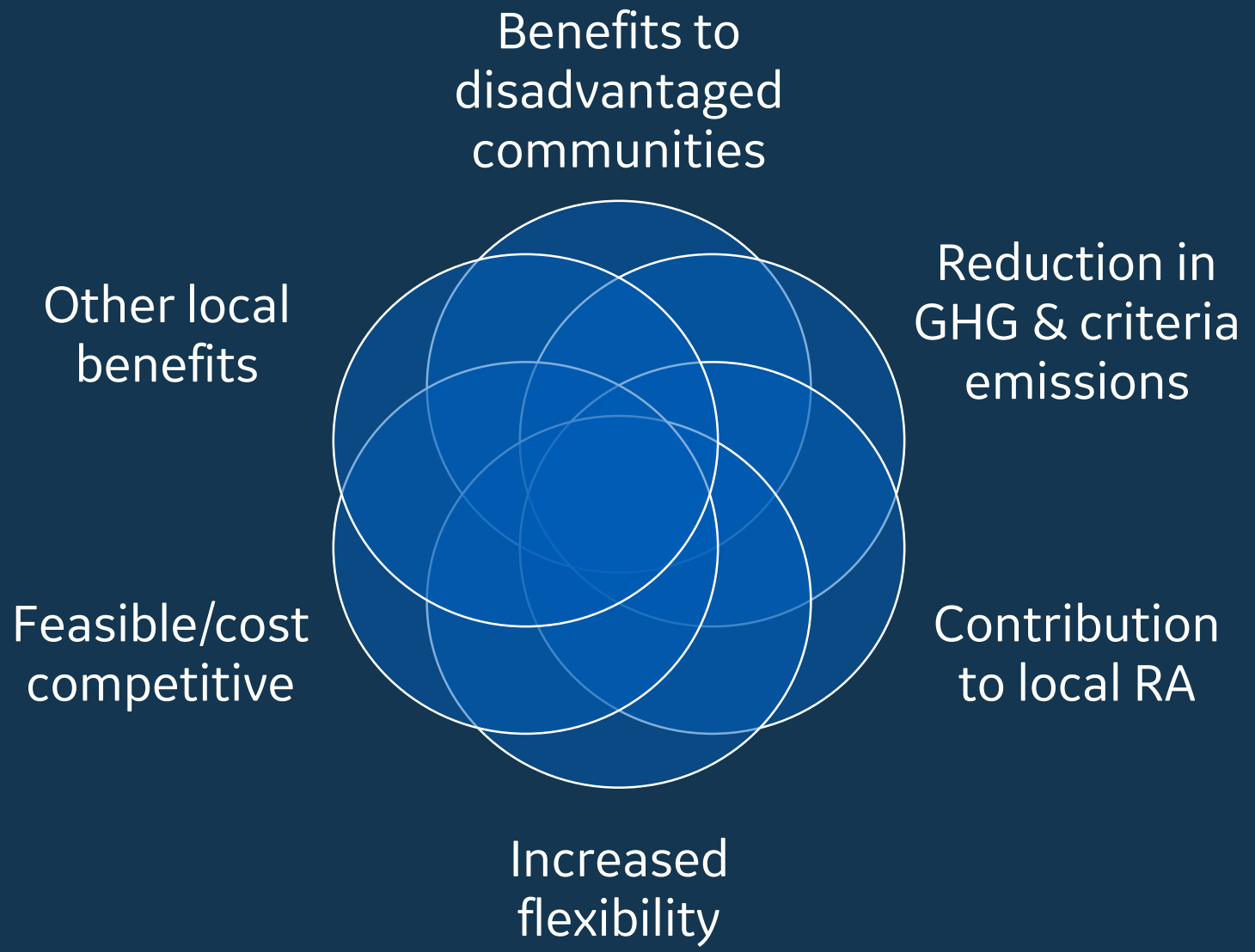
IID BOARD OF DIRECTORS REGULAR MEETING (21 AUGUST 2019)

"Without the battery, before, losing the S Line like that would've affected a much wider size of our territory. And the fact that it ... in the dead of summer ... that it was isolated still, I think is due to the battery."

"We had talked about the value of the battery from operational and in ... all inclusive, we had hit more than ***three-quarter million dollars a month in value****. [...] So it's a tremendous value."*

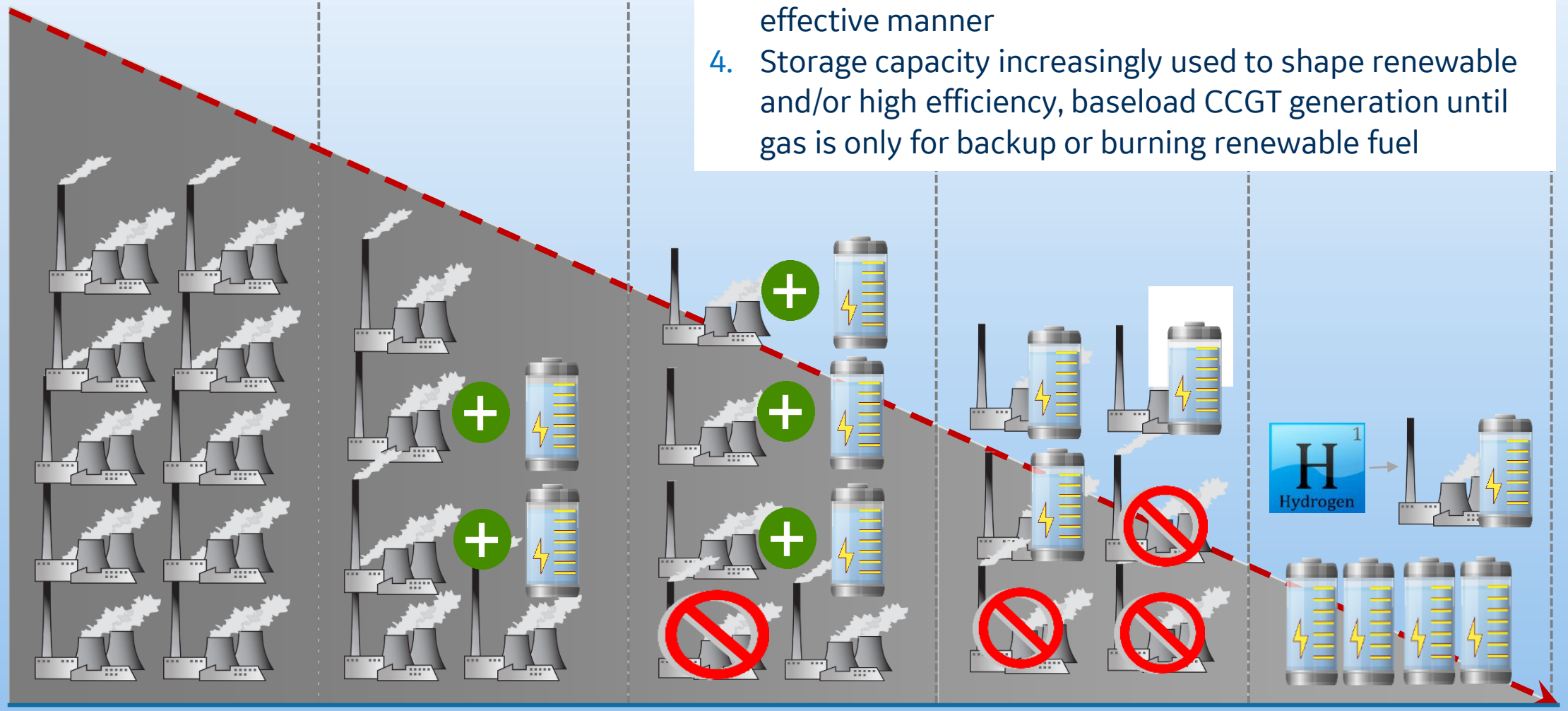
CONCLUSIONS, NEXT STEPS

ECONOMICAL, SOCIAL, & ENVIRONMENTAL BENEFITS OF THERMAL HYBRIDS

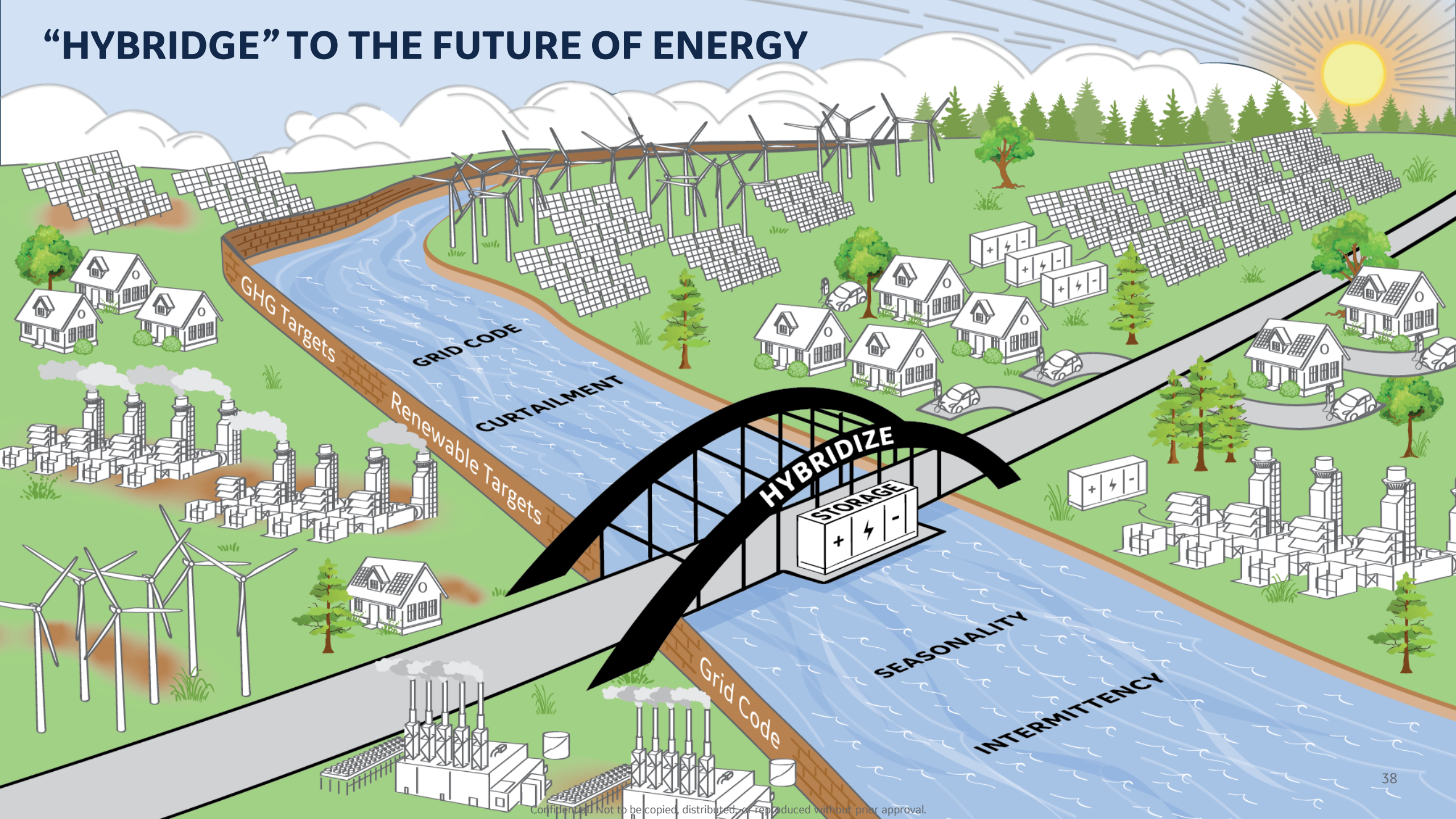


A ZERO CARBON ROADMAP USING EXISTING THERMAL RESOURCES

1. Achieves immediate air quality benefits
2. Could facilitate faster gas plant retirement
3. Ensures reliability (including local constraints) in a cost-effective manner
4. Storage capacity increasingly used to shape renewable and/or high efficiency, baseload CCGT generation until gas is only for backup or burning renewable fuel



“HYBRIDGE” TO THE FUTURE OF ENERGY



Q & A

Questions can be submitted through the chat box in your browser.

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Thank you

Please submit ideas for future webinars to
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