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GE Renewable Energy
Design and Optimization of Renewable Hybrid Plants

Speakers

Rahul Khandelwal
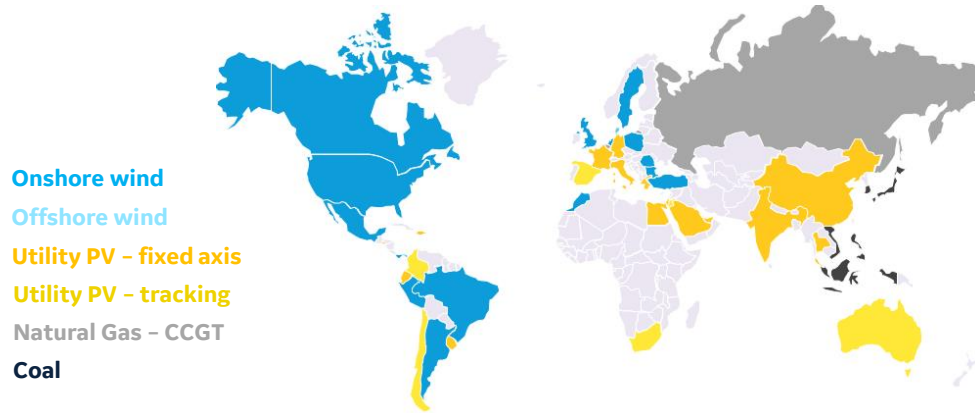Hybrids Technical Sales Engineer

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Martin Yan
Value Engineering Leader
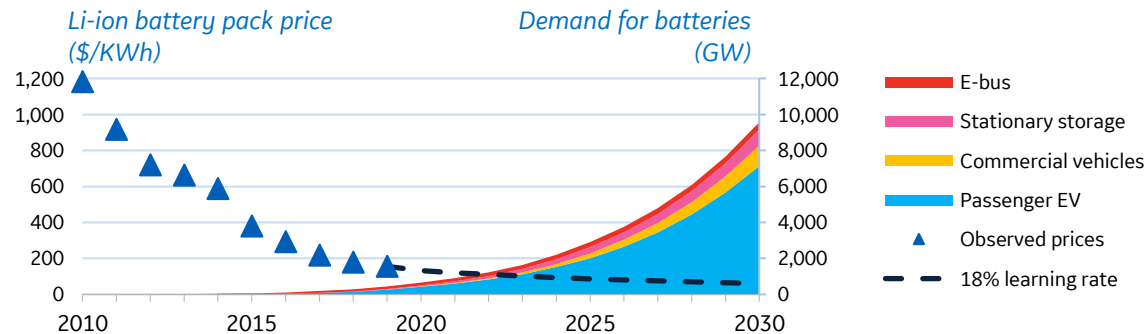
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Renewable Energy is Mainstream

WIND & SOLAR CHEAPEST ENERGY SOURCES FOR 2/3 OF THE WORLD

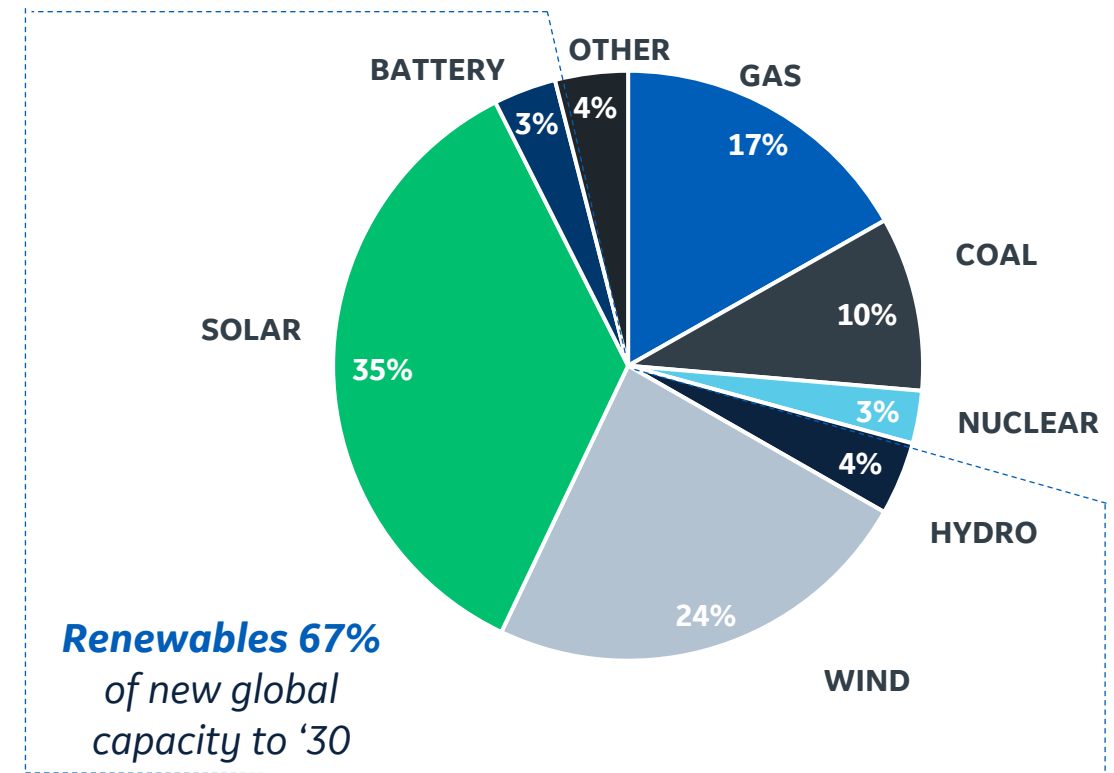*Most competitive source of new bulk generation in 2020*

Onshore wind
Offshore wind
Utility PV – fixed axis
Utility PV – tracking
Natural Gas – CCGT
Coal

Battery costs have reached point of inflection

Li-ion battery pack price ($/KWh)
Demand for batteries (GW)

- E-bus
- Stationary storage
- Commercial vehicles
- Passenger EV
- ▲ Observed prices
- --- 18% learning rate

WIND, SOLAR & STORAGE INSTALLS CONTINUE TO GROW

Projected Capacity Additions 2020-2030

- BATTERY 3%
- OTHER 4%
- GAS 17%
- COAL 10%
- NUCLEAR 3%
- HYDRO 4%
- WIND 24%
- SOLAR 35%

***Renewables 67%** of new global capacity to '30*

Increased RE penetration requires improved dispatchability, grid stability & efficiency/affordability that Hybrid Systems can provide
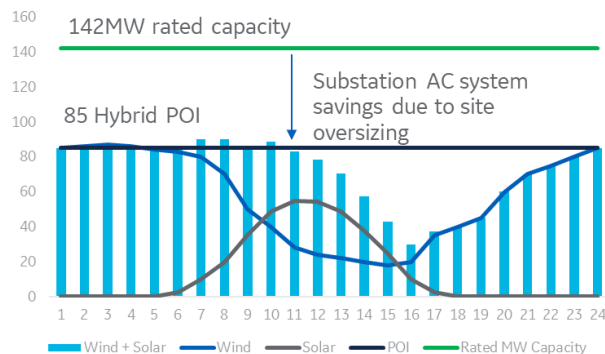
Integrating Storage
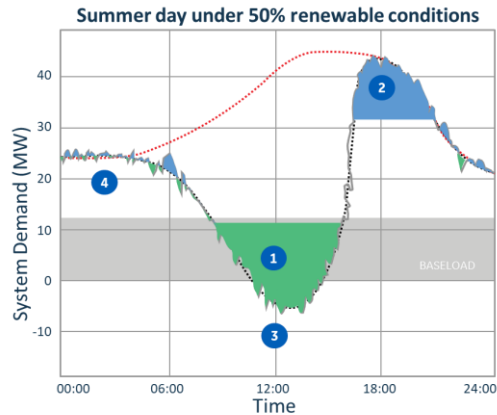
1 **Renewables curtailed** - ES charged with free or negative priced energy

2 **Peak Load** - ES discharged during peak demand

3 **Spinning Reserve** – ES discharged during dynamic events

4 **Frequency Regulation** – ES continuously charged and discharged to maintain grid stability

Integrating Wind and Solar

Leveraging complementarity of Wind and Solar to:
- Increase Capacity Factor
- Improve EBOP and interconnection
- Enhance use of land
- Improve combined LCOE

Increased RE penetration requires improved dispatchability, grid stability & efficiency/affordability that Hybrid Systems can provide
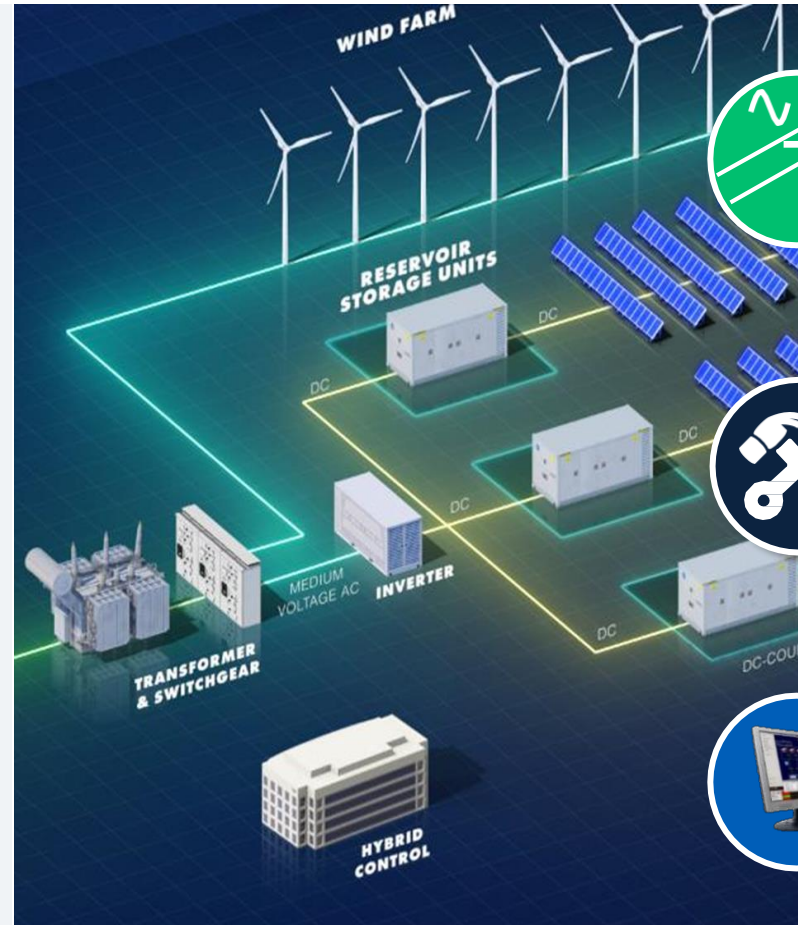
Who benefits?

Grid Operator

- Lower Wind & Solar variability
- Increased flexibility
- Grid CAPEX deferral
- Peaker replacement
- Grid security/blackout avoidance

Asset Owner

- Increased Capacity Factor
- Hybrid DEVEX, CAPEX & OPEX optimization
- Improved power forecasting & output
- Access to Energy, Capacity and Grid Services revenue streams

Improved Capacity Factor at Point of Interconnection

- Wind/Solar resource complementarity
- Lower Wind+Solar combined LCOE
- Curtailment avoidance

Synergies

- Common Electric Balance of Plant & interconnection
- DC-coupled *Solar+Storage* configuration
- Enhanced use of land and civil works
- Common O&M
- Single permitting process

Integrated Controls & Software

- Multi-asset coordinated plant control & grid compliance
- Dispatch optimization to maximize revenue or profit
- Hybrid plant monitoring & diagnostics

Hybrid Architect

User Input:

- Basic user: location, generation equipment, revenue & power output
- Expert level: allows adjustment of 70 variables finance, Capex, Opex, Equipment efficiency and degradation
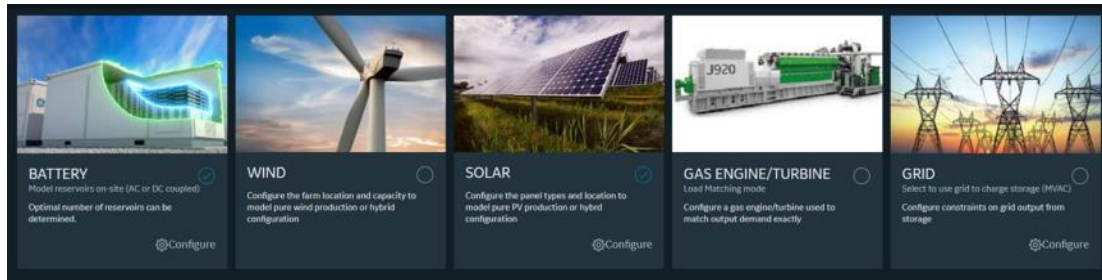
Output:

- Fine tuned hybrid system design configuration
- Multi-year proforma w/LCOE, NPV, IRR
- Curtailment Analysis
- Battery Capacity Addition Strategy for local incentives
- Power point summary

| Battery | Wind | PV | Grid | Gas |
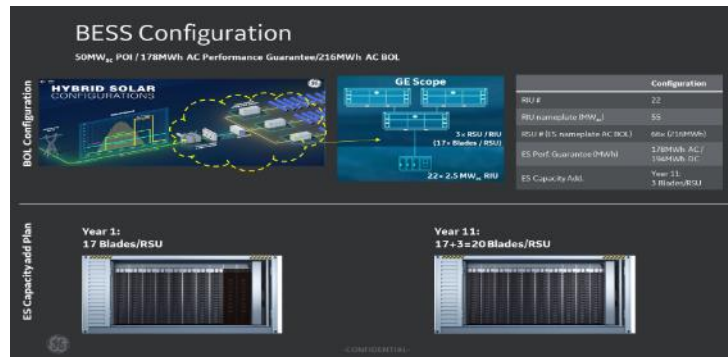
Applications/ Use Cases:

- Energy Shifting
  - Merchant/ Structured PPA
- Load Following/ Firming
- Capacity Payments
- REC for Revenue
- Curtailment
- Frequency Response
- Additional applications/use cases as market demands change.

General impact of Architect:

- Reduces design cycle time from weeks to hours
- improved configurations with up 10% additional value.
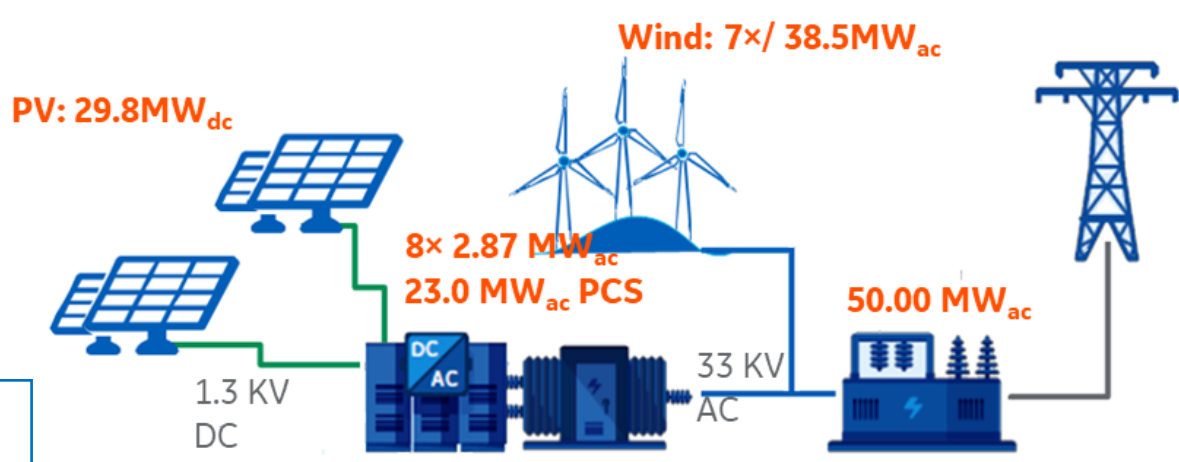
Synergies of Wind + Solar Hybrids

Theoretical Case Study: 50MW Project in Middle East (38MWac Wind, 23MWac PV)

1 **Wind + Solar P-value...** Uncertainty reduction of wind + solar generation from lower to higher P value, ~$1/MWh

2 **Aux loads...** supply aux loads from alternate generation, ~45% reduction in energy buy from grid

7 **PV AC maintenance...** helps to eliminate duplication of resources for AC maintenance, ~25% of total PV O&M

Wind: 7×/ 38.5MW$_{ac}$

PV: 29.8MW$_{dc}$

8× 2.87 MW$_{ac}$
23.0 MW$_{ac}$ PCS

50.00 MW$_{ac}$

1.3 KV DC

DC / AC

33 KV AC

3 **Substation Undersize...** AC BOS reduction from 61.5MW to 50MW ~$2.3MM Capex Savings

6 **DC BOS cost reduction ...** helps to eliminate cost duplication for PM, site mobilization, etc, ~$200k

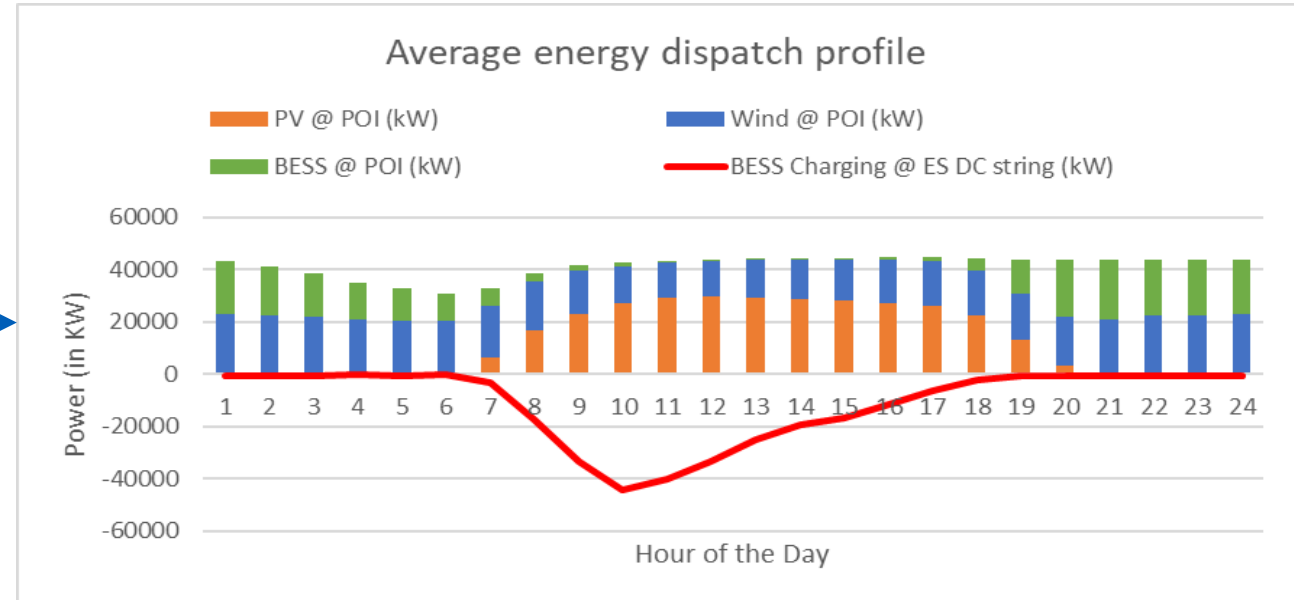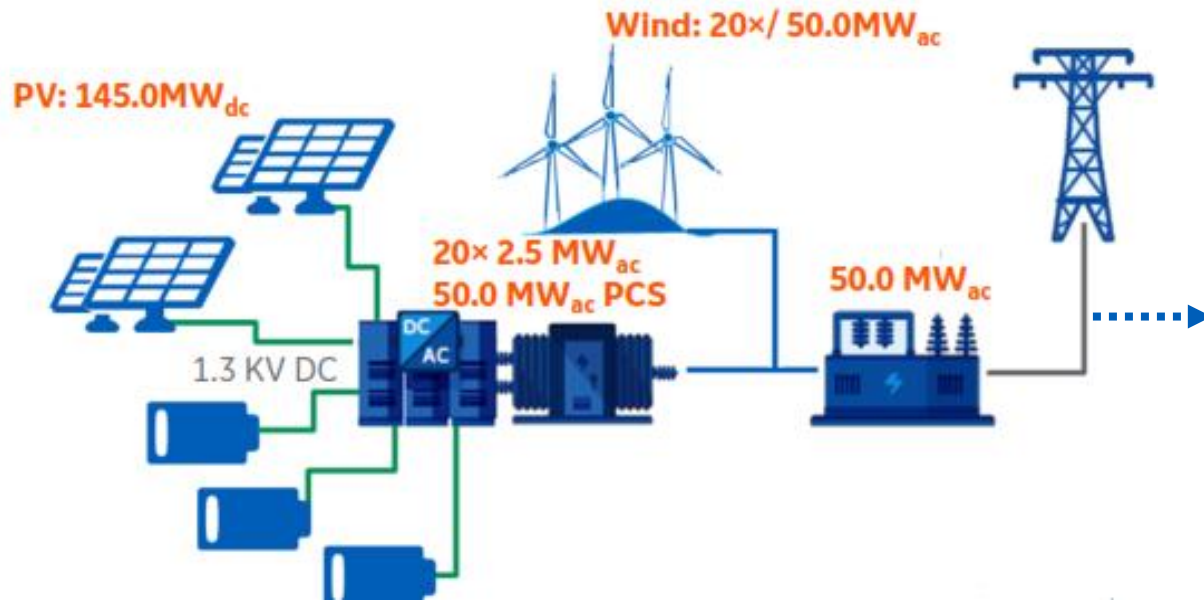**5** **Land ...** utilize available land between wind turbines for solar, ~$23k/MW

4 **eBOP loss...** helps to eliminate duplication of loss assumptions for wind/ solar (<2% loss)

Source: Internal GE analysis

Synergies, cost out and incremental MWhs drive ~10% lower LCOE

India – Round the clock (RTC)
Theoretical Case Study: 50MW Project in India (50MWac Wind, 50MWac/145MWdc PV, 335.47MWh ES)

Wind: 20×/ 50.0MWac

PV: 145.0MWdc

20× 2.5 MWac
50.0 MWac PCS

50.0 MWac

1.3 KV DC

DC / AC

Average energy dispatch profile

- PV @ POI (kW)
- Wind @ POI (kW)
- BESS @ POI (kW)
- BESS Charging @ ES DC string (kW)

Power (in KW) vs Hour of the Day

- Round-the-clock power output is based on a requirement of annual CUF (capacity utilization factor) of 80% through the 20-year project life

- As per the analysis carried out in Hybrid Architect tool, 50MWac Wind + 50MWac/145 MWdc PV + 335.5MWh (DC Coupled energy storage), helped achieve the annual CUF requirement greater than 80% at the lowest LCOE (based on the design space explored)

- Average energy dispatch profile graph validates the "dispatchability" of the Hybrid Power Plant.

KPI	Range Explored/Value
BESS/PV Inverter Nameplate (MWac)	22.5-50
DC/AC ratio	1.5 - 3
Wind Turbine Nameplate (MWac)	Upto max. Of 20 turbines
Annual CUF required (%)	80%
Achieved CUF (%)	82.79%
Objective Parameter	LCOE
LCOE ($/Mwh)	50.53

Summary

• Renewable hybrids with energy storage enable dispatchability, enhance grid stability, and faciliate higher renewable penetration.

• Synergies between renewable resources i.e., wind, solar &/ battery, make renewable hybrid more cost competitive.

• Thorough project planning based on techno-economic modeling combined with efficient operation using advanced plant dispatch & control softwares maximize return on investment for a renewable hybrid system.

• Fast decreasing battery price, continous evolution of wind & solar technologies, and volatility in energy markets, will make renewable hybrids more valuable in the clean energy transition.