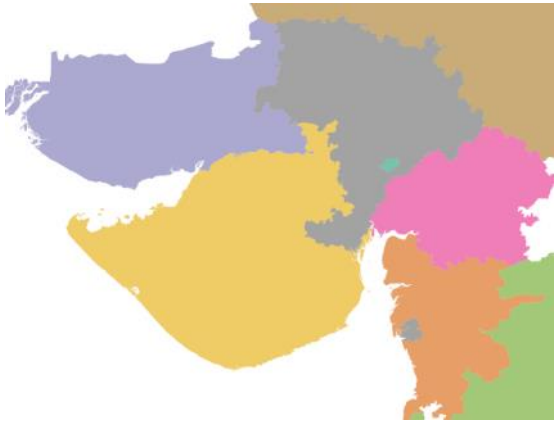
International Energy Agency

Gujarat power system modelling analysis

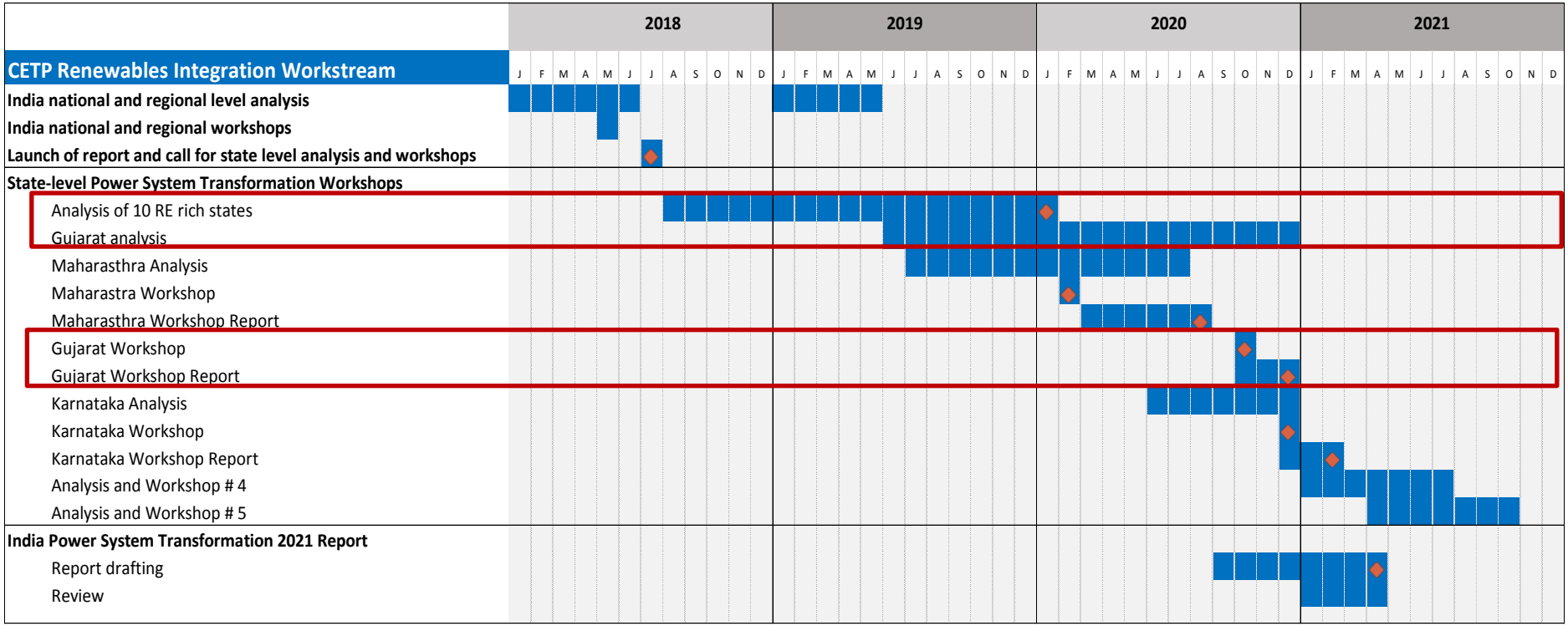
Szilvia Doczi, 07/10/2020

In collaboration with Centre for Energy Regulation, IIT Kanpur



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IEA Clean Energy Transition Program – India RE Integration work



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PRELIMINARY RESULTS

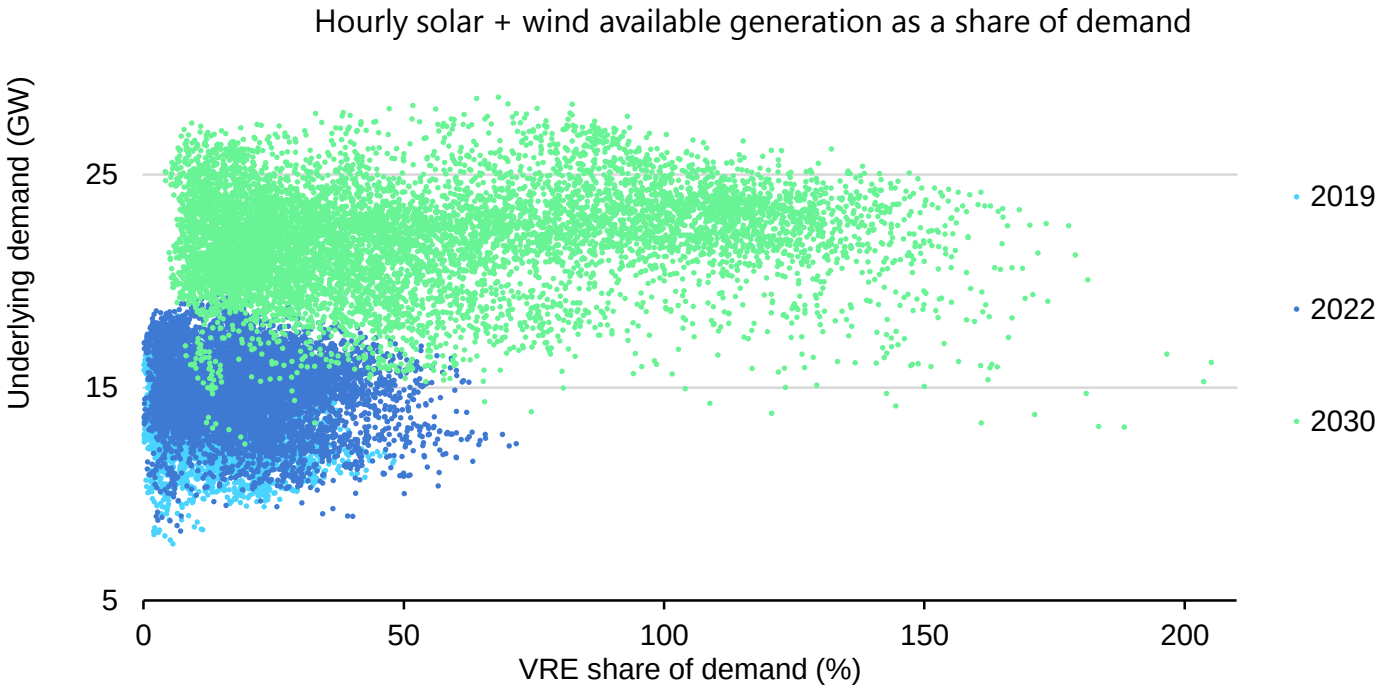
Preliminary results from IEA Gujarat's modelling study

Overview of scenarios and flexibility options examined:

Horizon	Flexibility options	VRE share (base case)	
		Capacity	Annual generation
Validation (FY2018-19)	Historical system	29%	12%
Short term (FY2021-22)	Power plant flexibility, demand response, pumped storage hydropower	42%	19%
Medium term (FY2029-30)	Power plant flexibility, demand response, pumped storage hydropower + grid expansion, batteries, electricity trade.	78%	54%

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Overall perspective: a changing system 1



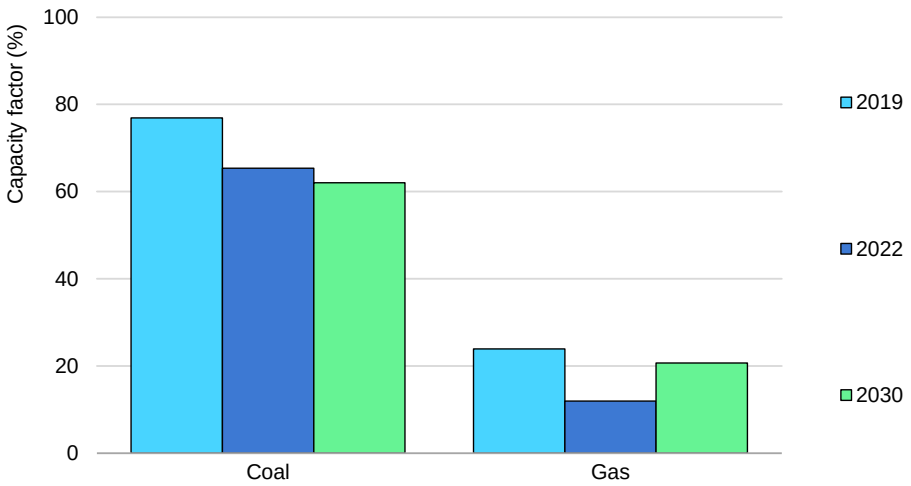
Increase in annual VRE to FY2021-22 to 20% will increase the maximum hourly share of variable renewables to around 65%. By 2029-30 we see much higher hourly shares even exceeding total demand, leading to integration challenges.

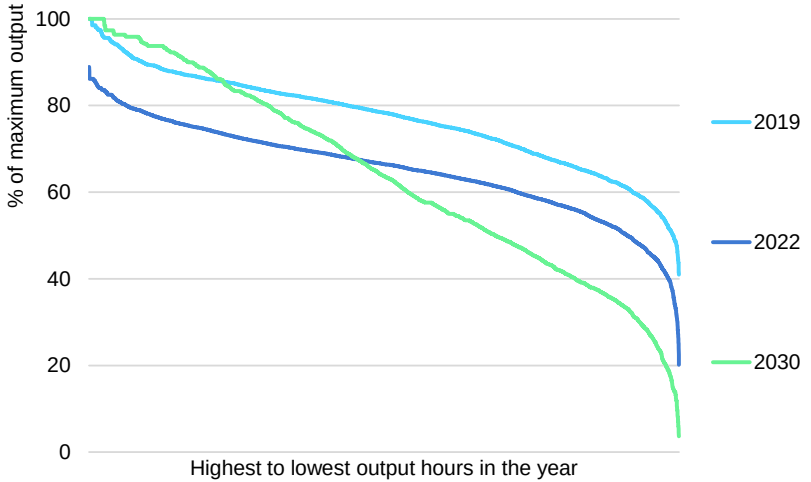
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Overall perspective: a changing system 2

PRELIMINARY RESULTS

Capacity factors (left) and fleet utilization by hours in the year (right) for coal and gas.



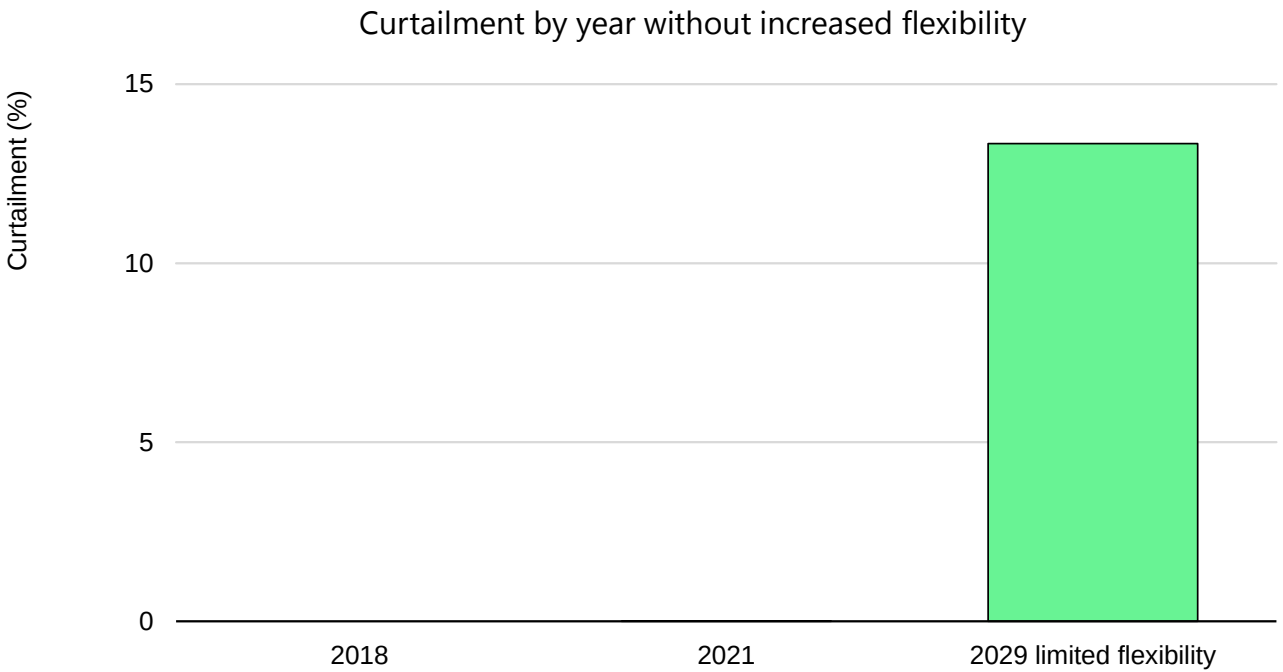


Coal and gas capacity factors decline to FY2021-22 due to new build and weak demand growth. But towards 2029-30, plant load factors change relatively little from 2022 due to reducing capacity and load growth.
However we see large change in operating patterns as conventional plants are more focused on flexibility.

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Overall perspective: a changing system 3

PRELIMINARY RESULTS



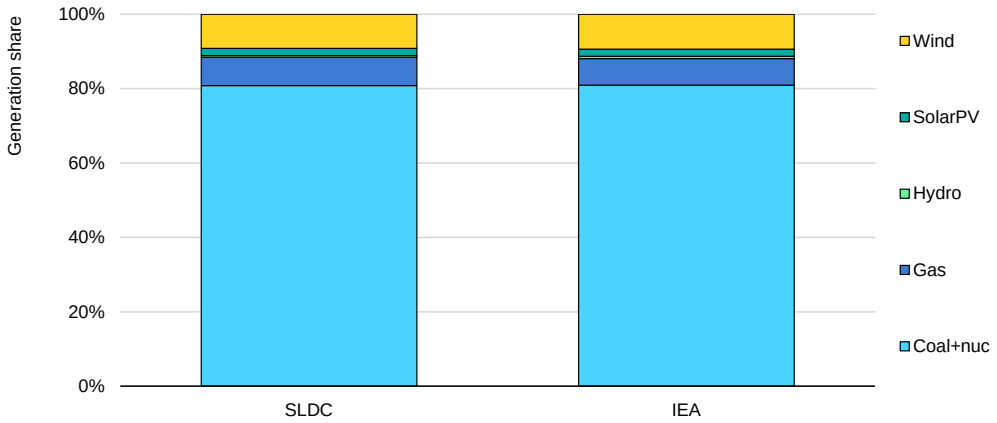
Without an increase in flexibility from today, increased VRE generation would lead to significant curtailment as well as increased dependency on imports during high demand periods

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PRELIMINARY RESULTS

Validation (FY2018-19)

- Overall generation mix is very close to historical
- Solar and wind generation patterns are overall similar to historical
- Integration challenges
  - Conventional generators already need to operate more flexibly
  - Some congestion is seen on high voltage lines from Kutchh but without resulting in curtailment
  - Local challenges can be present during high VRE periods, e.g.
    - Evacuation of RE from lower voltage levels
    - Local system strength



Source: historical values based on Gujarat SLDC annual report 2018-19

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Short term (FY2021-22) base case and scenarios

PRELIMINARY RESULTS

2021-22 base case – existing flexibility is activated more

- Increased ramping for dispatchable units (24% relative to 2018-19)
- Line congestion from the Kutchh region is similar to 2019 and a very small amount of curtailment is seen
- Capacity factors for coal and gas drop, due to increased capacity, weak demand growth and renewables increase

Additional flexibility options tested:

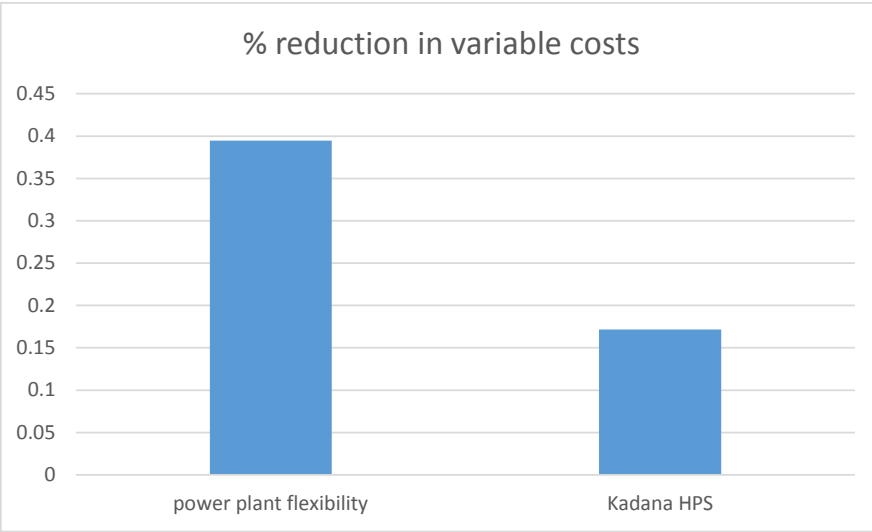
Scenario	Flexibility
2022 base	**Current**
2022 plant flexibility	Reduced minimum stable level (40%)
2022 pumped hydropower	Pump mode enabled for Kadana HPS

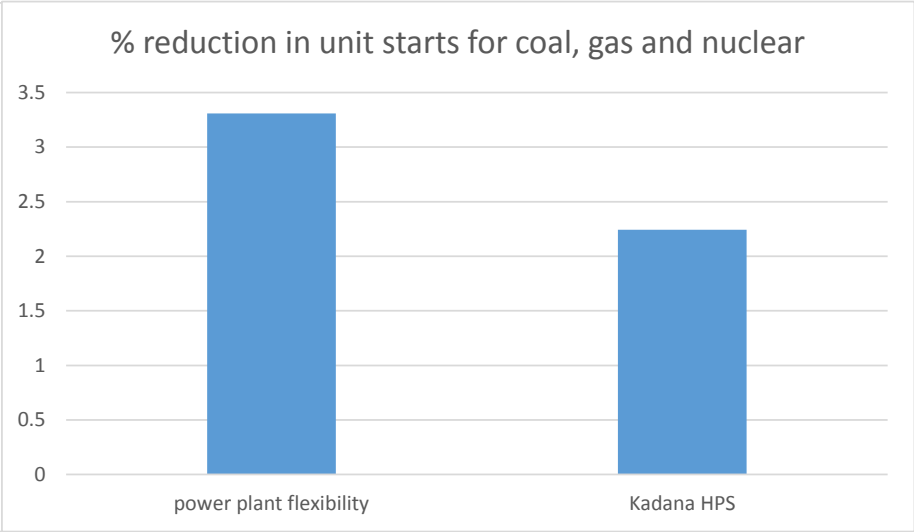
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Short term (FY2021-22) flexibility options

PRELIMINARY RESULTS

Reduction in variable costs (left) and coal, gas and nuclear unit starts (right) with power plant flexibility and activation of Kadana HPS in 2021-22





Increased flexibility in 2021 (from thermal plants and pumped hydro plants) provides small reductions in variable costs and unit starts for coal, gas and nuclear

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Medium term (FY2029-30) base flexibility options

- VRE share increases substantially with ambitious build-out, particularly in the Kutchh region
- Increased flexibility is required – this can come from demand response, power plant flexibility, grids and electricity trade, and energy storage

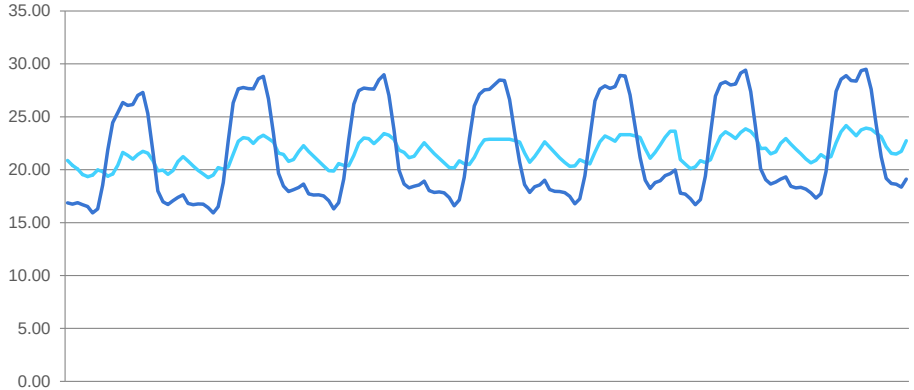
Scenario	Flexibility
2029 limited flexibility	Current
2029 agricultural shift	Agricultural demand during daytime
2029 Tx expanded	Tx expansion + agricultural demand shift
2029 base	**Kadana HPS active + agricultural demand shift + Tx expansion**
2029 plant flexibility	Base + reduced minimum stable level and ramp rate
2029 battery	Base + 2 GW (8 GWh) battery
2029 high wind	Base + Kutchh hybrid park 50% wind/solar

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PRELIMINARY RESULTS

Demand response is a key flexibility option in 2030

- Existing plans for shifting agricultural pumping loads (19% of state demand) to the daytime help demand to coincide with solar output
- Reduces curtailment (13.3 to 9.1%), and unit starts (with 40% reduction for coal and gas)
- Reduces variable costs from fuel, startups and ramp costs (9.6% overall reduction)
- Reducing high demand periods helps meet capacity needs (21GW to 19GW max net load) and reduces market purchases (36% reduction)
- Further potential from other loads (e.g. industrial, TBA)



Source: agricultural demand and shifted profiles from work of Khanna, 2020

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Grid expansion allows VRE generation to reach load centers or export nodes

Load and generation shares by region

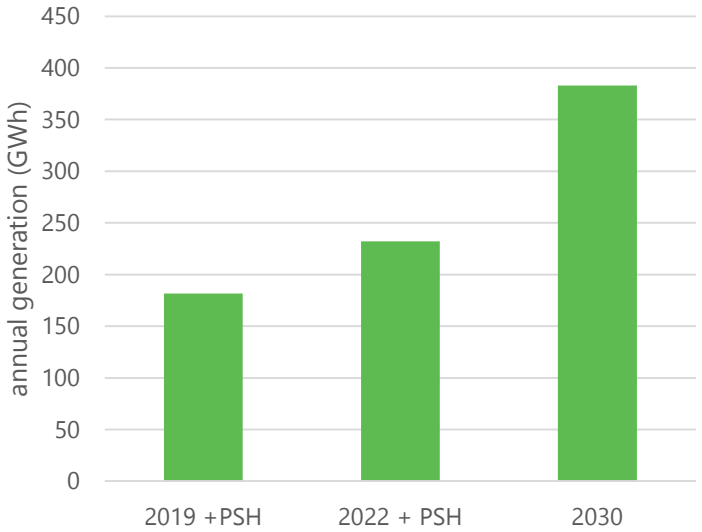
Region(s)	Load share (%)	Generation share 2019 (%)	Generation share 2030 (%)
PGVCL (incl Kutchh)	32	48	60
UGVCL + Ahmedabad	32	6	7
MGVCL	12	6	8
DGVCL+Surat	24	16	9
Import (incl contracted)	-	24	16

Generation concentration in PGVCL increases to 2030 due to concentrated renewables potential. Transmission expansion allows energy export during high generation periods and reduces curtailment from 9.1 to 6.6%

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Existing pumped hydro capacity has increasing potential

Sensitivity scenarios for Kadana HPS activation based on 2019, 2022 and 2030 conditions

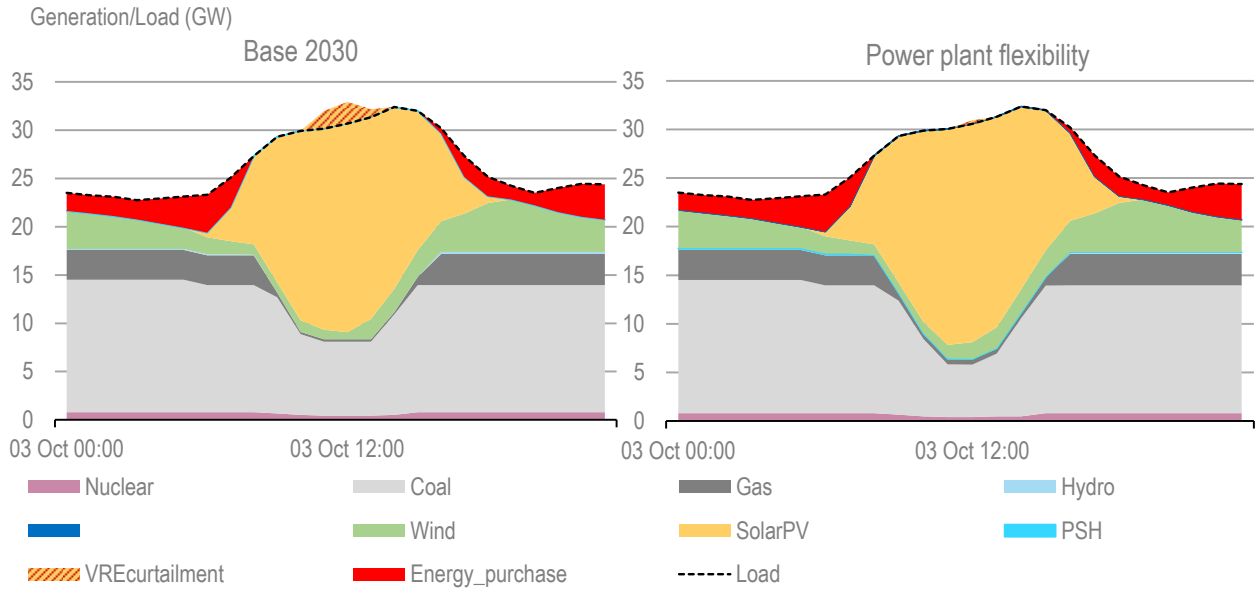


Kadana HPS pumped mode currently does not operate and relatively low efficiency (60%) will limit its application. Sensitivity scenarios including pump mode for Kadana show that its potential for cost effective usage increases into the future (small cost saving for 2030 around 0.1%)

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Power plant flexibility helps the system accommodate high VRE periods

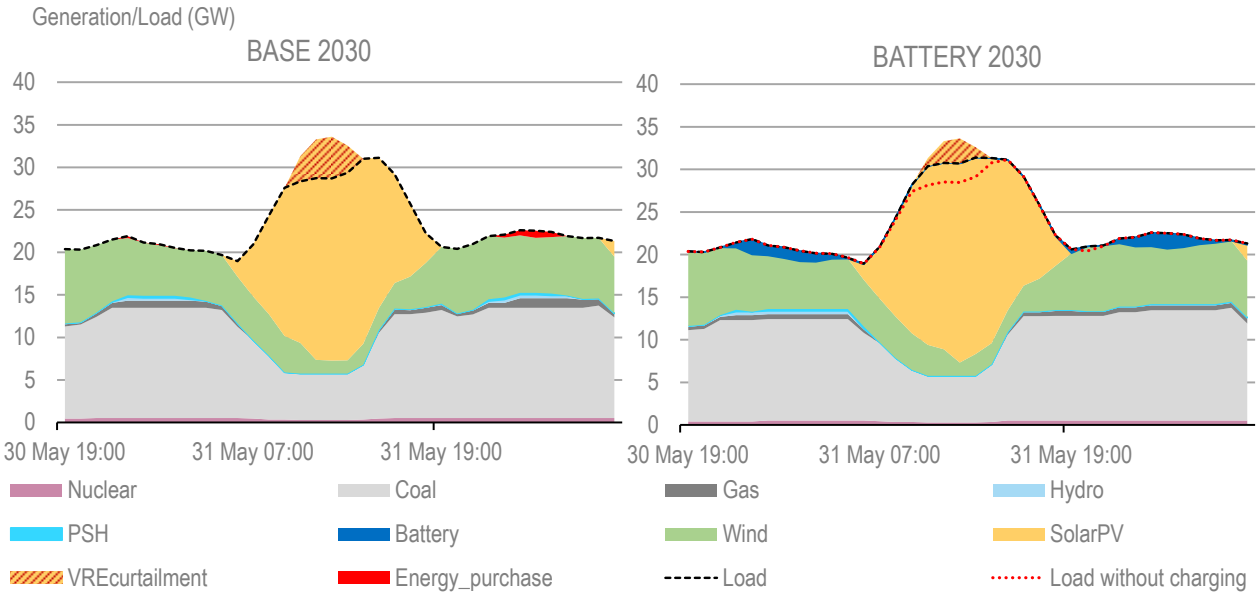
Daily dispatch curve with and without increased power plant flexibility



Increased power plant flexibility in 2030 reduces curtailment (6.3 to 5.5%) by allowing power plants to better accommodate solar generation and variable costs (2.2% reduction) mainly due to reduced startups.

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Battery storage absorbs VRE generation and helps meet peak demand

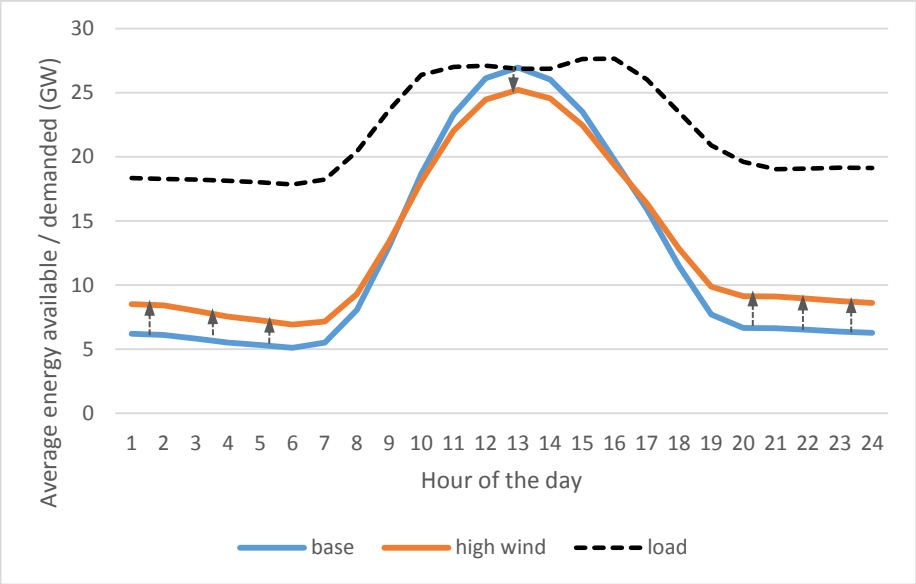


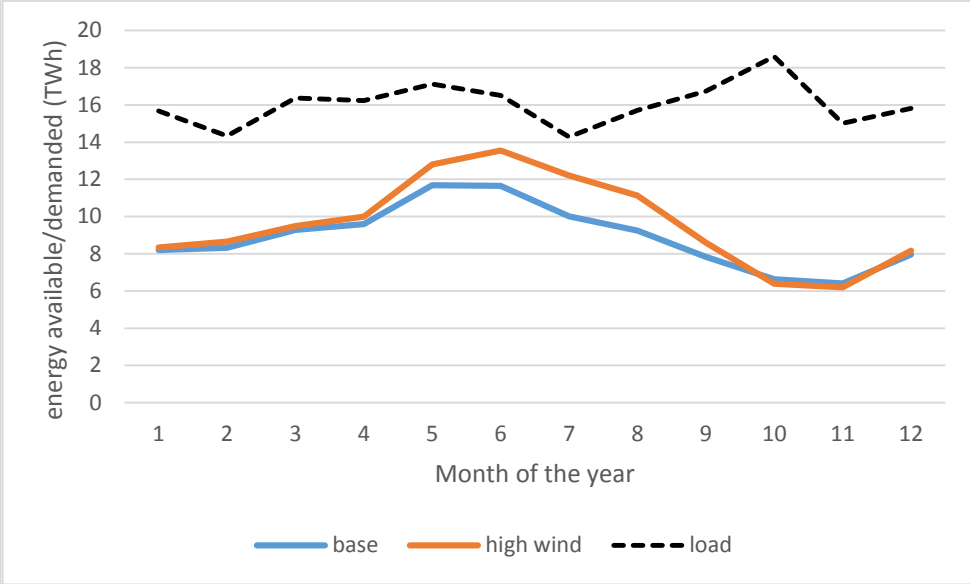
Battery storage allows high solar output during the day to be stored for later use to meet evening demand. This results in a reduction in variable costs including 1.8% reduction in variable costs (startup, fuel and ramp costs) as well as over 30% reduction in market purchases

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Higher wind scenario creates a smoother daily renewables distribution

Total wind + solar average daily generation pattern (left) and total monthly availability (right).





Increasing the wind share (from 45% to 57% of solar+wind generation) creates on average a more even distribution of renewables generation across the day, reducing curtailment (6.3% to 5%) and market purchases (17.5% reduction). However, increased wind does not improve the seasonal mismatch of renewables with demand, where both wind and solar output fall off in September to October as demand steps up.

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Conclusions & next steps

- Strong renewables deployment in Gujarat will require increasing flexibility to 2030
- Demand response and grid expansion have a key role
- Additional flexibility can be provided from energy storage, power plant flexibility and diversified renewables generation

Opportunities for model enhancement

- Further develop the export-import scenario with GUVNL and SLDC
- Additional DISCOM level load shape data for further demand response measures
- Consider additional scenarios based on workshop presentations and feedback from attendees

Next steps

- Bi-lateral calls on model improvement opportunities
- Workshop report drafting including the development of Gujarat RE Integration Roadmap 2030
- Workshop Report review in November 2020
- India Power System Transformation Report in 2021

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Appendices

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Key questions and scenario overview

Key questions: to evaluate the contribution of diverse flexibility options for the future Gujarat power system with an increasing share of variable renewables

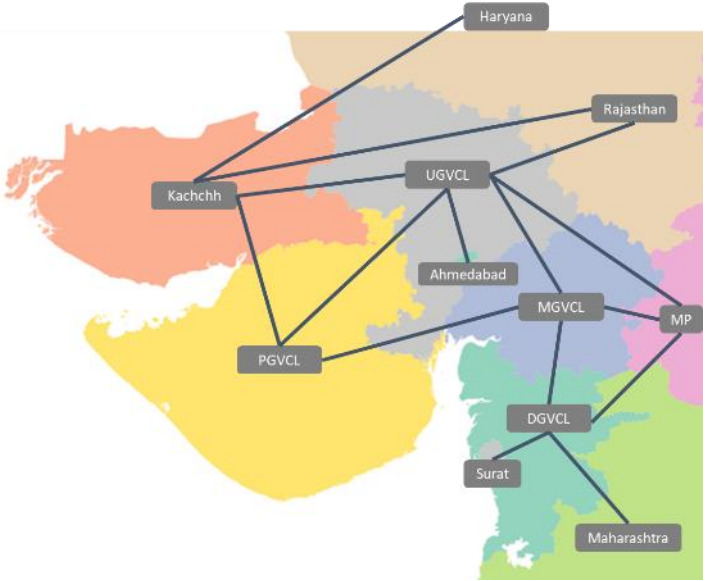
- What will be the impact of growing renewables in Gujarat over the next 2-10 years and what integration challenges will Gujarat experience?
- What are the roles of different flexibility options in addressing integration challenges in Gujarat: grids, electricity trade, power plant flexibility, pumped storage hydropower, batteries, demand response

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Structure of the model

- Intrastate nodes - one each for PGVCL, Kachchh, UGVCL, MGVCL, DGVCL, Surat and Ahmedabad
- Inter-state nodes - Rajasthan, MP, Haryana, Maharashtra
- Demand is modeled on the intrastate nodes, along with the generation capacity in that region
- Inter-state nodes only have generation capacity contracted by Gujarat and are the source of short term electricity market purchases (and sales)
- Commercial software tool (PLEXOS)

Installed capacity (GW)	2018-19	2021-22	2029-30
Coal	14.0	16.9	13.7
Gas	4.1	4.1	4.1
Hydro	0.6	0.6	0.6
Nuclear	0.6	0.8	0.8
SolarPV	1.8	7.8	47.3
Wind	5.7	7.7	17.9



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Data sources and assumptions (1)

Demand

- 15-minute (CER, Gujarat SLDC) / hourly (IEA, public data) demand profile
- Detailed demand projections by CER IIT Kanpur accounting for Covid-19 impact
- Discom-wise disaggregation based on annual totals
- Demand response: agricultural demand profile based on pumping schedules

Conventional capacity

- Existing contracted capacity (within state and outside) equal to 19000 MW considered as per the GERC tariff orders
- Capacity additions 2800 MW of new coal capacity and 238 MW of new nuclear capacity *contracted* between 2018 and 2021. No further additions of gas or coal capacity considered
- Retirement of about 2300 MW of lignite and coal capacity considered as per CEA plans
- Costs Fixed (including investment cost, O&M and depreciation) and variable cost (fuel cost) of operation taken as per that approved by GERC.
- Operational parameters for the thermal power plants are based on generic data from CEA.
- Gas availability based on historical for 2018-19 and 2021-22 and allotted for 2029-30
- Key flexibility assumptions In the base case 1) ramp up/ ramp down rates considered at 1-1.5%/min for coal power plants and 4%/min for gas 2) Min Stable Level considered at 55% for NTPC & new power plants, 75% for GSECL coal power plants. 40% for gas power plant. Flexible case: coal ramp of 3% and consider 40% MSL for central plants and 55% for state plants

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Data sources and assumptions (2)

Renewable capacity

- VRE locations for 2018-19 based on existing plants. Geospatial site selection for future years (e.g. accounting for land use, resource quality, distance from transmission).
- Generation profiles for based on ERA5 satellite RE analysis weather data (2018-19).
- Capacity for 2021-22 considered as per GUVNL input (15.5 GW wind+solar)
- Capacity for 2030 based on GUVNL input (65 GW wind+solar; Kutchh hybrid park is around 70% solar consistent with overall mix)

Storage

- Pumped storage hydropower based on re-establishment of pump mode at Kadana HPS)
- Battery storage 2GW

Transmission

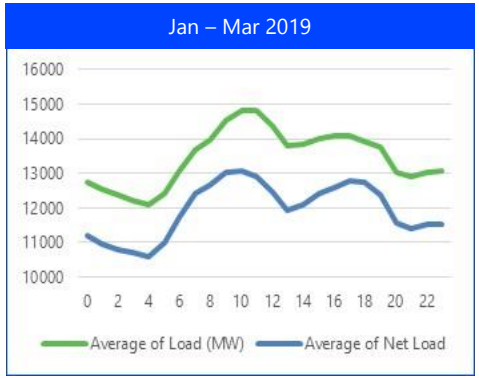
- All inter-state and intrastate, 400 kV and above transmission lines mapped and included in the model
- Limited expansion to address main congested corridors in 2030

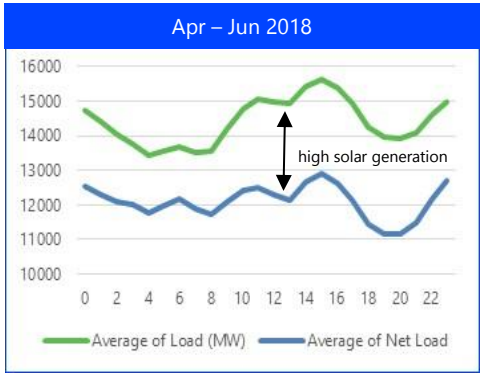
Trade

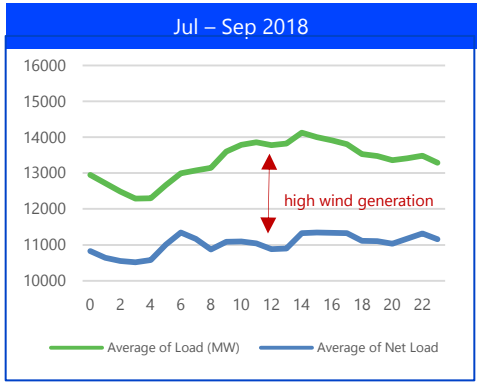
- Import availability from outer-state nodes within transmission constraint; prices set at $75 / MWh

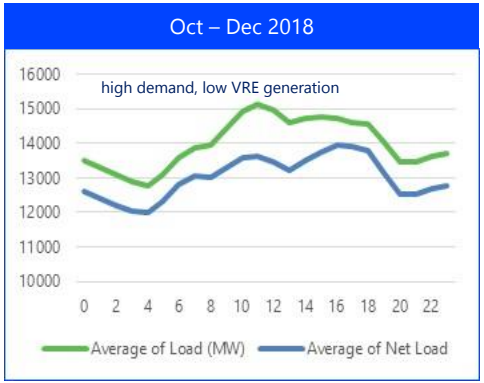
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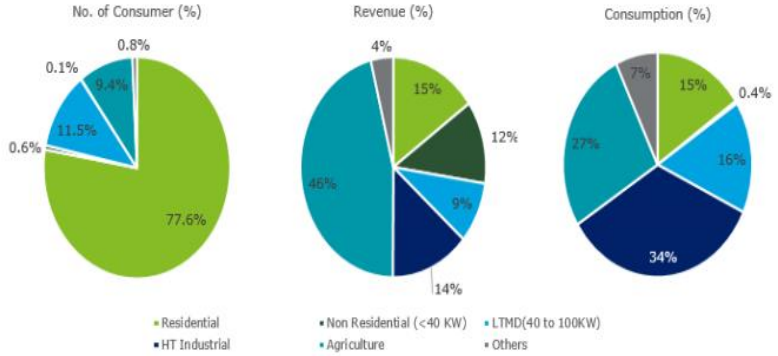
Overview of the Gujarat system











Source: GUVNL

- Max hourly demand in 2018-19 was ~18000 MW in Sep 2018 and the min was ~7600 MW in Nov 2018
- Average rate of growth in demand has been around 5-7% in the last 5 years
- Seasonally, demand is highest in the summer (Apr-Jun) and after the monsoons (Oct)
- In 2018-19 net load was highest in October, lowest in July. This would change with higher solar penetration
- Gujarat has a wide industrial base with industry accounting for 60% of consumption and revenue

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PRELIMINARY RESULTS

A bigger role for electricity trade

- Role of both imports and exports is expected to increase in 2030
- Uncertainty about trading potential during high and low VRE periods

	Max purchase (GW)	Total purchase (TWh)
2019	5.2	2.1
2022	4.4	1.1
2030	9.0	5.9

	Max curtailment without sales (GW)	Total curtailment without sales (TWh)
2019	0	0
2022	0.2	0
2030	16.0	6.7
2030 flex	15.5	3.7

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