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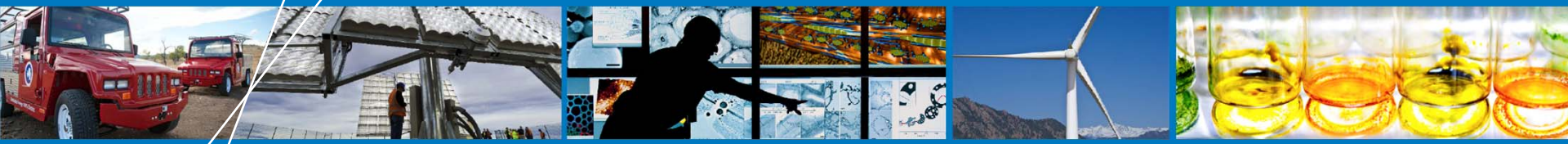
Variability of Power from Large-Scale Solar Photovoltaic Scenarios in the State of Gujarat



Renewable Energy World India

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Thank-You to my Coauthors

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Further analysis, methods, and results published in a NREL report at: : http://www.nrel.gov/docs/fy14osti/60991.pdf

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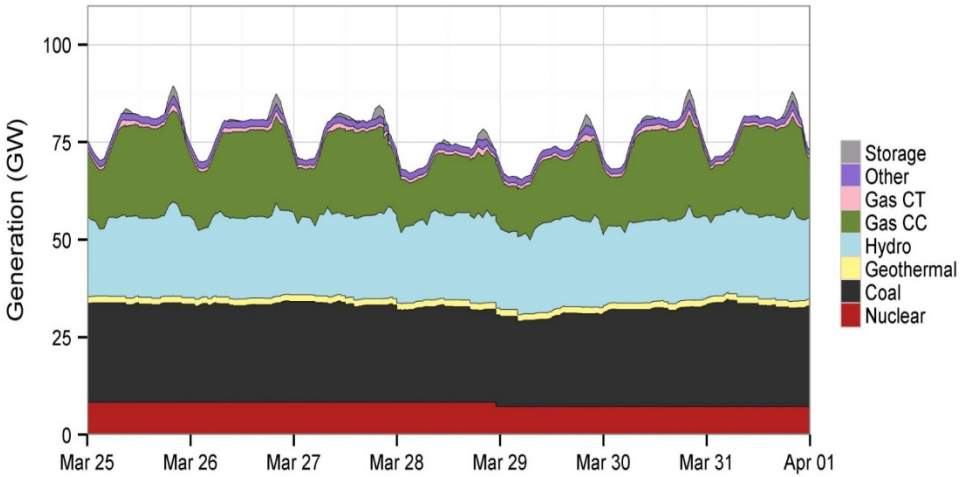
Background

- **Gujarat—India's state with highest solar capacity**
  - Over 855 MW_{DC} among plants >1 MW_{DC}
  - Solar + wind (3,240 MW) = 18% of generating capacity
  - To be doubled by 2017 (CEA)
- **What are the consequences to system operations?**
  - Additional flexible resources required to balance net-load variability
  - Adequate reserves needed to respond to renewable and load forecast errors

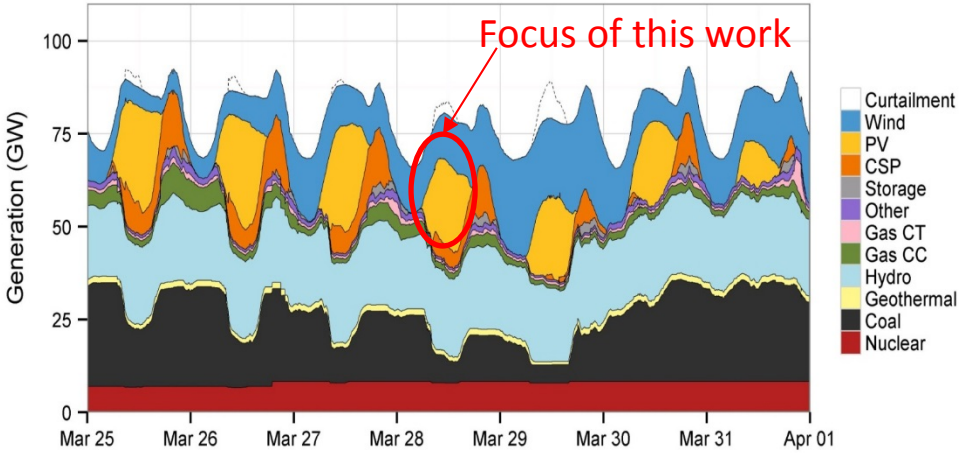
Context: Grid Operational Modeling

- Production modeling assesses challenges
- Realistic solar and wind generation profiles are critical
- This work focuses on the solar characteristics
- Example: Generation dispatch for a challenging spring week from the NREL Western Wind and Solar Integration Study

No Renewables



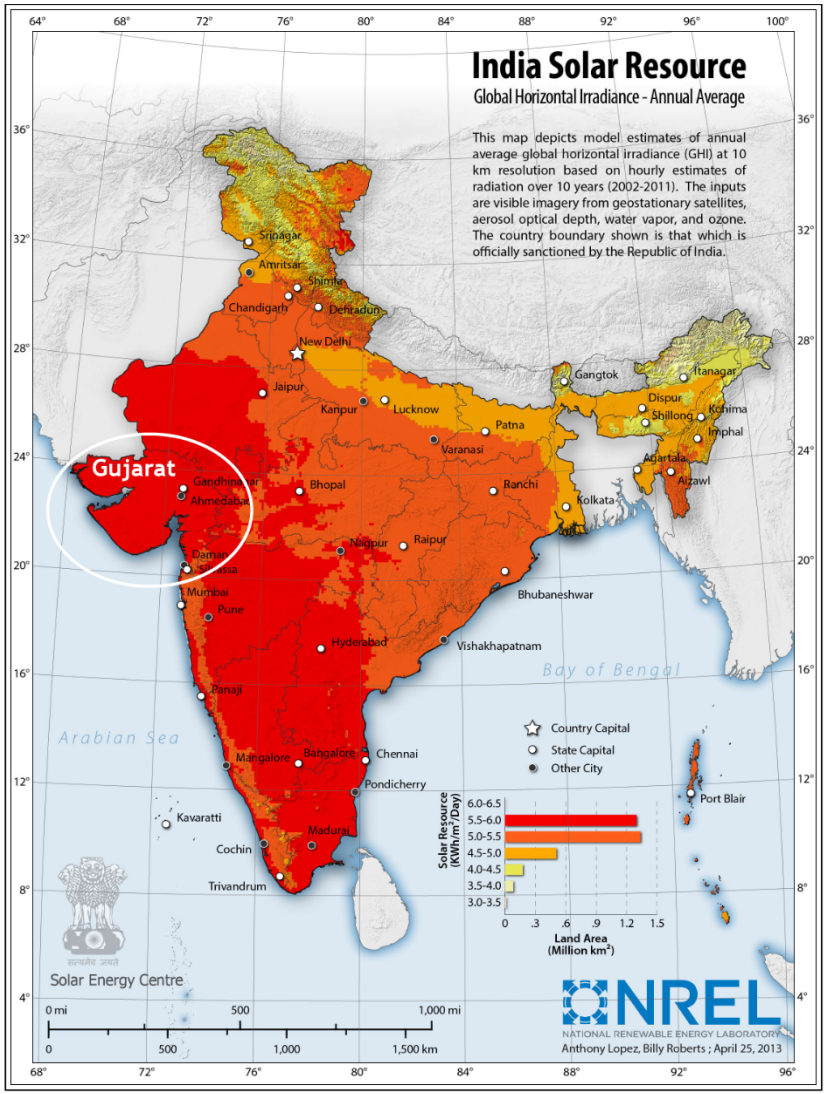
16.5% wind and 16.5% solar energy penetration



http://www.nrel.gov/electricity/transmission/western_wind.html

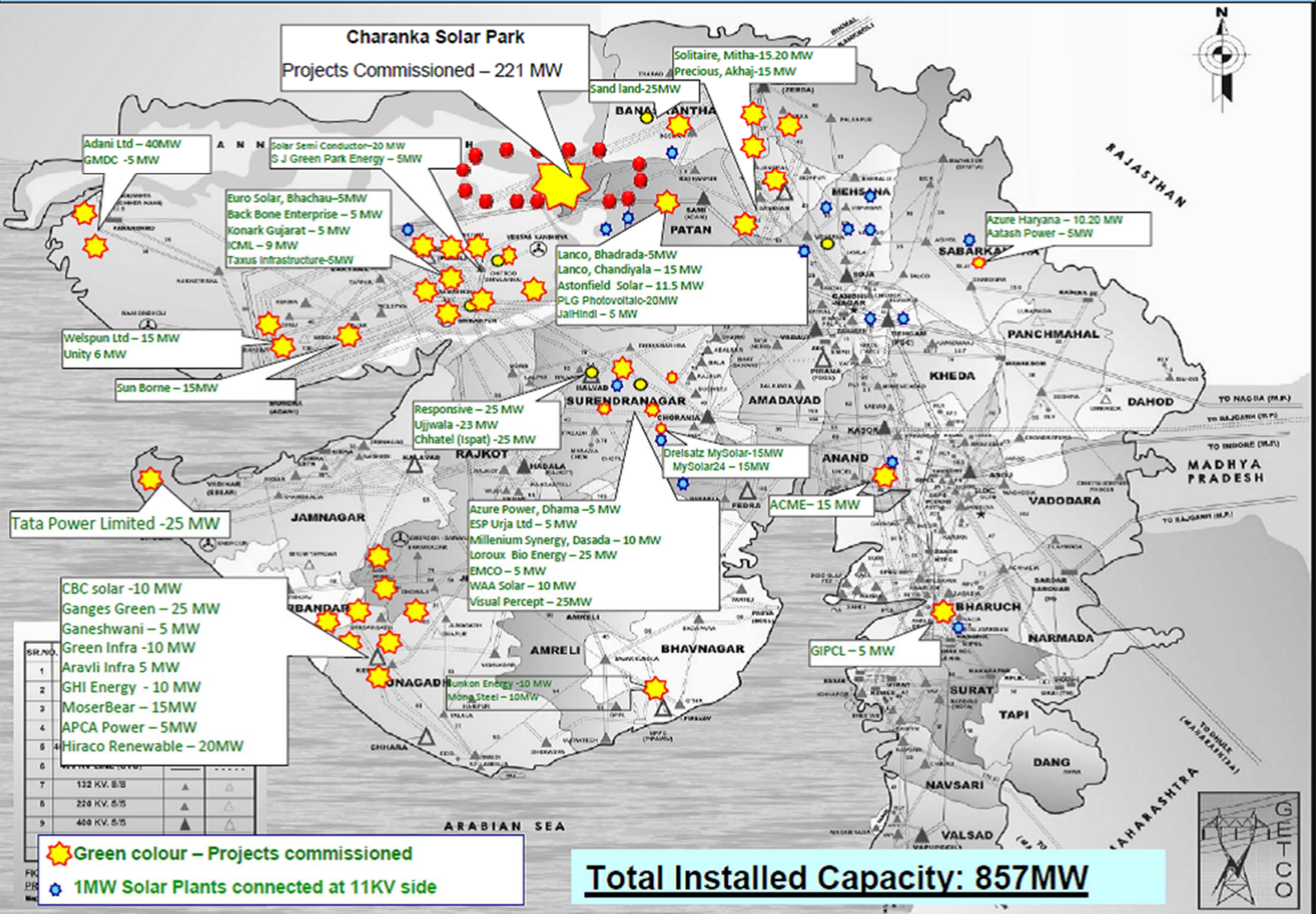
A new solar radiation data set is available for India*

- Meteostat satellite images capture localized atmospheric effects
- Hourly insolation for historic weather years 2001-2011
- An established method used to downscale to 1-minute resolution using cloud classifications and spatial statistics

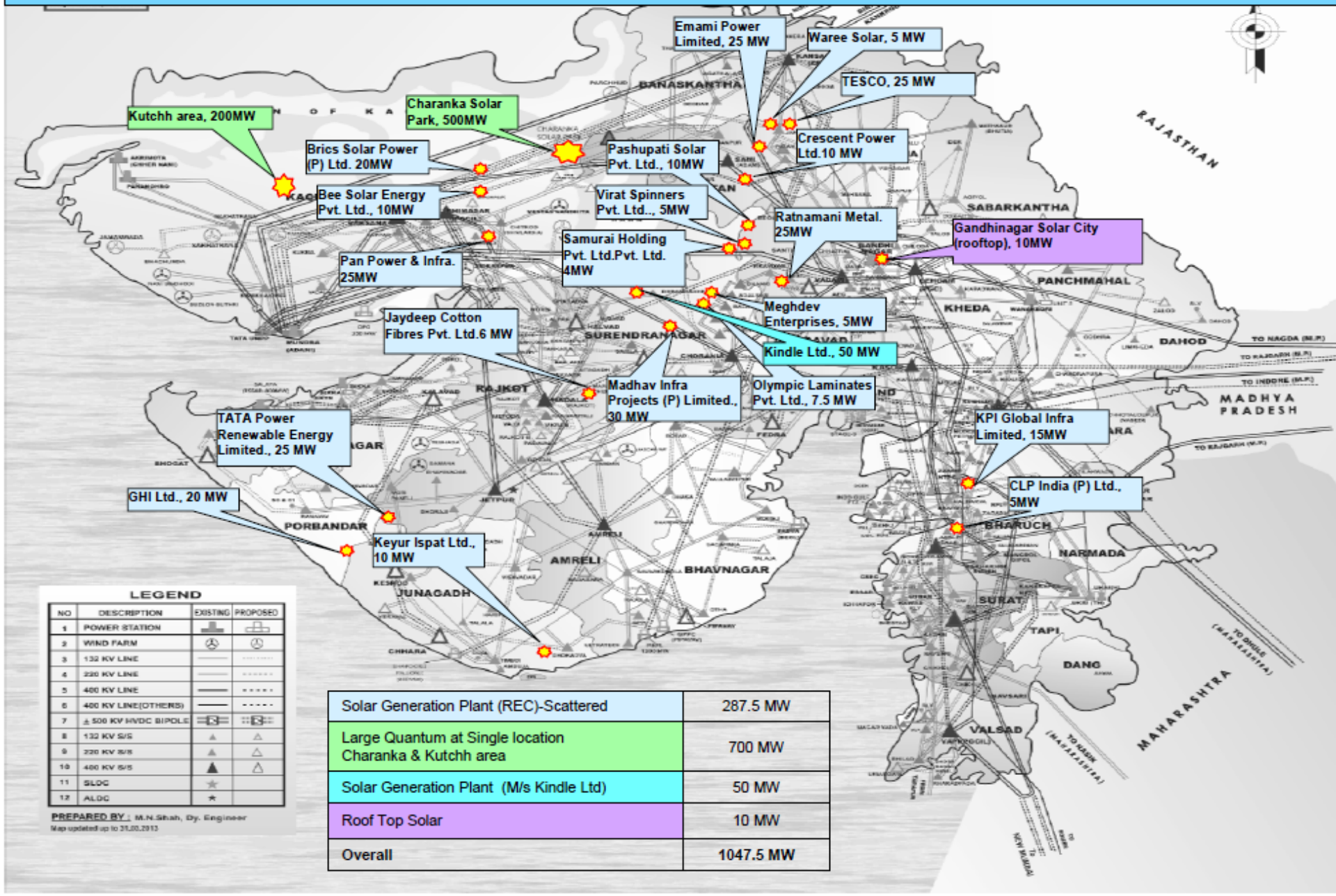


* http://www.nrel.gov/international/ra_india.html

Existing Solar Plants in Gujarat

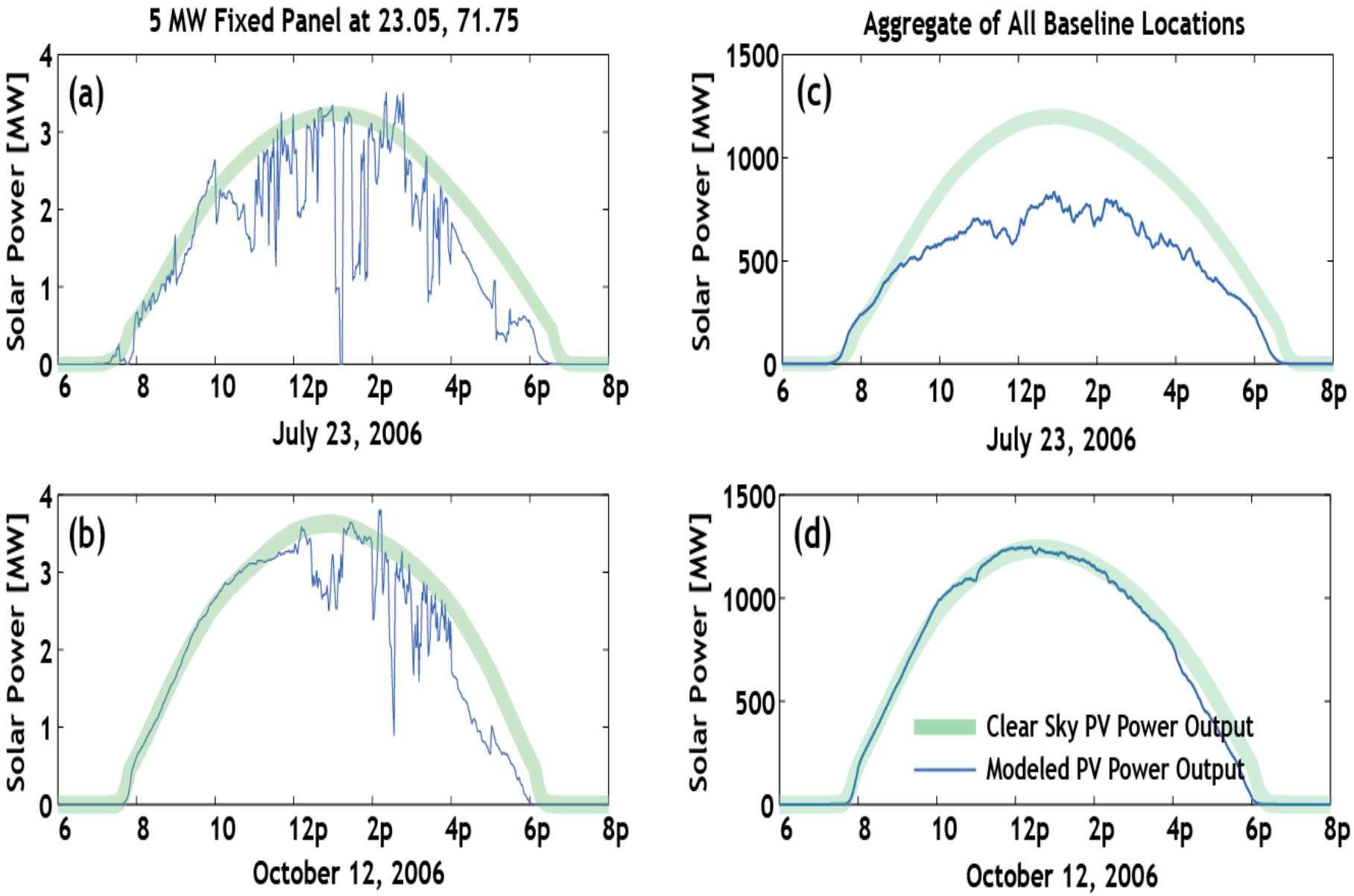


Solar Plants expected in Gujarat



Solar Generation Plant (REC)-Scattered	287.5 MW
Large Quantum at Single location Charanka & Kutchh area	700 MW
Solar Generation Plant (M/s Kindle Ltd)	50 MW
Roof Top Solar	10 MW
Overall	1047.5 MW

PV Power Conversion

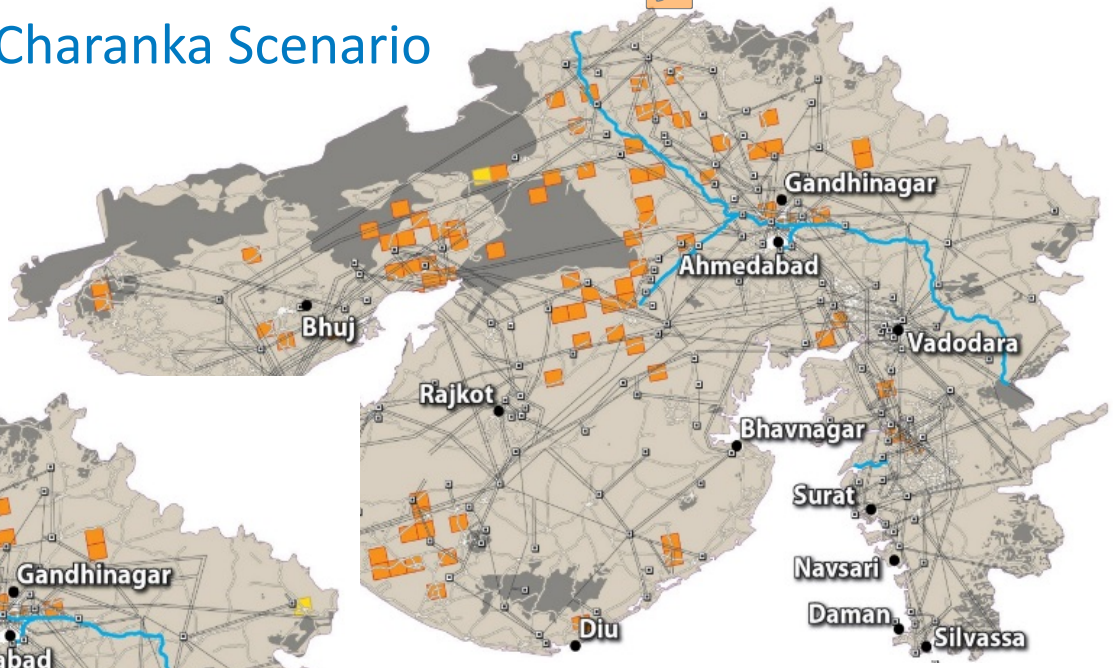


Five Postulated PV Expansion Scenarios

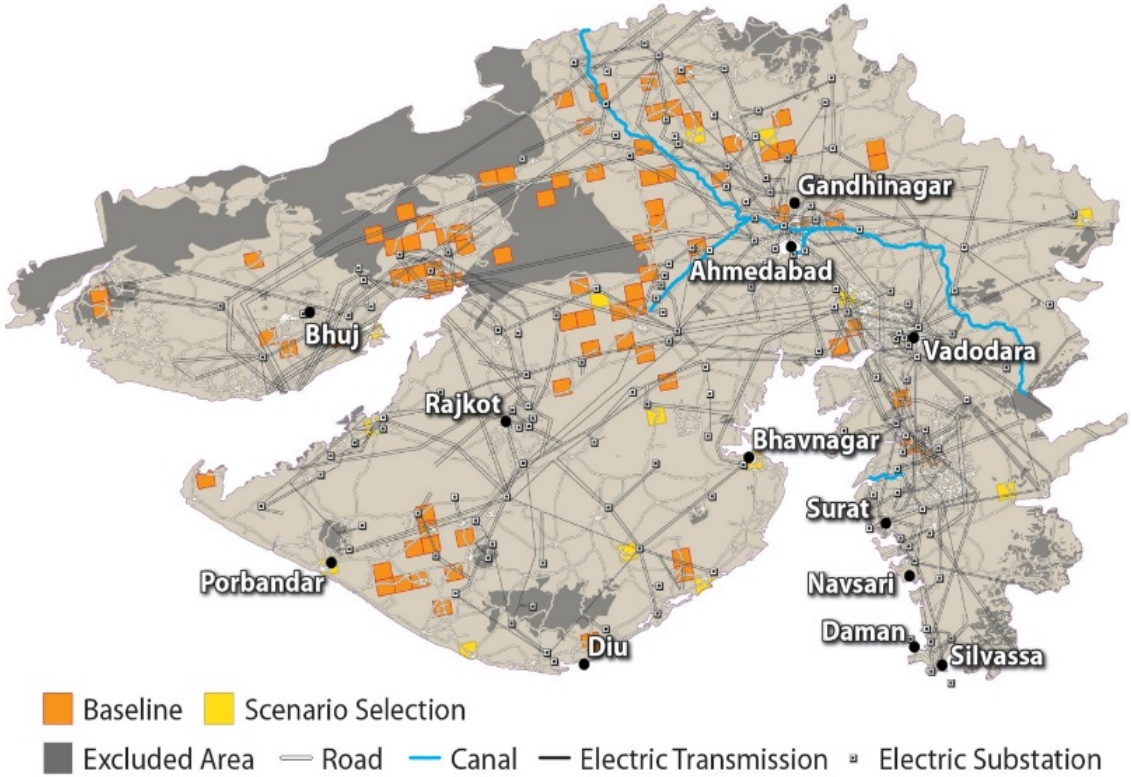
Examine geographic diversity, and effects on variability of central station vs. distributed rooftop

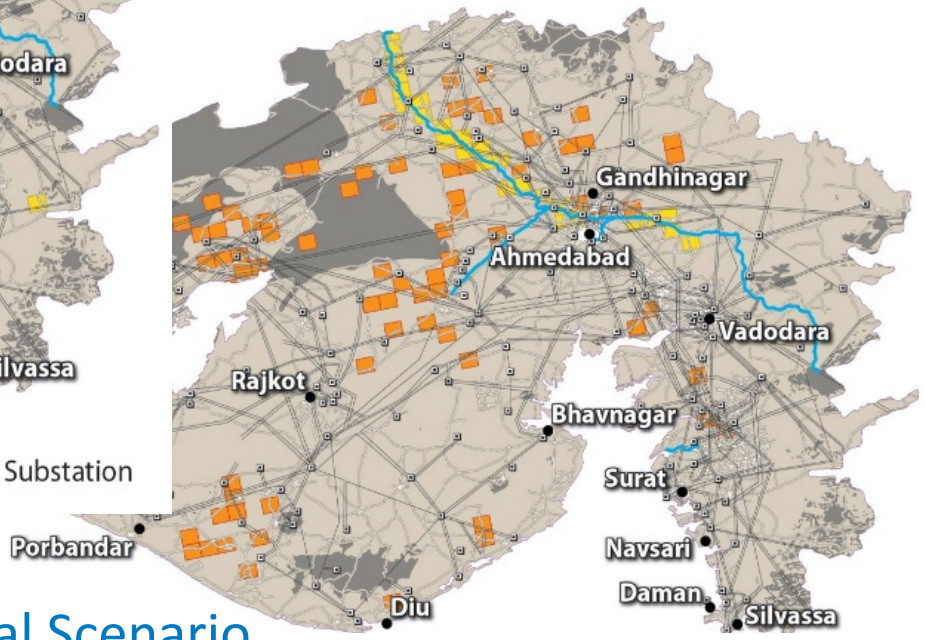
- Charanka – single location, 1 GW addition
- 7 Utility Scale plants, 1 GW total added, throughout Gujarat
- 6 Utility Scale plants, 1 GW total added in the Kuttch region
- 17 cities with rooftop distributed, 1 GW total
- Narmada Canal, 500 MW total

Charanka Scenario



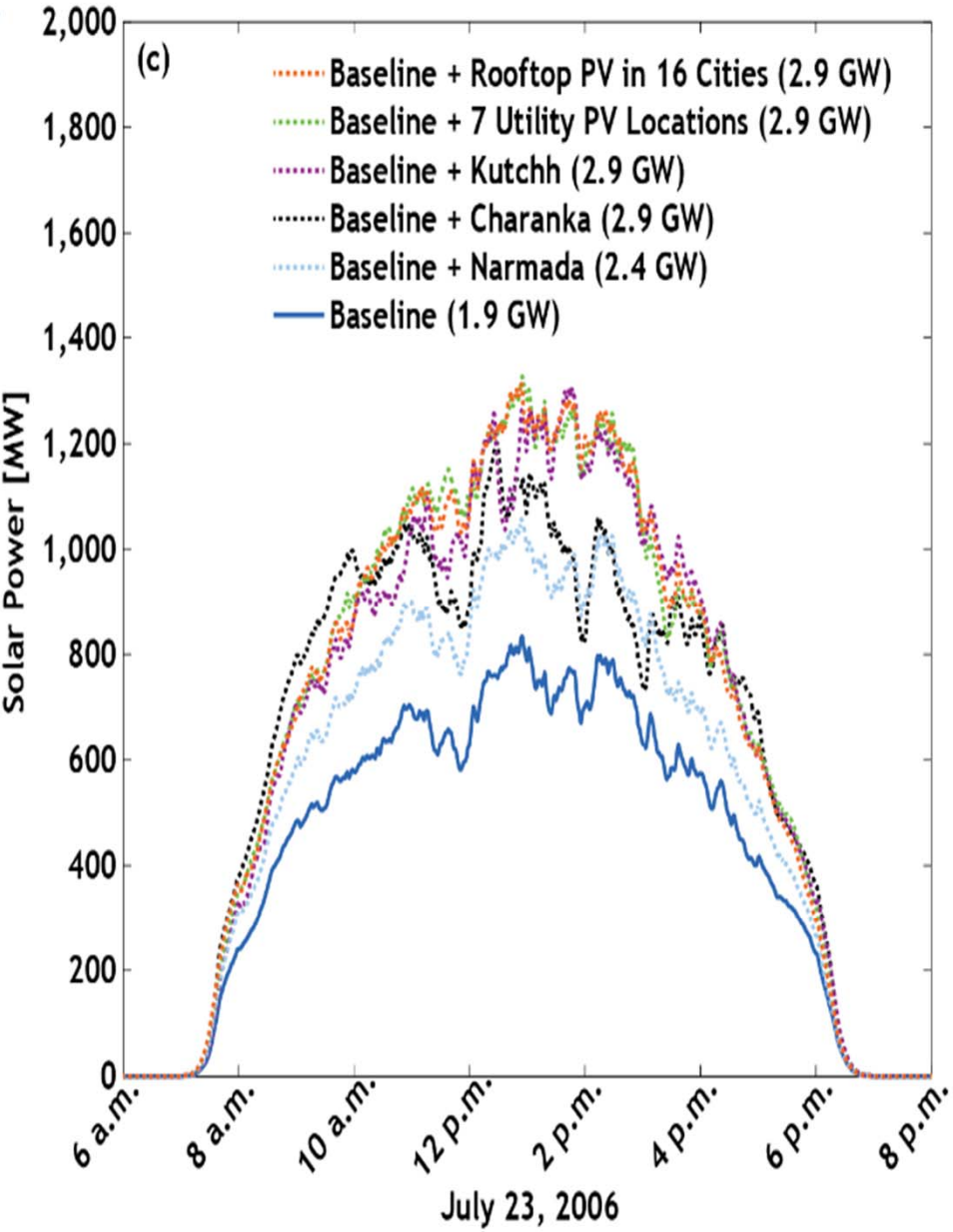
16 Cities, Rooftop Scenario

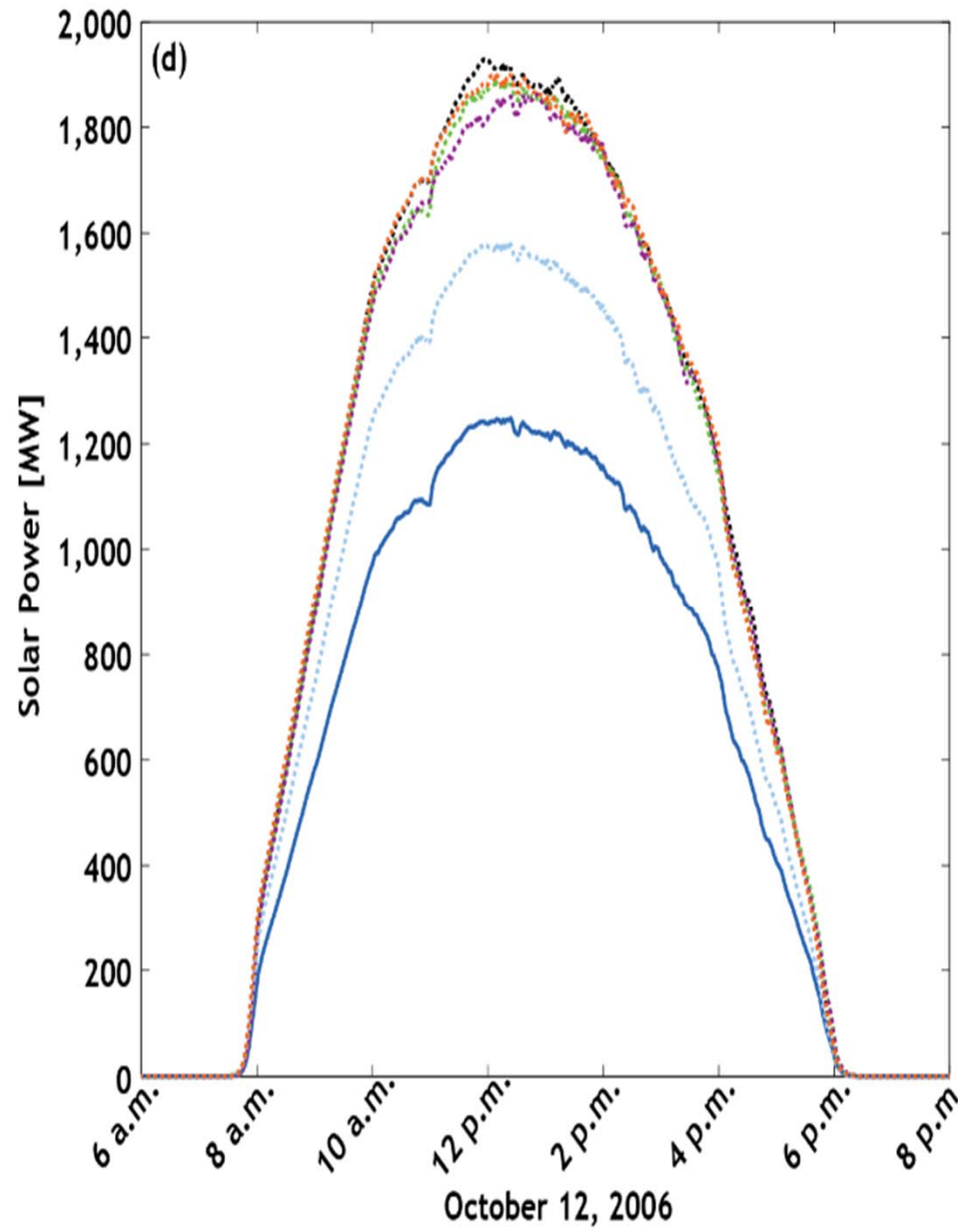




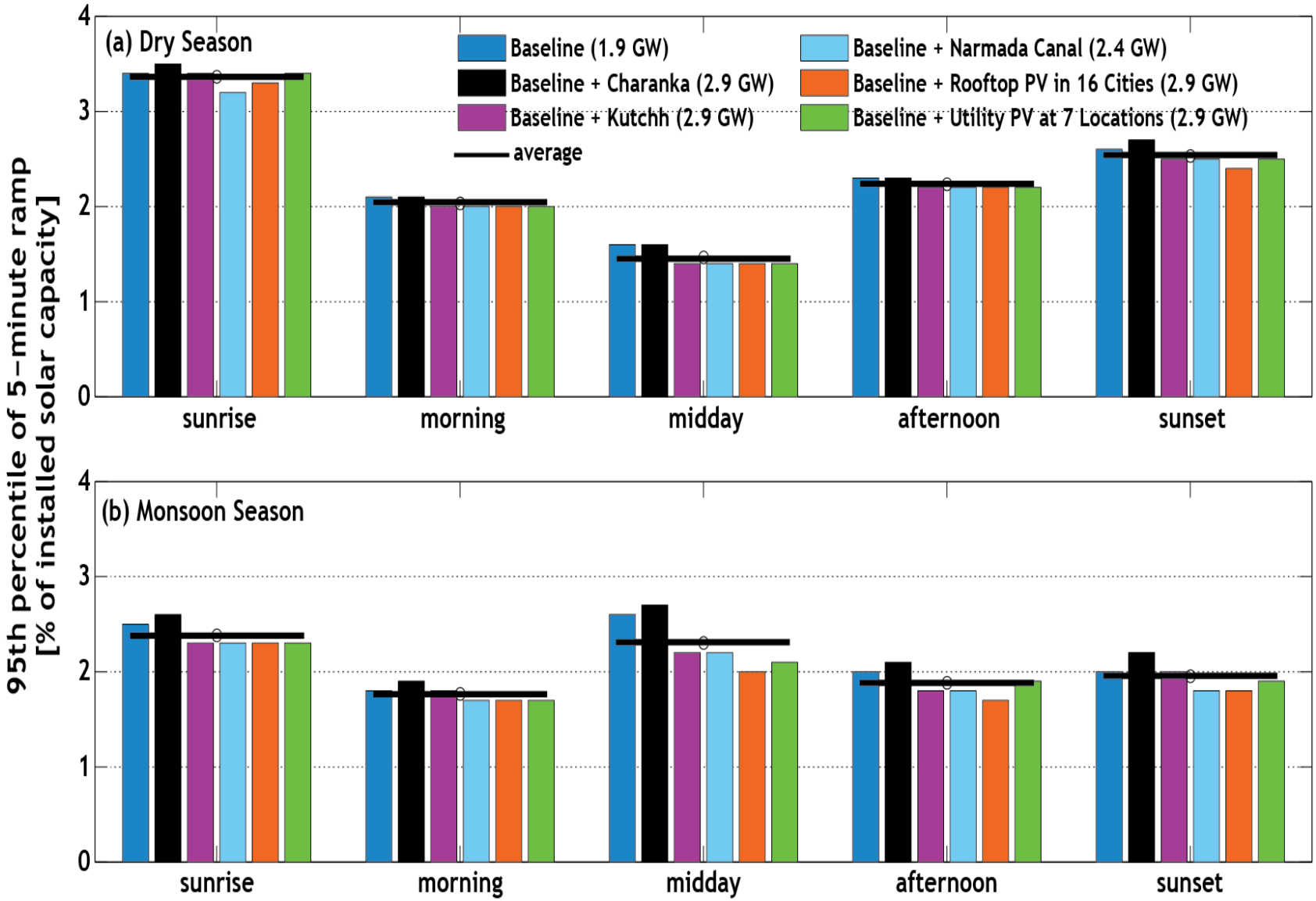
Narmada Canal Scenario

Aggregate power output of baseline plus expansion scenarios

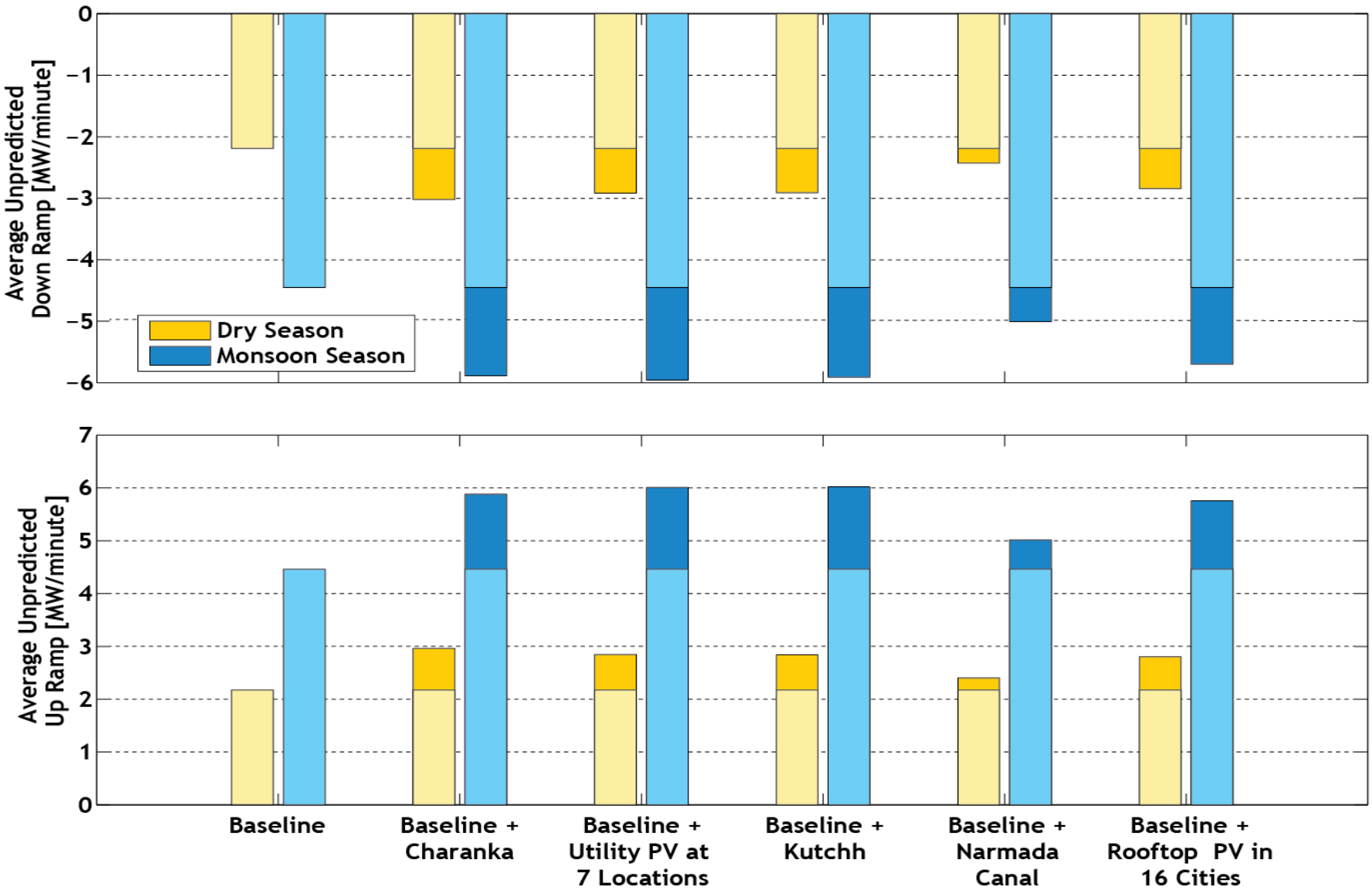




95th-percentile Five-Minute Power Ramps



Average unpredicted minute-to-minute change in solar production



Actions to Address the Variability of Wind and Solar Generation

Grid Reinforcement

- Evacuation, plus load and RE geographic diversity
- Access broader range of flexible resources
- Green Corridors Study
  - Electricity between States
  - Intra-state integration
- Renewable variability characterizations inform load flow and ramping mitigation analysis

Systems Operations

- Advanced forecasting
- Improved scheduling
- Ancillary services
- 1st Renewable Energy Management Centre in Gujarat
  - Better data flow
  - System awareness and visibility
  - Automated coordination with Load Dispatch Centers
- Seasonal and time of day variability can help define and schedule reserves

Commercial Impediments and Potential Solutions

Impediments

- Financial disincentives to back down conventional generation
- Limited state-state PPA opportunities
- Limited economic tools for real-time balancing
- Enforcement of state renewable energy targets

Potential Solutions

- Shorter interval rescheduling and intra-day market participation
- Compensation for part load, flexible operations, and ancillary services
- Interstate sharing of reserves

Results and Conclusions

- Potential future variability of solar is characterized
- Centralized Charanka scenario has 7-30% greater midday ramps than distributed rooftop PV in 16 cities scenario
- Variability characteristics are not as sensitive to the expansion scenario as expected
- Geographic diversity benefits should be larger if state-to-state grid cooperation is increased

Results and Conclusions (continued)

- Diurnal variability is based on a known solar path
  - Grid flexibility needs are known in advance
  - Facilitates grid operational day-ahead scheduling
- Variability shows strong seasonal characteristics
  - Known sunrise and sunset ramps during dry season
  - Unpredictable midday variability during monsoon season
- Individual plant variability is large due to cloud passage, but the aggregated power across all plants shows less volatility
  - Monsoonal derating of the solar capacity may help system operations
  - Applicable to other regions of the world
- Unpredictable variability statistics can be bounded, defining partially-loaded quick-ramp or quick start/stop reserve needs

Next Steps and Use of Results

Corresponding Wind Variability Analysis is needed

- Gujarat's wind capacity > 3 GW end of 2013
- +/- 500 MW 250 days, +/- 1,000 MW 58 days
- Meso-scale wind modeling for Gujarat is nearly complete
- System-level net-load (load minus wind minus solar) variability evaluations planned later this year

Potential Grid Integration Studies for Wind and Solar include:

- Intra- and interregional transmission load flow and expansion planning studies
- Resource adequacy-based reliability assessments, including wind and solar capacity credit determinations
- Market operations, unit commitment, and economic dispatch operational modeling of the integrated grid
  - Evaluate physical and institutional factors

Effective modernization measures based on international experience

- Improve forecasting in appropriate time frames
- Shorten unit commitment and dispatch intervals
- Alternative market structures and balancing mechanisms (ancillary services and reserves)
- Smart-grid modernization to improve situational awareness, data flow, and improved access to demand control measures
- Increase national-to-state and state-to-state balancing area cooperation
- Increase geographic dispersion of renewables
- Incentives for more flexible conventional generation
- Examine active power control capabilities on wind and solar plants, such as ramp rate control, inertial response, and automatic generation control.

Questions?

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