Operational Simulation Tools and Long Term Strategic Planning for High Penetrations of PV in the Southeastern United States

DOE SUNRISE Project

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UVIG Fall Workshop
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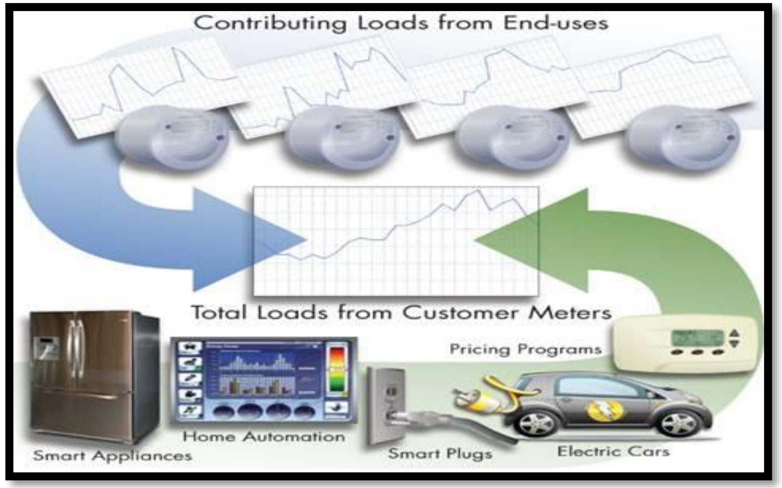
Trends Impacting Planning Processes & Tools

Changing Generation Mix

Consumer Choice/Control

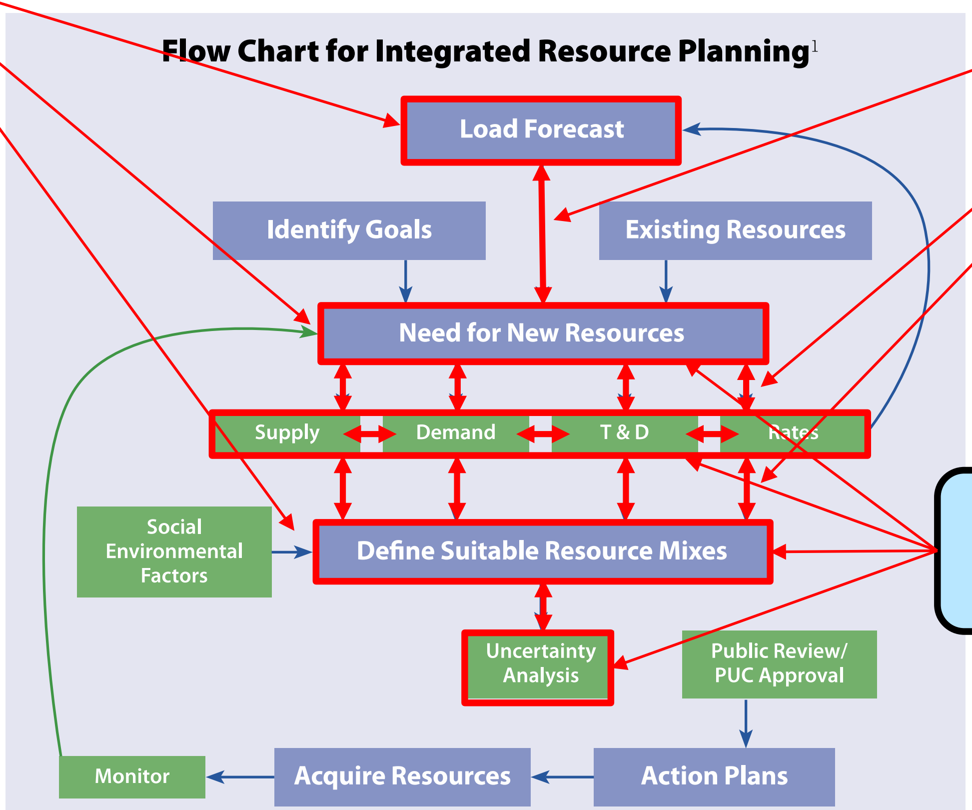


Active Distribution Systems

Traditional Planning Framework Has to Change

New load forecast, resource **models**, & analysis **methods** required to capture all values and costs

Top-down no longer works. Multi-directional **integration across** power system areas & external **systems** (e.g., gas, transportation, et. al.) required

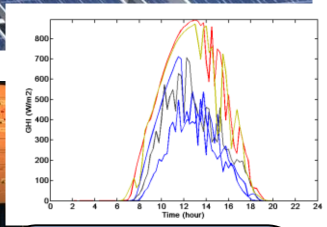


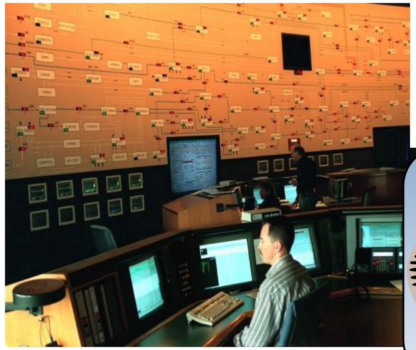
Source: Regulatory Assistance Project

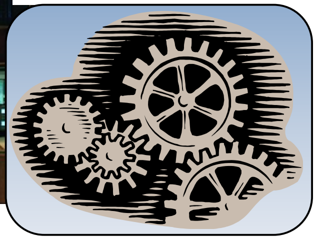
Operational Reliability must be considered across entire analysis chain

Impacts of Solar PV on Utility Strategic Plans

- Topic #1: Long Term Resource Adequacy
  - How much PV may be built?
  - How do we ensure flexibility to manage variability?
- Topic #2: Distribution System Operations
  - How will PV impact voltage levels?
  - How much can be accommodated?
- Topic #3: Transmission System Operations
  - What are the interconnection requirements needed?
  - What are complications due to distributed PV?
- Topic #4: Utility Business Models
  - What are the key drivers in a given area?
  - What business model adoptions are required?
- Topic #5: Balancing with Variability/Uncertainty
  - What are impacts on operating reserves?
  - How will system be operated in high solar future?







Targeted Studies in Each of These Areas

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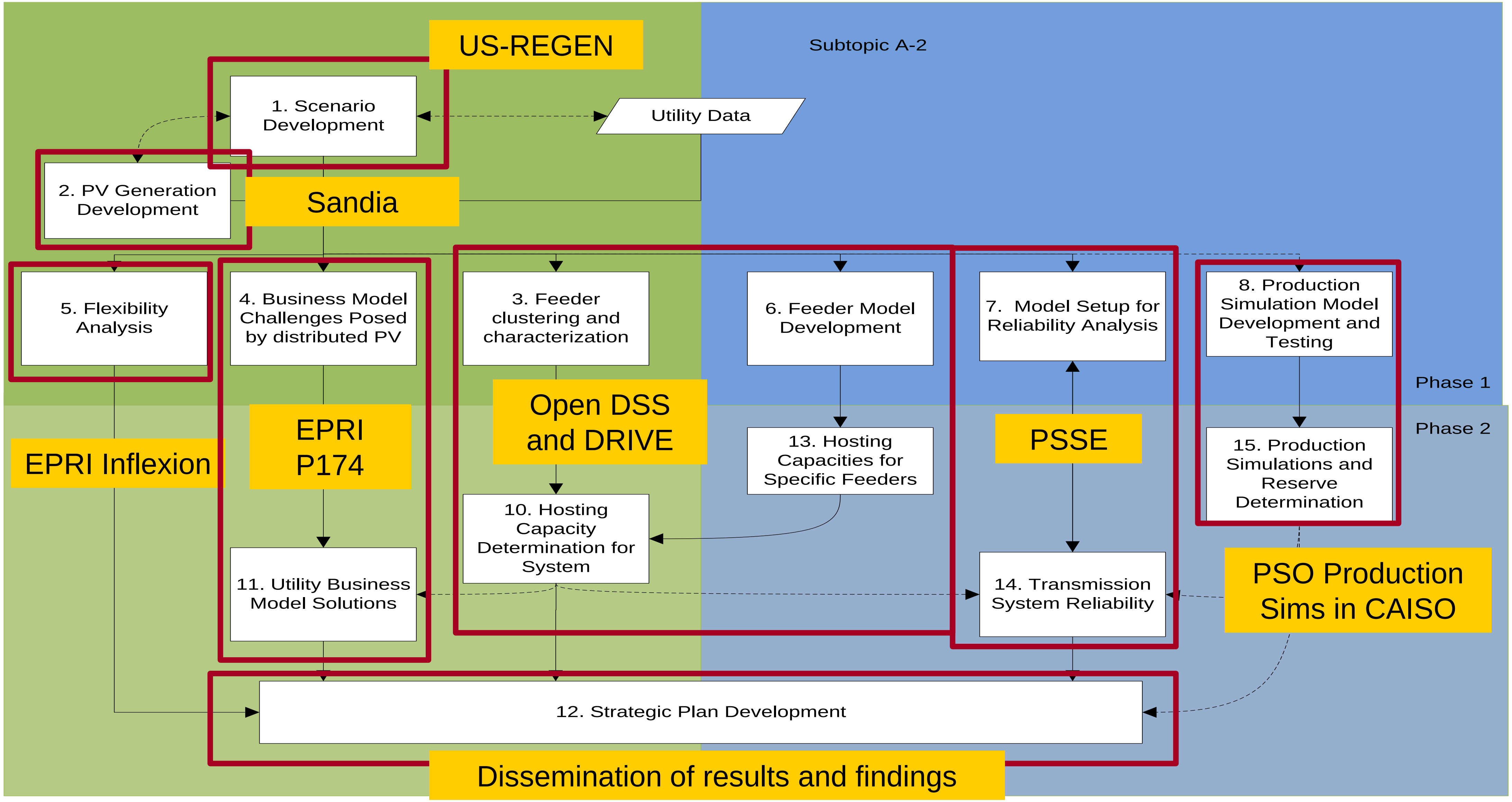
SUNRISE Project Overview

Project Tasks Flow



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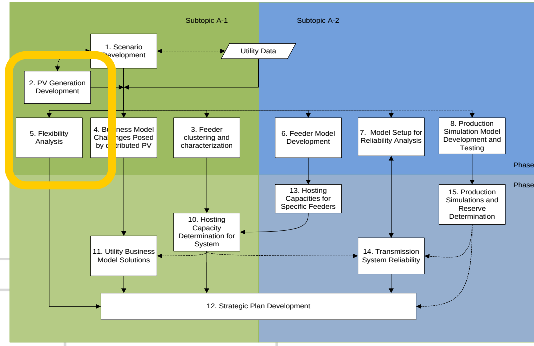
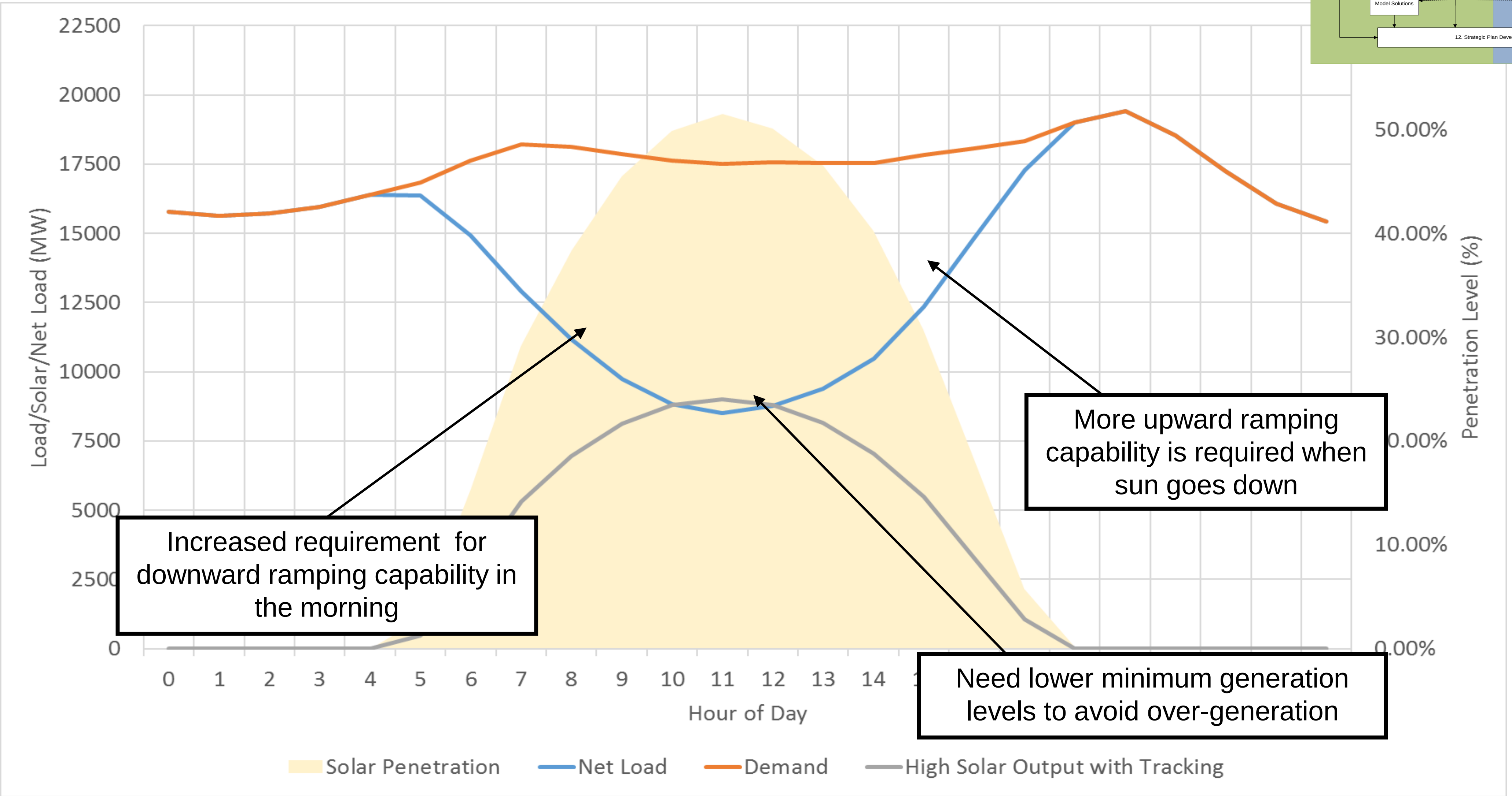
Flexibility: Simulated net load curve for 7 GW solar in Southern Company





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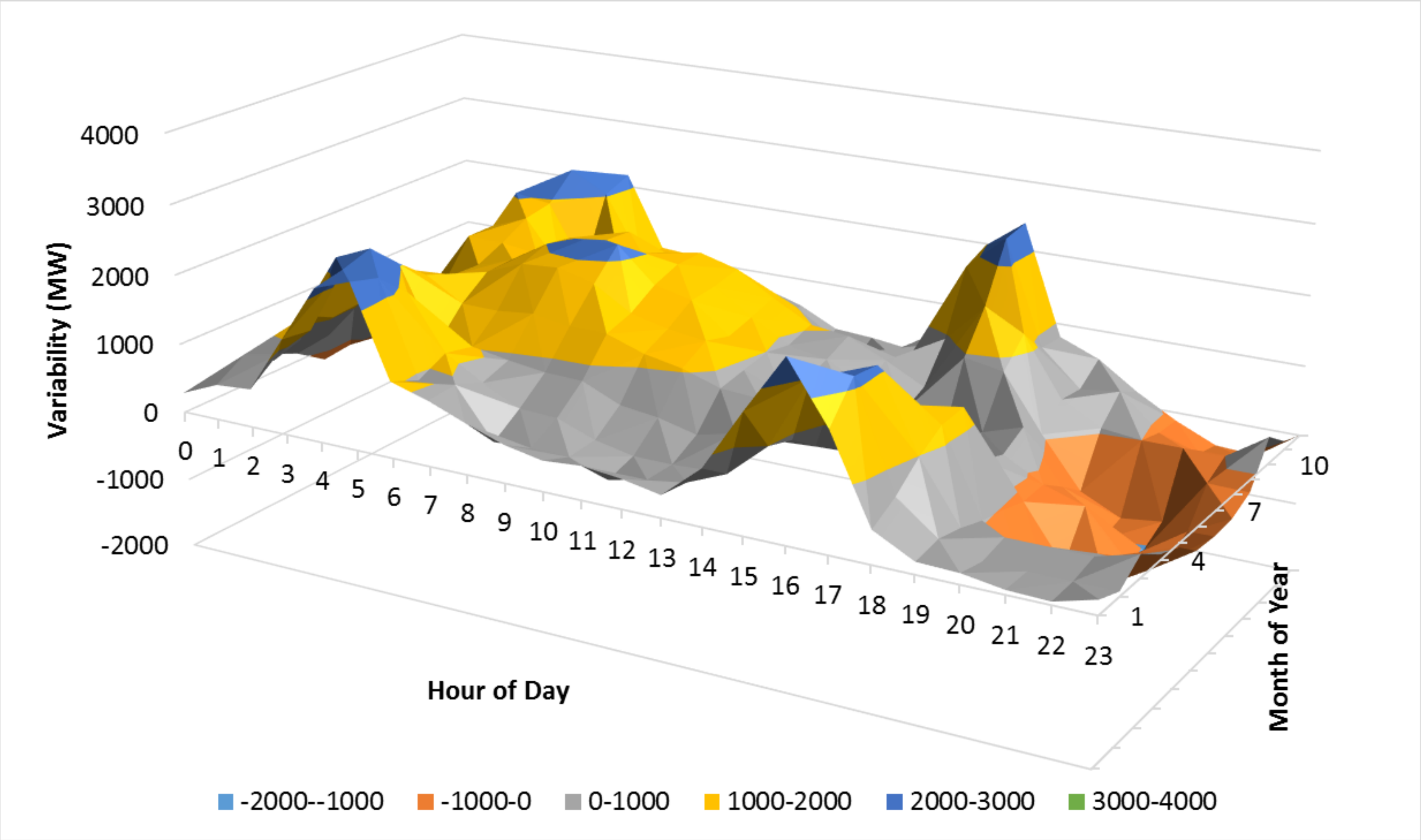
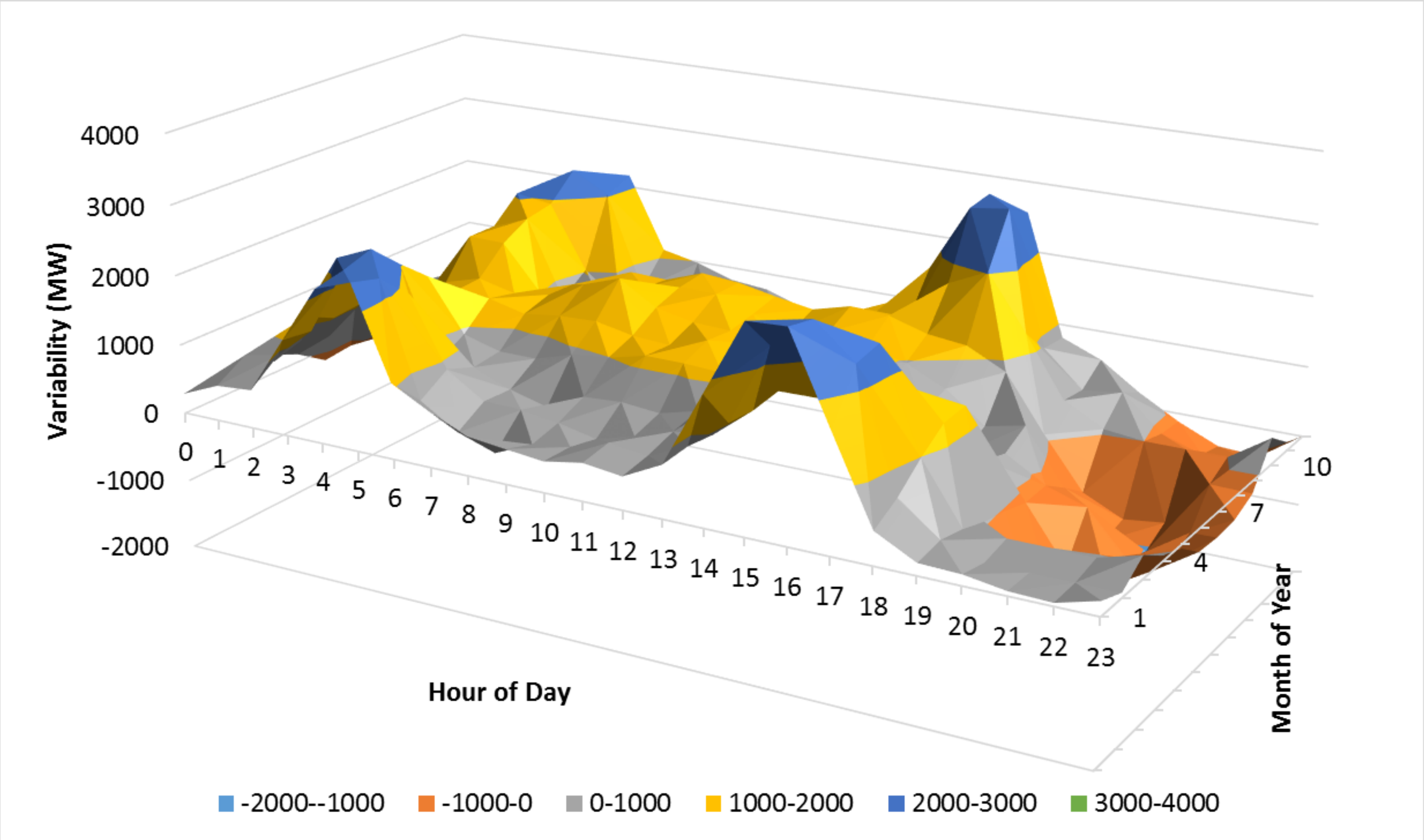
Hourly Ramping by Month – Demand Only



Large ramps in summer mornings, and winter evenings

Hourly Net Load Ramping by Month – 4 GW solar



Solar reducing summer morning ramps, increasing winter

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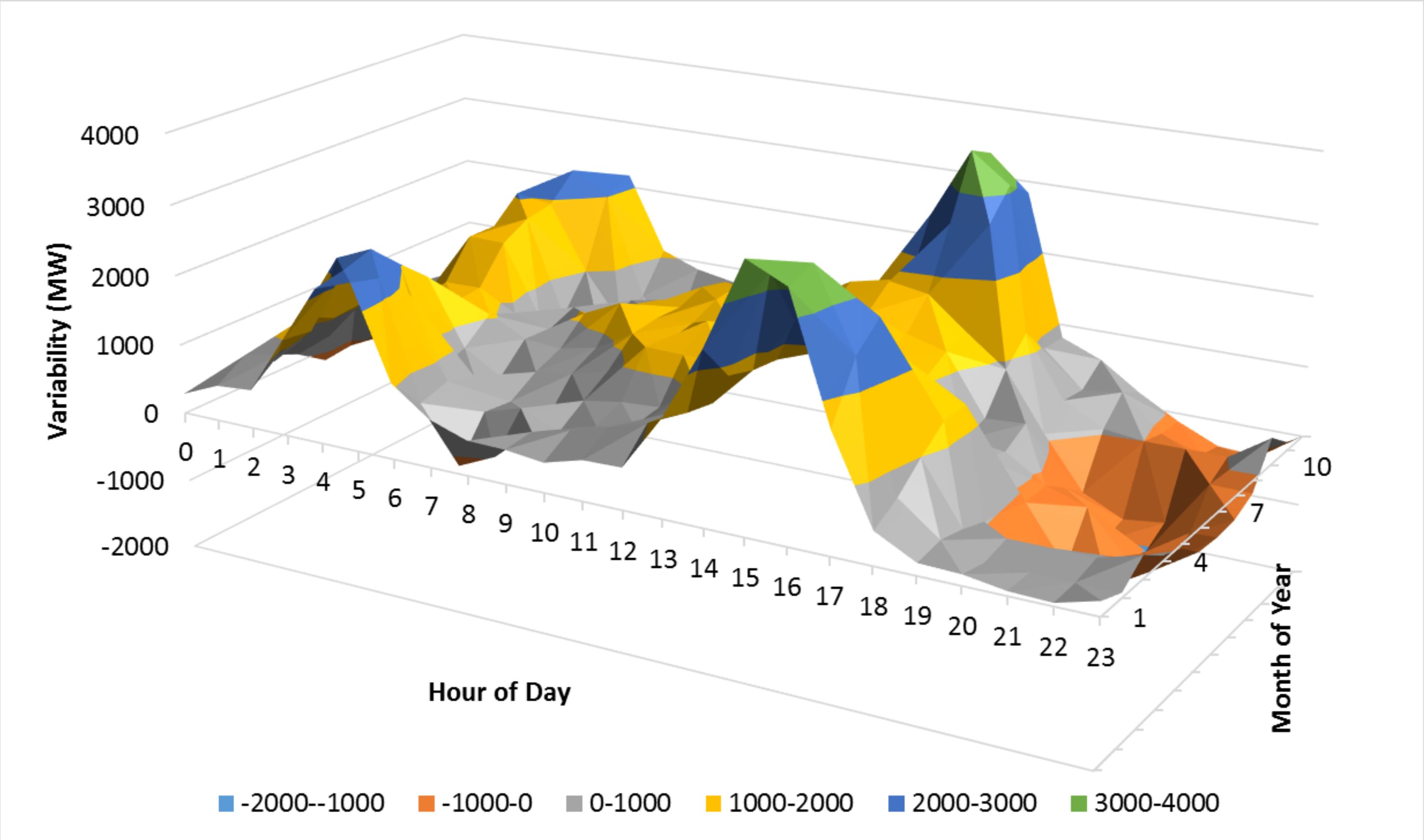
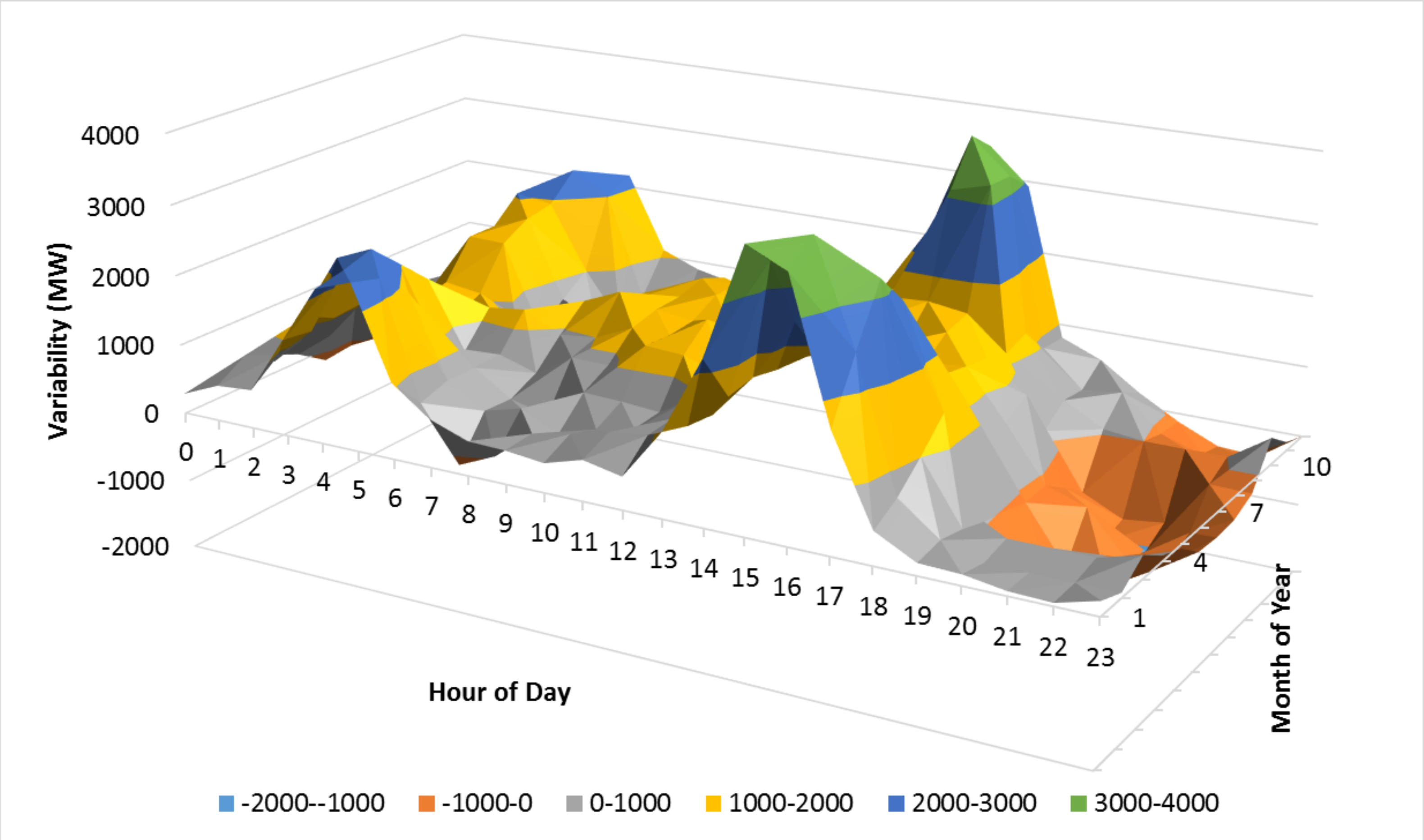
Hourly Net Load Ramping by Month – 7 GW solar



Significant increase in winter ramps, and shoulder months see ramping

Hourly Net Load Ramping by Month – 7 GW solar w/tracking



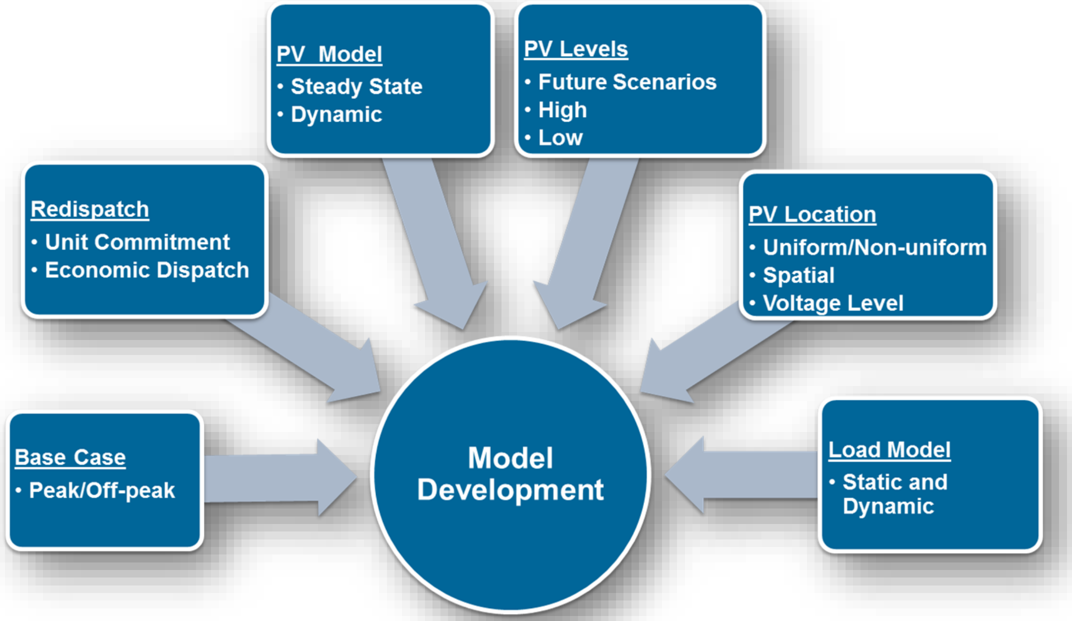
Tracking can make the ramps larger

Flexibility Study Conclusions

- 15-minute data was developed by Sandia National Laboratories utilizing data provided by EPRI, the utilities and satellite data
  - Even though total penetration in the year is relatively low, there were periods when over 50% instantaneous penetration was reached
- Ramping increases, particularly over long time horizons (>1 hour)
  - Periods of high ramping requirements may move from the summer to the winter, and become less predictable overall → impact on outage planning
  - Overall ramping ‘mileage’ was seen to increase throughout the year.
- Operating reserves could increase by an average of up to 10% of installed solar capacity, depending on risk preferences of the utility
- Further work will look at more years of data and start to baseline current system flexibility
  - EPRI methods could also be applied to more detailed production cost modeling for additional metrics - further study in this area is starting with TVA, leveraging findings from this work

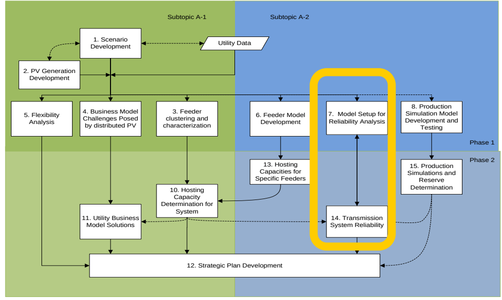
Study on Impact of PV on Voltage and Frequency

- Steady State Analysis
  - Impact on voltages
    - PV levels v/s voltages
  - Impact on voltage stability margins

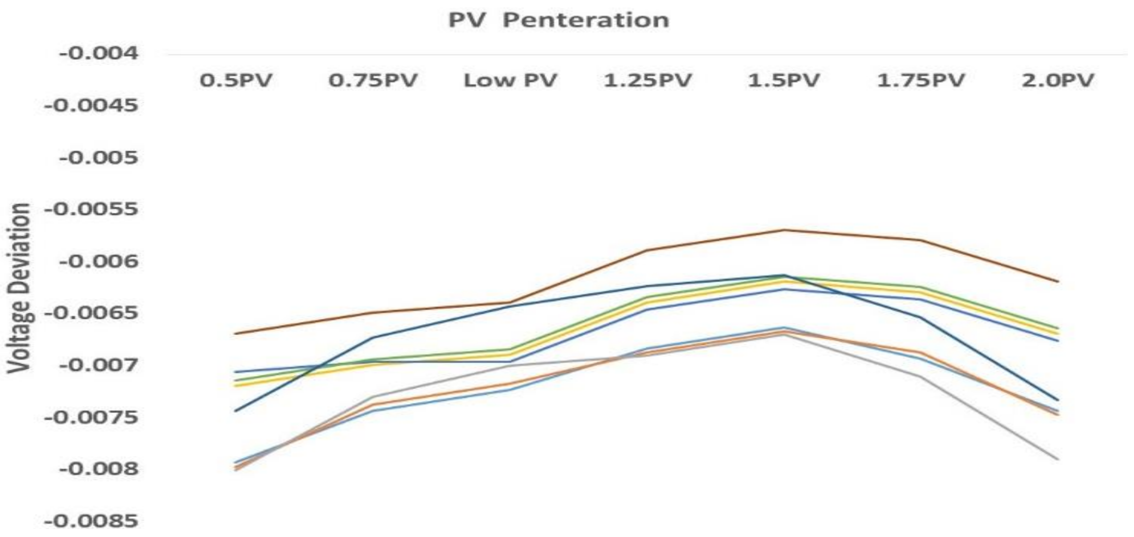


- Dynamic Analysis
  - Impact on transient stability
    - Impact on rotor angles following a fault
    - Impact on damping
    - Impact on voltages during/post fault
  - Impact of inverter controls
    - P-priority, Q-priority, active power recovery

Transmission System Case Studies: Steady State Analysis of increasing distributed PV



- Transmission-connected PV generation was fixed
- Distributed-connected PV generation was varied from 50% to 200 % of base levels



- Voltages rise initially as the distributed PV generation level increases but starts decreasing at higher penetration levels.
- As more synchronous generation is displaced any improvement in the voltage profile due to reduced power flow across the transmission line is offset by reduced reactive power capability; resulting in reduced voltages.

Transmission Reliability Case Studies : Key Observations

- Transmission-connected and Distributed PV generation can impact
  - Steady state voltage profile
  - Reactive power margins
  - Post-fault voltage recovery
  - Angular stability

- Bulk system impact of high levels of PV is very dependent on re-dispatch
  - If central station synchronous generation is displaced, there may potentially be negative impacts (e.g. reduced voltage recovery and fault voltages)

- Transmission-connected PV can improve system transient performance
  - Some functional inverter controls could be considered as part of interconnection requirements
  - Issues such as Q- or P-priority in dynamic voltage response need to be studied and considered

- Distributed PV could support bulk system performance
  - Such strategies are being studied as a part of EPRI's on-going research on DER modeling and representation of Active Distribution Systems

Solar PV can be accommodated but need to consider interconnection requirements and improve bulk system models and approaches

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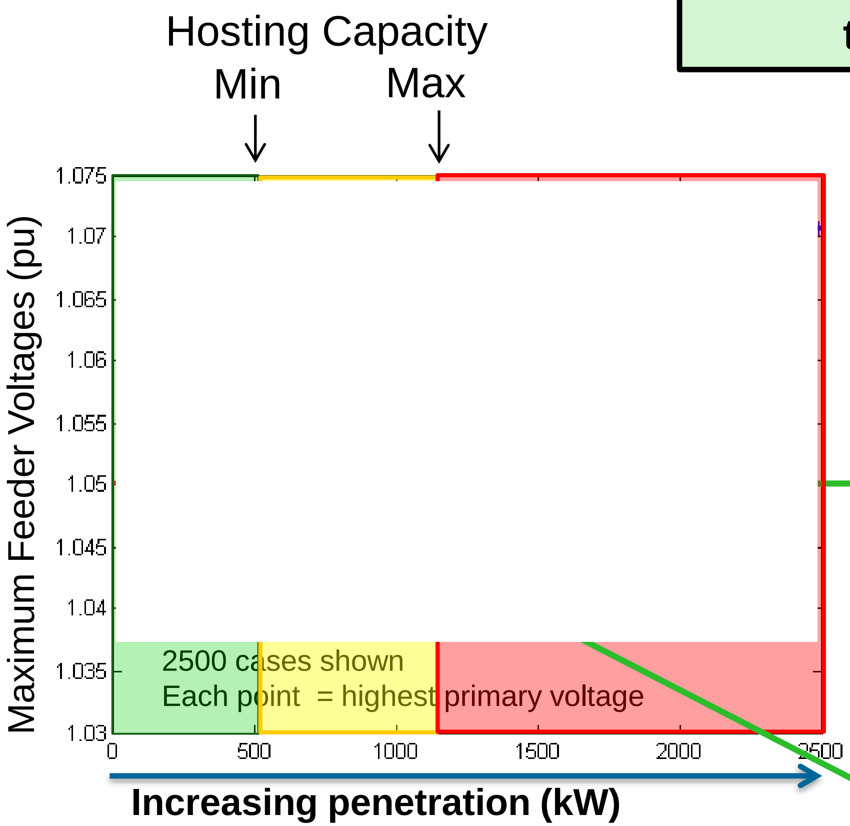
Topic #2: Distribution Feeder PV Hosting Capacity

Distribution Analysis must inform Gen & Trans Plan as to max DPV penetration levels regionally.

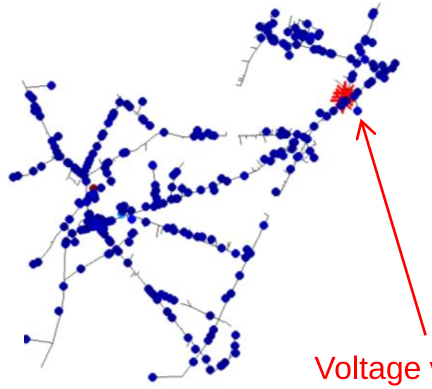


No observable violations regardless of size/location

Possible violations based upon size/location

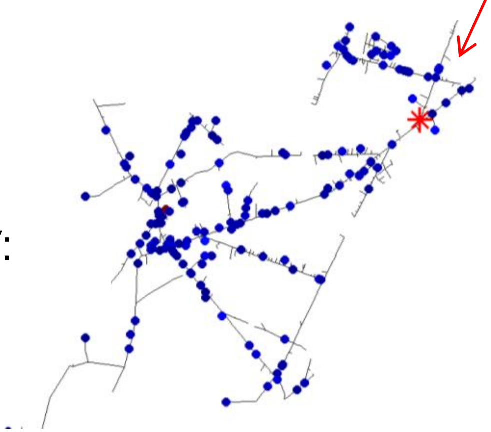
Observable violations occur regardless of size/location

Total PV: 1173 kW



Voltage violation

Total PV: 540 kW



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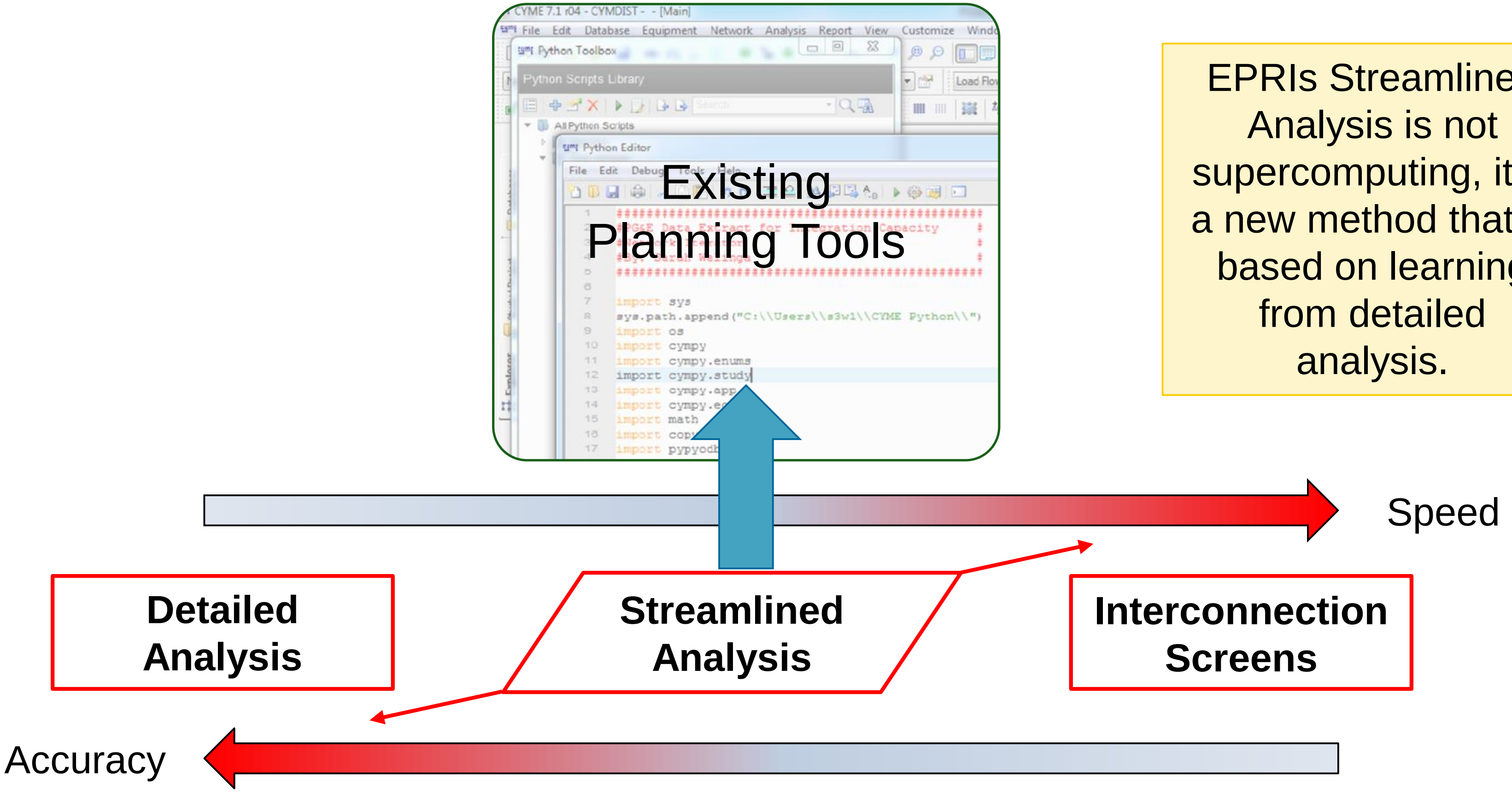
Streamlined Analysis

A new efficient and accurate method to determine how much DER can be accommodated and where.



EPRIs Streamlined Analysis is not supercomputing, it is a new method that is based on learning from detailed analysis.

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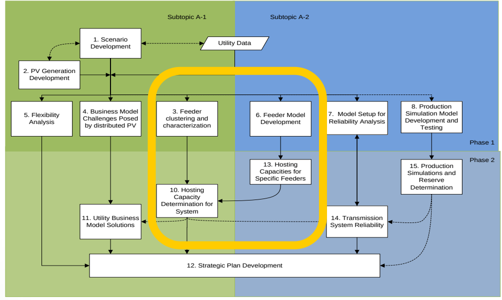
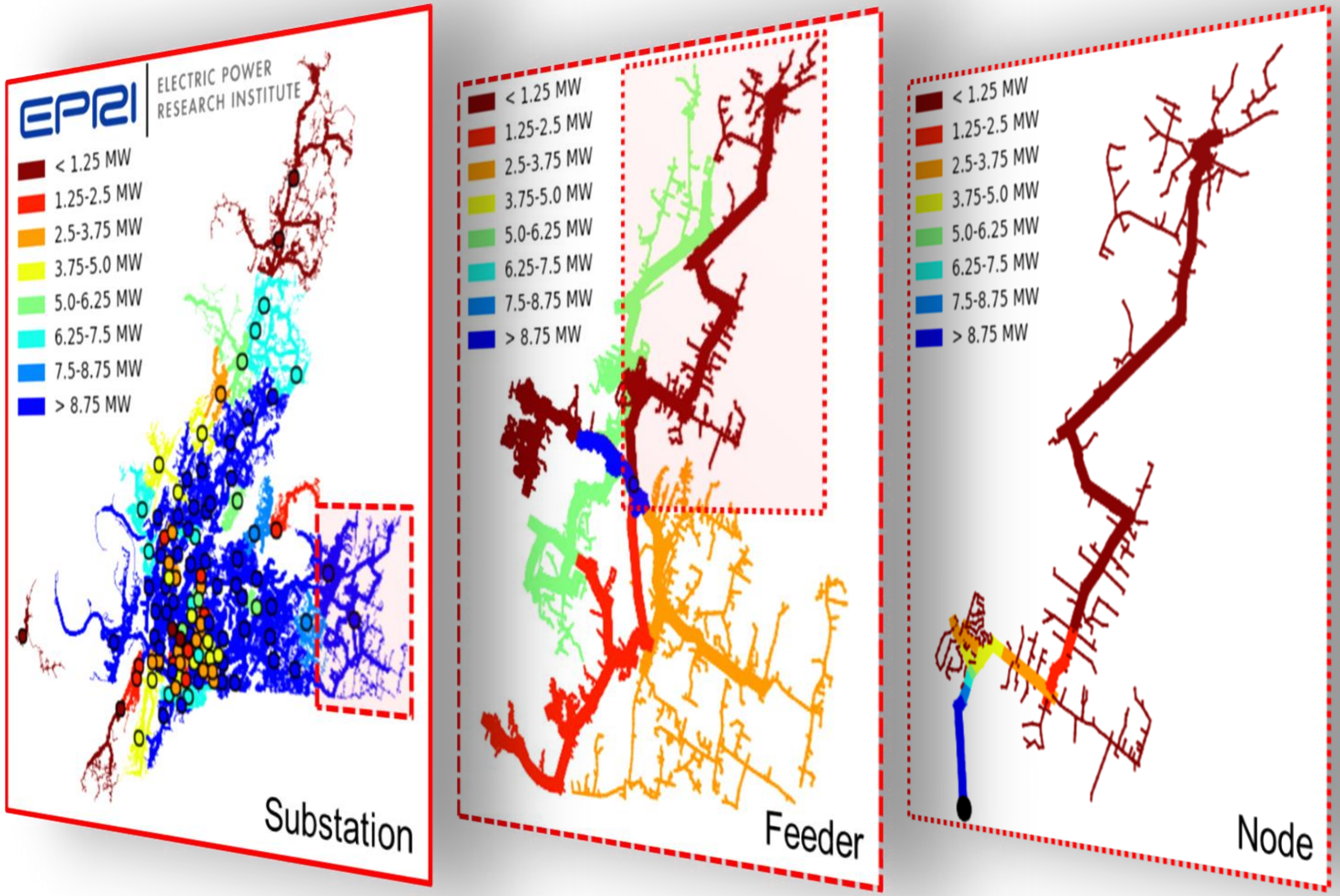
Centralized Large DER Hosting Capacity Example Result





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Feeder Hosting Capacity
Primary Thermal Overload

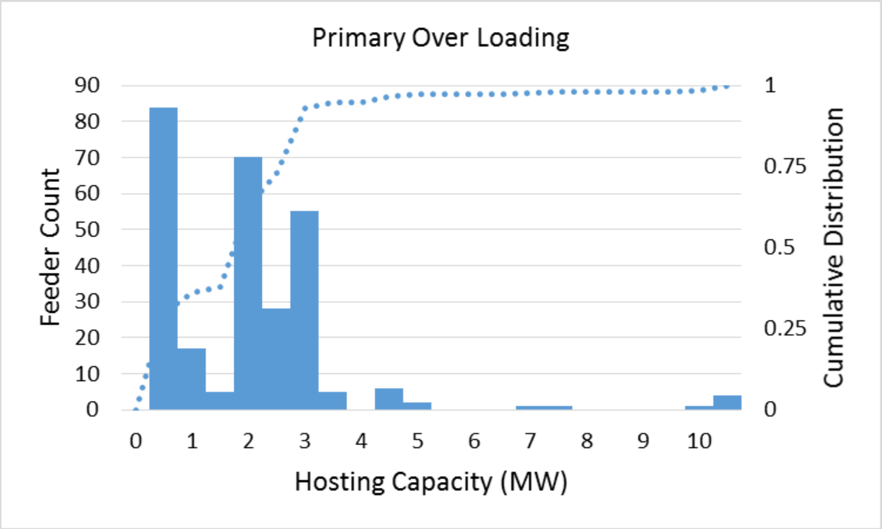
The distributions show the breakdown of hosting capacity among each of the feeders. Bins of 0.5 MW are used for the illustration to group feeders.

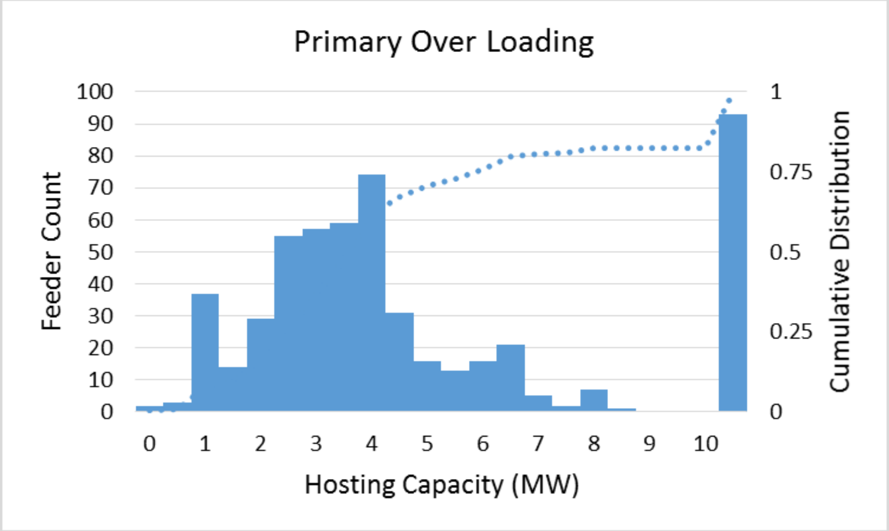
Tennessee Valley Authority
Distributor EPB

- Almost 90% of the feeders analyzed have an overloading hosting capacity less than 3 MW.

Southern Company Services
Operating Company 3

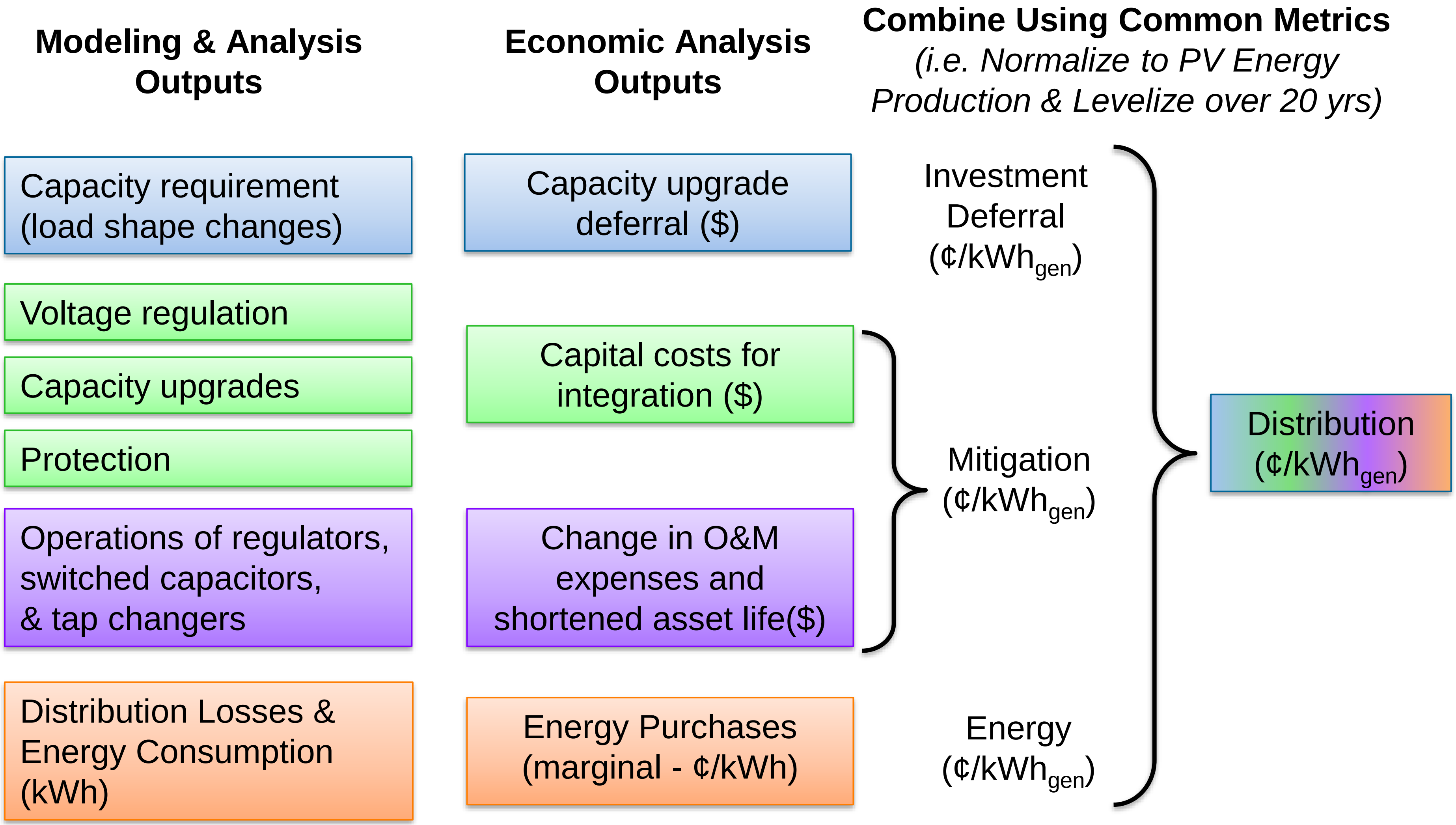
- The thermal hosting capacities are slightly higher due to higher ampacity conductors.





The hosting capacity is driven by the lowest rated three-phase conductor on the feeder. The hosting capacities elsewhere on the feeder can be considerably higher

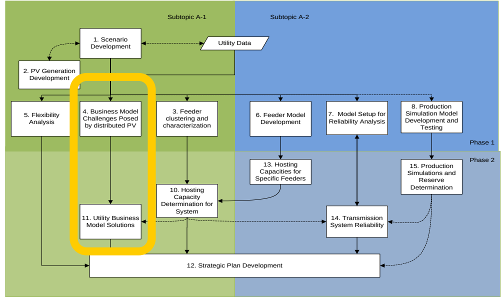
Topic #4: Business Model Cost-Benefit Analysis Considerations



Comparison Between Guided and Unguided Cases

Use Case	Description	Comparison
Roof vs. Roof (RvR)	Simulated use case in which guides distributed rooftop PV deployment to optimal areas on a distribution feeder, compared to unguided deployment of distributed rooftop PV.	Unguided rooftop vs. Guided rooftop
Centralized vs. Roof (CvR)	Simulated use case in which distributed PV is directed to optimal rooftop locations on a distribution feeder, compared to unguided deployment of centralized PV systems.	Unguided centralized vs. Guided rooftop
Roof vs. Centralized (RvC)	Simulated use case in which the deployment of centralized PV system(s) is directed in optimal areas of a distribution feeder, compared to deployment of randomly distributed rooftop PV.	Unguided rooftop Vs. Guided centralized
Centralized vs. Centralized (CvC)	Simulated use case in which the deployment of centralized PV system(s) is directed in optimal areas, rather than compared to the deployment of randomly located centralized PV systems.	Unguided centralized Vs. Guided centralized

Insights from Business Model Analysis

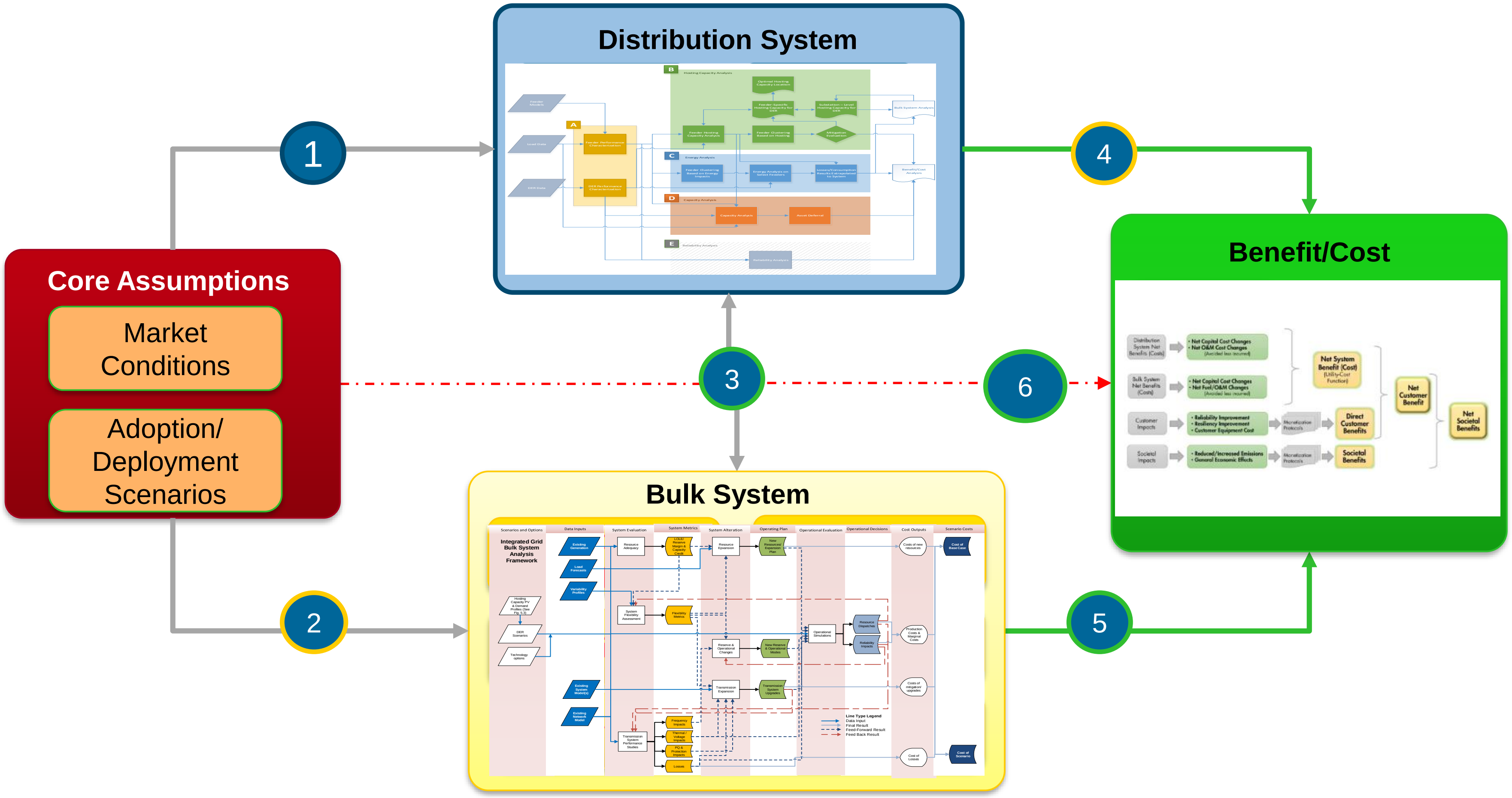


- Guided vs. Unguided Deployment
  - Few scenarios result in significant savings.
  - Feeder characteristics appears to be a major factor.
  - The effectiveness of guiding strategies depends on the approach employed.

- Centralized vs. Distributed Deployment
  - PV concentration was not observed to be a major factor

- High vs. Low PV Growth
  - The impact of PV penetration on distribution value is case specific

EPRI Integrated Grid Benefit Cost Framework



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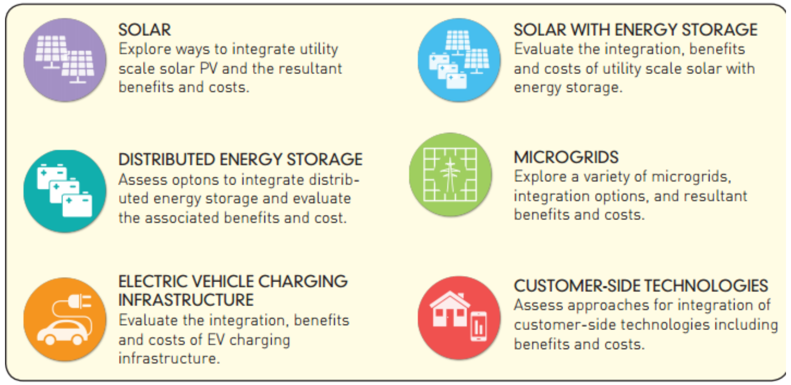
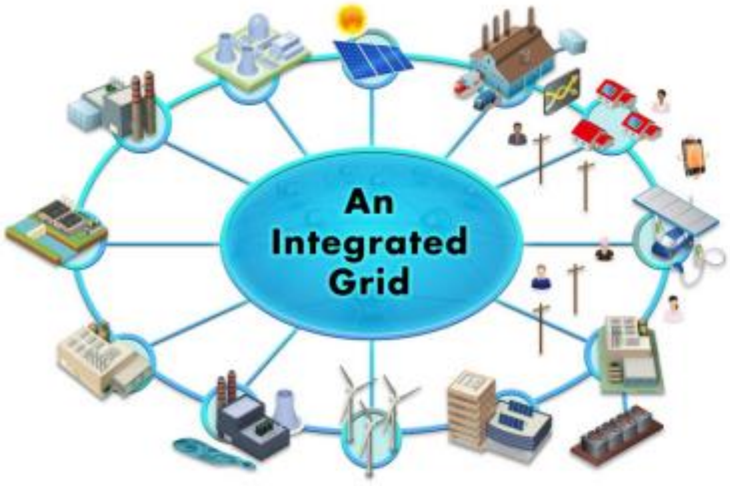
Conclusions and Next Steps

- Work is ongoing in this area in EPRI R&D programs
  - Transmission/Distribution interaction R&D
  - EPRI Integrated Grid Pilot Projects, Transmission Hosting Capacity for VG
  - Continued Development and Application of Streamlined Method
  - Flexibility Analysis methods continue to evolve and improve
  - Reserve determination projects to demonstrate methods
  - Integrated Grid Cost-Benefit Framework being applied more generally
- SUNRISE was first time all of these were done together, lessons learned will allow for continued improvement in methods
- Next steps would be to more closely coordinate studies for full Integrated Grid analysis
- An Integrated Energy Network will also include gas, water, end utilization, etc. and needs to be planned for
- Report Publicly Available – search DOE SUNRISE or 3002010004 on EPRI website





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