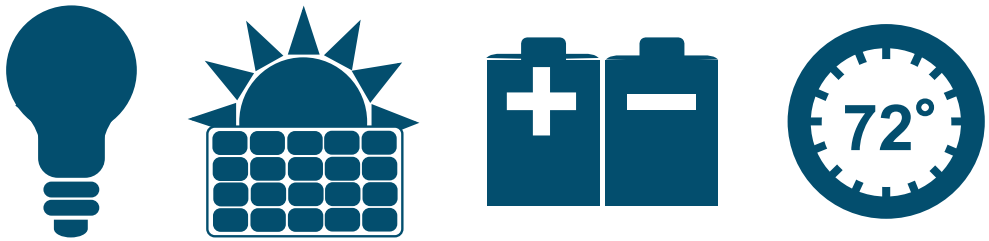
Partnership Between E3 Tata Power – DDL (TPDDL)

- E3 and TPDDL assessed the cost effectiveness of DERs in Delhi including:
  - Distributed solar
  - Energy efficiency
  - Demand response
  - Grid storage
  - Thermal energy storage



- Developed a planning tool that identifies the value of solar and other distributed energy resources
- **Key questions answered in the study:**
  - What will solar cost?
  - Will C&I customers adopt solar?
  - Will solar save money for Delhi ratepayers?
  - Is there an alternative policy to NEM that can help minimize tariff impacts?
  - Can a more diverse DER portfolio help reduce costs?

SOLAR MARKET DEVELOPMENT IN INDIA

- Low solar panel prices are driving opportunities for solar adoption in India and worldwide
- Solar has multiple benefits as part of the Indian grid:
  - Less imported fossil fuels
  - Greater energy price certainty
  - Fewer pollutant and greenhouse gas emissions
- Momentum with National Solar Mission (NSM)
  - National goal set at 20 GW by 2022
  - Proposed increase to 100 GW by 2022

- Delhi Electricity Regulatory Commission has adopted a Net Energy Metering Policy (NEM)

- **Key challenges to solar deployment in Delhi**
  - Targeting and outreach: Where should solar be sited? Who will adopt it?
  - Financing: How will it be financed? Who will pay for it?
  - Interconnection: How can the interconnection process be simplified?
  - Trust: assure customers of the quality and pricing of their installations

TPDDL CAN HELP OVERCOME CHALLENGES TO SOLAR MARKET DEVELOPMENT

TPDDL is well positioned to address the barriers to solar deployment

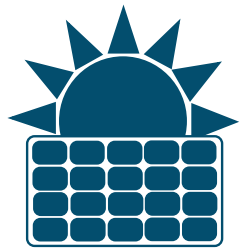
- **TPDDL business model applied: CAPEX**
  - Under capex model, the consumer owns the rooftop system with a choice to select the vendor via a list of partners
  - TPDDL will also assist consumers to arrange financing at competitive rates and facilitate the financing details/documentation including monthly EMI payment collection on behalf of the lender and de-risk the lenders' concern.

TATA POWER-DDL

- **TPDDL is well suited to demonstrate the solar opportunity**
  - Targeting and outreach: utilize existing technologies (AMI,GIS) and relationships to identify viable installations
  - Interconnection: Ability to streamline the process
  - Trust: Has good relationships with customers

- **TPDDL has also engaged in DSM and DR which help integrate solar and lower overall portfolio costs**

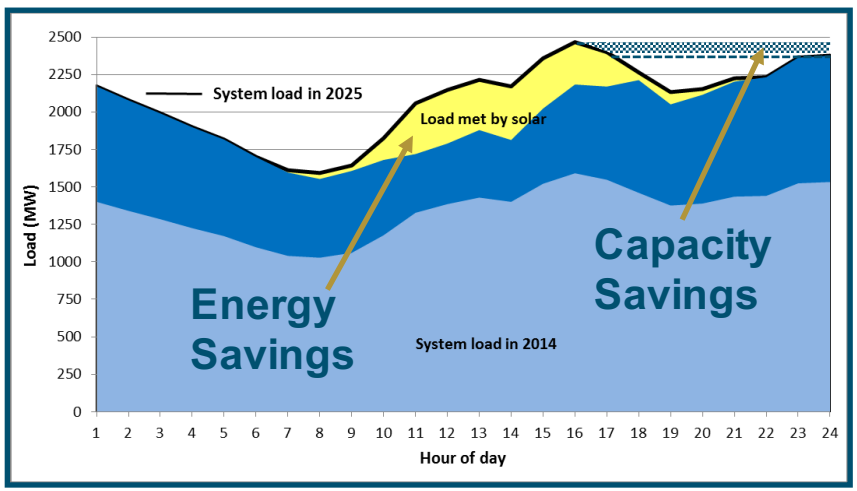
WHERE ARE THE OPPORTUNITIES FOR SOLAR ADOPTION IN DELHI?

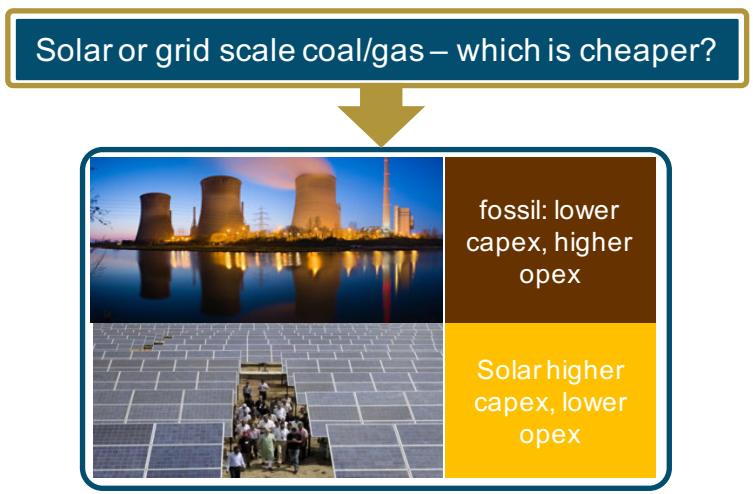


- Main opportunity is in commercial and industrial (C&I) sectors
- Under NEM, solar is cost-effective to C&I customers
  - For an installation today:
    - Without NSM incentive, net benefit to customer over the lifetime of the solar system is 2-3 INR/kWh
    - With NSM incentive, net benefit to customer over the lifetime of the solar system is 3-5 INR/kWh
- Value proposition to C&I customer classes will improve over time if solar costs decline and electricity tariffs increase
- However, cost effectiveness under NEM for C&I customers does not mean solar is cost effective to Delhi ratepayers as a whole
  - Cost effectiveness depends on the avoided energy cost and avoided capacity cost of procuring from coal or gas

WHAT WILL SOLAR COST RATEPAYERS?

- Solar costs depend on several drivers:
  - Global panel demand, technology innovation, inflation, exchange rate risk
- Net cost to rate payers depends on the cost of solar relative to the cost of the resources it replaces
  - Building solar avoids generating energy and building capacity elsewhere
  - Replaces coal and gas capital investments and fuel use
- How will the cost of supplying energy and capacity with solar compare to coal/gas in the future?



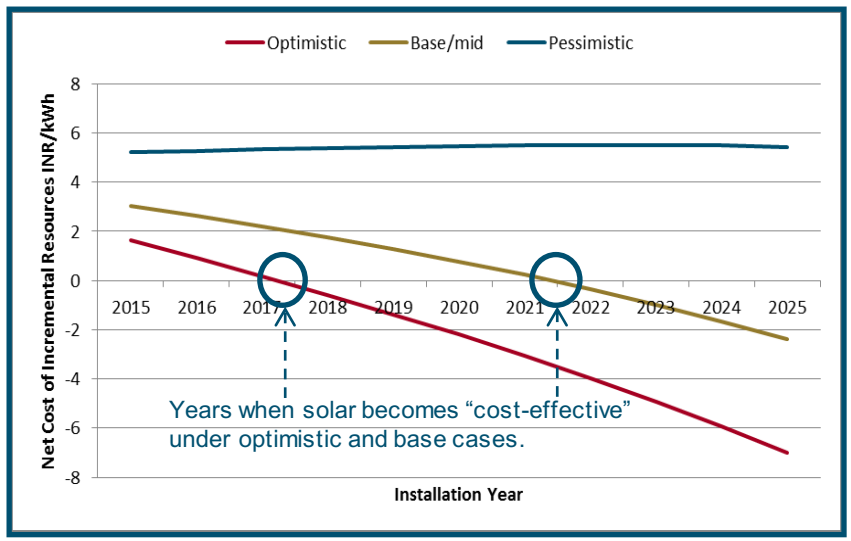


What will solar cost ratepayers?

- Three scenarios of how the different drivers affect costs of solar and coal/gas over time (assuming 15% NSM incentive)
  - Optimistic, Base, and Pessimistic

	Driver	Optimistic	Base	Pessimistic
Drivers affect panel and equipment costs	World demand for panels	Medium	Medium	High
	Technological innovation	High	Medium	Low
	Exchange rate risk	Low	Medium	High
Drivers affect installation and other costs	Learning	High	High	Low
	Inflation	Low	Medium	High

- Net cost: costs net of benefits
  - Benefits to TPDDL service territory (avoided energy capacity, T&D, losses)
  - Costs to TPDDL service territory (technology and program costs)
- Cost effectiveness reached in:
  - 2017 optimistic case
  - 2022 base case
  - never in pessimistic case



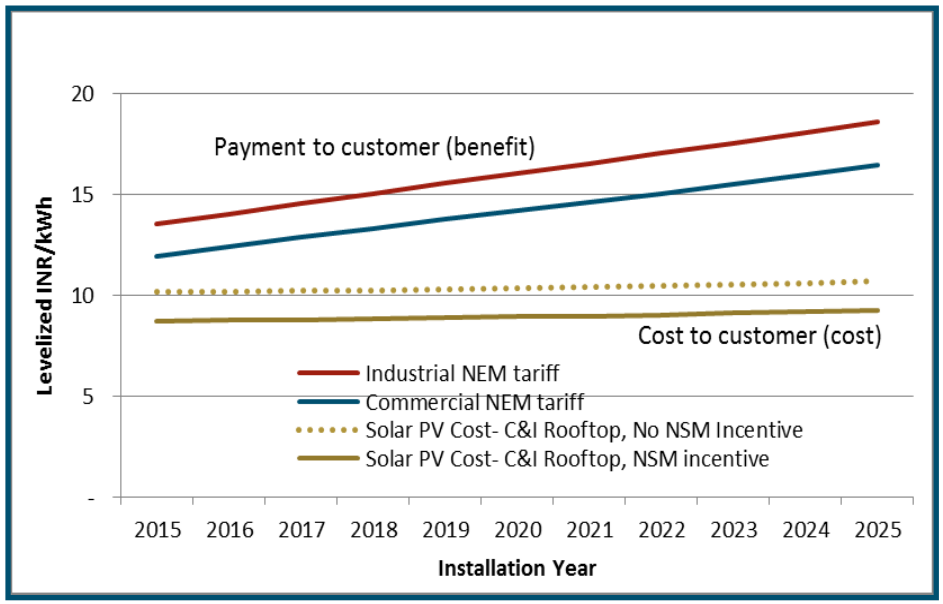
Will C&I customers adopt solar?

- What are the costs vs the benefits to a C&I solar customer under NEM?
  - Benefits: Levelized NEM tariff paid to the customer over the system lifetime
  - Costs: Cost of system with or without a 15% NSM incentive

- In all cases, the cost of solar is less than the NEM tariff
- Customer will save more money through the NEM bill credit than they will pay for the solar
- Economically rational C&I customers will adopt solar

Customer benefits always higher than costs

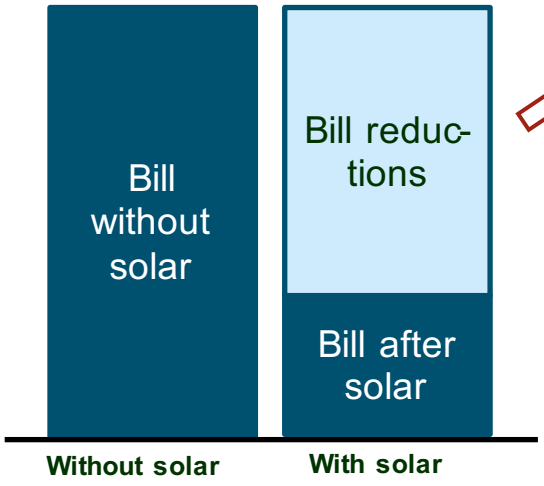
Even with no NSM, NEM is still favorable to customer



Tariff increases are expected because benefits to ratepayers are lower than bill savings to NEM customers

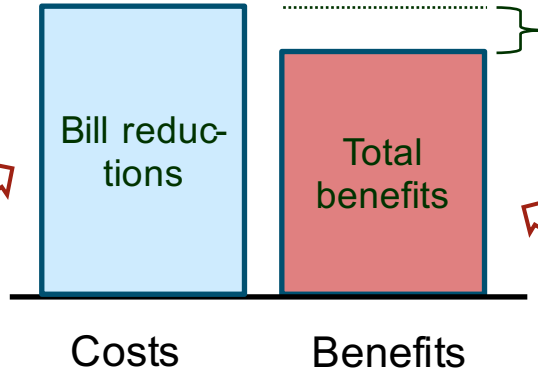
How does a NEM policy change customer tariffs?

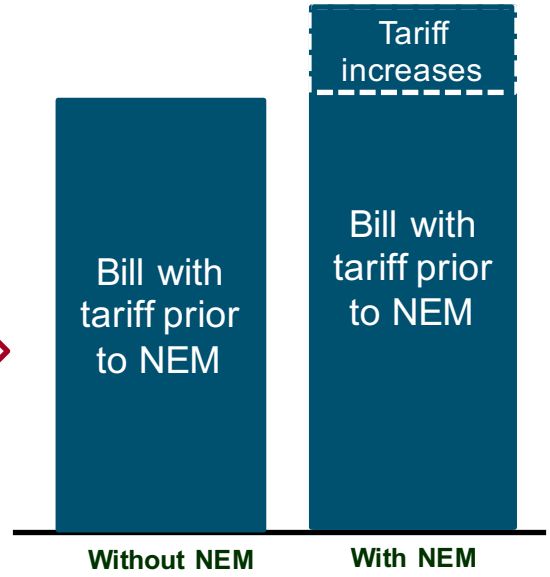
- Total bill reductions to NEM customers are greater than total benefits to the utility
- Total utility income from bills drops below what is required to operate and maintain the system
- Tariffs increase to cover the deficit, increasing the bills of customers without solar installed
- Cross-subsidy



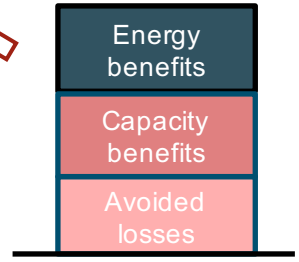
Bill savings for PV customer

Cost-benefit calculation





Bill increases to utility customers (C&I customer classes only)



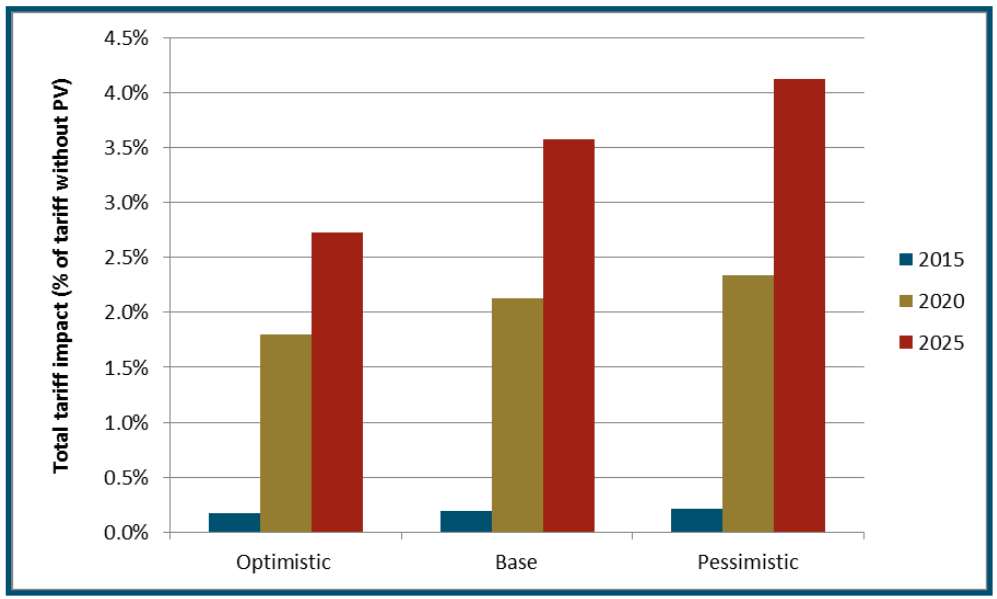
Total benefits/avoided conventional resources

WHAT IS THE TARIFF IMPACT TO C&I SECTOR UNDER NEM?

- Solar adopted under a NEM policy will increase tariffs under all 3 cases
- Impact in 2025 ranges from ~ 3% to 4% increase
- Tariff increases with NEM because the benefits to the ratepayer are less than the bill savings for NEM customers
- NEM is a useful policy for short term market development, but could cause large cross-subsidies in the long term
- Future cross-subsidies could be avoided by transitioning to a NEM alternative policy that can sustain a solar market and reduce costs to utility customers

Assumes all tariff increases are levied on the C&I sector

Based on solar penetrations of:
10 MW in 2015
160 MW in 2016
440 MW in 2025



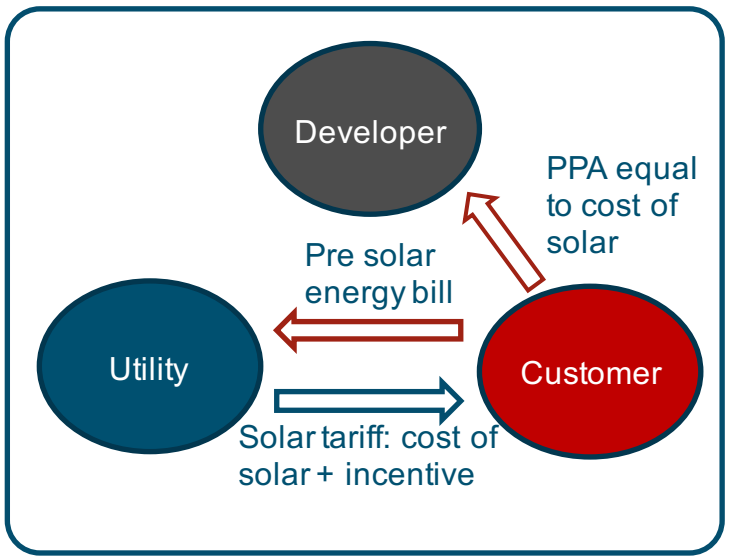
Tariff increases initially small, but increasing in later years

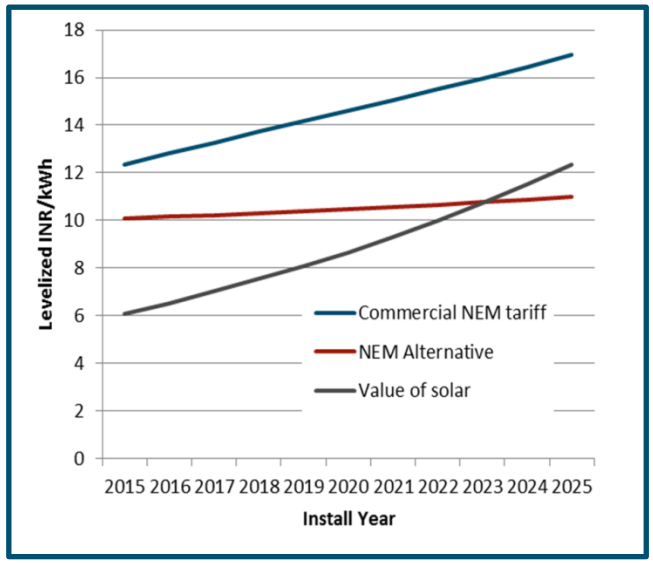
Large increases could be avoided by changing tariff in the future

WILL SOLAR SAVE MONEY FOR DELHI RATEPAYERS?

- Solar will increase the average bill to customers until cost effectiveness is reached (2022 in base/mid case)
- The average bill will drop after cost effectiveness, but non-participating customers will still see bill increases under NEM
- Bill increases can be reduced through a NEM alternative policy

- Example NEM alternative policy:
  - Customer signs a PPA with solar developer
  - Customer pays the utility for their pre-solar energy use
  - Utility pays the customer for the cost of the solar plus an incentive





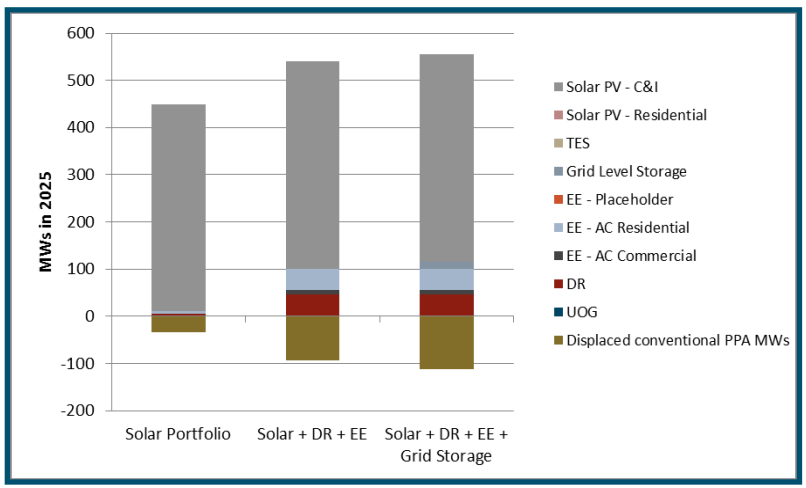
NEM Alternative becomes less than value of solar in 2023 (base/mid case)

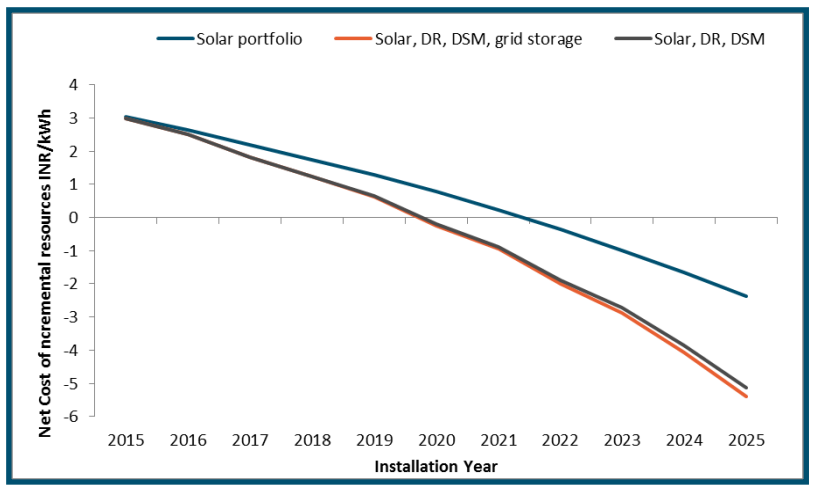
Solar will lower customer tariff under alternative from 2023 onwards

CAN A MORE DIVERSE DER PORTFOLIO HELP REDUCE COSTS?

- Other DERs can help lower overall costs to the ratepayer
  - EE is cost effective compared to solar
  - EE reduces revenue to utility but reduces costs overall to customers
- Other DERs bring complementary benefits to solar
  - DR, grid-storage are more effective at meeting capacity needs compared to solar and can substitute for new power plants
  - Customer sited storage brings power to customers during an outage

- Two diverse portfolios: PV+DR+EE and PV+DR+EE+Grid Storage (battery)
- Both portfolios were more cost effective to the ratepayer than solar alone
  - Capable of displacing more investment in conventional coal/gas PPAs
  - Reaches cost effectiveness 2 years earlier than solar alone

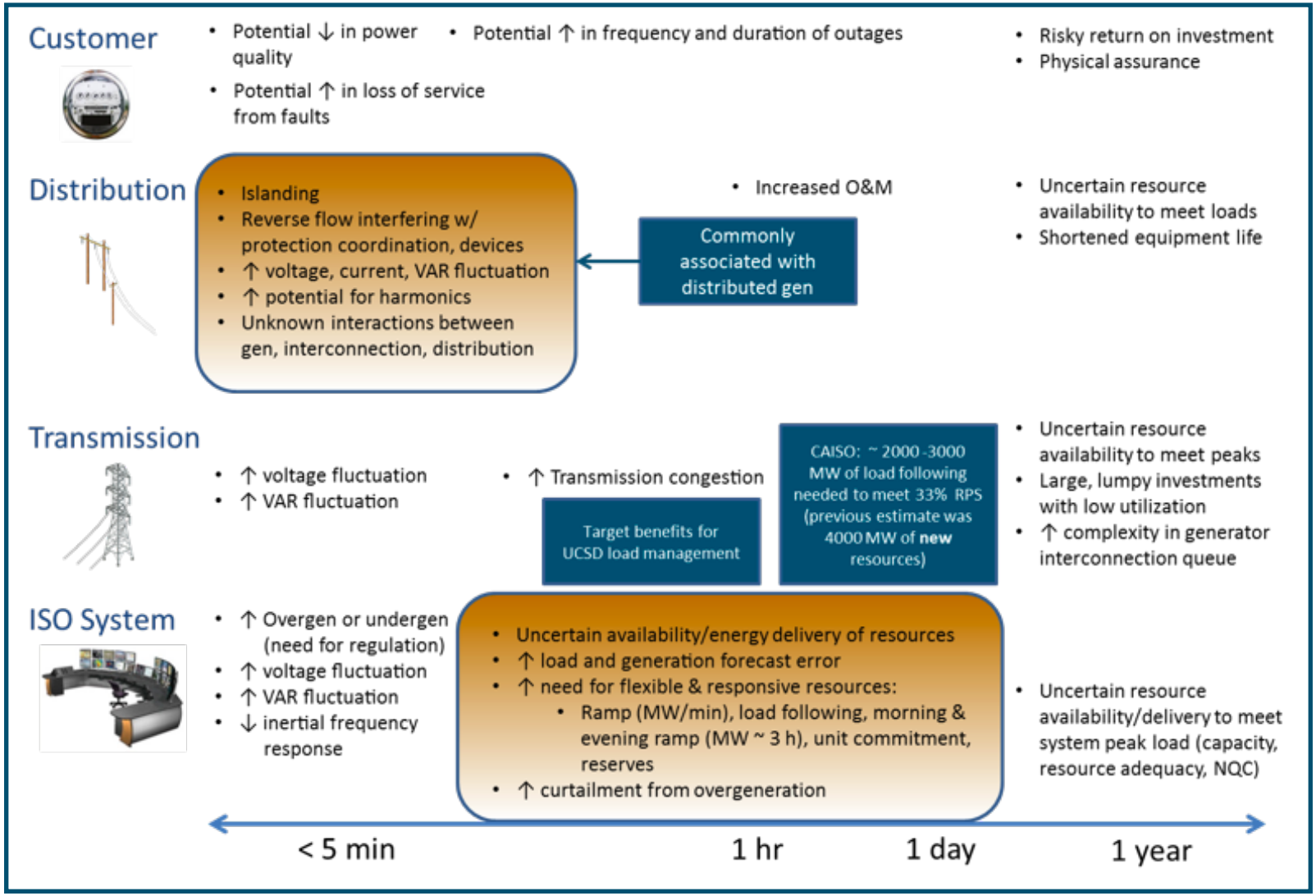




IMPLEMENTATION STRATEGY

- Implementation from customer/regulatory perspective
  - TPDDL can begin offering C&I customers quality and financially attractive rooftop solar systems by focusing on transparent procurement from solar manufacturers, utility financing options
  - Address new construction through codes and standards and partnerships with developers of DER technologies and real estate developers.
- Quality and Standards
  - Streamline the interconnection process for customer DG
  - Develop standards to ensure quality of solar installations; monitor, track and report system performance and costs to improve transparency
- Implementation from TPDDL perspective
  - Further develop complementary programs: DSM/EE, DR to maximize utility value from the solar
  - Anticipate and forecast the impact of the increasing DER on existing and new conventional power assets (e.g. T&D, natural gas and coal generation)

GRID CHALLENGES WITH INCREASED SOLAR - THE CALIFORNIA EXPERIENCE



E3, *Strategies for integrating high penetration renewables*, 2011

SOLAR/ DER INTEGRATION CHALLENGES

- Challenges with distributed generation such as rooftop solar exist across end-use, distribution, transmission and the system (operator) level.
- Unlike conventional generation, renewables such as solar is not a dispatchable source and we must cite them where the resource is available.
- **With variable generation resources, the supply and demand matching effort becomes more complex.**
- High penetration DG may introduce power quality challenges
- Unintentional islanding, interference with protection equipment from reverse power flow, increased voltage, current, VAR fluctuation (particularly from solar PV), increased potential for harmonics distortion

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STRATEGIES TO COUNTER CHALLENGES

Customer

Advanced inverters for real time Volt/VAR support and islanding security

Real time data collection on solar output and customer load

Distribution

Targeting to identify easy to interconnect zones at a substation or lower level and signal cost of interconnection to 3rd party players

Transmission

Meter solar systems and connect to the SCADA systems so that system operators have visibility into performance

ISO System

Understand planning implications for combination of DER and utility scale renewable resources. Total limits can be constrained on a system or local level. Consider grid scale investments and share over portfolio of resources instead of allocation to project which happens to trigger upgrade

< 5 min | 1 hr | 1 day | 1 year

LESSONS ON SOLAR POLICY & TARIFF DESIGN

- Key insight: NEM is effective to get the market going but is very difficult policy to sustain over the long term

- Advantages of NEM: NEM for rooftop solar has been popular in the United States; easy to understand; allowed for market installers - SunRun, SolarCity, Sungevity - to build models
- Disadvantages of NEM: Results in a transfer (cross-subsidy) because tariffs include the cost of building out and maintaining the grid
- NEM Alternative: What United States and Germany call "Feed in tariff" provides flexibility to utility and regulators as solar payment can be set independently of utility tariffs and changed over time. Payment can be set to incentivize adoption with a lower cross-subsidy than NEM, or used to pay only for the benefits of solar to the grid
- Moving away from NEM: Other regions have found it difficult to transition away from NEM; Can be avoided by sending a signal early on that the NEM policy will be time-limited

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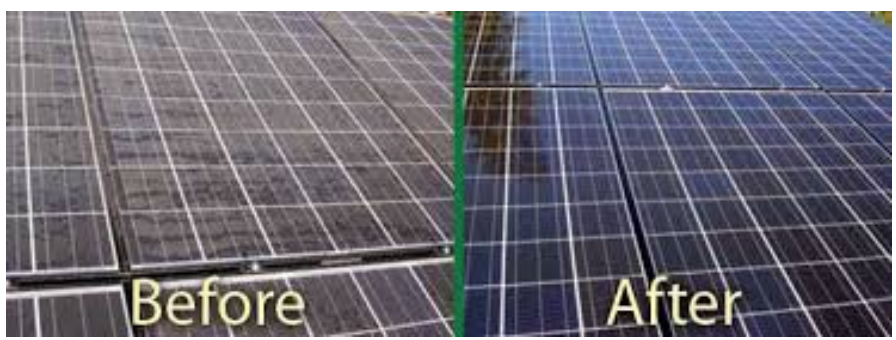
LESSONS ON SOLAR PERFORMANCE AND COST

- Maintenance/Monitoring: This is very important to achieving high solar performance and continuing to see predictable customer savings. Monitoring is coupled with O&M operations to ensure issues are resolved expediently

- Rooftop solar costs: have dropped considerably in regions with high solar adoption —experience reduces labor hours and construction costs; streamlined permitting and interconnection. Soft costs are equally important for overall cost-effectiveness and local “know-how” and competition improves probability of robust DER market

- Rooftop vs. central solar: In most places, rooftop solar is more expensive than central (with transmission costs); if goal is least cost procurement, rooftop solar may not be best resource but DER has other benefits



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QUALITY CONTROL FOR SOLAR AND CODES AND STANDARDS

Develop a set of best practices for CERC defined interconnection standards

- Maintain the high standard of reliability set by TPDDL
- Develop a database of installed projects to track customers with PV, installed MWs and system performance
- Develop a database of installed distribution side upgrades to create a record of experience
- Understand potential by distribution planning area to focus solar development where the grid is most resilient

New construction (new buildings) are ripe for investment in solar and other DER

- Codes can be developed to motivate "solar-ready" new construction
- Partnership with local authorities, green building labeling programs ("LEED") can help target new construction for solar, demand response and energy efficiency
- Utility or 3rd party financed solar, EMCS to facilitate DR and energy efficient operation

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TPDDL CAN MANAGE AND GROW THE SOLAR MARKET

- TPDDL is in a good position to encourage the rooftop solar market and transition to a sustainable solar future
  - TPDDL can use demand response, DSM/energy efficiency, and both thermal and battery storage to effectively integrate solar and reduce dependence on thermal resources
  - TPDDL is a trusted provider of energy for its customers
  - TPDDL can ensure quality installations that help develop the market, provide consumers confidence in solar for the long term, and set the standard business practice in the market
- TPDDL has an economic advantage for procuring low cost DER and will manage the risks and costs to its customers

BROAD CONCLUSIONS AND IMPLICATIONS ACROSS INDIA

- NEM can help grow the solar market in the near term but causes a cross-subsidy, increasing bills for non-participating customers
- To contain the cross-subsidy, a transition away from NEM is needed
- Complementary DER technologies can help integrate solar and lower overall portfolio costs

- This opportunity is scalable across India
  - Market development will increase as policies change to accommodate rooftop solar
  - Depending on future cost improvements, rooftop solar may become cost effective in the next few years
  - Regions with more reliance on backup generation have higher DER values though offset diesel

- Path to achieving greater social benefits on a larger scale
  - Improved air quality
  - Reduced coal and other fossil fuels