Energy+Environmental Economics

TATA POWER-DDL

TATA POWER DELHI DISTRIBUTION LIMITED
A Tata Power and Delhi Government Joint Venture

Business models for distributed energy resource deployment: Case study with Tata Power Delhi Distribution Limited

Study funded by the United States Trade and Development Agency

Prepared by:
Energy and Environmental Economics (E3)
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Prepared for: Tata Power Delhi Distribution Limited

Speakers: Dr. Priya Sreedharan (*) and Amy Wagner
Public Workshop 6 May 2015

* Dr. Sreedharan is presently on leave from Energy and Environmental Economics for a fellowship with the US Agency for International Development

E3: Energy and Environmental Economics

San Francisco consulting firm, founded in 1989, specializing in electricity sector techno-economics and policy analysis spanning supply/demand.

Regulatory / Policy

- ❑ Economic benefits of Net Energy Metering in California and across US
- ❑ Analyzed economics of solar and distributed energy resources programs (solar, DSM, DR)
- ❑ Analysis of feasibility of a 50% renewable portfolio standard for California

Utilities

- ❑ Developed utility business case for distributed solar programs and other distributed energy resources
- ❑ Advised PG&E, and many other utilities on distributed resource and renewables procurement and planning
- ❑ Assisting Hawaii utility on high penetration solar development

Developers, Technology Companies, IPPs, large consumers

- ❑ Provided economic, financing and strategy advice to many technology companies and developers including SunEdison, BrightSource Energy, First Solar, Recurrent Energy
- ❑ Work with microgrid, solar integration and storage companies to determine value of solar & renewables integration strategies; clients include Viridity, Enbala, Sunverge
- ❑ Advise developers and large consumers on the business case for distributed gen, solar, cogeneration (recently completed solar microgrid feasibility for Azure Power)

International and India experience

+ International work has focused on analysis techniques to support clean energy deployment

- Developed grid planning framework for valuing distributed, central and off-grid solar (presented at Shakti Foundation workshop)
- Recently completed solar microgrid feasibility study (USTDA and Azure Power)
- Distributed energy resource program analysis for Indian agricultural sector

Assessing the business case for rural solar microgrids in India: a case study approach

Final report

Prepared for Azure Power

October 30, 2014

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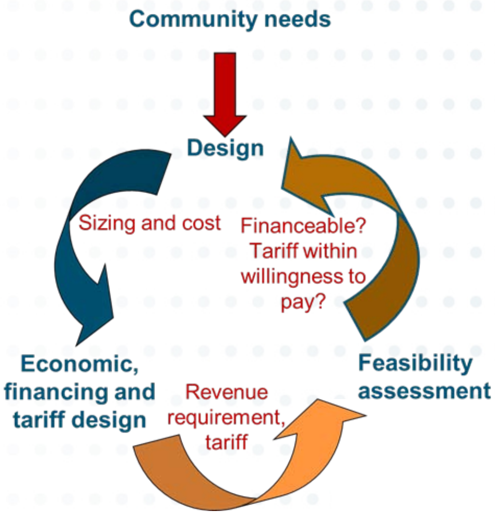


Outline of E3 presentation

+ Project introduction
+ Background
+ Summary findings
+ Model results
+ Implementation

Project introduction

- **Goal: Develop business models for distributed energy resources**
  - Distributed solar
  - Demand side management (energy efficiency)
  - Demand response
  - Grid storage
  - Thermal energy storage

USTDA
United States Trade and Development Agency

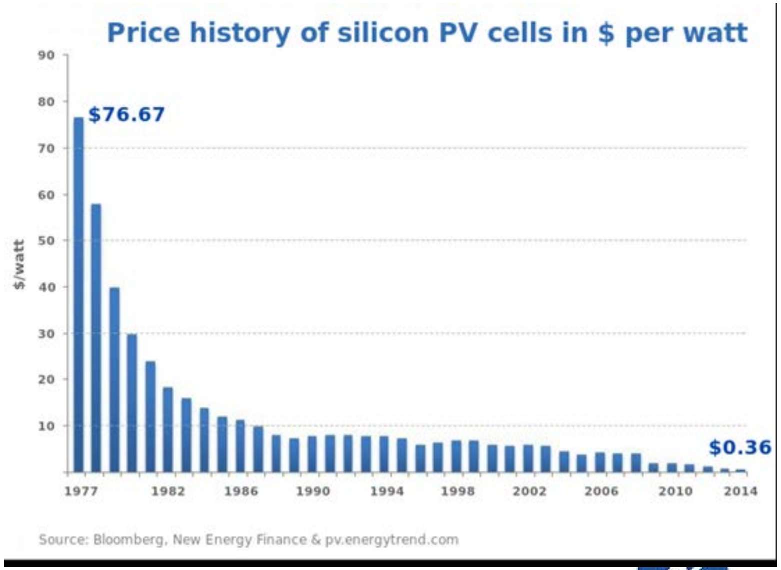
- **Emphasis on solar**
- **Case study: Tata Power Delhi Distribution Limited (TPDDL) utility**

Study provides tools to expand the solar and DER market

- **Developed a planning tool that identifies the value of solar and other distributed energy resources**
  - Tool enables utilities to incorporate solar into utility energy resource plans
  - Tool and method are flexible — can be used to value other energy resources
- **Exercised tool to identify**
  - Costs, benefits, environmental impacts of DER
  - Assessed the tradeoffs between solar policies
- **Developed implementation and regulatory strategies to enable TPDDL to take an active role in developing solar market**

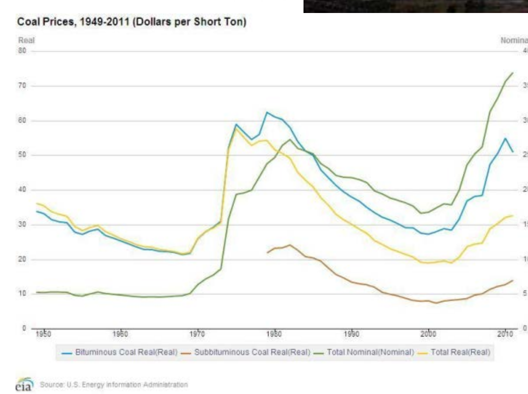
Costs of solar have been declining

- Costs of solar have fallen in last three decades
- Opens opportunities in India and worldwide



Solar has multiple benefits

+ **Multiple benefits from solar & clean energy**
  - Less imported fossil fuels
  - More certainty on energy prices
  - Fewer air pollutant emissions
  - Fewer greenhouse gas emissions



Projected Premature Annual Deaths due to Urban Air Pollution, Total and by Economic Group or Region, 2001–2020

Region	Premature Death (thousand per year
Established market economies	20
Former socialist economies	200
China	590
India	460
East Asia and the Pacific	150
Latin America and the Caribbean	130
South Asia	120
Middle East Crescent	90
Sub-Saharan Africa	60
World	1,810

Source: World Bank.

Policies support solar

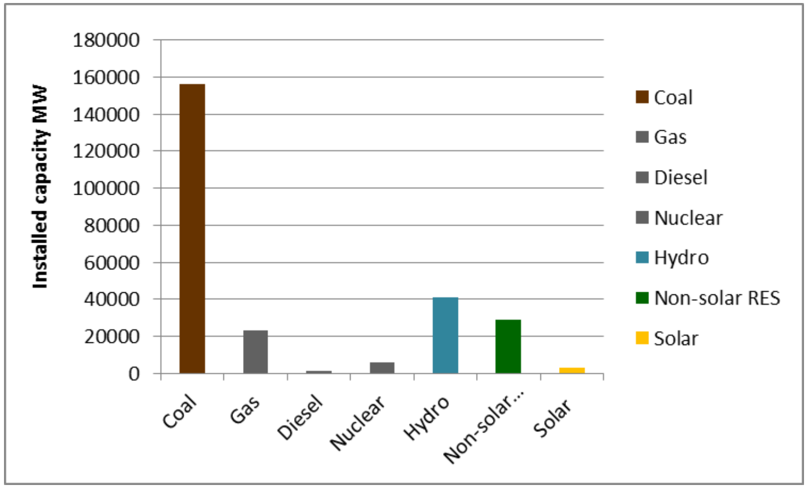
- **Solar is receiving high visibility and support at all levels**
- **India has momentum with National Solar Mission (NSM)**
  - National level goal was set at 20 GW in 2022
  - Recent announcement to increase goal to 100 GW in 2022
- **Delhi Electricity Regulatory Commission has adopted a Net Energy Metering policy**

"Our vision is to make India's economic development energy-efficient. Over a period of time, we must pioneer a graduated shift from economic activity based on fossil fuels to one based on non-fossil fuels and from reliance on non-renewable and depleting sources of energy to renewable sources of energy. In this strategy, the sun occupies centre-stage, as it should, being literally the original source of all energy. We will pool our scientific, technical and managerial talents, with sufficient financial resources, to develop solar energy as a source of abundant energy to power our economy and to transform the lives of our people. Our success in this endeavour will change the face of India. It would also enable India to help change the destinies of people around the world."

Solar market still small

+ Indian solar market has seen growth, however

- Solar installations are roughly 3000 MW or 1.2%
- Majority is in the utility scale solar PV not rooftop solar
- Not a meaningful mix of the energy supply
- Not been integrated into utility resource planning



Source of installed solar:
http://timesofindia.indiatimes.com/business/india-business/Cumulative-solar-installations-in-India-reach-3000MW-mark/articleshow/45232074.cms

Source of installed capacity:
http://cea.nic.in/reports/monthly/inst_capacity/jan15.pdf

Challenges to solar market expansion

+ **Current policies may not be sufficient to grow market**
+ **Key challenges must be overcome to encourage solar deployment in Delhi**
  - Targeting and outreach: Where should solar be sited? Who will adopt solar?
  - Financing: How will solar be financed? Who can access low cost financing?
  - Interconnection: How can interconnection process be simplified?
  - Trust: How can customers be sure that they are getting quality installations at reasonable prices?

TPDDL can help overcome challenges

- **TPDDL is well positioned to address the barriers to solar deployment**
- **TPDDL is well suited to demonstrate the solar opportunity**
  - Targeting & outreach: Utilize existing technologies (AMI, GIS) and relationships to identify viable installations
  - Financing: Access to low cost financing
  - Interconnection: Ability to streamline the process
  - Trust: Has good relationships with customers
- **TPDDL has engaged in DSM and DR which help integrate solar and lower overall portfolio costs**

Challenges:

- Targeting and outreach
- Financing
- Interconnection
- Trust

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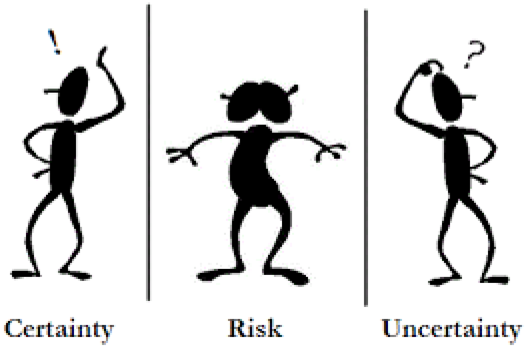
Where are the opportunities?

- **Main opportunity is in C&I sectors**
- **Under NEM, solar is cost-effective to C&I customers**
  - For an installation today:
  - Without NSM incentive, lifecycle NEM payment to customer exceeds lifecycle solar cost ~ 2-3 INR/kWh
  - With NSM incentive, lifecycle NEM payment to the customer exceeds the lifecycle solar cost by ~ 3-5 INR/kWh
- **Value proposition to the C&I customer classes likely to improve over time**
  - If solar costs decline and tariffs increase

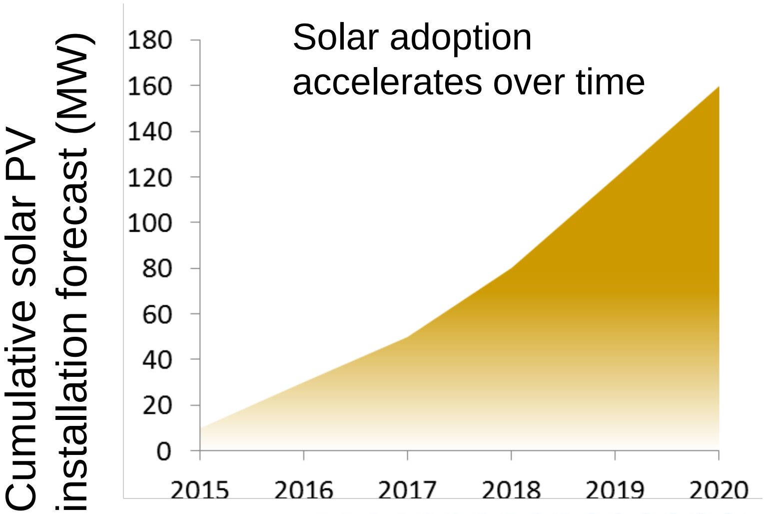
NEM has unintended consequences for all consumers and the utility

- **NEM may help grow the solar market, but there are unintended consequences**
  1. Under NEM, the utility pays customer for solar generated at retail tariff
  2. But, retail tariff is typically higher than the cost of supply
  3. This means a cross-subsidy will occur
  4. The cross subsidy may decrease over time:
     - As conventional fossil fuel supply costs increase
     - Utility load growth can mitigate impact of cross subsidy



How big is the cross-subsidy from NEM in the near term?

- **In the near-term, the impact on the utility net cost is small**
  - By 2020, with adoption of 160 MW, the tariff increase is ~ 1.8-2.3% to the C&I customer classes
- **E3 recommends that the cost impact can be contained within the C&I sectors who will benefit most from NEM policy**

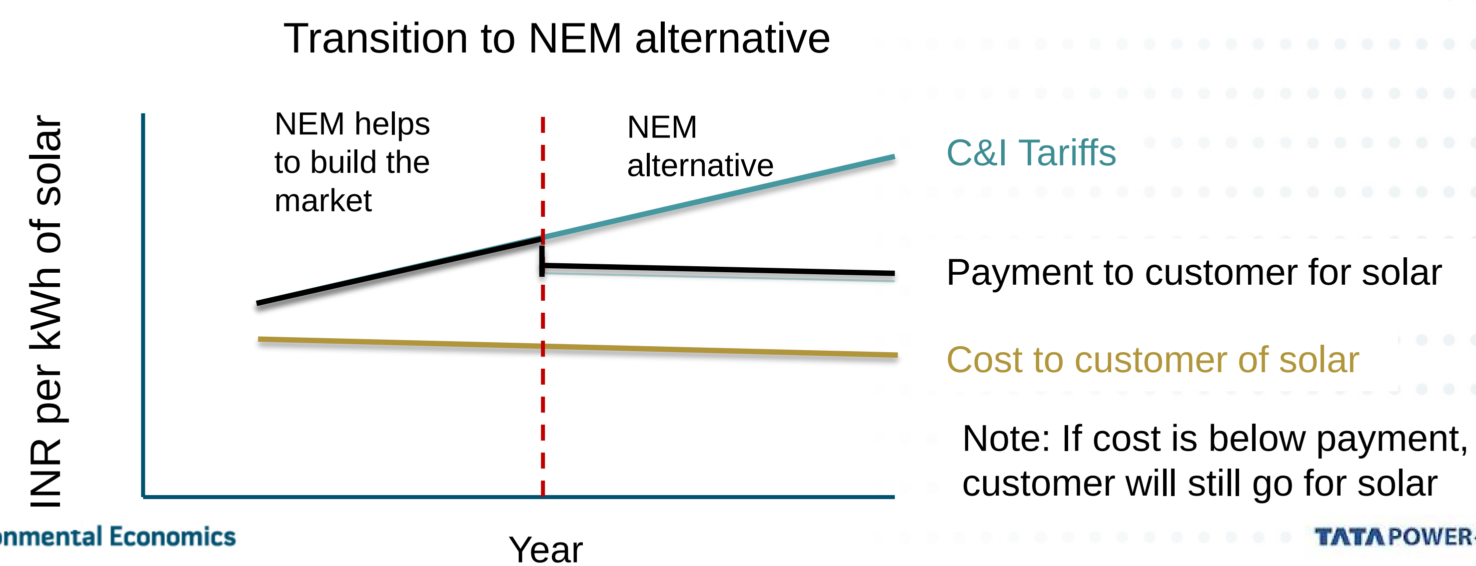


Estimate by TPDDL

Long term policy transition

- **By 2025, the potential tariff increases become larger as the cumulative installation capacity becomes larger**
  - By 2025, with an adoption of 440 MW, the impact on C&I customers will result in a tariff increase of 2.7-4.1% to the C&I customer classes.
- **As solar costs decline, NEM can be replaced with less generous offer to C&I customers and still maintain growth**

Diagram shows a concept. No numbers are shown by purpose.



Diverse DER technology portfolios are valuable

- **Solar is valuable for energy but has limited capacity value**
  - Solar helps meet daytime to early evening loads but not night loads
  - As solar penetration increases , peak loads will shift to later periods
- **Other DER resources can provide complementary benefits**
  - Demand response, DSM can help meet capacity needs
  - DSM also addresses nighttime loads if targeted at AC
  - Demand response and grid storage can help load balancing
- **Portfolios with DER are cheaper over all**
  - DSM more generally cost effective compared to solar on kWh basis
  - Demand response has capacity benefits and is cheaper than alternative conventional power plant types

Implementation

+ Identify key markets for solar

- TPDDL can begin offering C&I customers quality and financially attractive rooftop solar systems
- Address new construction through codes and standards, partnerships

+ Standardize and improve quality

- Streamline the interconnection process for customer DG
- Develop standards to ensure quality of solar installations; monitor and track system performance and costs

+ Manage utility portfolio

- Further develop complementary programs: DSM/EE, DR to maximize utility value from the solar
- As the installed solar increases, manage the conventional supply portfolio in a complementary manner

Summary: TPDDL can manage and grow the solar market

+ **TPDDL is in a good position to encourage the rooftop solar market and transition to a solar future**

    1. There are complementary programs that TPDDL can offer to get more value of solar and integrate solar with the overall resource plan

        Includes demand response, DSM/energy efficiency and managing the supply portfolio according to solar output

    2. TPDDL is a trusted provider of energy for its customers

    3. 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**

Summary: Broader implications

- NEM can help grow the solar market in near term but has unintended consequences in the form of a cross-subsidy
- To contain the cross-subsidy, a transition away from NEM is needed to mitigate the cross-subsidy
- Complementary DER technologies can help integrate solar and lower overall portfolio costs

MODEL RESULTS

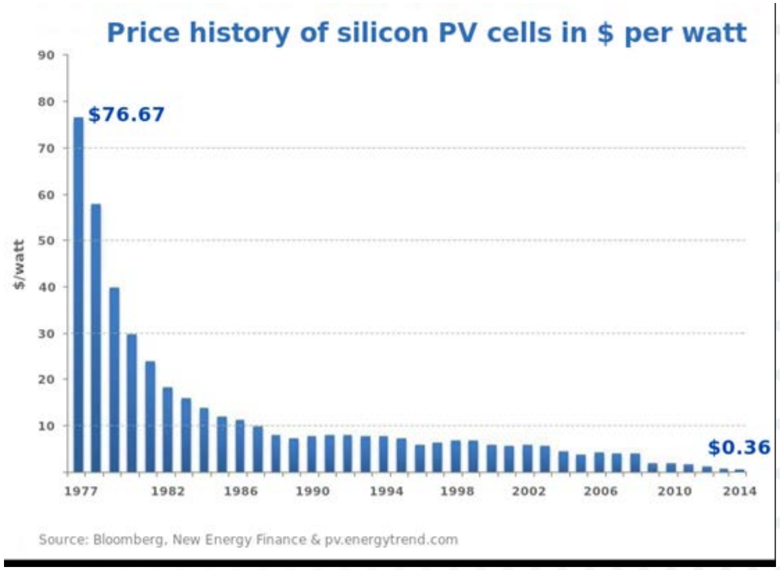
Outline of modeling results

- **Forecast of the cost of solar:**
  What will solar cost?
- **NEM policy value proposition to C&I sector:**
  Will C&I customers go for solar?
- **Value of solar from societal and utility perspectives:**
  Will solar save money for all Indians and Delhiites?
- **NEM solar policy:**
  What are the tariff impacts of the NEM policy and is there an alternative policy that minimizes tariff impacts?
- **Value of mixed DER portfolios:**
  Can other resources — energy efficiency, demand response, storage — bring down the cost?

What is the forecasted cost of solar?

How will solar costs evolve in the future given global solar markets?

- **Steep declines have been experienced over last few decades**
- **Many stakeholders in India expect rooftop solar prices to decline**
- **The following key drivers will influence how installed solar costs will vary in the future**
  - World demand for panels
  - Technological innovation
  - Learning
  - Inflation
  - Exchange rate risk



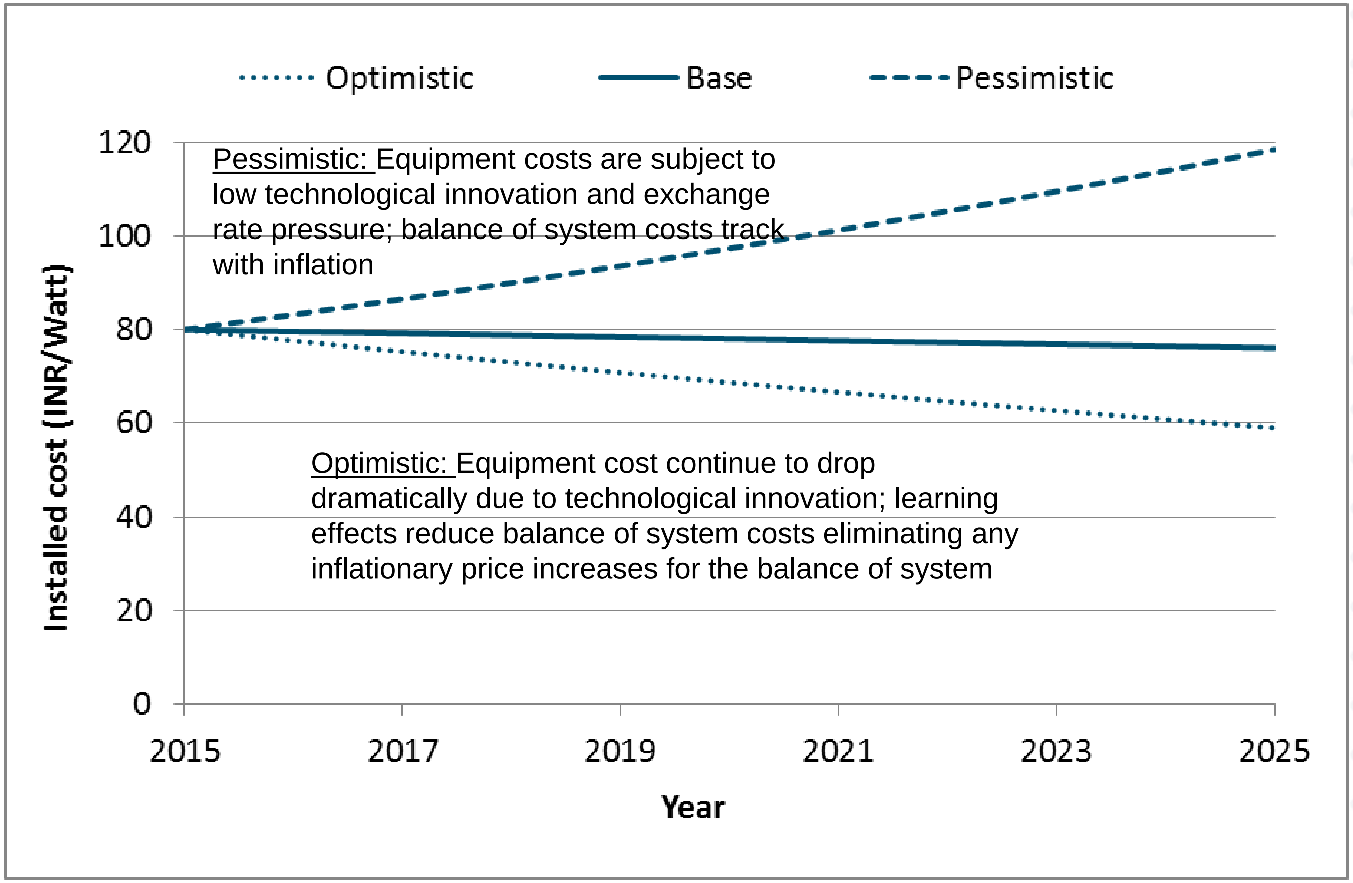
Key drivers influencing solar costs

- We developed “base” solar cost projections along with pessimistic and optimistic projections
- These reflect different relative contributions of the key drivers
- The table below describes the trends of each driver

	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

Installed solar cost trends assumed in this study

+ **After synthesizing effects of these drivers, we arrive at 3 cases for installed cost projections**



Base: Equipment cost declines are moderate with balance of system learning effects counteracting most of inflationary effect

How do you compare costs of different resources?

+ **Lifecycle cost of energy allows us to make comparisons on an "apple with apple" basis**

+ **To compare the cost of solar with alternatives (e.g., coal), we need an appropriate metric**
  - Capex is not suitable
  - Opex is not suitable
  - PPAs are not suitable

+ **Multiple cost streams**
  - Capex, opex, financing (cost of debt, cost of equity), taxes, incentives
  - Each resource (coal, solar) must be assessed taking into account all costs

Coal and fossil: lower capex, higher opex

Solar and renewables: higher capex, lower opex

- $LCOE = \dfrac{\sum_{i=1}^{n} \frac{Annual\ revenue\ requirement}{(1+rate)^i}}{\sum_{i=1}^{n} \frac{Annual\ load}{(1+rate)^i}}$
  - $Annual\ revenue\ requirement = Total\ operating\ expenses + debt\ and\ equity\ costs + taxes$
  - $Rate = weighted\ average\ cost\ of\ capital$

Input assumptions for lifecycle / levelized cost

Common inputs

- Solar capex cost (DC): 80 INR/Watt
- Capacity factor (DC): 17.4 %
- Fixed O&M: 1.5% of current installed solar cost, escalated at inflation
- Return of equity: 15.5%
- Cost of debt: 12.5%
- Debt/equity proportions: 70%/30%
- Degradation: 0.7% per year
- Inflation: 6% year on year

Differing inputs

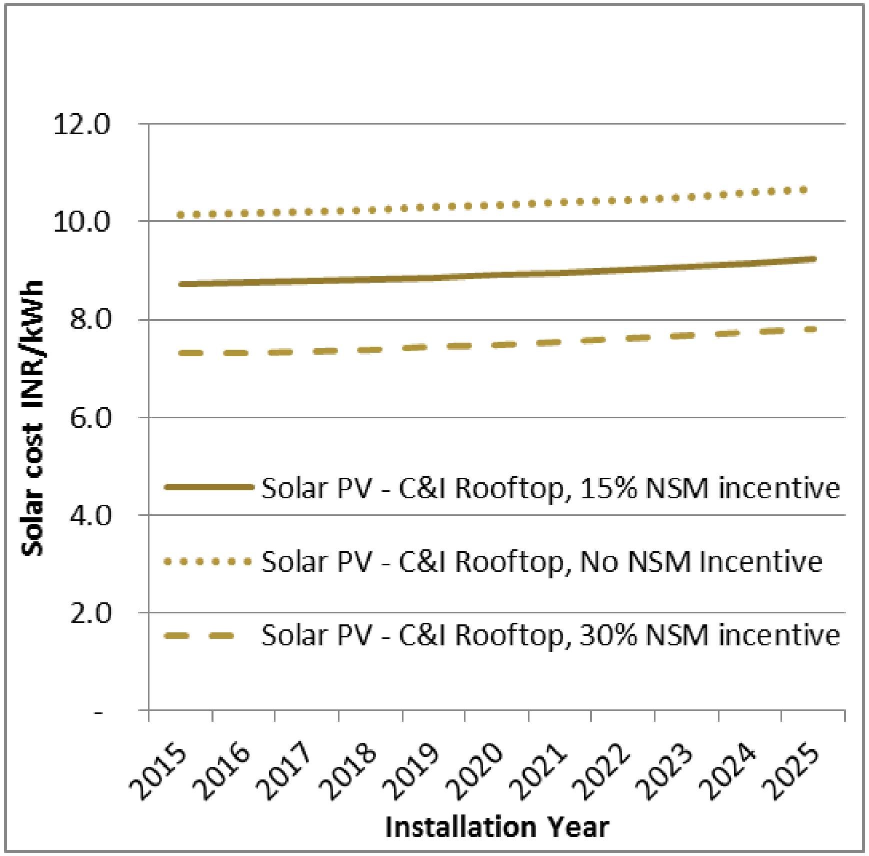
- Optimistic case:
  - Future installed cost: declines 3% per year
  - Cost of debt: 10.5%
  - NSM incentive: included (15%)
- Base cases:
  - Future installed cost: declines 0.5% per year
  - Cost of debt: 12.5%
  - NSM incentive: 3 levels (0, 15, 30%)
- Pessimistic case:
  - Future installed cost: increases 4% per year (sub-inflation)
  - Cost of debt: 12.5%
  - NSM incentive: excluded

Details are in report.

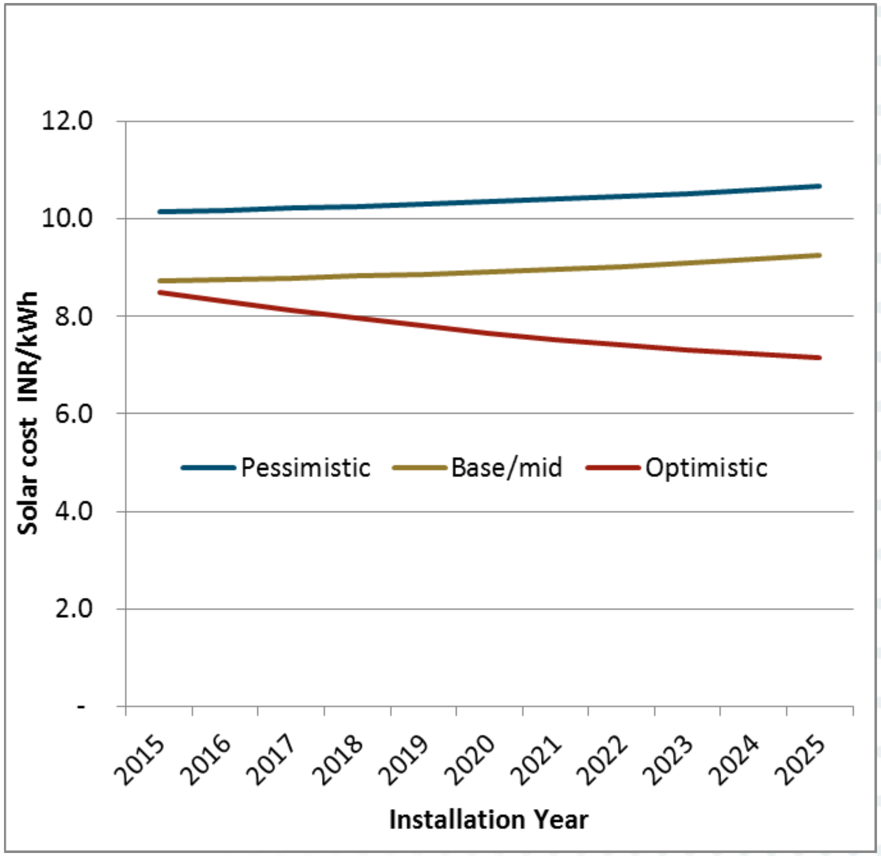
Lifecycle / levelized cost of solar

Figures show levelized solar cost over solar lifetime by installation year

Base case with 3 NSM levels:



Optimistic, base/mid and pessimistic cases:



Solar cost insights

- **Several drivers will impact future solar costs:**
  - Some exert downward pressure, some upward pressure
- **Future installed solar costs may decline or increase**
  - Our base/mid and optimistic cases show declines
  - Our pessimistic case shows increases
- **Installed costs must be converted to lifecycle or levelized costs to incorporate all cost streams**

Is solar economically feasible for C&I sector customers, given current solar costs, NEM policy and NSM incentives?

Key question and approach

Solar adoption in C&I sector under NEM policy

- **Is solar cost effective to C&I customers under NEM?**
  - Comparison of cost of solar to bill savings from NEM
- **How does export vs. onsite consumption affect the value proposition to C&I customers?**
  - Analyzed cases with 0-50% export
- **Assumptions:**
  - TPDDL tariff escalates at 5% per year thru 2020 and 3% after
  - Net exports are priced at average power purchase cost (5.6 INR/kWh)

What are the bill savings to the customer?

- **NEM policy allows the customer to receive a bill credit at the retail tariff for their solar generation**
- **Customers reduce their energy bills as follows:**
  - For each month
    - If solar is consumed on site, the customer's consumption is reduced by the amount of solar generation
    - If there is excess generation, then the excess generation is treated as credit and rolled into the next month as credit
  - At the end of the year remaining "credit" is paid at the "average power purchase cost" (or "export" price)

Example calculation: domestic customer

Domestic example (illustrative numbers):

- 4 kW solar system
- Slabs: 4 INR/kWh to 200 units; 5.95 INR/kWh to 400 units; 7.3 INR/kWh to 800 units; 8.1 INR/kWh to 1200 units; 8.75 INR/kWh above 1200 units

Month	Consumption (kWh)	Bill before PV (INR)	Solar generation (kWh)	Net consumption (kWh)	Bill after PV (INR)	Monthly savings (INR)
1	762	=200x4+ 200x5.95+ 362x7.3 = 4633	438	=762 – 438 = 324	=200x4+124 x5.95 = 1538	3095
…						
11	381	1872	486	- 105	0 (105 kWh is carried forward as credit)	1872
12	564	3187	449	115	115 x 4 – 105 x 4 (true up) = 40	3177
End of year calculation: There are no net energy credits remaining at the end of the financial year. Therefore, no additional payment is made to the customer. (If customer had been a net exporter, they would have received a payment at the APPC rate.)						

Example calculation: commercial customer

Commercial example (illustrative numbers):

- 160 kW solar system
- Tariff (NDHT) is 8.4 INR/kVAh with 20% surcharge for peak period consumption; 25% rebate for off-peak consumption; assume power factor =1
- Peak hours: April-Sep 1500-2400 hr; Oct-Mar 1700-2300 hr
- Off-peak hours: April-Sep 00-0600 hr; Oct-Mar 2300-0600hr

	Consumption before solar			Consumption after solar				
Month	Off peak	On peak	No-peak	Off peak	On peak	No-peak	TOU Adjusted consumption	Rolling credit
1	1132	4057	6529	1132	4006	-10933	-5277	5277
2	1019	3785	6094	1019	3447	-13368	-8467	13744
…								
12	1112	4481	7282	1112	4474	-11771	-4463	68348

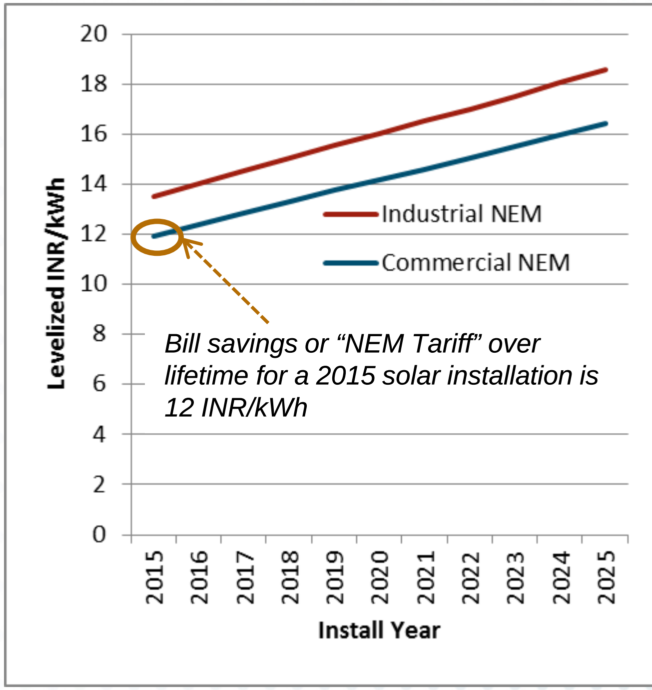
End of year payment for remaining net credit = 68348 x APPC (5.6) = 383,432 INR
In this particular example, the rolling credit increases in month 2 and after because for each subsequent month the consumer continues to be a net exporter. If the consumer had not been a net exporter in month 2, then the rolling credit would have decreased.

Lifecycle bill savings or "NEM Tariff"

For the customer installing solar under NEM policy, savings must exceed cost

- Savings under NEM policy are the "Bill savings" which we refer to as "NEM Tariff"
- "Bill savings" must reflect the payments made for onsite consumption and payments made to customer for exported solar generation
- To facilitate comparison with the lifecycle solar cost, we also represent bill savings as lifecycle number
- We refer to this as "NEM tariff" because this is the payment made, over the lifetime, to the customer
- Lifecycle NEM tariff for a particular installation year takes into account the TPDDL tariff escalation and is thus higher than the tariff in the installation year

Levelized tariff over solar lifetime by installation year

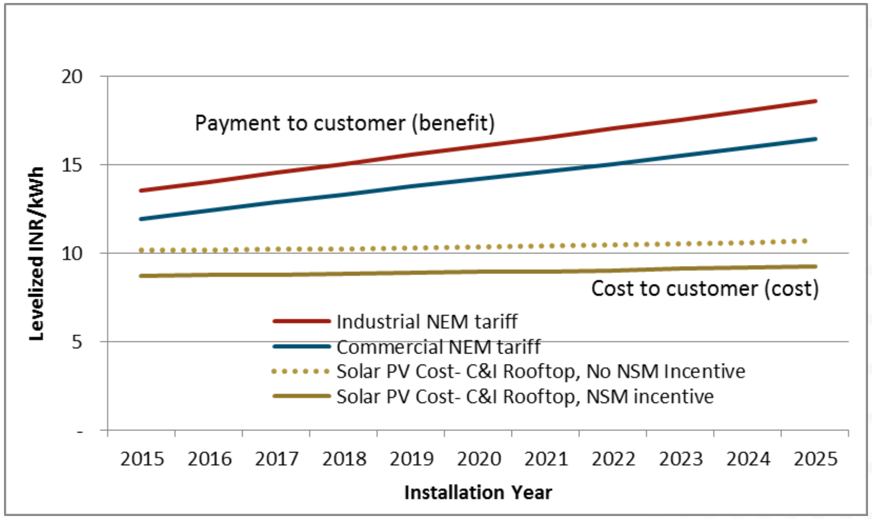


The assumed industrial customer has a higher connected load than the assumed commercial customer, thus is subject to higher tariff.

Compare the solar cost with the NEM Tariff (bill savings)

- **The figure compares the costs and benefits to the customer under the NEM policy**
  - The lifecycle NEM tariff is shown for C&I customers: this is the levelized tariff that the customer is paid for a particular year's solar installation
  - Solar costs with 15% NSM incentive and no NSM incentive shown
- **<u>Key insight</u>: In all cases, the lifecycle solar cost is less than the NEM tariff: customer will save more money through the NEM bill credit than they will pay for the solar**

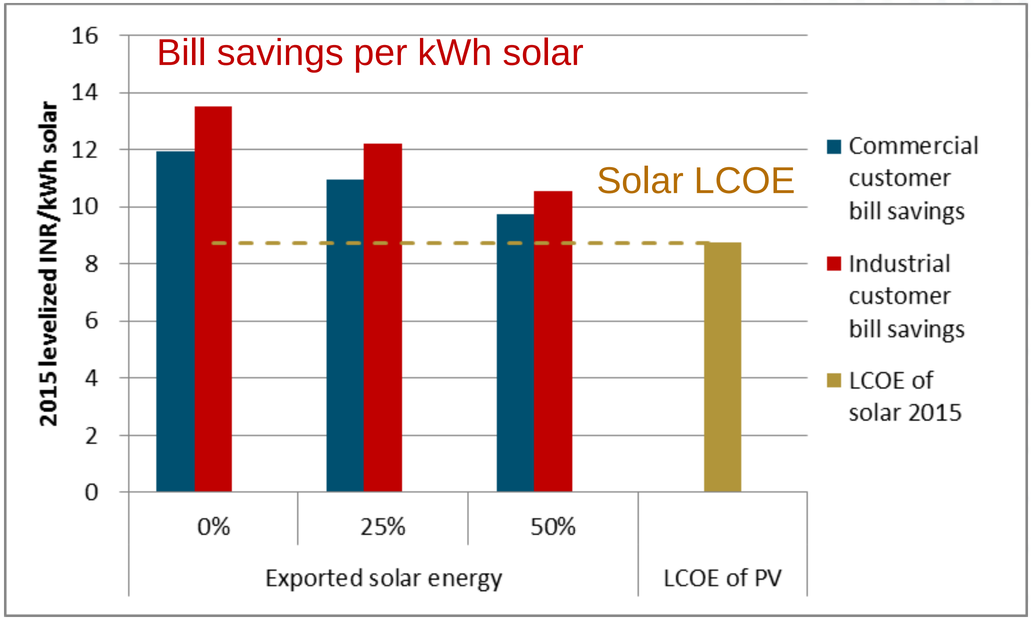
The solar system is sized so that 0% is exported.



Effect of exports on bill savings: 25% and 50% export results

- The figure shows how bill savings per unit of solar decreases as solar is exported
- We show this for two different types of customers using real load data using their tariffs
- At 50% export quantity, solar is still economically feasible to both C&I customers with 15% NSM incentive

Trend: Bill savings per kWh solar decreases as export % increases



NEM policy value proposition to C&I sectors insights

- **NEM policy value proposition to C&I sector: Will C&I customers go for solar?**

- **NEM policy makes solar economically feasible from the C&I customer segment**
  - Economically feasible at 0%- 25% export with & without NSM incentive
  - Economically feasible at 50% export with NSM incentive
- **Solar will become more attractive to C&I sector over time if solar costs decline and tariffs increase**

Value of solar from societal / utility customer perspectives

Key question

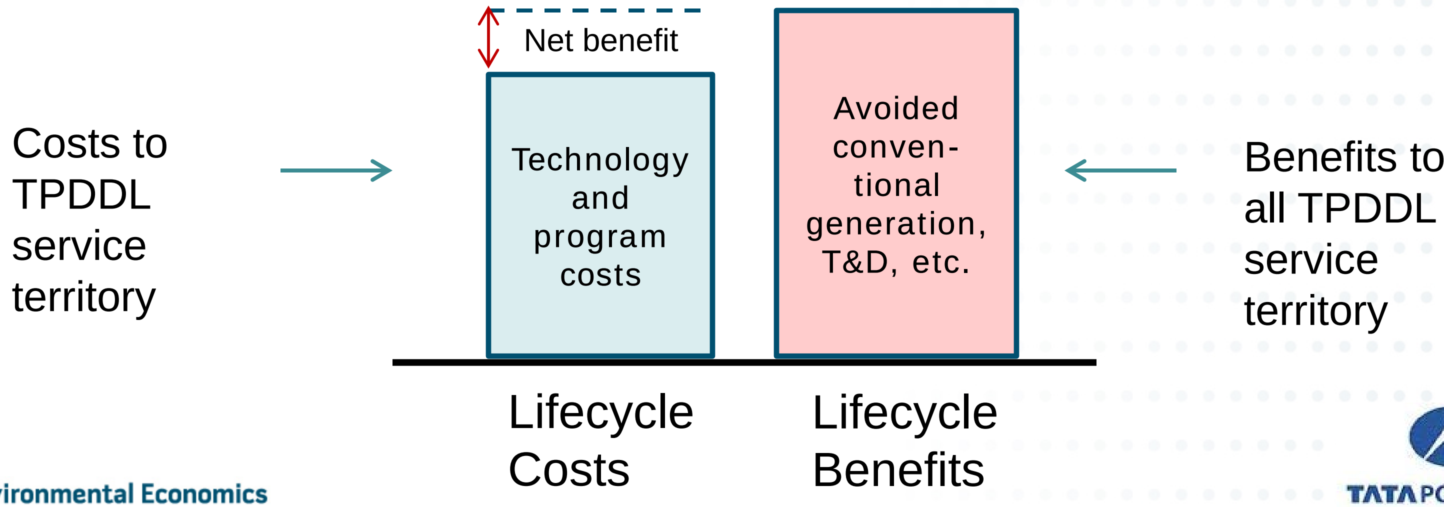
The solar owning customer perspective is only one perspective. The benefits and impacts to ALL utility customers must be evaluated from a regulatory perspective.

Value of solar from societal and utility customer perspectives

- **Will the total costs of energy in the TPDDL service territory increase or decrease with solar?**
- **Known as the "total resource cost" perspective or "wholesale" perspective (vs. retail)**

Valuation framework for regulatory program development

- **Valuation framework is used to estimate net costs to all customers from a solar program**
  - Valuation framework can help TPDDL and regulators answer the question of whether the overall cost of energy supply in the TPDDL territory will increase or decrease with solar
- **The valuation framework estimates how solar (and other DER) can reduce costs**



Two main classes of benefits

- **There are two main classifications of benefits that distributed solar may generate:**
  - Avoided energy or variable costs: fuel, losses
  - Avoided capacity or fixed costs: power plant fixed charges, new transmission and distribution capacity costs

Example: Coal is a fuel cost, which is an energy or variable cost

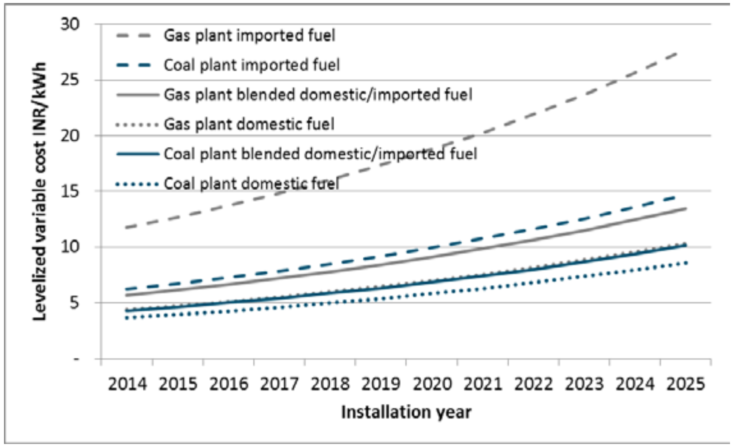
Example: Building a new coal power plant is a capital or fixed cost

Future conventional power: Costs of ‘proxy plant’ resources

+ These figures show levelized variable and fixed costs over time for different proxy plant types

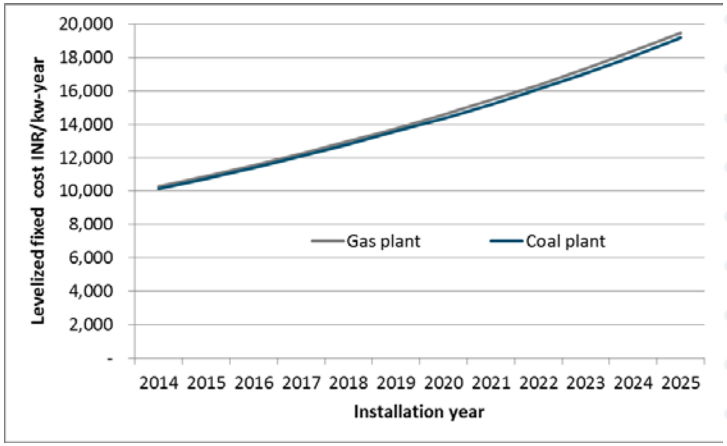
- Wider range of levelized variable costs than fixed costs
- Imported fuels more expensive than domestic

Lifecycle variable cost



Highest levelized variable cost is gas power plant with 100% imported fuel; lowest is 100% domestic coal

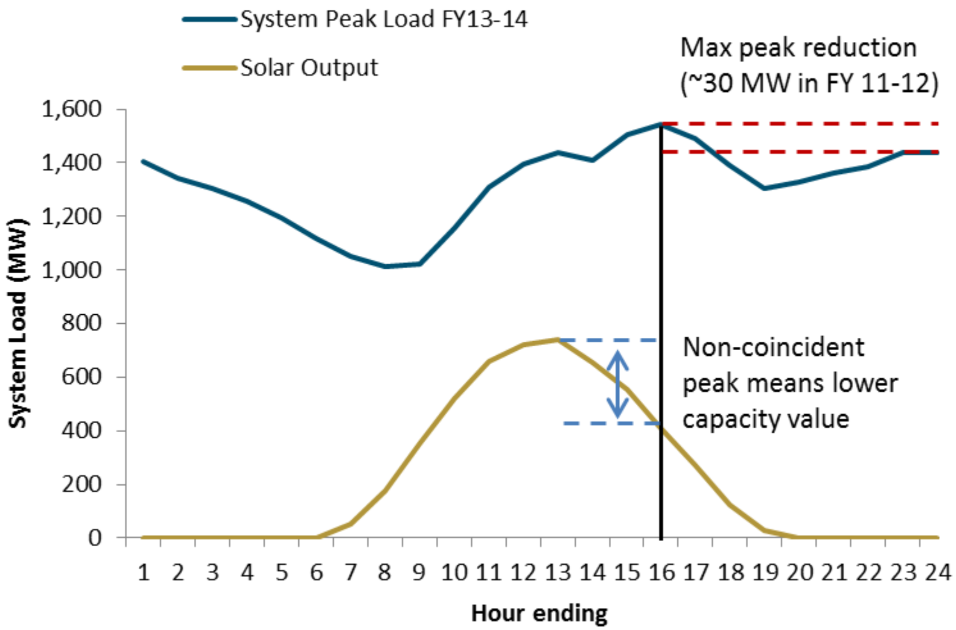
Lifecycle fixed cost



Small differences in fixed cost charges across the power plant types

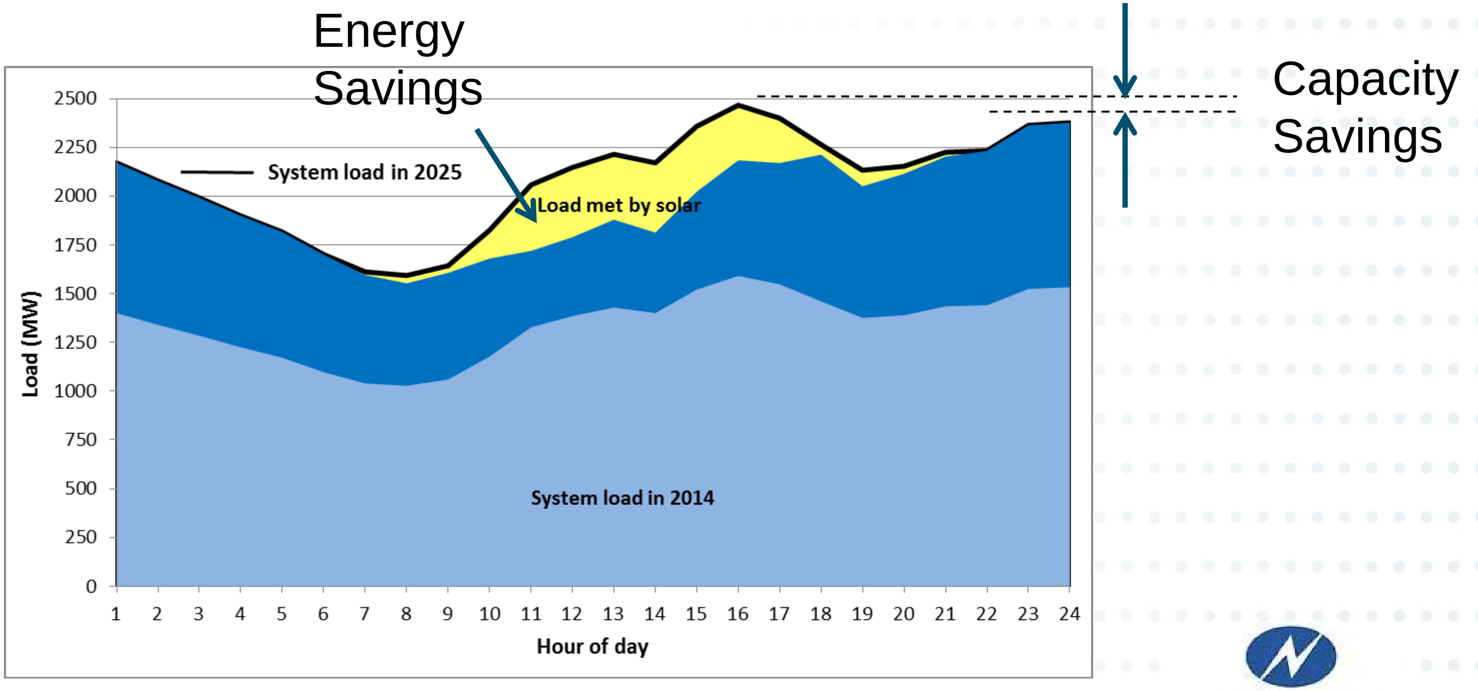
Capacity value depends on solar and system load coincidence

+ **Coincidence is important**
  - We compare output profile of DER to system load
  - Higher coincidence = higher capacity value
+ **There is a ceiling on the <u>capacity value</u> of PV**
  - Effectiveness declines with more MWs of PV (peak is shifted out)



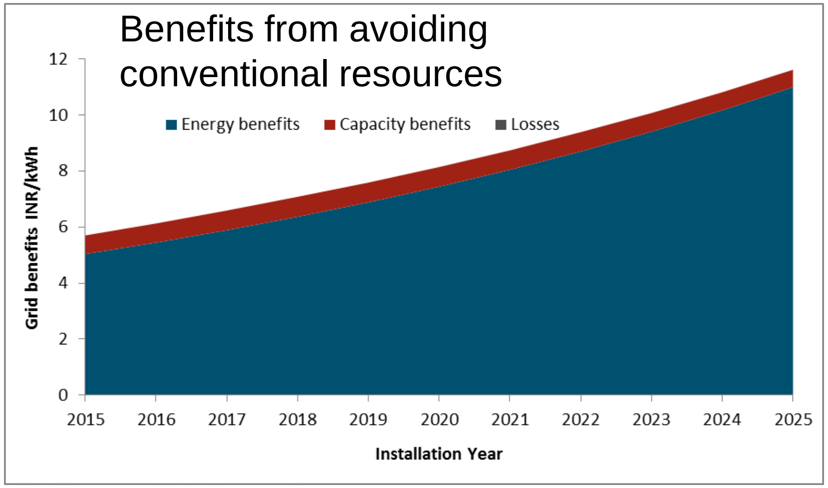
Capacity and energy value of solar

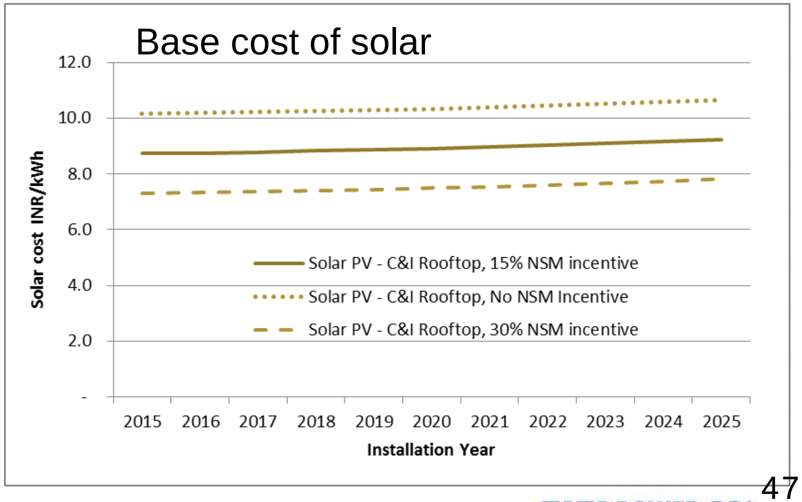
- **Example day (14th July)**
  - Energy savings during the day
  - Capacity savings in early evening
- **Nighttime peak limits solar PV contribution to peak load reductions**



Value of solar portfolio

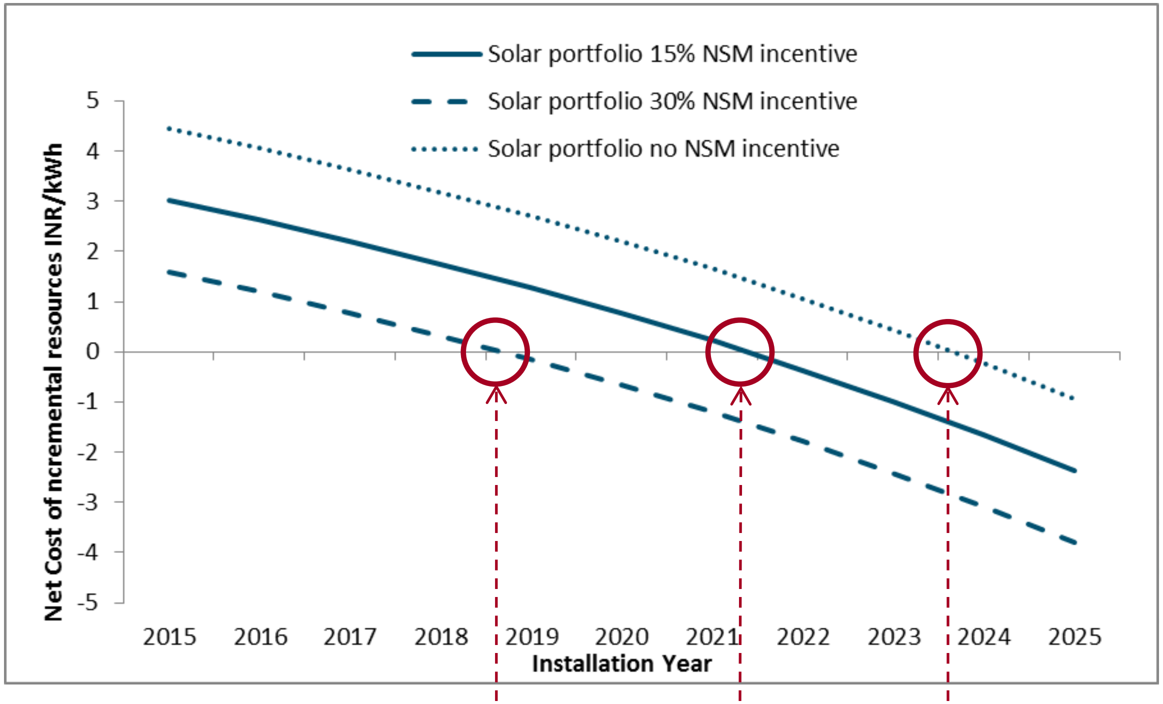
- **Benefits ("avoided costs") of building PV come from not having buying fuel for coal and gas generators, or building new plants**
  - 'Proxy plant' is the assumed avoided generation (fuel purchases) or capacity from building PV
- **Proxy plant choice greatly affects value**
  - Benefits higher when imported coal is displaced in BAU portfolio
  - Benefits lower when domestic coal is displaced in the BAU portfolio
- **Blend of domestic (75%) and imported (25%) coal in base case**





Total net cost of solar portfolio

- Figure shows net cost for solar portfolio (costs – benefits)
- Solar becomes cost effective under the base case proxy plant resource assumption as follows:
  - 2019 with 30% NSM incentive; 2022 with 15% NSM incentive; 2024 with 0% NSM incentive



Years when solar becomes "cost-effective" with 30%, 15%, 0% NSM incentive levels.

Development of two additional cases to explore uncertainty

- **Purpose: better understand the range of results and risks to TPDDL's customers**
- **Key drivers: solar and fuel costs, financing**

Case	Optimistic	Base/Mid	Pessimistic
Solar cost	Low	Base	High
Avoided cost	High	Base	Low
NSM incentive	Included (15%)	Included (15%)	Excluded
Solar capex	Declining 3%	Declining 0.5%	Increasing 4% (sub-inflation)
Financing cost of debt	TPDDL financing	3rd party developer financing	3rd party developer financing
Displaced fuel of proxy plant	95% coal (50% imported/50% domestic); 5% imported gas	75% domestic; 25% imported coal	100% domestic coal

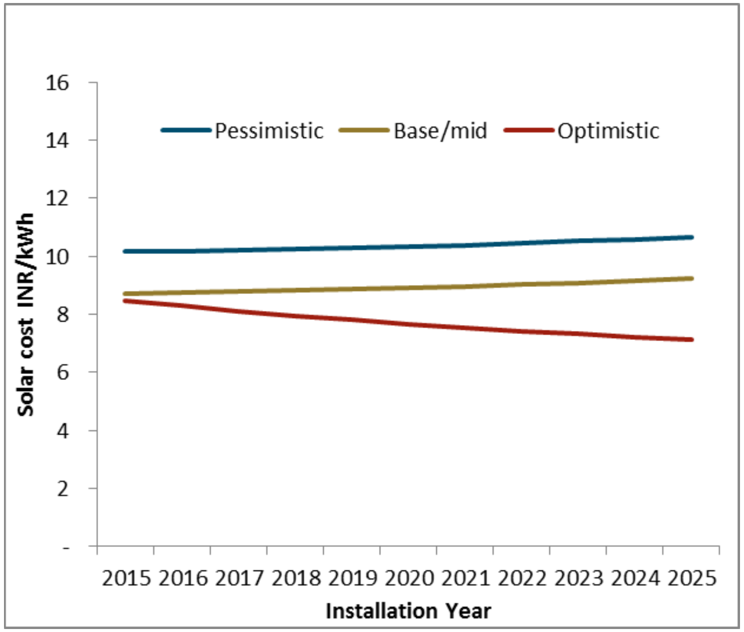
Two additional cases: "optimistic" and "pessimistic"

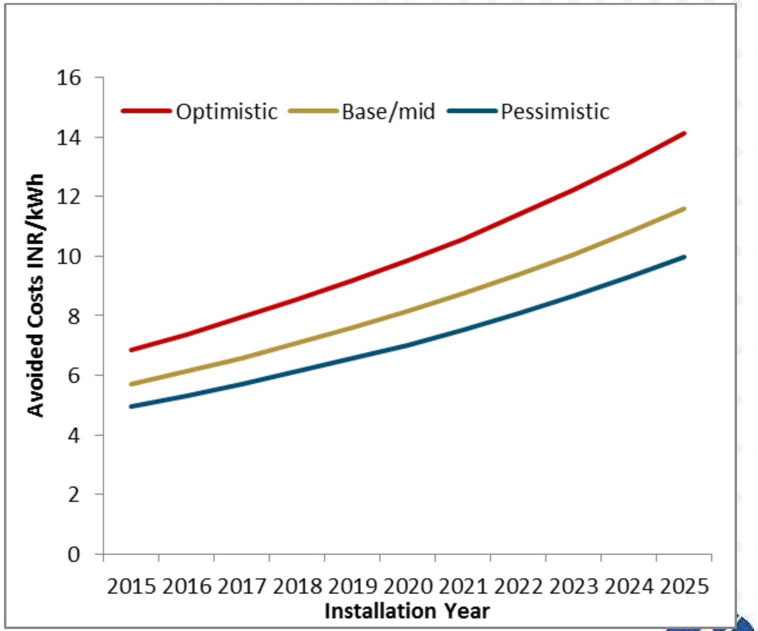
Optimistic, base and pessimistic cases: Costs and value of solar

Cost and benefits for the three scenarios are shown

- Significant differences in costs: by 2025, the cost projections vary by 4 INR/kWh

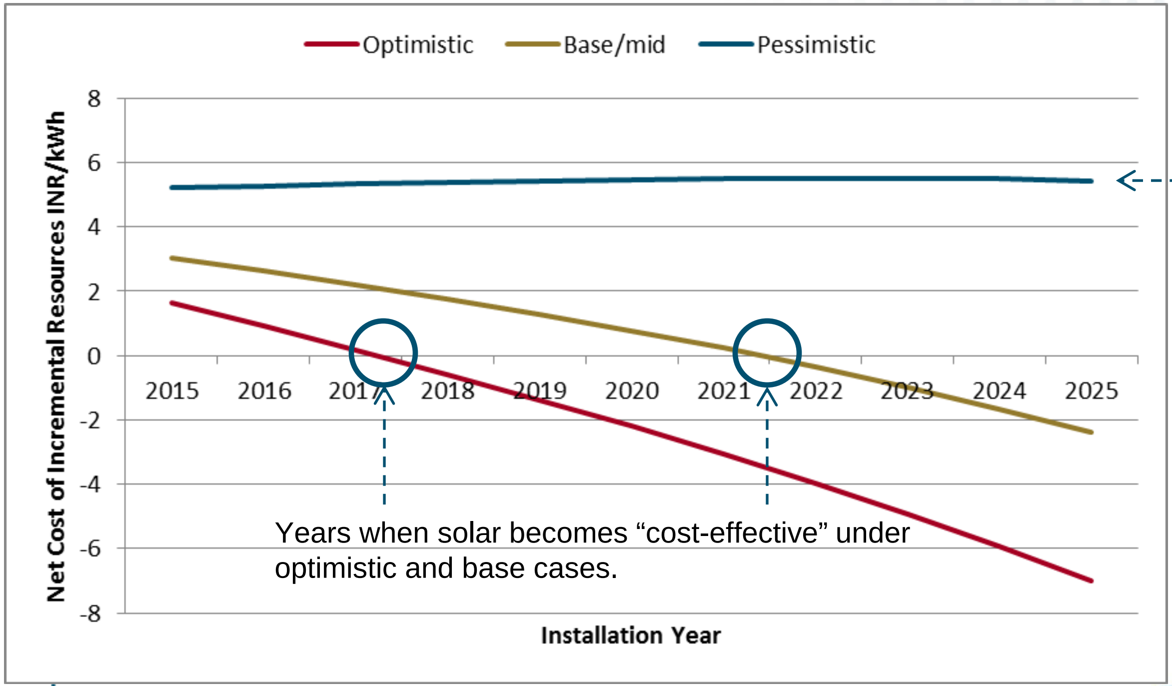
- Benefits higher when imported coal and natural gas is displaced
- Benefits escalate more rapidly than solar costs





Optimistic, base and pessimistic cases: Net cost of solar

- **Net cost for the three scenarios is shown**
- **The results show significantly different trends**
  - Optimistic scenario is becomes cost effective in ~ two years; pessimistic scenario is never cost-effective
  - Base scenario becomes cost effective by 2022 and is within ~2.5 INR/kWh of being cost effective in 2016



Under pessimistic case, solar would not become cost-effective for a very long time.

Insights on 'societal / all utility customer' perspectives

- **Value of solar from societal and an all customer perspective: Will solar save money for all Delhiites in TPDDL service territory?**

- **From a "societal / all utility customer" perspective, we need continued solar costs declines to reach cost-effectiveness**
  - In the base cases, solar becomes cost-effective between 2019-2024: With 30% NSM incentive by 2019; with 15% NSM incentive by 2022; without NSM incentive by 2024
  - Solar is cost effective in two years under optimistic case due to greater solar cost declines and increased dependence on imported fuel
- **In the near term, NSM incentives or other central level incentives can support the public case for solar in Delhi**
  - Incentives can come in multiple forms, such as tax incentives (e.g., removal of MAT, AD), additional capex incentive.

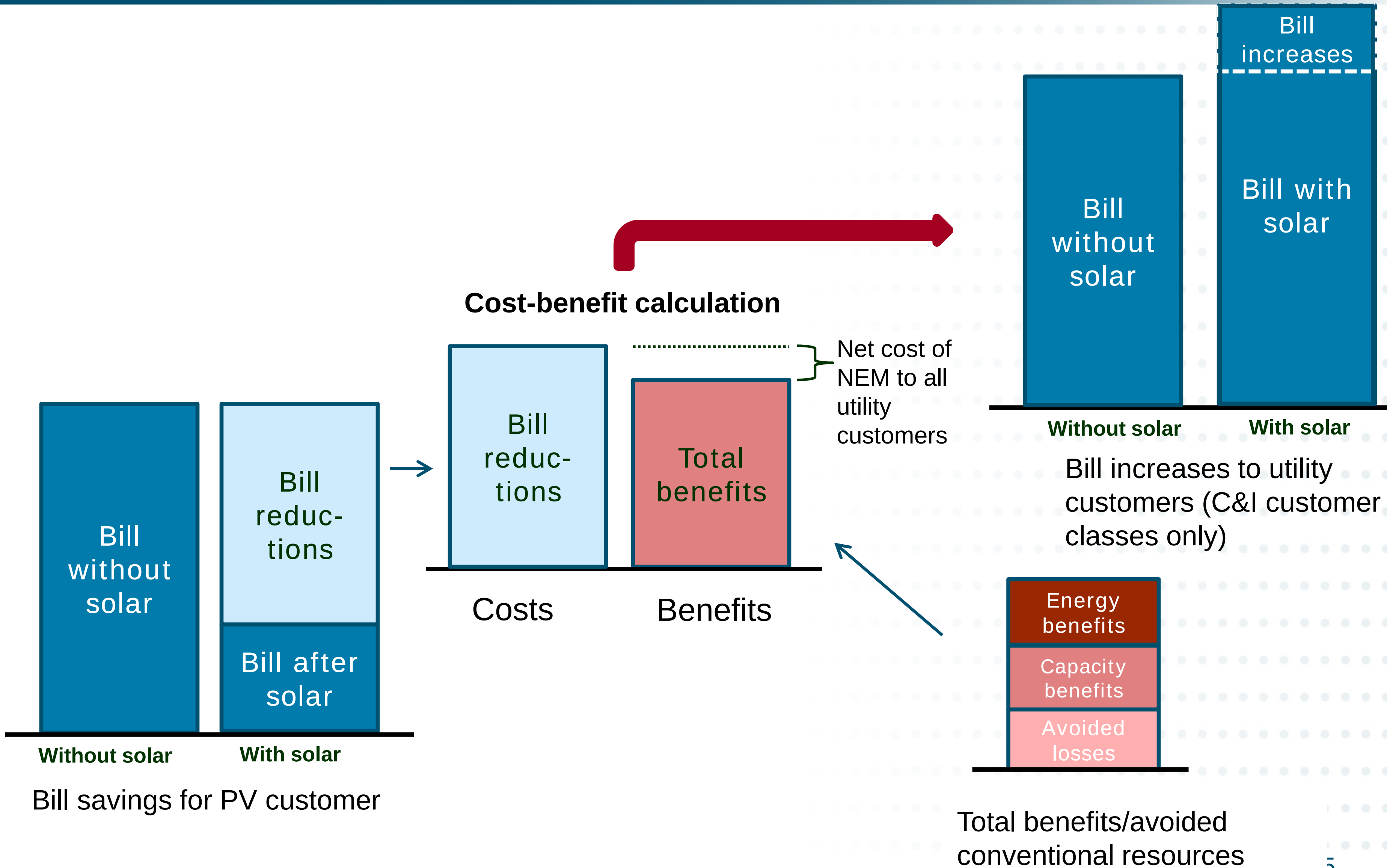
NEM policy tariff impact and alternative policy

Key question and approach

NEM policy analysis

+ **What is the tariff impact from the NEM policy?**
+ **What alternative solar policy can minimize tariff increases to TPDDL's customers?**
+ **Analysis:**
  - Assess the tariff impacts of the NEM policy
  - If tariff impact exists, what is an alternative policy
  - Tariff impact = Utility revenue losses (bill savings to customers adopting solar) minus utility resource cost savings (avoided cost benefits)
  - Note: Our estimates of the tariff impacts are contained to the C&I sectors, which are the sectors likely to benefit most from the NEM policy

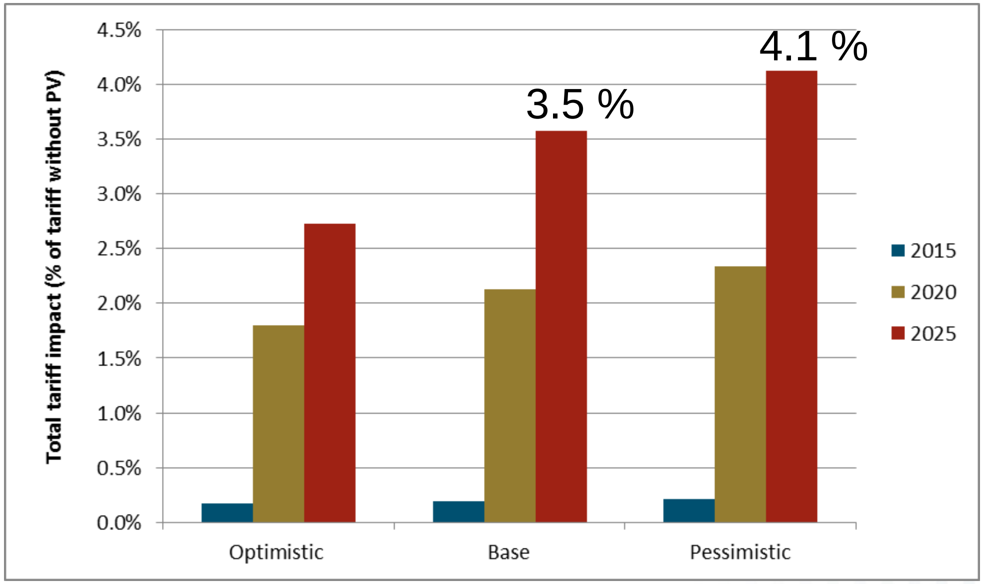
NEM policy tariff impact cost benefit methodology



Tariff impacts under NEM policy

- **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 utility are less than the bill savings from NEM**

Note: We contain the tariff increases to the C&I sectors, which are the sectors likely to benefit most from the NEM policy



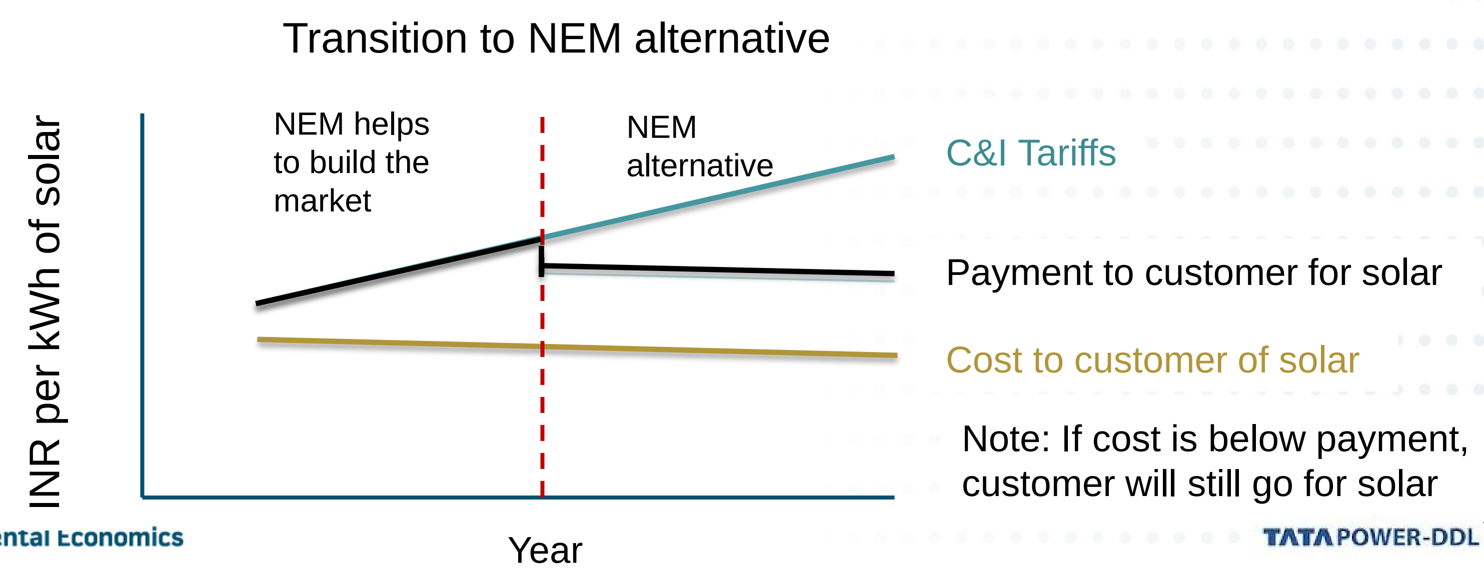
Penetration:
10 MW (2015)
160 MW (2020)
440 MW (2025)

For commercial tariff (NDHT)

NEM Policy alternative design

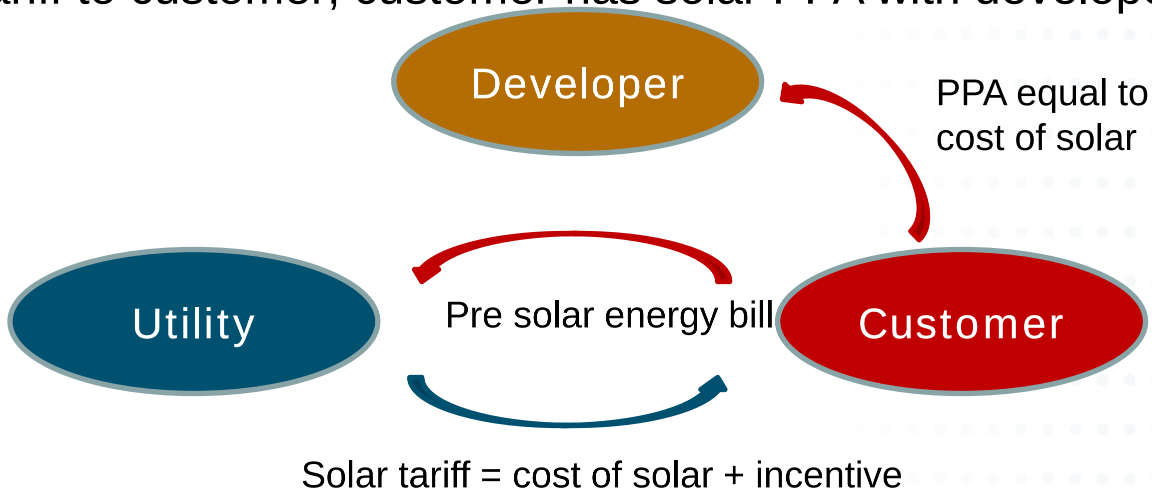
- **DERC could transition to a NEM alternative policy as solar costs to decrease that can sustain a solar market and reduce costs to utility customers**
- **Example alternative for our analysis is a Solar Tariff set at 1 INR/kWh above the cost of solar escalated at the tariff escalation rate**
  - The "1 INR/kWh" is a customer rooftop incentive payment

Diagram shows a concept. No numbers are shown by purpose.



How the NEM Alternative Works

Illustrative example business model and flow of payments: Utility provides solar tariff to customer; customer has solar PPA with developer



Other business models are possible: e.g., utility PPA with developer where utility/customer arrangement remains same.

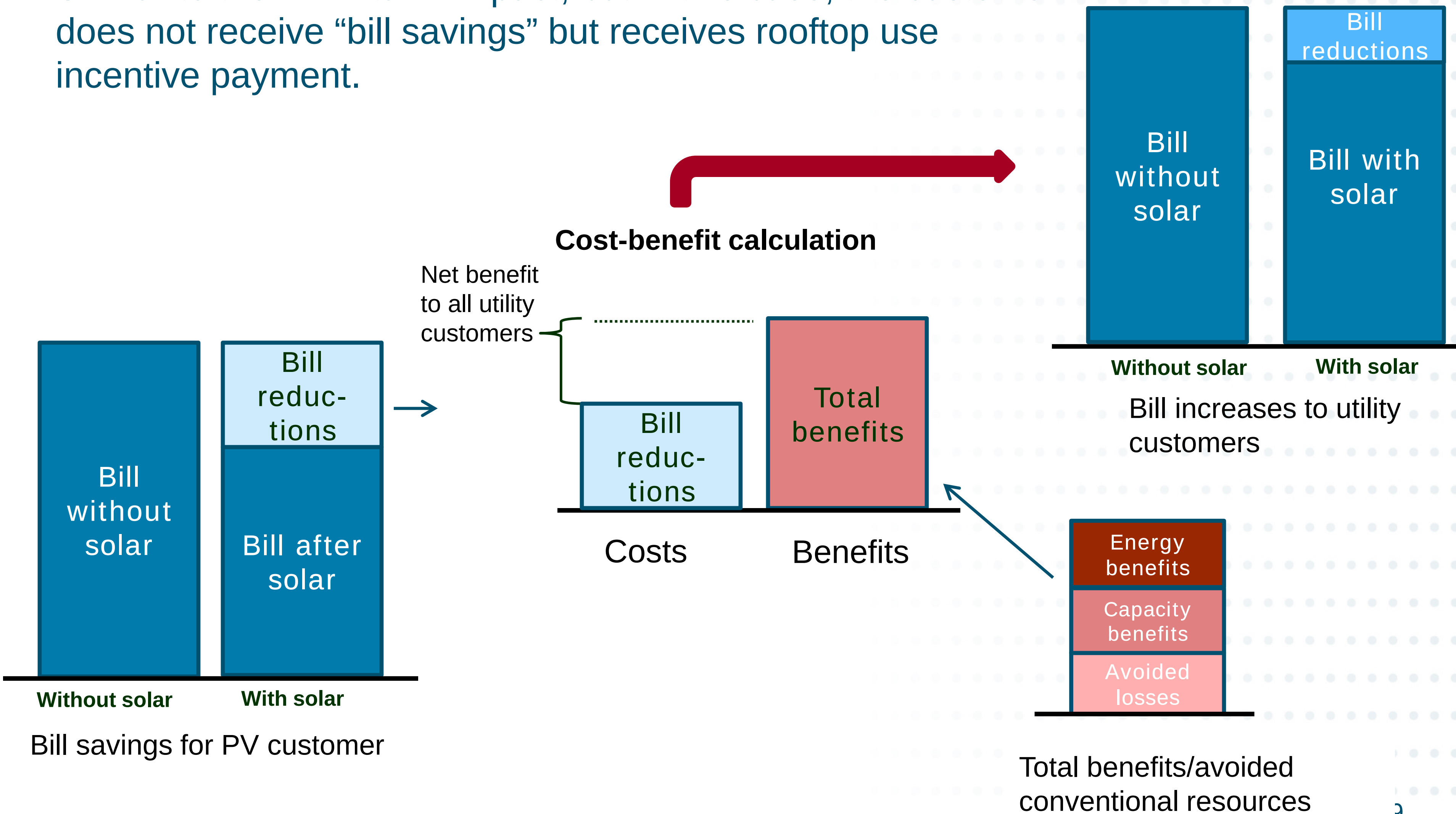
Domestic example under the above business model:

- **Assume cost of solar = 8 INR/kWh**
- **Solar tariff = Cost of solar + rooftop incentive = 9 INR/kWh**

Month	Consumption (kWh)	Bill before PV (INR)	Solar generation (kWh)	Solar tariff payment to customer	Bill after solar payment (INR)
1	762	4633	438	=438 x 9 = 3942	691

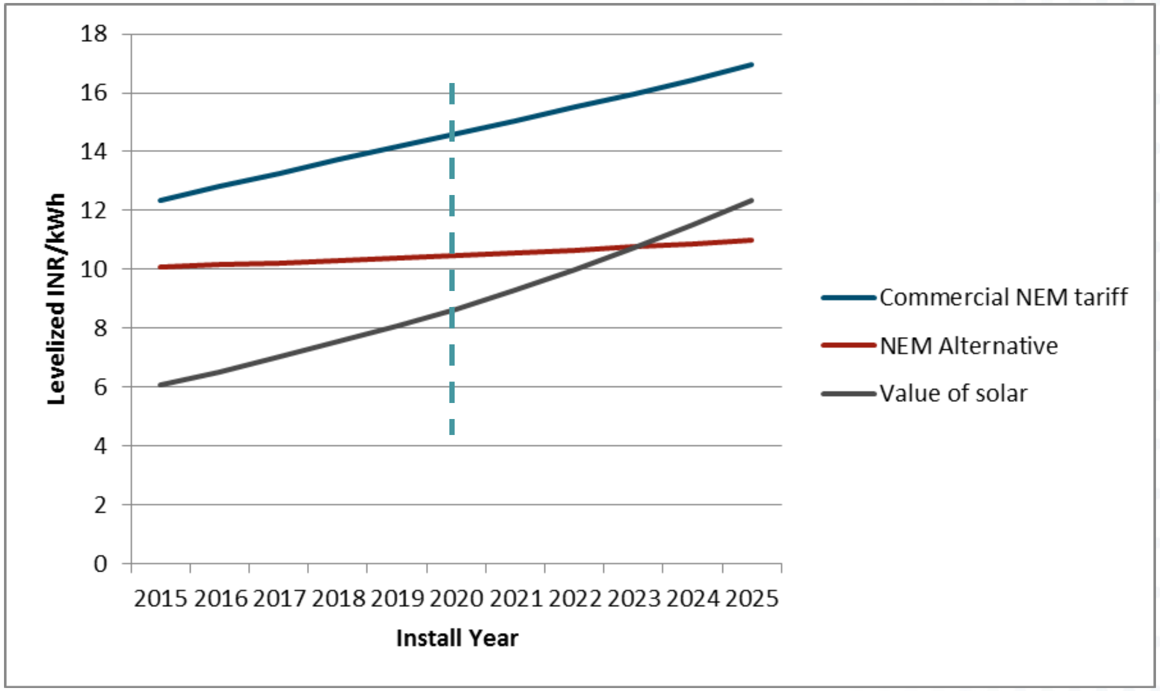
NEM Alternative policy tariff impact cost benefit methodology

Similar to the NEM tariff impact, but in this case, the customer does not receive "bill savings" but receives rooftop use incentive payment.



Comparing customer adoption between NEM and NEM Alternative policies

- As solar becomes more cost-effective, a transition to the NEM Alternative policy will mitigate the tariff increase



NEM alternative design is based on the solar cost with rooftop leasing payment

Transition could occur around 2020 when NEM policy will be revisited by DERC

Energy+Environmental Economics

TATA POWER-DDL

Comparing customer adoption between NEM and NEM Alternative policies

- Transition to a NEM alternative can mitigate tariff increases, potentially reducing tariffs
- In this example, we transition away from NEM by 2020

Tariff impact if transition away from NEM occurs by 2020

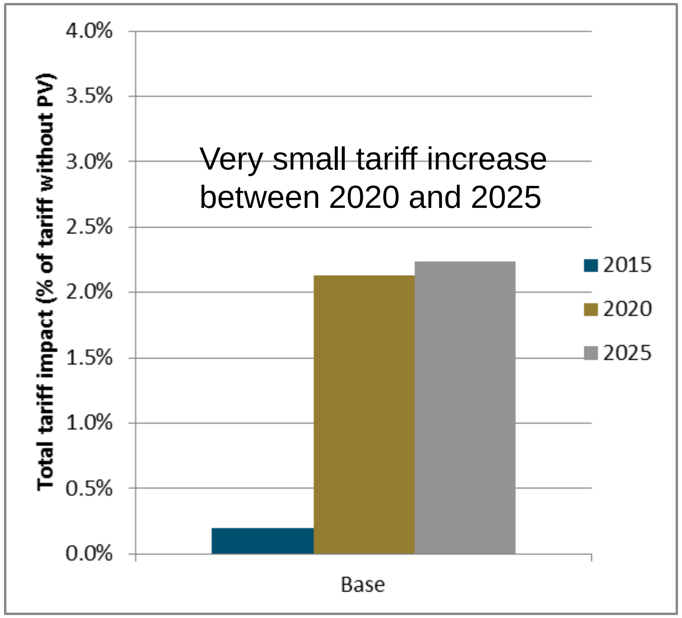
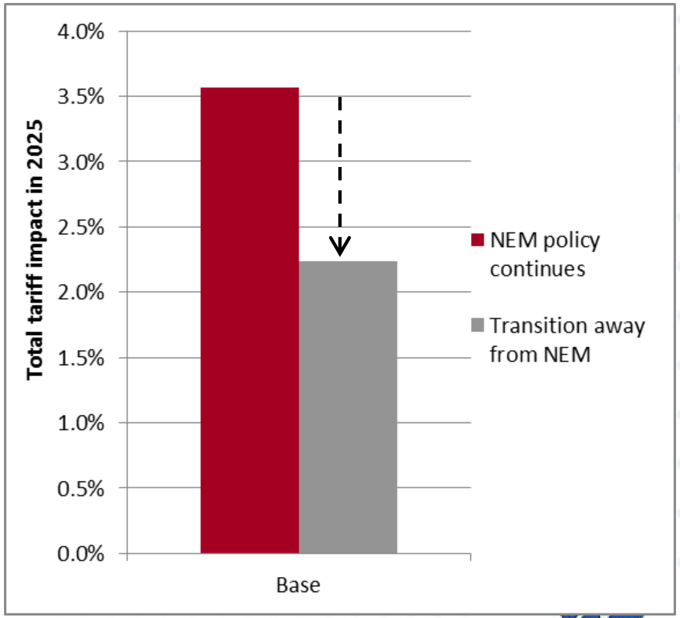


Figure compares tariff impact if NEM continues vs. transition occurs in 2020



NEM Alternative policy insights

+ **NEM policy alternative**
  Is there an alternative policy to NEM that can help minimize tariff impacts?

+ **NEM may promote adoption but will result in tariff increases**
+ **Over the long term, a transition from the NEM to NEM Alternative may be beneficial to Delhi customers**
  - NEM Alternative can avoid the tariff increases that NEM policy will create
  - Transition from NEM can occur after a set number of years or after capacity limit is reached (e.g., 100 MW)
  - If NEM sends an insufficient price signal, NEM Alternative can be set at a higher level compared to the NEM to encourage adoption

Value of mixed DER portfolios (solar, DSM, demand response, storage)

Key question and approach

Value of mixed DER portfolios

- **Will the total costs of energy in TPDDL service territory increase or decrease with portfolios that combine solar with DR, DSM, storage?**
- **Apply the "total resource cost" perspective or "wholesale" perspective**
- **Analysis:**
  - Comparison of lifecycle DER portfolio costs with benefits (avoided conventional resources or "avoided costs")

Description of mixed DER portfolios analyzed

+ Three DER portfolios were analyzed

Portfolio	DER technologies	Installation targets (2025)
1	Solar	440 MW solar
2	Solar, DSM/energy efficiency, demand response	440 MW solar 48 MW DSM/EE 42 MW DR
3	Portfolio 2 with the grid battery storage	440 MW solar 48 MW DSM/EE 42 MW DR 15 MW grid storage

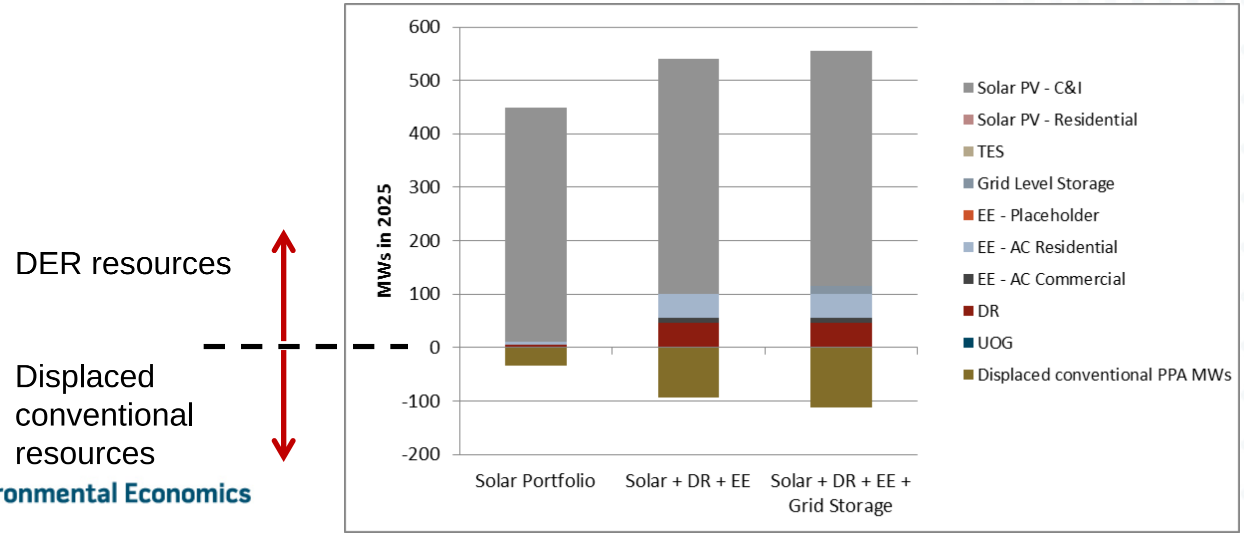
Star system for energy efficiency

Battery

See report for additional portfolio substituting grid battery storage with thermal energy storage in the report

Comparison of resource procurement across DER portfolios

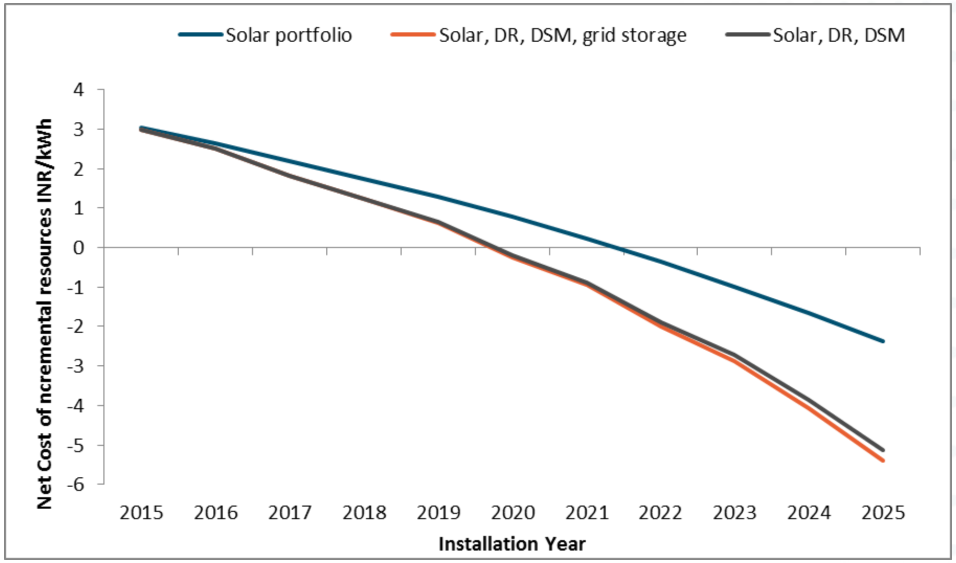
+ **Mixed DER portfolios can help avoid procurement of conventional resources because solar has limited capacity value**
  - Solar only portfolio (440 MW) reduces conventional resource procurement by 35 MW in 2025
  - Portfolios that also include DR and DSM reduce avoids 93 MW in 2025
  - Adding grid storage to the portfolio avoids 111 MW in 2025
+ **TPDDL experience with DR & DSM can be leveraged and scaled**
+ **Can offer more value to the grid and to customers by packaging different resource types**



Comparison of cost effectiveness across all the DER portfolios

+ The mixed DER portfolios are more cost effective than the solar only portfolio:

- DR is more cost effective (using TPDDL's pilot costs) than solar or any other resource for providing capacity value
- DSM/energy efficiency is assumed to be more cost effective than solar and provides excellent capacity and energy value
- Modest levels of grid storage further lowers portfolio cost



Combined DER portfolio insights

- **Value of mixed DER portfolios**
  Can other resources – energy efficiency, demand response, storage – bring down the cost?

- **Other DER can help lower overall costs, from a total resource cost perspective**
  - Most DSM/energy efficiency is cost effective compared to solar
  - DSM reduces revenue to utility but reduces costs overall to customers
- **Other DER bring complementary benefits to solar**
  - Demand response, 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

Additional benefits of DER not quantified

- **We developed 3 cases to explore the impacts of different conventional fuel cost projections and solar cost projections**
- **We did not quantify economically the impact of the following benefits:**
  - Greater certainty on cost of supply
  - Lower vulnerability to exchange rate risk that further increases conventional imported fuel costs
  - Greater energy security due to less dependence on conventional fuel
  - Health benefits from improvement in air quality

IMPLEMENTATION

Implementation

- **Identify key markets for solar**
  - Begin offering C&I customers quality and financially attractive rooftop solar systems
  - Address new construction through codes and standards, partnerships
- **Standardize and improve quality**
  - Streamline the interconnection process for customer DG
  - Develop standards to ensure quality of solar installations; monitor and track system performance and costs
- **Manage utility portfolio**
  - Further develop complementary programs: DSM/EE, DR to maximize utility value from the solar
  - As the installed solar increases, manage the conventional supply portfolio in a complementary manner
- **Transition strategy from NEM if tariff impacts increase to level of concern**

International best practices and lessons on solar

+ **India can learn from the best practices and lessons that other countries have made in developing their solar markets**

Arizona Utility Gets Approval for High Monthly Demand ...
Greentech Media - Feb 27, 2015
Solar rate changes will add about $50 to the average **solar customer's** bill, ... **charge**" based on the **customer's** peak **demand** during the **month**, ...

Feb 27 2015 Greentech Media

German cabinet approves 1.2GW of PV tenders to 2017

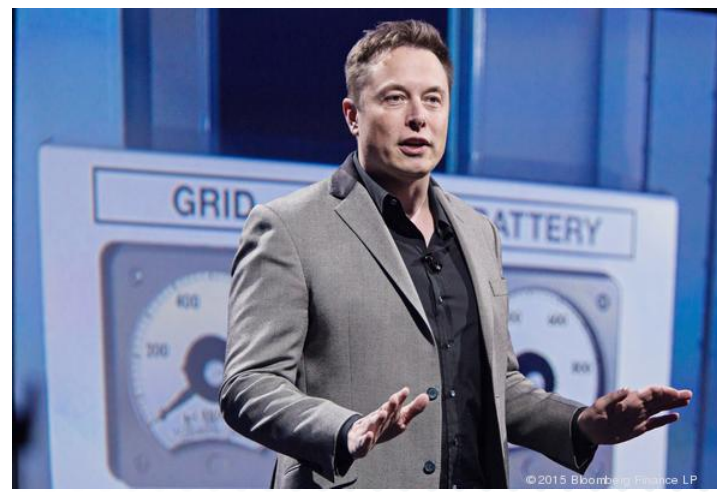
Angela Merkel and her energy minister Sigmar Gabriel — Bundesregierung

By Bernd Radowitz in Berlin Wednesday, January 28 2015
Updated: Wednesday, January 28 2015

SHARE STORY

Jan 28 2015 Rechargenews

SolarCity offers off-grid, Tesla battery storage systems to Hawaii residents



May 1 2015 Pacific Business News

Lessons on solar policy & tariff design

+ **<u>Key insight</u>: NEM is effective to get the market going but is very difficult policy to sustain over the long term**

  - <u>Advantages of NEM</u>: NEM for rooftop solar has been popular in the United States; easy to understand; allowed for market installers — SunRun, SolarCity, Sungevity to build models
  - <u>Disadvantages of NEM</u>: Often results in a transfer (cross-subsidy) because tariffs include the cost of building out and maintaining the grid
  - <u>NEM Alternative</u>: 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. The payment could be very high (e.g., Germany) comparable to value of solar
  - <u>Moving away from NEM</u>: 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.

Lessons on solar performance and cost

+ Maintenance: This is very important to achieving high solar performance

+ Rooftop solar costs: have dropped considerably in regions with high solar adoption —experience reduces labor hours and construction costs; streamlined permitting and interconnection

+ 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

Lessons on interconnection procedures

+ **Historically, most utilities have not collected real-time solar generation data and do not have visibility into the solar (utility meters run "backwards")**
  - Third party developers like Solar City monitor their solar installations but have not necessarily shared this with utilities or grid operators
  - Grid operators, also, have not had visibility into distributed solar which is creating operational challenges
  - Distributed solar has created challenges for forecasting load
  - Planning with large amounts of behind the meter solar impacts the ability to interconnect utility scale and "front of the meter" solar
+ **Interconnection processes have become more streamlined in the last few decades**
+ **Historically, most utilities have not anticipated the necessary grid investments associated with larger amounts of distributed solar**

Recommendations on interconnection procedures

- **Process**: Streamlining the process is critical to expand the distributed solar market; Clear timelines, steps and communication between customer and utility reduce barriers to adoption
- **Targeting**: Identify "easy to interconnect" resources on a substation or ideally at the feeder level. Easy interconnections do not require upgrades.
- **Advanced inverters**: These can improve interconnection by providing voltage support and islanding based on real time grid conditions
- **Setting limits**: Early interconnection of distributed generation in the United States imposed strict limits on local resources. Penetration thresholds have been relaxed as the effects of solar have become better understood and as more data is available.
- **Monitoring and visibility**: Meter solar systems and connect to the SCADA systems so that operators have visibility into performance.

Quality control for solar

+ **Develop a set of best practices that expands the 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

Role of codes and standards

+ 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

Leveraging non-solar DER for solar integration purposes

+ **<u>Key finding</u>: Other DER provide greater capacity value than solar and should be incorporated into DER programs to lower overall costs and integrate solar resources**

  - Due to high nighttime loads, energy efficiency (HVAC based EE) is very valuable and helps reduce the need for both energy and capacity resources.
  - Grid storage and demand response are very valuable to the utility on a capacity basis because they are dispatchable.
  - Customers can be targeted simultaneously for solar, demand response, thermal storage and energy efficiency
  - C&I customer types are the types of customers that are more likely to be able to adopt these other DER resources.

Leveraging smart grid investments to motivate DER: smart meters

- **Use customer interval data to identify suitable customers for different DER applications**
  - Customers with large evening loads, driven by air conditioning, could be good candidates for AC based DSM/EE
  - Customers with high contribution to peak load for a few hours can be targeted for DR
  - Customers with late afternoon and early evening cooling loads may be suited for TES
- **Utilize AMI to automate and facilitate implementation of demand response (Auto DR)**

Leveraging smart grid investments to motivate DER: GIS systems

- **Use GIS system to enhance DER program design and customer targeting**
  - Generate solar potential estimates using GIS and make this information available to customers (Sungevity uses GIS in this way)
  - Identify the types of energy efficiency technologies that might be suited for different types of customers and make this information available to customers and certified ESCOs

TPDDL pilot installation

+ **TPDDL intends to evaluate DER technologies using a pilot study at a TPDDL owned facility**
  - Possible locations include grid substation or TPDDL building
  - DER technologies to include grid-interconnected solar systems with possibility of grid-storage

TPDDL intends to move forward with a pilot and is dedicated towards nurturing and building a broader solar and DER market.

A view of the 66kV Rohini-28 grid substation.

Broader implications across India

- **This opportunity is scalable across India**
  - Market development will be greater as other areas form a rooftop market
  - Regions with more reliance on backup generation have higher value though offset diesel
- **Path to achieving the greater social benefits with increased scale**
  - Improved air quality
  - Reduced coal and other fossil fuels
- **Analytical methods are adaptable across regions and technologies**

Thank you!

+ **Thank you for your kind attention.**
+ **Next steps:**
  - Finalizing the report, which will be made public
  - We will incorporate feedback from this workshop
  - Please feel free to reach out to us if you have any questions/comments regarding the study.
+ **Speaker contact information:**
  - Dr. Priya Sreedharan (*)
    priya@ethree.com or psreedharan@usaid.gov
  - Amy Guy Wagner
    Amy@ethree.com

* Dr. Sreedharan is presently on sabbatical from E3 for a fellowship with the US Agency for International Development

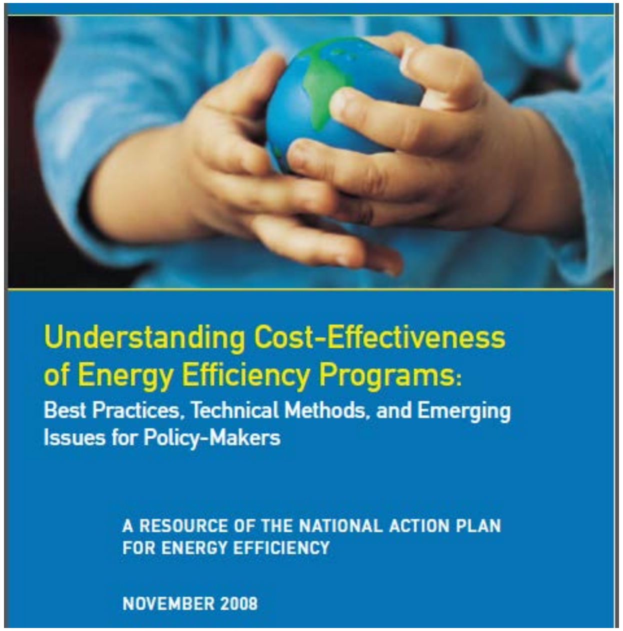
E3 extends its deepest gratitude to the entire TPDDL team who were incredibly supportive during the study and a pleasure to work with.

APPENDIX

COST EFFECTIVENESS METRICS

Background on cost-effectiveness analysis methods

- Origins are in integrated-resource planning: efficiency is compared against supply-side options
- The framework is used to analyze and support utility programs, labels, standards for distributed energy resources, but has broader applications



A public/private initiative facilitated by the US Environmental Protection Agency and US Department of Energy

Format of metrics

- The whole project has used the C/E framework but in previous slides, we have shown results in a form that is intuitive to any audience
- Normally, cost test metrics are shown as a benefit to cost ratio:

$$\frac{\text{Lifecycle DER Benefits}}{\text{Lifecycle DER Costs}}$$

  - Ratio greater than 1 means DER is cost effective
  - Ratio less than 1 means DER is not cost effective
- Benefit to Cost ratio provides simple metric to evaluate and compare cost effectiveness of different types of technologies, programs

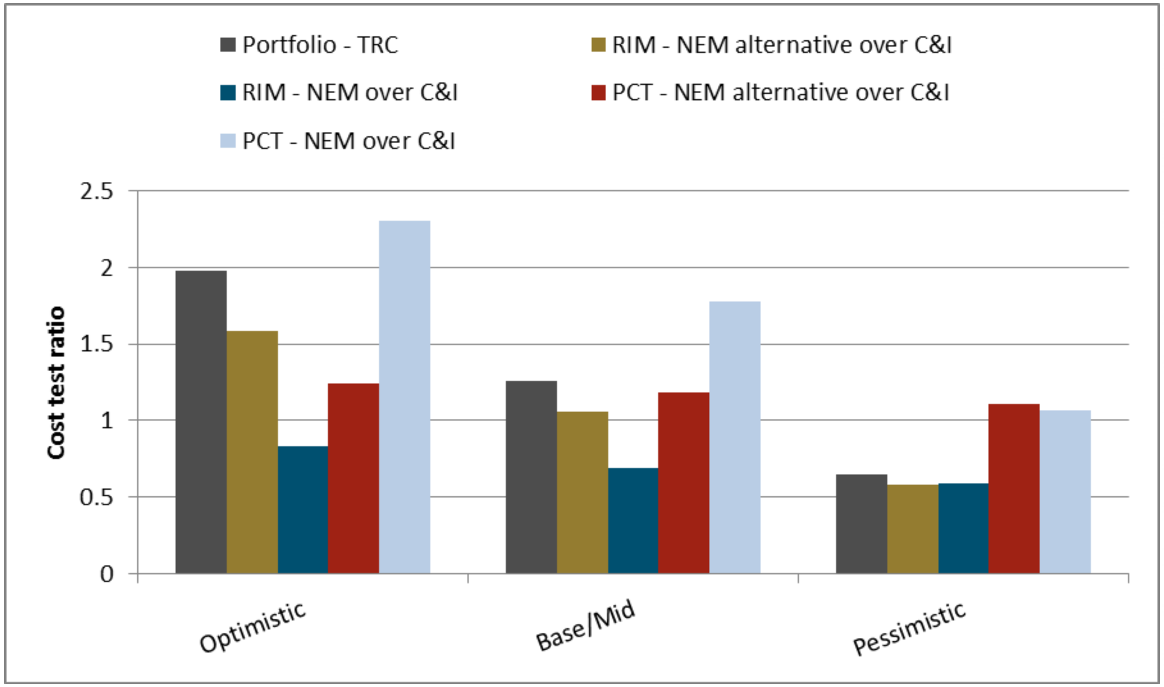
Definition of cost tests

Cost Test		Key Question Answered	Summary Approach
Total Resource Cost	TRC	Will the total costs of energy in the utility service territory decrease?	Comparison of program administrator and customer costs to utility resource savings
Participant Cost Test	PCT	Will the participants benefit over the measure life?	Comparison of costs and benefits of the customer installing the measure
Ratepayer Impact Measure	RIM	Will utility rates increase?	Comparison of administrator costs and utility bill reductions to supply side resource costs

Cost test results for optimistic, mid and pessimistic solar cases

+ **TRC perspective: solar is cost effective in mid and optimistic cases**

+ **TIM/RIM perspective: solar passes**



TRC result across DER portfolios

- Adding in other DER improves cost effectiveness from TRC perspective
- Pushes the TRC further above 1
- 50 MW of storage adds further value to the portfolio in 2024