

International Solar Alliance Expert Training Course

In partnership with the Clean Energy Solutions Center

Dr. David Jacobs

Session 8b: Rate Design (continued)

In partnership with the Clean Energy Solutions Center (CESC)

Dr. David Jacobs

Supporters of this Expert Training Series



ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Dr. David Jacobs

- Founder and director of IET
- Focus on sustainable energy policy and market design
- + 14 years experience in renewable energy policies
- + 60 publications on energy and climate
- + 40 countries work experience (consulting and presentations)
- <https://iet-consulting.com/>

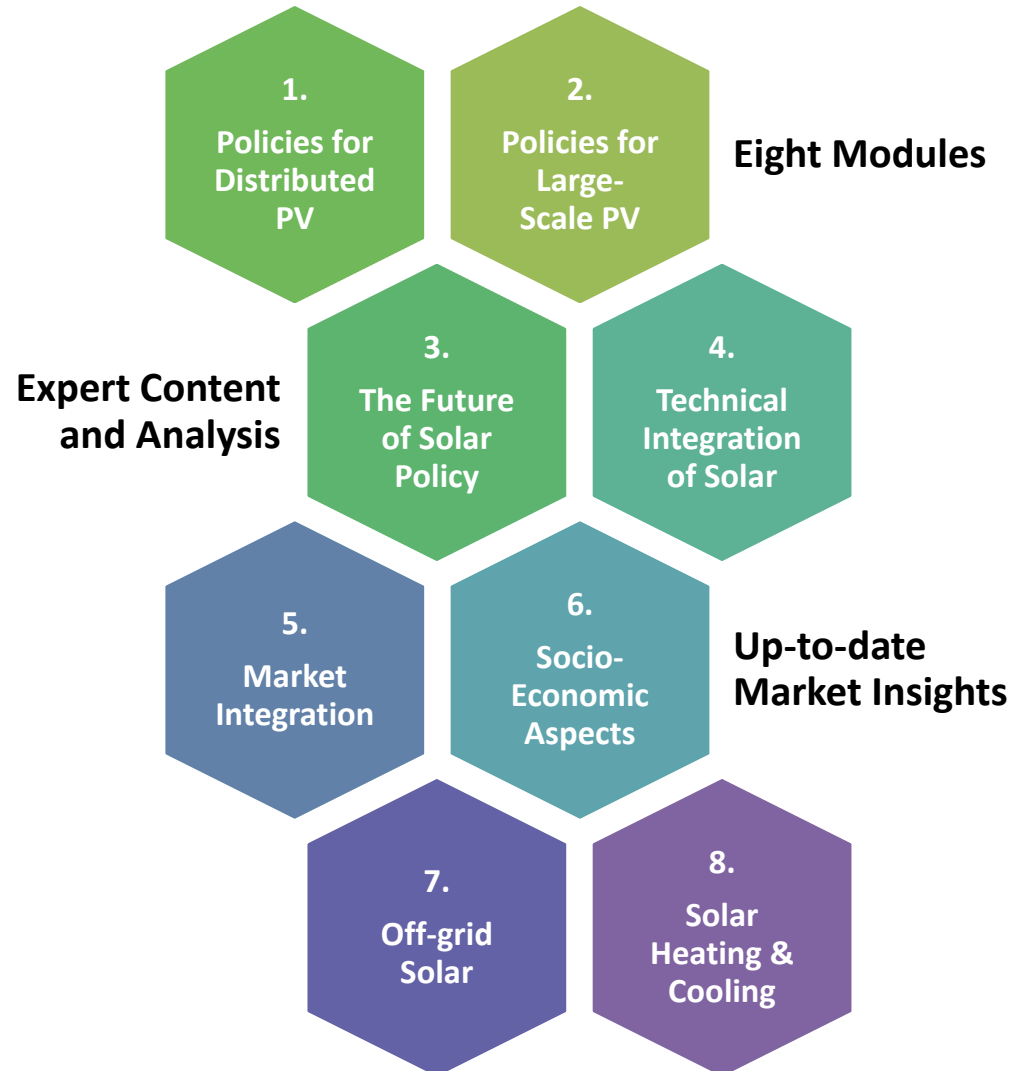


Training Course Material

This Training is part of Module 1, and focuses on Rate Design (2nd session)

Related training units are:

- ✓ 2. Introduction to Solar Policies: Net Metering, Net Billing, NET-FIT, FITs, and Auctions
- ✓ 3. Solar PV Policy Deep-Dive: Overview of Compensation Mechanisms for Rooftop Solar
- ✓ 6. Solar PV Policy Deep-Dive: Net Billing and Net Metering (and other self-consumption policies)



Overview of the Training Session



- 1. Introduction: Learning Objective**
- 2. Core Content: Understanding Smart Rate Design**
- 3. Further Reading**
- 4. Knowledge Check: Multiple-Choice Questions**

Introduction:

Learning Objective

Learning Objective

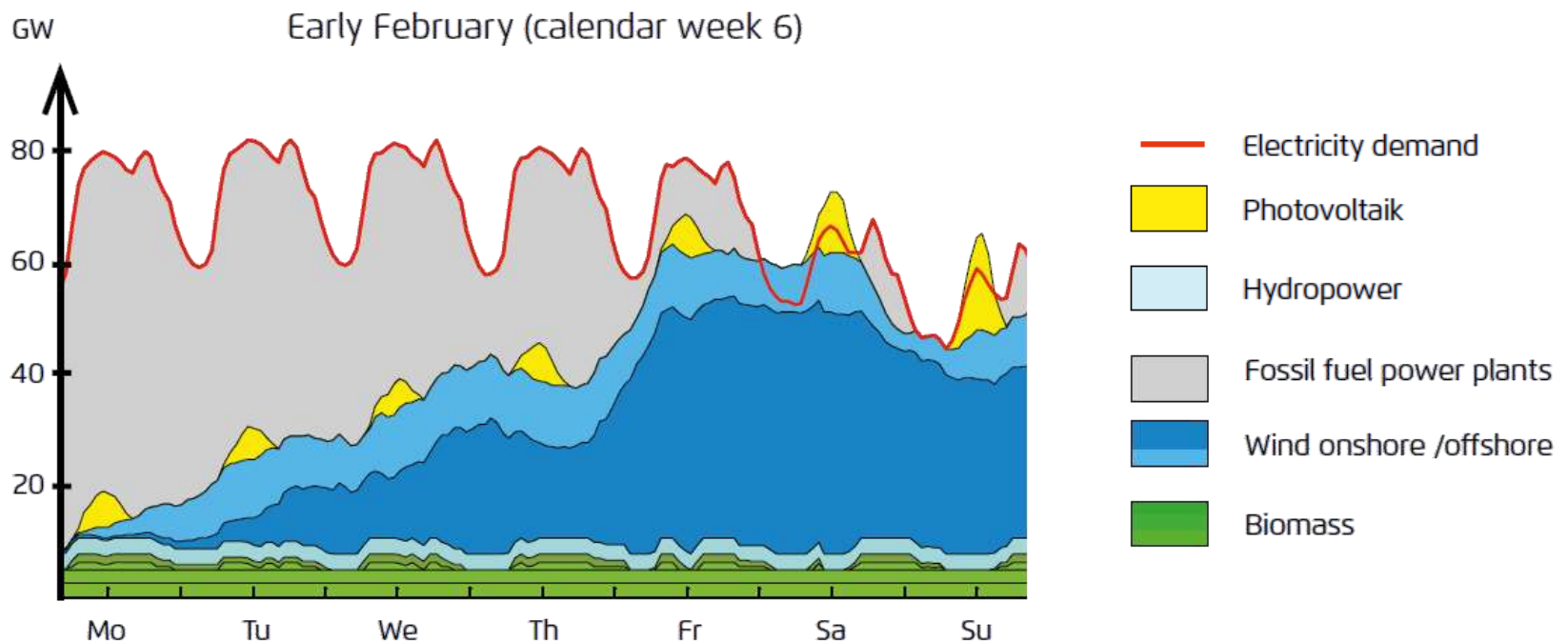
- Recapitulate the various objectives of rate design
- Understand time-varying rates
- Understand locational pricing
- Understand components of cost-benefit analysis of distributed generation/roof-top PV
- Outlook to two-way rate design (net metering, FIT)

Introduction:

Summary of Last Session (8a)

Flexibility is Key in Future Power Systems – including Demand Side

Electricity demand and renewable power generation in 2022



Source: Agora Energiewende 2012

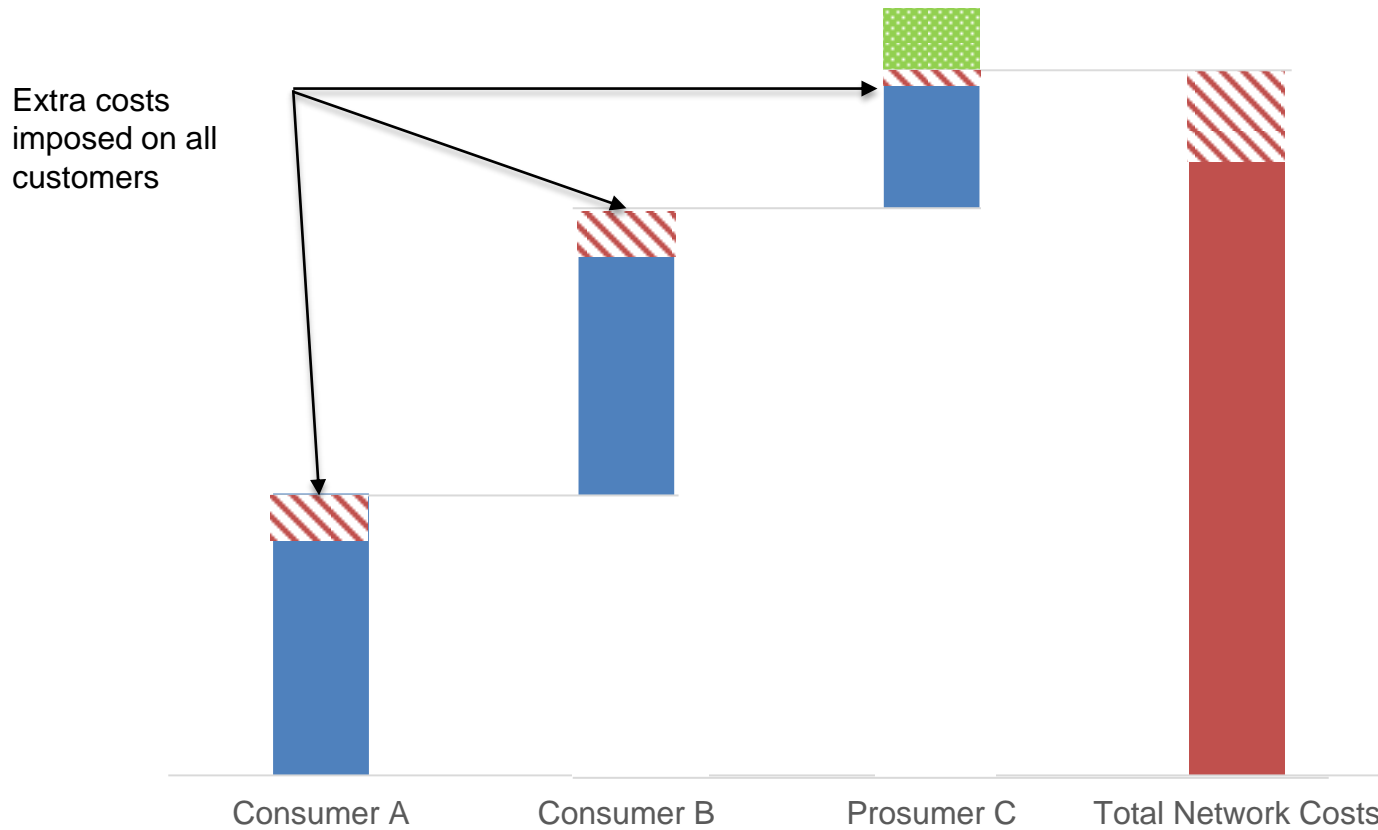
Objectives of Rate Design: Traditional

- Cost recovery
- Cost-efficiency
- Cost causation principle
- Cost allocation
- Affordability

Objectives of Rate Design: Emerging

- Demand side flexibility
- Enabling innovation and integrating new technologies
- Balancing utility and customer/prosumer interests
- Energy efficiency incentives
- Customer empowerment
- Assessing fixed costs based on long-term perspective
- Gradualism

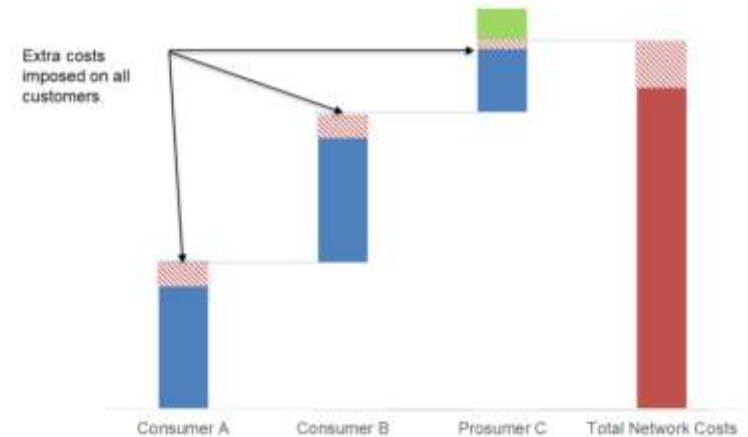
Volumetric Rates: Network Costs and Prosumers



Source: IET

Volumetric Rates: Network Costs and Prosumers

- **However:**
 - Impact of prosumerism is **negligible** at start.
 - Residential and (small)commercial customers only constitute a certain share of total demand (and system costs)
 - Cost of prosumers need to be compared with benefits (**Cost-Benefit Analysis**)
 - **Other policy objectives** need to be take into account (not exclusive focus on “cost causation”).



Source: IET

Glossary



Abbreviation	Word	Meaning
AMI	Advanced Metering Infrastructure	Meters and data systems that enable two-way communication between customer meters and the utility
CPD	Coincident Peak Demand	Energy demand by a customer or class of customers during periods of peak system demand.
CPP	Critical Peak Pricing	Pricing scheme where rates are low in off-peak times, but increase substantially when costs spike.
DG	Distributed Generation	Small-scale and modular electricity producing units that are directly connected to the distribution network (hence, closer to the end-user)
LRMC	Long-Run Marginal Costs	The long-run costs of the next unit of electricity produced. Also called long-run incremental costs
NM	Net-metering	Utility billing mechanism that credits residential and business customers who are producing excess renewable electricity and send it back to the grid.
RTP	Real-time Pricing	Pricing scheme where customers pay a rate that is directly linked to the hourly market price. Generally in use for large consumers (industry, commercial users)
ToU	Time-of-Use Rates	A form of time-varying rate, where the cost of electricity varies based on the time of day it is consumed
VRE	Variable renewable energy sources	Wind and solar PV

An Overview of Rate Design Options

Traditional rates

- Volumetric Charges
- Fixed Charges
- Minimum bills
- Demand Charges

Can be implemented based on **existing meter technologies**

Source: IET based on Cross-Call, D., et al. (2018), Linvill 2014

Rate Design:

**An Extended Overview of Rate
Design Options**

An Extended Overview of Rate Design Options

Traditional rates

- Volumetric Charges
- Fixed Charges
- Minimum bills
- Demand Charges

Smart rates

- Time-of-Use Pricing
- Critical Peak Pricing
- Real-Time Pricing
- Locational Pricing

Prosumer rates

- Two-way rates

Can be implemented based on **existing meter technologies**

Require **advanced metering infrastructure (AMI)**

Source: IET based on Cross-Call, D., et al. (2018), Linvill 2014

Smart Rates:

Technical Requirements

Smart Rates – Technical Requirements

- Time-varying and locational rates require **advanced metering infrastructure (AMI)**
- **Without advanced metering** , time-of-use rates can be offered as a **proxy**. However, this also **requires a meter that is capable of tracking at least two billing periods** (off-peak and peak).
- Advanced metering technologies are **currently rolled out** in many jurisdictions around the world.
- Customers will face **increasing metering costs**.
- Appliances will also have to become smarter (automated demand response)

Source: IET based on Faruqui, A., et al. (2012).

Smart Rates – Technical Requirements



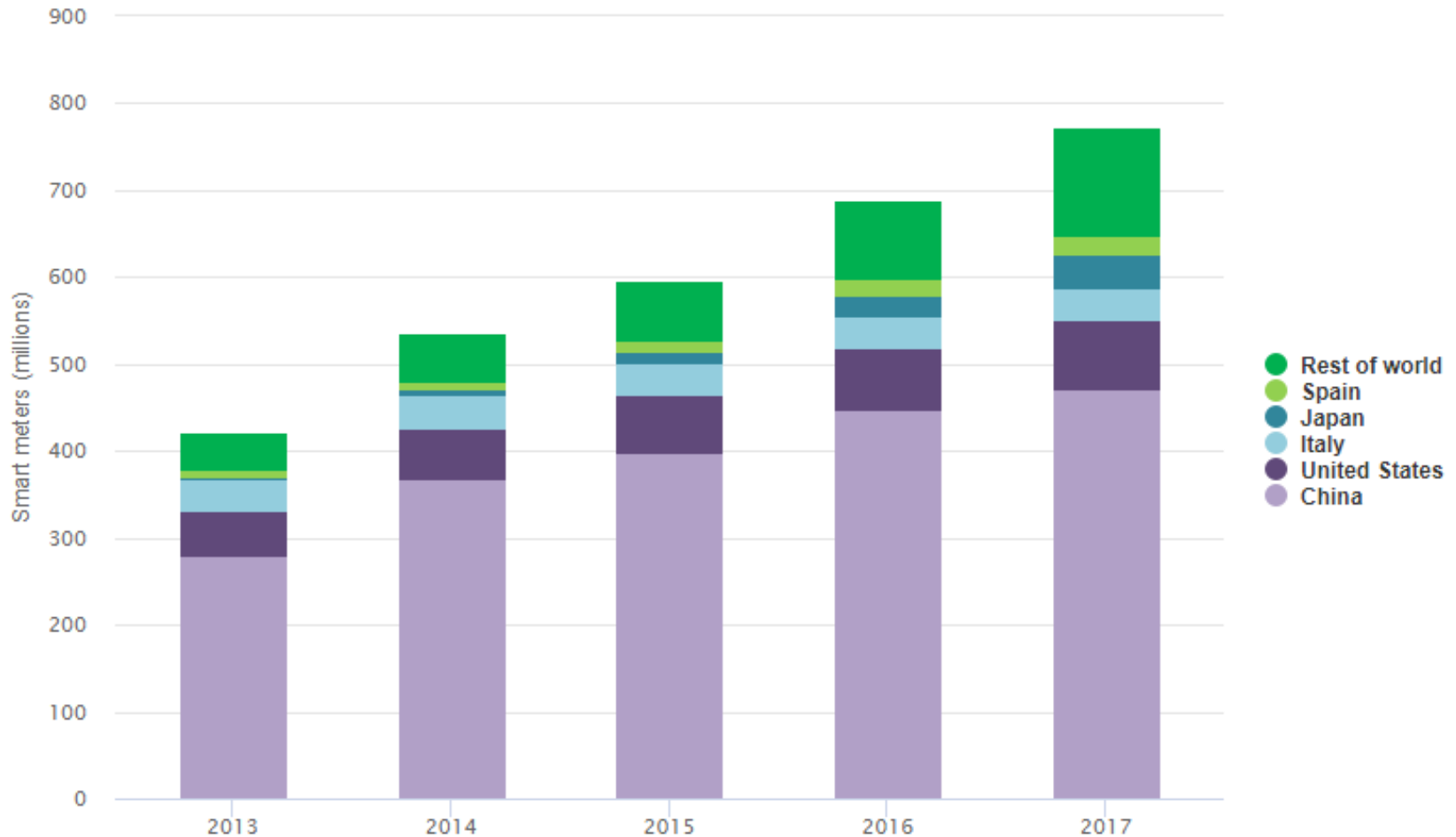
- Developing countries:
 - Utilities in **China** have installed over **408 million smart meters** representing 68.3% of tracked smart meter installations world-wide in 2017.
- (So-called) developed countries
 - **Ontario** (Canada) has rolled out smart meters for 4.8 million commercial and residential customers. The technology has however come under heavy fire, as savings expectations have not been met.
 - In Japan, all utilities were asked to present **plans to 2025** for the installation of smart meters to **every household**, nearly 80 million in total. (US DOC, 2015)

Smart Rates – Technical Requirements

- European Union
 - Currently **40% of EU citizens** have a smart meter. “By 2020, it is expected that almost 72% of European consumers will have a smart meter for electricity” (European Commission, 2014).
 - **Italy** was one of the first countries to embark on a nationwide smart-meter deployment. Between 2001 and 2006, Enel installed nearly **30 Million devices**, and is currently rolling out a second wave of smart-meters.
 - **Sweden** was the first EU country to reach **100% smart meter penetration** in 2009. It is now **mandated by law** for consumers to utilise smart meter technology in their homes.

Source: IET based on

Smart meters installations are quickly growing



Global cumulative smart meter installations

Source: IEA (2018)

Time-varying Rates:

Time-of-Use (ToU) Rates

Time-of-Use Rates

- Time varying rates have been used to create an **incentive to shift consumption to off-peak** times.
- Higher prices are designed to **deter consumption during peak times**
- Many utilities have offered **stepped rates** (lower at night, higher during the day) **to large industrial and commercial customers** for decades
- However, a growing number of markets are beginning to experiment with **time of use rates for residential customers**.

Time of Use Rates

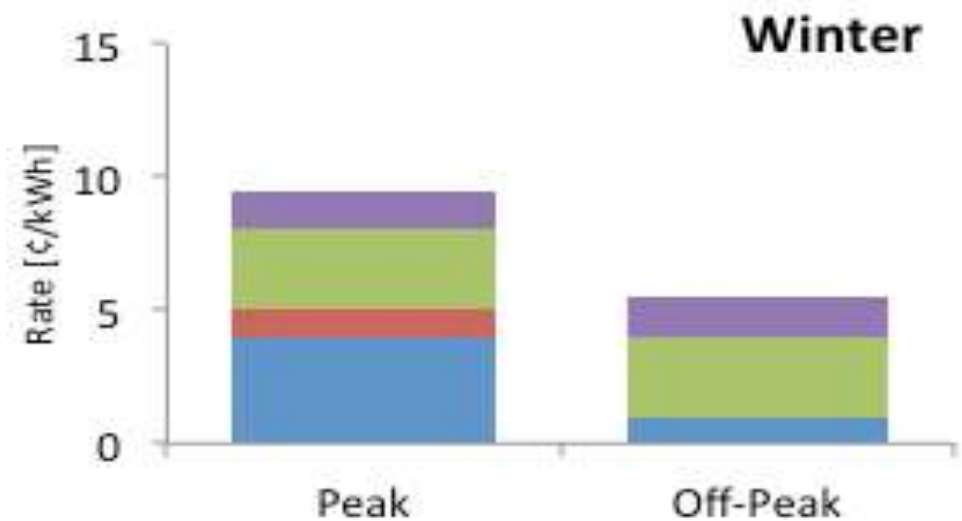
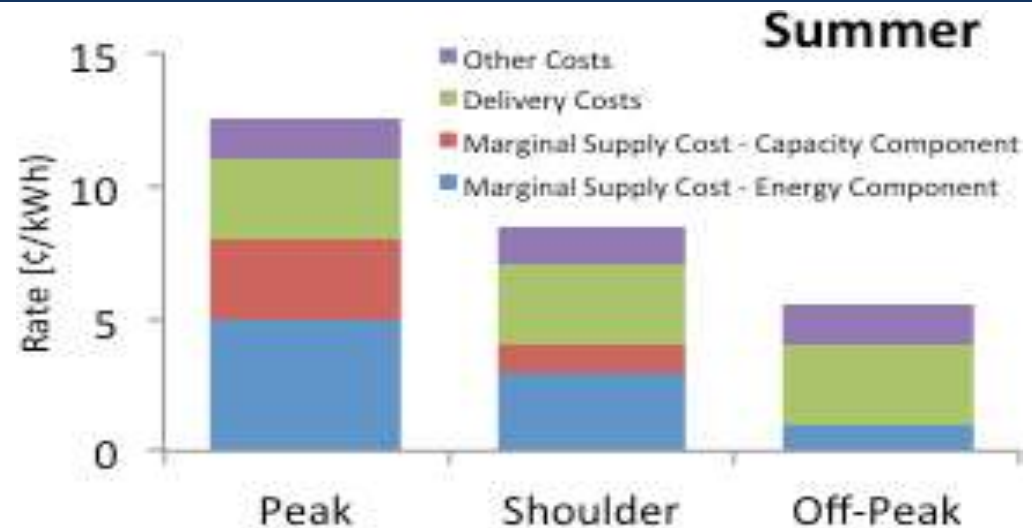
- Under time-of-use (TOU) rate design:
 - customers are billed according to the time of day at which power is consumed, typically across **peak, shoulder, and off-peak** periods
- TOU pricing sends a time-specific **price signal** to customers about the **high cost of energy/potential grid congestions** in an effort to shift and/or reduce use.
- Prices more closely reflect the real value of real-time generation (still a proxy).
- There is a **wide range of time-based rate options** with different levels of temporal granularity (e.g. 15 minutes, 30 minutes, 1-hour, etc.)

Time-of-Use Design: Decision Points

- **Peak/Off-peak price ratio** can be a strong predictor of customer peak load reduction, on which TOU can have a significant impact
 - **Higher ratios send a stronger price signal** to shift consumption away from peak hours
 - Time-of-use rates with a 5:1 ratio tend to double the peak reduction compared to a 2:1 ratio
- **Peak Period Duration** and **Peak Period Frequency** have a significant impact on customer **acceptance**.
 - When peak periods are **too long or occur too often**, customers may be less willing to enrol in a time-based rate.

Time-of-Use Design: Peaks, Shoulders, Off-Peaks

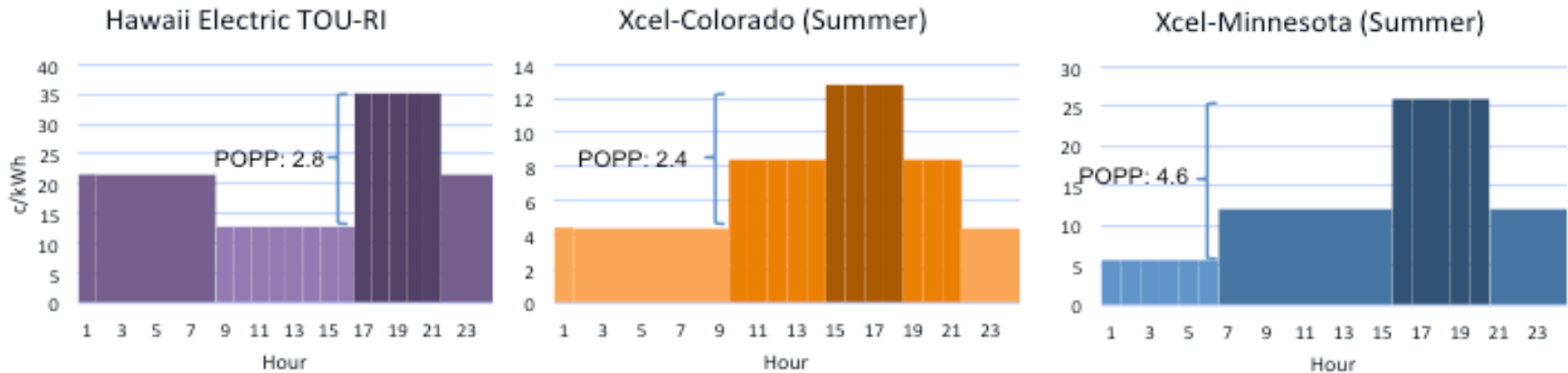
- Reasoning for peak, shoulder and off-peak price differentiation:
 - Marginal supply costs (energy and capacity component) are higher during peak periods



Source: Cross-Call, D., et al. (2018)

Time-of-Use Design in the USA

- Time-of-use rate structures offered in Hawaii, Colorado and Minnesota



	HECO	Xcel-CO Summer Winter	Xcel-MN Summer Winter
Peak to Off-Peak Price Ratio	2.8	2.4 1.7	4.6 2.1
Peak to Shoulder Ratio	1.7	1.43 1.36	3.9 1.8

Source: Cross-Call, D., et al. (2018)

Time-varying Rates:

Critical Peak Pricing

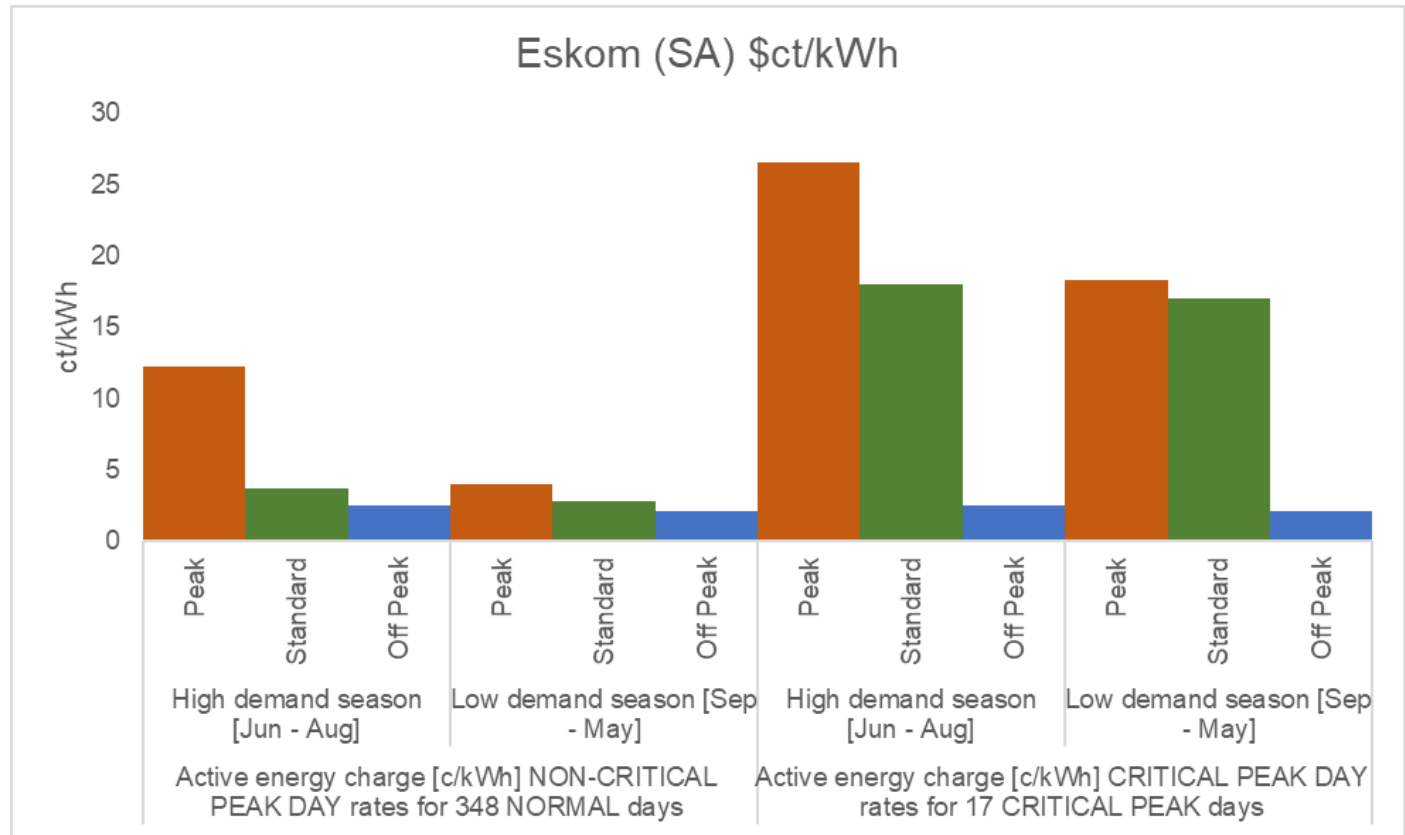
Critical Peak Pricing

- Critical Peak Pricing is a **variation** of standard time-of-use rates
- To capture additional value, some jurisdictions **introduce an additional critical peak period (CPP)**, which **occurs only during grid emergencies** or during the **most expensive hours** of the year.
- Electricity prices during this periods are **generally several times higher** than under normal conditions (high peak-to-off-peak price ratio)
- The **price is pre-determined**, as are the allowable time periods, but the actual peak events are finalized a **few hours to a day in advance**

Sources: IET based on E3 Analytics and RMI 2016

Critical Peak Pricing – South Africa

- 17 critical peak days, 248 non-critical peak days



Source: Eskom (2015), Ruraflex

Time-varying Rates:

Peak Time Rebates

Peak Time Rebates

- Under peak-time rebates (PTR), instead of charging a higher rate during critical events, **participants are paid for load reductions**
- Customers pay the regular rate at all hours, but receive a proportional rebate when they **reduce their consumption against their baseline consumption when the grid is under stress.**
- Peak-time rebates, in contrast to CPP, offers a **financial reward with no penalty** for the customer that does not change usage.
- May be seen as **“Training wheels” for Critical Peak Pricing (CPP)**

Sources: IET based on RAP online (2012)

Baltimore Gas & Electric (BGE) Peak Time Rebate

- A utility in Baltimore (USA) enrolled over 1 million customers in a Peak time Rebate program as of 2016
- Customers are notified by phone, email, or text the day before an “energy savings day”; if customers reduce their usage from 1pm to 7pm, they receive a \$1.25 per kWh bill credit.
- This achieved 209 MWs of peak demand reduction.



Time-based Rates:

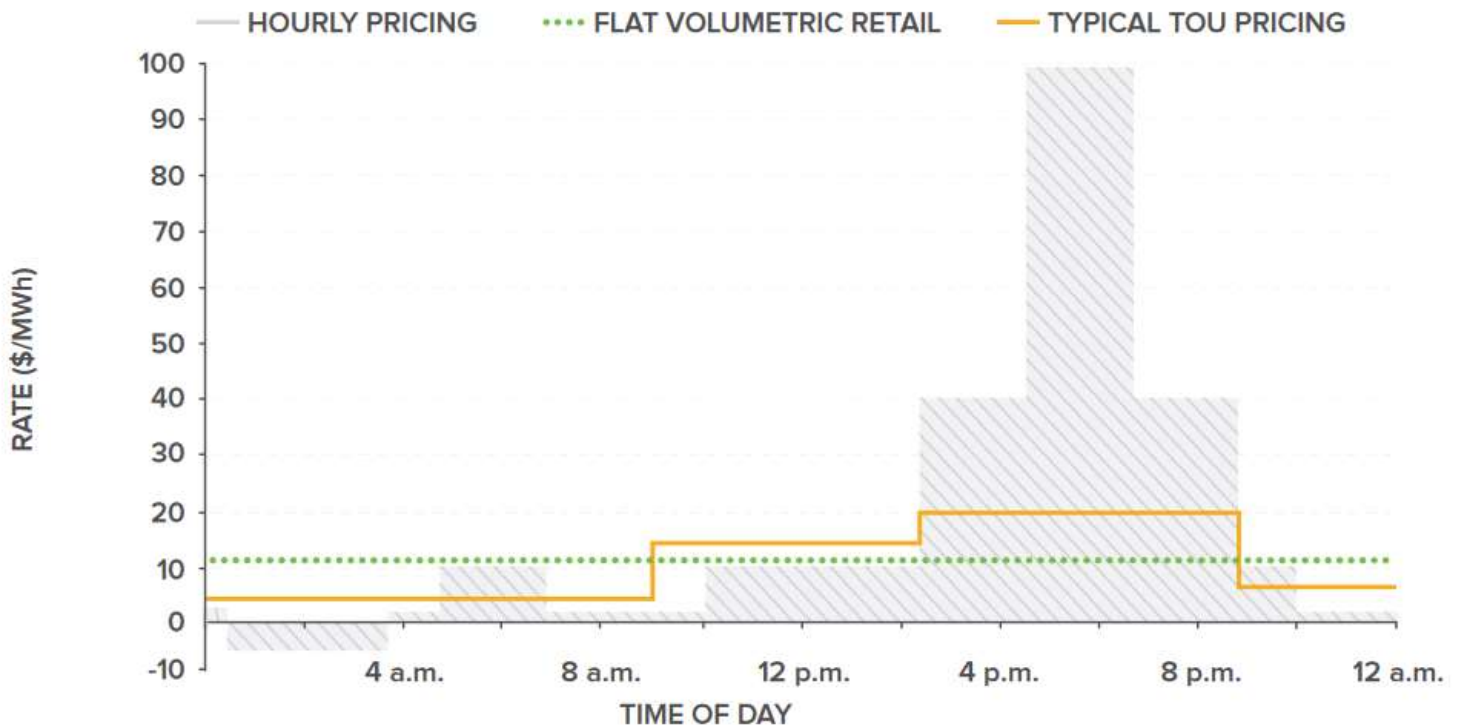
Real Time Pricing

Real-Time Pricing

- Participants in RTP programs pay for energy at a rate that is **linked to the hourly market price for electricity (reflecting influx from wind and solar and potential grid congestions)**.
- Depending on customer class, participants are made aware of hourly prices on **either a day-ahead or hour-ahead basis**.
- Typically, **only the largest customers** (commercial and industrial) in specific regions participate in RTP programs.
- RTP **uses hourly day-ahead** or sub-hourly (e.g., five minute interval) **spot market prices** to bill and compensate customers for services required and provided.

Real-Time Pricing

- Under **hourly pricing**, a customer may benefit from installing a **combination of solar PV and battery technology** that might not be economical under a less granular rate structure such as traditional TOU rates.



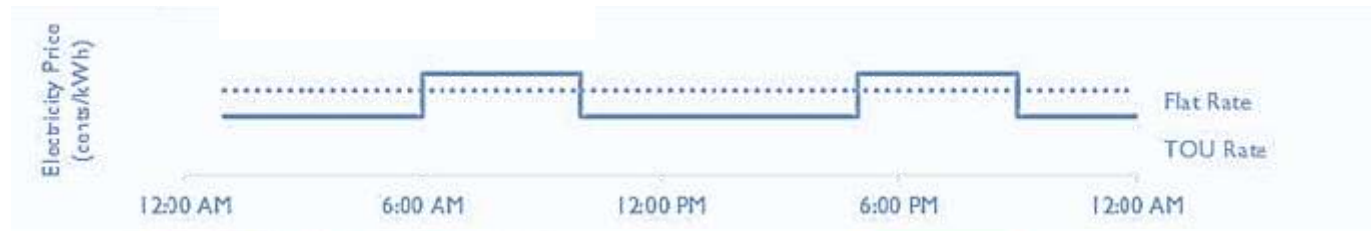
Source: RMI (2017)

Time-varying Rates:

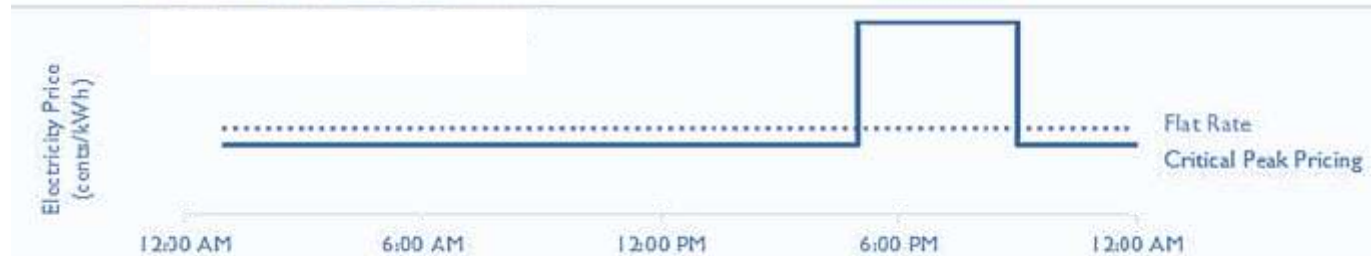
Advantages and Disadvantages

Overview of Time-Varying Rates

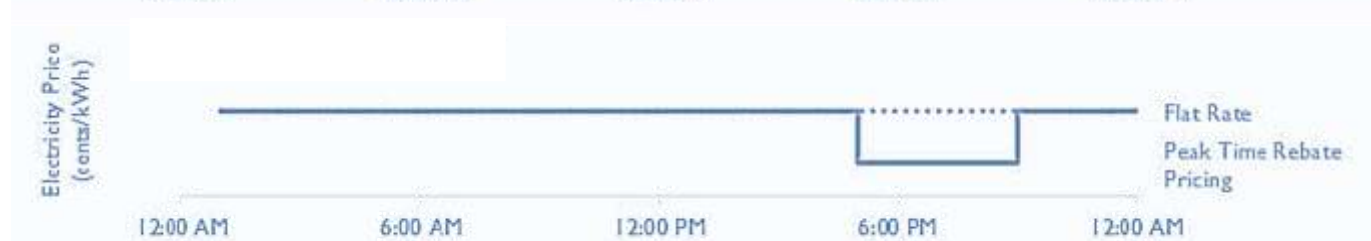
TOU rate



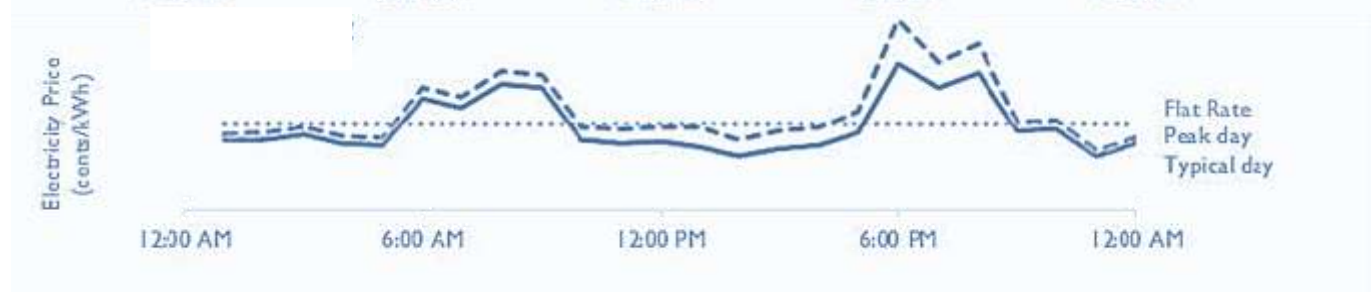
Critical Peak Pricing



Peak Time Rebate Pricing



Hourly / Real-Time Pricing



Source: Whited (2017)

Advantages of Time-Varying Rates (ToU)



- Encourage more efficient **timing of electricity use**
- Reduce need for expensive **peaking power plants** and **Save money for consumers** by shaving peaks (if enough customers participate).
- **Incentivize PV/DG** (depending on peaking time and design of rates)
- Help reduce **power outages**
- Create greater **awareness** among power users about their usage patterns.
- Trigger **demand-side flexibility** (and thus help integrating VRE)

Disadvantages of Time-Varying Rates (ToU)

- Increases **complexity**
- Typically require **smart meters** (e.g. AMI) and often only makes sense for commercial and industrial customers
- Harder for customers to **understand their bills.**
- Can **increase consumer bills** by increasing prices during times of high consumption
- May **penalize certain customers**, or customer classes (e.g. small businesses) who cannot easily shift their usage patterns.

Advantages and Disadvantages of Critical Peak Pricing

Advantages:

- Critical Peak Pricing can **further incentivize load-shifting** to stabilize the grid.
- **Avoid black-outs** in electricity networks with frequently occurring constraints (grid or power)

Disadvantages:

- Critical peak price **does not reflect real system costs** during critical events (costs change).
- Peak prices can **increase electricity bills** (or increase the revenues of the **supply company**).

Advantages and Disadvantages of Peak Time Rebates



Advantages:

- Provides a **level of bill protection** that is not embedded in other rates: a customer's bill **can only decrease** under the PTR in the short run.
- This leads to **greater acceptance** by policymakers and customers

Disadvantages:

- **Does not depict the true cost of electricity at peak times** and
- **Does not provide the price signal** necessary to encourage adoption of **distributed technologies**.
- Requires calculating the **baseline consumption** of every consumer. Inaccuracies can lead to significant cost increases for the utility.

Advantages and Disadvantages of Real-time Pricing

Advantages:

- Provides the **best available price signal** about the marginal value of power at a location to customers.
- RTP can **unleash innovation in distributed energy** (incentives for PV and combination with battery systems).

Disadvantages:

- Necessitates **automating technologies** (AMI) for customers to respond to prices.
- **Price uncertainty and volatility** can be obstacles for many consumers.

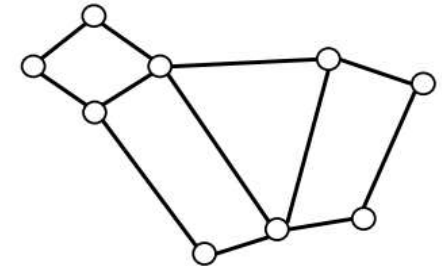
Smart Rate Design:

Locational Pricing

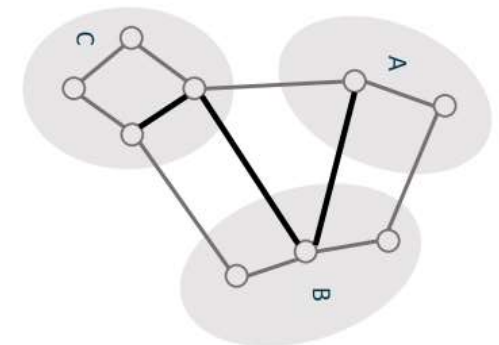
Locational pricing

- Instead of treating all customers equally regardless of their location on the distribution system, locational pricing provides **geographically differentiated price signals**.
- Locational (network) prices should reflect the **specific costs** to transmit electricity from generation to load
- Usually electricity networks are either **zonal** or **nodal** (and, in some cases, hybrid)

Nodal

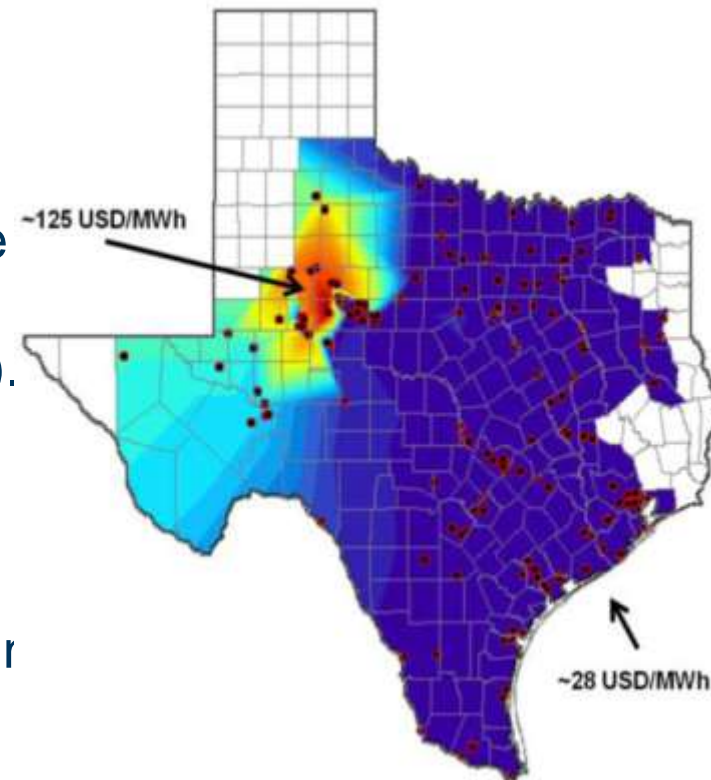


Zonal



Nodal Pricing – Wholesale

- Wholesale market prices are different at **each node of the electricity network**.
- Differences in marginal prices at each node **reflect the scarcity** of generation capacity and transmission capacity (i.e., congestion).
- Consumers at a high-priced nodes have an incentive to **lower demand**, and producers have an incentive to **increase generation** in these locations.



Source: Hirth (2018)

Zonal Pricing – Wholesale

- Similar to nodal pricing, zonal pricing establishes different marginal prices at **different locations/zones** due to transmission capacity constraints.
- The difference to nodal pricing is that only transmission constraints between zones are considered, leading to **uniform marginal prices within a zone**. Network constraints, such as transmission line limits within a zone, are not considered.

“Hot Spot Pricing” in the Distribution Network

- Under the nodal network system, the regulator can **identify “Hot Spots”**, i.e., locations on the distribution system that suffer from **grid congestion/scarcity of generation**.
- In order to meet (new) load, it can be cost effective to **signal customers to install distributed energy resources** (ranging from demand response to storage to distributed generation).
- Customers that install distributed generation in high-value locations could be **incentivized via credits/rebates** on their electricity bill.
- At the same time, new and **costly investment** into the distribution networks (e.g. new substations) **can be avoided** or delayed.

Sources: IET based on RMI (2017)

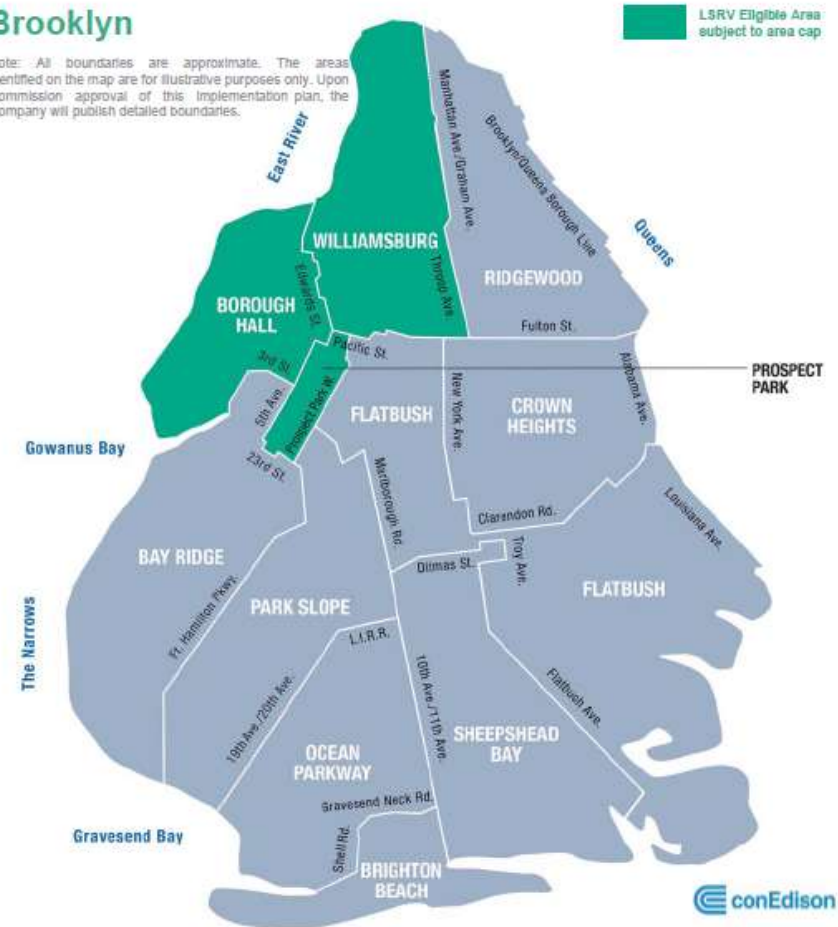
“Hot Spot Pricing” in Distribution Networks

Con Edison Brooklyn/Queens Demand Management Plan

- The plan tries to incentivize DG technologies (PV, storage, load management) to avoid upgrade of substations which by **cost up to \$1 billion**.
- The program is only available to customers within the area served by the existing substation.

Brooklyn

Note: All boundaries are approximate. The areas identified on the map are for illustrative purposes only. Upon Commission approval of this Implementation plan, the Company will publish detailed boundaries.

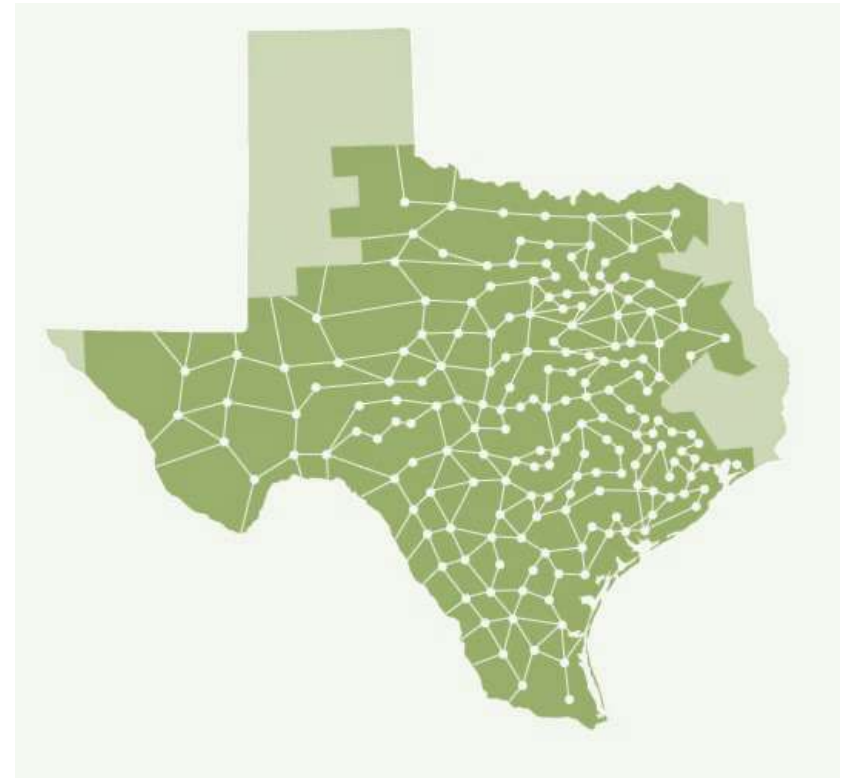


Source: ConEdison (2017)

Distribution Locational Marginal Pricing

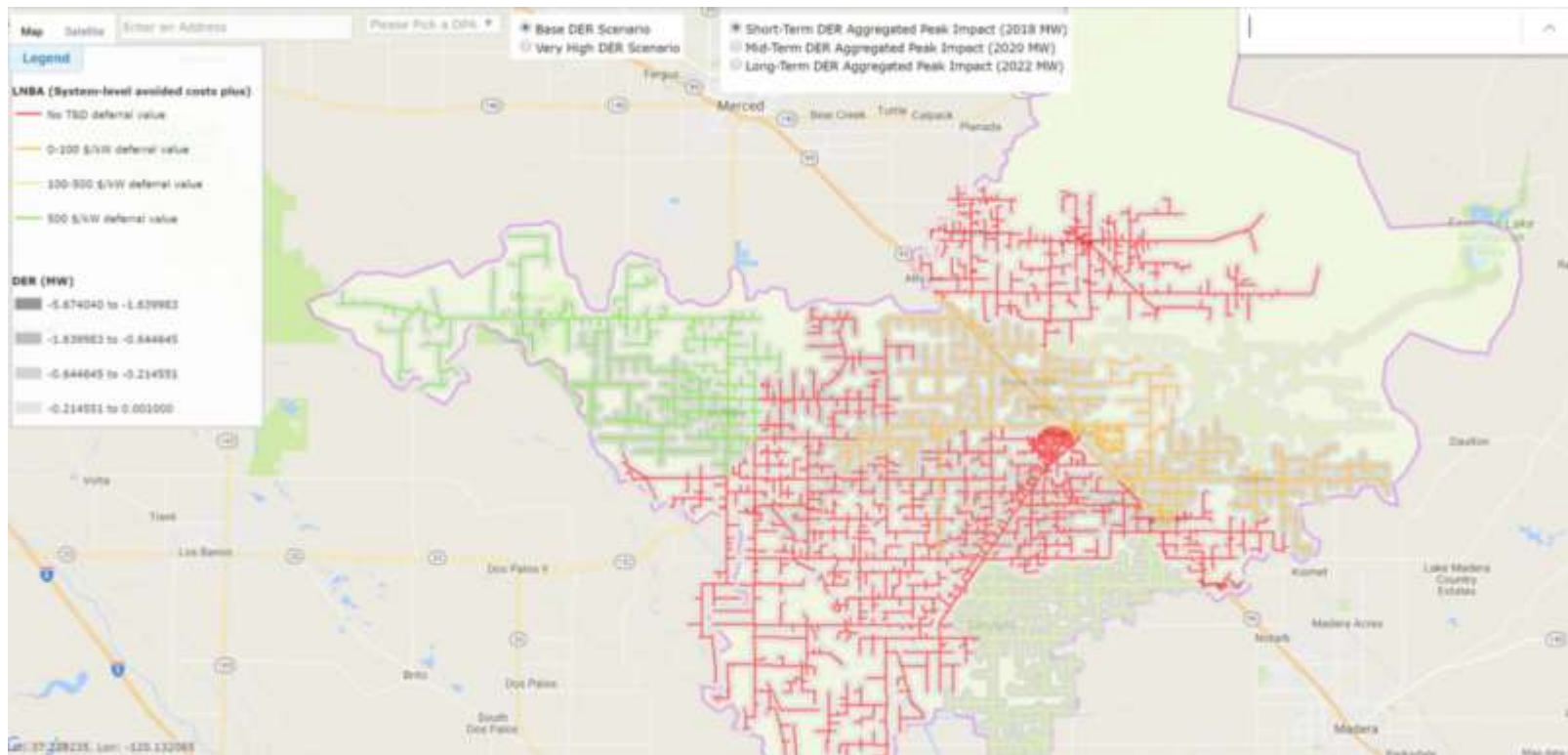
- Similar to locational marginal pricing in nodal markets:
- Hourly or **sub-hourly price signals are sent to nodes on the distribution system**

Nodes on Texas power system (ERCOT)



Incentives for DG in High Value Locations

- Grid operators/utilities should **publish maps** with constraints and needs for new DG capacity, value of avoided investment per MW installed



Source: SEIA (2018).

Locational Rates:

Advantages and Disadvantages

Advantages and Disadvantages of Locational Pricing

Advantages:

- Can help to overcome (distribution) network constraints.
- Can help to avoid investment in expensive distribution network upgrades.

Disadvantages:

- Locational constraints (and prices) can vary over time; Therefore, price signals for investment in DG might not be sufficiently long (uncertainty).
- Lack of acceptance: Customers might not agree with paying more or less depending on where they live.

Smart Rates:

Implementation Options

Smart Rates – Implementation

- Start with pilot projects for specific customer groups
- Make new rates optional at the beginning (mandatory implementation can follow later).
- Gradual roll-out of advanced metering infrastructure (starting with industrial and commercial customers)
- Specific rates for prosumers or rate design changes for all customers?

Balancing Interest of Actors in Line with Overall Objectives

Balancing Interests and Overall Objectives of Rate Design

Utility Interests

- Cost recovery
- Revenue security

Balancing Interests and Overall Objectives of Rate Design

Prosumer Interests

- Customer empowerment
- Enabling new technologies
- Incentives for PV

Utility Interests

- Cost recovery
- Revenue security

Balancing Interests and Overall Objectives of Rate Design

Overall Objectives of Rate Design

- Cost causation, cost allocation, fairness, affordability, gradualism
- Cost-efficiency (overall system costs); Flexibility (demand-side);
- Decarbonization; energy efficiency;

Prosumer Interests

- Customer empowerment
- Enabling new technologies
- Incentives for PV

Utility Interests

- Cost recovery
- Revenue security

Pre-Requisites for Fair Rate Design:

**Cost-Benefit Analysis of Distributed
Generation**

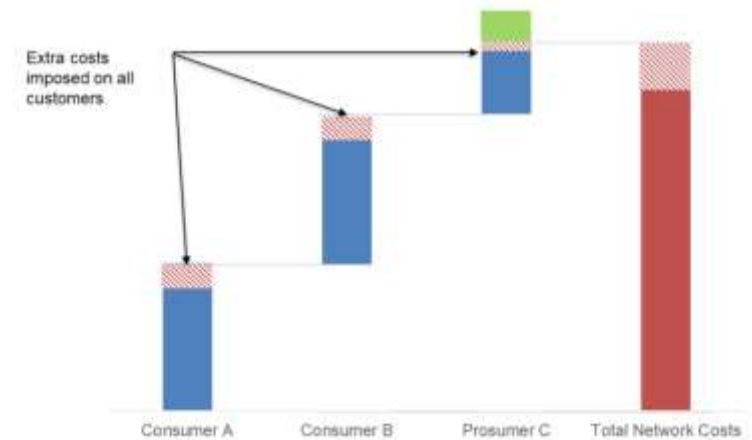
Benefits and costs: Establishing a standard methodology for assessment



- Costs for the prosumer/customer
 - Installation costs, insurance costs, maintenance costs, and inverter replacement
- Costs for the system (and the utility)
 - Integration costs
 - Lost revenue for the utility
 - Due to a shrinking customer base
 - Competition between (old) utility business and self-generation

Benefits and costs: Establishing a standard methodology for assessment

- Costs for the system (and the utility)
 - Billing and metering costs (administrative costs)
- Cost shifts from prosumers to non-prosumers
- Calculating reduced value of solar in high penetration scenarios



Source: IET

Benefits and costs: Establishing a standard methodology for assessment

- Benefits for the electricity systems
 - Avoided energy benefits
 - the cost of the electricity that the utility did not need to produce – “marginal generation displaced”
 - Peak shaving
 - Avoided line and system losses
 - Secure generation capacity (despite intermittency – system-wide analysis necessary)
 - Distribution and transmission impact (avoided congestions in the grid)

Source. IREC 2013

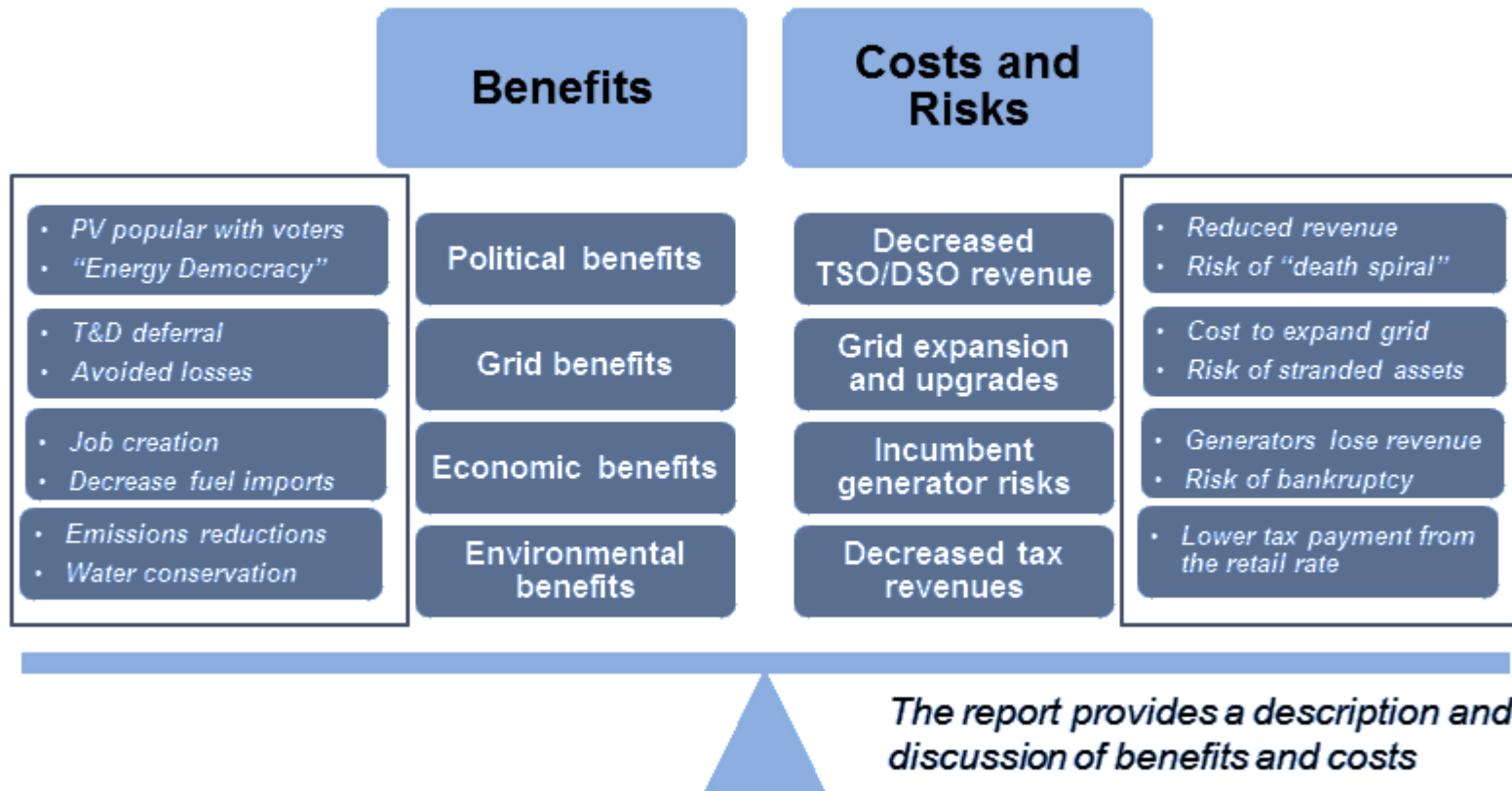
Benefits and costs: Establishing a standard methodology for assessment



- Benefits for the electricity systems
 - Grid support - ancillary services (reactive power, voltage control, frequency response)
 - Financial services (fuel price hedge)
 - Financial services (reduced market prices during peak hours)
 - Security services: resilience and reliability
 - Environmental services (carbon and other emissions)
 - Calculating macro-economic benefits (job creation)
 - Fast deployment of solar PV (compared to other technologies)
 - Democratization of energy system (not only “rich people”) – special programs for lower-income families?

Source. IREC 2013

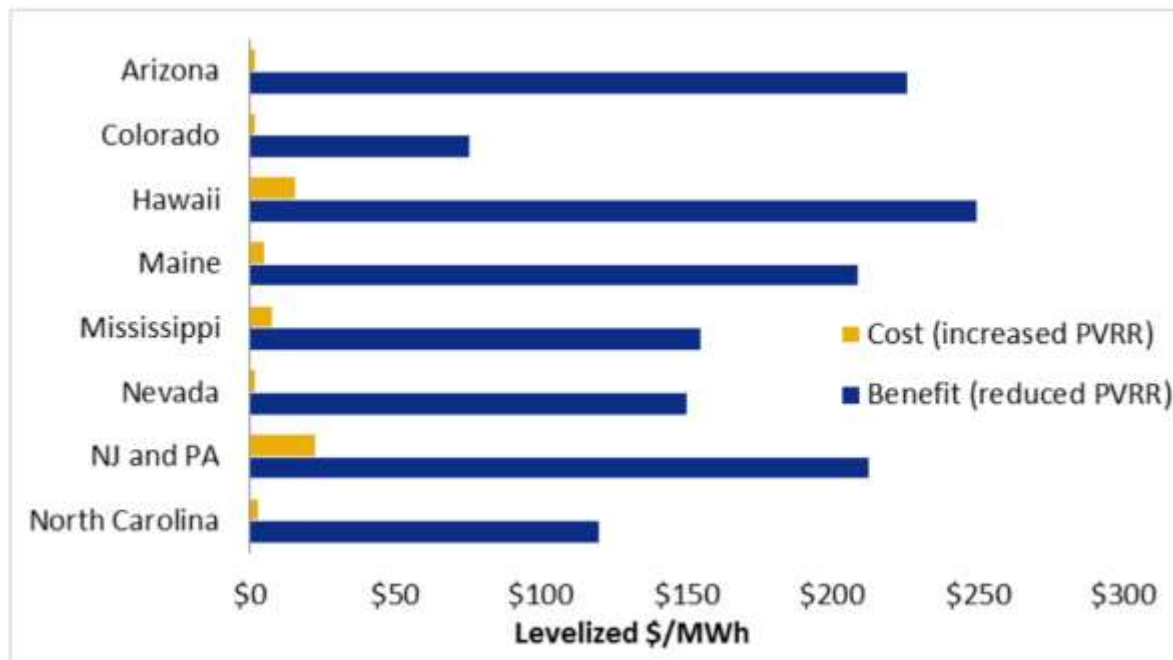
Cost and Benefits of Distributed Generation



Source: IEA RETD 2014

Cost and Benefits of Distributed Generation

- With low shares of distributed generation (up to 2% of total electricity), analyses in the US have shown that the benefits far outweigh the costs
 - Expressed as : present value of revenue requirements = revenue that the utility must recover from customers to cover the costs of serving customers.



Source: Whited 2016

Outlook:

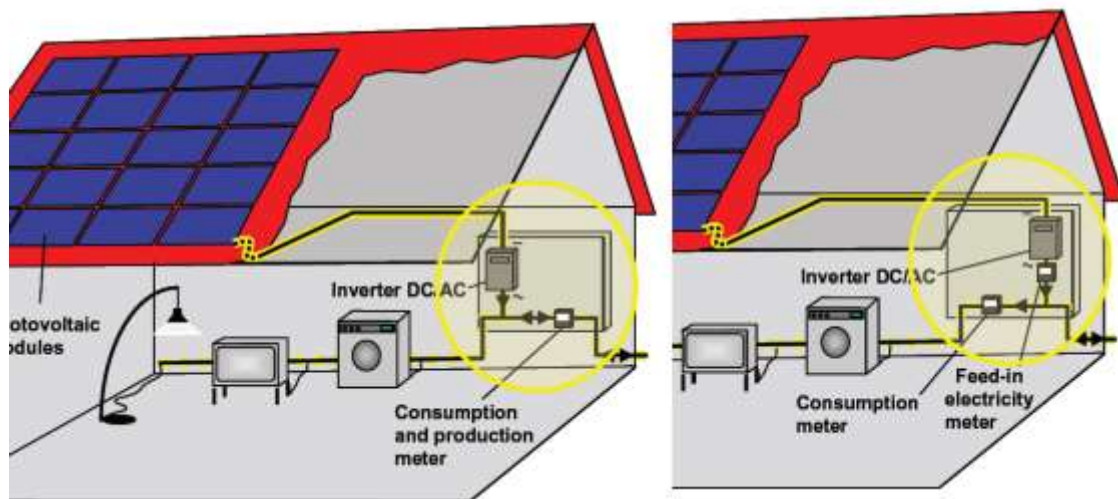
Two-Way Rate Design

Outlook: Two-Way Rate Design

- Classic Net Metering
- Net Metering 2.0
- Classic FIT
- NET-FIT
- Other compensation mechanisms and business models

Related training units are:

- ✓ 2. Introduction to Solar Policies: Net Metering, Net Billing, NET-FIT, FITs, and Auctions
- ✓ 3. Solar PV Policy Deep-Dive: Overview of Compensation Mechanisms for Rooftop Solar
- ✓ 5. Solar PV Policy Deep-Dive: FITs and Premium FITs
- ✓ 6. Solar PV Policy Deep-Dive: Net Billing and Net Metering (and other self-consumption policies)
- ✓ 7. Solar PV Policy Deep-Dive: NET-FITs
- ✓ 9. Deep-Dive: New Business Models



Source: RENAC

Further Reading/List of References

Further Reading: Smart Rate Design

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Thank you for your time!



ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

6. Knowledge Checkpoint: Multiple Choice Questions