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NREL NATIONAL RENEWABLE ENERGY LABORATORY

Understanding Utility Revenue and Customer Tariffs Impact of DPV Deployment: Thailand Case Study

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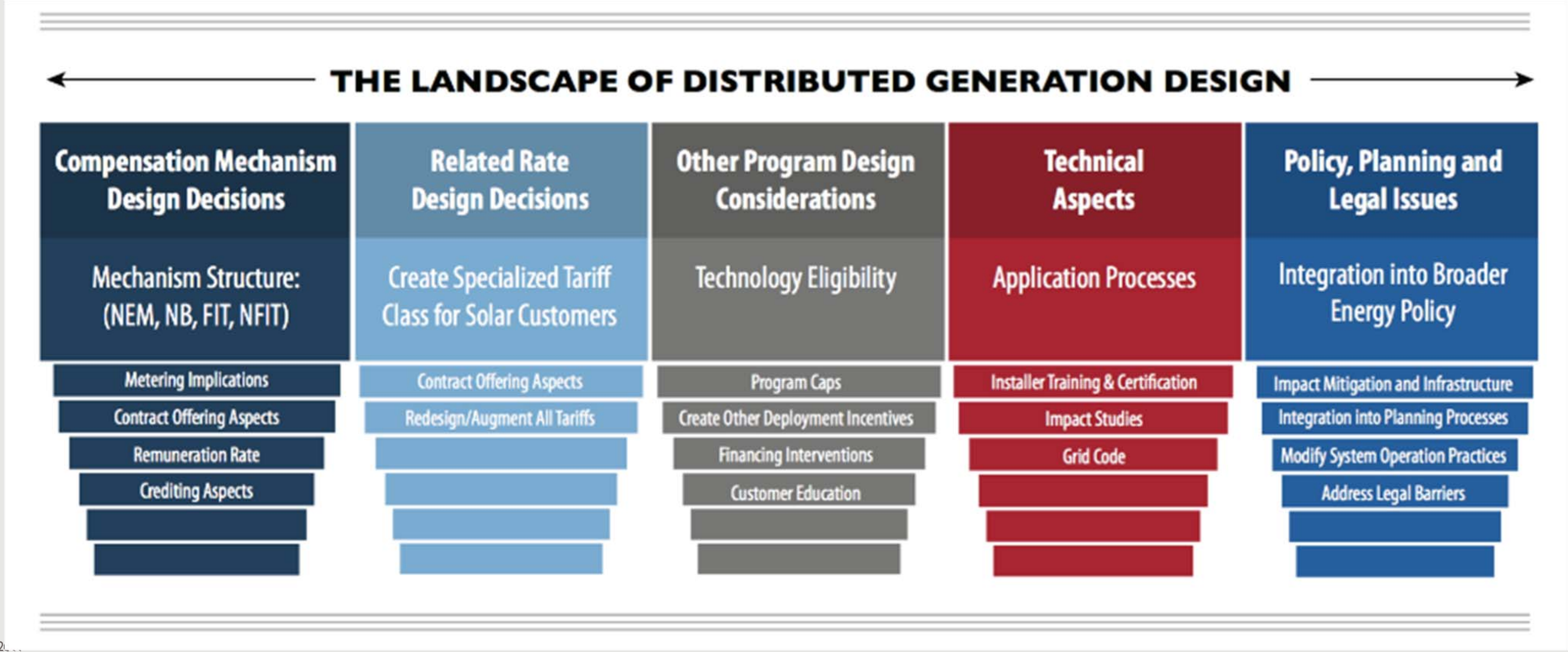
USAID Distributed PV Toolkit

- A multi-year program to assist USAID partner countries across the DPV spectrum in developing and implementing pilot projects to accelerate DPV market development.
- Objective: Help USAID partner countries address policy, regulatory, and technical barriers to safe, effective, and accelerated deployment of DPV through trainings, web-based resources, and targeted technical support.
- Alexandra Aznar (alexandra.aznar@nrel.gov) or Jeff Haeni (jhaeni@usaid.gov)



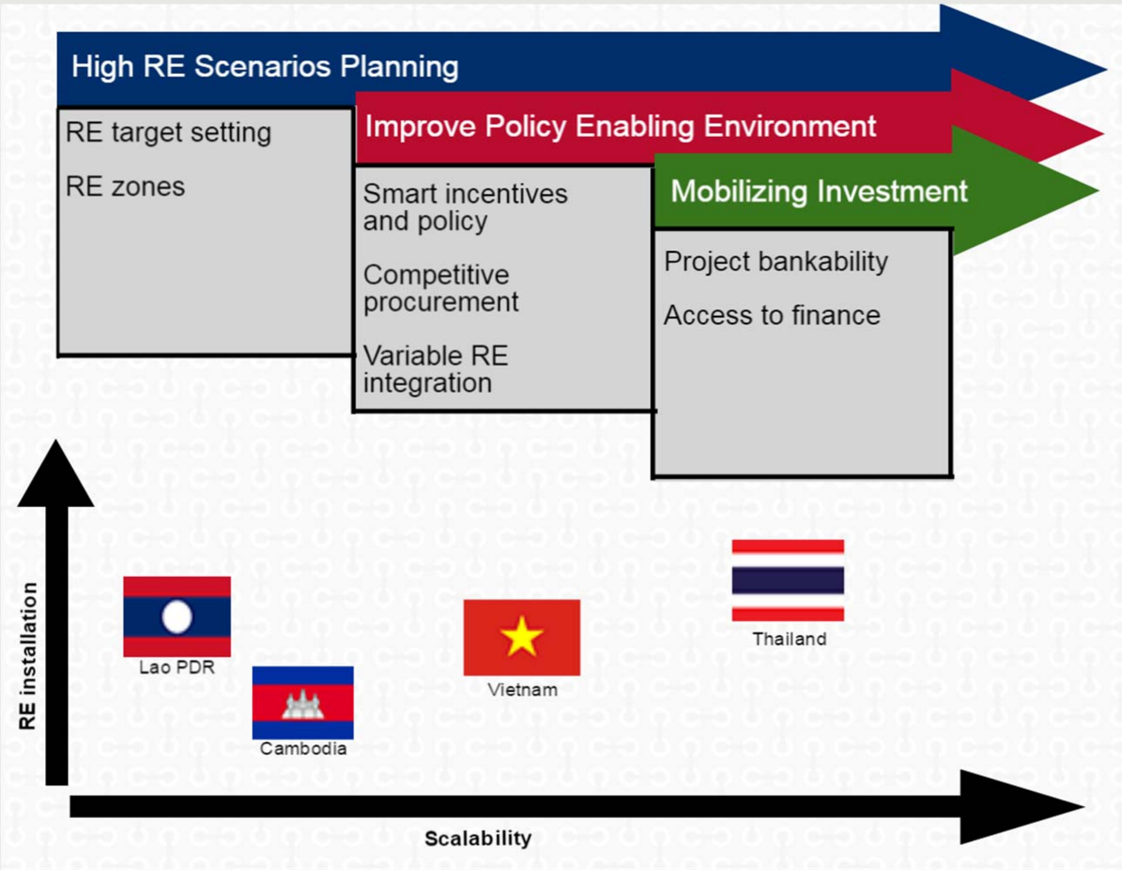
Where are we working on DPV issues?

Current pilot project

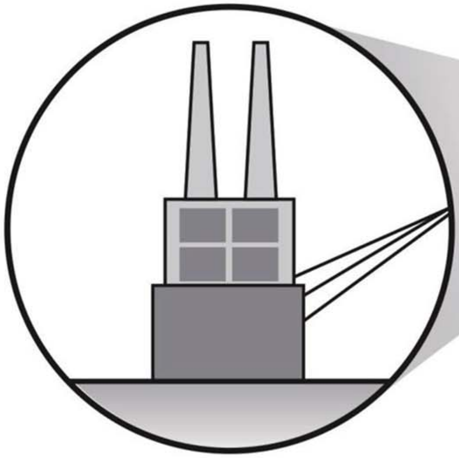
Potential pilot project

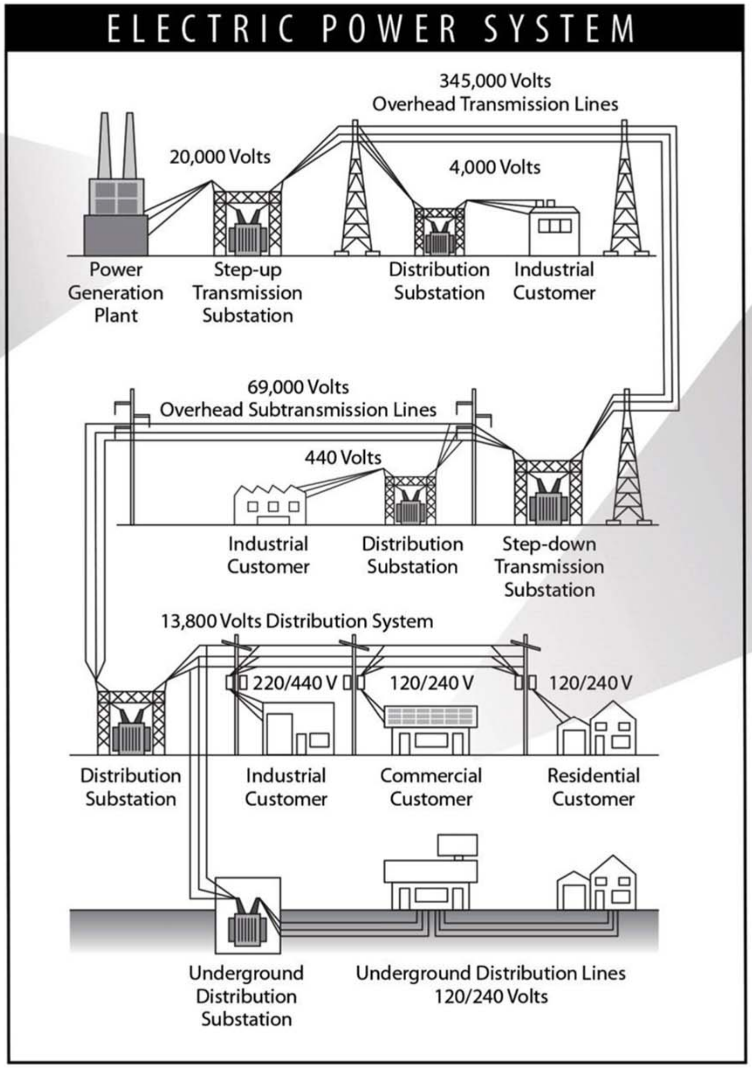
USAID Clean Power Asia aims to increase deployment in ‘grid-connected’ renewable energy in Asia

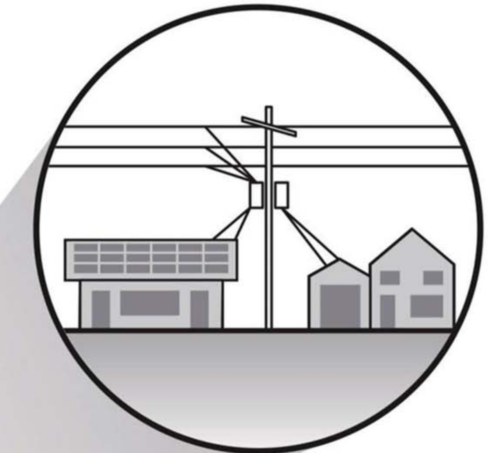
- 5 years: June 2016 – June 2021
- Regional clean energy program
- Focus on Cambodia, Lao PDR, Thailand, and Vietnam
- Goals:
  - 15 laws/policies/regulations
  - $750 M USD investment mobilization
  - 500 MW of installed RE
  - 3.5 M tCO2e reduction
- Implemented by Abt Associates and partners
- Funded by United States Agency for International Development (USAID)



What is distributed generation?







Centralized

Conventional generators and utility-scale renewables (e.g., hydropower, wind, solar photovoltaics, concentrating solar power, geothermal, biopower) interconnect at transmission and subtransmission levels.

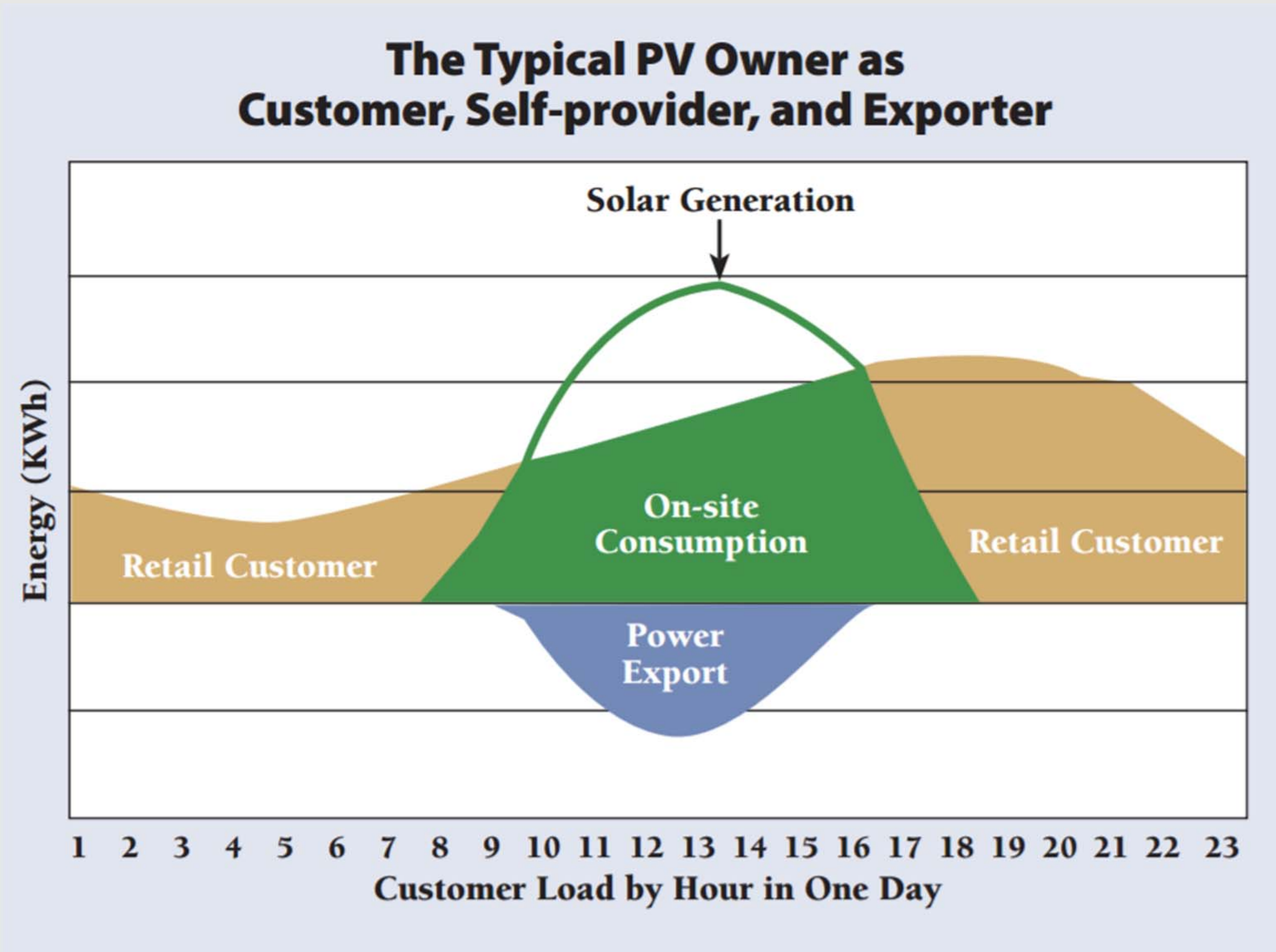
Distributed

Small-scale generators (e.g., distributed photovoltaics, small wind, run-of-river hydropower, fuel cells) interconnect at the distribution level.

What is Distributed Generation (DG)?

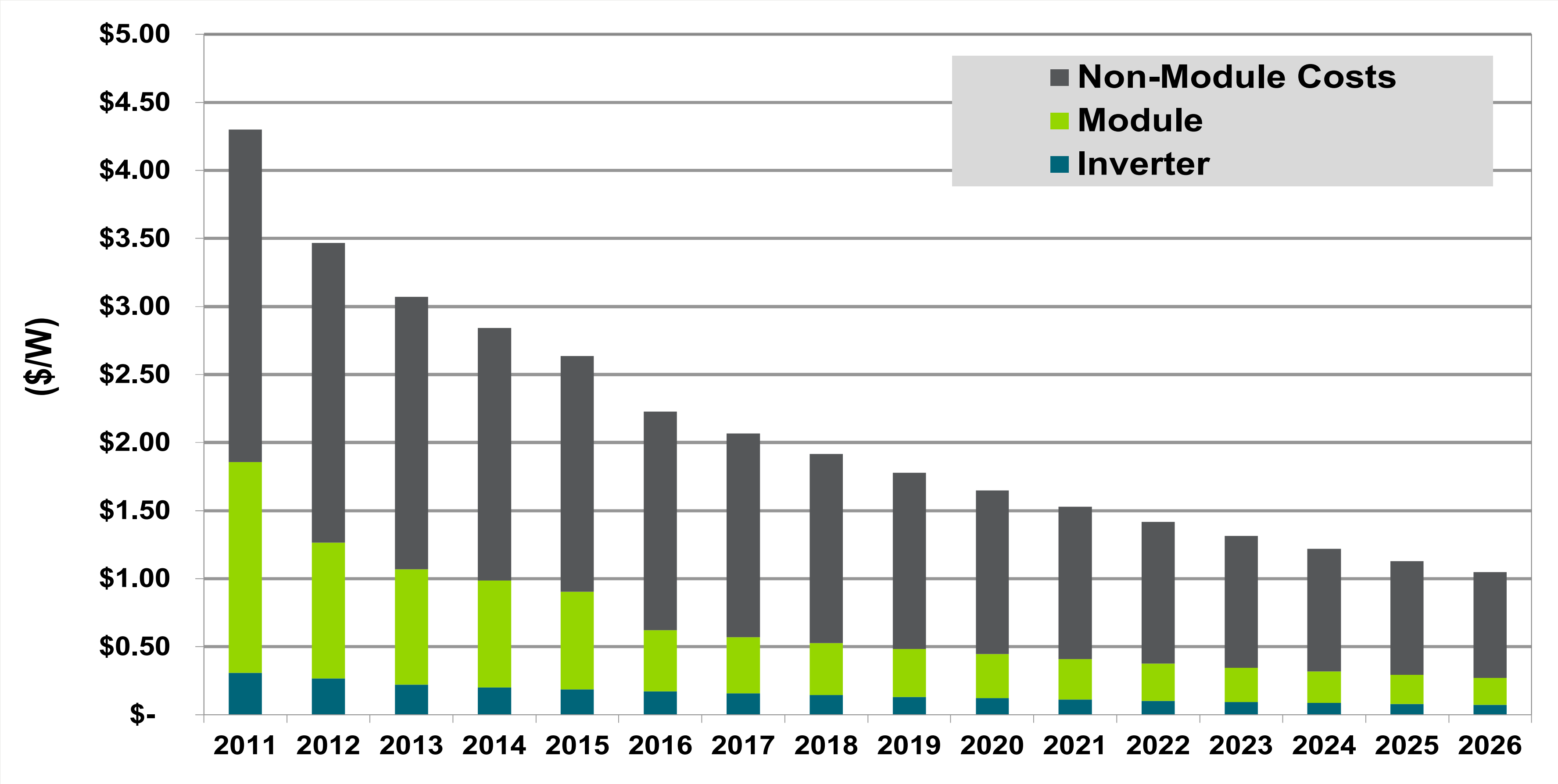
- Connected to the distribution network of an established, centralized utility system
  - Not microgrids or DG for electrification purposes (i.e. off grid)
- Connected "behind-the-meter" of retail electricity customers
- Smaller scale in nature
- In most cases, not owned/operated by distribution utility

What happens when a customer has distributed PV?



Source: Designing Distributed Generation Tariffs Well.

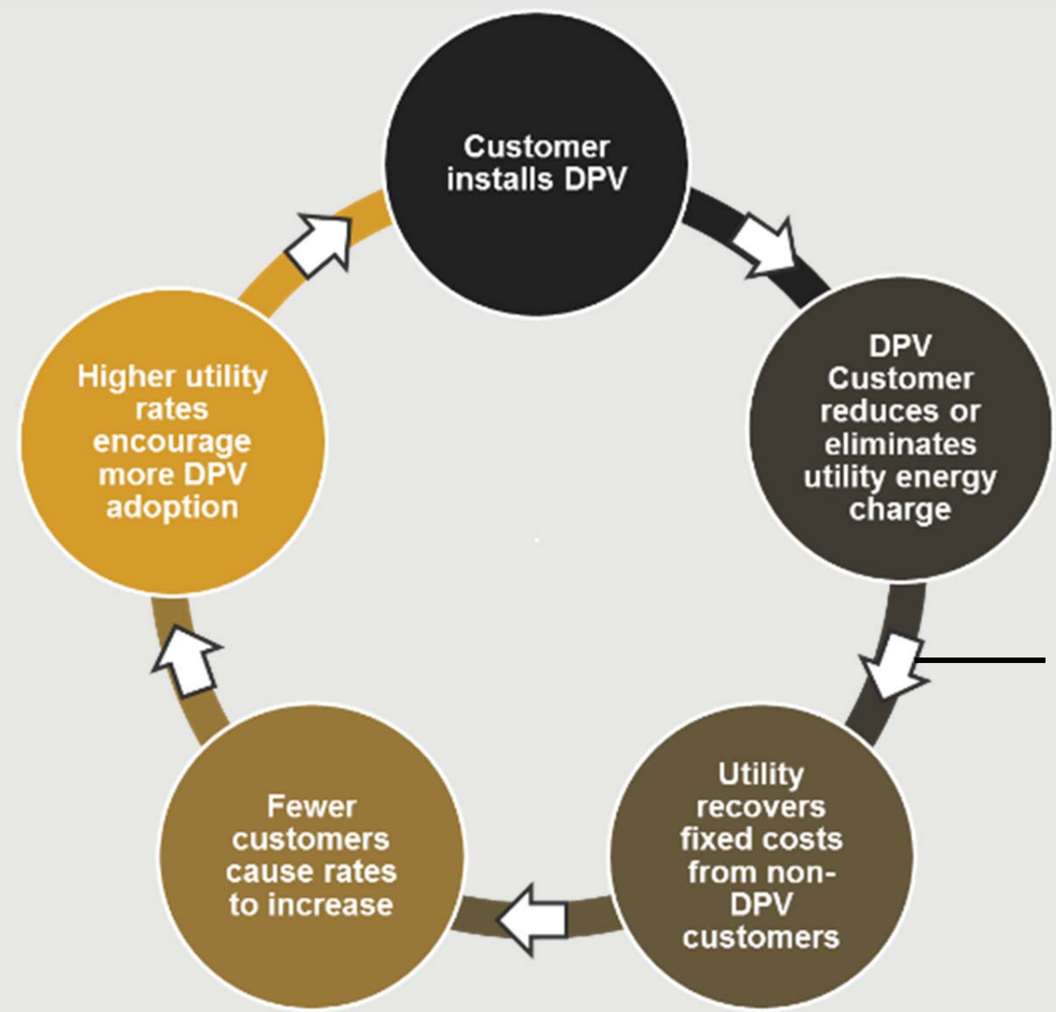
Global Trends: PV System Price Declines



Distributed Solar PV Installed System Prices (Non-Weighted Average) by Component, World Markets: 2011-2026

Source: Navigant Research, 2017

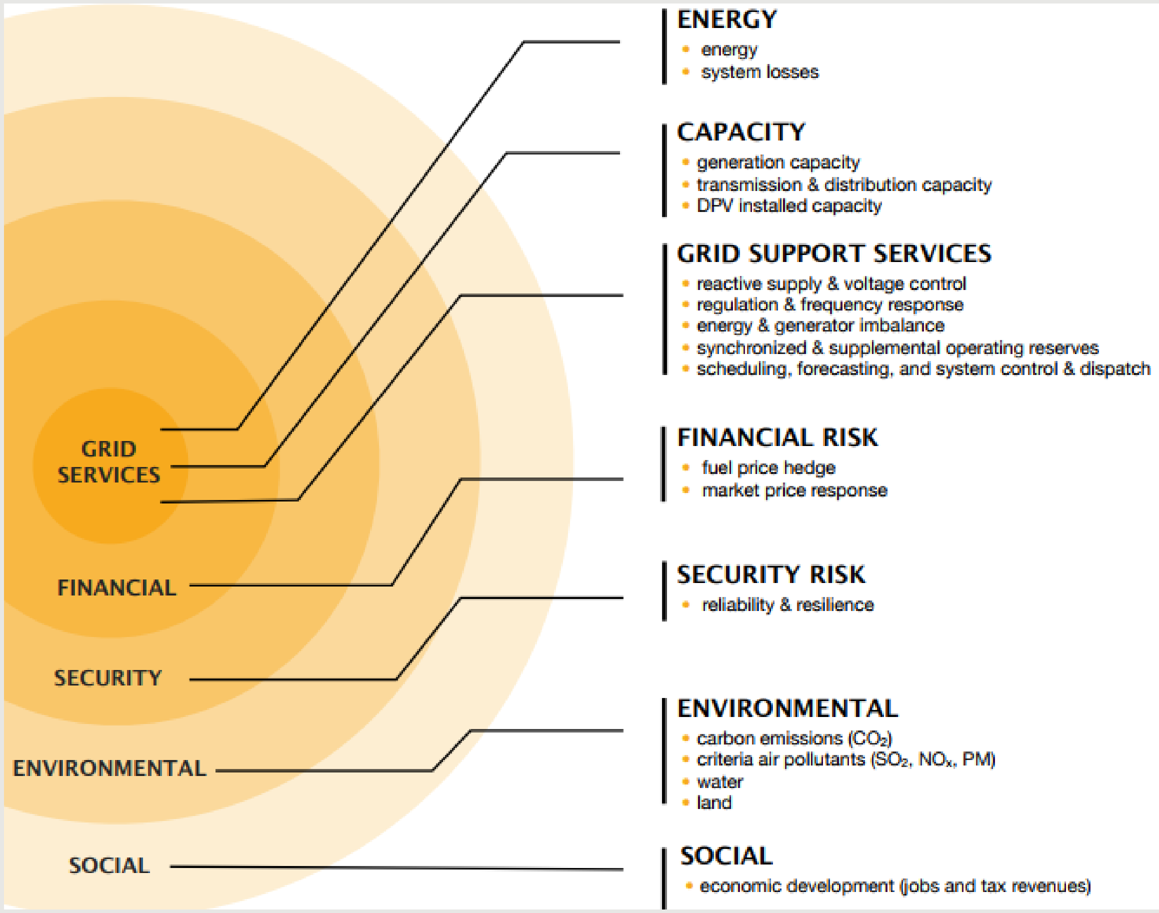
Under Typical Business Model, PV Adoption Can Create a Spiral That Incentivizes Customers Defection



Depends on compensation mechanism and tariff design

Adapted From: *Impact of Alternative Electricity Rate Structures on Solar and Non-solar Customer Bills.* NREL 2015. USA.

CATEGORIES OF BENEFITS AND COSTS OF DPV



Source: RMI (2013)

The quantification of these costs and benefits help inform policymakers and regulators on how to balance the interests of utilities, prosumers, ratepayers, and society at large.

Case Study: Impacts for Utilities' Revenue and Customers' Tariffs in Thailand

ELECTRICITY GENERATION CAPACITY: 57, 493 MW

UTILITY-SCALE SOLAR CAPACITY: 3,024 MW

DPV CAPACITY: 188 MW (0.3% of total installed cap.)

(Note: as of July 2017, Source: ERC (2017)

THAILAND'S CONTEXT:

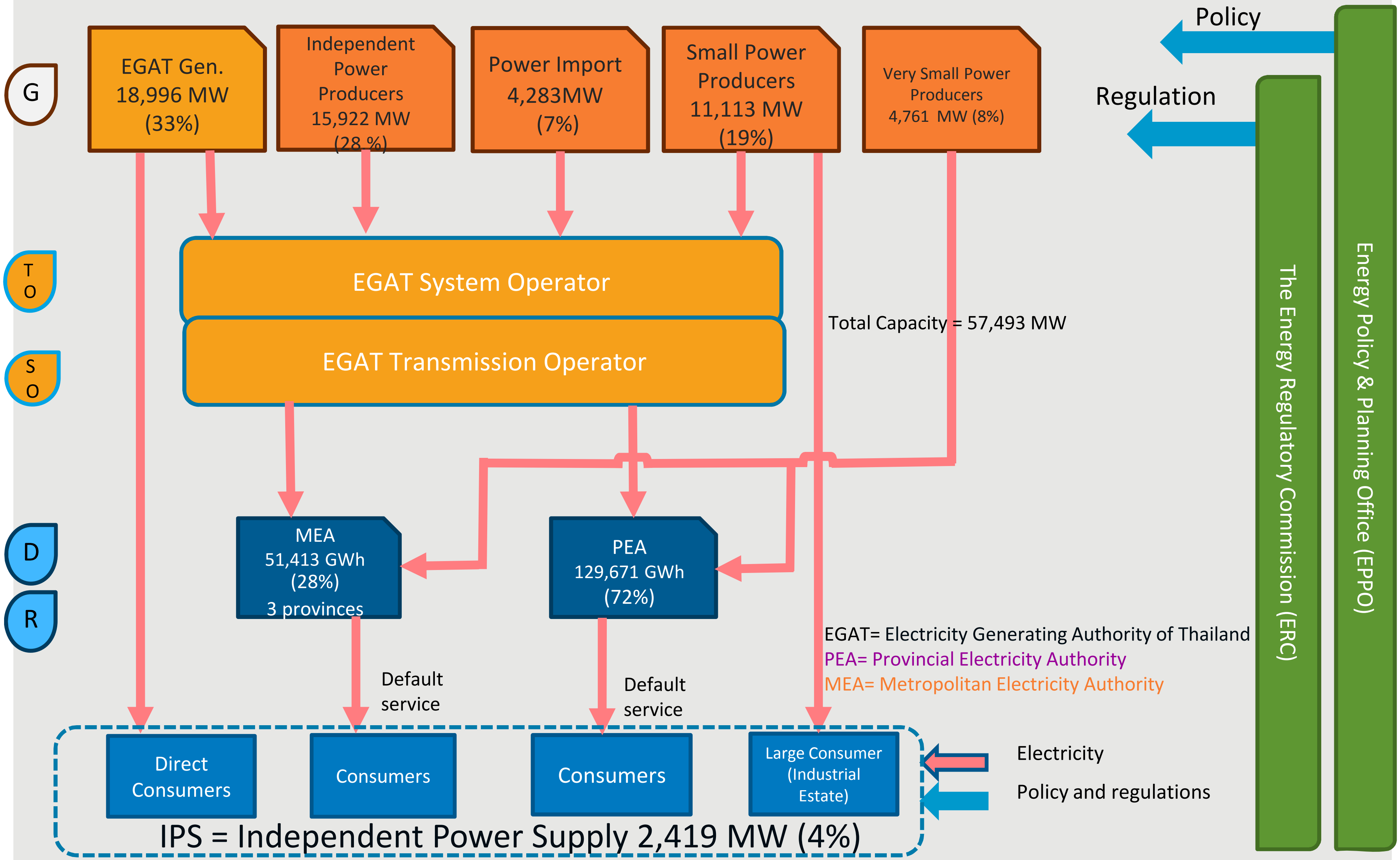
-Increasing popularity of DPV for self-consumption

-Levelized cost DPV electricity is already competitive with retail electricity prices for commercial-, industrial-scale customers.

-Launch of 2016 Pilot DPV Project (which did not compensate for injected electricity).

-Utilities expressed concerns on revenue decline from increasing DPV.

Thailand's Power Industry Structure



Source: ERC (2017); EPPO (2016)

Analysis Questions

- How would the deployment of DPV impact the revenue of distribution utilities and electricity tariffs under existing ratemaking regulations in Thailand?

- Focus:
    - Distribution utilities only (MEA & PEA)
    - Short-term impact by 2020
    - 3,000 MW DPV deployment
      (approx. 2.5% of projected sales in 2020)

Key Findings: Qualitative

1. **Thailand's current regulatory paradigm allows for 100% of all net costs associated with DPV deployment to be passed through to customers via tariff increases**
   - No direct medium- or long-term net revenue impacts
   - Retail tariffs calculation based on expected future sales → full cost recovery with DPV
2. **Thailand's regulatory structure is well-suited to support DPV deployment while protecting distribution utility revenues**
   - If DPV increases are properly planned and accounted for in rate cases.
3. **DPV self-consumption results in a short-term utility revenue loss followed by a rate increase after the rate case.**
   - If the compensation rate for injected DPV electricity is below EGAT's wholesale electricity price, Ft will decrease.
   - If the compensation rate is above EGAT's wholesale electricity price, Ft will increase.

Utility cost recovery and retail ratemaking in Thailand: without DPV

Fixed variable

$$T_{avg} = \underbrace{T_B}_{\text{Fixed}} + \underbrace{F_t}_{\text{variable}}$$

$$= \frac{\mathrm{RR}}{\mathrm{ES}} + F_t \qquad \text{(Equation 1)}$$

$$RR = (RAB * (1 + r)) + OPEX + D + T + BFC$$

All the costs associated with electricity production and delivery, such as capital costs, operation and maintenance costs, base fuel and power purchase costs, and the rate-of-return for the utility.

Utility cost recovery and retail ratemaking in Thailand: with DPV

$$T_{avg} = \frac{RR}{ES} + F_t$$

$$RR_0 - DI_B + DI_C + AC - DL - AP_{SC}$$

(+) additional costs associated with DPV increases

(-) additional benefits associated with DPV increases, e.g., distributed investment deferral benefit

$$ES_0 - SC$$

taking into account expected self-consumption caused by DPV

$$F_{t,0} + \frac{C_{inj} - AP_{inj}}{ES_0 - SC}$$

(+) costs of injected electricity

(-) benefit of injected electricity

Utility cost recovery and retail ratemaking in Thailand: without DPV

$$T_{avg} = \frac{RR_0 - DI_B + DI_C + AC - DL - AP_{SC}}{ES_0 - SC} + \left(F_{t,0} + \frac{C_{inj} - AP_{inj}}{ES_0 - SC}\right) \quad \text{(Equation 3)}$$

With DPV, there will be:

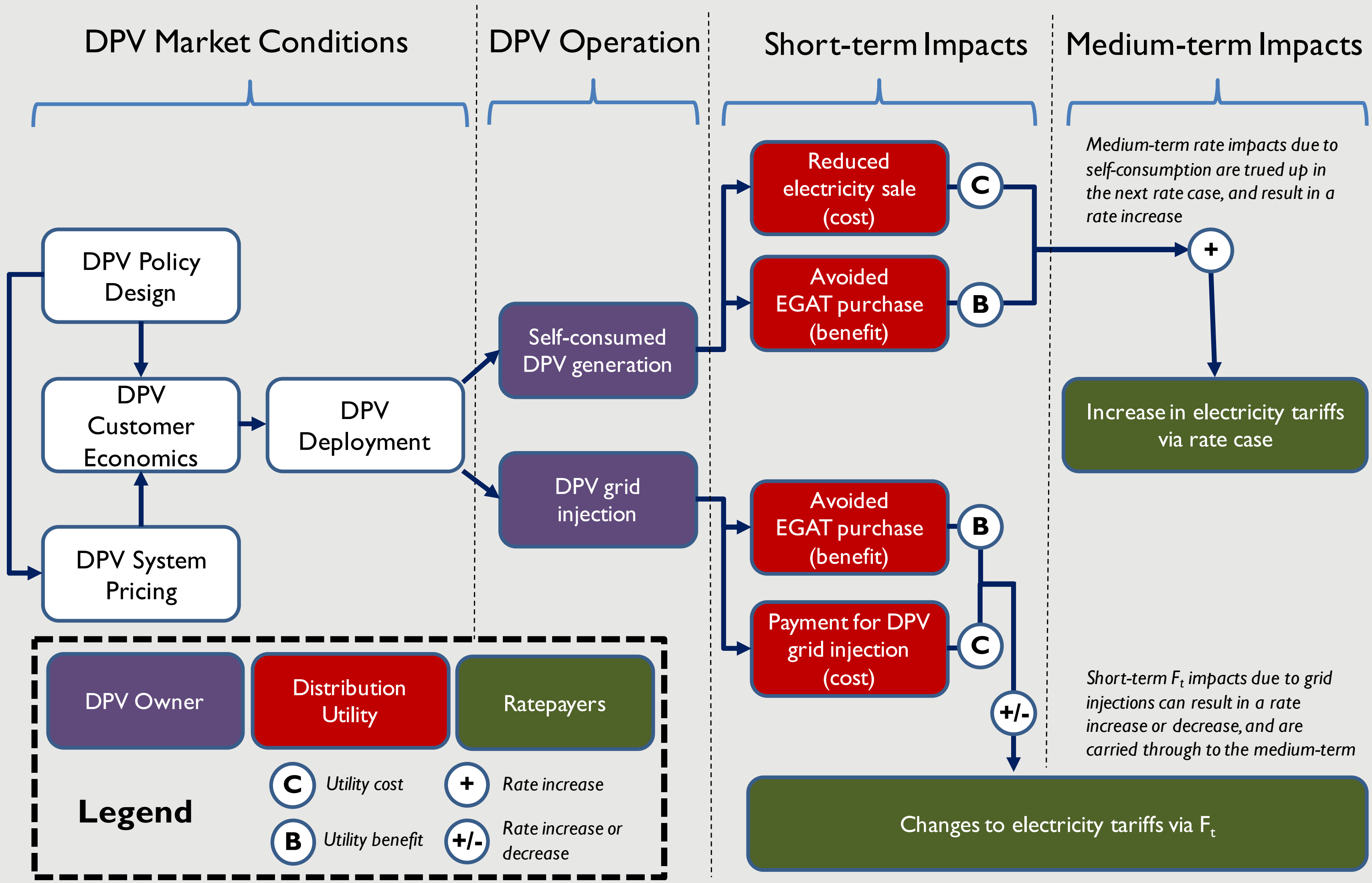
-fewer units of electricity sold
-costs and benefits associated with DPV deployment
-possible to take into account the impact of DPV in advance

Costs and Benefits of DPV: distribution level

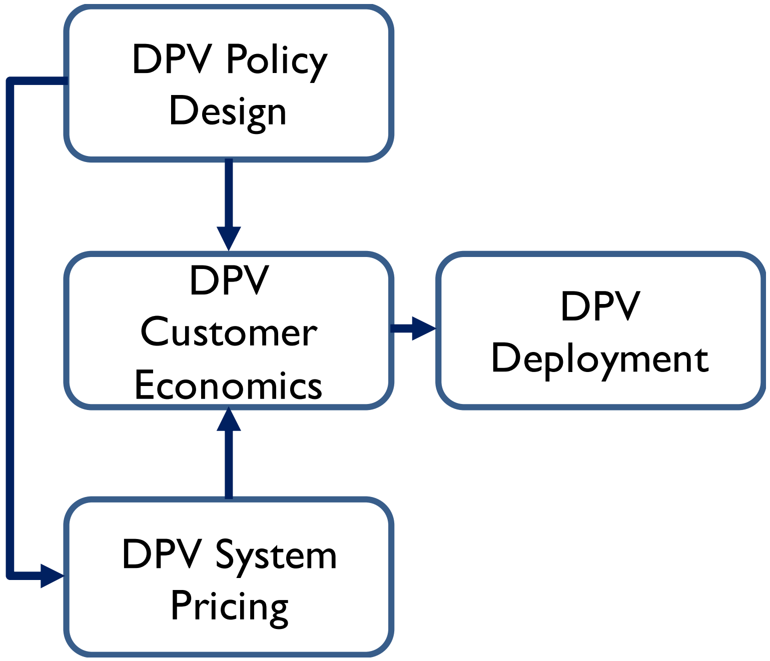
At the distribution level, DPV offers both costs and benefits to stakeholders:

COSTS	BENEFITS	
Utility revenue losses due to self-consumption	Avoided wholesale electricity purchases due to self-consumption	INCLUDED
Costs of purchased PV grid injection	Avoided wholesale electricity purchases due to grid injection	INCLUDED
Distribution system upgrade cost	Deferred distribution investment	OMITTED
Administrative cost	Avoided distribution losses	OMITTED

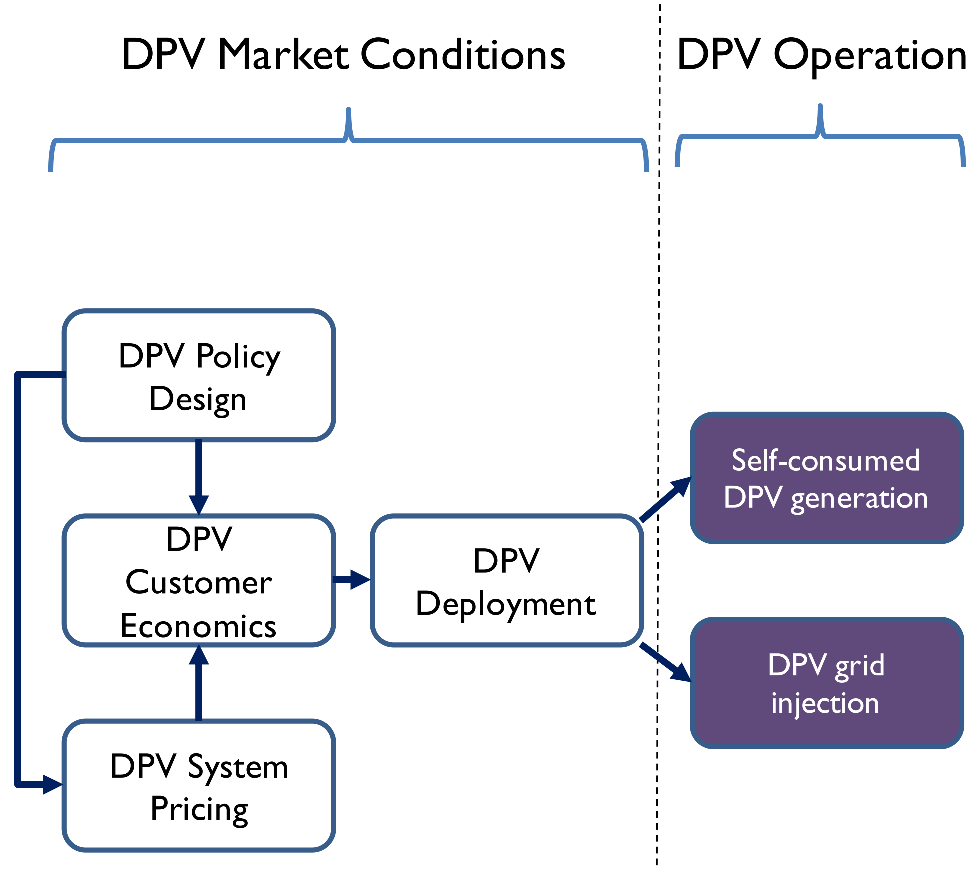
Framework for understanding the revenue and tariff impacts

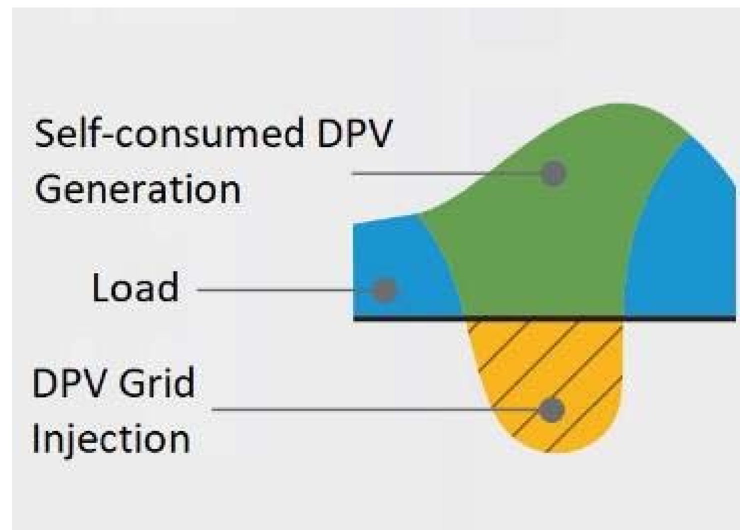


Framework: DPV Market Conditions

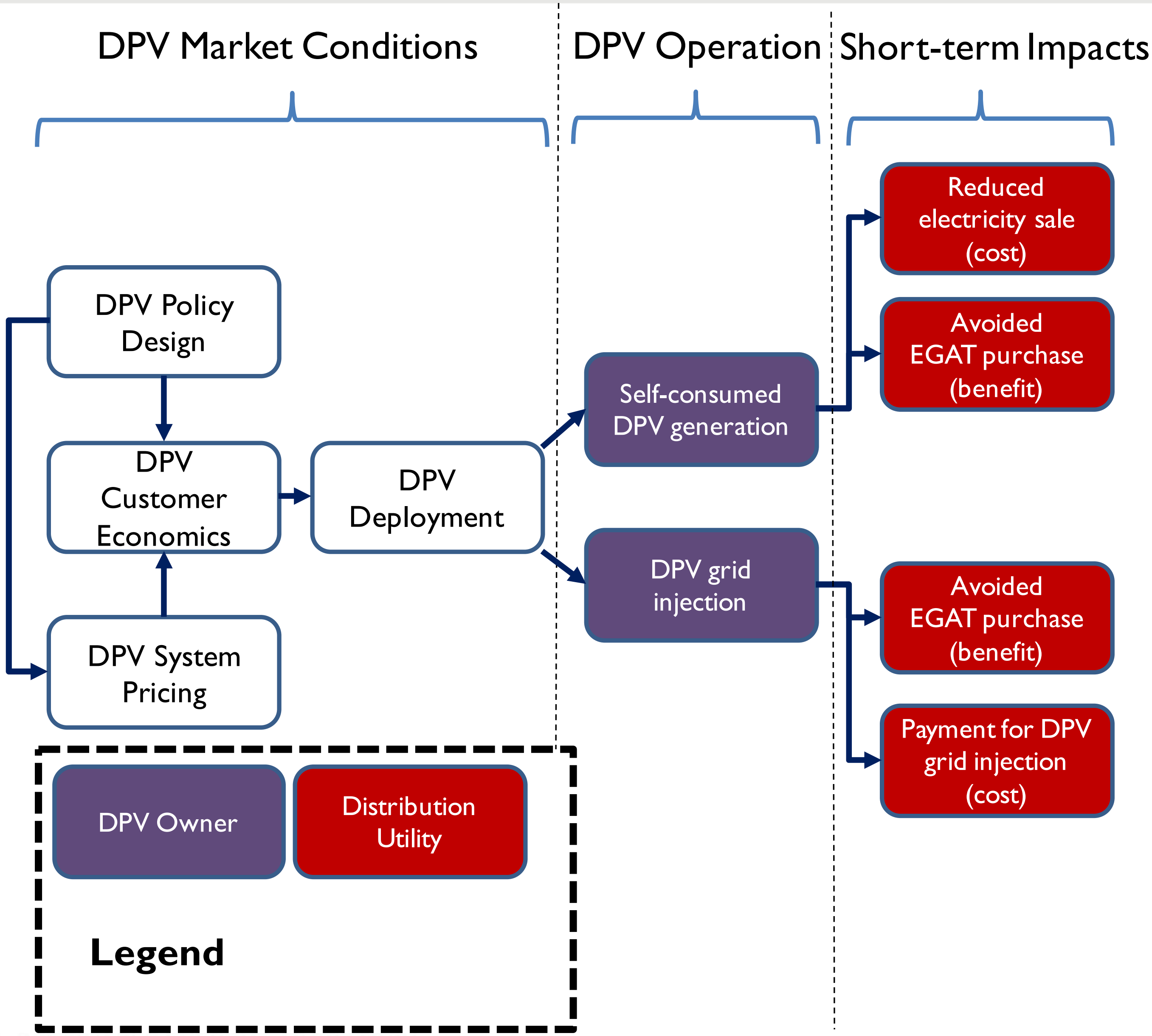


Framework: DPV Operation

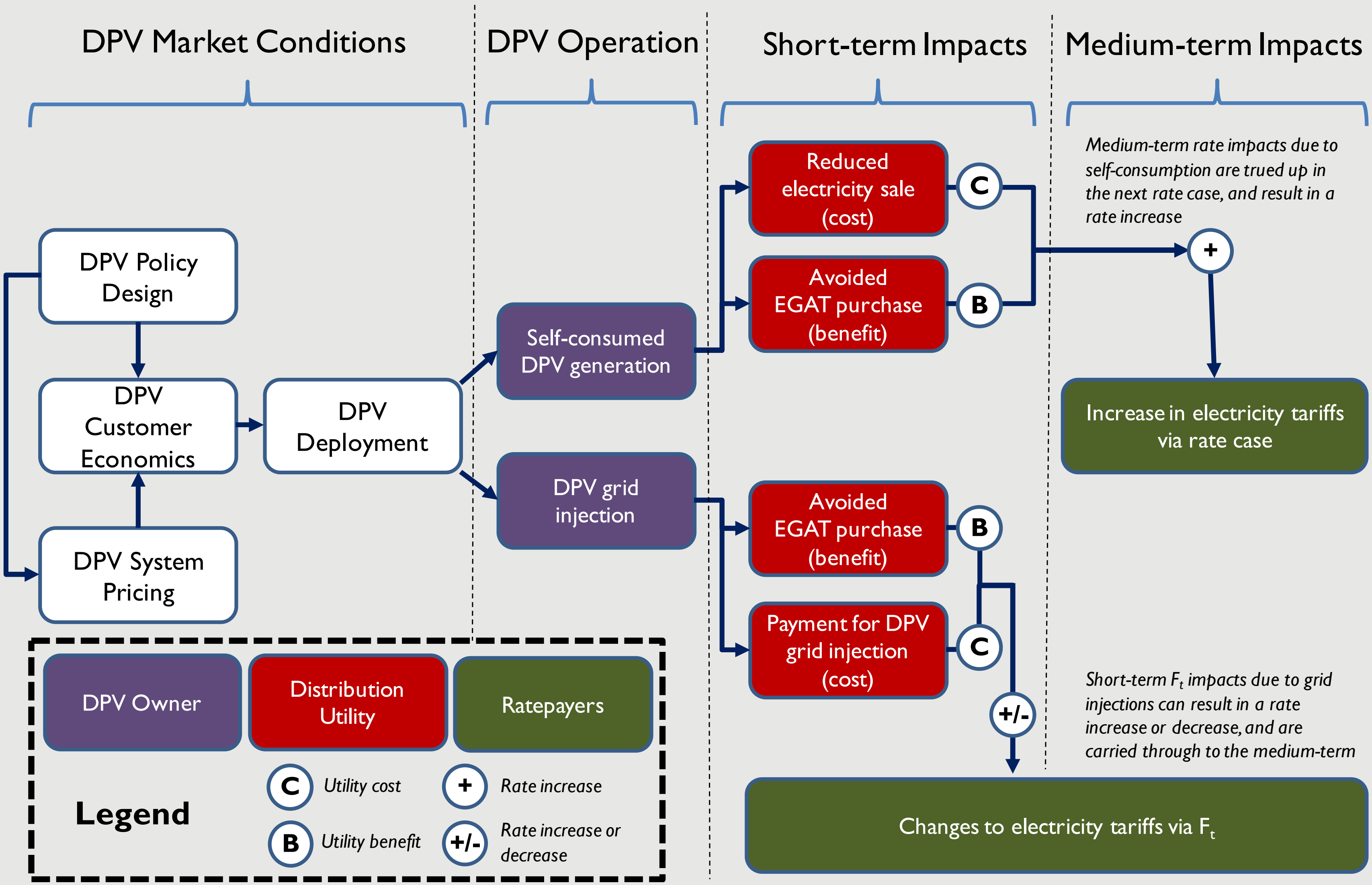




Framework: Short-term Impacts



Framework for understanding the revenue and tariff impacts



Assumptions: Scenarios

Input	values
PV deployment	- 3,000 GW of DPV over both utilities - Additional 500 MW of DPV per utility
PV system sizes	Residential: PV system sizes to generate 80% of annual electricity consumption Commercial: PV system sizes to generate 50% of annual electricity consumption
Geographic distribution	- MEA: all in Bangkok - PEA: equally distributed by load density in each of the 6 regions

Three core scenarios

Scenario Name	DPV Compensation Scheme	Customer Mix
Base Scenario	**Net Billing.** DPV grid injections compensated at 1.0, 2.0, 3.0 THB/kWh sell rate.	DPV installations proportional to total utility load by customer class
Low Impact	**Self-consumption only.** No compensation for DPV grid injections	
High Impact	Net Energy Metering. DPV grid injections credited at full variable retail electricity tariffs	DPV only installed in two rate classes with highest impact on utility revenue and rates

Methodology

To calculate revenue and tariff impacts from DPV:

- Quantify reduced sales and revenue from self-consumption
  - Calculate bill savings (baht) for DPV customers
- Calculate total cost of exports
  - Determine percent of total DPV generation exported, by customer type
- Calculate reduced cost EGAT purchases
  - Peak & off-peak electricity is generated by DPV

Methodology

- Use NREL's System Advisor Model to calculate individual customer bill savings by customer segment class (RES, SGS, etc.) and PV system size (PV-to-load ratio)
- MEA / PEA revenue reduction = aggregate bill savings for DPV customers
- Determine exported DPV generation for any given load profile
- From DPV generation profile, can determine percentage of DPV generation on peak and off-peak

Data: Retail Rates and Customer Locations

<table>
<tr><th>Distribution Utility</th><th>Total Number of Modeled DPV Customers</th><th>Tariff Classes</th><th>Distinct Locations</th></tr>
<tr><td>MEA</td><td>8</td><td rowspan="2">8
RES: Block rate / Time-of-use rate
SGS: Block rate / Time-of-use rate
MGS: Regular rate / Time-of-use rate
LGS: Time-of-day rate / Time-of-use rate</td><td>1
Bangkok</td></tr>
<tr><td>PEA</td><td>440</td><td>55 cities in 4 regions
Northern, Northeastern, Central, and Southern</td></tr>
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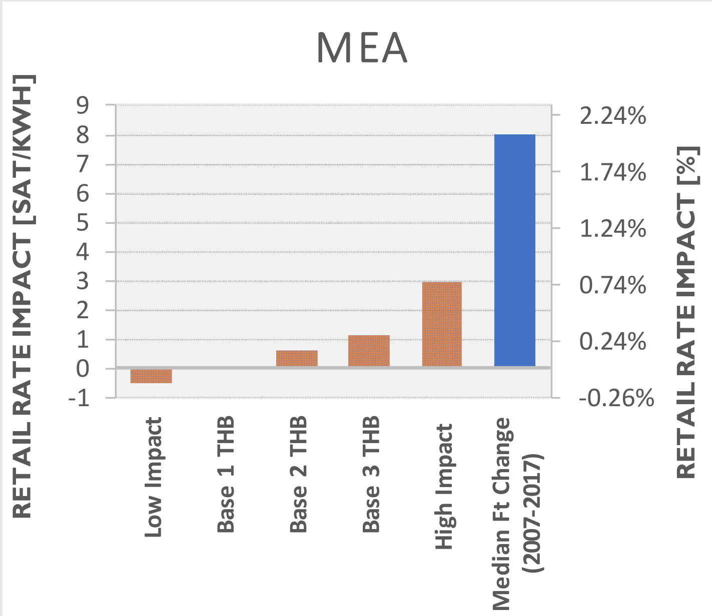
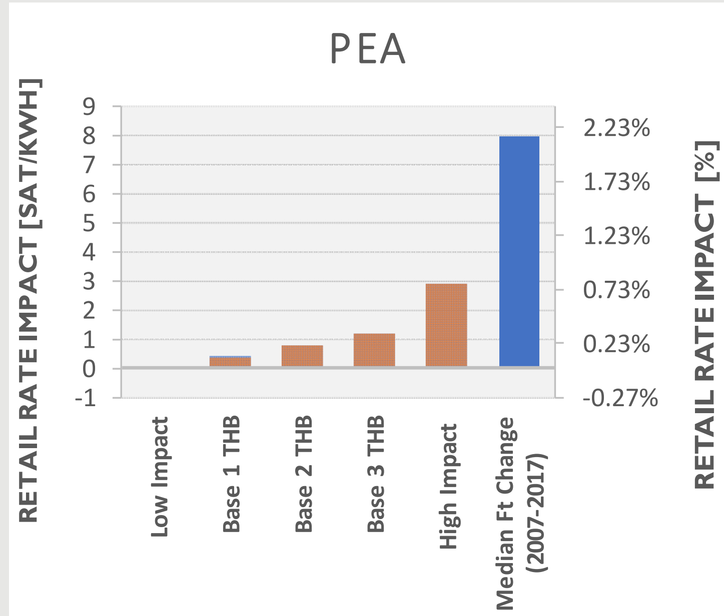
Data: Customer Characteristics

	MEA		PEA		System Design	Tariff Design	
	Annual Consumption of modeled DPV Customer [kWh/year]	Modeled DPV System Size [kW]	Annual Consumption of modeled DPV Customer [kWh/year]	Modeled DPV System Size [kW]	PV:load Ratio	Time-Invariant [% Customers]	Time-of-Use [% Customers]
Residential (>150 kWh / month)	10,780	6.4	6,766	4.3	80%	75%	25%
Small General Service	16,807	10.0	7,774	4.9	80%	50%	50%
Medium General Service	468,089	173.0	279,460	110.0	50%	25%	75%
Large General Service	9,270,085	2,060.0	8,446,735	1,994.0	50%	25%	75%

Results: Summary

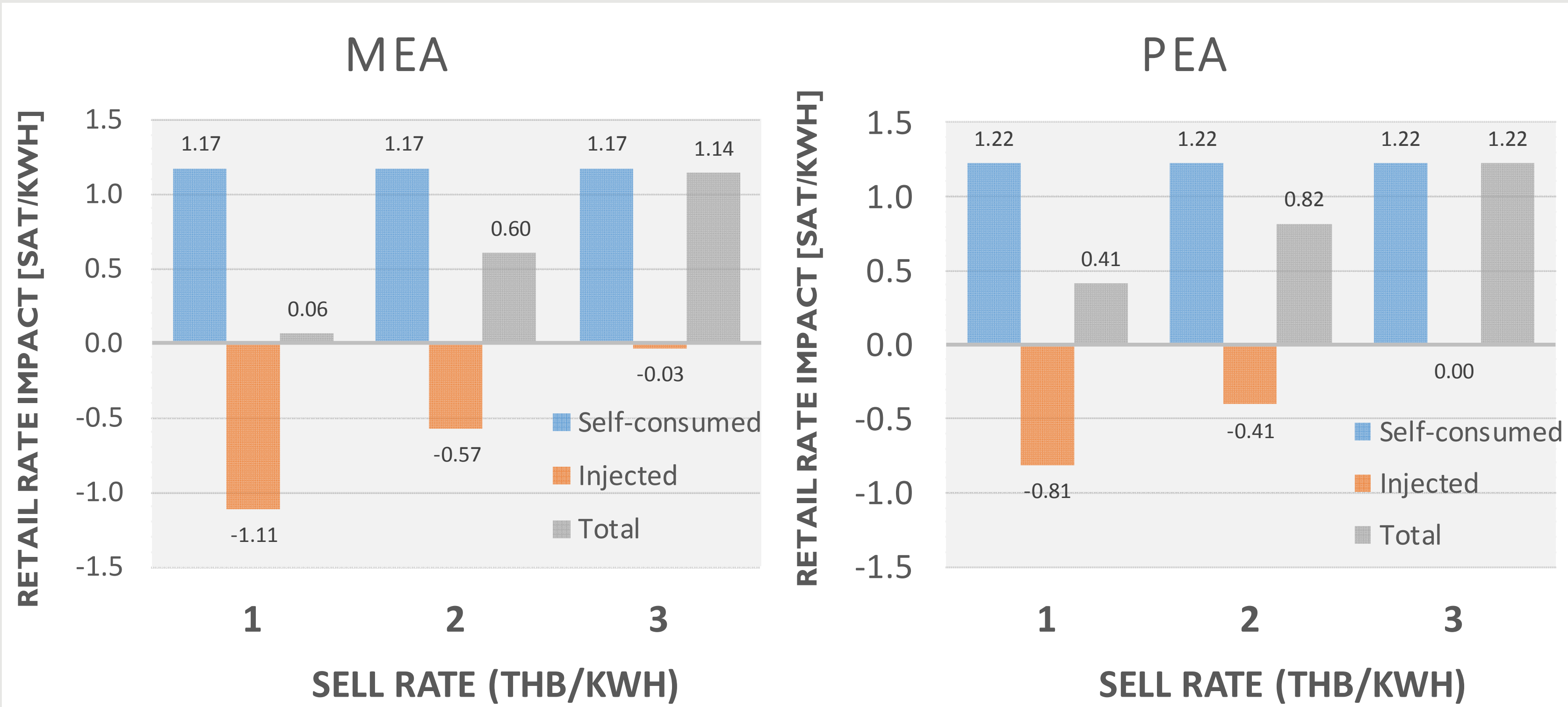




Retail Tariff Impact	**Utility**	**Low Impact**	**Base 1 THB**	**Base 2 THB**	**Base 3 THB**	**High Impact**	**Median F_t Change 2007-2017**
Satang/kWh	MEA	-0.48	0.06	0.60	1.14	2.96	7.98
	PEA	0.01	0.41	0.82	1.22	2.91	
%	MEA	-0.12%	0.02%	0.16%	0.29%	0.76%	2.1%*
	PEA	0.00%	0.11%	0.22%	0.33%	0.78%	

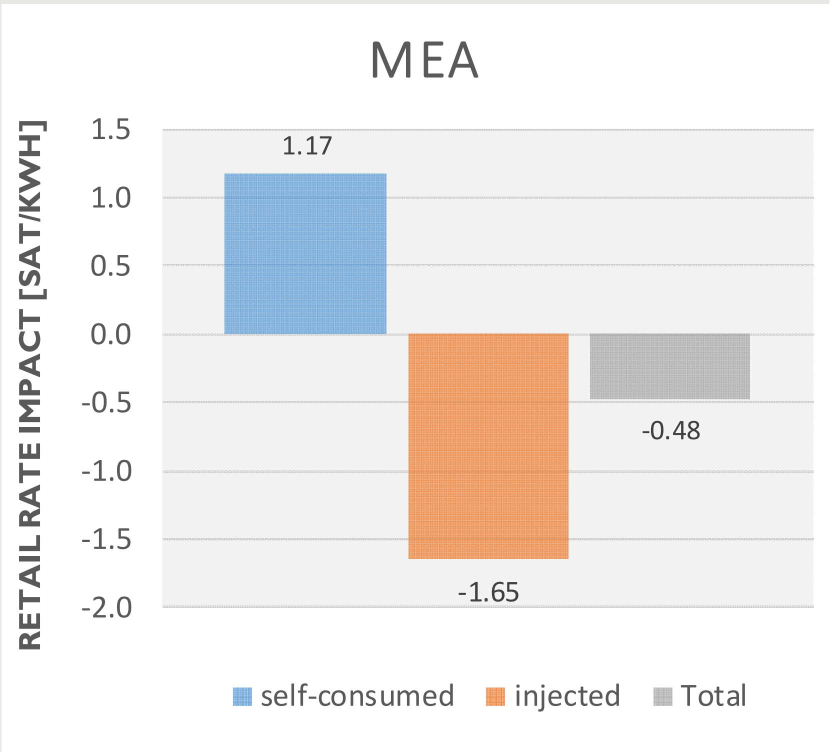
The retail electricity tariff impacts associated with 3,000 MW of DPV deployment, even under upper bound conditions for driving tariff increases, are small relative to normal fluctuations in retail rates due to the F_t.

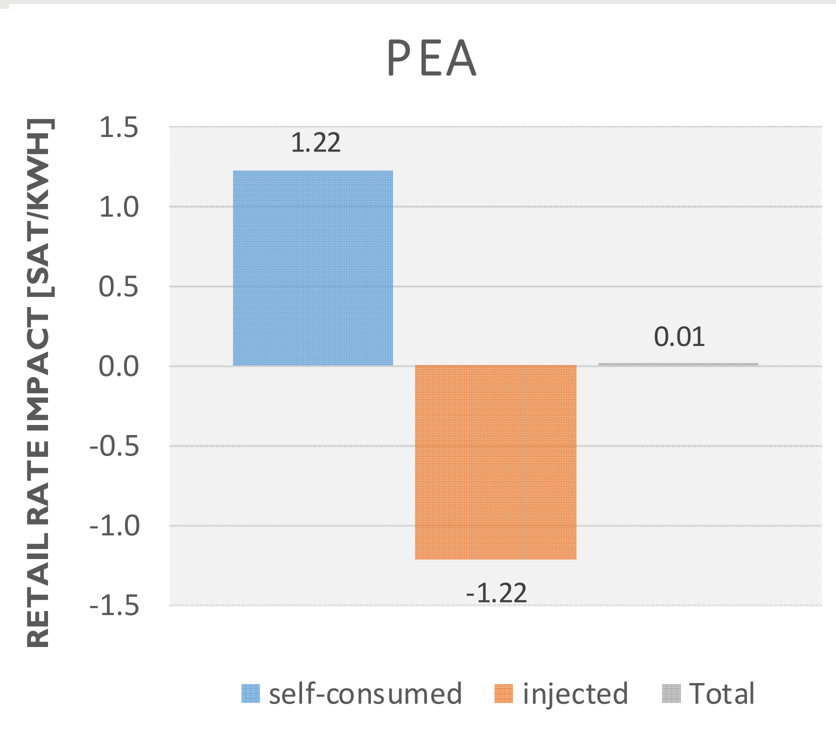
Results: Net Billing Scenarios



Under Net Billing schemes, retail electricity tariffs are impacted distinctly by self-consumption versus grid injections of DPV. When the sell rate for grid injections is lower than the wholesale electricity purchase price, the rate impact associated with DPV grid injections may be negative.

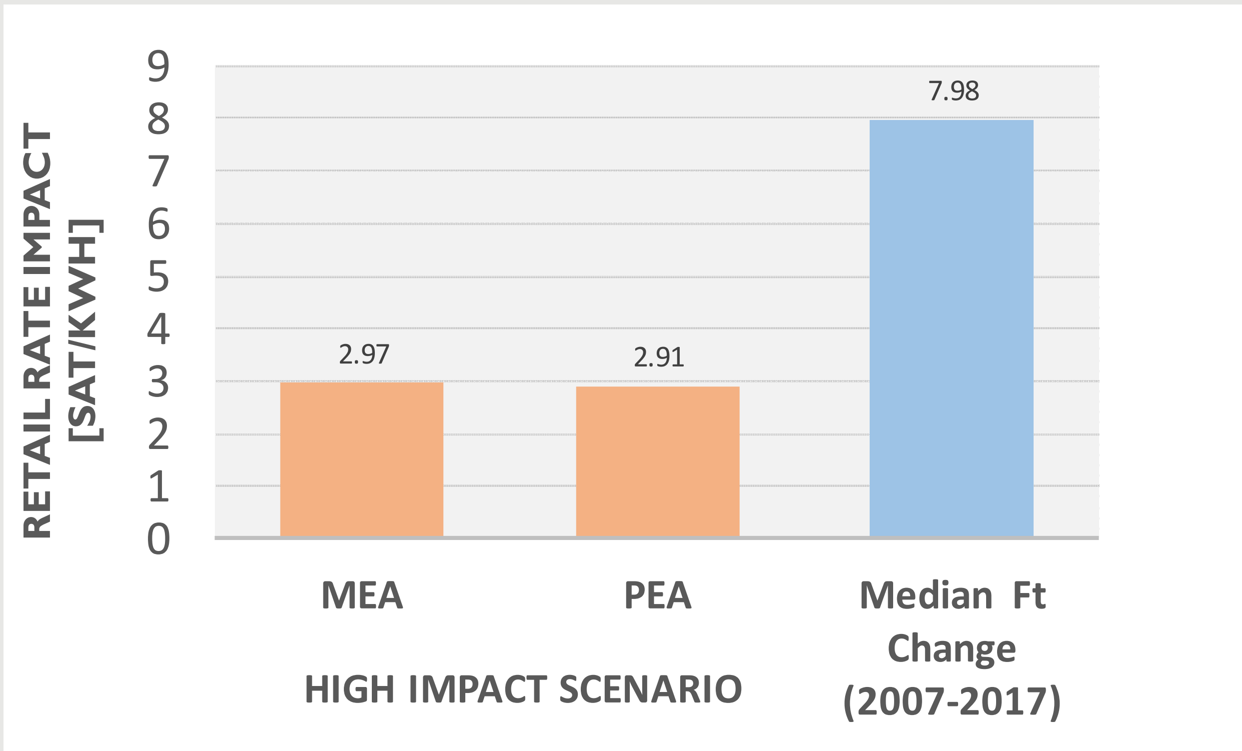
Results: Self-consumption only





Under the low-impact scenario, impacts are negligible because the average compensation for DPV generation is approximately equal to the reduced costs for the utility.

Results: High Impact Scenario (Net Metering)



Under high impact scenario, the retail rate increases slightly, as all PV generation is effectively compensated at the retail rate, which is higher than the wholesale purchase costs. This difference in costs for the utility results in higher rates.

Policy implications

- Electricity rates and utility revenue impacts in the medium term are minimal
  - Addresses policymakers concerns related to revenues and rates
- DPV policy is a balance between (a) incentivizing PV adoption and (b) moderating impacts on electricity rates and utility revenues
- There are policy mechanisms to ensure minimal impact going forward
  - System-wide deployment caps
  - Retail rate impact caps

Implications for Regulators

- Regulator ensures electricity rates are fair and utilities maintain acceptable rate of return
  - Consumer protection and utility protection
- Regulator can ensure financial health of utilities by maintaining current rules
- National DPV registration system and data collection effort would ensure regular monitoring of rate impacts from DPV and revision of framework if appropriate

Implications for Utilities

- Results highlight the importance of incorporating DPV in rate case
  - Ensures no revenue loss between rate cases
- Working with regulator to collect DPV data will enable accurate rate and revenue impact evaluation of existing DPV
  - National data registration system
  - Technical requirements for metering and billing infrastructure
- Utilities can begin tracking DPV program administration and interconnection costs

Lessons Learned: Process and Methods

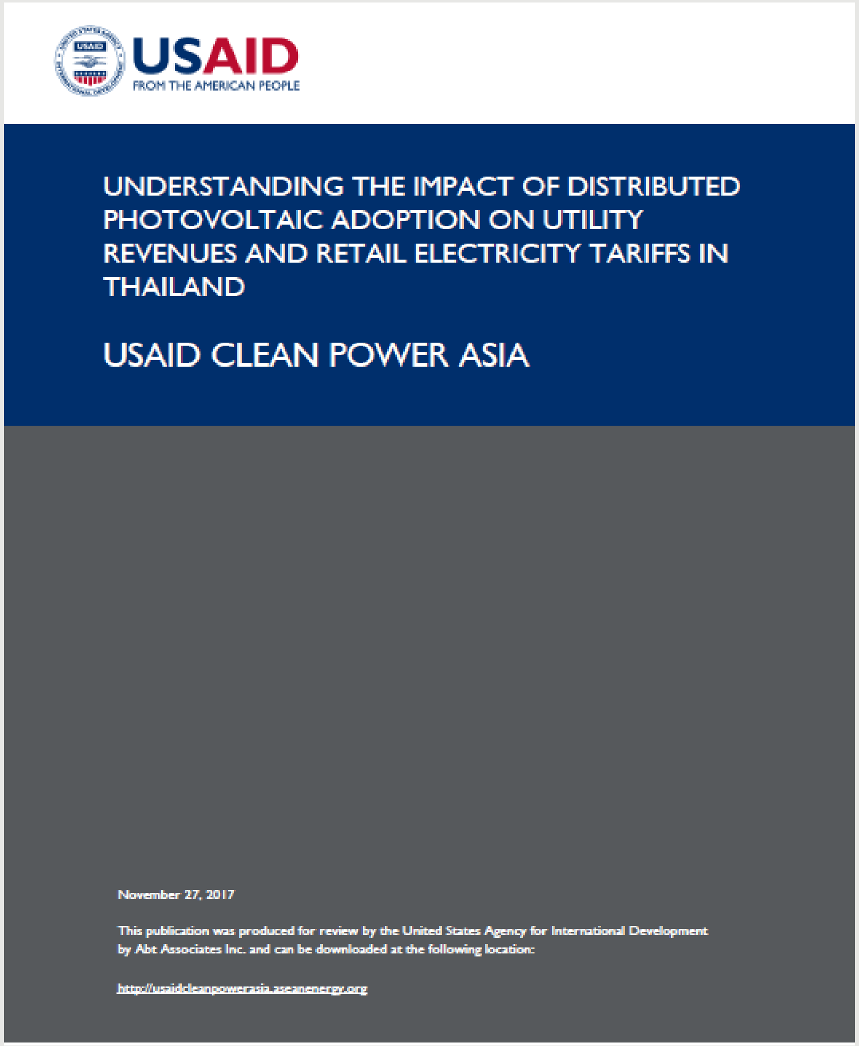
- Setting clear objectives (and limitations) up front is important to set up expectations
- Understanding how PV is compensated & rate and utility regulatory frameworks is key
    - Highlights importance of working closely with Energy Department, regulators, and utilities

- To maximize impact on future regulatory and policy decisions:
    - Utilize rigorous and transparent methods
    - Engage with stakeholders during all stages of the analysis
    - Local partners ensure access to most appropriate audience

Broader Applicability of Results

- Revenue and rate impacts from PV are always context-specific
  - Study scope:
    - PV targets
    - Short term vs. medium term vs. long term
  - Regulatory framework (rate-setting and PV compensation)
  - Customer and PV generation characteristics
  - Electricity costs and generation mix
- However, basic quantitative takeaways
  - If PV compensation ≠ avoided costs → rate and/or utility revenue impacts
  - Low PV penetration → low rate/revenue impacts

For more details, please read the full report.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UNDERSTANDING THE IMPACT OF DISTRIBUTED PHOTOVOLTAIC ADOPTION ON UTILITY REVENUES AND RETAIL ELECTRICITY TARIFFS IN THAILAND

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