Distributed Solar on the Grid: Key Opportunities and Challenges

National Renewable Energy Laboratory

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USAID FROM THE AMERICAN PEOPLE

ENHANCING CAPACITY FOR LOW EMISSION DEVELOPMENT STRATEGIES (EC-LEDS)

Outline and Learning Objectives

1. Brief global review of DGPV market and impact

2. Economic Issues and Opportunities for Distributed Solar
   – Understand the challenges of DGPV integration to traditional utility business models and identify potential solutions

3. Key Technical Challenges and Solutions for DGPV Integration
   – Understand the key strategies that can mitigate integration costs and help overcome technical challenges associated with DGPV integration

4. Conclusion and Additional Resources

5. Question and Answer Session

1. DISTRIBUTED SOLAR: OVERVIEW OF GLOBAL AND DEVELOPING COUNTRY CONTEXT

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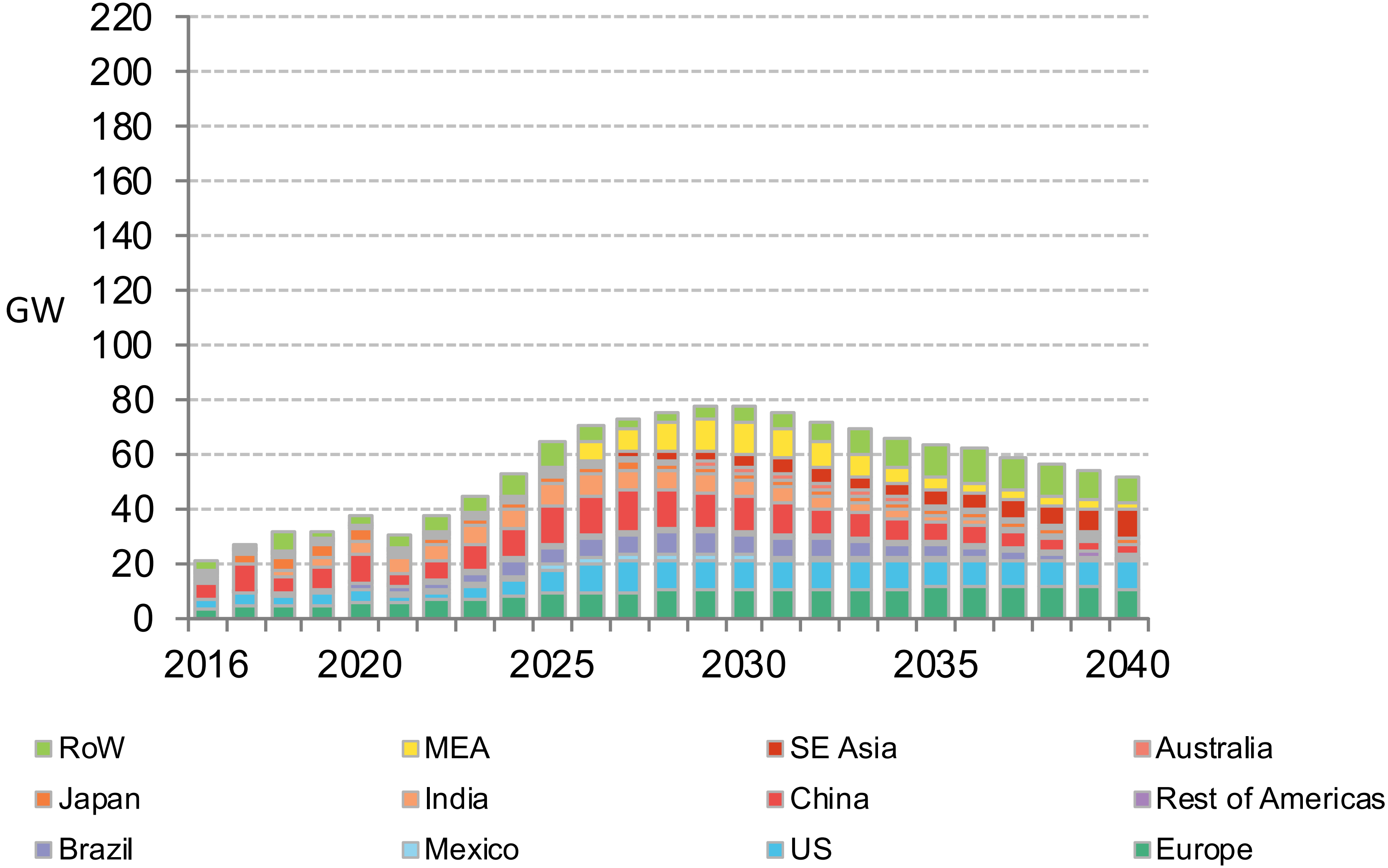
Projected DGPV Capacity Additions



Source: Bloomberg New Energy Finance

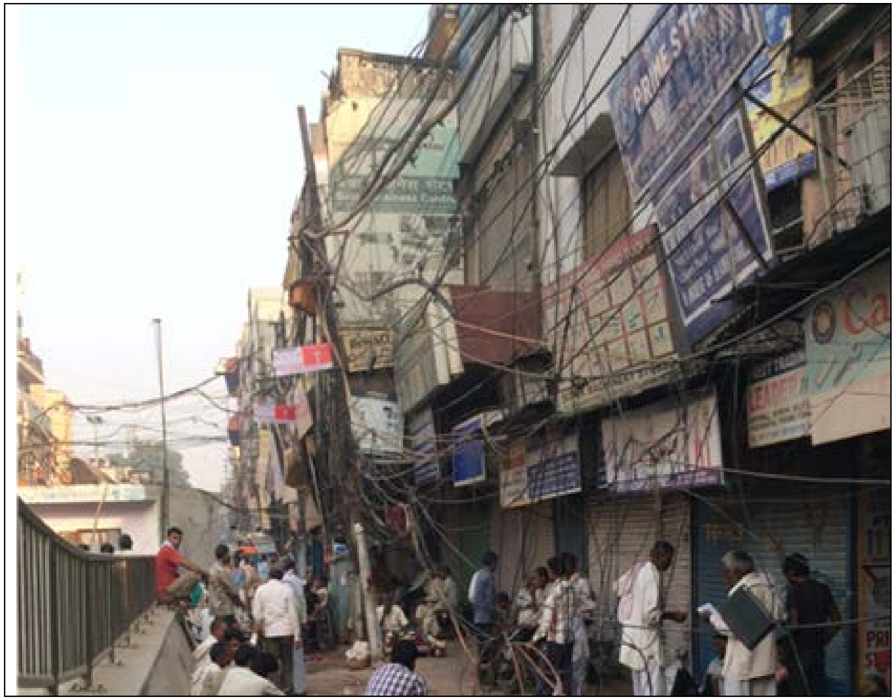
Global context: distributed generation

- Distributed generation is a key disruptive force shaping power system transformation worldwide; it presents a range of opportunities!
- Distributed generation is challenging how we plan, operate, regulate and even conceptualize the power system.
- Benefits and challenges of DPV are quite unique.

Consumers are no longer waiting for regulatory, legal, and technical issues to be resolved; they are simply deploying systems!

Global Trends and Developing Country Context

- Energy access issues
- Unreliable infrastructure
- Electricity theft
- Subsidized tariffs
- Lacking technical standards
- Governance
- And many others…



2. ECONOMIC ISSUES AND OPPORTUNITIES FOR DISTRIBUTED SOLAR

Owen Zinaman

National Renewable Energy Laboratory

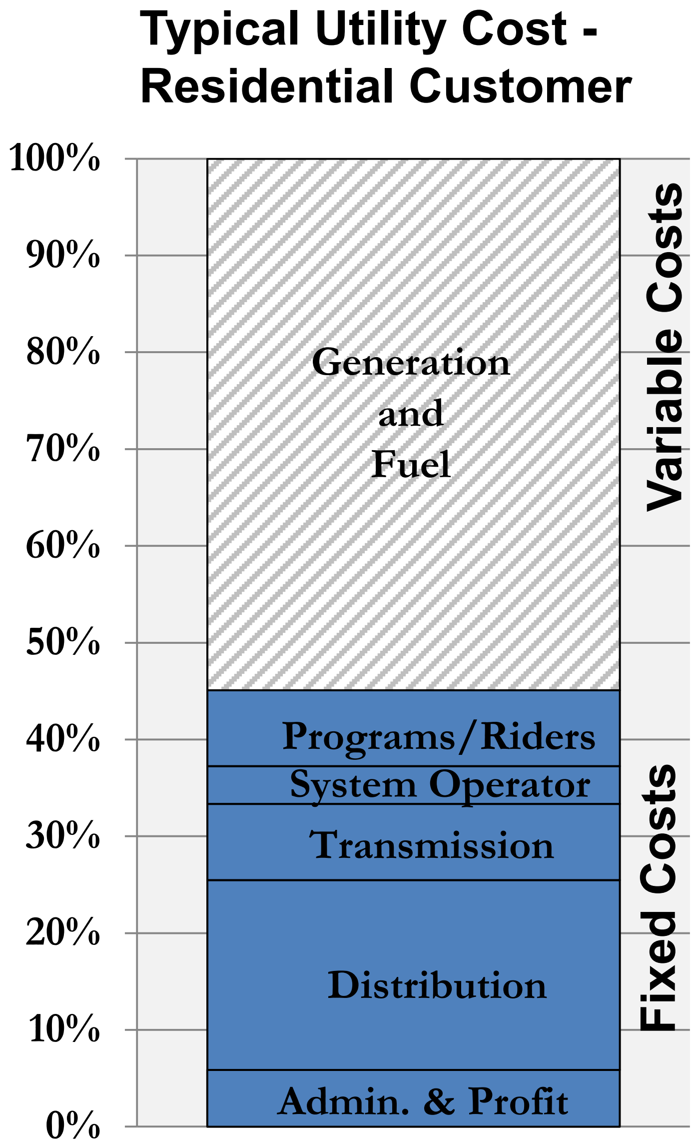
Distributed Solar Challenges the Traditional Utility Business Model

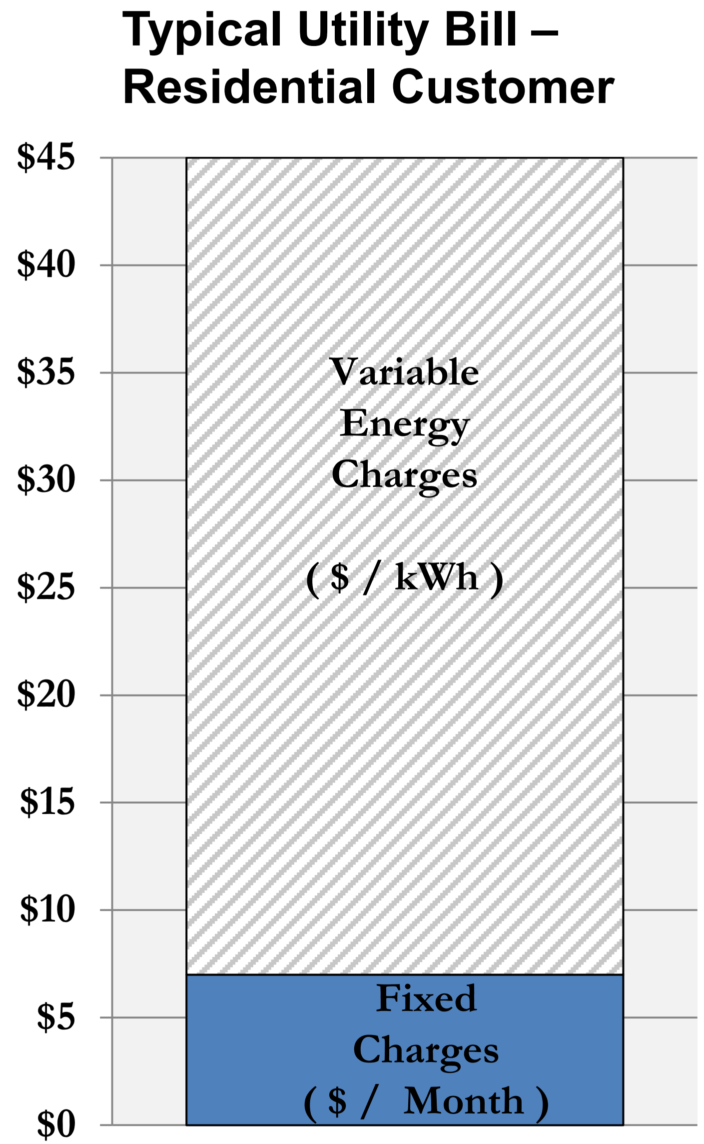
- **Selling power creates revenue to pay for infrastructure**
- **Distributed PV deployment reduces revenues**
- **DPV most appealing and accessible to customer groups that typically subsidize the system**

Utility Costs and Charges Typically Have Fixed and Variable Components

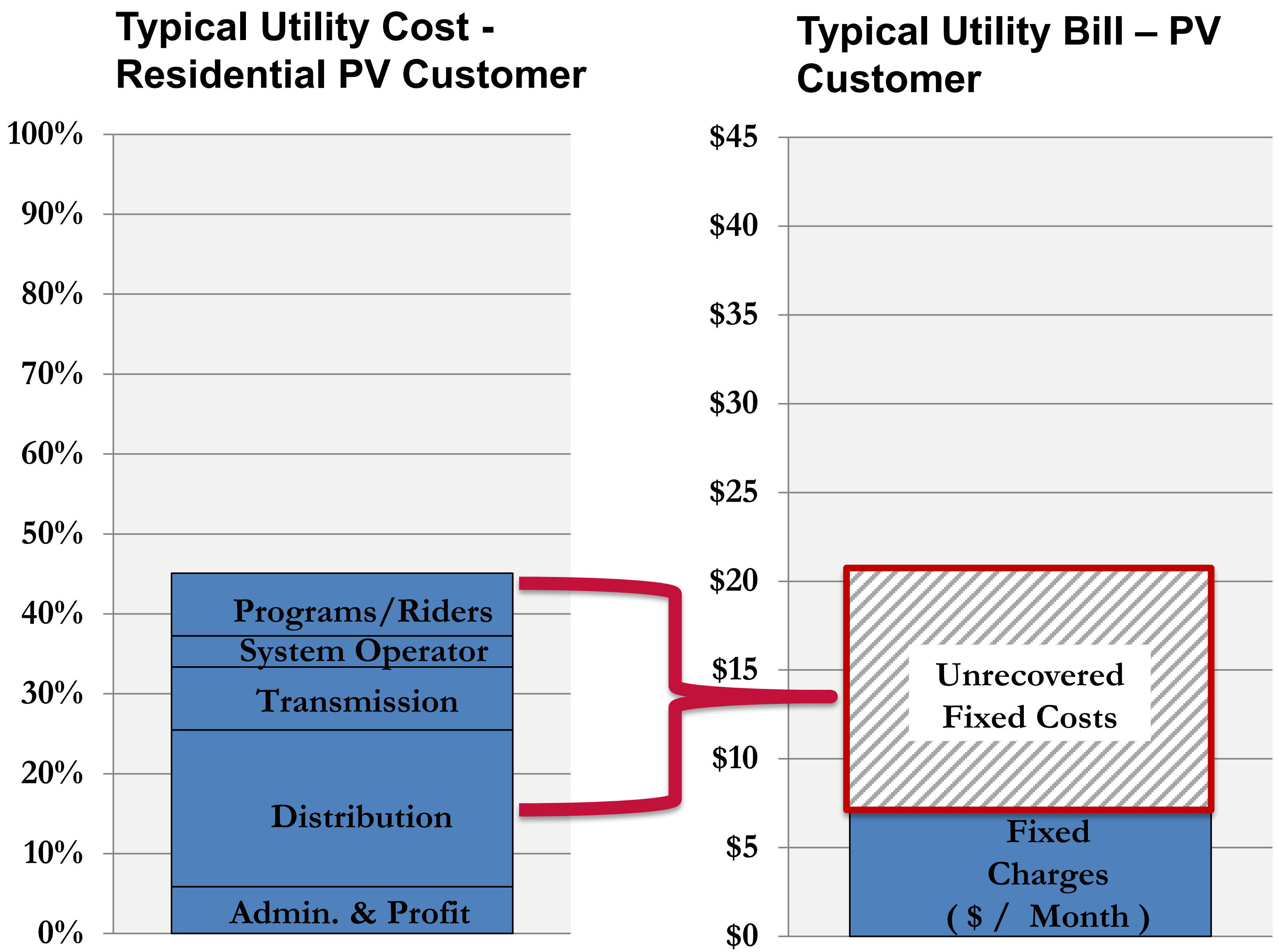
- **Cost = actual price incurred to provide electric service**
- **Charge = element of a tariff designed to recoup costs from electricity consumers**
- **Fixed costs are constant, regardless of consumption.**
  - **Ex: Network costs, billing**
- **Variable costs grow or fall with consumption**
  - **Ex: Fuel costs**
- **Charges can be also be fixed (e.g., $ / month) or variable (e.g., $ / kWh)**

Utilities Often Recover Fixed Costs Through Variable Energy Charges

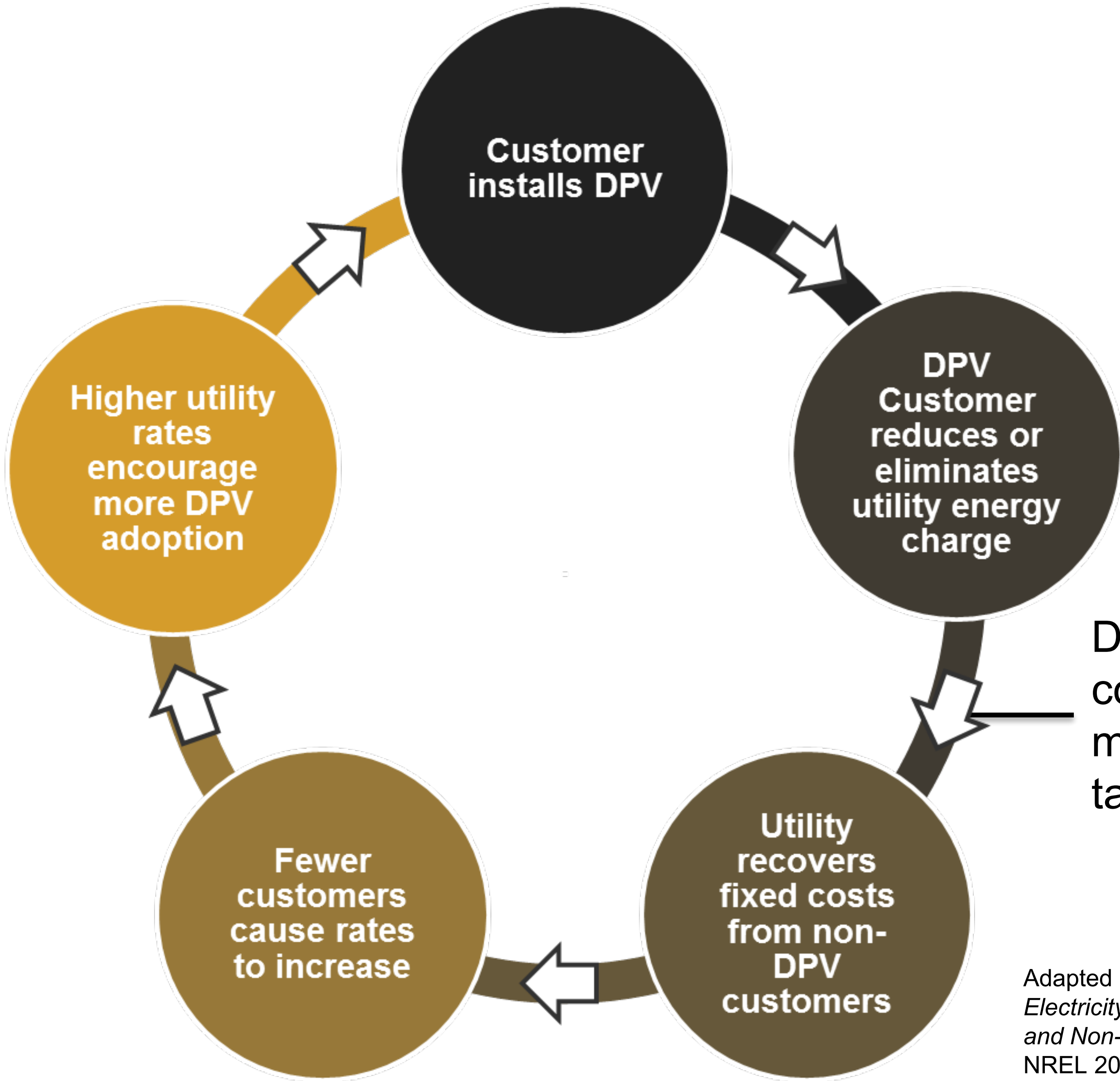




Distributed PV Creates Potential for Unrecovered Fixed Utility Costs



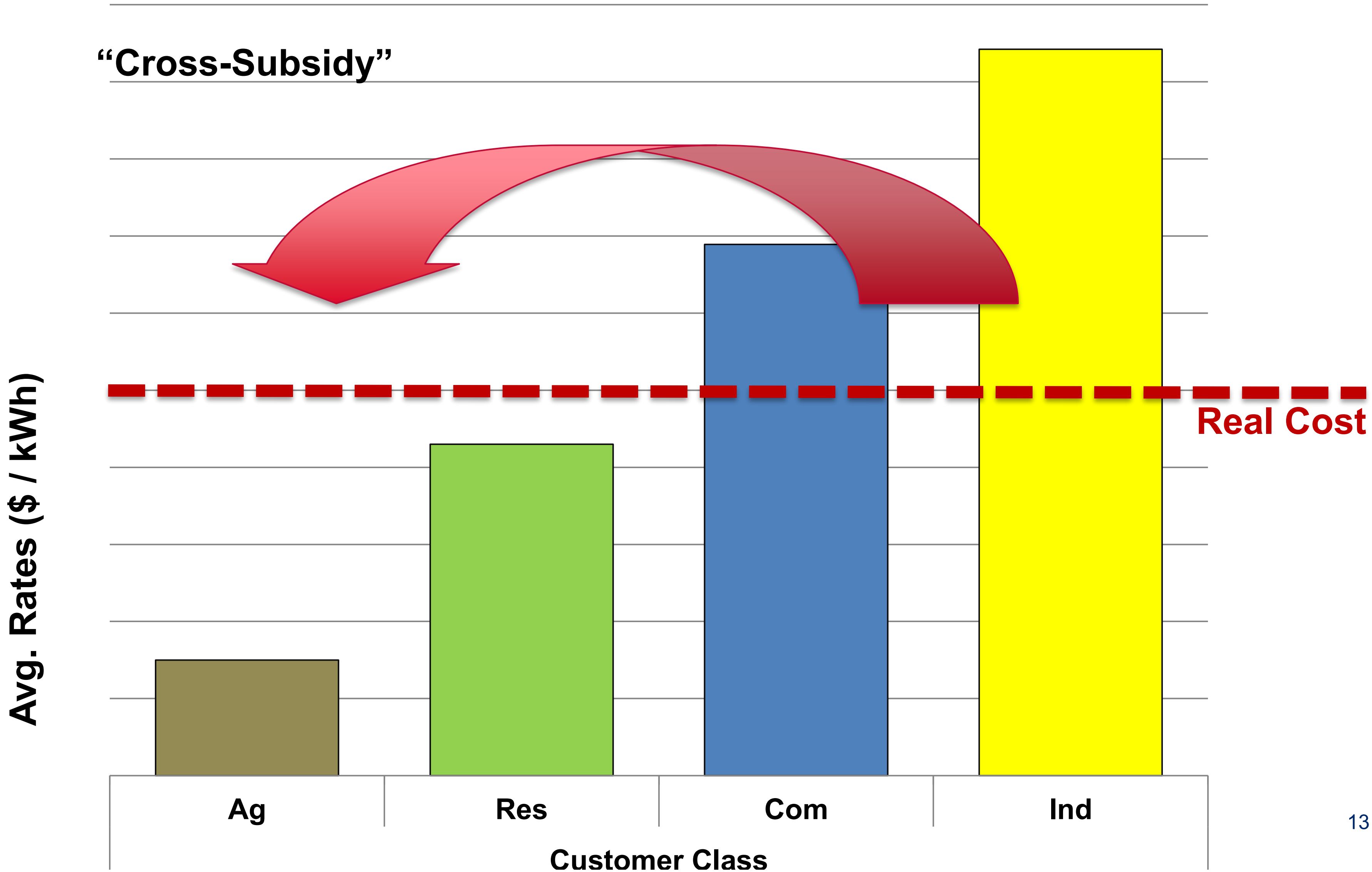
Under Typical Business Model, PV Adoption Can Create a Spiral That Incentivizes Customers Defection



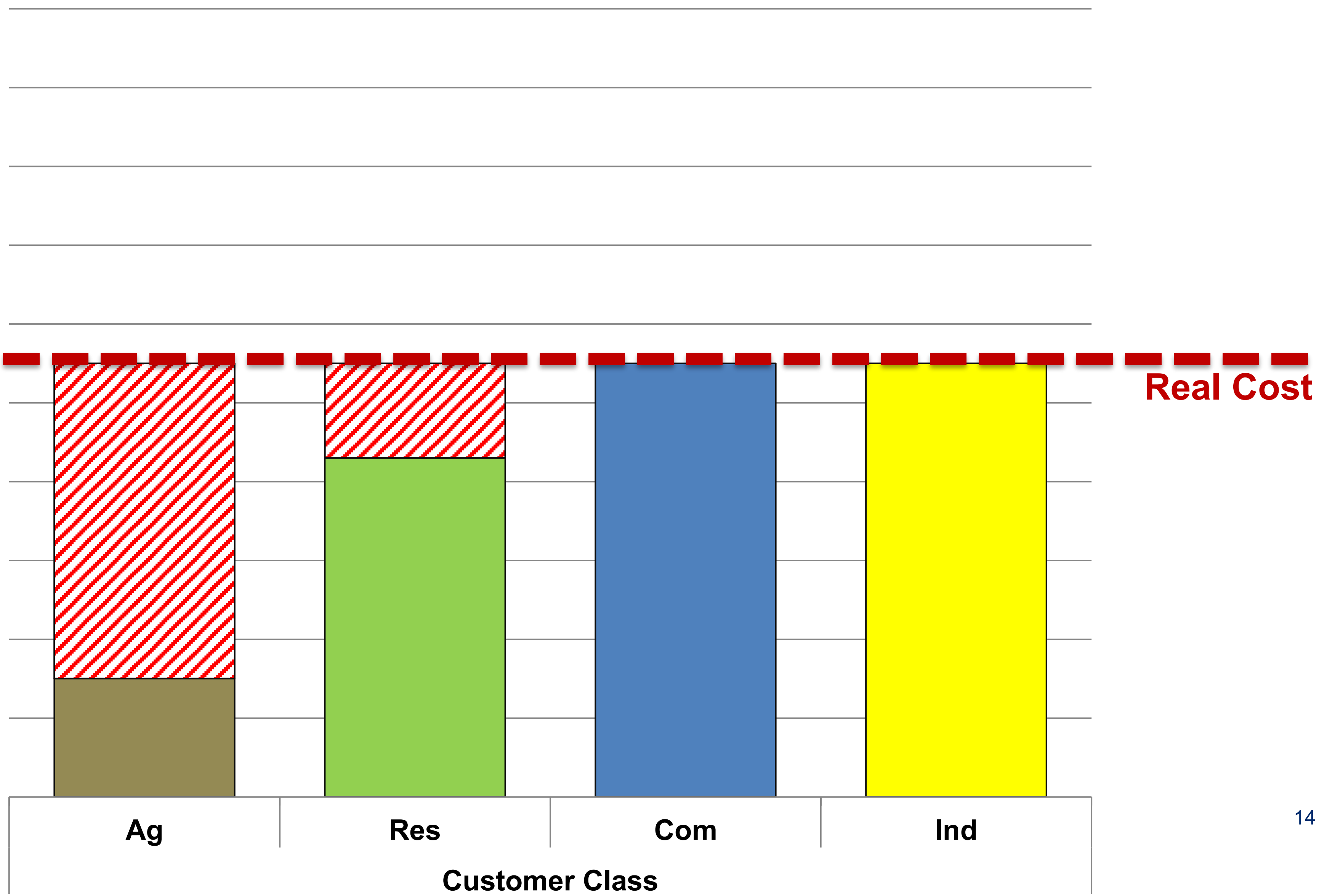
Depends on compensation mechanism and tariff design

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

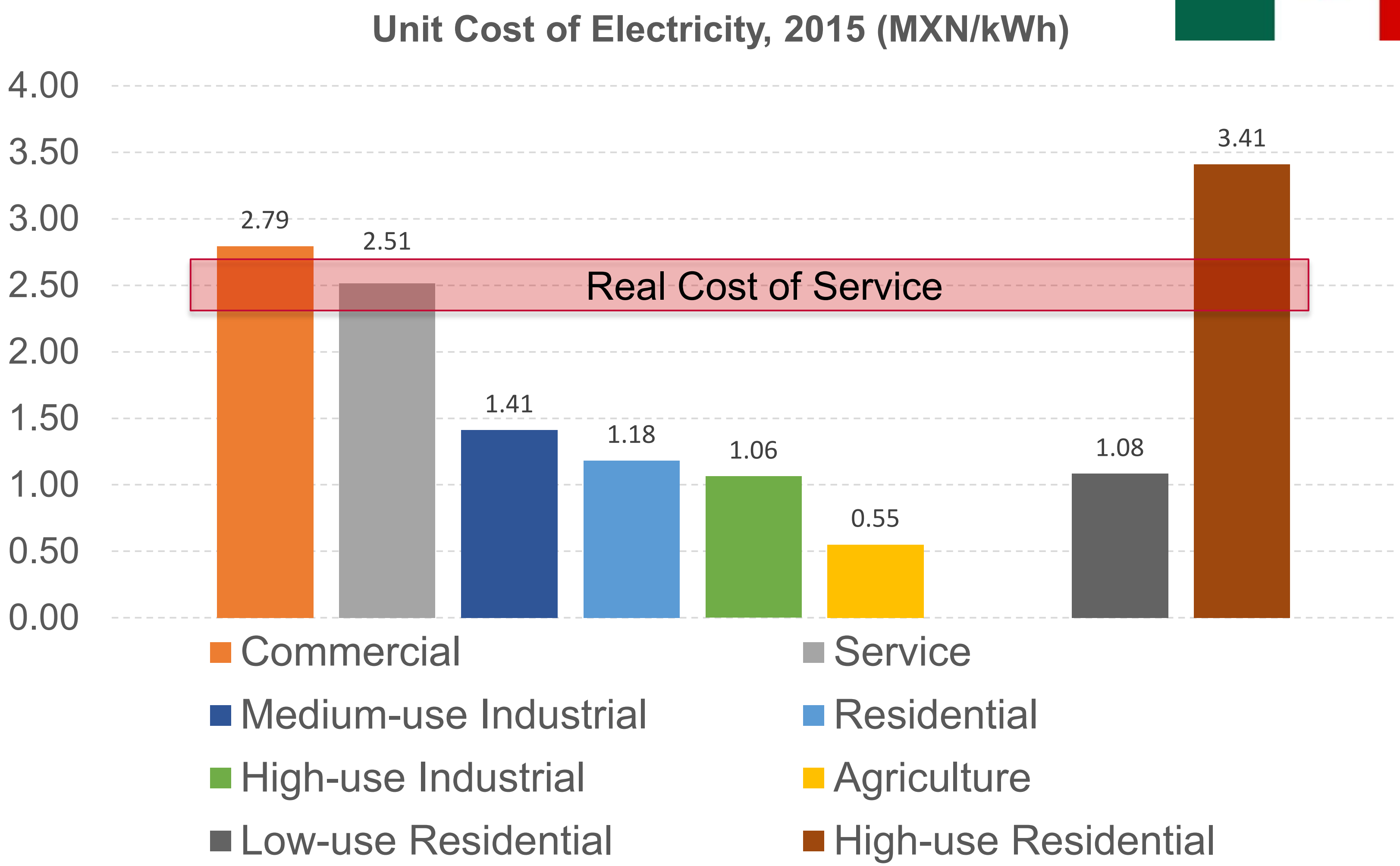
Certain Customer Classes May Subsidize Others



Alternatively, Government May Subsidize Rates



Mexico Direct and Cross Subsidies to Support Low-Use Customers



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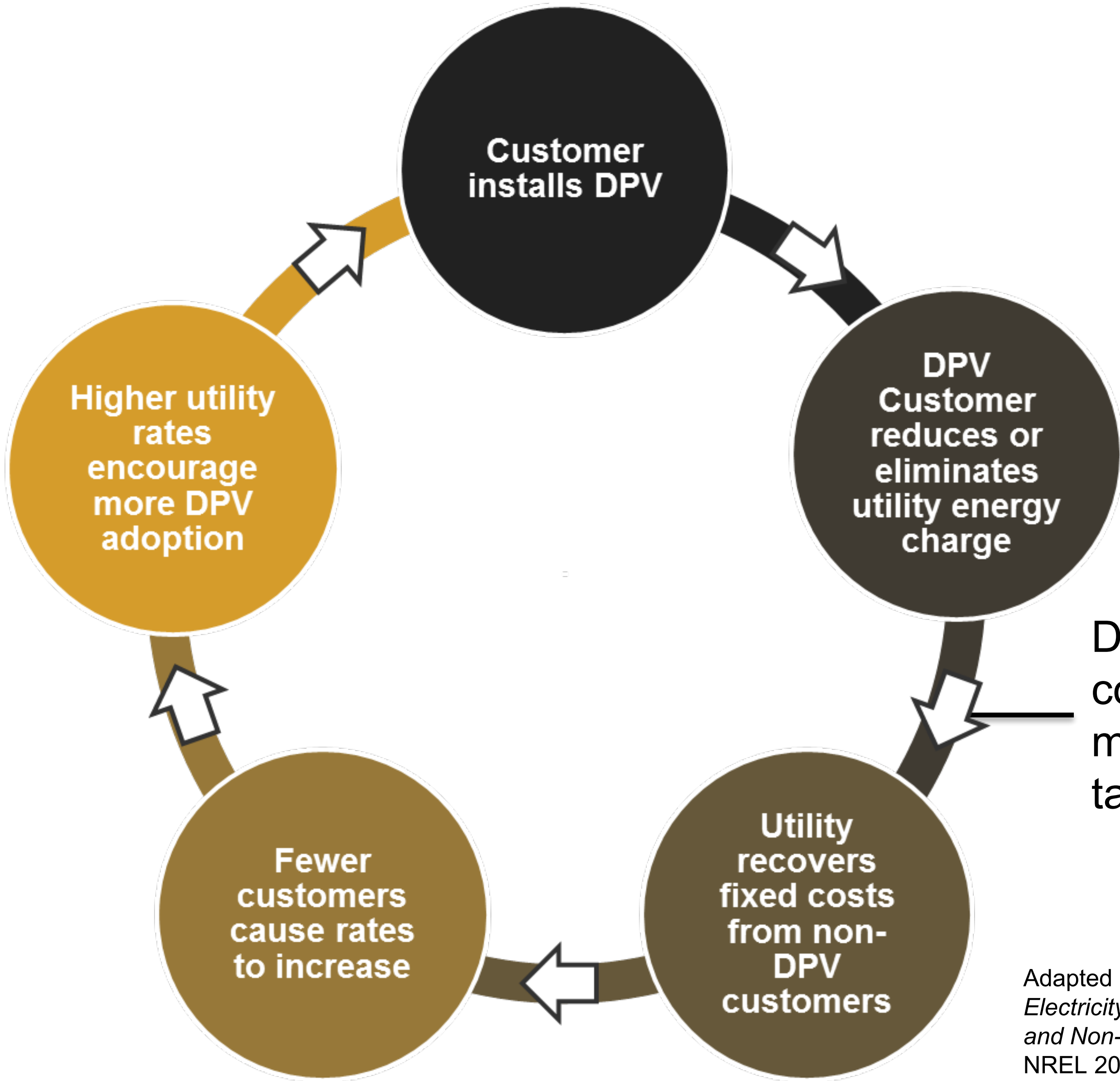

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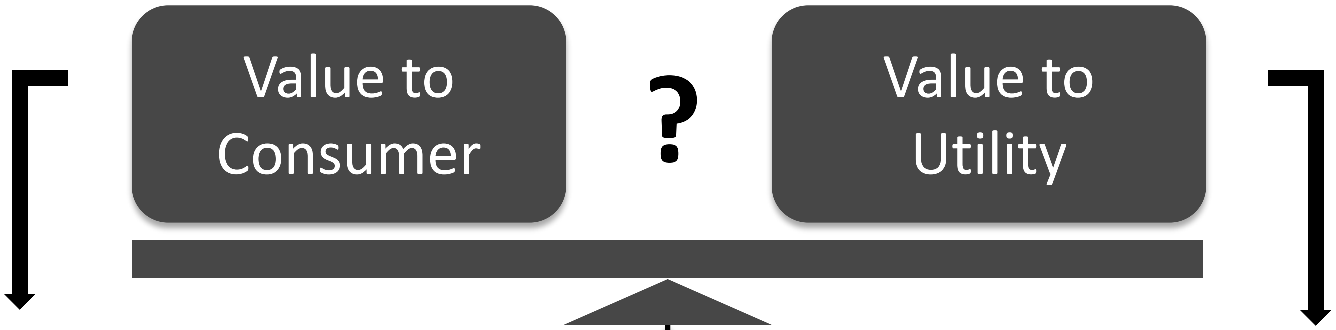
Fair Compensation for Distributed PV Can Resolve Economic Challenges to Utility Business Model

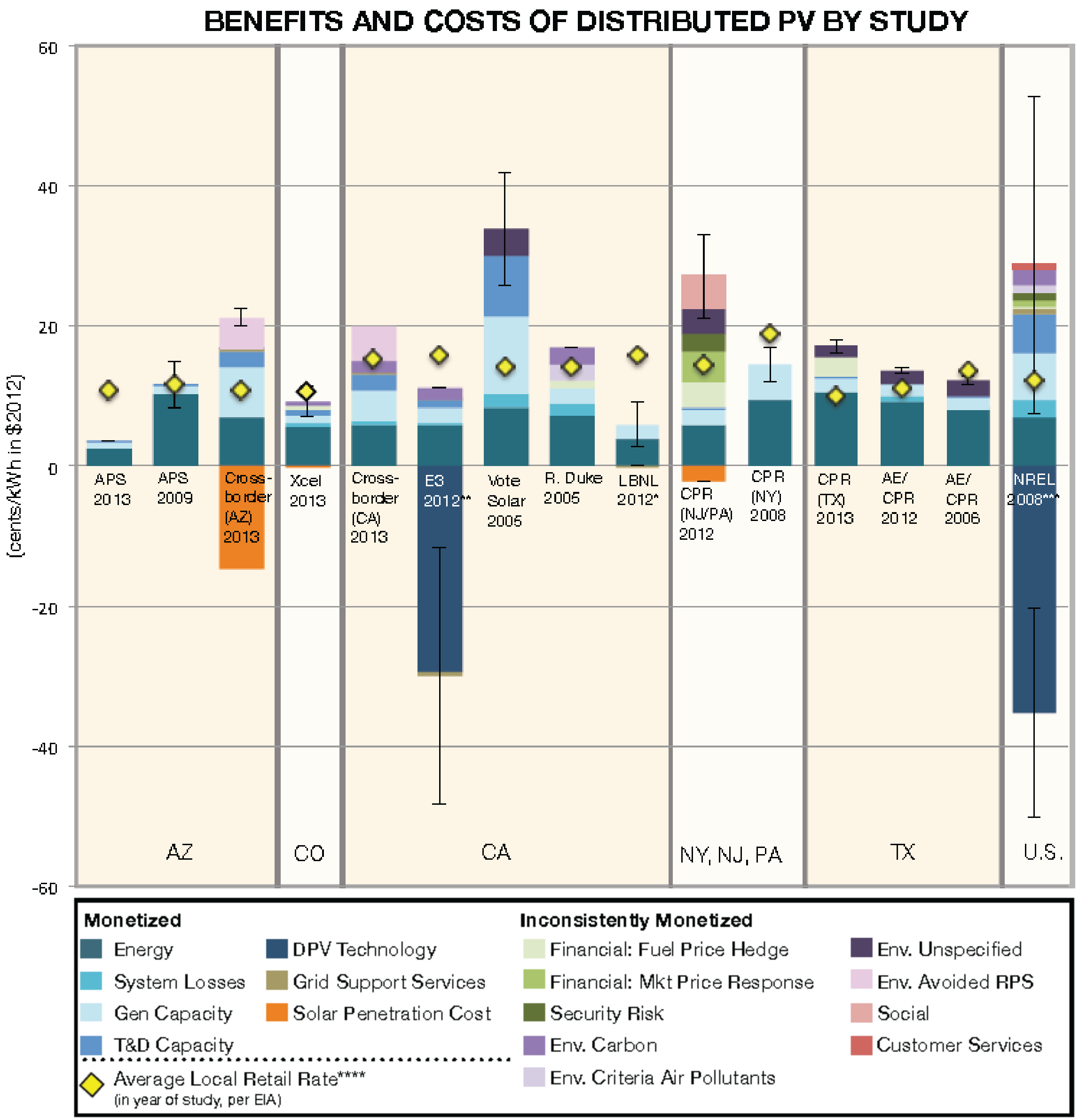
- **What does fair compensation mean?**
- **Many perspectives on the concept of “fair”**
  - **Utility**
  - **DPV Developer / Customer**
  - **Non-DPV Customer / Ratepayer**
  - **Society**

Compensation Can Balance Costs and Benefits of PV for Consumers and the Utility



DPV Customer Compensation Rate	**Accrued Benefits - Incurred Costs**
+ Reduced electricity bills Additional power availability*	+ Avoided generation costs Reduced line losses Deferred investments Regulatory compliance
– System cost Meter cost Interconnection cost	– Program administration Distribution network upgrades Lost fixed cost recovery Lost power re-sale margin
Relatively *simple* to calculate / predict	**Relatively *difficult* to calculate / predict**

Many Utilities and States are Studying the Value of Distributed PV to Determine Fair Compensation



Source: Rocky Mountain Institute, Review of Solar PV Benefit and Cost Studies, 2013

The Regulator is in the Center of the Fair Compensation Dialogue, Balancing Many Objectives

- Ensuring sufficient revenues are collected to maintain the grid
- Retail rates remain fair and equitable
- Customer choice
- Ensuring policy goals are achieved
- Level playing field for new technologies
- Competition and provision of customer services

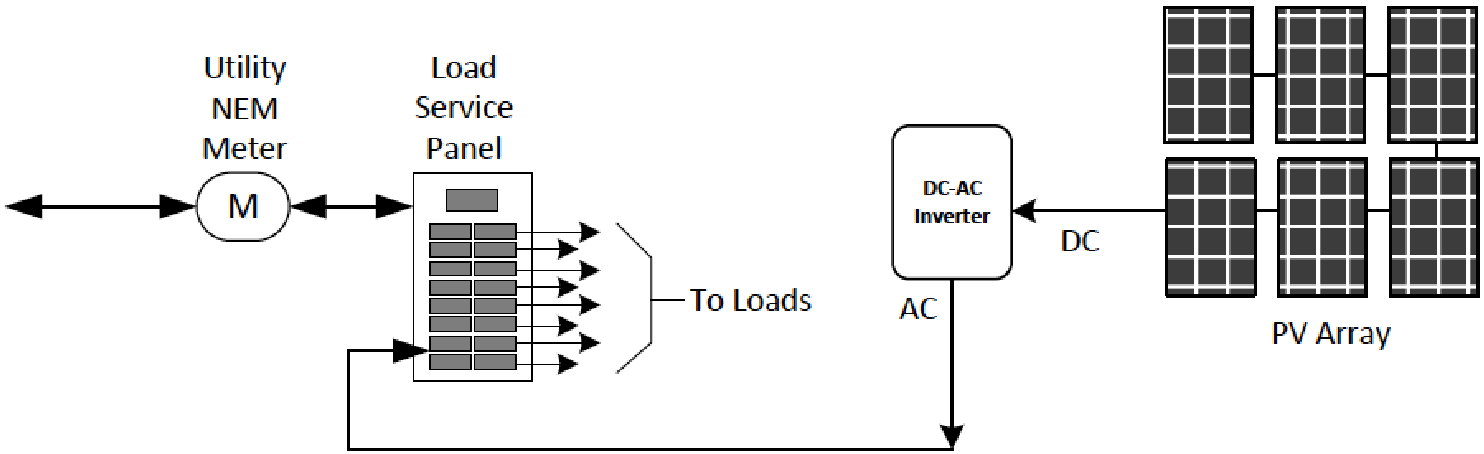
Three Tested Approaches for Encouraging Distributed PV and Fair Compensation

1. **Net Metering**
   – Self-consumption allowed; kWh banking; full retail rate as credit level; sell-rate and buy-rate are the same (except sometimes for *net excess generation*)

2. **Feed-in Tariff**
   – Self-consumption *not* allowed; buy-all / sell-all scheme, sell/buy rates are usually distinct

3. **Net Billing / Net Feed-in Tariff**
   – Self-consumption allowed; 1st meter measures real-time net consumption generation; 2nd meter measures real-time net generation; sell/buy rates are distinct

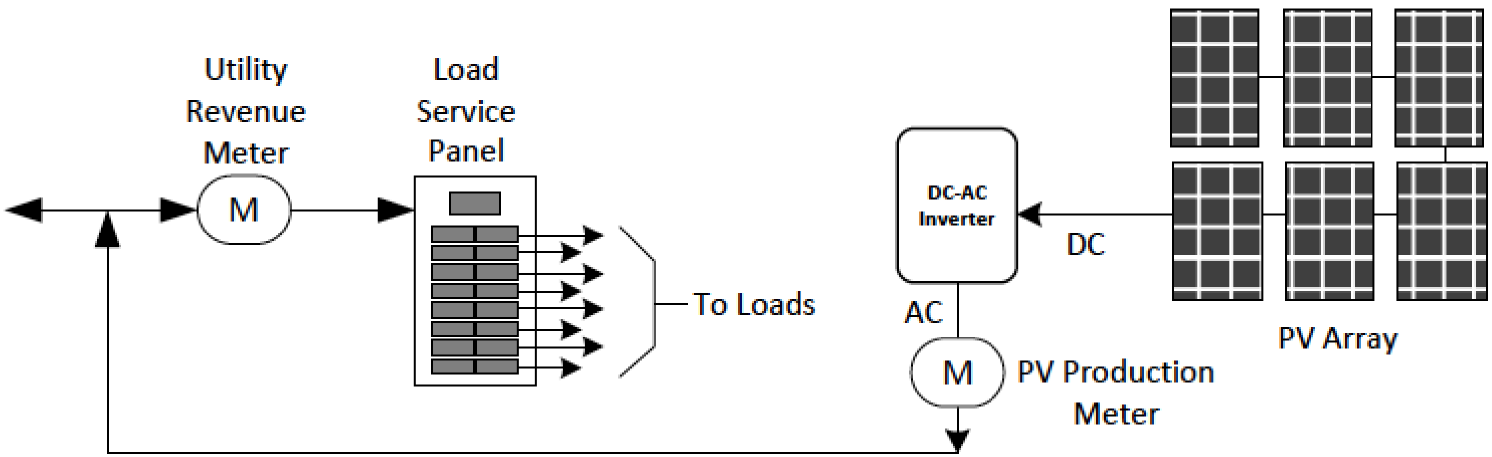
Approach #1: Net Metering



- Self-consumption required
- Kilowatt-hours are **banked** at full variable retail rate *within* and *between* billing periods
- Credits may expire after pre-determined period of time
- 1 bi-directional meter (optional export validation meter) *or* 2-unidirectional meters

- Rates/Crediting
  - Customer billed for *net consumption*
  - **Self Consumption**: Full variable retail rate (implicit)
  - **Net Consumption**: Pay full applicable variable retail rate
  - **Net Export:** Credit @ full applicable variable retail rate (until expiration)
  - **Expired Credits**: “Net Excess Generation” Rate

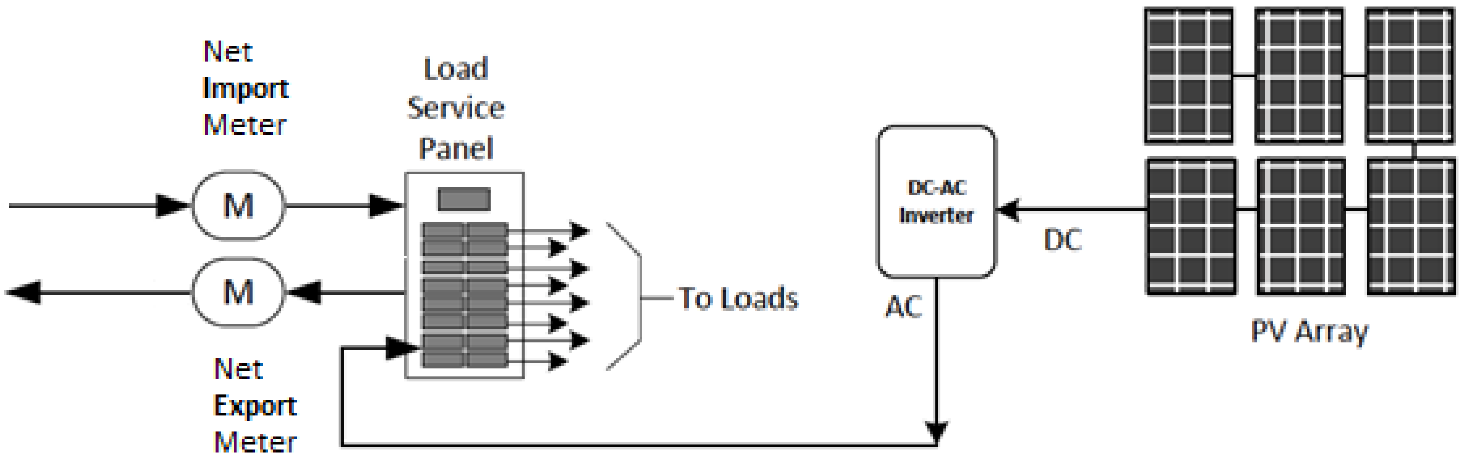
Approach #2: Feed-in Tariff (FiT)



- Self-consumption **not** allowed
- Buy-all / Sell-all scheme
- Exported kilowatt-hours are credited to utility bill or paid in cash at pre-determined FiT rate
- Additional export-only meter required
- Many approaches to setting fixed or dynamic FiT rates

- Rates/Crediting
  - Customer billed for full consumption and full export
  - **Self-consumption**: N/A
  - **All Consumption**: Pay full applicable retail rate
  - **All Export:** cash or utility credit at separate rate pre-determined by regulator (no expectation on level!)

Approach #3: Net Billing / Net FiT



- Self-consumption required
- Kilowatt-hours are not banked within or between billing periods; rather, Net Consumption and Net Export measured in real time
- Distinct rates for net consumption and net export
- Meter(s) must at least record *net* consumption and export metrics

- Rates/Crediting
  - Customer billed for *net consumption*
  - **Self Consumption**: Full variable retail rate (implicit)
  - **Net Consumption**: Pay full applicable variable retail rate
  - **Net Export:** Cash or utility credit at separate rate pre-determined by regulator

Retail Rate Design can Promote Fair Compensation and Utility Cost Recovery

- **Option 1:** Augment tariffs for all customers
- **Option 2:** Specialized solar customer rate class
  - Allows for more customized rate design and metering, including time-based rates, bi-directional distribution charges, minimum bills, demand charges, etc.

“Win-Win” Thinking can Increase Value of PV to the Grid

- Regulators/utilities are examining how to increase the value of PV to the grid
- Optimal siting to reduce congestion, avoid necessary T&D upgrades
- Through use of advanced inverters, PV could provide grid support (e.g., voltage)
- Orientation of panels can be aligned to utility peaks; requires customer compensation

A Range of Business Models Help Make Distributed PV an Option for More Consumers

Customer or 3rd-Party Owned

- Customer-owned model
- 3rd-party leasing model
- Community solar model

Innovative Financing

- Revolving loan programs
- On-bill financing

Utility Investments

- Utility build-own-operate
- Utility-led community solar projects
- Utility partnership and investments in 3rd-party leasing companies

Community Solar (Shared Solar) Extends Rooftop Solar to Consumers without Roof Space

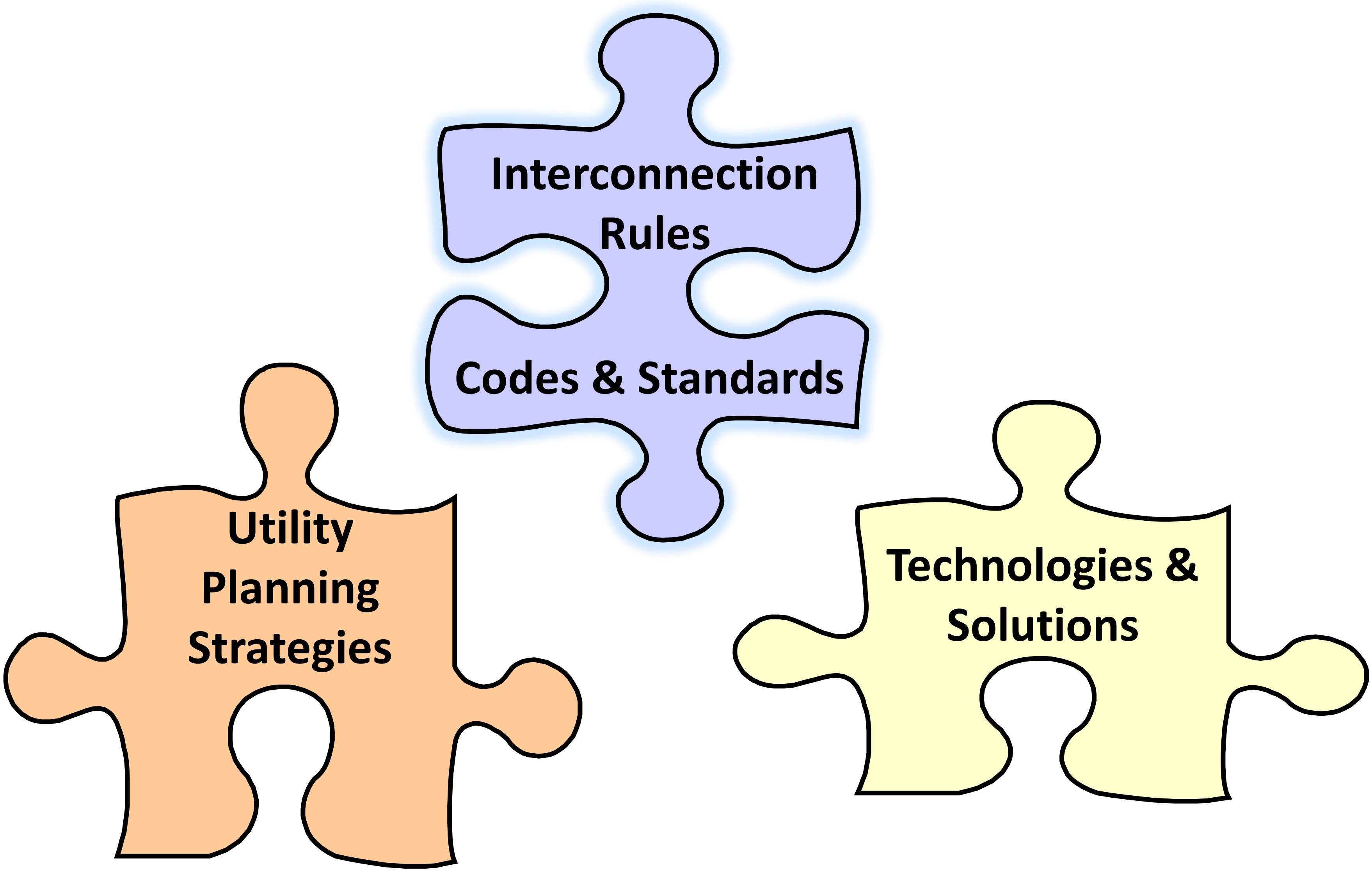
- Customers participate in solar project not located on their property
- Customers receive some of the project's power or financial benefits
- Varied ownership, management models
  - Utility, business, school, nonprofit
- Benefits:
  - Increase access to solar (for customers without on-site access)
  - Deliver solar at a competitive price; economies of scale with larger projects
  - Utility can play role in offering program

3. TECHNICAL CHALLENGES AND SOLUTIONS FOR DGPV INTEGRATION

Michael Coddington
National Renewable Energy Laboratory

- Essential “Pieces” of a Solid PV program foundation
- Overview of Major Utility Concerns about PV
- Foundational Codes and Standards
- Interconnection Processes – How Utilities manage the PV Interconnections
- Mitigation Strategies for Potentially Problematic PV
- Advanced Utility Distribution System Planning for a High Penetration PV Future
- Review of the PV Life Cycle

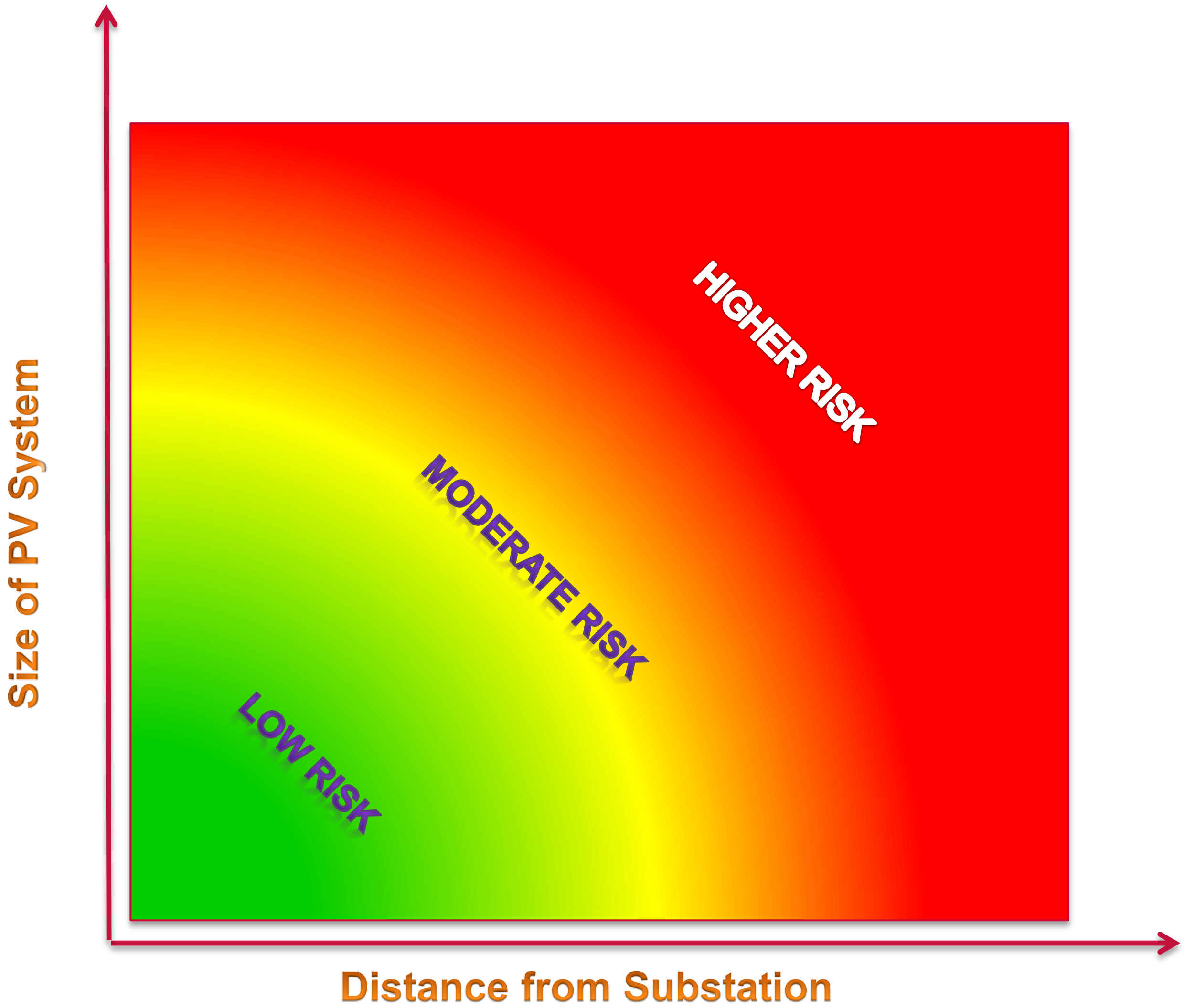
Putting a PV Program Together



Major Utility Concerns

- Voltage Regulation
- Reverse power flow
- Protection system coordination
- Unintentional islanding

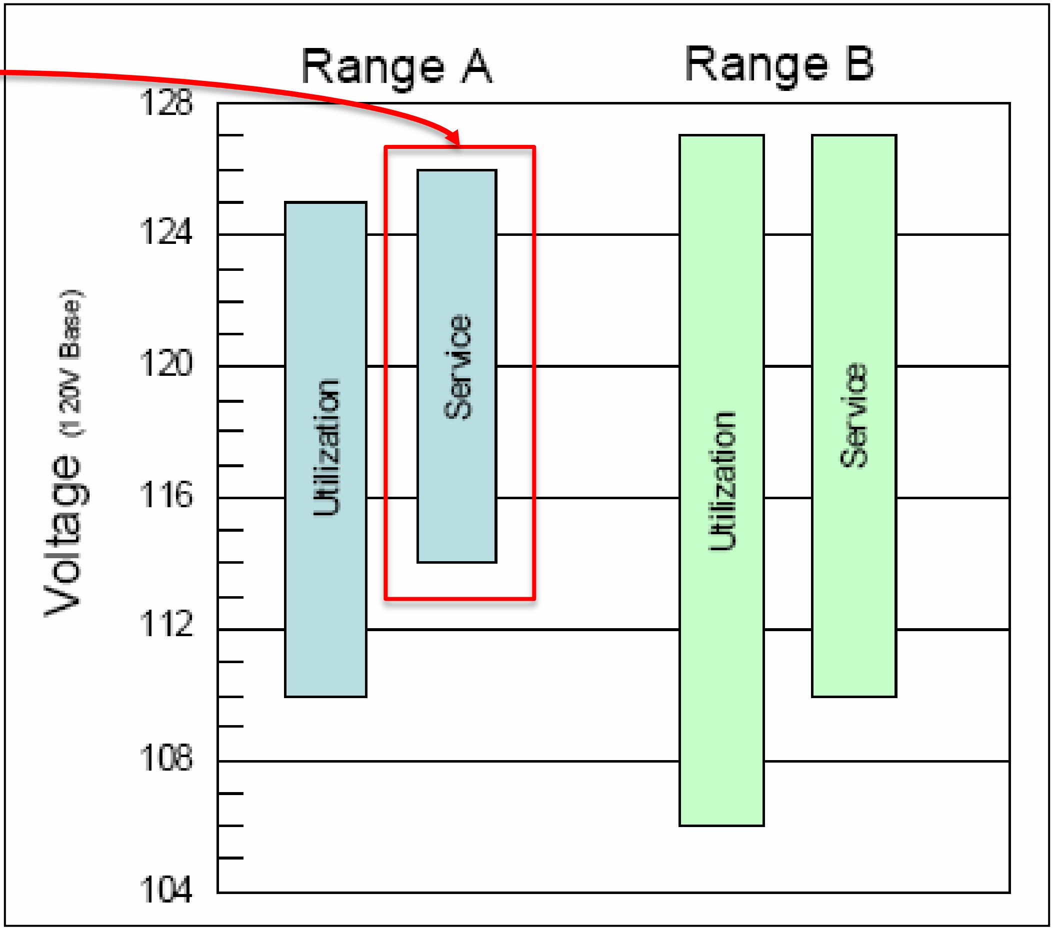
PV System Concerns and Risk Factors



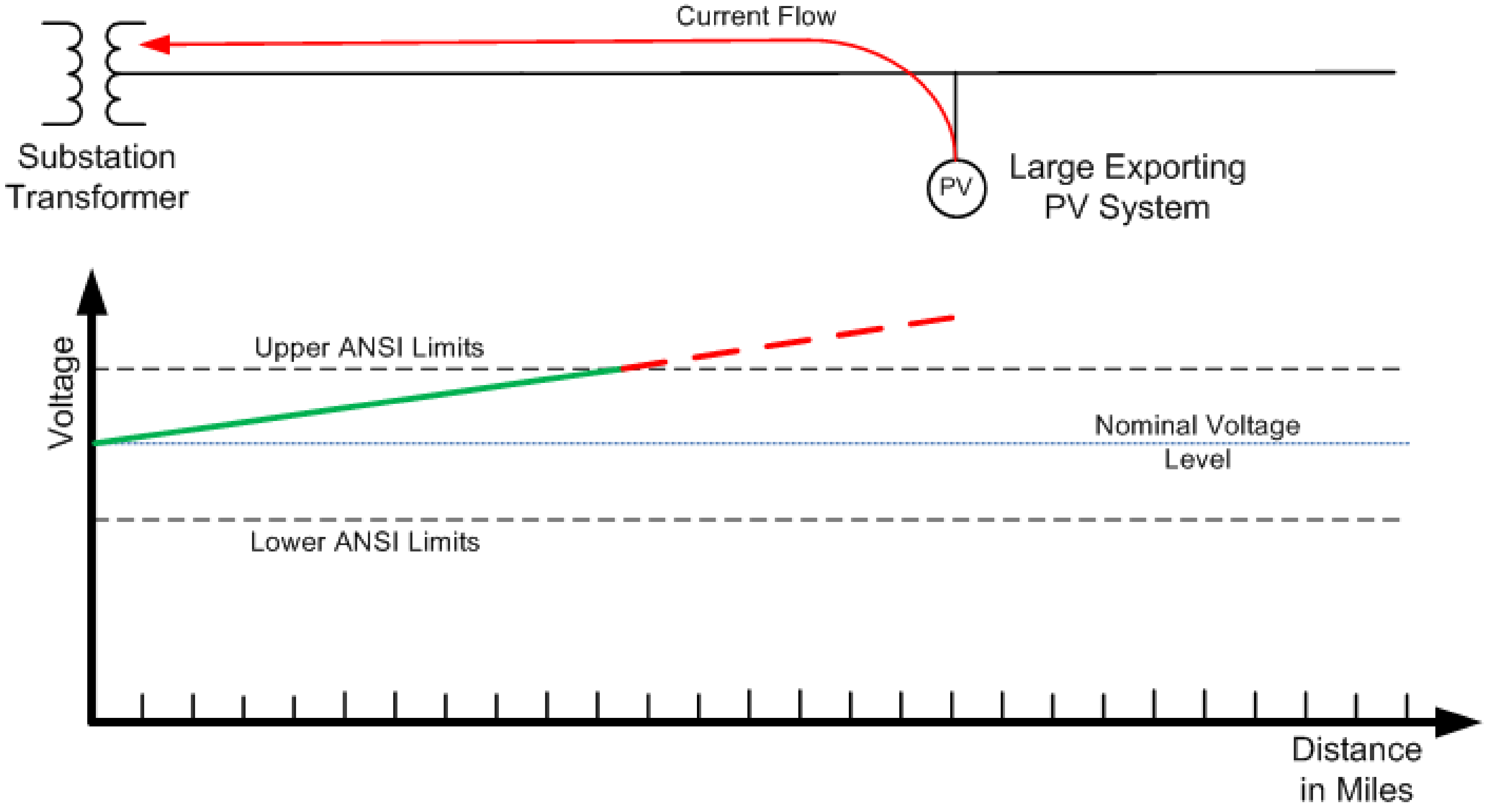
ANSI C84.1 Voltage Limits

Maintaining voltage ranges is critical to avoid damaging customer and utility equipment

Most Utilities seek to maintain the +/- 5% Range for Service Voltage Levels



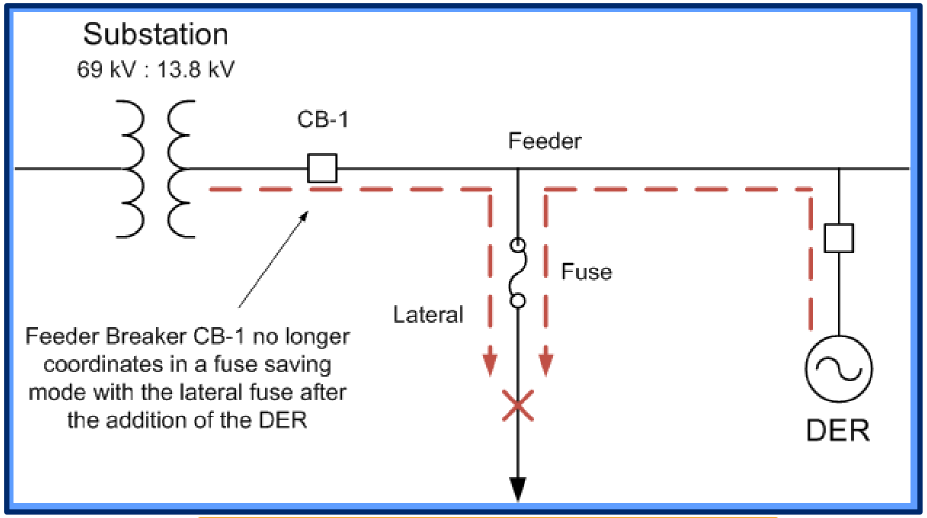
Reverse Power Flow can Disrupt Operations

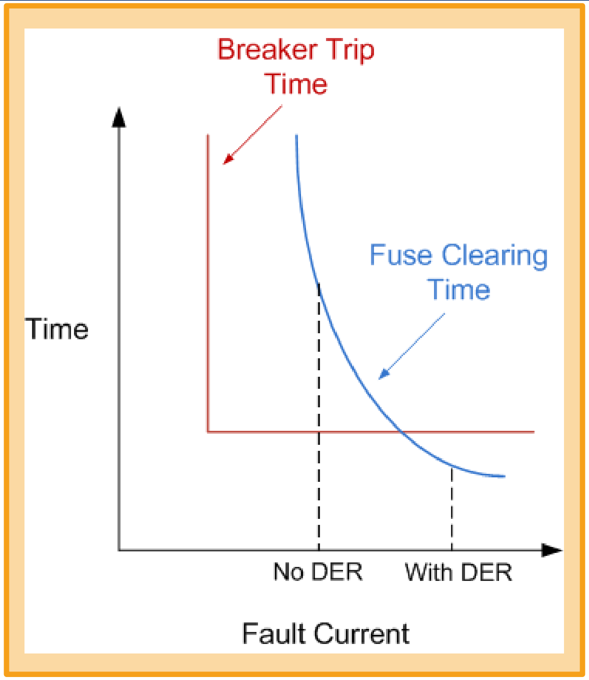


Protection System Coordination

Short-circuit Current Coordination

- Utility circuits utilize fuses and circuit breakers to minimize outages
- These protection devices are coordinated
- Significant amounts of PV can disrupt the coordination, causing larger outages





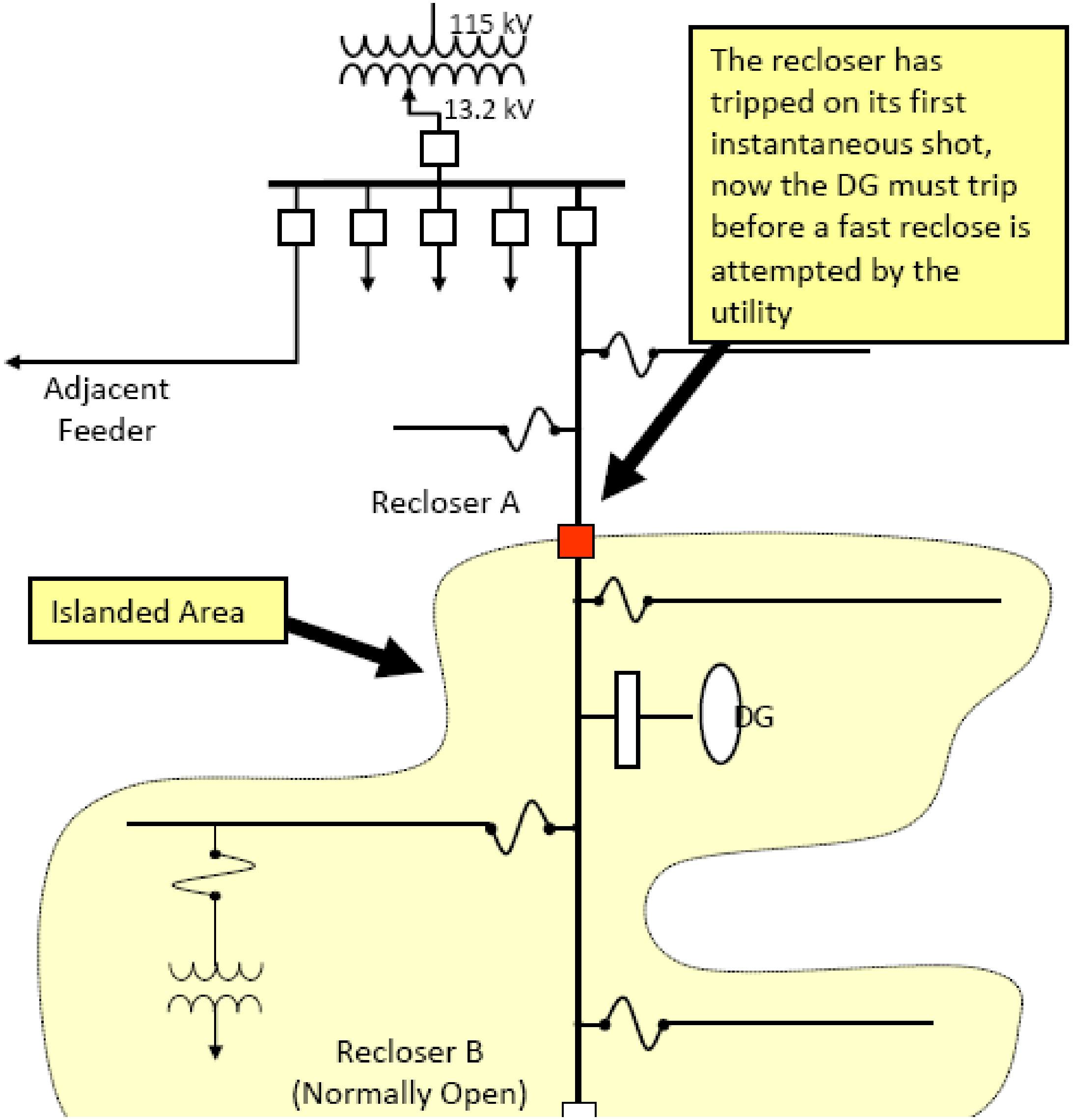
Unintentional Island Concerns

There are concerns that, in the event of a utility outage, part of the grid will remain energized by PV and other Distributed Generation

Assuming an unintentional island formed, there are concerns about voltage aberrations, damage to equipment, and safety

While it is possible to create an island under laboratory conditions, the probability of an unintentional island is remote

Some utilities require very expensive mitigation measures to avoid a problem that is statistically improbable



Applying Codes and Standards

Electric Utility Transmission &
Distribution Systems

National Electrical Safety Code
Utility Manual of Safe Practices

Voltage Standards

ANSI C84.1 in US

PCC (Point of
Common Coupling)

Interconnection Standards

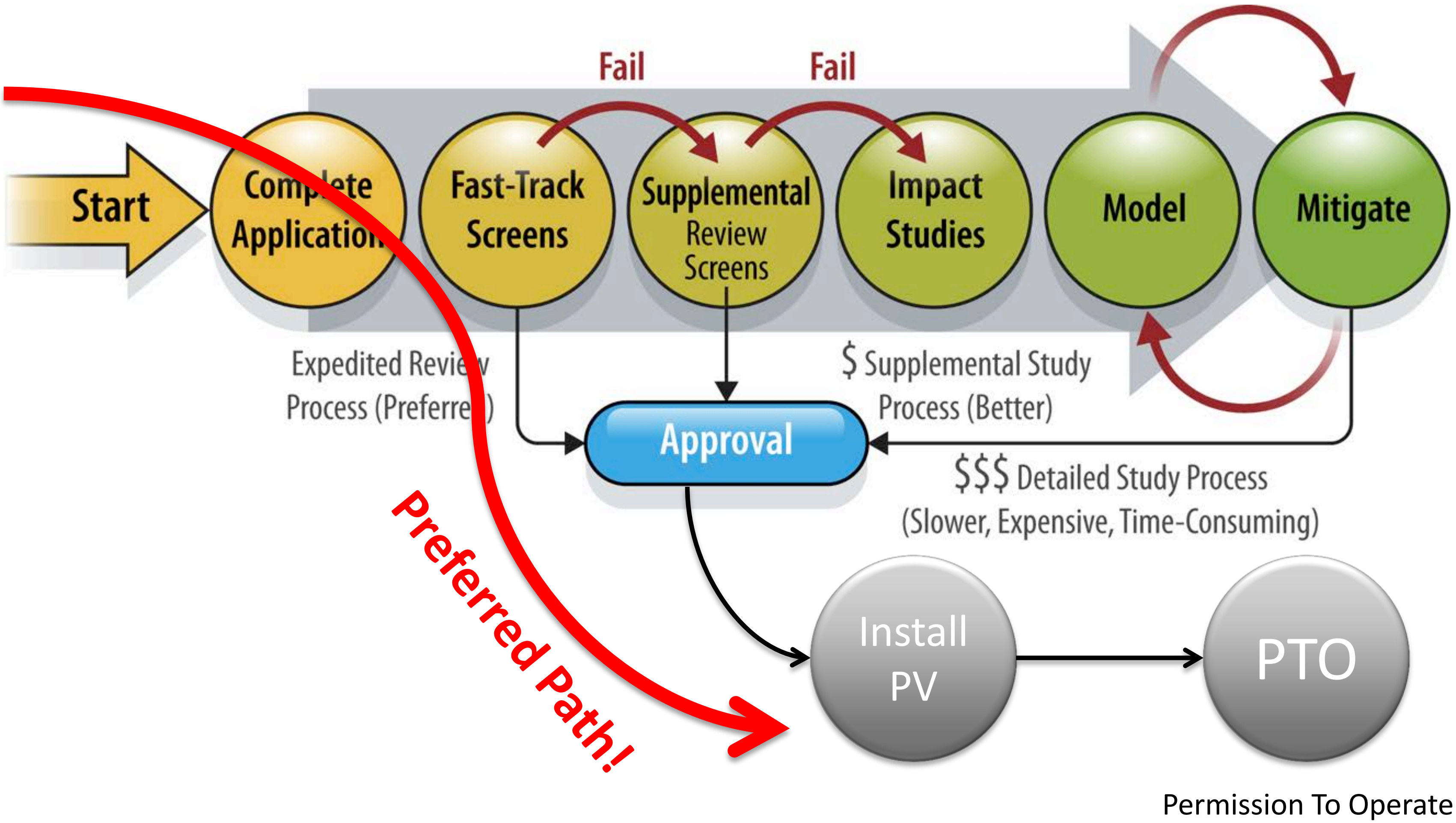
IEEE 1547 family of
standards in US

Industrial, Commercial,
Residential Buildings

Building Electrical Codes

National Electrical Code
(NEC) in US

Classic Interconnection Process



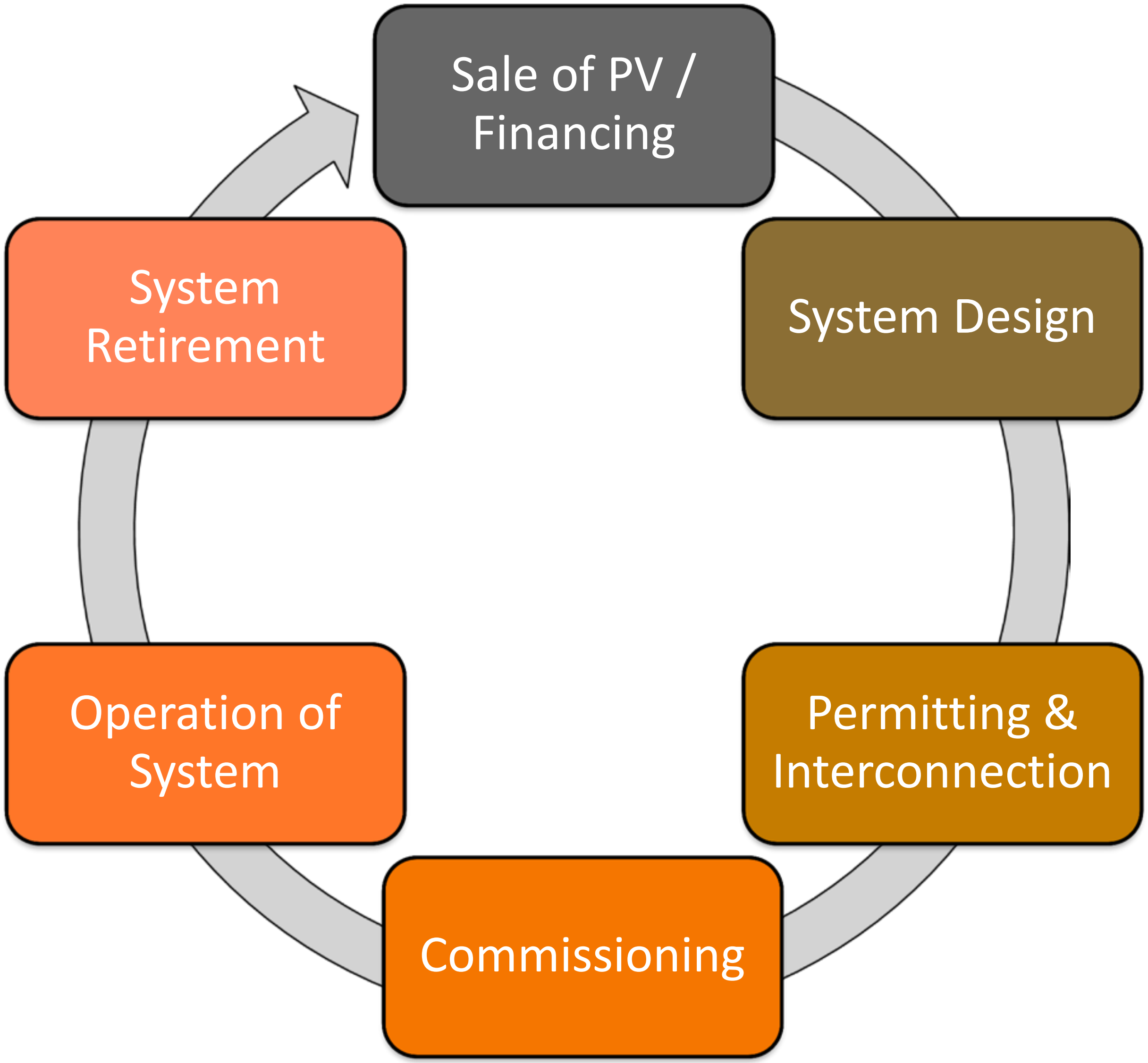
Mitigation Strategies

Type of Strategy in the Interconnection "Toolbox"
Advanced Inverters aka Smart Inverters
Modify protection settings/fuses
Voltage Regulation Devices and Controls
Upgrade the Conductor
Direct Transfer Trip (DTT) of the PV system
Battery Energy Storage Systems
Other "Smart Grid" devices

Electric Distribution Planning for Utilities

- Load Forecasting
- Annual Budget
- Major Feeder Design
- Reliability
- Feeder-Level protection
- Voltage support
- Future Distribution Planning should support DGPV policies, understand and publish “Grid Hosting Capacity”

Life Cycle of a PV System



3. CONCLUSION AND ADDITIONAL RESOURCES

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U.S. Agency for International Development (USAID)

Conclusion:

Compensation Mechanism Design Decisions

- **Mechanism Structure:** (NEM, NB, FIT, NFIT, VoS)
- **Metering Implications**
- **Remuneration Rate** For Overall or Net Excess Generation Rate
- **Crediting Aspects**
- **Contract Offering Aspects**
- **Allowed Ownership & Participation Structures**
- **Customer Class and Type Customizations**

Related Rate Design Decisions

- **Option**: Redesign/Augment All Tariffs
- **Option**: Create Specialized Tariff Class for Solar Customers
- **Select Tariff Building Blocks:** Energy, Capacity, Demand, Distribution, Grid, Minimum Bills, others

  Volumetric, Fixed, Demand Charge Interval Length

Other Program Design Considerations

- **Technology Eligibility**
- **System Size Limits**
- **Program Caps**
- **Other Cost Allocations**
- **Allocation of Incremental Distribution Network Costs**
- **Interactions with Existing Cross Subsidies**
- **Financing Interventions**
- **Create Other Deployment Incentives**
- **Tariff Design Revisitation Frequency**
- **Pro-poor Considerations and Strategies**
- **Customer Education**
- **Alternative Regulatory Paradigms**

Technical Aspects

- **Application Processes**
- **Screening**
- **Impact Studies**
- **Permitting**
- **Impact Mitigation & Infrastructure Upgrades**
- **Equipment Standards**
- **System Certification & Inspection**
- **Installer Training & Certification**
- **Interconnection**
- **Grid Code**
- **Smart Grid Considerations**
- **Modify System Operation Practices**
- **Modify Distribution Planning Practices**

Policy, Planning & Legal Issues

- **Address Legal Barriers**
- **Integration into Planning Processes (e.g., IRP)**
- **Integration into Broader Energy Policy**
- **Set Distributed Generation Program Goals**

21st Century Power Partnership
Distributed Generation Regulation Library

- Distributed Generation Ratemaking
- Understanding Impacts
- Interconnection
- Alternative Business and Regulatory Models
- Planning for Distributed Generation
- Case Studies

Available: http://www.21stcenturypower.org/dglibrary.cfm

USAID Energy Division Distributed Solar Technical Assistance Program

- 6 Technical Assistance Program Areas

1. Goals and Approaches to DPV Programs
2. Foundational Codes, Standards and Interconnection Processes
3. Modelling and Mitigating Impacts on the Distribution System
4. Distributed Generation Compensation and Tariff Design
5. Quantifying Distributed Solar Economic Impacts
6. Facilitating “Win-Win” Outcomes for Electric Distribution Companies

- Existing/planned work in Jamaica, Brazil, Mexico, Southeast Asia
- Email Jhaeni@usaid.gov for more info

Contacts and Additional Information

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