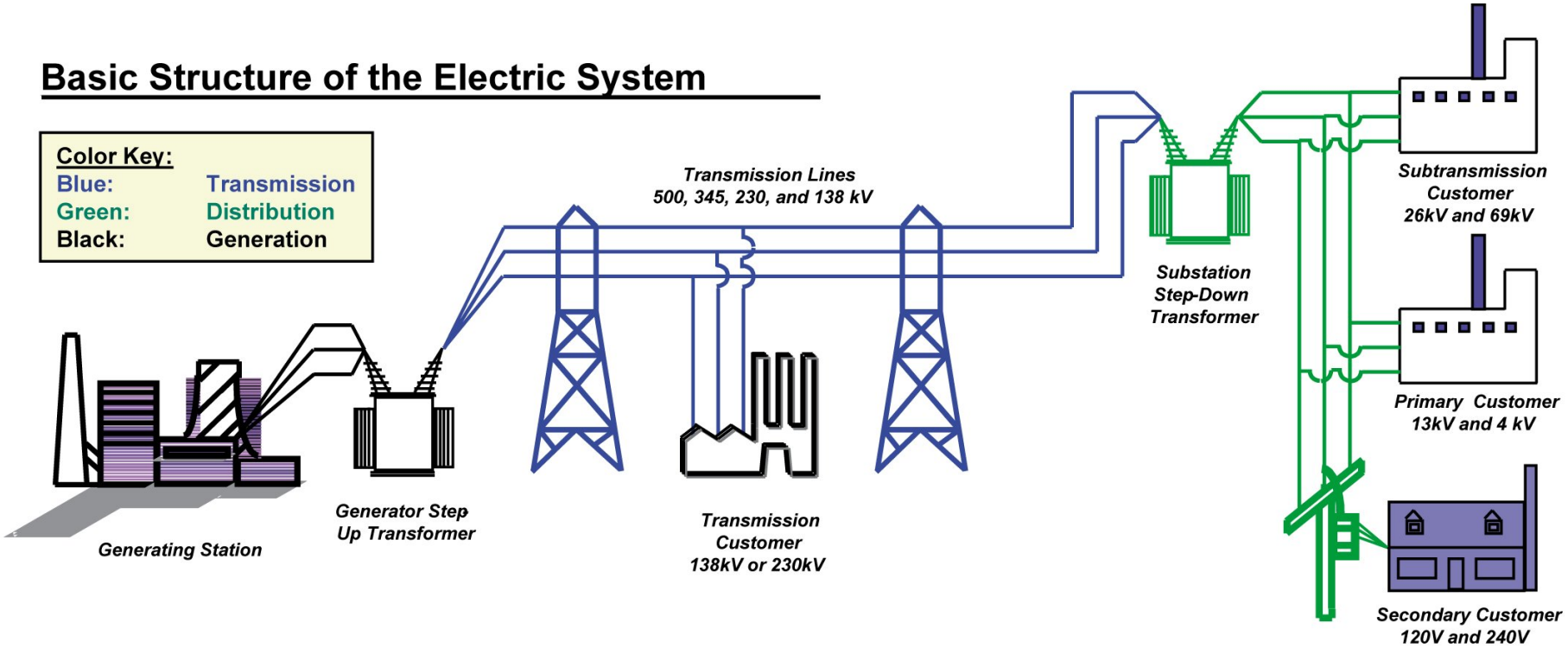
Electricity Markets 101: Framing for Solar PV Debate

Severin Borenstein
Haas School of Business and Energy Institute at Haas
University of California, Berkeley

What Makes Electricity Different?

- Components: Generation, Transmission, Distribution, Retailing
- Electricity is storable only at high cost, so intertemporal arbitrage is limited => marginal value of electricity can vary enormously minute to minute
- Electricity transmission is very low cost up to capacity constraints, but when constraints bind inter-locational arbitrage is limited
- All producers deliver electricity over a common system – the grid
- For the grid to remain stable (no blackouts or dangerous voltage or frequency fluctuation) – supply and demand must balance second by second

Last decade electricity systems in one slide

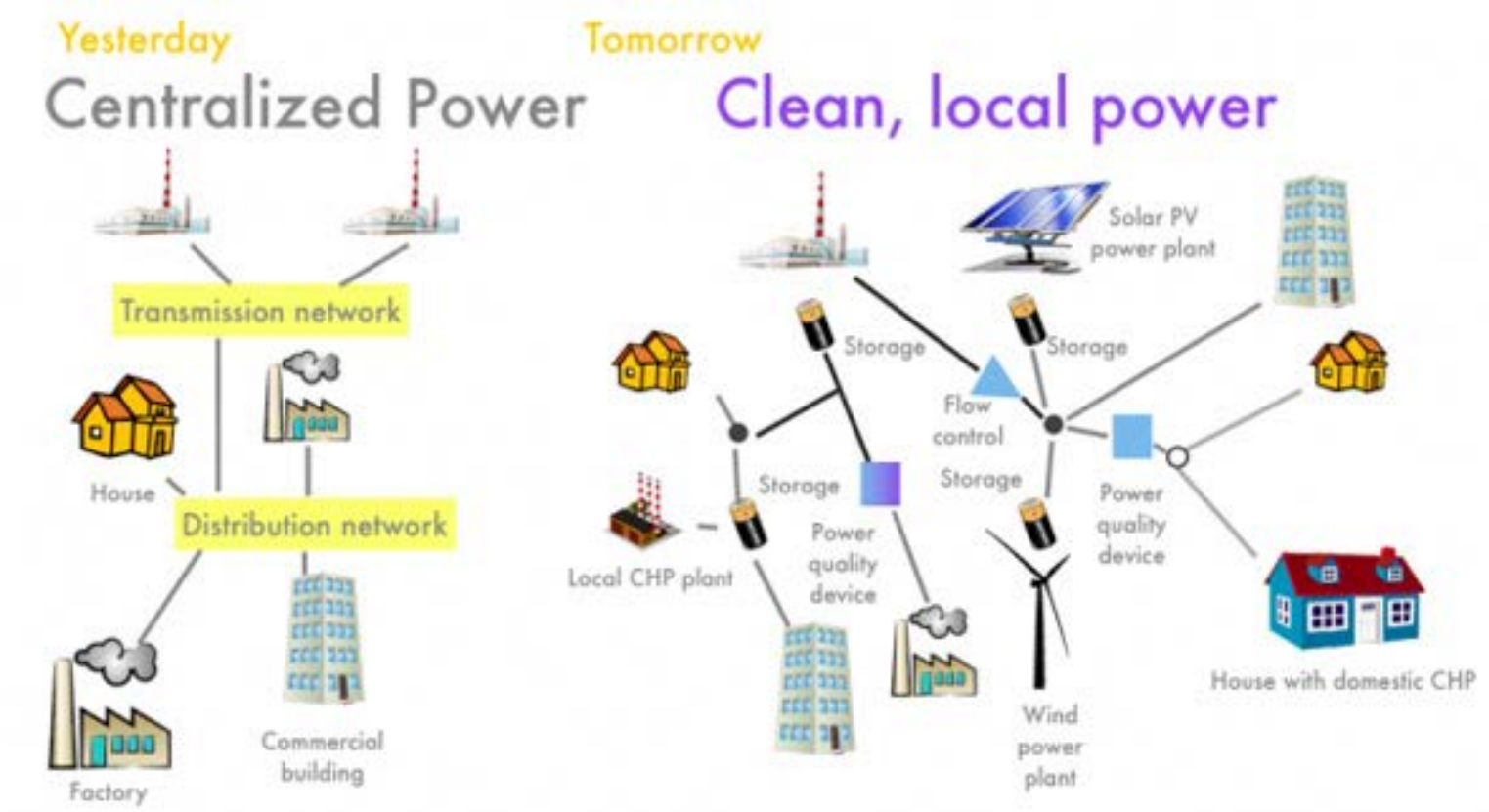


The Changing Electricity Business Model

- Utility Model: Generation+Transmission+Distribution+Retailing
- Experimentation began in the 1980s-90s with competitive generation supply
  - Natural gas utilities have always looked like this
- Continued in the late 90s/early 2000s with retail competition
  - Retail provider is in the business of procuring supply on behalf of customer, and in some cases managing billing and payment
  - Most recent incarnation is Community Choice Aggregation (CCAs)
- Incumbent utilities still provides delivery services
  - Economies of scale dictate natural monopoly in grid services, but not necessarily in generation or retailing
- Now distributed generation is changing the model further
  - Utility provides two-way distribution services
- Technology greatly improving real time monitoring/response

Another slide to include DG innovation

(http://www.mysolarhome.com/solar-panels-important-american-security/)



Models of Electricity Generation Markets

- Old model: all generation from central station, distributed to end-use consumer through grid
- New model: some central station generation, some distributer generation (DG) located at consumer site
- Value of wholesale power from central station generation depends on its location and timing
  - Impact on grid and line losses
- Distributed generation that is consumed on site is effectively “negative load” (reduced demand)
- How to value DG electricity injected into the grid?

Models of Electricity Retailing

- Old model: regulated utility procures or generates power "prudently" and customers pay for it
  - Utility assures reliability by buying or producing balancing and reserves within its control area
- New model: for-profit or non-profits compete for retail customers
  - Default "provider of last resort" (POLR) may be utility
  - Retail competition applies only to electricity generation, not to transmission or distribution
  - Balancing and reserves procured by Independent System Operator who assures supply=demand at all times
  - Cost of balancing (and some reserves) often socialized across all kWh sold – can create perverse incentives for retailer reliability

Model of Electricity Grid Services

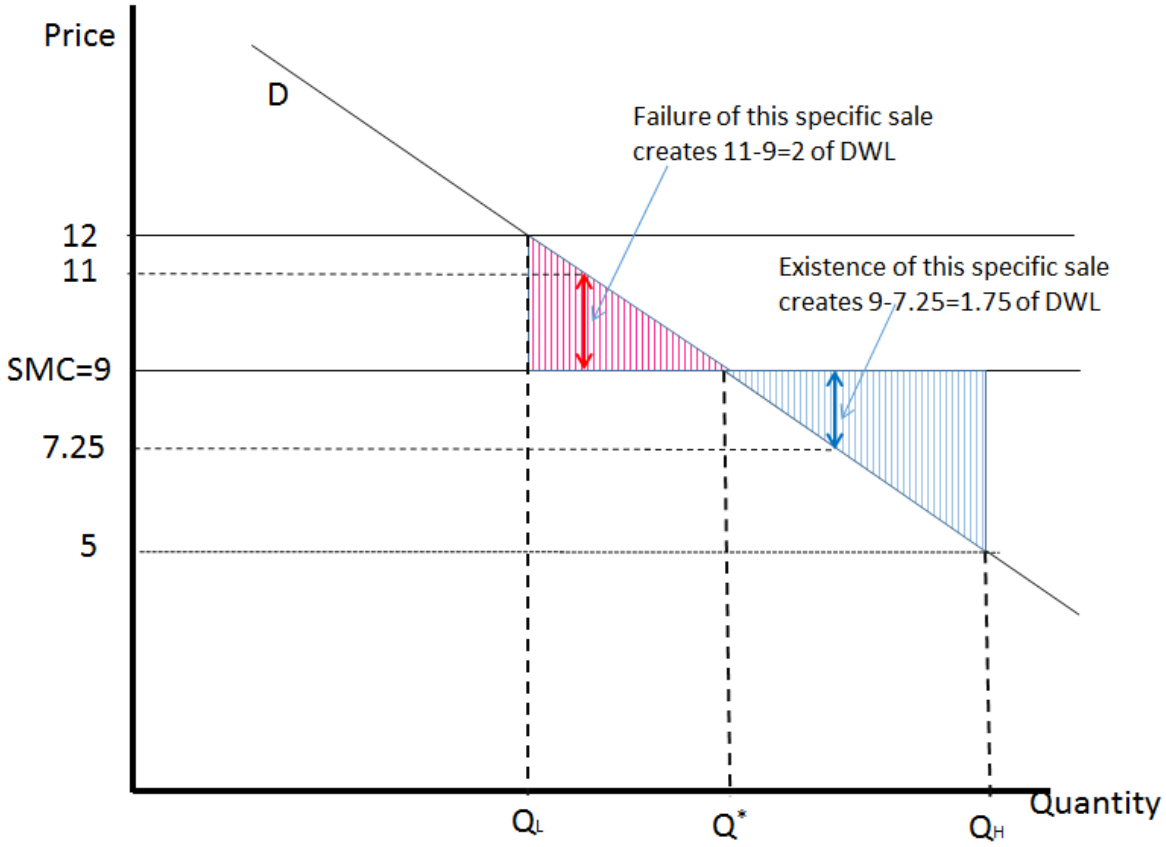
- Transmission and distribution services likely to be a natural monopoly as long as they exist
  - More efficient to have one firm provide all service, at least within an area, than to have competing providers
  - Means that the marginal cost is less than the average cost
  - So P=MC won't cover costs of the grid service provider
  - PLUS: with new models of generation and retailing, "public purpose" programs likely to be paid through grid services
  - How to recover revenue shortfall?
- How do grid service change in a system with distributed energy resources?
  - DG, demand side response
  - Less, more, different service

Retail Rate Design

- Economic efficiency dictates setting retail price equal to short-run societal marginal cost
  - Time-varying
  - Location-varying
  - Inclusive of marginal externality costs
- But efficient prices unlikely to cover all costs
  - Generation cost shortfall if wholesale price isn't allowed to rise when there is scarcity
    - » Due to price cap, no demand elasticity, excess capacity policy
  - Grid cost shortfall due to natural monopoly, P=SMC < AC
  - Need to recover costs of public purpose programs
    - » Energy efficiency, renewable energy, low-income programs
- And prices are far from efficient
  - Little time or locational variation, new challenge with DER

Remembering why we care about efficient pricing: P=social marginal cost

- Departures from efficient pricing cause behavior that reduces economic value creation



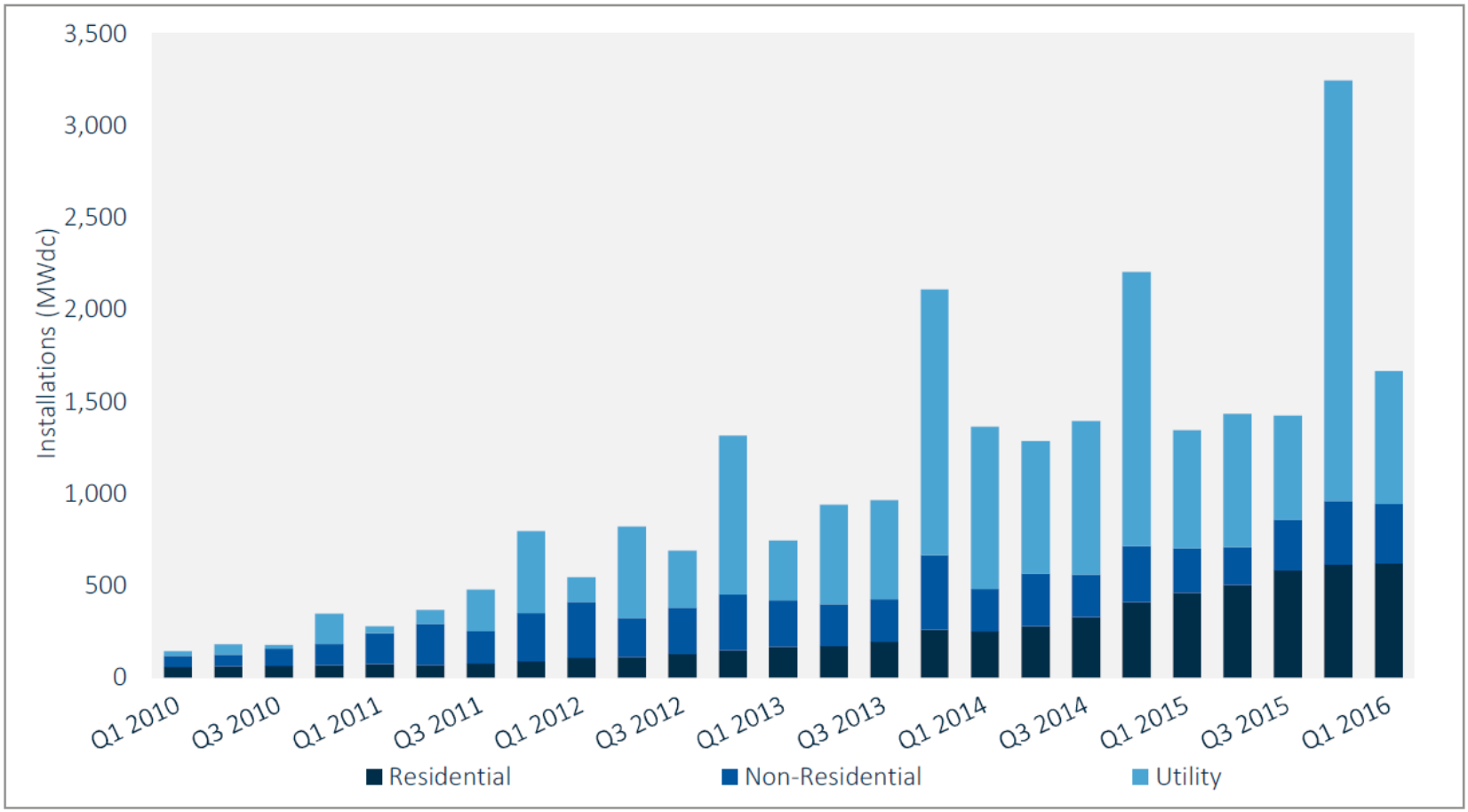
Options for Recovering Revenue Above Efficient Time/Location-Varying Pricing

- Average Cost Volumetric Pricing – traditional approach
  - Recover all additional revenue from flat volumetric adder
  - Recovers revenue shortfall proportionally to consumption
- Fixed Charge – independent of quantity consumed
- Increasing-Block Pricing
- Minimum Bills
- Demand Charges
  - Traditional definition: customer non-coincident peak usage
  - New usage: customer non-coincident usage during peak period
- These have very different implications for DG solar

A Short Introduction to Residential Solar PV Distributed Generation

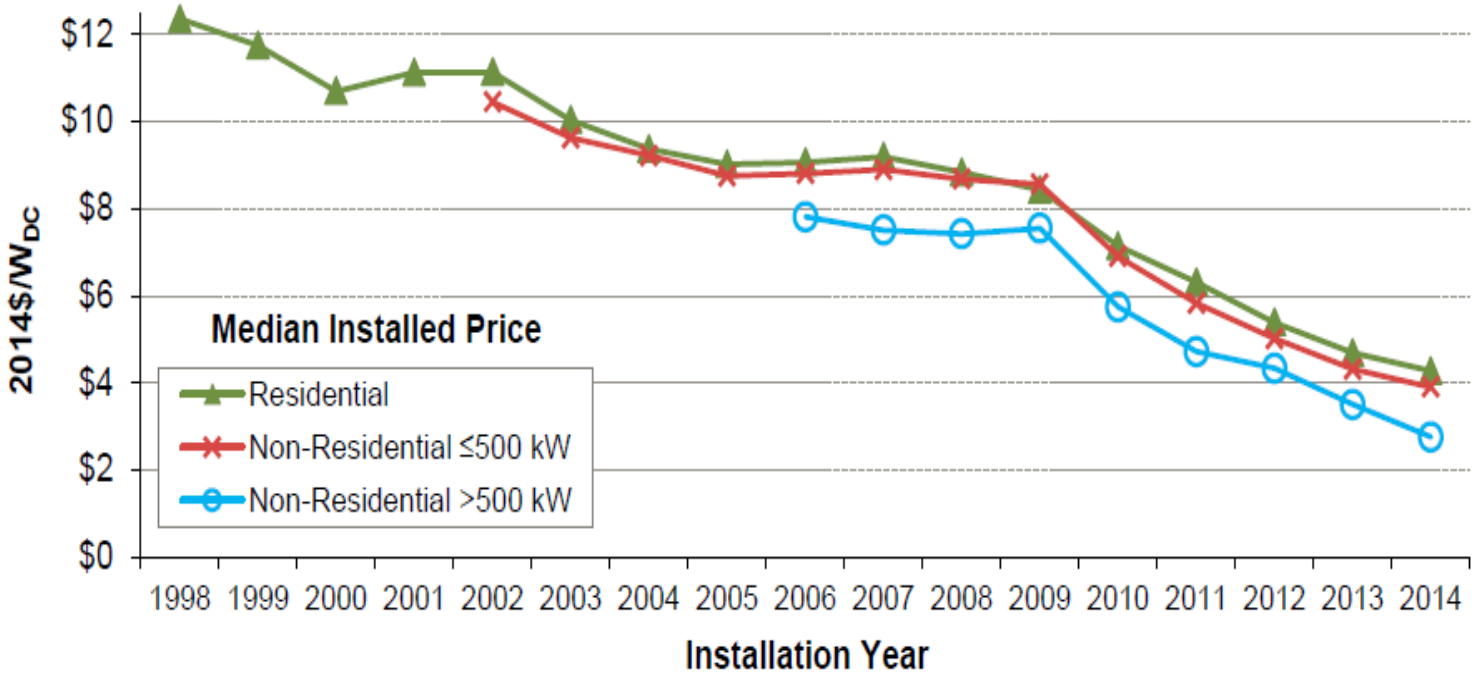
Residential Solar is Growing Rapidly

Figure 1.1 Annual U.S. Solar PV Installations, Q1 2010-Q1 2016



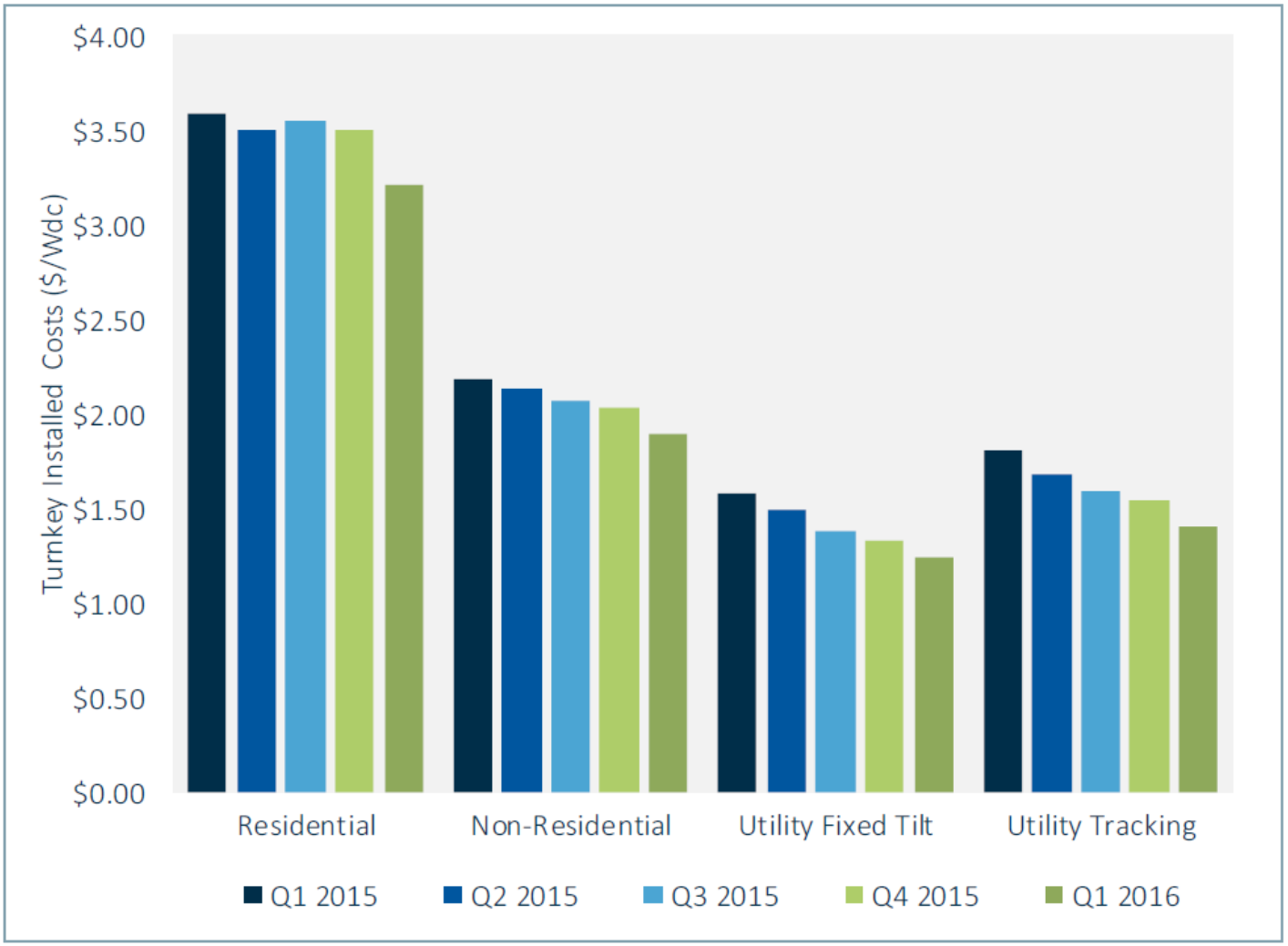
Source: GTM Research

Residential Solar Prices Have Declined Dramatically



Prices Continue to Decline

Figure 2.3 Modeled U.S. National Average System Costs by Market Segment, Q1 2015-Q1 2016



How Residential Solar Works

- Photovoltaic panels convert light to electricity
  - Not heat. In fact PV panels lose efficiency when hot
- An inverter converts the DC power from the panels to AC that the household is set up to use
- When the household's consumption is greater than the flow from the panels, then all electricity from the panels is used onsight and the rest is imported from the grid
- When the household's consumption is less than the flow from the panels, then all extra electricity from the panels is exported to the grid
- Storing electricity at the house is still very expensive, so the customer is almost always importing or exporting electricity
  - 50%+ of typical residential PV electricity is exported

Some Facts about Residential Solar

- About half of all new and installed capacity in the U.S. is in California
- About 70% of new residential solar is now owned by a third party (TPO), either leased to homeowners or the electricity is sold under a power purchase agreement
- Federal and State incentives have varied over time, but today
  - 30% investment tax credit
  - Accelerated depreciation for TPO, probably worth 10%-14%
  - Tradable renewable energy credits vary by state
  - Net metering policies set compensation at retail price for most electricity injected into the grid from residential solar
  - Retail price well above social marginal cost in some places
  - Much greater than tax subsidies for electricity from fossil fuels

Residential Solar Electricity Tariffs

- Net metering – electricity exported to grid at some times is netted out from electricity imported at other times. Customer pays bill for the net consumption.
  - Variants including netting within time periods
  - Varying treatments of customer net exports
- Feed-In Tariff – customer is compensated for electricity produced by solar panels at a pre-set rate.
  - All-buy/All-sell: Bill for household's consumption is entirely separate from compensation for solar production ("value of solar" tariff)
  - Net Feed-In Tariff: In each (very short) time period, customer pays for any net imports from grid at retail rate or is paid for any net exports to grid at FiT rate

Some Residential Solar Debates

- What is the value of DG solar electricity production?
- How much does the utility's costs drop when a customer installs solar? Compared to the revenue the utility loses.
  - Answers depend in part on what the alternative is
    - » Fossil fuel generation
    - » Grid-scale renewable generation
    - » Energy efficiency and reduced consumption

- How should rates for residential solar PV be designed to create efficient incentives for and competition from DG solar?
- How to make sure consumers are intelligent consumers of DG solar?