Review of Solar PV Cost Studies: Exploring Economies of Scale

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Solar PV economies of scale review

- Questions:
  - Are there important economies of scale in solar-PV?
  - Will existing economies of scale stay the same or change as PV technologies and supply-chains gain experience?
  - Do existing policies distort PV markets in unintended or undesirable ways because only some system types or sizes are favored?
  - Given limited funds for PV financial incentives, what policy types and program designs and features will best achieve public policy goals, while minimizing any negative spin-off effects?

Major research findings

- LCOE studies consistently show economies of scale: larger systems are cheaper per unit of capacity
  - The smallest systems sometimes cost roughly twice as much
  - Cost differences have been persistent over time
- LCOE studies are difficult to compare
- PV policies, incentives, and subsidies often differentiate by system size
- PV business models vary because of complex interactions among policies and incentives
- Other analysis techniques are needed to get a complete picture of solar PV costs and benefits (e.g., VOS, LACE, CONE, DMP)

Major differences in PV LCOE studies

- Existing studies ask and answer different questions:
  - What regions or service territories are included in the analysis?
    - How mature and competitive are the region's solar markets?
    - What are the region's insolation values?
    - What are the region's utility rates and tariffs, financial incentives?
  - What vintage(s) of system costs are modeled?
  - Are financial incentives, subsidies, and REC sales included?
  - Are interconnection, T&D, and grid integration costs included?
    - If yes, are they generic or specific?
  - Are environmental and social costs and benefits considered?
  - Are sensitivity analyses reported?

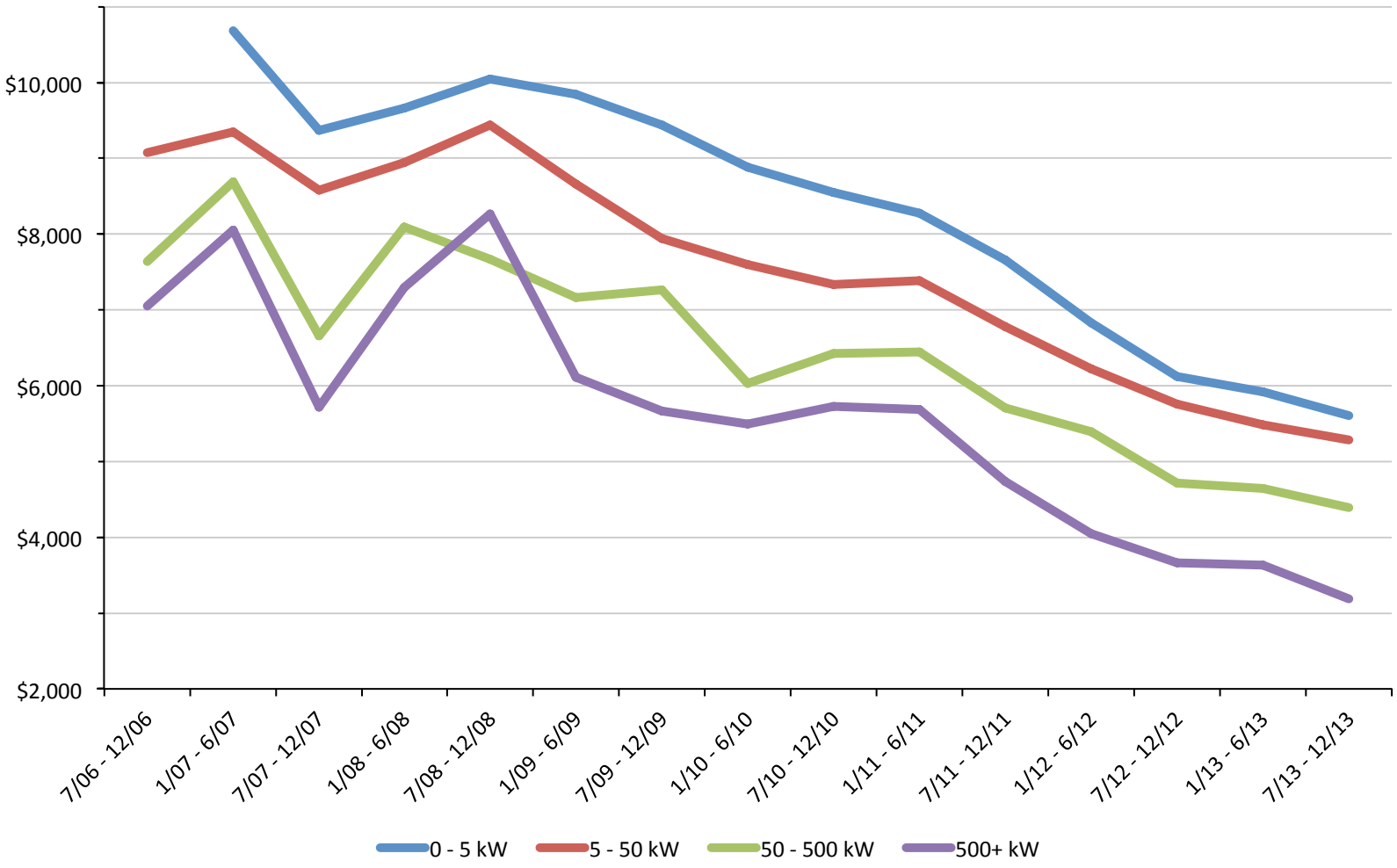
Factors influencing economies of scale

1. Modules (roughly 40-50% of total cost)
   - Subject to "Swanson's Law" manufacturing learning-curve effects and economies of scale, and through continuing technology improvements
2. Balance of system hardware (roughly ¼ to 1/3 of cost)
   - Mounting systems, inverters and power electronics, switches and wiring – also subject to Swanson's Law?
3. Soft costs (roughly, anywhere from ¼ to 1/2 of cost)
   - Marketing, customer acquisition, siting, permitting, regulatory and contractual work, financing, insurance, and property taxes

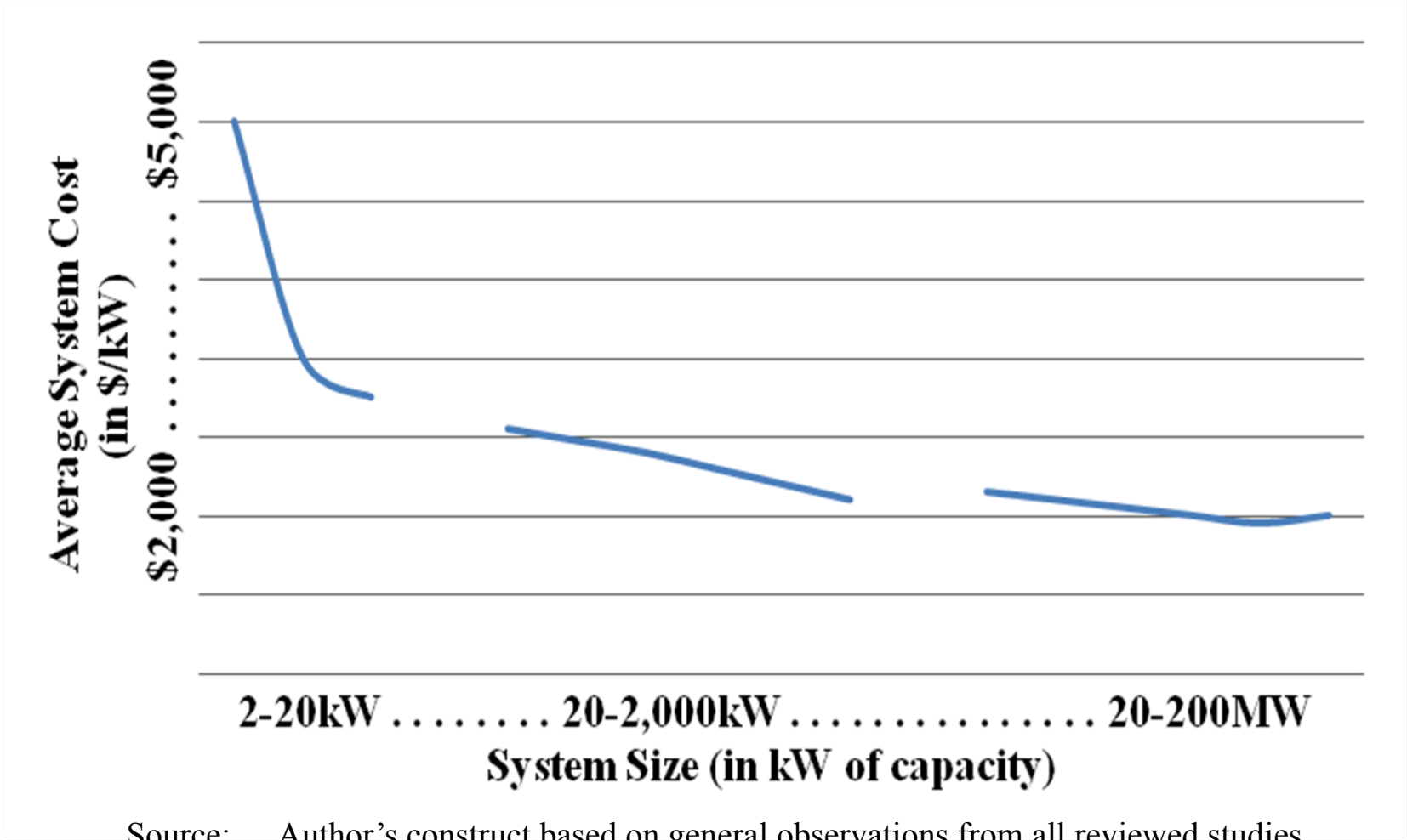
Average cost make-up of different size PV systems

Components	Utility-Scale Fixed Ground Mount	Utility-Scale 1-Axis Tracking Ground Mount	Commercial Rooftop	Residential Rooftop
Solar PV modules	51%	44%	45%	38%
Inverter	8%	7%	8%	7%
Installation materials	10%	10%	14%	8%
Electrical & hardware labor	11%	13%	7%	11%
Supply chain costs	7%	7%	14%	17%
Permitting and commissioning	<1%	<1%	4%	3%
Other	13%	20%	10%	16%
Total estimated installed cost in second half 2010	$3.80/Wp-dc	$4.40/Wp-dc	$4.59/Wp-dc	$5.71/Wp-dc
Source: Adapted from Goodrich, James, and Woodhouse, 2012.				

From California data:
Larger systems consistently cost less



General trends in reported PV cost



Source: Author's construct based on general observations from all reviewed studies, adapted from Goodrich, James and Woodhouse, 2012, Figure 4.

Common policy/market distortions

- Participation is limited to only certain system types and sizes
- Incentives apply unequally or only to certain types and sizes
- Interconnection rules and standards favor smaller systems
- Net metering and aggregated or virtual net metering are usually subject to system capacity limits
- Tax codes and some incentives treat systems differently by ownership type and size
- Several states have portfolio carve-outs requiring specific percentages of solar or distributed generation, other states have extra credit for solar generation