What are the financial and social costs and benefits of different community-based solar approaches?

Dr. Sharon Klein
Ms. Stephanie Coffey
University of Maine School of Economics

Why Community-based Solar?

- Expand access to solar
  - Only ¼ of U.S. residential buildings suitable for solar (NREL)
- Capacity in the United States projected to increase by

  1.8 GW through 2020

  (Green Tech Media)
- Peer effects, social norms more effective than individual incentives/education

Source: https://ilsr.org

What is Community-based Solar?

Provides power **or** financial **or** other benefits to a **group** of people

- Common local geographic area (town level or smaller)
- Common set of interests
- Some costs and/or benefits shared by group

Coughlin et. al, 2012

Walker & Devine-Wright, 2008

Where are Community-based Solar Projects in the US?

Asmus, P. (2008). Exploring New Models of Solar Energy Development. *The Electricity Journal*, *21*(3), 61–70. **(4 projects)**

Farrell, J. (2010). *Community Solar Power: Obstacles and Opportunities* (Rep.). Minneapolis, MN: New Rules Project. **(8 projects)**

Coughlin, J., Grove, J., Irvine, L., Jacobs, J., Phillips, S. J., Sawyer, A., & J. W. (n.d.). *A Guide to Community Shared Solar: Utility, Private and Nonprofit Project Development* (pp. 1-76, Rep.). Golden, CO: National Renewable Energy Laboratory. **(9 projects)**

Model Rules for Shared Renewable Energy Programs (pp. 1-28, Rep.). (2013). Latham, NY: Interstate Renewable Energy Council. **(38 projects)**

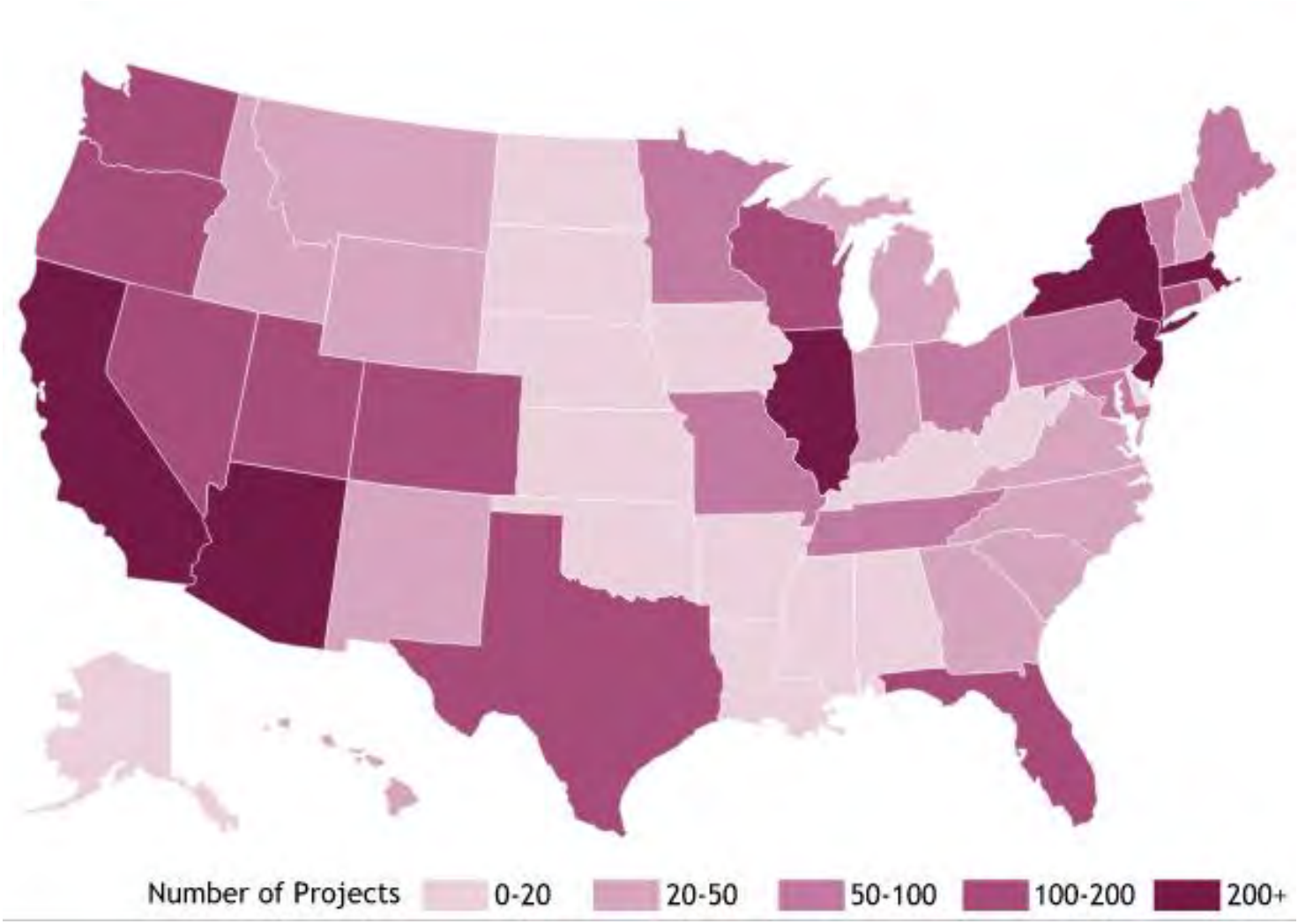
Siegrist, C. R., Barth, B., Campbell, B., Krishnamoorthy, B., & Taylor, M. (2013).*Utility Community Solar Handbook: Understanding and Supporting Utility Program Development* (Rep.). Washington, DC: Solar Electric Power Association. **(31 existing and planned projects)**

Noll, D, Dawes, M, & C., Rai, V. (2014). Solar Community Organizations and Active Peer Effects in the Adoption of Residential PV. *Energy Policy, 67,* 330-343. **(48 Solarize projects)**

Feldman, D., Brockway, A. M., Ulrich, E., & Margolis, R. (2015). *Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation* (pp. 1-71, Tech.). Golden, CO: National Renewable Energy Laboratory. **(41 existing projects and 16 planned projects)**

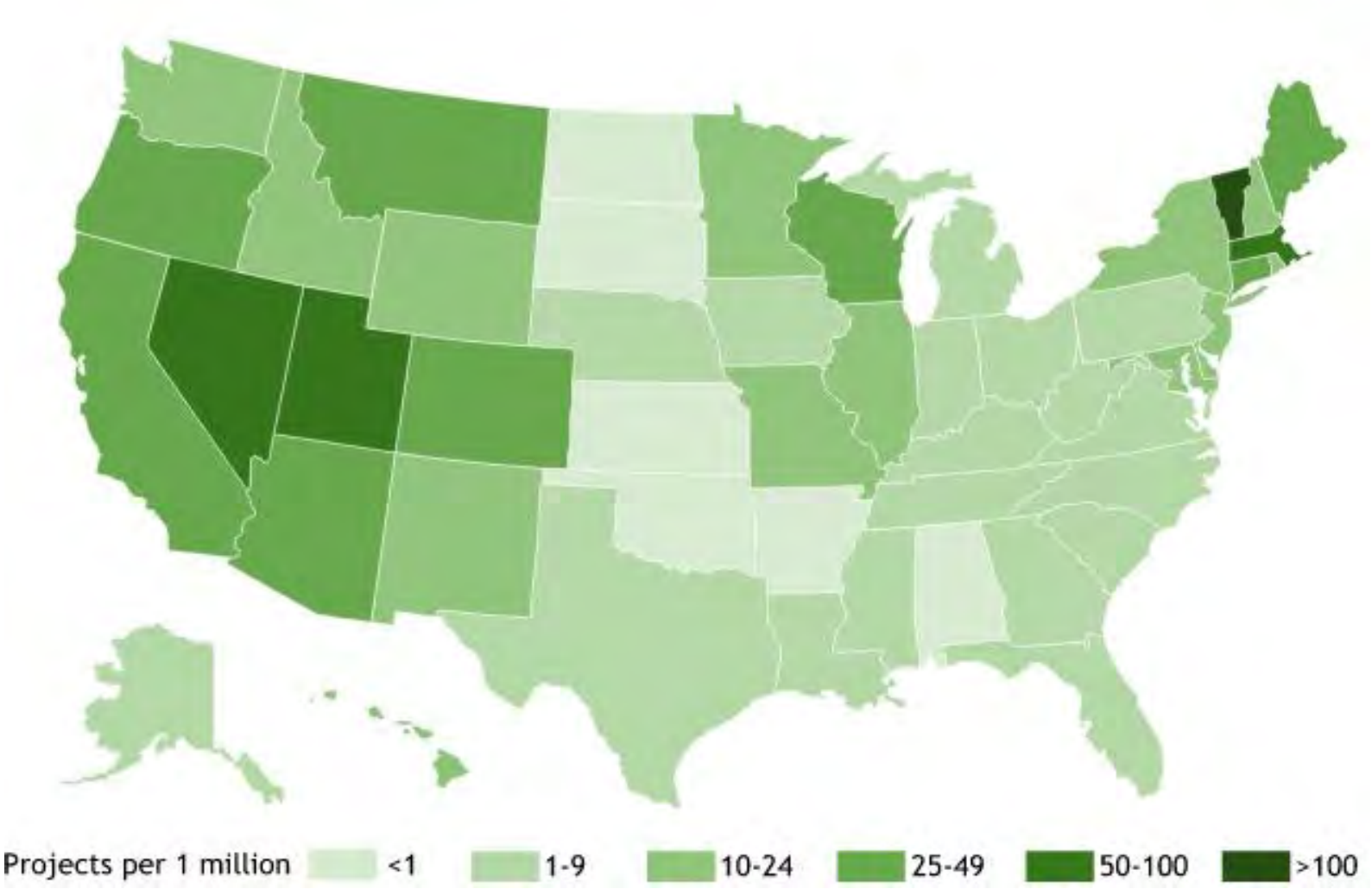
NEW US Community Solar Database

(>5,000 Community-based Solar Projects in 48 States)



COMING SOON (December?): http://communityenergyus.net/

Projects per Million Residents



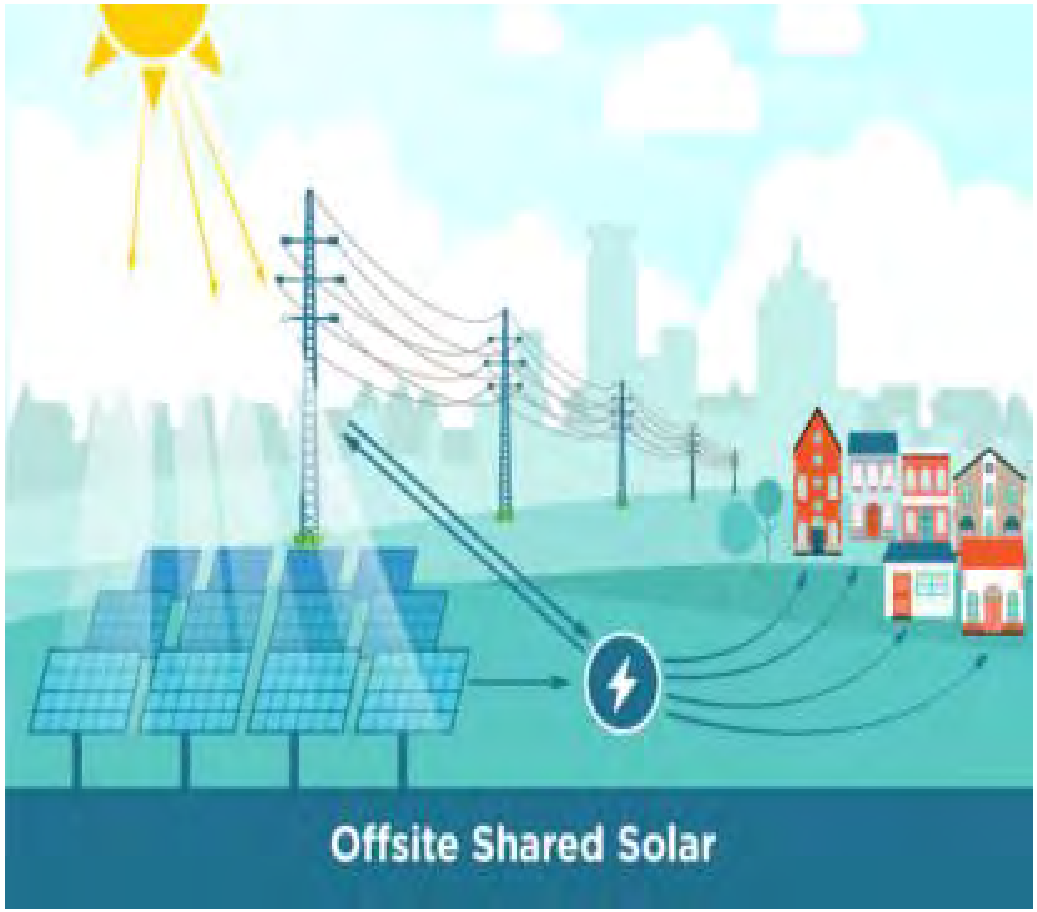
COMING SOON (December?): http://communityenergyus.net/

1. **Solar Farm/Garden**
(shared solar, community solar)

- Multiple people/businesses
- Single solar PV array
- Economies of scale

150 kW, Brattleboro VT, 6 residences & 3 businesses

Source: http://soverensolar.com/



http://energy.gov

2. **Bulk Purchase** *(Solarize, Solar Coops)*

- Multiple people/businesses
- Multiple solar PV (or thermal) arrays
- Reduced installation price – buying in bulk
- Urgency – limited time to participate
- Tiered pricing based on level of participation
  - More people = greater discount

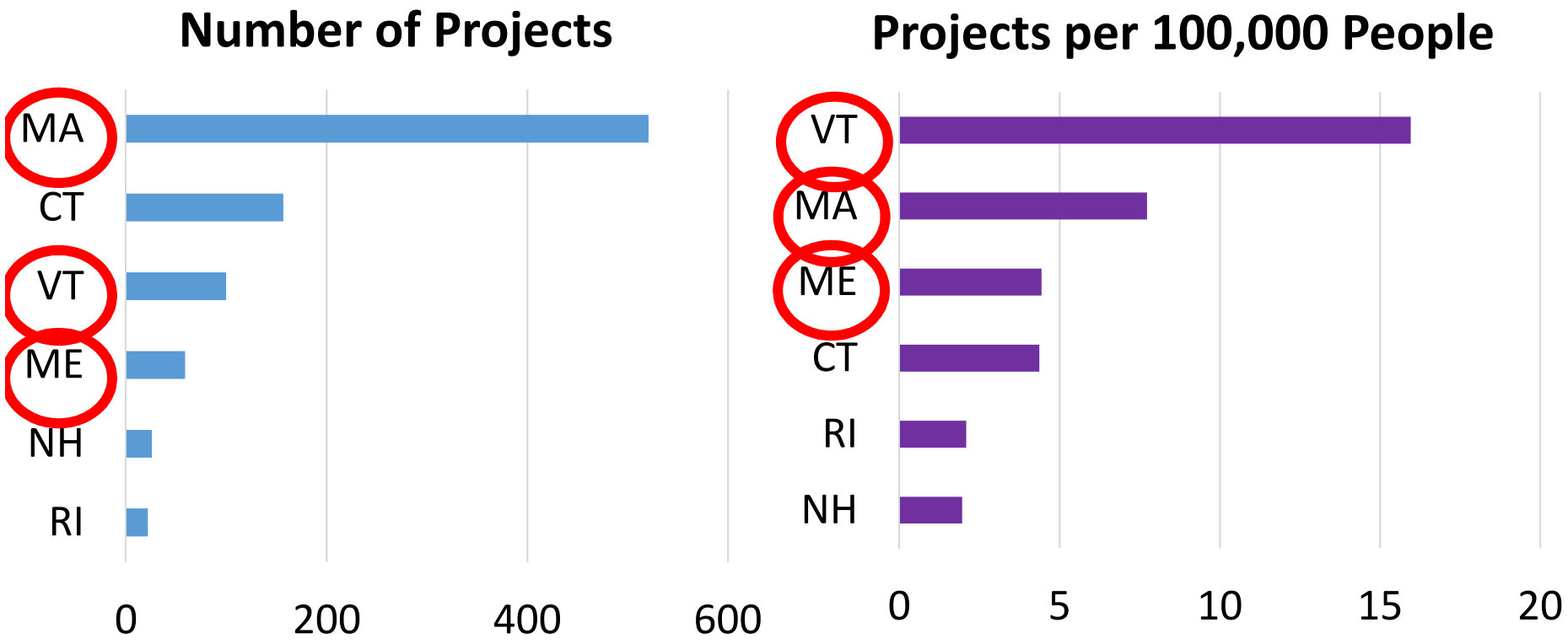
http://energy.gov

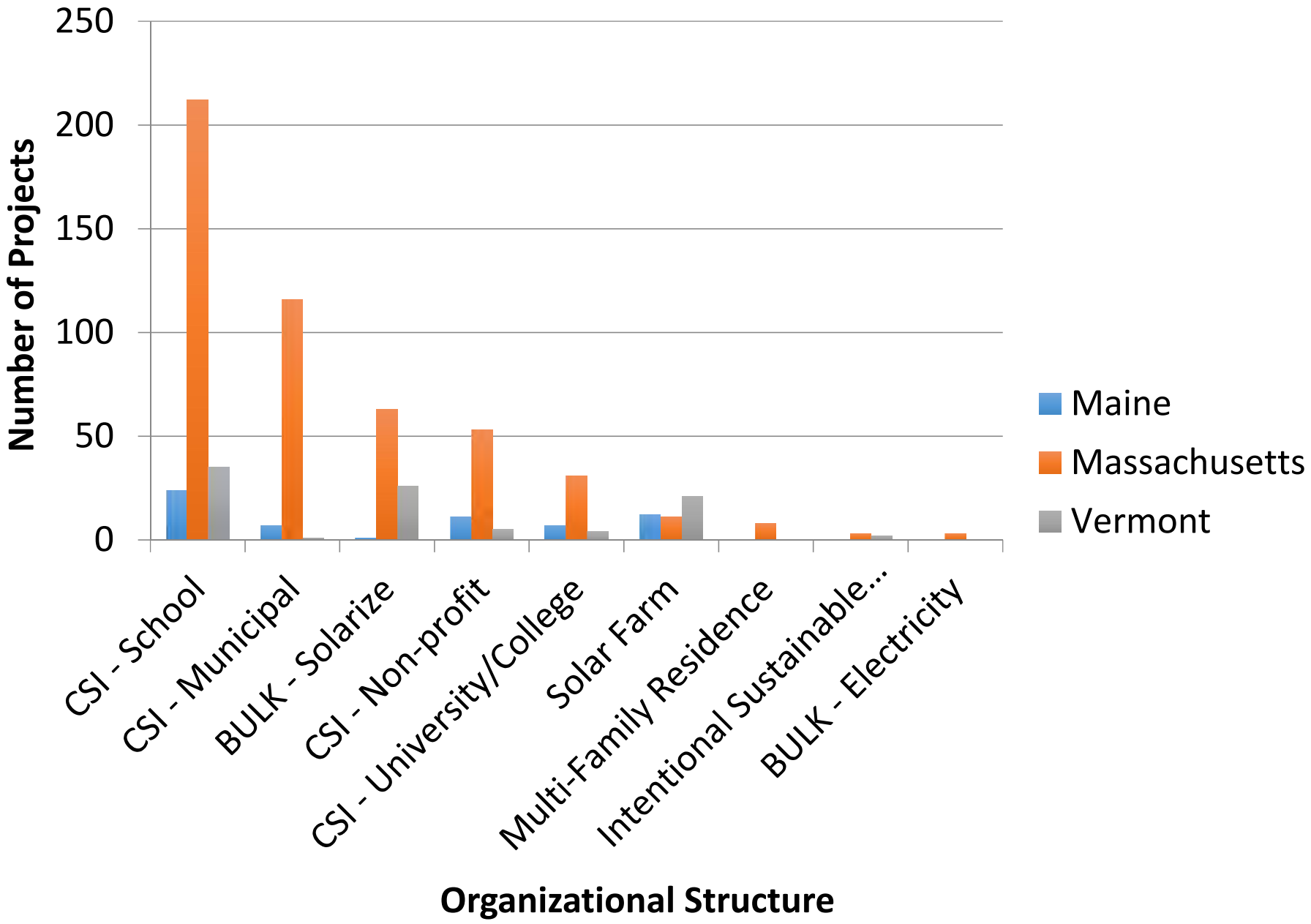
3. **Community-Serving Institutions (CSI)** *(Churches, Schools, Municipalities, etc)*

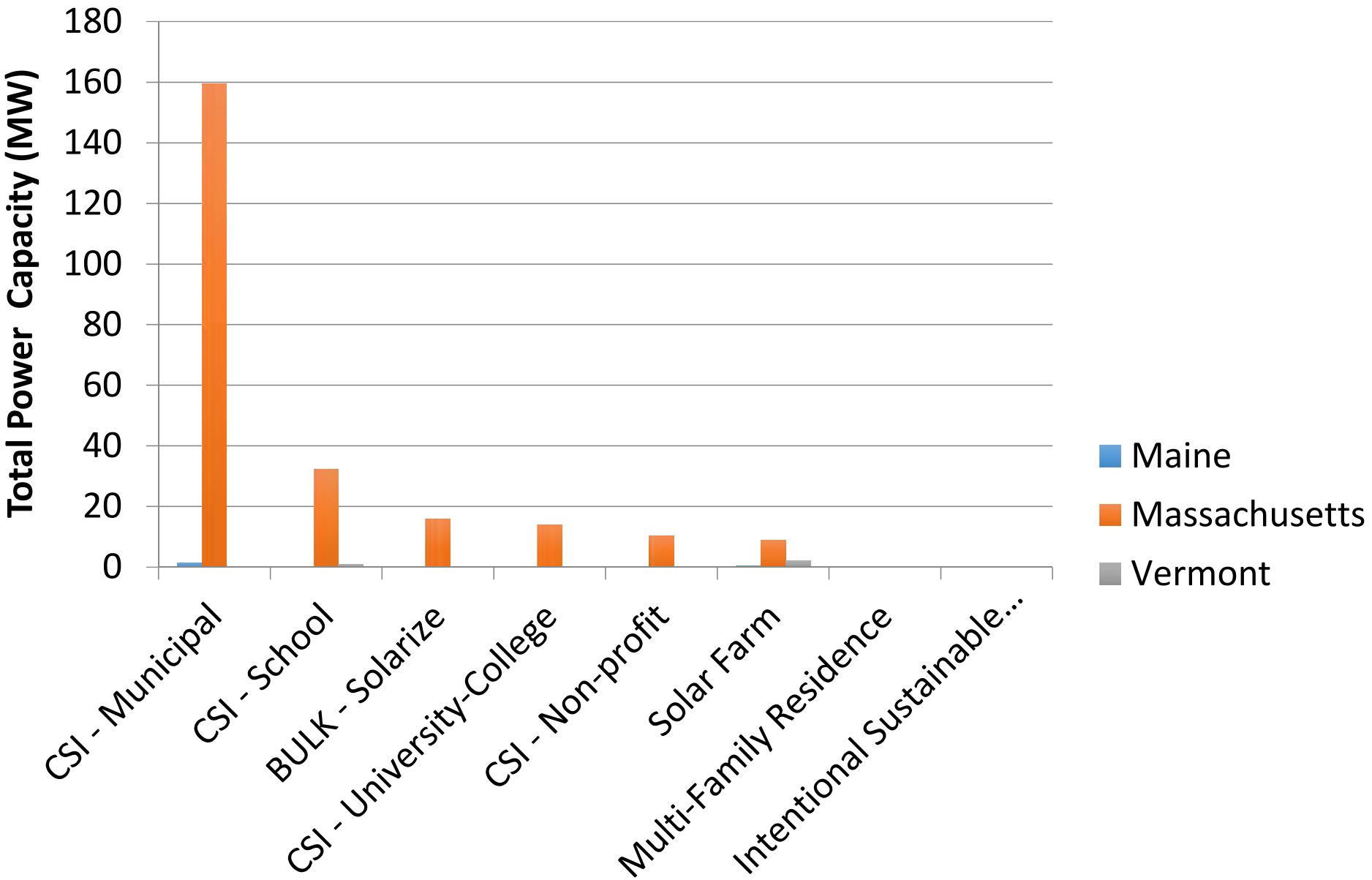
- Single institution serving multiple people
- Single or multiple array(s)
- Provide a “service” to a “community”
- Most with non-profit status (exception: some schools)

https://www.high-profile.com/sustainable-solar-development-of-closed-landfill-provides-revenue-benefits-to-billerica/

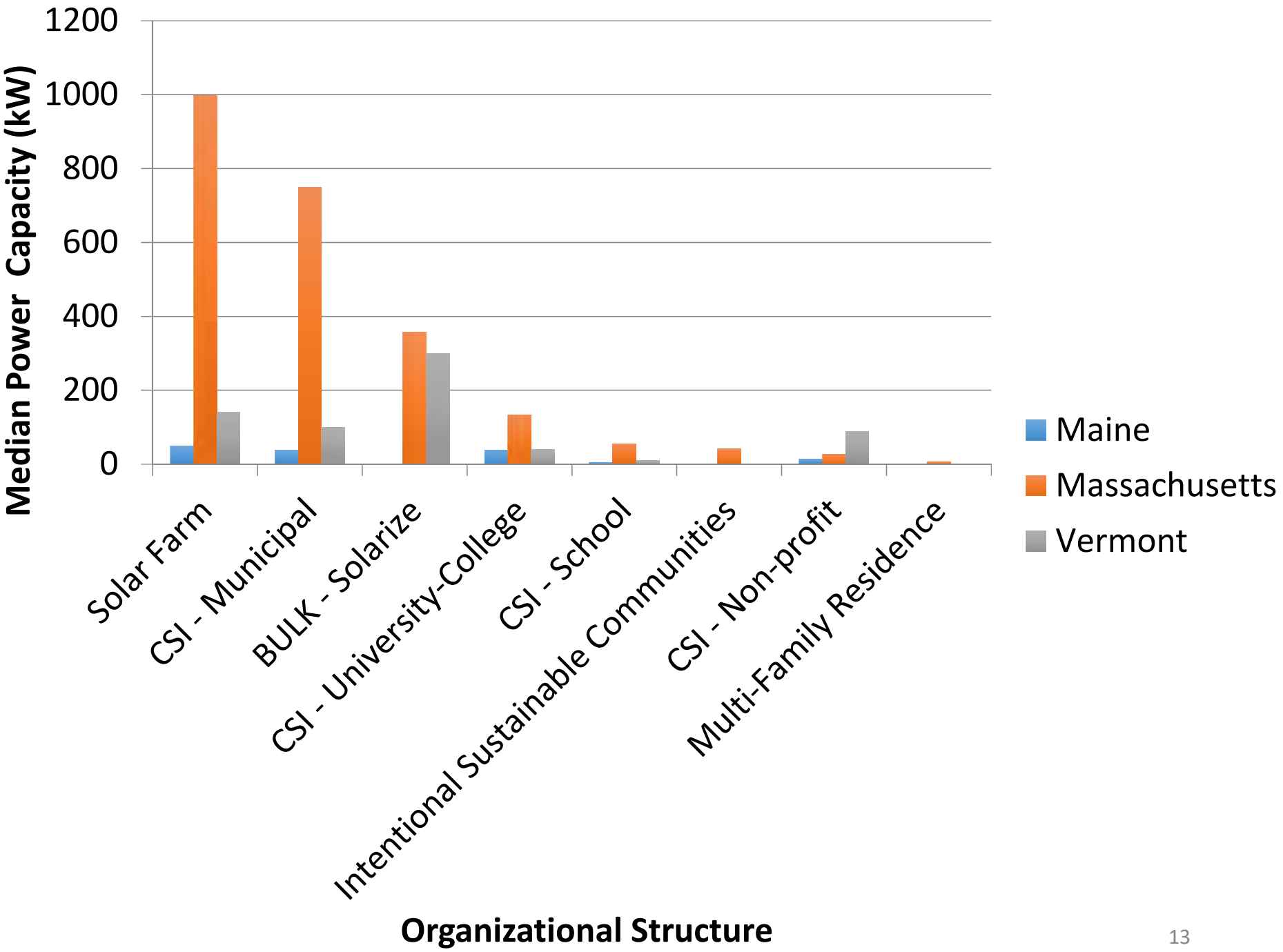
Community-based Solar Projects in New England

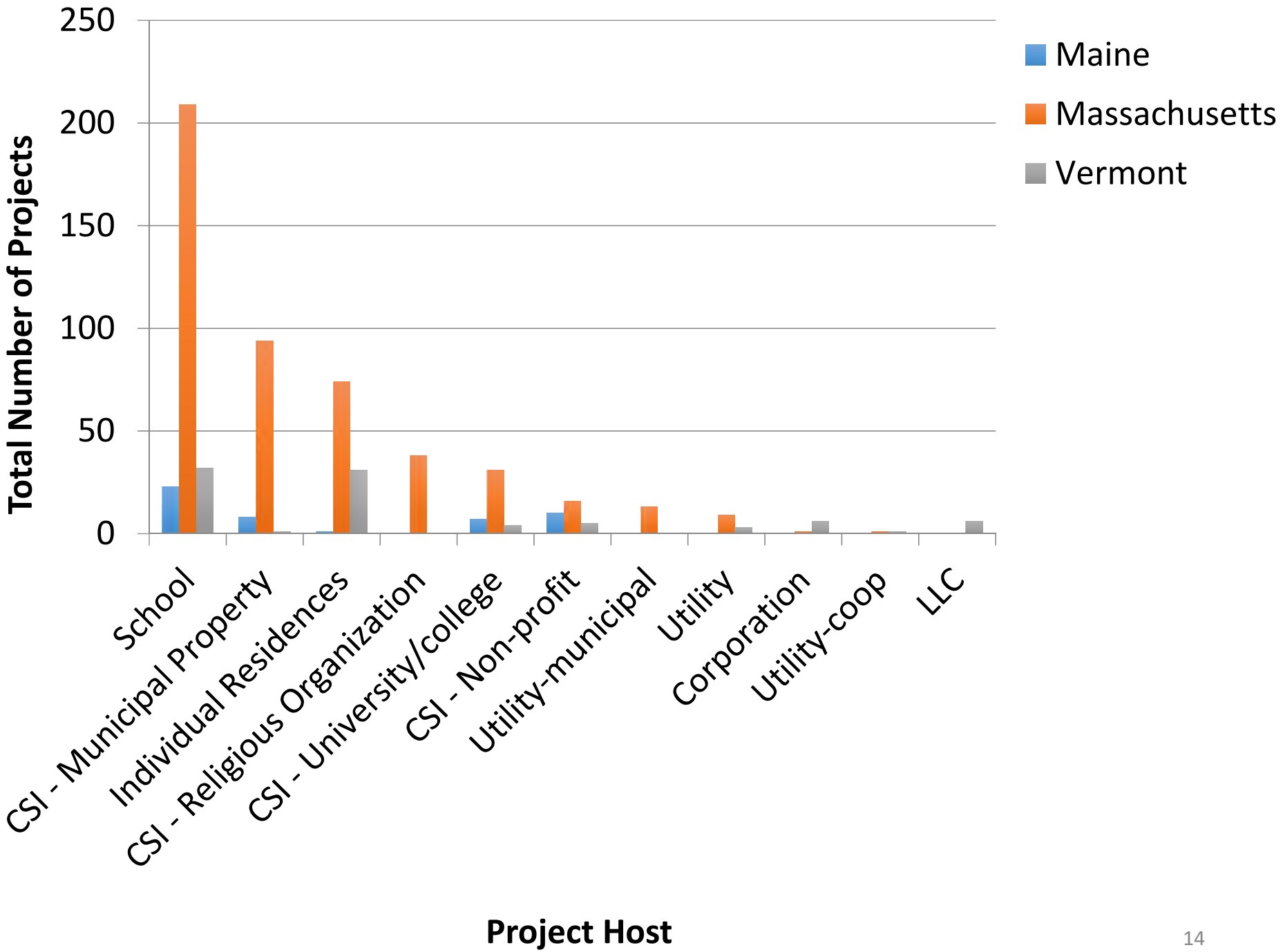


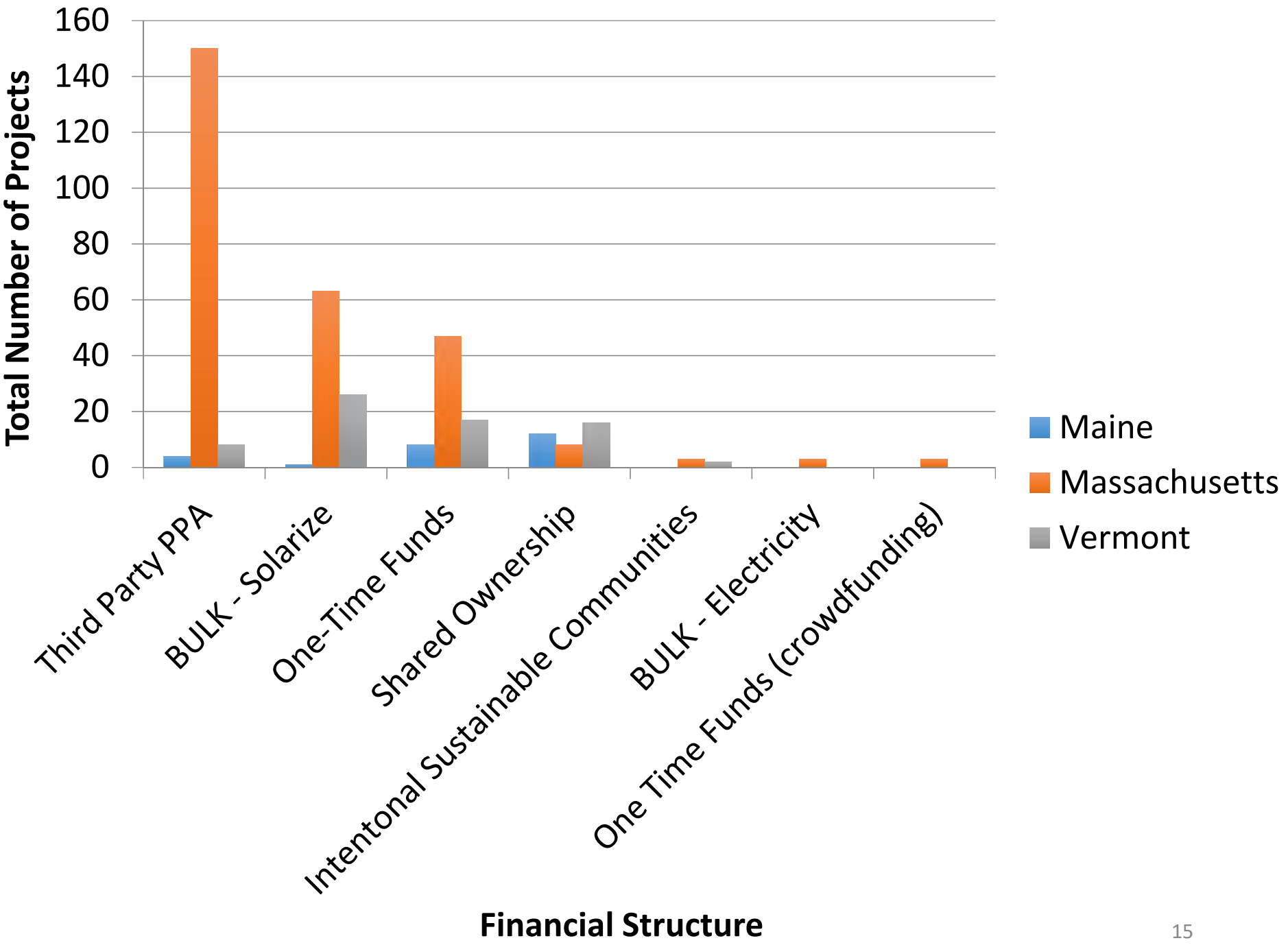

250
200
150
100
50
0
Number of Projects
CSI - School
CSI - Municipal
BULK - Solarize
CSI - Non-profit
CSI - University/College
Solar Farm
Multi-Family Residence
Intentional Sustainable...
BULK - Electricity
Organizational Structure
Maine
Massachusetts
Vermont



Organizational Structure


Median Power Capacity (kW)
1200
1000
800
600
400
200
0
Solar Farm
CSI - Municipal
BULK - Solarize
CSI - University-College
CSI - School
Intentional Sustainable Communities
CSI - Non-profit
Multi-Family Residence
Organizational Structure
Maine
Massachusetts
Vermont


250
200
150
100
50
0
Total Number of Projects
Maine
Massachusetts
Vermont
School
CSI - Municipal Property
Individual Residences
CSI - Religious Organization
CSI - University/college
CSI - Non-profit
Utility-municipal
Utility
Corporation
Utility-coop
LLC
Project Host


Total Number of Projects
160
140
120
100
80
60
40
20
0
Third Party PPA
BULK - Solarize
One-Time Funds
Shared Ownership
Intentonal Sustainable Communities
BULK - Electricity
One Time Funds (crowdfunding)
Financial Structure
Maine
Massachusetts
Vermont

How Can We Evaluate the Cost-Competitiveness of Solar?

Net Present Value = $\sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$

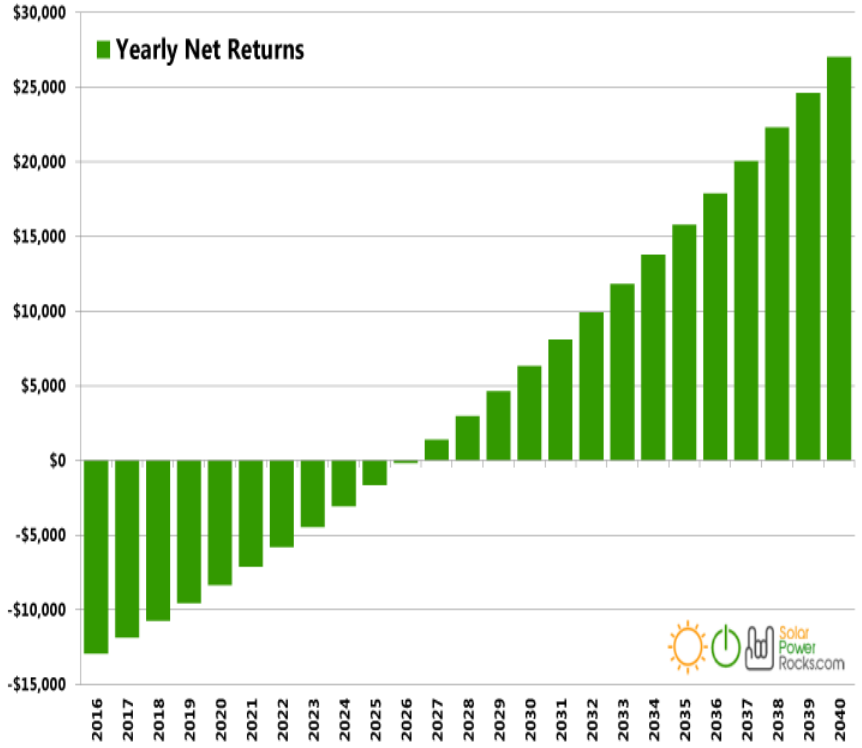
C_t = net cash flow in year

C_0 = initial project cost

r = discount rate

T = project lifetime

t = year t



Source: http://solarpowerrocks.com

Why is Discounting Important?

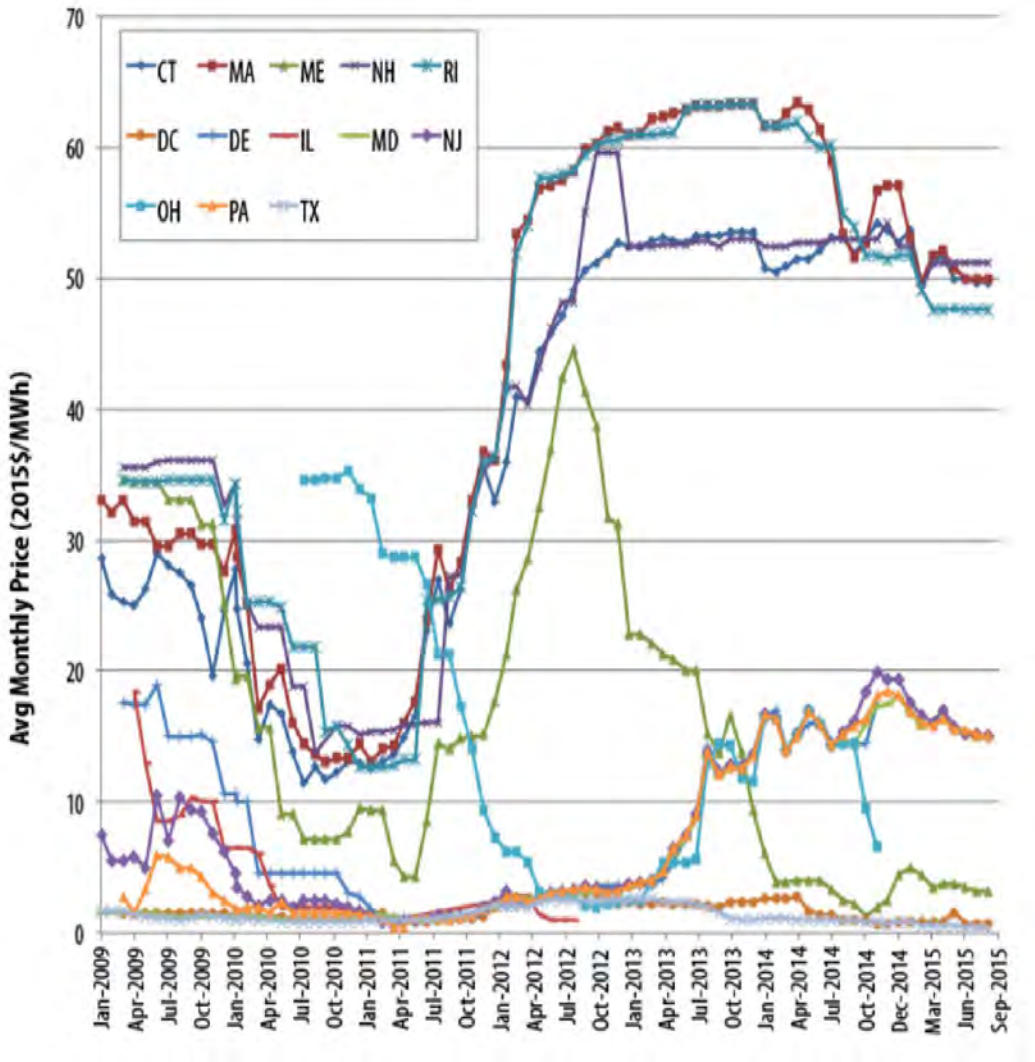
- Time Value of Money
- Inflation
- Opportunity cost
- Risk
- r = 5%

Now or in 10 years?

Simple payback period: ~~discounting~~

Important Solar Incentives (All 3 States)

- 30% Federal Tax Credit (I
- Renewable Energy Credi (RECs)
  - $40/MWh
  - >50 kW



Important Solar Incentives (Massachusetts)

Solar Renewable Energy Credits (SRECs)

- Solar PV only
- Only generated in MA
- Price set by policy
- $285/ MWh in 2015 (decreases to $180 by 2025)

15% State Tax Credit

Source: http://mysolar.com/solar-renewable-energy-credits/

Important Solar Incentives (Vermont)

Solar Adder

- Price guarantee for solar electricity
- $.20/ kWh for systems up to 15 kW
- $.19/ kWh for systems over 15 kW
- First 10 years of system operation

Source: http://isasolar.com/

Other Solar Policies

	MA	VT	ME
Aggregate Net Metering Cap (% of peak load)	9%	15%	1%
Program Designed to Encourage Community Energy	Yes	No	Yes[1]
State Tax Credit/Rebate	15%[2]	$.50 - $2.10/W[3]	No
Sales Tax Exemption	Yes	Yes	No
Property Tax Exemption	Yes	Yes	No
Third Party Ownership	Yes	Yes	Yes
Low Interest Solar Financing	Yes	Yes	Yes

1. Closed December, 31, 2015
2. Available for residential systems only
3. Closed January 1, 2015

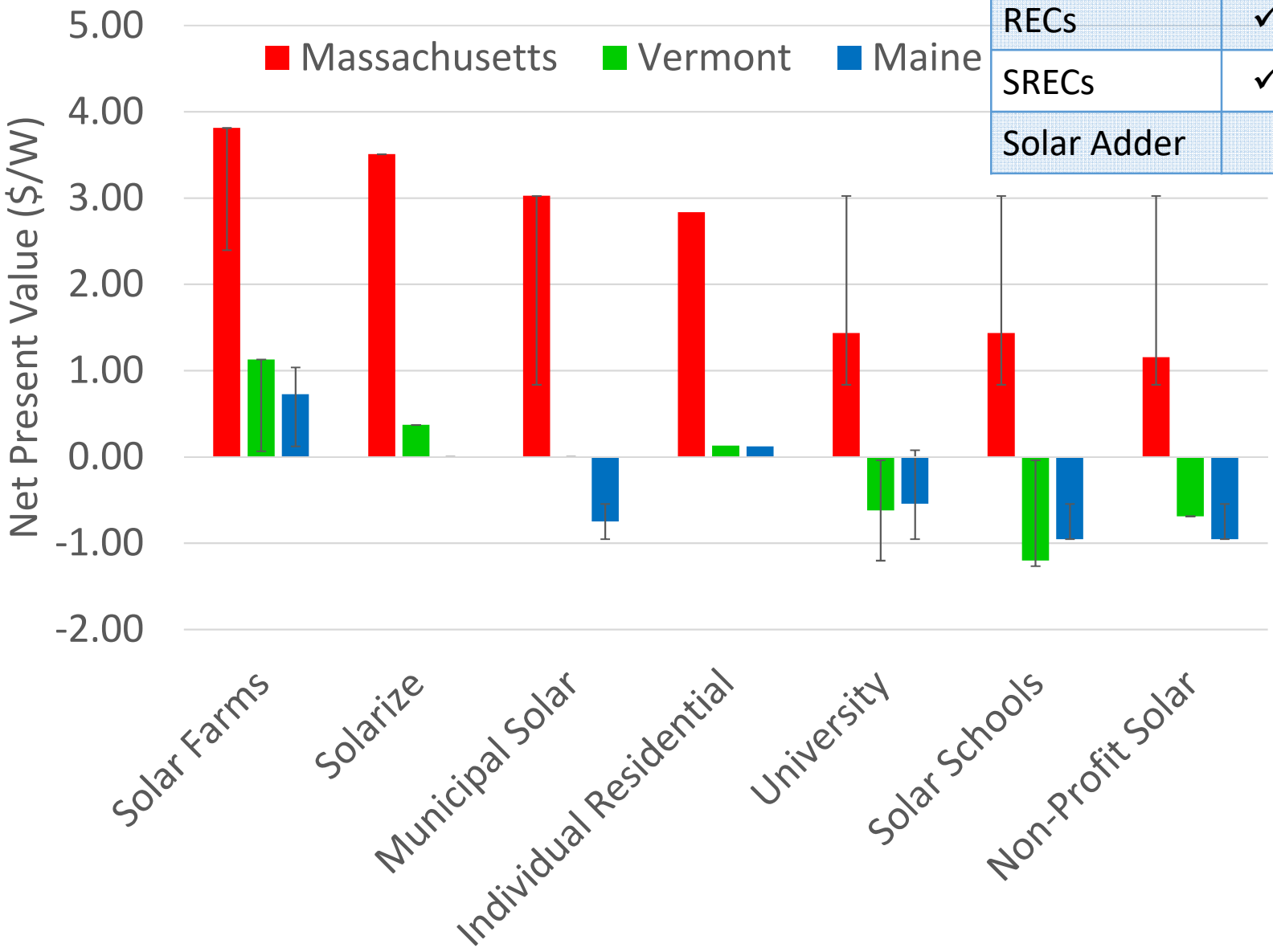
State Level Assumptions

Variable	Units	Default Value		
		Maine	Massachusetts	Vermont
C_{WATT} <25 kW	$/W	$3.59[1]	$4.44[1]	$4.44 [1]
25 kW ≤ C_{WATT} < 500 kW	$/W	$3.20[1]	$4.14[1]	$3.89[1]
500 kW ≤ C_{WATT}	$/W	$2.03[1]	$2.62[1]	$2.47[1]
P_{RETAIL}	$/kWh	$0.1577[2]	$0.1767[2]	$0.1775[2]
Solarize Discount	%	NA	25%	7%
Capacity Factor	%	13.2%[3]	13.6%[3]	13.8%[3]

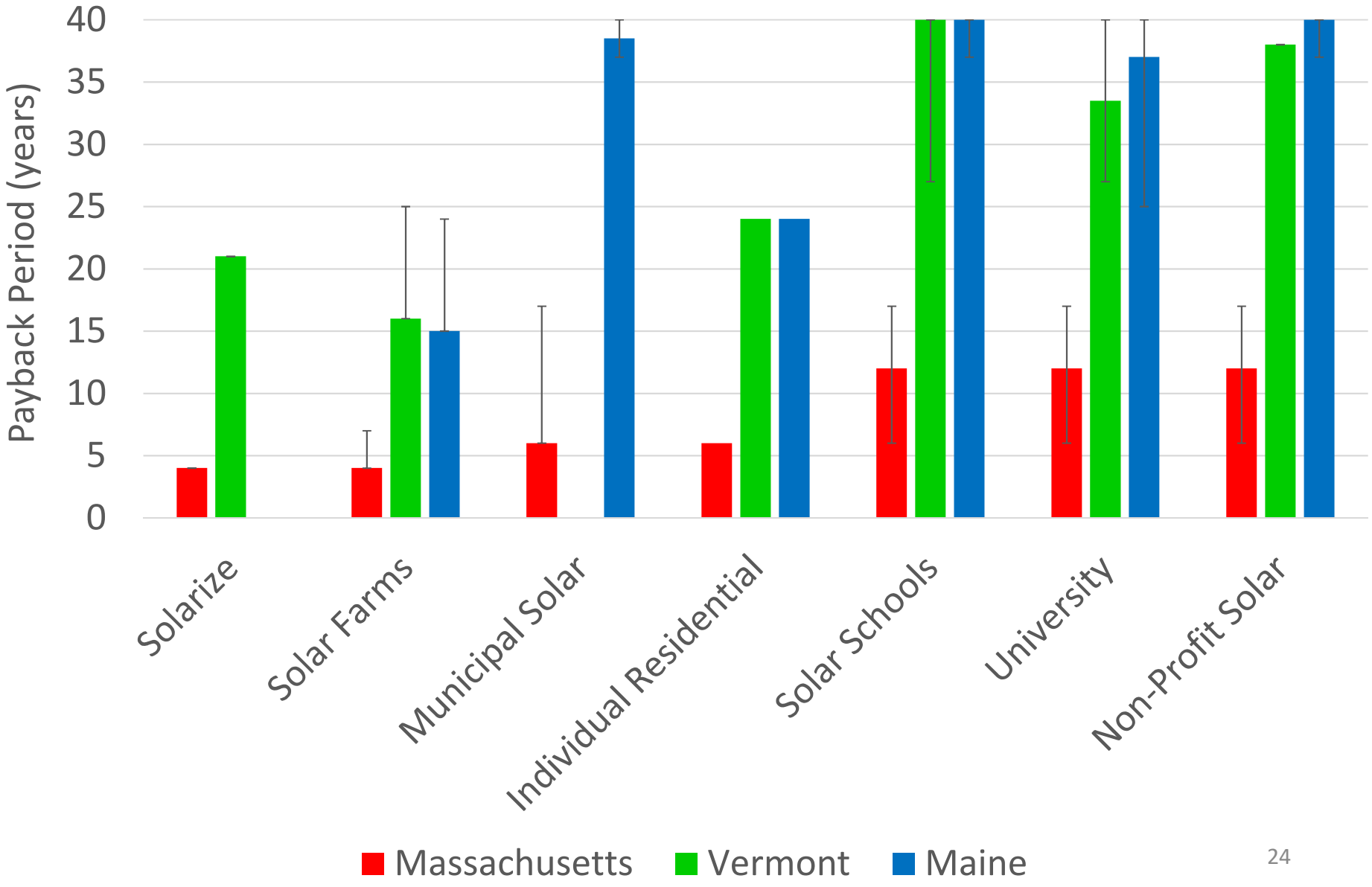
1. Lawrence Berkeley National Laboratory
2. Energy Information Administration
3. System Advisor Model

Results: NPV at 25 Years

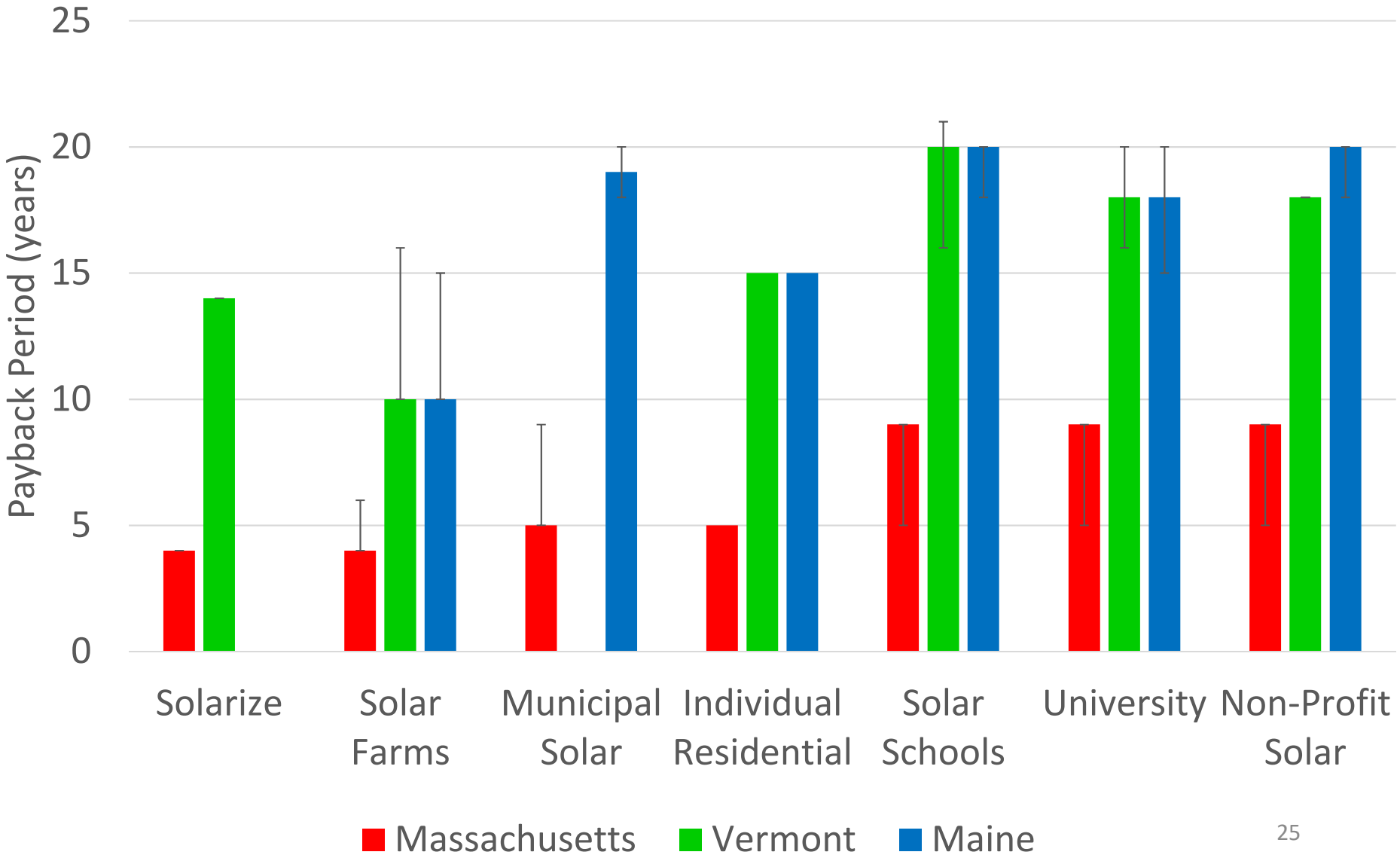
Incentive	MA	VT	ME
FTC	✓	✓	✓
STC	✓		
RECs	✓	✓	✓
SRECs	✓		
Solar Adder		✓	



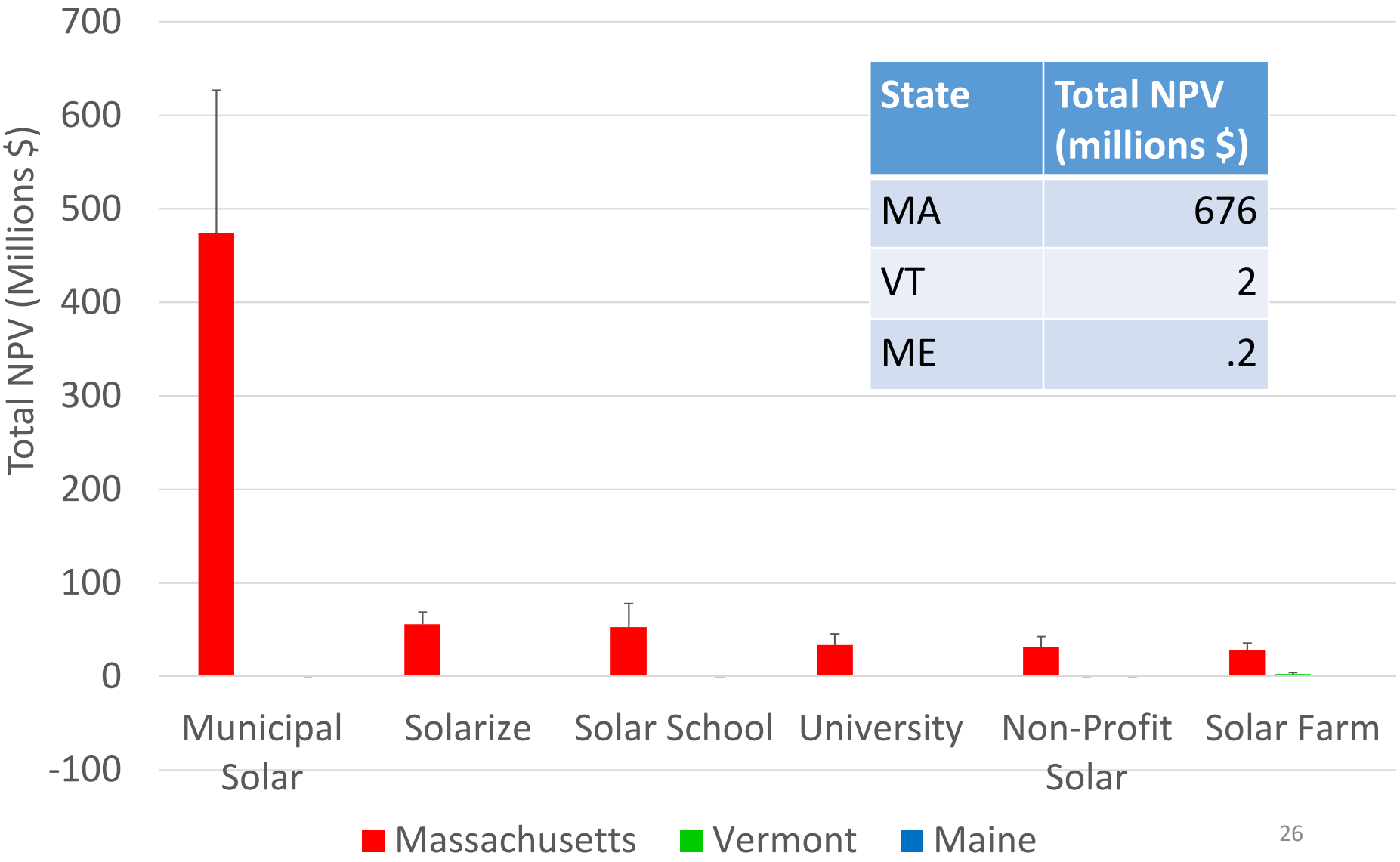
Results: Discounted Payback Period



Results: Simple Payback Period



Results: Total NPV



State	Total NPV (millions $)
MA	676
VT	2
ME	.2

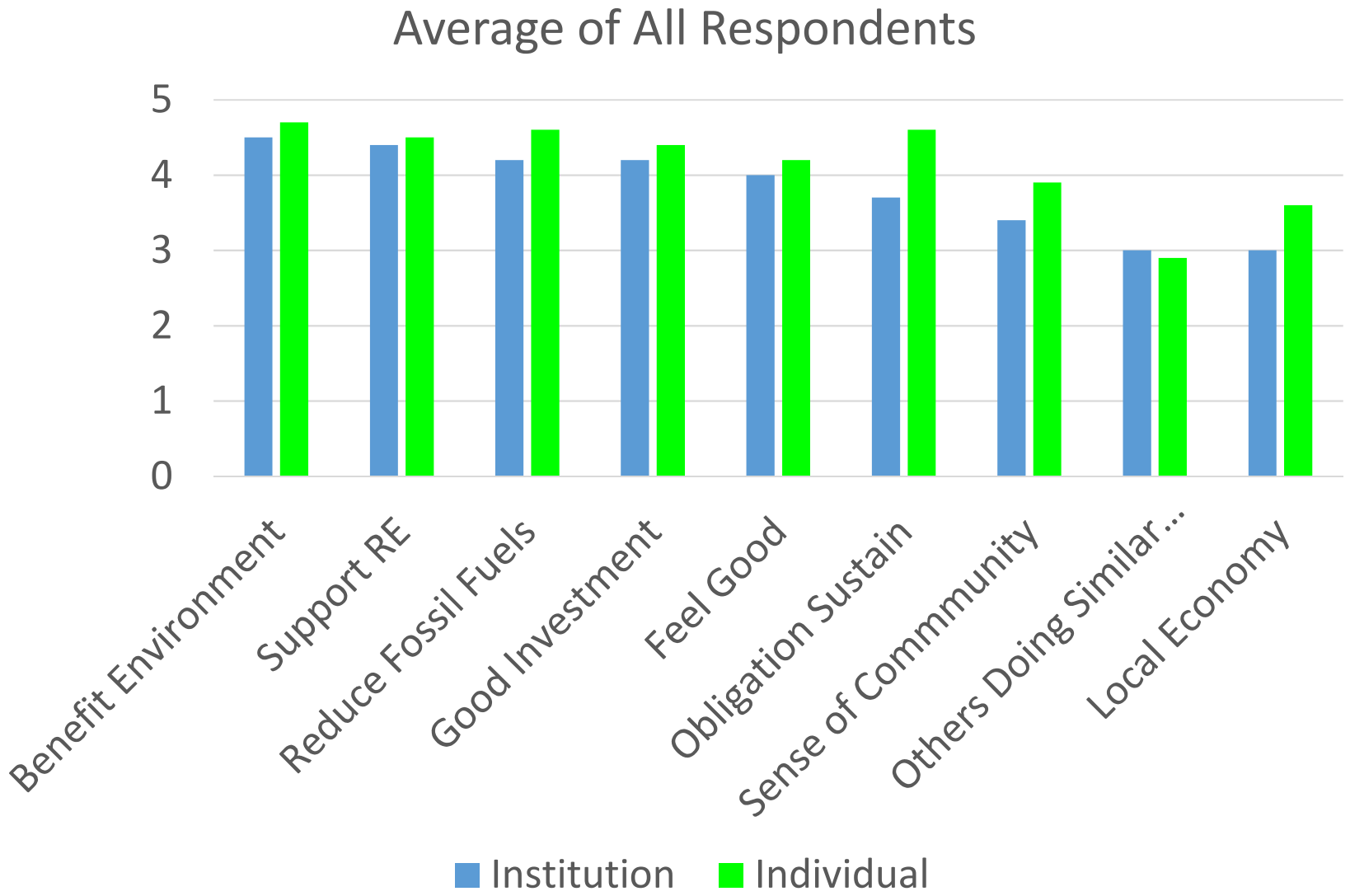
Tri-state survey 2015

Community Solar Category	# Sent	# Complete	# Partial	Completed Survey Response Rate
Solarize*				
Maine	0	0	0	N/A
Massachusetts	38	4	4	11%
Vermont	24	1	0	4%
TOTAL	*62*	*5*	*4*	*8%*
Solar Farms				
Maine	2	1	0	50%
Massachusetts	3	0	1	0%
Vermont	18	5	1	28%
TOTAL	*23*	*6*	*2*	*26%*
COMMUNITY-SERVING INSTITUTIONS				
Maine	36	4	2	11%
Massachusetts	287	19	7	7%
Vermont	37	3	0	8%
TOTAL	*360*	*26*	*9*	*7%*
ALL SURVEYS				
Maine	38	5	2	13%
Massachusetts	328	23	12	7%
Vermont	79	9	1	11%
TOTAL	**445**	**37**	**15**	**8.3%**

Who is participating (responding)?

- Wealthy (income > median)
- Educated (bachelor's degree or higher)
- Democrat
- Caucasian
- Older (77% >50 yrs old)
- Mixed gender (20 men, 15 women)
- Homeowners (33, vs 2 renters)

Why are they doing it?



1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree

How are they doing it? (Organizational structures)

Grassroots (bottom-up) community-engagement

"I expressed my interest, along with others. We then invited ReVision Energy to attend a meeting to discuss the details of the project. I was very interested in advancing the solar farm, and so volunteered to become the President of the association. I kept potential members informed (by email) until nine individuals were willing to commit to the project by placing a deposit with ReVision. I then assisted in moving the project along until final closing in April of 2015. We are the first member-owned community ***solar farm*** *in* ***Maine****."*

How are they doing it? (Organizational structures)

New business model

*"We learned about **Vermont**'s net metering law, learned that GMP allows solar and pays a premium for it. We learned that multiple people can participate in one project. We knew that the IRS allows tax credits to be taken for off-site renewable energy assets. We then bought land, found an installer, applied for a permit, marketed our offering and took on customers. It is the customers who finance the project. We use E-mail to communicate our progress and encourage folks to follow through on their interest"*

Solar farm

How are they doing it? (Organizational structures)

Top-down, Existing organization

"I procured grant funding and carried out the program as part of my job" **Solarize, Vermont**

"Wrote application, recruited solar coach, generated marketing ideas, executed some marketing campaigns, spoke at public meetings." **Solarize, MA**

Conclusions – US Community Solar:

- Quickly growing in US
- Many varieties
  - Organizational
  - Financial
  - Host
  - State-based policies
- More cost-competitive than individual residential (3 states)
  - Depends on financial incentives
  - MA most profitable
  - Alternative financial structures needed to make non-profit cost competitive
  - **Solar Farms** most profitable
  - **Individual Residential** profitable in all 3states

Conclusions – US Community Solar:

- Similar demographics to residential PV adopters
- Motivated by environmental benefits more than financial/social
- Perceived ripple effect
- Participants are likely to engage in energy efficiency

Future Work

- Launch website – grow database
- National survey (larger sample size)
- Access real energy use data
- National policy/financial analysis
- Estimate net cost/benefit to state for incentives
- Multi-criteria decision analysis tool

Acknowledgements

This work is supported by…

- The USDA National Institute of Food and Agriculture, Hatch project 0230040.
- The Senator George J. Mitchell Center for Sustainability Solutions at the University of Maine

Want to learn more?

- **Klein**, S.J.W. and S. Coffey, 2016, Building a sustainable energy future, one community at a time, *Renewable and Sustainable Energy Reviews*, vol. 60, pp. 867–880, doi: 10.1016/j.rser.2016.01.129.
- **Klein, S.J.W.** and Coffey, S., 2016, United States Community Energy. *Handbook on Energy Transition and Participation* Springer VS, Wiesbaden; Lars Holstenkamp and Jörg Radtke, editors. *In press*.
- National Community Solar Partnership: http://energy.gov/eere/solarpoweringamerica/national-community-solar-partnership
- **COMING SOON (December?): http://communityenergyus.net/**

Sharon.klein@maine.edu

Extra Slides

Why are they doing it?

"Promoting solar is as much personal as it is part of my job to reduce the cost of running the library for the taxpayers. Working in a building with solar panels is very satisfying for me as my personal values align every sunny day with my investment in my work."

– Municipal Solar Participant

"It became apparent to me that citizens could not rely on the government to advance clean energy. In order to… wean ourselves from the fossil fuels that are causing climate change, then, individuals must take the initiative."

-Solar Farm Participant

Possible Effects of Community Solar Participation

Ripple Effect: the "halo" associated with engaging in pro-environmental behavior may encourage an individual to subsequently adopt additional pro-environmental behaviors. (decrease energy use)

N. Mazar and Z. Chen-Bo, "Do Green Products Make Us Better People?," Psychological Sciences, vol. 21, no. 4, pp. 494–498, Apr. 2010.

Possible Effects of Community Solar Participation

Rebound Effect: gains in the efficiency of energy consumption result in an effective reduction in the per unit price of energy services. As a result, consumption of energy services should increase, partially offsetting the impact of the efficiency gain in fuel use. (increase energy use)

L. A. Greening, D. L. Greene, and C. Difiglio, "Energy efficiency and consumption — the rebound effect — a survey," Energy Policy, vol. 28, no. 6–7, pp. 389–401, Jun. 2000.

Licensing Effect: Individuals establish moral credentials, and thus feel less obligated to scrutinize the moral implications of their actions immediately after receiving a moral boost by performing a good deed. (increase energy use)

N. Mazar and Z. Chen-Bo, "Do Green Products Make Us Better People?," Psychological Sciences, vol. 21, no. 4, pp. 494–498, Apr. 2010.

I conserve energy by…	Before		After			
	Mean	SD	Mean	SD	Sig. (1-tailed)	95% LCB
Turning off lights when not needed	4.692	0.471	4.769	0.429	0.064	0
Adjusting my thermostat when no one is in the home	4.615	0.496	4.692	0.471	0.063	0
Turning off electronics when not needed	4.423	0.857	4.577	0.703	0.021*	0.038
Conserving water	4.308	0.618	4.423	0.578	0.021*	0.038
Using more energy efficient transportation	3.962	1.038	4.153	1.047	0.098	-0.038
Shutting down the computer when not in use for several hours	3.885	1.336	4.038	1.148	0.202	-0.154
Buying local food	3.808	0.939	4.038	0.958	0.016*	0.038
Unplugging appliances/electronics when not in use (or shutting off the power strip)	3.615	1.267	4.038	1.0786	0.001**	0.192

*indicates significance at the .05 level
**indicates significance at the .01 level
LCB = Lower Confidence Bound

I have made attempts to reduce fossil fuel energy in my home, including…	Before Participating in Project	While Participating in Project	After Participating in Project	Have Not Made Change
Updating to more efficient lighting	74%	13%	10%	3%
Buying energy efficient appliances	74%	6%	3%	16%
Adding insulation and/or weather-stripping	71%	0%	6%	23%
Reducing heat transfer through existing windows	65%	6%	6%	23%
Replacing old windows with more energy efficient windows	60%	3%	10%	27%
Upgrading heating system to more energy efficient technology	57%	3%	13%	27%
Installing an programmable thermostat	57%	0%	10%	33%
Having an energy audit	48%	10%	10%	32%

General Assumptions

Symbol	Description	Units	Default Value
C_{INV}	Cost of inverter replacement	$	9.5% of C_{SYS}[1]
d	Annual system degradation	%	0.50%[2]
None	Annual electricity price escalation	%	1.6%[3]
P_{REC}	REC price in year t	$/MWh	$40
r	Discount Rate	%	5%
T	System lifetime	years	25 years

1. Swift and Kenton, 2012
2. SAM
3. Energy Information Administration

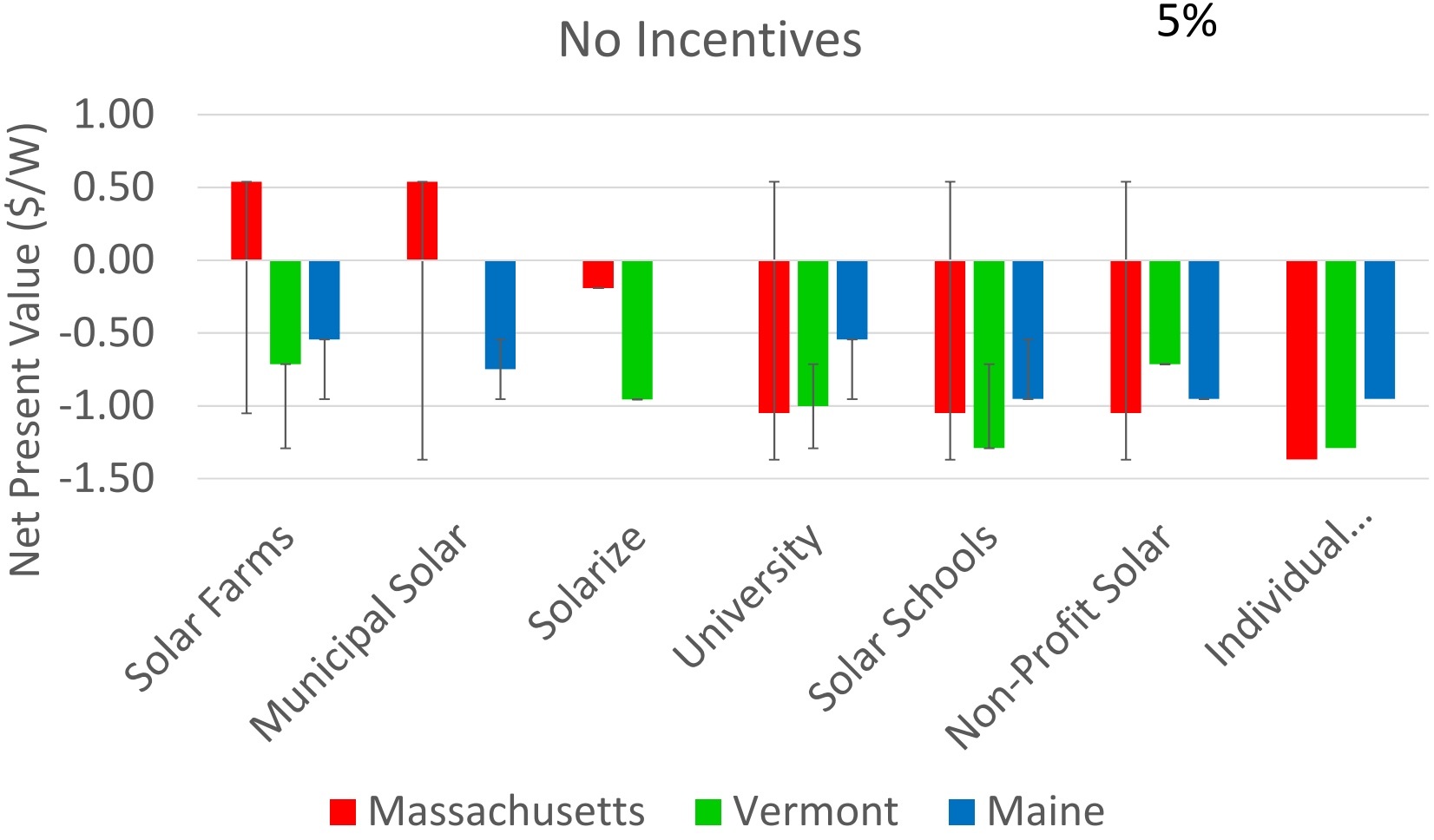
Capacity Factor

System Capacity * 8760 hours/year * Capacity Factor = Annual Production

Example: 10 kW * 8760 hours/year * .136 = 11,914 kWh/year

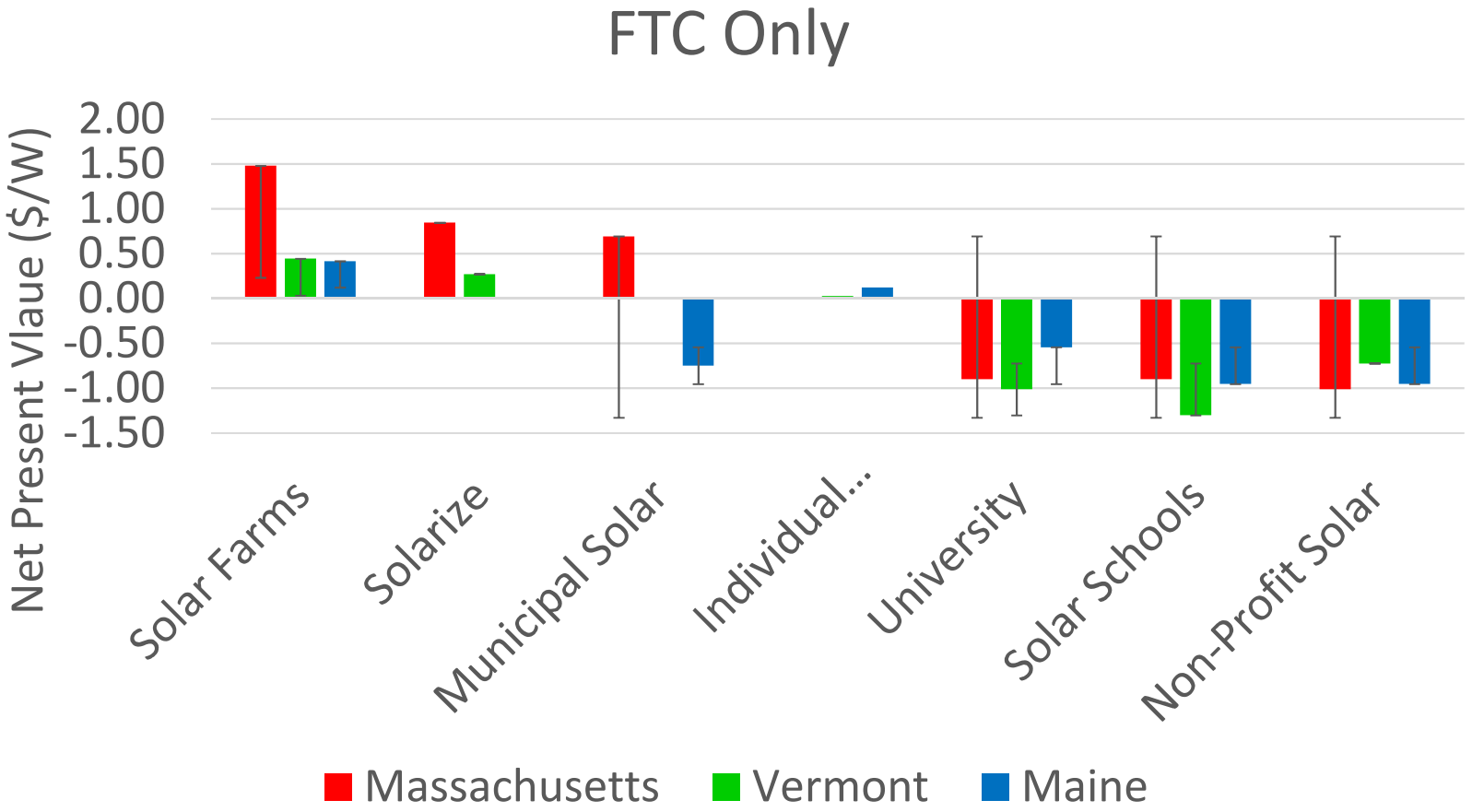
Results: NPV at 25 Years

Discount rate = 5%

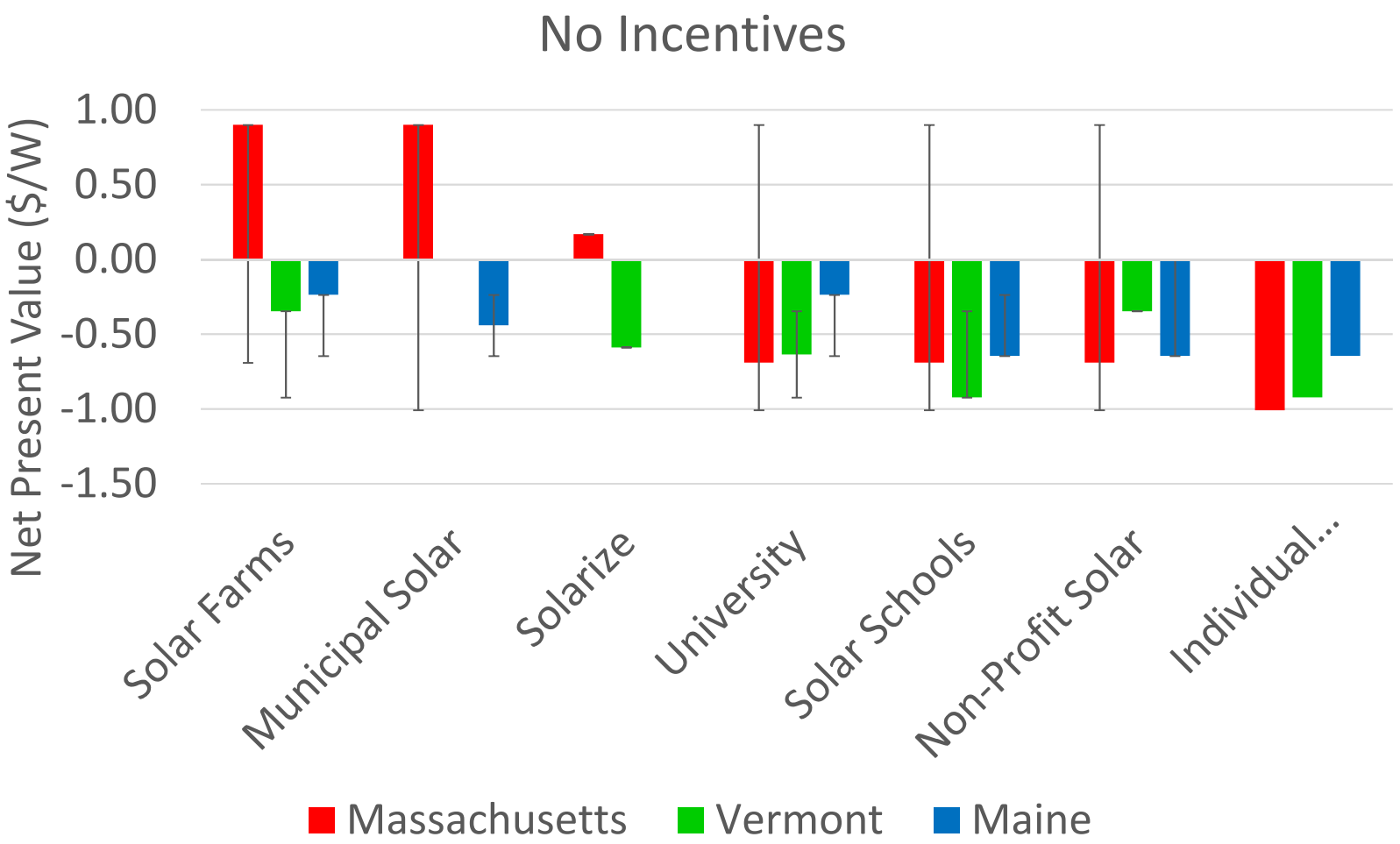


Results: NPV at 25 Years

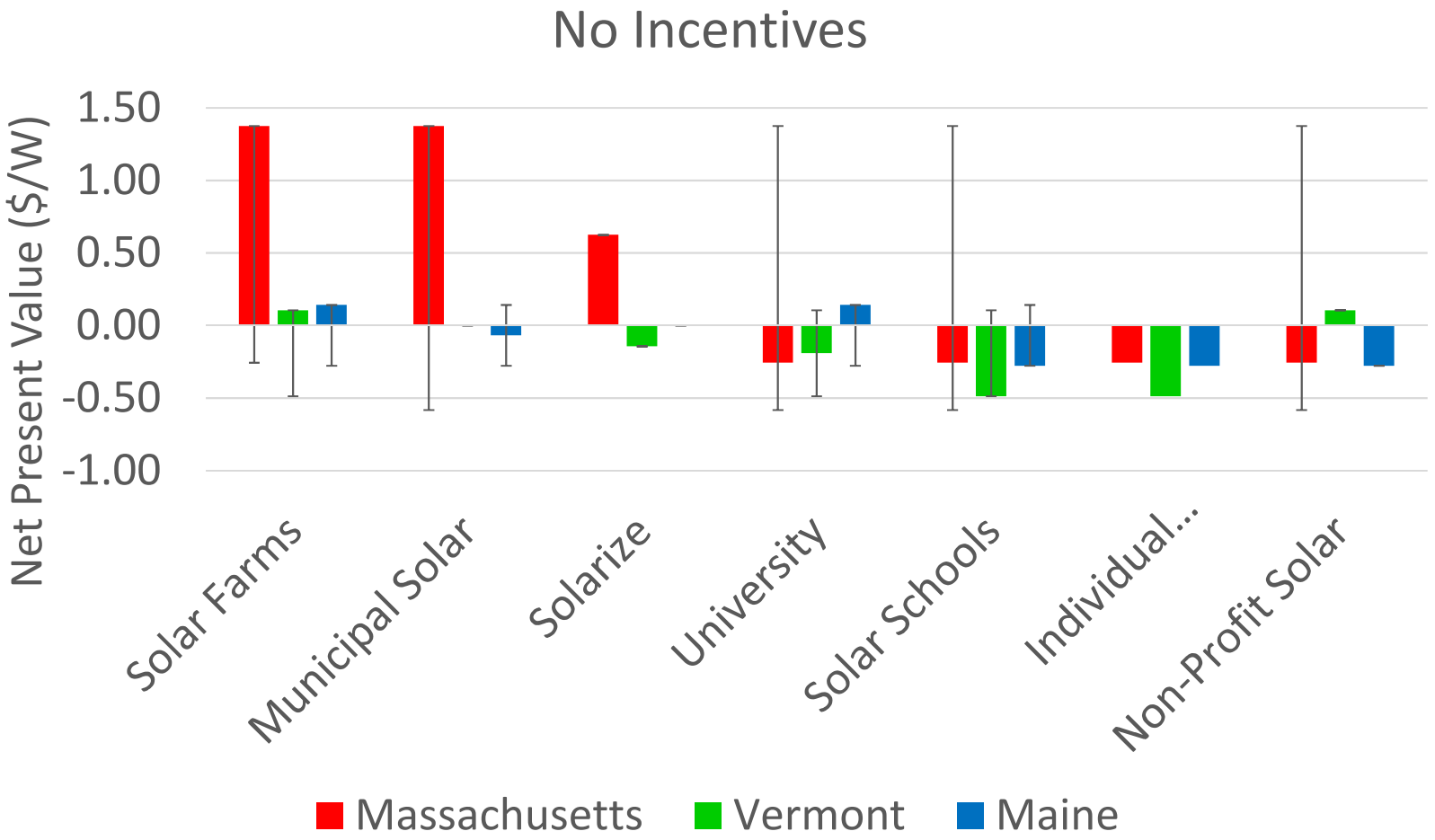
Discount rate = 5%



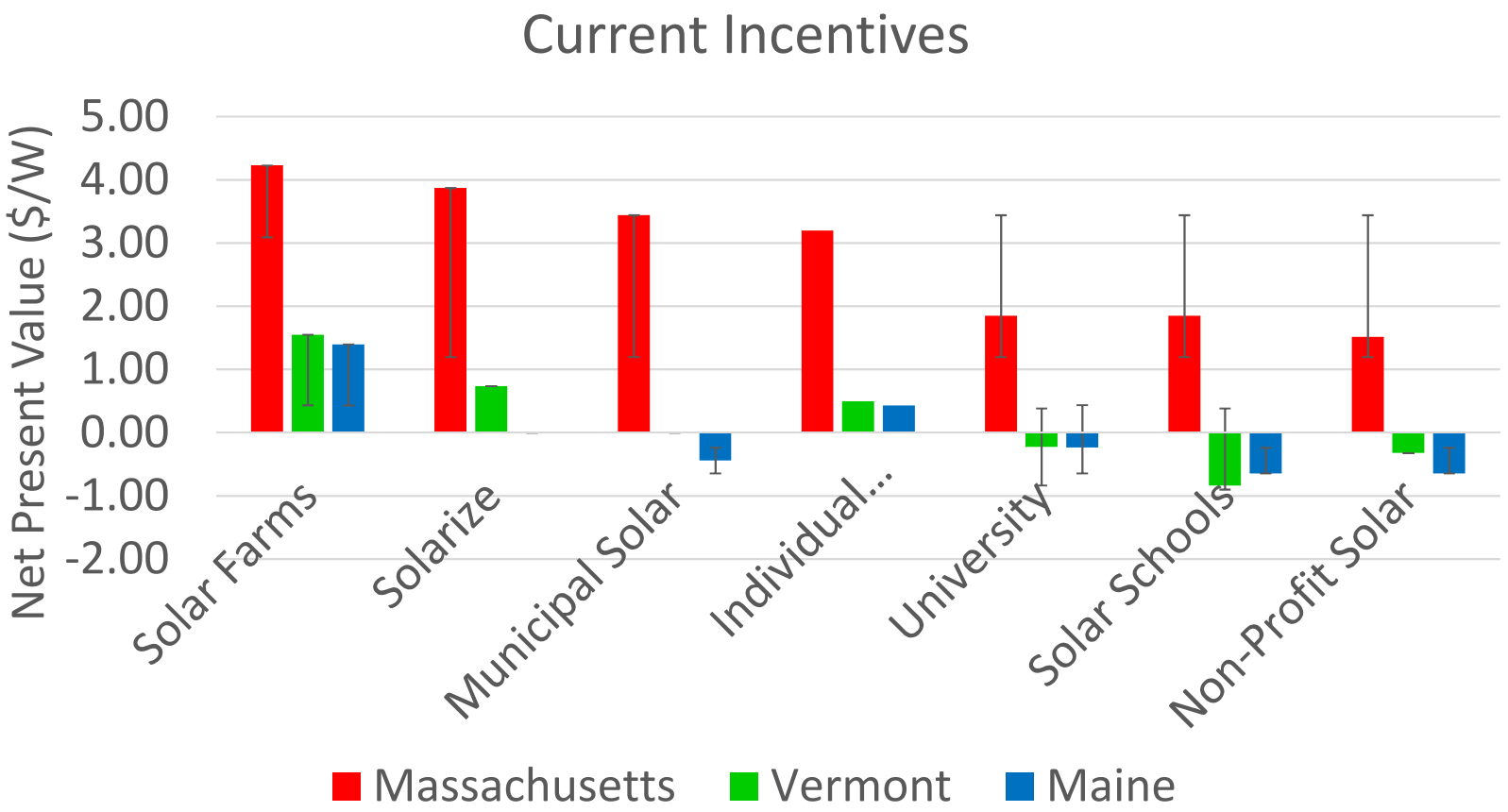
NPV at 30 Years: No Incentives



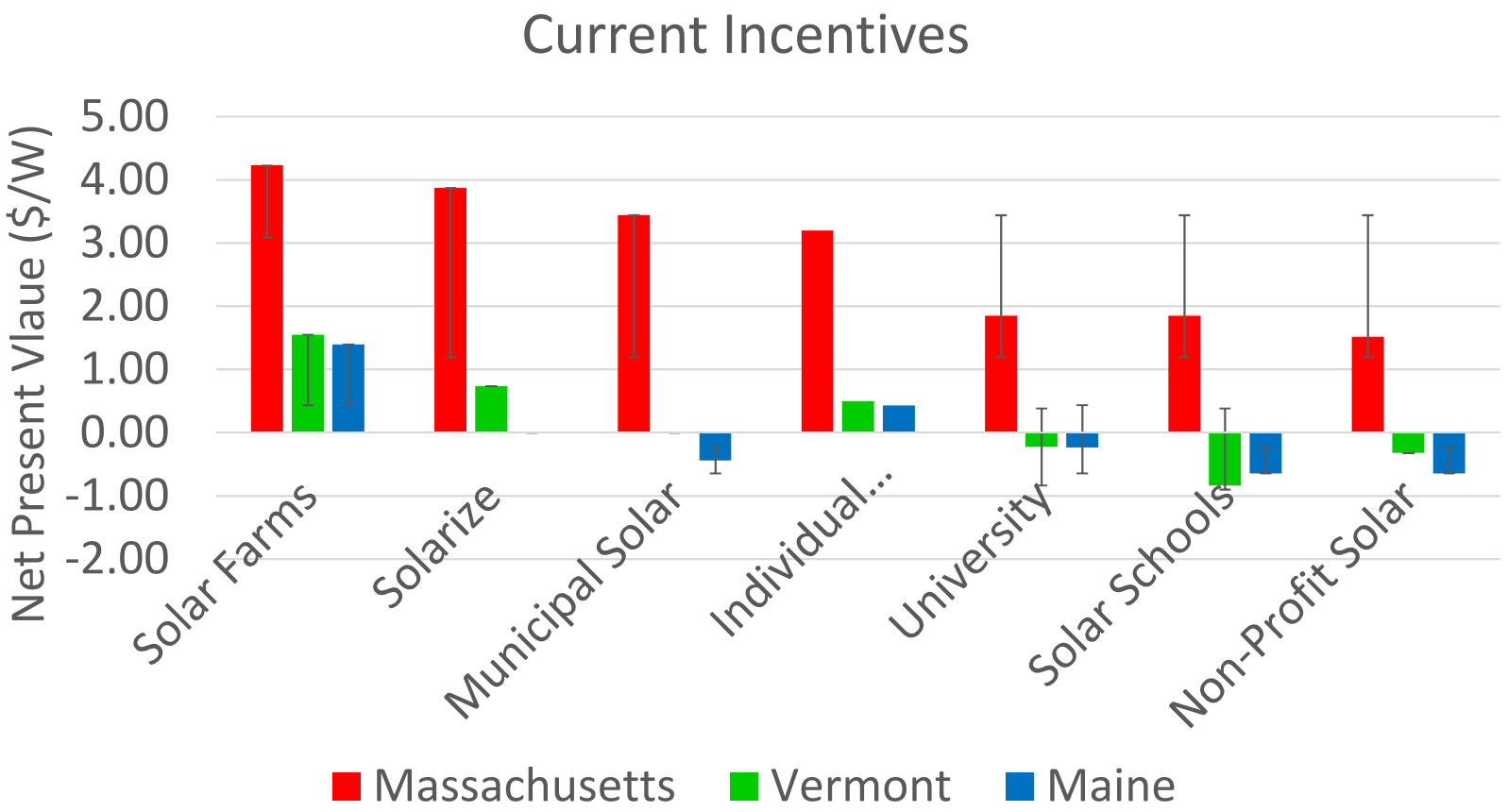
NPV at 40 Years: No Incentives



NPV at 30 Years: Current Incentives



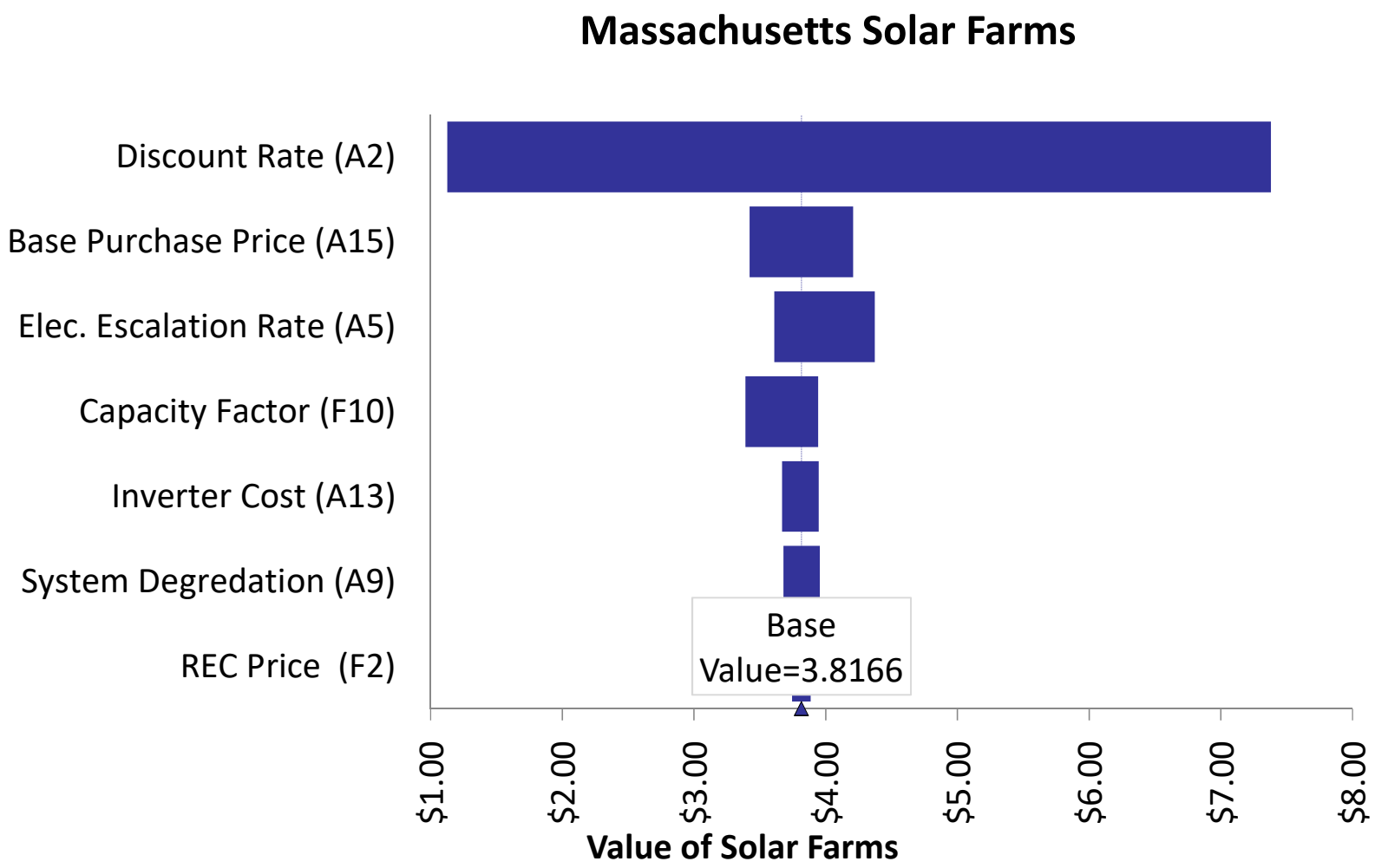
NPV at 40 Years: Current Incentives



Varied Inputs for Sensitivity Analysis

Symbol	Description	Units	Minimum	Nominal	Maximum
a	Elec. Escalation	%	1%	1.6%	3%
CF	Capacity Factor	%	12.6%	13.6%	14.9%
C_{INV}	Inverter Cost	% of system cost	0%	9.5%	20%
C_{WATT}	Base Purchase Price	$/W	3.55	4.44	5.33
d	System Degradation	%	0.2%	0.5%	0.8%
None	Capacity for price decrease	kW	10	25	50
None	Capacity for RECs	kW	25	50	75
None	Solarize Discount	%	15.0%	25.2%	40.0%
P_{REC}	REC Price	$/MWh	30	40	50
r	Discount Rate	%	0%	5%	15%

Sensitivity Analysis (Current Incentives)

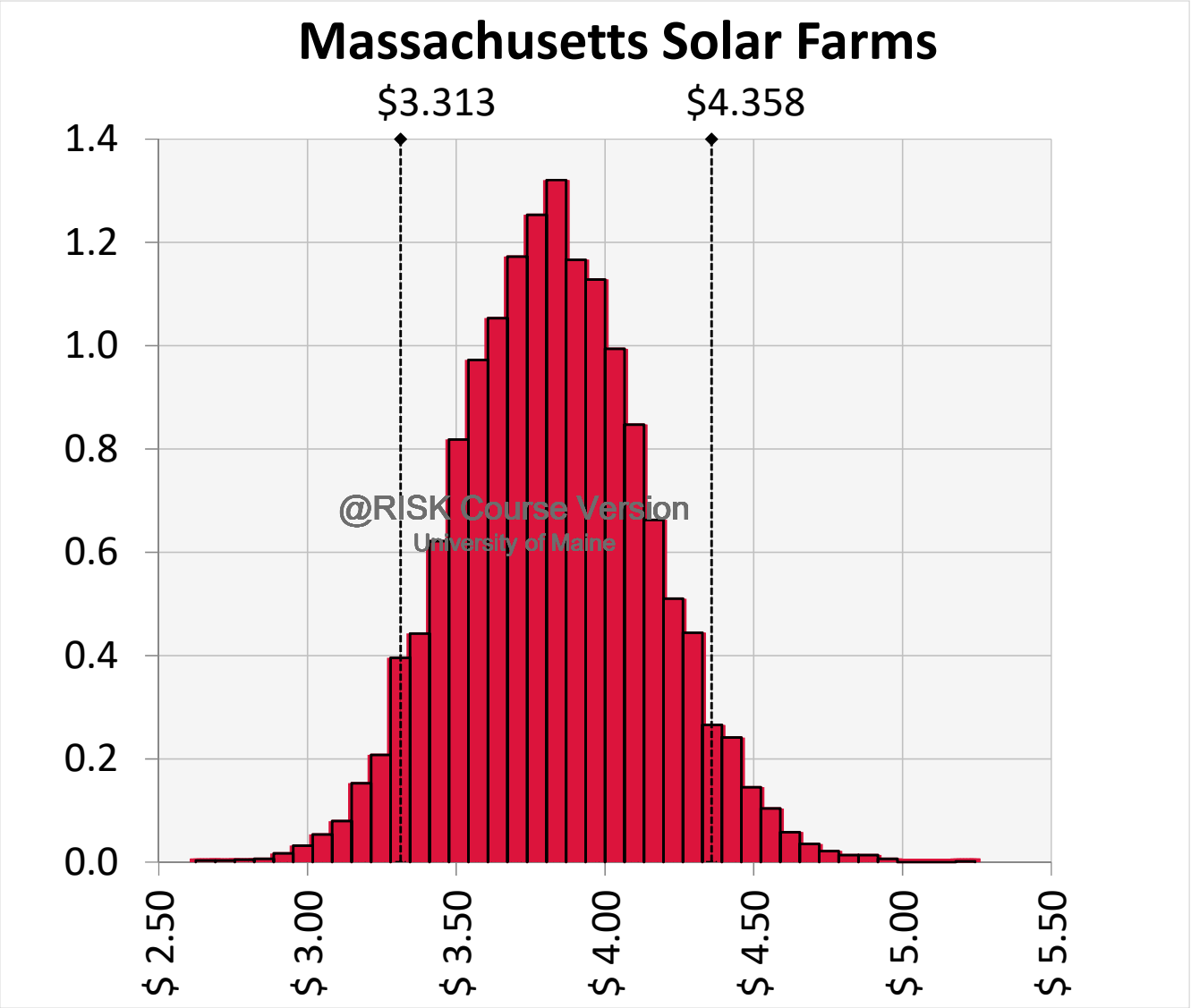


Monte Carlo Simulation (Current Incentives)

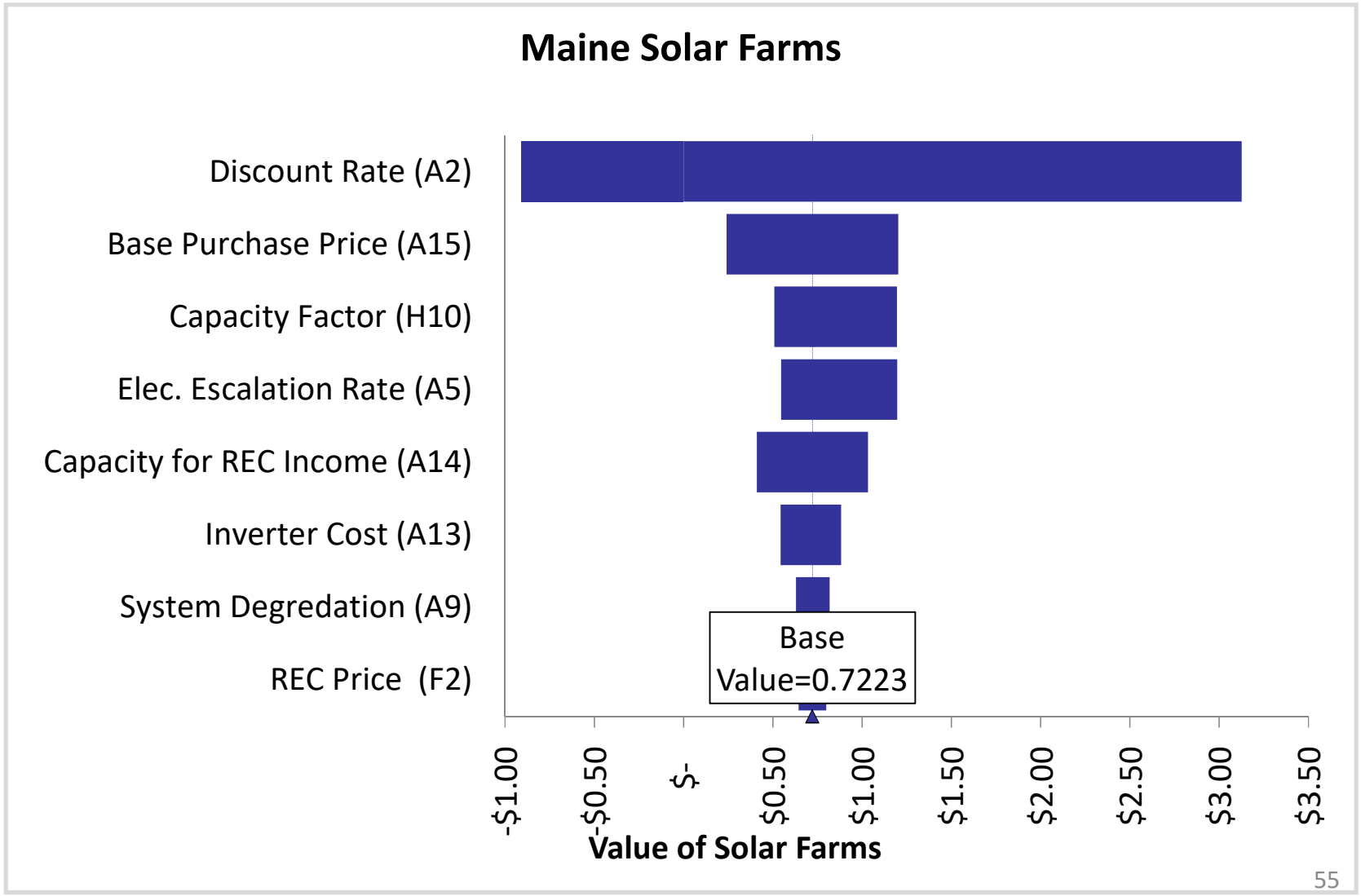
Discount Rate

Purchase Price

Elec. Escalation Rate



Sensitivity Analysis (Current Incentives)

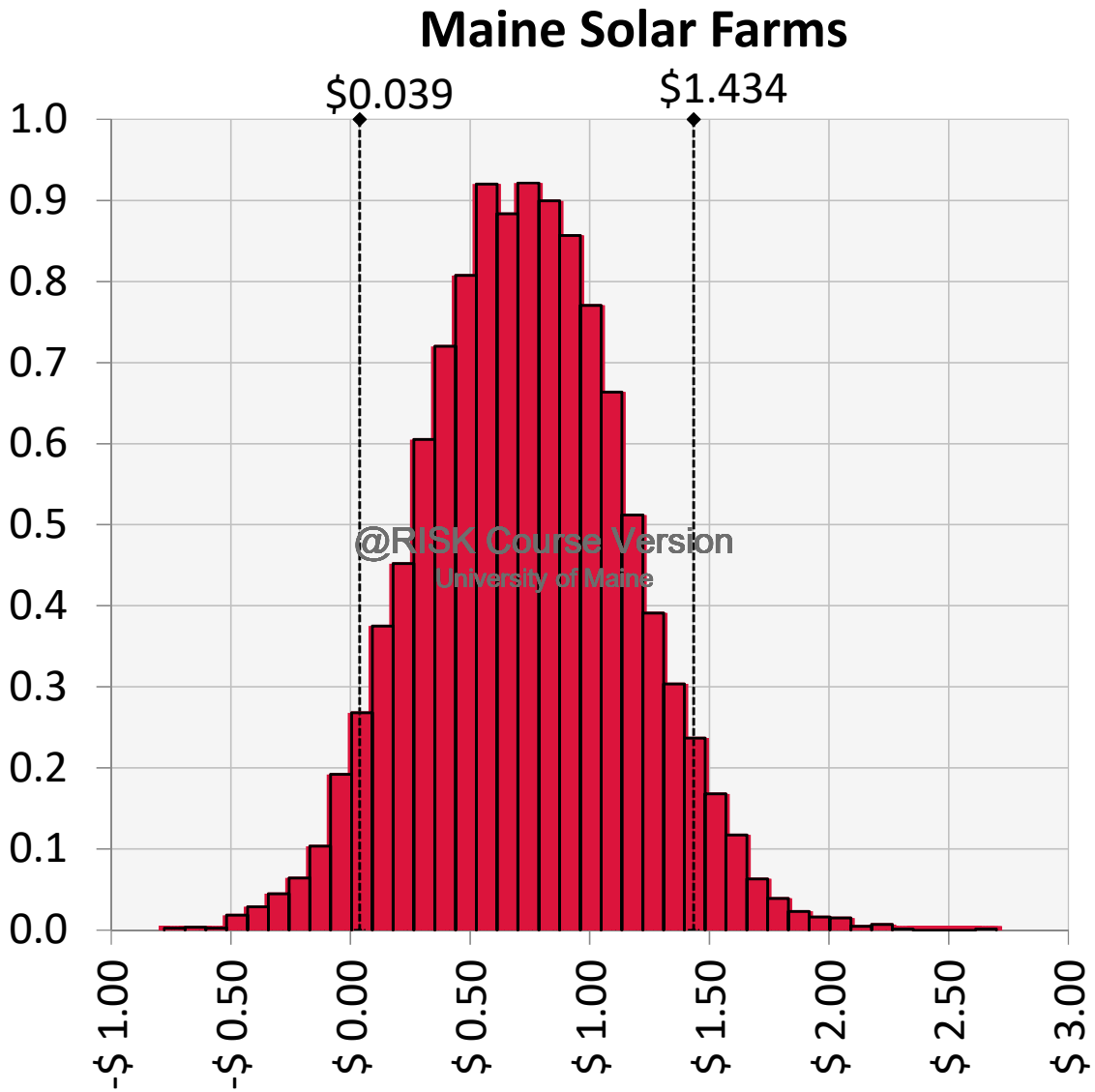


Monte Carlo Simulation (Current Incentives)

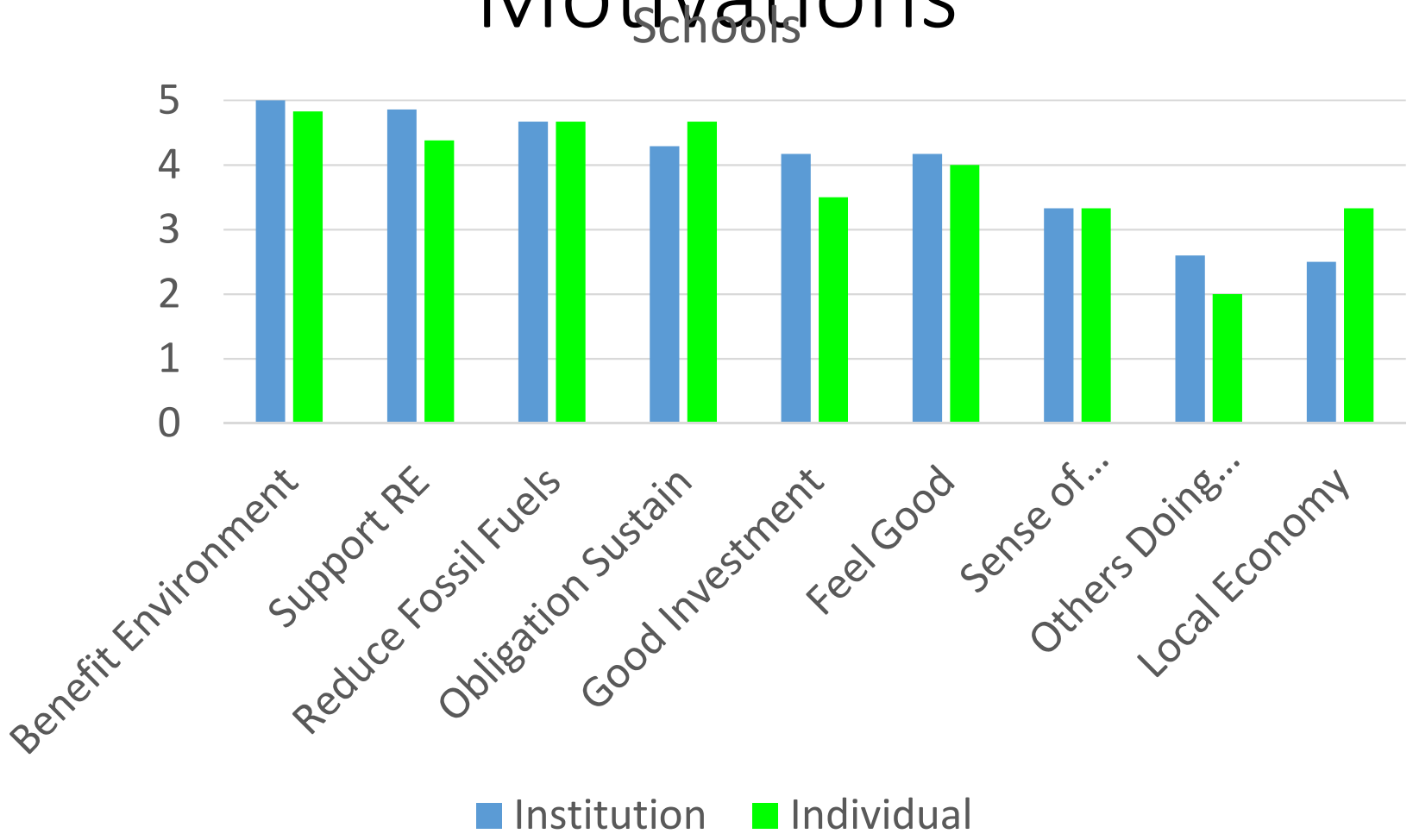
Discount Rate

Purchase Price

Capacity Factor

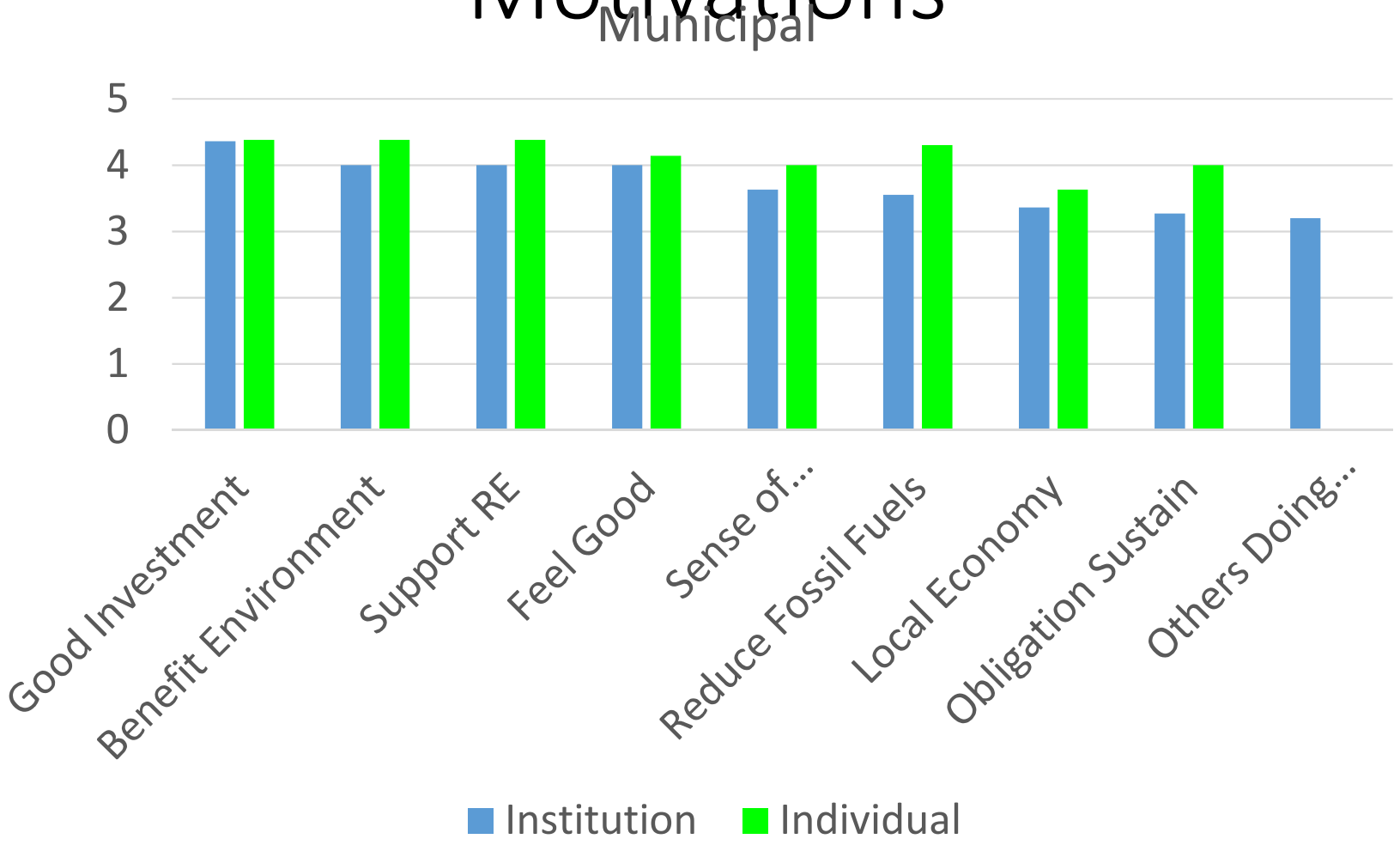


Individual vs. Institutional Motivations



1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree

Individual vs. Institutional Motivations



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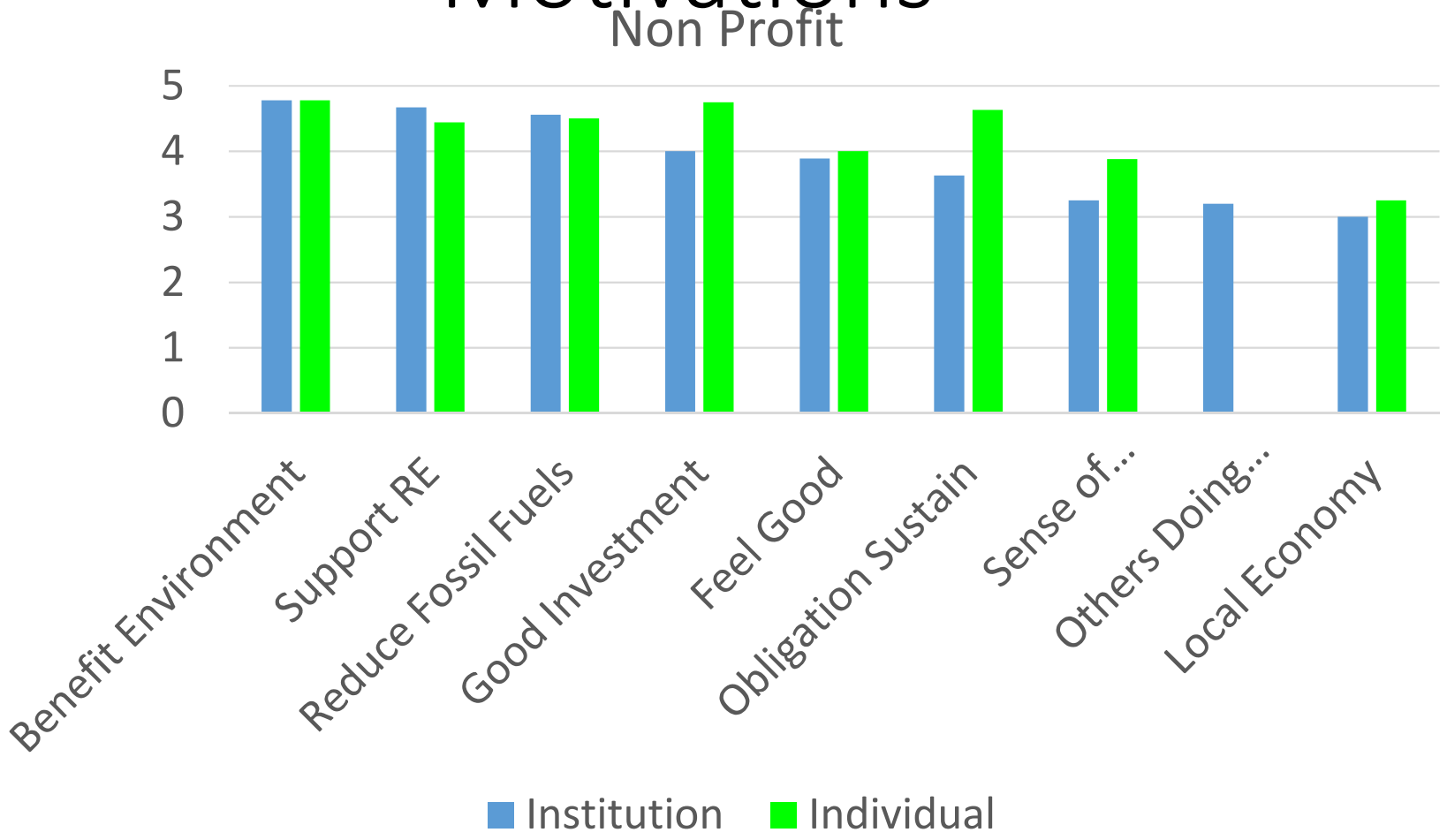
Individual vs. Institutional Motivations



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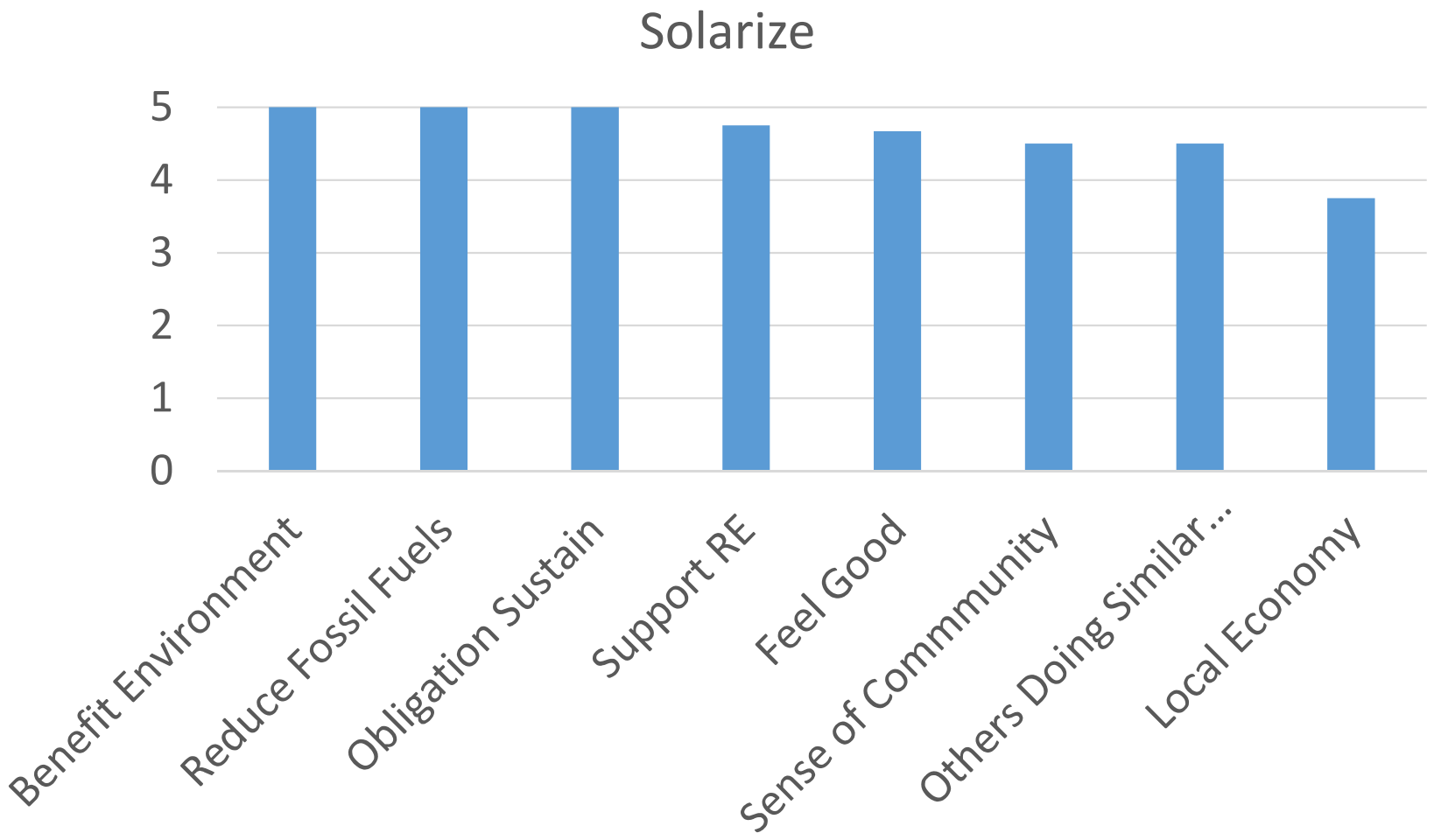
Individual Motivations



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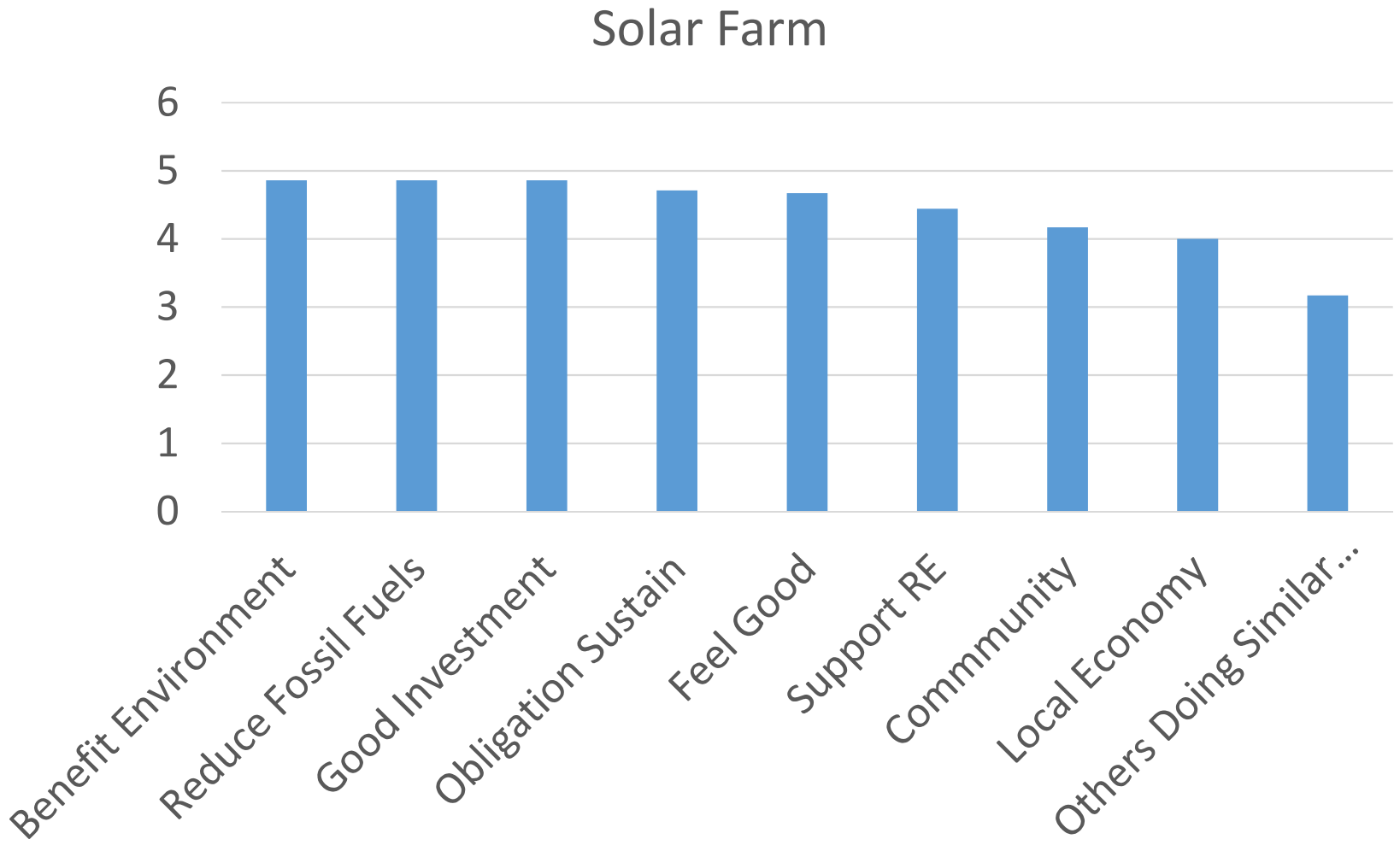
Individual Motivations



1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree

How are they doing it? (Organizational structures)

Grassroots (bottom-up) community-engagement

"I attended Midcoast Green Collaborative meetings for several months. Discussion turned to formation of a community solar farm for those of us whose properties are not suitable for solar panel installation. I continued to meet with the group that formed around that topic and decided to join in and become a solar farmer. At one of the organizational meetings I agreed to become an officer (Secretary) of the association that was formed to operate this particular community solar farm"

Vermont

How are they doing it? (Organizational structures)

Grassroots (bottom-up) community engagement

"Stated interest to follow-up recommendations in "The Inconvenient Truth" and solicited others in the congregation to come together to discuss, assigned individuals fact-finding responsibilites on hardware, vendors, contractors, state policy, etc. Eventually combined information and had a financial professional design a comparative spreadsheet to evaluate bids."

CSI – Non-profit

How are they doing it? (Organizational structures)

Top-down, Existing business

"I conceived of this model of Community Solar in which participants own panels in the field . I leased the field, my company built the project and sold the panels"

Solar farm

Vermont

How are they doing it? (Organizational structures)

Top-down, Existing organization

"My role was to follow up on the initial lead from the minister; see if the appopriate committee wanted to proceed; administer the project and determine costs and options; tee it up for a church vote; negotiate the contract and oversee installation" **CSI Non-profit, MA**

"Our Head of School took on this project and initiated it. I was involved in the scheduling of the contractor, meter installment from State and payment. " **CSI School, VT**