Demand subsidies vs. R&D:

Comparing the uncertain impacts of policy on a pre-commercial low-carbon energy technology

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Motivation

1. Technology Policy:

Technology Push

↓ *costs of innovation*

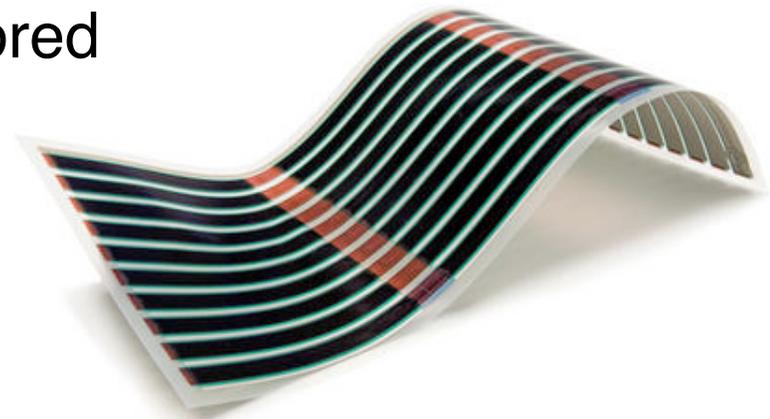| Demand pull |
|---|

↑ *payoffs to innovation*

- Large public funds at stake
- Allocation, Timing

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2. Pre-commercial technologies
difficult to model, often ignored
possible large impacts

Purely organic PV
- low cost, organic material
- scalable manf. process
- building integration

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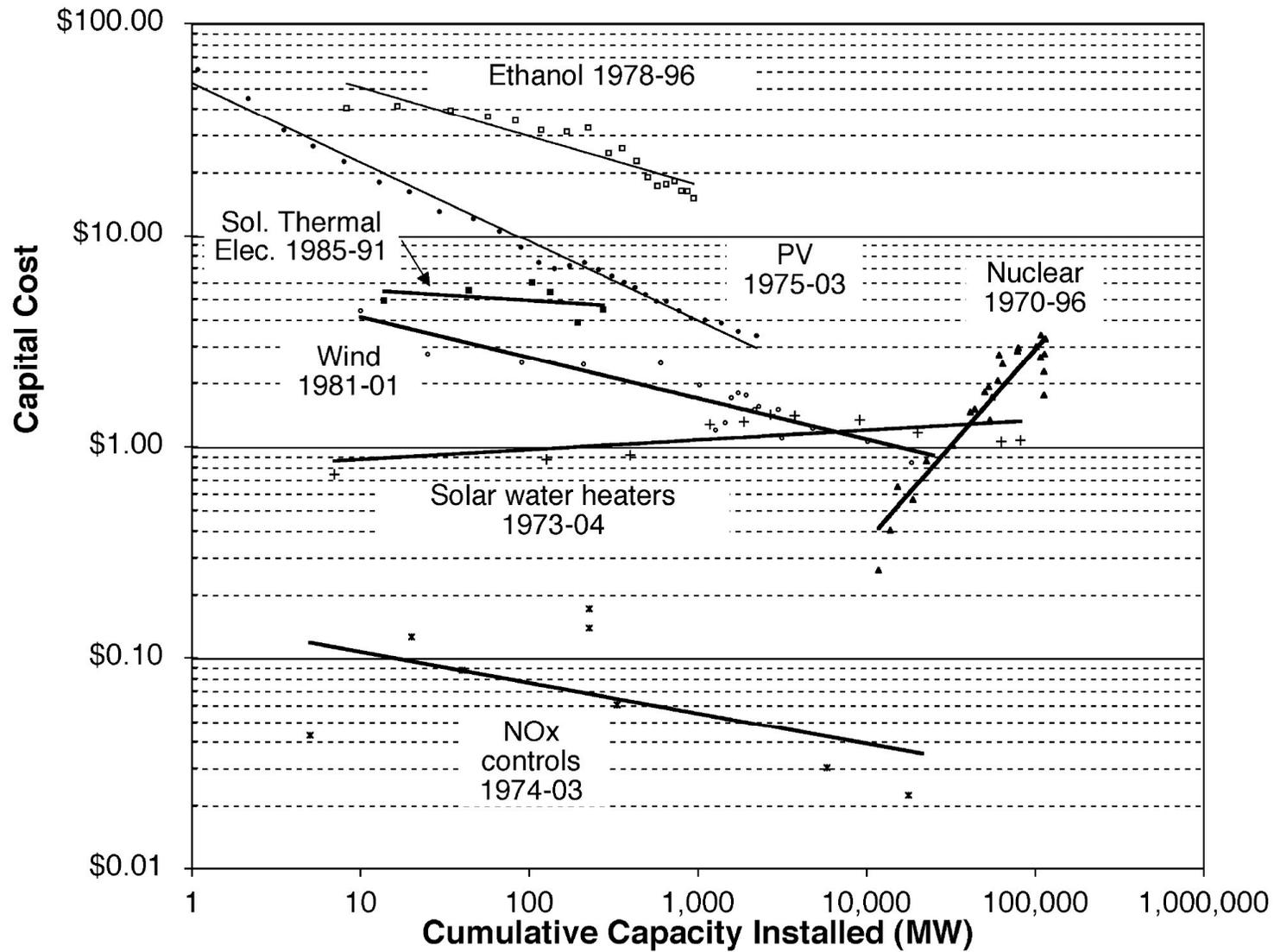# "Technology push" and "demand pull"

Technology Push: govt actions that reduce the **cost** of innovation to private actors

Demand Pull: govt actions that increase the **payoff** to successful innovation for private actors

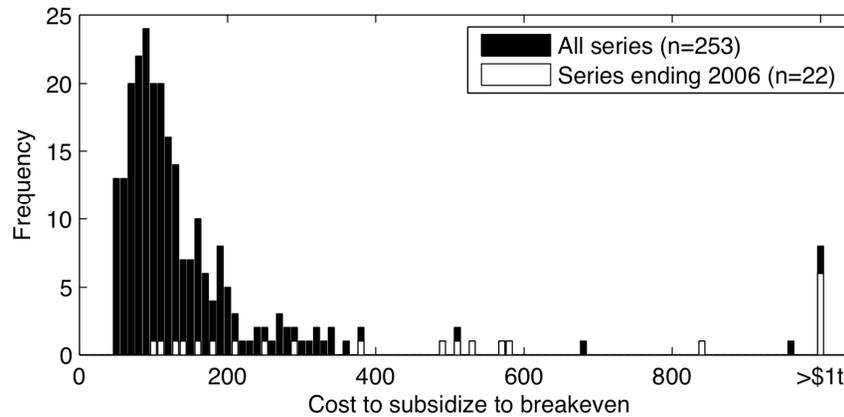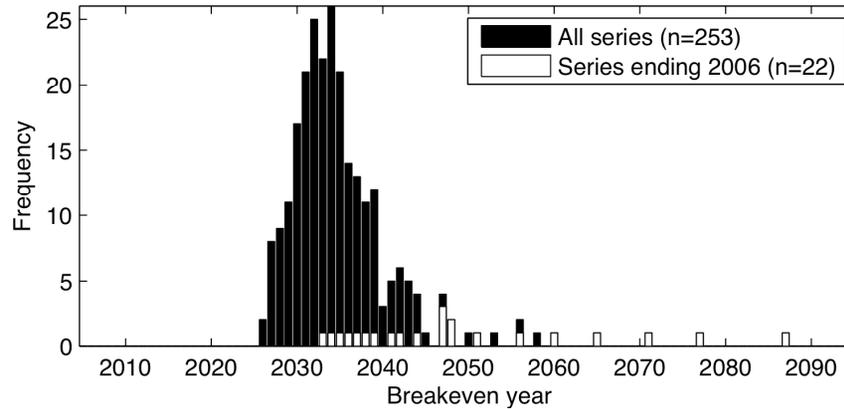|	**Technology push**	**Demand pull**
Govt Target:	↑ availability of knowledge	↑ size of market
Examples:	govt R&D, tax credits, education, demonstration projects, knowledge networks	IPR, tax credits, govt procurement, technology mandates, standards, taxes on substitutes

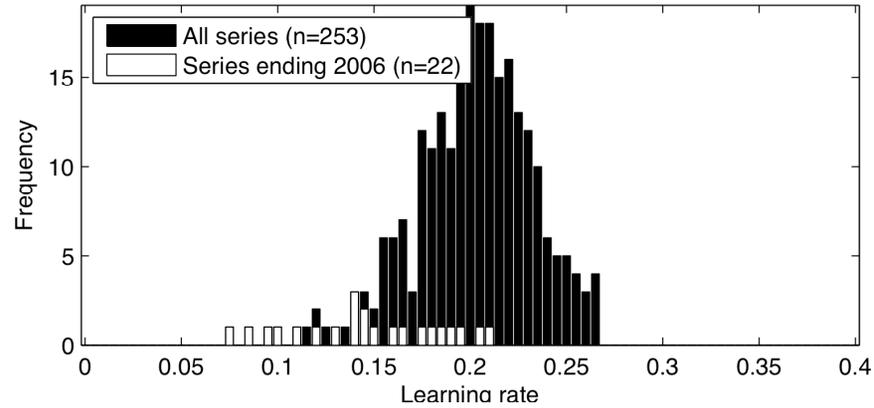Consensus: *both necessary, neither sufficient*
But how to allocate?

Source: Nemet (2007)

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Calculating subsidy program costs

Learning rate — All series (n=253); Series ending 2006 (n=22)

Breakeven year — All series (n=253); Series ending 2006 (n=22)

Large dispersion In program costs

Cost to subsidize to breakeven — All series (n=253); Series ending 2006 (n=22)

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Technological generations
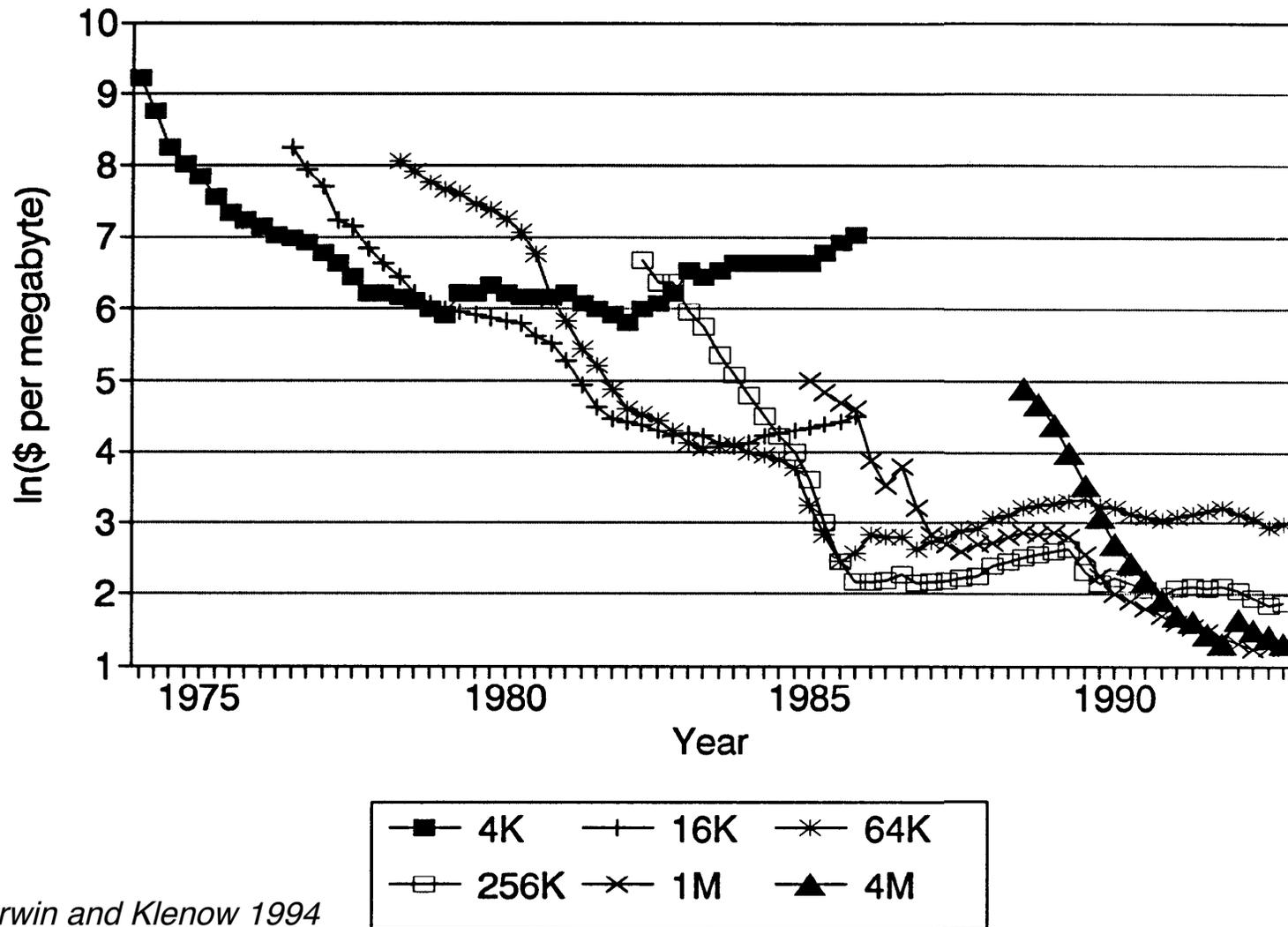
FIG. 1.—DRAM prices (source: Dataquest)

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Cost of electricity from photovoltaics 1957--2003

Source: Nemet (2006)

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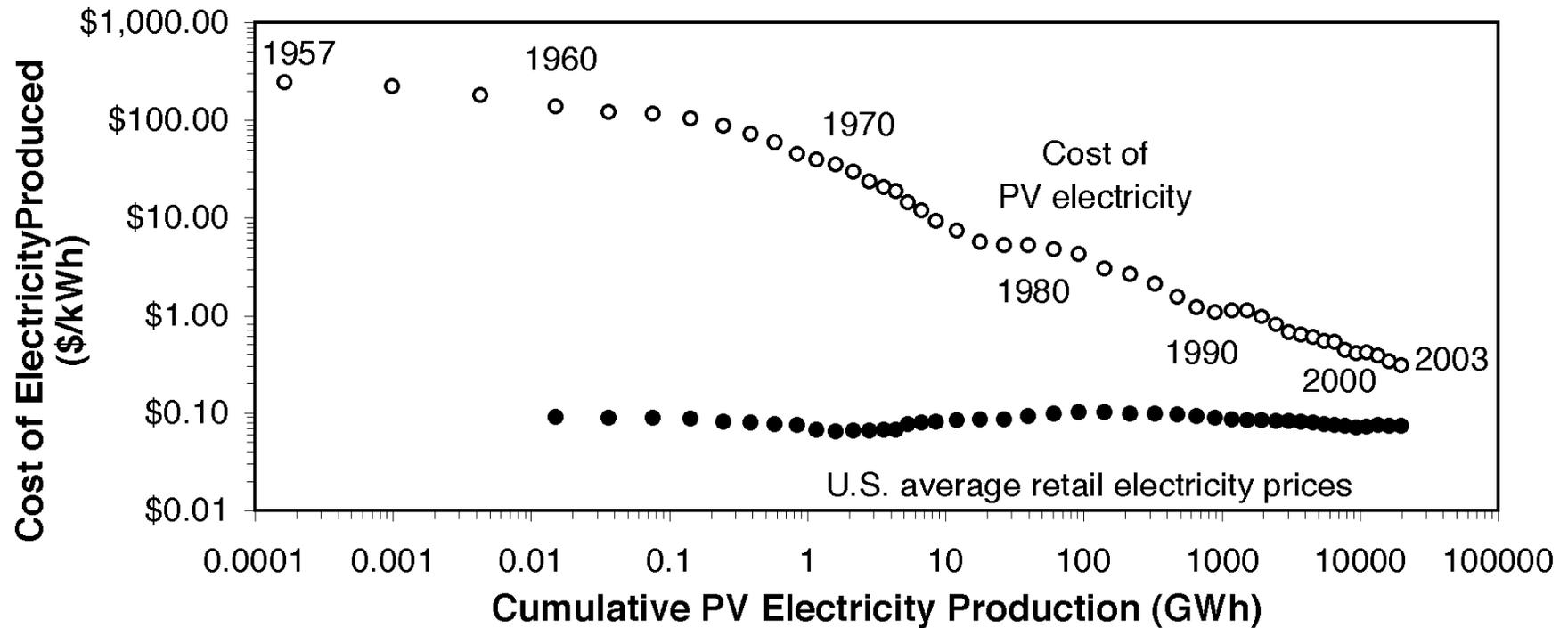
Price of PV modules

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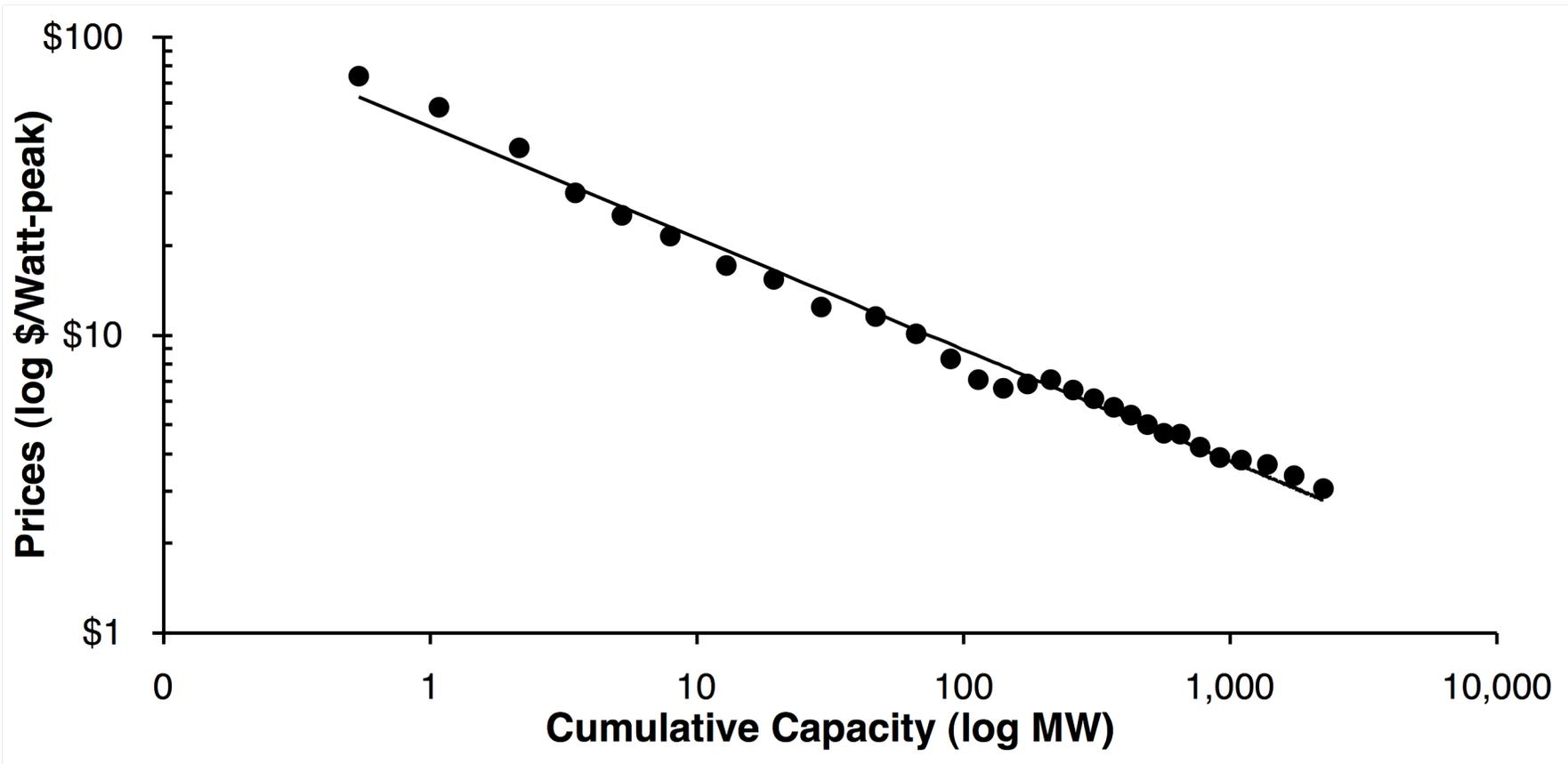
Sources of historical cost reductions for PV

85% of cost reduction due to R&D and expected demand
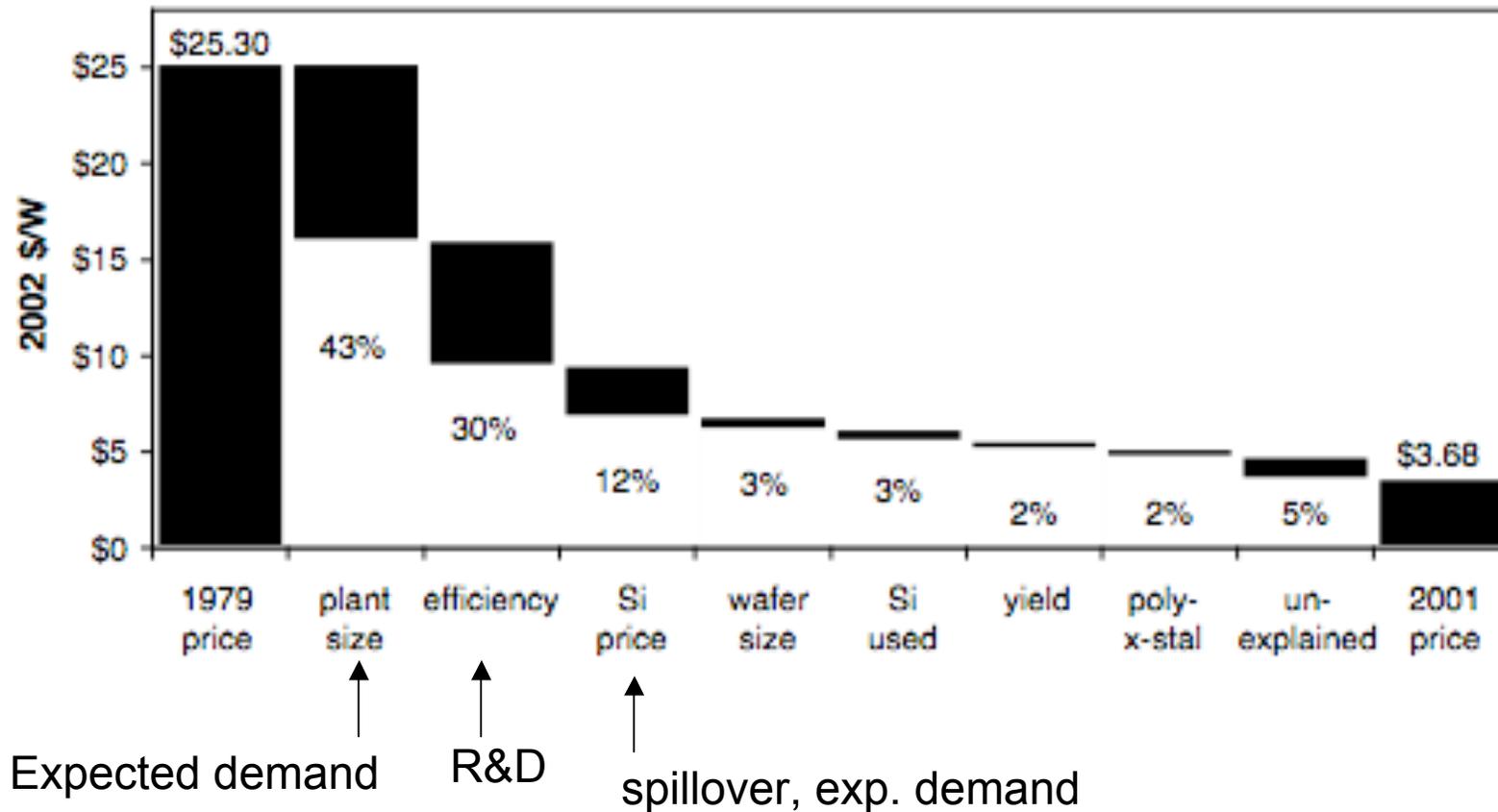
Expected demand   R&D   spillover, exp. demand

Source: Nemet (2006)

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Approach

*How best to choose **level** and **timing** of*
*__R&D__ and **subsidies** to achieve cost target?*

target:
4c
/kWh
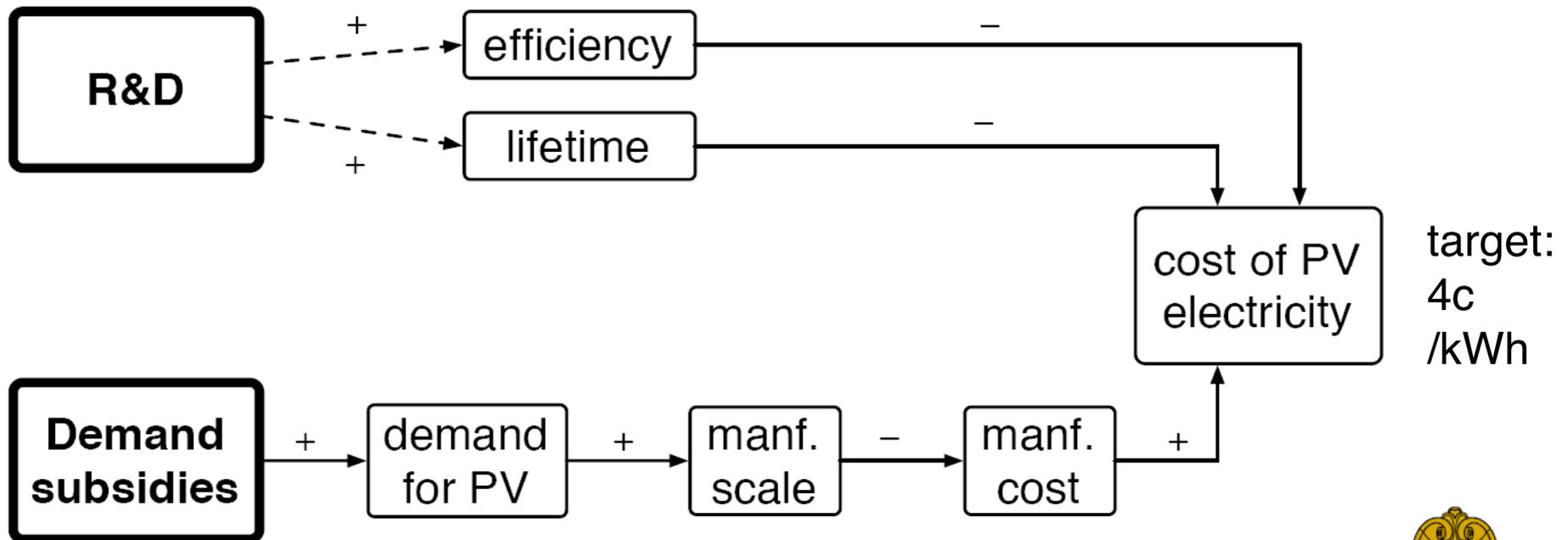
Effect of technical improvements and manufacturing cost on
Levelized Cost of PV Electricity ($/kWh)

Tech improvements

Lifetime:	5y	30y	15y
Efficiency:	5%	15%	31%
Manf. cost			
$100/m^2	0.61	0.08	0.04
$50/m^2	0.43	0.06	0.03
$25/m^2	0.35	0.05	0.03

Manf. cost

How to estimate effects of subsidies and R&D?

Manufacturing costs

Cost component	Costs ($/m^2)	Portion of total	Unit cost f(output)	b value
Materials	28.15	37%	Declining	0.2
Processes (labor costs)	8.00	11%	Declining	0.2
Processes (capital costs)	23.50	31%	Declining	0.2
Overhead (fixed)	8.18	11%	Declining	0.2
Overhead (variable)	8.18	11%	Static	0
Total	76.00			

Source: Kalowekamo (2007)

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R&D productivity: expert elicitations

Technical outcomes

Lifetime:	5y	30y	15y
Efficiency:	5%	15%	31%
No R&D	100%	0%	0%
Low R&D	63%	37%	0%
High R&D	42%	39%	19%

R&D investment

Source: Baker (2007)

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Calculating levelized costs

Manf costs $/m2

$$M_t = \sum_{i=1}^{5} m_{i,t-5} \cdot \left(\frac{k_t}{k_{t-5}} \right)^{b_i}$$

- Learning by doing
- Returns to Scale
- b = -0.20

scale

Cap. costs $/W

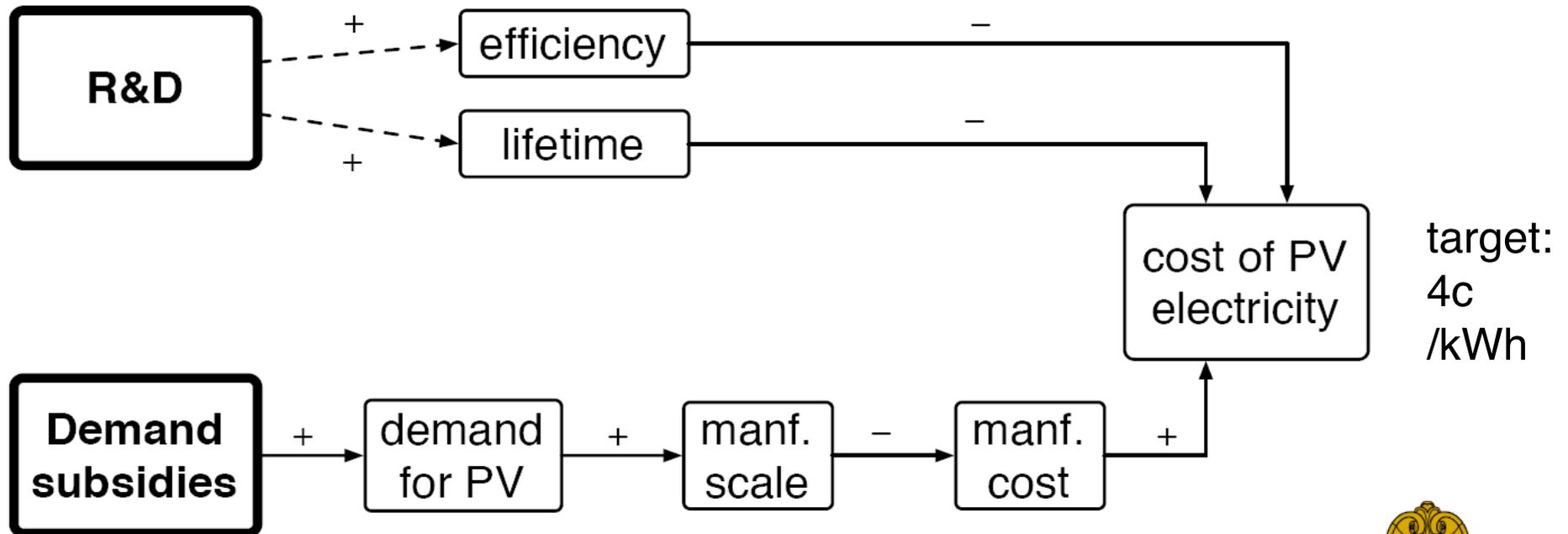$$C_p = \frac{\frac{M}{Y} + BOS}{S \cdot \eta}$$

R&D:
- efficiency
- lifetime

Levelized costs $/kWh

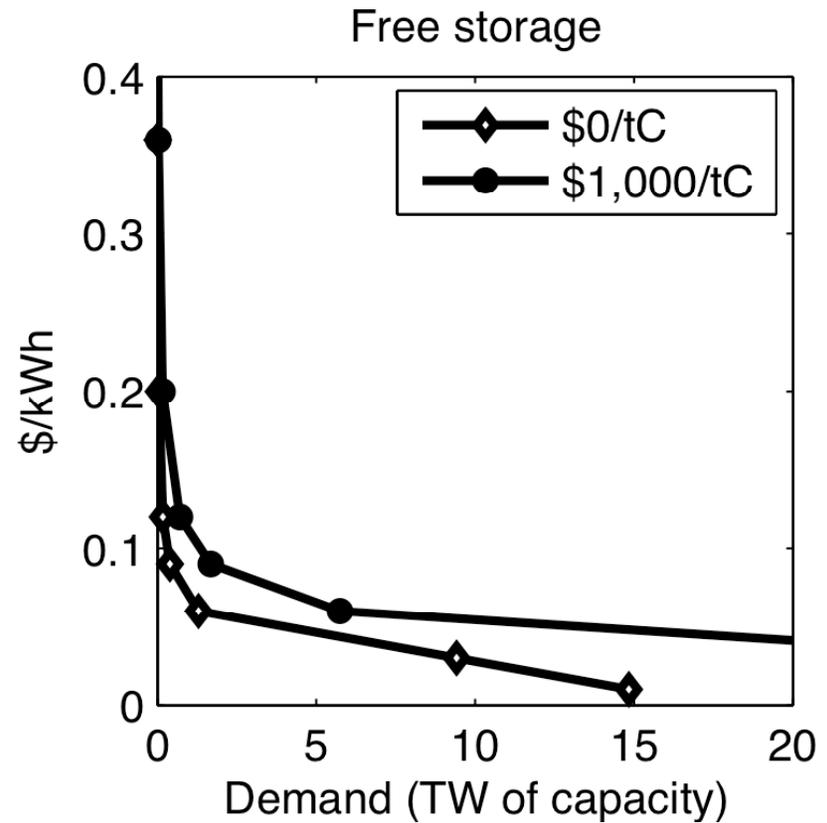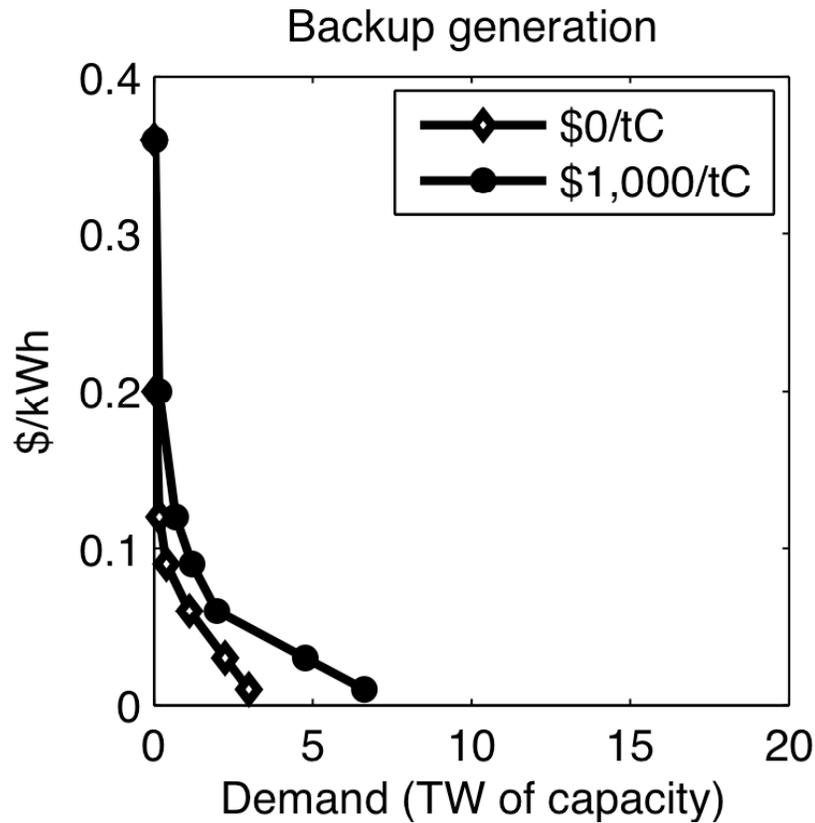$$C = \frac{C_p}{F \cdot h} \cdot \frac{\delta}{\left(1 - (1+\delta)^{-L}\right)}$$

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Approach

*How best to choose **level** and **timing** of*
***R&D** and **subsidies** to achieve cost target?*

3 levels of each

DEMAND CURVES

Backup generation · Free storage

Source: MiniCAM

RESULTS: PV Lev. costs ($/kWh)

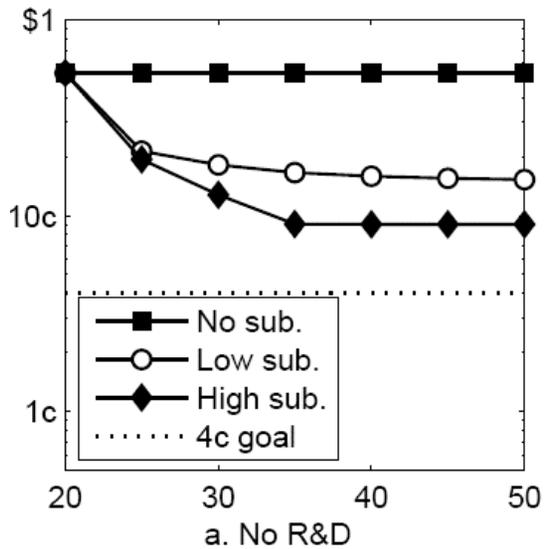|		Subsidy		
		None	Low	High
2040				
	None	0.536	0.201	0.162
R&D	Low	0.111	0.042	0.035
	High	0.087	0.033	0.028
2050				
	None	0.536	0.200	0.162
R&D	Low	0.014	0.016	0.016
	High	0.009	0.010	0.010

RESULTS: PV Lev. costs ($/kWh)
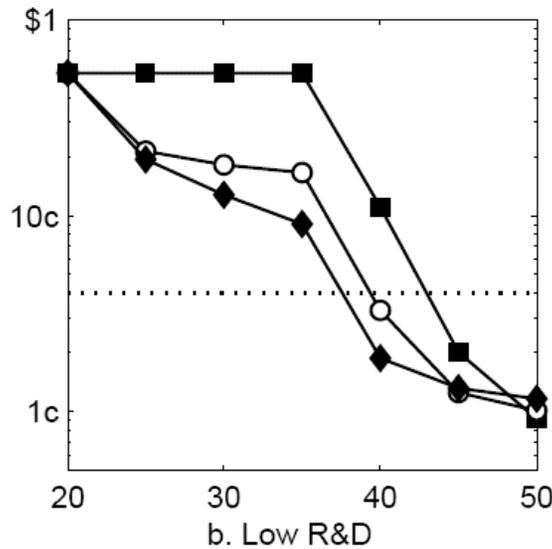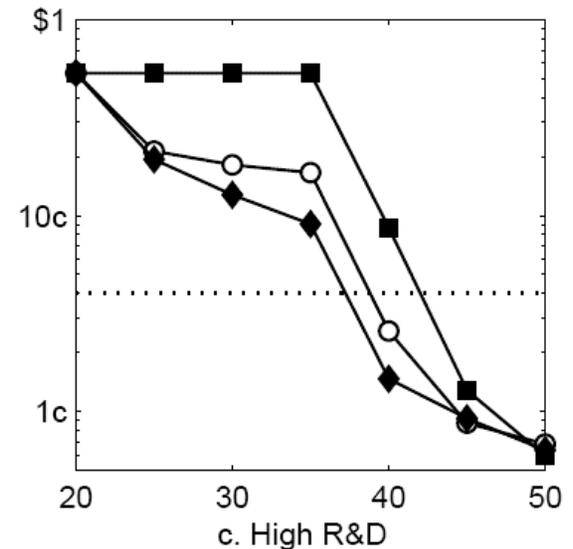## Impact of subsidies under 3 technical outcomes

5% efficiency

5 year lifetime

15% efficiency

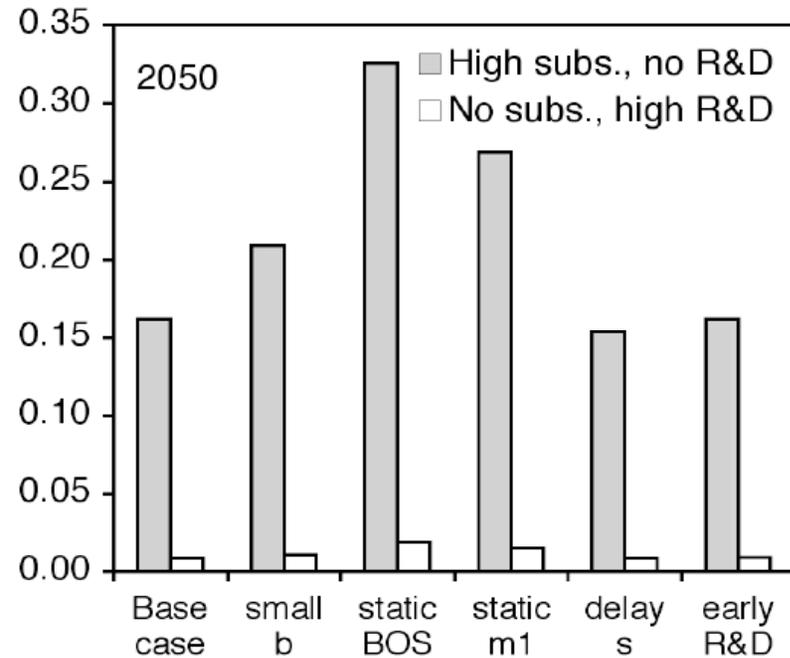30 year lifetime

31% efficiency

15 year lifetime
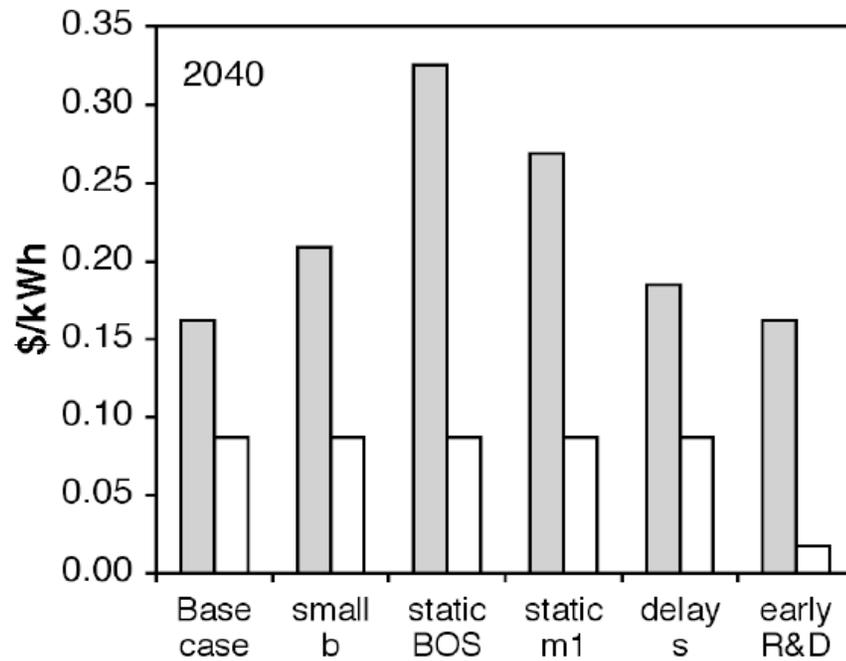
20% Capacity limit; no carbon tax; no CCS; advanced nuclear

SENSITIVITY of effectiveness of R&D and subsidies to assumptions

- Subsidies never close to effects of successful R&D
- Similar w/ carbon prices, free storage
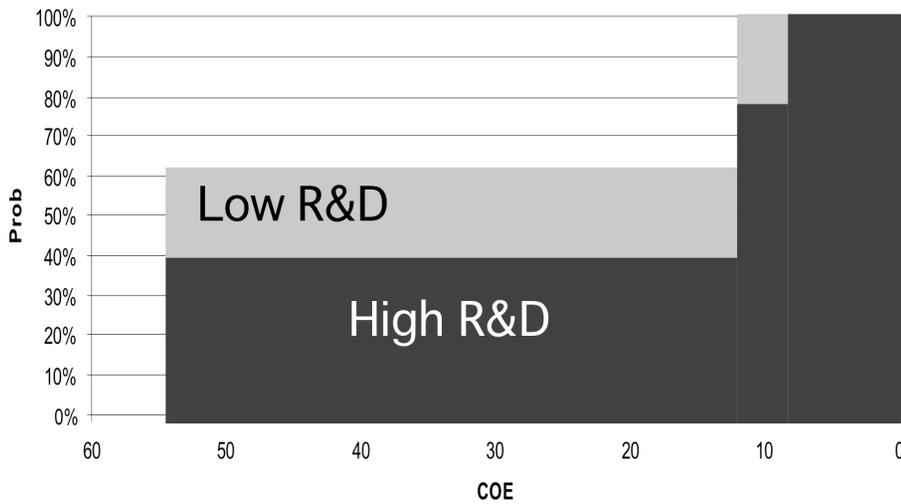
STORAGE AND CARBON PRICES

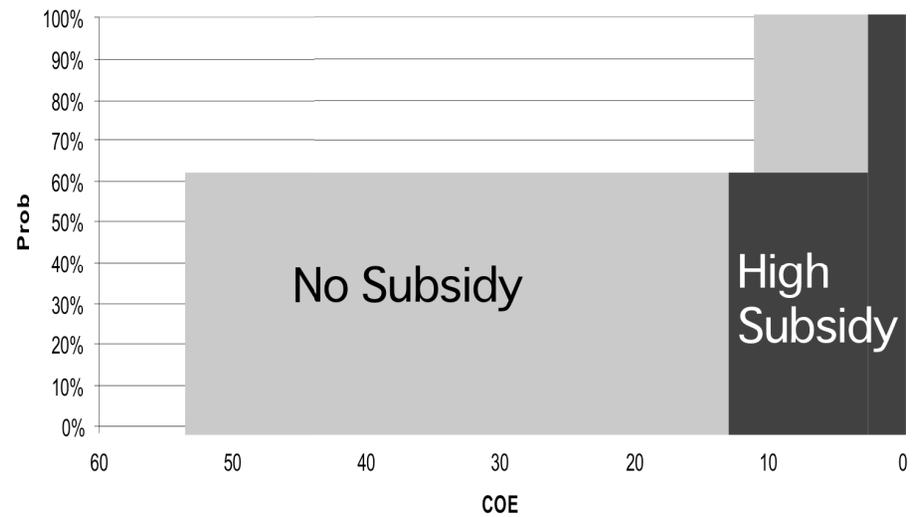|	Carbon price	Storage availability	
		Backup generation	Free storage
2040			
	$0/ton	0.035	0.035
	$1000/ton	0.026	0.019
2050			
	$0/ton	0.016	0.012
	$1000/ton	0.015	0.012

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STOCHASTIC DOMINANCE

Probability that COE will be at least as high
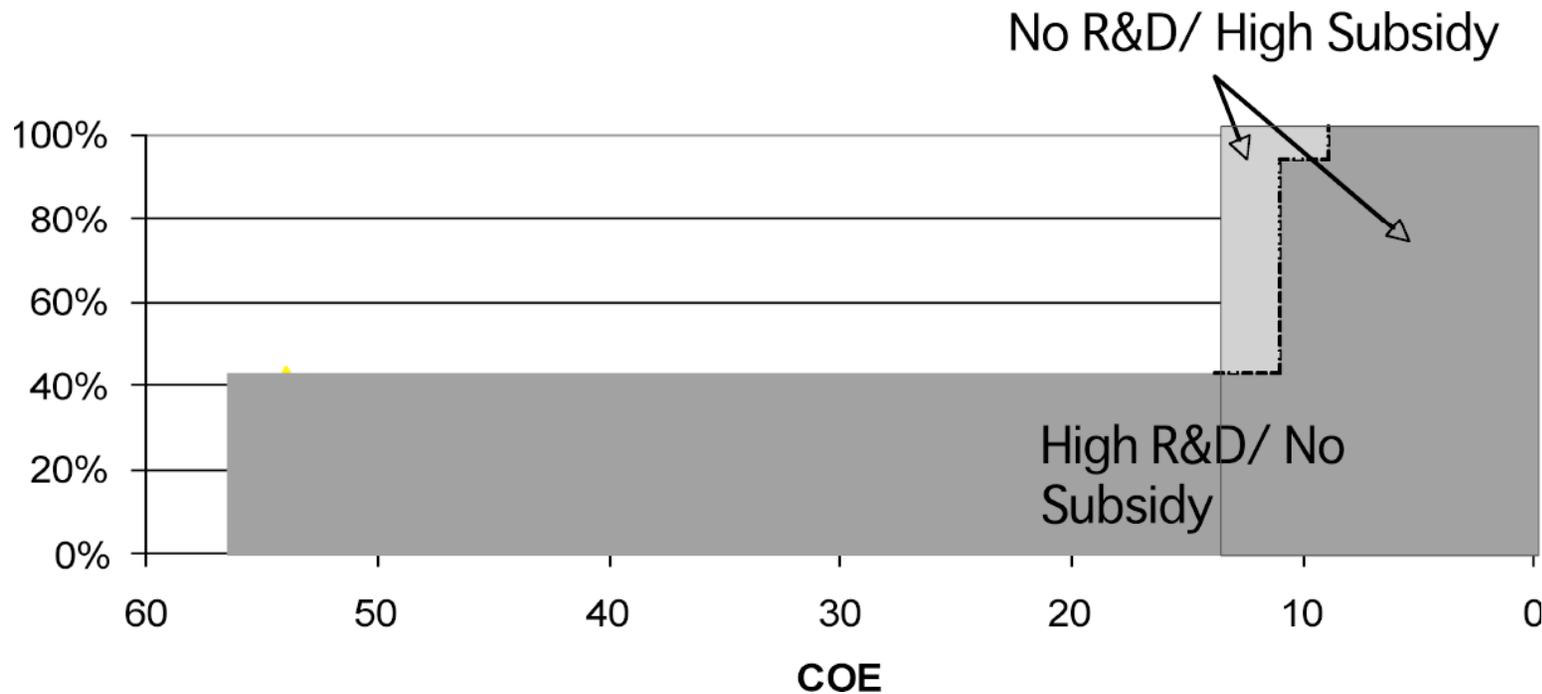

High R&D *FOSD* Low R&D

High subsidy *FOSD* Low subsidy

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STOCHASTIC DOMINANCE

No R&D/High subsidy SOSD High R&D/No Subsidy

Subsidy is a hedge against R&D failure

CONCLUSIONS

for this Pre-commercial Low-C tech:

• **Successful R&D** programs reduce costs more than **subsidies** do

• **Successful R&D** reduces costs to below the 4c/kWh target

• **Subsidies** alone do not reach this target

• **Subsidies** provide a hedge against failure in R&D programs.

• These conclusions robust to uncertainty in parameters…and C-price, storage.

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QUESTIONS

Is there a **positive interaction** effect between Learning by Doing (LBD) and R&D?

- - necessary to translate lab improvements to comm'l products?
- - if so, value of interaction effect must be very large

Is large demand necessary to induce industry R&D?
- - we are only considering government R&D
- - commercial products impossible without big private tech dev?

Is there real social value to 10c/kWh PV?
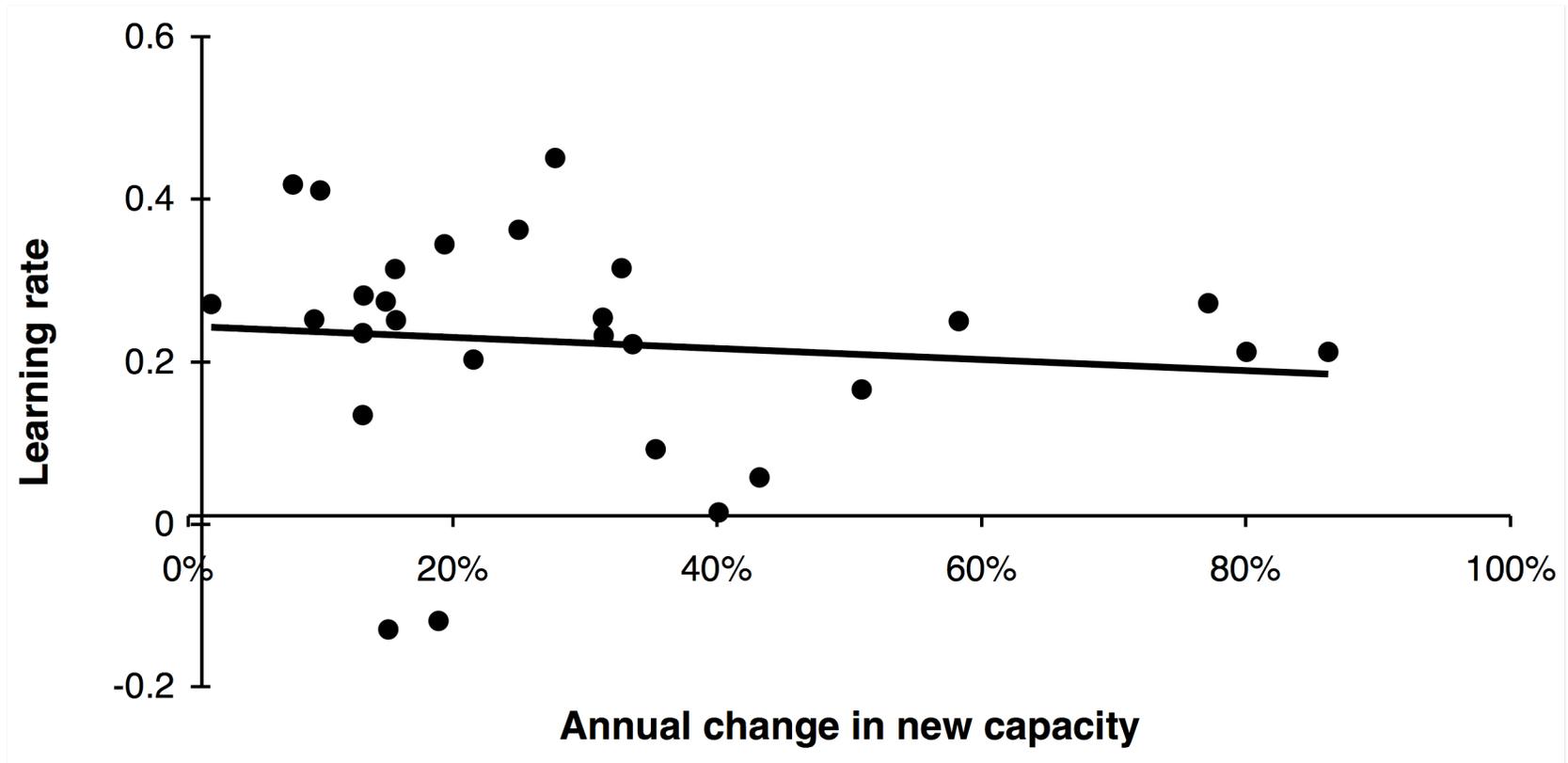
Is hedge still valuable with multiple technologies?

APPENDIX

R&D productivity: expert elicitations

Technology	$15M/yr 10 years			$80M/yr 15 years		
	Ex 1	Ex 2	Ex 3	Ex 1	Ex 2	Ex 3
Probability of Low success	0.43	0.27	0.40	0.50	0.36	0.32
Probability of High success	0	0	0	0.09	0.40	0.08
Probability of Failure	0.57	0.73	0.60	0.41	0.24	0.60

Source: Baker (2008)

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PV: LR and annual growth

END