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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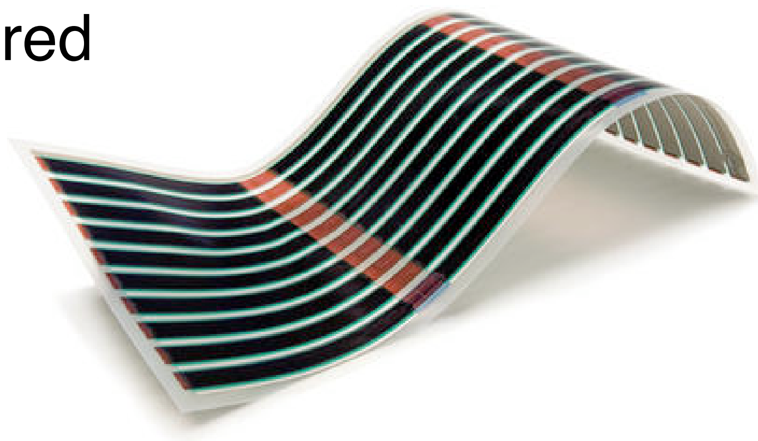
2. Pre-commercial technologies

difficult to model, often ignored
possible large impacts

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



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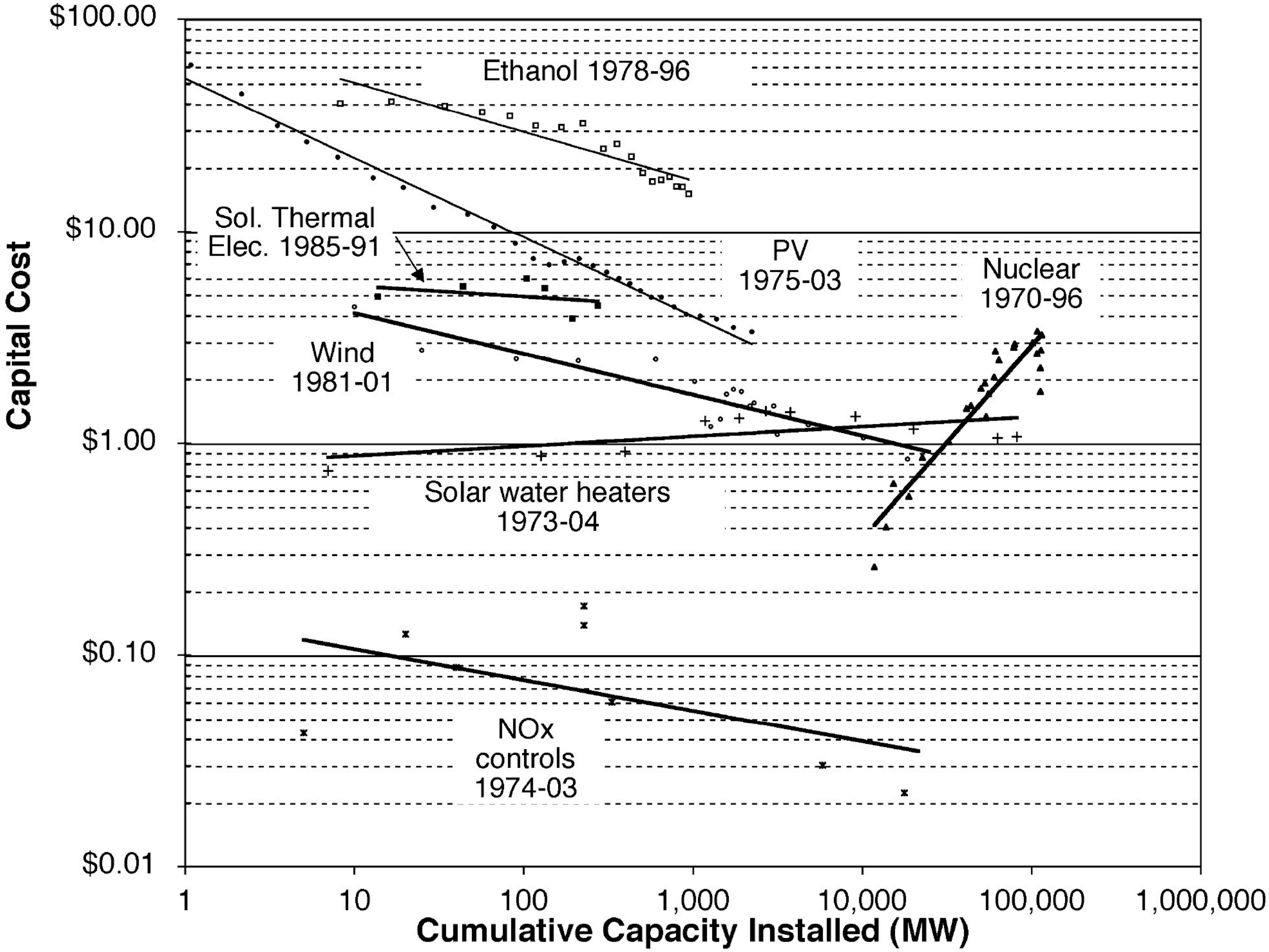
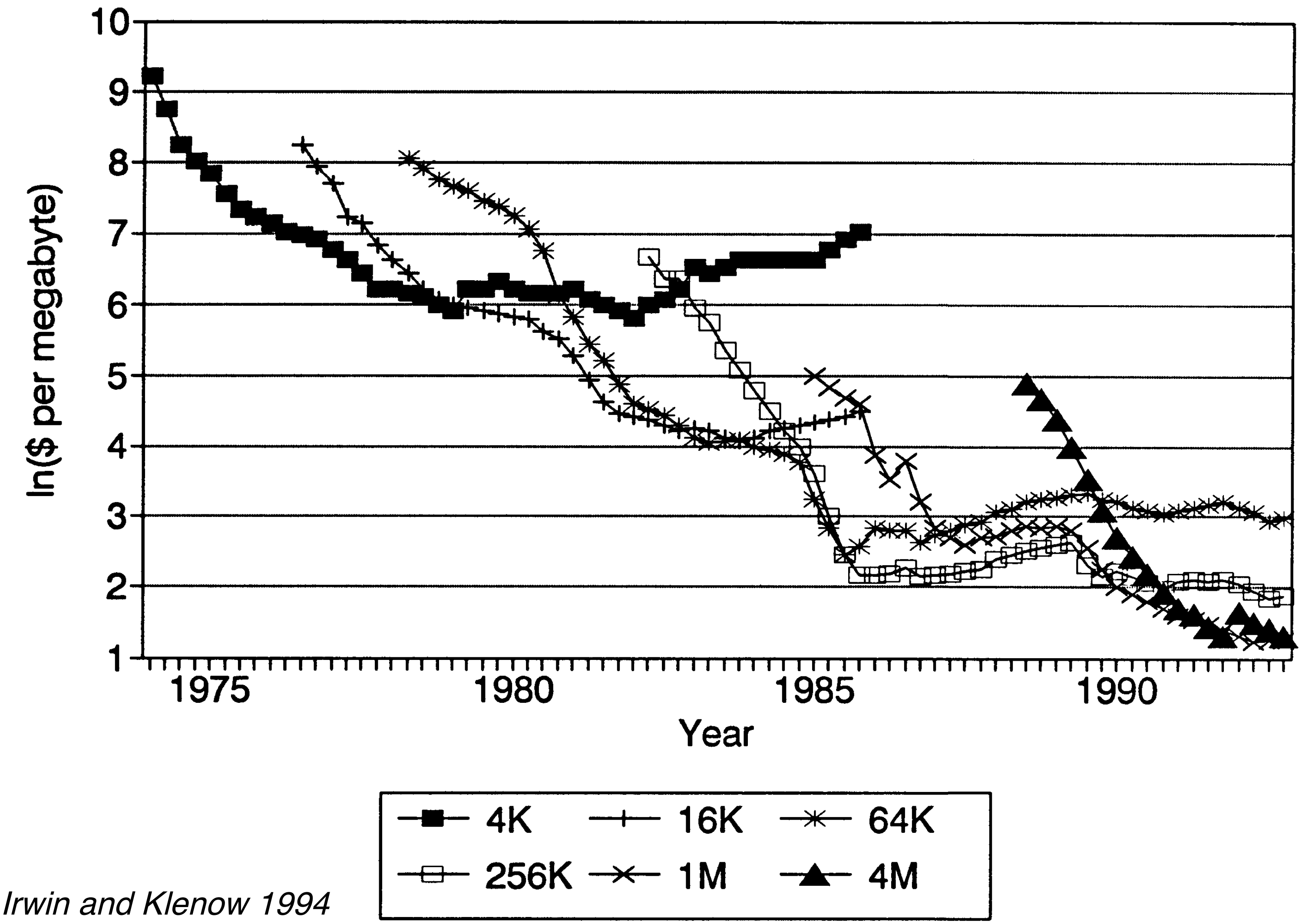


Source: Nemet (2007)

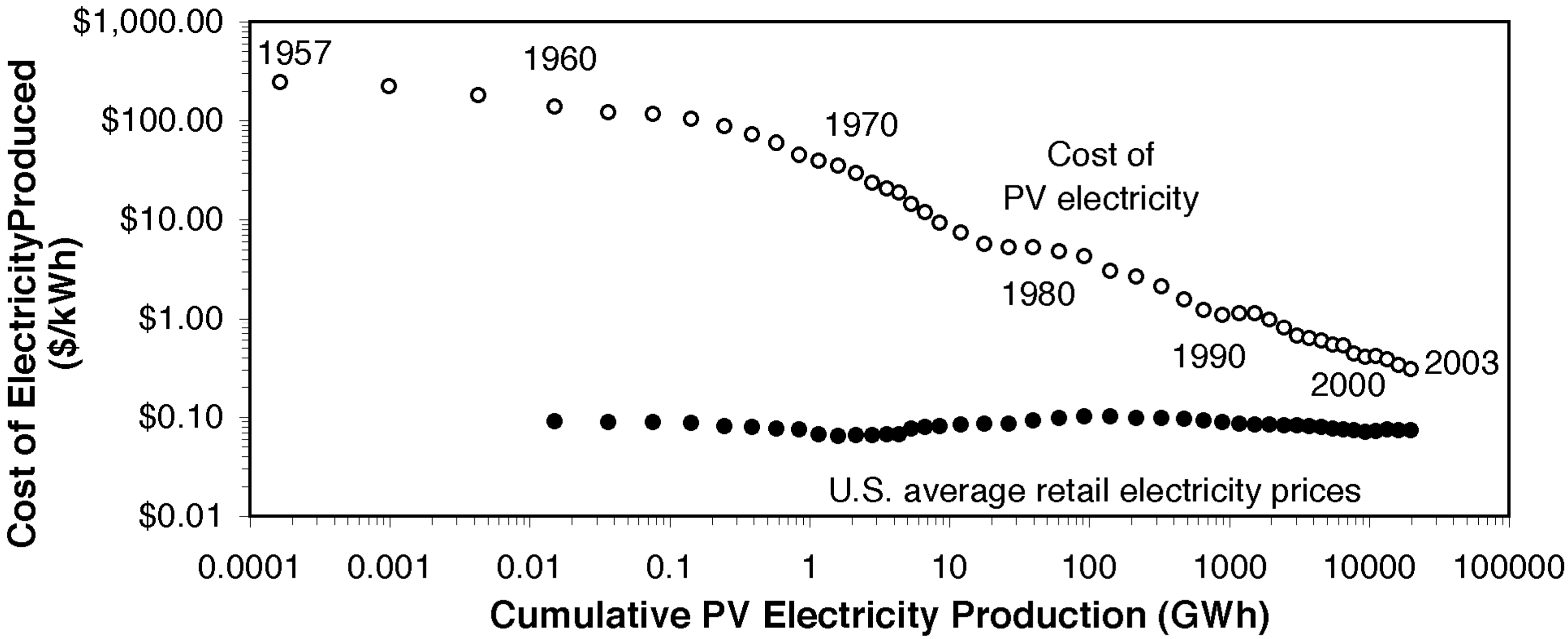
Technological generations



Source: Irwin and Klenow 1994

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

Cost of electricity from photovoltaics 1957--2003



Source: Nemet (2006)

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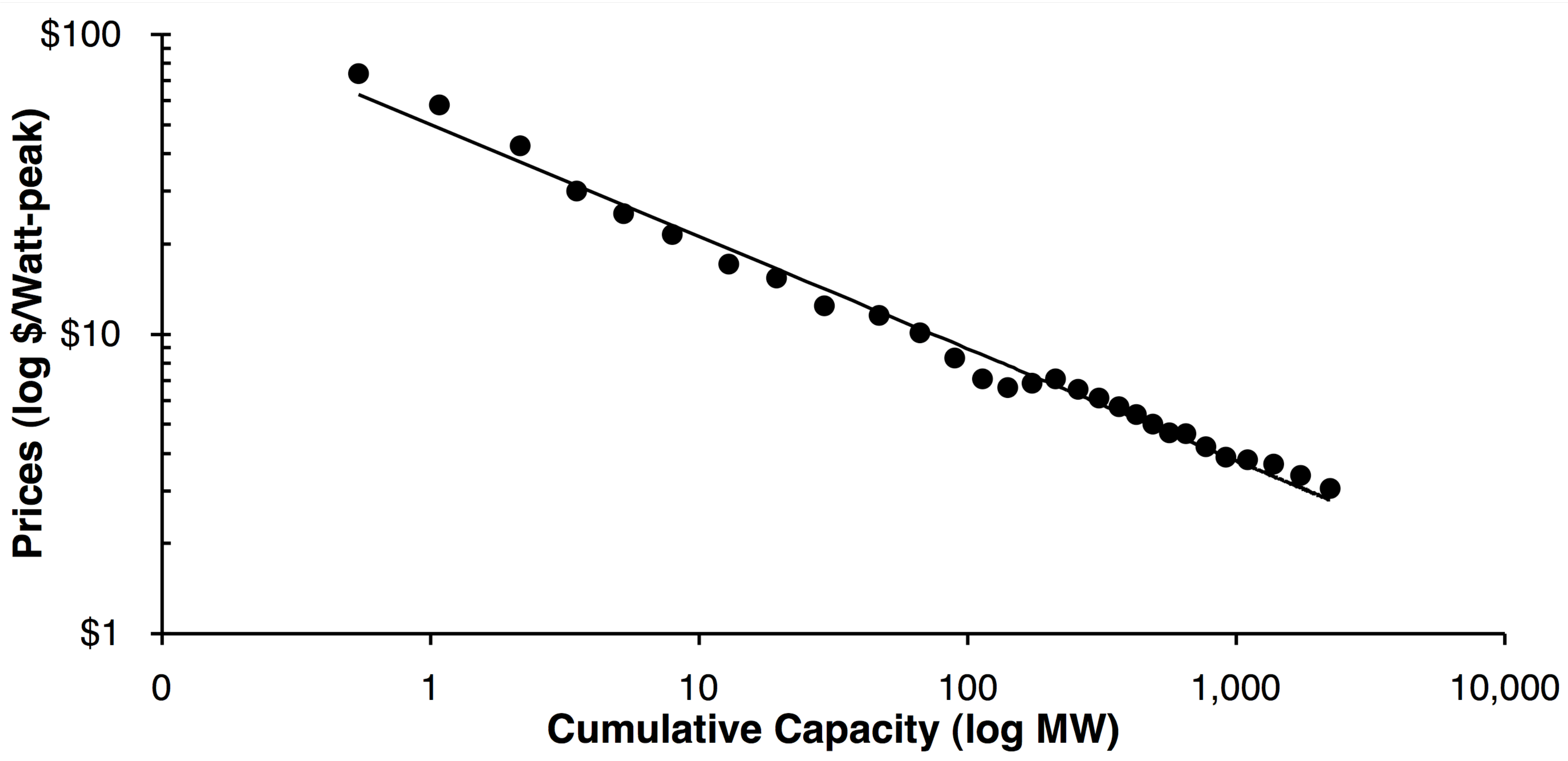
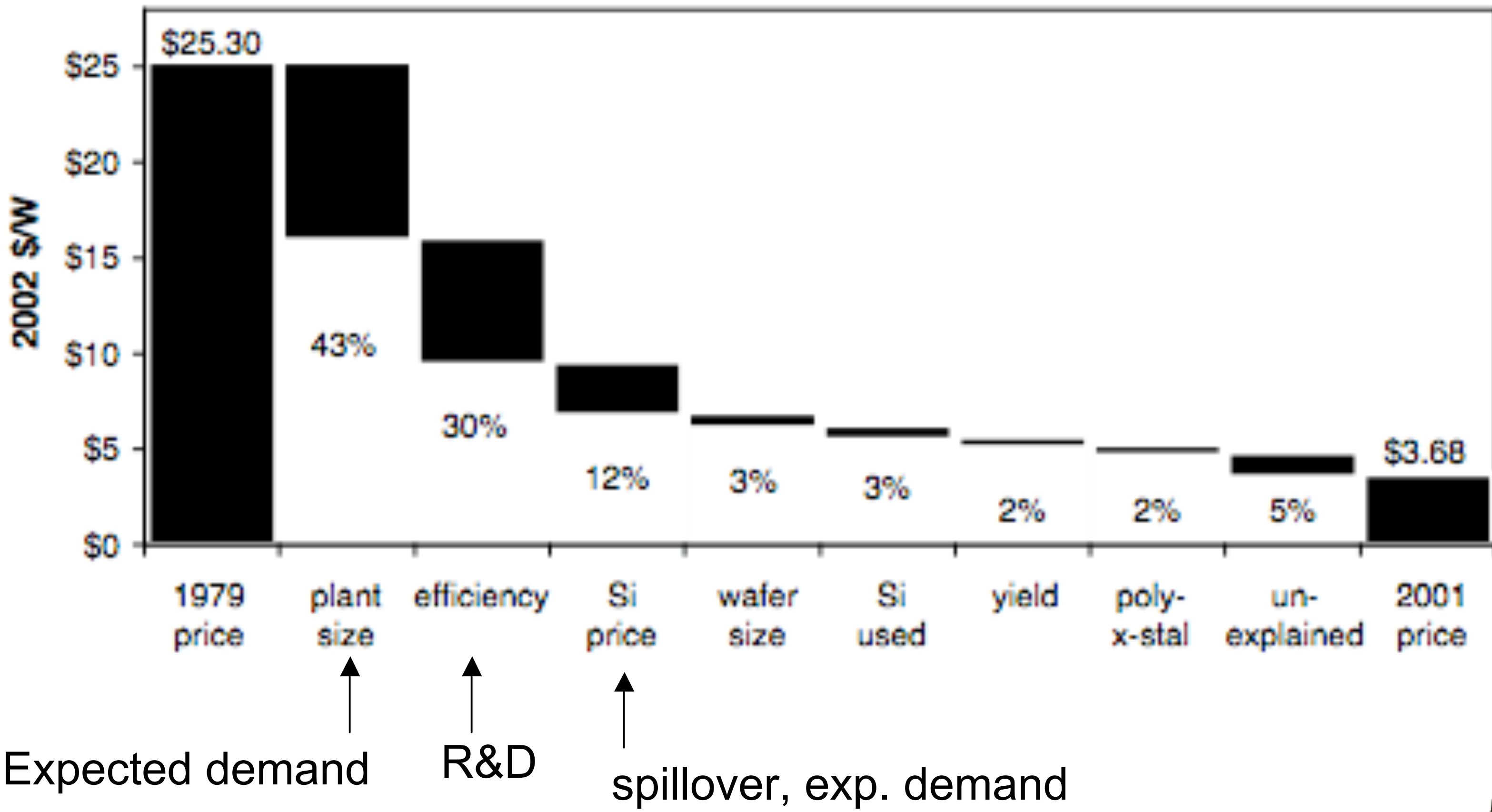
Price of PV modules



Source: Nemet (2006)

Sources of historical cost reductions for PV

85% of cost reduction due to R&D and expected demand



Source: Nemet (2006)

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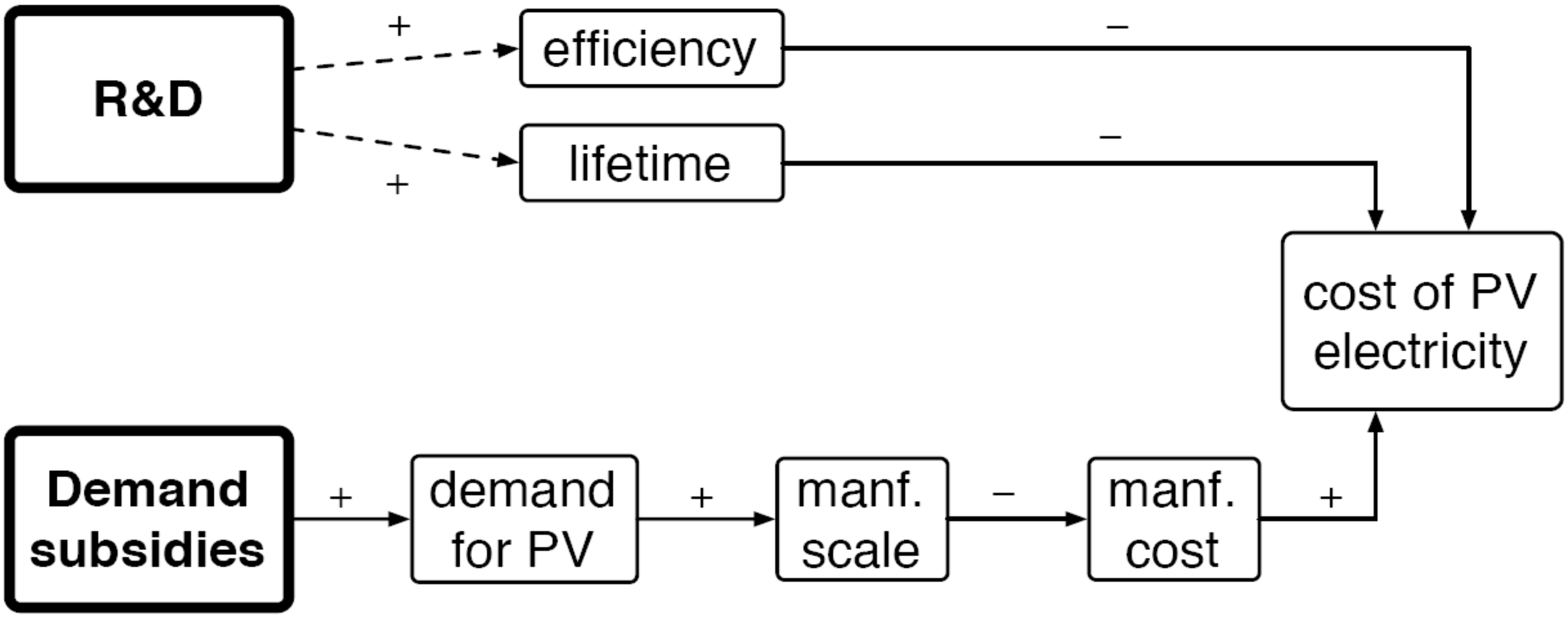
Approach

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



target:
4c
/kWh

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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			
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

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)

R&D productivity: expert elicitations

Technical outcomes

R&D investment

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%

Source: Baker (2007)

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

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

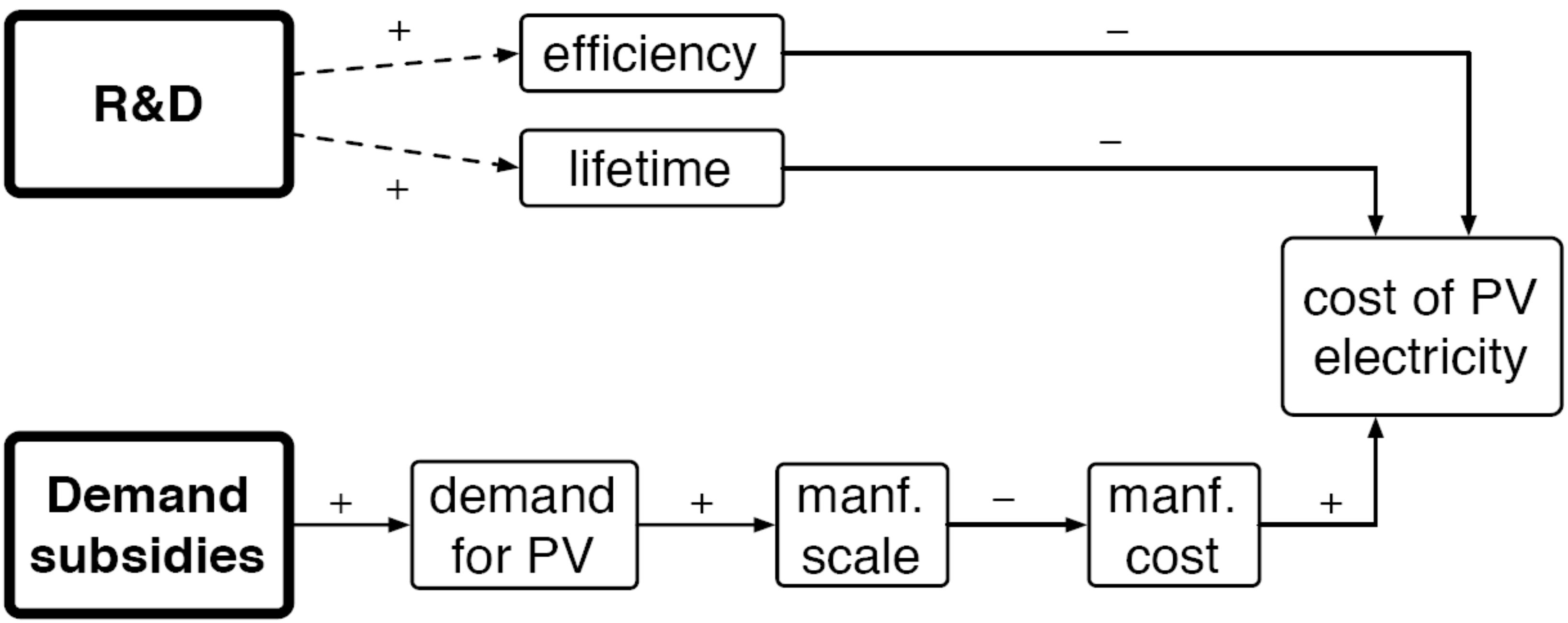
R&D:
- efficiency
- lifetime

Levelized costs
$/kWh

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

Approach

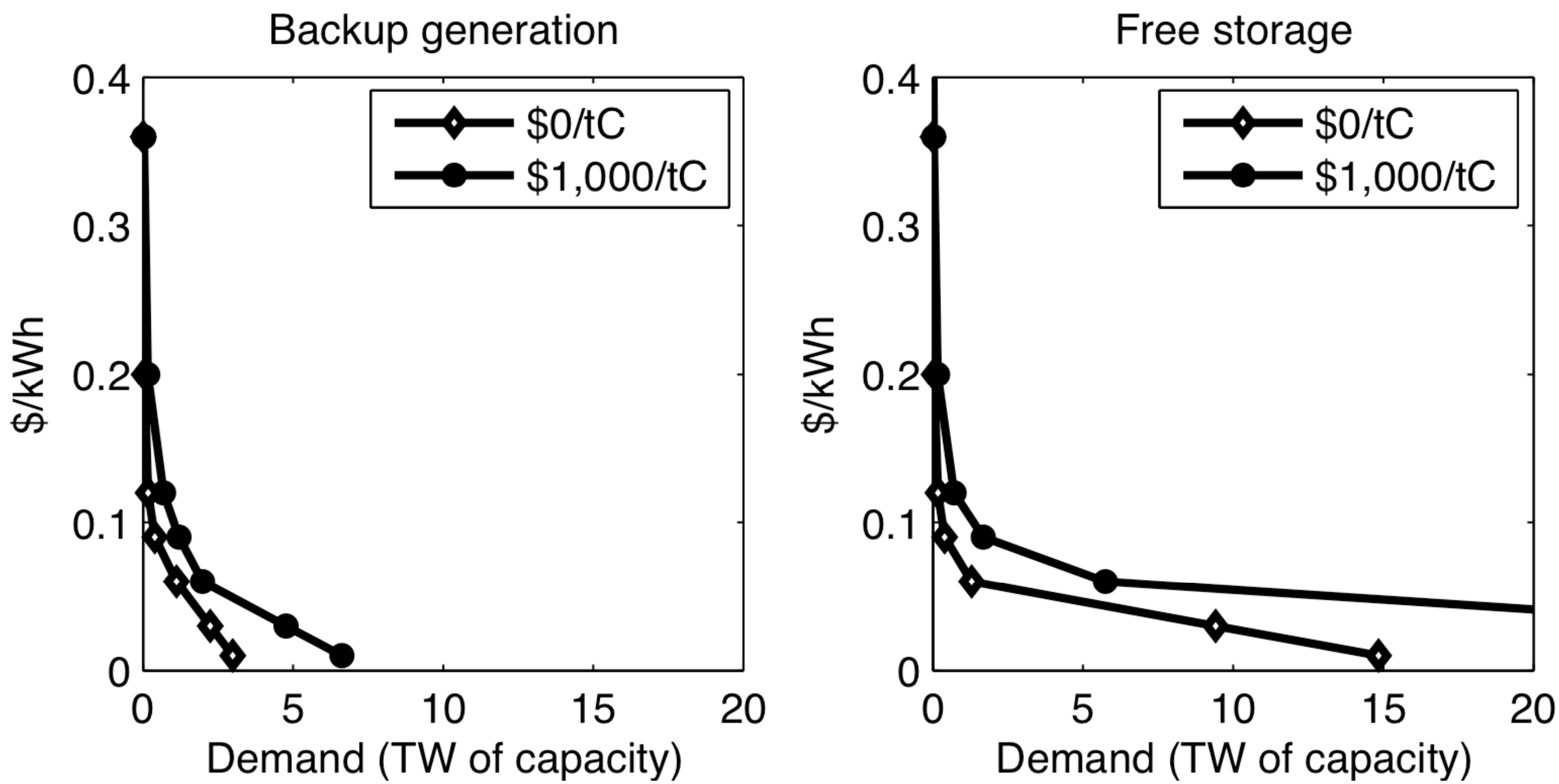
How best to choose ***level*** *and* ***timing*** *of*
R&D *and* ***subsidies*** *to achieve cost target?*



target:
4c
/kWh

3 levels of each

DEMAND CURVES



Source: MiniCAM

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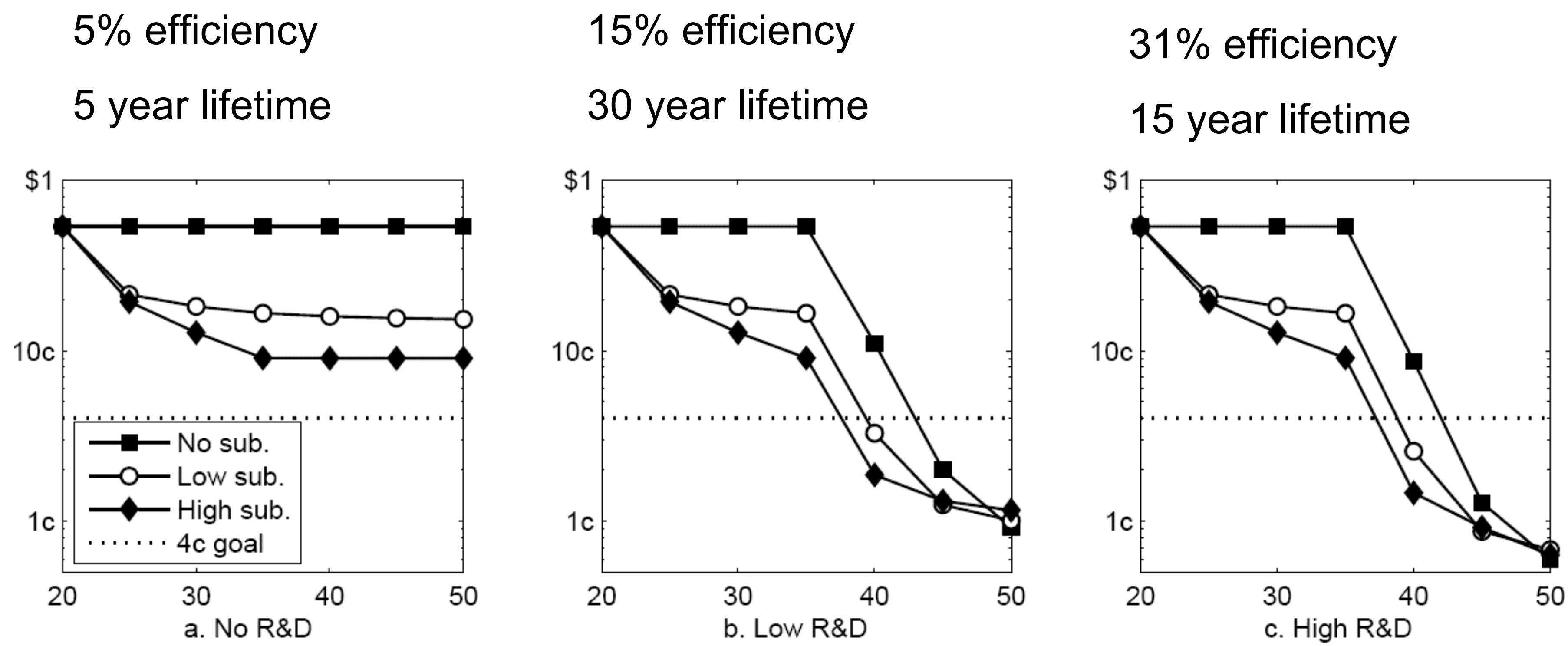
RESULTS: PV Lev. costs ($/kWh)

		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

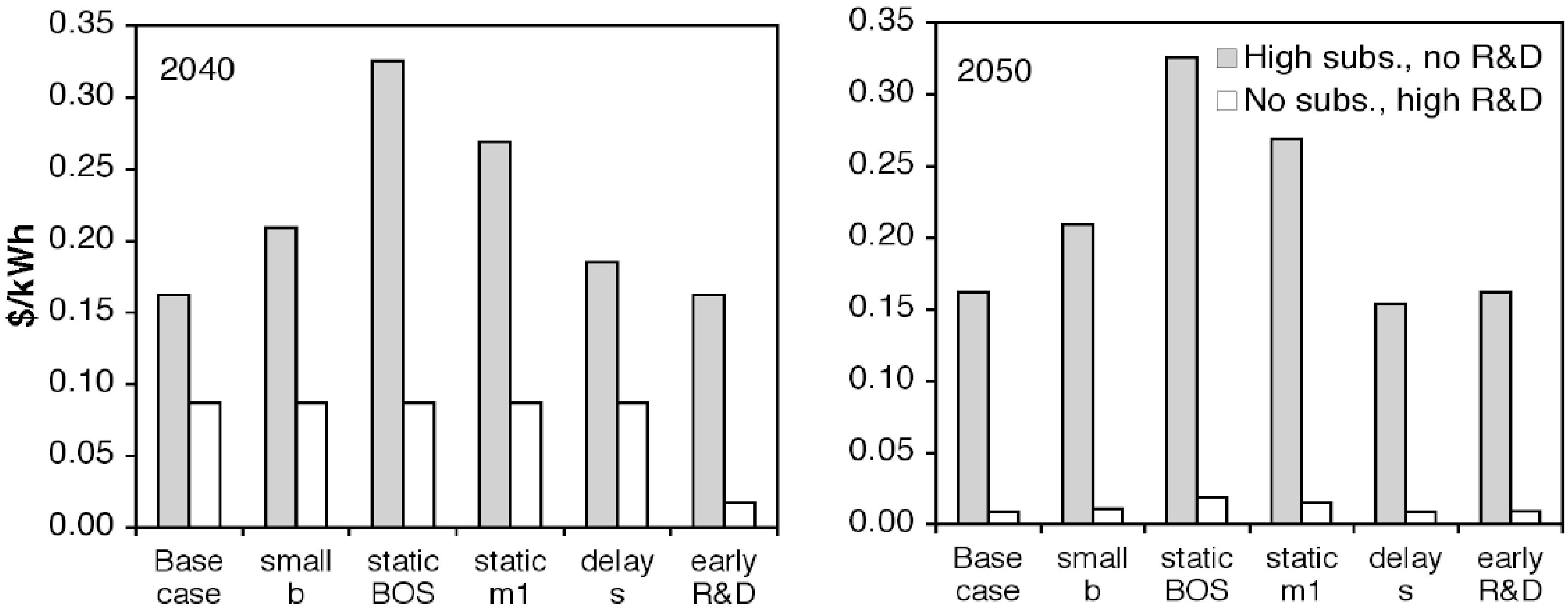
RESULTS: PV Lev. costs ($/kWh)

Impact of subsidies under 3 technical outcomes



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

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STORAGE AND CARBON PRICES

		Storage availability	
	Carbon price	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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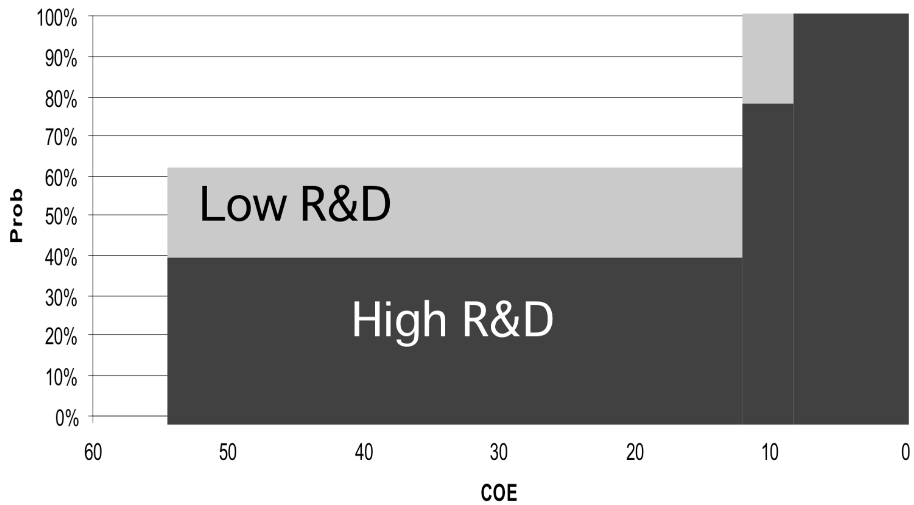
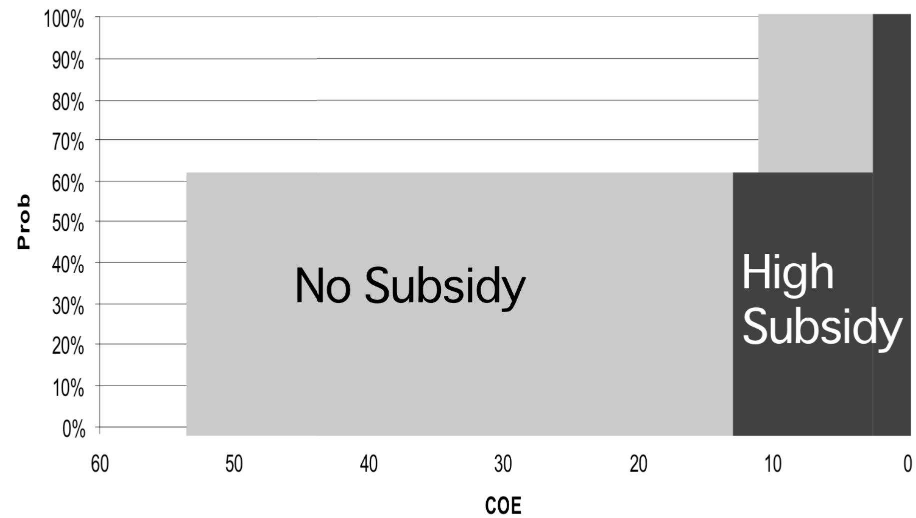
first order

STOCHASTIC DOMINANCE

Probability that COE will be at least as high





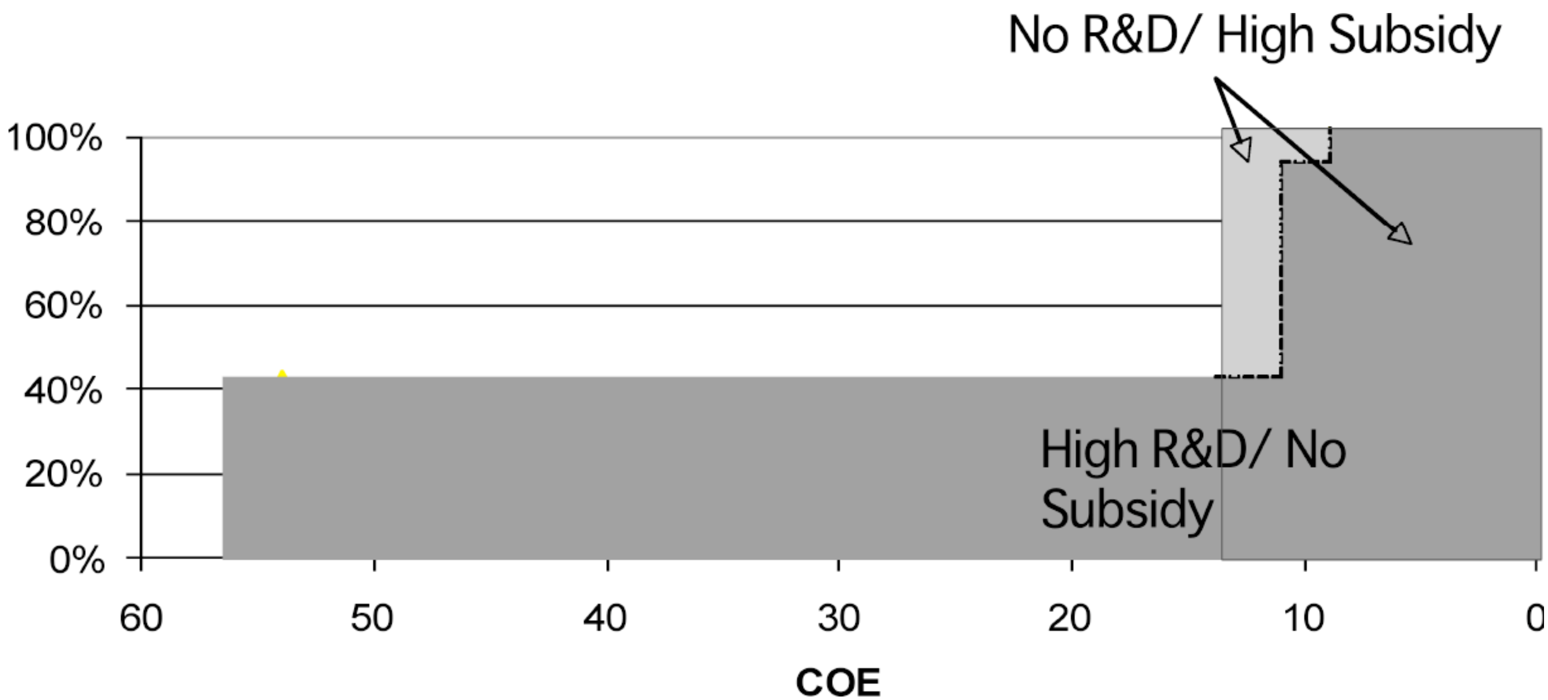
High R&D *FOSD* Low R&D

High subsidy *FOSD* Low subsidy

second order

STOCHASTIC DOMINANCE

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



Subsidy is a hedge against R&D failure

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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.

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?

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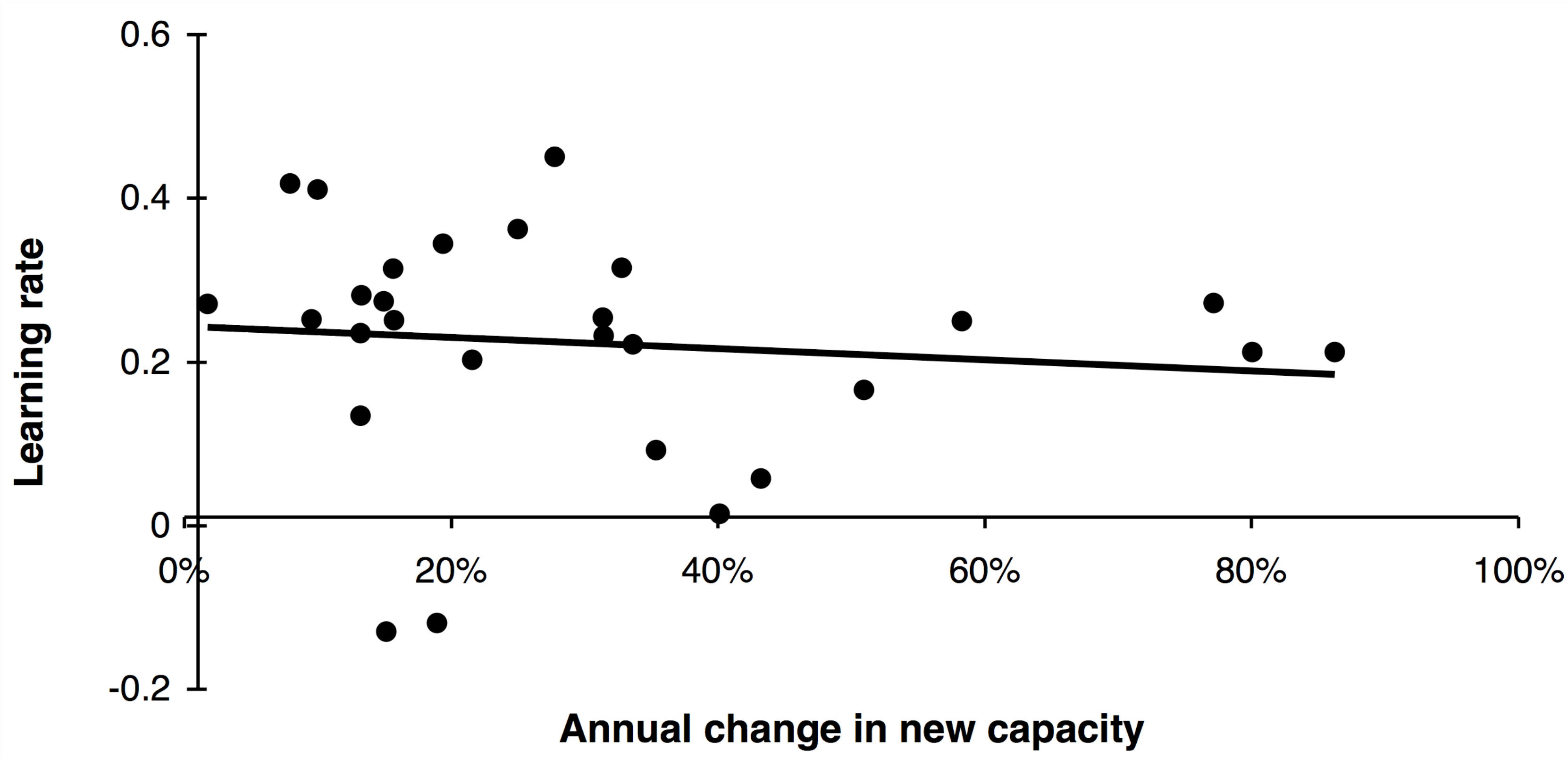
APPENDIX

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)

PV: LR and annual growth



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