


# Learning Curves

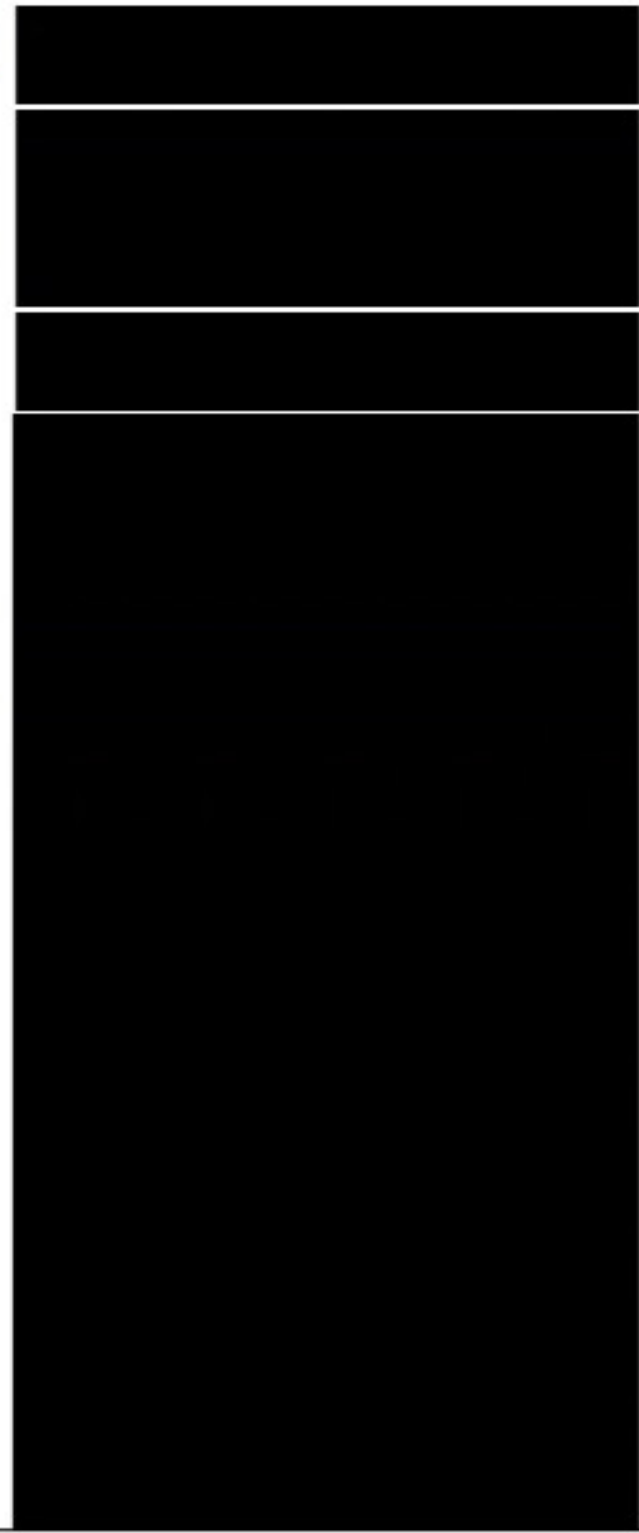
Jessie Knapstein

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1. Background/Motivation
  2. Tech Change in Climate/Energy Models
  3. Learning Curves
    1. Global and Local Learning Model
    2. National Energy Modeling System
  4. My Research
  5. Recap



Technology Cost \$/MWh

Subsidy Sunset  
Carbon Tax  
Cap & Trade  
RPS



Learning  
Tax Incent.  
FIT or NEM



## Supply Push

*Advances in Science  
and Technology*

R&DD

International Coop

Education/Training

## Demand Pull

*Changes in Market  
Demand*


Tax Incentives

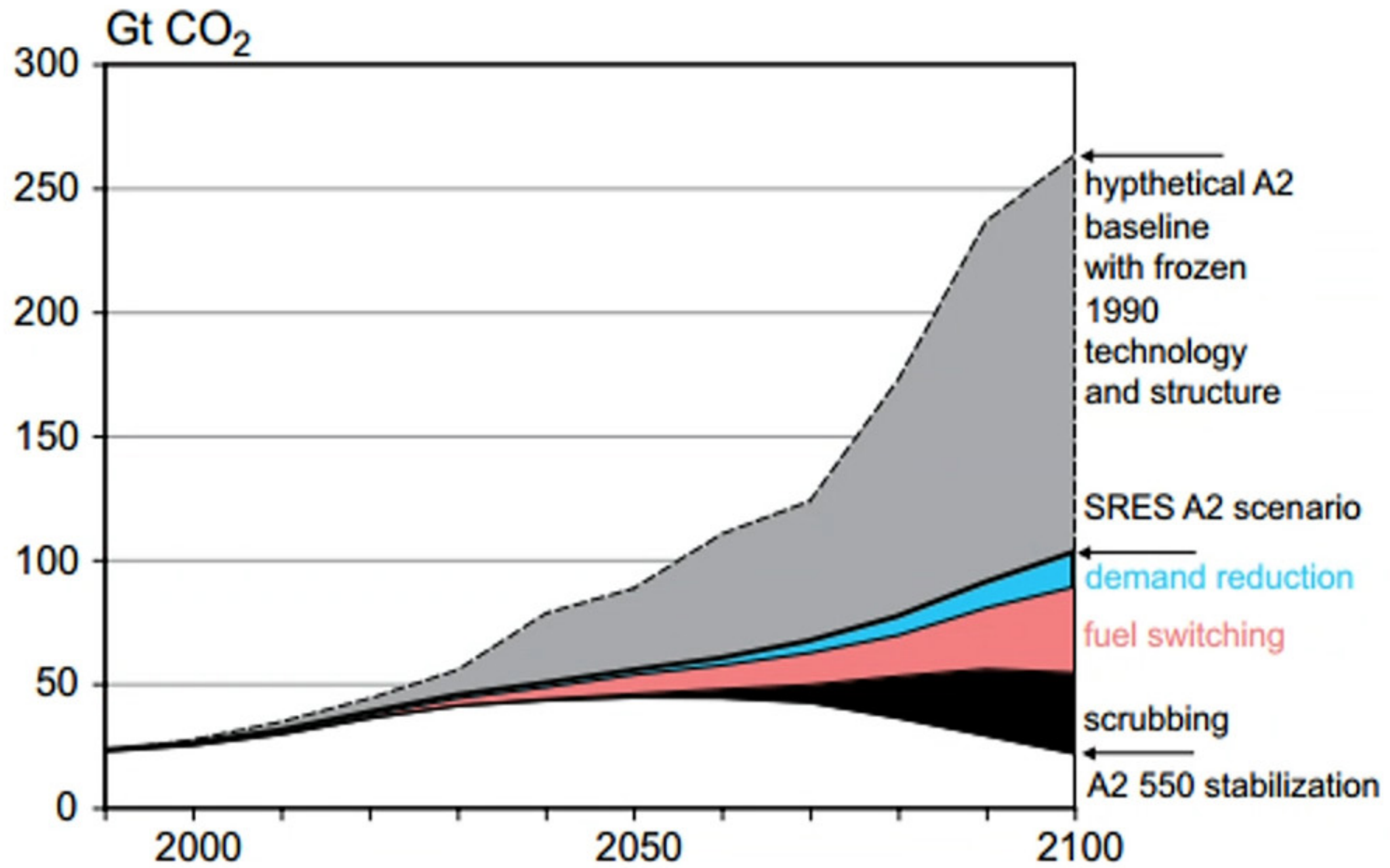
Subsidies

Cap & Trade

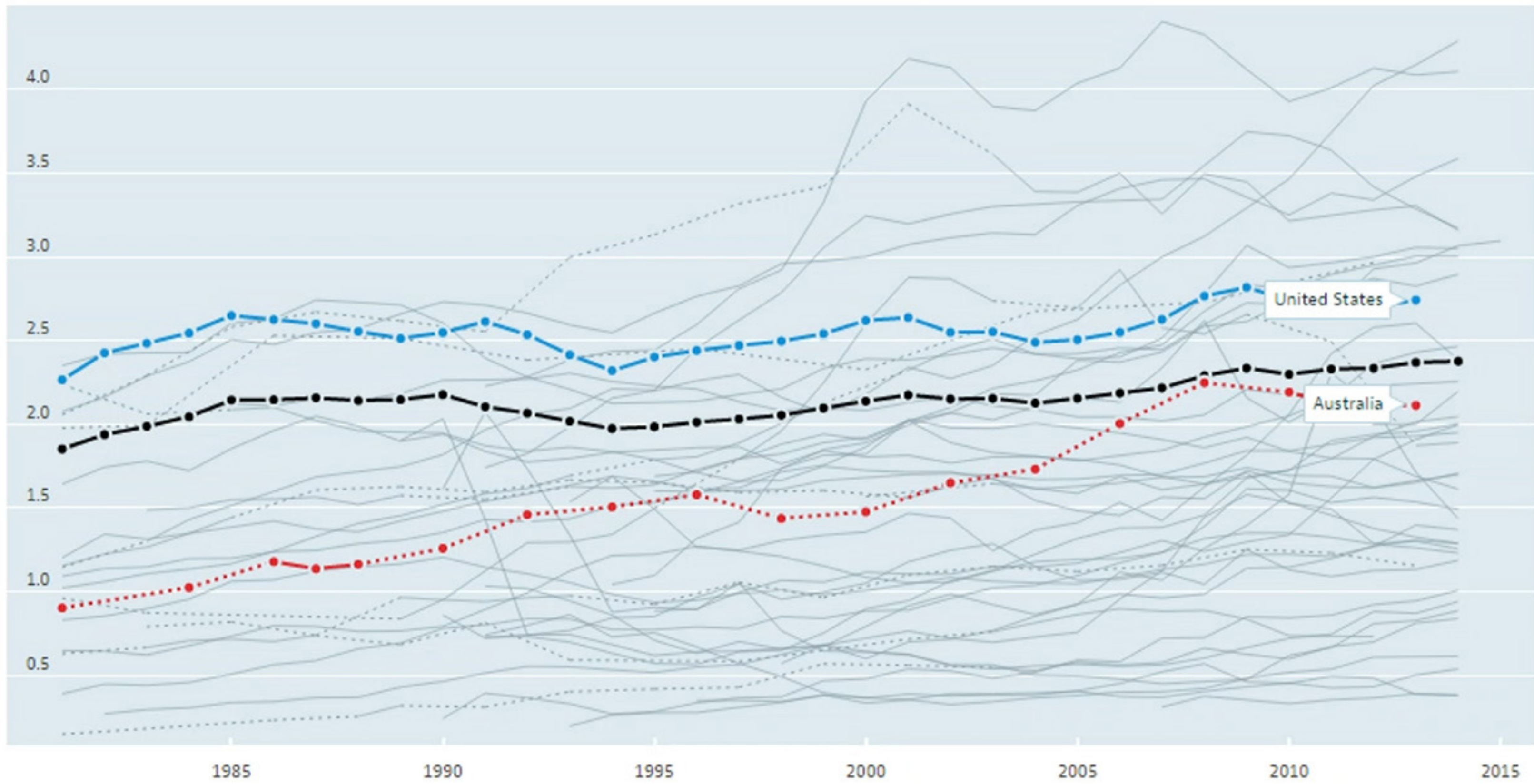
RPS



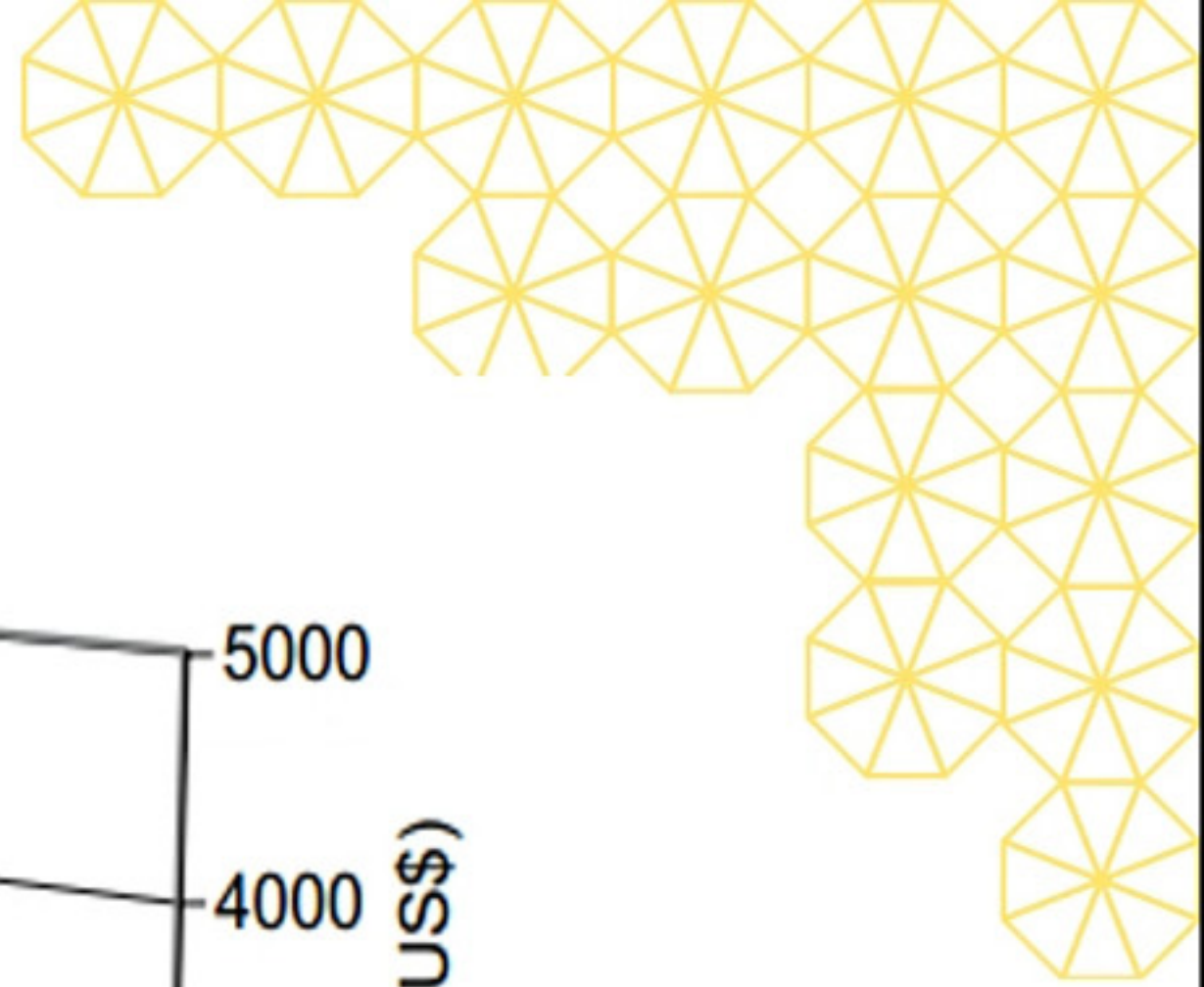
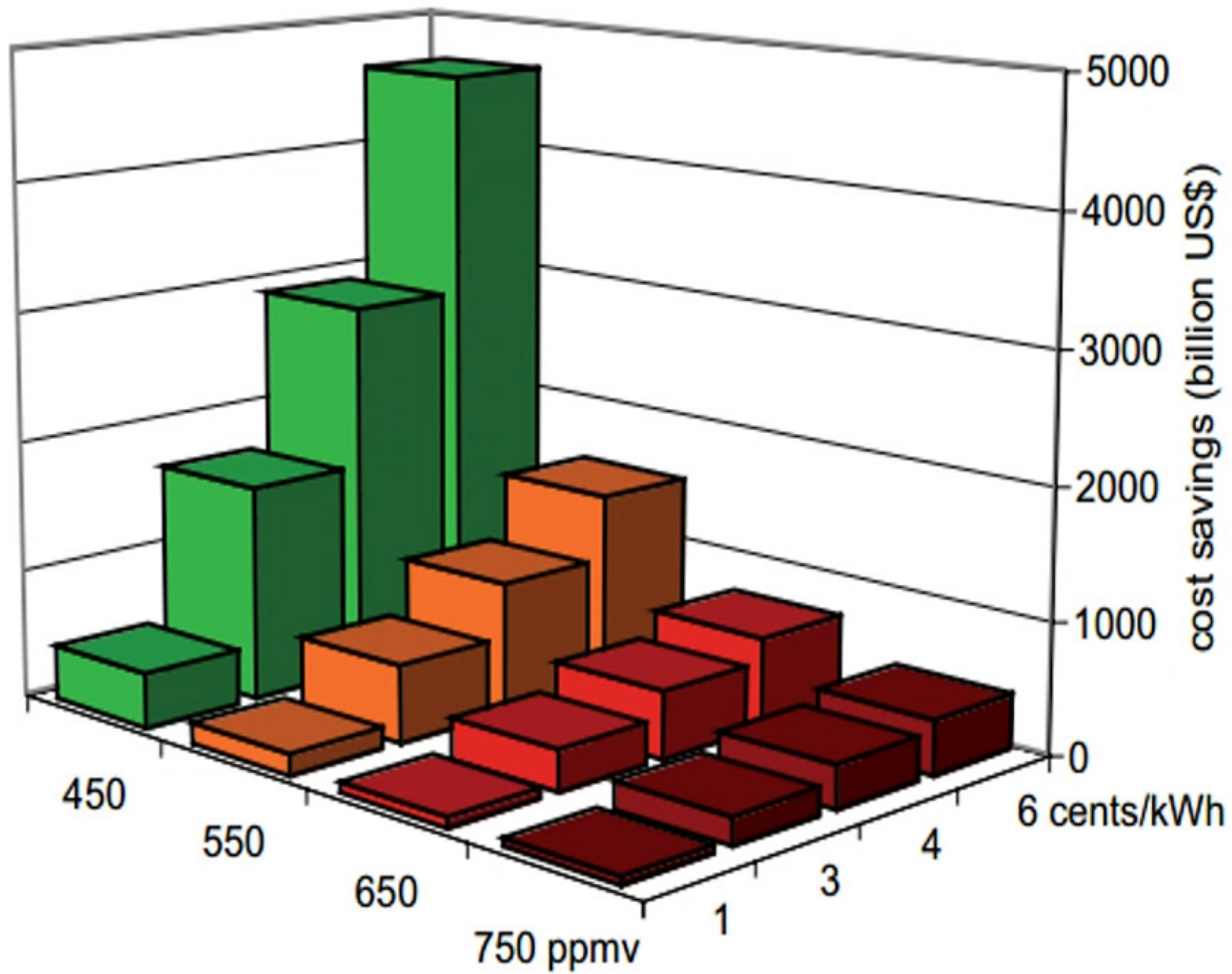
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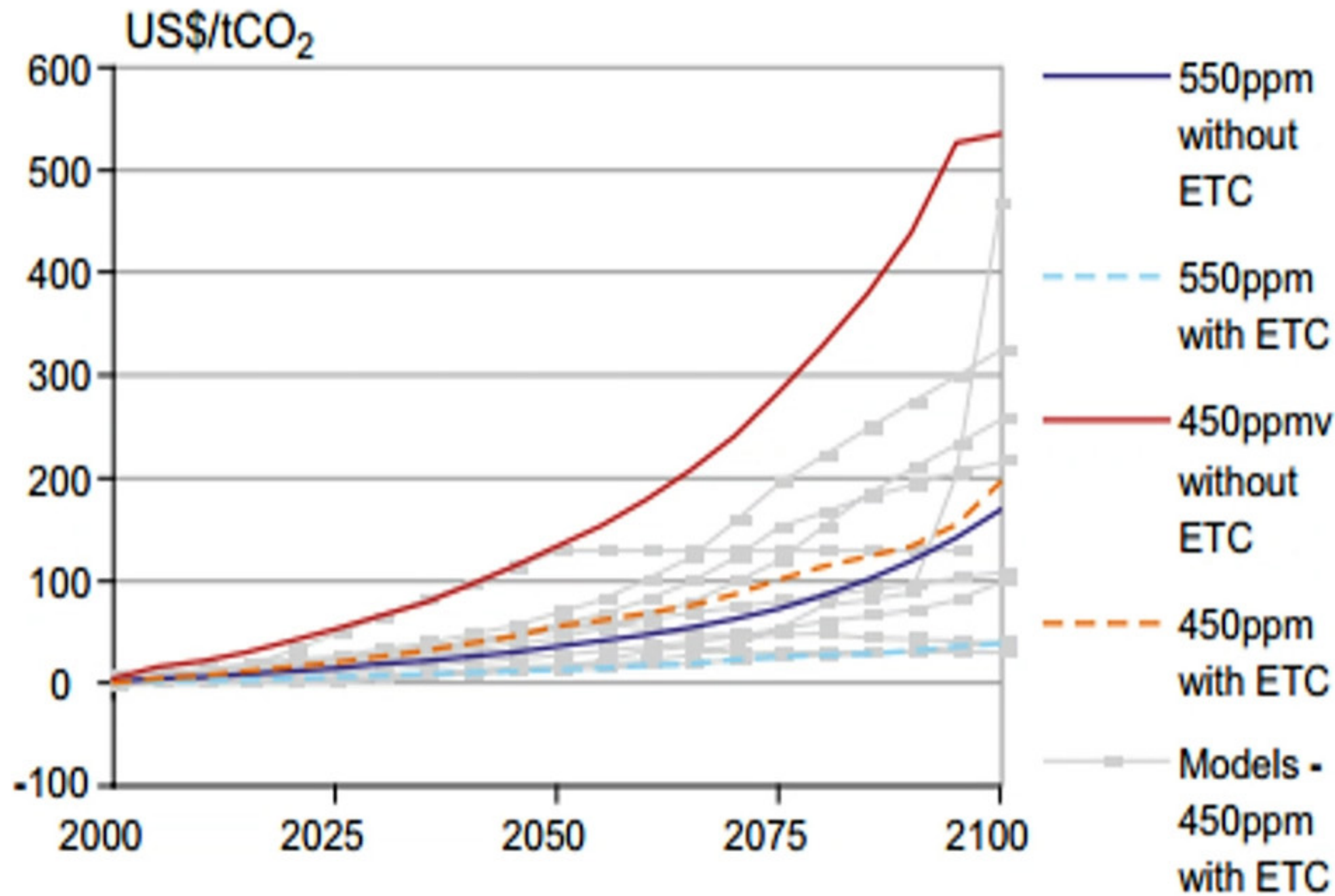









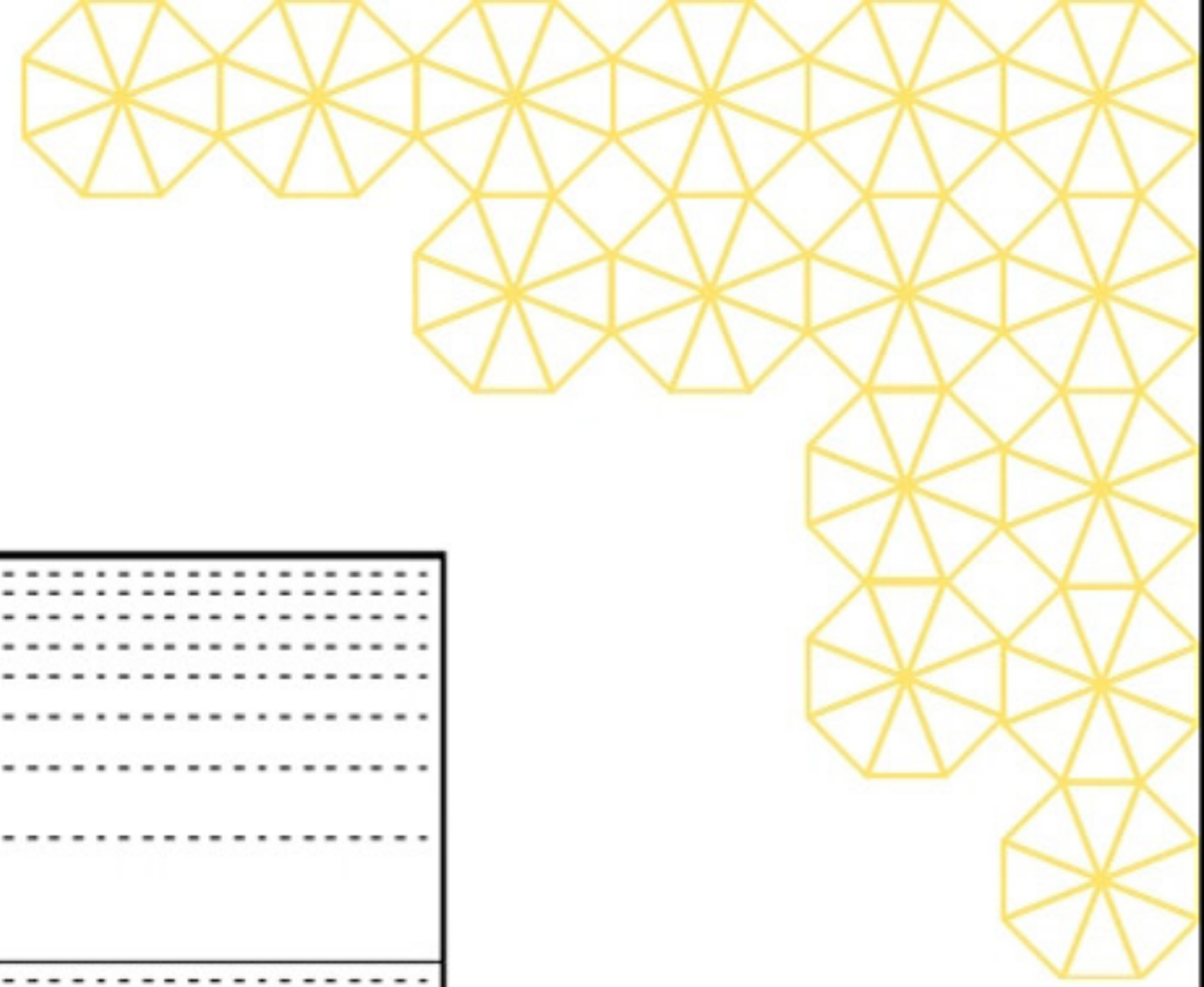
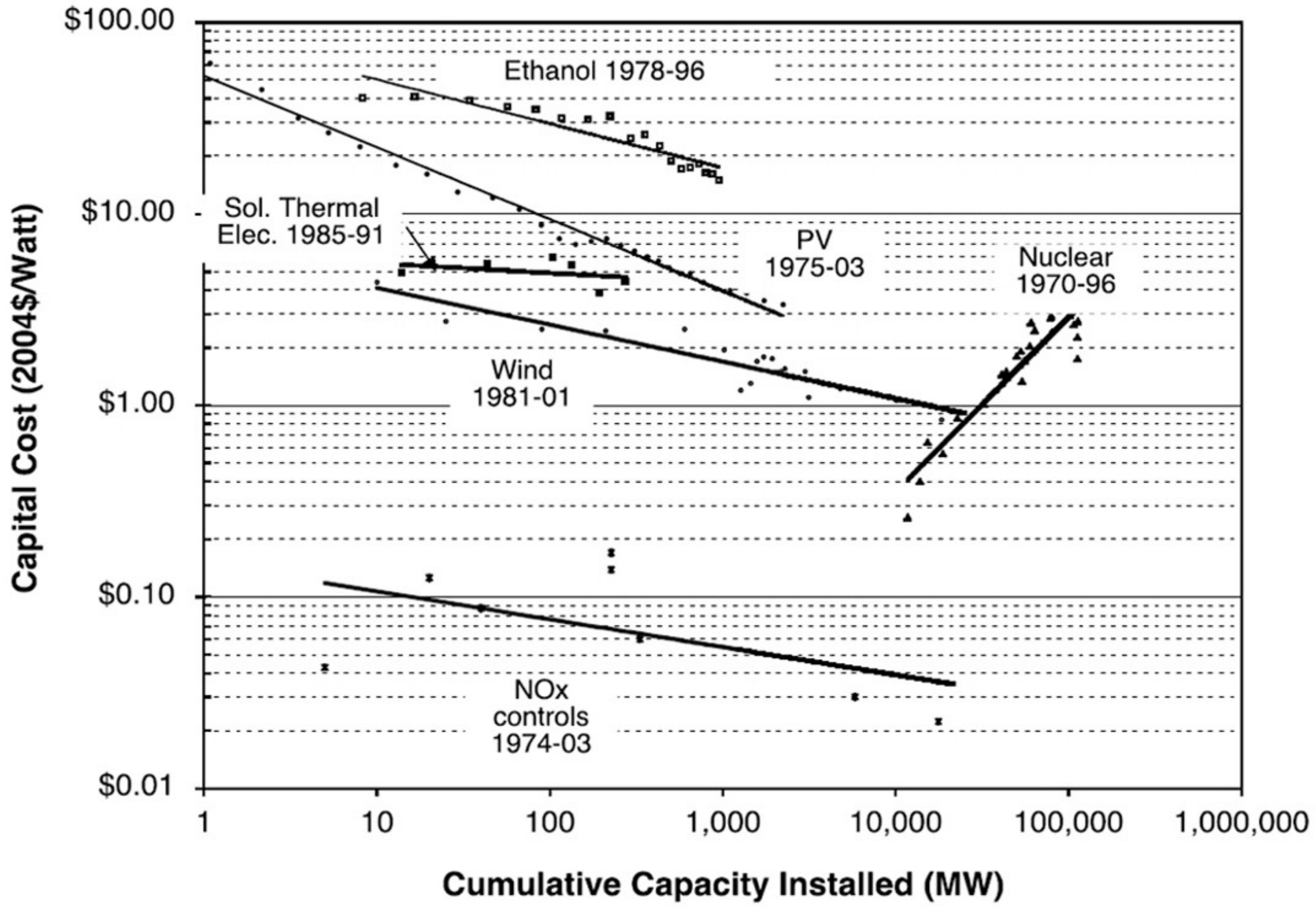
### (a) Averaged effects of including ETC on carbon price

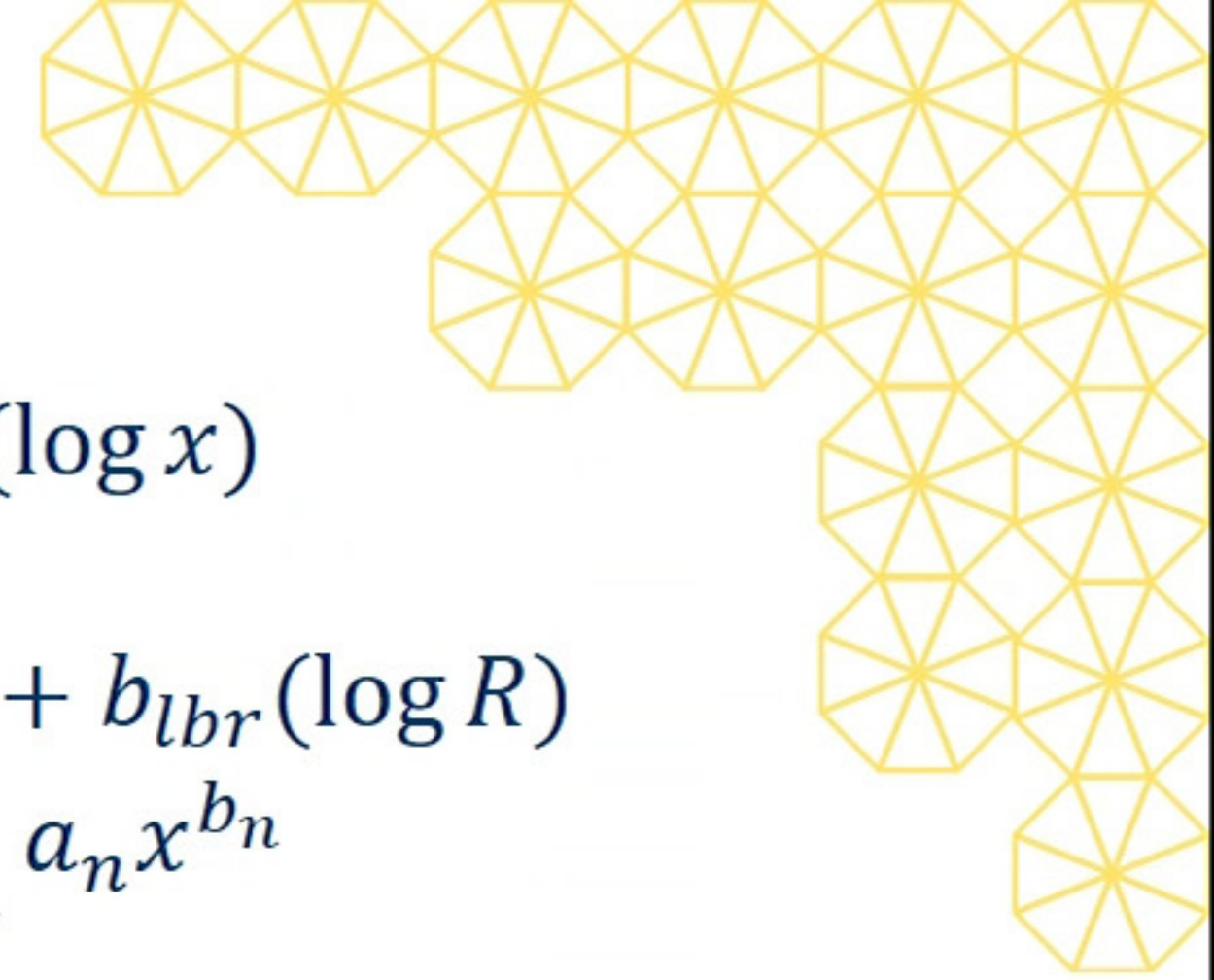




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$$Y = ax^b$$

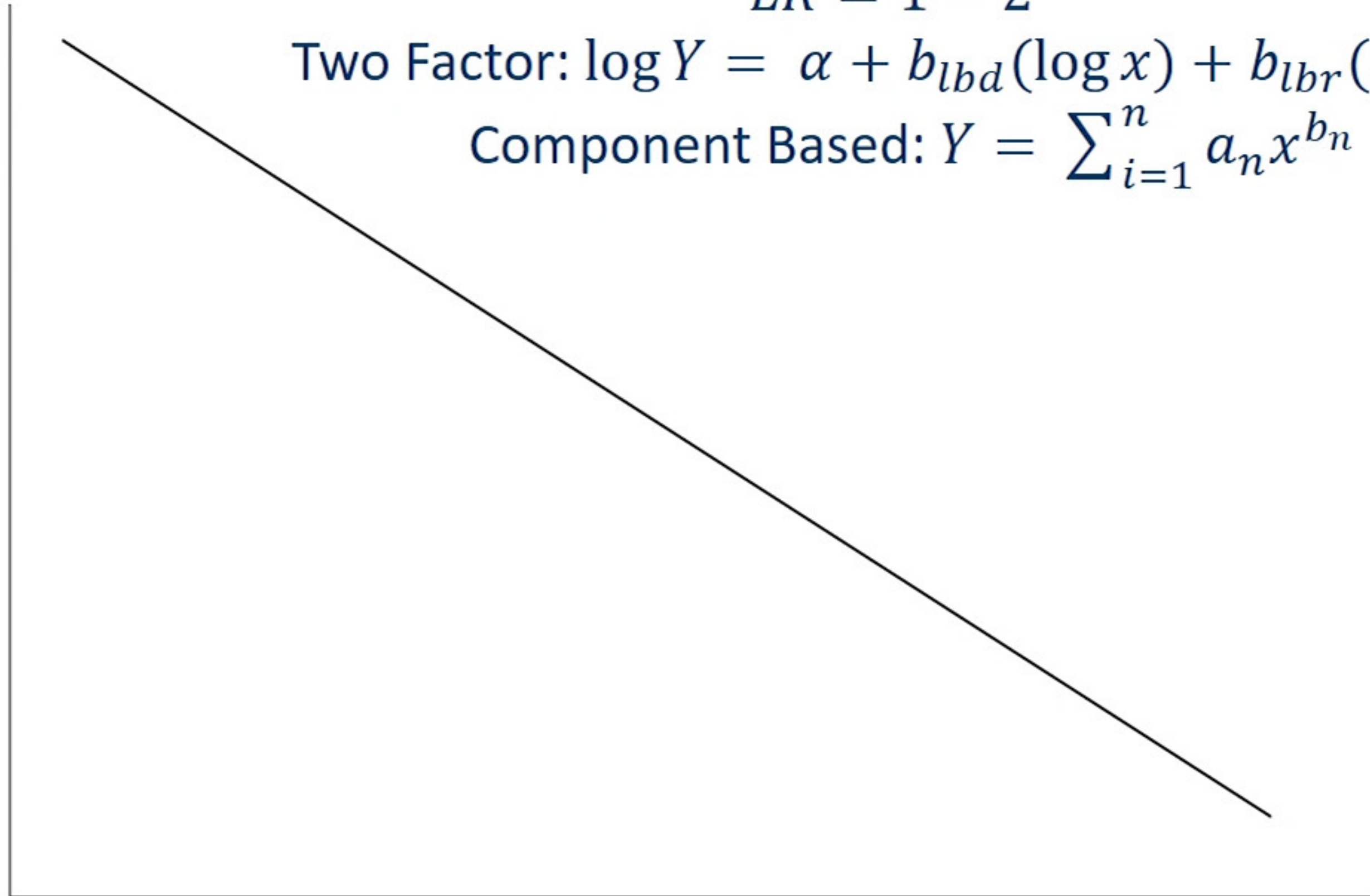
Single Factor:  $\log Y = \alpha + b(\log x)$

$$LR = 1 - 2^b$$

Two Factor:  $\log Y = \alpha + b_{lbd}(\log x) + b_{lbr}(\log R)$

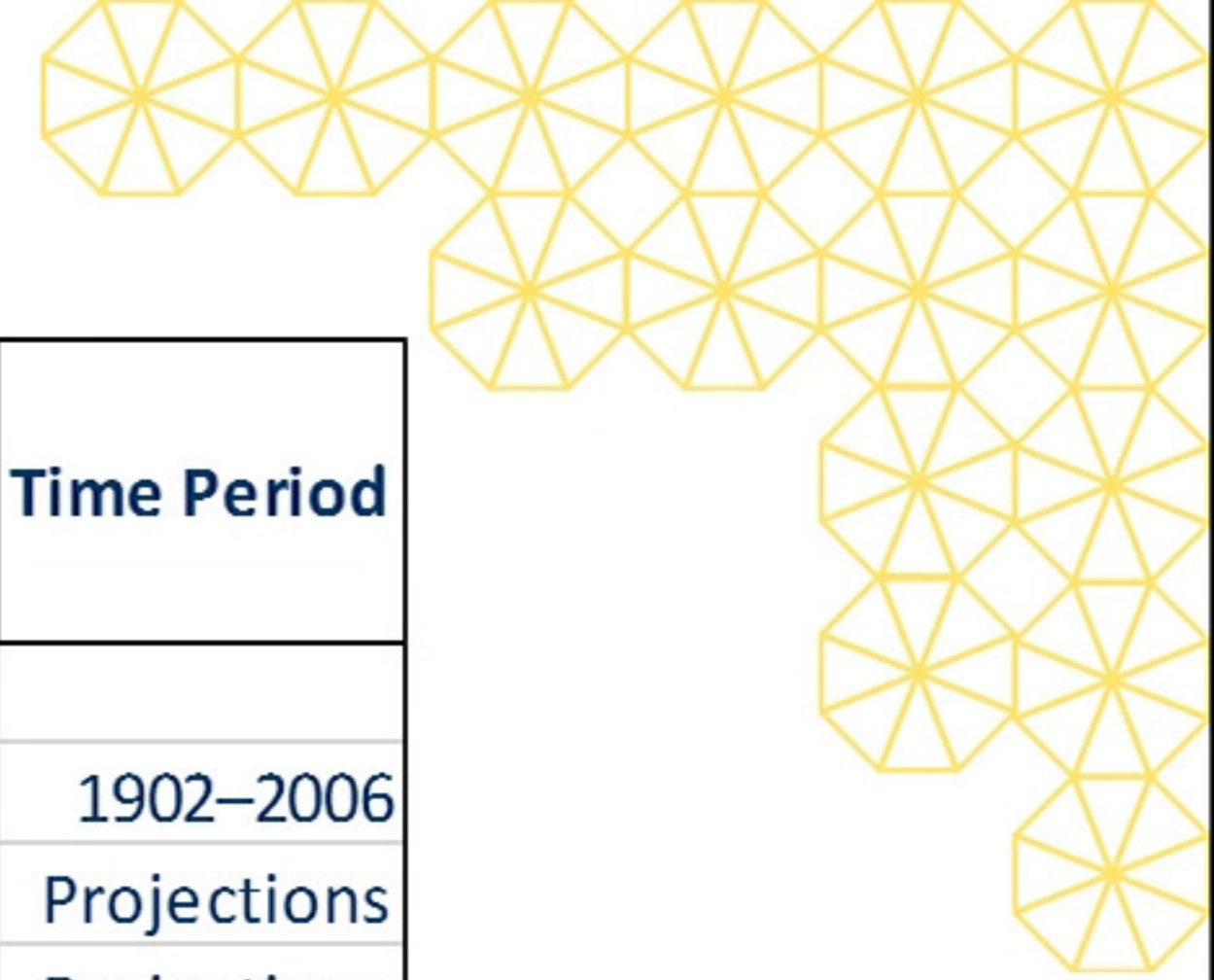
Component Based:  $Y = \sum_{i=1}^n a_n x^{b_n}$

Log Cost



Log Cumulative Capacity





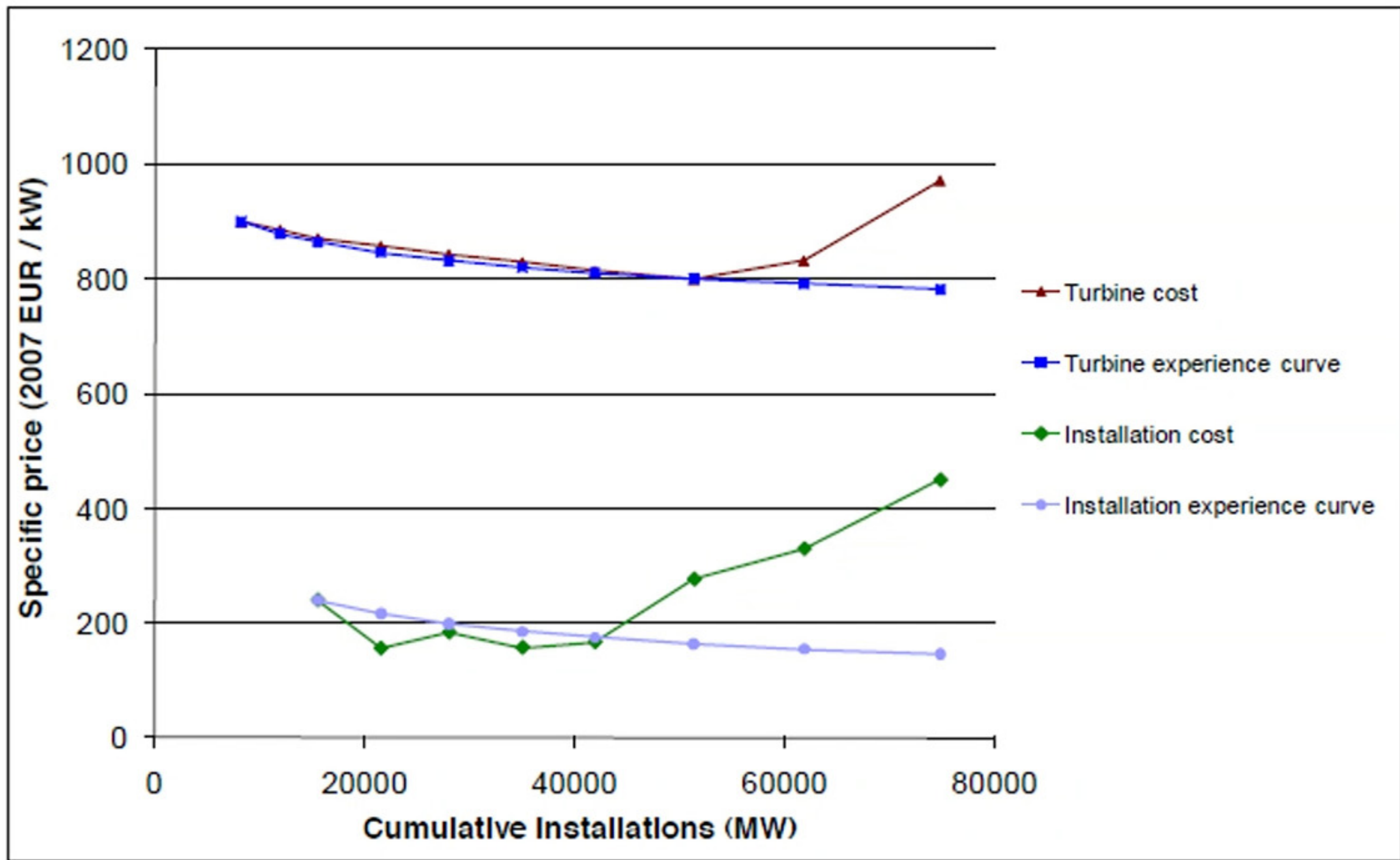
Technology & Energy Source	One Factor Models	Two Factor Models		Time Period
	Range of Learning Rates	Range of LBD rates	Range of LBR rates	
<b>Coal</b>				
<i>PC</i>	5.6–12%	–	–	1902–2006
<i>PC + CCS</i>	1.1–9.9%	–	–	Projections
<i>IGCC</i>	2.5–16%	–	–	Projections
<i>IGCC + CCS</i>	2.5–20%	–	–	Projections
<b>Natural gas</b>				
<i>NGCC</i>	–11 to 34%	0.7–2.2%	2.4–17.7%	1980–1998
<i>Gas turbine</i>	10–22%	–	–	1958–1990
<i>NGCC + CCS</i>	2–7%	–	–	Projections
<b>Nuclear</b>	Negative to 6%	–	–	1972–1996
<b>Wind</b>				
<i>Onshore</i>	–11 to 32%	3.1–13.1%	10–26.8%	1979–2010
<i>Offshore</i>	5–19%	1%	5%	1985–2001
<b>Solar PV</b>	10–47%	14–32%	10–14.3%	1959–2011
<b>Biomass</b>				
<i>Power generation</i>	0–24%	–	–	1976–2005
<i>Biomass production</i>	20–45%	–	–	1971–2006
<b>Hydroelectric</b>	0.014	0.5–11.4%	2.6–20.6%	1980–2001

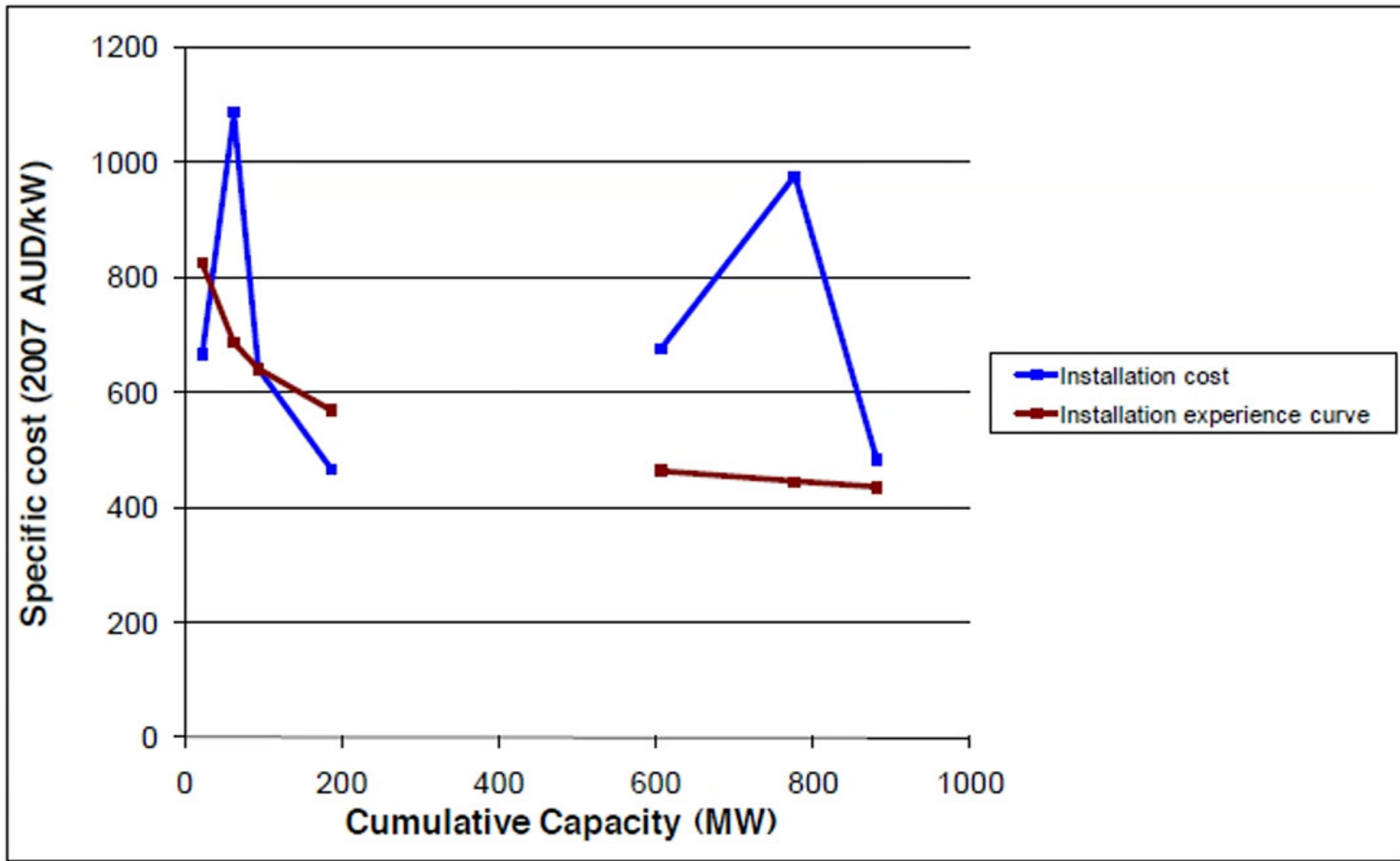
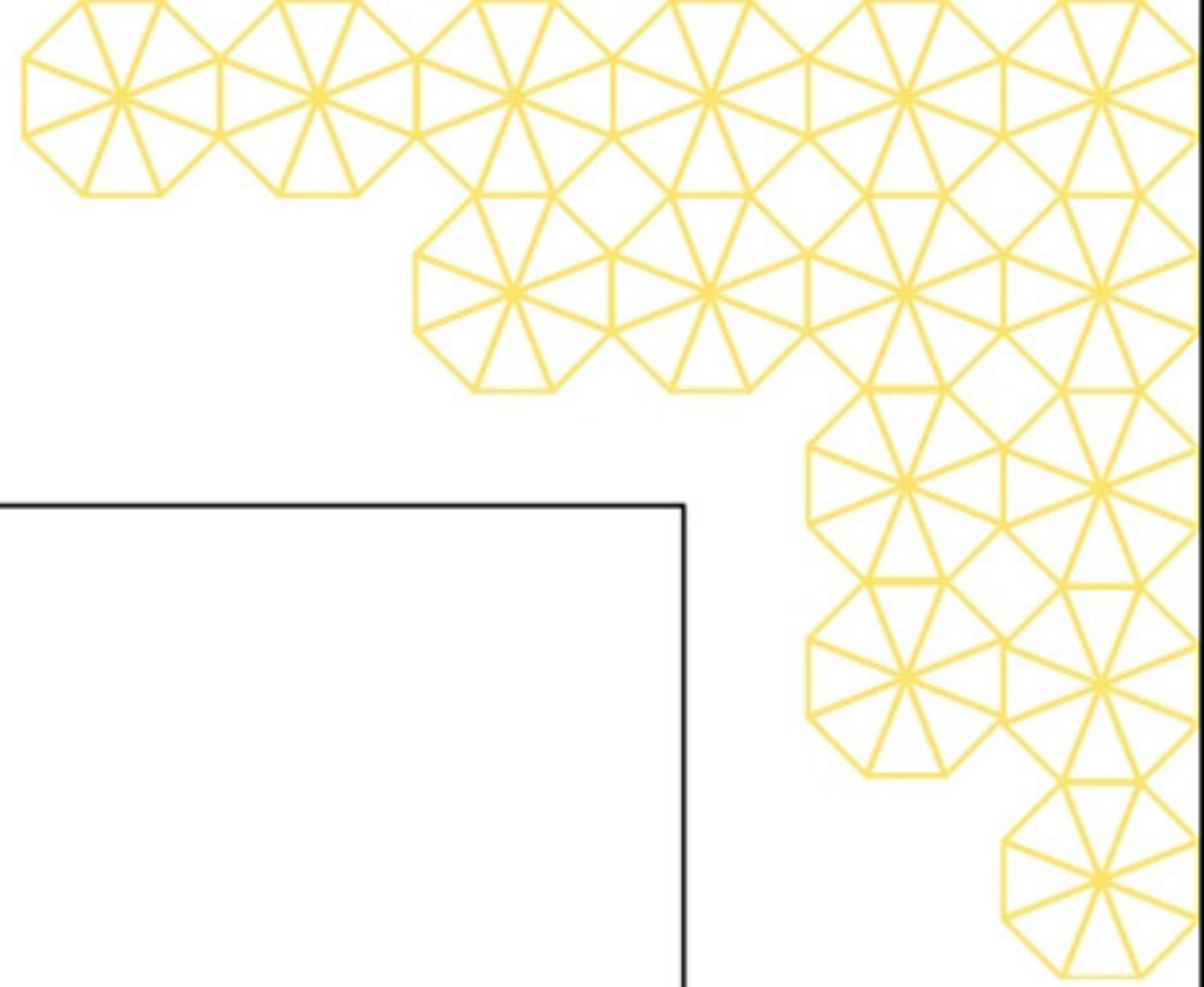




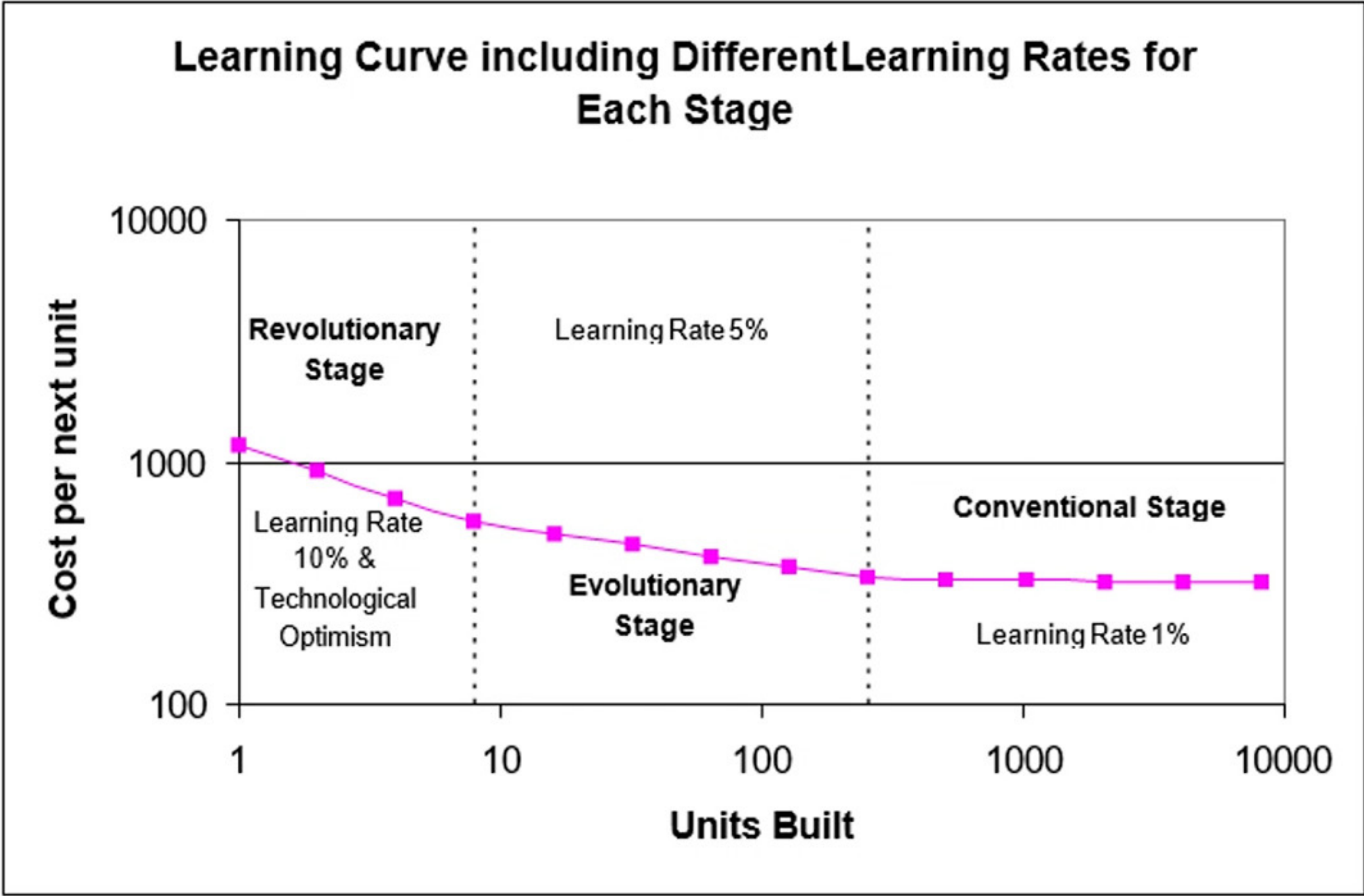
Technology	One Factor Models				Two Factor Models			
	ERIS	MARKAL	MERGE-ETL	MESSAGE	ERIS		MERGE-ETL	
					LBD	LBR	LBD	LBR
Advanced Coal	5%	6%	6%	7%	11%	5%	6%	4%
NGCC	10%	11%	11%	15%	24%	2%	11%	1%
New Nuclear	5%	4%	4%	7%	4%	2%	4%	2%
Fuel Cell	18%	13%	19%	-	19%	11%	19%	11%
Wind	8%	11%	12%	15%	16%	7%	12%	6%
Solar PV	18%	19%	19%	28%	25%	10%	19%	10%






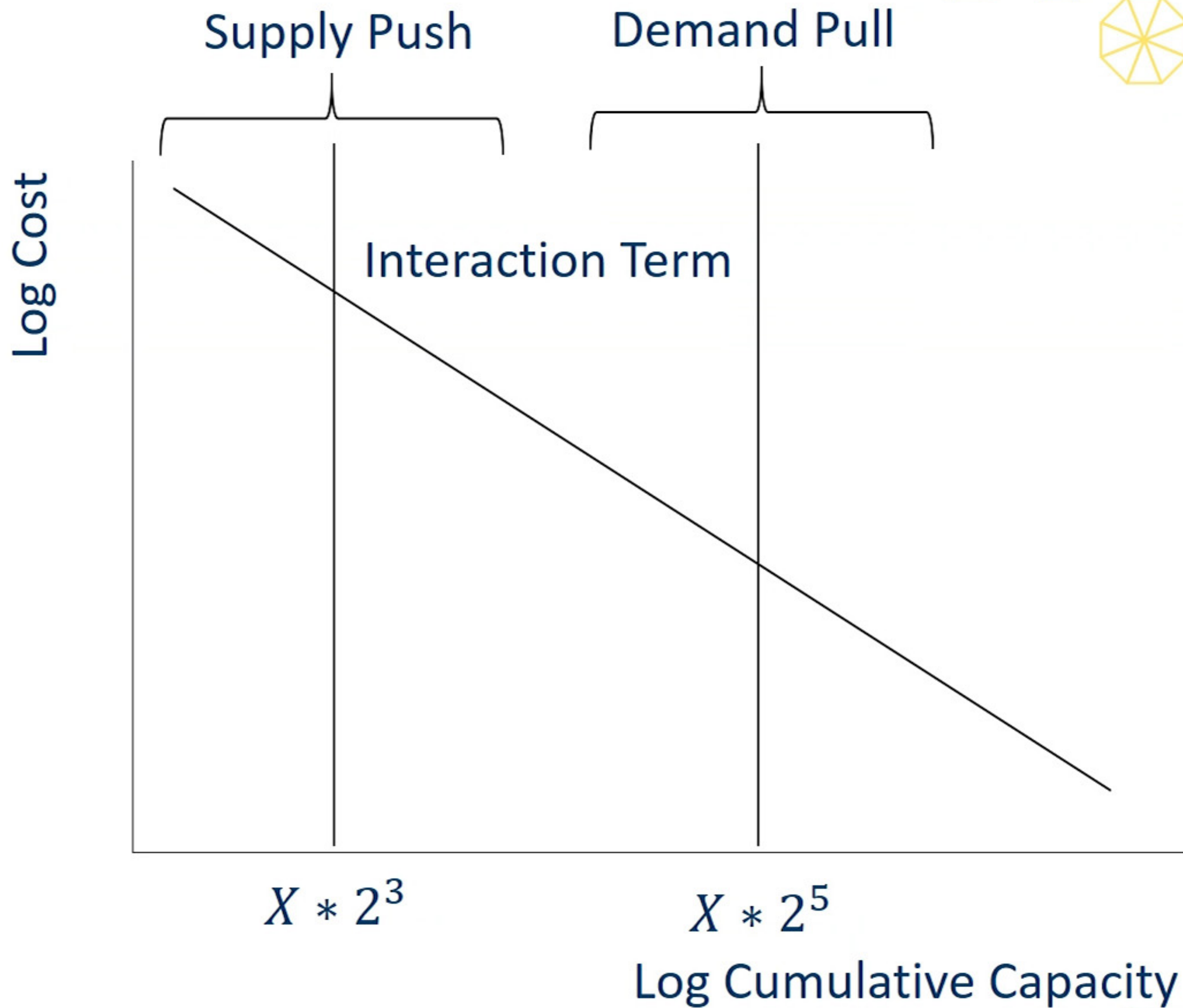


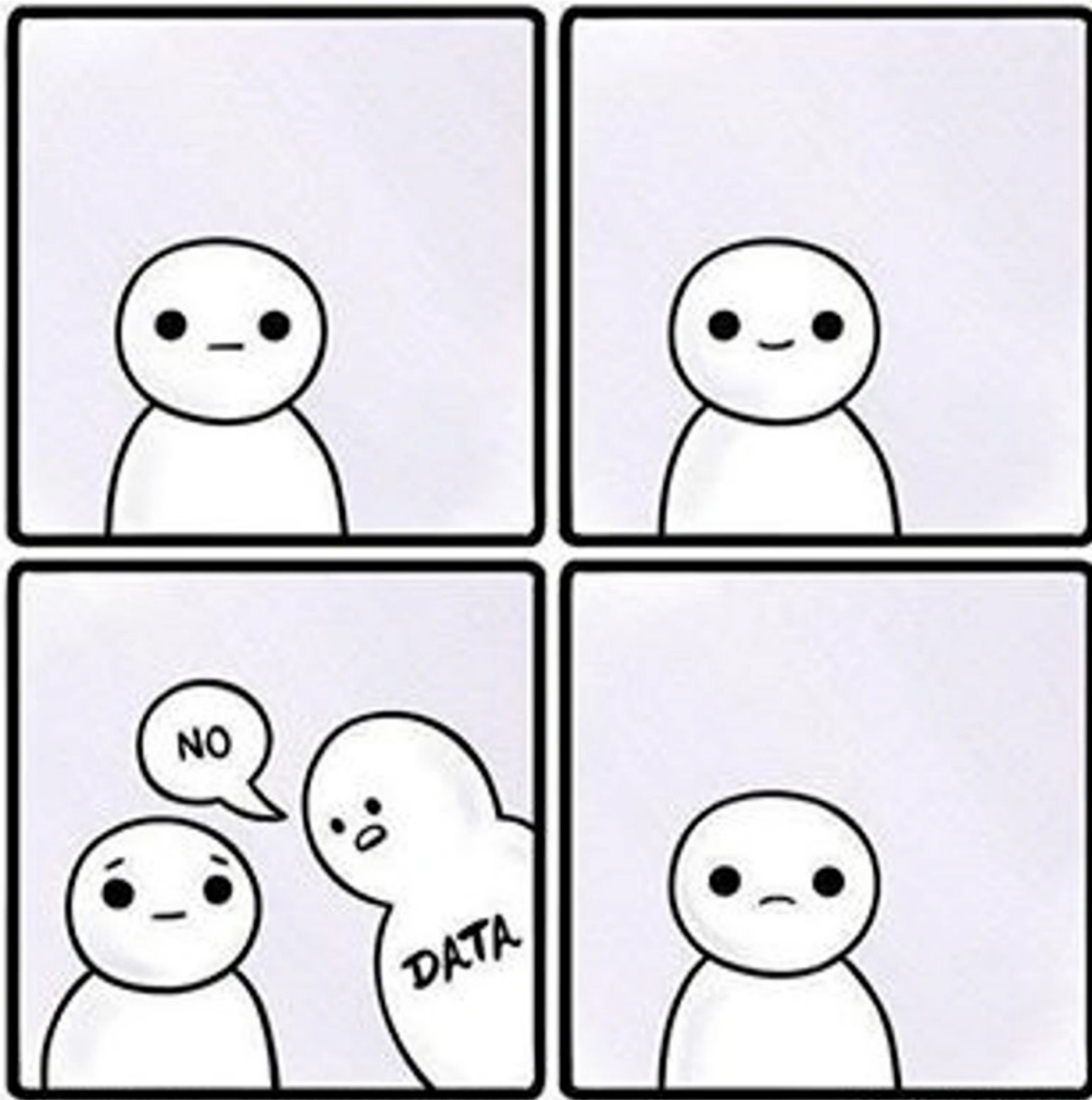




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THIS COMIC MADE POSSIBLE THANKS TO ADAM LINGELBACH

MRLOVENSTEIN.COM



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# Hazel Says: Thank You!

Questions?

