

Economies of Scale vs the Learning Curve

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BIEE 8th Academic Conference, 23 September 2010

POWER

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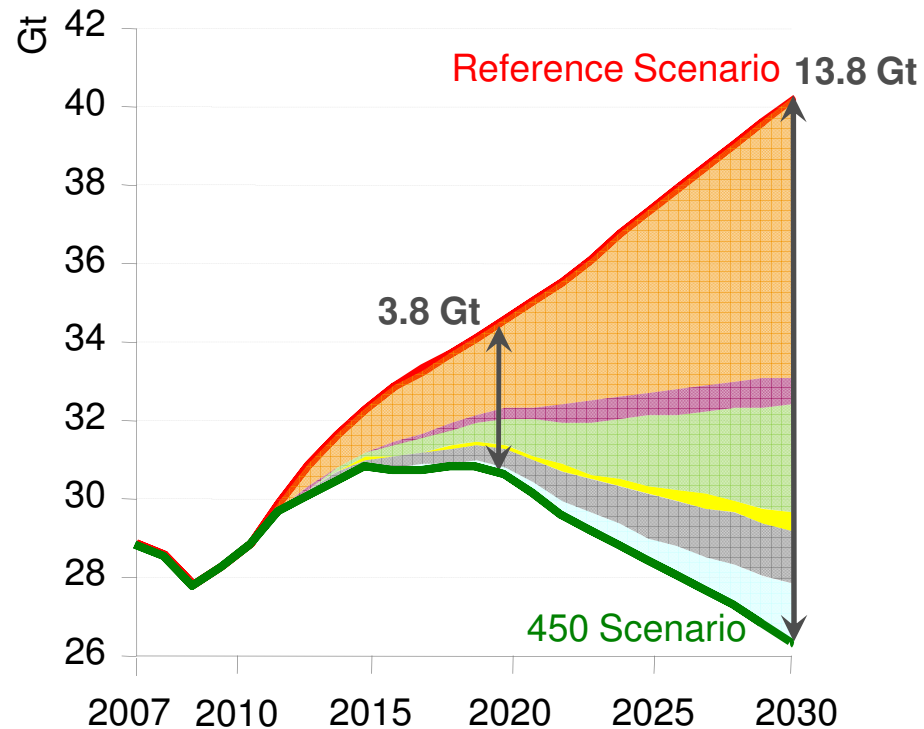
The challenge

Meeting the challenge in the power sector

The policy framework

Conclusions

World abatement of energy-related CO₂ emissions



	Share of abatement %	
	2020	2030
Efficiency	65	57
1. End-use	59	52
2. Power plants	6	5
Renewables	18	20
Biofuels	1	3
Nuclear	13	10
CCS	3	10

Source: International Energy Agency, "World abatement of energy-related CO₂ emissions in the 450 Scenario," **World Energy Outlook 2009**

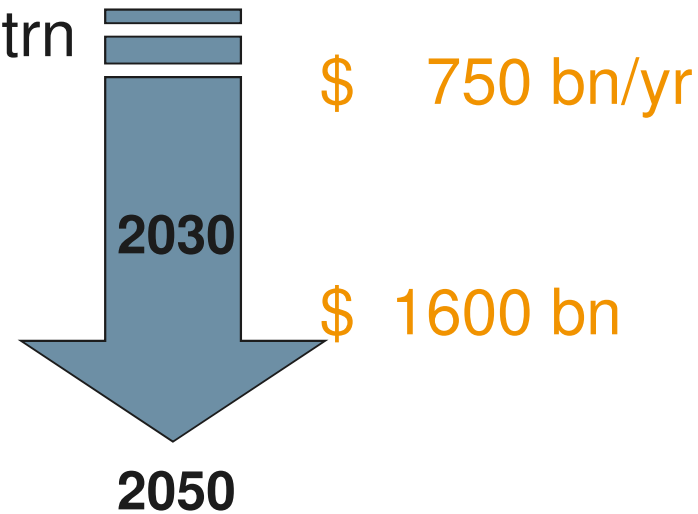
Investment, investment, investment



Baseline \$ 270 trn

“Blue Map”
= 450ppm scenario

\$ 46 trn



Source: International Energy Agency,
Energy Technology Perspectives 2010

**60% of 2030
emissions from existing plants**

**60% of 2030
plants still to be built**

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- **Technology Mix**

- Nuclear
- Renewables

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INVOLVEMENT



- **Production Efficiency**

- Fuel Preparation/Retrofit
- New generation plants
- Energy management



- **Carbon Capture and Storage**



Source: Power Systems analysis

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Meeting the challenge: The full portfolio of technologies is needed



Gas



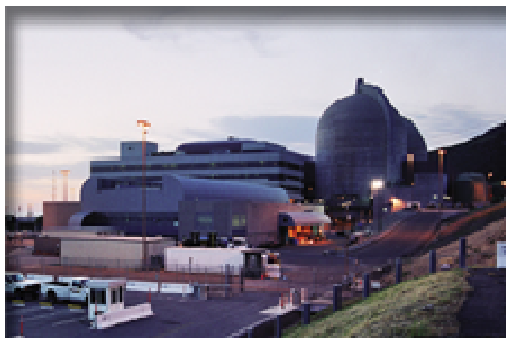
Coal



Oil



Hydro

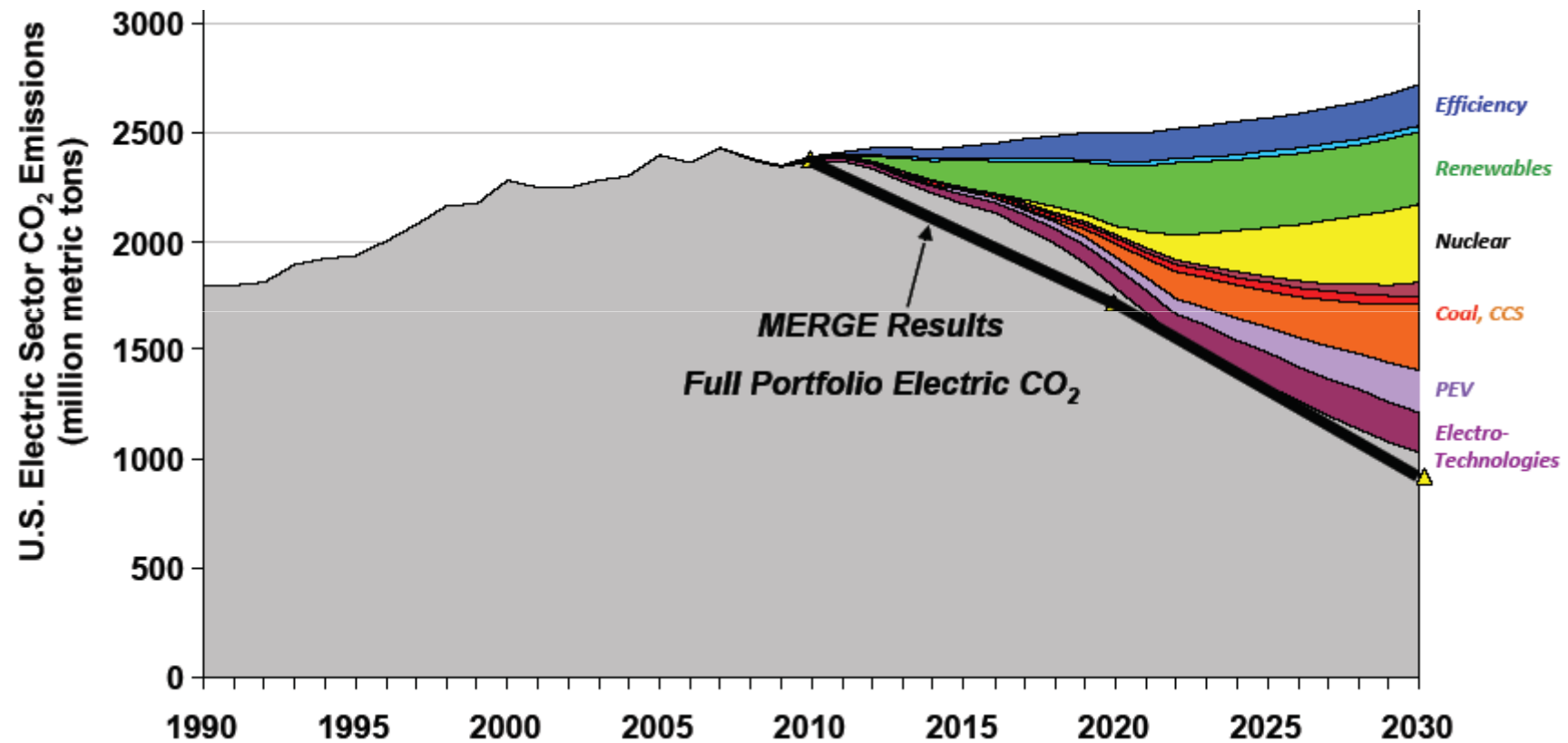


Nuclear (Conv. Island)



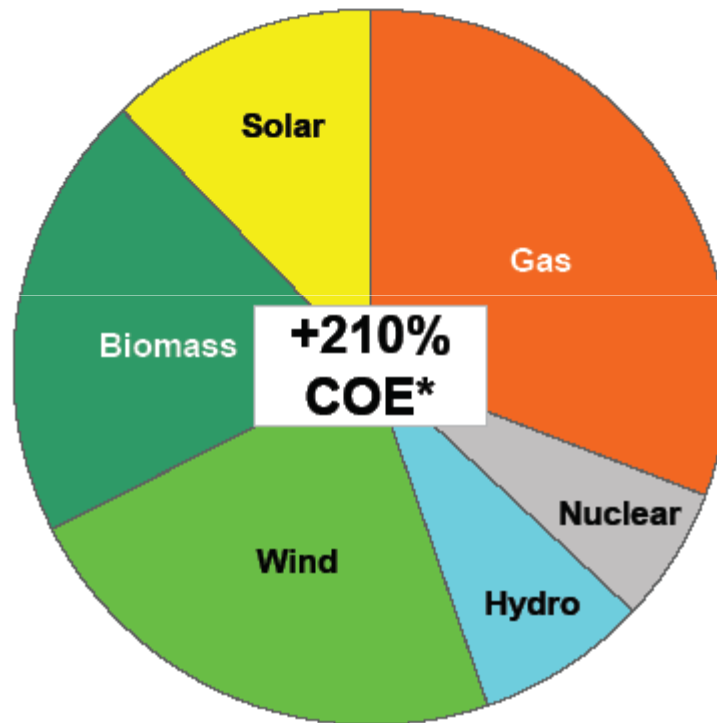
Wind

Meeting the challenge

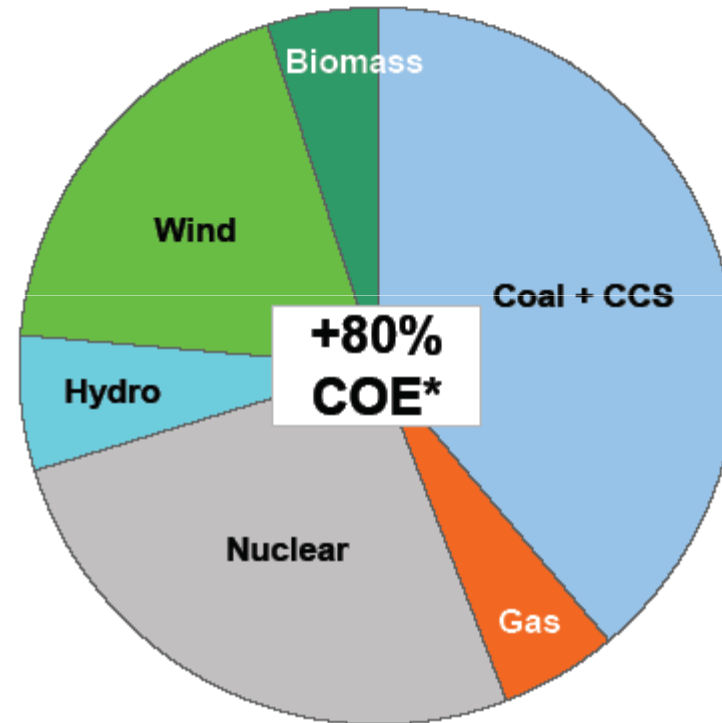


Source: EPRI, "Creating our future," 2009 Summer Seminar

Totally different futures in 2050



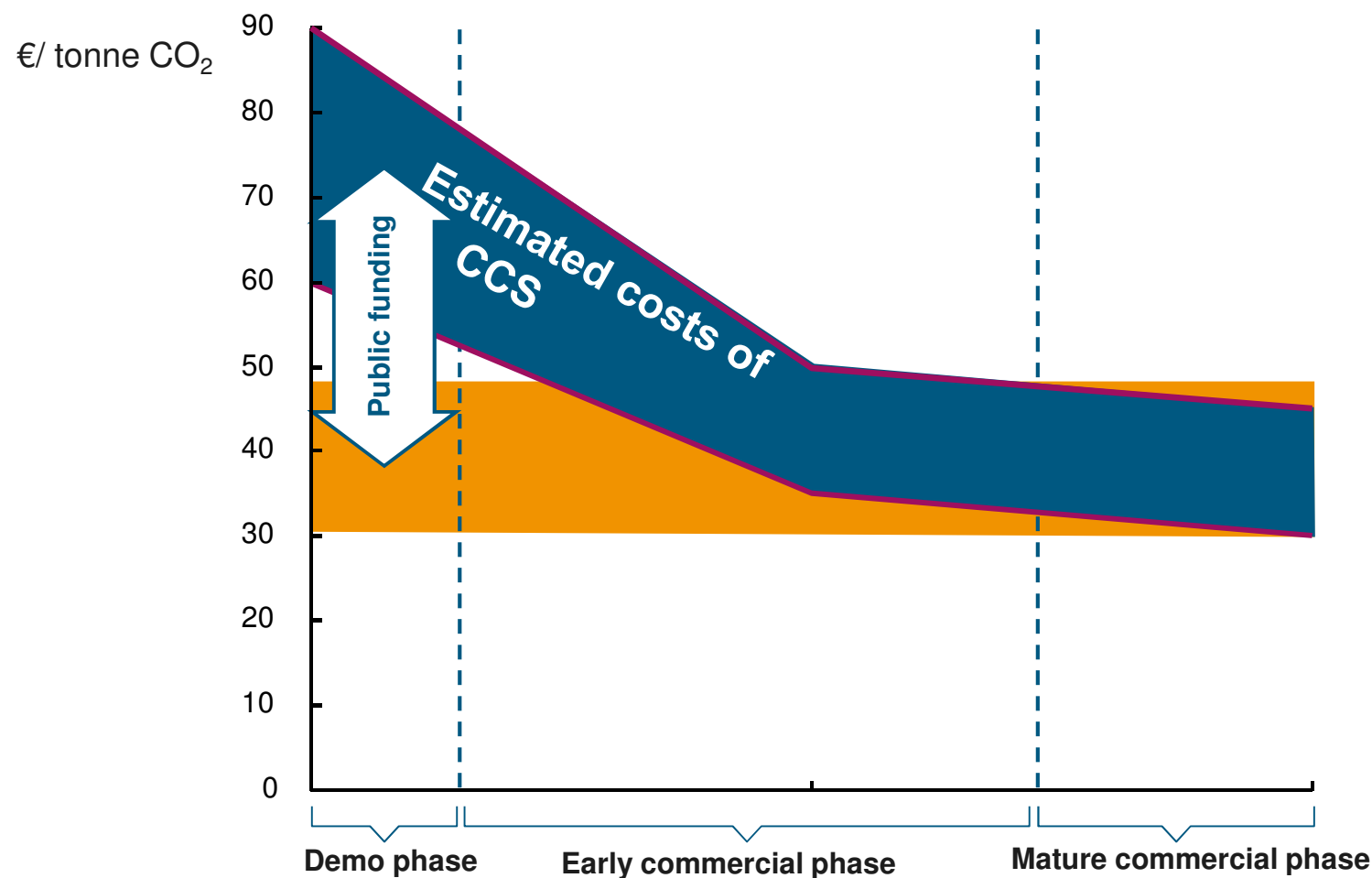
Limited Portfolio



Full Portfolio

Source: EPRI, "Creating our future," 2009 Summer Seminar

Meeting the challenge: evolution of cost of CO₂ avoided

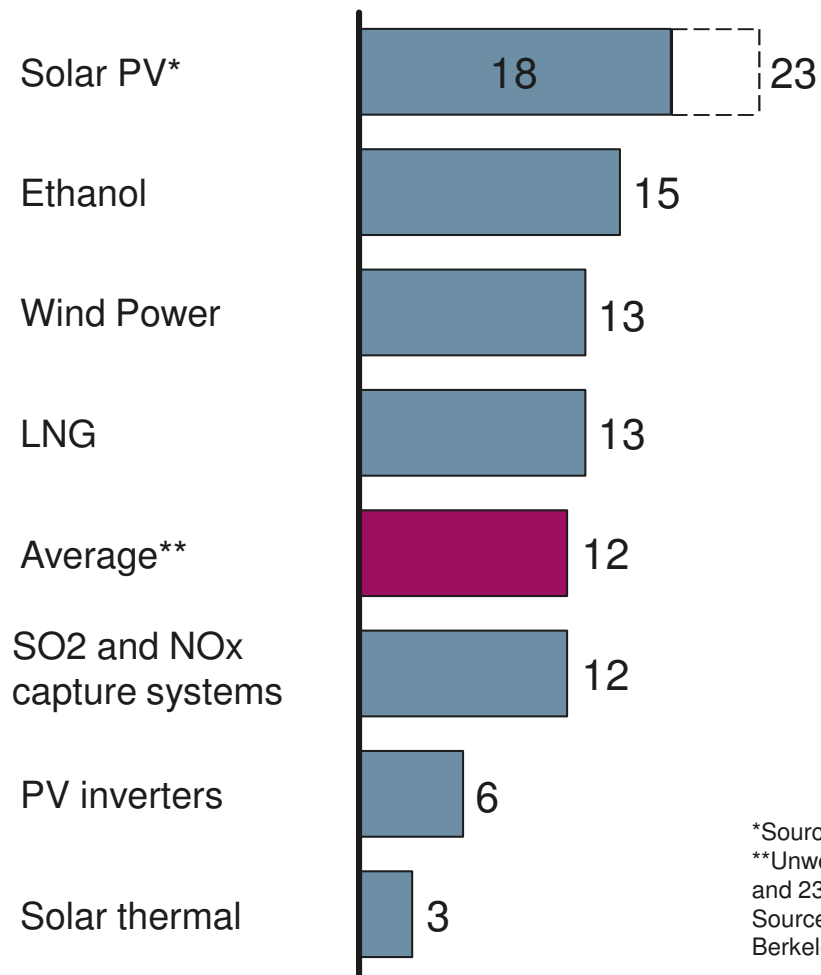


Source: McKinsey & Company "CCS – assessing the economics" for the cost numbers; policy implications drawn by ZEP

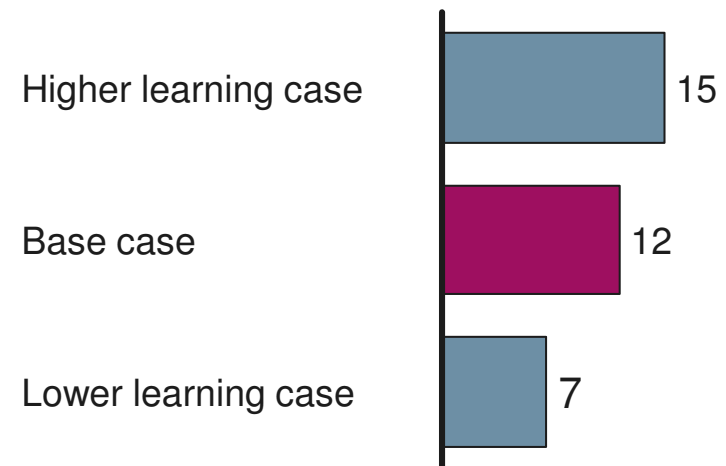
Meeting the challenge: learning rates



Implied learning rates per doubled capacity; various periods



Assumption for CCS

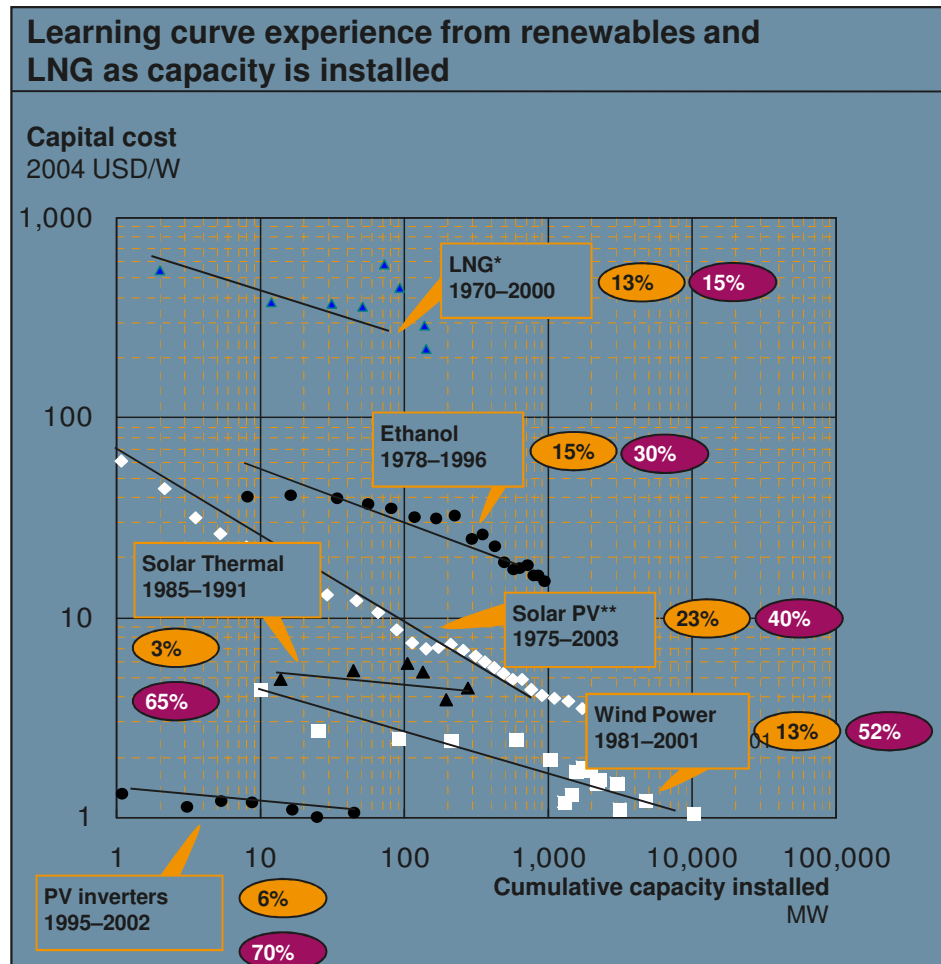


*Sources indicate learning rates between 18 and 23% for solar PV

**Unweighted average of the learning curves, with Solar PV taken at 20.5, the midpoint between 18 and 23

Source: Worldwatch Institute; IEA; IPCC; BTM consult; ABS; NREL; IIEE; ABI; Drewry 2007; UC Berkeley ERG; Navigant consult; McKinsey analysis

CCS learning curves compared to other industries



Implied learning curve per doubled capacity

Capacity CAGR

- **CCS differences: more mature component technologies**
- **CCS main opportunity areas**
 - Improving energy efficiency
 - Standardization of capture technologies

*LNG capital cost measured in USD/t and capacity measured in bcm

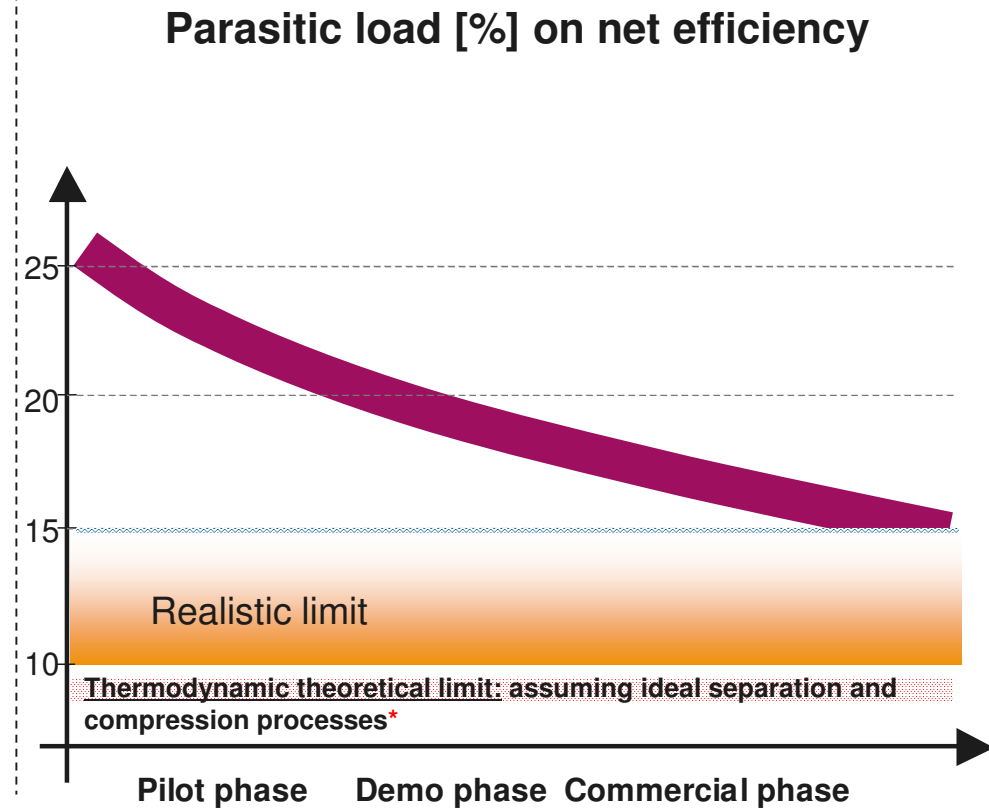
**Other sources indicate learning rates as low as 18% for solar PV

Source: Worldwatch Institute; IEA; BTM consult; ABS; NREL; IIIEE; ABI; Drewry 2007; UC Berkeley ERG; Navigant consulting; McKinsey analysis

Performance is already there...



	<u>CO₂</u> <u>capture rate</u>	<u>CO₂</u> <u>purity</u>
 We Energies Pleasant Prairie USA - Coal - Chilled Ammonia	90%	>99%
 AEP Mountaineer USA - Coal - Chilled Ammonia	90%	>99.9%
 Dow Chemical Co. Charleston USA - Coal - Advanced Amines	90%	>99.5%
 Vattenfall Schwarze Pumpe Germany - Lignite & Bit. Coal - Oxy	90%	>99.7%



...and will continue to improve...

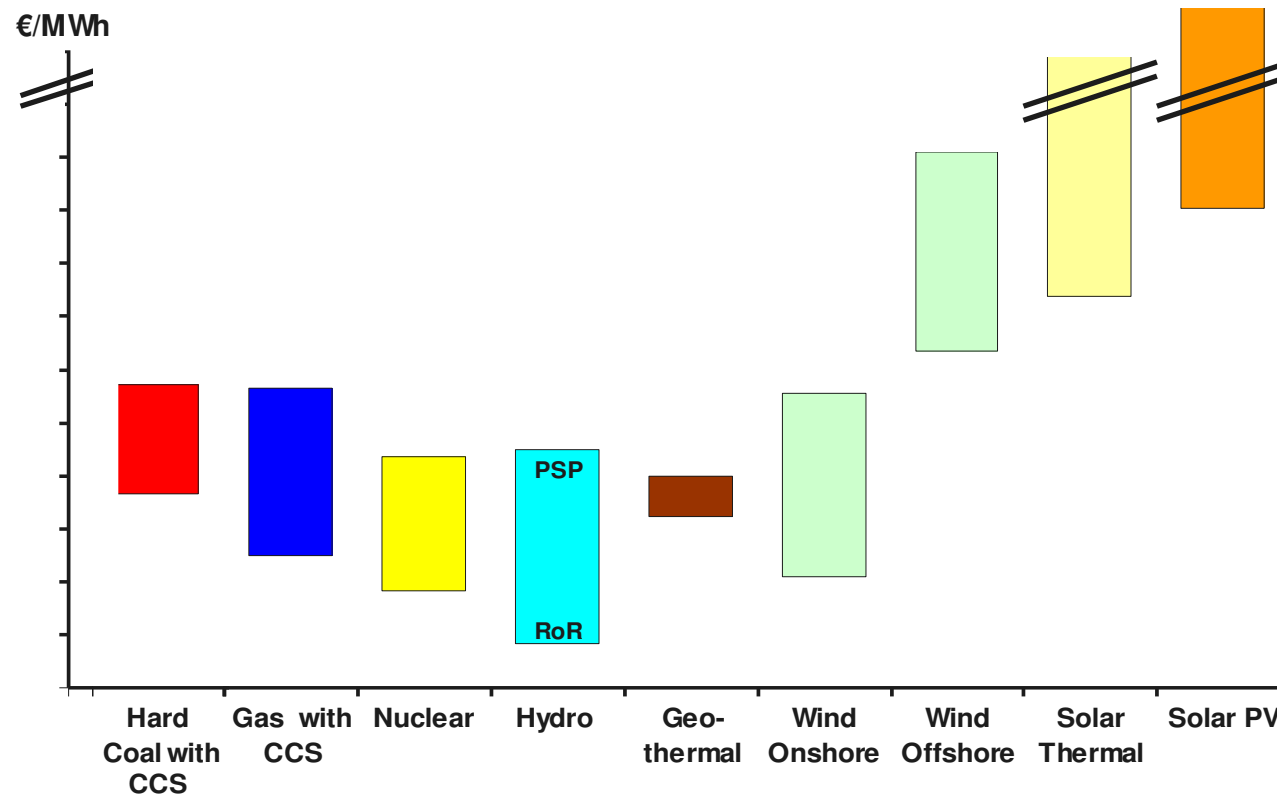
*Theoretical limit assumes ideal separation and compression processes (110bar): isentropic, no losses

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... at a competitive cost



Typical cost of electricity OECD new low carbon power plant construction



CCS is competitive with other decarbonized power sources

Source: Alstom Analysis

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- Funding for large scale demos
- Global – linked cap & trade systems (EU, US, Australia)
- Regional – strategic plan for transport, storage
- National –
 - Regulation of CO₂ storage, including liabilities
 - Regulatory framework – foundation for a commercial offering
- National/Local –
 - Public acceptability

Risks:

- Commercial
- Policy & regulatory (too little too late; inappropriate approaches to e.g. knowledge sharing/IP; tilted playing field)
- Political risk
- Absence of infrastructure

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- Consensus over decarbonising power sector by 2030
- Technologically entirely feasible
- All technology solutions required
- Policy framework to facilitate:
 - Level playing field
 - Targeted support
 - Tackling co-dependencies
 - Better risk management
 - Effective global co-ordination

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