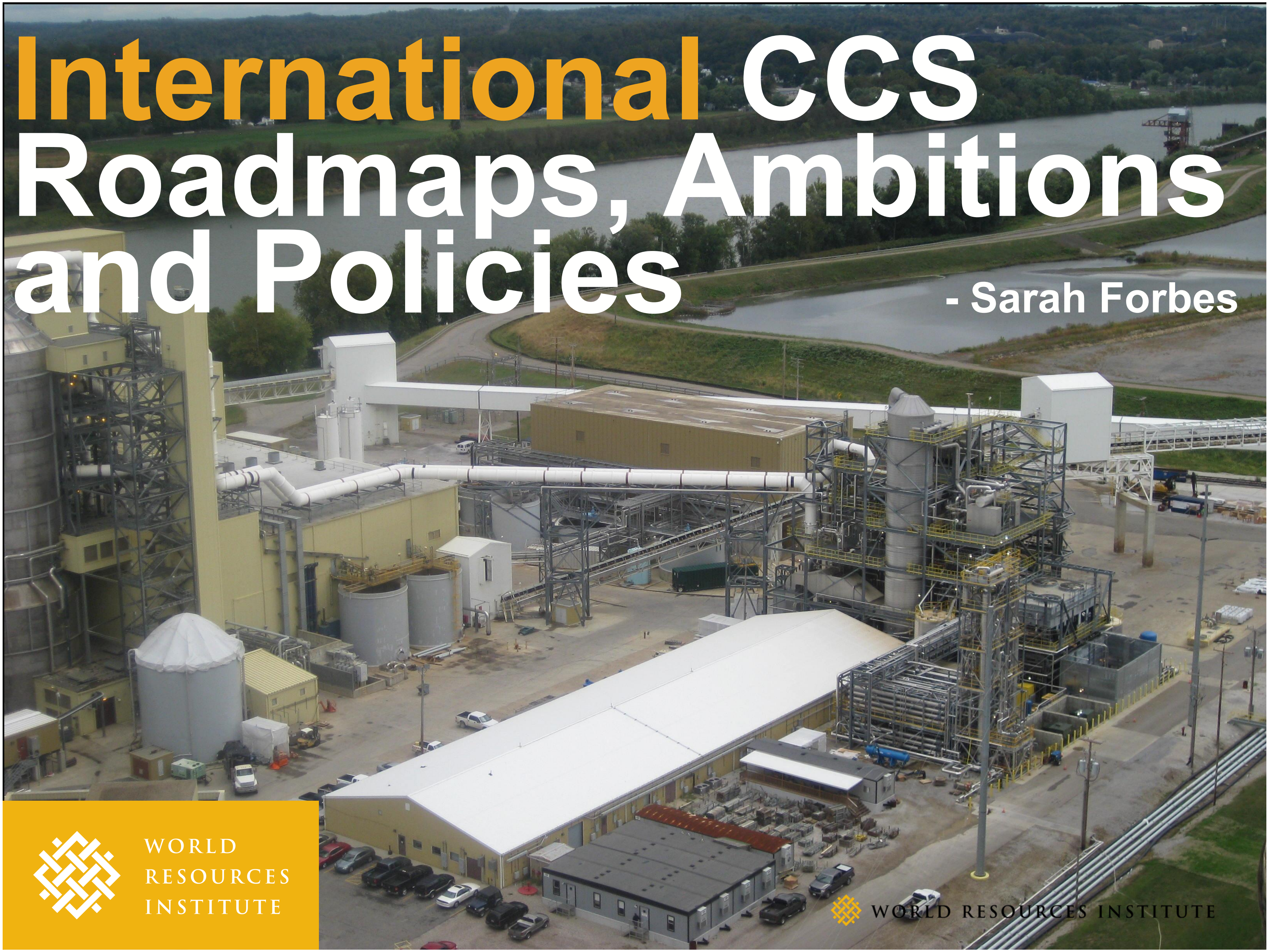
International CCS Roadmaps, Ambitions and Policies

- Sarah Forbes



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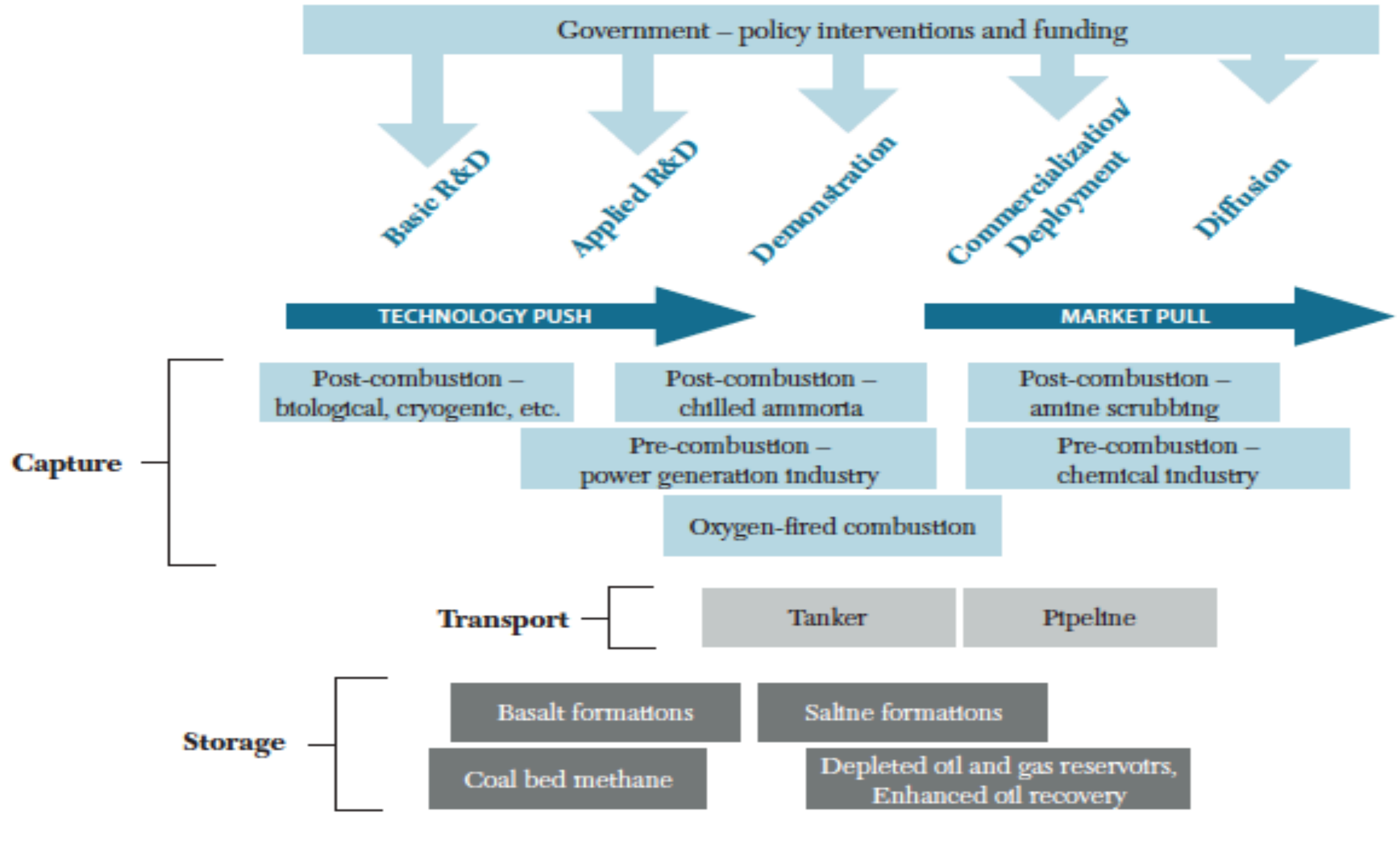
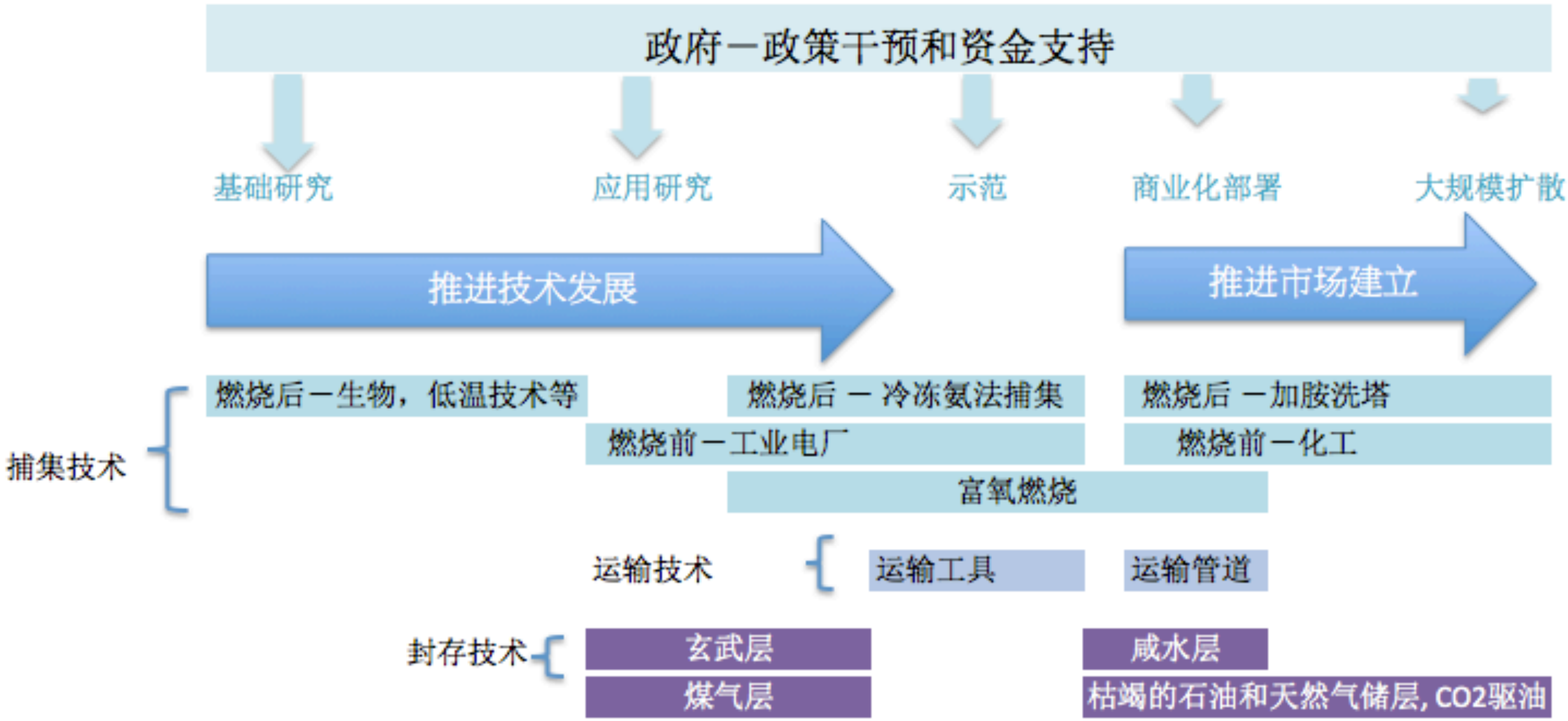
Range of CCS Technologies and Their Stage of Advancement as of 2010

(CCS的各项技术的发展现状，截至2010年)



Note: Innovation chain arrows adapted from E3G/Chatham House.

Range of CCS Technologies and Their Stage of Advancement as of 2010
(CCS的各项技术的发展阶段，截至2010年)



Will predicted costs of CCS be achieved?
碳捕集的预期成本能否达到？

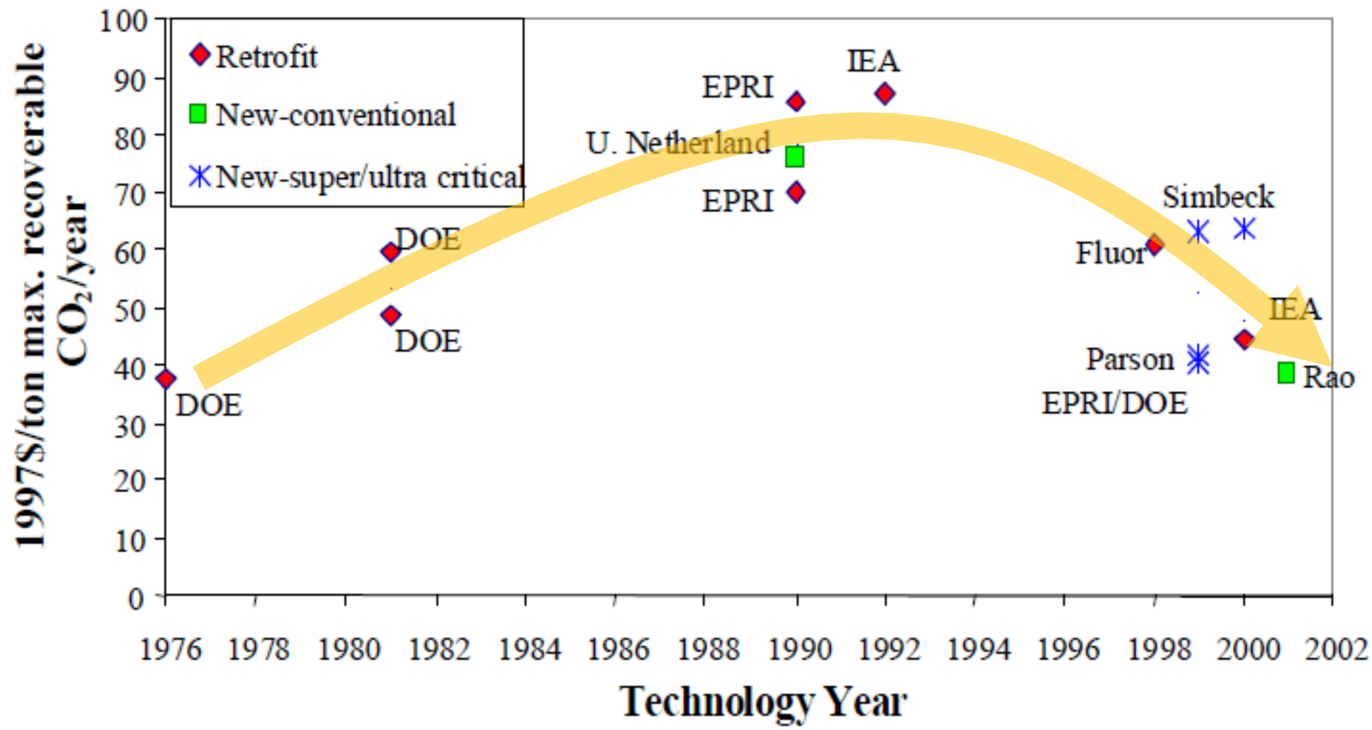


Figure 5. Estimated capital cost of an amine (MEA) carbon capture system at a standardized coal-fired power plant (500 MW, 90% CO_2 removal). These costs include the cost of CO_2 compression (to about 2000 psia) and drying but do not include the cost of power plant capacity needed to supply the energy required for capture plant operation [87].

Source: Yeh and Rubin, 2010. Uncertainties in Experience Curves for Energy-Economic Models

Characteristics of International Process for Developing Roadmaps
(国际上发展路线图的特点）

- Significant stakeholder input （重大利益相关者的参与）
- Usually led by government research organization （通常由政府研究机构领导）
- Deployment-focused roadmaps sometimes come from other types of organizations, including policy-makers and NGOs （这些以部署为主的路线图有时来自政策决策者和其他非政府机构）

Common features among CCS roadmaps（各路线图的共同特点）

- Cover technology development cycle from RD&D through Diffusion （覆盖整个技术的发展过程—从基础研究到最后的大规模应用）
- Feature integrated assessments like generation of National Atlases or source-sink matching （各种特征的有机结合，比如国家碳源的地图集和封存地的结合）
- Goals and milestones that are time-bound （有时限的目标和里程碑）
  - Cost of capture/electricity （捕集与发电的成本）
  - Tons of CO_2 stored （封存CO_2的数量）
  - Number of large-scale integrated CCS projects （大型全流程CCS工程的数量）

National and International Roadmaps for CCS （国家及国际机构的CCS路线图）

- International （国际）
  - IEA CCS Roadmap （国际能源署）
  - IEA/UNIDO CCS Industrial Roadmap （国际能源署与联合国工业发展组织的CCS工业化路线图））
- National （国家）
  - Australia （澳大利亚）
  - Canada （加拿大）
  - Egypt （埃及）
  - Hungary （匈牙利）
  - Japan （日本）
  - Malaysia （马来西亚）
  - Poland （波兰）
  - US （美国）
  - UK （英国）
  - South Africa （南非）

IEA. A pathway for wide deployment of CCS
(国际能源署对未来CCS部署的路线设计）

Next seven years:
Creating conditions for wide deployment
（未来7年创造条件）

2020-2030:
Large-scale deployment picks up speed
（2020-2030，大型项目开始加速）

2030 and beyond:
CCS is mainstream
（2030及未来，CCS成为主流）

2013 — 2020 — 2030 — 2050

Vision 2020:
Over 30 large projects are in operation storing 50Mt CO2 per year, providing experience and enabling cost reduction. Incentive policies are in place to drive early deployment. （到2020年，30个以上的大型CCS项目在电厂及其他行业运作，每年封存50Mt二氧化碳，提供技术经验。）

Vision 2030:
CCS is a veritable industry. Over 2Gt CO_2 is stored per year. Continued R&D and economies of scale reduce costs significantly. Business cases are consolidated and drive private investment. . (到2030年，每年2Gt以上CO2将被封存。继续的基础研发和经济上的规模化将大幅度降低成本。商业案例的成功，并驱动民资的进入。）

Vision 2050:
CCS is routinely used to reduce CO_2 emissions from power and all suitable industry. The total global storage rate exceeds 7 $GtCO_2$/yr. CCS projects are commercial under technology-neutral climate change policies worldwide in all sectors. (到2050年，每年7Gt以上CO2将被封存。CCS在工业及电厂上被常规化应用。在气候变化政策下，CCS实现商业化。）

Slide courtesy of IEA.

IEA. 7 key actions for the next 7 years

（国际能源署—未来7年的关键行动）

Lead stakeholder	*Actions*
Government	Introduce financial support mechanisms for demonstration and early deployment of CCS to drive private financing of projects.
Government	Implement policies that encourage storage exploration, characterisation, and development for CCS projects.
Government	Develop national laws and regulations as well as provisions for multilateral finance that effectively require new-build, base-load, fossil-fuel power generation capacity to be CCS-ready.
Industry	Prove capture systems at pilot scale in industrial pilot applications where CO_2 capture has not yet been demonstrated.
Government	Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology and the importance of its deployment.
Industry/R&D	Reduce the cost of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles.
Government	Encourage efficient development of CO_2 transport infrastructure by anticipating locations of future demand centres and future volumes of CO_2.

Slide courtesy of IEA.

IEA. 7 key actions for the next 7 years

（国际能源署－未来7年的关键行动）

关键利益相关者	行动
政府	引入财税激励机制引导民资支持技术示范和早期部署
政府	政策上鼓励封存地的探索，确定其特征，以及发展CCS工程
政府	发展国家政策法律以及多方融资条例，积极地要求新建化石能源电厂准备做好接入CCS的准备
工业界	证明捕集技术的技术成熟性
政府	努力提高公众和相关利益方理解CCS的重要性
工业界／科研机构	进一步提高CCS与电厂结合的经济性
政府	鼓励有效地发展CCS的运输的基础设施，并预计未来CO_2的消费区域以及CO_2的数量

Capture （捕集）

IEA. Capture technologies overview
（国际能源署－捕集技术的概况）

2013

- "First-phase industry" processes are commercial
- *Post-process capture* technology in the power sector is catching up

2016

- IGCC and DRI are demonstrated
- Chemical looping and some other advanced technologies are piloted

2020

- All gas and coal-fired power generation capture technologies demonstrated
- Most processes advanced from lab to pilot scale

US. Timeline for post-combustion research
（美国发展燃烧后技术的时间表）

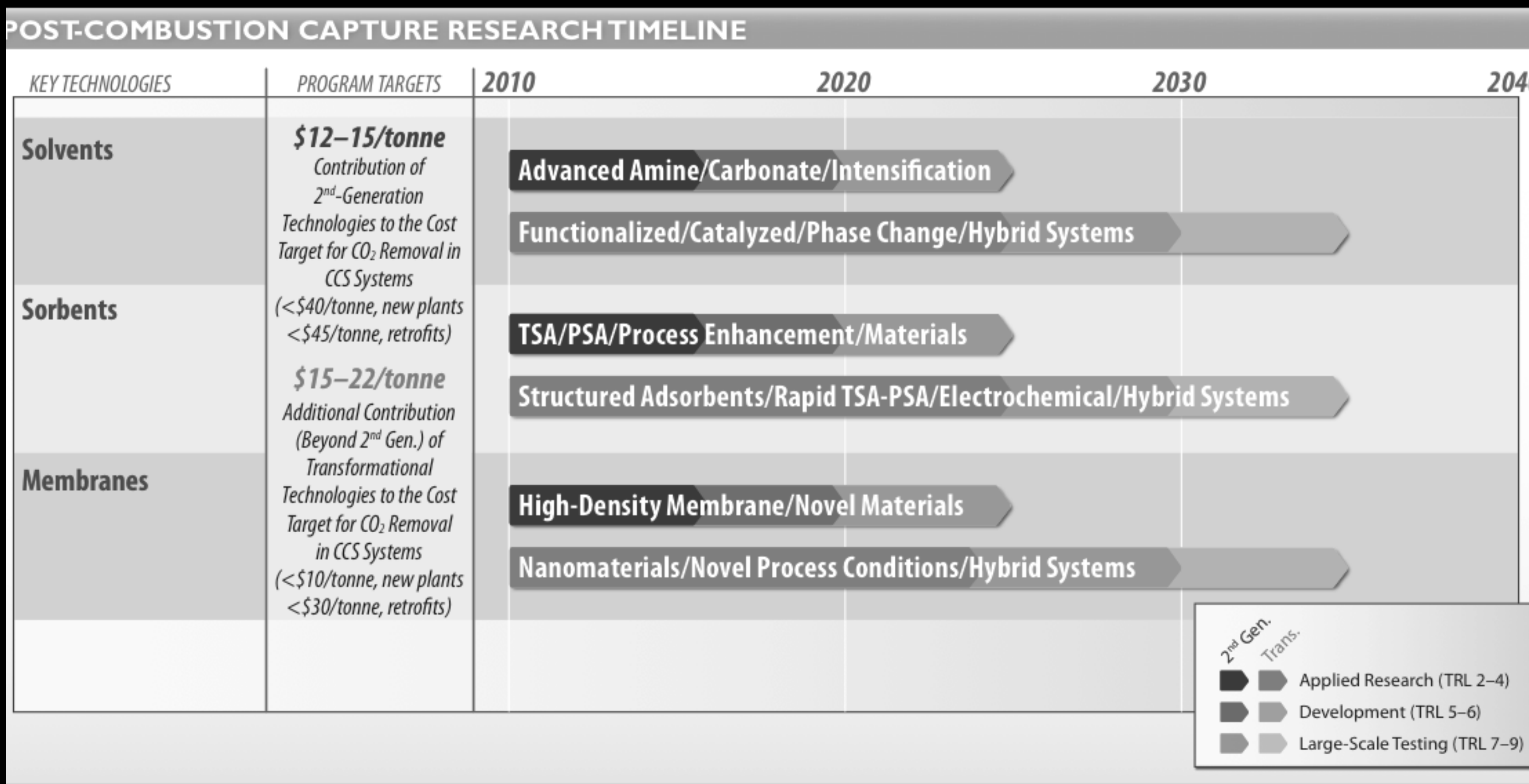
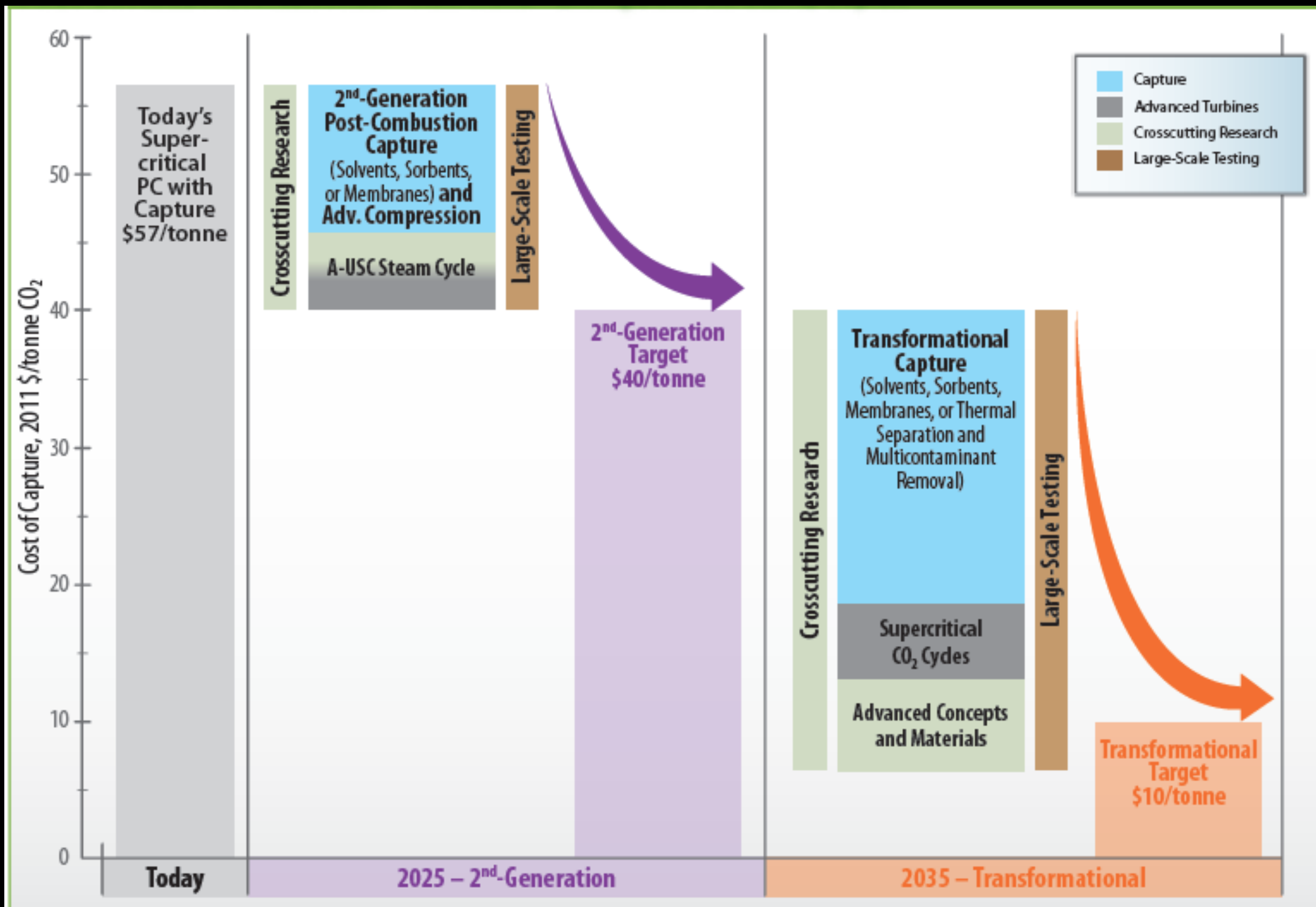


Figure 4-3. Post-Combustion Capture Development Timeline

US. Post-Combustion New Plants Pathway—Driving down the Cost of Capture
（美国燃烧后技术－新电厂的发展路径－降低捕集成本）



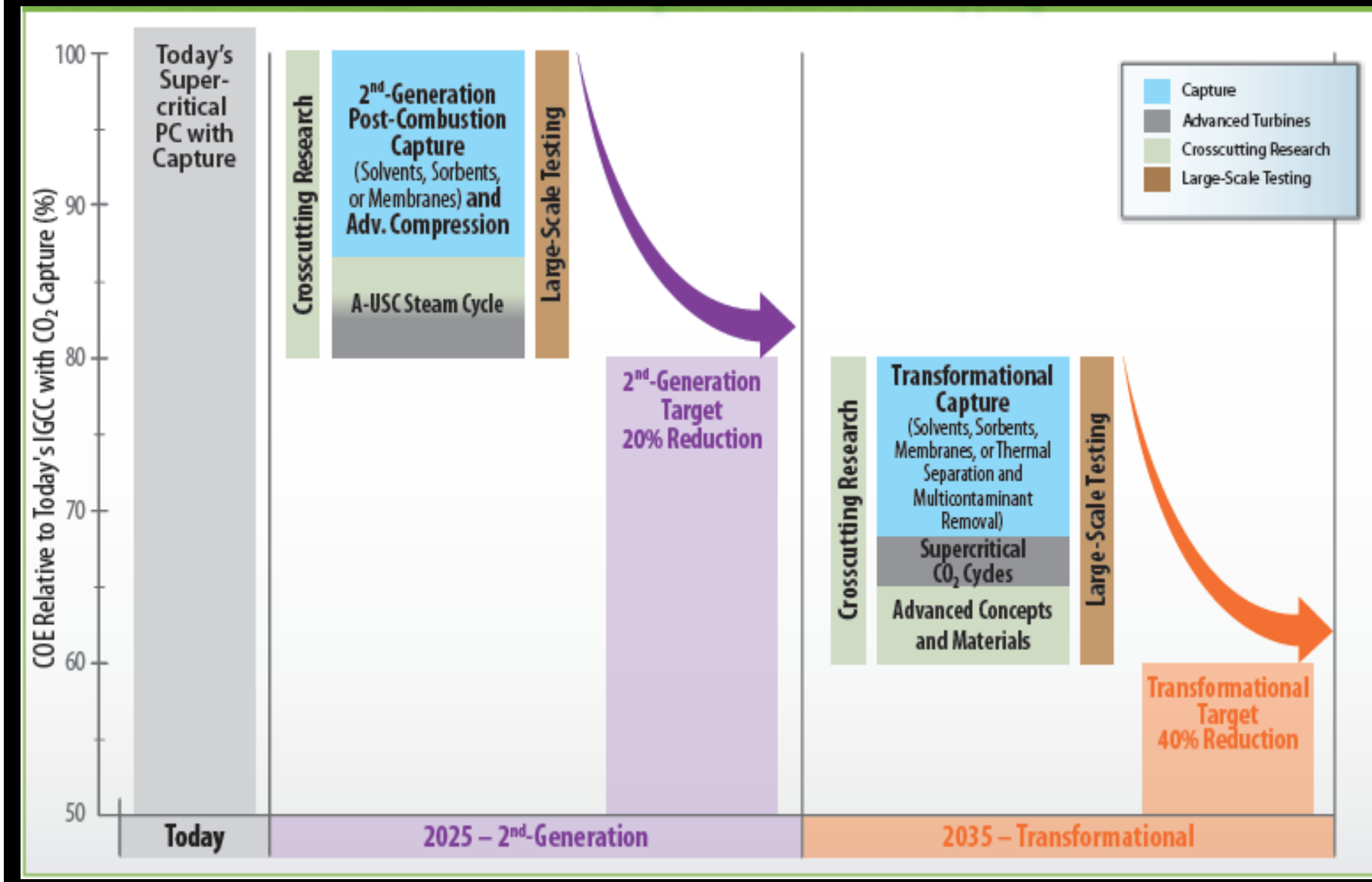
*今天在美国，超临界电厂燃烧后捕集的成本是 $57 / 吨。

*我们希望通过技术的研发提高和大型工程的测试，到2025年能实现$40 / 吨的捕集成本。

＊同样，到2035年，实现$10元 / 吨的捕集成本。

Slide courtesy of NETL/US DOE FE.

US. Post-Combustion New Plants Pathway —Driving down the Cost of Electricity



*这张图主要显示未来CCS电厂电价相对于今天IGCC＋CCS的电价目标。

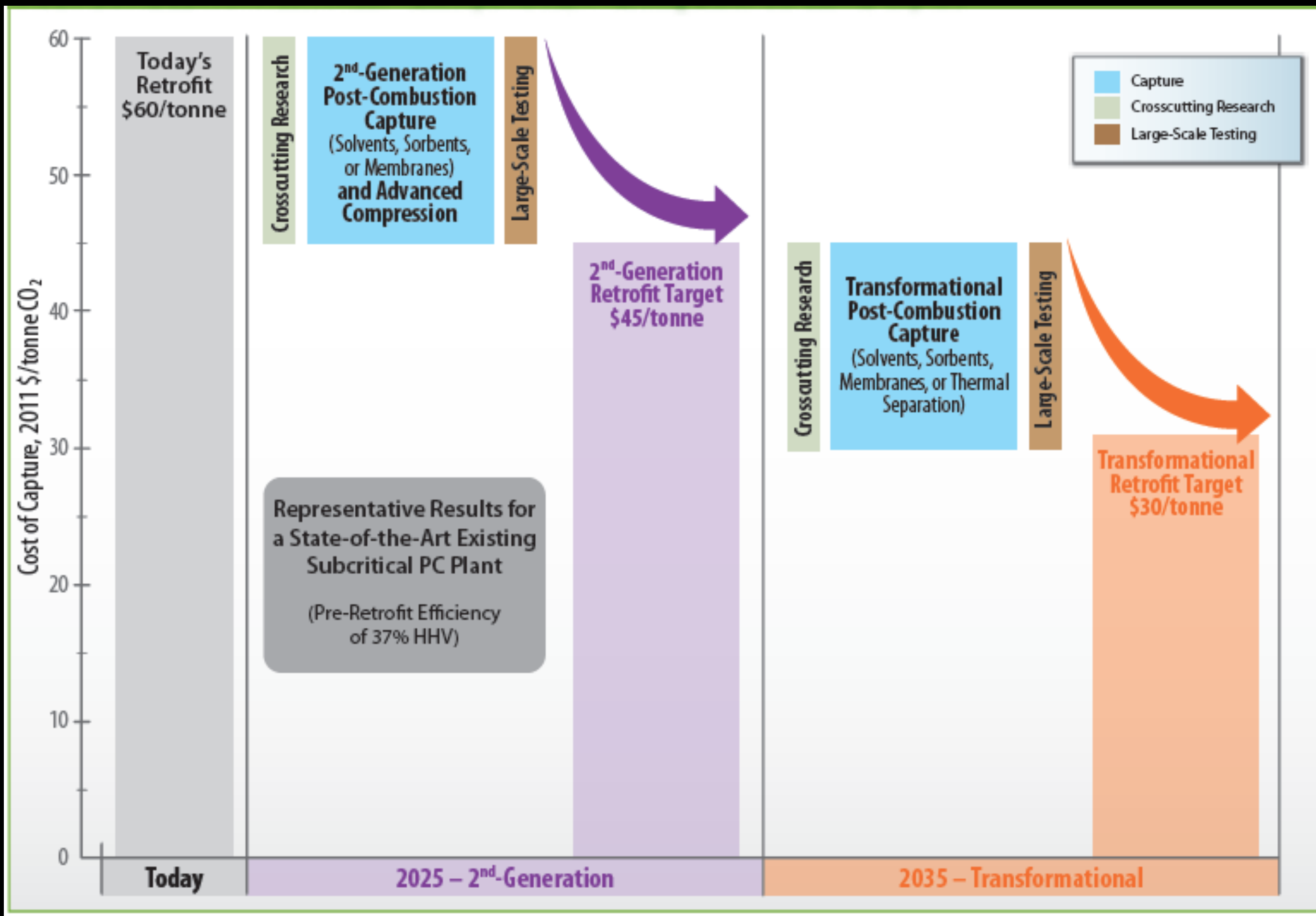
*我们希望通过技术的研发提高和大型工程的测试，到2025年能实现电价相对于今天20%的下降。

＊同样，到2035年能实现电价相对于今天40%的下降。

Slide courtesy of NETL/US DOE FE.

US. Post-Combustion Example Retrofit Pathway—Driving down the Cost of Capture

（美国燃烧后技术－旧电厂改造的发展路径－降低捕集成



*今天在美国旧电厂改造加燃烧后捕集的成本是 $60 / 吨。

*我们希望通过技术的研发提高和大型工程的测试，到2025年能实现$45 / 吨的捕集成本。

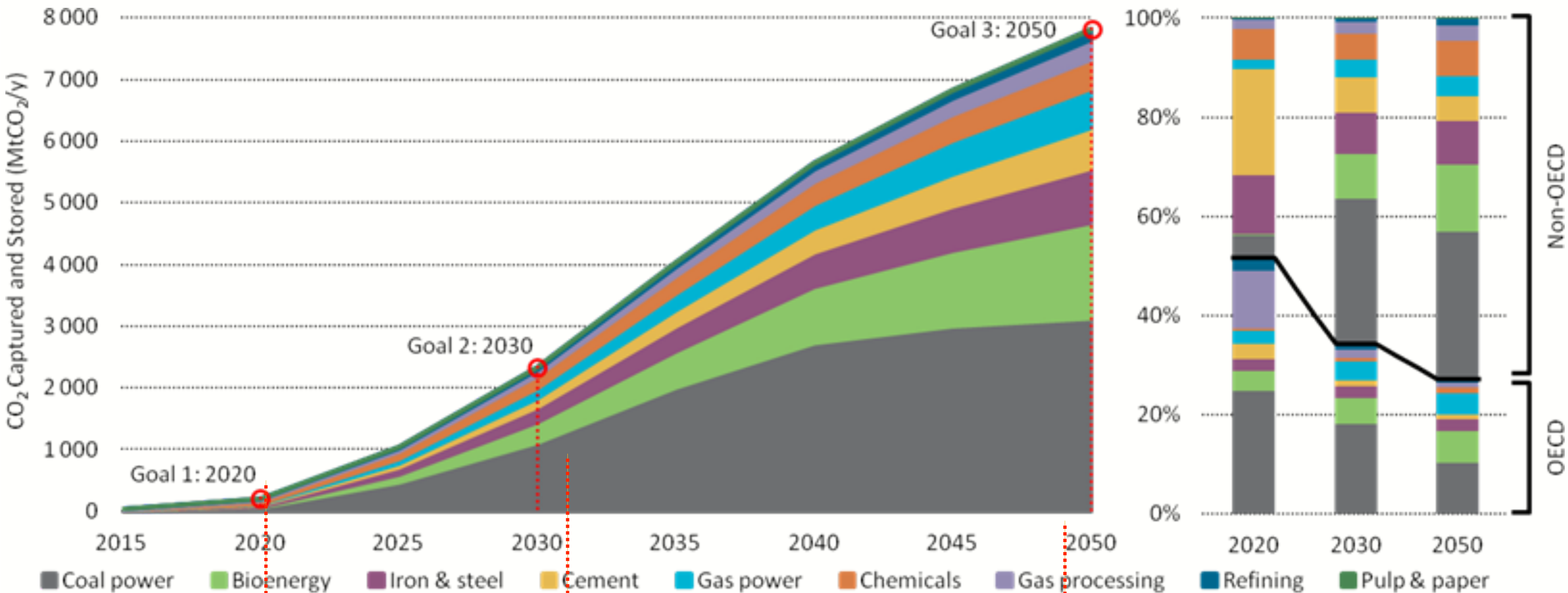
* 同样，到2035年，实现$30元 / 吨的捕集成本。

Slide courtesy of NETL/US DOE FE.

(Photo: Giorgio Giorgetti/Flickr)

IEA vision: 120 Gt of CO2 stored by 2050

（国际能源署的封存目标一到2050年，有120Gt的CO_2能被封存）



Goal 1: 2020:
Over 30 large projects are in operation in power and across a range of industrial processes, storing 50Mt CO_2 per year.
(到2020年，30以上的大项目在电厂及其他行业运作，每年封存50Mt二氧化碳）

Goal 2: 2030:
Over 2Gt of CO_2 is stored per year. CCS is routinely used in power and certain industrial applications
. (到2030年，每年2Gt以上CO_2将被封存。CCS被常规化应用在电厂和某些工业上）

Goal 3: 2050:
Over 7Gt of CO_2 is stored per year. CCS is routinely used in all applicable power and industry.
(到2050年，每年7Gt以上CO_2将被封存。CCS被常规化应用在电厂和工业上.）

US Goals for Carbon Storage
(美国在二氧化碳封存上的目标）

- ***2020—For*** first mover projects, develop and validate technologies to ensure 99 percent storage permanence while offsetting capture cost with utilization. For these projects, it is assumed that saline storage must comply with the EPA Class VI regulations... Large-scale testing of these technologies will be underway by 2020 and widespread commercialization will be underway by 2025.
- ***2030—For*** broad deployment projects, develop and validate technologies to improve storage efficiency, and ensure 99 percent storage permanence while ensuring containment effectiveness in all storage types. Large-scale testing of these technologies will be underway by 2030 and widespread commercial application will be underway by 2035.

US Goals for Carbon Storage
(美国在二氧化碳封存上的目标）

- ***2020***一对于先行的项目，开发和验证技术以确保99%的存储永久性，同时用利用技术来抵消捕捉与成本。对于这些项目，盐水封存必须符合EPA VI级法规…大规模测试将在2020年大范围进行，广泛的商业化将在2025年展开。

- ***2030***–对于大规模部署的项目，开发和验证技术提高存储效率，并确保99%的存储永久性，同时确保所有存储类型的存储效率。这些技术的大规模测试将在2030年开始进行，广泛的商业应用将是在2035年产生。


Policy （政策）

Regardless of Roadmaps, Design of policies will affect the timing and scale of CCS deployment

政策设计会影响碳捕集和封存的时机和规模

Reduce capital and operating costs
减少资金和操作成本

Tax incentives
税收鼓励

Loan guarantees
贷款担保

Develop enabling policies and experience
发展授权政策和经验

Infrastructure investments
基础设施投资

Environmental regulatory frameworks
环境制度框架

Grants for R&D
研发资金补助

Require Action
需要行动

Moratoriums on coal without CCS
中止无碳捕集的煤炭使用

Performance standards for power plants and industrial facilities
发电厂和工业设施的绩效标准

US EPA has proposed standards for new generation…

美国环保局对新的发电厂提出的标准…

499 kg CO_2/MwH Coal

454 kg CO_2/MwH gas

CCS emissions can be averaged over 7 years

碳捕集排放可以平均分布于7年中

Applies only to new generation

只对新的发电厂适用

Anticipates cost reductions

预期成本减少

Benefits of partial CO2 capture for SCPC plants via flue gas bypass (Hildebrand, 2009)
SCPC电厂通过烟气旁路进行部分碳捕集的好处

- Reduced size of equipment results in reduced capital costs
  设备尺寸变小导致资金花费变少
- Reduced and optimized steam extraction leads to improved plant output and efficiency
  抽汽的充分利用导致电厂产出和效率的改善
- Reduced parasitic power loss leads to improved plant output
  寄生功率损耗减少导致电厂产出提高
- Potential for temporary bypass gives greater dispatch and increased grid capacity during peak power
  暂时旁路的潜能在用电高峰期增加配电和输电网容量
- Reduced need for water and chemicals means lower operating costs
  对于水和化学物品需要减少，降低运营成本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