Economic assessment of CCS

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cags
China Australia Geological Storage of CO_2
中澳二氧化碳地质封存

CO2CRC

Aims of doing economics

- **Assess whether the project is economically viable**
  评估项目的经济可行性
- **Compare CCS with alternatives**
  对比CCS和其他减排技术
- **Design of CCS projects (trade-offs)**
  对比不同的CCS项目方案（权衡取舍）

Aims of presentation

- To show:
  - how to calculate CCS costs
  - some of the factors that affect CCS costs
  - how to use economics to compare different CCS projects
  - how economics can be used to make business and investment decisions for CCS

Outline

Part I – Economic methodology

- Cash flow analysis (现金流分析法)
- Present value (现值)

Part II – Measures of CCS economics

- CO_2 avoided (清除的CO_2)
- $ per tonne CO_2 avoided (清除每吨CO_2的单位成本)

Part III – Evaluating CCS projects

- Main factors affecting CCS costs
- Factors affecting capture costs
- Factors affecting transport and injection costs

Cash flow analysis

Cash Flow

- Cash flow is the cash received and the cash spent over a defined period of time

Net cash flow = cash received

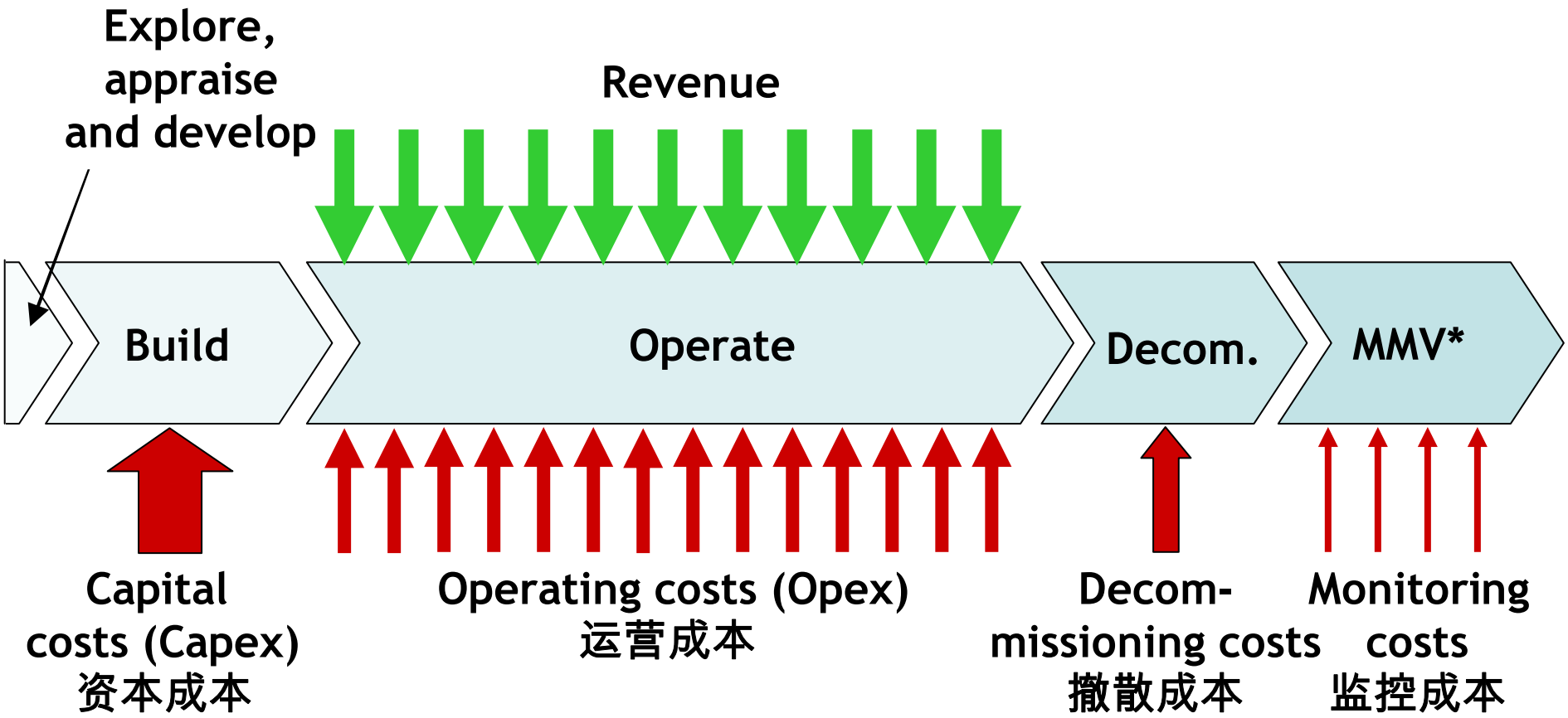
less

cash spent

Why use cash flow?

- It is simple.
- Projecting cash flow allows revenues and costs to change over time.
- The effect of tax, inflation and other costs can be added or changed over time.

Components of CCS cash flow



*MMV = Measurement, Monitoring & Verification

Typical CCS project cash flow

Build (2-3 yrs)	Operate (20-40 yrs)	Decom. (1+ yrs)
	Revenue (sales, carbon price)	
Capex	Opex	Decom. costs
Purchase and install capture plant, compressors, pipelines, platforms, drill and complete wells	Energy, material costs, cooling water, maintenance, office overheads, insurance, labour, etc.	Plugging and abandoning wells, site remediation, platform removal, etc.
Net Cash Flow		

Example of a CCS project cash flow

- A CCS project has -
  - a capital cost of $600 million
  - an operating cost of $90 million per year
  - a decommissioning cost of $140 million
- Project life is 28 years (2 yr build, 25 yr operate, 1 yr decommissioning).

CCS project Cash Flow ($ million)

Year	1	2	3	4	....	27	28
Capex	200	400					
Opex			90	90	....	90	
Decom. costs							140
Project cash flow	-200	-400	-90	-90	....	-90	-140

Present Value

Present value of project costs

- We use present value to represent future costs as a single number
- PV is the equivalent value of the costs today
- It is the amount of money we would need to invest today in a bank to enable us to meet the costs of the project over the entire project life

Discount rate（贴现率）

- In general, the discount rate is the return we would get on an alternative investment.
- For example -

  Bank

  Shares on the stock market

  Company's own shares

Calculating Present Value

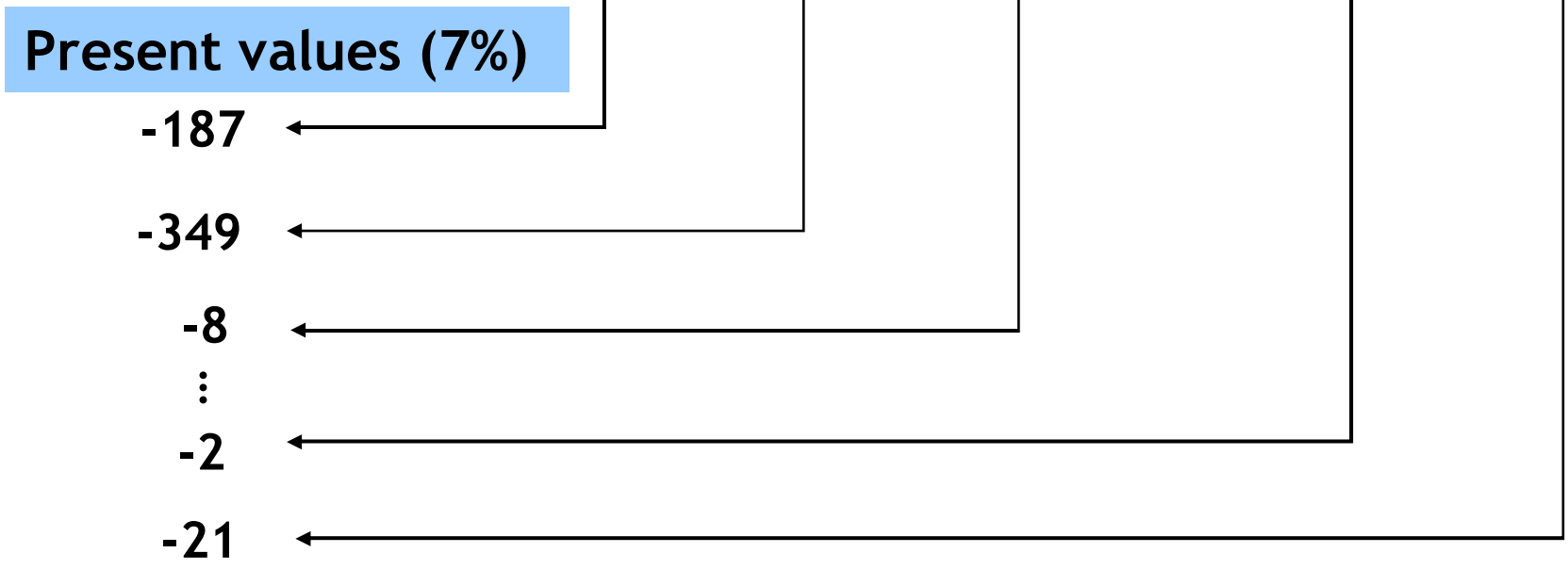
$$\text{Discount rate} = d\%$$

$$\text{Present value} = \frac{\$ \text{ in year } n}{(1+d\%)^n}$$

- Discount rate = 7%
- What is the present value of $100 received after one year?
- PV = $100 / $(1+7\%)^1$
  = $93.5

Calculating Present Value ($ million)

Year	1	2	3	....	27	28
Project cash flow	-200	-400	-90	....	-90	-140



Present Value of project costs = sum PVs = -1,473

Present Value (PV)

- It is the present value of project cash flow.
- It represents the project by a single number and takes time into account.
- It is the amount of money we would need to invest today in a bank to enable us to meet the costs of the project over the entire project life.

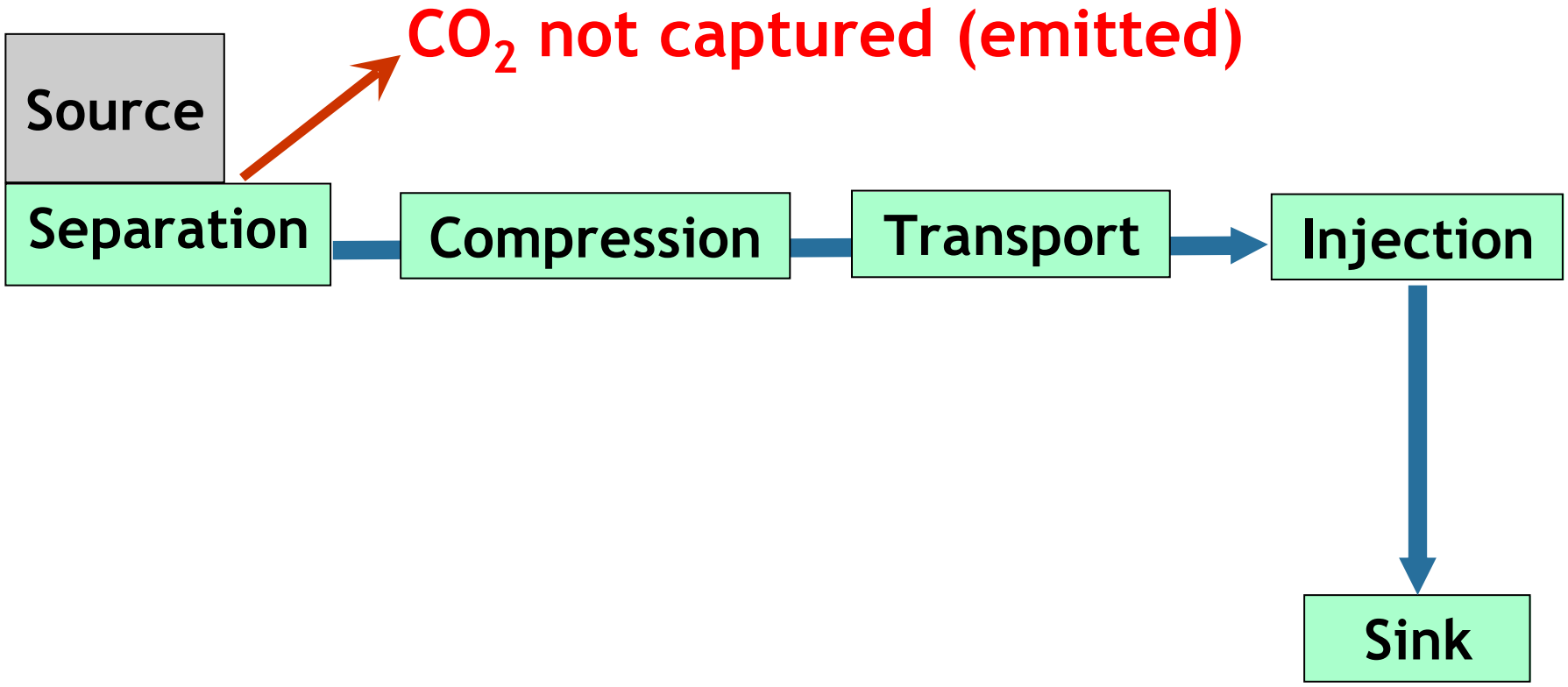
CO2CRC methodology

- Uses PV method and cash flow analysis over the project life because it is flexible.
  - Allows us to spread capital costs over several years
  - Allows costs to change over time
  - Allows us to change or add variables over time

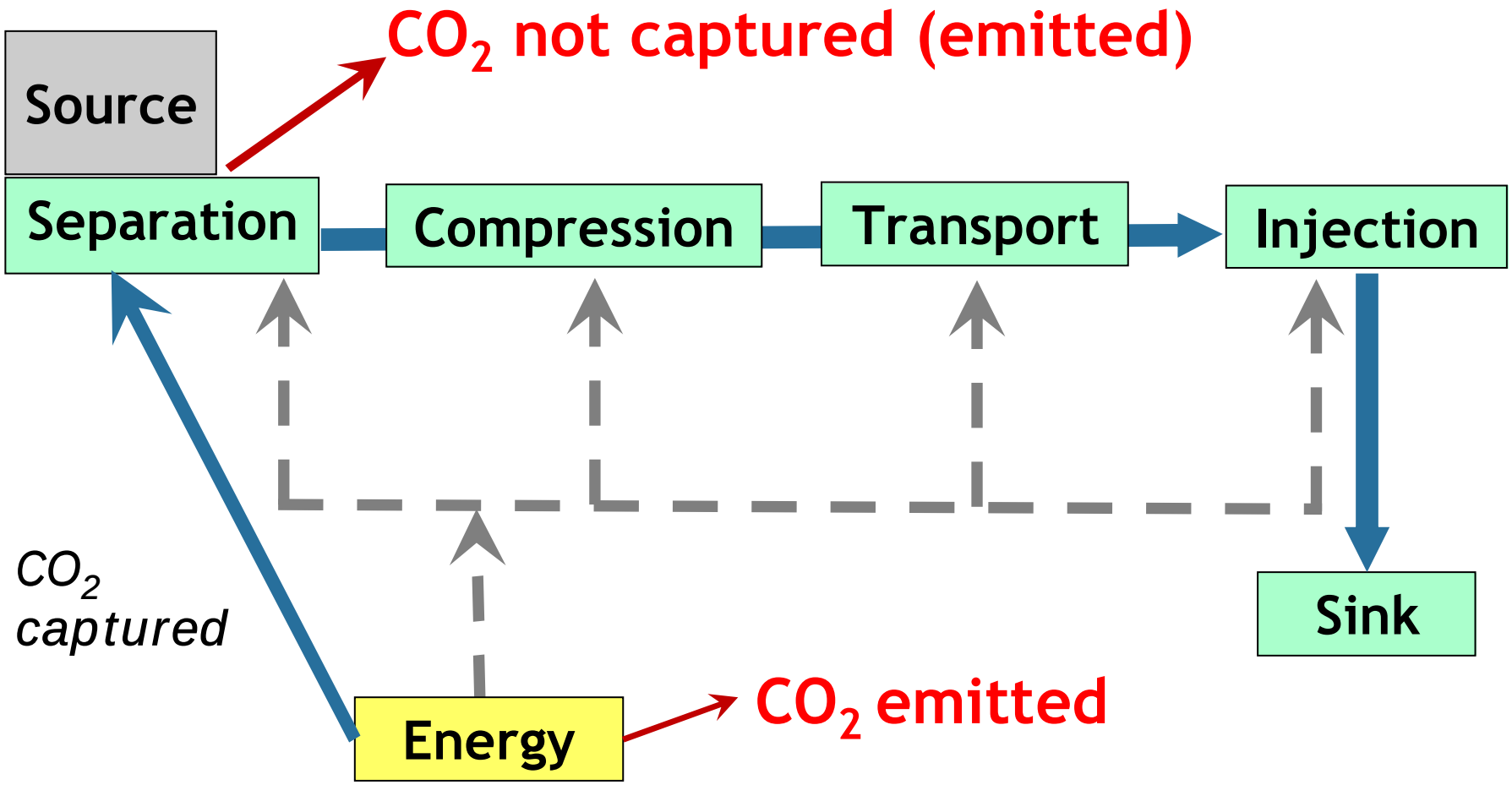
Measures of CCS economics

CO_2 avoided

Generic CCS process



Generic CCS process including energy



CO_2 avoided

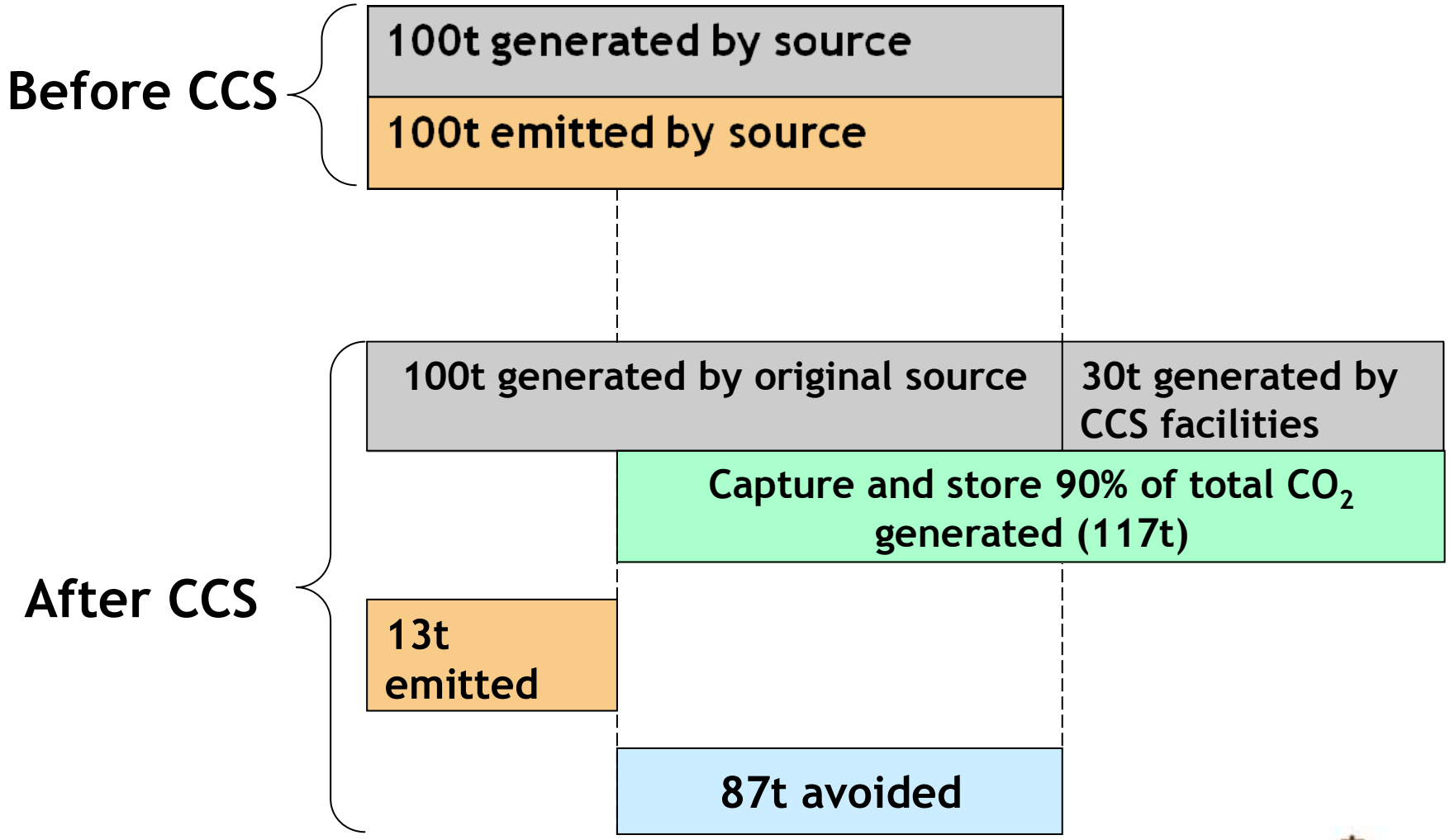
CO_2 avoided = CO_2 emitted without CCS

less

CO_2 emitted with CCS

The amount of CO_2 avoided is different from the amount of CO_2 captured and stored!

CO_2 avoided by CCS



Measures of CCS economics

$ per tonne CO_2 avoided

$ per tonne CO_2 avoided

- Specific cost of CO_2 avoided
- Describes overall CCS project costs

- Using PV -

$ per tonne CO_2 avoided =

PV of all costs for CCS

divided by

PV of CO_2 avoided

Cash flow for CCS

Year	Present Value	1	2	3	....	27	28
Project costs ($ million)	1,473	200	400	90	....	90	140
CO_2 avoided (million tonnes)	31			3	....	3	

$ per tonne CO_2 avoided = 1,473 / 31

= $48 per tonne avoided

Warning

- CO_2 avoided is different for CCS, capture alone and storage alone
- Therefore can't add capture $/t avoided to storage $/t avoided
- Do calculation on whole process

Measures of CCS economics

Cost of electricity
发电成本

Cost of electricity (COE) with CCS

PV of all costs = PV of costs for power plant plus PV of costs for CCS

$$\text{Cost of Electricity} = \frac{\text{PV of all costs}}{\text{PV of electricity sent out}}$$

Δ cost of electricity sent out

Change in cost of electricity ($/MWh)	=	Cost of electricity with CCS ($/MWh)	−	Cost of electricity without CCS ($/MWh)

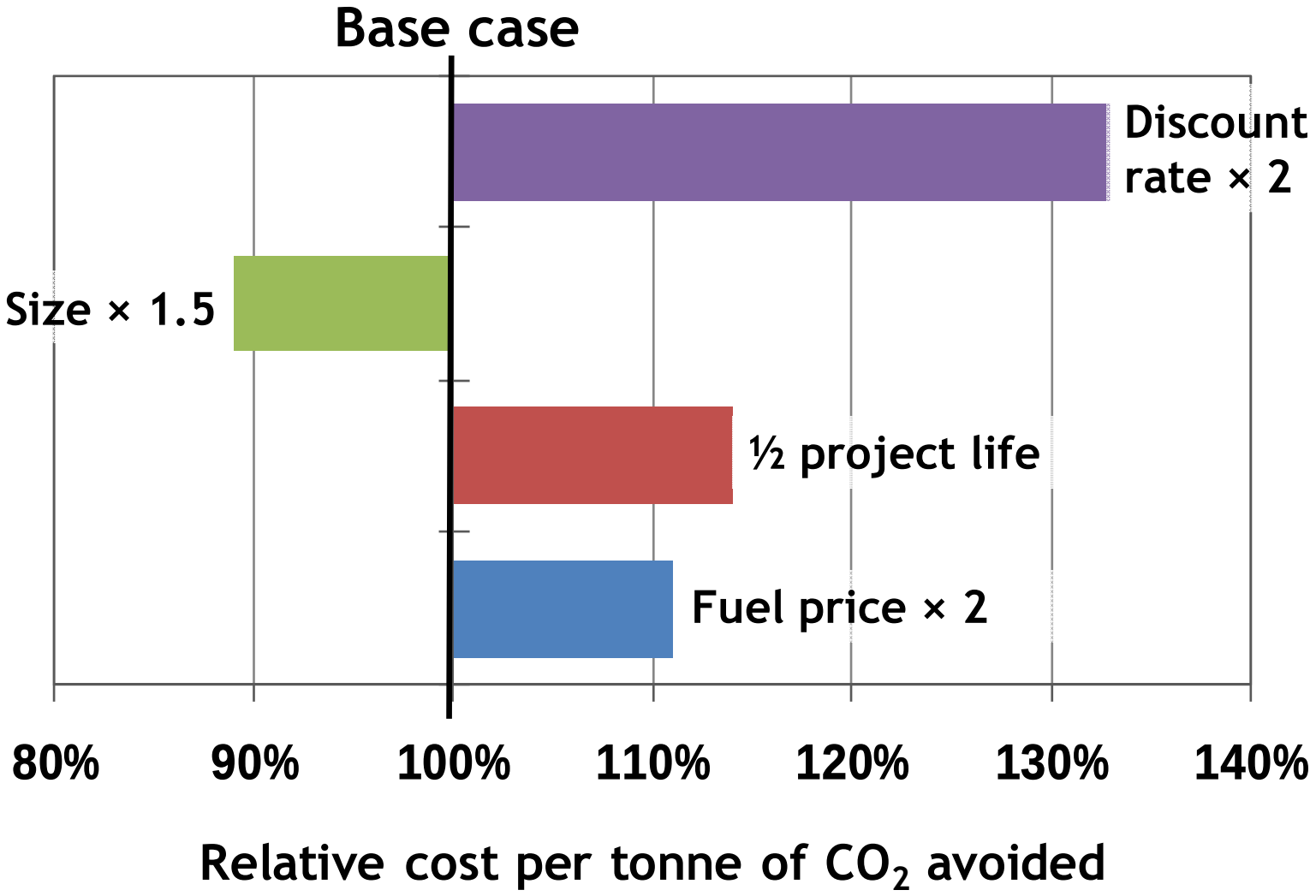
- Represents the increase in cost of electricity sent out from a power plant
- Important indicator in assessing the impact of CCS to the business

Factors affecting CCS costs

Economic factors

- Discount rate
- Project life
- Fuel costs
- Exchange rate
- Capex, Opex and Decom. costs

Effect of assumptions

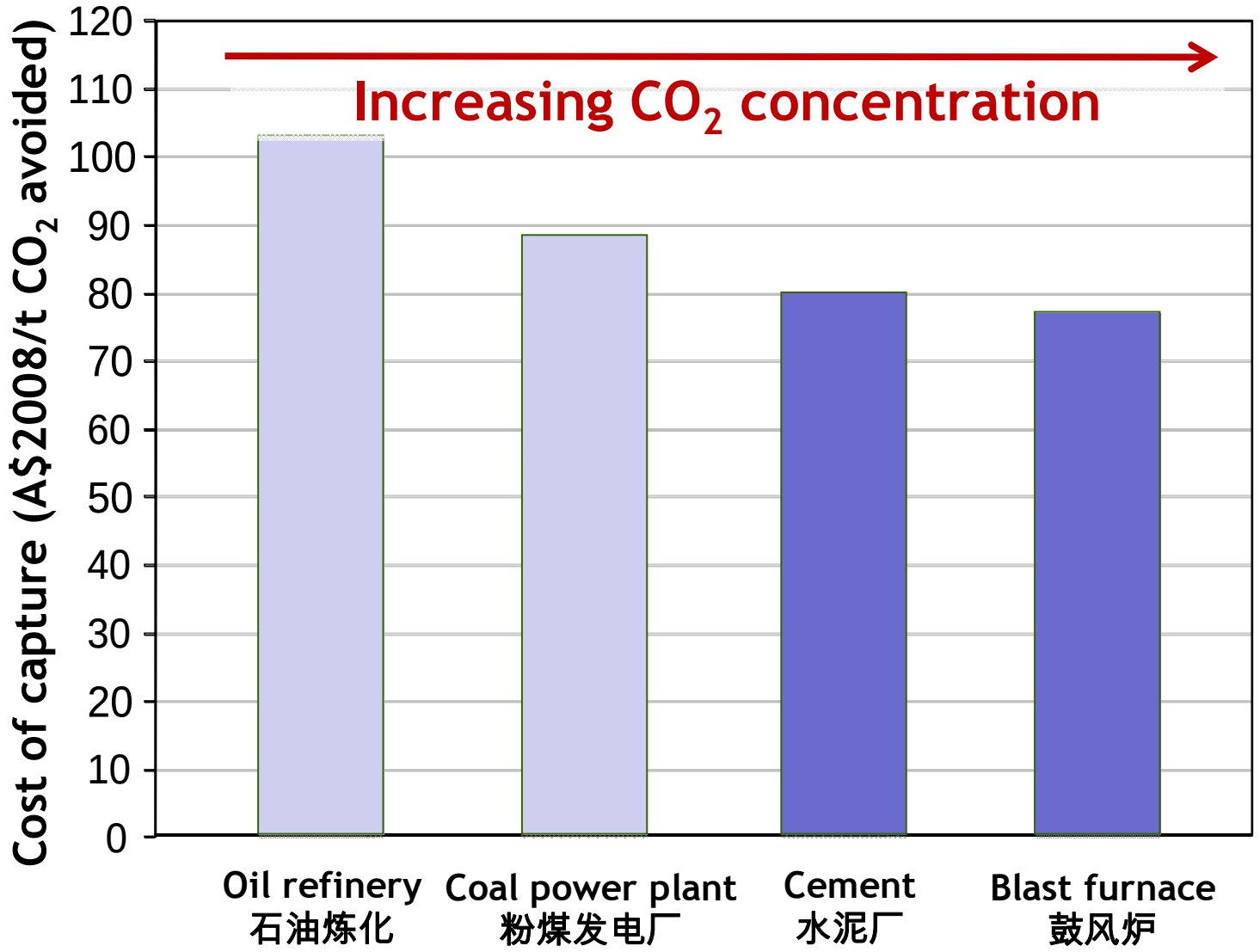


Project specific factors

Capture	Transport	Injection
CO_2 concentration	CO_2 concentration	CO_2 concentration
Flow-rate	Flow-rate	Flow-rate
Source type	Distances	Areal extent
Capture method	Onshore or offshore	Formation properties
Source temperature	Land use	Injection well type
Source pressure	Topography	Exploration
…	…	…

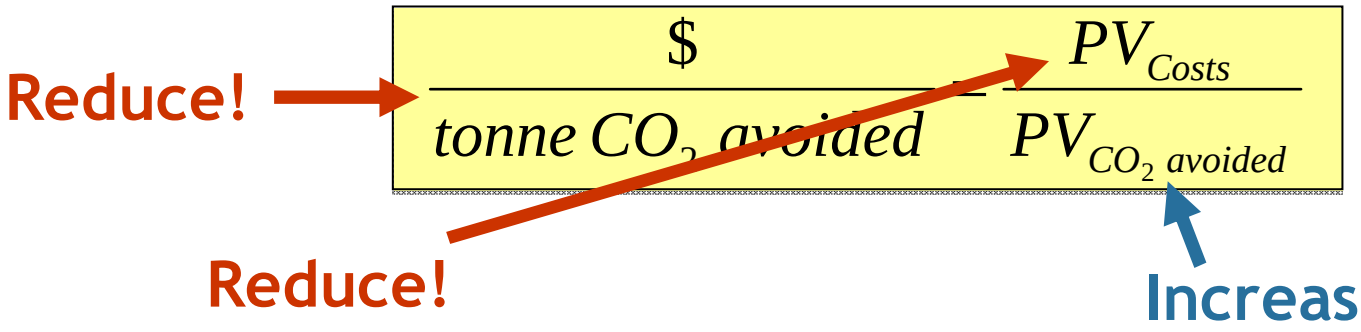
Factors affecting capture costs

Effect of CO_2 concentration



Ho et al., International Journal of Greenhouse Gas control, 2011. 5(1):p.46-60.

Reducing capture costs



- **Reduce Capex –**
  cheaper equipment
- **Reduce Opex -**
  more efficient equipment, less energy demand
- **Reduce energy required by capture –**
  use improved technologies, heat and process integration

- **Increase CO_2 captured –**
  improve capture rate
- **Reduce CO_2 emitted –**
  improve process efficiency, change fuel
- **Increase energy efficiency –**
  heat and process integration

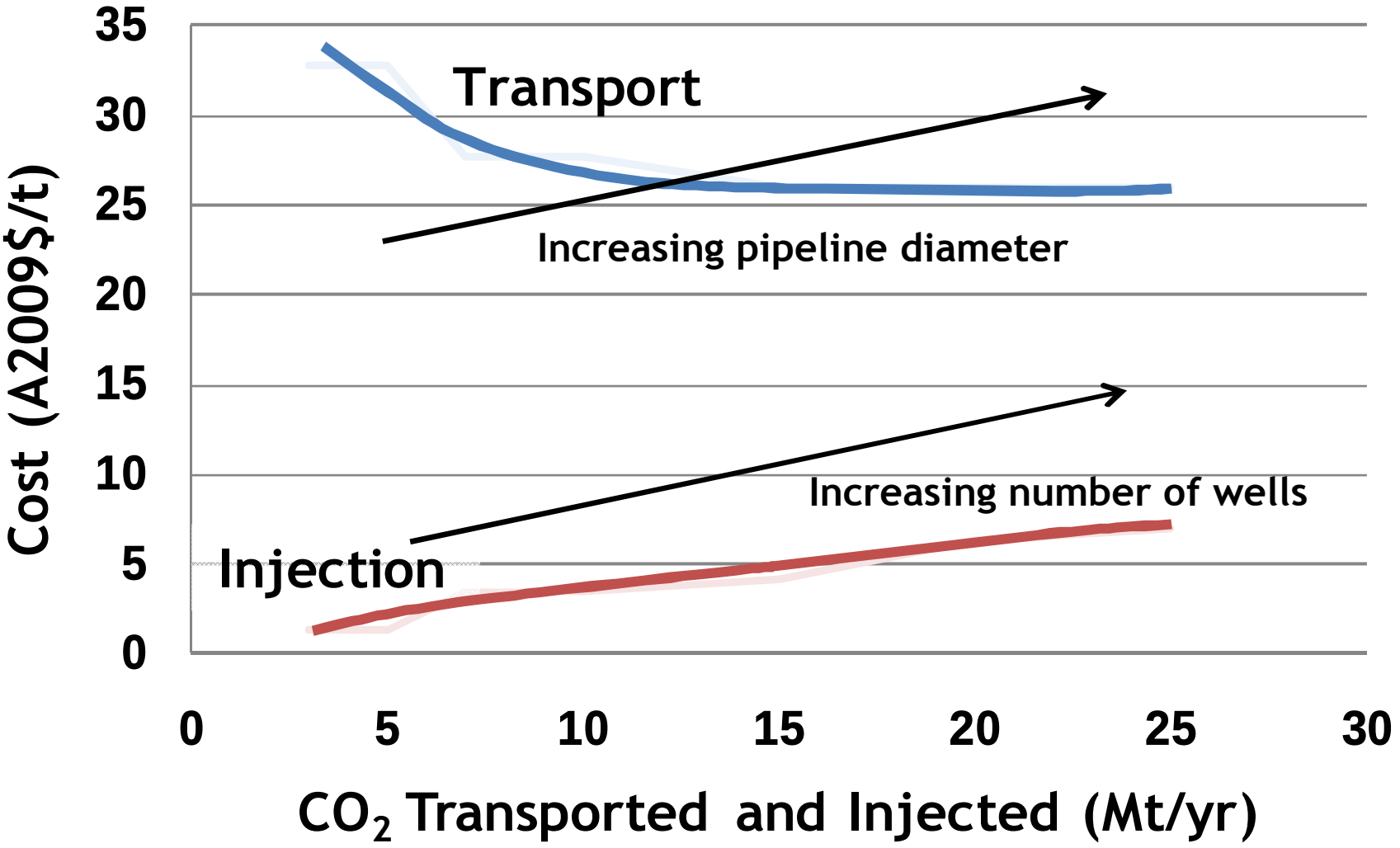
Example: Effect of improving capture technology

- Compare the energy requirement and costs using MEA or KS1 solvent absorption

Solvent	Solvent loss (kg solvent / tonne CO_2 captured)	Steam used (kg steam / kg CO_2 captured)	CO_2 avoided (tonne / MWh)	Capture Cost (A$2008 / tonne CO_2
MEA	1.6	1.8	0.500	65
KS1	0.35	1.5	0.542	53
	78% reduction	15% reduction	8% increase	18% reduction

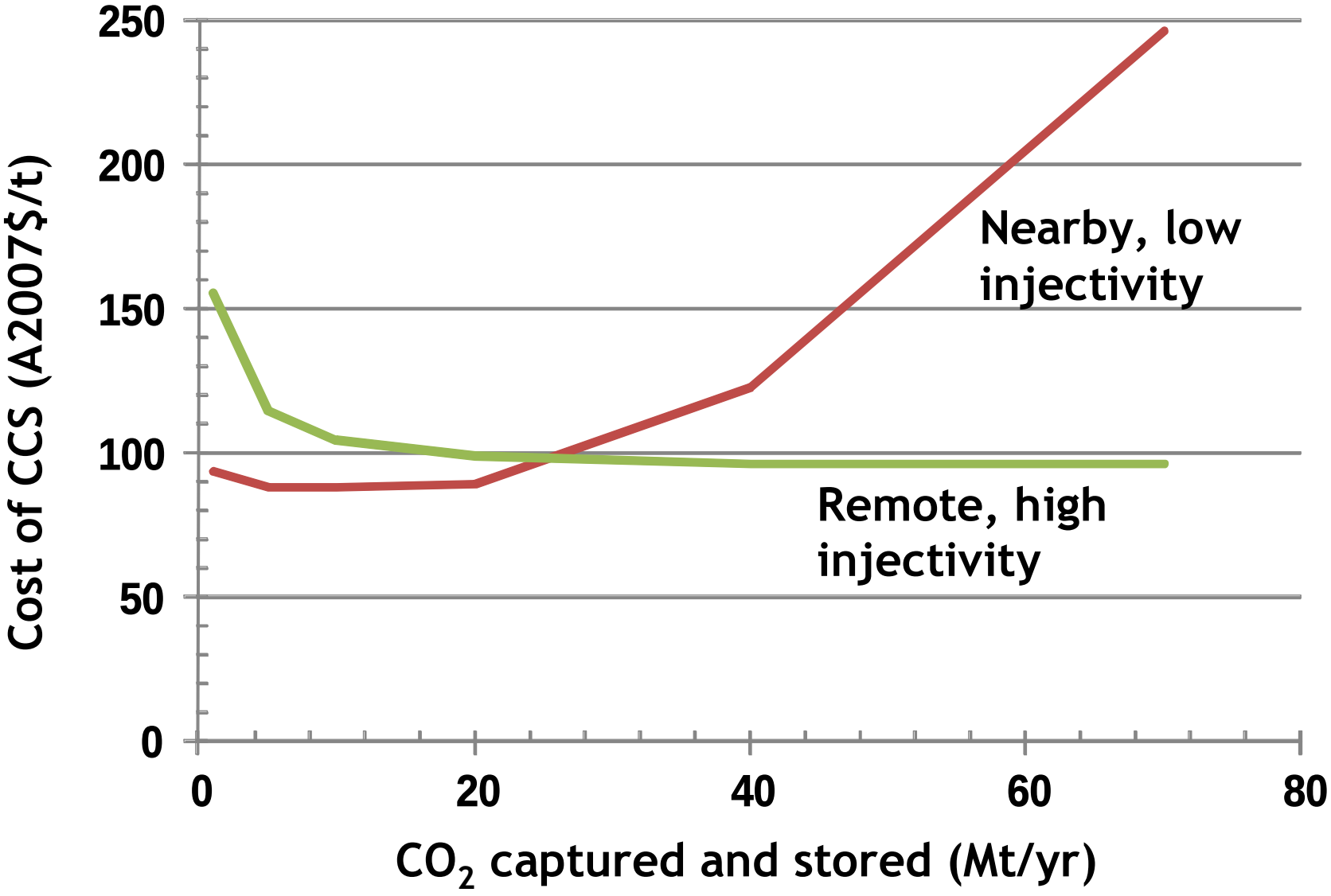
Factors affecting transport and injection costs

Effect of flow rate — economies of scale



Allinson et al., CO2CRC Report #09-1536, 2009.

Trade-offs in CCS costs
Choosing between two sinks



Cinar et al., SPE-114028, 2008.

Summary

- Represent costs over time using cash flow and present value

  用现金流和现值表示一段时间的成本

- $ per tonne CO_2 avoided gives the cost of avoiding emissions (breakeven)

  每吨CO_2的清除成本代表了清除二氧化碳排放的成本（盈亏平衡所需碳价）

- CCS costs are project specific

  CCS的成本由项目特定因素决定

CO2CRC Participants

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Queensland Government | Sasol reaching new frontiers | Shell | Solid Energy Coals of New Zealand | Stanwell Corporation Limited

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Supporting Partners: The Global CCS Institute | The University of Queensland | Process Group | Lawrence Berkeley National Laboratory | Government of South Australia | CANSYD Australia | Charles Darwin University | Simon Fraser University

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