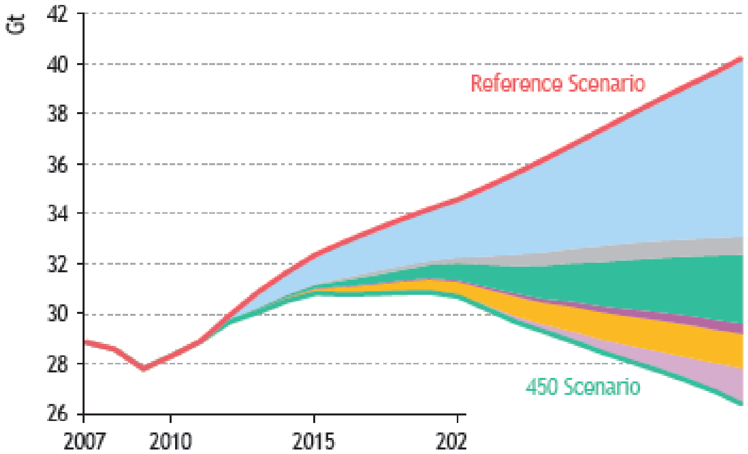
Consideration for Environmental

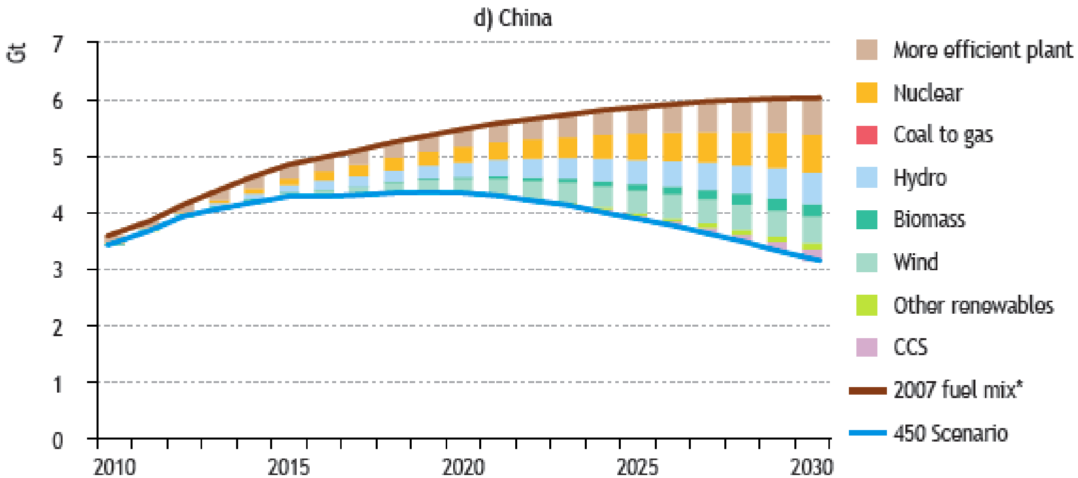
Liu Lan-Cui
Chinese Academy of Environmental Planning,
Ministry of Environmental Protection

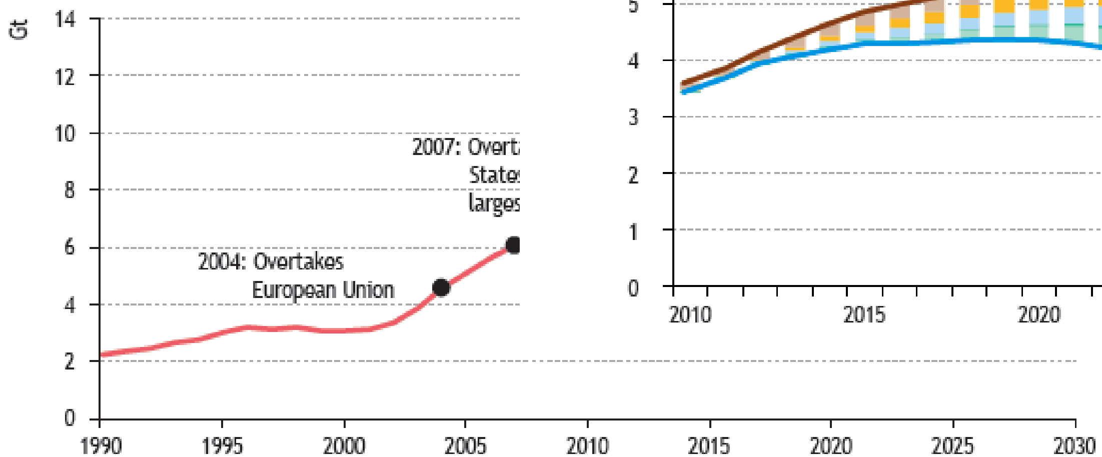
The contribution of

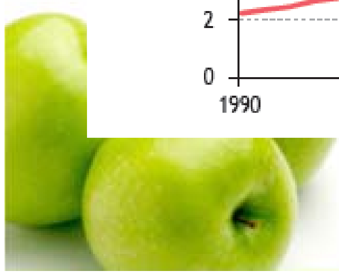
From 3% to 10%



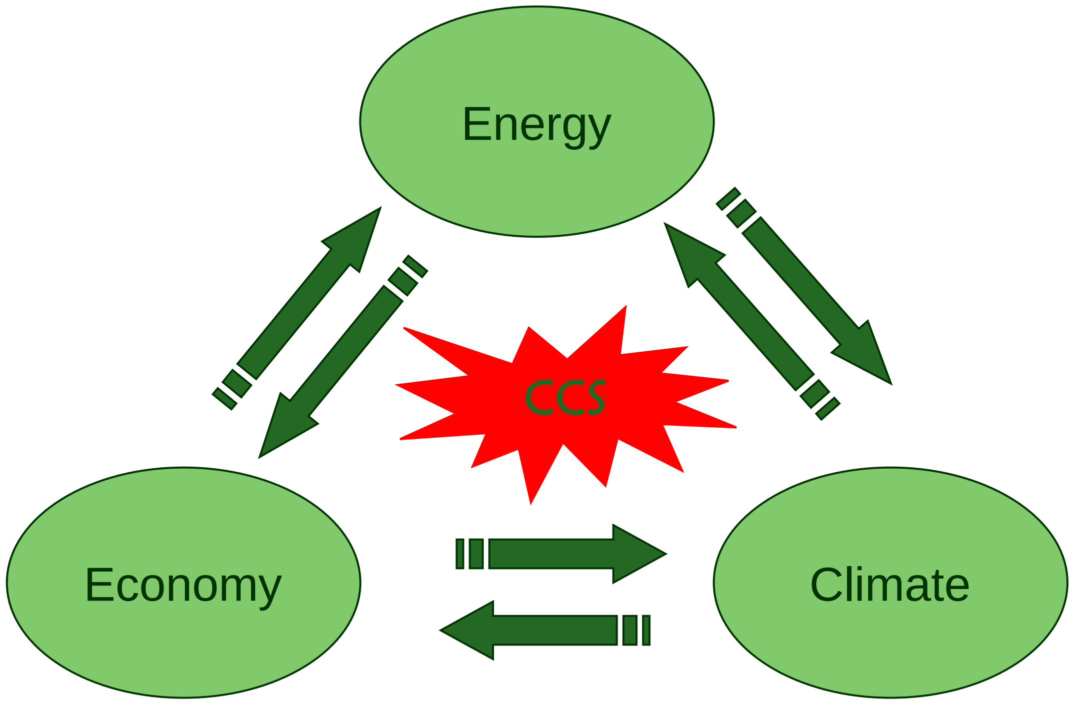
	Abatement ($Mt\ CO_2$) 2020	2030
Efficiency	2 517	7 880
End-use	2 284	7 145
Power plants	233	735
Renewables	680	2 741
Biofuels	57	429
Nuclear	493	1 380
CCS	102	1 410





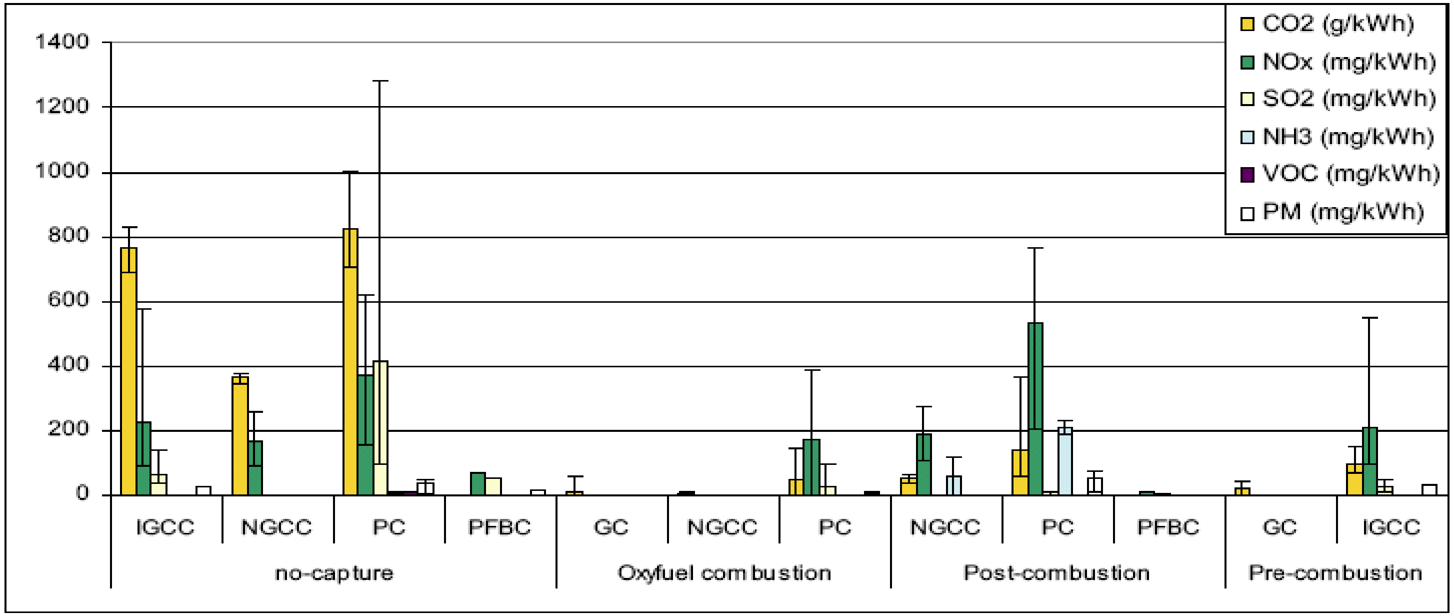


Sustainable Development



Energy penalty

Capture process	Conversion technology[a]	Generating efficiency[b] (%)	Energy penalty of CO_2 capture (% pts.)	Capture efficiency (%)
Post-combustion (chemical absorption)	PC	30-40	8-13	85-90
	NGCC	43-55	5-12	85-90
	PFBC	38[c]	-	90
Oxyfuel	PC	33-36	9-12	90-100
	GC and NGCC	39-62	2-19	50-100
Pre-combustion	IGCC	32-44	5-9	85-90
	GC	43-53	5-13	85-100

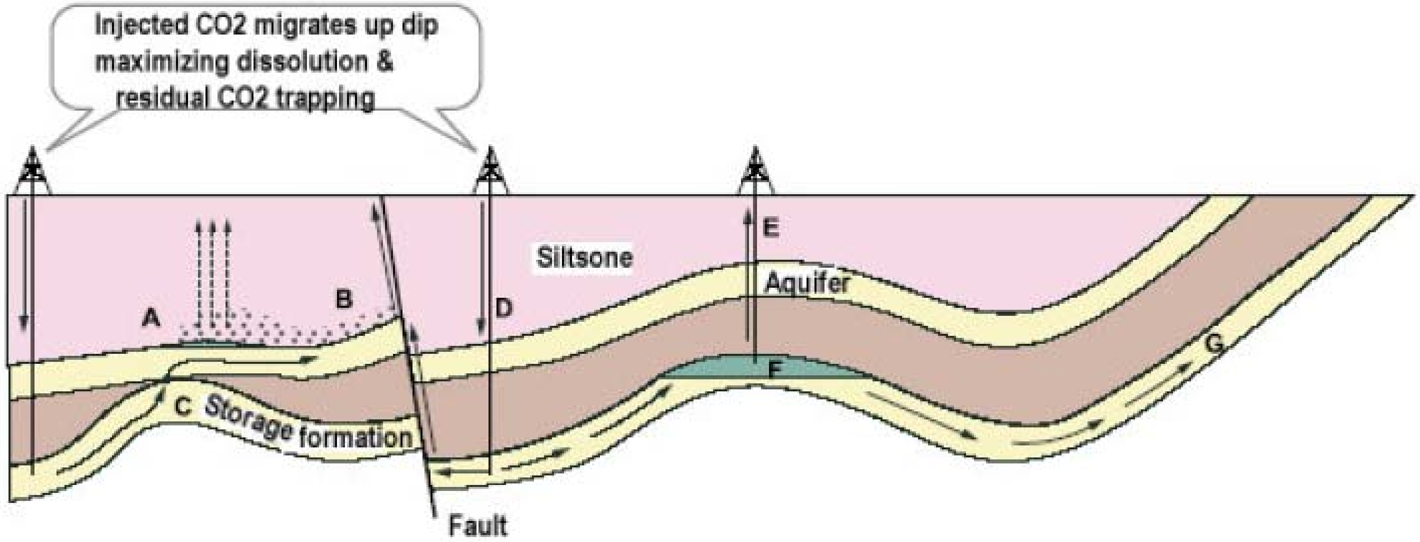


Conversion technology / CO_2 capture technology	Source	Water usage w/o capture ($L\ kWh^{-1}$)	Water usage with capture ($L\ kWh^{-1}$)	Annual increase[b] million ($m^3\ yr^{-1}$)	Relative increase in water use (%)	Relative increase in primary energy use (%)
IGCC/	[58][c]	2.57-3.12				
pre-combustion	[59][d]	0.6	0.9	1.97	50%	16%
	[56][e]	1.35-1.42	1.81-2.00	3.02-3.81	32-48%	18-28%
NGCC/	[58][c]	1.88				
post-combustion	[56][e]	1.02	1.84	5.39	81%	16%
PC subcritical/ post-	[58][c]	4.43				
combustion	[59][d]	3.1				
	[56][e]	2.56	5.04	16.30	96%	48%
PC supercritical/ post-	[58][c]	3.94				
combustion	[59][d]	3.1	4.1	6.57	32%	31%
	[56][e]	2.25	4.34	13.74	93%	44%
Oxyfuel combustion with CO_2 removal	[60][f]	-	2.97-3.01	4.84-5.13[g]	33-35%[g]	39-41%[g]

Waste streams and by products of coal fired power plants with and without CO_2 capture

Waste/ by product	Technology	Source	W/o capture ($g\ kWh^{-1}$)	With capture ($g\ kWh^{-1}$)	Annual increase[a] ($kt\ yr^{-1}$)	Relative increase (%)
Solvent waste	PC post-combustion	[69]	-	2.63 (Fluor)	17.29	-
		[69]		0.26 (MHI KS-1)	1.71	
		[21]		2.1 (MEA)	13.81	
	IGCC pre-combustion	[69]	0.01	0.02	0.07	100%
Gypsum	PC post-combustion	[21]	9.08	11.91	18.61	31%
		[40]	15.23	21.15	38.92	39%
		[69]	13.8	18.8-19.1	32.87-125.57	36%/38%
		[56]	53.6[b]	77[b]	153.84	44%
		[56]	47.8[c]	70.3[c]	147.93	47%
Sulphur`	IGCC pre-combustion	[69]	2.78[d]	3.48[d]	4.60	25%
		[69]	3.16[e]	3.81[e]	4.27	21%
		[56]	8.7[e]	10.4[e]	11.18	20%
		[56]	8.5[f]	10[f]	9.86	18%
		[56]	8[d]	10.3[d]	15.12	29%
Bottom-/fly-ash	PC post-combustion	[69]	39.3	48.9 (Fluor)	63.12	24%
		[69]		48.3 (MHI KS-1)	59.17	23%
		[56]	26.5/6.6[b]	37.2/9.3[b]	70.35/17.75	40%/41%
		[56]	24.8/6.2[c]	35.4/8.9[c]	69.69/17.75	43%/44%
	Oxyfuel combustion	[69]	39.3	48	57.20	22%
Slag	IGCC pre-combustion	[69]	44.7[d]	55.8[d]	72.98	25%
		[69]	54.1[e]	65.3[e]	73.63	21%
		[56]	38[e]	45[e]	46.02	18%
		[56]	34.4[f]	42.5[f]	53.25	24%
		[56]	32.2[d]	41.4[d]	60.49	29%

Potential escape

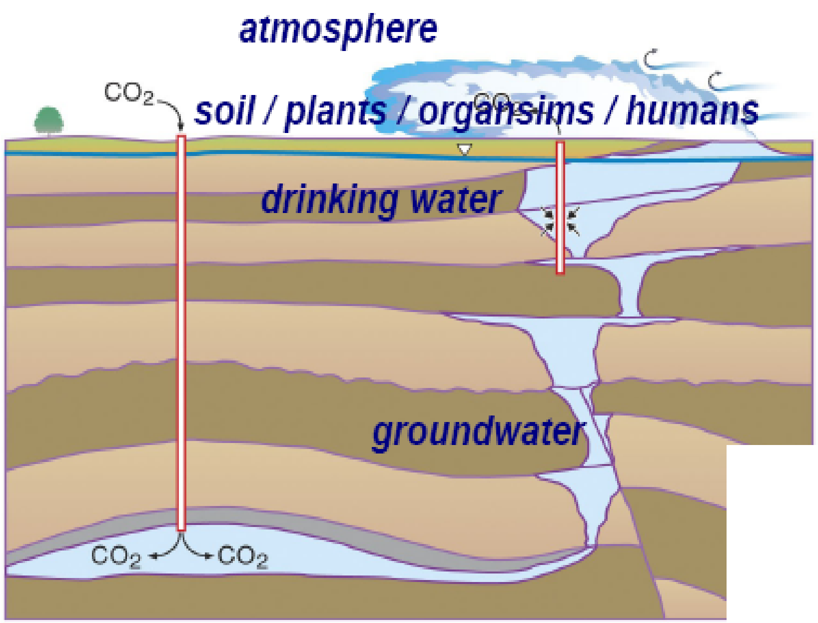


Potential Escape Mechanisms

- **A.** CO_2 gas pressure exceeds capillary & passes through siltstone
- **B.** Free CO_2 leaks from A into upper aquifer up fault
- **C.** CO_2 escapes through 'gap' in cap rock into higher aquifer
- **D.** Injected CO_2 migrates up dip, increases reservoir pressure & permeability of fault
- **E.** CO_2 escapes via poorly pluged old abandoned well
- **F.** Natural flow dissolves CO_2 at CO_2 / water interface and transports it out of closure
- **G.** Dissolved CO_2 escapes to the atmosphere or ocean

IPCC, 2005

Potential Environmental impact and risks



Risk of geologic storage of CO_2

- **Local risks**
  - CO_2 in atmosphere or shallow subsurface:
    - Suffocation of humans or animals above ground
    - Effects on plants above ground
    - Biological impact below ground on roots, insects ad burrowing animals
  - CO_2 dissolved in subsurface fluids:
    - Mobilisation of metals and other contaminants
    - Contamination of potable water
    - Interference with deep subsurface ecosystems
  - Displacement:
    - Ground heave
    - Induced seismicity
    - Contamination of drinking water by displaced brines
    - Damage to hydrocarbons or other mineral resources
- **Global risks**
  - Release of CO_2 into the atmosphere

SEA-capture

Environmental Quality Objective (EQO)	Oxyfuel, pulverized fuel, lignite plant		Oxyfuel, pulverized fuel, bituminous coal plant		Post-combustion pulverized fuel, bituminous coal plant		Oxygen-blown IGCC, bituminous coal plant	
	with CCS	without CCS	with CCS	without CCS	with CCS	without CCS	with CCS	without CCS
1. Reduced Climate Impact	2	-2	2	-2	2	-2	2	-2
2. Clean Air	2	-2	2	-2	2	-2	2	-2
3. Natural Acidification Only	1	-1	1	-1	1	-1	1	-1
4. A Non-Toxic Environment	0	0	0	0	-1	0	-1	0
5. A Protective Ozone Layer	0	0	0	0	0	0	0	0
6. A Safe Radiation Environment	0	0	0	0	0	0	0	0
7. Zero Eutrophication	1	-1	1	-1	1	-1	1	-1
8. Flourishing Lakes and Streams	0	-1	0	-1	0	-1	0	-1
9. Good-Quality Groundwater	0	-1	0	-1	0	-1	0	-1
10. A Balanced Marine Environment…	0	-1	0	-1	0	-1	0	-1
11. Thriving Wetlands	0	-1	0	-1	0	-1	0	-1
12. Sustainable Forests	0	-1	0	-1	0	-1	0	-1
13. A Varied Agricultural Landscape	0	-1	0	-1	0	-1	0	-1
14. A Magnificent Mountain Landscape	0	-1	0	-1	0	-1	0	-1
15. A Good Built Environment	1	-1	1	-1	1	-1	1	-1
16. A Rich Flora and Fauna	0	-1	0	-1	0	-1	0	-1
Sum	7	-11	7	-11	6	-11	6	-11
Average	0,44	-0,69	0,44	-0,69	0,38	-0,69	0,38	-0,69

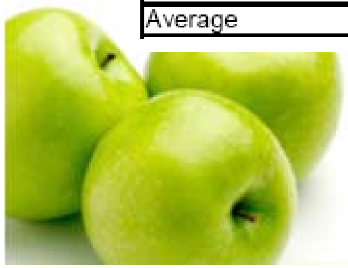
-2	The activity will have a severly negative effect on the fulfillment of the EQO.
-1	The activity could have a negative effect on the fulfillment of the EQO. The effects are clearly limited either in time, space or consequence level.
0	The activity is not expected to have any effect of the fulfillment of the EQO
+1	The activity could have a positive effect on the fulfillment of the EQO.The effects are clearly limited either in time, space or consequence level.
+2	The activity will have a strongly positive effect on the fulfillment of the EQO

SEA-Transportation

ıvironmental Quality Objective (EQO)	Onshore pipeline transport, sandy soil, oligotrophic lake, pipeline dug down 1m		Onshore pipeline transport, clay soil, euthrophic lake, pipeline dug down 1m		Onshore pipeline transport, pipeline on the ground		Offshore pipeline transport		Off-shore shipping tra	
	Concept works according to plan - no leakages	Short term high leakage rate	Concept works according to plan - no leakages	Short term high leakage rate	Concept works according to plan - no leakages	Short term high leakage rate	Concept works according to plan - no leakages	Short term high leakage rate	Concept works according to plan - no leakages	Short t high lea rat
educed Climate Impact	0	0	0	0	0	0	0	0	-2	-2
lean Air	-1	-2	-1	-2	-1	-2	0	0	-2	-2
atural Acidification Only	0	-1	0	0	0	0	0	-2	-1	-1
Non-Toxic Environment	0	0	0	0	0	0	0	0	-1	-1
Protective Ozone Layer	0	0	0	0	0	0	0	0	0	0
Safe Radiation Environment	0	0	0	0	0	0	0	0	0	0
ero Eutrophication	0	0	0	0	0	0	0	0	0	0
lourishing Lakes and Streams	-1	-1	-1	-1	0	0	0	0	0	0
ood-Quality Groundwater	0	0	0	0	0	0	0	0	0	0
A Balanced Marine Environment…	0	0	0	0	0	0	-1	-2	-1	-1
Thriving Wetlands	-1	-1	-1	-1	-1	-1	0	0	0	0
Sustainable Forests	0	-1	0	-1	-1	-1	0	0	0	0
A Varied Agricultural Landscape	0	0	0	0	-1	-1	0	0	0	0
A Magnificent Mountain Landscape	-1	-1	-1	-1	-1	-1	0	0	0	0
A Good Built Environment	0	-2	0	-2	0	-2	0	0	0	0
A Rich Flora and Faua	0	0	0	0	-1	-1	0	0	0	0
l	-1,5	-4,0	-1,5	-3,0	-2,7	-4,0	-1,0	-4,0	-7,0	-7,
rage	-0,14	-0,36	-0,14	-0,27	-0,24	-0,36	-0,09	-0,36	-0,64	-0,6

SEA-Storage

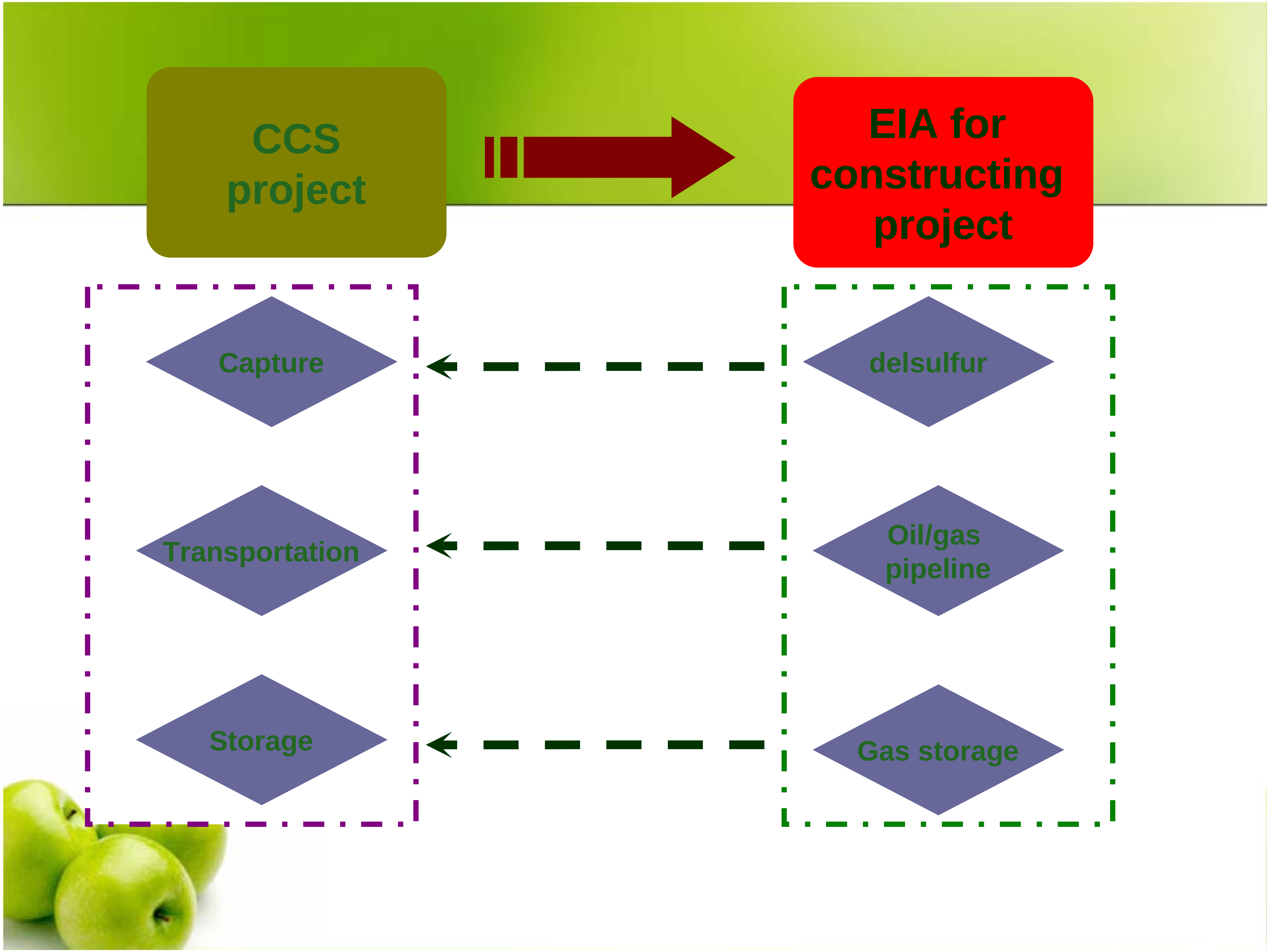
Environmental Quality Objective (EQO)	On-shore storage: Sandy soil with weak buffer capacity and oligotrophic lake in area above reservoir			On-shore storage: Clay-rich soil with strong buffer capacity and eutrophic lake in area above reservoir			Off-shore storage		
	Concept works according to plan - no leakages	Long term low leakage rate	Short term high leakage rate	Concept works according to plan - no leakages	Long term low leakage rate	Short term high leakage rate	Concept works according to plan - no leakages	Long term low leakage rate	Short term high leakage rate
1. Reduced Climate Impact	0	-2	0	0	-2	0	0	-2	0
2. Clean Air	0	0	-2	0	0	-2	0	0	-1
3. Natural Acidification Only	0	-1	0	0	0	0	0	-1	0
4. A Non-Toxic Environment	0	-1	-1	0	-1	-1	0	-1	-1
5. A Protective Ozone Layer	0	0	0	0	0	0	0	0	0
6. A Safe Radiation Environment	0	0	0	0	0	0	0	0	0
7. Zero Eutrophication	0	0	0	0	-1	0	0	0	0
8. Flourishing Lakes and Streams	0	-1	-1	0	-1	-1	0	0	0
9. Good-Quality Groundwater	0	-2	-1	0	0	0	0	0	0
10. A Balanced Marine Environment…	0	0	0	0	0	0	-1	-2	-2
11. Thriving Wetlands	-1	-1	-1	-1	-1	-1	0	0	0
12. Sustainable Forests	0	-1	0	0	-1	0	0	0	0
13. A Varied Agricultural Landscape	0	0	0	0	0	0	0	0	0
14. A Magnificent Mountain Landscape	-1	-1	-1	-1	-1	-1	0	0	0
15. A Good Built Environment	0	0	-2	0	0	-2	0	0	0
16. A Rich Flora and Fauna	-1	-2	-1	-1	-2	0	-1	-2	0
Sum	-1,3	-8,7	-5,8	-1,3	-6,7	-3,8	-2,0	-8,0	-4,0
Average	-0,12	-0,79	-0,53	-0,12	-0,61	-0,35	-0,18	-0,73	-0,36



Suggestions for EIA

CCS Planning → EIA for Planning

CCS Project → EIA for constructing project


CCS project
EIA for constructing project
Capture
Transportation
Storage
delsulfur
Oil/gas pipeline
Gas storage

Thanks for your attention