CO_2 Capture Project

Focusing For Success

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May 7th, 2003

CO_2 Capture Project

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  c. Common Economic Model (CEM)
- Results & Forward Program

CCP Objectives

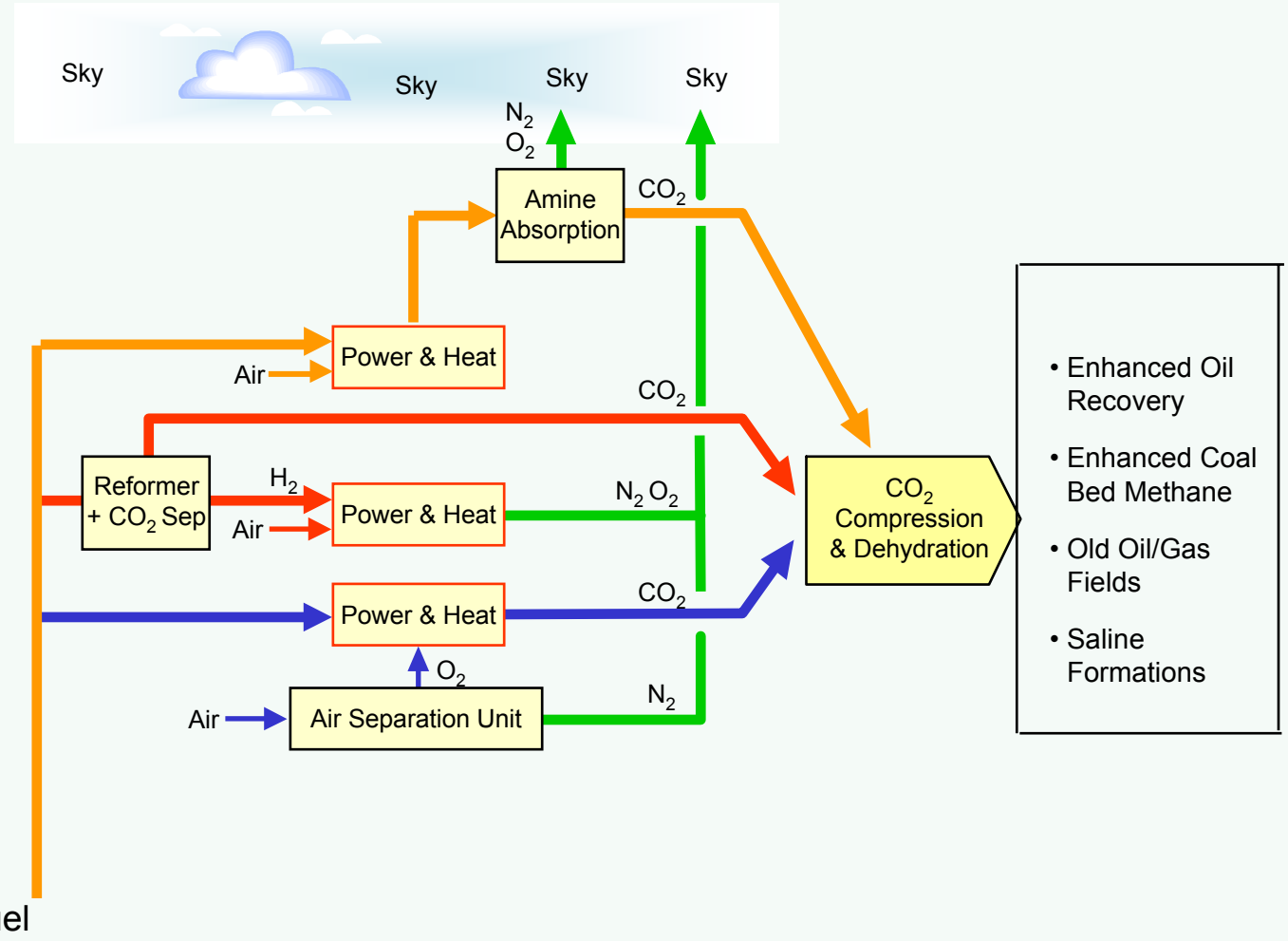
- Set stretch targets for CO_2 capture cost reduction
  a. Necessary to address the wide economic gap
  b. 50% for retrofit , 75% for new build plant
- Develop to 'proof of concept' by end 2003
  - Track economic performance against real 'Scenario's'
- Intent to follow with pilot & field demonstration,improve & learn by doing
  - In/outside the CCP as members choose
- Aim for commercial technology in 2010 time frame

CO_2 Capture & Storage Options

Post Combustion Decarbonisation

Precombustion Decarbonisation

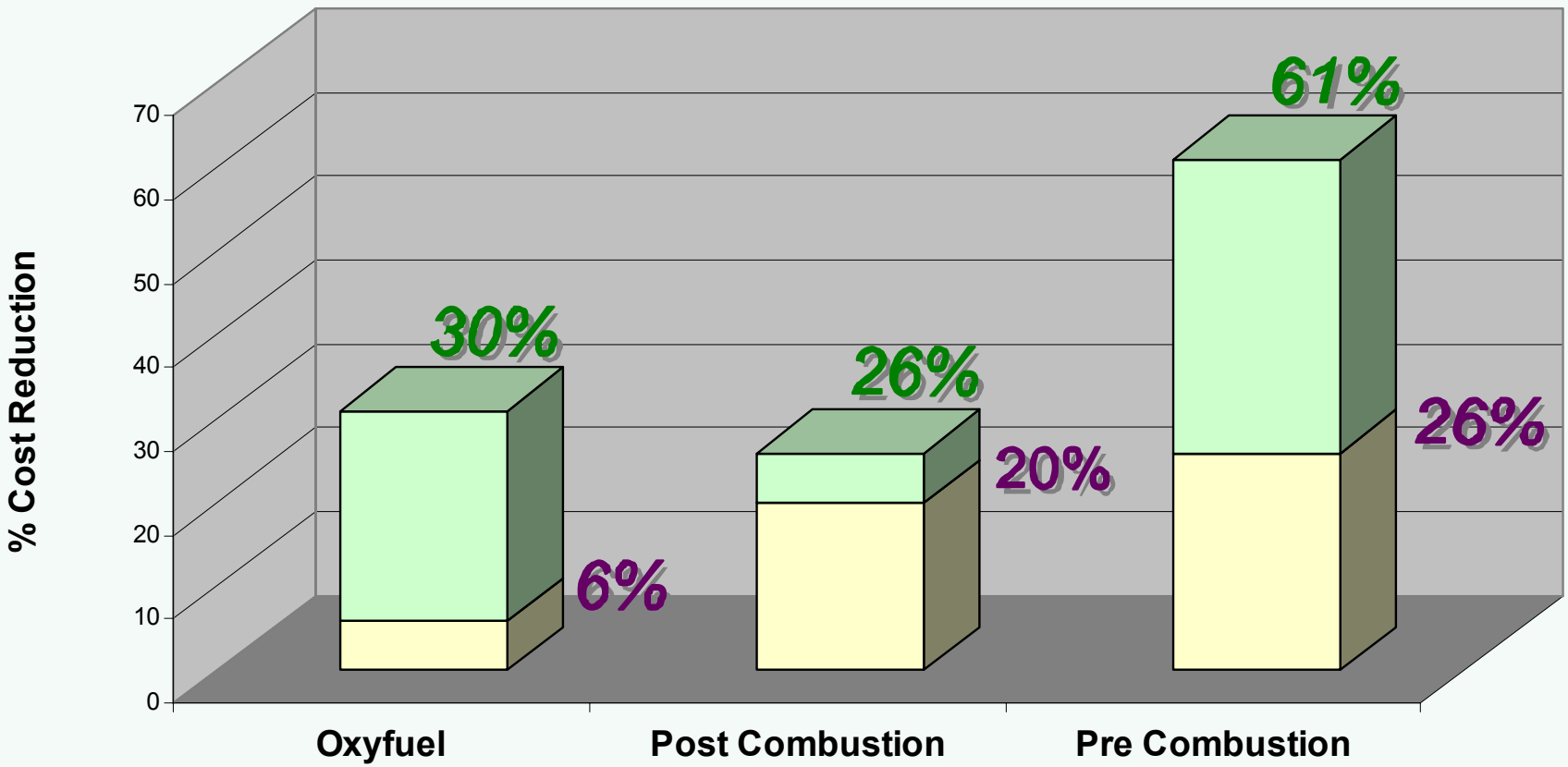
Oxyfuel



CO_2 Capture Technology/ Scenario Matrix
2002 Early Technology Evaluation Task Force Cases

	Distributed gas turbines system	*Combined cycle*	*Refinery Heaters and boilers*
Postcombustion			
Commercial Amines (Baseline)	■	■	■
Membrane Contactor		■	
Precombustion			
Sorbent Enhanced Water Gas Shift	■		
Membrane Steam Reforming		■	
Membrane Water Gas Shift Reactor			■
Electrical Swing Adsorption		■	
Oxyfuels			
Flue Gas Recycle			■
Chemical Looping			■

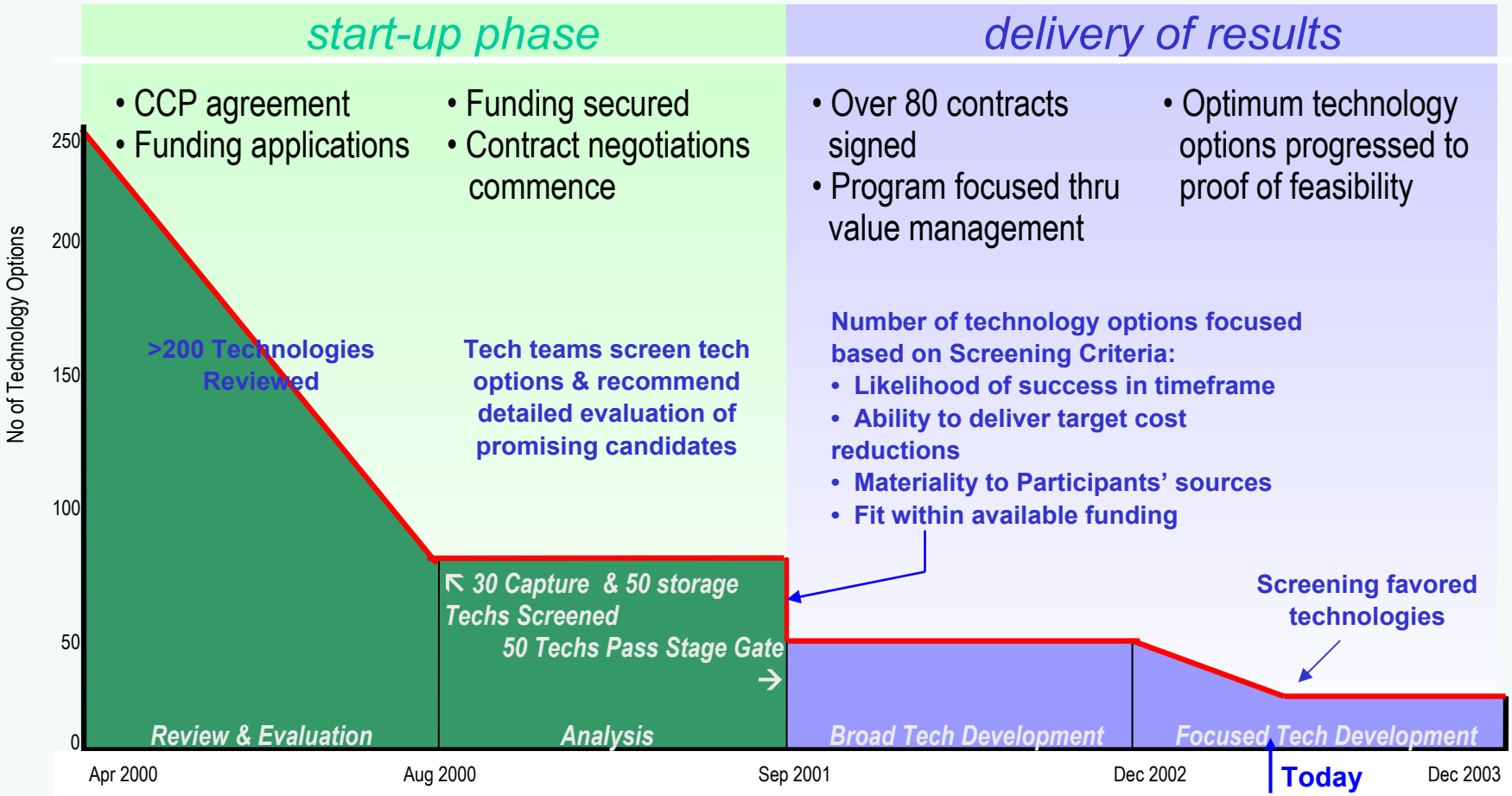
CO_2 Avoided Cost Reductions



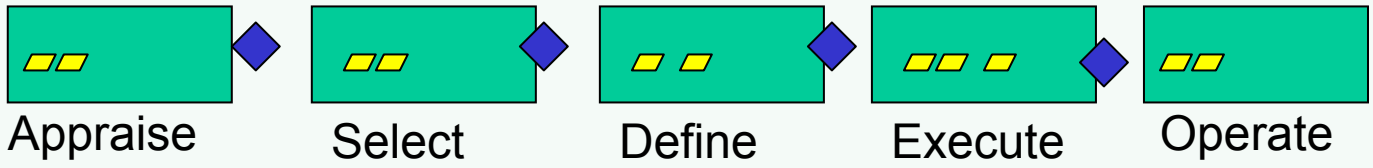
Strategy

- Cast net wide for step-change technology
  a. R&D is high risk, start off more projects than you can fund to completion ,since many will fail either fully or partially.
- Agree success criteria for each stage of technology investment,apply a rigorous Technology Assurance Process (TAP) to manage delivery
  a. review performance against criteria at key stage gates.
- Compare & rank technology performance
  a. Forward fund high potential technologies
- Continue search for new technologies & incorporate in the program as time & budget permits

Implementation



Technology Assurance Process



- The gate keeper (CCP Executive Board) takes the investment decision to stop, hold or pass on to the next stage

- Decision support packages (DSP's) contain the information needed to make decisions, these are completed by the technical teams and made available to the gatekeeper. Individual DSP's may also involve stage gate review in their generation, ie nested stage gates

Common Economic Model Team Activity 2000-02

- Development work
  - Early technology scoring criteria
  - Cost estimation approach
  - Economic screening model
- Operative work
  - Task Force - early economic screening

Early screening criteria (Wash.DC, Mar-01)

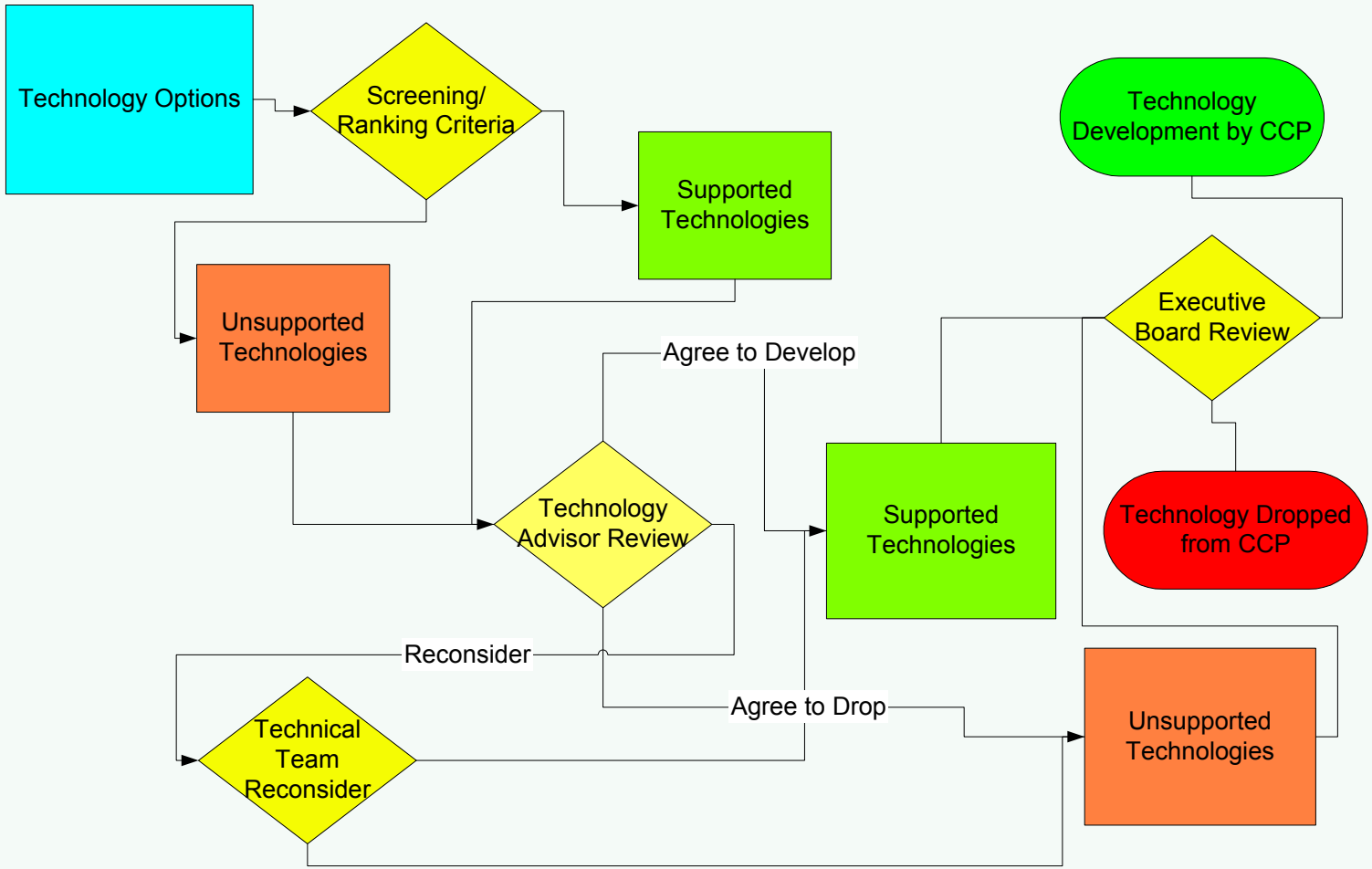
CCP Technology Screening Worksheet Analysis Phase Rev 4, February 28, 2001	CCP-Team: Technology: Date:								
	Application context	Weight factors Lev-1	Lev-2	Lev-3	Lev -4	Raw score 0 - 5	Lev-3/4	Weighted score x Lev-2	20 Lev-1
Overall score		100 %							***100***
Potential emission reductions		25 %							25.0
1 CO2-emission reduction potential of proposed technology from:			100 %					25.0	
European refinery				25 %					
	Retrofit				50 %	5	3.1		
	New-build				50 %	5	3.1		
Large scale powergen Norway				25 %					
	Retrofit				0 %	5	0.0		
	New-build				100 %	5	6.3		
Large Mid-West US coal boiler powergen				0 %					
	Retrofit				100 %	5	0.0		
	New-build				0 %	5	0.0		
Med-small Alaska open cycle powergen				25 %					
	Retrofit				50 %	5	3.1		
	New-build				50 %	5	3.1		
Canada coal gasification				25 %					
	Retrofit				0 %	5	0.0		
	New-build				100 %	5	6.3		
2 Overall environmental performance of proposed technology (Teams will provide comments on environmental considerations)			0 %			5	0.0	0.0	
Technology development		25 %							25.0
3 Expected development horizon			30 %						
Likelihood the technology be developed to a "proof of concept stage" within 3-5 years (2003-05):				50 %		5	3.8	7.5	
Likelihood the technology be developed to a "commercial stage" within 5-10 years (2005-10):				50 %		5	3.8		
4 Importance of CCP-program in developing this technology			25 %			5		6.3	
5 Are there technical developers who can commercialize this technology ?			30 %			5		7.5	
6 Market potential for technology outside CCP			15 %			5		3.8	
Abatement cost		50 %							50.0
7 Anticipated CO2 abatement cost of the proposed technology when applied in the CCP-scenarios ?	Retrofit & new-build		100 %					50.0	
European refinery				25 %					
	Retrofit				50 %	5	6.3		
	New-build				50 %	5	6.3		
Large scale powergen Norway				25 %					
	Retrofit				0 %	5	0.0		
	New-build				100 %	5	12.5		
Large Mid-West US coal boiler powergen				0 %					
	Retrofit				100 %	5	0.0		
	New-build				0 %	5	0.0		
Med-small Alaska open cycle powergen				25 %					
	Retrofit				50 %	5	6.3		
	New-build				50 %	5	6.3		
Canada coal gasification				25 %					
	Retrofit				0 %	5	0.0		
	New-build				100 %	5	12.5		
Development cost (additional)									
8 Expected budget to develop technology to a:				< 1 million	1-3 million	USD 3-5 million	5-10 million	> 10 million	
"proof of concept stage" :									
"commercial stage" :				< 10 million	10-100 million	100-300 million	300-500 million	>500 million	
Interpretation of scale 0-5 :			0	1	2	3	4	5	
> Performance level				Low		->		High	
> Importance level			No relevance,	Low		->		High	
> Size level			no contribution,	Low		->		High	
> Percentage change:			no knowledge	0-20 %	20-40 %	40-60 %	60-80 %	80-100 %	
> Probability of occurrence				0-20 %	20-40 %	40-60 %	60-80 %	80-100 %	
> Abatement cost USD/ton CO2				> 100	75-100	50-75	25-50	< 25	

Semi-quantitative criteria used in early screenings

CCP Technology Screening Worksheet	CCP-Team:			
Analysis Phase	Technology:			
Rev 4, February 28, 2001	Date:			
	Application context	Weight factors Lev-1	Lev-2	Lev-3
Overall score		100 %		
Potential emission reductions		25 %		
1 **CO2-emission reduction potential of proposed technology from:**			100 %	
European refinery				25 %
	Retrofit			
	New-build			
Large scale powergen Norway				25 %
	Retrofit			
	New-build			
Large Mid-West US coal boiler powergen				0 %
	Retrofit			
	New-build			
Med-small Alaska open cycle powergen				25 %
	Retrofit			
	New-build			
Canada coal gasification				25 %
	Retrofit			
	New-build			

Abatement cost			**50 %**			
7	**Anticipated CO2 abatement cost of the proposed technology when applied in the CCP-scenarios ?**	Retrofit & new-build		**100 %**		
	European refinery				**25 %**	
		Retrofit				
		New-build				
	Large scale powergen Norway				**25 %**	
		Retrofit				
		New-build				
	Large Mid-West US coal boiler powergen				**0 %**	
		Retrofit				
		New-build				
	Med-small Alaska open cycle powergen				**25 %**	
		Retrofit				
		New-build				
	Canada coal gasification				**25 %**	
		Retrofit				
		New-build				
Development cost (additional)						
					< 1 million	1-3
8	**Expected budget to develop technology to a:**					
	"proof of concept stage" :					
					< 10 million	10-1
	"commercial stage" :					
	Interpretation of scale 0-5 :			**0**	**1**	
	> Performance level				**Low**	
	> Importance level			**No relevance,**	**Low**	
	> Size level			**no contribution,**	**Low**	
	> Percentage change:			**no knowledge**	**0-20 %**	2
	> Probability of occurrence				**0-20 %**	2
	> Abatement cost USD/ton CO2				**> 100**	7

Technology Selection DSP review



The Trouble with Economics

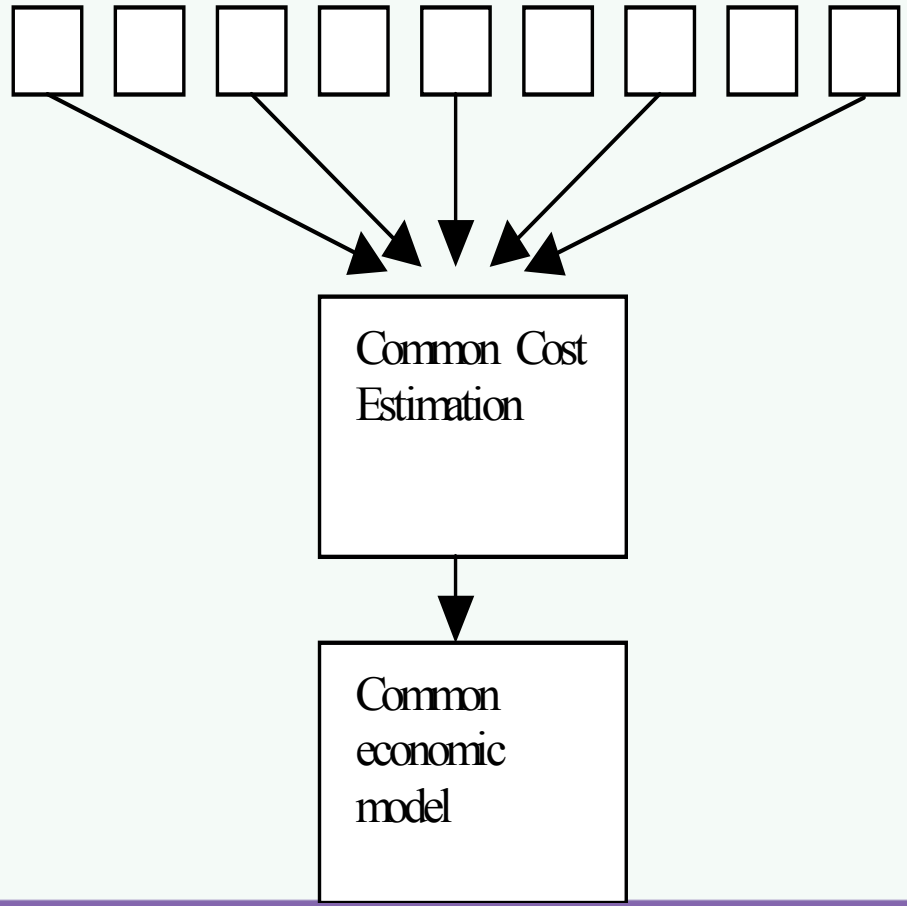
- Economic models need quality estimates.
  a. We had & have numerous cases (combinations of technologies and scenarios).
  b. Engineering studies required, they provide
     i. Design basis
     ii. Process studies
     iii. Equipment lists, plot plans
  c. Easy to generate numbers that cannot be compared. Need consistency:
     i. Location, retrofit/new construction, execution strategy.
     ii. Plant size, energy balance.

Common cost estimation and economic screening approach to secure consistent technology comparison

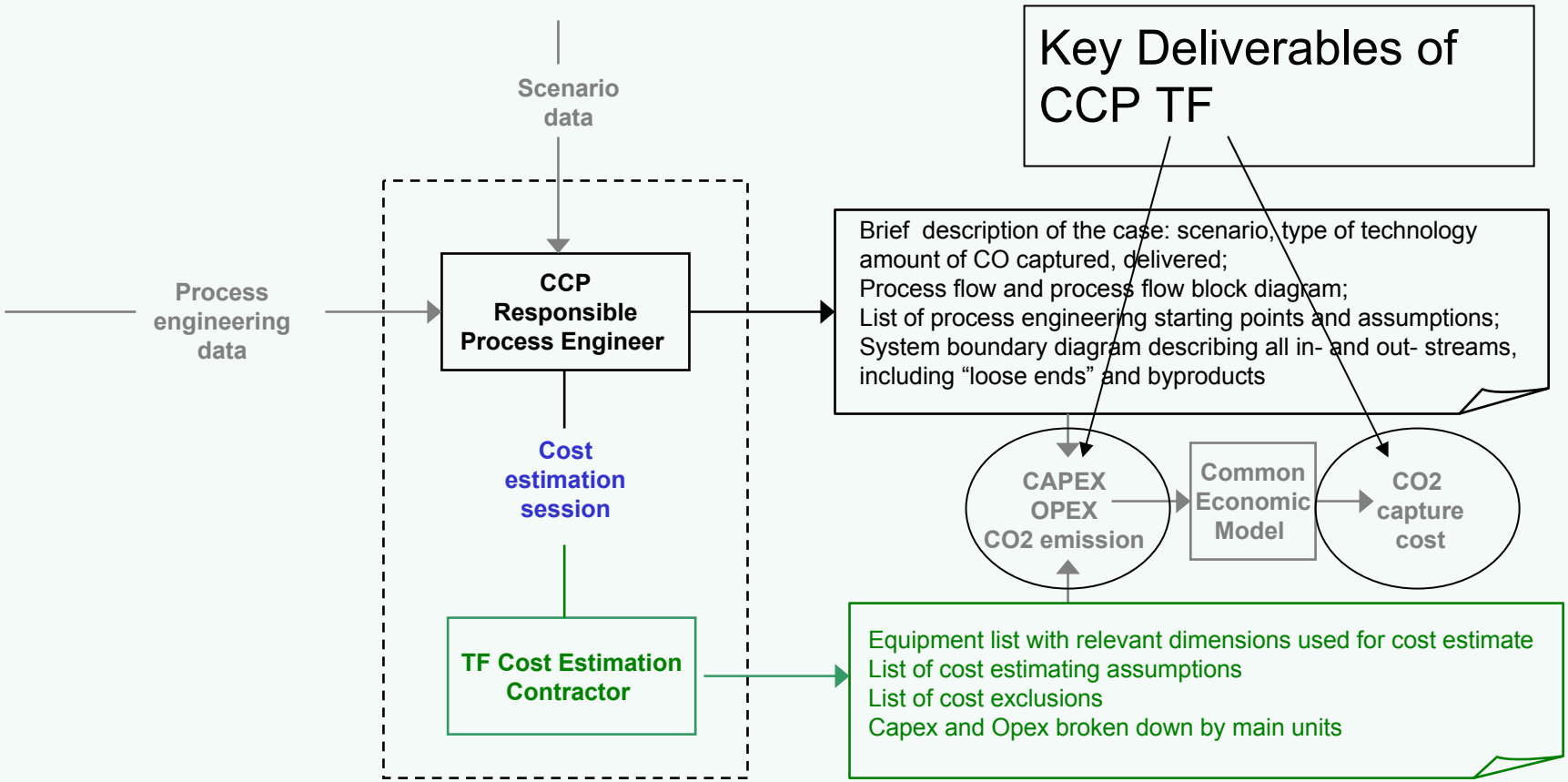
Individual CCP-Tech.Team/ Technology Supplier projects →

Common CCP cost-estimator →

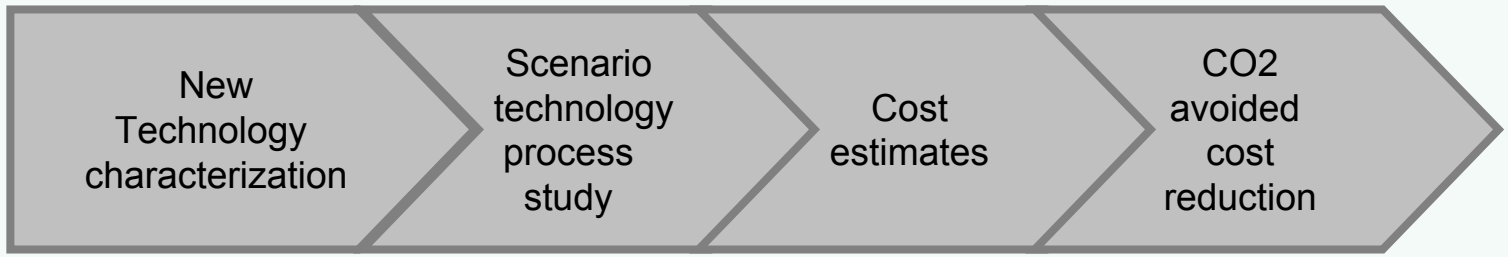
CEMT →



Roles in 2002 Early Technology Screening



Technology Evaluation Work flow

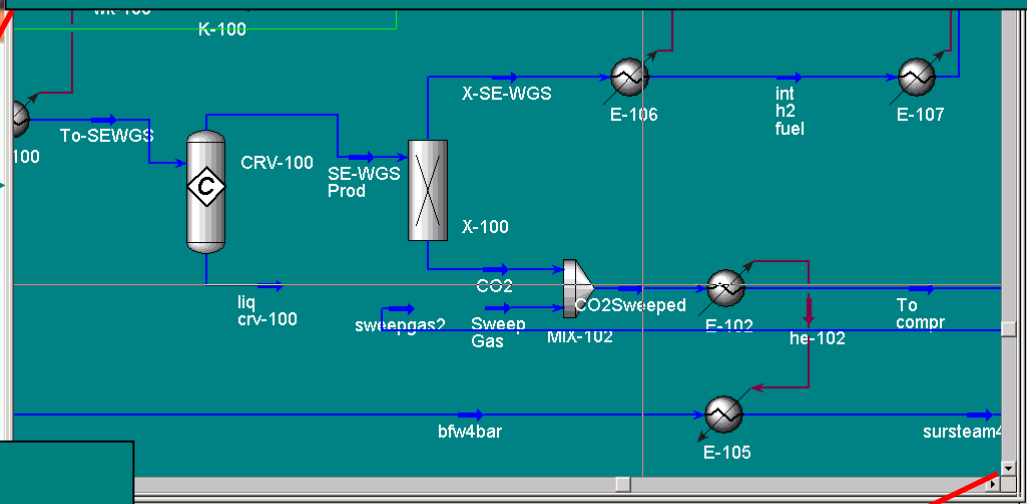


New technology characterisation

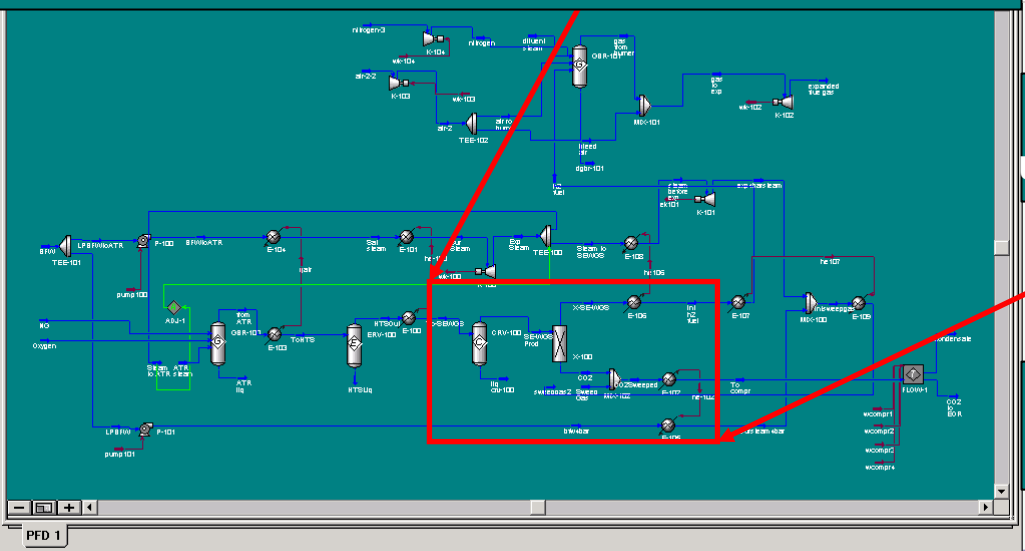
- New material (membrane, adsorbent, solvent, ...) properties (thermodynamics, kinetics, ...)
  a. (experimentally measured in line item activity or based on reasonable assumptions)
- mathematical model of the equipment based on the new material or concept (membrane reactor, membrane contactor, SEWGS reactor, REDOX reactors system)
- relationship between volumes and flows, T, P, (t for cyclic operated units), compositions, conversions, yields
- process simulation model

New technology characterization

Process simulation model of the new technology



Scenario/technology process study



Heat and material balances utilities consummables and products

Size or rating of main plant items

CAPEX estimate

Factorial estimating: main plant item installed cost using sub-factors

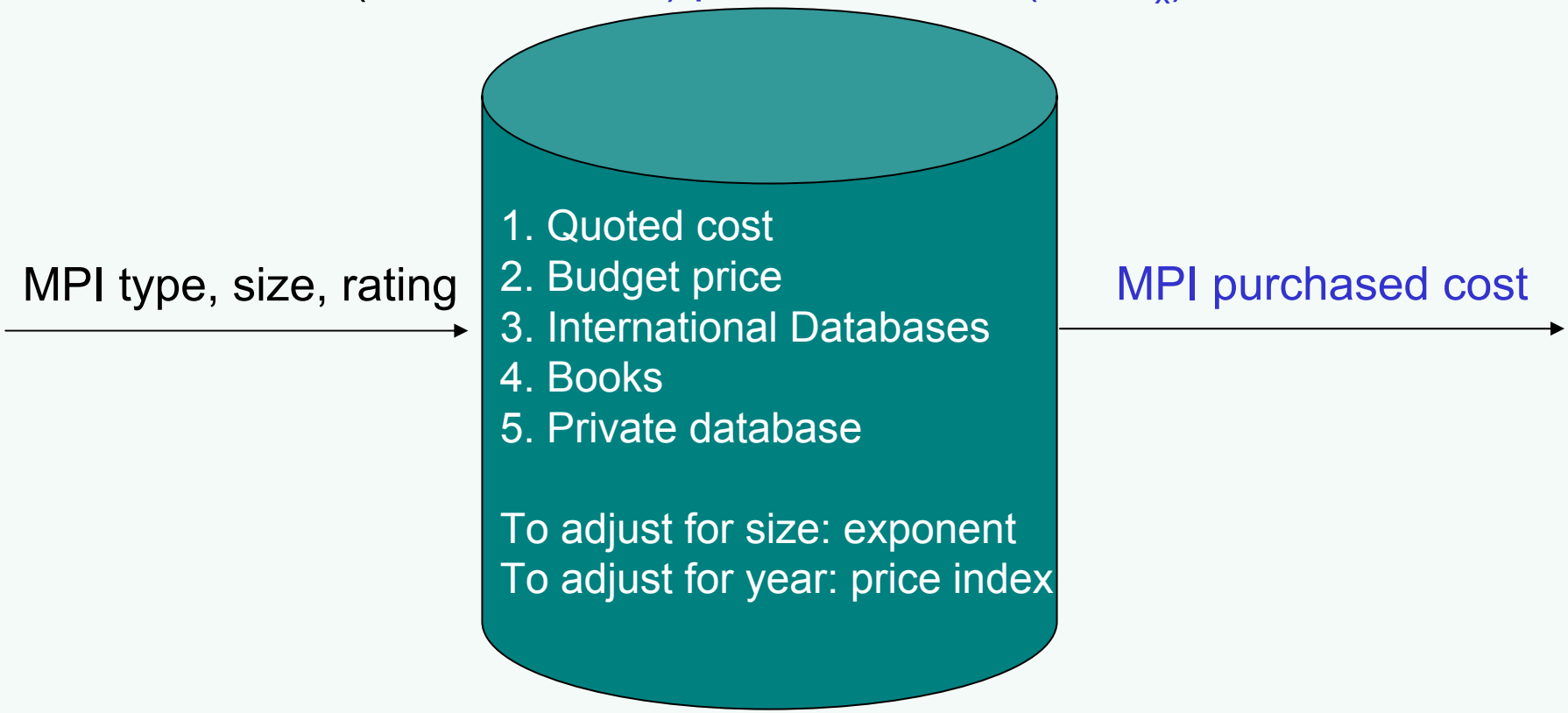
1. List all of the main plant items (MPIs)

Then for every MPI:

2. estimate its size or rating

CAPEX estimate
Factorial estimating: main plant item installed cost using sub-factors

3. estimate its (US Gulf Coast) purchased cost ($MPIC_x$)



CAPEX estimate Factorial estimating: main plant item installed cost using sub-factors

4.1 specify its material factor, f_m

4.2 convert $MPIC_x$ to carbon steel basis

4.3 convert MPI carbon steel basis estimated cost to reference USD

4.4 select appropriate subfactors:

f_p , piping factor	f_{er} , erection factor
f_i , instrumentation factor	f_e , civil factor
f_{cl} , electrical factor	f_l , lagging factor
f_{sb}, structures and buildings factor	

according to plant description in terms of: building type, ground condition, level of instrumentation and control, lagging/insulation level, electricity supply, piping system

4.5 calculate its installed cost, c, using:

$$c = (MPIC)((1+f_p)+(f_{er}+f_i+f_{el}+f_c+f_{sb}+f_l)/f_m)$$

CAPEX estimate
Factorial estimating: main plant item installed cost using sub-factors

5. calculate total equipment erected cost C = Σc
6. adjust C from reference USD to current USD, using a cost index
7. to obtain Identified Costs, multiply C by sub-factors for engineering design and supervision, for management overheads and for commissioning costs
8. to obtain Total Costs add contingency.

Utility & Energy OPEX estimates- applied to stream variables

- Generic US Gulf Coast Price List

	US Dollar	*Unit*
Oil	125	metric ton
Gas	3	mBtu
Electric power	0,04	kW
Steam		
- Low pressure	4	metric ton
- Medium pressure	6	metric ton
_ High Pressure	10	metric ton
Mains water (process water)	0,15	metric ton
Cooling water (cooling towers)	0,01	metric ton
Chilled water	0,08	metric ton
Demineralised water	0,2	metric ton
Compressed air (9 bar) (stp)	0,006	m3
Instrument air (9 bar)(dry)(stp)	0,01	m3
Refrigeration (00C)	0,005	MJ
Nitrogen (stp)	0,08	m3

Fluor baselines utilisation

During 2002, the TF received detailed class 3* scenario cost estimates incorporating Fluor's Econamine process to separate a CO_2 stream from flue gases produced by:

a. a NG combined cycle power station (Norwegian scenario)
b. a NG distributed gas turbines system (Alaska scenario)
c. the heaters & boilers of a refinery (UK scenario)

In these cases the TF cost estimator started from the MPIs Purchased Cost provided by Fluor and evaluated the Total Installed Cost using the factorial method described above.

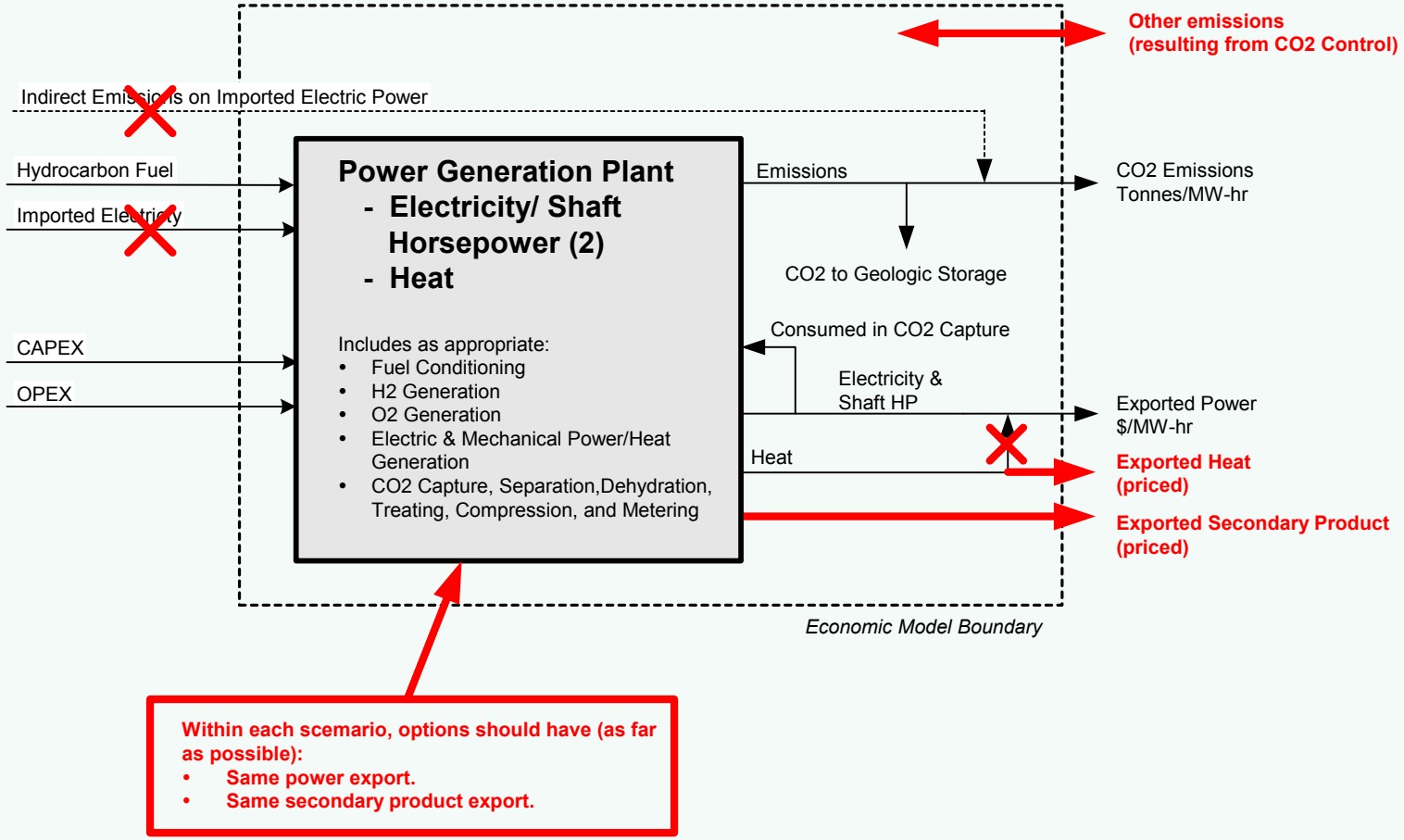
*+/- 30% cost estimates

Economic model parameters

- fuel gas price (HHV): 3 USD/Mbtu
- electricity price: 0.04 USD/kWh
- capacity utilisation factor: 8000/8760
- construction period: 2 years
- operating life time: 25 years
- real discount factor: 10%
- CO2 emission for imported electricity: 0.35 t/MWh

NB. All can be changed, all can be converted for montecarlo simulations and and sensitivity analysis.

Advisors early key recommendations



Further economic model development

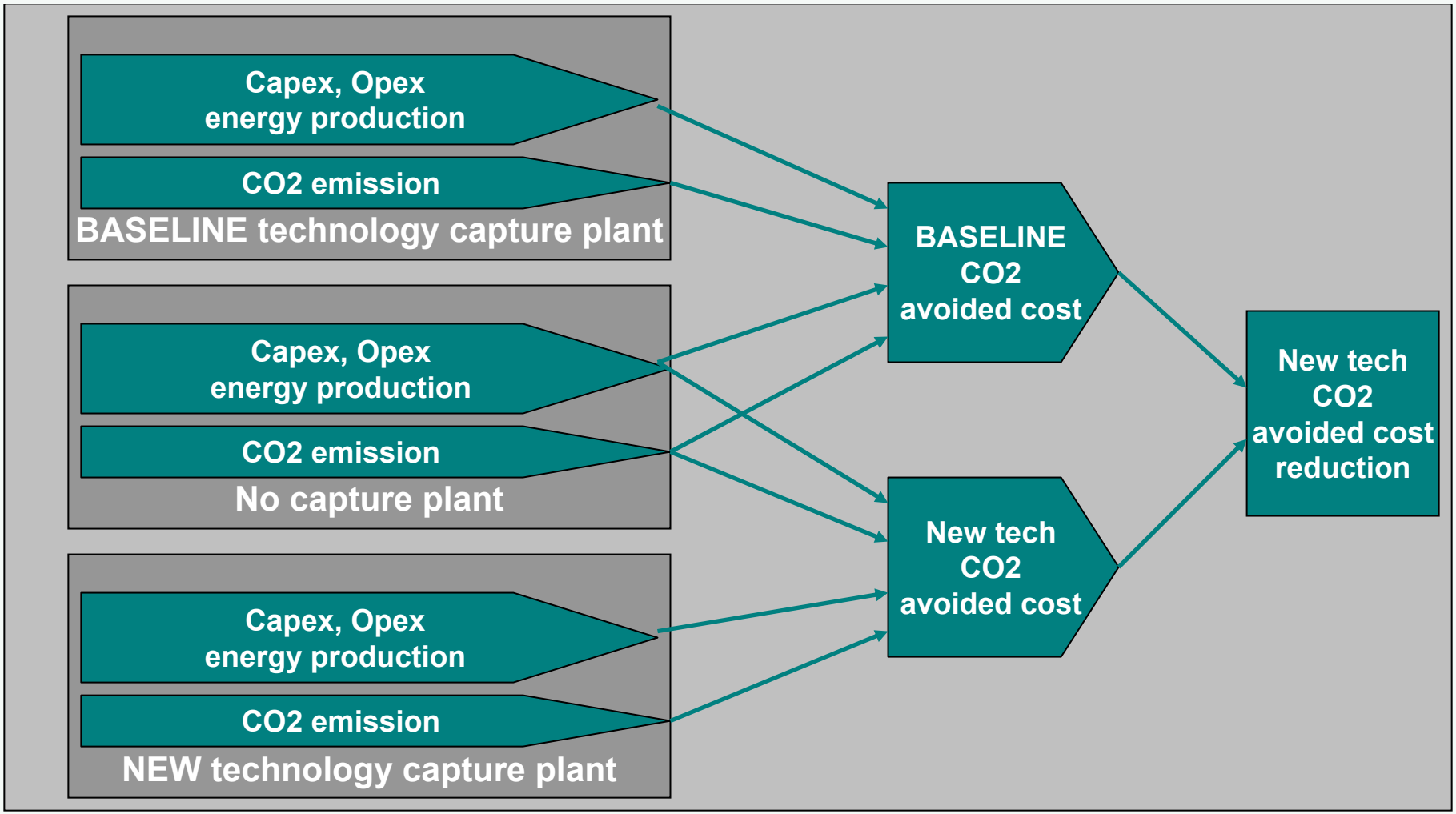
- Original model incorporated code to generate some of the variables in the power plant calculations, this detailed code was similar to that in several published power plant models most often applied to a single technology
  a. Worked for some scenario's and cases but not for others
- We needed to compare many technologies on a consistent basis when applied to a range of scenarios
- We have generated "real" data in this program and have access to experienced process engineers. So we deleted the detailed code and enabled direct data input

The economic screening model layout:

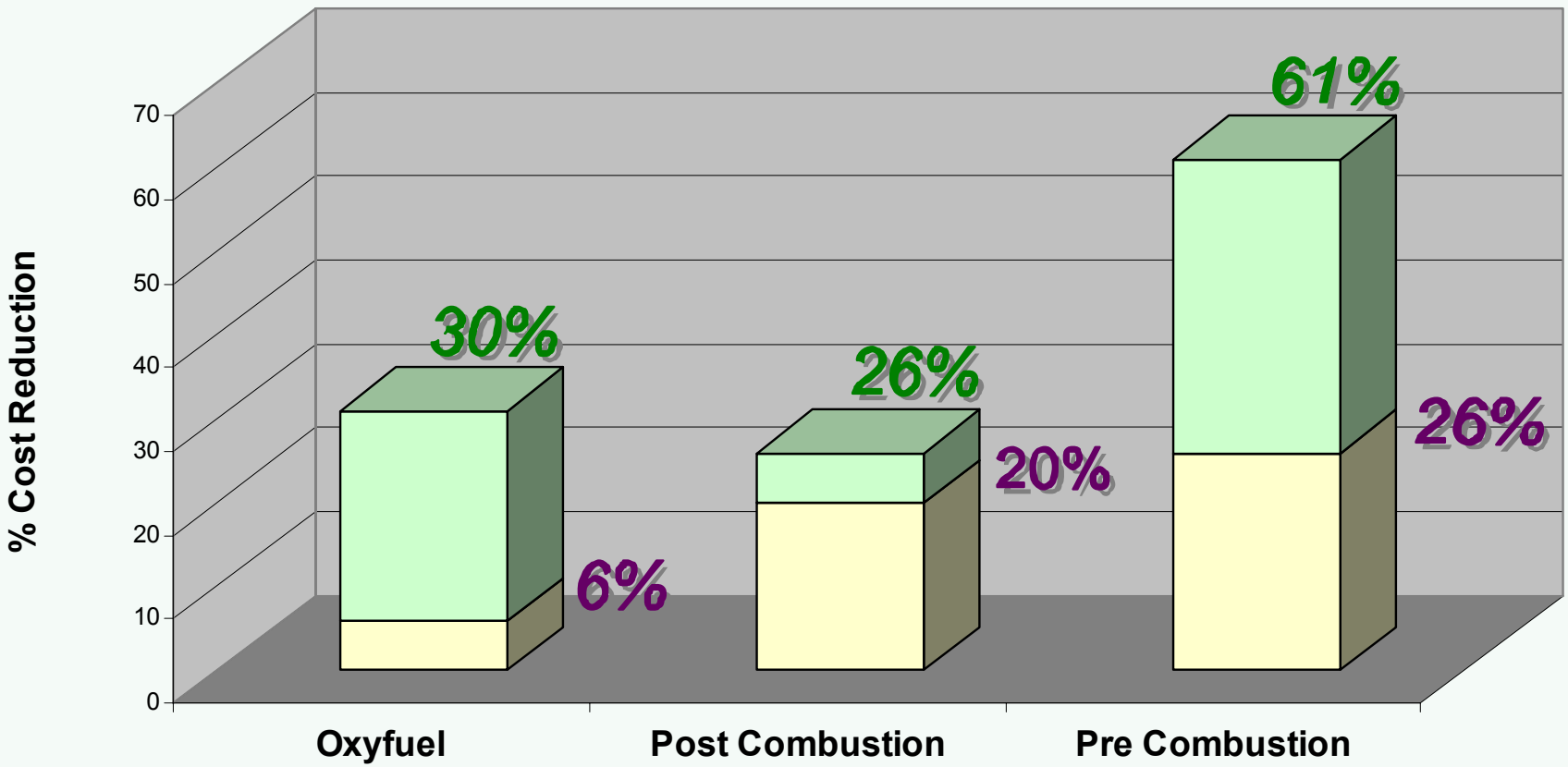
CO_2-cost calculation and comparison of capture technologies per scenario

General economic assumptions					
Scenario:					
Scenario & technology input data	Uncontrol	Baseline	NewTech 1	NewTech 2	NewTech 3
Summary economics					
Overall technology scoring					
Intermediate economics					

CO2 avoided cost reduction calculation in a scenario

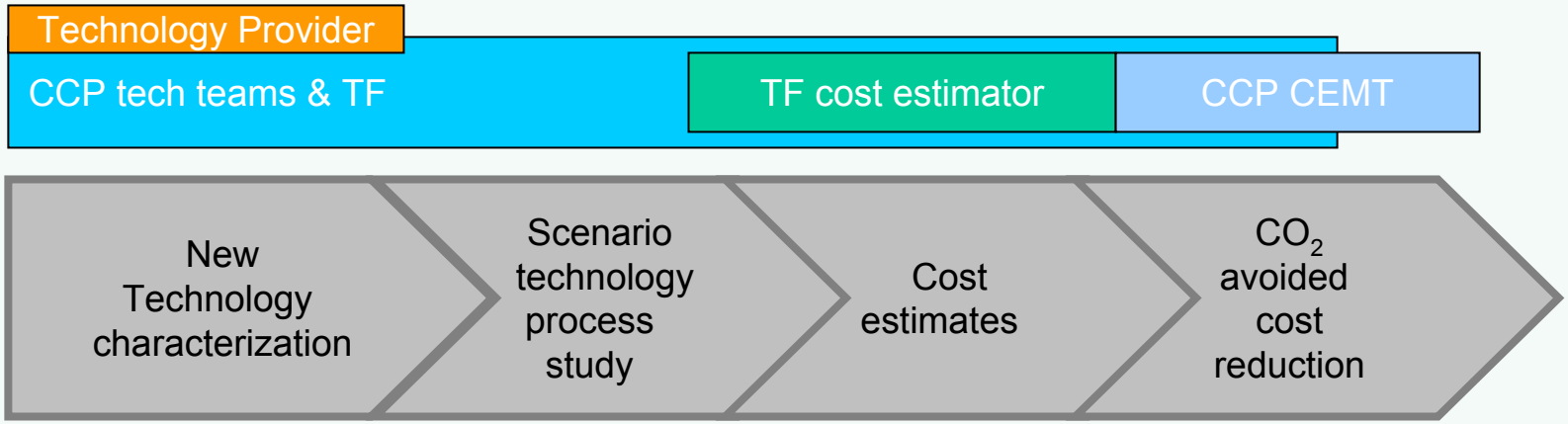


CO_2 Avoided Cost Reductions

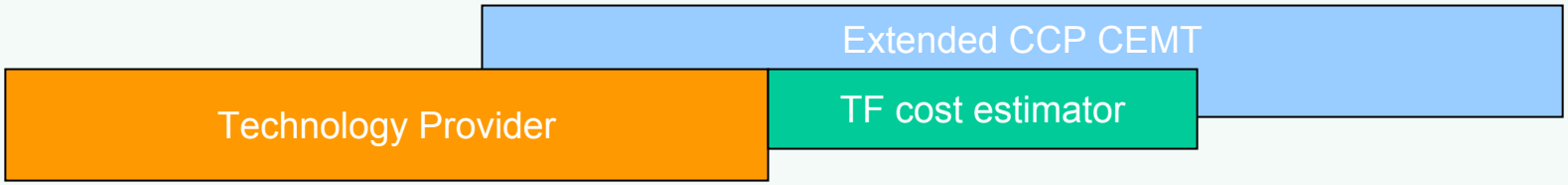


2002 vs.2003

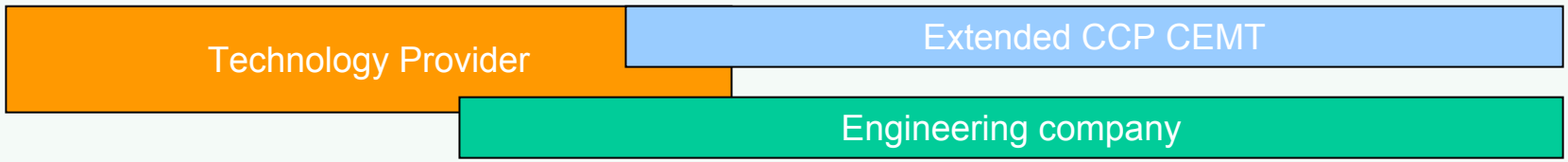
2002 Early Technology Screening



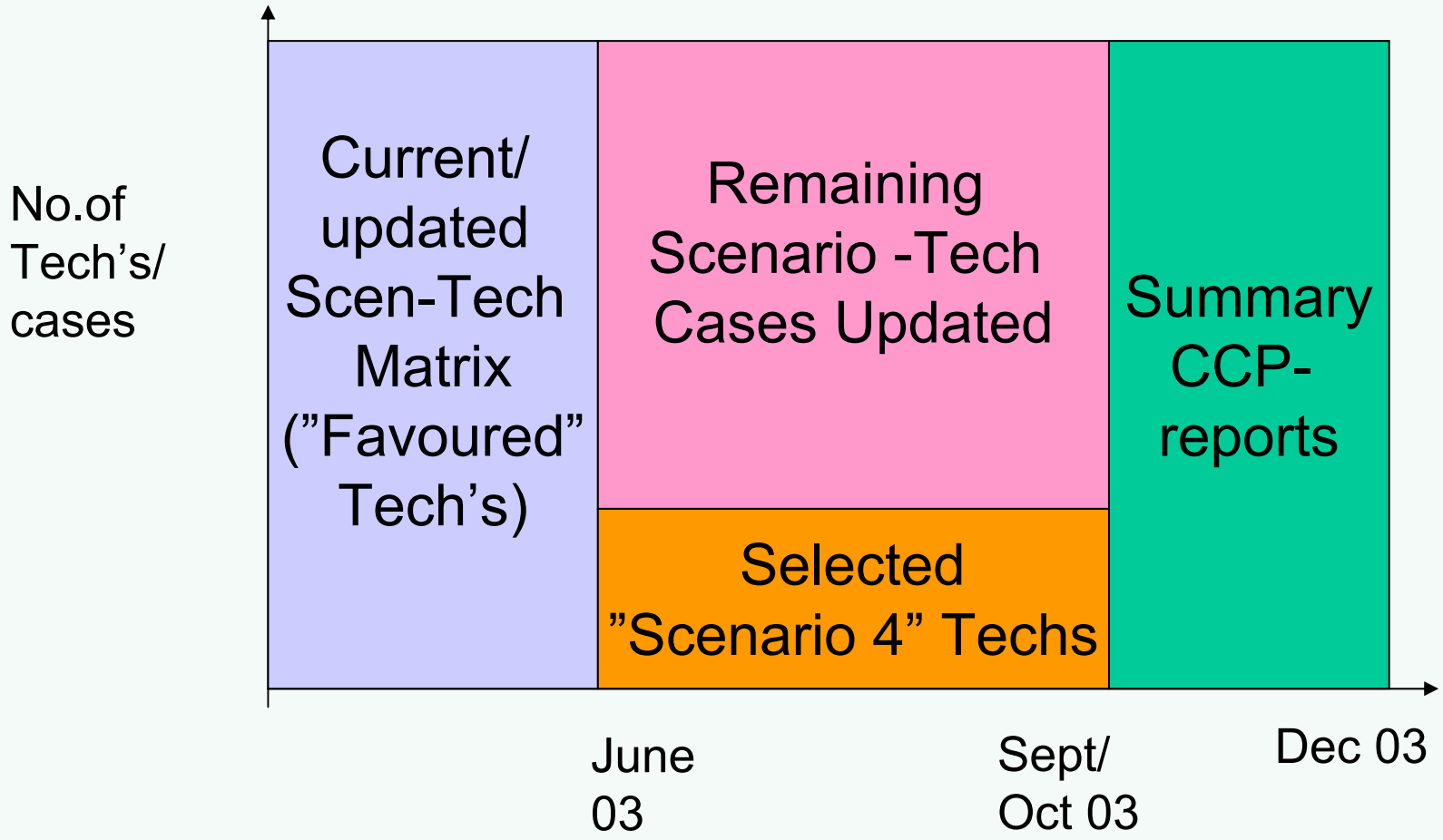
2003 Broad Technology Evaluation



2003 Detailed Technology Evaluation on 4 selected cases



CCP will finalize and report current program this year



Watch this space!

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