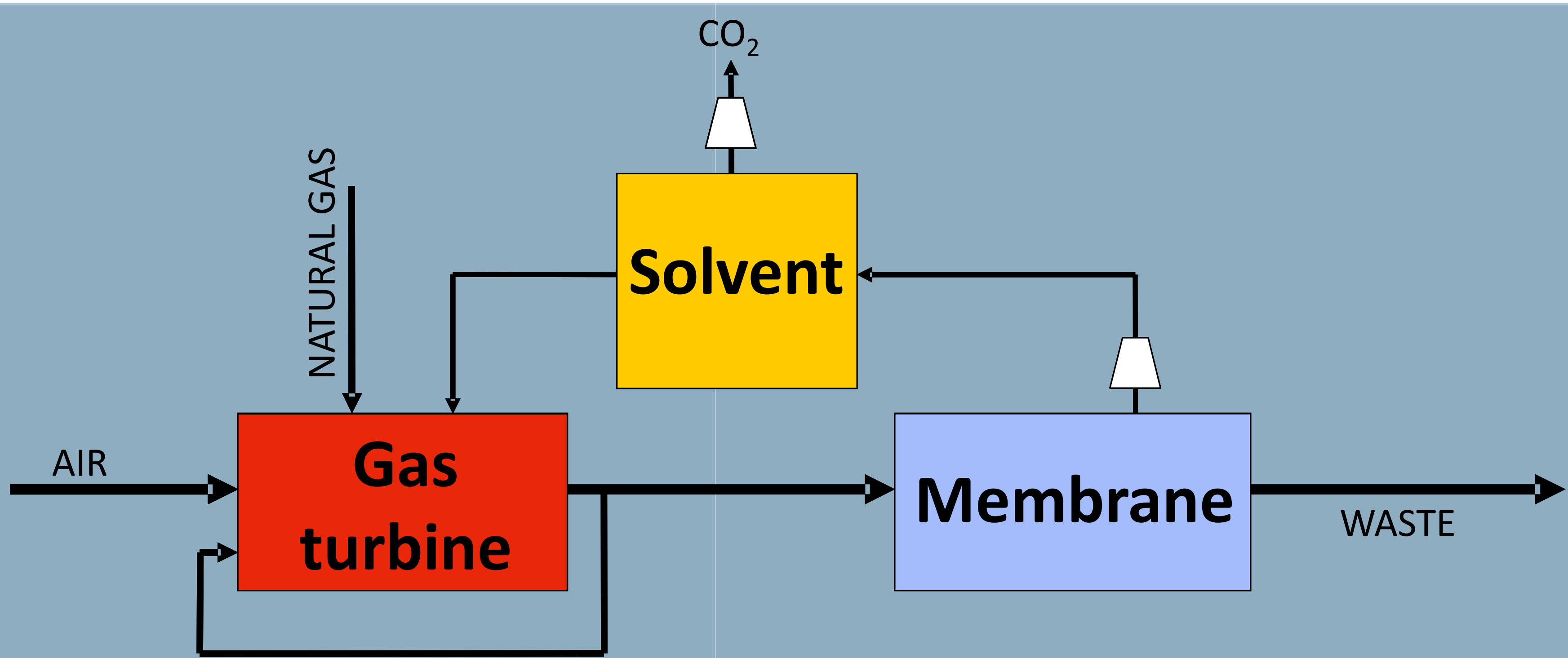
Hybrid absorber-membrane CO_2 capture



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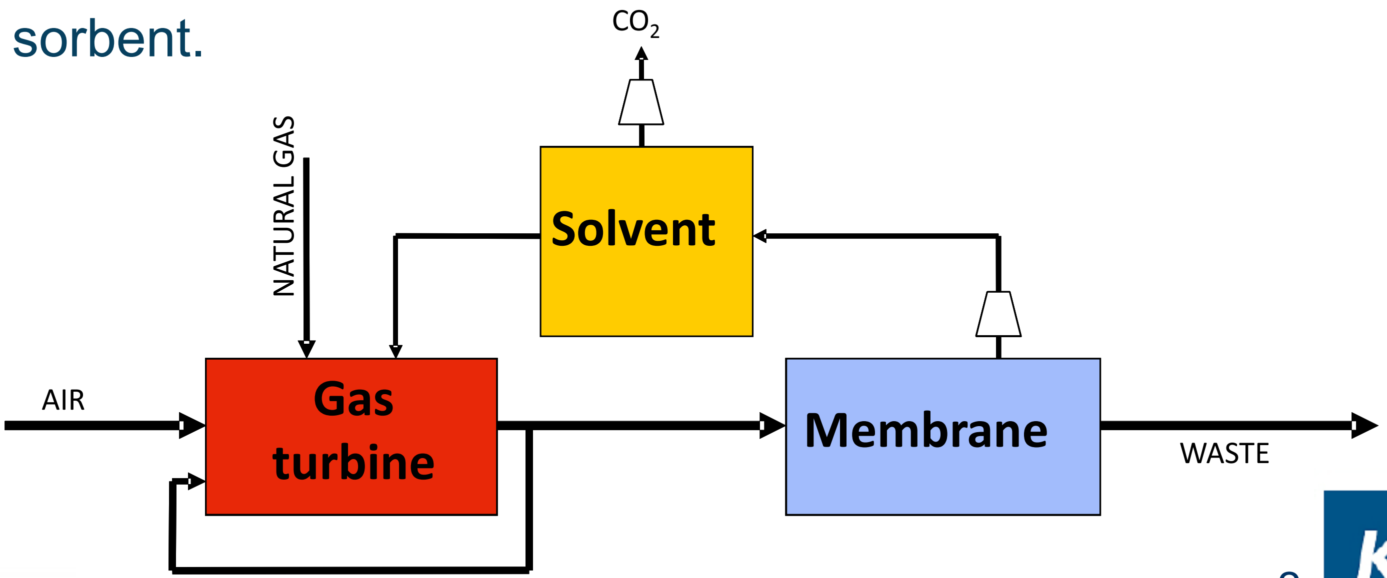
TCCS-6 Trondheim, June 16th, 2011

Idea for post-combustion CO_2 capture from gas-fired installations

- Recycling: looping back a fraction of the flue gas to the gas turbine to double the CO_2-concentration;
- Membrane preconcentration: applying CO_2-selective membranes sequentially leading to a CO_2-concentration of e.g. 50%;
- Absorber final capture: compressing this carbon dioxide rich flow and feed to a pressurized absorber where the CO_2 will be absorbed using a low energy consuming sorbent.



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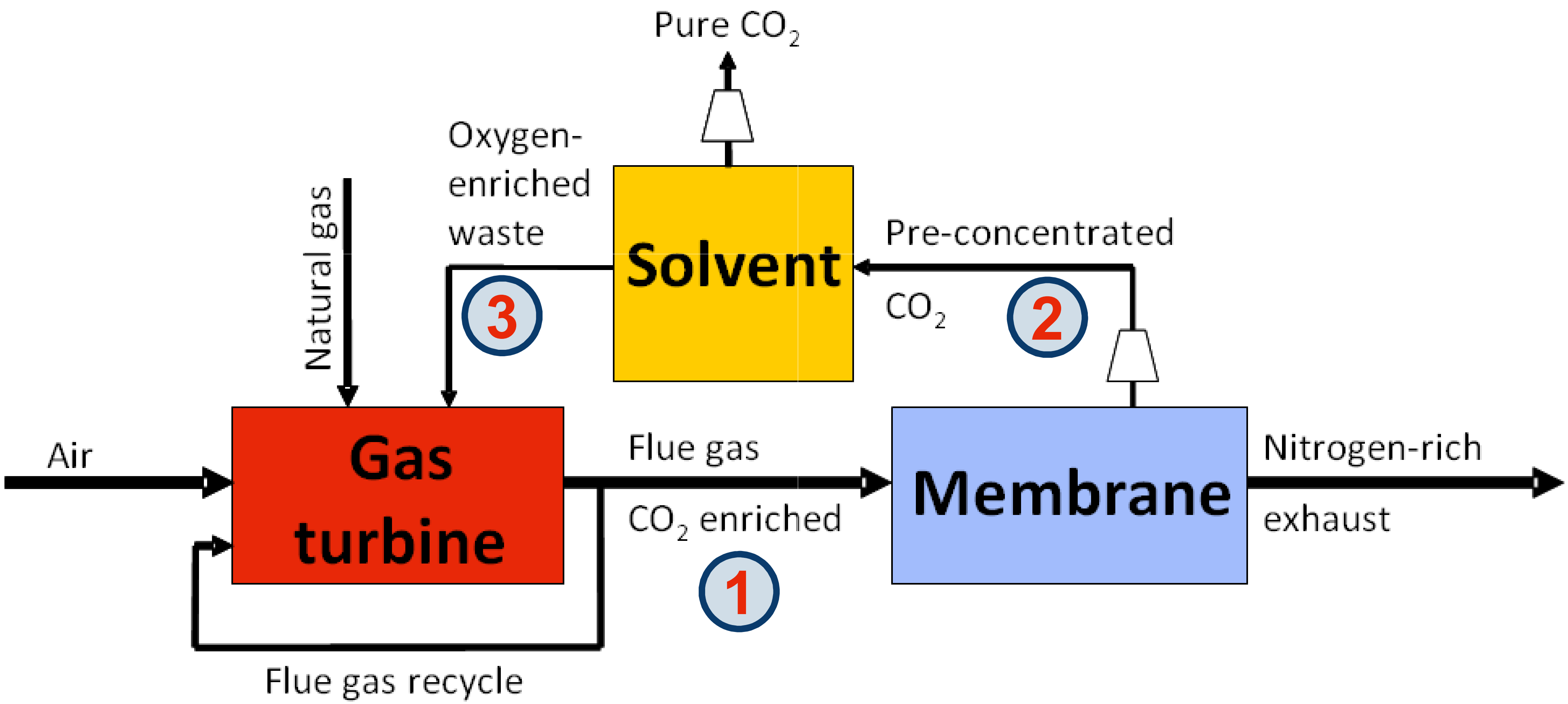
Concept overview *(patent granted)*



- Optimal performance membrane + absorber
  - Energetically favourable
- Enables post-combustion CCS for gas turbines
  - Major CO_2 emitters at low concentration

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Parameters at interface 1

1. Gas turbine – membrane unit

- 100 °C, but can be lowered as desired (heat exch.)
- Pressure ~1 bar (gas turbine durability and efficiency)

- Flue gas looping: modelled in KEMA’s SPENCE ® model
  - for simulation of processes for energy conversion and electricity production
  - plant design and performance calculations
  - online process calculations to control operation processes
  - 400 MW combined cycle power plant (2/3 of power originates from the gas turbine)

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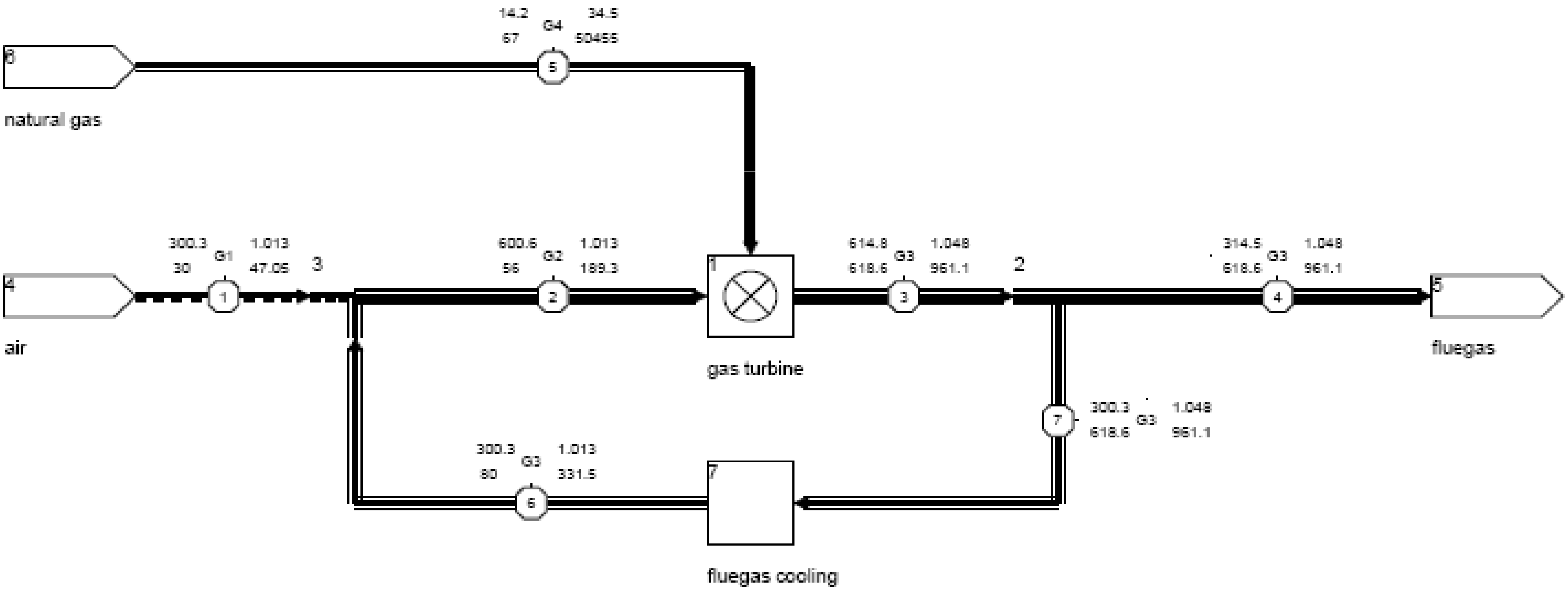
Flue gas looping in SPENCE: scheme



m [kg/s]	p [bar]
t [°C]	h [kJ/kg]
SPENCE 7.1	
GRASP 2.72	
GTmodel.STM	

Gas nr.	1	2	3	4
Ar	0.0092	0.00885	0.00851	
O2	0.20723	0.12708	0.04942	
N2	0.77237	0.7447	0.71788	0.0445
H2O	0.01069	0.08254	0.15195	
CO2	0.0003	0.03683	0.07223	0.0079
CH4				0.9365
C2H6				0.0107
C3H8				0.0004
Molweight [kg/kmol	28.845	28.3895	27.9482	16.9579

KEMA Opwekking Power Generation CATO-2

project

instructor draftsman

proj.nr. programmer

file D:\SPENCE\SPENCE projecten\CATO-2\FluegasLooping date 11/12

Flue gas looping in SPENCE: results

- Obviously dependent on specific GT, amount of looping etc.
- Indicative set of parameters and conditions chosen

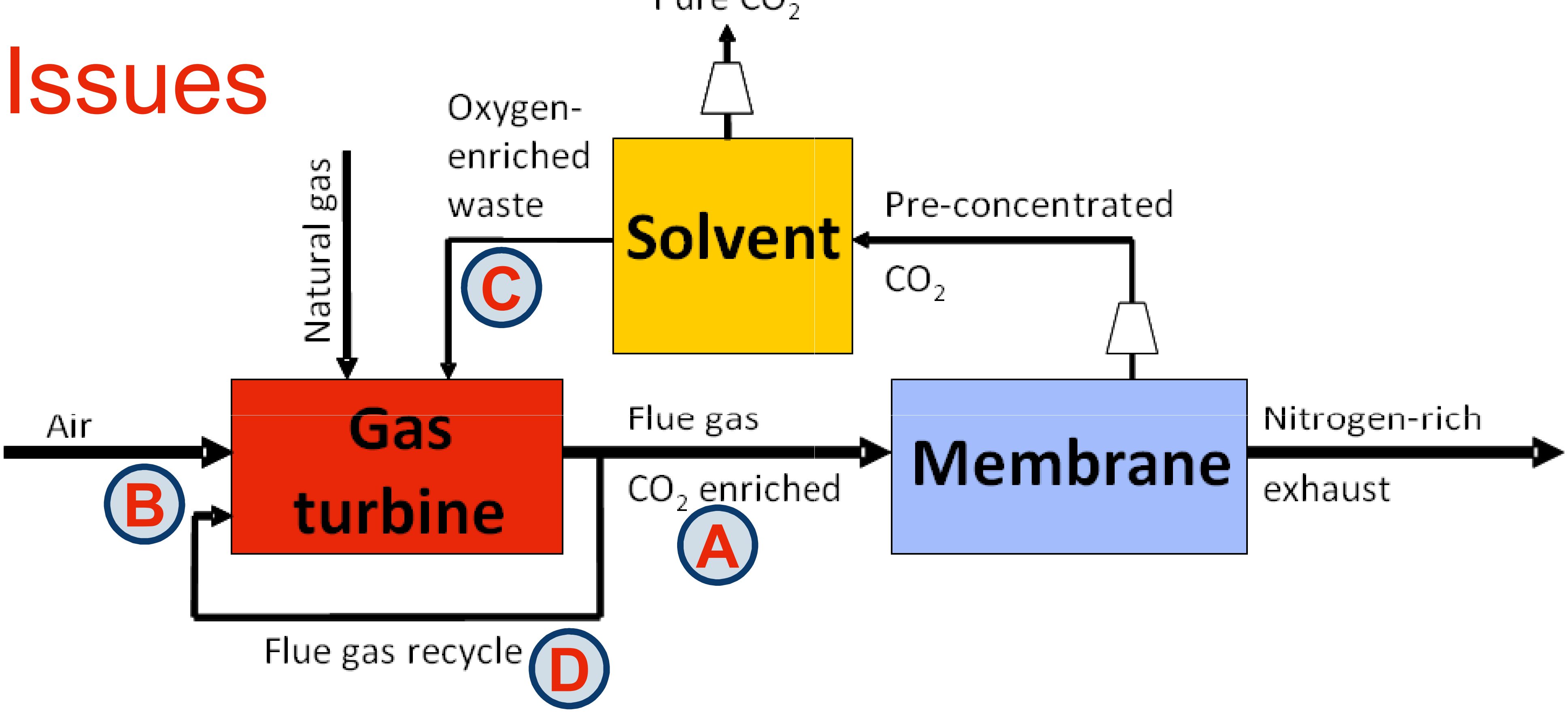
Gas composition	*Without looping*	*With looping*
Oxygen	12%	5%
Nitrogen	77.5%	72%
Water	6%	15%
Carbon dioxide	3.5%	7%
Flow temperature	50 ºC	70-75 ºC
Flow volume	600 kg/s	300 kg/s

Parameters at interface 2 & 3

2. Membrane unit – solvent unit
   - Optimisation: lower CO_2 permeate purity means lower *membrane* energy use, but higher = lower *absorber* energy
   - Preliminary target 50-70% CO_2
   - Feasibility investigated by modelling

3. Solvent unit – gas turbine (waste recycle)
   - O_2-rich waste stream: how to inject? Construct entrance, add expander, …?

Issues



- **A** T = 100 °C high for polymers; ceramics or heat exchanger.
- **B** SO_2 and trace elements in compressor. Corrosion?
- **C** High pressure O_2-enriched stream: how to inject in GT?
- **D** Looping means different inlet mix; how to deal with it?
  - Flow / compression / combustion / process startup.

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Membrane modelling: starting params

	Permeance [$Nm^3/m^2.h.bar$]	*Selectivity over N_2 (α)*
Carbon dioxide	2.7	50
Nitrogen	0.05	-
Oxygen	0.14	2.5

- Corresponding to one commercial preselection membrane
- Input for modelling → determine absorber conditions
- In a later stage: combine with absorber modelling and energetic evaluation

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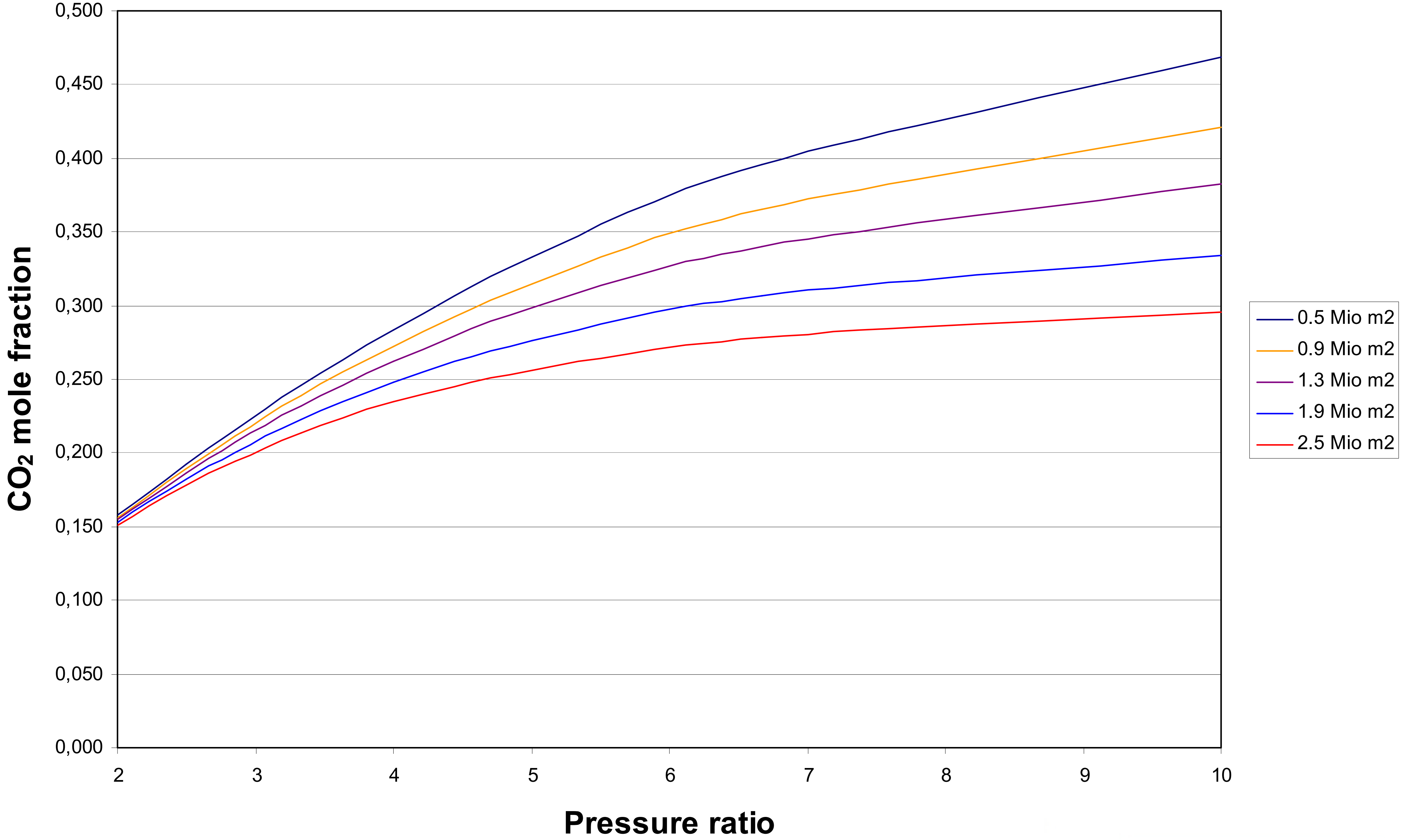
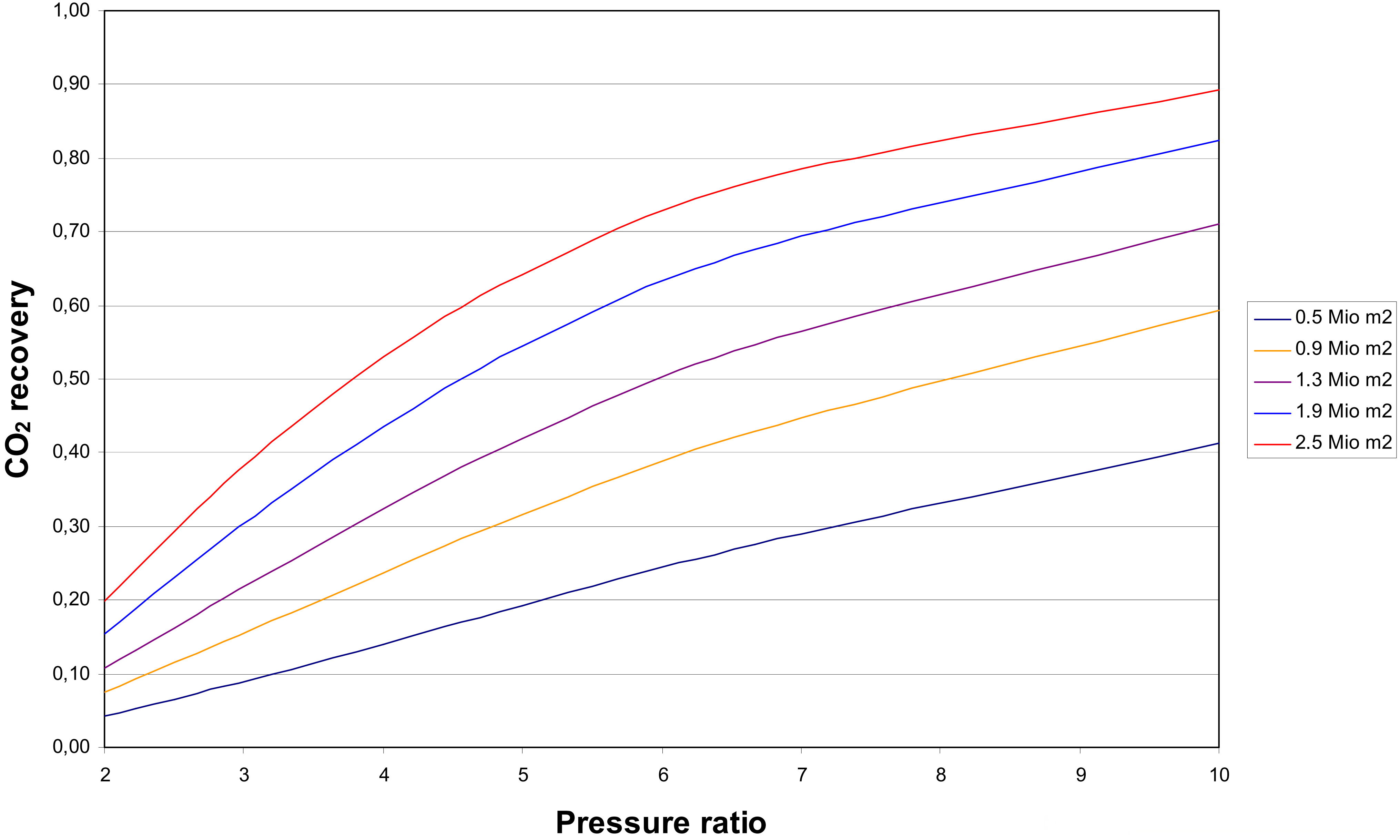
Membrane modelling: example



CO_2 permeate purity versus pressure ratio

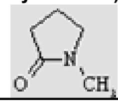
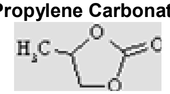
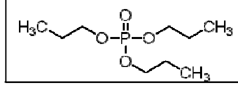
Membrane modelling: example



CO_2 recovery versus pressure ratio

Solvent selection for hybrid system

- Most promising look physical/hybrid solvents
  - NMP
  - Sulfolane
  - PC *(less stable, probably unsuitable)*
  - Tripropyl Phosphate
  - DEPG *(dimethyl ethers of polyethylene glycol)*
  - Sulfolane/amine mix

Solvent	m $[C_L/C_G]$	Viscosity solvent [mPa.s]	Density Solvent $[kg/m^3]$	Vapour pressure of solvent
NMP (N-Methyl 2 Pyrrolidone) 	3.7 4.03 3.84	1.8	1028	0.00045
Sulfolane 	3.32 2.98 3.07 [303K]	10.10	1260	0.000013
Propylene Carbonate 	2.95 3.66[293K] 4.25 3.55 3.54	2.51	1200	0.000039
Tripropyl Phosphate 	3.93		1012	

- Conclusion: solubility data of oxygen/nitrogen is mostly lacking or very limited

Process modeling of hybrid systems

- Base case:
  - Combined cycle power plant
  - Flue gas recycling
  - MEA absorption process
- Hybrid systems:
  - Combined cycle power plant
  - Hybrid membrane solvent system
  - Commercially available membranes
  - DEPG solvent

PROCEDE

For more information:

- Participate in NanoGLOWA's Workshop at ICOM 2011, July 24th, Amsterdam (www.icom2011.org)
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