SEVENTH FRAMEWORK PROGRAMME

OCTAVIUS

OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

IMPLICATIONS FOR INDUSTRIAL DEMONSTRATION

Robin Irons (E.ON)

Seven key investment parameters for a CO_2 capture plant (not exhaustive)

OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

	Definition
Efficiency	Impact of the technology on the electric efficiency of the power plant.
O&M Cost	Impact of the technology on operational and maintenance costs including fuel costs includes costs for e.g. solvent makeup or membrane replacement or system repair
CAPEX	Capital expenditures, i.e. impact of the technology on investment costs
HSE	Impact of the technology on health, safety and environment
Capture rate	The fraction of the CO_2 generated by the power plant that is actually captured.
Availability	Impact of the technology on availability
Operability	Impact of the technology on the operability of the system i.e. on flexibility (acceptable steady-state operation over a range of conditions), controllability (ability to move to new steady-state set-points and to handle process disturbances), start-up/shutdown characteristics and ability to handle equipment failures in a safe manner.

Source – ZEP Technology Task Force – working paper (2014)

OCTAVIUS – Its fit in the R&D landscape

OCTAVIUS builds on a series of earlier Carbon dioxide capture projects including EC Framework projects CASTOR, CESAR and National projects in NL, UK, Norway

We already have a large heritage of experience in pilot operation, analytical techniques and control philosophy.

Features different capture pilot designs and different power plants with variable inlet conditions.

Operational results represent some of the longest and most highly instrumented series of operational tests assembles in Europe.

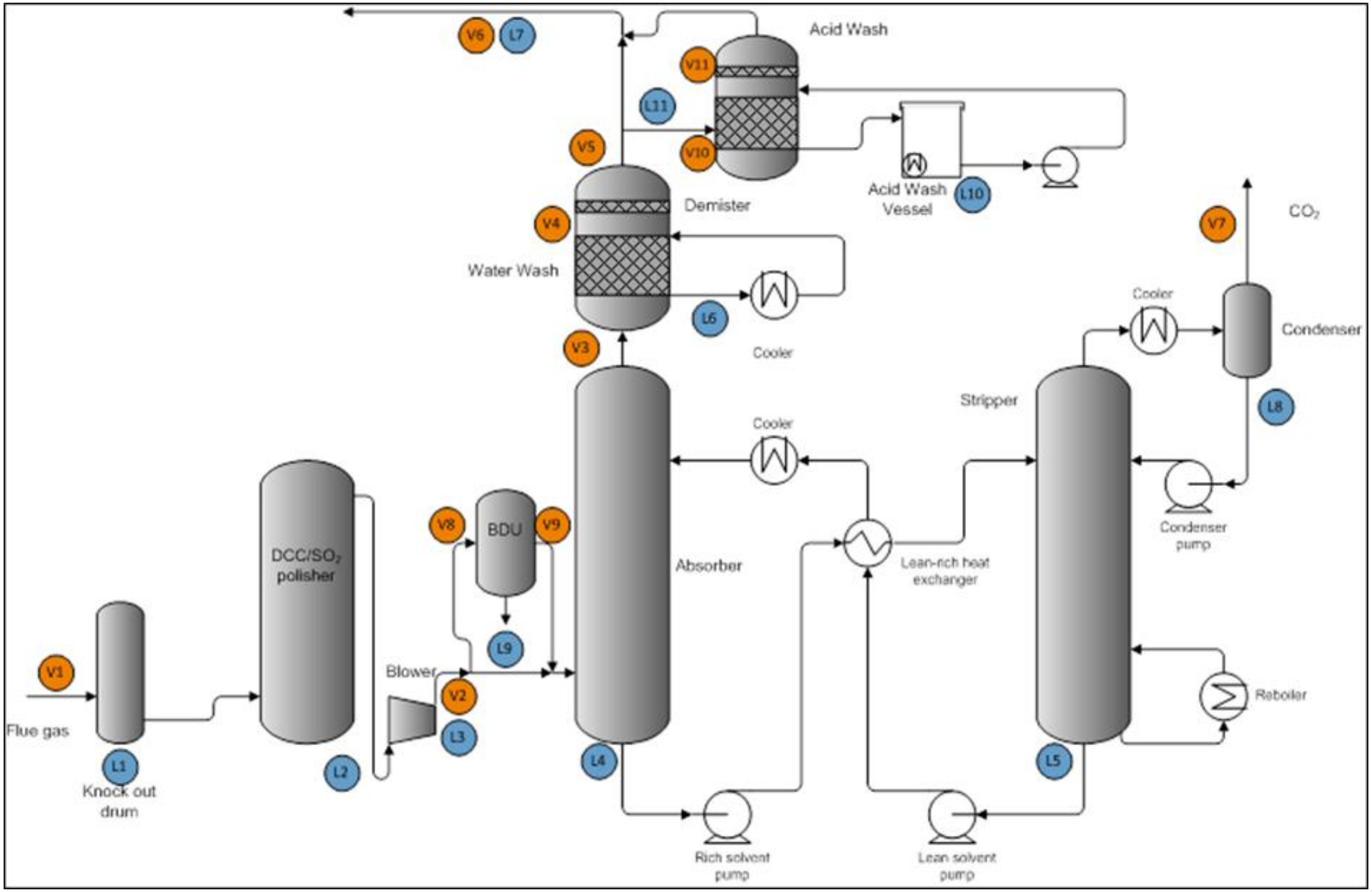
Offer comparisons of the same solvent in different facilities and different solvents in the same facility.

Major activities on supporting science (analytics) simulation and techno-economic assessment.

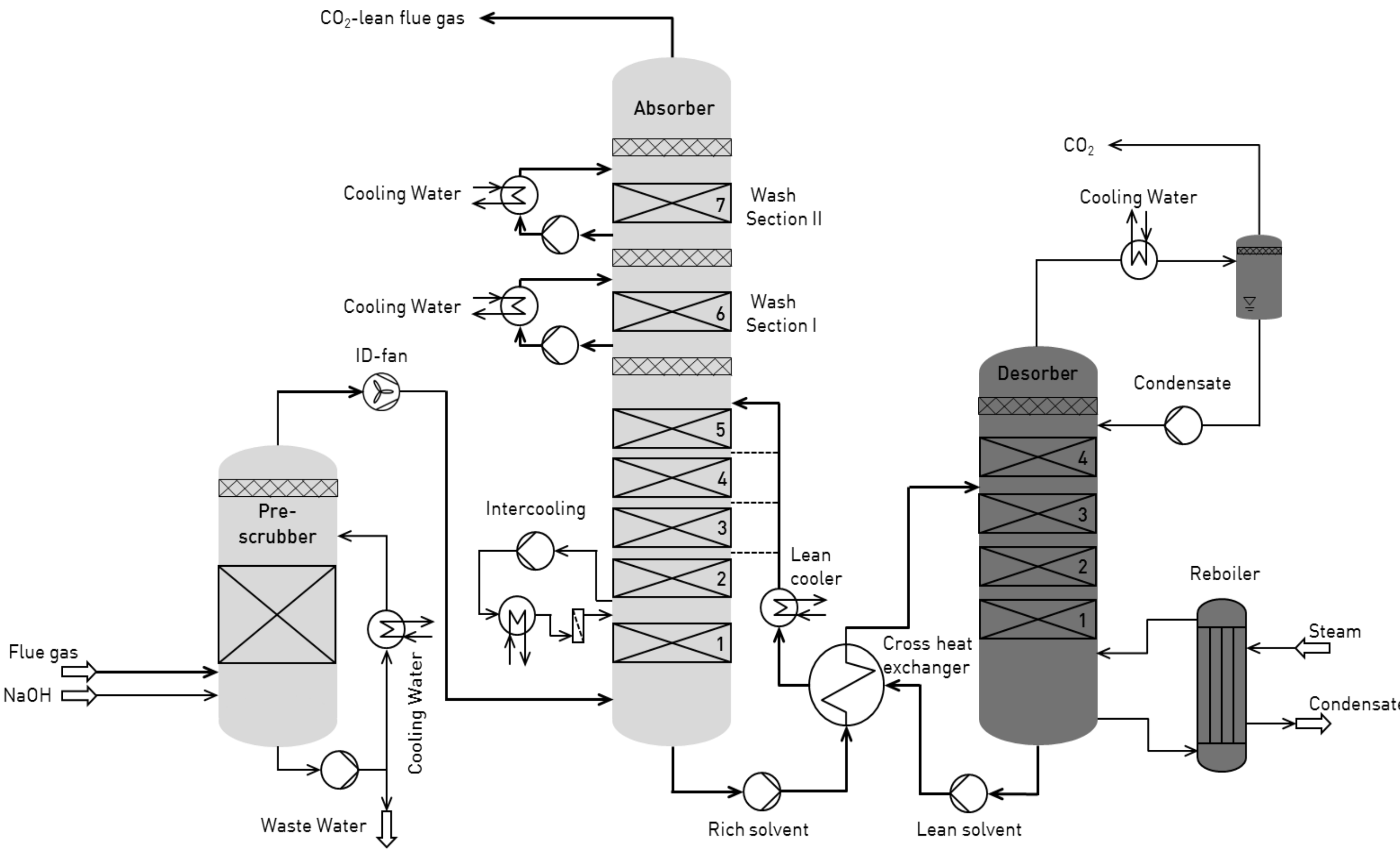
Pilot Testing

Pilot	Location	MW(th)	Campaigns	Solvent(s)
TNO	Maasvlakte		1 (+1)	MEA
ENEL	Brindisi		1	MEA
EnBW	Heilbronn		2	MEA, AMP + PZ

TNO Pilot

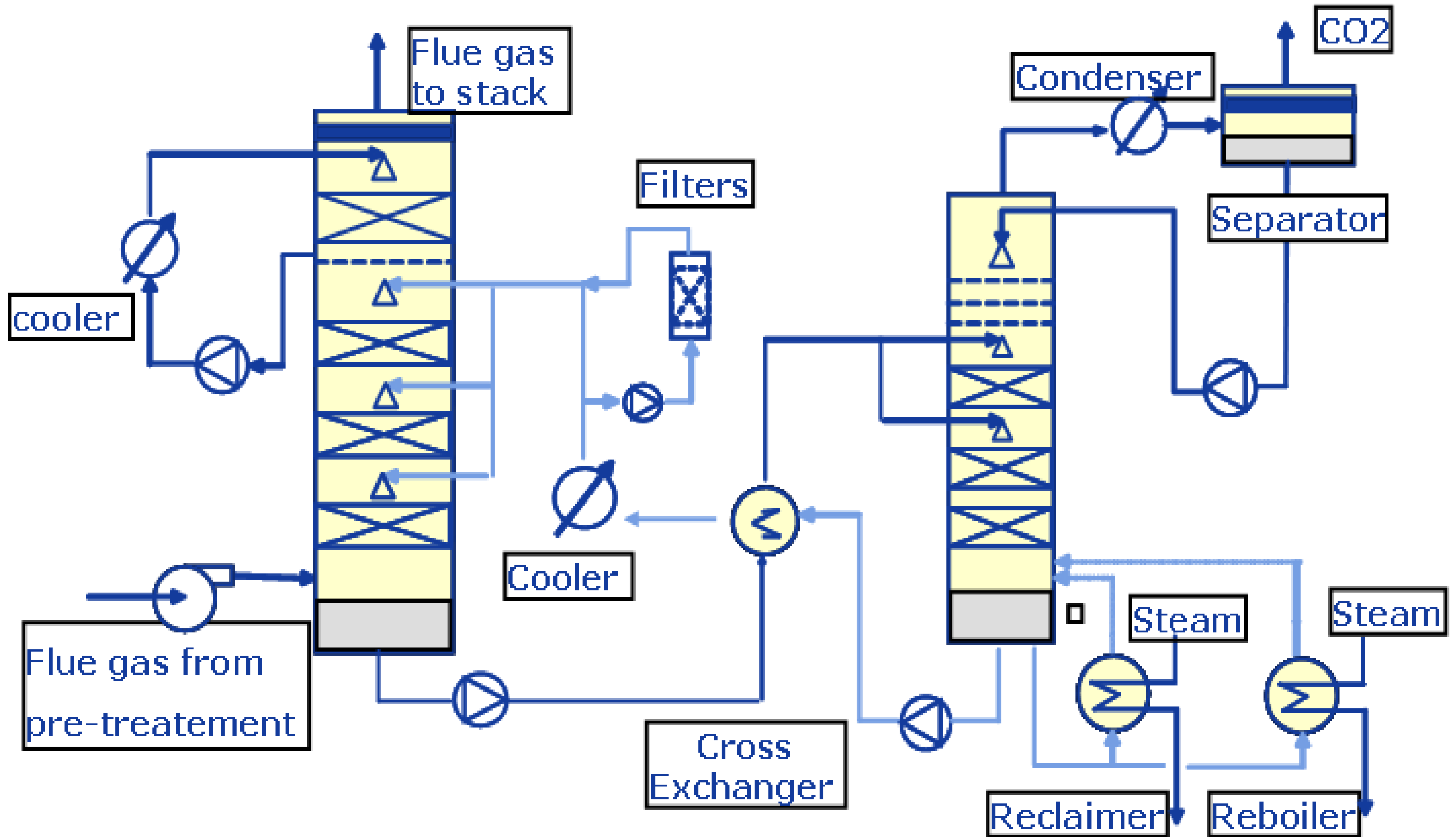

Acid Wash
V6
L7
V11
L11
V5
V10
Acid Wash
Vessel
L10
Demister
V4
Water Wash
L6
Cooler
V3
CO_2
V7
Cooler
Condenser
L8
Stripper
Cooler
Condenser
pump
BDU
V8
V9
DCC/SO_2
polisher
Absorber
Lean-rich heat
exchanger
L9
Blower
V1
V2
Reboiler
Flue gas
L3
L1
Knock out
drum
L2
L4
L5
Rich solvent
pump
Lean solvent
pump

EnBW Pilot



CO2-lean flue gas
Absorber
Cooling Water
Wash
Section II
Cooling Water
Wash
Section I
ID-fan
Pre-
scrubber
Intercooling
Lean
cooler
Flue gas
NaOH
Cooling Water
Waste Water
Rich solvent
Cross heat
exchanger
Lean solvent
CO2
Cooling Water
Desorber
Condensate
Reboiler
Steam
Condensate
7
6
5
4
3
2
1
4
3
2
1

ENEL Pilot



Flue gas
to stack
CO2
Condenser
Filters
Separator
cooler
Cooler
Flue gas from
pre-treatement
Cross
Exchanger
Steam
Steam
Reclaimer
Reboiler

Octavius Deliverables.

Deliverable Number	Deliverable Title	Lead beneficiary name	Delivery date
D21.1	Definition of EU and SA base cases Battery	E.ON	5
D21.2	Definition of operating window for the EU and SA capture demonstration cases	EnBW.KWG	5
D21.3	Guidelines for commercial scale demonstration plants	E.ON	46
D21.4	Public report on the guidelines for demonstration scale CO2 capture plants	E.ON	48
D22.1	Impact of oxidative and thermal degradation	TNO	44
D22.2	Demonstration of alternative reclaiming technologies including waste management procedures (4)	TIPS	40
D23.1	Pilot plant emission reduction to be applied within Octavius	TNO	26
D23.2	Interim report on emission control and reduction	TNO	26
D23.3	Final report on emission control and reduction	TNO	4
D23.4	HSE aspects for workers and the surrounding	TNO	33
D23.5	Process analytical techniques	DOOSAN	40
D23.6	Dynamics and control strategy	SINTEF	44
D24.1	Impact of power plant operation on the CCS-chain	TNO	45
D24.2	Alternative operating strategies for capture equipped power plants	SINTEF	43
D24.3	Market driven operation of capture plants (3)	E.ON	45
D24.4	Opportunities to avoid address solvent lock-in for demo and full scale capture plant	EDF	44
D25.1	Alternative materials	EnBW.KWG	39
D25.2	Opportunities to reduce through life cost of capture by improved plant integration	E.ON	46
D25.3	Literature review of process modifications and selection of processes to be assessed	SINTEF	14
D25.4	Flowsheet improvement comparison	EDF	34

Project Objectives

OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

- **Demonstration at Pilot Plants of:**
  - **Solvent life time;**
  - **Emission control and reduction;**
  - **Dynamics and control;**
  - **Alternative materials;**
  - **Flexibility – of design and solvents**

- **Development of Underpinning Tools – models, diagnostics, Commercial Assessment**
  - **Process Models (Steady-state)**
  - **Process Models (Dynamic)**
  - **Chemical Diagnostics – emissions, loading**
  - **Economic Models – How to optimise technoeconomic performance against (local) market drivers.**

Emissions

- **Aerosols in the inlet gas can lead to emission spikes of solvent.**
- **An operator must characterise the inlet flue gas particulate/aerosol levels as a function of time. Need to investigate options for control of the inlet aerosol**
- **NH3 emission rate is a direct indicator of solvent degradation.**
- **An acid wash is required to manage NH3 levels in emitted gas. (Or potentially a purge on the eater wash system).**
- **Acid wash does not attack solvent peaks. These must be addressed by tackling aerosol inlet levels.**
- **NNO will accumulate in the liquid phase – slowly – ultimately reclamation will be required to maintain this at an acceptable level. Very low concentrations were observed / most of them below detection limit.**
- **Nitrosamines will not track MEA emissions associated with aerosols.**

Solvent Degradation

- **Degradation correlates with Fe**
- **BDU or WESP at inlet could reduce oxidative degradation (by restricting iron entering system)**
- **Degradation products are driven by oxidative degradation. Thermal degradation is unimportant.**
- **Degradation kinetics are driven by the catalytic presence of metals in solution**
- **Avoid residence at (T, P, loading) conditions which lead to ‘free’ O2 in solvent.**
- **Oxidative reduction is a function of T and loading.**
- **Minimise reboiler sump residence time and the cross-lean heat exchanger when O2 is dissolved. Minimise residence time of hot oxidised solvent.**
- **A useful measurement is for dissolved oxygen in the solvent stream.**
- **Options exist for stripping O2 from the stream if necessary.**

Controllability: Speed of Response

We have been able to complete tests where we subject pilots to step changes and monitor their response.

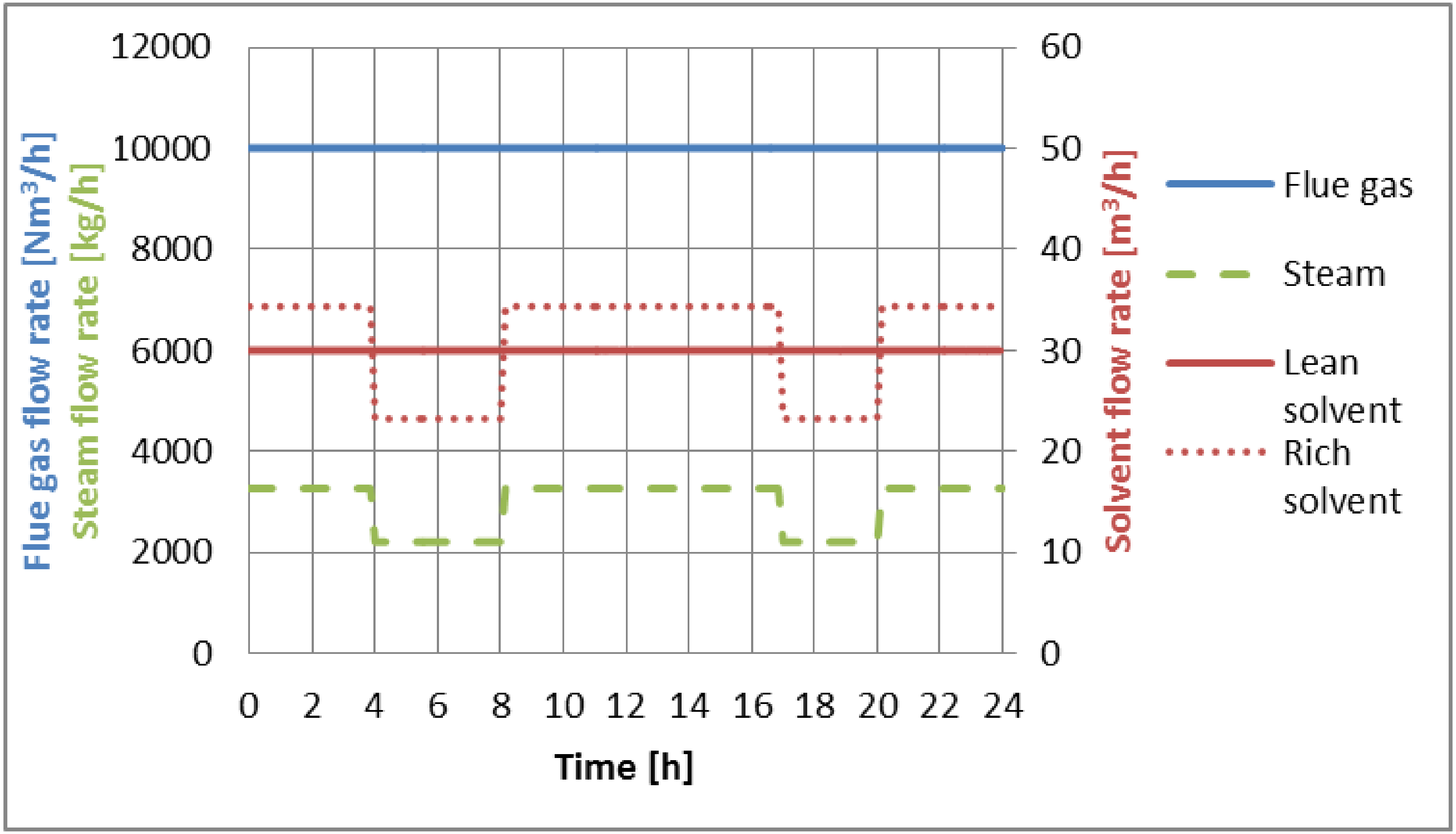
We can accurately model the behaviour of real pilot plant data.

The response of the system is, in general, sufficiently fast to match the rate of change required from power plants

Ratio control appears to be an effective strategy

Some transitions may impact plant water balance

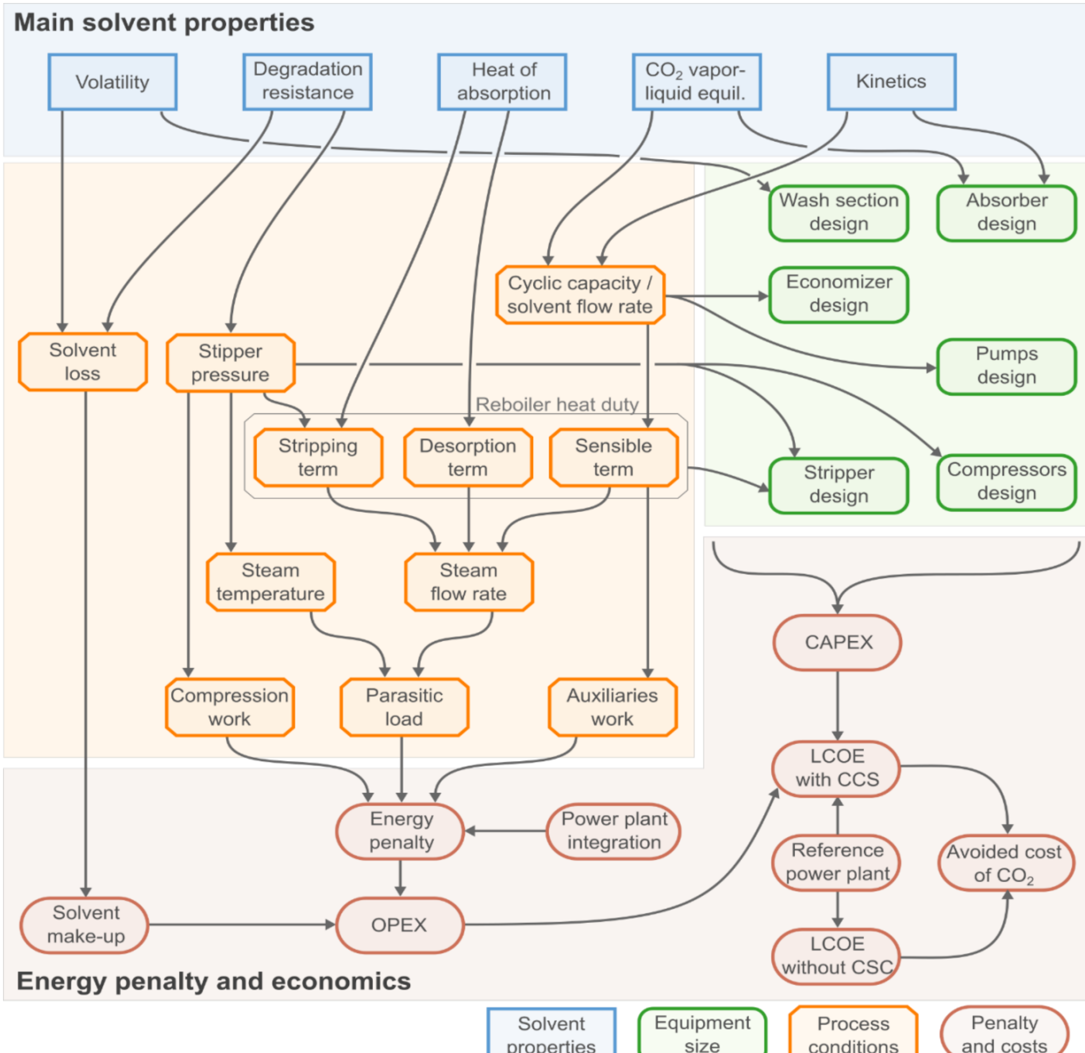
Speed of Response



Chemical Analytics

- Existing power plant flue gas CEMS equipment is capable of achieving the required analytical performance for the major flue gas constituents,
- FTIR may be a cost-effective means of monitoring many of the expected pollutants. Quantification is more challenging.
- Further development and demonstration is required for this and alternative online analytical techniques. [Quantify, streamline, ruggedise]
- It should be possible to modify existing power plant flue gas manual emission measurement techniques to provide satisfactory analysis trace species.
- Online analysis of solvent concentration and CO_2 loading requires significant development.
- Offline liquid analysis has made significant progress, again through development via laboratory and pilot plant studies.

Dependance on Solvent Properties



Source : NEVEUX, T., LE MOULLEC, Y. & FAVRE, E. 2015. Post combustion CO2 capture by chemical gas-liquid absorption: solvent selection, process modelling, energy integration and design methods.

Solvent/Plant Design Flexibility

- **EDF results (Deliverable 24.4) show how solvents behave in commercial scale plants not designed for them.**

Key messages.

- **A plant can be designed that is capable of using hugely different amine solvents (MEA and AMP)**
- **The performance of each solvent in the ‘hybrid’ plant is less good than in plant optimised for that solvent.**
- **The hybrid plant is more expensive than either of the ‘base-case’ plants**
- **For fundamentally different processes (e.g. DMX) cost to retrofit may be too high – WP3 curtailed at Stage Gate for this reason**

One plant can use two solvents – but at a cost!

OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

	Final design	Compared to the MEA design (size)	Compared to the AMP design (size)
Packing height, absorber	30 m + 2 m	300%	
Column diameter, absorber	15 m	111%	
Packing height, stripper	10 m		
Column diameter, stripper	10.4 m	117%	
LVC maximum pressure drop	1.5 bar	150%	
Stripper maximum pressure	2.5 bar	125%	
Rich pump capacity	1 MW		210%
Lean pump capacity	0.6 MW	165%	
LVC compressor capacity	23 MW	260%	
CO_2 compressor capacity	23 MW		108%
Reboiler area	4080 m²	117%	
Economizer area (global)	12300 m²	157%	

Commercial Operation (work in progress)

- **Optimal (economic) operation will vary from plant to plant, country to country.**
- **Impacted by**
  - **Load Factor**
  - **Power Plant Design**
  - **Life**
  - **Market Design**
  - **Local factors (H20 availability, CO2 usability)**
  - **…………..**

OCTAVIUS examines how different design configurations can operate technically – and also how that impacts economics for a range of markets.

So what did we learn in OCTAVIUS?

OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

	Definition
Efficiency	Impact of the technology on the electric efficiency of the power plant. ☑
O&M Cost	Impact of the technology on operational and maintenance costs including fuel costs includes costs for e.g. solvent makeup or membrane replacement or system repair 😐
CAPEX	Capital expenditures, i.e. impact of the technology on investment costs
HSE	Impact of the technology on health, safety and environment ☑
Capture rate	The fraction of the CO2 generated by the power plant that is actually captured. ☑
Availability	Impact of the technology on availability 😐
Operability	Impact of the technology on the operability of the system i.e. on flexibility (acceptable steady-state operation over a range of conditions), controllability (ability to move to new steady-state set-points and to handle process disturbances), start-up/shutdown characteristics and ability to handle equipment failures in a safe manner. ☑

Source – ZEP Technology Task Force – working paper (2014)