Accelerating CCS Technologies

4th ACT Knowledge Sharing Workshop

LAUNCH

Project no 299662, ACT – Accelerating CCUS technology

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Coordinator of LAUNCH

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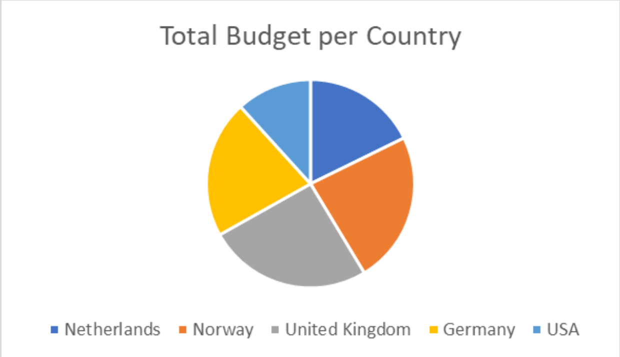
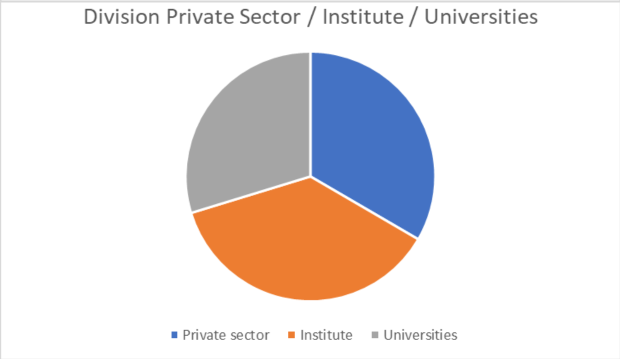
The Project

Lowering Absorption process UNcertainty, risks and Costs by predicting and controlling amine degradation

- 11 partners from NL, UK, DE, NO, USA
- Total budget: € 7.248.625
- Total funding: € 5.090.849





LAUNCH - Consortium

Universities and research centres

- TNO innovation for life
- SINTEF
- The University Of Sheffield.
- NTNU
- Los Alamos NATIONAL LABORATORY EST. 1943
- THE UNIVERSITY of EDINBURGH
- TEXAS The University of Texas at Austin
- INTERNATIONAL CCS KNOWLEDGE CENTRE
- 中英（广东）CCUS 中心 UK–China (Guangdong) CCUS Centre

Technology providers

- DOOSAN
- biobe
- MITSUBISHI HEAVY INDUSTRIES
- BASF We create chemistry
- ION ENGINEERING
- CCS Carbon Clean Solutions
- Shell

End users/test sites

- RWE
- AVR.
- Twence
- TOTAL

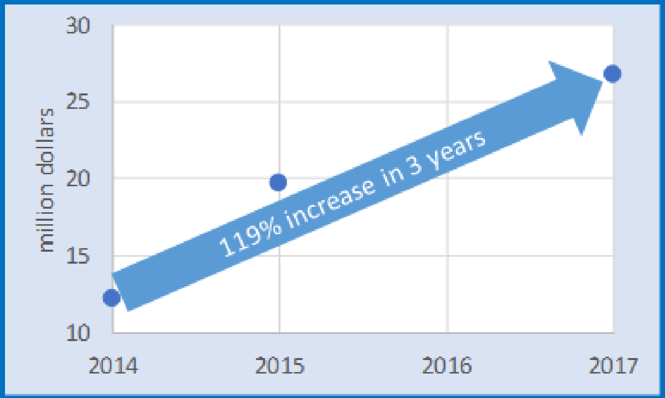
☐ LAUNCH partners

☐ Advisory Board members

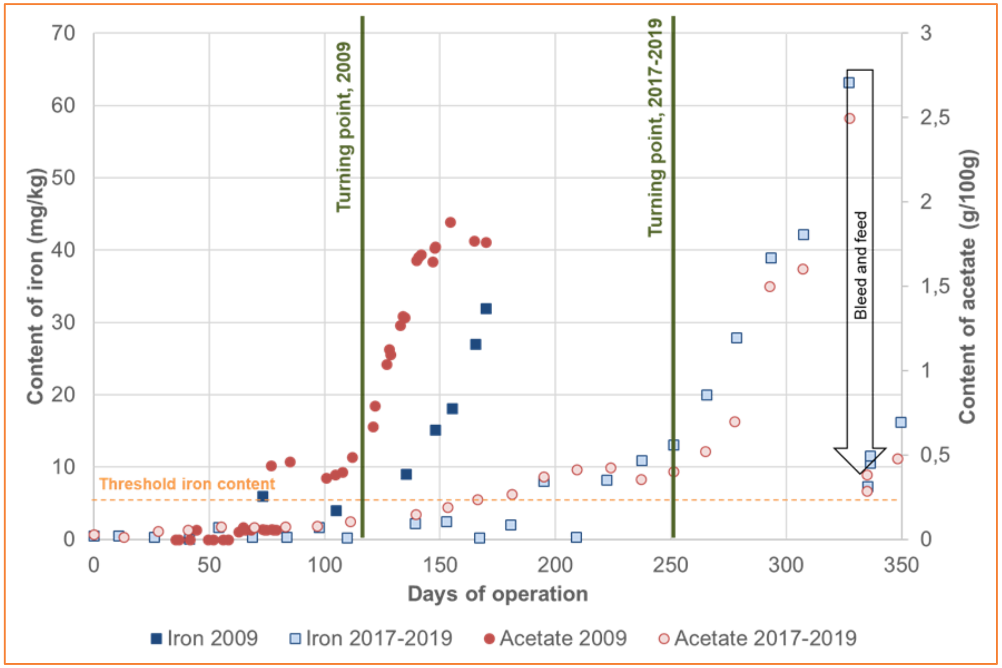
LAUNCH – The Issue

The costs of degradation – A real-life, full-scale example

The CCS facility at Boundary Dam Three (BD3), is a real-life full-scale example of how costly degradation can be. BD3 has reported that the costs of operation and maintenance are much higher than anticipated, because the solvent degrades more quickly than expected [25]. As a result, the BD3 operation and maintenance costs have risen from $12.2 million in 2014 to $26.7 million in 2017 [26].



BD3 operation and maintenance costs



The results of the MEA campaign at the RWE pilot plant in Niederaussem within the ALIGN project are a perfect example of the importance of the chosen process conditions. The degradation "turning point" was only achieved after 250 days of operation. This is a major contrast with the 2009 MEA campaign run at the same plant, in which the turning point was reached at around 100 days of operation.

LAUNCH – Response to MI-goals

Mission Innovation PRD C-2: Creating Environmentally Friendly Solvent Processes for CO_2 Capture
Solvents for post-combustion capture experience *losses due to oxidation*, nitrosation, aerosols, and other contaminants and mechanisms that are not fully understood. These losses lead to significant environmental impacts and costs for solvent makeup and reclamation to separate impurities. This PRD will close this knowledge gap by *systematic studies of contaminants and loss mechanisms* that will be *applicable to all solvents and all applications*. The research should develop *methods to mitigate solvent losses* that will *reduce the risk, cost, and environmental impact of deploying solvent systems for CCUS*.

The Mission Innovation also sets Research Directions which are directly linked to the WPs of LAUNCH:

Stated Mission Innovation Research Directions	**LAUNCH WP**
Identify and quantify degradation components	WP3
Mimic the degradation and emissions that may occur at large scale in the laboratory	WP4, WP5
Develop systematic understanding of chemical mechanisms and emission mechanisms	WP1, WP3
Develop models that allow reliable prediction of solvent loss at large scale	WP1
Identify and assess mitigation strategies	WP2, WP5, WP6

LAUNCH - Objectives

- **Main Objective:**
  - Accelerate the implementation of CO_2 capture in various industries and support the development and qualification of novel solvents by establishing a fast-track, cost-effective de-risking mechanism to predict and control degradation of capture solvents.
- **Sub-objective #1: Developing the ability to predict degradation of (novel) CO_2 capture solvents**
  - Within LAUNCH, a solvent degradation database and a generalized degradation network model will be developed and made publicly available.

LAUNCH - Objectives

- **Sub-objective #2: Developing strategies to control degradation, minimizing solvent loss and therefore the environmental impacts of CO_2 capture**
  - Within LAUNCH, degradation management strategies will be further developed. These strategies include optimized process design, flue gas pre-treatment and the removal of oxygen and iron from the solvent.
- **Sub-objective #3: Sub-objective #3: Developing and demonstrating the LAUNCH solvent qualification program**
  - The LAUNCH program aims to further reduce the testing time and scale, while leading to industrially representative results. Therefore, we will greatly ***accelerate the deployment of capture plants in the industry and the launching and market uptake of novel solvent-process combinations***. It is imperative for the LAUNCH program to be affordable and fast (100k€ / 2 months).

LAUNCH – Goal

- Development of **The LAUNCH Solvent Development Protocol**
  - This protocol will be made **public**.

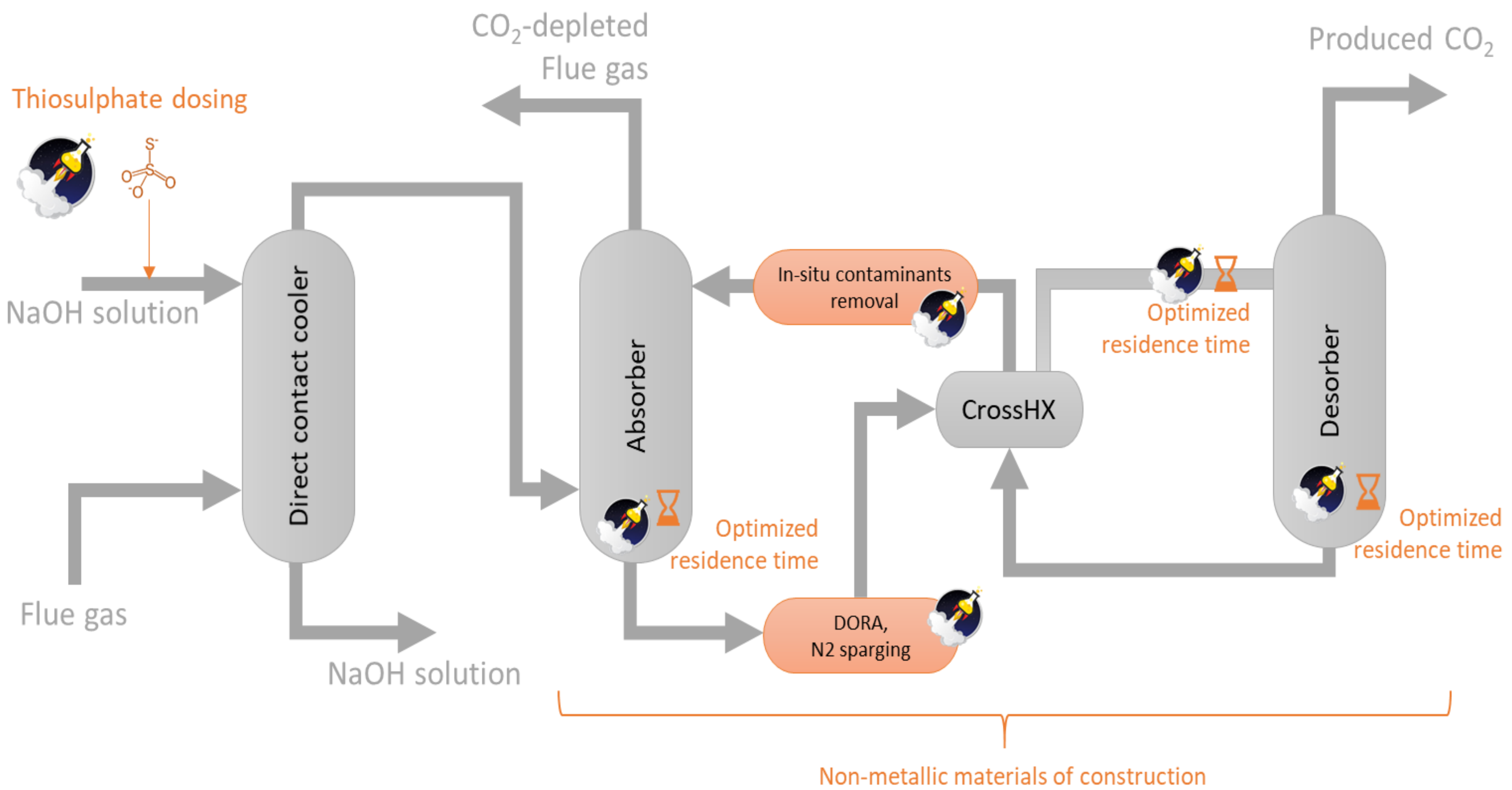
- This protocol will include:
  - guidelines for using the LAUNCH-developed solvent degradation database and the degradation network model for pre-evaluating solvents and management strategies;
  - guidelines for solvent testing and the drawings of a generic LAUNCH test rig.

Within LAUNCH, we will develop, validate and demonstrate the LAUNCH solvent qualification program, making use of multiple scales test facilities: lab experiments, LAUNCH rigs (up to 1 kgCO_2/h), 3 pilot facilities (up to 0,4 tonCO_2/h) and a commercial plant (0,4 tonCO_2/h). Solvents of 1st, 2nd and 3rd generation are included in the test program, representing multiple chemistries.

LAUNCH – Link with other projects

Project	Source of funding	Activities	Partners involved
ALIGN-CCUS	ERA-ACT	• DORA: development of technology • Network degradation model • Degradation measurement of CESAR1 solvent • Degradation modelling • Solvent management, demonstrated sampling and analytical methodology • Long-term campaign using 30wt% MEA and ion exchange as solvent management strategy • Long-term campaign using CESAR1	TNO NTNU SINTEF IND RWE
NCCS	Norges forskningsråd (NFR)	• DORA: material selection for MEA • Oxidative degradation studies	TNO NTNU SINTEF IND
DORA@PlantOne	Dutch national project (TKI-CCUS)	• Demonstration of DORA at TRL 7 for MEA	TNO AVR
DeNOVO	NFR	• Development of imidazoles-based solvents • Development of procedure for analysing degradation compounds of different solvents with NMR	NTNU
HiperCap	EU H2020	• SBF solvent development and characterization	NTNU SINTEF IND
3GMC	NFR	• Membrane development (will be used for DORA) • Development of new solvent blends	NTNU
iCap	EU H2020	• DEEA + MAPA solvent development	NTNU SINTEF IND
LEPS	NFR	• Solvent development, speciation studies using NMR, development of reaction mechanisms	NTNU
PZ/AFS at NCCC	U.S. DOE	• PZ Degradation measurements at bench-scale and in pilot with coal-fired gas, testing of N_2 sparging, NO_2 scrubbing and reduced stripper sump volume	UT
NO_2 at NCCC	TxCMP/U.S. DOE	• NO_2 scrubbing with thiosulfate dosing at NCCC	UT
PostCap	BMWi COORETEC	• Holistic development programme on advanced post combustion capture technology • Development of emission mitigation technologies • Investigation of long term degradation behaviour including counter measures	RWE
Big Data	Own funding	• Analysis and process optimisation of superheater fouling behaviour and flue gas desulphurisation of lignite fired power plants by neuronal networks	RWE

LAUNCH – Technology development



LAUNCH – Technology Development

- Thiosulphate dosing
  - To remove NO2 from the flue gas. Installation and demonstration at the SO2 scrubber at RWE.
- In-situ contaminate removal
  - In situ iron removal will be developed at lab scale and validated at pilot scale at RWE and the NCCC pilot.
- DORA
  - Upscaling and demonstration for 2nd and 3rd generation solvents at RWE.
- Non-metallic materials of construction
  - An non-metallic rig will be build to run corrosion free degradation studies.

LAUNCH – Predict degradation

- Setting up a searchable database with plant data, gathered from literature, experiments and other projects. Made public at the end of the project.

- Development of models to predict degradation as function of flue gas and plant design.
  - Base model is developed in ALIGN-CCUS but will be extended with other solvents.
  - The model will be validated within LAUNC
  - Made public at the end of the project.

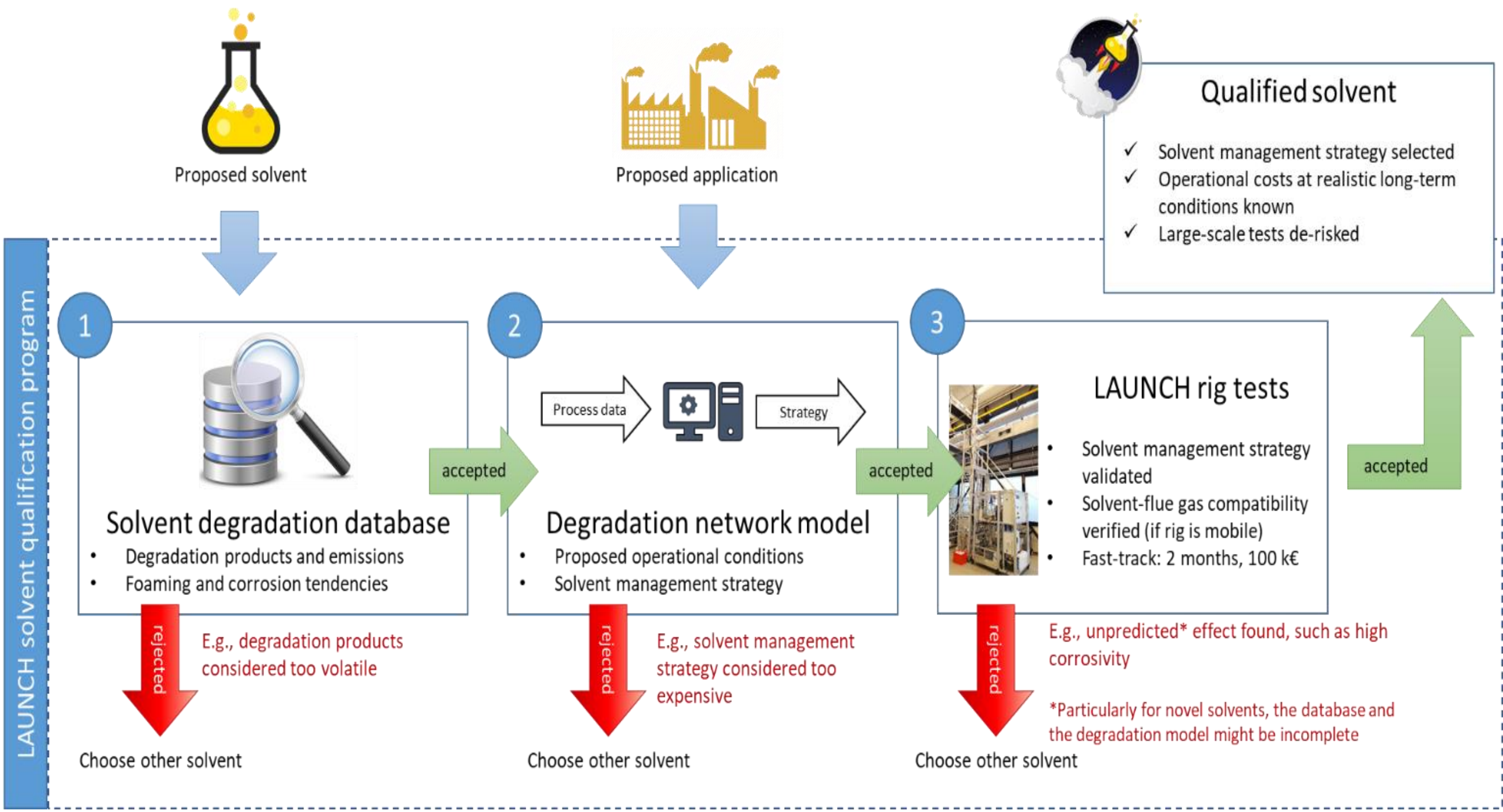
LAUNCH – Solvent Qualification program

- Demonstration by experiments at multiple scales:
  - The LAUNCH rigs (up to 25 kgCO2/day)
  - PACT (1 tonCO2/day)
  - RWE pilot (10 tonCO2/day)
  - AVR full scale plant (300 tonCO2/Day)

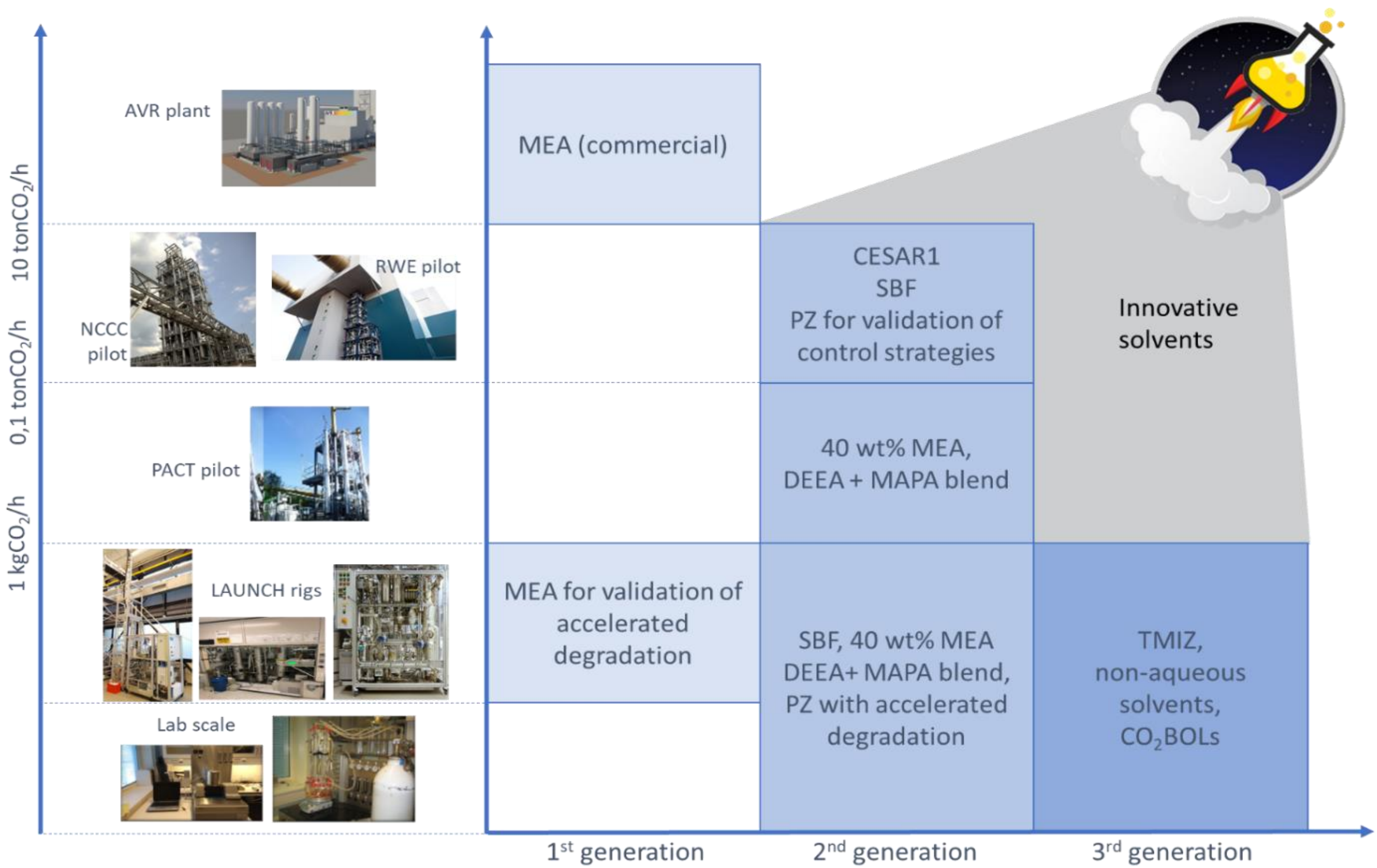
  - Thiosulphate dosing
  - To remove NO2 from the flue gas. Installation and demonstration at the SO2 scrubber at RWE.

- Qualification of LAUNCH rigs to evaluate solvent degradation
  - Comparison of degradation profiles at different scales in controlled circumstances
  - Head to head campaigns with solvent rigs at RWE and AVR

LAUNCH – Solvent Qualification



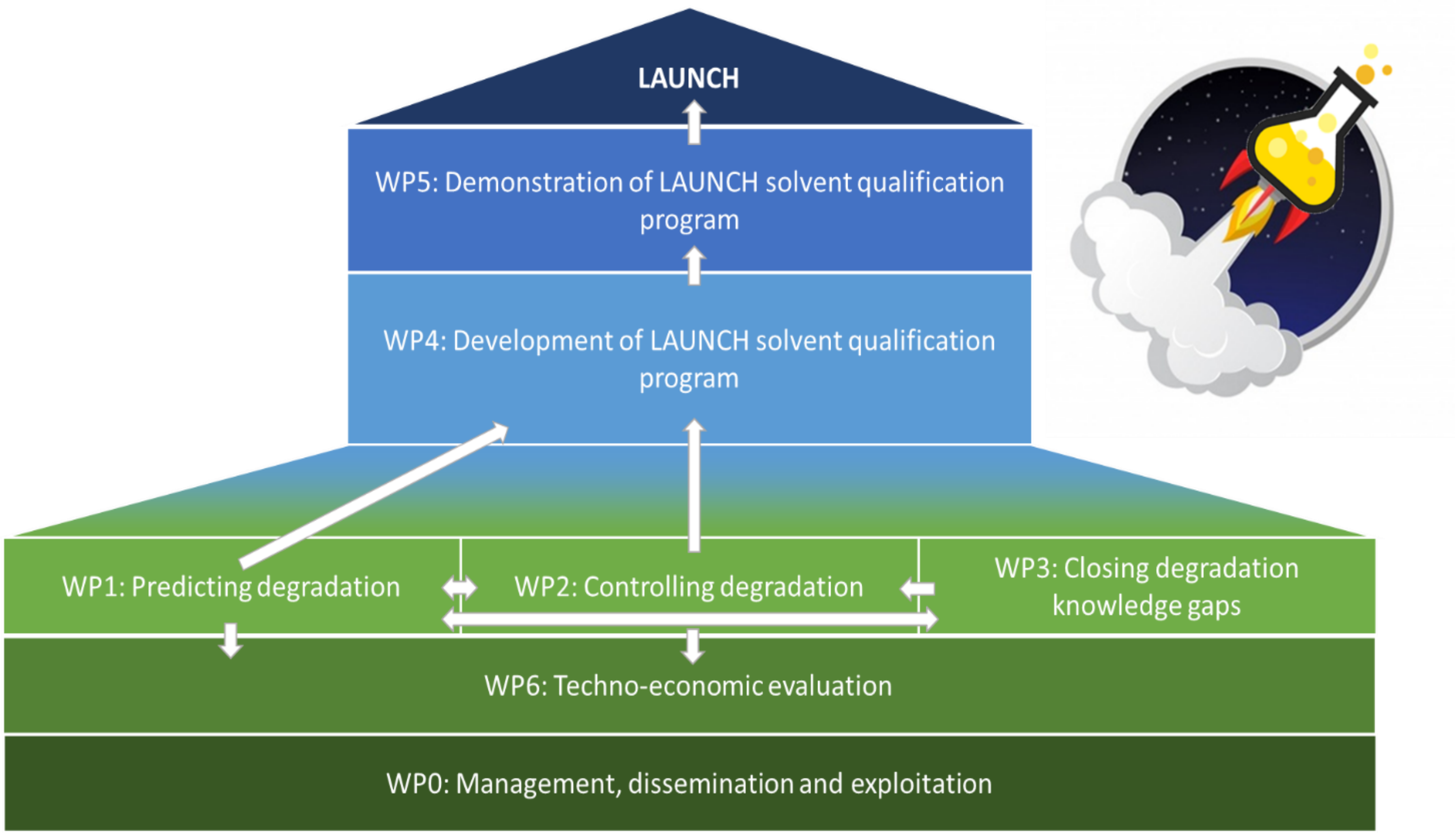
LAUNCH – Solvents



LAUNCH – Solvents

	Classes of solvents	Examples of solvents	Larger scale in LAUNCH	Background and test focus within LAUNCH
First gen.	MEA	30wt% monoethanolamine	Commercial plant at AVR	Used in the commercial plant of AVR, MEA is the state-of-the art solvent for industrial CO_2 capture. Most of open data on solvent degradation is focused on MEA. Within LAUNCH, MEA will be used in the head-to-head tests at AVR for ***validation purposes***. This include the validation of the LAUNCH rigs and strategies to accelerate degradation.
Second generation	Concentrated MEA	35-50wt% monoethanolamine (cMEA)	PACT facility	cMEA leads to higher degradation and corrosion. This campaign is proposed as a strategy to ***accelerate degradation***, as well as ***validate degradation control strategies***
	PZ	piperazine	Pilot plant at NCCC	UT has a long track record in operating capture systems with PZ, including the NCCC pilot. PZ is notable for having a high resistance to degradation. Within LAUNCH, PZ will be used in campaign for the ***validation of degradation control strategies***.
	Aqueous PZ blends	CESAR1: 2-amino-2-methyl-1-propanol (AMP) promoted by piperazine (PZ)	Pilot plant at RWE	CESAR1 has been developed in the CESAR and Octavius projects. Within ALIGN-CCUS, it will be demonstrated at the RWE pilot. Within LAUNCH, CESAR1 will be used in the head-to-head tests at RWE for validation purposes, ***taking advantage of already degraded solvent*** from ALIGN-CCUS.
	Aqueous MAPA blends	DEEA (diethylethanolamine) + MAPA (N-methyl-1,3-diaminopropane) blends	PACT facility	DEEA + MAPA blends have been investigated at NTNU since the H2020 iCap project. The two-phase 5M DEEA + 2M MAPA was piloted at NTNU (TRL5) with promising energy numbers [14]. A show-stopper for this technology is the ***low oxidative stability of MAPA***.
	Strong bicarbonate forming (SBF)	e.g, 1-(2-Hydroxyethyl)pyrrolidine promoted by benzylamine	Pilot plant at RWE	SBF class of solvents were developed by NTNU in the HiPerCap (FP7) [15] and 3GMC projects. Within LAUNCH, one SBF solvent will be demonstrated at the RWE pilot plant, and used in the LAUNCH rigs for ***demonstration of degradation control strategies***.
Third generation	(poly)alkylated imidazoles	e.g. 1,2,4,5-Tetramethylimidazole (TMIZ) (promoted by e.g. PZ)	LAUNCH rig	Imidazoles are highly thermally stable absorbents for CO_2 capture with low heat of absorption, and show promising results in mixed systems with piperazine. Promising polyalkylated imidazoles have been synthetized by NTNU in project DeNOVO. ***Oxidative degradation is yet unknown*** [16].
	CO_2BOL solvent	1-((1,3-dimethylimidazolidin-2-ylidene)amino)propan-2-ol	Lab scale	CO_2BOLs are water-lean organic solvents, developed for allowing regeneration at low temperature. This class of solvents has been demonstrated in bench scale. ***Degradation of CO_2BOLs is uncertain***.
	Lean aqueous solvents	Blends of amines and organic solvents (e.g., MEA + sulfolane)	Lab scale	(Partially) substituting water for organic solvents can lead to improved solvent capacity. The pKa of the solvent influences enhanced the kinetics. ***The impact on solvent stability is unknown.***

LAUNCH – Work Packages



LAUNCH – Work Packages

	Name	Participants (**Leader**)
WP1	Predicting degradation	**SINTEF IND**, NTNU, TNO, RWE, DOOSAN
WP2	Controlling degradation	**TNO**, LANL/UT, RWE, Biobe, NTNU
WP3	Closing degradation knowledge gaps	**NTNU**, SINTEF IND, LANL/UT
WP4	Development of LAUNCH solvent qualification program	**UnivShef**, TNO, SINTEF IND, NTNU, LANL/UT, DOOSAN, UEDIN
WP5	Demonstration of LAUNCH solvent qualification program	**RWE**, AVR, LANL/UT, TNO, NTNU, UnivShef
WP6	Techno-economic evaluation	**DOOSAN**, TNO, RWE, BIOBE
WP0	Management, dissemination and exploitation	**TNO**, SINTEF IND, NTNU, UnivShef, UEDIN, RWE, DOOSAN

LAUNCH – Risks

Impact				
4	11	14	17	20
3	9	12	15	18
2	7	10	13	16
1	5	8	11	14
	1	2	3	4
	Probability			

Low	Monitor
Medium	Retain and actively manage risk
High	Attempt to avoid or transfer risk
Very High	Must eliminate or transfer risk if feasible

Item	Description			
Technical	Critical impact: possible inability to meet objectives	De-scope or extensive workaround required	Some adjustments to baseline are required	Baseline approach retained, with minor modifications
Cost	Potential cost overrun more then 5%	Potential cost overrun between 0,5% and 5%	Potential cost overrun between 0,05% and 0,5%	Potential cost overrun less than 0,05%
Schedule	Cannot achieve a major project milestone	More then 6 months delay in project milestone	More than 1 month delay in project milestone (but less than 6 months)	A few weeks of impact on the project milestone
Impact (Score)	Very High (4)	High (3)	Moderate (2)	Low (1)

LAUNCH – Risks

Description of risk					WP / Task	Proposed risk-mitigation measures
Risk	**Consequence**	**P**	**I**	**Score**		
Delays of the project caused by plant failures.	Delays in validation of the LAUNCH rig and degradation management technologies	2	1-2	L-M	WP5	Site owner will immediately inform partners about plant shut downs which can have a serious impact on the timeline to adapt the planning of testing phases.
Difficulties to purchase the components of the tested solvents.	Cost overrun and delay of the testing program.	2	1-2	L-M	WPs 2, 3, 4, 5	The solvent selections have considered availability and cost of the solvent components. Alternative solvents can be used instead, as long as the results are equally valuable.
Validation of LAUNCH rigs fails, results not representative of large scale	LAUNCH rigs cannot be used for degradation tests	2	4	H	WP4	In case of failure, the LAUNCH rig#2 will be redesigned to be able to mimic degradation results of larger units. Validations at multiple scales are scheduled. Previous experience of LAUNCH rigs#1 and #2 indicate low probability of failure
Degradation network model cannot be generalized	Hindered ability to predict degradation	2	4	H	WP1	A specific degradation network model has to be proposed for each solvent, based on more extensive test programs. The LAUNCH solvent qualification protocol will be adjusted to include this.
Head to head testing not possible due to unavailability of resources or equipment	Re-planning necessary.	2	4	H	WP5	There is accounted for some flexibility in the planning, nevertheless this requires very close continuous monitoring and commitment from the partners.

Acknowledgements

ACT LAUNCH

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