PHASE II: *(Update)*
Large Pilot Testing of Linde-BASF Advanced Post-Combustion CO_2 Capture Technology at a Coal-Fired Power Plant (FE-0031581)

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PROJECT OVERVIEW

Funding: $3,736,684

DOE: $2,988,359

20% Cost Share: $748,325

Work Period: Sept. 1, 2019 – Jan. 15, 2020 (revised)

City Water, Light and Power (CWLP) Springfield, IL

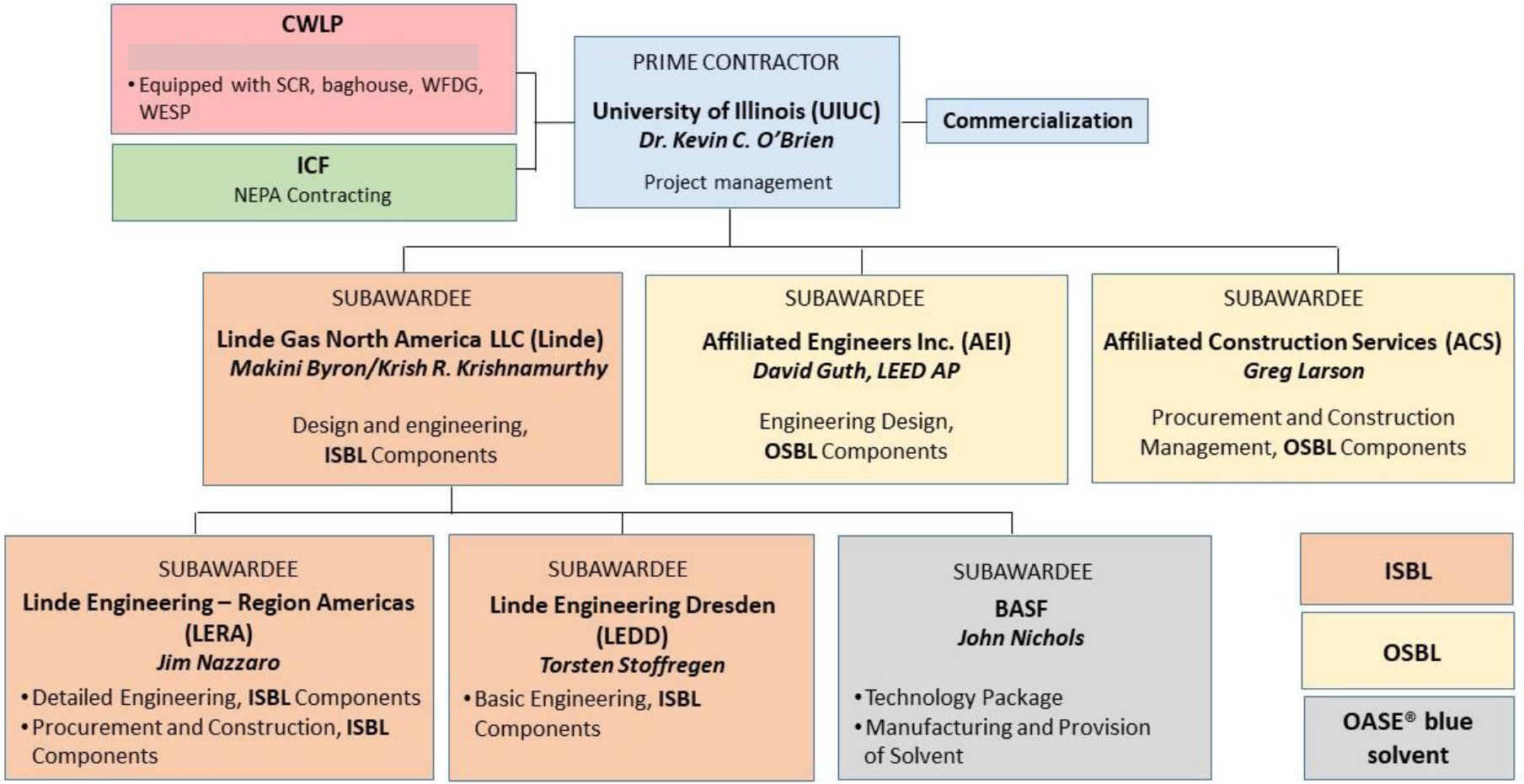
PROJECT OBJECTIVES:

Overall: Design, construct, and operate a 10 MWe capture system based on the Linde / BASF advanced amine-based, post-combustion carbon dioxide (CO_2) capture technology at CWLP Dallman Unit 4, Springfield, IL.

Phase II: Front End Engineering Design (FEED) study along with obtaining necessary regulatory approvals and funds for Build / Operate in Phase III.

Large Pilot Team Management Structure

Well-defined roles based on relevant capabilities



Capture Technology Evaluated up to 1.5 MWe

TECHNICAL BACKGROUND

Solvent and System Designed for Improved Performance

Reduced capital costs / energy costs

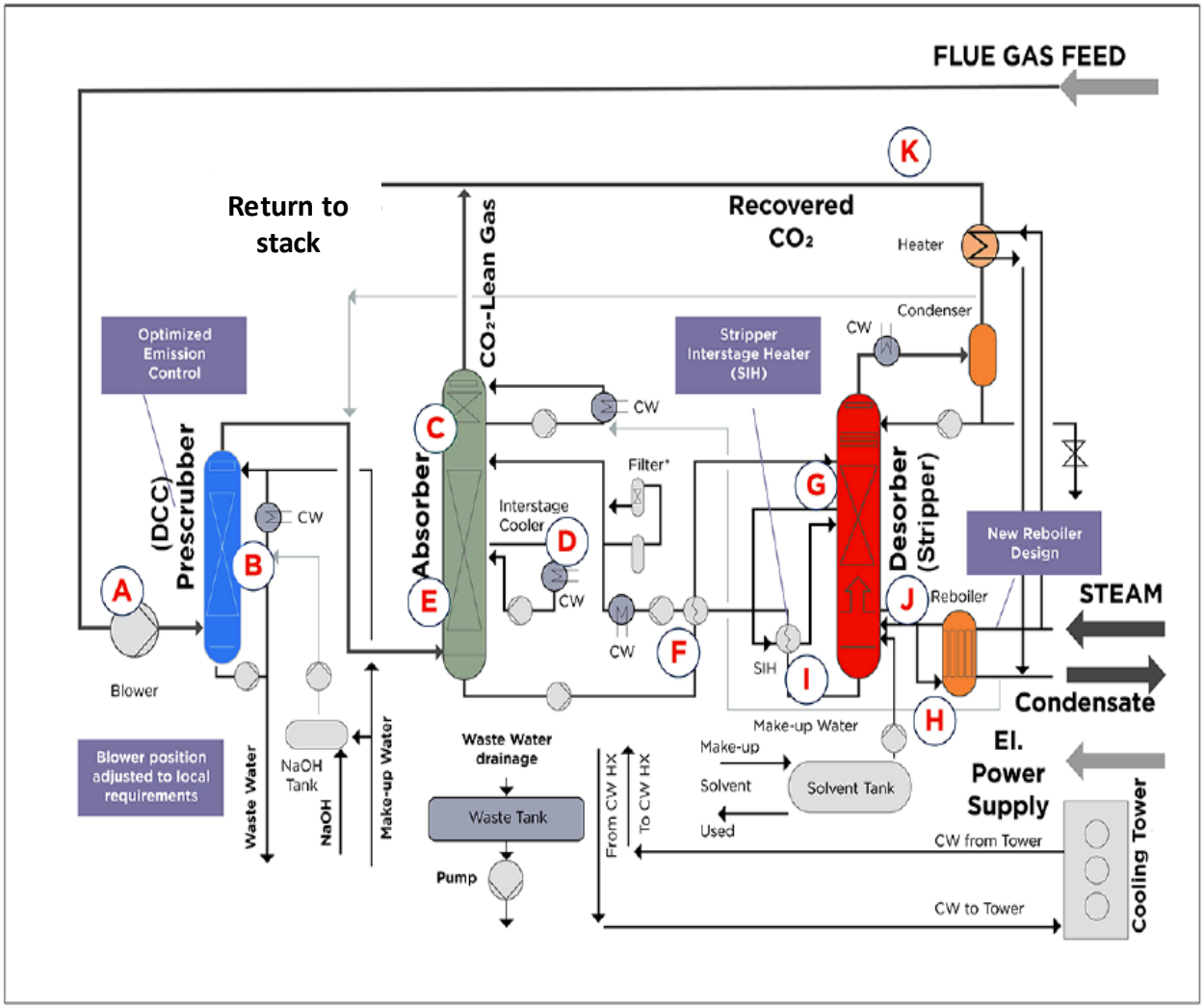
- Optimized BASF OASE® blue solvent
- Efficient CO_2 capture from low-pressure sources
- Longer solvent stability
- Lower solvent circulation rate

Notable Linde process improvements

(C, E) Dry bed water wash design to minimize solvent losses

(G) Stripper regeneration at 3.4 bars reducing CO_2 compressor cost and power consumption

(I) Advanced Stripper Interstage Heater to reduce regenerator steam consumption.



Attractive Techno-Economics for Linde / BASF Process

Baseline case: DOE-NETL supercritical PC power plants

Parameter	DOE-NETL Case B12A	DOE-NETL Case B12B	Linde-BASF LB1	Linde-BASF SIH	Linde-BASF WHR
Description	No CO_2 capture	90% CO_2 Capture w/ Cansolv PCC process	90% CO_2 Capture w/ OASE® blue	90% CO_2 Capture w/ OASE® blue and SIH	90% CO_2 Capture w/ OASE® blue, SIH, and WHR
Net Power Output (MWe)	550	550	550	550	550
Gross Power Output (MWe)	580	642	630.4	629.3	626.3
Coal flow rate (tonne/hr)	179.2	224.8	221.9	218.5	210
Net HHV plant efficiency (%)	40.70%	32.50%	3297.88%	33.40%	34.73%
Total Overnight Cost ($2011) ($/MM)	$1,379	$2,384	$1,970	$1,950	$1,921
Cost of CO_2 captured with T&S ($/MT)*	N/A	$68.00	$53.58	$52.71	$51.31
Cost of CO_2 captured without T&S ($/MT)*	N/A	$58.00	$43.58	$42.71	$41.31
COE ($/MWh) with T&S*	$82.30	$142.80	$127.97	$126.50	123.63
PCC specific reboiler duty (MJ/kg CO_2)	N/A	2.48	2.6	2.3	1.5

* T&S: Transport and Storage

7

City Water, Light and Power (CWLP)

Water and power supplier for City of Springfield

8

Phase II

PROJECT MANAGEMENT

Project Tasks

Designed for smooth transition to Phase III

Task #	Task
1.0	Project Management and Planning
2.0	Front-End Engineering Design (FEED)
3.0	NEPA / Permitting at Host Site
4.0	Team and Cost Share Commitments for Phase III
5.0	Updated Techno-Economic Analysis (TEA)

Milestones for Phase II

Budget Period	Task Number	Description	Planned Completion Date	Actual Completion Date	Verification Method
1	1	Updated Project Management Plan	9/30/2019	9/30/2019	Project Management Plan file
1	1	Phase II Kickoff Meeting	11/30/2019	10/4/2019	Presentation file
1	2	Finalized FEED study	12/15/2020*		Quarterly RPPR file
1	2.2	Completion of Basic Engineering Design Package, including HAZOP study report	3/3/2020	3/3/2020	Quarterly RPPR file
1	3	NEPA and permitting documentation complete	10/1/2020*		Quarterly RPPR file
1	4	Phase III cost share commitments complete	1/15/2021*		Quarterly RPPR file
1	5	Updated TEA	12/31/2020*		Quarterly RPPR file
1	1	Phase II Topical Report Completed	1/15/2021*		Topical Report File
1	1	Quarterly RPPR report	Each quarter		RPPR files

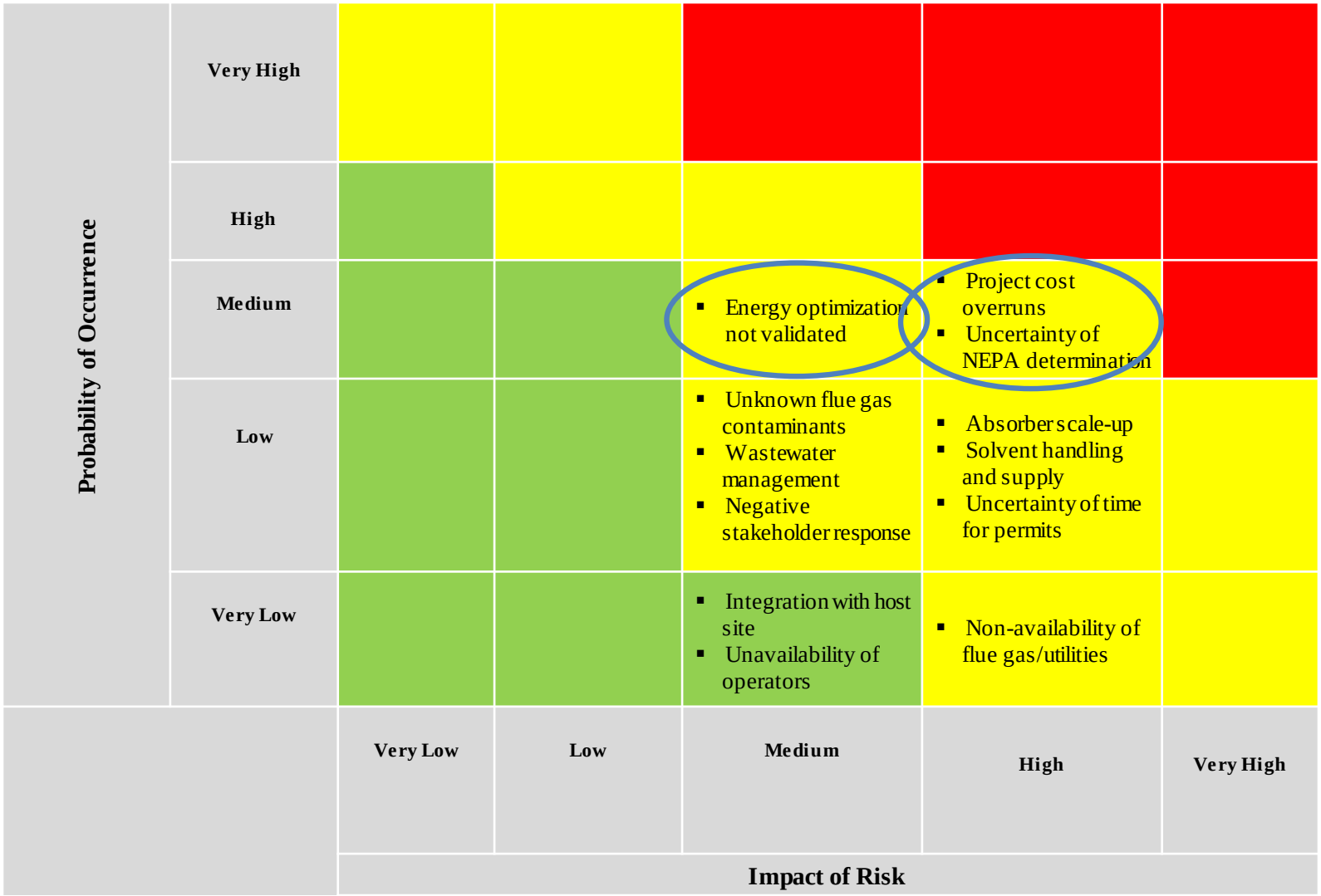
**NOTE: Milestone dates have been adjusted based on NETL / DOE communication received in March 2020 changing date for receipt of final Phase II Topical Report.*

FY20 Transformational Coal Pilots Peer Review February 4-6, 2020

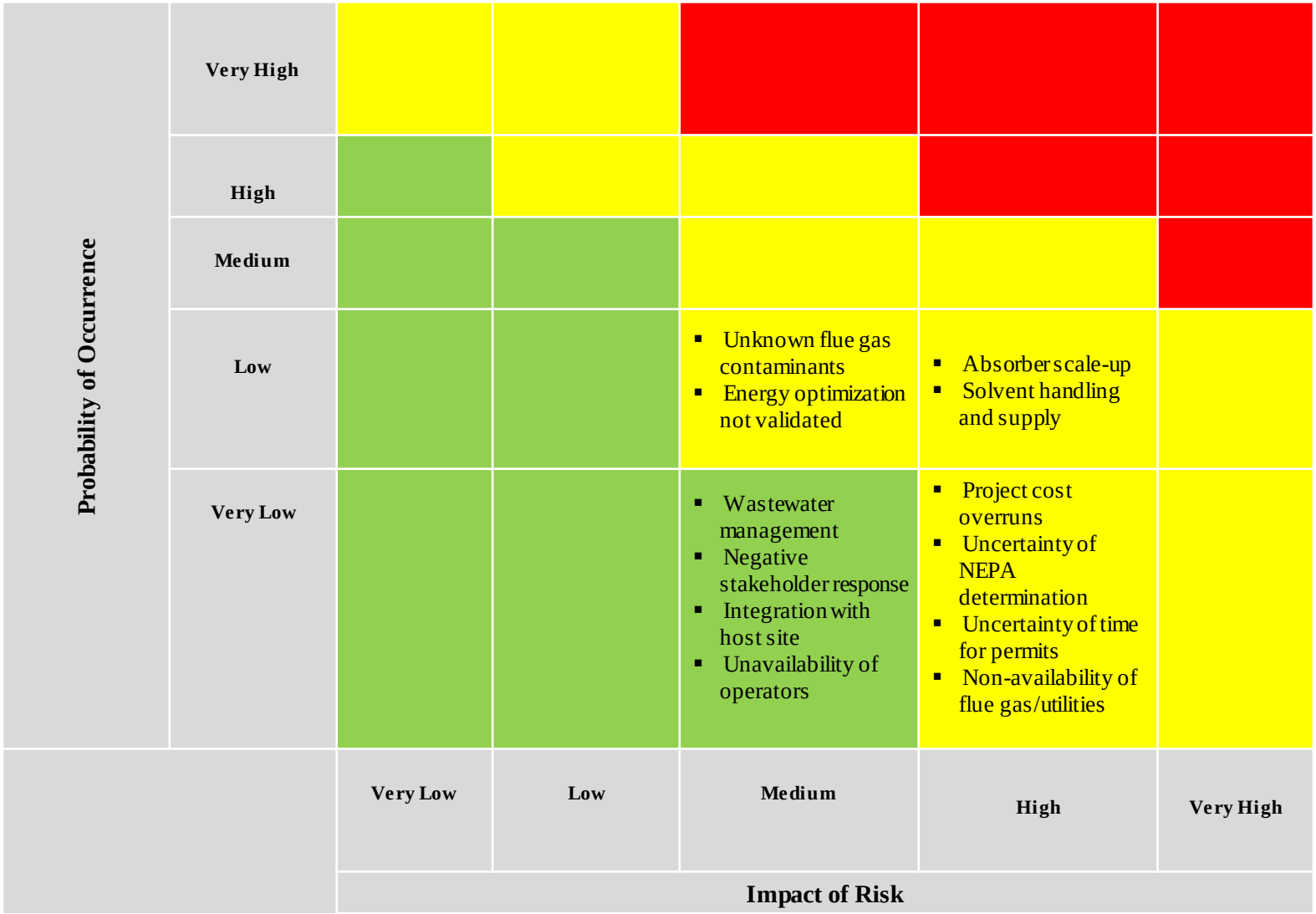
- ***Technical Feedback:*** Suggested means to reduce construction risks
- ***Managerial Feedback***: Suggested constructability review and value engineering
- ***Financial Feedback:*** Suggested planning on how to handle cost overruns
- ***Change in timeline for all projects***: shift Phase III proposal due date of January 15, 2021

Project team felt input was very useful from peer review.

Probability Impact Matrix : Phase II (August 2019)



Probability Impact Matrix : Phase II (August 2020)



14

Phase II

RESULTS FROM HAZOP & BASIC DESIGN/ENGINEERING

HAZOP Review – Recommendations & Responses

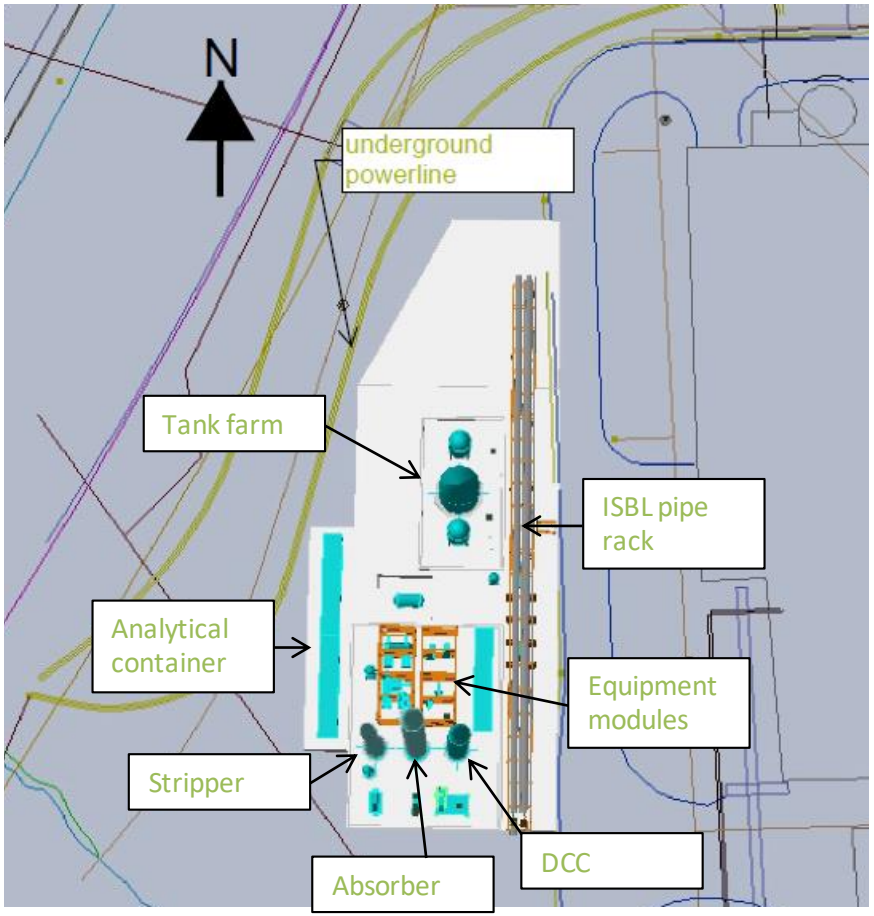
Recommendation	Mitigation and Response Strategy
Check safety measures upstream	Host site confirmed there is no foreseen likelihood of a negative pressure situation, the controls will be designed to shut down the pilot plant and dampers in the event of an upset
Check maximum possible pressure from boundary limit	Confirmed maximum pressure that could occur at the battery limit from the wet ESP if ID fans are on with no recycle pumps
Heat tracing required for low points in OSBL flue gas lines	Project will make every attempt to design OSBL flue gas lines at a constant slope with no low points – if low points must exist, they will include heat traced drain lines
Check maximum possible temperature at boundary limit	Confirmed maximum design temperature that could occur at the battery limit from the wet ESP and declared PPE requirements
Check maximum allowable amine emissions per local regulations	Confirmed maximum permissible amine emissions (categorized as VOC/VOM) based on Dallman 4 air permit limit and emission test results

16

Basic Engineering

Completed deliverables

- Design basis
- Process design
- Equipment list
- Process and mechanical data sheets
- P&IDs
- Logic diagrams
- Basic operating manual and analytical instructions
- Safety requirements
- Material specifications
- 3D model of site plan



Phase II

NEPA & PERMITTING

NEPA

A NEPA working team was formed consisting of the NEPA contractor, ISTC, Linde, CWLP, and NETL/DOE

- The public comment period yielded no comments that required a response
- NETL and DOE approved the Final EA and FONSI

PERMITTING

A working team for permitting issues was formed consisting of representatives from ISTC, CWLP, and the Illinois Environmental Protection Agency (IEPA)

- **Stormwater** – a construction permit will be submitted by project contractor; stormwater from project area covered by site NDPES permit
- **Air emissions** – emission values have been calculated; construction/operating permit will be managed as a "Modification to the Facility"
- **Hazardous waste** – a permit is not required; solvent contaminated waste will be tested to determine hazardous status and dispose appropriately
- **Wastewater** – 3rd party wastewater assessment complete; treatment design and costing initiated

19

Phase II

ACTIVE TASKS

DETAILED ENGINEERING

ISBL – Linde Engineering North America (LENA) issued definition package and is finalizing technical deliverables for internal approval process

OSBL – Soil borings performed, design complete and detailed estimates being finalized

OPERATING PLAN

Linde is developing an operating plan and budget to run the pilot plant

Acknowledgements

Organization	Name
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John Nichols	BASF
David Guth	Affiliated Engineers Inc (AEI)
Greg Larson	Affiliated Construction Services (ACS)

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