Net Zero Alumina – Putting it All Together

The 2024 AQW Workshop

Held in Dubai in conjunction with 'Alumina 2024', the 12th International AQW Conference.

The Friday Workshop, addressing a critical issue of the time, has become a hallmark of the triennial AQW Conference since the first Bauxite Residue Workshops sponsored by IAI in 2012 and 2015. These workshops led to significant progress on residue management and reuse through collaborative projects. The 2018 Workshop was the basis of the Alumina Technology Roadmap to 2050.

This 'Net Zero Alumina' workshop focused on today's defining issue: decarbonisation. It examined the issues and opportunities in adapting new and emerging technolgies with the goal of stimulating collaborative efforts to enable the industry to achieve its net zero goal.

26 APRIL 2024

Sponsored by IAI and South32

INTERNATIONAL ALUMINIUM
Aluminium, shaping a better tomorrow

SOUTH32

AQW ALUMINA 2024
12TH INTERNATIONAL ALUMINA QUALITY WORKSHOP

Net Zero Alumina – Putting it All Together

The 2024 AQW Workshop

Introduction

Across the world, alumina producers are committing to achieving significant reductions in greenhouse gas emissions, in line with global initiatives and government targets. These activities are occurring at both an individual level and through global consortia, and most of the worlds alumina producers have made commitments to supporting and developing one technological pathway or another. Much of the focus is being placed on alternative steam generation systems, electrical or hydrogen-fired calciners or kilns, heat and electrical storage systems, and so forth. These initiatives are well-funded and managed, and it is inevitable that unit operations based on these technologies will eventually become available for use in "refineries of the future."

But what of the massive existing investment in current alumina refining capacity? How best should these systems be integrated in current operations, and what other infrastructure will be required? How much of the existing infrastructure is suited to serving these alternative unit operations, in terms of metallurgical suitability, control systems, measuring devices, instrumentation, safety protocols, electrical or fuel distribution systems and the like? The potential list of affected sub-systems and processes is immense.

Are we ready for tomorrow's low-carbon technologies? And do we sacrifice some of the existing heat and energy minimization systems if these technologies are implemented? What do we not know that we don't know?

Objectives

In the transition of alumina refining to zero carbon operations, identify:

- The hidden complexities that, left unrecognised, can derail implementation of even the best new technology; and
- Areas of collaborative research and development required to support the implementation of the essential new technologies.

Topics and Goals

The following topics were chosen by a pre-workshop poll of participants:

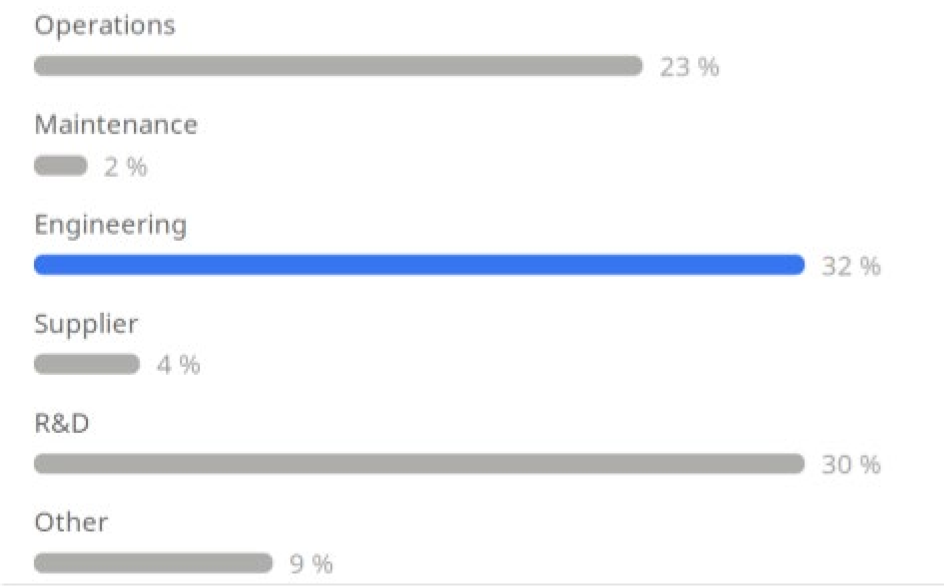
Topic	Goal
1. Optimizing Energy Use	Use a generic refinery flowsheet to identify: • Ways to narrow the gap between practical process limits • Small to 'quantum leap' energy efficiency opportunities
2. Circularity Pathways	Identify the decarbonisation potential of: • Alternative fuels • Improved quality & utilisation of raw material inputs • Carbon capture in outputs (esp. residue)
3. Thermal Storage	Examine potential of in-refinery thermal storage to assist electrification of Calcination and Steam Generation
4. Electric Calcination	Identify process issues associated with incorporating electric calciners into existing and future alumina refineries.

Setup & Facilities

- 5 Tables, approx. 10 /table.
- 2 Tables for Topic 1, 1 Topic each for others.
- Facilitator + Note-taker for each Table.
- Large general session room and smaller breakout rooms.
- Central presentation screen, individual flipcharts, whiteboards, and laptops.

Attendees

A full list of attendees is given in Appendix A. The professional profile of the cohort as determined by Slido poll was:

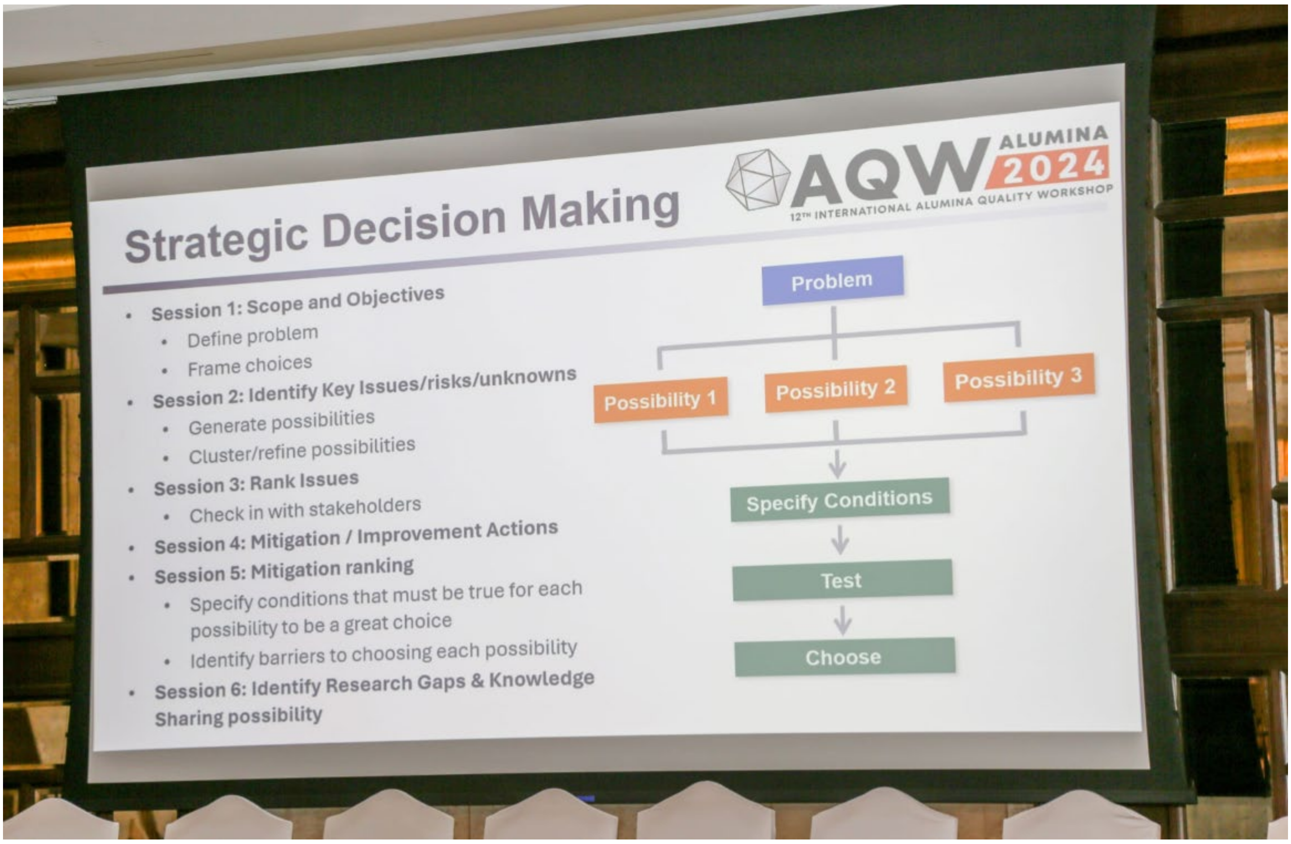


These alumina experts came from all continents and represented all major alumina-producing regions and companies, meeting in a cooperative and relaxed environment.

Process

The workshop followed a structured HAZID-style process over progressive sessions according to these 6 steps:

1. Scope and objectives:
   - Describe specific applications within table topic (where to install this technology in a refinery, what are the inlets and outlets, etc.)
2. Identify key issues/risks/unknowns:
   - Generate possibilities for selected applications
   - Cluster/refine possibilities
3. Rank key issues:
   - Rank by multi-voting process
4. Mitigation / improvement actions:
   - Identify mitigations for top-ranking issues
5. Mitigation ranking
   - Specify conditions that must be true for each possibility to be a great choice
   - Identify barriers to each
   - Rank with multi-voting process
6. Identify research gaps & knowledge sharing opportunities.



Outcomes

Detailed notes and voting results for each topic are included in Appendix B. Key outcomes are summarized in the tables below.

Topic 1: Optimising Energy Use

#	Application	Key Issue	Mitigation
1	MVR for vapor from barometric flash	Vapor Contamination and impeller scaling	Wet Scrubber
2		Capex Cost/ OPEX	Use HILT CRC as a hub to centralize the designs and IAI to host collateral if applicable
3	Heat Pumps with cooling water from evaporator as heat source	Capex Cost/ OPEX	Build large, centralized units
4		Energy efficiency	Operate at optimum temperature & COP at given evaporator economy
5		Dust particulates	• Scrubber design, desuperheating sprays, visualisation and diagnostic systems for MVR/compressor inlets • Removal of solids from the circuit, scaling, mass and heat balance. • Piloting
6	Waste heat utilisation from calcination using scrubbing tower + evaporator + MVR	Stack buoyancy	Plume dispersion modelling
7	Waste heat utilisation from blow-off steam using vapour scrubber and MVR	Fouling of compressor blades	• Bypass for compressor • Desuperheating sprays • Visualisation and diagnostic systems for MVR/compressor inlet • Smart vibration and conductivity monitoring systems

Collaboration Opportunities

- HILT CRC type of project (modelling and technology scouting) (Issue 1).
- Parallel vs series design requires documentation (Issue 2).
- De-risk with smaller units (Issue 3).
- Research opportunities to determine optimum criteria (Issue 4).
- Concept level study with appropriate modelling to understand options and viability, especially with regards heat sink. Recommendations made for a pilot plant trial. (Issue 5).
- Concept level engineering trade-off study completed; Understand the market better (Issue 7).

Topic 2: Inputs and Outputs Circularity

#	Application	Key Issue	Mitigation
1	Low bauxite grade makes the Bayer process more energy intensive	Beneficiation technologies need to be better / more efficient	Collectively, as an industry, look for alternative beneficiation options through partnership, collaborative efforts, etc.
2		There is currently no decarb incentive for miners to beneficiate bauxite. Need a value model for CO_2 reductions enabled by beneficiation.	• Quantify the CO_2 footprint/contribution of non-alumina bauxite material. • Add to VIU proposition for beneficiation.
3	Bauxite residue	Understand how much CO_2 sequestration value there is in BR, including biological components.	• IAI mineral carbonation project • Requires to further study the CO_2 capture (vegetation & microbiome) when BR is turned into soil
4		Losses of lime, soda and alumina impact the ability to reuse BR (positive Scope 3 impacts, e.g. clinker, SCM, etc.)	Include a carbon footprint aspect into studies for options to reduce those losses

Collaboration Opportunities

- HILT CRC type of project (modelling and technology scouting) (Issue 1).
- Industry sponsored/lead modelling project (Issue 2)
- IAI-BAC / company-led type of project (Issues 3).
- IAI-BAC project with a consultant and/or engineering (Issue 4).

Topic 3: Electrical Calcination

#	Application	Key Issue	Mitigation
1	Replace existing furnace with 100% electrical calcination (generic technology)	Intellectual property lockout	Commercialisation vehicle to enable: • sharing of technologies • guaranteed access to shared technologies (e.g. Leilac consortium in European lime).
2		Electricity supply and availability	Investigate variable calcination to align with electricity availability (hydrate storage, transitional alumina storage, etc.).
3			Alternative fuel source in combination with electrification (option 2 electrical pre-calciner)
4		Intellectual property lockout	Robust IP agreement with China
5		Alumina quality	Create a project to develop an electric particle preheater, leading to pilot
6			Engage downstream customers (smelters) to Discuss: • quality requirements and • opportunities to look more holistically + value chain requirements

Collaboration Opportunities

- IAI to assist with framework and board level discussions (Issue 1).
- HILT CRC type of project (modelling and technology scouting) (Issues 2 & 3).
- IAI to assist with framework and board level discussions (Issue 4).
- HILT CRC type of project (Issue 5).
- IAI-BAC project (Issue 6).

Topic 4: Thermal Storage

#	Application	Key Issue	Mitigation
1	Thermal storage to produce steam from condensate and make-up water	Process integration	Robust modeling - mass and energy modelling / transient modelling / physical transport modelling
2	Thermal storage to calcine alumina from hydrate	Process consistency and control	Calcination - new model needed to be integrated into existing calciners
3	Thermal storage to produce steam from condensate and make-up water	Heat transport to and from equipment	Material compatibility of heat transport system (off the shelf?)
4	Thermal storage to produce steam from condensate and make-up water		Gap could be to build the collaboration / bridge the various stakeholders / pilot plant demonstration.

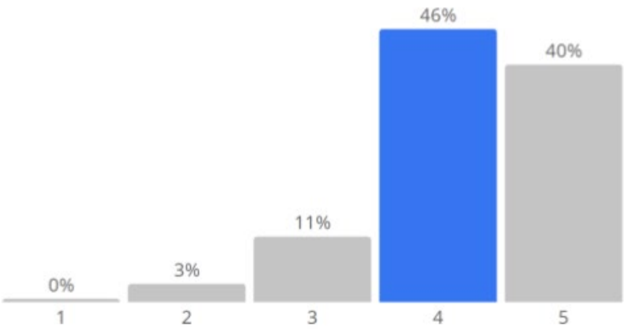
Collaboration Opportunities

- HILT CRC type of project (Issues 1-3).
- IAI to assist with framework and board level discussions (Issue 4)
- Vendor (Issues 2-4)

Wrap-Up Q&A with Slido

The Workshop concluded with an interactive Q&A session. Delegate participation was facilitated using the Slido App.

A Slido poll of participant satisfaction showed that 86% were very satisfied or above that the workshop successfully met its objectives.



"Industry collaboration" clearly emerged as the highest priority initiative participants would like to see as an action arising from the workshop. Group discussion on how for how this could be achieved included these suggestions:

- Holding regular meetings – e.g. HILT and/or IAI to convene regular, follow up on-line forums,
- Annual AQW conference,
- "Learn by doing" - start small / build on existing collaborations.

"**Sort out the IP**" was the priority action participants proposed as a next step, to be achieved by:

- Technology consortium approach to manage IP,
- Avoid IP, e.g. clarify and focus on pre-competitive areas where collaboration is easier,
- Community of Practice to prioritise challenges and co-ordinate approaches to them, and
- "Build from small wins" - start with existing projects / obvious areas and build from there.

Key Actions Arising

Topic	Issue	Action	Responsible
2 Inputs and Outputs Circularity	1 Beneficiation technologies need to be better / more efficient	Consider how to address beneficiation technologies for bauxite in existing HILT projects e.g.: • 1.008 Green Pyromet /Hydromet Beneficiation Pathways • 1.013 Alumina Refineries' Next Generation Transition (ALUMINext)	HILT CRC
3 Electrical Calcination	2, 3 Electricity supply and availability	Consider how to address integration of alternative fuel source in combination with electrification technologies in existing HILT projects e.g.: • 1.013 Alumina Refineries' Next Generation Transition (ALUMINext)	HILT CRC
3 Electrical Calcination	5 Alumina quality	Develop ideas for a 'net zero calcination' R&D facility including electric particle preheater and alternative heating pathways.	HILT CRC
4 Thermal Storage	1, 2 Process integration; Process consistency and control	Consider how to address thermal storage issues in current HILT projects, in particular need for robust modeling - mass and energy modelling / transient modelling / physical transport modelling and integration into current or new calciners, e.g. • 1.013 Alumina Refineries' Next Generation Transition (ALUMINext) • 2.009 Advancing the Viability of High Temperature Thermal Energy Storage for Industrial Applications – follow on project	HILT CRC
Wrap Up	Industry collaboration	HILT and IAI to discuss how to convene regular, follow up on-line forums (e.g. technical expert panel for emerging technology evaluation) and set up a centralized system to share publicly available reports from member companies.	IAI

APPENDIX A: List of Participants

Workshop Organising Committee

Leadership

Michael Reid, RTA
Workshop Leader

Jordan Param, HILT CRC
Lead Facilitator

Committee Members

Woei Saw, Uni of Adelaide/HILT CRC
Ian Stephenson, Alcoa
Sreeraj Balachandran, RTA
Vilas Tathavadkar, Hindalco
Glen Hanna, South 32
Emilio Pai, EGA
Erik Araujo, Hydro
Greg Power, Arriba Consulting

Workshop Participants

Observers: Carl Firman, IAI
Steve Rosenberg, EGA

Table 1: Optimising Energy Use		
Facilitator:	Nawaf Al Shehhi	EGA
Notetaker:	Emilio Pai	EGA
Participants:	Andrew Furlong	Worley
	Mehani Boufedji	Rio Tinto
	Rob Clegg	Sahl Regen
	Mike Sisley	Rio Tinto
	David Southwood-Jones	DSJ Consulting
	Mustafa Anwar Alabbasi	EGA
	Ahmad Badarani	EGA
	Gyorgy Banvolgyi	Consultant
	Siyun Ning	University of Adelaide

Table 2: Optimising Energy Use		
Facilitator:	Narendra Singh	EGA
Notetaker:	David Cochrane	South 32 (ret)
Participants:	Jorg Ruster (EGA) Callam Galt (Hatch) Richard Furness (QAL) Damien Boudeville (RT) Luke Kirwan (RT) Erik Araujo (Hydro) Andre Panov (UC RUSAL)	EGA Hatch QAL Rio Tinto Rio Tinto Hydro Rusal

Table 3: Inputs and Outputs Circularity		
Facilitator:	Mahra Abdulla	EGA
Notetaker:	Glen Hanna	South 32
Participants:	John Anawati Eloise Dixon Bruno Fecchio Sébastien Fortin (RT) Simon Gravel (RT) Virender Kumar Yufen Li Chawei Lin Matheus Paschoalino Daniel Propes Allan Reis Albert Rijkboer David Sutherland Yuto Uematsu Kazuhiko Yamasaki Panagiotis Davris	Hatch Alcoa Clariant Rio Tinto Rio Ttinto EGA Alcoa Texas A&M Solugen Texas A&M Hydro Rinalco BV D Sutherland &Assocs INPEX Corp INPEX Corp Mytilineos S.A.

Table 4: Electric Calcination		
Facilitator:	Petershane Ming	EGA
Notetaker:	Ian Stephenson	Alcoa
Participants:	Sergio Ferreira	Hydro
	Chris Baker	Alcoa
	Alistair Gillespie	QAL
	Michael Weatland	Calix
	Daniel Ang	Uni of Adelaide
	Elaine Tolentino	South 32
	Gus Nathan	Uni of Adelaide
	Mark Veach	QAL
	Francois Theriault	Rio Tinto
	Abdalla AlZarooni	EGA

Table 5: Thermal Storage		
Facilitator:	Fatima Ismail	EGA
Notetaker:	Woei Saw	Uni of Adelaide/HILT CRC
Participants:	Michael Tait	Worley
	Roberto Seno Junior	CBA
	Lachlan Graham	CSIRO
	Ben Seton	Alcoa
	Takou Harato	Waseda University
	Jenny Selway	HILT CRC

APPENDIX B: Topic Session Records

Topic Template

	Topic 1:	Insert Name		
	Workshop Session 1: Scope & Objectives		**Workshop Session 2: Identify Key Issues**	
	(Use generic calciner flowsheet to define scope)		**Key Issues / uncertainties List (brainstorming session)**	
	Boundaries	Where would you install this technology in a refinery?	Process (temperature, pressure, species, flows,...?)	
Application 1	Inlet flows			
	Outlet flows		Financial (equipment costs, operating cost, energy costs...)	
Application 2	Inlet flows			
			Safety (new safery risks)	
	Outlet flows			
			Equipment (footprint, compatibilty with existing equipment, maitenance intensity,...)	
Application 2	Inlet flows			
	Outlet flows			
			Environmental	
			Scale-up	
Facilitator guideline: 1) discuss and identify applications - can add more above if required. Be concious of not having too many topics for further discussion over the rest of the day. If there are significant numbers of applications, may need to vote/decide on priorities.			Facilitator guideline: 1) ask participants to take 5 minutes to write on post-it notes what they are the risks/uncertainty of the application. 2) Ask each participants to name one issue and ask if other participants had a similar issue before classifying the issue in a category.	
Notetaker guideline: write in Excel the application description and validate description with participants			Notetaker guideline: write in Excel sheet the issue description and validate description with participants. Copy the issue in the column F for ranking	

Workshop Session 3: Rank Issues

Key Issue	Risk Rank
Issue 1	1,0
Issue 2	2,0
Issue 3	3,0
Issue 4	4,0
Issue 5	5,0
Issue 6	6,0
Issue 7	7,0
Issue 8	8,0
Issue 9	9,0
Issue 10	10,0
	11,0
	12,0
	13,0
	14,0
	15,0
	16,0
	17,0
	18,0
	19,0
	20,0
Total	

Facilitator guideline: Use appropriate group ranking system

Notetaker guideline: Document risk and rank

Workshop Session 4: Mitigation / ImprovementActions

Key Issue	Mitigation / Improvement Action (R&D, benchmarck, piloting, engineering study, project,...)

Facilitator guideline: The facilitor will lists the top 5 risks and ask participants to take 5 minutes to write on pos-it notes on possible mitigiation. Ask each participants to name one mitigaton and asks if other participants had a similar mitigation. Try to summarize the mitigation for the notetaker

Notetaker guideline: write in Excel sheet the risk and mitigation description and validate description with participants. Copy the issue in the column Q for ranking

Workshop Session 5: Mitigation ranking

Key Issue	Mitigation	Risk Rating
		1,0
		2,0
		3,0
		4,0
		5,0
		6,0
		7,0
		8,0
		9,0
		10,0
		11,0
		12,0
		13,0
		14,0
		15,0
		16,0
		17,0
		18,0
		19,0
		20,0
Total		

Facilitator guideline: Use appropriate group ranking system

Notetaker guideline: Document risk and rank

Research Gaps & Knowledge Sharing

Mitigation	Research project opportunity	Public Knowledge Sharing Opportuniti	Research Providors	Research Sponsors

Notetaker guideline: Document which mitigation has public information available and research project opportunity with potentiel sponsor

Topic 1: Optimising Energy Use – Table 1 Proceedings

Red represents input from Workshop.

	Topic 1:	Opportunity to eliminate energy waste in a typic 200tphmultiple effect evaporator, 4 t/t economy (LS elimination)
	Workshop Session 1: Scope & Objectives (Use generic Bayer flowsheet to define scope)	
	Boundaries	Where would you install this technology in a refinery?
MVR	Inlet flows	Electrification of steam in an evaporation
	Vapour from Barometric flash (50 to 60C)	Location has to be specific in evaporation. Enough stages close
	Spray water for the recompression from conden	Require vapour scrubber/ Vapour separation
	Electricity	Multiple fans in series
	Outlet flows	
	5 Bar Steam saturated (160C)	
	10 tons of excess vapour at 5 Bars export to circuit	
Heat Pump	Inlet flows	Use cooling water from the Evaporation as a heat source to Heat Pump
	Cooling water at 60 C	Heat Pump (4 stages with propane and 4 stage with steam)
	Spray water for recompression	Propane
	Outlet flows	Reboiler/ compressor/ heat sink to reach 120C
	35 C water	Steam compression
	5 Bar Steam saturated (160C)	Heat pump can be installed anywhere
Application 2	Inlet flows	
	Outlet flows	

Workshop Session 2: Identify Key Issues	
Key Issues / uncertainties List (brainstorming session)	
Process (temperature, pressure, species, contaminants, flows,...?)	
Non condensable gases	
Vapour contamination	
control of 7 stages	
Steam for start up?	
Financial (equipment costs, operating cost, energy costs...)	
High Capex cost	
Poor understanding by upper management of the challenge	
Continuous renewable energy supply?	
Safety (new safery risks)	
Noise	
Equipment (footprint, compatibilty with existing equipment, maitenance intensity,...)	
Real estate	Poor support from the vendors
Maintenance Access	Equipment multiple new drives to maintain
Compressor impeller scaling	Operating factors of 7-8 units in servise
Equipment (fan) maintenance know-how	
Environmental	
Scale-up	
Failure of trial pilot scale unit	

Workshop Session 3: Rank Issues

Key Issue	Risk Rank
Vapour Contamination/ Impeller scaling	1.0
Capex Cost/ Opex	2.0
Low operating factor (7-8 units in service)	3.0
Continuous renewable electricity supply	4.0
Risks for MVR scale -up might be difficult and time consuming	5.0

Workshop Session 4: Mitigation / ImprovementActions

Key Issue	Mitigation / Improvement Action (R&D, benchmarck, piloting, engineering study, project,...)
1 - Vapour Contamination/ Impeller scaling 2- Capex Cost/ Opex 3 - Low operating factor (7-8 units in service) 4- Continuous renewable electricity supply 5- Risks for MVR scale -up might be difficult and time consumi	1 -Mist separator 1- Cyclone separator 1- wet scrubber 1- Heat exchanger/ reboiler 1- anti vibration using digital 1- conductivity for the scrubber 1- adopt caustic cleaning regime 2- How to buy a standard module to minimize cost? 2- use IAI/ HILT CRC as a hub to centralize the designs 2- Select the best COP in the design 3- By pass the system with a lot of Capex (not good option) 3- Running 12 stages in paralell so that if fail 1, no issue 3- Partnership with vendors. Invite for the next AQW 4- Evaluate to operate evaporator in campaigns (intermitent) 4- Store energy in the plant for the shortages (i.e. running the mill only during the day) 4- Design new refinery with priorities for the green energy usage 5- Develop pilots in a collaboration mode with good quality and inputs from broad industry expertise 5- Benchmark with existing or near future MVR operations 5 - HILT CRC to support in the MVR developments, with proper evaluation of the best arrangements and proper analysis to be shared

Workshop Session 5: Mitigation ranking		
Key Issue	**Mitigation**	**Risk Rating**
MVR 1- wet scrubber 3- Partnership with vendors. 2- use IAI/ HILT CRC as a hub to centralize the designs	Engage HILT CRC	

Research Gaps & Knowledge Sharing

Mitigation	Research project opportunity
1- wet scrubber 2- Partnership with vendors. 3- use IAI/ HILT CRC as a hub to centralize the designs	Know if applicable and how it works Paralell vs series requires documentation

Topic 1: Optimising Energy Use – Table 2 Proceedings

	Topic 1:	Insert Name			
	Workshop Session 1: Scope & Objectives		**Workshop Session 2: Identify Key Issues**	**Workshop Session 3: Rank Issues**	
	(Use generic calciner flowsheet to define scope)		**Key Issues / uncertainties List (brainstorming session)**	**Key Issue**	**Risk Rank**
	Boundaries	Where would you install this technology in a refin	Process (temperature, pressure, species, flows, ...?)		
Application 1	Waste heat utilisation, especially calcination optimisation (and stack gas heat recovery, blow-off steam, ISH heat reuse, cooling towers)	1. Calciner off-gas - scrubbing tower + evap + MVR		Calciner stack gas heat recovery Issue 1: Dust particulates	1,0
		2. Waste heat from blow-off steam - vapour scrubber and MVR		Issue 2: Corrosive gas	2,0
			Calciner stack gas - 150C, 50% water, 50% NCG, ~0.5GJ/t, 1bar Issues - corrosive, low temp off-gas, water balance from condensing water, space limitations, bio-fouling/ligonella, reduced stack gas buoyancy Main issues : dust particulates, corrosive gas, stack buoyancy, bio-fouling, water balancing	Issue 3: Stack buoyancy	3,0
			Blow-off steam - 100C+BPE, 1 bar, contamnants: alkali droplets, solids, VOC, Hg & NCG	Issue 4: Bio-fouling	4,0
			Main issues - fouling of compressor blades, sparing philosophy, management of non-co	Issue 5: Water balancing from excess water	5,0
					6,0
Application 2	Inlet flows		Financial (equipment costs, operating cost, energy costs...)		7,0
	High temp green heat for digestion - especially generating HP steam (>50bar) without fossil fuels	Molten salt Steam with green electricity Direct electric heating	Safety (new safety risks)	Blow-off steam utilisation Issue 1: Redundancy/operability	8,0
				Issue 2: Fouling of compressor blades	9,0
				Issue 3: Power house steam balance	10,0
				Issue 4: Digestion pressure profile	11,0
			Equipment (footprint, compatibilty with existing equipment, maintenance intensity,....)	Issue 5: Hg in condensate	12,0

Jorg Ruster, Callum Galt, Richard Furness, Damien Boudeville, Luke Kirwan, Erik Araujo, Andre Panov

Workshop Session 4: Mitigation / ImprovementActions		**Workshop Session 5: Mitigation ranking**			**Research Gaps & Knowledge Sharing**
Key Issue	**Mitigation / Improvement Action (R&D, benchmarck, piloting, engineering study, project,...)**	**Key Issue**	**Mitigation**	**Risk Rating**	**Mitigation**
Calciner stack gas heat recovery Issue 1: Dust particulates	Scrubber design, desuperheating sprays, visualisation and diagnostic systems for MVR/compressor inlets, removal of solids from the circuit,scaling, mass and heat balance, and piloting	1. Scrubber design, desuperheating sprays, visualisation and diagnostic systems for MVR/compressor inlets, removal of solids from the circuit,scaling, mass and heat balance, and piloting		1,0	Concept level study with approriate modelling to understand options and viability, especially with regards heat sink. Recommendations for a pilot plant trial.
Issue 2: Corrosive gas	Neutralising agent (caustic for acid gases)	2. Plume dispersion modelling		2,0	
Issue 3: Stack buoyancy	Plume dispersion modelling	2. Water treatment		3,0	
Issue 4: Bio-fouling	Water treatment	2. Neutralising agent		4,0	
excess water (flue gas, hydration)	Site water balance model (site specific)	2.Site water balance		5,0	
				6,0	
				7,0	
Blow-off steam utilisation Issue 1: Redundancy/operability	Benchmarking, centralised facility	1.Dynamic pressure control system required to manage blow-off variability, relief eng design study		8,0	Concept engineering study
Issue 2: Fouling of compressor bla	Bypass for compressor, desuperheating sprays, visualisation and diagnostic systems for MVR/compressor inlet, smart vibration and conductivity monitoringsystems	2. Benchmarking, centralised facility for redundancy & operability		9,0	Concept engineering trade-off study
Issue 3: Power house steam balan	Site specific modelling	3. Bypass for compressor, desuperheating sprays, visualisation and diagnostic systems for MVR/compressor inlet, smart vibration and conductivity monitoringsystems		10,0	Understand the market
Issue 4: Digestion pressure profile	Dynamic pressure control system required to manage blow-off variability, relief eng design study	4. Site specific modelling		11,0	
Issue 5: Hg in condensate	Consider where and how to collect mercury including the use of adsorbent systems	5. Consider where and how to collect mercury including the use of adsorbent systems		12,0	

Topic 2: Inputs and Outputs Circularity – Table 3 Proceedings

	<u>Topic 1:</u>	**Input & Output**		
			Bauxite	**Bauxite Residue**
	Workshop Session 1: Scope & Objectives		**Workshop Session 2: Identify Key Issues**	**Workshop Session 2: Identify Key Issues**
	(Use generic calciner flowsheet to define scope)		**Key Issues / uncertainties List (brainstorming session)**	**Key Issues / uncertainties List (brainstorming session)**
	Boundaries	Problem Statements	**<u>Process (temperature, pressure, species, flows,...?)</u>**	**<u>Process (temperature, pressure, species, flows,...?)</u>**
Application 1	Inlet flows	Bauxite residue is not being utilised to capture CO2. How can we use bauxtie residue to reduce a refinery's CO2 footprint (soil, carboncapture, biochar generation)	Current technologies are not efficient/available	potential is available (need metrics)
			Risk of creating another hazard or bayer process impoact from bene	
			Risk that beneficiation may lose gibbsite and compromise the value.	
	Outlet flows			**<u>Financial (equipment costs, operating cost, energy costs...)</u>**
			<u>Financial (equipment costs, operating cost, energy costs...)</u>	Short term it is always cheaper to pile and closure costs are significantly underestimated
			No incentive for miners to beneficiate	Carbon capture value not well understood for BxR
Application 2	Inlet flows	Bauxite quality is declining which will increase CO2 footprint per tAl at a refinery. What can be done to reduce the CO2 impact of low gibbsite reserves on a refinery		Bx residue is not attractive and there are often other solutions that are more attractive and other industry wastes are competing for the same opportunityt
				Location of Bx residue is often a long way from the market
	Outlet flows			**Environmental**
				Risk of liability for bx residue applications & social acceptance
				Safety/environmental impact of bauxite residue reuse options in the long term is not well understood
Application 3	*Inlet flows*	*Ineffective use of lime reduces the effective carbon capture potential. How can lime be used/replaced to improve CO2 caputre (calcite) or waste (TCA6)*		
	Outlet flows			
			Environmental	
			Scale-up	
				Scale-up

Workshop Session 3: Rank Issues

	Key Issue	Risk Rank
	Bauxite	
1	Current technologies are not efficient/available	12.0
2	Risk of creating another hazard or bayer process impact from bene	4.0
3	Risk that beneficiation may lose gibbsite and compromise the value.	6.0
4	No incentive for miners to beneficiate	11.0
	Bauxite Residue	
5	Understand how much CO2 sequestration value is available in bauxite residue	8.0
6	Short term it is always cheaper to pile and closure costs are significantly underestimated	8.0
7	Carbon capture value not well understood for BxR	9.0
8	Bx residue is not attractive and there are often other solutions that are more attractive and other industry wast	8.0
9	Location of Bx residue is often a long way from the market	4.0
10	Risk of liability for bx residue applications & social acceptance	8.0
	ety/environmental impact of bauxite residue reuse options in the long term is not well understood	8.0

Workshop Session 4: Mitigation / ImprovementActions

Key Issue	Mitigation / Improvement Action (R&D, benchmarck, piloting, engineering study, project,...)
Current technologies are not efficient/available	Collectively as an industry look for alternative beneficiation options for locations to test
No incentive for miners to beneficiate	Add a CO2 price impact into Bx tranfer price/VIU
Understand how much CO2 sequestration value is available in bauxite residue	IAI mineral carbonation project to define total potential Requires a study to quantify the CO sequestration potential of bauxite residue as a soil.
Losses of lime, soda and alumina impacts the ability/cost to reuse residue (incl scope 3)	A study to evalaute carbon footprint and cost of residue reuse options

Topic 4: Electric Calcination – Table 4 Proceedings

	Topic 1:	Electric Calcination	
	Workshop Session 1: Scope & Objectives		**Workshop Session 2: Identify Key Issues**
	(Use generic calciner flowsheet to define scope)		**Key Issues / uncertainties List (brainstorming session)**
	Boundaries	Where would you install this technology in a refinery?	Process (temperature, pressure, species, flows,...?)
Application 1 100% Electric calcination, replacing existing furnace	Inlet flows	Electricity supply	Alumina quality
		Hydrate	Ability to control the reaction
		Air	
		Impurities	Financial (equipment costs, operating cost, energy costs...)
	Outlet flows	Hot air and steam to refinery or atmosphere	Costs are currently unknown and will need to be defined.
		Alumina	
		Impurities	
			Safety (new safery risks)
Application 2 Electric Preheat with green fuel to furnace	Inlet flows	Electricity supply	
		Fuel supply	
		Hydrate	
		Impurities	Equipment (footprint, compatibilty with existing equipment, maitenance intensity,...)
	Outlet flows	Hot gas from electric heater (steam)	Retrofit vs greenfield
		Alumina from main furnace	Full implementtaion vs partial implementation
		Transitional phases from electric heater	
		Hot gas from the main fuirnace	
		Impurities	Environmental
Application 2 New flowsheet, separate to the existing units	Inlet flows		Water balance considerations
			Scale-up
	Outlet flows		

Workshop Session 3: Rank Issues	
Key Issue	**Risk Rank**
Alumina quality	20.0
Electricity supply and availability	17.0
Intellectual property lockout	14.0
Availability and supply of electric equipment	12.0
Footprint to install	10.0
Skilled personnel to maintain the new systems	9.0
Reliability	8.0
Maintaining existing throughput	4.0
Scaleability issues to maintain throughput	4.0
Overall Capex	4.0
Maintaining/increasing energy demand	3.0
Increase of OpEx costs	2.0
Impact on steam quality (VOCs etc)	1.0
Avoiding condensation in the process	0.0

Workshop Session 4: Mitigation / ImprovementActions	
Key Issue	**Mitigation / Improvement Action (R&D, benchmarck, piloting, engineering study, project,...)**
Alumina quality	Investigate steam in calcination reaction (research and industry cooperation)
Alumina quality	Create a project to develop an electric particle preheater, leading to pilot
Alumina quality	Engage smelters to discuss quality requirements and opportunities to look
Alumina quality	Pilot testing of alumina in smelter pots
a quality	Better understanding and control of particle properties before calcination
a quality	Understand the effect on alpha alumina and morphology/SSA on SGA
ity supply and availability	Investigate variable calcination to align with electricity availability (hydrate
ity supply and availability	Assess, communicate and advocate for energy supplier and user requirements
ity supply and availability	Assessing behind the meter generation as an option
Electricity supply and availability	Long term power purchase agreement
Electricity supply and availability	Alternative fuel source in combination with electrification (option 2 electrcial
tual property lockout	Industry wide corporate commitments to cooperation for net zero calcination.
Intellectual property lockout	Commercialisation vehicle to enable sharing of technologies & guaranteed access to shared technologies (e.g. Leilac consortium in European lime). IAI
Intellectual property lockout	Robust IP agreement with China

Workshop Session 5: Mitigation ranking

Key Issue	Mitigation	Risk Rating	
Intellectual property lockout	Commercialisation vehicle to enable sharing of technologies & guaranteed	11.0	IAI
Electricity supply and availability	Investigate variable calcination to align with electricity availability (hydrate	9.0	HILT
Electricity supply and availability	Alternative fuel source in combination with electrification (option 2	7.0	HILT
Intellectual property lockout	Robust IP agreement with China	7.0	IAI
a quality	Create a project to develop an electric particle preheater, leading to pilot	4.0	HILT
a quality	Engage downsteam customers (smelters) to discuss quality requirements	4.0	IAI
a quality	Pilot testing of alumina in smelter pots	4.0	
:tual property lockout	Industry wide corporate commitments to cooperation for net zero	3.0	
a quality	Investigate steam in calcination reaction (research and industry	2.0	
Electricity supply and availability	Assessing behind the meter generation as an option	1.0	
Electricity supply and availability	Long term power purchase agreement	1.0	
a quality	Better understanding and control of particle properties before calcination	0.0	
Alumina quality	Understand the effect on alpha alumina and morphology/SSA on SGA	0.0	
Electricity supply and availability	requirements	0.0	

Topic 5: Thermal Storage – Table 5 Proceedings

	Workshop Session 1: Scope & Objectives	
	(Use generic calciner flowsheet to define scope)	
	Boundaries	Where would you install this technology in a refinery?
Application 1	Inlet flows	Condenstate
	Digestion	Treated water
		Spent liquor
	Outlet flows	Steam
		Hot liquour
Application 2	Inlet flows	Air
	Calcination	Hydrate
	Outlet flows	Heated Air
		Dried hydrate or alumina
Application 2	Inlet flows	
	Outlet flows	

Workshop Session 2: Identify Key Issues	
Key Issues / uncertainties List (brainstorming session)	
Process (temperature, pressure, species, flows,...?)	
Steam condition	Quality of condensate and feedwater
Process consistency and control of	Steam contamination
Financial (equipment costs, operating cost, energy costs...)	
Round trip efficiency of TES	Commitment to long-term Net-Zero
CAPEX and OPEX of TES	CAPEX and OPEX of backup system
Return on Investment	
Safety (new safery risks)	
Contamination	Knowledge transfer-Workshop
Equipment (footprint, compatibilty with existing equipment, maitenance intensity,...)	
Footprint	Round trip efficiency TES
Heat transport to and from	Special material
Retrofitable into the existing unit operations	
Environmental	
Leak of heat transfer medium to the environment	
Scale-up	
Land availability/Size of TES	
Electricity supply	

Workshop Session 3: Rank Issues	
Key Issue	**Risk Rank**
Process integration	1.0
Process consistency and control	2.0
Heat transport to and from	3.0
Storage capacity	4.0
Contamination of Hydrate/Air	5.0
Return on Investment	6.0
Land availability/Size of TES	7.0
Knowledge transfer-Workforce	8.0
Special material	9.0
Electricity supply	10.0
	11.0

Workshop Session 4: Mitigation / ImprovementActions	
Key Issue	**Mitigation / Improvement Action (R&D, benchmarck, piloting, engineering study, project,...)**
	New concept development of integration into existing steam genration and calciner
Process integration	Modular installation to de-risk
Process	Robust modeling - Mass and Energy modelling Transient modelling /Physical transport modelling
	Operator training using digital twins (simulation)
	Bespoke solution (Steam generation)
	culture of organisation
Process consistency & Control	Definition of Process demand/load and capability then integrated solutions
Process	Instrumentation to monitor storage/inputs/outlets and control system
	Provide integrity to the existing system (back-up)
	Preventative maintanance Strategy
	Operation and Maintanance philosophy - Spare key equipment
Heat transport to and from	Choices of heat transfer medium (cost/safety/efficiency/OEMs)
Equipment	Instrumentation to monitor storage/inputs/outlets and control system
	Assessment of construction of heat transfer system (Transportation distance/efficiency/access to maintance
	Opportunity to colloborate and knowledge sharing
	Material specification fit for purpose, design layout to minimise distance
	Material compatability of heat transport system (Off the shelf?)

Workshop Session 5: Mitigation ranking		
Key Issue	**Mitigation**	**Risk Rating**
Process integration	Robust modeling - Mass and Energy modelling/Transient modelling /F	1.0
Process	Operator training using digital twins (simulation)	2.0
Process consistency and control	Definition of Process demand/load and capability then integrated sol	3.0
Process		
Heat transport to and from	Material compatability of heat transport system (Off the shelf?)	4.0
Equipment	Material specification fit for purpose, design layout to minimise dista	5.0

Research Gaps & Knowledge Sharing					
Mitigation	**Research project opportunity**	**Public Knowledge Sharing Opportunities**	**Research Providors**	**Research Sponsors**	**Vendor**
Robust modeling - Mass and Energy modelling/ Transient modelling /Physical transport modelling	x	x	x		
Operator training using digital twins (simulation) - generic software					x
Definition of Process demand/load and capability of the system then examine the potential integrated solutions					
Steam					x
Calcination - new model needed to be integrated into existing calciners	x (to define requirement)	x			x
Material compatability of heat transport system (Off the shelf?)	x				
How tes can be utilised/intergrated seemlessly (TES provider and EPC to work					x
demonstration.		x	x	x	x