16th STS-AIChE Southwest Process Technology Conference

- **What could Distillation look like in the next couple of decades?**

- Izak Nieuwoudt

- Fractionation Research Inc. (FRI)

Sept 22-23, 2025, University of Houston

16th STS-AIChE Southwest Process Technology Conference

Speaker Bio

Dr. Izak Nieuwoudt joined FRI in 2022. Izak holds B.Eng, M.Eng, PhD.Eng and D.Eng degrees in chemical engineering. He has 39 years of experience in the field of separation technology, is the inventor on 410 patents in 46 patent families, the author of 50 journal papers, 80 conference papers, and guided 14 M.Eng and 7 PhD students. Izak received several research and teaching awards, including the Alexander von Humboldt stipend. In 2022 he was honored by the Separations Division of AIChE for his contributions to the field of distillation. He previously worked for Sasol, UOP, Stellenbosch University and Koch-Glitsch. He is a visiting professor at the University of Stellenbosch. Izak's fields of expertise are mass transfer equipment development and design, separation process development, thermodynamic modeling and simulations, CFD studies, modeling of mass transfer equipment hydraulics and separation efficiency, decarbonization technology, troubleshooting, pilot plant construction, engineering education and plant safety. At FRI Izak is responsible for the planning and execution of the experimental programs, modeling, process safety and the FRI Distillation Academy training program.

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Million Dollar Questions

Let's look into the crystal ball

- With all the changes we are seeing, will we need distillation in the next couple of decades?
- Can distillation be replaced with other technology?
- Can distillation be powered with renewable energy sources?
- Can the energy consumption of distillation be reduced and how much of an impact can this have?
- How much of difference can improved distillation equipment make?

The Need for Distillation Decades from now

- Getting rid (100%) of crude oil and natural gas is most likely not realistic
- Refineries and gas plants could change, but would not go away
- Chemicals need to be synthesized, and mixtures need to be separated – this is integral to our quality of life
- Some sectors will still use some forms of liquid fuels – farming, aviation, shipping
- Alternative liquid fuel sources will still require distillation
- Other separation methods, such as membranes, still have a very long way to go (even as a pre-concentration step)
- Distillation will still be needed in a changing world !!!

➢ ***Responsible use of energy is our challenge and duty***

Competing/Complementary Technologies

- Membranes (stand-alone / pre-concentration / distillate treating)
  - Selectivity & Permeation rate
  - Fouling
  - Stability / Lifespan
  - Cost
- Catalysis (Don't make the mess in the first place)
  - Selectivity
  - Activity
  - Lifespan
  - Thermodynamic limits
- Adsorption / Absorption / Extraction / …….. - Niche markets and still require distillation

➢ ***No clear front-runner that can replace distillation***

Renewable Energy

- Solar power
  - 250 W/m^2 (state-of-the-art panels)
  - $ 190/m^2 installed cost without switch gear and transmission lines
  - $ 0.76 MM / MW
  - (Polysilicon production utilizes energy intensive distillation train)
  - Capacity factor = 0.24 => True cost = $ 3.2 MM / MW (Energy storage ???)
- Wind power
  - On-shore: 6 MW units at $ 6.6 MM => $ 1.1 MM / MW
  - Off-shore: 16 MW units at $ 48 MM => $ 3.0 MM / MW (highly location dependent)
  - Switch gear and transmission lines to be added
  - Maintenance cost: 2 cent / kW-h
  - Capacity factor = 0.36 – 0.45 => True cost ~ $ 3.1 – 6.6 MM / MW (Energy storage???)

➢ ***This is pretty darn expensive !!!***

Renewable Energy (Electricity) to drive Distillation Columns

- Distillation column with reboiler duty of 10 MW (8 -14 ft diameter):

  Solar power:

  – 166,700 m^2 of solar cell area = 0.1667 km^2 = 0.0644 mi^2
  – About 0.1288 mi^2 plot area required ≈ 630 x 630 yards
  – $ 32 MM installed cell cost – excluding transmission lines and switchgear

  Wind power:

  – Equivalent of 4.6 on-shore turbines of 6 MW each required
  – $ 30.6 MM installed turbine cost – excluding transmission lines and switchgear

- What do we do about energy storage to get an even supply? **Cost**?
- Do we electrify the process heaters, or do we electrify the heat generation (steam)?

Can we really afford this?

Shouldn't we rather work on reducing energy consumption?

Chemicals example: Ethylene Cracker

Electrification

- A 1.5 MM t/a world-scale ethylene plant consumes approx. 800MW

Solar power:

- 21.4 x 10^6 m^2 of solar panels needed
- $ 2,140 MM installed cost (excluding distribution costs)
- Has to be part of a larger grid to get a steady supply

Wind power:

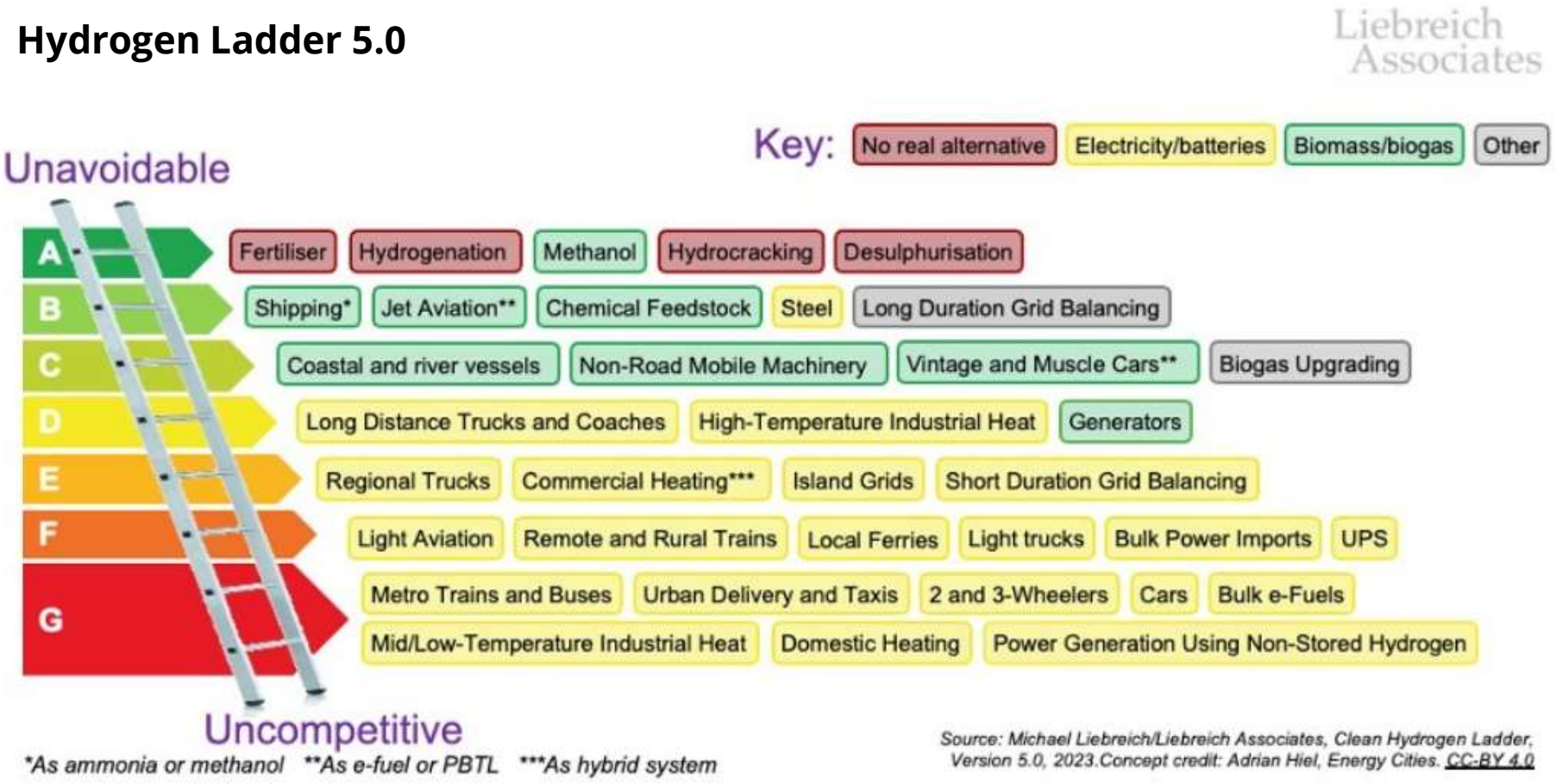
- 282 units of 8 MW needed
- $ 2,316 MM installed cost (excluding distribution costs)
- Has to be part of a larger grid to get a steady supply

- *Additional cost of an electric cracking furnace?*

Price tag of a conventional ethylene plant of this size is approx $ 3,000 MM
Are we willing to double the price tag?

Hydrogen as an Energy Carrier

Hydrogen Ladder 5.0



Hydrogen requires significant additional infrastructure and have high energy losses

Reducing Energy Consumption in Distillation

- Heat integration (Pinch analysis)
- Vapor compression
- Heat pump systems
- Dividing wall towers
- HIDiC arrangements
- Solvent assisted separations
  - Extractive distillation
  - Azeotropic distillation
  - Adding liquid extraction
- Adsorption
- Membranes (also as pre-concentration)
- Completely different processes & more selective catalysts ? .....
- More efficient equipment
- Operating equipment/processes more efficiently

Example: Methanol – Acetone Separation

10,000 kg/h feed of 50/50 mass mixture with 99.6% product purity (Heat pump COP = 4)

	Heating duty MW	Cooling duty MW	Heat pump duty MW	Column 1 diam m	Column 2 diam m	Column 1 height m	Column 2 height m	Relative energy input
Conventional distillation	**Not technically feasible (homogenous azeotrope)**							
Extractive distillation	9.89	8.67	0	1.45	1.55	31	17	100
Extractive distillation in a DWC	9.26	8.06	0	2.0		37		93.6
Extractive distillation with DWC and **heat pump**	1.2	0.8	1.8	2.0		37		30
Pressure swing distillation	14	13.7	0	2.0	1.8	18	22	142
Pressure swing distillation with heat integration	8.3	8.0	0	2.0	1.8	18	22	84
Pressure swing distillation with heat integration and **heat pump**	2.0	1.7	1.6	2.0	1.8	18	22	37

We need affordable high temperature heat pumps with proven reliability

Impact of Equipment on Distillation Energy Consumption

Packing

- Structured Packing
  - Geometry and surface texturing can be modified to increase efficiency at a given maximum capacity
  - Changing from an old style packing could reduce the energy consumption by as much as **15%**
  - Modern, optimized structured packing also have a lower pressure drop per theoretical stage – could be as much as 40%
- Random Packing
  - Modern random packing reduce useless pressure drop, stagnant zones and liquid shielding
  - Changing from an old-style packing could reduce the energy consumption by as much as **15%**
  - Modern packing also have a lower pressure drop per theoretical stage – could be as much as 70%

See FRI database for quantitative results

Impact of Equipment on Distillation Energy Consumption

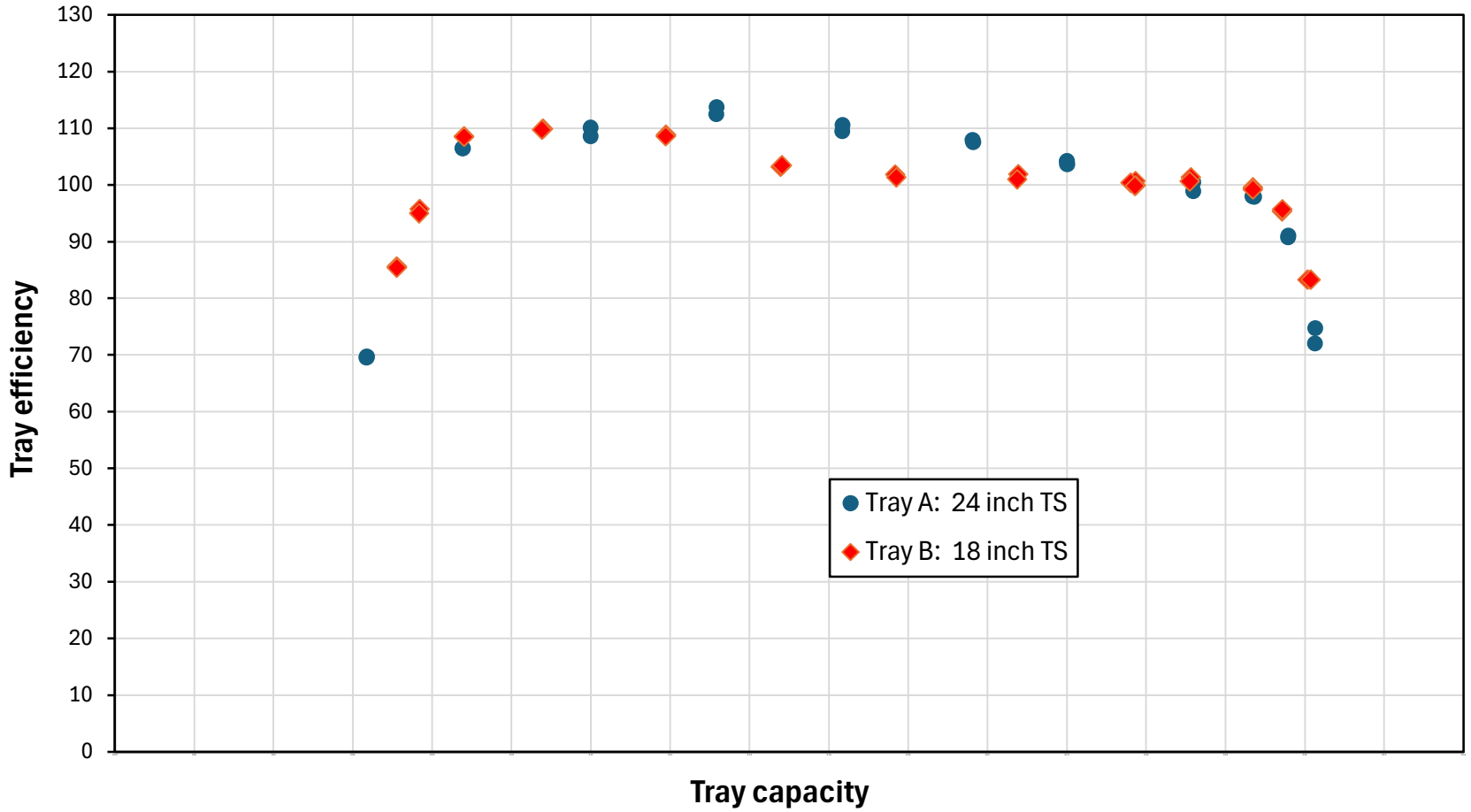
Cross-flow Trays

- Valve geometry has a significant impact on the tray efficiency
- Flow regulating devices can further enhance efficiency by ensuring plug flow of the froth
- Downcomer shape can impact froth flow on tray deck
- The combined impact could reduce the energy consumption by up to **20%**
- For systems operating deep in the spray regime:
  - Outlet weir picketing can improve tray efficiency, but do not over-estimate its effect
  - Using a serpentine flow arrangement can significantly enhance the efficiency and reduce energy consumption
- Trays with higher capacity can be installed on a lower tray spacing – this could yield up to a **25%** reduction in energy consumption

See FRI database for quantitative results

Tray data from FRI

4 ft diameter column – distillation of hydrocarbon mixture



Summary and Conclusions

- Distillation is not going to disappear!
- Renewable energy is abundant, but not cheap
- An all-or-nothing approach on renewable energy makes no sense – we need baseline providers to cover the variability of renewables (or very expensive storage)
- We **CAN** improve processes, flowsheets, equipment and operations
- Let's be engineers and not talking heads
- **Let's get to work!**

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We are hiring!

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Thank you for attending

Questions / Comments

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