Air Liquide
ENGINEERING & CONSTRUCTION

Cryogenics & Lurgi technologies

Acrylic Acid

A Technology Perspective

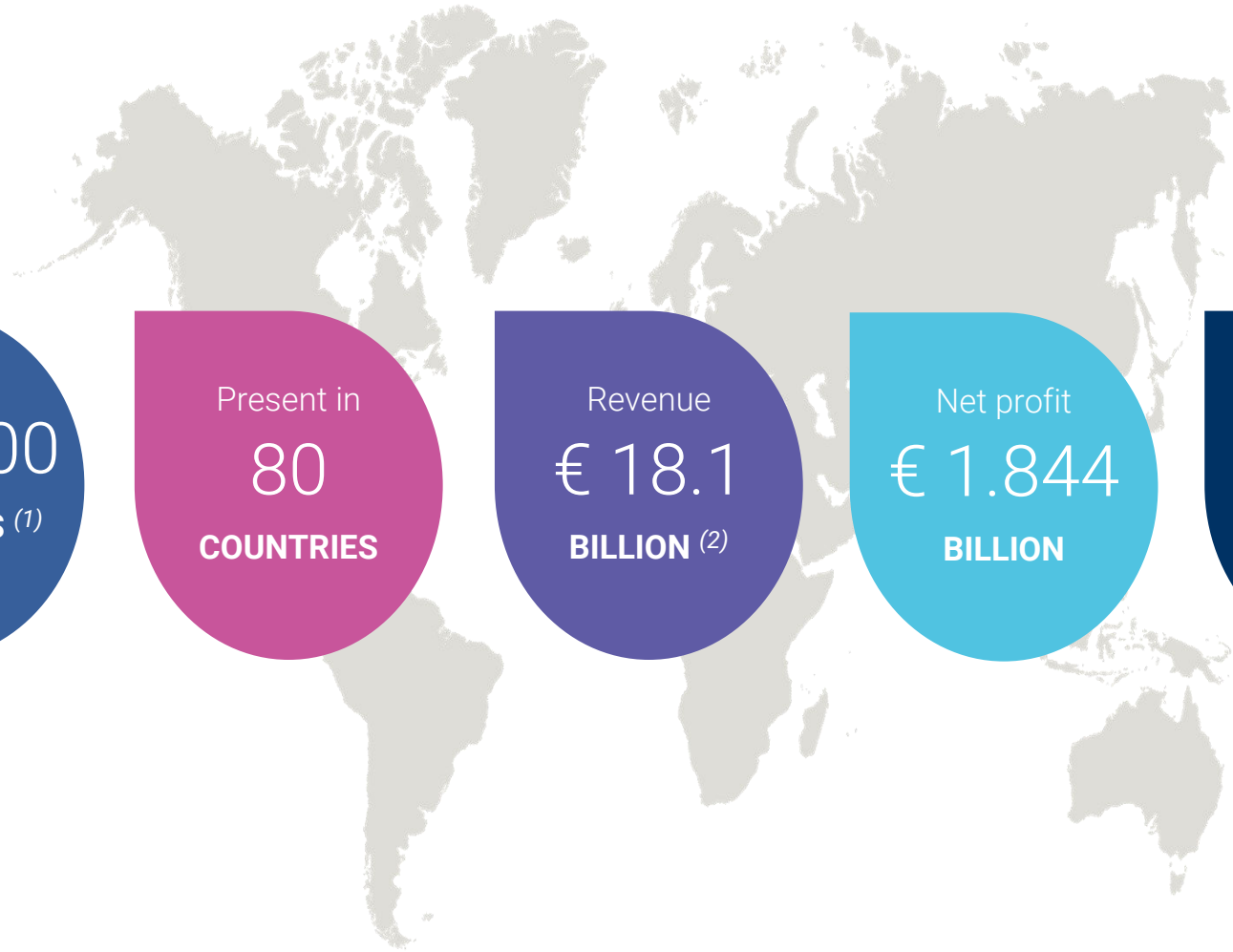
October 14, 2017

Air Liquide Engineering & Construction

Air Liquide Group

2016 Key figures

(Following the acquisition of Airgas on May 23rd, 2016)



~67,000
EMPLOYEES *(1)*

Present in
80
COUNTRIES

Revenue
€ 18.1
BILLION *(2)*

Net profit
€ 1.844
BILLION

More than
3 MILLION
CUSTOMERS & PATIENTS

(1) As of December 31st, 2016.
(2) Excluding Welding and Diving, restated as discontinued operations.

Air Liquide
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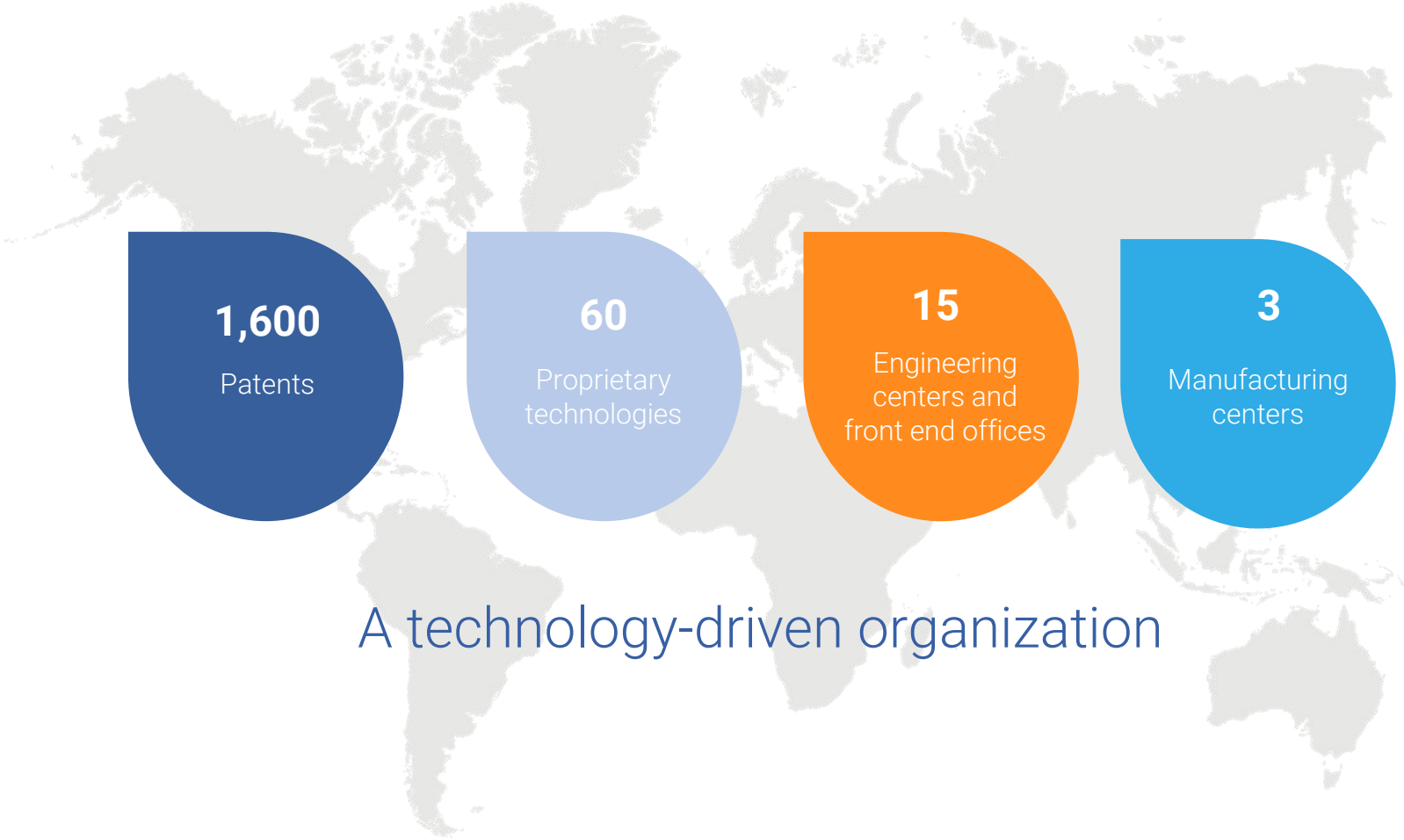
Air Liquide Global E&C Solutions



A technology-driven organization

Product lines managing our technology portfolio

Standard Plants

Cryogenics

Downstream & Petrochemicals

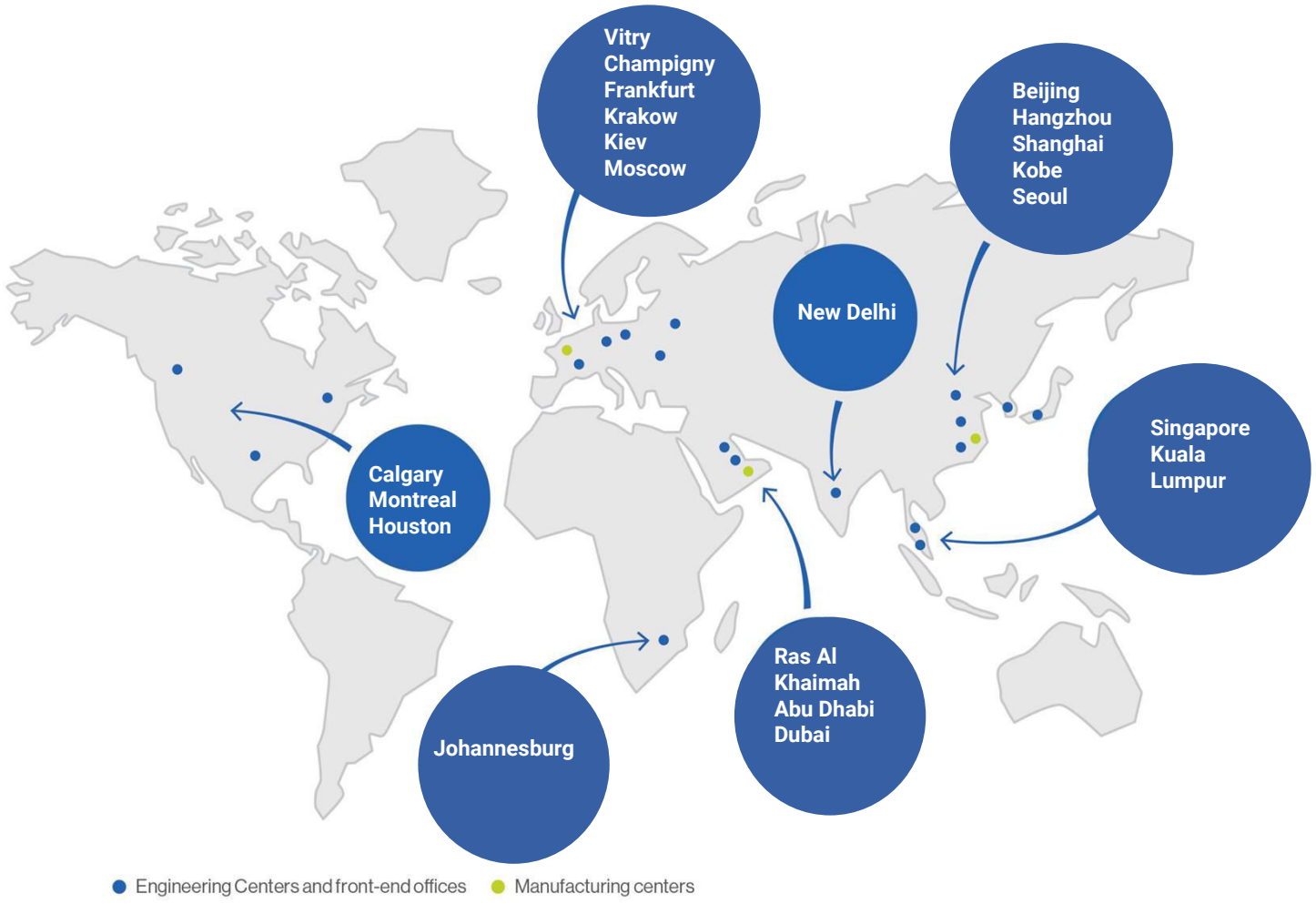
Hydrogen

Hydrocarbons

Oleochemicals

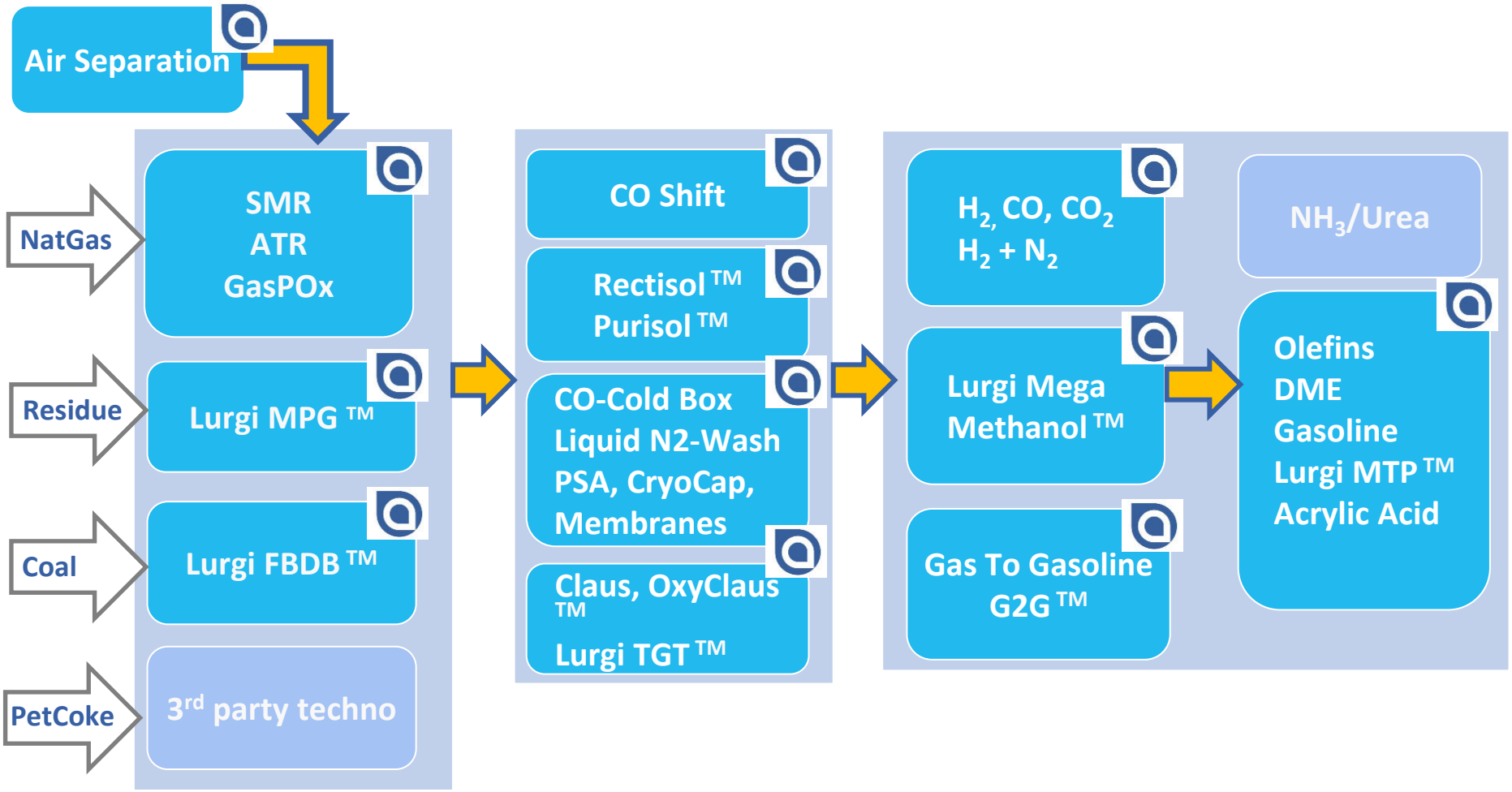
Customer Services

Our locations worldwide



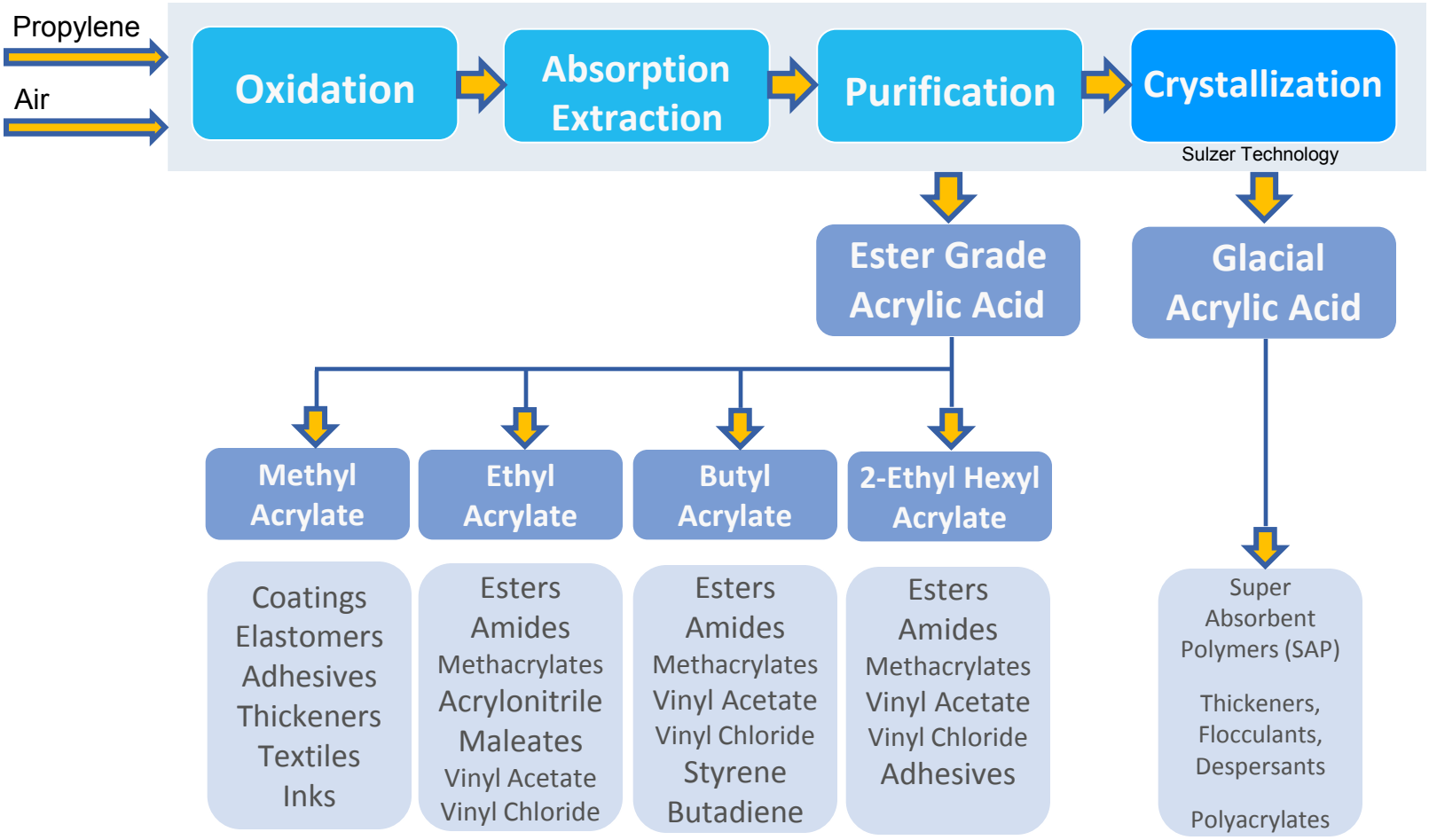
Air Liquide
Creating value via Syngas to Chemicals

AL E&C: Creating Value via Syngas to Chemicals & Fuels



AL provides all necessary techno bricks to produce valuable fuels and chemicals from crude and alternative feed-stock supported by a comprehensive petrochemical portfolio

Acrylic Acid Value Chain



Lurgi / NK
Ester Grade
Acrylic Acid Technology

Acrylic Acid - adding value to propylene

Growth driven by the increasing prosperity of population

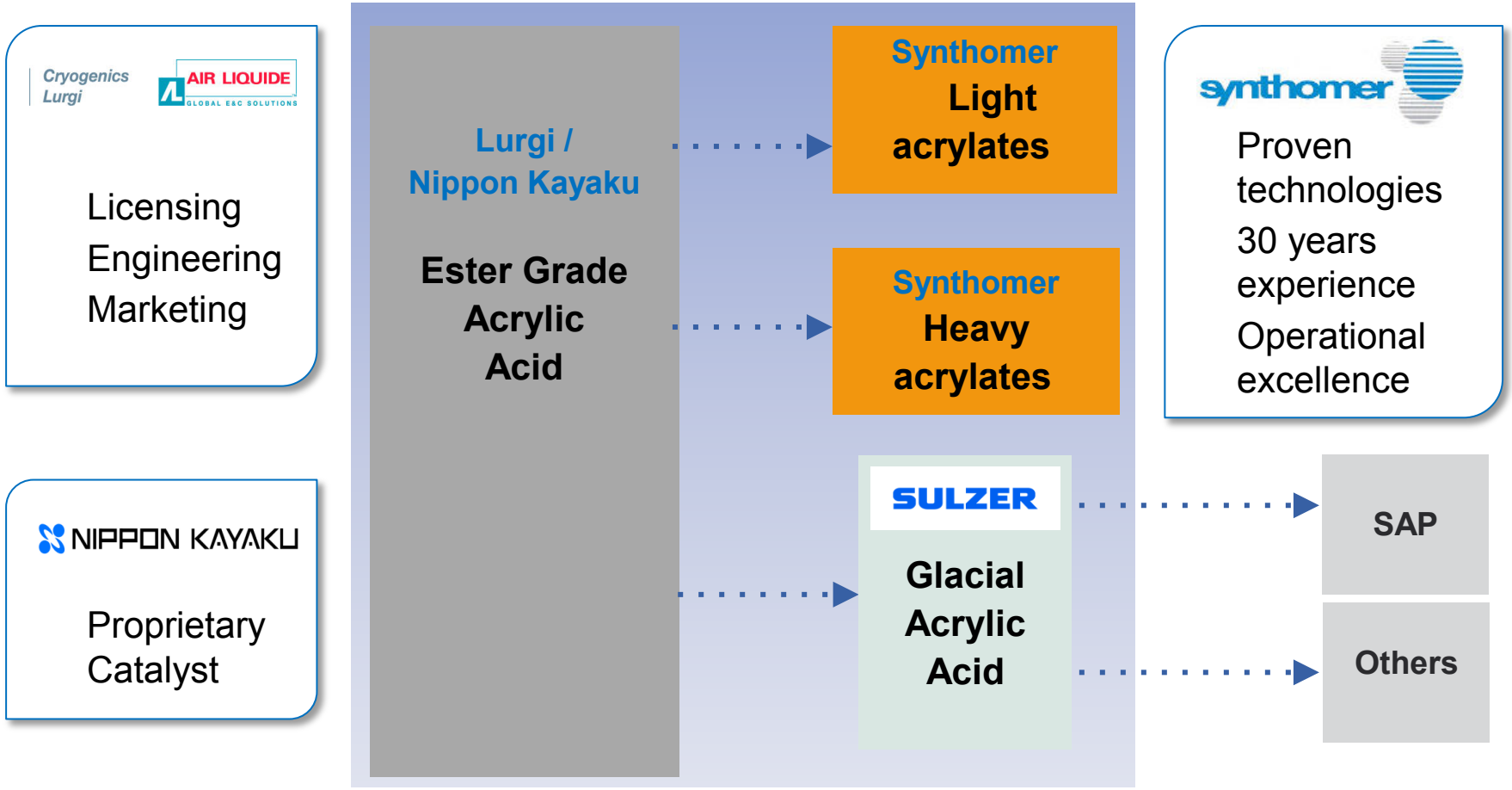
synthomer Lurgi NIPPON KAYAKU

Synthomer Sokolov Site, Czech Republic

- 1984 — 1st Acrylic Acid and Esters plant start up
- 1994 — 2nd Acrylic Acid and Esters plant start up
- 2002 — First Acrylic Acid plant revamp by Lurgi/NK
  Capacity increase by 50%
- Installed Capacities:
  - AA 56,500 tpa
  - MA 11,000 tpa
  - EA 11,000 tpa
  - BA 16,500 tpa
  - 2-EHA 26,500 tpa

Acrylic technologies - single line of responsibility

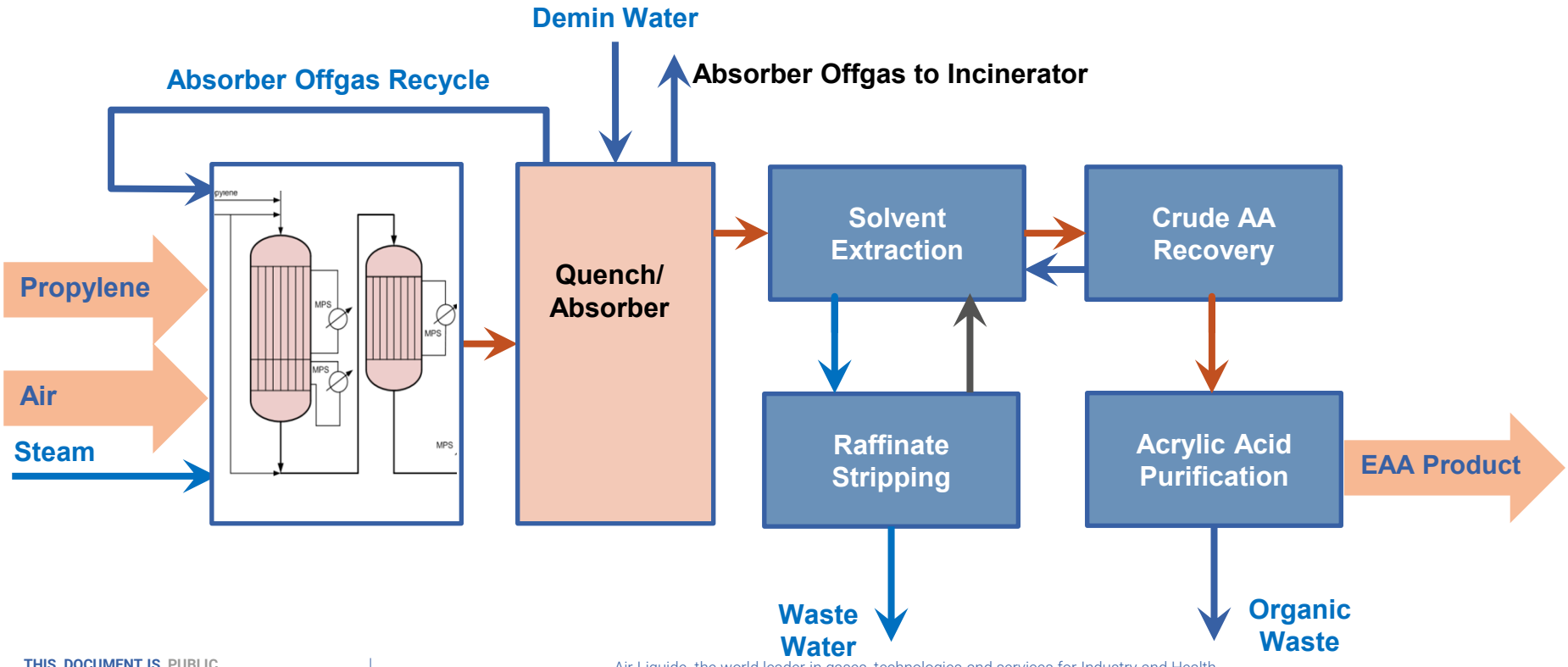
Our proprietary NK catalyst offers the highest performance on the market



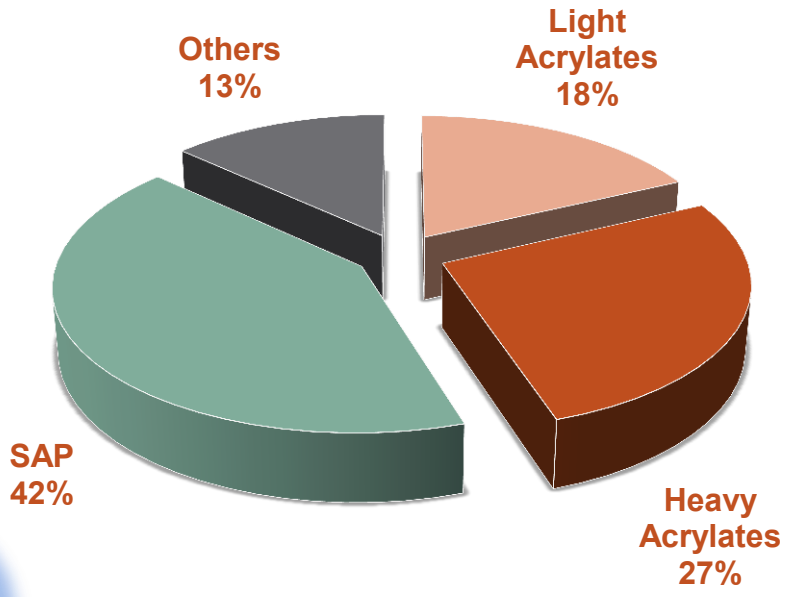
Technologies licensed by AL Global E&C Solutions

Acylic Acid Technology Features

- Special reactor design
- Offgas recycle → minimized waste generation
- Patented Crude Acrylic Acid Extraction with a non-toxic solvent
- Integrated Thermoplate Condensers → Inherent polymerization inhibition
- Use of Special baffle trays in Distillation Columns

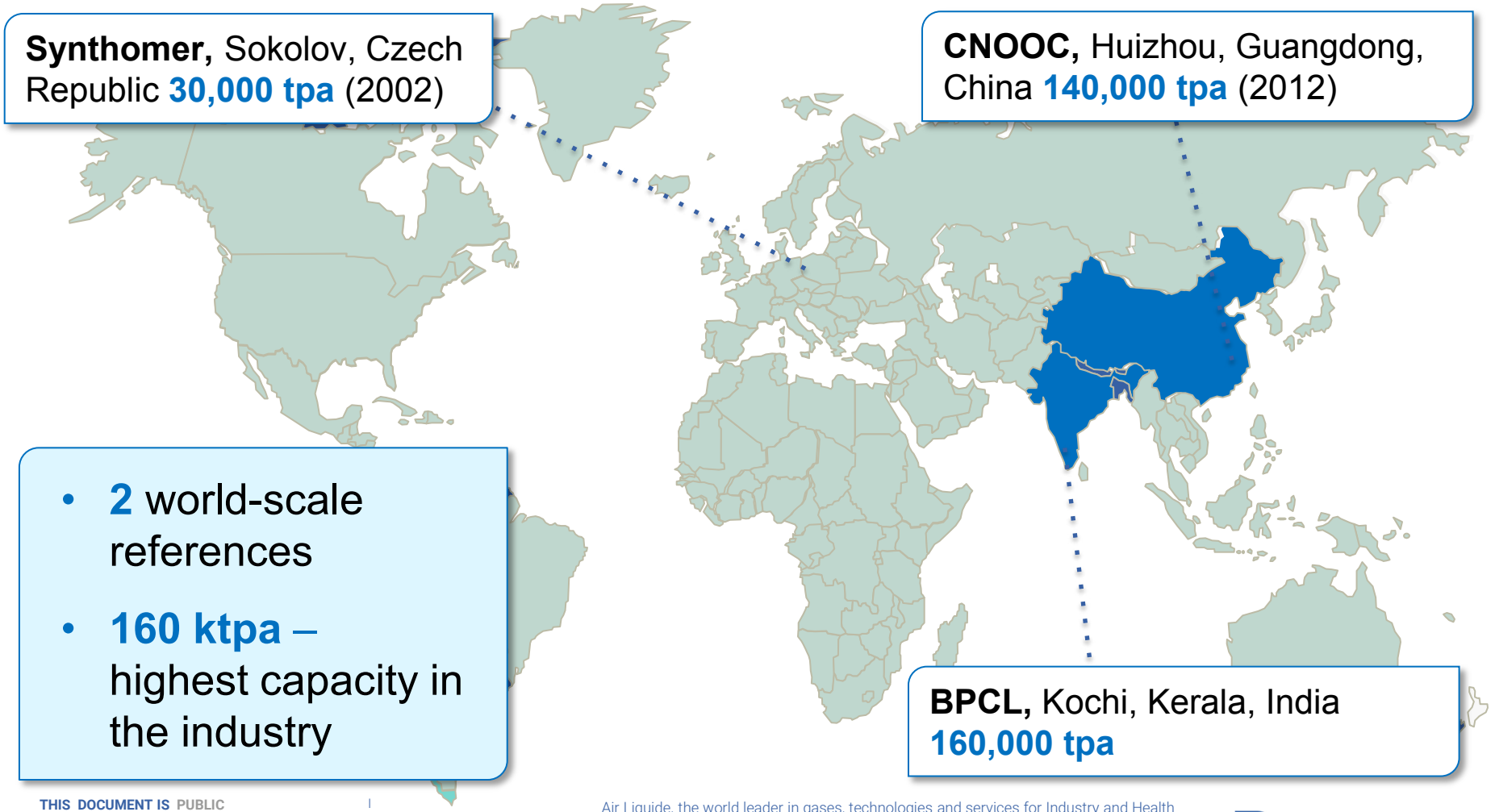


Market Shares



Straight licensing of Acrylic Acid technology

First Acrylic Acid production in India is based on our technology

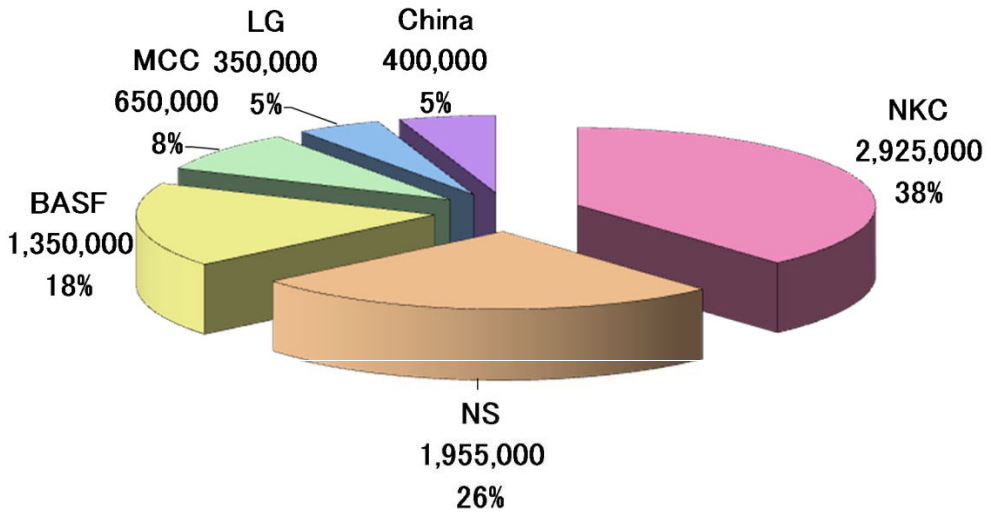


- **2** world-scale references
- **160 ktpa –** highest capacity in the industry

Market and Competition

- **High Performance Catalyst by Nippon Kayaku**
  - High selectivity
  - High Acrylic Acid yield / low Propylene consumption
  - Long term stability
  - Fast catalyst filling and catalyst exchange

- **Catalyst Map 2014**



Acylic Acid Technology Features

Superior Ester Grade AA Product Quality

Analysis	EAA typical	CAA (by others)	
Acrylic Acid	99.5 – 99.7	99.5	wt. %
Color	< 10	< 100	APHA
Water	< 0.1	< 0.15	wt. %
MeHQ	180 - 220		wt. ppm
Acrylic Acid Dimer	0.10 – 0.15		wt. %
Maleic Anhydrid / Acid	0.05 – 0.15		wt. %
Propionic Acid	< 0.05	< 0.05	wt. %
Acetic Acid	< 0.1	< 0.2	wt. %

Typical Raw Material Requirement

Specific consumption per ton of EAA

Propylene Consumption (typical SOR)	**691**	**kg**
Propylene Consumption (av. in 3 years)	**699**	**kg**

Costs

- Low CAPEX
  - Economy of Scale by 160,000 t/y Single Train Capacity
  - Smaller Reactors due to NK Catalyst Performance
  - Internal Thermoplate Heat Exchangers
  - Optimized Plot Space Requirement

- Low OPEX
  - Low Raw Material Consumption due to high Selectivity of Catalyst
  - Low Energy Consumption due to optimised Energy Integration
  - High On-Stream Efficiency due to optimised Process (e.g. Baffle Trays and Internal Heat Exchangers)

Experiences / References - Start up of CNOOC Plant

- First reference for a complete AA unit based on Combined Technology at world scale capacity went into commercial production

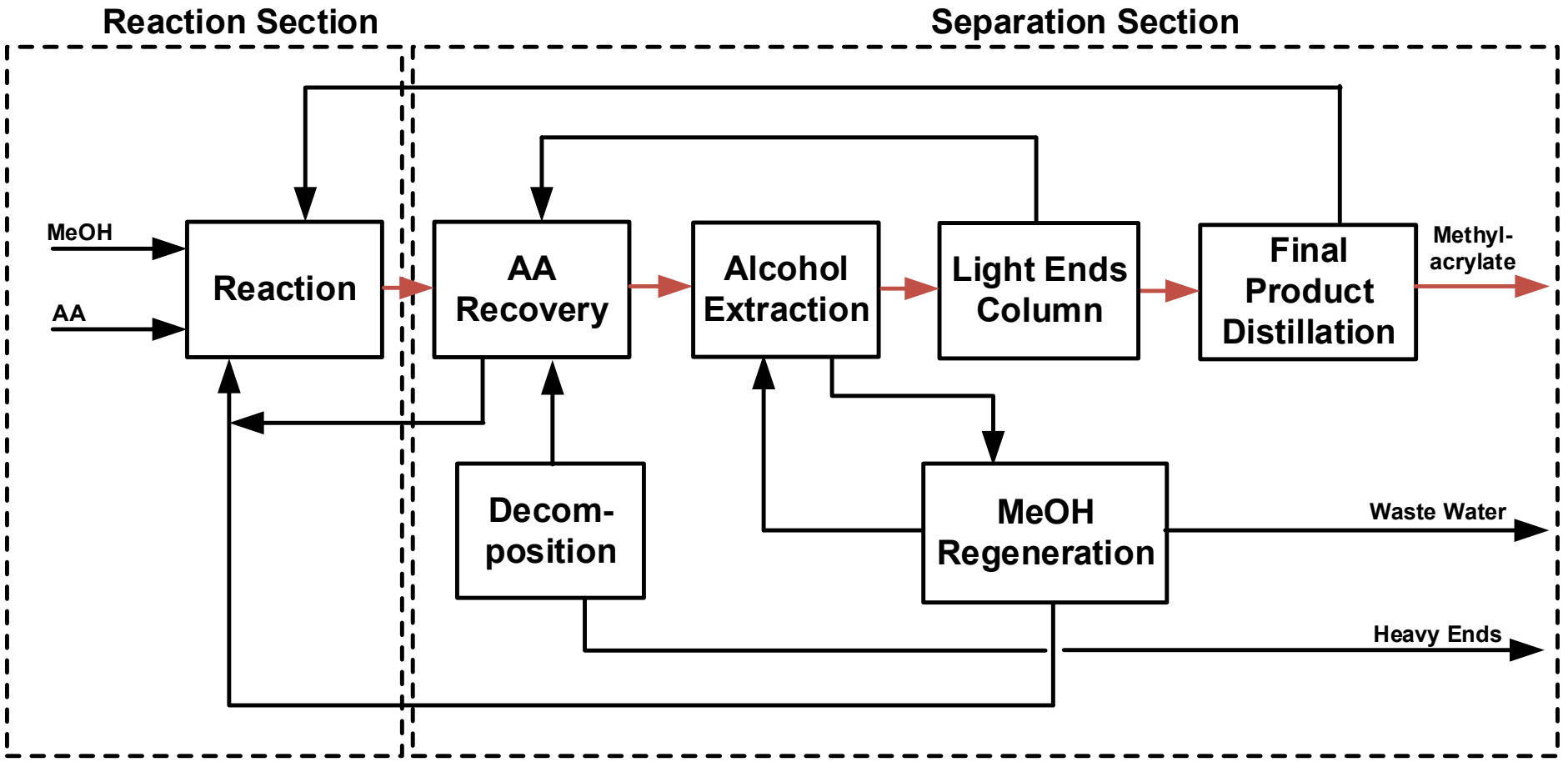
- Capacity: 140,000 t/a, plus 10 % add-on capacity
- Feedstock: Polymer Grade Propylene (99,6 wt-% purity)
- First propylene feed September 14, 2012
- 100% capacity February 18, 2013
- Performance Test: March 14 – 17, 2013
- Location: Huizhou, Guangdong Province, PR China

Wrap-up : AL E&C - The Technology Partner of Choice

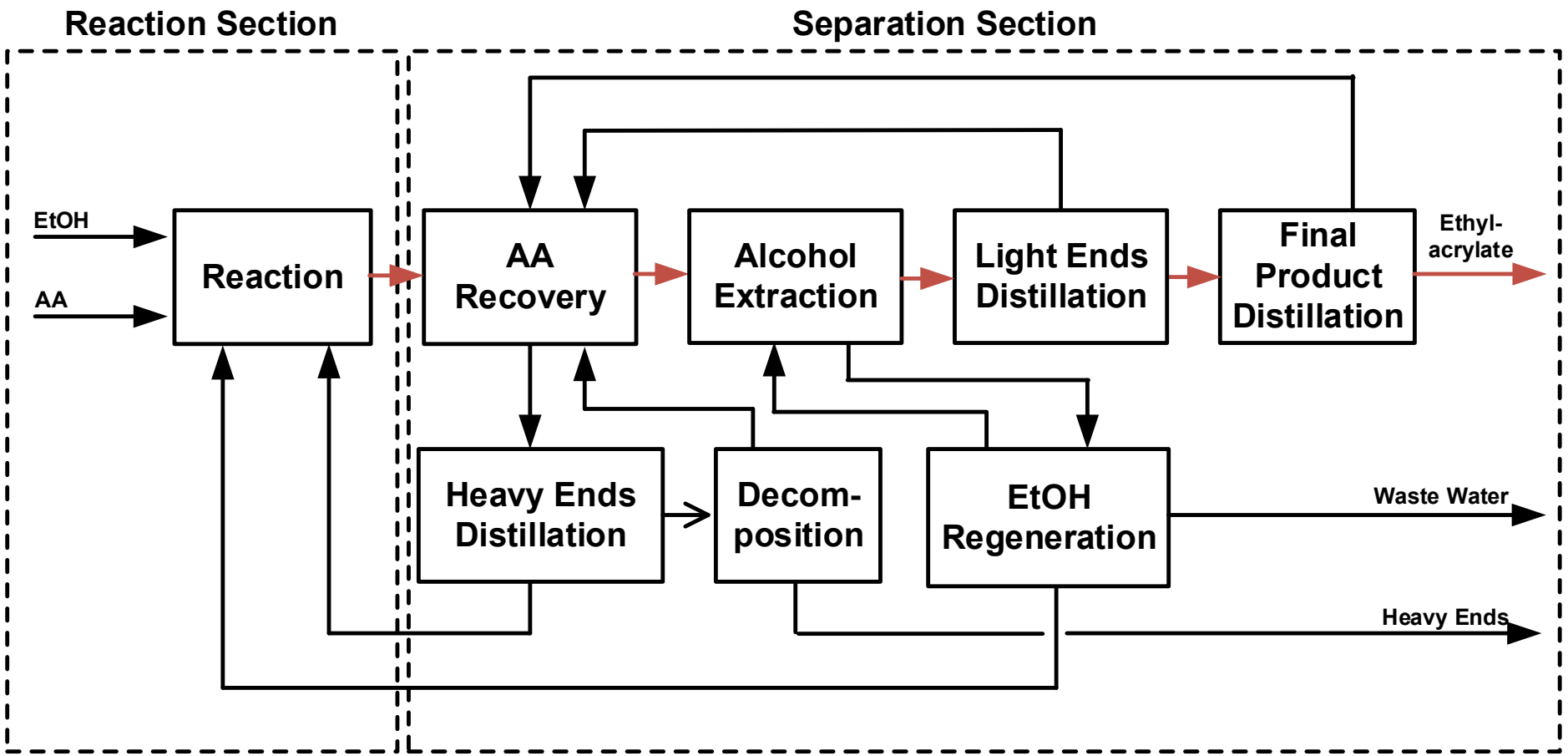
- Reactor Design in Cooperation with a renowned Manufacturer
- Single train capacity up to 160 ktpa
  - Lowest CAPEX
- Safety Standards for HC Oxidation fully mastered
- Highest performance catalyst on the Market
  - Lowest OPEX
  - Feedstock: Refinery Grade Propylene (> 80 wt.%)
- Technological Features to prevent Polymerization
  - Internal Thermoplate Heat Exchangers
  - Use of Baffle Trays in Columns
- Minimum Health & Environmental Impact
  - Non-toxic Extraction Solvent
  - Minimized Waste Generation

Hexion
Acrylates Technology

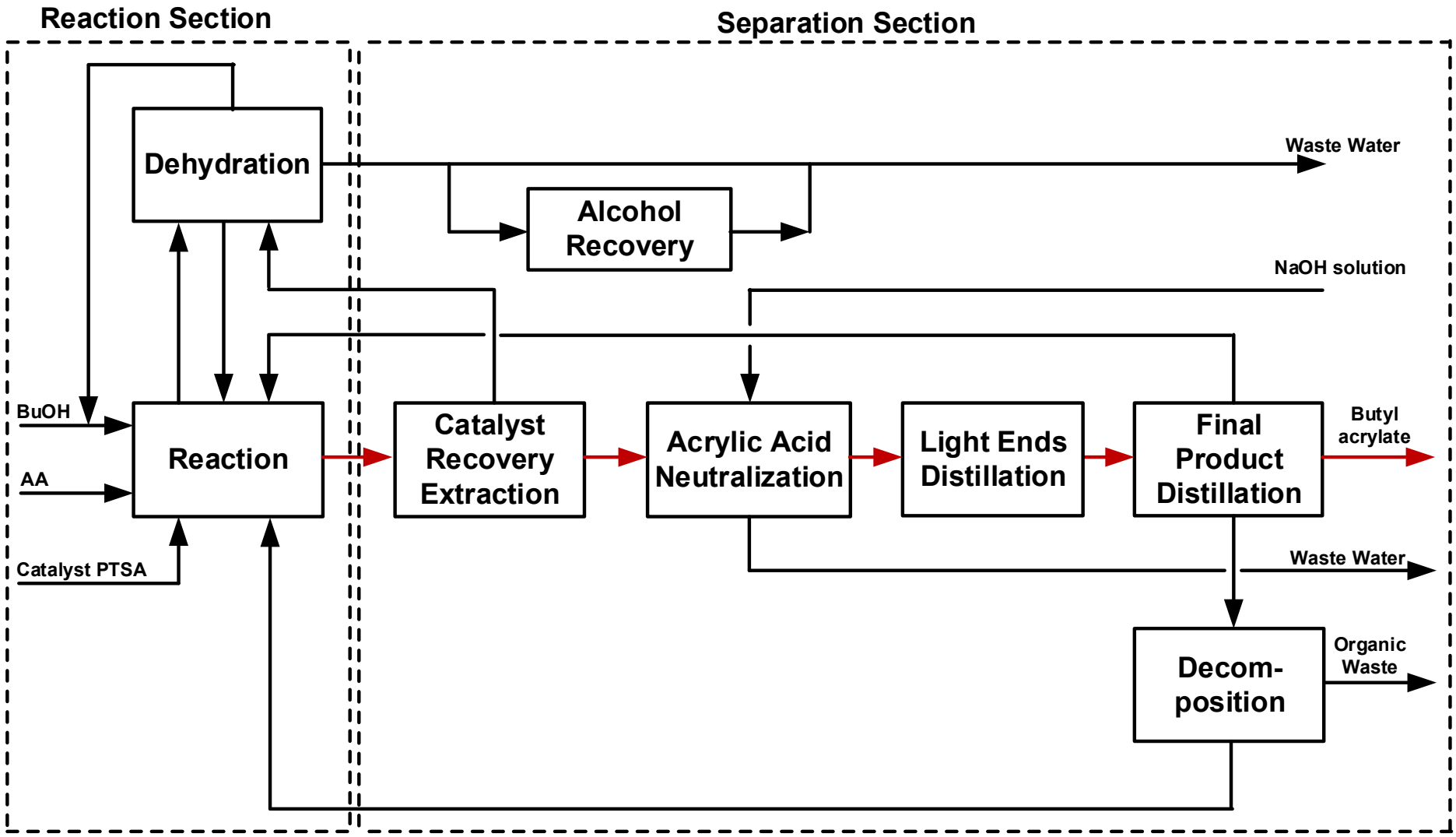
Methyl-Acrylate - Block Flow Diagram



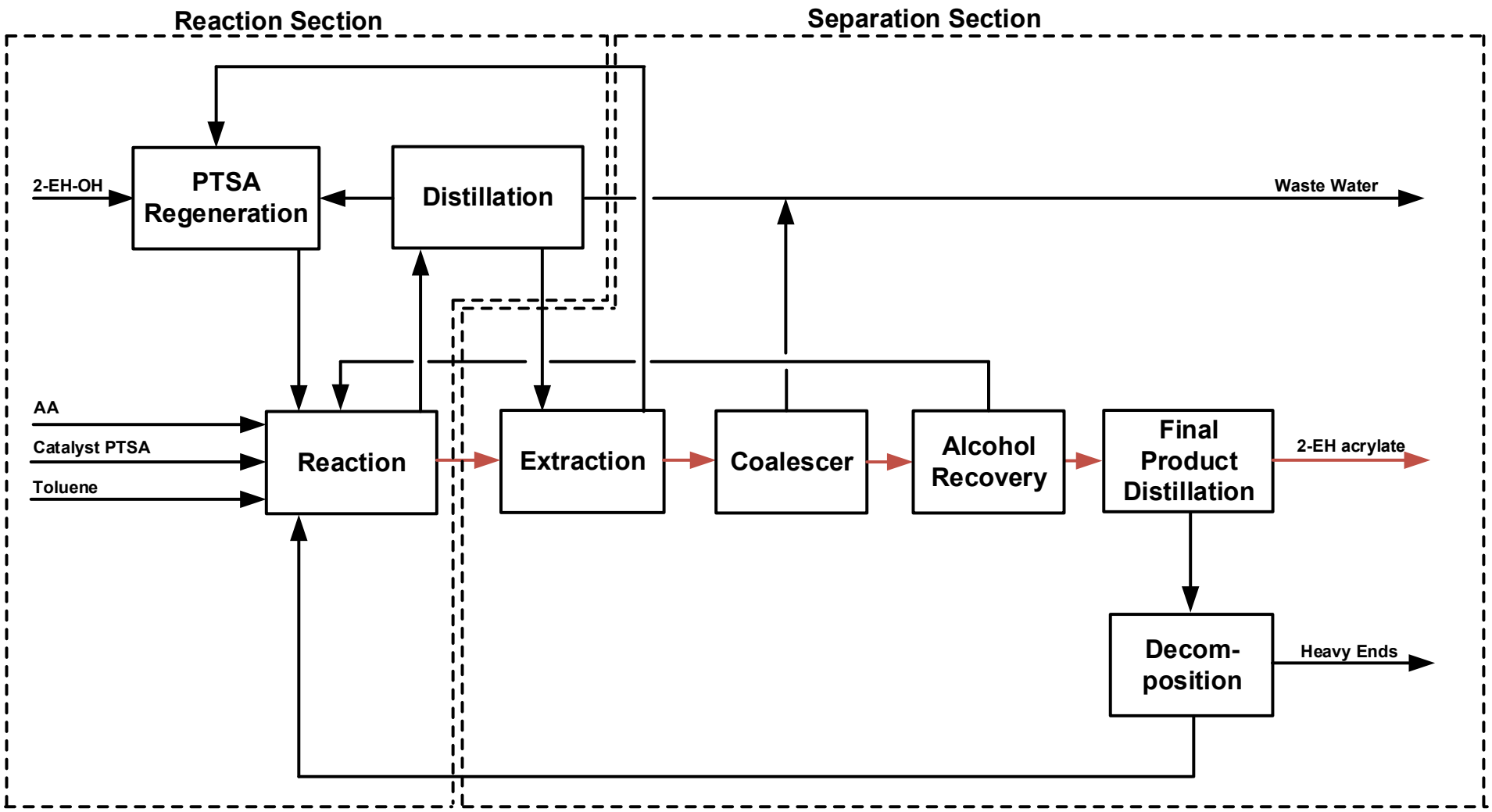
Ethyl-Acrylate - Block Flow Diagram



Butyl-Acrylate - Block Flow Diagram



2-EH-Acrylate - Block Flow Diagram



Light Acrylates

- Catalyst:
  - Ion exchanger
  - fixed bed catalyst, one stage for EA, two stages for MA
- Lifetime:
  - around 5 years
  - per 1 t/hr of product 7 m^3 of ion exchanger needed

Heavy Acrylates

- Catalyst:
  - Para toluene sulphonic acid (PTSA)
  - solid material, continuous addition to process dissolved in alcohol

- Consumption:
  - 1.2 kg/t of BA
  - 0.73 kg/t of 2-EHA

Wrap-up : Synthomer Acrylates Process Features

- Very high process reliability – more than 1 year operation without interruption due to optimized inhibition system, reliable equipment selection
- Excellent consumption of raw materials (alcohols, acrylic acid) due to optimized feed ratios
- Improved water/oil separation
- Very high recovery of liquid catalyst (PTSA) in heavy esters production by separate recycling column
- Long life of solid catalyst for light esters production
- Technology integrated vacuum system with minimized waste water generation
- Advanced propionates decomposition system
- Optimized utility consumption

Thank you

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