



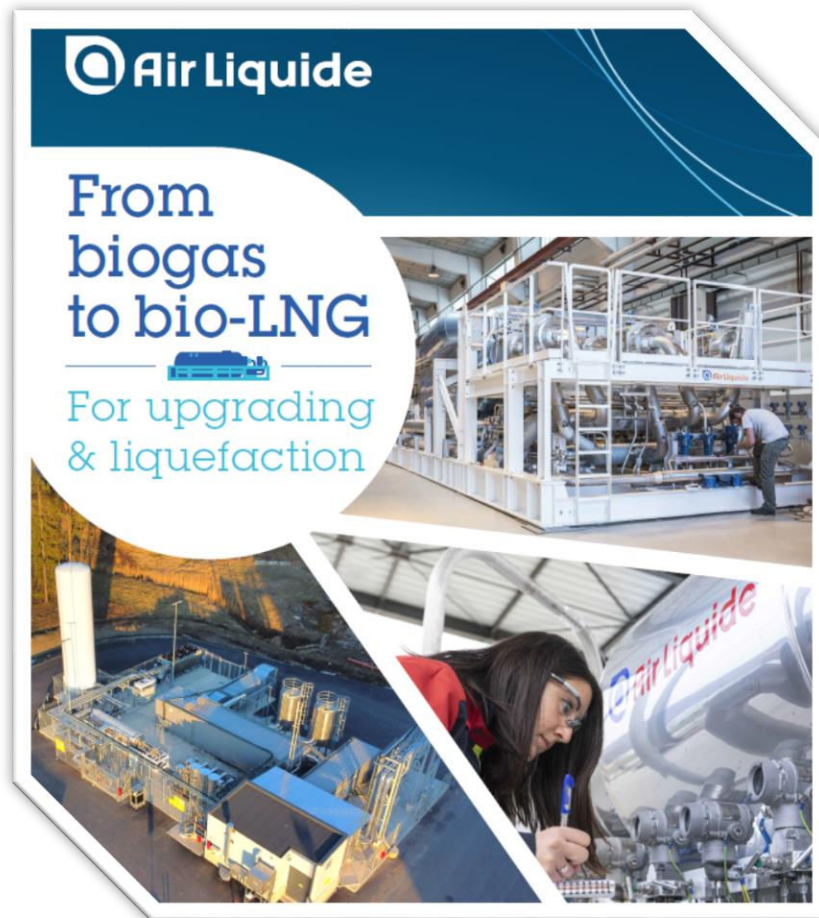
Air Liquide Advanced
Technologies (AL-aT)

***ssLNG (bioLNG) last
development in Europe.***



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Sept 2021 – Weimar, Germany

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Opening new business frontiers

GLOBAL MARKETS
& TECHNOLOGIES

From the sources to the market:



Biogas



Landfill gas



Pipeline gas



Flare gas



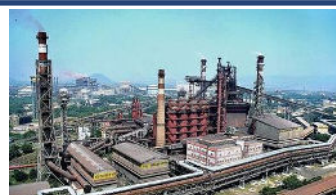
Boil off gas



HDVs



Maritime



Industry



Automotive

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ssLNG: facts and figures

Status	In operation					In construction		
Location	Lidköping, Sweden	Valle Tanaro, Italy	Turku, Finland	KIMM, Korea	Nymölla, Sweden	GREVE, Norway	Güstrow, Germany	Södertörn, Sweden
Delivery date:	Jan-10	Dec-20	Mar-20	Jun-21	Jul-21	Oct-21	Dec-22	April 23
Production rate	13 TPD	8 TPD	10 TPD	10 TPD	20 TPD	24 TPD	25 TPD	50 TPD
Energy produced	63 GWh/year	40 GWh/year	50 GWh/year		100 GWh/year	121 GWh/year	126 GWh/year	250 GWh/year
Feed gas	biomethane	biogas	biogas	methane	biogas	biomethane	biomethane & Nat gas	biomethane & Nat gas
Technology	Adsorption + BRAYTON	Adsorption + LIN2LNG	Membranes + Adsorption + Turbo Brayton	Turbo Brayton	Membranes + Adsorption + Turbo Brayton	Adsorption + Turbo Brayton	Adsorption + Turbo Brayton	Amine + Turbo Brayton
Scope AL	EP - polishing, liquefaction, commissioning	EP - upgrading, polishing, liquefaction storage commissioning	EPC - upgrading, polishing, liquefaction, storage, offloading	EP - liquefaction, commissioning	EPC - upgrading, polishing, liquefaction, storage, offloading	EPC - compression, polishing, liquefaction	EP - polishing, liquefaction	EPC - compression, polishing, liquefaction
Performance								

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LNG Technologies.....Small to Large

Air Liquide's Proprietary Liquefaction Technologies



LIN to LNG
< 10 TPD
6,000 GPD

TBL
10 TPD /
6,000 GPD

TBL
20 TPD /
12,000 GPD

TBL
50 to 60 TPD /
30,000 GPD

TBL
70 to 100 TPD /
60,000 GPD

Turbofin
90-400 TPD to
60k to 250k GPD

Smartfin
400 to 5,700 TPD
300k to 3,500k GPD

Liquefin
> 5,700 TPD
> 3,500k GPD

Turbo-Brayton Cryogenic Systems

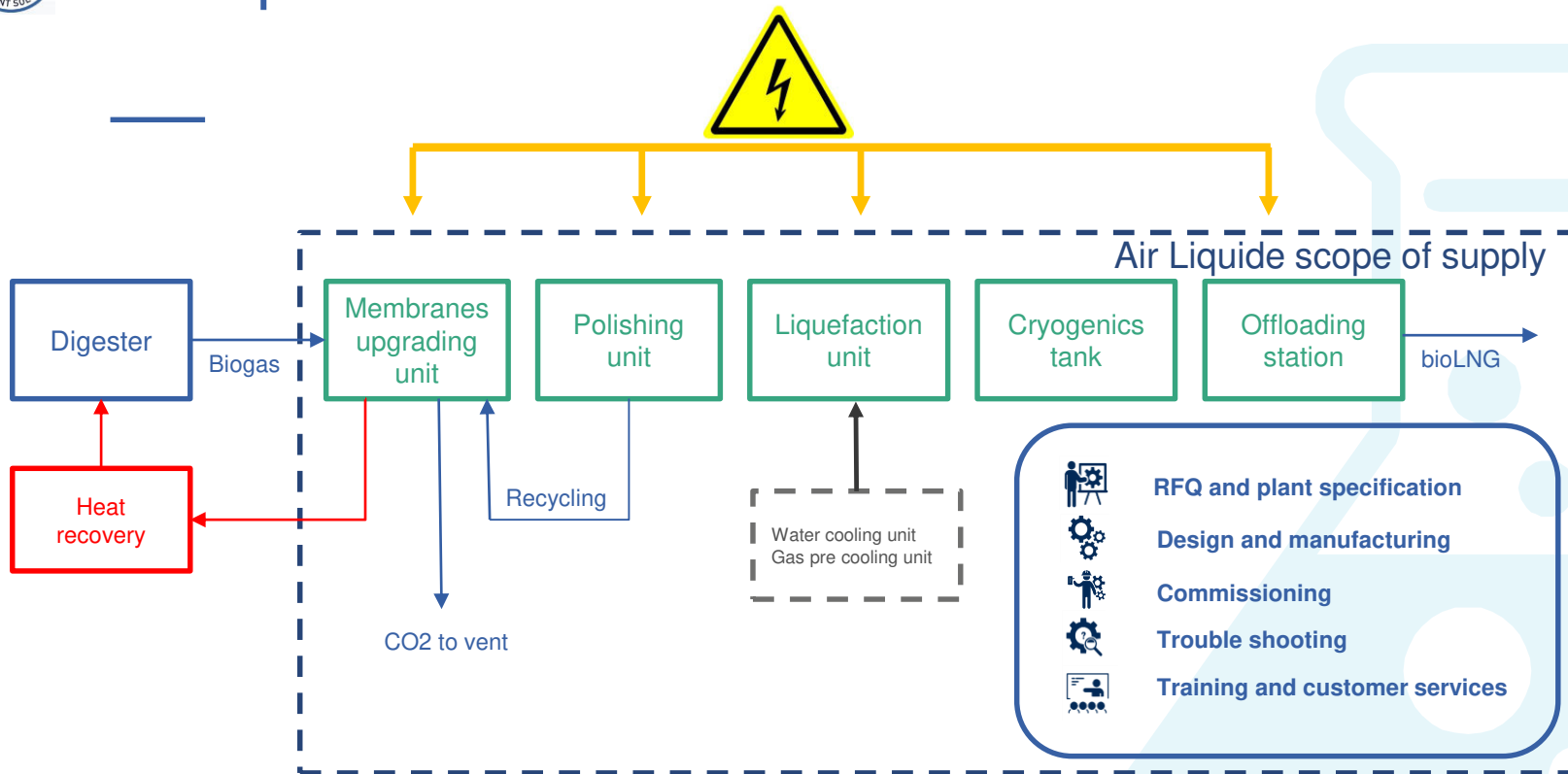
∞ Turbofin™

∞ Smartfin™

∞ Liquefin™

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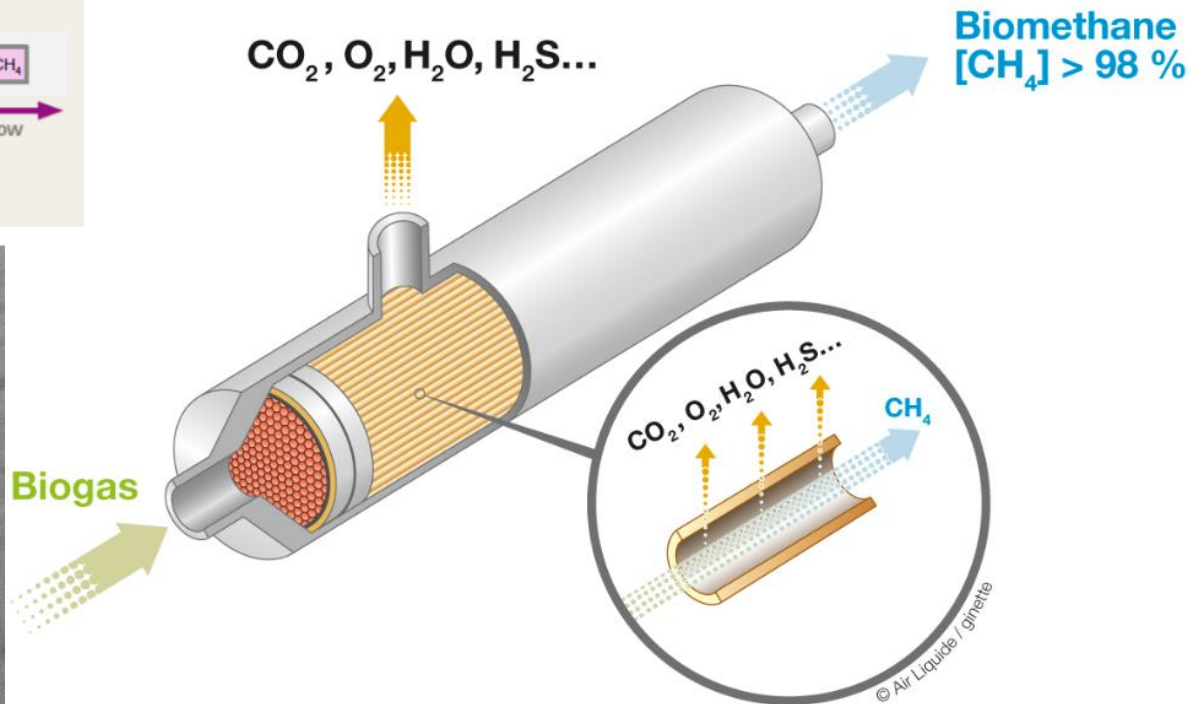
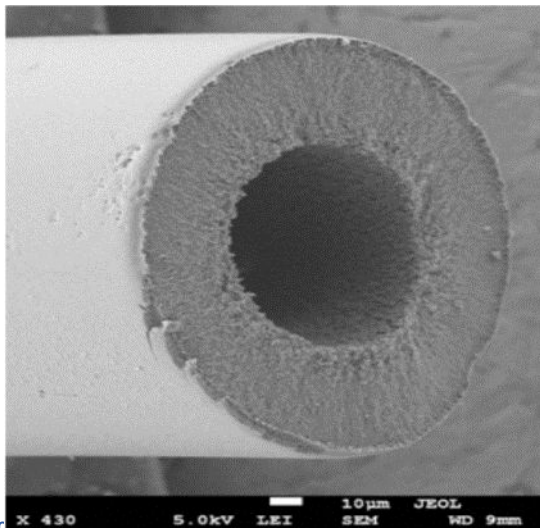
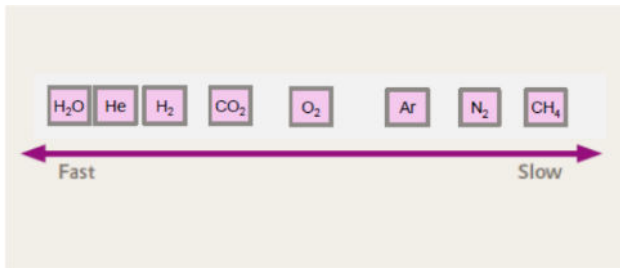
Air Liquide solution



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Air Liquide membrane: the key component



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CO₂ polishing with PTSA:



- Inlet gas: bio methane with ~2% CO₂ from 10 to 20 bar
- Outlet gas: bio methane with CO₂ < 50 ppm
- Off gas: ~10% of inlet flowrate to be recycled.
- Push Pull operation:
- 1 vessel in adsorption phase
 - 1 in regeneration phase
 - 1 in standby phase

CO₂ polishing with Amines



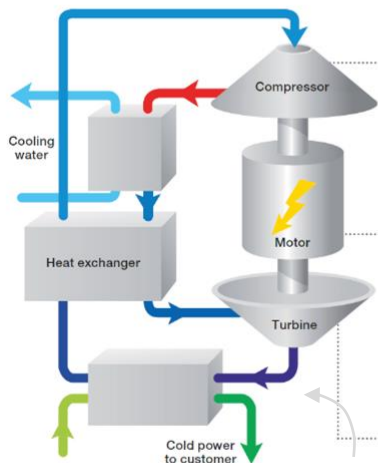
- Inlet gas: bio methane with ~5 % or more
- Outlet gas: bio methane with CO₂ < 50 ppm
- Suitable for large scale > 25 TPD
- Heat recovery

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Turbo-Brayton Overview

Air Liquide's innovative reverse Turbo-Brayton process essential innovation concerns the assembly of all active elements on a single shaft.



1 Centrifugal compressor



- High efficiency
- Oil-free

2 High-speed synchronous motor and active magnetic bearings



- Direct drive
- No gear box
- High compacity
- Contact free
- Unsurpassed lifetime

3 Centripetal expander



- More than 50 years experience in the design and manufacture of expanders
- High efficiency

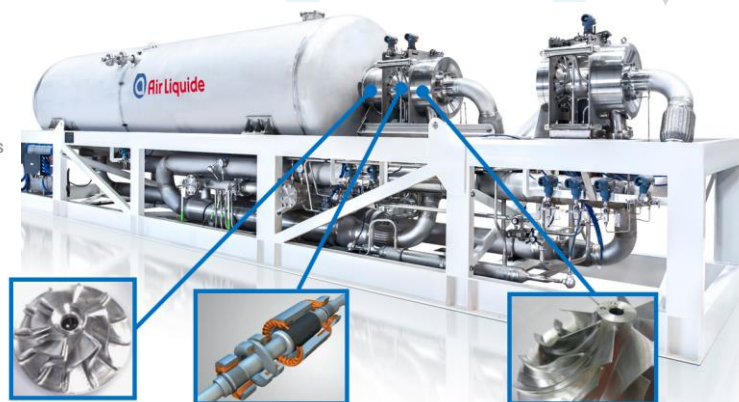
Safe
Technology
using inert
refrigerant

Fully Sealed
No Refrigerant
Losses

Easy
Operation
Fully
automatic

Maintenance
free for
5 years

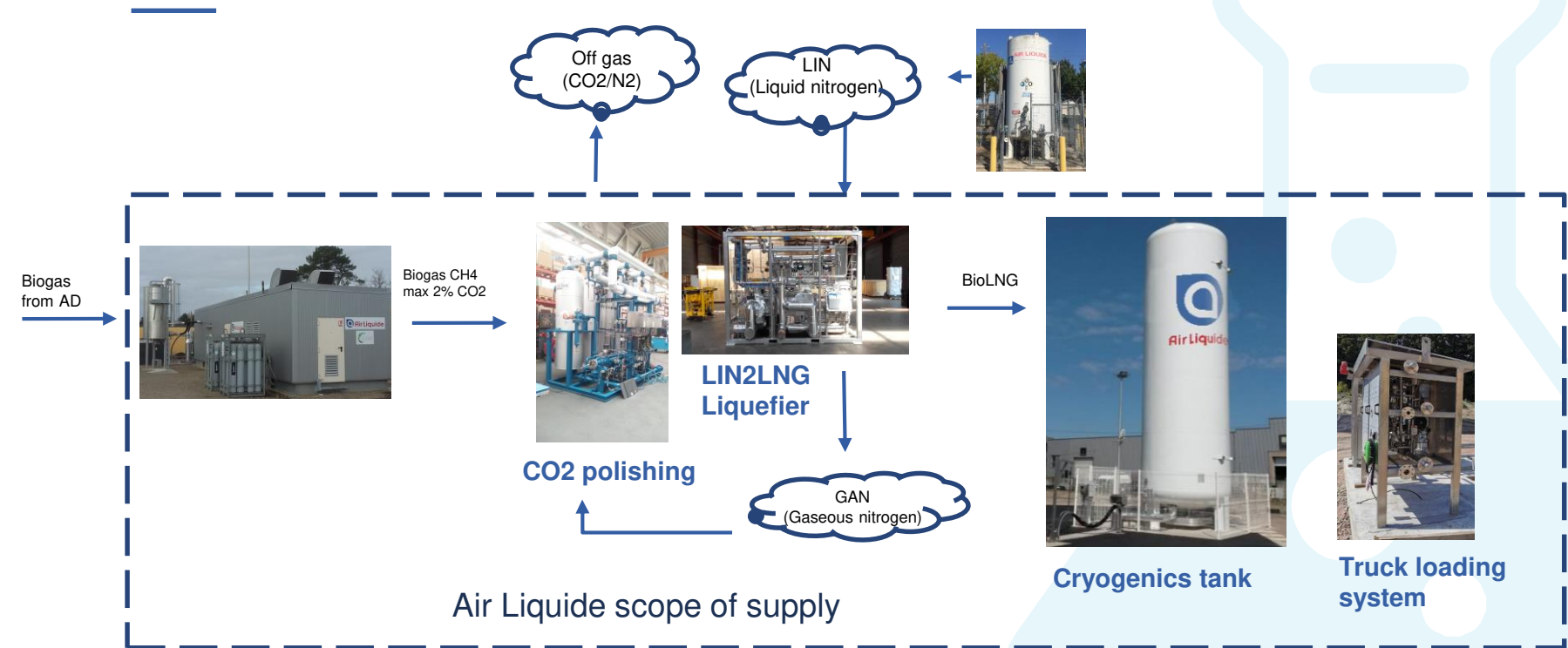
Plug and Play,
Compact



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Small scale < 8 TPD bioLNG plant (~40 GWh/year)



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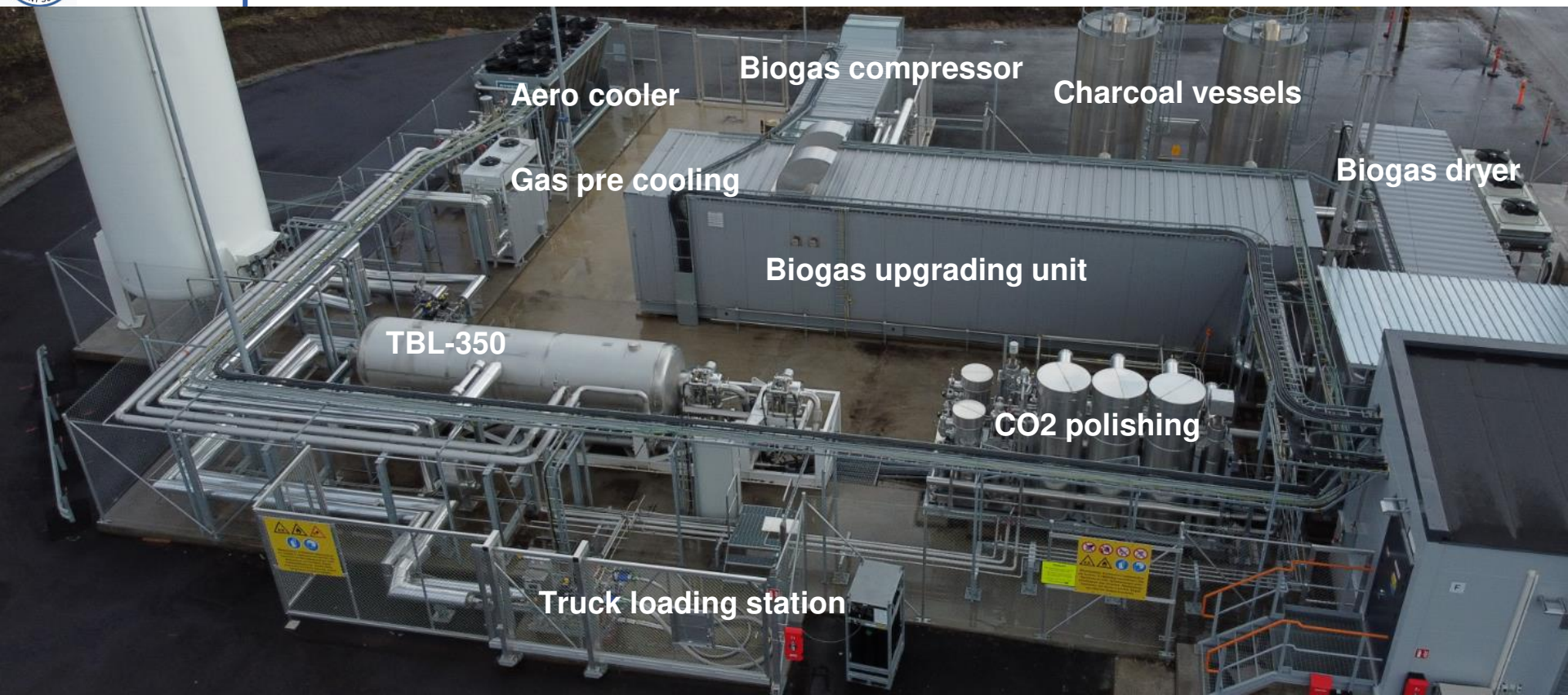
Bird view of Topinoja, Turku Finland 10 TPD



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Compact and skid mounted solution:



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Nymölla paper mill plant in Sweden (off design 20 TPD)



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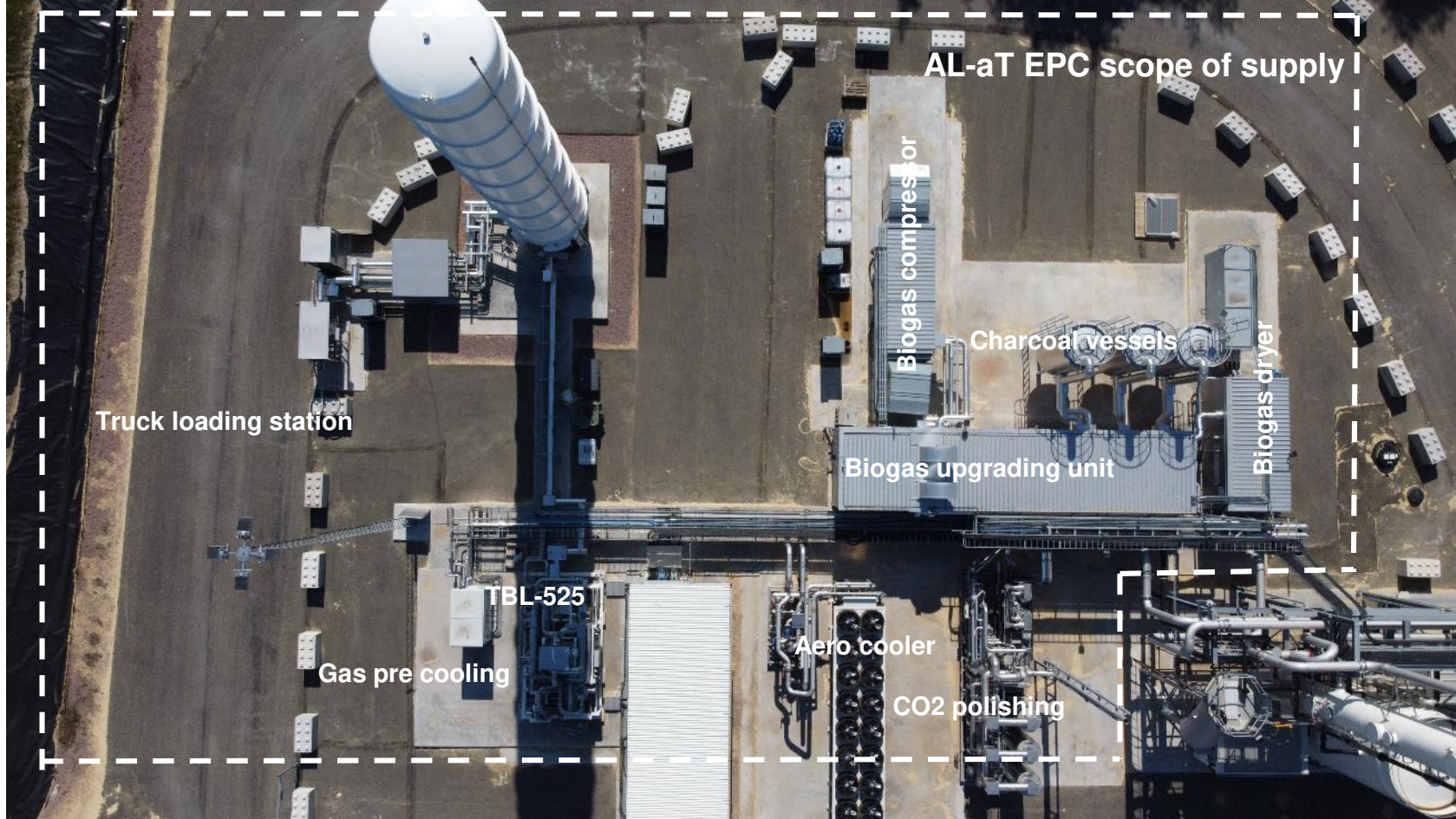
TBL-525/700 up to 25 TPD liquefaction rate (~130 GWh/y)



Onsite work at Stora Enso's Nymölla paper mill in Sweden.

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Easy handling



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TBF-1800 at test facility prior to shipment



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GM&T presentation

Opening new business frontiers

The Turbo Brayton, up to 50/100 tpd (~500 GWh/year)



TBL-350,
10 TPD

TBL-525,
20 TPD

TBL-700,
25 TPD

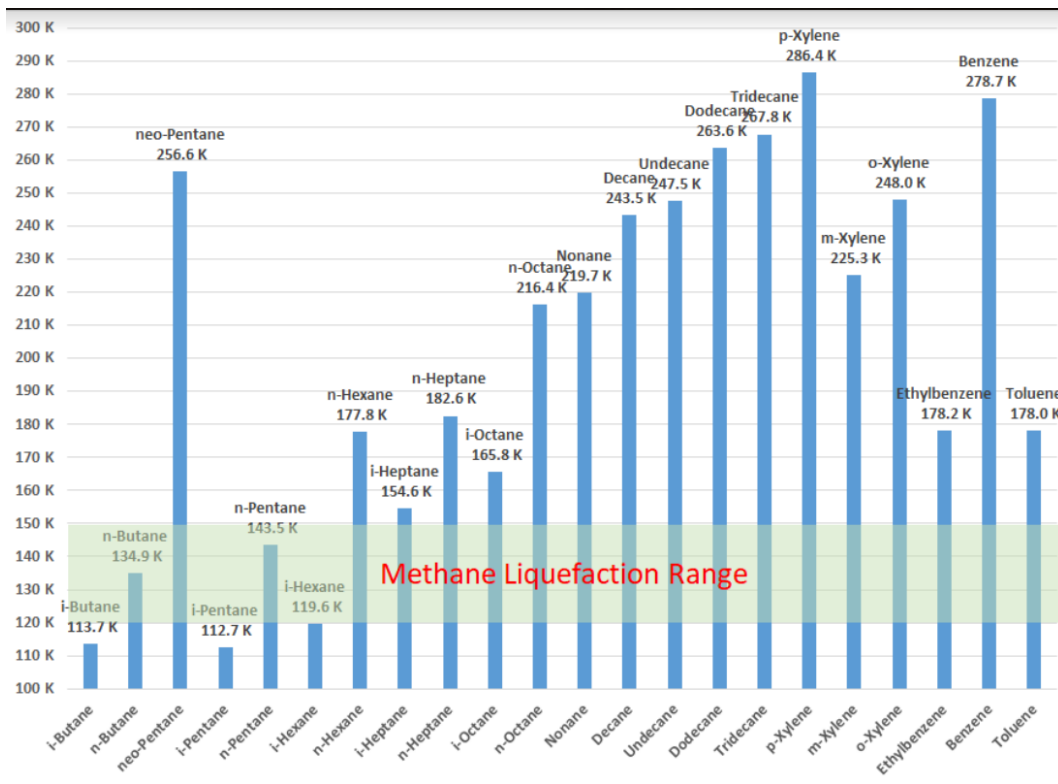
TBL-1800,
50 TPD

TBL-XXL,
100 TPD

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Technical challenge of HHC & Hg removal into the Nat Gas



The Heavy C6+ component, such as Benzene, Xylene will freeze at low temperature leading to heat exchanger **clogging**.

Mercury (Hg) leads to heat exchanger **corrosion**,

It is crucial to **totally** remove these components prior to liquefaction.

Series of ancillaries equipment:



Biogas upgrading
with membranes



CO2 polishing
with adsorption



Natural gas
cleaning
with amine



LNG cryogenics
tank

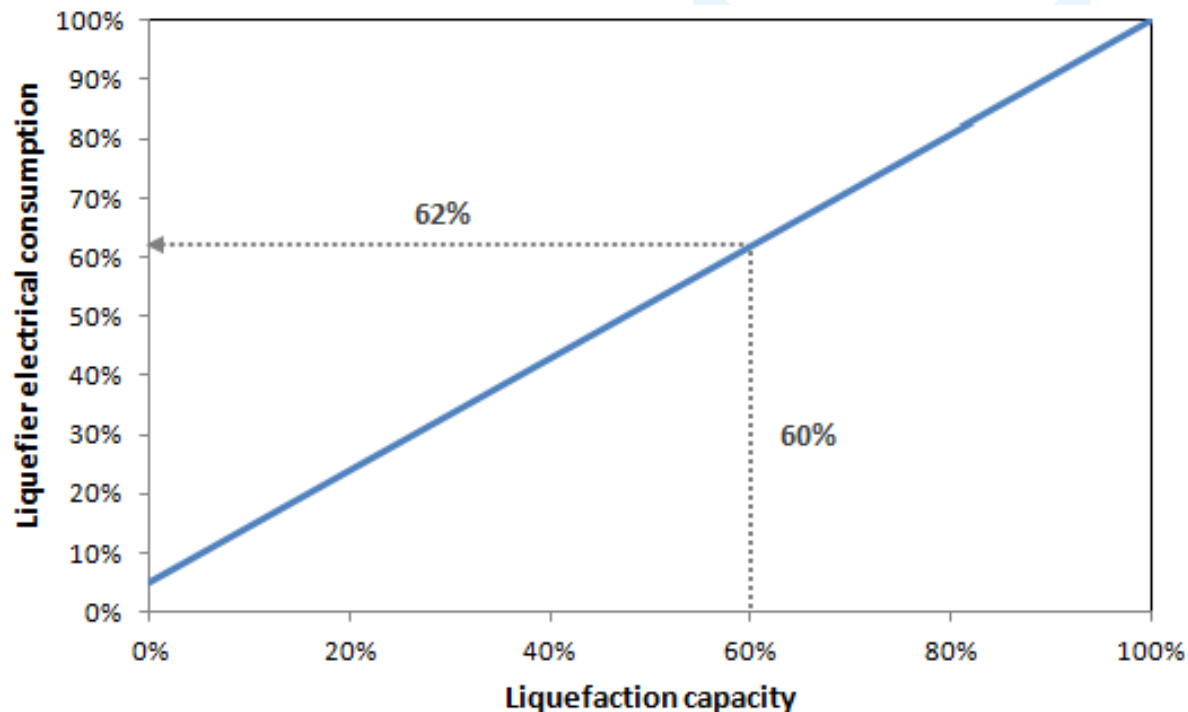


Truck loading
system

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Turbo-Brayton – Efficiency at Partial Flow Rates

- Electrical consumption is linear with liquefaction – **good for partial loading**
- At 60 % of nominal rate the overall efficiency decreases by **only 2 %**, achieved by varying the speed of the motor.
- **High turndown ratios** possible.



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Key benefits of the Turbo-Brayton liquefaction system

1. **Maintenance-free** for 5 years
2. **Low** electrical consumption and **high efficiency** on all operate range **from 0 to 100%** turn down
3. **Safe technology**: inert process gas, no refill of process gas required (no hydrocarbon mixture)
4. **Easy to operate** - Unmanned operation, fully automatic
5. Low installation cost and time: **plug and play**, compact (low footprint and weight)
6. Flash and boil off are avoided thanks to **methane sub cooling**,
7. **Utility-free**: no compressed air, no oil, no nitrogen
8. Cold power available instantaneously (**less than 5 min**) from stand-by mode



Thank you



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