

# Highly efficient and clean LNG plant concept

By: Dr. Heinz Bauer, Linde Engineering

Date: June 6<sup>th</sup>, 2012

Venue: Level 3 – Plenary Theatre



Patron



Host



Host Sponsor





**Plant Concept**

Maturing Phase

Performance Test

Outlook

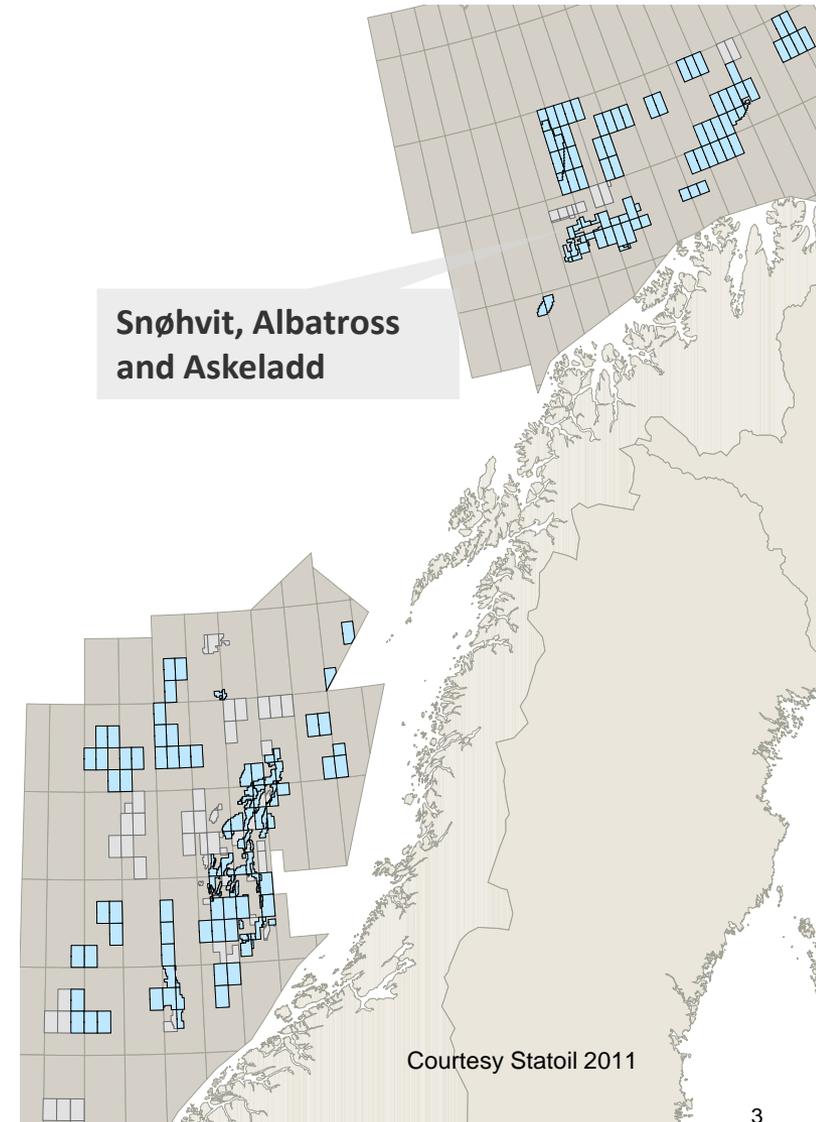
Conclusions

### Facts:

Discovered:	1981 – 84
Water depth:	250 – 340 m
Distance to shore:	143 km
Recoverable reserves:	193 GSm <sup>3</sup>
Condensate:	34 Mm <sup>3</sup>

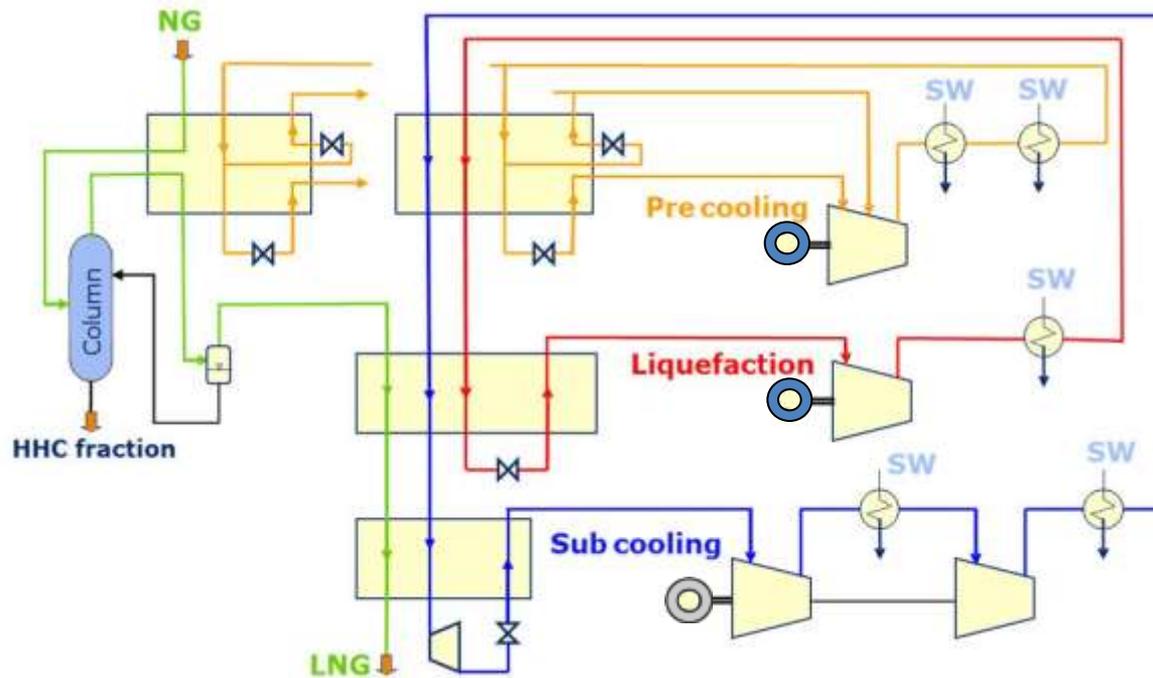
### Owners:

<b>Statoil ASA (Operator)</b>	<b>33.53%</b>
Petro AS	30.00%
Total E&P Norge AS	18.40%
GDF Suez Norge AS	12.00%
Hess Norge AS	3.26%
RWE Dea Norge AS	2.81%



- 1<sup>st</sup> world scale LNG plant for Statoil and Linde, joint development of a **proprietary liquefaction process (MFC<sup>®</sup>)** with immediate implementation
- 1<sup>st</sup> world scale **all electric drive system** of refrigerant cycle compressor
- **Full modularization** including large process module (22,000 t topsides weight)
- Inlet facilities designed for impact from **143 km multiphase subsea pipeline**
  
- Strong focus by Norwegian government on use of **best available techniques**
- Near island mode power plant with **highly efficient aero derivative GT's**, located all together on a process barge, resulting in **minimal CO<sub>2</sub> emission**
- 1<sup>st</sup> **CO<sub>2</sub> capture** from natural gas, clean-up, liquefaction and **sequestration**

### Mixed Fluid Cascade (MFC®) Process



Courtesy Statoil 2011

# Snøhvit LNG Plant



# Snøhvit LNG Plant



# Outline

Plant Concept



**Maturing Phase**

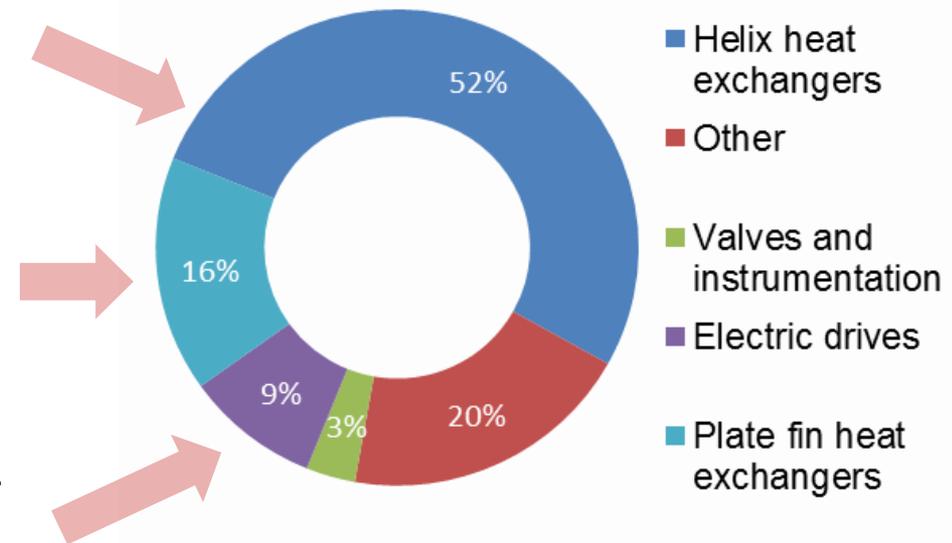
Performance Test

Outlook

Conclusions

- Novelty **heat exchangers** (HelixChanger®) for direct cooling of refrigerant against sea water **failed mechanically** causing lengthy shut-downs
- Multiple parallel **plate-fin heat exchangers** of pre-cooling section initially limited plant capacity
- Issues in the **electric system** (exciter machine, stator vibrations) reduced plant regularity

Distribution of downtime since start-up

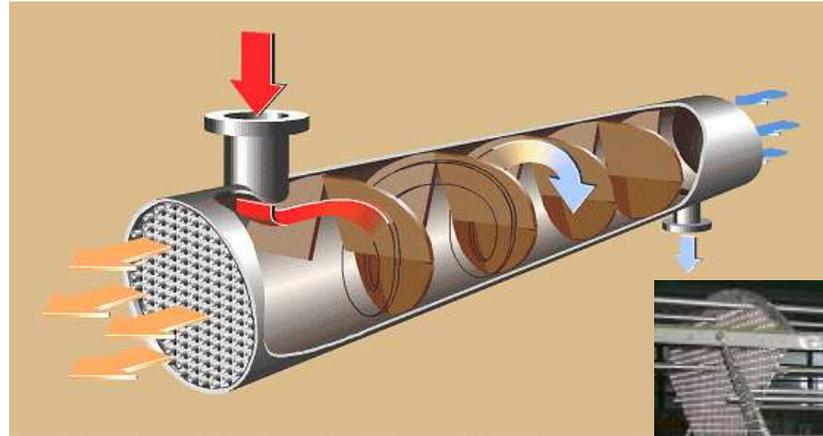
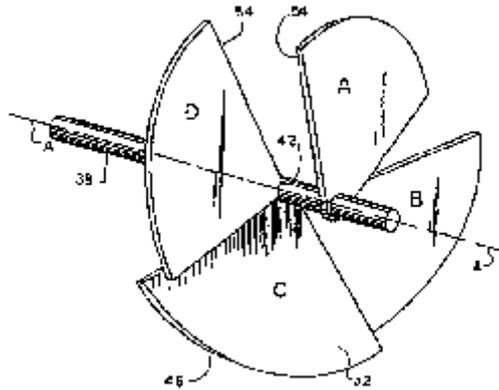


Courtesy Statoil 2011

# Plant Modifications

## HelixChangers®

US Patent 6,827,138



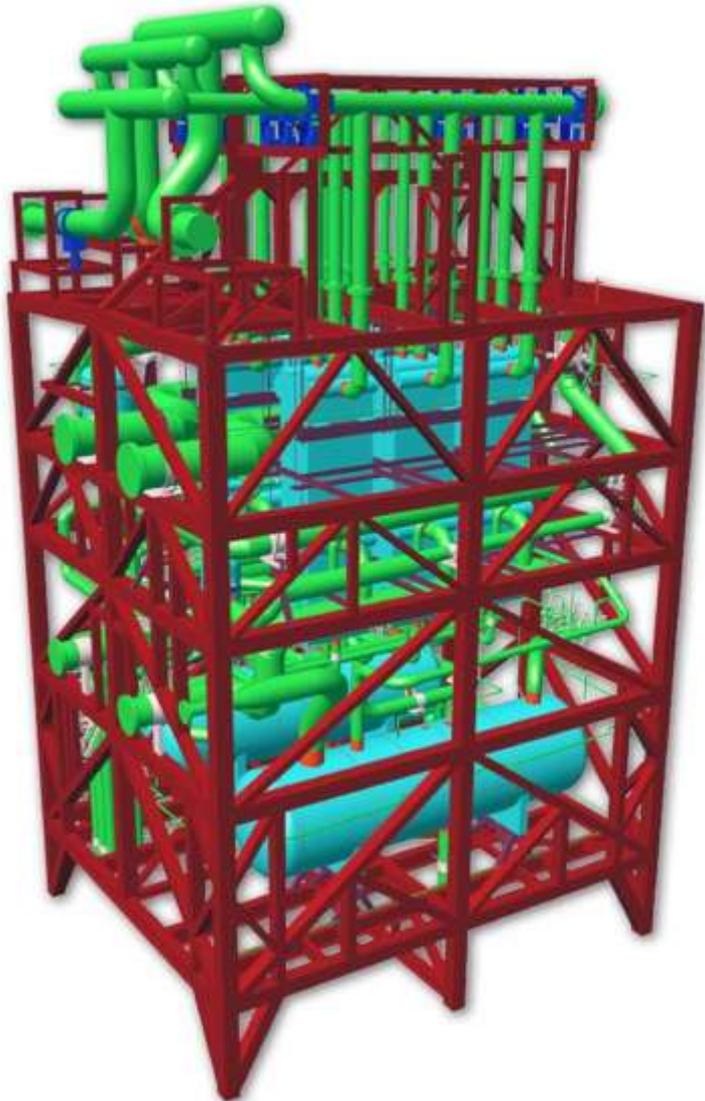
New MR Condenser



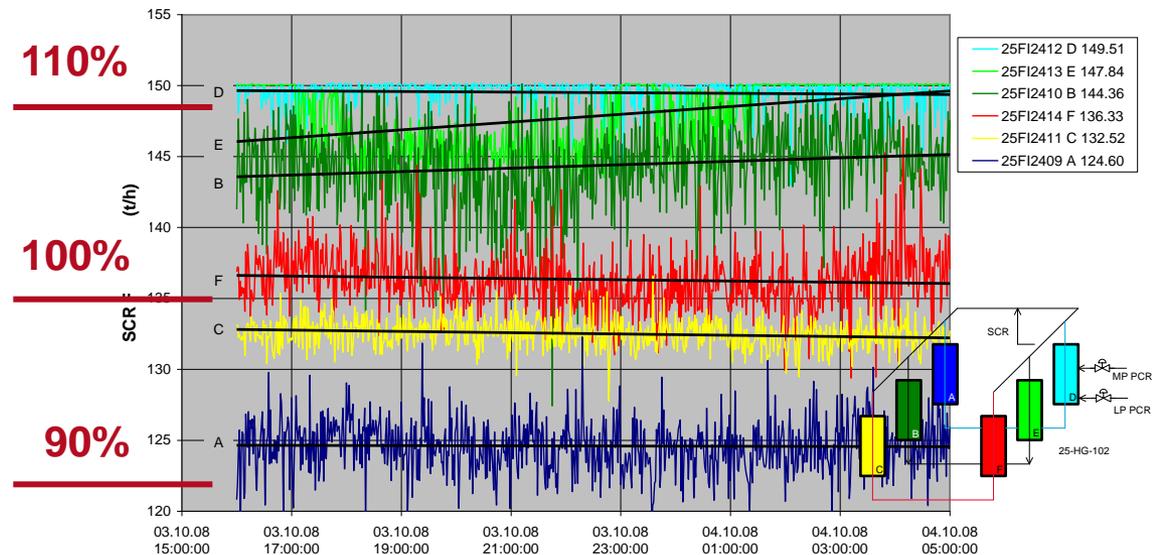
Failure mode was wear of the tubes against baffle plates caused by flow induced vibration

# Plant Modifications

## Brazed Aluminium Plate-Fin Heat Exchangers



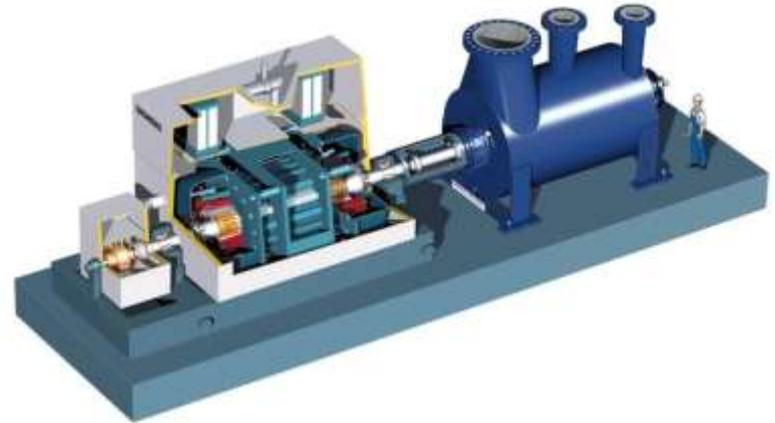
Flow mal-distribution and abnormal temperature profile caused by **contamination** with solid particles and by ambiguous **hydraulics**



# Plant Modifications

## Electric Drives

- **Exciter machines** had to be modified during RS2009 to avoid trip at high speed/high thermal load. No motor trip after stator exchange for sub-cooling cycle motor in RS2009. The Root Cause Analysis of VSDS motor stator failure has provided definite results
- Several measures were implemented into design of new upgraded VSDS motor stators. The experimental analyses at faulty and **upgraded stator** have confirmed that the countermeasures are qualified for long term reliable operation
- **Protection** against humidity and mechanical damaging was improved



# Outline

Plant Concept

Maturing Phase

 **Performance Test**

Outlook

Conclusions

## Results of the Performance Test

- The guaranteed plant **capacity** is exceeded by 4%
- The absolute production quantity is **550 t/h of LNG** (rising in tank)
- All guaranteed product **qualities** are fulfilled
- The specific refrigeration **power consumption** is 5.4% lower than guaranteed
- The achieved level of **243 kWh/t<sub>LNG</sub>** refers to a shrinkage of about **5.5 wt%**
- The specific **CO<sub>2</sub> emission** of the plant is **0.20 tons of CO<sub>2</sub> per ton of LNG**
- All **N<sub>2</sub>** from the feed stock is released to atmosphere with **<100 mol-ppm CH<sub>4</sub>**
- The guaranteed **levels of noise** are met
- The guaranteed **NO<sub>x</sub> levels** in the gas turbine exhaust gas are met

# Outline

Plant Concept

Maturing Phase

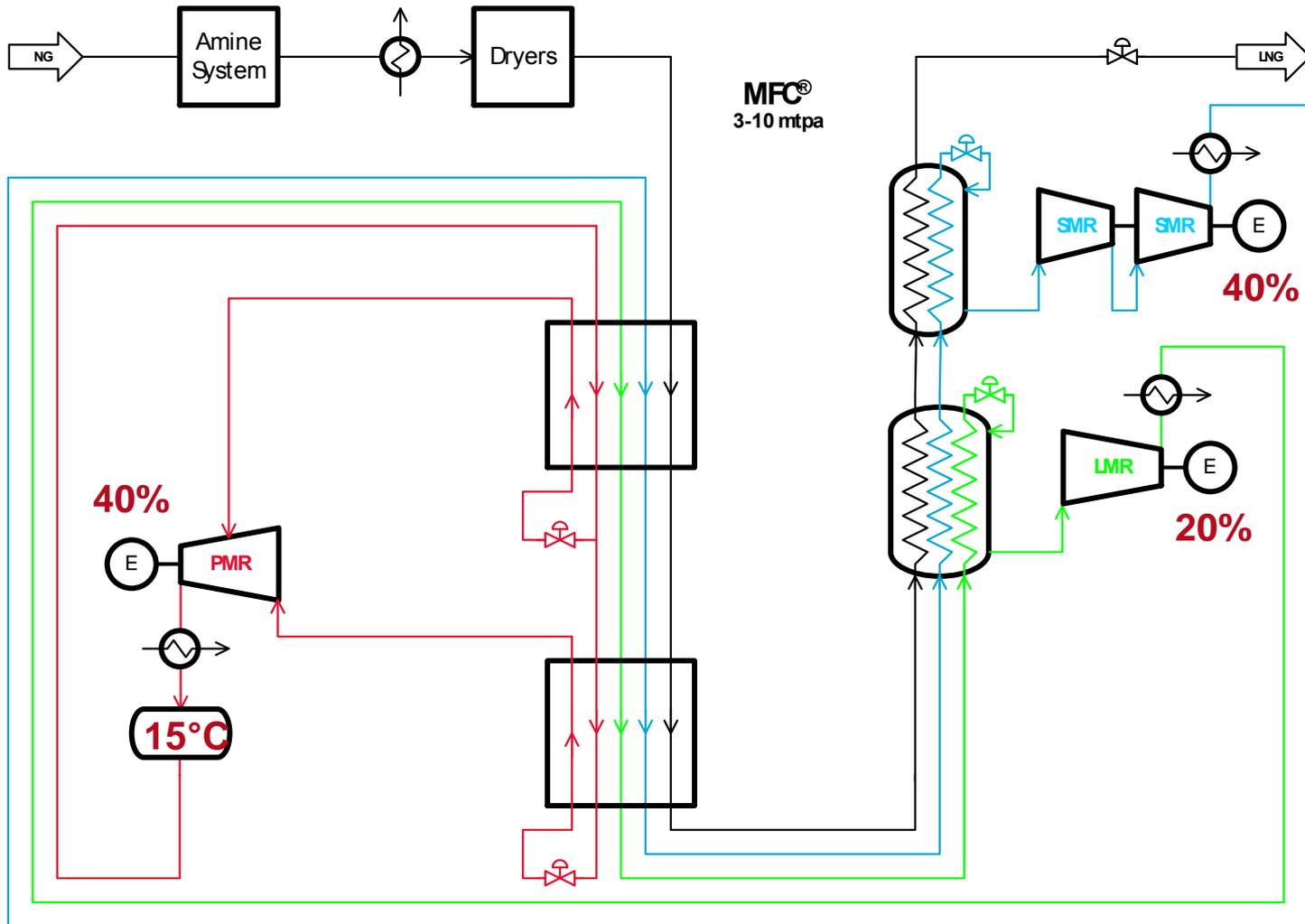
Performance Test



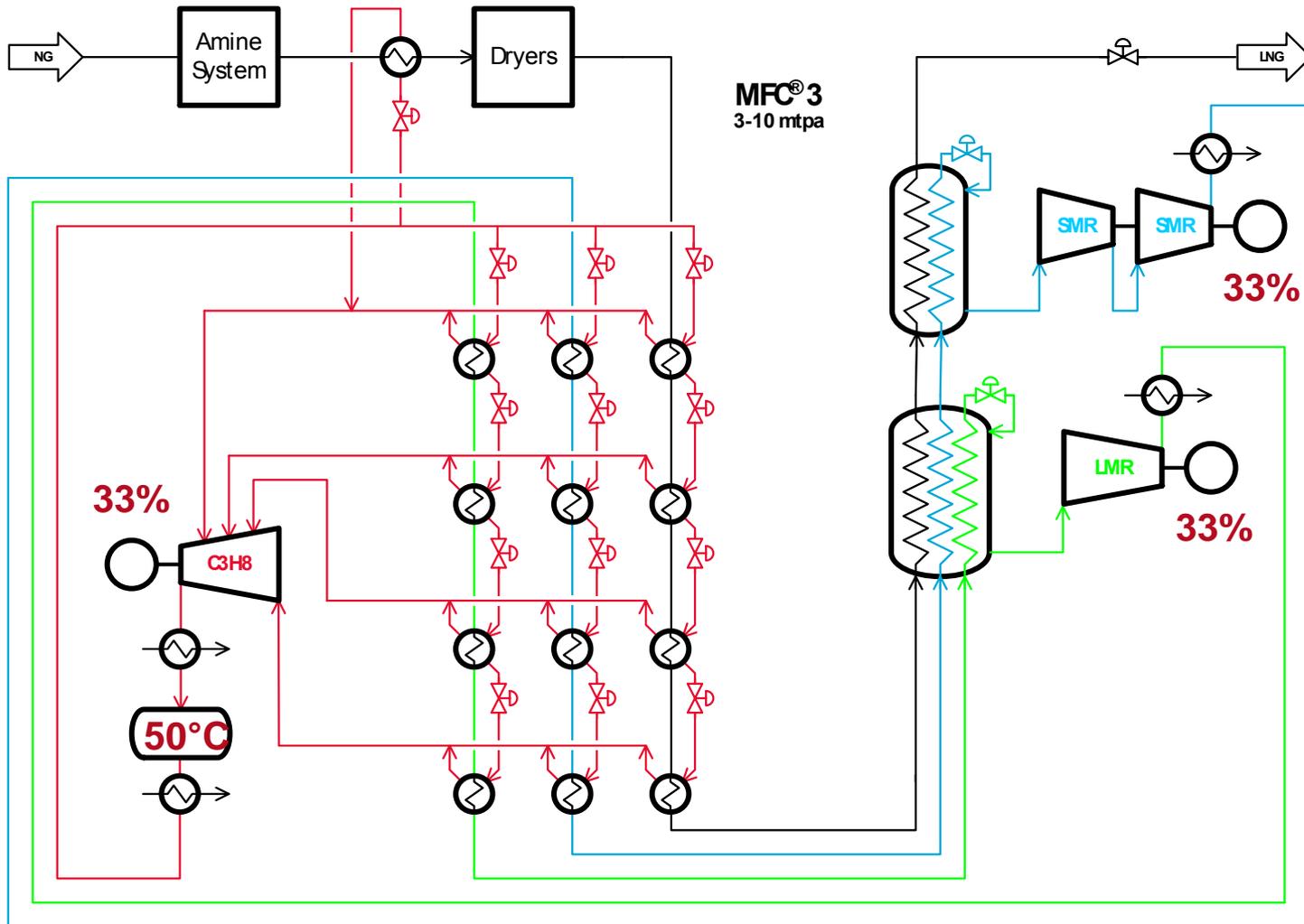
**Outlook**

Conclusions

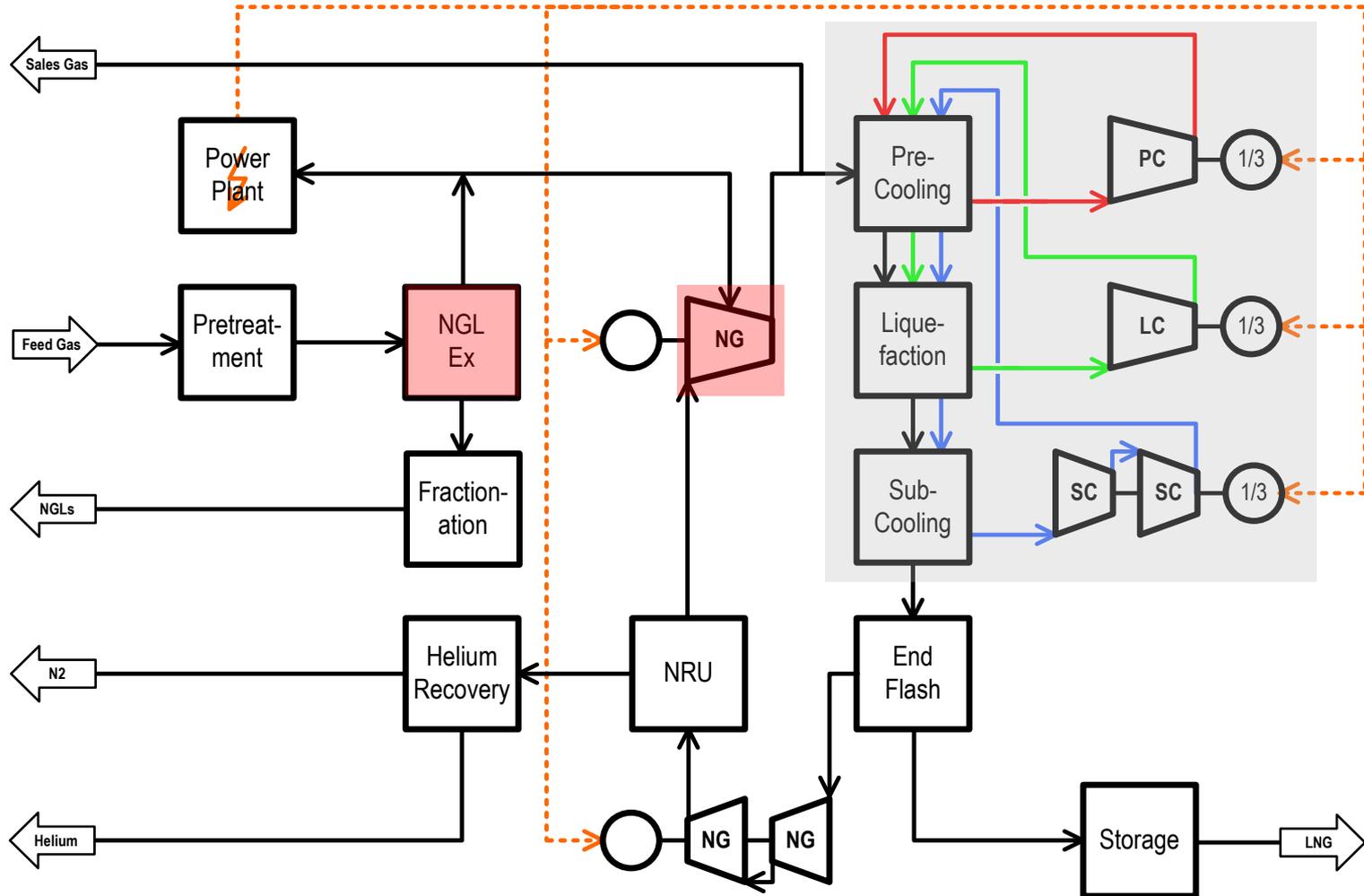
# Arctic Concept



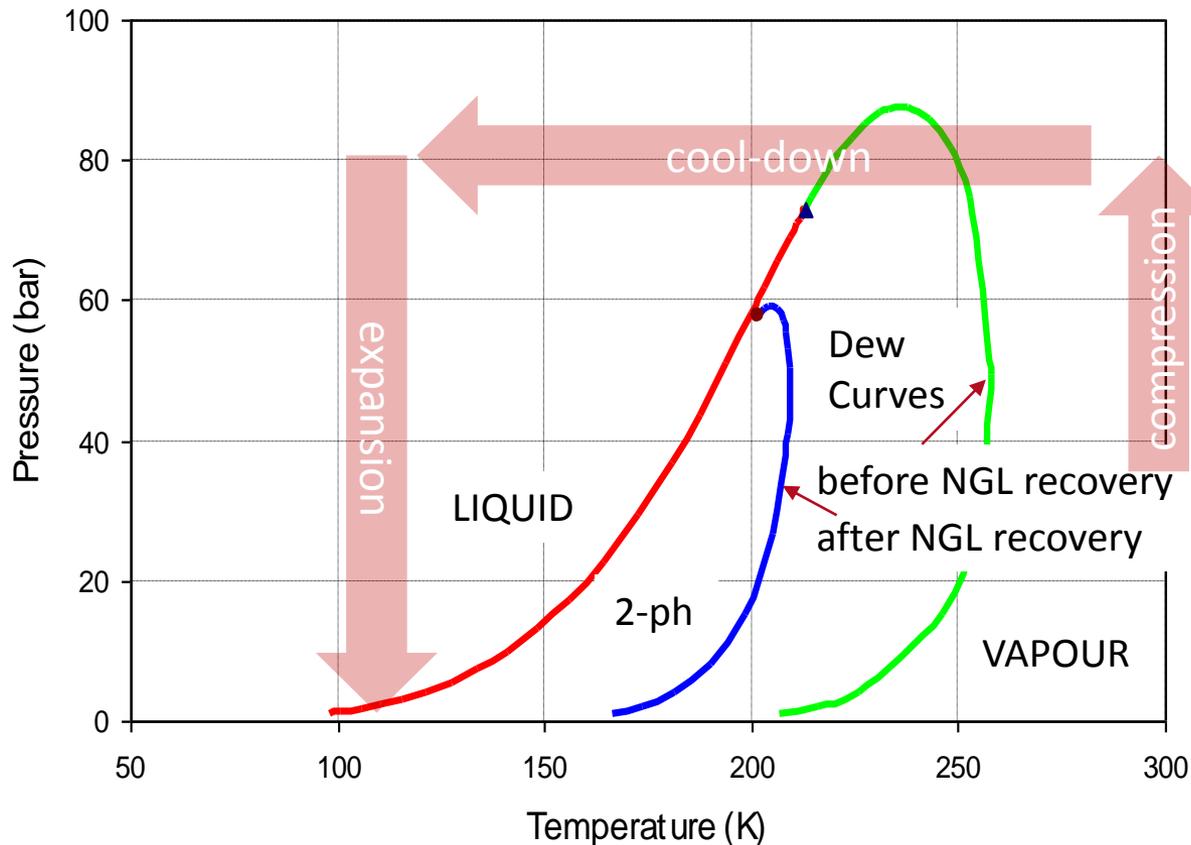
# Subtropical/Tropical Concept



# Overall MFC<sup>®</sup>3 Concept



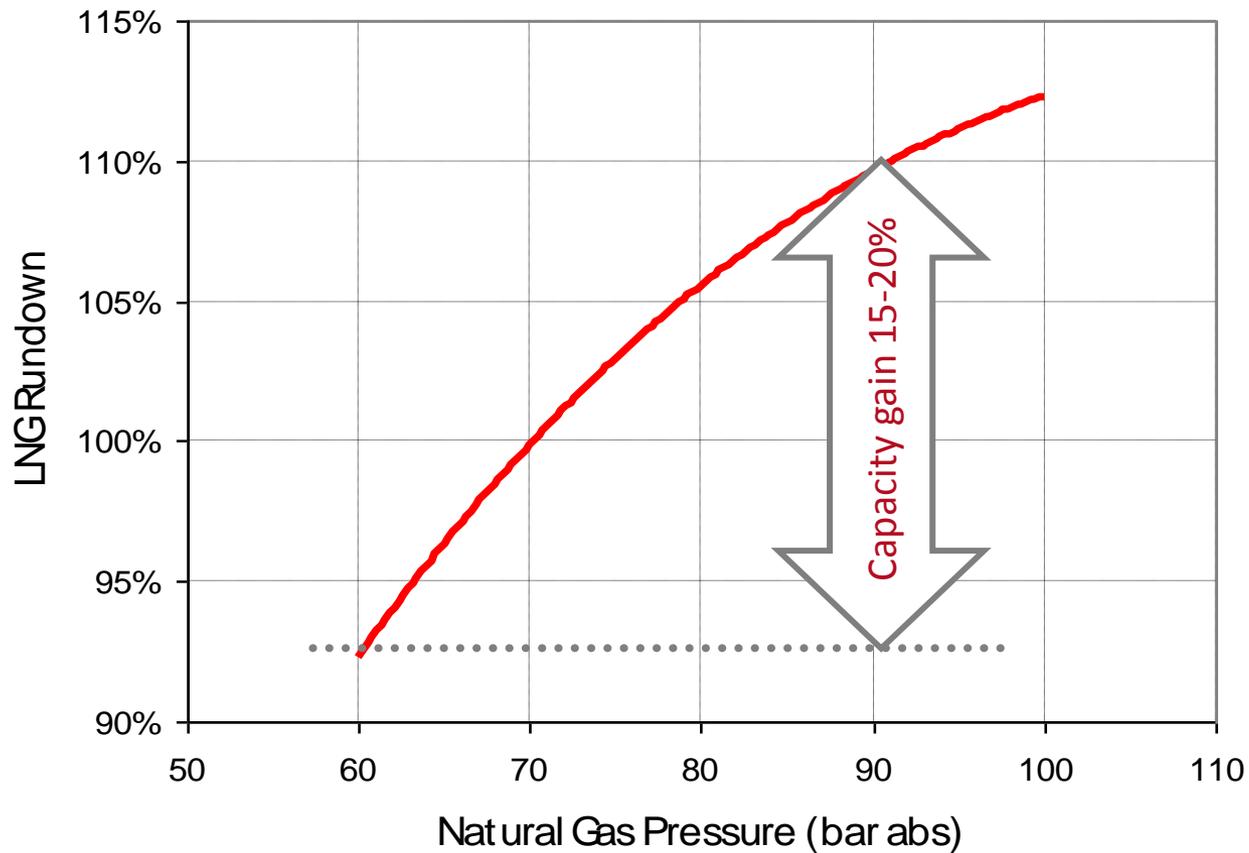
# NGL Extraction upstream Liquefaction



NGL extraction upstream of liquefaction avoids two-phase problems

Refrigeration cycle power is not used for NGL extraction  
capacity gain up to 10%

# Lean Gas Compression



Compression of lean natural gas increases plant capacity for given main compressors

# Evolution of the MFC<sup>®</sup> Concept

## CHALLENGES

- Subtropical/tropical climate
- Condensation at +50°C
- Capacity > 5 mtpa

## ANSWERS

- Symmetric compressor size with 3x70 MW compensates ambient temperature
- NGL extraction upstream adds about 10% capacity
- Liquefaction pressure of about 90 bar adds about 15-20% capacity
- **Realistic capacity is about 5.5 mtpa** for a single train all electric concept

# Outline

Plant Concept

Maturing Phase

Performance Test

Outlook

 **Conclusions**

- The **MFC process** has been proven **successfully** in Hammerfest
- Teething **problems** are understood and have been **overcome**
- A **migration** of the concept towards a warm/hot climate has been **completed**
  
- Single train capacities are available with
  - > **5 mtpa** using all electric drives (e.g. Siemens 70 MW motors)
  - > **10 mtpa** using gas turbine drives (e.g. Frame 9)

Thank you  
for your attention.

THE LINDE GROUP

*Linde*