RISC

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# LNG – What's all the fuss about?

August 2018

# Content

A Quick Global Overview

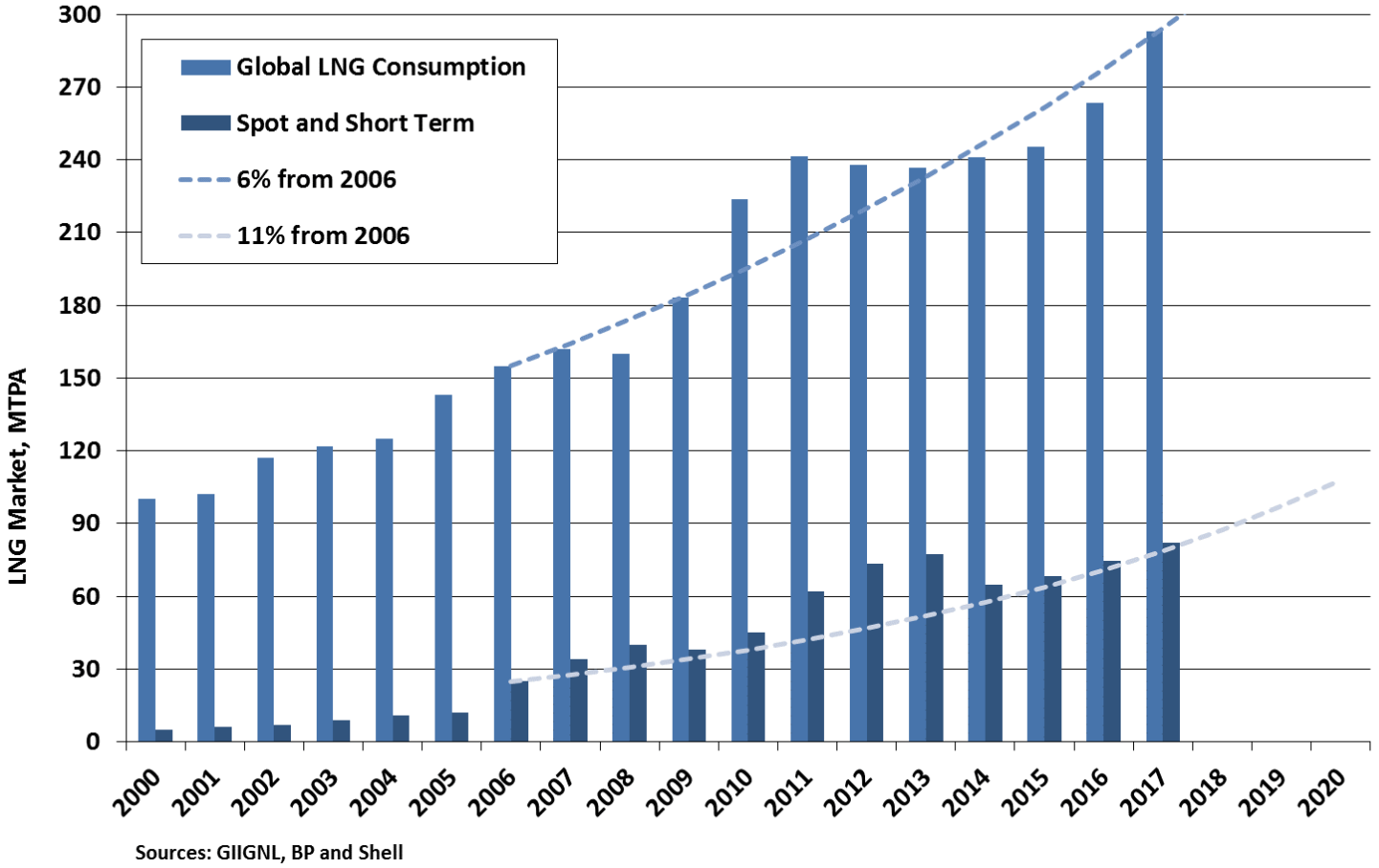
What is LNG?

How is it produced?

# A quick global overview

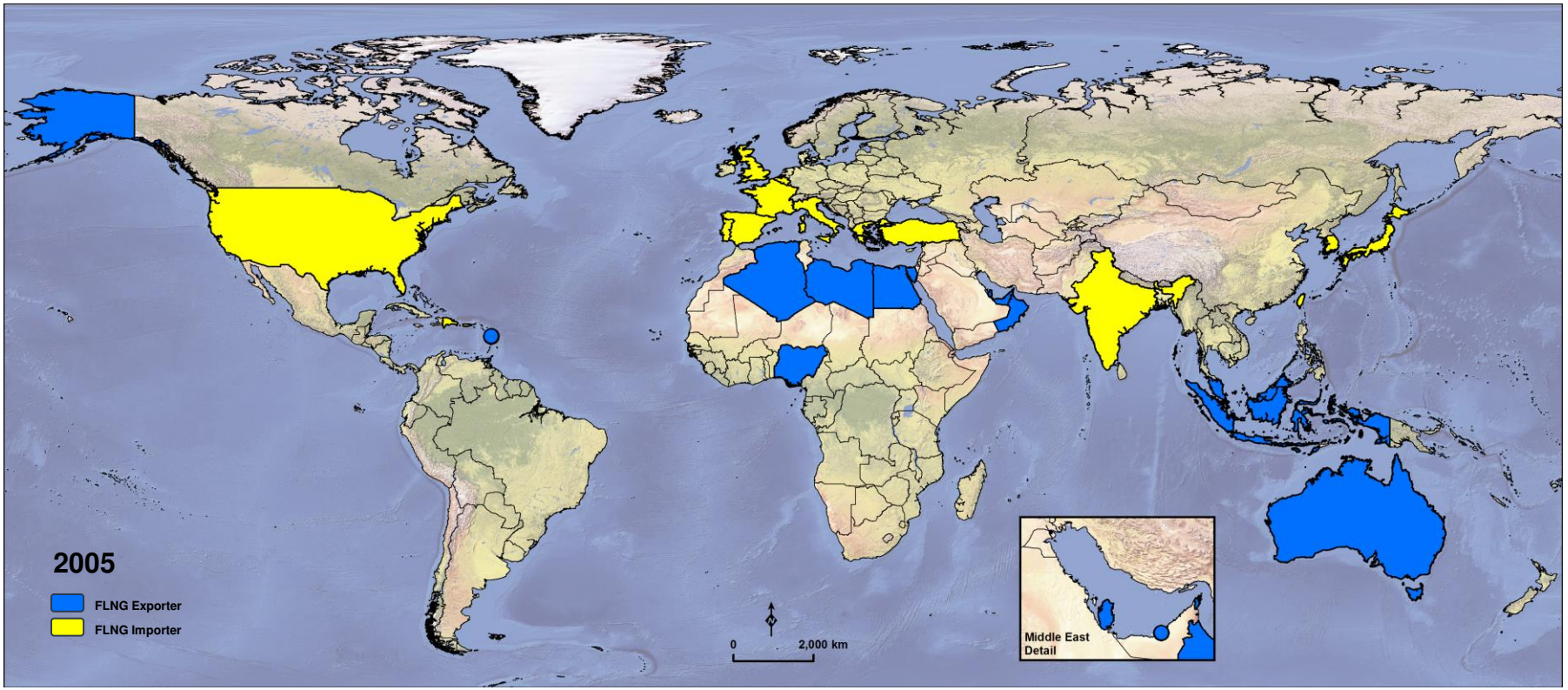
# The Global LNG Market has changed, liquidity is increasing:

- LNG development traditionally supported by long term contracts
- Significant increase in short term markets




Sources: GIIGNL, BP and Shell

# Changes in export and import countries….



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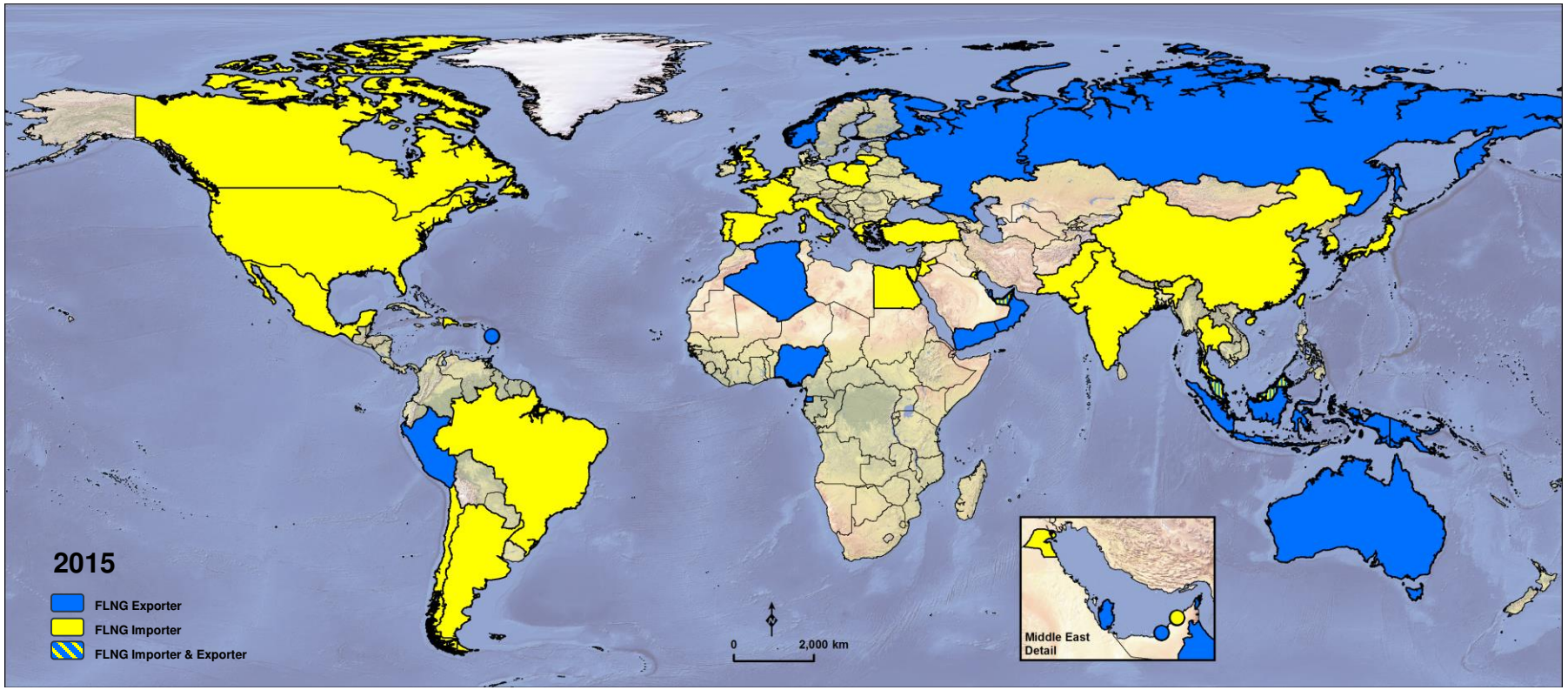
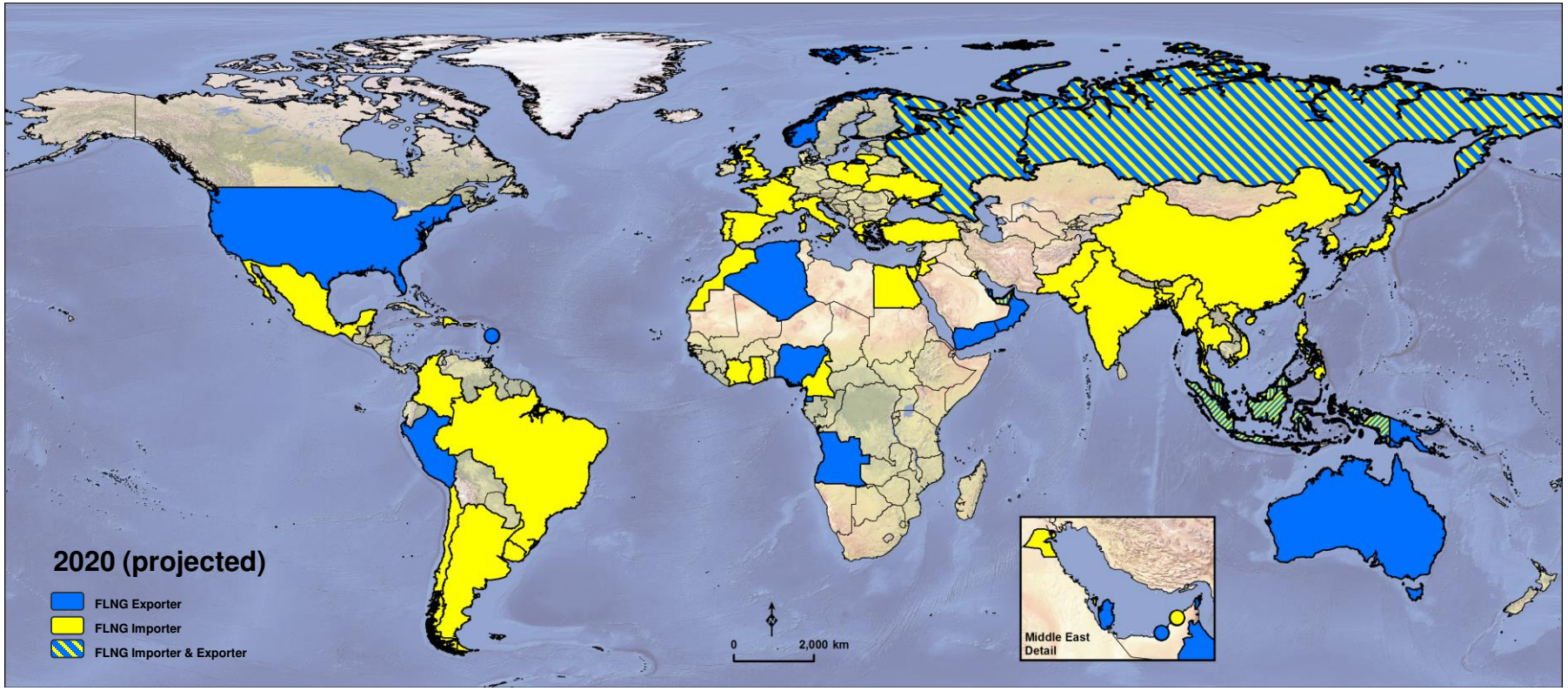
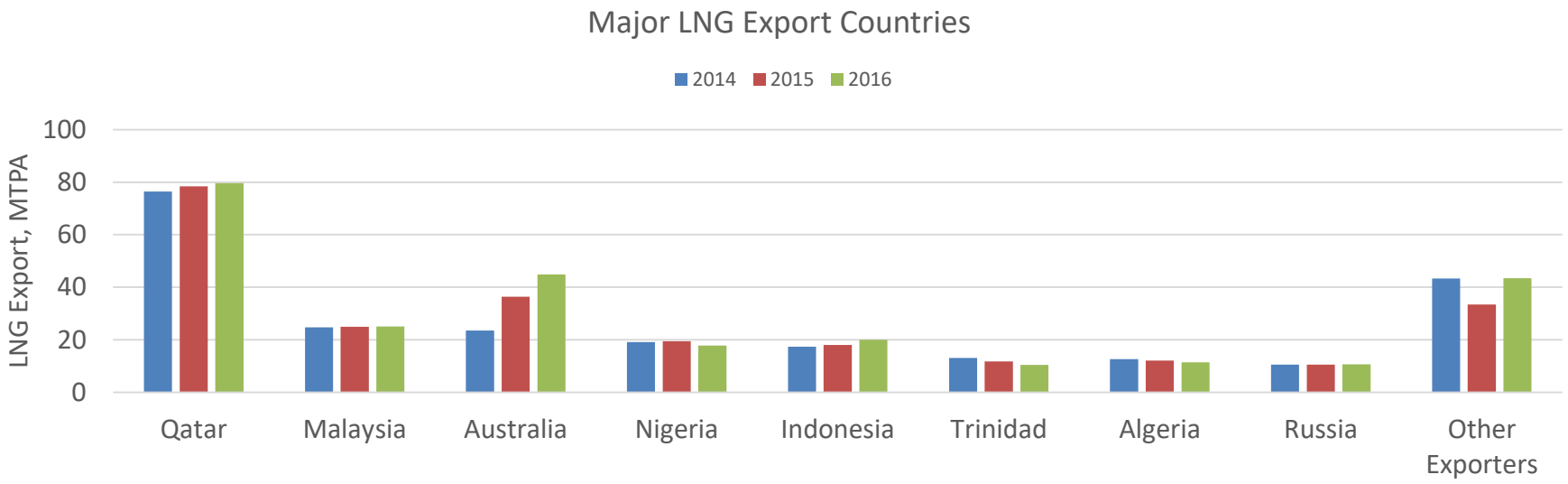
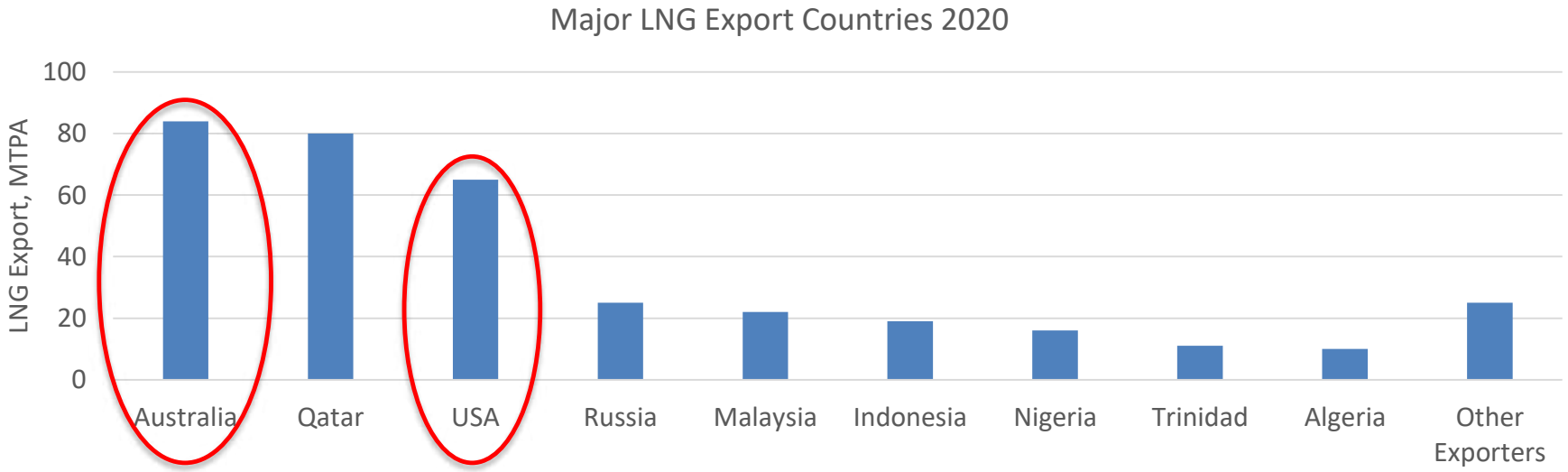


# Changes in export and import countries….

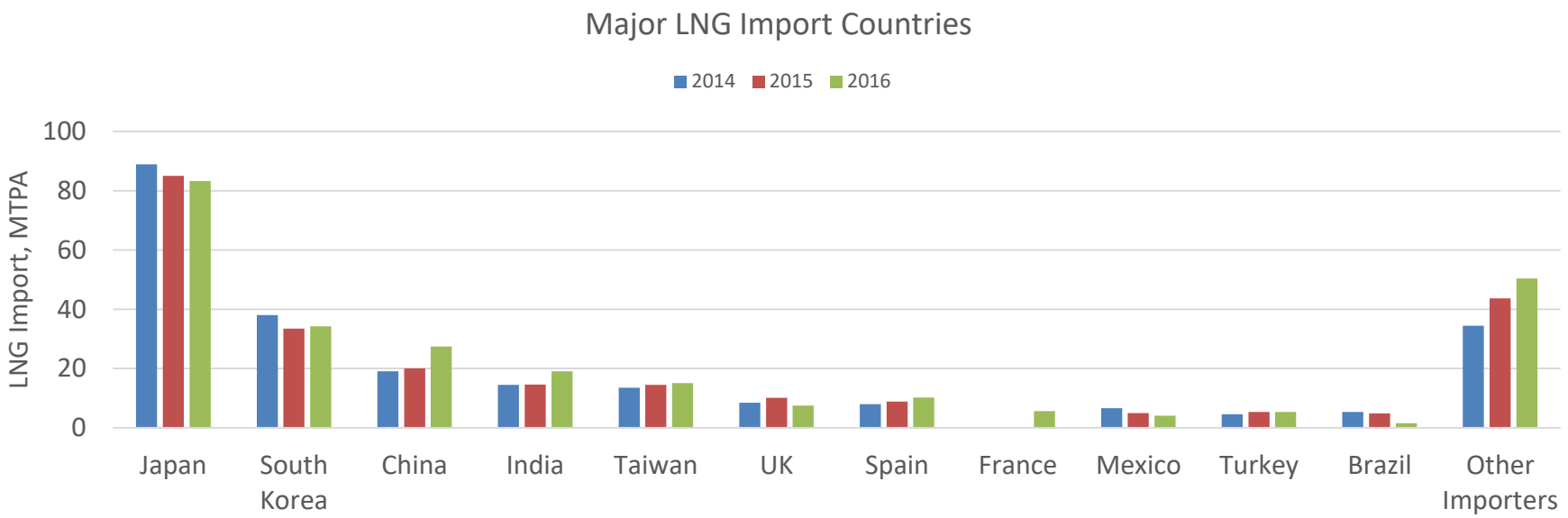


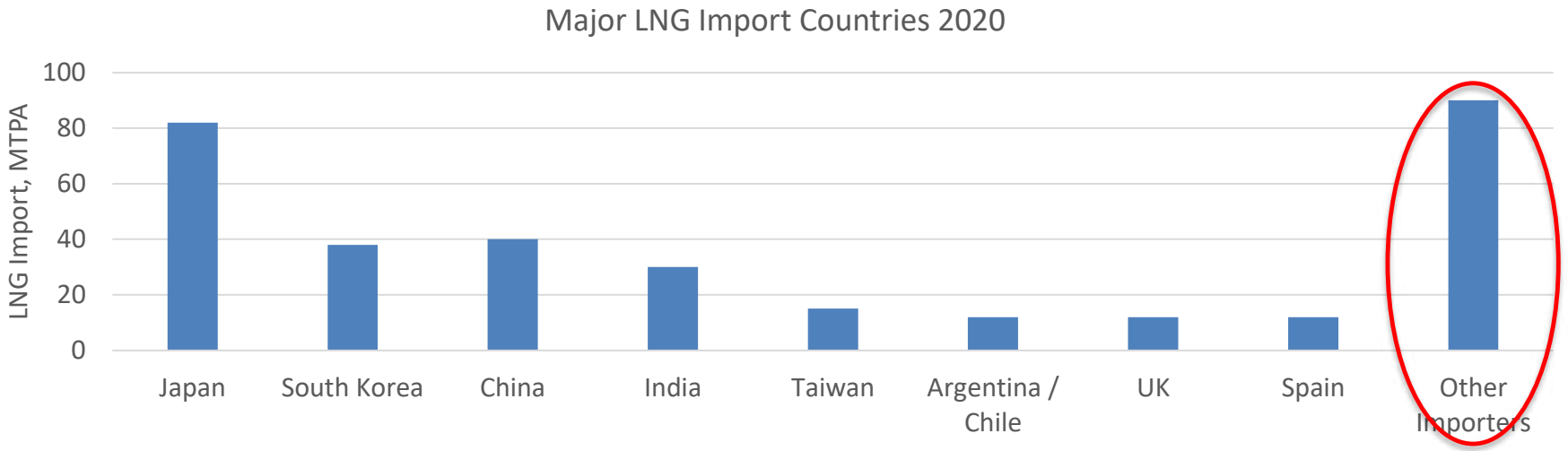
# Significant new export in next 4 years



# Increasing diversification of imports



# Mid and Long Term

## Between now and ~2020 a further 85+MTPA of capacity will be brought into production, mainly in the USA

- A significant amount of this, but not all, is already contracted
- Remainder of uncontracted LNG will create an overhang in supply into the early 2020's

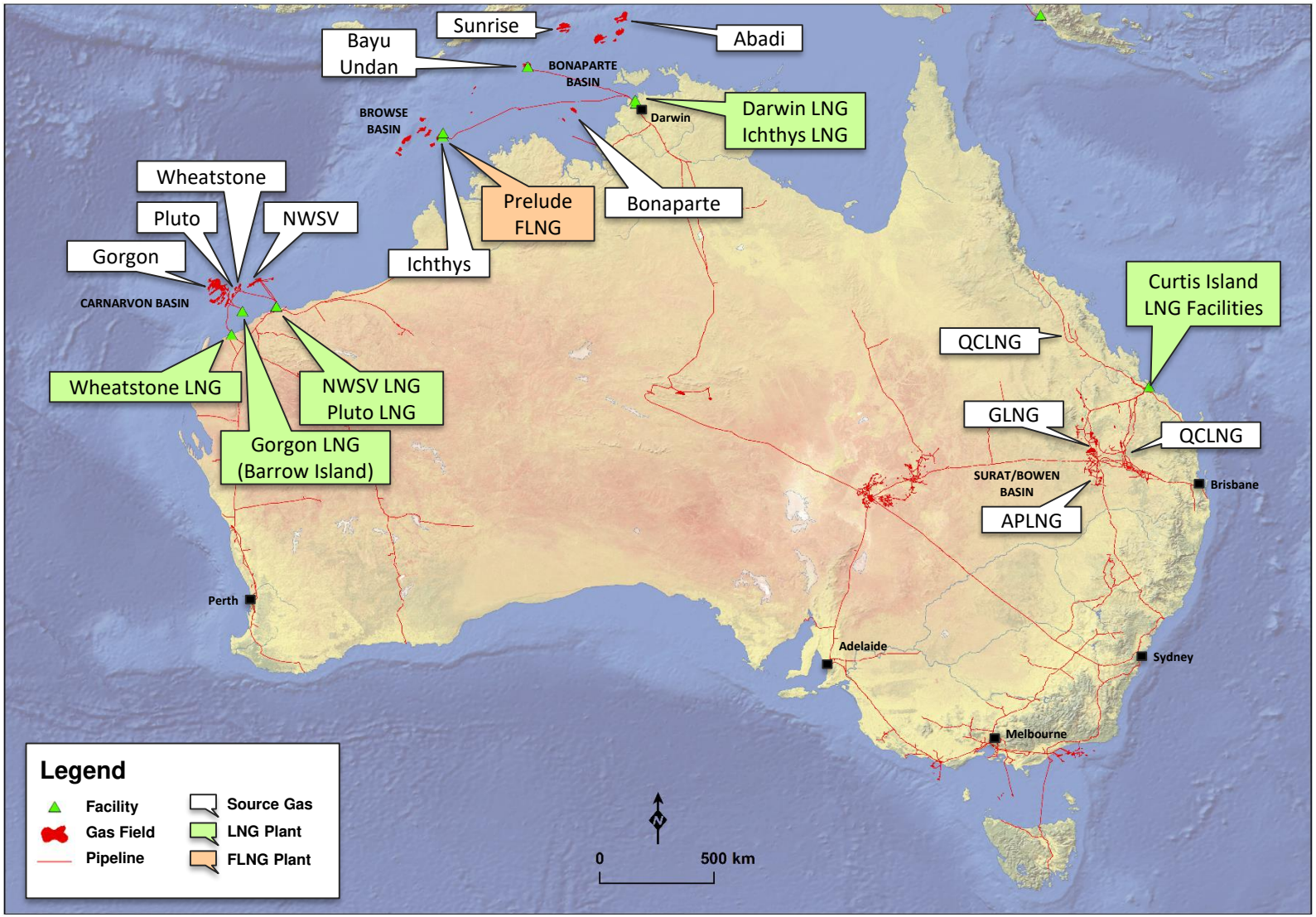
## Rapid diversification of LNG imports both geographic and market segment will see this rebalance

- Growth in importing countries - Asia, South America and Middle East
- FSRU's now the "entry level", which significantly reduces both cost and time to begin imports
  - Smaller scale regional distribution gaining momentum both in Europe and Asia
  - Transportation gaining momentum
  - …but timing is unclear
- FLNG offers the same change in "entry level" potential for upstream projects

## The rise of renewable energy creates both opportunity and risk

- Gas is the natural companion to renewables because of it ability to react quickly in line with variable renewable changes.
- Gas experiencing a "Green-Cheap Squeeze"
  - Not as green as renewables
  - Not as cheap as coal
- Large scale electricity storage is a potential game-changer in the power generation arena, but appears to be some way off.

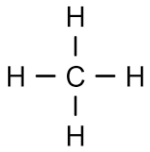
# Australia's LNG areas



# What is LNG

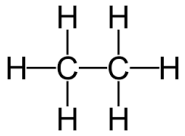
# What is Natural Gas

## Methane



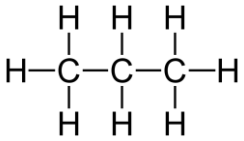
- CH4
- C1

## Ethane



- C2H6
- C2

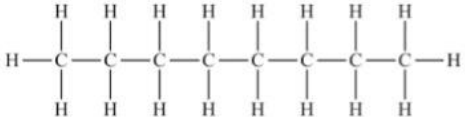
## Propane



- C3H8
- C3

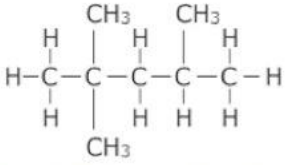
…

## Octane



Octane $C_8H_{18}$

Boiling point 258° F



2,2-4-Trimethylpentane $C_8H_{18}$ (Isooctane)

Boiling point 210° F

- C8H18
- C8

## …C30+

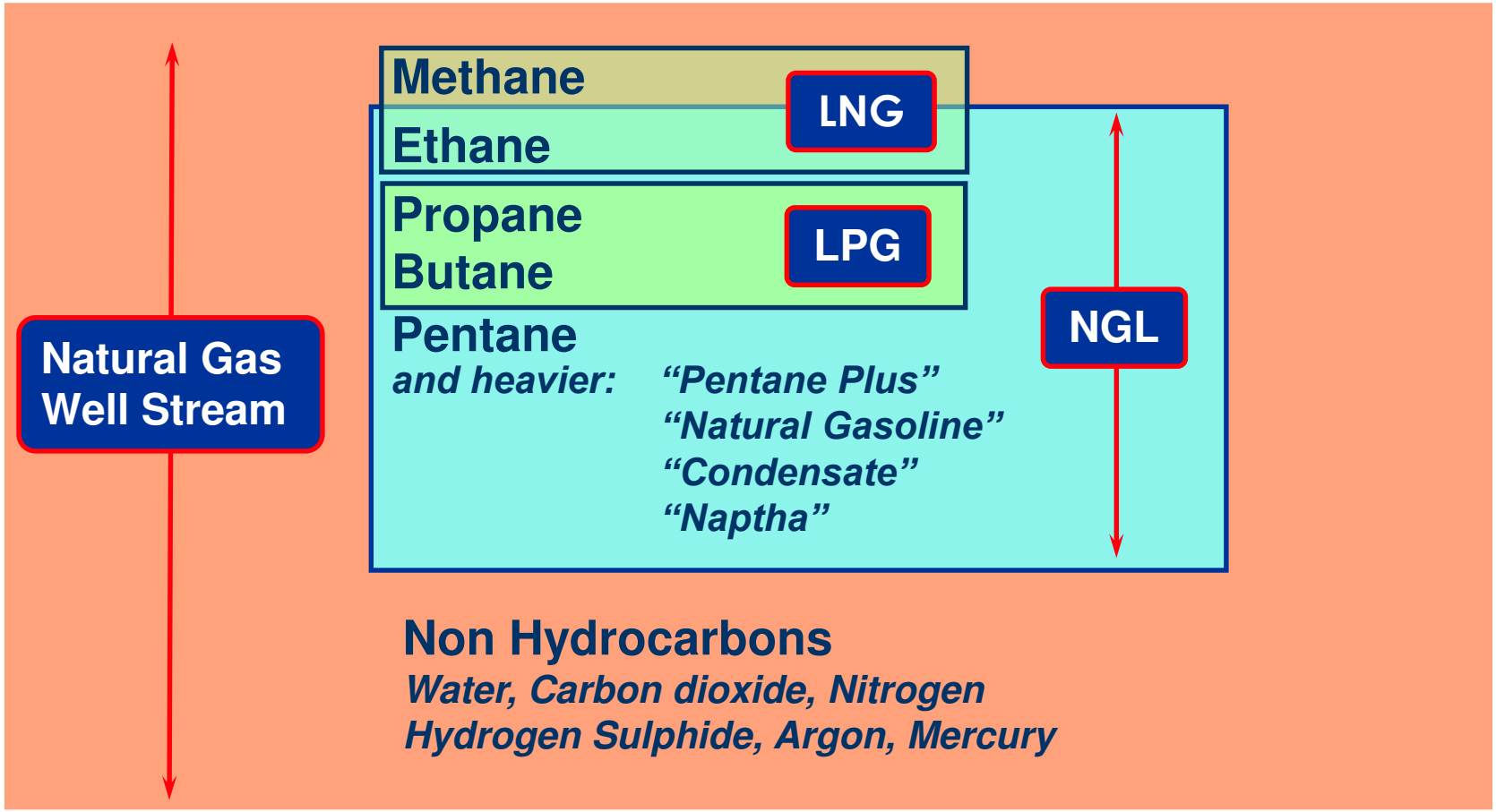
## Non Hydrocarbons:

- Water, Carbon Dioxide, Nitrogen, Hydrogen Sulphide, Mercury, Argon…

# What is Liquefied Natural Gas?

| Symbol | Component | Mol % 1 | Mol % 2 | Mol % 3 |
|---|---|---|---|---|
| CO2 | Carbon Dioxide | 3.35 | 0.38 | 12.00 |
| N2 | Nitrogen | 0.32 | 5.34 | 1.50 |
| C1 | Methane | 74.45 | 93.85 | 77.91 |
| C2 | Ethane | 10.77 | 0.41 | 3.00 |
| C3 | Propane | 4.19 | 0.01 | 2.50 |
| iC4 | i-Butane | 0.61 | 0.00 | 0.50 |
| nC4 | n-Butane | 1.24 | 0.00 | 1.05 |
| C5 | neo-Pentane | 0.01 | 0.01 | 0.02 |
| iC5 | i-Pentane | 0.42 | 0.00 | 0.40 |
| nC5 | n-Pentane | 0.47 | 0.00 | 0.60 |
| C6 | Hexanes | 0.56 | 0.00 | 0.30 |
| C7 | Me-Cyclo-pentane | 0.13 | | |
| | Benzene | 0.04 | | |
| | Cyclo-hexane | 0.27 | | |
| | Heptanes | 0.37 | 0.00 | 0.10 |
| C8 | Me-Cyclo-hexane | 0.37 | | |
| | Toluene | 0.16 | | |
| | Octanes | 0.40 | 0.00 | 0.05 |
| C9 | Ethyl-benzene | 0.02 | | |
| | Meta/Para-xylene | 0.14 | | |
| | Ortho-xylene | 0.03 | | |
| | Nonanes | 0.29 | 0.00 | 0.02 |
| C10 | Tri-Me-benzene | 0.04 | | |
| | Decanes | 0.26 | 0.00 | 0.00 |
| C11+ | Undecanes + | 1.10 | 0.00 | 0.05 |

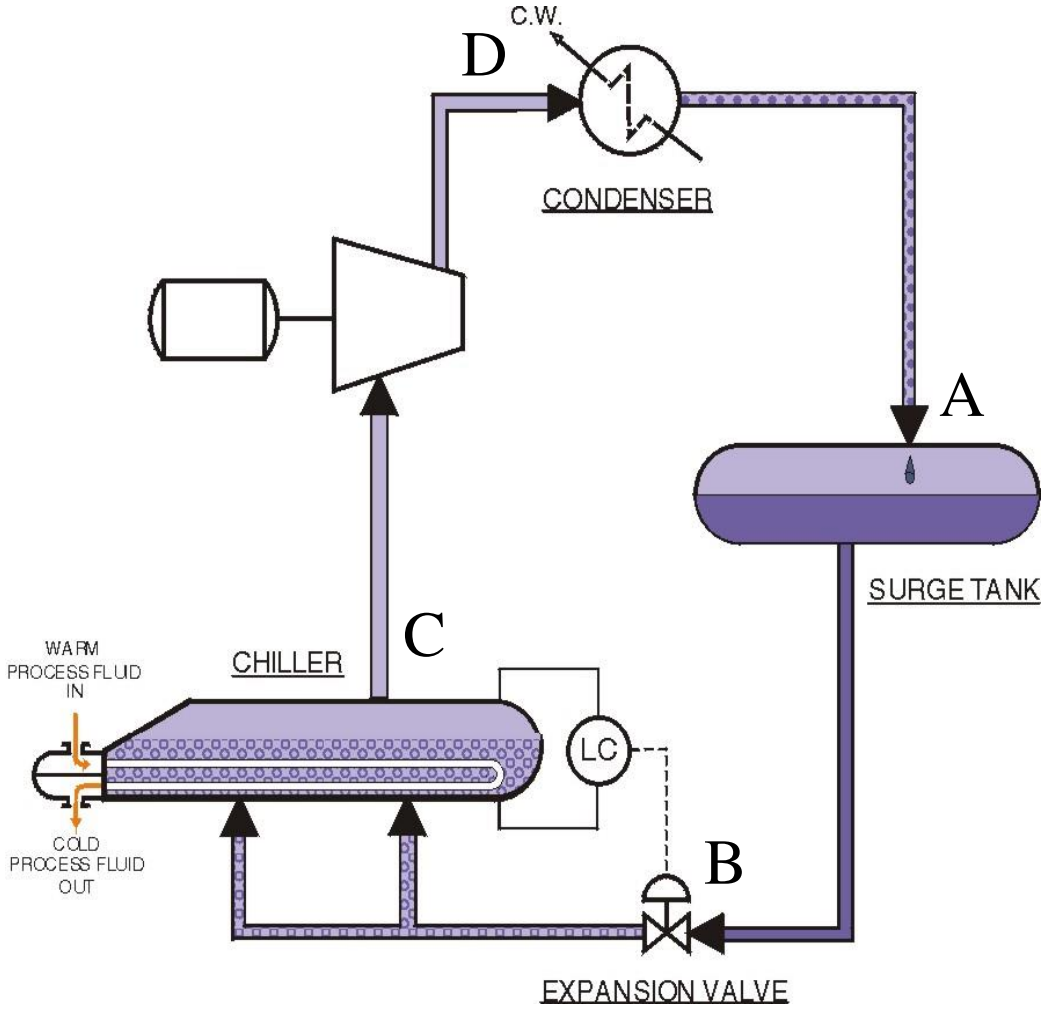
# Natural Gas terminology



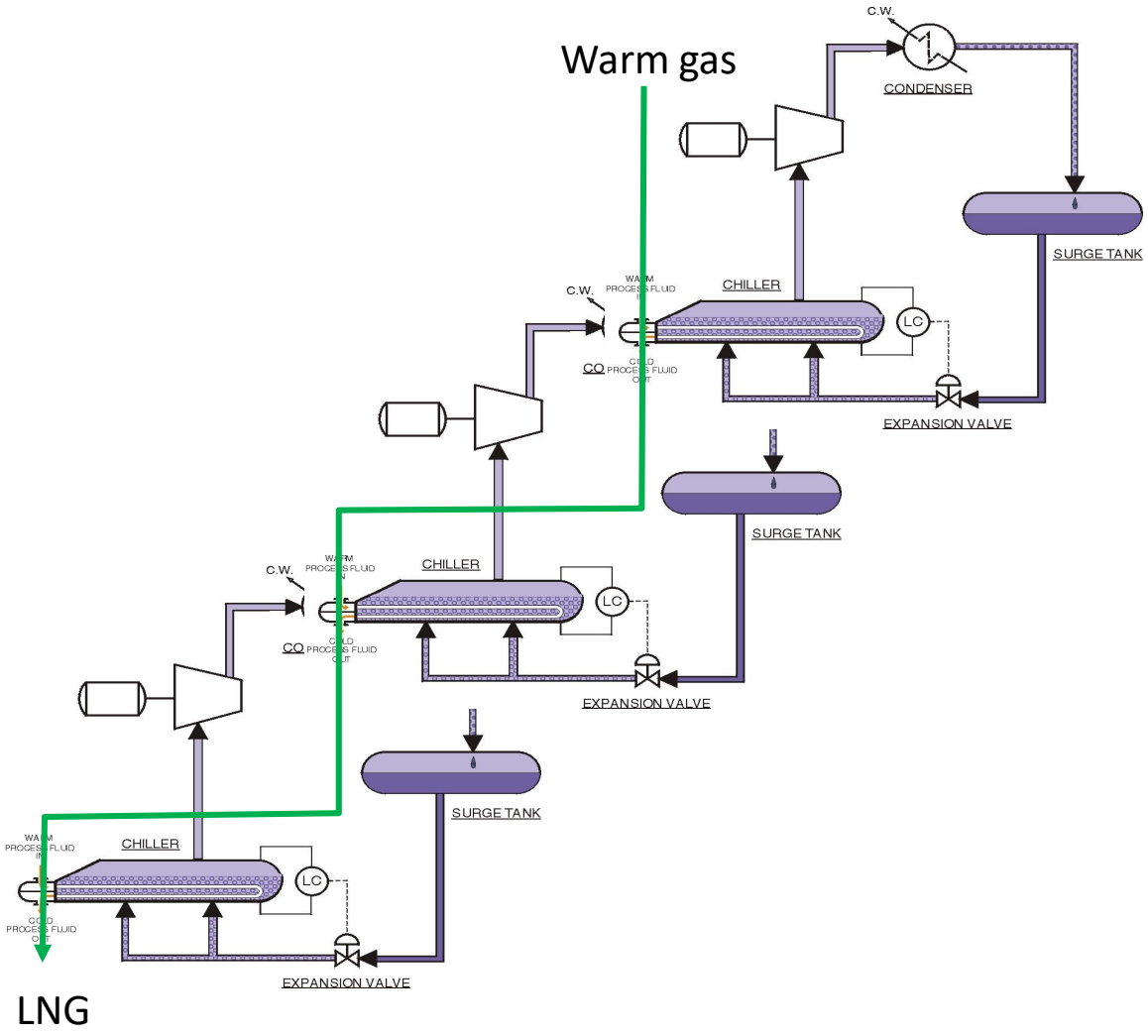
# History of Australian LNG

| | |
|---|---|
| 1963 | • Woodside awarded >370,000km$^2$ of NWS acreage |
| 1971/2 | • North Rankin and Torosa (Browse Basin) discovered; Goodwyn discovered |
| 1980/1 | • WA State Government agrees to underwrite domestic gas with take or pay contract and building DBNGP; Gorgon discovered |
| 1984/5 | • Domestic Gas supply starts form North Rankin A; NWSV signs agreements to supply LNG to Japan |
| 1989 | • LNG Shipments begin to Japan |
| 1995/6 | • Goodwyn A platform starts up; Perseus field discovered next to North Rankin |
| 2002/4 | • NWSV agrees LNG contracts with China |
| 2004 | • NWSV Train 4 start up: Darwin LNG Start up |
| 2007/8 | • Pluto FID; NWSV Train 5 start up |
| 2009 | • Gorgon FID; |
| 2010-11 | • QCLNG; GLNG; Prelude: APLNG; Wheatstone; Ichthys FIDs |
| 2012 | • NWSV 3500$^{th}$ Cargo; Pluto Start up |
| 2015 | • QCLNG Start up; GLNG Start up; APLNG Start up |
| 2016 | • Gorgon Start up |
| 2017 | • Wheatstone Start up |

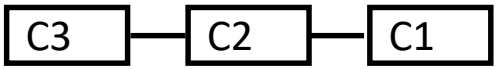
# Simple Refrigeration System



# Cascading Refrigeration



# LNG (…or Refrigeration) Technologies

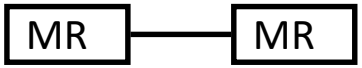



CoP OCP (3.5+mtpa)

- Many recent Trains (ALNG, ELNG, Darwin...)


APCI / Shell C3/MR (<5.5mtpa)

- Many Trains, incl NWS 1-5, Pluto 1

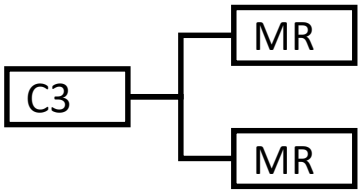



Shell DMR (<5.5mtpa)

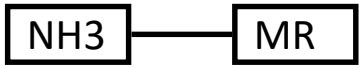
- Sakhalin, Persia LNG
- E-drive version with parallel compressors ~8mtpa (FEED)


APCI APX (7.8mtpa)

- Qatar, 6 Trains built



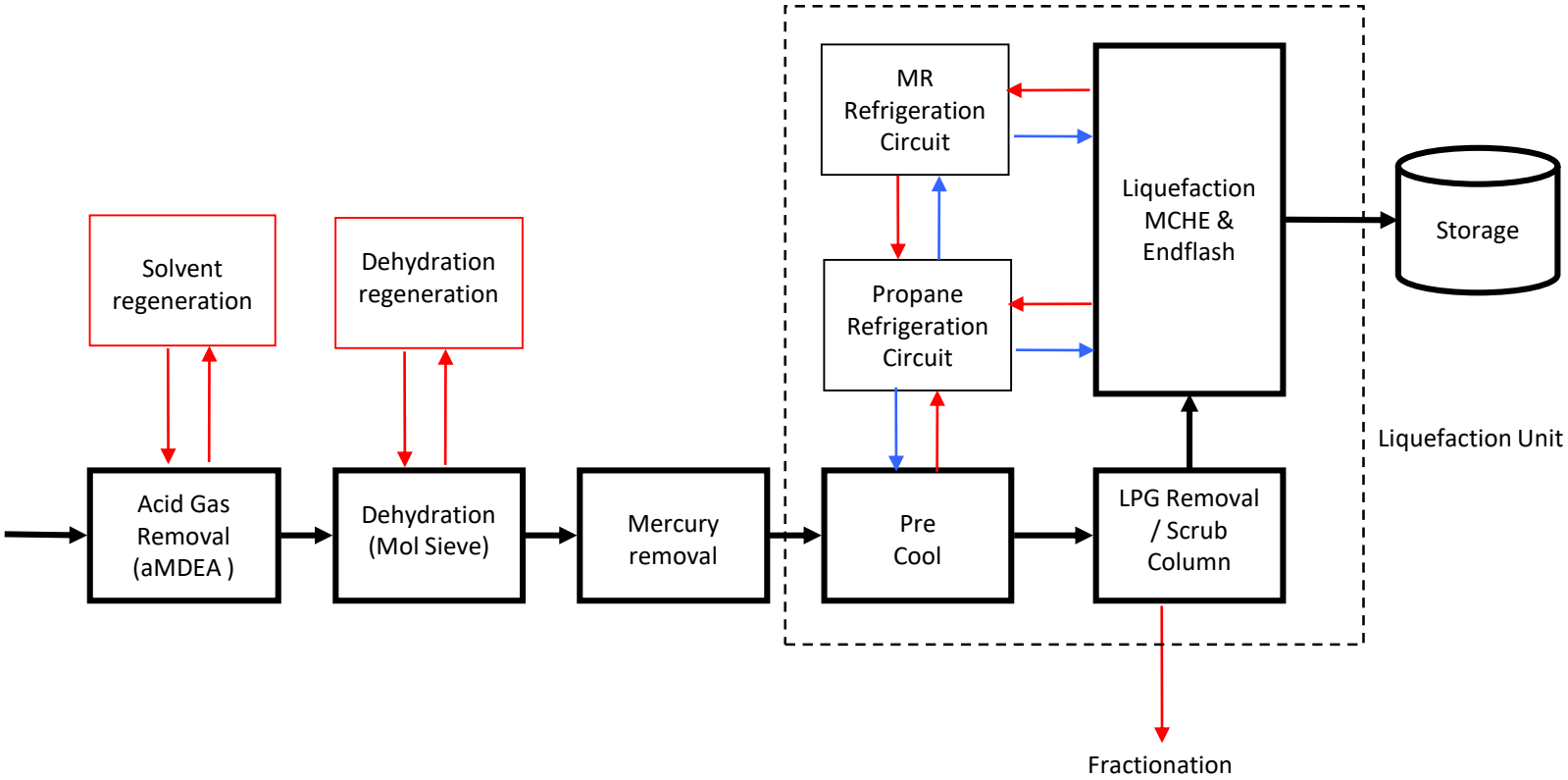

Shell – C3/PMR (never been built) (~8.5mtpa)




LNG Ltd – OSMR (never been built) (~1.5MTPA)

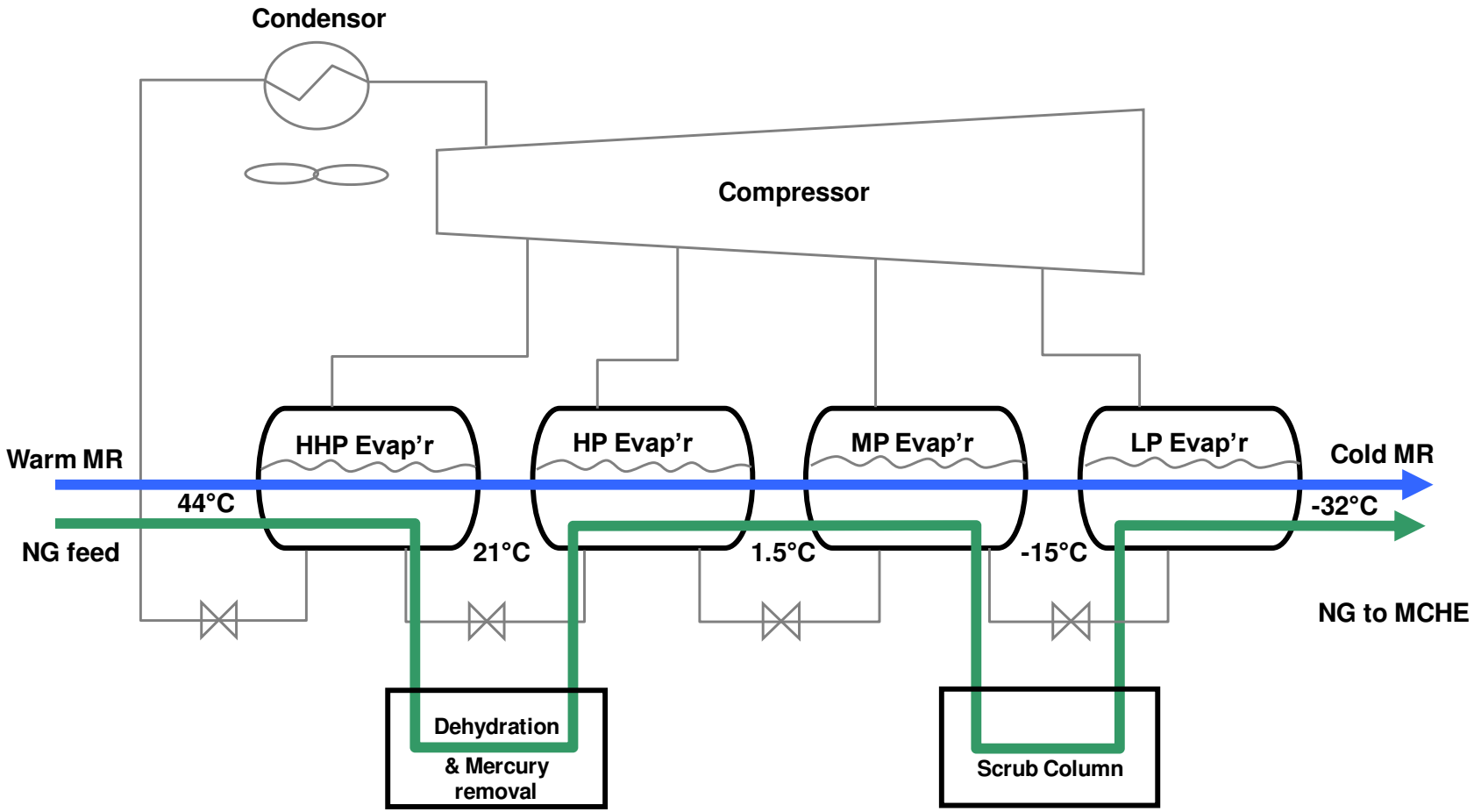
# How is LNG Produced

# Liquefaction “Train”



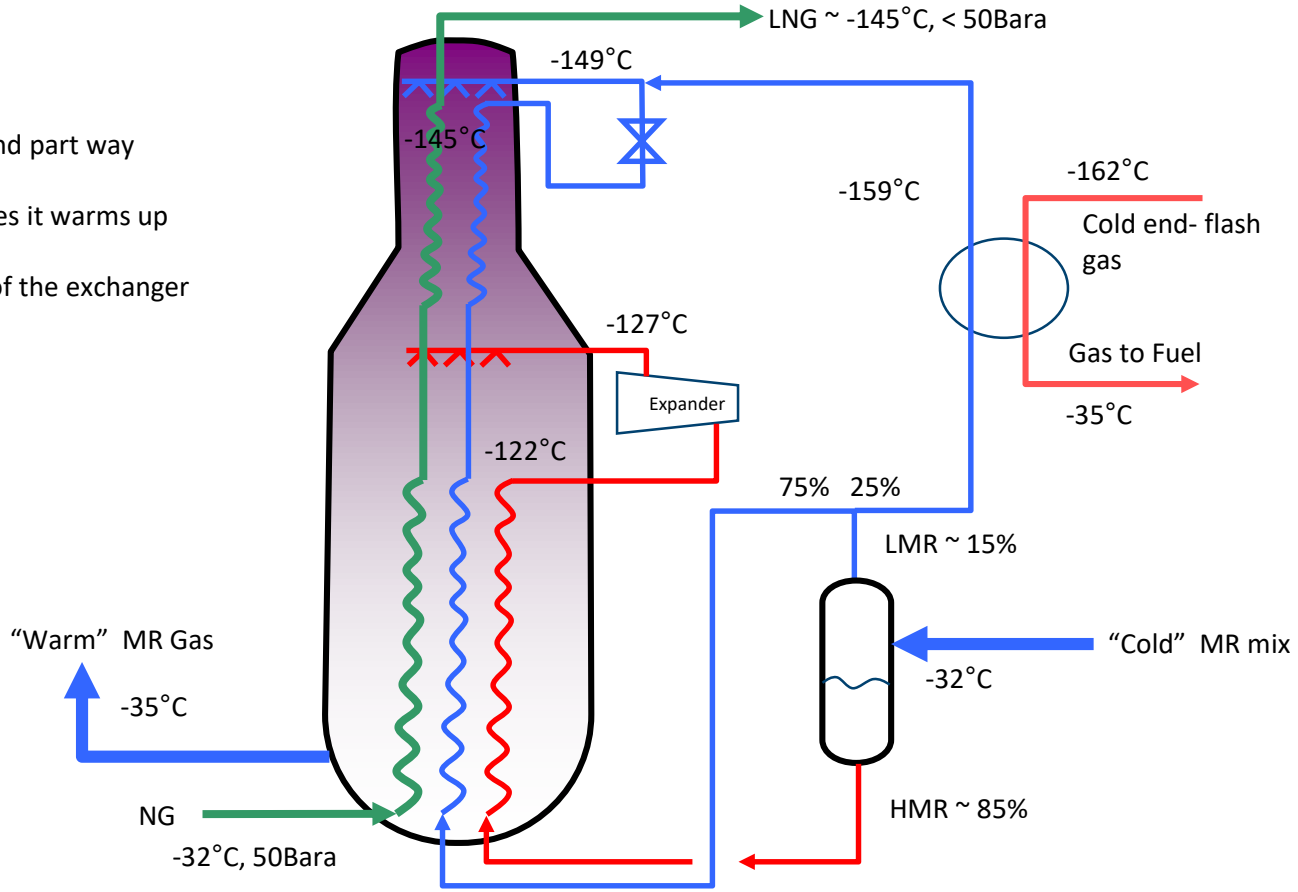
# Acid Gas Removal and Dehydration

# Propane Refrigerant condenses gas heavy ends & partially condenses Mixed Refrigerant



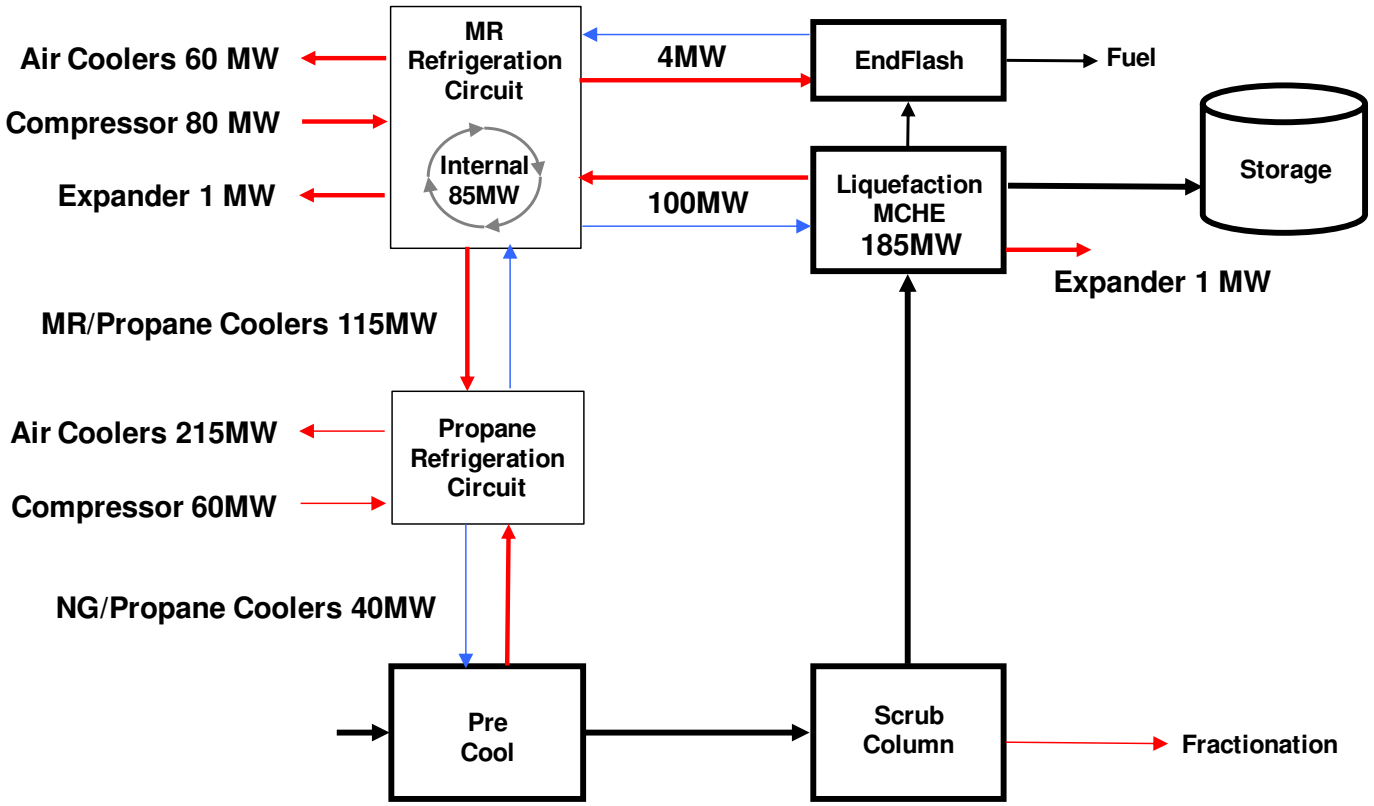
# MCHE

Cold Liquid MR is fed into the top of (and part way down) the MCHE.
As it runs down the Heat Exchange tubes it warms up and vapourises.
Warm gaseous MR leaves the bottom of the exchanger and returns to the compressor.



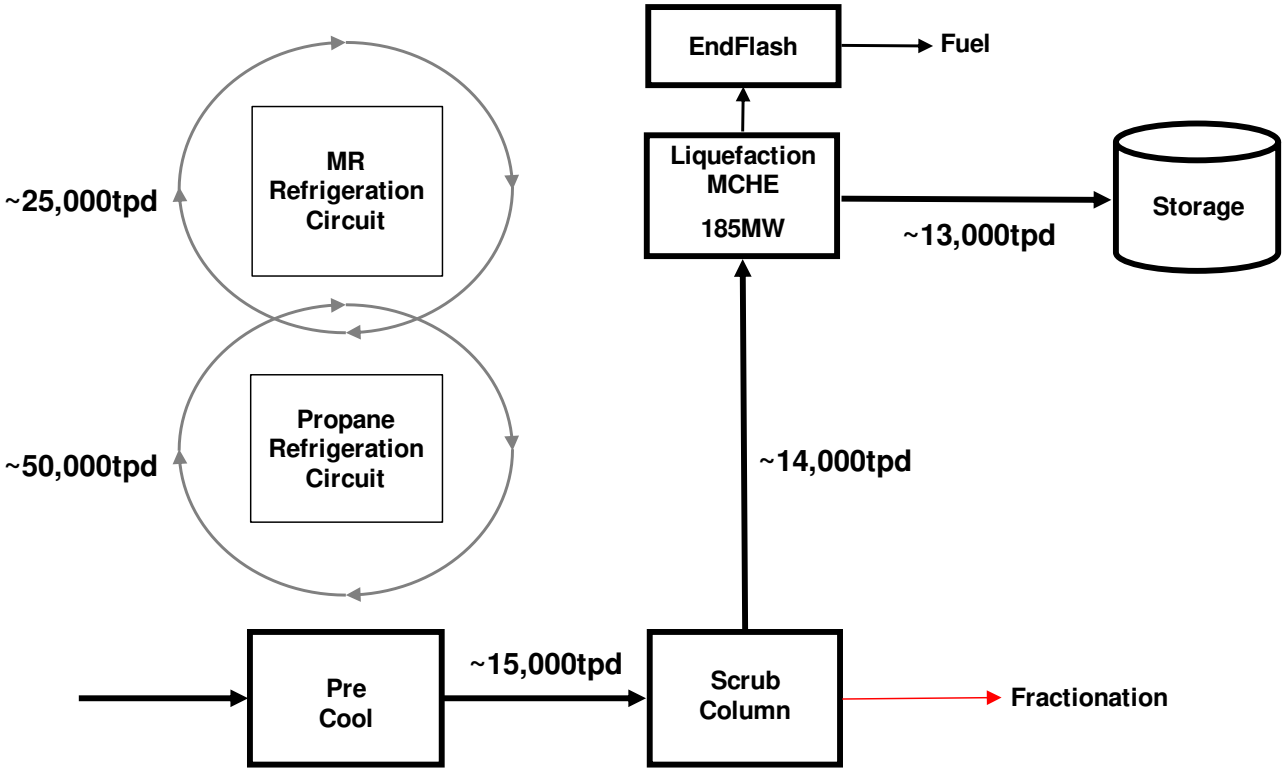
# The MCHE is Full – nothing like the diagram!

# Liquefaction process Energy Flows



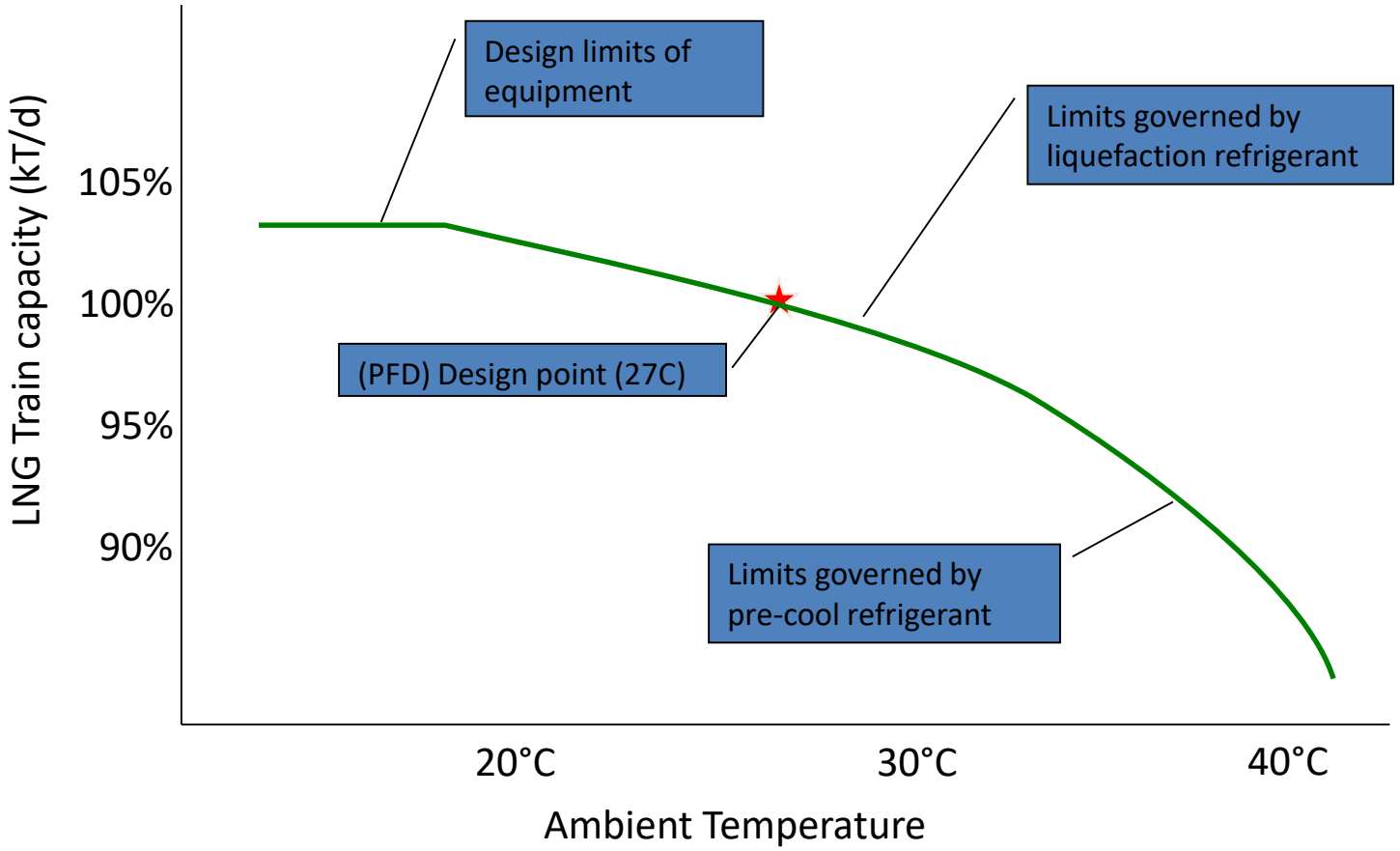

Based on ~4.3 MTPA

# LNG Liquefaction Process – Mass Flows

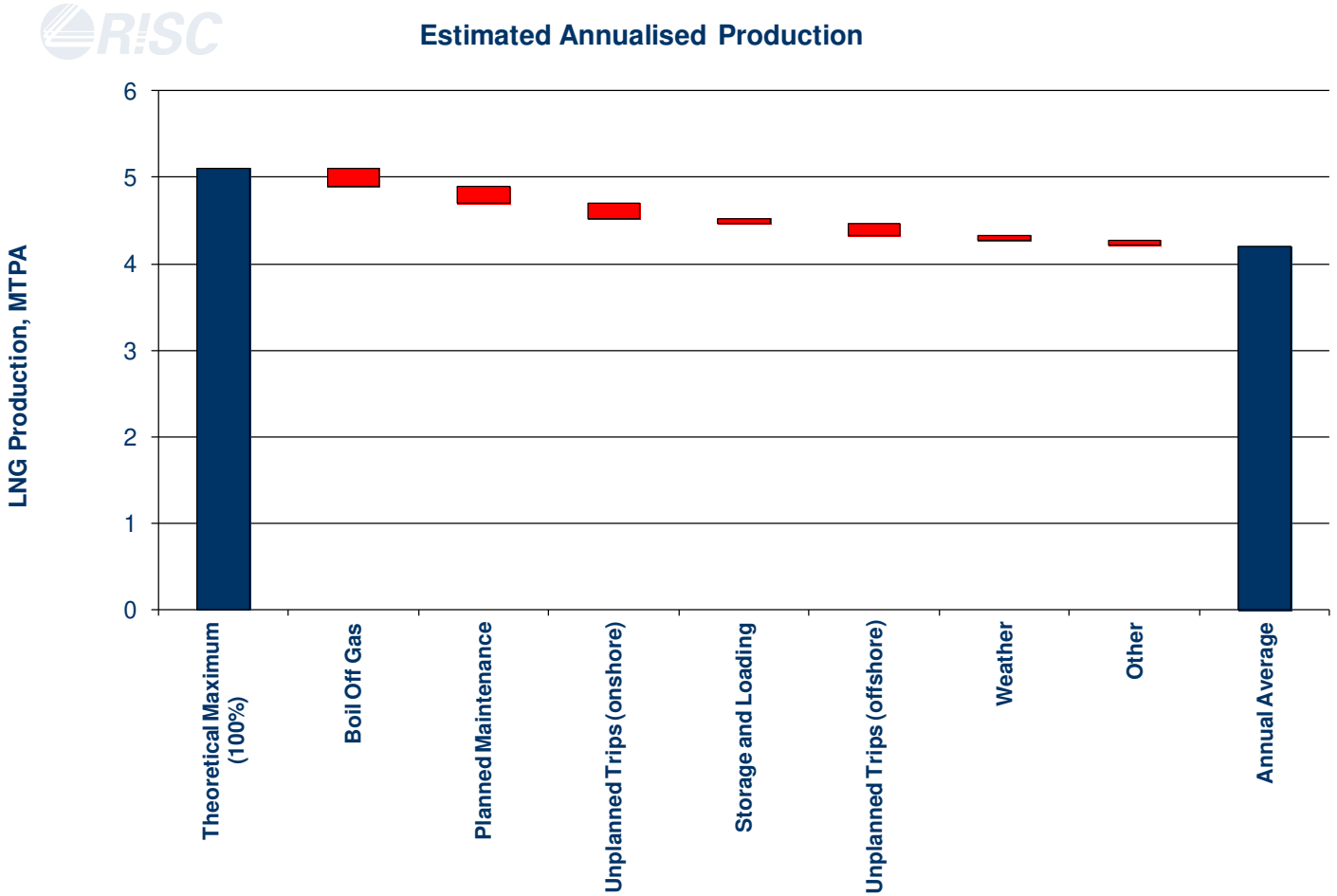



Based on ~4.3 MTPA

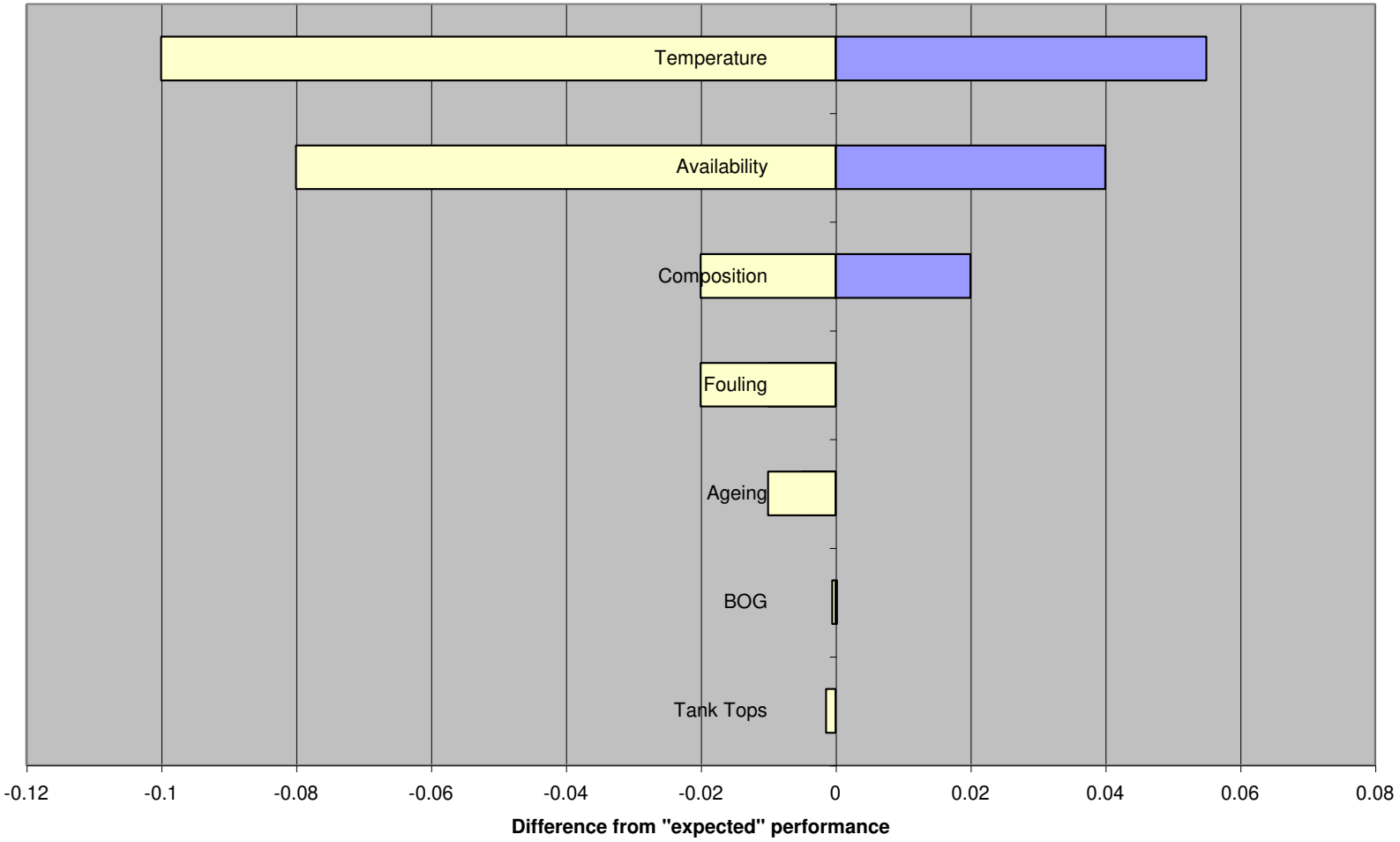
# Typical impact of temperature on LNG Train Performance



# Annualised Train LNG production



# Potential Impacts on LNG production



## Perth

Level 2
1138 Hay Street
WEST PERTH WA 6005
P. +61 8 9420 6660
F. +61 8 9420 6690
E. admin@riscadvisory.com

## Brisbane

Level 10
239 George Street
BRISBANE QLD 4000
P. +61 7 3025 3397
F. +61 7 3188 5777
E. admin@riscadvisory.com

## London

4th floor Rex House
4-12 Regent Street
LONDON UK SW1Y 4PE
P. +44 203 356 2960
F. +44 203 356 2701
E. admin@riscadvisory.com

## Dubai

Suite 503, Shangri La Offices
Sheikh Zayed Road
DUBAI UAE
P. +971 4 401 9875
F. +61 8 9420 6690
E. admin@riscadvisory.com

## Jakarta

Alamanda Tower, 25th Floor
Jl. T.B. Simatupang, Kav. 23-24
JAKARTA 12430 INDONESIA
P. +62 21 2965 7987
F. +62 21 2965 7888
E. admin@riscadvisory.com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