



# European Metrology Research on Liquefied Natural Gas

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# Outline

- Global trends in the energy mix
- Growing importance of LNG
- The LNG distribution chain
- Impact of measurement uncertainty
- Overview of R&D on LNG metrology
- LNG calibration facility – sneak preview



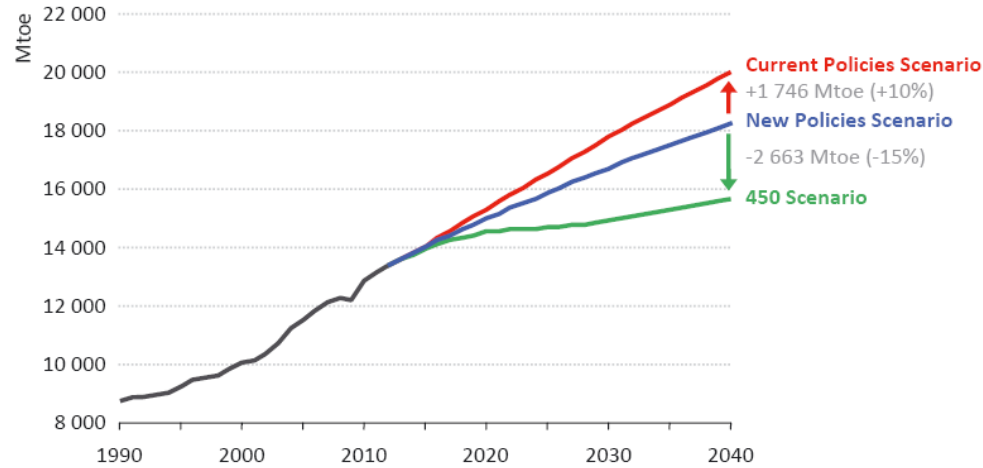
# Energy: grand challenge

- What everyone wants
  - Security of supply
  - Sustainability, clean energy
  - Competitiveness, affordability
- Role for metrology
  - Availability of affordable energy is a global issue, so are the consequences for environment
  - Metrology supports 'policies & strategies'
- Various 'levels of approach'
  - Development, optimization and efficiency of components in the energy chain, e.g. PV cell manufacturing, specifications of materials, development of fuel cells, reliability of windmills
  - Local energy consumption: households, energy efficiencies, industrial equipment
  - Primary energy, overall energy consumption/production, energy mix, energy system integration, transmission and distribution

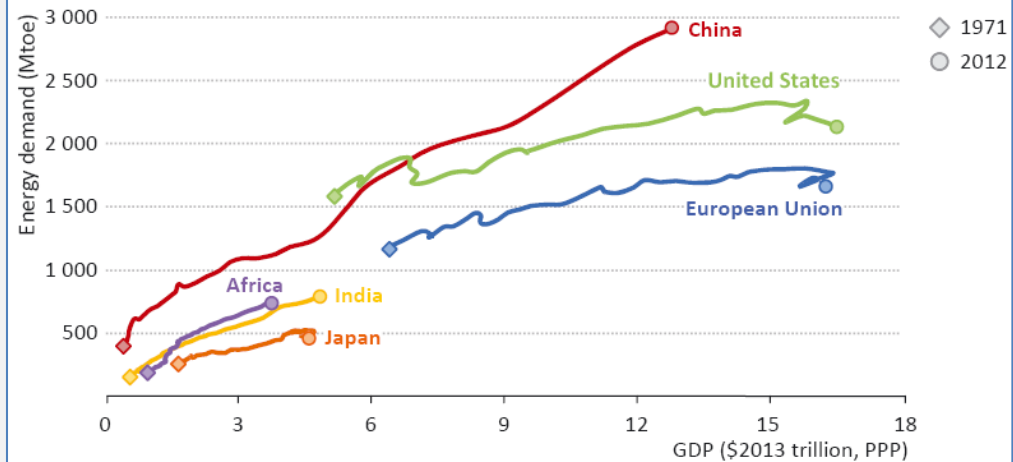


# Global Trends: energy demand

**Figure 2.1** ▷ World total primary energy demand by scenario



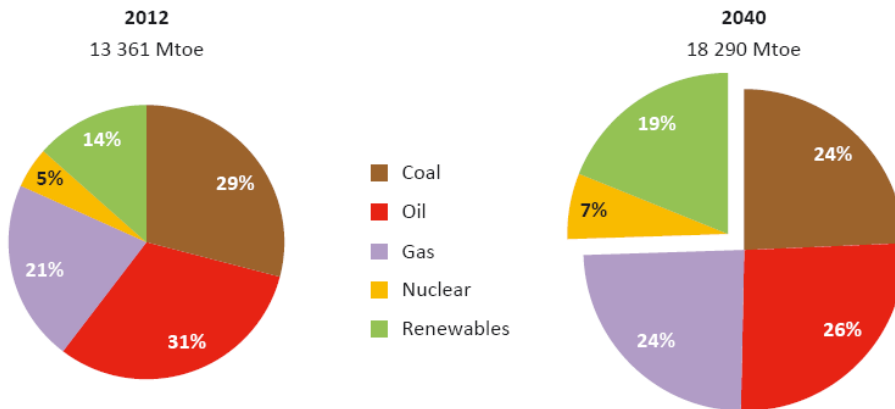
**Figure 1.1** ▷ Total primary energy demand and GDP in selected countries, 1971-2012



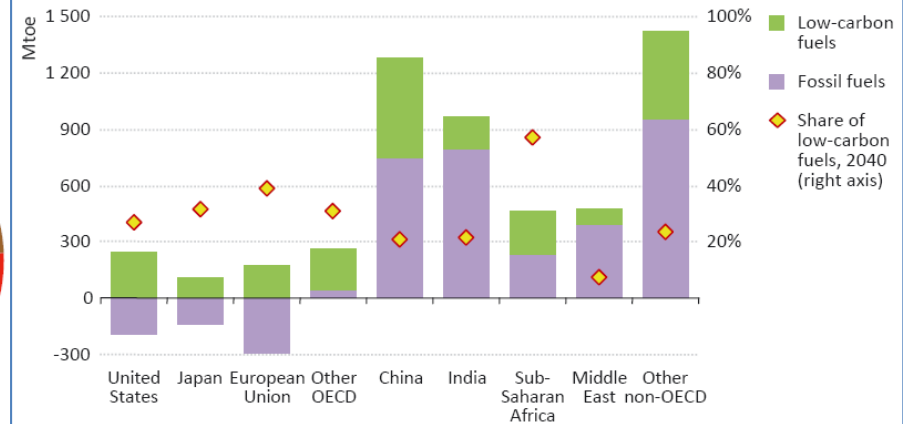
Note: Mtoe = million tonnes of oil equivalent.

# Global Trends: energy mix

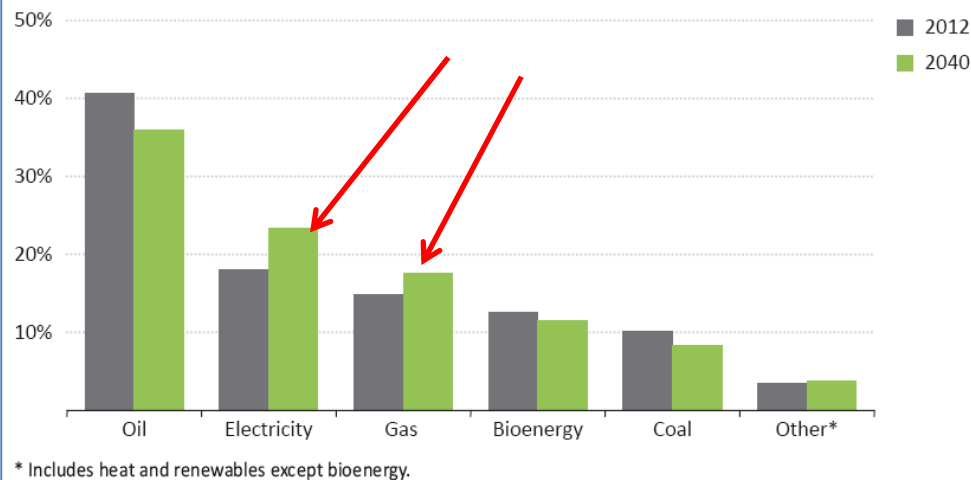
**Figure 2.2** ▶ Fuel shares in world primary energy demand in the New Policies Scenario



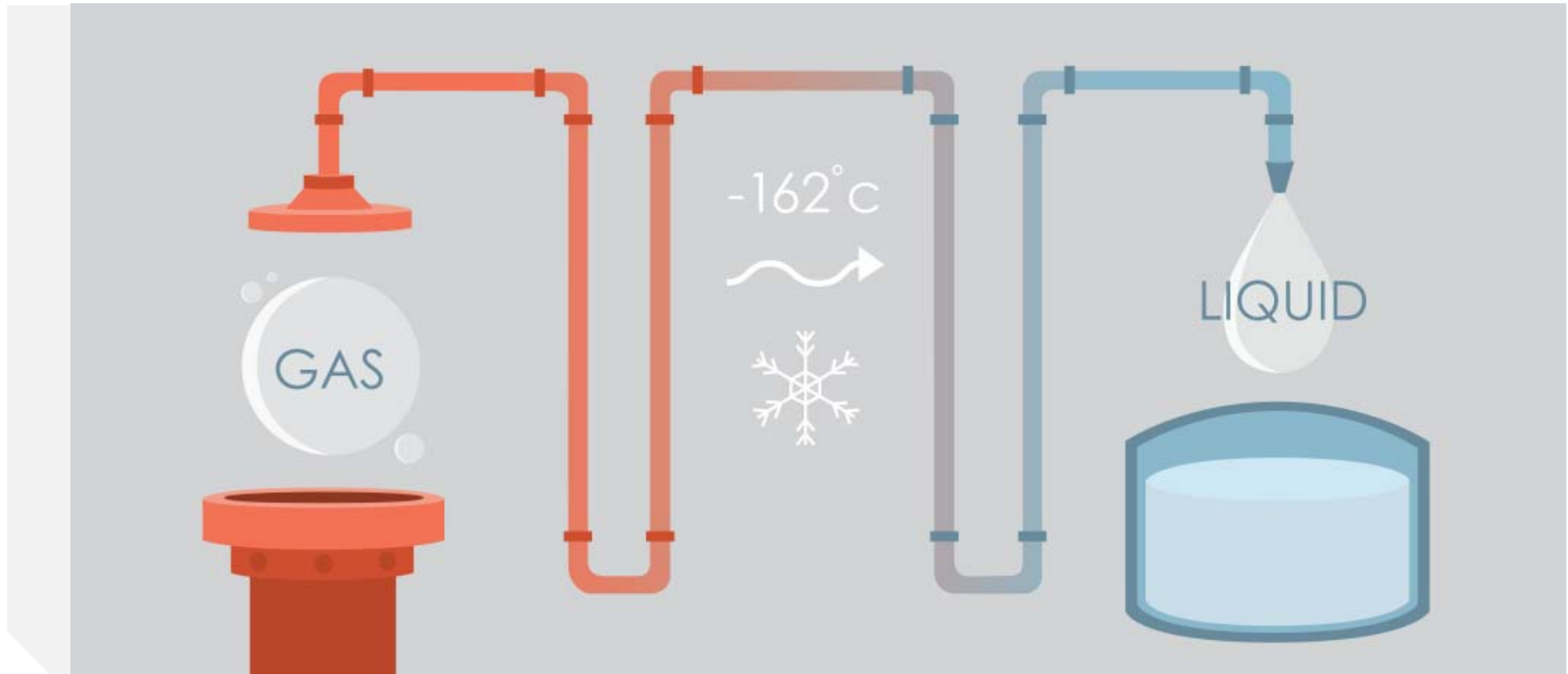
**Figure 2.3** ▶ Primary energy demand growth by region and fuel type in the New Policies Scenario, 2012-2040



**Figure 2.5** ▶ Fuel shares in global final energy consumption in the New Policies Scenario

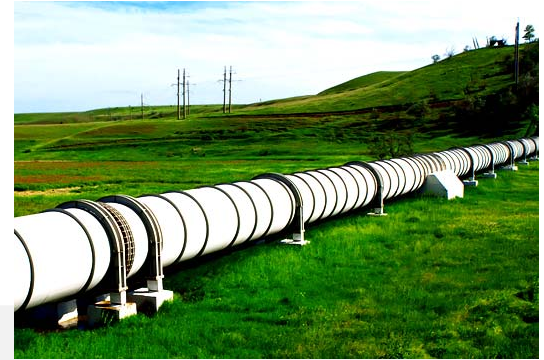


# What is LNG?





# Liquefied Natural Gas



- Alternative to pipeline
- Volume ratio gas to liquid is 600:1 (efficient)
- Allows trading without connecting pipelines (flexible)
- EU energy policy: diversified and secure energy supply
- Reduced emissions (cleaner and higher calorific value than oil)
- Globalization and short term contracts
- Strong growth
- LNG as fuel for trucks, ships, trains



# Growing importance of LNG

## Worldwide production of LNG

1990 50 Mtpa\*

2007 130 Mtpa

2014 246 Mtpa

\* Million ton per annum







# Large numbers

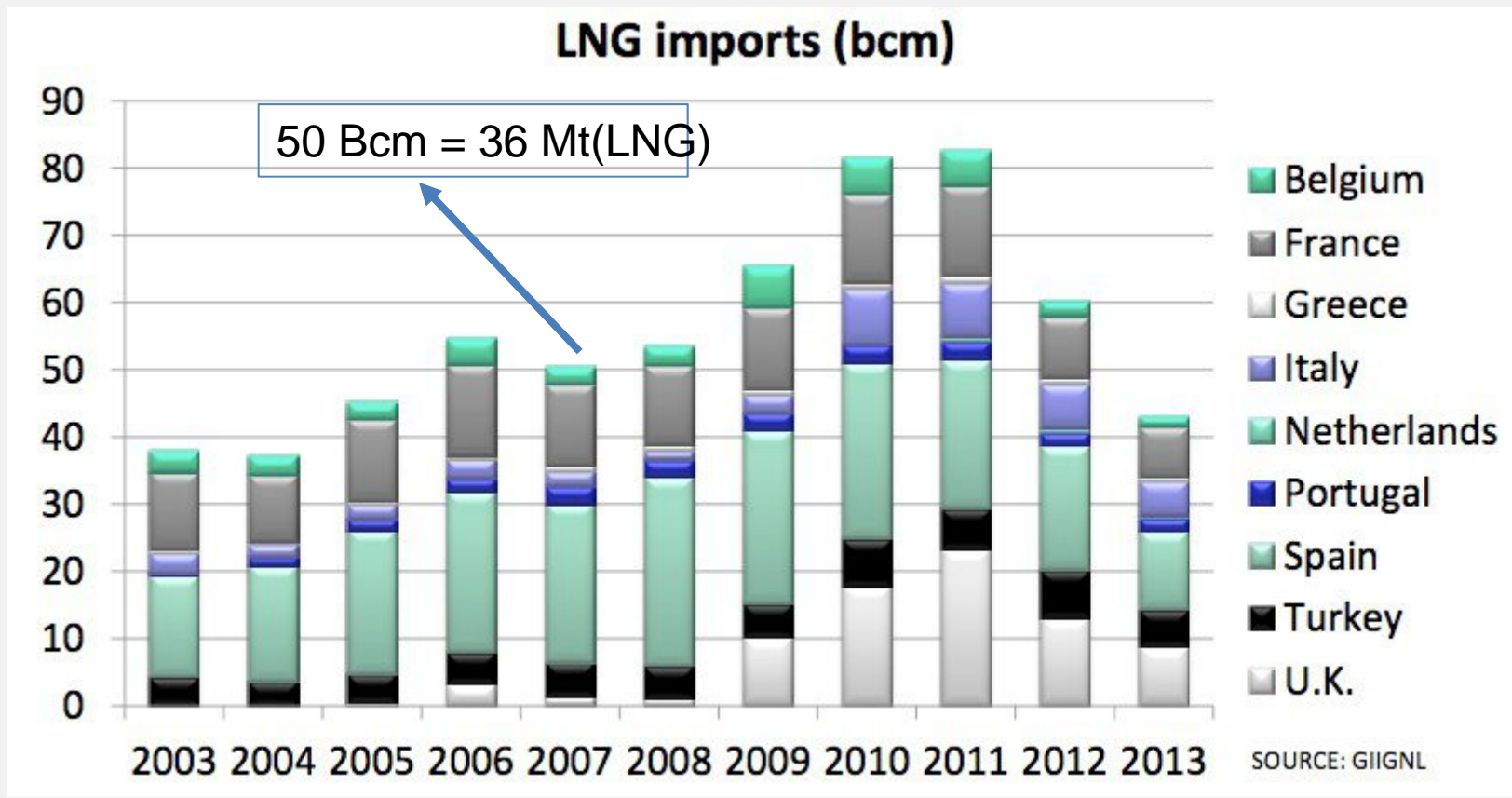
2014 Worldwide production capacity 301

Mtpa (Liquefaction capacity utilisation 82%)

- 301 Million ton LNG = = 4295 TWh = 15.462 PetaJoule
- This is 1000x the total electricity consumption in the city of Amsterdam

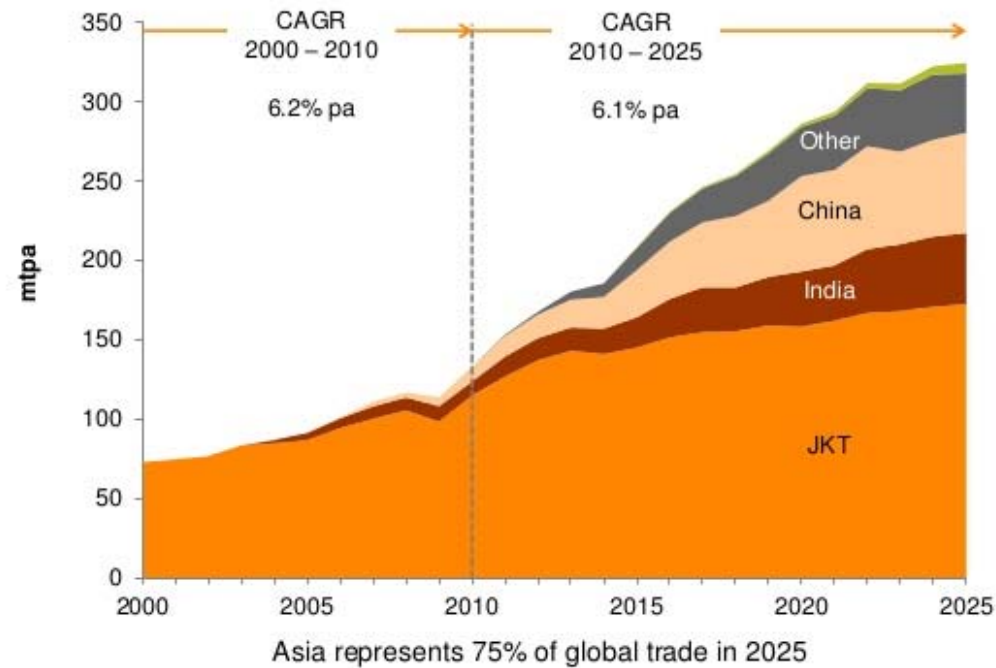
2015 128 Mtpa of liquefaction capacity under construction => mainly Australia (58 Mtpa) and US (44 Mtpa)

# LNG imports in Europe



# LNG imports outside Europe

## Strong Asian LNG demand growth



Source: BG Group outlook 2013

18



# Developments in LNG

2007

- Worldwide LNG production at 130 Mtpa
- Predominantly large scale LNG
- LNG as transport fuel hardly existing outside US
- Floating production storage and offloading (FPSO) units still on drawing tables
- First LNG metrology project (primary mass flow standard)

2016

- Worldwide LNG production capacity >350 Mtpa
- LNG as transport fuel fast growing market, Europe taking the lead, small scale LNG installed capacity 20 Mtpa in 2014
- 3 FPSO's under construction (6.8 Mtpa) >20 FPSO proposals announced (168 Mtpa)
- Many European NMIs and industrial partners collaborating in *Metrology for LNG II* program (*Metrology for LNG III*)



# LNG DISTRIBUTION CHAIN

**Large Scale LNG : Reducing Energy Measurement Uncertainties, Transparency, Simpler Processes**



Ocean tanker



Receiving terminal



Pipeline gas

Road tanker

Small ship



Bunkering/Fuelling stations



Trucks

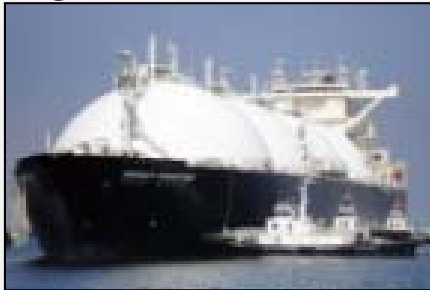
Ships

Buses

**LNG as fuel : Regulations (legal metrology), Certified Dispensing Systems, Flow Meter Calibrations**

# Measurements of LNG

Large scale LNG business => measurement of energy



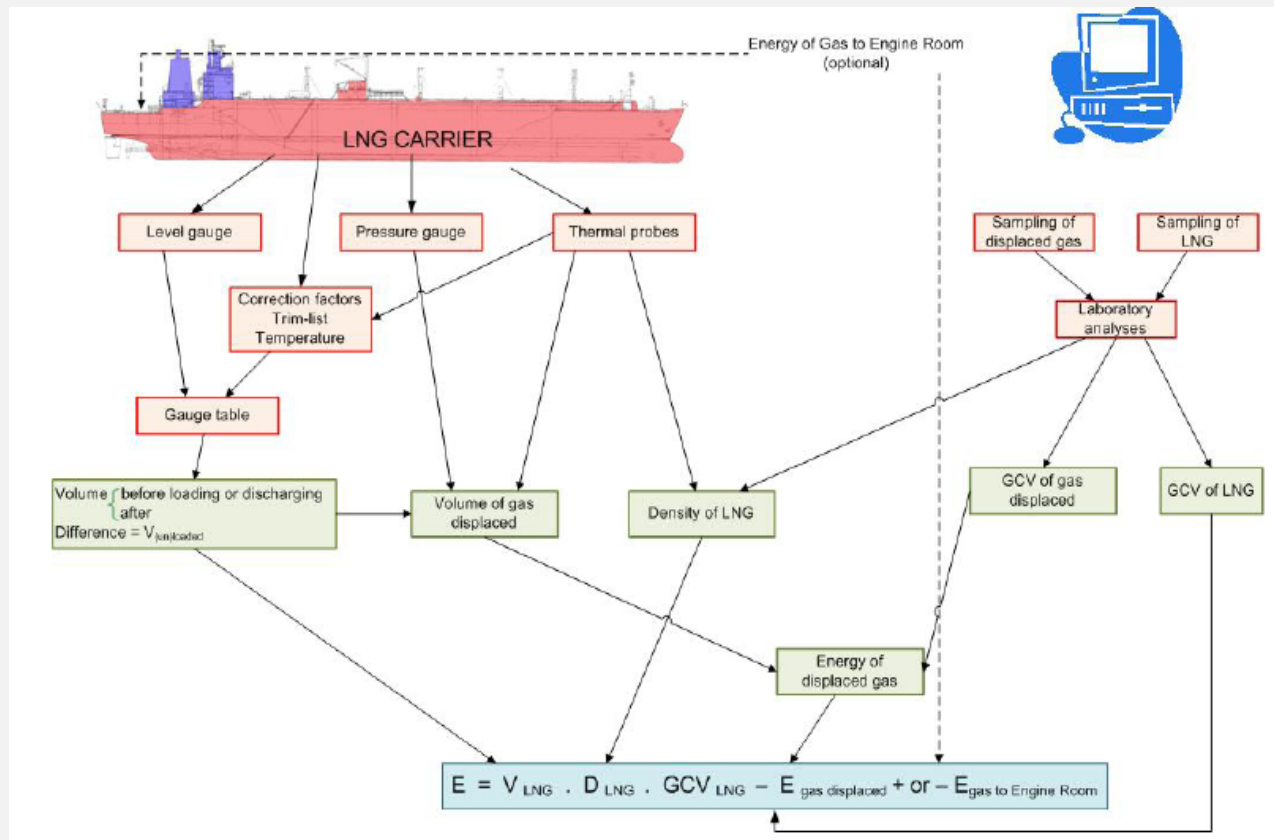
Small scale LNG business => measurement of energy?



or  
measurement of kilograms?  
or  
measurement of liters?

# Large scale LNG

**Energy = Volume x Density x Gross Calorific Value**



Source: GIGGNL Custody transfer handbook, 3<sup>rd</sup> edition

# Impact of Measurement Uncertainty

## Large Scale LNG

- **Typical terminal** ( $10 \text{ bm}^3(\text{N})/\text{year}$ )  
Measurement uncertainty **equivalent to 25 M€/year**
- One **cargo load** ( $Q_{\text{max}}$ ) Measurement uncertainty **equivalent to 500 k€**



## Small Scale LNG

- Measurement capabilities not at par with other fuel **legal metrological requirements**

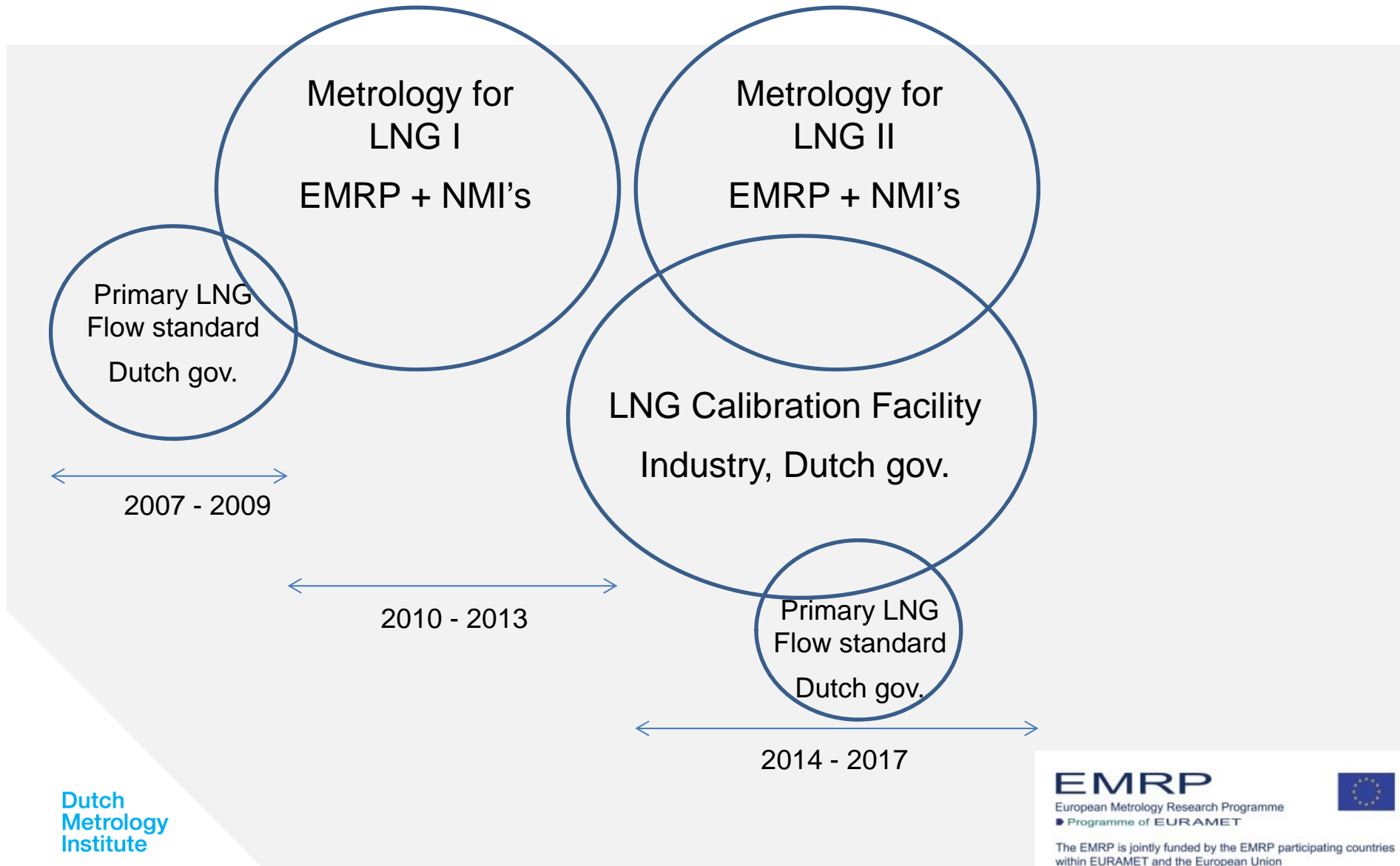






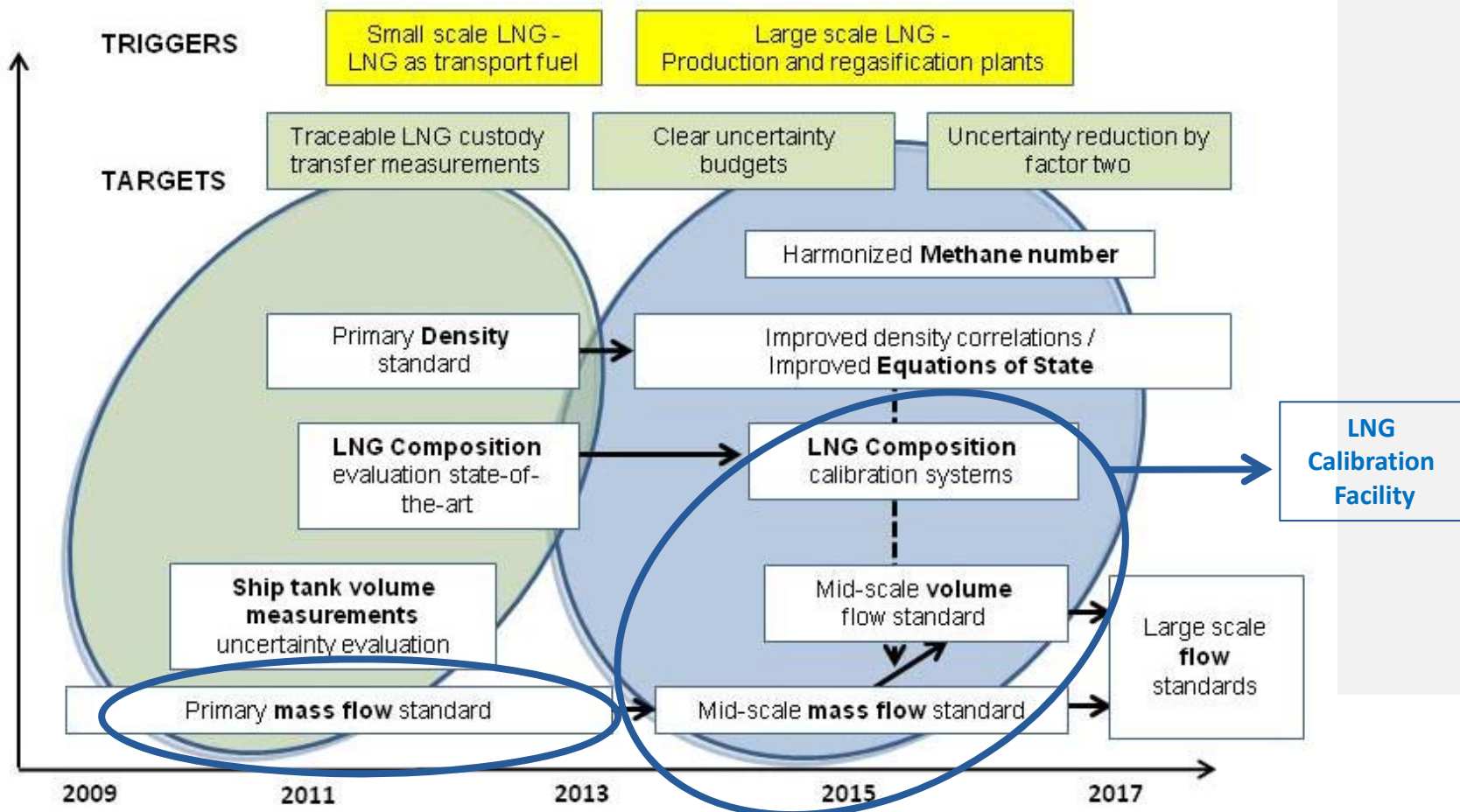


# Overview of R&D projects since 2007



# Metrology for LNG I and II

## Metrology for LNG Roadmap





Volume

Mass

Density

Gross  
Calorific  
Value

Energy

- Developing traceability for LNG flow meters **(WP1)**
- Testing and evaluating LNG quantity metering systems **(WP2)**

- Improving LNG composition measurement systems **(WP3)**
- Reducing uncertainties in LNG density calculations **(WP4)**

- Improving LNG composition measurement systems **(WP3)**
- Reducing uncertainties in calorific value calculations **(WP4)**

**WP5**

Measurement  
Guidelines

Written  
Standards

Legal  
Metrology

**Metrology for LNG I was designed for reducing energy measurement uncertainty**



# Metrology for LNG II



WP No	Work Package Name	Active JRP-Participants (WP leader in bold)
WP1	Mass & Volume Flow Measurements	CESAME, CMI, <b>FORCE</b> , JV, SP, VSL
WP2	Composition Measurements	CMI, <b>NPL</b> , SP, VSL, REG(RUB)
WP3	Methane Number	NPL, PTB, SP, <b>VSL</b> , REG(TUB)
WP4	Density, Enthalpy and Calorific Value	INRIM, NPL, <b>PTB</b> , VSL, REG(RUB)
WP5	Creating Impact	CMI, FORCE, INRIM, <b>JV</b> , NPL, PTB, SP, VSL
WP6	Management and Coordination	FORCE, JV, NPL, PTB, <b>VSL</b>



# Project partners

## Metrology for LNG II





# Some preliminary results

## Flow metering

- CMC of combined primary mass flow standard and flow m.u.t.: 0.12 - 0.15%.
- Coriolis type flow meter tested with the primary LNG flow standard and reference setup (weigh bridge test method)
- Improvements primary mass flow standard => uncertainty below 0.10%
- mid-scale mass and volume flow standard designed and engineered
- new ISO working group working on a draft ISO standard for LNG flow metering
- prototype LDV (Laser Doppler Velocimetry) flow metering standard built and tested

## Composition

- state-of-art of sampling based systems and Raman analyzer method
- reference composition measurement system designed, engineered, constructed
- sampling line system designed and built



## Level metering

- uncertainty evaluation report for tank gauging systems completed
- conclusion: uncertainty commonly used by the industry for transferred volume is underestimated.

## Density

- advanced primary LNG densitometer system => new reference data (very low uncertainty)
- measured data (expanded uncertainty between 0.06 and 0.08%) agreed better with the revised Klosek McKinley (within maximum 0.08 %) than with the GERG-2008 Equations of State
- primary densitometer now further improved to reach 0.05% uncertainty => validate and improve Equations of State





# LNG calibration facility



Scope of facility (flow and composition)

Planning

Sneak preview



# Mid-scale flow standard



## General

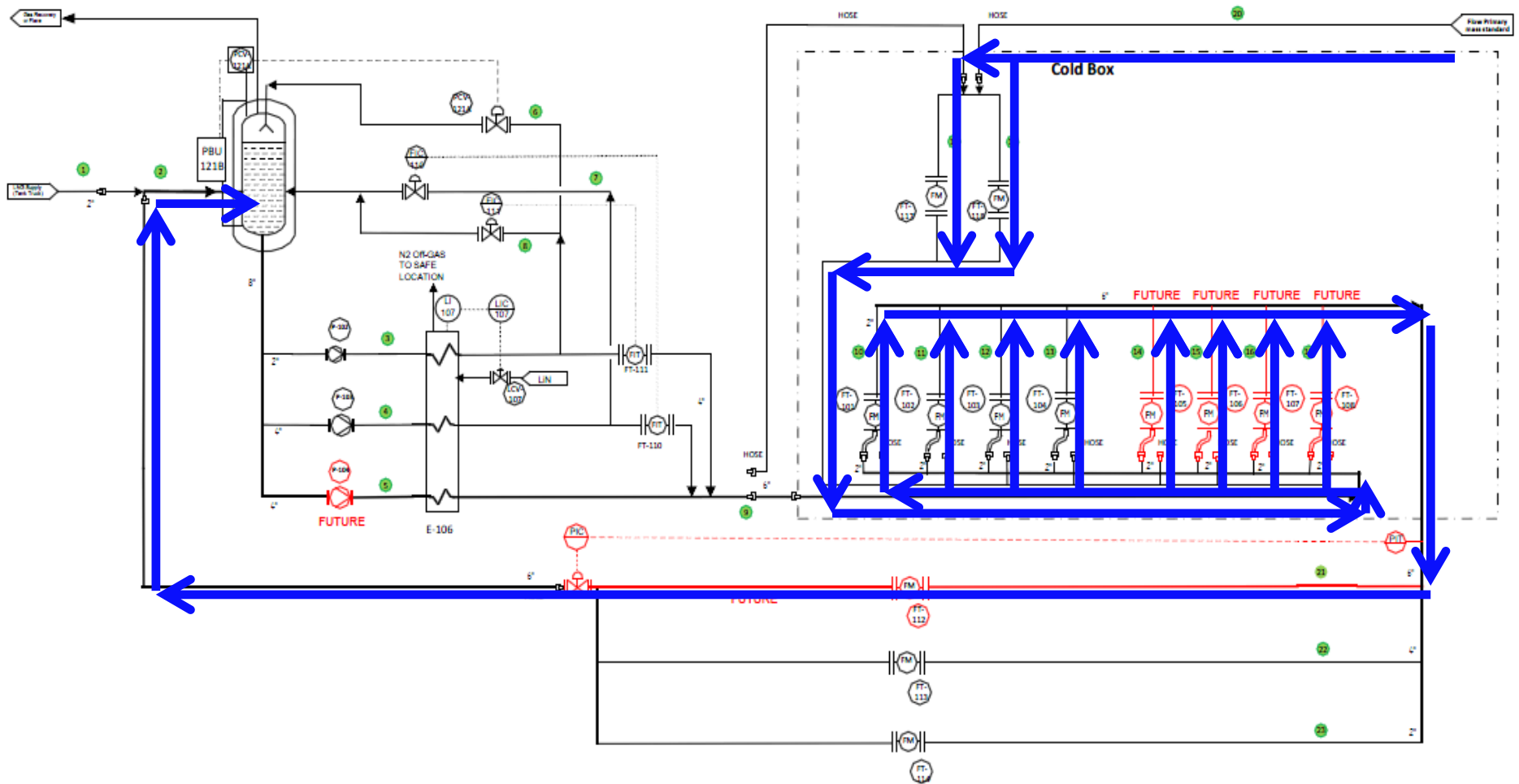
- Traceable to primary standard
- No boil-off, venting of methane to air minimized

## Control parameters

- Flow Rate                      5 – 200 m<sup>3</sup>/h (40 - 1600 kg/min)  
    Expandable to 400 m<sup>3</sup>/h
- Line pressure                      1 – 10 barg(g)
- Temperature                      -123 to -175 °C
- Composition                      Measured, not controlled

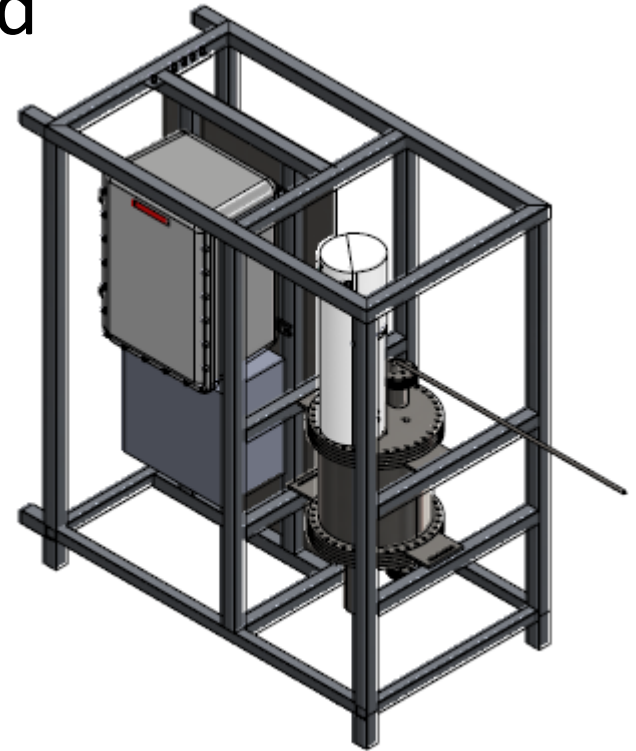


# Mid-scale flow standard



# Composition Standard

- Special design sampler (subcooled conditions)
- Vaporization at conditions above critical pressure
- Gas Chromatograph
- Sampling flow rate at 7,5 ml/min (LNG) / 5 l/min (gas)





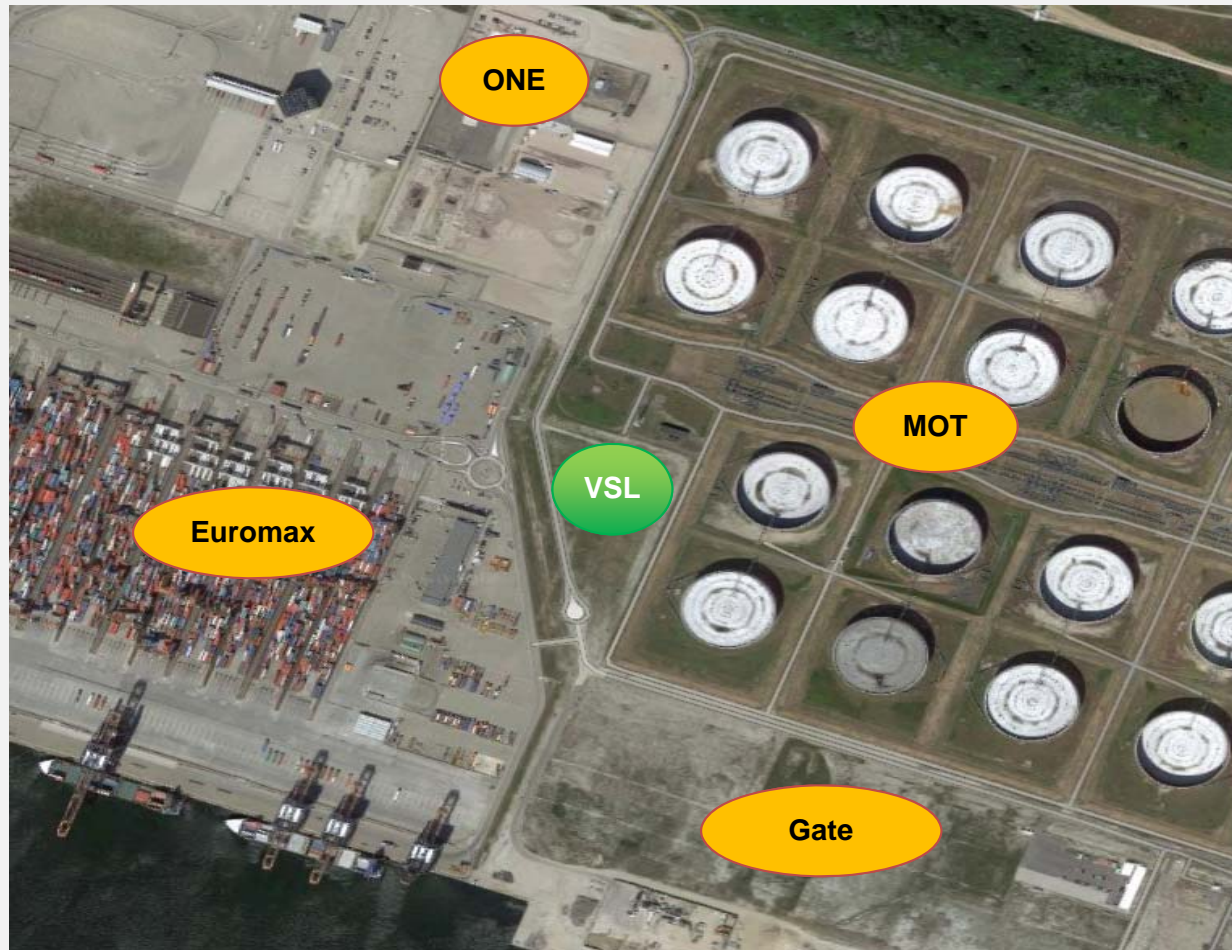
# LNG CALIBRATION FACILITY

## Project milestones

- |                                   |                |
|-----------------------------------|----------------|
| • Functional design               | Completed      |
| • Preliminary engineering         | Completed      |
| • Permitting                      | Completed      |
| • 10% accurate cost estimation    | Completed      |
| • Go-no-go decision               | Completed      |
| • Detail engineering              | In progress    |
| • Placing orders                  | In progress    |
| • Fabrication                     | next stage     |
| • Site preparation (civil)        | July 2016      |
| • Installation & commissioning    | Aug - Dec 2016 |
| • Validation and research program | Jan - May 2017 |



# Location



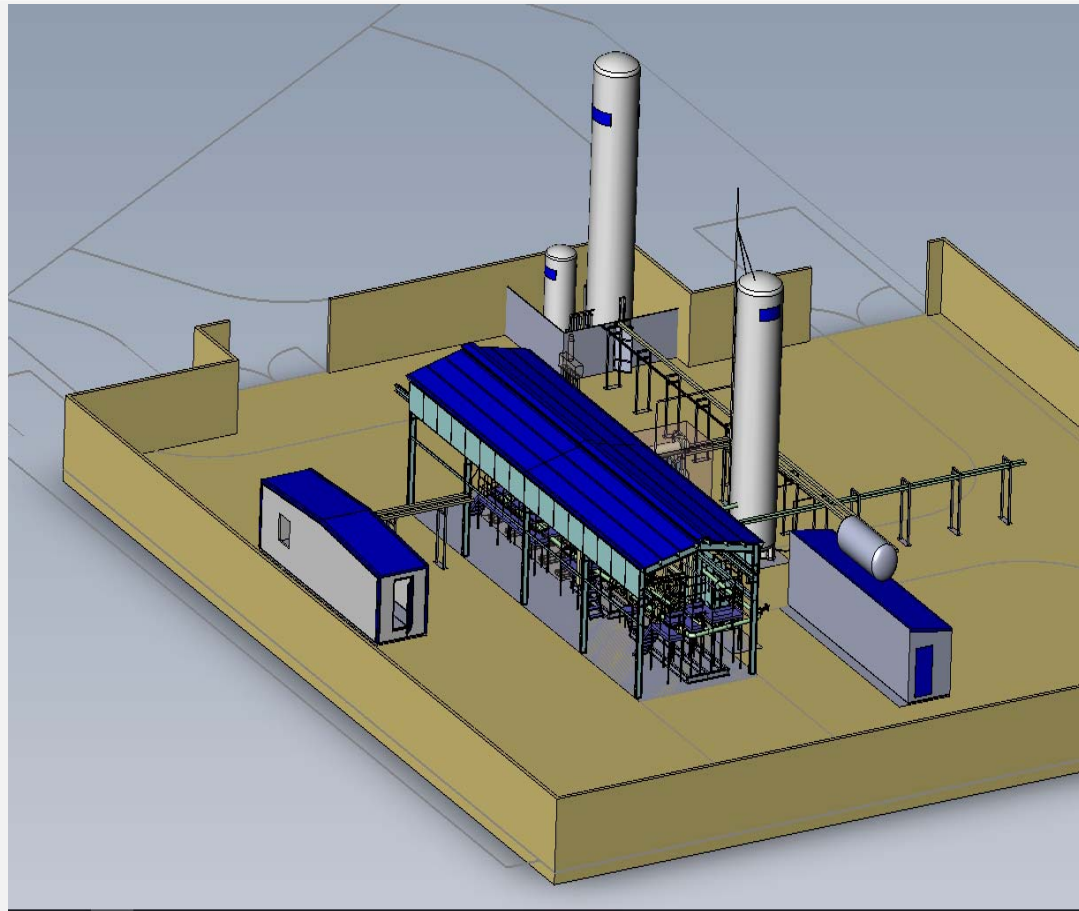


# Location





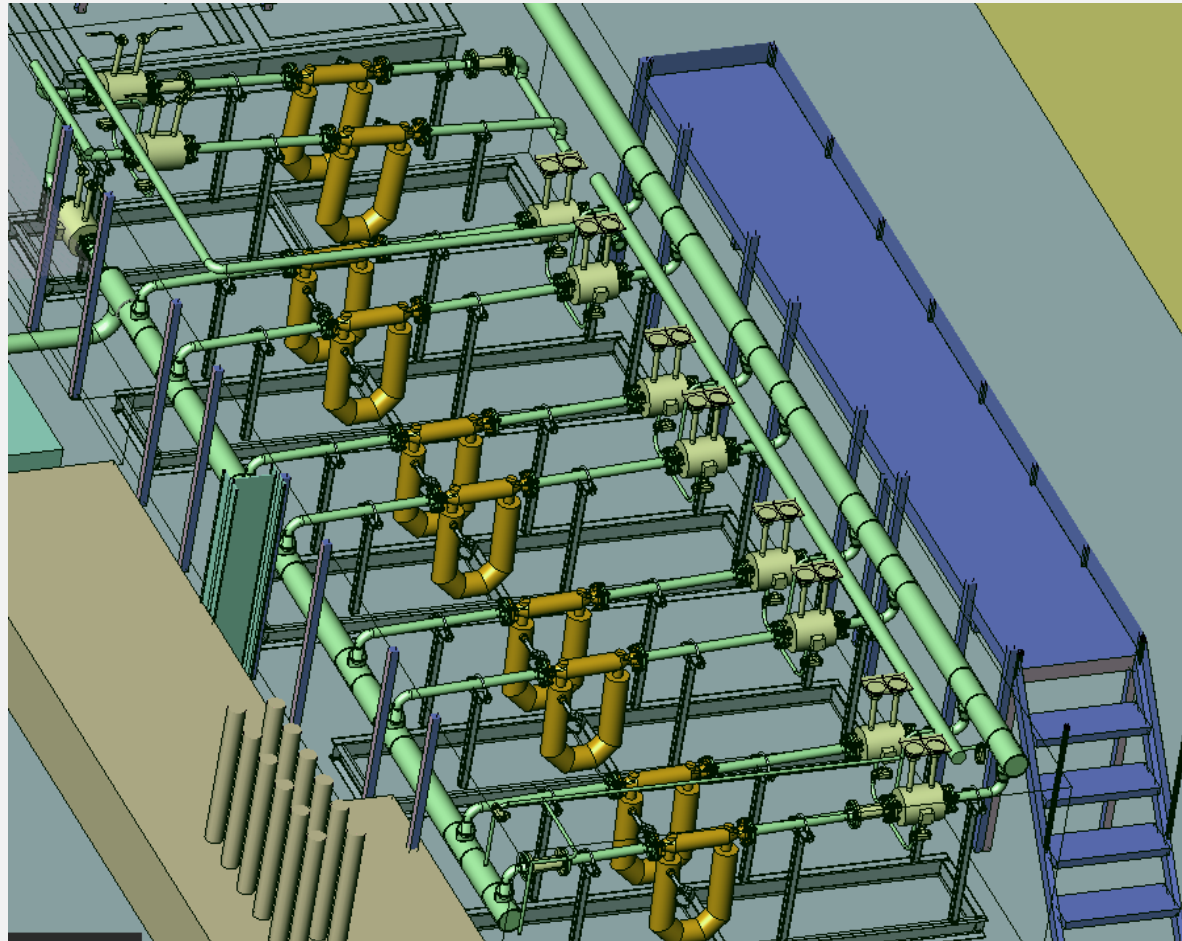
# Overview of Mid Scale & Primary LNG Test Loops





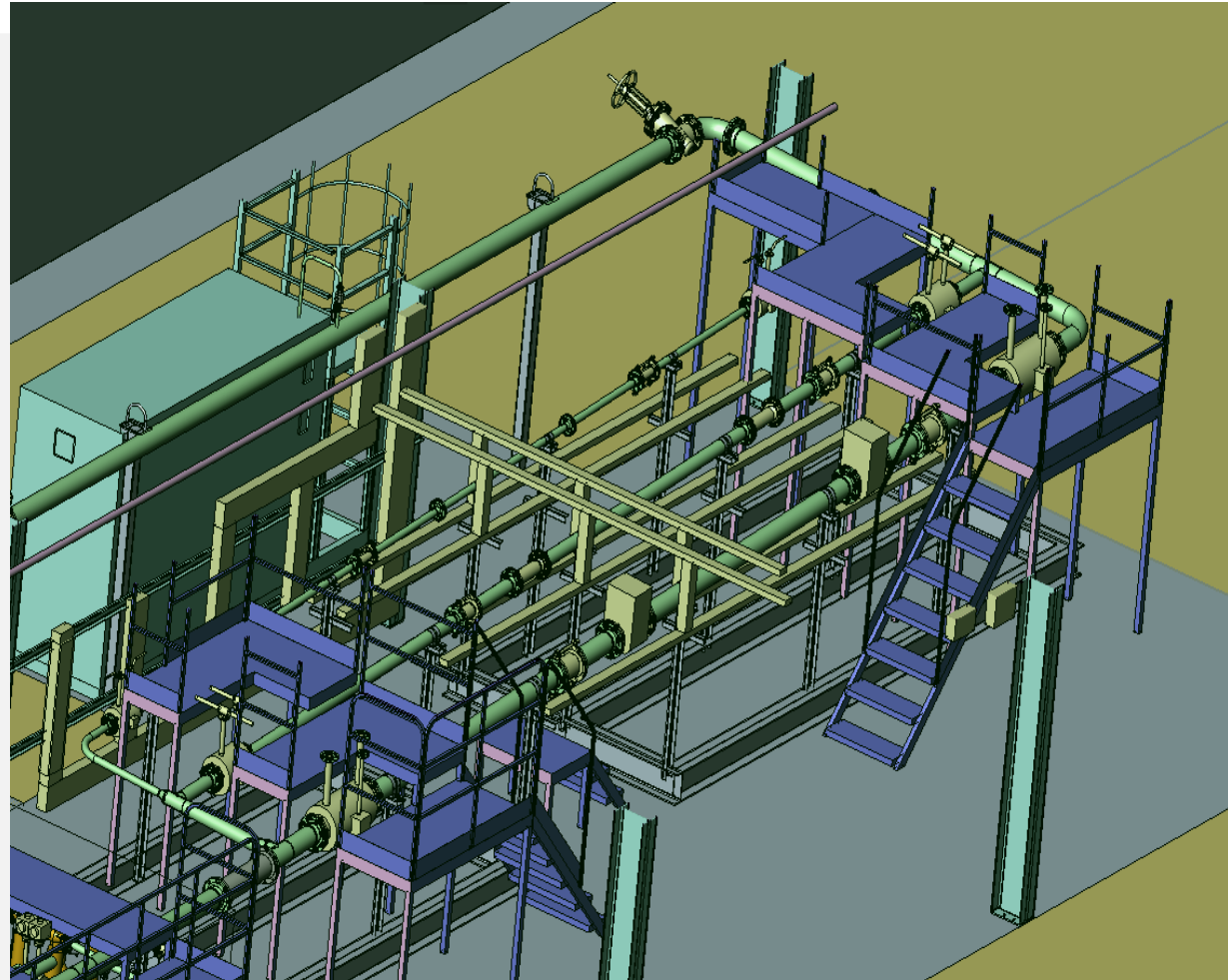


# Battery of Coriolis Master Meters



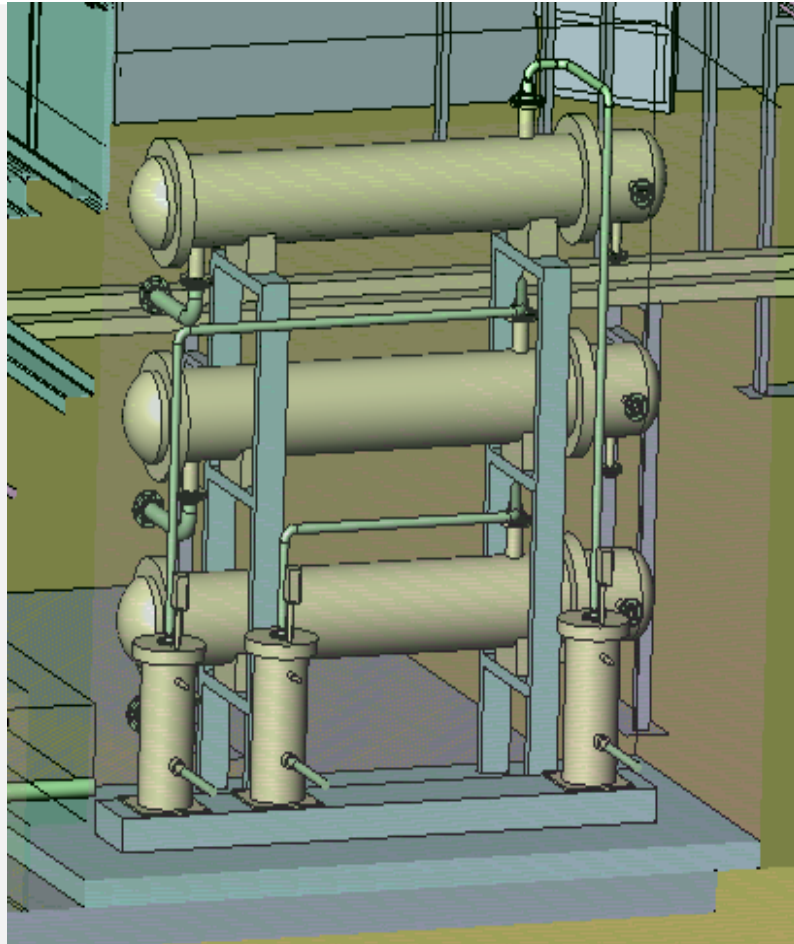


# 3 Adaptable Meter-under-Test Runs





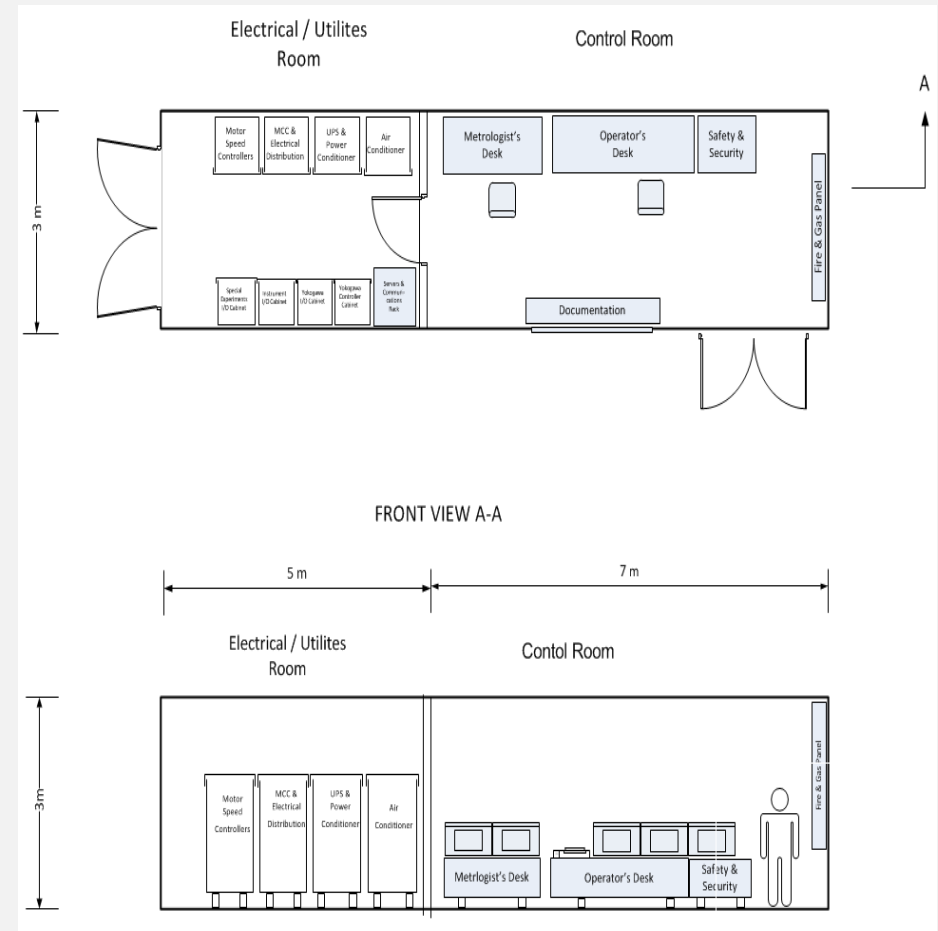
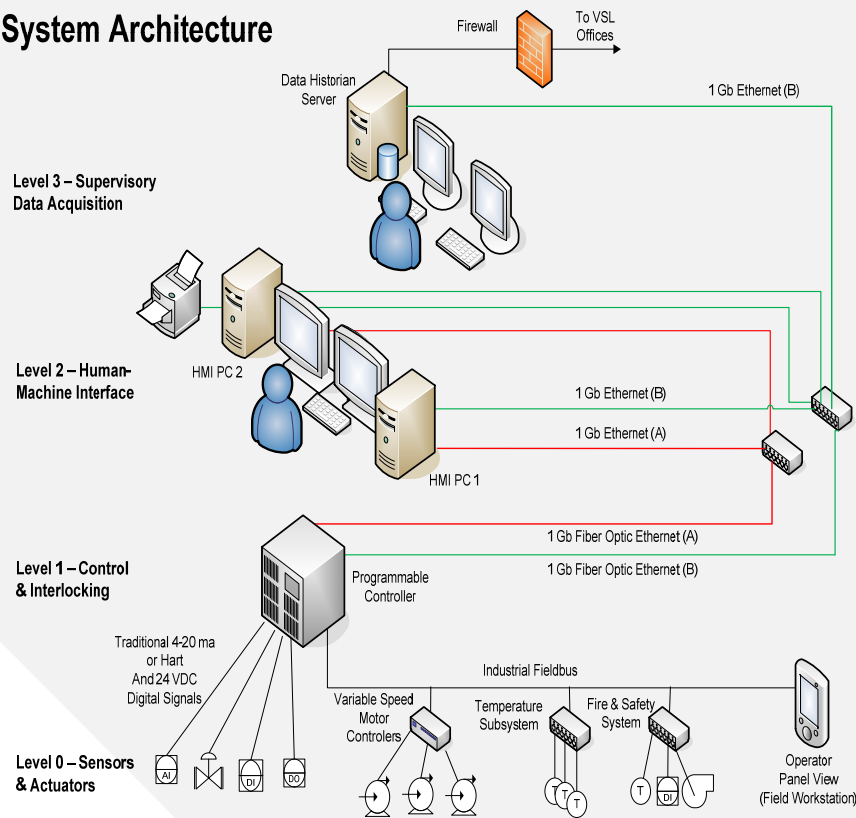
# Submerged Cryogenic Pumps and LNG Subcoolers





# State of the Art Fieldbus Instrumentation, Controllers and Data Acquisition System

## Control and Information System Architecture





# Partners Joint Industry Project LNG calibration facility





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