

# **Status of the Solid Oxide Fuel Cell System Development at Wärtsilä**

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- ❑ Wärtsilä in brief
- ❑ Wärtsilä fuel cell development
  - ❑ Stationary biogas unit
  - ❑ Marine methanol unit
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- ❑ Conclusions

# Wärtsilä in Brief

## Company statement

Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets.

By emphasizing technological innovation and total efficiency, Wärtsilä maximizes the environmental and economic performance of the vessels and power plants of its customers.

In 2010, Wärtsilä's net sales totaled EUR 4.6 billion with 17,800 employees. The company has operations in 160 locations in 70 countries around the world.

Wärtsilä is listed on the NASDAQ OMX Helsinki, Finland.



# This is Wärtsilä







SHIP  
POWER

POWER  
PLANTS

SERVICES



# Wärtsilä Ecotech

Customer need	ECOTECH Offering	
Emission excellence: ▶ NO <sub>x</sub> CO and HC reduction	Catalysts (SCR, Oxicat, etc.)	
Emission excellence: ▶ SO <sub>x</sub> and PM reduction	Flue Gas Desulphurisation & Scrubbers	
Emission excellence: ▶ Emission monitoring	Emission Monitoring Systems	
Total economy: ▶ Energy efficiency	Energy Efficiency (WHRS, etc.)	
Emission & efficiency excellence ▶ Energy efficiency	Fuel Cells	
Emission Compliance	Technical Support and Legislation Knowhow & Promotion	

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# WFC Strategy



## **Vision:**

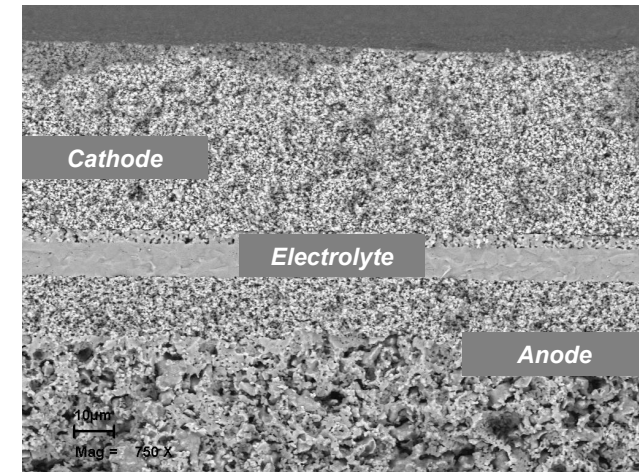
By 2020 the fuel cell technologies have established a position as one of the main energy conversion technologies in distributed generation. Wärtsilä will be among the leading companies in this market.

## **Mission:**

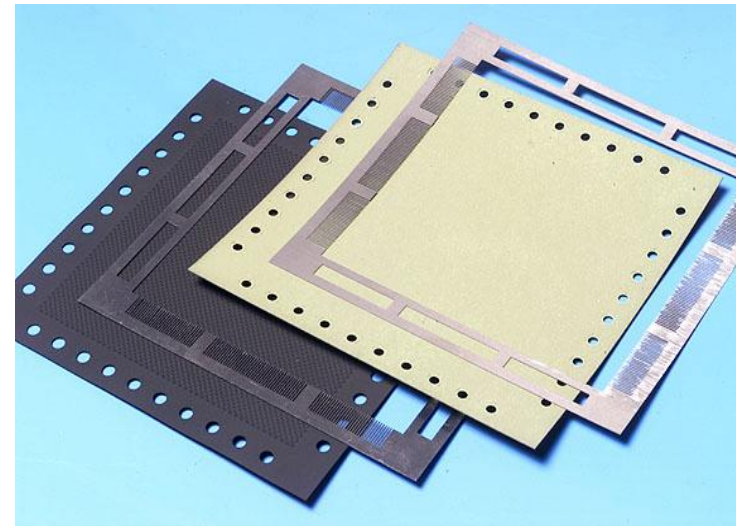
Wärtsilä will generate new business opportunities and support existing product portfolio by developing and commercializing fuel cell products. Fuel cell products will expand Wärtsilä power solutions offering by providing highly efficient and clean power generation products at lower power range (< 5 MW).

# Planar SOFC Stack

- One single fuel cell produces approximately 0.7...0.9 V
- Cells are connected electrically in series
  - 75 cell stack 52.5...67.5 V
  - Nominal stack power 1.2 kW / 2.6kW



**TOPSOE FUEL CELL**  
*clean, efficient and reliable*





# Applications & Customers



Short route ferries, car carriers, cruiser



Biogas from Landfills,  
Waste water and farms



Telecom/data centers, Hospitals, Banks

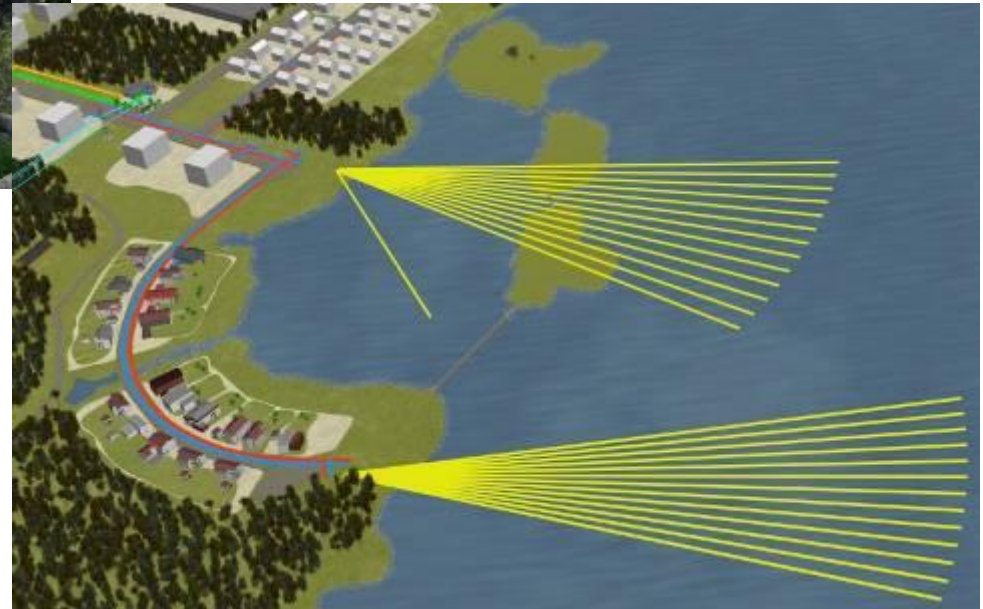


Hotels, malls, offices, industries

# New Energy project, Vaasa Housing Fair



- Landfill gas for SOFC
- Landfill gas for micro turbines
- District low temperature network
- Heat pumps for space heating
- District heating network





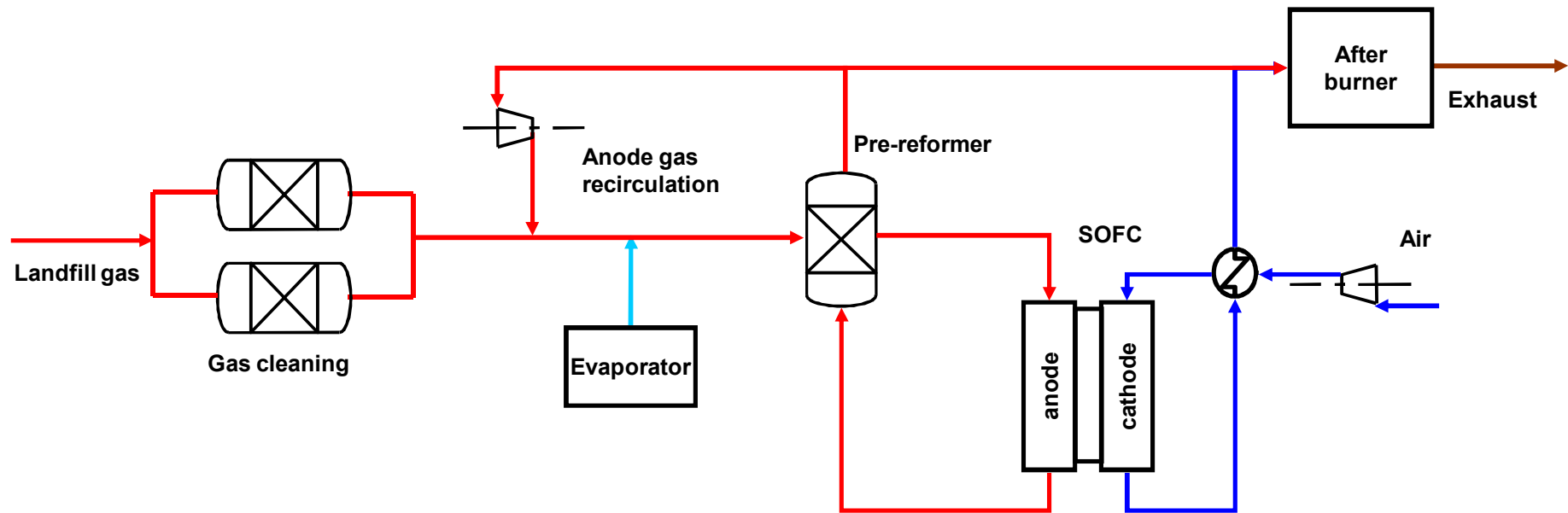
# WFC20 New Energy project

- WFC20 unit for landfill gas
- First planar SOFC operated with landfill gas
- Main achievements
  - Land fill gas operation
  - Gas cleaning
  - 3000 h operation, currently on load
  - Low emissions NO<sub>x</sub>, SO<sub>x</sub> and PM 0 ppm
  - Peak net efficiency 47 %
  - Low noise < 70 dB



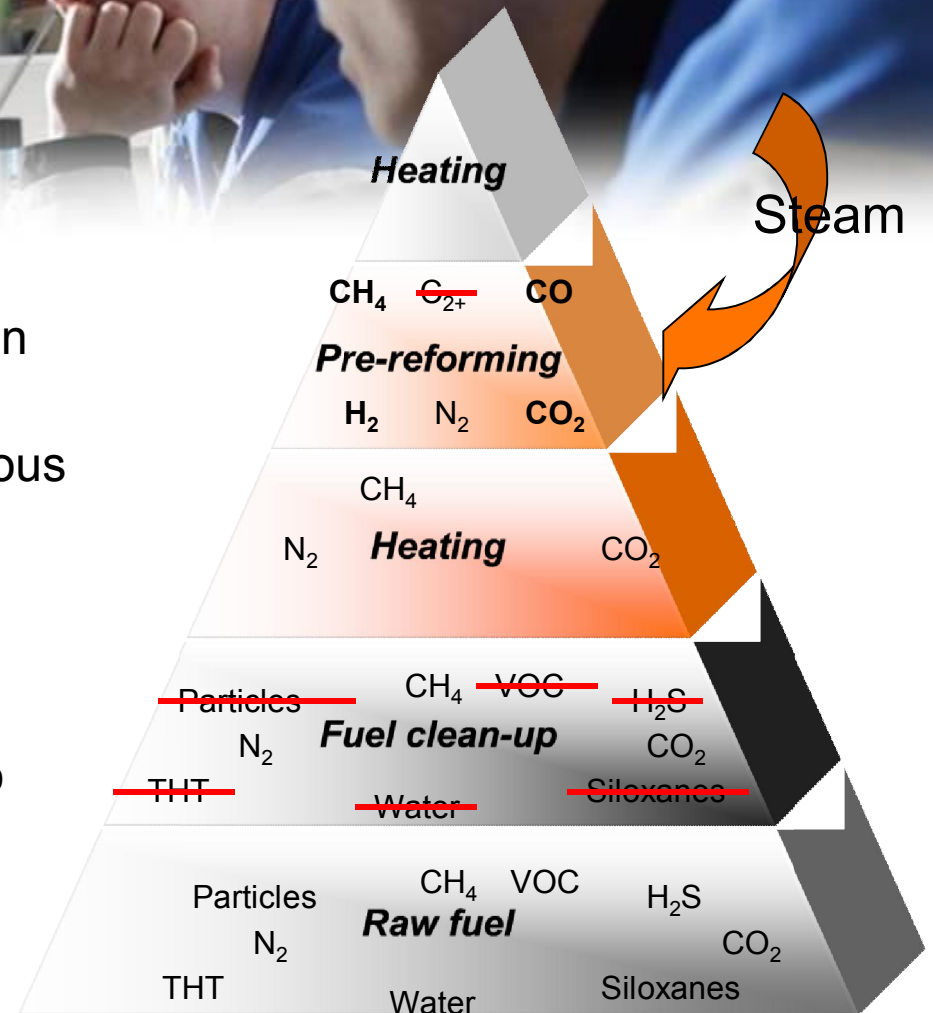


# Wärtsilä FC20 landfill gas unit



# Fuel treatment

- To reach the quality required for the actual fuel cells, fuel has to be treated in several steps
- Raw fuel has to be filtered, and poisonous components removed
- The fuel has to be heated for pre-reforming
- In pre-reforming, hydrocarbons are catalyzed in the presence of steam into mixture of  $\text{CH}_4$ ,  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{H}_2$  and  $\text{N}_2$
- After the final heating step, the gas is ready for the fuel cell



# Impurities after cleaning

Components	Landfill gas	After cleaning (new)	After cleaning (old)
<b>Siloxanes</b> TMS MOH L2 L3 L4 D3 D4 D5	~150 ppm	Below detection limit < 1 ppm	Below definition limit < 5 ppm
<b>VOC</b> Benzene Toluene Ethylbenzene Xylene	~100 ppm	~0.1 ppm	~0.1 ppm
<b>Sulfur</b> H <sub>2</sub> S DMS Ethyl mercaptan	~20 ppm	Below detection limit < 1 ppm	Below detection limit < 1 ppm
<b>Halogen hydrocarbons</b> R11 R12 Chlorine/Fluorine-compounds	~100 ppb	Below detection limit < 10 ppb	< 50 ppb
<b>Particles</b> Na Al Si K Ca Mg Fe Cl Au S Cr...	< ppb	<< ppb	<< ppb
<b>Oxygen</b>	~ 0.1 %	~ 0.1 %	~ 0.1 %



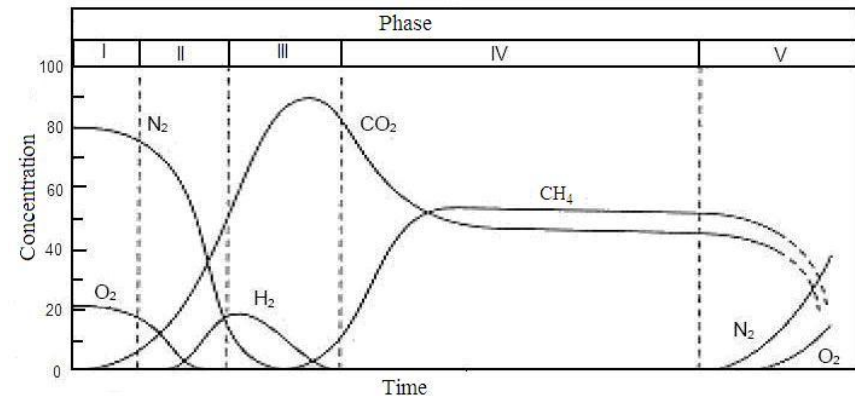
WÄRTSILÄ



# Lifetime of a landfill station

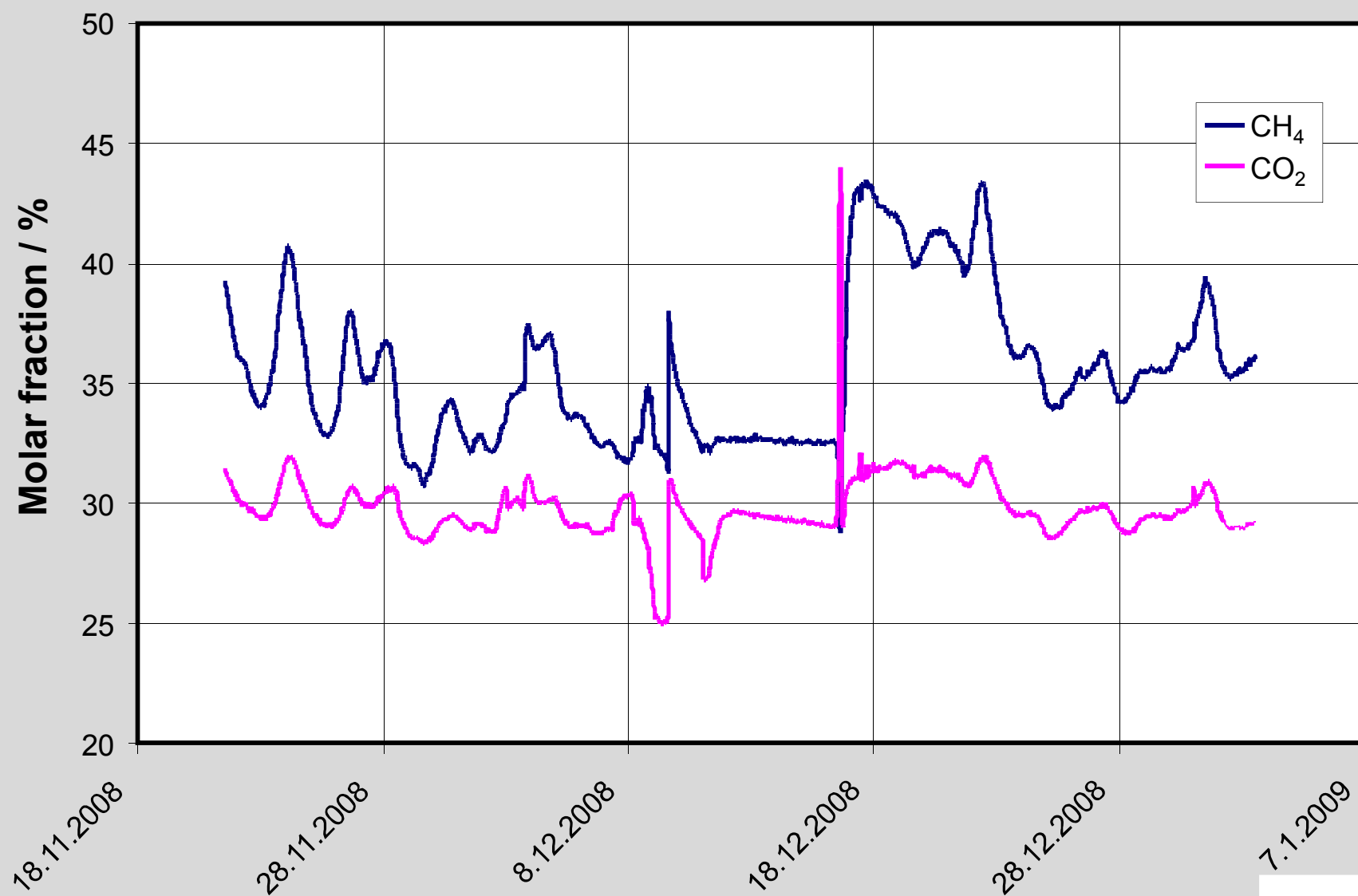


- Lifetime of a landfill station in means of gas formation can be divided into five phases
  - Phase I: aerobic phase, ~ 2 weeks
  - Phase II: acid phase, ~ 2 months
  - Phase III: acetogen phase, ~ 2 years
  - Phase IV: methane phase, pH is increased and methane bacteria works best, ~ 20 years
  - Phase V: humus phase, nutriment is consumed and air leakages increase



P. Väisänen, J. Salmenoja, Biokaasun muodostaminen ja sen hallittu käsittely kaatopaikoilla, (<http://www.biokaasuyhdistys.net/docs/kaatgas.pdf>, 31.12.2008)

# Biogas quality variations

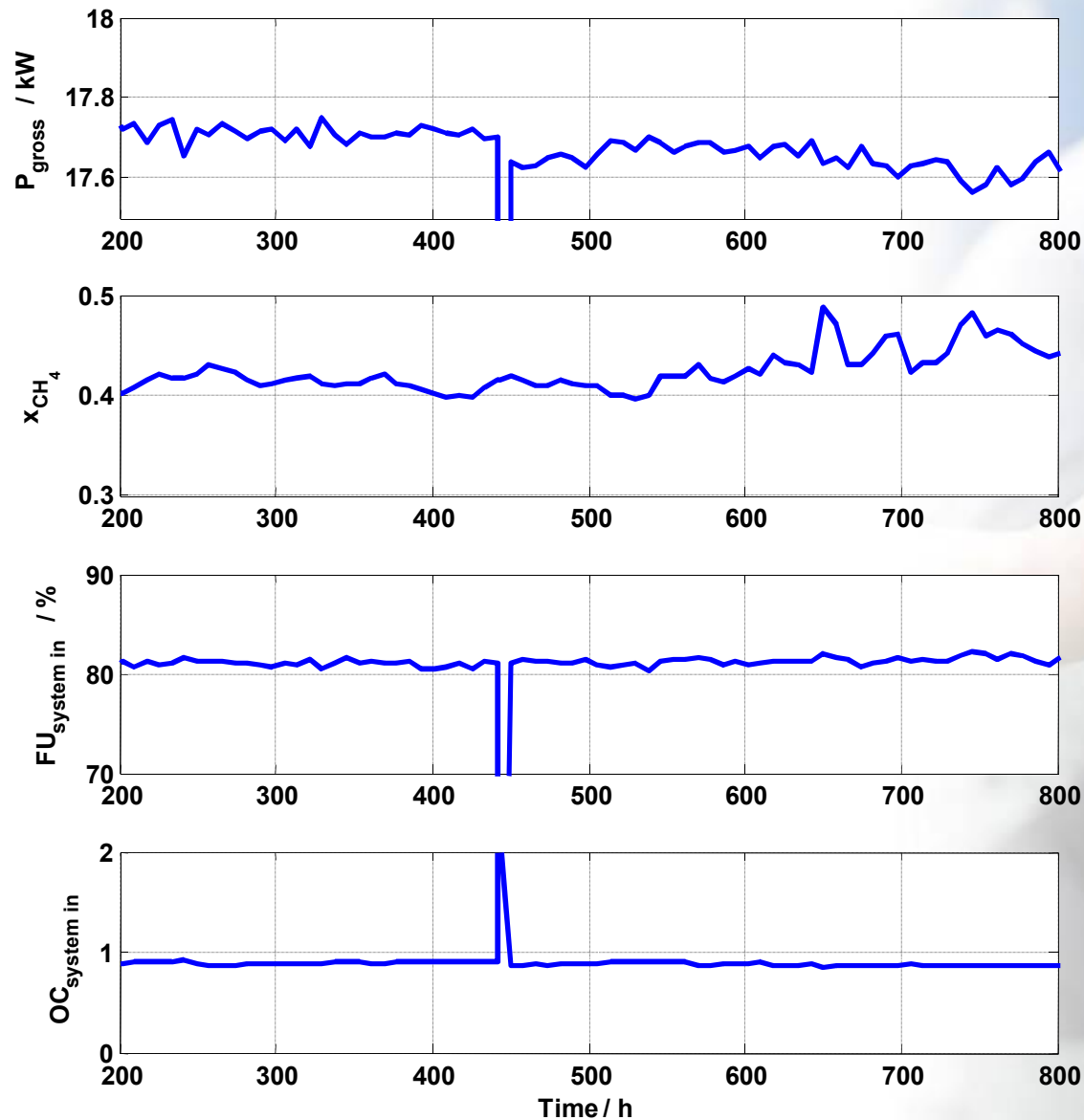


# Requirements for process control

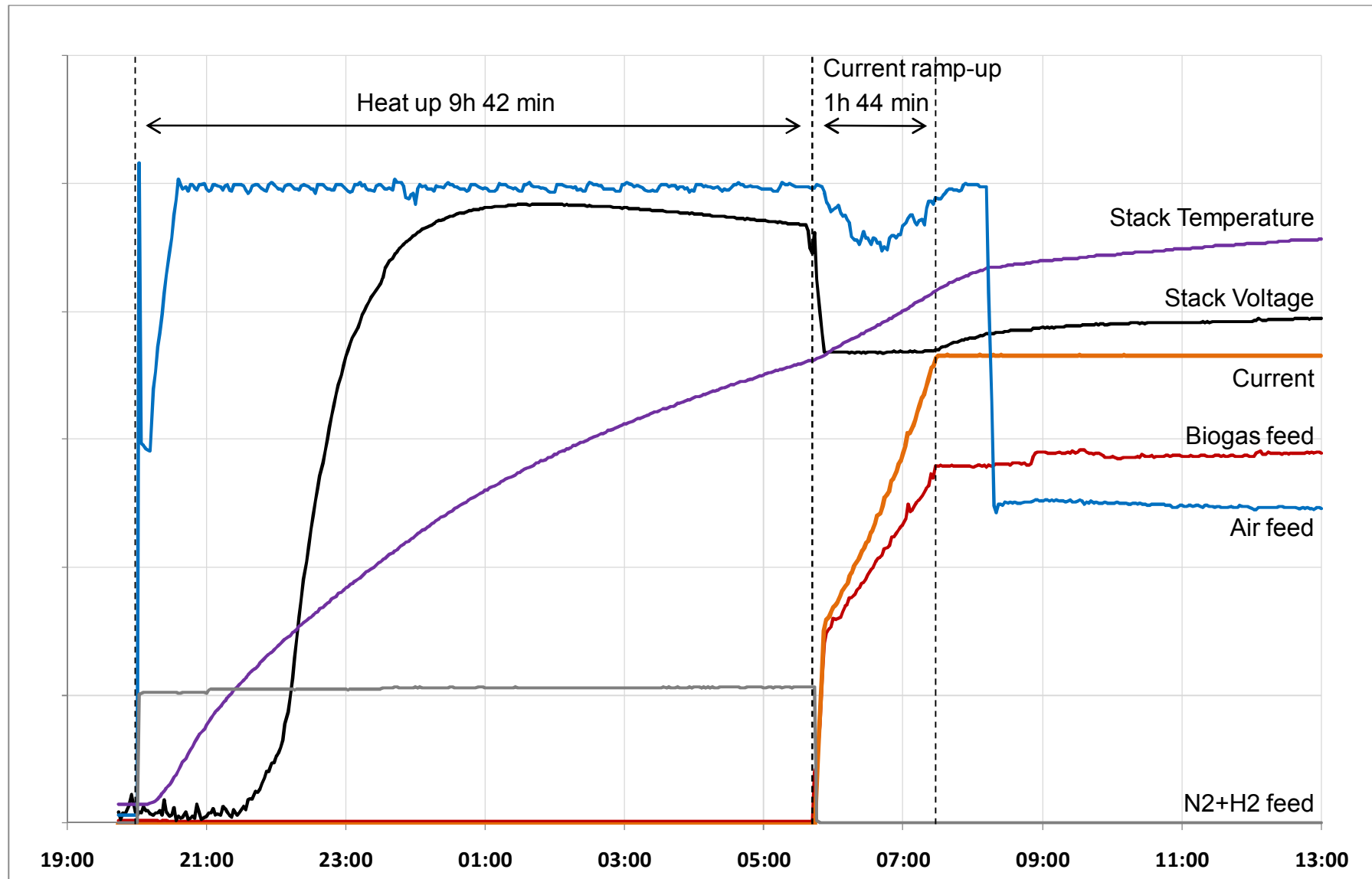
- Methane variation: 30 – 50 %
- Carbon dioxide variation: 25 – 38 %
- Fuel utilization:
  - mass flow control has to handle different gas compositions
  - online measurement for inlet gas composition required
- Oxygen-to-carbon-ratio
  - varying carbon formation region
  - steam flow has to be adjusted
  - flow rate and composition in anode gas recycle loop have to be known
- Heat management
  - heat value varies with  $\text{CH}_4$
  - air flow to the afterburner has to be controlled according to the inlet conditions



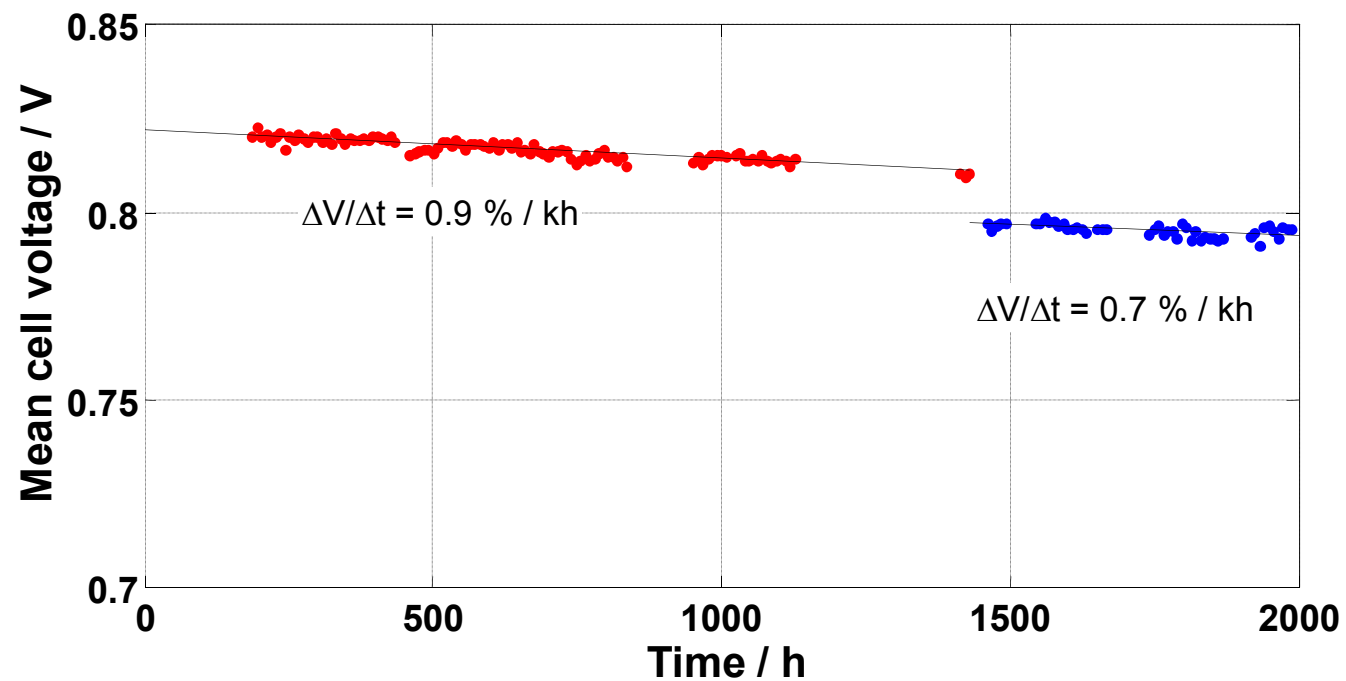
# Actual system response during stable operation



# WFC20 Autonomous Cold Start on Biogas



# Steady state degradation of WFC20





# METHAPU Project

“Validation of a Renewable Methanol Based Auxiliary Power System for Commercial Vessels” (METHAPU)

- Main Objectives
  - WFC20 development for Marine application
  - Validation of methanol fuelled SOFC unit
  - Installation and commissioning on-board
  - Field testing on-board in Marine environment



# Methanol based WFC20 unit

- METHAPU project
  - Laboratory testing completed
  - Methapu: regulation work together with Loyds Register
  - Extensive safety assessment conducted in the design phase
  - Demonstration on board of Wallenius Wilhelmsen
- METHAPU sea trial successfully completed



# METHAPU project

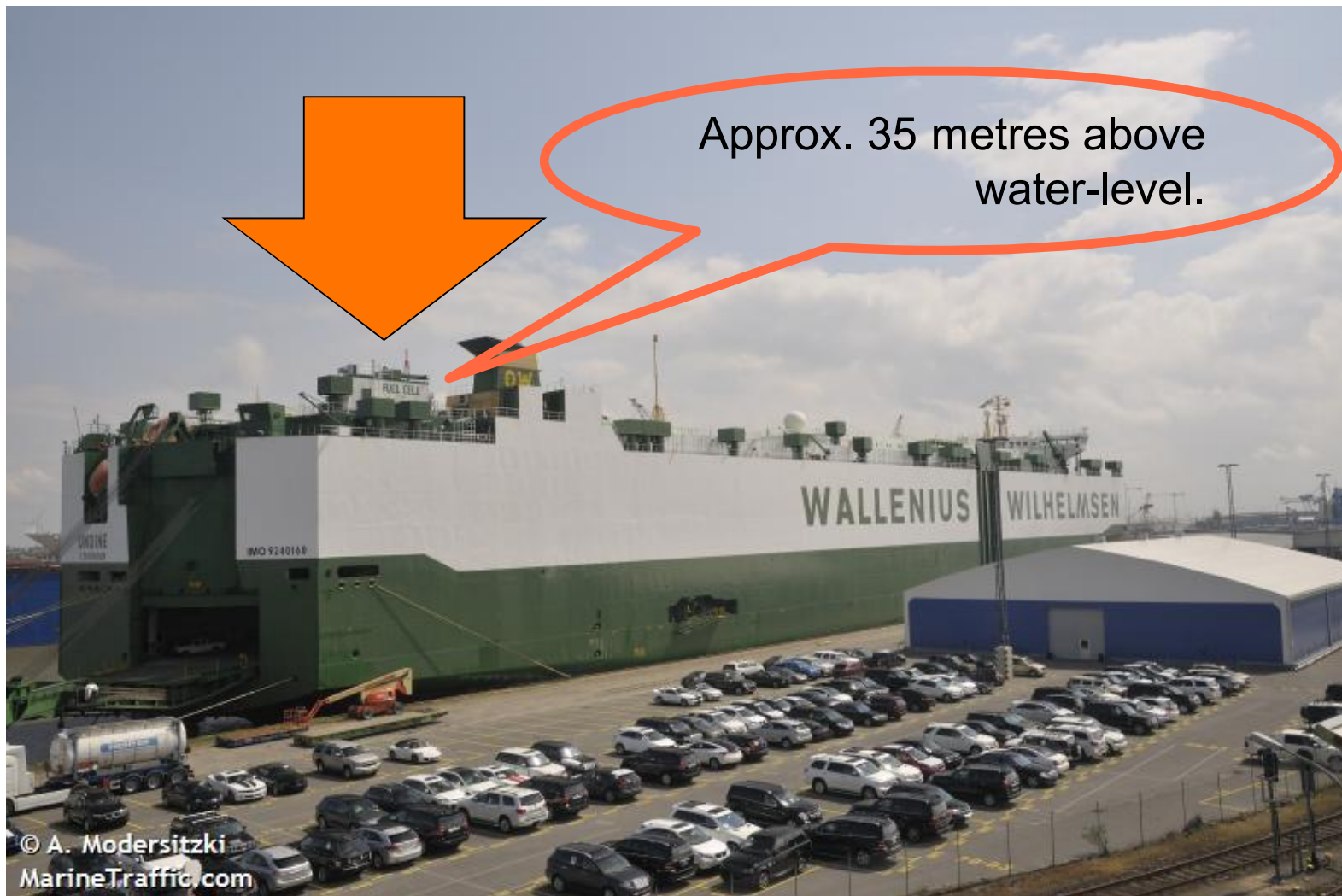
## Marine application environment

- Vibration
  - Vibrations from ship machinery
  - Ship movements due to rough sea
    - Requirement  $\pm 22.5^\circ$  inclinations
- Temperature
  - Varying temperature depending on location
    - Requirement  $-25...+45^\circ\text{C}$
- Moisture
  - Humidity in inlet process air
  - Condensation on cooled electric circuits
- Salt
  - Oxidation risk
  - Hot corrosion in process
  - Effect on cells





**Here she is!**





# Wärtsilä Fuel Cells

From 20kW towards 250kW Unit size



**WFC20**  
**α-Prototype**  
20kW  
NG  
41 % eff



**WFC20**  
**New Energy**  
Land fill gas  
> 43 % eff



**WFC20**  
**Methapu**  
Methanol  
> 43 % eff

**2 x WFC50,**  
50kW  
NG, Biogas  
~47 % eff  
Under testing



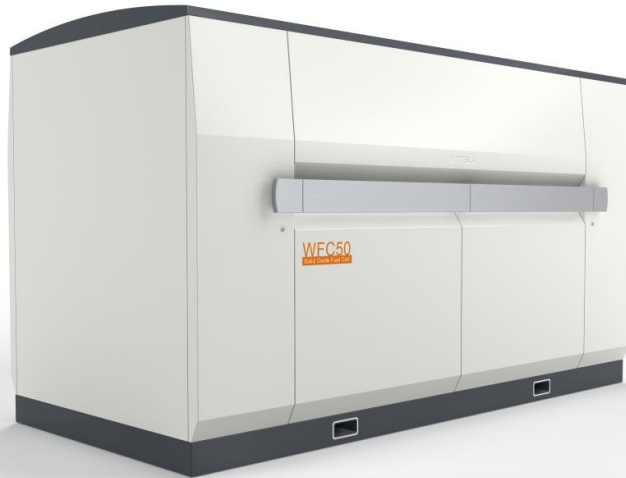
**WFC50 mkII**  
50kW  
NG  
~53 % eff



**WFC X00 concept**  
X00 kWe  
NG, methanol, bio gas  
 $\eta_e > 55 \%$



# WFC50 mkII



- Next generation WFC50 power unit
  - Improved performance
  - Reduced size and weight
  - Improved maintainability
- Modularity for different fuels

Emissions	
NOx	< 2 ppm
CO2	< 0.36 g/kWh
THC	< 3 ppm
Noise	< 65 db

WFC50 mkII	Targeted value (BoL)
Fuel	NG /BG
Fuel in LHV (kW)	103
Net power output (kW <sub>AC</sub> )	54.8
Gross stack output (kW,DC)	67
Electrical eff. (LHV)	53%
Overall eff. (LHV)	69%
Thermal output (kW)	17
Size (WxLxH) (mm)	1600 x 3500 x 2050

# Conclusions



- Fuel cell technologies have potential to provide ultra clean and efficient power both for marine and distributed generation applications
- Wärtsilä has established a position among the leading SOFC developers
- Both use of methanol and land fill gas have been demonstrated
- WFC20 and WFC50 units will provide extensive experience over SOFC in marine and biogas applications
- Strong focus on R&D and on the development of manufacturing processes will be continued before commercialization

**Thank You !**



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