2nd International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 27-28 September 2016

Performance Evaluation of Large Scale Innovative Systems of Waste Heat Recovery from Urban Facilities to Improve Efficiency of District Heating and Cooling Systems in Cities

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4th Generation District Heating Technologies and Systems

Presentation Summary

- CELSIUS Project
- CELSIUS Demonstrators
- Monitoring Methodology
- Key Performance Indicators
- Conclusions

CELSIUS Project Overview

- Gothenburg, London, Genoa, Cologne, Rotterdam
- 20 partner organizations
- Duration: April 2013 – December 2017
- 12 new demonstrators + 20 existing demonstrators
- 58 replication cities (as of September 2016)
- Total budget 26 M€ (EU contribution 14 M€)

CELSIUS Project Partners

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Stadt Köln
RheinEnergie
COMUNE DI GENOVA
D'APPOLONIA
UNIVERSITÀ DEGLI STUDI DI GENOVA
GENOVA RETI GAS
City of Gothenburg
Göteborg Energi
SWEDISH ICT
IMCG
SP
ISLINGTON
LSE THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE
UK Power Networks Delivering your energy
GREATER LONDON AUTHORITY
Imperial College London
Gemeente Rotterdam
Warmtebedrijf Rotterdam
TU Delft Delft University of Technology

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CELSIUS Opportunities

- Recovery of waste/renewable energy
- Storage and load control
- Development of ICT tools for the optimization of energy management
- New applications of the district heating for end-users
- Expansion of the existing district heating network
- Empowering the knowledge from DHC solutions with existing demonstrators

CELSIUS Demonstrators at a Glance

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System Integration

- Control system for efficient energy use
- System integration with other municipalities
- Vertical City – integrated systems
- Alternative heat supply solutions
- Heat hub to increase network capacity
- Integrated district-wide energy network

Sustainable Production

- Cooling by river water to homes
- Residential heating with biogas
- CHP and biofuels
- Recovery of waste incineration heat
- Vertical city "De Rotterdam" – biofuel co-generation
- Waste incineration heat distribution
- Integrating cooling solutions

Storage

- Short-term thermal storage
- Heat hub – storage
- Buildings for short-term storage

Infrastructure

- Total production and distribution system
- Heat hub to increase efficiency
- Small district heating system
- Connection to existing buildings
- Extension of district heating system

End User

- District heating for ships in harbour
- District heating to white goods
- Local energy efficiency initiative
- Climate agreement
- Industrial ecology
- Datacenter 1 Rotterdam
- Datacenter 2

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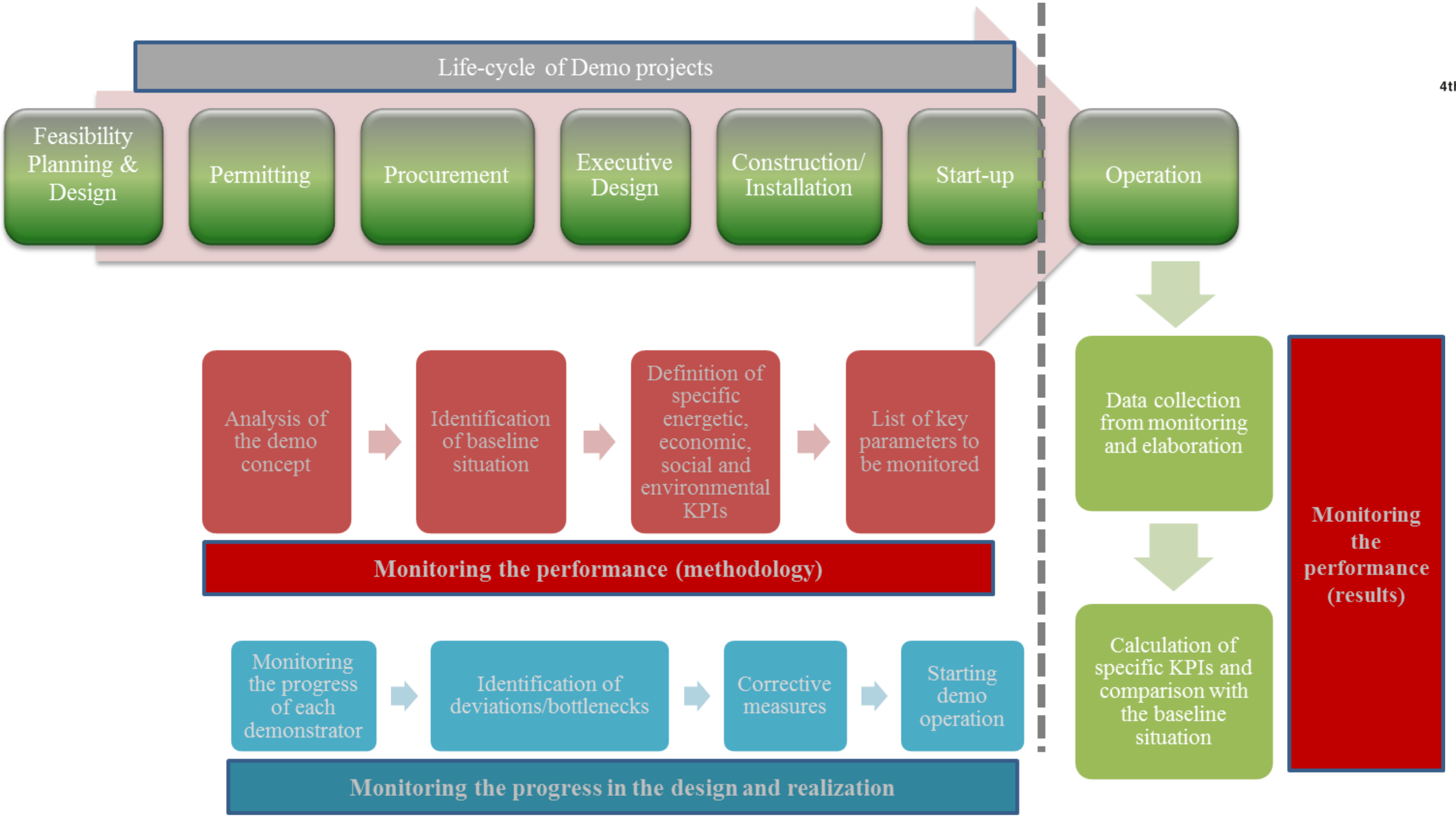
Monitoring Objectives

- Monitoring demo technologies means:
  - to keep project development under control, thus preventing critical issues or minimizing reaction time if problems occur
  - to investigate replicability conditions and possible enhancements to maximize systems' efficiency and minimize CAPEX/OPEX, primary energy needs and GHG emissions
  - to overcome technical and non-technical barriers (lack of awareness/information on resources and technologies available) and to create knowledge for possible investors

Monitoring Procedure

- Identify specific KPIs for energy, environmental and socio-economic performance of each demonstrator
- Define specific protocols for collecting data and monitoring demonstrators
- Periodically collect data and calculate KPIs
- Analyze KPI values to:
  - achieve deeper knowledge of demo technologies' operation during the year
  - evaluate costs and benefits of tested solutions
  - identify replication conditions
- During demo realization phase, monitoring also means:
  - optimizing business models, permitting procedures (unclear for innovative demos)
  - promptly adopting corrective actions for possibly occurring issues

Monitoring Procedure



Key Performance Indicators

- General KPIs

	General KPIs	UM
ENERGETIC	The yearly amount of thermal energy produced/provided by the new system	kWh/year
	Saved primary energy in comparison with baseline situation	kWh/year
	Energy efficiency of the project	%
	Energy recovery from waste/renewable sources	kWh/year
ENVIRONMENTAL	Yearly GHG savings in comparison with the baseline situation	%
	Yearly GHG emissions related to the project	ton CO_2 e/year
	Yearly pollutant emissions related to the project	kg/year
	Yearly reduction of polluting emission in comparison to baseline	
	Carbon footprint	ton C /year
	Ecological footprint	ha
ECONOMIC	IRR of the new investment	%
	Net present value	€
	Yearly depreciation rate per kWh of saved primary energy	€/kWh
	Yearly depreciation rate per ton of saved CO_2e	€/t CO_2e
	Total cost (yearly depreciation rate + OPEX) per kWh of saved primary energy	€/kWh
	Total cost (yearly depreciation + OPEX) per ton of saved CO_2e	€/t CO_2e
SOCIAL	Number of residents/users benefitting of the new project	
	Reduction/increase of complaints due to the implementation of new system in comparison with baseline situation	
	Variation of working hours per year for O&M of the new system in comparison with baseline situation	hours/year
	The internal floor area served by the new system	m^2

+ Specific KPIs

Case Studies: Selected CELSIUS Demonstrators

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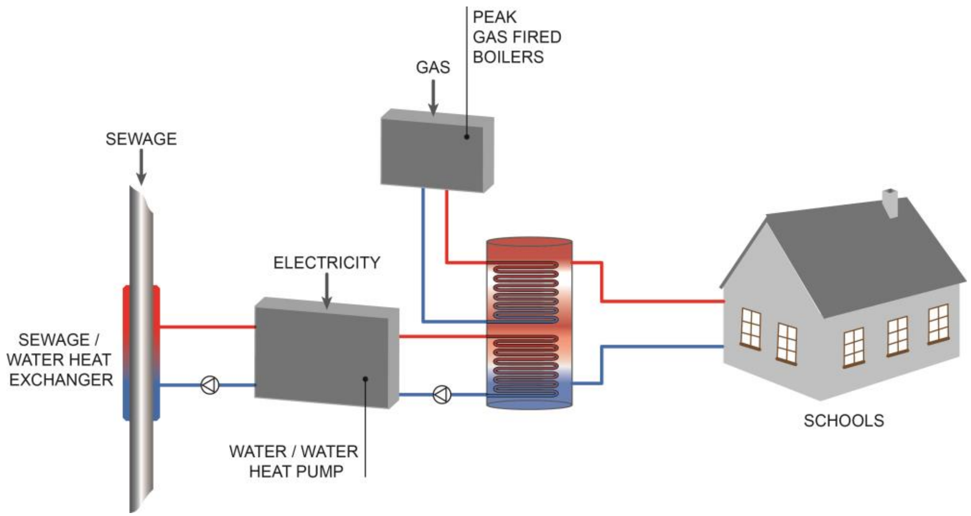
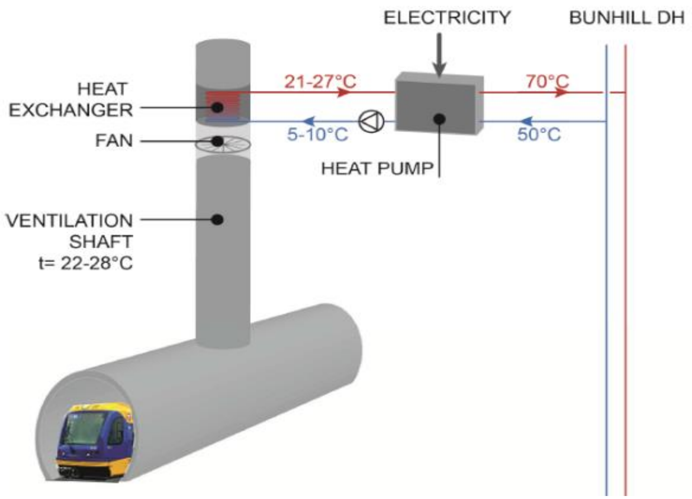
Alternative Heat Supply Solutions

- Heat Recovery from Sewage Water in Cologne
- Waste Heat Recovery from Tube Ventilation in London

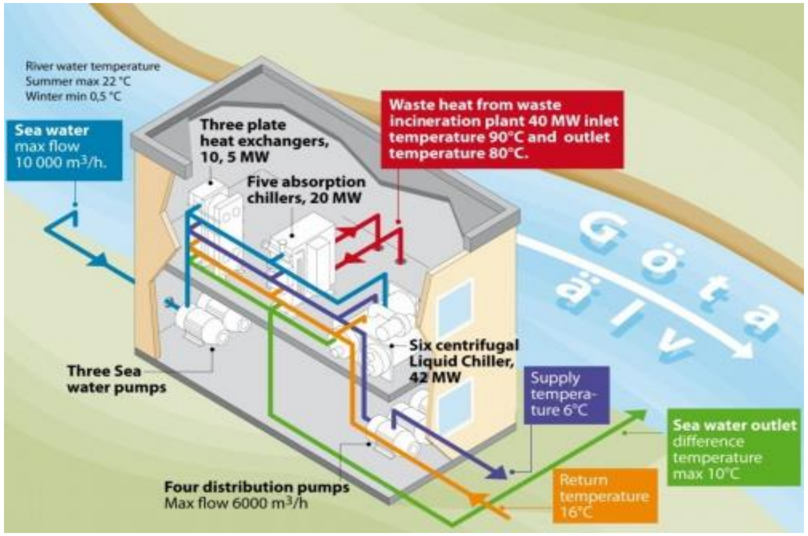


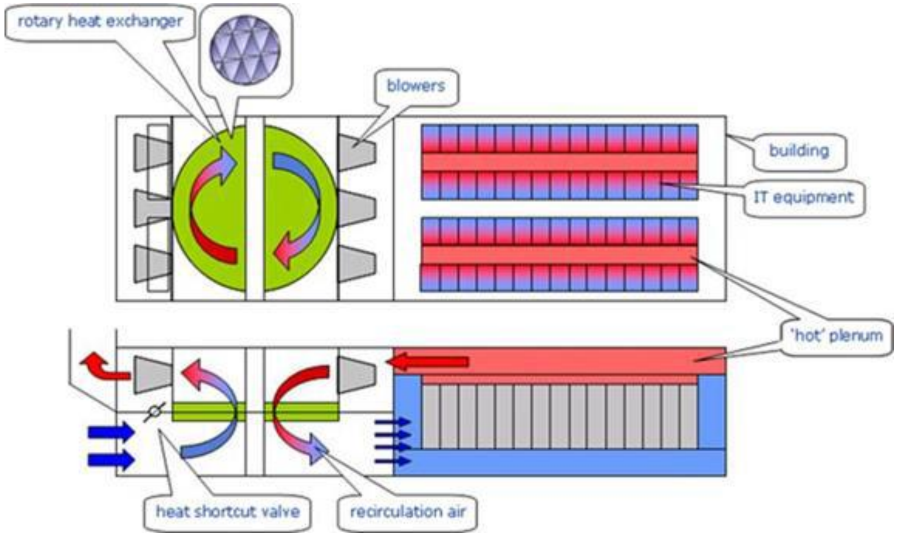


- baseline: heating with NG-fired boilers

Free Cooling Solutions

- Cooling by River Water in Gothenburg
- Efficient Cooling of Datacenters in Rotterdam

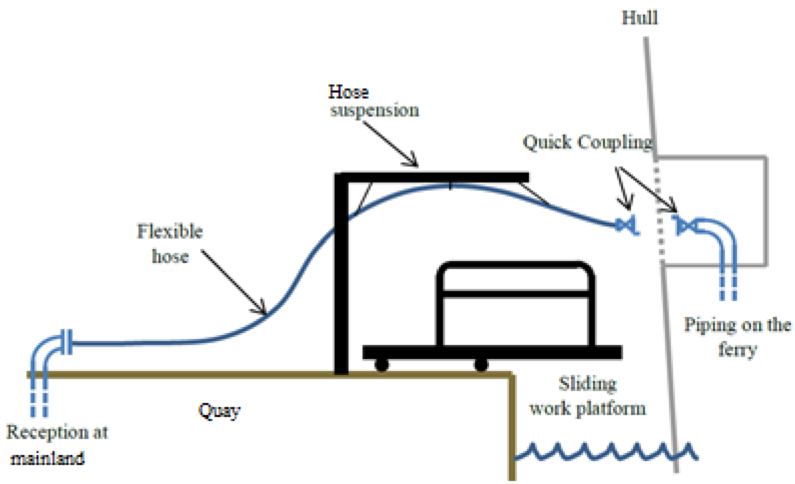


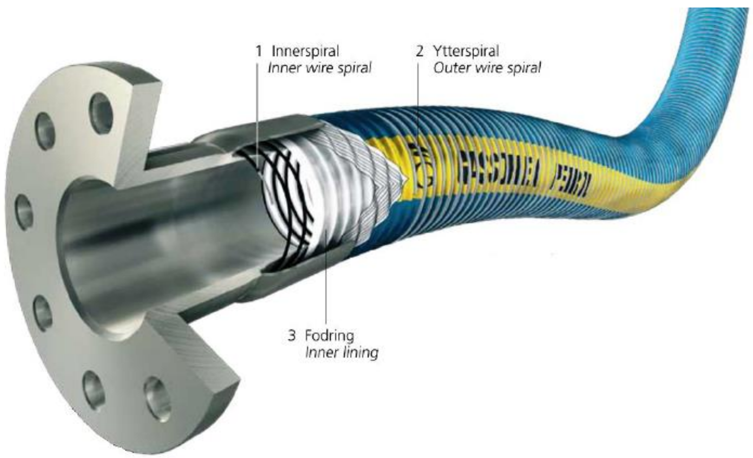


- baseline: cooling with conventional electric chillers

End-Users Solutions

- District Heating to Ships at Quay in Gothenburg



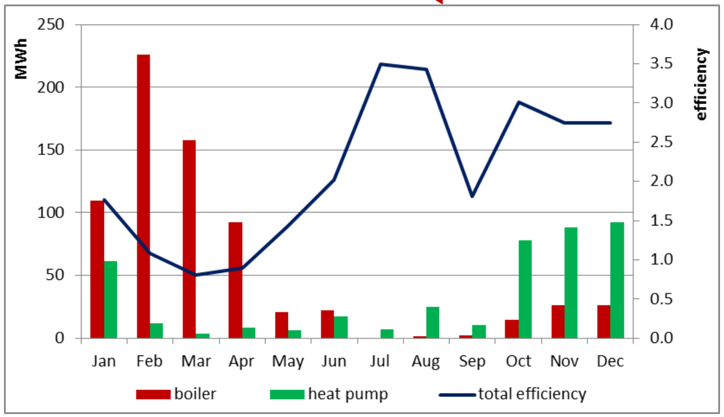


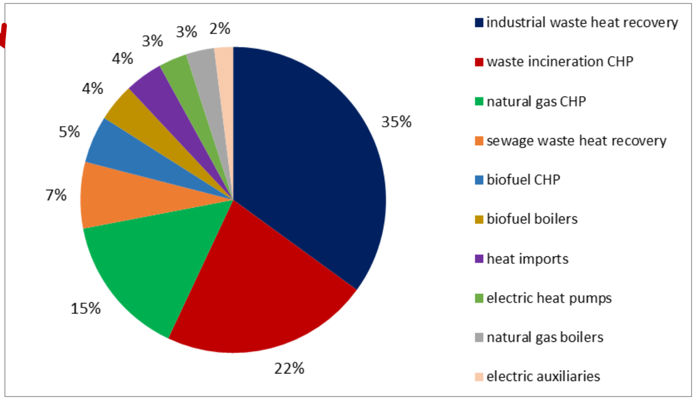
- baseline: heating with fuel oil-fired on-board boilers

Data Collection

- General Hypotheses and Input Data (PEF, GHG-EF, …)
- Annual Updates (e.g.: DH energy mix, climate conditions, …)
- Demo Operational Data, e.g.:
  - waste energy recovery
  - total heat supplied
  - …

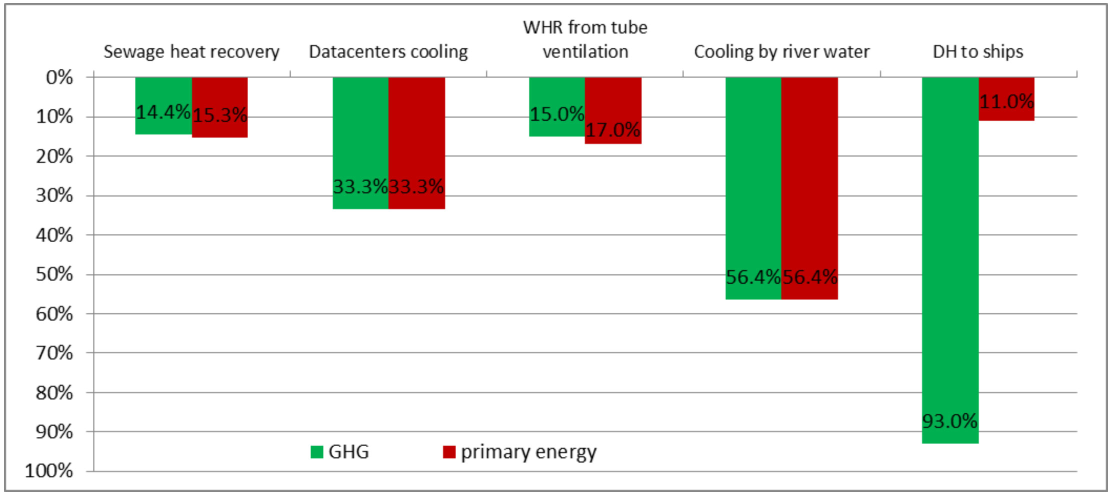
Energy Vectors	Location	Density	Heating Value	Emission Factor	Primary Energy Factor
		kg/m³	*kWh/kg*	*kgCO₂e/kWh*	*kWh/kWh*
natural gas	EU	750	13.33	0.202	1.1
diesel	EU	835	11.94	0.268	1.1
electricity	Germany	n.a.	n.a.	0.624	2.4
electricity	Netherlands	n.a.	n.a.	0.435	2.5
electricity	Sweden	n.a.	n.a.	0.023	1.5
electricity	United Kingdom	n.a.	n.a.	0.543	2.5





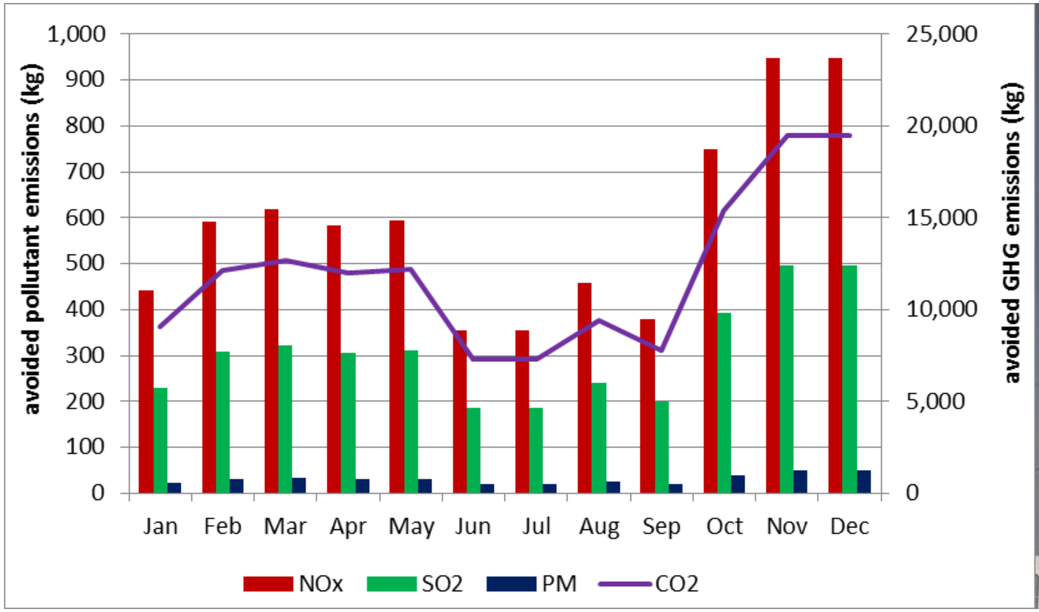
Primary Energy and GHG Savings

- Primary energy savings between 11% and 56%
- Avoided GHG emissions between 14% and 93%
- Three sub-cases identified:
  - reduction of electricity use
  - connection to DH
  - switch of energy source
- Warning: savings are «site-dependent»



Pollutant Emissions Reduction

- Avoided emissions in all selected case studies
- Huge benefits for DH-to-ships demonstrator
- But…warning: mainland electricity grid connection is required



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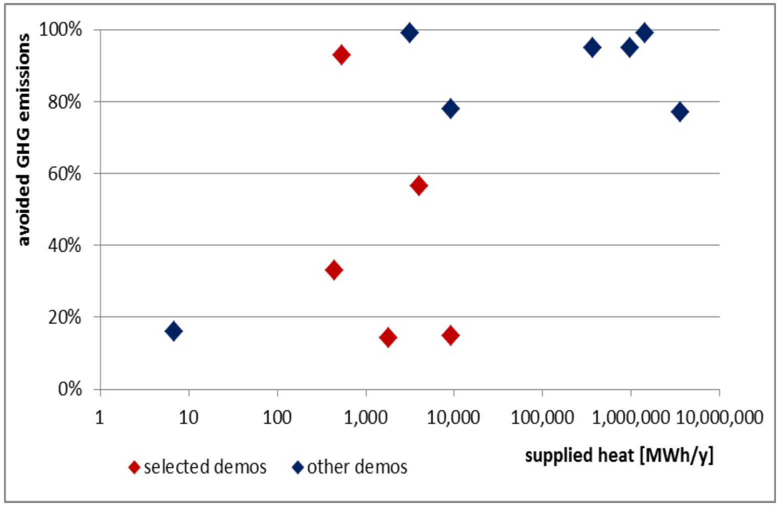
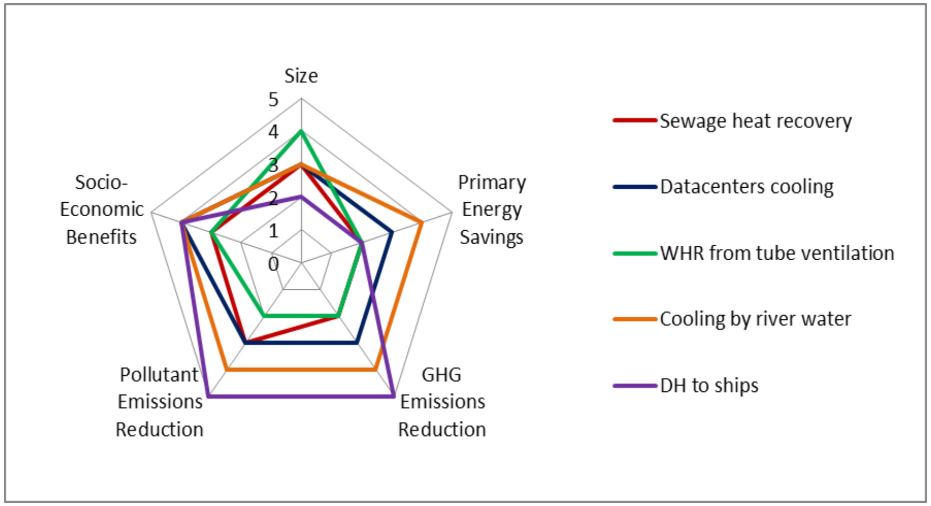
Comparative Assessment

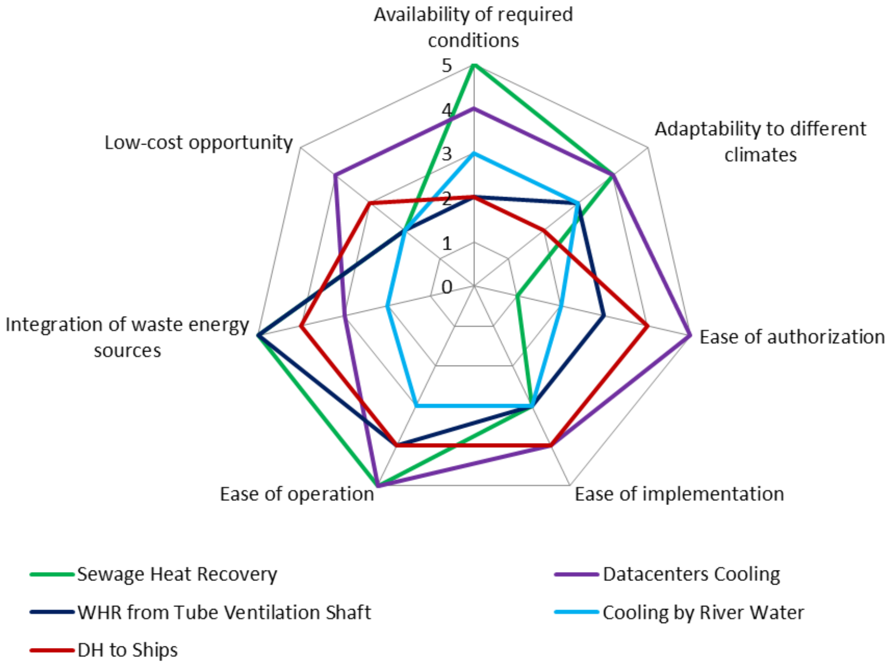
- Selected demonstrators are medium-sized, because of:
  - significant savings (primary energy, GHG emissions, …)
  - sufficient ease of implementation
- Relying on normalized KPIs, demonstrators can be compared





Replication Potential

- KPIs are a fundamental tool for multiplying CELSIUS impact
- Replication potential depends on cost/benefits, availability of required conditions, ease of authorization/realization/operation , etc.
- Highest replication potential for efficient datacenters, sewage heat recovery
- Under specific conditions, good opportunities for replication also for other technologies



Conclusions

- Waste heat recovery from industries and heat production from renewable sources have a huge potential in the EU
- Several sources of useful heat exist also within cities (e.g.: sewage, underground, ports, rivers, ...)
- Recovered waste energy can be integrated in existing/new DH network or used to heat single buildings
- To identify suitable locations for urban waste heat recovery systems and maximize benefits, heat mapping is crucial

From monitoring to planning...

MONITORING IS FUNDAMENTAL FOR THE OPTIMIZATION OF INNOVATIVE SOLUTIONS FOR URBAN WASTE HEAT RECOVERY

CRUCIAL FOR REPLICATION

- BENCHMARKING WITH OTHER TECHNOLOGIES
- SEARCHING THE PERFECT LOCATION/PERIOD FOR A TECHNOLOGY

...but not enough...

KEY ROLE OF URBAN WASTE HEAT MAPPING IN THE PLANNING OF SUSTAINABLE AND EFFICIENT HEATING AND COOLING SYSTEMS

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KPIs

MAPPING

PLANHEAT

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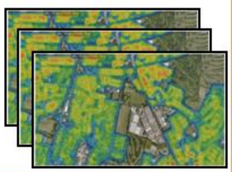
PLANHEAT Project

Integrated tool for empowering public authorities in the development of sustainable plans for low carbon heating and cooling

DEVELOPMENT AND VALIDATION OF AN INTEGRATED AND EASY-TO-USE OPEN SOURCE SUPPORT DECISION PLATFORM DEDICATED TO LOCAL AUTHORITIES FOR SUSTAINABLE RES/WASTE HEAT H&C FACILITIES

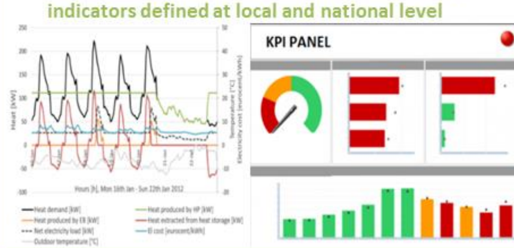
PLANHEAT Platform

Mapping and quantifying (annually and seasonally) H&C demand and local energy sources potential (including industrial waste heat)



- Selection of the sustainable and feasible H&C scenarios (sources and technological solutions)
- Baseline characterization
- Optimized DHC routes

- Hourly simulations of H&C demand and supply in the selected scenarios
- KPI assessment for new scenarios against target indicators defined at local and national level



Mapping demand and supply sources

Plan a new scenario based on the use of waste heat and RES

Simulation of the new scenario and KPIs evalution

PLANHEAT HIGHLIGHTS

- Development and Validation of the Platform (3 cities/scenarios: Lecce, Antwerp, Velika Gorica)
- Training Plan for Local Authorities (25 sessions, more than 150 People involved, 50 cities involved)
- Project Results Open Repository

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Thank you for your attention!

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This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 314441.