Regional Workshop on Low-Carbon Technologies for Micro, Small and Medium Enterprises (MSMEs) in the ASEAN

Energy-Efficient Technologies for MSMEs – Thermal Energy Networks and KIER Activities

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KOREA INSTITUTE OF ENERGY RESEARCH

CONTENTS

I. Introduction

1 History

Enable Happier World using KIER energy technology

• Korea Institute of Energy Research (KIER)

Over-40-years Research Experience on Energy Tech.

Early stage Sep.1977
- Korea Institute of Energy Conservation established
- The Solar Energy Research Institute established

Mar. 1980
- Renamed Korea Energy Research Institute (KERI)

Development Stage Jan.1981
- KERI and Korea institute of Geoscience and Mineral Resources(KIGAM) merged to Korea Institute of Energy and Resources(KIER)

Nov. 1991
- KIER Separated into Korea Institute of Energy Research(KIER) and KIGAM

Take off stage Dec.2000
- KIER's affiliation changed to Ministry of Knowledge Economy in Mar.2008

July 2017
- KIER's affiliation changed to Ministry of Science and ICT(MSIT)

Energy Economic Policy Division (Research branch in Seoul, Nov.1979) → Korea Energy Economics Institute (Independent institute, Sep.1986)

2 Vision

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KIER energy technology

KIER VISION

Toward a content and prosperous society,
led by **KIER** energy technology

Management Goal

Creating new value and market
through convergence andoriginality
- based energy technology

Strategies

Achieving technology competitiveness as a high global standing reserarch institute

Improving research productivity through performance-based managment

Strengthening parlnership for shared growth with small and midium sized enterprises

→ SMEs Cooperation Team

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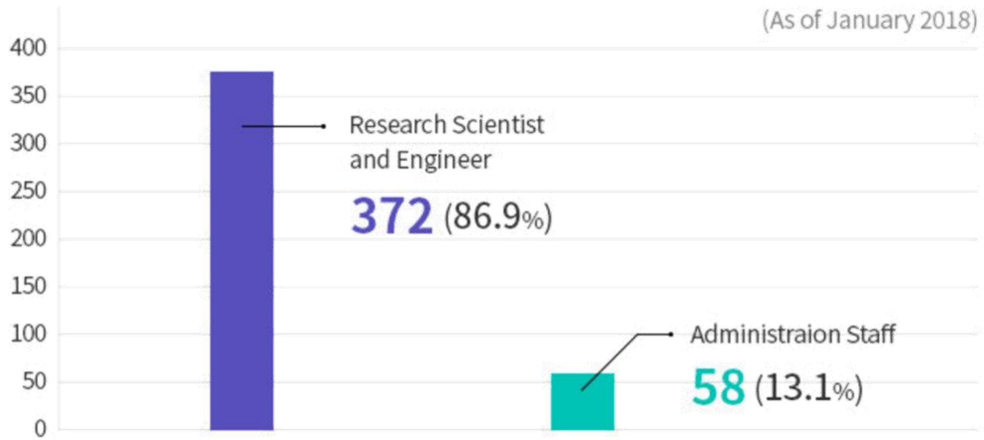
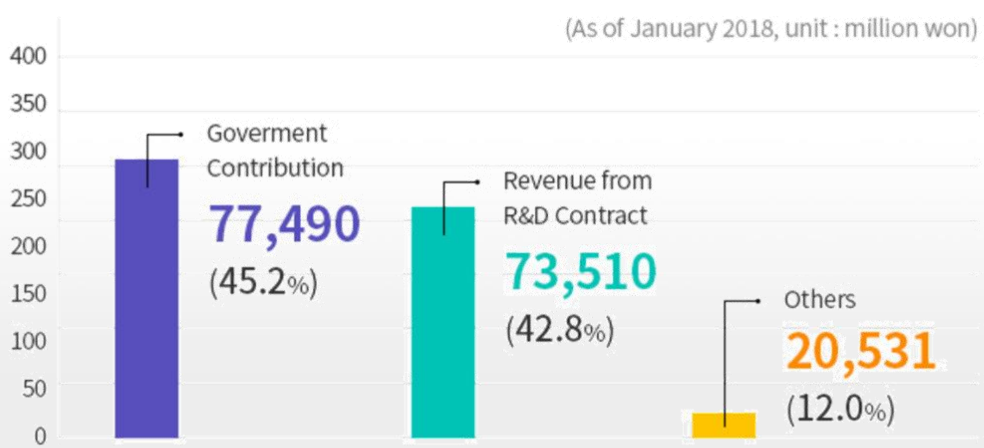
3 Personnel & Budget

Personnel



Total
430

Budget



Total
171,531
$160 M

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4 Organization (Mar. 2019)

- President
  - Auditor
    - Audit Division
      - Anti-corruption and Integrity Team
  - Organizational Culture Office
  - Vice President

● Main R&D Departments: 1 institute, 2 divisions

- New and Renewable Energy Institute
  - Photovoltaic Laboratory
    - Ulsan Advanced Energy Technology R&D Center
  - Solar Thermal Convergence Laboratory
    - New and Renewable Energy Resource & Policy Center
  - Fuel Cell Laboratory
    - Buan Fuel Cell Center
  - Hydrogen Laboratory
  - Jeju Global Research Center
- Energy Efficiency Technologies and Materials Science
  - Energy Saving Laboratory
  - Energy ICT·ESS Laboratory
  - Thermal Energy System Laboratory
  - Energy Network Laboratory
  - Separation and Conversion Materials Laboratory
  - Energy Materials Laboratory
- Climate Change Research Division
  - Greenhouse Gas Research Laboratory
  - Clean Fuel Laboratory
  - Biomass and Wastes to Energy Laboratory
    - Gwangju Bio/Energy R&D Center
- Business Development and Cooperation Division
  - Business Development Team
  - SMEs Cooperation
    - Biz. Incubation Center
- Platform Technology Laboratory

- R&D Strategy Division
  - R&D Planning Team
    - Climate Technology Stategy Center
  - Global Strategy Team
- Planning and Integration Division
  - Planning Office
  - Budget Management Office
  - Project Management Office
- Administrative Support Division
  - Human Resources Office
  - General Affairs and Accounting Office
  - Procurement and Asset Office
- KIER Overseas Branch
- FEP Convergence Research Center
- R&D Center for Reduction of Non-CO2 Greenhouse Gases
- Center for Environmentally Friendly Vehicle

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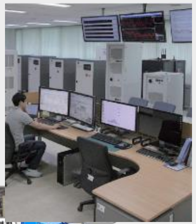
5 Energy Efficiency Technologies and Materials Science Division

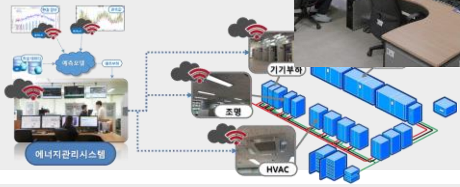
Energy Saving Technologies Laboratory

- Research for achieving the national energy saving goal through energy demand/supply management and energy saving technology development in the field of building, transportation, industry
- High efficiency complex **drying system** and **heat recovery** system, Alkali metal thermal to electric conversion, **Ultra-fine particles electro-spray wet** process, etc.

Energy ICT·ESS Laboratory

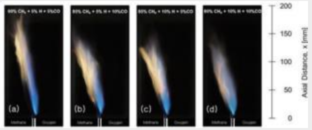


- Research for improving an energy supply/demand/transfer efficiency based on ICT convergence technology and conduct a research on energy integration management and operation for improving energy reliability
- **ICT convergence energy optimization** and energy saving, **distributed power** generation, **micro-grid** and **smart-grid**, intelligent energy harvesting future technology, etc.



Thermal Energy Systems Laboratory

- Research on **efficient conversion technologies** of **heat-heat/heat-electricity/electricity-heat**, and thermal energy utilization system including fossil and synthetic fuel combustion with an aim for efficient using high/low temperature thermal energy
- Future **power generation**, oxy-fuel **combustion** application, **heat-pump** application, excess enthalpy combustion, etc.



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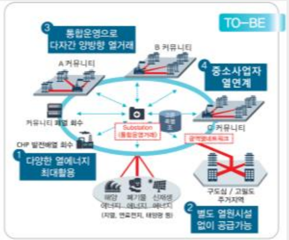
5 Energy Efficiency Technologies and Materials Science Division

Energy Network Laboratory

- Research for improving an energy utilization efficiency and reduce the greenhouse gas emission by realizing the **optimal energy management** system in physical/virtual energy network unit
- **Smart energy network**, development and performance evaluation of **the cogeneration plant**, high efficiency and low emission **boiler** system, etc.



Separation and Conversion Materials Laboratory

- Research on developing a materials technology overcoming limitations in order for improving market-oriented materials technology and next generation energy sector (needed for industry)
- Materials based on nano such as solar PV, thermoelectricity and secondary battery, etc. and separation materials based on various gas membrane for maximizing an industry efficiency

Energy Materials Laboratory

- Research on various cross-cutting technologies and convergence research on energy technologies such as AMTEC, SOFC/PEMFC, SOEC, carbon composites for high-temperature application and catalyst/adsorbents using a metal organic hybrid material
- Vision to become a global leader in materials and components commercialization with high efficiency and performance based upon energy/environmental technology (ET) and nanotechnology (NT)

Topic – Thermal Energy Efficiency

KIER

Energy Efficiency Technologies and Materials Science

- Thermal Energy Systems
- Energy ICT & ESS
- Energy Saving Technologies
- Energy Network
- Separation and Conversion Materials
- Energy Materials

Main R&D System

Power Generation, Heat Pump, Combustor

VISION Thermal Energy Systems Design for Highly Efficient Energy Society

- High Efficiency System
- **Thermal Energy Network**

#1 Low T. Network

- District heating 4.0
- Space heating / Hot water
- Sea water, Solar Thermal

#2 High T. Network

- Industrial application
- High temperature heat pump
- Process waste heat

#3 Monitoring

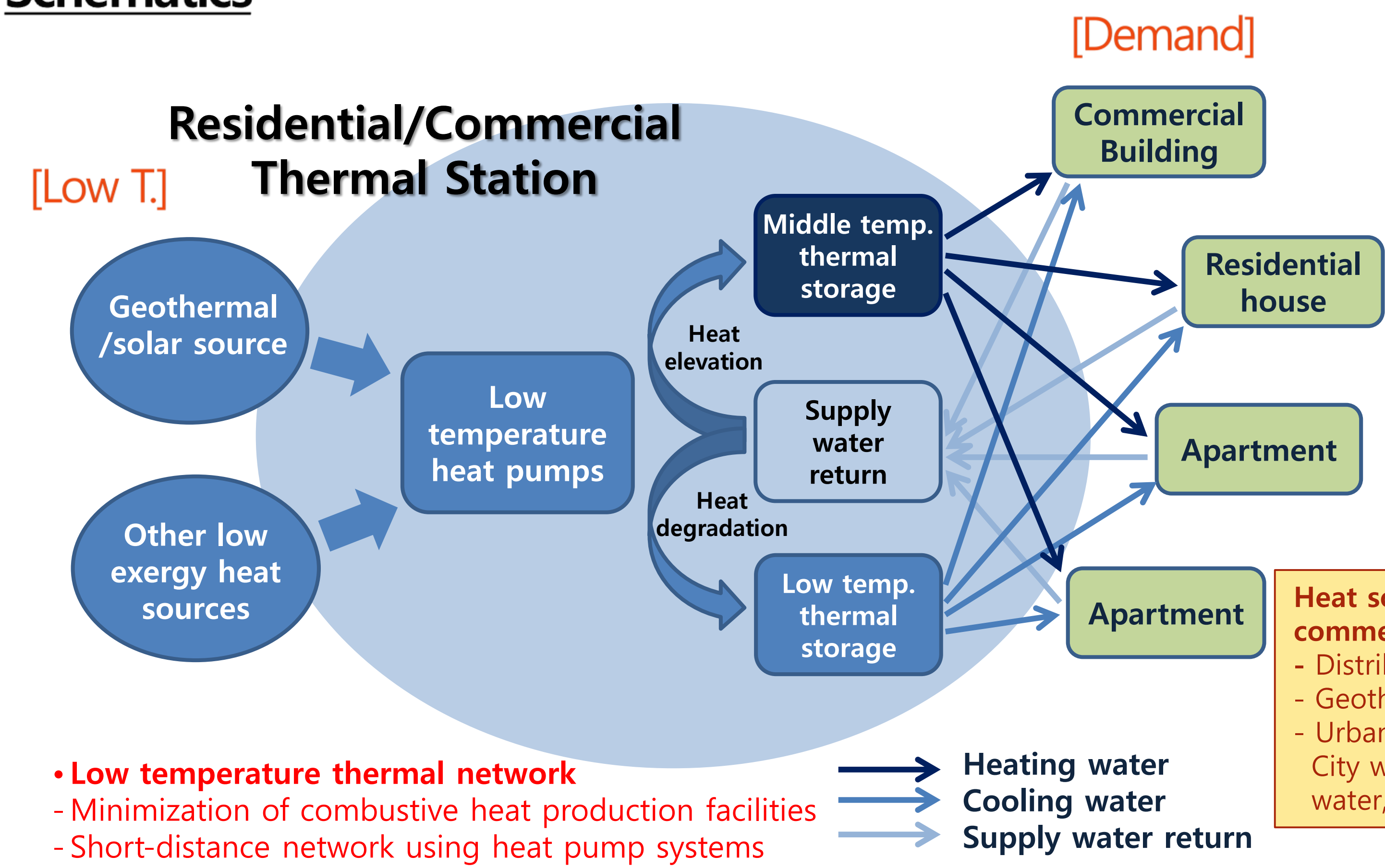
- Energy usage monitoring and management
- Big data, IoT, etc

II. Approach 1

Low Temperature Thermal Network

- Energy efficiency improvement by thermal network
  - Connecting unused low T. heat/energy to demand
  - Key components : Heat pump and thermal energy storage

Schematics



Heat source for residential/ commercial thermal station
- Distributed heat source supply
- Geothermal/solar heat
- Urban low exergy heat sources : City water, apartment sewage water, underground water

- **Low temperature thermal network**
  - Minimization of combustive heat production facilities
  - Short-distance network using heat pump systems

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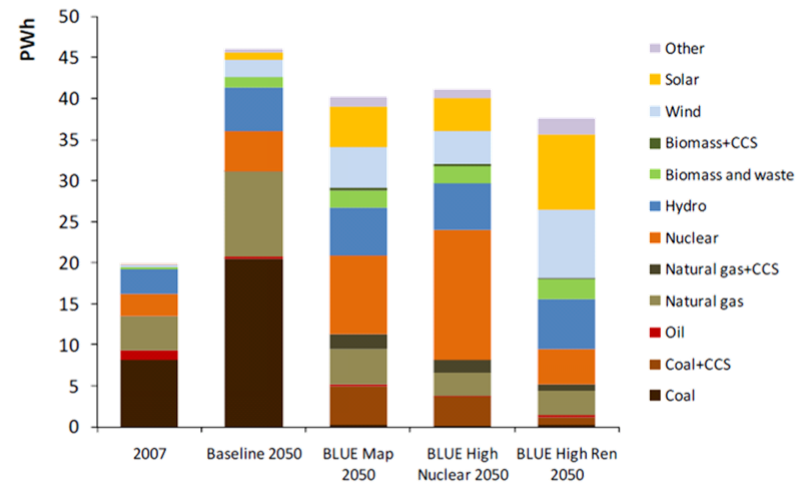
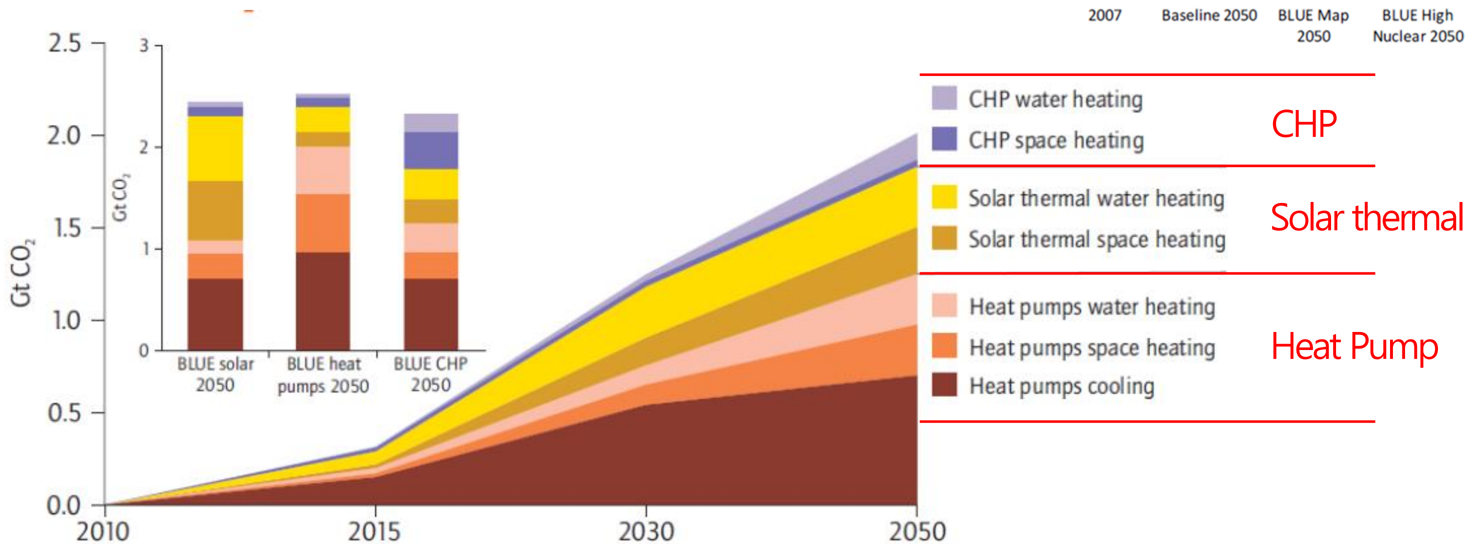
Heat Pump for Energy Saving

IEA Energy Technology Prospect for Building Energy 2010

- Vision on 3-core technologies for Building Energy sector
- Each BLUE prospects building energy will be supported mainly by Heat Pump, Solar Thermal and CHP

Decarbonising the power sector – a new age of electrification?

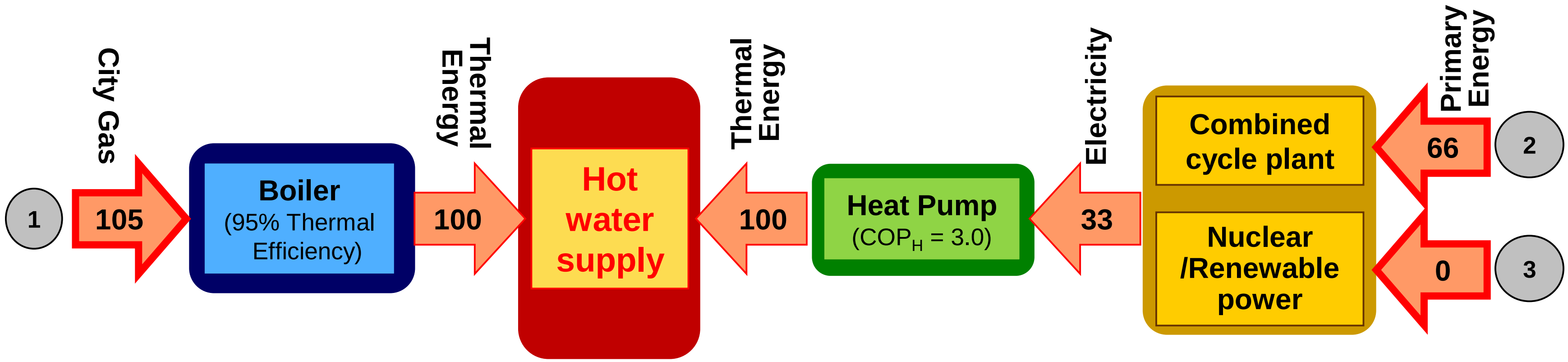




Note: Excludes the impact of improved building shells on reducing heating and cooling loads.

Heat Pump for Energy Saving

- Heat Pump Mechanism : Recovering energy from Low T. source and Transferring to High T.
  → Expected more than 30% energy saving compared to fuel combustion

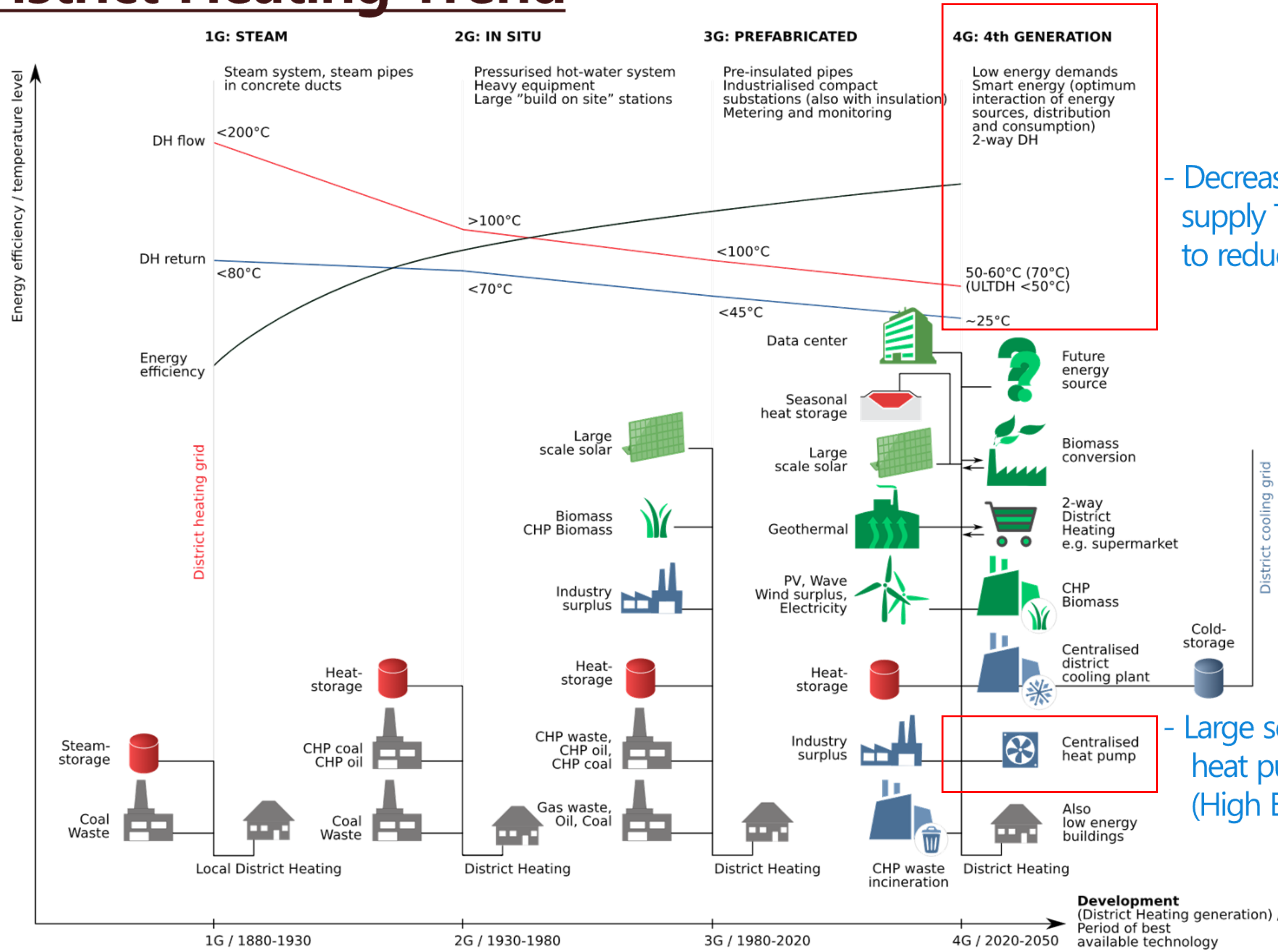


Heating Type		Primary Energy	Primary conversion efficiency	Secondary conversion efficiency	CO_2 emission (%)
Combustion Based	① Gas-fired boiler	105	N/A	0.95 (thermal)	100
	Oil-fired boiler	125	N/A	0.8 (thermal)	119
Combined Heat and Power + Heat Pump		66	0.32 (power) 0.55 (thermal)	3.0 (COP_H)	63.1
Heat Pump Based	② Combined cycle power plant	60	0.56 (power)	3.0 (COP_H)	56.7
	③ Nuclear/Renewable energy power plant	0	N/A	3.0 (COP_H)	0

* All the primary energy was calculated based on the supplying thermal energy to be 100 as shown above diagram.

→ **Best case : Active renewable thermal energy + Heat Pump**

District Heating Trend



- Decreasing supply T. to reduce loss

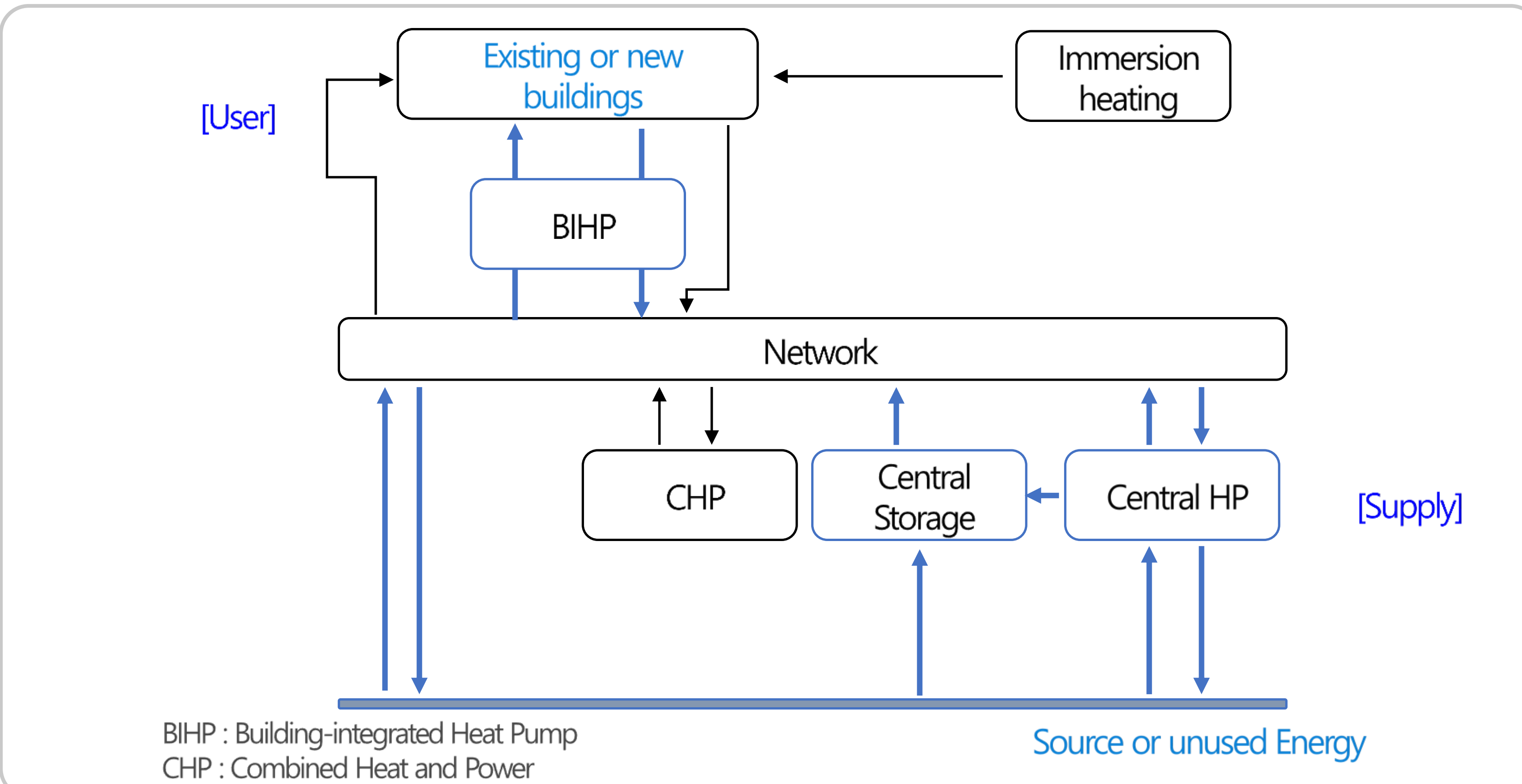
- Large scale heat pump (High Eff.)

Space Heating and Hot Water with DH

- 4^{th} Generation District Heating vs. Local Higher Temperature Demand
- Thermal Energy Network needs heat pumps in both supply and user side

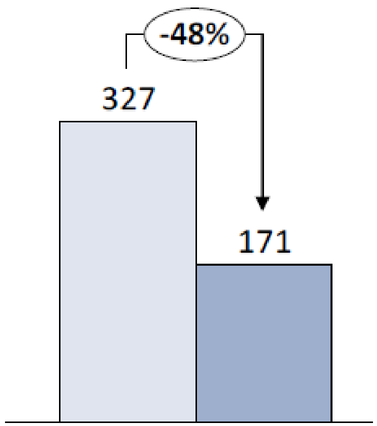
Thermal Energy Network for Space Heating and Hot water

- DECC (Department of Energy and Climate Change, UK) report



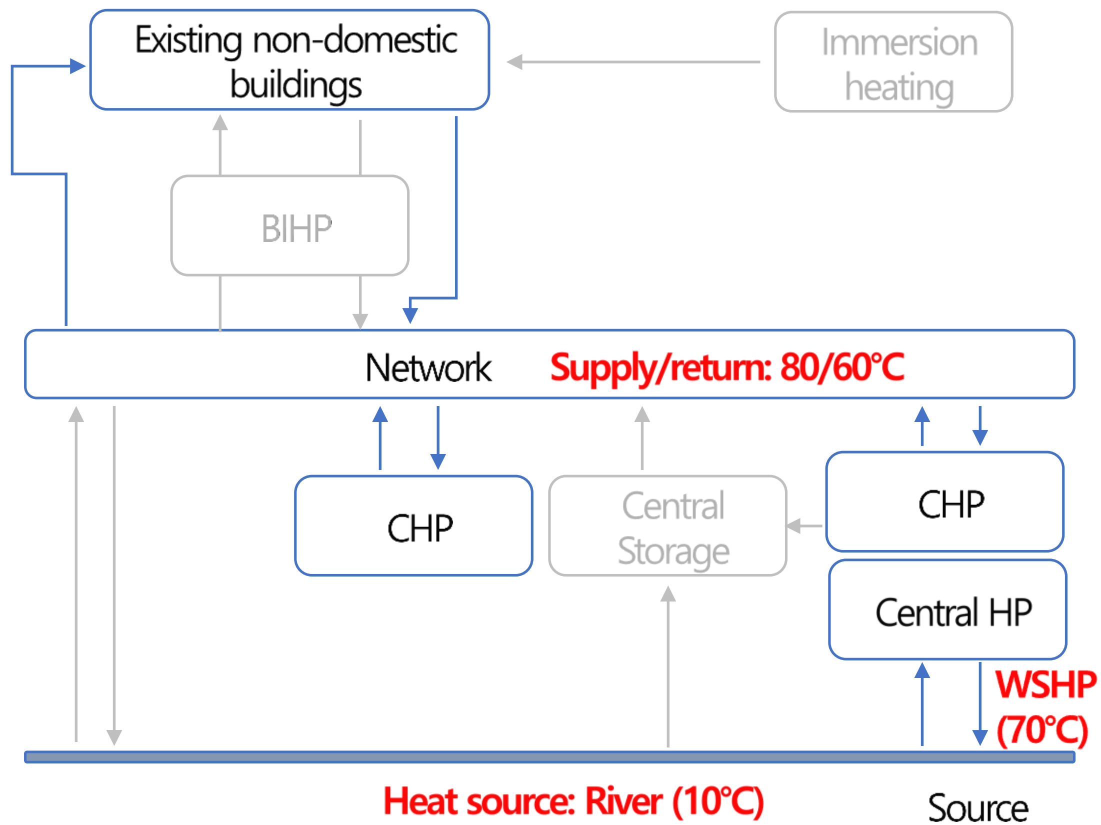
Space Heating and Hot Water with DH

- Case Scenario 1: Large-scale scheme serving a variety of existing non-domestic buildings
  - Supply temperature : 80℃



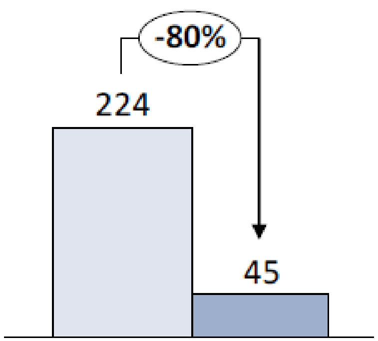
Scenario 1:
High T network,
Central HP
combined with CHP

- Utilization of unused (low T.) energy through heat pump
- High efficiency operation of CHP



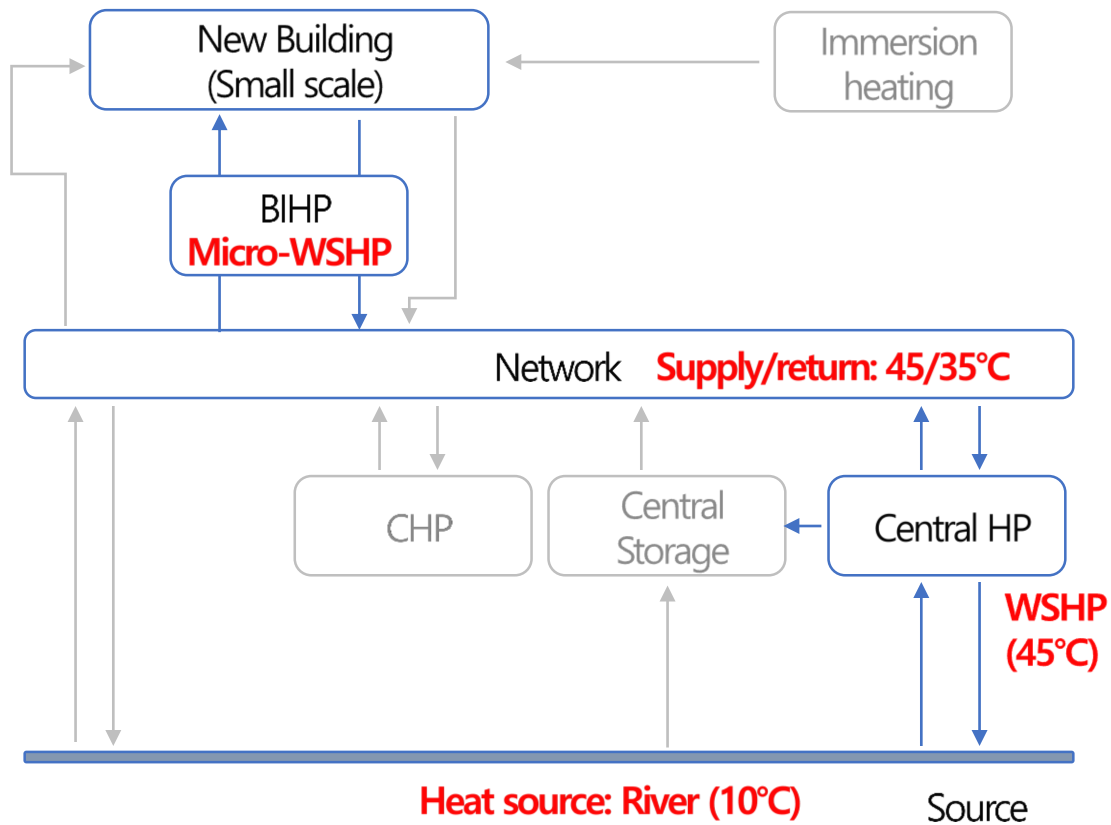
Space Heating and Hot Water with DH

- Case Scenario 4: Small-scale scheme serving a new development consisting of 400 residential flats (Supply temperature : 45℃)



Scenario 4:
Medium T network,
Central HP and
BIHPs

- Distribution of temperature lift to both supply and user sides
- Heat pump dominant network

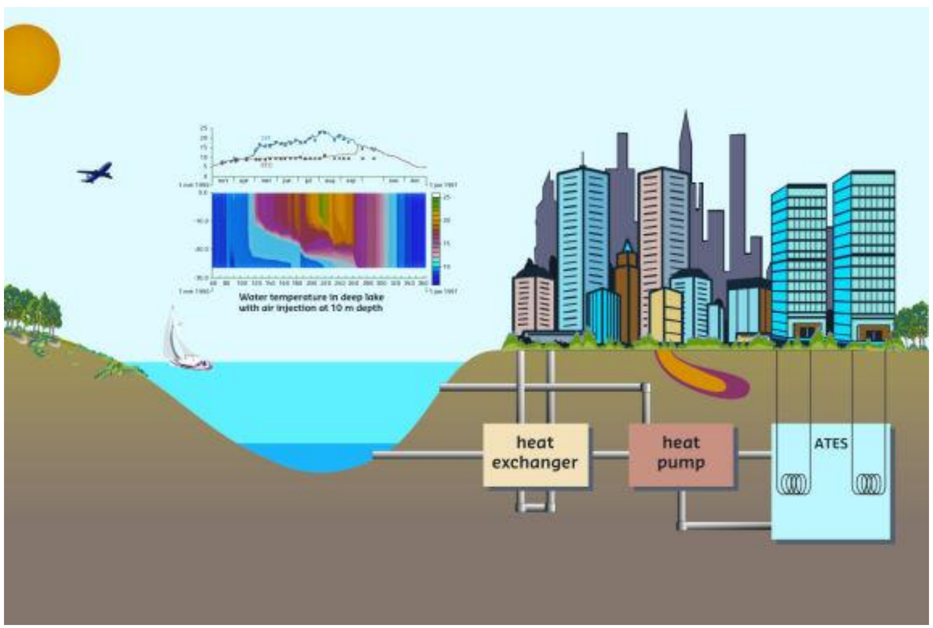


[Case Study] Energy Saving with Low T. Heat

- Low Temperature Thermal Network Research
  - Large-scale heat pump plant / locally optimized heat pump (user-demand)

Sea water heat pump application

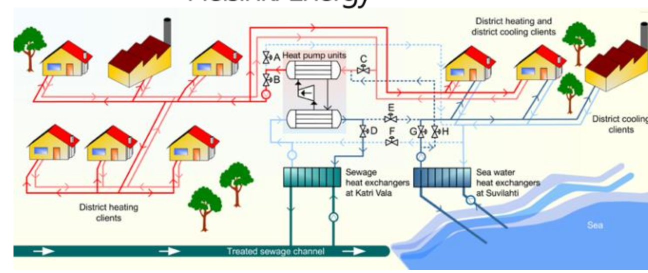
- (Might be) The most abundant unused heat source
- Generally large scale application (District heating)
- Free cooling possible during spring and autumn (Large energy savings)



< System Schematic Diagram >

Katri Vala Plant (Finland)

Helsinki Energy



- 5 Heat Pumps (Unitop 50FY, Friotherm)

Summer operation:	
Heating capacity	18,113 kW
Heating water flow	370 m³/h
Inlet/outlet temperature	45/88 °C
Power absorbed	6,113 kW
Electric motor	6,500 kW
Voltage	11 kV
Heat source (cooling) capacity	12,000 kW
District cooling in/out temp.	20/4 °C

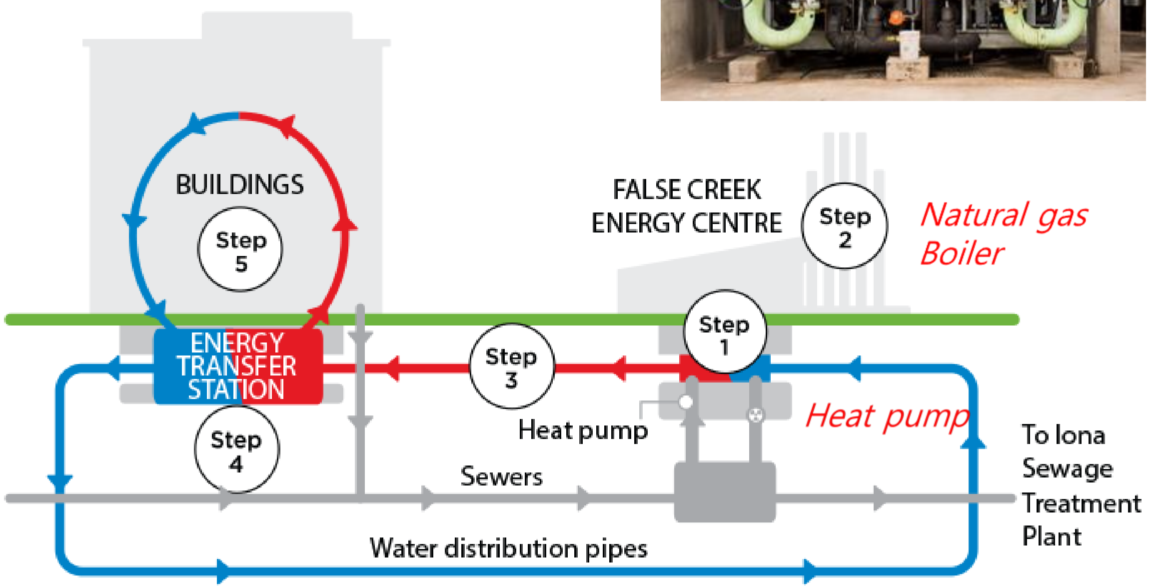
- The largest plant in the world to use heat pumps to produce district heat and district cooling from both Sewage Water and Sea Water
- District heat output : 90 MW
  District cooing output : 60 MW

[Case Study] Energy Saving with Low T. Heat

Southeast False Creek Neighborhood Energy Utility (Vancouver)

- Sewage Water as heat source
  - .. Huge amount vs. nearly zero applicability
- Heat pump
  - .. Source: sewage water
  - .. Sink: heating and hot water

Heat Pump Installation



Network between Sewage and Heating

BENEFITS

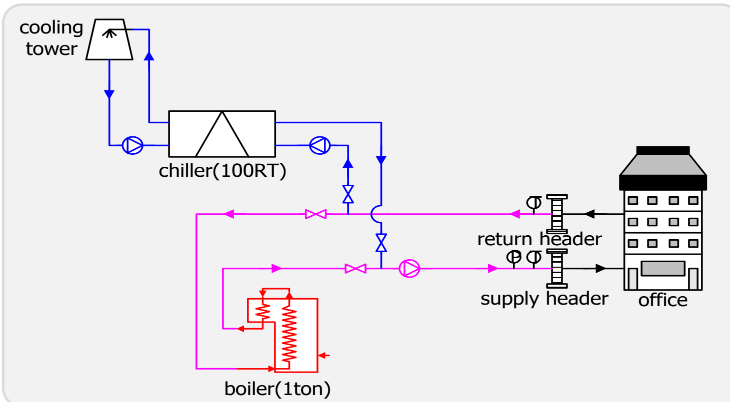
- Using waste thermal energy captured from sewage to provide space heating and hot water to buildings in Southeast False Creek
- Reported to eliminate more than 60% of the greenhouse gas emission associated with heating buildings
- The utility began operations in 2010 and since then has rapidly expanded to serve 395,000 m^2 of residential, commercial, and institutional space.

KIER's Research Activity

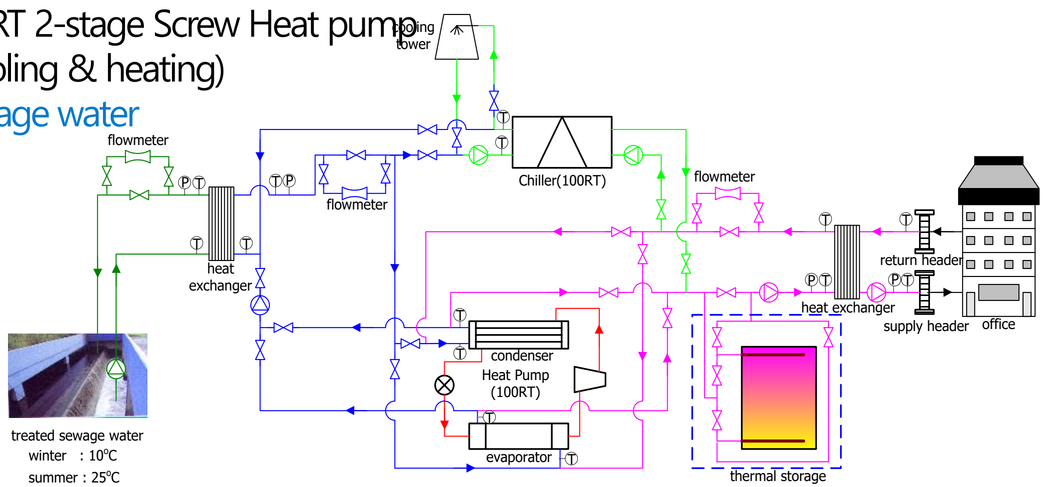
Energy Saving of Sewage Treatment Plant in Daegu Korea

- Network : (Heat source) Sewage Water → (Heat Demand) Cooling/Heating
- Heating COP 3.5 (Sewage 12.8℃), Cooling COP 4.5 (Sewage 23.0℃)

(Before)
- 120RT Chiller (cooling tower)
- 1 ton Boiler



(After)
- 100RT 2-stage Screw Heat pump (cooling & heating)
- Sewage water



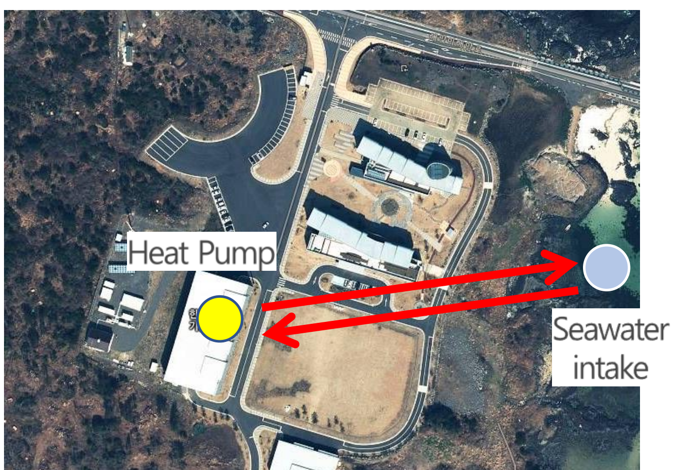
Heat Pump
Heating : 437kW
Cooling : 107USRT

KIER's Research Activity

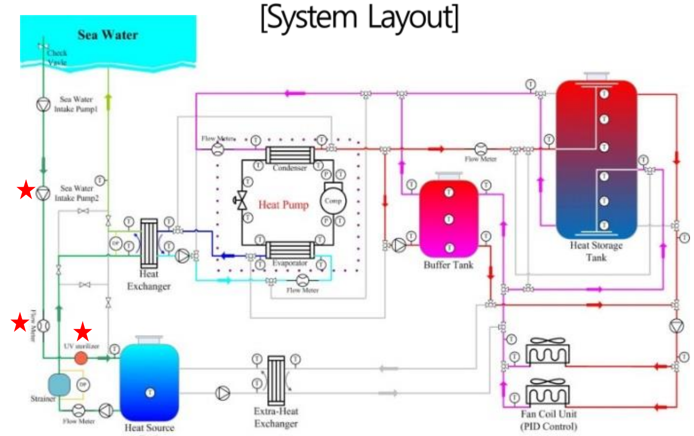
Sea water source heat pump for a low-temperature thermal energy network

- Objective of project : Development of CFC/HCFC-free 20 RT SWSHP
- Target performance
  Cooling COP in summer season : 4.5, cooling supply : 7℃ at sea water of 25℃
  Heating COP in winter season : 3.3, heating supply : 50~60℃ at sea water of 10℃
- Expected payback period : 5.9 year (with a subsidy from government)

[KIER JGRC]



[System Layout]

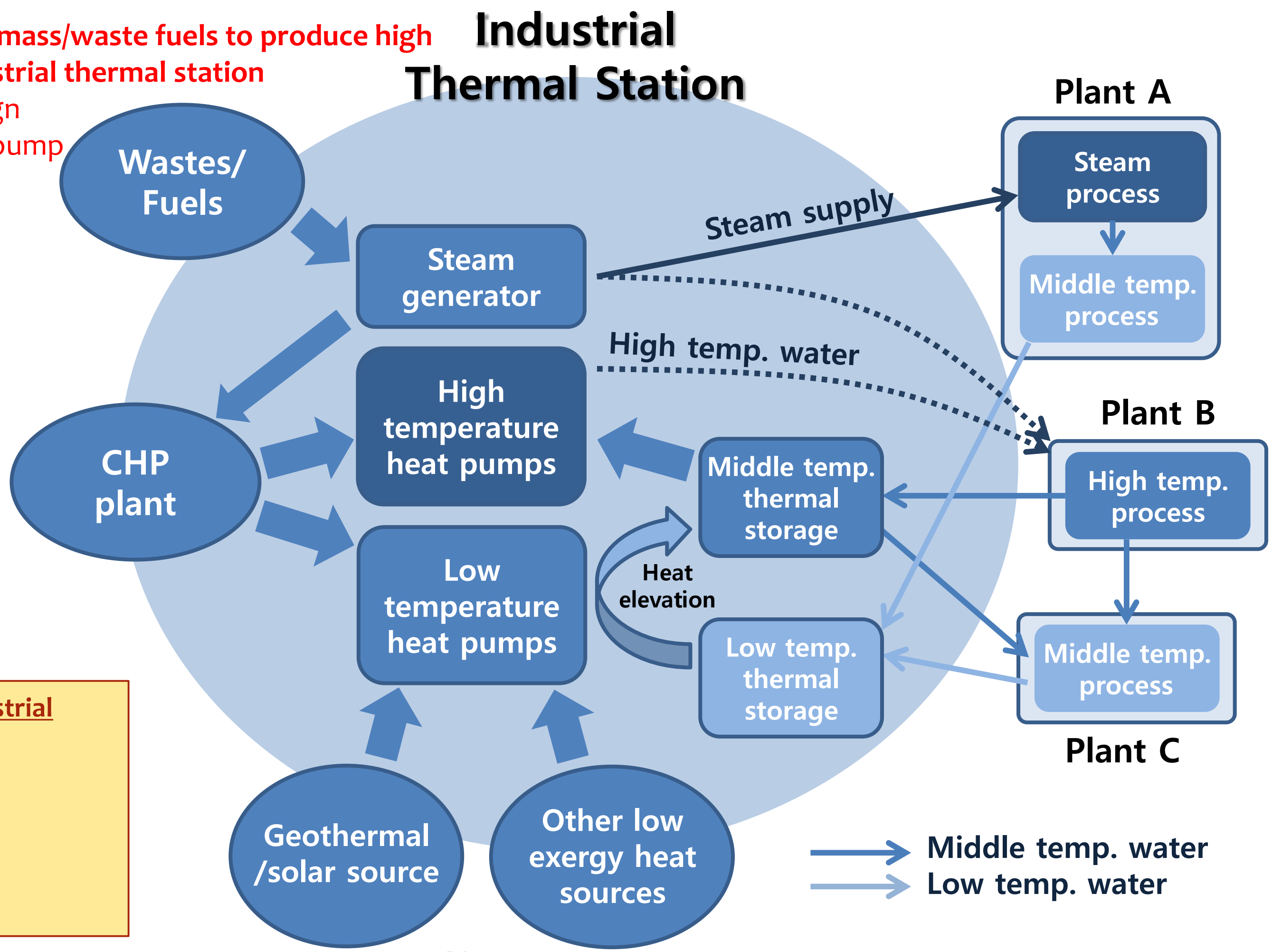


III. Approach 2

High Temperature Thermal Network

- Wider temperature range – more complex layout of heat storages and heat pumps
- Heat sources – Discharges from processes (flue gases, condensates, wastes, etc.) or Cooling processes

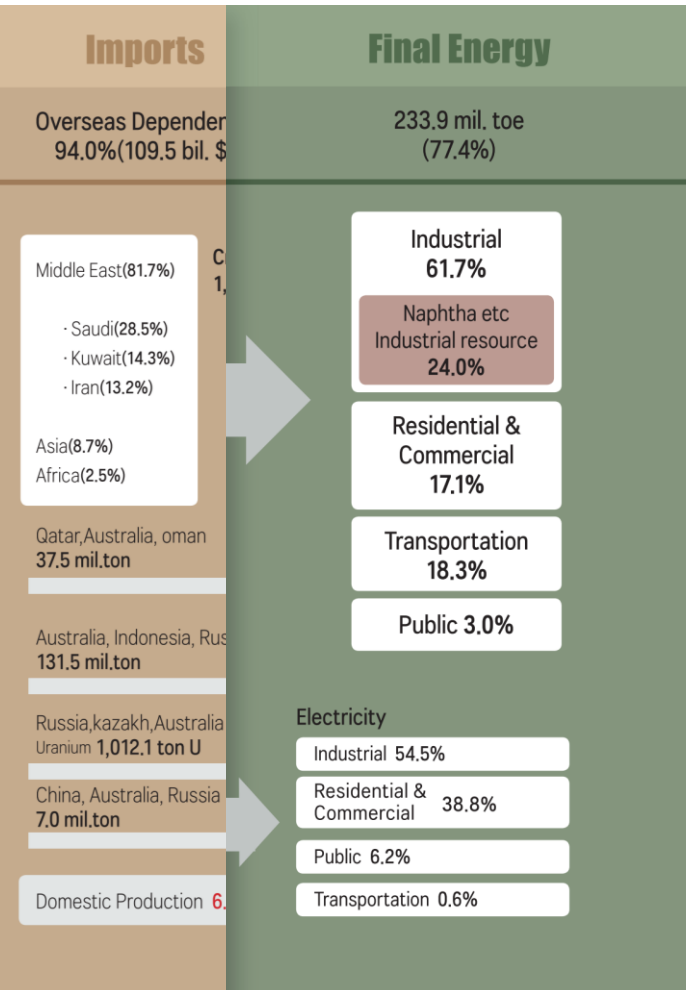
- **Combustive energy from biomass/waste fuels to produce high temperature supply for industrial thermal station**
  - Heat exchange network design
  - Ultra high temperature heat pump
  - Waste heat storage



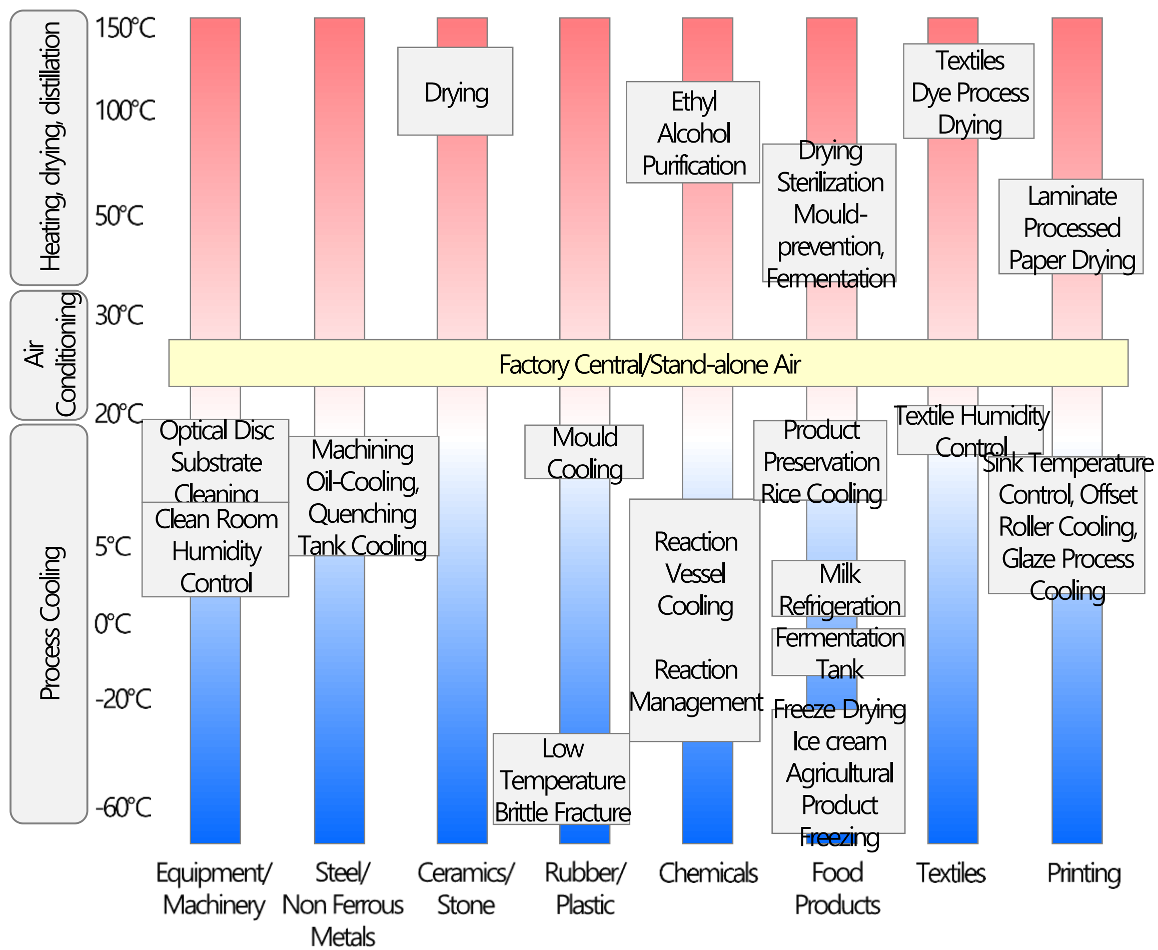
Heat source samples for industrial thermal station
- Heat sources of residential/ commercial thermal station
- Industrial waste heat
- Wastes/biomass fuels
- Sewage treatment center

Heat Demands in Industrial Processes

- Final energy consumption of Korea : Industrial ≫ Transportation ≥ Residential & Commercial
- Heat demands of industrial process : Both cooling and heating demands exist

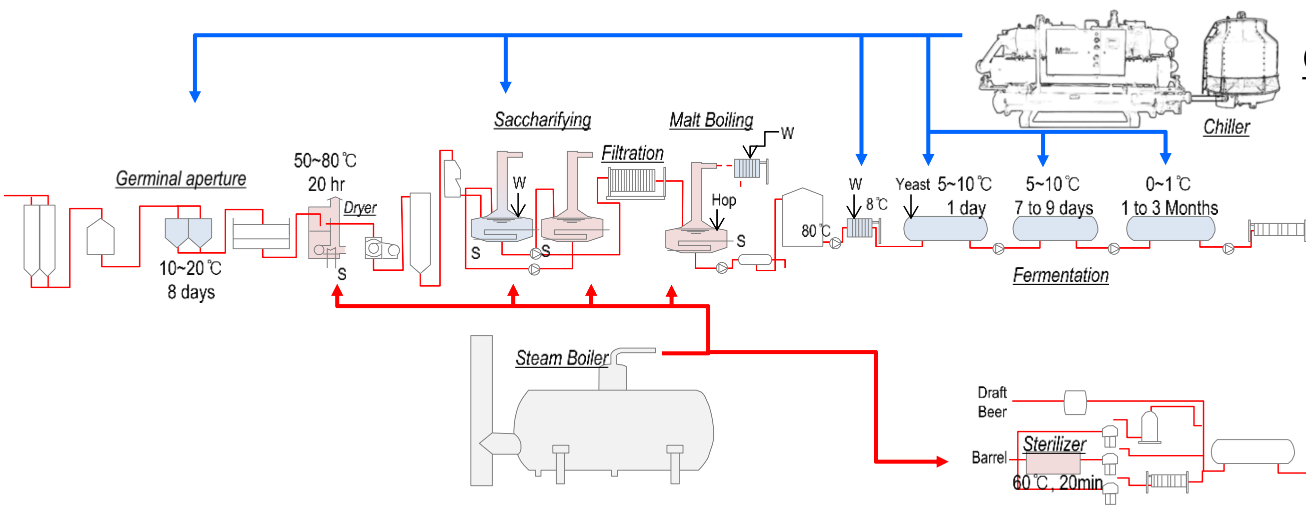


Temperature Distribution in Industrial Processes



Thermal Network Plan

- Thermal Network 1 : Matching refrigeration and heating demand to heat pump
- Thermal Network 2 : Re-utilize discharge heat (or energy) to generate process heat



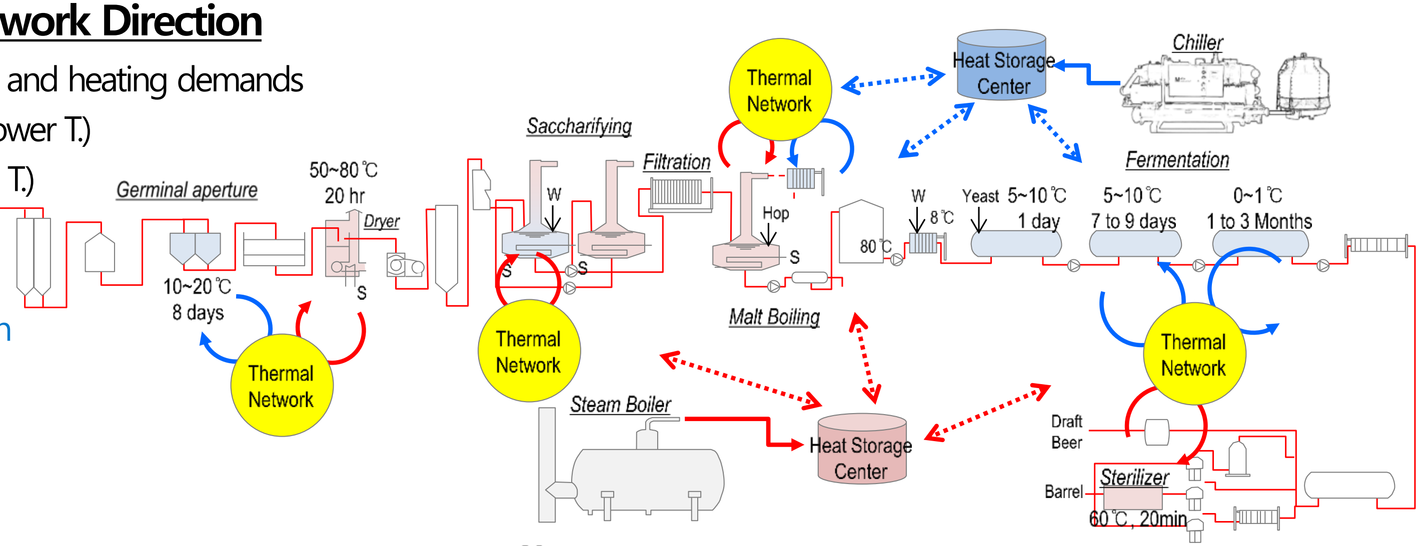
Current Heat Flow

- Centralized
  Separated heating and cooling
- Large transport loss

Thermal Energy Network Direction

1) Matching refrigeration and heating demands
2) Matching discharge (lower T.) and processes (higher T.)

→ Energy saving & Utilities optimization

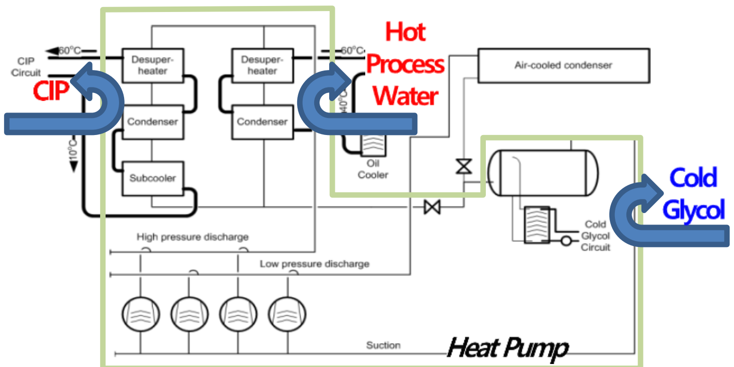


Thermal Networking : Refrigeration-Heating

- Food Factory : Large demands of heating and refrigeration for drying, sterilization, fermentation, etc. → Big potential of energy saving by refrigeration-heating network

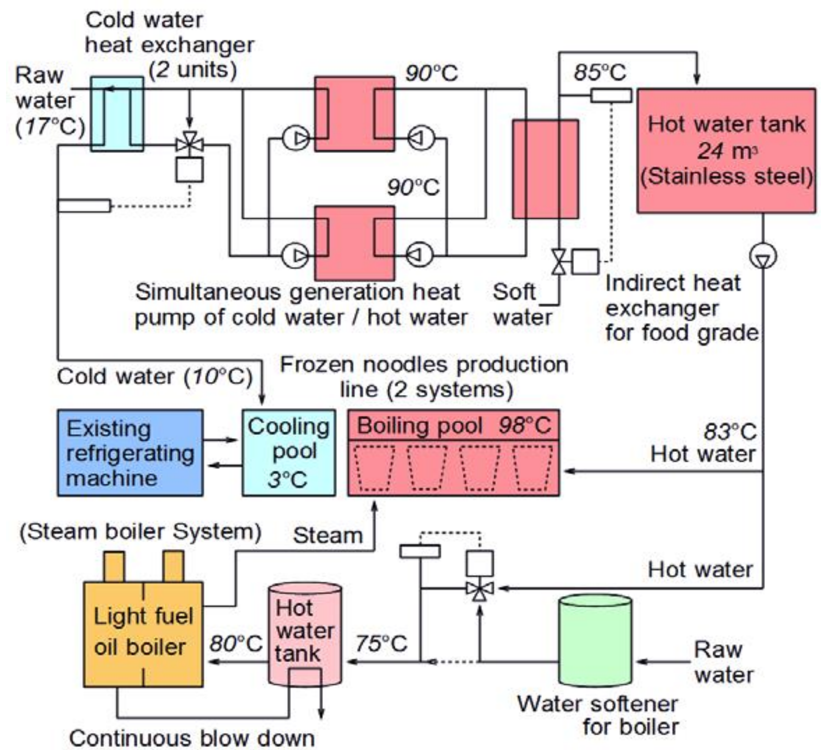
Chocolate Factory (Nestlé)

- Cooling: Process glycol (5℃ → 0℃)
- Heating: Process water (10℃ → 60℃)
- Boiler for 90℃ hot water
- €166,000/year cost saving expected



Noodle Factory

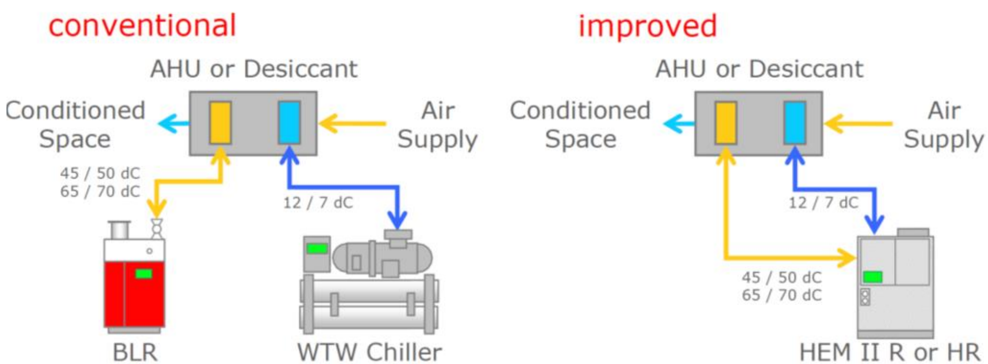
- Heat Source: 17℃ / Heat Sink: 85℃
- Reducing thermal load of existing equipment (boiler, refrigerating machine)



Thermal Networking : Cooling-Heating

Kobelco Report

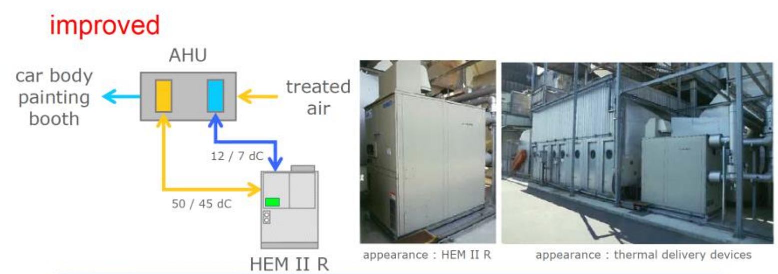
Application Sample / HVAC
Heat Pump Chiller Delivering H/W and C/W to HVAC



This system can be applicable to all HVAC system including inverter technology … for instance ,

Electronics, Semiconductor, Painting, Printing Process and etc., which requires space heating and drying air.

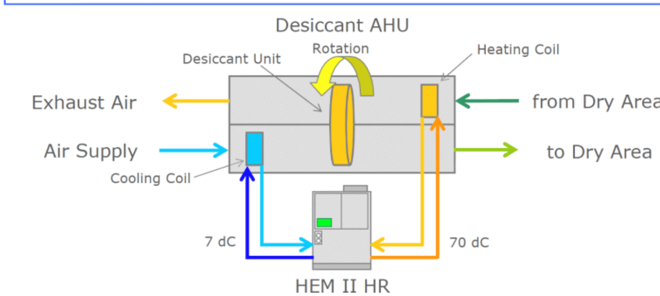
Case Study 2 : Clean Room in Car Body Painting Process
Energy-Saving Project in Car Industry Factory



Applying Kobelco Heat Pump to painting process …

Contribute to reduce
64% of energy cost and 61% of CO_2 emission.

Case Study 3 : Dry Area in Battery Cell Assembly
Energy Saving Project in a Semiconductor Factory



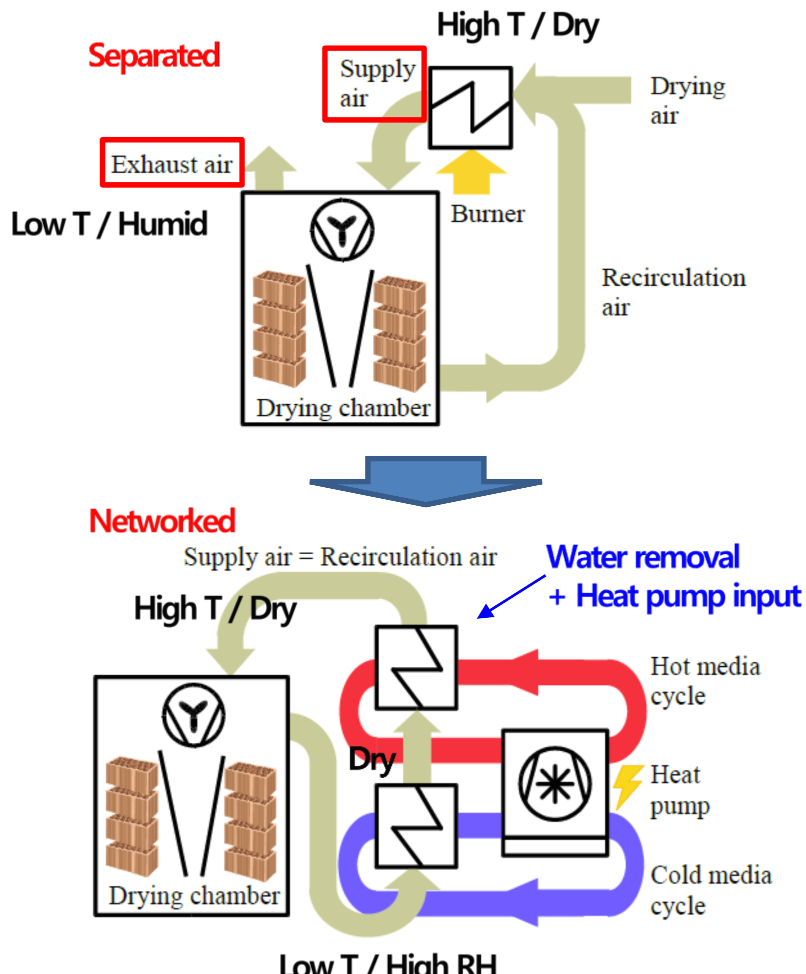
Applying more high efficiency system including Kobelco Heat Pumps …

Contribute to reduce
41% of energy cost and 55% of CO_2 emission.

Thermal Networking : Discharge-Process Input

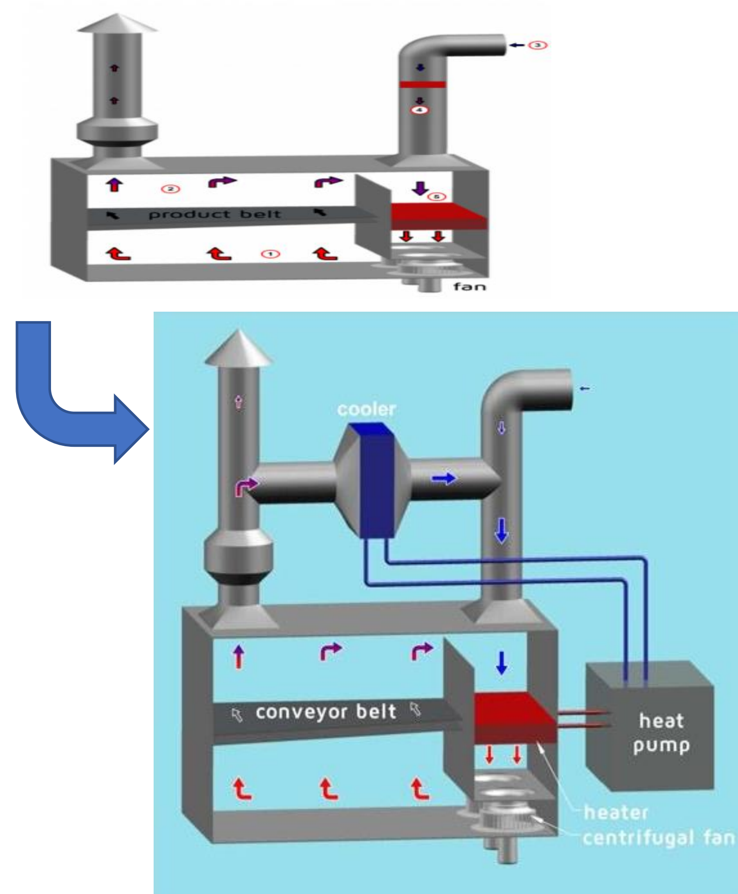
- Discharge flow from process : containing more energy (enthalpy) than outdoor air
  → Energy Saving by recovering both sensible and latent heat

Drying Process Energy Saving: Around 90℃



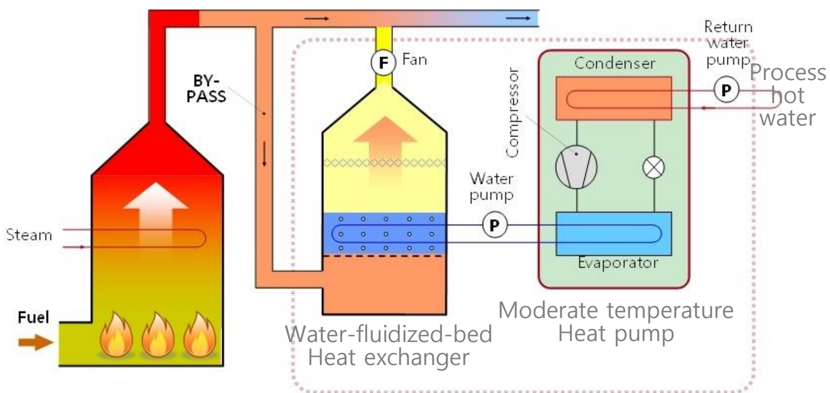
Application case: French Fry Drying Process

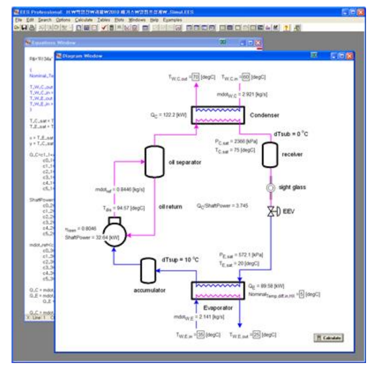
- Temperature requirement: around 70℃



KIER's Activities - Waste Heat Utilization

- Objective of project : Development of flue gases heat recovery Heat Pump for industrial purpose
- 100kW of heating capacity with a heating COP of 3.5 at 65-70℃ of hot process water
- Increase in boiler efficiency : 8% (both sensible and latent heat recovery)
  (Fuel consumption reduction: 12 kg/h, cost reduction: $44,000/year)
- Expected payback period : 3.5 year



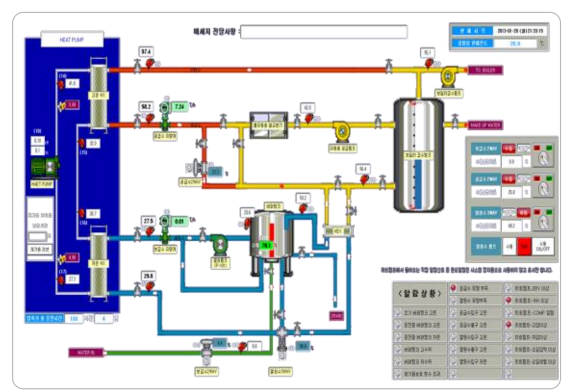


HP cycle analysis

Demonstration plant (Lotte food Co. Ltd.)

Water-fluidized-bed Heat exchanger

Heat pump

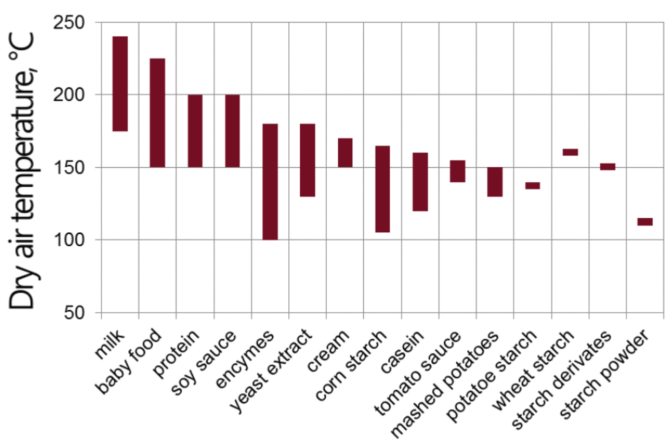


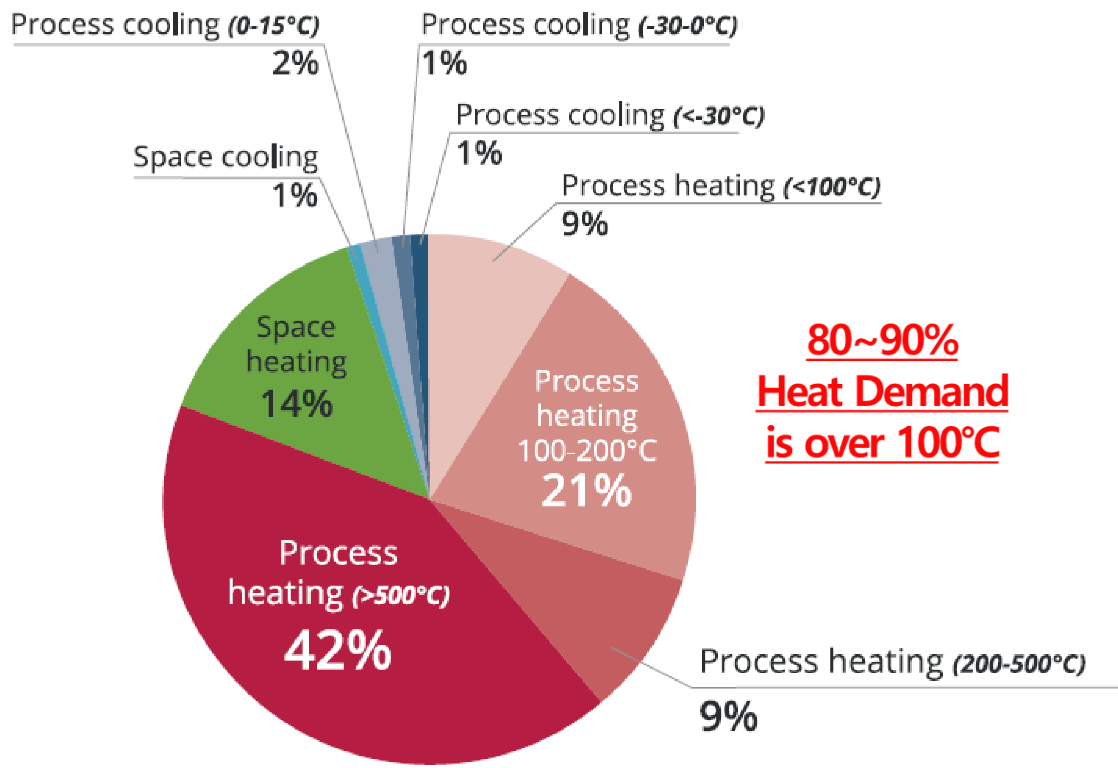
Control/ monitoring system

Heating Demands in Process

- Heat over 100℃ (steam, flue gases) occupies most of heat demands
  → Needs for energy saving (or energy network) devices of high temperature demand

High temperature process heat





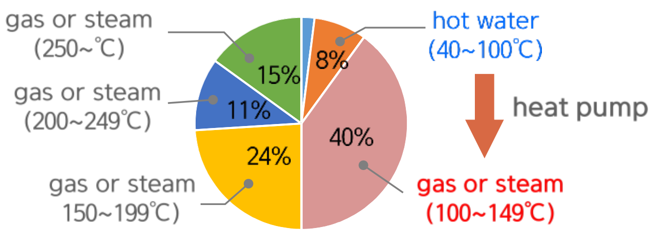
80~90% Heat Demand is over 100℃

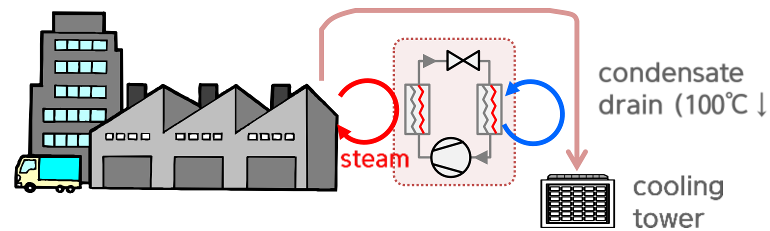
Figure 6: Industry final energy demand end-use (EU28, 2015)

KIER's Activities - Steam Heat Pump

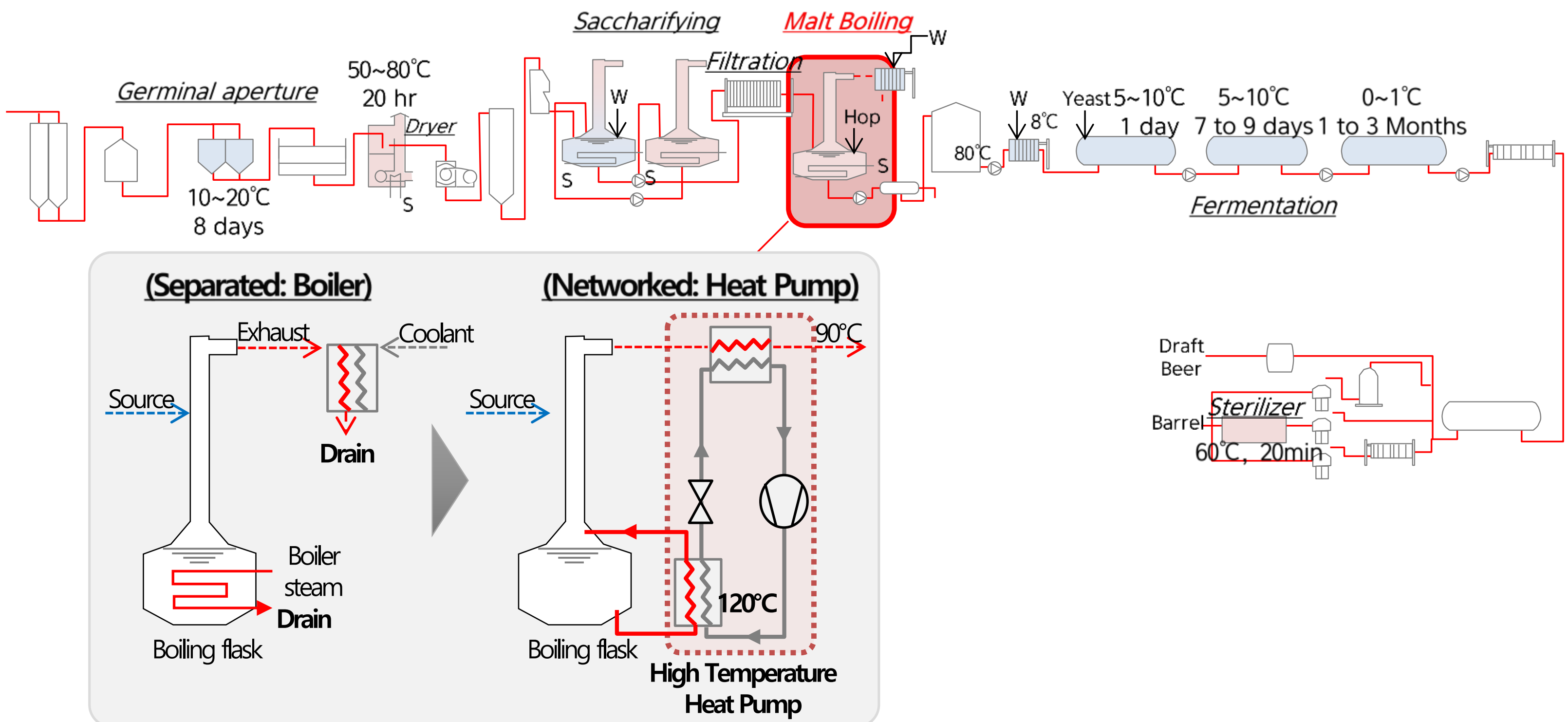
- Objective of project : Development of steam generation Heat Pump for industrial purpose
- Target performance : 300kW of heating capacity with a heating COP over 3.0 at 120℃ steam

[Heats in industrial sector (Japan)]





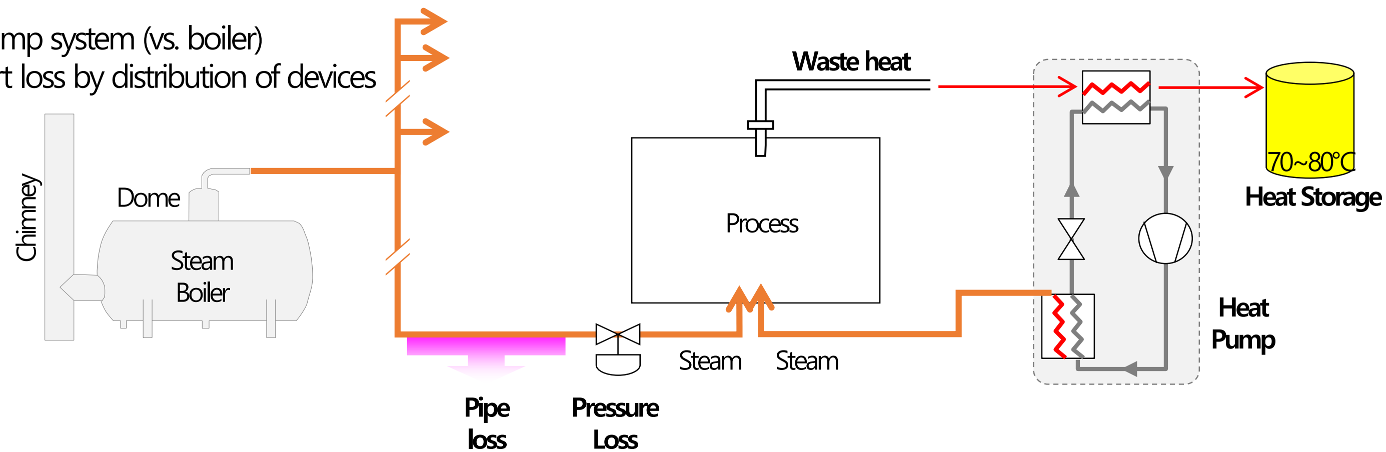
Case Study : Thermal energy network in Food (Beer) Production Process

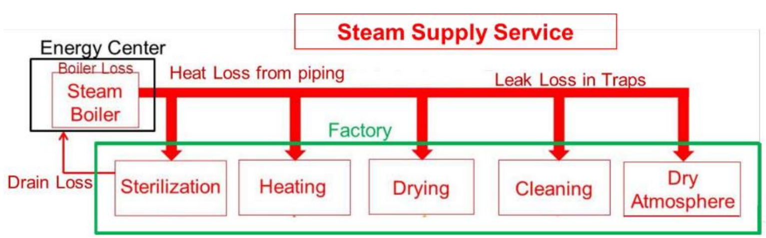


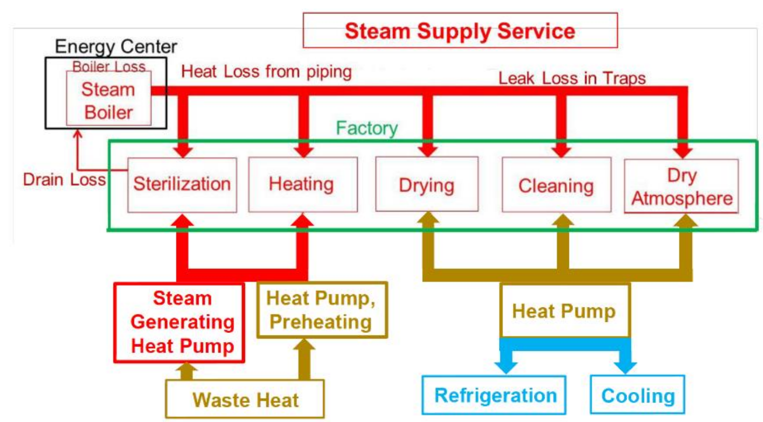
KIER's Activities - Steam Heat Pump

Design of thermal energy network for industrial processes using Steam Heat pump

- **Advantages**
  - High efficient heat pump system (vs. boiler)
  - Reduction of transport loss by distribution of devices



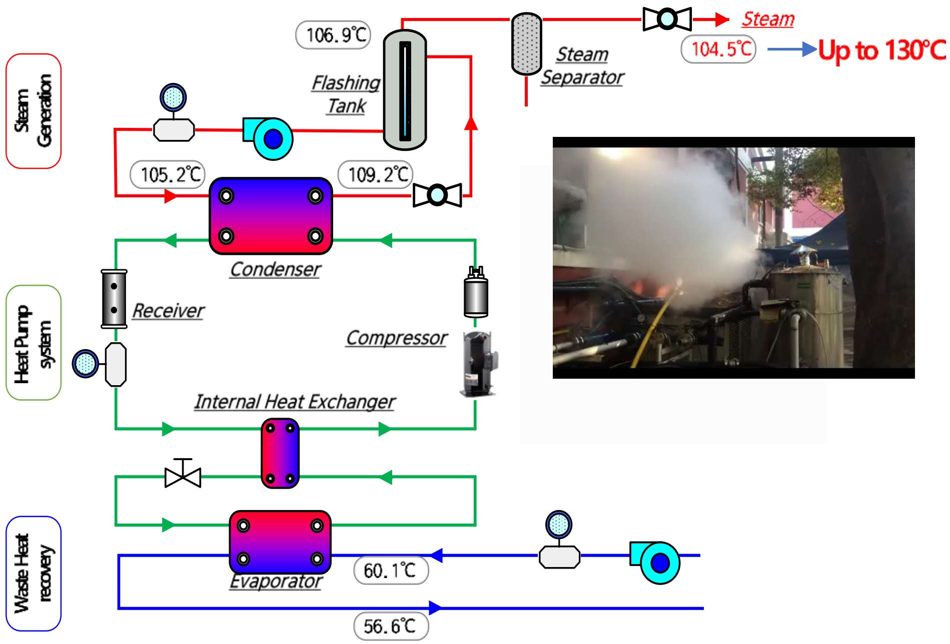




KIER's Activities - Steam Heat Pump

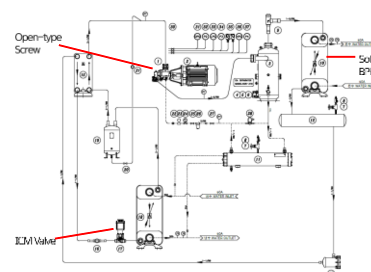
Heat Pump cycle design: Internal heat exchanger cycle

- Working Refrigerant : R-245fa
- Prototype of 40 kW_{th} : Reciprocating comp., R-245fa drop-in test
- Prototype of 100 kW_{th} : Screw comp., Cycle optimization



Prototype: 40 kW_{th}
- R-245fa drop-in, preliminary study


Prototype: 100 kW_{th}
- Open-screw, flash-tank steam generation

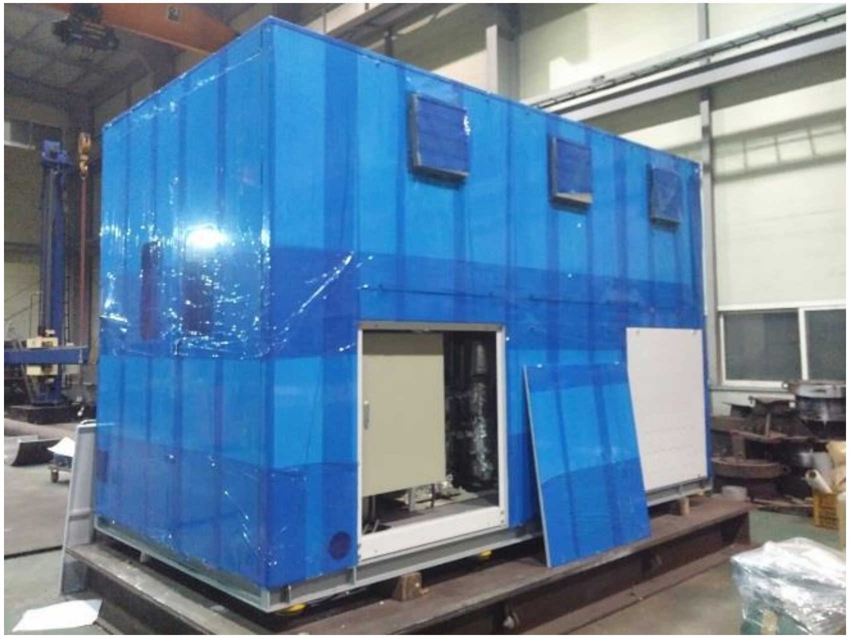


KIER's Activities - Steam Heat Pump

Prototype of High Temperature Heat Pump Unit for Low Pressure Steam Generation

- Generating 120℃, 2kgf/cm^2 for industrial processes using waste heat (50~70℃)
  - Heating capacity: 360kW$_{th}$ (corresponding to 0.5 ton/h steam)
  - COP$_h$: 3.6 (70℃ waste heat, 120℃ steam)

Heat Pump Unit (before casing)



Heat Pump Unit (after casing)

KIER's Activities - Steam Heat Pump

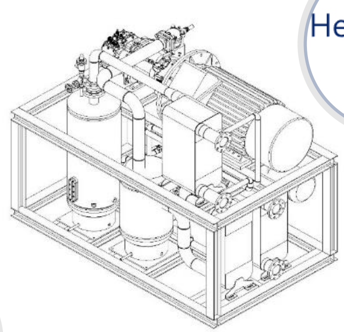
Demonstration Operation in a Poly-Carbonate Factory in Korea

- Waste heat : 50℃-55℃
- Target process: Waste Water Stripper process (using 110-120℃ steam)

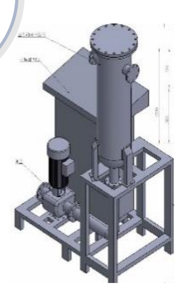
Parameter	Lab.	Site	Comment
Waste Heat(℃)	70.4	55.3	Lower temp.
Steam(℃)	119.6	115.2	Process demand
Capacity(kW)	364	348	Due to lower waste heat temp.

Prototype Units
- Capacity 360kW$_{th}$(300 Mcal/h))
- COP 3.6

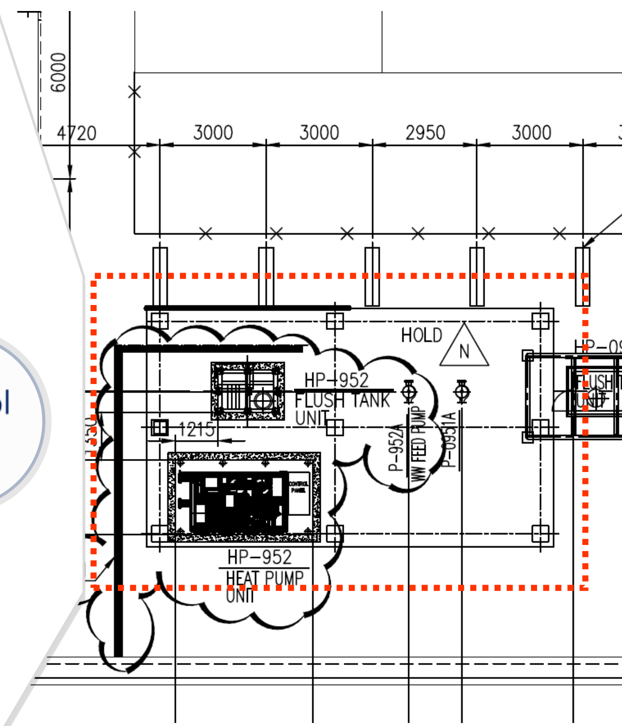
Heat Pump Unit



Flash Tank Unit



Control Panel



Demo. Site

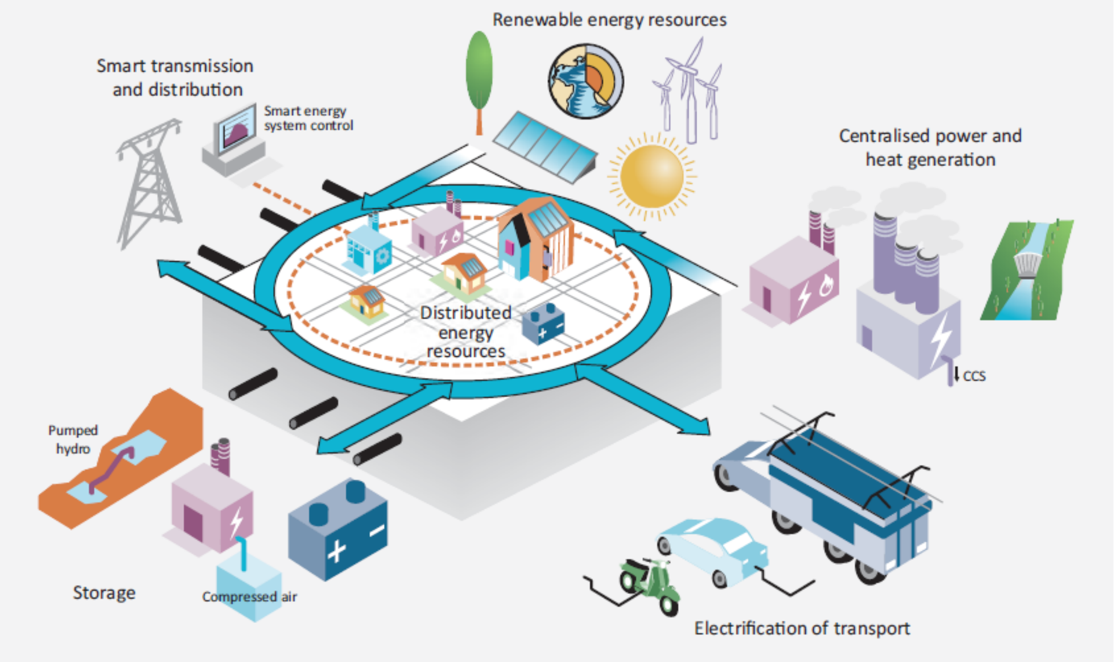
IV. Approach 3

Future Energy System

IEA Energy Technology Perspectives (ETP) 2014

Distributed Power System

Figure I.2 The integrated and intelligent electricity system of the future



Key point *To better integrate all elements of electricity systems will increase complexity, but improve operations, efficiency and resilience while optimising energy resources and investments.*

Monitoring

- Real-time monitoring of energy facilities
- Management of energy data base

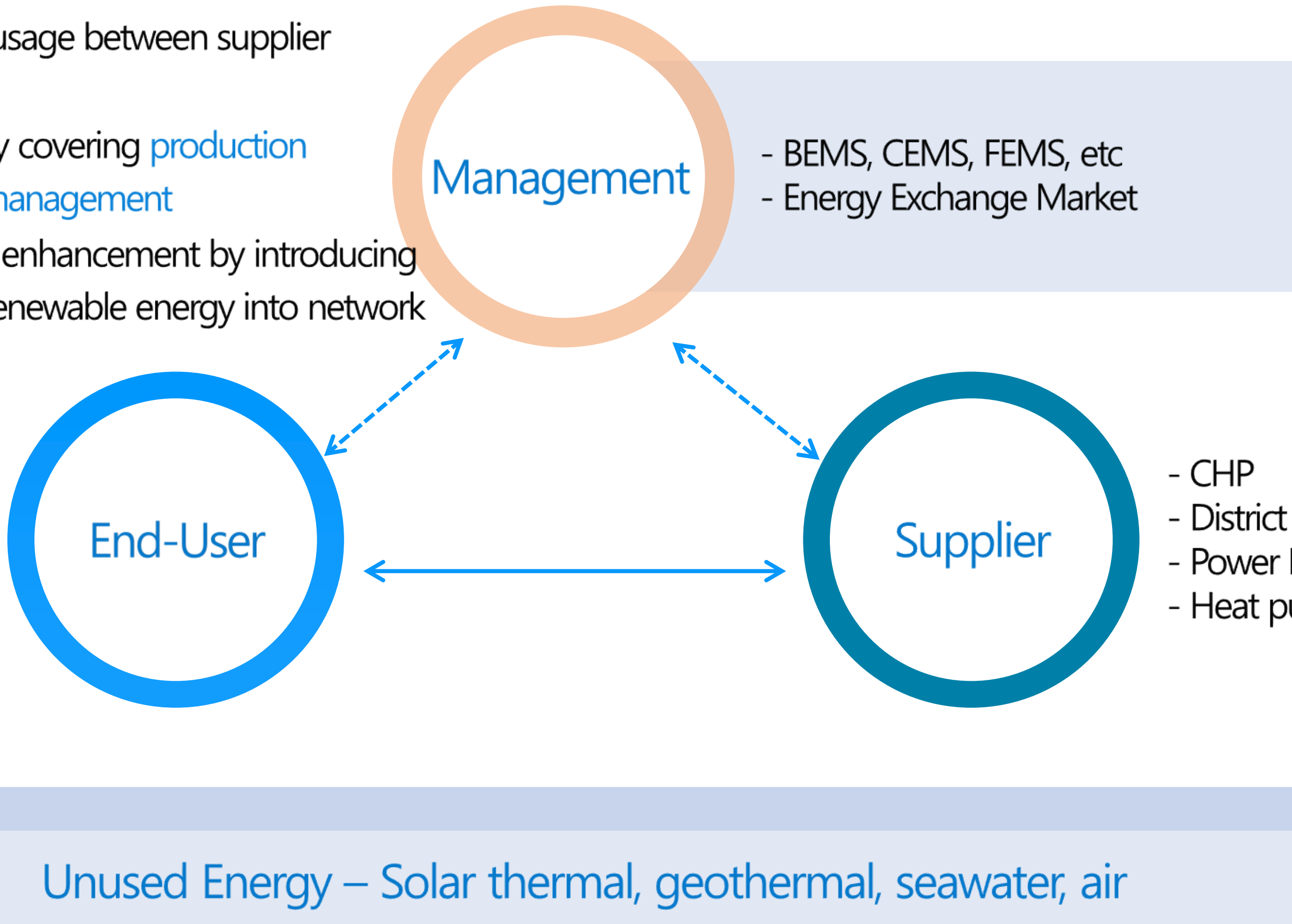
Control

- Optimizing energy resources and investments
- Improving total energy efficiency

Future Energy System

Thermal Energy Network

- Optimal energy usage between supplier and end-user
- Total R&D activity covering production -consumption-management
- Energy efficiency enhancement by introducing unused energy/renewable energy into network



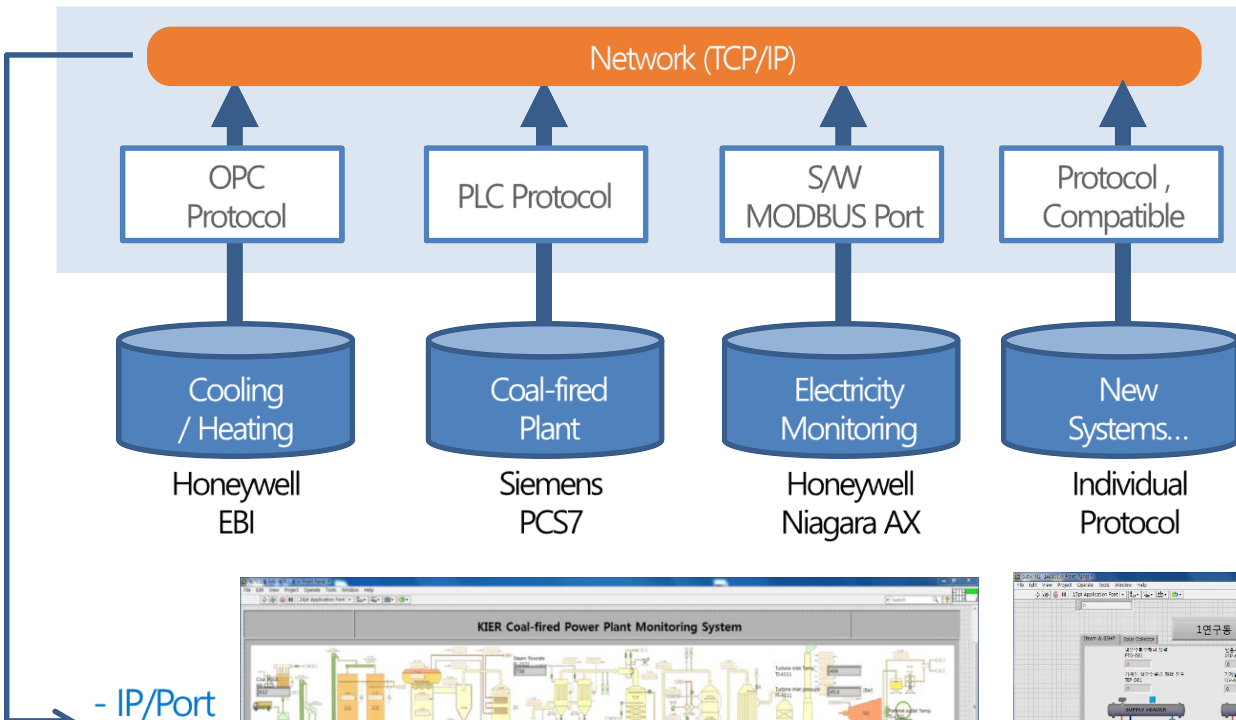
- Heat storage
- Heat pump
- Micro CHP

- CHP
- District heating
- Power Plant
- Heat pump Plant

KIER Energy Network – Communication Infra

KIER Energy Monitoring Infra – Prerequisite to Optimal Management

- Site characteristics : Individual operation of each energy facilities operate (Private monitoring protocols)
  → No integrated monitoring infra → Building Common Communication Language



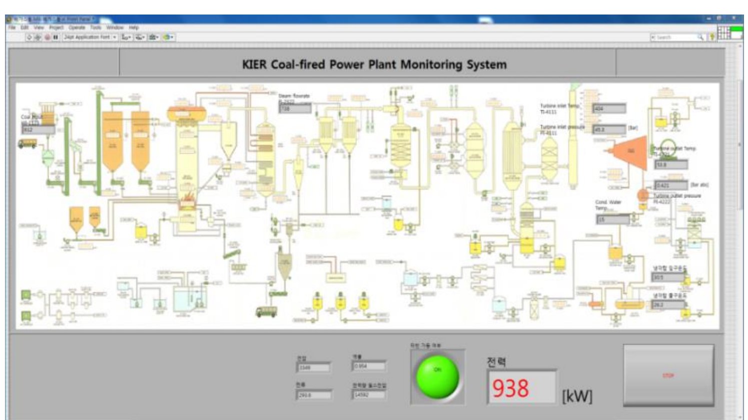
Constructing TCP/IP Protocol

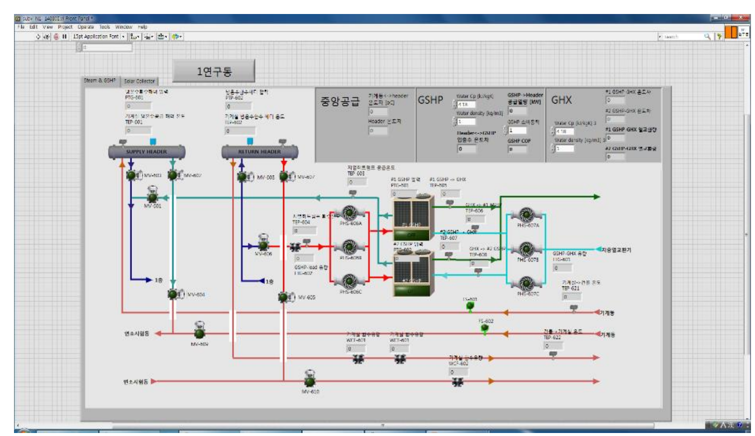
- Energy data can be accessed through network

Current systems

- Individual protocols for each system
- Independent network

- IP/Port
- Tags





KIER Energy Network – Web-based Monitoring

Constructing TCP/IP Protocol
- Energy data can be accessed through network

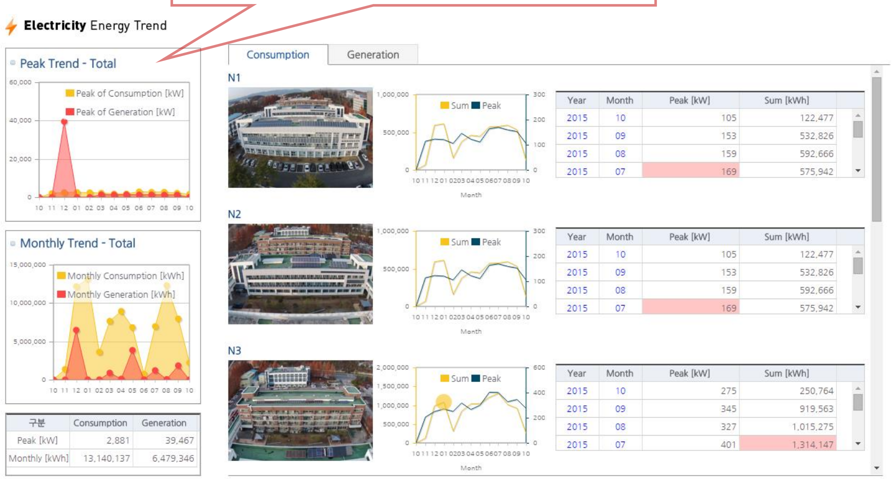
Network (TCP/IP)

Energy Network DB Server ①
- Realtime DB management
- Data history
- Restricted solvers

Real Time Data Server (Invensys InSQL) → Data Access Interface & Solvers → ② Oracle SQL Server → ③ DA (Data Access) WEB

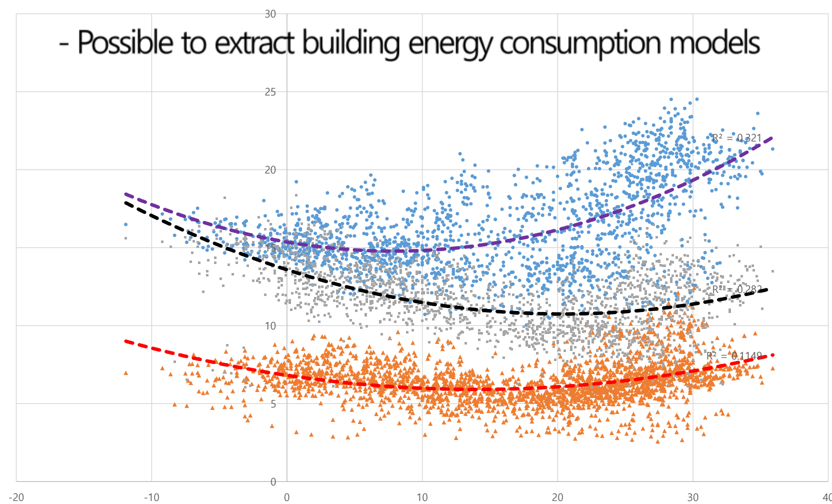
Web-based EMS System
- RTDB on HTTP platform
- Web-based monitoring and simulation (user friendly)

power usage in each building

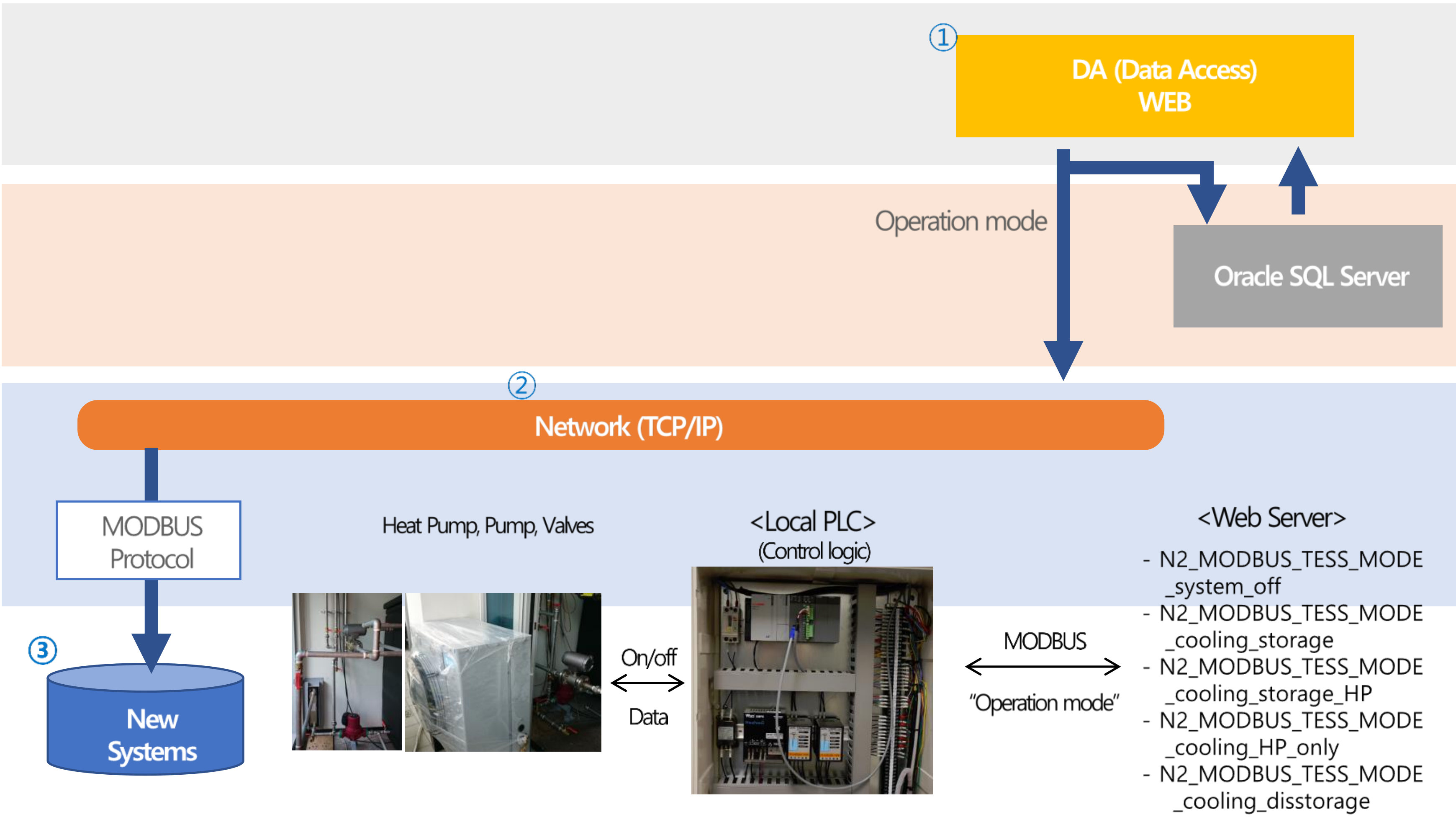


Usage for Stored DB: Elec. consumption

- Possible to extract building energy consumption models

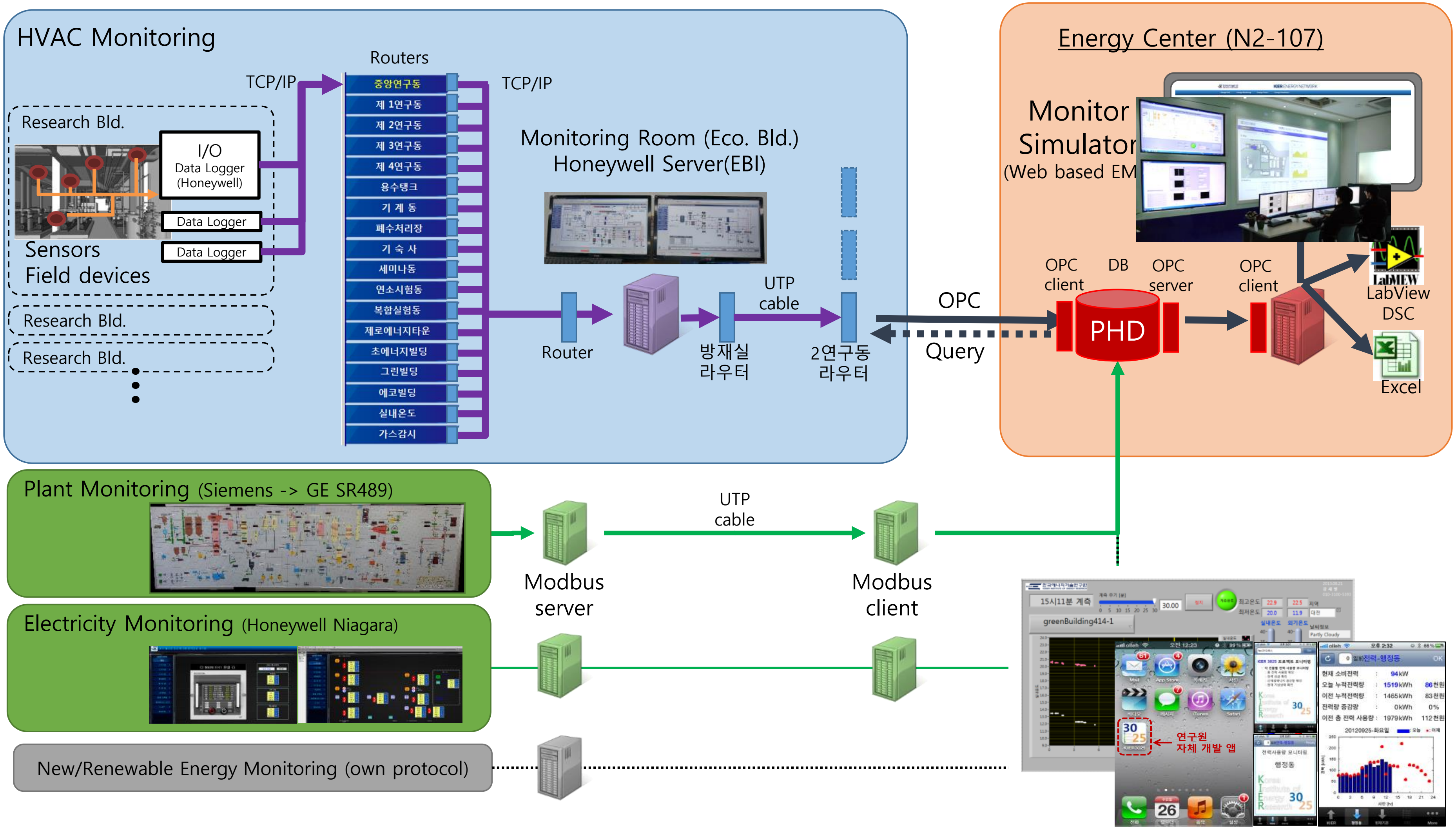


KIER Energy Network – Web-based Control



KIER Energy Network – Final Monitoring Infra

- Integrated Energy Data Management Infra (Energy Center)
  → First Stage to Total Energy Management of KIER



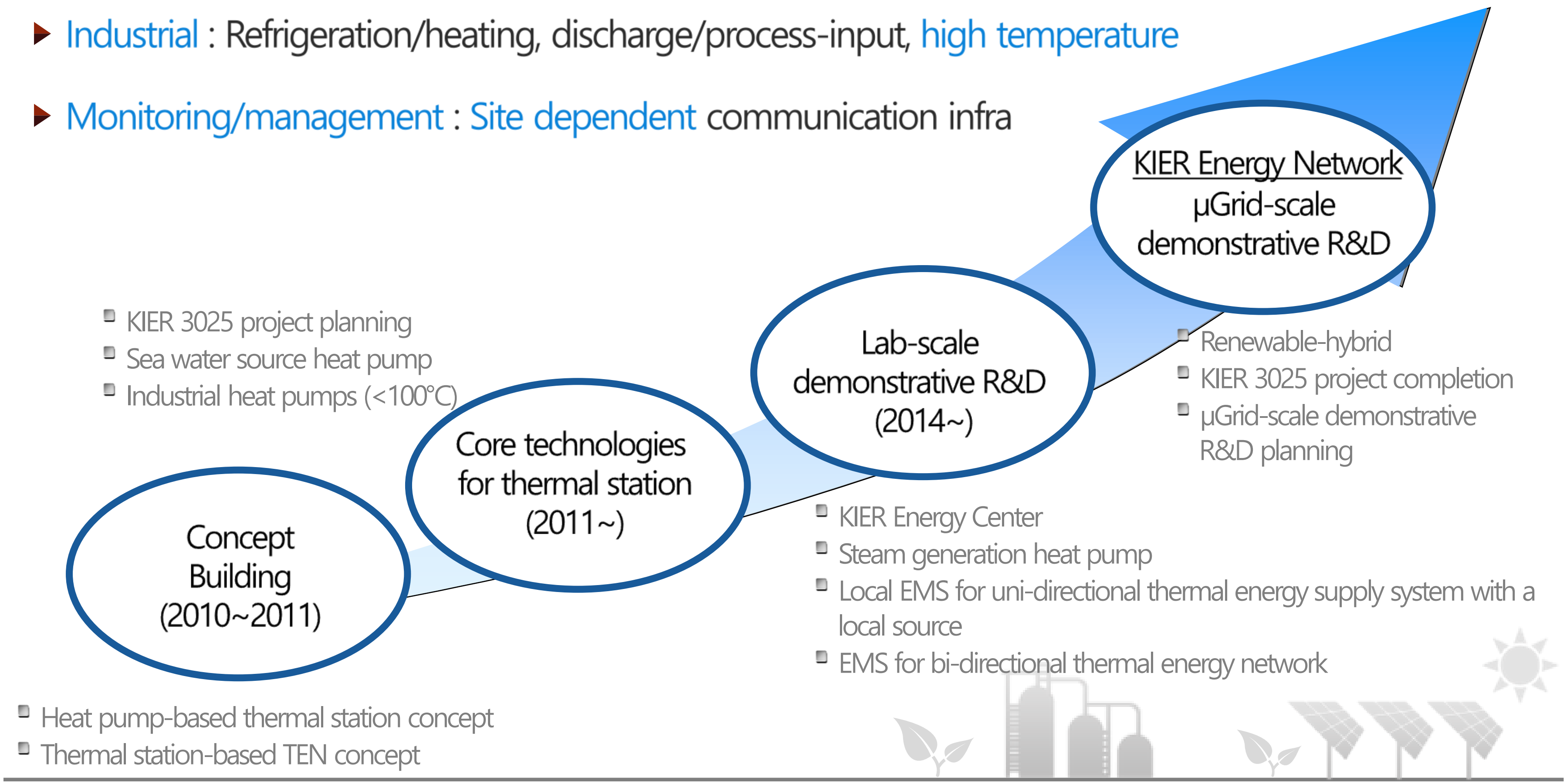
V. Summary

한국에너지기술연구원
KOREA INSTITUTE OF ENERGY RESEARCH

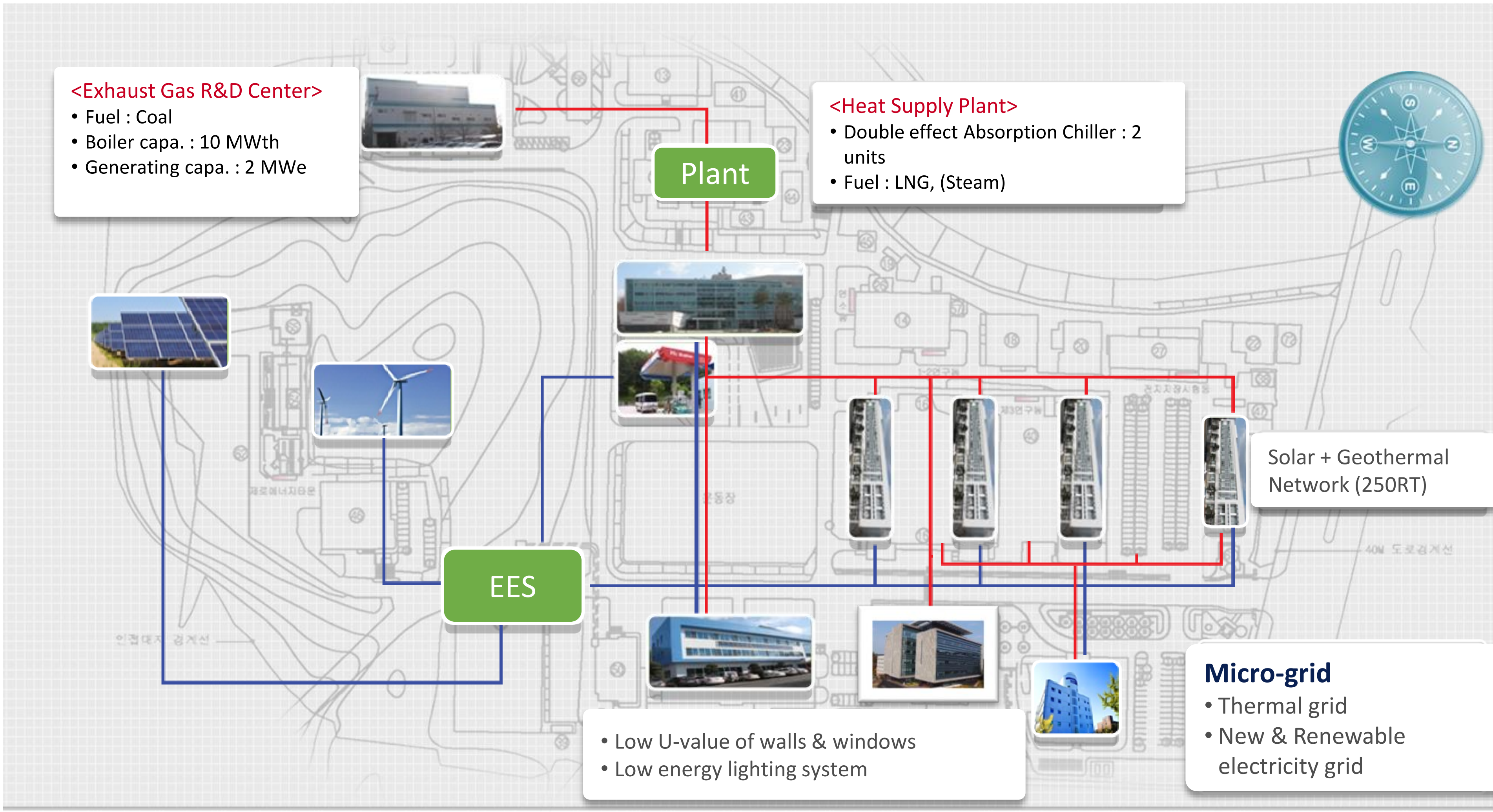
Thermal Energy Network

Maximizing the use of thermal energy by balancing energy production and consumption and by utilizing various unused energies near demand side

- Heating/hot water : Using low temperature energy around, Central heat pump/distributed heat pump
- Industrial : Refrigeration/heating, discharge/process-input, high temperature
- Monitoring/management : Site dependent communication infra



Tech Vision


<Exhaust Gas R&D Center>
• Fuel : Coal
• Boiler capa. : 10 MWth
• Generating capa. : 2 MWe
Plant
<Heat Supply Plant>
• Double effect Absorption Chiller : 2 units
• Fuel : LNG, (Steam)
EES
Solar + Geothermal Network (250RT)
• Low U-value of walls & windows
• Low energy lighting system
Micro-grid
• Thermal grid
• New & Renewable electricity grid

<1° To Keep the Earth Livable! KIER