GLOBAL KIER Energy technology innovation KIER
Korea Institute of Energy Research

IESI International Institute for Energy Systems Integration

Renewable Hybrid Thermal Energy System for Block Heating

2015.10.21

Center for Eco-Friendly Zero Energy Town, Jaehyeok Heo

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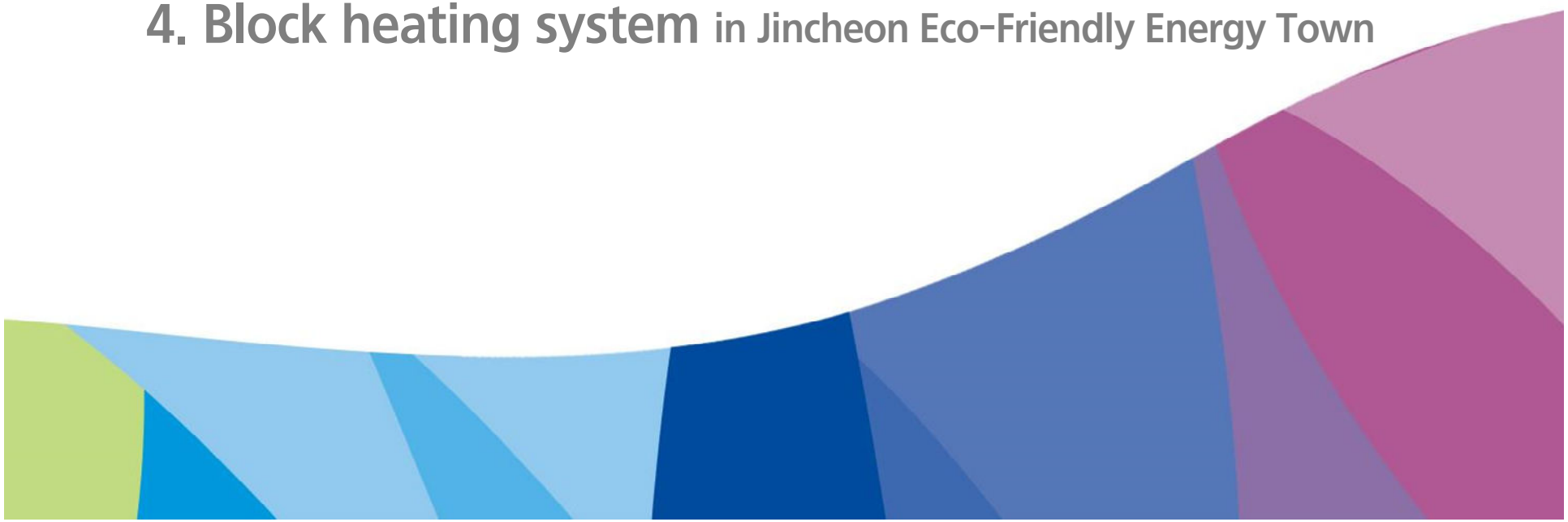

What?

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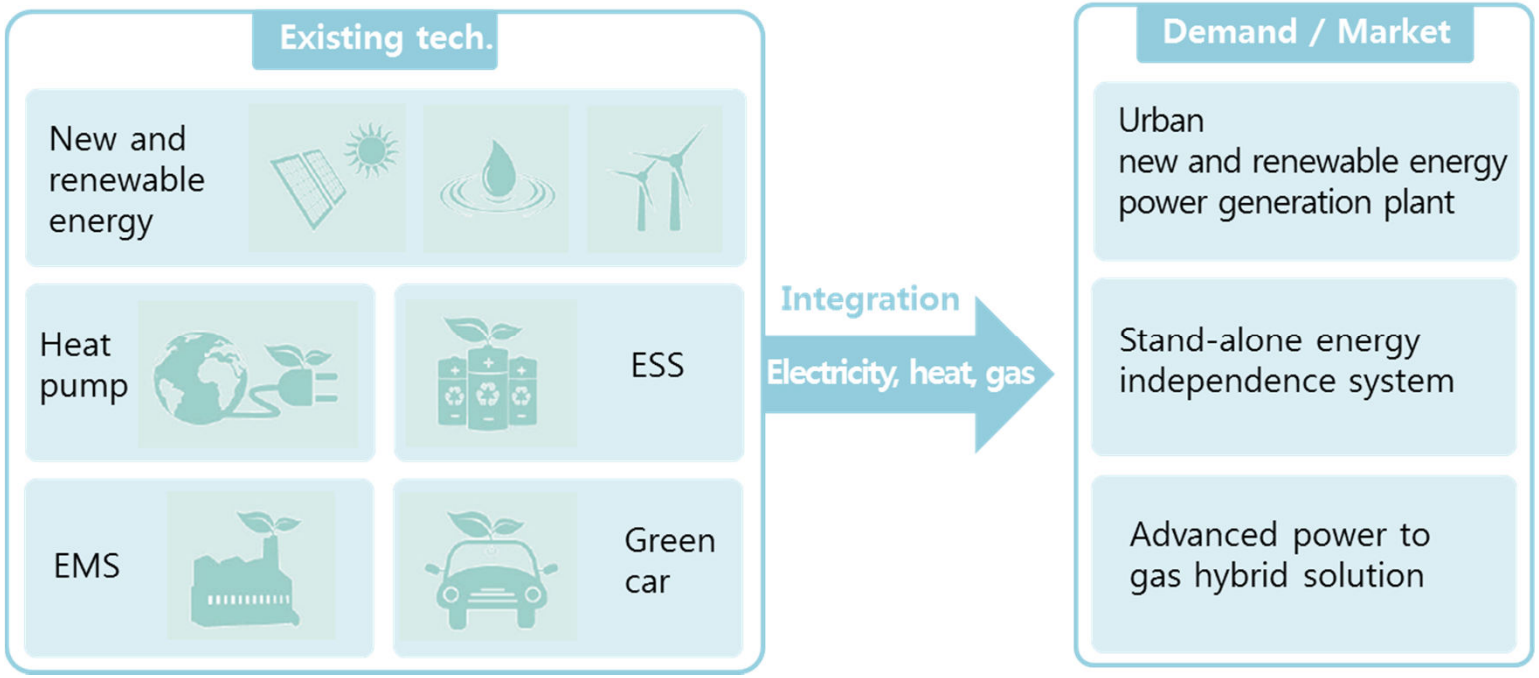
New and renewable energy hybrid system

*: uses **two or more** renewable energy sources together to provide **increased system efficiency,** reduce **power generation cost**, and improve **stability in energy supply*.***



*2014 energy technology innovation roadmap, KETEP

Why?

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Need change for energy system

: Renewable energy integration tech. is strongly needed to connect efficiently the renewable energy to power grid, building, industry, transport

- Distributed generation
- Localized power generation
- Micro-grid

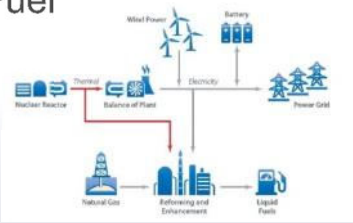
*

Prosumer

Global trend

Integration

- Electricity + Fuel
- Localization
- Optimization

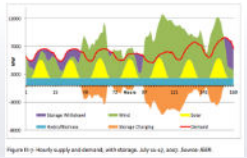


- Energy load ↑ at emerging economies countries

Energy Load ↑

Overcome intermittence

- Intermittence problem of renewable energy
- New generation tech of ESS is needed



**

energy system

Hybrid new and renewable energy system is the good solution!

* http://www.dt.co.kr/contents.html?article_no=2013111102011576650003

**http://planetsave.com/2012/03/14/100-local-clean-cheap-power-is-possible-in-minnesota/

Expected contribution?

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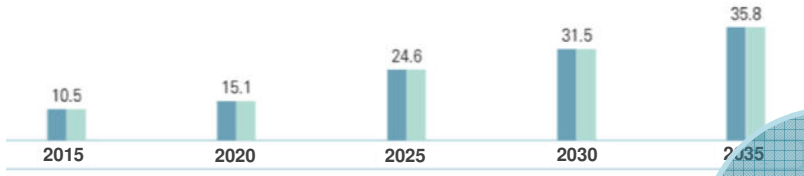
Government basic energy plan

*: Domestic new & renewable energy share; 3.18% ('14) → 11% ('35)**

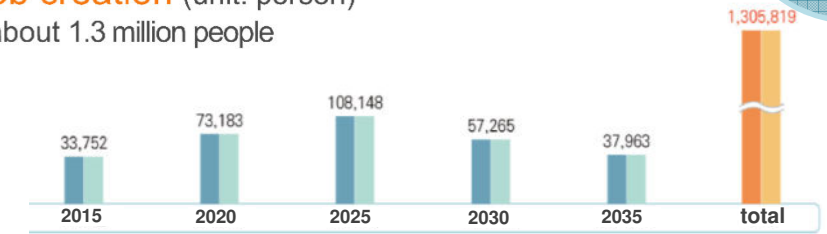
Crude oil imports savings (unit: trillion won)
- about 36 trillion won; crude oil 2.7 billion barrels *



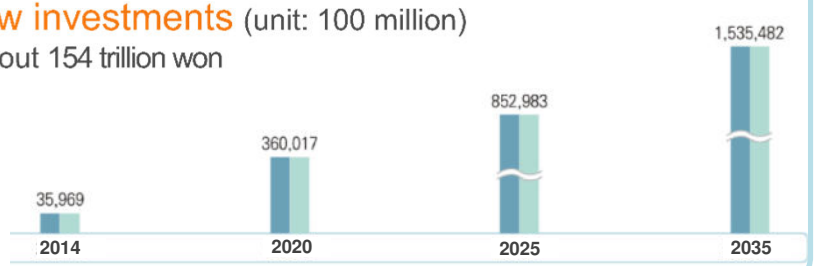
Greenhouse gas reduction (unit: tCO_2)
- 1.1 million ton, equivalent to emission from 15 thermal power plant

Expected contribution

Job creation (unit: person)
- about 1.3 million people



New investments (unit: 100 million)
- about 154 trillion won



Hybrid new and renewable energy system tech. is essential to accomplish the goal!

* The 4th new and renewable energy basic plan, 2014, Ministry of trade, industry & energy, Korea

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What?

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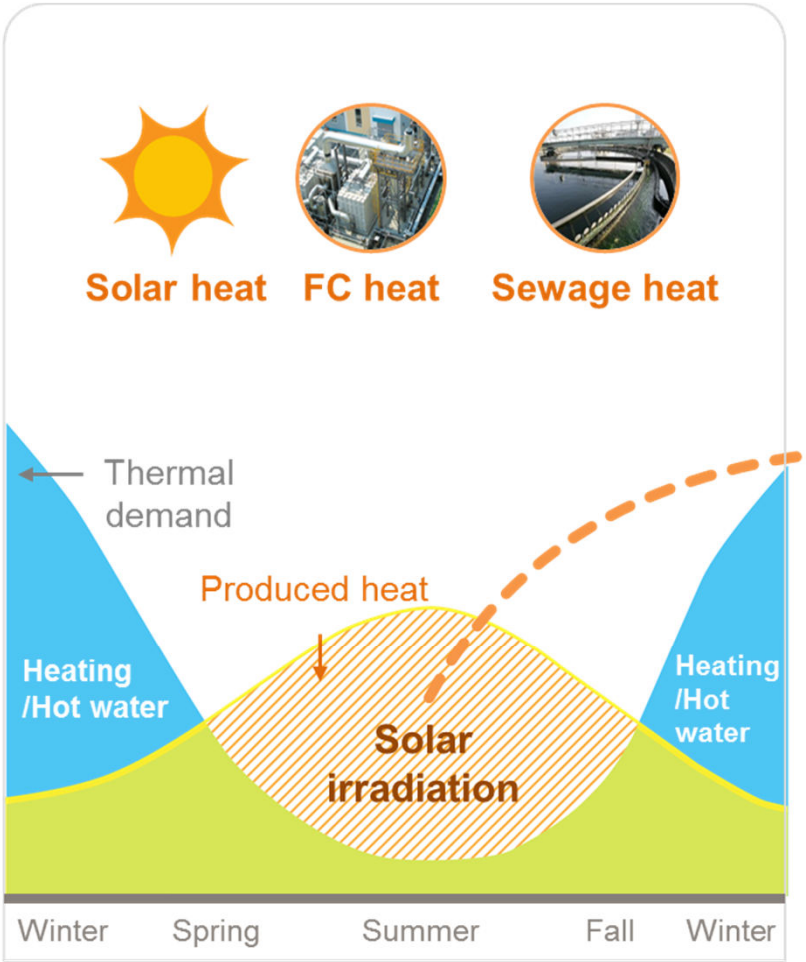
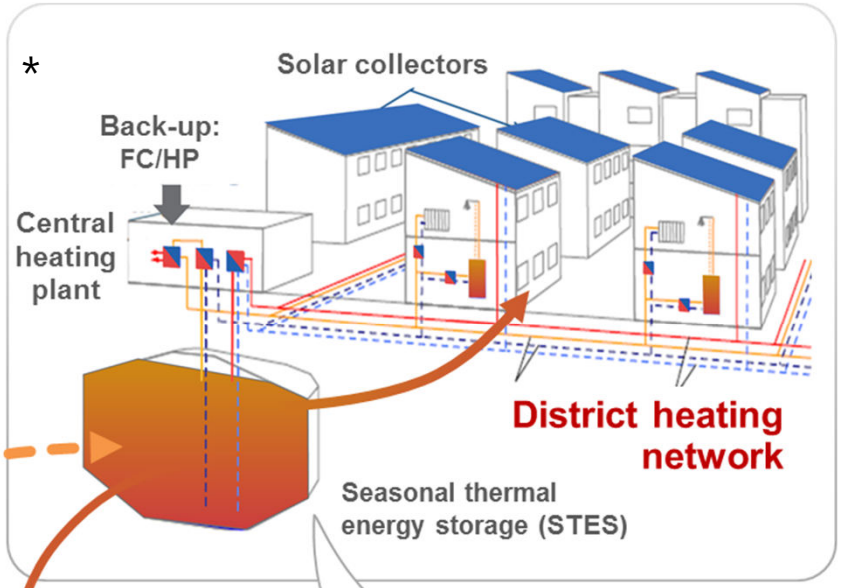
Block heating by Seasonal thermal energy storage





- Long-term storage of produced from solar thermal system.
- **Thermal renewable energy integration by FC/HP**
- Stored thermal energy supply to community

*NEW STEPS IN SEASONAL THERMAL ENERGY STORAGE IN GERMANY, Solites, Thomas Schmidt

Status?

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Solar district heating in Europe

- Demonstration project enabled since the mid-90s (Germany)
- Connection with CHP district heating (Denmark)
- Europe's ongoing STES multinational projects

SUNSTORE4 Project

- 100% renewable DH demonstration research
- Pit-type STES system
- Demonstration in Denmark Marstal

SUNSTORE 4

SDHPlus Project

- Subsequent project of SDHtake-off
- Research project for Business opportunity of SDH

SDH solar district heating

Einstein Project

- Research for STES application to existing building
- Europe FP7 support project
- Demonstration in Spain and Poland

EINSTEIN

Pitagoras Project

- STES of unused industrial process heat and solar heat
- Research for connection with existing DH line
- Demonstration in Italy and Austria

PITAGORAS

SDH : Solar District Heating, CHP: Combined Heat and Power, STES: seasonal thermal energy system

Status?

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SDH R&D Projects within Solarthemie-2000/2000plus

Hamburg (1996)

14,800 m² heated area,
3,000 m² flat plate collector,
4,500 m³ hot-water

Friedrichshafen (1996)

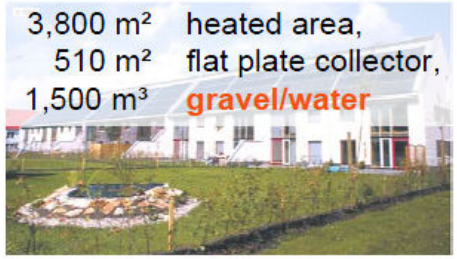
33,000 m² heated area,
4,050 m² flat plate collector,
12,000 m³ hot-water

Neckarsulm (1997) *

25,000 m² heated area,
5,300 m² flat plate collector,
63,300 m³ BTES

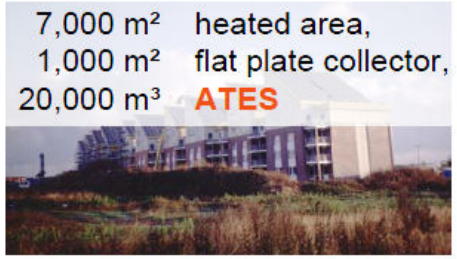
Steinfurt (1998)

3,800 m² heated area,
510 m² flat plate collector,
1,500 m³ gravel/water



Rostock (2000)

7,000 m² heated area,
1,000 m² flat plate collector,
20,000 m³ ATES

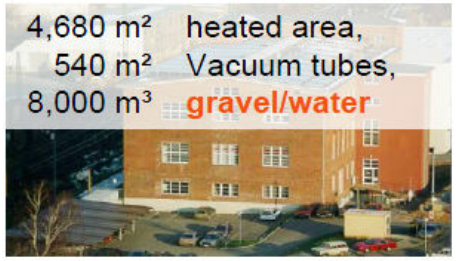


Hannover (2000)

7,365 m² heated area,
1,350 m² flat plate collector,
2,750 m³ hot-water

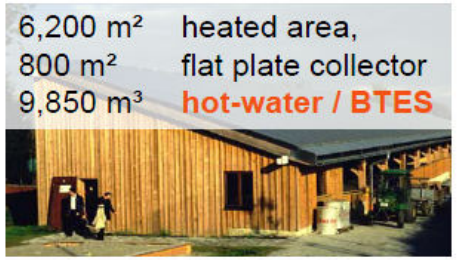
Chemnitz, 1. BA (2000)

4,680 m² heated area,
540 m² Vacuum tubes,
8,000 m³ gravel/water



Attenkirchen (2002)

6,200 m² heated area,
800 m² flat plate collector
9,850 m³ hot-water / BTES



2006: **Munich Crailsheim**

2007: **Eggenstein-Leopoldshafen**

*NEW STEPS IN SEASONAL THERMAL ENERGY STORAGE IN GERMANY, Solites, Thomas Schmidt

How?

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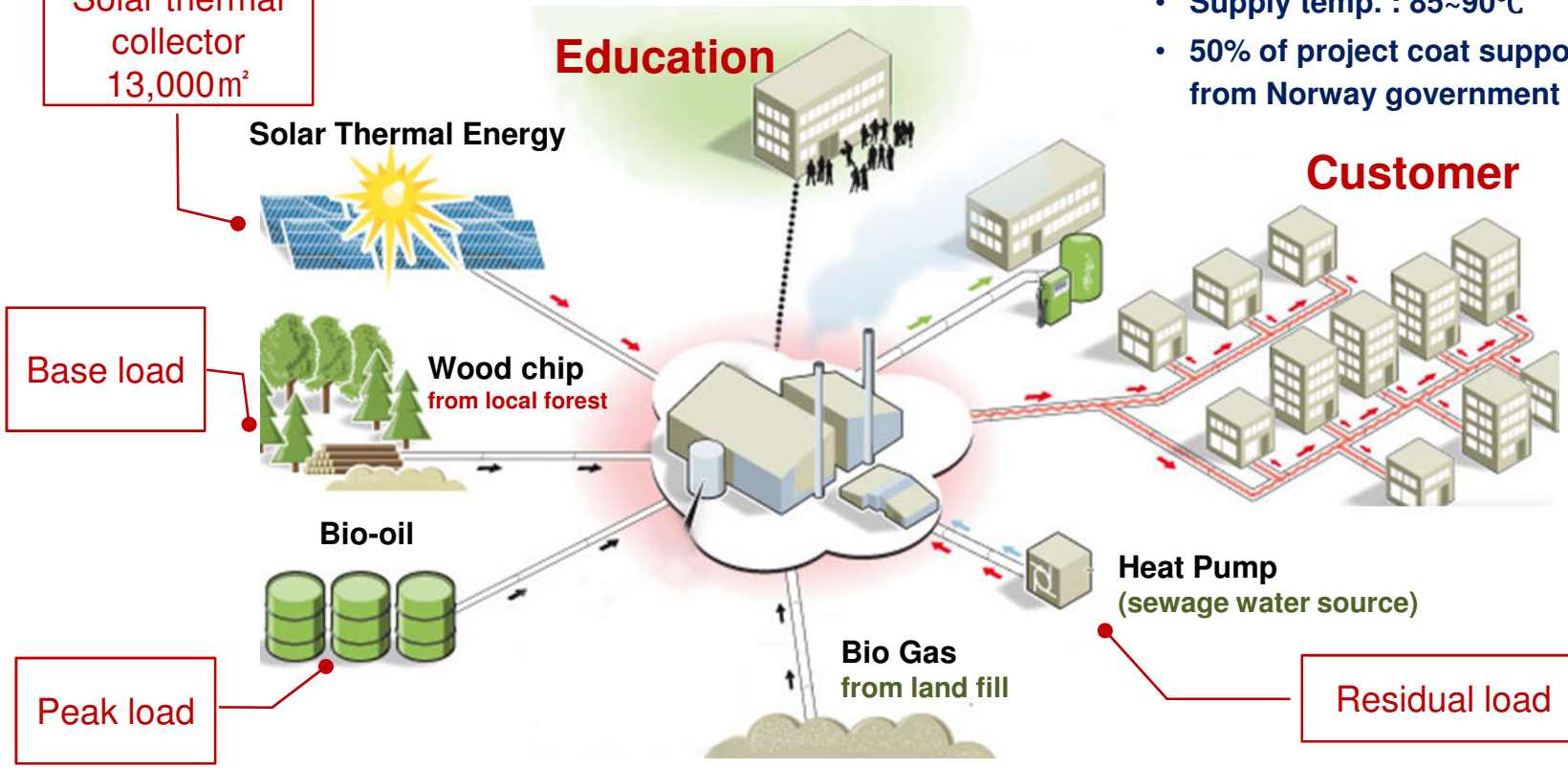
Norway Lillestrom district heating

- **2012. 11 Completion**
- Location : Lillestrom near Oslo
- Solar thermal cost: 5 billion won
- CO_2 reduction : 120,000 ton/yr

- **Plant Area: 13,000 m²**
- Heating network: 20 → 40 km
- Cooling network: 6 → 11 km
- **Near sewage center & landfill**

*

- **Supply temp. : 85~90℃**
- **50% of project coat supported from Norway government**



How?

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Norway Lillestrom district heating

Project data

- Heat pump - sewage water: 4,3 MW heat – 6 MW cooling
- Cooling machine – river water: 3,5 MW
- Cooling machine (peak)- air: 3,0 MW (2011)
- Bio- wood chips : 20 MW (including
- Boilers – peak/reserve: 50 MW (renewable oil)
- Landfill Gas boiler: 1,5 MW
- Solar panels: 10.000 m^2 panels (planned 2012)
- Accumulator: 1.200 m^3
- Heating network: today 20 km will expand to 40 km
- Cooling network: today 6 km, will expand to 11 km
- Heating: sales 2009, 30,5 GWh - fully developed approx. 150 GWh
- Cooling: sales 2009, 1,5 GWh – fully developed approx. 15 GWh

How?

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Central solar heating with STES in Munich (Germany)

District heating network

- **Start of operation: 2007**
- **Service area: 300 apartment**

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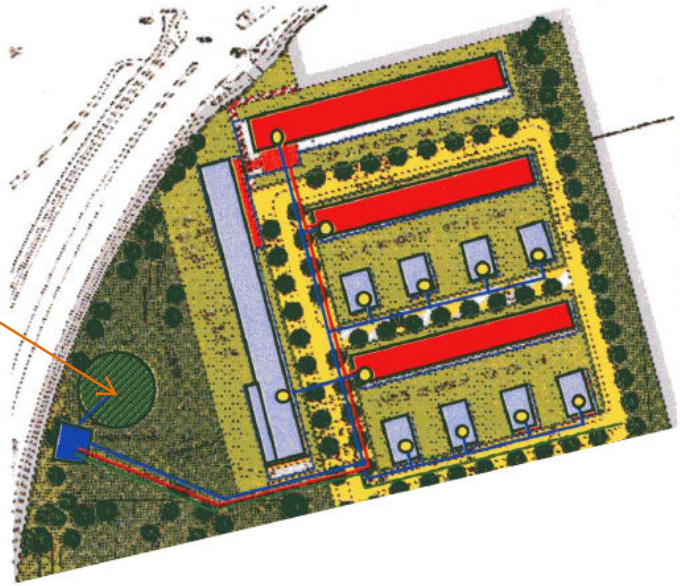
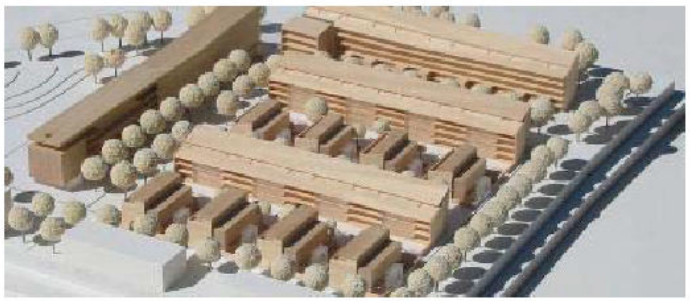


TTES: 5,700 m³

- thermal energy storage
- solar collectors on buildings
- buildings without solar collectors
- central heating plant
- local heat distribution network
- solar network
- district heating network
- heat transfer substation in buildings



*NEW STEPS IN SEASONAL THERMAL ENERGY STORAGE IN GERMANY, Solites, Thomas Schmidt

How?

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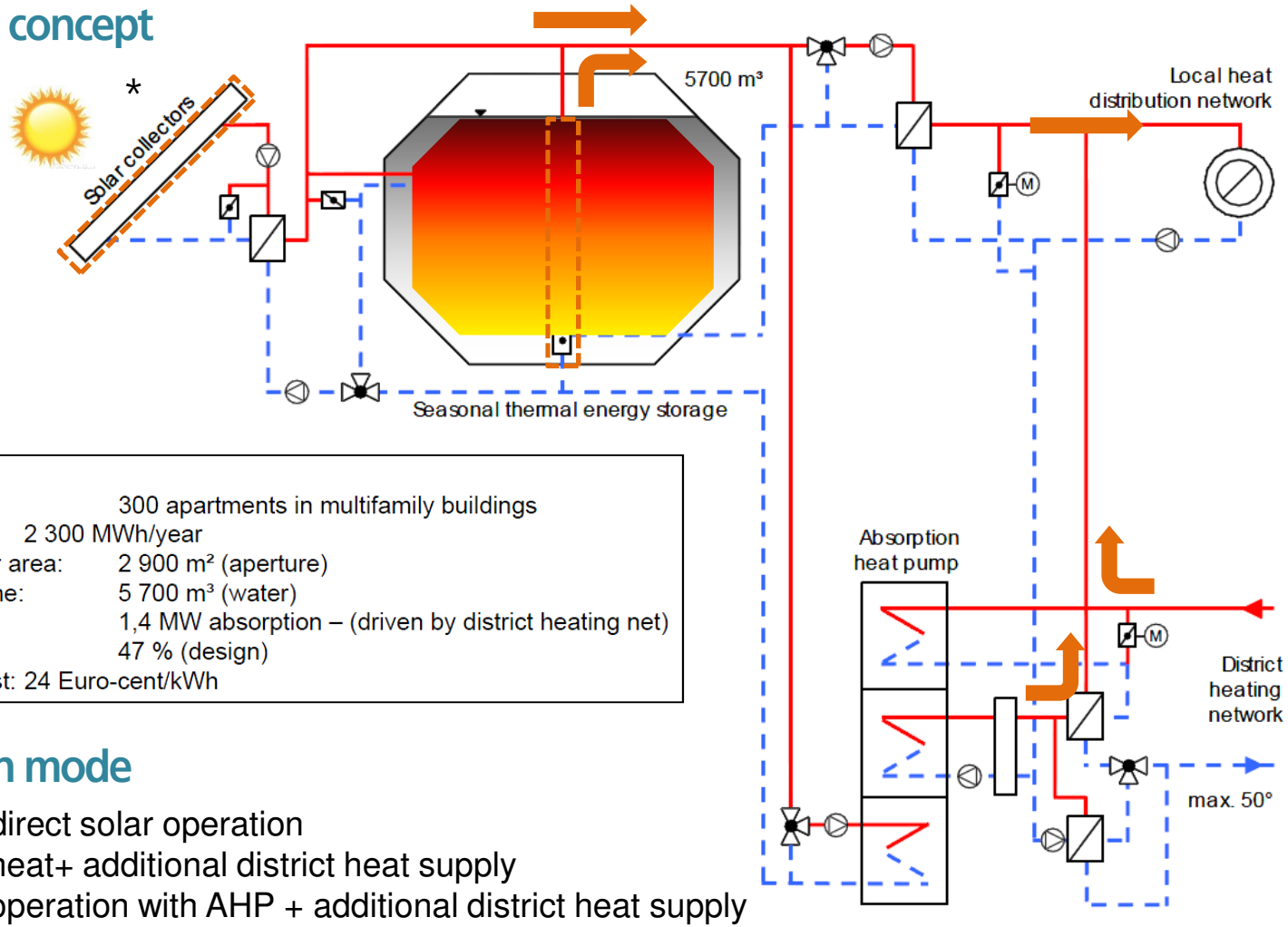
Central solar heating with STES in Munich (Germany)

System concept



Project data:

- service area: 300 apartments in multifamily buildings
- heat demand: 2 300 MWh/year
- solar collector area: 2 900 m² (aperture)
- storage volume: 5 700 m³ (water)
- heat pump: 1,4 MW absorption – (driven by district heating net)
- solar fraction: 47 % (design)
- solar heat cost: 24 Euro-cent/kWh

Operation mode

1. Storage/direct solar operation
2. Storage heat+ additional district heat supply
3. Storage operation with AHP + additional district heat supply

*NEW STEPS IN SEASONAL THERMAL ENERGY STORAGE IN GERMANY, Solites, Thomas Schmidt

How?

KIER KOREA INSTITUTE OF ENERGY RESEARCH

Central solar heating with STES in Crailsheim (Germany)

District heating network

- **Start of operation: 2007**
- **Service area: 260 apartment**

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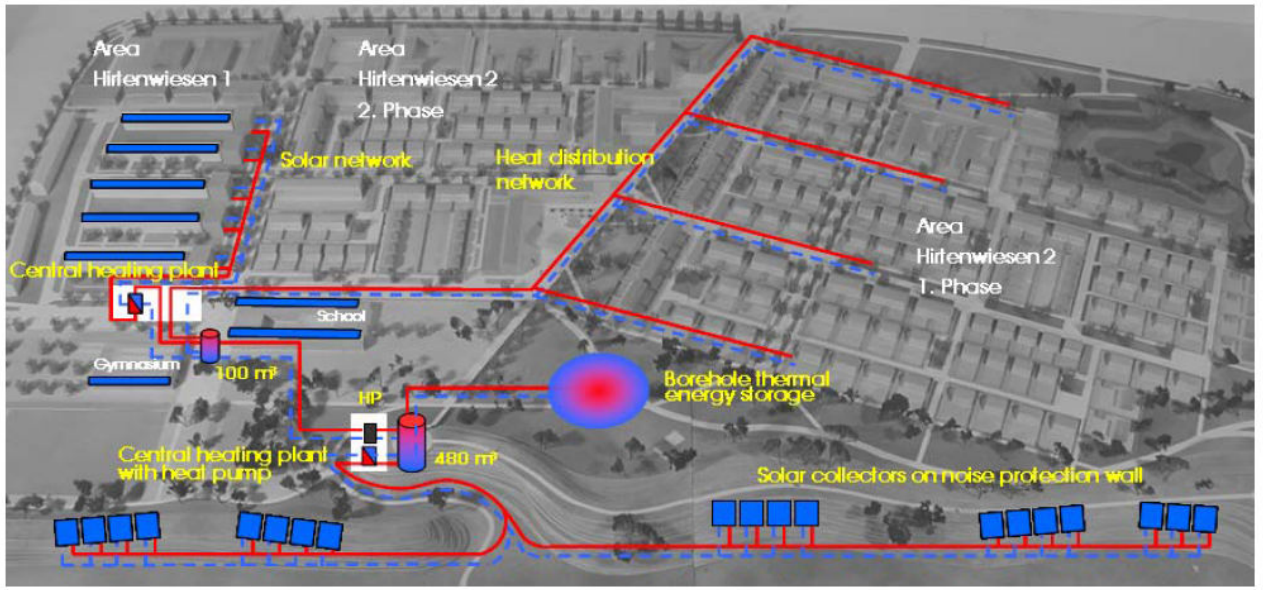

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How?

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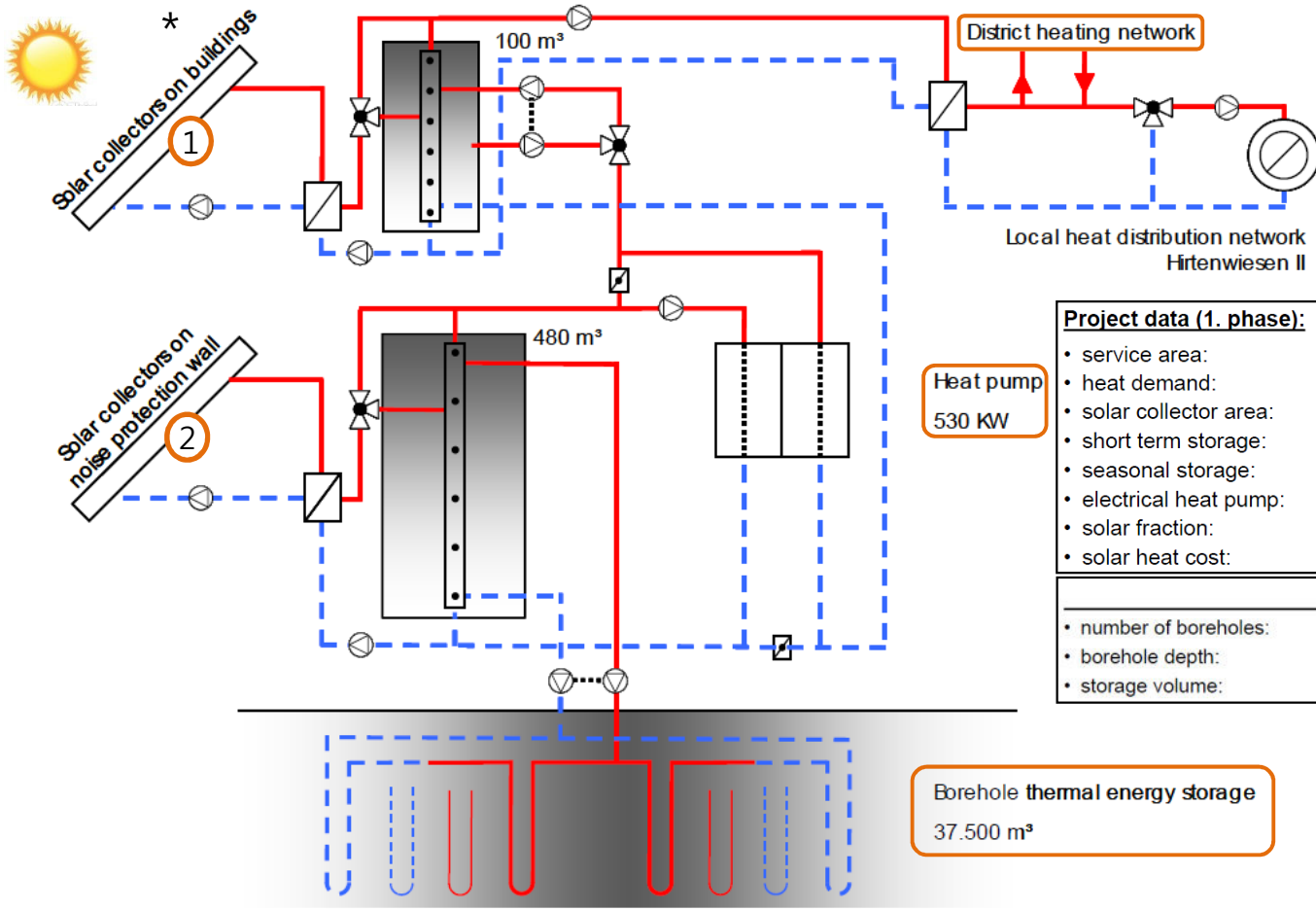

Project data (1. phase):

• service area:	260 apartments, school, gymnasium
• heat demand:	4 100 MWh/year
• solar collector area:	7 300 m² (aperture)
• short term storage:	100 m³ (water tank)
• seasonal storage:	37 500 m³ (BTES) + 480 m³ (water tank)
• electrical heat pump:	530 kW
• solar fraction:	50 % (design)
• solar heat cost:	19 Euro-Cent/kWh

	1. phase	2. phase
• number of boreholes:	80	160
• borehole depth:	60 m	60 m
• storage volume:	37 500 m³	75 000 m³

*NEW STEPS IN SEASONAL THERMAL ENERGY STORAGE IN GERMANY, Solites, Thomas Schmidt

SDH in Germany

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Several SDH system's information

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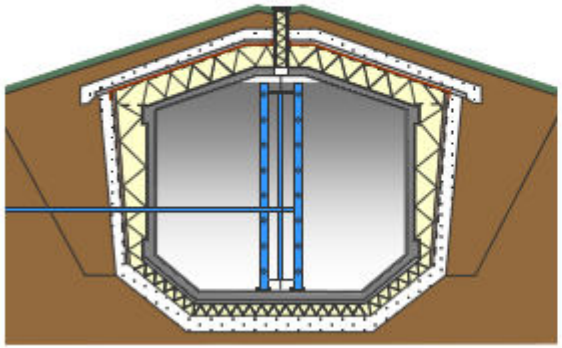
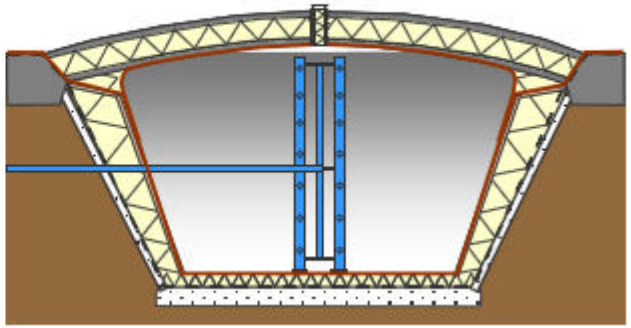
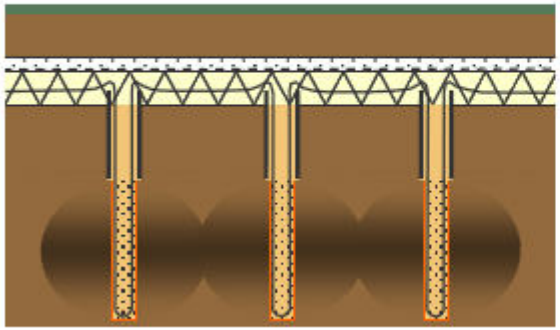
Tank thermal energy storage (TTES)
(60 to 80 kWh/m³)



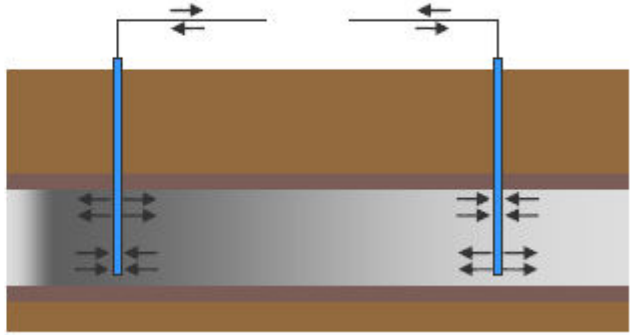
Pit thermal energy storage (PTES)
(60 to 80 kWh/m³)



Borehole thermal energy storage (BTES)
(15 to 30 kWh/m³)



Aquifer thermal energy storage (ATES)
(30 to 40 kWh/m³)



SDH : Solar District Heating

*The next Generations of Seasonal Thermal Energy Storage in Germany, Solites, D.Mangold et al.

SDH in Germany

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Specific investment cost

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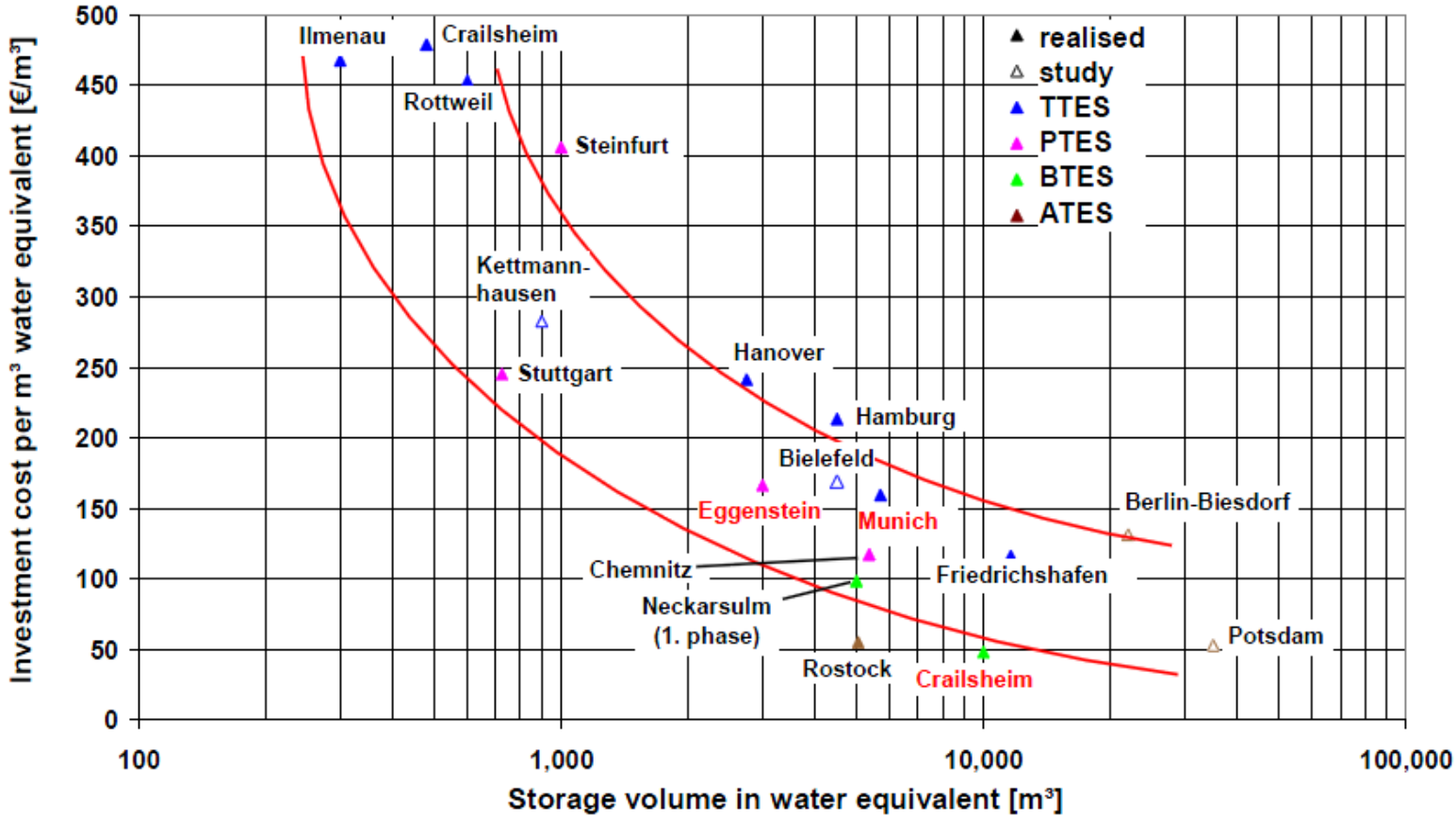

SDH : Solar District Heating

*The next Generations of Seasonal Thermal Energy Storage in Germany, Solites, D.Mangold et al.

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In case of Korea?

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History of Studies on Zero Energy Tech. of KIER

ZeSH I
(Daejeon, KIER)

ZeSH II
(Daejeon, KIER)

Zero Energy Community
(Gochang)

2002 — 2006 — 2010 — 2012 — 2014

2002 ~ 2006	2010	2012
-Primary goal: Energy saving 70% for thermal energy demand	-Primary goal: Energy saving 70% for total energy demand	-Primary goal: Energy saving 70% for total energy demand at the level of actual residential community
Thermal energy for a house	Thermal + electrical energy for a house	Thermal + electrical energy for community

SDH : Solar District Heating

*K.H. Lee, 2012, KIER's research towards zero energy house and community

In case of Korea?

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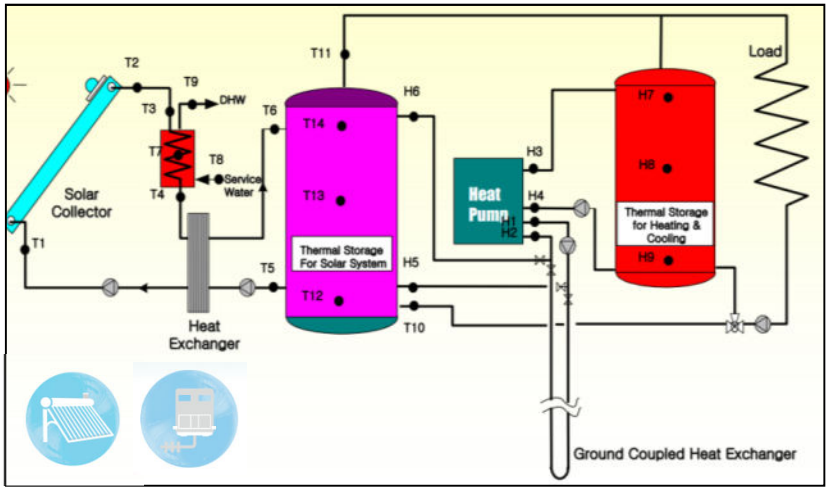
Zero Energy Solar House (Zesh) I in KIER

Zero energy tech.

System concept



☐ **Building information**
- Completion: 2002.12
- Structure: Reinforced concrete + external insulation + cement
- Floor area: 264.5 m^2 (total)
- Target: Energy independence 70% of thermal load

☐ **Passive solar system**
- Super insulation
- Transparent Mass wall, Trombe wall, Direct gain, movable shading device, night insulation

☐ **Heat recovery ventilation system**
- Small rotary type motor and htx is used for the system

☐ **Active solar system**
- FP Solar collector (26 m^2), low temp. floor radiant heating system, hot water system

☐ **Auxiliary heating and cooling system**
- Solar thermal and geo source heat pump system (10.5 kW(3RT),
- Bore hole depth 150 m

☐ **Result and Contribution**
- Several passive and active techniques are tested
- Energy independence is more than 70% of thermal load
- Operating experience, design technique, experience for the improved and economic house design

In case of Korea?

KIER KOREA INSTITUTE OF ENERGY RESEARCH

Zero Energy Solar House (Zesh) II in KIER

Zero energy tech.

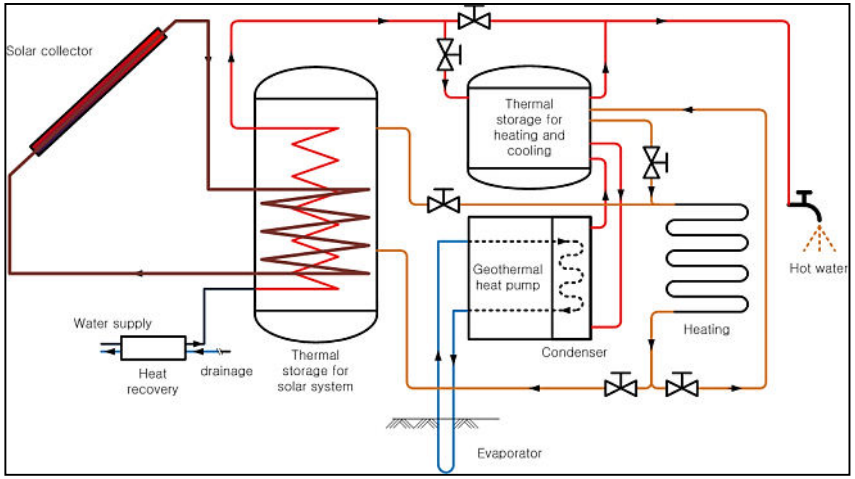
☐ **Building information**
- Completion: 2009.7
- Structure: Reinforced concrete (20 mm) + EPS + cement
- Floor area: 275.2 m^2 (total)
- Target: Energy independence 70% of thermal and electrical load

☐ **Window system**
- Triple loe-e glazing +Al insulation frame
- Heat transmission coefficient (U=1.2W.m^{2o}C)

☐ **Hybrid heat recovery & ventilation system**
- Air inlet by natural, Air vent by forced heat recovery
- Very small motor (24W ×3)
- Automatic control by air quality sensor (1000 ppm)

EPS: expanded polystyrene foam

System concept



☐ **Building integrated solar thermal system**
- Façade integrated solar mega collectors (25 m^2)

☐ **Solar/Geothermal hybrid heating and cooling system**
- geo source heat pump system (8.8 kW (2.5RT), bore hole depth 150 m)
- low temp. floor radiant heating system, hot water system
- Ceiling integrated FCU was installed

☐ **Building integrated PV system**
- Roof integrated PV system : 3.15 kWp, 80-100 kWh/month at 1 kW panel

☐ **Result and Contribution**
- Total construction cost < 120% of conventional construction cost
- Key technologies were transferred to big company (Hanwha)

In case of Korea?

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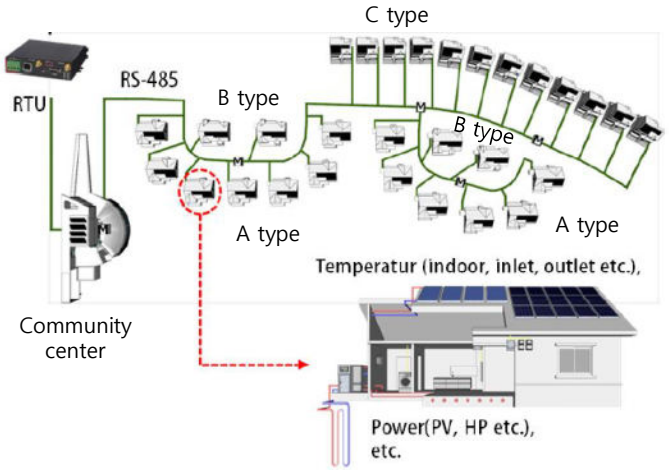
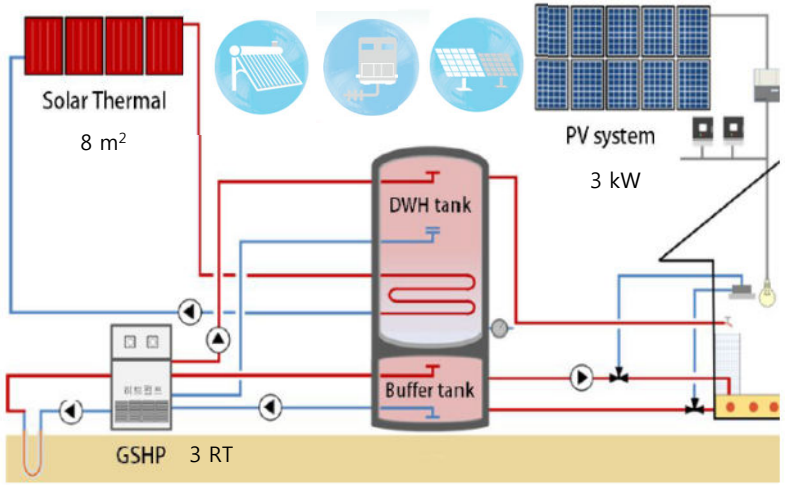
Gochang Zero energy town

Community views



*Lee et al., 2015, A study on the energy performance evaluation of zero energy house in ZET

System concept



House	Electricity load (1)	Heating load (2)	Water heating load (3)		Cooling load (4)	Total Energy load (5)	Power generation by PV (6)	Energy supply from outside (7) = (1)-(6)
			by Solar Thermal	by GSHP				
A house	3,841	4,803	2,638	423	633	12,338	3,886	-45
			3,061					
B house	5,350	4,311	2,609	674	183	13,127	3,913	1,437
			3,283					
C house	2,919	6,846	2,642	484	145	13,036	3,901	-982
			3,126					
Average	4,037	5,320	2,630	527	320	12,834	3,900	137
			3,157					

☐ **Monitoring results***

- Energy load of 29 zero energy houses were analyzed (2013.10.01~2014.09.30).
- Total energy load per house: 12,384 kWh (heating energy load: 53.2 kWh)
- Heating/cooling/water heating: 100% covered by solar thermal/geo-source hybrid system
- Water heating load: 80-86% covered by solar thermal system
- Avg. energy independence: 97%

CONTENTS

What?

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Eco-Friendly Energy Town Project

: concurrent solve of energy and environmental issues by eco-friendly energy facility installation to opposed area

Gov. DEPT.	MSIP Ministry of Science, ICT and Future Planning	MOTIE Ministry of Trade, Industry and Energy	ME Ministry of Environment
Location	Jincheon	Gwangju	Hongcheon
Period	'15 ~ '18	'15 ~ '16	'15 ~ '16
Opposed area	Near Sewage treatment center	Landfill	Near organic waste facility
Facility	PV, Solar thermal, FC, HP using ground and sewage heat	PV, solar thermal	Bio energy from organic waste, PV, small hydropower
Concept Figure			

※ PV: photovoltaic, FC: fuel cell, HP: heat pump

How?

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Jincheon Eco-Friendly Energy Town

: Basic instruction

Major information?

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Jincheon Eco-Friendly Energy Town

: Construction information

- Location:
  - Chungbuk Innocity
- Covered area:
  - 72,000 m^2
- Project period:
  - 2015~2019
- Accommodation
  - High school
  - Library
  - Youth center
  - Integrated management center
  - Daycare center
  - Public health center

Technical issues?

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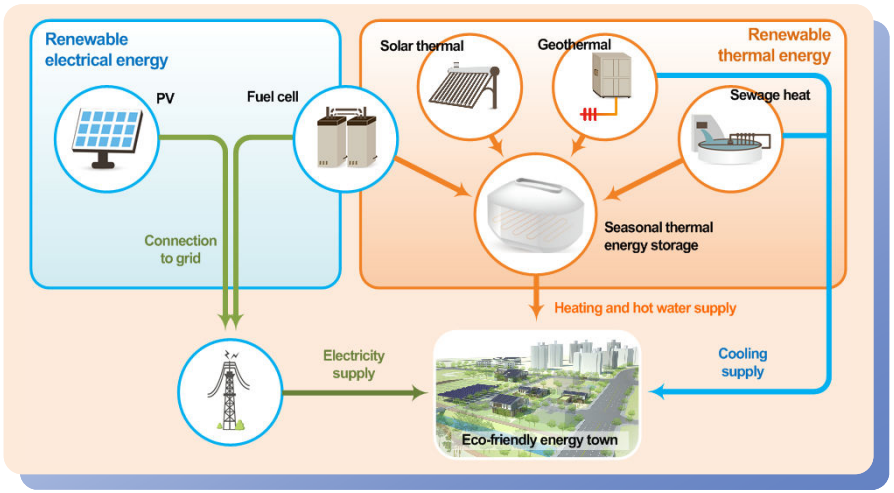
Renewable energy hybrid system with STES

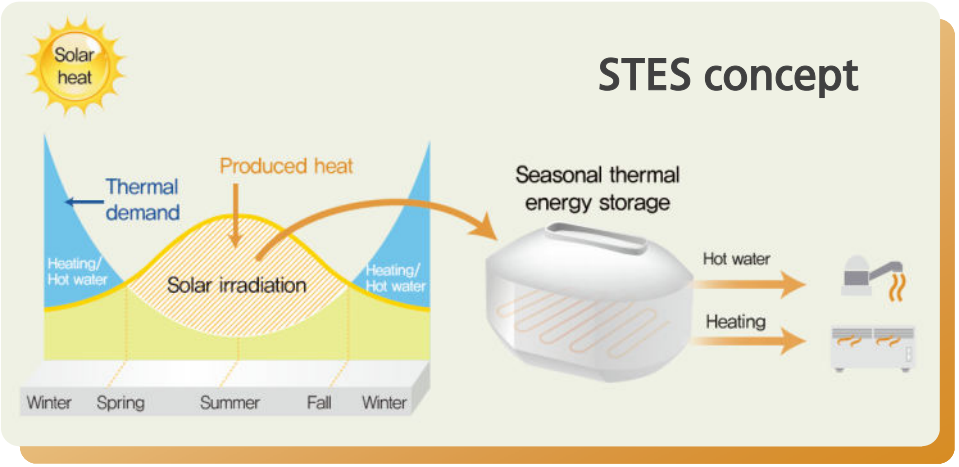
New and renewable energy hybrid tech.



100% standalone energy town by renewable hybrid energy system

- Integration tech. of renewable thermal energy system
- Optimum operation and control for multiple heat source usage

Seasonal thermal energy storage tech.



Heating and hot water supply by Inter-seasonal thermal energy storage

- STES design and annual operation analysis tech.
- STES construction and control tech.

STES : Seasonal thermal energy storage

Displacement plan?

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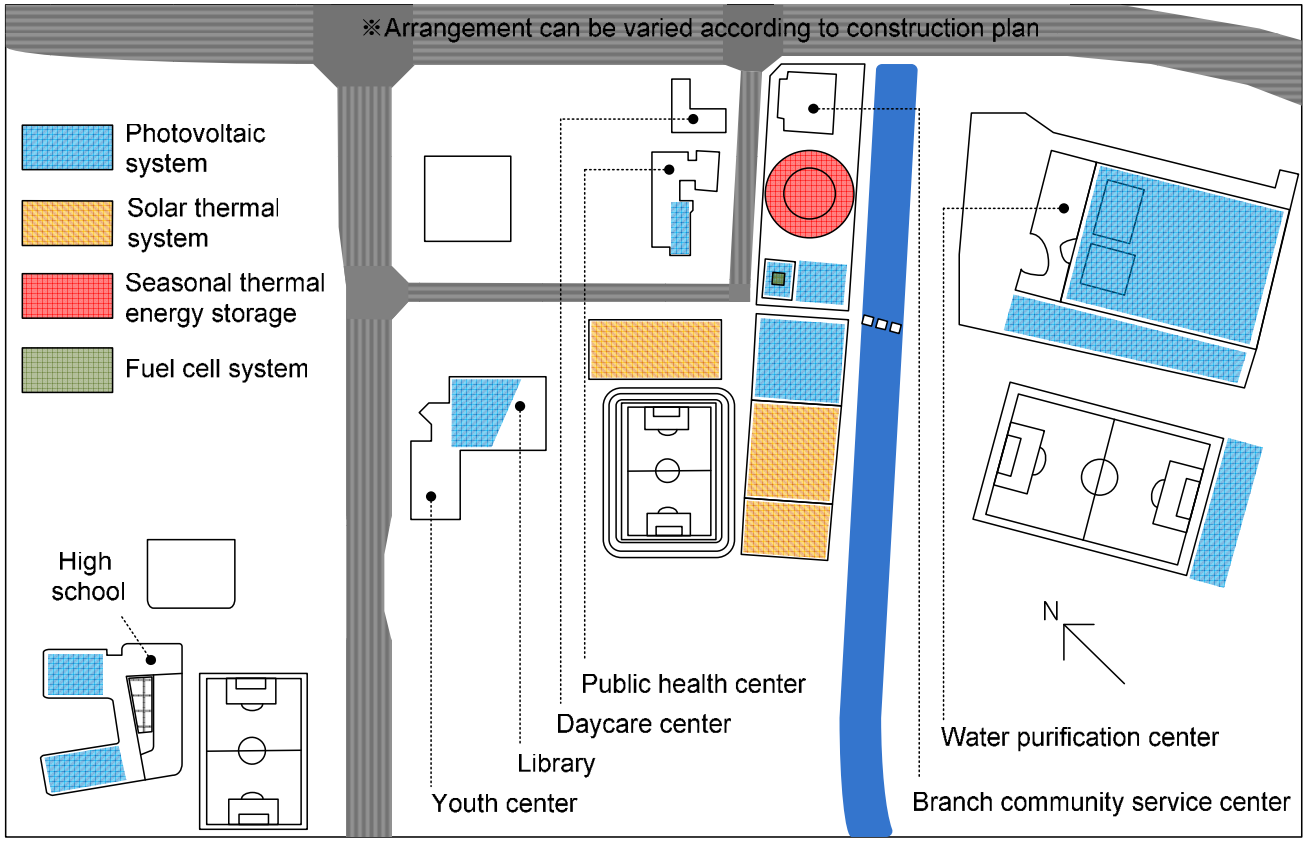
Public buildings and energy system plan



Public buildings	Yearly thermal load (kWh)		Yearly electrical load (kWh)
	Heating	Cooling	
High school	472,826	134,900	593,915
Library	136,967	86,048	154,144
Youth center	78,096	32,041	22,640
Integrated Management center	68,270	27,568	80,478
Daycare center	45,463	38,906	16,225
Public health center	25,850	16,478	11,655
Total load (kWh)	827,473	201,042	879,057

※ Expected annual energy load:

- Thermal: 830 MWh (heating), 201 MWh (Cooling)
- Electrical: 880 MWh (Electricity)

Basic system design for block heating

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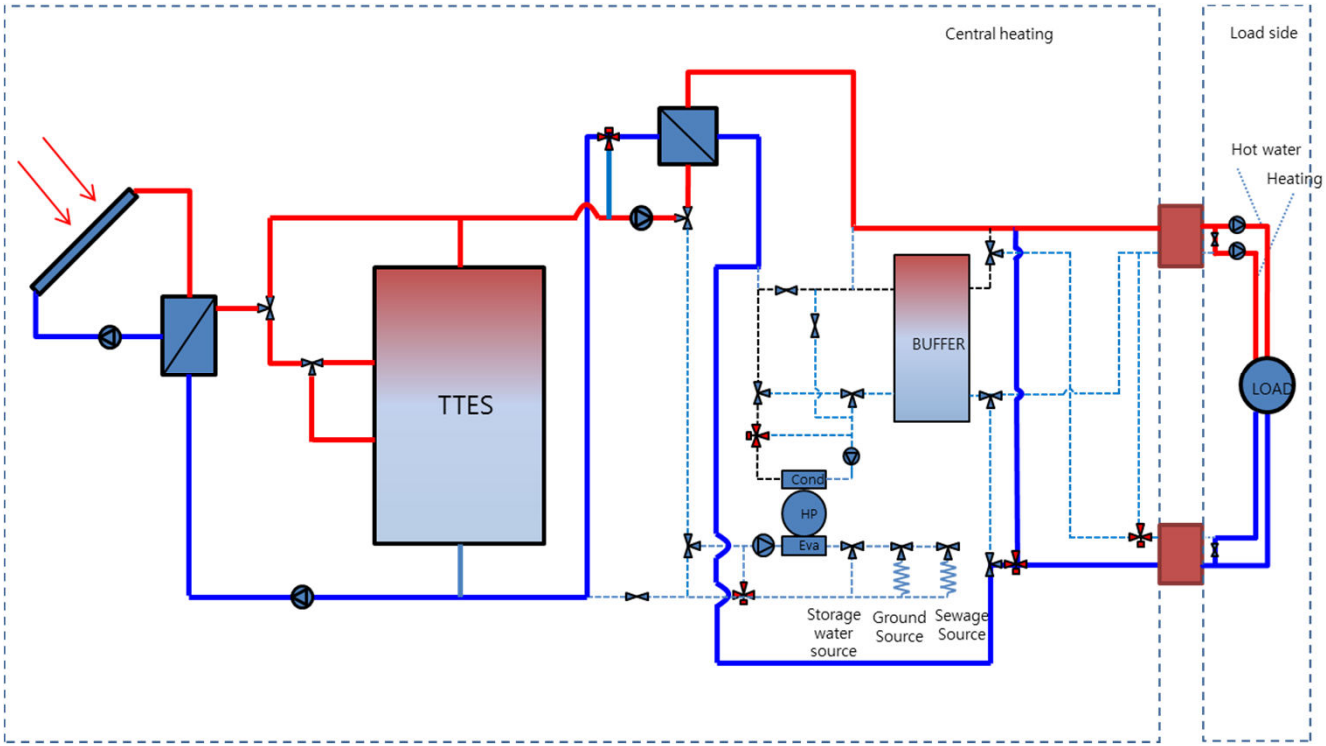
System configuration



System type	Capacity	Energy production (Year)
Photovoltaic	950 kW	955 MWh_p
Solar collector	2,000 m^2	700 MWh_t
Ground source and sewage heat source heat pump	570 kW	160 MWh_t
Fuel cell	10 kW	50 MWh_p, 64 MWh_t
Seasonal thermal energy storage	5,000 m^3	-

※ Operating option:

- Heating: STES only, STES + Auxiliary heating (HP)
- Cooling: hot water supply by STES + Cooling by HP
- HP heat source: water source in STES/Geo-source/sewage-source

STES : Seasonal thermal energy storage

Yearly heat balance?

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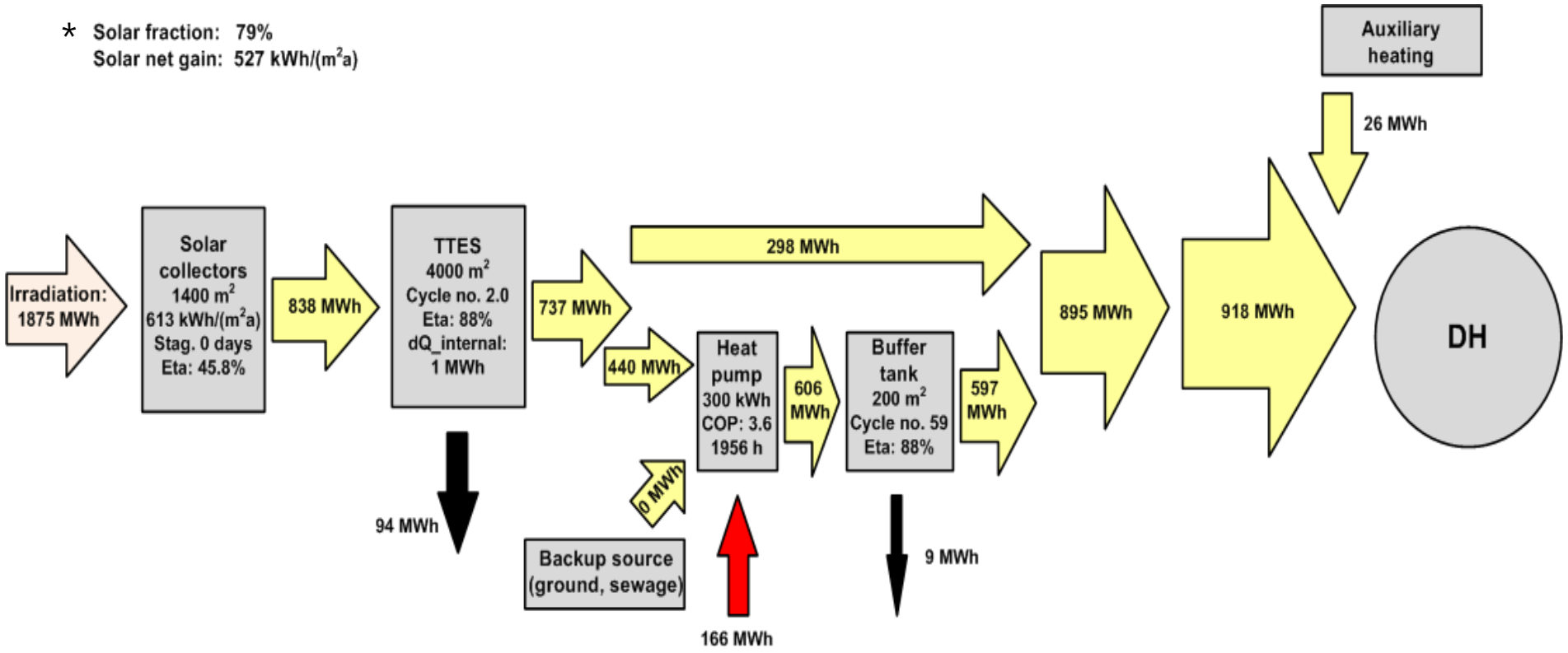
Jincheon Eco-Friendly Energy Town



* Simulation study result for the Jincheon eco-friendly energy town in Korea

Expected contribution?

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Jincheon Eco-Friendly Energy Town

The technology development and the demonstration study for the future forwarding zero-energy town will be performed.

- **100% energy independence (with new and renewable energy) town**
- 840 ton/year **green house gas reduction**
- **Test bed** for the new and renewable energy system integration
- Optimized design for the **future eco-friendly energy town** or energy independent city construction
- Contribution for job creation by **new industry field** in Korea

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Schedule?

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Public buildings

Public buildings	2015				2016			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
High school								
Library								
Youth center								
Integrated management center								
Daycare center								
Public health center								

New and renewable energy systems

New and renewable energy systems	2015				2016			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Photovoltaic system								
Solar thermal system								
Ground and water source Heat pumps								
Fuel cell								
Seasonal thermal energy storage								
District heating pipeline								

Monthly heat balance?

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Jincheon Eco-Friendly Energy Town

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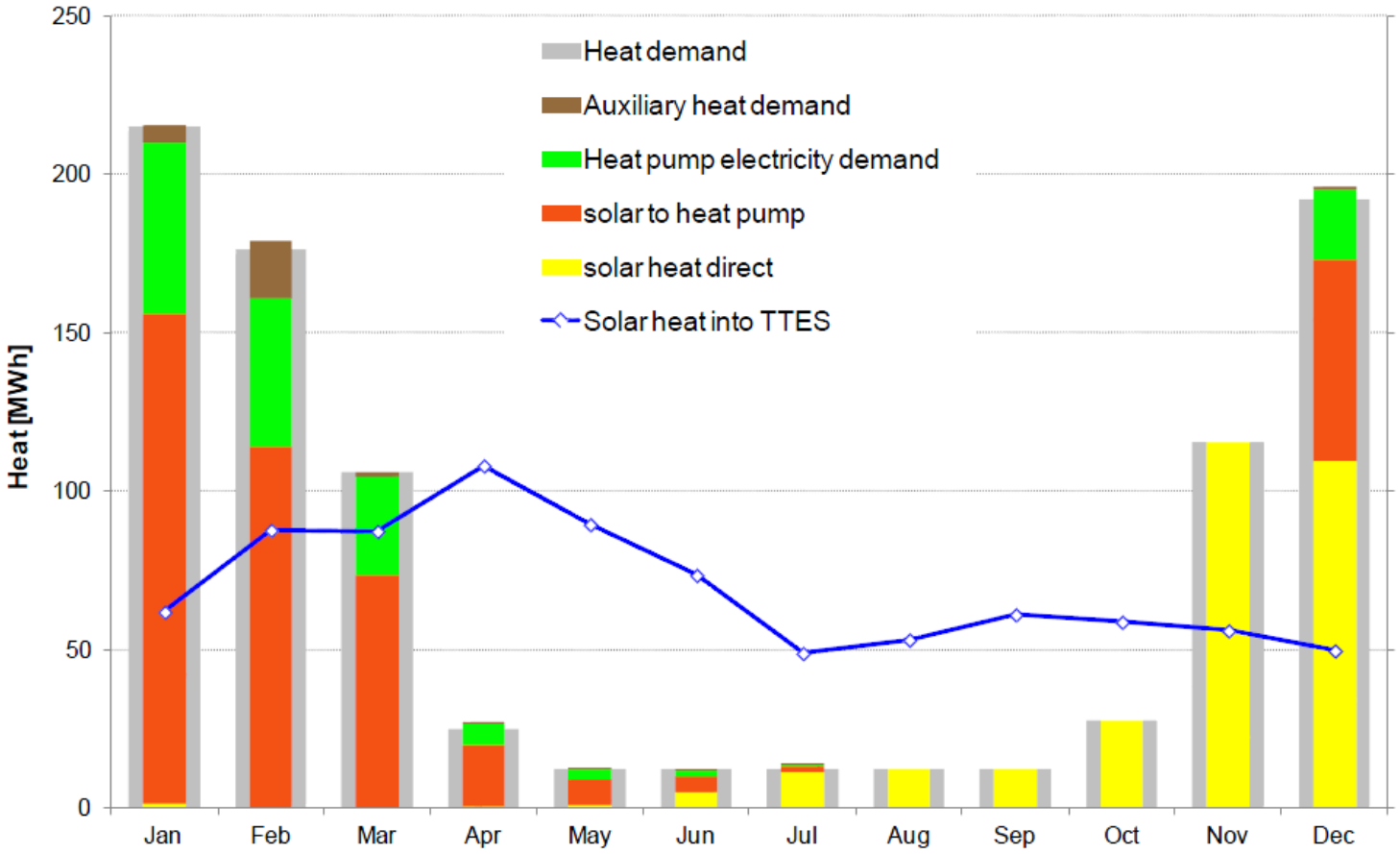

* Simulation study result for the Jincheon eco-friendly energy town in Korea

SDH in Germany

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Several SDH system's information

*		Hamburg[1]	Friedrichs-hafen[1] final stage design *(status 9.08)*	Neckarsulm[1] phase I *(phase II)*	Steinfurt[1]	Chemnitz[2] phase 1	Rostock[3]	Hanover[4]	Atten-kirchen[5]	Munich	Crailsheim phase 1 *(status 9.08)*	Eggen-stein
start of operation		1996	1996	1997 *(2001)*	1998	2000 (aborted: 2006)	2000	2000	2002	2007	2007	2008
service area		124 RH	final stage: 570 apart-ments in MFH *(390)*	6 MFH, shopping centre, school, gym., home for elderly etc.	42 apart-ments in 22 SFH and small MFH	design: office building, hotel and shopping centre	108 apartments in MFH	106 apartments in MFH	30 SFH	300 apart-ments in MFH	260 apart-ments in SFH, DH u. RH, school, gym.	school, sports centre, fire station
heated area	m²	14 800	39 500 *(33 000)*	*(25 000)*	3 800	4 680	7 000	7 365	6 200	24 800	40 000	12 000[6]
solar collector area (aperture)	m²	3 000 FP	5 600 FP *(4 050)*	2 700 FP *(5 469)*	510 FP	540 VTC	1 000 FP	1 350 FP	800 FP	2 900 FP	7 300 FP (5 050 FP)	1 600 FP
storage volume	m³	4 500 TTES	12 000 TTES	100 TTES + 20 000 BTES *(200 + 63 300)*	1 500 PTES	8 000 PTES	30 TTES 20 000 ATES	2 750 TTES	500 TTES + 9 350 BTES	5 700 TTES	480 + 100 TTES + 37 500 BTES	4 500 PTES
total heat demand	MWh/a	1 610	4 106 *(3 000)*	1 663 (2 200)	325	phase 1: 573	497	694	487	2 300	4 100	1 150
solar net energy*	MWh/a	789	1 915	832	110	phase 1: 169	307	269	378	1 080[5]	2 050[1]	430
solar fraction*	%	49	47	50	34	phase 1: 30	62[3]	39	55[#]	47[5]	50[1]	37*
cost solar system [§]	million Euro	2,2	3,2	3,5	0,5	phase 1 + 2: 1,4	0,7	1,2	0,76	2,9	4,5	1,1[6]
solar heat cost* [§]	Ct./-kWh	25,7	15,9	26,5	42,3	phase 1 + 2: 24,0	25,5	41,4	19,0	24,0	19,0	25,0

*: calculated values for long-term operation, #: primary energy saving, § without VAT and subsidies, with planning
[1]: data ITW University of Stuttgart, [2]: data TU Chemnitz, [3]: data Geothermie Neubrandenburg, [4]: data IGS University of Brunswick, [5]: data ZAE Bayern, [6]: data PKi
SFH: single family house, DH: detached house, RH: row house, MFH multifamily house
FP: flat plate solar collector, VTC: vacuum tube collector
TTES: tank thermal energy storage, PTES: pit thermal energy storage, BTES: borehole thermal energy storage, ATES: aquifer thermal energy storage

SDH : Solar District Heating

*The next Generations of Seasonal Thermal Energy Storage in Germany, Solites, D.Mangold et al.