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ITC

District heating systems

Customers for heat

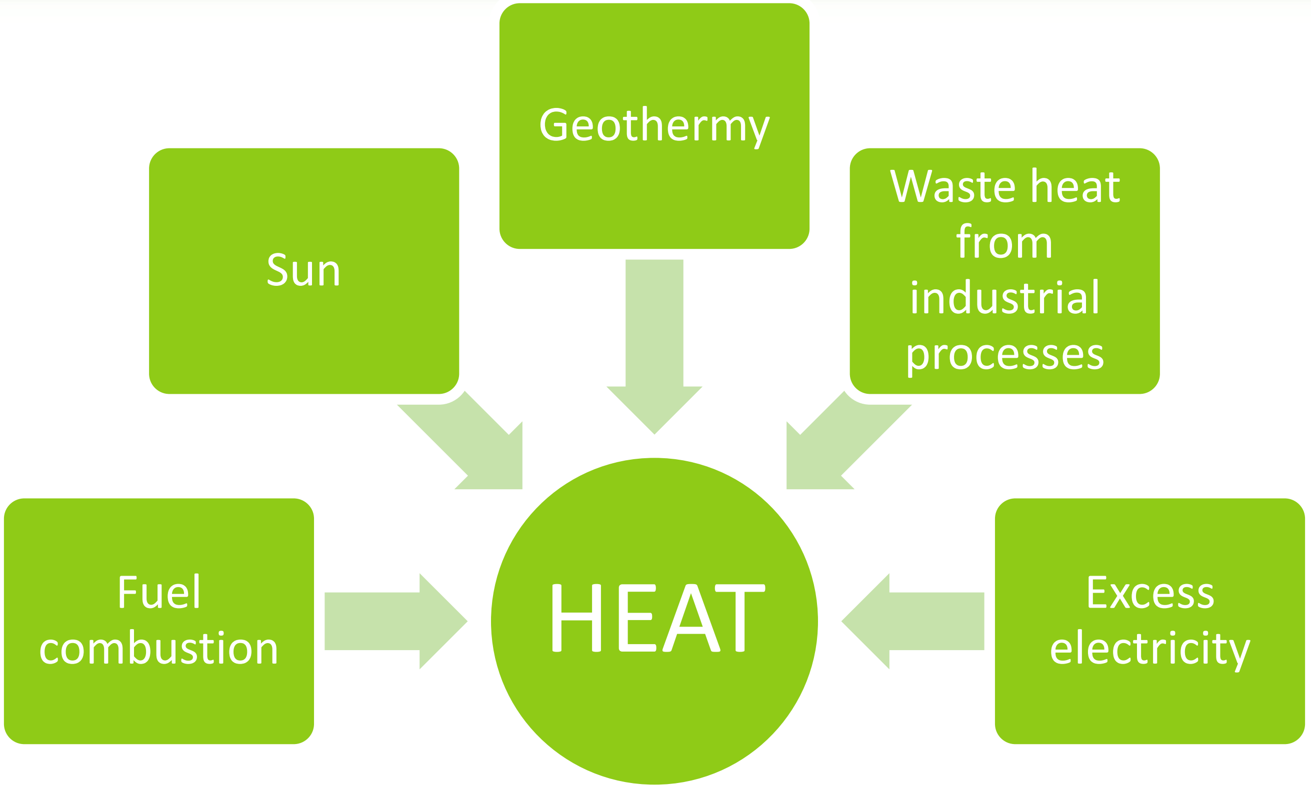
Households

- Hot tap water, 60˚C
- Heating (seasonal, climate-dependant)

Industry

- Space heating (seasonal, climate- or process-dependant)
- Process heat (may be anything up to 1000˚C)

Sources of heat



Heeat generation

Distributed

- House boilers
- Industrial heating plants & CHPs

Centralized

- District heating networks
- Large heating or CHP plants

District heating vs individual heating

Efficiency

- Larger plants are usually more eficient
- CHP means better fuel efficiency
- …but large DH network = losses

Environmental footprint

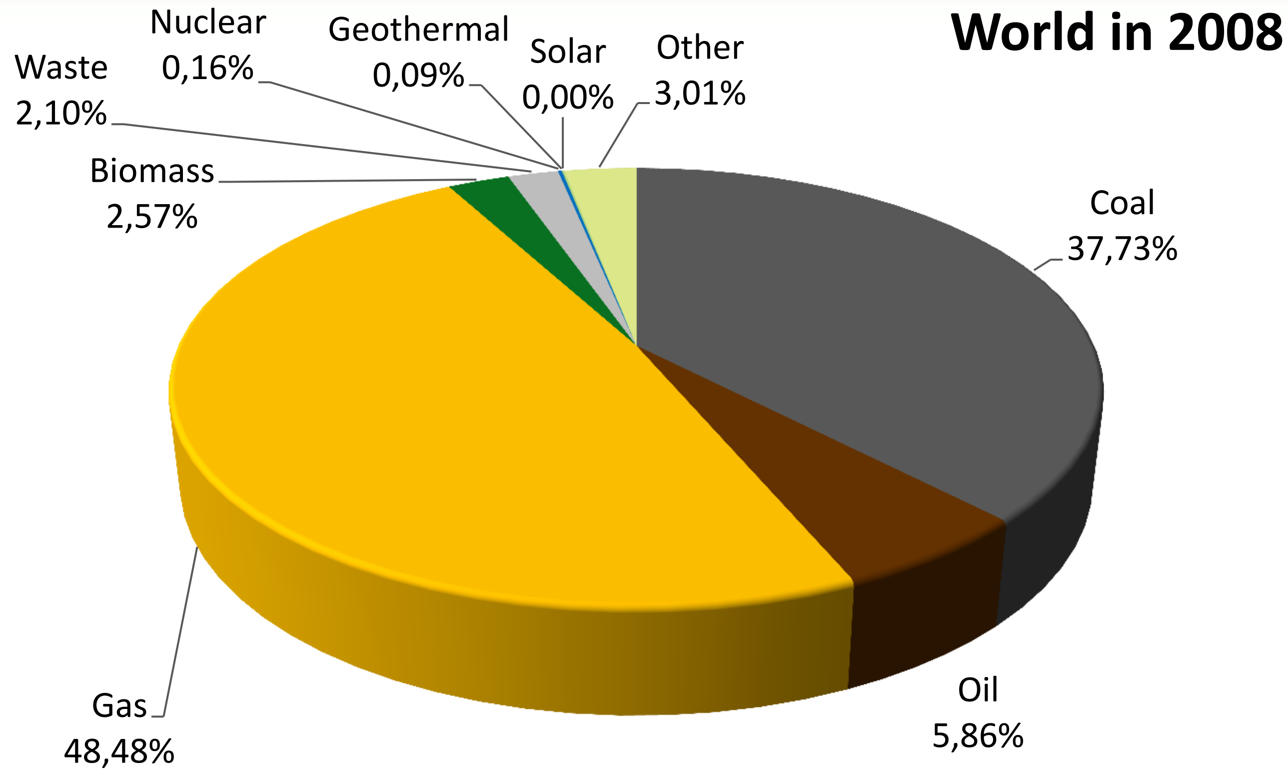
- Larger plants have better flue gas cleaning equipment
- …but in some cases individual heating uses cleaner fuels (Poland: gas instead of coal)

Economy

- Large plant = cheaper fuel
- …but large plant = large investment…
- …and DH network is a REALLY long-term investment.

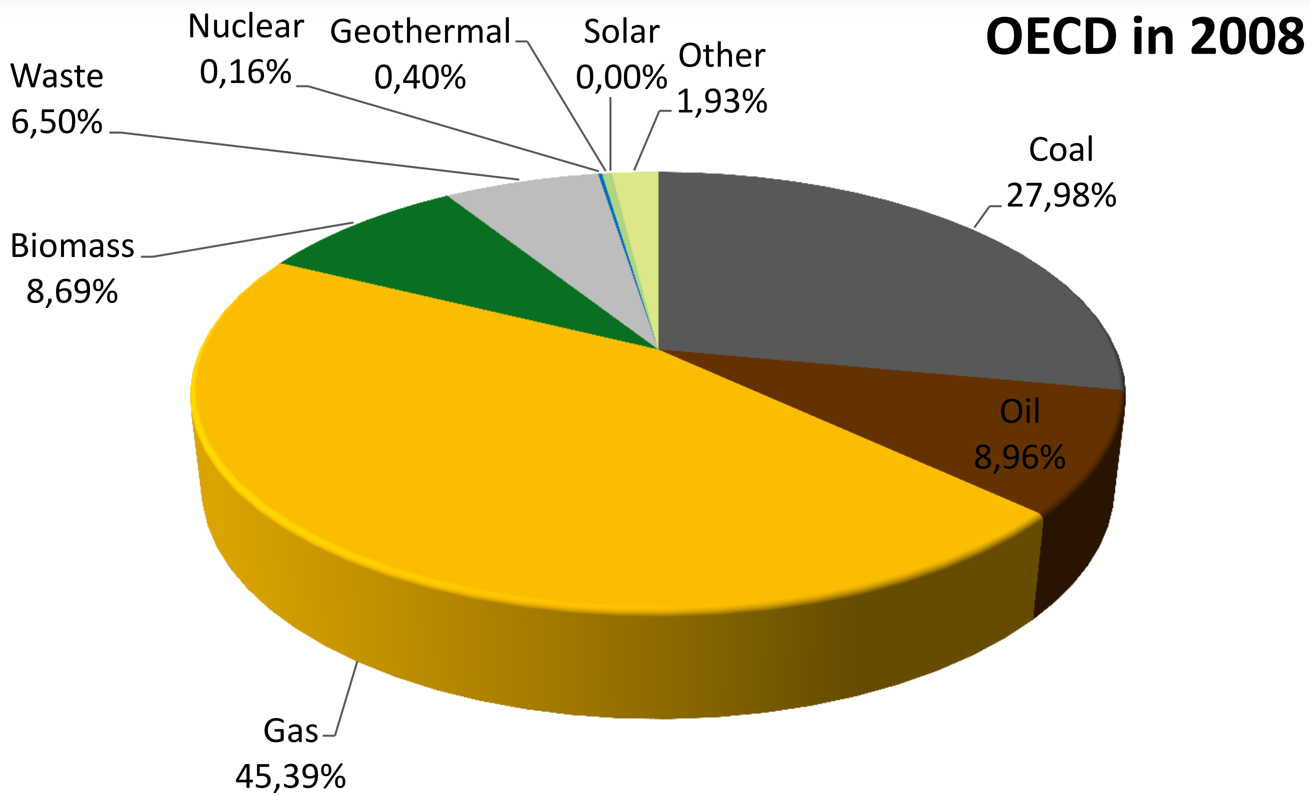
DH is nice if there is someone willing to pay for it!

Fuels for heat generation
Commercial/Industrial plants



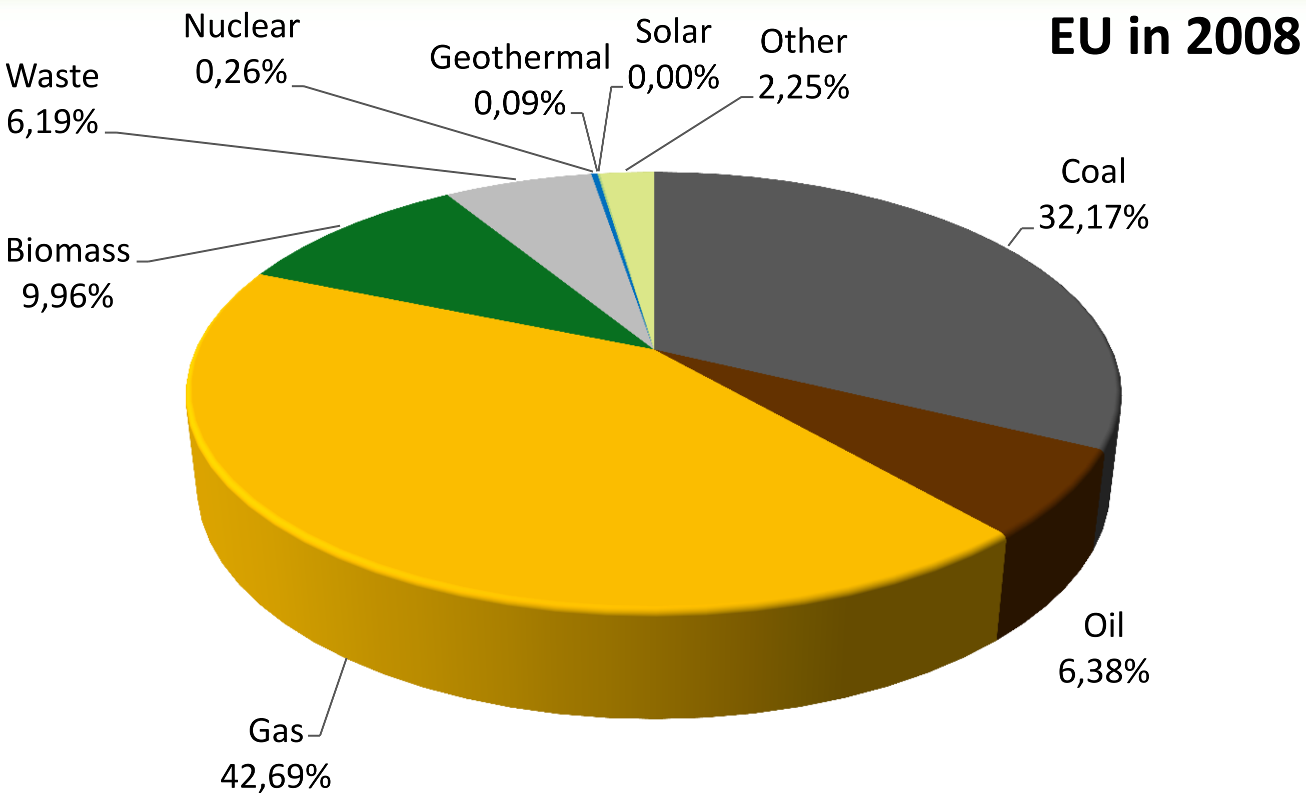
Data by:

Fuels for heat generation
Commercial/Industrial plants



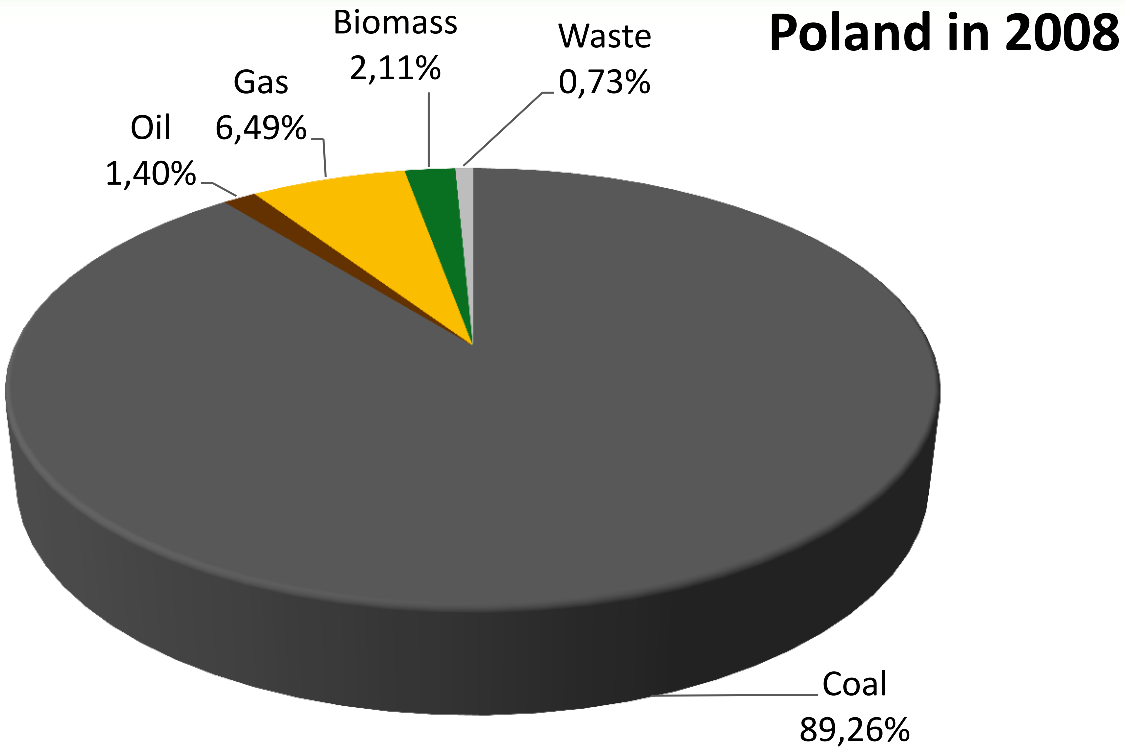
Data by:

Fuels for heat generation Commercial/Industrial plants



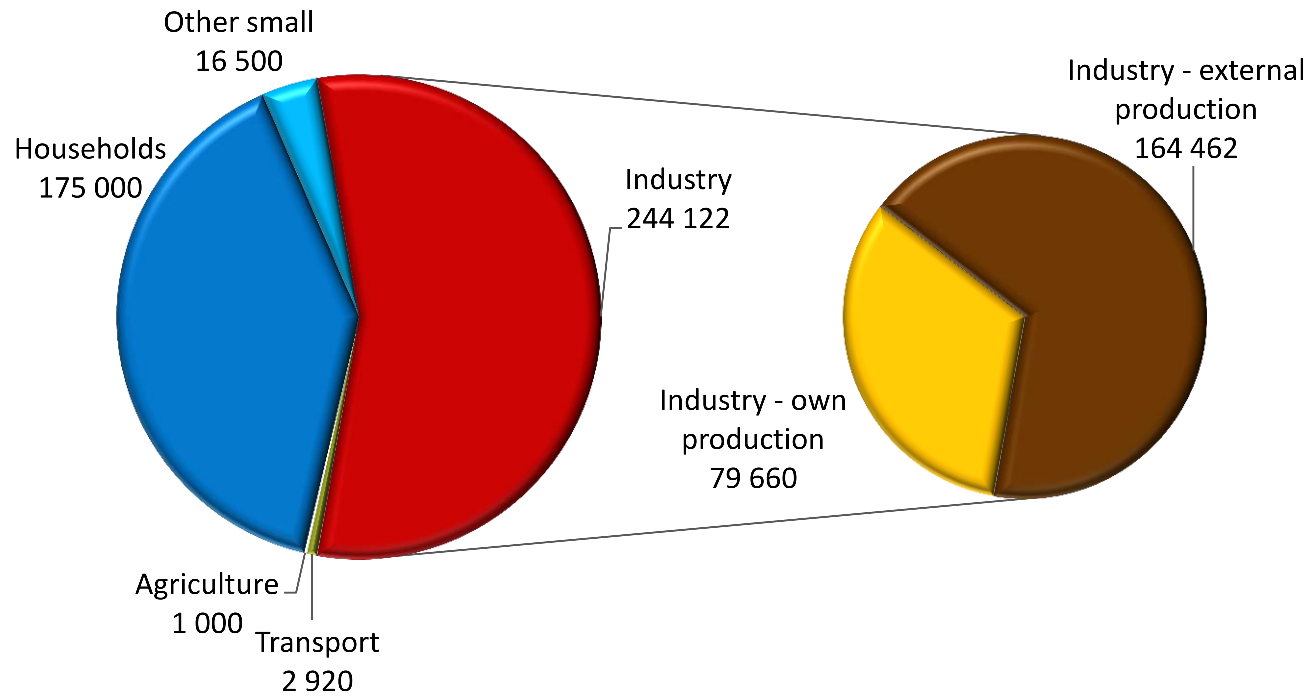
Data by:

Fuels for heat generation
Commercial/Industrial plants



Data by:

Heat consumption in Poland, 2008



Data by:

Heat generation in Poland

Sector	Production in 2009 (TJ)
Commercial thermal power plants (CHP)	184,162.5
Industrial thermal CHP plants	11,961.8
Heat-only boilers, commercial power plants	28,441.9
Commercial heating plants	76,068.6
Other heating plants	8,166.0
Coking plants	2,166.7
Waste&Biomass fired CHP	1,245.3

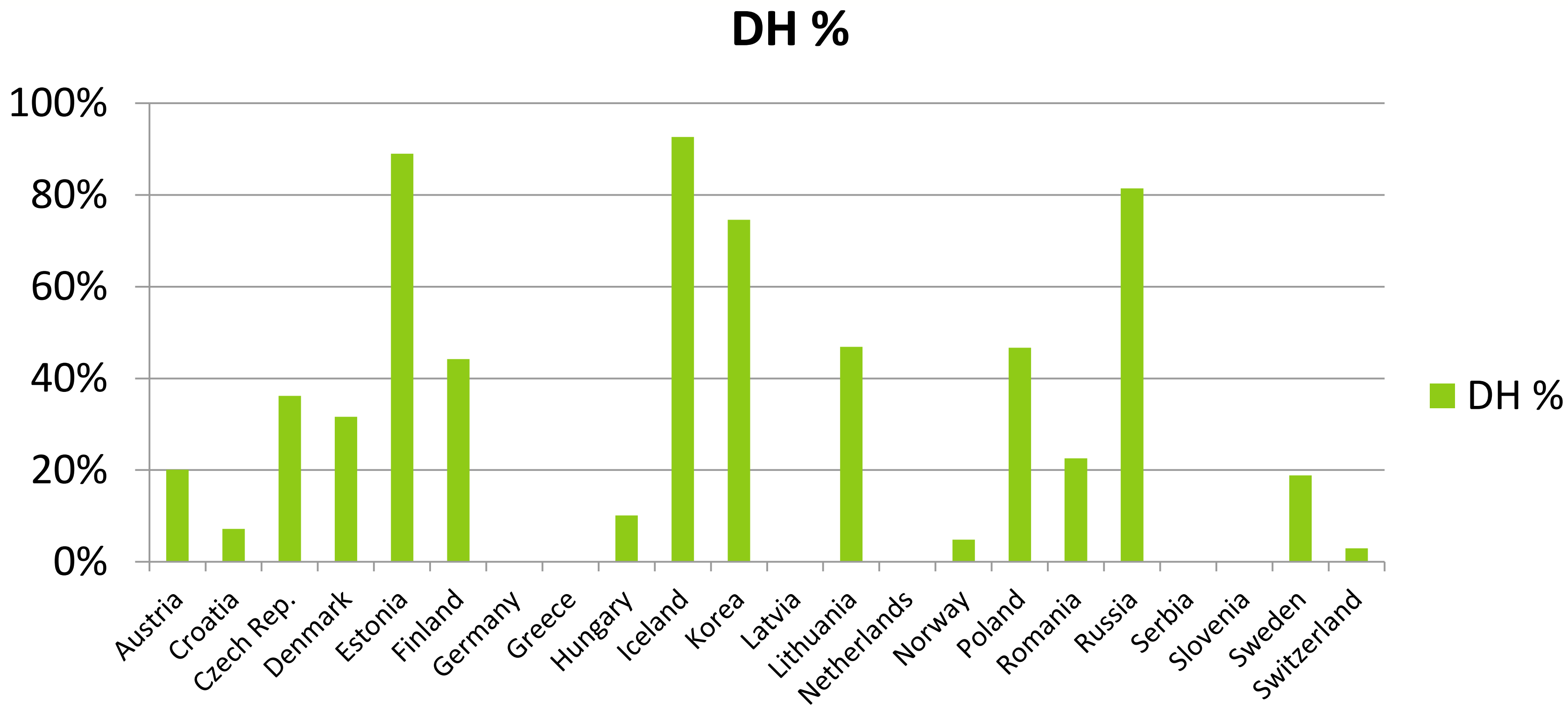
Total generation 312 PJ

Data by:

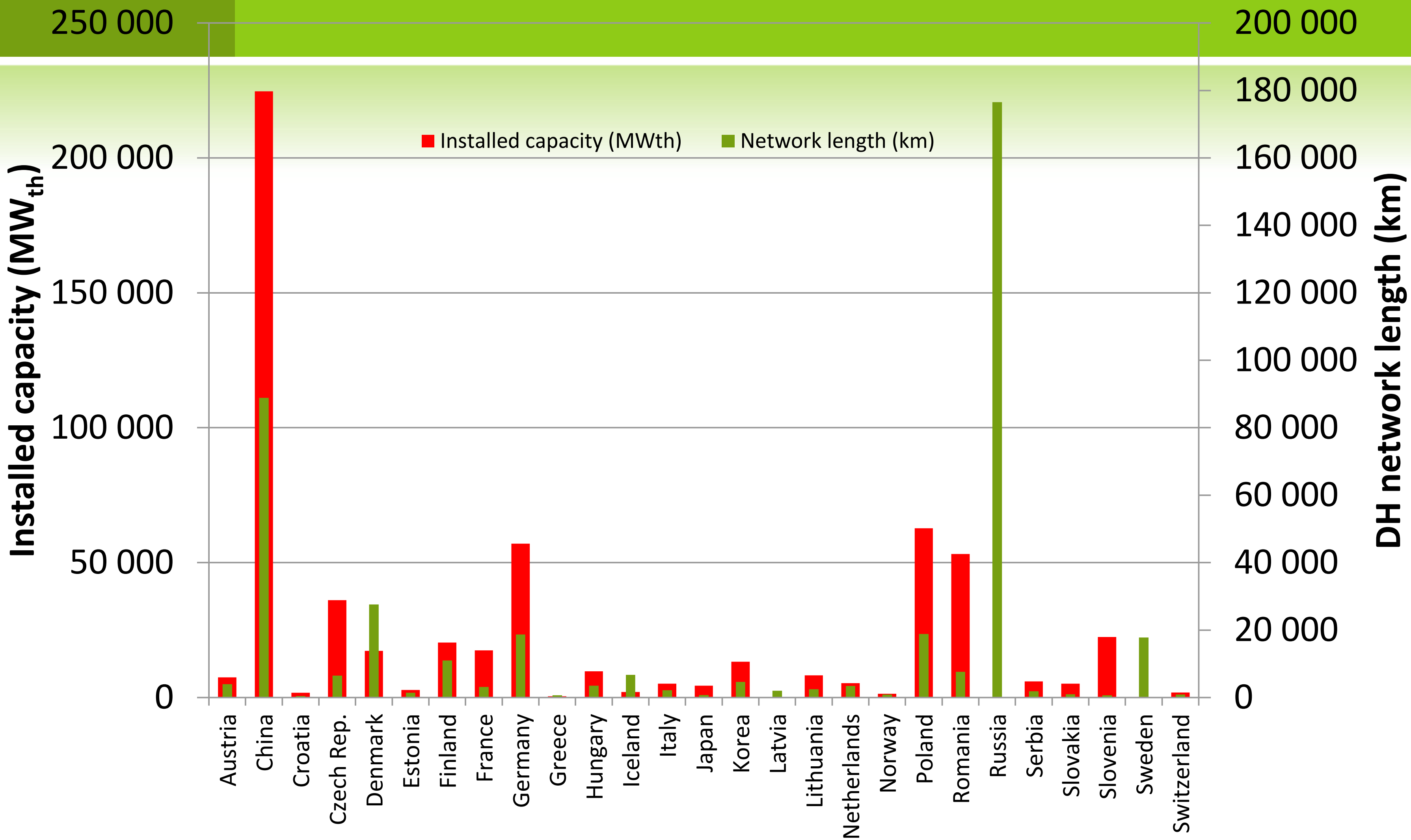
Geothermal heating plants in Poland

Location	Output (MW)	Temp. (˚C)	Well Depth (m)	Remarks
Bańska Niżna	4.5	86	2500	To be extended to 70 MW
Pyrzyce	15.0	60	1600	To be extended to 50 MW
Stargard Szcz.	14.0	95		
Mszczonów	2.8	42	1650	With heat pump
Uniejów	2.6			
Słomniki	1.0			
Lasek	2.6			
Klikuszowa	1.0			

DISTRICT HEATING AROUND THE WORLD



District heating around the world



District heating

Generation

- Heating plants (water or steam boilers)
- CHP plants (cogeneration of electricity and heat)
- Commercial power plants (minor volumes of waste heat from large plants)

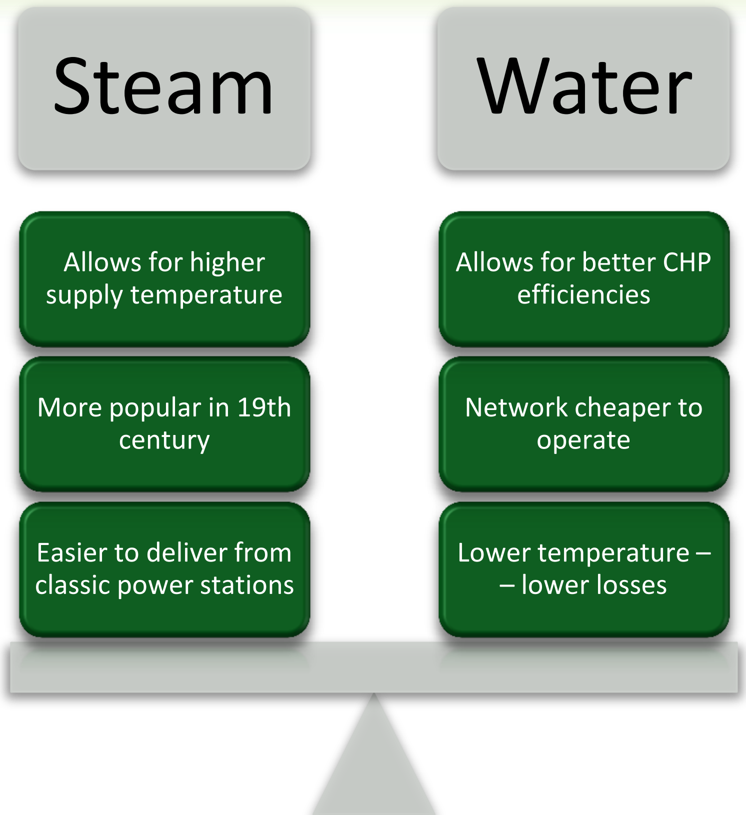
Distribution

- Network of pipelines
- Heat carried by steam or hot water

Consumption

- Heating centres – transfer of heat from DH system water to:
  - Tap water
  - Building’s heating system

District heating steam or water?



Steam CHP systems

Operational

- USA: New York City, Ft. Myer (25 MW)
- Dortmund (150 MW), Wurzburg (250 MW), Ulm (150 MW), … (totally around 100, length 1300 km)
- Paris (4285 MW)

Closed (degenerated)

- Multiple systems in USA

Replacement with new hot water system

- Braunschweig, Leipzig, Baden-Baden

Conversion to hot water

- Germany: Hamburg (250 MW), Kiel (320 MW), Munich (1250 MW – largest in Germany)
- Austria: Salzburg (170 MW)

Hot water DH system

Energy sources

- Water boilers
- Heat exchangers in CHP plants powered by steam

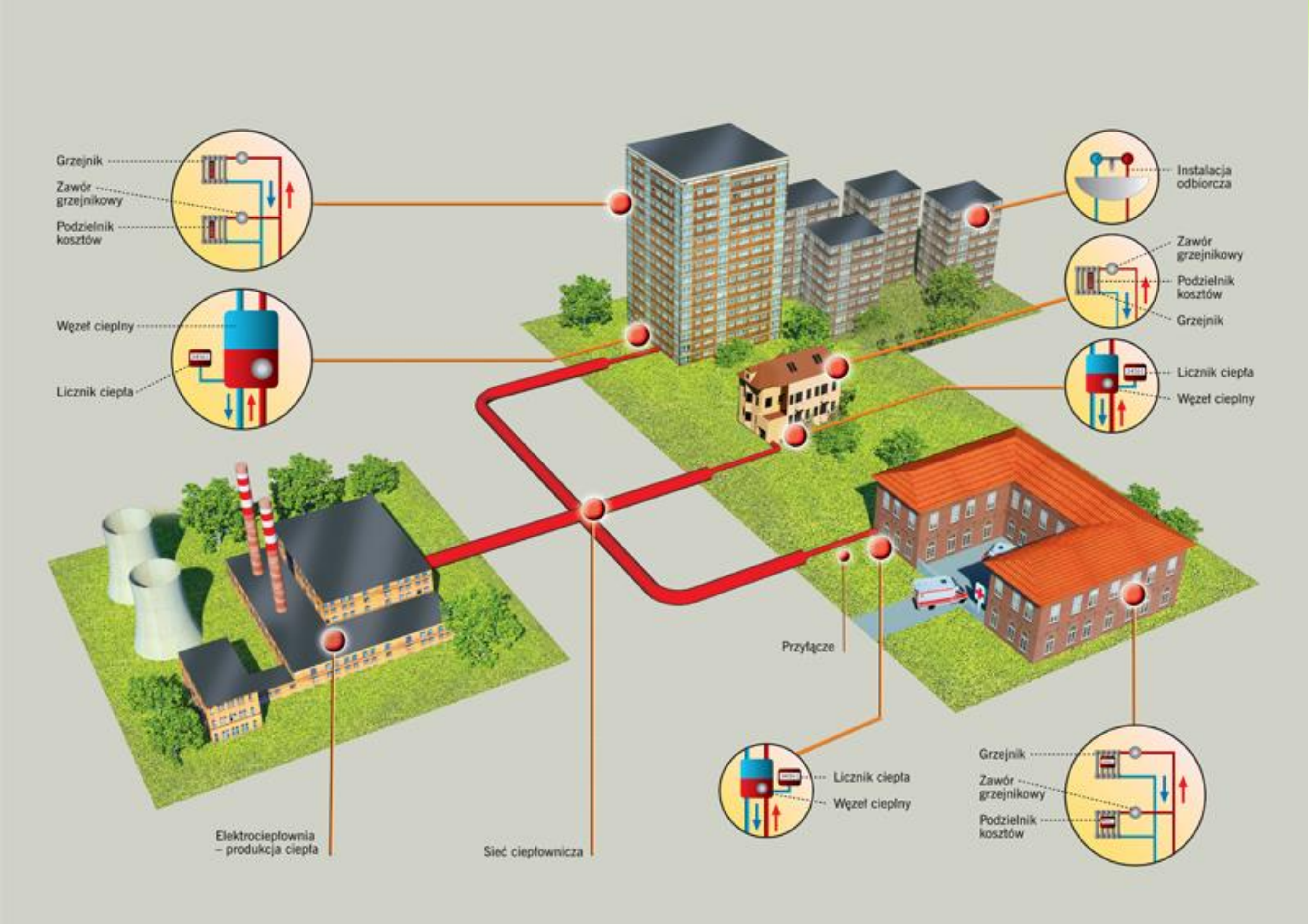
Distribution network

- Overground pipelines
- Pipelines in underground channels
- Pre-insulated pipelines buried in soil

Consumption

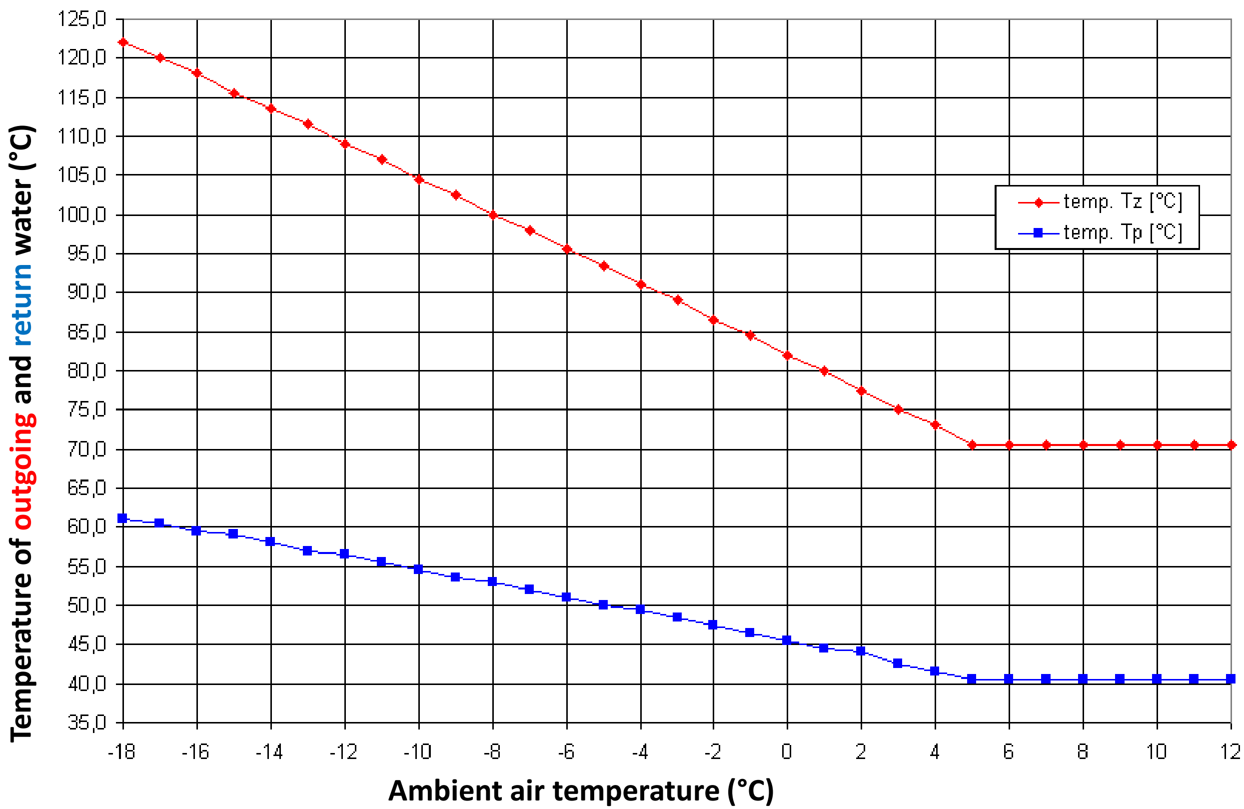
- Water-water heat exchangers at customers' sites

Hot water DH system

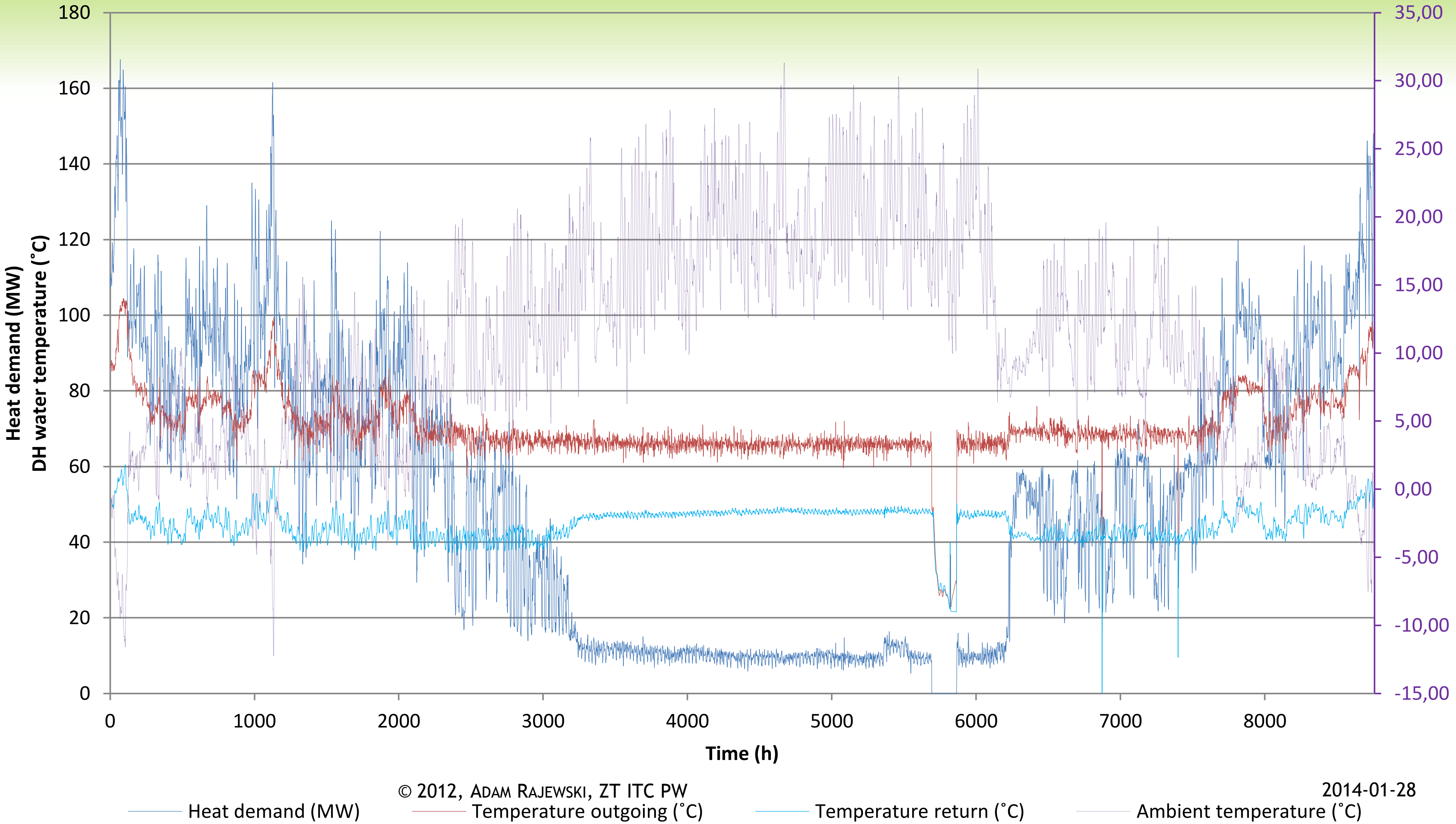


Drawing by: SPEC

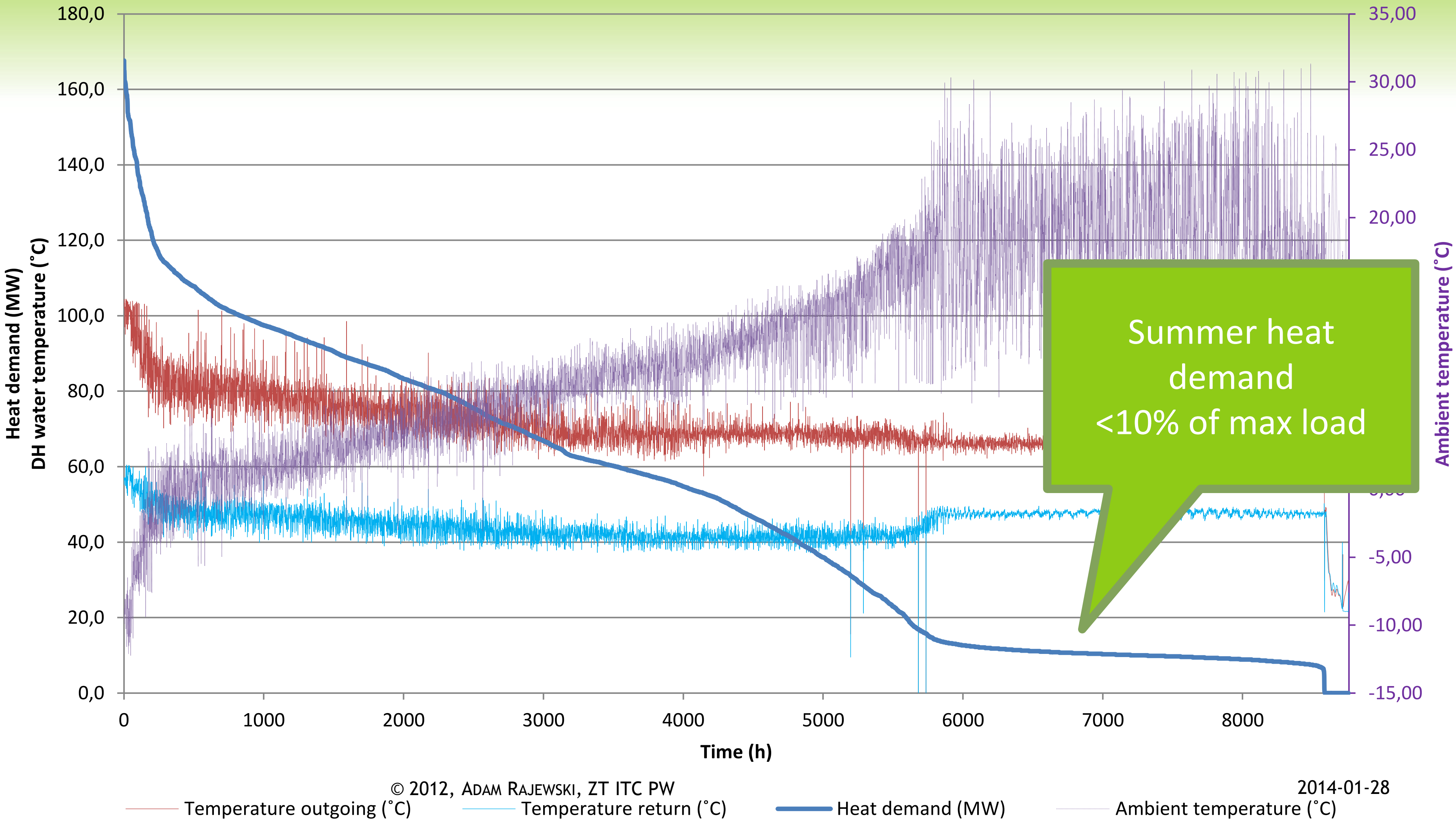
Temperatures in typical DH system in Poland



A Polish DH system



A Polish DH system



DH technology

Heating plant technical solutions

Hot water boilers

- Coal
- Biomass
- Oil (LFO, HFO)
- Gas

Geothermal sources

- Steam/water heat exchanger
- Water/water heat exchanger

Solar collectors

Electric boilers

- Used in systems with very high wind power capacity during low-load high-generation situations

Geothermal heating in 2005

Country	Production (PJ/a)	Capacity (GW)	Dominant applications
China	45.38	3.69	Bathing
Sweden	43.2	4.20	Heat pumps
USA	31.24	7.82	Heat pumps
Turkey	24.84	1.50	District heating
Iceland	24.5	1.84	District heating
Japan	10.3	0.82	Bathing (onsens)
Hungary	7.94	0.69	Spas/greenhouses
Italy	7.55	0.61	Spas/space heating
New Zealand	7.09	0.31	Industrial uses
63 others	71	6.80	
Total	**273**	**28**	**Space heating**

Cogeneration

Higher energy conversion efficiency

Separate heat production

- Efficiencies of up to 95%

Separate electricity production

- Max efficiencies:
  - 45% solid fuel, simple cycle
  - 50% fluid fuel, simple cycle
  - 60% fluid fuel, combined cycle

Combined heat and power generation

- Total energy conversion efficiencies 75…97%

Cogeneration

Higher energy conversion efficiency

- Allows to reduce heat losses during electricity production
- Generates electricity at efficiencies slightly lower than separated electricity generation
- Converts heat losses from electricity generation into useful heat
- Does not increase efficiency of heat production…
- …but increases its financial effectivness

CHP technologies

Solid fuels

- Rankine cycle – boiler + steam turbine

Fluid fuels

- Rankine cycle – boiler + steam turbine
- Otto cycle – reciprocating engine
- Diesel cycle – reciprocating engine
- Brayton cycle – gas turbine
- Combined cycle – engine/gas turbine + steam turbine
- Fuel cell

Geothermy

- Rankine cycle – boiler + steam turbine
- Organic Rankine cycle (ORC) – with organic working fluid (low boiling T)

Steam turbines for CHP

Backpressure turbine

- Turbine exhaust at higher temperatures and pressures
- Steam condensation at parameters allowing to use heat for DH purposes

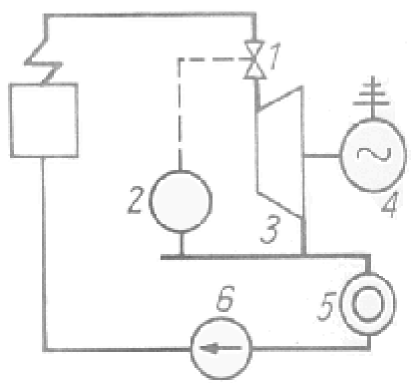
Extraction-condensing turbine

- Steam for DH purposes extracted from turbine's bleed
- Rest of steam expands to the low condenser pressure
- Bleed may be controlled – control over heat/electricity ratio
- May operate in condensing mode (e.g. in summer) maximizing electricity generation efficiency

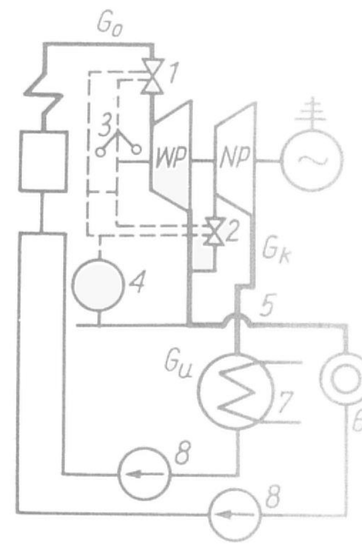
Extraction – backpressure turbine

- Combination of both
- Steam for heating at different pressure (and temperature) levels

Backpressure



Extraction-Condensing



Steam turbine CHP layout

Common header system

- Number of boilers generating steam for a common header
- Number of turbines fed from that header
- Numer of boilers does not need to match number of turbines

Unit (block) system

- Separated units with single (usually) boiler and single turbine connected to it

Steam turbine CHP

Source of heat

- Steam extraction from the turbine
- Exhaust steam from the turbine (backpressure)
- Temperature adjusted for needs, but typically between 100 and 200˚C

Efficiency

- Electricity generation 20…35%, depending on:
  - Size (the larger, the higher efficiency)
  - Turbine type (aeroderivate higher than industrial, but more expensive)
- Total over 80%

Size

- Anything from 1 MW up

Flexibility

- Increased heat production does not affect electricity generation
- Long start-up and shut-down procedures, slow electric load changes
- Unable to operate at low loads

Fuel

- Solid fossil fuels: coal, lignite, peat
- Solid renewable fuels: biomass, waste
- Theoretically any fuel will work, but for fluid fuels there are more efficient technologies

Gas turbine CHP

Source of heat

- Exhaust gas, 450-600˚C

Efficiency

- Electricity generation 20…35%, depending on:
  - Size (the larger, the higher efficiency)
  - Electricity generation does not depend on heat recovery conditions
- Total over 80%

Size

- Anything from 1 MW up, practically over 100 MW Combined Cycles are used

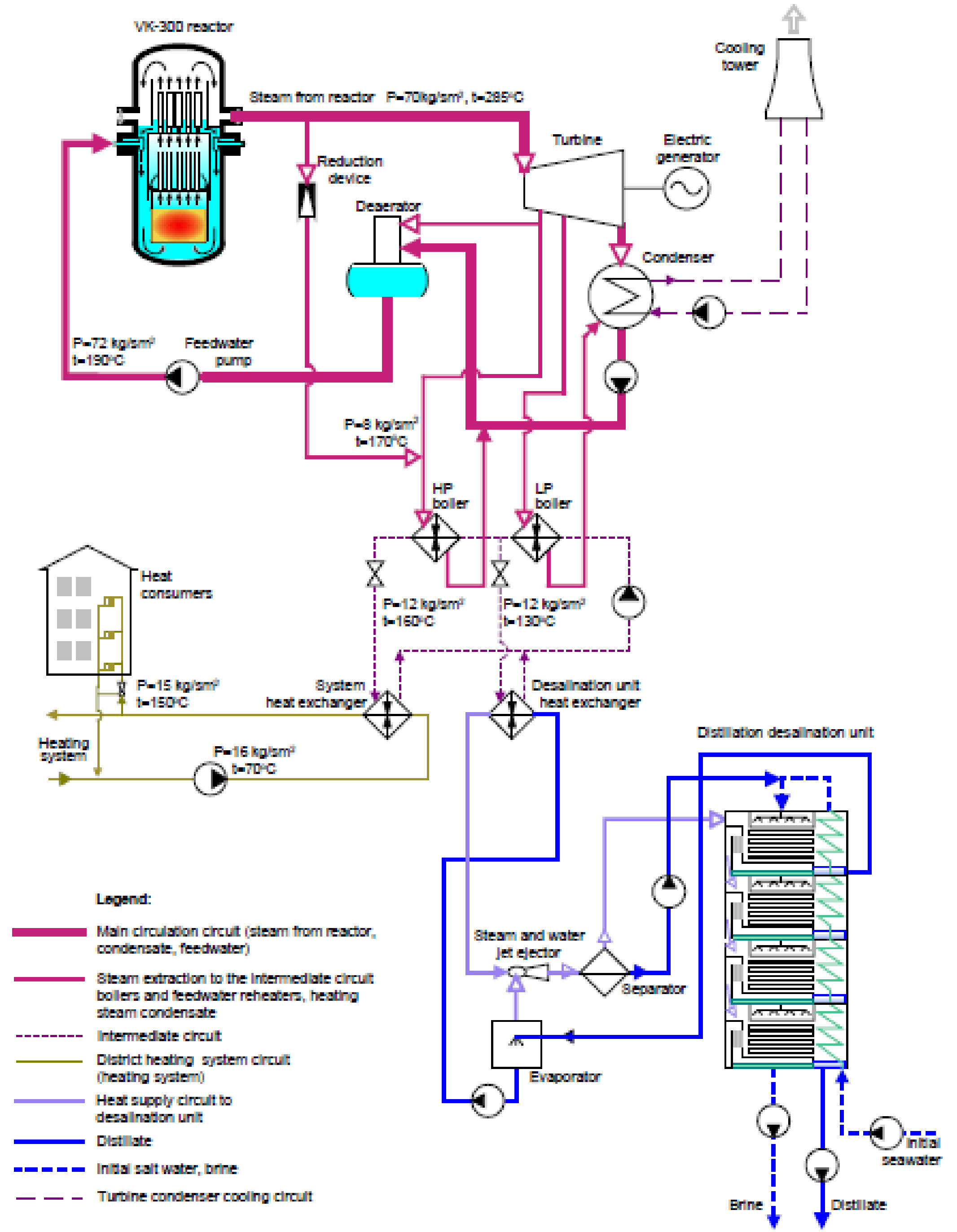
Flexibility

- Quite fast startup and shutdown procedures
- Simple system

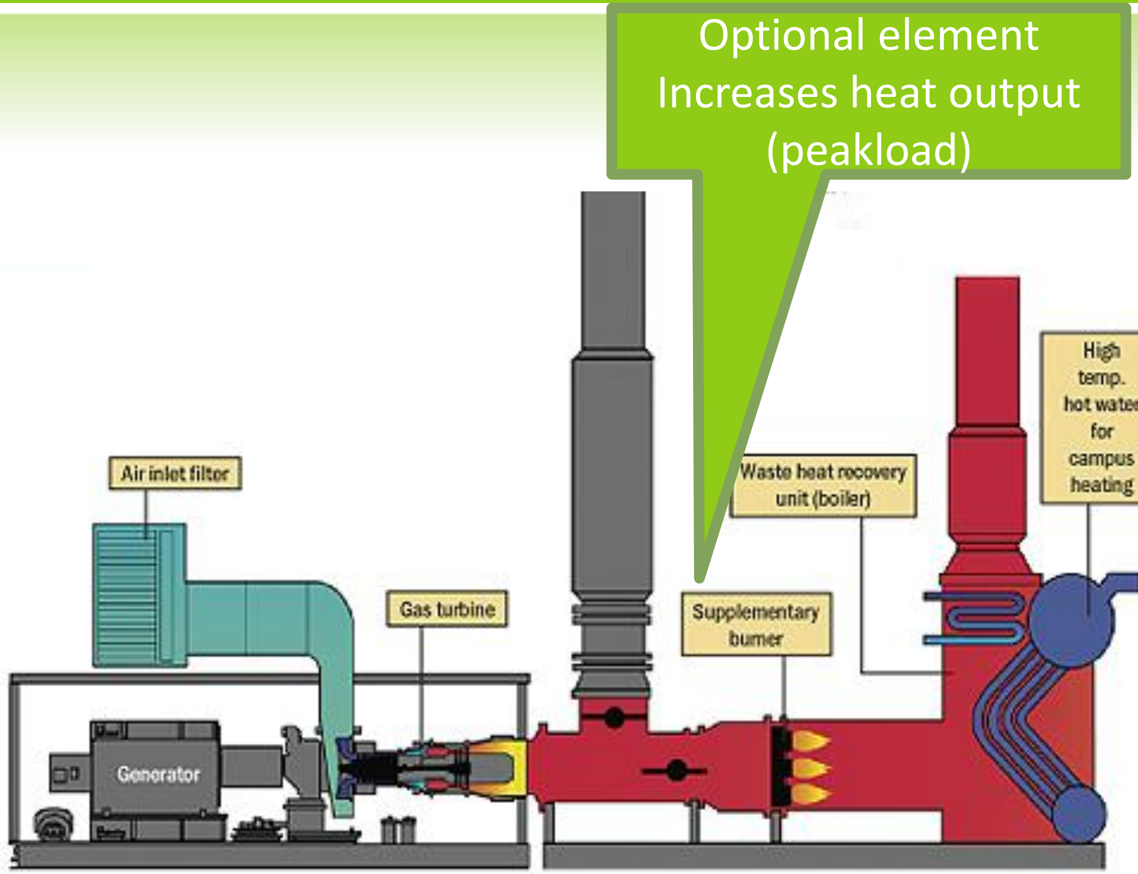
Fuels

- Natural gas, biogas
- LFO, HFO (for heavy duty models)

Nuclear CHP Concept VK300 BWR Russia



Gas turbine CHP



Reciprocating engine CHP

Sources of heat

- Flue gas, ca 400˚C
- Engine cooling liquid, ca 90˚C
- Engine lube oil, ca 60˚C
- Charge air (mixture) cooler (depending on engine design, may be two stage at different temperature levels)

Efficiency

- Electricity generation 35-45%, depending on:
  - Size (the larger, the higher efficiency)
  - Electricity generation does not depend on heat recovery conditions
- Total depends on return water temperature
  - At RW 70˚C ca 75%
  - At RW below 60˚C ca 85%
  - At RW below 30% ca 90% (with flue gas condensation even 96%)

Size

- Anything from 100 kW up, practically over 100 MW Combined Cycles are used

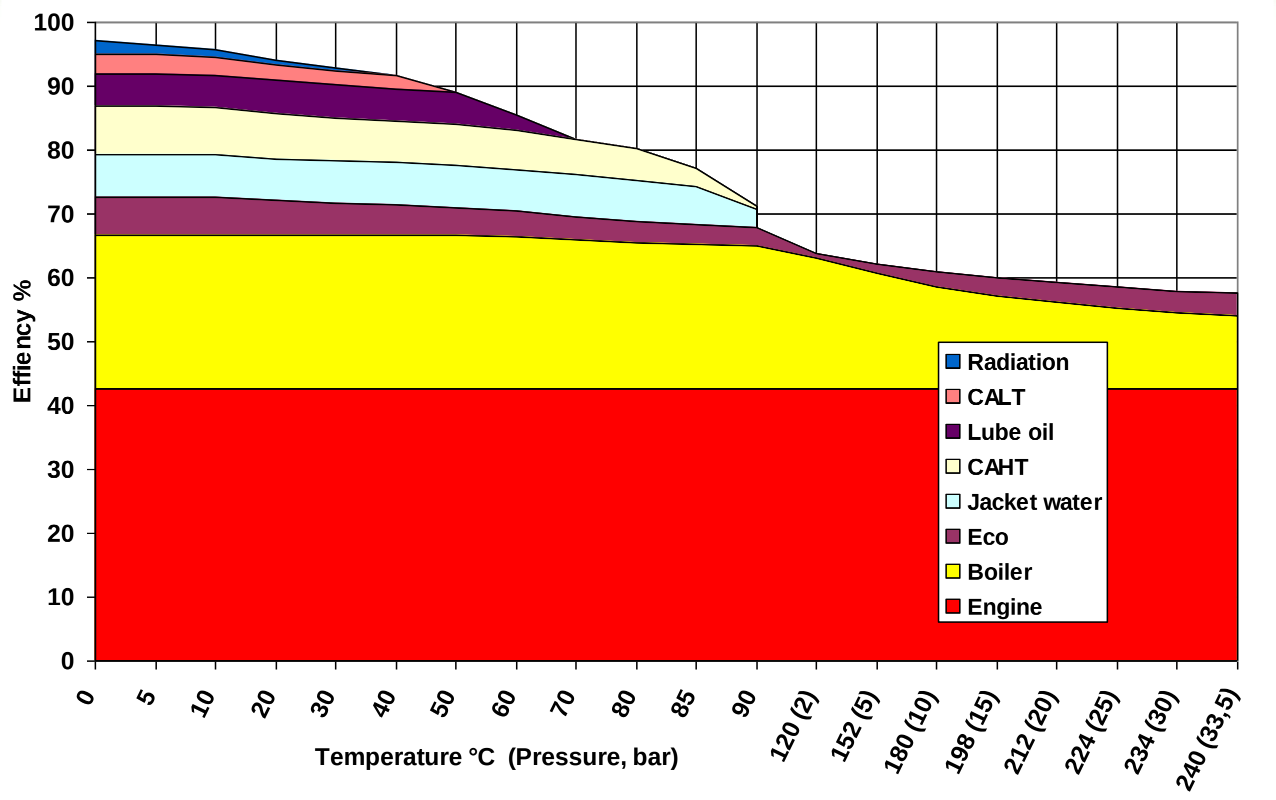
Flexibility

- Very fast startup and shutdown procedures
- Simple system

Fuels

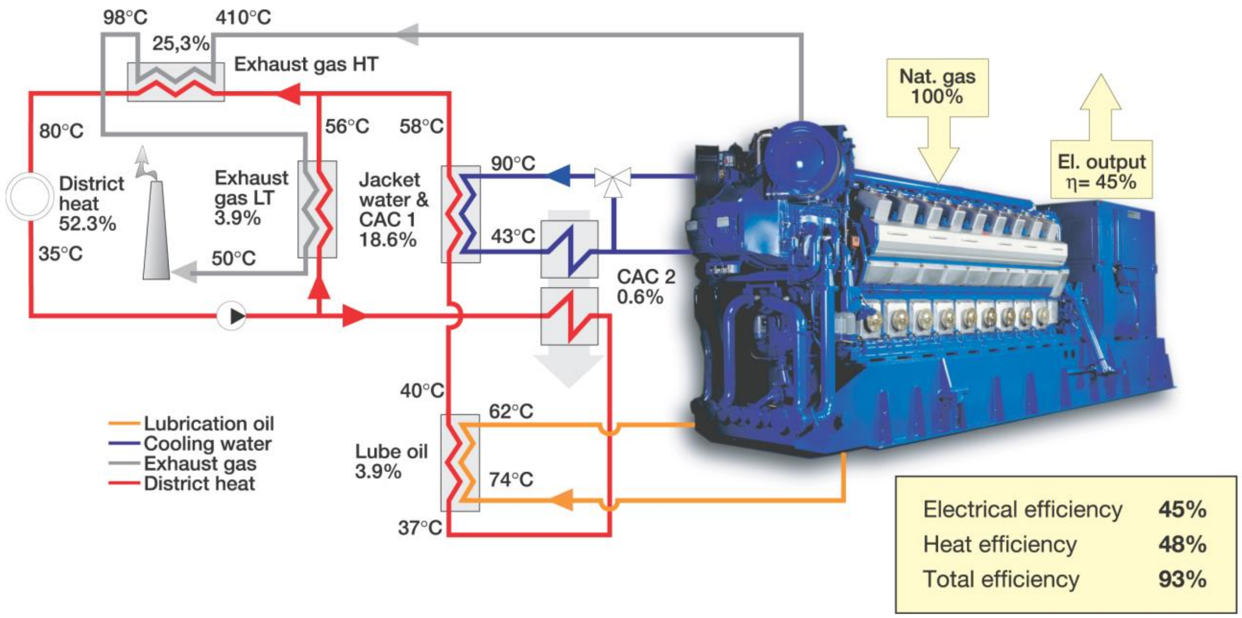
- Natural gas, biogas, coal mine ventilation gas, syngas
- LFO, HFO, oil residues, crude oil, crude vegetable oils, animal fats

Reciprocating engine CHP



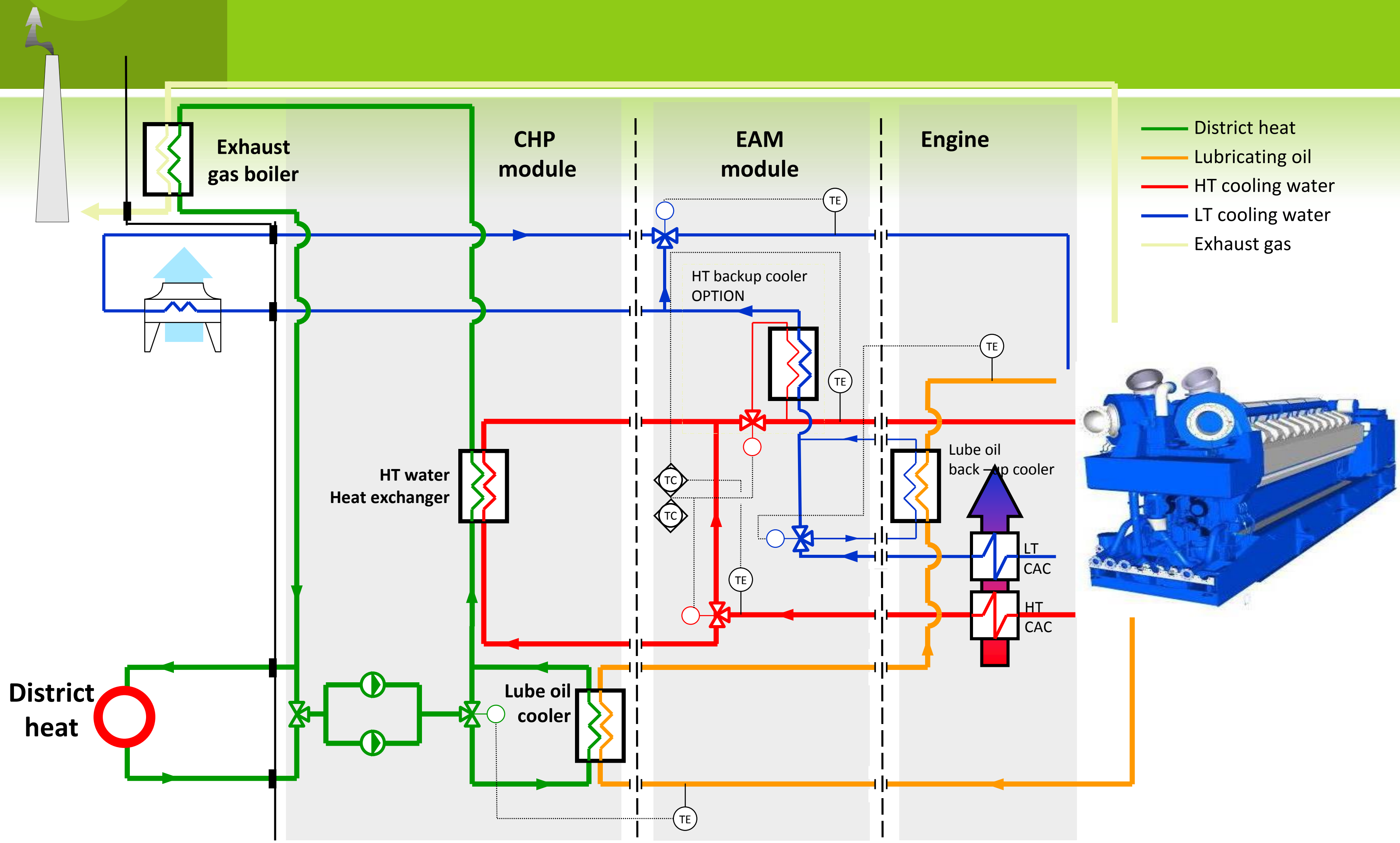
Reciprocating engine CHP Extreme case

Very high efficiency possible thanks to:
- very low return water temperature of 35˚C
- flue gas cooling down to 50˚C.



Typically Danish case!

Reciprocating engine CHP



GTCC CHP
Gas turbine + steam turbine

Source of heat

- Steam turbine exhaust or extraction
- Last part of exhaust gas boiler

Efficiency

- Electricity generation 50% or more
- Total over 80%

Size

- Practically over 50 MW

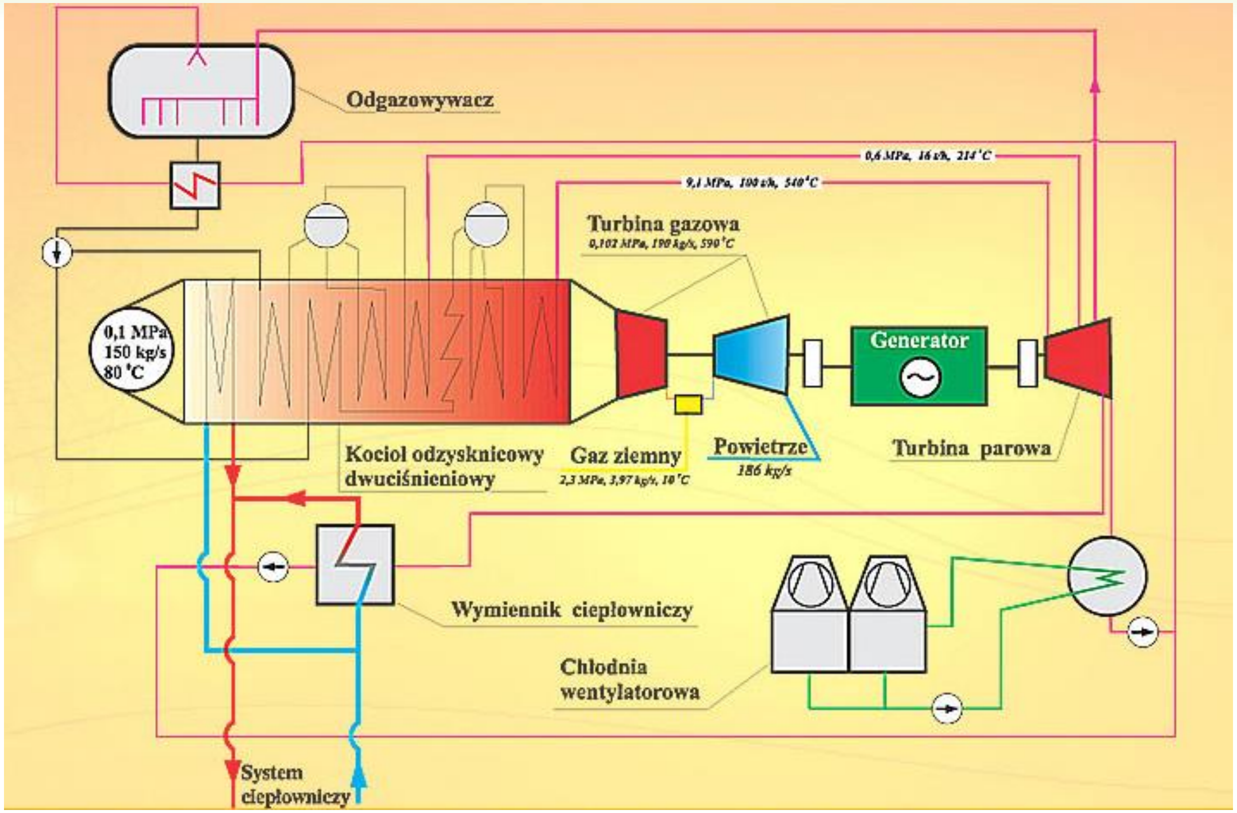
Flexibility

- Quite fast startup and shutdown procedures for gas part
- Entire unit not really flexible

Fuels

- Natural gas, biogas
- LFO, HFO (for heavy duty models)

Gas Turbine Combined Cycle – EC Rzeszów



Engine combined cycle
Recip. engine + steam turbine

Sources of heat

- Engine cooling liquid, ca 90˚C
- Engine lube oil, ca 60˚C
- Charge air coolers (90˚C, 40˚C)

Efficiency

- Electricity generation up to 50%
- Total depends on return water temperature, but usually max 75˚C
- If extraction/backpressure turbines are used then total efficiency will be higher, but at a cost of deteriorated electrical output and efficiency – normally this is not done

Size

- 30 MW up

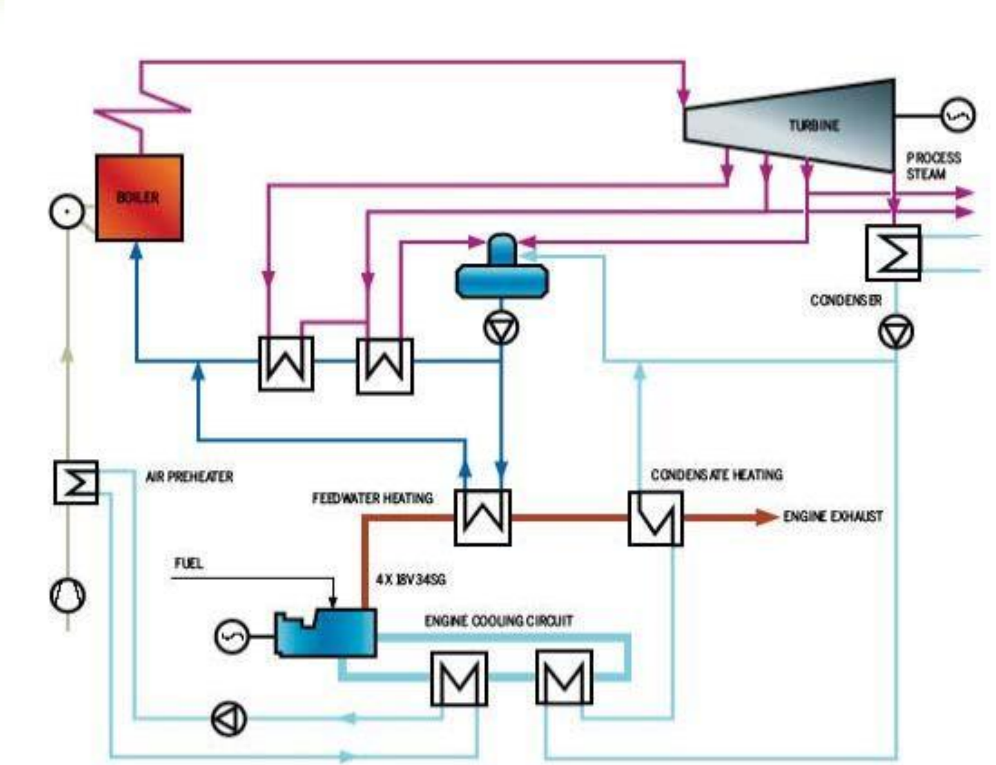
Flexibility

- Fast startup and shutdown procedures
- May operate as simple-cycle CHP, with nominal heat output and 90% electrical output

Fuels

- Natural gas, biogas, coal mine ventilation gas, syngas
- LFO, HFO, oil residues, crude oil, crude vegetable oils, animal fats

Engine combined cycle
Recip. engine + steam turbine



Examples of DH systems

The NYC Steam System

Operations started in 1882

Current network

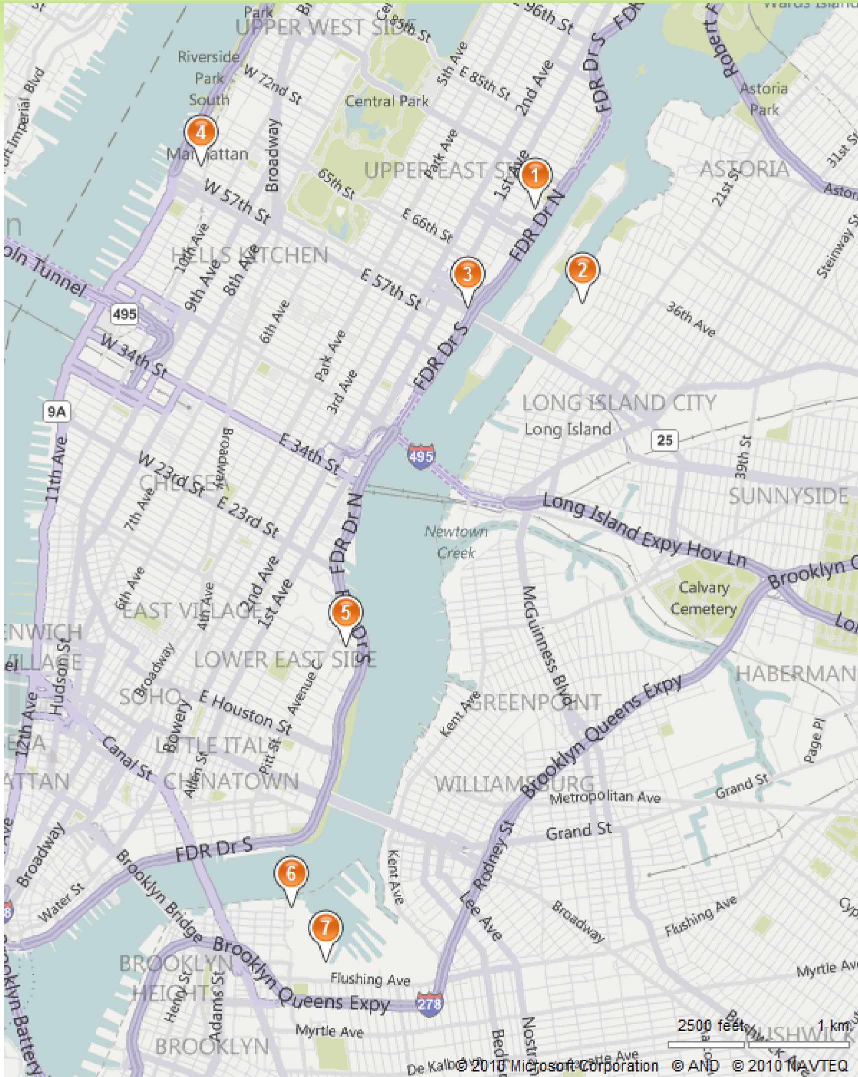
- Manhattan from Battery Park to 96th Street uptown on the West side and 89th Street on the East side of Manhattan
- 170 km of network
- 1800 customers, more than 100,000 residential & business establishments
- Peakload steam supply ca 4500 Mg/h at 350°F (~ 180°C)
- 13.64 million tons of steam per year
- 7 steam generation plants (3 of them CHP), running on oil & natural gas

Steam supply for:

- Heating
- Cleaning & disinfection
- Cooling (heat supply for chillers)

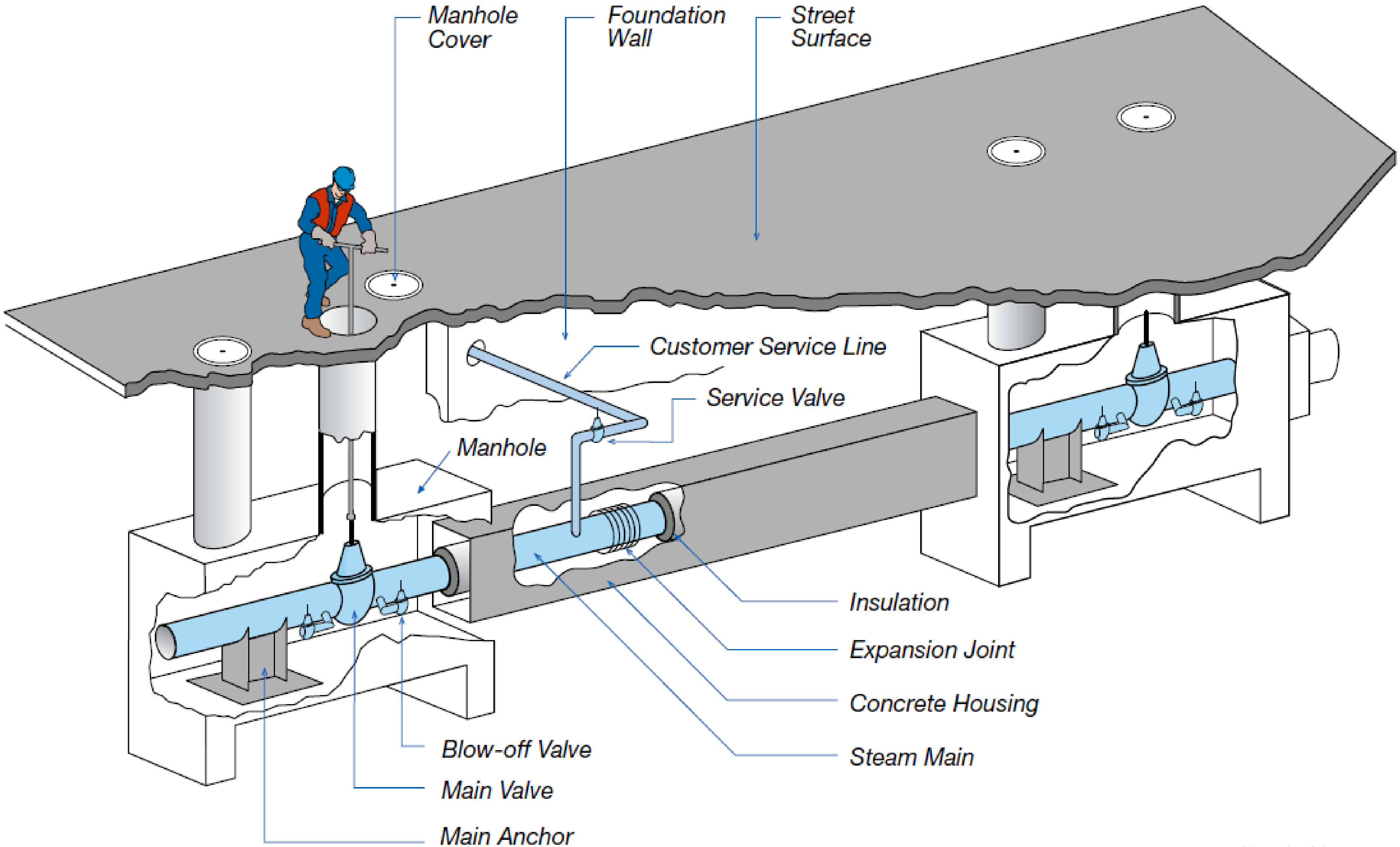
The NYC Steam System

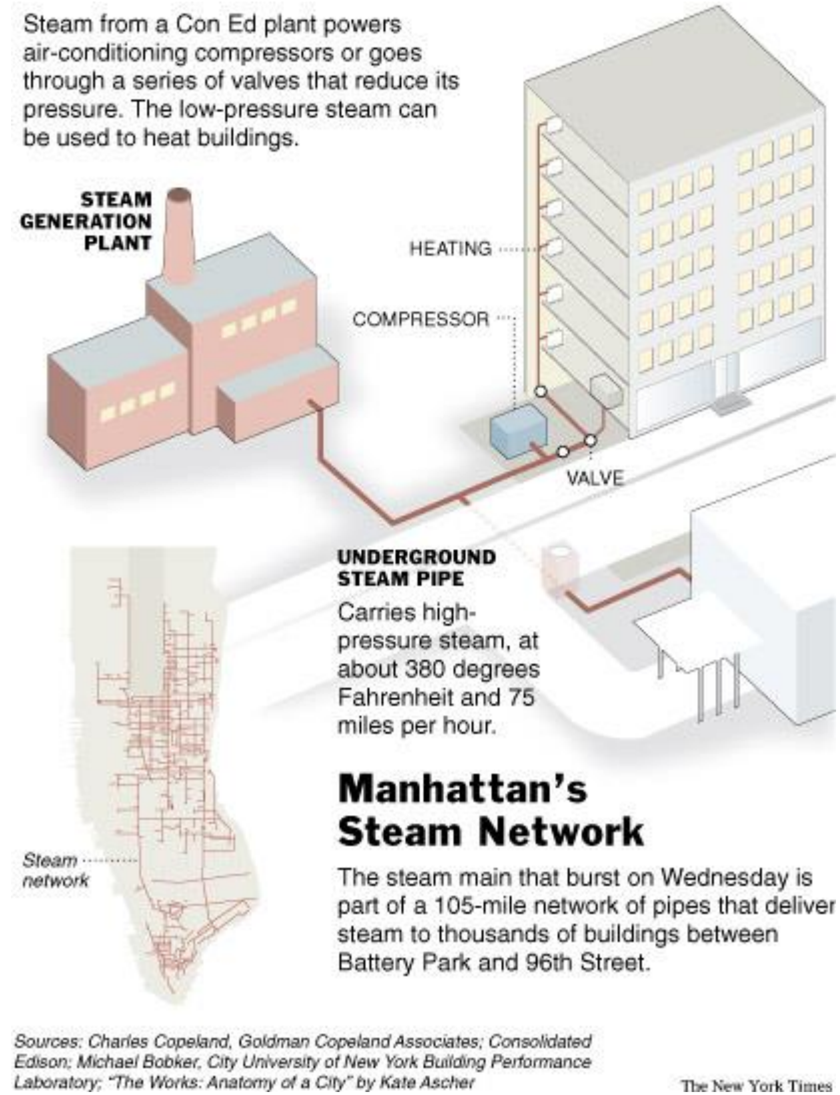
1. 74th Street Station
2. Ravenswood Station
3. 60th Street Station
4. 59th Street Station
5. East River Station (CHP)
6. Hudson Avenue Station
7. BNYCP Plant (CHP)



conEdison

Steam Distribution System




Steam from a Con Ed plant powers air-conditioning compressors or goes through a series of valves that reduce its pressure. The low-pressure steam can be used to heat buildings.
STEAM GENERATION PLANT
HEATING
COMPRESSOR
VALVE
UNDERGROUND STEAM PIPE
Carries high-pressure steam, at about 380 degrees Fahrenheit and 75 miles per hour.
Steam network
Manhattan's Steam Network
The steam main that burst on Wednesday is part of a 105-mile network of pipes that deliver steam to thousands of buildings between Battery Park and 96th Street.
Sources: Charles Copeland, Goldman Copeland Associates; Consolidated Edison; Michael Bobker, City University of New York Building Performance Laboratory; "The Works: Anatomy of a City" by Kate Ascher
The New York Times

DH in Paris

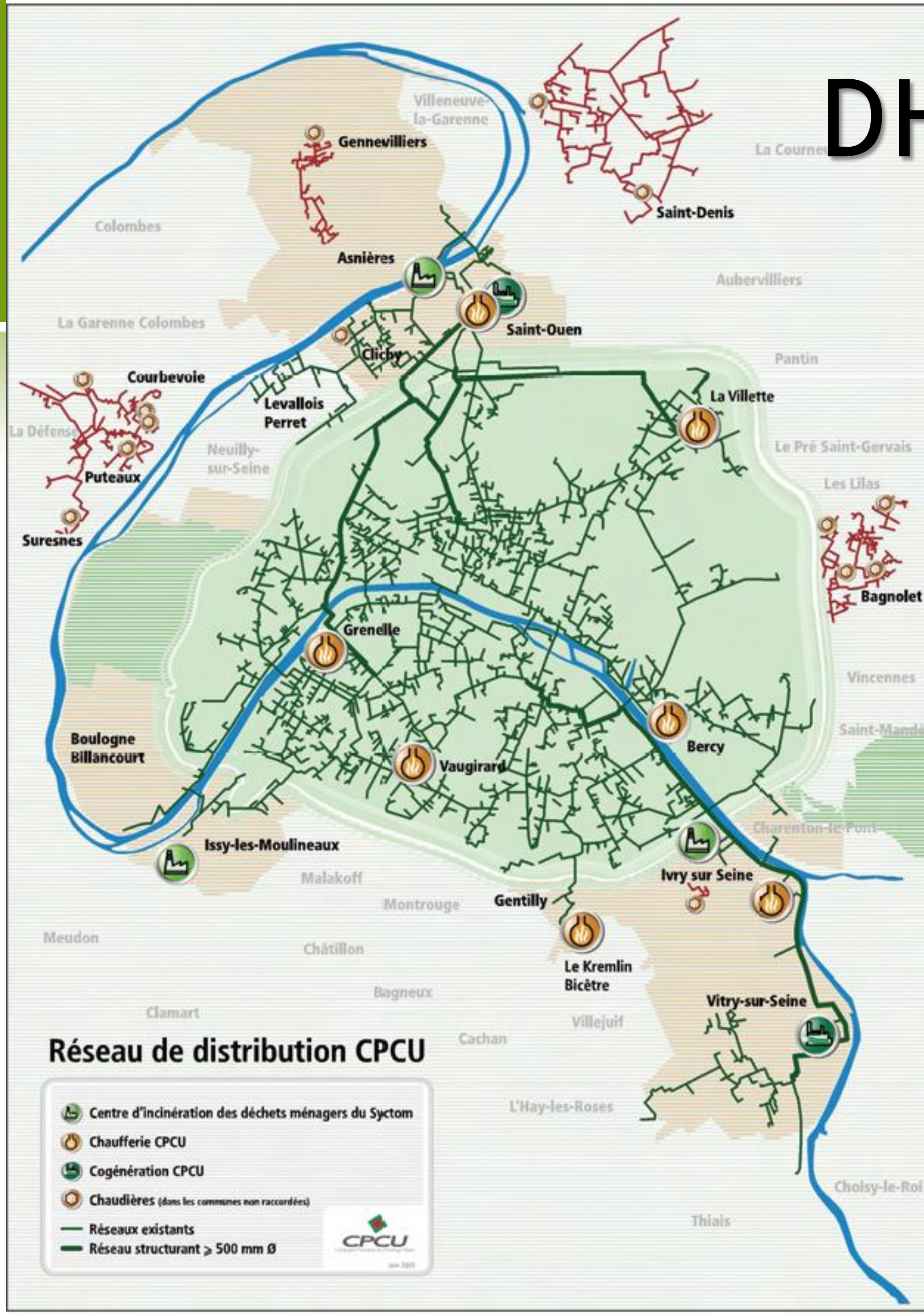
Capacity 3000 MW

- 10 plants

Production

- 6000 GWh/a heat
- 900 GWh/a electricity

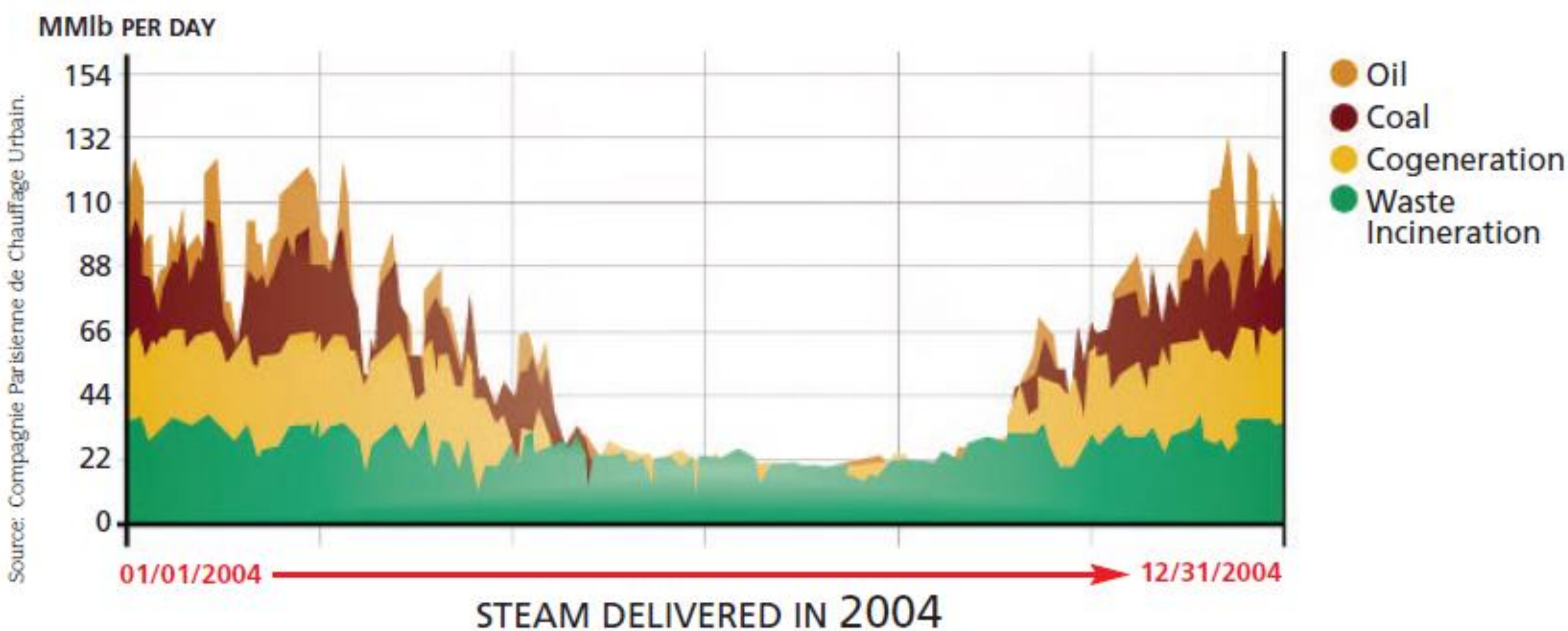
DH in Paris



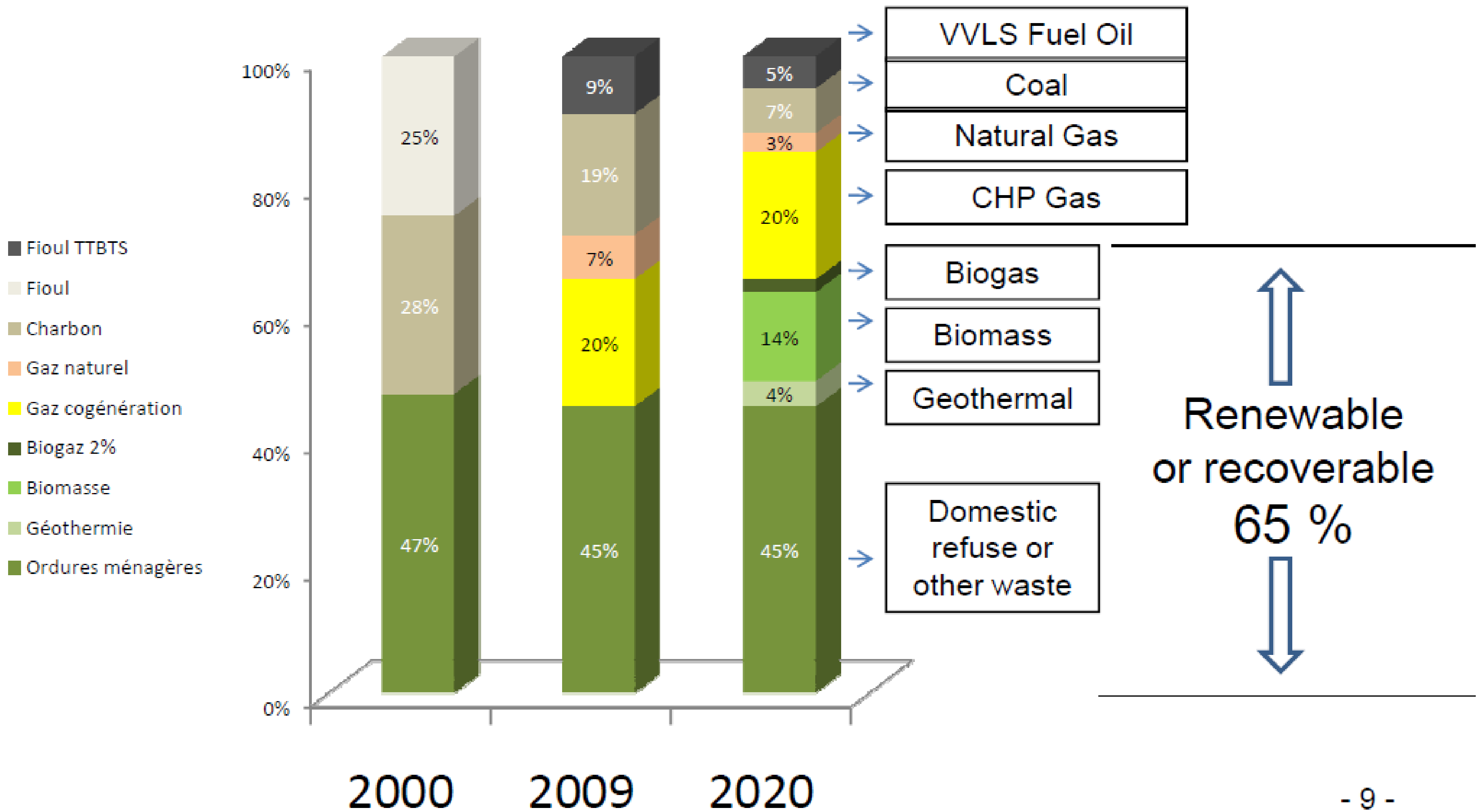
Eight plants:

21 oil boilers
2 gas boilers
2 coal boilers
2 CHP GT units

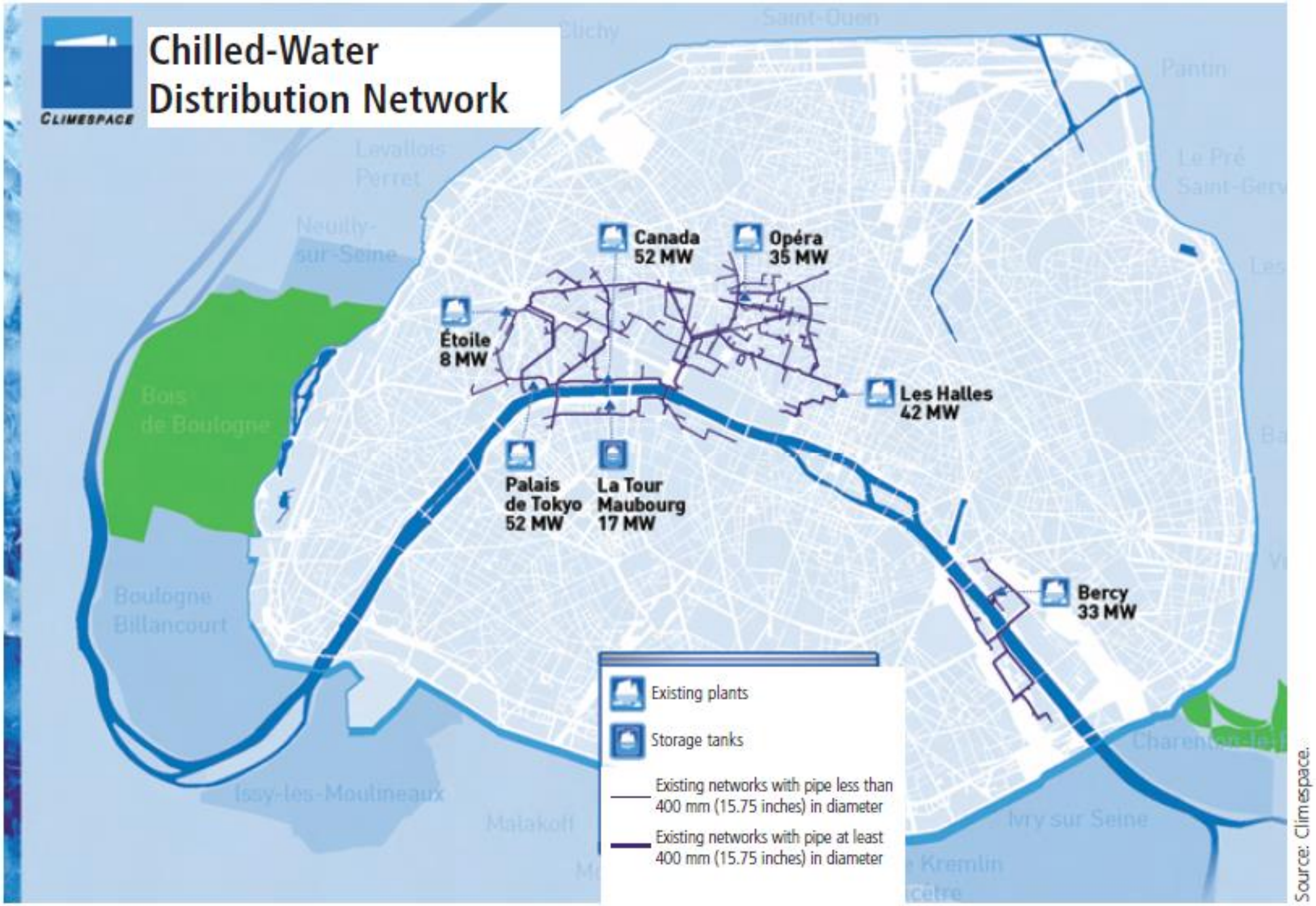
DH IN PARIS


MMlb PER DAY
154
132
110
88
66
44
22
0
Source: Compagnie Parisienne de Chauffage Urbain.
Oil
Coal
Cogeneration
Waste Incineration
01/01/2004
12/31/2004
STEAM DELIVERED IN 2004

CPCU : Paris District Heating Energy Mix 2000 - 2020



District Cooling in Paris



DH system in Warsaw

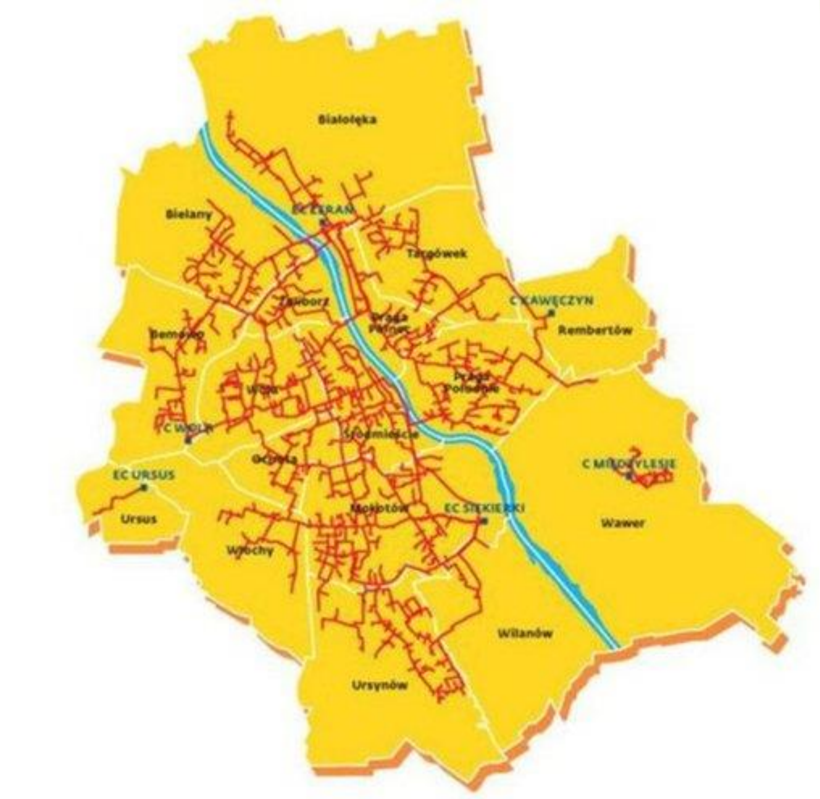
Operators

- Heating network: Dalkia Warszawa
- Heat sources: PGNiG Termika

System parameters

- 2 CHP plants (Siekierki, Żerań)
- 2 peakload heating plants (Wola, Kawęczyn)
- Contracted heat sources capacity 3700 MW_{th}
- 1700 km of pipelines
  - 300 km of mains (DN≥400)
  - 700 km of distribution pipelines
  - 700 km of connection pipelines
- 4 pumping stations: Batorego, Golędzinów, Marymont, Powiśle
- 15,000 customers' heat exchange centres (substations)
- Two small isolated systems: 10 km in Ursus, 14 km in Międzylesie
- Coverage 190 km^2, 80% of heat demand in Warsaw
- Losses 8-10% (winter), 25-28% (summer, due to low flow values)

DH system in Warsaw



DH system in Warsaw

Elektrociepłownia Żerań

- Commissioned in 1954
- Output 1561 MW_{th}, 350 MW_{el}
- CHP part, common header layout:
  - 2 fluidized bed boilers OFz-450
  - 4 pulverized bed boilers OP-230
  - 9 steam turbines
- 5 water boilers WP-120
- Fuel: hard coal

DH system in Warsaw

Elektrociepłownia Siekierki

- Commissioned in 1961
- Output 2081 MW_{th}, 622MW_{el}
- CHP part:
  - 4 CHP units
  - 4 common header boilers with 5 turbines
- 6 water boilers
- Heat storage tank
- Fuel: hard coal

DH system in Warsaw

Ciepłownia Wola

- Commissioned in 1973
- Output 465 MW_{th}
- Peakload operation, starting up at -10˚C
- 4 water boilers PTWM 100
- Fuel: LFO or HFO

DH system in Warsaw

Ciepłownia Kawęczyn

- Commissioned in 1983
- Output 605 MW_{th}
- Peakload operation, starting up at -4˚C
- 3 water boilers
- Fuel: hard coal
- 300 m stack – the tallest structure in Warsaw

CHP plant in Rzeszów Elektrociepłownia Rzeszów

- Gas Turbine Combined Cycle Unit
- 3 WR 25 Coal-fired boilers (grate)
- 1 WP 120 Coal-fired boiler (pulv.)

GTCC unit at Elektrociepłownia Rzeszów

Gas turbine Ansaldo V64.3A

- Single spool design, 17-stage compressor, 4-stage turbine
- Annular combustion chamber with 24 low-emission burners
- Fuel: natural gas, 23 bar
- Turbine inlet temperature ca 1200˚C

Heat Recovery Steam Generator/Boiler

- Dual pressure steam generation: 91 bar/540˚C (100 Mg/h), 6 bar/284˚C (16 Mg/h)
- Water preheater (economiser)
- Exhaust at 80˚C – below dew point

Siemens steam turbine

- Condensing-extraction type
- Closed cooling cycle with forced draft cooling towers

Common generator

- GT-G-ST layout
- Two gearboxes

GTCC unit at Elektrociepłownia Rzeszów

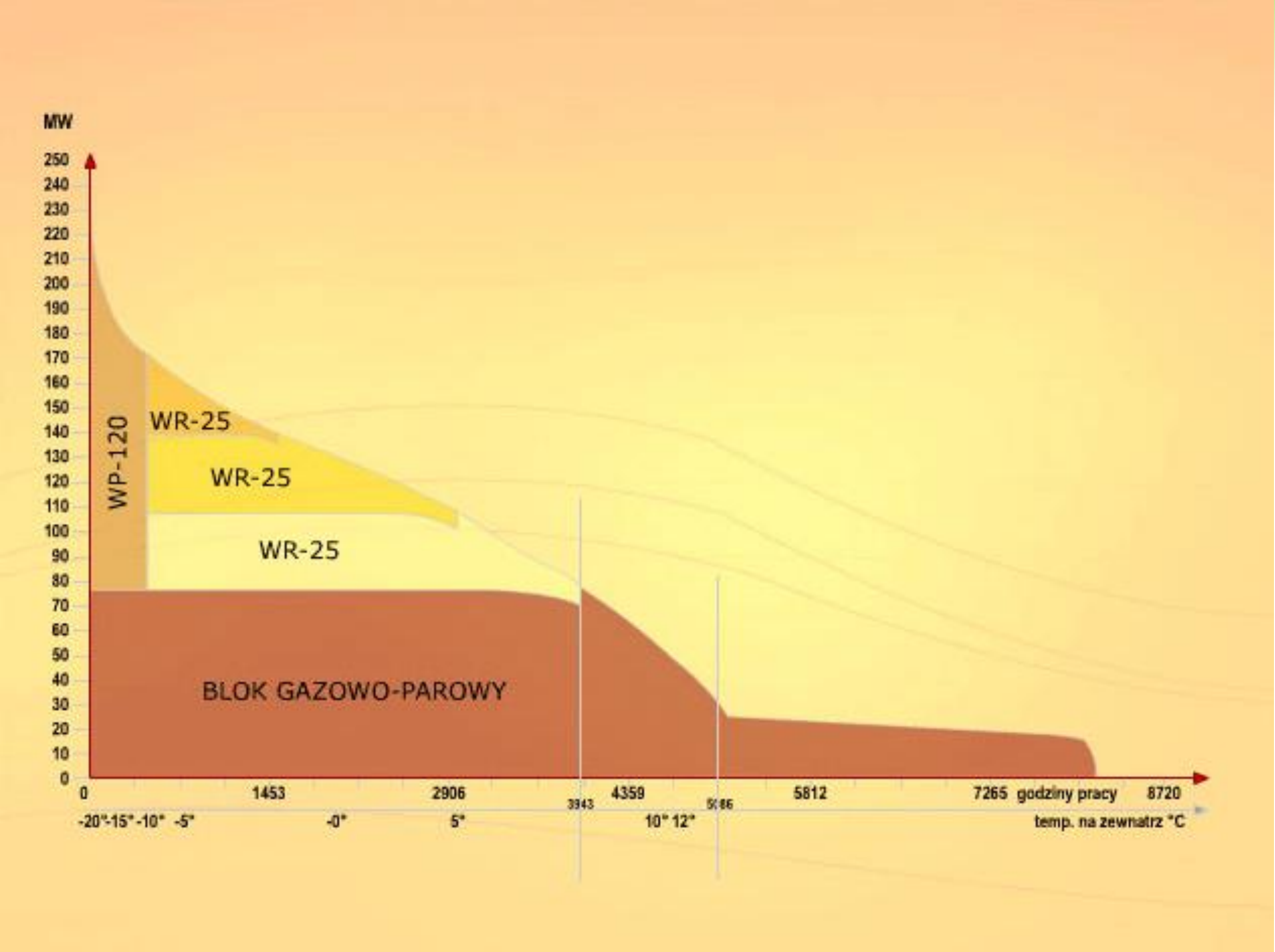
Nominal operation:

- Gross electrical output 95.75 MWel, efficiency 49.47%
- Net electrical output 93.30 MWel, efficiency 48.51%
- Thermal output 76.30 MWth, total efficiency 88.88%

Summer operation:

- Gross electrical output 93.90 MWel, efficiency 51.04%
- Net electrical output 92.04 MWel, efficiency 49.89%
- Thermal output 18.00 MWth, total efficiency 60.80%
- Total efficiency limited by low heat load from the system
- Need for a smaller baseload plant?

Elektrociepłownia Rzeszów Load dispatching



Thank you!