ENERGY PLANNING

# LOW GRADE WASTE HEAT SOURCES IMPACT ON DISTRICT HEATING SYSTEMS – DESIGN AND ECONOMICS

DAN KELLEY – RAMBOLL ENERGY

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# AGENDA

1. District Heating Systems
2. Traditional USA Based Approach
3. European Based Approach
4. Benefits of Hot Water Systems
    1. Wider opportunity for sources
    2. System losses
    3. Economic Impacts
5. Case Study 1 – Copenhagen
6. Case Study 2 – Vojens Solar Thermal

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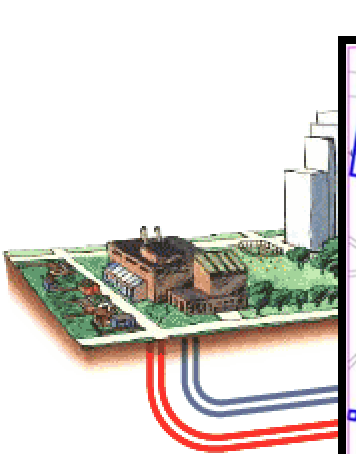
# DISTRICT HEATING SYSTEMS & NETWORKS



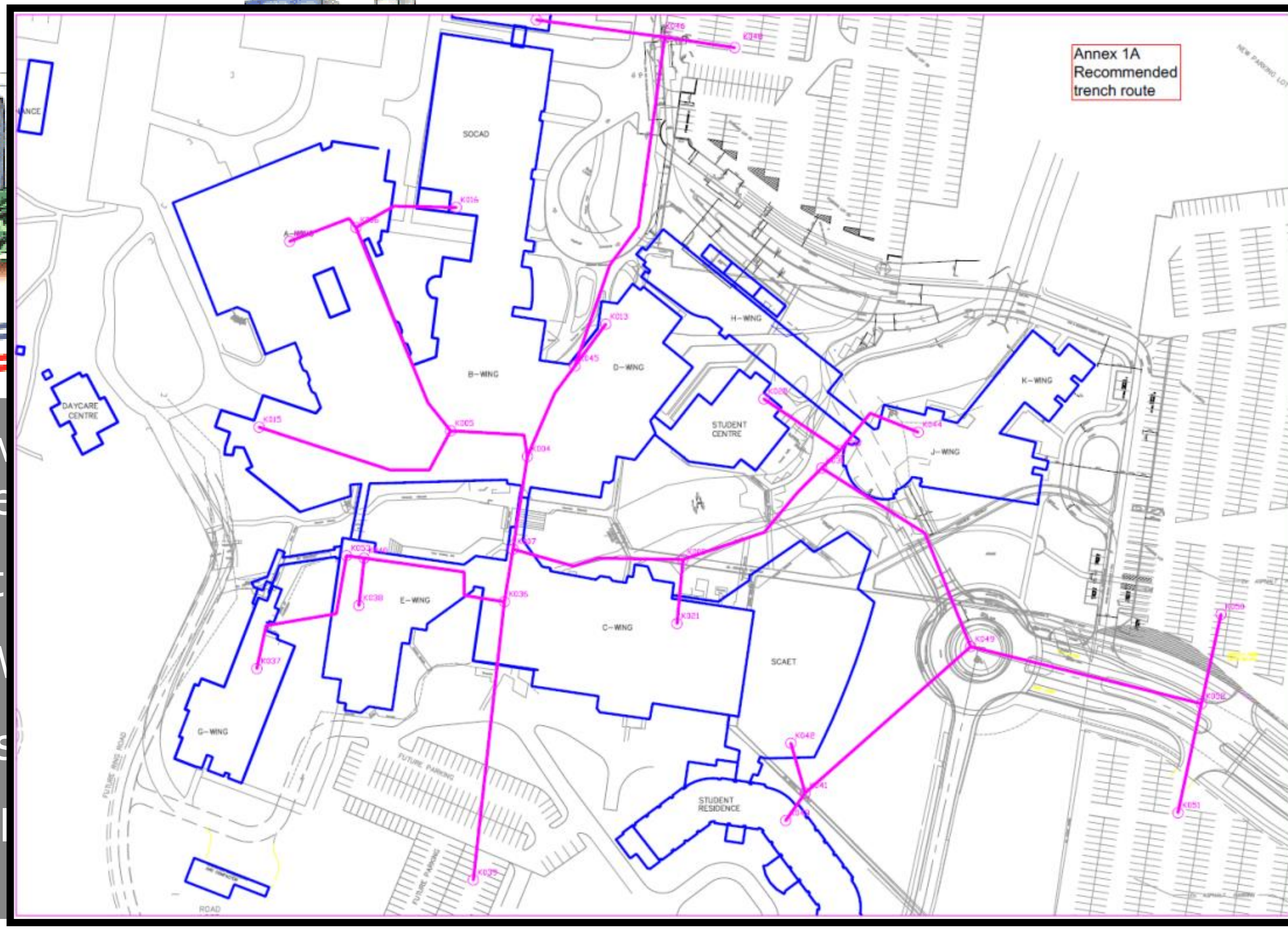
Thermal Netw
fittings, and e

Steam or Hot

Heating, DHW

Central plants

Private or Util

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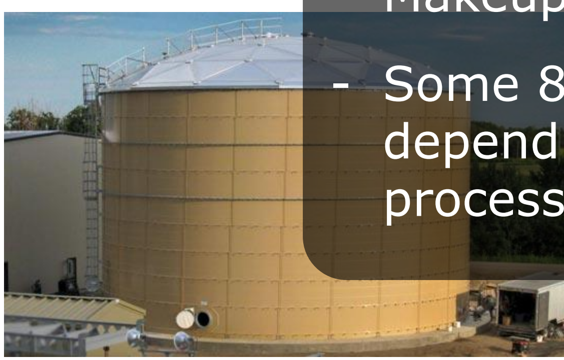
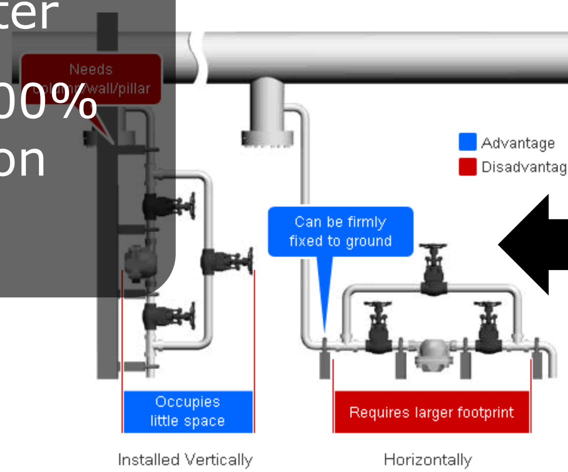
# TRADITIONAL DISTRICT HEATING SYSTEMS – USA (STEAM)

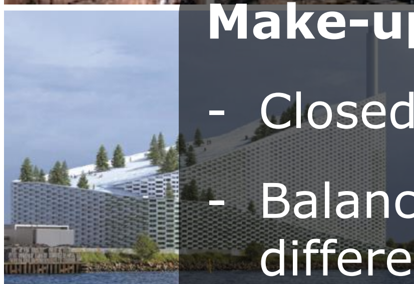


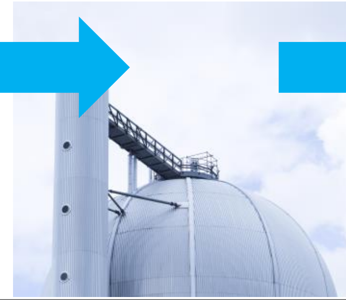
## Make-up Water

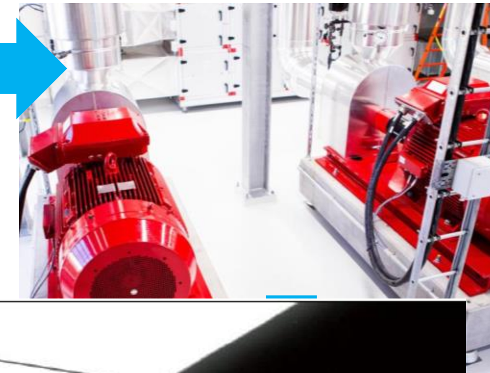
- Typical 20-30% Makeup water
- Some 80-100% depending on process



# TRADITIONAL DISTRICT HEATING SYSTEM – EUROPE (HOT WATER)

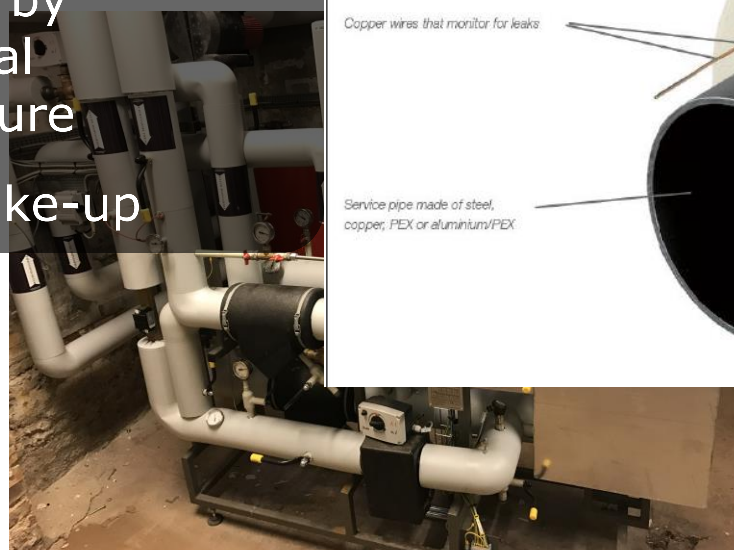


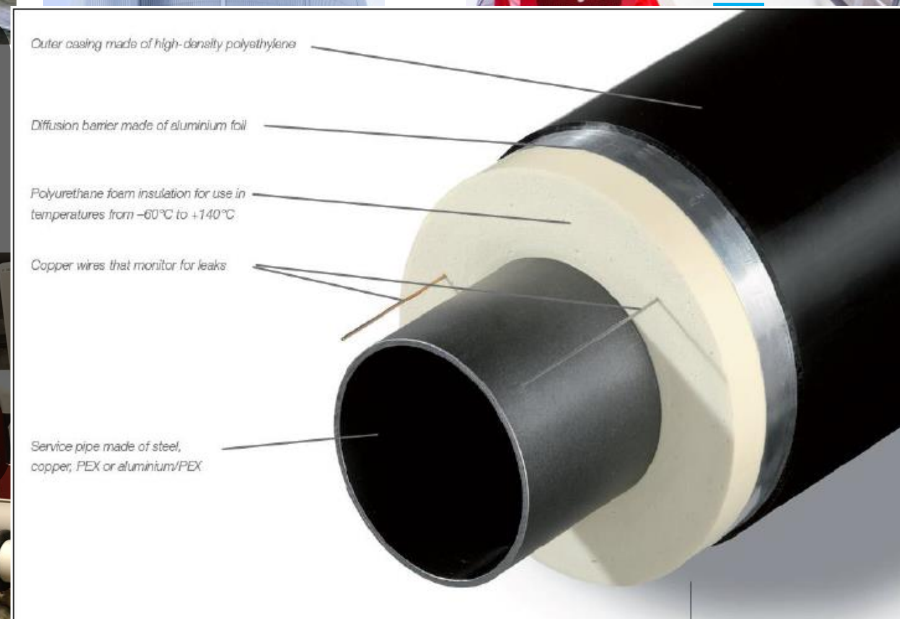




## Make-up Water

- Closed loop
- Balanced by differential temperature
- 0-3% make-up



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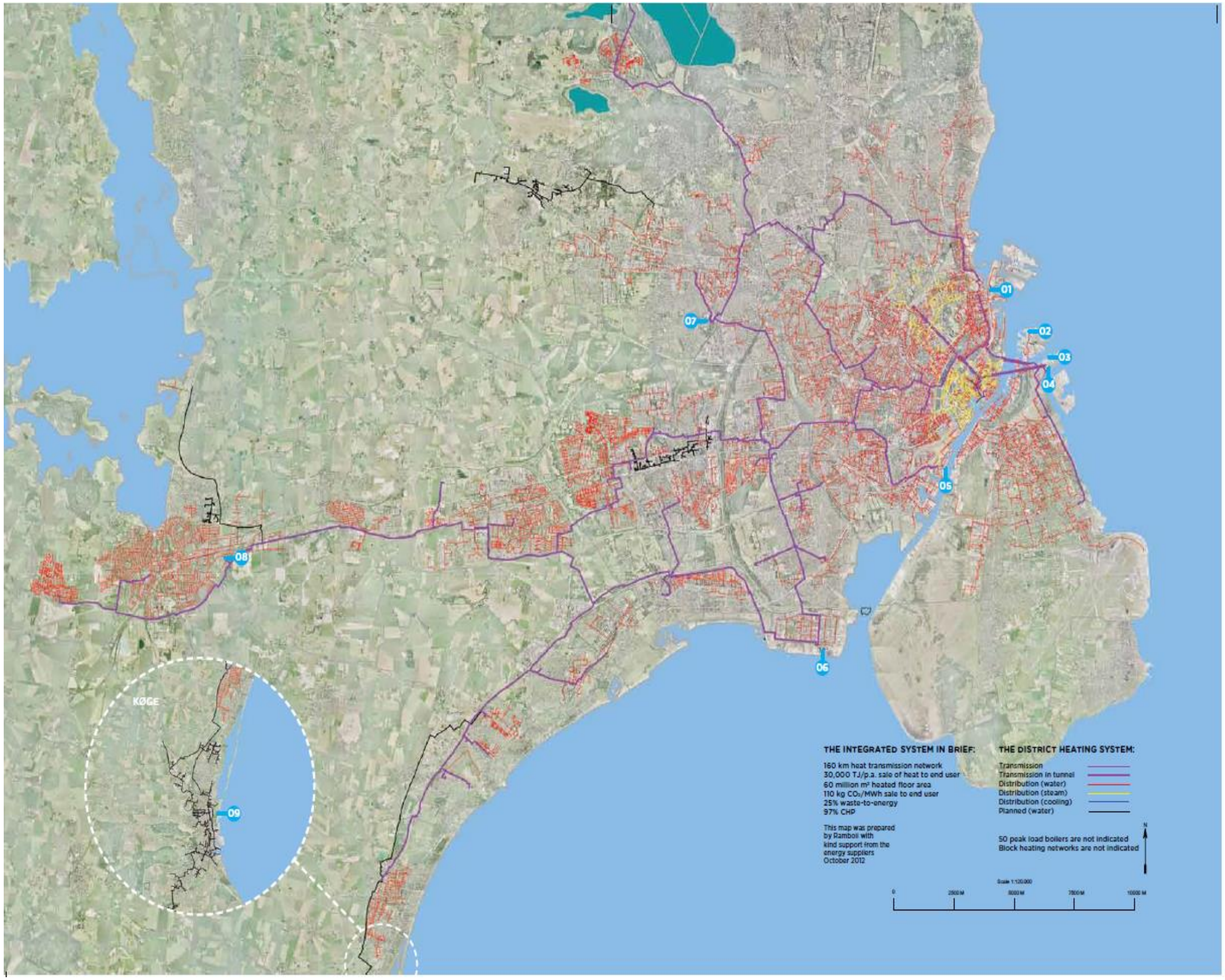
# COPENHAGEN DISTRICT HEATING SYSTEM





DONG ENERGY
SVANEMØLLEVÆRKET
Gas-fuelled CHP


LYNETTEFÆLLESSKABET
Waste-to-energy (sludge), heat only


VATTENFALL
AMAGERVÆRKET
Multi-fuel CHP, heat storage


AMAGERFORBRÆNDING
Waste-to-energy CHP


DONG ENERGY
H.C. ØRSTEDVÆRKET
Gas-fuelled CHP


DONG ENERGY
AVEDØREVÆRKET
Multi-fuel CHP, heat storage


VESTFORBRÆNDING
Waste-to-energy CHP


KARA/NOVEREN
Waste-to-energy CHP


VEKS
KØGE KRAFTVARMEVÆRK
Biomass CHP

## THE INTEGRATED DISTRICT HEATING SYSTEM IN GREATER COPENHAGEN

**Distribution, hot water**
Albertslund Forsyning
Avedøre Fjernvarme A.m.b.a
Avedøre Holme, Fjernvarmecentralen
Brøndby Fjernvarme A.m.b.a
Copenhagen Energy
Frederiksberg Forsyning
Gentofte Fjernvarme
Gladsaxe Fjernvarme
Glostrup Forsyning
Greve Strandby Fjernvarmeværk A.m.b.a
Hundige Fjernvarmeværk A.m.b.a
Hvidovre Fjernvarme A.m.b.a
Høje Taastrup Fjernvarme A.m.b.a
Ishøj Varmeværk
Køge Fjernvarme
Mosede Fjernvarmeværk A.m.b.a
Roskilde Fjernvarme
Rødovre Kom. Fjernvarmeforsyning
Solrød Fjernvarmeværk A.m.b.a
Svogerslev Fjernvarmecentral A.m.b.a
Tårnby Fjernvarmeforsyning
Vallensbæk Fjernvarmeværk A.m.b.a
Vejlegården Fjernvarmecentral A.m.b.a
Værløse Varmeværk

**Distribution, steam**
Copenhagen Energy

**Distribution, cooling**
Copenhagen Energy
Frederiksberg Forsyning

**Transmission**
CTR
VEKS
Vestforbrænding

**Waste-to-energy**
Amagerforbrænding
KARA/NOVEREN
Vestforbrænding
Lynettefællesskabet

**CHP plants**
DONG Energy
Vattenfall
VEKS

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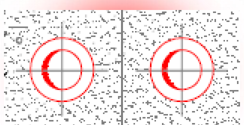
# BENEFITS – LOWER TEMPERATURES AND REDUCED HEAT LOSS

**HOT WATER**



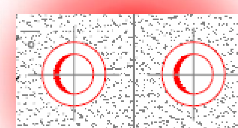
**Heat Loss**
**≈ 5-7%**

**Hot Water**
(Supply of Existing Buildings):
180 to 200° F
82 to 93° C

**STEAM**

**Steam**
575° F
302° C


**Hot Water**
(Supply of New Buildings):
120° F / 49° C



**Heat Loss**
**≈ 25-35%**

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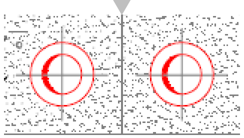
# BENEFITS – CONSTRUCTION TECHNIQUES

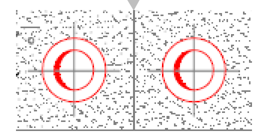
Steam – Concrete Duct

10-15 ft deep

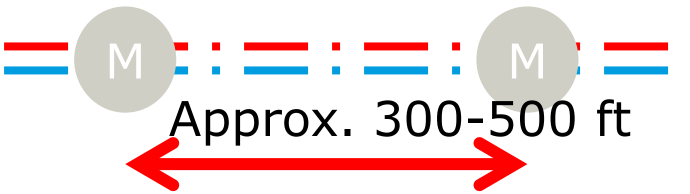
Hot Water – Direct Buried

3 ft deep

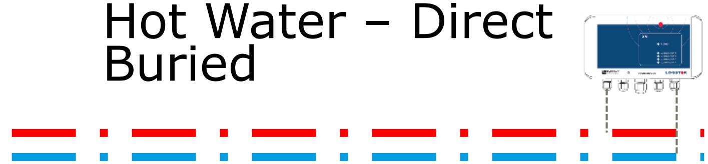


# BENEFITS – CONSTRUCTION COSTS AND MAINTENANCE

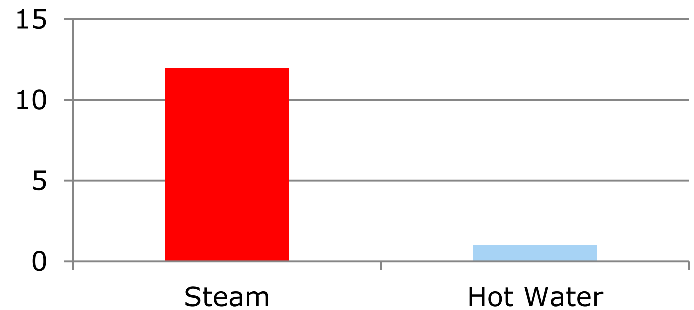
## Steam – Concrete Duct




## Hot Water – Direct Buried



## O&M Costs $/ft



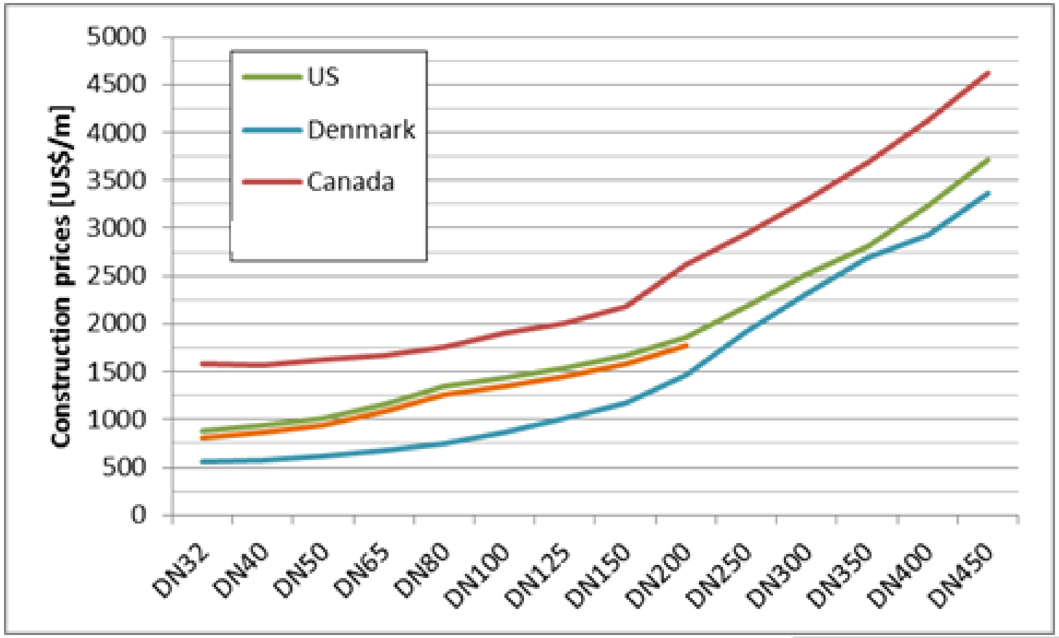

- Average O&M costs of steam vs hot water systems in Copenhagen
- $12/ft Steam vs. $1/ft Hot Water

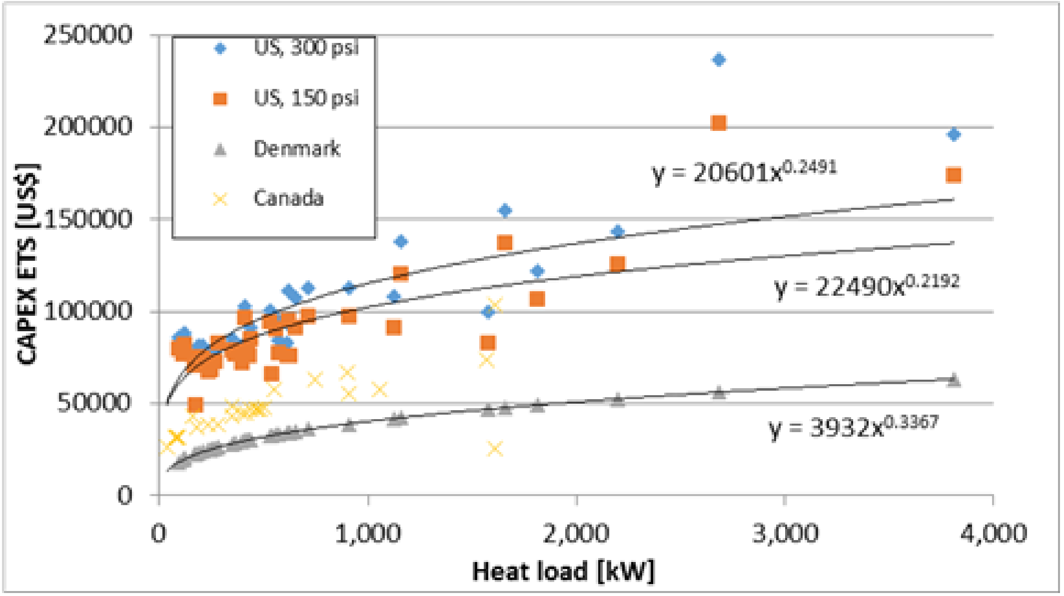
# BENEFITS – LOW TEMPERATURE SYSTEM

**A low temperature water based DH system:**

- enables a flexible and resilient energy system – able to produce at low costs independent on external assumptions
- can collect waste heat sources from e.g. industry, cogeneration, cooling etc. and utilize during winter period – lower fuel consumption and lower production costs
- can receive heat from typical heat pumps which can operate up to 185° F (newer HP models)
- has a very long technical lifetime (> 60 years)
- can increase the overall efficiency of the system significantly
- has significantly lower heat losses and maintains the insulation ability for more than 100 years (temperature dependent)
- has much lower investment costs than a steam based system
- has much lower operational costs than a steam based system

# INSTALLED COST COMPARISONS

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# OVERALL FUEL COST REDUCTION ESTIMATE

| | | | | | |
|---|---|---|---|---|---|
| Heat demand | 100000 | MWh | | | |
| Or | 341200 | MMBtu | | | |
| | | | | | |
| | | **Steam** | **Water** | | |
| Heat loss | | 30% | 5% | | |
| Heat production | GWh/yr | 143 | 105 | | |
| Boiler efficiency (LHV) | Pct. | 85% | 95% | | |
| Boiler input | GWh/yr | 168 | 111 | | |
| **Reduction in fuel input** | | | **34%** | | |
| | | **Fuel oil** | **Biomass** | | |
| Fuel prices | $/MWh | 30 | 20 | | |
| Fuel costs | Mill $/yr | 5 | 2.2 | | |
| **Savings in fuel costs** | **Mill $/yr** | | **2.8** | | |

**The savings could justify an investment of more than 30 mill $ based on a real discount rate of 4% and an economic lifetime of 15 years**

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Notes:
- A fuel oil price of 30 $/MWh corresponds to approx. 50 $/barrel
- A new network will have a lifetime of more than 60 years. Reinvestments in existing steam system should be subtracted the investment in hot water system
- Possible savings are higher if maintenance is included

# WHY HOT WATER??

## WIDER RANGE OF WASTE HEAT ENERGY SOURCES

## LOWER OVERALL INSTALLATION AND OPERATING COSTS

## REDUCED FUEL CONSUMPTION AND CARBON EMISSIONS

# WASTE HEAT RECOVERY FOR HOT WATER SYSTEMS

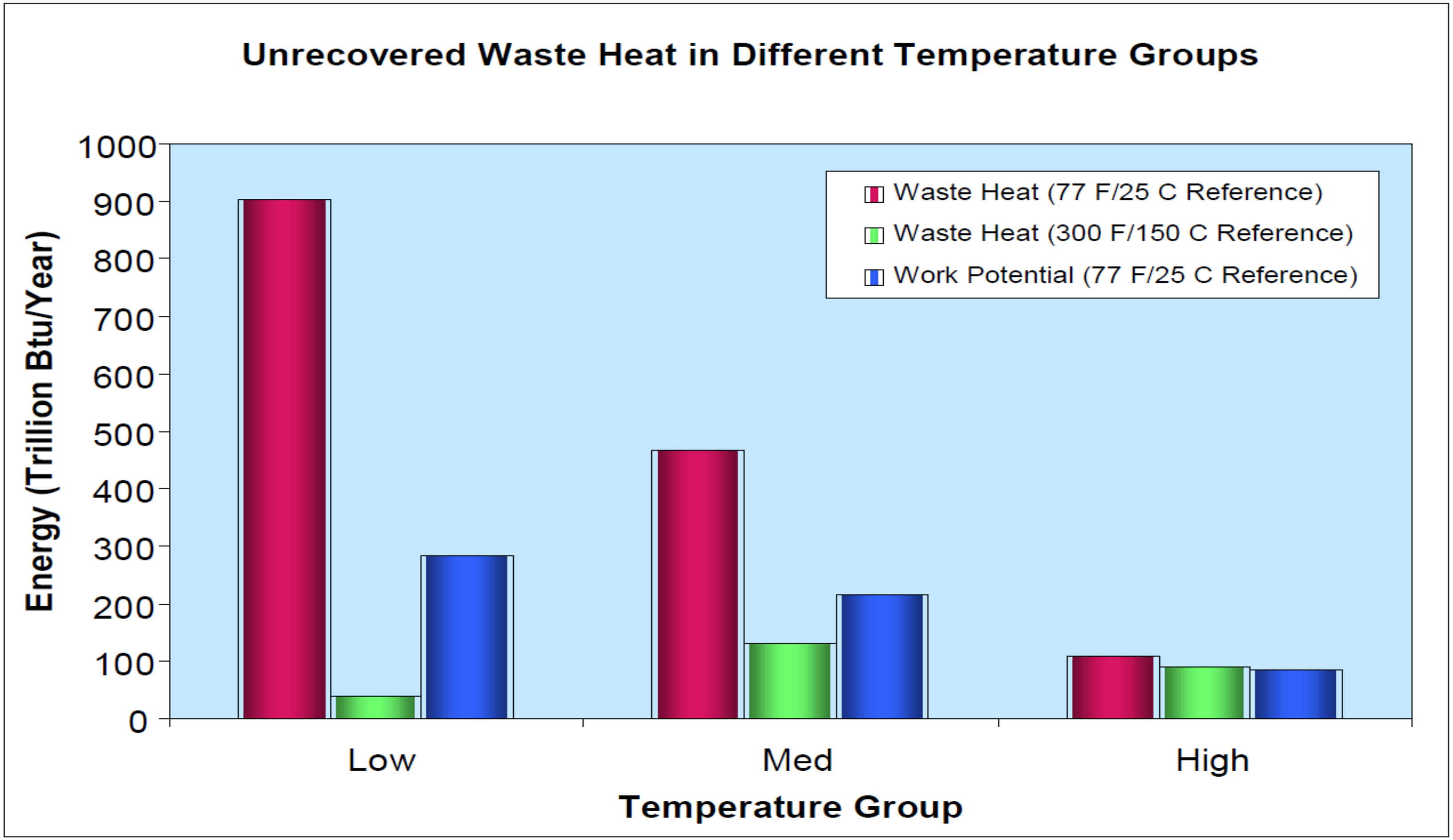


**Figure 30 - Unrecovered Waste Heat in Different Temperature Groups.**

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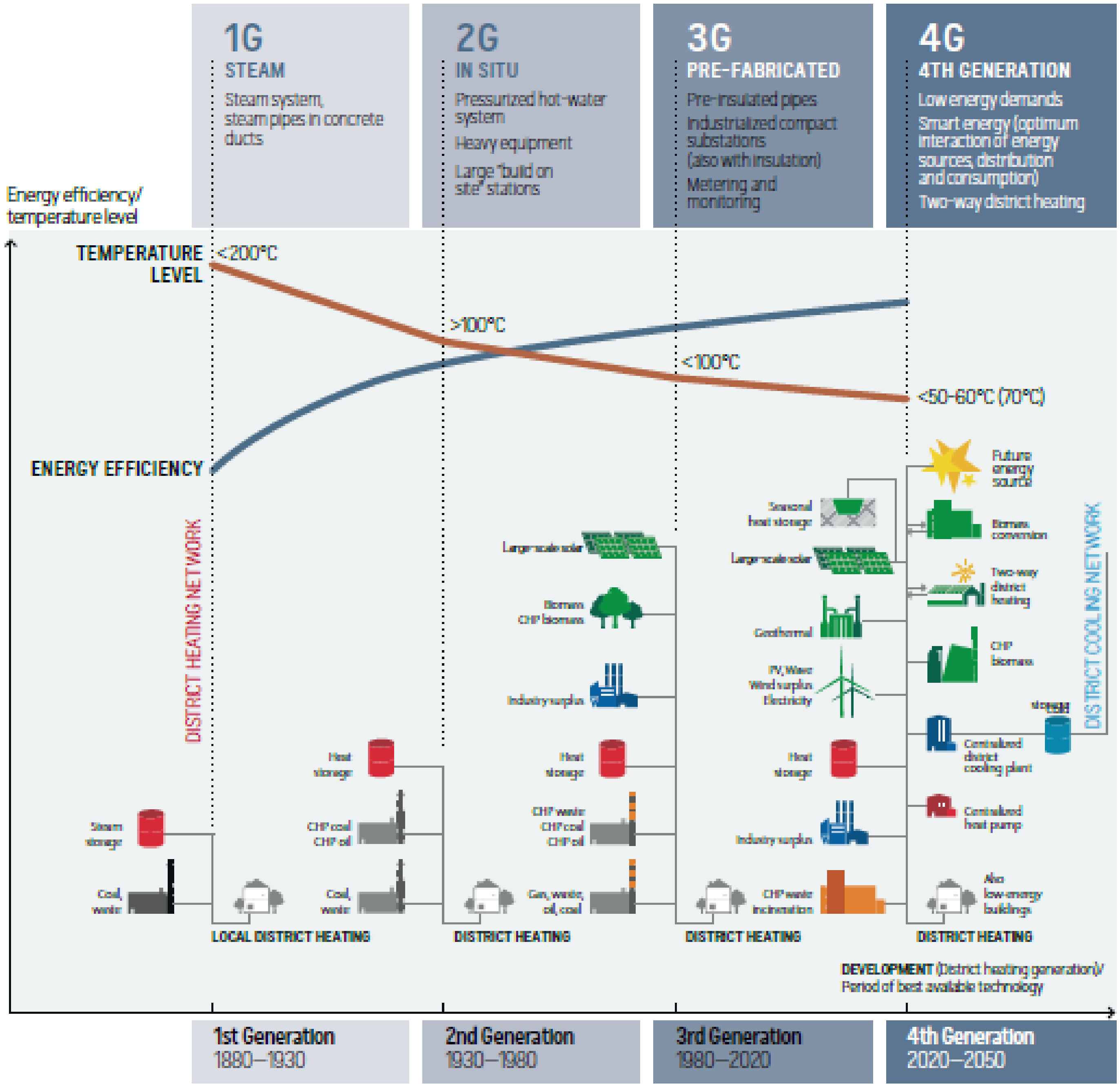


Source: Aalborg University and Danfoss District Energy, 2014

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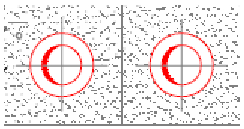
# COST SAVINGS FACTORS – HOT WATER SYSTEMS



**3-5%**

**Less Heat Loss**

**Lower Temp's by 185-300° F**

**$500/ft (avg) savings installation costs at lower temperatures**

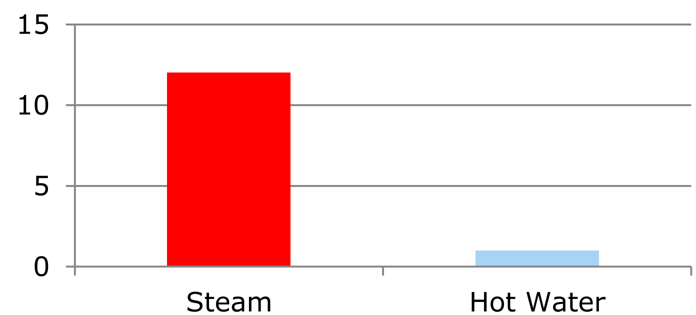
**25% Increase in Efficiency**

**22% GHG Reduction**

## Waste Heat Recovery

- Wider variety of sources
- Low or no cost fuel
- Renewables & Waste to Energy
- Combined Heat & Power

## O&M Costs $/ft




$12/ft Steam

$1/ft Hot Water

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# COPENHAGEN DISTRICT HEATING SYSTEM DENMARK

## Challenge

Utilisation of all available heat sources in the Copenhagen region in the most efficient way

## Solution

Main consultant to CTR for more than 30 years

Planning, design, implementation, optimisation

## Effect

One of the largest city-wide district heating systems in the world

Supplies low-carbon heat to one million people

$1/foot O&M Costs

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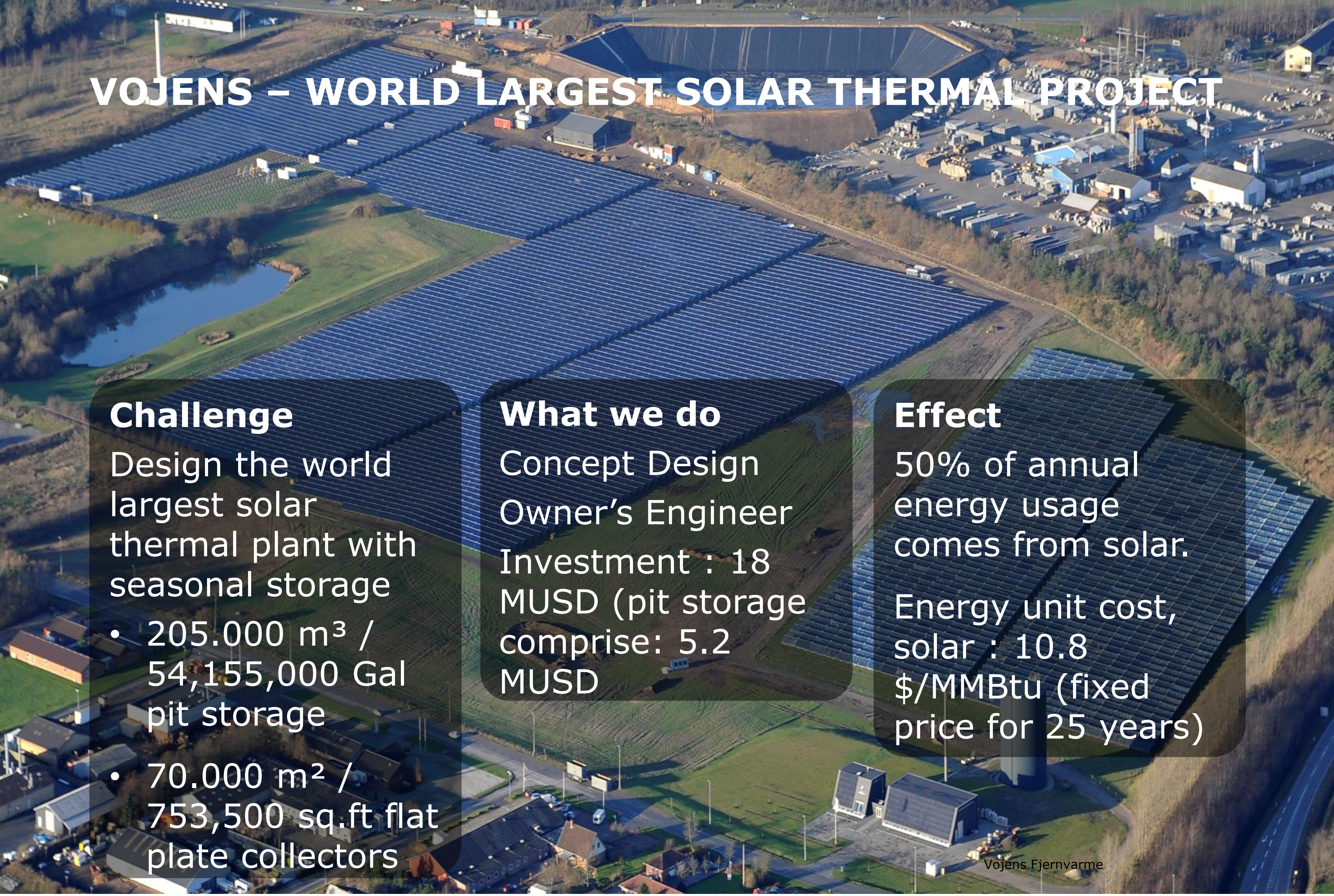
# VOJENS – WORLD LARGEST SOLAR THERMAL PROJECT



Vojens Fjernvarme

## Challenge

Design the world largest solar thermal plant with seasonal storage

- 205.000 m³ / 54,155,000 Gal pit storage
- 70.000 m² / 753,500 sq.ft flat plate collectors

## What we do

Concept Design

Owner's Engineer

Investment : 18 MUSD (pit storage comprise: 5.2 MUSD

## Effect

50% of annual energy usage comes from solar.

Energy unit cost, solar : 10.8 \$/MMBtu (fixed price for 25 years)

# QUESTIONS?

# THANK YOU

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**READ MORE ON OUR WEBSITE:**
**WWW.RAMBOLL.COM/ENERGY**