# Geothermal District Heating
# The Icelandic Experience

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Verkís - Iceland

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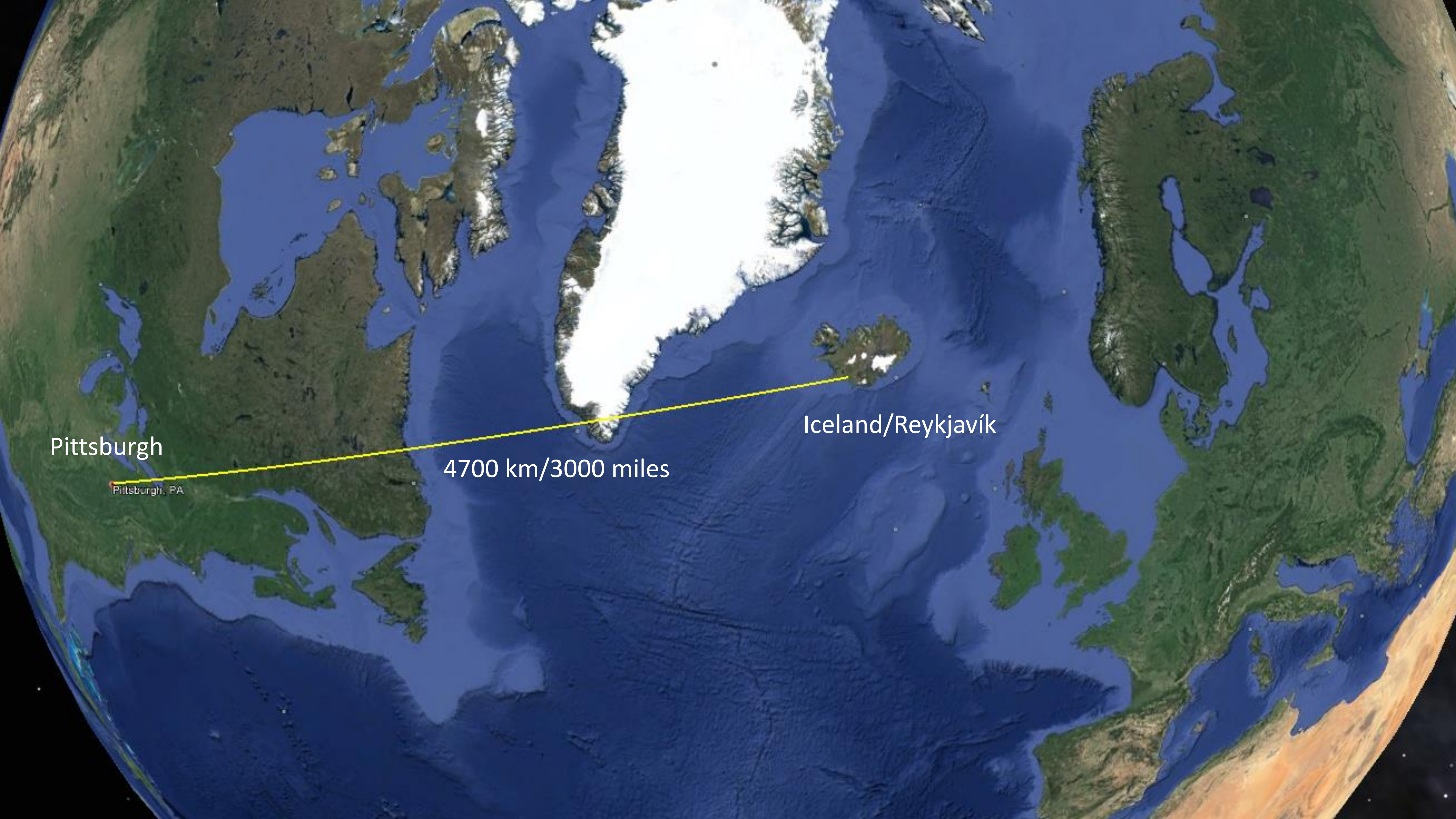

Pittsburgh
Pittsburgh, PA
4700 km/3000 miles
Iceland/Reykjavík

# Iceland /USA

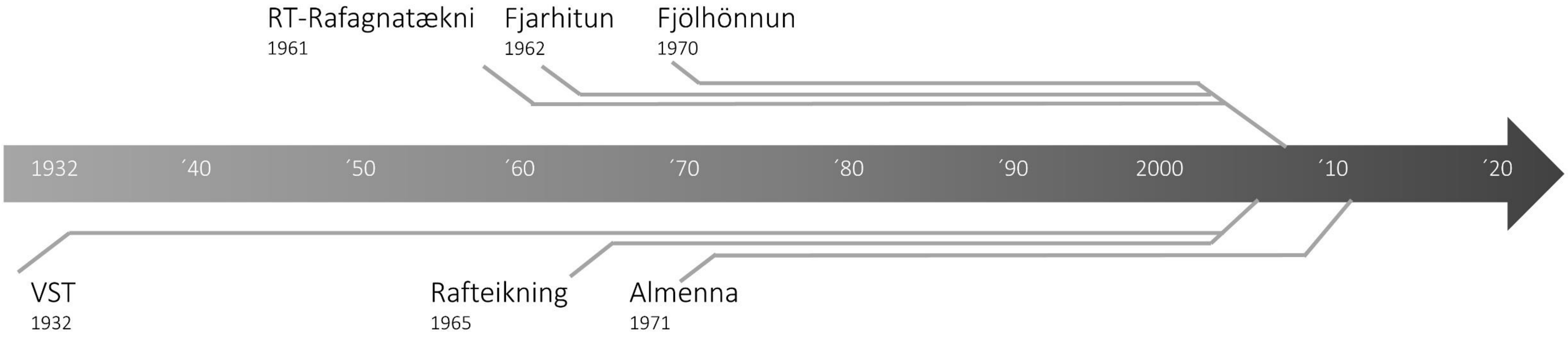
- Iceland
  - Population 330 000
  - Size 103 000 km$^2$
  - Population density 3.20 persons pr. km$^2$

- USA
  - Population 319 000 000 (1000 times more people)
  - Size: 9 900 000 km$^2$ (100 times bigger)
  - Population density 32.4 persons pr. km$^2$ (10 times more crowded)

VERKÍS
CONSULTING ENGINEERS

# Verkís Consulting Engineers

- Verkís was founded in 2008 by merger of five leading Icelandic consulting engineering firms
- The origin of the firm dates back to 1932
- Partnership owned by 93 professionals with a staff of 320 employees



Geothermal power

District heating

Geothermal utilization

Hydropower

Power transmission

Other renewables

Steam power plants

Steam field

Development
Operation assistance

Heat and power

Binary power plants

Well field

Integrated or cascaded arrangement

Supply mains

Storage tanks


Pumping stations

Distribution systems

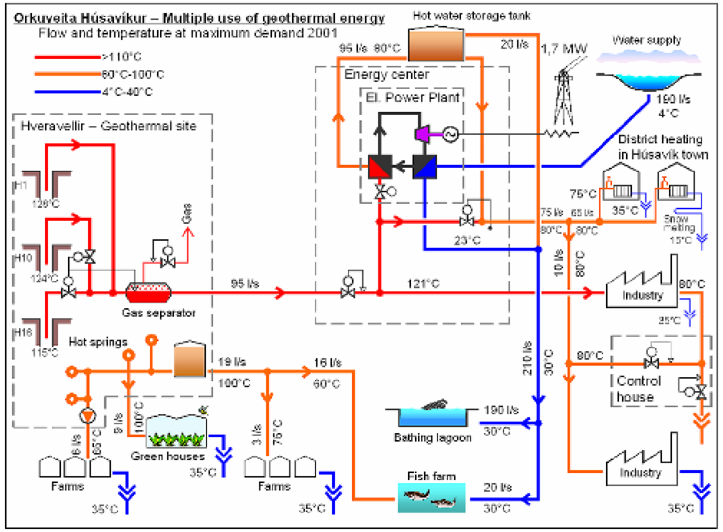
House connections

SPAs

Blue lagoon and clinic

Nauthólsvík

Greenhouses

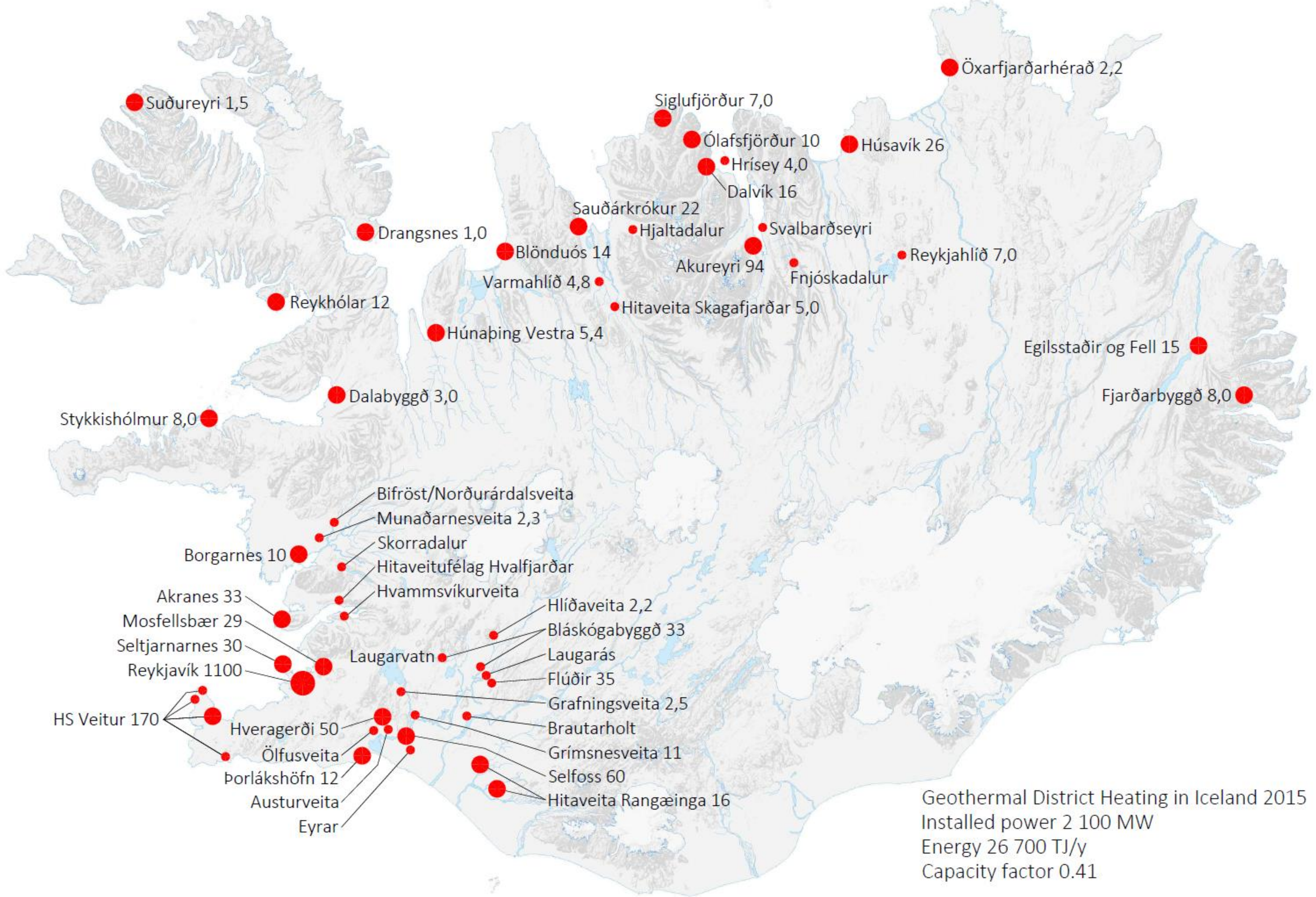



Cascaded use

Fish farming

# Geothermal District Heating in Iceland

Over 90% of all homes heated with geothermal

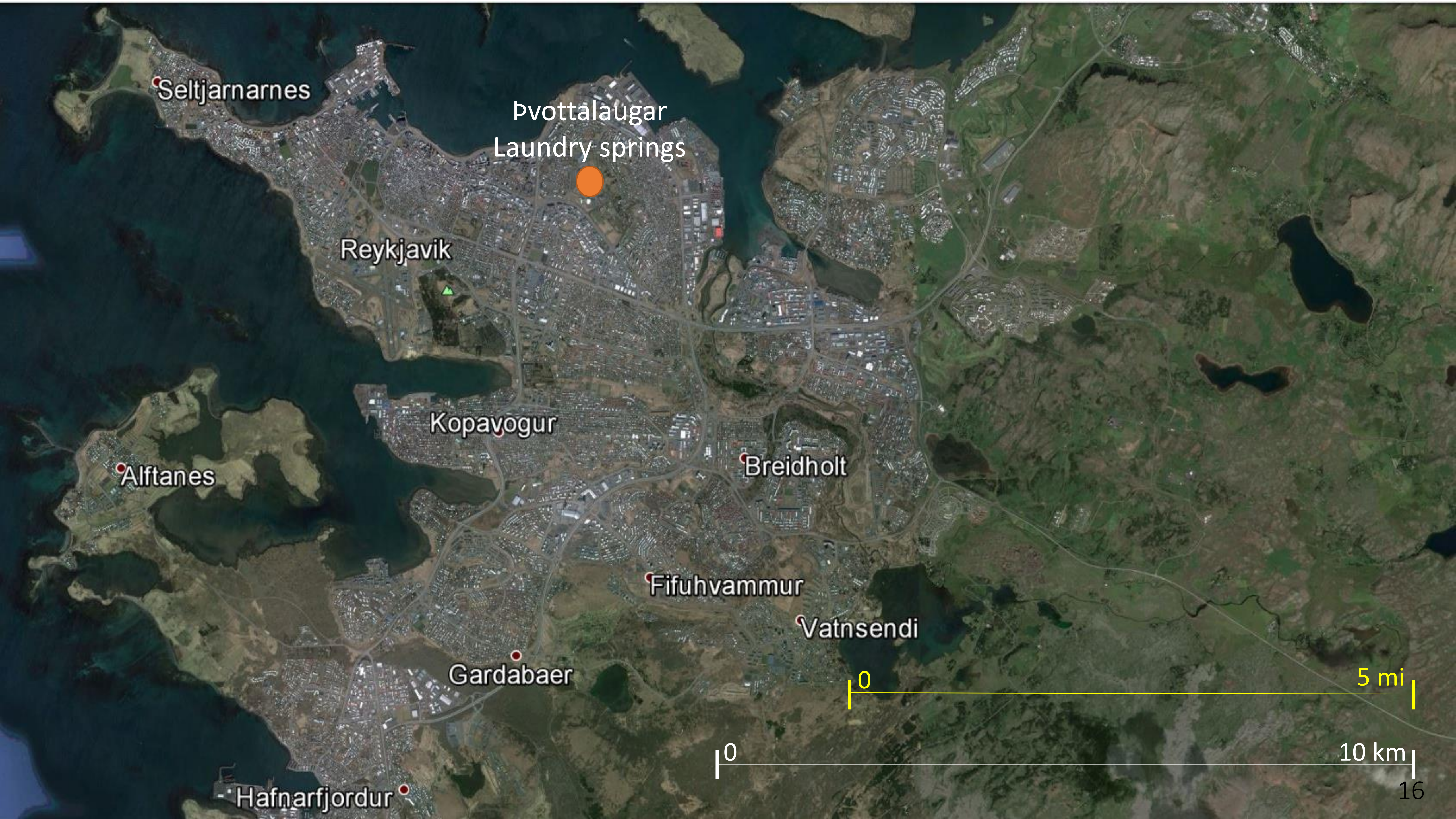



Geothermal District Heating in Iceland 2015
Installed power 2 100 MW
Energy 26 700 TJ/y
Capacity factor 0.41

# Reykjavík, prior to geothermal utilization

# Þvottalaugar - Laundry springs in Reykjvík

# Laundry springs in Reykjavík


Seltjarnarnes
Þvottalaugar
Laundry springs
Reykjavik
Kopavogur
Alftanes
Breidholt
Fifuhvammur
Vatnsendi
Gardabaer
Hafnarfjordur
0
5 mi
0
10 km

# Reykjavík Geothermal district heating

- 1908 - Farmer piped geothermal water from a hot spring into his house
- 1930 – Laugaveita
  - 14 shallow wells, 14 l/s of 87°C hot water in the vicinity of the laundry springs
  - 3 km long transmission pipeline from the hot springs towards the town center
  - Primary school, Austurbæjarskóli, Swimming pool and 60-70 houses heated
- 1943 – Reykjaveita
  - Shallow wells, self flowing, 200 l/s of 86°C hot geothermal water
  - 17 km long transmission pipeline, first Reykir piping main
  - 2 850 houses connected

# Reykjavík Geothermal district heating

- 1958 - More wells drilled and deep well pumps installed
- 1970 – All houses in Reykjavík heated. Increased capacity from Reykjaveita and second Reykir piping main. Expansion starts to the neighboring suburbs
- 1990 – Nesjavellir CHP power plant taken into service (Nesjavellir piping main)
- 2015 - Reykjavík and all suburbs heated, serving 190.000 people


Construction phases
1930

# Austurbæjarskóli, connected 1930

# Morgunblaðið

Vikublað: Ísafold. 25. árg., 24. tbl. — Sunnudaginn 30. janúar 1938. Ísafoldarprentsmiðja h.f.

## Kjósið hitaveituna í dag — C-listann

Reykurinn yfir bænum, sem hitaveitan útrýmir!

Burt með fyrirhöfn, óþrifnað og kostnað við kolakyndinguna.

Heitt vatn þarf að koma í öll eldhús, og gróðurhús að rísa um allan bæ.

Hreint loft yfir Reykjavík, þegar hitaveitan er komin! Sólar nýtur til fulls!

Kolakyndingu er útrýmt, kolaofnum, kolaryki, kolakostnaði. Með einu handtaki er hitanum veitt um íbúðirnar.

Með hitaveitunni kemur heitt vatn í eldhúsin. Og við húsveggina er hægt að koma upp gróðurskálum, þar sem ræktaðar verða matjurtir, blóm og aldini.

**Reykvíkingar! Tryggið yður hitaveituna með því að kjósa C-listann**

# Vote for the district heating today!

## Announcement regarding house heating systems

Due to plans of installing district heating in Reykjavik, those who are constructing new houses or renovating old ones shall install heating systems that can fully utilize the new district heating!

**Hitaveita Reykjavíkur.**

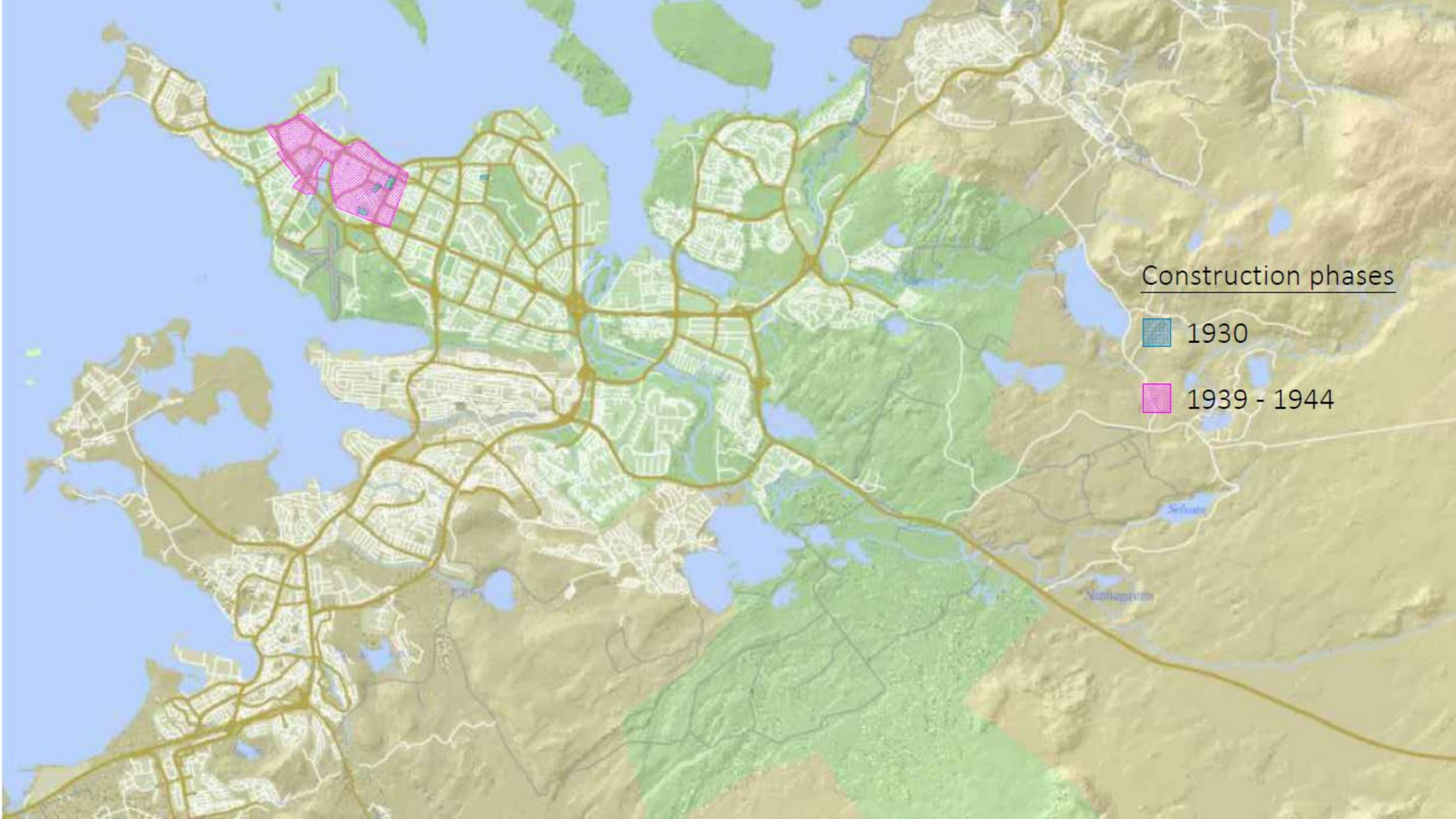
## Auglýsing viðvíkjandi hitalögnum

Vegna væntanlegrar hitaveitu er þeim, er byggja ný hús eða breyta gömlum húsum, ráðlagt að haga hitalögnunum í húsunum þannig, að fult tillit sje tekið til hinnar nýju hitaveitu, er hitalagnir eru ákveðnar.

Skrifstofa Hitaveitu Reykjavíkur, Austurstræti 16, mun gefa upplýsingar um þetta kl. 11—12 f. h. daglega.

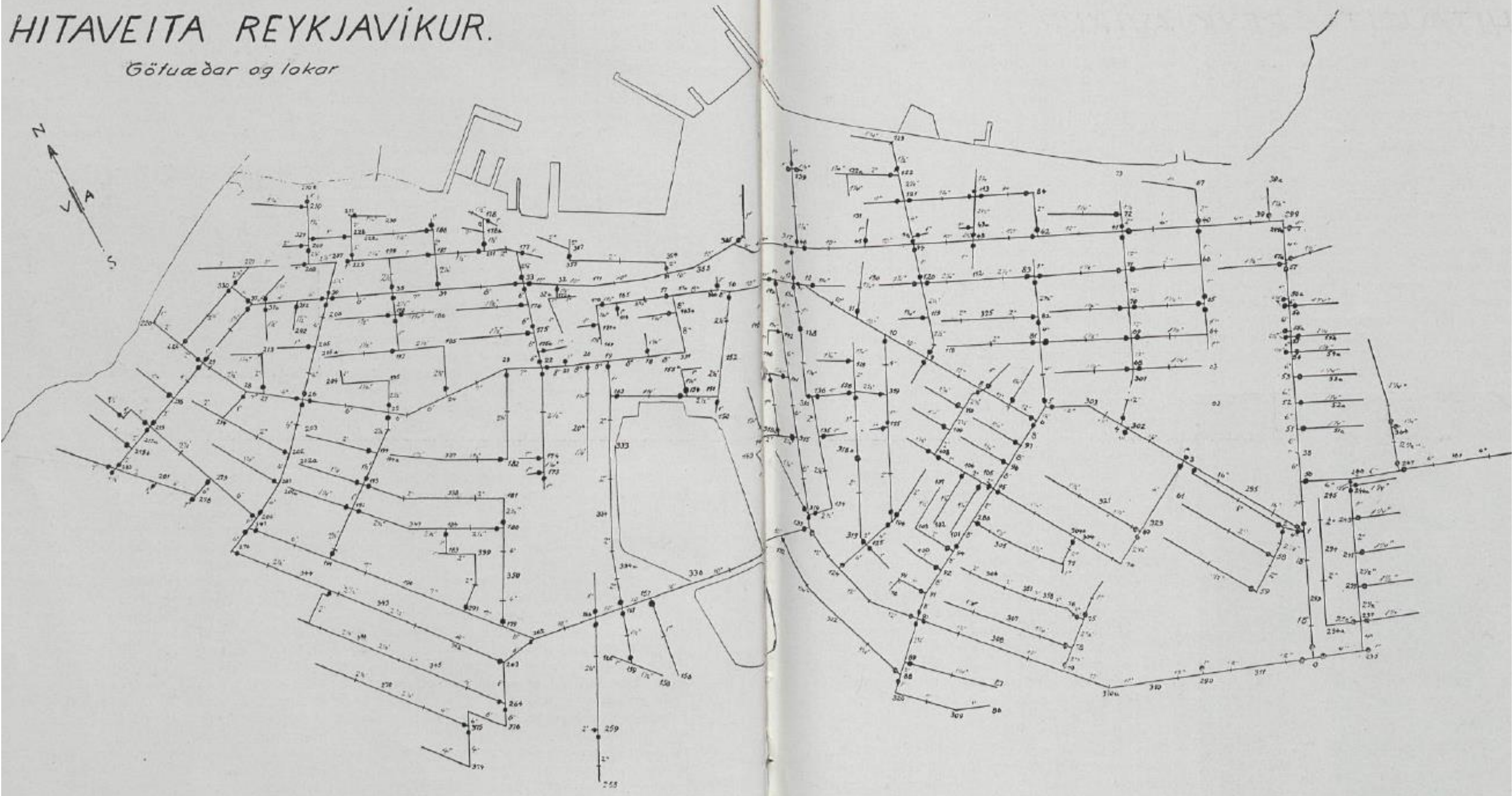
**Bæjarverkfræðingur.**

VERKÍS


Construction phases
1930
1939 - 1944

# HITAVEITA REYKJAVÍKUR.

*Götuæðar og lokar*

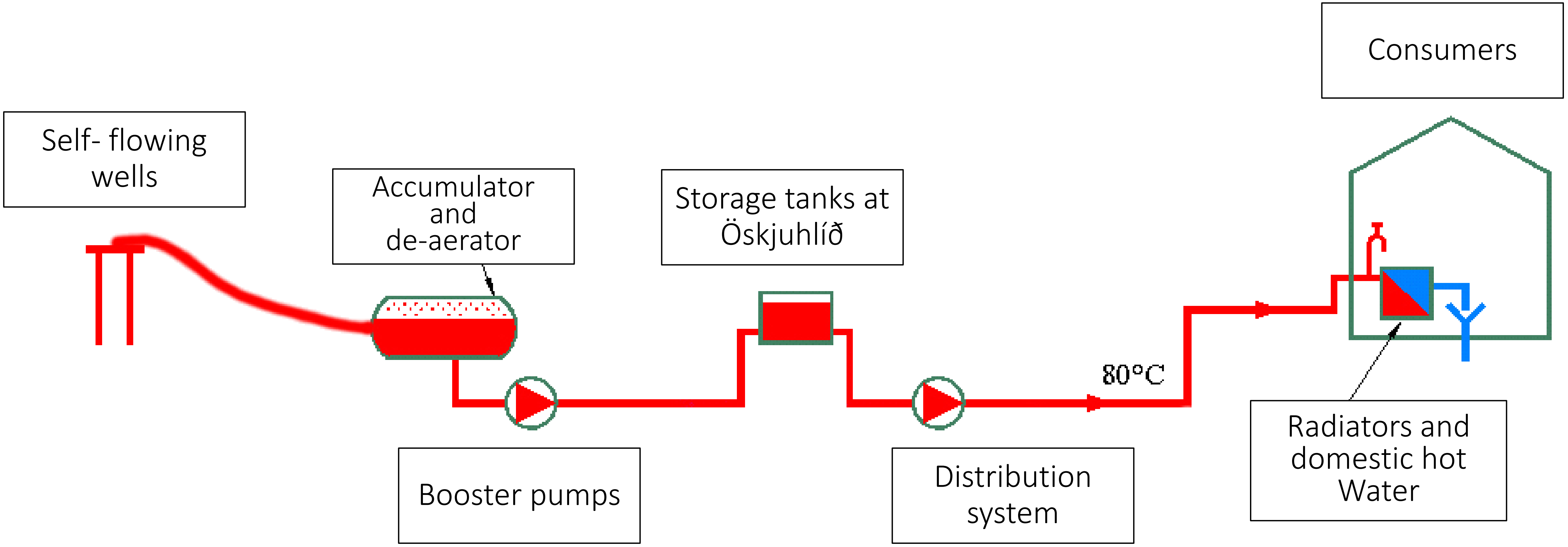


The first Reykir piping main 1943. 14 km, 2 x 14 in seamless steel pipes from USA

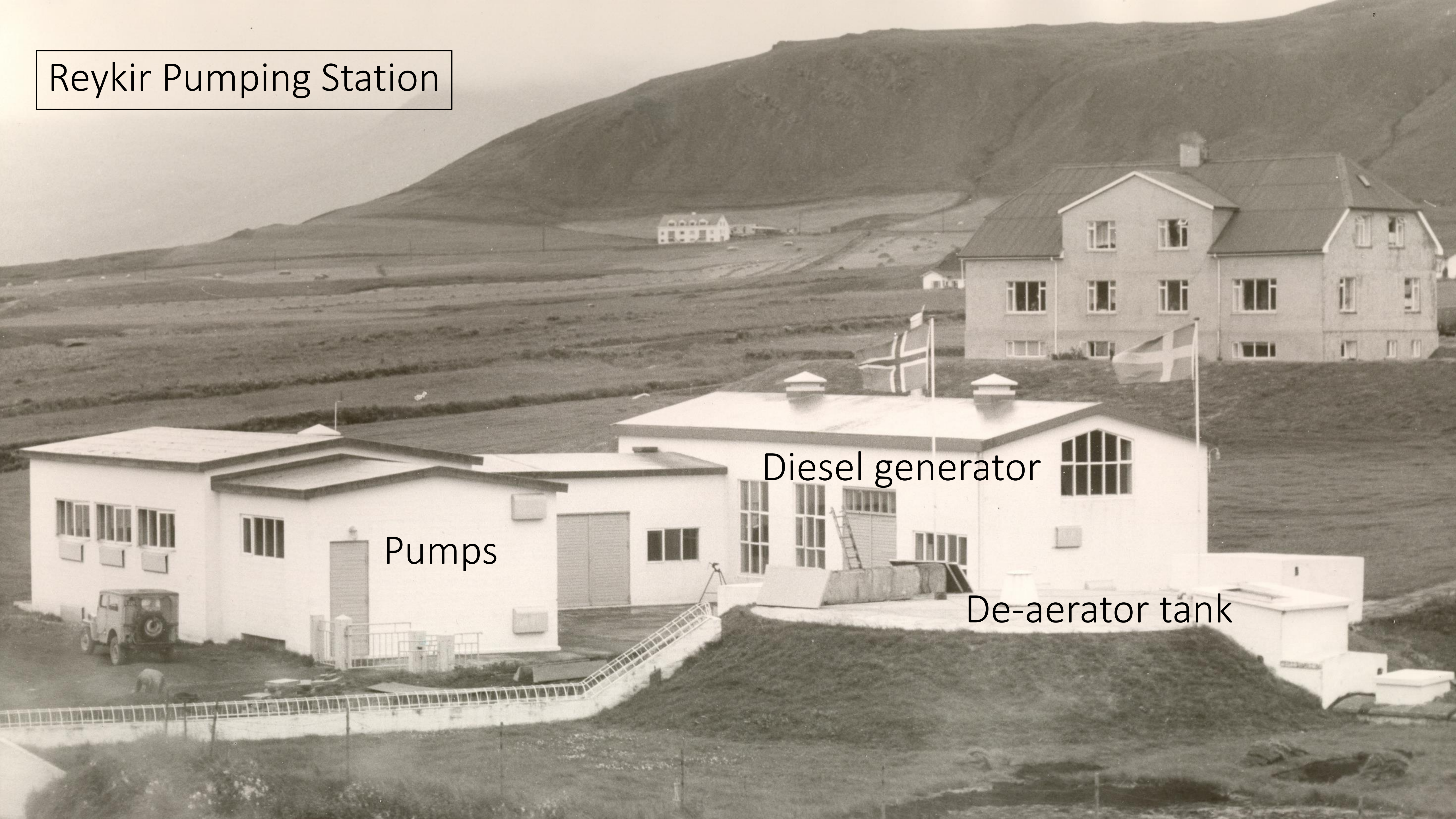
Insulation with Icelandic turf

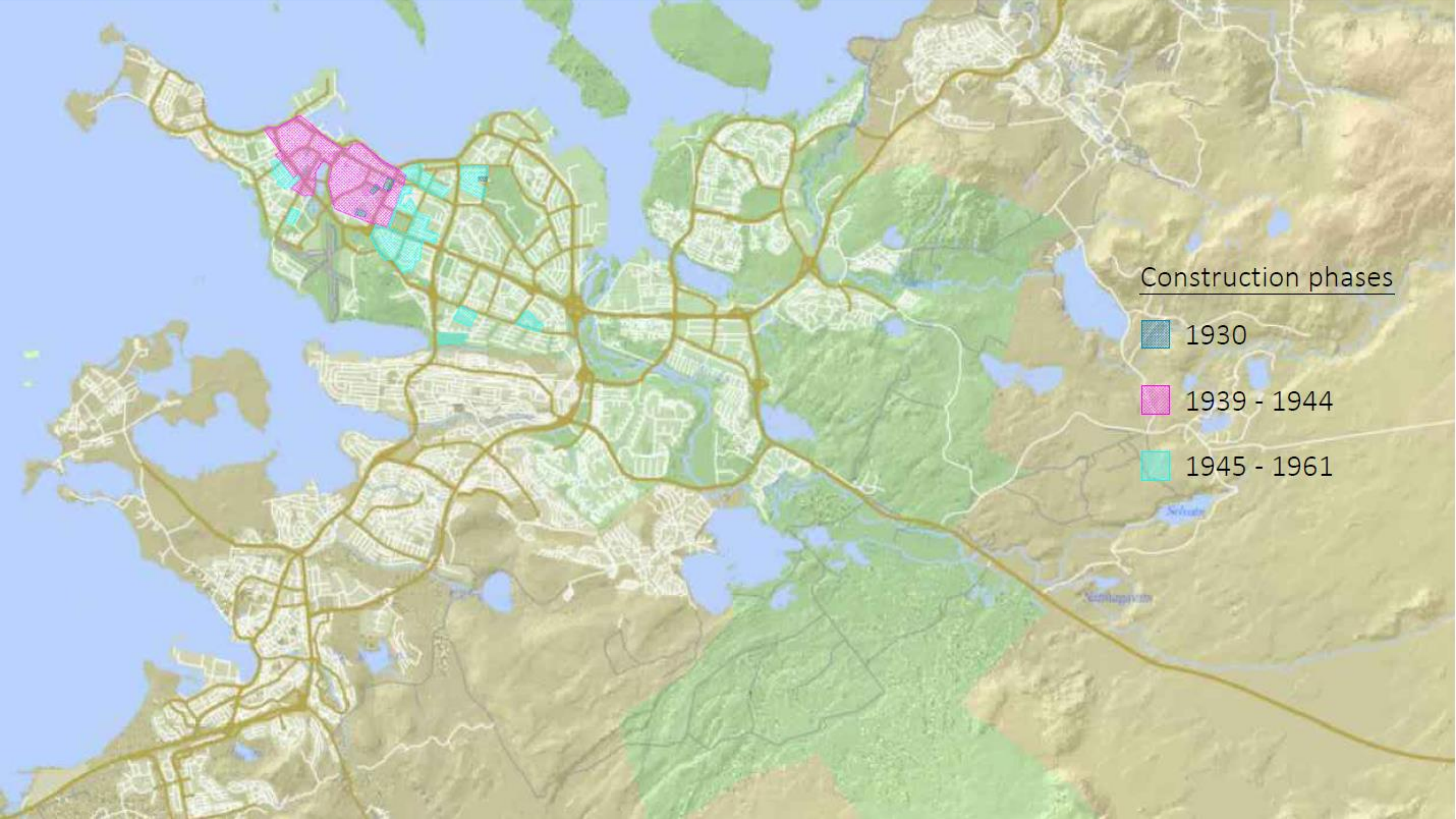
# Concrete duct and cover

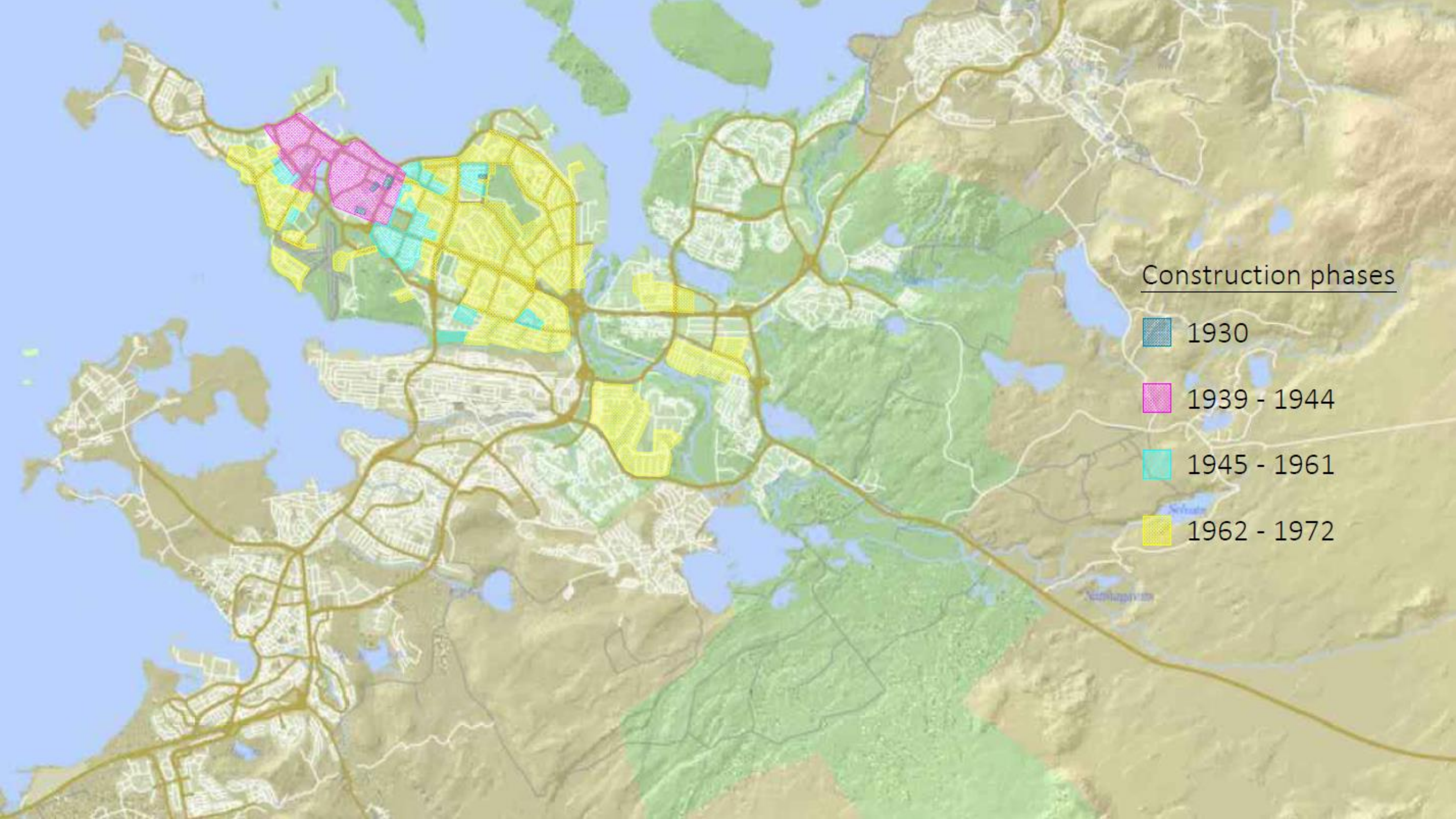
# Simple system

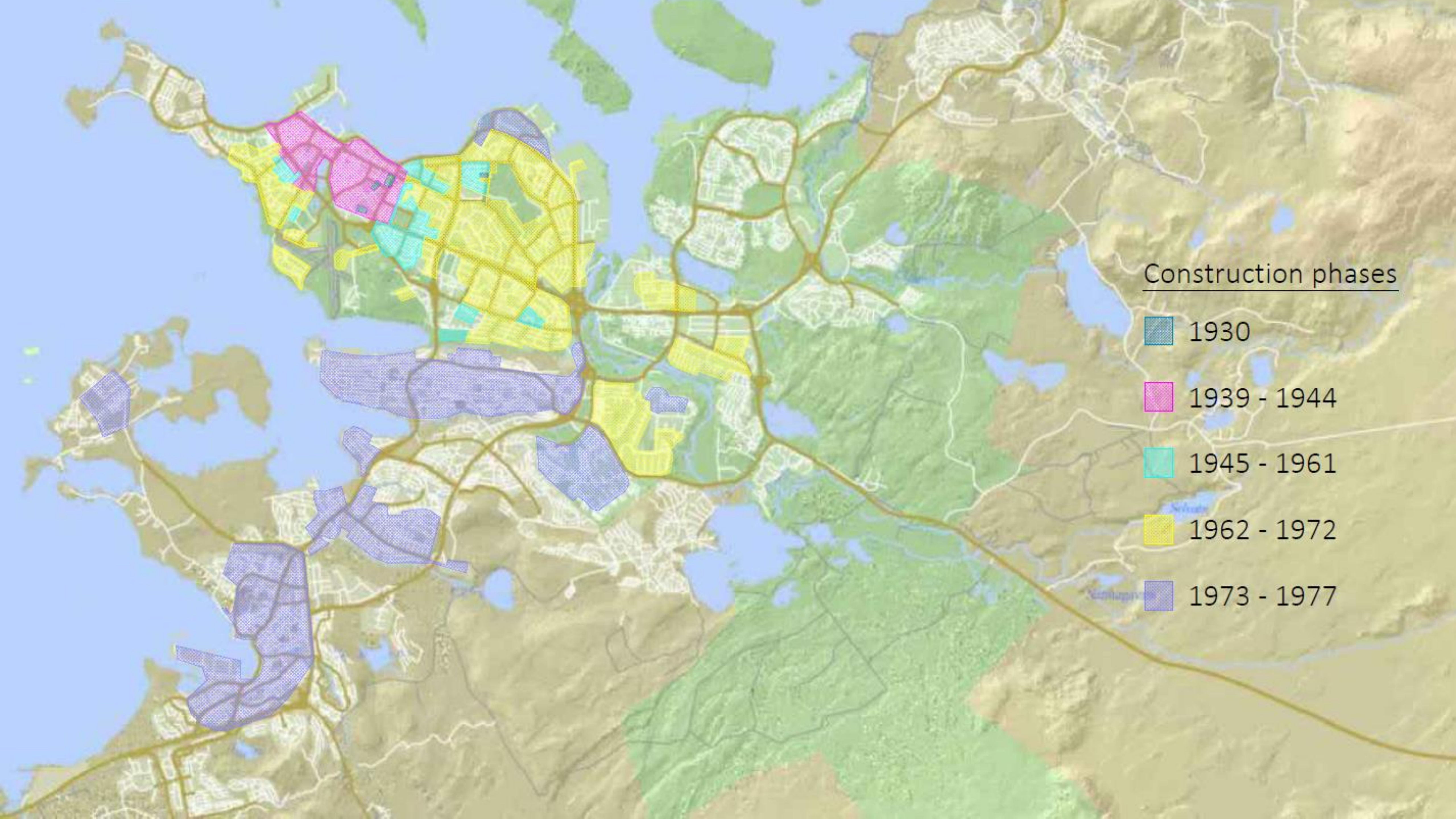


# Reykir Pumping Station



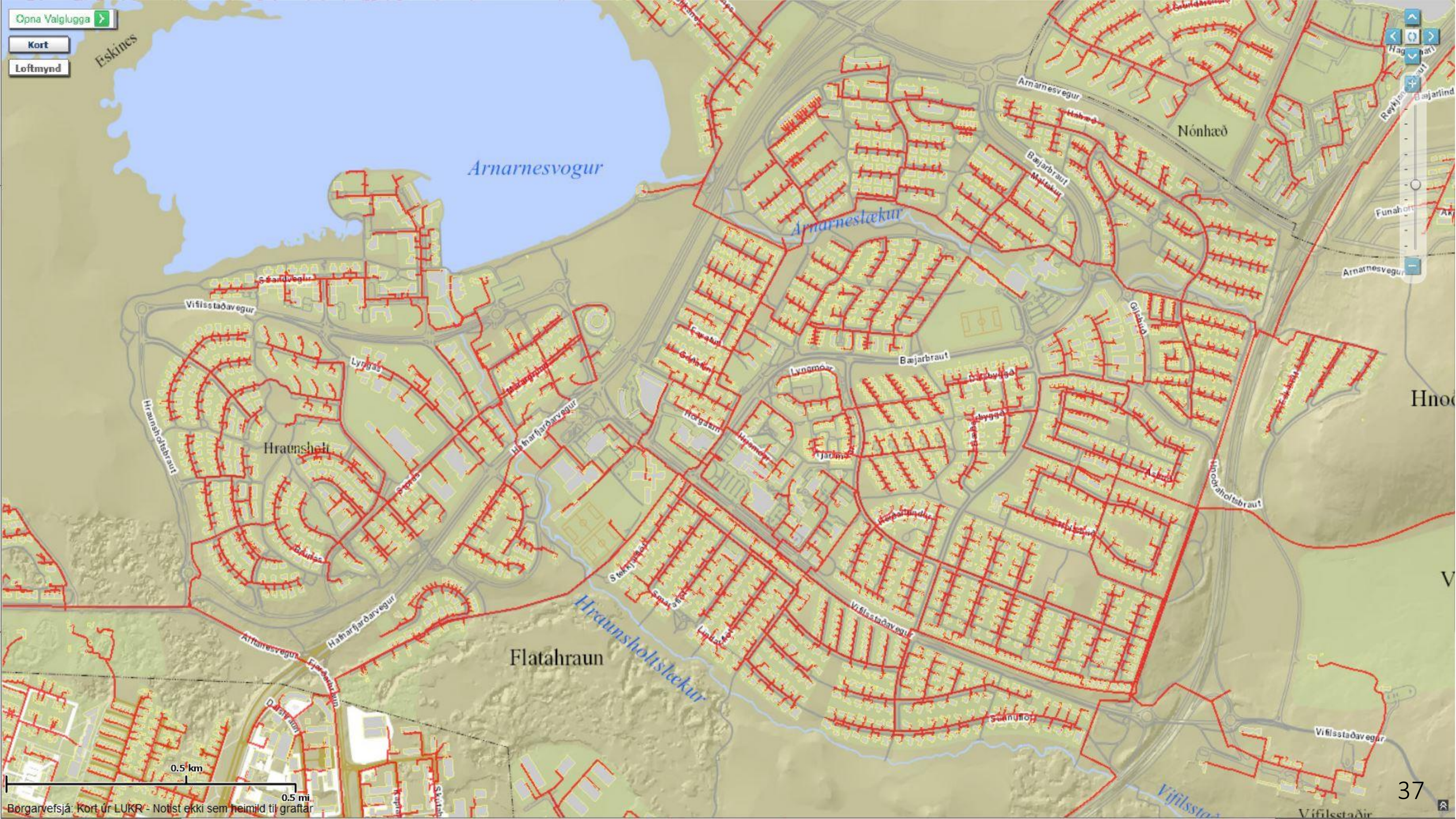

Construction phases
1930
1939 - 1944
1945 - 1961


Construction phases
1930
1939 - 1944
1945 - 1961
1962 - 1972

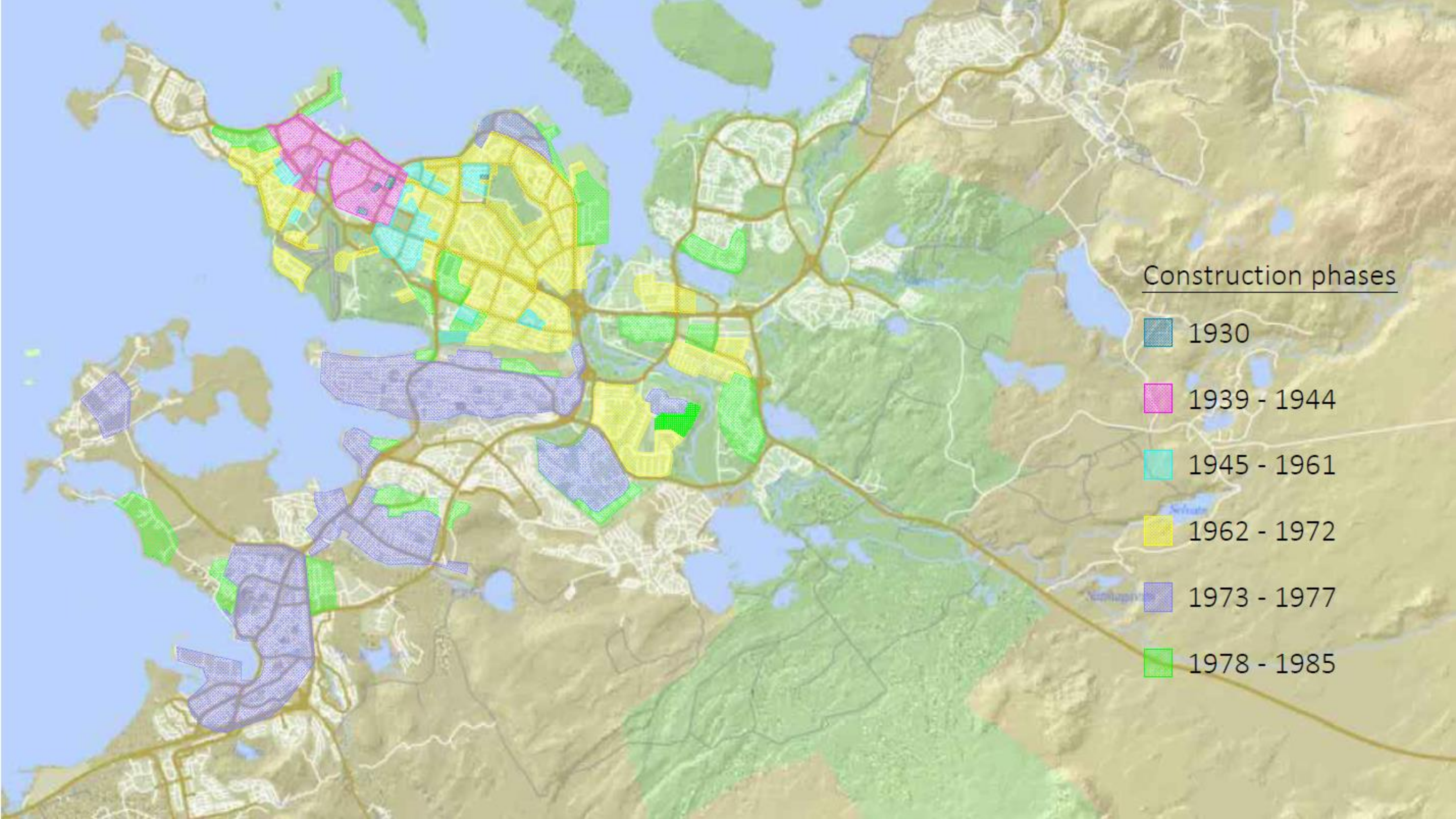

Construction phases
1930
1939 - 1944
1945 - 1961
1962 - 1972
1973 - 1977

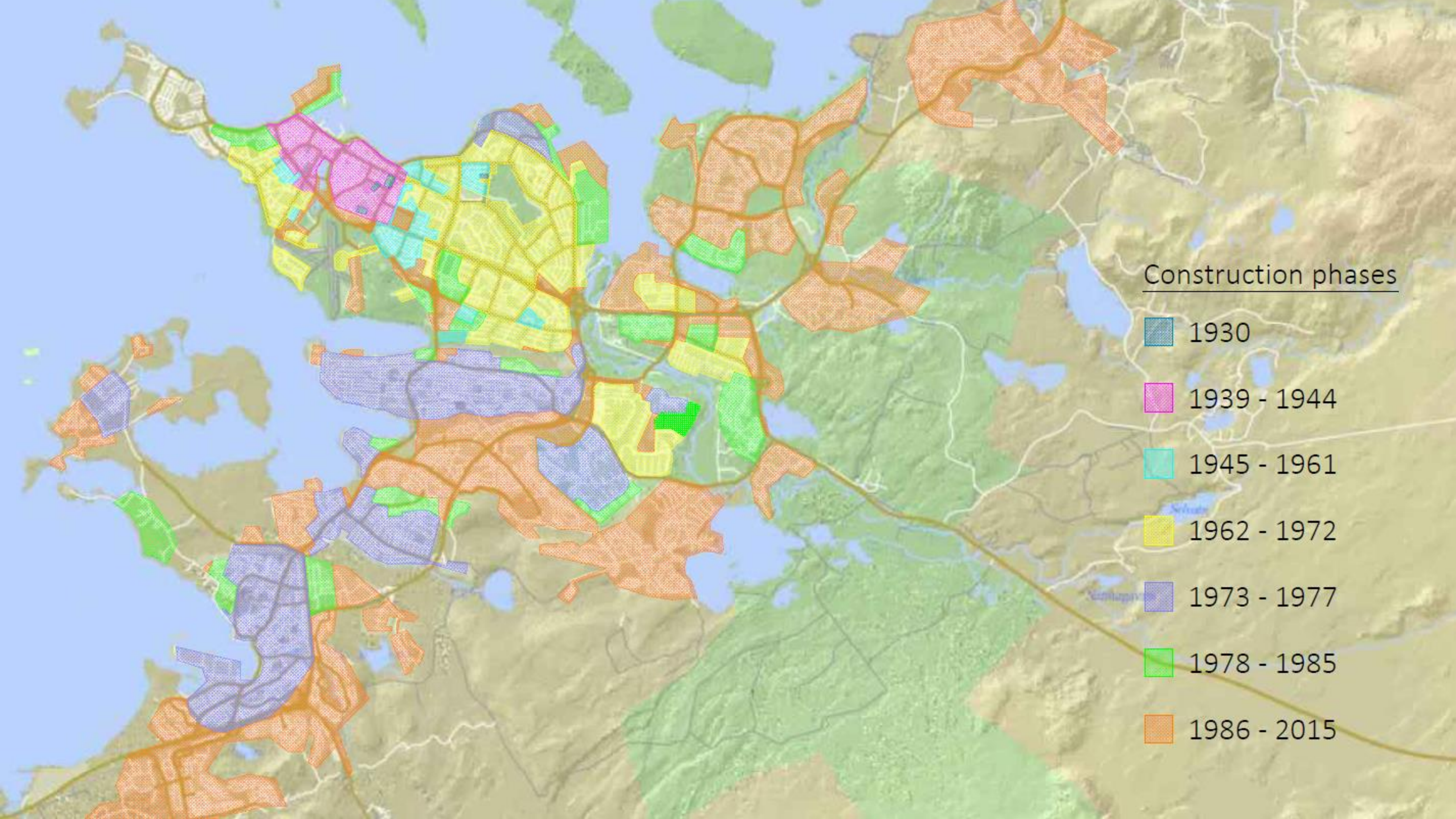
# Garðabær
# 1970

# Garðabær, 2015



Opna Valglugga
Kort
Loftmynd
Eskines
Arnarnesvogur
Arnarneslækur
Arnarnesvegur
Nónhæð
Bæjarbraut
Vífilsstaðavegur
Hraunsholt
Hraunsholtsbraut
Hafnarfjarðarvegur
Álftanesvegur
Flatahraun
Hraunsholtslækur
Hnoðraholtsbraut
0.5 km
0.5 mi
Borgarvefsjá: Kort úr LUKR - Notist ekki sem heimild til graftar

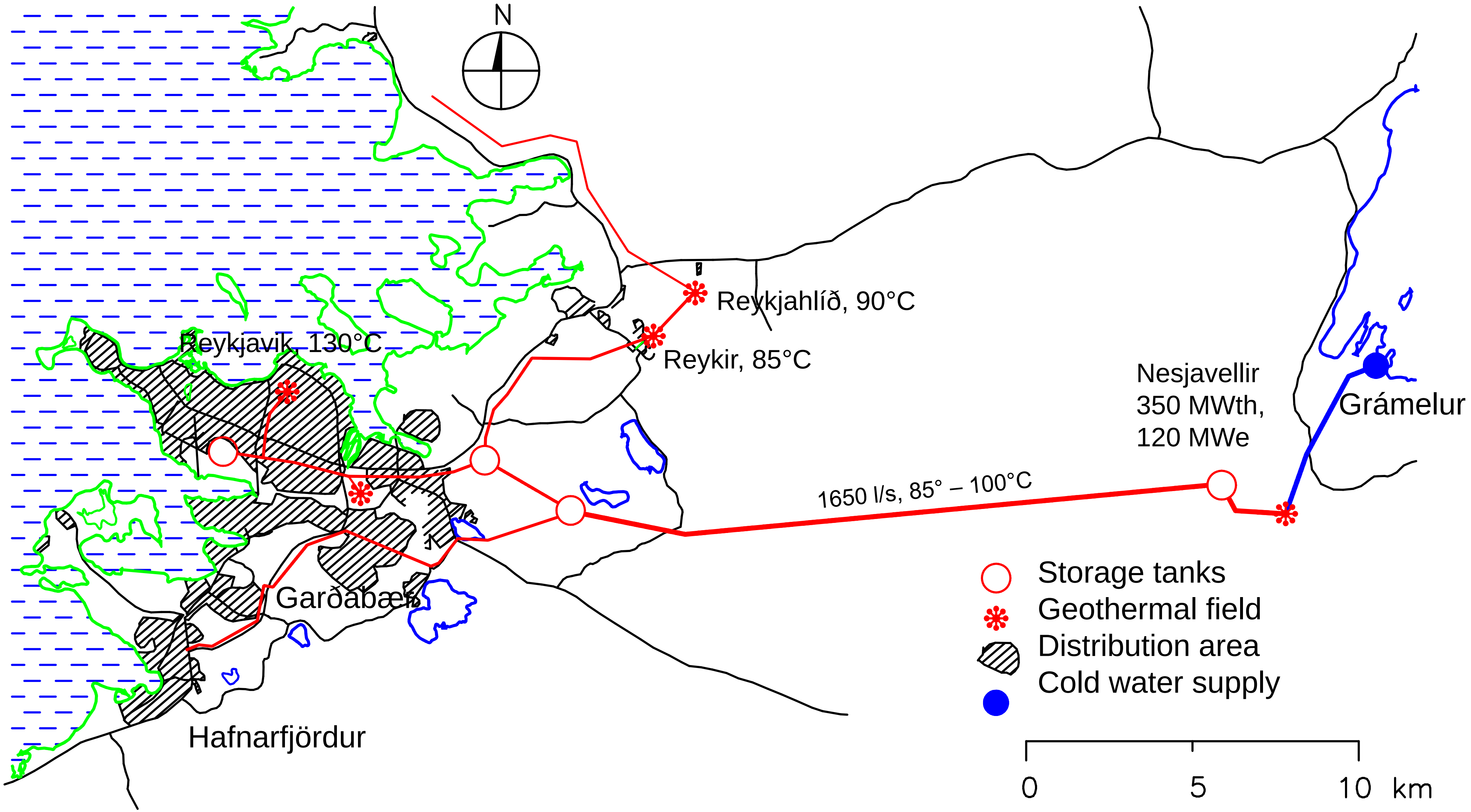

Construction phases
1930
1939 - 1944
1945 - 1961
1962 - 1972
1973 - 1977
1978 - 1985


Construction phases
1930
1939 - 1944
1945 - 1961
1962 - 1972
1973 - 1977
1978 - 1985
1986 - 2015

# Reykjavík geothermal fields, 1000 MW

- Laugarnes
  - 10 wells, 340 l/s, 125 – 130°C, 125 MWt
- Ellidaar
  - 8 wells, 260 l/s, 85 – 95°C, 50 MWt
- Reykir – Reykjahlid
  - 34 wells, 1980 l/s, 85 – 100°C, 375 MWt
- Nesjavellir – CHP
  - Heated and de-aerated cold water, 1680 l/s, 83°C, 300 MWt
- Hellisheiði – CHP
  - Heated and de-aerated cold water, 1300 l/s, 85°C, 150 MWt


Seltjarnarnes
Laugarnes
Reykir
Reykjavik
Ellidaar
Nesjavellir
25 km
Kopavogur
Breidholt
Alftanes
Hellisheidi
20 km
Fifuhvammur
Vatnsendi
Gardabaer
Reykajvík Energy
Geothermal Fields
Hafnarfjordur


N
Reykjahlíð, 90°C
Reykir, 85°C
Reykjavik, 130°C
Nesjavellir
350 MWth,
120 MWe
Grámelur
1650 l/s, 85° – 100°C
Garðabær
Hafnarfjördur
Storage tanks
Geothermal field
Distribution area
Cold water supply
0
5
10 km

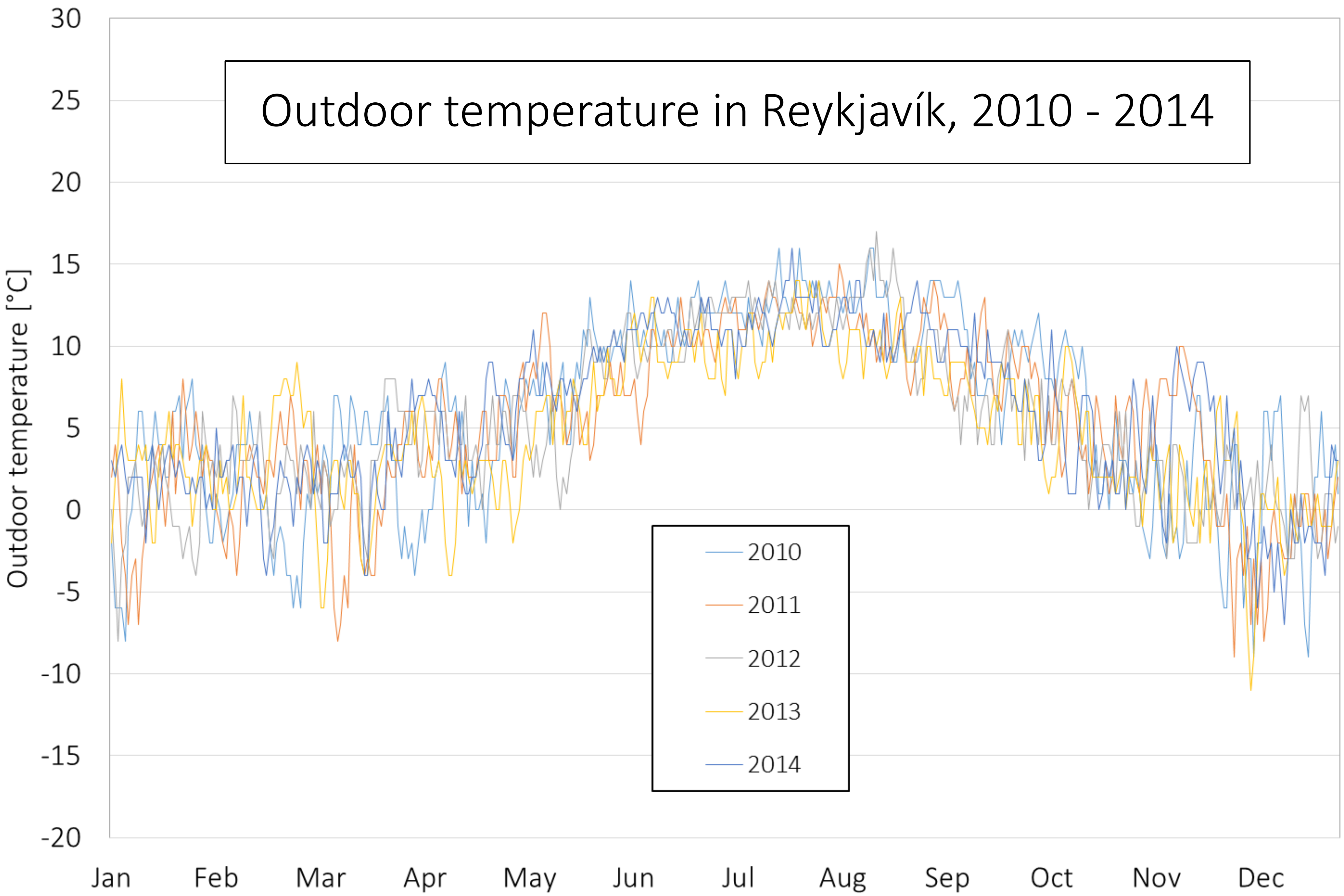
# Reykjavík geothermal systems

- High grade, high porosity „open“ hydrothermal reservoirs
- Relatively easy to harness
- „High quality“ low temperature (80-130°C) geothermal water, used directly on district heating systems
- No (or little) re-injection needed as long as you keep the inflow/outflow balance
- In CHP plants, cold water is heated in condensers and in heat exchangers with geothermal fluid from similar hydrothermal systems
- Key factors of why geothermal heating in Reykjavik is inexpensive!

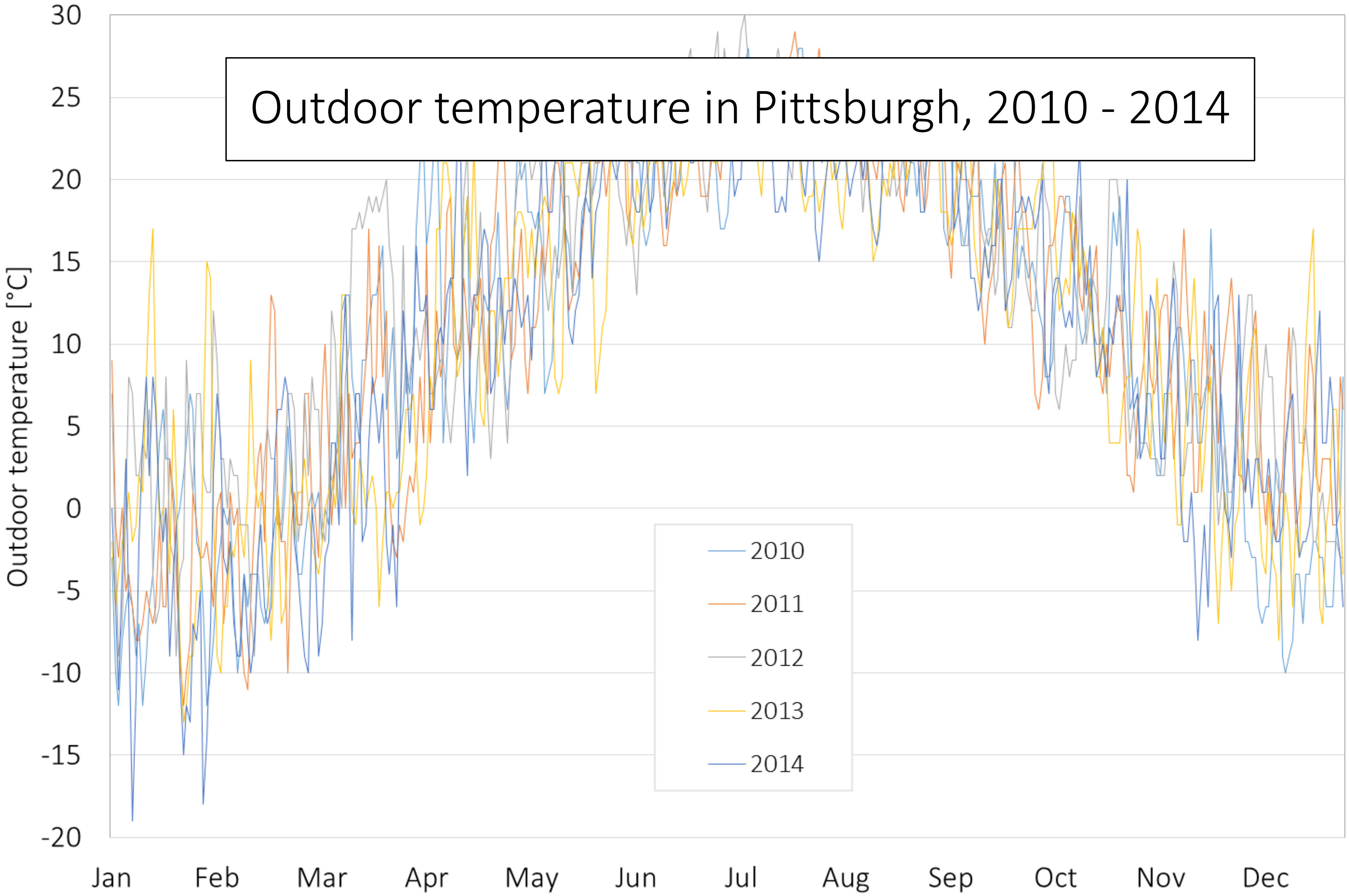
# Heating Requirements

Design of district heating systems

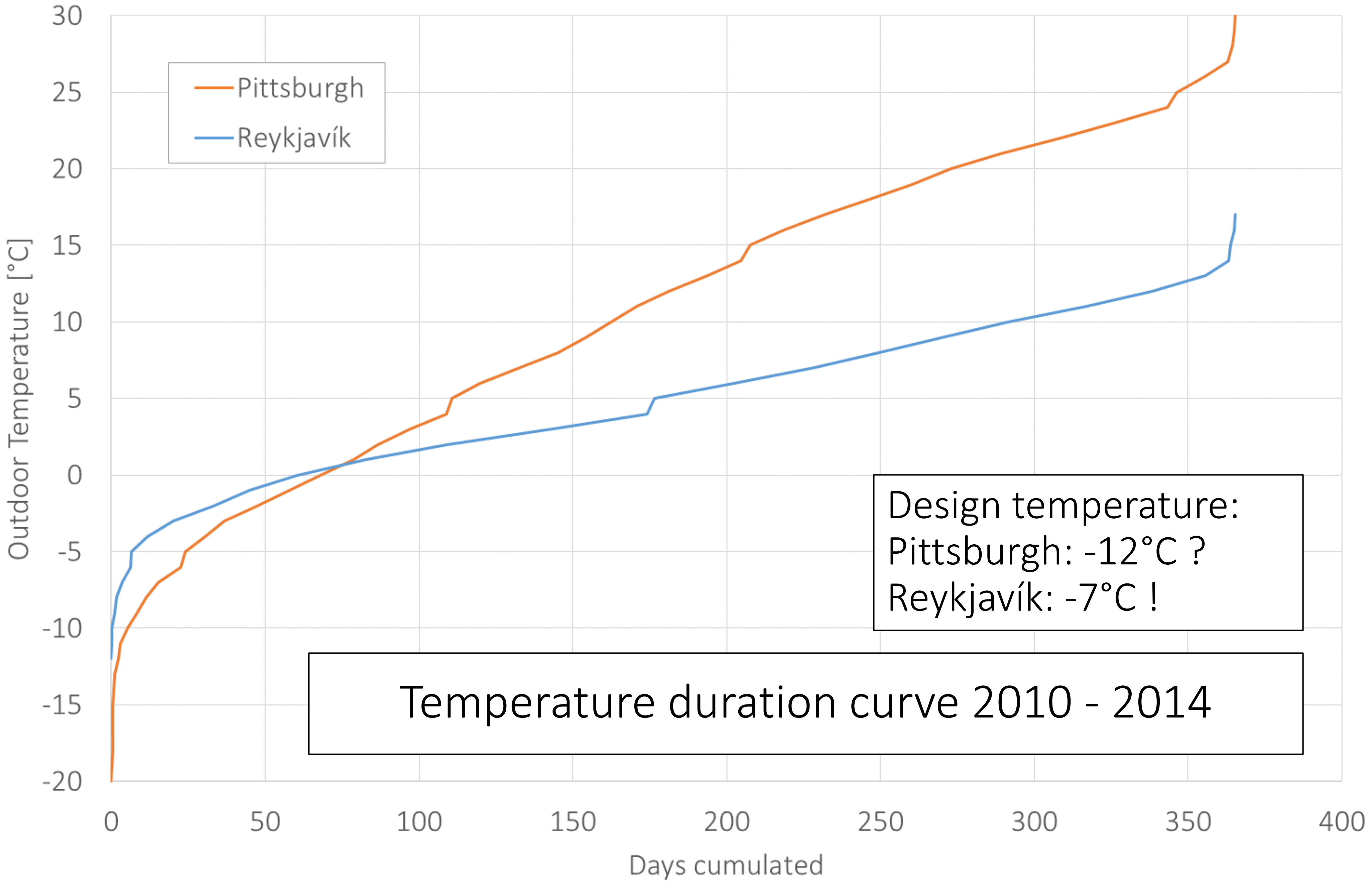
http://www.wunderground.com

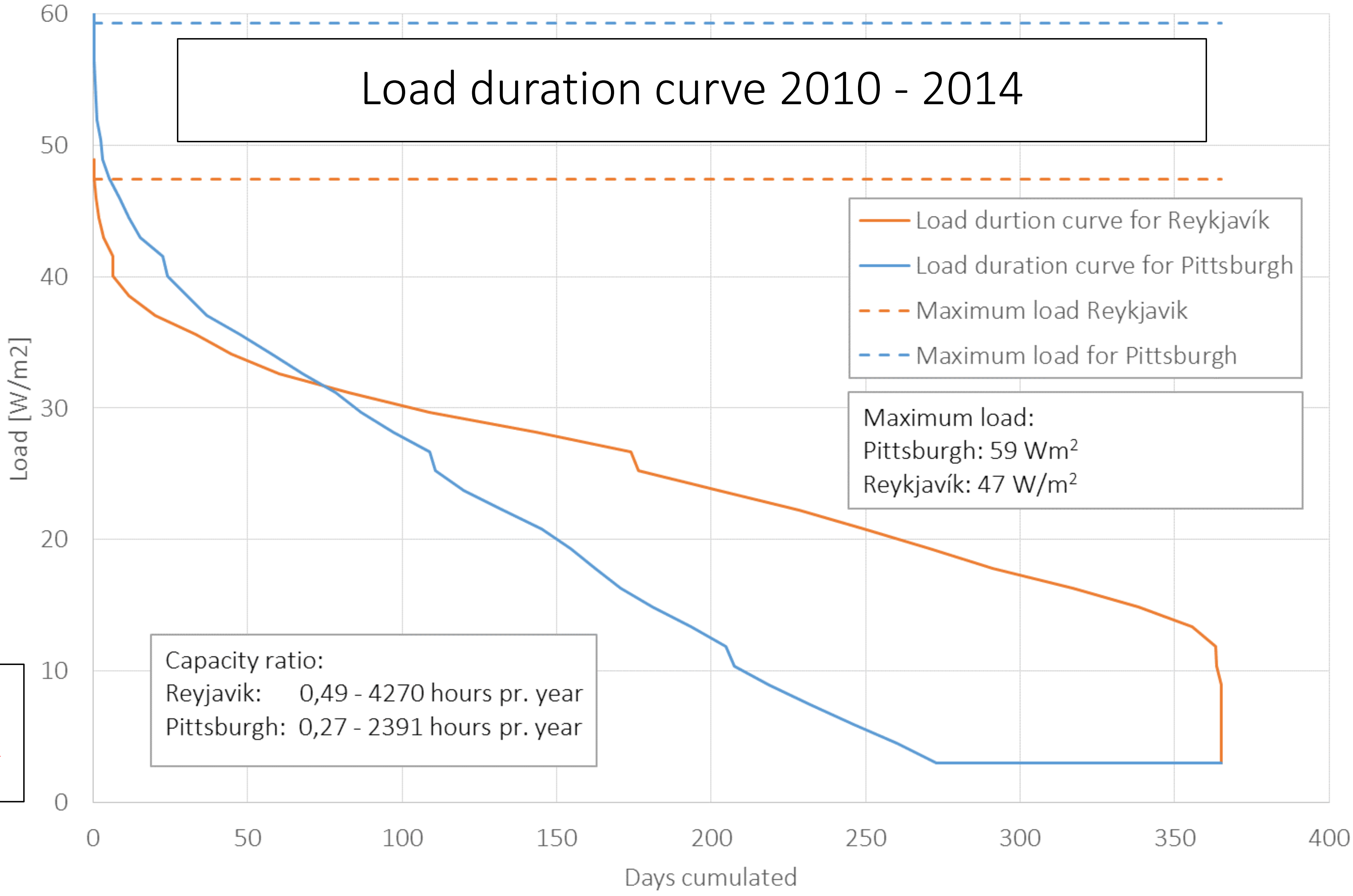


Outdoor temperature in Reykjavík, 2010 - 2014
Outdoor temperature [°C]
30
25
20
15
10
5
0
-5
-10
-15
-20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2010
2011
2012
2013
2014



Outdoor temperature in Pittsburgh, 2010 - 2014
Outdoor temperature [°C]
30
25
20
15
10
5
0
-5
-10
-15
-20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2010
2011
2012
2013
2014


30
25
20
15
10
5
0
-5
-10
-15
-20
Outdoor Temperature [°C]
0
50
100
150
200
250
300
350
400
Days cumulated
Pittsburgh
Reykjavík
Design temperature:
Pittsburgh: -12°C ?
Reykjavík: -7°C !
Temperature duration curve 2010 - 2014




Another key factor why geothermal heating in Reykjavik is inexpensive

# Heating requirements for single house

| | Room height | 1980 - 2015 | 1960 - 1980 | 1930 - 1960 |
|---|---|---|---|---|
| | m | W/m² | W/m² | W/m² |
| Single floor | 3,3 | 96 | 138 | 224 |
| One floor + cellar | 3,1 | 70 | 118 | 171 |
| Two floors + cellar | 3,0 | 53 | 84 | 129 |
| Three floor + cellar | 2,9 | 36 | 67 | 96 |
| Four floors + | 2,8 | 28 | 56 | 84 |
| Schools, office buildings etc. | 4,0 | 40 | 80 | 120 |

# Heating requirements for residential clusters

| | Room height | 1980 - 2015 | 1960 - 1980 | 1930 - 1960 |
|---|---|---|---|---|
| House type | m | $W/m^2$ | $W/m^2$ | $W/m^2$ |
| Single floor | 3,3 | 60 | 85 | 139 |
| One floor + cellar | 3,1 | 43 | 73 | 106 |
| Two floors + cellar | 3,0 | 33 | 52 | 80 |
| Three floor + cellar | 2,9 | 22 | 41 | 59 |
| Four floors + | 2,8 | 17 | 35 | 52 |
| Schools, office buildings etc. | 4,0 | 25 | 50 | 74 |

# Results

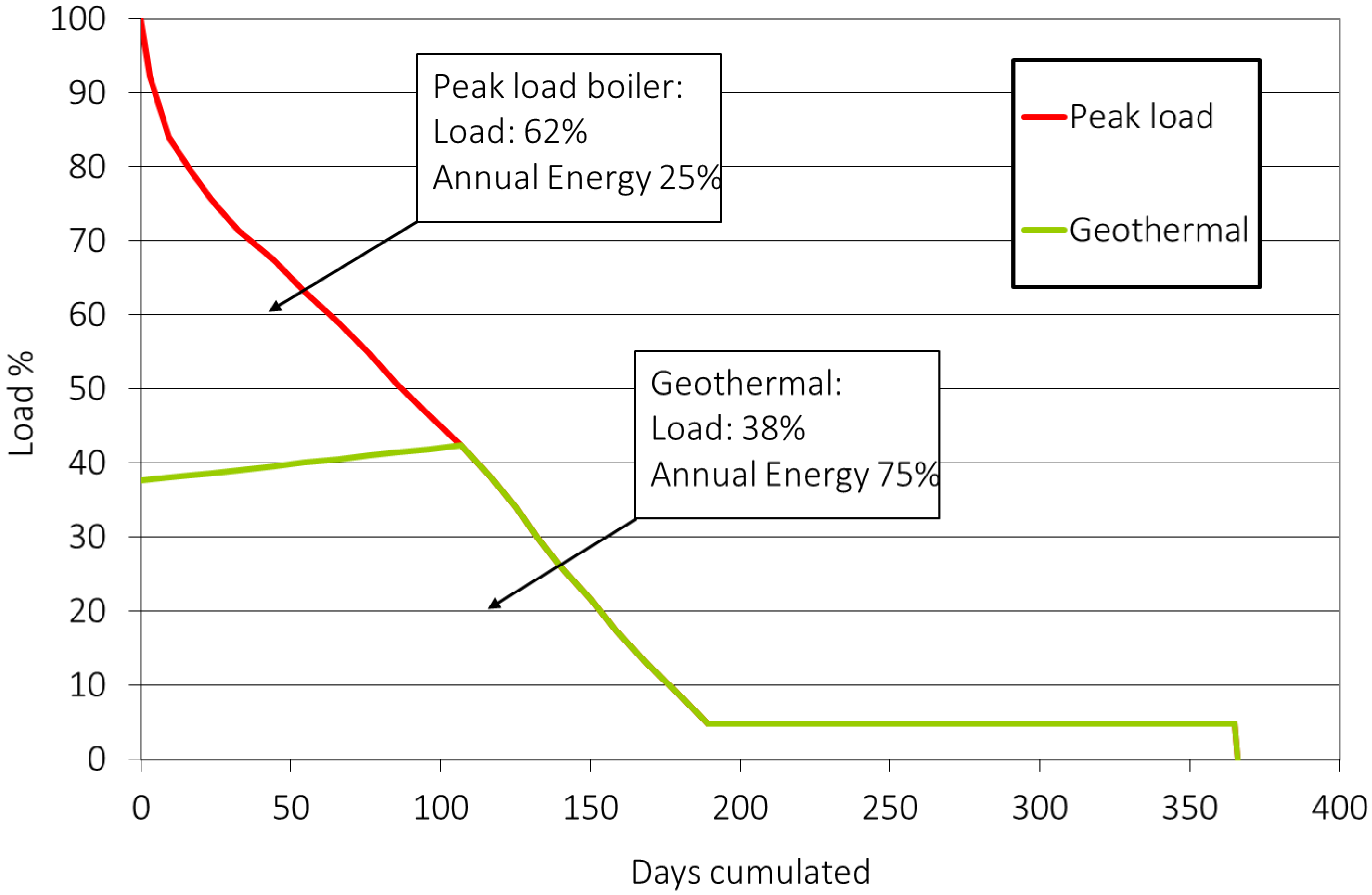
- Heating and Domestic hot water at consumers house connection
  - **Design load for Reykjavík 40 W/m$^2$ (Pittsburgh 47 W/m$^2$ ?)**
  - Supply water 80°C from pumping stations
  - Average temperature at consumers 75°C
  - Return from heating systems 35°C
  - Flow: 0,85 l/h pr. m$^2$ – 0,28 l/h pr. m$^3$ ( $\Delta T$ =40°C )
  - Design flow from pumping stations **0,32 l/h pr. m$^3$**
- Results for single family, single floor house 200 m$^2$
  - Heating - 20 kW
  - Domestic Hot Water Heating of 10 l/min of 5°C cold water to 60°C – 40 kW

# Reykjavík Energy 2013

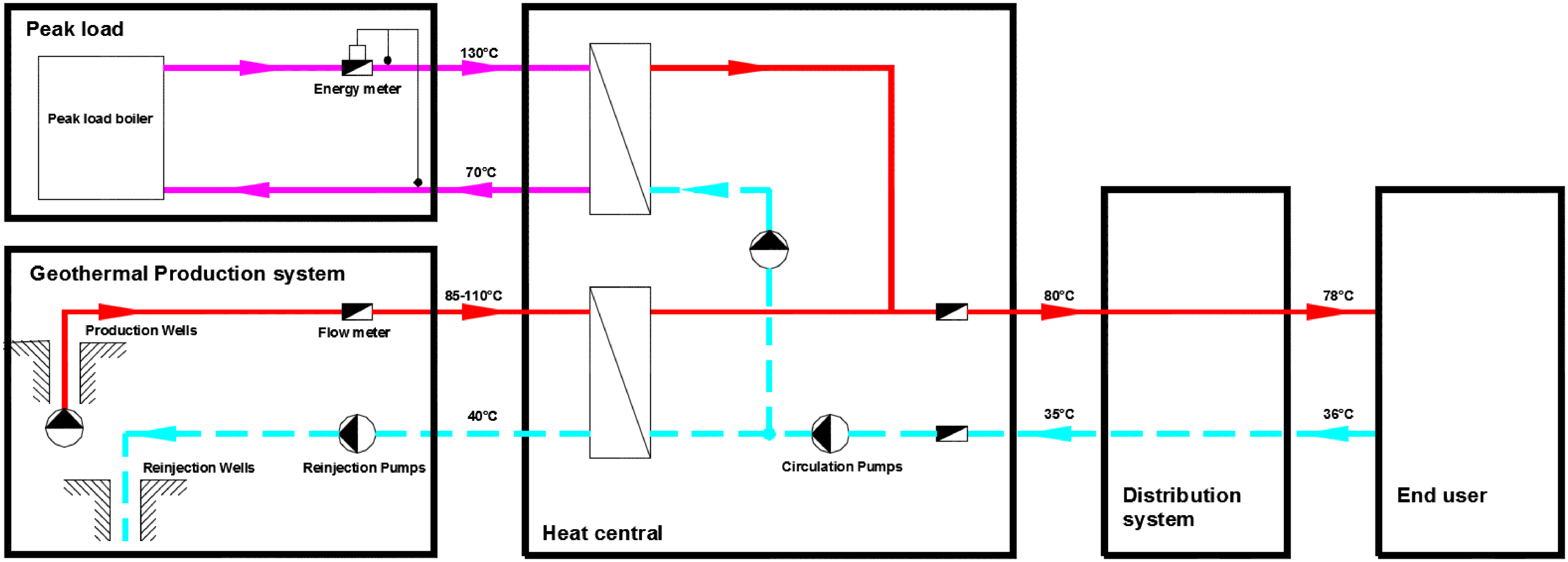
- Flow from boreholes and CHP plants
  - Average Flow 2 226 l/s
  - Average temperature: 86,4 °C
  - Estimated return temperature 35°C
- Average power 480 MW
- Maximum power from boreholes and heat plants 1000 MW
- Capacity factor 0,48
- Connected floor space 67 $Mm^3$ – 20 $Mm^2$
- Specific Load, measured at boreholes and heat plants - 50 $W/m^2$

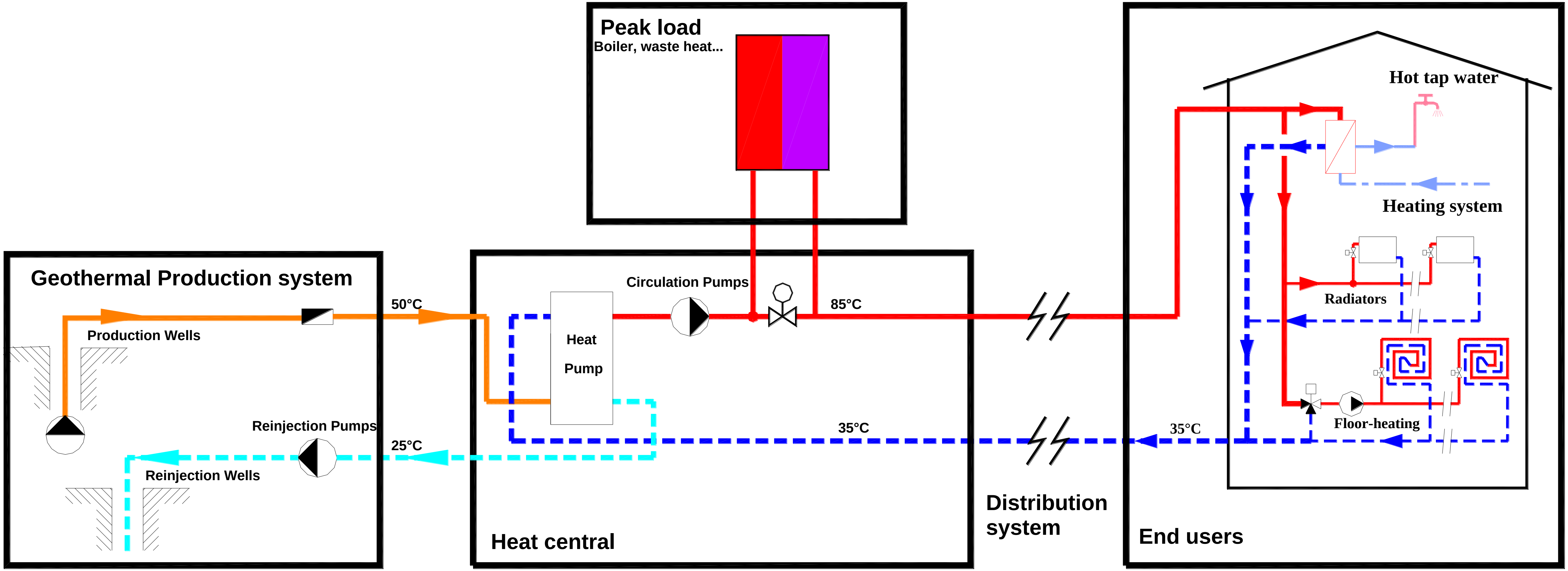
# Meeting the annual heat demand

Power and energy



100
90
80
70
60
50
40
30
20
10
0
Load %
0
50
100
150
200
250
300
350
400
Days cumulated
Peak load boiler:
Load: 62%
Annual Energy 25%
Geothermal:
Load: 38%
Annual Energy 75%
Peak load
Geothermal


Peak load
Peak load boiler
Energy meter
130°C
70°C
Geothermal Production system
85-110°C
Production Wells
Flow meter
40°C
Reinjection Wells
Reinjection Pumps
Circulation Pumps
Heat central
80°C
35°C
Distribution system
78°C
36°C
End user

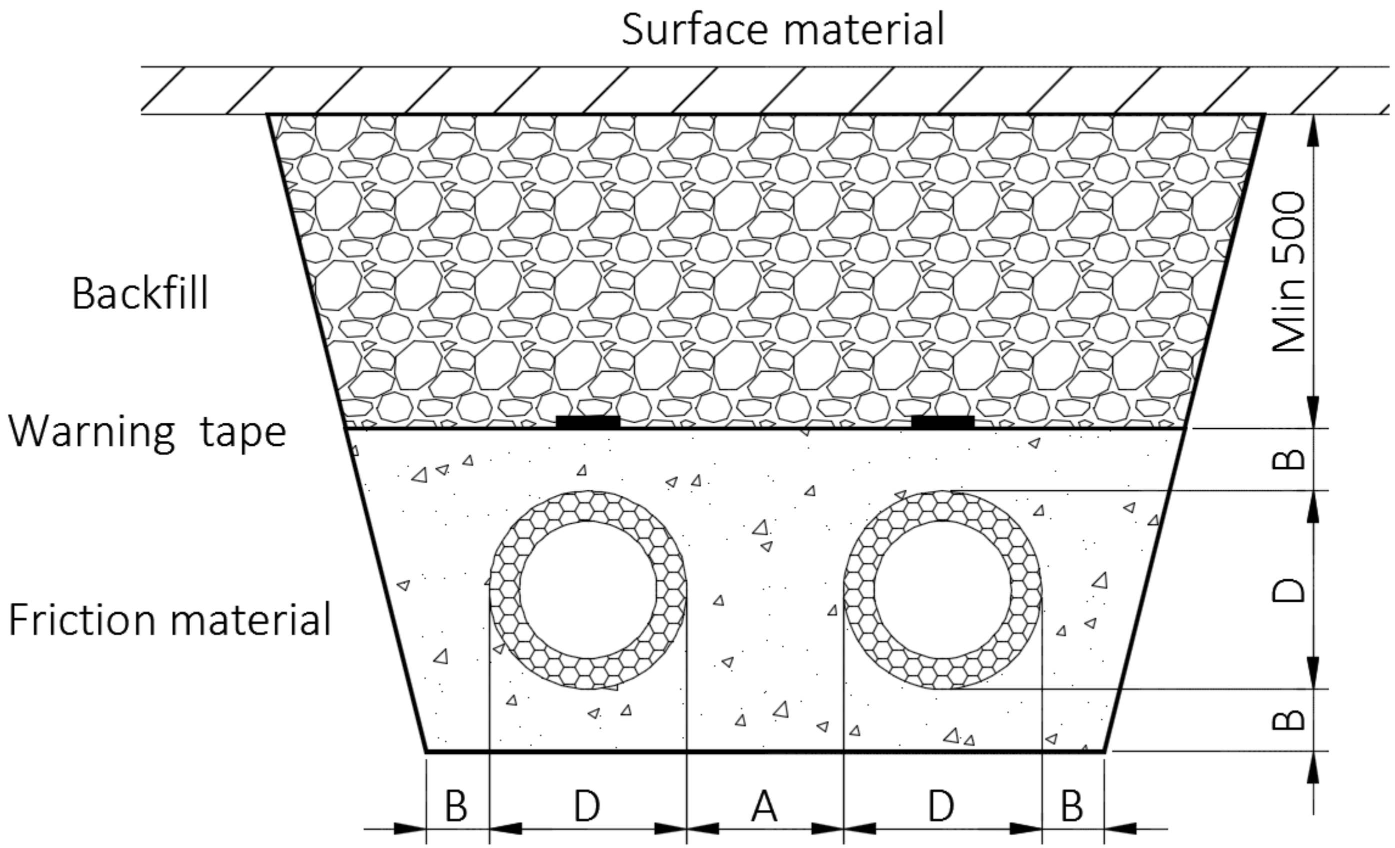

Peak load
Boiler, waste heat...
Hot tap water
Heating system
Radiators
Floor-heating
Geothermal Production system
50°C
Production Wells
Reinjection Pumps
25°C
Reinjection Wells
Circulation Pumps
85°C
Heat
Pump
35°C
Heat central
Distribution system
35°C
End users

# Piping and installation

Pipe systems and material

- Pre-insulated steel pipes according to EN 253
  - Steel pipe
    - St 37.0 (DIN 1626) or P235 TR1 (EN 10217 T1)
    - Weld factor 1,0
    - Manuf. certificate to EN 10204 – 3.1B
    - Beveling ends to DIN 2559 T1/T22 and ISO 6761
  - Insulation
    - Polyurethane
    - Density 60 kg/m$^3$
    - Compressive strength 0,4-0,6 N/mm$^2$
    - Closed cells > 88%
    - Continuous operating temperature: max 149°C for 30 years
  - Jacket pipe
    - HDPE
    - Optimum bonding between jacket and polyurethane

# Preinsulated piping system – Cross section



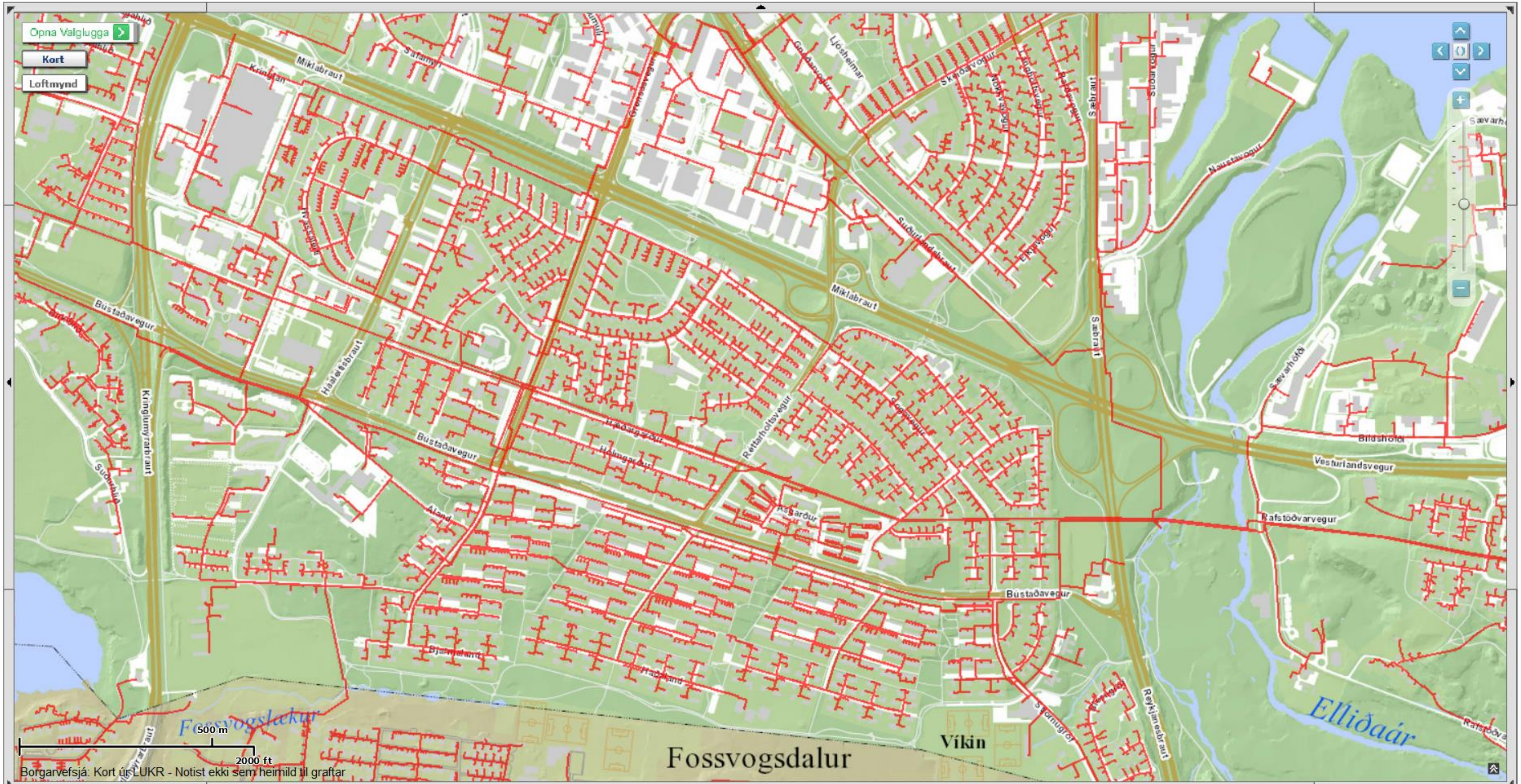

| D | A | B |
|---|---|---|
| 90 - 225 | 150 | 100 |
| 250 - 560 | 250 | 125 |
| 630 + | 300 | 150 |

# Installation cost, unit prices

| Double Distribution systems - Price 2015 | | | |
|---|---|---|---|
| Pipe size | | EN 253, insulation class I | |
| DN, mm | inches | New-construcion | Re-construction |
| DN20-25 | $^{3}/_{4}$ - 1 | 135 | 267 |
| DN32-40 | 1 $^{1}/_{4}$ - 1 $^{1}/_{4}$ | 152 | 283 |
| DN50-65 | 2 - 2 $^{1}/_{2}$ | 169 | 305 |
| DN80 | 3 | 199 | 336 |
| DN100 | 4 | 262 | 384 |
| DN125 | 5 | 294 | 419 |
| DN150 | 6 | 325 | 452 |
| DN200 | 8 | 433 | 569 |
| DN250 | 10 | 616 | 773 |
| DN300 | 12 | 733 | 901 |
| DN350 | 14 | 844 | 1020 |
| DN400 | 16 | 993 | 1182 |
| DN500 | 20 | 1291 | 1507 |
| DN600 | 24 | 1527 | 1757 |
| DN700 | 28 | 1743 | 1985 |

Borgarvefsjá

Heim | Hliðra | Leita | Þysja | Mæla | Teikna | Geymsla | Prenta | Meira | Eigindaleit | Tengill | Teikningar | GPS | Prófíll | Skýringar | Lifandi gögn | Hreinsa | Hjálp



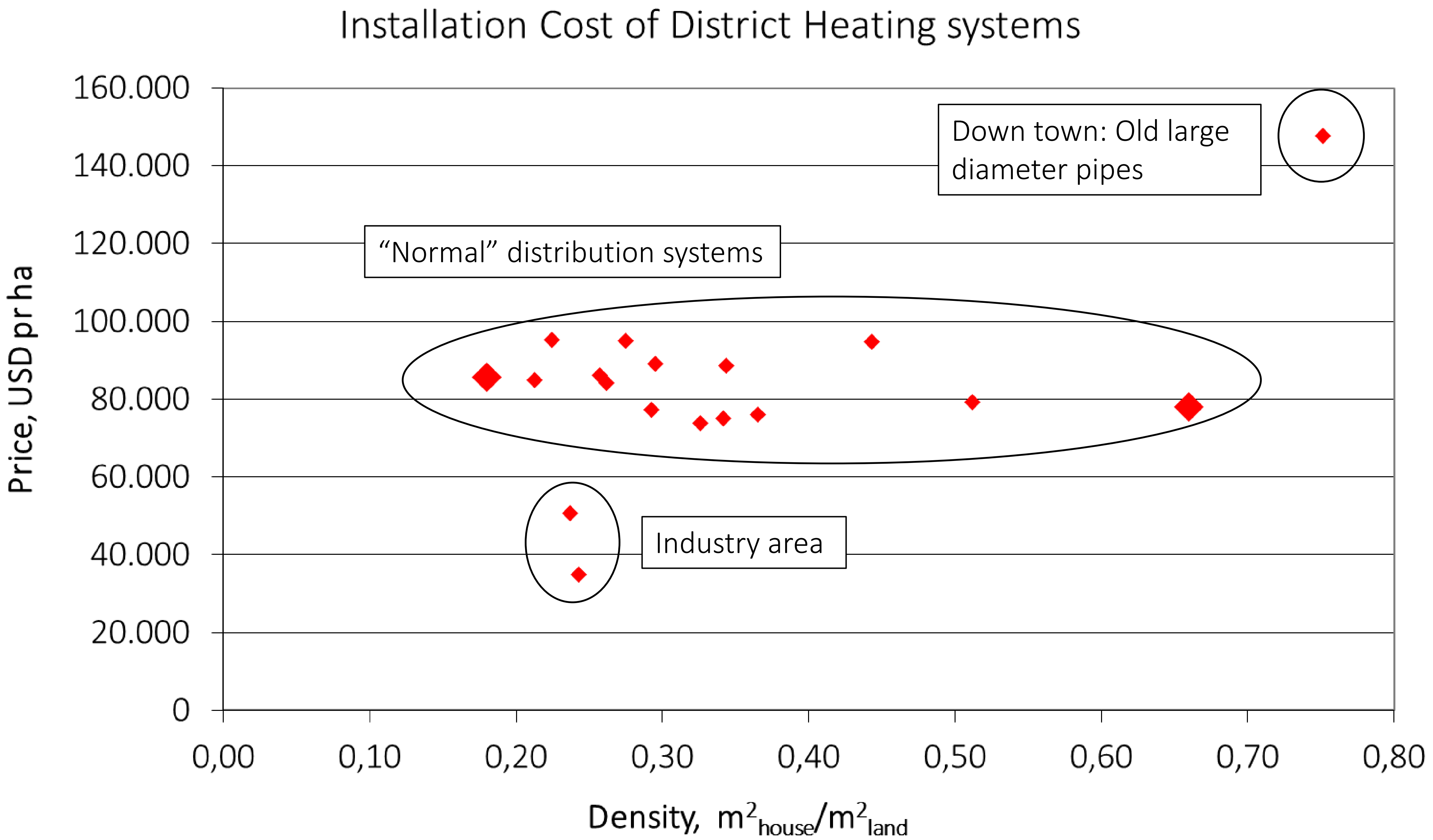

SAMSÝN

Kvarði 1:10.000 - X:358.547 Y:405.631

Útgáfa: 4.2

# Estimation of pipe quantity in an area

- Extract all pipes within a given area from the Reykjavík Energy graphical information system,
- Group pipes according to sizes, DN 20, DN 25.....etc.
- Calculate sum of pipes within each size range
- Add the unit price
- Calculated the price of all pipes within a given area
- ....and the results


Installation Cost of District Heating systems
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
Price, USD pr ha
Down town: Old large diameter pipes
"Normal" distribution systems
Industry area
0,00
0,10
0,20
0,30
0,40
0,50
0,60
0,70
0,80
Density, $m^2_{house}/m^2_{land}$

# House Connections and house heating systems

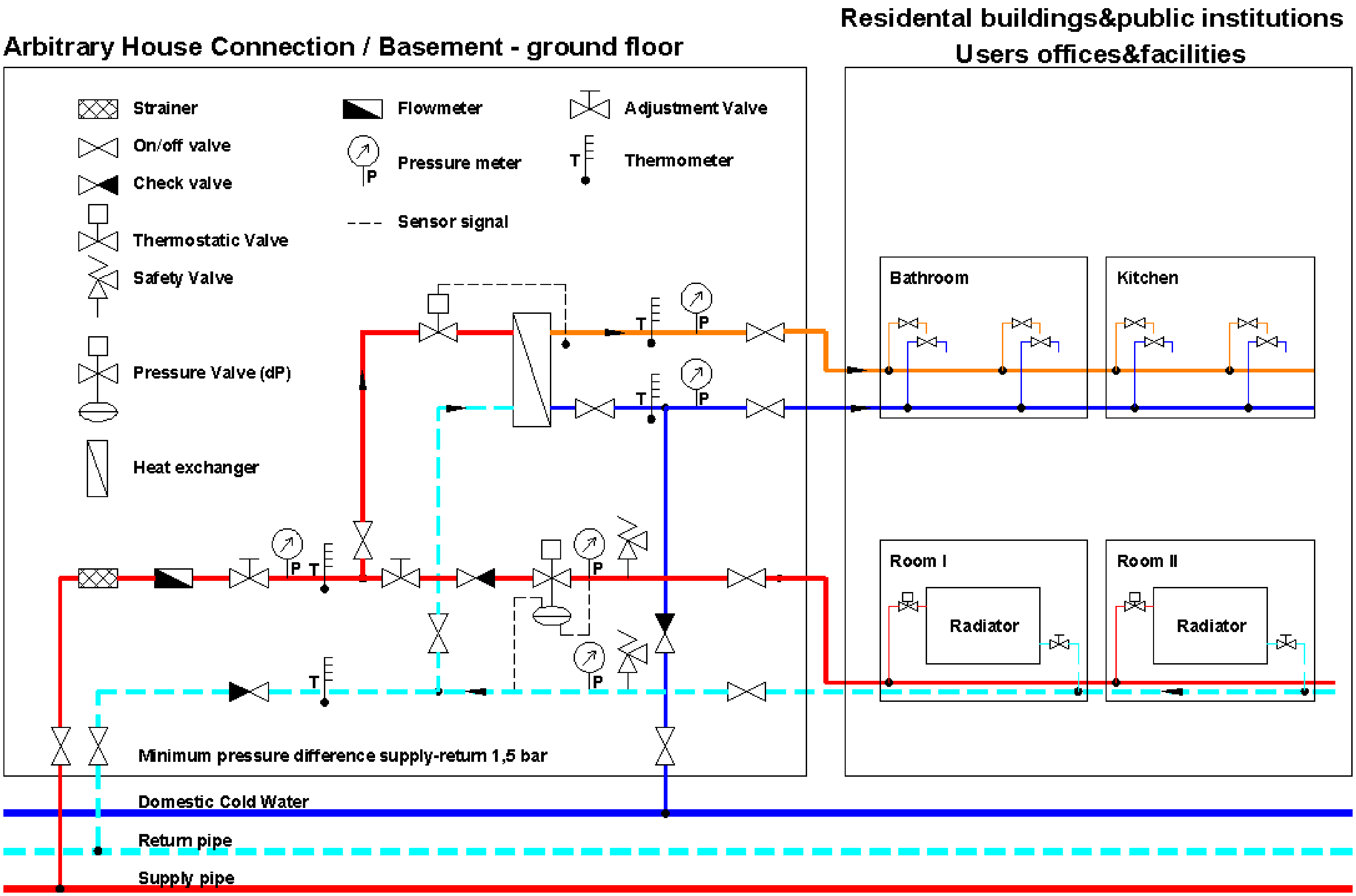
Which house heating system suites geothermal district heating?

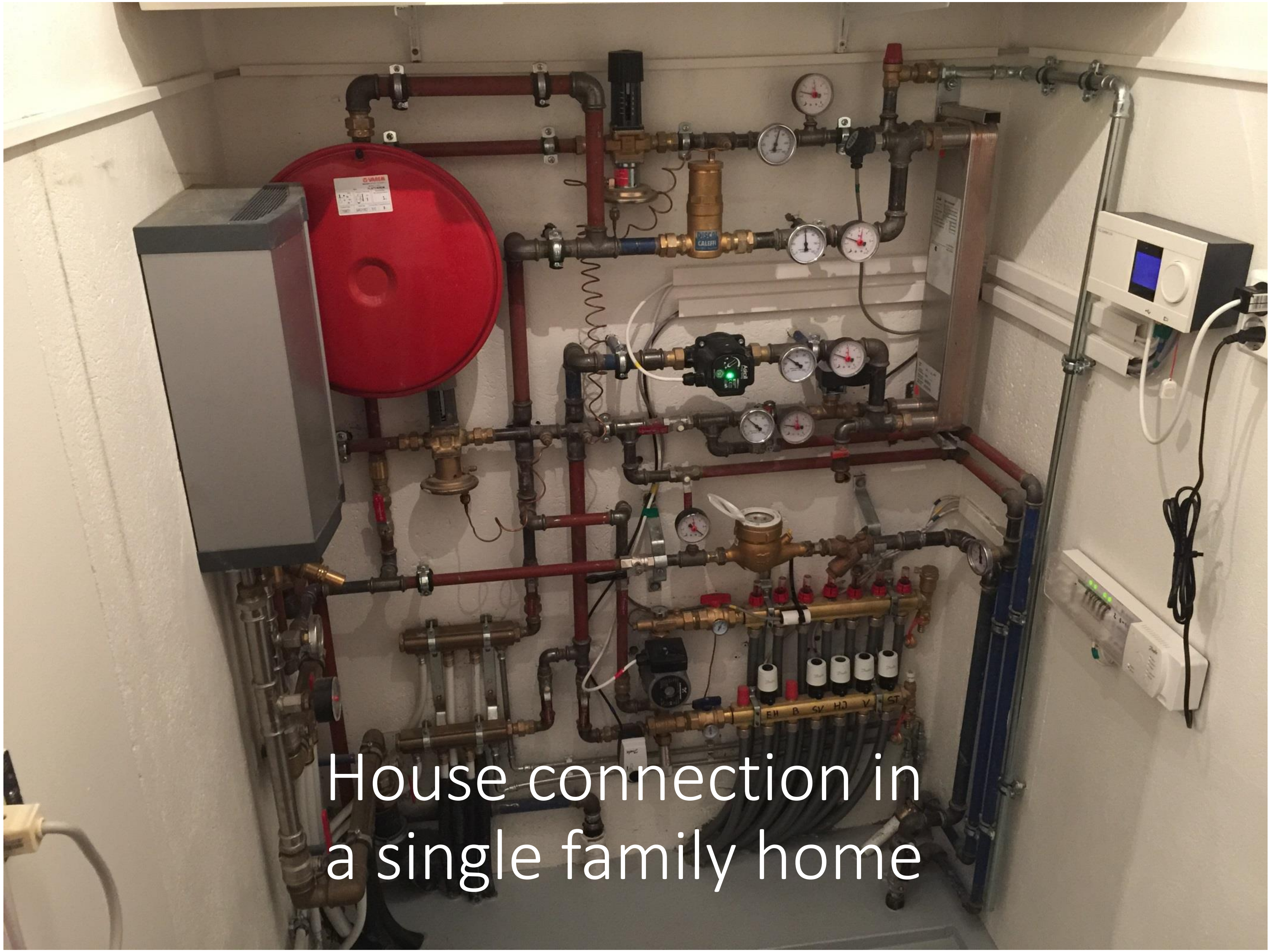
# House heating systems

- Old radiator systems – bad for geothermal
  - Supply temperature 90°C
  - Supply temperature 70°C

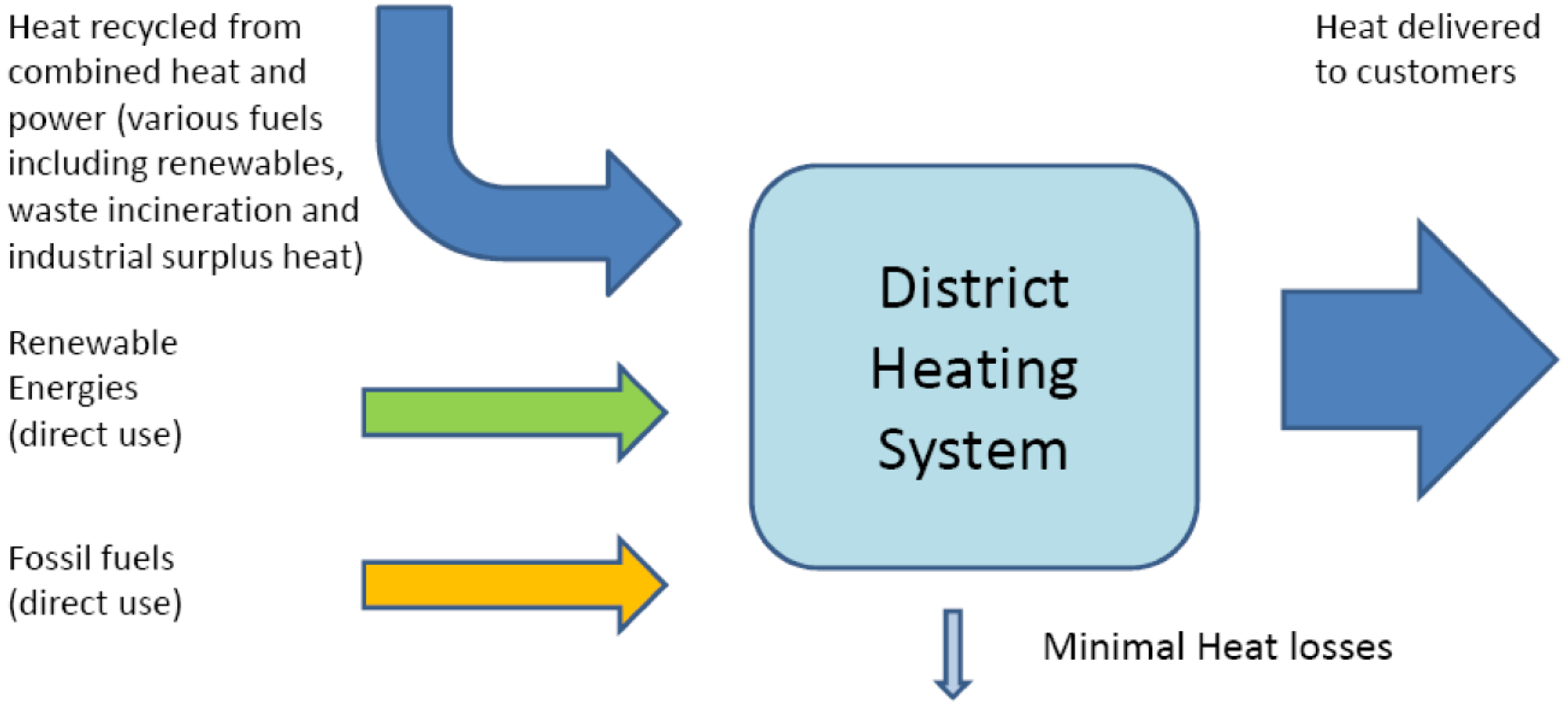
- Modern radiator systems – good for geothermal
  - Supply temperature 75°C
  - Return temperature 35°C

- Floor heating – excellent for geothermal
  - Supply temperature 45°C
  - Return temperature 35°C


Residental buildings&public institutions
Users offices&facilities
Arbitrary House Connection / Basement - ground floor
Strainer
On/off valve
Check valve
Thermostatic Valve
Safety Valve
Pressure Valve (dP)
Heat exchanger
Flowmeter
Pressure meter
Sensor signal
Adjustment Valve
Thermometer
Bathroom
Kitchen
Room I
Room II
Radiator
Radiator
Minimum pressure difference supply-return 1,5 bar
Domestic Cold Water
Return pipe
Supply pipe


House connection in
a single family home

# District heating is not only about geothermal





http://www.euroheat.org/Files/Filer/documents/Publications/District%20Heating%20in%20buildings_final.pdf

# Benefits of District Heating

- District heating is comfortable and effortless
- No need for individuals to purchase and handle fuels
- Limited servicing of equipment's for individuals
- Steady temperature at all times
- Secure supply and reduced risk of fires or explosions
- Pricing stable
- Reduces consumption, despite some heat losses in the network
- With access to geothermal heat as a base load, a win – win solution

VERKÍS

# Thank you

Do what you can with what you have where you are.
(Theodore Roosevelt)