District Energy Systems

Canada's Missing (Low Carbon) Infrastructure

TorchLight Bioresources

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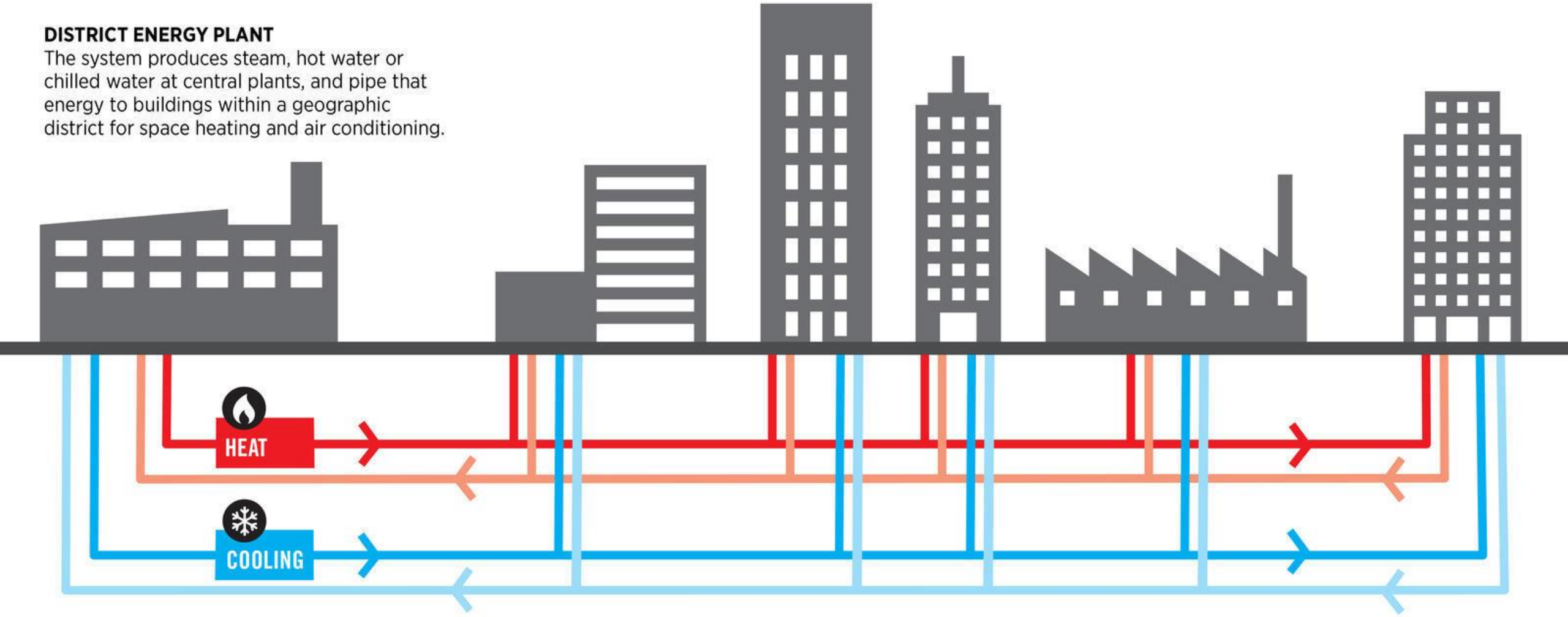
What is District Energy?



What is District Energy?

- Central energy plant producing heat and/or cooling and sometimes electricity
- Fuelled by biomass/wood, natural gas, municipal waste, waste heat (pumps)
- Other resources such as deep water cooling
- Connect buildings using hot water pipes
- Energy transferred to buildings using heat exchangers; space heat & hot water
- Buildings do not have separate furnaces/boilers
- Municipal-owned, P3, private, co-operative ownership models
- Examples: Charlottetown, Toronto (Enwave), Ottawa (PSPC), London, Markham, Surrey, universities, DND bases, hospitals (~180 DES in Canada)

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What is District Energy?

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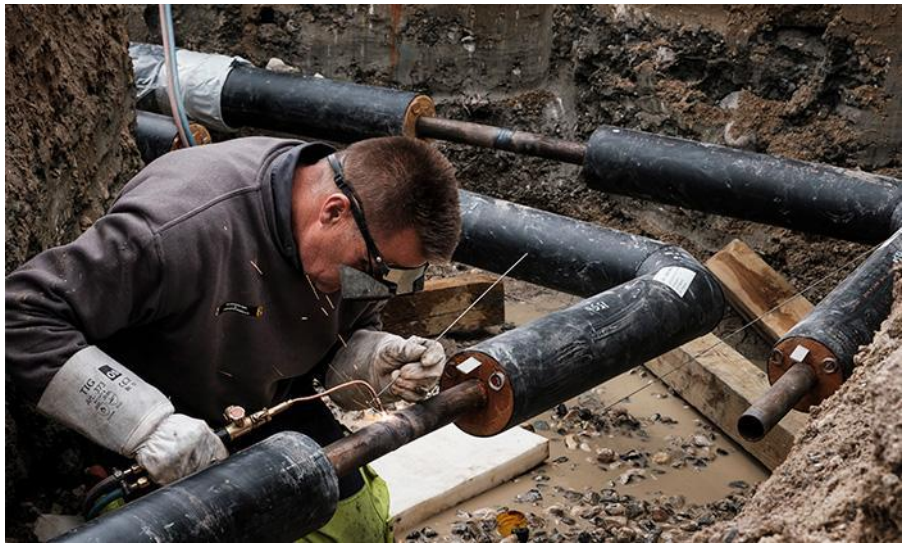

In-Building Energy Distribution

- Options
  1. Radiators
  2. In-floor
  3. Hydronic air handler & ducting
  4. Fan coil

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Why District Energy?

1. Fuel flexible, **FUTURE-PROOF** infrastructure for cities & towns

2. The **PROVEN** approach for urban decarbonization

3. Enable the use of low cost, unprocessed **LOW CARBON FUELS**

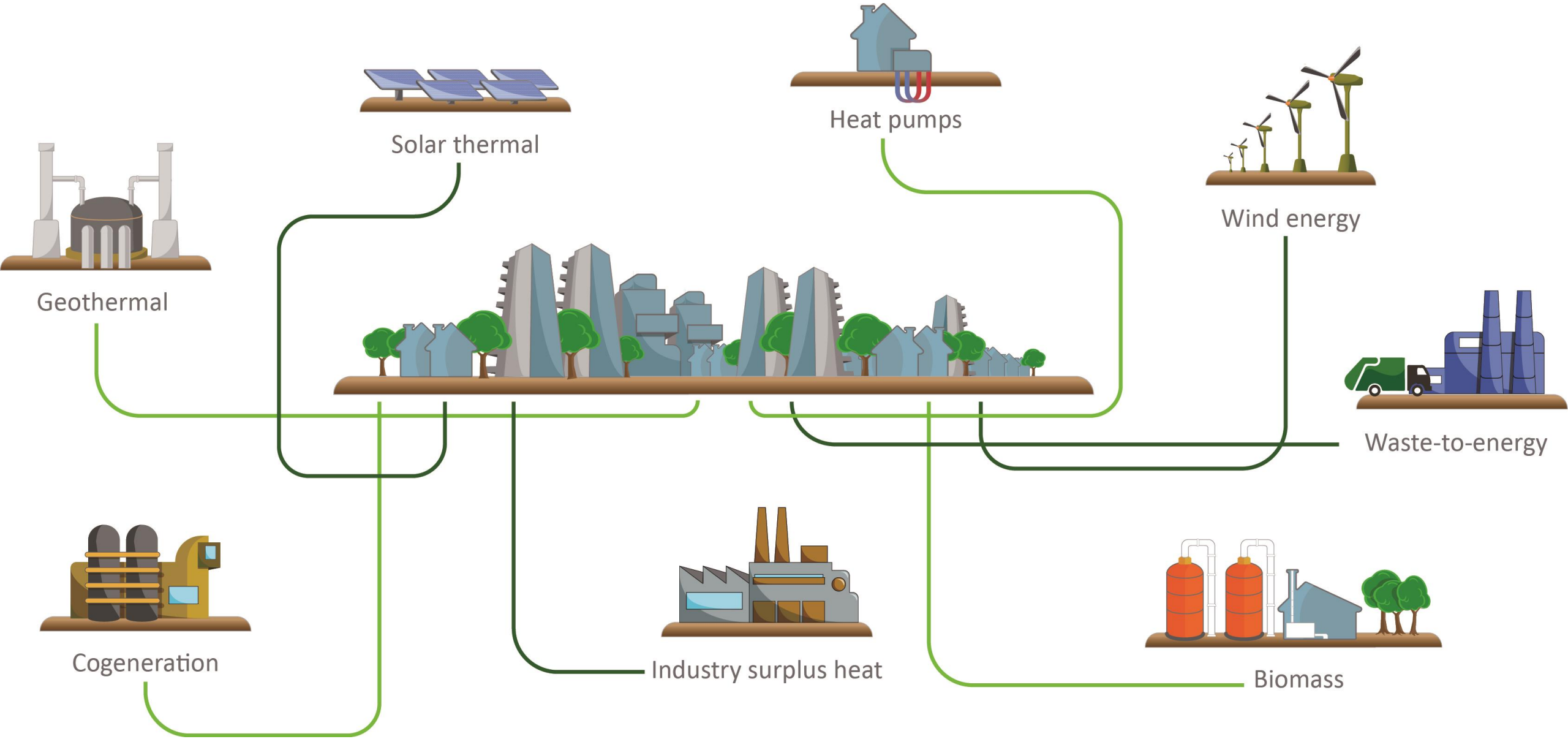
4. Address **URBAN-RURAL** divide on decarbonization and job creation

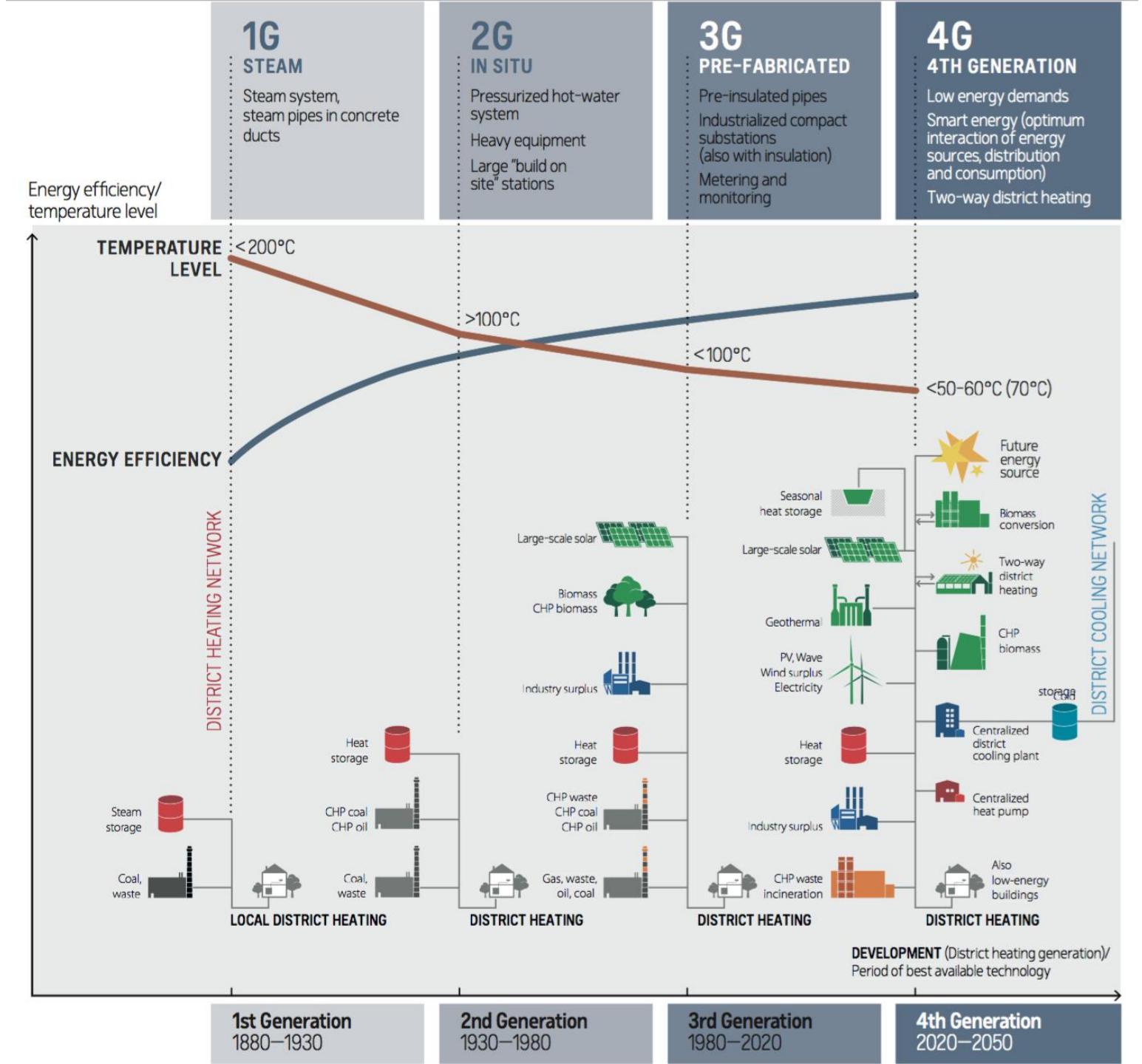
5. Development requires same **SKILLS AND TRADES** as oil and gas

6. Enables Climate-Smart Forestry, including climate **ADAPTATION**

7. Centralization of energy generation permits **NEGATIVE EMISSIONS** via BECCS

8. Source of **INCOME** for municipalities, increasing robustness and resiliency


Solar thermal
Heat pumps
Wind energy
Geothermal
Waste-to-energy
Cogeneration
Industry surplus heat
Biomass


1G
STEAM
Steam system, steam pipes in concrete ducts
2G
IN SITU
Pressurized hot-water system
Heavy equipment
Large "build on site" stations
3G
PRE-FABRICATED
Pre-insulated pipes
Industrialized compact substations (also with insulation)
Metering and monitoring
4G
4TH GENERATION
Low energy demands
Smart energy (optimum interaction of energy sources, distribution and consumption)
Two-way district heating
Energy efficiency/ temperature level
TEMPERATURE LEVEL
<200°C
>100°C
<100°C
<50-60°C (70°C)
ENERGY EFFICIENCY
DISTRICT HEATING NETWORK
DISTRICT COOLING NETWORK
Steam storage
Coal, waste
Heat storage
CHP coal CHP oil
Coal, waste
Large-scale solar
Biomass CHP biomass
Industry surplus
Heat storage
CHP waste CHP coal CHP oil
Gas, waste, oil, coal
Seasonal heat storage
Large-scale solar
Geothermal
PV, Wave Wind surplus Electricity
Heat storage
Industry surplus
CHP waste incineration
Future energy source
Biomass conversion
Two-way district heating
CHP biomass
storage
Centralized district cooling plant
Centralized heat pump
Also low-energy buildings
LOCAL DISTRICT HEATING
DISTRICT HEATING
DISTRICT HEATING
DISTRICT HEATING
DEVELOPMENT (District heating generation)/ Period of best available technology
1st Generation 1880–1930
2nd Generation 1930–1980
3rd Generation 1980–2020
4th Generation 2020–2050

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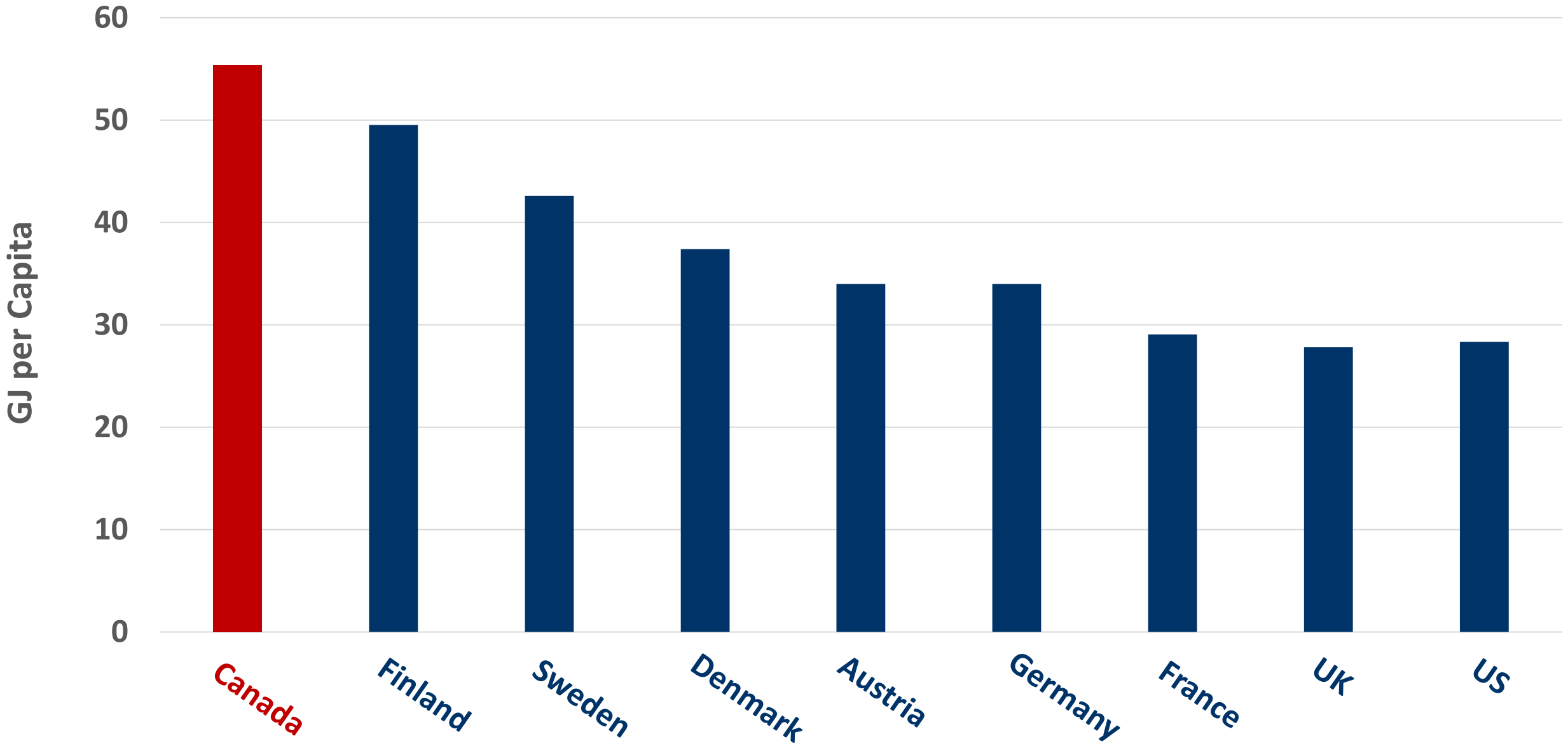
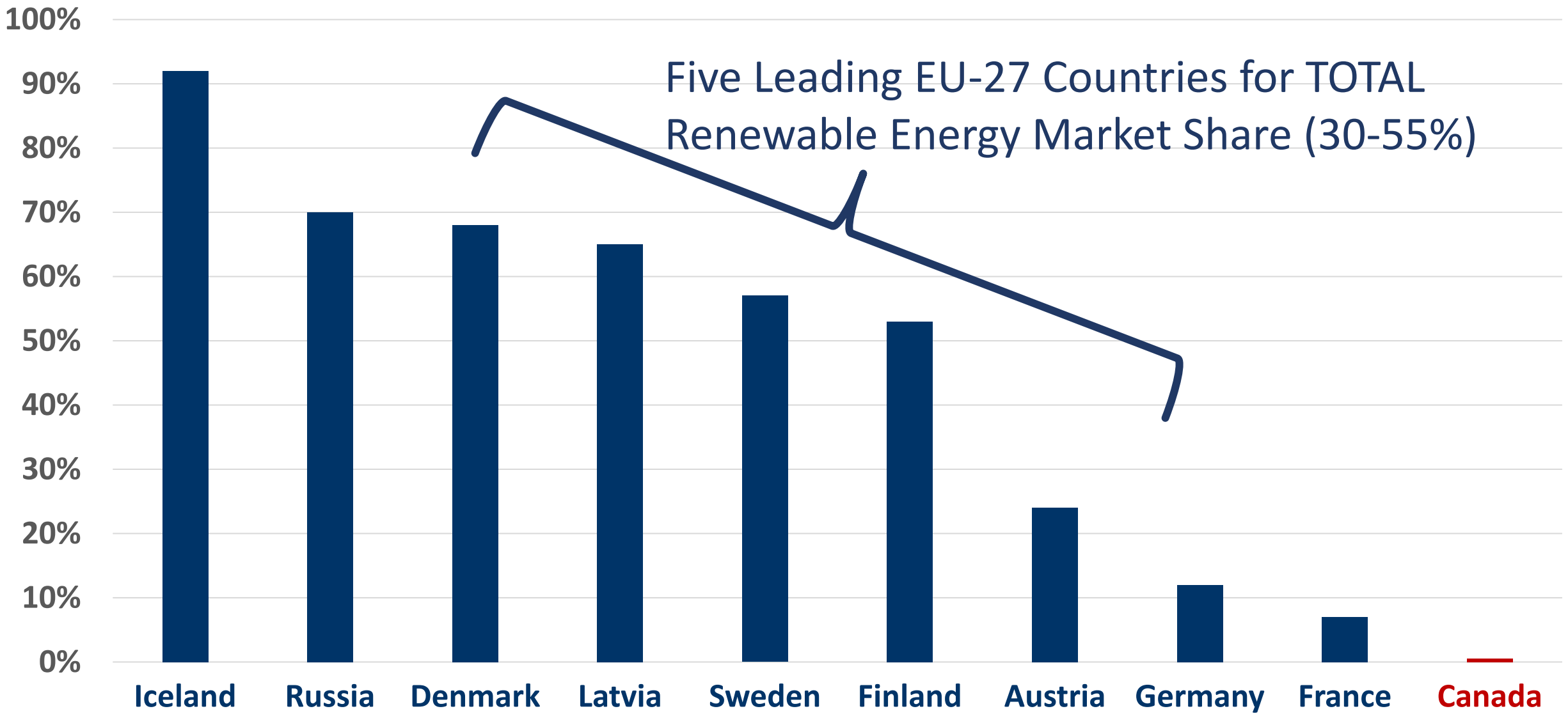
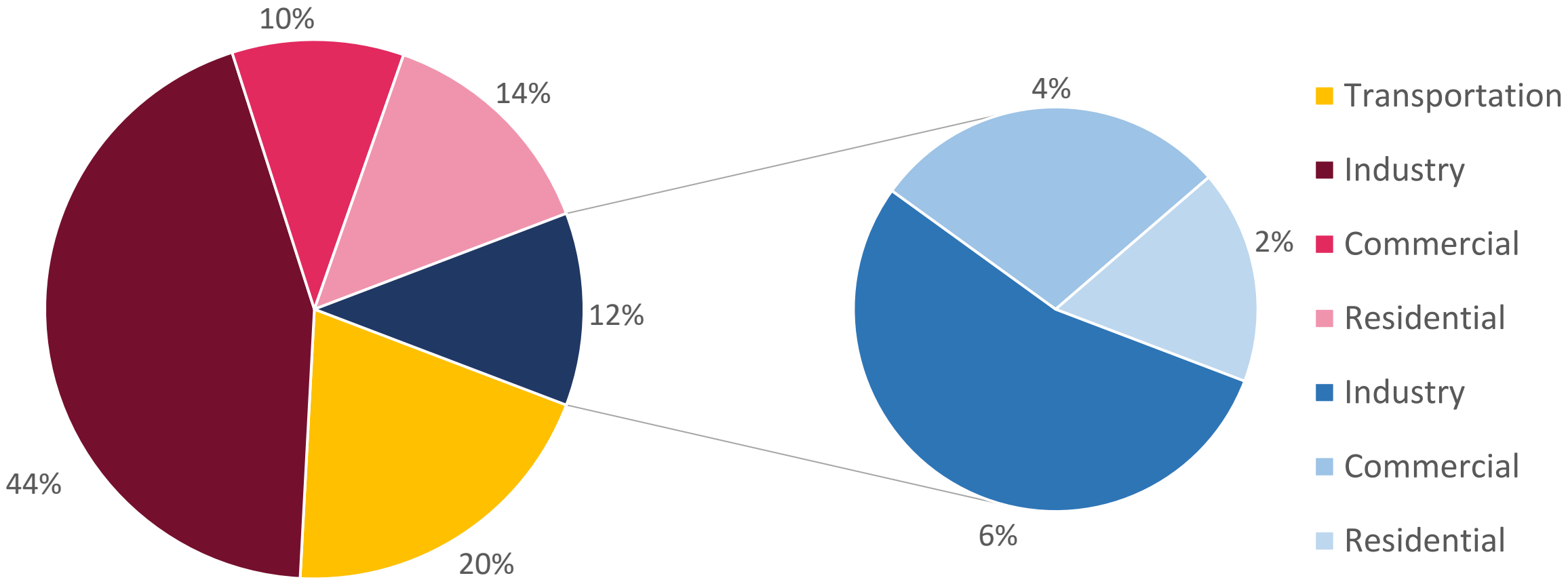
Building Space and Hot Water Demand



Northern Country Population Served by DE



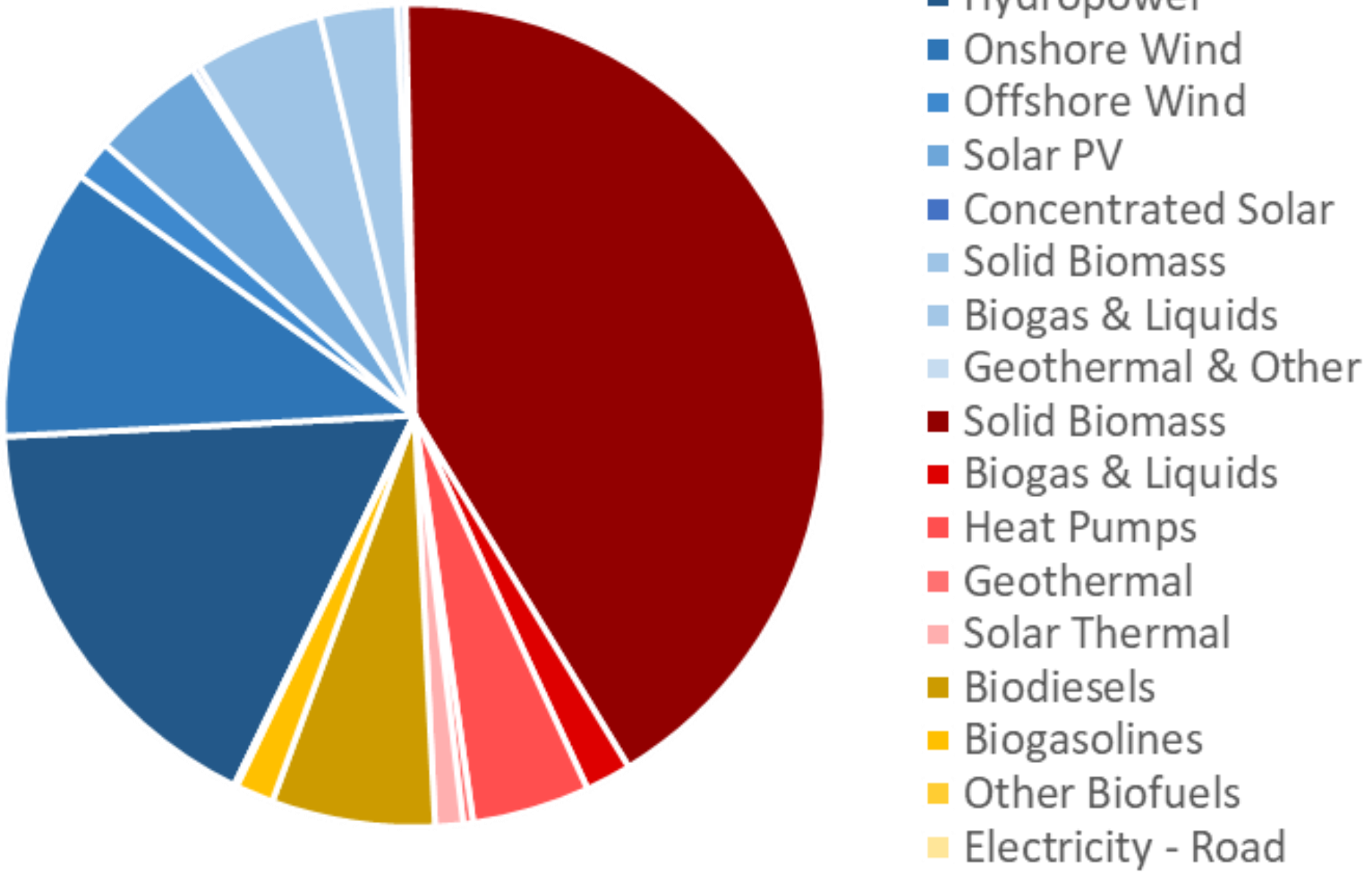
Energy Demand in Canada



- Thermal energy is approximately 60-65% of Canada's energy demand
- Excluding existing electrical heating, electricity is 12% of Canada's energy demand
- Heating residential buildings requires more energy than ALL of Canada's electricity demand

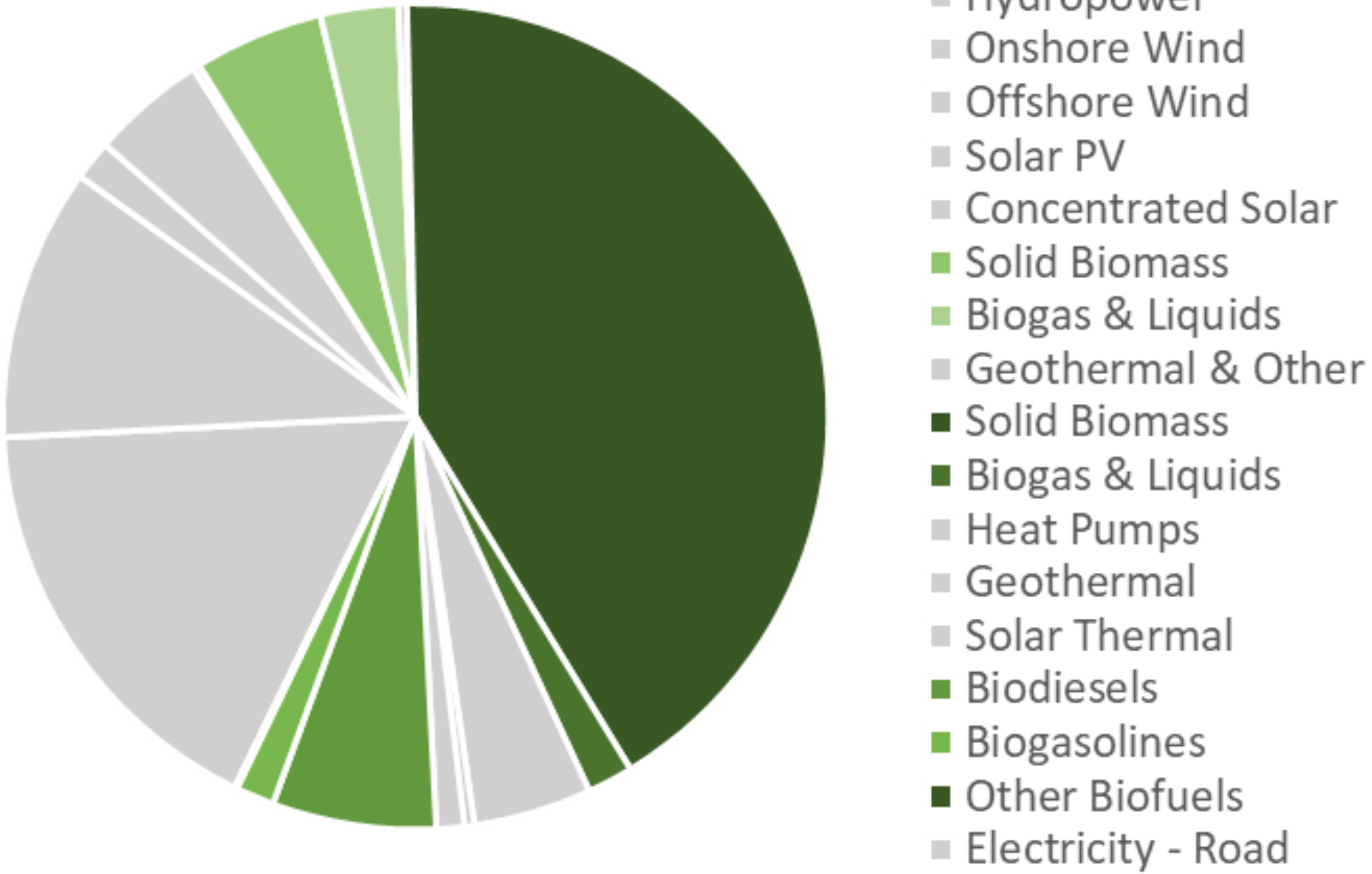
Renewable Energy in the EU

Total: 8.5 EJ

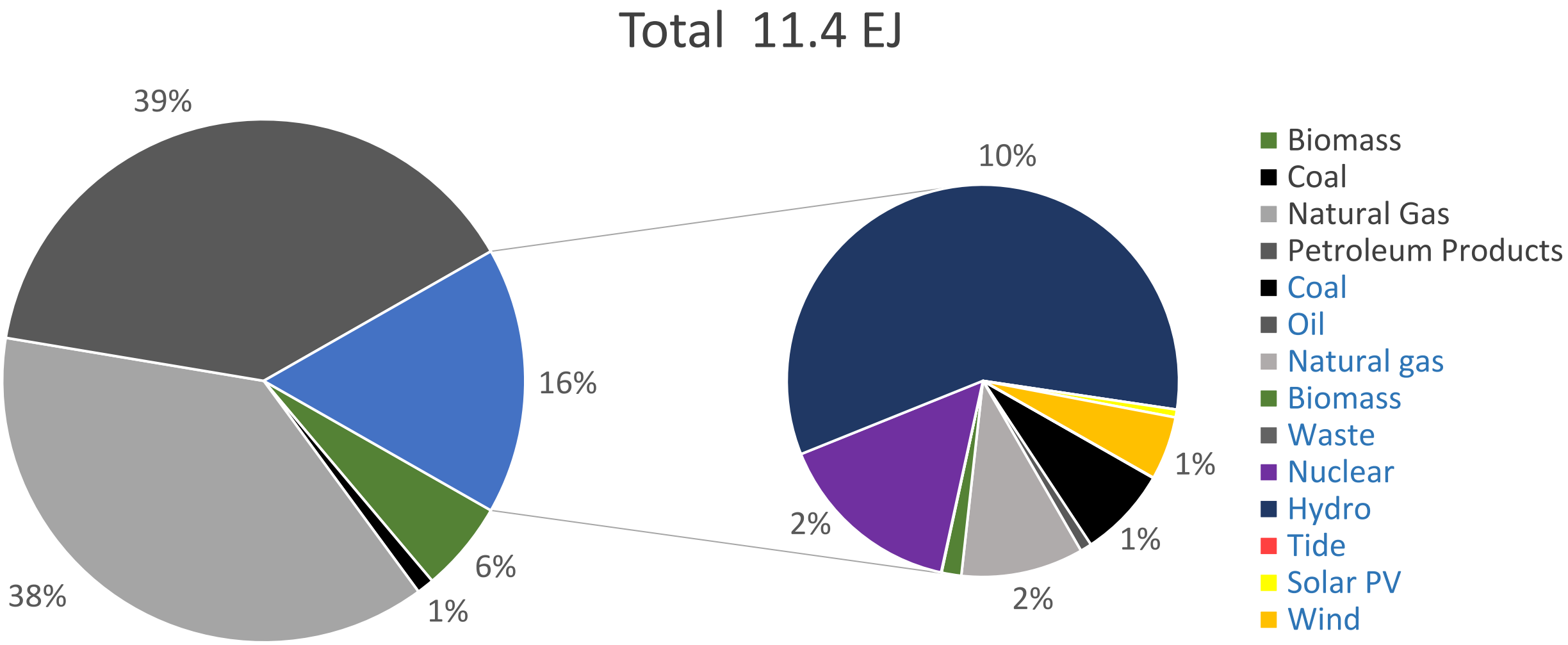


Bioenergy in the EU

Bioenergy in 2017:
211 Mt CO_2e reductions



Energy Consumption in Canada



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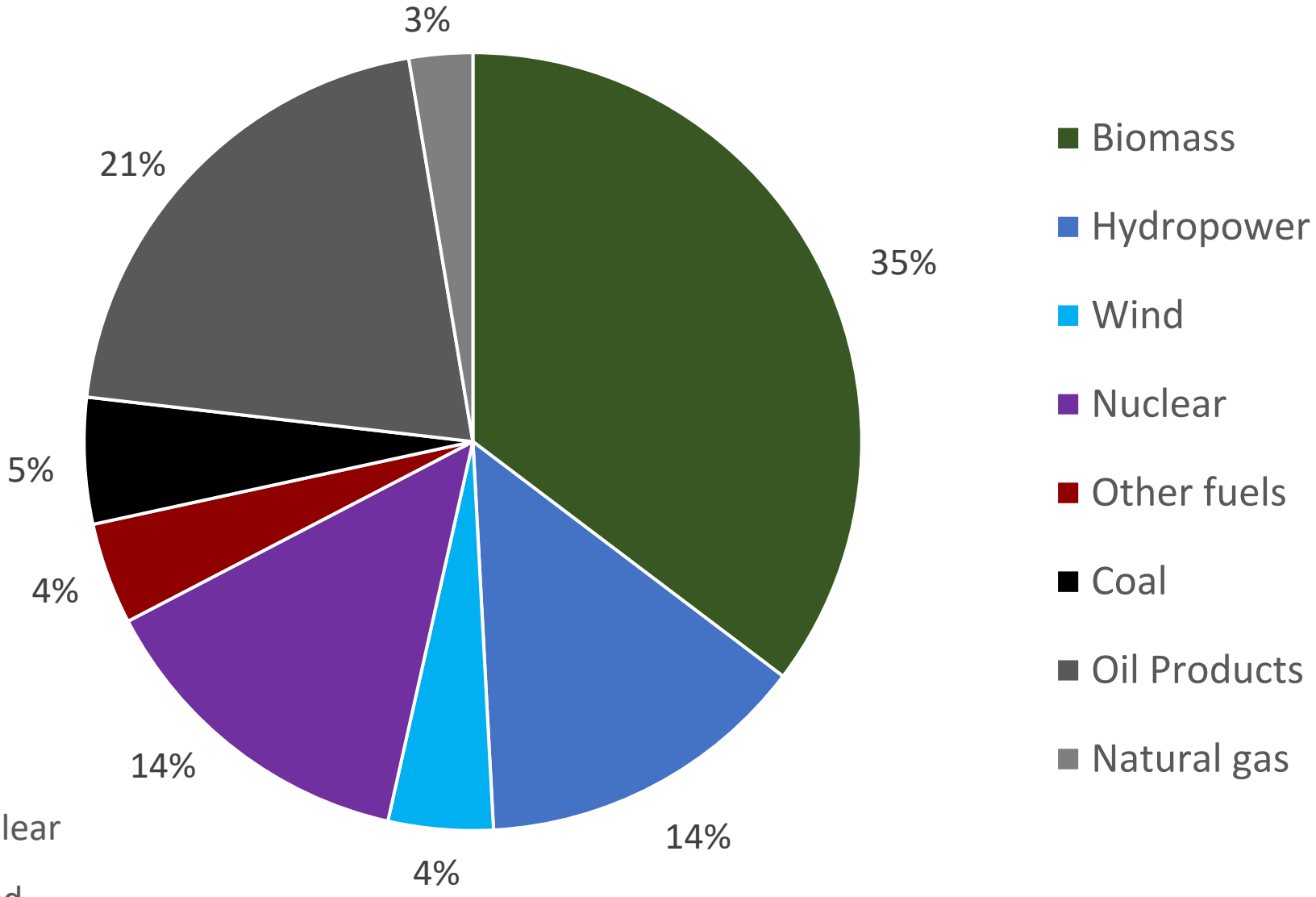
What is ‘Bioheat’?

Energy Consumption in Sweden



- 53-55% renewable + 14% nuclear
- 80% of biomass is forest-based

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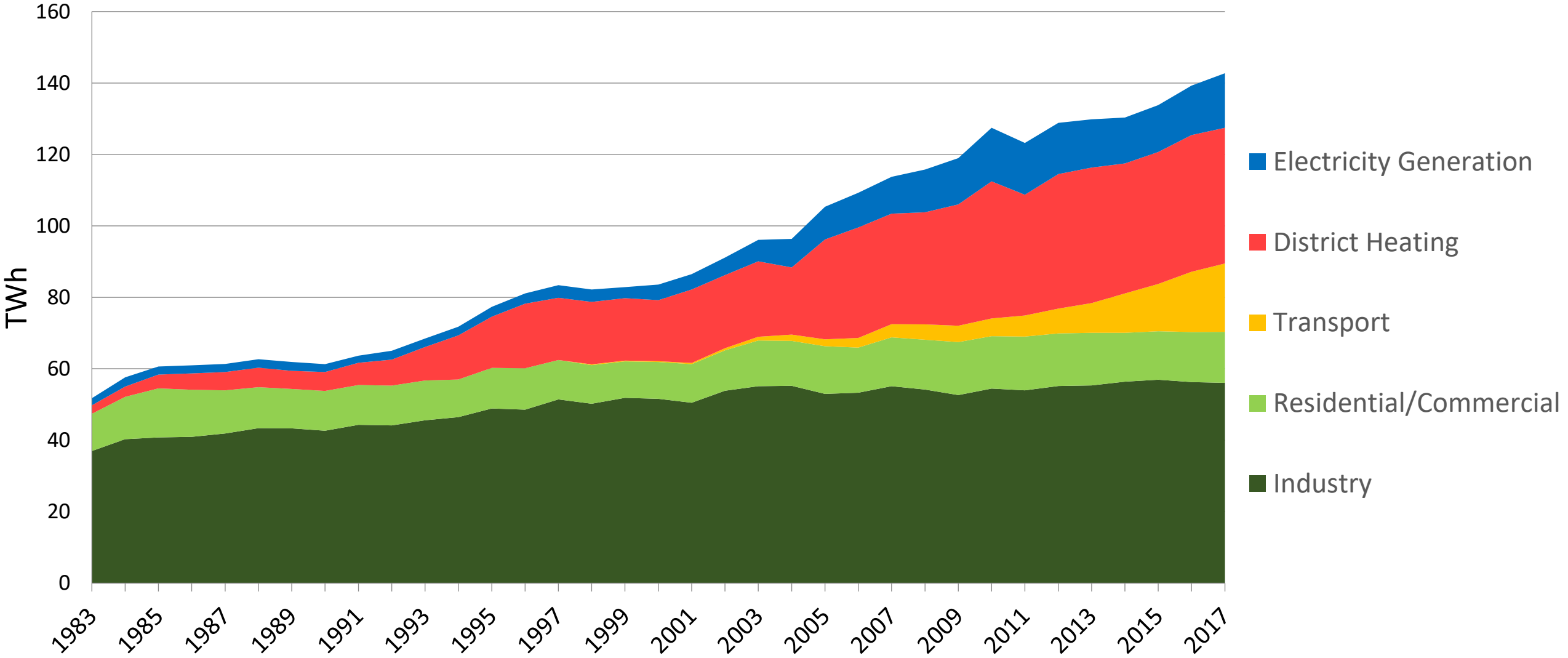
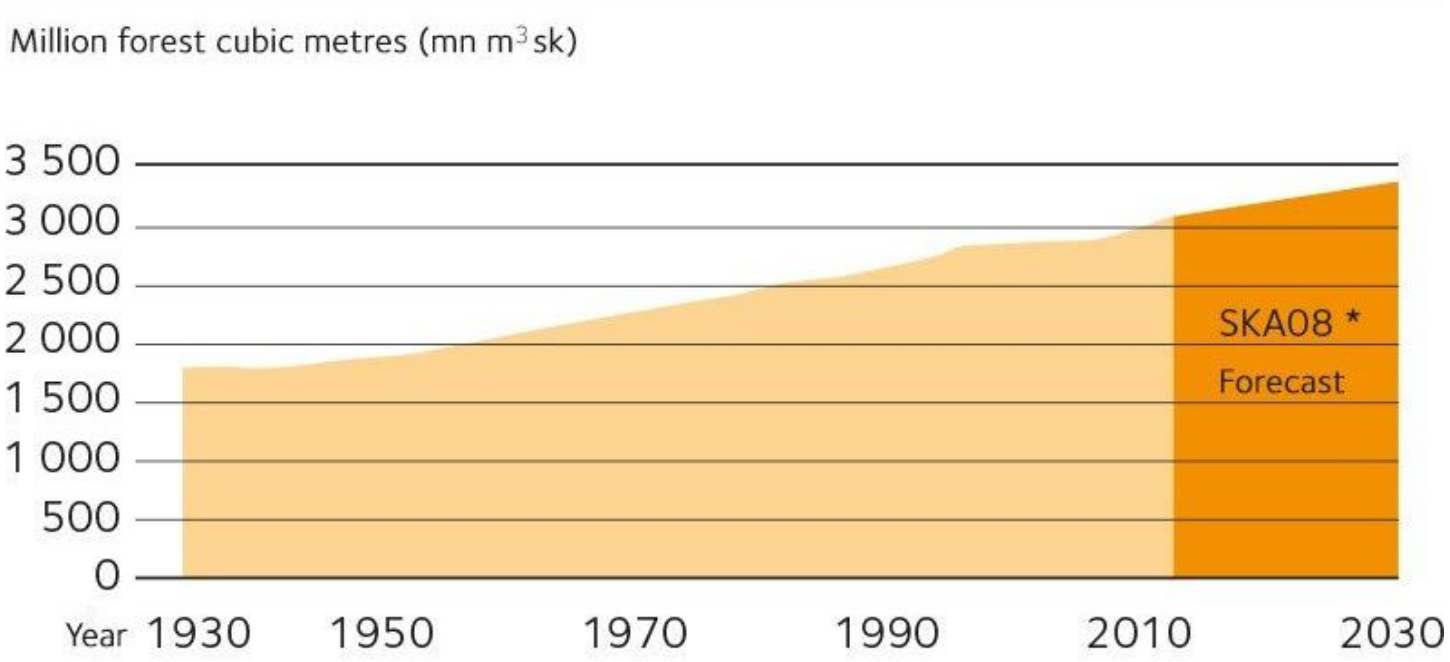
Bioenergy Demand in Sweden

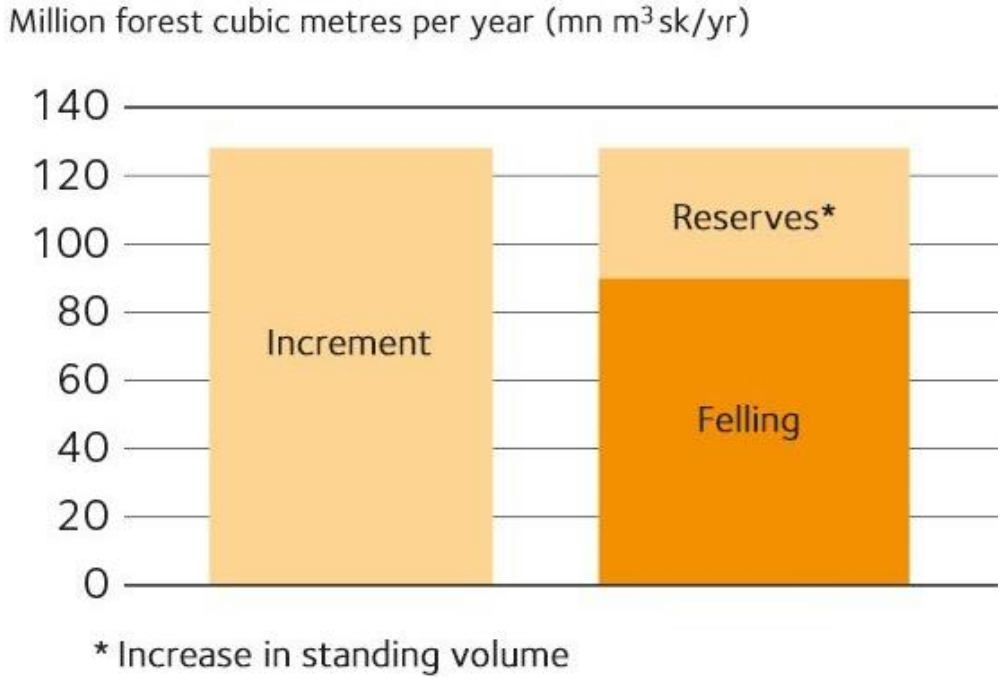


Forests in Sweden

Standing Timber



Growth & Removals



- NET carbon uptake (increase in standing volume) reduces Sweden's national GHG emissions by 80%
- Per Capita GHG Emissions:
  - Sweden = 0.9 t CO_2e/pp
  - Canada = 19.7 t CO_2e/pp

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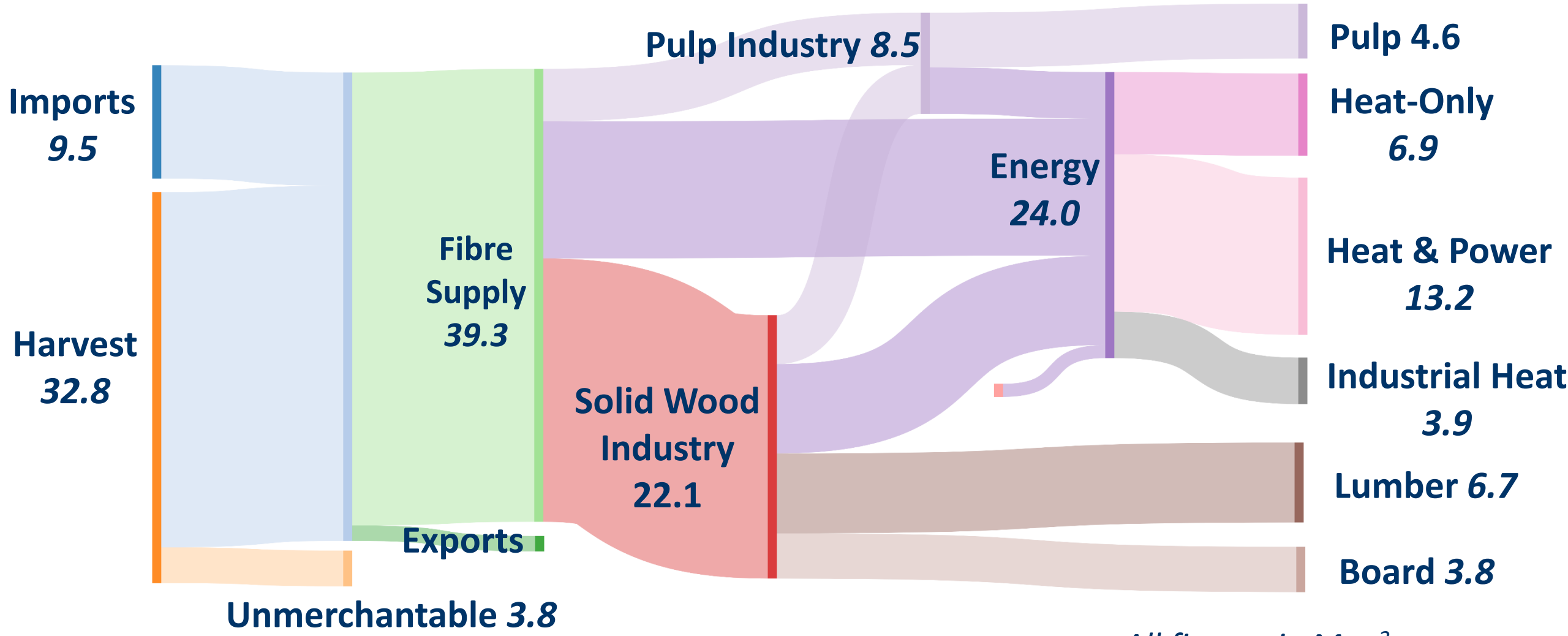
Mass Timber

Austrian Forest Sector – C$9 B/yr



Highly profitable mass timber industry supported by heat market

Forested area: <4 M ha; highly mountainous; stocks increased 45% since 1960

All figures in M m^3

Total NS Harvest ~3 M m^3

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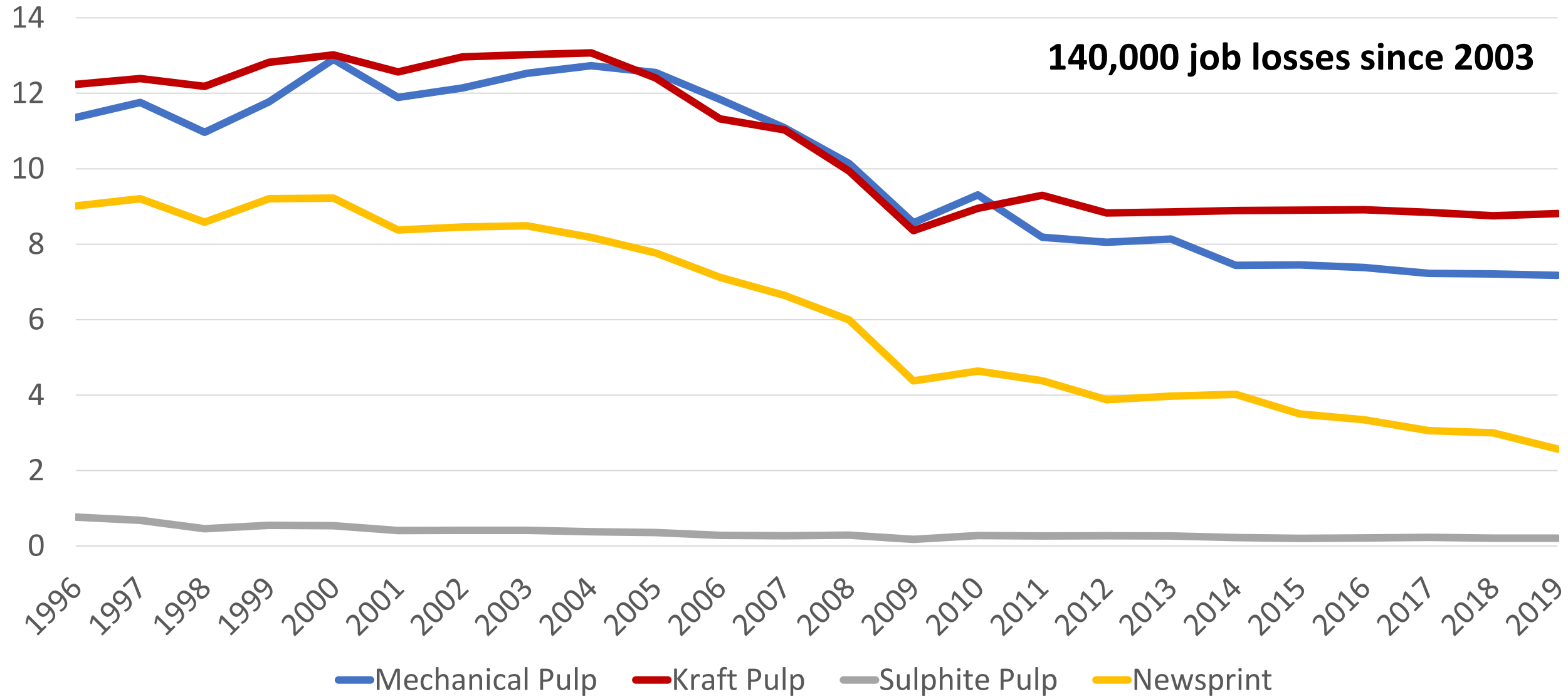
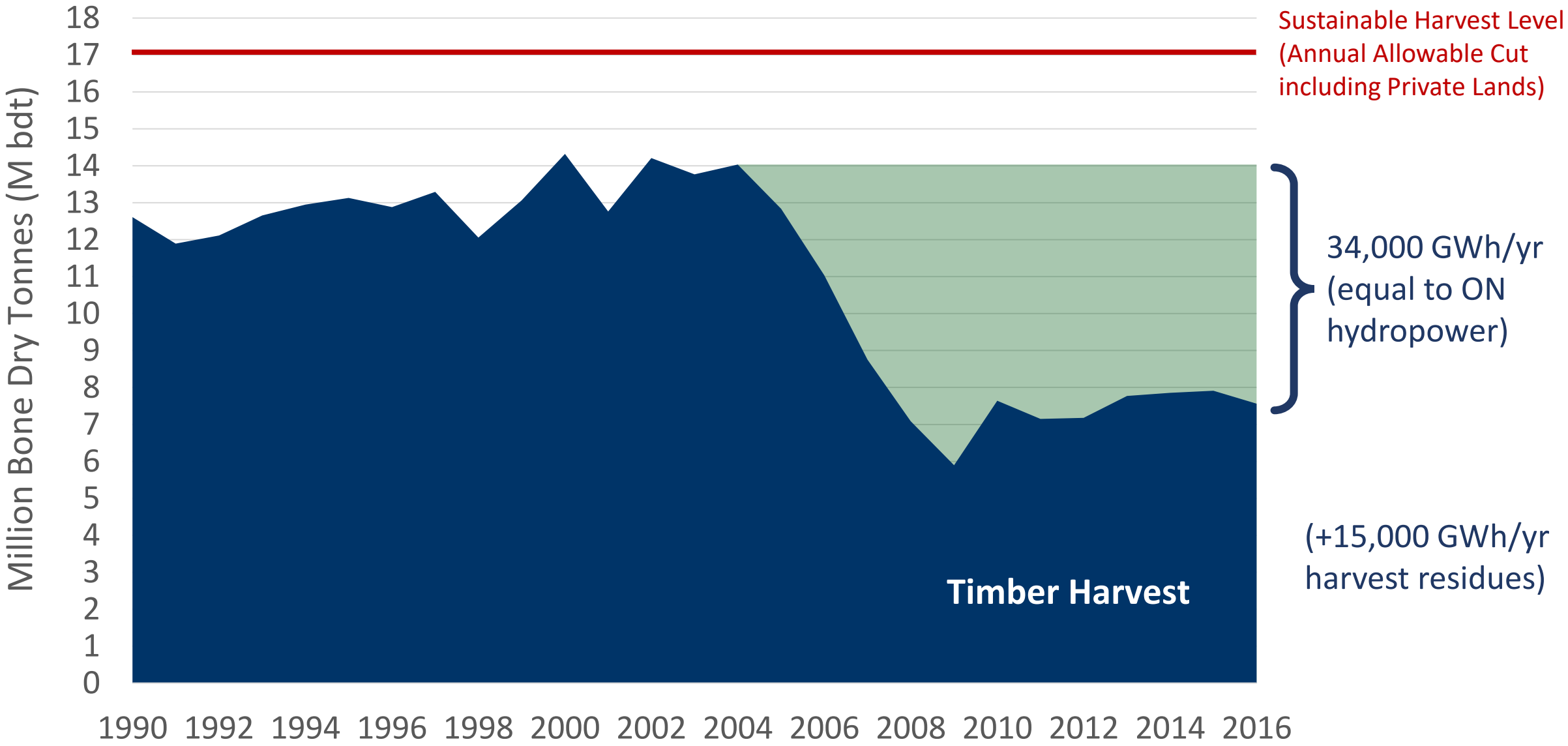
Wood Pulp Production in Canada

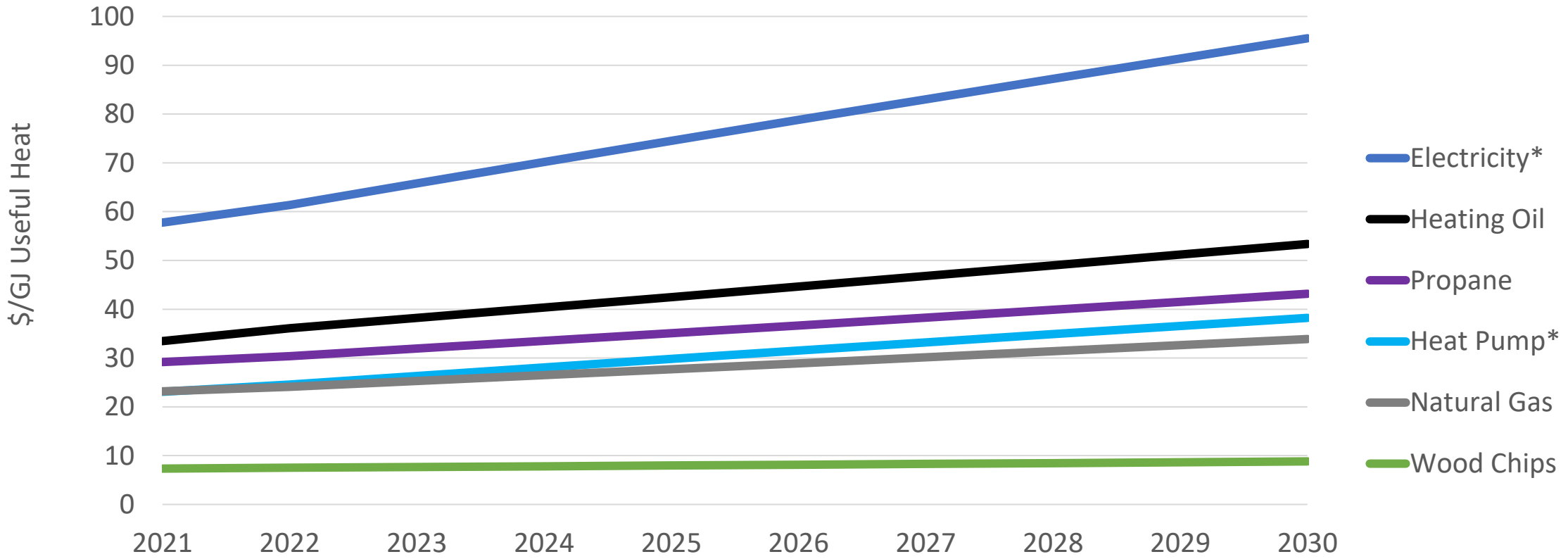


Timber Harvest in Ontario



Nova Scotia Carbon & Fuel Pricing

- $170/t CO_2e adds $8.70/GJ to natural gas; $0.45/L to heating oil



* Assumes 100% of emissions subject to carbon pricing; rates increases as projected by NSP Integrated Resource Plan
* Grid CI of 650 g CO_2e/kWh in 2021 decreasing to 500 g CO_2e/kWh by 2030

- Heating oil cost includes Clean Fuel Standard compliance
- Cost assumes 2% annual inflation

Södertälje, Sweden (285 MW_{th})

Blackburn Meadows, UK (55 MW_{th})

Lienz, Austria (17 MW_{th})

Trollhättan, Sweden (21 MW_{th})

Uppsala, Sweden (110 MW_{th})

Schwendi, Germany (7 MW_{th})

Bioheat in Canada

- 460 Commercial/Institutional Bioheat Projects in Canada (75-5,000 kW scale)
- Industry growing at 15% per year
- >99% wood chips or wood pellets
- Wood (cordwood, pellets) provides 11% of residential energy supply
- Wood provides 10% of industrial energy supply
- Carbon intensity energy used by pulp and paper sector decreased 60% (1990-2015) by fuel switching




Prince County Hospital, Summerside, PEI

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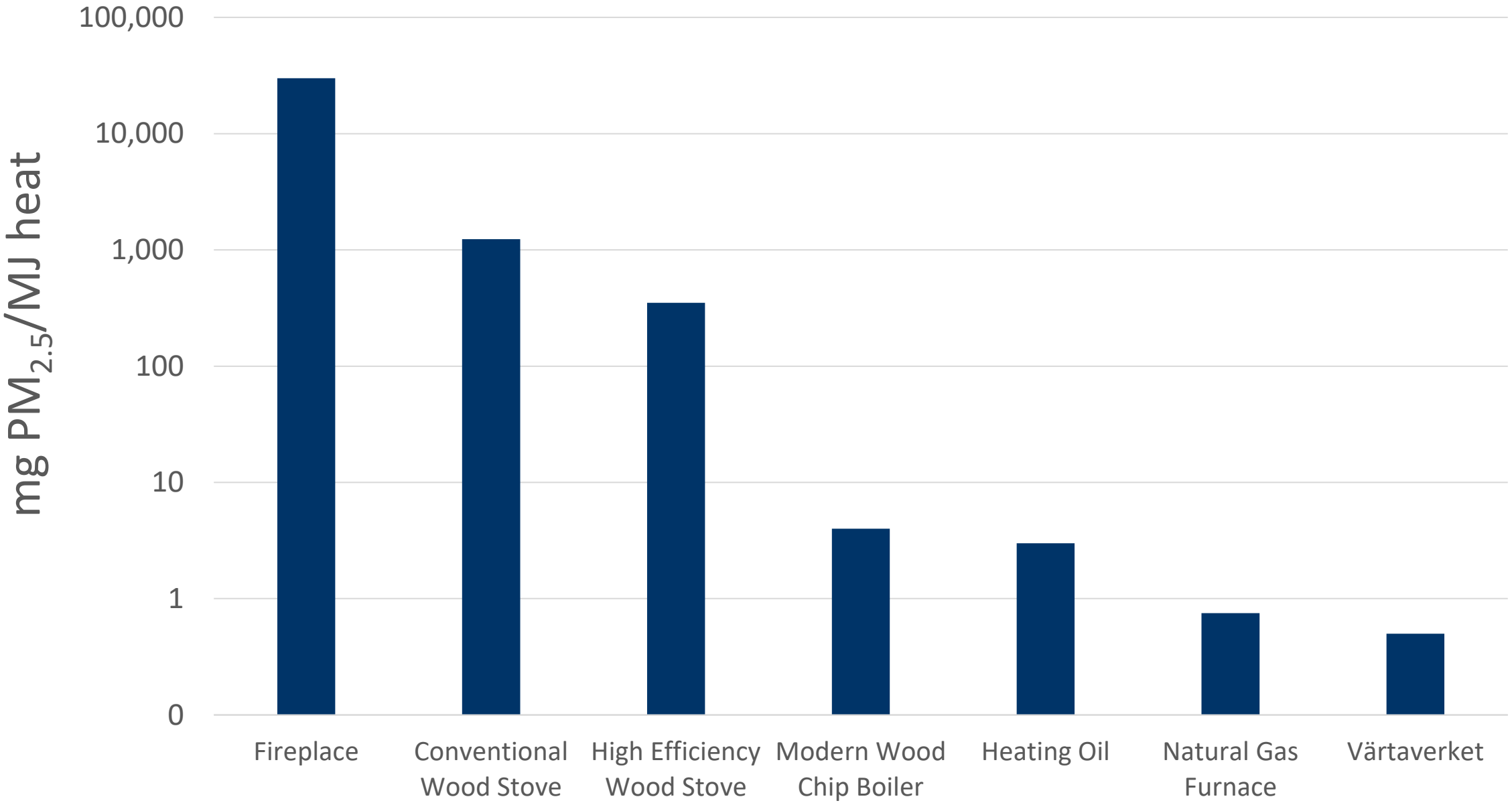
Customer Perspective

- Customers sign heat utility supply agreement
- Heat transfer unit (HTU) installed in each building – owned by utility
- Customer controls temperature/consumption using existing thermostat(s)
- Existing heat systems can be retained for backup (but not necessary)
- Track heat consumption online
- Monthly billing
    - Connection fee, consumption, billing fee
- Billing & customer information services could be contracted to third party
    - E.g., NorthStar Utilities Solutions

Fine Particulate Matter ($PM_{2.5}$) Emissions



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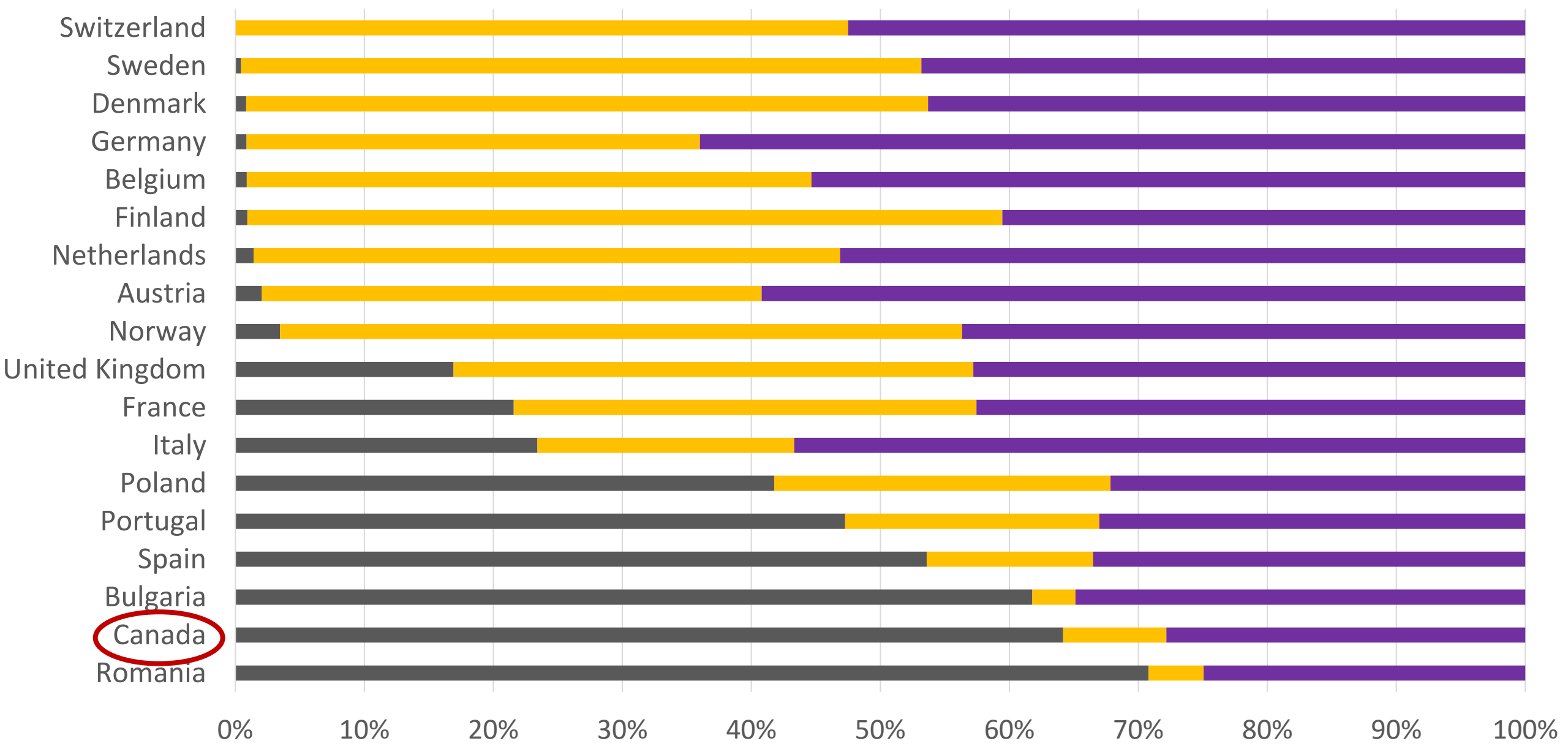
Waste Fate, 2017



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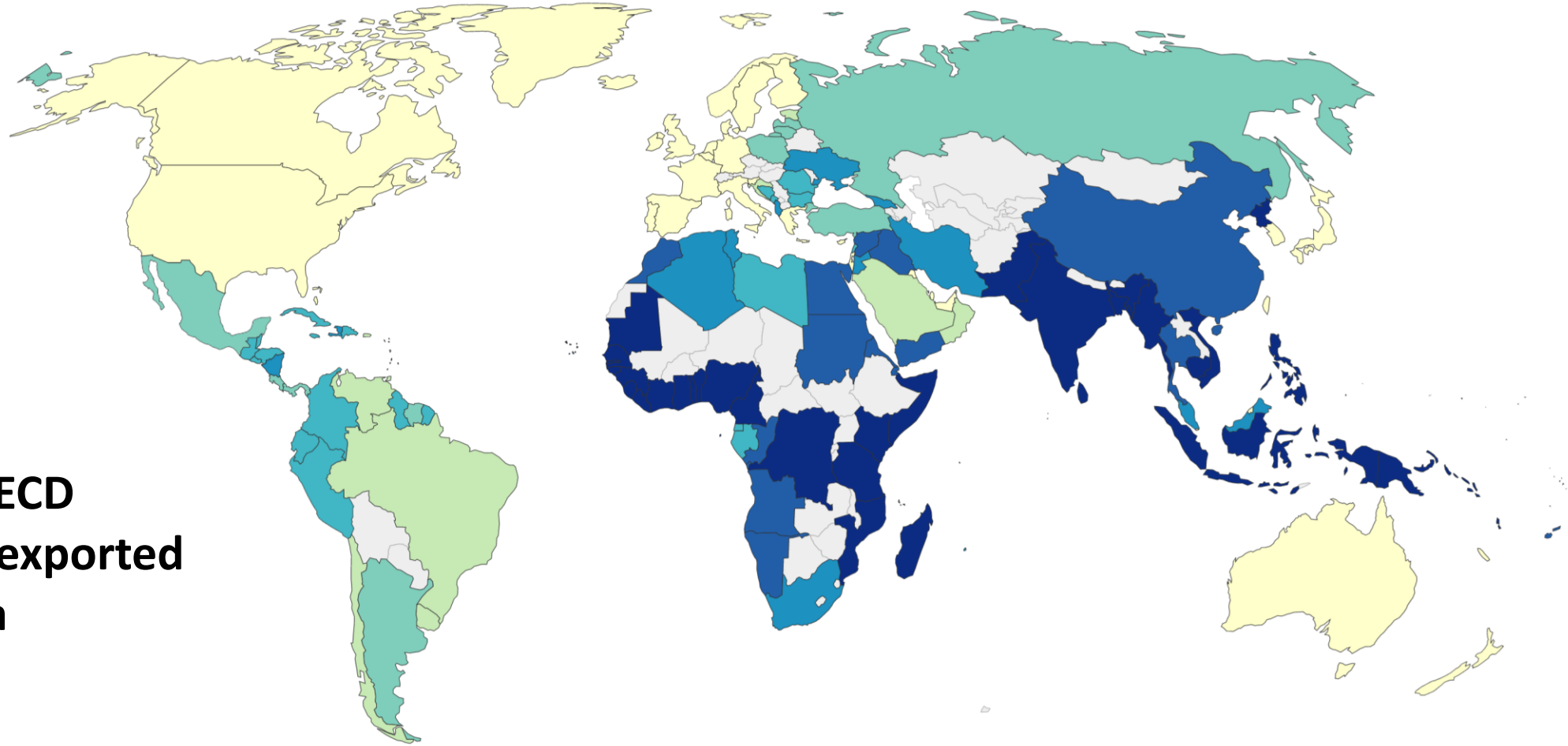
Share of Plastic Inadequately Disposed

70% of OECD plastic is exported to SE Asia



Source: Jambeck et al. (2015)

Stockholm, Sweden – Net Zero before 2030

Stockholm Exergi District Energy System (P3 with Fortum)

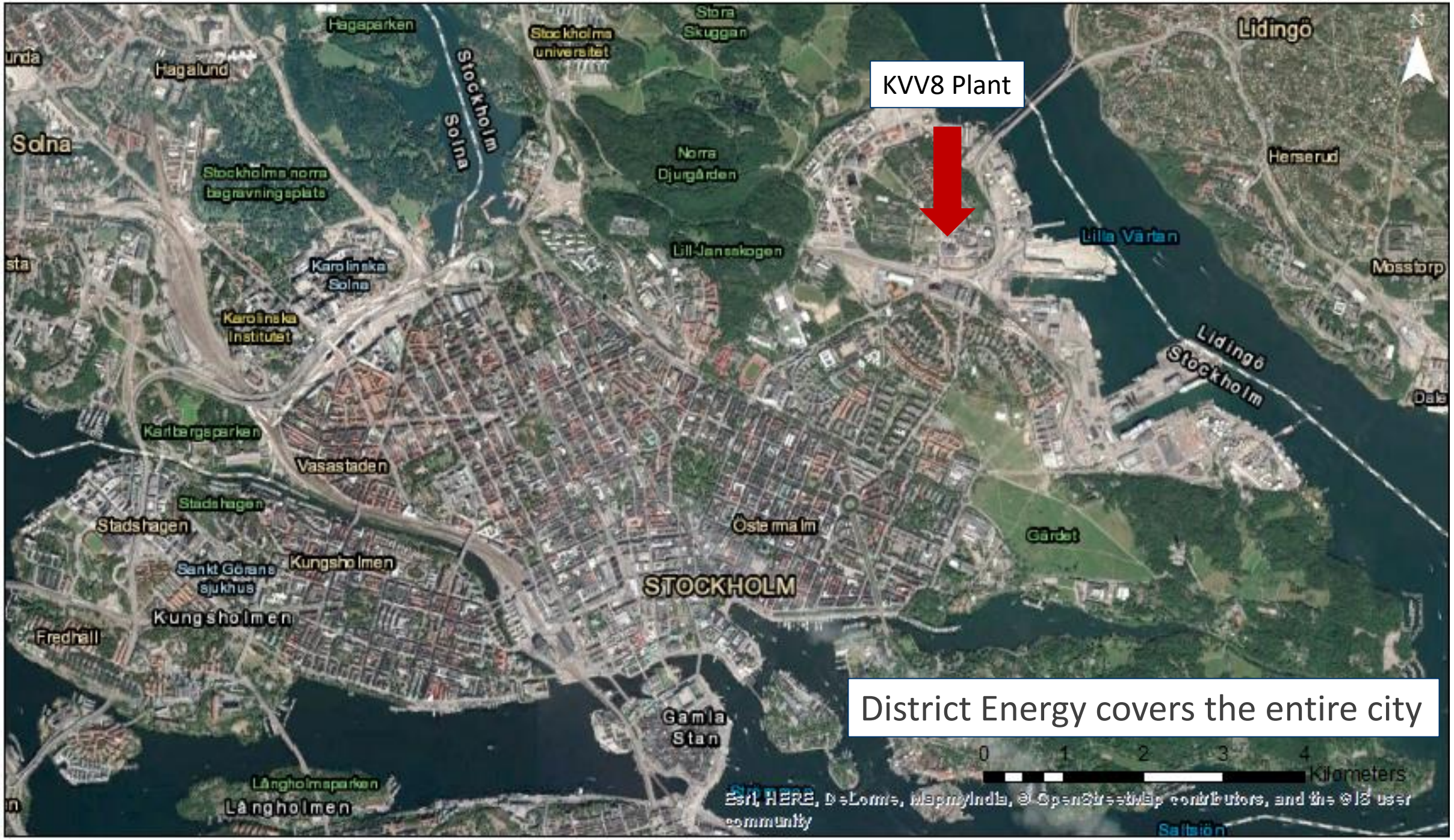
- 7,350 GWh/yr; 4,000 MW* (580 MW_e) peak capacity
- 350 km of transmission pipes; 2,800 km of distribution pipes
- >95% of buildings in Stockholm
- 90% renewable/low carbon; Net Zero by 2030
- Wood chip combined heat & power, waste-to-energy
- Currently planning 620 MW_{th} waste/biomass plant
- Planning full scale Bioenergy Carbon Capture and Storage (BECCS) for negative emissions

	Canada	Sweden
GDP Per Capita (USD)	48,100	51,300
GHG Emissions Per Capita (t CO_2e)	19.4	5.4
GHGs Per Capita (t CO_2e), incl. LULCF	18.6	0.9

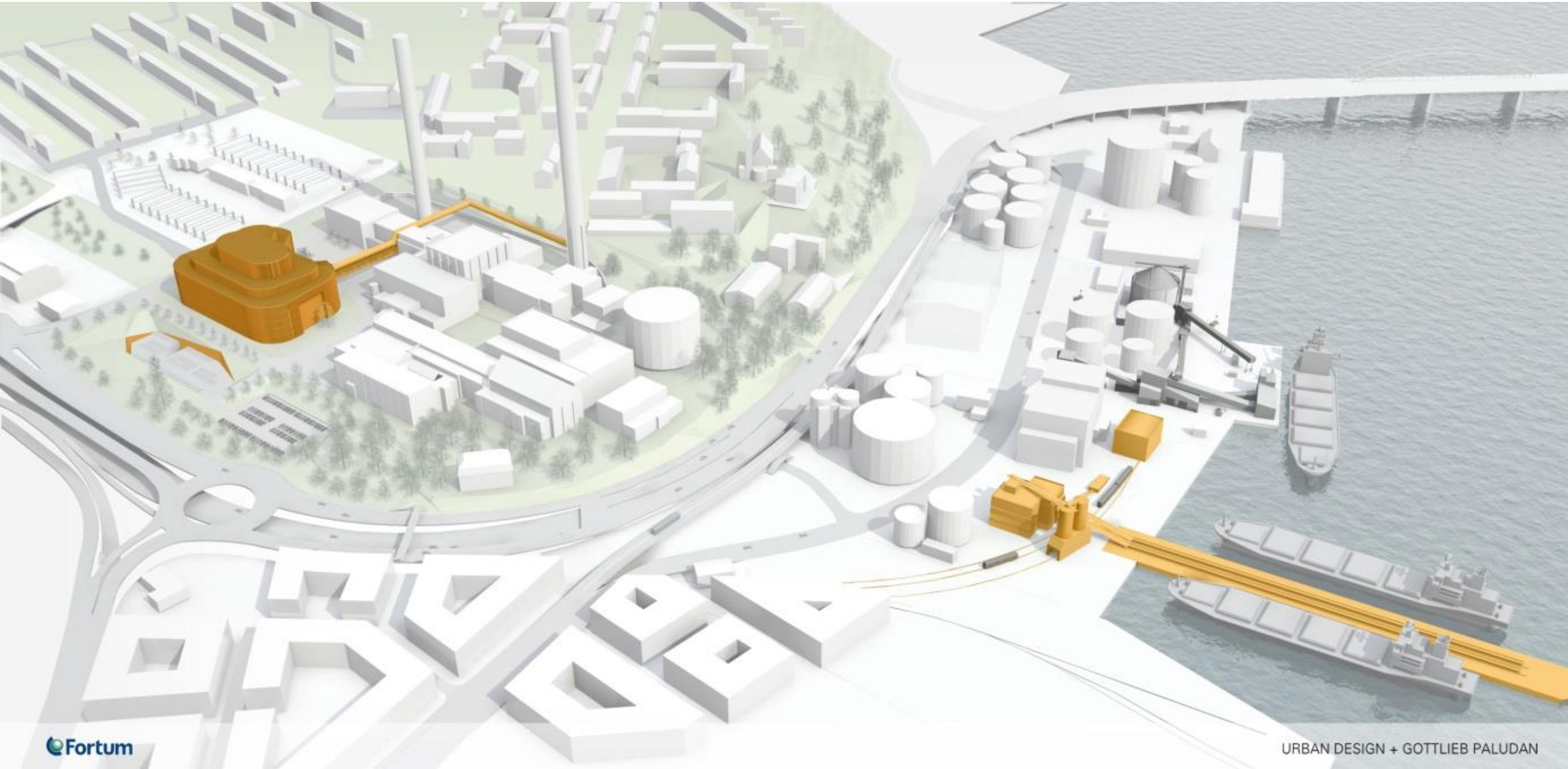
*Current Toronto (Enwave) DES peak ~380 MW; 761 GWh/yr

Stockholm Värtaverket KVV8 Biomass CHP Plant

- 400 MW_{th}
- Heats 190,000 homes via DE
- 100% wood chips (3,500 t/day)
- Commissioned in 2016
- CapEx: C$750 M
- 1,700 GWh heat (>2x Enwave)
- 750 GWh electricity
- 60% marine/40% rail
- Reduce: 650,000 t CO_2e/yr
- Footprint: 6,000 m^2
- PM emissions < natural gas

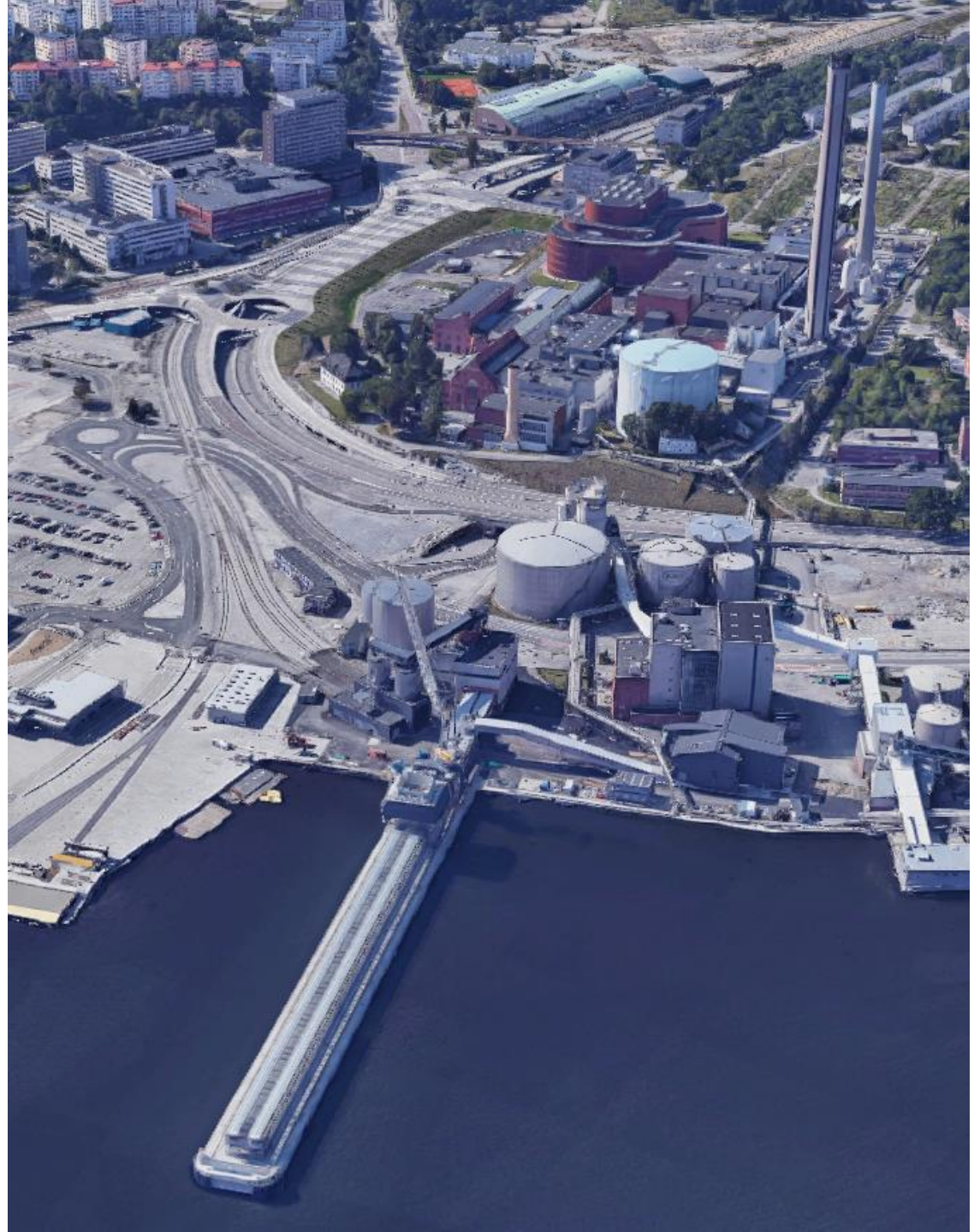

KVV8 Plant
District Energy covers the entire city
Hagaparken
Stockholms universitet
Stora Skuggan
Lidingö
Hagalund
Solna
Stockholm
Solna
Norra Djurgården
Herserud
Stockholms norra begravningsplats
Lill-Jansskogen
Lilla Värtan
Karolinska Solna
Karolinska Institutet
Mosstorp
Lidingö
Stockholm
Dale
Kristbergsparken
Vasastaden
Stadshagen
Stadshagen
Östermalm
Gärdet
Kungsholmen
Sankt Görans sjukhus
STOCKHOLM
Kungsholmen
Fredhäll
Gamla Stan
Långholmsparken
Långholmen
0 1 2 3 4 Kilometers
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


N
Residential
Stack
KVV8 Plant
0
250
500
750
1,000
Meters



Fortum

URBAN DESIGN + GOTTLIEB PALUDAN



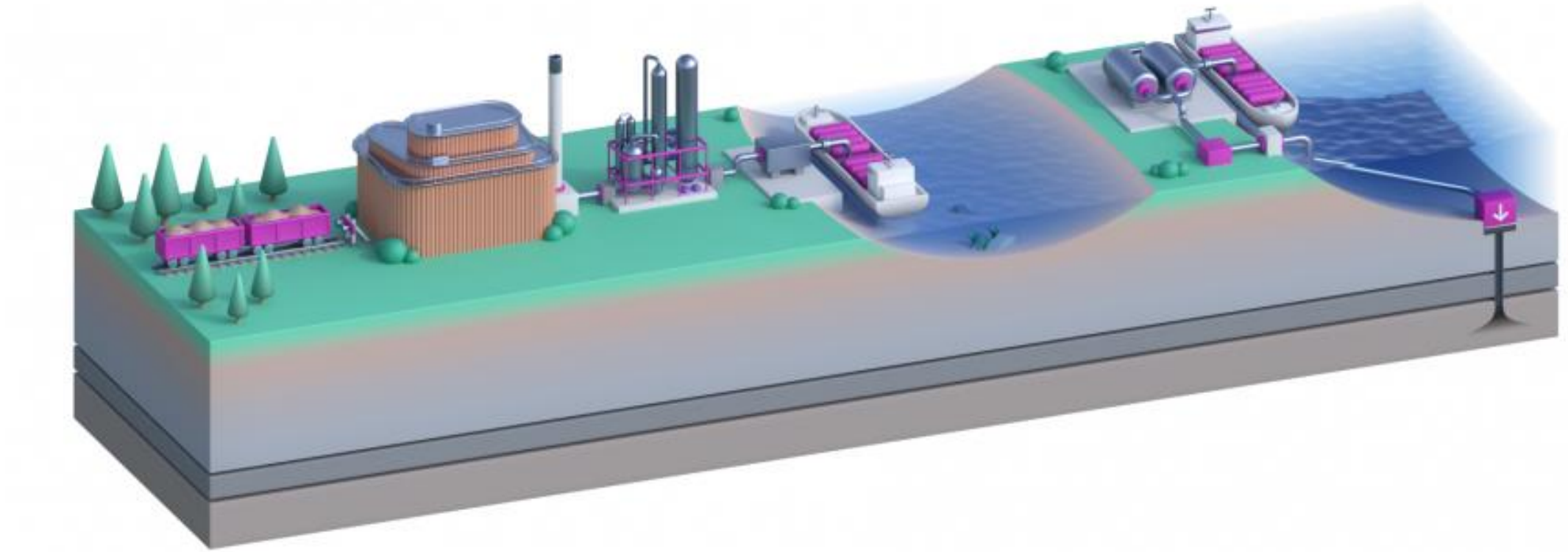

Fortum
85
innofreight


innofreight
sappi


innofreight
green cargo


innofreight
KR 200
WOODY...stephoun

BECCS at Värtaverket KVV8



Negative emissions double offset Stockholm transportation emissions

Copenhagen, Denmark – Net Zero by 2025

Copenhagen HOFOR District Energy System (City-owned)

- 8,350 GWh; 4,000 MW peak capacity
- 180 km of transmission pipes to 21 distribution systems (1,500 km)
- 99% of buildings in Copenhagen; >800 M sq ft
- 4 large biomass CHP; 4 large WtE; 2 sludge incinerators; gas peakers
- 74,000 m^3 buffer storage
- Denmark has ~400 DES – most municipality-owned or co-operatives

	Canada	Denmark
GDP Per Capita (USD)	45,000	56,300
GHG Emissions Per Capita (t CO_2e)	19.6	8.3
GHGs Per Capita (t CO_2e), incl. LULUCF	19.1	8.8

Bioenergy consumption in Denmark 2.5x greater than wind

Copenhagen Amager Bakke WtE Plant

- 247 MW_{th}
- Flex output: 0-63 MW_e/157-247 MW_{th}
- 15-18% of city's heat demand
- 560,000 t MSW/yr (>TO landfill)
- Commissioned in 2018
- CapEx: C$840 M
- Downtown Artificial ski slope
- World's highest climbing wall
- >90% efficient
- 1,000,000 MWh heat
- 400,000 MWh electricity

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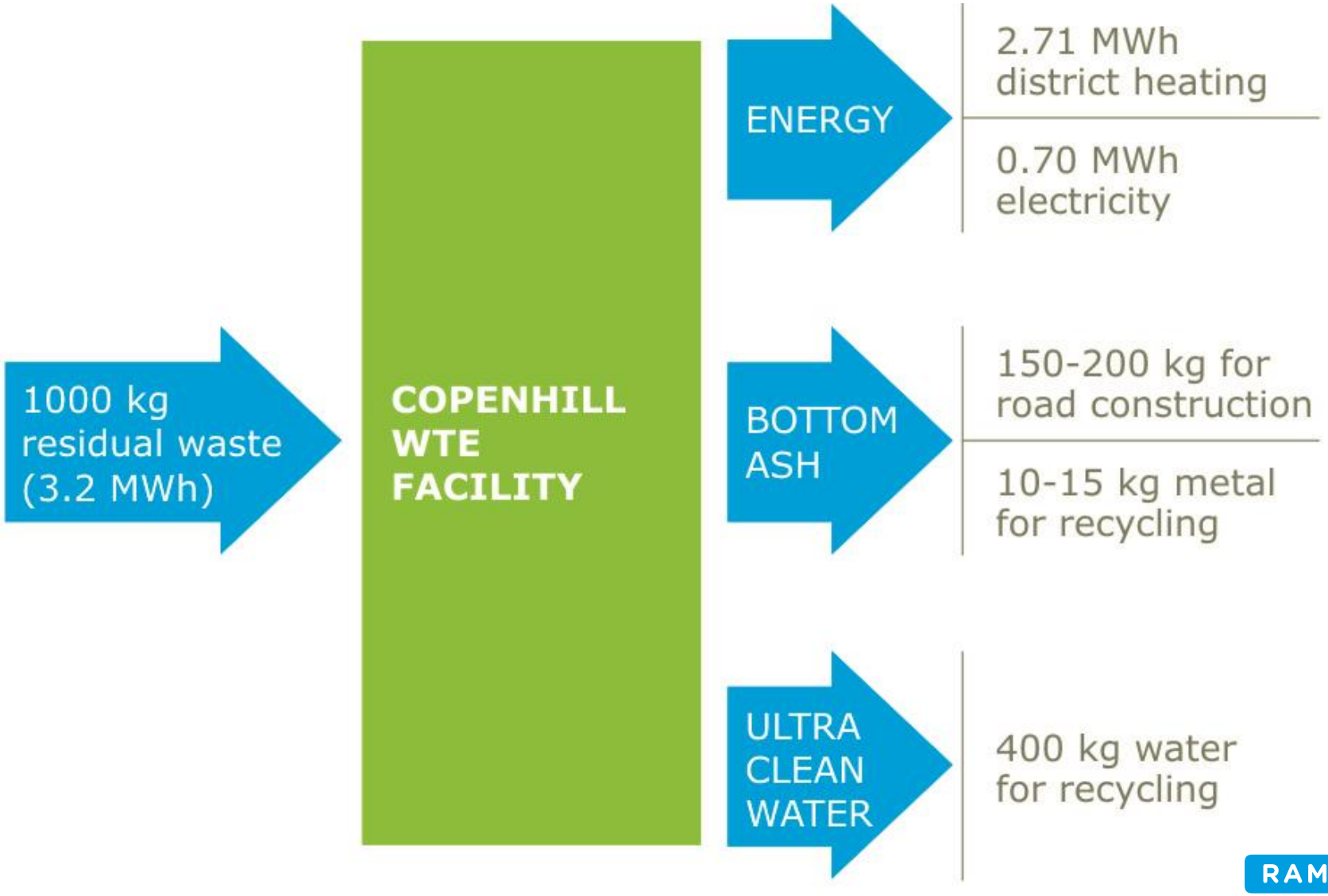
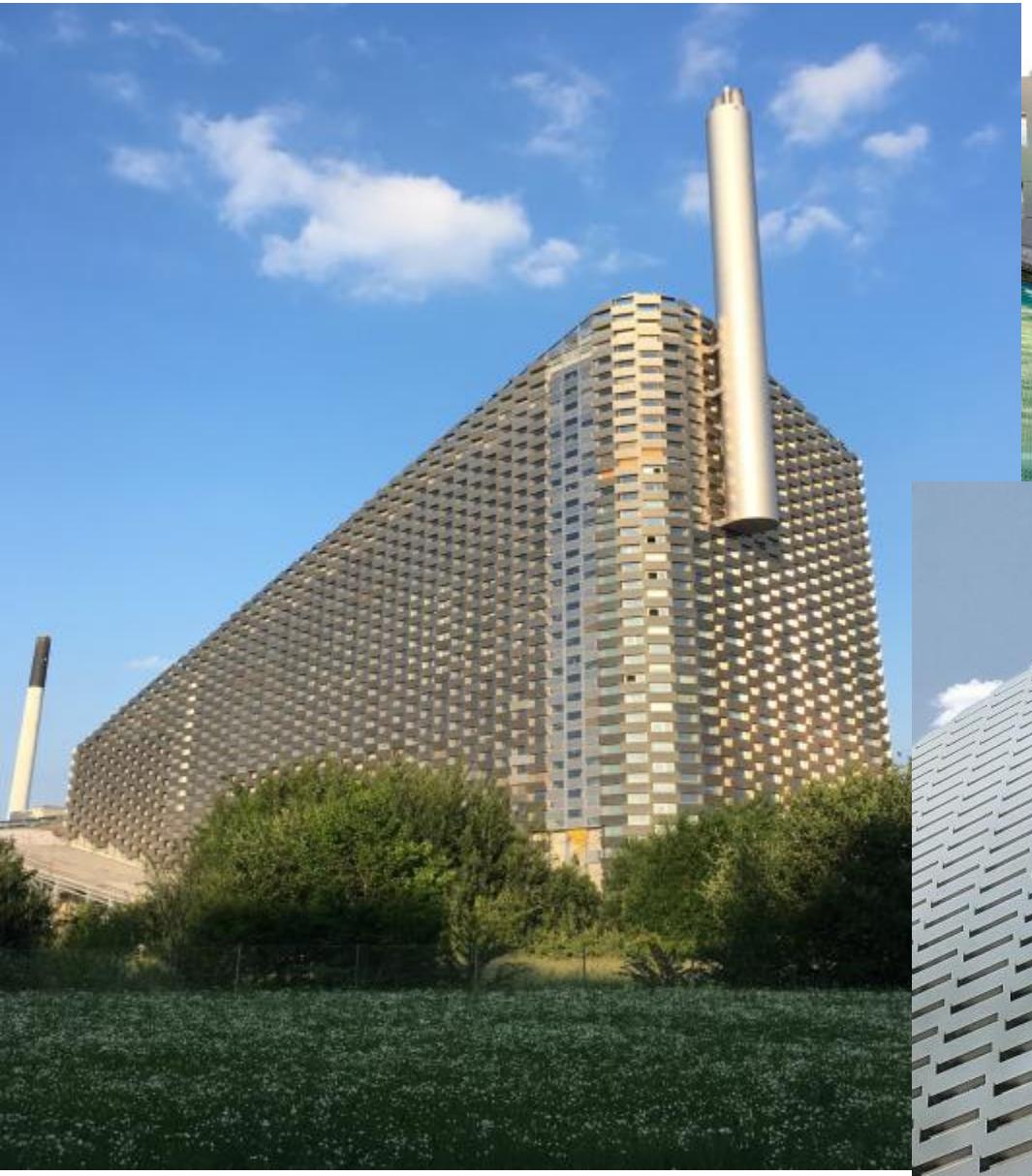
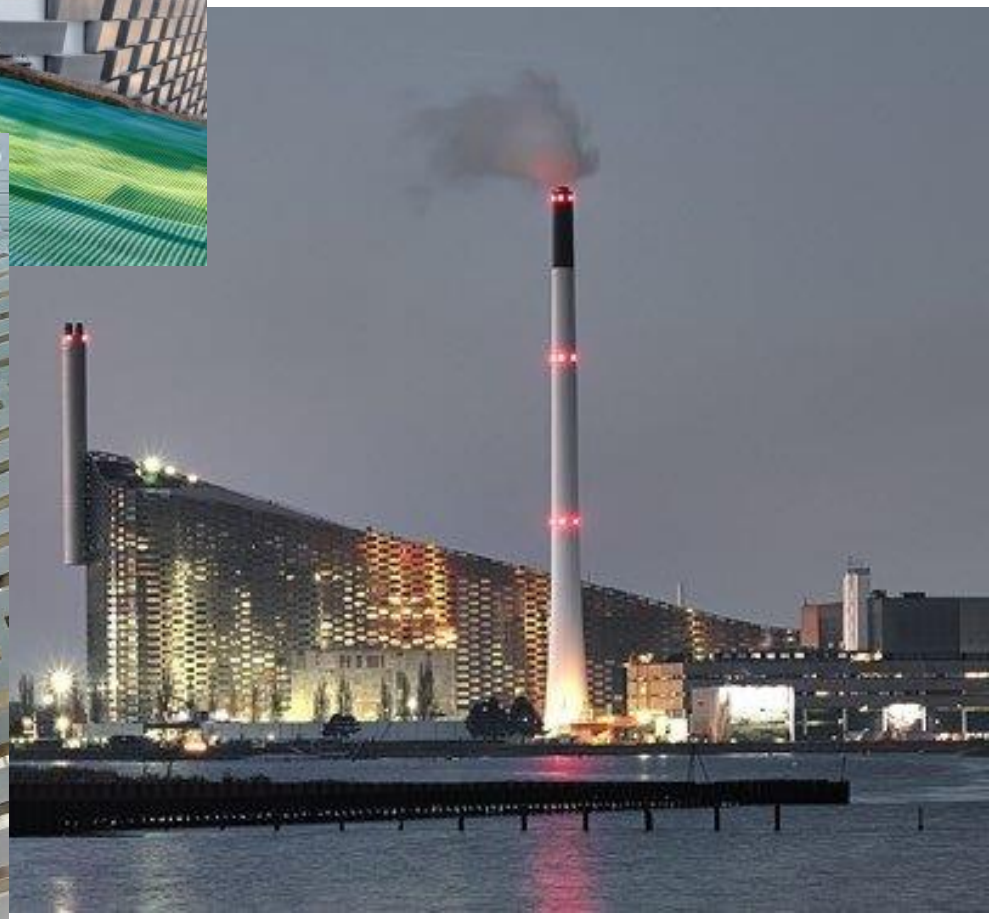
Amager Bakke Balance



RAMBØLL





Amager Bakke Emissions

Air Emission, daily average mg/m³, ref.*	EU Industrial Emissions Directive (IED), (3)	Environmental permit, (4)	Expected operational emissions
CO	50	39	10
Total organic carbon	10	8	1
Dust	10	5	3
HCl	10	5	0.5
HF	1	1	0.05
SO_2 and SO_3 (as SO_2)	50	30	2
NO_x (as NO_2)	200	100	15
NH_3	-	3	0.5
N_2O	-	-	0.5
Cd + Tl	0.05	0.025	0.001
Σ 9 metals 1)	0.5	0.25	0.015
Hg	0.05	0.025	0.001
PAH	-	0.0025	0.002
Dioxins and furans, TEQ (ng/m³, ref.*)	0.1	0.1	0.02

* ref. is reference condition,

EPA/EEA Natural Gas Furnace

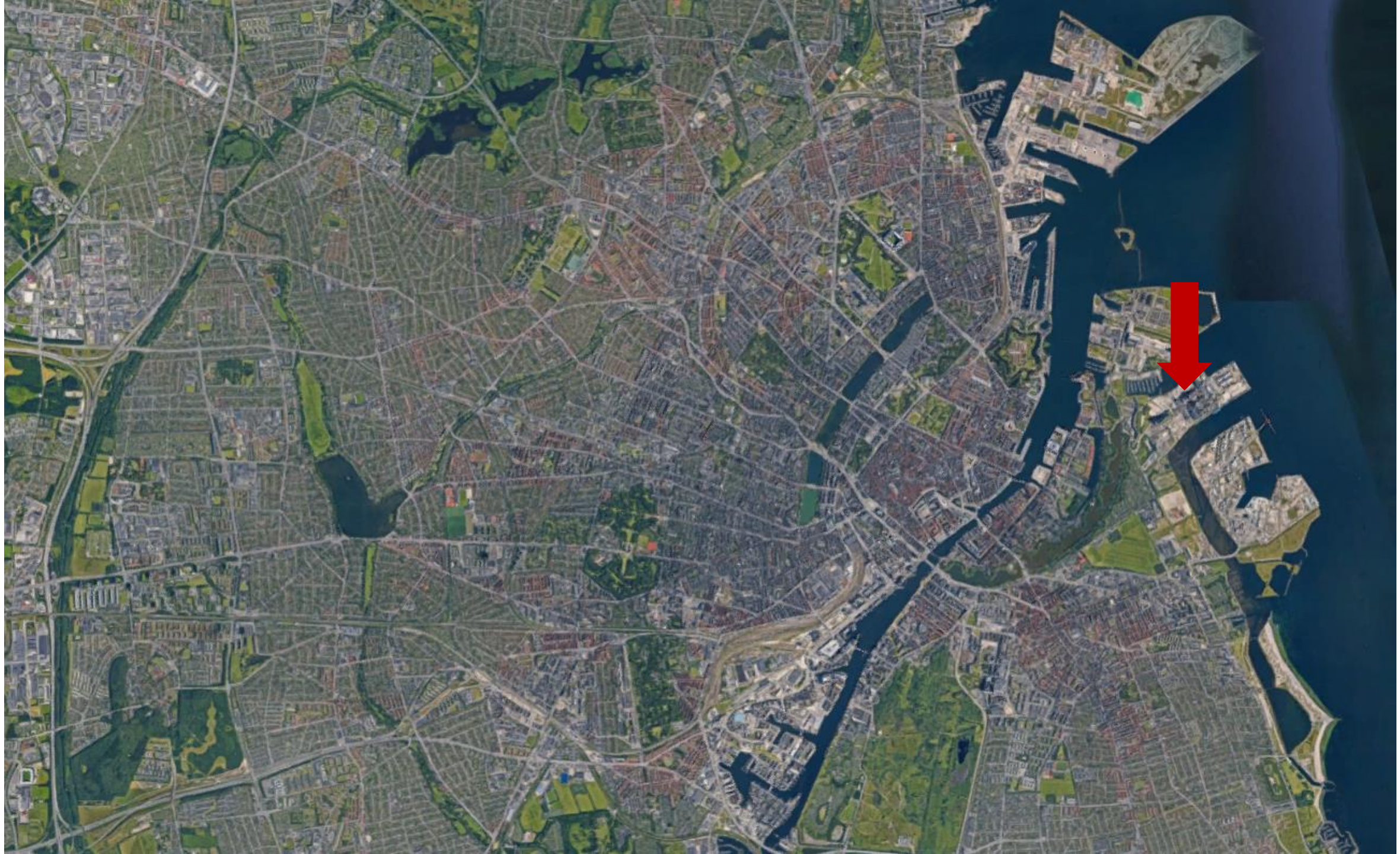
50-60

4-9

100-140

Copenhagen Amagerværket Biomass CHP Plant

- 500 MW_{th} (280_{th}/120_{e})
- Heats 210,000 homes
- 100% wood chips (4400 t/day)
- Commissioned 2020
- CapEx: C$1 B
- 2700 GWh heat (>3.5x Enwave)
- 1000 GWh electricity
- 100% marine
- Reduce: 1,200,000 t CO_2e/yr
- 25% of city heat demand
- PM emissions < natural gas
- Requires DES for operation




Residential
Residential

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Copenhagen

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Oil & Gas Vs. DE & Biomass Professions

Profession	Oil & Gas	District Energy & Biomass
Pipelayer	✓	✓
Pipefitter & Steam Fitter	✓	✓
Boilermaker	✓	✓
Welder	✓	✓
Electrician	✓	✓
Instrumentation Technician	✓	✓
Heavy Equipment Operator	✓	✓
Underground Construction	✓	✓
Architect	✓	✓
Civil Engineer	✓	✓
Concrete Finisher	✓	✓
Iron Worker	✓	✓
Survey Engineer	✓	✓
Operating Engineer	✓	✓
Stationary Engineer	✓	✓

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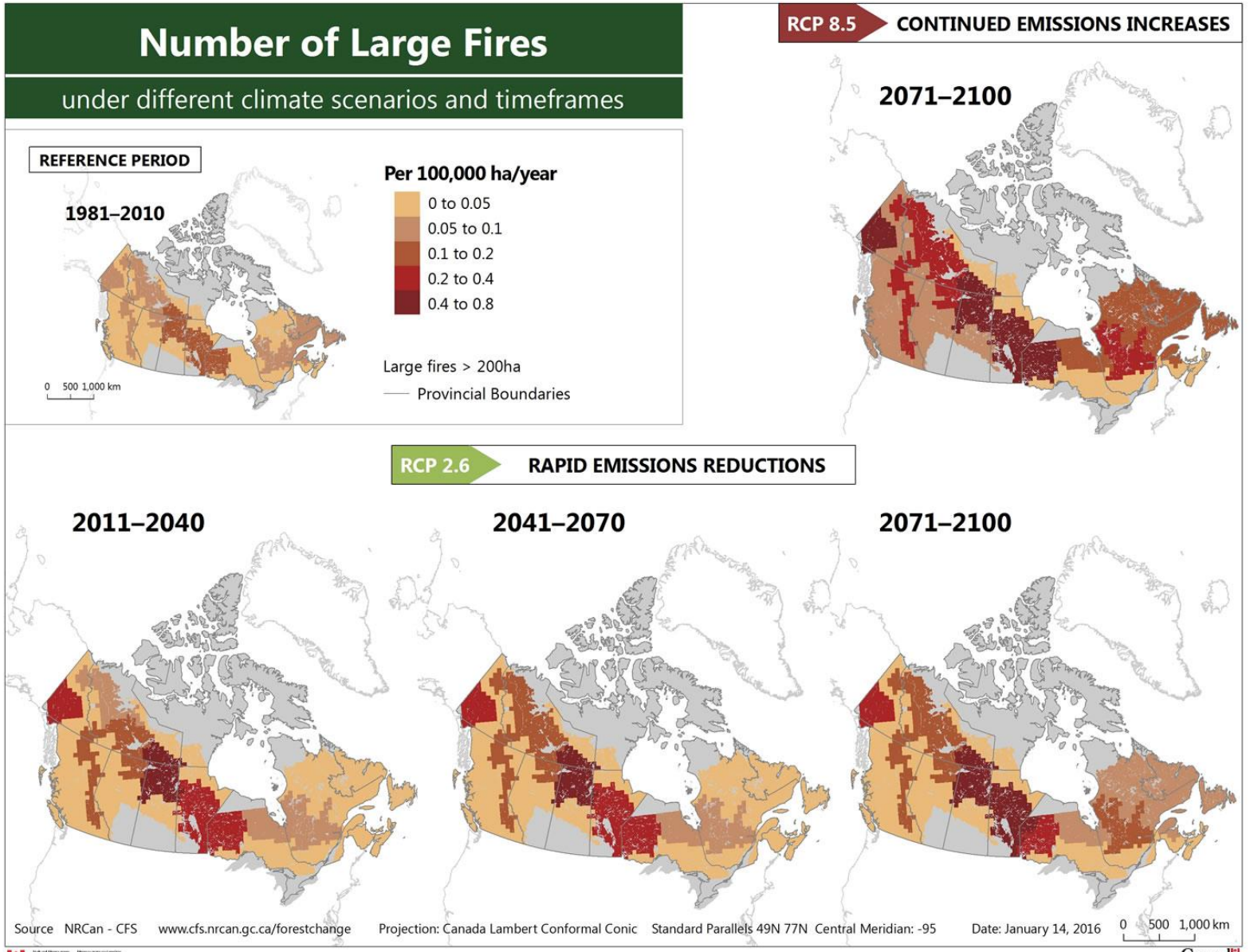
Bioenergy for Adaptation



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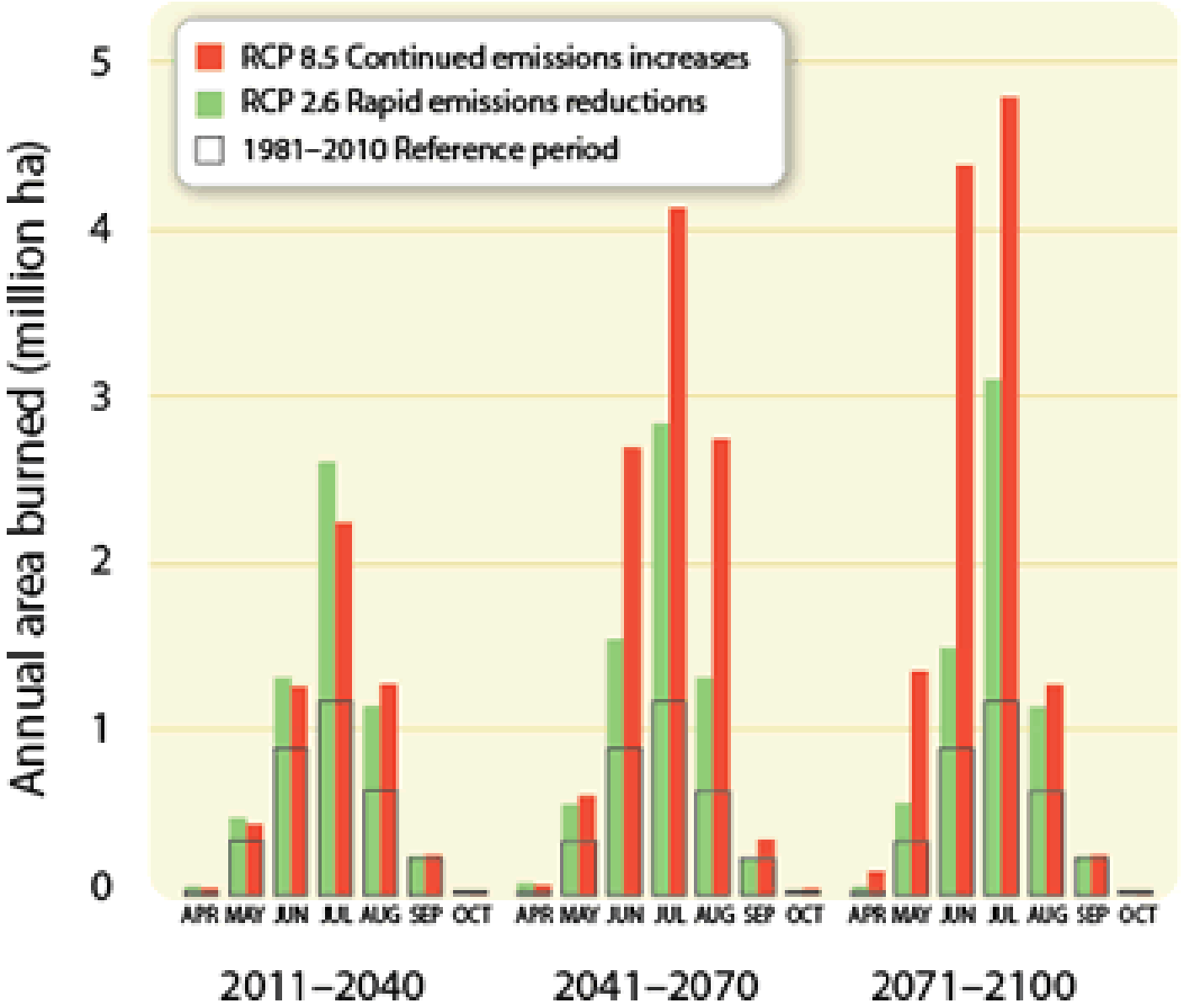
Bioenergy for Adaptation



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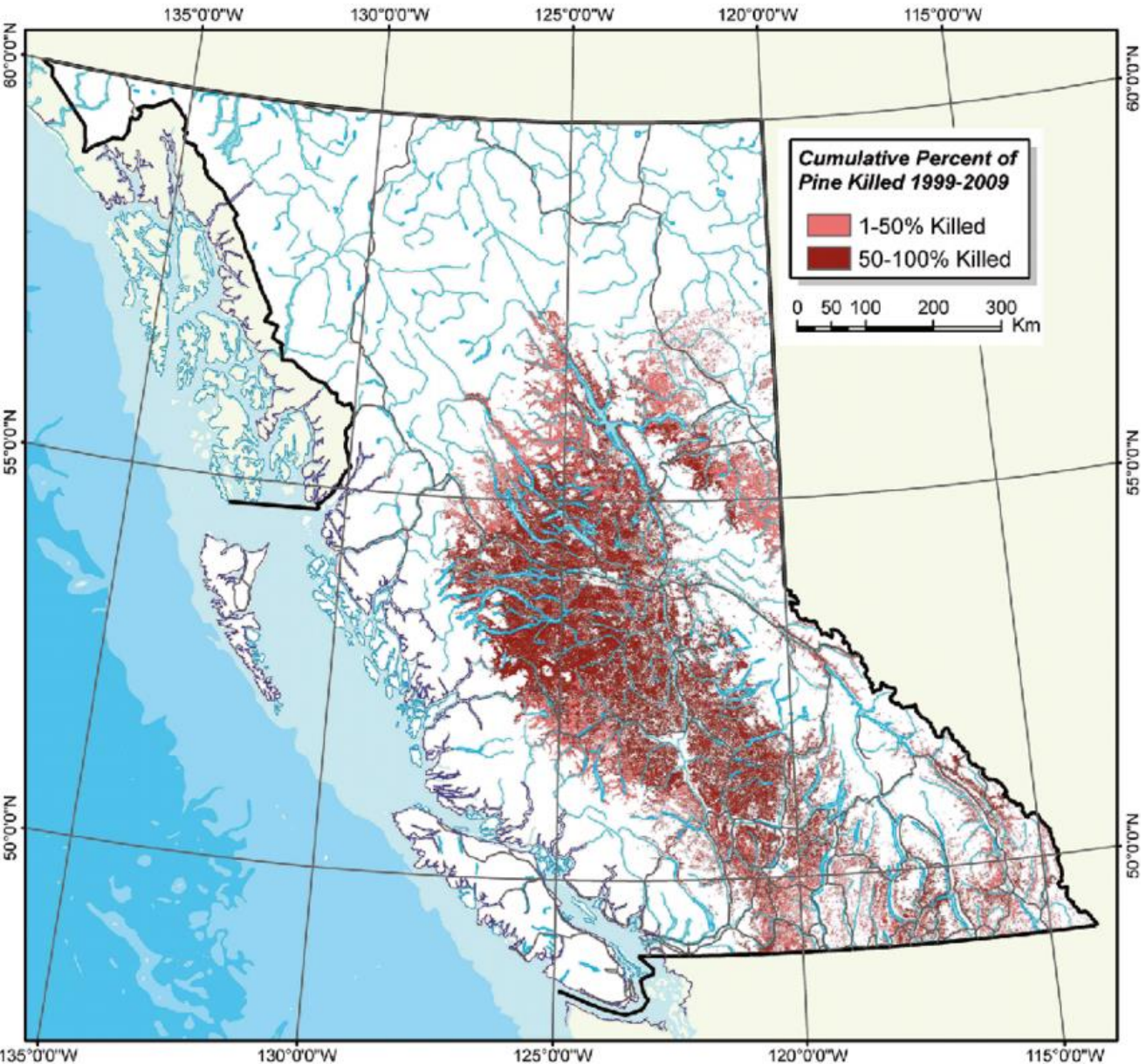
Bioenergy for Adaptation



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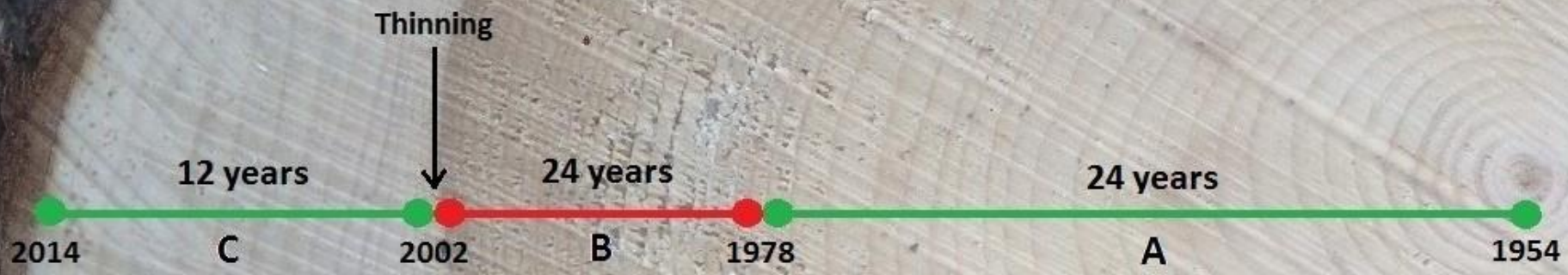
Growing Carbon Stocks

- Trees need light and space
- Active forest management INCREASES productivity & carbon uptake
- Sweden has 9% of Canada's forests, but 60% more NET carbon uptake
- Forestry reduces net GHG emissions by 80% in Sweden and 40% in Finland
- Finland & Sweden harvest 8-10x the volume per forested acre as Canada
- Removal of diseased/poor quality trees to improve forest vigour & resilience
- Single tree selection, uniform shelterwood
- Strip cut & clear cut where needed –dominant species stunting productivity
- Complete avoidance of high-grading

EFFECT OF THINNING ON TREE GROWTH



Average Growth of Diameter

Period B: 0.16 cm/year
Period C: 0.50 cm/year

Percentage of increase in growth after thinning: 212%

A. Period of rapid growth

- Water and light available in large quantity

B. Period of Declining Growth or Stagnation Period

- Competition among trees for water and light

C. Period of increased growth

- Increase in growth after thinning due to the greater amount of water and light available

Courtesy of Mathieu Leblanc
ACFOR Energy

BIO CCS

BIOENERGY WITH
CARBON DIOXIDE
CAPTURE & STORAGE

01

SUSTAINABLE BIOMASS GROWTH

Non-food biomass is grown, absorbing CO_2 from the atmosphere and energy from the sun.

02

BIOMASS TRANSFORMATION

Energy in Biomass is converted into, Heat, Electricity or Biofuels.

03

CO_2 CAPTURE & COMPRESSION

The CO_2 from biomass is captured and prevented from returning to the atmosphere. The CO_2 is compressed ready to transport.

04

CO_2 TRANSPORT

The CO_2 is transported via pipeline or ship.

05

PERMANENT CO_2 STORAGE

CO_2 is injected deep underground at specially selected and researched storage sites, trapped in microscopic pores in deep rocks.

TorchLight Bioresources

Why District Energy?

1. Fuel flexible, **FUTURE-PROOF** infrastructure for cities & towns

2. The **PROVEN** approach for urban decarbonization

3. Enable the use of low cost, unprocessed **LOW CARBON FUELS**

4. Address **URBAN-RURAL** divide on decarbonization and job creation

5. Development requires same **SKILLS AND TRADES** as oil and gas

6. Enables Climate-Smart Forestry, including climate **ADAPTATION**

7. Centralization of energy generation permits **NEGATIVE EMISSIONS** via BECCS

8. Source of **INCOME** for municipalities, increasing robustness and resiliency

District Energy Systems

Canada's Missing (Low Carbon) Infrastructure

TorchLight Bioresources

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