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# Is district heating a cost-effective way to heat Irish buildings ?

Jason Mc Guire & Prof. Hannah Daly
Energy Policy & Modelling Group at MaREI, UCC
ESRI Climate & Energy Research Seminar, 30th May 2023

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# What is District Heating?

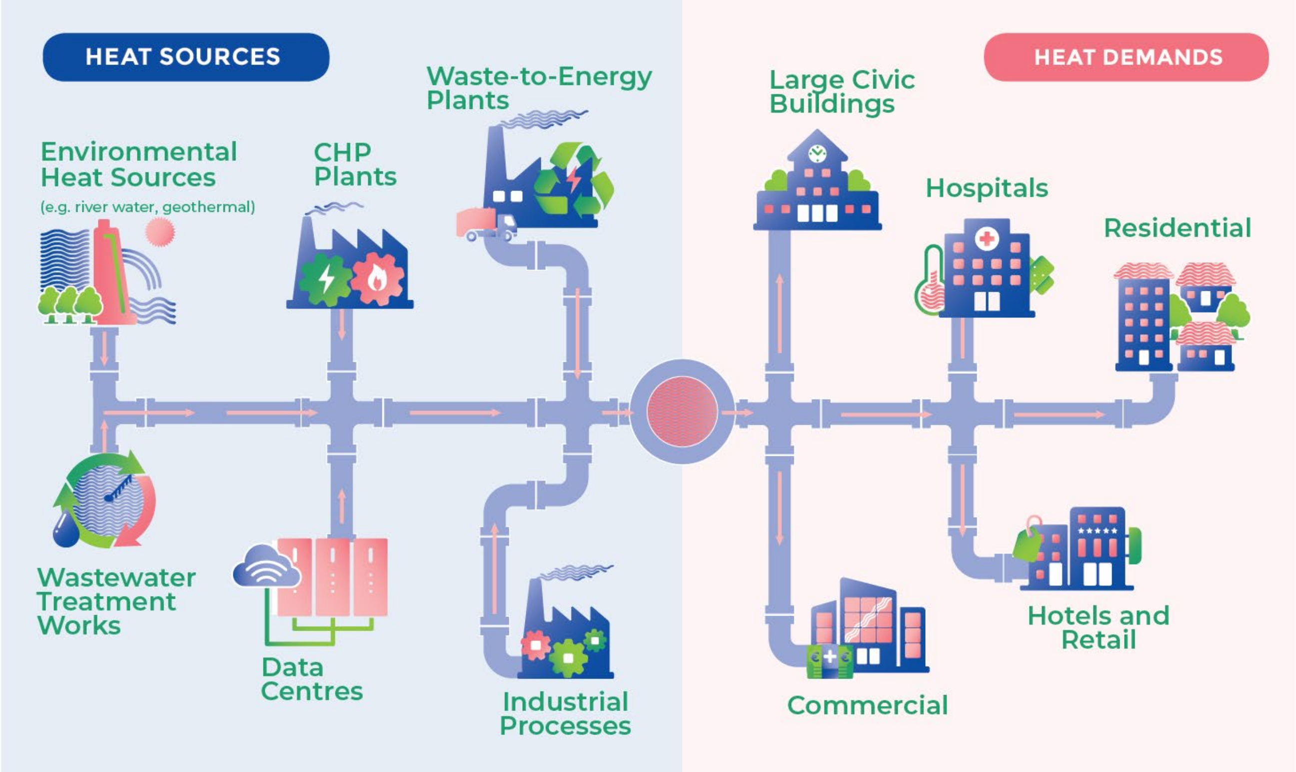


**Figure 1.** Simplified District Heating Overview.
(https://guidetodistrictheating.eu/guidance-for-cities-and-towns/is-district-heating-suitable-for-my-area/ )

District Heating (DH) is a network of insulated underground pipes that transport pressurized heated water from heat sources to buildings.



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# Why District Heating?

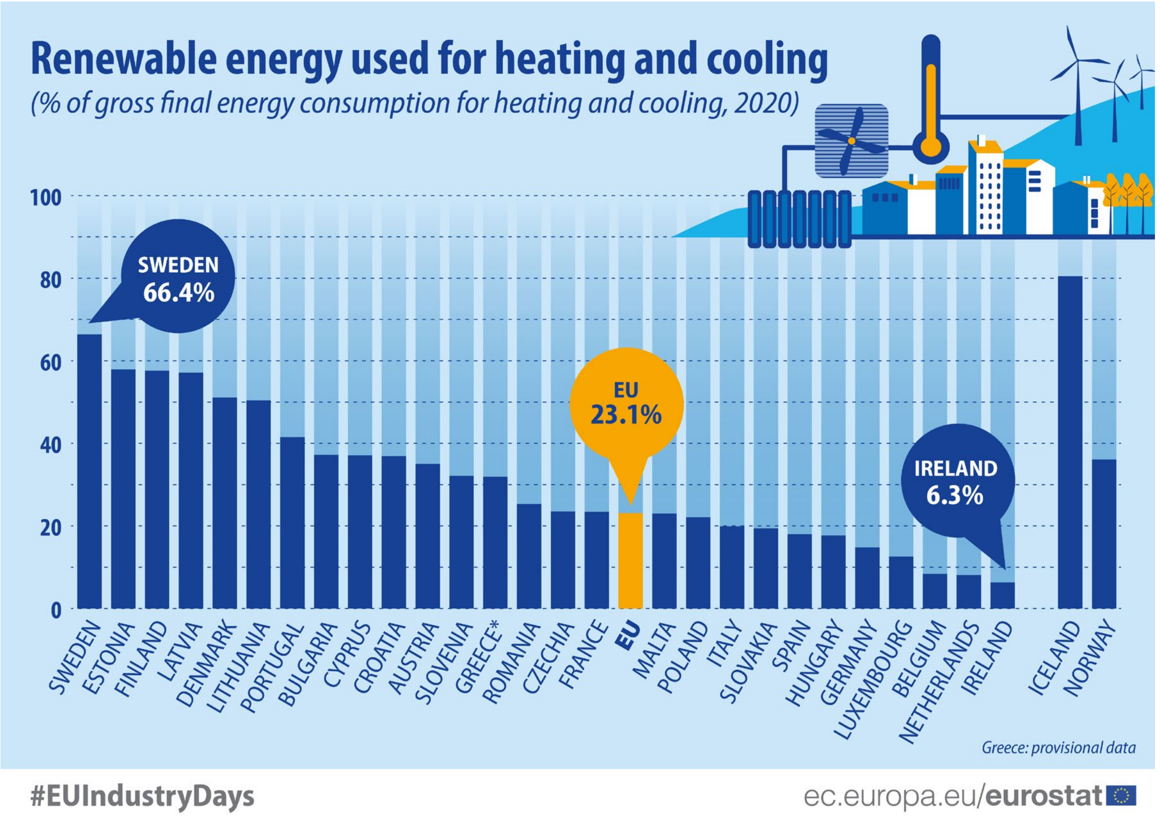


**Figure 2.** Renewable Heating in Europe

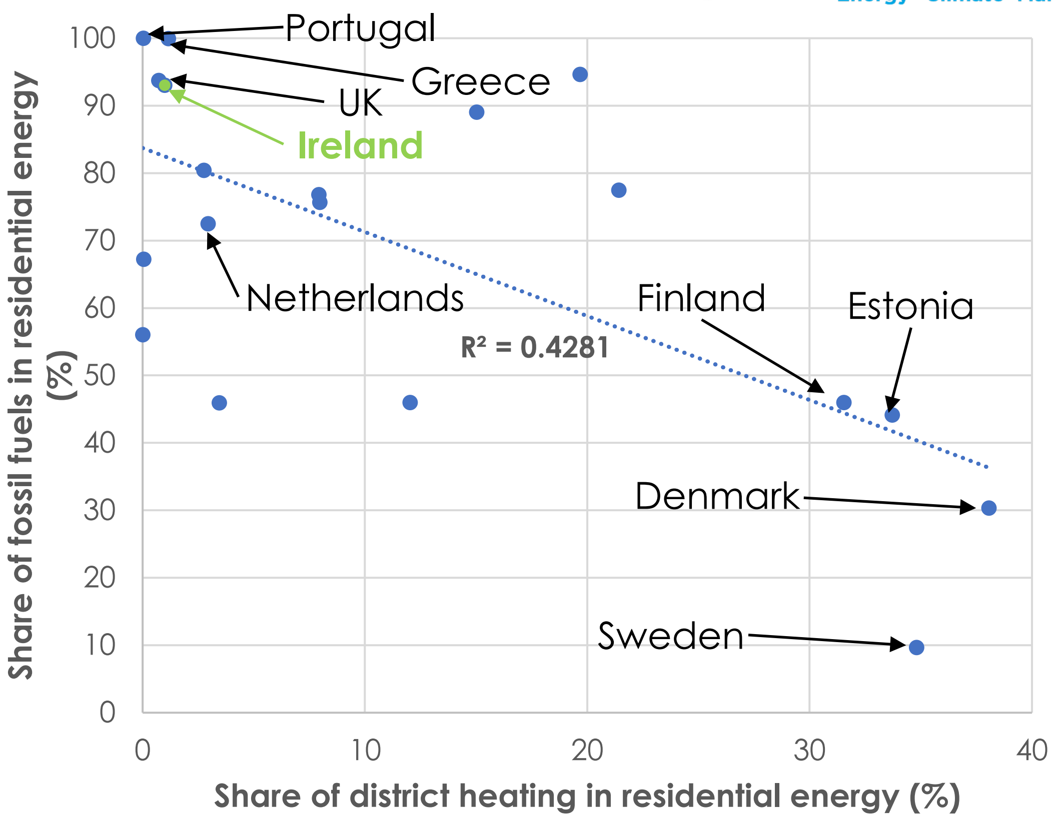


**Figure 3.** Share of residential energy demand against the share of fossil fuel in DH in 2017

DH systems provide local **employment** & improved **air quality.** They were initially developed to enhance **energy security** & **decrease expenses**, and as a result, they typically relied on fossil fuels. However, modern DH systems prioritise **decarbonisation.**

# Previous DH Studies in Ireland

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| DH Potential | Surplus Heat Potential | Report by | Published Year |
|---|---|---|---|
| 1.5% | 1% | AECOM & SEAI | 2015 |
| **57%** | 67% | Irish District Energy Association (HRE Methodology) | 2019 |
| **56%** | 57% | Renewable Energy Ireland | 2021 |
| **54%** | 38% | SEAI Heat Study | 2022 |

**Table 1.** The potential share of heat in the residential and services sector, which district heating networks could serve, and the potential share of surplus heat supply within the district heating networks

DH was not a decarbonisation option in Ireland due to low modelling feasibility thresholds, which have now multiplied by 10. Recent studies reveal DH potential of **54-57%** in Ireland. Furthermore, the Dublin Regional Energy Master Plan (2021) shows that DH can feasibly supply up to **87%** of Dublin's heat demand by 2050.



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# Methodology Roadmap

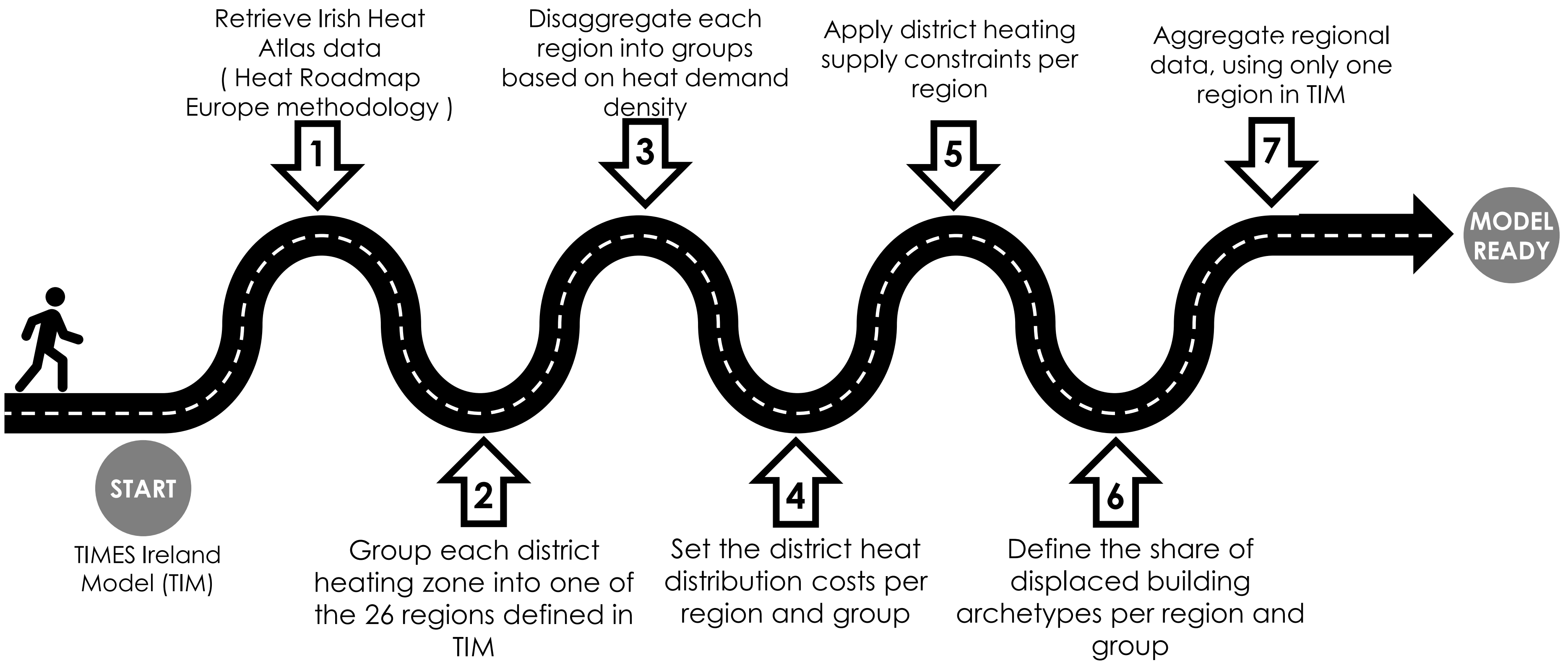
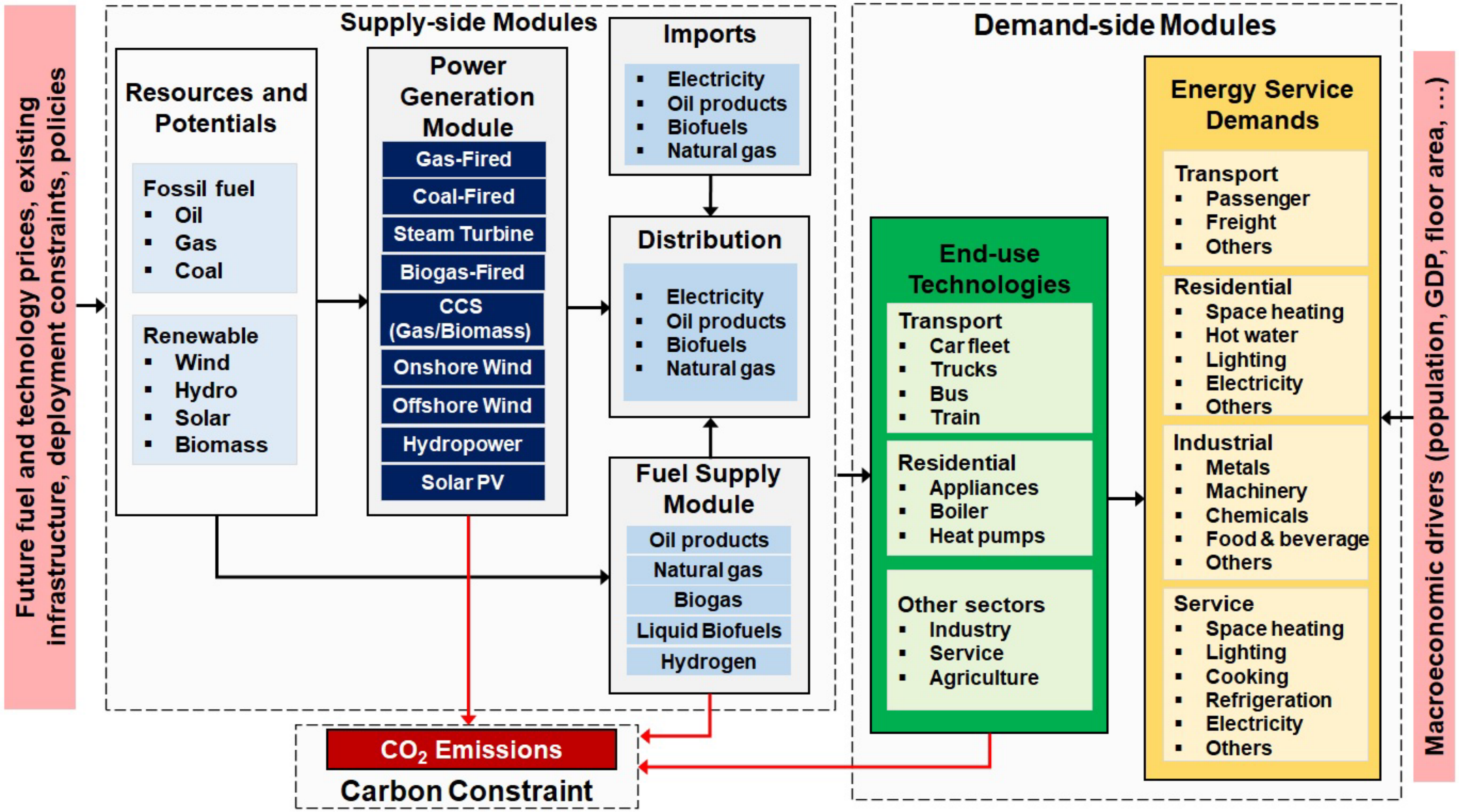



**Figure 4.** District Heating Methodology Roadmap Overview

This study analyses demand data, calculates distribution costs, and quantifies regional DH supply. The aggregated data simplifies the model, while scenarios are illustrated later in this presentation.

# TIMES-Ireland Model (TIM)

*TIM is an Energy Systems Optimisation Model (ESOM) which calculates the "least-cost" configuration of the energy system which meets future energy demands, respecting technical, environmental, social & policy constraints defined by the user.*




Download full documentation paper: https://tim-carbon-budgets-2021.netlify.app/documentation/tim-documentation-paper.pdf

## Given

- Final energy demands
  - e.g., passenger kms, home heating
- $CO_2$ constraints on energy
  - e.g., carbon budget, annual target
- Technology, fuel costs & efficiency
  - Existing & future cost and performance
- Resource availability
  - e.g., on/offshore wind, bioenergy
- User-defined constraints
  - e.g., speed of technology uptake, policies

## TIM calculates

- "Least-cost" energy system meeting all constraints
- Investment and operation of energy technologies
- Emissions trajectories
- Total system cost
- Imports/exports
- Marginal energy prices

# District Heating Schematic

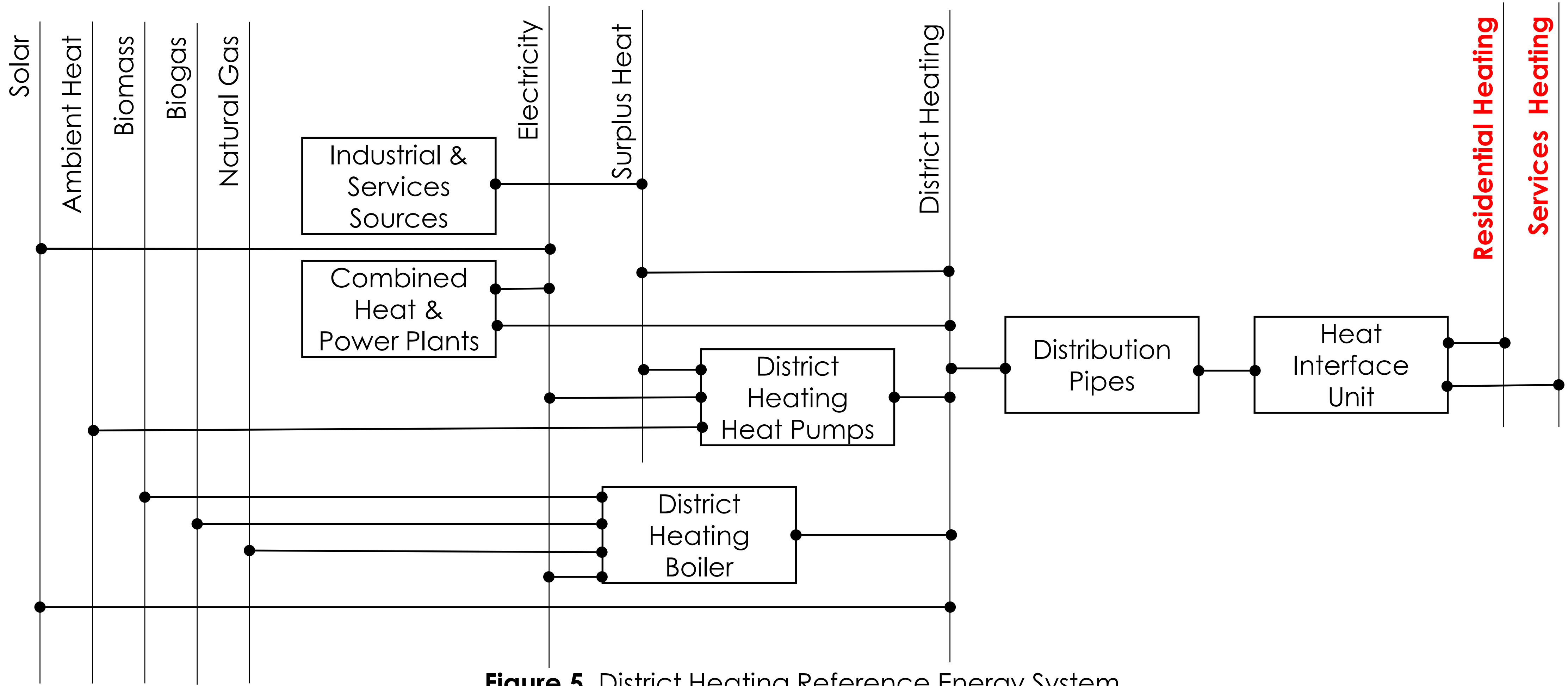



**Figure 5.** District Heating Reference Energy System

The flow of DH from supply to demand in TIM is illustrated from left to right. Furthermore, the sectoral heating is divided into different groups shown on the next slide.

# Heat Demand Density Groups

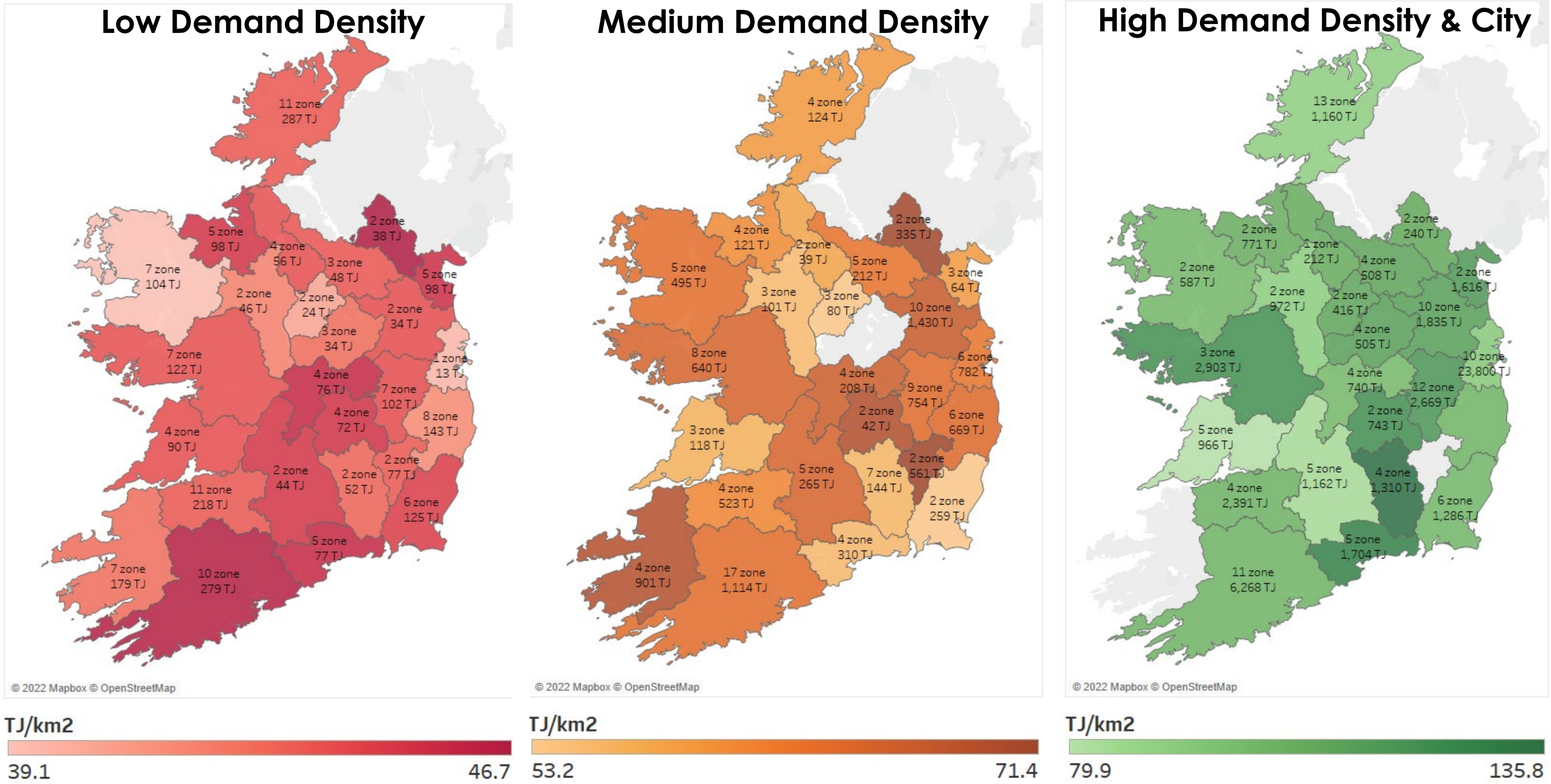



**Figure 6.** Number of potential DH zones and the cumulative heat demand per group and region

| Group | Condition | Heat Market |
|---|---|---|
| City | Municipality | 15,944 TJ |
| High density demand | > 75 TJ/km$^2$ | 12,026 TJ |
| Medium density demand | 50-75 TJ/km$^2$ | 5,145 TJ |
| Low density demand | < 50 TJ/km$^2$ | 1,268 TJ |

**Table 2.** National Overview of DH market per group.

The heat demand density threshold is based on an even distribution of DH zones per heat density demand group. There are 369 potential DH zones.

# Scenarios

| Sector | 2018 | CB1 (2021-2025) | CB2 (2026-2030) | CB3 (2031-2035) | 2050 |
|---|---|---|---|---|---|
| Electricity | 10 | 40 | 20 | | |
| Residential | 7 | 29 | 37 | | |
| Services | 2 | 7 | 23 | | |
| Other | 49 | 219 | 120 | | |
| **Total** | **68** | **295** | **200** | **151** | **0** |

**Table 3.** Ireland's sectoral and national carbon budgets, & climate targets ($MtCO_2$) used in TIM

Sectoral and national carbon budgets, and the net-zero target are core constraints in each scenario

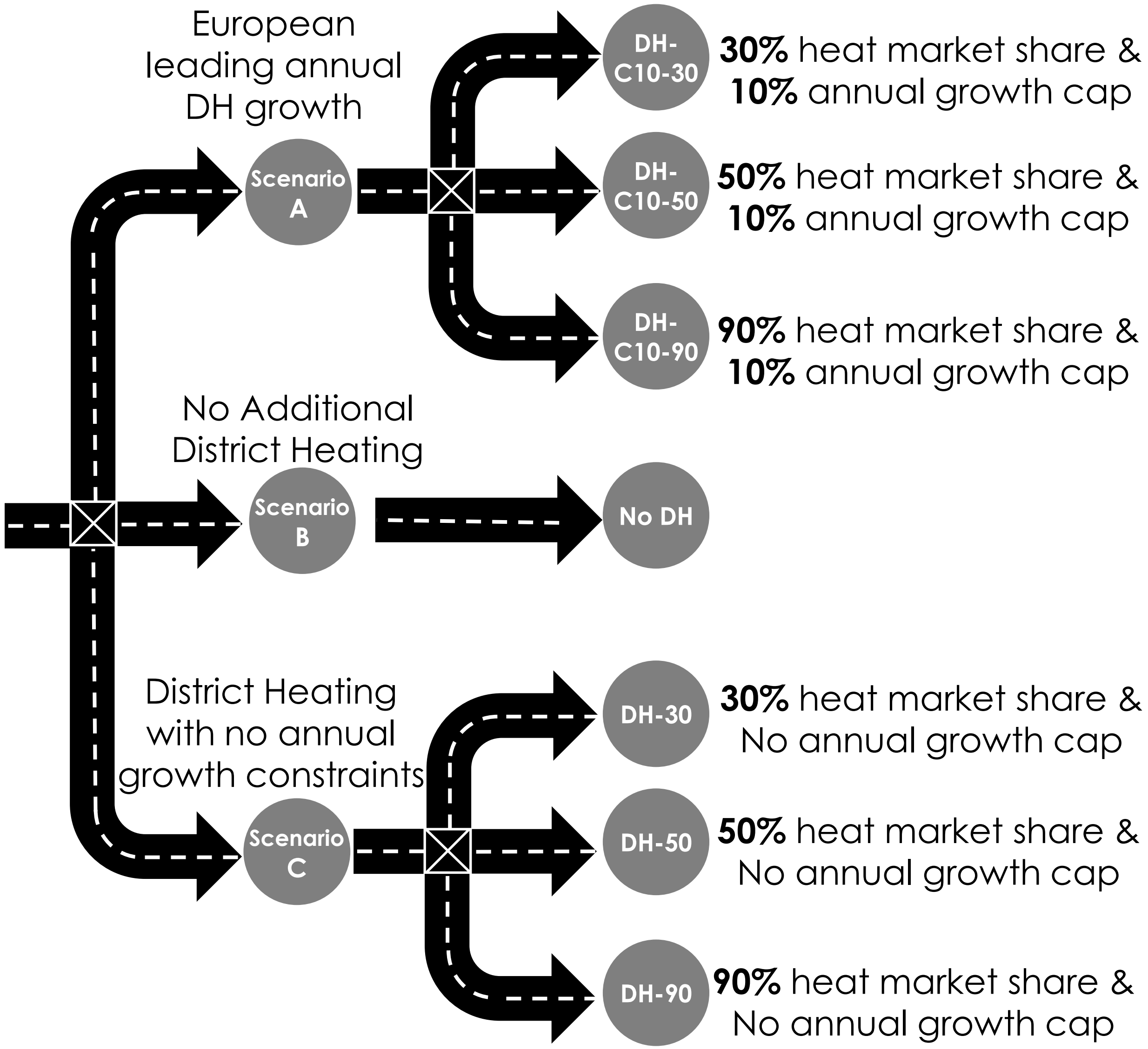



**Figure 7.** Scenarios

# Scenarios – Cost

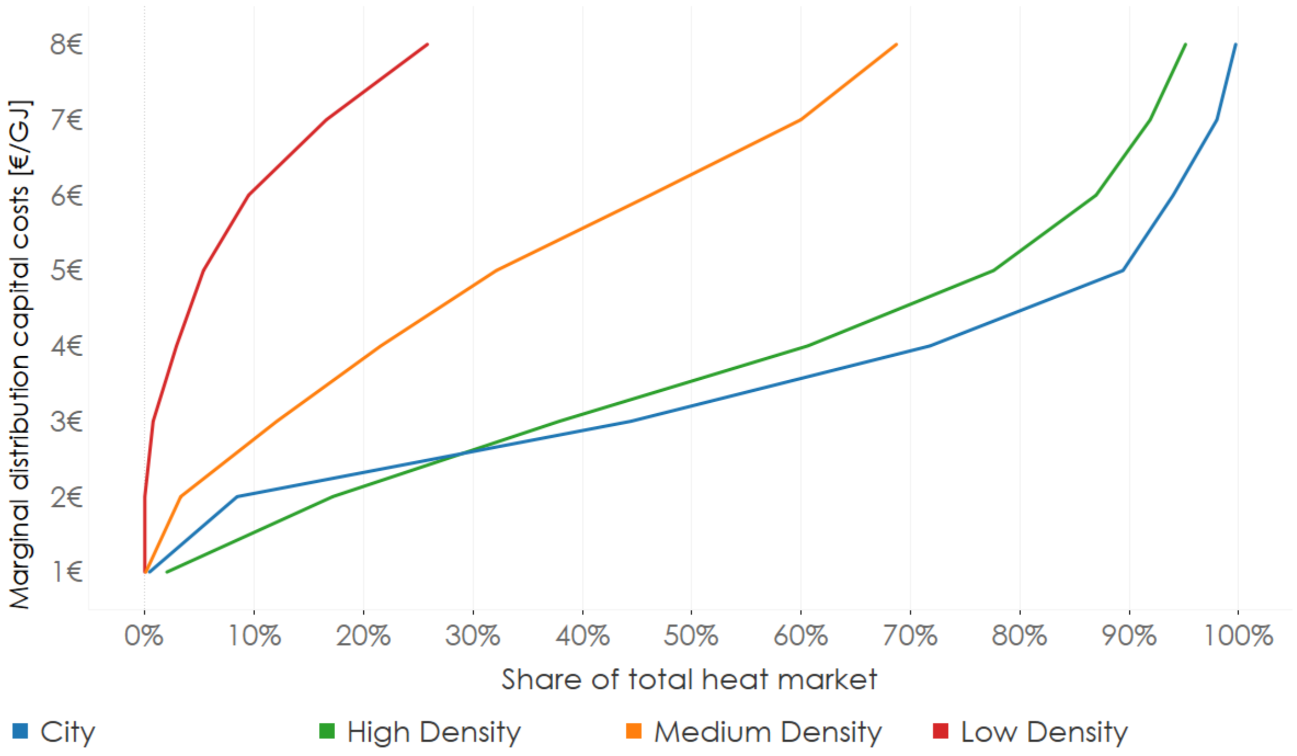



**Figure 8. Marginal** distribution capital cost, $C_d$, is illustrated for each group and the corresponding district heat market shares ( Source: Irish Heat Atlas)

| | 30% | | 50% | | 90% | |
|---|---|---|---|---|---|---|
| | $C_{d,a}$ | $Q_s$ | $C_{d,a}$ | $C_{d,a}$ | $C_{d,a}$ | $Q_s$ |
| City | 2.37 | 9.6 | 3.04 | 15.9 | 4.88 | 28.7 |
| High demand | 2.54 | 7.2 | 3.23 | 12 | 5.49 | 21.6 |
| Medium demand | 4.35 | 3.1 | 5.68 | 5.1 | 10.15 | 9.3 |
| Low demand | 9.24 | 0.8 | 12.2 | 1.3 | 20.8 | 2.3 |

**Table 4. Average** distribution capital cost, $C_{d,a}$ (€/GJ) and associated Heat sold $Q_s$ ( PJ) used.

The **average** distribution cost is used here, expressing the accumulated costs by accumulated heat demands for each **marginal** distribution cost level (10 levels). A sensitivity analysis (30,50 & 90%) explores the cost & heat market effect.

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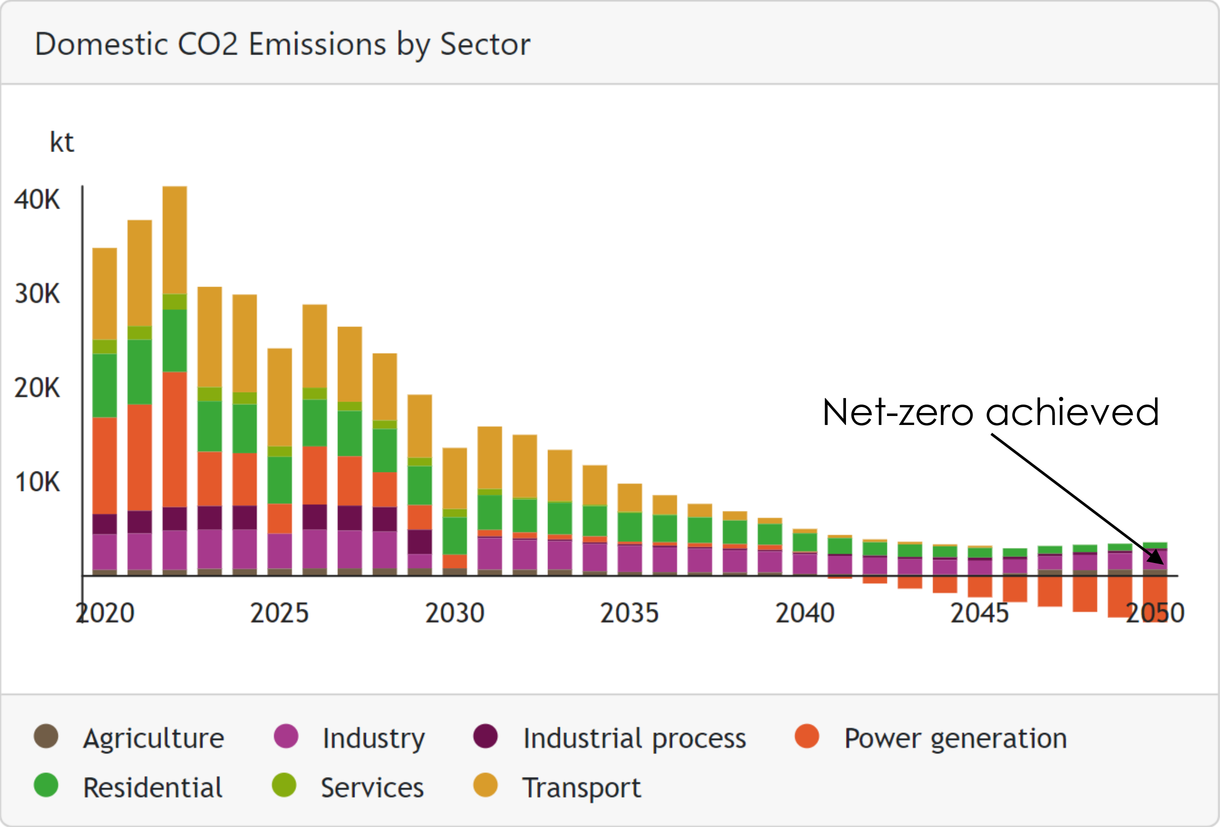


**Figure 9.** DH-C10-90 Annual Sectoral Emissions

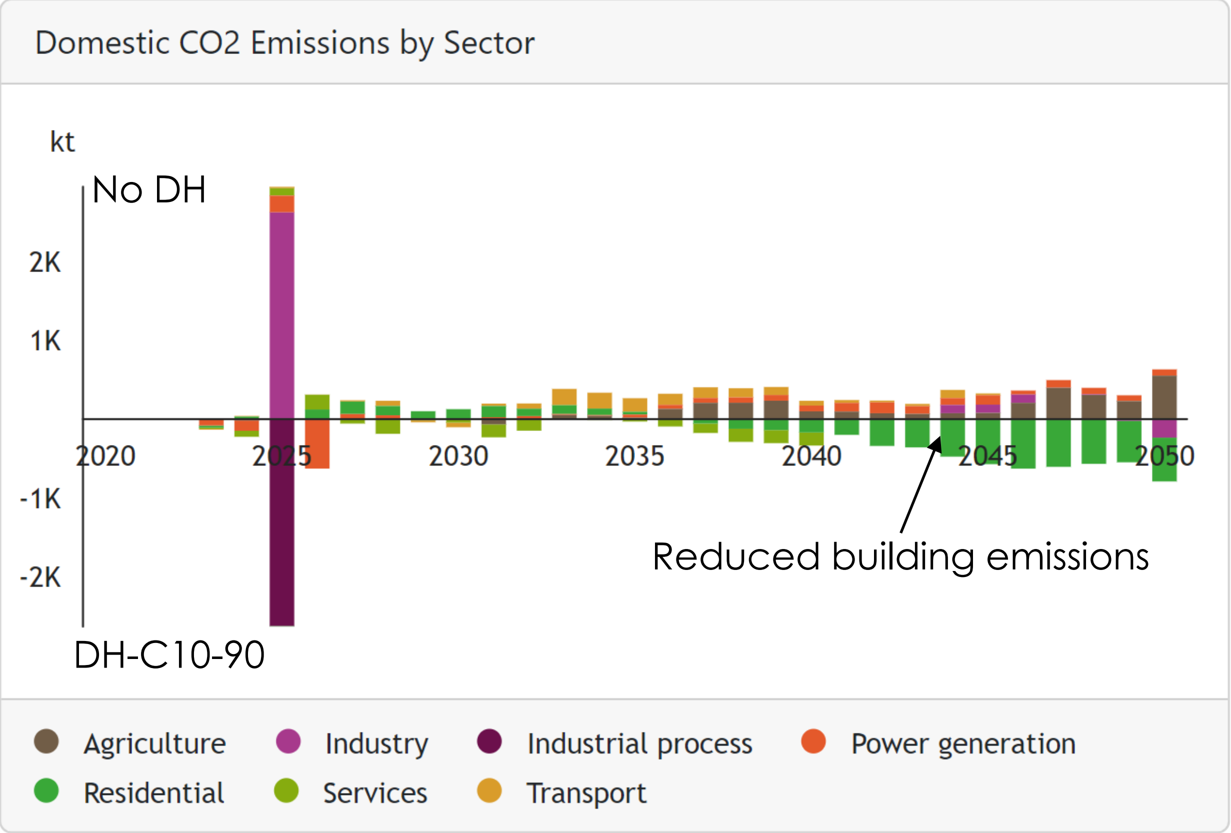


**Figure 10.** DH-C10-90 vs No DH Annual Sectoral Emissions

The power generation will reach net-zero by 2040, offsetting the remaining industry and residential emissions to achieve a net-zero energy system by 2050,

Allowing DH reduces services and residential emissions while increasing sectoral transport emissions targets.

Web-based results: [https://epmg.netlify.app/Jason_DH/results/](https://epmg.netlify.app/Jason_DH/results/)



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# Overall Result | Marginal $CO_2$ cost

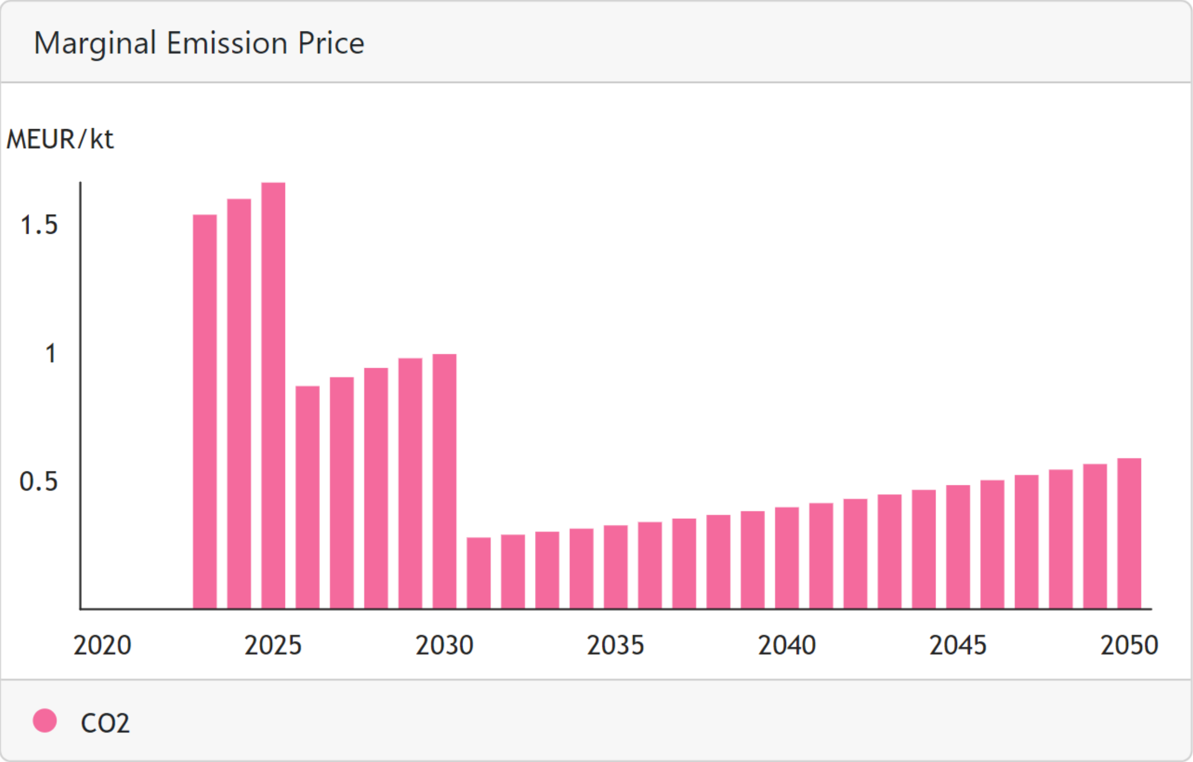


**Figure 11.** DH-C10-90 Marginal Emission Price

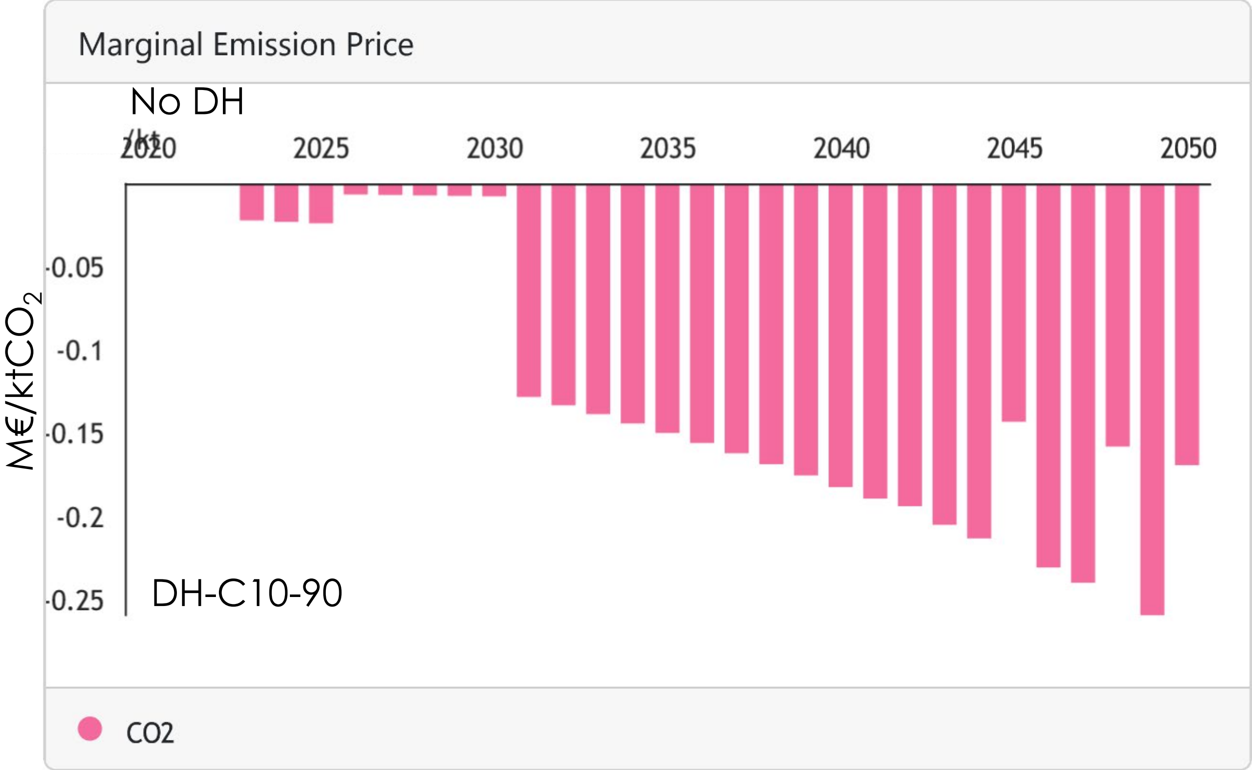


**Figure 12.** DH-C10-90 vs No DH Marginal Emission Price

The marginal emission prices are highest pre-2030 due to ambitious carbon targets, and different scenarios show slight variations pre-2030.

DH-C10-90 has a slightly lower marginal emission price compared to NoDH pre-2030. After 2030 the marginal emission price difference is €130/ $ktCO_2$

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# Results | DH Supply

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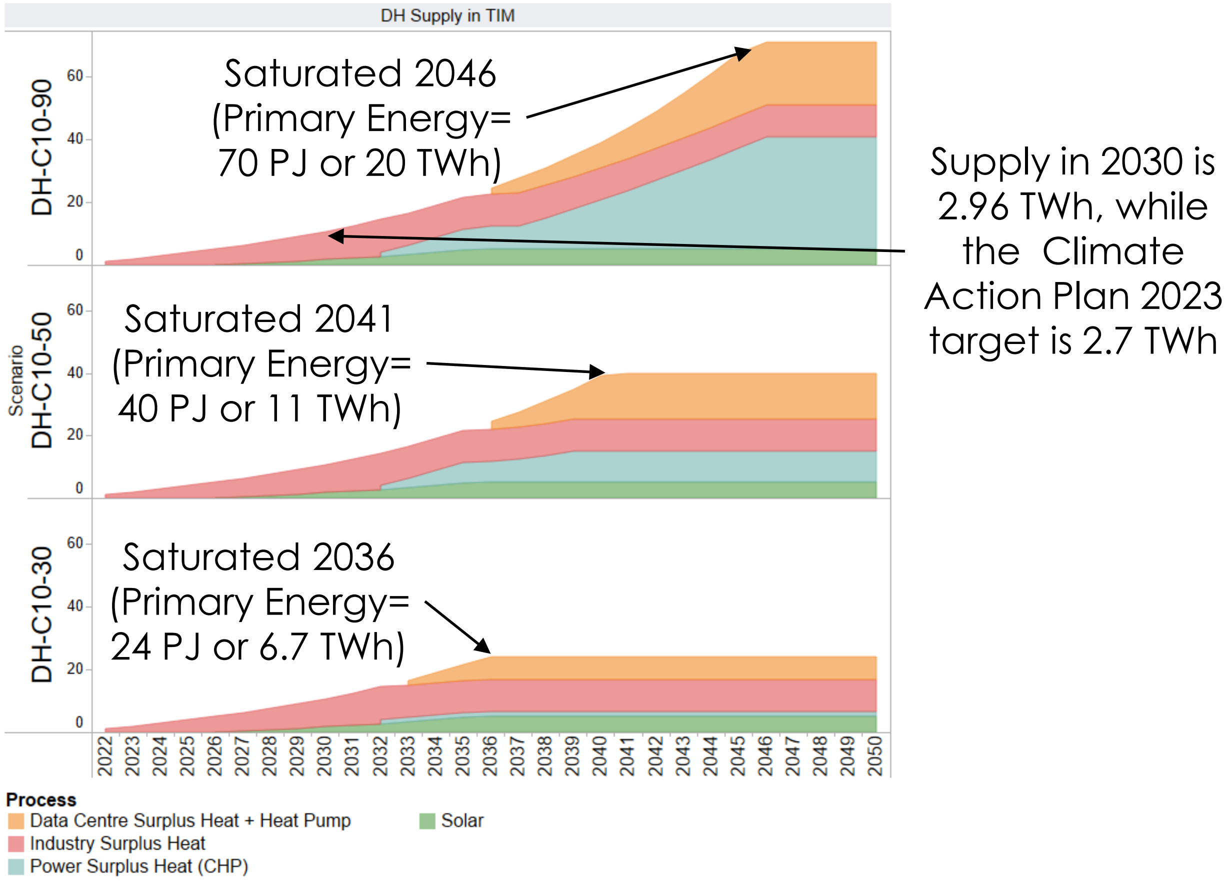


**Figure 13.** DH Supply 10% Annual Growth

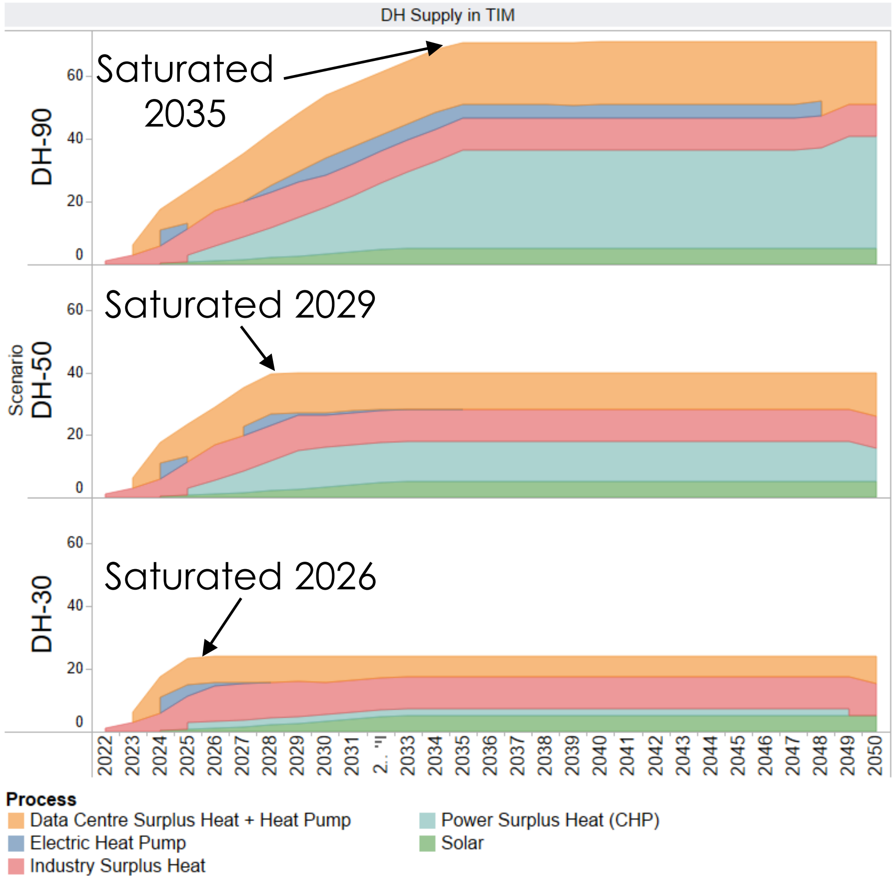


**Figure 14.** DH Supply No Constraint

In the 10% constraint scenarios, DH supply is predominantly driven by surplus heat, particularly from industries. The saturation of DH within the heat market confirms its feasibility.

In the no-constraint scenarios, a similar supply fuel mix with unfeasible market saturation timelines are observed.



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# Sectoral Result | Fuel

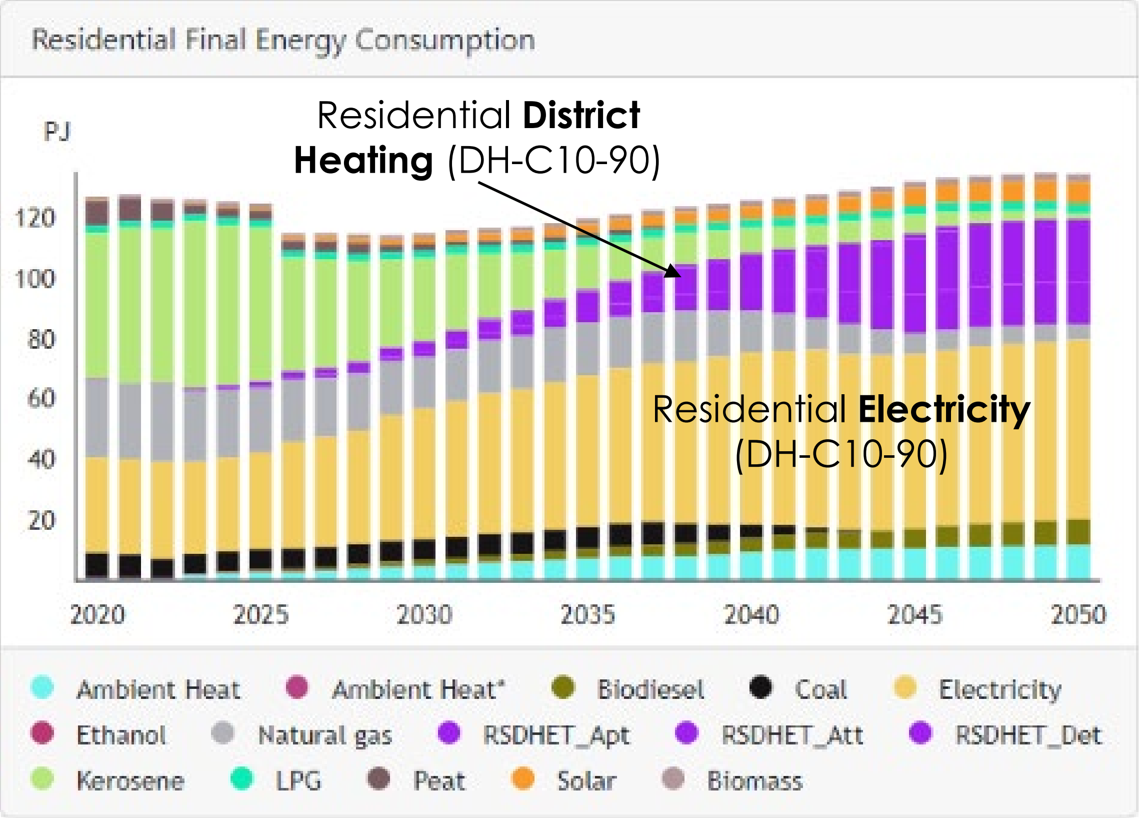


**Figure 15.** Residential Fuel in DH-C10-90

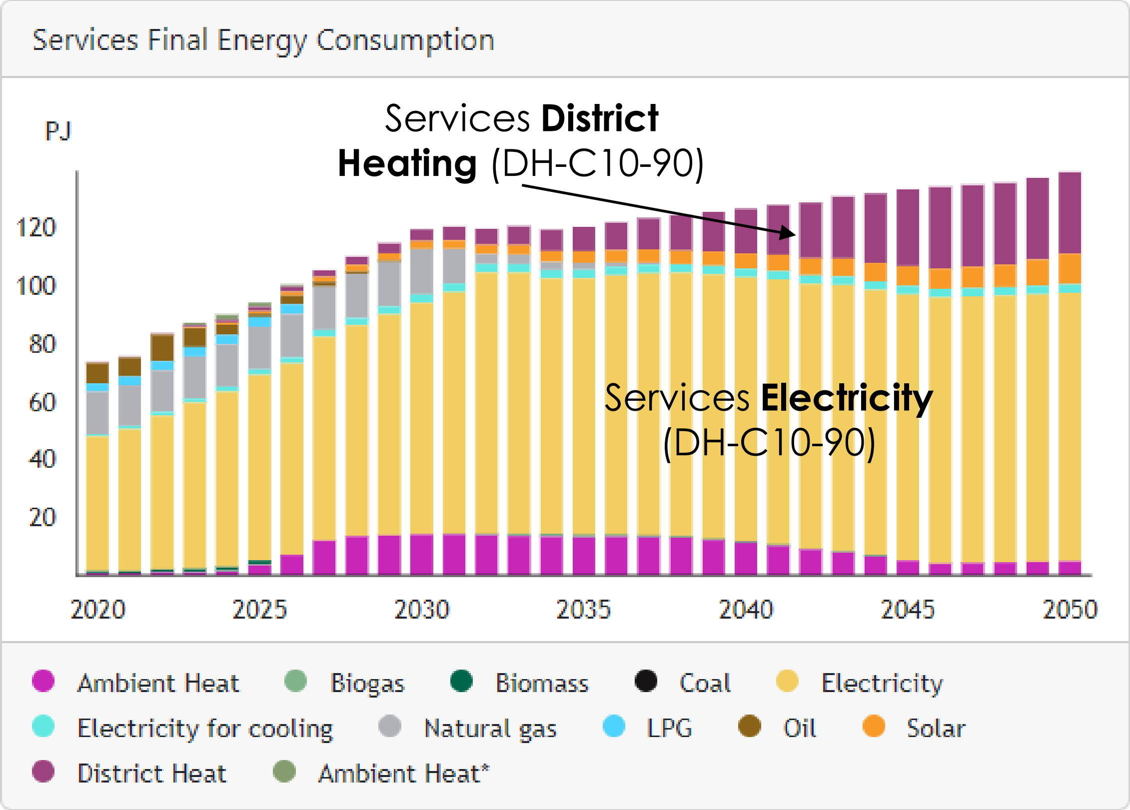


**Figure 16.** Services Fuel in DH-C10-90

Based on previous gas consumption, TIM assumes 55% of DH demand is residential & 45% services. The graphs above show the final energy demand after passing through the DH network with an efficiency of 86%.

# Sectoral Result | Fuel Displacement

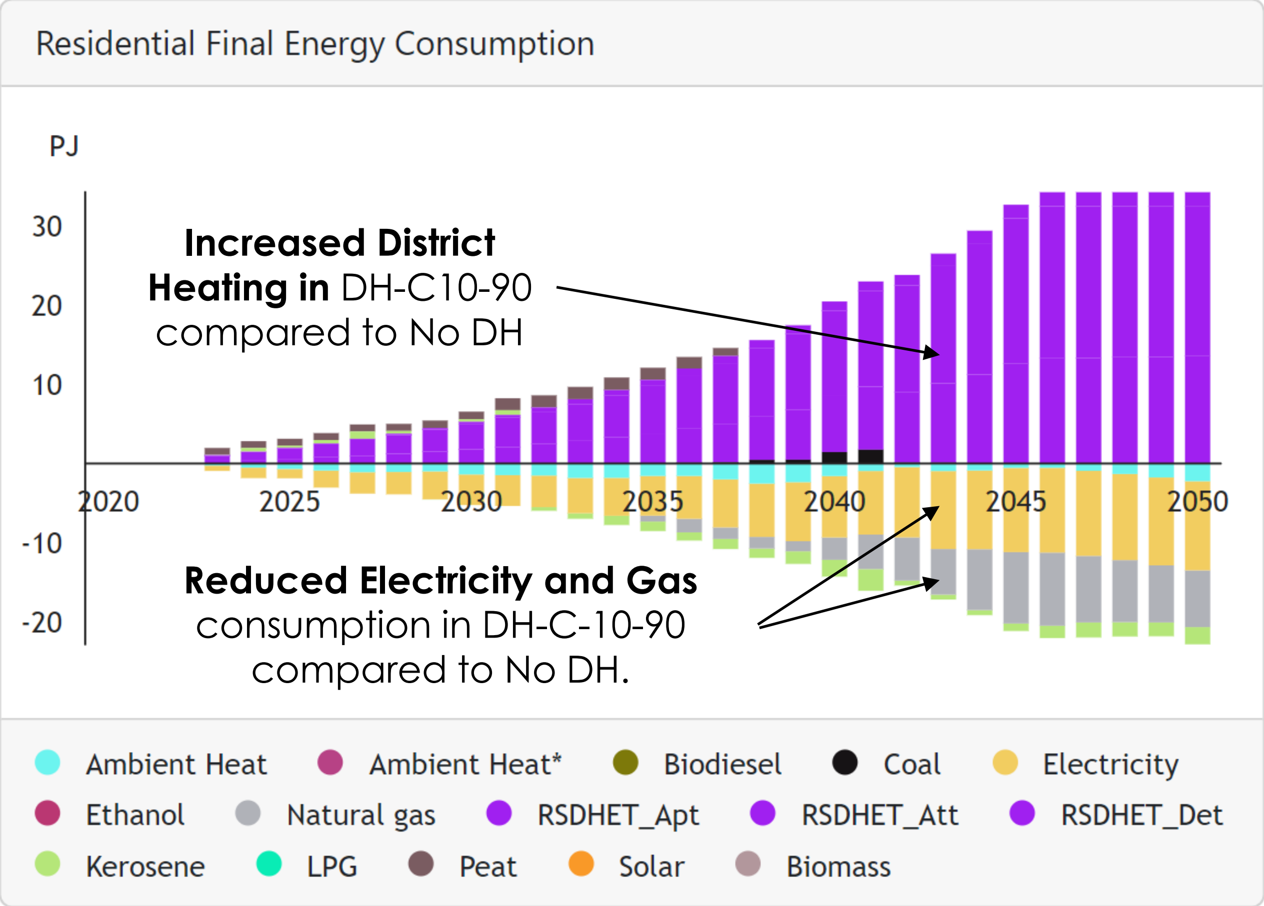


**Figure 17.** DH-C10-90 Residential Fuel Consumption

DH displaces electricity and gas while reducing national fuel demand & other transmission network investments.

# Summary

## Conclusions

- While not as significant as electricity, DH is key in cost-effectively decarbonising Irish buildings.
- In the energy system, DH is a low-hanging fruit but requires a significant investment.
- DH mainly replaces gas & electricity with low carbon intensity, reducing carbon savings.

## Strengths

- Irish energy sector coupling advancement.
- Climate policy insights & sensitivity analysis provide more robust insights.
- Scenarios align current climate targets.

## Limitations

- The cost of surplus heat & the distance to heat demand is not accounted for.
- Greater spatial detail is required for further policy insights; however, a thermo-hydraulic model with pressure, flow and heat calculations is ultimately required to explore each DH project's feasibility.

## Future Work

- Account for new CHP as a supply option & electricity infrastructure cost.
- Thermal Storage coupled with high RES-E
- Services retrofitting options

# Additional studies with TIMES-Ireland Model

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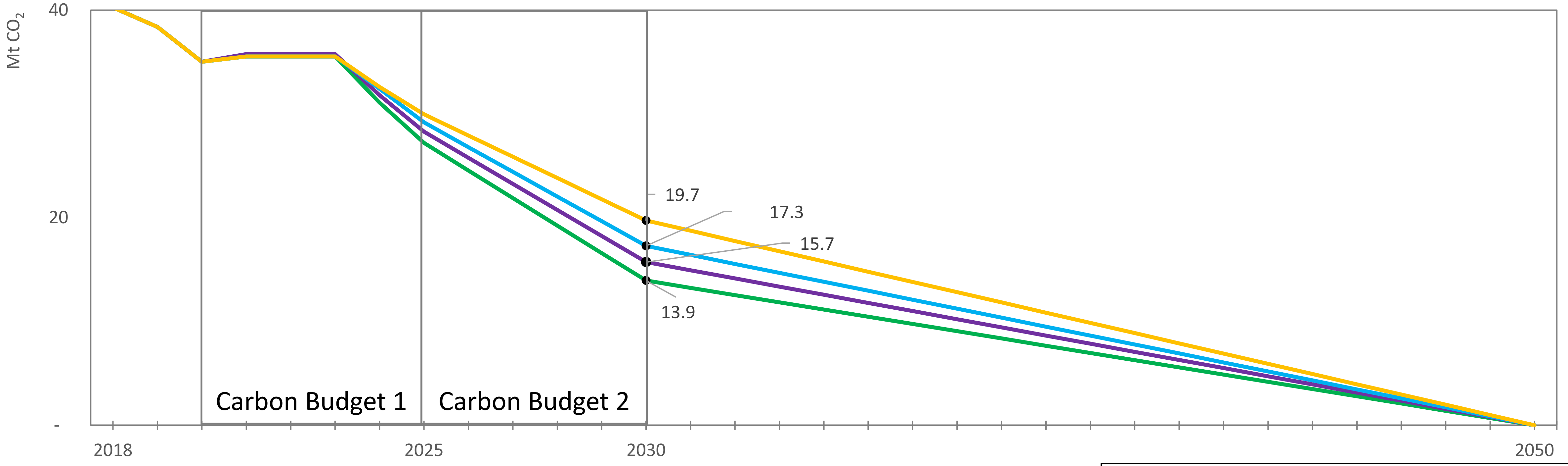
# Decarbonisation trajectories modelled in TIM & carbon budget outcomes



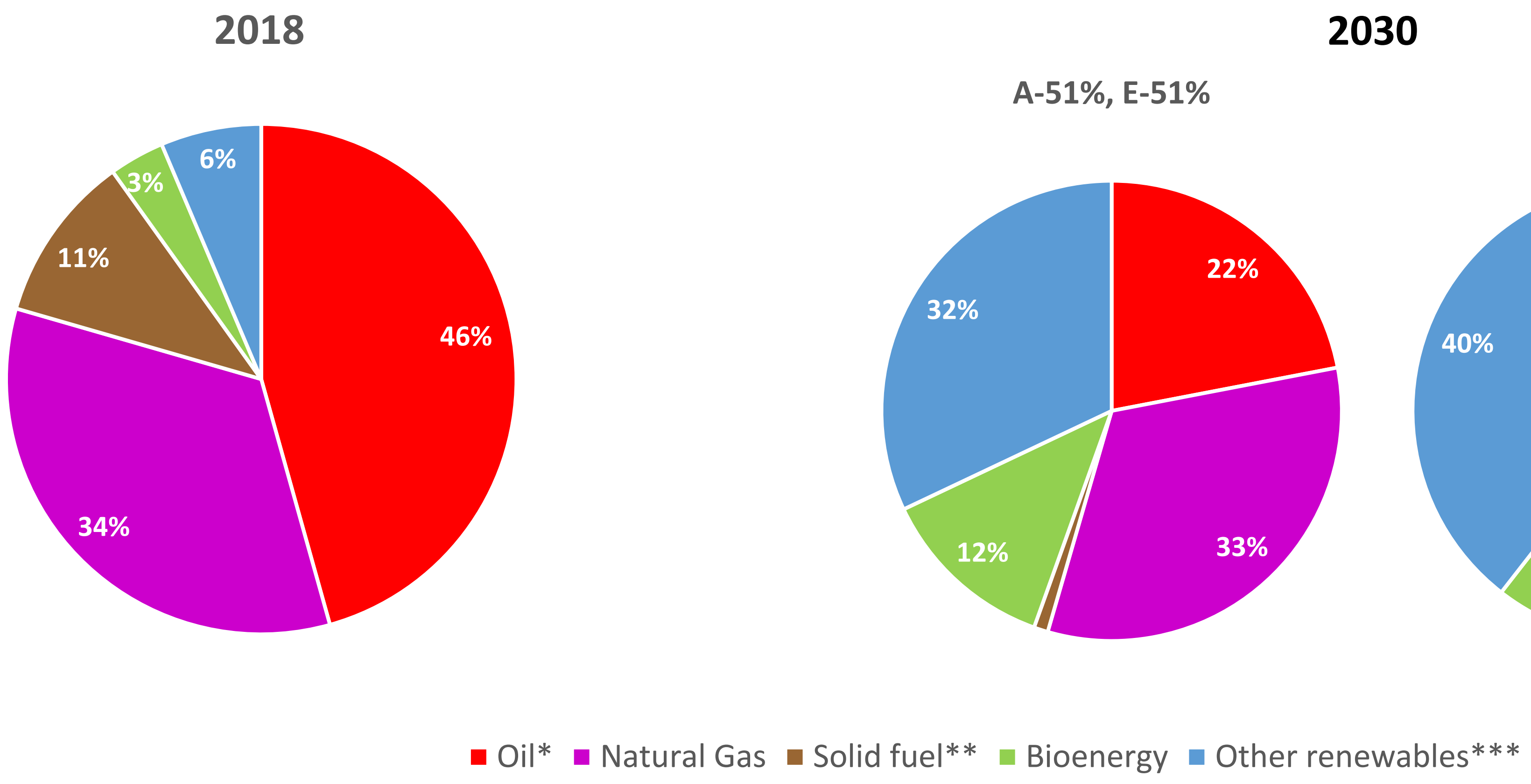

| | | |
|---|---|---|
| 1. Agri-25%, Energy-65% | 165 | 96 |
| 2. Agri-33%, Energy-61% | 167 | 104 |
| 3. Agri-40%, Energy-57% | 168 | 110 |
| 4. Agri-51%, Energy-51% | 169 | 119 |

Carbon budgets implied for energy & process ($MtCO_2$)

All scenarios are consistent with a total Carbon Budget as follows:
CB1: 262 $MtCO_2e$
CB2: 181 $MtCO_2e$

Including agriculture, excluding LULUCF and International Aviation & shipping

# Fossil fuels fall from 90% of primary energy demand in 2018 to 45-56% in 2030




* Oil excludes kerosene for international aviation
** Coal, peat and MSW
*** Primary wind, solar, ambient heat, hydro & ocean

Prof. Hannah Daly, University College Cork

# Marginal Abatement Cost (2025-30 average) in core mitigation scenarios and scenario variants

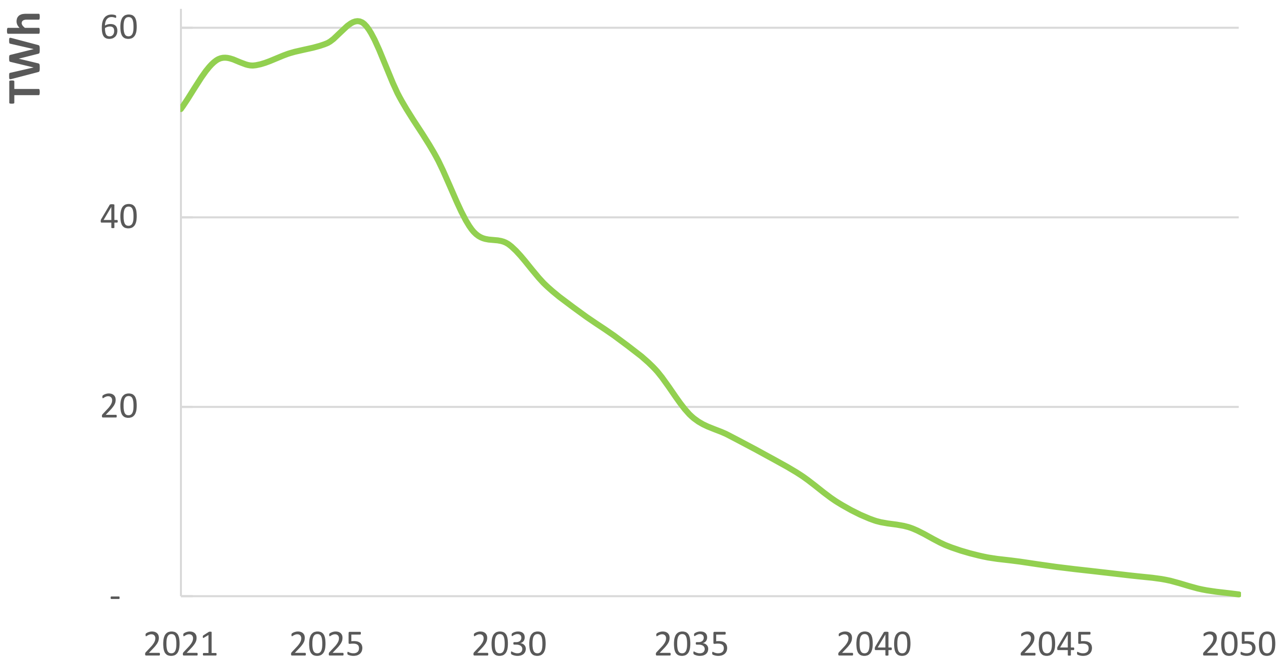
| | | A-51%,E-51% | A-40%,E-57% | A-33%,E-61% | A-25%,E-65% |
|---|---|---|---|---|---|
| **Core** | "BAU" demands, no bioenergy imports, 4-times 2018 indigenous bioenergy, no power-CCS available, no H2 import, 18 GW VAR-RE | **€674** | **€1,100** | **€1,292** | **€1,485** |

The Marginal Abatement Cost represents the cost of mitigating the most expensive tonne of $CO_2$ in each scenario for the energy sector

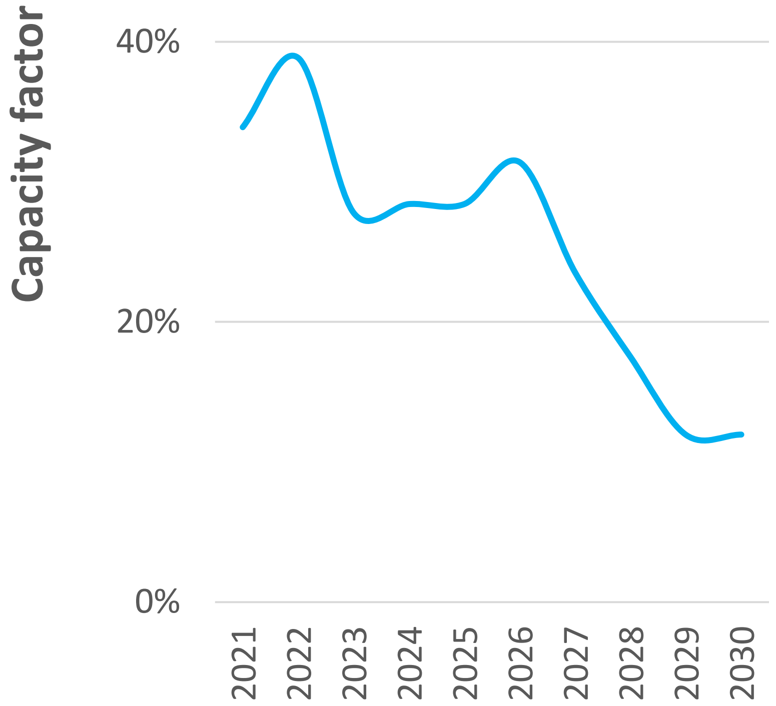
# The future of natural gas

## Carbon budgets require rapid reduction and phase-out of natural gas

### Total natural gas demand in power, buildings and industry consistent with climate targets



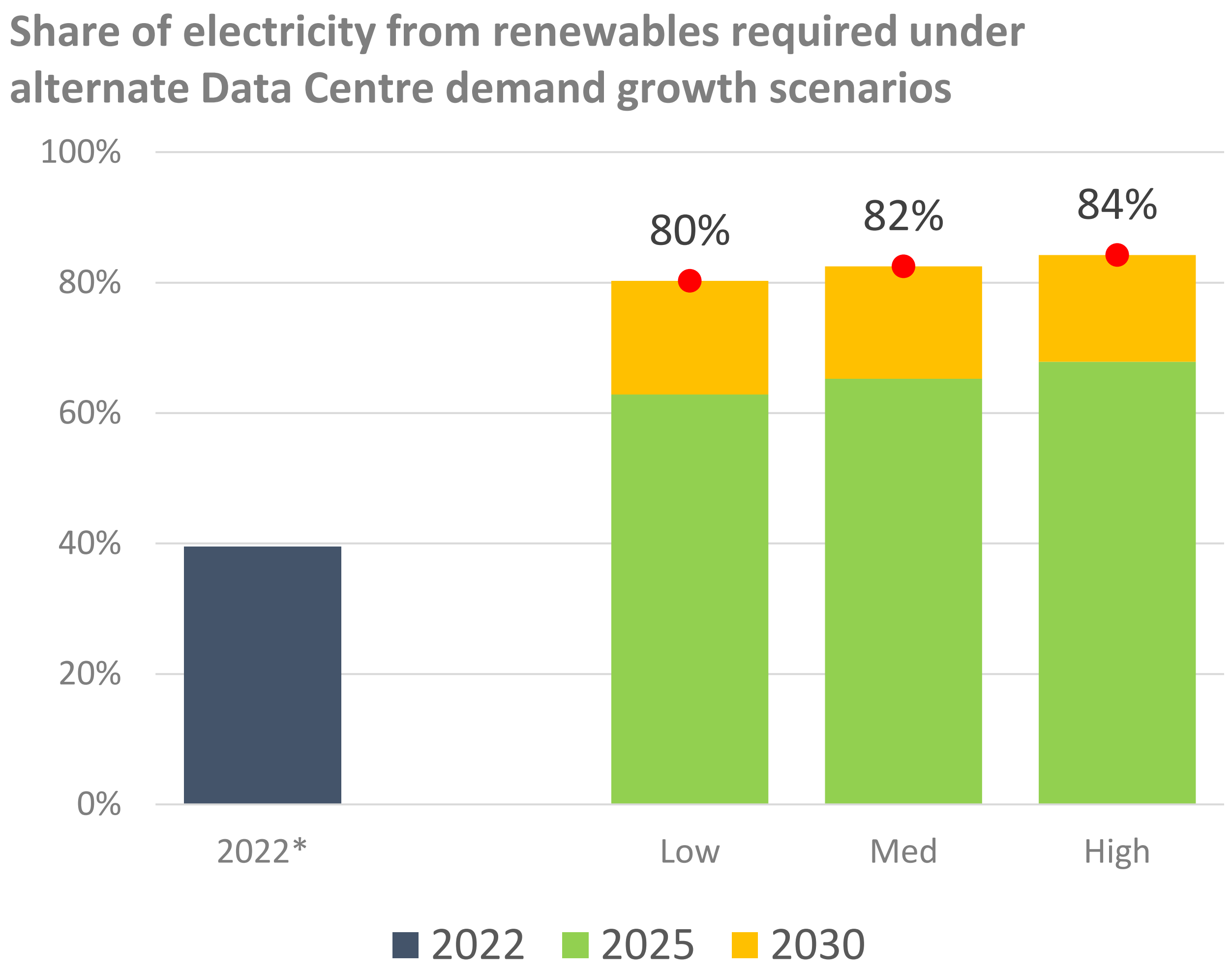

### Utilisation rate of natural gas power generation capacity

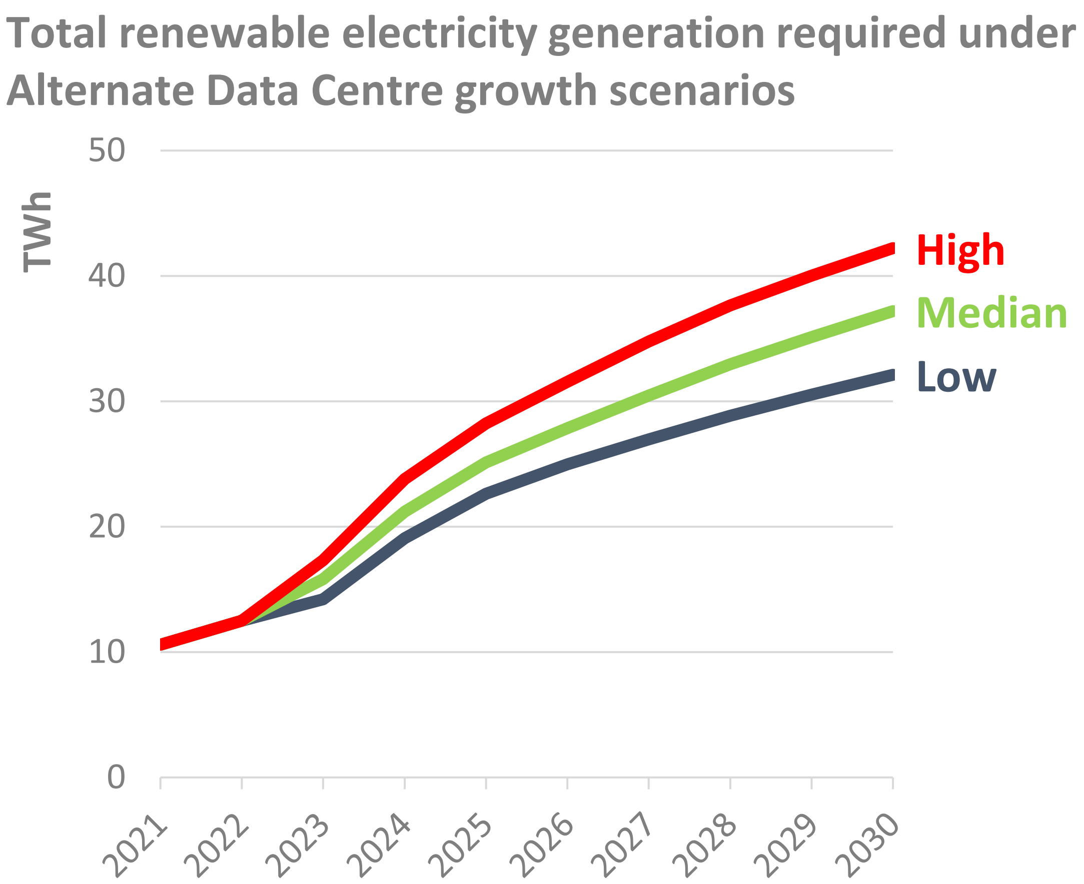



**Any failure to rapidly deploy far greater renewable electricity capacity would lead to an increased utilisation rate of natural gas capacity, causing emissions to exceed sectoral carbon budgets**

# Data centres threaten carbon budget delivery

To remain within Sectoral Emissions Ceiling, electricity growth from data centres requires infeasibly strong renewables growth



# Low Energy Demand (LED) scenario enables a more feasible energy transition & can bring multiple benefits

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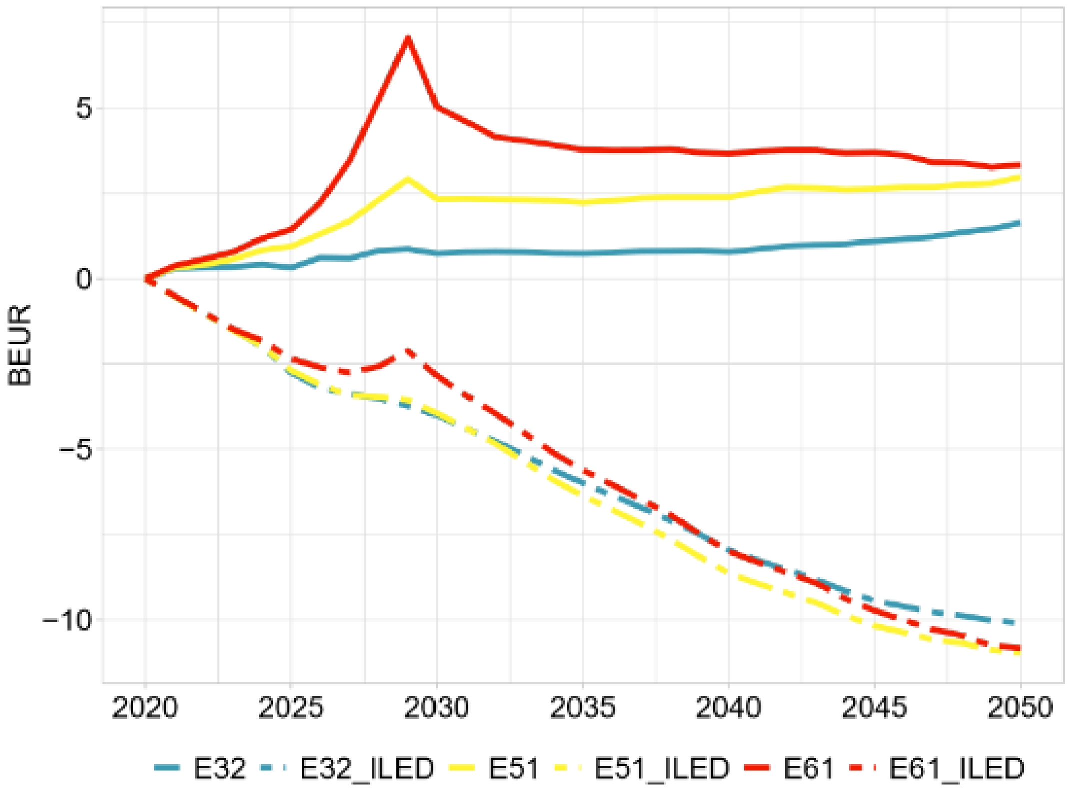
$$\frac{CO_2}{capita} = \frac{consumption}{capita} * \% * \frac{energy\ use}{consumption} * \frac{emissions}{energy\ use}$$

(Activity * Structural change * Intensity * Fuel Mix)

| Sector | End-use service | Avoid | Shift | Improve |
|---|---|---|---|---|
| Transport | Passenger kilomtres | Less cars<br>Increase in occupancy<br>Shorter distances<br>Lower trip frequency | Public transport<br>Active modes (walking & cycling | Efficiency<br>Fuel economy<br>Electrification |
| | Freight | Fewer vehicles<br>Carbon tax<br>Circular economy | Modal shift | Electrification |
| | Aviation | Decrease in international travel<br>Carbon tax | Large scale modal shift | |
| Residential | Dwelling | Lower per capita space<br>Higher occupancy in houses | Multi-family homes<br>Building material substitution | Retrofit<br>Technology upgrade<br>Durability of appliances |
| | Comfort | Changing thermostat level<br>Shorter & lesser showers<br>Using washing machine & dishwasher on full load | | |
| Industry | | Dematerialisation<br>Recycling | Material substitution<br>Smart devices & low carbon products | Process and material efficiency |

## Total undiscounted annualised energy system costs relative to "no mitigation" case




Paper under peer review: https://github.com/ankitagaur93/Irish-Low-Energy-Demand-Scenario/blob/main/ILED_under_review.pdf

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# Building Heating Demand

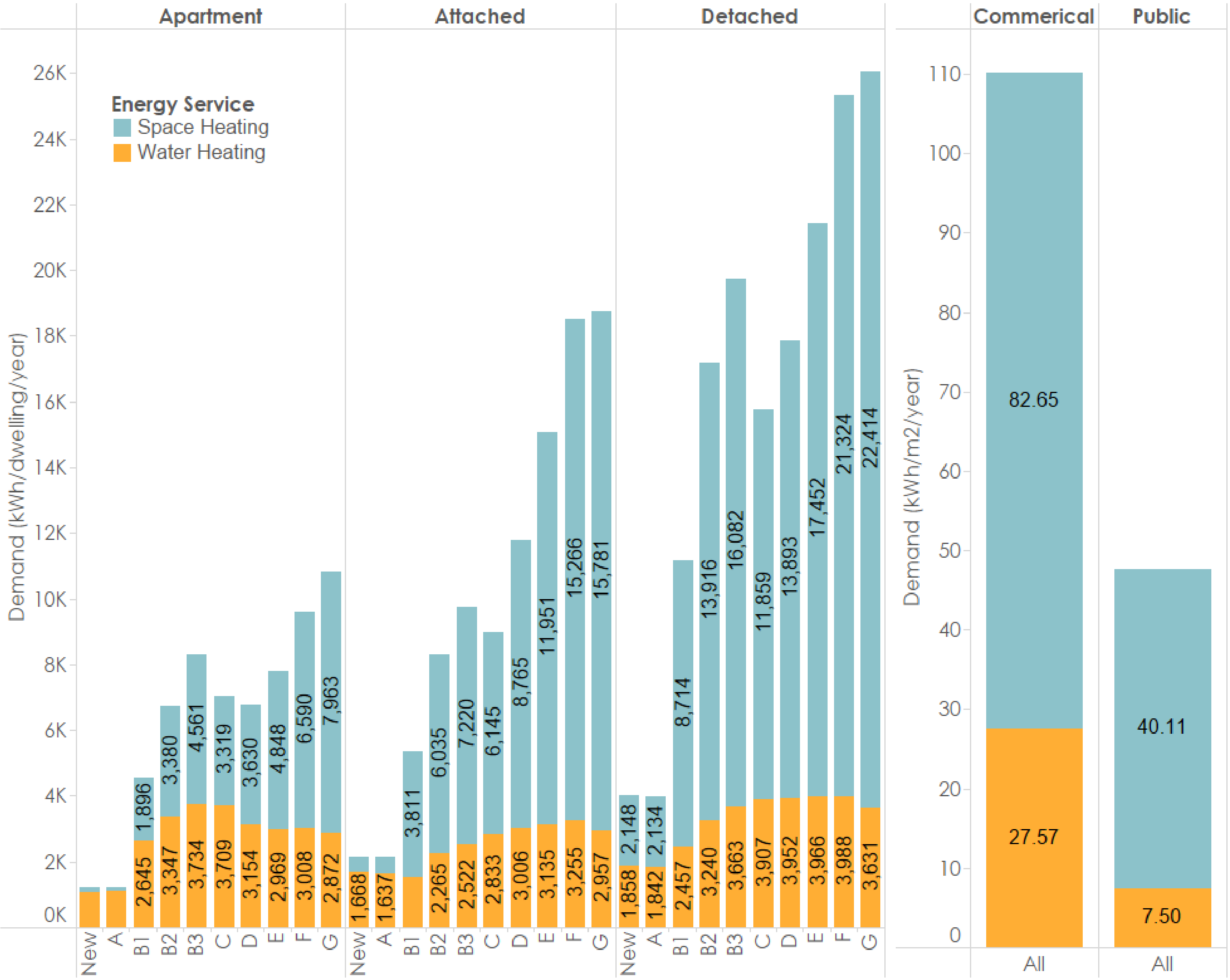


**Figure 9.** Building Space & Water Heat Demand

Residential space and water heat demand are defined per dwelling. The dwelling categories are three building archetypes, nine energy ratings for existing dwellings, and a new dwelling heat demand. Internal temperature assumptions are applied as data is obtained from the BER database (J. Mc Guire et al.).

Services space and water heat demand is based on floor area per service category – commercial or public.

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Table A.7: TIM District Heating Supply Opitions

| Technology | Invesment (M€/GW) | O&M (M€/GW/yr) | Efficieny (%) | Lifetime years | Capacity PJ |
|---|---|---|---|---|---|
| Electric Boiler | 70 | 1.07 | 99 | 20 | - |
| Gas Boiler | 60 | 1.95 | 94 | 25 | - |
| Biomass Boiler | 490 | 48.2 | 98 | - | |
| Solar | 310 | 0.06 | 45 | 30 | 5 |
| Electrical ASHP | 860 | 2 | 350 | 25 | - |
| Electrical Geothermal HP | 2700 | 23.2 | 548 | 25 | 5 |
| Gas Geothermal HP | 1386 | 11.1 | 165 | 25 | 5 |
| Surplus Industry | 668 | 38 | 100 | 25 | 10.3 |
| Surplus Power | 2003 | 38 | 100 | 25 | 44.6 |
| Surplus Data Centre + ASHP | 898 | 24.9 | 460 | 25 | 15 |
| Centralised Storage | 161 | 2 | 70 | 35 | - |
| Decentralised Storage | 823 | 2 | 98 | 30 | - |

# European DH Studies

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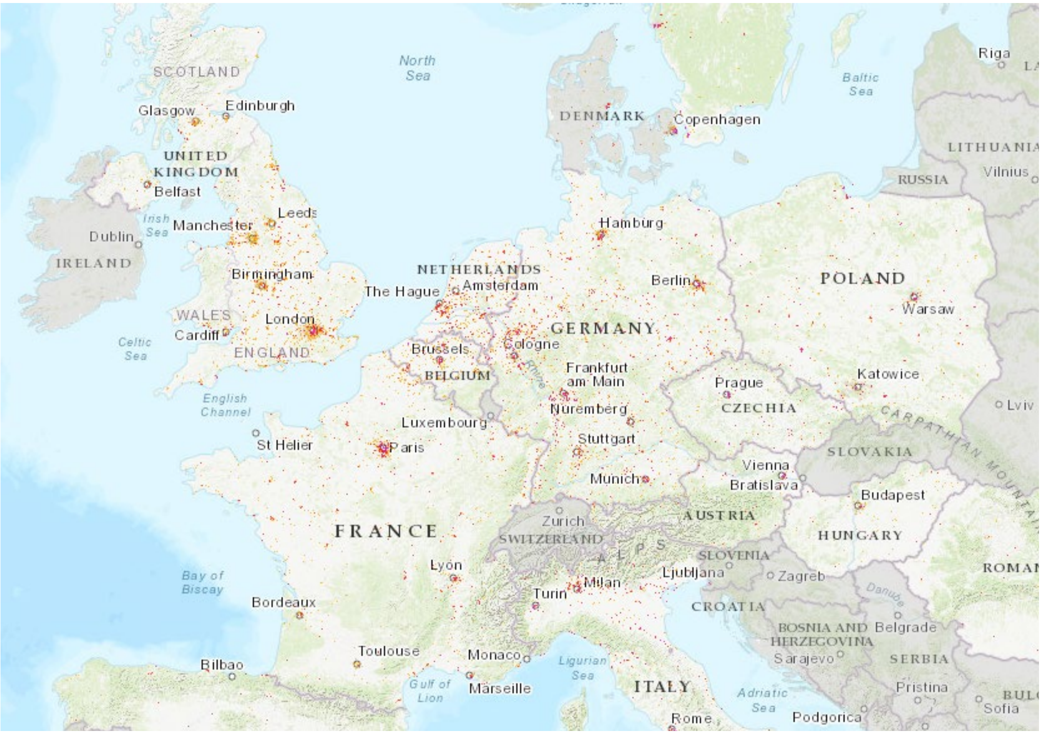
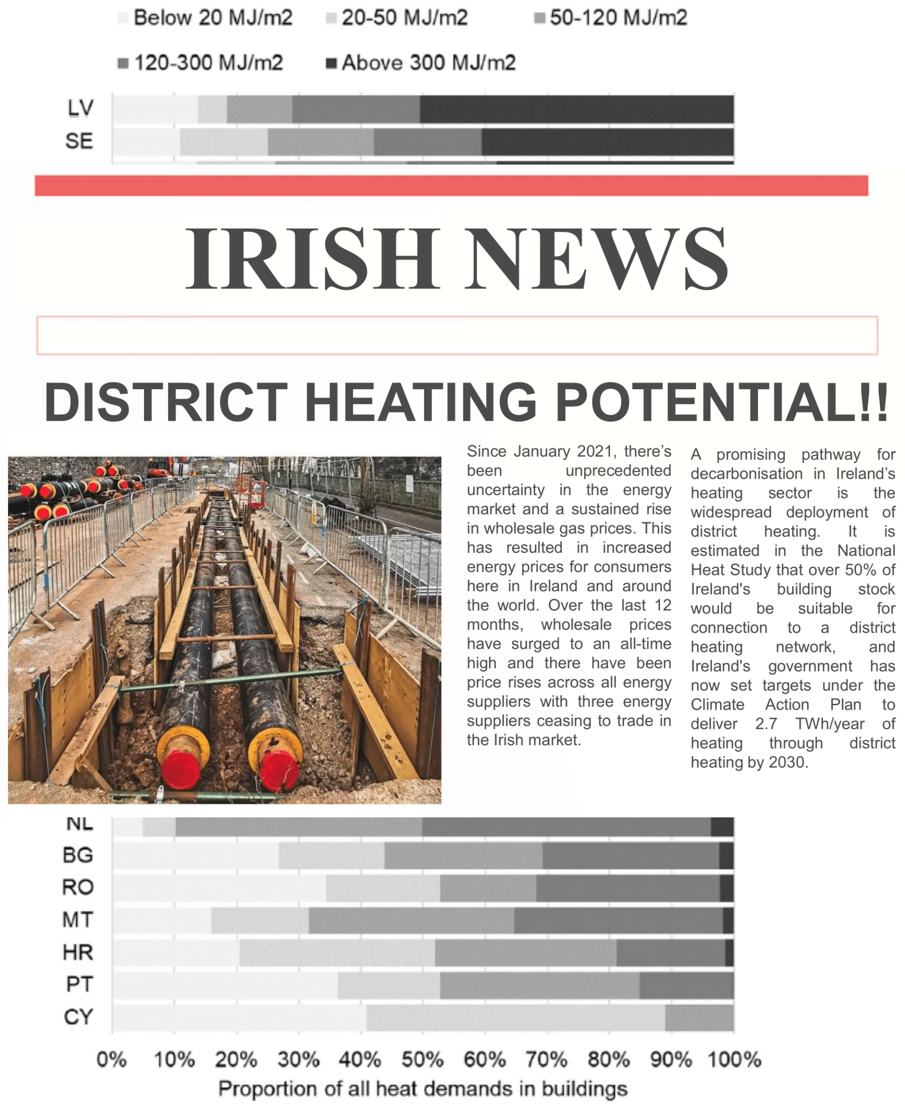



**Figure 4.** The Pan-European Thermal Atlas (PETA)

(https://heatroadmap.eu/peta4/ )

Heat Roadmap Europe (HRE) is a series of studies carried out since 2012. HRE uses four models, including PETA and TIMES. PETA geographically represents supply potential & heating and cooling demands.




IRISH NEWS

DISTRICT HEATING POTENTIAL!!

Since January 2021, there's been unprecedented uncertainty in the energy market and a sustained rise in wholesale gas prices. This has resulted in increased energy prices for consumers here in Ireland and around the world. Over the last 12 months, wholesale prices have surged to an all-time high and there have been price rises across all energy suppliers with three energy suppliers ceasing to trade in the Irish market.

A promising pathway for decarbonisation in Ireland's heating sector is the widespread deployment of district heating. It is estimated in the National Heat Study that over 50% of Ireland's building stock would be suitable for connection to a district heating network, and Ireland's government has now set targets under the Climate Action Plan to deliver 2.7 TWh/year of heating through district heating by 2030.

**Figure 5.** Heat Roadmap Europe: Heat distribution costs

(U. Persson et al. / Energy 176 (2019))



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