Energy Use and Consumption in German Households

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DigEn vs SOEP

DigEn vs SOEP

DigEn:

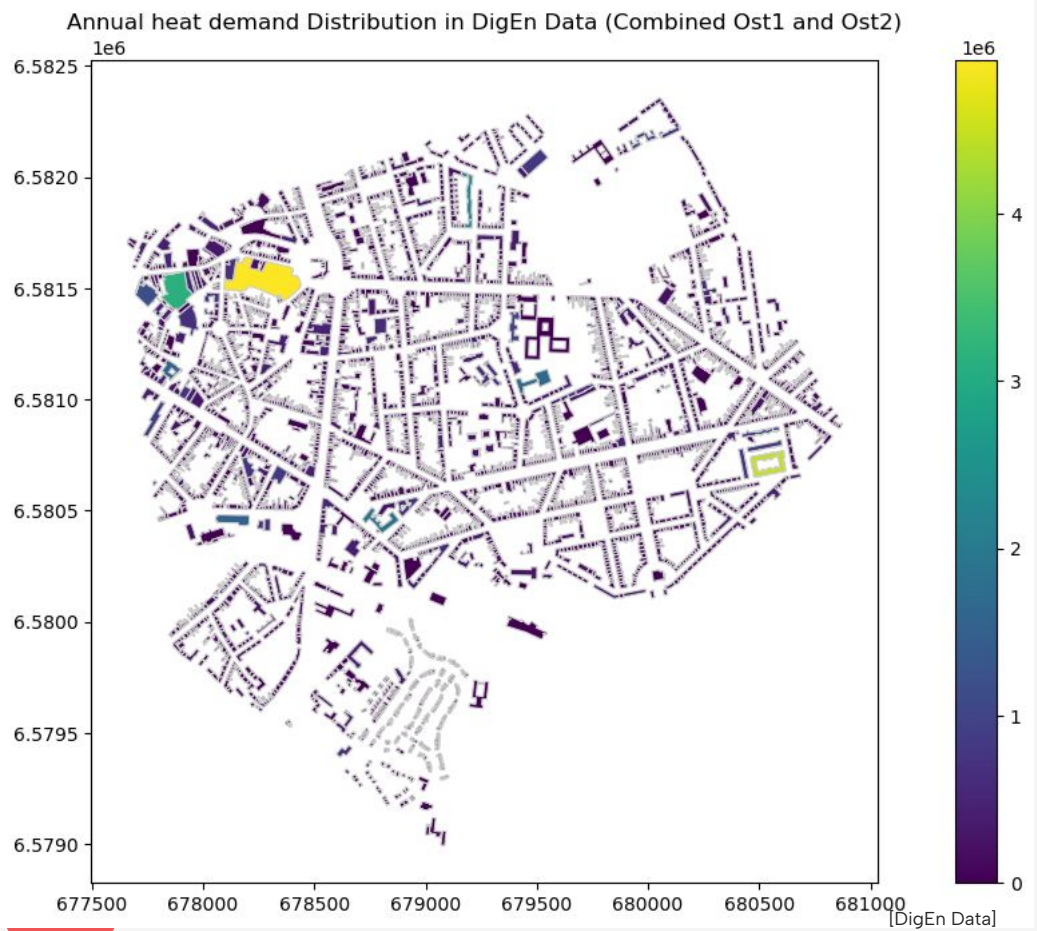
- Intuitive distribution of energy demand & energy type
- Some specific variables about the characteristics of the building (heat space, construction age, roof type)
- Different building uses: commercial vs residential

SOEP:

- Trends in some key variables over time (heat consumption, energy type)
- Information about the economy is provided (net income and rents)

02

DigEn:
The heat demand &
The energy type

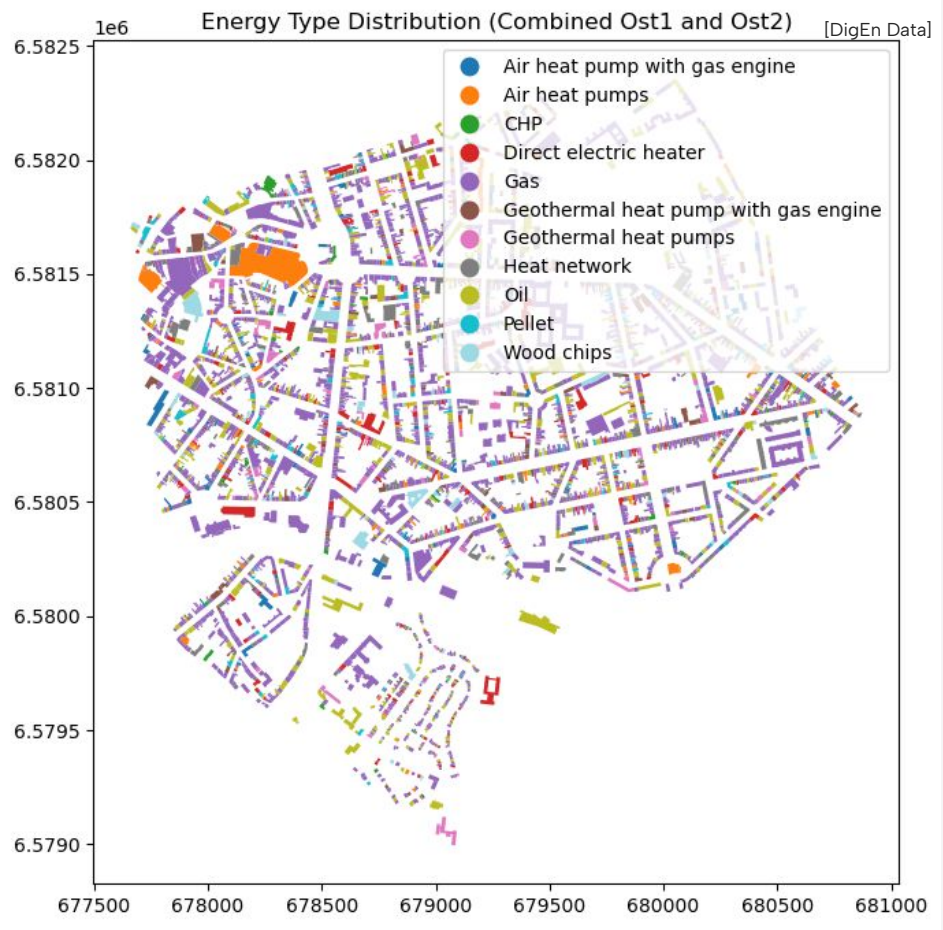


- **The Highest:**
  4.9e+06 KWh

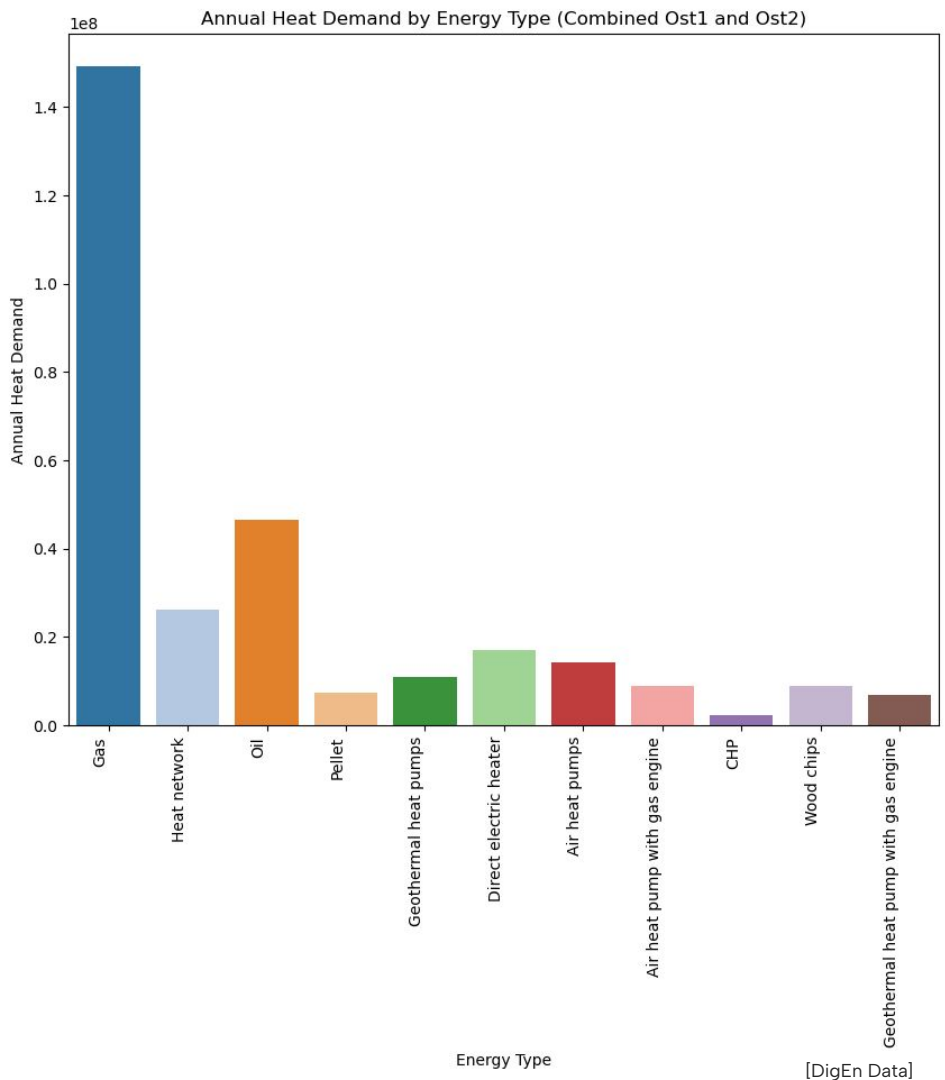
- **The Mean:**
  8.5e+04 KWh

- **Two areas with significantly higher heat demand**
  - Aquis Plaza: 4.9e+06
  - Aachen Galeria: 3.1e+06

Commercial Area



- The most common choose
  - **Gas**
  - **Oil**
- Two higher heat demand area
  - **Gas** (Galerie)
  - **Air heat pumps** (Aquis)

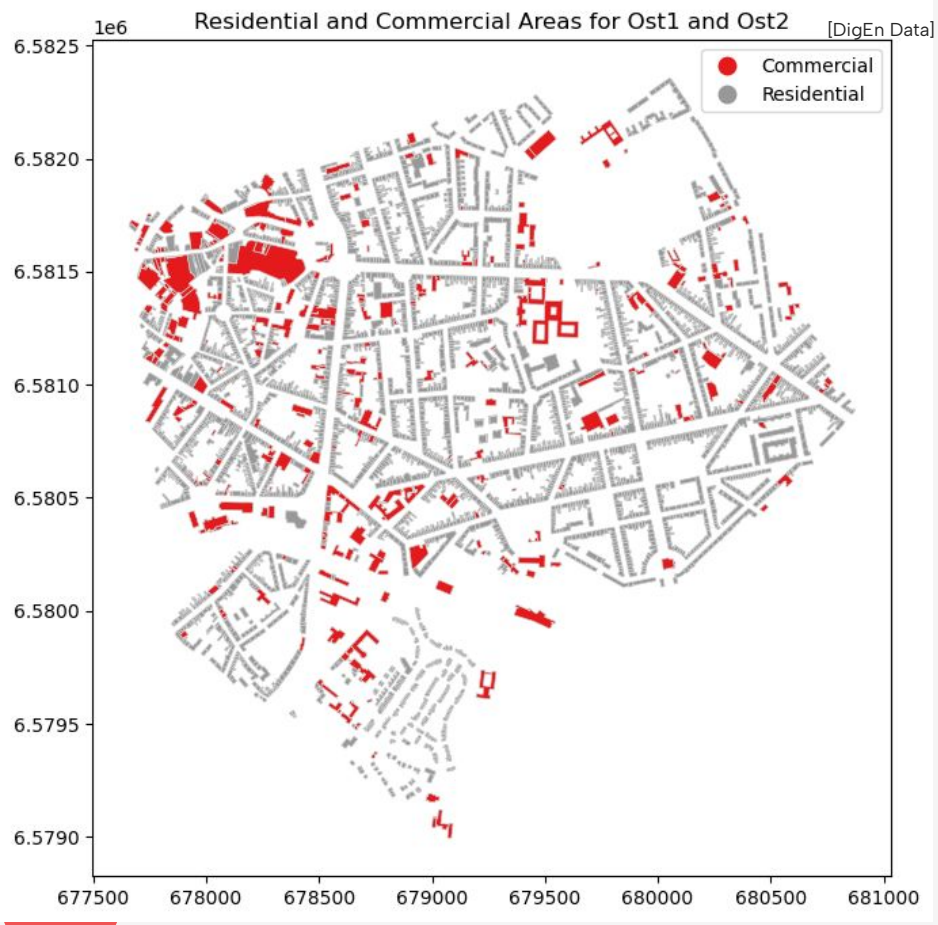


For the overall,

Gas provides most of the heat demand.
It is still the main source of heat supply.

Oil also occupies a relatively important part of other energy types

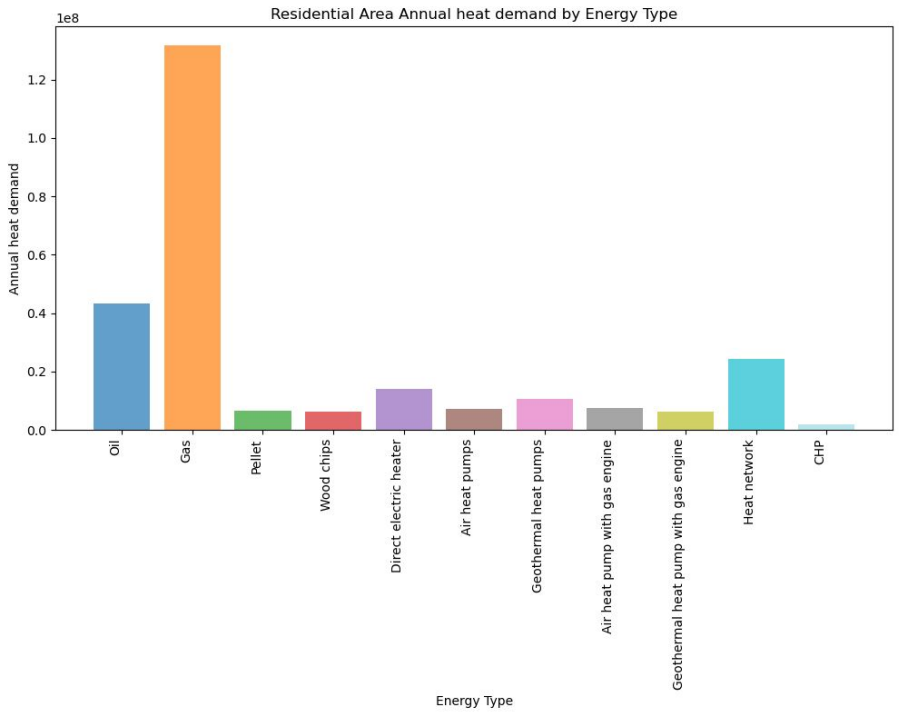
Heat network should not be overlooked

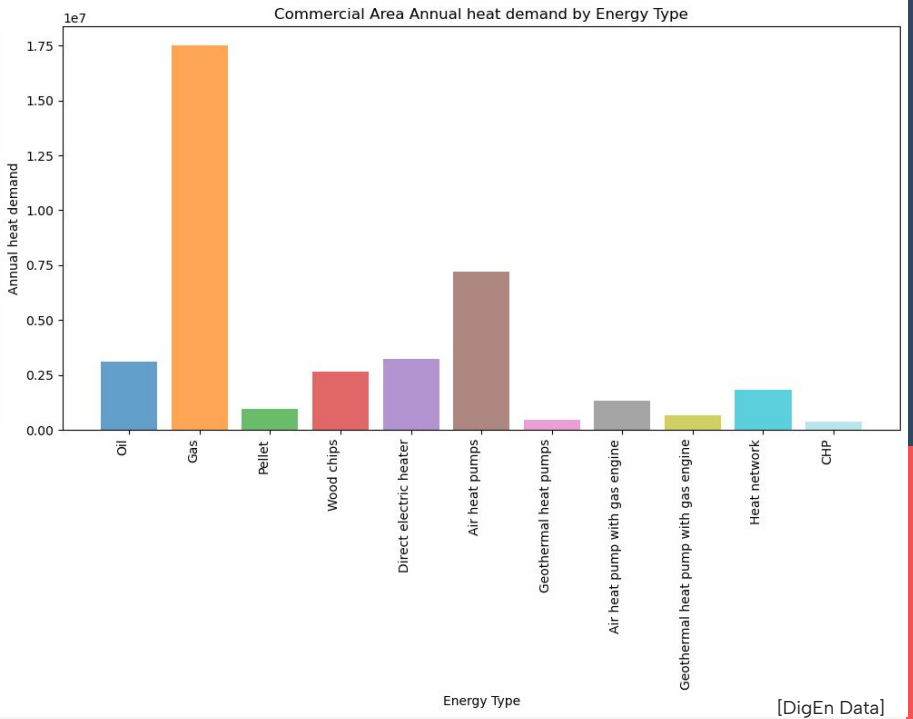


Whether there are differences in the types of energy preferred by different area?

Split data to

- **Residential Area**
  Full Space:
  1.2e+06
  Total Energy Demand:
  1.3e+08 KWh
- **Commercial Area**
  Commercial Total Full Space:
  3.5e+05
  Total Energy Demand:
  1.6e+07 KWh





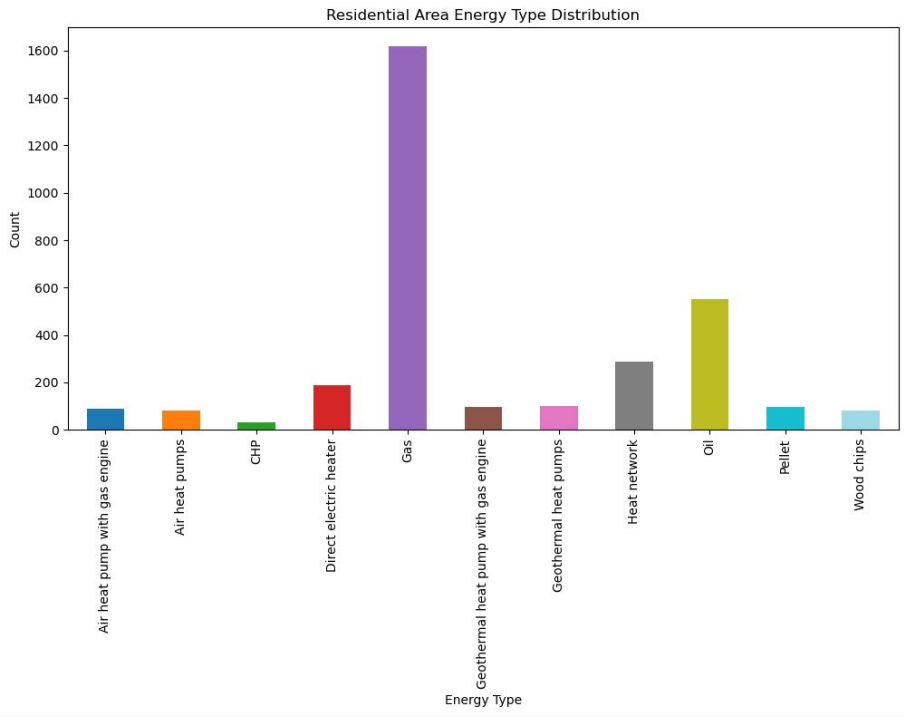
[DigEn Data]

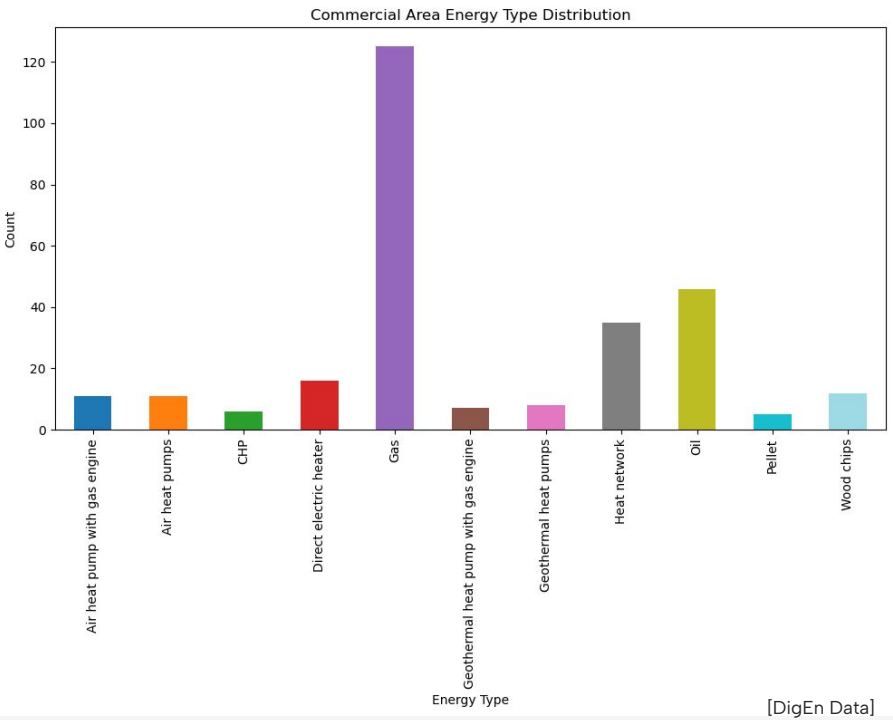
Residential Area:

The main heating energy source: **Gas**
Oil and **Heat network** followed

Commercial Area:

the main heating energy source: **Gas**
The second one: **Air Heat Pump**
(Galerie occupies a large part**)**





[DigEn Data]

Residential Area:

The main heating energy source: **Gas**
Oil and **Heat network** followed

Commercial Area:

We can see that the **Heat network** also chosen by many commercial buildings.
Air heat pump is not so widely used

Why the highest heat demand building *Aquis Plaza* choose the Air heat pump?

Aquis Plaza

- as a large commercial building, occupies a **large space size** and a large **open spaces** inside
- Its daily traffic and **population density** are also much higher than in other areas.

the building has a very high heating load.

Air heat pump

- provide heat **efficiently**.
- compared with traditional energy sources, it can adjust the temperature more **flexibly** and more **environmentally friendly**.

The main type of energy used for heating

1. **Gas**
2. Oil
3. Heat network

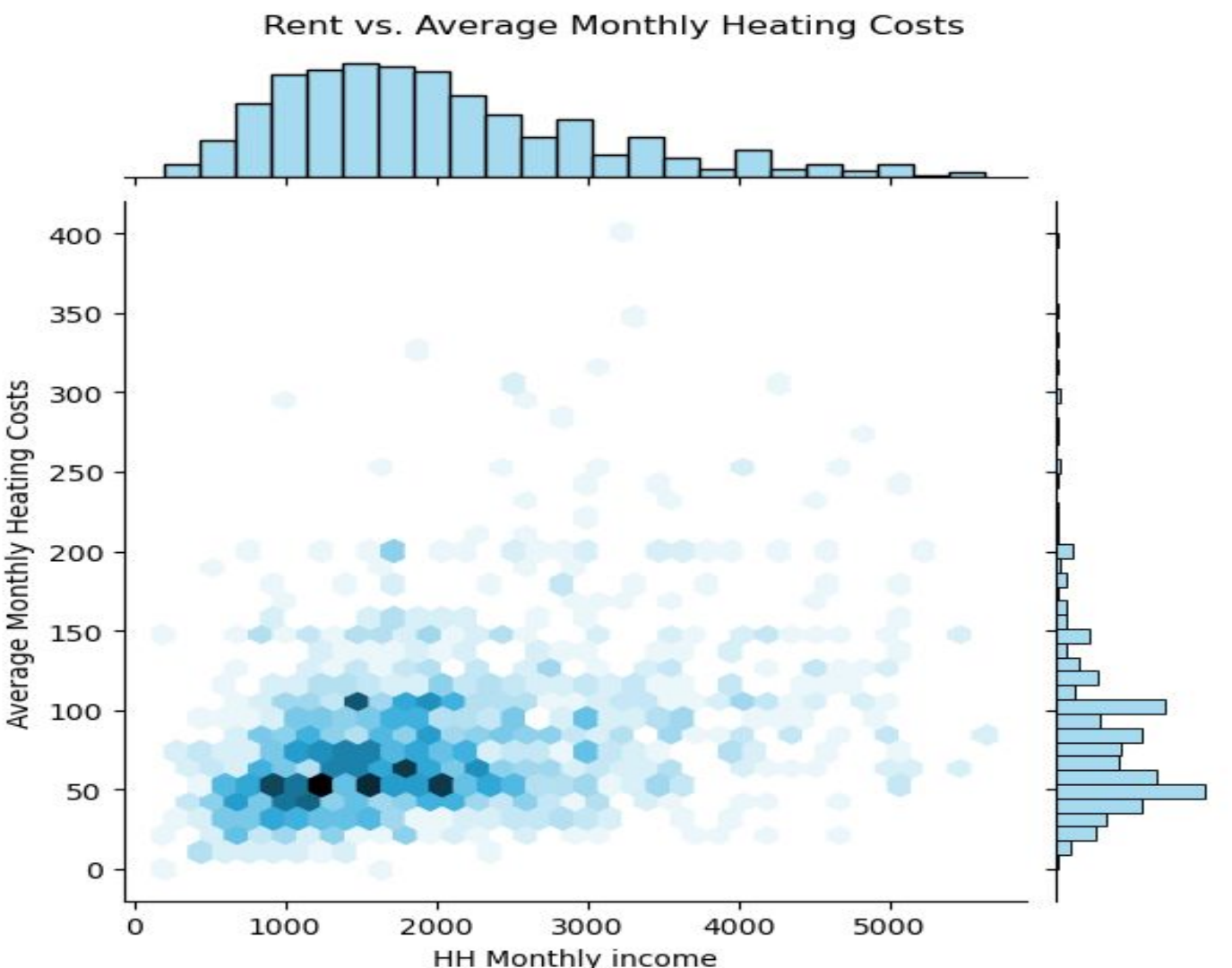
Questions:

1. What are the factors that affect the heating demand?
2. Why most buildings use Gas?

To find some trend in SOEP

03

Findings from income and Energy Costs

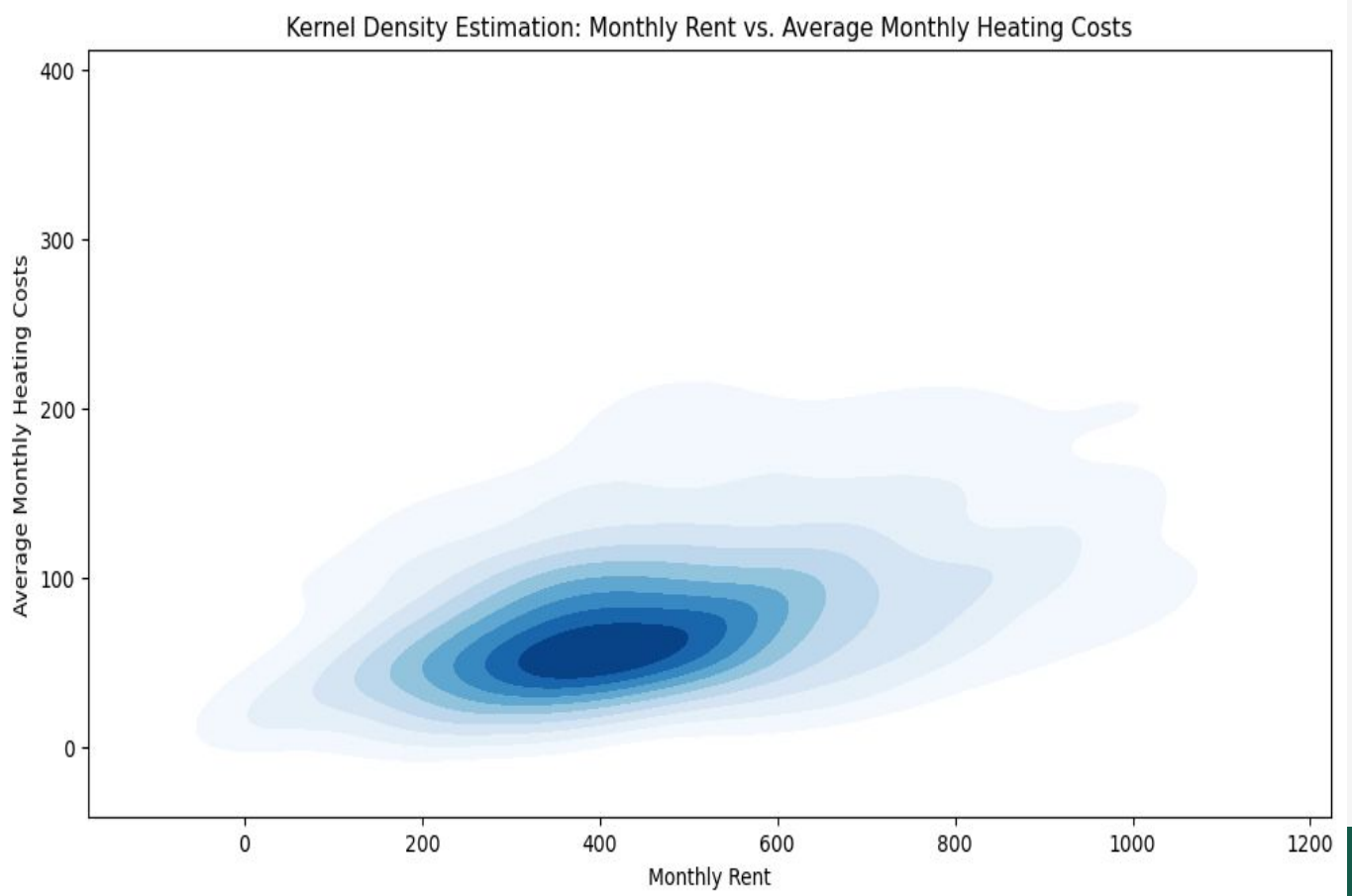


📌Heating cost paid by people from different income, falls within the same range.

📌Most outliers in heating cost, are actually from the middle range of income. Not from the highest income.

📌This should be more researched with the size of dwelling.

Heating costs considering monthly rent



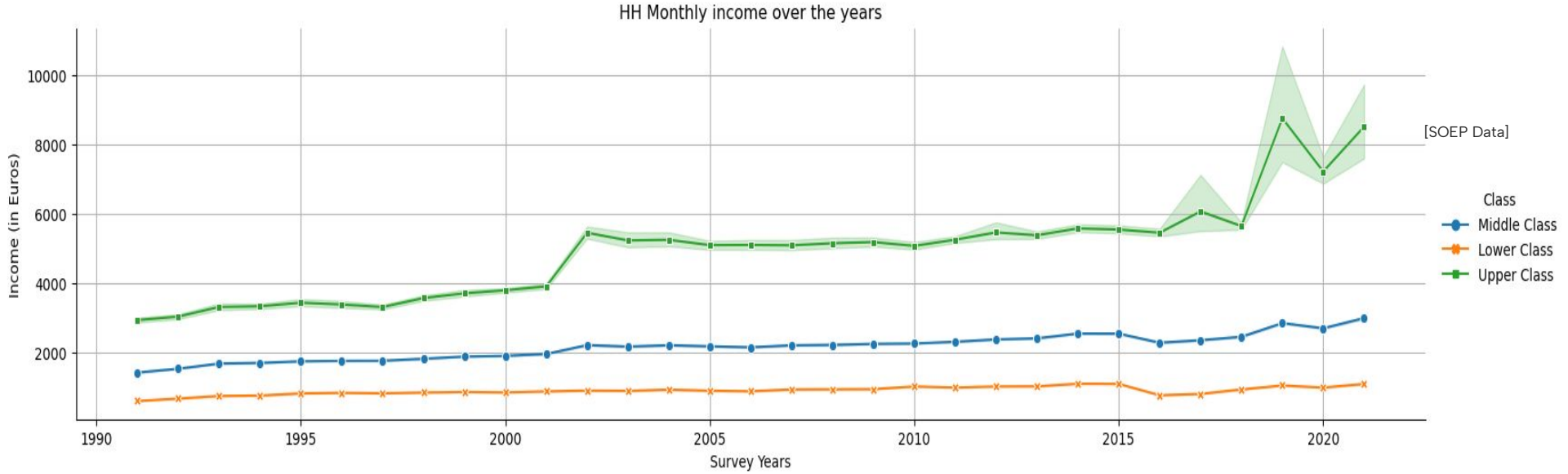
Here, again:

📌We see that heating costs fall into a defined range and don't follow a trend with respect to the monthly rent.

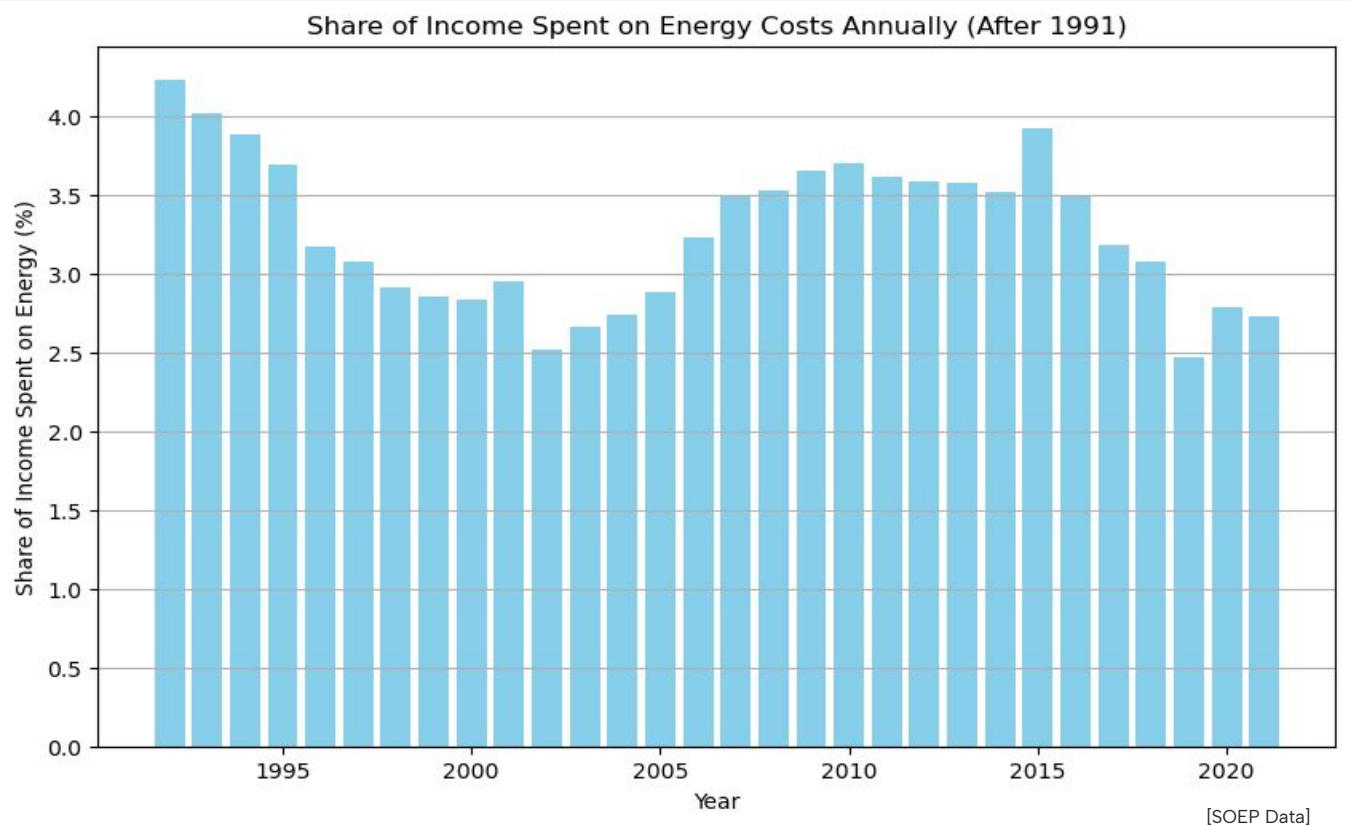
📌There are several outliers in heating cost, mostly seen in middle classes of rent.

Income

📌People from upper class of income, are getting richer by time. The increase for middle and low classes is going very slow and steady.



What share of income is spent on energy costs?



[SOEP Data]

📌The increase starting from 2020 is due to the impact of COVID-19.

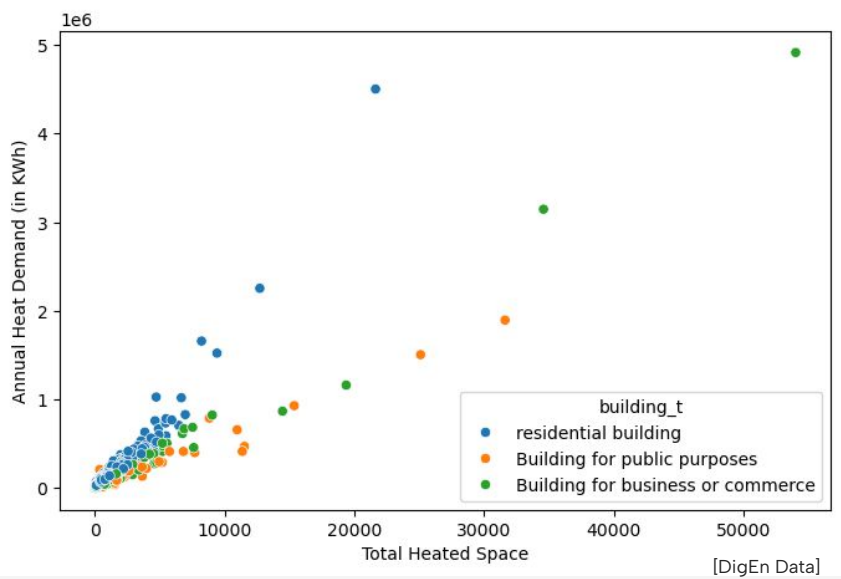
📌Data after 2022 could give insight regarding the increase in energy costs due to the Russia and Ukraine war.

📌3 assumptions for the increase in 2015: Energy conservation law entered into force on May 2014. There was an increase in usage of renewable energies, also we had a different questionnaire.

04

Space and Heat Analysis

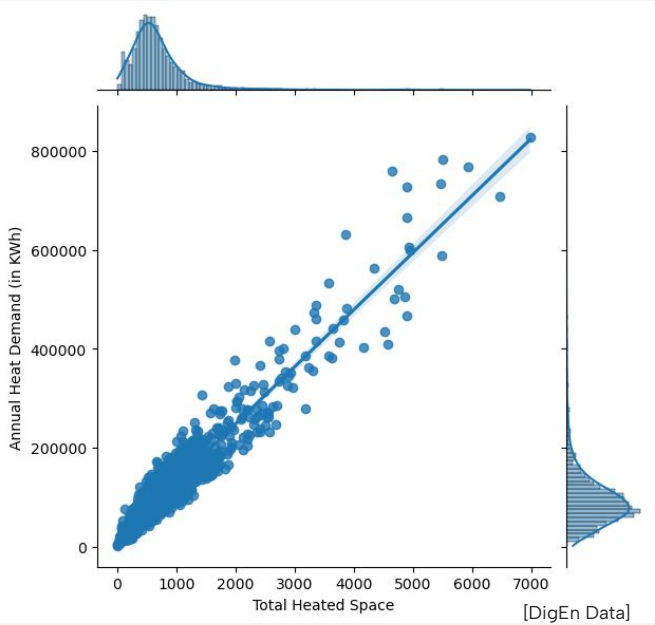
Living Space and heating demands



Bigger Living Space = Higher Heating demand?

- Relationship between annual heat demand and size of the heated space for different building types.
- Here we can see **outliers with high consumption**.
- Outliers were from commercial and public buildings

Living Space and heating demands



Bigger Living Space = Higher Heating demand?

- Relationship between annual heat demand and size of the heated space for different building types.
- Here we can see outliers with high consumption.
- Outliers were from commercial and public buildings
- Eliminated the outliers with very high value of heat demand
- **High Correlation** between heated space i.e. size of dwelling and heat demand of dwelling
- Here we are focusing only on Residential buildings into consideration.

Living Space and heating demands

OLS Regression Results

Dep. Variable:	KWh_th_a	R-squared:	0.904
Model:	OLS	Adj. R-squared:	0.904
Method:	Least Squares	F-statistic:	2.355e+04
Date:	Thu, 25 Jan 2024	Prob (F-statistic):	0.00
Time:	20:40:36	Log-Likelihood:	-28666.
No. Observations:	2497	AIC:	5.734e+04
Df Residuals:	2495	BIC:	5.735e+04
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	1.679e+04	716.673	23.423	0.000	1.54e+04	1.82e+04
full_space	115.5418	0.753	153.452	0.000	114.065	117.018

Omnibus:	581.305	Durbin-Watson:	1.879
Prob(Omnibus):	0.000	Jarque-Bera (JB):	4839.824
Skew:	0.863	Prob(JB):	0.00
Kurtosis:	9.599	Cond. No.	1.45e+03

Bigger Living Space = Higher Heating demand and costs?

- Regression Results based on full_space
- near zero p-value
- high R-Squared value
- Indicates that full_space variable has significant impact on annual heat demand.

What does this imply?

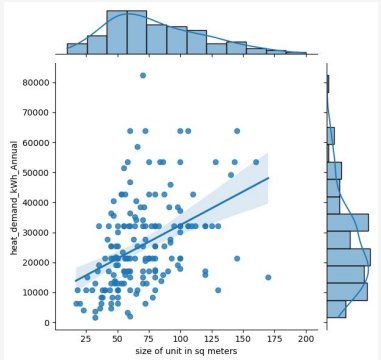
- The values seem too perfect for heating prediction.
- Let us analyze the SOEP data from this perspective.

Living Space and heating demands

Bigger Living Space = Higher Heating demand and costs?

- Space and heating demand relations in SOEP Data

1991 Data



[SOEP Data]

OLS Regression Results

Dep. Variable:	heat_demand_kWh_Annual	R-squared:	0.181
Model:	OLS	Adj. R-squared:	0.176
Method:	Least Squares	F-statistic:	38.63
Date:	Wed, 31 Jan 2024	Prob (F-statistic):	3.64e-09
Time:	20:55:54	Log-Likelihood:	-1935.2
No. Observations:	177	AIC:	3874.
Df Residuals:	175	BIC:	3881.
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	1.009e+04	2688.134	3.754	0.000	4786.619	1.54e+04
size of unit in sq meters	223.4210	35.946	6.215	0.000	152.477	294.365

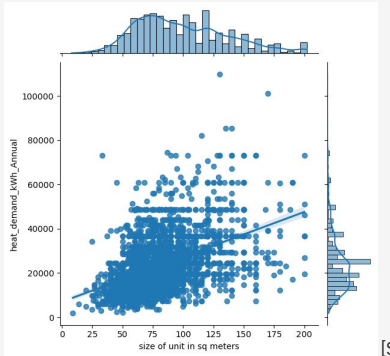
Omnibus:	30.012	Durbin-Watson:	1.910
Prob(Omnibus):	0.000	Jarque-Bera (JB):	43.804
Skew:	0.946	Prob(JB):	3.08e-10
Kurtosis:	4.535	Cond. No.	196.

Living Space and heating demands

Bigger Living Space = Higher Heating demand and costs?

- Space and heating demand relations in SOEP Data

2010 Data



[SOEP Data]

OLS Regression Results

Dep. Variable:	heat_demand_kWh_Annual	R-squared:	0.207
Model:	OLS	Adj. R-squared:	0.207
Method:	Least Squares	F-statistic:	733.2
Date:	Wed, 31 Jan 2024	Prob (F-statistic):	1.09e-143
Time:	20:55:49	Log-Likelihood:	-30208.
No. Observations:	2814	AIC:	6.042e+04
Df Residuals:	2812	BIC:	6.043e+04
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	7001.3930	647.848	10.807	0.000	5731.087	8271.699
size of unit in sq meters	203.0052	7.497	27.078	0.000	188.305	217.706

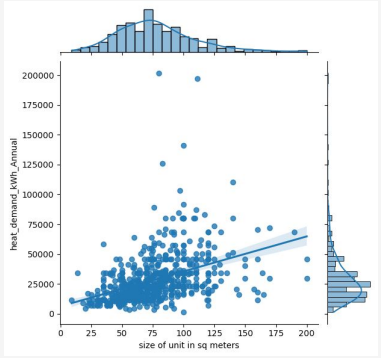
Omnibus:	663.131	Durbin-Watson:	1.955
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1780.677
Skew:	1.245	Prob(JB):	0.00
Kurtosis:	5.998	Cond. No.	267.

Living Space and heating demands

Bigger Living Space = Higher Heating demand and costs?

- Similar relation in SOEP data.
- But not as strong correlation as DigEn dataset.
- Thus the predictability here is not as good as DigEn dataset.
- What does this imply?
- Entries in DigEn dataset are too good to be true.
- DigEn : synthetic data, engineered for analysis.
- SOEP : Survey based, contains noise, based on guesstimates of the people during survey.
- Personally I would prefer combination of DigEn and SOEP.

2021 Data



[SOEP Data]

OLS Regression Results

Dep. Variable:	heat_demand_kWh_Annual	R-squared:	0.166
Model:	OLS	Adj. R-squared:	0.165
Method:	Least Squares	F-statistic:	124.9
Date:	Wed, 31 Jan 2024	Prob (F-statistic):	1.46e-26
Time:	20:55:40	Log-Likelihood:	-7070.3
No. Observations:	628	AIC:	1.414e+04
Df Residuals:	626	BIC:	1.415e+04
Df Model:	1		
Covariance Type:	nonrobust		

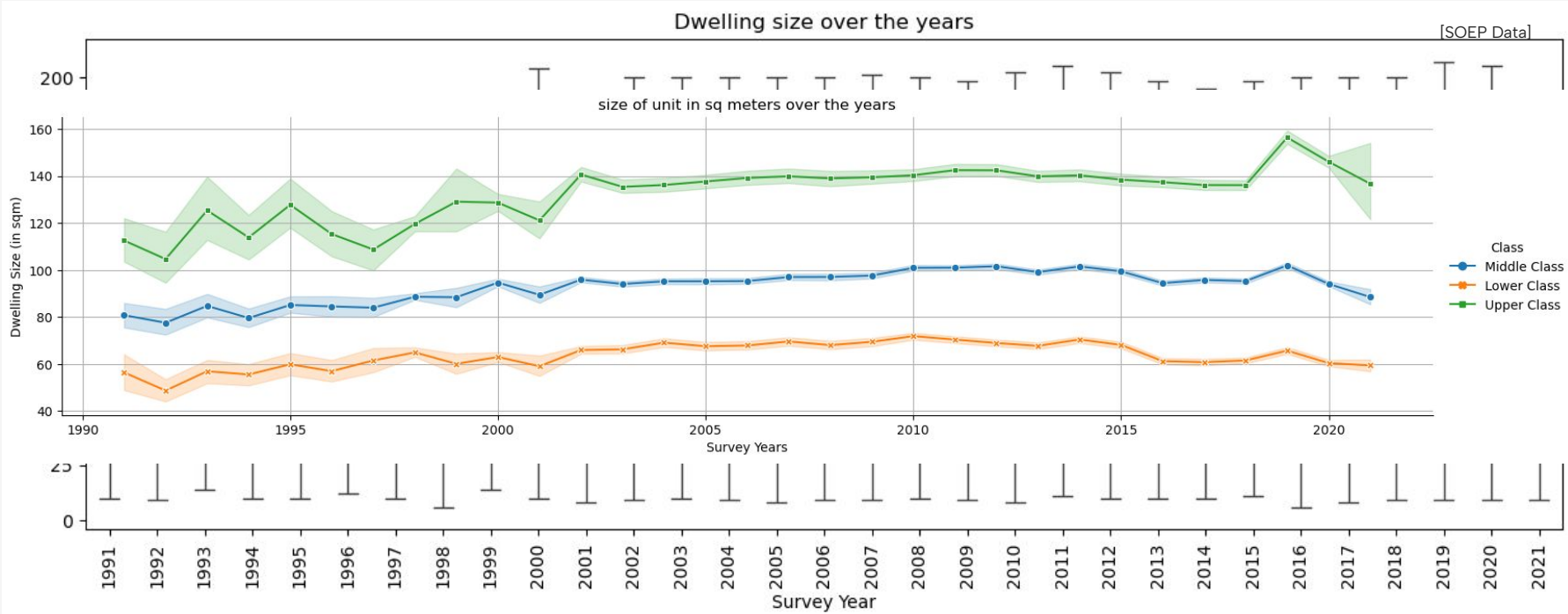
	coef	std err	t	P>|t|	[0.025	0.975]
const	6258.9889	2143.265	2.920	0.004	2050.129	1.05e+04
size of unit in sq meters	292.9452	26.215	11.175	0.000	241.464	344.426

Omnibus:	487.047	Durbin-Watson:	1.952
Prob(Omnibus):	0.000	Jarque-Bera (JB):	12752.319
Skew:	3.193	Prob(JB):	0.00
Kurtosis:	24.132	Cond. No.	234.

05

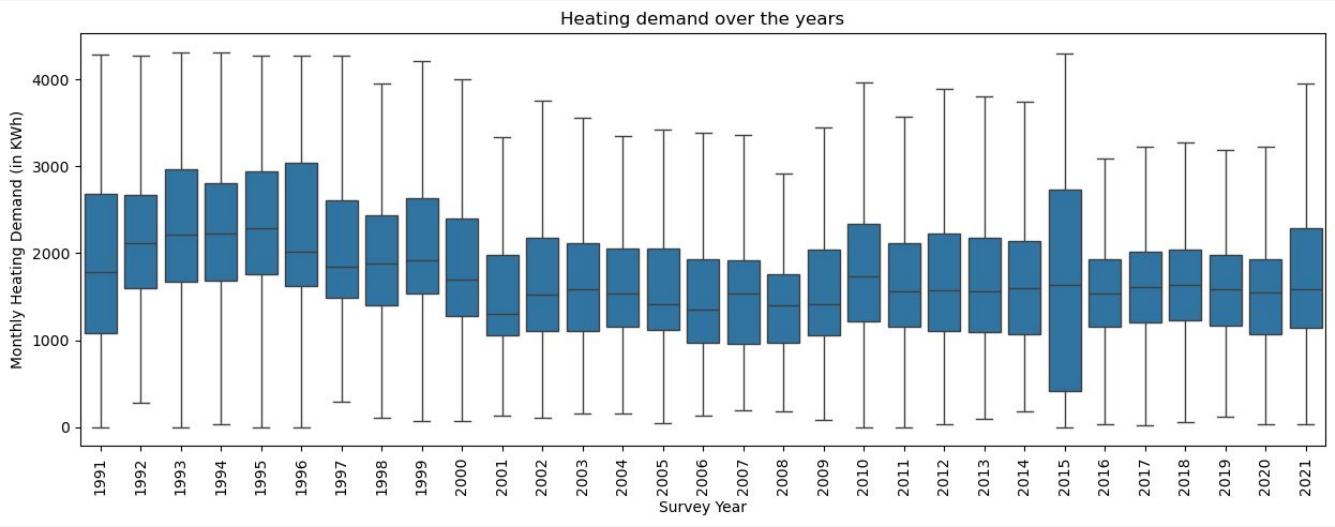
Heating Costs w.r.t Living Space

Living Space and Heating costs



- Lower class is living in small apartments
- The wage gap in different classes affect their choice of housing.

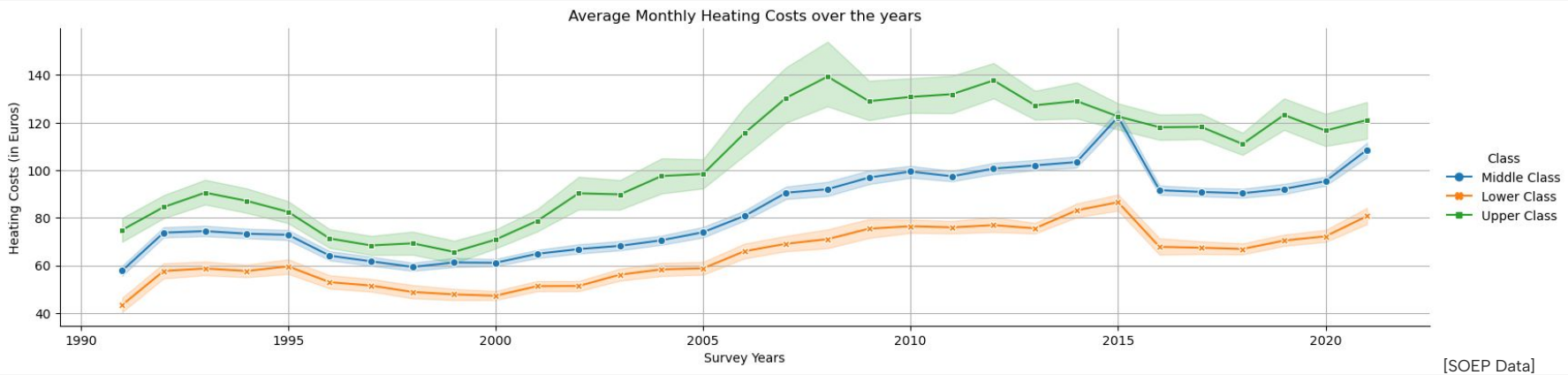
Living Space and Heating costs



[SOEP Data]

- Monthly heating demand has remained **stable** with average between 1000 KWh and 2500 KWh
- Note:2015 Data was imputed based on few additional questionnaire, thus it looks more broad compare to others.

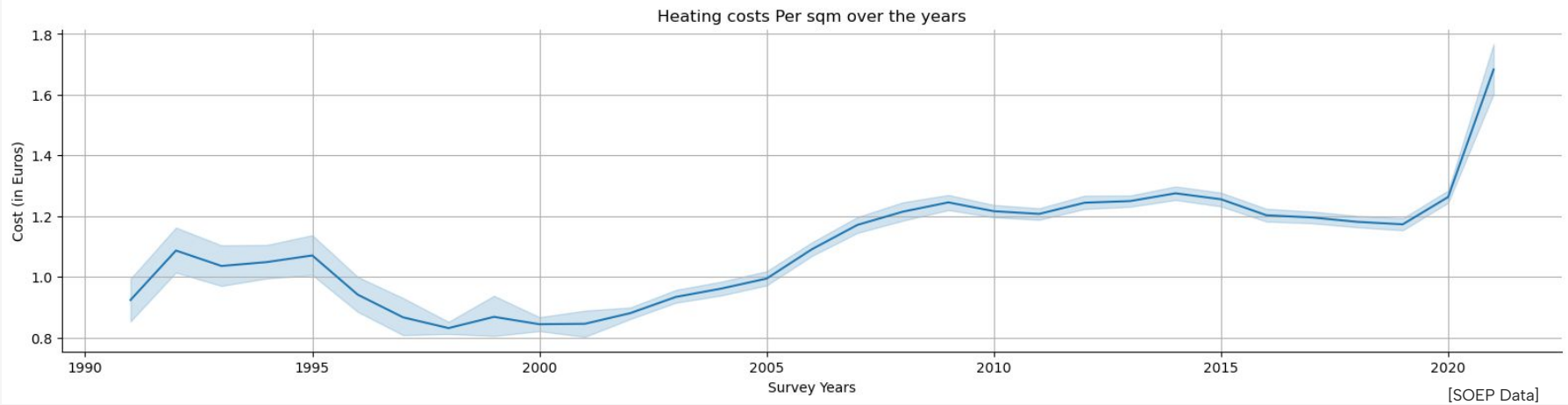
Living Space and Heating costs



[SOEP Data]

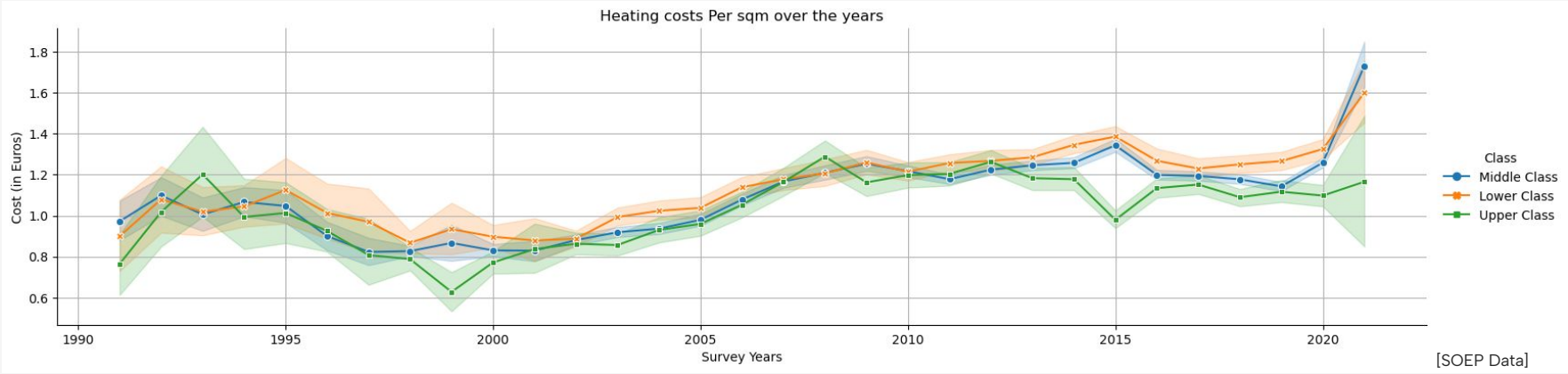
- 1991: Different classes are within 40 euro range
- 1995-2000: Gap reduces to 30 Euro
- Post 2005: Gaps grow wider with inflation and rising costs.
- Post 2020: again on the rise.
- Even though the energy demand for heat has remain stable, there is increase in heating costs.

Heating costs per Sqm of living space



- Average costs per Sqm of living space have increased.
- All time high in 2021 from SOEP data
- Bigger apartment might not be the best option.
- Only residential buildings were covered for this info.

Heating costs per Sqm of living space



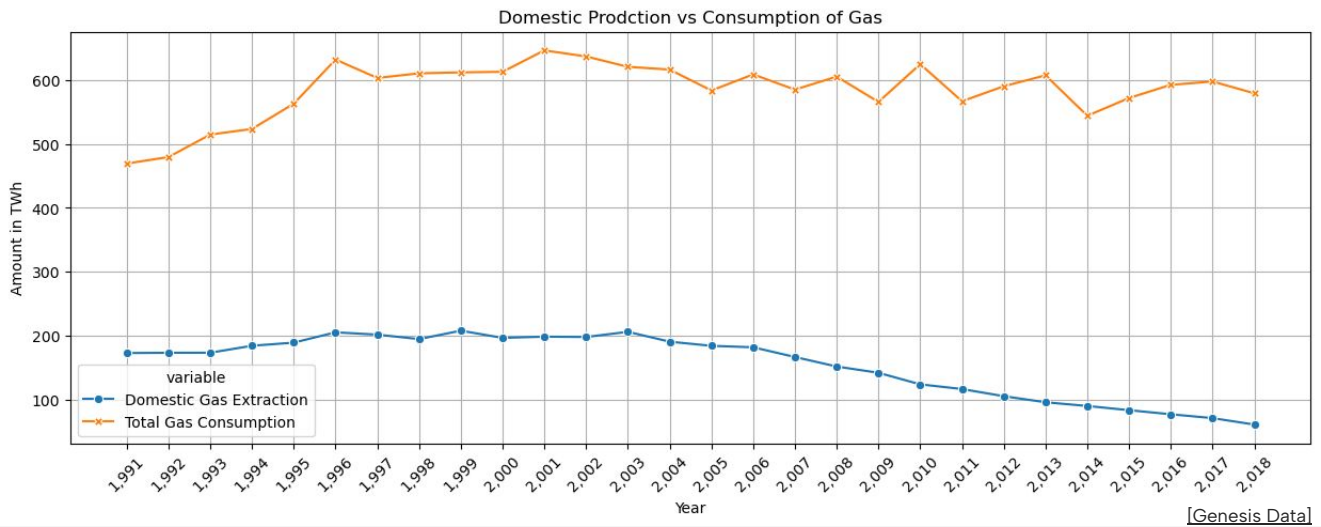
[SOEP Data]

- Wait this is surprising !!!!
- Upper class population is paying less money on heating per Sqm of living space.
- Lower class is paying the most.
- This may be caused by efficient heaters used by upper class.

06

Why Choose Gas ?

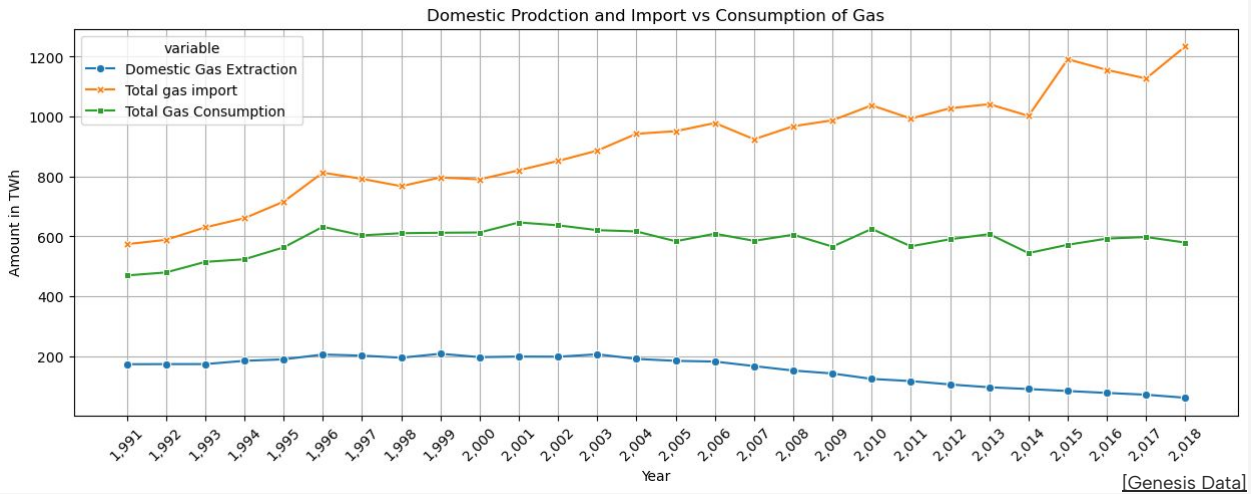
Consume more than we produce



[Genesis Data]

- We are dependent on gas.
- Consume more than we produce it.

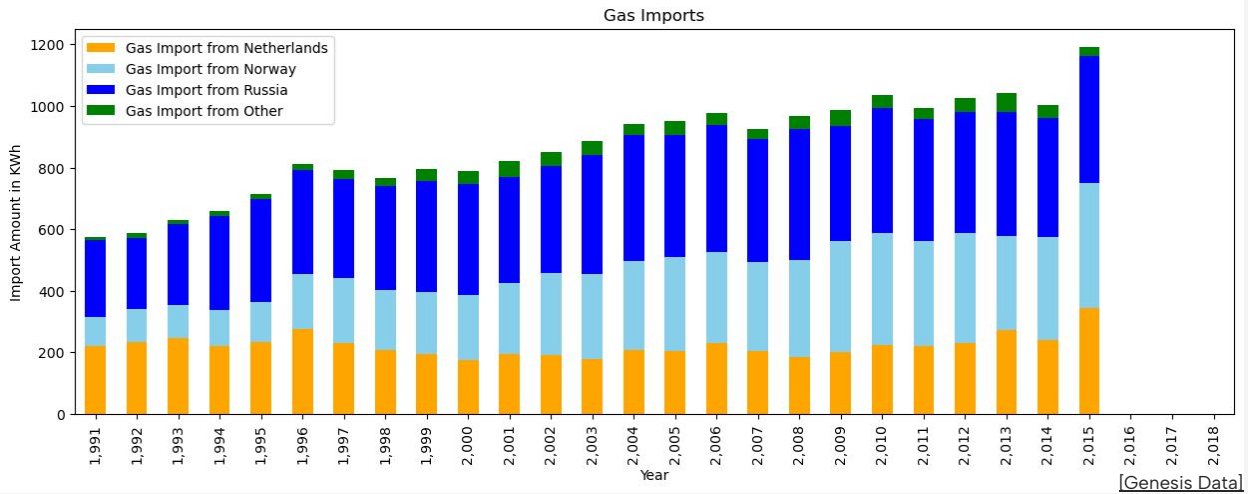
Consume more than we produce



[Genesis Data]

- We are dependent on gas.
- Consume more than we produce it.
- Thus arises the need to import to fulfil the demands.
    - Import volumes are increasing to keep up with the demand

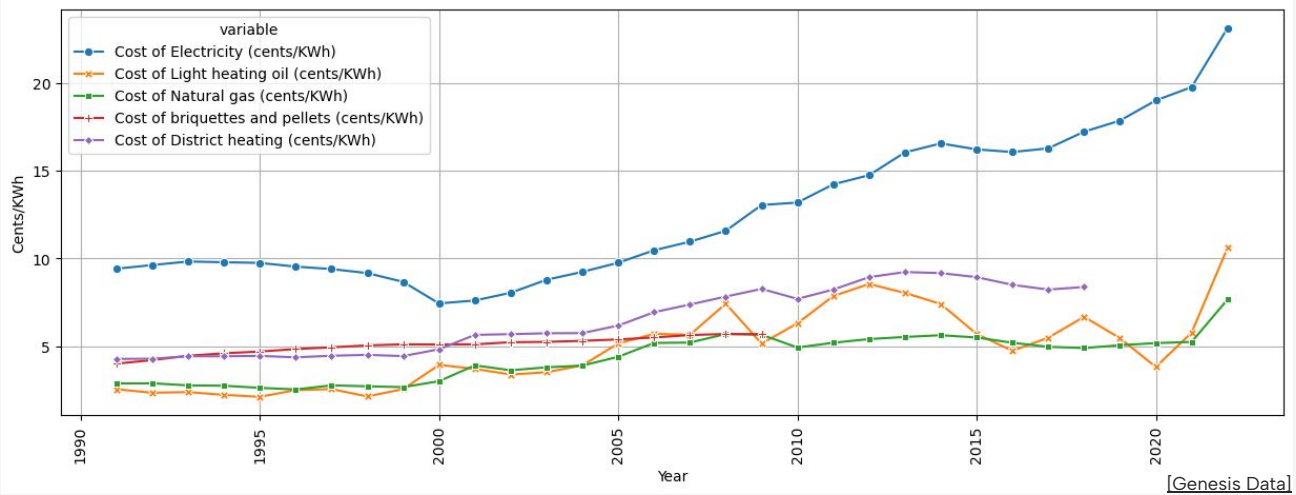
Consume more than we produce



[Genesis Data]

- We are dependent on gas.
- Consume more than we produce it.
- Thus arises the need to import to fulfil the demands.
- Import amount has increased over the years
    - Import volumes are increasing to keep up with the demand.
    - With ongoing economic sanctions on Russia, the supply has reduced and costs have increased.

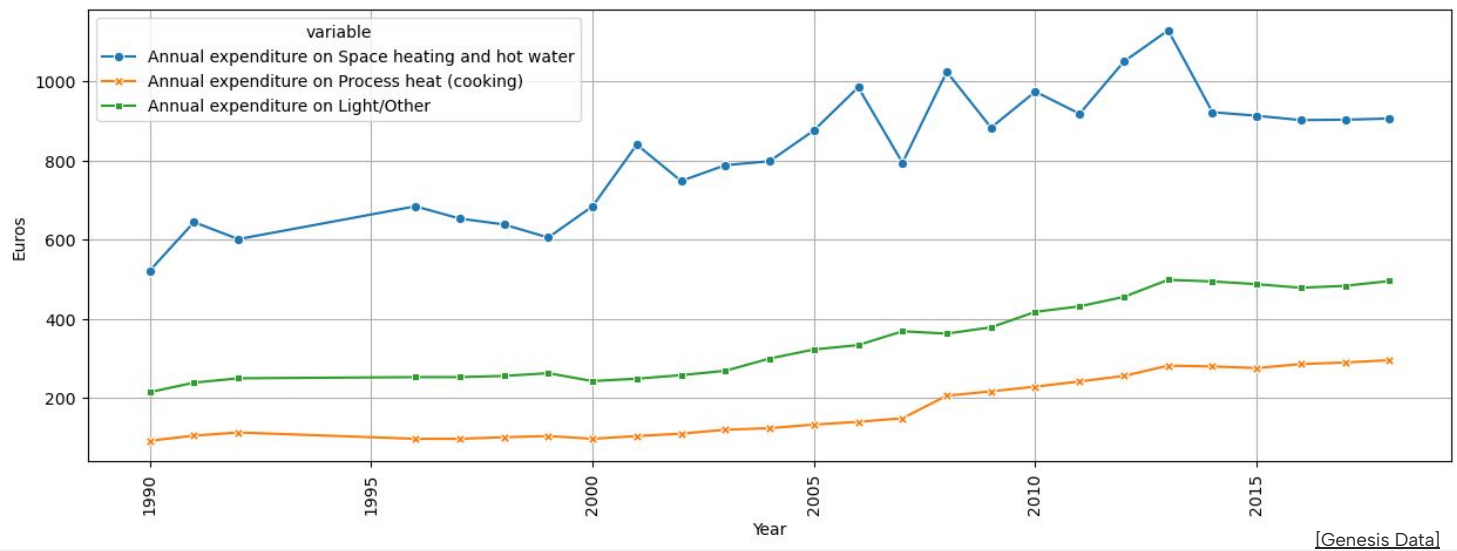
Costs of Gas, oil and electricity over the years



[Genesis Data]

- Costs are on the rise
- Gas is the most affordable option among these.
- The spike in 2022 is due to Ukraine-Russia Conflict.
- But the price is still affordable
  - Germany quickly reached out to other countries for import of gas and LNG. [1]
  - But the demand from household usage has also been decreased by 20% in 2023. [1]
- What does this imply?

Annual expenditure on energy



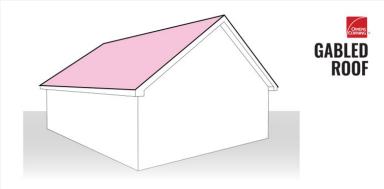
[Genesis Data]

- Costs are on the rise
- Gas is the most affordable option among these.
- The spike in 2022 is due to Ukraine-Russia Conflict.
- But the price is still affordable.
- What does this imply?
    - The annual expense is higher on energy, but still affordable. (but for how long?)

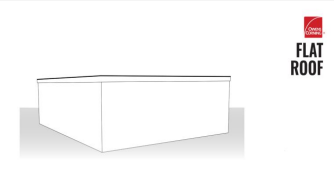
07

Effect of building architecture on heating

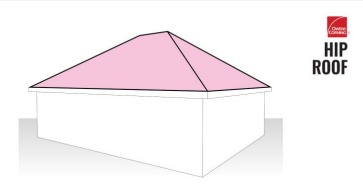
Roof Type



Gabled Roof : Roof with Two Slopes

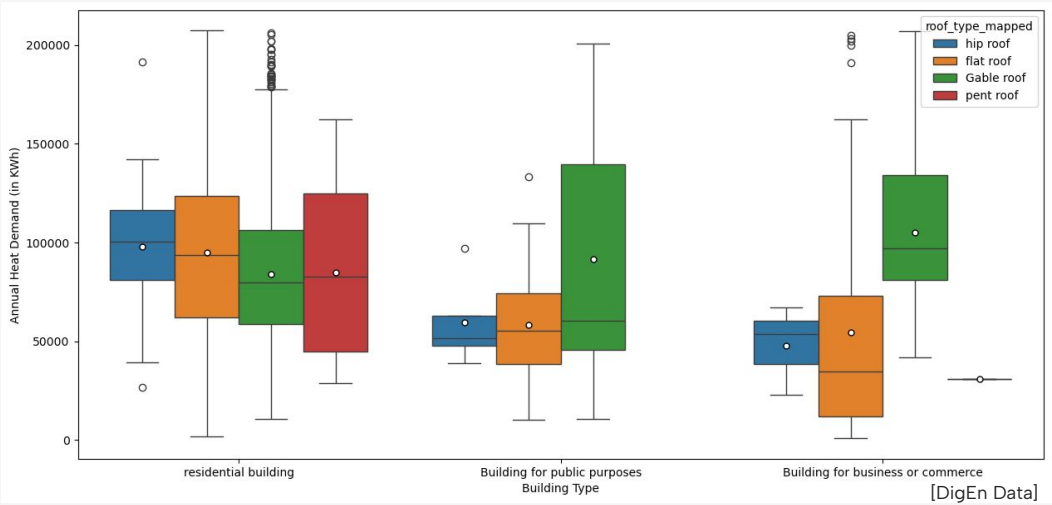


Flat Roof : Horizontal rooftop



Hip Roof : 4 Sloping sides

Pent Roof : 1 Sloping side

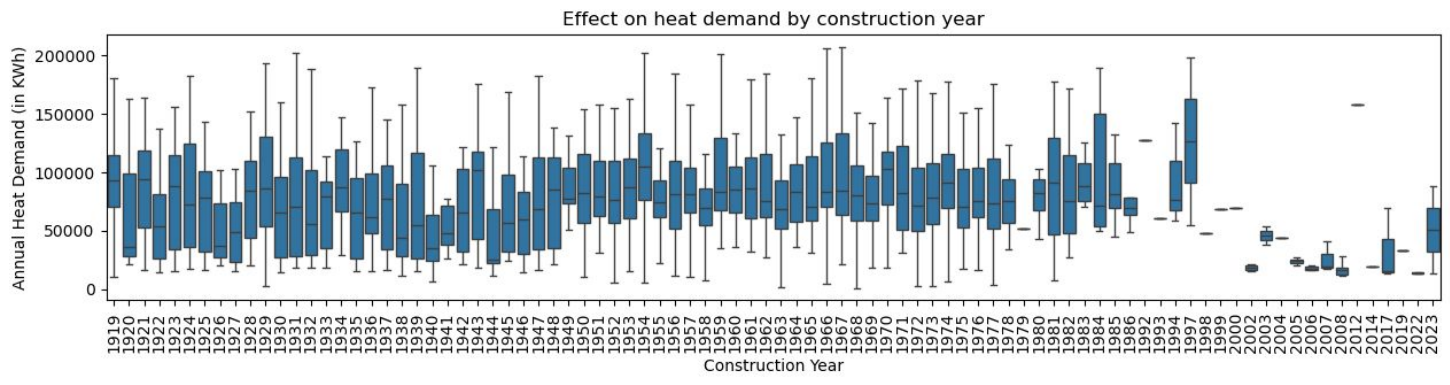


Comparing annual heat demand for different roof types (and for three building types)

- Gable Roof :
  - Used in Majority of houses
  - Lowest median value despite high number of houses.

The data suggests that Gabled roof is most efficient in the residential houses.

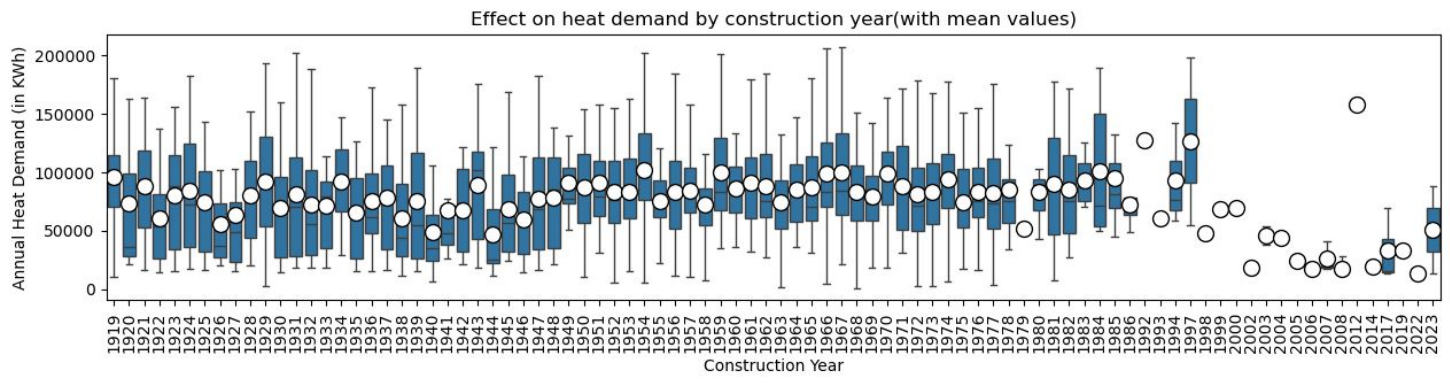
Construction Year



[DigEn Data]

- In general we have higher number of apartments constructed before 2000's
- With heat demand between 50000 KWh and 100000 KWh
- After 2000's we see lower heat demand
- Are newly constructed apartments are more efficient in heat retention?

Construction Year



[DigEn Data]

- In general we have higher number of apartments constructed before 2000's
- With heat demand between 50000 KWh and 100000 KWh
- After 2000's we see lower heat demand
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- Analysing the means of these shows us the heat demand for new houses is indeed lower

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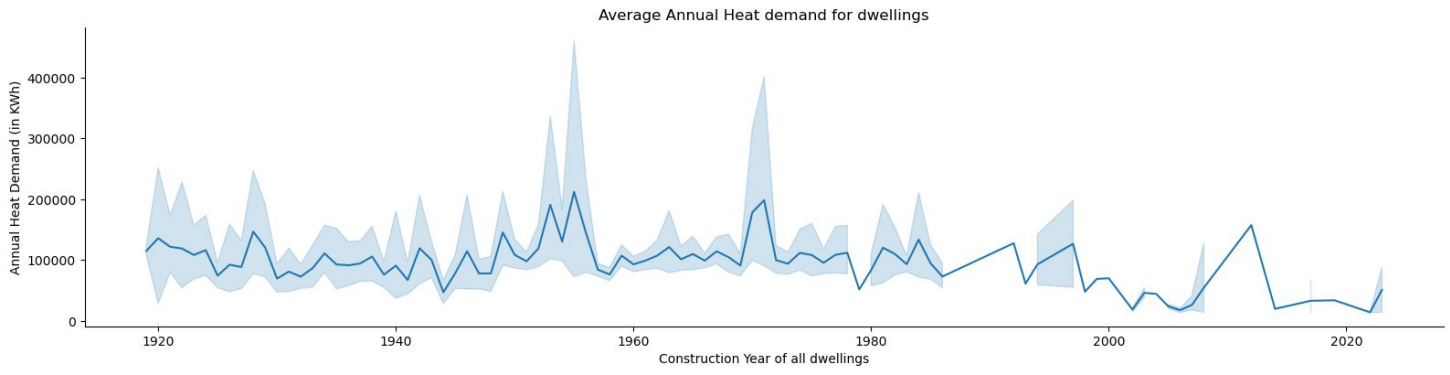

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Conclusion: New House = More Efficient heating

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Final Thoughts

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- In Spite of increased price of Gas people are using it as the primary source for heating.
- Moderately sized apartments with Gabled roof and Gas as heating source are suggested for an average household.
- The Wage differences between different class is increasing by the year and people from lower class are paying more on heating.

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Key Findings

Key findings

- In Spite increased price of Gas people are using it as the primary source for heating.
- Lower class population is spending more money on heating per sqm of their living space.
- Construction age and Roof type also good indicator of heating efficiency of an household

Reflection on Work Process

Reflection on Work Process

- Survey Data is not the easiest to handle
  - Questionnaires change from year to year, resulting in either missing data or finding the data in different sections
- Don’t be restricted to data on the hand, do your own research and understand the domain you are working with.
- Having good questions in mind and a critical mindset are two important factors in finding meaningful results.

Thanks!

Do you have any questions?