An econometric model for energy demand forecasting in transport & buildings sectors fo the EU countries

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Outline of the presentation

- **Aim of the paper**
- **Data used**
- **Forming of econometric models**
- **Results**
- **Conclusions**

Aim of the paper

This paper is a result from the task WP4.3 of the **ongoing HERON project** (being funded European Union's Horizon 2020 research and innovation programme under grant agreement No 649690).

"Forward-looking socio-economic research on Energy Efficiency in EU countries"

According to the description of the WP4.3, "**Linking energy consumption with economic factors**", the task aims at providing:

"The mathematical reflection of
energy consumption
as a function of
GDP,
household income and any
other **relevant economic factors** for the EU countries."

Aim of the paper

To develop econometric models to estimate **aggregate energy demand** for the

- **transport** and
- **buildings** sector,
  - residential and
  - tertiary sectors.

for **8 EU countries**:

- Belgium,
- Bulgaria,
- Estonia,
- Germany,
- Hellas,
- Italy,
- Serbia,
- UK,

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Data sources

The required data have been collected from two official EU sources, namely the **EUROSTAT** and the **ODYSSEE** databases.

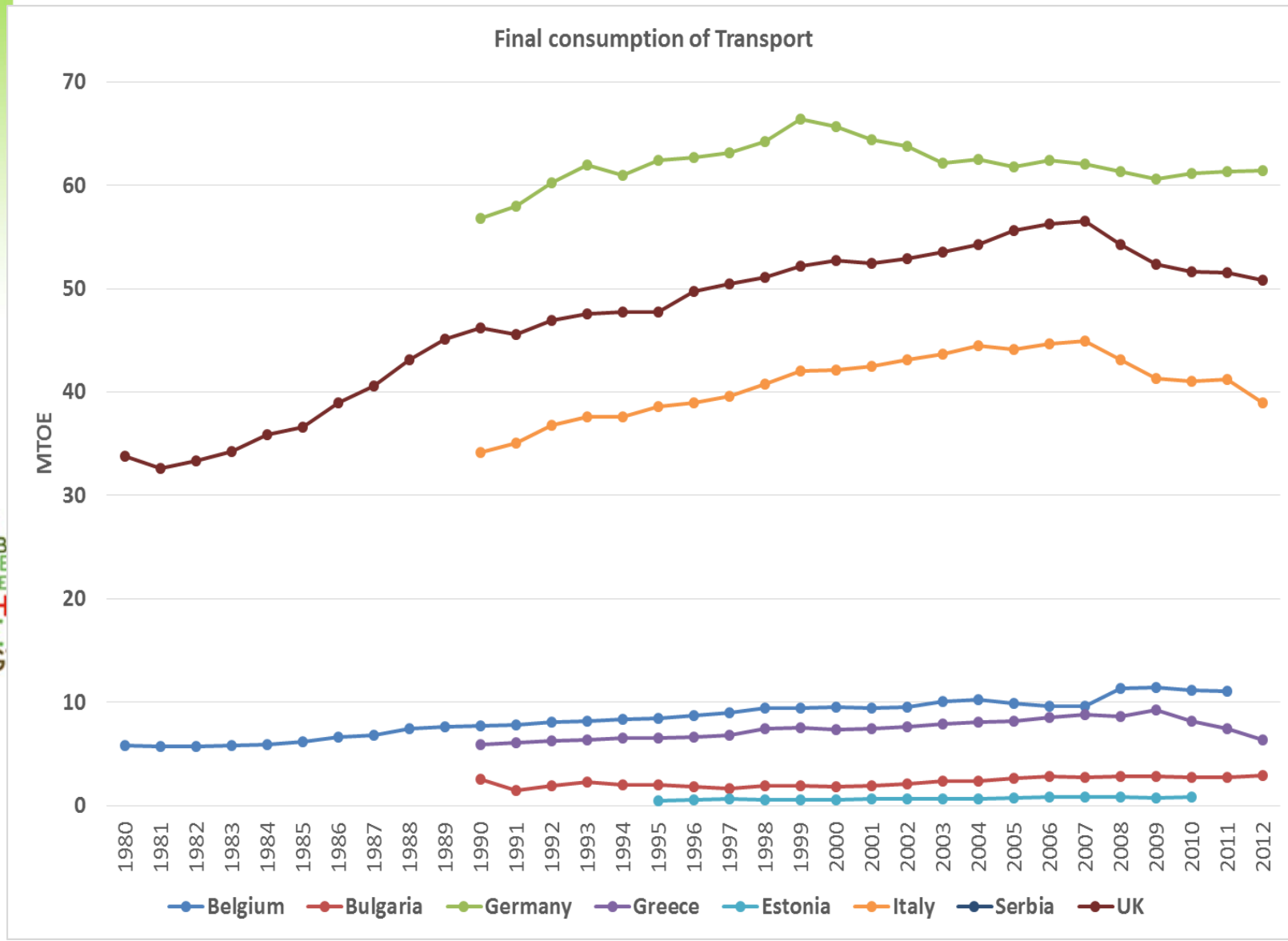
The **ODYSSEE** database is part of the ODYSSEE-MURE project. A network of **33 partners from 28 countries** participate to the ODYSSEE MURE project, usually **national Efficiency Agencies** or their representatives.

The ODYSSEE database is managed by Enerdata that contains detailed energy efficiency and CO2-indicators with data on energy consumption, their drivers (activity indicators) and their related CO2-emissions.

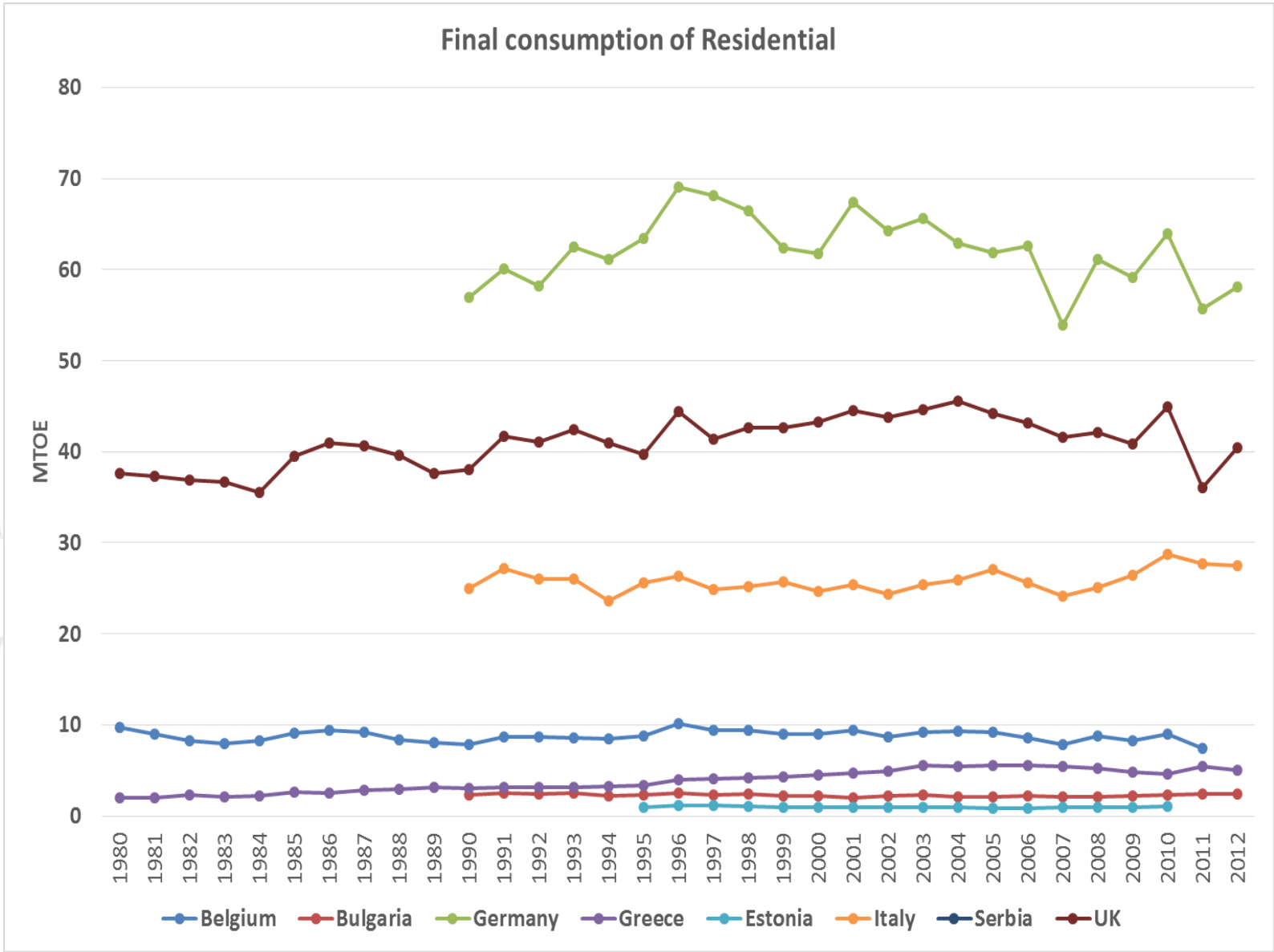
List of variables elaborated

Residential	Tertiary	Transport
Electricity Price	Electricity Price	Electricity Price
Gas Price	Gas Price	Gas Price
HICP - All products	HICP - All products	HICP - All products
HICP - Liquid fuels	HICP - Liquid fuels	HICP - Liquid fuels
HICP - Energy	HICP - Energy	HICP - Energy
Coal consumption of residential sector	Coal consumption of tertiary	Annual distance travelled by cars
Degree-days	Degree-days	Average specific consumption (l/100 km) of cars
Electricity consumption of residential	Electricity consumption of tertiary	Car traffic
Energy efficiency gains in residential	Electricity intensity of services sector	Degree-days
Energy efficiency index of households	Electricity unit consumption in private offices	Diesel consumption of cars
Final consumption of residential	Employment of tertiary	Diesel consumption of transport
Floor area of dwellings (average)	Energy efficiency gains in tertiary	Electricity consumption of transport
Gas consumption of residential sector	Energy efficiency index of tertiary	Energy efficiency gains in transport
GDP per inhabitant (ppp)	Energy intensity of services sector (at purchasing power parities)	Energy efficiency index of transport
Number of households	Final consumption of tertiary	Energy intensity of transport
Oil consumption of residential sector	Floor area of tertiary	Final consumption of transport
Population	Gas consumption of tertiary	Fuel oil consumption of transport
Private consumption per households (ppp)	GDP per inhabitant (ppp)	Gas consumption of transport
Renewable consumption of residential tertiary ...	Oil consumption of tertiary	GDP per inhabitant (ppp)
Stock of dwellings (permanently occupied)	Population	Oil products consumption of transport
Total stock of dwellings	Total consumption of tertiary (with climatic corrections)	Population
	Value added of tertiary at exchange rate	Share of public transport in total land passenger traffic
		Stock of cars
		Total consumption of road transport
		Total passenger traffic

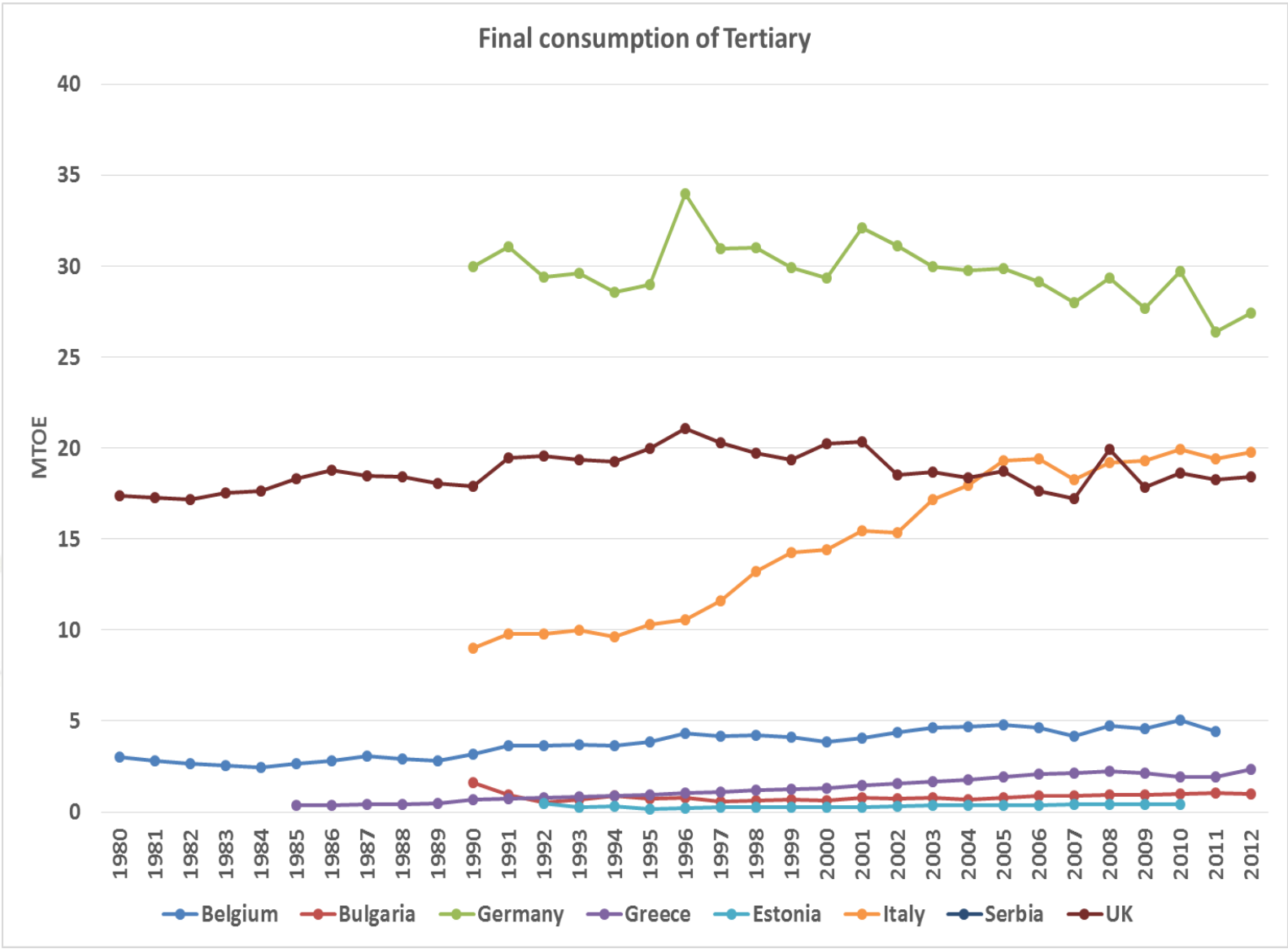
Energy consumption in transport



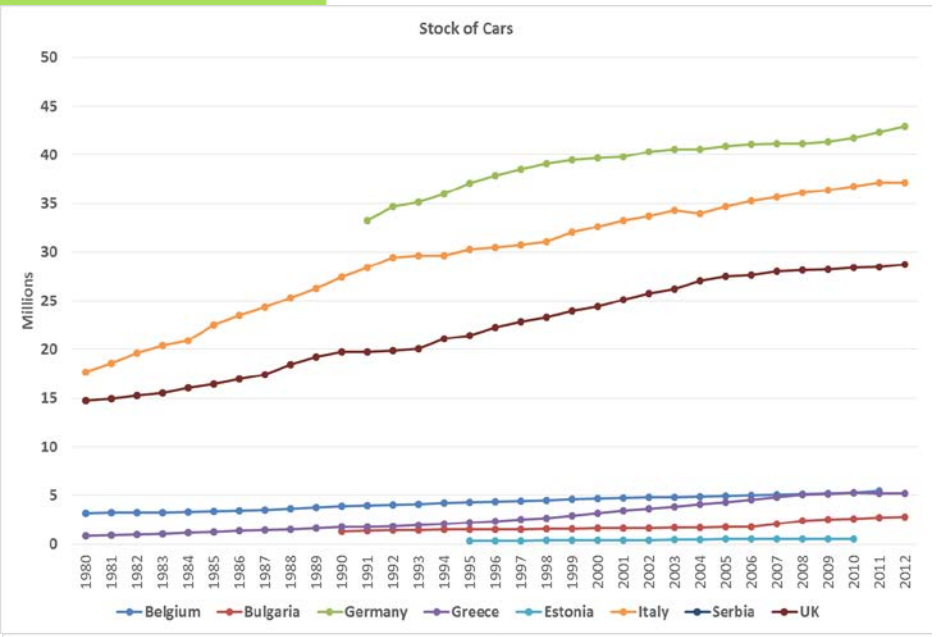
Energy consumption in residential

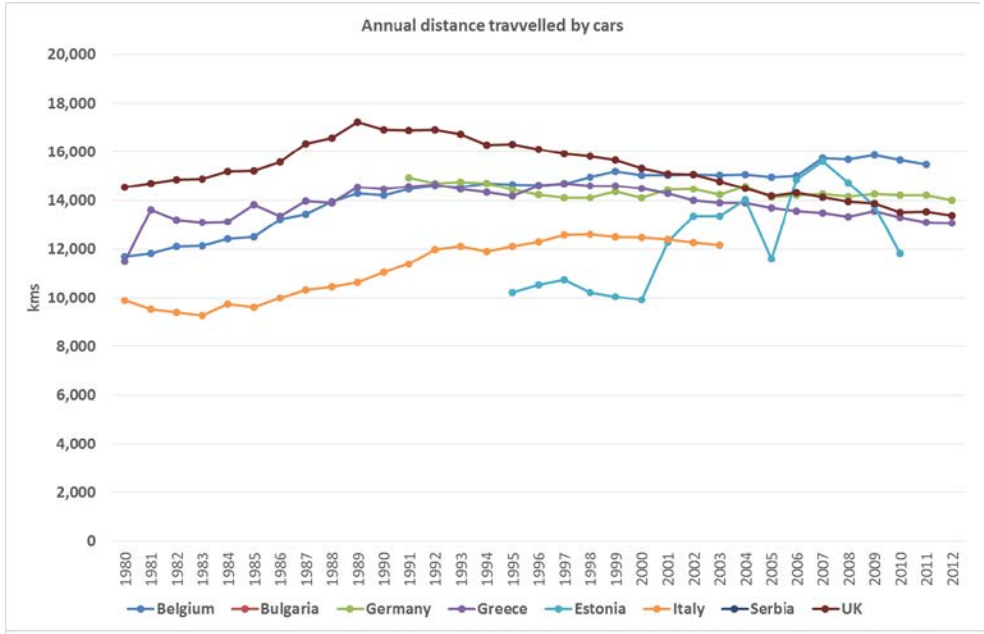


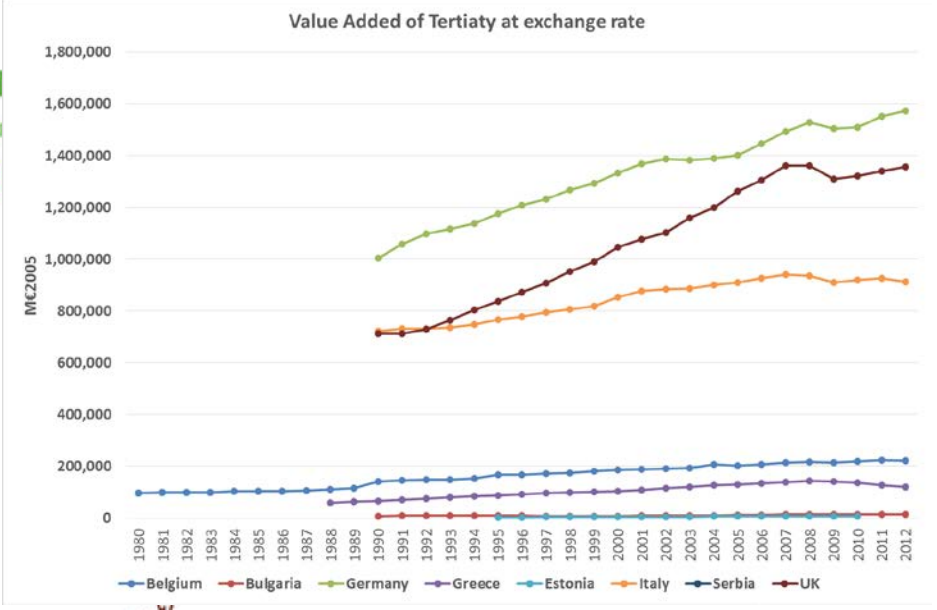
Energy consumption in tertiary

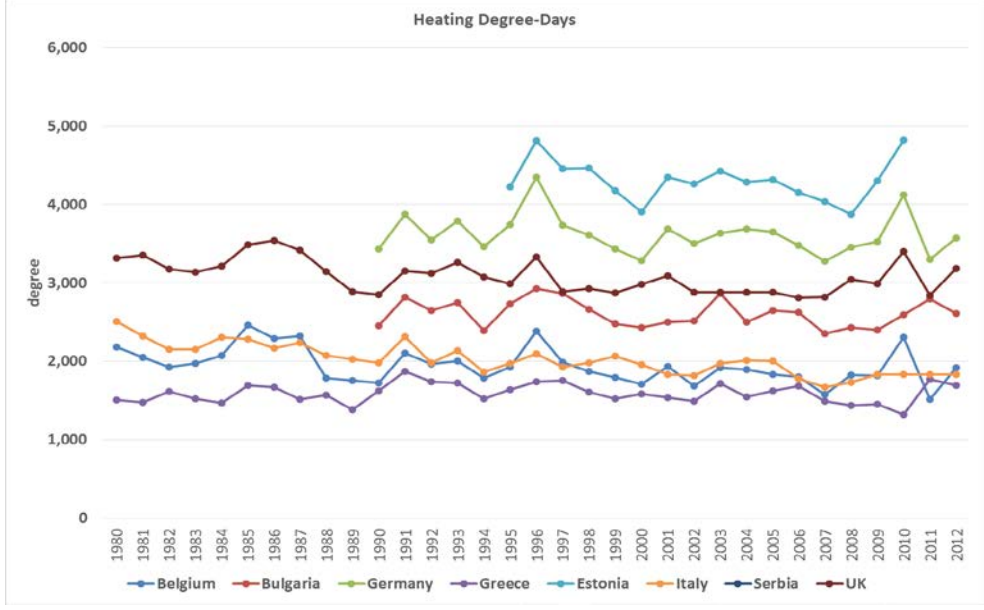


Indicative explanatory variables used









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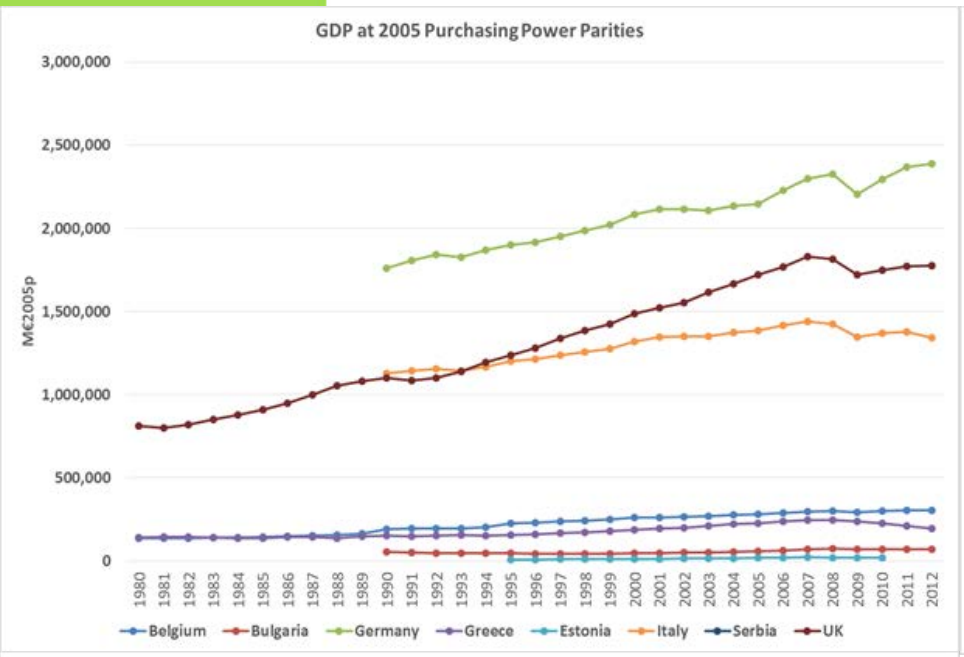

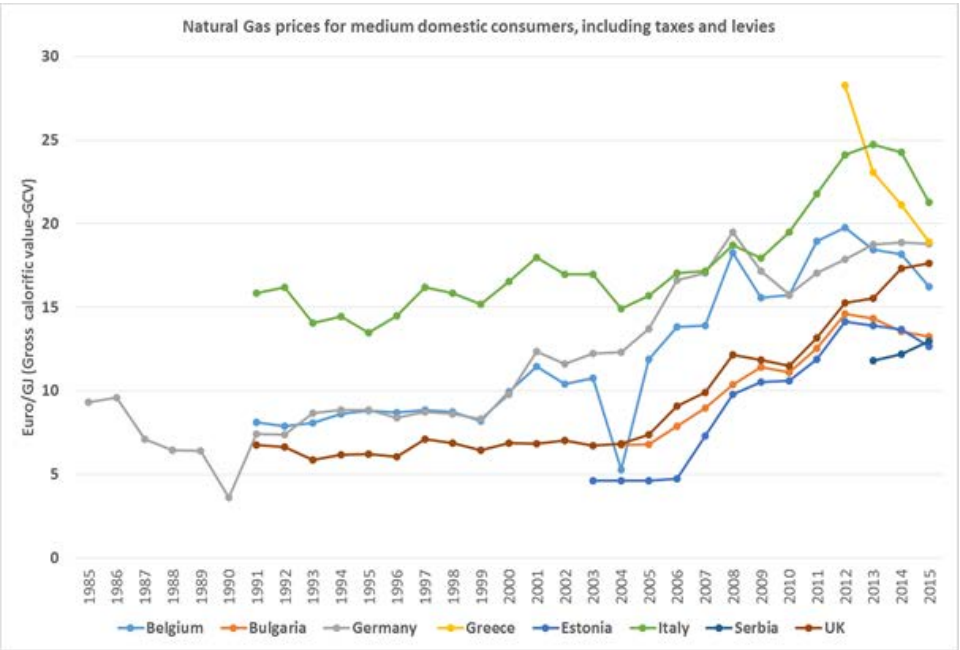

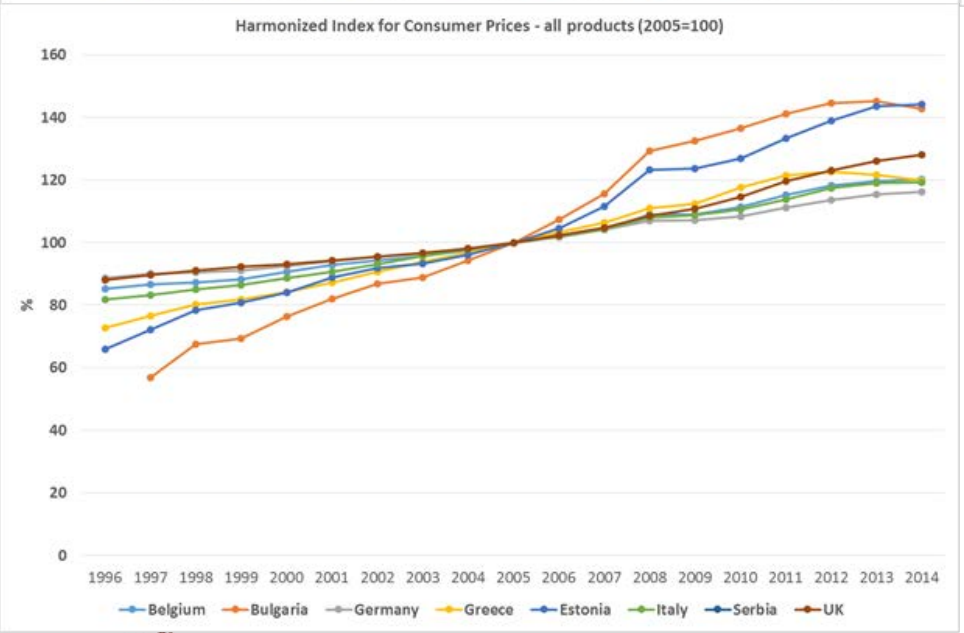

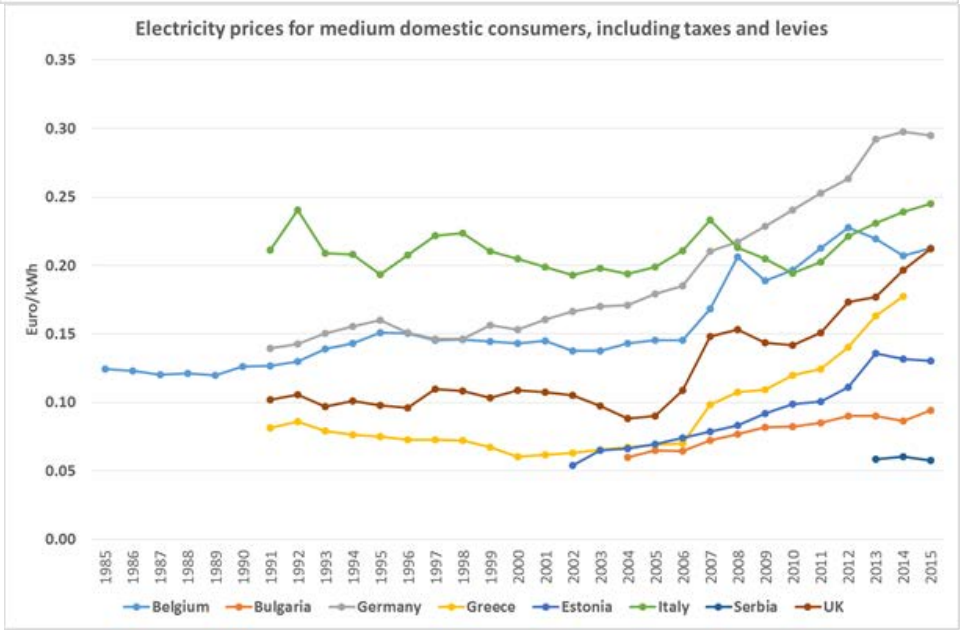

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Econometric model

For comparison reasons (among sectors and countries), we developed a **general aggregate energy demand** model with the following form:

$$E_{i,t} = f\left(\Pr_{i,t}, EA_t, St_{i,t}, Pop_t, HDD_t\right)$$

where:

- $E_{i,t}$, concerns the **Energy demand** for energy product i in year t
- $Pr_{i,t}$, concerns the **Price** (energy prices of product i or of competitive products,
- **Harmonized Index for Consumer Prices** for energy product i in year t
- EA_t, concerns the **Economic Activity** (GDP per Capita, Value Added of the sector) in year t
- $St_{i,t}$, concerns the **Stock** (of dwellings, appliances, cars) for energy product i in year t
- Pop_t, concerns the **Population** in year t
- HDD_t, concerns the Heating **Degree Days** (and/or Cooling DD if available) in year t

Data inspection and elaboration

Prior to building the econometric model, we examined the variables, concerning the

- Existence of missing data
- Existence of outliers
- Stationarity tests

This has eliminated the available data to shorter datasets from the initial.

We also applied logarithmic values, as in the literature.

Selection of models

The criterion for selecting the variables are:

1. a. having a general model (meaning same variables among countries)
2. b. having a high Adjusted R square, as measure of the fitting of the model,
3. c. having low forecast errors in the last 5 years
4. d. the coefficients having the expected sign and
5. e. the coefficients are statistical significant.

Selection of models

This has led to the **omission of some critical values**, such as the population for residential demand, although it developed the model but provided **no logical signs** of coefficients for some countries e.g. Belgium.

Moreover, several models have **coefficients that are not statistical significant**, which normally would lead for judging them as not suitable.

Finally, some models have **low Adjusted R square**, e.g. 0.64 for Estonian residential demand, which means that the model is not good.

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Adjusted R2
of the econometric models

	Belgium	Bulgaria	Germany	Greece	Estonia	Italy	Serbia	UK
Residential	0.79	0.79	0.67	0.83	0.64	0.79		0.80
Tertiary	0.85	0.88	0.64	0.96	0.95	0.96		0.45
Transport	0.53	0.95	0.36	0.94	0.74	0.93	0.62	0.92

Most of the models have a **high R square (R2)**, which is a strong indicator of the **reliability** of those models.

Results for residential sector

	Belgium	Bulgaria	Germany	Greece	Estonia*	Italy	UK
Intercept	6.644716	6.942301	-1.27007	-16.0672	-48.6965	-19.4146	4.450599
HICP - Energy	-0.02108	0.054807	-0.04524	-0.30224	-1.5315	-0.15074	-0.11411
Degree-days	0.470227	0.561068	0.654841	0.821086	0.098886	0.54168	0.806856
GDP per inhabitant (ppp)	0.428408	0.841065	-0.25323	1.220438	1.602099	0.54529	0.862163
Private consumption per households (ppp)	0.61676	-0.81246	1.760128	-0.81926	-1.21666	-0.32967	0.023787
Stock of dwellings (permanently occupied)	-1.36568	-1.29629	-0.48143	1.474649	8.460281	1.876187	-0.94882

The model results are in most cases **aligned with the expectations**, concerning the **sign of the coefficients.**

- **price variables have a negative sign**,
- **GDP per capita, Heating Degree Days** variables have a **positive sign**.

Economic activity and degree days have strong influence, while price has small.

Results for tertiary sector

	Belgium	Bulgaria	Germany	Greece	Estonia*	Italy	UK
Intercept	-12.5342	-8.09318	-2.53256	-9.48986	-7.62804	-40.2479	7.900009
HICP - Energy	-0.03651	-0.04047	-0.09076	0.311446	0.492289	0.246878	0.012283
Degree-days	0.303009	0.48769	0.530791	-0.09133	0.293637	0.481809	0.284845
Value added of tertiary at exchange rate	0.513663	0.981458	0.724086	0.481483	0.793702	3.334077	0.433527
Employment of tertiary	0.692706	-0.68676	-0.81028	0.45619	-0.85352	-0.77659	-1.32425

The model results in most cases are **aligned with the expectations**, concerning the **sign of the coefficients.**

- **Value added, Heating Degree Days** variables have a **positive sign**.

Economic activity and degree days have strong influence.

Results for transport sector

	Belgium	Bulgaria**	Germany	Greece	Estonia*	Italy	UK
Intercept	-9.98797	-1.64209	-3.35107	-5.13737	-3.51785	-0.88684	-15.0239
HICP – Energy	-0.08566	-0.0867	-0.06149	-0.04174	-0.00031	-0.05584	-0.00635
GDP per inhabitant (ppp)	0.602727	0.614875	0.349436	0.456985	0.135699	1.200908	0.946292
Annual distance travelled by cars	0.569595	-0.21002	1.407486	0.275746	0.208329	0.090018	1.83165
Car traffic	1.133717	0.801685	-1.75556	1.043383	0.364363	-0.02138	-0.63283
Stock of cars	-0.04463	-0.54616	1.361329	-0.83029	-0.10203	0.103819	0.737281

* Variable "HCIP - All Products" instead of "HCIP Energy"

** Variable "Total Passenger Traffic" instead of "Annual distance travelled by cars"

The model results are in most cases **aligned with the expectations**, concerning the **sign of the coefficients.**

- **price variables have a negative sign**,
- **GDP per capita, annual distance travelled** variables have a **positive sign**.

Economic activity and distance have strong influence, while price has small.

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Conclusions

The paper presents econometric models, developed for the needs of the EU Horizon 2020 project “HERON”, to model aggregate energy demand for the buildings and transport sectors in 8 EU countries.

Using data from the EUROSTAT and ODYSSEE databases, a **generic econometric model** is developed, for comparison reason among sectors and countries.

$$E_{i,t} = f\left(\mathrm{Pr}_{i,t}, EA_t, St_{i,t}, Pop_t, HDD_t\right)$$

Most of the models have a **high R square (R2)**, which is a strong indicator of the **reliability** of those models.

The model results in most cases are **aligned with the expectations**, concerning the **sign of the coefficients.**

- **price variables have a negative sign**,
- **economic activity, stock, Heating Degree Days** variables have a **positive sign**.

The models can be used from the national experts, to form scenarios on the impact of socio-economic and other factors on the aggregate energy demand in buildings and transport sectors for EU countries.

Thank you
for your attention!

A new **Energy & Environmental Policy laboratory** established in July 2016 at the **University of Piraeus**.

Will be online in October 2016
Energypolicy.unipi.gr

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