ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

cepe
Centre for Energy Policy and Economics
Department of Management, Technology and Economics

Underlying Energy Efficiency in the Residential Sector : an Economic Perspective

Massimo Filippini

Atlantic Workshop on Energy and Environmental Economics
2014

Outline

- Motivation
- Energy efficiency and productive efficiency
- Econometric approaches to measure the "Underlying Energy efficiency"
- Study 1: "Underlying Energy efficiency" in the EU
- Study 2: "Underlying Energy efficiency" in the US
- Conclusions

A) Motivation and Goals

- All countries around the world are implementing **energy efficiency policy instruments**

- **Improving energy efficiency** is one of the most cost-effective ways of

↳ reducing CO_2 emissions

↳ reducing air pollution

↳ increasing security of energy supply

- In the **new EU energy strategy** (Energy 2020) energy-efficiency is listed among the first 5 priorities: 20% energy savings to be achieved by 2020 (EC, 2010)

- The majority of **the US states** are implementing energy efficiency policies although with different approaches. **Federal level**: Discussion on the introduction of an Energy efficiency improvement Act (2014)

- Recently **China** revised its energy conservation law and emphasized the relevance of the level of energy efficiency in all sectors of the economy (12th Five Year Plan binding targets for energy efficiency)

House passes Welch bipartisan energy efficiency legislation

(passed the House of Representatives, but has not come to a vote in the Senate yet)

News Release — Rep. Peter Welch, D-Vt.
March 5, 2014

WASHINGTON, D.C. – By a vote of 375-36, the U.S. House of Representatives this afternoon approved energy efficiency legislation authored by Representative Peter Welch. The Energy Efficiency Improvement Act, H.R. 2126, is the first significant bipartisan energy initiative approved by the House in the 113th Congress.

The Energy Efficiency Improvement Act has four key components:

· Establishes energy efficiency best practices for commercial tenants renting space in commercial buildings and creates a new TENANT STAR certification program. TENANT STAR will be modeled after the existing ENERGY STAR program which certifies commercial buildings as highly energy efficient.

http://vtdigger.org/2014/03/05/house-passes-welch-bipartisan-energy-efficiency-legislation/

- In order to increase the level of efficiency in the use of energy it is important

➥ To **measure in a precise way the level of efficiency in the use of energy (**aggregate/disaggregate)

➥ to analyze the **impact of energy policy instruments and socioeconomic variables on the level of efficiency in the use of energy**

- **How to measure the level of energy efficiency?** *Patterson (1996)*

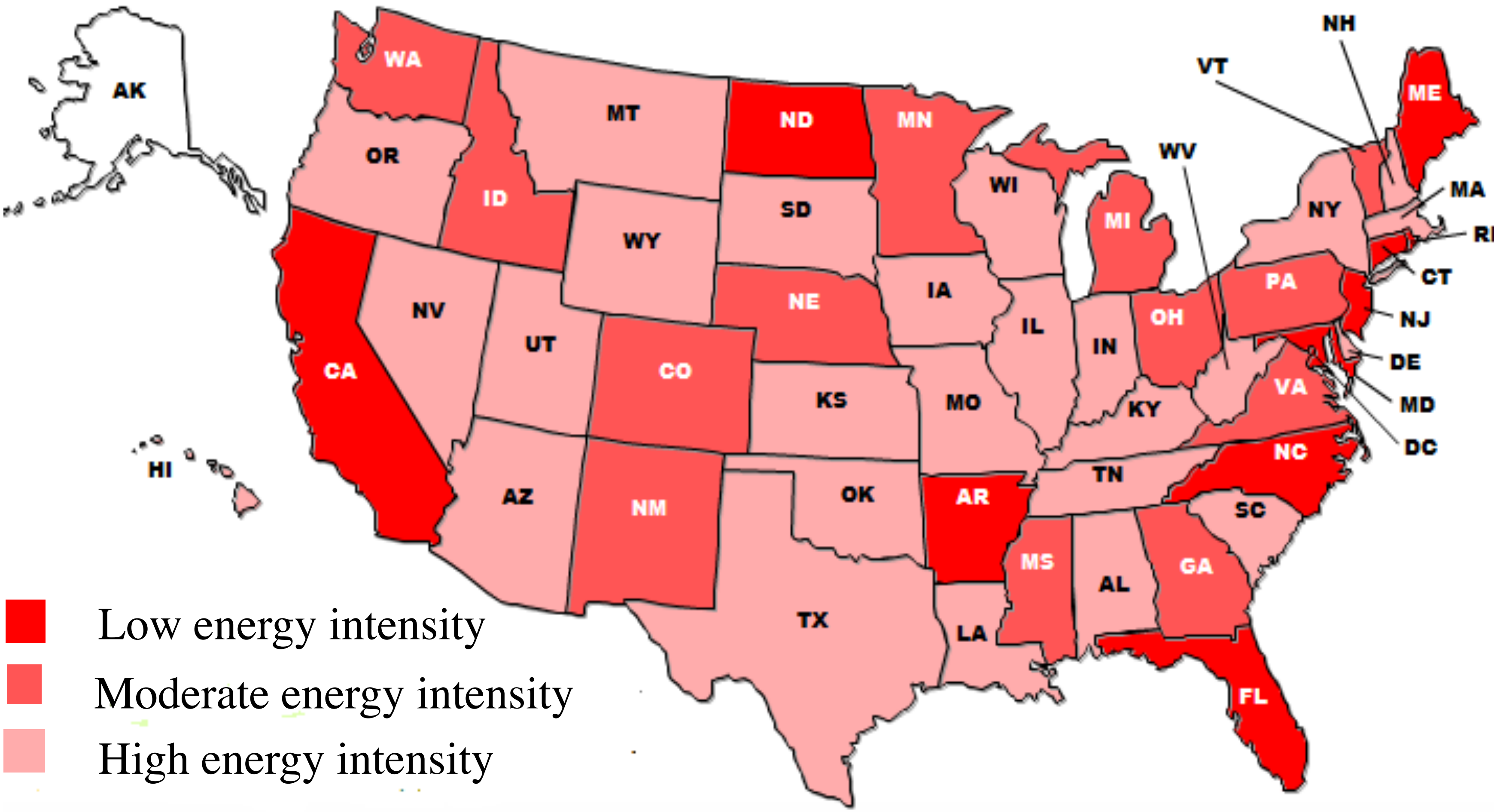
- *Physical–thermodynamic indicators:* energy input is measured in thermodynamic units and output is measured in physical units
- *Economic–thermodynamic indicators* of energy efficiency: energy input is measured in thermodynamic units and output is measured in monetary value
- *Economic indicators*

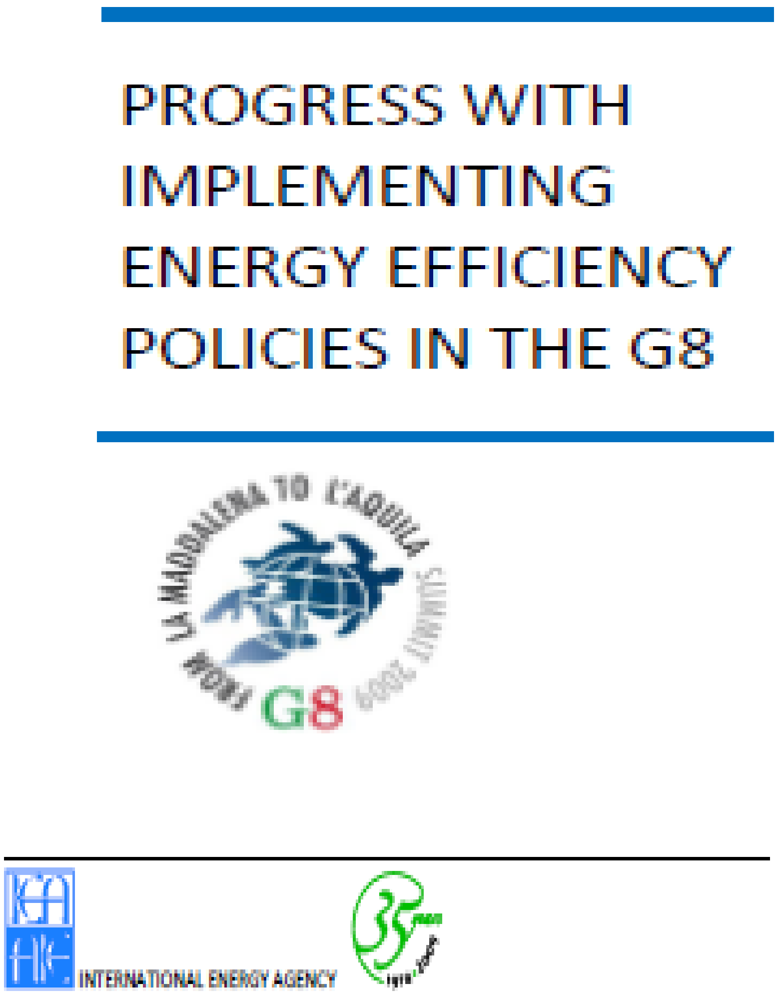
- Example of a well known economic–thermodynamic indicator of energy efficiency for the whole economy

↪ **Energy intensity (Energy consumption/GDP)**

↪ Energy productivity (inverse of energy intensity)

Classification of member states based on the energy intensity (whole economy)



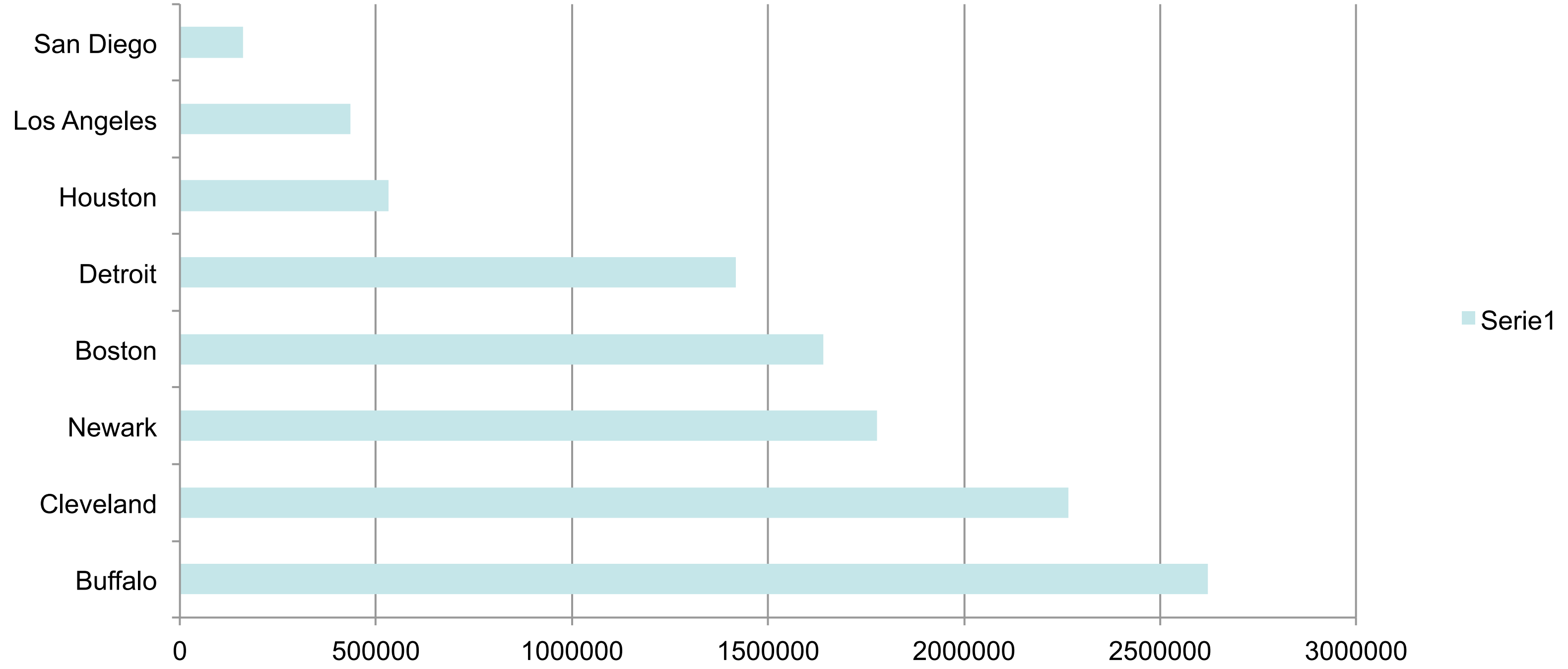

PROGRESS WITH IMPLEMENTING ENERGY EFFICIENCY POLICIES IN THE G8

"Energy intensity is commonly calculated as the ratio of energy use to GDP. Energy intensity is often taken as a proxy for energy efficiency, although this **is not entirely accurate** since changes in **energy intensity are a function of changes in several factors** including the structure of the economy, climate,… and energy efficiency"

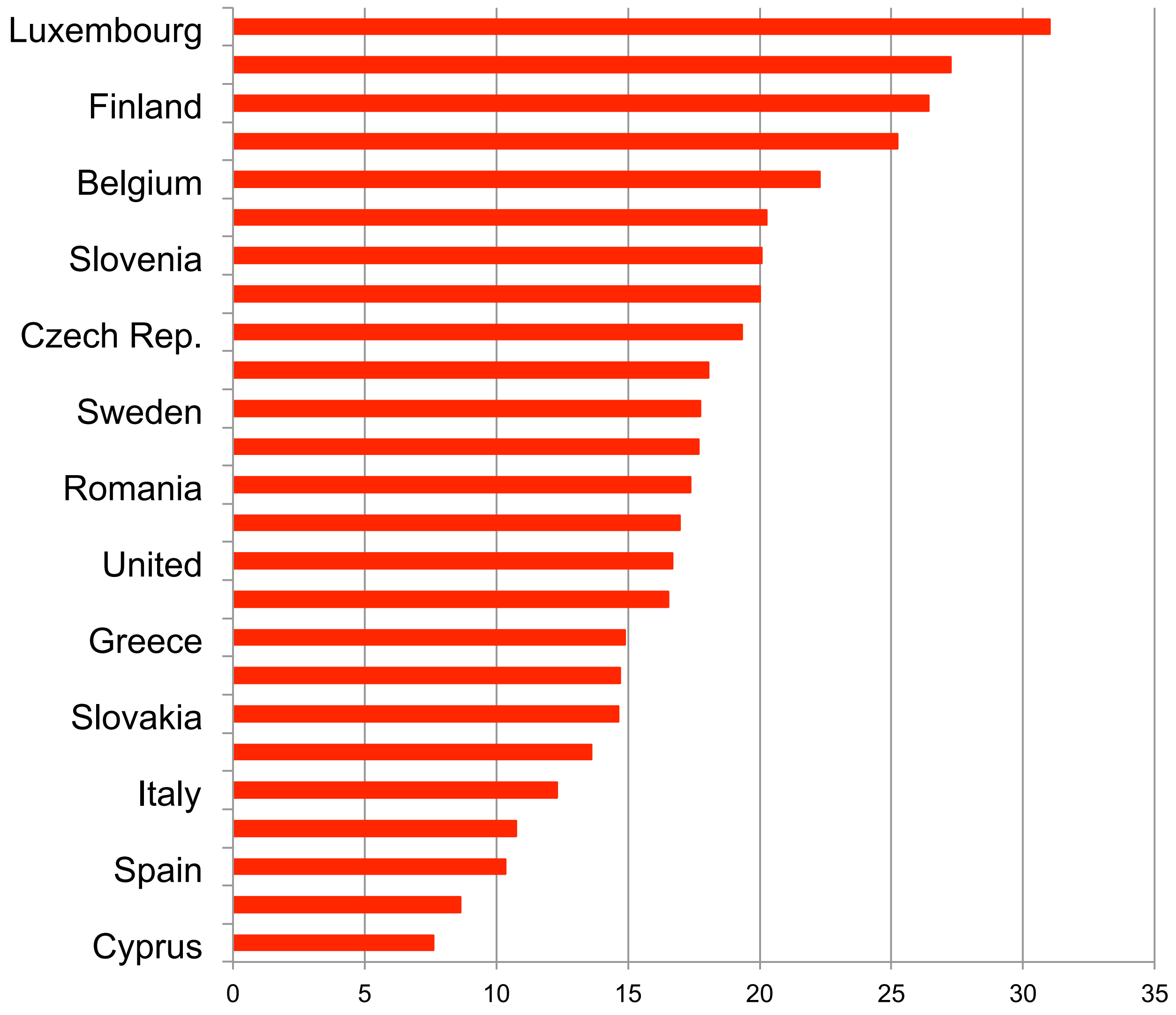
Measurement of energy efficiency in the residential sector using simple *Physical–thermodynamic indicators*

- Energy consumption per household
- Energy consumption per square meter
- Energy consumption per dwelling
- .....

Residential energy consumption (BTU) per square foots (2009)



Residential energy consumption (Kwh) per square meters (2011)



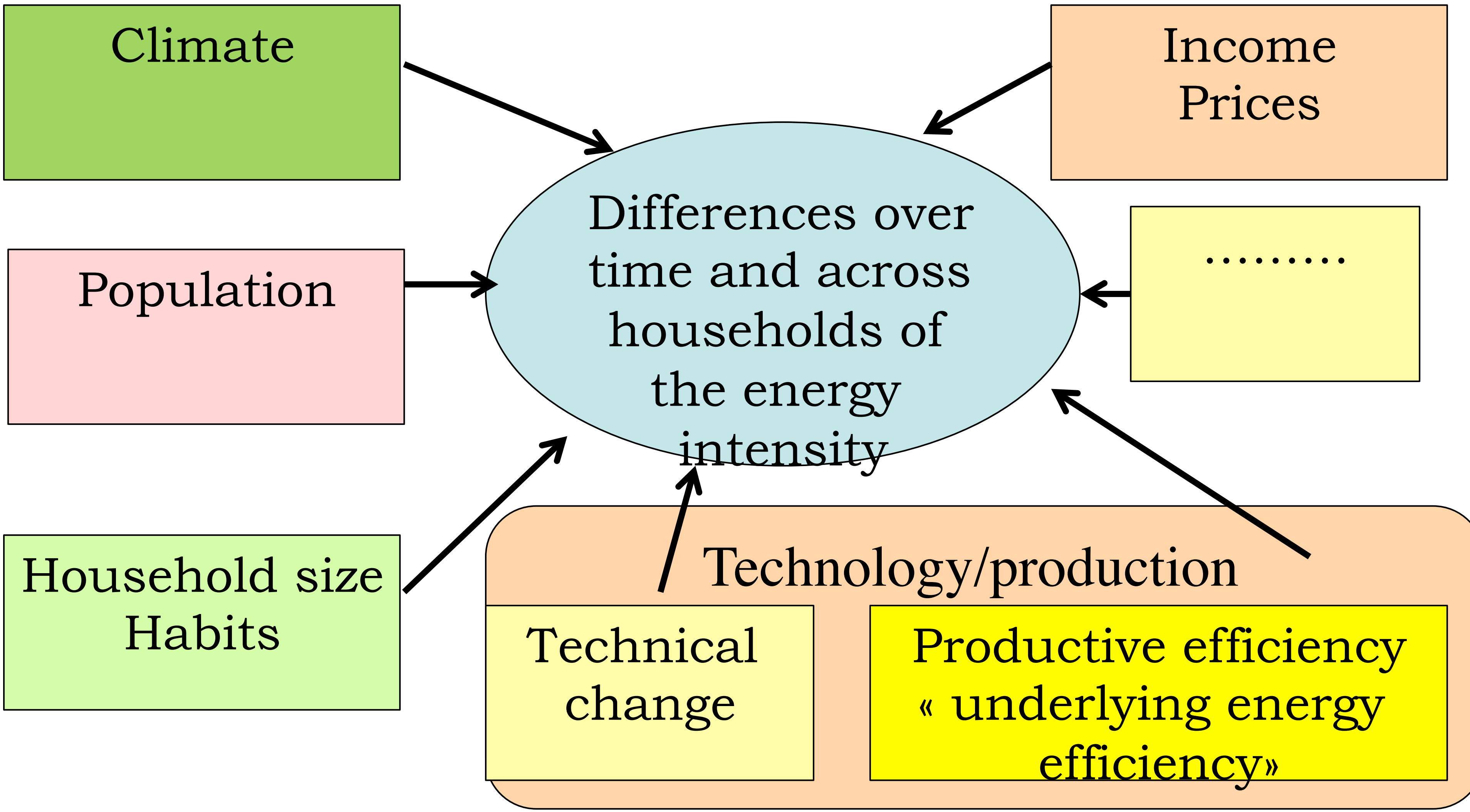
Limitations of the Energy-Intensity Indicators

Independent Statistics & Analysis
U.S. Energy Information Administration

http://www.eia.doe.gov/emeu/efficiency/ee_ch3.htm

- .."Four energy-intensity indicators were presented in this chapter that may be used as the basis for the measurement of energy efficiency. All four indicators are imperfect…."…..
- Changes in energy intensity are a function of changes in several factors

Factors that influences the level of energy intensity



Research area

- **Methodological:**
  - ↳ To estimate the level of energy efficiency applying a relatively novel approach based on: 1. the microeconomics of production; 2. the use of econometric methods and stochastic frontier analysis for panel data (Filippini and Hunt (2011));
- **Policy-oriented:**
  - ↳ To analyze the **impact of energy policy instruments** on the level of residential energy efficiency
  - ↳ To analyze the **impact of socioeconomic factors** on the level of residential energy efficiency

B) Energy-efficiency, microeconomics of production and productive efficiency

Energy services

- Households are not consuming directly energy
- Households are consuming energy services:
  - *Cooking, lighting, washing, heating ,……*
  - ………………
- Behind any **energy service** we have a **production process** and an associated **production function**.
- Use of capital , energy, labor, knowledge in building design

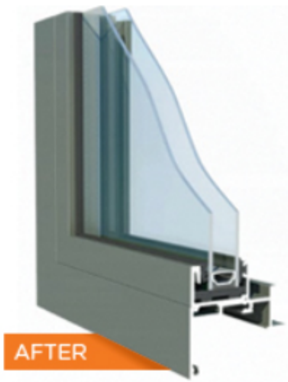
Energy services

- The production of energy services implies investment decisions characterized by ***medium/long-term*** horizon
- Example: renovation of a house or the construction of a new house ➔ choice of a **standard technology** or a **new technology**
- Investment analysis and the decision depends on several factors (relative prices, expected prices, discount rate,…

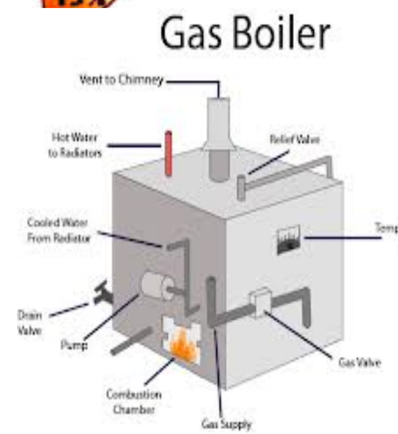
Energy services and production function

Standard technology

More capital and less energy

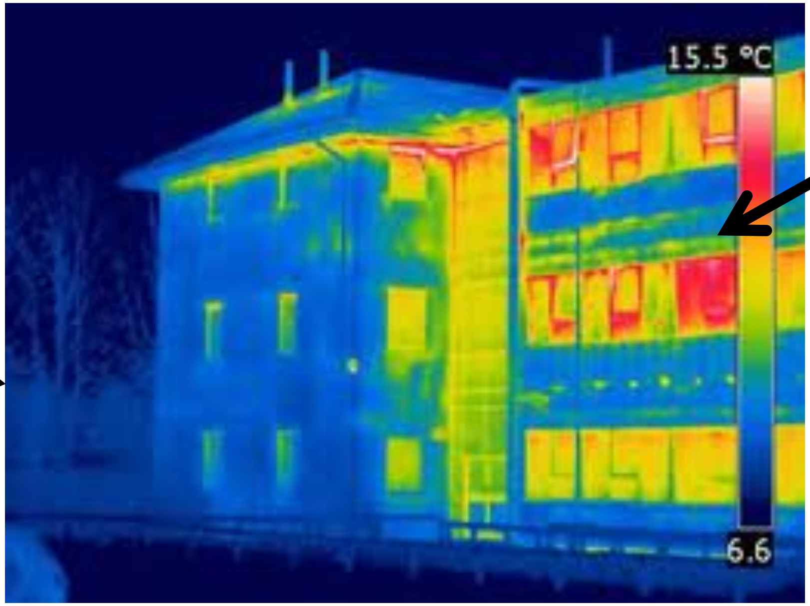


More energy and less capital



Heat loss and insulation (thermal image)

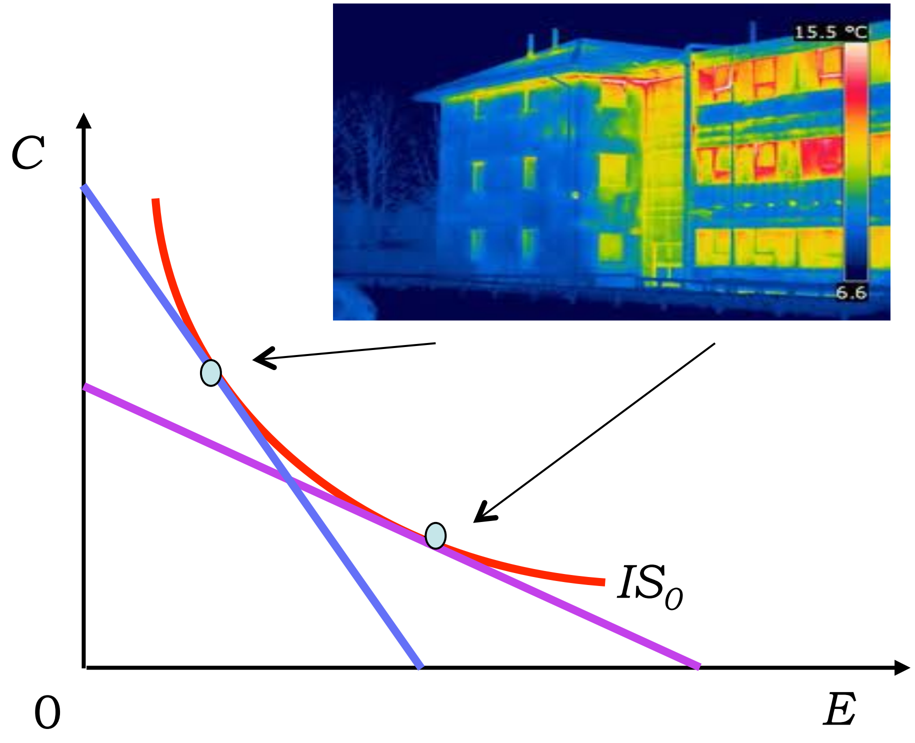
Good
insulation



Bad
Insulation: heat loss
in this part of the
building

Choice should depend on prices

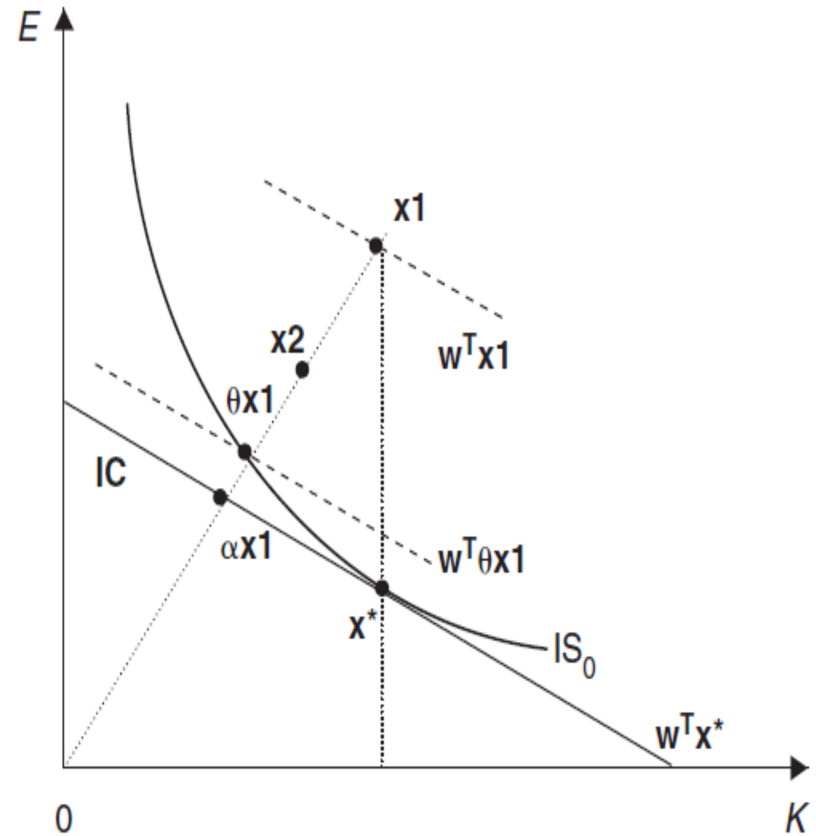
Microeconomics of production



Architects economists and the increase of the thermal *insulation standards*

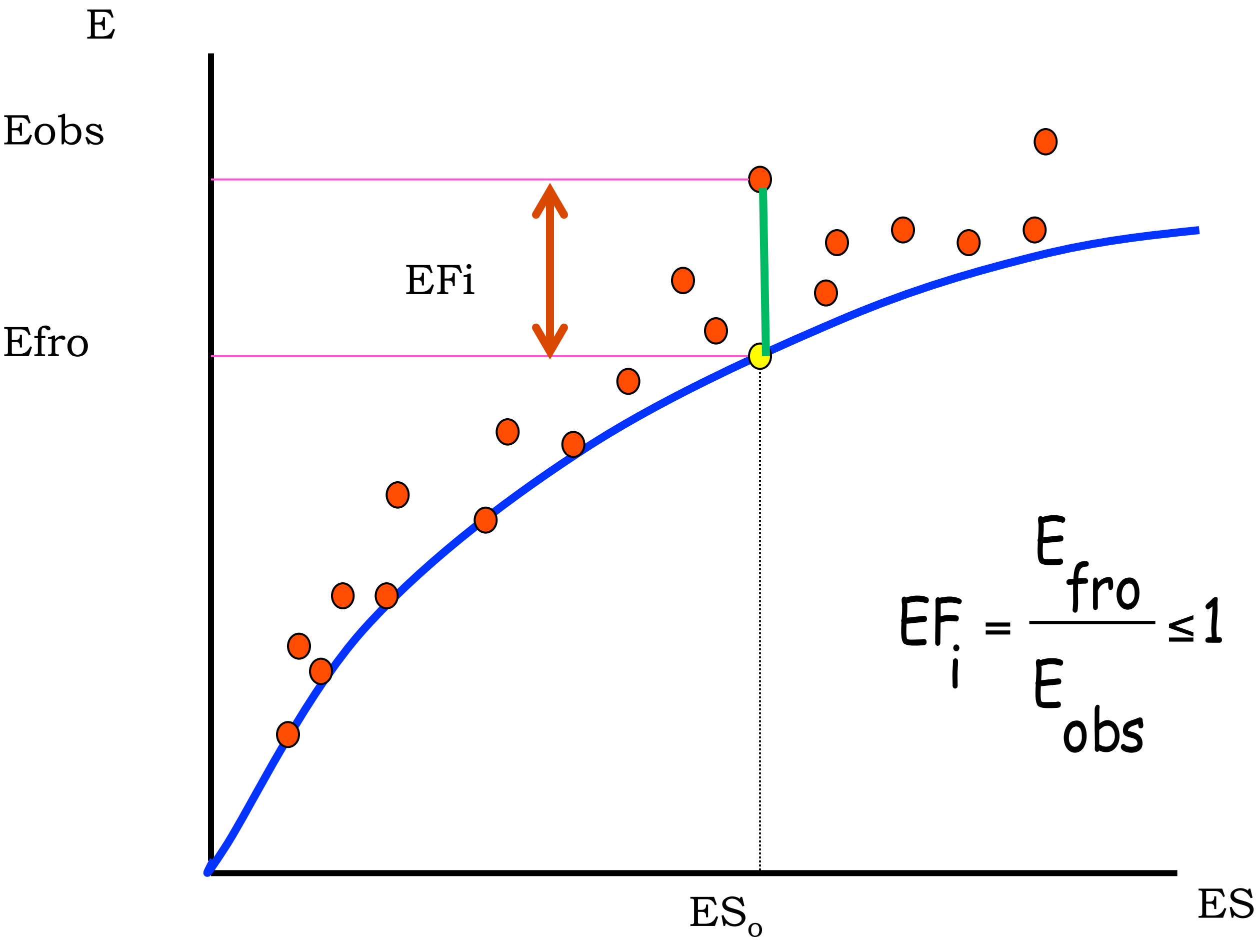
Productive inefficiency

- In the production of energy services we can observe:
  - ***Inefficiency in the use of energy and capital***
  - From the microeconomics point of view the term energy efficiency is not precise ➔ related to the concept of **productive efficiency** (Farrell 1957)



An energy demand frontier model

simplified model E=f(energy services)



$$EF_i = \frac{E_{fro}}{E_{obs}} \leq 1$$

Energy efficiency measures the ability of an household to minimize the energy consumption, given a level of energy services

Estimation an energy demand frontier equation

ETH

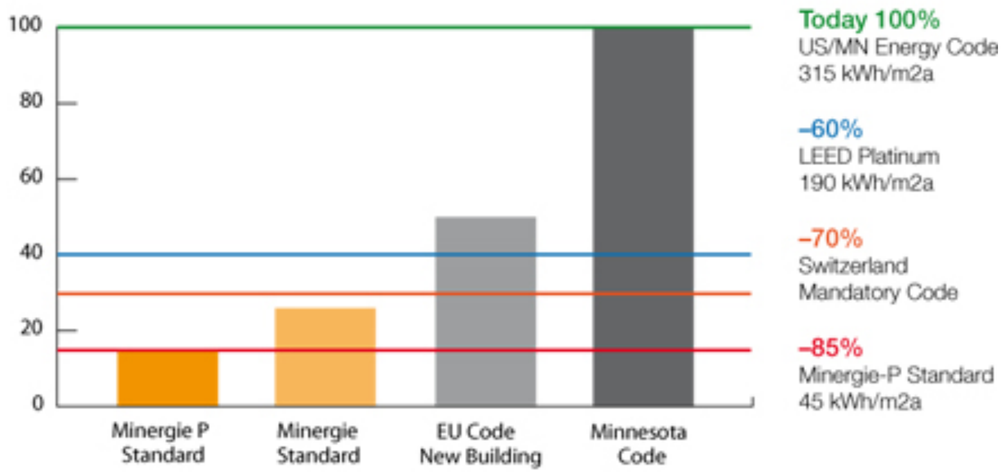
cepe

Centre for Energy Policy and Economics

Department of Management, Technology and Economics

- ***New technology***: **Low-energy-consumption building**
  - High insulation
  - Continuous renewal of air in the building using an energy-efficient ventilation system
  - Partially Renewable energy sources
  - Design

Swiss/US Building Energy Efficiency, Performance Comparison



Source: INTEP Example, State of Minnesota, Educational Buildings

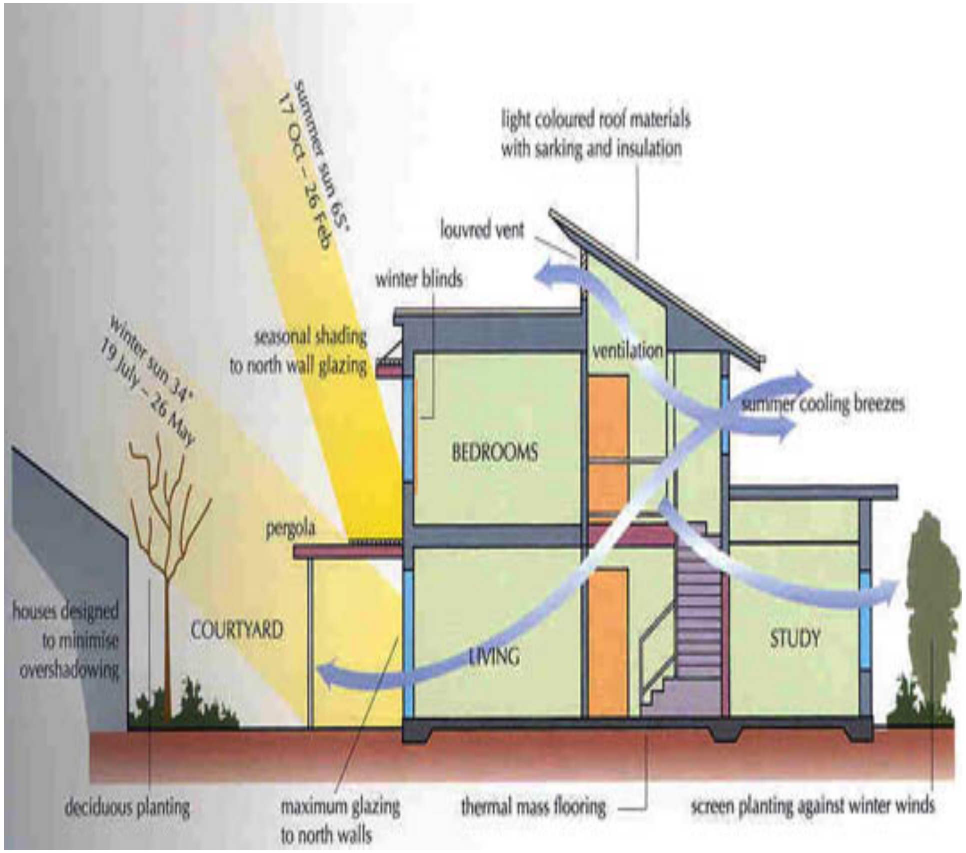
- Swiss Label: MINERGIE

Building design and energy efficiency

- shape and orientation of the building
- solar protections, passive solar systems,
- design and orientation of the windows

- Natural and mechanical ventilation system

- ***Inputs: energy, capital, "knowledge"***



Technical progress /new technology

When **technological change** allows the economic agent to produce the same level of the energy service y, with less energy and capital, such technical progress **shifts the isoquant**.

In the production of energy services we can observe:

- ***Inefficiency in the choice of the technology (energy efficiency gap)***

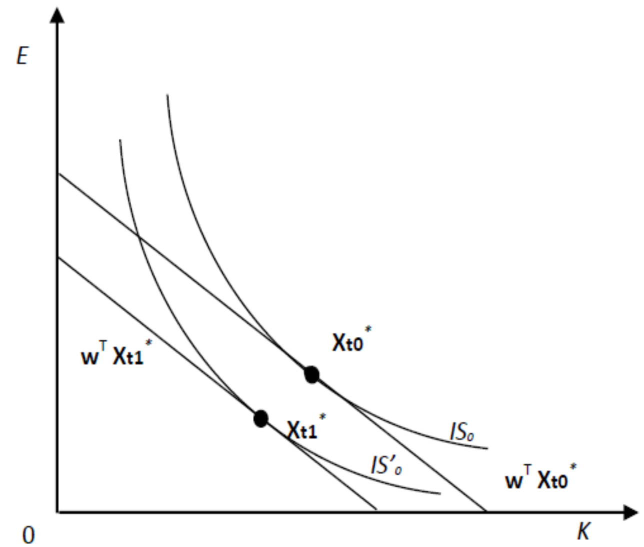


Figure 2: Technical progress

Improuve the efficiency in the use of energy and capital

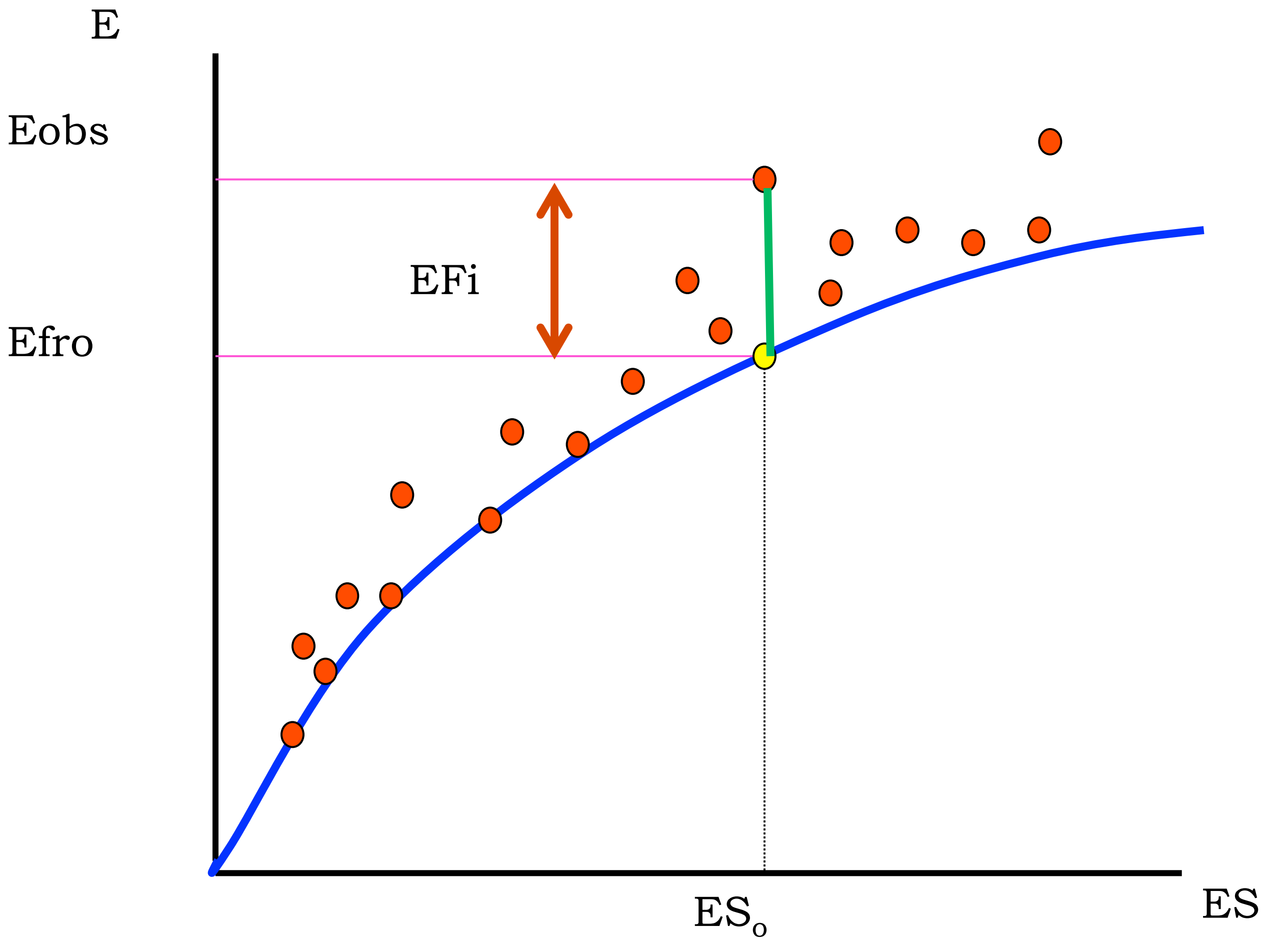
- ***Behavior***: a household could optimise the amount of time that windows are opened during the day; optimises the use of a cooling/heating system (temperature); turn off the lights,…

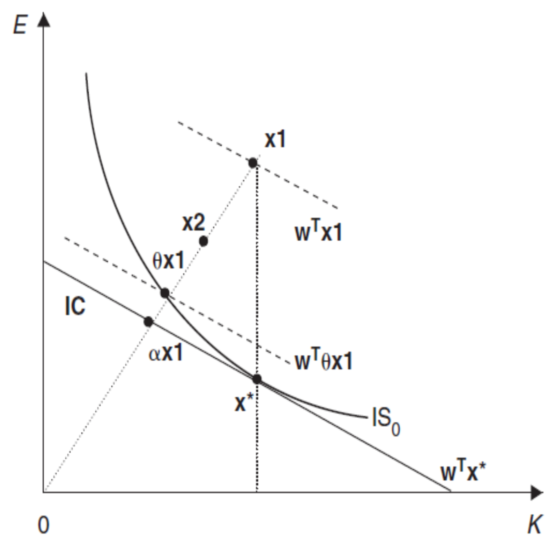
- ***Substitution of energy with capital***: installing a device on a cooling system to improve the function of the system; substitution of the windows; insulation of the building

- ***Adoption new technology***: new building technology; "smart buildings"

C) Econometric approaches to estimate the level of productive efficiency in the production of energy services

An energy demand frontier model

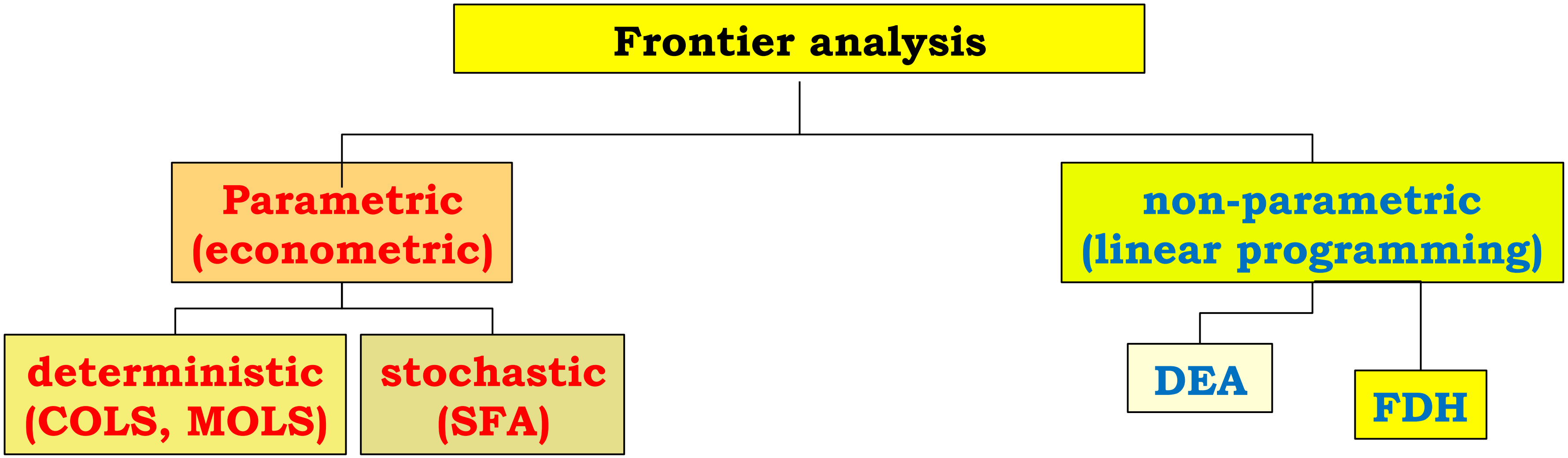




Two approaches

The literature distinguishes two main approaches to estimate a cost frontier ➔ measure efficiency:

- **the econometric *(parametric)* approach and**
- **the linear programming *(non-parametric)* approach.**



Two approaches

- Both approaches – ***econometric* and *linear programming*** – have their own advocates. **At least in the scientific community neither one has emerged as dominant**.
- **I will concentrate on the parametric SFA (**Unobserved heterogeneity and panel data)
- **Production function, distance function, cost function and/or input demand function (energy demand frontier function)**

Journal of Productivity Analysis

Editor-in-Chief: William H. Greene
Editor: C. O'Donnell; V. Podinovski

ISSN: 0895-562X (print version)
ISSN: 1573-0441 (electronic version)

Journal no. 11123

Previous studies on the measurement of EE

Econometric approach

- Filippini and Hunt (2011): estimation of an aggregate total energy demand stochastic frontier model; Panel data for OECD countries

- Filippini and Hunt (2012): estimation of an aggregate residential energy demand stochastic frontier model ; Panel data for US states (Pooled Model, Pitt & Lee model with Mundlak,..)

- Filippini and Hunt (2013): estimation of an aggregate total energy demand stochastic frontier model ; Panel data for US states
- Filippini M., Hunt L. and Zoric J. (2014), Impact of Energy Policy Instruments on the Level of Energy Efficiency in the EU Residential Sector"

Linear-programming approach

- Zhou and Ang (2008): estimation of the energy efficiency of the OECD countries; DEA model

- Wei et al. (2009): estimate energy efficiency in China by DEA method, panel data for 29 provinces

- Hu and Wang (2006): estimate total-factor energy efficiency by DEA model, panel data for 29 provinces

Input demand function

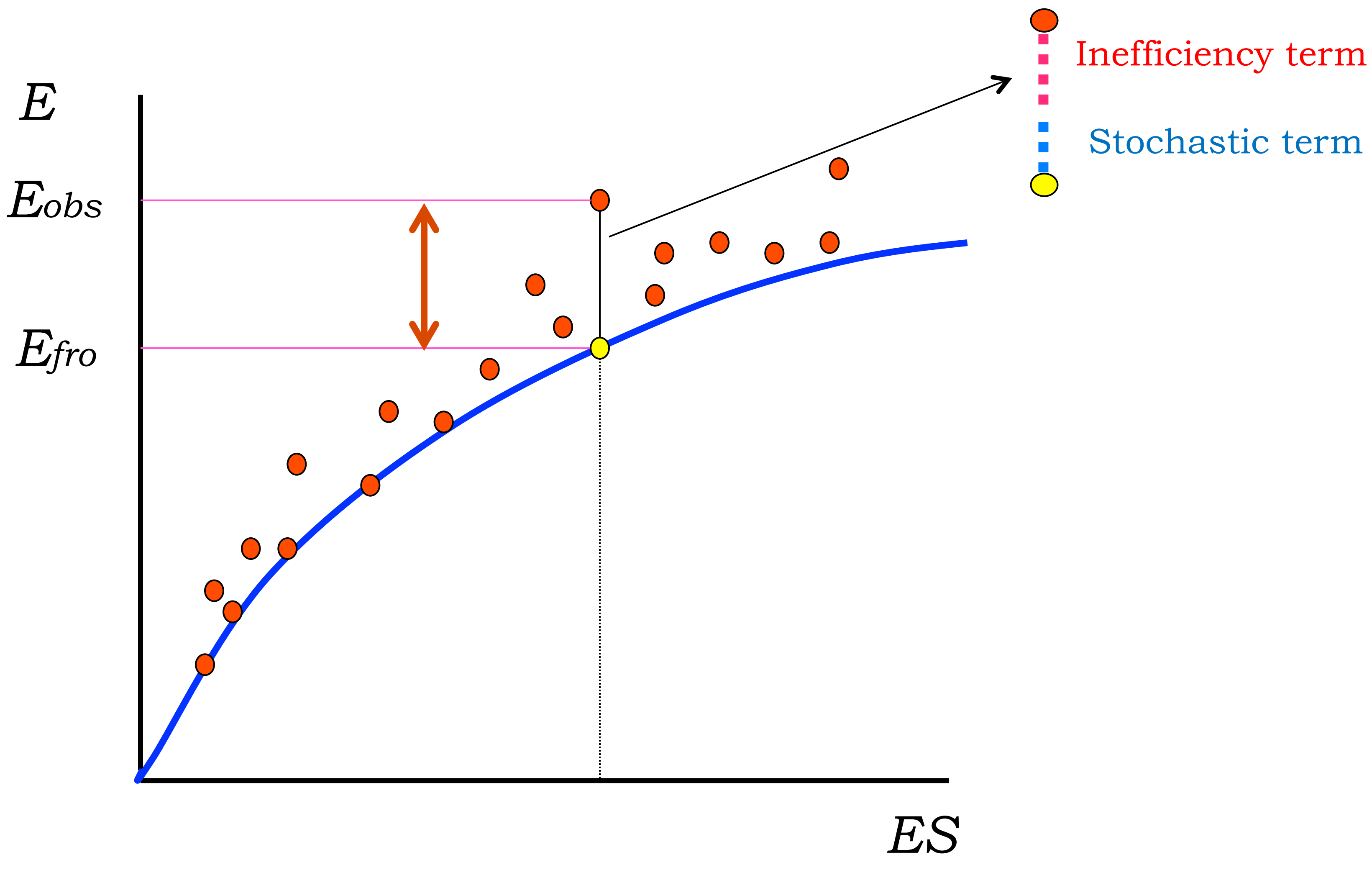
- we estimate one input demand frontier function

- ***ED = f(PE, Y, HDD,....)***

- Interpret the distance from the input demand frontier as a proxy for energy inefficiency (Cobb-Douglas: productive inefficiency increases demand for each input by the same %)

- (Lowel and Schmidt (1979))

Stocastic frontier energy demand model



Stocastic frontier model

$$Ln\ E_{it} = \alpha + \alpha_y\ lnY_{it} + \ldots + \alpha_T\ T + v_{it} + u_{it} \qquad u_{it} \geq 0$$

Time trend or time dummies
capturing the effect of
Technical change

a symmetric disturbance capturing the effect of noise and as usual is assumed to be normally distributed

is interpreted as an indicator of energy efficiency and is assumed to be half-normal distributed
Time varying inefficiency

Stochastic Frontier Models SFA
Panel data models

Pooled model

Aigner, Lovell and Schmitt (1977)
Pitt and Lee (1981)

FE and RE Models

Original

Pitt and Lee (1981)

Schmidt and Sickles (1984)

Battese and Coelli (1986)

True random and true fixed effects

Transient and persistent part

Filippini/ Greene (2014)

Original

Greene (2005)

With Mundlak correction

Farsi,Filippini and Kuenzle (2005)

Farsi, Filippini, Greene (2005)

Latent class models

Kumbhakar , Orea (2005)

Pooled model

$$\ln E_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_i + v_{it} + u_{it}$$

$$v_{it} \sim N[0, \sigma_v^2]$$

$$u_{it} = |U_{it}| \text{ and } U_{it} \sim N^+[0, \sigma_u^2]$$

v_{it} and u_{it} are distributed independently of each other, and of the regressors

v_{it}: a symmetric disturbance capturing the effect of noise and as usual is assumed to be normally distributed

u_{it}: is interpreted as an indicator of energy efficiency and is assumed to be half-normal distributed
Time varying inefficiency

RE model (PITT and LEE)

$$\ln E_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_i + v_{it} + u_i$$

v_{it}: a symmetric disturbance capturing the effect of noise and as usual is assumed to be normally distributed

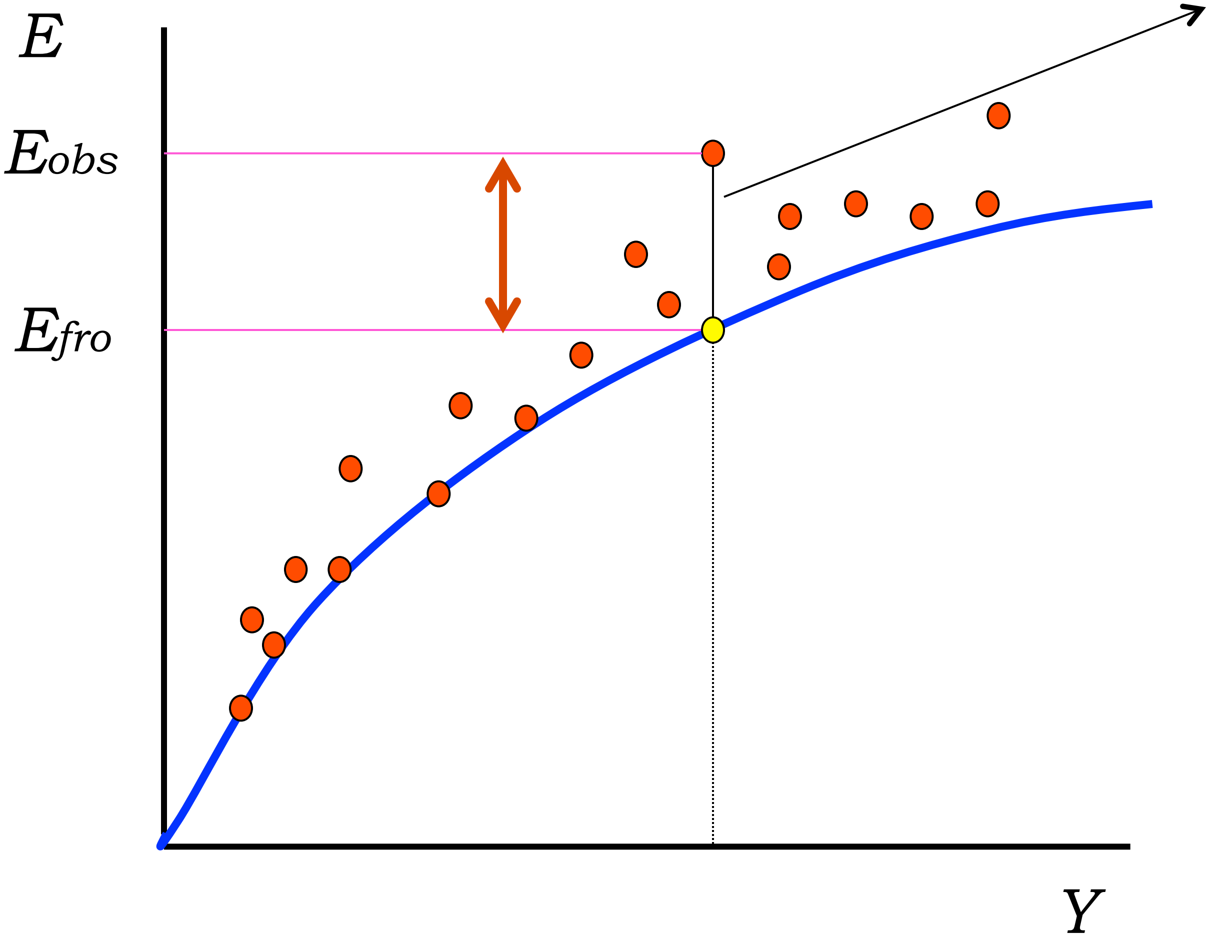
u_i: is interpreted as an indicator of energy efficiency and is assumed to be half-normal distributed
Time invariant inefficiency

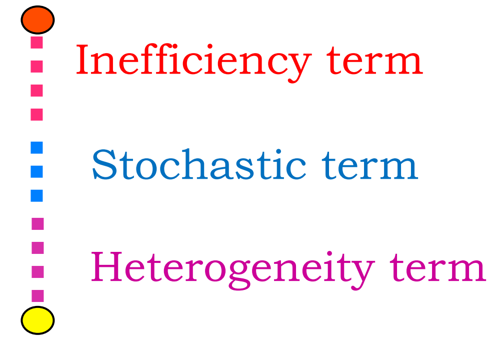
$$v_{it} \sim N[0, \sigma_v^2]$$

$$u_i = |U_i| \text{ and } U_i \sim N^+[0, \sigma_u^2]$$

v_{it} and u_i are distributed independently of each other, and of the regressors

True random effects model (TRE)





Energy efficiency: measures the ability of a state to minimize the energy consumption, given a level of Y

$$EF_i = \frac{E_{Frontier}}{E_{Observed}} \leq 1$$

TRE model

$$\ln E_{it} = \alpha_i + \boldsymbol{\beta}'\mathbf{x}_{it} + v_{it} + u_{it}$$

Unobserved time invariant heterogeneity

a symmetric disturbance capturing the effect of noise and as usual is assumed to be normally distributed

is interpreted as an indicator of energy efficiency and is assumed to be half-normal distributed
Time varying inefficiency

$$v_{it} \sim N[0, \sigma_v^2]$$

$$u_{it} = |U_{it}| \text{ and } U_{it} \sim N^+[0, \sigma_u^2]$$

α_i, v_{it} and u_{it} are distributed independently of each other, and of the regressors

Maximum Simulated Likelihood (RPM)

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

cepe
Centre for Energy Policy and Economics
Department of Management, Technology and Economics

TRE model Mundlak

$$\ln E_{it} = \gamma_i + \boldsymbol{\beta}'\mathbf{x}_{it} + \boldsymbol{\beta}'\overline{\mathbf{x}}_i + v_{it} + u_{it}$$

$$v_{it} \sim N[0, \sigma_v^2]$$

$$u_{it} = | U_{it} | \text{ and } U_{it} \sim N^+[0, \sigma_u^2]$$

γ_i, v_{it} and u_{it} are distributed independently of each other, and of the regressors

Mundlak adjustment a $\alpha_i = \gamma_i + \boldsymbol{\beta}'\overline{\mathbf{x}}_i$

Unobserved time invariant heterogeneity

a symmetric disturbance capturing the effect of noise and as usual is assumed to be normally distributed

is interpreted as an indicator of energy efficiency and is assumed to be half-normal distributed
Time varying inefficiency

TRE model (persistent/transient)

$$\ln E_{it} = \alpha_i + w_i + \boldsymbol{\beta}'\mathbf{x}_{it} + v_{it} + u_{it}$$

Unobserved time invariant heterogeneity

a symmetric disturbance capturing the effect of noise and as usual is assumed to be normally distributed

Time transient inefficiency

Time persistent inefficiency

$$v_{it} \sim N[0, \sigma_v^2]$$

$$u_{it} = |U_{it}| \text{ and } U_{it} \sim N^{+}[0, \sigma_u^2]$$

$$h_i \sim \mathrm{N}^{+}(0, s_h{}^2)$$

α_i, h_i, v_{it} and u_{it} are distributed independently of each other, and of the regressors

Filippini /Greene (2014)

Maximum Simulated Likelihood (RPM)

D) Model specification and econometric approaches (European study)

Filippini M., Hunt L. and Zoric J. (2014), ***"Impact of Energy Policy Instruments on the Level of Energy Efficiency in the EU Residential Sector"***

Goals of the paper

- Measure the level of the «underlying energy efficiency» for the European residential sector
- to analyze the impact of energy policy instruments on the level of energy efficiency

Empirical analysis

Estimation of an aggregate energy demand frontier function for the residential sector

Three econometric approaches

panel data set, 27 EU member states, 1996 to 2010

↓

Estimation for each country of an indicator of the level of energy efficiency for the residential sector

↓

Analysis of the impact of the energy policy measures on the level of energy efficiency

Model Specification & Data

$$\ln ED_{it} = a + b_{PE} \ln PE_{it} + b_Y \ln Y_{it} + b_{POP} \ln POP_{it} + b_{DSIZE} \ln DSIZE_{it} + b_{HDD} \ln HDD_{it} + b_{HOT} HOT_i + b_t t + \boldsymbol{v_{it}} + \boldsymbol{u_{it}}$$

where:

ED_{it} – final residential energy consumption (in toe)
Y_{it} – GDP in PPP (in constant US$ prices)
PE_{it} – real energy price (2005 = 100)
POP_{it} – population
$DSIZE_{it}$ – average size of a dwelling (in m^2)
HDD_{it} – heating degree days
HOT_i – hot climate dummy
T – time trend (technical change)
$\boldsymbol{v_{it}}$ – random noise
$\boldsymbol{u_{it}}$ – indicator of the inefficient use of energy

Table 4: Estimated energy efficiency scores.

Variable	Mean	Std. Dev.	Min	Max	Cases
EFBC95	0.8340	0.0989	0.6230	0.9708	349
EFBCM95	0.8961	0.0453	0.8590	0.9882	349
EFTFE	0.9398	0.0437	0.8607	0.9926	349

Member states and estimated average energy efficiency (~12%)

Energy efficiency score (EFBCM)	Group	Member states
Below 86%	***Inefficient states***	BE, CY, DE, DK, EE, FI, GR, HU, IT, LV, PT
From 86% to 93%	***Moderately efficient states***	AT, FR, LU, PL, RO, SE, SI, SK
Above 93%	***Efficient states***	BG, CZ, ES, IE, LT, NL, UK

The efficiency estimates are found to be very poorly correlated (-0.07) with energy intensity (*EI*),

Energy Policy instruments

- **Traditional regulation ('command & control')**
  - *Emission limits, technology standards, energy performance standards…*
- **Economic instruments**
  - *Energy taxes , targeted subsidies, tax credits ….*
- **Promotion of information**
  - Labeling, rating and certification…

Energy-efficiency (EE) policy measures in the EU

	Measure type	Share in %
1	**Legislative/Normative**	**37.3**
1.1	Mandatory standards for buildings	15.0
1.2	Regulation for heating and hot water systems	15.6
1.3	Other regulation in the field of buildings	2.3
1.4	Mandatory standards for electrical appliances	4.4
2	**Legislative/Informative - labelling**	**15.2**
3	**Information/education**	**13.1**
4	**Financial**	**31.3**
4.1	Financial - grants, subsidies	26.3
4.2	Financial - loans, other	2.3
4.3	Financial - Tax Exemption/Reduction	2.6
6	**Others measures**	3.1
	Total	**100.0**

Source: Mure II database

Impact of the energy policy measures on u_{it}

$$u_{it} = \eta' \mathbf{z}_{it} + e_{it} \qquad (2)$$

$\mathbf{z}_{it}$ – a vector of policy measures, introduced as dummy variables

- **Energy-efficiency policy measures considered:**
  - performance standards of buildings and heating systems (BH_{it})
  - performance standards of electrical appliances (APP_{it})
  - informative measures ($INFO_{it}$)
  - financial incentives and fiscal measures (FIN_{it})

Impact of the energy policy instruments on the level of efficiency

- The results show that

➥ financial incentives seem to have an influence on reducing energy inefficiency of the residential sector (financial dummies *FIN1* and *FIN2* highly significant)

➥ There is also some evidence that performance standards of buildings, heating systems and appliances contribute to improved efficiency (standard dummies significant only at 10%)

E) Model specification and econometric approaches (US study, household data)

Alberini A. and Filippini M. (2014) ***"Underlying Energy efficiency" in the US Residential Sector"***

Goals of the paper

- Measure the level of the «underlying energy efficiency» for the US residential sector

- to analyze the impact of income and vintage of the houses on the level of energy efficiency

- Residential sector (30-40 % of the final energy consumption) is identified as being one of the areas **with the greatest potential for energy savings**

- **McKinsey (2009)** estimated that the United States by 2020 could reduce annual energy consumption by 23 % from a Business-as-usual projection

  (based on future available technologies)

- **Electric Power Research Institute (2009)** ~10%

(based on today commercial available technologies)

Empirical strategy

Estimation of an energy demand frontier function for the US residential sector

Three econometric approaches (Pool, PoolM, TRE,TREM)

Unbalanced panel data set, 11315 households, 1996 to 2010 N= 40412

American Housing Survey

Estimation for each household of an indicator of the level of energy efficiency *(benchmarking)*

Analysis of the impact of the level of income on the level of energy efficiency

Model Specification

$$
\begin{aligned}
Ln\,E_{it} = {} & \alpha + \alpha^{p} \ln P_{it} + \alpha^{y} Y_{it} + \alpha^{SIZE} \ln SIZE_{it} + \alpha^{ROOMS} \ln ROOMS_{it} + \alpha^{PERS} \ln PERS_{it} \\
& + \alpha^{HDD} \ln HDDCDD_{it} + \alpha^{AGEH} \ln \mathrm{AGEH}_{it} + \alpha^{DGAS} GAS - HEAT_{it} + \alpha^{DGAS} GAS - HEW_{it} + \alpha^{DGAS} GAS - DRY_{it} \\
& + \alpha^{DAC} AC - ROOM_{it} + \alpha^{DAC} AC - CENTRAL_{it} + \alpha^{DFLOOR} DFL1_{it} + \alpha^{DFLOOR} DFL2_{it} + \alpha^{DFLOOR} DFL3_{it} \\
& + \alpha^{CITY} DCITY_{it} + \alpha^{t} Dt + v_{it} + u_{it}
\end{aligned}
$$

where

- ***E*** is energy consumption in thousand BTU
- ***Y*** is real income,
- ***P*** is the real energy price per thousand BTU,
- ***SIZE*, *ROOMS*, *PERS***,
- ***GAS-HEAT*, *GAS-HEW*, *GAS-DRY*** dummy variables for a gas
- ***DAC*** dummy variables for AC Central and rooms
- **DFLOOR*1* , DFLOOR*2* , DFLOOR*3***
- ***HDDCDDD*** heating and cooling degree days
- **DCITY*j*** is a city-specific effect,
- D_t is a series of time dummy variables

Level of efficiency

Variable	Mean	Std.Dev.	Minimum	Maximum	Cases	Missing
EPOOLY	.830370	.060381	.203679	.942147	40412	0
EPOOLMY	.817129	.062088	.254637	.940887	40412	0
ETREY	.795648	.078383	.343236	.954782	40412	0
ETREMY	.797299	.078122	.316898	.955822	40412	0

A	1	2	3	4
1	1.00000	.981774	.783977	.782735
2	.981774	1.00000	.853775	.869246
3	.783977	.853775	1.00000	.986196
4	.782735	.869246	.986196	1.00000

Impact of factors on u_{it}

$$u_{it} = \eta' \mathbf{z}_{it} + e_{it} \qquad (2)$$

$\mathbf{z}_{it}$ – a vector of variables (income, vintage period)

- The results show that

➥ Income has a positive impact on the level of energy efficiency

➥ Vintage has a negative impact on the level of energy efficiency

E) Conclusions

- Potential energy saving
  - ↪ In Europe 10-15%
  - ↪ In the US 20/25%
  - ↪ Less evidence of an impact of the effect of informative measures such as labelling and educational campaigns

- Improved energy efficiency can be linked to
  - ↪ the introduced financial incentives and energy performance standards
  - ↪ Less evidence of an impact of the effect of informative measures such as labelling and educational campaigns

E) Conclusions

- Residential sector holds a relatively high potential for energy savings
- Energy intensity indicator cannot be considered as a good proxy for energy efficiency and should be combined with other indicators
- The estimates for the *underlying energy efficiency* using an approach based on microeconomics and frontier analysis seems appealing
- Promising research area that can be extended to the estimation of distance functions, production functions, … to the use of disaggregated data
- Studies that can help policy makers

Thank you for your attention

Market failures related to energy inefficiency

- **Energy use negative externalities**
  - *Energy tax*
- **Investment inefficiencies (**consumers' lack of economic information, principal–agent problems, liquidity constraints, myopic behavior, bounded rationality, positive externalities in the adoption of new technologies)
  - *Information*
  - *Subsides*
  - *Standard*

Energy efficiency gap

- ***Energy efficiency paradox***: Some energy efficient technologies that would pay off for adopters are nevertheless not adopted

- ***Energy efficiency gap:*** Some energy efficient technologies that would be socially efficient are not adopted

Energy Efficiency and productive efficiency

- Estimation of a production frontier/ distance function

↪ estimate the **input specific technical inefficiency** (Reinhard et. al (1999); Kumbahakar (1989), Karagiannis et. Al. (2003) , Ang and Zhou (2008)

- «Ad hoc approach» : estimate an **input demand frontier equations → an energy demand frontier**

Input demand function

- Schmidt and Lovell (1979) using a Cobb_Douglas **production frontier** derive a system of log-log stochastic cost-minimizing **input demand frontier equations** → where the error term contains both allocative as well technical inefficiency
- In this study we estimate one of this input demand frontier
- Interpret the distance from the input demand frontier as a <u>proxy for energy inefficiency (Cobb-Douglas: productive inefficiency increases demand for each input by the same %)</u>

- Filippini M., Hunt L. and Zoric J., ***"Impact of Energy Policy Instruments on the Level of Energy Efficiency in the EU Residential Sector"*** (forthcoming in Energy policy)

- Alberini A. and Filippini M. ***"Underlying Energy efficiency" in the US Residential Sector and Potential CO2 Savings***

Results (1)

Table 3: Estimation results of energy demand model

Parameter	BC95 model	BC95M model	TFE model
Parameters of the demand function			
Constant	5.4989***	0.3779	-8.3131***
LPE	0.0449	**-0.2561*****	**-0.1857*****
LY	0.6962***	**0.3318*****	**0.4199*****
LPOP	0.3014***	0.7252***	1.2598***
LDS	-0.3193***	0.3428	-0.4327**
LHDD	0.3348***	0.3473***	0.3708***
t	-0.0146***	0.0006	-0.0028
HOT	-0.4225***	-0.5839***	/
MLPE	/	1.1016***	/
MLY	/	0.3165***	/
MLPOP	/	-0.3746**	/
MLDS	/	-0.0189	/
MLHDD	/	-0.4596	/

Note: ***, **, * - significant at 1%, 5% and 10% level, respectively

EU Energy policy

- Until 1996 ➔ large autonomy of the EU Member states in the definition of the energy policy
- *Directive* on the internal energy markets (1996)
- *Directive* on the promotion of electricity from *renewable energy* sources
- *Directive* on the *energy performance* of *buildings (2002)*
- *Directive* on the Energy End-Use Efficiency and Energy Services (2006)

Table 1: Adopted energy-efficiency policy measures in the EU countries

	Number of adopted policy measures by measure type					
Member state (MS)	**Legislative/ Normative**	**Legislative/ Informative - Labelling**	**Information/ Education**	**Financial/ Fiscal**	**Other**	**Total**
Austria	7	2	6	7	1	23
Belgium	9	6	6	16	0	37
Finland	8	6	10	7	1	32
France	15	8	5	24	1	53
Germany	18	12	4	7	4	45
Greece	11	6	3	13	2	35
Italy	17	10	2	5	0	34
Spain	42	9	6	25	3	85
Sweden	4	7	4	6	2	23
United Kingdom	25	3	10	15	2	55
Total	**302**	**123**	**106**	**253**	**25**	**809**

Source: MURE II database.