New methods to assess the impact of energy efficiency policies on energy consumption and energy savings in the EU Member States

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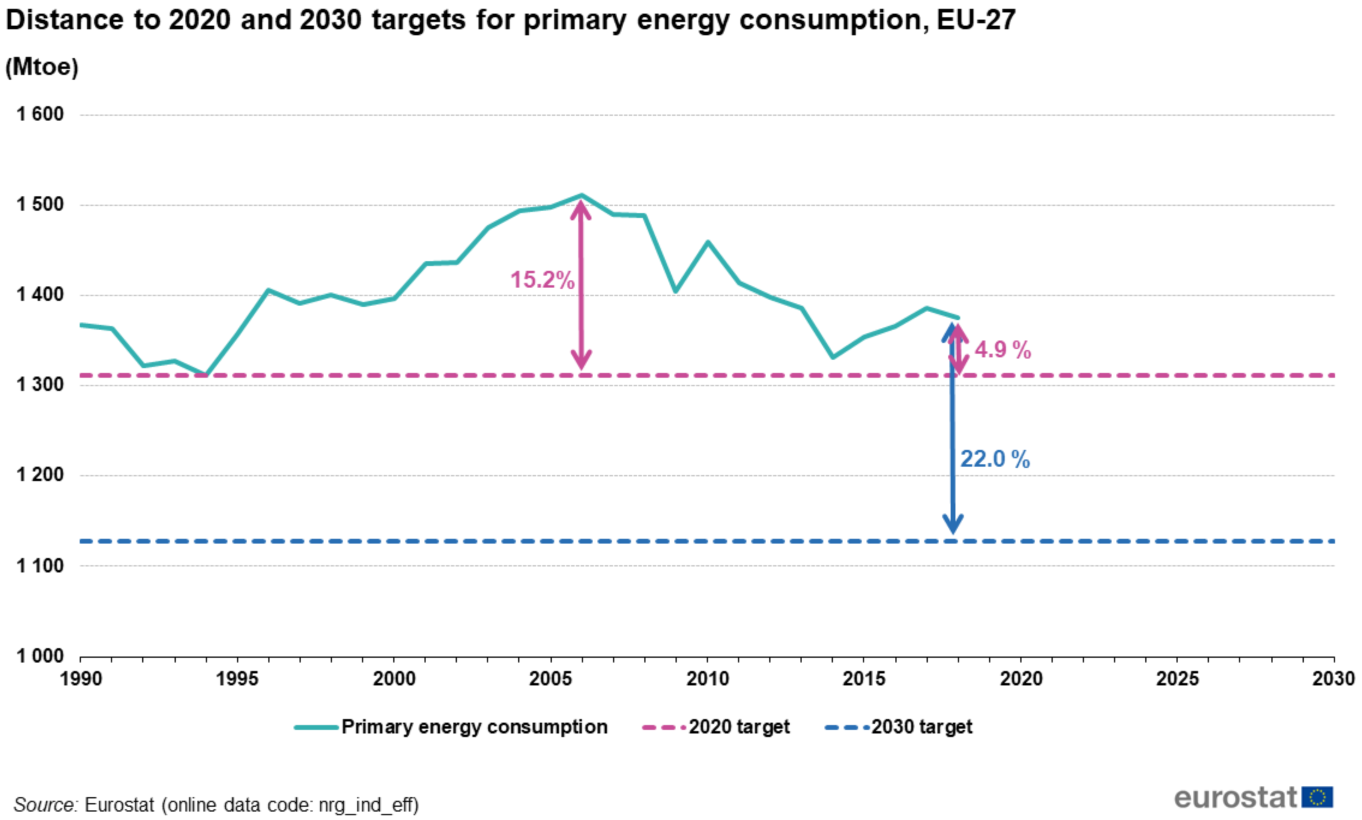
EU Energy Efficiency Targets



- Current Energy Efficiency target for 2030 set at 32.5% compared to BaU scenario.
- New proposal for GHG reduction of -55% for 2030.
- Consumption should further be reduced in 2030, achieving savings of 36-37% (FEC) and 39-41% (PEC).
- Actions required across all sectors of the economy and launch of revisions of the key legislative instruments.

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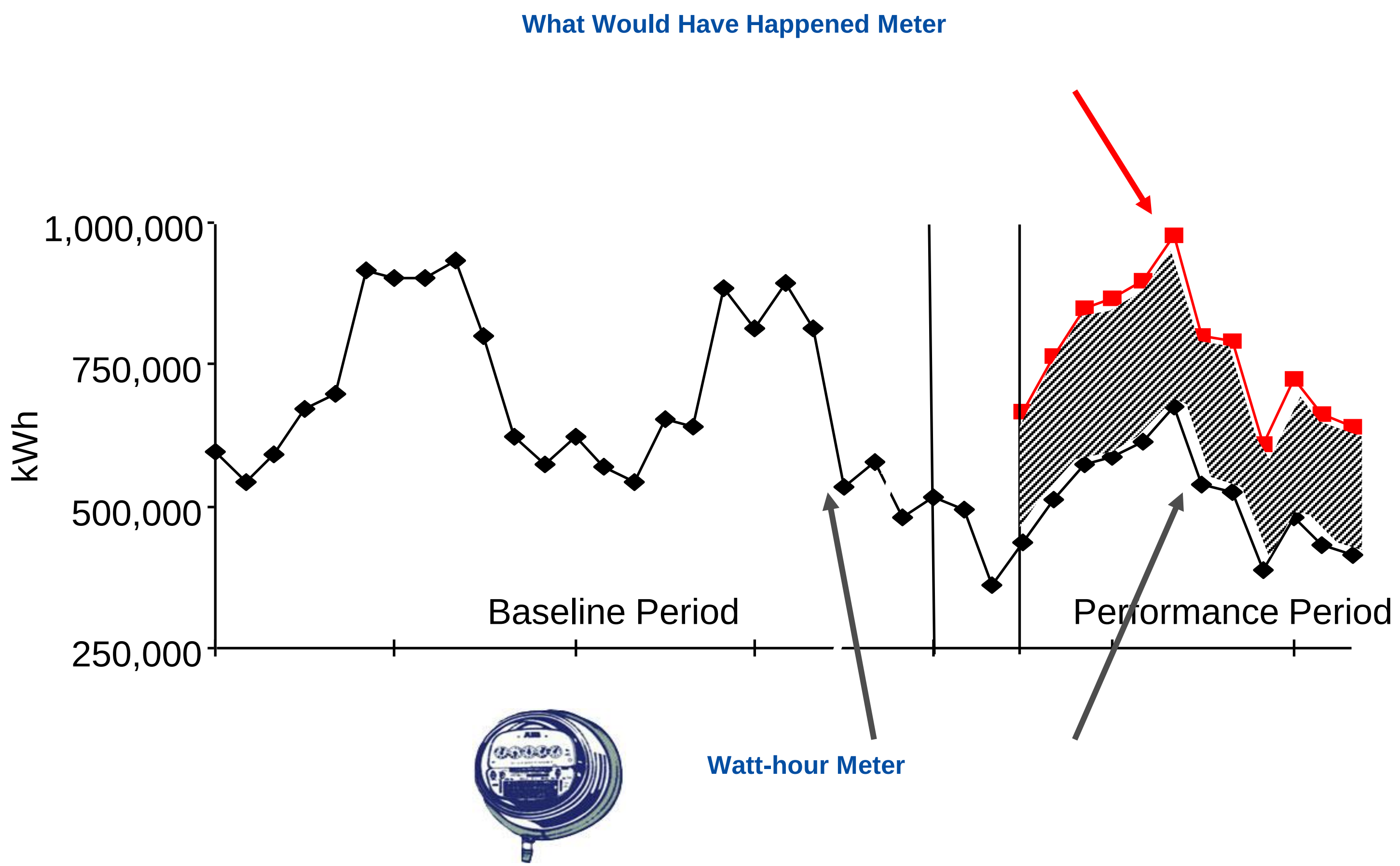
Measuring Energy Savings (not Efficiency)



This is valid:

- For single project (e.g. renovation of a building)
- For a programme (e.g. subsidy by a utility under EEOs)
- For a policy (e.g. a national EEOs or building code)
- For a set of policies (e.g. NEEAP)

Methods to calculate savings in the ESD - 2006

- The 2006 ESD required that energy savings be determined using a **'harmonised calculation' model**. The envisaged harmonised model was a combination of **Top-Down** (TD) calculation methods that use aggregated national statistics and **Bottom-Up** (BU) methods that assess measure-specific savings.
- TD and BU methods provide **two complementary approaches** to assess energy savings.

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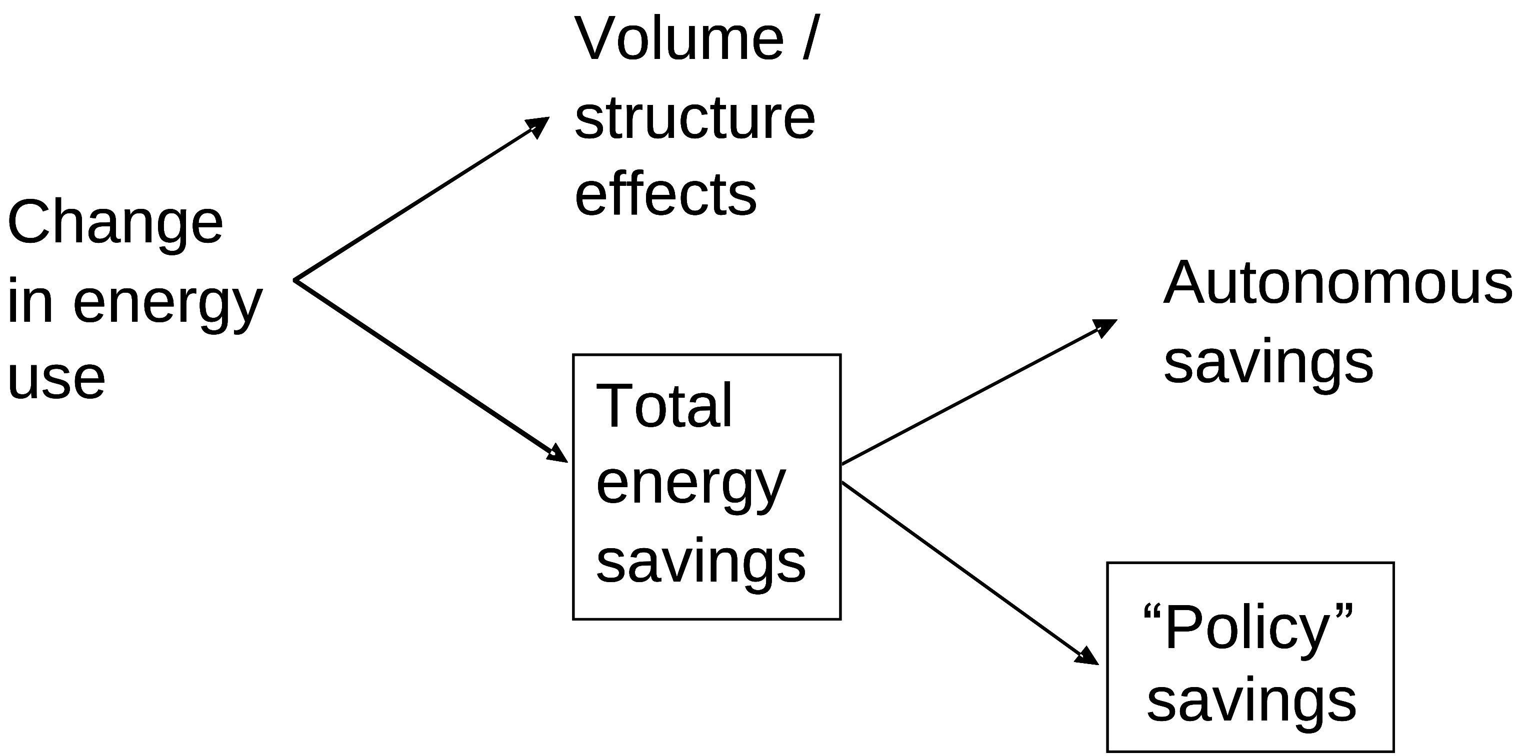
Bottom Up

- The **BU** assesses the energy savings in each individual project covered by the policy and then sums the individual savings.
- **BU** methods do not adequately capture behavioural changes, which may increase or decrease the calculated energy savings and the rebound effect.
- In addition, **BU** methods needs the definition of baselines, which can be subject to different assumption.

Decomposition analysis



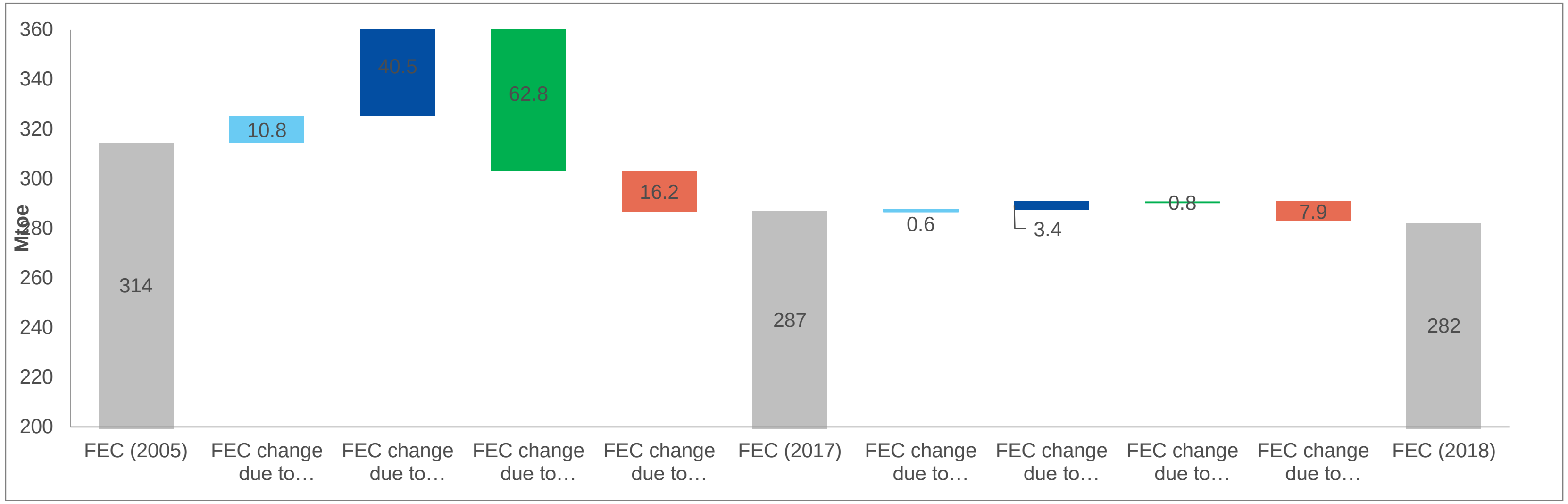
Top Down

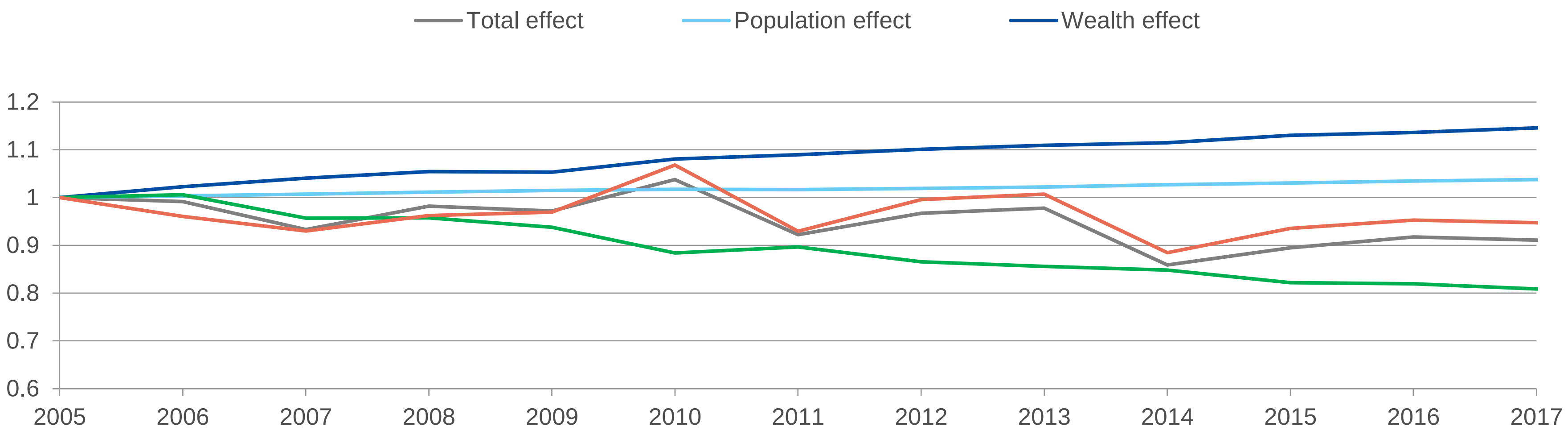
- **TD** methods use an aggregate measure of energy consumption, normalised by an exogenous variable that adjusts for scale across cross-section observations (e.g. kWh/m2), usually derived from national statistical data.
- To calculate the energy savings, the aggregate measure is multiplied by the activity level (e.g. total floor area in m2) in different years.
- **TD** methods include all the policies covering the sector/equipment, the autonomous effects (e.g. technologies improvements not induced by specific policies) and structural effects (e.g. changes in activity)
- Therefore, **TD** methods capture all savings and corrections to calculate only the policy-induced savings are thus difficult.

Decomposition analysis

- The separation of energy efficiency impacts from **structural** and **activity** changes of the economy as well as other factors has been examined extensively in the literature through the application of decomposition analysis techniques.
- Index decomposition analysis, and in particular Logarithmic Mean Divisia Index (LMDI-I) has been used to decompose changes in final energy consumption.
- In its simplest form, the energy consumption change is decomposed in activity, structure and intensity effects.
- Many of these studies commonly relate energy efficiency with energy intensity, although more recent attempts have been made focusing on the use of physical indicators (in addition to monetary indicators) to measure output.

Decomposition analysis





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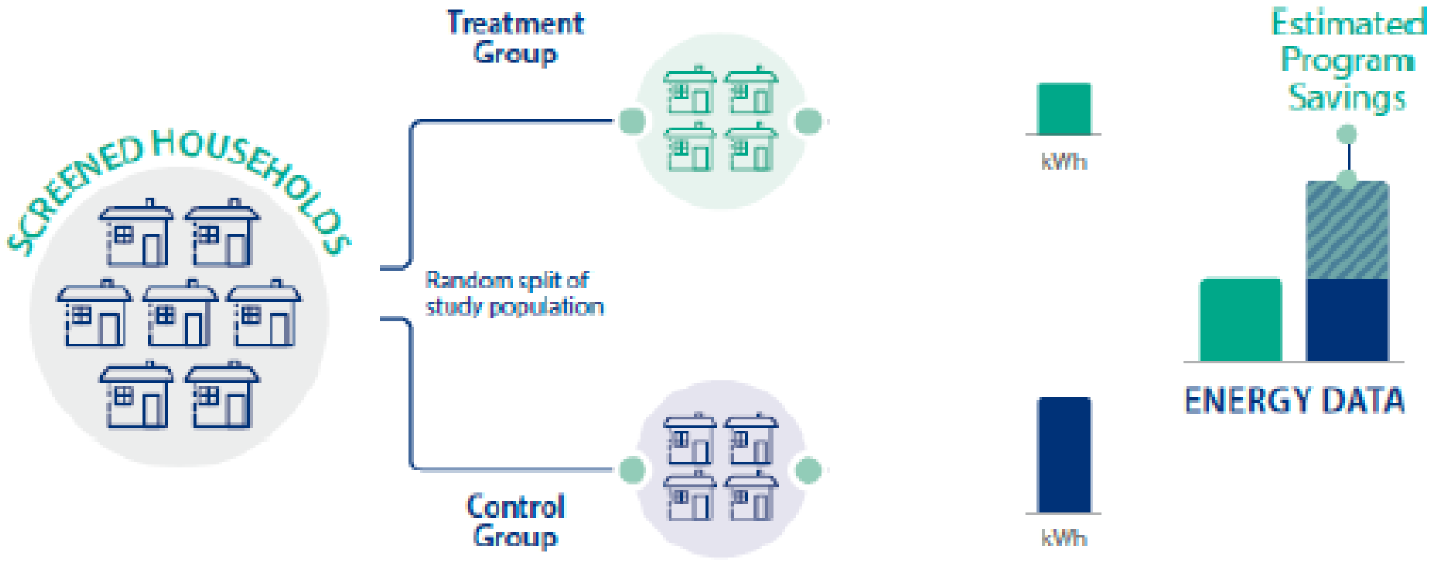
Randomised control trials



Source: Sustainable Energy Authority of Ireland

- Used for programme evaluation. Tends to be expensive and not easy to implement.

Other methods

- **Regression discontinuity** (RDD) design has many of the assets of a randomised experiment, but can be used when random assignment is not feasible. It is a popular quasi-experimental design that exploits precise knowledge of the rules determining the eligibility into treatment. Only for the micro level.
- The **Difference-in-Differences** (DID) method explores the time dimension of the data to define the counterfactual. It requires having data for both treated and control groups, before and after the treatment takes place.

Econometric models - 1

- Researchers have proposed the use of **econometric models** as an alternative to the BU and TD methods to overcome the limitation of BU and TD methods.
- The objective of econometric models is to identify the **energy savings induced by policies** as compared to other factors such as economic growth, structural changes, populations, production levels, energy prices, etc.
- Examples:
  - Laes et al. (2018) reviewed the effectiveness of individual policies or policy packages for CO_2 emission reduction and/or energy savings by using a panel econometric model.
  - Aydin and Brounen (2109) have assessed the impact of specific policies on electricity and non-electricity energy consumption by focusing on two types of regulatory measures: mandatory energy efficiency labels for household appliances and building standards.

Econometric models: Example 1*

- The economic model includes energy prices, GDP, HDD and the population, plus variables for energy efficiency (e.g. the stock of electric appliances - refrigerators).

- The general econometric model consists of a dependent variable and **multiple explanatory variables**. In this project the dependent variable is defined as the energy consumption of a single fuel (electricity or gas) divided by population.

- Energy demand is then estimated as a function of these factors. Based on the model, we also forecast energy demand for a pre-specified period (2 and 4 years).

- The forecasted consumption is then compared with the actual consumption. The differences between the forecasted and the actual consumption can be interpreted as energy savings

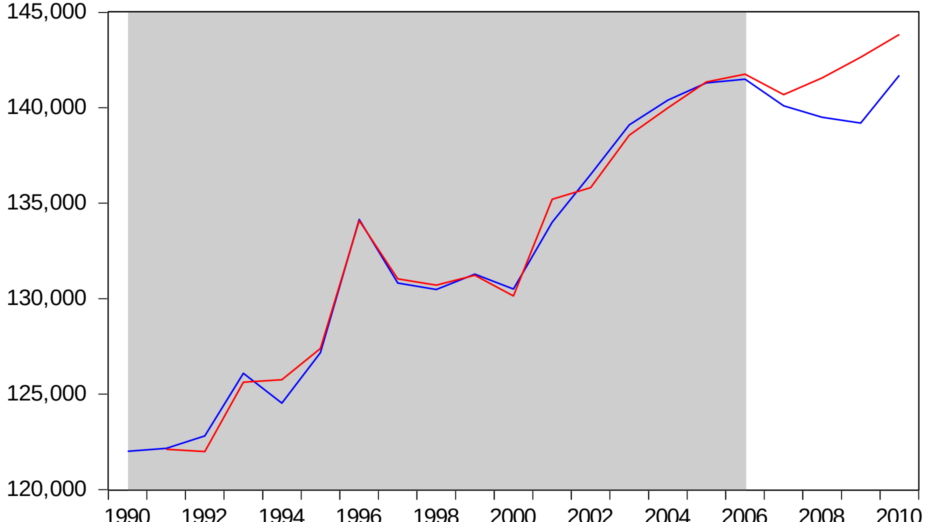
- * Presented at IEPPEC 2014

Econometric models: Example 1

- A series of different models (individual time series models and panel models) with different specifications (i.e. varying explanatory variables) are estimated and the estimated energy savings for the same countries differ between the models. The first approach is to estimate individual time series models with OLS. The second approach is to estimate a panel model with country fixed effects (LSDV) including either all 27 EU Member States

Cut-off period 2006

Germany



Econometric models - 2

- Some researchers have introduced an **explicit measure of energy policy** as an independent variable in their models through dummies. Ó Broin proposed a methodology to construct time series indexes, which increase as more policies are introduced and decrease as policies become obsolete. .
- The energy policy indicator used in Horowitz and Bertoldi (2015) is based on a methodology for transforming the ODEX bottom-up energy efficiency indicators
- In Bertoldi and Mosconi (2020), a direct indicator based on the MURE database of energy policy measures as been used.

Econometric models: Example 2

Energy Economics 51 (2015) 135–148

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Energy Economics

journal homepage: www.elsevier.com/locate/eneco

A harmonized calculation model for transforming EU bottom-up energy efficiency indicators into empirical estimates of policy impacts

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Econometric models: Example 2

$$Y_{it} = \alpha_i + \gamma R_t + \beta X'_{it} + \phi Z_{it} + \varepsilon_{it}$$

- Non-policy factors collectively referred to as *situational* factors: ***α*** *(cross section FE)*, ***R*** (time series FE, or time trend), and ***X'*** *(econ, socio, demo, physical, weather, etc.)*
- ***Z*** is an energy efficiency progress variable incorporating both autonomous changes and changes due to governmental initiatives (collectively referred to as energy efficiency *policy),* Depending on whether the model is for the household or manufacturing sector the target variable Z is either ODEXH or ODEXM.

Econometric models: Example 2

Cumulative energy savings, 28 EU member states (TJ).

MS	Household sector				Manufacturing sector			
	E	C_{FULL}	C_{EARLY}	C_{LATER}	E	C_{FULL}	C_{EARLY}	C_{LATER}
	2011	2000–11	2000–05	2006–11	2011	2000–11	2000–05	2006–11
Austria	113,589	24,067	17,598	6469	210,768	8257	5270	2987
Belgium	186,146	59,868	7619	52,249	348,829	12,110	36,421	−24,311
Bulgaria	41,626	3810	2804	1006	65,672	58,912	35,427	23,485
Croatia	46,270	2907	124	2783	32,584	6390	1506	4884
Cyprus	6203	1445	54	1392	1904	725	229	496
Czech Rep.	134,957	33,292	17,191	16,101	173,372	34,630	19,978	14,651
Denmark	63,099	8125	2115	6009	61,282	10,152	3016	7136
Estonia	9126	866	665	201	12,122	6053	5562	490
Finland	77,573	2708	1221	1487	168,166	17,106	19,456	−2350
France	977,918	260,605	85,075	175,529	783,875	95,478	49,419	46,059
Germany	1,318,987	265,684	114,768	150,916	1,622,266	14,177	−14,576	28,753
Greece	78,031	2550	1266	1284	75,946	2172	9860	−7688
Hungary	164,919	5872	−183	6054	77,582	19,716	9479	10,237
Ireland	53,605	18,213	2946	15,267	60,239	1501	3006	−1505
Italy	1,005,694	143,660	122,950	20,710	850,774	156,871	41,183	115,688
Latvia	10,852	4499	1905	2594	13,276	3038	4279	−1242
Lithuania	15,487	850	441	409	21,479	11,599	5474	6126
Luxembourg	12,101	2597	175	2422	22,810	−441	−743	302
Malta	2153	206	116	90	1897	−188	−967	779
Netherlands	379,646	95,552	61,956	33,596	349,931	93,202	43,466	49,735
Poland	237,200	55,258	50,886	4371	293,402	157,512	70,867	86,645
Portugal	60,308	14,923	6315	8609	109,209	7058	−3479	10,537
Romania	139,312	48,671	41,847	6824	199,339	83,513	20,114	63,399
Slovakia	65,311	2028	983	1044	79,560	22,008	15,854	6154
Slovenia	16,301	4178	2396	1782	38,922	10,488	−600	11,088
Spain	416,836	16,612	12,899	3713	586,764	16,597	−33,239	49,835
Sweden	134,064	37,375	10,640	26,736	207,760	17,127	18,556	−1429
Unit. King.	1,352,386	374,746	52,598	322,148	736,402	96,064	44,965	51,100
Total	7,119,700	1,491,167	619,370	871,797	7,206,132	961,826	409,783	552,043
% 2011 TJ		20.9%	8.7%	12.2%		13.3%	5.7%	7.7%

Econometric models: Example 2

EU energy efficiency policy harmonized energy savings.

	Household	Manufacturing	2 sectors
	MS = 28	MS = 28	Combined
Full period (2000–2011)			
PJ (EL plus NG) 2010	7120	7206	14,326
Bottom-up (ODEX) savings	1491	962	2453
As % 2011 PJ	20.9%	13.3%	17.1%
Net policy savings	722	415	1136
As % 2011 PJ	10.1%	5.8%	7.9%
90% confidence (+/−)	20.5%	26.0%	16.1%
Net-to-Bottom-Up Ratio	48.4%	43.1%	46.3%
Early period (2000–2005)			
Bottom-up (ODEX) savings	619	410	1029
As % 2011 PJ	8.7%	5.7%	7.2%
Net policy savings	116	213	329
As % 2011 PJ	1.6%	3.0%	2.3%
90% confidence (+/−)	55.0%	23.4%	24.6%
Net-to-Bottom-Up Ratio	18.8%	52.0%	32.0%
Later period (2006–2011)			
Bottom-up (ODEX) savings	872	552	1424
As % 2011 PJ	12.2%	7.7%	9.9%
Net policy savings	605	202	807
As % 2011 PJ	8.5%	2.8%	5.6%
90% confidence (+/−)	22.1%	47.4%	20.3%
Net-to-Bottom-Up Ratio	69.4%	36.6%	56.7%

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Econometric models: Example 3

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Energy Policy

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Do energy efficiency policies save energy? A new approach based on energy policy indicators (in the EU Member States)

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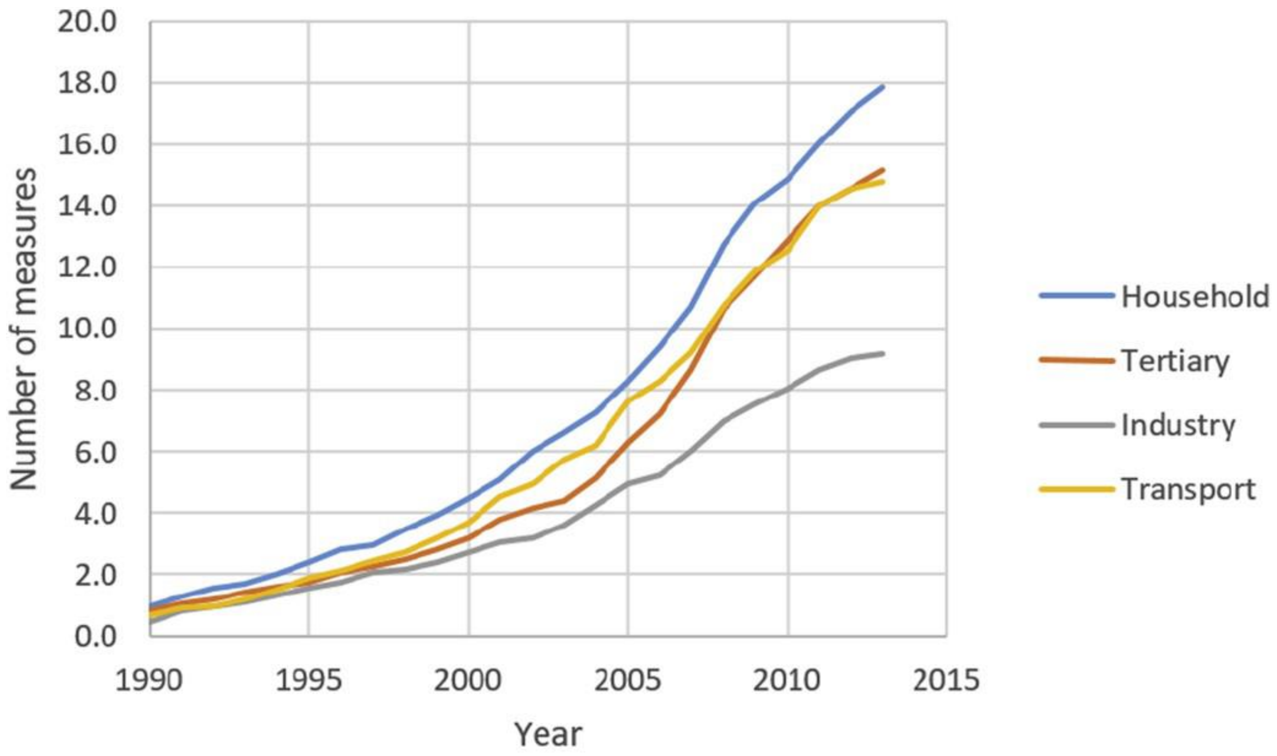
Econometric models: Example 3

- Similar to the previous model in this econometric models for energy demand an indicator of energy policy intensity is introduced as explanatory variable, along with the classical control variable, based on the MURE database. The policy indicator simply cumulates the national measures over time.



Econometric models: Example 3

- .

$$ln\left(q^{3}_{00,it}\right) = \beta^{00}_{0,i} + \rho^{00} ln\left(q^{3}_{00,it-1}\right) + \gamma^{00} pol_{00,it} + \beta^{00}_{1} ln\left(\frac{p^{3}_{00,it}}{def_{it}}\right) + \beta^{00}_{2} other^{3}_{00,it} +$$

$$+\beta^{00}_{3} ln(pop_{it}) + \beta^{00}_{4} ln(rgdp_{it}) + \beta^{00}_{5} ln(hdd_{it}) + \beta^{00}_{6} t + \beta^{00}_{7} t^{2} + \varepsilon^{00}_{i,t}$$

- This approach is like a negative image of the counterfactual simulation approach: there, the model is estimated without the policy variable using the pre-policy period, and then the energy policy is set to zero in the simulated period, leaving the other variables at their historical level.
- Here we estimate the model using the entire period, and then we simulate the entire period as if the other variables are fixed, allowing only the policy variable to change.

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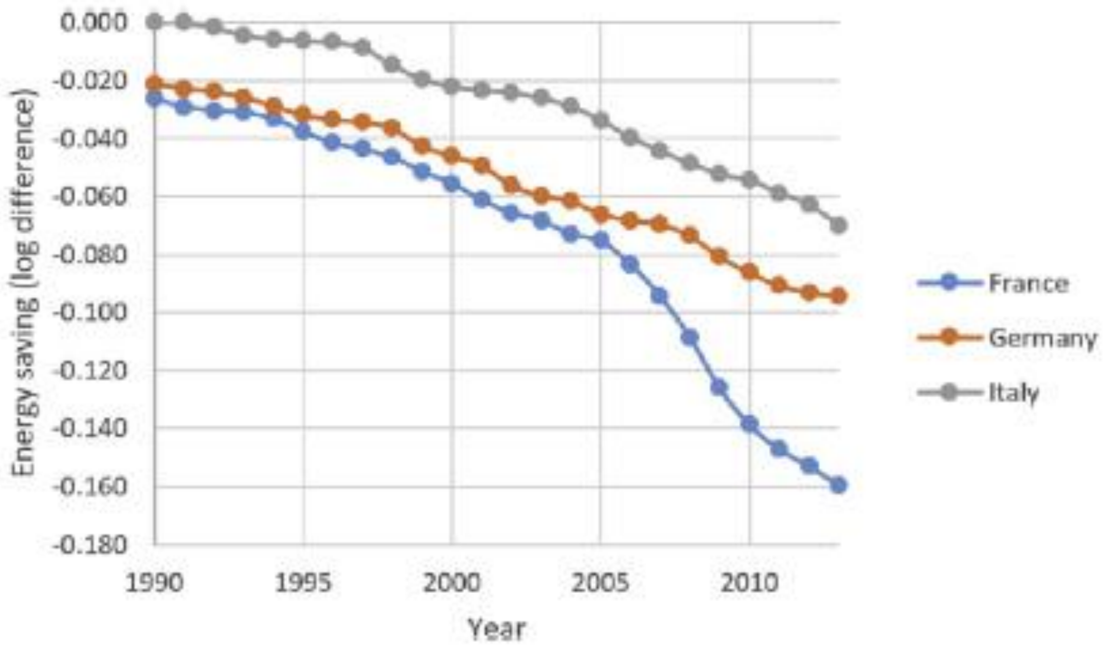
Econometric models: Example 3

Estimated short and long run elasticities of policy measures on energy consumption in each sector.

SECTOR	SHORT RUN ELASTICITY	LONG RUN ELASTICITY
Household	*−0.17%*	*−0.35%*
Services	−0.05%	− 0.10%
Industry	*−0.83%*	*−2.02%*
Transport	*−0.26%*	*−0.59%*



Dynamic simulation of the estimated effect of energy policies in the household sector in France, Germany and Italy.

t (year)	pol_t			$ln(q_t) = 0.52ln(q_{t-1}) - 0.0017pol_t$		
	France	Germany	Italy	France	Germany	Italy
1989	7	6	0	−0.025	−0.021	0.000
1990	8	6	0	−0.026	−0.021	0.000
1991	9	7	0	−0.029	−0.023	0.000
1992	9	7	1	−0.030	−0.024	−0.002
1993	9	8	2	−0.031	−0.026	−0.004
1994	10	9	2	−0.033	−0.029	−0.006
1995	12	10	2	−0.038	−0.032	−0.006
1996	13	10	2	−0.042	−0.034	−0.007
1997	13	10	3	−0.044	−0.034	−0.009
1998	14	11	6	−0.047	−0.037	−0.015
1999	16	14	7	−0.051	−0.043	−0.020
2000	17	14	7	−0.056	−0.046	−0.022
2001	19	15	7	−0.061	−0.049	−0.023
2002	20	18	7	−0.066	−0.056	−0.024
2003	20	18	8	−0.068	−0.060	−0.026
2004	22	18	9	−0.073	−0.062	−0.029
2005	22	20	11	−0.075	−0.066	−0.034
2006	26	20	13	−0.083	−0.068	−0.040
2007	30	20	14	−0.094	−0.070	−0.044
2008	35	22	15	−0.109	−0.074	−0.049
2009	41	25	16	−0.126	−0.081	−0.052
2010	43	26	16	−0.139	−0.086	−0.054
2011	44	27	17	−0.147	−0.091	−0.059
2012	45	27	19	−0.153	−0.093	−0.063
2013	47	27	22	−0.159	−0.094	−0.070

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Econometric models: Example 3

Estimated Policy-Induced Energy Savings based on the model (percentage and absolute value, in TJ).

COUNTRY	Household		Services		Industry		Transport		All Sectors	
	Saving in 2013		Saving in 2013		Saving in 2013		Saving in 2013		Saving in 2013	
	%	TJ	%	TJ	%	TJ	%	TJ	%	TJ
Austria	3.5%	5973	0.9%	597	6.0%	16422	6.5%	23532	5.3%	46525
Belgium	6.2%	22187	2.0%	4063	14.1%	49016	5.9%	23841	7.6%	99107
Bulgaria	7.0%	2976	1.5%	491	24.7%	19949	5.8%	6654	11.1%	30070
Croatia	5.2%	2642	1.6%	456	10.0%	3959	13.8%	12425	9.3%	19482
Cyprus	2.2%	226	0.5%	37	7.9%	626	5.8%	2146	4.9%	3034
Czech Republic	5.3%	7486	0.6%	633	11.6%	24141	5.3%	13063	6.4%	45322
Denmark	3.4%	2696	0.3%	145	2.9%	2211	4.6%	9002	3.5%	14054
Estonia	6.4%	608	2.1%	263	22.0%	4091	7.2%	2356	9.9%	7318
Finland	7.8%	7709	2.8%	2167	29.0%	76285	12.0%	24604	17.2%	110766
France	15.9%	247717	2.4%	22685	34.4%	431977	16.4%	346315	17.8%	1048694
Germany	9.4%	200437	2.4%	32011	20.1%	410471	10.3%	272638	11.3%	915558
Greece	3.5%	4062	0.9%	711	10.6%	11658	6.2%	16554	5.8%	32985
Hungary	5.6%	8277	0.5%	437	12.0%	15536	6.4%	9717	6.6%	33966
Ireland	8.5%	8509	2.3%	1235	30.0%	27986	13.8%	25638	14.6%	63368
Italy	7.0%	80730	1.6%	10193	26.1%	268379	14.7%	247598	13.4%	606900
Latvia	3.8%	498	0.9%	138	18.4%	3044	6.1%	2756	7.2%	6436
Lithuania	4.5%	756	2.1%	298	11.3%	2747	5.9%	3859	6.3%	7659
Luxembourg	4.0%	734	0.4%	78	14.2%	2903	3.5%	3714	4.5%	7429
Malta	6.9%	237	1.5%	35	9.4%	204	2.7%	333	4.0%	809
Netherlands	8.8%	39151	1.3%	4487	38.2%	214580	9.4%	58959	16.0%	317178
Norway	8.0%	11619	2.2%	2237	35.6%	88041	5.8%	13052	16.0%	114949
Poland	1.0%	2784	0.6%	1580	12.0%	47408	5.2%	34588	5.5%	86360
Portugal	5.3%	4117	1.2%	852	6.0%	8045	10.4%	28179	7.4%	41193
Romania	3.8%	5982	1.2%	761	13.6%	30781	5.3%	11576	7.4%	49100
Slovakia	5.8%	3919	1.8%	1276	23.7%	28075	4.0%	3839	10.5%	37109
Slovenia	4.5%	1118	1.0%	180	11.9%	5357	5.1%	3985	6.4%	10639
Spain	10.2%	54897	3.7%	15089	29.1%	255559	26.1%	387900	21.6%	713447
Sweden	4.0%	5716	0.5%	638	11.7%	29835	7.8%	26099	7.2%	62288
United Kingdom	5.4%	90806	1.4%	10043	12.9%	116562	8.8%	190396	7.5%	407808
All countries	8.5%	824569	1.9%	113816	22.4%	2195848	11.9%	1805319	12.1%	4939552

Conclusions

- Assessing the impact of policies on energy savings at EU or national level is needed to assess the polices effectiveness and, if needed, to re-design them.
- BU and TD methods have limitations.
- RCTs are difficult to be used the macro level/
- Various econometric models have been used.
- A new approach is to have an independent Policy variable in the model
  - One model use ODEX
  - One mode use the policy in the MURE database.

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