4th AIEE Energy Symposium- December 10-12, 2019 – LUMSA University, Rome, Italy

Assessing energy efficiency: econometric evidence and implications for Italian energy policy

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Abstract. Energy efficiency represents one of the key objectives of the Clean Energy Package. In this context, EU member countries determine the optimal policies for energy efficiency. This papers aims to develop econometric evidence on country-level energy efficiency performance based on stochastic frontier analysis, with a specific focus on Italy's efficiency levels. The analysis is based on data for a sample of 17 European companies over the period 1996-2016. Overall, Italy's historical efficiency and performance ranking is consistently above the sample average and is on an increasing path since 2012. However, efficiency benchmarking shows that there may be scope for efficiency savings above and beyond the 2030 targets in the set out in the National Energy Plan. Disaggregate econometric analysis shows that part of these additional efficiency savings may stem from the industrial and residential sectors. To the authors' knowledge, this is the first attempt to directly compare the efficiency assumptions in a National Action Plan using econometric benchmarking approaches.

1 European objectives and energy efficiency targets

Promoting efficiency is one of the key energy policy priorities in the European Union (EU). In 2010, the EU adopted strategy Energy 2020 for competitive, sustainable and secure energy. Energy efficiency improvements was one of the top five priorities (EC, 2010).[2]

The European Efficiency Directive (EED) (Directive 2012/27/EU) sets the EU energy efficiency target for 2020, which can be expressed in terms of either primary energy consumption or final energy consumption (EU, 2012).[3,4] Meeting both targets requires a reduction in primary and final energy consumption by 20% compared with levels projected for 2020 in the European Commission's Energy Baseline Scenario (EC, 2008). Taken together, these targets should contribute to achieving the EU's objective of reducing energy consumption by 20 % by 2020.[5] Directive 2012/27/EU sets an indicative 32,5% target by 2030 relative to 2007.

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[1] This paper reflects the views of the authors and does not necessarily reflect the views of Oxera or UCL.

[2] European Commission (2010), Energy 2020 – a strategy for competitive, sustainable and secure energy. COM (2010) 639 final, Brussels, 10 November 2010.

[3] EU, 2012, Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (OJ L 315/1, 14.11.2012, pp. 1-56).

[4] Primary energy consumption covers consumption of the energy sector itself, losses during transformation and distribution of energy, as well as final consumption by end users.

[5] However, a challenge in assessing EU progress is that the aggregation of individual Member States' targets does not add up to a 20 % EU-level reduction in energy consumption by 2020.

Table. Energy efficiency objectives at the EU level

	2020 objective	**2030 objective**
Reduction in primary energy consumption compared to the PRIMES 2007 scenario	-20%	-32,5% (indicative)
Reduction in final energy consumption through energy efficiency obligations	-1,5% per year (without transport)	-0,8% per year (with transport)

Note: based on a common methodology, 2030 targets are set by country.

However, if energy consumption were to continue growing at its current rate, the EU would not meet its 20 % energy efficiency target for 2020.[6] In a recent statement to the Commissioner of DG Energy, President-elect of the European Commission Ursula von der Leyen stated the importance of following the energy-efficiency-first-principle, specifically looking at how to ‘further improve the energy performance of buildings and speed up renovation rates’.[7]

During the last two decades most of the EU member states have introduced different types of efficiency enhancing measures. Performance standards in buildings, heating systems and electrical appliances have been introduced in an attempt to improve the level of energy efficiency in the residential sector. Member states have also introduced monetary incentives such as subsidies and tax credits. Germany is the country that has put in place the largest number of policy savings measures, followed by France and Spain. For the sample examined by MURE, household measures are the most common ones (25%), followed by those in the services sector (24%) and the transport sector (21%).

The European Commission (2006) identified the residential sector as the one with the greatest potential for cost-effective savings which are estimated to be 27%, where large energy saving opportunities were found to lie in retrofitted roof and wall insulation of buildings as well as improved appliances and other energy-using equipment.

2 National targets, efficiency levels, and future policies: the case of Italy

Italy’s 2030 target amounts to 43% reduction in primary energy and 39,7% of final energy compared to 2007. This would amount to 158 millions of tonnes of oil equivalent (mtoe) and 124 mtoe respectively of primary and final energy consumption.

[6] For Italy, this is shown in table 3.16 of ENEA (2018), *Rapporto Annuale Efficienza Energetica 2018: principali risultati,* luglio. The table shows that only around 52% of the energy saving target will be reached by 2020.
[7] Ursula von der Leynen, Mission letter to Kadri Simson, Commissioner-designate for energy, September.

Table. Energy efficiency objectives in Italy

	2020 objective	**2030 objective (PNIEC)**
Reduction in primary energy consumption compared to the PRIMES 2007 scenario	-24%	-43% (indicative)
Reduction in final energy consumption through energy efficiency obligations	-1,5% per year (without transport)	-0,8% per year (with transport)

Note: The PRIMES model simulates a market equilibrium solution for energy supply and demand and is used to create energy outlooks for the EU.

Source: Ministero delle Infrastrutture e dei Trasporti (2018), Piano Nazionale Integrato Per L'Energia E Il Clima, December.

The Italian National Action Plan (Piano Nazionale Integrato Per L'Energia E Il Clima, PNIEC) outlines the measures that will be taken going forward, and aims to use a mix of regulatory and financial measures articulated across different sectors and aimed at different actors.[8]

Interestingly, the PNIEC indicates the possible scope of saving in energy consumption by economic sector. Compared to period 2016-2018, PNIEC estimates a cumulated saving in total final energy consumption amounting to 51,4 Mtoe, or 9,3 Mtoe per year. For 2030, So efficiency savings are broken down as follows:

Table. 2030 objectives for Italy

	Energy savings (Mtoe)	Share of saving, %
Residential	3,3	35%
Tertiary	2,4	26%
Industry	1,0	11%
Transport	2,6	28%
Total	**9,3**	**100%**

Source: Ministero delle Infrastrutture e dei Trasporti (2018), Piano Nazionale Integrato Per L'energia E Il Clima, December.

PNIEC's targets are based on an assessment of cost-effectiveness and aimed at identifying the sectors with the greatest efficiency potential. Limited information is available on the methodology used and the sources of evidence considered. However, it is indicated that TIMES (a bottom-up model generator for energy scenarios) was used.

Evidence is available on the annual efficiency savings achieved over period 2011-2017 in comparison to the expected efficiency savings for 2020:

[8] Ministero dello Sviluppo Economico, Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Ministero delle Infrastrutture e dei Trasporti (2018), Piano Nazionale Integrato Per L'energia E Il Clima, December.

Table. Difference between expected efficiency savings in 2020 and efficiency improvement achieved since 2011

	Energy savings (Mtoe) Achieved until 2017	Energy savings (Mtoe) Expected in 2020	% Target
Residential	3,64	3,67	99,2%
Tertiary	0,22	1,23	17,5%
Industry	2,5	5,1	49,0%
Transport	1,69	5,5	30,7%
Overall	**8,05**	**15,5**	**51,9%**

ENEA (2018), Analisi e Risultati delle Policy di Efficienza Energetica Del Nostro Paese, June, table 3.16.

The table shows that, until 2017, the tertiary, the transport and the industry sectors are the one characterised by the greatest gaps between achieved savings and 2020 savings targets. Almost all expected savings associated with residential consumption have already been met.

From the analysis, it is possible to draw a number of general considerations. First, the residential sector is the only sector where Italy has made significant progress. The residential sector will continue to have a key role in achieving longer term targets. For 2030, the largest expected share of savings is from residential (35%), followed by transport (28%), tertiary (26%) and industry (11%). Transport (30,7%) and industry (49%) are the sectors characterised by the greatest gap relative to the European targets.

3 The concept of energy efficiency

Energy efficiency is captured in several ways. EU-level targets are set with respect to volume reductions. In the context of EU wide target setting, energy efficiency is approximated by energy intensity input-based ratios. For example, EC (2000, p. 3)[9] recognises that 'Changes in energy intensity for final energy consumption are a first and rough estimate indicator for changes in energy efficiency.' IEA (2009, p. 19) notes that 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 several factors including the structure of the economy and energy efficiency.'[10]

Filippini and Hunt (2011) developed a stochastic frontier framework for the empirical analysis of energy efficiency, as opposed to more conventional energy intensity indicators.[11] With this method, it is possible to estimate an input demand function frontier which gives the minimum level of energy input used for any given level of output. Such measure of energy efficiency controls for a range of economic and other factors and is therefore viewed as a more suitable approach to measure energy efficiency. A number of papers have used the SFA approach. For example, Filippini and Hunt (2011, 2012), Saussay et al. (2012) make use of the SFA approach to analyse the impact of introduced

[9] EC, 2000. Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. Action Plan to Improve Energy Efficiency in the European Community. COM(2000) 247 final. Brussels, 26.04.2000.

[10] Another commonly used efficiency measure is ODEX, an aggregate energy efficiency indicator. It is argued that ODEX 'is cleaned from temperature, structural, and behavioural changes as well as from capacity effects as occurring in an economic crisis'. ODEX reflects a technical efficiency improvement.
Moreover, Economidou et al (2019) used the Logarithmic-Mean Divisia Index method (LMDI) method, to study both aggregated and sectoral energy consumption changes at EU and MS levels over the period 2005–2016. Index decomposition analysis (IDA) is used to break down changes in an aggregate indicator and assign the effects to a number of predefined factors.

[11] Filippini, M., Hunt, L. (2011), Energy Demand and Energy Efficiency in the OECD Countries: A Stochastic Demand Frontier Approach, Energy Journal 32 (2), 59-80.

building codes on the energy efficiency of residential space heating in selected European countries. Filippini, Hunt and Zorić (2014),[12] used SFA analysis to assess the impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector. This approach represents the focus of the present paper and is broadened to consider overall as well as disaggregate energy efficiency in Europe.

4 Methodology

This research combines the approaches taken in energy demand modelling and frontier analysis in order to econometrically estimate the level of energy efficiency. For total consumption, the main model can be expressed as follows:

$$Consumption_{it} = f(EnergyPrice_{i,t}, GDP_{i,t}, Population_{i,t}, EF_{i,t})$$

In other words, total final consumption ($Consumption_{it}$) is estimated as a function of real energy prices ($EnergyPrice_{i,t}$) real gross domestic Product ($GDP_{i,t}$), population ($Population_{i,t}$).

The error term $EF_{i,t}$ is assumed to be composed of two independent parts: a stochastic error, capturing the effect of noise, and a one-sided non-negative disturbance capturing the effect of inefficiency. In line with Filippini and Hunt (2011, 2012) the second term is interpreted as an indicator of the inefficient use of energy. SFA models are based on a log-log specification. Similar regression models will be estimated with respect to the transport, residential and industrial sectors.

The analysis considers different SFA approaches, each characterised by specific assumptions.

The panel data models considered are Battese and Coelli (1995) (BC95),[13] the random-effects model by Pitt and Lee (1981) (PL81),[14] the true fixed effects (TFE) model,[15] and the four-component model by Kumbakhar et al (2012) (SK12).[16]

[12] Filippini, M., Hunt, L., Zorić, J. 2014, Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector, Energy Policy, January.

[13] Battese, G.E.,Coelli, T.J., 1995 .A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Econ. 20, 325–332.

[14] Pitt, M.,Lee,L.F.,1981. The measurement and sources of technical inefficiency in the Indonesian weaving industry .J.Dev.Econ.9, 43–64.

[15] Greene, W. (2005) Reconsidering heterogeneity in panel data estimators of the stochastic frontier model. Journal of Econometrics 126: 269-303.

[16] Kumbhakar, S.C., Lien, G. and J.B. Hardaker (2011), 'Technical efficiency in competing panel data models: A study of Norwegian grain farming', Journal of Productivity Analysis, September.

Table. Modelling assumptions

Estimation approach	Modelling assumptions
BC95	v_{it}: normally distributed error term $u_{i,t}$: one-sided nonnegative term representing inefficiency. Truncation at zero of the normal distribution
PL81	v_{it}: normally distributed error term u_i: one-sided nonnegative term representing inefficiency. Half-normal distribution (time invariant)
TFE	v_{it}: normally distributed error term $u_{i,t}$: one-sided nonnegative term representing inefficiency a_i: time-invariant unmeasured heterogeneity captured through fixed effects
SK12	Error term split into a normally distributed component (noise) and a one-sided component (transient inefficiency). Random effects split into one sided non-negative term representing persistent inefficiency and in a term measuring time invariant heterogeneity

BC95 and TFE are helpful in that they enable the estimation of a stochastic frontier model in which the level of efficiency can be expressed as a specific function of explanatory variables representing the number of policy measures. These two models were considered in Filippini et al (2014).[17] Unlike BC95, TFE models includes fixed effects in the equation. A shortcoming of TFE is that any unobserved, time-invariant, group-specific heterogeneity is considered as inefficiency.

PL81 was used in Filippini and Hunt (2011).[18] PL81 interprets the panel data random effects as inefficiency rather than heterogeneity. Inefficiency is assumed to be time invariant.

The limit of these models is that the level of inefficiency does not include persistent inefficiency that might remain constant over time. In the SK12, the error term is split into four components, namely time invariant heterogeneity, persistent (or time-invariant) inefficiency, time-varying inefficiency, and noise.

5 Data

The data is obtained from various sources which include Eurostat and Odyssee databases, and is used to construct a perfectly balanced panel dataset of 17 countries over 21 years (period 1996-2016).

[17] Filippini, M., Hunt, L., Zorić, J. 2014, Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector, Energy Policy, January.

[18] Filippini, M., Hunt, 2011, US Residential Energy Demand and Energy Efficiency: A Stochastic Demand Frontier Approach, CEPE Working Paper No. 83, April.

Table. Main variables considered

Variable	Unit	N	Mean	Std. Dev.	Minimum	Maximum
Total Consumption	Thousands toe	357	51.6	59.3	1.5	231.4
Consumption, residential	Thousands toe	357	13.1	16.4	0.2	69.0
Consumption, transport	Thousands toe	357	15.9	18.6	0.7	66.4
Consumption, industrial	Thousands toe	357	14.4	15.8	0.2	64.6
Consumption, other	Thousands toe	357	8.2	9.4	0.2	39.8
Y	€b, '10 ex. rate	357	569.4	720.6	9.8	2870.6
POP	Million	357	21552.2	24671.6	656.3	82536.7
PE	2005=100	357	78.1	22.4	20.5	121.7
DWELL	Floor area of dwellings	325	94.85	20.2	52.5	146.0
DEGREE	Heating degree days	325	2793.6	1034.5	453	4947

Note: variables DWELL and DEGREE have been considered as a sensitivity but have not been included in the key specification due to missing data.

6 Results

The coefficients of the SFA aggregate models are shown in the following table:

Table. SFA models, model coefficients, total consumption, 1996-2016

Estimation approach	BC95	PL81	TFE[1]	SK12
Parameters of the total demand function				
Ln(Energy prices)	-0.06	-0.09***	-0.09***	-0.09***
Ln(GDP)	0.45***	0.50***	0.46***	0.51***
Ln(Population)	0.51***	0.43***	0.21***	0.38***
Time trend	-0.01*	-0.01***	-0.01***	-0.01***
Constant	-3.89***	-3.31***		-2.62***
Parameters in the one sided error (u)				
Constant	-2.70***	0.09***	-14.68	
Variance parameters for the compound error (v)				
Constant	-5.74***	0.00***	-5.93***	
Observations	357	357	357	357

Note: [1] country specific dummies are not reported in the table. *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

The estimated model coefficients are of the expected sign and are generally statistically significant (with the exception of energy prices in the BP95 models). The estimated price elasticity is negative in all four models. This is consistent with the expectation that energy price increases reduce overall energy demand.

The estimated income elasticity is positive and significant in all three models. The results suggest that EU demand is price and income inelastic, consistent to the obtained results for the US residential consumption in Filippini and Hunt (2012). Similarly, population is found to be positive and statistically significant.

Finally, the time trend is shown to significantly reduce energy demand across all models. This may be interpreted as evidence of technical progress common to all countries over time. This may also represent other exogenous factors that are not captured in the model.

The following table provides summary statistics for the efficiency scores in the sample, as well as the average efficiency score for Italy over the period 1996-2016:

Table. SFA models, efficiency scores (%), total consumption, 1996-2016

Estimation approach	Sample	Italy	Average	Standard deviation	Minimum	Maximum
BC95	357	89.28	78.62	12.5	46.0	97.9
PL81	357	86.96	79.42	13.7	50.6	98.7
TFE	357	99.95	99.95	0.0	99.9	99.9
SK12	357	97.25	97.19	0.2	96.7	97.6

Note: for SFA analysis with an enhanced specification (N=324) including area of dwellings and degree days, efficiency scores for Italy are 94.2 (BC95), 67.0 (PL81), 99.9 (TFE), 99.9 (SK12).

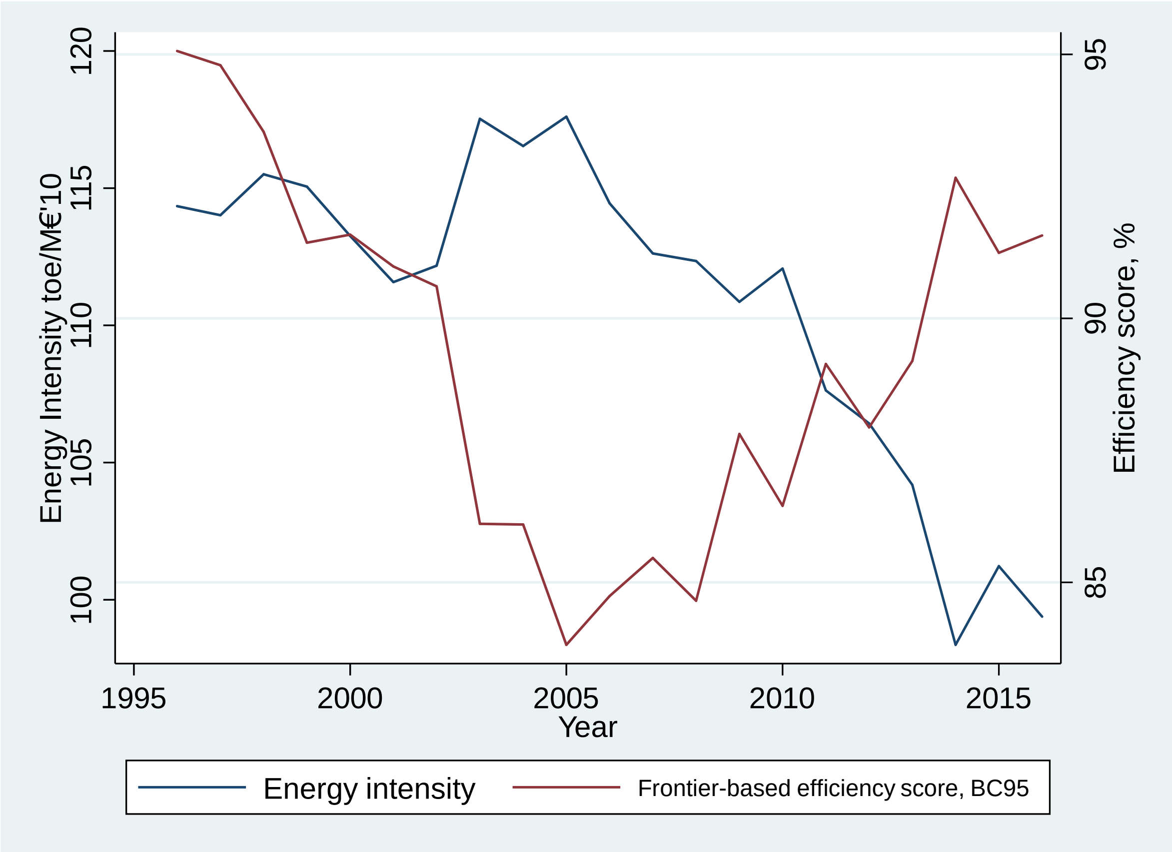
The most striking result concerns the TFE model, which does not show evidence of inefficiency in the sample. As stated in Filippini, Hunt and Zorić (2014),[19] 'inefficiencies of the TFE model may be underestimated as they do not include the persistent inefficiencies that might remain constant over time and are captured by the individual effects. The TFE model commonly results in very high average efficiency scores and small differences in efficiency scores between different countries, so there may be virtually nothing left to be explained by different policy measures in place.'

The BC95, PL81 and SK12 model show average efficiency scores of 78.6, 79.4 and 97.2, respectively. Italy's efficiency score is consistently above average. Based on average efficiency scores, Italy ranks 5th, 6th and 7th with BC95, PL81 and SK12, respectively.

Considering in greater detail the evolution of efficiency over time based on the BC95 model,[20] it is possible to observe an increase in efficiency since 2012 (with the exception of 2015), from 87.9% to 91,6%. This results appears to be consistent (that is, negatively correlated) with the evolution of the energy intensity indicator, which reports Mtoe/GDP:

[19] Filippini, M., Hunt, L., Zorić, J. 2014, Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector, Energy Policy, January.
[20] The PL81 models assumes constant efficiency over the sample period.

Graph. Energy intensity and efficiency score (BC95), Italy, 1996-2016



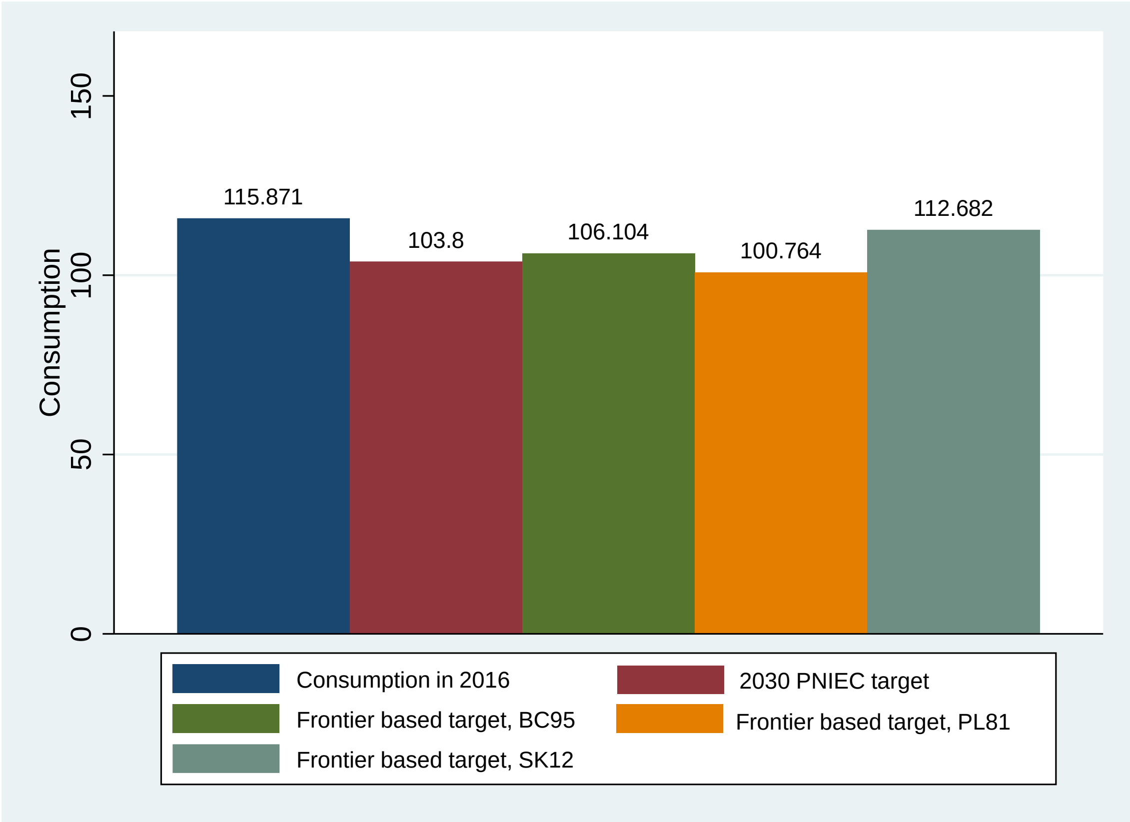
Analysis of efficiency scores across different estimation approach shows high levels of correlation for BC95, PL81 and SK12:

Table. SFA models, correlation coefficients

	BC95	PL81	TFE	SK12
BC95	1.00			
PL81	0.93	1.00		
TFE	0.26	0.00	1.00	
SK12	0.87	0.97	0.00	1.00

The analysis can be used to derive frontier based target for Italy, for a comparison with the 2030 consumption target indicated in the PNIEC, amounting to 103.8 Mtoe. It is worth noting that the two values have been derived based on significantly different approaches. While the SFA analysis is based on a backward looking analysis, the targets in the PNIEC are claimed to be based on future energy scenarios, considering the evolution of technology until 2030.

Graph. SFA models, Comparison between 2016 consumption levels, 2030 targets and frontier based targets



Compared to 2016 consumption, amounting to around 116 Mtoe, frontier-based predictions result in significantly lower consumption levels, between 100,8 Mtoe (PL81) and 112,7 (SK12). The 2030 consumption target set out in PNIEC lies within this range and amounts to 103.8 Mtoe.

For a preliminary assessment of efficiency levels across different sectors, we undertake a disaggregate analysis for the residential, industrial and transport sectors.[21] The results based on BC95 models are shown below:

[21] A sector classified as 'other' is considered to take into account other sectors of the economy, and is derived as a residual between total consumption and consumption in the main three sectors.

Table. SFA models, model coefficients, disaggregated consumption, 1996-2016, BC95

Estimation approach	**BC95**	**BC95**	**BC95**	**BC95**	**BC95**
Demand	Total	Residential	Industrial	Transport	Other
Parameters of the total demand function					
Ln(Energy prices)	-0.06	0.08	-0.40***	0.13**	-0.26**
Ln(GDP)	0.45***	0.29***	0.44***	0.57***	0.44***
Ln(Population)	0.51***	0.69***	0.68***	0.36***	0.53***
Time trend	-0.01*	-0.01**	-0.01***	-0.01**	0.01
Constant	-3.89***	-6.40***	-5.41***	-4.96***	-4.84***
Parameters in the one sided error (u)					
Constant	-2.70***	-5.37	0.28	-0.25	-5.36
Variance parameters for the compound error (v)					
Constant	-5.74***	-2.37***	-6.17***	-4.44***	-2.67***
Observations	357	357	357	357	357

Note: country specific dummies are not reported in the table. *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

The estimated models display stable coefficients, with the exception of the residential and transport sectors. The price coefficient in the residential sector is consistent with Filippini, Hunt and Zorić (2014).[22] These models result in the following efficiency scores:

Table. SFA models, efficiency scores (%), total consumption, BC95, 1996-2016

Demand	**Sample**	**Italy**	**Average**	**Standard deviation**	**Minimum**	**Maximum**
Total	357	89.3	78.6	12.5	46.0	97.9
Residential	357	99.7	99.7	0.0	99.7	99.7
Industrial	357	85.2	64.3	23.7	17.1	98.6
Transport	357	92.1	90.4	6.4	63.7	97.6
Other	357	99.6	99.6	0.0	99.6	99.6

It is worth noting that for both the residential and 'other' sectors the models do not identify any significant source of inefficiency.

The disaggregated models based on PL81 are shown next:

[22] Filippini, M., Hunt, L., Zorić, J. 2014, Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector, Energy Policy, January.

Table. SFA models, model coefficients, disaggregated consumption, 1996-2016, PL81

Estimation approach	**PL81**	**PL81**	**PL81**	**PL81**	**PL81**
Demand	Total	Residential	Industrial[1]	Transport	Other
Parameters of the total demand function					
Ln(Energy prices)	-0.09***	0.03	-0.19***	0.01	-0.19***
Ln(GDP)	0.50***	0.15***	0.69***	0.88***	0.31***
Ln(Population)	0.43***	0.90***		0.01	0.65***
Time trend	-0.01***	-0.01***	-0.01***	-0.01***	0.00**
Constant	-3.31***	-8.12***	-2.29***	-3.17***	-5.92***
Parameters in the one sided error (u)					
Constant	0.09***	0.61***	2.40**	0.23**	0.23***
Variance parameters for the compound error (v)					
Constant	0.00***	0.01***	0.01***	0.00***	0.01***
Observations	357	357	357	357	357

[1] The population variable has been dropped in that it resulted in negative coefficients, which runs counter to expectations.

Note: country specific dummies are not reported in the table. *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

This modelling approach results in the following efficiency scores:

Table. SFA models, efficiency scores (%), total consumption, PL81, 1996-2016

Demand	**Sample**	**Italy**	**Average**	**Standard deviation**	**Minimum**	**Maximum**
Total	357	86,9	79.4	13.7	50.6	98.7
Residential	357	60,2	51.8	18.8	31.7	97.9
Industrial	357	17,8	29.2	21.9	11.0	97.0
Transport	357	63,8	66.6	14.4	49.2	98.5
Other	357	80,8	68.5	17.4	43.1	98.0

Overall, based on BC95 and PL81 models, it is possible to show the following rank positions for Italy over the analysis period:

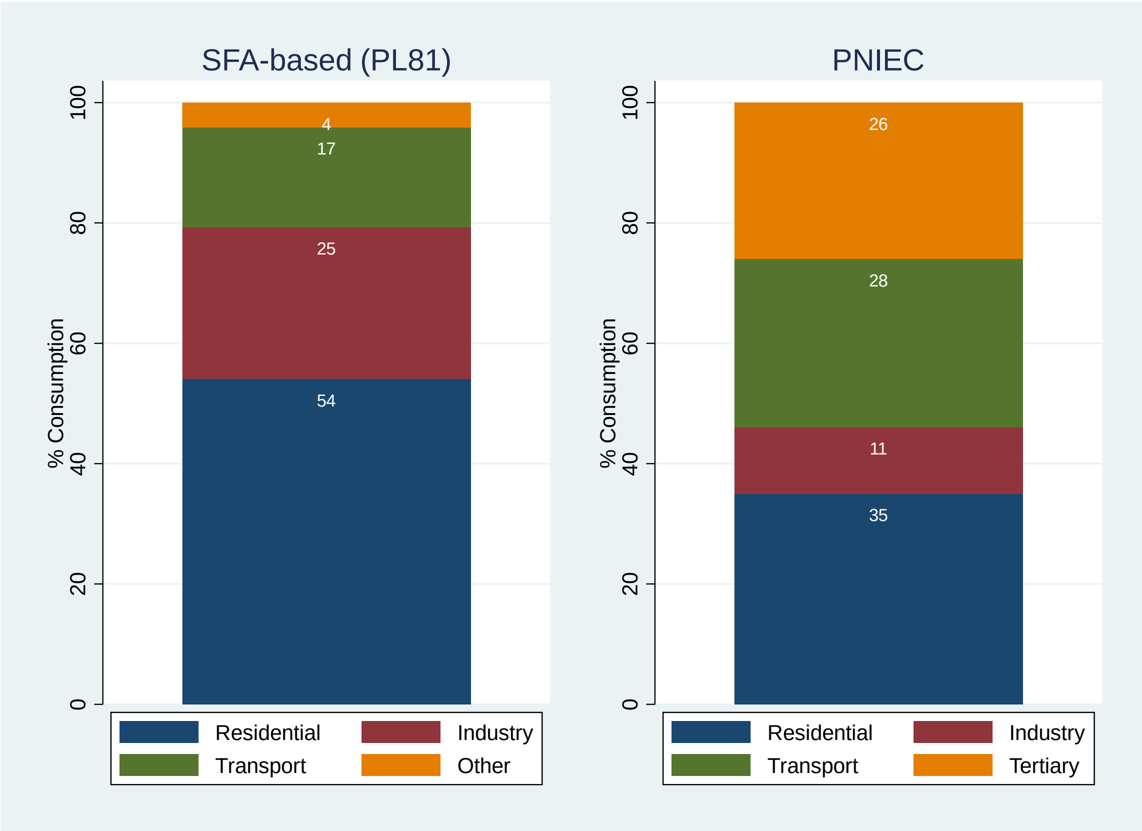
Table. SFA models, Italy, rank position (out of 17), 1996-2016

Consumption	**BC95**	**PL81**
Total	5	6
Residential	4	4
Industrial	3	11
Transport	7	11
Other	4	5

The analysis shows consistent performance for total consumption, which places Italy in the 5th-6th position. Italy's best performance is with respect to the residential sector. Mixed evidence is shown for the industrial and transport sector, since the PL81 models result in significantly lower efficiency ranks.

Disaggregated analysis can be used to derive sector-specific targets, also relative to those set out in the national plan. PNIEC expects a reduction in energy consumption based on active policies amounting to around 9.3 Mtoe/year in 2030, achieved 'mainly in non-ETS sectors'.[23] The modelling approach used in the PNIEC to establish such savings consider the different cost/effectiveness ratios for different measures, so to achieve the targets in the Directive. In addition, the modelling approach appears to take into account the evolution of performance and cost of different technologies, other sector-specific considerations and the achievement of renewables targets (e.g. in relation to heat pumps).

Graph. Comparison frontier-based composition of efficiency savings versus PNIEC



Note: composition of efficiency savings from PNIEC based on Ministero delle Infrastrutture e dei Trasporti (2018), Piano Nazionale Integrato Per L'Energia E Il Clima, December, chart n. 18 on p.55. In absolute terms, the estimated target based on PL81 amounts to 85.3 Mtoe, which compares to cumulated savings at 2030 of 51.3 Mtoe according to the PNIEC.

So far, as observed in section 2, most of the savings have been achieved from the residential sector. PNIEC confirms that residential sector is a significant area for improvement. SFA analysis identifies an further efficiency potential going forward (both as a share of overall savings and overall).

Based on SFA analysis, industry shows significant scope for efficiency. Although PNIEC reports relatively low expected efficiency, it states that it is a sector with 'significant opportunities'.

[23] Ministero delle Infrastrutture e dei Trasporti (2018), Piano Nazionale Integrato Per L'Energia E Il Clima, December, p.55.

The PNIEC’s targets for the transport sector are based on the expectation of significant measures and technological progress, including smart mobility, increase in freight transport by rail, car efficiency. The SFA models predict a lower efficiency gap.

7 Conclusions

The present paper provides a top-down, backward looking assessment of Italy’s energy efficiency. The results of the analysis are used to cross-check the key assumptions set out in the National Plan.

Relative to the sample, which covers 17 EU countries over the period 1996-2016, the analysis confirms the presence above-average efficiency, between 70.6% and 87.0%. Compared to 2016 consumption, amounting to around 116 Mtoe, frontier-based predictions result in significantly lower consumption levels, between 81,8 Mtoe and 106,1. The 2030 consumption target set out in PNIEC lies within this range and amounts to 103.8 Mtoe.

Disaggregate econometric analysis shows high historical performance with respect to the residential sector, although it confirms that further scope for efficiency may exist. Mixed evidence is shown for the industrial and transport sector.

To the authors’ knowledge, this is the first attempt to directly compare the efficiency assumptions in a National Action Plan using econometric benchmarking approaches. While these presents a number of limitations (e.g. it does not consider the significant evolutions in technology that may be emerge over the next decade), it represents a helpful tool to identify areas for improvement relative to existing best practice.