

Article

Planning a Regional Energy System in Association with the Creation of Energy Performance Certificates (EPCs), Statistical Analysis and Energy Efficiency Measures: An Italian Case Study

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Abstract: Directive 2002/91/EC EPBD introduced the Energy Performance Certificate (EPC) as a tool to guide the real estate market in the creation of products (buildings) with improved energy performances. The EPC's information could be useful in the determination of relevant policies and also in studying the characteristics of the building resources of the territory. This paper presents a case study related to the EPC Database of the Emilia-Romagna Region in mid-northern Italy. The case study shows a way of elaborating the EPC information in statistical analysis evaluations with aggregate data, in order to measure a territory and then direct energy policies toward energy efficiency. A statistical approach was used to define a characteristic statistical indicator index of the EPC database, and compare the energy index with the bottom-up and top-down methods, in order to identify some energy policy scenarios.

Keywords: energy systems; planning; statistical analysis; energy efficiency measure; baseline energy consumption; quantification of energy saving

Nomenclature

Symbol	Name	Description
	Sampling statistic average	Average value of index EP
(x)	Median	Numerical value separating the higher half of sampling from the lower half
	Standard deviation	Dispersion from the average value
(δ)	Confidence interval	Actual value of any other data is not known, but an interval can in most cases be defined, that has a high probability (e.g., 95% or 99%) to contain the actual value
(μ)	Expected value	Random variable is the weighted average of all possible values that this random variable can take on
Indicator		
(GFEC)	Gross final regional energy consumption	Estimated sum of total regional primary energy consumption
(GDSU)	Gross dwelling net floor surface	Estimated sum of dwelling urban units net floor surface, result of product from average urban units floor surface and number of dwellings
Index EP _{tot}	-	Energy performance index EP, primary energy consumption, for heating (EP _i) and DHW (EP _{acs}), calculated for following standard UNITS 11300
(AIEP)	Average Index EP _{AIEP} (AIEP)	Result of an average of Index EP _{tot} for each building
(AAIEP)	Aggregate Average Index EP _{AAIEP} (AAIEP)	Result of ratio between <i>total energy consumption</i> (kWh/year) and <i>gross volume</i> or <i>units floor surface</i> for residential buildings
Subscription		
(RER)		Value refers to the Region
(VER)		Value refers to Verucchio
(corr)		Value corrected by gap percentage
Average		Average value
pro		Projection value
GSU		Gross urban units net floor surface
ASU		Average urban units net floor surface
SU		Urban units net floor surface
E		Energy
DBp		DATABASE projection
DBm		DATABASE measured (by SACE)

1. Introduction

Directive 2002/91/EC (EPBD) [1] and Directive 2010/31/EU (EPBD-recast) [2] introduced the Energy Performance Certificate (EPC) in the European Union real estate market, and was adopted by each Member State in different ways [3–6]. The EPBD was endorsed in Italy by L. Decree 192/2005 [7] and M. Decree of 26 June 2009 [8], but on this matter the Italian Constitution authorized the Regions to make their own laws provided they respected the general and national norms established [9,10].

Each Region therefore adopted its own rules to define the EPC energy class ratings, to be cited on the certificate and also several EPC model certificates with their own list of certifiers (independent

experts). The Italian case study presented in this paper could be applied in other European State Members [11–16]. The Emilia-Romagna region has adopted a specific discipline on matters of EPC and created an online Sistema Accreditamento Certificazione Energetica (SACE—System for the online issuance of Certificates) that can monitor the EPC trends. SACE is an Emilia-Romagna Region online application in order to submit official EPCs, and SACE is therefore a Regional EPC Database.

The EPC was introduced as an information tool for the EU real estate market. In Italy the EPC is required in the same cases and also for the sale or lease of a building or building units. The EPC thus contains sensitive information about a building, and is useful to the owner, buyer or the real estate market. The data also increases awareness of legislators or Public Administrators who may lay down energy policies and incentives on the basis of the energy performance features of their own building estates. This paper describe how the EPC can be used as an index to measure energy performance of buildings in a region and in relation to possible scenarios for energy policies, funding and incentives.

Energy performance evaluation processes are studied through statistical research using [17,18] the *top down* [19,20] or *bottom up approach* [21]. The top down method, also used in econometric studies, is based in national statistics of energy usage, related for example, to national (or regional) gas consumption [22], as referred to territorial indicators (such as homes or buildings) issued by ISTAT (Italian National Institute of Statistics) Census [23].

These methods are used in urban planning or energy scheduling on a large scale such as for the European Union and nations or regions, to support policy makers in determining the expected changes in customs or behavior based on certain indicators and corrective systems. For energy and environmental planning, the top-down methodology refers to energy-cumulative value (aggregates) composed of the sum of energy consumption obtained from several resources: institutional research centers, energy sales agencies or energy distributors, and energy buyers. These values are only cumulative because they are personally identifiable information, and are related to privacy norms and contracts between energy sales companies and customers.

The bottom-up approach is based on a hierarchy of disaggregated levels for each energy technology. The bottom-up evaluation in energy performance of buildings and of the energy performance certificate (EPC) may relate to only one building, taken as a representative element (reference building) and multiplied by the number of similar buildings, or could otherwise be related to existing building stocks. The building stock could be aggregated according to:

- (a) Continuity, (quarters, city districts);
- (b) Building types, (high-risers, villas, block buildings, housing estates, *etc.*);
- (c) Designated use (dwellings, schools, hospitals, *etc.*);
- (d) Adopting energy evaluation methods following the standards.

The *top-down* and *bottom-up* assessments are founded on two different data sets: in the *top-down* method the data set is related to boundary investigation, while in the *bottom-up* method the data set is related to the sampling of a single territory. This paper compares both methods:

- (a) The top-down by using the aggregate data set of all regions taken from ISTAT and databases of the Emilia-Romagna Region;
- (b) The bottom-up by using the single sampling statistic based on the EPC from SACE databases, where each EPC is related to a single urban unit.

For an in-depth view of the top-down and bottom-up methods, consult [24–26].

For example, the requirements for minimum renewable energy provided by Directive 2009/28/EC [27] for each EU Member State, are defined as the ratio between the sums of energy produced from renewable energy sources and the *Gross Final Energy Consumption* (GFEC).

Furthermore, the studies on energy performance of new and existing building stocks, are based on the statistical analysis of the aggregate database. Another approach is based on energy building performance (EBP) with the evaluation of exemplificative buildings, generally residential estates or the estimation of average transmittance incidences multiplied by the total number of buildings, or other statistical data [28].

2. Aim of Paper

This paper illustrates a specific case of the Energy Performance Certificate (EPC) database of a commune in the Italian Emilia-Romagna Region. The aims of the paper are:

- (a) To describe the EPC database, in order to define the statistical indicator index applied to the case study, and therefore only urban units equipped with an EPC, to be taken as a statistical sample representative of the whole municipal territory.
- (b) To compare the energy index between the *bottom-up* method, at town level, obtained by the sum of energy performances reported in the EPC database, and the top-down method, at regional level, obtained from the aggregate value supplied by energy distributors according to national statistics.
- (c) Once the criteria have been defined, passing from bottom-up to top-down scales, and *vice versa*, with the relative *statistical error gaps*, we will compare some simulation scenarios, each of which will have a different percentage distribution of energy class of the new EPC, in order to study the changes in the statistical energy index indicator. The criterion adopted is the following: if the value (x) percentage of certified buildings compared to the total of existing buildings in the territory, with a (y) distribution of energy class rating, have determined values of the energy index indicator in cases where a scenario changes with a ($x + dx$) percentage of EPC buildings and a (z) distribution of energy class rating, what changes will come about in the energy index indicator? Can these changes be used to measure energy efficiency of the trends of energy policies or the real estate market?
- (d) To study future regional scenarios in order to schedule region energy policy decision;
- (e) To compare the EPC database results for 2010 with those for 2011 and to verify statistical data, as per point (c).

The study focuses on two scales:

1. On a *large scale*, related to the Emilia-Romagna Region, located in the center north of Italy;
2. On a *small (or local) scale*, related to Verucchio town (almost 10,000 population) located south-east of the Emilia-Romagna Region.

The databases and values used in this paper are:

1. ISTAT Database, for the number of buildings and territorial surfaces;
2. SACE Database, for EPC, energy index EP_{tot} and Energy Class of Verucchio town.

In order to clarify the interpretation of the energy index, it is important to point out that this paper does not deal with the metering methods in calculating energy performance of a single building through software and dynamic simulations of building behavior, such as the Energyplus, TRNSYS, *etc.*). These simulations are generally used for single building scales to evaluate and compare the real energy consumption of some parameters of single buildings (energy temperature, radiating mean temperature, ventilation, *etc.*) with the calculation model.

In this paper, the index EP_{tot} , in kWh/m²year of primary energy, is related to heating and Domestic Hot Water (DHW) energy consumption. The energy class rating depends on the EP_{tot} range value. The independent expert records the EPC on the database, inserting the EP_{tot} value, calculated following standards UNITS 11300 [29], which are the national application of EN ISO 13790 [30]. The calculation methodology is based on the building's energy balance.

This paper makes a statistical study of the index EP_{tot} , value taken as such from the SACE Database-using the top-down method, and the single values of the EP_{tot} index indicator aggregates. The evaluations are based solely on the EPC Database values which are obviously the tools used to acquire the energy performance values of buildings on a large-scale. Not knowing the real energy behavior of all the buildings, or their geometries or any other kind of thermo-physics parameters, the assessment of energy behavior of the buildings is like a *black box* where we adopt the EPC value registered in the SACE database by independent experts.

The aggregate energy value refers to a percentage of total buildings in Verucchio, that acts as *sampling statistics* from which we have adopted two pathways:

1. The bottom-up (EPC value) approach to top-down values: the aggregate value of Verucchio and the Region's energy index are determined from the aggregate statistical energy index of the SACE database;
2. The top-down approach to bottom-up values: the aggregate statistical energy index of the SACE is verified from the total regional energy consumption (in MWh/year). The assessment described in this paper is based on basic statistical tools such as the following data input: Territory surface size km²; dwelling apartments (by ISTAT); number of apartments per building; Apartment/km² (dwelling density); total floor net surface (m²); average floor surface SU (m²) of dwellings in pursuit of energy territorial indices to measure energy status and scenarios.

3. Energy Performance Certificate (EPC) in the Emilia-Romagna Region

Emilia-Romagna is a Region located in mid-northern Italy, which has adopted a specific law and discipline governing the implementation of the EPBD. The differences between regional provisions regard energy class ratings and accreditation of independent certification experts, without considering differences between energy evaluation calculation methodologies. The Emilia-Romagna Region has approved the DAL 156/2008 and DGR 1366/2011 [31] laws, which define minimum energy

performance requirements, energy performance certificates and independent certification experts. The DAL 156/2008 created an online procedure for the issuance of EPCs called SACE [32]. The Accredited Energy Certifiers record all the information of the buildings for which they have to issue the certificates, to be subsequently sent to the regional database, with an assigned unique identification code number.

The Emilia-Romagna Region activated the online service on 1 January 2009 for the compilation, issuance and dispatch of Certificates as per DAL156/2008 [31]. The online application can be accessed by every Independent Expert (Certifier) through their User IDs and passwords. The software SACE Sistema Accreditamento Certificatori Energetici version 2.2[©] 2010 was developed by *CERMET certification and research for quality* [33], and the new 2.2 version was made available online on 5 October 2010. The procedure provides for the registration of cadastral data, floor plans, energy performance indices, HVAC plant efficiency and instructions for the improvement of energy performance.

3.1. The SACE Database

The SACE is the regional database where all EPC data are archived. Also the energy information in EPC and in SACE are recorded by each *independent expert* and calculated following standard UNITS 11,300, for which each *independent expert* is held liable under the law's Penal Code in case of errors or false statements. In drafting the EPC evaluation for each building, the independent expert will follow standard UNITS 11,300, independently obtaining the data for input values, floor plans, and thermo-physics and inserts the results in the SACE database in order to issue the EPC. In the Emilia-Romagna region as of April 30 2011, 198,839 EPCs have been issued, of which 43,811 were related to new or retrofit urban units (22.03%). The number of EPCs for dwellings are 163,885 of which 39,393 are related to new or retrofit urban units (24.04%). Most of the EPC buildings are in the energy Class G, with an energy performance index of more than 210 kWh/m²year, (about 30.82% equal to 61,272 EPCs), whereas most of the new EPC buildings are in energy Class C, with energy performance index between 60 and 90 kWh/m²year, (about 31.90% of new or retrofit buildings are equal to 13,976 EPCs).

The number of existing dwelling units in the Emilia-Romagna region is at 1,969,235 following the ISTAT 2001 Census, and 10.10% of these as of April 2011, were certified.

So this means that the reference *sample statistics* represent 10.10% of the total regional real estate resources, and based on that representative percentage, the regional energy indicators are determined. Out of 10.10% of buildings certified with EPC, 30% are new buildings or subject to interventions, and 85% are dwelling units. Therefore, nearly 10% of urban units are certified and from the statistical viewpoint this 10% could be considered an important sample.

In order to study the SACE database we had to recall sampling error margins due to the fact that:

1. The EPCs are related to urban units and not to apartment buildings, but in the case of centralized plants where heating is not metered and therefore without the possibility of distinguishing between single units or apartment buildings, an EPC for every unit is considered (though there could be more);
2. The energy evaluation standard UNITS 11,300 used to calculate energy performance index EP, have a $\pm 5\%$ range of errors;

3. The energy evaluation refers to a standard use of a steady-state procedure (24 on 24 h) with regulation activity, and standard climate data required by standard UNI 10349 [34];
4. Last but not least, each EPC and energy index value is registered by each independent expert, and therefore may contain subjective negligence, errors or inaccuracies, though considering the expertise of the Independent Certifiers, and the EPC as a legal document, these errors could be considered marginal.

3.2. Energy Performance Scale

In Emilia-Romagna, the energy performance scale of buildings is determined on the basis of the total energy performance index EP_{tot} , expressed in kWh/m^2 year of primary energy. The EP Index includes heating and domestic Hot Water (DHW) standard consumption calculated following standard UNITS 11,300. The scales do not take into account the climate or pattern variations. Table 1 shows the energy performance scale.

Table 1. Emilia-Romagna Region: Energy class performance—DAL 156/2008 Annex 9.

EP_{tot} value	Energy class residential buildings	kWh/m^2 year	EP_{tot} value	Energy class non-residential buildings	kWh/m^3 year
-	A+	$EP_{tot} < 25$	-	-	-
$EP_{tot} > 25$	A	$EP_{tot} < 40$	-	A	$EP_{tot} < 8$
$EP_{tot} > 40$	B	$EP_{tot} < 60$	$EP_{tot} > 8$	B	$EP_{tot} < 16$
$EP_{tot} > 60$	C	$EP_{tot} < 90$	$EP_{tot} > 16$	C	$EP_{tot} < 30$
$EP_{tot} > 90$	D	$EP_{tot} < 130$	$EP_{tot} > 30$	D	$EP_{tot} < 44$
$EP_{tot} > 139$	E	$EP_{tot} < 170$	$EP_{tot} > 4$	E	$EP_{tot} < 60$
$EP_{tot} > 170$	F	$EP_{tot} < 210$	$EP_{tot} > 60$	F	$EP_{tot} < 80$
-	G	$EP_{tot} > 210$	-	G	$EP_{tot} > 80$

4. Case Study: Verucchio Town's Database

The SACE database was studied in August 2010 and regards the EPCs of the little town of Verucchio in mid-northern Italy (and in the southeastern region of Emilia-Romagna in the Rimini hinterlands).

The Commune of Verucchio measures 27 km^2 , with 1735 residential buildings, and 4509 urban dwelling units (ISTAT Census 2001).

The data analysis arouses interest because it is a large-scale top down description (aerial assessment) with the relevant marginal errors.

As of 2010, the number of EPCs was 257 for new and existing buildings, of which 200 were regarded as dwelling urban units, equal to 4.44% of all the residential buildings in Verucchio.

The percentage of EPCs issued gives an initial description of *energy indicators* of the commune's building stock, and helps to verify whether, from the statistical viewpoint, the evaluations of the data in the database convey an idea of the actual state and allow for possible simulations.

The distribution of the energy use of the certified buildings are: 77.82% of EPCs are dwelling units (E.1); 7.39% are designated as office units (E.2); 3.11% are for recreational activity, for example bars,

pubs, restaurants (E.4); 5.06% are market units and include shopping centers (E.5); 3.50% are for school activities (E.7) and only 1.95% are for production activities (E.8). Hospitals are not present.

The gross volume percentage distribution highlights how the percentages of residential buildings are only 3.56%, and 68.82% of gross volume are for shopping centers. This is because in such a small territory, the presence of one big shopping center (E.5) distorts the data.

The Energy Class distribution show that only 1.56% of EPCs belong to Energy Class A, 9.73% to Class B, and 22.18% to Class C. These rates presumably refer to new or retrofit buildings. To continue, 16.73% belong to Class D, 10.51% to Class E, 7.00% to Class F, and 13.23% to Class G.

The percentages of worse energy Classes F and G are lower than the regional value. The number of buildings without EPCs due to the lack of heating plants or for other reasons is 19.07%, which is a significant rate. The uncertified buildings are those without heating systems or those having less than 15 kW rated power.

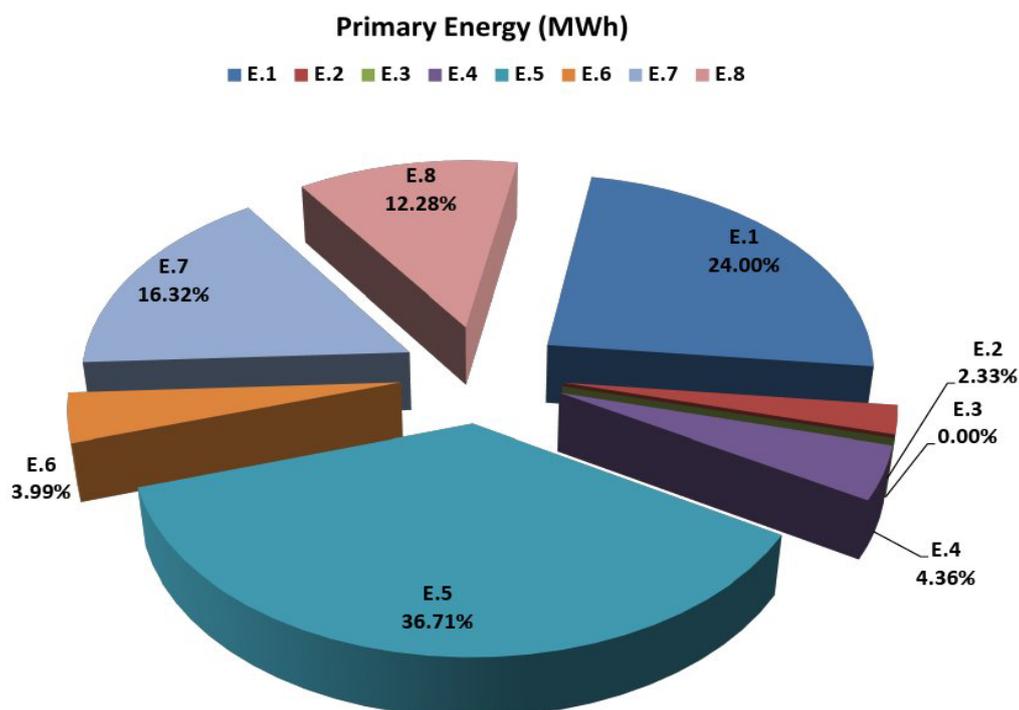
The energy index drawn from the database is called energy performance index EP_{tot} (or Index EP_{tot}) of primary energy, measured in (kWh/m² year), for dwellings, or in (kWh/m³ year) for other buildings. The energy consumption for each building, is expressed in kWh/year of primary energy, and this is achieved by multiplying the Index EP_{tot} by the gross volume and in the case of non-residential buildings, the volume is divided by 2.70 m average height presumed for dwelling units.

Table 2 shows the total sums of energy consumption for each building according to assigned usage. In this case the bigger consumption is related to shopping centers (E.5), with bigger volumes, followed by school buildings (E.7). The energy performance index of dwellings is 24%, without considering the shopping centers (which are an exception). The incidence of dwellings is 37.91% (Figure 1).

Table 2. Verucchio Energy Performance Certificate (EPC) Database–Volume, number energy and energy Index EP_{tot} .

Building typology	Volume (m ³)	Numbers	Energy (MWh)	AAI EP_{tot}	AI EP_{tot}	Gap (%) ***
E.1 Dwellings	7195.11 **	208	3,092.87	159.21 ****	114.50 ****	±28.08%
E.2 Offices	3101.94	19	300.85	35.92	35.80	±0.33%
E.3 Hospitals	0	0	0	0	0	±0.00%
E.4 Recreational activities	3997.12	8	561.71	52.05	55.87	±7.34%
E.5 Markets/shopping centers	138,561.85	13	4730.52	12.64	38.52	±204.61%
E.6 Sport buildings	7258.00	3	514.32	26.25	27.38	±4.34%
E.7 School activities	24,586.81	9	2102.70	31.67	36.48	±15.58%
E.8 Production activities	17,220.36	5	1582.05	34.03	39.50	±16.10%
TOTAL	201,921.20	257	12,885.00	31.44 *	34.49 *	±9.71%

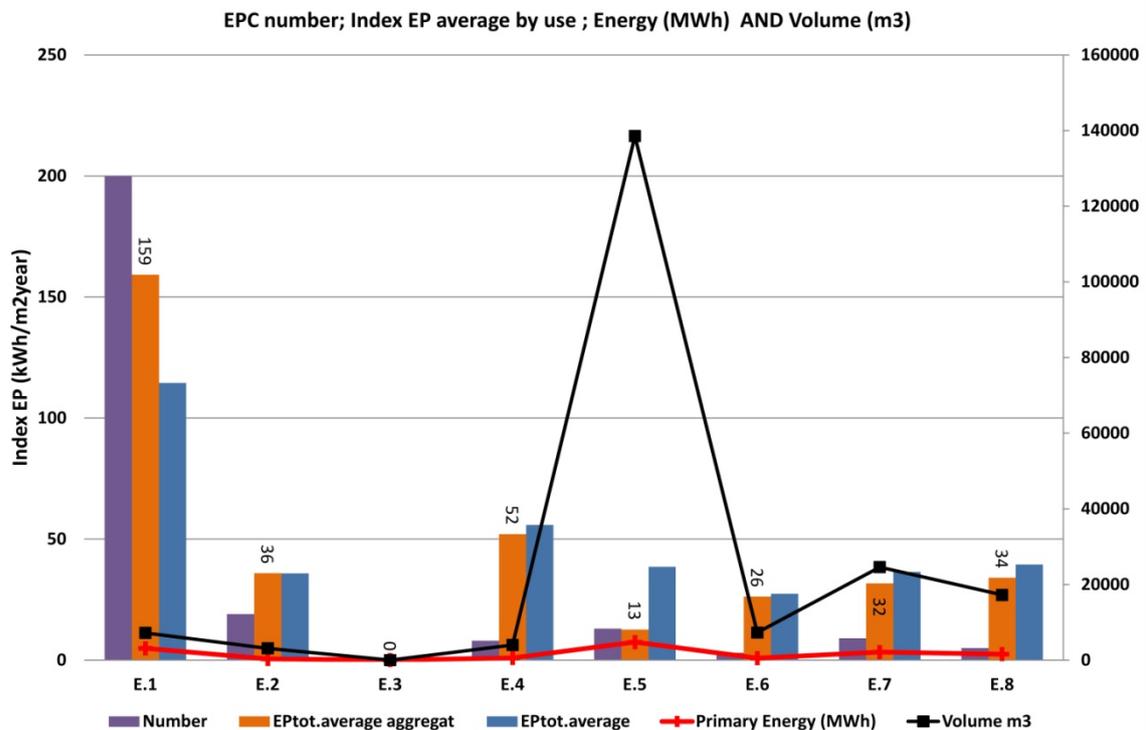
Notes: *: Average Index EP_{tot} based on value express in kWh/m³year; **: Floor Surface = 39,983.17 m²; ***: Gap between (AAI EP_{tot})/(AI EP_{tot}); ****: Values in kWh/m²year.

Figure 1. Primary energy by building energy use, excluding E:5 shopping center.

The Average Index EP_{AIEP} (AIEP) is the result of an average of Index EP for each building. On the other hand the Aggregate Average Index EP_{AAIEP} (AAIEP) results from the ratio between *total energy consumption* (kWh/year) and *gross volume* or *floor surface units* according to the assigned usage. The AIEP and AAIEP values do not concur; the gap depends on the assigned use of the building and the number of certified buildings. The greater the number of buildings (residential) or the size variables (shopping centers), the greater will be the gap between the mean value and the mean aggregate value. Figure 2 shows the energy consumption (MWh) according to the assigned use of the buildings, the number of EPC certificates issued, the EP index average (AIEP) and EP mean aggregate (AAIEP). The figure shows the non-uniformity of the relationships between the number, energy performance and consumption demand, especially in cases of buildings where the variable volume has an impact on energy consumption particularly regarding ventilation and bigger plants, as seen in the assigned uses, such as shopping centers (E.5) and schools (E.7).

Figure 2 highlights the relation between energy performance and gross volume. In fact, the incidence of the variability of the air-conditioned volume between the assigned usages, is greater compared to that of the energy. Of 257 certificates issued, 209 have an EP_{tot} index. The other 48 regard buildings without heating plants, equal to 18.86%, and also this is anomalous. Of the 209 certified, 25 have an EP index greater than 250 kWh/m² year, and the anomalous incidence is at 11.96%.

Figure 2. Comparison between number of building, AIEP_{tot}, primary energy (MWh) and gross volume.



5. Statistical Analysis of SACE Database 2010

The statistical analysis of the Database results was performed on index EP, EP_i and EP_{acs}, registered on the EPC. Furthermore, each of these indices has a confidence interval range of $\pm 5\%$. This confidence interval range depends on the Thermo-technical software certified by CTI (Comitato Termotecnico Italiano—Italian Thermo technical Committee), in addition to the expertise of the single *independent expert* in performing the calculations and gathering the input data.

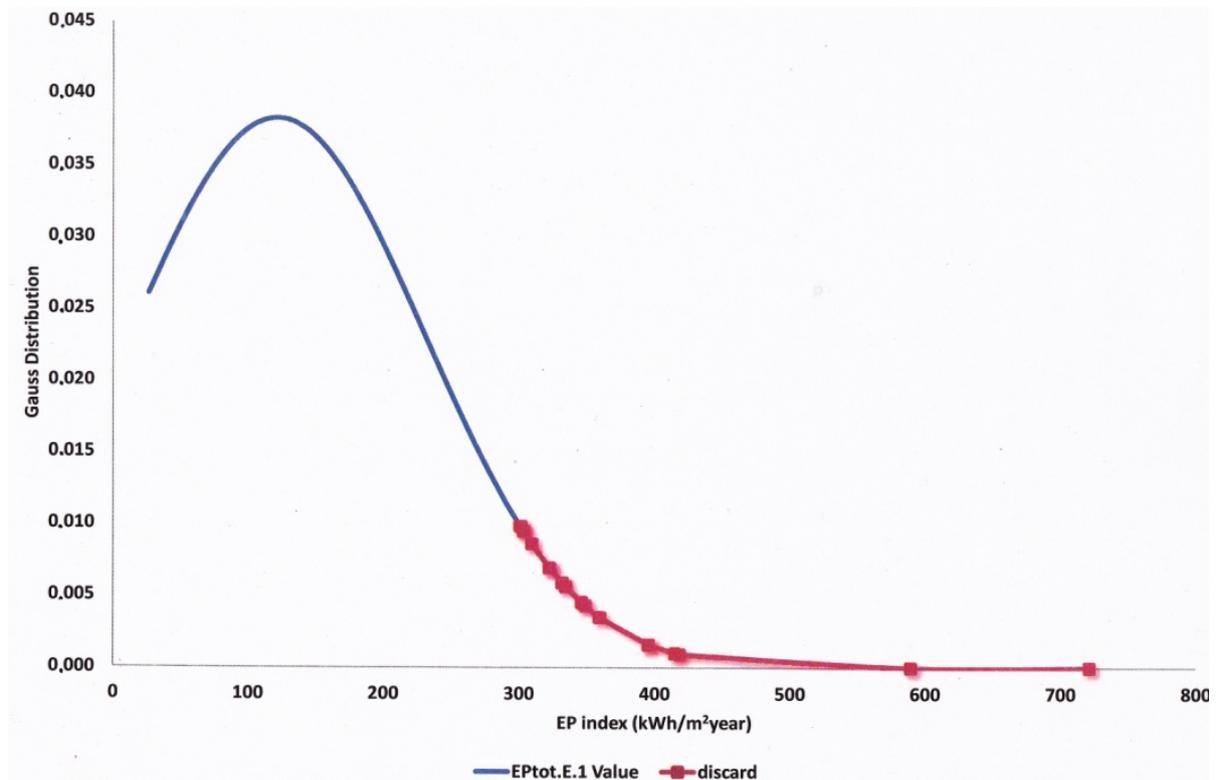
Generally speaking, we can say that the energy performance index EP for energy Class A, B or C related to new buildings, calculated with certified software, with data input taken from building plans as is, are more precise with respect to the index values higher than those of the existing Class E, F or G buildings.

The *sampling statistic average* is described as the mean value of the index EP of 257 EPCs, of which 208 EPCs are regarded as residential buildings (77.82%). The *sampling statistic average* for 208 dwellings is 114.50 kWh/m² year; this value is a *territorial energy indicator*. In this case the *median* value of the EP is 87.79 kWh/m² year. The comparison between *statistic average* and *median* shows a high impact of the greater index EP over the average value. If we excluded EPCs without the EP index due to the lack of heating plants, the number of samples would fall to 154 EPCs (77% of total dwellings) where:

1. The *territorial energy marker* is 149.30 kWh/m² year;
2. The *median* is 121.86 kWh/m² year;
3. The *standard deviation* (δ) is 108.72 kWh/m² year, with more unevenness referring to average value of EP_{tot} 149.30 kWh/m² year.

The Gaussian function of residential buildings with EPCs show a large normal distribution of values (Figure 3).

Figure 3. Gauss function of dwelling EPC.



6. Comparison between Bottom-Up and Top-Down Evaluations and Scenario Simulation

The database analysis of the EPCs issued for the single commune of Verucchio must be compared with energy and settlement data at regional level. This is a matter of comparing the top-down (regional data) with the bottom-up (EPC data) evaluations.

The first step is to verify whether the Verucchio sample can act as a representative model. The extent of the Verucchio commune represents 0.12% of the total regional territory, and 0.18% of the total regional dwelling units.

In the Regional Energy Actual Program 2011–2013, the energy consumption related to residential buildings is 2851 ktoe (based on ENEA [35] and REA 2007 [36]), equal to 33,150.79 GWh/year of primary energy. The energy incidence for Verucchio is 58,297.35 MWh/year (0.18% of regional dwellings).

The sample of 208 certificates is at 6.01%, with an energy demand percentage attributable to the sample, equal to 3501.55 MWh/year, to compare with the bottom-up value. Thus a top-down value of 501.55 MWh/year must be compared with the bottom-up value gathered from the regional database (*bottom up*—Table 3) equivalent to 3,092.87 MWh/year. Therefore, there is a gap between top-down and bottom-up values, of 11.67%. Firstly, the database value could be compared with the regional value with just an 11.67% gap.

The regional index $EP_{AAIEP, RER}$ of 175.31 kWh/m² year, is the result of the ratio between (GFEC) *gross final regional energy consumption* and (GDSU) *gross dwelling net floor surface*. This value

must be compared with the sampling statistics average of 114.50 kWh/m²year (Table 3) with a gap of 34.06%. In this case, the comparison between top-down (*top-down*—Table 4 and Regional indexes value in Table 5) and bottom-up values shows a great confidence interval.

Table 3. Statistical data. SACE database 2010.

EP indexes	EP _{tot}	EP _{inv}	EP _{acs}
Dwellings including those with EPC with Energy Class not determinable (ND)			
Number of simple samples	208	208	208
Index EP _{AI EP} —Sampling statistic average	114.50	103.45	11.05
Index EP—Sampling Median	87.79	72.54	5.83
Index EP—Standard deviation (δ)	114.72	109.94	12.55
Dwellings only with EPC with Energy Class			
Number of simple samples	154	154	154
Index EP _{AI EP} —Sampling statistic average	149.30	134.65	14.65
Index EP—Sampling Median	121.86	105.65	16.49
Index EP—Standard deviation (δ)	108.72	107.06	12.17

Table 4. Statistical data of Emilia-Romagna Region and Verucchio town.

EP indexes	[RER] Emilia Romagna	[VER] Verucchio	Gap, ratio between [VER]/[RER]
Territory surface size km ² (by ISTAT)	22,123.09	27.07	0.12%
Dwelling average floor surface SU—m ² (by ISTAT)	96.95	104.06	107.33%
Residential buildings (by ISTAT)	735,066	1735	0.24%
Apartments (by ISTAT)	1,969,235	3463	0.18%
Number of apartments per building	2.68	2.00	-
Total floor net surface—m ²	190,917,333.25 ^a	360,359.78 ^b	-
MWh/km ²	1,498.47	2,153.58	-
kWh/m ² of territory	1.50	2.15	-
Apartments/km ² (Dwelling density)	89.01	127.93	-

Notes: ^a: Gross RER urban units net surface $GSU_{RER} = \text{number of RER buildings} * SU_{\text{average}}$; ^b: Gross VER urban units net surface $GSU_{VER} = \text{number of VER building} * SU_{\text{average}}$.

Table 5. Verucchio: ISTAT Data, SACE Database and simulation data.

Indicators	Number of building	Incidence Database/ISTAT
Urban units by ISTAT	3,463	-
Urban units by SACE Database	257	7.42%
Residential urban units by SACE Database	208	6.01%
Residential urban units by SACE Database exclude EPC without energy rating	154	4.45%
New residential urban units simulation	238	6.87%
Floor average surface for dwelling—simulation (m ² /apartment)	80	-
New floor surface—simulation (m ²)	2400	-

The Verucchio town index EP_{AAI EP, VER} of 161.78 kWh/m² year, is the result of the ratio between gross final Verucchio energy consumption (58.297.36 MWh/year) and gross dwelling net floor surface

(3463 dwellings for 104.06 m² average unit floor surface). If we compare the same bottom-up value with these top-down values, the confidence interval is at 29.22%. The comparison between top-down and bottom-up EP_{AAIEP} value shows a high confidence interval gap ($\approx 30\%$). This may be due to the ratio numerator and denominator and the uncertainty of the total gross floor surface.

As matter of a fact, the value of the total floor surface of the units of the sample of 208 certificates, with average floor surface of 104.06 m² \times 208 samples is 21,644.48 m² whereas the database value is 19,416.81. There is a gap of 10.29% (10,416.81 m²), in value of the useful surface area of the Database projection. The comparison between index EP_{AIEP,DB} 159.29 kWh/m²year of Database and EP_{AAIEP,VER} 161.78 for the entire Verucchio town (see below) is at 1.54%. In the same way if we proceeded inversely, from index EP to energy consumption (Table 6) the steps are:

1. EP_{AIEP} 11,450 kWh/m²year (Table 3);
2. EP_{AIEP,corr} 11,626 kWh/m²year corrected with 1.54% confidence intervals;
3. The total energy consumption of Verucchio is 41,895.55 MWh/year, the result of the multiplication of total gross floor surface (19,416.81 m²) by the number of dwellings (3463) and index EP_{AIEP,vorr} 116.26 kWh/m² year.

Table 6. Top-down to bottom-up evaluation.

Units	[RER] Emilia Romagna	[VER] Verucchio	[DBp] DATABASE projection	[DBm] DATABASE measured	Gap DBm/DBp
-	\Rightarrow	\Rightarrow	\Rightarrow	-	-
[E] Energy	2851 (ktoe) ^a	-	-	-	-
-	119,342,860 (GJ)	-	-	-	-
[E] Energy (MWh)	33,150,794.44	58,297.36 ^b	3501.55 ^c	3092.87	11.67%
[GSU] Floor units surface	190,917,333.25	360,359.78	21,644.48 ^c	19,416.81 ^d	10.29%
Index EP _{AAIEP}	173.64 ^e	161.78 ^e	161.78 ^e	159.29 ^e	1.54%
-	Gap [VER]/[RER]:6.83%		-	-	-
	Index EP _{AIEP}			114.50 ^d	-
Correction factor (by 6.01% building with EPC)				EP _{AIEP} /EP _{AAIEP} :	-
				28.12%	
Correct EP _{AAIEP,corr}	124.20 ^f	116.26 ^g	116.26 ^g	114.50 ^d	-

Notes: ^a: according to Regional Energy Plan 2011–2013; ^b: [E_{VER}] = [E_{RER}] \times 0.18% incidence of Verucchio apartment with respect to Region; ^c: [E_{DBp}] = [E_{Ve}] \times 6.01% incidence of SACE Database numero respect to Verucchio; ^d: [DBm] value refer to SACE database (average index EP); ^e: EP_{medio} = [E]/SU; ^f: EP_{average,sampling,corr} = EP_{average,sampling,VE} / (1 + 6.83%); ^g: EP_{average,sampling,corr} = EP_{average,sampling,DBm} / (1 + 1.54%).

The gap between 41,895.55 MWh/year and the Verucchio total energy consumption of 58,297.36 MWh/year, is ± 28.13 coinciding with the same gap value between EP_{AAIEP} and EP_{AIEP}.

The index EP_{AAIEP} over 154 EPCs of the database with values excluding those certified with ND (Not Determinable) is equal to index EP_{average,sampling} at 149.30 kWh/m² year, with a gap of 23.31% compared to the mean sample value including the NDs at 6.27% compared to index EP_{average} value of 159.29 kWh/m² year. Table 7 shows that the path followed in gathering the database values (bottom-up) generally had a reduced error margin.

Table 7. Bottom-up to top-down evaluation.

Indicator units	[RER] Emilia Romagna	[Ve] Verucchio	[DBp] database projection	[DBm] database measured
[E] Energy (MWh)	33,150,794.44	58,297.36	3501.55	3092.87
[SU] Floor Units Surface (m ²)	190,917,333.25	360,359.78	21,644.48	19,416.81
Index EP _{AIIEP}	173.64	161.78	161.78	159.29
Index EP _{AAIEP}	-	-	-	114.50
Correction factor (by 6,01% building with EPC)	-	-	-	EP _{AIIEP} /EP _{AAIEP} = 28.12%
-	←	←	←	-
[E _{pro}] Energy consumption–projection (MWh) da EP _{AAIEP} DBm	23,712,686.12 ^c	41,895.55 ^b	-	2,223.22 ^a
[E _{pro}] Energy consumption–projection (MWh) with correction factor	32,988,232.89 ^g	58,283.58 ^f	3,500.72 ^e	3,092.87 ^d
Gap between tra [E] and [E _{pro,cor}]	0.49% ^h	0.02% ^h	0.02% ^h	0.00% ^h
[E _{pro}] Energy consumption–simple proposition projection (MWh)	29,281,672.38 ^l	51,493.31 ⁽ⁱ⁾	-	3092.87

Notes: ^a: [E_{pro}] = EP_{AAIEP} × [SU_{DBm}]; ^b: [E_{pro}] = EP_{AAIEP} (116,26) × ASU [VER]; ^c: [E_{pro}] EP_{AAIEP} (124,20) × ASU [RER]; ^d: [E_{pro,cor,DBm}] = [E_{ric,DBm}]/(1 – 28.12%); ^e: [E_{pro,cor,DBp}] = [E_{ric,DBp}]/(1 – 28.12%); ^f: [E_{pro,cor,Ve}] = [E_{ric,Ve}]/(1 – 28.12%); ^g: [E_{pro,cor,RER}]/(1 – 28.12%); ^h: Gap = [E]/[E_{ric,cor}]; ⁱ: [E_{pro,Ve}] = EDBm/6.87% (Incidence Database/ISTAT Dwelling urban units by SACE Database); ^l: [E_{pro,RER}] = [E_{pro,Ve}]/0.18% (Dwelling apartment (by ISTAT) Gap, ratio between [RER]/[VER]).

Table 6, from top-down to bottom-up, shows the path proceeding from the Regional value, accepted data equal to 33,150.80 GWh, and the projection of this value related to the percentage of buildings with EPCs in Verucchio, equal to 3501.55 MWh. The same value measured from the SACE Database is 3092.87 MWh, with a 11.67% error-gap, whereas the 1.54% error gap refers to the EP_{AAIEP} index. The index EP_{tot} for each building is the ratio between primary energy consumption in a year, and the surface area, expressed in kWh/m² year. The EP_{AAIEP} Index considers the energy performance index EP_{tot} as if it referred to a single large building with a primary energy consumption and floor surface area composed of the sum of the total demands and floor surfaces of the certified buildings. The ratio between index EP_{AIIEP} and EP_{AAIEP} is 28.12%. This value represents the ratio between index EP_{tot} taken from the average value of EP_{tot} for each building, compared to the value of index EP_{tot} data taken as the sum of all the buildings as one. This gap shows how the average value of EP_{tot} of the buildings is better than the sum of all the demands together.

Table 7 (from bottom-up to top-down) shows the path proceeding from the value measured (from the SACE Database) equal to 3092.87 MWh, and the projection of that value related to the value of the entire Emilia-Romagna Region (projection). This value, equal to 29,281.67 GWh must be corrected by 28.12%, a ratio between the EP_{AIIEP} and EP_{AAIEP} indices. Therefore the projection of the Regional value of consumption is equal to 32,988.23 GWh, with a gap of 0.49%.

The next data elaboration step is to simulate five scenarios to verify which statistical analysis values could be used to measure real estate energy savings and characteristics.

The five scenarios described in Table 8 are as follows:

scenario 1: new EPCs having the same energy class percentage distribution as the existing database;
 scenario 2: casual subdivision of energy classes;
 scenario 3: equal energy class distribution;
 scenario 4: worst situation, all new EPCs belonging to energy classes E, F, G or ND;
 scenario 4: best situation, all new EPCs belonging to energy classes A, B or C.

Table 8. Scenarios sharing new EPC divided by number of EPCs and energy class, in percentage.

Scenario	Class A	Class B	Class C	Class D	Class E	Class F	Class G	ND	Total
Scenario 1	3.33%	10.00%	20.00%	16.67%	6.67%	10.00%	13.33%	20.00%	100%
Scenario 2	10.00%	13.33%	20.00%	13.33%	6.67%	10.00%	13.33%	13.33%	100%
Scenario 3	13.33%	13.33%	13.33%	13.33%	13.33%	13.33%	13.33%	13.33%	100%
Scenario 4	0.00%	0.00%	0.00%	0.00%	26.67%	26.67%	26.67%	20.00%	100%
Scenario 5	40.00%	40.00%	20.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100%
Index EP kWh/m ² year	30	50	70	110	150	180	250	0	-

The statistical analysis value for each scenario is shown in Tables 9 and 10.

Table 9. Statistical analysis indicator and scenarios.

letters	Indicator units	Actual data	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
(A)	n.° of total building in Verucchio by ISTAT Census	3463	3463	3463	3463	3463	3463
(B)	Number of EPC sampling	208	230	230	230	230	230
(C) = A/B	Sampling incidence (A/B)	5.78%	6.64%	6.64%	6.64%	6.64%	6.64%
(D)	Sampling increase percentage	-	13.04%	13.04%	13.04%	13.04%	13.04%
(E)	Index EP _{AIEP} Sampling statistic average (x)	121.31	121.65	120.61	121.16	128.76	113.33
(F)	Index EP Median	87.61	88.33	87.61	88.33	98.42	75.88
(G)	Standard deviation (δ)	106.23	103.07	103.08	102.81	103.81	103.23
(H)	Expected value (μ)	213.88	208.69	208.39	208.06	212.19	206.96

The sampling statistic average value is very variable: increased in the worst case scenario 4 and decreased in the best case scenario 5. In other scenarios this value has a variability of about 1.00%, and is insignificant. The *median* value has the same trend as the *sampling statistic average*, with more differences between the worst and best case scenarios.

This distribution is shown in Table 11 and the confidence interval in Table 12. It evidences how the best case scenario 5 has a greater number of EPCs (63.03%) with a *sampling statistic average* EP index smaller than EP_{AIEP}, whereas in the worst case scenario 4, it is smaller, at 59.48%. As confirmation one can note how the same difference is found in the median value.

Table 10. Energy and statistical indicator for each of the scenarios.

Indicator units	[RER] Emilia Romagna	[VER] Verucchio	[DBp] database projection	[DBm] database measured
[E] Energy (MWh)	33,150,794.44	58,297.36	3501.55	3092.87 ^c
[GSU] Gross units floor surface (m ²) estimation	190,917,333.25	360,359.78	21,644.48	19,416.81
[E _{pro}] Energy—Projection (MWh)	31,072,054.01	54,641.79	3281.98	2898.93
[GSU _{pro}] Total units floor surface (m ²) estimation	211,919,560.42 ^b	400,001.85 ^b	24,025.52 ^b	21,816.81 ^a 10.29% ^d
EP _{AAIEP} [Scenario-1]	-	-	-	121.65 ^e
Index EP _{AAIEP,pro}	163.20 ^f	152.05 ^f	173.98 ^f	169.24 ^f
[E _{pro,DBm}] Energy database projection	-	-	-	2362.05 ^g
[E _{pro,corr}] Energy projection correct	34,585,998.12 ^h	60,821.24 ⁱ	4180.03 ^m	3692.17 ^l
Difference (MWh)	1,435,203.68 ⁿ	2523.88 ⁿ	678.49 ⁿ	
Gap (%)	4.15%	4.15%	16.23% ^o	
EP _{AAIEP} [Scenario-2]	-	-	-	120.61
Index EP _{AAIEP,pro}	161.81	150.75	172.50	167.79
[E _{pro,DBm}] Energy database projection	-	-	-	2,631.33
[E _{pro,corr}] Energy projection correct	34,290,318.40	60,301.27	4,144.30	3660.60
Difference (MWh)	1,139,523.96	2,003.91	642.75	-
Gap (%)	+3.32%	+3.32%	+15.51%	-
EP _{AAIEP} [Scenario-3]	-	-	-	121.16
Index EP _{AAIEP,pro}	161.81	151.44	173.28	168.55
[E _{pro,DBm}] Energy database projection	-	-	-	2643.31
[E _{pro,corr}] Energy projection correct	34,290,687.48	60,576.25	4163.20	3677.30
Difference (MWh)	1,295,893.04	2,278.89	661.65	-
Gap (%)	+3.76%	+3.76%	+15.89%	-
EP _{AAIEP} [Scenario-4]	-	-	-	128.75
Index EP _{AAIEP,pro}	172.73	151.44	184.14	159.41
[E _{pro,DBm}] Energy database projection	-	-	-	2499.91
[E _{pro,corr}] Energy projection correct	36,604,580.83	60,576.25	4,163.20	3477.79
Difference (MWh)	3,453,786.39	2,278.89	661.65	-
Gap (%)	+9.44%	+9.44%	+15.89%	-
EP _{AAIEP} [Scenario-5]	-	-	-	113.33
Index EP _{AAIEP,pro}	152.04	141.65	162.08	157.66
[E _{pro,DBm}] Energy database projection	-	-	-	2472.50
[E _{pro,corr}] Energy projection correct	32,220,560.35	56,661.50	3894.15	3439.65
Difference (MWh)	-930,234.09	-1,635.86	392.60	-
Gap (%)	-2.89%	-2.89%	+10.08%	-

Notes: ^a: The *gross units floor surface project* [GSU_{pro}] include the additional surface for the new 30 EPC supposedly 80 m² each. Therefore the increase of *total units floor surface project* is 2400 m² [SU_{pro}] = [SU] + 2400 = 21.81681 m² of sampling, equal to an increase of 11.00%; ^b: [SU_{pro}] = [SU] + 11%; ^c: Ratio:[DBp/DBm]; ^d: Ratio SU DBm/DBp; ^e: Value from Table 11; ^f: EP_{medio,pro} = [E_{pro}]/[SU_{pro}]; ^g: [E_{DBm}] = EP_{media,camp} * [SU_{pro}]; ^h: [E_{pro,corr}] = [E_{pro,corr,Ve}]/0.18%; ⁱ: [E_{pro,corr,Ve}] = [E_{pro,corr,DBp}]/6.01%; ^l: Correct value [EP_{pro,corr}] = [E_{DBm}]/(1 - 28.12%); ^m: [E_{pro,corr,DBm}] = [E_{pro,corr,DBm}]/(1 - 11.67%); ⁿ: Gap between [E_{pro,corr}] and [E]; ^o: Ratio between [E_{pro,corr}]/[E].

Table 11. Statistical analysis indicator and scenarios: percentage increase.

Letters	Indicator units	Actual data	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
(E)	Index EP _{AAIEP} Sampling statistic average (x)	0.00%	0.28%	−0.58%	−0.13%	6.14%	−6.58%
(F)	Index EP Median	0.00%	0.82%	0.00%	0.82%	12.35%	−13.39%
(G)	Standard deviation (δ)	0.00%	−2.97%	−2.97%	−3.22%	−2.27%	−2.82%
(H)	Expected mean value (μ)	0.00%	−3.24%	−2.40%	−3.09%	−7.93%	4.02%

Table 12. Scenarios confidence interval of statistical index.

Sampling statistic average (x)	Actual data	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Confidence interval (+)	133.67	132.83	131.79	132.31	140.02	124.53
Confidence interval (−)	108.96	110.47	109.43	110.01	117.50	102.14
Gap	24.71	22.36	22.36	22.30	22.52	22.39

7. Results of the SACE Database as of 2011 and Verification

On 20 June 2011 there was another survey on the SACE Database for Verucchio to check the progress of the EPCs.

7.1. SACE Database 2011: Statistical Analysis

The comparison between the 2010 and 2011 SACE databases revealed some surprises. Firstly, the EPC trends saw a bigger increase of +40.09% (Table 13). This growth may depend on the obligation to issue EPCs when apartments are rented out and not only when sold or purchased, thus the increase of buildings with bad energy performances.

Table 13. Verucchio EPC Database—Gab between 2010 and 2011 value of Volume, number energy and Index EP_{tot}.

Building typology	Volume (m ³)	Numbers	Energy (MWh)	AAI EP _{tot}	AI EP _{tot}
E.1 Dwellings	48.59%	41.24%	55.41%	−10.90%	34.00%
E.2 Offices	7.37%	5.00%	4.04%	−2.72%	−3.23%
E.3 Hospitals	-	-	-	-	-
E.4 Recreational activities	29.41%	33.33%	40.74%	17.86%	9.87%
E.5 Markets/shopping centers	0.84%	35.00%	2.96%	71.35%	−198.14%
E.6 Sport building	0.00%	0.00%	0.00%	4.13%	−4.30%
E.7 School activities	0.00%	0.00%	0.00%	13.19%	−15.19%
E.8 Production activities	21.85%	54.55%	37.75%	24.12%	7.54%
TOTAL	7.14%	40.09%	29.33%	17.35%	−0.52%

Table 14 shows the percentage distribution of scenario 4 as being similar to that of the 2011 SACE Database.

In comparing Table 6 (from *top-down* to *bottom-up* values) we have a more accurate view of the detailed sampling statistics, and the gap between the values of index EP_{AAIEP} and Index EP_{AIIEP}

decreases from 28.12% to 18.95%. Thus the average value of index EP_{tot} calculated with the top-down methodology is more accurate. In comparing Table 7 (from *bottom-up* to *top-down* value) we observe how the regional energy consumption projections are more accurate if we use the index of energy consumption projection [E_{pro}] instead of the index of energy consumption projection with the correction factor [$E_{pro,corr}$].

Table 14. Energy Class distribution confrontation between database 2010, Scenario 4 and database 2011.

Database and scenarios	Class A	Class B	Class C	Class D	Class E	Class F	Class G	ND	Total
Database 2010	4	25	57	43	27	18	34	49	257
Scenario 4 increase	0	0	0	0	8	8	8	6	30
Scenario 4	4	25	57	43	35	26	42	55	287
Database 2011	4	29	82	77	50	40	87	60	429
Scenario 4 percentage distribution	1.39%	8.71%	19.86%	14.98%	12.20%	9.06%	14.63%	19.16%	100.00%
Database 2011 percentage distribution	0.93%	6.76%	19.11%	17.95%	11.66%	9.32%	20.28%	13.99%	100.00%
[A] Gap 2010/Scenario 4	0.00%	0.00%	0.00%	0.00%	22.86%	30.77%	19.05%	10.91%	-
[B] Gap 2010/2011	0.00%	13.79%	30.49%	44.16%	46.00%	55.00%	60.92%	18.33%	-
[C] Gap Scenario 4/2011	0.00%	13.79%	30.49%	44.16%	30.00%	35.00%	51.72%	8.33%	-
Gap [A]/[B]	0.00%	0.00%	0.00%	0.00%	49.69%	55.94%	31.27%	49.40%	-

The comparison also shows the increase by 7% of the certified volume, compared to the increase of 48.59% only for the residential units, whereas from the viewpoint of energy consumption (MWh), there was an increase of 29.33%, with an increase of 55.41% for dwellings. This confirms a lower incidence of energy performance of dwellings in the total buildings, but not in energy consumption. The Average Index EP_{AIEP} ($AIEP_{tot}$) shows an increase in cases of dwellings (+34.00%) and a smaller reduction for total buildings (−0.52%).

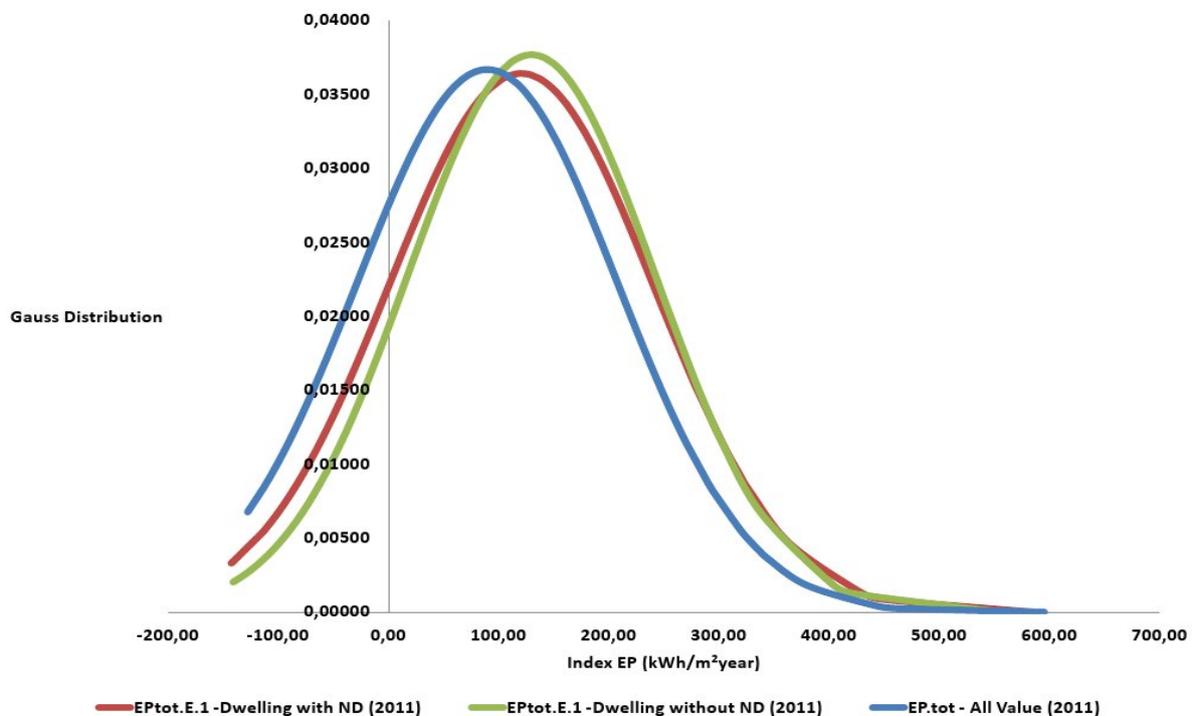
The Aggregate Average Index EP_{AAIEP} ($AAIEP$) showed a decrease in cases of dwellings (−10.90%) and an increase for total buildings (+17.35%). This means that dwellings register an increase of total energy performance ($AAIEP_{tot}$) but not for single buildings ($AIEP_{tot}$), or rather some dwellings have such a high single index EP_{tot} as to alter the average index EP_{tot} value.

On the other hand, compared to the total buildings the single index EPs (expressed in kWh/m³year) remain unchanged, but the $AAIEP$ index worsens, and proves the impact of the heating of buildings with big volumes. Among the simulation scenarios in Table 9, the final result resembles that of Scenario 4: the worst case. Table 15 shows how, compared to the gap foreseen for 2010/Scenario 4, the real gap for 2010/2011 for classes E, F, G and ND has an increased percentage, ranging between 31.27% and 55.94%. Of the $EP_{AAIEP,pro}$ index indicators the situation of Scenario 4 is the worst, due to the fact that the increase is caused by the obligation to issue the EPCs in cases of lease and these refer above all to the existing buildings. The results confirm the fact that specific energy policies have not been adopted.

Table 15. Statistical data for database 2011 and gap between 2010 and 2011 database.

Dwelling enclosed EPC with energy class not determinable (ND)	EP_{tot}		EP_{inv}		EP_{acs}	
	value	Gap 2010/2011	value	Gap 2010/2011	value	Gap 2010/2011
Dwelling including those with EPC with Energy Class not determinable (ND)						
Number of simple samples	346	+39.88%	346	+39.88%	346	+39.88%
Index EP_{AIEP} —Sampling statistic average	140.61	+18.57%	133.95	+22.77%	6.66	−65.92%
Index EP—Sampling Median	120.50	+27.15%	105.51	+31.25%	0.00	-
Index EP—Standard deviation (δ)	120.06	+4.45%	118.80	+7.46%	11.61	−8.10%
Dwelling only EPC with Energy Class						
Number of simple samples	291	+47.08%	291	+47.08%	291	+47.08%
Index EP_{AIEP} —Sampling statistic average	167.57	+10.90%	159.46	+15.56%	8.11	−80.64%
Index EP—Sampling Median	129.88	+6.17%	124.94	+15.44%	0.00	-
Index EP—Standard deviation (δ)	112.08	+3.00%	112.62	+4.94%	11.61	−4.82%

Figure 4 shows the Gaussian curve for Database 2010 and 2011, evidencing that the curve for EPC dwellings without ND is higher and narrower compared to the total value, reducing the error of single EPCs.

Figure 4. Indexes EP 2010 and 2011 comparison of Gaussian distribution.

7.2. Comparison between Bottom-Up and Top-Down Evaluation for Database 2011

The comparison between bottom-up and top-down evaluation for database 2011 (Table 16) reports an increase of the incidence of urban units and dwellings (with EPC values). The incidence of urban

units with EPC with respect to the total number in Verucchio (sampling) increased from 7.42% to 12.39% for all buildings, and from 4.45% at 8.40% for dwelling units with EPC values.

The incidence of buildings with EPCs is at 12.39% of the total and 8.40% for dwellings, and these values are representative of the single commune. On the other hand, Verucchio has a smaller incidence compared to the Emilia-Romagna Region: 0.12% of the territory and 0.18% of dwelling apartments. The reduction of this representative model is reflected in the error between bottom-up and top-down methods.

Table 17 reports the evaluation of the Top-down to Bottom-up method. The energy consumption measured by the SACE Database (DBm = 6936.70 MWh) is greater than the projection (DBp = 5824.69 MWh) and the gap DBm/DBp is -19.09%. The energy consumption projection from top-down to bottom-up value is underestimated with respect to the real measurements performed by the Database 2011. This error depended on the fact that the GSU projection was lower than the GSU measured (-11.05%), and also because the average urban units surface of Verucchio is estimated at 104.96 m², but the measured value is 115.56 m². Therefore, the Database projection value [DBm] is lower than the Database measured [DBm]. Therefore to compare with Table 7, the gap between the 2010 and 2011 index EP_{AIEP} is smaller than the index EP_{AAIEP,corr}, corrected by ratio coefficient: EP_{AIEP}/EP_{AAIEP}. (18.95%).

Table 16. Verucchio: ISTAT Data and SACE Database 2011.

Urban units	Number of buildings	Incidence database/ISTAT
Urban units by ISTAT	3,463	-
Urban units by SACE Database	429	12.39%
Residential urban units by SACE Database	346	9.99%
Residential urban units by SACE Database exclude EPC without energy rating	291	8.40%

Table 17. Database 2011: top-down to bottom-up evaluation.

Indexes	[RER] Emilia Romagna	[VER] Verucchio	[DBp] database projection	[DBm] database measured	Gap DBm/DBp ^a
Flow chart	⇒	⇒	⇒	-	-
[E] Energy (MWh)	33,150,794.44	58,297.36 ^b	5824.69 ^c	6936.70	19.09%
[GSU] Floor units surface	190,917,333.25	360,359.78	36,004.76 ^c	39,983.17 ^d	-11.05%
Index EP _{AAIEP}	173.64 ^c	161.78 ^c	161.78 ^c	173.49 ^c	-7.24%
-	Gap [VER]/[RER]: 6.83%		-	-	-
Index EP _{AIEP}				140.61 ^d	-
Correction factor (by 8.40% building with EPC)				EP _{AIEP} /EP _{AAIEP} : 18.95%	-
-	⇐	⇐	⇐	-	-
Correct EP _{AAIEP,corr}	161.10 ^f	150.80 ^g	150.80 ^g	140.61 ^d	-

Notes: ^a: by Regional Energy Plan 2011–2013; ^b: [E_{VER}] = [E_{RER}] × 0.18% incidence of Verucchio apartment respect to Region; ^c: [E_{DBp}] = [E_{Ve}] × 9.99% incidence of SACE Database number respect to Verucchio; ^d: [DBm] value refer to SACE database (average index EP); ^e: EP_{medio} = [E]/SU; ^f: EP_{average,sampling,corr} = EP_{average,sampling,VE}/(1 + 6.83%); ^g: EP_{average,sampling,corr} = EP_{average,sampling,DBm}/(1 + 7.24%).

Table 18 gives the evaluation from the Bottom-up to Top-down method. In this case the energy consumption projection $[E_{\text{pro}}]$ has a gap of +7.22%. The result of the projection of energy consumption from Database values measured (6,983.70 MWh), is higher than the Regional Energy Actual Program 2011–2013: $E_{\text{pro,corr}} = 37,947,956.37$ (MWh) in comparison to the Regional value $E = 33,150,794.44$ (MWh) with a gap of 14.47%. The same error occurs also when adopting a simple proposition compared to the incidence of the sample and the territory (19.09%). The *error gap* (7.22% or 19.09%) projected for both assessments cannot depend on the difference between the estimated GSU and the real one, given that the Database project 2011 has a gap of –11.05% whereas for Database 2010 the gap is at 10.29% (Table 7). In reality, what was called the *error gap* (7.22% or –19.09%) projected must be considered as an increase of energy consumption $[E]$, from 33,150 GWh to 37.947 GWh or 39,379 GWh, during the years 2007–2011. The lack of feedback from the current consumption at 2011 has been verified.

Table 18. Database 2011: bottom-up to top-down evaluation.

Indexes	[RER] Emilia Romagna	[Ve] Verucchio	[DBp] database projection	[DBm] database measured
[E] Energy (MWh)	33,150,794.44	58,297.36	3501.55	3092.87
[SU] Floor Units Surface (m ²)	190,917,333.25	360,359.78	36,004.76	39,983.17
Index EP _{AAIEP}	173.64	161.78	161.78	173.49
Index EP _{AAIEP}				140.61
Correction factor (by 8.40% building with EPC)				EP _{AAIEP} /EP _{AAIEP} = 18.95%
-	←	←	←	
[E _{pro}] Energy consumption— projection (MWh) from EP _{AAIEP} DBm	30,756,549.85 ^c	54,340.64 ^b		5622.15 ^a
-	Gap between [E]/[E _{pro}]: 7.22%			
[E _{pro,corr}] Energy consumption— projection (MWh) with corr. factor	37,947,956.37 ^g	67,046.42 ^f	6698.83 ^e	6983.70 ^d
Gap between [E]/[E _{pro,corr}]	–14.47% ^h	–14.47% ^h		–15.01% ^h
-	←	←	←	
[E _{pro,simple-prop}] Energy consumption— simple proposition (MWh)	39,479,763.78 ^l	69,427.17 ⁱ	-	6936.70
-	Gap between [E]/[E _{pro,simple-prop}]: –19.09%			

Notes: ^a: $[E_{\text{pro}}] = EP_{\text{AAIEP}} \times [SU_{\text{DBm}}]$; ^b: $[E_{\text{pro}}] = EP_{\text{AAIEP}} (116,26) \times ASU [VER]$; ^c: $[E_{\text{pro}}] = EP_{\text{AAIEP}} (124,20) \times ASU [RER]$; ^d: $[E_{\text{pro,corr,DBm}}] = [E_{\text{ric,DBm}}]/(1 - 18.95\%)$; ^e: $[E_{\text{pro,corr,DBp}}] = [E_{\text{ric,DBp}}]/(1 - 18.95\%)$; ^f: $[E_{\text{pro,corr,Ve}}] = [E_{\text{ric,Ve}}]/(1 - 18.95\%)$; ^g: $[E_{\text{pro,corr,RER}}]/(1 - 18.95\%)$; ^h: Gap = $[E]/[E_{\text{ric,corr}}]$; ⁱ: $[E_{\text{pro,Ve}}] = E_{\text{DBm}}/6.01\%$ (Incidence Database/ISTAT Dwelling urban units by SACE Database); ^l: $[E_{\text{pro,RER}}] = [E_{\text{pro,Ve}}]/0.18\%$ (Dwelling apartment (by ISTAT) Gap, ratio between [RER]/[VER]).

8. Conclusions

Before drawing a conclusion, we would like to make an analogy between energy consumption in the foregoing with that in the transport sector.

The energy consumption in the transport sector depends on the energy performance of the single means of transport (car, bus, van, *etc.*). The approach used to study a solution for the reduction of energy consumption could concern a single means of transport, such as engine efficiency, or the use of a different kind of fuel (gasoline, GPL, natural gas, fuel cell) or hybrid systems. On the other hand, a second approach to be used to study reduction of energy consumption in transport could concern land settlement and focus on the route taken by each vehicle, that is, road traffic. Efficient as the single vehicles may be, either petrol consumption is stopped or else they have to use fuel from 100% renewable energy resources. However, even if energy consumption can be reduced, it depends on the length of the route, and therefore, on traffic. Therefore, to reduce energy consumption in the traffic sector we must work on the flow of traffic, the route and length, and amplify the approach from the single vehicle to the territorial settlement.

This uncommon analogy allows us to clarify the approach adopted in this paper, since it could be transferred to the building sector where the single item is a building (or urban units), already subjected to several studies, and a settlement area is a town or region. In this paper we studied a statistical energy index and energy benchmarking which could pinpoint a territory for energy planning. If we would like to reduce energy consumption, we must act on all the players involved in the building process: designers, contractors, builders, *etc.* and also policymakers, and regarding the latter, offer a tool that can measure the effectiveness of energy policy decisions.

To conclude:

1. The EPC database allows us to gather data on the actual situation with the AAIEP and AIEP indices (although considering the error due to the independent experts) as well as energy class percentage distribution which, if expressed in percentage, only measures the characteristics of buildings. As a matter of fact, in 2011 energy distribution worsened compared to 2010, since only the EPCs of existing buildings increased (we thus excluded the error of independent experts since this was aggregate data, and with the possibility of fraud).
2. We could avail of statistical indicators, that can help monitor the trend; as seen, the median or standard deviation (δ) allowed us to avoid misconstructions due to the excessive increase in the database 2011.
3. The comparison between top-down to bottom-up evaluation methodologies and *vice versa*, should be refined with statistical and poll surveys. In any case it is evident that the relation between the geometry (territorial extension or GSU) and energy consumption is not linear, and the *error gap* may also reach 20%. However, the comparison between both top-down and bottom-up methods is able to identify the error gap, in this case, between $\pm 14.47\%$ and $\pm 19.09\%$.
4. The Scenarios could be useful tools in choosing energy options, as long as they elaborate a statistical index to measure top-down and bottom-up results, and their *error gaps*.

This approach could be repeated in other situations, also without the SACE database, if we adopted other kinds of energy databases as long as the data are related to the single urban units or single buildings: e.g., the databases of energy distributors or retail energy sales companies.

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Conflict of Interest

The authors declare no conflict of interest.

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