Chapter

Efficiency, Energy Saving, and Rational Use of Energy: Different Terms for Different Policies

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Abstract

In recent years, the increasing interest for energy efficiency has multiplied the number of players and the issuing of legislative documents, so the very notion of "efficiency" has taken different meanings in a more or less wide range of definitions, sometimes overlapping between them. These definitions often evoke different concepts such as "energy saving," "rational use of energy," "efficient use of resources," "reduction of consumptions," etc., in an amalgam shadowed by ambiguous interpretations. This paper proposes a clarification of the different expressions by defining their functional and conceptual boundaries and interrelationships, focusing the attention on the energy aspects, and leaving out other dominions that might govern or accompany that variable, such as, sustainability, competitiveness, economy, etc. The issue is not merely lexical or taxonomic. In fact, the strict definition of a concept defines its area of interest, and the decision-maker, when issuing a measure, should choose from his portfolio of available tools only those consistent with the involved domain.

Keywords: efficiency, energy saving, rational use of energy, definition, classification

1. Introduction

In recent years, the increasing interest for energy efficiency has multiplied the number of players and the issuing of legislative documents, so the very notion of "efficiency" has taken different meanings in a more or less wide range of definitions, sometimes overlapping between them [1, 2]. These definitions often evoke different concepts such as "energy saving," "rational use of energy," "efficient use of resources," "reduction of consumptions," etc., in an amalgam shadowed by ambiguous interpretations. The Energy Efficiency Plan 2011 of the European Commission [3] quotes, for example:

> *Technically, "energy efficiency" [4] means using less energy inputs while maintaining an equivalent level of economic activity or service; 'energy saving' [5] is a broader concept that also includes consumption reduction through behavior change or decreased economic activity. In practice the two are difficult to disentangle and—as in this communication—the terms are often used interchangeably.*

According to IEA [6], "energy efficiency" is a concept that can be difficult to define since it can mean different things to different people. One difference of opinion usually lies in whether energy efficiency encompasses only the technical efficiency of an energy service, i.e., the energy consumed as a result of a technological performance, or whether non-technical factors such as behavior are included in the interpretation of energy efficiency.

Directives 2006/32/EC and 2012/27/EU contain their own definitions of "energy efficiency" and "energy saving," but ambiguity between the terms persists. This paper proposes a clarification of the different expressions by defining their functional and conceptual boundaries and interrelationships, focusing the attention on the energy aspects, and leaving out other dominions that might govern or accompany that variable, such as, sustainability, competitiveness, economy, etc. The issue is not merely lexical or taxonomic. In fact, the strict definition of a concept defines its area of interest, and the decision-maker, when issuing a measure, should choose from his portfolio of available tools only those consistent with the involved domain. There would otherwise be the risk of using resources to promote "efficiency" using "energy-saving" tools possibly insufficient or even incompatible with the desired goal.

The lack of strict definitions in the field of the rational use of energy is, on one side, a source of uncertainty in the identification of targets, in their degree of achievement and selection of most suitable policy tools, and, on the other side, a reason of unwilled policy bias toward specific option and result [7, 8]. The main weaknesses of the energy policies developed in these conditions are the lack of criteria for monitoring performance, the lack of adequate financial assistance, and inappropriate communication in terms of message as well as targeted audience.

An example of great importance that corroborates our position is linked to the effects of the Green Deal (GD) [9], a vast plan to promote energy saving in homes launched in the UK in 2013, and which has shown signs of suffering since the first year of application (e.g., compared to a target of 2 million homes to be retrofitted each year, only 6000 had been retrofitted every year by the end of 2016). The vast literature produced in this regard has identified the following, among the various causes:

1. The GD did not require that the financeable efficiency measures should achieve given levels of energy savings nor provide criteria for monitoring the performances, thereby introducing uncertainties on the degree of achievement of the targets and on the corrective measures to be introduced (an energy saving must be measurable).

2. In a first phase (2013–2014), no state subsidies were envisaged that would make the efficiency improvement measures profitable (the net present value of energy savings must be positive).

3. In a second phase (2014–2015), state funds were made available, but not to the extent required by demand or in a long-term perspective (energy savings must be stable over time).

4. The government team that introduced the GD was composed of generalist officials with no experience in the field of energy efficiency, and above all without experts in the social-psychological, marketing, and communication fields (a given goal should require dedicated professionalism).

5. The GD could finance energy efficiency measures (e.g., insulation of walls), energy waste reduction (e.g., draft proofing), and use of renewable sources (e.g., solar panels) altogether. These actions aim at conceptually different goals and should have required different tools to be implemented.

A proper definition of the terms "energy saving," "efficiency," and "rational use" will therefore make correlations possible like

$$\text{"area of interest} \rightarrow \text{tool"}$$

as support for the policy-makers when establishing the principles of an action plan and for the analysts to check the results and the inner consistency between the goals and the means used to achieve them.

2. The classification issue

In recent decades many pieces of legislation on the issue of energy conservation at EU and national levels have been produced. Their stated goal is the improvement of the use of energy by end users through both prescriptive standards and direct/indirect financial support. Over time, such legislative tools have limited temperature in homes at 20°C, provided tax deductions for energy-saving interventions in buildings, granted energy efficiency certificates for measures in the industry sector, introduced labeling and energy performance certification, stimulated the market for the ESCOs, stated the appointment of an energy manager, supported the practice of energy audits and energy performance contracts, etc., thus creating a fertile ground for the identification of additional areas—in productive activities and in social life—of improvement. This legislative and regulatory process [10] is still in progress, and Italy and the EU Member States consider it as a cornerstone of their energy policy. On the other hand, energy can be saved even when turning off the lights when leaving a room, recovering heat in a production process, buying four-star appliances, installing a cogeneration plant, joining the local district heating, using stairs instead of elevators or bikes instead of cars, eliminating drafts under doors at home, connecting an inverter to an electric motor, becoming vegetarians, funding ads and documentaries on TV to create awareness among consumers, inserting the chapter "How to Use energy" in the books for elementary schools, and installing smart meters or modifying the wing profile of an aircraft or favoring the recycle of glass. Given the current regulatory framework, it would be difficult to identify, between those listed above, the "rational use of energy" or "energy-saving" or "energy efficiency" measures. The task we want to deal with in the next chapter is the survey of these families but also of other and different ones, in which the various measures listed above are logically contained.

3. Limiting energy consumptions

Any kind of measures able to save energy, e.g., those listed in the previous chapter, could belong to two classes: technical and nontechnical measures. All the initiatives related to plants or machineries with better performance than those previously installed may belong to the first family, while initiatives derived from behaviors of certain social classes (e.g., public employees, workers, students, families) or from the way certain productive processes are managed may belong to the second. The family of the technical measures could be further subdivided by the energy carrier (electricity, steam, fuel, etc.), by the primary source saved (natural gas, oil, coal, biomass, etc.), etc.

Another possibility is to classify the measures according to the kind of approach, whether top-down or bottom-up. Top-down measures "command and control" imposed by a higher authority; bottom-ups are those stemming from a free decision of the final users.

Another criterion might be related to the kind of final uses, for example, buildings (walls or the HVAC plants), industry (the utilities or the process), the tertiary sector, and transports and, again according to the production chains (paper, glass, textile, etc.), by types of services provided (by schools, offices, retail, etc.) or kind of transport means (land, air, naval).

Other methods could address the complexity of the measures (from “no cost good housekeeping” practices such as turning off lights to complex project with relevant financial implication)

The criteria partially exposed above, in the absence of a unifier element, seem, however, biased toward a simple cataloging, able in case to put order in the great family of “measures to limit energy consumptions” but unable to provide added values for the decision-maker/legislator when establishing an integrated policy.

A new method based on a classification by areas of interest is presented below; uniform measures will be referred to any given field, to be implemented with consistent and dedicated resources and tools.

4. Energy saving

Let’s start from the “energy-saving” concept through a clear and precise definition interpreting the expectation of a given policy, namely, an available and effective tool for the reduction of the energy consumptions in a framework of increased competitiveness, sustainability, and alleviation of the trade balance with foreign countries.

First of all let’s ask ourselves if, reducing the energy consumption in a given context from a value E1 to a value E2, one could call “energy saving” the difference of E1-E2. We think it is possible as far as the following conditions are met.

First, “energy saving” should be voluntary and programmable. As such, it must come from a plan considering the final users’ consumption profile, the technological offer, and the trend of energy markets. If a reduction of the demand came from nonvoluntary factors instead—for example, thanks to the favorable climatology or to the market dynamics making low-energy products or services more attractive in certain periods—such reduction might constitute a lucky contingency, but it couldn’t be called “energy saving” because the feature of planning, linked to any policy action, would be missing.

Second, “energy saving,” meaning the difference between an ex ante and an ex post consumption, must be measurable: the decision-maker, whether public or private, must be able to precisely determine the quantitative effect E1-E2 that the chosen initiative, once realized, will be able to produce in order to assess the adequacy to achieve a given objective, to follow the evolution of the results produced in time and to compare the actual results against the amount of resources fielded. In this regard, let’s consider the typical asymmetry between the ex ante and ex post measurements: when implementing an initiative to rationalize a given device, consumptions ex ante are certainly measurable, while the future ones will only be alleged and uncertain, and, if possible, they can only be estimated using engineering formulas. However, when the initiative is put in place at present, consumptions ex post are surely measurable; the effects are then determined (in the absence of a meter already installed on the machine), counting ex ante consumptions through empirical and/or statistical methods. The lack of a meter measuring ex ante or ex post consumptions necessarily causes uncertainty in the calculation of actual savings.

From the need to measure energy savings, one can argue that the technological initiatives, whose ex ante and ex post consumptions are certainly measurable, fall certainly within the definition; it will not be so easy for non-technological initiatives (it can be difficult to measure the energy saving derived form an increased "energy culture" of the end users or produced by an information campaign etc.).

Third, "energy saving" should produce net positive energy savings compared to the ex ante situation. While measurability is a precondition, it is also necessary that the balance between ex ante and ex post consumptions is positive, and therefore it should always be E1-E2 > 0. This condition is apparently tautological (talking about "savings" the difference of E1-E2 should de facto be greater than zero) because the assessment of the energy balance of the initiative must not only take into account the consumption of the unit or the system improved but even all the changes in power consumption that the initiative has caused in the associated context (cross-media effects). For example, a heat recovery through an exchanger between two streams increases the load losses in the circuits, and therefore the energy consumption of pumps or fans increases. When planning the measure, such components have to be identified and calculated, in order to prevent their occurrence possibly nullifying the operation, causing an increase of the global consumptions: E2 > E1. The absolute ex post consumption may increase rather than decrease when there was a change in the flow of products or services provided after the implementation of the measure; in such a case, a normalization procedure, according to EU Directive 06/32 "whilst ensuring normalization for external conditions that affect energy consumption" [11], is mandatory.

Fourth, the reduction of the energy consumption obtained after the energy-saving operation should remain stable over time. A new and effective measure implemented should become the new benchmark or the new baseline for the same type of energy use and the same final user; since the decision-maker can't accept that, in the midterm, consumptions increase again, nullifying the resources (always scarce and precious) used to implement the measure: a legislative decree, or a company policy, must necessarily induce lasting effects considering the resources invested.

Fifth, the cost-benefit analysis of an energy-saving initiative should provide positive results. The measure must, in fact, be capable to generate, for a number of years established by the decision-maker, a cash flow able to offset the investment necessary for the implementation of the measure itself and to produce an extra advantage, the net present value (NPV). Since the NPV is determined as present money, it can be used to finance further energy-efficient initiatives showing positive NPVs, thus triggering a virtuous spiral. If the energy-saving measure showed a negative NPV instead, the final result would be the loss of money, the value of the total energy saved not being able to pay back the initial investment, making it impossible to trigger any virtuous spiral. This fifth condition moves "energy saving" from the domain of energy to the domain of economy, fixing an inescapable two-way relationship between energy and economy: there is no energy saving if there is no money saving.

In conclusion, "energy saving" can be defined as an operation due to a voluntary and programmable action put in place by the decision-maker, producing a stable, positive, and measurable reduction of energy consumptions between an ex ante and an ex post situation, profitable under an economic point of view.

5. The measures to limit energy consumptions

We have just seen the features for an initiative to be called "energy saving." Let's now see the possible ways to reduce energy consumptions, to discriminate among them only those deserving the "energy-saving" status.

If in a given context it is necessary to submit energy uses to a deep assessment due to consumptions increasing uncontrollably or to associated costs verging on unsustainability[1], possible implementable measures will be the following:

1. Improvement of energy efficiency.
   - In intrinsic way.
     - Via technology.
     - Via management.
   - Joint replacement.
   - Technological standards.
2. Energy waste reduction.
3. Behavioral change.
4. Energy rationing.

We go now to describe respective meanings and operation fields.

5.1 Improvement of energy efficiency

Before getting into the description of this measure, it would be appropriate to clarify the meaning of "energy efficiency," and it would be better to remain in the technical-scientific field, since the concept of "efficiency" comes from the concept of thermodynamic "output." To this purpose it seems consistent what the 2006/32 EC Directive states: energy efficiency is "the ratio of output of (1) performance, (2) service, (3) goods or (4) energy, to the input of energy" (figures added by the author). It is tacit that output and energy input are referred to the same time period, which could be instantaneous (then the efficiency is a ratio between powers) or as long as you like. We can mention the following examples:

1. Performance: for an organization delivering administrative services, energy efficiency could be the ratio between the number of files issued and the energy used as resulting from energy bills.
2. Service: for transport of passengers, it is the ratio between the "number of passengers × kilometers traveled" and the consumption of fuel and/or electricity.
3. Goods: for a paper mill, it is the ratio between the tons of paper produced and the cubic meters of natural gas used in the production process.
4. Energy: for a heat generator, it is the ratio between the thermal energy produced (and fed into the distribution system) and the consumption of primary energy fed to the burner. By definition, the latter type of efficiency coincides

[1] This consideration is not marginal. The entire analysis assumes that an operational context needing energy exists, and it is useful and important. In such a situation, a voluntary interruption of the energy supply is therefore not conceivable, which would seriously prejudice the delivery of the product/service. The article will not therefore consider actions like the interruption of the power supply for a production process during the normal working hours, the turning off of the lights leaving bystanders in the dark, etc.

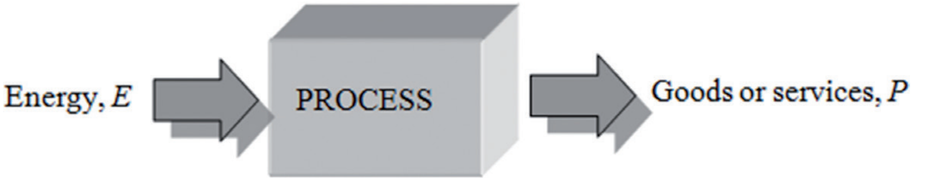

Figure 1.
Energy efficiency as the ratio of goods-services provided and the energy input.

with the first principle of thermodynamic output related to the process taking place in the heat generator.

The measure "improving energy efficiency" is composed of three subsets: the intrinsic improvement, joint replacement, and technological standards.

5.1.1 Intrinsic improvement of efficiency

If the efficiency of a process improves thanks to a planned measure, energy saving will be produced, which is therefore the effect of the improvement of efficiency. Let's suppose a given process (see **Figure 1**) which, thanks to the input of energy E, produces the stream of goods or services P. By definition, the energy efficiency of the process is given by.

$$\varepsilon = P/E. \tag{1}$$

If the efficiency of the process improves from ε_1 to ε_2 ($\varepsilon_2 > \varepsilon_1$), the energy savings achievable, R, will be given by

$$R = E_1 - E_2 = P\left(\frac{1}{\varepsilon_1} - \frac{1}{\varepsilon_2}\right) \tag{2}$$

The formula gives essence to the difference between the increase of efficiency and the energy saving: efficiency is a ratio between two quantities that, in the case where the output consists of a supply of energy, becomes a pure number between zero and one. Energy saving is a physical amount of energy instead (measurable in toe, kWh, MJ, etc.), no longer consumed thanks to the increased efficiency. So, increase in efficiency and energy saving are not concepts alternative to one another or possibly overlapping: the first is the cause, the second the effect.

Given the definition of "efficiency" as the ratio $\varepsilon = P/E$, it follows that the inverse of the efficiency is the specific consumption cs = E/P.

5.1.1.1 Improving efficiency via technology

The intrinsic increase of the efficiency is obtained via technology when the set of physical equipment driving the process has a better efficiency than the ex ante situation. This occurs, for example, in the presence of IE3 class electric motors instead of IE1-IE2 classes, inverters driving electric motors connected to variable loads, heat exchangers to recover energy from exhaust, steam recompression, turbo expanders in place of lamination valves of gases or steam, etc.

5.1.1.2 Improving efficiency via management

Efficiency can be increased by changing not the hardware but (1) the nature of the stream of matter/energy as the process input/output and (2) different management methods. Obviously the current configuration (machineries and the way they are managed) must be an average reference, or baseline, and the possible solution must be a real innovation, not just a realignment with what is already consolidated in the same production sector (we would otherwise fall into the "joint replacement" described in section 5.1.2). Management measures are, for instance:

- The adoption of raw materials with lower energy requirements for a change of state (lower temperatures for melting/boiling) or for pumping (lesser viscosity/density fluids) and use of additives in raw materials conferring the previous properties (e.g., thinners in the production of paper, low-melting additives for the production of glass, etc.)

- The production of lower-energy intensity goods or services (e.g., lighter bricks, lesser-thickness glass containers, avoiding to print documents in favor of dematerialization, etc.)

- The adoption of different management modalities of the process, e.g., "tuning" the different production phases eliminating intermediate stations and queues, using of dedicated software for automation/optimization of process parameters, etc.

5.1.2 Improving efficiency: joint replacement

Joint replacement savings are obtained when a device of a given residual life is replaced by a new one, belonging to the same technological series. The resulting savings are transitional and could even go to zero.

In fact, the efficiency of a new equipment, left to itself, would degrade naturally over time from the rated value ε1 to ε1, f at the end of the use. If at time t1 it was replaced by a new equipment, but belonging to the same technological series of ε1 efficiency, energy savings that could be achieved through the formula (1) would have a purely illusory character (see **Figure 2A**) because, through a normal maintenance, the efficiency would remain at its rated value and consequently the achievable saving would be next to zero (**Figure 2B**).

As we will see in section 5, the energy savings resulting from an intrinsic increase in the energy efficiency (**Figure 2C**) are the only "additional," resulting as marginal quantity of energy corresponding to the value given by (R1), and really saved.

5.1.3 Improving efficiency: measures based on standards

Some decision-making authority may impose minimum performance standards for energy equipment, excluding the circulation in the market of not compliant

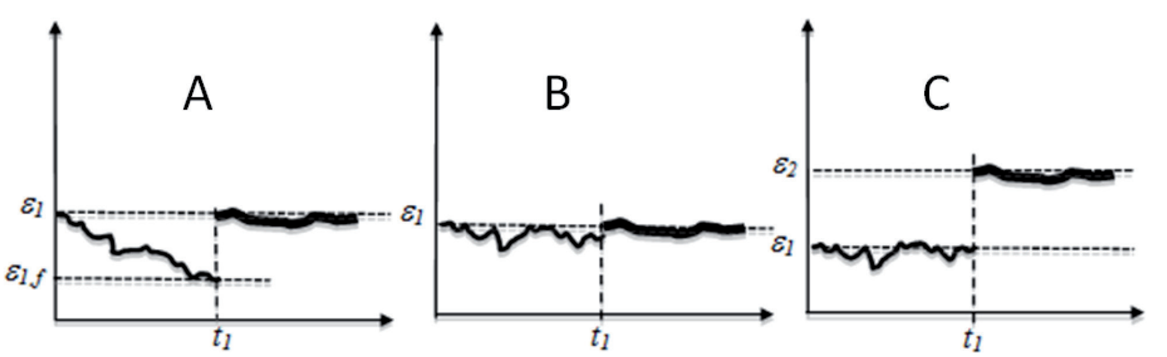

Figure 2.
Type of savings. (A) Illusory savings: when ε1-ε1, f degradation due to lack of maintenance. (B) With proper maintenance saving should be next to zero. (C) The saving is given by an intrinsic improvement of efficiency.

solutions. The obligations imposed by regulations on energy performance in buildings [12, 13] or the minimum standards established by the Ecodesign regulations [14] for different kinds of wide diffusion devices (light bulbs, electric motors, boilers, etc.) belong to this kind of measures.

5.2 Waste energy reduction

The reduction of energy waste comes from the "normal" behavior and it does not need the design of a specific energy project. It simply consists in the realignment to the normal situation at rated consumption, starting from a previous high-energy consumption situation. The energy waste should never be confused with the low efficiency of an appliance, intrinsic or due to wear, which can be increased by substitution with a better device: energy waste is due to negligence, and as such it should not be tolerated and should not be hosted in the country of energetics. If one was currently seeing a "free" degradation of energy, for example, neglected losses of compressed air, steam, and water; lights, printers, and monitors unnecessarily left switched on after office hours; wasted fuel caused by unnecessary travels of the vehicle; etc., the share in case recovered after an initiative of restoration would have the same meaning of the "due" mending of the purse from which a trickle of coins is happening: once the purse is mended, no one should consider as "saved" the money that it is now able to retain.

Metaphors aside, the savings associated with a limitation of wasted energy are illusory: this form of recovery cannot be counted as revenue, and the manager of the local plant is responsible for such a loss.

5.3 Behavioral change

When an energy-saving behavior is adopted, we are dealing with a non-technological measure, related to sociocultural cycles having a complex, long-lasting, unpredictable dynamics difficult to quantify even in ex post conditions. Such an approach exploits the deep motivations of users—citizens—and associates, to a behavior oriented to saving energy, acceptability by the reference community, or the satisfaction of inner instances of public participation, making an active social role evident.

5.4 Energy rationing

Consumptions of energy can be limited by imposing restrictions on energy uses (reducing available streams or the periods of use) or decreasing the quality of performance. This usually happens after serious crises threatening the continuity or security of energy supply or following traumatic increases in energy prices. This kind of tools are typically policies of austerity (i.e., the 1973 Yom Kippur oil crisis) [15, 16] as well as those regulations limiting the temperature in homes.

Given the different measures seen so far to limit consumptions, the following measures belong to the definition of "energy saving" claimed before and substantiate it:

- Intrinsic improvement of efficiency.
- Joint replacement.
- Technological standards.
- Energy rationing whose requirements remain in force in the medium term.

Recovering energy wastes should not strictly be an operation of "energy saving" since it doesn't produce net savings (third condition); on the other hand, the behavioral change and energy rationing measures, the prescriptions of which are in force for a short period of time, do not ensure the stability of savings for years to come (fourth condition).

6. Normalization and additionality

Savings induced by energy rationing policies are not obtained under the same conditions as before, since the end user is encouraged to accept a downgrading of energy performance, for example, using energy only in certain periods of time, having reduced available thermal power, enduring lower temperatures in winter compared to average comfort conditions, higher temperatures—and higher humidity—during summer, etc. Saving energy by increasing efficiency involves, however, the same conditions between ex ante and ex post situations, thus at the same degree days, humidity, services, goods produced, etc. using conventional normalization methods. For example, an operation increasing the efficiency of a process from ε_1 to ε_2, with increased production from P_1 to P_2, would produce, at the same production ex post P_2, an energy saving given by

$$R = E_1 - E_2 = \frac{P_2}{\varepsilon_1} - E_2 = E_2\frac{\varepsilon_2}{\varepsilon_1} - E_2 = E_2\left(\frac{\varepsilon_2}{\varepsilon_1} - 1\right) = E_2\left(\frac{P_2\,E_1}{P_1\,E_2} - 1\right) \tag{3}$$

Since the saving is positive (in respect of the third condition), it follows that $\varepsilon_2 > \varepsilon_1$, which produces a further tautological condition:

$$\frac{P_2\,E_1}{P_1\,E_2} > 1 \Rightarrow \frac{P_2}{P_1} > \frac{E_2}{E_1} \tag{4}$$

stating the following rule: in order to have positive energy savings as a result of an increase in efficiency and production, the relative increase in production must be more than proportional to the relative increase in energy consumption.

The same applies in the event of increase in efficiency with reduction of production.

Of all the ways to save energy, only the intrinsic increase of efficiency has the characteristics of additionality. For instance, as defined in Annex A to document 9/11 of the Italian Authority for Electricity, Gas and Water System, [17] savings are additional when "purified of all not additional energy savings, i.e., those that would have happened anyway as a result of technological, regulatory and market evolution." When, therefore, some savings are achieved because of mandatory legislation, or after installing a "market average" device (even though more efficient than the replaced device), or if providing a service that the market demands with a given minimal performance, all that cannot be considered additional and, in some contexts, may not receive incentives (e.g., in the Italian system of White Certificates).

When a policy boosts improvements in energy efficiency imposing technological standards, the consequent energy savings cannot be considered additional at end-user level, but they can at the national level.

7. The rational use of energy

Let's now jump to the next level and ask ourselves the best definition of "rational use of energy."

For example, the Italian 10/91 law reported the following definition: "set of organic actions intended to promote energy conservation, appropriate use of energy sources (i.e., avoid waste), improvement of technological processes using or transforming energy (i.e., increasing energy efficiency), the development of renewable sources of energy, the replacement of imported energy sources (i.e., the development of indigenous energy sources)." In practice, the rational use of energy is part of the strategy the country adopts to face the energy challenge, whose motivation and urgency comes from the need of security of energy supplies and from the gradual rise of energy prices due to the depletion of fossil fuels. However, the definition of the 10/91 law, in the light of the above, seems inadequate and ambiguous. It considers energy saving and increased efficiency at the same level, officially weaving the two concepts perhaps for the first time. Moreover, the definition does not mention non-technical aspects such as the behavioral change.

We might then reformulate the concept of "rational use of energy" as the "set of organic actions aimed at reducing consumptions through (1) promotion of energy conservation, energy waste reduction, and behavioral change; (2) development and use of renewable energy sources; and (3) development and use of domestic sources of energy," in such a manner of explicitly identifying as many fields of action, conceptually not interfering with one another, each one deserving a specific promotional policy-making use of dedicated tools; in fact it seems logical that a strategy

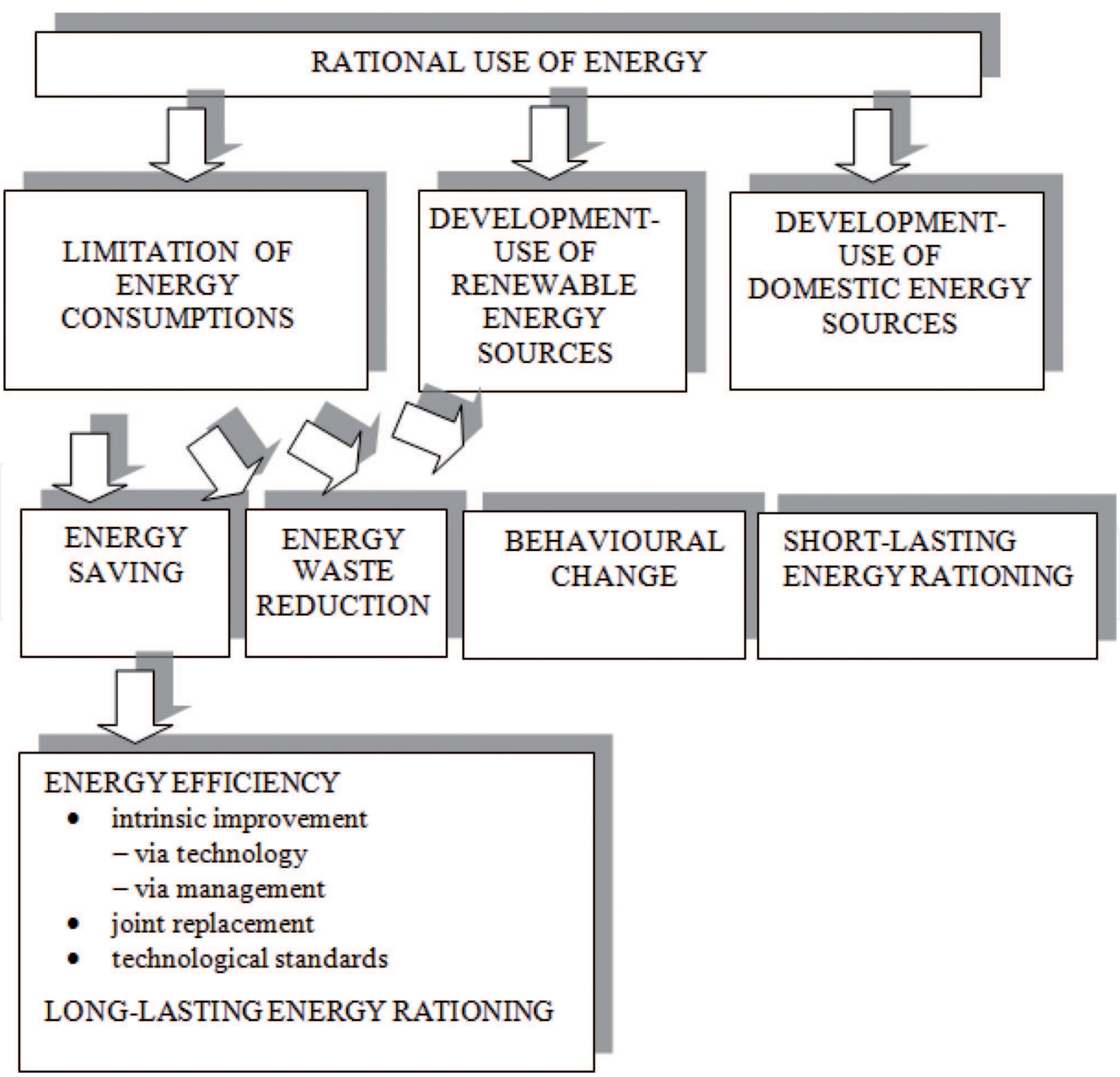

Figure 3.
Rational use of energy: the fields of interest.

for increasing, e.g., intrinsic efficiency, should leverage instruments different than those for behavioral change, joint replacement, etc.

Figure 3 summarizes the proposed definition, depicting the various fields of interest for a policy of rational use of energy.

The diagram shows that energy efficiency is a subset of the family of higher-level "energy saving," an instrument of the class "limitation of consumptions," measure per se of rational use of energy. This should definitely clarify the respective positions and meanings of "efficiency" and "saving."

8. The fields of interest

The proposed subdivision segregates different areas of activity, each one needing dedicated operational tools and skills. Referring to the diagram in **Figure 3**, it is the case at this point to catalog such instruments according to the areas, limiting the analysis to consumption-reducing measures, thus not considering the development and use of renewable and endogenous energy sources.

8.1 "Energy-saving" policies

8.1.1 Intrinsic improvement of energy efficiency

This specific energy-saving measure stands on the planning abilities of the end user—in terms of choice between a number of available technological options or between a range of projects—privileging the solutions with the best efficiency, after assessing them with ad hoc cost-benefit analyses. If the end user has no choice, since the market offers, or the law requires, or customers want only specific equipment or processes, we should not strictly call this measure as "efficiency" for it is not characterized by additionality. Some energy efficiency measures could be as follows: (1) some specific policy granting incentives, for example, based on White Certificates, recognized only if additionality of the energy saved is proven; (2) companies could impose the internal use of efficient equipment and adopt remote and automated control systems; and (3) politics could operate on the demand but even on the offer side, getting industries to produce efficient equipment and granting incentives for process and/or product innovation; etc. To implement policies aiming at increasing energy efficiency, decision-makers must gather mainly technical (researchers and experts in energetics, industrial processes, efficient technologies) and economy-finance skills for the assessment of project profitability.

8.1.2 Joint replacement

This measure should not be subject to specific programs or incentives, since it deals with "average market" practices to be normally adopted at the end of the devices' lifetime and when the efficiency is constantly kept at the rated level thanks to normal maintenance cycles. When, however, the ordinary maintenance is made, but the efficiency of the component degrades necessarily in time, energy saving is obtained by inducing a more frequent renewal of such components (see Appendix). In this regard the Italian Law n. 10/91, Art. One states: "In order to improve the energy transformation processes [...] the provisions of this Title shall promote and encourage [...] a more rapid replacement of systems in particular in the areas with higher energy consumptions" [18]. The implementation of this measure demands technicians and analysts to know the diagrams of decay of the efficiencies in time

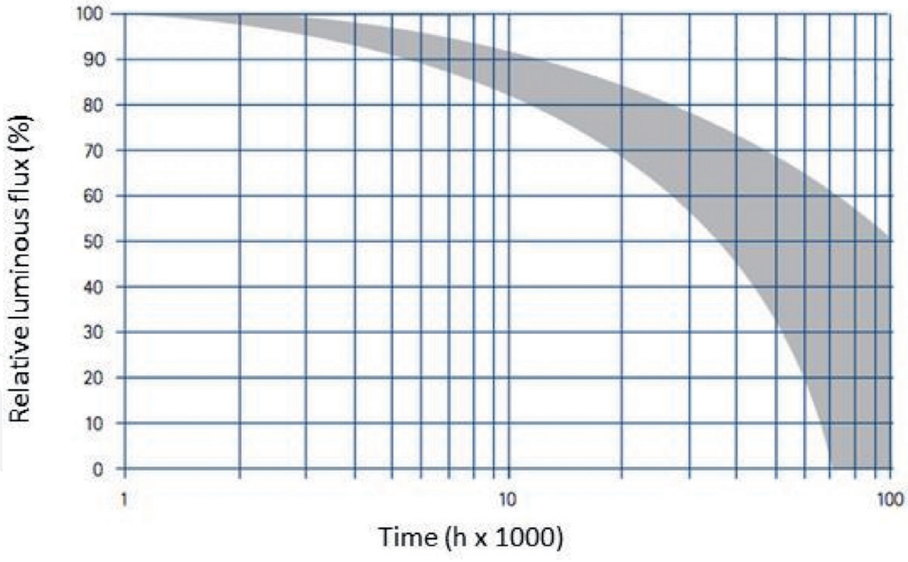

Figure 4.
Decay probability of the luminous flux over time: LED lamps (gray area), source ETAP, LED dossier October 2014.

for the different devices (see, e.g., the decay of the luminous flux for LED lamps [19] in **Figure 4**) and to determine the optimal replacement time through the application of cost-benefit analyses.

8.1.3 Technological standards

Energy saving is achieved by eliminating low-efficiency equipment from the market and allowing only the trade of equipment having an efficiency higher than a given level. European Ecodesign Directives (2005/32/EC, 2009/125/EC, and subsequent regulations) for home and industrial appliances (light sources, digital receivers, electric motors, etc.) leverage this specific item of energy saving. Other measures belong to this category, i.e., imposition of minimum values of transmittance for the building envelope, carrying out of energy audits in large companies, and annual refurbishment of 3% of the buildings of the central public administration (12/27 EED Directive); the requirement for new buildings owned or occupied by public government as of 1 January 2019 has to be "nearly zero energy," while other new buildings will follow the prescription since 1 January 2021 (90/2013 Italian Act).

Such a measure is intended for wide diffusion devices, the number of which constitutes the driver in the country, more than the quantitative increase in efficiency. Efficiency standards are set at EU or Member State level and require the involvement of staff where technical, economic, market knowledge, production processes, protocols for measuring energy consumptions, etc. skills coexist.

8.1.4 Energy rationing

These are measures to be adopted during energy crises involving rapid increases in prices and difficulties in getting supply. When necessary, to achieve drastic reductions of consumptions at whole country, tariffs are increased and energy rationed. For instance, during the 1973–1974 austerity period [20–22], the following measures were adopted in Italy: (1) ban of motorized vehicles (including aircraft and boats) during holidays; (2) end of TV broadcasts at 10:45 pm and evening news moved from 8:30 to 8:00 pm; (3) shops closed at 7:00 pm with the obligation not to hold lightened signs, advertising signs, and shop windows; (4) bars and restaurants closed by h. 00:00 am; (5) cinemas and theaters closed by h. 11:00 pm; (6) immediate increase by

30% in fuel prices; (7) obligation to reduce public lighting by 40%; and (8) reduction of speed on roads to 50 km/h in urban areas, to 100 km/h on country roads, and to 120 km/h on motorways. In other countries the crisis of 1973 was the opportunity to introduce the daylight-savings time [5, 23], while in the USA the bike race Daytona 200 was competed for 180 miles.

In Japan [24, 25], following the tsunami that damaged the Fukushima nuclear power plant (2011), the government implemented a series of measures such as turning off air conditioning and escalators in the subway, turning off the large advertising screens in city centers, decreasing the speed of trains, and reshaping the hours of work, including hours of weekend when the electrical load on the network was lower. Part of these measures were spread by the movement of opinion Setsuden (see **Figure 5**, a poster aimed at private households encouraging energy-saving behavior from unplugging appliances vs. standby mode to turning lights off when not needed and switching to LED lights). Some were removed in late 2011, but part of them was incorporated permanently in the habits of Japanese citizens and companies.

Options foreseen in national laws on energy uses in buildings, for example, limiting the temperature inside homes or in industrial mills during winter and the length of the heating seasons for households, can be considered as belonging to the energy rationing measures.

Planning this instrument primarily requires skills in the field of social psychology, mass psychology, and communication.

8.2 "Energy waste reduction" policies

There are no specific rules in this field because of the difficulty to conduct ex post controls to evaluate the results; however, there are more general measures able to induce at end-user level, among other effects, also an attitude aimed at reducing losses, for instance, a policy accompanying the introduction of energy management systems, possibly compliant with the ISO 50001 Standard [26]: in fact a management system, having among its cornerstones the "continuous improvement," necessarily has to address the problem of energy wastes and the identification of the measures for their reduction. Awareness of the problem of energy waste is also catalyzed by the increase in energy prices. The imposition of limits not to be exceeded for energy-specific consumption at end-user level is aimed at the same

Figure 5.
Banner of the movement of opinion Setsuden (energy saving).

goal. This last measure has never been implemented so far, and, especially in the industry sector, it would be with great difficulty because of the enormous variety and peculiarities of different production cycles and the impossibility to identify and agree with stakeholders the specific energy consumption benchmarks.

Policies to reduce the energy waste, rather than by the central authorities, should be implemented by end users themselves, using local technicians who are familiar with the current consumption profiles, with industry benchmarks to compare energy performances and, of course, with the technical "weaknesses" of their plant. In the end, it is a matter of common sense.

8.3 Behavioral change policies

The behavior of end users regarding the conscious use of energy should be addressed toward proactive attitudes and not toward the trivial (and already due) waste energy reduction. Such a policy should not be therefore aimed at turning the lights off when leaving the living room (or office or department), or shutting the windows when the HVAC plant is switched on, or avoiding the use of compressed air to wipe floors or clothes, or preferring public transport to private cars. Similar fields should already have been fixed by the reasonable user, who knows that unnecessary consumption of electricity or gasoline or methane is a money trickling down; using common sense to prevent similar drippings is enough: there is no need of a law but the law of nature to know that energy—meaning money—shouldn't be wasted. Behavior should change in a proactive way instead, i.e., toward attitudes able to predict the effects of our choices or behaviors about the variable "energy" and then to act accordingly. As a consequence one should consider the energy class label when purchasing a piece of appliance; use elevators and escalators as little as possible and use stairs instead; go walking or cycling for short trips instead of using motorized vehicles; prefer "0 km" products (with same quality and price) and avoid the consumption of fruit and vegetables out of season (greenhouses operating off season must be conditioned, and energy consumptions increase); keep the electrical consumption of the dwelling under control, possibly with automatic meters showing in real time the power requested in that very moment; encourage conference calls or video conferences instead of face-to-face meetings; introduce new summer dress codes in offices, in favor of light and informal clothes (getting rid of jacket-tie suits); learn how to build a solar panel; understand the principles of thermodynamics—stating that (a), once used, the energy can't be created once

	Area of interest	Competences
Energy efficiency improvement	Intrinsic improvement	Energetics, industrial processes, efficient technologies, management systems, economy, finance
	Joint replacement	Technical knowledge of performances of energy components, economy
	Technological standards	Energetics, engineering, economy, knowledge of markets, of productive processes, and of energy consumptions measurement protocols
	Energy rationing	Social psychology, mass psychology, communication
	Energy waste reduction	Common sense
	Behavioral change	Communication, marketing

Table 1.
Behavioral change: skill vs. areas of interest.

again and (b) electricity should never be converted into heat; etc. To achieve such goals, an intense, extensive, and prolonged public information/training plan should be launched, favoring the spread of best practices and involving schools at all levels [9]. Therefore, skills in communication and marketing are mainly needed.

The following table summarizes the most important skills needed in all areas of interest.

9. Conclusions

The definitions and the areas of interest shown so far for the different measures to limit energy consumption have a universal value, not necessarily the one that the different regulations define in terms of "energy saving," "efficiency," "rational use of energy," etc. The distinction proposed between the individual measures by level, areas of interest, and competence requirements can contribute to a better integration of the various regulatory measures and to an optimal identification and customization of planning and implementation tools, while avoiding overlapping and duplications.

The word "energy" has, for the ordinary citizen, a range of meanings: there are vital, moral, mental, psychic, internal, emotional, etc. "energies." These are pure abstract concepts, inhabitants of the world of ideas. The object of policies is, instead, that "energy' is—always abstract but measurable—dealing with the two principles of thermodynamics[2]—and that pragmatically warms us during winter and cools us during summer, making refrigerators and cars run. The policies refer to this energy as a "tangible" energy that burns and gives electric shocks and that can be measured and billed, and that is why the energy efficiency dealt with by the policies should remain restricted to a technical-scientific domain. An invasion of collective areas—behavior modification, increasing awareness, the maturation of a culture or motivational domains, "I feel myself realized" or "If everyone did like me…"—is desirable, but in view of an increased social sensitivity, not of an increase in efficiency, since between the two aspects there is not necessarily a two-way relationship: when sensitivity to energy efficiency is high, the efficiency of the context is normally low (e.g., in energy crisis times), whereas when efficiency is high, sensitivity is low (as in current times). This phase shift may be another form in which we experiment the rebound effect [27–31].

The lack of strict definitions in the field of the rational use of energy has been identified as the main reason for the failure of energy policies aiming at conceptually different goals but with an incoherent bias toward a specific tool to be implemented. When a large-spectrum policy is aimed at different targets, policy-makers should moreover be reminded of the Tinbergen's rule, stating that when trying to achieve multiple economic targets, at least one policy tool for each policy target is needed: the achievement of a target can preclude the achievement of another one.

Another context that the analysis can help to clarify lies in the semantics of the term "energy efficiency." In recent years, the European Union has issued a series of acts in the field of energy conservation: action plans, green papers, directives, framework programs, decisions, etc. These have always invoked the concept of "energy efficiency," and that address was reflected on individual Member States during the adoption of the various acts and directives. This may seem incongruous since, as seen so far, the increase in efficiency is only one of the ways in which energy can be saved.

[2] E = 0 and $\Delta S > 0$: in the course of a phenomenon confined in a closed system, the energy E is conserved and entropy S increases.

One answer may lie in semantics.

The main conceptual contender of efficiency is, as seen so far, "energy saving," the instrument that, by virtue of its large domain of intervention, should be invoked in general policies. The concept of "saving" might however not be well received by the end users (nor by the legislature), if recalling—consciously or unconsciously—pauper horizons in which to engineer oneself, having to tighten belts, giving up opportunities, and accepting a lower quality of life. Other terms often used in this context, such as "limitation," "containment," "reduction," and "conservation," remind similar scenarios. Instead the word "efficiency," from the semantic point of view, resonates the positive concept of improvement related to the advent of futuristic technologies: it does not foreshadow some arduous and colorless future overshadowed by attitudes of thrift and saving, but it contains an unlimited, optimistic, and enthusiastic confidence in technology. We do certainly prefer being branded as "efficient" rather than "thrifty." In the collective imagination, efficiency is Thomas Alva Edison, saving is Scrooge. Saving is the bear, efficiency is the bull.

One could say that the choice of the word "efficiency" itself can be seen as the first and most powerful measure of behavioral change that, internalized by European citizens, may have a significant impact in the socioeconomic system.

Appendix: Effects of an increased frequency of replacement of the same efficiency pieces of equipment

Let's naturally decrease the efficiency ε of a given device "1" over time. In **Figure 6** the curve A-B-C represents the evolution in time of the specific power consumption Ps (= $1/\varepsilon$). During the life (at time H), the device would consume the energy represented by the A-C-H-F area. If device "1" is replaced with one identical "2" at half of its life (time G), the new consumption of the process would be represented by A-B-D-E-H-F area, and the area B-C-E-D would represent the energy saved in this way.

To become an effective energy-saving option, the initiative has to achieve at least the economic parity, so the discounted cash value of the saved energy (black area) in the life of the project must equal the difference between the value of equipment "2" installed at the time G and the residual discounted values of equipment "1" disposed at time G and equipment "2" disposed at time H.

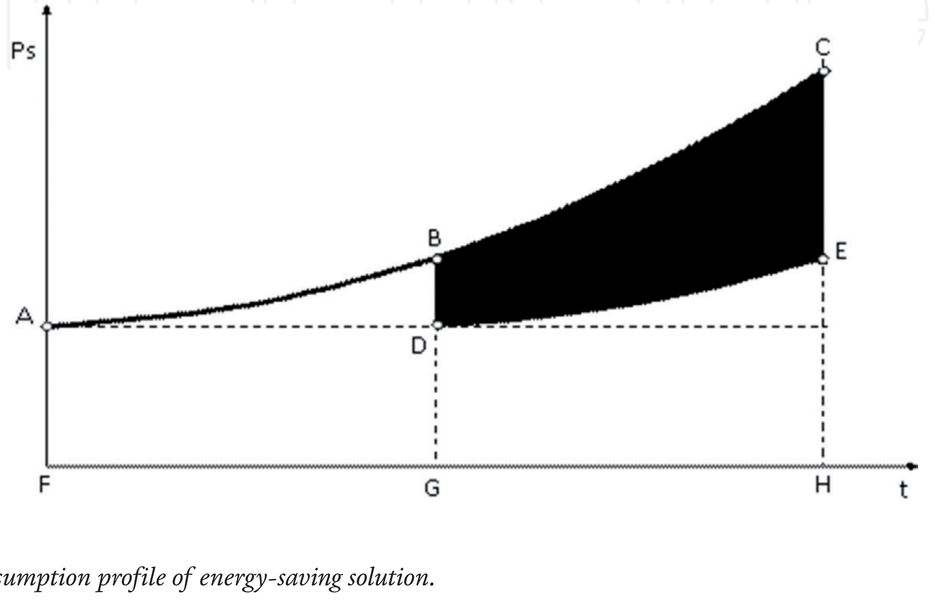

Figure 6.
Power consumption profile of energy-saving solution.

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References

[1] Doms ME, Dunne T. Energy intensity, electricity consumption, and advanced manufacturing-technology usage. Technological Forecasting and Social Change. 1995;**49**:297-310

[2] de Lovinfosse I. How and Why do Policies Change? A Comparison of Renewable Electricity Policies in Belgium, Denmark, Germany, the Netherlands and the UK. Bruxelles: P. I. E. Peter Lang; 2008

[3] European Commission. Energy Efficiency Plan. 2011. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Aen0029

[4] Lovins AB. Energy efficiency, taxonomic overview. In: Encyclopedia of Energy. Vol. 2. San Diego/Oxford, UK: Elsevier; 2004. pp. 383-401. 6 vols

[5] Schipper L. Energy saving in the U.S. and other wealthy countries: Can the momentum be maintained?. In: Tester JW, Wood DO, Ferrari NA, editors. Energy and the Environment in the 21st Century. Cambridge, MA: The MIT Press; 1990:475-484

[6] International Energy Agency. Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements. Insight Series. Paris, France: International Energy Agency; 2012

[7] Niall K, Gouldson A, Barrett J. The rationale for energy efficiency policy: Assessing the recognition of the multiple benefits of energy efficiency retrofit policy. Energy Policy. 2017;**106**:212-221

[8] Kern F, Kivimaa P, Martiskainen M. Policy packaging or policy patching? The development of complex energy efficiency policy mixes. Energy Research and Social Science. 2017;**23**:11-25

[9] Rosenow J, Eyre N. A post mortem of the Green Deal: Austerity, energy efficiency, and failure in British energy policy. Energy Research & Social Science. 2016;**21**:141-144

[10] Decreto-legge 4 giugno 2013, n. 63, recante: Disposizioni urgenti per il recepimento della Direttiva 2010/31/UE. Rome, Italy: G.U. Serie Generale n. 130. del 05-06-2013, (Italian legislation: implementation of EU Directive 2010/31)

[11] Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC. Official Journal of the European Union, L114, 27/4/06

[12] Decreto Legislativo 19 agosto 2005, n. 192, Attuazione della direttiva 2002/91/CE relativa al rendimento energetico nell'edilizia. Rome, Italy: G.U. n. 222. del 23-09-2005, (Italian legislation: implementation of EU Directive 2002/91)

[13] Decreto interministeriale 26 giugno 2015—Adeguamento linee guida nazionali per la certificazione energetica degli edifici. Rome, Italy: G.U. Serie Generale n. 162 del 15-07-2015; Suppl. Ordinario, n. 39 (Italian regulation: national guide lines on building energy efficiency)

[14] 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. Official Journal of the European Union, L 315, 14/11/12

[15] Alpanda S, Peralta-Alva A. Oil crisis, energy-saving technological change and the stock market crash of 1973-1974. Review of Economic Dynamics. 2010;**13**(4)824-842

[16] Chick M. Electricity and Energy Policy in Britain, France and the United States since 1945. Cheltenham: Edward Elgar; 2007

[17] Linee guida per la preparazione, esecuzione e valutazione dei progetti di cui all'articolo 5, comma 1, dei decreti ministeriali 20 luglio 2004 e s.m.i. e per la definizione dei criteri e delle modalità per il rilascio dei titoli di efficienza energetica. Milano, Italy: ARERA, delibera 103/03; (Italian Authority for electricity, gas and water system, Annex A to document 9/11 of Italian Authority for electricity, gas and water system)

[18] Legge 9 gennaio 1991, n. 10 Norme per l'attuazione del Piano energetico nazionale in materia di uso nazionale dell'energia, di risparmio energetico e di sviluppo delle fonti rinnovabili di energia. Rome, Italy: G.U. n. 13. del 16-01-1991. (Italian Law n. 10/91, Art. 1, National energy plan)

[19] ETAP. Lighting with a new light source. In: LED Dossier. 5th ed. Slough, UK: ETAP; 2014

[20] Bernardini C, Salvini G. La Crisi Energetica Nel Mondo e in Italia: da Enrico Fermi e Edoardo Amaldi a Oggi. Bari: Dedalo; 2007. p. 234. (Energy crisis in the world and in Italy)

[21] Caruso E. L'economia italiana negli anni '70-'80, La crisi petrolifera degli anni '70 si abbatte sulle imprese, in «Impresa Oggi», 1999, sezione Economia-Sviluppo economico, Milano, Italy (The Italian economy in the 70s, the oil crisis and the industrial system)

[22] International Energy Agency. Oil Crisis and Climate Challenges, 30 Years of Energy Use in IEA Countries. International Energy Agency: Paris, France; 2004

[23] Tonini A. The EEC commission and european energy policy: A historical appraisal. In: Bardazzi R, Pazienza M, Tonini A, editors. European Energy and Climate Security. Lecture Notes in Energy. Vol. 31. Cham: Springer; 2016

[24] McLellan BC, Zhang QN, Agya U, Hooman F, Ishihara KN. Analysis of Japan's post—Fukushima energy strategy. Energy Strategy Reviews. 2013;**2**(2):190-198

[25] Jupesta J, Suwa A. Sustainable Energy Policy in Japan, Post Fukushima. International Association for Energy Economics, IAEE Forum, Fourth Quarter. Paris, France: IAEE; 2011

[26] ISO 50001—Energy Management. Available from: https://www.iso.org/iso-50001-energy-management.html

[27] European Commission. Action Plan for Energy Efficiency. COM(2006)545 final Brussels, 19/10/06

[28] European Commission. Action Plan to Improve Energy Efficiency in the European Community 2000-2006. Available from: https://ec.europa.eu/energy/en/topics/energy-efficiency [Accessed: April 26, 2000]

[29] European Commission. Green paper on energy efficiency or doing more with less. 2005, COM(2005) 265 final, Brussels, 22.6.2005

[30] European Commission. The Communication from the Commission "Energy efficiency: Achieving the 20% target." 2008, COM(2008) 772 final, Brussels, 13.11.2008

[31] 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/EC90/2013 Italian Act. Final, Brussels: Commission Staff Working Document, Swd; 2016. p. 397. 30.11.2016