The Economic Evaluation of Energy Efficiency in Industry: an Innovative Methodology

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ABSTRACT

An empirical research involving 130 Italian industrial firms showed that the economic viability of energy efficiency projects is mostly evaluated through indicators like Pay-Back Time (PBT) and Internal Rate of Return (IRR), whose acceptability thresholds are affected by decision makers' risk propensity and other contingencies (such as competing priorities).

However, this approach hinders the adoption of several energy efficiency technologies - such as CHP, electric motors, inverters -, which provide economically viable results from a lifecycle cost perspective.

This paper addresses this issue by identifying an innovative evaluation method for energy efficiency investments. Inspired by the lifecycle economic assessment methodology for energy production plants – the so-called Levelized Cost Of Electricity (LCOE) or Levelized Energy Cost (LEC) - our indicator, called Levelized Energy Efficiency Cost (LEEC), correlates the energy savings that can be achieved through the implementation of an energy efficiency technology and the total costs incurred throughout the entire technology lifecycle (e.g. initial investments, O&M, disposal). A technology can be considered as economically viable if the LEEC is lower than the energy price incurred by the firms, because in that case the economic benefit of the saved energy is higher than the sustained cost to obtain it.

The application of such methodology in different Italian energy-intensive industrial sectors (e.g. automotive, cement, iron&steel and pulp&paper) demonstrates that most of the considered technologies are economically viable. Therefore the LEEC is a clear and simple tool for companies' decision makers to evaluate energy efficiency projects.

Introduction

In recent years, energy efficiency has become a hot topic within national and international policies, being recognized as one of the main contributions to an environmental and economic sustainable growth. The industrial sector represents one of the greatest potential sources of energy efficiency. In Italy, the industrial sector accounts for 24% of the national energy consumption (ENEA, 2014).

The European Union, through the famous "20-20-20 package", settled a not-binding target of 20% improvement in energy efficiency of the EU compared to projections for 2020, and recently approved the Energy Efficiency Directive - 2012/27/EU - which indicates to member states how to achieve the 20% target on energy efficiency by 2020. Each Member State shall set its own non-binding national energy efficiency target, subsequently monitored by the European Commission. If necessary, the Commission will intervene with binding measures and adjustments for those nations that fall short of meeting their performance targets. Member States have brought into force the laws, regulations and administrative provisions necessary to comply with this Directive before 5 June 2014. The Directive requires industrial and other large enterprises to conduct energy audits.

Italy's National Energy Strategy prioritizes energy efficiency as a cornerstone for a secure energy supply, the energy cost reduction for citizens and businesses, and the environmental protection through greenhouse gas reductions. Among current energy efficiency incentives, the White Certificates scheme[1] is the most relevant for the industrial sector.

Also thanks to a proactive legislation, important results have been already achieved in Italy, which is in second place worldwide among the most efficient countries (ACEEE, 2014). However, much remains to be done. In fact, there are several barriers to energy efficiency, one being the proper economic evaluation of enabling investments. Focusing on a huge sample survey of Italian industrial companies, the aim of this paper is to analyze current energy efficiency project evaluation methods and their drawbacks. A new indicator - the so-called Levelized Energy Efficiency Cost - is proposed in different application fields.

Literature review

This section synthetizes from literature the main indicators used to evaluate the economic feasibility of energy efficiency projects. Examples consider the industrial sector as well as other sectors (households, services and public sectors). From the 76 papers examined, these indicators predominantly emerge:

- Net Present Value (NPV)
- Pay- Back Time (PBT)
- Internal Rate Of Return (IRR)

NPV utilizes discounted cash flows generated by the investment during its operation at a discount rate, which expresses the risk level of the investment (Tudisca et al. 2014). In other words, NPV compares the present values of the net cash inflow in the future to an initial investment to determine the profitability of the investment or project (Samba Sowe et al. 2013).

$$NPV(t) = \Sigma\ CF_t/(1+i)^t$$

t = project duration in years,
i = discount rate,
CF = expected benefit at the end of the year.

Therefore, an investment is acceptable if the NPV is positive.

The main issue related to NPV calculation regards cash flow estimation, which is inherently uncertain. Secondly, companies have different ways of identifying the discount rate, although a common method is using the expected return of other investment choices with a similar level of risk (Xinjing Zhang et al. 2014).

A similar tool for evaluating two or more alternative investments is Net Present Cost (NPC), which represents the total discounted cost of an asset during its entire lifetime (Dalton et al. 2007; Rohani et al. 2013). Between two or more alternative investments, the one with the smallest NPC is preferred.

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[1] White certificates, also known as "Energy Efficiency Certificates" (EEC), are tradable instruments giving proof of the achievement of end-use energy savings through energy efficiency improvement initiatives and projects. The white certificates scheme was introduced into the Italian legislation by the Ministerial Decrees of 20 July 2004.

The PayBack Time (PBT) of an investment is a measure of period of time that is required to reach the break-even point, i.e. when the sum of cash inflows (discounted or not discounted) is equal to the sum of cash outflows (discounted or not discounted, consistently to the previous ones). Differently from the above-mentioned NPV, the PBT is a "relative" indicator, in a sense that a decision-maker must impose a subjective threshold to define economic feasibility for investments. As discussed later, Italian industry's typical acceptable payback threshold is around 2-3 years. PayBack Time is often used because it is easy for most individuals to apply and understand, regardless of academic training or field of endeavor.

The Internal Rate of Return (IRR) of an investment is a measure of the average profitability of an investment, given that it represents the discount rate that adjusts a future cash flow so that it is equal to the investment outlay. Like the PBT, the IRR is a "relative" indicator; therefore, a subjective threshold has to be defined for the investment economic evaluation (Tudisca et al. 2014).

Generally the NPV and the PBT are the most used indicators among the reviewed papers (around 40%), followed by the IRR. Industry decision-makers apparently have no tendency to use any one metric when analyzing the investment performance of a particular technology solution. Table 1 shows the frequency of use of the analyzed indicator for different application fields (i.e. households/services/public sector and industrial sector) and evaluated technologies (e.g. CHP plants, electric motors).

Table 1. Literature review summary: number of papers analyzed

Energy efficiency solutions	NPV and NPC	PBT	IRR
CHP	7 papers on production processes applications 3 papers on buildings applications	6 papers on production processes applications 3 papers on buildings applications	2 papers on production processes applications 2 papers on buildings applications
Heat pumps	11 papers on production processes applications 10 papers on buildings applications	5 papers on production processes applications 7 papers on buildings applications	3 papers production processes applications 3 papers on buildings applications
Inverter	3 papers on production processes applications		
UPS	3 papers on production processes applications	1 papers on production processes applications	
Compressed air	1 papers on production processes applications	2 papers on production processes applications	
Electric motor	3 papers on production processes applications	1 papers on production processes applications	

The empirical analysis

The following section describes an empirical analysis of Italian industrial firms seeking to reveal the most common criteria to evaluate energy efficiency investments. For this purpose, we carried out 130 interviews with individuals directly involved in energy efficiency projects. Table 2 shows the coverage of the different Italian industrial sectors by the companies interviewed and the main features of interviewed parties.

Table 2. Main features of companies interviewed

Industrial sector	**Number of companies interviewed [#]**	**Average annual turnover [€]**	**Market coverage [% of industry turnover]**	**Average annual energy bill [€]**
Food&beverage	20	1.060.000.000	19%	21.000.000
Textile industry	10	450.000.000	7%	9.000.000
Pulp&paper	18	395.000.000	35%	24.000.000
Chemical and Petrochemical	8	1.380.000.000	6%	30.000.000
Metallurgy	25	900.000.000	40%	56.000.000
Buildings materials	15	330.000.000	18%	25.000.000
Mechanical	34	1.720.000.000	19%	26.000.000

Source: ENERGY&STRATEGY GROUP

Table 2 shows that the sample mainly includes big firms, which are currently the most proactive with reference to energy efficiency investments, although the Italian industrial sector is mainly made of SMEs. However, the market coverage, expressed in terms of turnover, is pretty high, ranging from 6% to 40%

The Table 3 shows the main topics covered during the interviews.

Table 3. Topics of interviews

Topic #1	Description of the energy efficiency project implemented
Topic #2:	Description of the decision making process of energy efficiency projects. Steps to beginning an energy efficiency project
Topic #3:	Description of the evaluation methods for energy efficiency project economic viability assessment
Topic #4:	Description of implementation barriers for energy efficiency project implementation

All firms interviewed have already implemented some kind of energy efficiency project, regarding both the reduction of the energy consumption and the on-site energy production. The most common energy efficiency projects already implemented by the Italian industrial firms are old lighting systems replaced with emerging LED technology, improvements to compressed air systems, heat recovery from production processes, replacement of obsolete electric motors with more efficient ones (e.g. “IE3” class according to the Regulation EC No 640/2009) and installation of CHP plants.

Energy efficiency upgrades are often a facility’s internal initiative. External participants are occasionally involved, especially when highly specified knowledge is required. For example, a food&beverage firm asked an Energy Service Company to design, construct and manage a CHP plant on its premises. Typically, operation managers promote energy efficiency projects, while the Energy Management department supports the project’s planning and design phases while also securing top management approval for the project. In almost all cases, top management have final approval authority; less than 10% of interviewed parties indicate that Operation or Energy Managers have autonomous approval authority. As for project finance, almost all the companies interviewed have relied primarily on equity. Rarely did respondents seek bank loans or other third parties instruments.

All respondents use PBT to evaluate the economic feasibility of energy efficiency projects. Around 20% of the surveyed companies use IRR together with the PBT to evaluate such investments, while NPV is used quite seldom.

Even more interestingly, Italian industrial firms usually adopt a very tough threshold to evaluate the economic viability of energy efficiency investment, equal to 2-3 years. This is mainly because energy efficiency is currently seen as a secondary priority by decision makers within the firms (i.e. the Top Managers in almost all cases, as previously discussed), for which very short PBT are allowed. This represents the main barrier to energy efficiency investments by Italian industrial firms.

The survey clearly show a mismatch between decision-makers’ of energy efficiency investments. On one hand, Energy Managers usually understand the importance and the strategic value of energy efficiency investments and consequently they should be inclined to employ more compelling investment criteria. This may include some combination of proposing higher thresholds (for PBT-based or IRR-based investment evaluations), or introducing alternative methods to evaluate energy efficiency investments that consider the full economic impact of energy efficiency investments. On the other hand, however, Top Managers, which in almost all cases have the power and responsibility to decide about energy efficiency investments, are characterized by a different mindset with reference to energy efficiency.

The new methodology

The empirical analysis brings to light that companies use traditional methods (mainly PBT) in order to evaluate the economic viability of energy efficiency improvements, even though such indicators rely on very short-term returns that effectively penalize energy efficiency solutions. In other words, the energy efficiency market needs new criteria to estimate the economic viability of investments that entail energy and economic savings also in the medium and even long term.

Starting from this market need and inspired by the Life Cycle Assessment (LCA) criteria, we create a new index called “Levelized Energy Efficiency Cost” (LEEC) that considers total achievable savings accruing from an energy efficiency solution throughout its life cycle.

In particular, our new methodology consists in two main phases:

- PHASE 1: LEEC calculation
  The index represents the overall cost that the investor (customer of the energy efficiency intervention) has to incur in order to achieve a total volume (usually kWh) of energy saved. In other words, LEEC indicates the cost per kWh of energy saved thanks to the use of an energy efficiency solution in a specific context (productive process or building). In particular, the LEEC is defined according to the following formula:

$$LCEE\ (t) = \Sigma\ ([C_{pa;t} + CapEx_t + OpEx_t]\ /\ \text{Total energy saved}_t)$$

$$t = \text{project duration in years,}$$

The Table 4 explains each item of the formula

Table 4. Description of LEEC items

Item	Description
$C_{pa;t}$	This cost item includes the costs of the activities preliminary to the implementation of energy efficiency intervention, such as audit, design, planning, etc.
$CapEx_t$	This cost item considers the cost of purchase and installation of the energy efficiency solution (also considering eventual capitals obtained through third party financing)
$OpEx_t$	This cost item considers the cost of operation and maintenance of the energy efficiency solution (also considering eventual interest costs due to third party financing)
Total energy saved_t	This item considers the energy saved each year thanks to the use of the energy efficiency solution

- PHASE 2: LEEC comparison
  In order to establish an energy efficiency project's cost effectiveness, the index calculated in phase 1 must be compared to a benchmark value. In particular, our new methodology considers two benchmark values, each representing a distinct typology of energy saving:

  - Electricity-saving projects: the LEEC has to be compared to the cost of purchasing a kWh from the electricity system (i.e. energy retailers).
  - Thermal-energy saving projects: the LEEC has to be compared to the customer's current cost to locally produce a kWh of thermal energy.

  If the LEEC turns out to be lower than the benchmark value, the overall cost of the specific energy efficiency intervention is fully repaid by the overall achievable energy savings. In other words, the difference between the LEEC and the benchmark value represents the gain that the customer obtains for each kWh saved.

The application of LEEC

In order to test the effectiveness of our new methodology, we compared the economic viability of different type of energy efficiency investments. The comparison poses traditional methods of PBT against the LEEC index.

We started with Italy's most energy-intensive industries, as showed in the Table 5.

Table 5. Energy features of Italy's most energy-intensive industries

Industrial sectors	Annual electricity consumption [GWh/year]	Share of Italian industrial electricity consumption	Annual thermal energy consumption [GWh/year]	Share of Italian industrial thermal energy consumption
Metallurgy	20.641	21%	68.698	35%
Mechanical	25.235	23%	24.293	10%
Buildings materials	6.530	6%	41.508	24%
Pulp&paper	9.597	10%	18.687	8%

Source: Adapted from ENERGY&STRATEGY GROUP (2013)

Thanks to energy audits and information gathered through direct interviews with industry managers, we defined for each of the sectors mentioned above the energy features of a typical production process for the firms we have sampled (as shown in Table 6).

Table 6. Energy features of most energy-intensive productive process in Italy

Industrial sectors	Productive process	Electricity consumption	Thermal energy consumption
Metallurgy	Production of crude steel (Electric Arc Furnace - EAF)	350 - 800 kWh/ton	-
	Production of crude steel (Integral Cycle - IC)	100 - 200 kWh/ton	4.500 - 5.600 kWh/ton
Mechanical	Subcompact car assembly line	900 - 3.300 kWh/car	500 - 750 kWh/car
Buildings materials	Production of clinker	80 - 150 kWh/ton	800 - 1.200 kWh/ton
Pulp&paper	Production of paper	500 - 80 kWh/ton	800- 1200 kWh/ton

Source: Adapted from ENERGY&STRATEGY GROUP (2013)

Considering the production processes previously described, we decided to evaluate the economic viability of five different energy efficiency interventions, full-equity financed. The selection of the energy efficiency technologies that characterized the investment depends on:

- The energy features of the productive processes (e.g. consumption, intensity, temperature required, concurrence of thermal and electrical demand, etc.)
- The technical features of the energy efficiency solutions (e.g. reliability, modularity, performance, etc.)

The Table 7 shows the features of the energy efficiency investments considered in application of LEEC analysis.

Table 7. Features of energy efficiency investments evaluated

Industrial sectors		Energy efficiency solutions				
Name	Yearly production	Compressed air	Electric motor	Inverter	UPS	CHP
Metallurgy	200.000 tons with EAF and 200.000 tons with IC	Power: 0,5 MW Increase of efficiency: 10%	Power: 2,7 MW Increase of efficiency: 9%	Power: 1,6 MW Increase of efficiency: 20%	Power: 20 MVA Increase of efficiency: 5%	n.a.
Mechanical	300.000 cars	Power: 1 MW Increase of efficiency: 10%	Power: 3,5 MW Increase of efficiency: 9%	Power: 2 MW Increase of efficiency: 20%	Power: 200 MVA Increase of efficiency: 5%	Power: 20 MW Increase of efficiency: 30%
Buildings materials	350.000 tons	n.a.	Power: 4,8 MW Increase of efficiency: 9%	Power: 2,9 MW Increase of efficiency: 20%	Power: 6 MVA Increase of efficiency: 5%	n.a.
Pulp&paper	350.000 tons	Power: 1 MW Increase of efficiency: 10%	Power: 15 MW Increase of efficiency: 9%	Power: 9 MW Increase of efficiency: 20%	Power: 38 MVA Increase of efficiency: 5%	Power: 30 MW Increase of efficiency: 30%

Source: Adapted from ENERGY&STRATEGY GROUP (2013)

Considering the threshold value of 2-3 years for the PBT index (according to the survey previously described) and the benchmark value for the LEEC index of 10 c€/kWh for the electricity and 4,7 c€/kWh for thermal energy generation (prevailing Italian energy supply prices), Table 8 shows the effectiveness of our new methodology compared to the traditional one.

Table 8. LEEC [c€/kWh] and PBT [Years] methodologies results

	Energy efficiency solutions									
	Compressed air		Electric motor		Inverter		UPS		CHP	
Industrial sectors	PBT	LEEC[2]	PBT	LEEC[2]	PBT	LEEC[2]	PBT	LEEC[2]	PBT	LEEC[3]
Metallurgy	1-2	1-2	5-6	1,5-2,5	0,5-1	0,5-1	4-6	3-5	n.a.	
Mechanical	1-2,5	2,7-3,5	5,5-7	2,5-3,5	2-3	2-3	5-8	7-9	3-5	0,4-1
Buildings materials	n.a.		5-6,5	2,5-3,5	1-1,5	0,6-1	4-6	3-5,5		
Pulp&paper	1-2	1-2	4-6,5	2,5-3,5	0,5-1	0,5-1	3,5-5	2,5-3,5	3-5	0,3-0,7

The PBT index indicates that few energy efficiency investments would be economically viable. However, the comparison of LEEC index with the benchmark value proves the substantial economic feasibility of all energy efficiency solutions for each productive process.

Conclusions

Policy makers worldwide recognize energy efficiency as a means to guarantee an economic and environmental sustainable growth while offsetting climate and environmental threats. Nevertheless, there are still many opportunities for energy efficiency in all economic sectors, from industry to services to households. However, implementation of such improvements is often barred by the misapplication of investment feasibility measures.

The industrial sector presents some the of the largest energy efficiency opportunities. Empirical research involving 130 Italian industrial firms shows that, even though most have already implemented some energy efficiency investments, additional opportunities have been missed, mainly due to reliance on Pay-Back criteria, which typically imposes very low thresholds of 2-3 years. This is because industry managers perceive energy efficiency investments as “non-core” activities. Accordingly, low payback thresholds are imposed to offset the risk of diverting investment capital away from core business pursuits. An evaluation based on the impact over the entire lifecycle, i.e. taking into account all the benefits and costs accruing to the investor over the asset’s useful life, may positively impact on the diffusion of energy efficiency opportunities.

[2] Must be compare with the benchmark of electricity savings (10 c€/kWh)
[3] Must be compare with the benchmark of thermal energy savings (4,7 c€/kWh)

A literature review, involving 76 papers, confirms the prominent importance of the PayBack Time as the most used indicator to evaluate energy efficiency investments, irrespective to the technology evaluated or the sector analysed.

Therefore an innovative lifecycle-based indicator to evaluate energy efficiency projects is recommended as an alternative approach. The so-called Levelized Energy Efficiency Cost (LEEC) represents the overall cost that the investor has to incur in order to achieve each unit of energy saving (usually kWh). In other words, LEEC indicates the cost per kWh of energy saved by an energy efficiency solution in a specific context. An energy efficiency solution can be considered economically viable if the LEEC is lower than the cost typically paid by the same investor to buy or self-produce the same electrical or thermal energy unit (kWh). In other words, if the LEEC is lower than such benchmark value, it means that the overall costs of the specific energy efficiency intervention (i.e. cost for preparatory activity, capital expenditures and operational expenditures) are a value which in total is less than the cost of maintaining the technology which it replaces.

The application of the LEEC in different Italian energy-intensive industrial sectors (i.e. iron&steel, automotive, cement and pulp&paper) clearly shows that all the technologies evaluated in the different application fields are economically viable, while most of them would be rejected by a typical investor evaluating such investments through the PayBack Time with a 2-year threshold.

The empirical analysis suggests that a decisive shift – that can be even considered as a useful "cultural shift" - from traditional investment evaluation methods, like PayBack Time to lifecycle-oriented indicators like LEEC represents an opportunity to boost industrial demand for energy efficiency.

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