PROCEEDINGS

12th Italian LCA Network Conference

Life Cycle Thinking in decision-making for sustainability: from public policies to private businesses

Messina
11-12th June 2018

Edited by: Giovanni Mondello, Marina Mistretta, Roberta Salomone
Arianna Dominici Loprieno, Sara Cortesi, Erika Mancuso

Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Rete Italiana LCA

Life Cycle Thinking in decision-making for sustainability:
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convegnoretelca2018@gmail.com

Conference program

JUNE 11th, 2018 - Monday

08.30 - 09.00 **Registration to Italian LCA Network Conference**

09.00 - 09.30 **Italian LCA Network Conference - Opening ceremony**

Salvatore Cuzzocrea - *Rector of the University of Messina*
Augusto D'Amico - *Director of the Department of Economics*
Maurizio Cellura - *President of the Italian LCA Network*
Roberta Salomone - *Conference Chair*

09.30 - 11.00 **SESSION I** (in Italian language)
LCA, LOCAL GOVERNMENTS, AND CIRCULAR ECONOMY

Chairs: Maurizio Cellura – University of Palermo
Giuseppe Saija – University of Messina

EU Policies for ENERGY Research: the SET Plan and the new 2018-19 Horizon 2020 Work Program
Riccardo Basosi – *Italian Permanent Representative H2020 Energy EU Programme and MIUR Delegate in the SET Plan Steering Committee*

Life Cycle Assessment of electrochemical storage technologies
Marco Ferraro – *CNR-ITAE*

European Environmental Footprint methods: status update and future outlook
Michele Galatola – *European Commission - DG Environment - Sustainable Production, Products & Consumption*

The Accredia's experience in environmental conformity assessment, supporting LCA-based activities
Filippo Trifiletti – *General Director ACCREDIA*

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ENERGY AND BUILDING

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Marina Mistretta – Mediterranea University

Comparative LCA of renovation of buildings towards the nearly Zero Energy Building
Grazia Barberio – *ENEA*

Life Cycle Analysis of an innovative component for the sustainability in the building sector
Maria Laura Parisi – *University of Siena*

Life Cycle Assessment of building end of life
Serena Giorgi – *Politecnico of Milano*

ELISA: A simplified tool for evaluating the Environmental Life-cycle Impacts of Solar Air-conditioning systems
Sonia Longo – *University of Palermo*

A comparative study between a Prefab building and a Standard building for the characterisation of production and construction stages
Mónica Alexandra Muñoz Veloza – *Politecnico of Torino*

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Simone Maranghi – *University of Siena*

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14.00 - 15.00 Poster Session

15.00 - 16.30 **SESSION III**
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Roberta Salomone – University of Messina

Steps towards SDG 4: teaching sustainability through LCA of food
Nicoletta Patrizi – *University of Siena*

The blue water use of milk production in North Italy – a case study
Doriana Tedesco – University of Milan

Practitioner-related effects on LCA results: a case study on Energy and Carbon footprint of wine
Emanuele Bonamente – University of Perugia

Environmental impacts and economic costs of nectarine loss in Emilia-Romagna: a life cycle perspective
Fabio De Menna – University of Bologna

Grana Padano and Parmigiano Reggiano cheeses: preliminar results towards an environmental eco-label with Life DOP project
Daniela Lovarelli – University of Milan

Life Cycle studies in agrifood sector: focus on geographical location
Anna Mazzi – University of Padova

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Chairs: Grazia Barberio – ENEA
Andrea Raggi – University "G. d'Annunzio"

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Luca Ciacci – University of Bologna

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Cristian Chiavetta – ENEA

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Andrea Fedele – University of Padova

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Serena Righi – University of Bologna

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Anna Dalla Valle – Politecnico Milano

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Silvia Bobba – Politecnico Torino

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Marzia Traverso – RWTH Aachen University

Life cycle assessment applied to biofuels from sewage sludge: definition of system boundaries and scenarios
Serena Righi – University of Bologna

Analysis of a recycling process for crystalline silicon photovoltaic waste
Fulvio Ardente – European Commission - Joint Research Centre

Environmental comparison of two organic fraction of municipal solid waste liquid digestate's management modes
Federico Sisani – University of Perugia

Life Cycle Thinking for Food waste management alternatives, an experience in Costa Rica
Laura Brenes-Peralta – University of Bologna/Researcher Instituto Tecnológico de Costa Rica

The way towards sustainable policies: combining LCA and LCC for construction waste management in the region of Flanders, Belgium
Andrea Di Maria – KU Leven

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Giuseppe Tassielli – University of Bari "Aldo Moro"

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Paola Masotti – University of Trento

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Rosa Di Capua – University of Bari "Aldo Moro"

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Jonathan Schmidt – RWTH Aachen University

Bioplastics in designing beauty and home packaging products. A case-study from Aptar Italia SpA
Michele Del Grosso – APTAR Italia SpA

16.30 - 17.00 Tea break

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Moderators: Maurizio Cellura – University of Palermo
Bruno Notarnicola – University of Bari "Aldo Moro"

Methodological advancements and remaining challenges after 5 years of Environmental Footprint road field testing
Michele Galatola – European Commission - DG Environment - Sustainable Production, Products & Consumption

Life Cycle Thinking in the U.S. Public Policy
Sangwon Suh – University of California

Life cycle based environmental assessment of EU consumption
Serenella Sala – European Commission - Joint Research Centre - Directorate D – Sustainable Resources, Bio-Economy Unit (D1)

18.30 Bus transfer to Regional Museum

19.00 - 21.30 Guided tour of the regional Museum and Light Dinner

PREFACE

The 12th Italian LCA Network Conference (the 7th Italian LCA Network Association Conference) was held on 11-12 June in Messina (Italy), under the patronage of Ministry for Environment, Land and Sea Protection, SETAC Italian Branch, Municipality of Messina, ARPA Sicilia, AIDIC, AICARR, the Council of Sicily consultant associations of Engineers, the consultant associations of Engineers of Palermo, Agrigento, and Ragusa Provinces, and the consultant association of Architects of Trapani Province.

The conference focused on the role of the "Life Cycle Thinking" (LCT) approach as support to decision-making in the definition of sustainability strategies, thus supporting both public and private businesses in making more informed decisions.

Indeed, life-cycle information is considered crucial to guide policy decisions and business strategies in many contexts.

Policy makers have to promote sustainable consumption and production strategies to respond to national and international environmental challenges, by gathering baseline and future-oriented environmental impact information for market-oriented policies and developing strategies for resource efficiency and eco-design.

Private businesses have to improve efficiency to boost margins and competitiveness, while contributing to sustainability.

Thus, LCT and product sustainability aims to reduce their environmental and socio-economic burdens, while maximizing economic and social value.

The Italian LCA Network conference has become a representative venue for enterprises, public authorities, international academics and researchers in the LCT field in order to discuss, share, and disseminate innovative ideas and advancement on the LCT methodology and case-studies.

The papers published in the volume contribute to new approaches, methods and applications, in order to discuss developments, current policy progress and pathways toward sustainability.

The conference proceedings report 60 papers, which were presented at the conference, both in the oral and poster sessions, after a *double blind peer review* process, managed by the Scientific Committee.

The following topics were covered in the conference:

- Life Cycle Thinking methods and tools in public policies: experiences, limitations and perspectives.
- Life Cycle Thinking methods and tools in private businesses: experiences, limitations and perspectives.
- Life Cycle Thinking and Circular Economy: policies and practices.
- Life Cycle Thinking and the UN Sustainable Development Goals.
- Methodological developments of LCA, LCC, S-LCA and integrated Life Cycle Sustainability Assessment.

The last section includes the three papers awarded the 9th Edition of LCA Young Researcher Award, addressed to promote and disseminate the research activities of young researchers involved in the Life Cycle Assessment research activities.

The President of Italian LCA Network
Maurizio Cellura

ENERGY AND BUILDING

Comparative LCA of renovation of buildings towards the nearly Zero Energy Building

Cutaia L.[1], Barberio G. [1], Elmo G. [1], Longo S. [2], Cellura M.[2], Guarino F.[2], Gulotta T.M.[2]

[1]ENEA, Italy

[2] Università degli Studi di Palermo, Italy

Email: laura.cutaia@enea.it

Abstract

*The building sector is one of the key sectors to achieve the 20/20/20 targets of the EU as there is the potential to lead to significant energy savings reducing the EU's total energy consumption by 5-6% and lowering CO_2 emissions by 5%. One powerful mechanism to apply principle and criteria of nearly zero-energy buildings **(nZEB)**. This work, done in the framework of the agreement between the Italian Ministry of Economic development and ENEA on the "Research of electric system" (Ricerca di Sistema Elettrico), has the aim to evaluate the environmental impacts of the technological improvements needed for enhancing the performances of an average building to a nZEB (or at least in the direction of a nZEB), performing a comparative Life Cycle Assessment study. Data on building upgrading and energy consumption reduction come from a test case performed by Università degli Studi di Palermo.*

1. Introduction

Buildings are responsible for approximately 40% of energy consumption and 36% of CO_2 emissions in the EU and almost 75% of building stock is energy inefficient, while only 0.4-1.2% (depending on the country) of building stock is renovated each year. So, the building sector is one of the key sectors to achieve the 20/20/20 targets of the EU and to achieve reductions of greenhouse gas emissions in the residential and service sectors of 88% to 91% compared to 1990 by 2050. In particular, renovation of existing buildings can lead to significant energy savings, which could reduce the EU's total energy consumption by 5-6% and lower CO_2 emissions by about 5% (European Commission). Main directive, laws and strategies, at European and international level, have been promoted to foster the requalification and improve the energy efficiency of building (for instance Energy Performance of Buildings Directive and Energy Efficiency Directive of the EU Parliament). So building renovation and new buildings construction will require low amount of energy and this energy will come mostly from renewable sources, following the principle of nearly zero-energy buildings ***(nZEB)***. Improving the energy efficiency of buildings can also generate other economic, social and environmental benefits.

This work has been done in the framework of the agreement between the Italian Ministry of Economic development and ENEA on the "Research of electric system" (Ricerca di Sistema Elettrico - RdS) that foresee R&D activities for reducing cost of energy for end-users, boosting the quality of service provided, reducing impacts on environment and health of electric system and using energetic resources in a better way. The amount for the contribution for financing the RdS is defined by the Italian Authority for the Electric Energy, Gas and Water Service. Activities are planned every 3 years and subdivided year by year (from October to September). This work has been realised between October 2016 and September 2017, as second year of the three years 2015-

2017 and it is in the specific part of the project addressed to improving and studying energy efficiency and energy use in the building sector.

Aim of the study is evaluating the environmental impacts of the technological improvements needed for enhancing the performances of an average building to a nZEB (or at least in the direction of a nZEB) on their life cycle. Practical application of this kind of assessment is choosing technologies or technical solutions for improving performances of buildings towards a nZEB, with energetic and environmental load that doesn't overcome, over the life cycle, the reduction of consumption during the use phase. This work focus the investigation on environmental performance of a restored office building in two main scenarios: a medium upgrading and a high upgrading towards nZEB conditions, performing a comparative Life Cycle Assessment study on different geographical areas in Italy (North, Centre, South Italy). The focus of this paper is the South Italy (Palermo - Sicilia Region).

1.1. Building certification

Sustainability in building is defined as the control of impacts that the entire building process has on the environment and on the quality of life of users. The following figure shows the articulation of ISO standards on the theme of sustainable construction (Barucco, 2011).

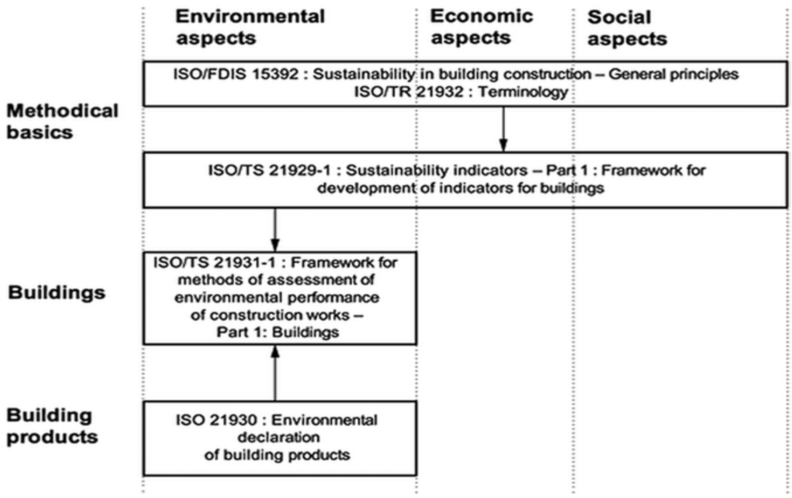

Figure 1: of ISO standards on the theme of sustainable construction

The EU regulation n. 305/2011 establishes conditions for the marketing of construction products, introducing the requirement of sustainable use of natural resources. Buildings shall be designed, built and demolished according to the sustainable use of resources. The reuse or recyclability of construction materials after demolition shall be guaranteed, as well as the use of environmentally compatible raw and secondary materials (Barucco, 2011).

The sustainability criteria of buildings are grouped in six thematic areas: - Efficiency in resource consumption; Limitation of the impact of construction materials, Optimization of the relationship between the building and the surrounding environment, Indoor comfort, Safety, maintenance and building management, and Ethical and social aspects.

Assessments of building sustainability with rating system methods, based on life cycle thinking approach, are used with the purpose give an environmental label to the examined building. Thanks to the certification and the label the overall sustainability performance of a building becomes “visible” to the end-users. The rating system methods work as an “environmental report” of the building, which is then evaluated according to different requirements grouped into classes with a minimum threshold. Final rating goes from a minimum - corresponding to the achievement of threshold values - to a maximum ranking level. The scoring methods depend on the type, size and destination of the building. For example, a requirement on energy performance can not include the same thresholds for both residential and commercial buildings, new buildings or major renovations (Bertagni, 2016).

The most important certification methods or protocols used in Italy are ITACA (Manfron, 2005), LEED (Bertagni, 2016) and BREEAM (Bertagni, 2016).

The **ITACA** Protocol has been adopted by many local administrations to promote sustainable construction through: regional laws, building regulations, calls for tenders, urban plans, etc. The Protocol is derived from the SBTool international evaluation model, adapted to the Italian environmental context. ITACA protocol has different versions, for the evaluation of residential, commercial, school, industrial buildings, etc. both for the new building and for the major renovations. ITACA divides the various requirements into five evaluation areas: Site Quality / Resource Consumption / Environmental Loads / Indoor Environmental Quality / Service Quality (www.proitaca.org).

The **LEED** protocol is managed by United States Green Building Council. There are numerous versions of LEED, valid for different types of buildings. LEED divides the various requirements in the following areas: Site Sustainability / Water Management / Energy and Atmosphere / Materials and Resources / Internal Environmental Quality / Design Innovation / Regional Priority. LEED provides different levels of performance (result of the sum of totalized points), ranging from basic level to Silver, Gold and - the highest level - Platinum.

The **BREEAM** protocol is developed by the British Institute Building Research Establishment. BREEAM also has numerous versions that adapt to different types of applications. BREEAM divides the requirements into classes: Energy / Health and wellbeing / Innovation / Land use / Materials / Management / Pollution / Transport / Waste / Water. Depending on the score obtained with BREEAM the certificates vary in five levels: Exceptional, Excellent, Very Good, Good, Sufficient.

The Directive 2010/31/EU set a limit on December 31st, 2020, when all new buildings are expected to be nZEB. The key points for a design aimed at creating a nZEB building include architectural planning aspects deriving from a detailed knowledge of the geographical context where the building will be located and from design aspects related to technological systems. All these aspects can be well connected in each phase using a certification protocol. In summary the guiding criteria for a nZEB building construction are (Sasso, 2006; Bertagni, 2016):

- The layout must favour the maximum level of sunshine and protection from the prevailing winter winds.
- Compact and lightly dispersed forms shall be preferred.
- The type of building must guarantee the same thermal/energy potential for every accommodation. Terraced and in-line buildings are preferred.
- The internal distribution must favour the positioning of staircases and bathrooms towards the North front and living spaces on the South front.
- Use of passive systems for thermal control and for proper ventilation (thermal mass, greenhouses and solar spaces, solar chimney, green roof, etc.).
- Introduction of shading systems for summer radiation control (vegetation, fixed or adjustable screens).
- Use of active systems for the reduction of residual energy consumption (solar thermal and photovoltaic collectors)
- The openings system must guarantee an excellent level of natural lighting inside each accommodation.
- A careful study of the thermal bridges must be carried out for subsequent elimination or attenuation where not possible.
- Each building must be constructed using eco-compatible materials and with excellent thermal insulation performance of the surface (thermal coat).
- Providing storm-water collection systems reducing water consumption.

2. LCA Study

The comparative LCA study was aimed to evaluate the environmental performance of an average “conventional” building upgrading towards a nZEB by means of new plants and substitution of materials and components. Data on upgrading and energy consumption reduction come from a Test Case analysed by University of Palermo.

2.1. Goal and scope definition

This work has been done in the framework of the RdS activities, financed by part of the fee for the electric energy consumed by Italian end-users, and the whole study will be published on ENEA website and on the CSEA (Cassa per i Servizi Energetici ed Ambientali) website.

Aim of the study is the evaluation of potential advantages coming from building retrofit actions for improving the energy efficiency respect to the potential impacts of upgrading itself in two retrofit scenarios (European Parliament 2010; Presidenza della Repubblica Italiana, 2011, 2015 and 2017): Scenario 1: medium level of retrofitting; Scenario 2: retrofitting to nZEB.

A comparative Life Cycle Assessment study has been carried out on different geographical areas and the focus of this paper is the South Italy (Palermo). The assessment method is Impact 2002+ and the tool used in the study is Simapro 8.5.

Functional unit is the whole retrofitted building, considering 1 year of activity. Concerning system boundaries of the comparative study, the following phases are considered (same phases are deleted in the comparison): new materials production and supply; building maintenance; retrofit actions (new processes and materials replacement, removal and disposal); use phase (energy consumption and production). A general description of retrofit actions and their lifespan is shown in the following table (more details in paragraph 2.2):

Table 1: Retrofit actions and related lifespan

Category	Scenario 1	Scenario 2	Lifespan (y)
Opaque wall	External insulation with EPS	External insulation with EPS	30
Transparent wall	Replacement of the existing fixtures	Replacement of the existing fixtures	30
Power generation	Replacement of the power generation and distribution system.	Replacement of the power generation and distribution system.	15
Lighting system	Replacement of the lighting system with LED	Replacement of the lighting system with LED	8
Renewable sources	NO	Solar thermal system	15
	NO	Photovoltaic system	20

2.2. Life Cycle Inventory

2.2.1 The examined building

The examined building is an office of the 70s located in Palermo (South Italy) with an area of 403.5 m^2, a net height of 3 m and a volume of 1,210.50 m^3. The layout of the building is shown in Figure 2.

The buildings structure is made of reinforced concrete. The external walls (U = 1.183 W/m^2K) include 27 cm of perforated brick blocks, with lime-based external plaster and gypsum internal plaster. The internal walls (U = 3.045 W/m^2K) are 8 cm of perforated bricks covered with gypsum and painting. The floor (U = 1.974 W/m^2K) is 17 cm thick, including bricks and ceramic slabs. The flat roof (U = 1.453 W/m^2K) has a structure made by reinforced concrete and brick blocks, mortar, screed and a clinker external floor.

With regard to the transparent surface, it is about 24 m^2 and represents about 12% of the external vertical surface. In detail, the building is equipped with metal frame and single-glazing windows (U_{frame} = 7.00 W/m^2K; $U_{glazing}$ = 5.75 W/m^2K), with no shielding and blinds.

The building lighting is made by ceiling lights with 34 fluorescent lamps (total power of about 2.3 kW).

Heating and domestic hot water (DHW) are provided by a 36 kW diesel boiler and an 80 l water storage. The heating system is equipped with cast iron radiators and insulated copper pipes for the distribution, except for office 4 that is equipped with a fan-coil system, due to the high heating loads. The heating system uses also further components such as distribution manifolds, electric pumps, valves, etc., while a cooling system is not available.

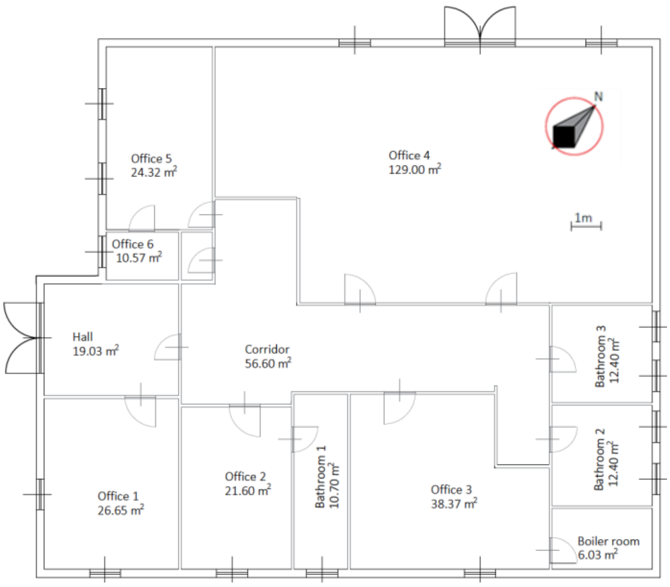

Figure 2: Layout of the building

The energy performance of the building was calculated with a simulation of the thermo-physical characteristics of the building, performed with an energy simulation tool certified by the Comitato Termotecnico Italiano. According to the Italian law, the energy class of the building is E (Presidenza della Repubblica Italiana, 2015).

2.2.2 The retrofitting scenarios

In order to improve the energy performance of the building and to move towards Scenario 1 and 2, some retrofit actions were identified and simulated. In detail, the two scenarios are based on the transmittance limits for both the glazed and opaque surfaces reported in (Presidenza della Repubblica Italiana, 2015) respectively for medium level of retrofitting and nZEB retrofitting.

In order to plan economically, technologically and operationally realistic interventions and to avoid demolition and subsequent replacement in the two scenarios, the retrofit actions of Scenario 1 were selected to be able also to ensure compliance with the nZEB requirements, except for the retrofit of vertical opaque walls. For Scenario 1, the following retrofit actions have been identified:

- External insulation of opaque walls by using EPS (vertical wall) and XPS (floor and roof) insulation panels;
- Replacement of the existing fixtures with PVC frames, with thermal break 12 mm air chamber (air) and 24 mm glass surfaces ($U = 2.98\ W/m^2K$);
- Replacement of the power generation/distribution system. In detail, the new air conditioning system is made by a reversible air/water heat pump

equipped with an inverter and a distribution system with fan coils. The DHW is produced by an electric water heater. Other components complete the system (copper pipes, distribution manifolds, electric pumps, etc);

- Replacement of the lighting system composed by 37 LED lamps with a total power of 1 kW.

To achieve the nZEB requirements (Scenario 2), considering the low transmittance of the roof and the floor, only an additional insulation of the vertical opaque walls was hypothesized (1 cm thickness of EPS). In addition, two renewable energy systems were introduced:

- A photovoltaic system of about 1 kW (8 m^2 and 5 PV modules) for electricity production;
- A solar thermal system (2.5 m^2 of flat collectors and a tank with a storage capacity of 180 l) for DHW production.

Table 2 shows the energy consumption during operation for the three scenarios, highlighting the energy savings during the operation due to the implemented scenarios.

For each retrofit action and for each scenario, the main materials and components needed for their implementation were estimated. As an example, Table 3 shows the materials required for retrofit the vertical opaque walls in both scenarios.

Table 2: Energy consumption of the building during operation

	Existing building	**Scenario 1**	**Scenario 2**
Electricity consumption (kWh/year)	13,330.38	7,059.22	5,676.83*
Diesel consumption (kg/year)	5,902.95	0	0
*1,327.52 kWh/year self-consumption			

Table 3: Materials required for retrofit the vertical opaque walls (kg)

Material	**Scenario 1**	**Scenario 2**
Mesh reinforcement	77.35	77.35
EPS	284.72	35.59
Adhesive	3,321.78	3,321.78
Water	2,524.56	2,524.56
External plaster	6,643.56	6,643.56

2.3. Life Cycle Assessment and conclusion

Main results from Life Cycle Impact Assessment are here presented: comparative results from normalisation and single score assessment and sensitivity analysis on different time horizons. From the single score assessment, that is the most aggregated result, is possible the identification of the worst performance and the scenario 2 seems to have greater environmental impacts respect to scenario 1 (Figure 3a). From the normalisation, most significant impact categories are, for both scenarios, respiratory inorganic, global warming and non-renewable energy (Figure 3b).

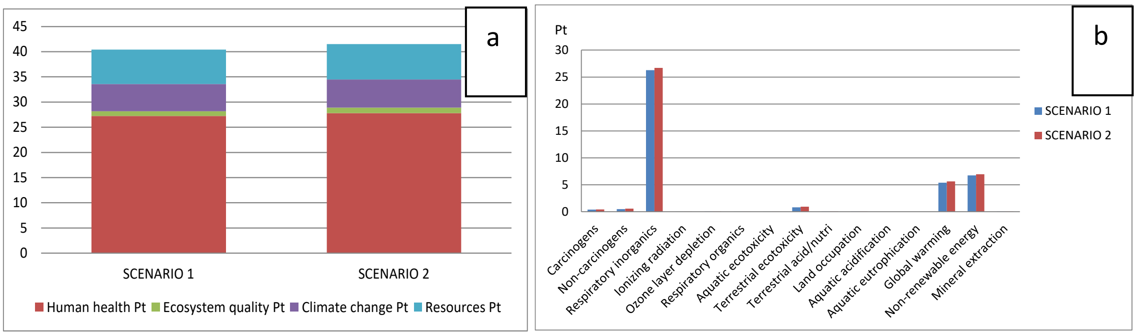

Figure 3: Comparative LCA single score (a) and normalisation (b) results (IMPACT 2002+)

Significant contribute to respiratory inorganic value is due to the opaque wall retrofit action; global warming and non-renewable energy are mainly related to energy consumption and transportation of materials supply, in particular for opaque walls retrofit actions and for new energy systems (photovoltaic and solar thermal systems). A sensitivity analysis has been performed to evaluate a time horizon of 20 years, in order to compare lifespan of the different technologies used as retrofit actions.

As final result it is important to underline that benefits achieved in building upgrading for enhancing energy efficiency not always reflect advantages on other environmental indicators. Further investigations on other R&D actions in technological improvements and further integrated analysis with other payback evaluation are needed in order to have a holist evaluation and to guarantee that energy saving options and policies are coupled to environmental and economic exploitations.

3. References

European Parliament, 2010, Directive 2010/31/EU of The European Parliament and of the Council of 19 May 2010 on the energy performance of buildings –EPBD (recast), Official Journal of the European Union. L 153/13, 18.6.2010.

European Commission, Building Stock Observatory project. Support for setting up an observatory of the building stock and related policies. Service contract n. ENER/C3/2014-543.

Presidenza della Repubblica Italiana, 2011, Decreto Legislativo 3 marzo 2011, n. 28, Attuazione della direttiva 2009/28/CE sulla promozione dell'uso dell'energia da fonti rinnovabili, recante modifica e successiva abrogazione delle direttive 2001/77/CE e 2003/30/CE. (11G0067) (GU Serie Generale n.71 del 28-03-2011 - Suppl. Ordinario n. 81).

Presidenza della Repubblica Italiana, 2015, Decreto interministeriale 26 Giugno 2015 – Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici.

Presidenza della Repubblica Italiana, 2017, Decreto interministeriale 19 giugno 2017 - Piano per l'incremento degli edifici a energia quasi zero.