International Energy Agency

Evaluation of Embodied Energy and CO_{2eq} for Building Construction (Annex 57)

Energy in Buildings and Communities Programme

July 2016

EBC is a programme of the International Energy Agency (IEA)

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Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 29 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes. The mission of the Energy in Buildings and Communities (EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA-EBC Programme was known as the Energy in Buildings and Community Systems Programme, ECBCS.)

The research and development strategies of the IEA-EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. The research and development (R&D) strategies of IEA-EBC aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five focus areas for R&D activities:

– Integrated planning and building design
– Building energy systems
– Building envelope
– Community scale methods
– Real building energy use

The Executive Committee

Overall control of the IEA-EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA-EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA-EBC Executive Committee, with completed projects identified by (*):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)

Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48: Heat Pumping and Reversible Air Conditioning (*)
Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51: Energy Efficient Communities (*)
Annex 52: Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis & Evaluation Methods (*)
Annex 54: Integration of Micro-Generation & Related Energy Technologies in Buildings (*)
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy & CO2 Emissions Optimization in Building Renovation
Annex 57: Evaluation of Embodied Energy & CO2 Equivalent Emissions for Building Construction
Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements
Annex 59: High Temperature Cooling & Low Temperature Heating in Buildings
Annex 60: New Generation Computational Tools for Building & Community Energy Systems
Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings
Annex 62: Ventilative Cooling
Annex 63: Implementation of Energy Strategies in Communities
Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles
Annex 65: Long Term Performance of Super-Insulating Materials in Building Components and Systems
Annex 66: Definition and Simulation of Occupant Behavior Simulation
Annex 67: Energy Flexible Buildings
Annex 68: Design and Operational Strategies for High IAQ in Low Energy Buildings
Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings

Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)

Summary

Introduction

By the time the Annex 57 was launched within the preparation phase, as part of the EBC's strategic plan for 2007-2012, it was said that, "LCA methods still need a great amount of research and international collaboration". The evaluation of energy consumption and related GHG emissions resulting from the use of buildings is becoming more accurate and being applied in the design of more energy efficient building envelopes, systems and regulations. This means that the percentage of the energy consumption as well as GHG emissions, namely due to carbon dioxide, methane, fluorocarbon gases (Reference 1 and 2) and other greenhouse gases, caused by stages other than the buildings use is increasing, and their evaluation and reduction will be more important in the future. It is clearly an appropriate time to further study the scientific basis of embodied energy and GHG emissions for building construction, and therefore the Annex 57 project was created and organized with an international team as part of IEA EBC.

Embodied energy and GHG emissions, originated from buildings construction and civil engineering, account for about 20% of the World's energy consumption and GHG. The embodied GHG emissions due to construction industries are approximately 5 to 10% of the entire energy consumption in developed countries and 10 to 30% in developing countries. Though the rates greatly vary depending on the country and region, the reduction of embodied energy and GHG emissions may have a tremendous effect on the reduction of global energy consumption and GHG emissions.

Annex 57 research reveals the actual situation of embodied energy and GHG emissions (referred to collectively in this document as "embodied impacts") as well as surveys their calculation methods and theoretical background. The methods and effects of reducing embodied energy and GHG emissions are shown through case studies.

Research issues

The importance of embodied energy and GHG emissions has been gradually recognized; however, the current situation is that calculation conditions (prerequisite, boundary condition, etc.) and calculation methods greatly vary depending on the country or researcher, and the results also differ widely. Further, there are very few documents or guidelines covering methods for reducing embodied energy and GHG emissions. Annex 57, in cooperation with individual countries, organizes various calculation methods, as well as provides a guideline for practitioners' use, in order to contribute to the reduction of embodied energy and GHG emissions.

Objectives

To find solutions for the research issues, the following specific objectives are focused upon:

Subtask 1 - Identify and clarify the methodological issues related to the definitions and fundamental concepts of embodied energy and GHG emissions, develop recommendations for tackling the identified methodological issues when it comes to the assessment of embodied energy and GHG emissions at the building level, as well as define the relationship between actors and targets related to embodied energy and GHG emissions for building construction

Subtask 2 - Collect existing research results concerning embodied energy and GHG emissions owing to building construction, analyze and summarize them into the state of the art.

Subtask 3 - Develop methods for evaluating embodied energy and GHG emissions resulting from building construction.

Subtask 4 - Use collected building's case studies to develop measures for the design and construction of buildings with reduced embodied energy and GHG emissions.

Subtask 5 - Develop a project summary report outlining the technical results of Annex 57 and disseminate research results and guidelines of Annex 57.

Official deliverables

Deliverables

Project report of Annex 57 (Subtask 1 –Subtask 4 reports)

Subtask 1 report; Basics, Actors and Concepts

Subtask 2 report; A Literature Review

Subtask 3 report; Evaluation Methods of Eembodied Energy and Embodied GHG in Building and Construction

Subtask 4 report; Recommendations for the reduction of embodied greenhouse gasses and embodied energy from buildings

Separate reports; Subtask 4: Case study collection report

Summary report of Annex 57

Overview of Annex 57 results

Guideline for designers and consultants-part 1

Guideline for designers and consultants-part 2

Guidelines for construction products manufacturers

Guidelines for policy makers

Guidelines for education

RE: All reports will be published electronically except the project summary report.

1. Summary of Annex 57 Project Report

1.1. General context

The importance of embodied energy and CO_2 is increasingly being acknowledged; however, the current situation is that calculation conditions and calculation methods vary greatly depending on the country or researcher, as do the results. Further, there are very few documents or guidelines covering methods for reducing embodied energy and greenhouse gas emissions. Annex 57, in cooperation with individual countries, reviews various calculation methods, and provides a guideline for practitioners' use, in order to contribute to the reduction of embodied energy and CO_2.

In general, the building sector is responsible for more than 40% of global energy use and contributes approximately with 30% of the total global Greenhouse Gas (GHG) emissions (Reference 2 and 3). Reductions in energy consumption and GHG emissions in this sector would make a significant contribution to the efforts of reduction of resource depletion and of global warming, (UNEP, 2009). Given also, the high construction rates in rapidly developing nations and emerging economies coupled with the inefficiencies of existing building stock worldwide, if nothing is done, the percentage of these contributions will likely continue to rise in the future. Under these circumstances, intensifying the efforts for conserving the resources and reducing the adverse effects to the environment becomes increasingly important in the building sector and decision makers are called to take much more vigorous actions towards this direction than they have done to date.

The work of Annex 57 was divided into four main subtask groups, each of which was responsible for a specific aspect, and each of which has authored a discrete report. The overview of these subtask group reports is given in the separate sections below.

1.2. Subtask 1: Basics, Actors and Concepts

This report emerged from the results of Subtask 1 (ST1) with the purpose to identify and clarify the methodological issues related to the definitions and fundamental concepts of embodied energy and embodied GHG emissions. At the same time, ST1 aims at presenting a comprehensive framework and transparent reporting format that can be used by design professionals and consultants for the determination, assessment and reporting of embodied energy and embodied GHG emissions at the building level. The intent is to ensure the appropriate interpretation and application of the embodied impacts assessment results.

Another objective of this subtask is to identify relevant actor/stakeholder groups and decision-making situations. There is a need for discussing and investigating whether and to what extent specific actions are required and how a stronger integration of embodied impacts into the decision-making processes can be achieved. In this sense, this report also analyses the tasks and roles of individual stakeholder groups, works out the peculiarities in connection with the demand for and supply of information related to embodied impacts and encourages the development of specific guidelines/recommendations for selected groups of actors.

1.3. Subtask 2 : A Literature Review

In the past, environmental impacts from building operation were the only issue to evaluate the environmental performance of building. In recent times however, more and more awareness relating embodied energy and GHGs has been increasing among environmental professionals, companies or other stakeholders as parameters to evaluate environmental impacts from building construction activities, especially since the 90s. The ST2 report communicates the results of literature review, aiming to find relations between subjects and calculation methods, giving support to a more concrete base for the development of Annex57's guidelines.

In the reviewed papers, researchers have set different range of system boundaries, the research period of assessment, and the calculation parameters depending on the purpose of the study. Considering that all methodologies revealed their own advantages and limitations, it's not appropriate to suggest one recommended, superior and suitable methodology for the assessment of embodied energy and GHGs (EEG). Therefore, the ST1, 3 and 4 guidelines will provide a clear framework for embodied energy and GHGs assessments of the building's lifecycle in order to compare and understand various results by different stakeholders and environmental professionals.

1.4. Subtask 3 : Scope of the assessment of energy and carbon emissions related building renovation measures

The subtask 3 (ST3) purpose is to present the different types of data sources and calculation methodologies to evaluate the EE and EG of a building, based on a common framework and a transparent reporting format. The ST3 is mainly constituted by three parts; quantification methods, databases and embodied energy and GHG evaluation. For quantification methods, the ST3 presents existing quantification methods of the assessment of embodied energy and GHGs (EEG) for buildings. Depending on the purpose and scope of analysis or evaluation, the required level of detail, the acceptable level of uncertainty, and the available resources, the primary datasets (original EE and/or EG data) are calculated using one of the following methods: Process-based life cycle assessment, Input-output (IO) analysis, or Hybrid analysis, which combines the other two methods. This section presents the technical elements, basis and procedure for calculating EEG impacts using these methods.

In the database section, ST3 shows the content related aspects of creating EE and EG databases. Six minimum requirements for embodied impact database (LCI data) are identified and discussed; materiality, consistency, transparency, timeliness, reliability and quality control. These requirements demand a professional operation and maintenance of LCA databases. In relation to this, several international and European standards are available for EEG for building and construction, which include; ISO 21930, ISO/TS 14067, ISO 21931, EN 15804, EN 15978, Product environmental footprint (PEF) etc. These standards differ in their requirements on modelling, in particular in the multifunctional allocation and recycling. This issue is discussed in detail in the database section in ST3 report.

The ST3 implemented preliminarily survey for EEG databases from the participants in Annex 57. The survey identified that an EEG database exists in most of participants Annex 57 countries but only as LCI data for building products. Thus, there is a need to convert the LCI data into embodied impact using impact assessments (GWP or total energy usage etc.). Process based LCA was found as the dominate methodology to quantify the EEG data. EEG databases did not cover the emerging products but was rather more focused on general products. EEG impacts from capital equipment are not included in the EEG data except for Japan, where a hybrid process is used with IO based methodology in the official EEG data, and for Switzerland, where capital equipment are part of the process based LCIs.

For the EEG evaluation of buildings, the ST3 shows the calculation of EE and EG emissions in the building design stage. As demonstrated in the illustrative example in the ST3 report (Chapter 5.2.2), the building structure and HVAC system have greatly contributed to the total embodied impacts (energy and GHG emissions), being responsible by 85% of the total embodied energy and GHG emissions. This example shows the importance of the material selection in a building structure. Additionally, fluorocarbons from the cooling system also could highly affect the total EG. This study illustrates as well that it is possible to reduce energy and GHG emissions of buildings through the smart use/selection of building materials in the design stage. In this section, the embodied impacts of key building materials, for typical residential buildings (detached) in different countries are compared.

The ST3 also discusses other important issues (transportation, on site emissions, waste management, imported products, etc.), which may have a high influence though often are ignored in the quantification of the building EEG.

Lastly, the subtask 3 shows a macro (country-level) approach to quantify the EEG emissions for the building construction industry using the World IO table. This could help policy makers to identify the key industries affecting building construction in their country in line with their own country's intended contribution to the Paris Agreement.

1.5. Subtask 4 : Recommendations for the reduction of embodied greenhouse gases and embodied energy from buildings

The Subtask 4 report describes the research conducted by Subtask 4 (ST4) of Annex 57 of the International Energy Agency implementing agreement. ST4 has collected a large number of case studies from the wider Annex 57 group, the majority quantitative but with the addition of some providing qualitative information. These have been inserted using a specially designed template format conceived to enable transparency and accurate comparisons between cases: the full collection of these completed templates is included in the accompanying Annex 57 ST4 Case Study Report. Supplementary data was collected through surveys and discussions with the Annex 57 participants, and through discrete literature reviews. The methodology used to first develop the template and then collect the case studies, and for the surveys and discussions, is described briefly in chapter 1 of the ST4 report, and in more detail in Malmqvist et al (2014).

Chapters 2 to 5 of the report then present a different focus, based on analyses of the data. The first analysis in chapter 2 considers the impact of methodology on the quantitative case studies collected, and explains how the different systems boundaries and calculation approaches affect the outcome. Chapter 3 uses the quantitative case study results to analyse the impact of different components and life cycle stages on the total embodied impacts. Chapter 4 further develops this to describe some strategies for the reduction of embodied energy and greenhouse gas emissions. Chapter 5 then considers the impact of different contexts on how and whether decisions to measure and reduce impacts might be practical.

The final chapter of the report summarises the conclusions from the previous four analysis chapters, and then makes some general recommendations.

The analyses of the case studies provided in the ST4 report have shown the wide range of numerical results emanating from current academic calculations of EEG. The numbers have been analysed to demonstrate the impacts of the chosen methodology, of the data accuracy, of the boundaries, and of the assumptions made in the calculations; these impacts explain the reasons behind many of the differences in these numbers. Using this knowledge, the case studies were then used to propose specific design strategies which can reduce the embodied impacts of buildings, the contexts in which the decisions to measure and reduce EEG of buildings may be taken, and the responsibilities of different stakeholders for reducing embodied impacts under different circumstances.

The use of the case study template was, to our knowledge, a unique approach to gathering diverse data from a wide number of academic participants. Each case study was based on a more extensive publication, including peer-reviewed journal and conference papers or postgraduate dissertations. The collection of the case studies, and their careful analysis through four different approaches, has produced an important body of work, as contained within this report and the accompanying case studies report. This will push forward the understanding of the extent of embodied impacts of buildings, and of the methods by which we can reduce them.

There is one appendix report to the ST4 report:

- Case study collection report with around 80 case studies from 11 countries.

2. Summary of Guidelines

2.1 Guideline for Designers and Consultants – part 1

Unfortunately, there is still no consensus on exactly how embodied energy and GHG emissions should be defined, calculated and assessed. Different assumptions and boundary conditions are used which leads to widely differing results. Undertaking such assessments is not as straightforward as it may seem and without a standard methodology, agreed rules and available data, clients cannot be assured of consistent and evidenced results.

In this guideline, a basic understanding about the assessment of embodied impacts at the building level for participants in the building industry is established, targeting particularly design professionals and consultants. The group of design professional and consultants includes architects, engineers and quantity surveyors among others.

This publication is part of a series of guideline publications targeted to specific groups of actors working within the construction industry (construction product manufacturers and policy makers) and the education sector (educators).

While detailed information on basics, as well as background information on system boundaries and indicators is available in the ST1 report "Basics, Actors and Concepts", the aim of this guideline document is to translate those results into more comprehensive and easily digestible recommendations and supporting information for designers and consultants.

The main objectives of the guidelines are:

- to inform designers about the importance of integrating embodied impacts considerations into the design and decision-making processes
- to help them achieve this as early as possible in the design process and in the most transparent way as possible.

In particular, this guideline document:

- explains the role of this stakeholder group in the information flow and supply chain
- provides an understanding on how an assessment of embodied impacts can be integrated into the typical design process
- provides specific guidance on how to calculate, assess and report embodied impacts
- provides knowledge and recommendations on which standards, datasets and tools to use depending on the availability and transparency

Acquiring a complete understanding of both operational and embodied impacts allows design teams to create the best possible design solutions and specifications for a low energy and emissions building. This guideline document ensures a better understanding of the assessment of embodied impacts being part of an integrated design process.

2.2 Guideline for Designers and Consultants – part 2

This second part of the guideline is also targeted specifically to design professionals and consultants and should be seen as a supplement to Guideline for Designers and Consultants – part 1. However, the aim of this guideline is to communicate and illustrate the key design strategies and illustrate their potentials for reducing embodied energy and emissions through the use of case study examples.

The guideline gives a brief introduction to designers and consultants about how the life cycle approach and evaluation of EEG can be integrated in the design process. This is illustrated in the second half of the guideline through selected examples from the 80 international Annex 57 case studies. The reader of the guideline can refer to the ST4 report which includes detailed analyses of the 80 cases studies. The aim of this guideline is to translate those academic and technical results into a more easy to understand series of illustrated recommendations for designers and consultants.

Four main design strategies are highlighted:

1 Substitution of materials:
   - Natural materials
   - Recycled & reused materials and components
   - Innovative materials
2 Reduction of resource use
   - Light-weight constructions
   - Building form and design of layout plan
   - Design for flexibility and adaptability
   - Low maintenance need
   - Design for service life extension
   - Reuse of building structures
3 Reduction of construction impacts
   - Reduction of construction stage impacts
4 Design for low end-of-life impacts
   - Design for disassembly
   - Design for recyclability

To conclude, the guideline discusses and illustrates different design and construction strategies focusing on reducing the embodied energy and emissions. However, the relationship between operational energy and embodied energy also has to be taken into account. For example, a material with a low insulation value has low embodied energy, but can potentially result in high operational energy and vice versa. These relationships need to be taken into account at an early design stage, because decisions during this phase have the greatest potential for minimising the whole life cycle energy.

2.3 Guidelines for Construction Products Manufacturers

This guideline is targeted specifically to construction products manufactures. The aim is to raise awareness on the subject of embodied impacts in relation to construction products, to present the starting points for the integration of embodied impacts assessment into the continuous improvement of production-related processes and product-related characteristics and information. One additional goal is to provide access to related guidance, data, information sources and assessment tools respectively. This guideline is specifically intended for use by small and medium-sized manufacturing enterprises (SMEs) seeking to improve their market competitiveness usually hindered by lack of resources and limited access to information.

The purpose of this guideline is to improve the understanding and management of embodied impacts of construction products and related primary raw materials across the construction product-manufacturing sector. In assistance of the SMEs in the construction products industry this guideline document provides:

a. methodological guidance for a simplified calculation and assessment of embodied impacts

b. recommendations to improve the production and procurement processes as well as related environmental product information

c. options for the declaration of environmental product information, in addition, it is indicated which relationships exist between investigating embodied impacts and creating an environmental claim, such as e.g. an Environmental product declaration (EPD).

Since the first oil crises in the 1970’s operational energy efficiency has become an increasingly important aspect of the design of buildings, as well as a subject of legislation respectively. As a result, the operational energy and related operational impacts of new buildings have decreased considerably since that time. Figure 1 pictures schematically the ratio between the operational impacts and the embodied impacts due to the erection of a building till it´s end of life (EoL). It can be noted that embodied impacts are gaining more and more importance due to the additionally added building products.

Specifically, in this document, the term “embodied impacts” refers only to the primary energy consumption and the adverse effects on the climate resulting from greenhouse gas (GHG) emissions that arise in the life cycle of construction products due to their production, installation into the building or construction works, maintenance and end of life; the so called embodied energy and embodied GHG emissions. These have a great influence on the embodied impacts for building construction in connection with the use of resources (in this case energy resources) and the adverse effects on the environment (here global warming potential - GWP).

It can be seen that over the life cycle of building embodied impacts can arise in all life cycle stages. Construction product manufacturers have a significant influence from raw material supply to manufacturing process over the building use phase and end-of-life and related recovery, reuse, recycling potential respectively. In contrast to other aspects the embodied impacts are directly linked to a particular building product but cannot explicitly be recognized as such, wherefore the construction product manufacturers need to pay special attention to them.

In this guideline, essential results of the Annex 57 are summarized and specific recommendations are presented, accompanied also by supporting information. Specifically, construction product manufacturers are strongly advised to inform themselves concerning the applicable methodological guidance, the recommendations given to improve their production and procurement processes as well as related environmental product information.

2.4 Guidelines for Policy Makers

This document is the deliverable "Guidelines for policy makers", developed within the Subtask 1 of IEA - EBC Annex 57 "Evaluation of EE and Greenhouse Gas Emissions for Building Construction". It also includes guidelines for including EE and EG considerations into the procurement process.

The main goal of Subtask 1 is to clarify the connections between actors and targets related to EE and carbon for building construction. Building EE and EG are affected significantly not only by the construction methods adopted, but also by the energy efficiency of the material production processes and by the energy generation mix.

In such a context, the guidelines for policy makers aim towards informing about EE and EG in the building sector, give recommendations about standardization of methodological principles and technical data requirements, as well as guidance and tools to support planning.

These guidelines can provide an insight to policy makers on the main issues related to embodied energy (EE) and embodied GHG (EG) in building construction, having as final aim a wide integration of EE and EG assessment into local policies. The main objectives of the guidelines are:

- To inform about the importance of EE and EG (referring to all the contributions required during the production and end-of-life of a building, opposed to the "use" of the same building), in relation to energy consumed in building operation, considering them in the context of the life-cycle environmental impacts;
- To inform and support the planning, design and assessment of policy instruments and schemes;
- To provide insights to policy makers about the main tools aimed to push the market towards low EE and EG building design.

In particular, this report:

- provides definitions of energy use, EE and EG;
- assesses the state of art of EE and EG in buildings;
- examines the importance of measuring and managing EE and EG in building sector as allowable solution to reduce the GHG emissions;
- considers the importance of the life-cycle perspective in building energy efficiency;
- provides guidance for policy makers on EE and EG in buildings, in terms of elements to include in legislation. Policy makers can confirm their policies by tracing items in suitable checklists.

Clearly there is a role for every stakeholder in the reduction of EE and EG of buildings. National and international policy makers should include EE and EG in compulsory regulations for buildings, in order to involve significant targets on the behavior of different actors of the building sector.

Finally, the whole discussion reported in these guidelines is summarised in the following final synthesis table, including the most relevant facts highlighted in the document and the most relevant challenges policy makers would need to face when dealing with the topics of embodied energy and GHG in buildings.

KEY MESSAGES					
1.	The consistency of measuring EE and Ec_{eq} must improve.	**2.**	Calculation should focus on major structural elements with the notion that granularity can be adressed at a later date.	**3.**	Design teams must be challenged to come up with innovative solutions that adress Embobied Carbon.
4.	Closed loop systems should be promoted so to maximise resource efficiency and lower EE and Ec_{eq} (i.e. new build should be designed for re-use).	**5.**	It is unlikely that legislation will address embodied carbon in a sufficient manner in the near future. In light of this industry should lead.	**6.**	The focus for reducing embodied carbon should be on every day builds rather than iconic ones.
7.	OE and OC should be maintained as priority. Embodied and operational energy and carbon are not conflicting issues, but they should be dealt with in tandem.	**8.**	Data should be trasparent and openly available across the industry.	**9.**	Better benchmarking and data sources are required.
10.	A business case for reducing EE and Ec_{eq} is needed.	**11.**	EE and Ec_{eq} modelling does not have to be overly complicated to be useful.	**12.**	Stronger links between researchers and practitioners should be forged.
13.	EE and Ec_{eq} savings made now are important and will help to offset climate change.	**14.**	Architectural approaches exist that can reduce both embodied and operational energy and carbon.		

2.5 Guidelines for Education

This guideline is targeted especially to educators, teachers at different levels of education (primary schools, secondary schools, universities etc.) and to all other specialists involved in the education and dissemination area. The aim is to bring basic information on the importance of consideration of embodied impacts (embodied GHG emission and embodied energy) and to provide ideas and basic principles for education at different levels and different types of education process.

This guideline is based on the work and results of IEA EBC ANNEX 57 “Evaluation of Embodied Energy & Embodied GHG Emissions for Building Construction”.

This publication is a part of a series of guideline publications targeted specific groups of actors working in the education system.

Several practical approaches on how to reduce the environmental impacts can be found:

a) Sustainable design

Sustainability should be a visible part of the educational environment. School building itself should serve as a good example of sustainable building (within all life cycles) with visible solutions focused especially to energy and CO_2 footprint reduction. For instance, this can be achieved through the following:

- integration of living roofs;
- planting within the building;
- low-embodied energy and sustainable timber construction, and the
- use of renewable energy technologies. (OECD, 2010)

Development of new school buildings should be targeted for zero carbon concept solution of buildings.

b) Reduction of impacts from operation

Schools should encourage:

- reducing emissions from energy use in school buildings;
- reducing emissions from school procurement and waste;
- reducing emissions from school travel and transport. (Departement for children, 2009)

c) School procurement

Procurement of goods and services represents a large proportion of schools’ carbon footprint. The impact can be lowered by the help of a “Strategic framework” (Department for children, 2009), including

- strategic commitment;
- supply chain engagement;
- specifications of goods and services (available tools that allow to procure low carbon goods and services);
- product choice and labelling (e.g. source local food);
- accreditation of suppliers;
- product market development; etc.

d) Pupils involvement = behavioral change

Pupils and staff are involved in monitoring energy and waste around the school and regularly visit other schools, colleges and community groups to present their environmental work and encourage others to follow their example. (Department for children, 2009).

This approach includes:

- practical projects around the school;
- monitoring and reporting (energy, waste);
- setting targets for energy reduction.

As a consequence children can influence other members of their families (parents, grandparents and other relatives and friends) to change their pattern of life.

e) Inter-school collaboration

f) Involvement of local authority professionals

Summary & Outlook

Various actors in the building and construction industry have recently recognised the growing importance of embodied energy (EE) and embodied greenhouse gas emissions (EG). However, a significant, and still considerably untapped, opportunity to limit these impacts along with the operational impacts of buildings remains. However, the embodied impacts are important and indispensable aspects of the overall performance and sustainability of construction works and thus, their consideration and calculation should become the norm worldwide.

Towards this direction, Annex 57 identified key actor/stakeholder groups influencing embodied impacts along the building supply chain and investigated whether and to what extent specific actions are required. Additionally, Annex 57 investigated how to achieve a stronger integration of embodied impacts into the diverse decision-making processes. As a result, actor-specific guidelines were developed.

Besides that, Annex 57 investigated the transition of the existing experiences of dealing with "embodied energy" to the newest concept of “embodied GHG emissions” and made a clear distinction between the latter and stored carbon. At the end, as a result of this analysis, recommendations for uniform definitions were developed and a basis for the description of system boundaries was provided. For the first time, such an analysis was used as a basis to declare and classify diverse case studies from different countries in an overall system. Finally, the necessity to improve the transparency and quality of data for construction products and assessment results for buildings was identified and analysed.

Operational and embodied impacts work hand in hand**,** and therefore they should be combined to form an overall approach that would have, among others, consequences for the further development of the EPBD in Europe. The relationships and interdependencies between operational and embodied impacts should be analysed in a future project. Additionally, extending the scope of GHG assessments to include embodied GHG in addition to operational GHG facilitates the determination and assessment of a carbon footprint for the building. Finally, more than ever EEG targets and benchmarks should be defined to assist the design process.

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