ANNEX 57 – EVALUATION OF EMBODIED ENERGY AND CARBON DIOXIDE EMISSIONS FOR BUILDING CONSTRUCTION

Tatsuo OKA
DEN201, 20 Arakicho, Shinjuku, Tokyo, Japan, okatatsuo@e-mail.jp

Takao SAWACHI
Building Research Institute, Tachihara 1, Tsukuba, Ibaraki, Japan, tsawachi@kenken.go.jp

Summary

The total energy consumed by a building during its whole life cycle includes both embodied and operational energy. Embodied energy is 'embedded' in construction materials during all production processes, on site construction and demolition and final disposal, while operating energy is consumed in operating and maintaining the internal environment of a building. The accuracy of operational energy use and related carbon dioxide (CO_2) emissions prediction methodologies has been improved in recent years, resulting in more energy efficient building designs. As operational energy use is so reduced, the embodied energy and CO_2 emissions become proportionally more significant.

The project (IEA ECBCS, Annex 57, 2012–2015) is investigating methods for evaluating embodied energy and CO_2 emissions of buildings, to develop guidelines that contribute to practitioners' further understanding, and to find better design and construction solutions for buildings with less embodied energy and CO_2 emissions.

Keywords: IEA ECBCS, Embodied energy, Embodied CO_2, Data base, Case study

1 Introduction

1.1 Importance of embodied energy and CO_2 emissions

The evaluation of energy consumption and related carbon dioxide (CO_2) emissions due to the use of buildings is becoming increasingly accurate and is being applied in the design of more energy efficient building envelopes and systems. As such, the importance of energy consumption and CO_2 emissions due to stages other than the use of buildings is increasing, and, consequently, the methods used to estimate energy consumption and CO_2 emissions will become increasingly important. Therefore, the scientific basis of the embodied energy and CO_2 emissions for building construction should have been investigated by organizing the new Annex and an international team for the IEA ECBCS program.

1.2 Scope

The Annex 57 deals with methods for evaluating embodied energy/CO_2 of buildings in order to develop guidelines that contribute to improved understanding of evaluation methods and help developers to find better design and construction solutions for buildings with reduced embodied energy/CO_2. ***Fig.1*** shows a rough estimation of the total CO_2 emissions in each country and the fractions of embodied CO_2 due to building construction and civil engineering. The green area indicates global embodied CO_2.

Fig.2 shows total annual CO_2 emissions in Japan estimated by IO (Input-Output) analysis. Embodied CO_2 is 19.2 % and the operation of buildings, 23.2 % respectively. In particular, fractions of embodied CO_2 are higher in developing countries and even often exceed the building operation energy.

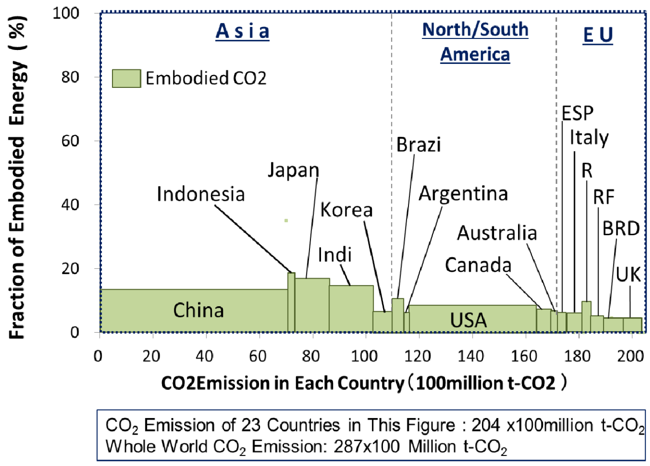

Fig. 1 *Relationship between total CO_2 emissions in each country (horizontal axis) and fraction of embodied CO_2 (vertical axis).*

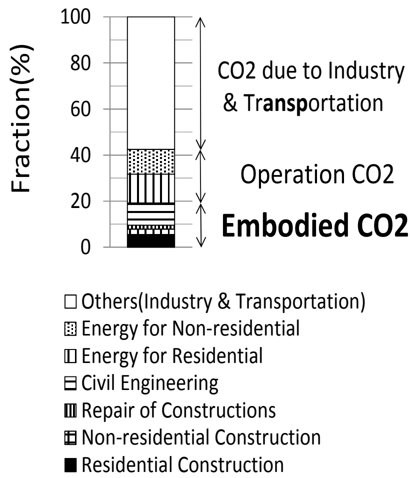

Fig. 2 *Fraction of Embodied CO_2 in Japan (1.29 Billion t-CO2, 2005)*

2 Research areas of Annex 57

2.1 Basics

[1] Actual trends and activities related to embodied energy/CO_2 in the world
[2] Demands related to embodied energy/CO_2 by various groups of actors (survey)
[3] Integration of embodied energy/CO_2 into decision making process (survey)

2.2 Literature Survey

[1] Definition of key concepts and technical terms of embodied energy/CO_2
[2] Characteristics of existing databases of embodied energy/CO_2 intensities and tools to quantify building materials and components
[3] Current trends and future perspective

2.3 Evaluation methods for embodied energy and CO_2 emissions

[1] Methodology for databases of the embodied energy/CO_2 intensities and quantifying volumes of building materials, components, equipment, and other elements
[2] Recommendations on how the databases and methods should be used

2.4 Design and construction methods for buildings with low embodied energy and CO_2 emissions

[1] Options for design and construction to reduce embodied energy and CO_2 emissions
[2] Use of recycled or reused materials and components
[3] Life of building and its prolongation
[4] Retrofit with low embodied energy and CO_2 emissions
[5] Consideration of GHGs other than CO_2
[6] Case studies and best practices

3 Deliverables

[1] The state of the art for embodied energy/CO_2 due to building construction.
[2] Guidelines of evaluation methods for embodied energy/CO_2 due to building construction.
[3] Guidelines of design and construction methods for buildings with low embodied energy and CO_2 emissions.
[4] Project summary report summarizing the technical outputs from Annex 57

4 Some remarks in Annex 57

4.1 Database and the calculation method

The databases of embodied energy/CO_2 for building materials compiled by ISO or IO analysis are widely provided as tables for energy consumption and CO_2 emission factors. ISO tends to show the factory efficiency more than the embodied energy/CO_2 due to building construction. Although databases complied by the IO analysis seem to be more relevant, the number of building components is much less than that of the ISO based database from a practical standpoint. ***Tab.1*** shows the fraction of embodied CO_2 of building components in the gate factory, which is the final factory of the supply chain. The energy consumption in the gate factory is small compared with the whole embodied energy/CO_2, and therefore shows that the embodied energy/CO_2 of input materials into the gate factories should be estimated accurately.

Tab. 1 *Fraction of Energy Consumption in Gate Factory*

Industrial sector	Energy consumption in industrial sectors (%)			
	Cement product	Hot rolled steel	Air con	Non wooden building
Cement	32.40	0.00	0.10	5.50
Cement products	18.70	0.00	0.00	0.40
Pigiron	11.40	78.90	21.60	27.40
Hot rolled steel	0.00	5.90	1.20	2.00
Air con	0.00	0.00	5.90	0.00
Non wooden building	0.00	0.00	0.00	6.40
Electricity	15.40	6.20	33.80	16.00
Road freight transport	2.10	0.40	2.30	4.00
Transport (passengers)	1.70	0.30	4.00	9.90
Total	82.50	91.80	68.90	71.50

4.2 Rough estimation of embodied CO_2 of the buildings

Approximate estimation was made to find significant factors to reduce embodied energy/CO_2. ***Fig.3*** shows the reduction of embodied CO_2 by prolongation of building life in Japan. Since 30 % more quantity of steel is necessary to prolong the building life, 21 % of whole embodied CO_2 a year can be saved.

60 % of global warming is due to CO_2 and 14 %, Freon gases which are used in insulation boards in some countries and electrical refrigerators. ***Fig.4*** shows the impact due to insulation boards involved Freon gases, which shows the global warming impact by Freon gases is enormous. ***Fig.5*** also shows CO_2 equivalent of refrigerators in case where Freon gases are not recovered. It shows recovery measures are absolutely necessary to reduce embodied CO_2. ***Fig.6*** shows waste of building/construction materials in Japan. Most of materials like concrete are recycled by reusing in different industrial sectors.

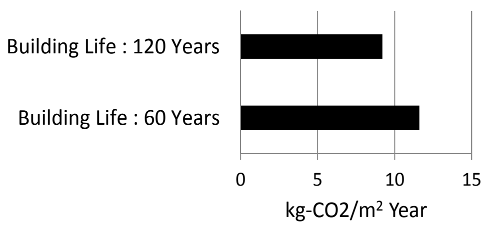

Fig. 3 *Reduction of Embodied CO_2 due to Prolongation of Building Life*

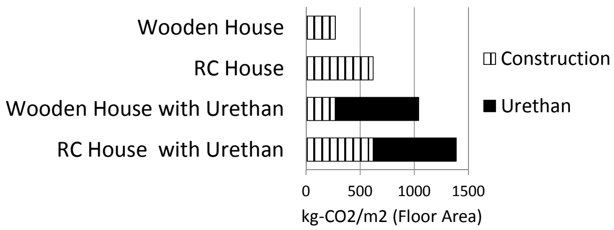

Fig. 4 *GWP due to Freon Gas in the Insulation Material*

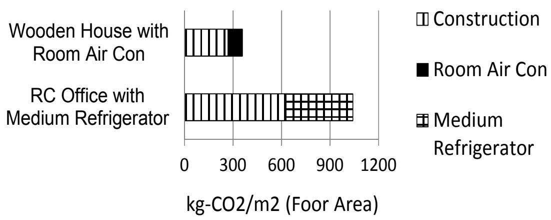

Fig. 5 *GWP due to Freon Gas in the Refrigerator*

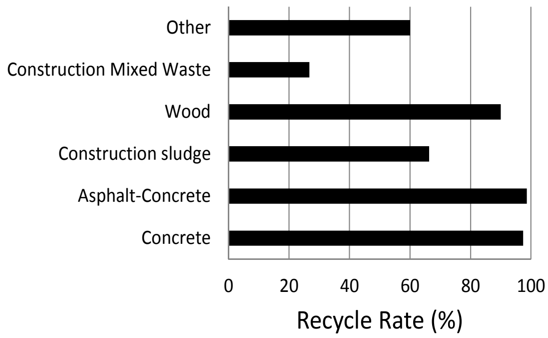

Fig. 6 *Recycle Rate in Japan (Steel and aluminium are 100% recycled)*

5 Conclusions

The proposal of Annex 57 and the significant measures to reduce embodied energy and embodied CO_2 due to building construction were described.

6 References

[1] www.ecbcs.org/annexes/