InDeWaG

INDUSTRIAL DEVELOPMENT OF WATER-FLOW GLAZING SYSTEMS

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D 7 – 7 : REPORT ABOUT THE MARKET ANALYSIS, THE LIFE-CYCLE ASSESSMENT AND THE TOTAL COST OF OWNERSHIP CALCULATION	
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NATURE OF THE DELIVERABLE		
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SUMMARY	
Keywords	Life Cycle Assessment
Abstract	Final report about the market analysis, the Life Cycle Assessment and the Total Cost of Ownership.

HISTORY			
Author	**Date**	**Related to WP/Task**	**Comments**
Sina Hahn, Christoph Maurer			First version
Sina Hahn, Christoph Maurer, Simon Frederik Haeringer	14.8.2020		Revised and improved version according to reviewers comments

1 Content of Deliverable

The Deliverable is a report about the market analysis, the Life Cycle Assessment and the Total Cost of Ownership calculation. The results of those activities can be used for marketing and developing the business plan.

2 Results and Discussion

The aim of work package 7 was to identify and analyse market potential, costs and environmental impacts of the fluid-flow glazing (FFG). Deliverable 7.7 gives an overview of the results and how they are connected.

2.1 Market analysis

The FFG façade is seen as a promising technology for reducing the costs for nearly zero energy buildings (nZEB). The market for nZEB in Europe is currently a small fraction of the construction market but in the near future (in the next 4-5 years) it is expected to undergo significant change due to the adopted regulatory changes underlined in The Energy Performance in Buildings Directive (Directive 2010/31/EU) and the Energy Efficiency Directive (Directive 2012/27/EU).

The curtain wall market is the potential segment where the FFG façade is expected to succeed. Combining the features of different systems like solar collectors, insulation, shades etc. the FFG is expected to bring significant cost advantages compared to conventional curtain walls and other existing glass façade solutions. Its transparency and similarities with the glass façades give the architects the freedom of incorporating the FFG in a variety of building types without losing the aesthetics of a clear glass.

As the demonstrators will be assembled in Bulgaria and Spain, those will be the countries where the market penetration of the final product is expected to happen in the initial market stages. The easy access to the demonstrators and the possibility to introduce it to various stakeholders will facilitate the realization of the business potential of FFG. Also, in those countries the higher rate of media coverage is expected to contribute for raising the public awareness in the field of innovative energy efficient technologies and to attract the attention of the construction industry.

The total annual construction of curtain walls in Bulgaria sums up to 67 000 square meters. It must be considered that some of these quantities are exported as a semi-finished product, so the number of the real usage in Bulgaria should be decreased with an average of 10 % leading to a final total of approximately 60 000 m2 used in Bulgarian projects. Every project has different price according to the specifics. However an average number of 450 BGN/m^2 (230 €/m^2) could be used for standard curtain wall executed on project in Bulgaria. Hence, approximately the total spending on curtain wall projects in Bulgaria is on average 13.8 million €/year.

The expenditures for new buildings in Germany are ten times higher than those in Bulgaria. An approximate amount between 7 bn € and 10 bn € was spent for construction of new office buildings annually in the period 2012 - 2014. The newly constructed offices with curtain wall constitute significant part of the new office buildings. On average 400 million € to 1.3 billion € are expected spending's for curtain wall projects in Germany including construction of new buildings and renovation of old façades. Due to the weighting in terms of population, Germany is considered to be one of the "key" countries in the EU-27. The improvements in thermal performance of buildings are largely driven by the series of regulations that have been in place since 1977. The U-values have improved over the last 40 years.

Germany has the greatest number of offices, covering the largest floor area out of all the EU- 27 countries. The energy efficiency of building property is a factor of growing importance in Germany. Energy savings and a switch to renewable energy supplies are high on the agenda for many home owners, renters and policy makers. Germany as a nation leading in technology and industry plays a pioneering role here. Moreover, 40 % of the end energy consumption in Germany is used for heating and hot water, therefore FFG technologies appears as an attractive option for realization of energy savings on site. Germany due to its stable economic and social situation and the well-established, steadily growing construction market could be viewed as the best of the three countries for introducing the FFG façade on a large scale.

Compared with other countries in the EU, Spain has a relatively young office building stock, mainly a consequence of the accelerated building activities in the 1990s. The pre-1980 stock would benefit the most from upgrades to the office building stock. In the non-residential stock, the total floor area sums up to 349,000,000 m². The non-residential stock is distributed across different building types as follows: Offices 28 % with gross floor area of 102 000 000 m², Educational buildings 18 %, Hospitals 7 %, Hotels & Restaurants 13 %, Sport facilities 4 %, Wholesale and retail trade 27 % and other types of energy-consuming buildings 3 %.

The construction output in Spain for 2014 is 63 bn €. Despite the negative trend during the years 2013 and 2014 regarding the growth rate of construction of new office buildings in Spain, the market size of this segment is most likely still larger than in Bulgaria.

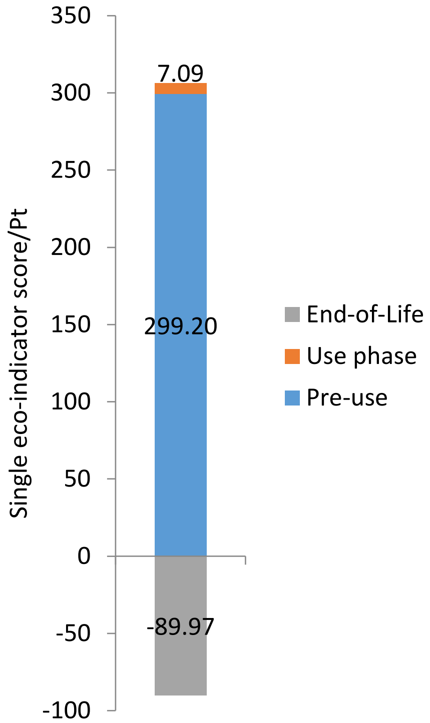
The estimated value of the construction output in whole Europe amounts to 1412 bn € in 2016 and 1450 bn € in 2017, the level of construction activity should reach 1478 bn € by 2018. Ten years ago, in 2007, total construction output of the 19 leading European countries was 1532 bn €. Biggest growth contributors considering the market size and the changes together are Germany, UK, France, Italy, Spain and Poland. What seems particular in 2016 is that all the six biggest markets of Europe are among the largest positive contributors to growth, which is something that has not happened for years. From the total 3 % predicted growth for 2016, six countries are contributing by 2.3 percentage points. In other words, out of the total 3 % expansion of the market (estimated to be EUR 40 bn) 75 % will be produced by these countries, which is around 30bn €.

The total nZEB revenues were around 500 million € in 2014 and were mostly within the European countries. In the near future the majority of investments in the nZEB sector are expected to take place in Europe. In the optimistic scenarios after 10 years the revenues in the nZEB market will be 1000 thousand times more than the current nZEB market revenues, which equals 500 bn € in the EU itself in 2025. While several pilot projects are trying to prove the investment savings in lower energy bills, a stronger driver for the adoption of nZEBs is regulation. Policies like the EU’s Energy Performance of Buildings Directive (EPBD) are forcing nZEB markets to come into place for new commercial, new residential, and retrofitted commercial space. In different regions, but predominantly in the EU residential market nZEB projects will be realized by current green building companies and conventional builders and supplier as they shift their strategies and products portfolios to conform to the new code requirements. Although the general forecast for the expansion of the nZEB market is very optimistic, the process is expected to start slowly and to gain momentum after 2019. The FFG has a high potential for market entry, especially in the area of building envelopes with a high degree of visual transmission. For example, a fully glazed high-rise building in a top location, ideally including a hotel area with constant domestic hot water demand to use the solar thermal heat of the FFG in summer.

2.2 Life Cycle Assessment

In terms of sustainability, the development of technologies should not only focus on economic feasibility but should also take the environmental impact of the new systems into account. Therefore, the focus of work package seven also was on the Life Cycle Assessment of the FFG system according to ISO 14040 and 14044. The Analysis has been performed with the Software SimaPro, background data were taken from the database ecoinvent 3.4. Foreground data have been assessed together with the project partners. ReCiPe 2008 has been chosen as method for Life Cycle Impact Assessment.

A detailed cradle-to-grave Life Cycle Assessment of one FFG module (3.9 m^2) has been performed. More detailed information on system boundaries and the product system can be found in previous reports and deliverables for work package 7. The impacts at both endpoint and midpoint level have been analyzed. As for endpoint level, the environmental impact of one modular unit of the FFG façade system expressed as the single ecopoint score is 216.42 Pt, which equals to the annual average impact of 0.22 European inhabitants. The production processes related to aluminum processing and the uncoated flat glass are the two largest causes of the environmental impacts.



	Pt
Production	**299.20**
Glazing	81.70
Circulator	18.50
Aluminum frame	199.00
Use phase	**7.09**
Transport	2.60
Maintenance	4.49
End-of-Life treatment	**-89.87**
Recycling of aluminum	-96.70
Incineration & landfill	6.32
Transport	0.51

Fig. 1 LCA results at endpoint level, analyzed with the LCIA method ReCiPe 2008. The single eco-indicator score is expressed as ecopoints, where one ecopoint is interpreted as one thousandth of the annual environmental load of one average European inhabitant.

Figure 2 displays the share of single score points of the different impact categories and the attribution to the three phases of the product life cycle. The categories with the highest value have the highest impact on the total single score indicator. The dominant categories are fossil and metal depletion, climate change (ecosystems and human health), particulate matter formation and human toxicity. While the pre-use phase, which includes manufacturing and transportation to the installation site, has the highest share on the score, the usage phase has a negligible impact. The end of life even has a negative impact due to recycling of a share of the used materials and recovery of energy.

The largest contribution to the environmental impact is the global warming potential (91.67 Pt) with the amount of emissions of CO_2 and other greenhouse gases being 2030 kg CO_2 eq. The annual GWP of the FFG façade system is 52.05 kg CO_2 eq/m², when its service lifetime is assumed to be ten years and the area of one modular unit is 3.9 m². The main contribution of the annual GWP comes from the production phase, which is 77.18 kg CO_2 eq/m².

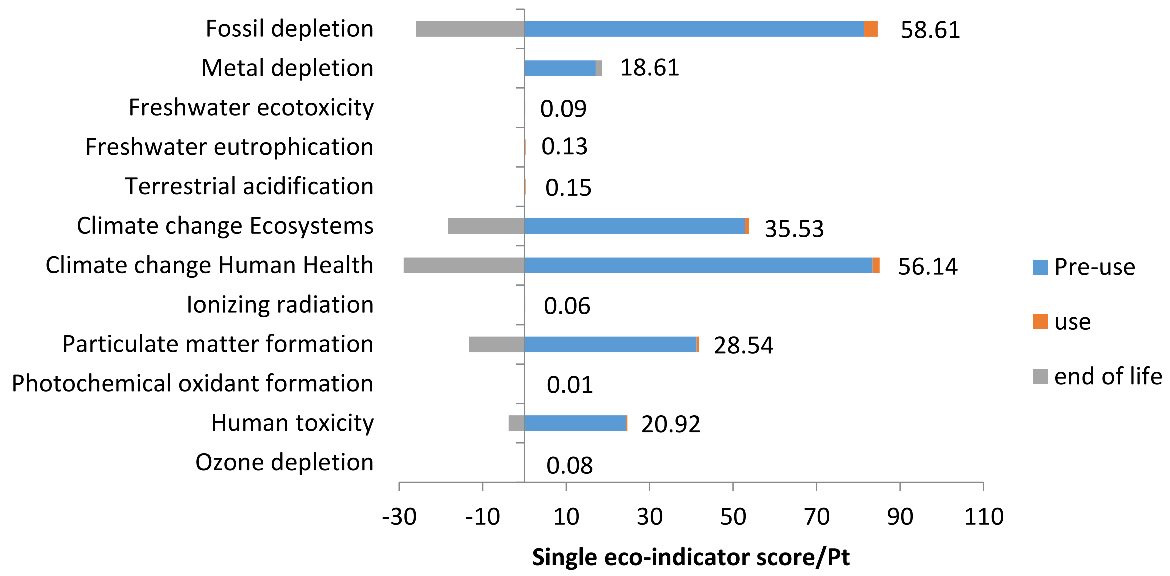
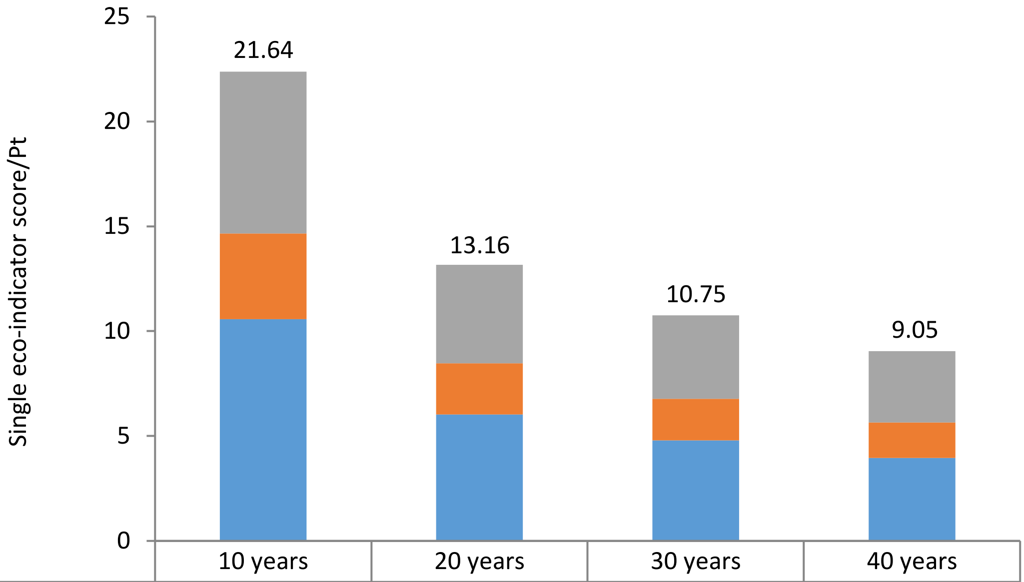


Fig. 2 LCA results at endpoint level, analyzed with the LCIA method ReCiPe 2008. Positive and negative impacts of production (pre-use), use and end-of-life phase analyzed according to twelve impact categories.

In order to evaluate the service life impact, the eco-indicator score is used again (Figure 3). As for the individual categories both the positive and negative scores are considered and the net score is taken as a reference value. The pre-use phase has the largest impact on the total score, the different usage scenarios need to be considered in the context of the duration of the usage phase. While during the usage phase maintenance is required, which is increasing the total score, the average yearly single eco-indicator score is reduced by the number of years of operation of the system.



	10 years	20 years	30 years	40 years
Resources	7.72	4.70	3.98	3.41
Ecosystems	4.08	2.44	1.98	1.68
Human Health	10.58	6.03	4.79	3.96

Fig. 3 Impact of service life variation on the overall single score result for the FFG system after 10, 20, 30 and 40 years.

In Figure 4, the FFG module has been compared to a state-of-the-art glass curtain wall façade module, which is similar to the FFG but without circulator and fluid-flow system. Due to the higher material use in the FFG module, the state-of-the-art module has a lower environmental impact when energy savings during the use phase are not considered.

To calculate the benefits of the energy savings during the use phase of the façade system, results from the simulations for the Sofia Demonstrator performed in work package 1 have been used. The simulations suggest a possible energy saving of 107 kWh per modular unit (3,9 m^2) electric energy by providing optimal daylight utilization and 133 kWh per modular unit (3,9 m^2) of thermal energy by regulating room climate. To calculate possible energy savings, the purchased energy (cooling and heating demand) from the “Sofia office WFG case” has been subtracted from the “Sofia office reference case” (see simulation results in Deliverable 1.5) to account for the additional consumption of the reference case. In the LCA, thermal energy has been considered to be provided by natural gas. The electric energy was calculated with the Bulgarian energy mix, since the simulation results are valid for the Sofia reference case.

The overall impacts for all three systems (FFG, FFG with energy savings and state-of-the-art façade) for an estimated lifetime of 10 years are displayed in Figure 4. The FFG without energy savings has the highest impact with 217 Pt, followed by the state-of-the-art façade with 194 Pt. When the possible energy savings of the FFG over a lifetime of 10 years are being considered as explained above, its environmental footprint is almost halved (123 Pt). Compared to the state-of-the-art façade, the environmental impacts of the FFG with energy savings are reduced by roughly one third. This shows the great potential of the FFG system to reduce emission in the building sector. A ten year service lifetime was proposed as very conservative estimation for the FFG's lifetime since no other data on service lifetime are available so far. It can however be assumed that the actual lifetime will be longer than 10 years, thereby further decreasing the environmental footprint of the FFG module as displayed in Figure 3.

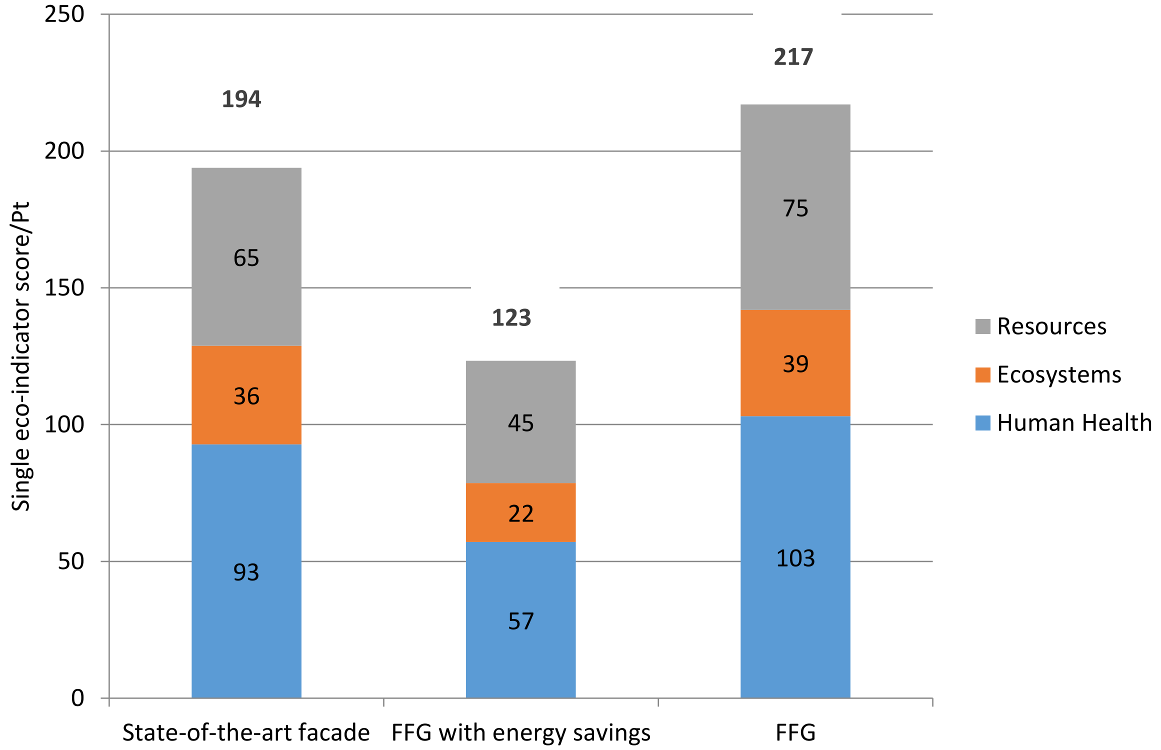


Fig. 4 Comparison of the environmental impact of one FFG module without energy savings, one FFG module with possible energy savings and a state-of-the-art glass curtain wall façade module at endpoint level. Service lifetime is considered to be 10 years.

Figure 5 displays the relative impacts of all three systems at midpoint level. It is obvious, that the FFG without energy savings has the highest impact followed by the state-of-the-art façade in all categories except for the impact category ozone depletion. Here, the FFG with energy savings shows a higher environmental impact than the state-of-the-art façade. This is due to the O-Ring in the circulator of the FFG, as already described in earlier reports (30-month report). The O-Ring consists mainly of Chlorodifluoromethane, which releases ozone depleting substances.

Looking at absolute numbers, the amount of CFC-11 eq. (Trichlorofluoromethane) released during the O-Ring production is with 0.68 g per module relatively small. Still, the substitution of the O-Ring material should be considered in future FFG production lines.

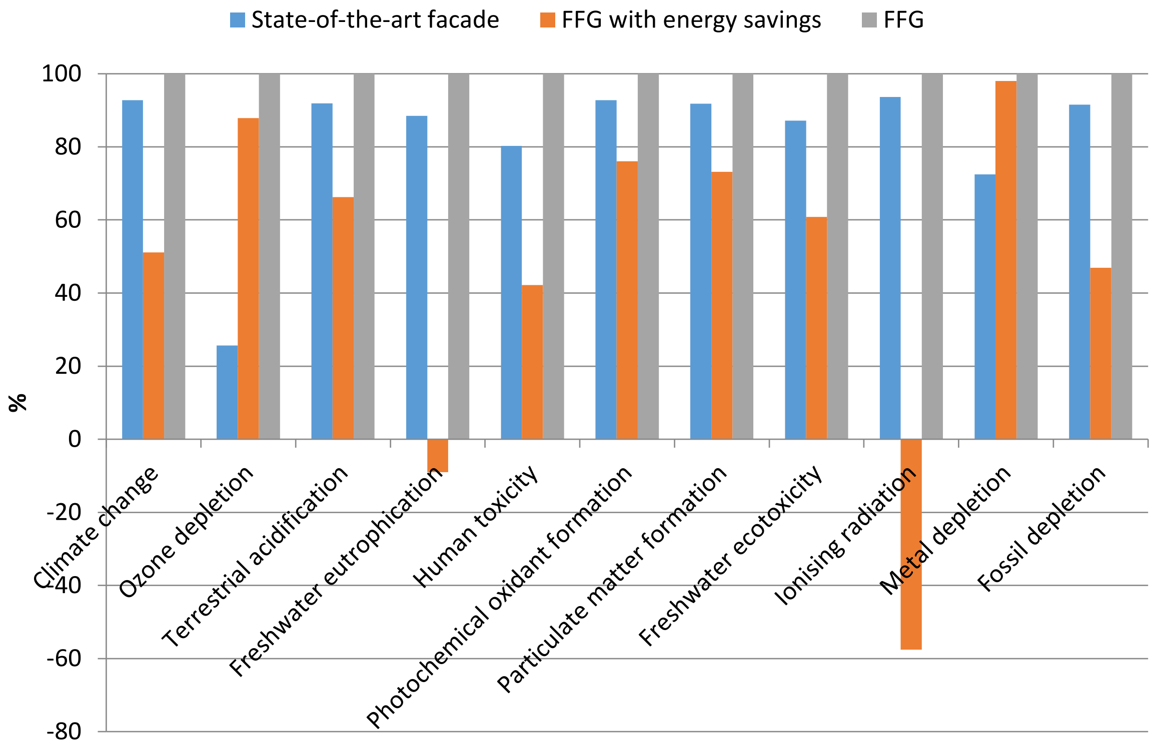


Fig. 5 Comparison of the environmental impact of one FFG module without energy savings, one FFG module with possible energy savings and a state-of-the-art glass curtain wall façade module at midpoint level. Results are presented relative to each other: For each category, the module with the highest impact is defined to have 100 % impact. Service lifetime is considered to be 10 years.

All in all, the results of the Life Cycle Assessment identify the environmental hotspots of the FFG and show the great potential to reduce heating and cooling related emissions in the building sector. Since the highest impacts derive from the two energy intensive processes of aluminum and flat glass production, the FFG would highly benefit from a higher share of renewable energy in the country specific energy mixes. A long service lifetime of the façade system and a high recycling rate could also contribute in lowering the total impacts. Another significant approach to enhance the environmental performance would be to minimize the distances between raw material suppliers, component producers and the constructing sites since the study also showed the significant impact of the transport on the overall result. A replacement of the material for the O-Ring in the circulator should be considered, to reduce the emission of ozone depleting substances.

The embodied energy of one 3.9 m^2-module of this façade is 57.12 GJ. The energy used for the production of this façade in relation to its area is therefore 14.65 GJ/m^2.

The comparison of this value to other figures in literature is complicated, due to the various functional units that were used. In 2011 Kim [1] conducted a LCA study on a transparent composite façade system (TCFS) and a glass curtain wall system (GCWS). The functional unit of this study is a façade area of 19.6 m^2. The embodied energy for the TCFS amounts to 7.55 GJ/m^2 which is roughly twice the amount of energy needed compared to the GCWS with 3.67 GJ/m^2. [1]

Azari [2] examined a "hypothetical 2-story office building with 335 m^2 of floor area" (p. 157) with six different kinds of façades without giving any reference to the façade area. The embodied energies in the "pre-use" phase in these scenarios range from 300 to 500 GJ for the façade of the entire building. [2]

Another LCA on facade variations from natural stone and glass was conducted in 2014 for the German Natural Stone Association (Deutscher Naturwerkstein-Verband e.V., Würzburg") [3]. The energy needed in the production of the façades ranged from 1.32 GJ/m^2 for a conventional natural stone façade to 3.51 GJ/m^2 for a glass façade. The total produced façade area that was considered in this study was 37,000 m^2. [3]

2016, King and Settembrini [4] studied the correlation between the embodied energy of a façade and its production costs. The average energy demand for the production within their different scenarios ranged from 2.88 GJ/m^2 to 3.42 GJ/m^2. [4]

Giordano et al. [5] also researched the embodied energy in different façades. Their results range from 2.7 GJ/m^2 for a "single skin insulated glass window wall" [5] to 6.84 GJ/m^2 for a double skin façade with insulated glass stratified glass, spandrel panel and mechanical ventilation. [5]

Most of the literature values are close to 3 GJ/m^2 of façade. However, the range of these values is quite large. The result from this study with 14.65 GJ/m^2 is quite high compared to the presented literature values. Almost three-quarter of the embodied energy in this case is needed for the production of an aluminum frame. The comparison is particularly complex, since the values are given in various forms. Some of the sources give additional information in order to transform the values to a comparable unit (e.g. GJ/m^2 façade). However, this is not always the case, as seen in the research from Azari [2] where the values cannot be transformed due to missing information and therefore the comparison to other literature values is not possible.

2.3 Total Cost of Ownership / Life Cycle Costing

For the calculation of the Total Cost of Ownership (TCO) or Life Cycle Costs (LCC) of the FFG and its economic comparison with alternatives, an Excel tool was developed and presented in Deliverable D7.6 “Excel Tool for Building Cost Analysis of ZEB with FFG”. This section presents results of the tool, including variation of parameters to explain how it will be used for future FFG products.

For the FFG a promising application case was determined as basis for the LCC analysis:

- FFG for domestic hot water (DHW) preheating plus heating in winter nights with location in Valencia

The solar thermal yield of the FFG is thus assumed to reduce the heating demand and additionally to support DHW heating.

Four relevant reference façade systems, to which the FFG is compared to, are included in the Excel tool:

- Façade with a solar control glazing (Cool-Lite SKN 154 3-panes)
- Closed-Cavity Façade with venetian blinds within the cavity between the glazing panes
- Façade with external venetian blinds
- Façade with internal roller blinds

The first reference façade is a high-quality solar control glazing aiming to keep the cooling demand low while maintaining high visual transparency (Cool-Lite SKN 154 3-panes by Saint-Gobain Building Glass). Owing to its low U value as triple glazing it also helps reduce thermal losses and the heating demand. All reference facades use established technologies. The first reference facade reaches a high ratio between the visual transmittance and the g value. But the FFG can reach higher ratios and is able to provide renewable heat.

The second reference façade is a Closed-Cavity façade (CCF) which is a type of double-skin façade, typically built as element façade[2]. It consists of an exterior single glass pane and an interior double glazing. The venetian blind is placed between these glass panes. The cavity is supplied with cleaned air at a slight overpressure minimizing soiling with the cavity. The glass surfaces facing the inside of the cavity and the venetian blind therefore don't require cleaning. The venetian blind is effective in keeping cooling demands low, while the three glass panes help to reduce heating demands. CCF can switch between low and high g values. But FFG can reach a better visual contact to the exterior and are able to provide renewable heat.

The third and fourth reference use typical venetian blinds in combination with state-of-the-art glazings, but without special coatings like they are used by the first reference. External venetian blinds are ideal for lowering cooling demands, internal roller blinds are the most inexpensive façade system considered, offer glare protection but are not as effective in lowering cooling demands. Both references can switch between low and high g values. But FFG can reach a better visual contact to the exterior and are able to provide renewable heat.

The second, third and fourth reference have also an aesthetically different appearance compared to the FFG and the solar control glazing.

The cost data on manufacturing, construction and installation were acquainted by partners of the consortium which have a good overview about the markets in which they operate. For each case, the costs were estimated as presented in Table 1 with default values for general cost values in the Excel tool (Table 2). At this point, more details are not known or cannot be published as they concern business secrets. The focus is on establishing the LCC tool that later allows planers in construction projects involving FFG to produce more accurate estimates with detailed cost of the specific building to be constructed.

The energy demand of all cases for a façade area of 52.8 m² (i.e. the area of 15 FFG elements) was obtained by simulations in IDA ICE carried out by B+G (Bollinger + Grohmann Consulting GmbH). The FFG was simulated using the simplified model (cf. deliverables 1.1 and 2.4). The energy demand of all five cases was simulated as presented in Table 3.

Table 1: Estimated costs as input for the case study.

FFG	installation cost	annual maintenance cost
Facade elements with FFG [€/m²]	1130 or 904[1]	16.86
Installation of the facade element [€/m²]	included above	
Service life of the facade without FFG [a]	10 or 25	
Solar control glazing: Cool-Lite SKN 154 3-panes		
Facade elements with solar control glazing instead of FFG [€/m²]	1130	16.86
Installation of the facade element [€/m²]	included above	
Service life of the facade without FFG [a]	25	
Closed Cavity Facade		
Facade element [€/m²]	1130	16.86
Installation of the facade element [€/m²]	included above	
Service life of the facade element [a]	25	
Facade with external venetian blinds		
Facade element [€/m²]	680	19.96
Installation of the facade element [€/m²]	included above	
Service life of the facade element [a]	25	
Facade with internal roller blind		
Facade element [€/m²]	610	18.86
Installation of the facade element [€/m²]	included above	
Service life of the facade element [a]	25	

[1] The cost of a FFG depends not only on the materials, but also the amounts, the labor and the requirements. It depends therefore on each specific building project. This is indicated by the results of two approaches to estimate the cost. They lower cost may be reach for example in a well suited project.

Table 2: General cost values used in case study.

Cost per kWh of heating demand	0.0353 or 0.08[2]	€/kWh
Cost per kWh of cooling demand	0.0598	€/kWh
Real discount rate for facade investments (approx. nominal discount rate minus inflation rate)	0.010	[-]
Real rate of increase of energy prices (approx. nominal rate of increase minus inflation rate)	0.029	[-]

Table 3: Inputs based on building energy performance simulations for a façade of 52.8 m² (i.e. the area of 15 FFG elements).

FFG		
Solar thermal performance	8592	kWh
Heating demand	1409	kWh
Cooling demand	162	kWh
Solar control glazing		
Heating demand	4850	kWh
Cooling demand	2150	kWh
Closed Cavity Facade		
Heating demand	5220	kWh
Cooling demand	746	kWh
Facade with external venetian blinds		
Heating demand	5383	kWh
Cooling demand	551	kWh
Facade with internal roller blind		
Heating demand	5058	kWh
Cooling demand	1492	kWh

The results of the LCC calculation are as follows. If an FFG service life of 25 years is reached similar to the reference cases, energy can be saved but costs (annuity) is considerably higher than all reference cases as presented in Table 4. In this case, each kWh of saved end energy costs 9.1 ct. compared to the solar control glazing. For a very conservative estimated FFG service life of 10 years each kWh of saved end energy costs 49 ct. compared to the solar control glazing (cf. Table 5). If the cost for heating is increased to 0.08 €/kWh, each kWh of saved end energy costs 3.4 ct. compared to the solar control glazing as presented in Table 6. If additionally, the FFG can be delivered at 20% lower investment costs than estimated in the base

[2] The energy prices depend on the building project.

case, for example with a well suited large project, then according to Table 7, each kWh of saved end energy costs 5.2 ct. compared to the solar control glazing. When combining both increased heating costs and reduced investment, the FFG is a more economical solution than the solar control glazing, but with extra costs per saved end energy compared to all other reference cases (cf. Table 8).

Table 4: Overview of the results of the LCC with 25 years of service life for all five cases.

Facade	Service life [a]	Net present value [€/m²]	Annuity [€/m²]	End energy demand [kWh/m²]	Additional cost per saved energy [€/kWh]
FFG	25	**-2217**	**-100**	-133	
Solar control glazing	25	**-1686**	**-76**	133	0.091
Closed Cavity Facade	25	**-1643**	**-74**	113	0.106
Facade with external venetian blinds	25	**-1258**	**-57**	112	0.177
Facade with internal roller blind	25	**-1191**	**-54**	124	0.181

Table 5: Overview of the results of the LCC with 10 years FFG service life, and 25 years for the references.

Facade	Service life [a]	Net present value [€/m²]	Annuity [€/m²]	End energy demand [kWh/m²]	Additional cost per saved energy [€/kWh]
FFG	10	**-1952**	**-206**	-133	
Solar control glazing	25	**-1686**	**-76**	133	0.488
Closed Cavity Facade	25	**-1643**	**-74**	113	0.535
Facade with external venetian blinds	25	**-1258**	**-57**	112	0.607
Facade with internal roller blind	25	**-1191**	**-54**	124	0.591

Table 6: Overview of the results of the LCC with 25 years of service life for all five cases and increased energy cost for heating demand.

Facade	Service life [a]	Net present value [€/m²]	Annuity [€/m²]	End energy demand [kWh/m²]	Additional cost per saved energy [€/kWh]
FFG	25	**-2020**	**-92**	-133	
Solar control glazing	25	**-1819**	**-82**	133	0.034
Closed Cavity Facade	25	**-1786**	**-81**	113	0.043
Facade with external venetian blinds	25	**-1405**	**-64**	112	0.114
Facade with internal roller blind	25	**-1329**	**-60**	124	0.122

Table 7: Overview of the results of the LCC with 25 years of service life for all five cases and reduced investment cost of FFG by 20%.

Facade	Service life [a]	Net present value [€/m²]	Annuity [€/m²]	End energy demand [kWh/m²]	Additional cost per saved energy [€/kWh]
FFG	25	**-1991**	**-90**	-133	
Solar control glazing	25	**-1686**	**-76**	133	0.052
Closed Cavity Facade	25	**-1643**	**-74**	113	0.064
Facade with external venetian blinds	25	**-1258**	**-57**	112	0.135
Facade with internal roller blind	25	**-1191**	**-54**	124	0.141

Table 8: Overview of the results of the LCC with 25 years of service life for all five cases, increased energy cost for heating demand and reduced investment cost of FFG by 20%.

Facade	Service life [a]	Net present value [€/m²]	Annuity [€/m²]	End energy demand [kWh/m²]	Additional cost per saved energy [€/kWh]
FFG	25	**-1794**	**-81**	-133	
Solar control glazing	25	**-1819**	**-82**	133	-0.004
Closed Cavity Facade	25	**-1786**	**-81**	113	0.002
Facade with external venetian blinds	25	**-1405**	**-64**	112	0.072
Facade with internal roller blind	25	**-1329**	**-60**	124	0.082

A summary of the case study is shown in Table 9 were the FFG is compared to the strongest competitor – solar control glazing – and the most economic benchmark – internal roller blinds. It can be concluded that the FFG is suited best for projects which are planning with a high visual transmittance without venetian blinds and ambitious energy targets. Political decisions are needed to turn the costs of climate change into internal costs of the energy demand.

Table 9: Summary of results of case study of FFG compared to reference solar control glazing (Ref1) and internal roller blind (Ref4)

Case	Add. cost per saved energy – Ref1 [ct./kWh]	Add. cost per saved energy – Ref4 [ct./kWh]
25a FFG service life	9	18
10a FFG service life	49	59
25a, increased heating cost	3	12
25a, 20% reduced invest	5	14
25a, 20% red. Invest + incr. heating cost	-0.4	8

3 Degree of Progress

All activities of this work package have been finalized and final results were presented according to schedule.

4 Dissemination

The results have already been presented to the consortium at the periodic meetings and at the final Review Meeting. The results have not been published anywhere else so far.

Literature

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