D8.6
Report of the Techno-economic assessment of the Case Studies

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OSIRYS

"Forest based composites for façades and interior partitions to improve indoor air quality in new builds and restoration"

COOPERATION

Grant agreement no.: 609067

	Dissemination level
X	**PU** = Public
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	RE = Restricted to a group specified by the consortium (including the EC)
	CO = Confidential, only for members of the consortium (including the EC)

Document history			
	Date	Author	Description
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Contents

1. Summary

The Deliverable D8.6 is a Public document of the OSIRYS project, delivered in the context of WP8 “Exploitation and Dissemination”, Task T8.4. “Report on Techno-Economic Assesssment of the Case Studies”. The objective of T8.4 is to summarise the technical and economic factors relating to the case studies created in the project. This report therefore looks at each case study in isolation, the 4 case studies being:

- A multi-layer facade
- A curtain wall system
- An interior partition system

For each case study the following are considered:

- A summary of the materials and manufacturing technologies used with comparison to the incumbent materials and manufacturing methods
- Installation and in-situ performance data
- An LCC analysis based on the 'Present Value' model

It should be noted that as a Public document this report has limited details in some areas where IP protection is required.

2. Introduction

The primary aim of the OSIRYS project is to investigate, develop and validate sustainable materials for the construction industry with a particular focus on indoor air quality. A holistic approach has been adopted as building envelopes and interiors are complex structures and require a number of elements to work in harmony.

A great deal of energy has been spent within OSIRYS on the detailed design of the components, to optimise them for the bio-based products that have been used. These technical developments are described elsewhere. This report concentrates on the advantages or disadvantages of the resultant systems and whether they could be commercially competitive on the marketplace.

Each of the OSIRYS products is compared with other standard solutions within their respective categories. The multi-layer façade system is compared with typical infill walls, the curtain wall façade system with standard curtain walls, and the partition system with other typical interior partition walls.

The comparison is focused on three areas of interest:

A summary of the materials and manufacturing technologies used with comparison to the incumbent materials and manufacturing methods
This section puts the OSIRYS solutions/products in context with what is on the market already, comparing constituent materials, weights, costs and embodied energy.

Installation and in-situ performance data
This section describes the materials, labour, equipment and energy used to install the products and how its in-situ performance compares in terms of thermal insulation, durability and sustainability.

An LCC analysis based on the 'Present Value' model
This section takes a broad view across the lifetime of the product and generates a 'present value' taking into account:

- Existing energy price
- Expected yearly increase of energy price during life time
- Imputed rate of interest
- Inflation
- Expected lifespan for the product (calculation period)

This generates a comparison figure which can highlight the long-term effects of investment, useful for organisations that expect or want to know about financial impacts over time.

3. Techno-Economic Assessments

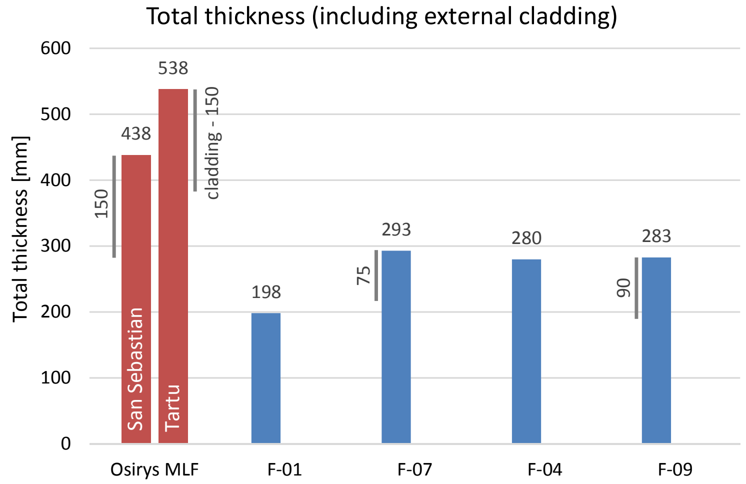
3.1 Multilayer Façade

Below is a table with the description of infill-wall facades used in the comparison. All options include surface finishing. The examples were chosen to match the typology described in the report D 6.1 and represent the most common technologies used in Europe.

Name	Type	Composition (outside to inside)
Osirys MLF	Osirys Multi-Layer Façade	Thermoset biopolymer exterior finish panel - 20/40mm (on aluminium framing) Ventilated space – 150mm Thermoset biopolymer wall board - 15mm Thermoset biopolymer structural profile - 162mm (insulated with 162mm cork inside) Thermoset biopolymer wall board - 15mm **optional additional insulation - polystyrene - 100mm* Thermoset biopolymer profile - 60mm (insulated with 60mm cork inside) Cork insulation - 10mm Plasterboard + skim - 15mm Photocatalytic active coating- 1mm
F-01	Heavy wall (precast concrete panels) with insulation on the inside	Exterior paint Precast concrete panels - 120mm Rockwool insulation - 50mm Interior plasterboards - 25mm Finish plaster - 3mm Interior paint
F-07	Heavy wall (concrete masonry units) with insulation on the outside and ventilated air gap.	Ceramic tiles cladding - 15mm Ventilated air chamber - 60mm Rockwool insulation - 50mm CMU wall - 140mm Interior plasterboards - 25mm Finish plaster - 3mm Interior paint
F-04	Heavy wall with no thermal insulation	Exterior plaster (cement) - 20mm Brick masonry wall - 240mm Interior plaster (gypsum) - 20mm Interior paint
F-09	Lightweight wall (steel stud wall) with insulation on the outside and ventilated air gap	Stone cladding - 30mm Ventilated air chamber - 60mm EPS insulation - 40mm Exterior plasterboards - 25mm Insulated stud cavity - 100mm (100mm Rockwool inside) Interior plasterboards - 25mm Finish plaster - 3mm Interior paint

3.1.1 Summary of the materials and manufacturing technologies used with comparison to the incumbent materials and manufacturing methods

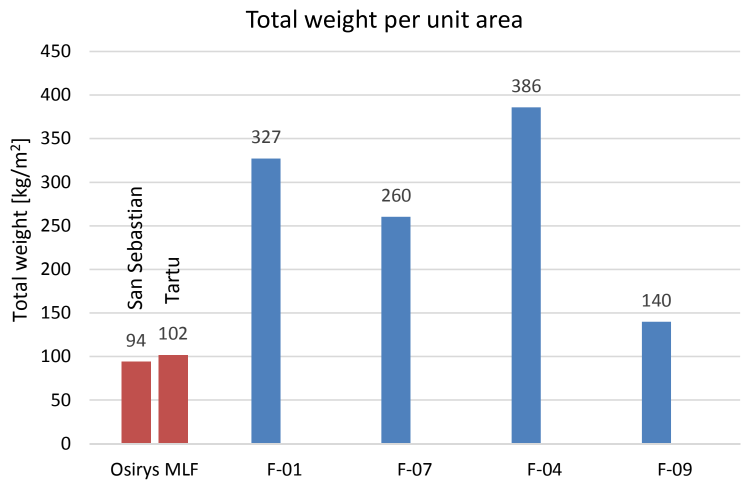
Total thickness: mm



(thickness of the air gap under the cladding is shown next to each column)

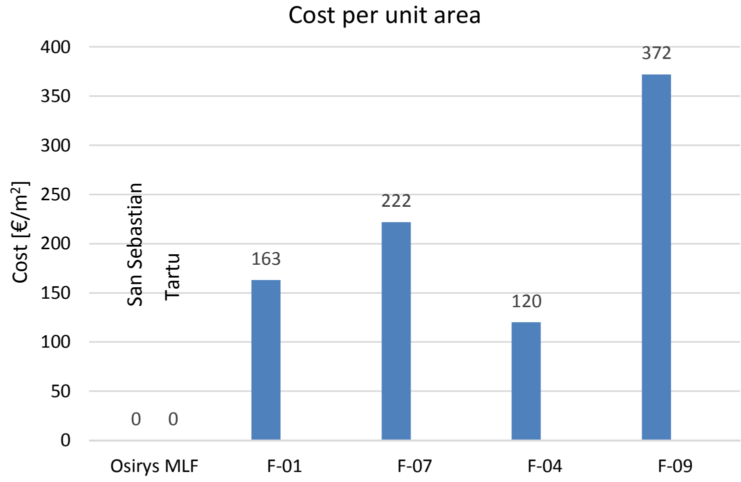
- Total thickness greatly depends on the amount of thermal insulation and ventilated air gap under the cladding.
- Thickness of the Osirys MLF is slightly higher compared to all the standard technologies, even if the external cladding is excluded.
- This influences the overall dimensions of the building and the usable floor area.

Weight: kg/m^2



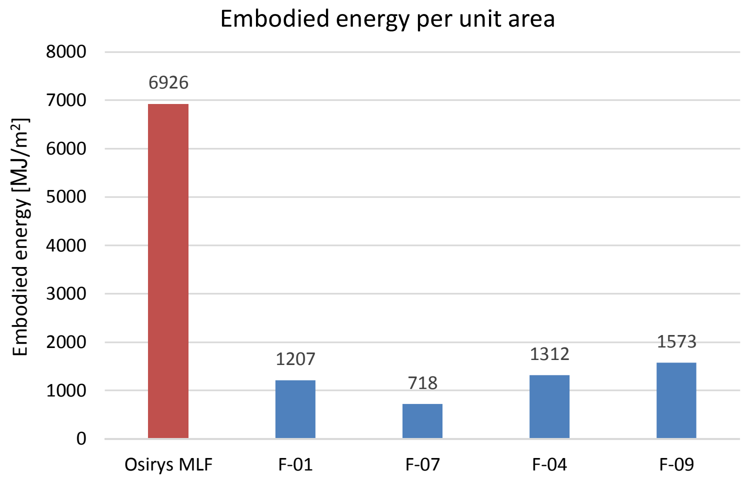
- Weight of the Osirys MLF is significantly lower compared to all the standard technologies, even the typical lightweight stud wall.
- This allows for great saving in transportation and installation costs, as less manpower and machinery must be used in the process.
- Osirys MLF panels are mostly pre-fabricated therefore the assembly time is much lower compared to walls constructed in-situ.

Cost: Euro/m^2



- *Missing info regarding the Osirys costs*

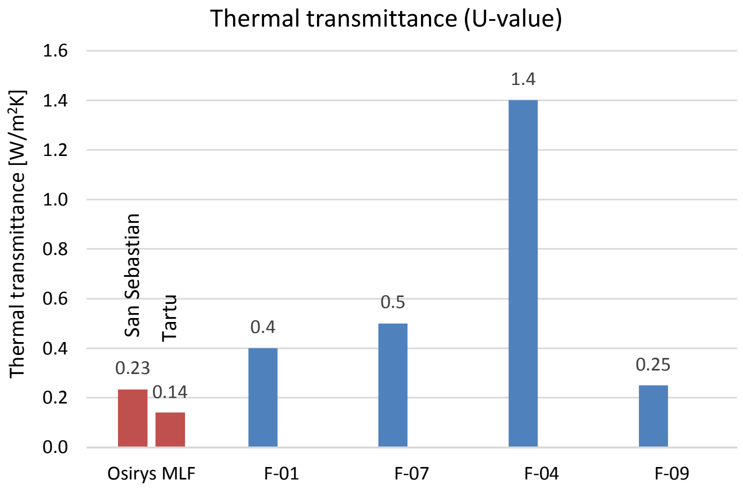
Embodied Energy: MJ/m^2



- Huge embodied energy in Osirys MLF due to composite materials – according to I.C.E the embodied energy in typical GRP composite is ~100 MJ/kg (30x more than in concrete). If that value can be reduced then the results might be improved.

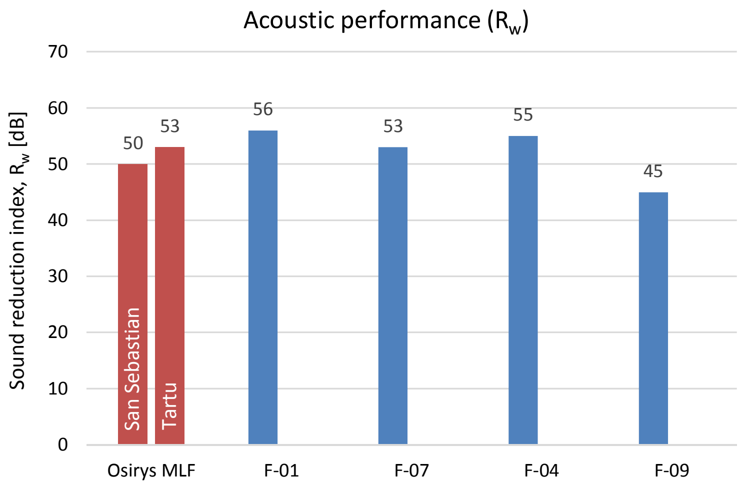
3.1.2 Multi Layer Façade Installation and in-situ performance data

U-value: W/m^{2}K



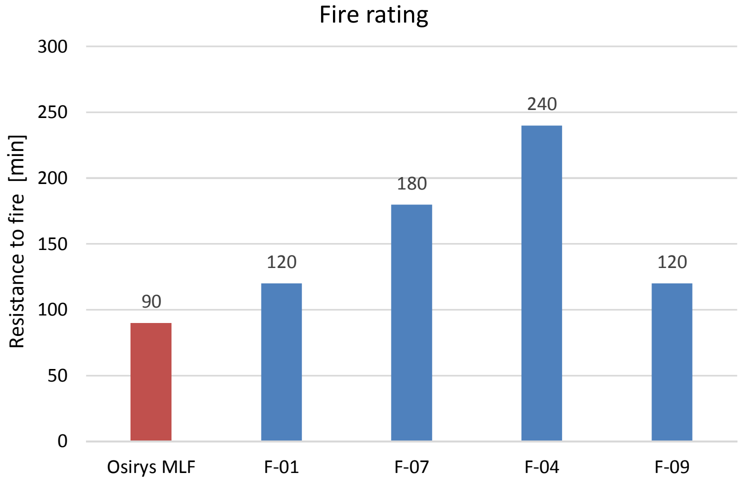
- Superior performance to all the alternative constructions
- Energy saving, reduced heating and cooling costs, sustainable …

Acoustic performance, R_w: dB



- Similar performance to the alternative constructions, even at very low structural mass.

Fire rating, REI/EI: minutes



- Lower than heavy walls, similar to lightweight stud wall.
- Passes the rating even with light structure and bio-based materials.

Installation:

- Osirys MLF is significantly lighter than all the alternative solutions
- Required manpower and machinery is therefore much lower
- Osirys MLF panels are mostly prefabricated, which speeds up the assembly tremendously
- Prefabrication reduces amount of waste generated on site

Durability and Sustainability

Name	Durability	Sustainability
Osirys MLF	Durable biopolymer wall board, protected from moisture and rainwater	*Materials:* Structure is durable, but less robust than heavy walls Lightweight materials reduce impact on the environment Prefabrication is more efficient and allows to reduce waste All materials can be recycled Natural insulation material - Cork Bio-based structural material – Bio-composite *Thermal comfort:* Lower thermal mass for climate control and thermal comfort Excellent thermal insulation - reduced energy losses *Acoustic comfort:* Good acoustic performance *Indoor air quality:* Minimal moisture buffer – Cork
F-01	Very robust, not sensitive to moisture	Structure is durable and resilient Prefabrication is more efficient and allows to reduce waste Concrete is usually produced locally All materials can be recycled (but thermal insulation is not widely recycled) High CO2 footprint - concrete High thermal mass for climate control and thermal comfort Average thermal insulation - susceptible to energy losses Good acoustic performance Good moisture buffering - Concrete
F-07	Very robust, well protected from moisture	Structure is durable and resilient All materials can be recycled (but thermal insulation is not widely recycled) High CO2 footprint - masonry units High thermal mass for climate control and thermal comfort Average thermal insulation - susceptible to energy losses Good acoustic performance Good moisture buffering – masonry units
F-04	Robust, but not protected from moisture and low temperatures	Structure is durable and resilient Bricks can be recycled or re-used High CO2 footprint - masonry units High thermal mass for climate control and thermal comfort Low thermal insulation - high energy losses Good acoustic performance Good moisture buffering - bricks

F-09	Well protected from moisture, but less robust than heavy walls	Durable but less resilient/robust structure Lightweight materials reduce impact on the environment All materials can be recycled (but thermal insulation is not widely recycled) Good thermal insulation - reduced energy losses Lower thermal mass Lower acoustic performance No moisture buffering

3.2 Curtain Wall System

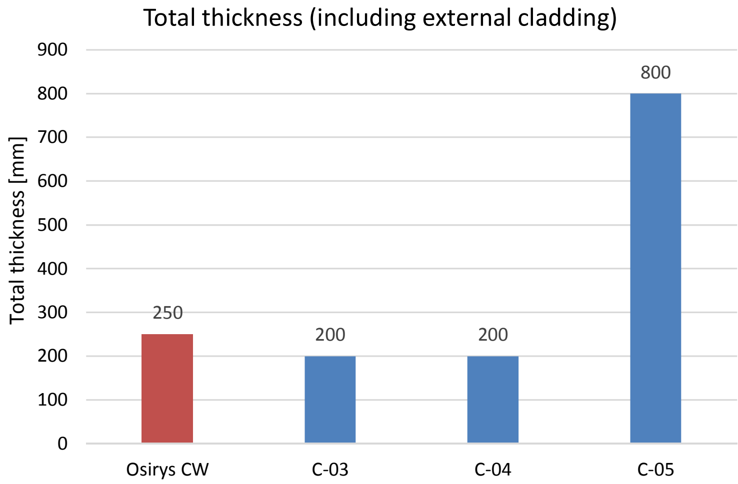
Below is a table with the description of curtain walls used in the comparison. The examples were chosen to match the typology described in the report D 6.1 and represent the most common technologies used in Europe.

Name	Type	Composition
Osirys CW	Osirys Curtain Wall	Bio-composite frame Outside 'fin' with variable thickness *(assumed weight 5kg/m^2)* Glazing 10T / 20 / 8 *(assumed weight 55kg/m^2)*
	Typical stick-system curtain wall	Aluminium frame - 50mm profiles *(assumed weight 5kg/m^2)* Glazing 8 / 15 / 4+4 *(assumed weight 50kg/m^2)*
C-04	Typical unitised curtain wall	Aluminium framing *(assumed weight 5kg/m^2)* Glazing 8 / 15 / 4+4 *(assumed weight 55kg/m^2)*
C-05	Double-skin system – unitised curtain wall with aluminium louvres	Aluminium framing *(assumed weight 5kg/m^2)* Glazing 8 / 16 / 5+5 *(assumed weight 55kg/m^2)* Vertical aluminium louvres on aluminium frame, distance 60cm *(Assumed weight of second skin: 10 kg/m^2)*

3.2.1 Summary of the materials and manufacturing technologies used with comparison to the incumbent materials and manufacturing methods

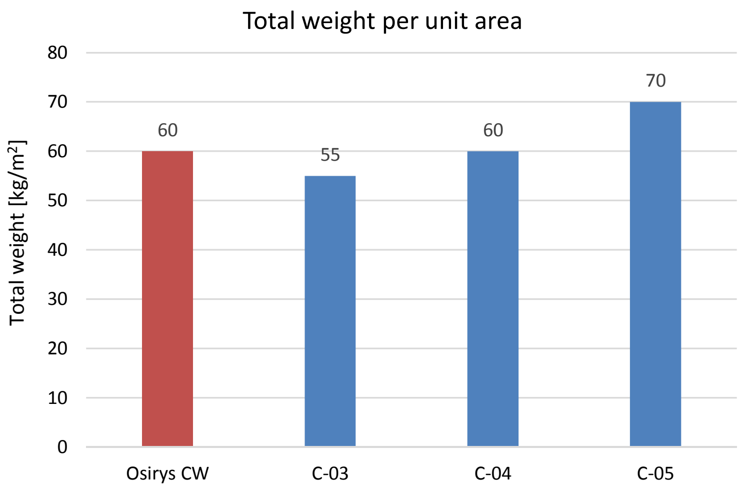
Basically all the parameters are based on assumptions or average values form D6.1. No significant differences can be highlighted.

Total thickness: mm



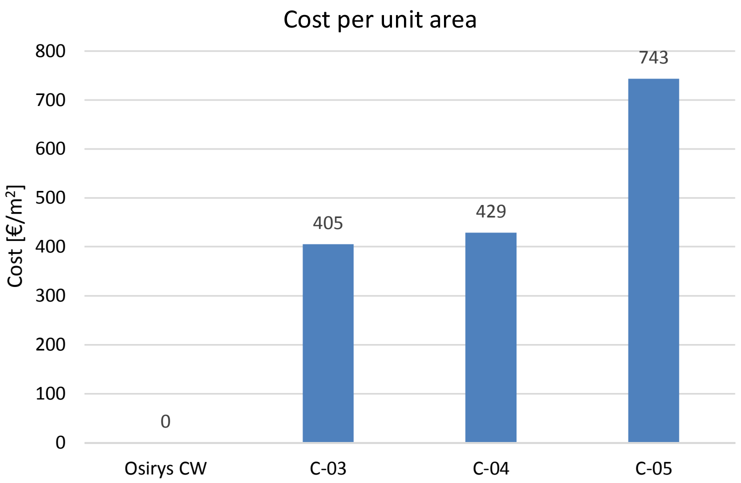
- Total thickness depends only on the thickness of the profiles and optional second layer.
- Osirys CW profiles are slightly larger compared to the average standard curtain walls.

Weight: kg/m^2



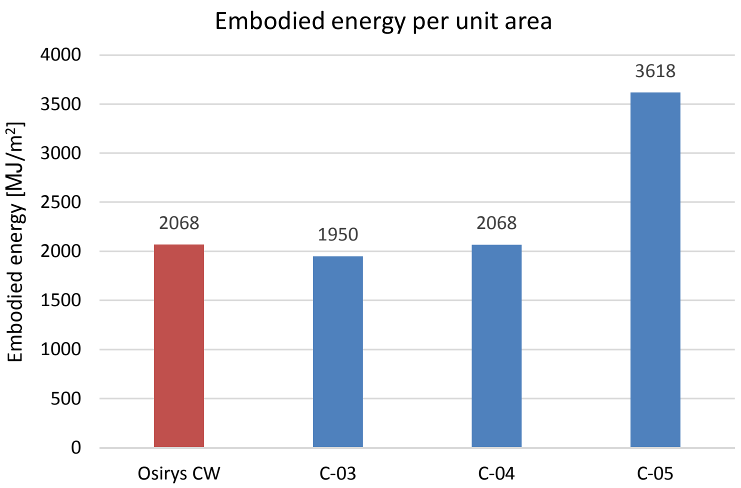
- Weight of the Osirys CW is the same as a typical unitised curtain wall (based on assumptions)

Cost: Euro/m²



- Missing info regarding the Osirys costs
- Cost of the second skin in double-skin wall is taken from Report D6.1

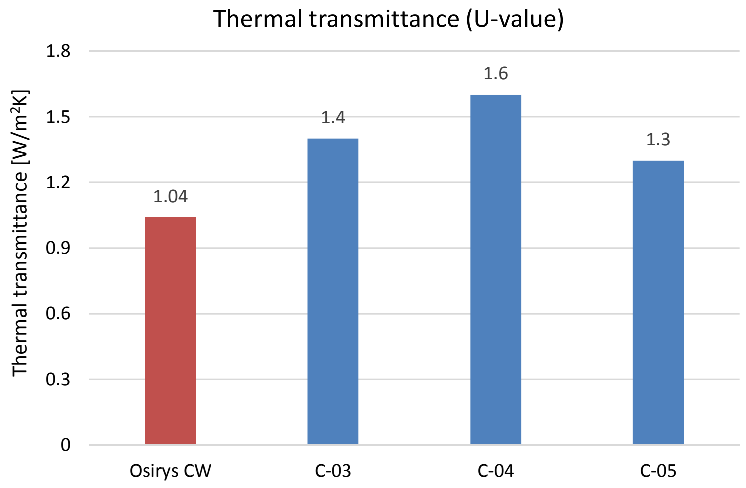
Embodied Energy,



- EE in the Osirys CW is the same as for a typical unitised curtain wall (based on assumptions).

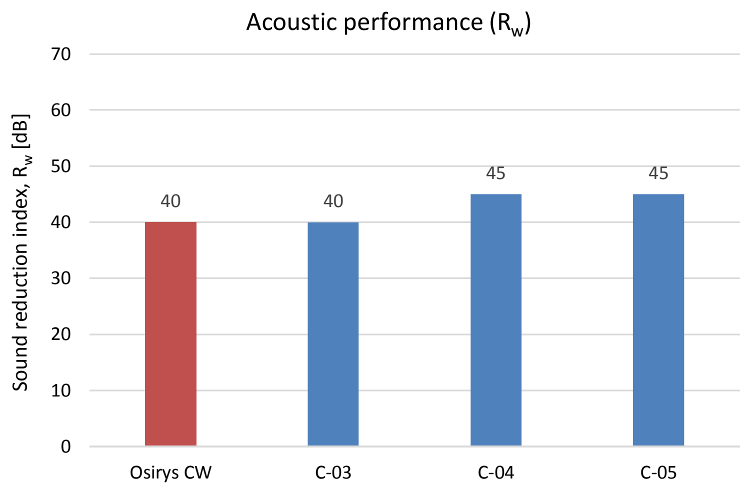
3.2.2 Installation and in-situ performance data

U-value: W/m²K



- Superior performance to all the alternative constructions.
- Energy saving, reduced heating and cooling costs, sustainable …

Acoustic performance, R_w: dB



- Similar performance to the alternative constructions…

Installation:

- Osirys CW is a unitised system, therefore allows for very fast installation
- External ‘fins’ are easily attached to provide additional shading and aesthetic effects
- The above effects are obtained without expensive and heavy secondary frames
- Prefabrication of unitised panels reduces amount of waste generated on site

Other performance parameters:

- Osirys CW obtained water-tightness rating of R7 which is the same or better than average ratings for other curtain walls (R6 / R7 – according to Report D6.1)

- Osirys CW obtained a satisfactory air-permeability rating of A1

Durability and Sustainability:

Name	Durability	Sustainability
Osirys CW	Durable aluminium frame, air- and water-tight	*Materials:* Aluminium frames are widely recycled Prefabrication reduces installation time and site waste *Thermal comfort:* Relatively higher thermal insulation No thermal mass Maximum daylight use External 'fins' provide some protection from overheating (shading) *Acoustic comfort:* Moderate acoustic performance *Indoor air quality:* Air-tight - good indoor air quality control
C-03	Durable aluminium frame, air- and water-tight	Aluminium frames are widely recycled Low thermal insulation No thermal mass Maximum daylight use Good acoustic performance Air-tight - good indoor air quality control
C-04	Durable aluminium frame, air- and water-tight	Aluminium frames are widely recycled Prefabrication reduces installation time and site waste Low thermal insulation No thermal mass Maximum daylight use Moderate acoustic performance Air-tight - good indoor air quality control
C-05	Durable aluminium frame, air- and water-tight, additional protection from damage and sunlight (UV)	Aluminium frames are widely recycled Prefabrication reduces installation time and site waste Low thermal insulation No thermal mass Maximum daylight use Additional protection from overheating (shading) Moderate acoustic performance Air-tight - good indoor air quality control

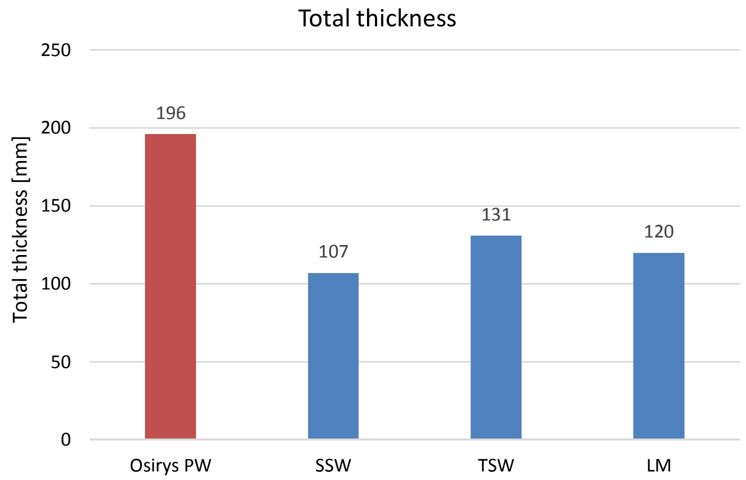
3.3 Interior Partition System

Below is a table with the description of interior partition system used in the comparison. All options include surface finishing. The examples were chosen to represent the most common technologies used in Europe.

Name	Type	Composition
Osirys PW	Osirys Partition Wall	Interior paint Finish plaster - 3mm Plasterboards x2 - 25mm Cork insulation - 10mm Stud cavity - 100mm (2 x 20mm cork insulation inside) Cork insulation - 10mm Plasterboards x2 - 25mm Finish plaster - 3mm Interior paint
SSW	Steel stud wall	Interior paint Finish plaster - 3mm Plasterboards x2 - 25mm Insulated stud cavity - 51mm (50mm acoustic insulation inside) Plasterboards x2 - 25mm Finish plaster - 3mm Interior paint
TSW	Timber stud wall	Interior paint Finish plaster - 3mm Plasterboards x2 - 25mm Insulated timber frame - 75mm (25mm acoustic insulation inside) Plasterboards x2 - 25mm Finish plaster - 3mm Interior paint
LM	Light masonry wall (Autoclaved Aerated Concrete blocks)	Interior paint Finish plaster - 10mm Light CMU 'Air-crete' wall - 100mm Finish plaster - 10mm Interior paint

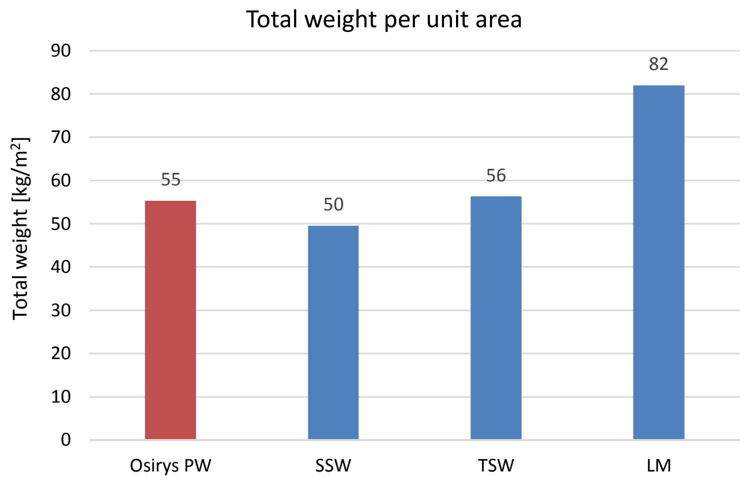
3.3.1 Summary of the materials and manufacturing technologies used with comparison to the incumbent materials and manufacturing methods

Total thickness: mm



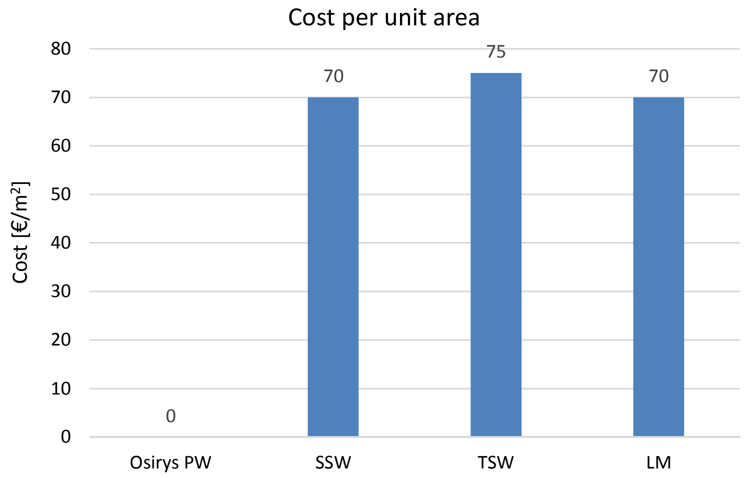
- Thickness of the Osirys PW is slightly higher compared to all the standard technologies, mainly due to bigger stud profiles.
- This influences the usable floor area inside the building

Weight: kg/m^2



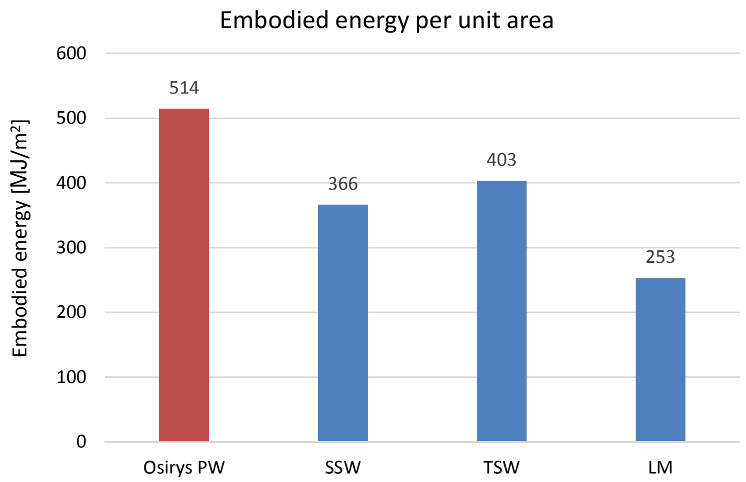
- Weight of the Osirys PW is similar to all the standard technologies, even the typically very light steel stud wall.

Cost: Euro/m²



- Missing info regarding the Osirys costs

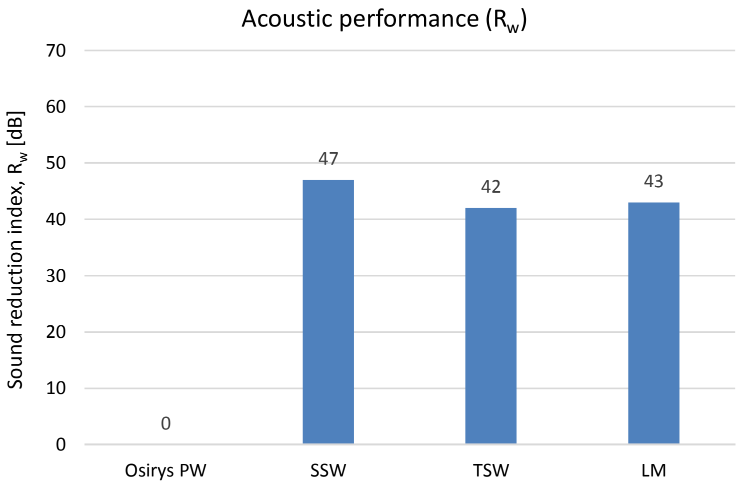
Embodied Energy: MJ/m²



- High embodied energy in Osirys MLF due to composite materials – according to I.C.E the embodied energy in typical GRP composite is ~100 MJ/kg (30x more than in concrete). If that value can be reduced then the results might be improved.

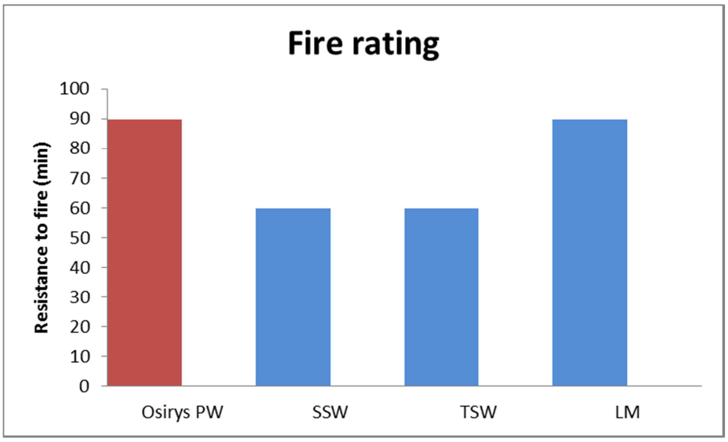
3.3.2 Installation and in-situ performance data

Acoustic performance, R_w: dB



- This data is not required for interior partitions, so it is not available for OSIRYS system

Fire rating, EI: minutes



- EI 90 minutes in the OSIRYS solution
- Osirys PW successfully obtained good rating, similar lightweight to other partition walls

Installation:

- Osirys PW is a lightweight system, allows for very fast installation with minimal training
- Cork insulation is allows for easier and cleaner handling than EPS and rockwool
- Plasterboards with pre-applied first layer of cork speed up the assembly
- Osirys PW is a modular system and can be assembled in multiple different ways

Durability and Sustainability:

Name	Durability	Sustainability
Osirys PW	Lightweight, not very robust, might be sensitive to moisture (depending on plasterboard type)	*Materials:* Lightweight materials reduce impact on the environment All materials can be recycled Natural insulation material - Cork Bio-based structural material – Biocomposite *Acoustic comfort:* Good acoustic performance (assumed according to results from the multilayer) *Indoor air quality:* Minimal moisture buffer – Cork
SSW	Lightweight, not very robust, might be sensitive to moisture (depending on plasterboard type)	Lightweight materials reduce impact on the environment All materials can be recycled (but thermal insulation is not widely recycled) Average acoustic performance No moisture buffering
TSW	Lightweight, slightly more robust than aluminium studs, might be sensitive to moisture (depending on plasterboard type)	Lightweight materials reduce impact on the environment Natural structural material - Timber All materials can be recycled (but thermal insulation is not widely recycled) Average acoustic performance Minimal moisture buffer – Timber
LM	Very robust and not sensitive to moisture	Heavy materials - increased impact on environment All materials can be recycled No artificial insulation materials Average acoustic performance Good moisture buffer – masonry units

3.4 LCC Analysis

A Life Cycle Cost analysis is a method that can be used to illustrate the advantage of new investments and to compare different investment options with each other. The Life Cycle Cost (LCC) is defined as the total cost that is generated over the entire life cycle of an object.

In a procurement process, it is common to focus only on investment costs or to make a payoff calculation that shows how long it takes before the investment is repaid. With an LCC it becomes clear that it is not always good to focus only on investment costs. It is short- term thinking that can lead to a greater overall cost. An economic assessment should take into account all costs of a product or system throughout its lifetime, from installation until it is discontinued. Not only investment costs but also cost of energy and maintenance.

The costs in an LCC calculation cannot be added directly. This is because costs arise at different times and a future payment may have a different value. A euro is worth more today than one euro tomorrow because the euro of today can be invested and immediately generate interest. With a present value calculation, the costs for different years can be converted to one and the same time with the chosen discount rate. Future costs are discounted, moved backwards, to a time when they can be compared to the initial investment (beginning of the calculation period, i.e. year 0) according to the formula:

$$q_{\mathrm{d}} = \frac{1}{(1+d)^n}$$

where

d is the expected real discount rate per annum;

n is the number of years between the base date and the occurrence of the cost.

For the LCC-tool used here the discount rate should be "real". Here "real" means that the inflation rate is taken out of the analysis. This due to the fact the forecast is made in real monetary value, i.e. fixed monetary value. This means that all cost elements in the analysis are affected equally by the inflation and it is therefore not necessary to include any compensation for inflation in the discount rate.

With the discount rate it is possible to handle the difference in value of money over time. The choice of discount rate is critical for calculating the present day values. A high rate favours short term investments with low capital cost. A low rate gives the opposite effect. The LCC analysis should use the most likely rate and, if necessary, supplement it with a sensitivity analysis. In this case a discount rate of **5%** has been chosen as a sensible European average.

The LCC has been carried out on the external cladding systems for both case studies, San Sebastian and Tartu. A combination of data measured within the project and standard industry information has been used and each is identified in the text.

3.4.1 San Sebastian Case Study

An LCC calculation sheet, supplied by partner IVL, has been used to compile a comparison between a Baseline (current practice) model and the OSIRYS model.

Parameter	Baseline	OSIRYS	Notes
Functional Unit (m2)	62	62	
Lifespan over which LCC is conducted (years)	30	30	1
Discount rate	5%	5%	
Initial cost	3600	3960	2, 3
Reinvestment cost (€)	9625/10 years	9625/10 years	4
Yearly maintenance costs (€)	15,000	15,000	5
Energy cost (kWh/year)	4944	4796	6
Energy cost (Euro/kWh)	0.24	0.24	7
Liquidation costs (€/m2)	1000	1000	

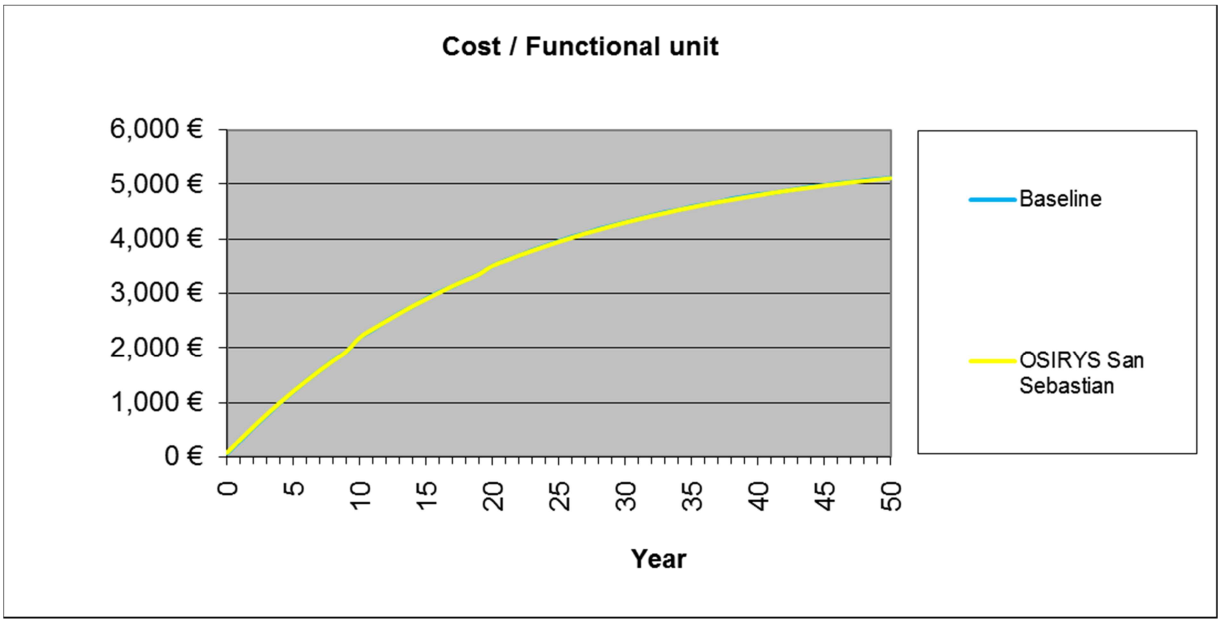
1: General guidelines are 30 years for residential, 20 years for non-residential
2: For baseline the F-01/F-02 models from D6.1 are used. Average cost €180/m2
3: For OSIRYS a 10% uplift has been added to account for it being a new, lower volume product
4: The reinvestment costs have been kept equal due lack of long-term data
5: Yearly maintenance costs have been kept equal due to lack of long term data
6: Energy costs based on: Yearly energy usage: SPAHOUSEC /Eurostat report 2011 (San Sebastian is in Gizpukoa region - Northern Spain in 'North Atlantic' category, as opposed to continental or Mediterranean
7: Energy costs based on http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Electricity_and_gas_prices,_second_half_of_year,_2013%E2%80%9315_(EUR_per_kWh)_YB16.png

The outputs from this exercise is a comparison table, shown below. Considering that there is some significant work in generating the input data, the output data might be considered to be rather disappointing. The baseline and OSYRIS data sit almost on top of each other. However, what is shown is that a 10% increase in initial investment is off-set by the energy saving resulting from the higher U-value of the OSIRYS products. The result is that, over the lifetime of the building, the use of more sustainable materials can be justified on an economic basis.

It is worth noting some of the assumptions that inevitably have to be made when working with development materials.

- The initial costs have been increased by 10% for the OSIRYS solutuon. This is a sensible adjustment to account for a newer system which has not had long on the market and will not be produced in such high volumes as the incumbent materials. However, no real data is available from the partners on the actual production costs. There is a possibility they might be lower cost.
- Re-investment and maintenance costs are estimated. Since no long-term data is available for the OSIRYS products this has been left equal to the incumbents.
- The heating and energy costs are more accurate. Figures are available for the average energy use and the cost of energy. A factor has been applied to reflect the higher insulation value of the OSIRYS products. These are actual measured figures.

- Note that allowance has been made for the fact that 50% of the facade is glazed and would be the same for the baseline and Osyris systems. There the energy saving has been more than halved to compensate.



LCC comparison table – San Sebastian case study

3.4.2 Tartu Case Study

An LCC calculation sheet, supplied by partner IVL, has been used to compile a comparison between a Baseline (current practice) model and the OSIRYS model.

Parameter	Baseline	OSIRYS	Notes
Functional Unit (m2)	400	400	
Lifespan over which LCC is conducted (years)	20	20	1
Discount rate	5%	5%	
Initial cost (per m2)	72000	79200	2, 3
Reinvestment cost (€)	9625/10 years	9625/10 years	4
Yearly maintenance costs (€)	15,000	15,000	5
Energy cost (kWh/year)	10608	7426	6
Energy cost (Euro/kWh)	0.13	0.13	7
Liquidation costs (€/m2)	1000	1000	

1: General guidelines are 30 years for residential, 20 years for non-residential
2: For baseline the F-01/F-02 models from D6.1 are used. Average cost €180/m2
3: For OSIRYS a 10% uplift has been added to account for it being a new, lower volume product
4: The reinvestment costs have been kept equal due lack of long-term data
5: Yearly maintenance costs have been kept equal due to lack of long term data
6: Energy costs based on: ‘2012 Household Energy Consumption Survey from 'Statistics Estonia'

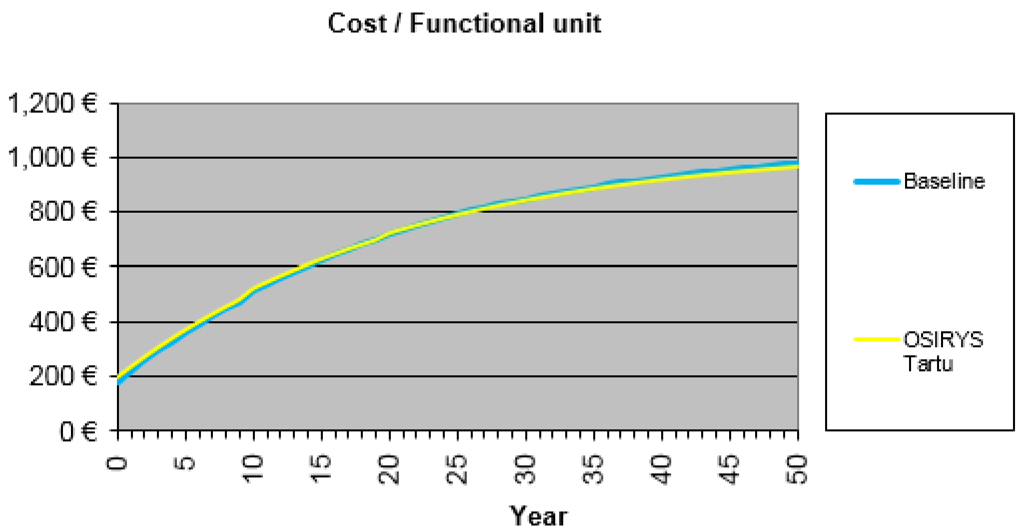
7: Energy costs based on http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Electricity_and_gas_prices,_second_half_of_year,_2013%E2%80%9315_(EUR_per_kWh)_YB16.png

The outputs from this exercise is a comparison table, shown below. The graph shows a more significant advantage for this case study as the improvement in U value is greater (30%) and the amount of energy used for heating (in a more Northern European climate) is greater. Since in the Tartu case study there is no in-situ comparison a U-value based on national guidelines has been used as what might typically be used in this region. (Baseline 0.2 W.m2k, OSIRYS 0.139 W/m2k)

There is therefore an indication that over a 20 year lifetime there is an advantage to using a better performing system (be it Osirys technology or alternative technology). In general the result is that, over the lifetime of the building, the use of more sustainable materials can be justified on an economic basis.

It is worth noting some of the assumptions that inevitably have to be made when working with development materials.

- The initial costs have been increased by 10% for the OSIRYS solutuon. This is a sensible adjustment to account for a newer system which has not had long on the market and will not be produced in such high volumes as the incumbent materials. However, no real data is available from the partners on the actual production costs. There is a possibility they might be lower cost.
- Re-investment and maintenance costs are estimated. Since no long-term data is available for the OSIRYS products this has been left equal to the incumbents.
- The heating and energy costs are more accurate. Figures are available for the average energy use and the cost of energy. A factor has been applied to reflect the higher insulation value of the OSIRYS products. These are actual measured figures.
- The figures used for energy do take into account that a high proportion of homes are heated
  from District Heating systems



4. Conclusions

There are still some data to be recalculated:

- Cost of the OSIRYS solution
- Embodied energy associated to Deliverable D8.4 which need to be revised too.

When the new data are available, this deliverable will be updated.