

## Façades as a Product-Service System

The potential of new business-to-client relations in the facade industry

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# | Preface

## **The importance of an integrated (facade) design**

The following report encompasses the research and product development I have done, as part of my Master's Graduation Programme in the field of facade design and engineering, with a special focus on innovative business and financial models.

This research follows my personal interest in the increasingly complex challenges to be met by architects, engineers and investors in order to deliver projects which are simultaneously energy efficient, architecturally creative and economically feasible.

If we want to reach the ambitious goals set by regulatory bodies towards a global sustainable development, we need to come up with solutions that are not only technically efficient and aesthetically pleasing, but which will offer the client and end-user a direct and quantifiable financial advantage.

This research tries to reconcile these three interests as far as possible, towards a fully integrated facade development practice. I invite the reader to contact me with any doubts or suggestions that might extend the currency and relevance of this topic.

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## **New strategies for designing and marketing facades**

Modernist architecture constituted an almost obsessive attempt to achieve an international style, which completely disregarded local conditions and instead highly depended on emerging mechanical climatic systems. As heirs to that practice, architects since the end of the twentieth century have been polarized towards recovering and developing diverse values of site-dependant architecture.

Architecture at the start of the 21st century seems to be divided among three main groups: the technocrats, who are on a search for ever-more-advanced digital design and manufacturing tools; the sustainability experts, who are trying to re-engage the sustainable wisdom of vernacular architecture with the latest green building technologies; and the “corporate” architects, who combine a different degree of each of the previous two groups in order to deliver the most market-oriented architectural product.

Whether we are talking of architecture as an artistic and aesthetic tendency, or as an integrated collaboration of a series of highly technical disciplines, the only way to achieve a truly sustainable culture is by matching the needs and interests of these three main groups. Finding the way to integrate technology, nature and real estate needs into horizontally integrated design solutions.

This research explores the value of facades and their impact on the overall user-, energy- and financial-performance of an architectural project. It then analyses commercial and financial

scenarios which have been in practise (successfully) in other industries, and finally proposes architectural and technological strategies for adapting the facade industry, as well as the way in which we envision and produce facades, to emerging trends in marketing and asset management practices.

Facades must be understood throughout this report not only as a building component that encloses structure, spaces and installations, but as a climatic skin which can significantly increase the value and performance of a building: it can integrate all required mechanical and electrical systems to fully define indoor comfort levels; it also constitutes the visual appearance of the construction, significantly increasing (but also potentially decreasing) its market value; it has an important role in the types of uses and activities that can be realized behind it; and finally, more important from a humanistic point of view than all the previous points, it reflects the state of social, technological, architectural and economic development of its time. In a world where innovation is replacing tradition, and in which the cycles of integration of new systems is becoming increasingly short, the best strategy for a technology to remain attractive is for it to be flexible, adaptive and efficient.

## Conceptual frame and fields of research

Calculating the effects of a facade system on the overall performance of a building is, needless to say, a highly complex process. Even if we try to analyze the facade system in terms of its most straight-forward and theoretically expectable performance (as a component that delivers a certain range of indoor climate values) the number of variables to be considered is huge. First of all, differences between the planned and designed system and the one built or installed on-site can already make an important difference, air leaks due to poor craftsmanship or inaccurate on-site adjustments are just a couple of the thousands of small mistakes that can pile up throughout the planning and construction stages of a building, and which will result in practical values significantly different from the theoretical calculations. Exterior temperatures can also play a big role in the correct function of indoor climate systems, sometimes the weather data we currently have proves to be too recent to account for extra-long-term cycles and specific climatic variations.

Indoor climate, however, is just one the many functions a facade or building envelope has to fulfill. And if some of them are difficult (but possible) to quantify, some others fall completely into the realms of the abstract, the statistical or the emotional. Marketing value, user satisfaction, cultural and heritage significance, are just some of the many aspects we take into account when projecting what we could consider the “value” of a building. In order to design

a new methodology for planning and producing integral, and hopefully more valuable, facade systems we first have to analyse and understand what it is that makes a facade a significant asset, or a determining drawback, for a building. Which are the performance criteria that we can identify as being in the common interest of all stakeholders, and which can set the ground for a measurable facade value?

Once this has been established, I will analyse recent trends in commercial architecture in the Netherlands, using as a case study projects developed by Dutch universities over the last 10 to 15 years. The wide range of data available on this topic, and gathered by one of my graduation tutors, Alexandra den Heijer, in her book *Managing the University Campus* (1) will help provide a sample of the parameters to be considered when developing a new commercial construction, and those which are more closely observed by investors and other decision-makers.

I will finish this introductory chapter by presenting and evaluating different methods for marketing and financing assets currently being used in other industries. Manufacturers of other types of technological products have found innovative ways of maintaining a close relation to their costumers, from which architecture and building engineering have a lot to learn.

(1) Alexandra Den Heijer, 2013. *Assessing facade value - how clients make business cases in changing real estate markets. 1.* Delft, NL: Delft University of Technology Department of Real Estate and Housing

*Right*  
Aesthetic and technological development, sustainability and resource-management, and the financial demands of the real estate market are the three main interests that have to be properly balanced to deliver a successfully integrated project or product.

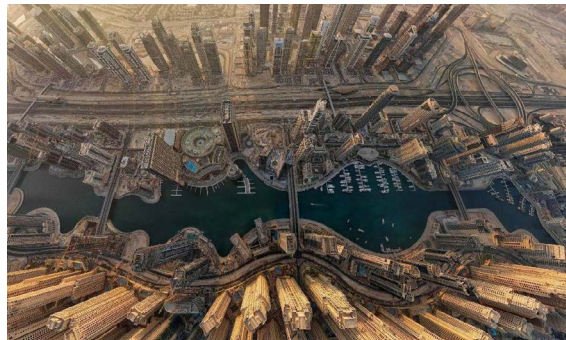
## Technology



### Building Technologies

New digital technologies for design and manufacturing expand the range of possibilities

## Sustainability



### Sustainability

Demands a more efficient use of resources with a higher energy to performance ratio

## Real Estate



### Real estate

Accelerating changes in real estate models and building use trends shorten investment-cycles

## | 1.a. Assessing Facade Value

### What is Value?

Value, not only as a term assigned to facades but as a universal concept, is a deeply personally and culturally assigned idea. Unlike price, which determines the number of monetary units a person is willing to pay for a product or service at a specific moment in time, and which is defined mostly by the tendencies of supply and demand, value can't be reduced to a purely financial concept. For example, marketing value can be seen as the success of a specific asset in promoting adjacent direct or indirect business activities, historic value is an emotional response to an object which carries a symbolic cultural weight, while energetic value is a relative concept that determines how efficient a product or service is in delivering certain results with the least amount of resource consumption. So, if value is not a single unit but a complex combination of both quantifiable and non-quantifiable subjective assumptions (because value wouldn't exist if there was not a subjective "Evaluator" willing to assess and assign it) how can I expect to base an entire scientific research on it?

As a starting point, we can look at a real-estate approach to building value (as real-estate should not only be seen as the art of selling houses, but as a complex science which determines the relevance and temporal value of land and constructions to a determined society at a specific moment). From this point of view, the value of a building, and this can be extended to analyse the value of its facade, can be determined by a series of performance-

oriented criteria which can be divided as follows (2):

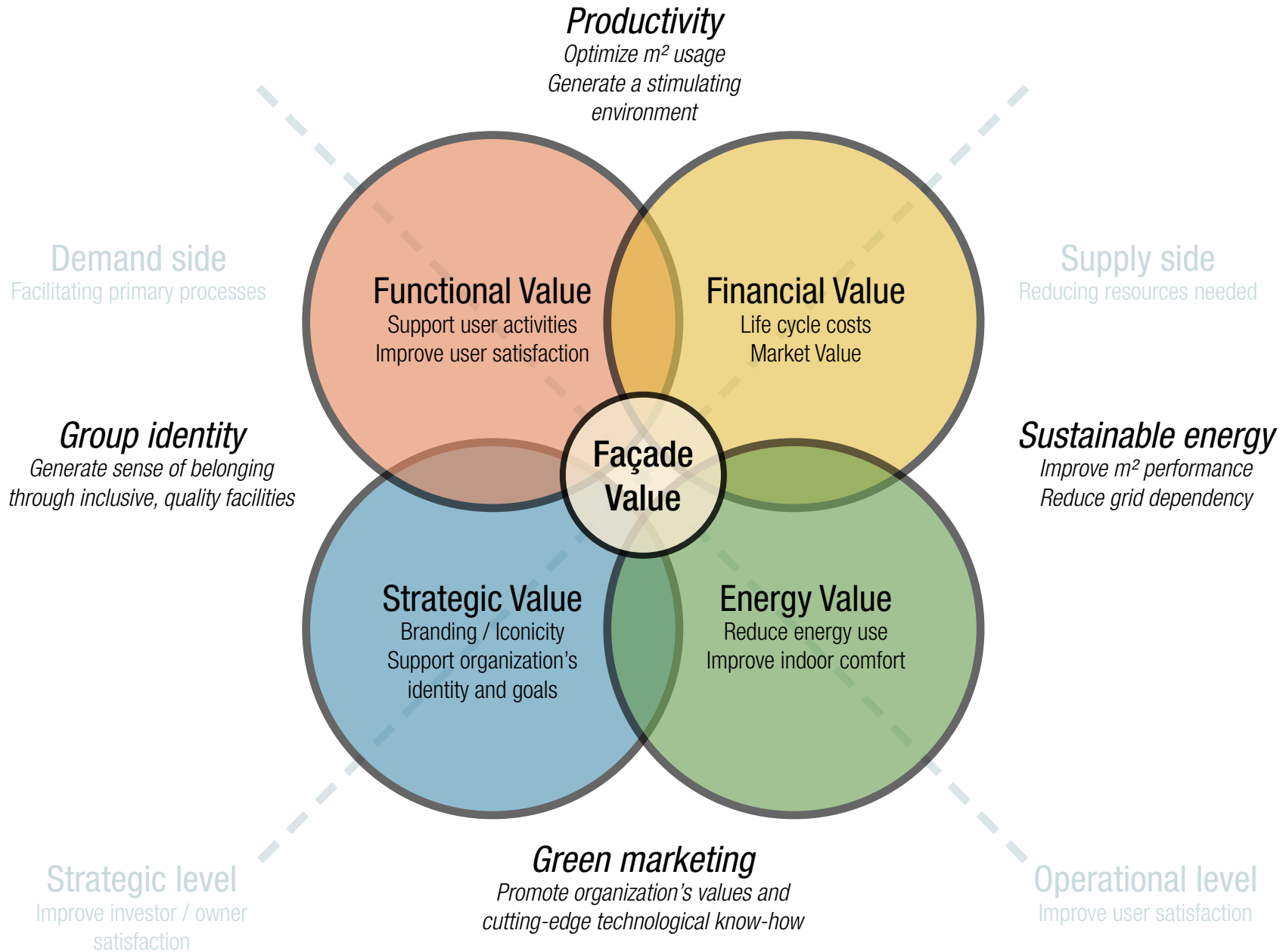
Functional value refers to the extent to which a construction promotes and facilitates the activities taking place within and around it; Financial value represents the success of a construction in recovering its monetary input by producing a direct return on investment or by allowing adjacent activities which will; Energy value describes the amount of resources being used by the building during all its stages of existence, from construction through operation and up to demolition and reprocessing, comparing this value to the average practice and the desired benchmarks; Finally, Strategic value is connected to the concept of branding and identity-creation, how does the building promote the public and social image of an institution as well as its cultural presence.

When analyzing a building, however, it is hard to find examples of these values being assigned in their purest form. It is more likely we will find one of them being used in terms of, or as a result of another. For example, energy sustainability is rarely a goal on its own (though of course there are examples of green buildings being done for purely ethical reasons) but are more commonly the result of a client's interest in reducing resource use (and therefore financial expenses), or as a marketing strategy to highlight the technological and philosophical view of an individual or an institution.

(2) *Assessing "facade value", linked to performance criteria (Den Heijer 2011, edited)*  
*The structure of this image has been remodelled from the original reference, and new caption in the overlapping regions (in italics) have been added to reflect my own conviction that in most cases performance values are not pure and specific, but a combination of decisions being taken on one field for the improvement of another.*



# | Evaluation methodology



## | 1.a. Assessing Facade Value

### Priority Values

Each architectural project is developed with a specific set of goals in mind. These goals are defined not only by the time and place in which the construction is built, but by the political, economic and social context in which they are set. This is done in order to get the best possible performance-as-return, which can be seen as user satisfaction, monetary investment, activity fulfilment, among other parameters. Using the performance-based evaluation criteria described in the previous page, we can have a rough understanding of the values (whether conscious or accidental) that are dominant in a specific construction, and which in many cases are shared throughout a certain building typology.

A poorly integrated building will be based on one strongly dominating strategy, for example getting the fastest return on investment no matter the functionality, or reducing energy consumption no matter the cost. However, these examples tend to perform poorly on a universal level, and the lacks in neglected Value criteria generally eclipse the gains (regardless of how big they might be) in the dominant value.

Successful projects, and more specifically successful facade systems, are those that manage to combine a satisfactory performance in a range of different aspects (even if not specially over-achieving in any of them), or those which have a huge performance in a specific area without alternative values being

pushed aside under an acceptable limit. In the opposite page I have arranged a series of projects according to their location in the spectrum of performance-oriented values. We can see that projects such as Disneyland (top right corner), for example, are built with a dominantly financial value in mind. This means the business plan under which the project has been developed financially justifies the relatively astronomical expenses and possible inefficiencies in other areas (for example the financial and material expenses of developing a completely customized fantasy-world, and the extraordinary energy expenses associated with running it).

On the other hand we find projects such as the ZiggoDome in Amsterdam, or Frank Gehry's Guggenheim Museum in Bilbao, which are built with such a high regard for marketing and strategic values, that they become iconic structures far beyond their spatial boundaries. If these "high-profile" projects are sometimes criticized for disregarding the needs and comfort of their users, we have to ask ourselves who the users of such buildings really are? The people that walk through them and spend time inside of them? Or everyone else, regardless if they're on the opposite side of the world, who recognize this structure as a landmark and therefore assign a strategic value to the building and its institution far beyond the financial cost of its materialization and operation?

#### *Right*

*Analysis of selected projects and/or building typologies according to their location in the spectrum of performance-based value priorities. As mentioned before, it is almost impossible to find examples of buildings that have been built with one single goal in mind, rather I tried to identify those values or combination of values which can be described as dominant in the buildings' realization and operation.*

# | Facade Catalogue



**Industrial facilities** function dictates



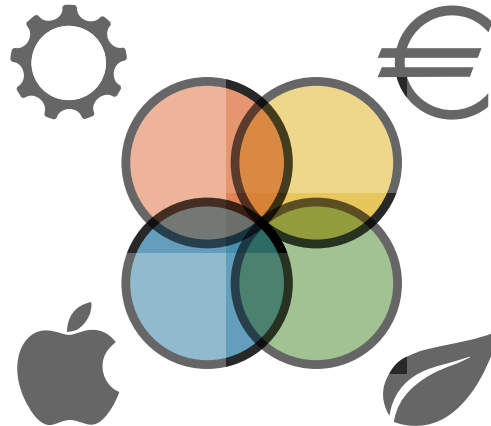
**Storage block** function / commercial activ.



**Disneyland** high maintenance / high profit



**NY by Gehry**  
Real estate enhanced by branding



**East-block facade renovations**  
energy cost reduction



**ZiggoDome** Branding for urban presence



**Solar Fabrik** sustainability as branding



**Igloo** local availability, max. performance

## | 1.b. The Dutch University Campus as a case study

### Why University Buildings?



**TU Delft BK City**

Renovation project impulsed by availability and time restrictions in special circumstances



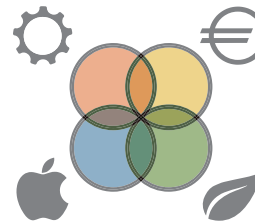
**Harvard GSD Building**

Optimal building functionality, promotion of a specific academic environment



**SCI-Arc Building**

Branding through the use of an uncommon, historically appealing structure



Left

*Images of three architecture school facilities in Europe and the United States. Academic buildings are a special type of commercial construction in the sense that they combine very diverse and highly specific uses, while (ideally at least) promoting and exhibiting the specific philosophic and technologic ideology of the institution in regards to the teaching and practice of a determined discipline.*

University campus are a specially interesting typology for a case study of building and facade value due to a series of intrinsic characteristics, the most important of which are:

**High “4-Value” demand** - The university campus and its buildings should perform well on all 4 areas, not only so they can function and remain financially feasible, but also because universities are meant to represent the epitome of human knowledge, and should therefore showcase the highest values and the most strict demands.

**Unique client scenario** - Investor, developer, manager and end-user are (generally) branches of the same organization. Horizontal value integration is in their best interest to create a holistic product that will satisfy all the different parties and stages involved.

**Unique transcendence** - Unlike other commercial buildings, such as offices and retail spaces, university buildings can be used for decades or even centuries with only slight modifications to their original form. It is not uncommon to find academic buildings which have been part of a university for three or four centuries.

**Specific branding** - As already mentioned, university buildings are meant to express more than their simple, functional use. They are a billboard of their institution's stance in terms of philosophical and technological ideology.

**Similar condition** - In the case of the 14 Dutch universities

analyzed in Alexandra den Heijer's book (1), their building portfolio is greatly made up of buildings erected during the 1960's and 70's (almost 50% of their structures have been built in these two decades). A similar, and predominant, level of decay can be seen across this sample, allowing for similar renovation strategies to be implemented globally in a wide market.

**Low rate of use** - The irregular nature of academic practices result in a highly variable rate of use per m<sup>2</sup>, with wide use-intensity peaks. Between class terms and holidays, and even throughout the day, huge building areas are either over-used or scarcely used. This results in an extremely high level of expense on the part of Universities to maintain their real estate portfolio (around 14% of overall expenses among the 14 universities analyzed).

**Changes in strategic planning** - Specially in the last 50 years, higher education institutions have seen extreme swings in the number of students enrolling for diverse academic programs. The intermittent popularity of some programs against others, or even some institutions against others, make it very difficult to maintain an updated, flexible building portfolio that can adjust quickly and cheaply enough to changes in demand.

The availability of information on this topic, and all the particular characteristics described above, make University Campus an interesting case study subject towards designing a value-oriented constructive system.

## I 1.b. The Dutch University Campus as a case study

### Institutional strategies since 1995

Ever since Dutch universities became responsible for managing their own real estate assets, in 1995, planning an effective development strategy has become increasingly important to guarantee a sustainable academic institution. In this section, I have extracted the main strategic points outlined by the campus managers of the 14 universities analyzed. We can clearly identify a series of common interests or concerns shared among all institutions, which have to be taken into account for any new project or renovation planned over the next decade and beyond.

From a strategic point of view, universities are trying to take advantage of their premium location within urban contexts, as well as their valuable green spaces and historical buildings. All this to create an appealing environment which will attract the increasingly demanding audience of highly educated professionals, who are now looking at a global academic market from which to choose an institution to attend or collaborate with. This urban approach to the Univer-city and the green campus, however, is only indirectly connected to a facade research project.

On the other hand, if we take a look at the other three performance oriented values listed, they can all be compressed into one main common goal: to make the university campus a more compact, flexible and intensely used space, which can be better connected to the city and which can share a series of programmatic activities with its urban surroundings. A more intense and diversified use

of the universities' real estate is not only extraordinarily interesting from a financial point of view (allowing the institutions to lower their real estate management costs and instead use these funds to promote new research or better, more competitive academics). It would also result in a more energy-sustainable campus, which can offer a wide portfolio of flexible spaces which can be temporarily rented out to other activities and industries, and which will be able to adapt and evolve seamlessly to changes in academic trends, student enrollment and technological innovation.

This sets the basic parameter to be considered when developing a facade system for this market typology. A flexible use of interior spaces can be negatively affected by a rigid facade system. The extremely long technical and financial terms associated to real estate investments (regularly planning buildings and facades to last at least 30 years in their original state) has to be adjusted to create shorter cycles with greater possibilities for adjustments and upgrades along the way. Sustainable architecture, in the meantime, dictates that these changes and upgrades should be done using the minimum amount of energy and materials possible. Therefore, flexible facade systems should transform and exchange materials, rather than replace and dispose of them.

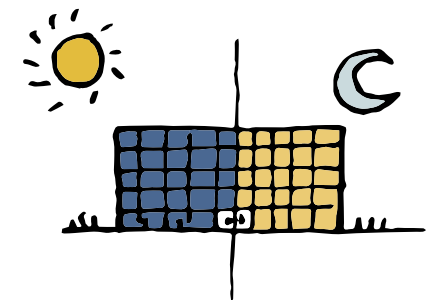
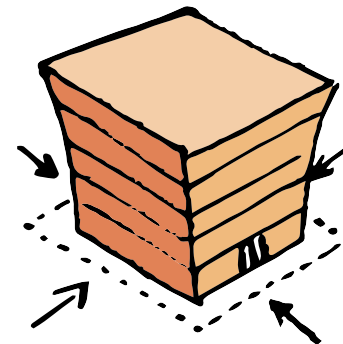
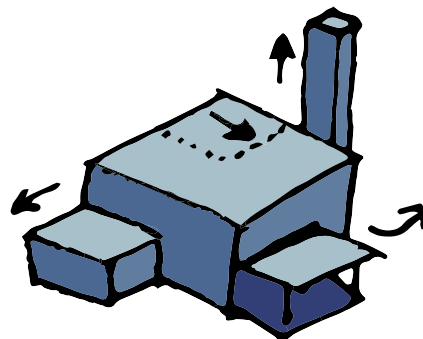
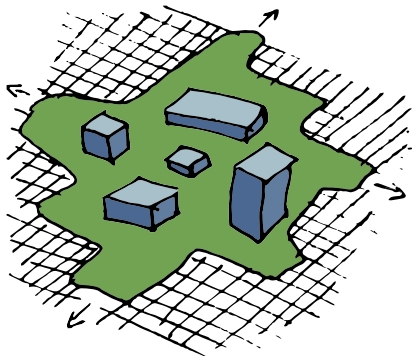
How would such a system look, work and be financed are all topics within the scope of this research.

#### *Right*

*Institutional strategies throughout the country have naturally focused on a few key subjects: Fomenting the idea of a Univer-city, which is fully integrated into its urban context and shares programmes and activities with its city; intensifying the use of university property by generating more flexible spaces; and reducing the overall footprint of university real estate.*

# Façade Value | Which are currently the main strategic goals of the university campus?

	PERFORMANCE VALUES			
University	Strategic	Functional	Sustainable	Financial
EUR	Park campus	Flexible workspace	Reduce footprint	Intensify use (implied)
LEI	Univer-city	Flexible workspace	Reduce footprint	Intensify use
OU (online)			CO2 Neutral	
RU		More users	Maintain park	
RUG	Preserve history	Expand / renovate		
TUD	Univer-city	Diversify uses		Industrial park
TUE		Diversify uses	Reduce footprint	Industrial connection
UM		Flexible workspace	Reduce footprint	Intensify use (implied)
UT	Renovate image	Intensify use	Reduce footprint	Intensify use (implied)
UU	Expand historical portfolio	Flexible workspace	Reduce footprint	Intensify use (implied)
UvA	Renovate historical image	Cluster for service sharing		
UvT		Flexibility and diversity	Maintain small footprint	Intensify use (implied)
VU	Replace buildings	Expansion and diversity	Flexible uses / small footprint	Intensify use (implied)
WU	Park campus	Share uses / reduce footprint	Share uses / reduce footprint	Intensify use (implied)
Most mentioned	Park campus / Univer-city	Expand / diversify uses	Reduce footprint	Intensify use / Reduce costs
	Historical value	Create more flexible workspaces	Renovate buildings (implied)	Connection to city and industry



## I 1.b. The Dutch University Campus as a case study

### What types of projects have been funded in the last decade?

Appendix II of Alexandra den Heijer's book "Managing the University Campus" (1), includes a list of 38 architectural projects developed by the fourteen Dutch universities mentioned, over a period of roughly ten years up to 2007. The information included summarizes not only expenses related to their initial investments, but also resources consumed by the buildings' operation. This provides important insight into the types of projects that have been developed recently, and the general trends and priorities taken into account by decision-makers when evaluating a new project.

We can see that from a general perspective, buildings which are plainly fulfilling the function for which they are designed are becoming decreasingly popular. Added value is being assigned to projects which promote a sense of community and facilitate social interaction, while institutions increasingly search for projects with a specific identity that can act as a landmark or symbol of the university. As mentioned before when discussing the effect of the Guggenheim Museum in Bilbao, new buildings don't only have to be comfortable for the users within and around them, they have to be visually appealing, recognizable and memorable, to be showcased as a marketing asset in a global network.

It is also interesting to note that facilities management (and more specifically campus management in the case of universities) provides an important amount of information regarding the expenses

related to a building's yearly operation. Previously regarded as a minor concern, rising prices in energetic and material resources are assigning a new dimension to the field of operation-cost estimation. A building might be very cheap to construct, but if the quality of systems and materials is not up to standards, operation costs in the long run might turn a healthy investment into a constant loss.

Breaking down the operation costs of a standard commercial building (4), we can see that a major part of global expenses can be attributed, fully or partially, to the performance of the building envelope. Cleaning and maintenance are in some cases specially complicated and expensive when they involve inaccessible and technically complex facade systems, while utility expenses are closely tied to the performance of the facade and its (potentially integrated) mechanical and electrical systems. Also, fixed and administrative costs, of which an important fraction is made up of financing costs incurred while building the facade and mechanical systems, could be significantly lowered by developing a new financing system for these.

Overall, I have estimated that over 25% of yearly operation costs could be "outsourced" to a third-party providing facade-leasing and indoor climate services. This by adding a fraction of each expense concept which could be attributed to the operation of a facade and its supporting systems.

#### *Right*

*Data-sheet of the 38 projects developed by Dutch universities between roughly 1997 and 2007. Strategic priorities, project dimension and financial costs are summarized in this section.*

*(1) Alexandra Den Heijer, 2013. Assessing facade value - how clients make business cases in changing real estate markets. 1. Delft, NL: Delft University of Technology Department of Real Estate and Housing*

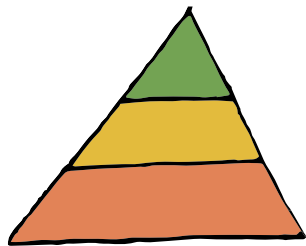
*(3) BOMA. 2010. Practical Industry Intelligence for Commercial Real Estate.*



General Information						Strategic Value	Functional Value					Financial Value					GFA	UFA	UFA:GFA	Flo	
Code	Project	Campus	Project Type	Year	Location	Maslow's Pyramid	M2 ufa / student	M2 ufa / staff	Students	Staff	FTE	Student:staff ratio	Maintenance	Energy	Cleaning	Construction	Investment				
UU-5	Drift 10	Inner city	Acquisition + Renovation	2008	Utrecht	Plain & Efficient	-	7.6	-	93	80	-	€ 12,000.00	€ 30,000.00	€ 12,000.00	€ 1,700,000.00	€ 1,700,000.00				
RUG-3	Storage Library	Zernike	Expansion	2006	Groningen	Meeting Place	3.4	-	350	-	0	-	€ 17,000.00	€ 13,000.00	€ 10,000.00	€ 1,700,000.00	€ 2,100,000.00				
RUG-6	GMW Education	Inner city	Expansion	2008	Groningen	Meeting Place	-	-	-	-	-	-	€ 15,000.00	€ 2,900,000.00	€ 3,900,000.00	€ 3,900,000.00	€ 3,900,000.00				
VU-2	W&N Faculty	VU Campus	Expansion	2008	Amsterdam	Meeting Place	-	11.5	-	52	51	-	€ 22,000.00	€ 3,400,000.00	€ 3,800,000.00	€ 3,800,000.00	€ 3,800,000.00				
<b>Averages</b>													€ 14,500.00	€ 21,500.00	€ 14,750.00	€ 2,666,666.67	€ 2,875,000.00				
EUR-2	T Building	Woudestein	New	2005	Rotterdam	Meeting Place	0.5	18.6	6888	793	665	4.72	€ 368,000.00	€ 537,000.00	€ 404,000.00	€ 52,800,000.00	€ 72,500,000.00				
EUR-3	L Building	Woudestein	New	1990	Rotterdam	Meeting Place	0.3	15.15	5679	537	352	6.39	€ 199,000.00	€ 193,000.00	€ 182,000.00	€ 22,100,000.00	€ 36,200,000.00				
UM-1	UNS 60 Building	Randwyck	New	2004	Maastricht	Meeting Place	1.8	14.8	968	200	155	2.73	€ 81,000.00	€ 110,000.00	€ 158,000.00	€ 8,600,000.00	€ 15,100,000.00				
LEI-1	Van Oort Building	Leeuwenhoek	New	1998	Leiden	Representative	-	-	-	-	-	-	€ 90,000.00	€ 125,000.00	€ 85,000.00	€ 16,200,000.00	€ 16,200,000.00				
RU-1	Gymnasium	Heyendaal	New	2003	Nijmegen	Meeting Place	0.3	0.9	12000	2890	-	4.15	€ 209,000.00	€ 265,000.00	€ 621,000.00	€ 40,200,000.00	€ 58,700,000.00				
RU-2	Huygens	Heyendaal	New	2006	Nijmegen	Meeting Place	2.3	13.6	1491	86	812	1.84	€ 1,250,000.00	€ 66,000.00	€ 85,100,000.00	€ 132,700,000.00	€ 132,700,000.00				
RUG-1	Zernikeborg	Zernike	New	2003	Groningen	Representative	2	15.8	170	86	-	1.98	€ 112,000.00	€ 110,000.00	€ 66,000.00	€ 10,100,000.00	€ 11,500,000.00				
RUG-4	Bernoulliborg	Zernike	New	2007	Groningen	Representative	2.9	17.5	537	248	176	1.27	€ 172,000.00	€ 166,000.00	€ 129,000.00	€ 19,200,000.00	€ 26,500,000.00				
UU-1	NITG Building	De Uithof	New	2002	Utrecht	Representative	4.4	12.4	340	357	-	0.95	€ 75,000.00	€ 118,000.00	€ 170,000.00	€ 28,300,000.00	€ 44,900,000.00				
UU-2	Hijmans van der Bergh	De Uithof	New	2005	Utrecht	Representative	0.8	15.8	6802	162	-	41.99	€ 147,000.00	€ 86,000.00	€ 26,400,000.00	€ 38,500,000.00	€ 38,500,000.00				
UU-3	Jeanette Donker-Voet	De Uithof	New	2006	Utrecht	Plain & Efficient	-	6.4	155	-	-	-	€ 147,000.00	€ 25,500,000.00	€ 26,200,000.00	€ 26,200,000.00	€ 26,200,000.00				
UVt-1	Tias Building	Tilburg	New	2002	Tilburg	Representative	4.7	12.4	444	263	-	1.69	€ 111,000.00	€ 79,000.00	€ 108,000.00	€ 16,400,000.00	€ 22,600,000.00				
UVa-1	REC E Faculty	Roetersland	New	1999	Amsterdam	Meeting Place	0.4	15.6	2583	353	305	3.93	€ 279,000.00	€ 167,000.00	€ 128,000.00	€ 21,700,000.00	€ 31,200,000.00				
VU-1	OZW Building	VU Campus	New	2006	Amsterdam	Representative	1.8	11	3669	294	207	7.32	€ 797,000.00	€ 400,000.00	€ 375,000.00	€ 39,900,000.00	€ 39,900,000.00				
TUD-2	L&R Extension	TU Campus	New	2002	Delft	Plain & Efficient	2.4	15.5	12	144	-	0.08	€ 146,000.00	€ 107,000.00	€ 8,800,000.00	€ 12,800,000.00	€ 12,800,000.00				
UT-3	Meander	Drienerlo	New	2007	Eindhoven	Representative	-	11.6	61	237	-	0.26	€ 316,000.00	€ 1,079,000.00	€ 344,000.00	€ 43,600,000.00	€ 62,500,000.00				
TUE-1	Helix	TU/e	New	1998	Eindhoven	Plain & Efficient	3.9	15.4	700	350	-	2.00	€ 165,000.00	€ 365,000.00	€ 45,000.00	€ 22,200,000.00	€ 31,500,000.00				
TUE-3	Spectrum	TU/e	New	2002	Eindhoven	Representative	-	11.5	25	24	-	-	€ 59,000.00	€ 27,000.00	€ 24,000.00	€ 4,100,000.00	€ 4,700,000.00				
WU-1	Main Building Lisse	Lisse Terrein	New	2003	Lisse	Meeting Place	-	14.5	-	65	-	-	€ 600,000.00	€ 521,000.00	€ 230,000.00	€ 54,000,000.00	€ 75,900,000.00				
WU-2	Rikilt Building	Wageningen	New	2009	Wageningen	Meeting Place	-	8.8	-	154	154	-	€ 600,000.00	€ 521,000.00	€ 230,000.00	€ 54,000,000.00	€ 75,900,000.00				
WU-3	Forum Building	Wageningen	New	2007	Wageningen	Representative	2.7	28.7	3000	130	130	11.54	€ 273,000.00	€ 124,000.00	€ 133,000.00	€ 22,400,000.00	€ 26,000,000.00				
TUD-1	TBM Faculty	TU Campus	New (2 phases)	2000	Delft	Meeting Place	1.7	15.1	962	352	270	1.55	€ 225,000.00	€ 384,000.00	€ 295,000.00	€ 53,900,000.00	€ 53,900,000.00				
LEI-2	Kamerlingh Onnes	Inner city	New + Renovation	2004	Leiden	Representative	0.5	13.6	4286	411	292	6.10	€ 2,474,000.00	€ 1,161,000.00	€ 1,036,000.00	€ 120,200,000.00	€ 186,300,000.00				
UVa-2	FNWI Faculty	Science Park	New + Renovation	2010	Amsterdam	Meeting Place	3	10.2	2170	1500	1160	0.82	€ 388,000.00	€ 317,789.47	€ 243,105.26	€ 31,009,523.81	€ 43,912,500.00				
<b>Averages</b>													€ 388,000.00	€ 317,789.47	€ 243,105.26	€ 31,009,523.81	€ 43,912,500.00				
UM-2	Bonnefanestraat 2	Inner city	Renovation	2005	Maastricht	Plain & Efficient	0	10.5	0	160	110	0.00	€ 73,000.00	€ 67,000.00	€ 68,000.00	€ 4,900,000.00	€ 7,400,000.00				
UM-3	Zwingelpot 4	Inner city	Renovation	2006	Maastricht	Meeting Place	5.7	12	300	30	24	5.56	€ 72,000.00	€ 43,000.00	€ 60,000.00	€ 4,300,000.00	€ 6,600,000.00				
UU-4	Kruyt Building	De Uithof	Renovation	2009	Utrecht	Plain & Efficient	5.6	14.4	350	450	-	0.78	€ 1,903,000.00	€ 410,000.00	€ 410,000.00	€ 19,300,000.00	€ 19,300,000.00				
TUD-3	Mijnbouwstraat 120	TU Campus	Renovation	2009	Delft	Representative	-	-	-	-	-	-	€ 55,000.00	-	-	€ 7,600,000.00	€ 8,000,000.00				
UT-1	Noordhorst + Oosthorst	Drienerlo	Renovation	2004	Twente	Plain & Efficient	3	10.7	1200	40	-	30.00	€ 391,000.00	€ 308,000.00	€ 344,000.00	€ 28,100,000.00	€ 38,000,000.00				
UT-2	Westhorst	Drienerlo	Renovation	2005	Twente	Plain & Efficient	8.5	8.9	4800	3020	-	1.59	€ 153,000.00	€ 339,000.00	€ 42,000.00	€ 2,300,000.00	€ 2,800,000.00				
TUE-2	Vertigo, Faculty BK	TU/e	Renovation	2002	Eindhoven	Representative	2.2	13.5	1957	336	222	3.51	€ 246,000.00	€ 231,000.00	€ 132,000.00	€ 11,000,000.00	€ 14,500,000.00				
TUE-4	Black Box	TU/e	Renovation	2006	Eindhoven	Representative	-	0.3	500	-	-	-	€ 25,000.00	€ 13,000.00	€ 17,000.00	€ 1,100,000.00	€ 1,300,000.00				
RUG-5	FEB Offices	Zernike	Renovation (rethink)	2007	Groningen	Meeting Place	-	12.1	-	548	-	-	€ 291,800.00	€ 100,100.00	€ 107,300.00	€ 5,930,000.00	€ 12,420,000.00				
RUG-2	Education Building	Inner city	Transformation	2005	Groningen	Plain & Efficient	-	-	-	-	-	-	€ 357,903.23	€ 262,296.30	€ 191,700.00	€ 23,177,419.35	€ 31,305,263.16				
<b>Averages</b>									861	508	36		€ 291,800.00	€ 100,100.00	€ 107,300.00	€ 5,930,000.00	€ 12,420,000.00				
<b>Overall Averages</b>									1624	391	138		€ 357,903.23	€ 262,296.30	€ 191,700.00	€ 23,177,419.35	€ 31,305,263.16				

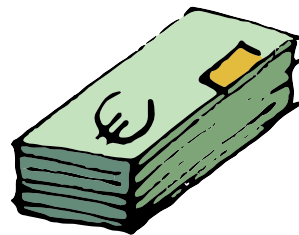
### Strategic value of projects (1)

Representative 35%  
 Meeting Place 40%  
 Plain & Efficient 25%



New 45%  
 Meeting Place 40%  
 Plain & Efficient 15%

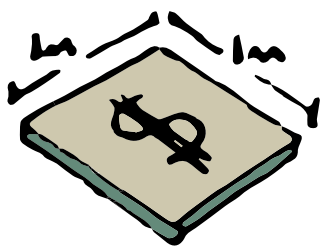
### Operation costs breakdown for a commercial building (3)



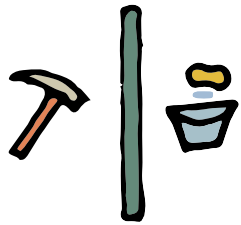
Standard costs (\$/sq ft 2009)	Cost	%	Potential PSS
Cleaning	\$ 1.50	13%	3%
Maintenance	\$ 1.75	15%	5%
Utilities	\$ 2.25	19%	10%
Grounds	\$ 0.25	2%	
Security	\$ 0.75	6%	
Administrative	\$ 1.25	11%	3%
Fixed	\$ 4.00	34%	6%
	\$ 11.75	100%	<b>27%</b>

# 1.b. The Dutch University Campus as a case study

Physical Value				Users				Investment				Façade investment potential						
GFA	UFA	UFA:GFA	Floors	Users	M2 UFA per User	Const \$ per User	Inv \$ per User	Const:Inv Ratio	Cost per m2 (GFA)	Financing costs (per year) under current 2% long-term interest rate	Operation costs (per year)	OpCosts:Inv	Façade area (40% of gfa)	Façade construction (20% of overall)	Façade cost per m2	Available façade financing (30% of financing costs (20% for façades + 10% for installations) + 30% of operating costs)	Financing per m2 of façade (per year)	Façade PSS financing per year
1300	800	62%	5	173	4.62		€ 9,826.59		\$ 1,307.69	€ 34,000.00	€ 42,000.00	2%	520	€ 340,000.00	€	€ 22,800.00	€ 43.85	€ 22,800.00
3160	2600	82%	3					81%	\$ 664.56	€ 42,000.00	€ 22,000.00	1%	1264	€ 420,000.00	€ 332.28	€ 19,200.00	€ 15.19	€ 19,200.00
1560	1210	78%	2	350	3.46	€ 8,285.71	€ 11,142.86	74%	\$ 2,500.00	€ 78,000.00	€ 45,000.00	1%	624	€ 780,000.00	€ 1,250.00	€ 36,900.00	€ 59.13	€ 36,900.00
1620	700	43%	3	103	6.80	€ 33,009.71	€ 36,893.20	89%	\$ 2,345.68	€ 76,000.00	€ 22,000.00	1%	648	€ 760,000.00	€ 1,172.84	€ 29,400.00	€ 45.37	€ 29,400.00
1910	1328	66%	3	157		€ 20,647.71	€ 19,287.55	82%	€ 1,704.48	€ 57,500.00	€ 32,750.00	1%	764	€ 575,000.00	€ 918.37	€ 27,075.00	€ 40.89	€ 27,075.00
46100	22200	48%	19	8346	2.66	€ 6,326.38	€ 8,686.80	73%	\$ 1,572.67	€ 1,450,000.00	€ 1,309,000.00	2%	18440	€ 14,500,000.00	€ 786.33	€ 827,700.00	€ 44.89	€ 827,700.00
16600	13100	79%	8	6568	1.99	€ 3,364.80	€ 5,511.57	61%	\$ 2,180.72	€ 724,000.00	€ 574,000.00	2%	6640	€ 7,240,000.00	€ 1,090.36	€ 389,400.00	€ 58.64	€ 389,400.00
10700	5250	49%	7	1323	3.97	€ 6,500.38	€ 11,413.45	57%	\$ 1,411.21	€ 302,000.00	€ 349,000.00	2%	4280	€ 3,020,000.00	€ 705.61	€ 195,300.00	€ 45.63	€ 195,300.00
6930	4190	60%	6						\$ 2,337.66	€ 324,000.00	€ 300,000.00	2%	2722	€ 3,240,000.00	€	€ 187,200.00	€ 67.53	€ 187,200.00
36000	21800	61%	6	14890	1.46	€ 2,699.80	€ 3,942.24	68%	\$ 1,630.56	€ 1,174,000.00	€ 1,095,000.00	2%	14400	€ 11,740,000.00	€ 815.28	€ 680,700.00	€ 47.27	€ 680,700.00
50100	26900	54%		2303	11.68	€ 36,951.80	€ 57,620.50	64%	\$ 2,648.70	€ 2,654,000.00	€ 1,250,000.00	1%	20040	€ 26,540,000.00	€ 1,324.35	€ 1,171,200.00	€ 58.44	€ 1,171,200.00
5220	2910	56%	6	256	11.37	€ 39,453.13	€ 44,921.88	88%	\$ 2,203.07	€ 230,000.00	€ 288,000.00	3%	2088	€ 2,300,000.00	€ 1,101.53	€ 155,400.00	€ 74.43	€ 155,400.00
12000	7350	61%	8	961	7.65	€ 19,979.19	€ 27,575.44	72%	\$ 2,208.33	€ 530,000.00	€ 467,000.00	2%	4800	€ 5,300,000.00	€ 1,104.17	€ 299,100.00	€ 62.31	€ 299,100.00
16900	10600	63%	3	697	15.21	€ 40,602.58	€ 64,418.94	63%	\$ 2,656.80	€ 898,000.00	€ 363,000.00	1%	6760	€ 8,980,000.00	€ 1,328.40	€ 378,300.00	€ 55.96	€ 378,300.00
14300	9500	66%	5	6964	1.36	€ 3,790.92	€ 5,528.43	69%	\$ 2,692.31	€ 770,000.00			5720	€ 7,700,000.00	€ 1,346.15	€ 231,000.00	€ 40.38	€ 231,000.00
6310	4070	65%	4	155	26.26	€ 164,516.13	€ 169,032.26	97%	\$ 4,152.14	€ 524,000.00	€ 233,000.00	1%	2524	€ 5,240,000.00	€ 2,076.07	€ 227,100.00	€ 89.98	€ 227,100.00
11100	6130	55%	8	707	8.67	€ 23,196.61	€ 31,966.05	73%	\$ 2,036.04	€ 452,000.00	€ 298,000.00	1%	4440	€ 4,520,000.00	€ 1,018.02	€ 225,000.00	€ 50.68	€ 225,000.00
13200	6730	51%	13	3241	2.08	€ 6,695.46	€ 9,626.66	70%	\$ 2,363.64	€ 624,000.00	€ 574,000.00	2%	5280	€ 6,240,000.00	€ 1,181.82	€ 359,400.00	€ 68.07	€ 359,400.00
20100	12500	62%	13	4170	3.00	€ 9,568.35			\$ 1,985.07	€ 798,000.00	€ 1,572,000.00	4%	8040	€ 7,980,000.00	€	€ 711,000.00	€ 88.43	€ 711,000.00
5320	3520	66%	4	156	22.56	€ 56,410.26	€ 82,051.28	69%	\$ 2,406.02	€ 256,000.00	€ 253,000.00	2%	2128	€ 2,560,000.00	€ 1,203.01	€ 152,700.00	€ 71.76	€ 152,700.00
10200	6280	62%	3	298	21.07	€ 44,295.30	€ 63,087.25	70%	\$ 1,843.14	€ 376,000.00			4080	€ 3,760,000.00	€ 921.57	€ 112,800.00	€ 27.65	€ 112,800.00
29900	17100	57%	6	1050	16.29	€ 41,523.81	€ 59,523.81	70%	\$ 2,090.30	€ 1,250,000.00	€ 1,739,000.00	3%	11960	€ 12,500,000.00	€ 1,045.15	€ 896,700.00	€ 74.97	€ 896,700.00
7760	4430	57%	4	49	90.41	€ 453,061.22	€ 642,857.14	70%	\$ 4,059.28	€ 630,000.00	€ 575,000.00	2%	3104	€ 6,300,000.00	€ 2,029.64	€ 361,500.00	€ 116.46	€ 361,500.00
2680	1920	72%	2	65	29.54	€ 63,076.92	€ 72,307.69	87%	\$ 1,753.73	€ 94,000.00	€ 110,000.00	2%	1072	€ 940,000.00	€ 876.87	€ 61,200.00	€ 57.09	€ 61,200.00
5650	3520	62%	4	308	11.43	€ 20,454.55	€ 28,571.43	72%	\$ 1,557.52	€ 176,000.00			2260	€ 1,760,000.00	€ 778.76	€ 52,800.00	€ 23.36	€ 52,800.00
35300	20900	59%	8	3260	6.41	€ 16,564.42	€ 23,282.21	71%	\$ 2,150.14	€ 1,518,000.00	€ 1,351,000.00	2%	14120	€ 15,180,000.00	€ 1,075.07	€ 860,700.00	€ 60.96	€ 860,700.00
13300	8580	65%	6	1584	5.42	€ 14,141.41	€ 16,414.14	86%	\$ 1,954.89	€ 520,000.00	€ 530,000.00	2%	5320	€ 5,200,000.00	€ 977.44	€ 315,000.00	€ 59.21	€ 315,000.00
20500	12100	59%	4	4989	2.43	€ 10,803.77			\$ 2,629.27	€ 1,078,000.00	€ 904,000.00	2%	8200	€ 10,780,000.00	€	€ 594,600.00	€ 72.51	€ 594,600.00
70300	46900	67%	5	4830	9.71	€ 24,886.13	€ 38,571.43	65%	\$ 2,650.07	€ 3,726,000.00	€ 4,671,000.00	3%	28120	€ 37,260,000.00	€ 1,325.04	€ 2,519,100.00	€ 89.58	€ 2,519,100.00
19436	11603	61%	6	2920		€ 51,832.91	€ 64,664.47	72%	€ 2,298.89	€ 878,250.00	€ 895,476.19	2%	7775	€ 8,782,500.00	€ 1,148.13	€ 498,537.50	€ 62.76	€ 498,537.50
5000	2040	41%	4	270	7.56	€ 18,148.15	€ 27,407.41	66%	\$ 1,480.00	€ 148,000.00	€ 208,000.00	3%	2000	€ 1,480,000.00	€ 740.00	€ 106,800.00	€ 53.40	€ 106,800.00
4770	2190	46%	4	354	6.19	€ 12,146.89	€ 18,644.07	65%	\$ 1,383.65	€ 132,000.00	€ 175,000.00	3%	1908	€ 1,320,000.00	€ 691.82	€ 92,100.00	€ 48.27	€ 92,100.00
49400	23600	48%	12	800	29.50	€ 24,125.00			\$ 390.69	€ 386,000.00	€ 2,313,000.00	12%	19760	€ 3,860,000.00	€	€ 809,700.00	€ 40.98	€ 809,700.00
13800	8380	61%	3						\$ 579.71	€ 160,000.00	€ 55,000.00	1%	5520	€ 1,600,000.00	€ 289.86	€ 64,500.00	€ 11.68	€ 64,500.00
8900	5800	65%	2	1240	4.68	€ 11,935.48			\$ 1,662.92	€ 296,000.00			3560	€ 2,960,000.00	€	€ 88,800.00	€ 24.94	€ 88,800.00
4800	3020	63%	2	7820	0.39	€ 1,470.59			\$ 2,395.83	€ 230,000.00			1920	€ 2,300,000.00	€	€ 69,000.00	€ 35.94	€ 69,000.00
26000	15800	61%	11	2515	6.28	€ 11,172.96	€ 15,109.34	74%	\$ 1,461.54	€ 760,000.00	€ 1,043,000.00	3%	10400	€ 7,600,000.00	€ 730.77	€ 540,900.00	€ 52.01	€ 540,900.00
1730	780	45%	3	500	1.56	€ 4,600.00	€ 5,600.00	82%	\$ 1,618.50	€ 56,000.00	€ 534,000.00	19%	692	€ 560,000.00	€ 809.25	€ 177,000.00	€ 255.78	€ 177,000.00
10800	7660	71%	11	548	13.98	€ 20,072.99	€ 26,459.85	76%	\$ 1,342.59	€ 290,000.00	€ 609,000.00	4%	4320	€ 2,900,000.00	€ 671.30	€ 269,700.00	€ 62.43	€ 269,700.00
1730	870	50%	5						\$ 751.45	€ 26,000.00	€ 55,000.00	4%	692	€ 260,000.00	€ 375.72	€ 24,300.00	€ 35.12	€ 24,300.00
12693	7014	55%	6	1405		€ 13,228.20	€ 16,343.97	78%	€ 1,306.69	€ 248,400.00	€ 624,000.00	6%	5077	€ 2,484,000.00	€ 615.53	€ 224,280.00	€ 62.05	€ 224,280.00
15817	9314	60%	6	2154		€ 42,711.70	€ 49,291.09	74%	€ 1,975.21	€ 626,105.26	€ 725,090.91	3%	€ 6,326.74	€ 6,261,052.63	€ 1,005.63	€ 376,736.84	€ 60.27	€ 376,736.84

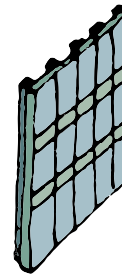


**Construction cost / m<sup>2</sup>**  
 Avg = € 1,975.00 / m<sup>2</sup>  
 Max = € 4,152.00 / m<sup>2</sup>  
 Min = € 390.00 / m<sup>2</sup>



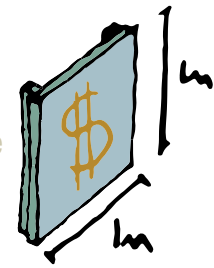
**Cons : Oper Ratio**  
 Avg = 3%  
 Max = 19%  
 Min = 1%

= GFA x 40%  
 Average ratio for low-rise, non-iconic buildings (4)



**Façade area**  
 Avg = 5,080 m<sup>2</sup>  
 Max = 28,120 m<sup>2</sup>  
 Total = 240,000 m<sup>2</sup>

= InvCost x 20%  
 Average ratio of facade costs against overall investment costs (4)



**Façade cost / m<sup>2</sup>**  
 Avg = € 1,000.00 / m<sup>2</sup>  
 Max = € 2,030.00 / m<sup>2</sup>  
 Min = € 390.00 / m<sup>2</sup>

## Estimating the market for (new) facade systems

Any realistic design research must start with a benchmark. Whether we are speaking of energetic performance or financial feasibility, having reference values to determine how successful the new system could be (compared to other products available in the market) is vital. In this section I have used industry standards, from “The tall buildings reference book” (4), to extract a rough estimate of the area of facade in each of the projects listed, as well as the related financial parameters.

We find that, even though the range of results is wide (due to some projects being simple renovations while others are new constructions), the average cost per m<sup>2</sup> of construction is around € 2,000, while operation costs average a yearly 3% of the initial investment. If we multiply a standard facade-to-floor area ratio of 40% (the most conservative value according to reference (4) for low-rise non-iconic constructions) we get that on average these projects use 5,000m<sup>2</sup> of facade surface, for a total of 240,000m<sup>2</sup>. If we consider this is only for projects built by 14 universities in the Netherlands during a decade, we can barely imagine the volume of the facade market on a global scale.

Multiplying these values by 20% (the standard relative cost of facades against total construction costs according to (4)), we get that the average building-owner invests € 1,000 per m<sup>2</sup> of facade, with a maximum of over € 2,000 per m<sup>2</sup> for certain projects.

Since a leasing model would aim at not only staying under this investment benchmark, but also differing payments and reducing risks over a long-term business-to-client agreement, it is important to have these values as a reference when calculating cost and marketing strategies for a new business model.

The specific numbers associated with what we could expect an investor to be willing to pay for a Leasable Facade System will be analyzed further in a later section of this report. First, it is important to understand what a leasing system is (in its various forms), how it works, and what are the advantages and disadvantages related to them for clients and product/service providers.

For now it is important to highlight the numbers associated with the universities' investments. If we look at the figure of 240,000m<sup>2</sup> of facade construction, and we multiply it by an average €1,000/m<sup>2</sup>, we get that only among these 38 building, roughly €240,000,000 were invested by Dutch universities into new facades, plus another approximately 100 million euros which could be attributed to the mechanical and electrical installations of these same buildings. If new constructions represent only a small fraction of the institutions' building portfolio, the market for renovating their 50% building stock of structures from the 60's and 70's already constitutes a huge market for the implementation of innovative technologies and re-interpreted facade systems.

### Left

*Data-sheet of the 38 projects developed by Dutch universities between roughly 1997 and 2007. I have used industry standards to extrapolate relevant information regarding facade areas and approximate related investments.*

*(4) Parker, David. , 2013. The Tall Buildings Reference Book. Edition. Routledge.*

### What types of business-to-client relations exist and how do they work?

#### 1. Leasing

Financing and leasing as means to facilitate business activities have been around in one form or another since ancient times. If you couldn't pay for a new plough to grow your crops with, you would secure the "purchase" of the new plough by sacrificing a certain percentage of your yearly crop production to your creditor (in this case the plough-maker). In more current terms, however, and specially in the sense of financing technological assets (such as computers and printers, not ploughs), leasing is a relatively new concept. If we look at leasing copying machines, which for me are a great example, the first case ever of such a practice was introduced by the Los Angeles County (client) and Konika (provider) in the mid-1990's to facilitate the replacement of over 500 obsolete copying machines the County was stuck with (5).

In the case of Technological Leasing, the fact that the product and service provider retains ownership of the assets results in a series of advantages for both parties:

- For the client, it means he can pay not for the printer as a product but as a service, the machine therefore doesn't have to be considered as a company asset which will depreciate and eventually become obsolete, and the payment of the machine can be done not through cash or financing, but through differed payments for a period established in the leasing contract. This means the client can replace technology more often, as new printers which are faster and have a better printing-quality become available, without having

to sell the previous ones at a lower price, and without having to squeeze the last drop of life off their printers in order to get the greatest return on investment.

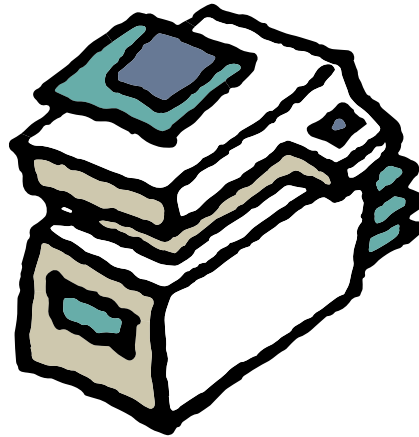
- For the provider, on the other hand, it guarantees a long-term relation with the client. Instead of just selling a printer as a one-off sale, and then having the client hire maintenance and buy supplies and consumables in the wider market, the provider assures that the client will always go to him for all his printing needs. Because the provider is not selling a printer but the service of having a printer, he is fully responsible for assuring the machines will be running, becoming also responsible for the maintenance of the machine and the replacements of parts (a service which is charged implicitly in the month to month leasing cost). What's more, because the manufacturer retains ownership of the product, he doesn't have to worry about the second-hand market of printers which will be flooding the market, and of which he will make absolutely no profit.

On top of this, from a sustainability point of view, the fact that the provider is the owner of the machine, which means he is the owner of all the raw materials, parts and electronics involved, means that it will be in his best interest to re-use these materials to produce the next generation of machines. This would result in less garbage being produced, compared to the current purchasing trend in which no one cares or becomes responsible for what happens to products once their service life is over.

(5) <http://en.wikipedia.org/wiki/Xerox>

#### *Right*

*A few examples of alternative financing models, marketing strategies and business-to-client relations implemented in other technology- or design-based industries. Transferring liabilities, assuring long-term client interaction and compensating for accelerating technology replacement are just a few advantages of these models.*

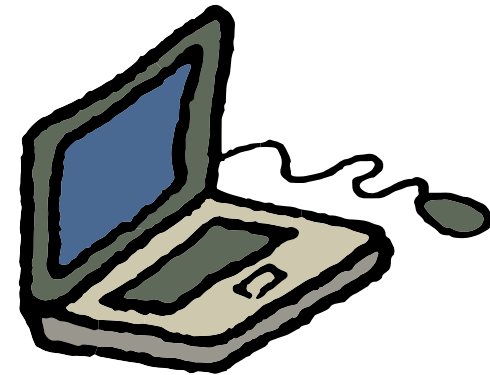


### Konika model

- Service-based, not hardware based
- Provides constant cutting edge technologies
- Provider retains ownership
- Allows for material reuse
- Eliminates second-hand market

### Technological leasing

- Capital and operational leasing
- Frees cash and credit for other investments
  - Outsources depreciation
- Increases asset flexibility and reduces risk
- Prevents “squeezing the last drop” out of obsolete assets effect



### What types of business-to-client relations exist and how do they work?

#### 2. Product-Service System Provider

Product-service systems take the principles behind the leasing concept one step further. Under a PSS agreement, the client would not only be leasing the printer, he will be leasing the service and act of printing. This means the PSS service provider is fully responsible for assuring the machines will be running, ink cartridges will be full, and even paper will be supplied. Since the PSS provider will be a company fully specialized in the specific combination of products and services needed to deliver a result, they can constantly balance costs against benefits to keep providing the contracted service while using resources in the most efficient way. The more successful they are at increasing the gap between what they charge for the service and how much it costs them to deliver it, the higher their profit margin will become. This means new technologies (which use less energy or less materials) will find their way into the market faster, since it will be in the best interest of the PSS provider to keep upgrading their technologies. On the other hand, since all hardware and software involved in providing the service are centrally owned by the PSS provider, he will try by all means possible to extend the service life of materials by re-using them for new-generation technologies.

Product-service systems have been specially developed in the industry of mobile communications. As a marketing tool, being able to offer regular phone replacements in very short-term cycles (as short as one year) is very appealing to costumers constantly hungry for the newest and most advanced equipment. Also, since a PSS is

based not on the phone itself but the service of calling, texting and data-access, the financing cost includes a full-coverage insurance against the phone ceasing to work or being stolen. This outsource of risk and liability, plus the fact that a PSS service will not require any up-front investment, makes it a very interesting option for consumers, who are willing to pay up to 50% more, in the long run, against a regular purchase type of contract (6).

A PSS approach to product development can also be applied in a way in which it doesn't necessarily imply a month-to-month financing structure. If we look at the marketing model of the jewelry brand "Pandora", their business-to-client relation is based on an initial "lower-cost" product (a silver bracelet), which is then upgraded over time, in a personal and unique process which is up to each client to decide by purchasing add-ons to the original system. In this way the product ceases to be a one-off purchase, which would imply that every time a client decides to buy jewelry he would decide from the entire range of jewelers and models, to a system in which the Pandora brand greatly improves the odds of a client returning to buy an add-on to their system. With costumers increasingly demanding accessories which can be replaced more frequently to stay within acceleration fashions, an upgradable product exploits the best of both worlds: it appeals to the costumers' emotional attachment to an item, while allowing for regular, smaller investments related to the pride of using a new item (or at least part of it) for the first time.

(6) *www.att.com, 2014*

*Right*

*A few examples of alternative financing models, marketing strategies and business-to-client relations implemented in other technology- or design-based industries. Transferring liabilities, assuring long-term client interaction and compensating for accelerating technology replacement are just a few advantages of these models.*

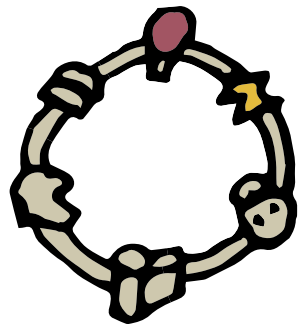
## Telecommunications

- Provides a new phone every year
- Requires no initial investment
- Increases client dependance
- Fully absorbs risks and depreciation



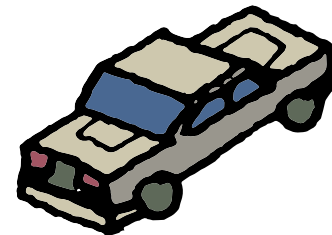
	AT&T phone + plan (Purchase)	AT&T 2 year (Leasing)	AT&T Next (PSS)
Initial cost	\$ 649.00	\$ 199.00	\$ -
Monthly financial cost	\$ -	\$ -	\$ 25.00
Plan costs	\$ 20.00	\$ 60.00	\$ 45.00
Total (24 month term)	\$ 1,129.00	\$ 1,639.00	\$ 1,680.00

\* iPhone 5c 16gb  
Unlimited call + text  
300mb data (6)



## Pandora bracelet

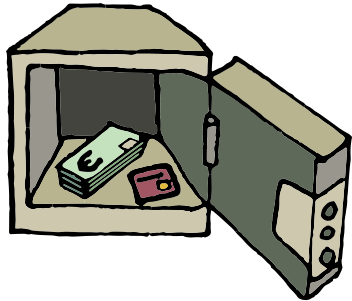
- Guarantees client return
- Allows full personalization
- Splits investment into a number of smaller transactions
- Connected to sustainable idea of up-grade, not replacement



## UK Car Hire

- Service-based, not product based
- Car, gas and maintenance included
- Simplifies corporate invoicing
- Guarantees better condition of cars for second-hand market

# 1.c. Business and Financing models in other industries



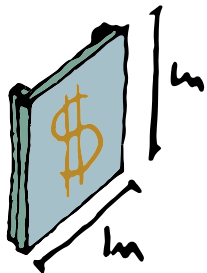
## Locks

Cash and credit resources



## End-of-life

Is no-one's responsibility



## Functional Cycle

Is tied to investment return



## Branding

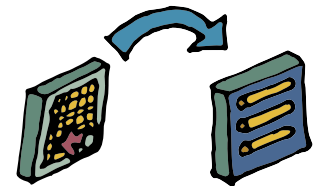
Is based not on form but on customization, personalization and flexibility

	Purchase	Lease	Product-Service System
Financial	Large initial capital investment <b>Financing "locks" cash or credit resources which could be used for other institution priorities (professors, research, equipment, etc)</b>	Higher financial costs Frees cash and credit for other uses.	Lower planing and construction costs <b>Lowens initial capital investment and overall financial costs</b>
	Depreciation is fully absorbed by the building owner (eg. University)	Allows for shorter replacement cycles.	Depreciation taken by the PSS provider, minimized through layered, life-cycle dependant design
	Financially unfeasible when interest rates are high		Allows for specialized sponsoring or grant seeking
Taxes	Full sales-taxes have to be paid up-front	In a capital lease taxes are spilt into monthly payments, in operation leases taxes are deductible as operation costs	<b>No physical assets are owned by the client, therefore the entire cost can be considered an operation cost</b>
Sustainable	<b>No one (neither the owner nor the manufacturer) take responsibility for end-of-life processing</b>	<b>Once leasing term is done, the assets normally enter the second-hand market, where their end-of-life scenario is equivalent to that of a purchased item.</b>	All climate-related systems (façade, mechanical intallations, ventilation untis) are owned by the service provider.
			Replacement with new (more efficient) technologies is the service provider's best interest
			Reprocessing of used units into brand new, or refurbished, pieces is in the service provider's best interest
Functional	Functional life is in most cases determined by financial costs (squeeze the last drop off your equipment scenario)	Shorter fixed terms allow for more frequent reassessment of system needs and functional or strategic priorities.	<b>With an extensive enough building portfolio changes can be done between clients and building incurring only installation and transportation costs.</b>
	<b>Long-term financial cycle results in very tight, unflexible systems which can't be altered or replaced without a negative economic impact</b>	<b>Systems can be upgraded or replaced any time by recalculating the monthly fee or by making a one-time payment.</b>	Service costs can be recalculated and redefined after each modification.
Strategic	<b>Form and image are completely free, modular design is not required.</b>	Strategic value in terms of appearance is limited by system modularity.	Strategic value comes from the degree of systems personalization.
	Full costumization is possible, price varies according to complexity of design.	Strategic value would reside in the potential constant interventions to the façade and the enhanced adaptability of the façade to the building uses	<b>Many technology and fashion brands have used the same "one of a kind combination" marketing approach. Pandora bracelets, block-phone, smart-phone service providers.</b>



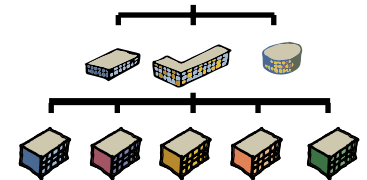
## Capital investment

Significantly reduced



## Renovation / Upgrade

Is in the service provider's best interest



## Building portfolio

Asset swapping, extends material cycles



## Evaluating the most appropriate business-to-client relation model

If we evaluate each one of these financing and marketing strategies (Purchase, Leasing and Product-Service System) according to the 4 performance-oriented values (Strategic, Sustainable, Financial and Functional), we find that there is huge potential in substituting the way in which the facade industry (as well as many other manufacturers and service providers) relate to their clients.

To start, we can see that the purchasing model has a series of determinant drawbacks for companies and individuals. First, it locks financial resources, in cash or credit, into products which might be only indirectly related to their business activities, and which might completely lack liquidity (The degree to which an asset or security can be bought or sold in the market without affecting the asset's price (7)). This full up-front investment also means the functional life-time of the product needs to be tied to its financial life-time (if you buy a machine for making plastic bottles, which will return its full investment after producing 1000 bottles, and if that same machine breaks down or is replaced after only producing 500 bottles, then the investment was obviously unhealthy and money was lost).

In the case of facades this results in an undesirable situation in which the considerable initial investment in the envelope and mechanical systems of the building mean that these systems can't be replaced until they have been paid off. This results in a major

part of constructions having obsolete or sub-standard components due to upgrades being financially unfeasible. On top of this, and as I have mentioned before, in a Purchasing scenario the manufacturer (who has more experience in the types of materials and processes involved in producing the item, and would therefore be better prepared to reprocess it at the end of its life-time) surrenders ownership, and with it any link to, or interest in the product. Since consumers are rarely bothered with finding out how to reprocess these materials, a lot of manufactured goods and useful components end up in landfills.

On the other hand, a Leasing or PSS scenario offers a series of advantages from a financial and marketing perspective. Unlike purchasing, initial investment is normally waived or limited to a small "contract and installation" fee (this fee can also be adjusted by the client to reduce their month-to-month expenses later on). The central ownership of the assets (in this case facade modules) means the service provider can balance upgrades in terms of cost against benefits, and can re-use modules throughout their client portfolio in their original form or through minor adjustments or material re-processing. The branding of the system would also rely not only on form, but on functionality, flexibility and evolutionality of its components. Financial and technical cycles can be reconciled and end-of-life scenarios significantly improved.

(7) [www.investopedia.com/terms/l/liquidity.asp](http://www.investopedia.com/terms/l/liquidity.asp)

*Left*

*Comparison chart of a Purchase, Leasing and PSS system evaluated through the 4 performance-based criteria previously established to determine the value of facades. This table can be used to determine the potential strengths and weaknesses of each model according to the demands of the real estate market.*

### Marketing strategies and product development

As stated in the introductory chapter, building envelopes and mechanical support systems can be englobed, for the purposes of this research, within a single concept as indoor-climate delivering systems. Using as a reference previous master-level research done within our faculty on the ideas of Service-Integrating Facades (8) and Disassemblable Facade Systems (9), and on the work done by my tutor, Tillmann Klein, for his PhD on the subject of Integral Facade Construction (10), the grounds for considering these systems as parts of a single, larger frame are set.

Building envelopes and mechanical systems have more than a few characteristics in common: First, each of them has a great influence on the correct performance of the other. An airtight facade with a poor mechanical ventilation support, for example, will lead to a “sick” building, while the most efficient heat-exchanging ventilation unit will be wasted in a building with a poorly sealed envelope. Second, these systems are much more similar to each other in terms of material use, assembly, replaceability and service-life expectancy than they are to other components within the building. While facades and mechanical systems are generally expected to perform properly over a period of 20 to 30 years, the primary structure of the building can easily have a service life of 100 years or more. Even more important for the topic of leasable facades, technological innovation in the fields of curtain-wall and indoor-climate support systems happens much faster and in a far

more determinant fashion than they do in the case of other building components. While concrete or steel construction has not radically changed, but just been optimized, over the last century, a curtain wall which was built 30 years ago might already be completely obsolete in terms of energy-management, hazardous material-use or outdated production processes.

It is on these aspects of “indoor-climate delivering systems” as components with a quick evolution, radical innovation and constant standards-review that my marketing strategy and product development will be based. The interrelated nature of such systems result in the current industry-to-client relation being ineffective in terms of investment cycles and sustainability. The fact that the building-owner has to rely on a number of suppliers to maintain and update his building's systems mean that these systems will not necessarily be designed and chosen to work together in the most efficient and balanced way. Instead, each contractor will make sure his specific discipline is working properly in order to cover his own liabilities, regardless of the others.

A holistic approach to building climate design would manage (and package) all these systems as one. It would take into account that all the different components within the system have to be chosen not because they are the most current or effective on their own, but because when integrated with the others they will have the greatest benefits against cost from an overall perspective.

#### *Right*

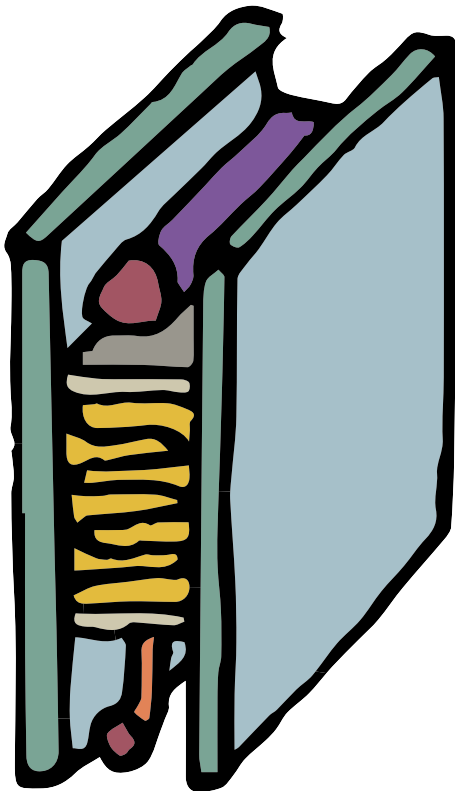
*The challenges to be met by the facade industry in order to approach the concept of integral curtain-wall systems as technological assets. Similar to a car or a computer, the final product in terms of indoor-climate delivery is more than the sum of its components. Certain technologies can be bundled together to result in a more effective overall performance.*

*(8) Hövels, Joep - Open Modular Facade - TU Delft 2008*

*(9) Matthijs Bloemen - Design for disassembly of facades - TU Delft 2011*

*(10) Tillmann Klein - Integral facade construction - TU Delft 2013*

*"Facades (and Climate Control Systems) are increasingly becoming technological assets in terms of their complexity, their shortening rate of technological currency and the role they play in a building's overall energy performance. They are not currently treated as such because of.."*



### **The way we (don't) bundle them**

- As independent systems that the client has to manage technically and financially
- As general purpose systems which will provide not one final result, but a whole range of (possibly useless) outcomes.

### **Our business-to-client relation**

- One-of sales with no possibilities for future upgrades.
- Sold as a product, not a service, therefore the facade manufacturer has no say, or interest, after the system is installed.

### **The way we finance them**

- Straight purchase requires long-term financing with no possibilities for upgrade or exchange.
- Items' financial lives are in many cases much longer than their useful, pre-obsolete service lives

### **The way we dispose of them**

- Lack of industry-wide standards result in assemblies which are impossible to break down and re-process in a cost-effective way.
- Lack of standardization and interchangeability increase logistic costs exponentially as each project becomes a one-off case.

## I 2.a. Design parameters and system requirements

### Facade-Integrated Building-Climate Services Provider

A complicated term for a complicated concept, an FIBC Service provider would be an organism in charge of centrally managing indoor-climate hardware and software, in order to constantly deliver the most effective results with the lowest use of resources.

In a current typical building scenario (left on the opposite page) the building owner will, through financing, purchase a variety of systems from a wide range of suppliers. Ventilation, heating, automation, curtain-walls, and all the other components of an indoor-climate system will all be provided by independent parties according to the general plan of the architect. It is then up to the building's maintenance and facilities management teams to keep these systems running, replace any parts that might break down and eventually upgrade entire systems when they become obsolete.

The end-service, which in this case is a comfortable range of indoor-climate values, is therefore the last link in the chain of processes required and parties responsible for fulfilling them. If any part of the system requires major renovation or upgrade, the cycle returns to the top of the line, and the client financially reinvests in a new technology provided by the same, or a different supplier. As mentioned before, this methodology makes technological currency difficult to maintain, as the building owner is purchasing the diverse systems, and will therefore have to use them as long as possible to increase his return on investment.

In an FIBC service provider scenario (right on the opposite page), on the other hand, all financial, technological and human resources required to deliver the final service (indoor-climate values) are centrally managed by the service provider. The building and its owner are therefore at the end of the supply chain, as they simply hire the service of maintaining this indoor-comfort level; Outsourcing everything implied in delivering it to a third-party with a full, specific experience in doing it.

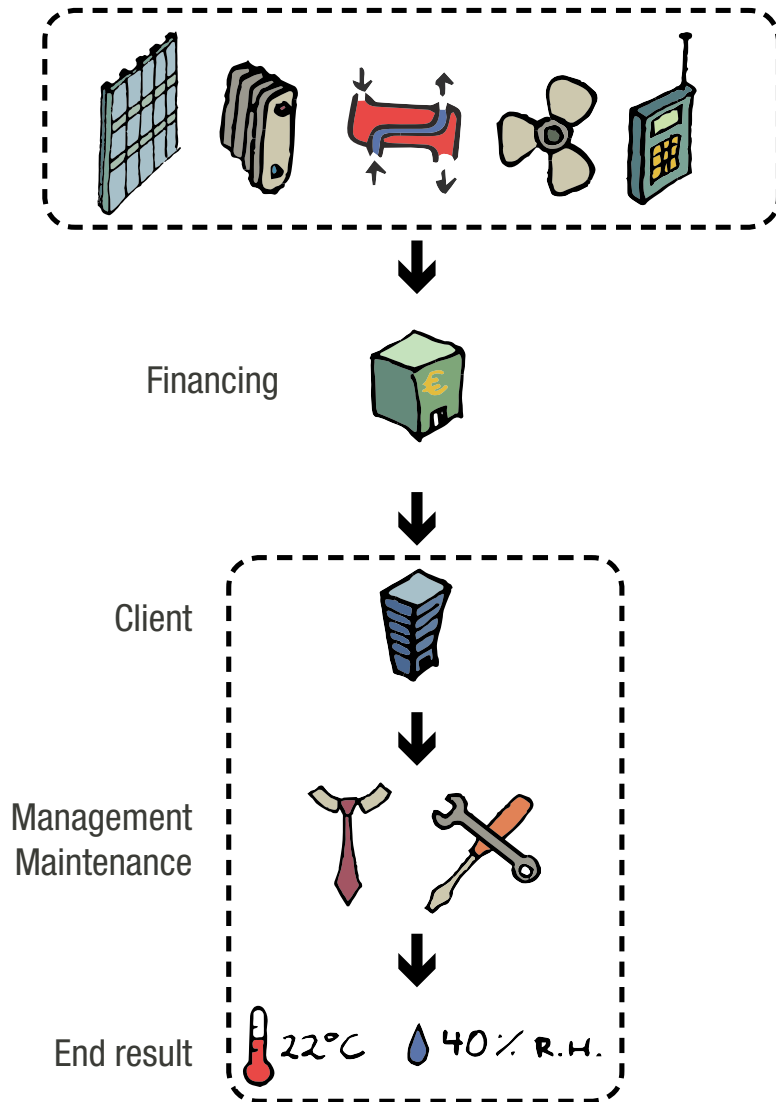
Since all the systems involved will be integrated into the diverse layers of the curtain wall, it is the service provider's responsibility to design these layers accordingly (taking into account materials' life-cycle analysis and end-of-life scenarios), as well as to balance all the technologies, manufacturing processes and installation methods to deliver a holistic system that works together in the most effective way. It is also his role to continually evaluate modifications or upgrades that might reduce his costs for delivering this service (therefore increasing the difference to what they charge for it, and optimizing their profit). Since ownership of materials is maintained by the central service provider, he can more easily remanufacture his old equipment into raw materials and new technological applications. This would mean technological turn-around cycles would be accelerated, as financial cycles will be tied to material cycles, and material cycles will be more efficient in transforming, (instead of disposing of) obsolete components.

#### *Right*

*Information and material flow in a traditional purchase/leasing scenario (left), and a product-service system scenario (right). The fact that in a traditional purchase method the building owner needs a team of in-house facilities managers further increases the administrative and financial costs of this type of system. By outsourcing the entire process, the building owner can focus on more important strategic business decisions.*

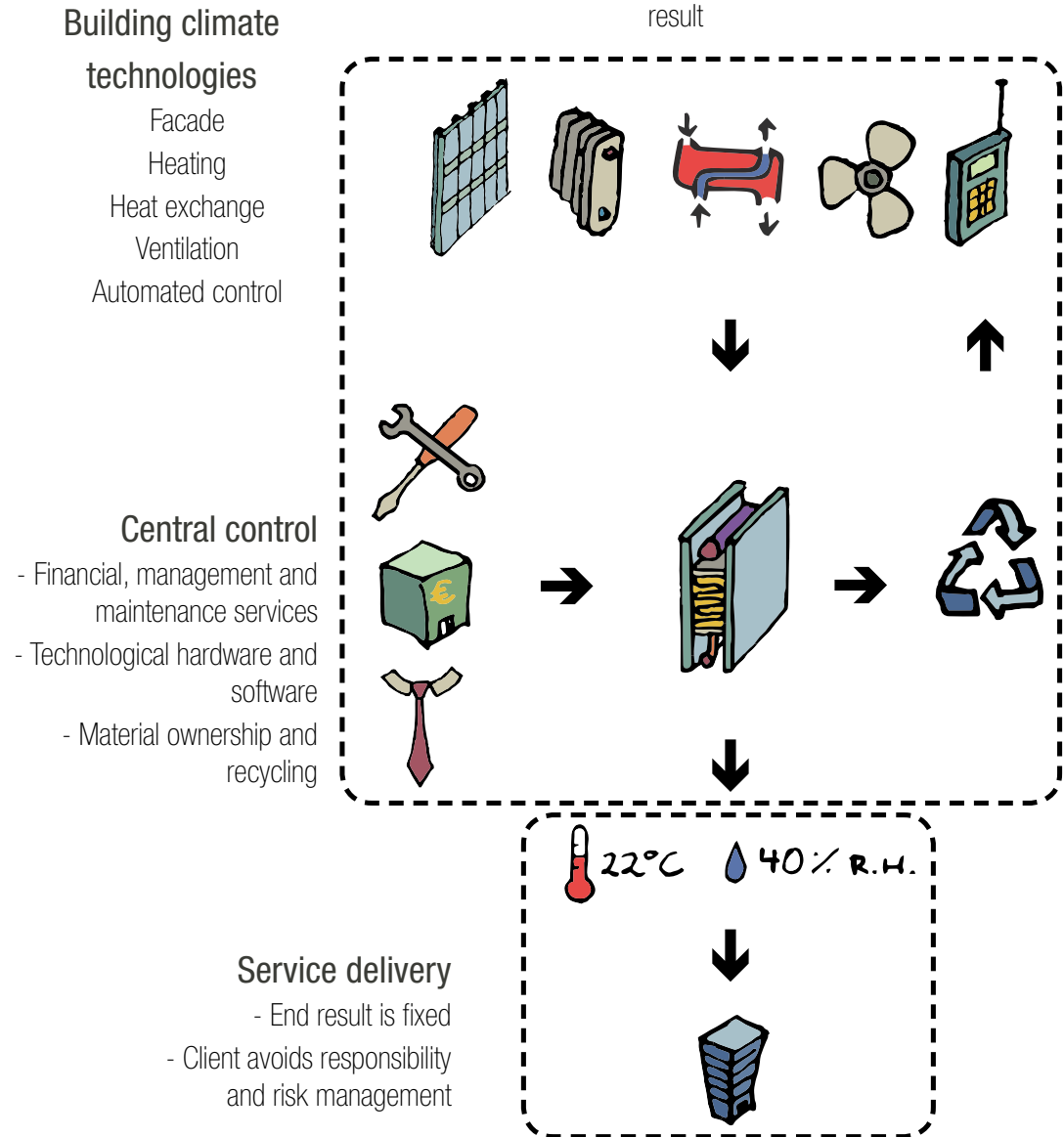
## Traditional purchase or leasing

Financing and managing of technological products to obtain a range of final results



## Product-Service System

Bundled products and services based on final result



### Designing an attractive modular system

From a marketing perspective, the biggest challenge of modular facade systems is the common conception of architects that they will limit the formal freedom of their designs. This has caused promising attempts at creating modular, service-integrating facade systems to either fail or have a smaller market share than expected. Two examples of this type of curtain wall systems, the E<sup>2</sup> and the TEmotion, are widely discussed by Joep Hövels in his master thesis (8). The main drawbacks in these designs is that they are more restrictive than regular systems in terms of the positioning of components within the panelized curtain-wall. This is logical, as the location of these components is dictated by functional requirements, not by an arbitrary design intent.

To compensate for the fact that a leasable facade system has to be, by definition, modular, the marketing perspective of the product would be that flexibility is no longer a literal formal attribute, but the result of modifications and upgrades being done to the system over time.

To go back to the example of mobile phones, we can all remember phones in the mid-2000's reaching a peak in formal design variables. Phone designers at the time were trying every single possible variation to create an "innovative" product, from phones that would open into two halves, rotate, slide, eject a keyboard from their back, be small enough to make it hard to

type a number in, among other, often absurd ideas. Contrasting this against phone design today, we find that flexibility is no longer to be found in terms of visual appearance but in terms of performance. Most phones nowadays look exactly the same, with a slightly bigger or smaller touch-screen and a button in the lower center. Value in this case is assigned to in-built software and hardware (functional attributes) and to the brand and operating system of the unit (mostly a strategic attribute).

Extending this case-study to the current topic of facades, the diverse hardware layers offered to the client through a system catalogue should compensate for the apparent rigidity of a geometrically modular system. What's more, such a system would be specially interesting for building renovations, in which the formal language of the building is predetermined and difficult to change, regardless of the formal ambitions of the architect.

As we have discussed before, a major part of the buildings in Dutch universities (and this is also the case for most commercial and residential constructions throughout Europe) have been built in the 60's and 70's during the times of economic prosperity after the Second World War. These buildings are in most cases examples of functionalist, block-like architecture, built with the modernist approach to standardization and modularity, and would therefore be perfect candidates for renovation through leasable facades.

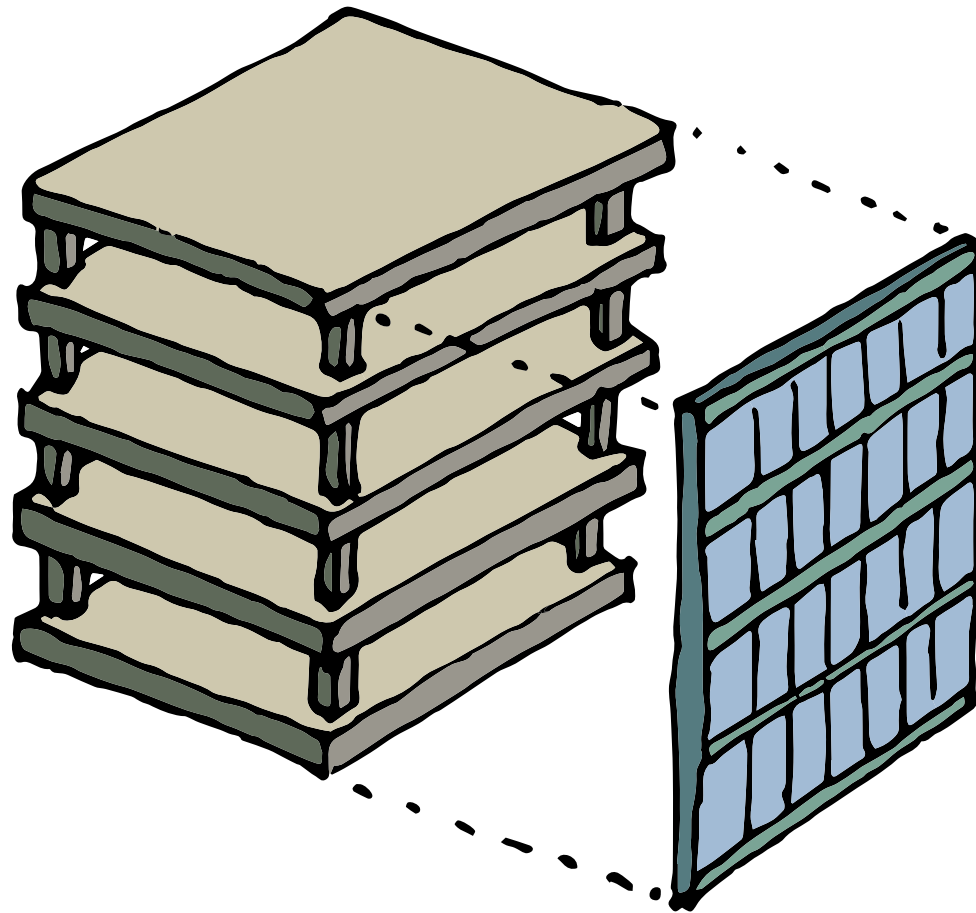
*(8) Hövels, Joep - Open Modular Facade - TU Delft 2008*

#### *Right*

*Many of the newest facade systems are trying to appeal to the high-end iconic facade market which generally dislikes modular solutions.*

*Intended for the huge portfolio of buildings from the 60's and 70's which are in need of renovation, and which are already built with a standard, modular approach.*

Not ONLY intended for iconic buildings



**Structural**  
Support layer

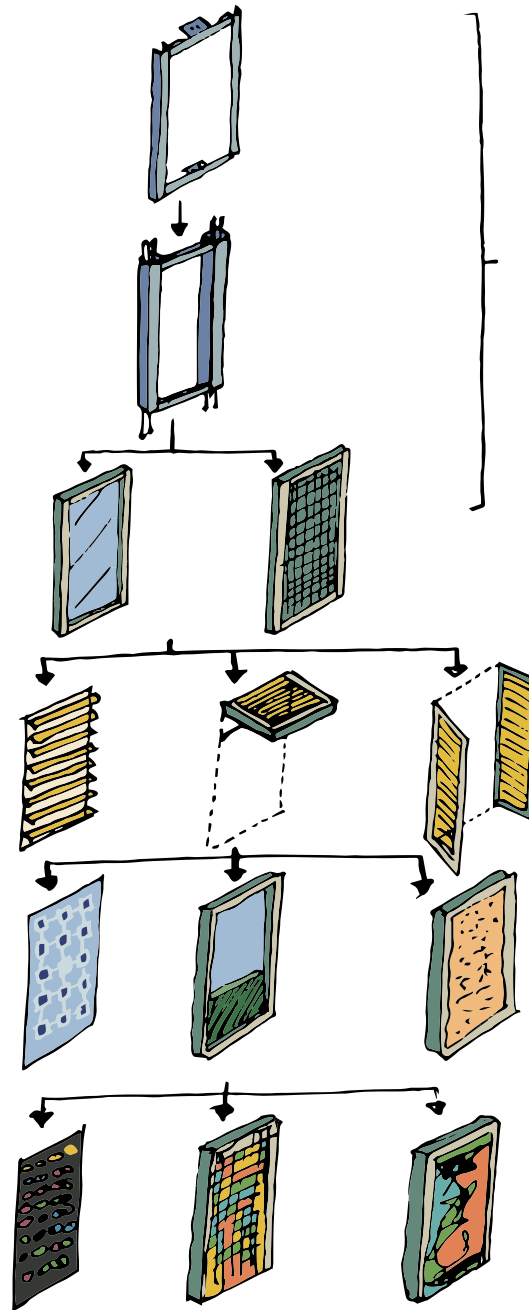
**Mechanical**  
Installations and systems

**Performative**  
Watertightness and appearance

**Solar Shading**  
Fixed or adaptable

**Energy**  
Generation / Storage

**Media**  
Sponsorship / Informative



**Base Systems**  
Required initial investment  
Longer term contract

**Add-on's**  
Shorter term upgrades for  
strategic flexibility  
Modular interchangeability  
throughout building portfolio



## | 2.b. Marketing Appeal



### Top

*Exploded diagram of the concept design for the Phoneblock mobile device. Blocks containing individual functions would be independently sold and attached to a basic main-frame, upgrading or replacing obsolete components without the need to replace the entire device.*

### Left

#### **Unit catalogue**

*Would expand through time as new technologies become available, older units become cheaper and stocks of second-hand panels vary.*

As in the case of other technological products, such as a computer's motherboard or the main support-card of the still conceptual Phoneblock (pictured on the left), the system would be designed following the idea of plug-and-play upgrades to a basic infrastructural frame.

The layering of the system would therefore take advantage of the degree of use of the different components and the materials in which these are fabricated, to optimize the durability and performance of each system. The primary support layers, for example, would be fabricated with very durable materials to extend their financial and functional life. These layers, which would provide the basic curtain-wall needs such as structural stability, insulation and watertightness, and which would house the mechanical installations running through the facade, would be expected to change less frequently. Therefore they would be designed to last for a longer term of between 10 and 30 years.

The secondary layers, which would be designed to act as mosaic components to be installed on to the primary frame, would provide the additional value-oriented features that each specific client wishes to enhance. Either as single components, or as a combination of layered panels, they would provide the final appearance, additional functions such as solar shading, energy production and storage, media and advertisement showcasing, etc. These layers would be produced with the idea of more frequent

replacement, and would be designed to be fully disassemblable to facilitate end-of-life material re-use.

Since the requirements and standards of all buildings are not equal, more demanding buildings would take advantage of the fastest-changing technologies, while previous generation technologies would be downgraded and used in construction with lower standards. So, for example, the buildings with the largest area and energy consumption would be the first ones to get a new solar panel module installed by the service provider. This is logical since such a project would result in greatest financial and energetic profit by saving the most resources. The panels that are removed from this building when the new ones are installed would then be re-assessed, to be either broken down and re-processed into new technologies (if they are past their optimal service-life) or re-used in another building within the service provider's portfolio, whose energy demand might be smaller or whose solar panels are even older and less performing.

The selection and combination of panels from the catalogue would result in a re-calculation of the monthly leasing fee. With only a minor installation cost due to its easy plug-and-play mechanism. This would make it easier for building-owners to make the decision of changing or upgrading their curtain wall system, as they would not have to make a full investment from scratch.

## User-defined service layers

## I 2.c. Financial Feasibility

### How much could a client invest in such a system?

In order to calculate the financial feasibility of a leasable facade system, I first calculated the overall costs attributed to indoor-climate delivering systems (curtain wall and mechanical installations) in a typical, commercial, low-rise building. Using the data I had extracted from the 38 university projects in chapter **(1.b.)** of this report, and extrapolating basic financial parameters by using industry standards from “The tall building reference book” (4), I got as a result approximate values for the investment and operation costs of a standard commercial building.

As shown in the diagram in the opposite page, direct curtain-wall investment is generally around 20% of overall construction costs (this applies more accurately to non-iconic buildings with a 40% facade area: gross floor area ratio). On top of this we can consider an additional 10% of overall construction expenses which are usually related to mechanical indoor-climate systems such as ventilation, heating, cooling, heat exchange and automation. This means nearly 30% of a new construction’s initial investment can be attributed to indoor-climate delivery systems, plus their corresponding financial costs (currently the long-term interest rate is extremely low, around 2% a year, but such a low value is generally an exception).

As I had previously calculated in **page 17**, we can add another 30% of yearly operation costs which are directly and indirectly related to the resource and energy consumption of the same

indoor-climate delivery systems. By adding the initial investment costs (divided into yearly financing payments and accounting for accumulated compound interests) and yearly operation costs, I have calculated how much a building-owner spends per m<sup>2</sup> of facade in a traditional 30 year investment. Since the goal of this project is to also show that a leasable facade could be produced within a justifiable price-range of a traditional purchased system, these benchmark values will become important when designing the types of user-defined service components that will be available in the catalogue.

We see that, from the data of the 38 projects listed, the average building-owner spends approximately € 60.00 per m<sup>2</sup> per year on indoor-climate-related systems. This value, however, can be as high as € 256.00 per m<sup>2</sup> per year for more iconic constructions. In principle, a leasable facade could be rented out for a slightly higher cost than these parameters (up to 50% if it was to behave in a similar way to the iPhone scenario analyzed earlier). This higher cost could potentially balance, in the eyes of an investor, against the considerable reduction in initial investment, as well as the outsourcing of major risks and liabilities. From the point of view of the service provider, liabilities would be minimized through highly specific expertise in the understanding of building physics and the delivery of indoor-climate services.

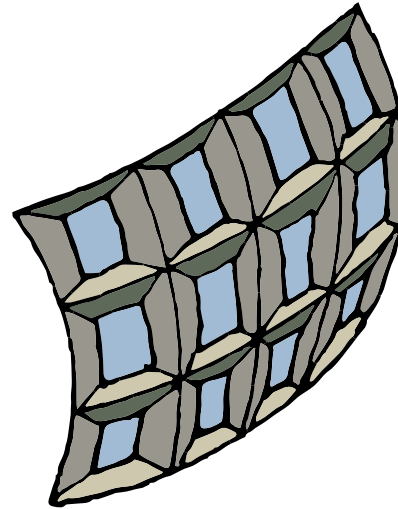
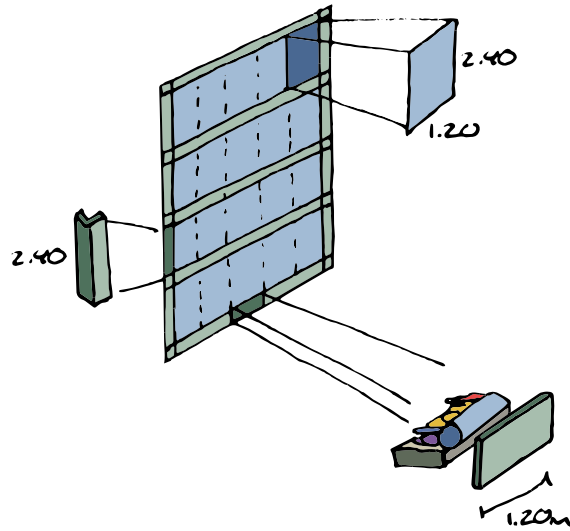
(4) Parker, David. , 2013. *The Tall Buildings Reference Book*. Edition. Routledge.

#### *Right*

*Breakdown of yearly expenses related to building envelope and mechanical support systems. Yearly financing of initial investment plus percentage of yearly operation costs result in the yearly cost per square meter of facade paid every year by the building owner. These values will be the reference when calculating and appropriate market price for a leasable system.*



## | 2.d. Technical and design considerations



### Grid Definition

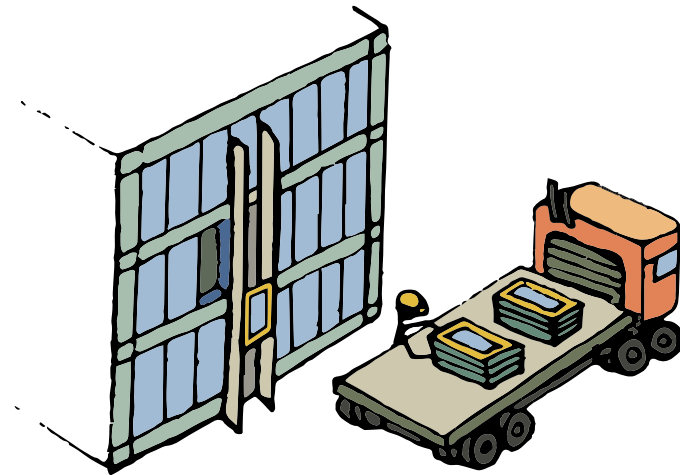
A modular design would enable panel interchangeability and unitary upgrades. Specific financial and material cycles would be taken into account when designing and developing each type of modular system or technology. The panel size has to be determined in order to fit the widest range of building configurations, reducing the size of the adjustment modules in order to preserve an attractive exterior appearance.

Vertical and horizontal adjustment units with long durability, easily disassemblable for fast re-processing would be installed (as more permanent components) in the gaps between the performance panels. These units would house certain integrated systems such as ventilation and heating. Since these panels would be custom-made to fill in the variable dimensions of each building, they would be financed as a long-term lease with more limited change possibilities.

### Adaptability to complex shapes

As a further step, the same modular panels that can be used in classic, orthogonal buildings could be used as tiles to produce complex geometrical surfaces. The main variation would be in the geometry and relative cost of the custom-made adjustment panels, as they would be the ones filling in the curvature or irregularity of the non-orthogonal curtain wall.

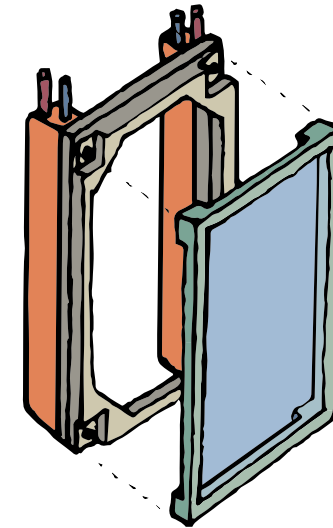
While such a system could result unattractive to architectural designer because of the proportion of transparent/modifiable panels against infill modules, the fact that it would still offer long-term upgrade possibilities might be enough to guarantee its success in certain types of projects.



## Prefabrication

The entire business model is based on the catalogue modules being easy to exchange and replace. On-site construction should be very limited, and most adjustments should be done during the original installation of the basic infrastructure panels and the adjustment modules. Since watertightness and basic insulation would be guaranteed in the bottom layers, modules attached on top of these should be simple to remove and replace without requiring on-site modifications.

In order for the system to be successful, logistic and transportation costs should be kept to a minimum. Moving new panels from the manufacturing facility to the building, and among buildings (when exchanging used panels between them) should be as easy and quick as possible. Material life-cycles should be considered for the design of each type of panel, making a special distinction between base panels and add-on's

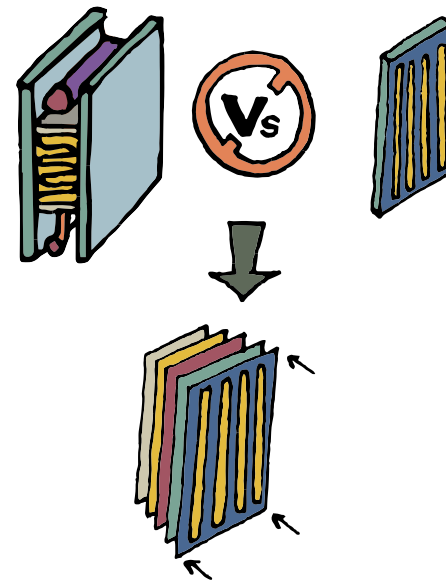
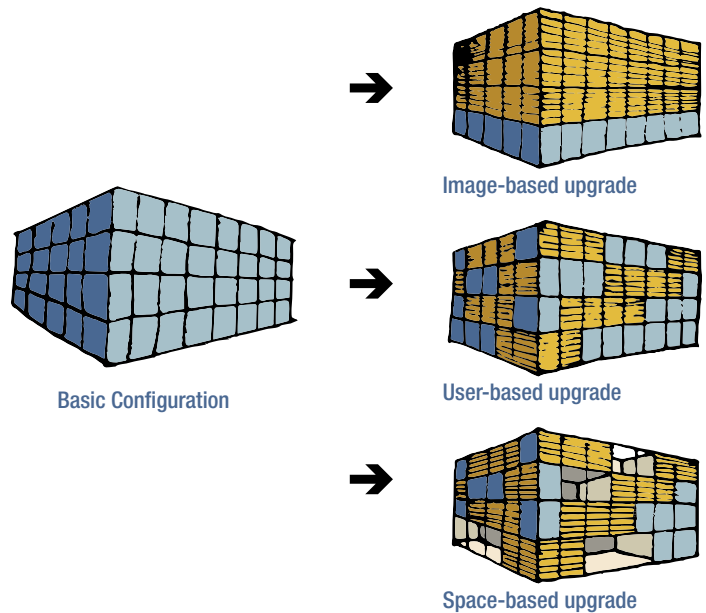


## Plug-and-Play system

The prefabricated panels have to be designed in order to allow for standard connections and plug-and-play interfaces throughout the module catalogue. Any change in the type of connection between lower and upper layer would result in a new cycle of on-site adjustments. These changes would be expensive, time consuming, and potentially disturbing to the client and building-users, which would completely defeat the marketing perspective of the system as being simple, flexible and non-intrusive.

Special attention will have to be given to electrical or mechanical connections between layers. Since some of the upper panels might be complex systems for energy generation, mechanical automation or media visualization, they will need a safe, durable and fail-proof connection to the main-frame.

## | 2.d. Technical and design considerations



### User flexibility and personalization

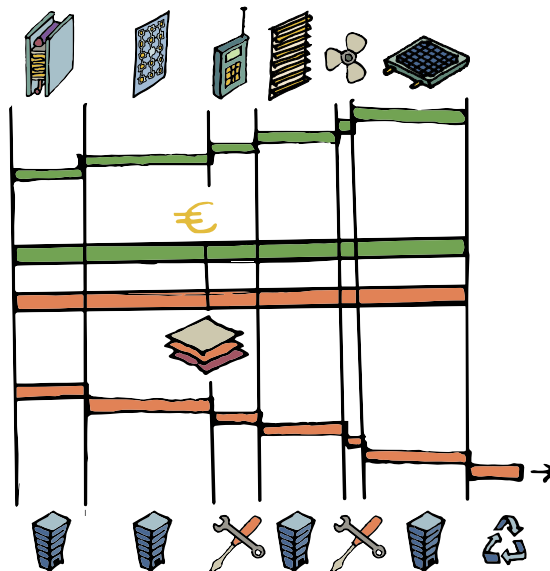
As previously mentioned, all adjustments should be done in the structural and base-panel layers, making sure the grid is properly aligned to make the installation of future add-on panels as simple as possible. Once this base infrastructure is set geometric, visual or technological modifications and upgrades can be done with only a minor investment and within a fraction of the construction time.

Real-estate trends are changing at an accelerated pace, the flexibility of a building to adjust through time to new types of activities and uses of space will significantly increase its chance of remaining current and extending its service-life. A leasable facade simplifies the process of re-inventing a building, inside and outside, to make up for fashion trends in architecture or changes in tenant requirements. From a building-owner perspective this would improve the chances of keeping their building occupied and their investment safe.

### Absorbs emerging technologies

Constant changes and innovations in facade technologies result in a constant competition between developers in which new technologies displace existing ones, as these become obsolete or no longer cost-effective. A modular, leasable system would allow new technologies to be integrated into an existing infrastructure (instead of completely replacing the old which would result in higher financial and material costs).

Modular Integration would allow new technologies and emerging systems to be absorbed into the catalogue and immediately available to the client-base. Since the service provider would be in charge of balancing and acquiring new technologies for implementation throughout their building portfolio, they would be able to down-cycle older technologies to buildings with lower requirements, while using the newest and most effective systems in the most demanding constructions.



## Reconciles Financial and Material cycles

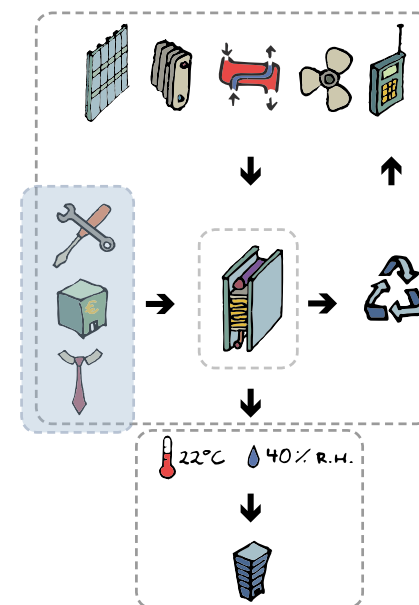
Material and financial cycles are currently uncomfortably tied, buildings can't afford to keep renewing their climate control systems until they finish paying for the previous ones. A leasable indoor-climate delivery system would optimize the use of financial and material resources by being:

**Upgrade-based** (instead of replacement based)

New technologies for climate-control and energy demand reduction should be integrated as they become available.

**Re-use and refurbish based** (instead of disposal based)

Shorter cycles of exchange within the service provider's building portfolio would extend the service life of units to their maximum life-cycle potential. Central ownership would guarantee full material reuse

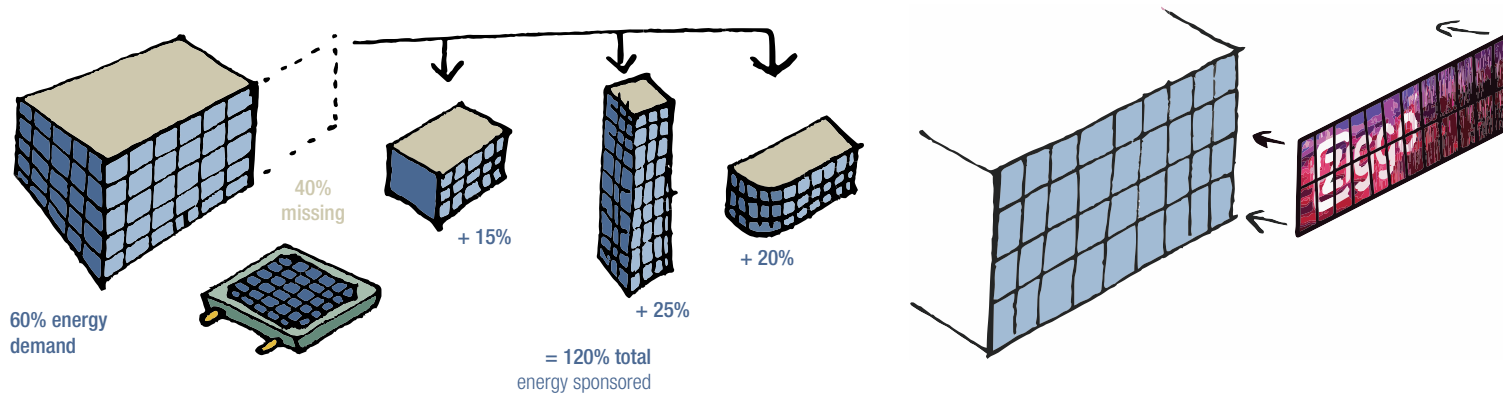


## Outsources management and risks

A service-based business-to-client relation would promote innovation and integration of latest technologies towards a more energy and cost effective service delivery. Systems would be evaluated, according to holistic approach which would consider financing, installation and operation, and decisions regarding system upgrades would be centrally taken and the applied throughout client buildings.

Individual facilities managers could then concentrate on strategic decisions regarding their primary business activities. Building owners would no longer require to keep an in-house team of indoor-climate experts and maintenance staff, these costs could be handled by the service provider and therefore shared across the building portfolio.

## | 2.d. Technical and design considerations



### Sponsor- and subsidy-friendly

The application of a modular leasable facade across a number of buildings would greatly facilitate interaction and support among building owners, and from third parties. The service provider would in this case be a mediator between sponsoring or subsidizing parties in the target building(s). Two scenarios in which this might become practical would be:

#### For CO<sub>2</sub> Point Acquisition

A current system for CO<sub>2</sub> point exchange allows companies with a high CO<sub>2</sub> emission to trade-off positive points by investing in green technologies, renewable energy sources or low-emission facilities. The idea is to allow buildings which can't be energy neutral within their boundaries to become so by balancing out on a wider, global scale.

In a leasable facade system grants, subsidies or cross-

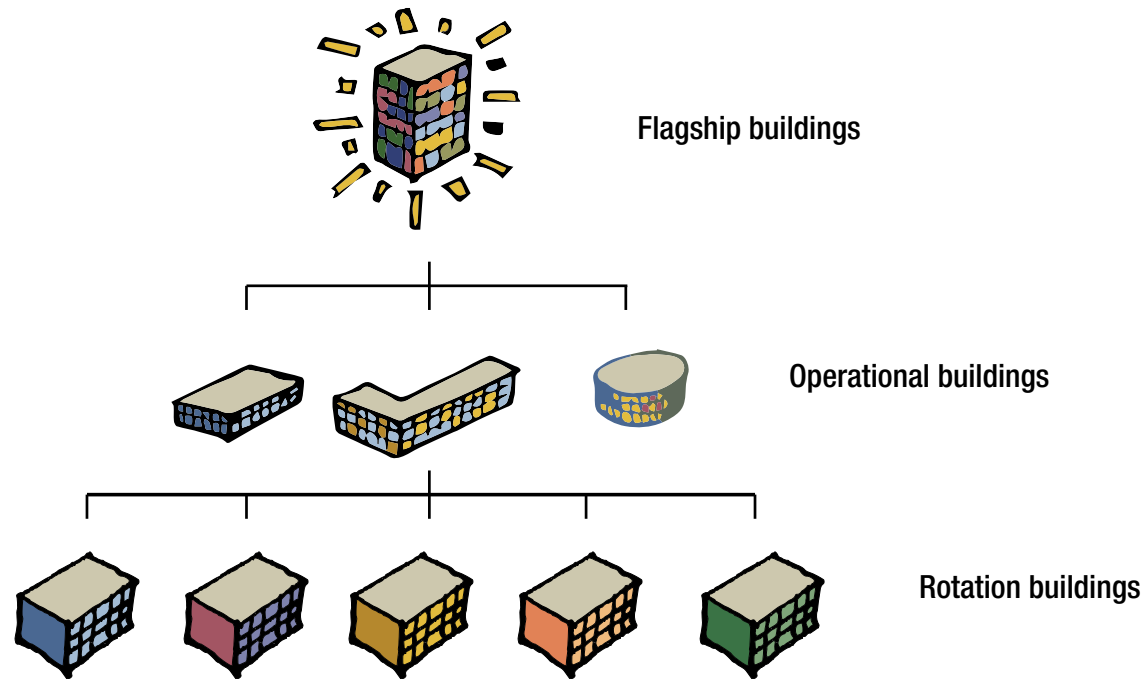
investments would allow building-owners to get energy-efficient modules installed on their property by third-parties interested in balancing out their emissions. Energy points would therefore be exchanged and balanced among clients.

#### For marketing or information display

In this scenario, third-parties or tenants can sponsor media or showcase add-on's by paying only for the installation fees and month to month (additional) expense.

This would greatly reduce the initial capital investment required by a sponsor to install a media facade or billboard on a building. Since the media modules would not be purchased but simply temporarily leased, the decision to sponsor media panels on a building would be easier and risk-free.





## Cascading business model

To guarantee a constant use of the available panel stock, the service provider would constantly evaluate and circulate the available system panels between his client-buildings. Following a model which is widely used in the retail industry, client-buildings could be divided into Flagship, Operational and Rotation buildings.

Flagship buildings would be used mainly to showcase the newest available technologies. They would be highly sponsored by either the service provider or by interested third-parties (as in the previous page), and not necessarily used to generate profit on their own, but more as a marketing tool for the facade lessor. Ideally, Flagship buildings should be iconic and memorable independently of the installed facade modules.

Operational buildings would constitute the core of the building portfolio, and should generate most of the profit in practice. These

would be buildings with a high energetic demand, in which constant renovation and upgrade of the technological systems integrated in the leased panels would generate an increased gap between the cost of the service to the provider and the price paid by the client.

At the bottom level, Rotation buildings would be used to circulate older panels which have been removed from Operational or Flagship buildings as new technologies have become available. They would ensure that second hand modules, which are neither the latest technologies nor as-yet obsolete, are not lying around in a warehouse but being used fully until the end of their service-life. These units can be largely sponsored by energy grants (for example, they would be very interesting for making social-housing projects more sustainable with a small investment).

## I 3.a. Case Study - Applying PSS to an existing structure

### TU Delft 3mE Building

#### A case-study on energetic and financial optimization

In order to apply the principles of a PSS system, in terms of financial parameters and constructive systems, I have chosen to use as a reference the 3mE Building in TU Delft's campus. Rather than use the real physical characteristics and performance values of the building (which have proven to be difficult to access, and are not necessarily vital) I have used an industry standard for energy consumption (of 200 kWh/m<sup>2</sup>-year for a building approaching the end of its original service-life) and I have used only the basic dimensions and proportions of the current facade for the sake of designing the new constructive strategies.

This can be justified in this case, because I am dealing with the development of a PSS system, due to the following reasons:

**Energy consumption** - When developing a financial model for calculating the success and appeal of a PSS system as opposed to other methods of renovation, relevance lies in the relation between the different models, not in the specific values applied. For example, using a cost of €600/m<sup>2</sup> of facade, against using €800/m<sup>2</sup> of facade will not affect the final performance of one model against the other as they will all be affected equally by the financial decisions taken (as my model considers all physical interventions to be exactly the same, otherwise the values wouldn't be comparable). Since my final goal is to produce

a series of renovation schemes (in terms of general design direction and physical construction), whose cost it might be very difficult to evaluate accurately within the scope of this report, I have used rough estimations for each expense, but applied them equally to all scenarios. What we are measuring is not how good the technical solutions are (as they are all the same) but how different ways of financing them could lead to different benefits for the stakeholders.

**Building technologies** - In the case of the building's real cross section and details, they are irrelevant due to the fact that most PSS systems would necessarily be based on a complete replacement of the current facade, or the construction of a secondary facade on top of it. Modularity is a primary concern in all my design strategies because they will allow the service provider more control over the production and performance of his systems (as they will be built in a similar way for all projects), and because it would improve his profit in the long run by allowing him to take advantage of the economy of scale implied in producing a large number of almost identical facade elements. The 3mE's characteristics are therefore only important as a basic shell where to install the new systems, as they are not supposed to work together, but instead of.

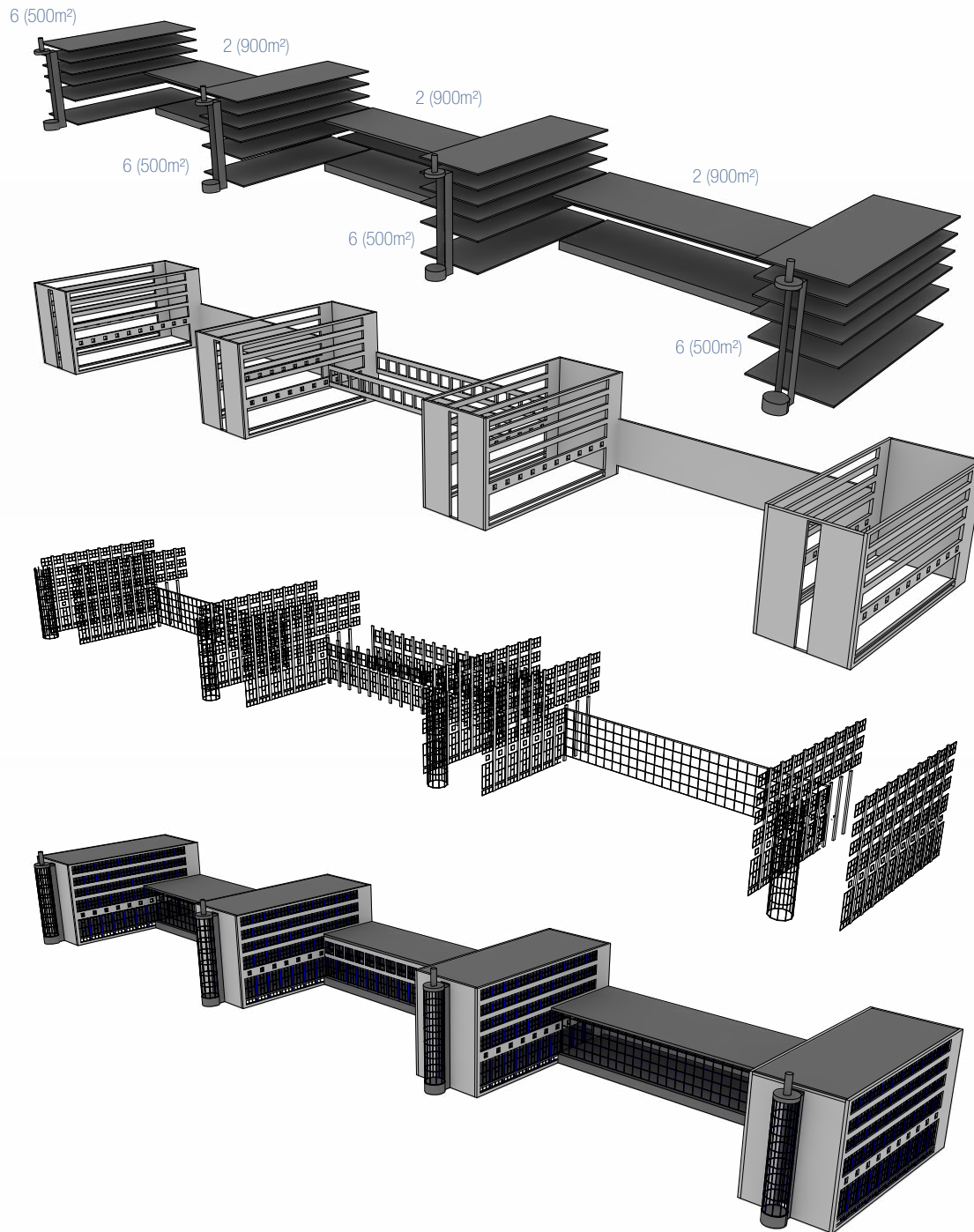


#### Top

*Current view of the 3mE building, I have chosen it due to its relative simplicity (in terms of geometry and transparent:solid surface ratio).*

#### Right

*Surface breakdown of the building. Proportion of transparent and solid surface will remain the same for the sake of the financial analysis, but apart from that the current facade will be considered to be useless. This is important because the service provider's model is based on being able to deliver the same results in any building. This would be easier (and administratively cheaper) if he relies uniquely on his products to do deliver the final performance. If adjustments have to be done in a case-by-case basis, the savings in material might be offset by higher planning costs.*



$$\text{gfa} = (500 \cdot 6 \cdot 4) + (900 \cdot 6) = 17,400\text{m}^2$$

$$\text{concrete area} = (280 \cdot 8) + (500 \cdot 3) + (225 \cdot 6) + 130 = 5,780\text{m}^2$$

$$\text{glass area} = (350 \cdot 6) + (440 \cdot 2) + (150 \cdot 4) + 1370 = 4,950\text{m}^2$$

## | 3.b. Long-term renovation schedules following the interests of each stakeholder

### Client-based scenario

#### Optimize Strategic and Functional values through flexibility

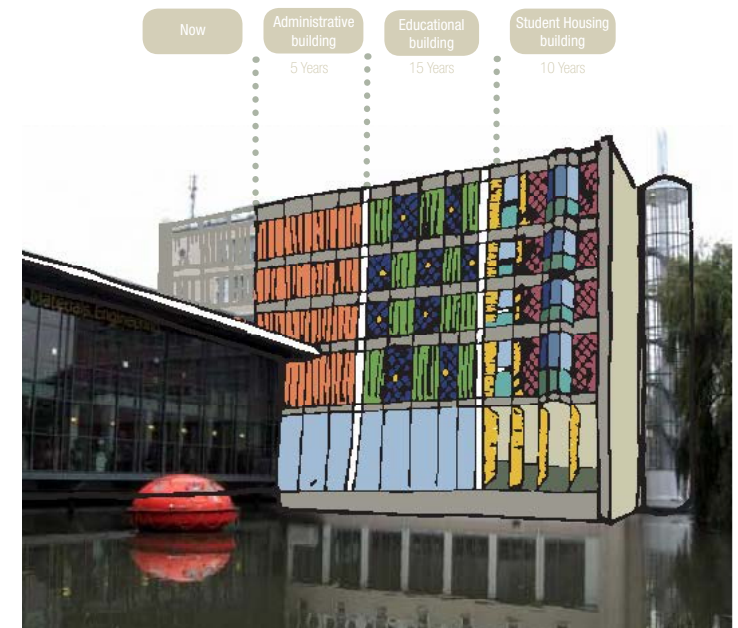
In order to gain an initial understanding of the interests and perspectives of each stakeholder, I decided to outline a renovation schedule based on the main specific demands of the client, the service provider and a third-party sponsor. This are not intended to be design solutions, but instead a strategy to understand which changes in a building's facade could potentially be introduced by each stakeholder's performance priorities.

From the clients perspective, the systems main "selling point" would be the added value of flexibility to face changes in strategic or functional requirements. In this example (an extreme scenario using as inspiration the history of the current BK City building) the 3mE structure would be used, at first, as an administration building. After 5 years, due to strategic demands, the building is converted into an Educational building, and 15 years later, due to economic and functional priorities, it is modified to provide student housing.

Even though such radical and frequent changes are rare in today's built environment, they are becoming increasingly common due to complex and sometimes unpredictable series of factors that have to be considered in an organization's development plan. In the case of a university, fluctuations in the number of

student enrollments, financial obligations and priorities, or other strategic reasons might force a building owner to consider such changes in his building portfolio's use. With current construction and financing methods, these changes are difficult, and have to be avoided or realized in a sometimes clumsy way (for example having student housing buildings that still look clearly like laboratories). A PSS system would provide greater functional and cosmetic freedom, as any changes in the facade's physical appearance would be possible by paying a small sum for the replacement of certain components. If these components are modular (which should be a main design intention) the service provider can use them in another buildings reducing the investment required from the client who wants to make the change.

In this scenario functional and cosmetic components are replaced with every change of the building's use. Cosmetic components to reflect the intent of the structure (increase its branding and strategic value) and the functional ones to adapt to the demands of a different user (adjusting its functional value to prevent shortage or waste). Some systems would have to be upgraded to house a more demanding program, while others could be downgraded with a lower occupation.

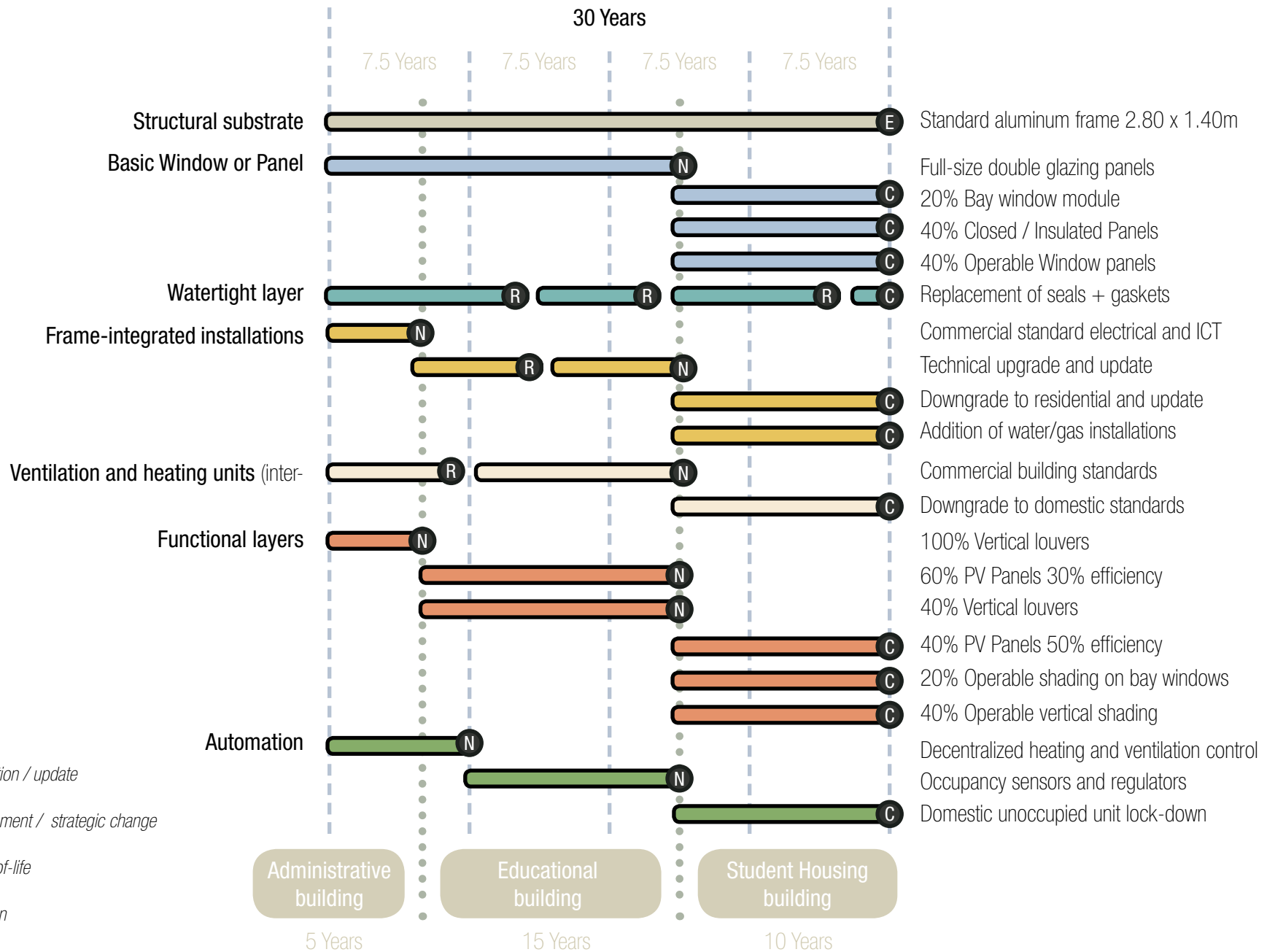


#### Top

Diagrammatic visual projection of the building's outer appearance. A PSS system would allow radical changes in building use to be combined with radical changes in the facade's appearance, increasing the overall value of the building.

#### Right

Conceptual renovation scheme following the client-based scenario. System renovation and upgrades are pointed according to the reason for the modification (whether technical service-life, functional upgrade or strategic decision). Many systems might be more efficiently replaced at the same time as other mayor changes occur, even if they haven't reached the end of their service-life. This would be energetically optimum only in the case that all materials are fully renewable .



- R** System renovation / update
- N** System replacement / strategic change
- E** Technical End-of-life
- C** Unit continuation

## 3.b. Long-term renovation schedules following the interests of each stakeholder

### Service provider-based scenario

#### Optimize Sustainable and Financial values through system upgrades

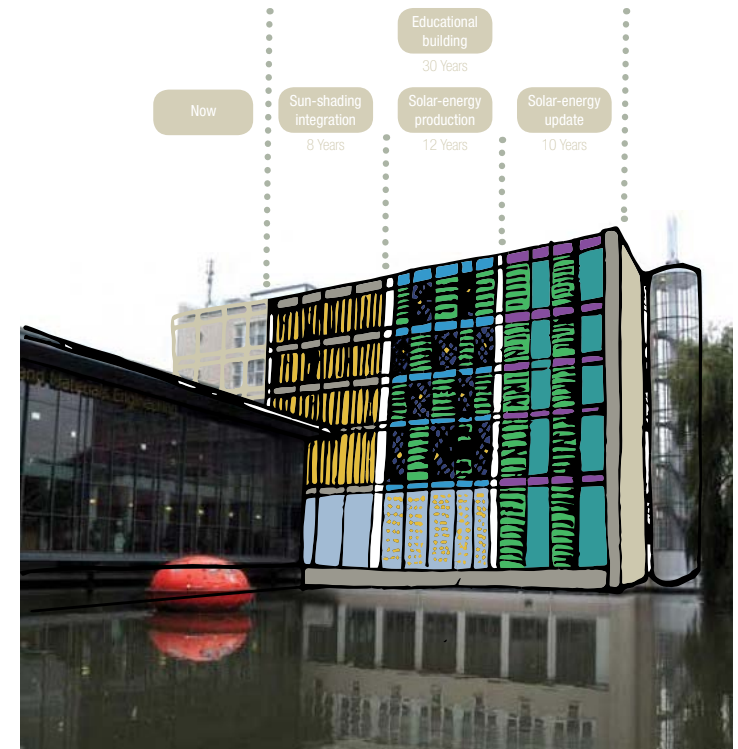
From the point of view of the system provider, his main goal would be to increase the performance of the building in terms of operation. Since the fee being paid by the client would be fixed (as in leasing models in other industries), the better the building performs, the larger the gap will be between what he is charging to the service, and how much it costs him to provide it.

This is where a PSS system shows the biggest potential for resource efficiency and technological innovation. While in a normal scenario the facade's designer and manufacturer would be different, and they would only hold an interest in the system until the moment when it's installed (except for warranty fulfilment) the client is left with the ownership of a product which he doesn't technically understand (at least not as much as the manufacturer) and which might not offer the highest possible level of efficiency (because the future operation costs are not an issue to the facade's producer).

By tying designer, manufacturer and client into a long term relation - the same that is being currently done by contracting systems such as a DBFOM - cost-efficiency and reliability are in the combined interest of all parties. The producer will want to make sure he can provide the service for the whole economic period

at the lowest possible price, while the client will be guaranteed to pay a fixed fee for the delivery of the service.

In this case, changes are done mostly from a financial and sustainable perspective. The service provider, who would have a high degree of technical expertise, would constantly evaluate emerging technologies looking for new investments which might give a faster return by reducing his costs. New energy-generating technologies, for examples, would be attractive to a service provider with a contract for another 20 years, and he might upgrade these systems in a building with a higher consumption, and use the old ones in another building he services with a lower energetic demand. The implementation cycles of new technologies would therefore be significantly reduced. A client who has just installed solar panels in his building five years ago will not want to replace them now, even if the technology is better, because he would have no use for the old ones. A centralized service provider with a number of buildings under his attention might decide to make the extra investment and swap his physical resources among clients. Again, modularity is of primary importance as these exchanges would otherwise be impossible.

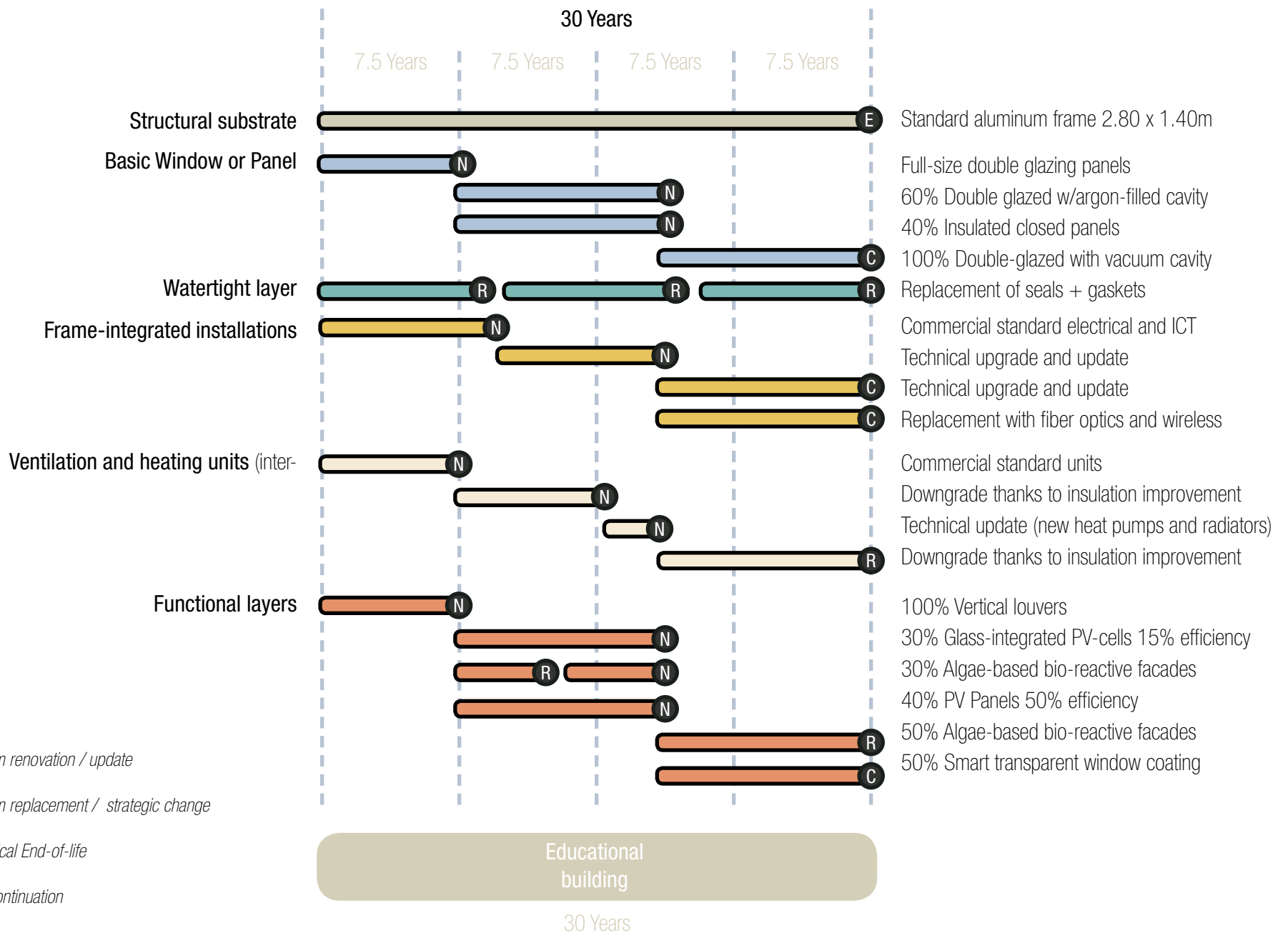


#### Right

Development diagram, changes are done to increase energy generation or to lower consumption. Cosmetic decisions would be secondary, unless they affect the interests of the client.

#### Right

Conceptual renovation scheme following the optimum energetic performance of the building, as well as the service-life of each component. Outdated components can lead to higher maintenance costs which would reduce the profit of the service provider by reducing his margin.



## 3.b. Long-term renovation schedules following the interests of each stakeholder

### Sponsor-based scenario

#### Optimize Strategic and Sustainable values through third-party interventions

The third scenario is based on the possibility that third-parties might be interested in the investment potential offered by a technically flexible system. Two types of sponsoring are considered:

**Energy sponsoring** - A practice becoming increasingly popular in the building construction and management industry, CO<sub>2</sub> point acquisition allows companies with a high energetic demand and a limited renewable energy generation capacity, to invest in projects with a positive energetic value, in order to neutralize their emissions.

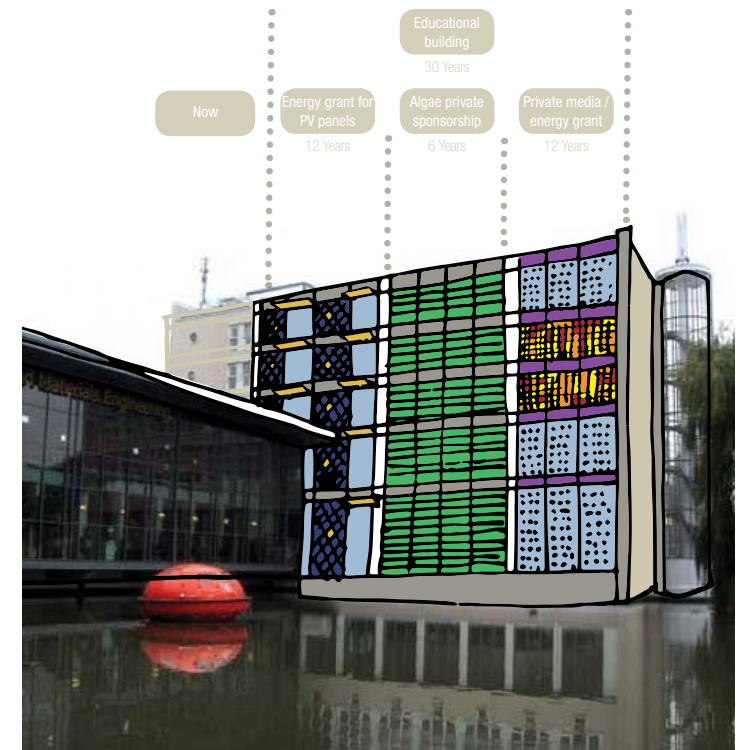
Currently, this is done on a global platform, buildings like Schiphol Airport can invest on sustainable technologies in China in order to claim energy neutrality. A similar scheme could be implemented into a PSS system. The service provider, with his portfolio of buildings and knowing the interests and capacities of his clients, could create connections between owners who are looking to invest in CO<sub>2</sub> points, and those with the capacity to generate this energy. The sponsor would then only have to pay for the installation of the solar panel component onto the sponsored structure, and get a positive energetic reputation (a huge strategic value in today's market).

**Marketing sponsoring** - In a similar scenario, a

company looking to invest in its public presence, for example by installing commercial LED facades, could be contacted with a building which is open to the idea (and which is in a location that would make such an investment attractive) and the functional preparations could be done with a fraction of the investment it would require if done to a regular facade.

Under certain subsidies, building owners can get cost-effective credits to improve the energetic performance of their buildings. This could pay for the basic installation and operation costs of the support components (those that provide structural stability and protection against the elements). Additional, private party sponsoring could then be used to enhance the building's value by adding functional layer, to the benefit of both parties involved (and increasing the service provider's fees). This could lead to a complex system of building renovation in which the interests not only of the building owner and user are taken into account, but also those of a much wider market.

Technical layers which are needed to keep the system working would still be replaced at regular intervals to guarantee an efficient overall performance, and sponsor-based systems would only add to this base-function.



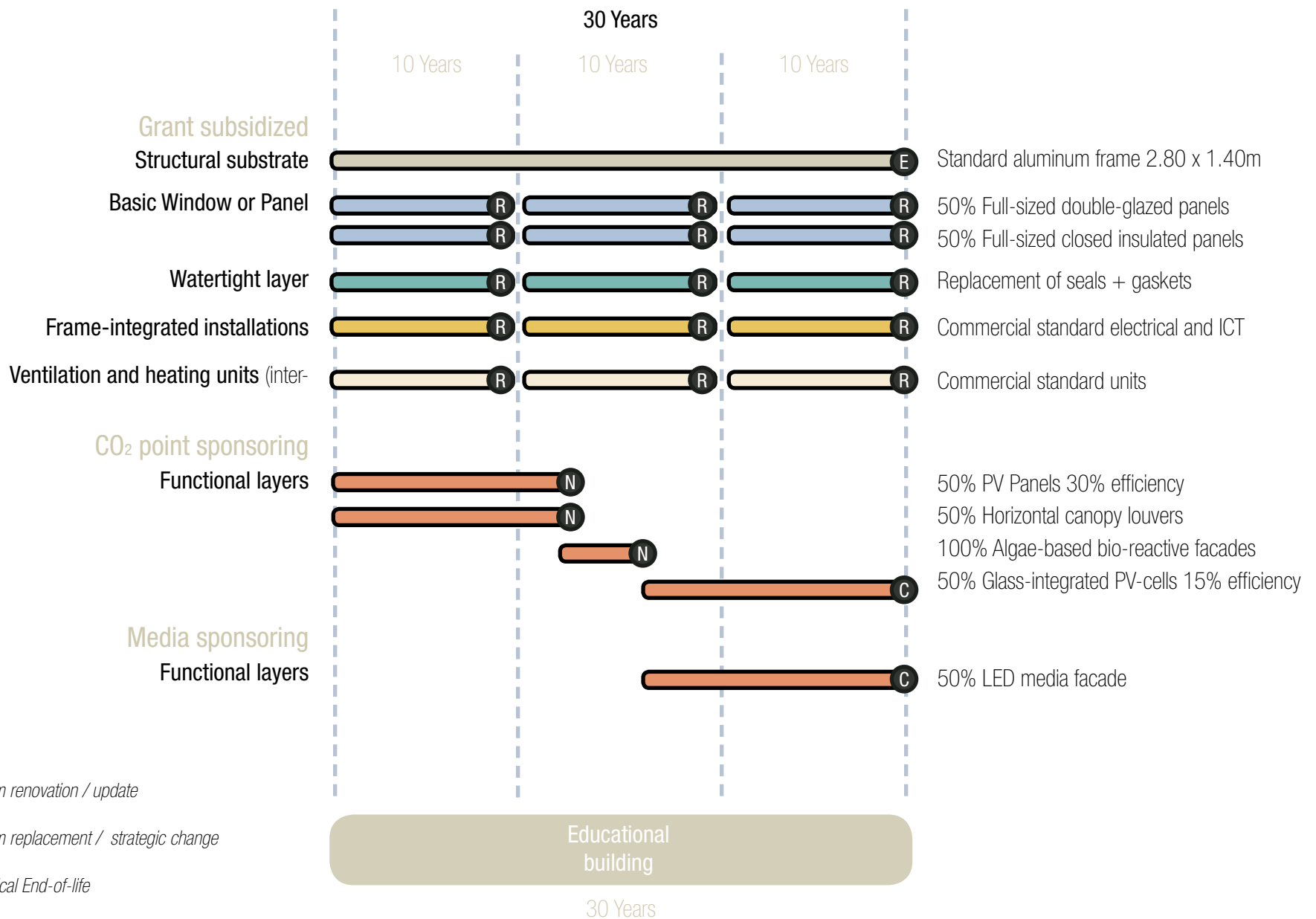
#### Top

Renovation schedule for a sponsored scenario. The basic functions of the facade have to be guaranteed throughout the service-life of the buildings, but functional add-on's can be installed according to the interests of available third-party investors.

#### Right

Basic functions are guaranteed by replacing components as they reach the end of their service-life. Additional functional such as energy-generation or publicity can be short-term according to the sponsors needs.





## I 3.c. Financial analysis of a simplified, 30-year construction and service schedule

### General parameters

#### Setting up comparable scenarios

In order to roughly calculate the financial performance of a PSS strategy, and then evaluate its performance related to other types of project financing, I set up a datasheet measuring the primary expenses (construction, maintenance and energy) of each scenario over a 30-year period. The model is based on the basic surface areas measured in the 3mE building, differentiating solid surfaces and transparent surfaces, and measuring the effects of initial construction costs and projected interventions done to the facade over this period of time.

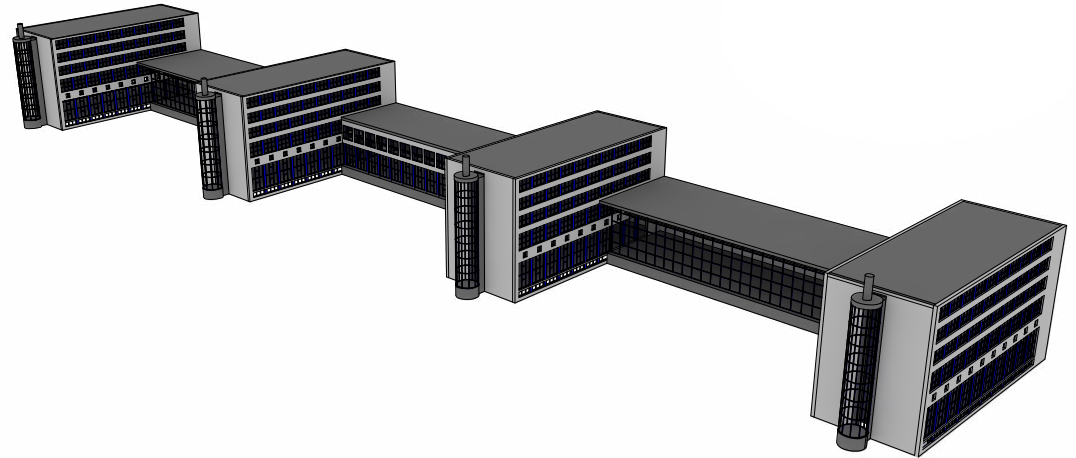
Due to lack of information (until this moment, though I expect to get the actual values) I have used a standard energy consumption of 200 kWh/m<sup>2</sup>-year, and a commercial price for energy of €0.21 per kWh. Considering that the current trend is for energy to roughly duplicate in price every 10 years, we get an approximated inflation on energy of about 7%. This, compared to the general inflation value of nearly 2%, shows the importance of applying energy-efficient solutions, as they will become more determinant than any other type of expense in guaranteeing the long-term financial health of a construction.

The interest rate determines financial costs of ownership after acquiring a loan, while the average

inflation rate is used to project all expenses into their NPV (Net Present Value), which allows for comparison in today's terms in order to decide which option offers the greatest benefits with the lowest amount of unexpected risks.

From the system provider point of view, a lower production and maintenance cost (of between 80 and 90%) is used to reflect the advantages of an economy of scale, by centrally managing a range of facades from different clients, the unitary costs per square meter of facade (built, cleaned or maintained) would be reduced. This potential reduction will vary in each strategy, and would need further development as a continuation of this graduation project. It would greatly determine the success and financial appeal of the business model, should it be taken into more realistic grounds. The ROI (Return On Investment) value for the PSS provider is calculated at 10% yearly, considering all capital invested to pay for the systems and a backup fund to pay for up to one year of expenses (in case the client fails to pay for operation costs).

From the point of view of the client, funds which could potentially be freed by a leasing contract could be invested into his primary business activity, which is calculated to have a ROI of 8% annually.



Right

Project parameter data sheet:

This spreadsheet is an initial attempt to generate a calculation model which can be applicable to any type of project (whether it involves facades or other constructive systems). Architectural projects can be radically different among them (in terms of priorities, types of contract, methods of construction, etc), just as their geographic position and local regulations can widely affect their financial scenario. In this case I have used rounded, average values for the Netherlands in 2014.

In principle, any project can be evaluated by changing the values in this spreadsheet, all further calculations are determined by these parameters.

3ME Building Parameters	
Sq Meters of Construction	17,400
Sq Meters of Façade	10,730
Floor:Façade Area Ratio	62%
Current Energy Use (kWh/sqm-year)	200
Cost of Energy (kWh)	€ 0.214
Current Energy Expense (per year)	€ 744,720
Rate of Interest (30 Year Loan)	6%
Rate of Inflation	2%
Rate of Inflation (for energy prices)	7%
Yield of Alternative Investment	8%
PSS Production and Maintenance Costs (Economy of scale)	90%
Down Payment (20%)	€ 1,277,276
PSS Return On Investment	10%
Maintenance Costs (% of overall costs)	3%
Façade Maintenance Costs (% of maintenance costs)	16.50%

## I 3.c. Financial analysis of a basic, 30 year service schedule

### Cost of construction works

#### Construction, renovation and demolition expenses

The 30 year cost analysis is based on the construction of a regular, high performance facade, which will be subject to three mayor improvements along its service life, to then be demolished at the end of this period. All costs implied in this process will be calculated (as well as their cumulative value in terms of NPV), considering a final residual value of zero. This will help simplify the process (as depreciation is a complex concept to calculate, more so in the case of new, untested constructive systems), while it will also give a result in terms of the “worst possible scenario”, if the business model turns out to be financially attractive without a residual value, if the residual value was included (no matter how small) the final return would be even higher than predicted.

Using the case of the 3mE building, an entirely new facade will be built around the whole perimeter of the building, therefore the dimensions of all wall surfaces are taken into account and split into transparent and solid surfaces (*columns b*) as the proportion between them will be maintained. Initial construction is calculated based on today's industry standards for an regular quality, energy-efficient facade. This facade will be upgraded three times along the 30 years (more frequently than an average facade would) to improve

its energetic performance and measure its financial impact (*column a*). All construction costs, including demolition will be calculated in terms of today's value, by adding up compound inflation until the year at which the investment takes place (*columns c*).

The accumulated overall construction costs are shown independently, to provide a better visualization of the impact of smaller or larger interventions at an earlier or later moment in time (*columns d*). It is generally preferable to have more costly interventions at an earlier time, as their price in terms of NPV will be lower.

Finally, the accumulated expenses over time are figured in (*column e*). The values attributed to each concept are rough estimations, as looking into them in too much detail would take attention away from the main goal of this thesis. It is important to take into account that even if these values vary, the relation between them is the same. That is to say, if the price of demolition turned out to be €80m<sup>2</sup> instead of €60m<sup>2</sup> it wouldn't necessarily affect the conclusion of PSS being better or worse than other models, as they would all be recalculated according to the same values. I am not comparing construction costs, but instead methods of financing.

#### *Right*

*Basic construction costs considered over the 30 year service-life of the new facade. Renovation concepts are simply suggestions, and the expected energetic performance and reference cost is not an actual reference, but a rough example. The goal is not to actually schedule the performance of the facade and its components, or to suggest how they would actually work in a realistic scenario, but to show different ways in which the systems (whichever they might be) could be paid for in different financial models.*

	Façade Construction (Purchase system)														
Year	Project	M² Transparent	M² Solid	M² Total	€/ m² Transparent	€/ m² Solid	Façade Initial Cost (with X% inflation)	Upgrade / Renovation Costs (with X% inflation)				Total Construction Costs	Years		
2014	Construction	4,930	5,800	10,730	€ 726	€ 484	€ 6,387,000	€ -	€ -	€ -	€ -	€ 6,387,000	30		
2015							€ 6,515,000	€ -	€ -	€ -	€ -	€ 6,515,000	29		
2016							€ 6,645,000	€ -	€ -	€ -	€ -	€ 6,645,000	28		
2017							€ 6,778,000	€ -	€ -	€ -	€ -	€ 6,778,000	27		
2018							€ 6,913,000	€ -	€ -	€ -	€ -	€ 6,913,000	26		
2019							€ 7,052,000	€ -	€ -	€ -	€ -	€ 7,052,000	25		
2020							€ 7,193,000	€ -	€ -	€ -	€ -	€ 7,193,000	24		
2021							€ 7,336,000	€ -	€ -	€ -	€ -	€ 7,336,000	23		
2022							€ 7,483,000	€ -	€ -	€ -	€ -	€ 7,483,000	22		
2023							€ 7,633,000	€ -	€ -	€ -	€ -	€ 7,633,000	21		
2024	Major maintenance (replace ventilation units) (85% Energy Use)	4,930	5,800	10,730	€ 183	€ -	€ 7,785,000	€ 902,000	€ -	€ -	€ -	€ 8,687,000	20		
2025							€ 7,941,000	€ 920,000	€ -	€ -	€ -	€ 8,861,000	19		
2026							€ 8,100,000	€ 938,000	€ -	€ -	€ -	€ 9,038,000	18		
2027							€ 8,262,000	€ 957,000	€ -	€ -	€ -	€ 9,219,000	17		
2028							€ 8,427,000	€ 976,000	€ -	€ -	€ -	€ 9,403,000	16		
2029	Functional retrofit (improve energy generation) (50% Energy Use)	4,930	5,800	10,730	€ 404	€ 404	€ 8,596,000	€ 996,000	€ 4,333,000	€ -	€ -	€ 13,923,000	15		
2030							€ 8,768,000	€ 1,016,000	€ 4,419,000	€ -	€ -	€ 14,202,000	14		
2031							€ 8,943,000	€ 1,036,000	€ 4,508,000	€ -	€ -	€ 14,486,000	13		
2032							€ 9,122,000	€ 1,057,000	€ 4,598,000	€ -	€ -	€ 14,776,000	12		
2033							€ 9,304,000	€ 1,078,000	€ 4,690,000	€ -	€ -	€ 15,071,000	11		
2034							€ 9,490,000	€ 1,099,000	€ 4,784,000	€ -	€ -	€ 15,372,000	10		
2035							€ 9,680,000	€ 1,121,000	€ 4,879,000	€ -	€ -	€ 15,680,000	9		
2036	Major maintenance (90% Energy Use)	4,930	5,800	10,730	€ 77	€ 77	€ 9,874,000	€ 1,144,000	€ 4,977,000	€ 830,000	€ -	€ 16,823,000	8		
2037							€ 10,071,000.00	€ 1,167,000.00	€ 5,077,000.00	€ 847,000.00	€ -	€ 17,159,000.00	7		
2038							€ 10,273,000.00	€ 1,190,000.00	€ 5,178,000.00	€ 863,000.00	€ -	€ 17,503,000.00	6		
2039							€ 10,478,000.00	€ 1,214,000.00	€ 5,282,000.00	€ 881,000.00	€ -	€ 17,853,000.00	5		
2040							€ 10,688,000.00	€ 1,238,000.00	€ 5,387,000.00	€ 898,000.00	€ -	€ 18,210,000.00	4		
2041							€ 10,901,000.00	€ 1,263,000.00	€ 5,495,000.00	€ 916,000.00	€ -	€ 18,574,000.00	3		
2042							€ 11,119,000.00	€ 1,288,000.00	€ 5,605,000.00	€ 935,000.00	€ -	€ 18,945,000.00	2		
2043	Demolition	4,930	5,800	10,730	€ 109	€ 109	€ 11,342,000	€ 1,314,000	€ 5,717,000	€ 953,000	€ 1,167,000	€ 20,490,000	1		
30 Year Total							€ 11,342,000	€ 1,314,000	€ 5,717,000	€ 953,000	€ 1,167,000	€ 20,490,000			



## I 3.c. Financial analysis of a basic, 30 year service schedule

### “No Renovation” Model

#### The cost of not replacing an outdated facade

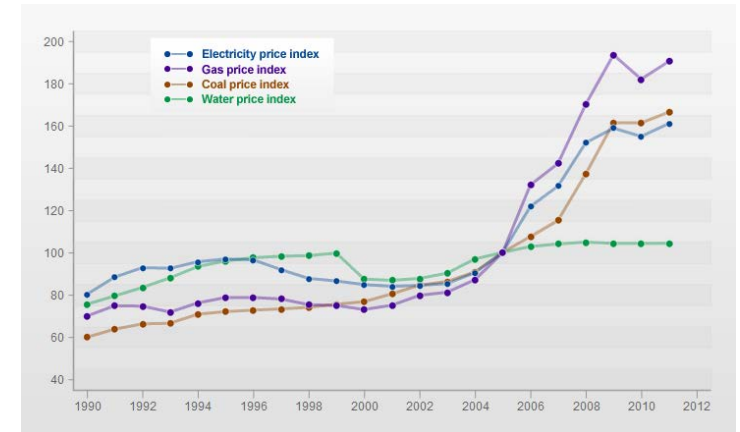
As a point of reference I have estimated the cost, over the same 30-year period, of continuing to operate the building without replacing the facade (in the case that this was practically possible and the building didn't have to stop operation due to adjacent health and safety issues). In this scenario construction costs would be zero (*column f*), but maintenance costs (*column g*) would rise constantly, from their current 3% of initial construction cost per year up to 6% by the end of the period, plus two peaks (at year 10 and 20) which represent mayor maintenance thresholds (replacing facade gaskets, for example).

On top of this, and even more determinant, is the expected increase in the cost of energy. If we look at the behavior of energy prices since around the year 2000, we see that they have been rising at approximately 7% per year (more than three times the average inflation). If this trend was to continue (and unless we see radical changes in the construction of renewable energy infrastructure there is no reason to think it wont) the costs of energy to the building owner / operator will roughly double every decade (*column h*). After 30 years the energy used to heat the building

would be over 7 times as expensive as it is today. This is probably the most convincing argument towards the implementation of energy-efficient technologies in any industry.

Even though a properly insulating facade will significantly reduce energy expenses (in this case I have calculated the building's consumption will decrease from 200kWh/m<sup>2</sup> down to 30kWh/m<sup>2</sup>, or an 85% improvement) only energy-generating technologies will allow for a risk-free cost estimation. Since the increase in the price of energy is not guaranteed to follow current trends, but might turn out to be lower or higher, systems such as solar panels, which reduce the impact of such price fluctuations on the building's operations, are the most effective way of predicting the success of the financial model.

Yearly costs are then extracted (by adding maintenance and heating energy), and independently added towards a cumulative total. These two lists of values (*columns i*) will we compared to a regular renovation project (financed though a bank loan) and to a product-service system scenario involving the long-term rent of a facade from a service provider.



#### Top

Historical utility prices in the UK between 1990 and 2012. The rapid increase in the cost of energy that followed the oil crisis in the 70's ended in a period of relative calm in the last decade of the 20th century. However, this trend has again accelerated in the last 15 years and is unlikely to revert.

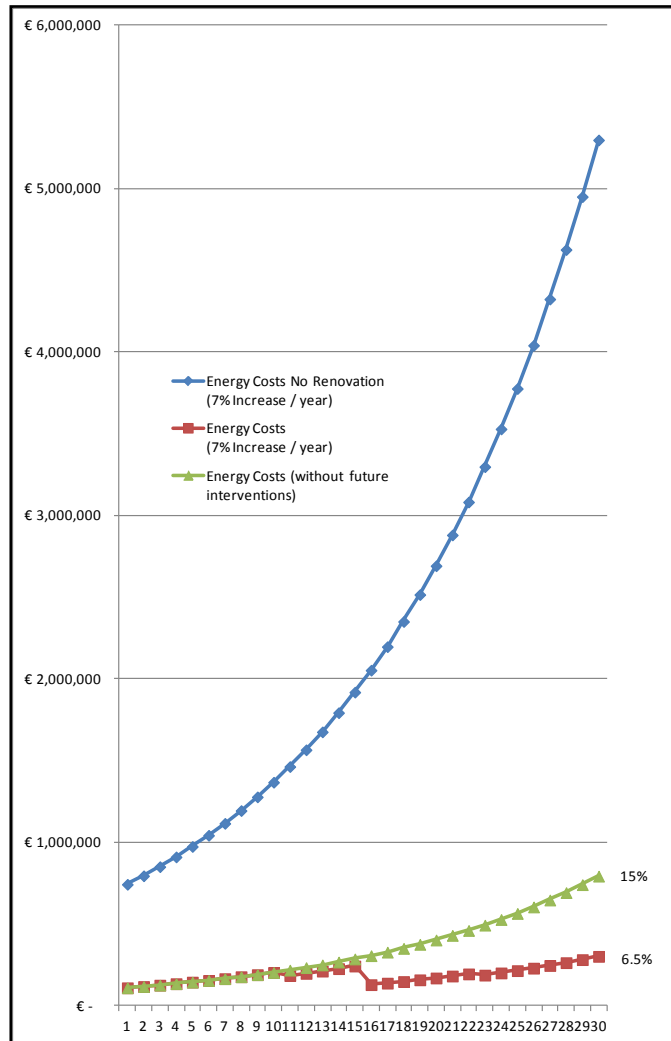
<http://www.politics.co.uk/news/2012/02/13/energy-companies-attacked-as-hypothermia-deaths-soar>

#### Opposite left

Graph showing the yearly cost of energy for the reference building (estimated as an industry example, not based on real data yet). A renovation project would increase the R value of the facade to provide a consumption of 30 kWh/m<sup>2</sup>-year, this would bring down demand to 15% of its current levels. Further, smaller intervention meant to increase efficiency or generate renewable energy would then push this limit even lower to about 6.5% of the current levels.

#### Opposite right

No-renovation scenario expense breakdown



Without Renovations				
Construction (with X% inflation)	Maintenance Costs (Z% Façade costs)	Energy Costs No Renovation (7% Increase / year)	Total No Renovation	Cumulative No Renovation
€ -	€ 166,000	€ 745,000	€ 911,000	€ 911,000
€ -	€ 178,000	€ 797,000	€ 975,000	€ 1,885,000
€ -	€ 190,000	€ 853,000	€ 1,042,000	€ 2,927,000
€ -	€ 202,000	€ 913,000	€ 1,114,000	€ 4,041,000
€ -	€ 214,000	€ 977,000	€ 1,191,000	€ 5,231,000
€ -	€ 227,000	€ 1,045,000	€ 1,272,000	€ 6,502,000
€ -	€ 241,000	€ 1,118,000	€ 1,358,000	€ 7,860,000
€ -	€ 255,000	€ 1,196,000	€ 1,451,000	€ 9,310,000
€ -	€ 269,000	€ 1,280,000	€ 1,549,000	€ 10,858,000
€ -	€ 284,000	€ 1,370,000	€ 1,653,000	€ 12,511,000
€ -	€ 896,000	€ 1,465,000	€ 2,361,000	€ 14,872,000
€ -	€ 315,000	€ 1,568,000	€ 1,882,000	€ 16,754,000
€ -	€ 331,000	€ 1,678,000	€ 2,009,000	€ 18,762,000
€ -	€ 348,000	€ 1,795,000	€ 2,143,000	€ 20,904,000
€ -	€ 365,000	€ 1,921,000	€ 2,286,000	€ 23,189,000
€ -	€ 383,000	€ 2,055,000	€ 2,438,000	€ 25,627,000
€ -	€ 402,000	€ 2,199,000	€ 2,600,000	€ 28,227,000
€ -	€ 421,000	€ 2,353,000	€ 2,773,000	€ 31,000,000
€ -	€ 441,000	€ 2,518,000	€ 2,958,000	€ 33,957,000
€ -	€ 461,000	€ 2,694,000	€ 3,154,000	€ 37,111,000
€ -	€ 482,000	€ 2,882,000	€ 3,364,000	€ 40,474,000
€ -	€ 504,000	€ 3,084,000	€ 3,587,000	€ 44,061,000
€ -	€ 526,000	€ 3,300,000	€ 3,825,000	€ 47,886,000
€ -	€ 549,000	€ 3,531,000	€ 4,079,000	€ 51,964,000
€ -	€ 573,000	€ 3,778,000	€ 4,350,000	€ 56,314,000
€ -	€ 1,790,000	€ 4,042,000	€ 5,832,000	€ 62,145,000
€ -	€ 622,000	€ 4,325,000	€ 4,947,000	€ 67,092,000
€ -	€ 648,000	€ 4,628,000	€ 5,276,000	€ 72,367,000
€ -	€ 675,000	€ 4,952,000	€ 5,626,000	€ 77,992,000
€ -	€ 702,000	€ 5,299,000	€ 6,000,000	€ 83,992,000
€ -	€ 13,645,000.00	€ 70,347,000.00	€ 83,992,000.00	€ 83,992,000.00

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## I 3.c. Financial analysis of a basic, 30 year service schedule

### “Loan” Model

#### Renovating the facade through long-term financing

In the case of applying for a bank loan in order to finance the facade renovation project, the interest rate will of course be the most determining factor. Financing institutions generally try to share their risk, when getting involved in a new project, by asking for a down payment of around 20%. This payment serves as proof of the borrower's commitment to the success of the project (as now also his own cash is at stake, not only his credit reputation).

Compound interest is then calculated by splitting the full amount of the loan (minus the down payment) into 30 (to establish the first payment), and then applying a yearly compound interest rate over the 30 year term. *Columns j* contain this information by separating Principal Costs (how much of the principal debt the client pays), Principal Debt (how much is still left to pay) and Interest Costs (yearly interests he has to pay on the total amount he has borrowed so far). As before, it is very important to plan when main renovation works will take place (if any are needed within the 30 year period). Costly renovations (specially if they involve manual labour, which in the case of Europe carries specifically high costs) should be done as early as possible, as their cost in terms of today's value will be lower (due to a shorter period of accumulated inflation)

and their impact on the performance of the building - in case of solar panels for example - will provide benefits (and pay back the investment) over a longer period of time.

Energy costs (*column k*) are significantly reduced relative to the previous scenario, by replacing the facade which, in this example, lead to an energy saving ratio of 85%. Future renovations improve this performance even further by installing even more efficient equipment, or by applying energy-generation technologies. The closer a building is to energy neutrality, the easier it will be to secure cost estimations from the unpredictability of energy prices.

Maintenance costs (*column l*) are considered as an equal percentage over the entire period. This can still be improved, in reality these costs would be very low at the beginning of the term, as equipment would be new, and would then rise steadily as more work becomes necessary to keep systems running. One or two peaks could also be found along the way as mayor interventions becomes necessary (again, changing rubber gaskets for example).

Finally, yearly costs and accumulated costs are calculated (*columns m*) for comparison with the other models.

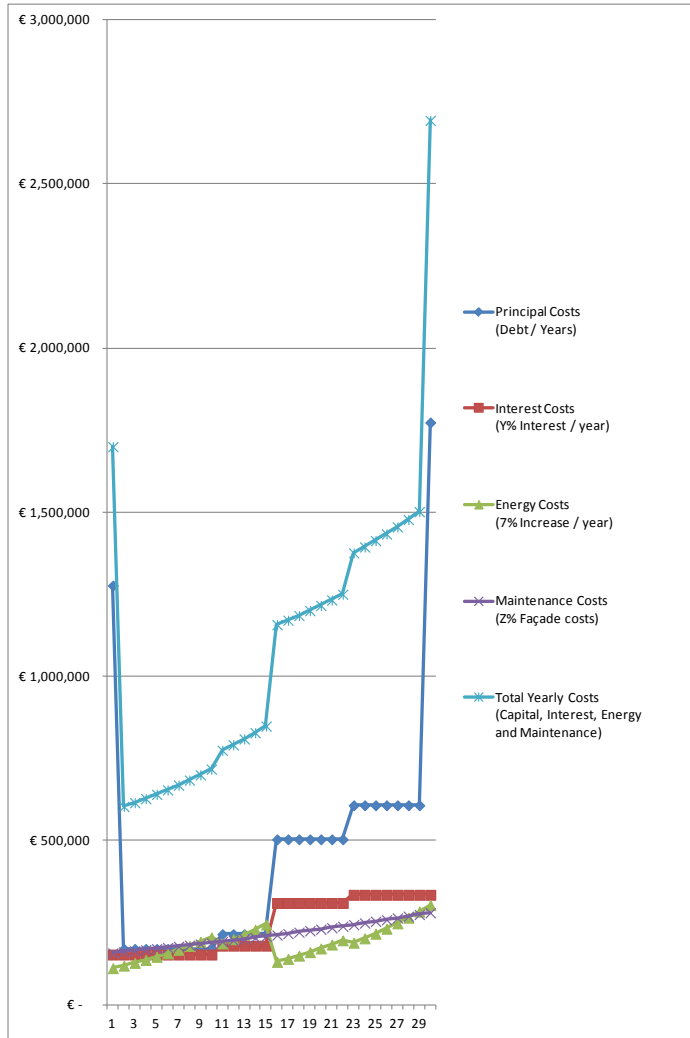
#### *Opposite left*

*Graphic breakdown of the different yearly expenses necessary over a 30 year loan-financed renovation. The high peak at the beginning (down payment) and the one at the end (to pay for demolition costs) make the model unattractive, specially if we consider the demolition of this facade will be done, most likely, within close proximity to the investment required to replace it.*

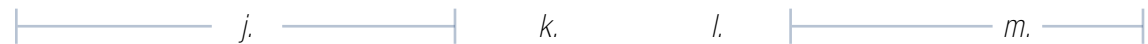
#### *Opposite right*

*Expenses calculated in the “Loan” renovation model.*





Loan						
Principal Costs (Debt / Years)	Principal Debt (Total Debt)	Interest Costs (Y% Interest / year)	Energy Costs (7% Increase / year)	Maintenance Costs (Z% Façade costs)	Total Yearly Costs (Capital, Interest, Energy and Maintenance)	Cumulative Loan
€ 1,278,000	€ 5,110,000	€ 154,000	€ 112,000	€ 159,000	€ 1,701,000	€ 1,701,000
€ 171,000	€ 4,939,000	€ 154,000	€ 120,000	€ 162,000	€ 605,000	€ 2,305,000
€ 171,000	€ 4,769,000	€ 154,000	€ 128,000	€ 165,000	€ 616,000	€ 2,921,000
€ 171,000	€ 4,599,000	€ 154,000	€ 137,000	€ 168,000	€ 629,000	€ 3,549,000
€ 171,000	€ 4,428,000	€ 154,000	€ 147,000	€ 172,000	€ 642,000	€ 4,190,000
€ 171,000	€ 4,258,000	€ 154,000	€ 157,000	€ 175,000	€ 655,000	€ 4,845,000
€ 171,000	€ 4,088,000	€ 154,000	€ 168,000	€ 179,000	€ 670,000	€ 5,514,000
€ 171,000	€ 3,917,000	€ 154,000	€ 180,000	€ 182,000	€ 685,000	€ 6,199,000
€ 171,000	€ 3,747,000	€ 154,000	€ 192,000	€ 186,000	€ 701,000	€ 6,900,000
€ 171,000	€ 3,577,000	€ 154,000	€ 206,000	€ 189,000	€ 718,000	€ 7,617,000
€ 216,000	€ 4,263,000	€ 181,000	€ 187,000	€ 193,000	€ 776,000	€ 8,393,000
€ 216,000	€ 4,048,000	€ 181,000	€ 200,000	€ 197,000	€ 793,000	€ 9,185,000
€ 216,000	€ 3,832,000	€ 181,000	€ 214,000	€ 201,000	€ 811,000	€ 9,995,000
€ 216,000	€ 3,617,000	€ 181,000	€ 229,000	€ 205,000	€ 829,000	€ 10,824,000
€ 216,000	€ 3,401,000	€ 181,000	€ 245,000	€ 209,000	€ 850,000	€ 11,673,000
€ 505,000	€ 7,230,000	€ 311,000	€ 131,000	€ 213,000	€ 1,159,000	€ 12,831,000
€ 505,000	€ 6,725,000	€ 311,000	€ 141,000	€ 217,000	€ 1,172,000	€ 14,003,000
€ 505,000	€ 6,221,000	€ 311,000	€ 150,000	€ 222,000	€ 1,186,000	€ 15,188,000
€ 505,000	€ 5,717,000	€ 311,000	€ 161,000	€ 226,000	€ 1,201,000	€ 16,389,000
€ 505,000	€ 5,213,000	€ 311,000	€ 172,000	€ 231,000	€ 1,217,000	€ 17,605,000
€ 505,000	€ 4,709,000	€ 311,000	€ 184,000	€ 235,000	€ 1,234,000	€ 18,839,000
€ 505,000	€ 4,204,000	€ 311,000	€ 197,000	€ 240,000	€ 1,251,000	€ 20,089,000
€ 608,000	€ 4,426,000	€ 336,000	€ 190,000	€ 245,000	€ 1,377,000	€ 21,466,000
€ 608,000	€ 3,818,000	€ 336,000	€ 203,000	€ 250,000	€ 1,395,000	€ 22,861,000
€ 608,000	€ 3,210,000	€ 336,000	€ 217,000	€ 255,000	€ 1,415,000	€ 24,275,000
€ 608,000	€ 2,602,000	€ 336,000	€ 232,000	€ 260,000	€ 1,435,000	€ 25,709,000
€ 608,000	€ 1,994,000	€ 336,000	€ 249,000	€ 265,000	€ 1,456,000	€ 27,165,000
€ 608,000	€ 1,387,000	€ 336,000	€ 266,000	€ 270,000	€ 1,479,000	€ 28,643,000
€ 608,000	€ 779,000	€ 336,000	€ 285,000	€ 276,000	€ 1,503,000	€ 30,145,000
€ 1,775,000	€ 171,000	€ 336,000	€ 304,000	€ 281,000	€ 2,694,000	€ 32,839,000
<b>€ 13,446,000.00</b>	<b>€ 171,000.00</b>	<b>€ 7,288,000.00</b>	<b>€ 5,694,000.00</b>	<b>€ 6,413,000.00</b>	<b>€ 32,839,000.00</b>	<b>€ 32,839,000.00</b>



### 3.c. Financial analysis of a basic, 30 year service schedule

#### “PSS” Model

#### Outsourcing risks and responsibilities

As discussed in the first chapters of this report, various industries use leasing and PSS models as incentive for clients to make easier decisions regarding investments they might otherwise reconsider. For most people, buying a new smartphone is more attractive if the price of the equipment does not have to be covered at the beginning of the contract, but is instead spread throughout the entire term. As we saw before, in the case-study of an iPhone 4S bought from AT&T, people are willing to pay up to 50% extra, in the long-run, for the comfort of a lower capital investment, and the guarantee that their service is safe in case the phone is lost, stolen or becomes obsolete.

Through a similar strategy, Facades and integrated systems could be commercialized as leasable products and services. The final cost will be slightly higher, but the it will be spread more equally over time (allowing for easier financial planning), will carry lower in-house administrative costs for the client, and it will free him from the risk and responsibility of managing his building's envelope (which is generally not within his primary business activities).

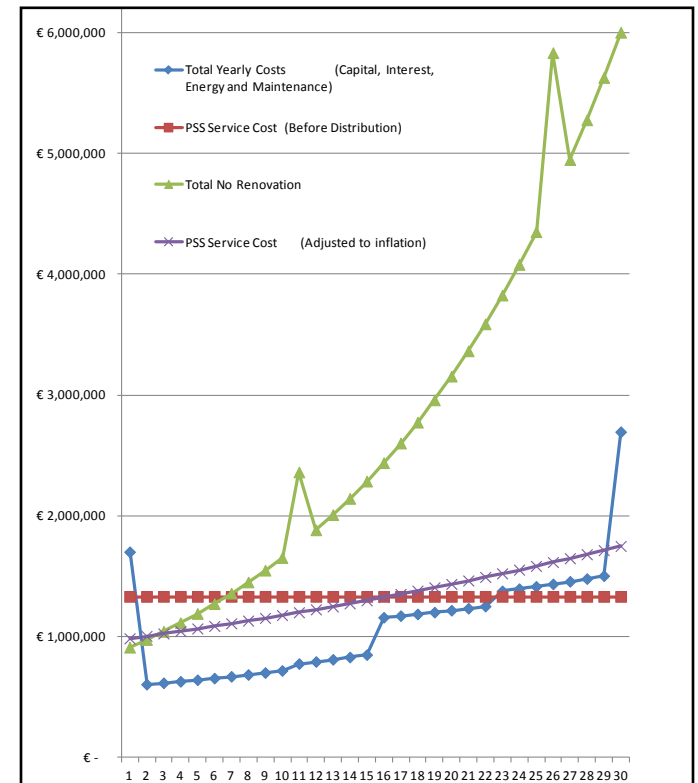
To calculate it, I have first defined the yearly costs the Service provider would have along the 30 year period (*column n*), these costs include construction

and renovation works, as well as their accumulated inflation over time, and are reduced as principal costs are paid.

*Column o* indicates the capital investment the PSS provider would need to have available (capital he used for construction, and backup money he needs to pay for utilities and services, for a year, in case the client falls behind on payment), this value is important because it will determine the ROI value for the provider.

*Columns p* calculate the yearly cost of the service to the client, based on the provider's capital costs (*o*) and his expected ROI (in this case 10% per year). These values are first calculated as year to year expenses (which vary widely according to new investments required), then they are spread equally along time (in case the client was expected to pay the exact same amount (at NPV) each year. Since this would result in very high payments at the beginning and very low ones at the end, it can also be calculated in a way that service price increases every year according to inflation.

Finally, the yearly costs of a PSS service (both distributed and adjusted to inflation) are compared to the yearly costs of a loan (*columns q*) and the final accumulated costs are added up (*column r*).



#### Top

Graphic comparison of the 3 financial models. We can see that the “no-renovation” model's costs (green) are increasingly higher, due to the high expected inflation on energy prices. The “loan” model (blue) has high peaks at the start and end of the term, which might cause the organization trouble if they coincide with other expenses. An equally spread PSS model (red) would have high costs, in NPV terms, for the first half of the economic period, but would be more cost-effective in the second half. While a PSS price adjusted to inflation (purple) would follow a similar trend to the “loan” scenario, without peaks or fluctuations.

**Right**

Financial breakdown of a PSS model, including costs and capital investment required from the service provider, and expected payment scheme from the client. Return On Investment for the service provider is calculated at 10% per year and his expenses for construction and maintenance are considered to be 80% of commercial value (due to economy of scale).

Final cost to the client would be 22% above those needed from a Loan scenario. This 22% is justifiable as it represents administrative and financial risk lifted from the building owner by outsourcing the production and management of his facade.

Product-Service System								
PSS Provider Costs (% of private purchase)	PSS Investment (Provider Capital Investment)	PSS Service Cost (Before Distribution)	PSS Service Cost (Distributed) (Client Pays)	PSS Service Cost (Adjusted to inflation)	% PSS to Loan (Yearly Basis)	% PSS to Loan (Adjusted to inflation)	Cumulative PSS	
€ 5,748,000	€ 6,002,000	€ 1,062,000	€ 1,332,000	€ 985,000	78%	58%	€	1,332,000
€ 5,863,000	€ 5,932,000	€ 1,070,000	€ 1,332,000	€ 1,005,000	220%	166%	€	2,664,000
€ 5,980,000	€ 5,858,000	€ 1,078,000	€ 1,332,000	€ 1,025,000	216%	166%	€	3,996,000
€ 6,100,000	€ 5,778,000	€ 1,086,000	€ 1,332,000	€ 1,045,000	212%	166%	€	5,328,000
€ 6,222,000	€ 5,693,000	€ 1,095,000	€ 1,332,000	€ 1,066,000	207%	166%	€	6,660,000
€ 6,346,000	€ 5,603,000	€ 1,103,000	€ 1,332,000	€ 1,087,000	203%	166%	€	7,992,000
€ 6,473,000	€ 5,507,000	€ 1,113,000	€ 1,332,000	€ 1,109,000	199%	166%	€	9,324,000
€ 6,603,000	€ 5,405,000	€ 1,122,000	€ 1,332,000	€ 1,131,000	194%	165%	€	10,656,000
€ 6,735,000	€ 5,298,000	€ 1,132,000	€ 1,332,000	€ 1,154,000	190%	165%	€	11,988,000
€ 6,870,000	€ 5,184,000	€ 1,142,000	€ 1,332,000	€ 1,177,000	186%	164%	€	13,320,000
€ 7,818,000	€ 5,843,000	€ 1,225,000	€ 1,332,000	€ 1,200,000	172%	155%	€	14,652,000
€ 7,975,000	€ 5,690,000	€ 1,232,000	€ 1,332,000	€ 1,224,000	168%	154%	€	15,984,000
€ 8,134,000	€ 5,528,000	€ 1,239,000	€ 1,332,000	€ 1,249,000	164%	154%	€	17,316,000
€ 8,297,000	€ 5,359,000	€ 1,246,000	€ 1,332,000	€ 1,274,000	161%	154%	€	18,648,000
€ 8,463,000	€ 5,180,000	€ 1,254,000	€ 1,332,000	€ 1,299,000	157%	153%	€	19,980,000
€ 12,531,000	€ 8,762,000	€ 1,638,000	€ 1,332,000	€ 1,325,000	115%	114%	€	21,312,000
€ 12,782,000	€ 8,370,000	€ 1,621,000	€ 1,332,000	€ 1,352,000	114%	115%	€	22,644,000
€ 13,037,000	€ 7,959,000	€ 1,602,000	€ 1,332,000	€ 1,379,000	112%	116%	€	23,976,000
€ 13,298,000	€ 7,528,000	€ 1,583,000	€ 1,332,000	€ 1,406,000	111%	117%	€	25,308,000
€ 13,564,000	€ 7,078,000	€ 1,562,000	€ 1,332,000	€ 1,435,000	109%	118%	€	26,640,000
€ 13,835,000	€ 6,607,000	€ 1,541,000	€ 1,332,000	€ 1,463,000	108%	119%	€	27,972,000
€ 14,112,000	€ 6,115,000	€ 1,518,000	€ 1,332,000	€ 1,493,000	106%	119%	€	29,304,000
€ 15,141,000	€ 6,326,000	€ 1,571,000	€ 1,332,000	€ 1,522,000	97%	111%	€	30,636,000
€ 15,443,000	€ 5,708,000	€ 1,538,000	€ 1,332,000	€ 1,553,000	95%	111%	€	31,968,000
€ 15,752,000	€ 5,063,000	€ 1,503,000	€ 1,332,000	€ 1,584,000	94%	112%	€	33,300,000
€ 16,067,000	€ 4,390,000	€ 1,466,000	€ 1,332,000	€ 1,616,000	93%	113%	€	34,632,000
€ 16,389,000	€ 3,689,000	€ 1,428,000	€ 1,332,000	€ 1,648,000	91%	113%	€	35,964,000
€ 16,716,000	€ 2,958,000	€ 1,389,000	€ 1,332,000	€ 1,681,000	90%	114%	€	37,296,000
€ 17,051,000	€ 2,198,000	€ 1,348,000	€ 1,332,000	€ 1,714,000	89%	114%	€	38,628,000
€ 18,441,000	€ 2,456,000	€ 1,445,000	€ 1,332,000	€ 1,749,000	49%	65%	€	39,960,000
€ 18,441,000.00	€ -	€ 39,937,000.00	€ 39,937,000.00	€ 39,936,000.00	122%	122%	€	39,960,000



## 3.c. Financial analysis of a basic, 30 year service schedule

### Conclusions from the financial analysis

#### Strengths and weaknesses of the business model

Looking specifically at the financial aspect of a PSS facade renovation model, without taking into account for now additional values it might bring to the client or additional marketing perspectives it might offer the provider, it is possible to draw a number of positive conclusions:

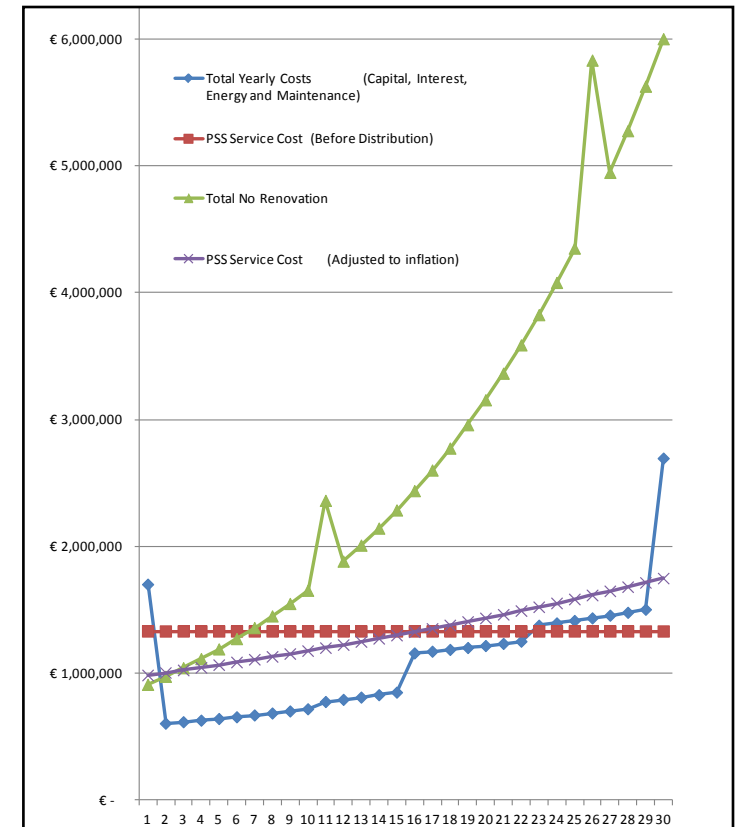
**1. It implies no special effort** - From the point of view of the client (as we can see in the graph on this page) its yearly cost, starting from year 1, is almost identical to the costs of operating the building if no renovation is done. After year 3, the PSS model will have become cheaper than the “no-renovation” model, and by year 30 it will have accumulated savings of over 50% compared to the same non-intervention model. This means at no moment is the PSS model more expensive than suffering the consequences of an increasingly dysfunctional building. Since building-owners start their decisions not by choosing how to renovate a building, but by defining if they should renovate it to begin with, this offers an important incentive: a risk free solution that is guaranteed to offer savings, without the need of additional spending.

**2. Costs are within an acceptable range of a client-lead project** - The regularly-spread cost of a PSS system, opposed to a loan system, removes peaks in expenditure due to initial costs of investment, upgrades and demolition. This means final costs to

the client are stabilized, allowing him to have more predictable financial obligations (at least with regards to his building’s operation). The overall price differential of 22% is within a very acceptable range (if we compare it to the over 50% people would spend on a PSS iPhone), in exchange for the comfort of outsourcing risks, administration and operation costs.

**3. Cash / Credit is freed for more important uses** - One of the main strengths of a leasing or PSS model is that it does not affect the credit-line of the client. While a loan would lock part of the client’s credit capacity into a 30 year investment (lowering available resources for his primary business activities) a PSS system is independent of credit, and is instead accounted for as a contracted service. For organizations who are interested in cash investments, the yearly cash requirements of a PSS model are significantly lower than a full renovation investment, allowing the building-owner to invest that cash into other business activities with a bigger yield.

**4. Payment freedom** - The client can choose a frozen payment scheme in which the yearly amount is the same every year (red) - this would result in more expensive payments the first fifteen years, less expensive ones the last fifteen (in terms of NPV) - or an adjusted scheme in which the service fee increases following inflation (purple).



#### Top

Year-to-year expenses of each model (see page 58 for details)

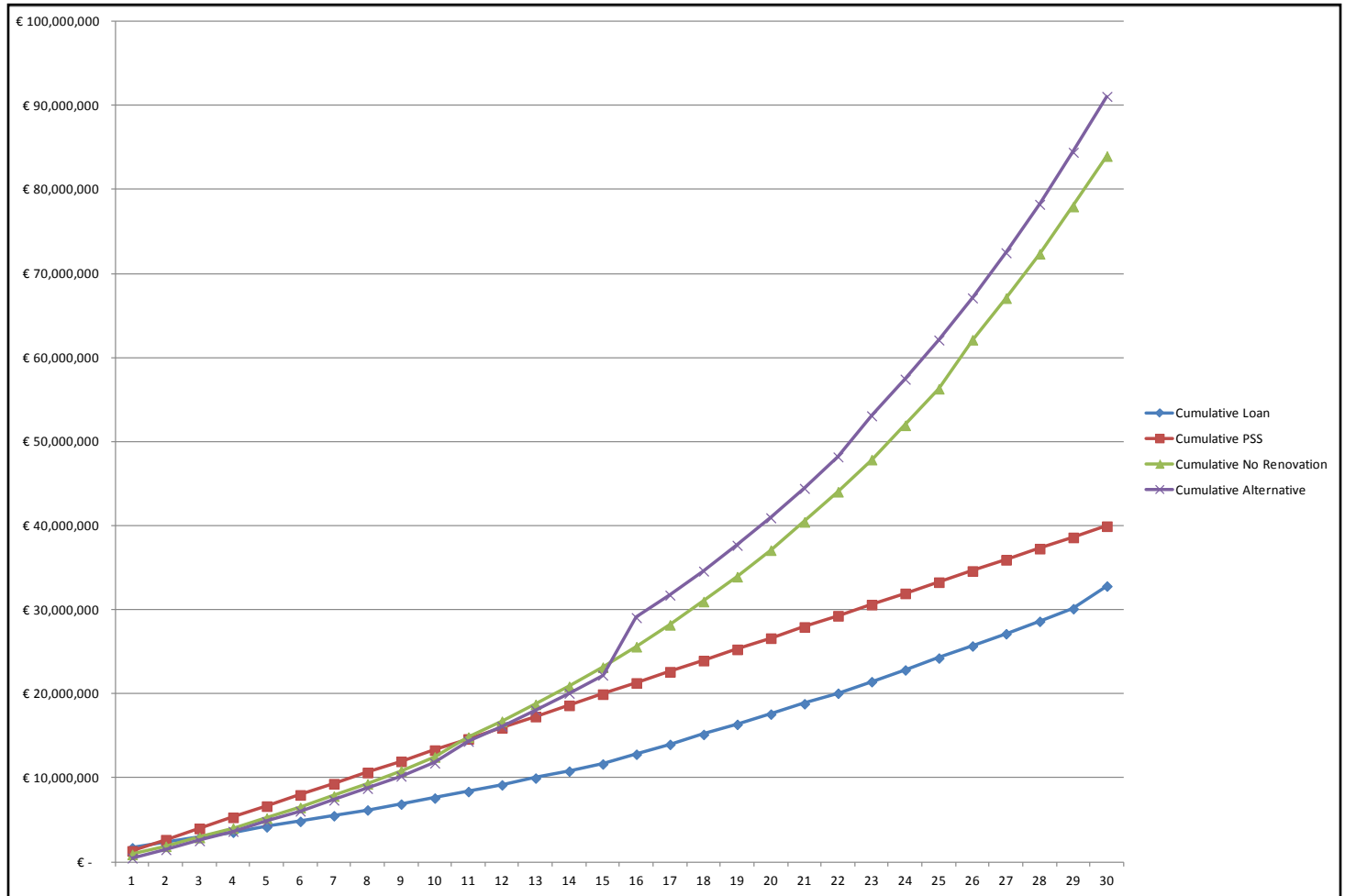
#### Opposite Top

Main expense breakdown for each renovation model. The PSS system can be seen to be within a very close range of the Loan model.

#### Opposite Bottom

Accumulated costs, for each model, over the 30 year economic period.

	Construction	Maintenance	Energy	Total	%
<b>Loan</b>	€ 20,734,000.00	€ 6,413,000.00	€ 5,694,000.00	€ 32,839,000.00	39%
<b>Without Renovation</b>	€ -	€ 13,645,000.00	€ 70,347,000.00	€ 83,992,000.00	100%
<b>PSS</b>	€ -	€ -	€ -	€ 39,936,000.00	48%
<b>Alternative Investment</b>	€ 78,984,000.00	€ 13,645,000.00	€ 5,694,000.00	€ 98,322,000.00	117%



## | 4.a. Intervention strategies enabled by a PSS model

### Value Engineering of a PSS facade system

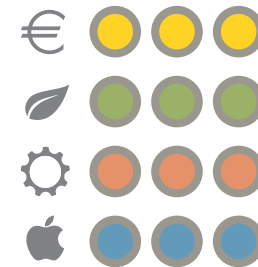
#### Time frames and production strategies

As we have seen, a PSS-based model could potentially lead to a series of modifications (and in principle improvements) to the way in which we design, produce and operate facades. For example, a cheaper way of producing and assembling curtain walls would shorten the financial cycle of the product, which would in turn allow for a shorter expected service-life and more frequent cycles of technological innovation. Diverse production scenarios could then be envisioned, each one of them with a different strategy in terms of Value Engineering.

A term commonly used in other industrial practices, Value Engineering is a method to optimize the projected “value” of a good, service or combination of these, by examining its expected function over time. Value, as understood in this case, is the result of a product’s cost in relation to its intended delivered function (eg. its performance). Value Engineering strategies have a primary impact in the methods of design and production chosen by a fabricator, as they will greatly define key aspects such as marketing angle, expected service-life, and branding of an item. A common strategy used in Value Engineering, which we as consumers are very familiar with, is “planned obsolescence”, an industrial process in which the expected service-life of a product is intentionally reduced, by design, to promote

consumer spending in future replacements. Planned obsolescence can be applied in many forms. It can be built into the way in which a product is operated: by physically limiting its life-cycle (producing it with cheaper materials), programming eventual failure (as in software becoming outdated), or rendering it useless by adjusting the system within which it functions (changing the shape of a phone’s charger). On the other hand, it can also be built into the psychological mind-set of its users (a good example of this is the clothes industry, in which style, as a psychological method of attributing value, is used to turn physically-functioning products into undesirable, outdated “waste”).

In this section, I have defined 6 different strategies for designing and producing facades. These have been divided into 3 main investment time frames: 10 years for short-term, 30 years for long-term and 3x10 years for long-term investments made up of short-term applications / users. For each one of these time frames there are two main strategies: the Reusable strategy is based on increasing the initial energy and material used to produce the system, minimizing its later upkeep, while the Disposable strategy is based on minimizing initial resources, while increasing the number of cycles these resources will go through. These concepts will be further explained in the next page.



#### Top - Grading Methodology

Each one of the 6 design / production strategies will be graded according to a 3-point system for each of the 4 performance values (financial, sustainable, functional and strategic). The grade is a subjective measure according to the following structure:

1 point - The strategy has a significant fault in this field.

2 points - The strategy is balanced with no significant faults nor advantages.

3 points - The strategy has a significant advantage on this field.

The goal of this grading system is to offer a rough comparison of each scheme’s performance in relation to the others. The criteria for assigning points will be as follows:

*Financial value* - The cost of producing / installing the facade could effectively correspond to its intended investment time frame.

*Sustainable Value* - Use of energy and resources can be optimized (initial energy-use is low in the case of solutions that require constant re-processing, or material service-life is long in the case of solutions that require a large initial input).

*Functional Value* - The range of services delivered by the facade (indoor climate, energy production, etc) will be regular throughout the expected service-life, otherwise, does the system facilitate technological updating.

*Strategic Value* - Does the facade offer an additional branding potential (additional user flexibility, reuse potential, visual recognition, among others).

		Term		
		10 Years	30 Years	3 x (10) Years
Strategy	Reusable			
	Disposable			

*Top - Brands as a natural evaluation system*

*Value, as I have mentioned before, is a highly subjective concept. Even in the case of specific performance-based evaluations, each performance will be up to the criteria and interests of the person analyzing it. Therefore, as an auxiliary way of designing (for me) and explaining (for the reader) the values behind each of these abstract facade strategies, I have used a more familiar, equally abstract, system of attributing value.*

*Brands, which are to the industry what words are to language, carry a complex system of meaning (and values) which as consumers we have become familiar with to the point that we implicitly assign them to the mention of the brands name or the recognition of its logo.*

*I have chosen 6 brands which are generally well-known, and each of which embodied a certain combination of values which corresponds to those intended from each design scheme. These values might be in terms of their products' performance (how long their products last, how fashionable and desirable they are) or in terms of their manufacturing and marketing processes (some brands are based on producing low-cost items which match the current fashion trend, such as IKEA, others aim to sell a single super-luxurious item which will last for decades and become a classic, such as Rolls Royce).*

*Some of these brand relations are more literal than others, they will be explained in more detail on each of their chapters.*

## | 4.b. The mentality of production

### Reusable Vs. Disposable

#### Financial and material cycles in resource-efficient facades

In a Product-Service System, a service provider delivers a final function by combining material components (products) and administrative overview (services). The physical, material resources of which these products are composed remain in the ownership of the service provider, and the financial resources that are used to process (and reprocess) these material components remain under his management. This aspect of PSS economic models facilitate the planning of circular economies, in which the input of one industrial cycle is used, at the end of its service-life, as input for the next one, therefore preventing the generation of waste (by-products which can no longer be used as input because their reuse would be physically impossible or economically unpractical).

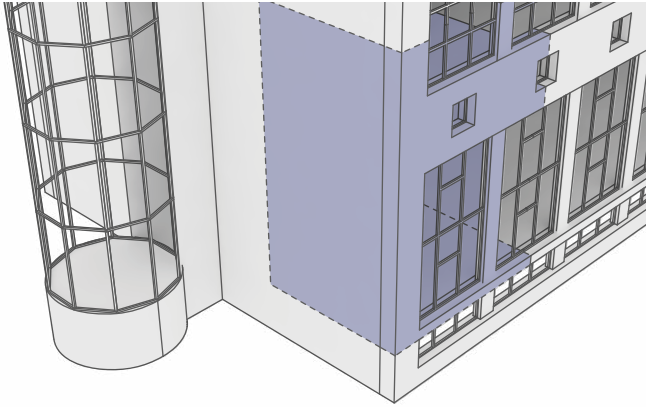
The 6 schematic design paths are divided according to their expected service-life time frame, as well as their circular economy strategy. The reusable and disposable terms are not used in their strict meaning, but as general ways of managing material and financial resources, they can be understood as follows:

**Reusable strategies** are those that extend the life of initial material and financial resources to their longest possible use term. This means Planned Obsolescence is minimized, and instead products are meant to remain current (in their original form) throughout all necessary

cycles of use. This might in practice occur either by applying the products to a single building (in the case of facades) and using them for the longest term possible, or by installing the same products in different buildings over time, without the use of intermediate resources (apart from installation and deinstallation costs) along the way. Currently, most facades are produced under a reusable mentality, even though they are not practically reused at the end of their service-life, their use is generally extended until the last possible moment with minimal intermediate investments.

**Disposable strategies**, on the other hand, minimize resource-use at the time of planning and fabrication, in order to reduce initial costs, and instead depend largely on upgrades done to the system over time, or entire replacement of components. In the case of disposable products, planned obsolescence plays a big role, as the cost of producing an item has to be carefully planned to make sure its function will be significantly reduced at approximately the time when it has accomplished its return on investment. The client will be satisfied by getting the expected (however short) service-life, and he will be ready to invest further to extend its use. IKEA and Apple are two brands whose business model is largely based on the planned disposability of their products.





**Left**

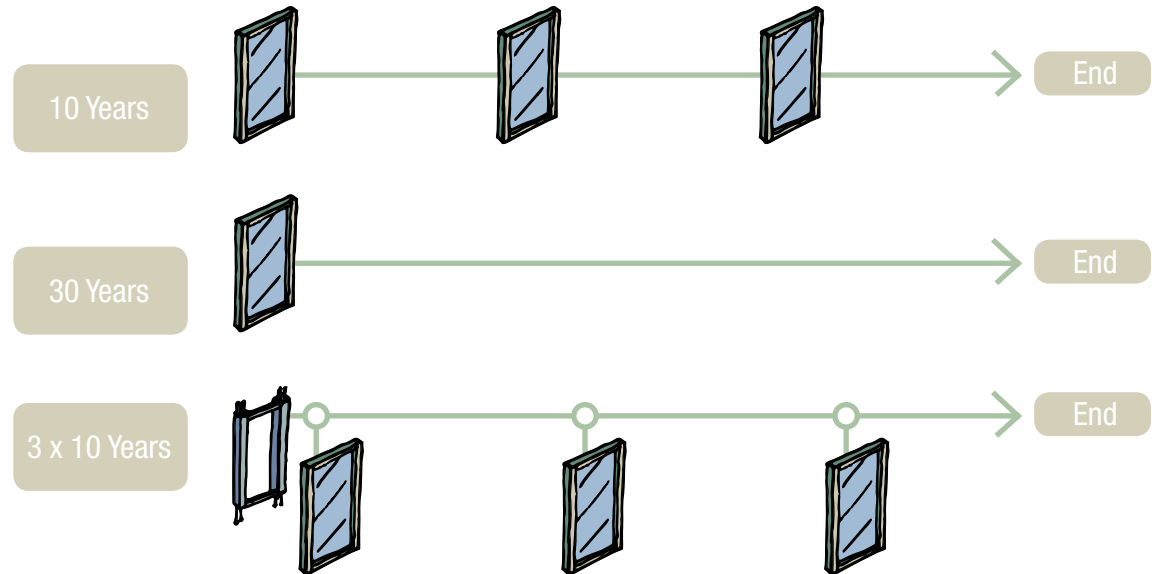
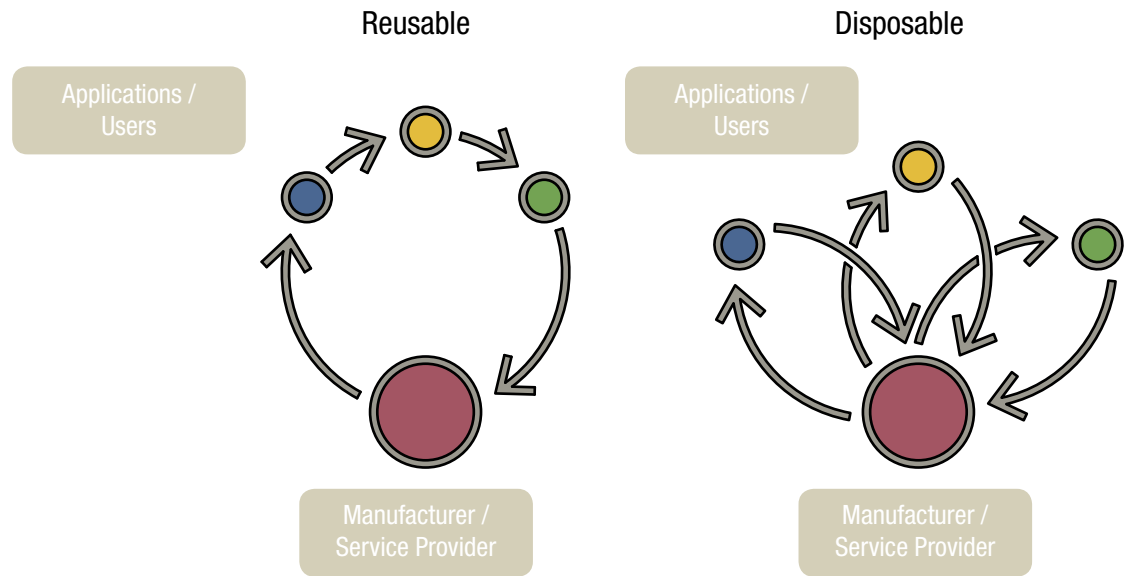
Segment of the 3mE building refurbished according to the 6 different strategies. Specific technical information of the 3mE building has not been of major importance since the PSS models are based on the idea of exchangeability, standardization and mass production. Therefore, only measurements have been used as design parameters, interaction between the existing structure and the new systems is limited to reflect the intention that these models should be applicable to most building facades, as additions or replacements, regardless of their dimensions and current construction systems.

**Right Top**

Diagrammatic concept of Reusable and Disposable production strategies. Reusable products and systems can be applied by the same, or different user over the longest period of time without the need for intermediate interventions or reprocessing. Disposable products or systems have to go back to their source after each (shorter) service-life cycle. The overall use of energetic and material resources could, in theory, be the same in both cases, the difference is at what point in their functional cycle are these resources applied.

**Right Bottom**

Diagrammatic concept of the three time-terms analyzed. A 10 year model can be considered mostly disposable, as it would be fully replaced in relatively short intervals (for industry standards). A 30 year model is similar to the currently used, in which the system receives only minor interventions along the way (maintenance and component replacement). A 3x10 years model reflects the full potential of a leaseable system, in which supporting structure and other long-term components are fixed under a long term contract, but technical and cosmetic components are replaced within shorter cycles as new technologies or trends become available.



Project Term	Production Strategy	Financial Strategy	Fabrication Strategy	Financial Strength	Sustainable Strength	Functional Strength	Strategic Strength
10 Year	ReUsable	<ul style="list-style-type: none"> <li>- Long term</li> <li>- Cheap adjustment</li> <li>- Medium construction costs</li> </ul>	<ul style="list-style-type: none"> <li>- Trimmable, adjustable components.</li> <li>- Durable materials and techniques               <ul style="list-style-type: none"> <li>- Universal Connections</li> </ul> </li> <li>- Mass production, fast (dis)assembly</li> </ul>	<ul style="list-style-type: none"> <li>- Low investment with long use potential with intermediate adjustment expenses</li> </ul>	<ul style="list-style-type: none"> <li>- Correct material selection would lead to flexible durable materials that could serve many buildings over a single service-life</li> </ul>	<ul style="list-style-type: none"> <li>- Fast installation and low initial investment. Material reutilization would allow more flexible contracts</li> </ul>	<ul style="list-style-type: none"> <li>- Rough finishes and sustainable material use would appeal to a popular Green / Industrial look.</li> </ul>
	Disposable	<ul style="list-style-type: none"> <li>- Short Term</li> <li>- Cheap reprocessing</li> <li>- Low construction costs</li> </ul>	<ul style="list-style-type: none"> <li>- Fixed components.</li> <li>- Economic / biodegradable materials</li> <li>- Cheap recycling / reshaping</li> <li>- Universal connections</li> <li>- Mass production, fast (dis)assembly</li> </ul>	<ul style="list-style-type: none"> <li>- Low investment with quick return and constant material reuse</li> </ul>	<ul style="list-style-type: none"> <li>- Design for fast disassembly and reprocessing would allow for constant material reuse</li> </ul>	<ul style="list-style-type: none"> <li>- Frequent full functional renovations due to short, closed financial cycles.</li> </ul>	<ul style="list-style-type: none"> <li>- Short service and design cycles would allow for constant trend-based redesign.</li> </ul>
30 Year	High End	<ul style="list-style-type: none"> <li>- Long Term</li> <li>- Low operation costs</li> <li>- High construction costs</li> </ul>	<ul style="list-style-type: none"> <li>- Fixed, highly specific components.</li> <li>- Durable materials and connections</li> <li>- Customizable shapes and complex joints</li> <li>- Limited production, labor-intensive (dis)assembly</li> </ul>	<ul style="list-style-type: none"> <li>- Safer, predictable performance and return.</li> <li>- Long term business-to-client relation</li> </ul>	<ul style="list-style-type: none"> <li>- Lower production energy by fully exploiting original service life of materials</li> </ul>	<ul style="list-style-type: none"> <li>- Uninterrupted service-life, few renovations and less invasive maintenance increase user comfort.</li> </ul>	<ul style="list-style-type: none"> <li>- High-end, luxurious appearance with endless potential for customization due to case-by-case design and production.</li> </ul>
	Economic	<ul style="list-style-type: none"> <li>- Medium Term</li> <li>- High operation costs</li> <li>- Low construction costs</li> </ul>	<ul style="list-style-type: none"> <li>- Fixed, replaceable components.</li> <li>- Component-specific durability</li> <li>- Customizable shapes and complex connections</li> <li>- Combined production, accessible (dis)assembly</li> </ul>	<ul style="list-style-type: none"> <li>- Lower initial investment (lower capitalization and more diversified interests)</li> </ul>	<ul style="list-style-type: none"> <li>- More frequent replacement of vulnerable components with advancing technologies</li> </ul>	<ul style="list-style-type: none"> <li>- Frequent maintenance interventions give a chance for (limited) functional adjustments and upgrades along the way.</li> </ul>	<ul style="list-style-type: none"> <li>- Lower initial investment frees resources for future upgrades. Limited by the long-term nature of the base system.</li> </ul>
3(10) Year	Standardized	<ul style="list-style-type: none"> <li>- Long Term</li> <li>- Cheap exchange</li> <li>- Expensive planning and logistics</li> </ul>	<ul style="list-style-type: none"> <li>- Modular catalogue components.</li> <li>- Long material and connection durability</li> <li>- Limited customization with rigid grid definition</li> <li>- Industrial / Mass fabrication</li> <li>- Plug-and-play (dis)assembly</li> </ul>	<ul style="list-style-type: none"> <li>- Potential for cheaper fabrication processes due to economy of scale.</li> <li>- Shorter reinvestment cycles throughout portfolio</li> </ul>	<ul style="list-style-type: none"> <li>- Optimized production techniques due to large-scale planning and standard fabrication</li> <li>- Faster market integration of emerging technologies.</li> </ul>	<ul style="list-style-type: none"> <li>- Catalogue selection of interchangeable components with plug-and-play connections allow cheap, frequent and radical functional changes.</li> </ul>	<ul style="list-style-type: none"> <li>- Catalogue components allow radical redefinition of the overall facade appearance. Functional layers can act as a showcases for client or third parties.</li> </ul>
	Stratified	<ul style="list-style-type: none"> <li>- Combined Term</li> <li>- Expensive exchange</li> <li>- Cheap planning and logistics</li> </ul>	<ul style="list-style-type: none"> <li>- Combined components.</li> <li>- Component-specific material and connection durability</li> <li>- Intermediate customization with rigid grid definition</li> <li>- Combined fabrication</li> <li>- Intermediate (dis)assembly</li> </ul>	<ul style="list-style-type: none"> <li>- Potential for cheaper fabrication processes due to economy of scale in certain components.</li> <li>- Potential for new mid-term investments at appropriate</li> </ul>	<ul style="list-style-type: none"> <li>- Optimized material use according to layer service-life, reducing reprocessing energy.</li> <li>- Shorter technical cycles allows for more frequent improvement.</li> </ul>	<ul style="list-style-type: none"> <li>- Separation between long term substrate and short term add-ons reduce the dominance of the grid and allow for greater flexibility.</li> </ul>	<ul style="list-style-type: none"> <li>- Appearance can be adjusted more freely and external aesthetic layers are replaced more frequently. Long term structural layers are less dominant.</li> </ul>

Notes

\* Short - Short service life with low intervention  
 Medium - Long service life with high intervention  
 Long - Long service life with low intervention  
 Combined - Component-specific service life

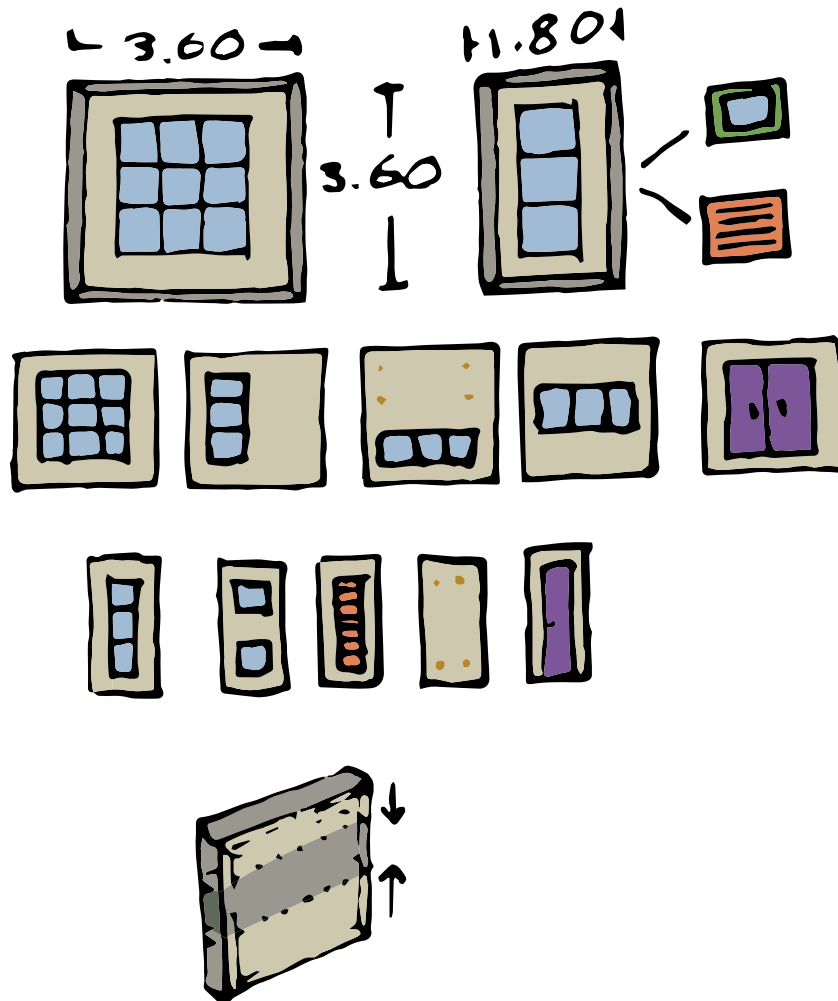
System Keystone(s)	Risks for Provider	Benefits for Provider	Benefits for Client	Main difference against current model	Best for
<ul style="list-style-type: none"> <li>- Flexible, durable materials</li> <li>- Universal connections</li> </ul>	<ul style="list-style-type: none"> <li>- Costs and limits of adapting components to new buildings and uses. Might result in costs higher than starting from scratch.</li> </ul>	<ul style="list-style-type: none"> <li>- Splits projects into smaller, shorter interventions. Project risks attached to large contracts are reduced as investments and service lives become smaller.</li> </ul>	<ul style="list-style-type: none"> <li>- Replacement after 10 years is an option (allowing renovation and re-branding) but is not forced by technical end-of-life.</li> </ul>	<ul style="list-style-type: none"> <li>- Assembly</li> </ul>	<ul style="list-style-type: none"> <li>- Unpredictable practices</li> </ul>
<ul style="list-style-type: none"> <li>- Low-cost manufacturing and assembly.</li> </ul>	<ul style="list-style-type: none"> <li>- Technical difficulties of building a system to last for 10 years. 30% of the service life should be delivered by 30% of the cost.</li> </ul>	<ul style="list-style-type: none"> <li>- Producer can take advantage of technological innovations for every cycle of production, use and disposal. Theoretically optimizing material and industrial processes.</li> </ul>	<ul style="list-style-type: none"> <li>- Reduced cost and quick fabrication / installation for clients without long-term vision possibilities.</li> </ul>	<ul style="list-style-type: none"> <li>- Fabrication</li> </ul>	<ul style="list-style-type: none"> <li>- Temporary applications</li> </ul>
<ul style="list-style-type: none"> <li>- Fabrication quality control</li> <li>- Accuracy of financial model (price against costs)</li> </ul>	<ul style="list-style-type: none"> <li>- Time frame and communication with other project parties. Risks have been minimized by years of practice.</li> </ul>	<ul style="list-style-type: none"> <li>- Largest one-time return due to highest initial investment. Performance of facade and financial estimation more likely to be accurate as operation costs are reduced.</li> </ul>	<ul style="list-style-type: none"> <li>- Financial and technical stability, limited interventions for uninterrupted service. High quality for demanding aesthetic standards.</li> <li>- High customization possibilities.</li> </ul>	<ul style="list-style-type: none"> <li>- Financing</li> </ul>	<ul style="list-style-type: none"> <li>- Commercial / solid institutions</li> </ul>
<ul style="list-style-type: none"> <li>- Frequent maintenance</li> </ul>	<ul style="list-style-type: none"> <li>- Liability in useful life of components, the client must understand the reasons for a lower initial investment and be aware of the higher maintenance costs.</li> </ul>	<ul style="list-style-type: none"> <li>- More frequent (though smaller) returns over time due to the need for frequent renovation and replacement.</li> </ul>	<ul style="list-style-type: none"> <li>- Smaller initial investment.</li> <li>- Potential for small adjustments at maintenance thresholds.</li> </ul>	<ul style="list-style-type: none"> <li>- Maintaining</li> </ul>	<ul style="list-style-type: none"> <li>- Limited-resource organizations</li> </ul>
<ul style="list-style-type: none"> <li>- Fabrication techniques and universal interconnectivity.</li> <li>- Marketing appeal and component circulation.</li> </ul>	<ul style="list-style-type: none"> <li>- Financing strategies. Service provider becomes a financial entity with long-term ownership.</li> <li>- Storage of unused panels and logistics of replacement.</li> </ul>	<ul style="list-style-type: none"> <li>- Marketing appeal of a flexible system could result in higher service fees. The frequency in which this flexibility is actually used could result in a positive profit difference.</li> </ul>	<ul style="list-style-type: none"> <li>- Optimized flexibility with minimum risk and without further investment.</li> <li>- Functional and strategic freedom for long-term owners with short-term planning possibilities.</li> </ul>	<ul style="list-style-type: none"> <li>- Planning</li> <li>- Marketing</li> <li>- Fabricating</li> </ul>	<ul style="list-style-type: none"> <li>- Long-term owners with frequently changing needs</li> </ul>
<ul style="list-style-type: none"> <li>- Material- and fabrication-process selection to guarantee expected service-lives.</li> </ul>	<ul style="list-style-type: none"> <li>- Service life expectancy of different components. Materials and production processes must be carefully selected to deliver the intended performance and lifespan.</li> </ul>	<ul style="list-style-type: none"> <li>- Reduced "inventory" costs, panels don't have to be managed and stored between clients, only materials are reprocessed. Reduced risk of unused inventory.</li> </ul>	<ul style="list-style-type: none"> <li>- Wider flexibility in the definition of a grid. Form is not tied to universal components, presence of infrastructure or support layers is minimized. Functional and strategic flexibility is still possible.</li> </ul>	<ul style="list-style-type: none"> <li>- Planning</li> <li>- Producing</li> <li>- Installing</li> </ul>	<ul style="list-style-type: none"> <li>- Long-term owners with infrequently changing needs</li> </ul>

## Strategy planning and comparison

### Left

*This table helped me define the main design aspects to be considered for each of the 6 intervention strategies. Aspects such as their main performance potential (according to the 4 value criteria), as well as the main risks and benefits they could imply to the different stakeholders, their principal design challenges and their specific market potential have been roughly identified in this comparison.*

## 4.c. Value-Engineered design scenarios - 10 year Reusable



**Related branding:** Temporary solutions to momentary problems



### 4-Value Performance:

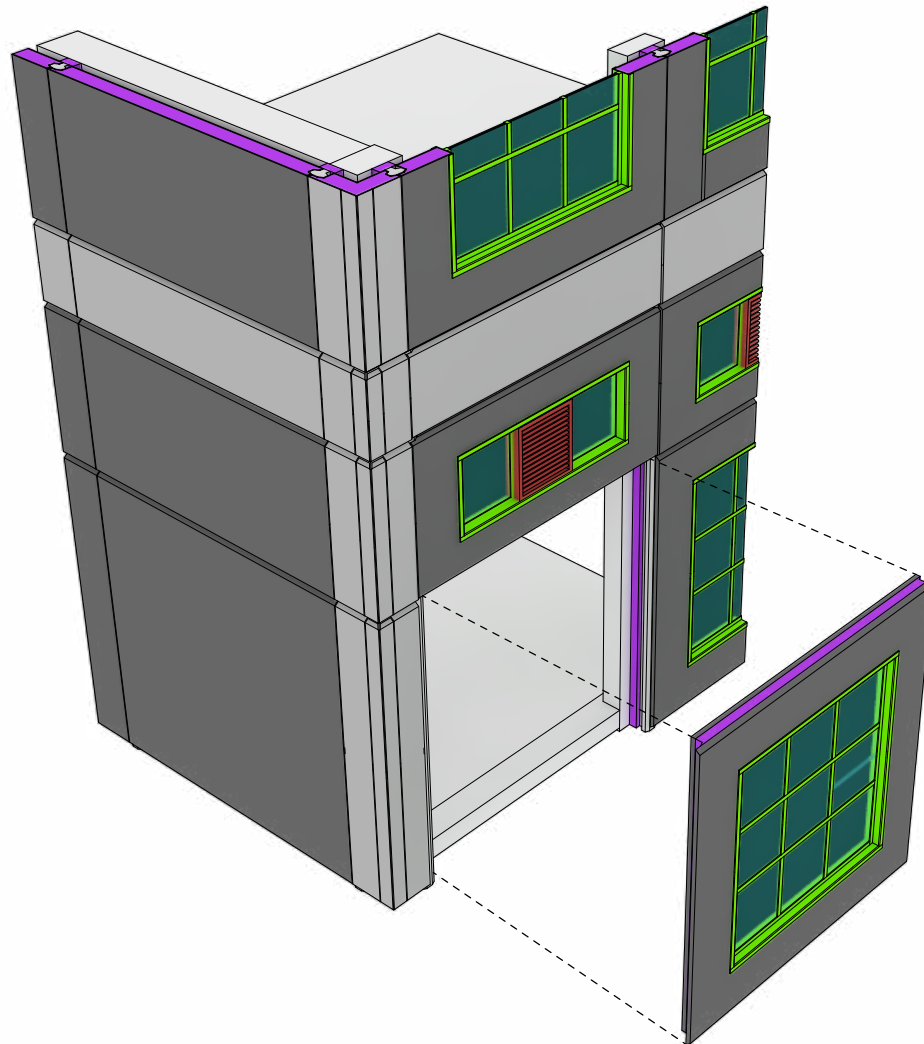
- € ●●○ Increased return in the long-run / Risk of dead inventory
- 🍃 ●●● Serves many buildings without reprocessing resources
- ⚙️ ●●● Fast installation and removal for flexible contracts
- 🍏 ●○○ Standard / Prefab look is generally utilitarian

### Suitable for:

- Temporary interventions or temporary structures
- Extending service-life of structure before major renovation or demolition
- Utilitarian applications where function is more important than appearance.
- Organizations with short-term planning possibilities

### Design Keystone:

Assembly, durability and transportability are the main design issues. Facades should be built to last over 2 or 3 cycles of installation / use / deinstallation. Cleaning and maintenance would preferably be done at the manufacturer's facilities between uses.



## Modular, integrated, prefabricated facades

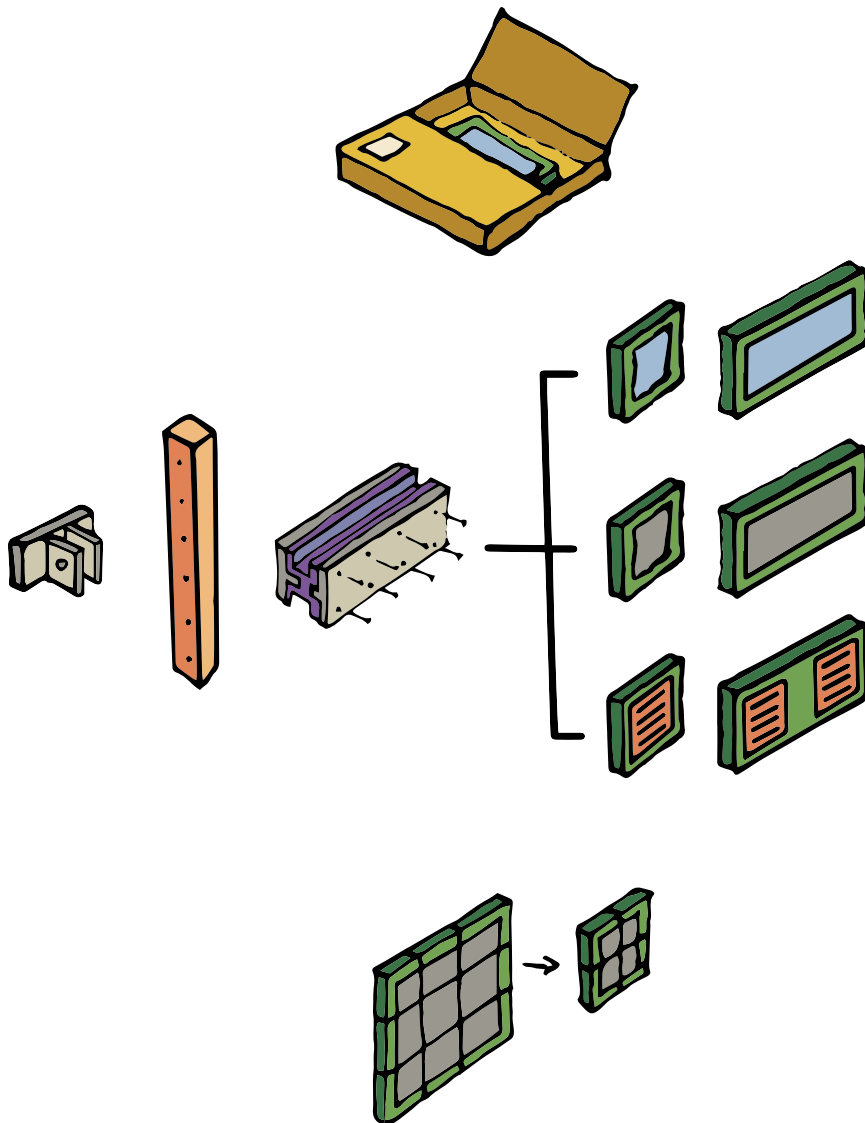
### Lease on-demand

Modular prefabricated facades would be specially appealing to clients with unpredictable future needs. Similar to prefabricated modular constructions, they are a fast response to peaks in demand which might not necessarily last too long. These facades can be used to temporarily extend the service-life of structures that might not be deemed safe or comfortable enough, while they wait for a more thorough renovation or to “squeeze” a few more years before demolition. It can also be a good solution to clad structures which have been left unfinished due to financial complications in the project’s management during construction. The reusability of the components would result in low end-of-contract fees in case the client wants to change to a more permanent solution.

Integrated modules would be designed to last over various cycles of installation, use and deinstallation, resulting in a (potentially) more optimum use of materials after the initial energy input. Resource use over time would be limited since assembling and disassembling would be the only interventions necessary.

From the point of view of the client, these facades would be a cost-effective solution in the short term, when used as a temporary solution to immediately improve his primary activities. As a long term solution it would most likely result more expensive as the mechanisms that would allow for transportation would be wasted when used in a fixed location. From the point of view of the provider, return on investment would be based on constantly finding new users for his module inventory. Dead or slow inventory would present the principal risk. On the other hand, charging a premium for the “temporary” nature of the system would result in larger returns in case all modules are constantly in use.

## 4.c. Value-Engineered design scenarios - 10 year Disposable



**Related branding:** Trendy design, cheap to produce, easy to assemble



### 4-Value Performance:

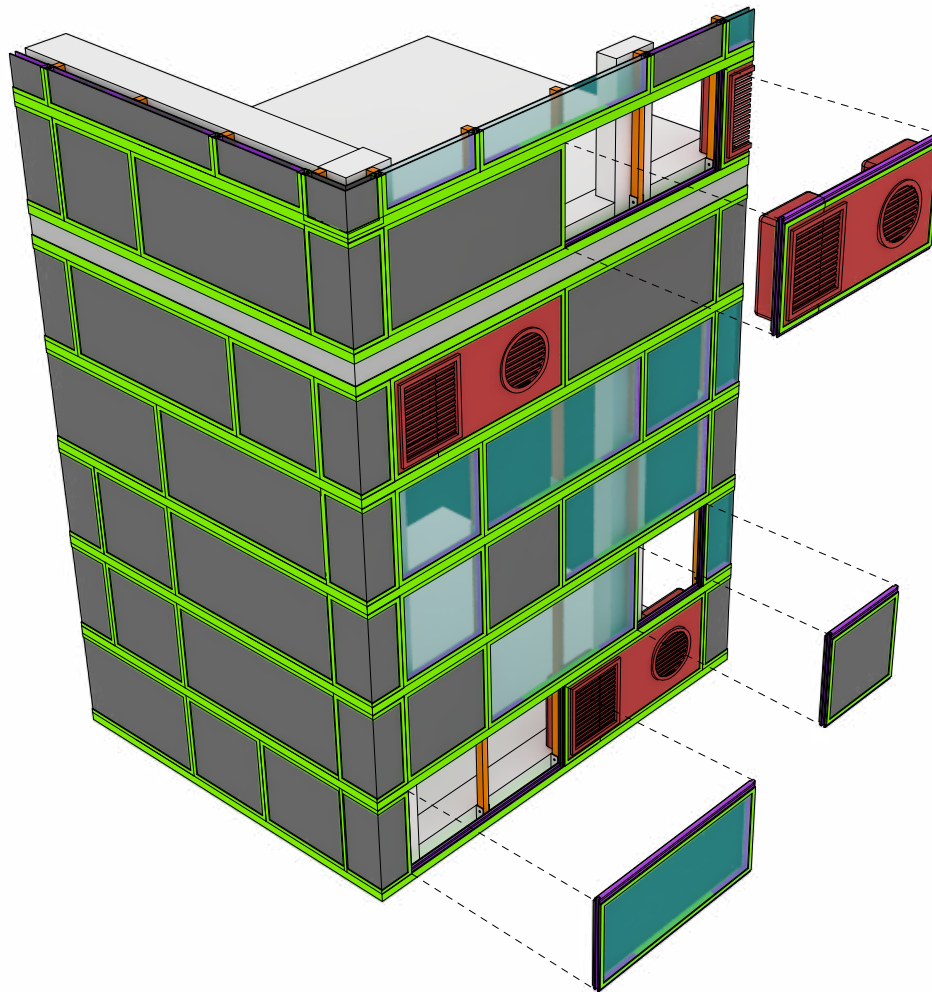
€	● ● ○	Small initial cost foments regular replacement Long-term cost might end up being higher
🍃	● ● ○	Hard to regulate service-life of all components equally
⚙️	● ● ●	Constant functional renovations possible
🍏	● ● ●	Trend-based design possible

### Suitable for:

- Buildings with frequent, radical changes in uses or functions.
- Buildings that need constant cosmetic renovation to stay up-to-date with design trends (for example retail spaces).
- Short-term building owners, or even building users who don't own the property but want to improve its performance during their period of use.
- Temporary interventions or temporary buildings.

### Design Keystone:

As with IKEA manufacturing processes, materials should be mostly renewable or recyclable, with highly standardized one-fits-all joints and connections. A short life-cycle is then embedded into the design. A PSS scenario would facilitate a circular economy by ensuring that all parts go back to the producer for reprocessing.



## Modular, assemblable, mass-produced facades

### Temporary facades for temporary uses

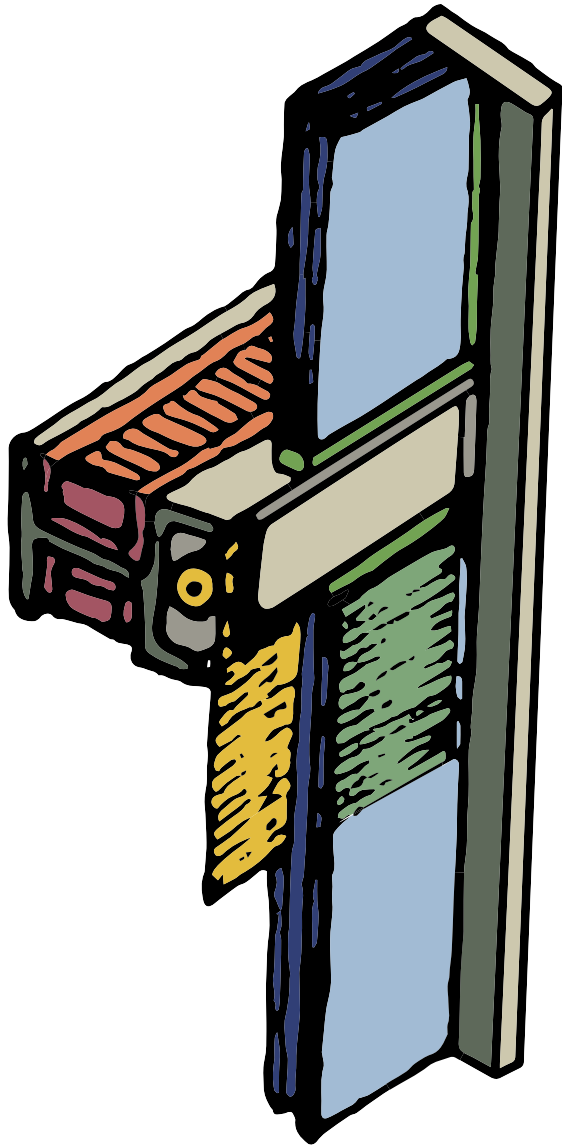
Prefabricated, disposable facades would allow greater design flexibility than the “DeMeeuw Facade” model. This would be specially attractive for clients for whom a constant trendy look is important. A short, closed financial cycle would give the client time of functional use before a wider renovation, without the downside of a temporary-looking large-module prefabricated facade.

As with IKEA furniture, the main value is in strategic and functional terms, being able to redefine your institution’s image, at a low cost and with limited durability. The financial aspect might be very attractive in the short term, but might result in higher overall costs over time, as the facade will have to be replaced not only for cosmetic reasons, but because the components will have reached the end of their planned service-life.

The concept would highly depend on the cost - in terms of energy and material - of producing the components, to ensure the entire system can be fully paid within the first 10 years of use, so it can be replaced by a new model at this term’s end. It would also highly depend on the design of connections and joints, as well as the universal applicability of the modules. The base components (brackets, structural supports and rails) would be pre-perforated at modular distances to adapt to the building’s dimensions, while the modules could be sold as individual pieces to allow for customer combination according to his specific needs.

This scenario has the biggest risk of turning into an important source of waste, as components are designed to perform for the shortest time-span. The use of renewable materials, the design of composite components to allow easy disassembly, and the cost-effective reprocessing of all parts are essential to the sustainable success of this model.

## 4.c. Value-Engineered design scenarios - 30 year High-End (reusable)



**Related branding:** Invest once, use forever



### 4-Value Performance:

- € Higher investment is justified by higher predictability
- Without space for updates obsolescence is always a risk
- Materials are used for as long as possible
- One-system-fits-all, limited flexibility over time
- High customization potential and long term recognition

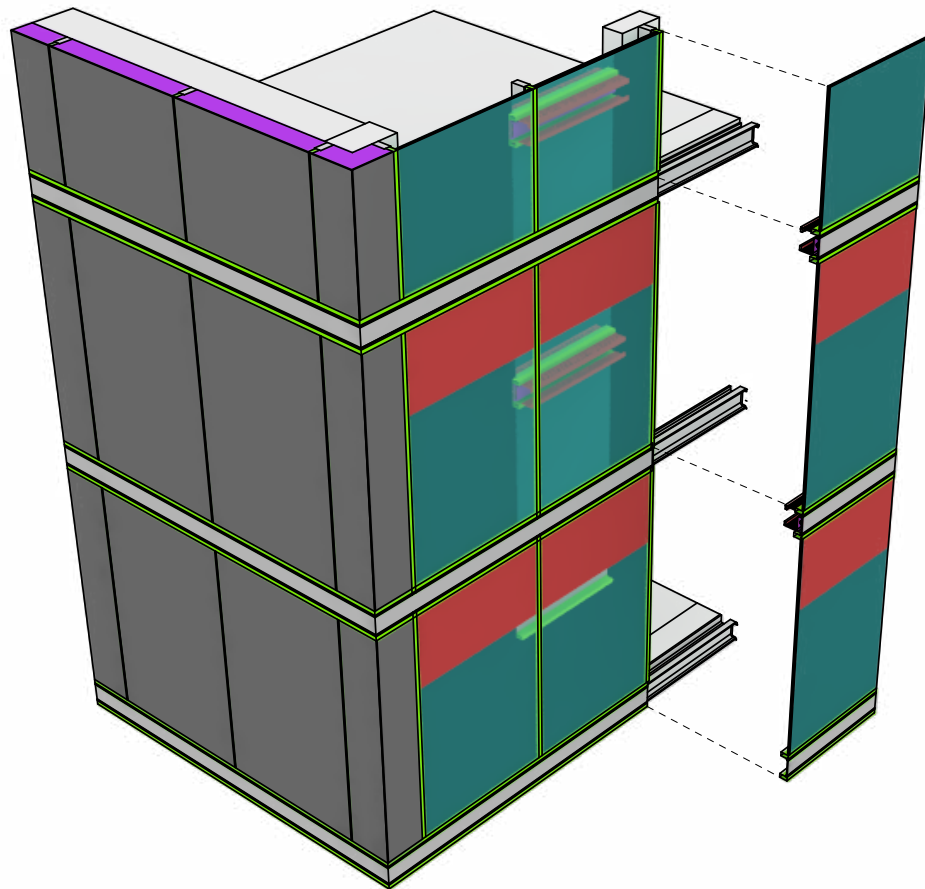
### Suitable for:

- Institutions with long-term plans (long-term ownership) and long-term financial possibilities.
- Buildings which require an up-to-date technological appearance (eg. those which represent the image of a corporation).
- Clients with an experienced facilities management team that can guarantee the correct function of the complex systems involved over time.

### Design Keystone:

Since this is the common method currently used to produce facades, it has the benefit of long-term experience and progressive development. Cost estimation is an important aspect, but solidly established industrial parameters increase their accuracy. Planning and assembly is a complex process, and system testing can be an expensive process in the case of non-standard systems. Continuity from one project to the next is limited as both the scenario and the work-team are frequently very different.





## Case-by-case design and production

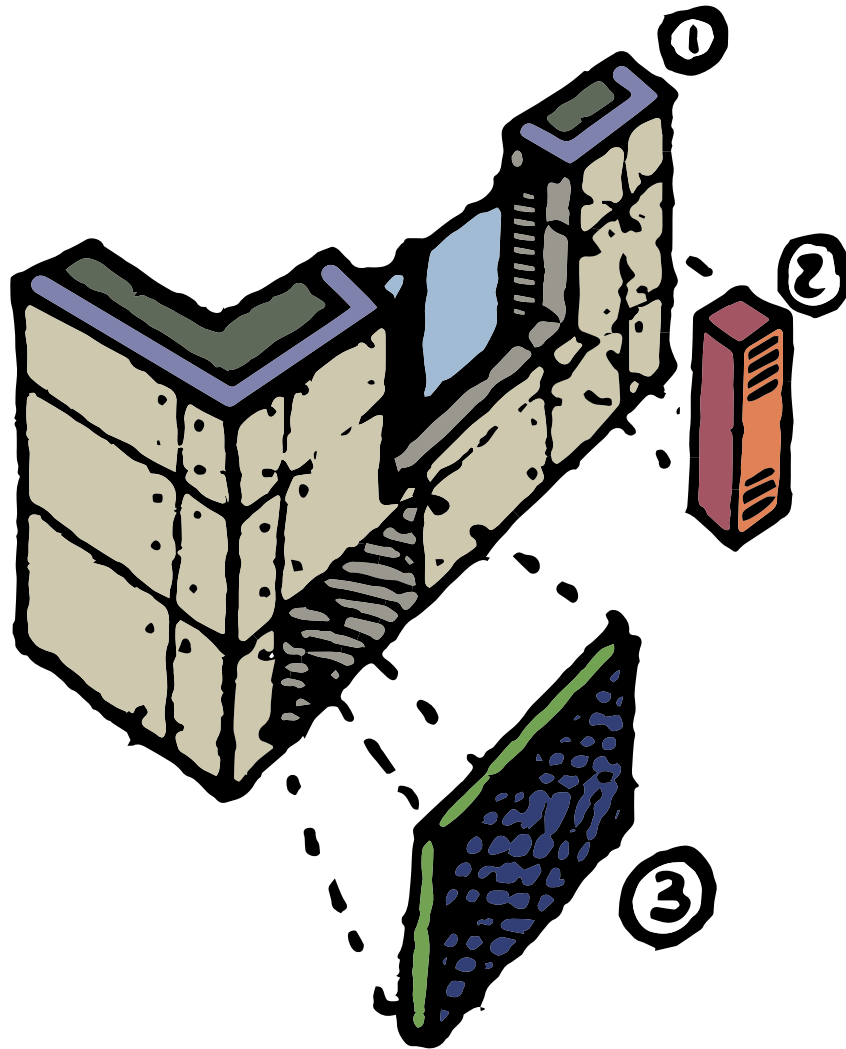
### Today's regular facades financed in a different way

This model closely resembles the most common model for facade renovation currently practiced. A large initial investment is required to pay for the high planning costs, customized manufacturing and manual assembly used to produce project-specific building envelopes. This means a single financial cycle often extends into a long-term range of 30 to 40 years. Producing this type of facade under a PSS model would still be possible, and could be done in a way that benefits both the producer and the client. The producer could change his role from a one-time builder to a long-term manager and operator, while the client could outsource responsibilities and risks and reduce his financial and administrative expenses. (please see previous chapter "3.a. Case Study" for a more detailed analysis of these benefits).

Rolls Royce has been chosen as the related brand because of its history of providing a "single investment" policy. This meant that a person buying their cars wouldn't have to worry about service (as service expenses were included in the original cost), he would therefore be investing a long-term transportation solution, as he was also betting that from a strategic point of view the car would retain value by eventually becoming a classic.

Similar to this, facades today are built to maximize initial resource use while minimizing eventualities. The facade should in theory perform appropriately over the next 30 or 40 years, without the need of mayor interventions or upgrades. This becomes a problem in today's technological context, in which the rate at which new, more effective technologies become available, rendering the previous technologies obsolete or at least sub-optimal. Investing in a 40 year facade in the 1950's was a guarantee, today it might be tying your resources down to a system that will not perform to its best capacity before the end of that term.

## 4.c. Value-Engineered design scenarios - 30 year Economic (upgradable/ disposable)



**Related branding:** The more you spend the more fun you get



### 4-Value Performance:

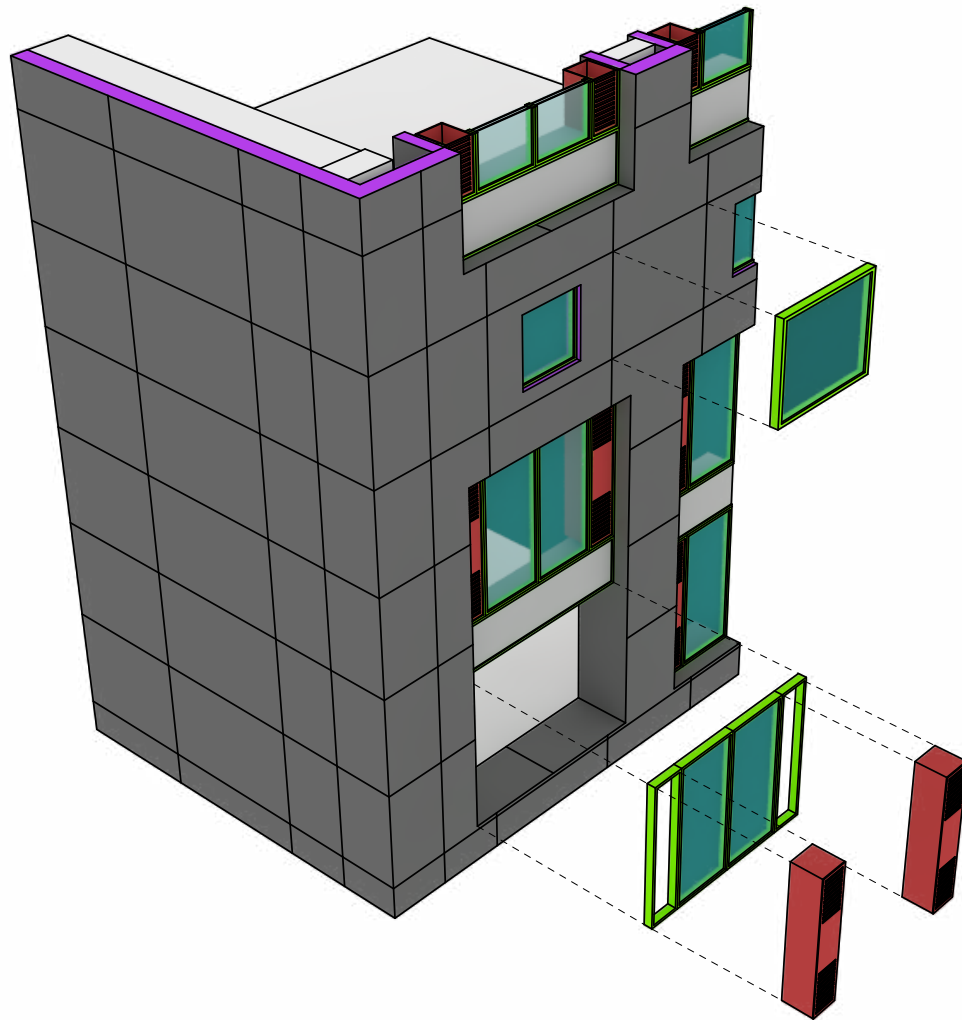
€	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	Smaller Initial investment Service-life of certain components not exploited
🌿	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	Material use not optimized, energy savings gradual
⚙️	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	Changes done according to necessity and possibility Range of intervention increasingly limited
🍏	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	Visual continuity might be a problem, activities affected

### Suitable for:

- Clients with limited financial resources, who can only commit to exceptionally necessary interventions.
- Buildings with specific constructive restrictions (such as historically preserved structures), which are not allowed to have a radical renovation, but only to improve localized systems.
- Clients with short-term planning capacity, that want to improve the performance of their facade without the risk of committing too many resources to a building they might not use for such a long period of time.

### Design Keystone:

If future renovations are not taken into account, the cost of planning and adjusting to the restriction of previous interventions might result in unnecessary spending. The most effective way of designing such a system would be to prepare the infrastructure for future improvements, in order to make them faster, cheaper and better integrated.



## Improvement-based renovation

Replace or upgrade components as needed

Another method currently used for improving the performance of building facades is to spread resource investment into smaller interventions over a longer period of time. Opposed to the previous model, in which the full investment is done at the beginning to guarantee a low resource use in the long-run, in this case individual investments are limited, performance and value vary over time as components are replaced and systems upgraded.

This method is frequently used in cases where full renovations are impossible (such as in historically preserved buildings, where only localized solutions are allowed), or in cases where the client doesn't want to commit the high amount of initial resources demanded by the "Rolls Royce" model.

The main drawback to this strategy is the compromised continuity between interventions. Because all components are not replaced at the same time, and because they are not specifically designed from the start to work together, they might not be optimally compatible, or they might reach the end of their service-lives at different moments. This will force all future interventions to be done in the same way (as components need replacement), or in the case that the entire facade is eventually replaced some components might have not reached their full use-potential as they are removed earlier than planned.

The reference to the Xbox brand comes from their business model, in which the main console (the mainframe that allows all related products and services to work) is sold at a very low profit margin, or even at a loss. In exchange, their business is based on the distribution of products (such as controllers, accessories, memory expansions, etc) and software (games, movies, online content). The base performance of the console, on its own, is limited, increase in performance (in this case entertainment) is tied to the amount of money invested.

## 4.c. Value-Engineered design scenarios - 3x(10) year Standardized (reusable)

**Related branding:** Catalogue sales, continuous client engagement



**PANDORA**  
UNFORGETTABLE FACADES

### 4-Value Performance:

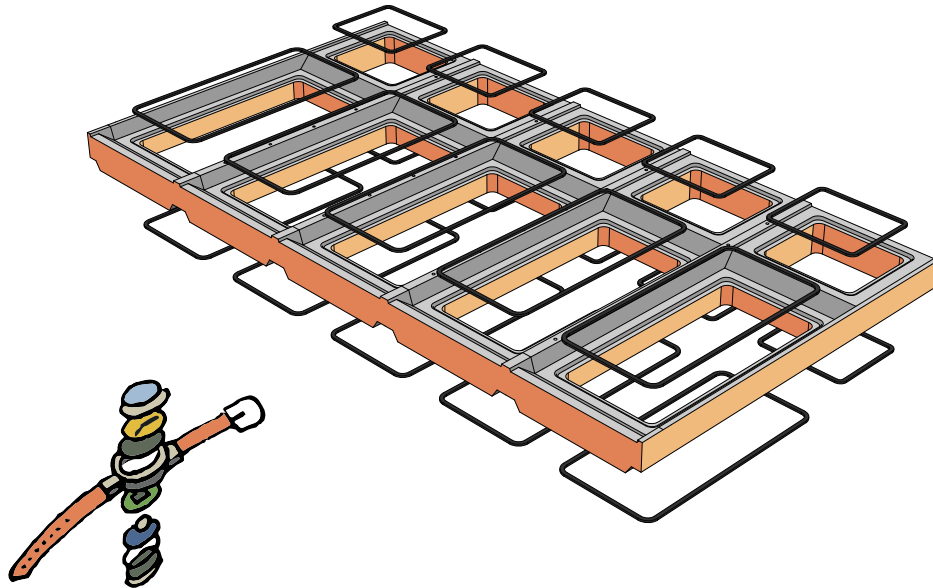
€	● ● ○	Components available on demand, cost-effective production Risk of dead inventory
🌿	● ● ●	Material life optimized, intermediate energy-use limited
⚙️	● ● ●	High degree of flexibility with low cost and free term
🍏	● ○ ○	Cosmetic personalization very limited

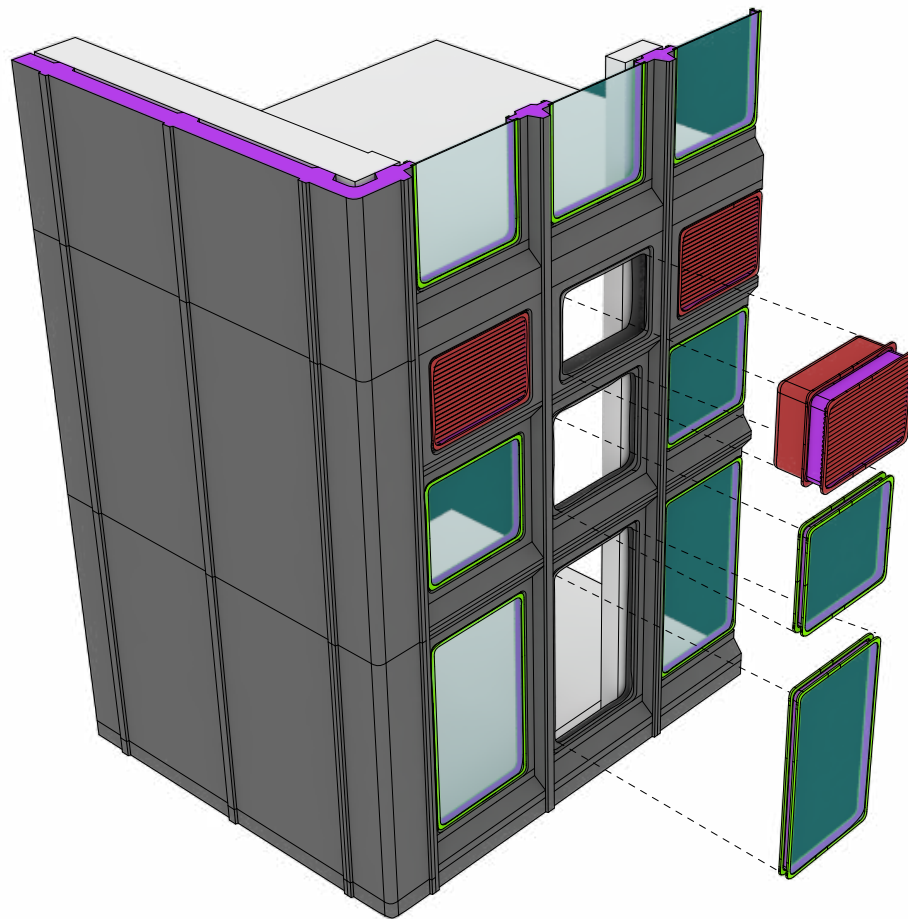
### Suitable for:

- Buildings with frequent functional changes.
- Buildings with a specially high energy demand that could benefit from constant technological updates.
- Clients with limited resources who could invest in the "infrastructure" layers, and then rely on third-party involvement for their functional add-on's.

### Design Keystone:

Fabrication techniques and universal inter-connectivity. Fast and cost-effective installation and deinstallation would be needed to reduce interruption of activities and make panel circulation effective in practice. Marketing and a large client-base would be essential to guarantee inventory circulation and optimum use of resources.





## Fixed infrastructure, interchangeable components

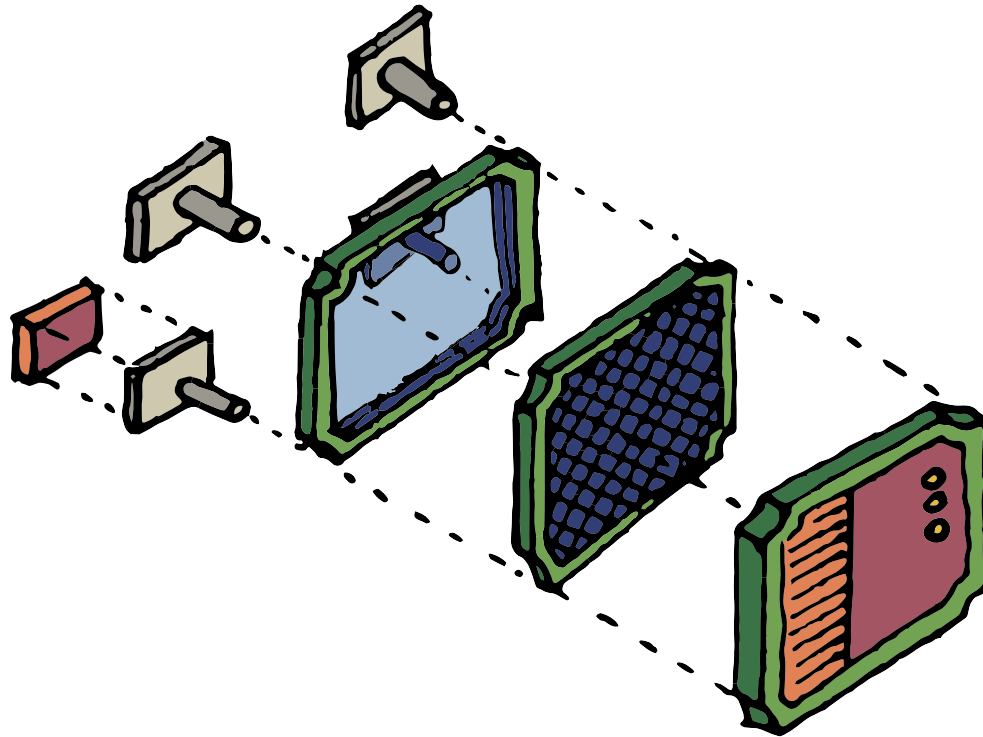
### Catalogue facades

The jewelry brand “Pandora” based its marketing strategy on the idea that, by selling small parts of a product in each transaction, customers were more likely to return to them to expand their purchase. Therefore, they sell a base product (a silver bracelet) which acts as a universal infrastructure, which can be “upgraded” by adding as many charms (components) as the client desires. Charms are selected from a catalogue, and personalization is based on the combination of these pieces.

A similar approach to facade design would require a large degree of standardization: The infrastructure (the long-lasting components of the facade such as those that provide structural stability and general insulation) would be installed for a long-term functionality (30 or 40 years), and would in turn be prepared to be connected to a series of functional panels. These panels would need to be perfectly standard (in order to facilitate circulation among clients), and their functions (whether single or layered) could differ widely, to be chosen by the building owner from a catalogue, and installed on to the building for as long as they are needed.

Such a system would allow constant reinvention of a building's functions and appearance (though within the restricted grid established by the standard components). The long-term durability of the functional panels, with low installation costs, would enable temporary interventions from the building owner or from third parties (such as marketing sponsors or energetic subsidies). Industrial-scale planning and manufacturing would reduce cost and increase control of materials, and disassembly and reuse could easily be integrated into the original design of the components. Components with a lower performance, which are no longer fit for demanding clients, could still be used to improve buildings with lower

## 4.c. Value-Engineered design scenarios - 3x(10) year Stratified (disposable)



**Related branding:** Planning for obsolescence



**iFacade**

### 4-Value Performance:

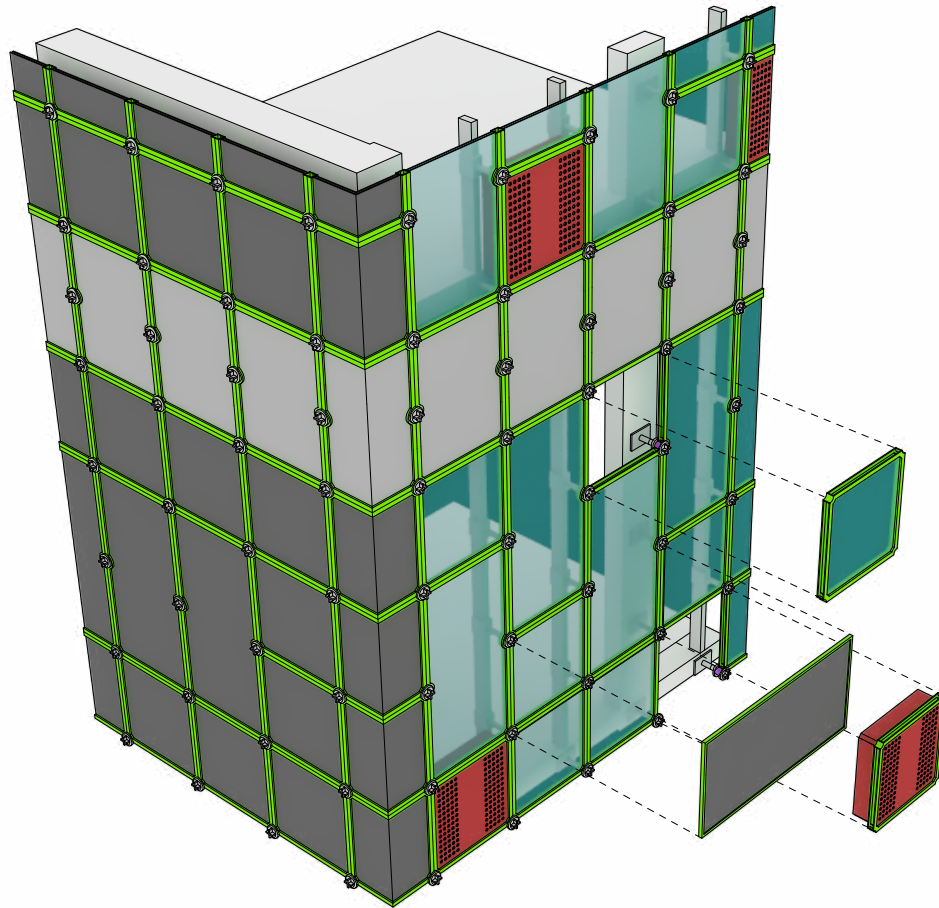
€	● ● ○	Investment according to necessity Planned obsolescence results in higher final costs
🍏	● ● ○	Technological integration optimized High reprocessing energy
⚙️	● ● ●	High flexibility, components always "new"
🍏	● ● ●	Constant redesign of top layers guarantee currency

### Suitable for:

- Buildings with a high demand in strategic and functional terms. Which are important for the public image of their institution or are subject to regular changes in use or function.
- Long-term owners who can commit to the permanent nature of the system, as the substructure layers would be designed to last for as long as technically possible.

### Design Keystone:

Material and production process selection have to be carefully planned to satisfy specific service-lives. The use of resources can become a mayor risk if embodied energy is not account for and material re-processing is not guaranteed. Allowing for a cost-effective circular economy is specially challenging in this scenario.



## Component-specific service-life, planned obsolescence

The effects of fashion and function

The average service-life of a smartphone in the US is 23 months, a laptop is expected to work at its full capacity for the first 2 years, be technically obsolete by 4 years, and economically unfixable after 6 years. These statistics are defined by user behavior, which is in turn being modified by built in obsolescence. Apple, as a producer of technological gadgets, has exploited this user trend by designing products that will perform and be fashionable during almost exactly the expected time, to be then rendered obsolete by all possible mechanisms at once. To use an example, iPhones, as a social status symbol, becomes psychologically obsolete the moment a new model comes out, as a technological equipment, it loses capacity to run ever-more-demanding applications, and in terms of software, official updates are designed to slow down its processor. The entire Apple brand is designed around the confidence that loyal customers will keep replacing their gadgets as new ones are released.

An Apple-modeled facade would follow the same principle. Each component would be designed and produced (value engineered) to fulfill its expected, and desirable, service-life. Structural layers, which everyone agrees should be quiet and in the background, would last for a long term (30 years), cosmetic layers (glazing and shading) would last for 15 years (to prevent a worn appearance), functional components such as solar panels would last for 10 years (to encourage their replacement with new emerging technologies), and monitoring systems would last for 5 years (to constantly design new, more attractive and user friendly interfaces). The result would be a highly flexible facade, with regular cosmetic and functional upgrades, and with a less dominating grid than the "Pandora" model. Special care would be needed in the use of materials and energy for producing components with an intentionally short service-life.

## 4.c. Value-Engineered design scenarios - Scenario evaluation

### Strategies according to intended / potential client

#### Studying the possibilities of a one-size-fits-all model

Applying a scientific grading methodology to the 6 system strategies proposed is almost impossible due to many factors: their conceptual level of development, the complexity of each scenario (which goes far beyond what has been studied so far), the different points of view from which they could be graded, and the abstract nature of some of these value criteria. The grading system is therefore a simple visual way of describing which strategies would seem to have a greater potential in one specific area, or which ones have a determining drawback which could eventually render them unpractical.

One thing that can be identified, however, is the general type of client for whom each of these strategies might be more attractive, or more applicable. Short term facades, quite predictably, could be suited for clients with short-term planning possibilities, or for those who need fast renovation cycles due to their strategic branding requirements. This follows the lines of some types of contracts which are currently being offered by commercial real estate owners, such as a "Fit-out" agreement. Under these contracts, the tenant has the freedom to fully design the architectural program and interior finishings of a building, which is rented out as an empty "shell". A short-term facade system would allow such contracts to provide additional freedom to

tenants, by allowing them to make changes not only to the interior of the building, but also to its exterior. Another potential for these facades is as life-extending systems. In buildings that are scheduled for demolition or projects that have been put on hold during the construction process, temporary facades could be a cost-effective solution to extend the service-life of the building for a few more years, until a more permanent solution becomes economically feasible.

Within the long-term facades we find very distinct users. Rolls Royce facades could be attractive to very solid institutions with long-term guaranteed plans (of which there are fewer in times of economic uncertainty), while Xbox facades would be attractive to long-term users with limited access to cash, or for buildings with historic value which are restricted in the types and scopes of their renovations.

3x10 years systems would be attractive for clients with long-term ownership but short term planning possibilities (an obvious case would be universities) who can get the most advantage out of the flexibility and adaptability of the system. This while being able to invest in a strong, fixed supporting layer that will reduce overall costs in the long run (compared to systems which require full replacement, such as the IKEA and DeMeeuw models)

*Opposite*

*Summary of the 6 strategic model, showing (some) potential clients, and an approximate performance in terms of each one of the 4 value criteria.*





Temporary life-extension or market-integration projects

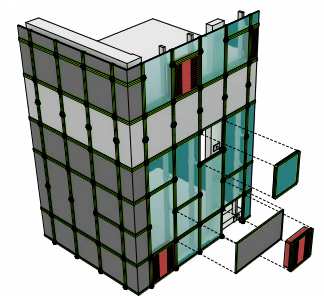
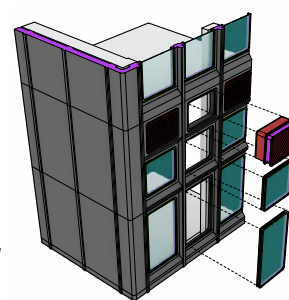
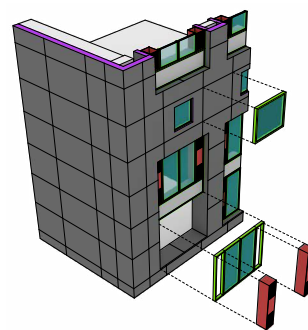
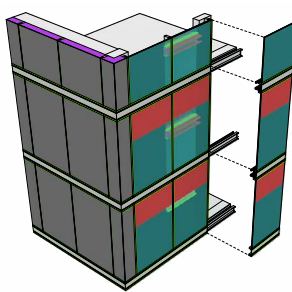
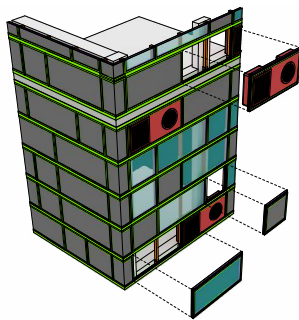
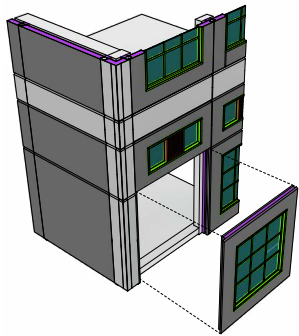
Short-term owners and "Fit-out" tenants

Stable organizations with long-term ownership and planning capacity

Limited resources or permission, unpredictable occupation

Long-term owners with changing needs (eg. Universities)

Long-term owners with demanding functional and branding needs



## 5.a. Evaluation

### Stakeholder interviews and analysis

#### What is preventing such models from being implemented?

As a way of evaluating the proposed strategic models, we arranged interviews with representatives of diverse stakeholders within the system. The goal of these interviews was to identify the main incentives a PSS model would offer (to the different parties that could eventually be involved in making the transition happen), as well as to explore the challenges and drawbacks that would have to be addressed if the project is to advance to a more realistic stage. Another key question was to identify the institution (whether existent or newly created) that could combine the right amount of capital backup, reliability, technical knowhow and financial expertise, to provide such a complex network of products and services.

A brief presentation and discussion was arranged with decision-makers from different corners of the supply / demand spectrum: Nico Kremers and Andre Mulder, co-directors of Kremers Tilburg, an aluminum and facade manufacturing company, represented the producers of curtain wall systems; Remco Nieuwenhuijs, expert in project management and cost estimation for BBN Adviseurs, represented the interests of contractors (specially those working towards DBFOM contracts); while Kelvin Berghorst and Rob Weststrate, from TU Delft's Facilities management and real estate office,

represented the interests of a potential client. Bert Lieverse and Martijn Veerman, of the facade industry organization VMRG were also consulted during the conceptual stages of the research, and helped give a better direction to the rest of this project.

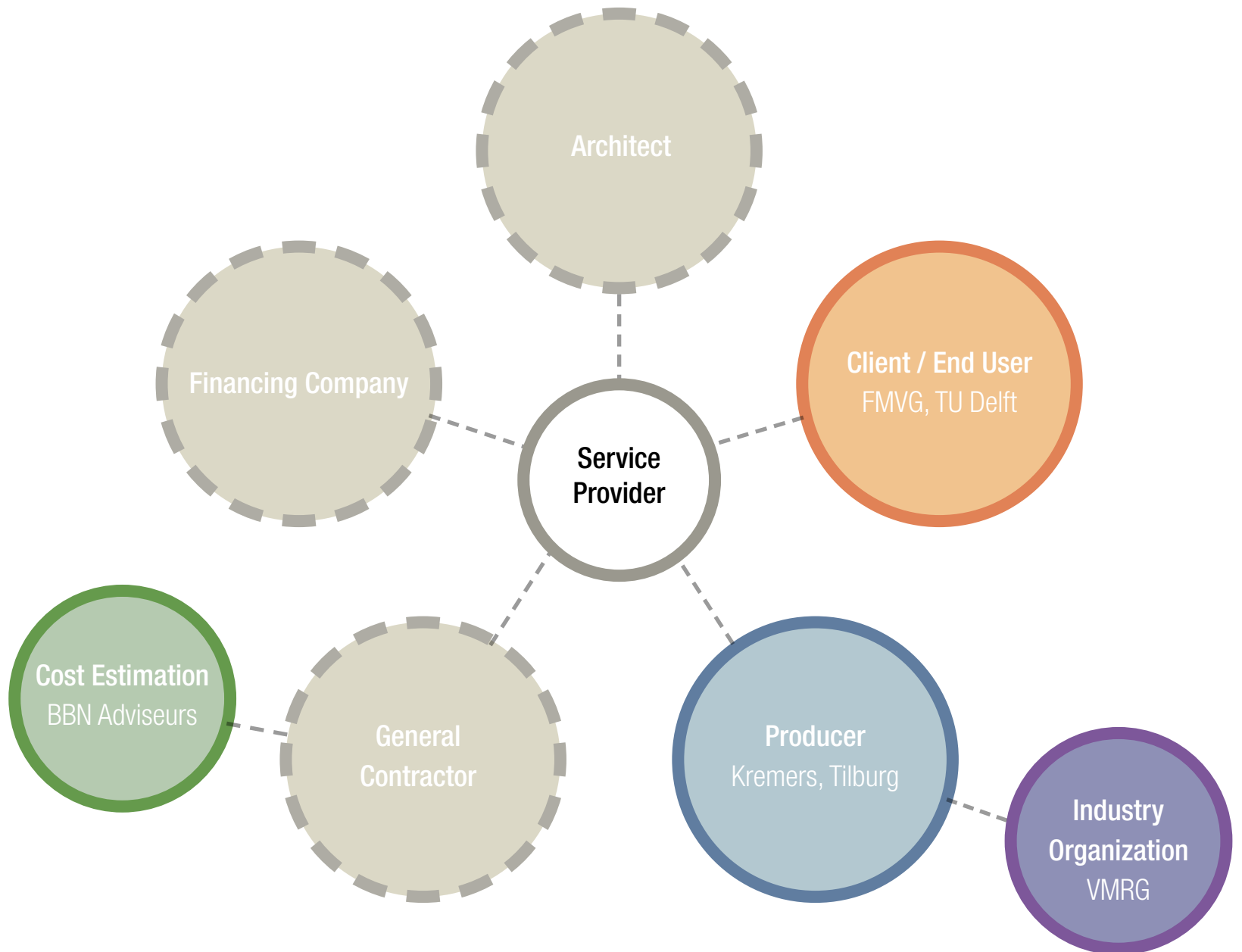
Throughout these interviews, suggestions came up for additional stakeholders that could be included in the discussion: Architects, general contractors (directly) and existing financing companies specialized on leasing technological assets. Unfortunately, due to time limitations, I have not been able to accomplish interviews with them. I will, however, try to include their point of view during the following evaluation, based on the comments of the people consulted, and my own general understanding of these trades and their interests.

This process was extremely interesting and informative, even more so when I learned that most of these stakeholder were already familiar with the concept of facade leasing. The great potential of this idea was very accurately summarized by Andre Mulder when he said all the stakeholder are sitting around a table, looking at each other, waiting for someone to make a move.

#### *Opposite*

*An ideal system will offer incentives throughout the supply and demand spectrum., even if these incentives will not always come in the same form, or at the same time. By contacting some of these interested parties early-on in the process, it is possible to slightly modify the course of the research to offer more attractive possibilities to all the decision-makers involved.*

*One of the main questions is illustrated by the central circle "Service Provider". It is important to define which of the stakeholders, if any, has the necessary infrastructure to deal with this kind of project.*



## 5.a. Evaluation

### System Advantages

What can the stakeholders (and society) win from this?

Some general benefits of a PSS model have been outlined throughout this report, in most cases based on examples from other industries where these ideas are already implemented, and in a few others based on projections and expectations.

Many of my predictions regarding the benefits of this system centered on added value for the client (in terms of broader building flexibility, performance and functionality) and positive results for society as a whole (promoting sustainable innovation and reducing the volume of unprocessed waste). These predictions were mostly confirmed during the interviews, when the “clients” mentioned that financial concerns, such as a higher investment cost, would not be determinant at the moment of making a decision. This can be explained by one main factor: Universities don't use their real estate as a primary business, but instead as a resource to facilitate their main activities. Since the cost of these other operations is much higher than the cost of real estate, any solution that can improve productivity, densify building use, and increase value, can potentially lead to much higher returns than the system's higher price tag. It could also be used as a marketing tool, specially due to its sustainability-promoting characteristics.

From the point of view of the supply industries the benefits are still present, but are slightly more

complicated to see, and in most cases require a complete shift in mentality and business structure which can be costly, risky and time-consuming.

One of the main benefits from the producer's perspective is the bundling of construction and maintenance services. This would provide greater stability to manufacturing companies, as they would guarantee a fixed flow of maintenance income through a permanent service contract with their clients. A facade system that is relatively cheap and easy to update would also add the benefit of quickly integrating the top 20% of performance, even if it is one generation behind. As Nico Kremers said, one of the main questions when choosing a facade is if you want to get the top 20% of performance, which will rise your investment to as much as twice the price. If components are replaced at shorter cycles, this type of decision will be made easier, and newer systems will have a faster market-integration.

From the point of view of contractors, broader standardization would reduce planning costs and construction risks. While architects could smartly use such a system to attract additional renovation and planning services, even if their design freedom is slightly compromised in the facade by limiting their decisions to a selection of components.

#### *Opposite*

*List of some of the main advantages to stakeholders according to their primary performance value. Icons represent each stakeholder as follows:*



*Client*



*Producer*



*Architect*



*Contractor*



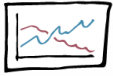
*Financing company*



*Cost estimation consultant*



More frequent upgrades to the top 20% performance



Long-term investment opportunities, unlike short-term technological leasing



Increased information continuity from project to project



Standard iconicity is cheaper than formal uniqueness



Simplify design, maintain certain degree of design choices



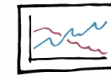
Wider stability/predictability for DBFOM contracts



Continuity of business-to-client relation over the service-life of the facade



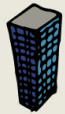
Economy of scale due to system standardization



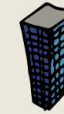
Entirely new business field



Lower risks and liabilities, increase reliability.



Broader portfolio flexibility



Longer service-life, improved performance, optimize use of space



Faster new-system integration

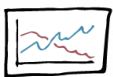
Potential for product-based marketing



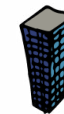
Anchor service for additional renovation projects



Service recognition and permanent partnership integration



Diversifies financing options to attract different clients



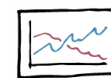
Building's efficiency remains the provider / contractor's responsibility



Material ownership promotes reusing-recycling



Familiarity with system would lead to reduced waste and higher efficiency



Reliable, long-term investments prove financially sustainable.



## 5.a. Evaluation

### System Challenges

#### Who can make it happen?

One of the main concern in this model has been to identify an organization (or in case it doesn't exist, define one) which can combine a series of requirements that would make this project feasible, such as:

1. Capital - The initial investment required, as well as the length of the investment, would require an important amount of starting capital, specially if we consider the next point.

2. Portfolio diversity - The system has greater chances of being successful if the provider can spread risks over a large number of buildings. This rules out most facade producers who work on a limited number of projects per year.

3. Solidity - When offered a 30, 40 or 50 year contract, clients require guarantees that the service provider will be in business over that time. A solid institution, or one with solid backing, would be more successful.

4. Financial expertise - Unlike a product-based business, a PSS provider derives most of its profit from financial activities. A poor financial planning and projection would ruin the possibilities of a PSS-based business model.

5. Technical expertise - The service provider would commit not only to build the facade, but to maintain and

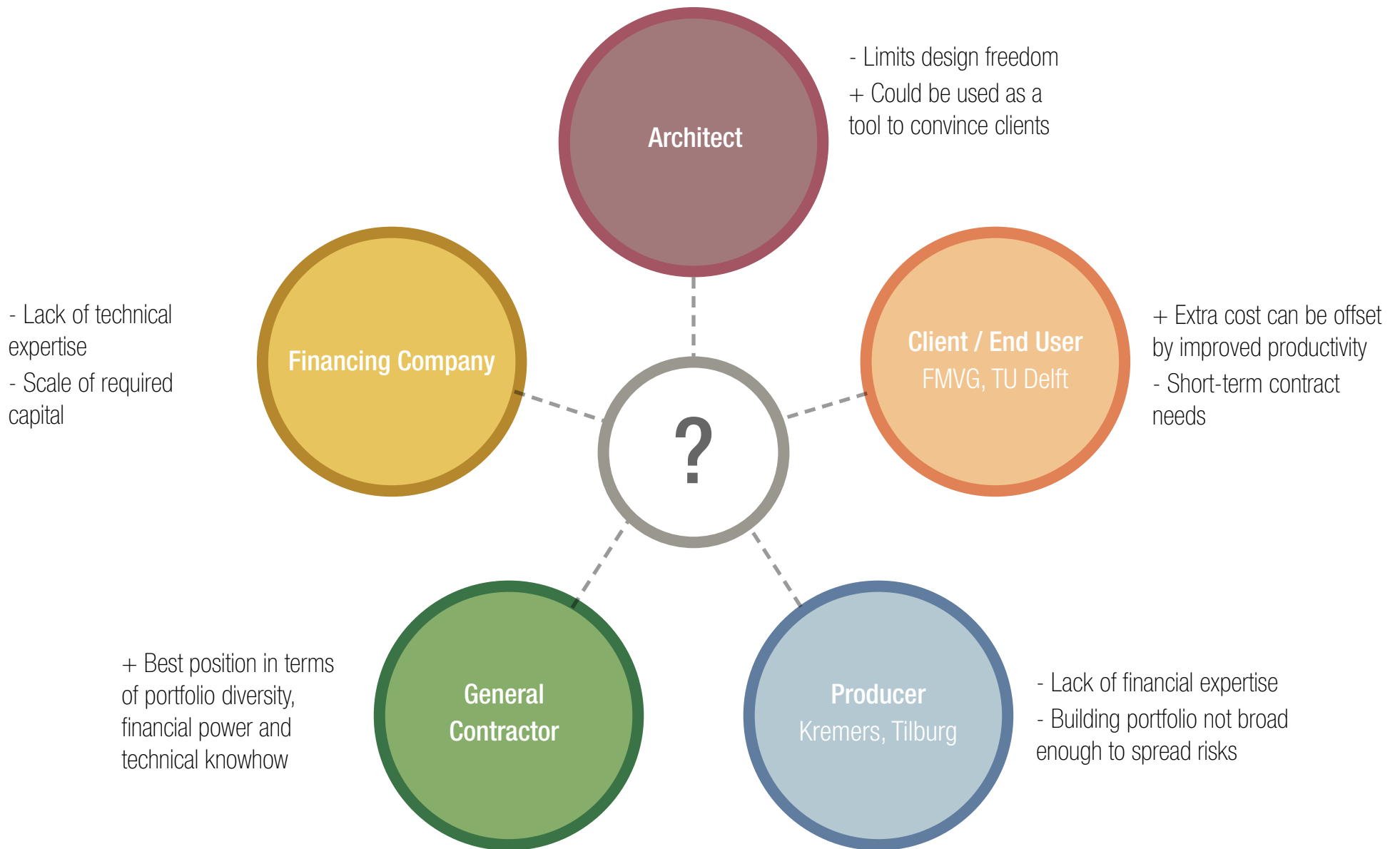
manage it over a long period of time (extending one or two generations). Technical expertise is therefore a requirement for the system to run effectively, and increase profit margin.

6. Courage - Maybe the most important factor. A PSS facade model would require a complete turnover in an industry which is famous for being traditional and slow-to-react (more about this on the next page). Unlike the product industry it is based on, which generally works with lower unit costs and short-term use, facades require a high investment and long operation time. The gains would therefore come at relatively high initial risk (at least until the system is perfected and allows for greater predictability).

Taking all these factors into account, practically all of the interviewees agreed that the company most suitable to start this kind of enterprise would be a large general contractor, (this explains why they seem to be the ones taking further steps in this direction). They combine the fields of experience, the client and portfolio diversity, and (one would hope) the solidity to navigate crises along the way. Worrying to some are the negative effects this could have on healthy competition, as massive service-providing contractors would form a type of oligopoly, to the disadvantage of both producers and clients.

#### *Opposite*

*Identifying a potential service-provider is a difficult task. Not only does he have to meet the requirements, he should also be in a "neutral" position, which does not motivate unhealthy business practices. A figure that becomes too central, such as a general contractor/service provider, could eventually ruin the benefits for other stakeholders by, for example, demanding unrealistic prices from system manufacturers in order to offer attractive (but unsustainable) prices to the client.*



## 5.a. Evaluation

### Transforming the industry

#### Can construction projects be treated as products?

One of the biggest challenges facing the construction industry (more so if we consider climate change deadlines) is the extraordinarily slow rate of widespread innovation and technological absorption. The image on the right illustrates this by comparing the amount of units a customer is likely to consume, of a given product, over a 40 year period. If we consider each one of these units is an opportunity for innovation, it is not surprising (and no one's fault) that construction is exceptionally slow at introducing new methods on a large scale. I specify "large scale" because we can surely find very innovative products and projects around us, but decades are generally needed for these new practices to be implemented widely (while iPhone's can change our mobile behaviour radically within the space of a few months).

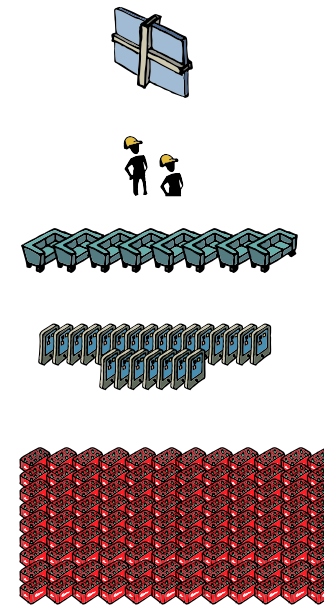
I have found two specially attractive aspects of a PSS facade model:

**1. It can shorten the rate of innovation -** Bringing the construction industry (first as facades, later as any other building component) closer to the language and practices of product design. By treating facade components as quickly interchangeable, flexible, user-defined, plug-and-play add-on's we shorten the unfortunately long market-life of a facade into a series of short-term decisions with correspondingly

lower investments. This would result in facades which can provide continuous opportunities to providers, manufacturers, clients, users, and all other parties involved. This as opposed to current systems which are designed to stay in place in their original form, with the minimum intervention, over one or two generations of professionals.

**2. It puts an end to the disadvantages of a product-based system -** From a fundamental point of view, a product-based system is supported on the concept of punishment. For example, warranties and liabilities impose a penalty of manufacturers if their system does not provide the desired outcome (forcing them in many cases to absorb the risk of improper use). A product-service system is, on the other hand, based on incentives. By binding clients, providers and suppliers into a long-term commitment, each party uses its particular knowledge to ensure their components are delivering the best possible results, constantly. Risks are then transferred from a legal system which might be out of proportion (for example having to pay millions in lawyers to dispute a faulty ventilation system which might cost a few thousand to replace), to a techno-centered system in which things that don't work are simply fixed by the component's owner.

Generations within 40 years:  
(servings per client)



<i>Typical facade:</i>	1
<i>Architects:</i>	1.5
<i>IKEA Sofas:</i>	8
<i>SmartPhones:</i>	24
<i>CocaCola's:</i>	29,200

#### Top

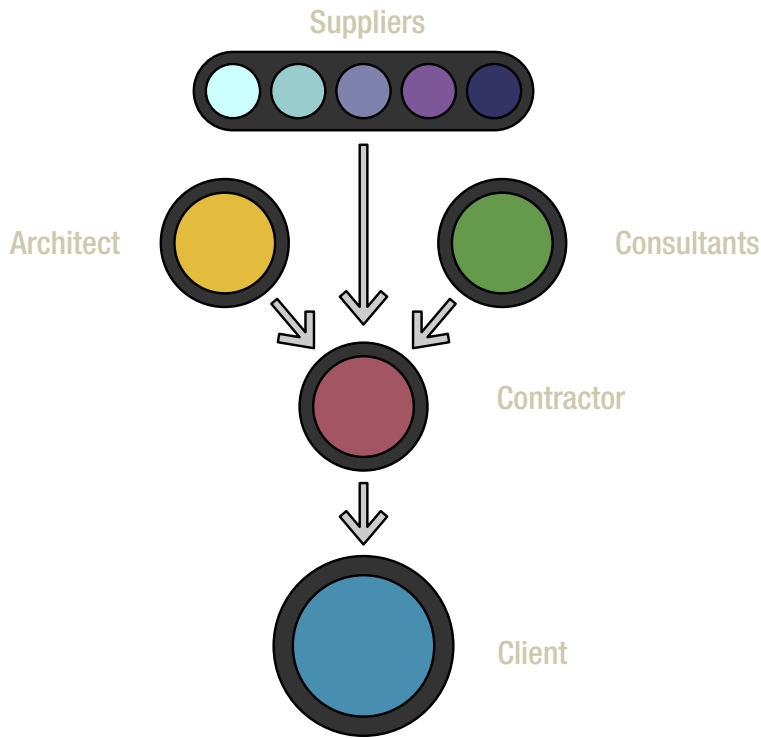
*Rate of innovation in the facade industry: The exceptionally long service-life of construction components make continuity and wide-spread application of new technologies much more difficult than in other industries.*

#### Opposite

*Shift from a system based on "punishment" to one based on "incentive". Instead of a faulty system leading to a legal process or a replacement fee, a better system will lead to broader profit margins for the unit provider.*



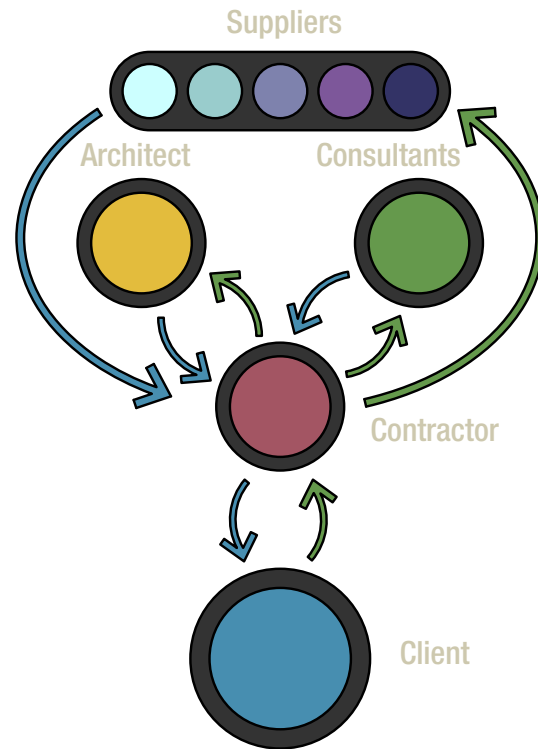
Legal system



**Product-based**  
Warranties and liabilities

Poor communication and continuity

Technical system



**Service delivery-based**  
Performance

Constant communication.  
Continuity of materials and knowledge.

## 5.b. Future research

### Technical and design definition

#### Detailing a system prototype

An interesting discussion, during the interviews, revolved around the 6 brand-inspired system models. This was very useful for understanding which of these strategies resulted more attractive to each stakeholder, as well as how realistic they could eventually be from different points of view.

While all strategies received some degree of attention, the most attractive ones turned out to be also the most extreme. The “DeMeeuw facade” stood out due to it being highly realistic (as DeMeeuw’s current business model of integrated construction units is quite similar, technically, to the proposed facade model). Aside of this, the apple-inspired “iFacade” and the “IKEA Facade” caused a lot of interest because they integrate the idea of a solid, permanent support structure, which at the same time offers some degree of formal flexibility and interchangeable “add-on” components. This would result in part of the facade being not too far away from current practices in terms of durability and construction, with the additional value of having external components which provide constantly transformable applications to the building.

The first step, to continue this research, would be to combine all the different design parameters that have been identified throughout this report, into a single, technically-developed design proposal. Such a proposal would take into account the expected performance

and service life of the different components that make up a facade, determining which layers should be permanent, or at least long-term. And which should be exchangeable within shorter cycles to enhance technological innovation, provide user-flexibility or add value to the strategic presence of the building.

As an initial idea, this model would combine diverse aspects of the 6 strategies proposed before, such as:

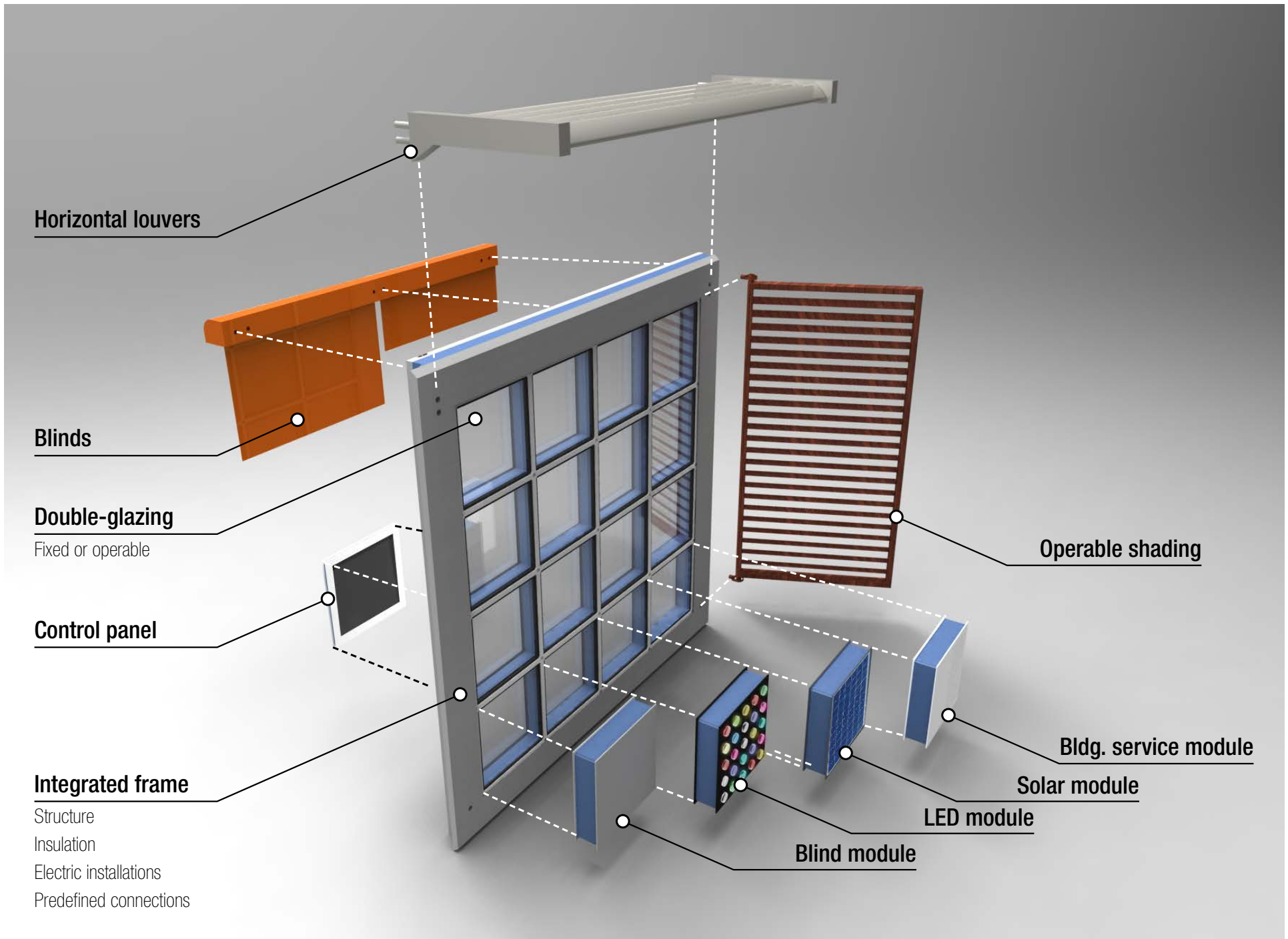
DeMeeuw’s integrated construction - A large panel that integrates structural and mechanical needs would be effective from the point of view of construction, installation and transportation. Reducing the number of primary connections, and allowing entire sections of the facade to be removed simultaneously.

IKEA’s modular system - A fixed grid with interchangeable modular components, within a thinner frame of the DeMeeuw supporting structure, would increase designer/user flexibility with a simpler installation and replacement process.

Apple’s planned obsolescence - Would be a great way of guaranteeing the constant circulation of panels, and an economically healthy system in which cheaper panels are reprocessed more often, while more expensive panels are expected to last longer. The rate of innovation, which is a main driver of my research, depends on this aspect.

#### *Opposite*

*Exploded view of an initial prototype. The main design parameters have been taken into account to separate the main service layers. Some of these layers should be fixed over a longer period of time (though they should still be disassemblable to allow short-term, non-binding contracts), while other layers such as ICT monitoring tools, integrated buildings services and automated controls should be replaceable as new, more effective technologies become available.*



## 5.b. Future research

### TU Delft - The first fully transformable campus

#### A micro-scenario and case-study

Ron Weststrate of FMVG (TU Delft's Facilities management and real estate organization), proposed a very promising strategy for introducing such a model, with lower risks and challenges than a market-wide introduction: Instead of looking at universities as potential clients, they could be seen as a closed environment in which they can play the role of financing company, service provider, client and end-user simultaneously. This would be possible thanks to the specific characteristics of university real estate:

- A broad building portfolio that allows them to spread risk of individual buildings throughout their properties.

- A relative homogeneity in the general typology of buildings in their portfolio, as well as a clear overall building age (as construction booms within a campus tend to produce a large proportion of buildings that will require mayor maintenance within a similar time period).

- A solid financial backing that provides greater stability than other types of clients (who might be more reluctant to get into such long-term agreements).

- Unique needs as an end user. A very low use-density leads to relatively high operation costs in their

real estate. This means any solution that increases functional flexibility and densifies use can easily offset its higher investment cost by increasing productivity.

- Value given to strategic image. As a leading technological institution, TU Delft needs buildings that reflect the state-of-the-art in sustainable practices and cross-campus innovation. Facilities that can evolve and adapt to changing trends in student enrollment are a very visible, marketable icon.

The TU Delft campus could be a realistic and effective way of testing the principles behind this research. An important amount of data is already available on the cost and performance of its buildings (making energetic and financial performance calculation easier and more accurate). A closed loop could be generated between the different departments that work within the campus, to design a service that could satisfy all stakeholders to the further extent possible.

The strategic value of a campus that can adapt and evolve continuously is, in my opinion, extremely attractive. In an age in which institutions are competing for the most iconic, recognizable buildings, it could be a unique marketing asset to have the world's first fully transformable campus.

#### *Opposite*

*Conceptual view of TU Delft as the world's first fully transformable campus. A place in which buildings are not forced to contain activities that sometimes conflict with the spaces and installations, but instead evolve to house the specific needs of educational, administrative or even housing programs.*



## I 5.c. Conclusions

### General Conclusion

#### Producing and commercializing more resource-efficient facades

The practice of drawing references and comparisons with other industries has become quite common in the field of architecture and construction. While other disciplines are often used as inspiration in terms of formal exploration, or as technical analogies for the fabrication of new components, it is hard to find examples of architects looking at other industries to learn how to market their products. The most simple way of explaining this would probably follow the argumentation lines: “You can’t sell a building like it was a cell-phone, or a TV, or a car”. The main intention of this project has been to show that, actually, you could.

Leasing and other mechanisms for combining products and services have been used for decades, by other industries, to promote client loyalty, eliminate second-hand markets and increase the rate of replacement (securing their production flow). They have proven to have the additional and extraordinarily positive (though not necessarily intentional) effect of enabling a more effective use of resources. They do so by conserving material ownership in the hands of the manufacturer (and therefore financial interest in these materials), and by binding all stakeholders in the market spectrum (suppliers, manufacturers, providers and clients) into a shared, long-term commitment in which performance is in the best interest of all parties

(though their perspective of value and performance might center on diverse aspects of the product and/or service).

The magnitude of architectural projects (which can easily cost hundreds of millions of euros and span over decades of economic life) make the implementation of new construction, financing or marketing strategies especially slow for our industry. It might take an entire generation to find out if a project typology or building technology has actually turned out to be effective. However, we can generally assume that a system that has been proven over and over again in more manageable, short-cycled industries can at least lend some of its principles to our own.

By analyzing the different categories of performance-oriented values, and identifying their relevance to the different stakeholders at different points along a project’s life, I was able to draw certain similarities between product-design and -service practices, and the complex variables of building construction. It seems like a positive start to further research work to understand how the financial structure of such a system would work if applied to a building’s facade. I have also established the basic design parameters that would have to be taken into account, and come up with a series of schematic design strategies that might

fit within the broader requirements of the system, and which would provide different benefits and potentials to the diverse parties involved.

Before the end of this project, I plan to further evaluate these strategies, and try to come up with an objective method to determine their feasibility in real terms. This is a complex matter, as possibilities are limited by many factors: the financial and industrial capacity of the service provider (in case he is also the manufacturer), the specific regulations within his jurisdiction, the interest and type of client he can expect to deal with, among others. There are, as well, external factors that might affect the decision-making process, and which can hardly be predicted by any of the stakeholders. DBFOM (Design Build Finance Operate and Maintain) contracts are increasingly popular among public-private projects in great part because governments have a. the financial stability to guarantee them, and b. the capacity to determine values such as interest and inflation rates, so that they don't have a mayor impact in the project further down the line.

In a private enterprise, collaboration between different parties would be a complex matter: determining which values will be used to calculate financial health and secure everyone's stake will be difficult, clients and managers will want guarantees that back the service-

providers claim of uninterrupted service in case he might fall into financial difficulties, and so on.

I believe I have shown key evidence, throughout this report, that Product-Service Systems applied to facades could improve not only the way in which we design, produce, operate and dispose of essential building elements, it could also improve the difficult communication process that occurs in most business-to-client relations during construction projects.

Estimating the efficiency of an investment over the next 30, 40 or 50 years is almost similar to trying to predict the future, not only is the space for error big, it also amplifies with time and can lead to disastrous consequences. By bringing all parties into the table, at the right moment, and ensuring that these same players will be forced to collaborate during the entire life of the project, we can increase the chances of successful initiatives, reduce the margin of error and unnecessary risks, and shift our methods of production so that they are more inclusive, transparent and respectful of the environment.

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## 01. Strategic plan and general statistics for the 14 dutch universities analyzed

University	PERFORMANCE VALUES				Maslow pyramid			Historical Group		
	Strategic	Functional	Sustainable	Financial	Plain	Meeting	Iconic	< 1940	1950 - 80	1980 - Now
EUR	Park campus	Flexible workspace	Reduce footprint	Intensify use (implied)	-30%	20%	10%		37%	63%
LEI	Univer-city	Flexible workspace	Reduce footprint	Intensify use	-12%	11%	1%	6%	46%	47%
OU (online)			CO2 Neutral		-68%	68%				100%
RU		More users	Maintain park		-15%	15%		1%	49%	50%
RUG	Preserve history	Expand / renovate			-32%	14%	18%	13%	46%	41%
TUD	Univer-city	Diversify uses		Industrial park	-10%	10%		3%	80%	18%
TUE		Diversify uses	Reduce footprint	Industrial connection	-5%	25%	10%	0%	72%	28%
UM		Flexible workspace	Reduce footprint	Intensify use (implied)				16%	14%	69%
UT	Renovate image	Intensify use	Reduce footprint	Intensify use (implied)	-15%	10%	5%		81%	19%
UU	Expand historical portfolio	Flexible workspace	Reduce footprint	Intensify use (implied)	-32%	32%		18%	39%	43%
UvA	Renovate historical image	Cluster for service sharing			-10%	15%	-5%	4%	64%	32%
UvT		Flexibility and diversity	Maintain small footprint	Intensify use (implied)		19%	-19%		53%	47%
VU	Replace buildings	Expansion and diversity	Flexible uses / small footprint	Intensify use (implied)	-40%	40%			91%	9%
WU	Park campus	Share uses / reduce footprint	Share uses / reduce footprint	Intensify use (implied)	-20%	10%	10%	4%	62%	34%
Most mentioned	Park campus / Univer-city	Expand / diversify uses	Reduce footprint	Intensify use / Reduce costs	<b>-289%</b>	<b>289%</b>	30%	5%	<b>52%</b>	43%
	Historical value	Create more flexible workspaces	Renovate buildings (implied)	Connection to city and industry						

Condition						Financial					Functional			
Excellent	Good	Reasonable	Moderate	Bad	Very Bad	Total Income	Total Expenditure	Cost Ownership	% Profit	% Real Estate Expenditure	UFA / GFA	Office m2 UFA Staff	Office m2 UFA Fte	Education m2 UFA Student
34%	54%	9%	3%			€ 461,000,000.00	€ 439,000,000.00	€ 18,000,000.00	5%	4%	60%	19.3	22.5	1.4
6%	27%	25%	29%	14%		€ 405,000,000.00	€ 416,000,000.00	€ 44,000,000.00	-3%	11%	53%	16	19.3	2.1
12%	21%	14%	53%			€ 62,000,000.00	€ 59,000,000.00	€ 5,000,000.00	5%	8%	64%	16.4	20.1	0
39%	35%	15%	11%			€ 473,000,000.00	€ 466,000,000.00	€ 34,000,000.00	1%	7%	60%	12.7	15.2	1.5
16%	57%	26%	1%			€ 515,000,000.00	€ 486,000,000.00	€ 20,000,000.00	6%	4%	62%	20.5	24.2	1.8
11%	39%	3%	37%	9%		€ 488,000,000.00	€ 473,000,000.00	€ 66,000,000.00	3%	14%	64%	20	22.6	4.1
10%	10%	10%	10%	20%	40%	€ 265,000,000.00	€ 258,000,000.00	€ 28,000,000.00	3%	11%	67%	28.7	31.6	5.1
18%	39%	40%	3%			€ 312,000,000.00	€ 300,000,000.00	€ 20,000,000.00	4%	7%	54%	12.6	15	2.3
4%	51%	9%	36%	1%		€ 268,000,000.00	€ 251,000,000.00	€ 27,000,000.00	6%	11%	62%	17.5	19.8	2.3
1%	28%	25%	15%	25%	6%	€ 695,000,000.00	€ 708,000,000.00	€ 77,000,000.00	-2%	11%	57%	18.1	22.1	1.9
5%	5%	20%	20%	20%		€ 568,000,000.00	€ 545,000,000.00		4%	0%	62%	19.2	23.2	1.6
12%	41%	31%	13%	4%		€ 150,000,000.00	€ 142,000,000.00	€ 12,000,000.00	5%	8%	60%	18.4	23	1.4
8%	3%	73%	14%	1%	1%	€ 421,000,000.00	€ 408,000,000.00	€ 28,000,000.00	3%	7%	54%	15.7	19.2	1.7
4%	51%	9%	36%	1%		€ 224,000,000.00	€ 218,000,000.00	€ 29,000,000.00	3%	13%	63%	13	14.9	5
<b>13%</b>	<b>33%</b>	<b>22%</b>	<b>20%</b>	<b>7%</b>	<b>3%</b>	<b>€ 379,071,428.57</b>	<b>€ 369,214,285.71</b>	<b>€ 29,142,857.14</b>	<b>3%</b>	<b>8%</b>	<b>60%</b>	<b>17.7</b>	<b>20.9</b>	<b>2.3</b>
												43%	51%	6%

# Façade Value | Appendix A - University campus research

## 02. Statistic data, approximate expenses and extrapolated financial and constructive parameters of the 38 university projects studied.

General Information						Strategic Value	Functional Value						Financial Value					GFA	UFA			
Code	Project	Campus	Project Type	Year	Location	Maslow's Pyramid	M2 ufa / student	M2 ufa / staff	Students	Staff	FTE	Student:staff ratio	Maintenance	Energy	Cleaning	Construction	Investment					
UU-5	Drift 10	Inner city	Acquisition + Renovation	2008	Utrecht	Plain & Efficient		7.6		93	80		€	€	€	€	€					
RUG-3	Storage Library	Zernike	Expansion	2006	Groningen	Meeting Place							€	12,000	€	10,000	€	1,700,000	€	2,100,000		
RUG-6	GMW Education	Inner city	Expansion	2008	Groningen	Meeting Place	3.4		350	0	0		€	17,000	€	13,000	€	15,000	€	2,900,000	€	3,900,000
VU-2	W&N Faculty	VU Campus	Expansion	2008	Amsterdam	Meeting Place		11.5		52	51		€		€	22,000	€	3,400,000	€	3,800,000		
Averages													€	14,500	€	21,500	€	14,750	€	2,666,667	€	2,875,000
EUR-2	T Building	Woudestein	New	2005	Rotterdam	Meeting Place	0.5	18.6	6888	793	665	4.72	€	368,000	€	537,000	€	404,000	€	52,800,000	€	72,500,000
EUR-3	L Building	Woudestein	New	1990	Rotterdam	Meeting Place	0.3	15.15	5679	537	352	6.39	€	199,000	€	193,000	€	182,000	€	22,100,000	€	36,200,000
UM-1	UNS 60 Building	Randwyck	New	2004	Maastricht	Meeting Place	1.8	14.8	968	200	155	2.73	€	81,000	€	110,000	€	158,000	€	8,600,000	€	15,100,000
LEI-1	Van Oort Building	Leeuwenhoek	New	1998	Leiden	Representative							€	90,000	€	125,000	€	85,000	€		€	16,200,000
RU-1	Gymnasium	Heyendaal	New	2003	Nijmegen	Meeting Place	0.3	0.9	12000	2890		4.15	€	209,000	€	265,000	€	621,000	€	40,200,000	€	58,700,000
RU-2	Huygens	Heyendaal	New	2006	Nijmegen	Meeting Place	2.3	13.6	1491		812	1.84	€	1,250,000	€		€	85,100,000	€		€	132,700,000
RUG-1	Zernikeborg	Zernike	New	2003	Groningen	Representative	2	15.8	170	86		1.98	€	112,000	€	110,000	€	66,000	€	10,100,000	€	11,500,000
RUG-4	Bernoulliborg	Zernike	New	2007	Groningen	Representative	2.9	17.5	537	248	176	1.27	€	172,000	€	166,000	€	129,000	€	19,200,000	€	26,500,000
UU-1	NITG Building	De Uithof	New	2002	Utrecht	Representative	4.4	12.4	340	357		0.95	€	75,000	€	118,000	€	170,000	€	28,300,000	€	44,900,000
UU-2	Hijmans van der Bergh	De Uithof	New	2005	Utrecht	Representative	0.8	15.8	6802	162		41.99	€		€		€	26,400,000	€		€	38,500,000
UU-3	Jeanette Donker-Voet	De Uithof	New	2006	Utrecht	Plain & Efficient		6.4		155			€	147,000	€		€	86,000	€	25,500,000	€	26,200,000
UVT-1	Tias Building	Tilburg	New	2002	Tilburg	Representative	4.7	12.4	444	263		1.69	€	111,000	€	79,000	€	108,000	€	16,400,000	€	22,600,000
UvA-1	REC E Faculty	Roeterseiland	New	1999	Amsterdam	Meeting Place	0.4	15.6	2583	353	305	3.93	€	279,000	€	167,000	€	128,000	€	21,700,000	€	31,200,000
VU-1	OZW Building	VU Campus	New	2006	Amsterdam	Representative	1.8	11	3669	294	207	7.32	€	797,000	€	400,000	€	375,000	€		€	39,900,000
TUD-2	L&R Extension	TU Campus	New	2002	Delft	Plain & Efficient	2.4	15.5	12	144		0.08	€	146,000	€	107,000	€		€	8,800,000	€	12,800,000
UT-3	Meander	Drienerlo	New	2007	Twente	Representative		11.6	61	237		0.26	€		€		€	13,200,000	€		€	18,800,000
TUE-1	Helix	TU/e	New	1998	Eindhoven	Plain & Efficient	3.9	15.4	700	350		2.00	€	316,000	€	1,079,000	€	344,000	€	43,600,000	€	62,500,000
TUE-3	Spectrum	TU/e	New	2002	Eindhoven	Representative		11.5		25	24		€	165,000	€	365,000	€	45,000	€	22,200,000	€	31,500,000
WU-1	Main Building Lisse	Lisse Terrein	New	2003	Lisse	Meeting Place		14.5			65		€	59,000	€	27,000	€	24,000	€	4,100,000	€	4,700,000
WU-2	Rikilt Building	Wageningen	New	2009	Wageningen	Meeting Place		8.8		154	154		€		€		€	6,300,000	€		€	8,800,000
WU-3	Forum Building	Wageningen	New	2007	Wageningen	Representative	2.7	28.7	3000	130	130	11.54	€	600,000	€	521,000	€	230,000	€	54,000,000	€	75,900,000
TUD-1	TBM Faculty	TU Campus	New (2 phases)	2000	Delft	Meeting Place	1.7	15.1	962	352	270	1.55	€	273,000	€	124,000	€	133,000	€	22,400,000	€	26,000,000
LEI-2	Kamerlingh Onnes	Inner city	New + Renovation	2004	Leiden	Representative	0.5	13.6	4286	411	292	6.10	€	225,000	€	384,000	€	295,000	€		€	53,900,000
UvA-2	FNWI Faculty	Science Park	New + Renovation	2010	Amsterdam	Meeting Place	3	10.2	2170	1500	1160	0.82	€	2,474,000	€	1,161,000	€	1,036,000	€	120,200,000	€	186,300,000
Averages													€	388,000	€	317,789	€	243,105	€	31,009,524	€	43,912,500
UM-2	Bonnefanestraat 2	Inner city	Renovation	2005	Maastricht	Plain & Efficient	0	10.5	0	160	110	0.00	€	73,000	€	67,000	€	68,000	€	4,900,000	€	7,400,000
UM-3	Zwingelput 4	Inner city	Renovation	2006	Maastricht	Meeting Place	5.7	12	300	30	24	5.56	€	72,000	€	43,000	€	60,000	€	4,300,000	€	6,600,000
UU-4	Kruyt Building	De Uithof	Renovation	2009	Utrecht	Plain & Efficient	5.6	14.4	350	450		0.78	€	1,903,000	€		€	410,000	€		€	19,300,000
TUD-3	Mijnbouwstraat 120	TU Campus	Renovation	2009	Delft	Representative							€	55,000	€		€		€	7,600,000	€	8,000,000
UT-1	Noordhorst + Oosthorst	Drienerlo	Renovation	2004	Twente	Plain & Efficient	3	10.7	1200	40		30.00	€		€		€		€		€	14,800,000
UT-2	Westhorst	Drienerlo	Renovation	2005	Twente	Plain & Efficient	8.5	8.9	4800	3020		1.59	€		€		€		€		€	11,500,000
TUE-2	Vertigo, Faculty BK	TU/e	Renovation	2002	Eindhoven	Representative	2.2	13.5	1957	336	222	3.51	€	391,000	€	308,000	€	344,000	€	28,100,000	€	38,000,000
TUE-4	Black Box	TU/e	Renovation	2006	Eindhoven	Representative		0.3		500			€	153,000	€	339,000	€	42,000	€	2,300,000	€	2,800,000
RUG-5	FEB Offices	Zernike	Renovation (rethink)	2007	Groningen	Meeting Place		12.1		548			€	246,000	€	231,000	€	132,000	€	11,000,000	€	14,500,000
RUG-2	Education Building	Inner city	Transformation	2005	Groningen	Plain & Efficient							€	25,000	€	13,000	€	17,000	€	1,100,000	€	1,300,000
Averages									861	508	36		€	291,800	€	100,100	€	107,300	€	5,930,000	€	12,420,000
Overall Averages									1624	391	138		€	357,903.23	€	262,296.30	€	191,700.00	€	23,177,419.35	€	31,305,263.16

Physical Value				Users				Investment					Façade investment potential													
GFA	UFA	UFA:GFA	Floors	Users	M2 UFA per User	Const \$ per User	Inv \$ per User	Const:Inv Ratio	Cost per m2 (GFA)	Financing costs (per year) 2% long-term interest rate	Operation costs (per year)	OpCosts:Inv	Façade area (40% of gfa)	Façade construction (20% of overall)	Façade cost per m2	Available façade financing (30% of financing costs (20% for façades + 10% for installations) + 30% of operating costs)	Financing per m2 of façade (per year)	Façade PSS financing per year								
1300	800	62%	5	173	5	€	9,827		€	1,400	€	34,000	€	42,000	2%	600	€	340,000	€	22,800	€	40	€	24,000		
3160	2600	82%	3					81%	€	700	€	42,000	€	22,000	1%	1300	€	420,000	€	400	€	19,200	€	15	€	19,500
1560	1210	78%	2	350	3	€	8,286	74%	€	2,500	€	78,000	€	45,000	1%	700	€	780,000	€	1,200	€	36,900	€	55	€	38,500
1620	700	43%	3	103	7	€	33,010	89%	€	2,400	€	76,000	€	22,000	1%	700	€	760,000	€	1,100	€	29,400	€	45	€	31,500
1910	1328	66%	3	157		€	20,648	82%	€	1,750	€	57,500	€	32,750	1%	825	€	575,000	€	900	€	27,100	€	39	€	28,375
46100	22200	48%	19	8346	3	€	6,326	73%	€	1,600	€	1,450,000	€	1,309,000	2%	18500	€	14,500,000	€	800	€	827,700	€	45	€	832,500
16600	13100	79%	8	6568	2	€	3,365	61%	€	2,200	€	724,000	€	574,000	2%	6700	€	7,240,000	€	1,100	€	389,400	€	60	€	402,000
10700	5250	49%	7	1323	4	€	6,500	57%	€	1,500	€	302,000	€	349,000	2%	4300	€	3,020,000	€	800	€	195,300	€	50	€	215,000
6930	4190	60%	6						€	2,400	€	324,000	€	300,000	2%	2800	€	3,240,000	€	1,200	€	187,200	€	70	€	196,000
36000	21800	61%	6	14890	1	€	2,700	68%	€	1,700	€	1,174,000	€	1,095,000	2%	14400	€	11,740,000	€	900	€	680,700	€	50	€	720,000
50100	26900	54%		2303	12	€	36,952	64%	€	2,700	€	2,654,000	€	1,250,000	1%	20100	€	26,540,000	€	1,400	€	1,171,200	€	60	€	1,206,000
5220	2910	56%	6	256	11	€	39,453	88%	€	2,300	€	230,000	€	288,000	3%	2100	€	2,300,000	€	1,100	€	155,400	€	75	€	157,500
12000	7350	61%	8	961	8	€	19,979	72%	€	2,300	€	530,000	€	467,000	2%	4800	€	5,300,000	€	1,200	€	299,100	€	65	€	312,000
16900	10600	63%	3	697	15	€	40,603	63%	€	2,700	€	898,000	€	363,000	1%	6800	€	8,980,000	€	1,400	€	378,300	€	60	€	408,000
14300	9500	66%	5	6964	1	€	3,791	69%	€	2,700	€	770,000	€			5800	€	7,700,000	€	1,400	€	231,000	€	40	€	232,000
6310	4070	65%	4	155	26	€	164,516	97%	€	4,200	€	524,000	€	233,000	1%	2600	€	5,240,000	€	2,100	€	227,100	€	90	€	234,000
11100	6130	55%	8	707	9	€	23,197	73%	€	2,100	€	452,000	€	298,000	1%	4500	€	4,520,000	€	1,100	€	225,000	€	50	€	225,000
13200	6730	51%	13	3241	2	€	6,695	70%	€	2,400	€	624,000	€	574,000	2%	5300	€	6,240,000	€	1,200	€	359,400	€	70	€	371,000
20100	12500	62%	13	4170	3	€			€	2,000	€	798,000	€	1,572,000	4%	8100	€	7,980,000	€	1,000	€	711,000	€	90	€	729,000
5320	3520	66%	4	156	23	€	56,410	69%	€	2,500	€	256,000	€	253,000	2%	2200	€	2,560,000	€	1,200	€	152,700	€	70	€	154,000
10200	6280	62%	3	298	21	€	44,295	70%	€	1,900	€	376,000	€			4100	€	3,760,000	€	1,000	€	112,800	€	30	€	123,000
29900	17100	57%	6	1050	16	€	41,524	70%	€	2,100	€	1,250,000	€	1,739,000	3%	12000	€	12,500,000	€	1,100	€	896,700	€	75	€	900,000
7760	4430	57%	4	49	90	€	453,061	70%	€	4,100	€	630,000	€	575,000	2%	3200	€	6,300,000	€	2,000	€	361,500	€	115	€	368,000
2680	1920	72%	2	65	30	€	63,077	87%	€	1,800	€	94,000	€	110,000	2%	1100	€	940,000	€	900	€	61,200	€	60	€	66,000
5650	3520	62%	4	308	11	€	20,455	72%	€	1,600	€	176,000	€			2300	€	1,760,000	€	800	€	52,800	€	25	€	57,500
35300	20900	59%	8	3260	6	€	16,564	71%	€	2,200	€	1,518,000	€	1,351,000	2%	14200	€	15,180,000	€	1,100	€	860,700	€	65	€	923,000
13300	8580	65%	6	1584	5	€	14,141	86%	€	2,000	€	520,000	€	530,000	2%	5400	€	5,200,000	€	1,000	€	315,000	€	60	€	324,000
20500	12100	59%	4	4989	2	€			€	2,700	€	1,078,000	€	904,000	2%	8200	€	10,780,000	€	1,400	€	594,600	€	75	€	615,000
70300	46900	67%	5	4830	10	€	24,886	65%	€	2,700	€	3,726,000	€	4,671,000	3%	28200	€	37,260,000	€	1,400	€	2,519,100	€	90	€	2,538,000
19436	11603	61%	6	2920		€	51,833	72%	€	2,350	€	878,250	€	895,500	2%	7821	€	8,782,500	€	1,362	€	498,600	€	64	€	512,854
5000	2040	41%	4	270	8	€	18,148	66%	€	1,500	€	148,000	€	208,000	3%	2000	€	1,480,000	€	800	€	106,800	€	55	€	110,000
4770	2190	46%	4	354	6	€	12,147	65%	€	1,400	€	132,000	€	175,000	3%	2000	€	1,320,000	€	700	€	92,100	€	50	€	100,000
49400	23600	48%	12	800	30	€			€	400	€	386,000	€	2,313,000	12%	19800	€	3,860,000	€	200	€	809,700	€	45	€	891,000
13800	8380	61%	3					95%	€	600	€	160,000	€	55,000	1%	5600	€	1,600,000	€	300	€	64,500	€	15	€	84,000
8900	5800	65%	2	1240	5	€			€	1,700	€	296,000	€			3600	€	2,960,000	€	900	€	88,800	€	25	€	90,000
4800	3020	63%	2	7820	0	€			€	2,400	€	230,000	€			2000	€	2,300,000	€	1,200	€	69,000	€	35	€	70,000
26000	15800	61%	11	2515	6	€	11,173	74%	€	1,500	€	760,000	€	1,043,000	3%	10400	€	7,600,000	€	800	€	540,900	€	55	€	572,000
1730	780	45%	3	500	2	€	4,600	82%	€	1,700	€	56,000	€	534,000	19%	700	€	560,000	€	800	€	177,000	€	255	€	178,500
10800	7660	71%	11	548	14	€	20,073	76%	€	1,400	€	290,000	€	609,000	4%	4400	€	2,900,000	€	700	€	269,700	€	65	€	286,000
1730	870	50%	5					85%	€	800	€	26,000	€	55,000	4%	700	€	260,000	€	400	€	24,300	€	35	€	24,500
12693	7014	55%	6	1405		€	13,228	78%	€	1,400	€	248,400	€	624,000	6%	5200	€	2,484,000	€	1,000	€	224,300	€	64	€	240,600
15817	9314	60%	6	2154		€	42,712	74%	€	2,100	€	626,200	€	725,100	3%	6400	€	6,261,100	€	1,300	€	376,800	€	61	€	390,211

242200

[http://ycharts.com/indicators/netherlands\\_long\\_term\\_interest\\_rates](http://ycharts.com/indicators/netherlands_long_term_interest_rates)

The tall buildings reference book page 61

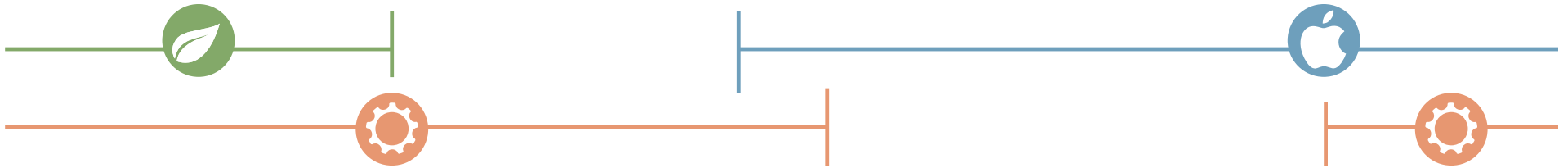
<http://www.building.co.uk/cost-model-office-design/3044443.article>

# Façade Value | Appendix B - Façade component study

01. List of components, connections and design opportunities according to facade literature.



Primary Function		Create durable constructions				Allow reasonable building methods				Provide a comfortable interior climate						
Secondary Function	Bear vertical and horizontal structural loads	Enable water and vapor management	Keep materials and components in working conditions	Reduce external risks	Design Methods	Production methods	Transportation	Assembly and disassembly	Control daylight radiation	Control air exchange and humidity levels	Reduce energy losses	Maintain climate range	Provide acoustic control	Provide visual comfort	Minimize energy consumption	
Part	Component	Frame	Gasket	Overall	Overall	Overall	Overall	Module	Module-to-module / Module-to-addon	Shading / Automation	Ventilation	Insulation	Building services	Acoustic insulation	Shading	Module
	Design intent	Maximize functions	Minimize need	Disassembly	Centralize production processes	Discipline integration	Standardization and customization	Limit size	Increase tolerance	Optimize - fixed or variable	Heat exchange	Simplify	Integrate	Optimize	Optimize - fixed or variable	Adaptation through automation or planning
Term	Material / Technological	Long	Short	Long	N/A	N/A	N/A	N/A	N/A	Medium	Long	Medium	Short	Medium	Long	Medium
	Financial	Long	Short	Long	N/A	N/A	N/A	N/A	N/A	Long	Long	Long	Long	Medium	Long	Long
	Installation / Maintenance	Long	Medium	Short	N/A	N/A	N/A	N/A	N/A	Short	Medium	Medium	Short	Medium	Medium	Medium
Connection	Total	Long	Short	Short	N/A	N/A	N/A	N/A	N/A	Medium	Medium	Medium	Short	Medium	Medium	M
	Section	X		-	-	-	X	X	X			X	X	X		
	Slot		X	-	-	-	X		X	X			X		X	X
	Bus			-	-	-	X		X		X		X			



**Sustainable use of resources**

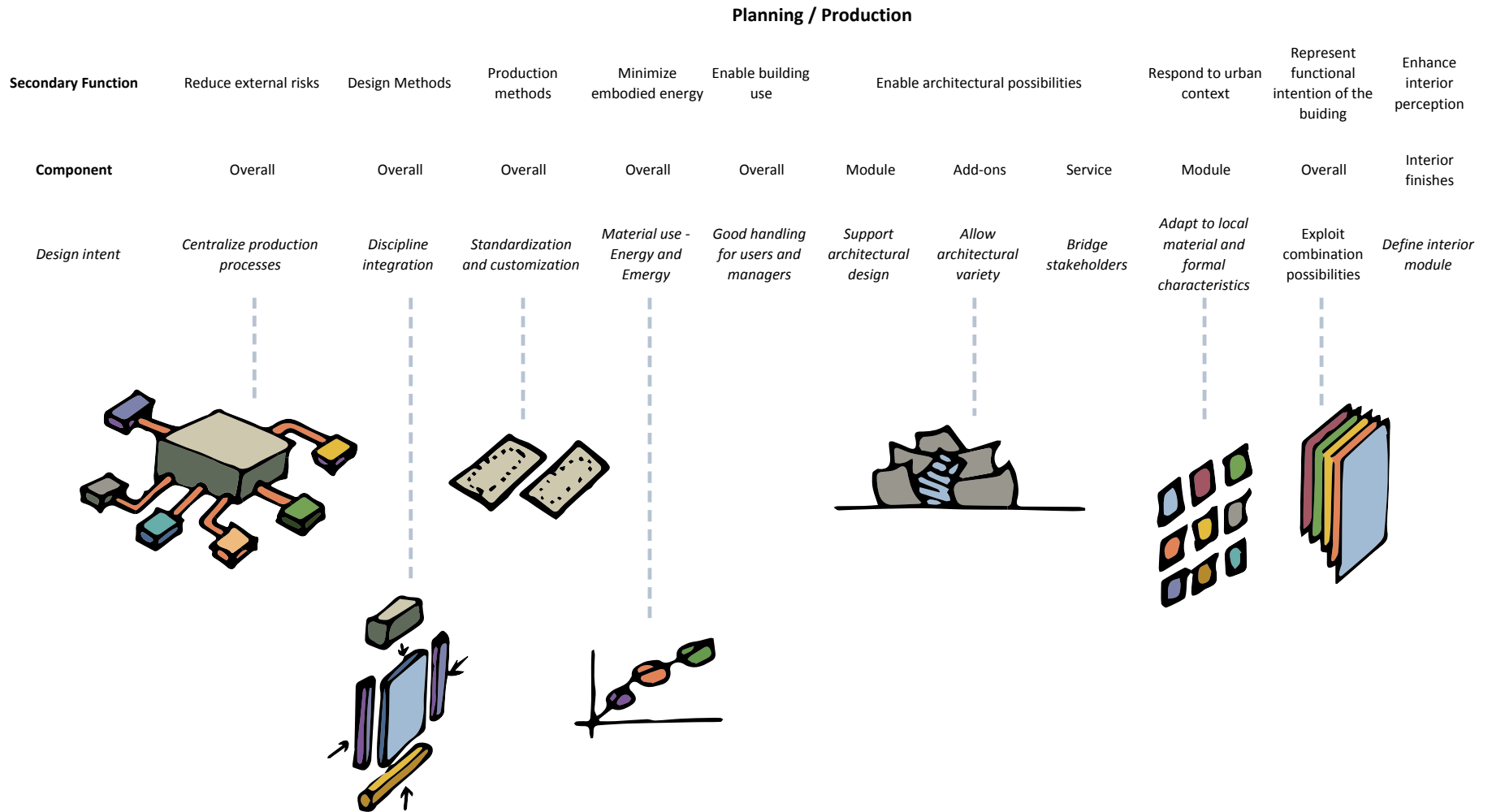
**Support use of the building**

**Spatial formation**

Option during use	Minimize embodied energy	Reuse and recycle	Generate energy	Store Energy	Provide a safe environment			Enable building use	Maintain efficient performance	Maintain value	Enable architectural possibilities			Respond to urban context	Represent functional intention of the building	Enhance interior perception
	Overall	Overall	Solar collectors	Thermal mass	Overall	Structure	Railing / Operable windows	Overall	Monitoring systems	Overall	Module	Add-ons	Service	Module	Overall	Interior finishes
<i>Transparency without overheating</i>	<i>Material use - Energy and Emergy</i>	<i>Disassembly</i>	<i>Extend use</i>	<i>Implement</i>	<i>Prevent or delay fire</i>	<i>Allow deformation without failure</i>	<i>Prevent accidents</i>	<i>Good handling for users and managers</i>	<i>Improve real-time communication</i>	<i>Maintenance and life-cycles</i>	<i>Support architectural design</i>	<i>Allow architectural variety</i>	<i>Bridge stakeholders</i>	<i>Adapt to local material and formal characteristics</i>	<i>Exploit combination possibilities</i>	<i>Define interior module</i>
Glass	Overall	Overall	Solar collectors	Thermal mass	Overall	Structure	Railing / Operable windows	Overall	Monitoring systems	Overall	Module	Add-ons	Service	Module	Overall	Interior finishes
Medium	N/A	N/A	Medium	Long	N/A	N/A	Long	N/A	Short	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Long	N/A	N/A	Long	Long	N/A	N/A	Long	N/A	Long	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Medium	N/A	N/A	Medium	Long	N/A	N/A	Long	N/A	Short	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Medium	N/A	N/A	Medium	Long	N/A	N/A	Long	N/A	Short	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	-	X		X	-	-		-	-	-	X			X	X	X
X	-	X	X		-	-	X	-		-		X	X	X		X
		∨		∨					∨				∨			

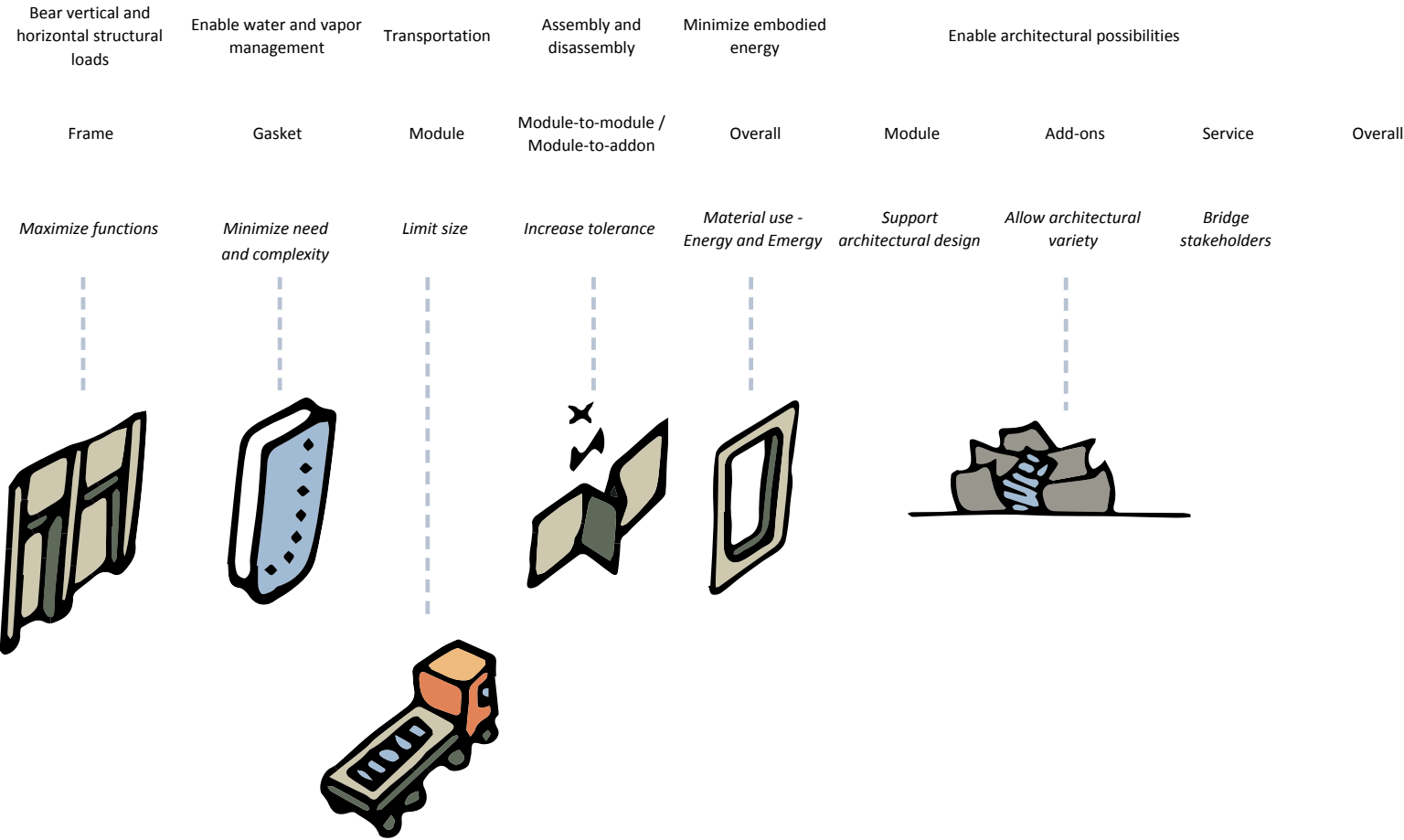
# Façade Value | Appendix B - Façade component study

02.a. List of components, connections and design opportunities according to stage in the construction process.



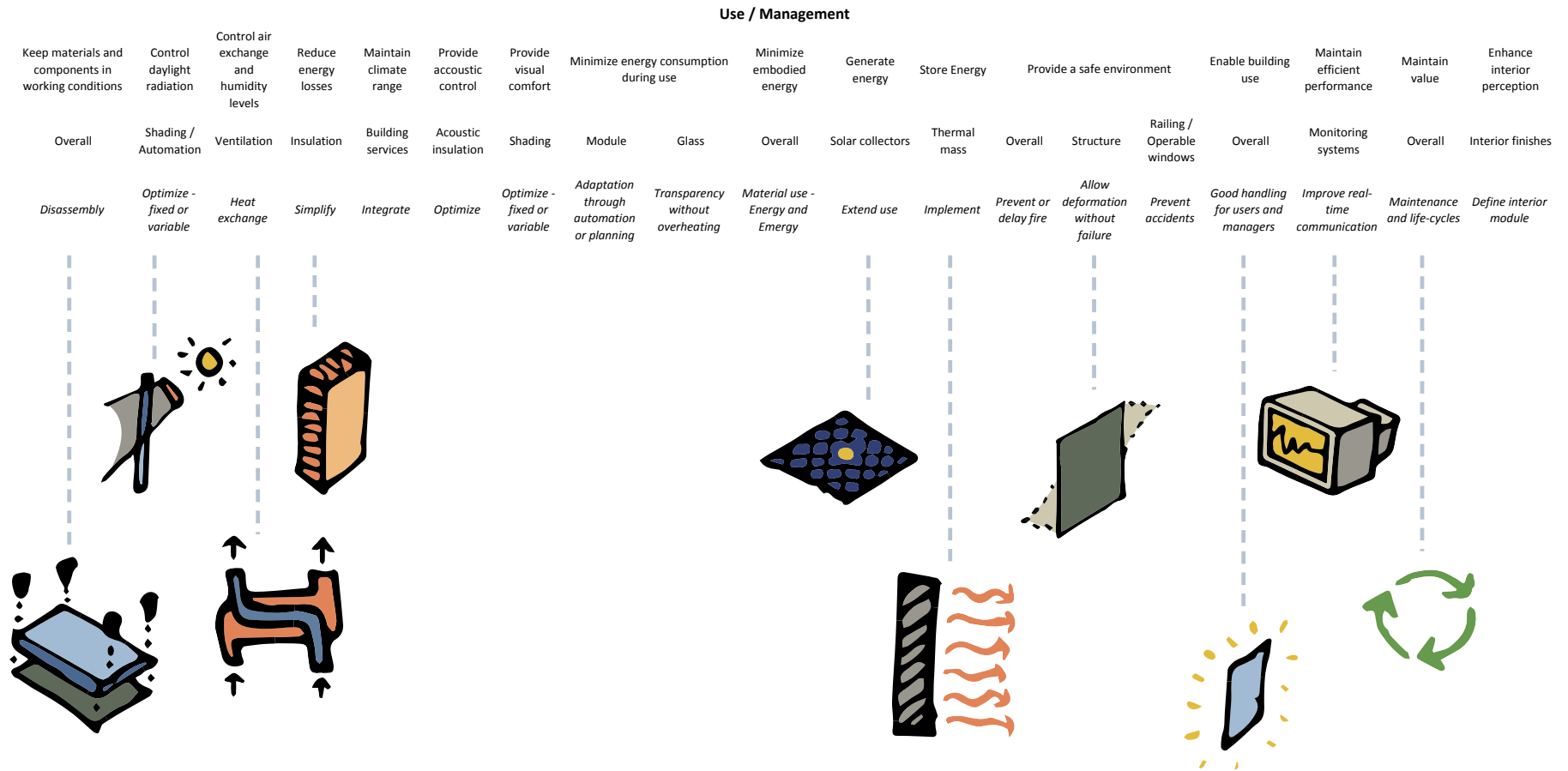


**Installation / Construction**



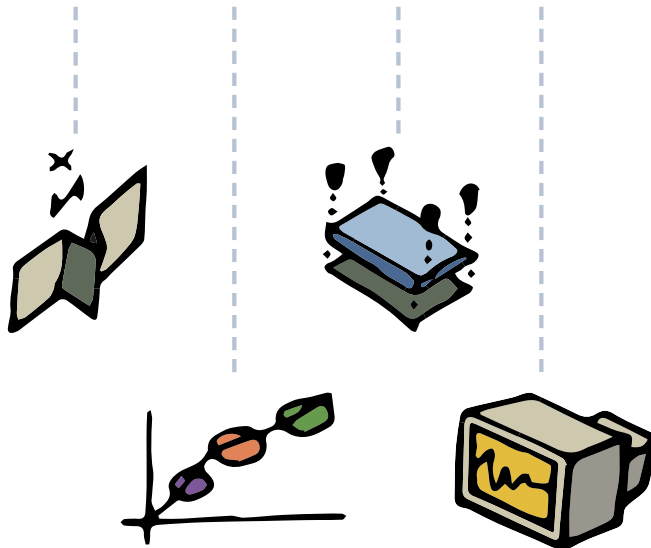
# Façade Value | Appendix B - Façade component study

02.b. List of components, connections and design opportunities according to stage in the construction process.



**Reuse / Recycling**

Assembly and disassembly	Minimize embodied energy	Reuse and recycle	Maintain efficient performance
Module-to-module / Module-to-addon	Overall	Overall	Monitoring systems
<i>Increase tolerance</i>	<i>Material use - Energy and Emery</i>	<i>Disassembly</i>	<i>Improve real-time communication</i>



# Façade Value | Appendix C - Financial study

## 01. Basic comparisson between financing systems according to the 4 performance values.

	Purchase	Lease	Product-Service System
Financial	Large initial capital investment	Higher financial costs	Lower planing and construction costs
	Financing "locks" cash or credit resources which could be used for other institution priorities (professors, research, equipment, etc)	Frees cash and credit for other uses.	Lowers initial capital investment and overall financial costs
	Depreciation is fully absorbed by the building owner (eg. University)	Allows for shorter replacement cycles.	Depreciation taken by the PSS provider, minimized through layered, life-cycle dependant design
	Financially unfeasible when interest rates are high		Allows for specialized sponsoring or grant seeking
Taxes	Full sales-taxes have to be paid up-front	In a capital lease taxes are spilt into monthly payments, in operation leases taxes are deductible as operation costs	No physical assets are owned by the client, therefore the entire cost can be considered an operation cost
Sustainable	No one (neither the owner nor the manufacturer) take responsibility for end-of-life processing	Once leasing term is done, the assets normally enter the second-hand market, where their end-of-life scenario is equivalent to that of a purchased item.	All climate-related systems (façade, mechanical intallations, ventilation untis) are owned by the service provider.
			Replacement with new (more efficient) technologies is the service provider's best interest
			Reprocessing of used units into brand new, or refurbished, pieces is in the service provider's best interest
Functional	Functional life is in most cases determined by financial costs (squeeze the last drop off your equipment scenario)	Shorter fixed terms allow for more frequent reassessment of system needs and functional or strategic priorities.	With an extensive enough building portfolio changes can be done between clients and building incurring only installation and transportation costs.
	Long-term financial cycle results in very tight, unflexible systems which can't be altered or replaced without a negative economic impact	Systems can be upgraded or replaced any time by recalculating the monthly fee or by making a one-time payment.	Service costs can be recalculated and redefined after each modification.
Strategic	Form and image are completely free, modular design is not required.	Strategic value in terms of appearance is limited by system modularity.	Strategic value comes from the degree of systems personalization.
	Full costumization is possible, price varies according to complexity of design.	Strategic value would reside in the potential constant interventions to the façade and the enhanced adaptability of the façade to the building uses	Many technology and fashion brands have used the same "one of a kind combination" marketing approach. Pandora bracelets, block-phone, smart-phone service providers.

## 02. Financial parameters for the 3Me Case-Study

3ME Building Parameters		
Sq Meters of Construction		17,400
Sq Meters of Façade		10,730
Floor:Façade Area Ratio		62%
Current Energy Use (kWh/sqm-year)		292 <a href="http://www.energymonitor.tudelft.nl/">http://www.energymonitor.tudelft.nl/</a>
Cost of Energy (kWh)	€	0.214 <a href="http://www.costtotravel.com/cost/electricity-in-netherlands">http://www.costtotravel.com/cost/electricity-in-netherlands</a>
Current Energy Expense (per year)	€	1,087,291
Rate of Interest (30 Year Loan)		6% <a href="http://www.bankrate.com/calculators/mortgages/loan-calculator.aspx?MSA=&amp;MSA=&amp;MSA=">http://www.bankrate.com/calculators/mortgages/loan-calculator.aspx?MSA=&amp;MSA=&amp;MSA=</a>
Rate of Inflation		2%
Rate of Inflation (for energy prices)		7% <a href="http://www.politics.co.uk/news/2012/02/13/energy-companies-attacked-as-hypothermia-deaths-soar">http://www.politics.co.uk/news/2012/02/13/energy-companies-attacked-as-hypothermia-deaths-soar</a>
Yield of Alternative Investment		8% <a href="http://people.stern.nyu.edu/wsilber/couponbonds.pdf">http://people.stern.nyu.edu/wsilber/couponbonds.pdf</a>
PSS Production and Maintenance Costs <i>(Economy of scale)</i>		90%
Down Payment (20%)	€	1,277,276
PSS Return On Investment		10%
Maintenance Costs (% of overall costs)		3%
Façade Maintenance Costs (% of maintenance costs)		16.50%

# Façade Value | Appendix C - Financial study

## 03. 30 year standard renovation model - Construction / renovation / demolition

		Façade Construction (Purchase system)												
Year	Project	M² Transparent	M² Solid	M² Total	€/ m² Transparent	€/ m² Solid	Façade Initial Cost (with X% inflation)	Upgrade / Renovation Costs (with X% inflation)				Total Construction Costs	Years	
2014	Construction	4,930	5,800	10,730	€ 726	€ 484	€ 6,387,000	€ -	€ -	€ -	€ -	€ -	€ 6,387,000	30
2015							€ 6,515,000	€ -	€ -	€ -	€ -	€ -	€ 6,515,000	29
2016							€ 6,645,000	€ -	€ -	€ -	€ -	€ -	€ 6,645,000	28
2017							€ 6,778,000	€ -	€ -	€ -	€ -	€ -	€ 6,778,000	27
2018							€ 6,913,000	€ -	€ -	€ -	€ -	€ -	€ 6,913,000	26
2019							€ 7,052,000	€ -	€ -	€ -	€ -	€ -	€ 7,052,000	25
2020							€ 7,193,000	€ -	€ -	€ -	€ -	€ -	€ 7,193,000	24
2021							€ 7,336,000	€ -	€ -	€ -	€ -	€ -	€ 7,336,000	23
2022							€ 7,483,000	€ -	€ -	€ -	€ -	€ -	€ 7,483,000	22
2023							€ 7,633,000	€ -	€ -	€ -	€ -	€ -	€ 7,633,000	21
2024	Major maintenance (replace ventilation units) (85% Energy Use)	4,930	5,800	10,730	€ 183	€ -	€ 7,785,000	€ 902,000	€ -	€ -	€ -	€ -	€ 8,687,000	20
2025							€ 7,941,000	€ 920,000	€ -	€ -	€ -	€ -	€ 8,861,000	19
2026							€ 8,100,000	€ 938,000	€ -	€ -	€ -	€ -	€ 9,038,000	18
2027							€ 8,262,000	€ 957,000	€ -	€ -	€ -	€ -	€ 9,219,000	17
2028							€ 8,427,000	€ 976,000	€ -	€ -	€ -	€ -	€ 9,403,000	16
2029	Functional retrofit (improve energy generation) (50% Energy Use)	4,930	5,800	10,730	€ 404	€ 404	€ 8,596,000	€ 996,000	€ 4,333,000	€ -	€ -	€ -	€ 13,923,000	15
2030							€ 8,768,000	€ 1,016,000	€ 4,419,000	€ -	€ -	€ -	€ 14,202,000	14
2031							€ 8,943,000	€ 1,036,000	€ 4,508,000	€ -	€ -	€ -	€ 14,486,000	13
2032							€ 9,122,000	€ 1,057,000	€ 4,598,000	€ -	€ -	€ -	€ 14,776,000	12
2033							€ 9,304,000	€ 1,078,000	€ 4,690,000	€ -	€ -	€ -	€ 15,071,000	11
2034							€ 9,490,000	€ 1,099,000	€ 4,784,000	€ -	€ -	€ -	€ 15,372,000	10
2035							€ 9,680,000	€ 1,121,000	€ 4,879,000	€ -	€ -	€ -	€ 15,680,000	9
2036	Major maintenance (90% Energy Use)	4,930	5,800	10,730	€ 77	€ 77	€ 9,874,000	€ 1,144,000	€ 4,977,000	€ 830,000	€ -	€ -	€ 16,823,000	8
2037							€ 10,071,000.00	€ 1,167,000.00	€ 5,077,000.00	€ 847,000.00	€ -	€ -	€ 17,159,000.00	7
2038							€ 10,273,000.00	€ 1,190,000.00	€ 5,178,000.00	€ 863,000.00	€ -	€ -	€ 17,503,000.00	6
2039							€ 10,478,000.00	€ 1,214,000.00	€ 5,282,000.00	€ 881,000.00	€ -	€ -	€ 17,853,000.00	5
2040							€ 10,688,000.00	€ 1,238,000.00	€ 5,387,000.00	€ 898,000.00	€ -	€ -	€ 18,210,000.00	4
2041							€ 10,901,000.00	€ 1,263,000.00	€ 5,495,000.00	€ 916,000.00	€ -	€ -	€ 18,574,000.00	3
2042							€ 11,119,000.00	€ 1,288,000.00	€ 5,605,000.00	€ 935,000.00	€ -	€ -	€ 18,945,000.00	2
2043	Demolition	4,930	5,800	10,730	€ 109	€ 109	€ 11,342,000	€ 1,314,000	€ 5,717,000	€ 953,000	€ 1,167,000	€ -	€ 20,490,000	1
30 Year Total							€ 11,342,000	€ 1,314,000	€ 5,717,000	€ 953,000	€ 1,167,000	€ -	€ 20,490,000	

04. 30 year expense summary for “No Renovation” and “Lease-based” scenarios

Without Renovations					Loan						
Construction (with X% inflation)	Maintenance Costs (Z% Façade costs)	Energy Costs No Renovation (7% Increase / year)	Total No Renovation	Cumulative No Renovation	Principal Costs (Debt / Years)	Principal Debt (Total Debt)	Interest Costs (Y% Interest / year)	Energy Costs (7% Increase / year)	Maintenance Costs (Z% Façade costs)	Total Yearly Costs (Capital, Interest, Energy and Maintenance)	Cumulative Loan
€ -	€ 166,000	€ 745,000	€ 911,000	€ 911,000	€ 1,278,000	€ 5,110,000	€ 154,000	€ 112,000	€ 159,000	€ 1,701,000	€ 1,701,000
€ -	€ 178,000	€ 797,000	€ 975,000	€ 1,885,000	€ 171,000	€ 4,939,000	€ 154,000	€ 120,000	€ 162,000	€ 605,000	€ 2,305,000
€ -	€ 190,000	€ 853,000	€ 1,042,000	€ 2,927,000	€ 171,000	€ 4,769,000	€ 154,000	€ 128,000	€ 165,000	€ 616,000	€ 2,921,000
€ -	€ 202,000	€ 913,000	€ 1,114,000	€ 4,041,000	€ 171,000	€ 4,599,000	€ 154,000	€ 137,000	€ 168,000	€ 629,000	€ 3,549,000
€ -	€ 214,000	€ 977,000	€ 1,191,000	€ 5,231,000	€ 171,000	€ 4,428,000	€ 154,000	€ 147,000	€ 172,000	€ 642,000	€ 4,190,000
€ -	€ 227,000	€ 1,045,000	€ 1,272,000	€ 6,502,000	€ 171,000	€ 4,258,000	€ 154,000	€ 157,000	€ 175,000	€ 655,000	€ 4,845,000
€ -	€ 241,000	€ 1,118,000	€ 1,358,000	€ 7,860,000	€ 171,000	€ 4,088,000	€ 154,000	€ 168,000	€ 179,000	€ 670,000	€ 5,514,000
€ -	€ 255,000	€ 1,196,000	€ 1,451,000	€ 9,310,000	€ 171,000	€ 3,917,000	€ 154,000	€ 180,000	€ 182,000	€ 685,000	€ 6,199,000
€ -	€ 269,000	€ 1,280,000	€ 1,549,000	€ 10,858,000	€ 171,000	€ 3,747,000	€ 154,000	€ 192,000	€ 186,000	€ 701,000	€ 6,900,000
€ -	€ 284,000	€ 1,370,000	€ 1,653,000	€ 12,511,000	€ 171,000	€ 3,577,000	€ 154,000	€ 206,000	€ 189,000	€ 718,000	€ 7,617,000
€ -	€ 896,000	€ 1,465,000	€ 2,361,000	€ 14,872,000	€ 216,000	€ 4,263,000	€ 181,000	€ 187,000	€ 193,000	€ 776,000	€ 8,393,000
€ -	€ 315,000	€ 1,568,000	€ 1,882,000	€ 16,754,000	€ 216,000	€ 4,048,000	€ 181,000	€ 200,000	€ 197,000	€ 793,000	€ 9,185,000
€ -	€ 331,000	€ 1,678,000	€ 2,009,000	€ 18,762,000	€ 216,000	€ 3,832,000	€ 181,000	€ 214,000	€ 201,000	€ 811,000	€ 9,995,000
€ -	€ 348,000	€ 1,795,000	€ 2,143,000	€ 20,904,000	€ 216,000	€ 3,617,000	€ 181,000	€ 229,000	€ 205,000	€ 829,000	€ 10,824,000
€ -	€ 365,000	€ 1,921,000	€ 2,286,000	€ 23,189,000	€ 216,000	€ 3,401,000	€ 181,000	€ 245,000	€ 209,000	€ 850,000	€ 11,673,000
€ -	€ 383,000	€ 2,055,000	€ 2,438,000	€ 25,627,000	€ 505,000	€ 7,230,000	€ 311,000	€ 131,000	€ 213,000	€ 1,159,000	€ 12,831,000
€ -	€ 402,000	€ 2,199,000	€ 2,600,000	€ 28,227,000	€ 505,000	€ 6,725,000	€ 311,000	€ 141,000	€ 217,000	€ 1,172,000	€ 14,003,000
€ -	€ 421,000	€ 2,353,000	€ 2,773,000	€ 31,000,000	€ 505,000	€ 6,221,000	€ 311,000	€ 150,000	€ 222,000	€ 1,186,000	€ 15,188,000
€ -	€ 441,000	€ 2,518,000	€ 2,958,000	€ 33,957,000	€ 505,000	€ 5,717,000	€ 311,000	€ 161,000	€ 226,000	€ 1,201,000	€ 16,389,000
€ -	€ 461,000	€ 2,694,000	€ 3,154,000	€ 37,111,000	€ 505,000	€ 5,213,000	€ 311,000	€ 172,000	€ 231,000	€ 1,217,000	€ 17,605,000
€ -	€ 482,000	€ 2,882,000	€ 3,364,000	€ 40,474,000	€ 505,000	€ 4,709,000	€ 311,000	€ 184,000	€ 235,000	€ 1,234,000	€ 18,839,000
€ -	€ 504,000	€ 3,084,000	€ 3,587,000	€ 44,061,000	€ 505,000	€ 4,204,000	€ 311,000	€ 197,000	€ 240,000	€ 1,251,000	€ 20,089,000
€ -	€ 526,000	€ 3,300,000	€ 3,825,000	€ 47,886,000	€ 608,000	€ 4,426,000	€ 336,000	€ 190,000	€ 245,000	€ 1,377,000	€ 21,466,000
€ -	€ 549,000	€ 3,531,000	€ 4,079,000	€ 51,964,000	€ 608,000	€ 3,818,000	€ 336,000	€ 203,000	€ 250,000	€ 1,395,000	€ 22,861,000
€ -	€ 573,000	€ 3,778,000	€ 4,350,000	€ 56,314,000	€ 608,000	€ 3,210,000	€ 336,000	€ 217,000	€ 255,000	€ 1,415,000	€ 24,275,000
€ -	€ 1,790,000	€ 4,042,000	€ 5,832,000	€ 62,145,000	€ 608,000	€ 2,602,000	€ 336,000	€ 232,000	€ 260,000	€ 1,435,000	€ 25,709,000
€ -	€ 622,000	€ 4,325,000	€ 4,947,000	€ 67,092,000	€ 608,000	€ 1,994,000	€ 336,000	€ 249,000	€ 265,000	€ 1,456,000	€ 27,165,000
€ -	€ 648,000	€ 4,628,000	€ 5,276,000	€ 72,367,000	€ 608,000	€ 1,387,000	€ 336,000	€ 266,000	€ 270,000	€ 1,479,000	€ 28,643,000
€ -	€ 675,000	€ 4,952,000	€ 5,626,000	€ 77,992,000	€ 608,000	€ 779,000	€ 336,000	€ 285,000	€ 276,000	€ 1,503,000	€ 30,145,000
€ -	€ 702,000	€ 5,299,000	€ 6,000,000	€ 83,992,000	€ 1,775,000	€ 171,000	€ 336,000	€ 304,000	€ 281,000	€ 2,694,000	€ 32,839,000
€ -	€ 13,645,000.00	€ 70,347,000.00	€ 83,992,000.00	€ 83,992,000.00	€ 13,446,000.00	€ 171,000.00	€ 7,288,000.00	€ 5,694,000.00	€ 6,413,000.00	€ 32,839,000.00	€ 32,839,000.00

# Façade Value | Appendix C - Financial study

## 05. 30 year cost breakdown for PSS model

Product-Service System							
PSS Provider Costs (X% of private purchase)	PSS Investment (Provider Capital Investment)	PSS Service Cost (Before Distribution)	PSS Service Cost (Distributed) (Client Pays)	PSS Service Cost (Adjusted to inflation)	% PSS to Loan (Yearly Basis)	% PSS to Loan (Adjusted to inflation)	Cumulative PSS
€ 5,748,000	€ 6,002,000	€ 1,062,000	€ 1,332,000	€ 985,000	78%	58%	€ 1,332,000
€ 5,863,000	€ 5,932,000	€ 1,070,000	€ 1,332,000	€ 1,005,000	220%	166%	€ 2,664,000
€ 5,980,000	€ 5,858,000	€ 1,078,000	€ 1,332,000	€ 1,025,000	216%	166%	€ 3,996,000
€ 6,100,000	€ 5,778,000	€ 1,086,000	€ 1,332,000	€ 1,045,000	212%	166%	€ 5,328,000
€ 6,222,000	€ 5,693,000	€ 1,095,000	€ 1,332,000	€ 1,066,000	207%	166%	€ 6,660,000
€ 6,346,000	€ 5,603,000	€ 1,103,000	€ 1,332,000	€ 1,087,000	203%	166%	€ 7,992,000
€ 6,473,000	€ 5,507,000	€ 1,113,000	€ 1,332,000	€ 1,109,000	199%	166%	€ 9,324,000
€ 6,603,000	€ 5,405,000	€ 1,122,000	€ 1,332,000	€ 1,131,000	194%	165%	€ 10,656,000
€ 6,735,000	€ 5,298,000	€ 1,132,000	€ 1,332,000	€ 1,154,000	190%	165%	€ 11,988,000
€ 6,870,000	€ 5,184,000	€ 1,142,000	€ 1,332,000	€ 1,177,000	186%	164%	€ 13,320,000
€ 7,818,000	€ 5,843,000	€ 1,225,000	€ 1,332,000	€ 1,200,000	172%	155%	€ 14,652,000
€ 7,975,000	€ 5,690,000	€ 1,232,000	€ 1,332,000	€ 1,224,000	168%	154%	€ 15,984,000
€ 8,134,000	€ 5,528,000	€ 1,239,000	€ 1,332,000	€ 1,249,000	164%	154%	€ 17,316,000
€ 8,297,000	€ 5,359,000	€ 1,246,000	€ 1,332,000	€ 1,274,000	161%	154%	€ 18,648,000
€ 8,463,000	€ 5,180,000	€ 1,254,000	€ 1,332,000	€ 1,299,000	157%	153%	€ 19,980,000
€ 12,531,000	€ 8,762,000	€ 1,638,000	€ 1,332,000	€ 1,325,000	115%	114%	€ 21,312,000
€ 12,782,000	€ 8,370,000	€ 1,621,000	€ 1,332,000	€ 1,352,000	114%	115%	€ 22,644,000
€ 13,037,000	€ 7,959,000	€ 1,602,000	€ 1,332,000	€ 1,379,000	112%	116%	€ 23,976,000
€ 13,298,000	€ 7,528,000	€ 1,583,000	€ 1,332,000	€ 1,406,000	111%	117%	€ 25,308,000
€ 13,564,000	€ 7,078,000	€ 1,562,000	€ 1,332,000	€ 1,435,000	109%	118%	€ 26,640,000
€ 13,835,000	€ 6,607,000	€ 1,541,000	€ 1,332,000	€ 1,463,000	108%	119%	€ 27,972,000
€ 14,112,000	€ 6,115,000	€ 1,518,000	€ 1,332,000	€ 1,493,000	106%	119%	€ 29,304,000
€ 15,141,000	€ 6,326,000	€ 1,571,000	€ 1,332,000	€ 1,522,000	97%	111%	€ 30,636,000
€ 15,443,000	€ 5,708,000	€ 1,538,000	€ 1,332,000	€ 1,553,000	95%	111%	€ 31,968,000
€ 15,752,000	€ 5,063,000	€ 1,503,000	€ 1,332,000	€ 1,584,000	94%	112%	€ 33,300,000
€ 16,067,000	€ 4,390,000	€ 1,466,000	€ 1,332,000	€ 1,616,000	93%	113%	€ 34,632,000
€ 16,389,000	€ 3,689,000	€ 1,428,000	€ 1,332,000	€ 1,648,000	91%	113%	€ 35,964,000
€ 16,716,000	€ 2,958,000	€ 1,389,000	€ 1,332,000	€ 1,681,000	90%	114%	€ 37,296,000
€ 17,051,000	€ 2,198,000	€ 1,348,000	€ 1,332,000	€ 1,714,000	89%	114%	€ 38,628,000
€ 18,441,000	€ 2,456,000	€ 1,445,000	€ 1,332,000	€ 1,749,000	49%	65%	€ 39,960,000
€ 18,441,000.00	€ -	€ 39,937,000.00	€ 39,937,000.00	€ 39,936,000.00	122%	122%	€ 39,960,000



## 04. 30 year summary of alternative investment yield

Alternative Investment									
Façade Capital Costs (against alternative X% yield investment)	Additional Costs (Energy and Maintenance)	Total Costs (against alternative investment)	Cumulative Alternative	Yearly Yield (Against No Renovation)	Yearly Yield (Against PSS)	Yield %	Yearly Yield (Against Loan) (Imaginary Scenario)	Yield %	
€ 6,387,000	€ 270,000	€ 483,000	€ 483,000	#NUM!	€ (579,000)		€ (1,218,000)		
€ 6,898,000	€ 281,000	€ 1,005,000	€ 1,488,000	€ 31,000	€ (65,000)	-210%	€ 400,000	1290%	
€ 7,450,000	€ 293,000	€ 1,058,000	€ 2,545,000	€ 16,000	€ (20,000)	-125%	€ 442,000	2763%	
€ 8,045,000	€ 305,000	€ 1,114,000	€ 3,658,000	#NUM!	€ 28,000	#NUM!	€ 485,000	#NUM!	
€ 8,689,000	€ 318,000	€ 1,174,000	€ 4,832,000	#NUM!	€ 79,000	#NUM!	€ 532,000	#NUM!	
€ 9,384,000	€ 332,000	€ 1,240,000	€ 6,071,000	#NUM!	€ 137,000	#NUM!	€ 585,000	#NUM!	
€ 10,135,000	€ 346,000	€ 1,310,000	€ 7,380,000	#NUM!	€ 197,000	#NUM!	€ 640,000	#NUM!	
€ 10,946,000	€ 361,000	€ 1,385,000	€ 8,765,000	#NUM!	€ 263,000	#NUM!	€ 700,000	#NUM!	
€ 11,821,000	€ 378,000	€ 1,466,000	€ 10,231,000	#NUM!	€ 334,000	#NUM!	€ 765,000	#NUM!	
€ 12,767,000	€ 395,000	€ 1,553,000	€ 11,783,000	#NUM!	€ 411,000	#NUM!	€ 835,000	#NUM!	
€ 14,762,000	€ 380,000	€ 2,588,000	€ 14,371,000	€ 227,000	€ 1,363,000	600%	€ 1,812,000	798%	
€ 15,943,000	€ 397,000	€ 1,791,000	€ 16,161,000	#NUM!	€ 559,000	#NUM!	€ 998,000	#NUM!	
€ 17,218,000	€ 415,000	€ 1,903,000	€ 18,063,000	#NUM!	€ 664,000	#NUM!	€ 1,092,000	#NUM!	
€ 18,595,000	€ 434,000	€ 2,024,000	€ 20,087,000	#NUM!	€ 778,000	#NUM!	€ 1,195,000	#NUM!	
€ 20,083,000	€ 454,000	€ 2,154,000	€ 22,241,000	#NUM!	€ 900,000	#NUM!	€ 1,304,000	#NUM!	
€ 26,369,000	€ 344,000	€ 6,843,000	€ 29,083,000	€ 4,405,000	€ 5,205,000	118%	€ 5,684,000	129%	
€ 28,478,000	€ 358,000	€ 2,680,000	€ 31,762,000	€ 80,000	€ 1,059,000	1324%	€ 1,508,000	1885%	
€ 30,756,000	€ 372,000	€ 2,863,000	€ 34,625,000	€ 90,000	€ 1,261,000	1401%	€ 1,677,000	1863%	
€ 33,217,000	€ 387,000	€ 3,060,000	€ 37,684,000	€ 103,000	€ 1,477,000	1434%	€ 1,859,000	1805%	
€ 35,874,000	€ 402,000	€ 3,273,000	€ 40,957,000	€ 119,000	€ 1,711,000	1438%	€ 2,056,000	1728%	
€ 38,744,000	€ 419,000	€ 3,502,000	€ 44,458,000	€ 139,000	€ 1,961,000	1411%	€ 2,268,000	1632%	
€ 41,843,000	€ 437,000	€ 3,749,000	€ 48,206,000	€ 162,000	€ 2,231,000	1377%	€ 2,498,000	1542%	
€ 46,087,000	€ 434,000	€ 4,890,000	€ 53,096,000	€ 1,065,000	€ 3,319,000	312%	€ 3,513,000	330%	
€ 49,773,000	€ 452,000	€ 4,352,000	€ 57,448,000	€ 273,000	€ 2,814,000	1031%	€ 2,957,000	1083%	
€ 53,755,000	€ 471,000	€ 4,666,000	€ 62,113,000	€ 317,000	€ 3,163,000	998%	€ 3,251,000	1026%	
€ 58,056,000	€ 492,000	€ 5,005,000	€ 67,118,000	#NUM!	€ 3,539,000	#NUM!	€ 3,570,000	#NUM!	
€ 62,700,000	€ 513,000	€ 5,370,000	€ 72,488,000	€ 424,000	€ 3,942,000	930%	€ 3,914,000	923%	
€ 67,716,000	€ 536,000	€ 5,765,000	€ 78,252,000	€ 490,000	€ 4,376,000	893%	€ 4,286,000	875%	
€ 73,133,000	€ 560,000	€ 6,190,000	€ 84,441,000	€ 564,000	€ 4,842,000	859%	€ 4,687,000	831%	
€ 78,984,000	€ 585,000	€ 6,649,000	€ 91,090,000	€ 649,000	€ 5,204,000	802%	€ 3,955,000	609%	
€ 78,984,000	€ 12,106,000	€ 91,090,000.00	€ 91,090,000	#NUM!	€ 51,153,000	#NUM!	€ 58,250,000	#NUM!	