Building Integrated Photovoltaic Systems and Leasing Facades

Exploring financial and technical conditions for BIPV technologies integration into a leasing façade system

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1. Introduction

1.1. Building Integrated Photovoltaics —Potential

The built environment accounts for 24% of green house gas emissions and 40% of the world's total primary energy use (task40.iea-shc.org). Global targets have been set to reduce this environmental impact. The European energy regulation and local governments call for meeting this targets. It is the Dutch government's ambition to have 14% renewable energy by 2020 and 16% in 2023. In addition to other energy renewable sources, PV systems will play a significant role in accomplishing these goals. The photovoltaic sector expects to have installed between 4 and 8 GWp by that time, which would be 3-6% of the total electricity supply of the country (RVO, Netherlands Enterprise Agency, 2013).

Consequently, the integration of the photovoltaic in the built environment has the potential to become a main driver in the PV market. PV can either be *added (BAPV)* or *integrated* in the building envelope *(BIPV).* However, BIPV ability to replace regular building envelope components at competitive prices such as the case of facade materials (Verberne, 2014) and contribute to aesthetic *value* while generating electricity —revenue for the life time of the material in an high priced energy market, all combined, give BIPV a significant edge over BAPV technologies. Further, approximately only 1% and 3% of all PV installed is BIPV, which indicates promising niche markets for further growth (Report IEA-PVPS T1-24:2014, 2014).

However, many barriers are steep and impose great challenges in the dissemination of the technology implementation towards a successful large-scale market implementation —on both ends: technological and financial. Furthermore, Sozer et al. (2007) declares that these barriers occur due to inability to assemble and present the technical and financial data to persuade a client that BIPV would make economic sense. Additionally, Sozer discusses full integration can be achieved only when close interface develops between the PV System and the elements of the building, the main barrier identified are: (1) lack of interface (integration with typical building process and building facade components), (2) lack of common language, (3) mismatched potential, (4) unknown performance, and (5) lack of economic analysis within the design process.

Moreover, according to Pagliaro et al. , the future of BIPV hinges on the development of not only its advancement in multi-functionality but its ability to adapt and respond to a competitive financial market. In addition, material innovation will probably determine the future development of BIPV to a much greater extent, with solar cells on a flexible substrate as a potential candidate for use in BIPV, promising as innovative solutions. (Pagliaro, 2008)

Despite the challenges, the demand for nearly-Zero Energy Buildings is contributing to change the industry approach. Towards this objective, the building skin is to be transformed from a passive envelope to a sensible, active and adaptive layer, with multi-functionality at the core of the requirements, with the building façade as the target terrain for development of BIPV implementation.

1.2. Building Integrated Photovoltaics —Façade Value

Double sided, BIPV technology includes electric technology and construction technology. Equally, a dual approach to the implementation is needed, which relates not only to the technical implications but also to the value added to the façade by the BIPV components, including PV energy and technical performance of the building.

Parallel to adaptability and flexibility, façade value emerges at the heart of the factors affecting in greatest dimension wider implementation of BIPV. Despite impressive cost decline compared to 10 year ago —60% reduction since 1998 (Barbose, 2014) BIPV remains having barriers of significant importance., which are not all qualified in cost terms.

Heinstein P. et al, identifies the following financial aspects: (1) *Misconception of BIPV market volume.* BIPV is understood to have marginal participation in comparison to other PV applications at 2% of total PV industry. However, this 2% can be translated into a significant market of 800 Billion Euros per year (German solar and construction industry) including roofs and facades installations. (2) *The complex symbiosis of manufacturers, planners and architects and the lack of specialized BIPV consultancies.* As BIPV does not represent a hard standardized product, but the integration of multiple functions. The high level of integration demands a tight intertwining of all stakeholders, from the manufacturer to the architect and installers, placing BIPV in a very demanding context. A high level of complexity in implementation translates into investor blindsided decision based on fears of cost and not vision of value. (3) *Ambiguous role of the building industry*, part of the industry has vital economic motivation to advance expansion of BIPV, such as low energy housing development, future development of commercial facades and commercial roof applications. However, other sides of the industry such as the roof tiles, is fearful to lose market share and is reluctant to promote the change. (4) *Misunderstanding of cell efficiency percentage rates*. The cell-efficiency as a percentage has been used as the catchiest-easy formula to define progress and associated performance of PV technology. In such a complex scenario, decision makers have opted to simplify assessment of BIPV by looking at just this number. In this aspect, the assessment falls short by high expectations and inability to include other factors. It will make more sense, to have a common form of measurement, sophisticated enough to account for the added value a multifunctional building component can offer to the calculation. (Heinstein, P., Ballif, C., & Perret-Aebi, L. E. , 2013).

Therefore in regards to value assessment, the question is how to measure performance and value added by BIPV components in relation to the decision making process of project development, and more specifically the building envelope. In a complex business environment, with multiple acting decision makers in the process, the task is how to assemble and develop the project —financially and technically in order to influence the decisions that BIPV would make economic sense.

A holistic façade value assessment based on better performance is imperative. Under these terms, the stakeholders and decision makers would have maximum understanding of the business possibilities of a decision and clear view of the "return of investment". The value of any intervention in the built environment would be most relevant for the stakeholders that are investing in it, if all costs are balanced with the benefits —not necessarily financial, but also added value to the performance of the organization, productivity, profitability and sustainable development(Heijer, 2013).

1.3. Building Integrated Photovoltaics — In leasing facades business model

As energy generator, the economic factor contained in BIPV systems implies distinctive selling points, as well as revised business models. Added façade value, policy incentives and regulations offer opportunities for innovative business models and market balancing.

Conventional design approach of buildings considers performance, programmatic and aesthetical architectural requirements under a product delivery model. Evaluating the cost of the BIPV within the facade, its contribution to building value and its cost in relation to the cost of the building furthers promising economical dimensions. Under these terms, leasing as a business model approach for proposing a different scenario where value is increased and cost is decreased is promising. (Azcarate-Aguerre, 2015). Leasing of PV —as a form of PSS has been implemented by the solar energy industry before, one example is Solar City in the United States, however BIPV as integral component of the facade has not been explored under a leasing business environment.

As stated by Azcarate-Aguerre (2015), within the current project design, development and maintenance process there is a gap between supply-side and demand-side needs, which obstruct the implementation of resource efficient facades. Facade leasing as a product-service system (PSS) keeps suppliers committed, throughout the building's service-life, to safeguard optimum performance in operation while actively stimulating clients to adopt innovative technical solutions.

2. Problem Statement

This research project deals with determining BIPV technologies and identifying corresponding multifunction system applications capable of supporting a façade leasing concept under competitive business models which could potentially lead to a cost effective and lessor-lessee profitable BIPV successful project execution.

Recent industry Economic Forum on Advanced Building Skins 2015, pointed up that BIPV technologies should aim to be adaptable, modular and multifunctional; and be aesthetical and cost conscious towards value in order to allow for the technology successful mass realization, i.e. (Vroon, 2015) (Renken, 2015) (Minderhoud, 2015). Further, the parameters impacting BIPV value contribution to the façade should be clearly identifiable by all stakeholders—from the financial and technical perspective in order to facilitate educated decision processes. Policy support continues to be relevant but is quickly moving towards new more market oriented business models.

Nevertheless, BIPV current framework is complex and faces difficulties. Decision makers misbelieve the technology restricts aesthetic and refrain freedom of design decisions The complex set of variables —technical, energetic, aesthetic, regulatory, etc, demand adopting individual solutions according to the requirements of each project, which means the need for complex architectonic services, translating into a higher level of integration. Ultimately, compromising decisions by product suitability with the design. In addition to this, there is uncertainty of a stable state of the market, as successful manufacturers and products suddenly disappear with ease from the commercial activities. All this, unsettles the private individual, the architect and the project developer. (Heinstein, P., Ballif, C., & Perret-Aebi, L. E. , 2013).

In addition, the multitude of stakeholders involved, in both the supply side —producers, and the demand side —consumers/clients increases the level of complexity, such as the application, form of ownership, market segment, consumer model, construction type and business models. All combined create an complex, most of the time unfavorable environment for the system implementation.

SUPSI-SEAC BIPV status report (2015) reveals that BIPV technologies implementation today is economic driven and therefore a crucial factor in its success. Initial investment and other factors within life-cycle understanding like adequate maintenance, energy management and optimization and product high quality and satisfactory installation are critical in understanding not only cost but value within the decision process. BIPV is an integral part of the building that cannot be single out and solely considered in terms of architecture and energy behavior or cost. A more precise evaluation should consider all the costs, repayment in the life cycle and residual value assessment.

As presented by Azcarate (2015) under a product delivery system, these variables would be taken into account from a different perspective and foster a positive economic model for greater façade implementation, in this case BIPV system. New product service systems can potentially lead to new types of façade and more resource efficient solutions, including end of life scenarios.

If design objectives are not longer limited to cost, aesthetic and programmatic requirements but performance, environmental and financial responsibility, the quality of the product would rely on the performance capability of the system (Façade) and its adaptability properties. The highly adaptable performance of an adaptable system will compensate for the implicit aesthetic rigidity of the system itself.

Optimization of BIPV constructional components for integration in the façade under the leasing facade concept, identification of the BIPV energetic, aesthetic and financial effects and definition of a BIPV resource efficient technology responsible to the leasing facade concept is crucial for the effective implementation and development of successful BIPV projects.

2.1 Main Propositions

The proposition behind the research project is that in order to support integration of BIPV systems in leasing facades, product design and business development must be consider in tangent and be inclusive of two aspects — technical (architectural integration) and financial (value proposition)

Facade architectural integration of BIPV systems requires a holistic approach to facade design — from PV module to building envelope. This approach, should overcome technical aspects (production and construction) and advance multifunction system applications capable of supporting new forms of business models, such as leasing façades which could potentially lead to a cost effective and lessor-lessee profitable BIPV successful project execution.

A revised business model approach will lead to improved products that include circular economy values, and will create new business prospects for the market. A product—service based designed oriented system, has the potential to essentially alter existing economic models.
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3. Research Questions

3.1 General Question

Exploring financial and technical conditions —how can BIPV technologies be integrated into a leasing façade system?

3.2 Specific Questions

1. Which BIPV technologies could support a leasing facade system?

2. How can BIPV constructional aspects be optimized for integration in a leasing facade system?

3. Which financial conditions could favor stakeholders decisions for the implementation of BIPV in a leasing facade system?

4. What defines business successful criteria for BIPV technologies implementation within a leasing façade system?

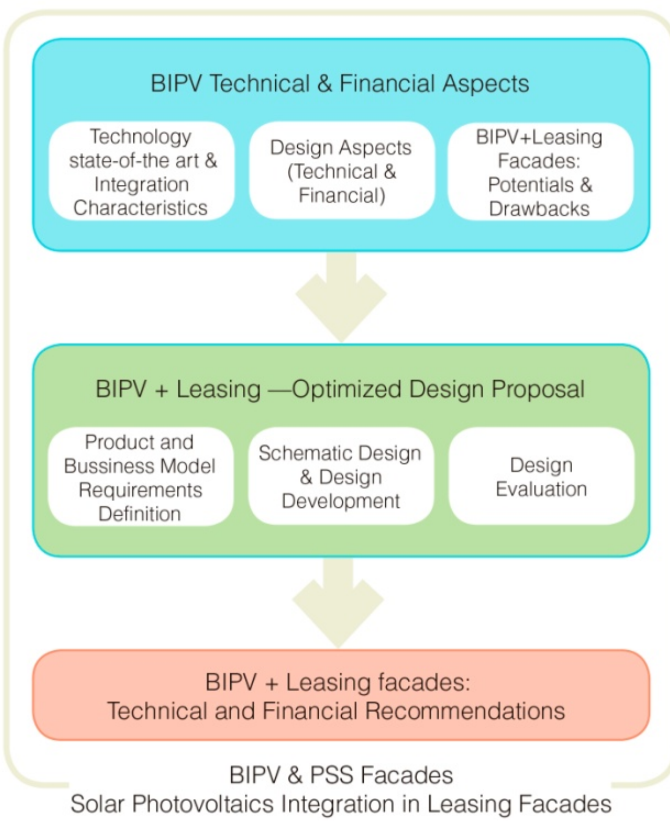

Figure 1 - Research Project Structure Scheme

4. Objectives

4.1 General Objective

To determine the BIPV technology that enables integration into a leasing façade system, throughout exploration of the technology—technical and financial aspects, toward a design proposition for an optimized BIPV suitable application.

4.2 Technological Specific Objectives

1. To review BIPV technologies state of the art and differentiate product integration application characteristics.

2. To identify BIPV facade and roof application —constructive and functional design strategies to implement in the concept of leasing facade system.

3. To identify and assess what strategic, financial, energetic and functional aspects affect the value proposition of BIPV technologies for integration into a leasing facade system.

4. To propose an optimized BIPV system responsive to the identified design criteria as suitable.

5.3 Business Specific Objectives

1. To perform business analysis and identify market environment —for the demand and supply stakeholders for BIPV implementation within a leasing façade system.

2. To define what business model criteria motivates the stakeholders implementation of BIPV under a leasing façade system.

5. Research Strategy and Methods

5.1. Research Process — Theoretical Approach

The theoretical perspective adopted to formulate the questions is in principle pragmatic (Creswell, 2003); in this aspect the research concentrates on understanding, application and solution of the problem stated. Consequently, the research direction strategy will apply a mixed methods approach, different approaches to collect information will be employed in attempt to provide best understanding of the research problem. In principle the general strategy associated with the mixed method will be a transformative procedure , where a theoretical lens will provide framework for the methods of collecting information and study of topics of relevance. Lastly, the specific research procedure will employ varied forms of methods of information and analysis, such as literature study of articles, reports, websites, example case review and interviews of industry experts.

5.2. Study Design —Methodology & Methods

The research project integrates two aspects —the technical and the economic as input for the design of building integrated photovoltaics within the realm of leasing facades:

- Broad research on technology concept.
- Detail research on technology and products state of the art.
- Research on relevant contextual economic aspects of BIPV in leasing facades.
- Interviews of stakeholders —supply and demand side.
- Example study —TU Delft EWI Building.
- Conceptual product design proposal. Based on literature review, research (technology and products) case reviews and interviews feedback.
- Conceptual business model proposal. Based on literature review, research on PSS systems, case reviews and interviews feedback.
- Design Proposal representation elaboration.
- Evaluation of final design and recommendations.

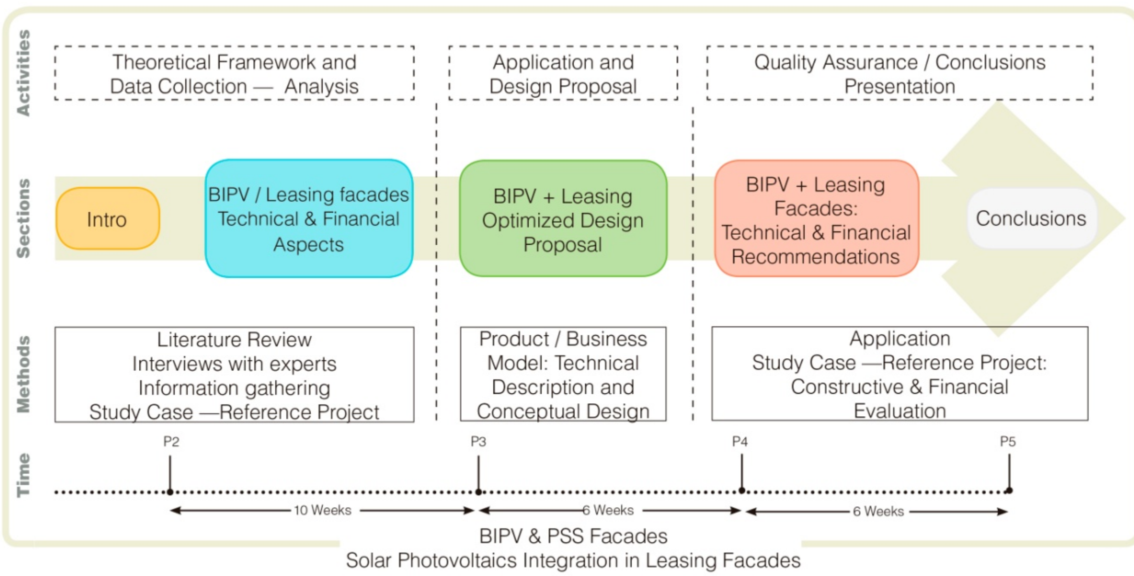

Figure 2 - Research Strategy Scheme

5.3. Graduation Plan

The research started with the selection of the graduation topic of leasing facades focused on building integrated energy generation components. Photovoltaic technologies, successful installation cases and industry implementation barriers were studied.

According to this, the preliminary research phase will deal with BIPV technologies and products state of the art, constructive and functional characteristics, classification of products and different definitions of BIPV architectural integration. To further comprehend the concept of leasing facades, PSS different types will be reviewed. This toward understanding the technical requirements for implementation of BIPV as a component of the building envelope systems. The research will crossanalyze BIPV products against leasing facades technical requirements and it will conclude with identifying what BIPV technologies support and ideal leasing facade scenario. It will extract ideal product characteristics for design optimization and feasibility in a leasing facade system.

Following, additional literature review an analysis of technical, strategic, financial, energetic and functional aspects will be done. Prior reaching the design proposal, a review of the market environment will be carried out to gain contextual reference of the economic aspects driving the supply and demand sides (PV manufacturers, architects, building owners, building companies, installation companies, grid operators and system integrators) —this in order to identify stakeholders expectations by the implementation of BIPV within a leasing facade towards, this towards defining a successful business criteria for the implementation of BIPV in a leasing facade.

Subsequently, based on gained knowledge and preliminary conclusions from previous phase, interviews of stakeholders will be conducted. Stakeholders from the supply side —such as the manufacturers and from the demand side —such as architects or building owners will be interviewed. This will further expand the product and conceptual development strategies and business model economic driving forces. The stakeholders invited to participate will be drawn from the ongoing project carried out by the facade design team within TU Delft Faculty of Architecture, the TU Delft EWI building.

Consequently, prior moving into the design proposal phase. And following the undergoing research project mentioned above, EWI Building will be employed as a building example for applying BIPV products within leasing facades. Different BIPV technological solutions and different benefits for the stakeholders will be mapped. Potentials and drawbacks of the technology implementation within the leasing facade concept will be determined. After collecting the needed data and organizing the research results, a definition of the final design requirements will be done. The aspects that fulfill the objective of defining how BIPV products can be optimized (financially and technically) for integration in a leasing facade system will be identified.

To follow is the concept design phase. Conceptual product design will start with the brainstorm ideas part, following design ideas definition at sketch level will be drafted, and design concepts will be selected for design definition. A business model will be drafted within an ideal facade leasing scenario. Finally, these will be evaluated by applying it to the building case mentioned above. To conclude recommendations with regards to technical and economic shortfalls and advantages of BIPV components integration into the leasing facade concept will be made. The final stage of the project will concentrate efforts in preparing the data, findings and conclusions for final report delivery and presentation.

6. Relevance

6.1. Scientific Relevance

Barriers in the BIPV façade implementation reveal lack of close interface between the PV system with typical building process and the building facade components. In addition, a compiled lack of multifunctional capacity, adaptability and ability to be industrialized are the leading negative aspects hindering greater achievements (Kuhn, 2015).

Forecasted success of BIPV projects development will rely in the scientific and technical aspects. As technical aspects emerge as one of the leading barriers, smart engineering and manufacturing of BIPV products will assure the future of the technology. In these terms, the technology ability to be produced at low cost in away to approach the price vs. value challenge where buying decisions are minimized, can be potentially solved from the technological point of view. The capacity to offer flexibility to the market and adapt to customized applications will rely in the technological aspect to successfully bring to realization an aesthetic and cost effective BIPV product.

6.2. Economic Relevance

The further development of BIPV façade market in Europe can be predicted based on current market situation. The key driver in this segment is the European Directive 2010/31/EU, which states that each new building should be made 'nearly zero energy' from 2020 onwards (The European Parliament and the Council of the European Union, 2010). Facades systems are essential to meet this demand. In this aspect, considering ratio solar electricity production potential and electricity consumption —for roofs and facades combined in Netherlands is 32.2%, despite roof potential exceeding facades utilization factor in relative terms, of 0.4 for roofs and 0.15 for facades, it is through the maximum utilization of building envelope that achievable levels will be met. If all the architecturally suitable building area is used, the achievable levels are nearly double (from 30% to 120%). It is worth noting this number varies across various different building types, e.g. residential vs. industrial and commercial (Marcel Gutschner, Stefan Nowak, 2002). In addition, when comparing regular material substitution for BIPV components, it is the BIPV facades applications that reflect more competitive prices than roof materials (Verberne, 2014).

Secondly, steady factors due to stable and predictable building directives and regulations show BIPV as the way to meet energy regulation in buildings and at the same time satisfy façade value. (SUPSI-SEAC, 2015). In addition a market demand for the development of harmonized standards and technical rules and building codes and a potential for the development for financial incentives under competitive market stimulation for PV application, are among others some of the reasons BIPV facades application probes financially promising.

In addition, Report IEA-PVPS T1-27:2015 by the International Energy Agency PVPS, confirms PV technologies large scale global deployment and increased competiveness, with the global installed total PV capacity estimated at roughly 177 GW at the end of 2014, and continues growing.

Altogether, these are encouraging signs of a maturing industry which is however only at the early beginning of its future market relevance (International Energy Agency, 2015).

7. Time Schedule

7.1. Benchmark Dates

P2 Submittal - January 15, 2016
P3 Submittal - March 2nd / 3rd Week (March 24)
P4 Submittal - May 2nd / 3rd Week (May 13)
P5 Submittal - June 30th

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