graduation . **PLAN**

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PERSONALIA

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STUDIO

Name of studio	Architectural Engineering
Teacher Architecture	Anne Snijders
Teacher Research	Marcel Bilow

TITLE AND CHOICE

Title project	***PV as art:*** *integration of roof-mounted solar energy and daylight systems*

Choice studio
During my time at the TU Delft I was given the opportunity to study abroad; one time in la bella Venezia and another time in London. I discovered that there are several different ways of approaching the architectural field and that there exists a gap between the more aesthetic and narrative approach of architecture and the technical method. This 'grey area' where architecture and engineering come together interests me a lot. I believe that this integration will become more important in the future since the rol of an autonomous architect is changing to an interacting architect/entrepreneur.

PROBLEM STATEMENT

The roof is the crowning glory of a building and often special care is given to their appearance. Each style period does have its own distinctive roof or facade designs. For example, the Gothic architecture has steep roofs, steeples and towers that transform a relatively nondescript building to striking homes, churches or cathedrals.

In contrast the current way of mounting solar panels on roofs, is not fed by an architectural approach, it is mostly induced by the ecology and economic policies and a sustainable, guilty feeling. When the property owners make the decision, contact is made with the solar contractors. These companies advice the building owners with the best intentions, but this advice will not go further then a calculation of the amount of panels and choice of a mounting system. Moreover the interest of the solar contractors is to sell as much as possible solar panels. The MRE (Material Related Energy) of PV's is high, since the cells consist of many energy expensive materials (a.o. mono-crystalline silicon). Solar tracking is an eco-efficient strategy for improving the efficiency of the solar cells. With the same number of MRE a higher energy production can been reached in the morning and afternoon. Moreover research has to be done to the prospective regulation for curtailment to prevent overloading on the current power grid; one of the main problems in the future.

In short, the roof-mounted solar systems are an addition to the - by Koolhaas so-called - "*Junkspace*". Beside the solar cells or panels are not used on their best way. Therefore it is important that research will be done to the possibilities for an aesthetically appealing and eco-efficient roof-mounted solar system.

RELEVANCE

By the end of 2014 the Netherlands have been achieved an increase of 40% in electric power by solar energy compared to 2013. (*Source: CBS, 29.02.2016*) Around 250 thousand households and businesses have solar panels on their roofs, which represents 1 gigawatt electrical power; comparable to the production of two coal plants. Keeping in mind the European Parliament mandate for all new buildings constructed in Europe after 2020 to be nearly carbon-neutral, it is generally expected that in this century photovoltaics will become a substantially contribution to the mainstream power production of buildings.

Due to the stimulation of policies of more and more countries which view PV as a power source with a large potential for the future, also property owners of existing buildings are installing solar panels on their roofs. Unfortunately the majority of these added solar panels are BAPV, which makes sense due their high efficiency and minimum costs. To clarify: PV systems for buildings can be divided in two groups, Building Applied Photovoltaics (*BAPV*) and Building Integrated Photovoltaics (*BIPV*). This last group represents photovoltaic materials that are used to replace conventional building modules in parts of the building envelope such as the roof, skylights or facades. The advantage of integrated photovoltaics over more common non-integrated systems (BAPV) is that the initial cost can be offset by reducing the amount spent on building materials and labor that would normally be used to construct the part of the building that the BIPV modules replace. Additionally BIPV systems - if designed in a good way - can improve the building's indoor climate (think of natural daylight instead of artificial lighting) and can add architectural interest to the building.

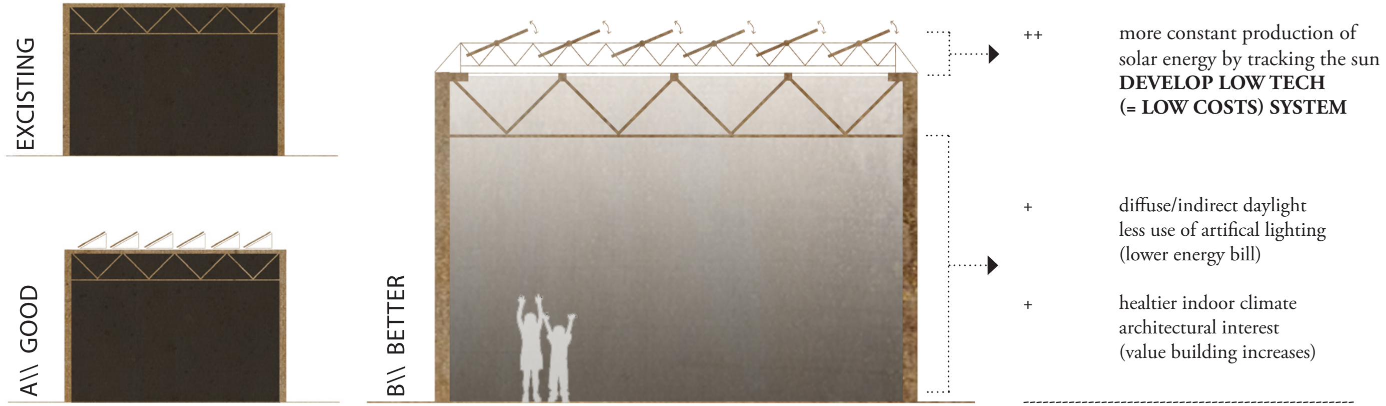
The fact that the added solar panels on the existing building stock are BAPV, means that the chances to improve the buildings' indoor climate are not be utilized and that the architectural quality of the building stock is even more decreased. The absence of an attractive, adaptable and especially low cost solar system for the existing building stock, that has both the qualities of BAPV (*high efficiency of PV's*) and BIPV (*improving indoor climate and architectural interest*) is a problem that has to be solved.

OBJECTIVE

A guiding principle for this innovation is the term eco-efficiency. This sustainable development principle was established by the World Business Council for Sustainable Development (WBCSD) in the 1990s. By them eco-efficiency is defined as "*eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity.*" In short, it is concerned with creating more value with less impact or in other words, eco-efficiency encourages low-impact growth.

Focusing this term on the current situation of adding solar panels to the existing building stock, it is important for creating a viable new solution to take into account both pillars of the term eco-efficiency: ecology ánd economy. The objective is to develop an attractive, adaptable and low costs solar system with both a high energy performance (economy) as a positive effect for the indoor climate (ecology). Only if the new solar panel system is economically attractive for the existing building stock, it can be realistic. The philosophy of eco-efficiency says that this can be reached by reducing the ecological impact of the solar panels. In that way ecology and economy work together.

The use of tracking systems for the solar panels is an eco-efficient strategy for improving the ecology and economy: potentially lowering both costs and lifecycle environmental impacts per kWh generated. A good sun-tracking system must be reliable and able to track the sun at the right angle even in the periods of cloud cover. An autonomous, natural solar tracker can be cheaper and needs less maintenance due the absence of electrical components than existing solar tracking systems. **In other words the integration of a tracking system improves both the solar energy production (more constant) as the indoor daylight qualities (reflecting direct sunlight) (*more value*) without using significant more material (*less impact*).**



current situation
=
adding solar panels

objective
=
integrate solar energy & daylight system

VIABLE SOLUTION
<=>
for economy & ecology

OVERALL DESIGN QUESTION

In which **aesthetic and eco-efficient** way, **solar energy and daylight** can be integrated in a **roof-mounted system**, using an existing building on the Marineterrein in Amsterdam as a test subject?

THEMATIC RESEARCH QUESTION

How can **solar energy and daylight** be integrated in a roof-mounted system, by using a **low tech solar tracking system**?

RESEARCH METHODS

L = Literature study
I = Interview
R = Reference analysis
V = Visit
D = Research by Design

thematic research | **integration** | **testing & applying**

I . DAYLIGHT

- What are the advantages and disadvantages of allowing daylight in a building through the roof? (L)
- What are good architectonic examples for allowing daylight through the roof? (R + V)
- In which way these examples reflect the direct sunlight? (make database) (L + R)

II . SOLAR ENERGY

- What are the principles of solar tracking? (L + I)
- Which mechanical systems exit for solar tracking and what are their advantages and disadvantages? (L + I)
- Which active and passive drive systems exit for solar tracking and what are their advantages and disadvantages? (L + I)
- Introduce passive drive tracking system using elektromagnetisme and magnetic influence (L + R)

III . MARINETERREIN

- In which way the Marineterrein can contribute to the energy transition (from a central to a decentral / independent energy system)? (L + I + R)
- Which building on the Marineterrein would suited the best as a test subject? (L + V)
- How is the relevant building constructed and what are the current climate and lighting systems? (L + I + V)
- How is the insolation on the relevant building? (L)
- In which way or pattern panels can be placed on the roof to create a pleasant indoor climate? (make digital and physic models) (D)

IV . PROTOTYPE

- Make and test prototype (D)

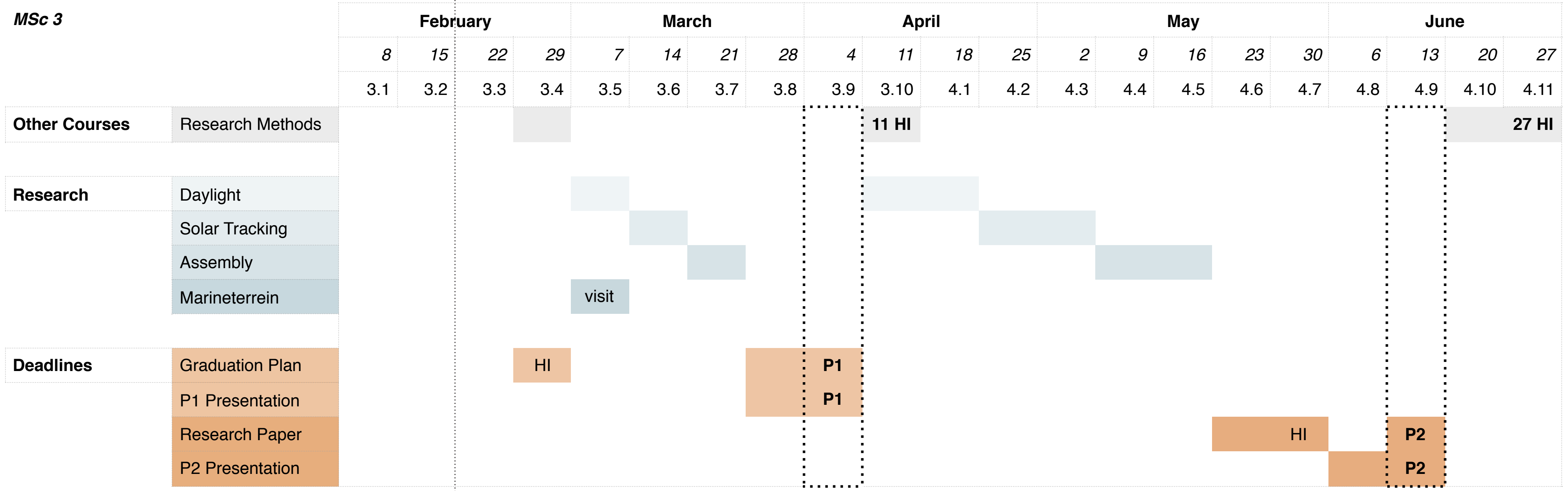
V . DESIGN

- Design and apply the roof system to an existing building on the Marineterrein in Amsterdam (V + D)

MSc 3
research

MSc 4
design (+research)

PLANNING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Other Courses
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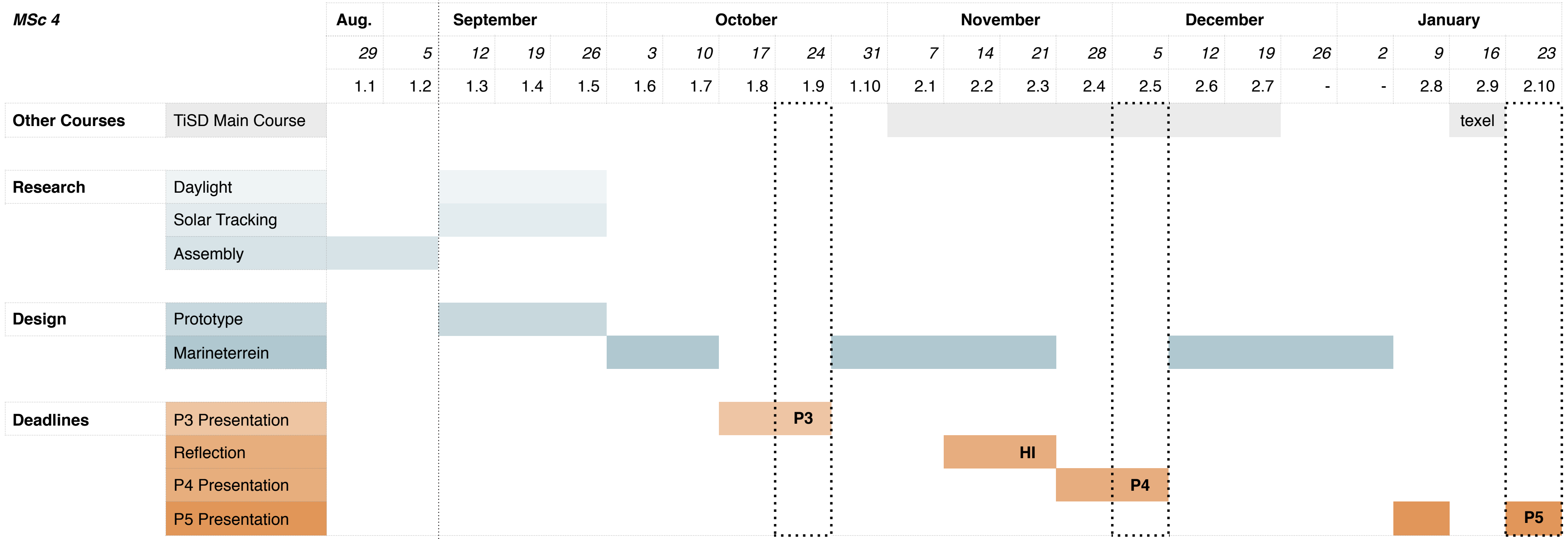
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Prototype
Marineterrein
Deadlines
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P4 Presentation
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P5 Presentation
P5

LITERATURE

I . DAYLIGHT

literature

Evans, B.H. (1981). *Daylight in Architecture*. New York: McGraw-Hill Book Co.

Kersbergen, D. van (2011). *Schiphol Interchange Station: Integrated design research for the wind and daylight performance of the building envelope* (Graduation Report). Delft: Building Technology and Architecture TU Delft

Pittaluga, F. (2008). *Architettura e luce*. Venezia: IUAV Università

Pittaluga, F. (2014). *Stanze di luce.* Ariccia: Aracne Editrice

Pittaluga, F., & Scavuzzo, G. (2007). *Variazioni di luce in un interno*. Ariccia: Aracne Editrice

Ramos, E.V. (2015). *Light in Architecture: The Intangible Material.* London: RIBA Publishing

II . SOLAR ENERGY

literature

Catarius, A., & Christiner, M. (2010). *Azimuth-Altitude Dual Axis Solar Tracker* (Master Qualifying Project). Worcester: Worcester Polytechnic Institute

Dabbagh, N. (2015). *Football stadium: solar envelope as an architectural tool* (Graduation Report). Delft: Architectural Engineering TU Delft

Dhanabal. R., Bharathi. V., Ranjitha. R., Ponni. A., Deepthi. S., Mageshkannan. P. (2013). Comparison of Efficiencies of Solar Tracker systems with static panel Single- Axis Tracking System and Dual-Axis Tracking System with Fixed Mount. *International Journal of Engineering and Technology, 5*(2), 25-33

Eiffert, P., & Kiss, G.J. (2000). *Building-Integrated Photovoltaic Designs for Commercial and Institutional Structures: A Sourcebook for Architects and Engineers.* Collingdale: DIANE Publishing

Farooqi, S. (2015). *Architectural Integration of Solar Energy: Integration of Active Solar Systems in Building Envelope* (Graduation Report). Delft: Architectural Engineering TU Delft

Kondratyev, K.Ya. (1969). *Radiation in the Atmosphere*. New York: Academic Press Inc.

Martin, C.L. (2015, February 16). *Heliotropolis: Designing with the Sun* (Lecture). Delft: TU Delft

Middelink, J.W., Engelhard, F.J., Brunt, J.G., & e.a. (1999). S*ystematische Natuurkunde: Kernboek N2 VWO1.* Baarn: NijghVersluys

Planbureau voor de Leefomgeving. (2014). *PV Potentieelstudie: Het potentieel van zonnestroom in de gebouwde omgeving van Nederland.* Den Haag: PBL publications

Saarberg, M. (2015, February 23). *Building Integrated PV and White Roofs* (Lecture). Delft: TU Delft

Sampatakos, D. (2014). *Development of three dimensional PV structures as shading devices for a decentralized facade unit of the future* (Graduation Report). Delft: Building Technology TU Delft

Sinha, P., & Dailey, S. (2013). Tracking Systems boost Eco- Efficiency. *Solar Industry Magazine, 6*(11), 8-11

Solar Fast Track. (n.d.). *Content of Chapter 8: Application - BiPV.* Retrieved March 2, 2016, from http:// www.solarfasttrack.com/English/chap8/index.html

Strong, S. (2011). Building Integrated Photovoltaics [Online publication]. *National Institute of Building Science.* Retrieved March 2, 2016, from http://www.wbdg.org/resources/ bipv.php

Sullivan, M. (2013). *Building Integrated Photovoltaics in the Context of the Australian Construction Industry.* Melbourne: International Specialized Skills Institute

Zomeworks Corporation. (2015). *Passive Solar Tracker for Photovoltaic Modules.* Retrieved March 2, 2016, from http:// www.zomeworks.com/photovoltaic-tracking-racks/

interview

Robin Berg of LomboxNet (i.a. the project "Smart Solar Charging")
> *innovation*

Marc Buijs - previous solar system contractor
> *commercial*

III . ASSEMBLY

literature

Cabrinha, M. (2008). *Gridshell Tectonics: Material values digital parameters.* San Luis Obispo: California Polytechnic State University

Kuijvenhoven, M. (2009). *A design method for timber grid shells* (Graduation Report). Delft: Structural Engineering TU Delft

Linden, L. van der (2015). *Innovative joints for gridshells* (Graduation Report). Delft: Civil Engineering TU Delft

interview

Henk Berghege - owner Bouwbedrijf Berghege
> *reality in building industry*