3TU.Bouw

center of excellence for the built environment

7 Lighthouse Projects 2015

Lighthouse Projects aim at promoting and starting up imaginative research projects that are related to a current and urgent theme. The 'imaginative' nature of the research as well as the delivery of tangible results within a timeframe of one year distinguishes Lighthouse Projects from other funding schemes.

Update 4 Lighthouse Projects 2014

Four of the eight initial Lighthouse Projects have seen further development beyond the scope of the actual Lighthouse program: 'proof of concept' or 'proof of failure'. These developments range from extended research supported through other funding schemes, to commercial implementations.

Future Formats for Applied Research

In sessions with reasearchers, a venture capitalist, a crowdfunding specialist and university management, we investigated how formats for applied research need to adapt to a fast changing world in which 'startups' are the way to explore new ideas.

De Toekomst Wordt Gebouwd

Within the realm of the three technical universities – built environment – an inventory has been produced on relevant and urgent topics for developments in the coming years.

Real Additive Manufacturing

Additive Manufacturing (AM) is regarded as a very promising technique, but what are the important functions and characteristics of AM produced building components? Can additive manufactured elements already be implemented widely in the building industry, or should their performance be improved first?

5 Professional Doctorates in Engineering

PDEng is a two-year professional post-academic degree, where university graduates work in close collaboration with the industry on an urgent and industrially relevant topic. It offers a dedicated professional education programme to deliver young professionals that are able to bridge the gap between academia and the market.

15 Lighthouse Projects 2016

In 2016, fifteen new research proposals will start with a Lighthouse Project funding. All of them are closely related to one of the themes of 'De Toekomst Wordt Gebouwd'. They function as catalysts and results in the process of activating these urgent topics.

TU Delft Delft University of Technology   TU/e Technische Universiteit Eindhoven University of Technology   UNIVERSITY OF TWENTE.

Lighthouse Projects 2016

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3D Printing Concrete on Non-planar Surfaces
INTEGRATIE & ORGANISATIE: SMART CONSTRUCTION

Combining existing flexible mould technology for concrete casting with 3D concrete printing, allowing printing on non-planar surfaces, thus enabling the production double-curved and free-form concrete structures.
Roel Schipper – h.r.schipper@tudelft.nl

3D printing material efficient structures to scale
INTEGRATIE VAN INNOVATIES

Design tool for 3D-printed optimised structures which are more intuitive to designers, aiming at new, minimal-material design of structures.
Jeroen Coenders – jeroencoenders@white-lioness.com

A Public Space for Refugees
PERCEPTIE & ACCEPTATIE: DE MENSELIJKE MAAT

Design of community building for refugee-camps, to create an environment of hope and dignity, to be build, maintained and managed by the inhabitants themselves, with locally available materials and other resources.
Juliette Bekkering – j.d.bekkering@tue.nl

Autonomous robotic intelligent extruder bots
INFORMATIE & INTERACTIE: INTELLIGENTIE IN DE BOUW

3D-printing of structures through a 'swarm of autonomous, mutually communicating and self-managing robots.
Aant van der Zee – a.v.d.zee@tue.nl

Bio Based Bridge
ENERGIE & GRONDSTOFFEN: CIRCULAR ECONOMY

Design, production and placement of a structurally sound and fully bio-based composite pedestrian bridge, using natural and completely recyclable materials.
Rijk Blok – r.blok@tue.nl

Convective Concrete
INTEGRATIE & ORGANISATIE: SMART CONSTRUCTION

3D-printing of a porous, thermally responsive (heat storing) concrete constructions as component in a future thermal smart-grid.
Dennis de Witte – d.dewitte@tudelft.nl

Fibrous Smart Material Topologies
ENERGIE & GRONDSTOFFEN: CIRCULAR ECONOMY

Adaptive, low-energy, real-time responsive interior environments by 'designed engineering' of fibres with variable material response behaviour.
Nimish Biloria – n.m.biloria@tudelft.nl

Pilot Home - The Next Level Housing
ANTICIPATIE & ADAPTATIE: KLIMAAT

A sustainable, reusable and cheap building block for safe and incremental self-construction of dwellings in the informally build parts of mega-cities (3 billion new inhabitants in 35 years, mainly in slums).
Marcel Bilow – m.bilow@tudelft.nl

Restorative Glass
INTEGRATIE VAN INNOVATIES

A methodology that uses glass for the replacement of missing elements in a damaged monumental structure, hence ensuring minimal impact on historical values. Case: kasteelruïne Lichtenberg, Maastricht.
Faidra Oikonomopoulou – f.oikonomopoulou@tudelft.nl

Smart Monitoring of Bridge Performance
INFRASTRUCTUUR & VERVOER: SMART MOBILITY

'Structural health monitoring' 2.0 techniques applied to the rapidly ageing 'population of bridges', based on newly available cheap sensors and using tailored and advanced structural response models.
Andreas Hartmann – a.hartmann@utwente.nl

Smart Sensor System
INFRASTRUCTUUR & VERVOER: SMART MOBILITY

Ensuring the quality of a newly build or refurbished pavement structure by in-situ measurement of critical performance parameters through a smart, fibre optic sensor based technology.
Seirgei Miller – s.r.miller@utwente.nl

Solar Bikes - Understanding User Preferences, Experiences and Acceptance
LEEFBAAR & EFFICIENT: SMART CITIES

Understanding people's preferences, conditions for acceptance and experiences with Solar-bikes.
Pauline van den Berg – p.e.w.v.d.berg@tue.nl

Sound Absorbing Glass
PERCEPTIE & ACCEPTATIE: DE MENSELIJKE MAAT

Glass-based sound absorbing panels, for minimal visual impact and optimized acoustic properties for repurposed cultural heritage structures. Pilot: Laurenskerk, Rotterdam
Martin Tenpierik – m.j.tenpierik@tudelft.nl

Spongy Skin - A 3D printed façade system enabling movable fluid heat storage
ANTICIPATIE & ADAPTATIE: KLIMAAT

Adaptive, 3D-printed concrete porous (artery system) façade system containing moveable (heat) storage fluid, for optimized thermal comfort.
Michela Turrin – m.turrin@tudelft.nl

Spying the Underground
INFORMATIE & INTERACTIE: INTELLIGENTIE IN DE BOUW

Enriching Cadaster data from the subsurface with 3D information, and utilizing this with Augmented Reality tools like Google Glass for construction and maintenance of subsurface infrastructures.
Léon olde Scholtenhuis – l.l.oldescholtenhuis@utwente.nl

3TU.Bouw represents the collaboration between the 3 Technical Universities in the Netherlands on the large topic of 'The Built Environment'. The cooperation consists of the Department of the Built Environment at TU Eindhoven, the faculty of Engineering Technology at Twente University, and the faculties of Architecture and Civil Engineering and Geosciences at TU Delft. The goal of the 3TU.Bouw initiative is to promote collaboration between the member faculties, industrial partners and government, in order to meet the grand challenges ahead.

Built Environment is the biotope of the modern citizen, providing infrastructure for transport, defence against flooding, shelter, space for working, meeting and leisure activities, etc. The demands upon reliability, safety and comfort of these structures is continuously increasing. Meanwhile the Built Environment sector is confronted with enormous challenges like scarcity of resources, climate change, accelerated population growth and demographic changes. These challenges require joint strategies and collaboration between end-user, academia, the industry and governmental agencies, the so-called golden triangle. Therefore, in the context of the Dutch 'Nationale Wetenschapsagenda', 3TU.Bouw, with its partners, has identified the important, societal and scientifically relevant research themes: 'De Toekomst Wordt Gebouwd'.

These themes have been utilized as context for the 3TU.Bouw Lighthouse programme 2016: fifteen dedicated, fast track innovation projects have been started, all addressing aspects of the agenda. These projects should provide a proof of concept – or failure – of new technologies that will contribute to solid approaches and solutions to the challenges ahead, for all stakeholders. Next to this, a dedicated PDEng-training programme contributes to the future availability of well-trained specialists, meanwhile bridging the gap between academia and the market. 3TU.Bouw strives to respond rapidly to the ever faster changes, often emerging bottom-up, that new technologies bring about, by organizing workshops, brainstorms and training sessions with relevant stakeholders, and by forming dedicated consortia that act jointly. Only by such joint actions positive changes with respect to the urgent themes are expected to happen.

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center of excellence for the built environment

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PUBLICATION
Editing & graphic design: bureaubakker – **Siebe Bakker & Mariet Sauerwein**
Images: bureaubakker, creative projects (P. 2, 4, 8, 10, 13, 14, 18, 19, 26, 28, 30, 32, 34), Dennis de Witte (P. 22, 23), participating researchers

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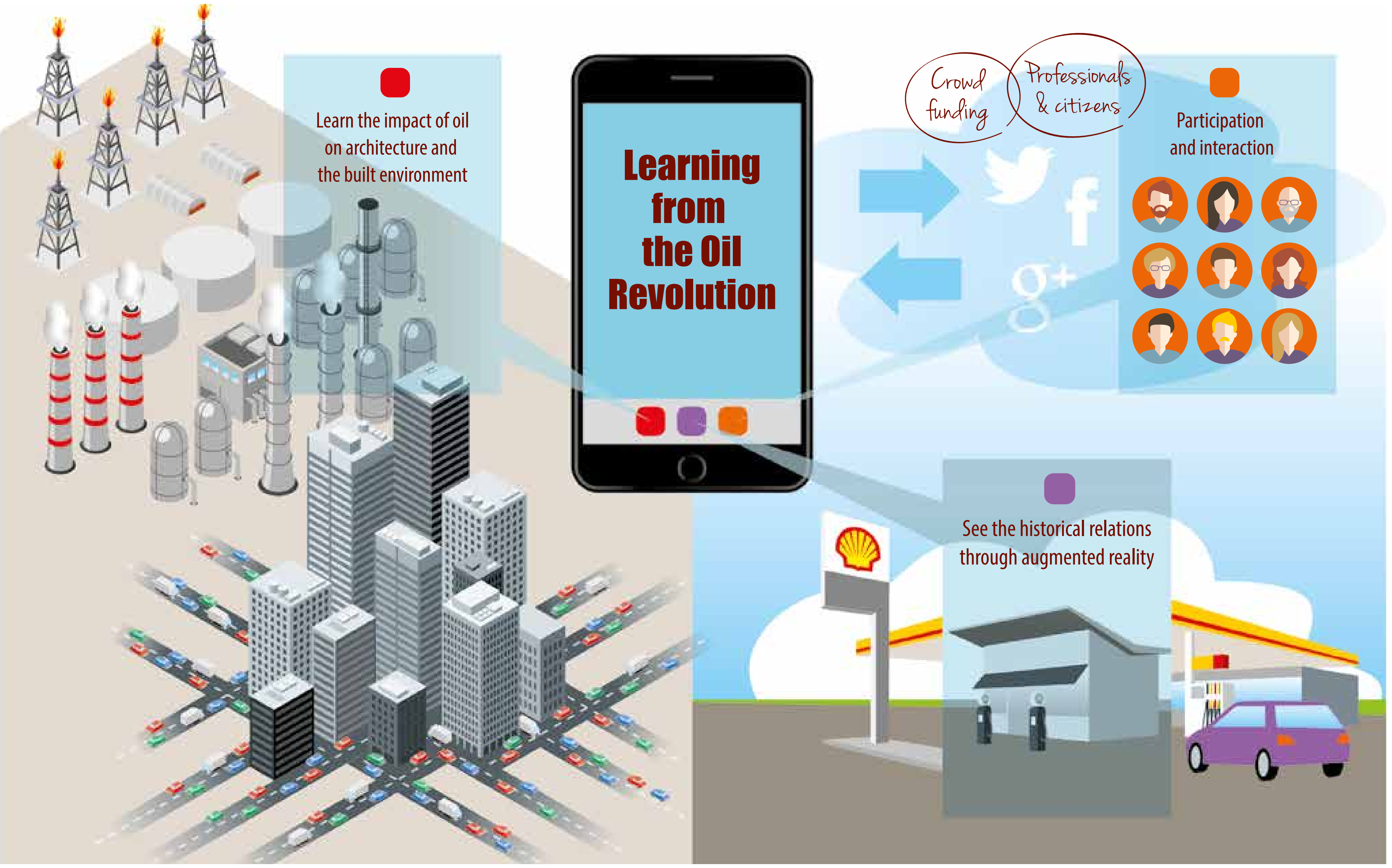


To understand the complex challenges of sustainable energy futures beyond oil and to meaningfully imagine new futures, we need to first understand the extent to which oil is part of our physical environment as well as our mindscapes. We have to understand the historical spread of oil-related industrial, administrative, and retail structures in conjunction with urban planning, policymaking, and architectural design. To help scholars and the general public track the history, location, and spread of petroleum in our built environment and to explore its impact on our spatial imagination and memory, we have devised both an open access webpage and an interactive augmented reality tool. Our case study is the Randstad and notably the Rotterdam/Den Haag area. Using an average smartphone (or tablet), users here can easily retrieve local information about oil and see it superimposed on their own landscape; they can also upload their own stories and information (citizen narrativesW) to the database. Viewers thus learn how oil infrastructure has shaped the urban form and function of the Randstad. We hope that they will also use these tools to think about the necessity to connect alternative energy futures with interconnected urban spaces.

Current computing technologies allow us to connect our readings and interpretations of the built environment to extensive background information. We can retain research data, and comprehensively and coherently, superimpose the data on representations of the built environment. Viewers can directly see where the information comes from or what it refers to. Furthermore, it is possible to establish flexible connections between digital information and what we perceive in reality. Replacing fixed narratives laid traditionally down in written form for readers, these new tools invite viewers to discover or invent new narratives.

We have to understand the historical spread of oil-related industrial, administrative, and retail structures in conjunction with urban planning, policymaking, and architectural design.

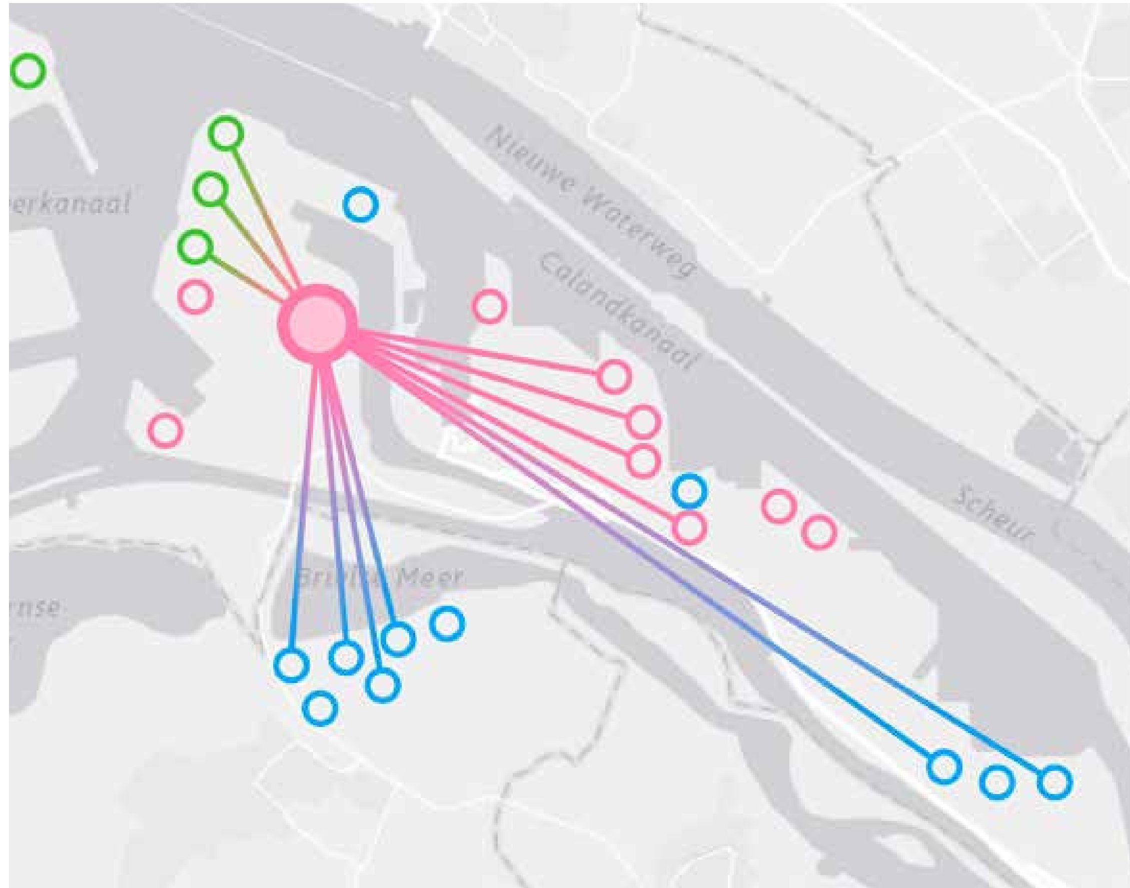
The augmented reality tool adds three dimensions to what we perceive:

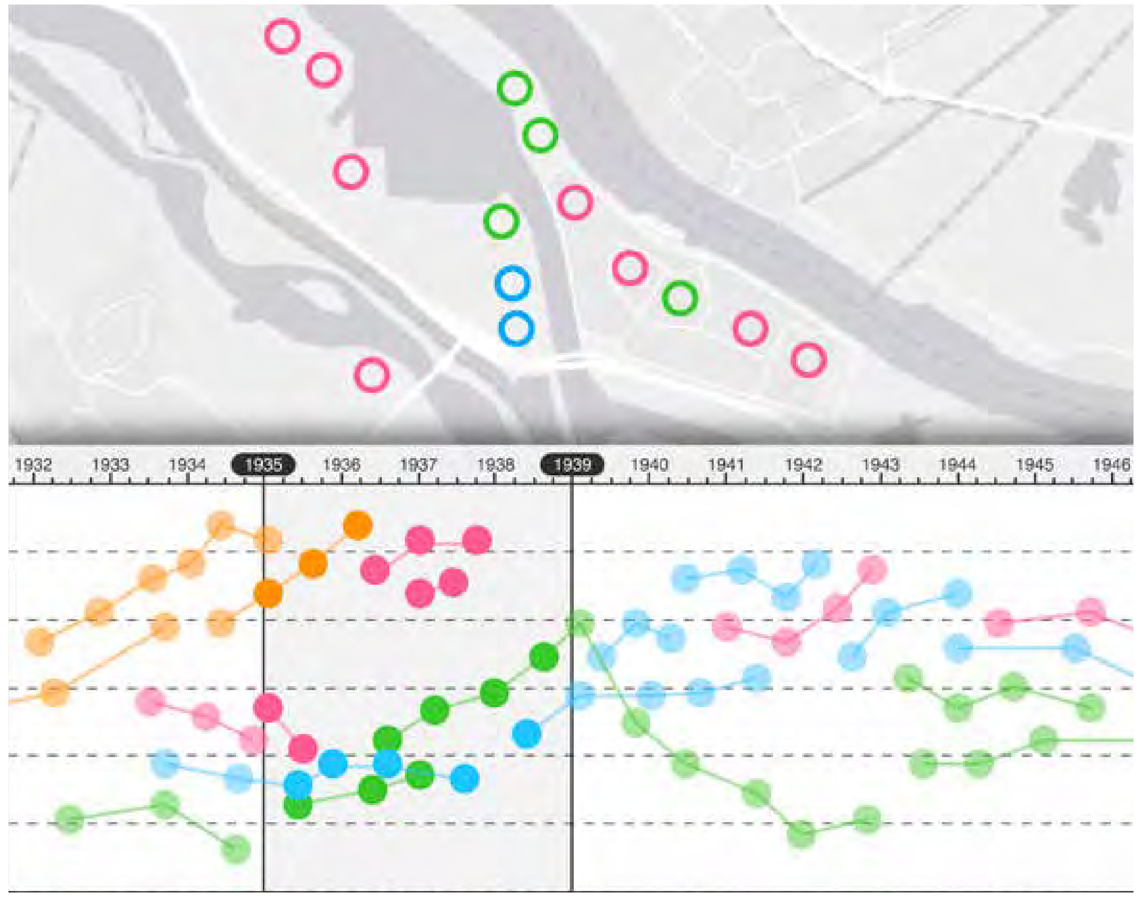
1. A historical viewpoint. It explains the tangible, physical building in front of the observer, revealing its background story: construction dates, alterations, or demolitions; why and how it was made in a certain way; the people involved in its creation and use. It traces the past through the present. Showing what was there before, it allows people to see how and why the built environment has changed.
2. A citizen viewpoint. It makes visible the intangible - commodity flows, financial patterns, and human relations - linking the built environment to its wider uses. The augmented reality tool draws information from a website (www.oilscapes.com) that is itself part of our output; it gives us the opportunity to share research data with others, especially the wider public. Users can not only explore the data with the overview the site affords but also contribute to it by uploading their own data and stories.
3. A tourist viewpoint. It facilitates understanding of the physical landscape through a topical lens—such as energy—while also appealing to curiosity.

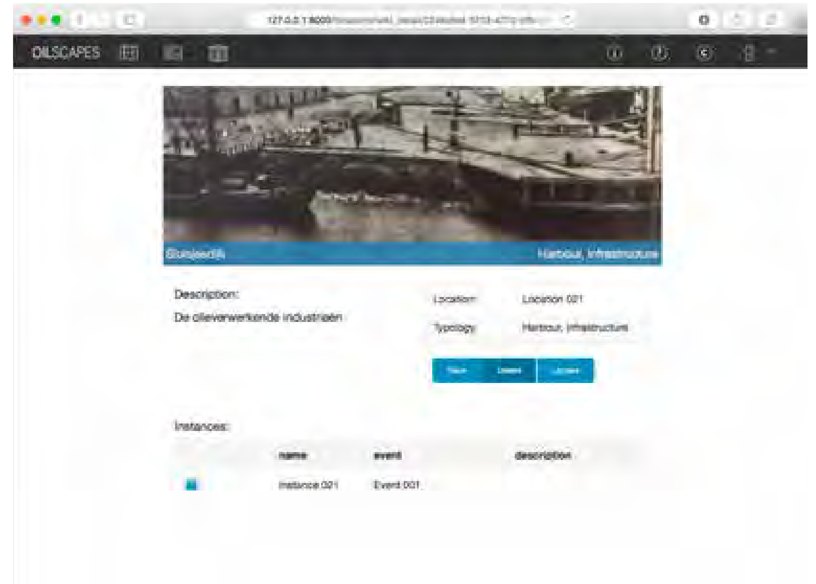
Such a tool must support a challenging combination of overview and detail, and let users make smooth transitions between views of reality and views of multimedia digital information. Even solving these problems, technical issues like the size of smartphone screens and viewing conditions can limit what viewers see. And there are human limitations too. Despite our familiarity with smartphones and daily interaction with their touchscreens, augmented reality is still largely new to most people. Many lack experience with the interfaces in question. So we have opted for simple interactions and a primarily visual digital content, with texts and diagrams playing a supporting role (e.g. for making transparent transitions from one item to another).
In an early stage we recognized that these challenges reach beyond the production of computer code alone, and the real trials lie in the user experience. The development of the interfaces followed an archetypical user-first idiom. We decided how to program and design the interface itself by making storyboard-like depictions of actions that viewers might take. We visualized the actual geospatial data with a small handpicked dataset, restricted in time and space: roughly 400 oil-related objects from the 1860s to1940 in the Port of Rotterdam and tested it with a small group of users.

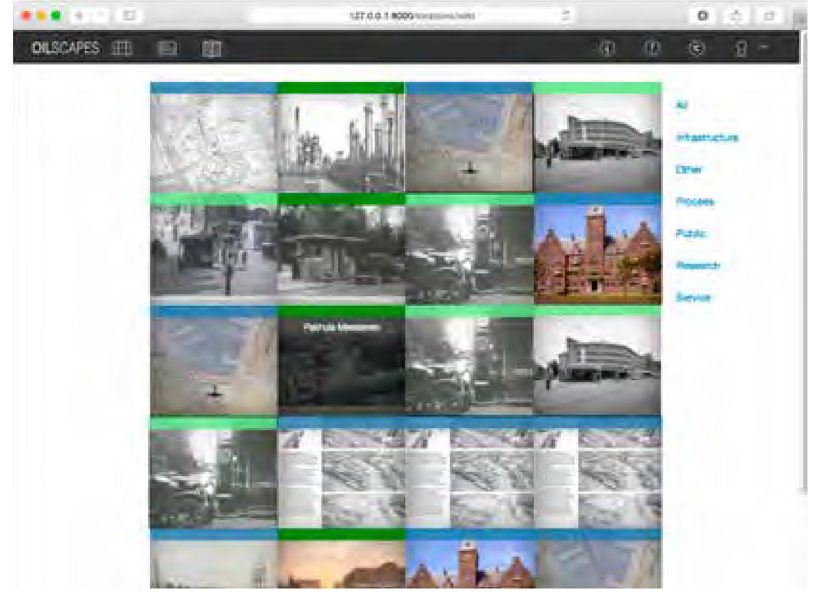
These open access tools provide a unique opportunity for citizens, scholars and planners alike to comprehend the interconnected spatial and cultural aspects of petroleum and to imagine and promote alternative energy futures.

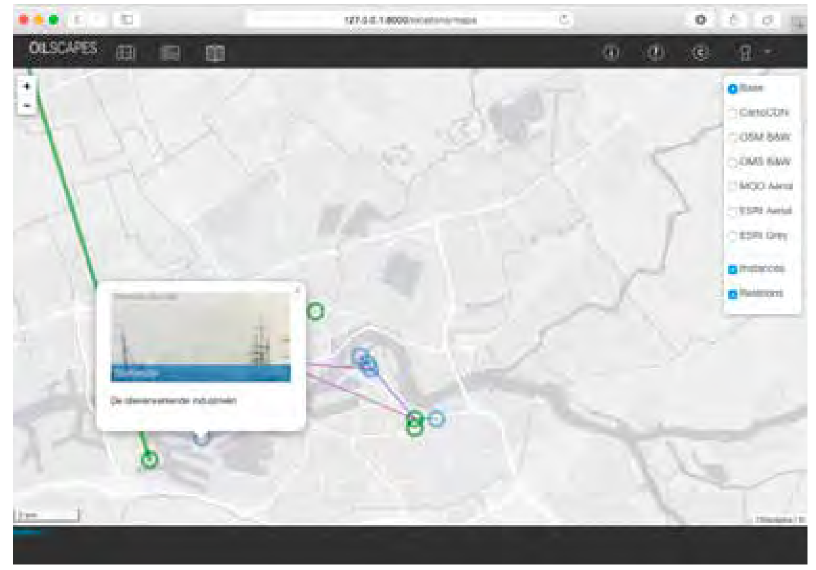
Then, based on this first experience, we enlarged the geo-temporal search-area to the greater Randstad region between 1860s and 2010, resulting in an updated collection of roughly 6000 historical objects. This time we employed several automated data acquisition strategies, mimicking the rather unbound workings of a crowd-sourced open data platform. In this stage, we realized that systematic cartographic prototyping of the augmented reality layers was needed in order to adequately display large and dynamic crowd-sourced geospatial data, and started closely collaborating with mapmakers at TU Delft. We all learned more about the concurrent and











multidisciplinary use and enrichment of data; about color, iconography, and typography in mapping; and about typological groupings, levels of scale, historical time framing, geospatial clustering, and geometric representations. We used these insights to improve the tool, and are working with test users to finalize its design.

For now, the first version is available to the public. We hope that it helps users gain a fuller understanding of the ubiquity of petroleum in our built environment, and that such understanding will also lead us all to new approaches to sustainable and green energy networks, as well as to new approaches to heritage and its preservation. For example: Once petroleum is in our past, how will we contextualize oil-related structures such as headquarters or gas stations that are part of our heritage, even already added to the national heritage list? The oil pomp Jaknikker in Schoonebeek is already included in the register of national monuments, but will we "preserve" the networked heavily polluted industrial heritage of oil – the storage tanks, pipelines, and drilling platforms, and also the highways? These open access tools provide a unique opportunity for citizens, scholars and planners alike to comprehend the interconnected spatial and cultural aspects of petroleum and to imagine and promote alternative energy futures.


web based data collection platform


mobile augmented reality experience

Delft University of Technology
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Ir. **Seyed Sedighi** PhD., Ing. **Lars van Vianen**

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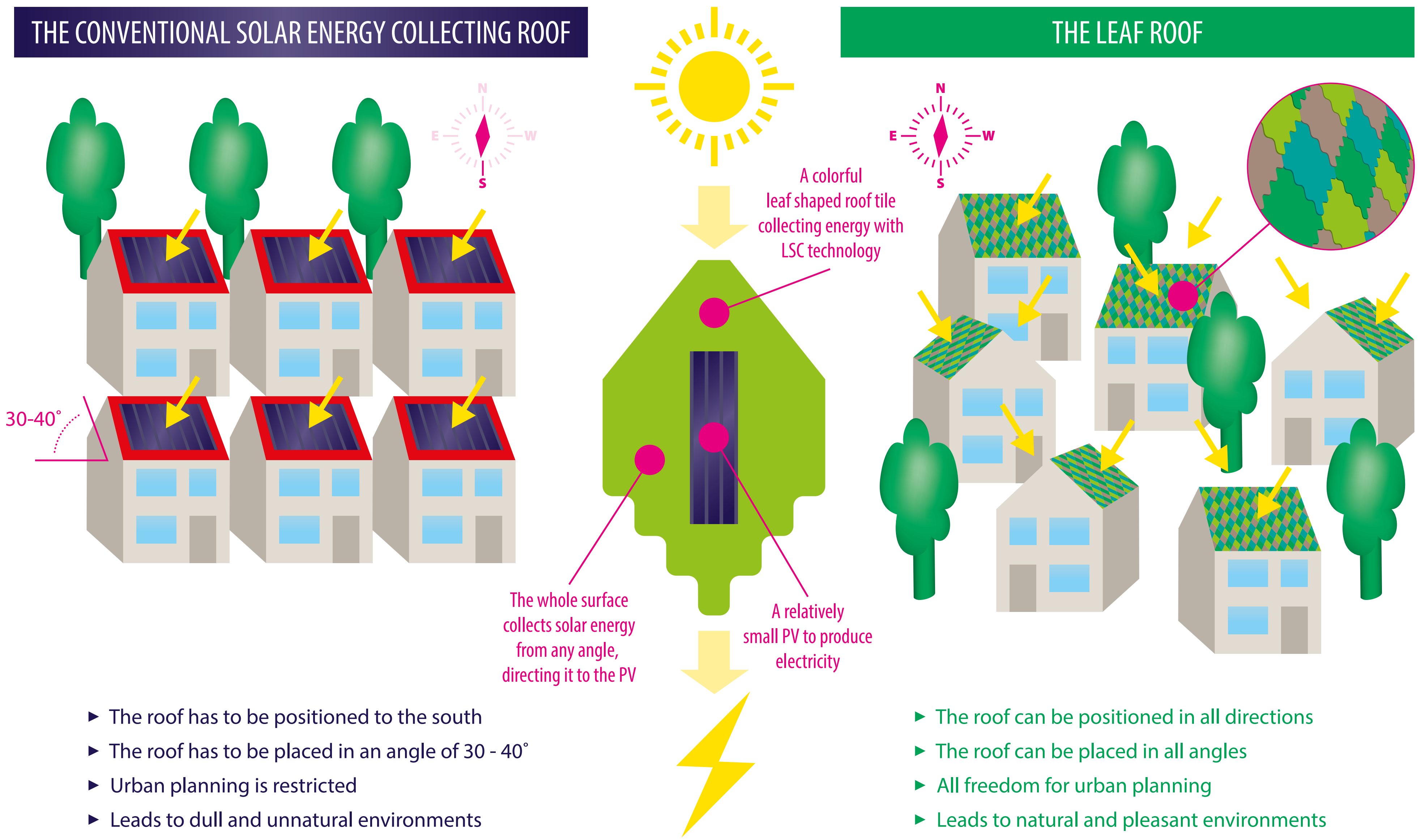
Prof. dr. **Bernard Colenbrander**, Ir. **Femke Stout**

LEAFROOF

LHP2015



The 3TU Lighthouse Leafroof project focuses on creating a roof design, inspired by the natural shape of leaves. Each of the leaf-shaped shingles incorporates the Luminescent Solar Concentrator (LSC) technology, which enables the system to "trap" solar irradiation, concentrate it to a much smaller area of PV cells and thus harvesting energy. This approach allows more freedom of building orientation and roof inclination compared to conventional PV systems. This project has successfully demonstrated a "leaf roof" prototype including feasible solar energy collection technology that also allows aesthetic design considerations.

The work has been carried out by the project partners from the Building Lighting group at the Eindhoven University of Technology (TU/e) and the Industrial Design Engineering group at University Twente (UT). TU/e was responsible for the development of the prototype while UT carried out simulations towards optimization of the design. The collaboration has been set up to establish an active interaction between the participating groups. Both, simulations and lab measurements impacted the design of a first prototype. The project concluded with a successful proof of concept. The prototype was turned into a demonstrator that was exhibited at the Dutch Design Week 2015 in Eindhoven.

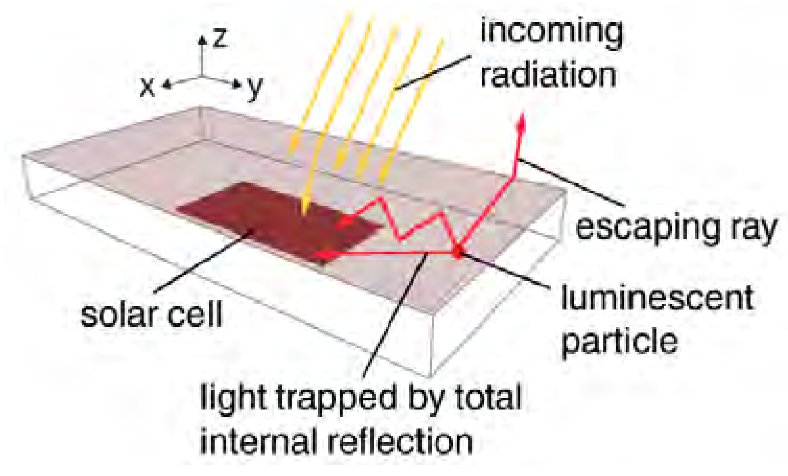


Figure 1. Working principle of an LSC taken from [1]

Luminescent solar concentration

Luminescent Solar Concentration (LSC) is a concept for harvesting solar energy that is comprised of a transparent shape acting as a lightguide with a large top surface. This lightguide consists of a material with a refractive index higher than air and containing luminescent material, usually called 'dye'. Photons originating from solar irradiance, that enter the LSC get absorbed, subsequently re-emitted at longer wavelengths and next scattered by the dye. A large fraction of the re-emitted radiation gets trapped in the lightguide as it undergoes total internal reflection at the material's surface. Because the re-emitted radiation has longer wavelengths there is hardly any secondary interaction such as re-absorption with the dye. The trapping is interrupted at the interface between the lightguide and an attached solar cell, where the photons get converted into electricity (see figure 1) [1].

Simulations

In order to identify the most suitable features of an LSC for the leaf tile, several numerical simulations has been carried out by UTwente. Three-dimensional models of waveguides with optical properties of the materials involved have been simulated using ray-tracing software PVtrace and LightTools. It allows the performance evaluation of an optical system without the physical realization of the system itself. Also the absorption and emission curves of dyes can be input of both software packages. The evaluation of the influence on LSC harvesting performance looked into parameters such as:

- Shape of the tile,
- Tile size,
- Tile thickness,
- Dye content, and the dye's absorption and emission characteristics,
- Position and size of the PV cells.

Two key simulation results will be addressed in more detail: the overall shape of the tile and the configuration of the PV cells. Table 1 provides an overview of the simulation results, which clearly point out an advantage of a rhombic shape over the other selected shapes with respect to photon density at the PV elements.
Subsequent investigation revealed that within the leaf-like shape, optimum arrangements for the PV cells are those that do not concentrate all PV cells in the center of the tile (see results overview in table 2).
Based on the discussion of the results and additional considerations with regards to potential ease of production, the configuration "Skewed parallel" has been chosen for the final design of the prototype.

Design of the prototype

The first pre-concepts of the roof tiles were simple rectangles and evolved via a rhombus to a leaf shape. The first leaf-shaped tile was developed resembling the leaf of a European birch, a common tree in the Netherlands. In order to avoid a flat and dull impression of the roof, it has been thought that the tiles should have different colors. The composing pattern was designed with different colors, among them three different green variations.
Three guiding criteria are considered during design of leaf shapes:
- overlapping,
- travelling distance, and
- positioning of solar cells.

Overlapping of tiles must be reduced to enhance the energy performance (maximize the exposed surface hence light harvesting) and reduce costs (minimizing the overlap, hence material demand). The travelling distance of photons in the lightguide must not be longer than ten centimeters in order to minimize extinction (according to the exponential Beer-Lambert law for absorption of photons in matter) and re-absorption losses due to the dye. In order to maximize the utilization of light reflected from edges via reflective foils, the orientation of the solar cell relative to the LSC system is of importance. Different colors have been chosen to realize the LSC leaf tile. The spectral absorbance and emittance for each color was measured and are shown in figure 2. One can see that according to the theory, the emission spectra are shifted to the infrared part of the irradiance spectrum, compared to the absorption spectra.
For the prototype design, a tile configuration consisting of 6 PV cells has been chosen. The total area covered by PV cells is then 312 cm2. Different configurations have been evaluated with regards to their efficiency by numerical simulations conducted by UTwente. The solar cells used are Sunpower C60 solar cells GEN C BIN J with 22,5% efficiency under Standard Text Conditions (STC). During lab tests of prototypes it has been observed that dark elements such as PV cells concentrate lots of radiation and subsequently heat up their local surrounding leading to a temperature gradient with the plastic waveguide. This, in turn, creates small bends in the prototype. The resulting mechanical stress might lead to the breakage of the interface between cell and waveguide. To overcome this drawback a configuration was chosen that allows a greater distance between cells, as shown below in fig. 3.

The leafroof prototype

The leafroof prototype has been demonstrated at the Dutch Design Week. figure 4 shows a photograph of the exhibit at the event.

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[1] Doudart de la Gree, G.C.H., Papadopoulos, A., Debije, M.G., Cox, M.G.D.M., Krumer, Z., Reinders, A.H.M.E. & Rosemann, A.L.P. (2015). A new design for luminescent solar concentrating PV roof tiles. Poster : *42nd IEEE Photovoltaic Specialists Conference 2015* (PVSC-42), 14-19 June 2015, New Orleans, LA
[2] Rosemann, A., Doudart de la Grée, G., Papadopoulos, A., Debije, M., Cox, M., Reinders, A. and van Zeeland, F., Leaf Roof, *SPOOL, doi:10.7480/spool.2015.2.966,* 2(2), pp 21-23, 2015

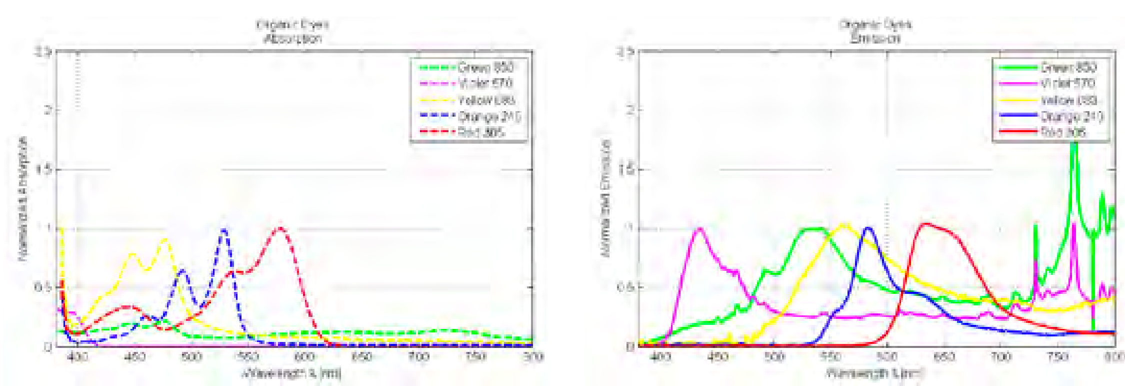


Figure 2. Normalized spectral absorbance (left) and emittance (right) of four different dyes

PV shingles with Luminiscent Solar Concentrator technology

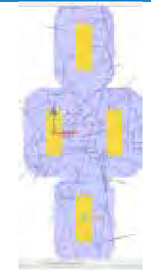
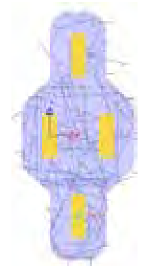
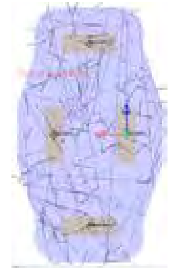
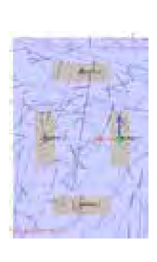
Config.	4 units fused	Saturn	Rhombic	Barrel	Barrel 80mm	Rectangle
Layout						
# harvested rays	18809	19562	20661	20305	18697	14882
Area	1290 cm²	1510 cm²	1380 cm²	1560 cm²	2110 cm²	1400 cm²
Photons per cm²	14.6	13.0	15.0	13.0	8.7	10.6

Table 1. Simulation results for variation of lightguide shapes for a four cells configuration

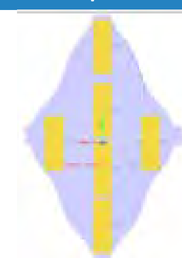
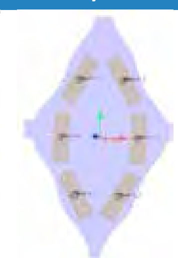
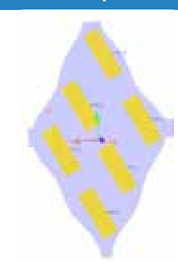
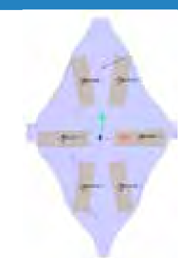
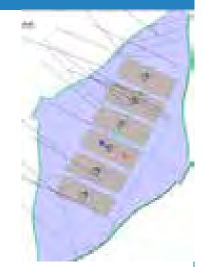
Config.	Veins parallel	Eye	Skewed parallel	Snowflake	Parallel
Layout					
# harvested rays	24246	24088	23708	23381	21222
Rays per cell	4041	4015	3951	3897	3537

Table 2. Simulation results of six cells configurations.

This project has successfully demonstrated a "leaf roof" prototype including feasible solar energy collection technology that also allows aesthetic design considerations.

Figure 4. The Leafroof prototype exhibited at the DDW 2015

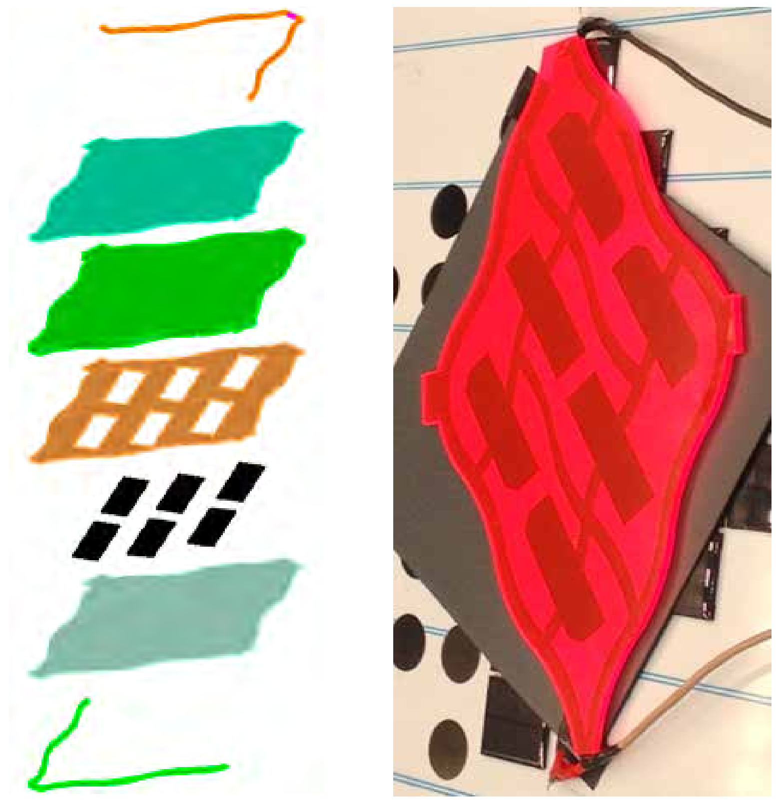


Figure 3. Photo of the final prototype: design (left) and photo of a complete tile (right)

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Ir. Ing. **Guillaume Doudart de la Grée**,
ir.MEng. **Argyrios Papadopoulos,** Dr. **Michael Debije,**
Ir. **Mark Cox, Riccardo Capperucci**

University of Twente
Prof. Dr. **Angèle Reinders,** Dr. **Zachar Krumer**

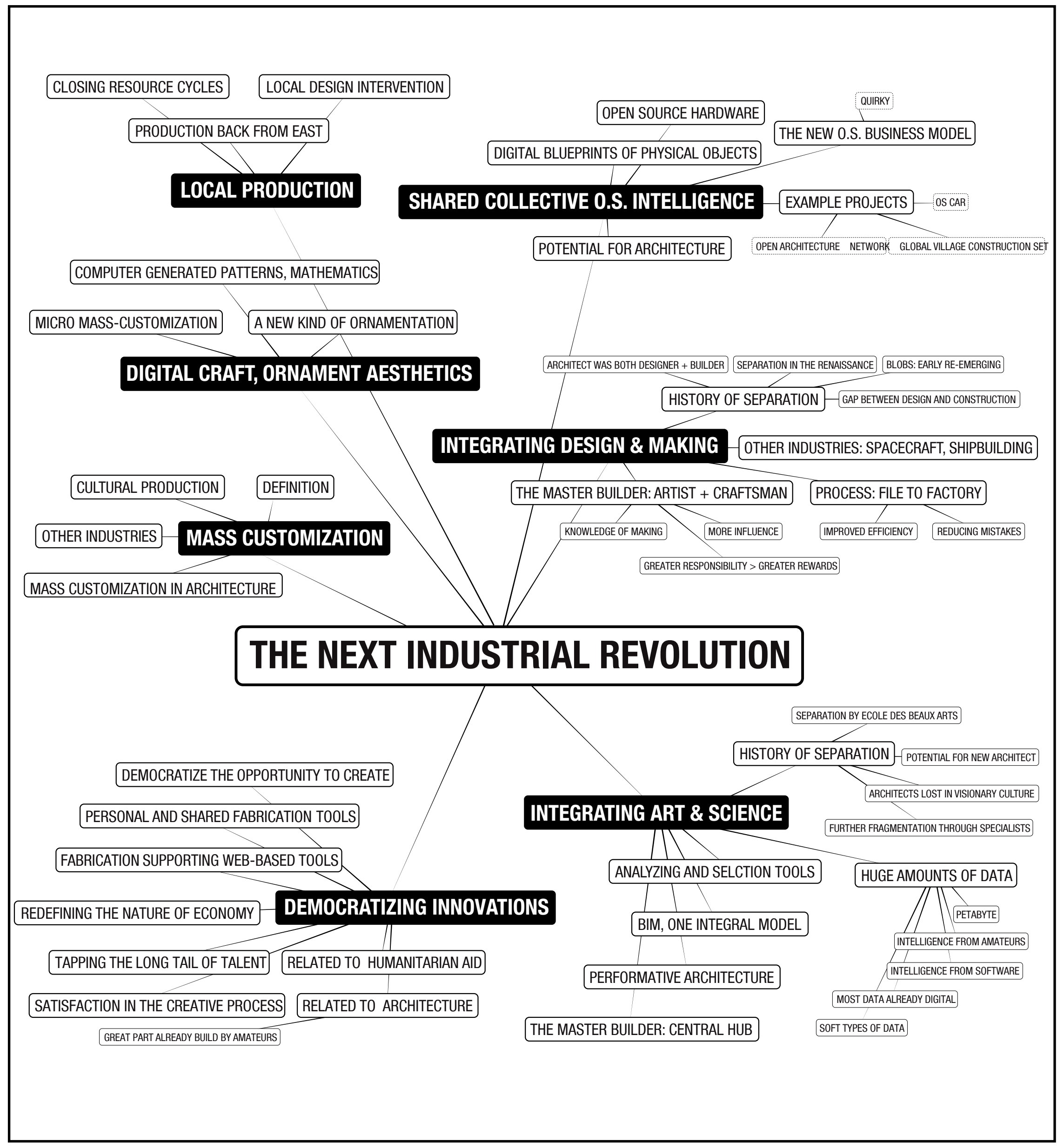
Municipality of Laarbeek
mr. **Frans van Zeeland**

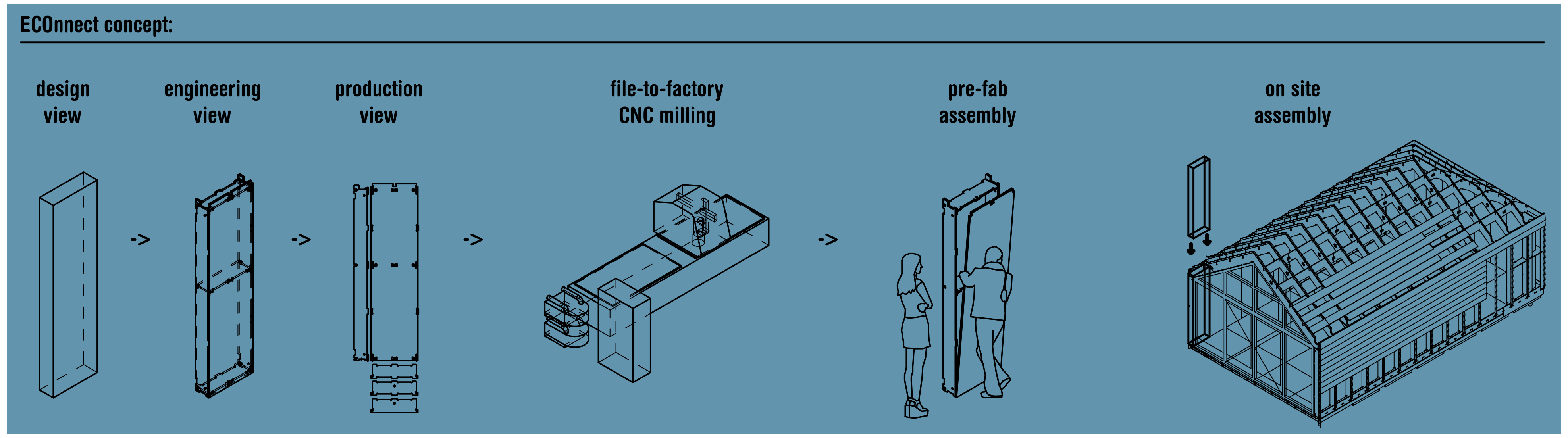
While architects and engineers work already entirely digitally to create our build environment, contractors and craftsmen on the building site still rely mostly on printed paper plans. This practice bears the risk of failure costs. With a growing demand for more sustainable and affordable housing it seems to be about time to start the digital revolution in this sector as well. With the help of computer controlled machines such as a CNC router we are able to fabricate building components based directly on the design of the architects. The digitally created files are sent to a router that cuts components out of wooden or natural fiberboards with high accuracy and speed. While all details that form a system of pre-engineered solutions will form a database of building blocks, costs will be lowered and quality increased. Within the Product Development Lab project the file to factory approach is investigated in form of the first fully digitally produced house as a demonstrator on the campus of the Faculty of Architecture. The project is embedded in the graduation education program, and offers a unique environment to explore the possibilities but also restrains of this approach.

Current building practice and potential
Every building is unique, while the majority of problems during erection seem to continue to repeat themselves. It is up to the craftsmen to solve problems on the fly. Some of the related costs are named failure costs. In the Netherlands, these failure costs in the building industry are an estimated 10,6% of its total turnover, resulting in annual costs of over 5 billion euro.

Imagine a building assembled from a well thought through kit of parts, like a kitchen from Ikea; with an infinite number of options available, the system used allows freedom to design within its system boundaries. Installations like light, water and gas or the placement of different third parties appliances are already taking into account and based on a highly industrialized production chain, meaning that the costs remain low and

With the help of computer controlled machines such as a CNC router we are able to fabricate building components based directly on the design of the architects.





the task on site can be done with less effort.
File to Factory – digital fabrication – CNC milling
Such mass-customization in design combined with the benefits of industrial production could become possible with digital fabrication. Emerging digitally driven construction processes like 3D printing and CNC milling create a direct link between digital and physical. This so called file-to-factory process has the potential to bridge the gap between designing and making, as digital design information is directly used in construction to drive computer controlled machinery. While most of the productions in the automotive, marine and aerospace industries are already digitally designed and digitally produced with highly advanced fully automated production technologies, the quality of our buildings often still relies on the sharpness of the pencil point on the building site. Automation is the solution to our demands for individualism, comfort and human being. It allows for products with high precision, quality and at an affordable price.

Automation is the solution to our demands for individualism, comfort and human being.

Project goals
Therefore, in this PD Lab project we do not use expensive technologies to make even more expensive architecture, but use the potential of these technologies to create high quality, low energy consumption affordable buildings that respond to our demanding challenge towards an energy neutral future. We would like to increase the quality of the building process and the building itself. The question is how this method or process can contribute to an economic and ecological advantage for the building sector. With this lighthouse project a platform will be developed to explore the applications of building sector related product development – the PD Lab.

Building system
Currently CNC milling already has great potential to create fully digitally produced building structures with integrated friction-fit connections, as shown in professor Larry Sass's (MIT) CNC house at MOMA and the open-source Wikihouse project. Pieter Stoutjesdijk developed this principle further with ECOnnect in Delft, using 600mm wide demountable integrated building components and making optimal use of the third axis on a CNC router to create 2.5D connections. Boards from agricultural waste and wood serve as the main building materials, therefore the structures roughly store their own weight in carbon emissions. Through the file-to-factory process, the components have the potential to be mass customized globally before being produced locally. The precision of the digital production process allows for fast and easy assembly and disassembly through integrated connections and airtight construction details. While the use of standardized building components accepts the reuse of the components like Lego blocks, the building itself allows a high amount of flexibility over time. Due to the use of environmental friendly materials the blocks themselves can be easily disassembled after its lifetime and fed back into the ecological cycle.

Conclusion
We take a pragmatic approach to architecture from an understanding of manufacturing and an appreciation of the way things go together. Up to now we have already concluded that the engineering part of such a system demands a high collaboration within all joining disciplines, communication on a digital platform or one common 3D model seems to be essential to allow the integration of all components. Scale tests and mock-ups to test fit and assembling orders become more and more essential; also as a base for discussion. In addition to the technological challenges a design methodology was set up as well to validate and judge requirements and demands. First iterations already showed that details and components will look differently if the requirements are set up differently.

The role of product design changes from delivering systems prior to the actual design and building process towards an integrated product building solutions. Here, the PD Lab itself is a case study and serves as a platform to explore new methods in product design. The project is supported by teaching activities at TUD.

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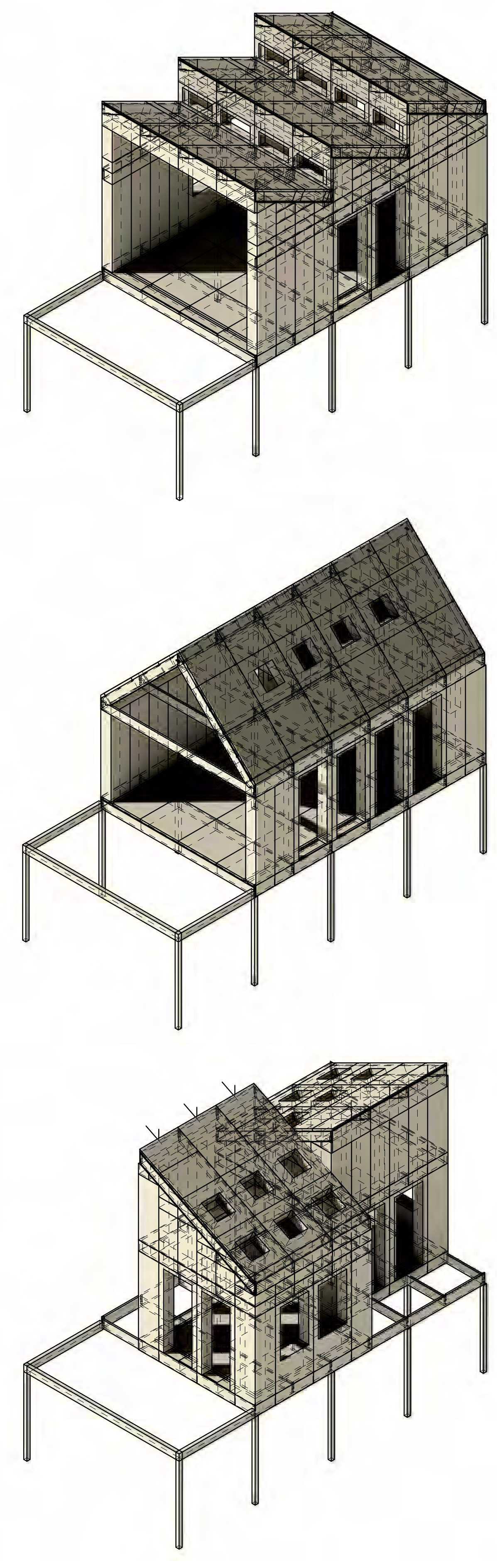
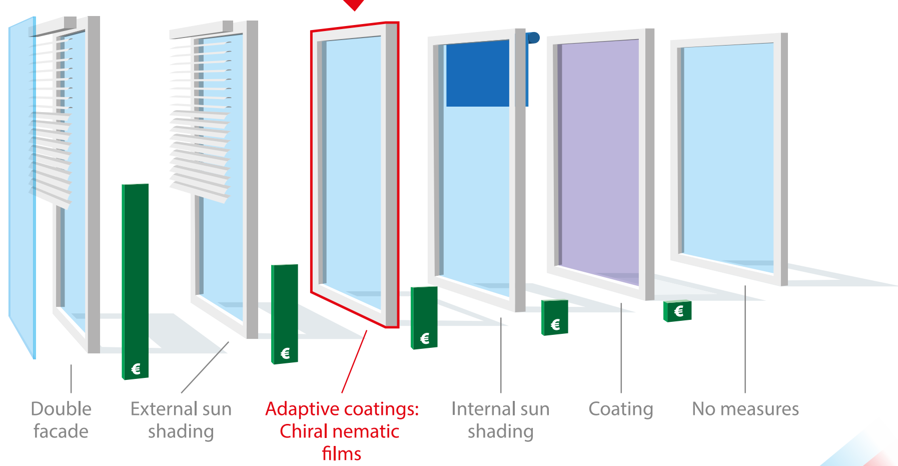
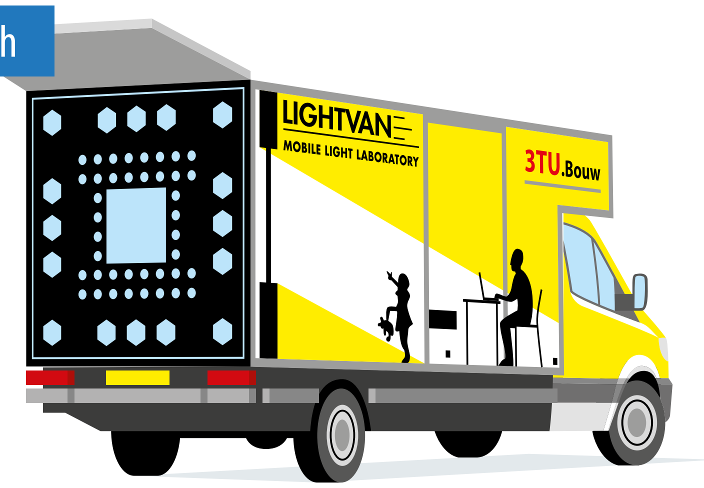
Fabrication Factory, ECOnnect, Rollecate bv, Reynobond Alcoa Architectural Products, HECO-Schrauben GmbH & Co, Festool Group GmbH & Co, Maasstad Hout & Plaat bv, Isolvas Oisterwijk BV, PARK4ALL b.v.



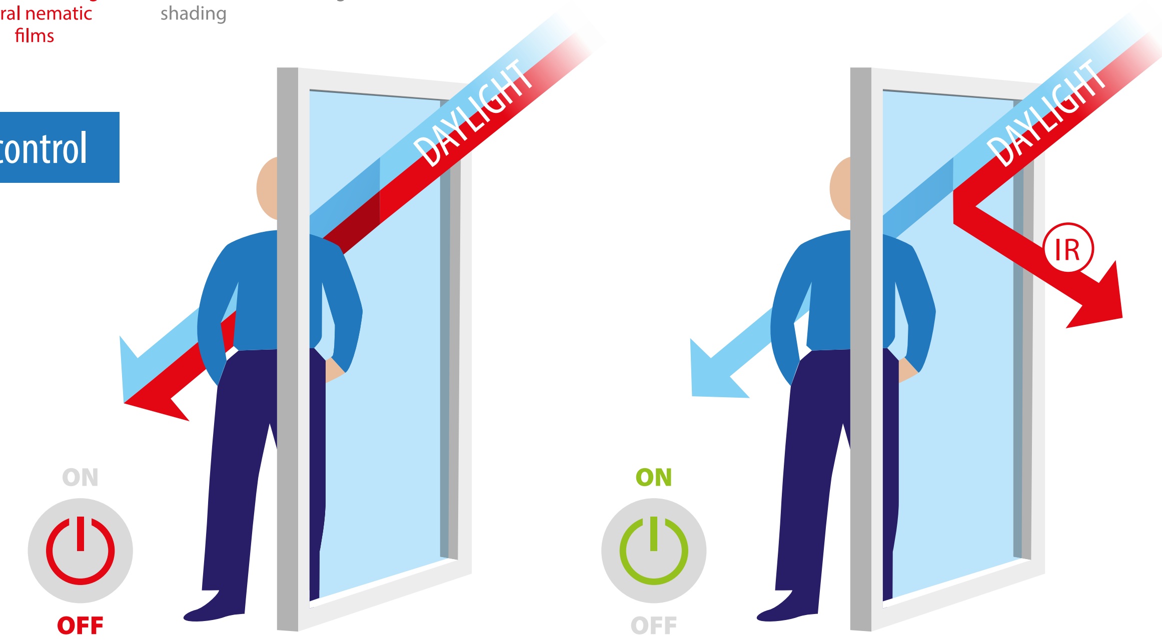
Cost efficiency



Research



Dynamic daylight control



- Window is completely transparent
- In the winter heating by IR light
- In the summer no heating by IR light
- No cooling needed, no cooling costs

The challenge of the future is to minimize the energy consumption of buildings while maintaining an optimal comfort level in the interior. Controlling the energy streams into and out of the building and daylight management play an important role. Polymer technologies and especially responsive liquid crystal networks can improve the daylight management capabilities of building envelopes by making it adaptive on the Nano scale. A similar technology as used in this project is widely applied in LCD screens today but the integration into building technology poses many challenges.
In order to explore the possibilities of transferring polymer technologies into the field of building technology, an interdisciplinary research team has been established, covering the scientific areas of facades design and building physics on one side and chemical engineering on the other.
In a first step the PolyArch project focuses on applying reflective coatings on glass as a means of sun shading. Experiments and simulation show that adaptive coatings can have a clear energetic advantage when compared to current fixed metallic coatings.
The project outlines the need for further research on technology development, colouration light perception studies, energy savings potential and other high potential applications.

The building envelope as a potential field of application

Building envelopes need to deal with many, sometimes conflicting functions: Generally a maximum of natural lighting is desired to reduce the need for energy for artificial lighting which in today's buildings accounts for approximately 30% of the total electricity demand. But daylight also contains a lot of energy that is sometimes unwanted and needs to be controlled For example, we need to block sun radiation in summer to prevent overheating, whereas in winter this incoming energy is desired to reduce the need for heating energy.
There are several traditional strategies to control daylight such as metallic coatings, exterior and interior sunshades. Existing daylight management strategies are rather inefficient or they involve considerable constructive effort, high investment costs and high maintenance and cleaning expenditures. On top of that the architectural impact of additional external or internal functional layers is big and they often do not comply with the designer's vision.
In this first approach, the project focuses on daylight management, but responsive polymer coatings also show a great potential for other building related applications such as responsive surfaces to control heat absorption/emission, responsive insulation and colour change of architectural surfaces.

The challenge of the future is to minimize the energy consumption of buildings while maintaining an optimal comfort level in the interior

New polymer coating technologies

Our collaborating party, the Department of Functional Organic Materials and Devices at the TU/e is a leader in developing new responsive coatings. These materials are able to switch physical properties such as colour, reflectance and heat transfer. For instance, so called 'responsive liquid crystal networks' may adapt the degree of reflection. The position of the reflection band in the electromagnetic spectrum can be dynamically shifted in response to temperature or light. Reflection can be shifted in the near infrared part of the spectrum, thus controlling heat flux without affecting transparency in the visible part of the spectrum. When applied on a glass window this film determines whether the heating part of sun light is being transmitted or reflected, thus offering a new and unique method to manage daylight in the built environment.

Potential energetic performance and lighting quality

Due to the high intensity of sunlight in the wavelength range just outside the visible region, it is worthwhile to explore whether reflectivity of the switchable NIR coating in this range can be improved. A simulation study was carried out with idealized dynamic reflection properties in the range between 700 and 800 nm, to evaluate what the effect of such an improvement would be. The simulation results showed that for a south facing office zone in the climate of Madrid, an additional 15% of cooling energy reduction is possible compared to the existing window prototype.
The analysis of the samples' transmittances in the visible wavelength region has revealed that there is no negative impact on the interior illumination by daylight. At the same time, their spectral transmittance does not impact the quality of the light entering a building. Still it needs more research into perception studies because the film is light angle dependent which means that the colour disturbance could occur at different angles of sight.

It shows that the technology would reduce the cooling needs for south facing offices by about 15% as compared to existing static coatings.

Conclusion and outlook

Up to now, the focus of the PolyArch project lies in applying reflective coatings on glass as a means of sun shading. A core feature of this technology is that the effect can be turned on and off. One can imagine a mirror that would switch to a transparent state. The switching determines if the sun radiation is transmitted into the room or reflected (in summer).
First samples have been created, measured and simulated for a coating in the infrared light spectrum, just outside the visible light. The human eye would thus not see the switching effect. It shows that the technology would reduce the cooling needs for south facing offices by about 15% as compared to existing static coatings.
Theoretically the reflection could even be extended into the visible light range, displaying a

sun-glass effect to prevent discomfort by glare and delivering a higher energetic effect.
Since the coating is responsive, this technology will potentially deliver a much better performance than current static metallic coatings.
Polymer coatings can be applied by embedding them into prefabricated insulated glass units.
That means it can relatively easy be adopted into established design and building processes without the need for additional constructive effort for external sun shading devices. We can expect a high acceptance by decision-making parties.
But other applications need to be researched as well, such as opaque building envelopes that change colour according to architectural desires or absorbing and reflecting surfaces. 3TU.Bouw funding enabled a proof of concept for applying polymer technologies to the field of building construction and justifies the need for research into coloration light perception studies, energy savings potential, application possibilities and of course the development of switchable polymer coatings.

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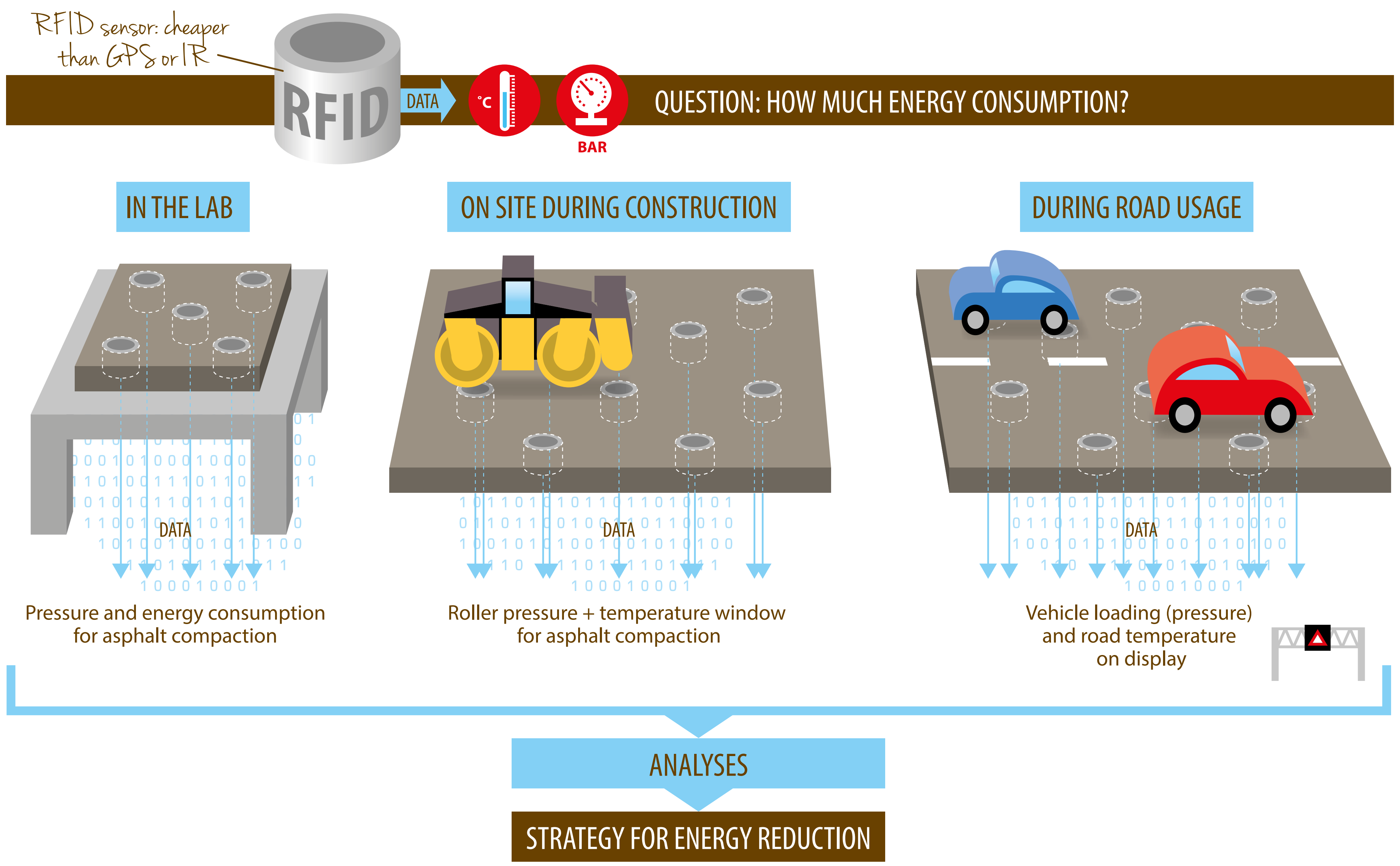
monitoring compaction temperature during asphalt construction



This project set out to prove that Radio Frequency Identification (RFID) sensors can be used to monitor, to begin with, compaction temperature and pressure during the asphalt construction process and afterwards during a typical life cycle of the paved asphalt layer. Several RFID sensor manufacturers have suggested that the technology is robust enough to be applied in the rather harsh asphalt construction environment. If it is and if sensors become small enough ("smart dust"), it will become possible to store all relevant composition, construction and performance data on sensors in the asphalt. It would revolutionize pavement management by having the information available "on the spot". By having car sensor data linked to pavement locations and sensors, a smart road that actually signals when repairs are needed becomes feasible.
The aim of this LightHouse project was to see if the sensors are indeed robust and small enough and to find out if they could be used in practical applications. We started by firstly finding temperature and pressure sensors that could withstand the high asphalt mix temperatures and heavy pressures of roller compactors and the resulting shear stresses between aggregates. The sensors were then to be tested in two laboratory and two site testing phases.

It would revolutionize pavement management by having the information available "on the spot".

Finding appropriate sensors
Asphalt construction is an intensive process where sensors will have to survive high asphalt temperatures and compaction pressures during paving and compaction. A desk study and initial contact with several RFID manufacturers highlighted a first challenge. While several RFID temperature sensors were found to be suitable for possible use in asphalt applications, few suitable pressure sensors were found. A choice was therefore made to test passive RFID temperature sensors given that they are wireless, make use of an external energy supply (reader) and are relatively inexpensive when compared to active sensors.

Sensor placement in asphalt layers
A huge challenge turned out to be the placement of the sensors in the asphalt layer so that it remains stable during measurements. Anchoring was trailed in asphalt slabs including fixing it to plates, testing mastic asphalt mounting blocks and using bitumen strips. Anchoring success was measured against displacement, tilt, compaction and pressure against the sensor. The placements were tested using a gyrator and a hand-held roller compactor. A multi-criteria analysis showed the mastic asphalt blocks and bitumen strips to be most suitable for mounting the sensor in the asphalt layer.

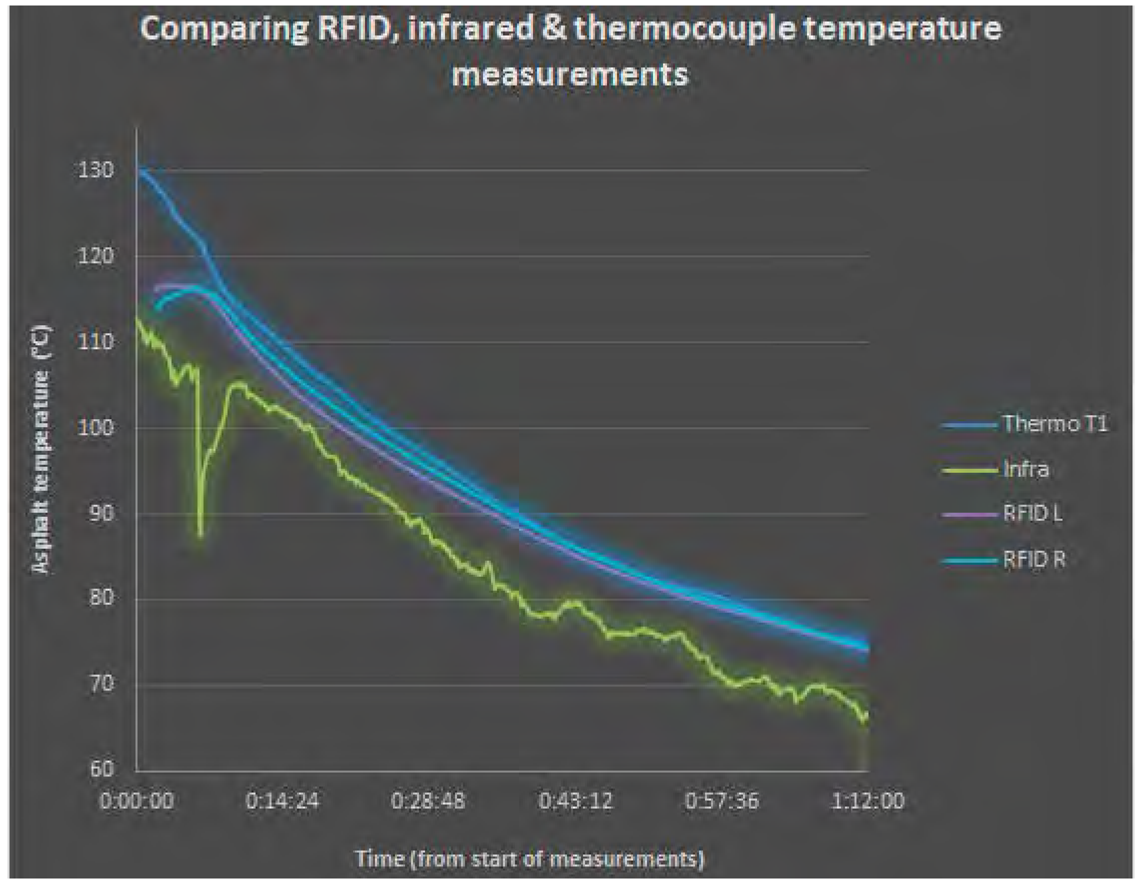
Pilot installation on site
Mounting the RFID sensor with molten mastic asphalt proved indeed to be the most secure method during several field tests. A comparison of the core temperature measurements using the thermocouples and RFID sensors shows good correlation between the respective cooling curves and a difference of ±2°C between the in-asphalt temperature measurements. This difference is not considered significant given the temperature ranges in which compaction takes place. The RFID sensor is most reliable with no failures during the on-site tests. However, the thermocouples reliability is questionable given inaccurate results in two tests. This probably occurred because thermocouples tend to move under compaction. The surface temperature measurements correlate well with the sensor's in-asphalt measurements and as expected, are lower given the water used during compaction and ambient weather conditions.

Vehicle load simulator tests
The Road and Railroads Research Laboratory of Delft University of Technology has a linear accelerated testing facility, LINTRACK. Since no suitable pressure sensor could be found, work at the facility focused on the integration of the temperature sensor into the measurement process. The limitations of the RFID technology became immediately apparent given that the loading machine is located inside a temperature control room and has to be completely closed during testing. The reader's limited reach resulted in no measurements being able to be undertaken in real time. For field applications this means that the road needs to be closed to traffic to take readings, which seriously limits the applications. The sensor was, nevertheless, able to withstand the heavy vibrations and harsh environment of the LINTRACK facility evidenced by the successful temperature measurements taken afterwards and with no apparent damage to the sensors during testing. Also, in this project the sensors are placed underneath Hot Mix Asphalt (ZOAB) and they withstood those temperatures without damage.

Project Enschede – long term temperature monitoring
In cooperation with the Gemeente Enschede, several RFID sensors are currently being installed in newly constructed surfacing layers in the city. The installed sensors will be monitored by ASPARi researchers over the next two years to assess its long-term monitoring capabilities, especially during the winter months.

In cooperation with the Gemeente Enschede, several RFID sensors are currently being installed in newly constructed asphalt layers in the city

Promising benefits for monitoring temperature but .....
The results of this project show that the passive RFID sensor is a feasible technology to monitor temperature progression during compaction albeit for asphalt having an upper temperature threshold of approximately 125°C. It also appears feasible for monitoring asphalt temperature during winter periods when freeze-thaw cycles may damage and reduce the performance of the asphalt layer.
However, while the technology is promising, the study has highlighted limitations. Firstly, the absence of a suitable pressure sensor to capture the density progression during compaction activities is disappointing. Secondly, the limited temperature range probably excludes it being applied to the majority of HMA mixtures here in the Netherlands, although in the TU Delft application they were used under HMA. Thirdly, taking sensor readings is labour-intensive and cumbersome given the need to place the reader very close to the sensor (within 20cm) to take accurate readings. This presents significant safety problems in a heavy machinery environment and in heavy traffic during the life of the asphalt layer. Also, considering the size and the precautions needed to place the sensors, adding them in bulk for track & trace pavement management is not yet feasible.
Applying appropriate sensor technology in the asphalt construction process requires predictable and reproducible sensor performance given the nature of the asphalt construction process. Placing any sensor in the asphalt layer during construction is both challenging and promising. It is challenging since it needs to be done in a non-invasive manner and in such a way that it does not disturb the very properties being measured. Promising, since if done properly, it opens up opportunities for measuring a range of properties during and after construction given the rapid development of sensor technology. The work into studying suitable sensors, sensor modalities and wireless communication will continue given the results of this project. Further industrial partners are invited to contact us and discuss the possibilities.



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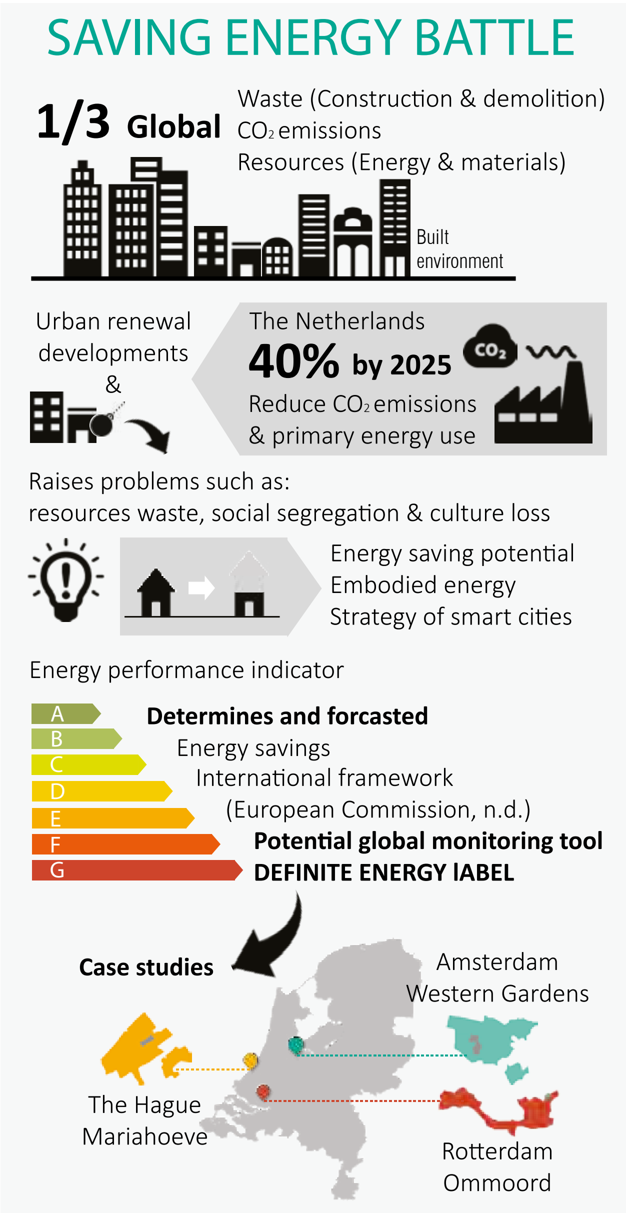

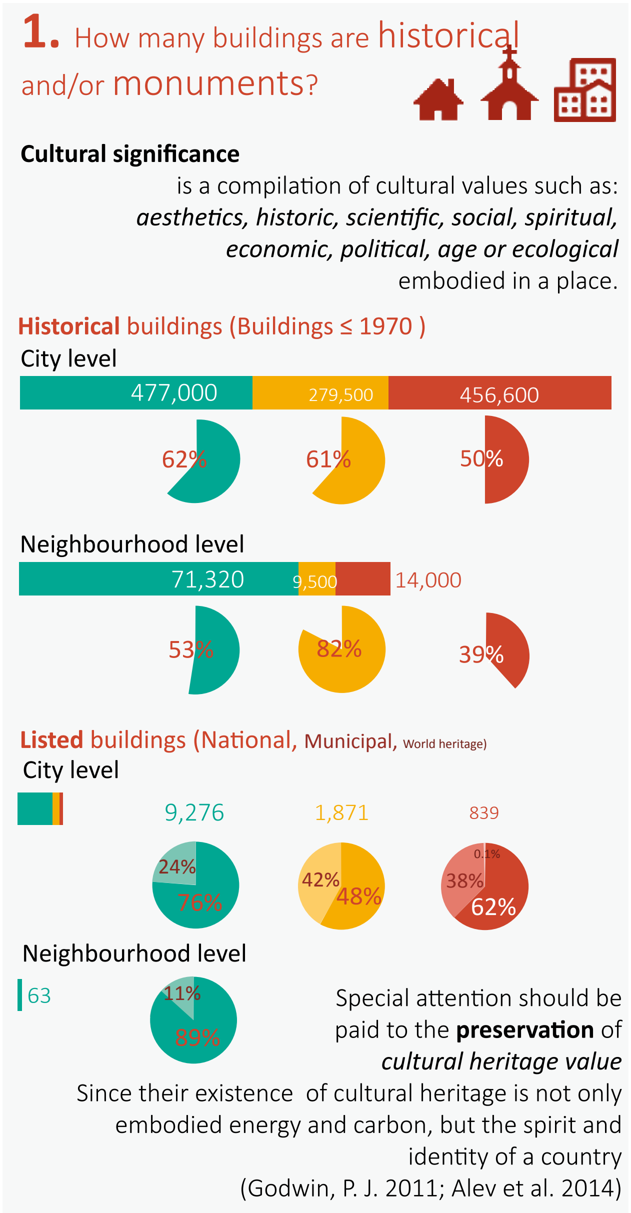

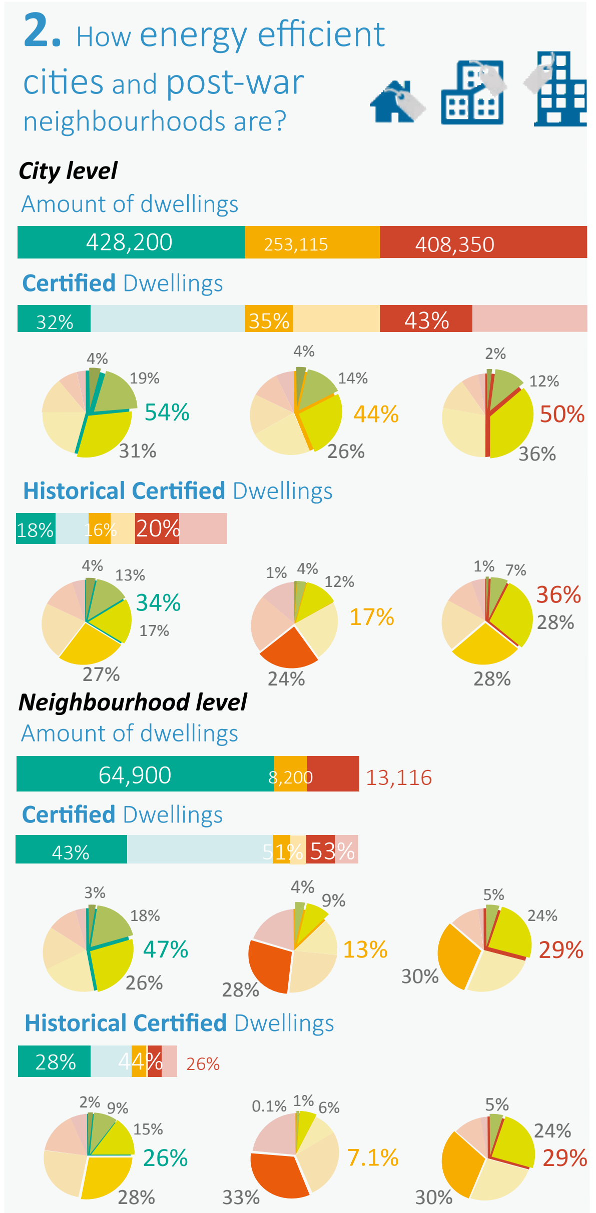

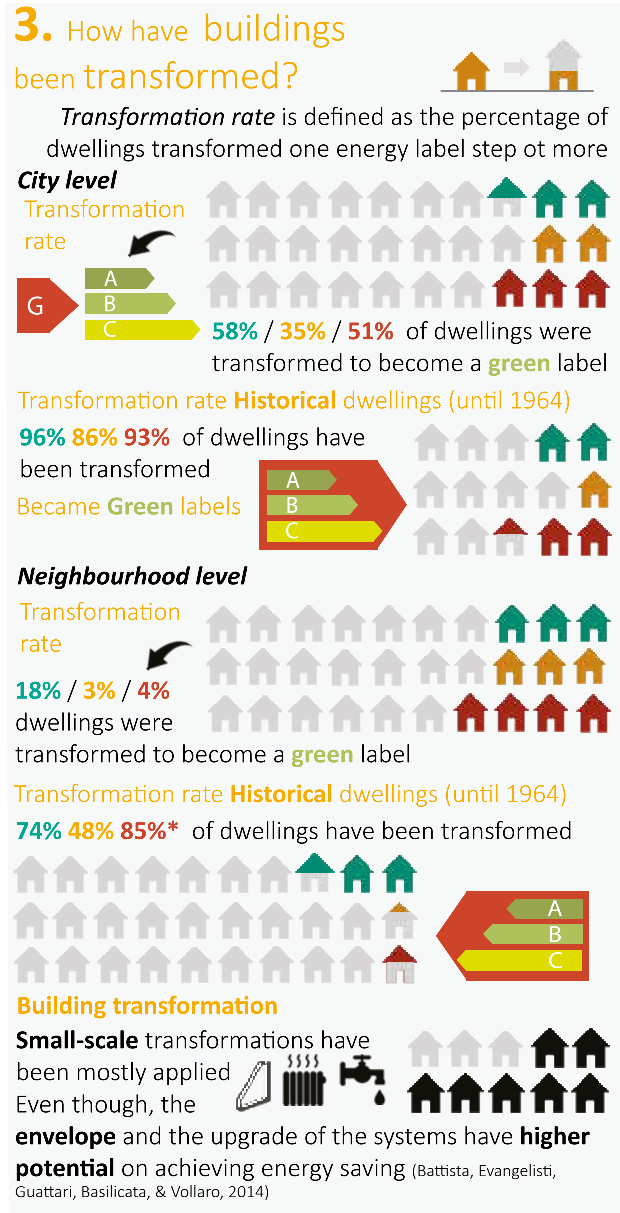

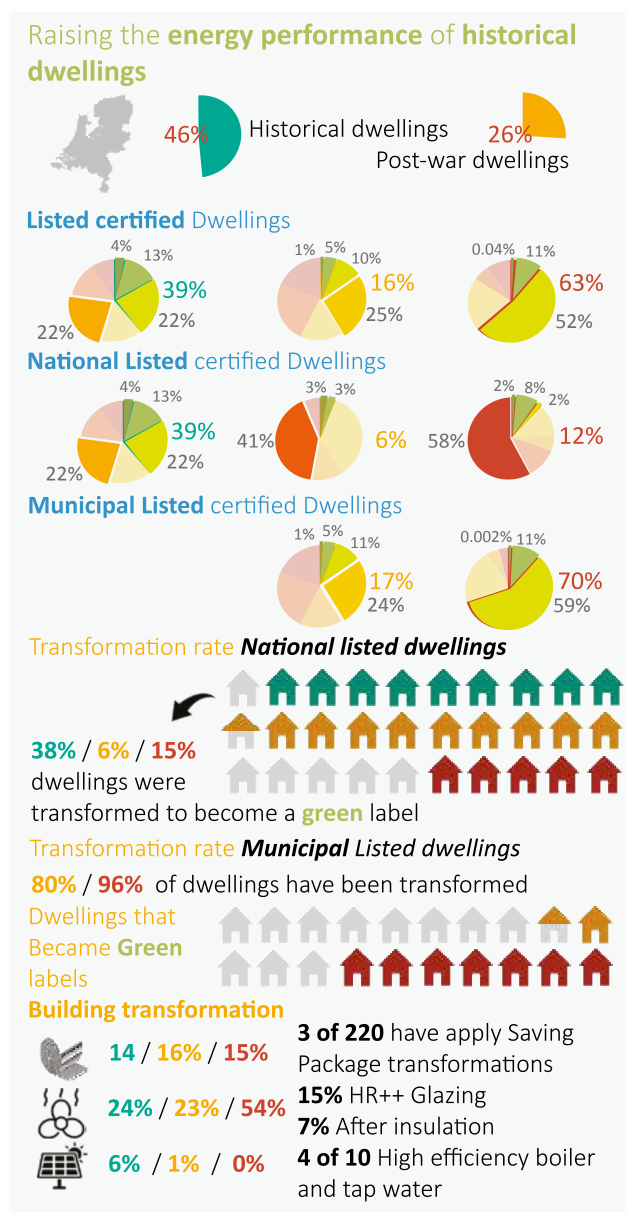

Energy efficiency is a priority to many cities, with programs being implemented to stimulate energy savings in the built environment. Cities aim to reduce carbon footprint, but also to cut energy costs. This has led to urban renewal developments, where neighborhoods were demolished and replaced by new neighborhoods, assumingly more sustainable. Some neighborhoods built during the post-war period are now under trial for their poor materialization and energy inefficiency. Though, they are also the massive expression of a rising idealism from the 20s and 30s, where public officers and professionals, as urban planners, architects and engineers had the opportunity to give the working class a larger, healthier and greener living environment. The demolition of these neighborhoods is accompanied by problems such as waste of resources, social segregation and cultural loss. Instead, the main energy and CO2 saving potential lies in the existing building stock (Petersdorff et al, 2006; Energy DG, 2013). Transformations can save not only energy costs, but also embodied energy. When it comes to heritage-designated buildings special attention should be paid to the preservation of their heritage values (Godwin, P. J. 2011; Alev et al. 2014). Their existence is not only embodied energy and carbon emissions, but also the spirit and identity of a community (Godwin, P. J. 2011).

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There is a growing body of knowledge on energy efficiency in the built environment, though, primarily derived from samples (Murphy, 2014), models (Melo et al., 2014), and/or buildings owned by housing associations (Nieboer et al., 2012). There is still very little known on the energy efficiency of post-war neighborhoods, and even less on the contribution of private homeowners' efforts to raise energy savings through the transformation of their buildings. Yet, their transformation patterns can feed the debate and help determine the energy efficiency of buildings and post-war neighborhoods. A framework for energy performance certification, as the Energy label, provides information on the energy efficiency of buildings, but also enables energy savings to be determined and forecasted. It also systematically records information about the building stock and its transformation. There is great criticism on the reliability of the Energy label, particularly on the new process implemented in the Netherlands since January 2015. Though, being an international framework (EC, 2015), there is great potential to keep developing it into a reliable global monitoring tool.

The potential of post-war buildings to raise energy savings is largely underestimated since the results show that energetic improvements are achievable.

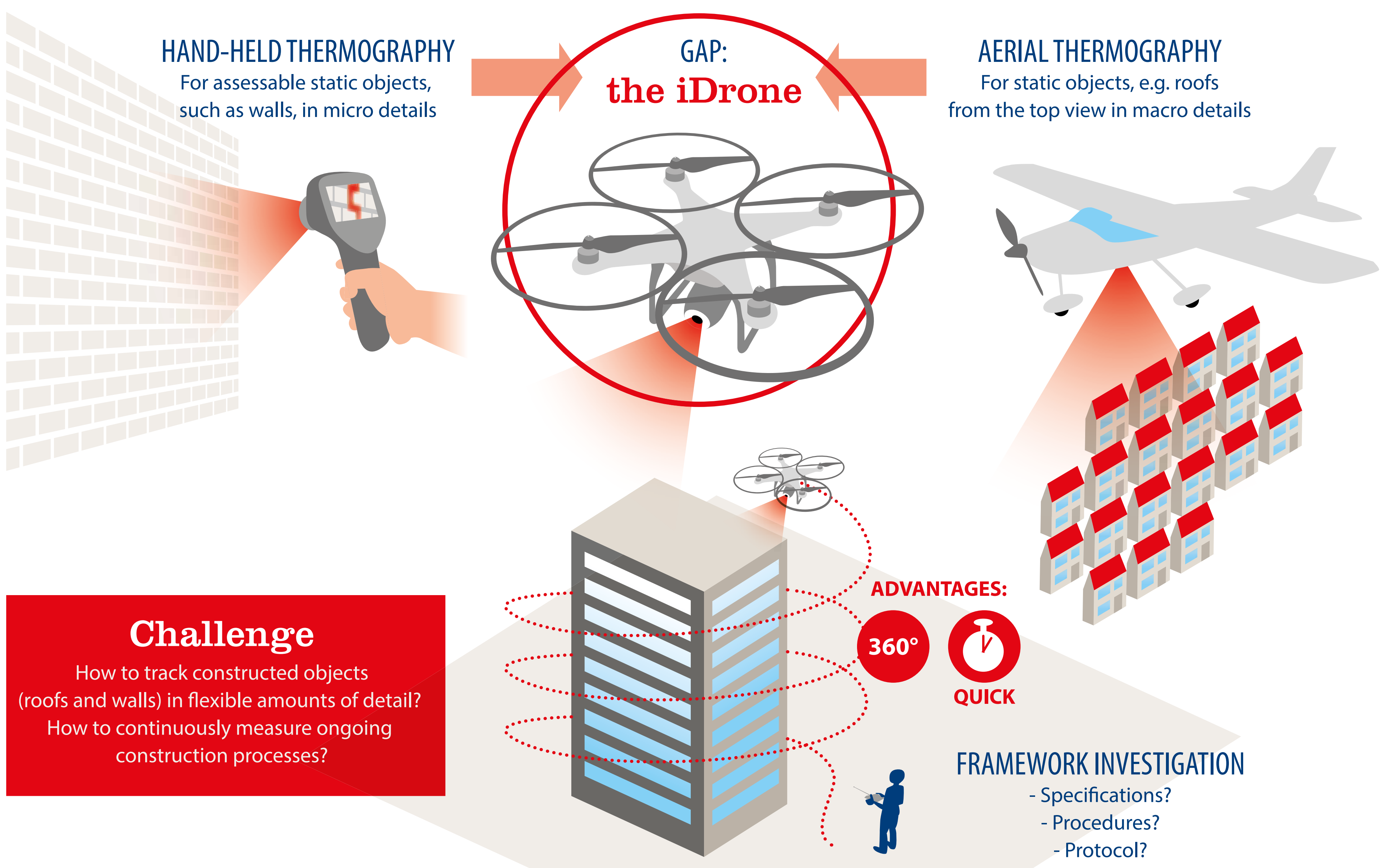
This research focused on unveiling the role of historical buildings, and those designated as heritage in particular, in raising the energy performance in three Dutch cities. Results reflect the correlation of three research questions, aiming to identify and classify historical buildings on their heritage designation, energy performance and building transformations. Dwellings are taken as case study, and private owners in particular, as they are now leading the new energy certification method. The correlation between the available data was made possible due to the common construction unit, based on the BAG (Basic Administration Addresses and Buildings). Buildings are distinguished according to their heritage-designation, as global (UNESCO World Heritage), national and municipal. The Energy label was used to derive the energy performance, as well as, the transformation rate, through the alteration of the Energy Label over time. And finally, more information about building transformations, such as the rationale to implement them, was gathered during the event 3TU Saving Energy Battle (sEB).

The sEB took a first step in this global monitoring tool (http://savingenergybattle.nl/), by testing this new process of energy performance certification (Definite Energy label), in three post-war neighborhoods of Dutch cities: Westelijke Tuinsteden, Amsterdam; Ommoord, Rotterdam; and Mariahoeve, Den Haag. This monitoring tool was organized as a live event where the staff and students from TU/e and TUDelft, as well as, volunteers teamed up to assist building owners to upload the requested information. The sEB was won by Den Haag (127), followed by Amsterdam (118) and Rotterdam (62). The results were shared and disseminated in a publication prepared by both universities. Previous to the event, the website offered short courses, created to ease the submission process. Nowadays, the website offers the timeline and outcomes of the sEB project. Through this research the Energy label has been successfully used to monitor the energy performance and transformation of buildings at large scale. It enabled us to compare and distinguish cities to neighborhoods, and historical to modern dwellings. Findings showed that post-war neighborhoods have worse energy performance than their cities as a whole, evidenced by 20% less green labels. Historical dwellings have on average a lower energy performance than modern dwellings, which is more evident at neighborhood level with an average of 10% less green labels. Historical dwellings in post-war neighborhoods are lagging behind compared to their transformation at city level, with around 20% less dwellings transformed. The results are more evident when analyzing the case of Mariahoeve.

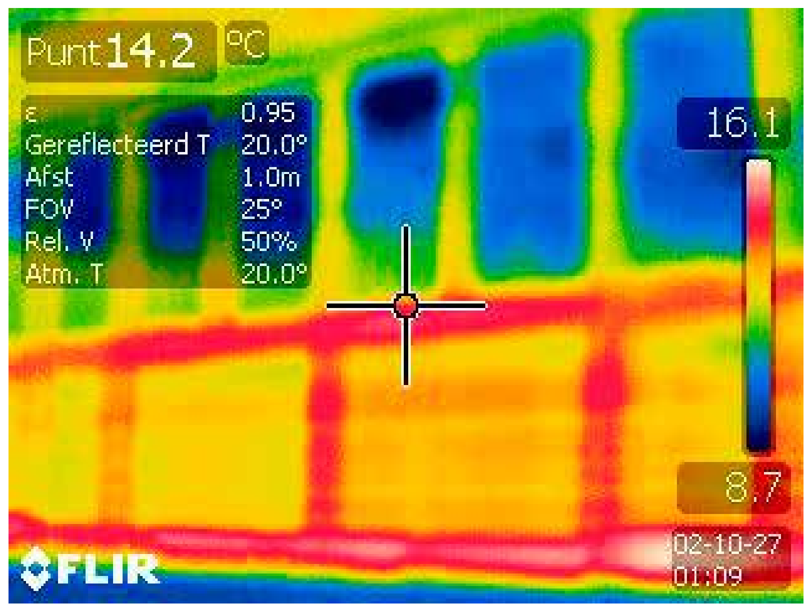
The energy label should be seen as a potential tool, to monitoring buildings on their energy performance, determining the impact of building transformations and underline potential areas of transformation. Post-war neighborhoods were built due to a housing shortage leading to a massive production of dwellings with similar characteristics, technical and cultural wise. Therefore, identifying the main sources of energy waste, solutions can be address at building level but applied to a bigger ensemble (block or neighborhood), enhancing the energy performance of the whole area and preserving its identity. Yet, these actions demand a close collaboration between the various stakeholders such as developers, corporations and most important municipalities (Bijlsma et al, 2008) The potential of post-war buildings to raise energy savings is largely underestimated since the results show that energetic improvements are achievable, 77% of these dwellings were transformed and 11% achieved green labels. On average 41% of the measures studied were applied, in most cases this consisted of around 80% glazing, heating and tap-water systems. Without severe actions in the built environment the energy demand will increase 50% by 2050 (GNP, 2013). Therefore, urban planning and architecture should become stricter on how to best transform the built environment towards sustainability, including renovations and heritage-designated buildings, as findings showed that their transformation is possible and happening, though with only few energy saving measures and not on their full potential.

THROW IN THE I-DRONE

the missing link between micro and macro temperature mapping



Although many consider drones to be toys, multiple industries, such as the agriculture and mining industry, already know what advantages professional Unmanned Aerial Vehicles (UAVs) can offer. However, many companies in the construction industry do not seem to be familiar yet with the possible advantages of UAVs for their projects. In our 3TU Lighthouse project "Throw in the I-drone" we, the University of Twente, Delft University of Technology, HeightTech and BeemFlights, would like to make the construction industry aware of the possibilities UAVs have by demonstrating possible usages, by providing a protocol on how to use them and by simplifying the interpretation of data collected. Especially, the use of UAVs with an infrared camera will have our attention, because these systems can help in improving the energy performance of buildings reducing their environmental impact.



The gap: mesa scale temperature mapping
Thermography enables us to distinguish surfaces with different temperatures. Temperature data from infrared cameras can, for instance, pinpoint flaws in the thermal shell of buildings or electric problems in the meter cup board. The application of thermography on buildings is already a well-known practice. Unfortunately, this process is tedious and time consuming. On the other hand, large-scale airborne temperature mapping is both applicable and useful to document temperature signatures on the scale of whole suburbs at once. Still, that method is expensive and less controllable. As a result, these micro- and macro-scale of temperature mapping solutions help specific niches, while the intermediate mesa-scale stays underexplored.

Unmanned Aerial Vehicles (UAVs) with an infrared camera can help in improving the energy performance of buildings reducing their environmental impact.

The challenge: showing UAVs with IR to the construction industry
The University of Twente, Delft University of Technology, HeightTech and BeemFlights want to collaboratively challenge the current rules of temperature mapping by exploring this mesa-scale. We target to provide the missing link for the micro to macro temperature mapping continuum. Specifically, we aim to leverage current advances in IR-technologies and remote control Unmanned Aerial Vehicles (UAVs) to fill this gap by utilizing an "i-drone". The versatility of a UAV combined with enhanced IR vision enables new innovative type of temperature mapping, not available on micro and macro level.
This challenge has not widely been taken up by the construction industry, due to the risk of failing to repay the costs of the equipment. We expect it to open new horizons and enrich a number of practices. Among other tasks, the UAV will be very useful in monitoring building processes, studying the thermal losses of roof-systems, malfunctioning photovoltaic panels and for the inspection regarding building regulation. We will test the combination of UAV and IR cameras for constructions in use, e.g. dwellings, industrial buildings, and/or office buildings.

The results: research and knowledge valorisation
Our first efforts resulted in great footage to support our research and external communication. With the help of an UAV with a conventional camera a teaser was made to show the opportunities drones can offer in the construction industry when equipped with an infrared camera. Meanwhile, it was possible to establish a collaboration with drone manufacturer HeightTech. Secondly, a literature study by means of a capita selecta by a master student was conducted on thermography, UAVs and the combination of both providing insights in the current fields of knowledge.
Thirdly, as part of a bachelor thesis assignment a questionnaire was composed and interviews were taken among construction companies, facility managers and building advisors to find out what solutions an UAV could offer, enabling us to assess the potential impact of utilizing drones in the construction industry.
More technical elements in our research project, a fourth step, were focusing on how data is being collected by an infrared camera and how photovoltaic systems can be inspected with the help of an infrared camera.

We target to provide the missing link for the micro to macro temperature mapping continuum.

The future: testing and follow-ups
Currently, we are studying how to integrate the data obtained by the UAV and the output of data analysis into standard automated assessment procedures, reducing the amount of time normally needed to select, prepare and analyze the data. We are also developing a flight protocol. We plan to test our protocol for a building in use and a photovoltaic system by the end of February 2016. Last but not least, a follow up of the i-drone project is being discussed with companies in the field. It seems that multiple challenges still need to be overcome, before the construction industry and buildings can benefit from the use of professional UAVs in their full potential. A continuation by means of a PDEng trajectory seems an appropriate next step.

Delft University of Technology
Ir. **Eric van den Ham**, dr. **Regina Bokel**

University of Twente
dr. ir. **Bram Entrop**, dr. **Alexandr Vasenev**

BeemFlights
Sander Mutsaards

Height-Tech Benelux B.V.
Ernst Thijsen

DOUBLEFACE TO DOUBLEFACE 2.0

The Lighthouse DoubleFace project aimed at designing and prototyping an adjustable translucent modular system featuring thermal insulation and thermal absorption in a calibrated manner, which is adjustable according to different heat loads during summer- and wintertime. The output consisted of a proof of concept, a series of performance simulations and measurement and a prototype of an adjustable thermal mass system based on lightweight and translucent materials: phase-changing materials (PCM) for latent heat storage and translucent aerogel particles for thermal insulation.

Based on the results of the Lighthouse DoubleFace project, the STW Research Through Design proposal DoubleFace2.0 was submitted. The proposal was awarded and the project will run for 2 years starting from 2016. The research will focus on a specific demonstrator, using novel production techniques, like 3D printing, to explore their potential for creating high quality translucent and highly performative products. The approach is unique in that it aims for a system with high levels of adjustability to the specific conditions at hand and in which the functioning will be part of the identity of the product. This latter aim will be realized by a.o. the adjustability and shape of the system and by the materials that have a changing appearance depending on their physical state (solid or liquid). While dealing with the use of engineering performances as principles to trigger design creativity, ultimately, this research will result in a set of design concepts and in general knowledge on thermal performances.

info: **Michela Turrin** – m.turrin@tudelft.nl

ENERGY EFFICIENT FAÇADE LIGHTING
Sculpture the façade with optical fibres

This project investigated the design of an energy-efficient lighting solution for highlighting architectural details of façades based on optical fibres. The project team consisted of members from the TU/e Building Lighting group, the TU Delft group Architectural Engineering + Technology, and the industrial partner BL Innovative Lighting from Canada. The lighting system has been tested for its photometric characteristics and was demonstrated in a pilot demonstration to showcase the suitability of this solution for façade lighting.

What happened after the completion of this project?
The project has received national and international recognition. Besides the successful demonstration at the Utrecht Bouwbeurs in February 2015, a project overview is published in the magazine of the Building Physics and Services (BPS) study association 'INSide Information', and the results are distributed to the members of the Plastic Optical Fiber Trade Organization (POFTO). The Canadian project partner BL Innovative Lighting was pleased with the overall results. The measurements proved that the system performs really well. The company is currently transforming the prototype into a product. The knowledge and experience gained in/during this 3TU.Bouw Lighthouse project has provided useful input for further product design. At the time of writing the company awaits the results from product safety testing. BL Innovative Lighting is eager to introduce the product to the market and considers showcasing it at European, Asian, and North American trade shows.

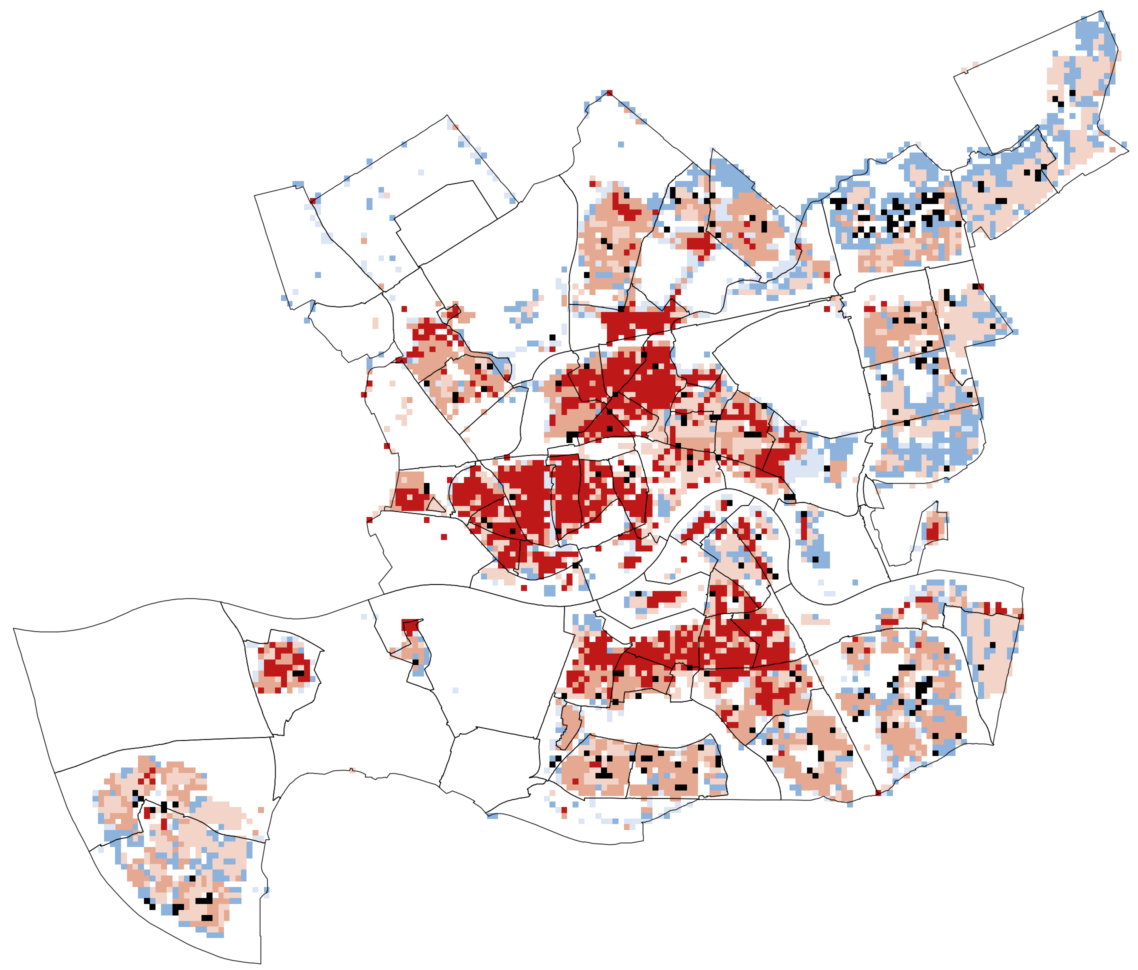
info: **Alexander Rosemann** – a.l.p.rosemann@tue.nl

IMPENETRABLE INFILTRATION; A SHORT REFLECTION

In 2014 "Impenetrable Infiltration" became part of the first edition of 3TU lighthouse projects. In this project the University of Twente, Eindhoven University of Technology and SelektHuis had the collaborative aim to improve the understanding of the air tightness of buildings by assessing the variables that have an impact on the infiltration rate of a building.
Due to the provided grant, it was possible to purchase equipment to conduct blower door tests. This equipment was used to measure the airtightness of several new detached houses. The project also resulted in two master projects, of which one was already completed. The results of a literature study and our research in the field were put down in two professional publications in TVVL Magazine.
Although we were able to collect and analyse 300 blower door test reports, this number was still too small to draw clear conclusions regarding what building characteristics are exactly related to airtightness. However, the current ongoing collaboration with SelektHuis and NBVL makes us believe that the future will bring more insights.

info: Bram Entrop – a.g.entrop@ctw.utwente.nl

SENSING HOTTERDAM



The aim of the Sensing Hotterdam project was to gain a better understanding of urban heat in Rotterdam. Heat was measured with sensors in homes and outdoors while the surface energy balance was modelled as well. Social and physical features of the city were identified in detail with the help of satellite images, GIS and 3D models.
The project produced two heat maps, an atlas of underlying data and a set of adaptation measures which, when combined, will make the city of Rotterdam and its inhabitants more aware and less vulnerable to heat wave-related health effects.
In different ways, the pre-war districts of the city warmer and more vulnerable than are other areas of Rotterdam. Homes seem to have their own dynamics, in which the house's age plays a role.
The above-average mortality of those aged 75 and over during the July 2006 heat wave in Rotterdam can be easily explained on the basis of a) the concentration of people in this age group, b) the age of the homes they live in, and c) the sum of sensible heat and ground heat flux.
A varying mix of impervious surfaces, surface water, foliage, building envelopes and shade make one area or district warmer than another. Adaptation measures are in the hands of residents, home owners and the local council alike, and relate to changing behaviour, physical measures for homes, and urban design respectively.
A follow-up project for the city of The Hague will be kicked off in the summer of 2016 and will measure urban temperatures for the duration of three years.

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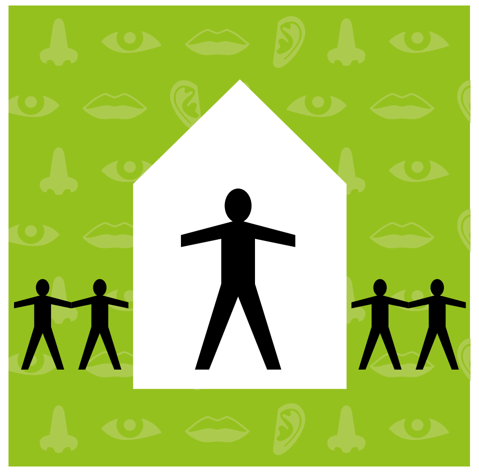
DE TOEKOMST WORDT GEBOUWD

thema's voor de Nationale Wetenschapsagenda



PERCEPTIE & ACCEPTATIE: DE MENSELIJKE MAAT

Bouwen gaat in de eerste plaats over mensen van alle leeftijden, met verschillende culturele achtergronden en sterk uiteenlopende behoeften. Ze hebben behoefte aan beschutting, ontmoeting en samenzijn, maar ook aan vrijheid, herkenning, concentratie en rust; dit alles in een veilige en gezonde leefomgeving. Tegelijkertijd wordt hun leefomgeving steeds complexer. De wereld digitaliseert, de mens individualiseert en wordt ouder dan voorheen. Er worden hogere eisen aan burgerschap en persoonlijk initiatief gesteld. Daarnaast worden stedelijke gemeenschappen pluriformer en is opleiding een voorwaarde om mee te doen.
Hoe kunnen ingrepen in de gebouwde omgeving bijdragen aan het leven van de mens als individu en als onderdeel van een gemeenschap?

Alle ontwikkelingen in Nederland vinden plaats in een volledig door de mens gecreëerde omgeving die identiteit en herkenning verschaft, of juist gevoelens van onbehagen en achterstand doet ontstaan. Nederland blijkt een redelijk gelukkig land te zijn, maar toch wordt er steeds meer hinder ervaren van medeburgers, van bouwactiviteiten en van verkeer; fijnstof, stank, lichtvervuiling en geluidshinder. Hinderbeperking en flexibel bouwen worden belangrijker.

Door maatschappelijke trends zoals vergrijzing en veranderingen met betrekking tot wonen, zorg, pensioenen en multi-culturaliteit neemt de aandacht voor de wensen en behoeften van eindgebruikers en de vraag naar comfort, gemak en maatwerk toe.

De focus op techniek verandert naar een focus op de mens: de techniek socialiseert. De gebouwde omgeving moet niet alleen praktische en esthetische, maar ook ecologische en sociaal-maatschappelijk doelen dienen. Gebruikers moeten meer betrokken worden in processen in de bouw, co-creatie, om daarmee tegelijkertijd legitimiteit en acceptatie te borgen.

Daarnaast is het zaak dat de eindgebruiker professionaliseert, eventueel met digitale ondersteuning, om optimaal gebruik ten aanzien van de levenscyclus te bereiken. Er ontstaan nieuwe vraagstukken wat betreft privacy, de gebruiker mede-verantwoordelijk maken voor de openbare ruimte en het optimaliseren van de voordelen van dicht op elkaar wonen. Onderzoek is nodig naar passende ruimtelijke oplossingen en nieuwe voorzieningen, met een focus op de mens.

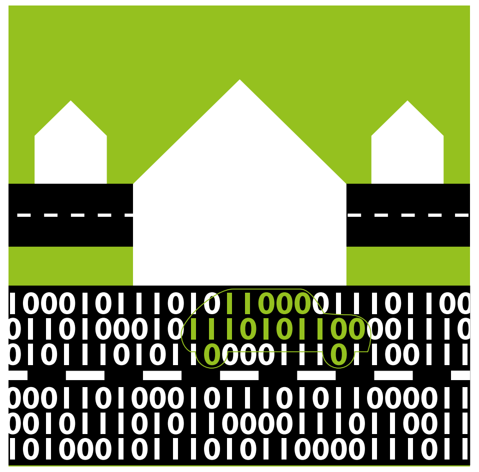
LEEFBAAR & EFFICIENT: SMART CITIES

Over de hele wereld en ook in Nederland trekken steeds meer mensen vanuit landelijk gebieden naar de stad, er ontstaan nieuwe metropolen en mega cities. Daarnaast hebben demografische trends, zoals vergrijzing en kleinere huishoudens, een grote invloed op de stedelijke omgeving en haar samenstelling. Om steden leefbaar en toekomstbestendig te houden is een transitie van de stad noodzakelijk. Maar, de stad is een complex systeem dat niet met louter korte termijn maatregelen te veranderen is. Hoe ziet de stad van 2050 er uit en hoe kunnen wij hier naartoe werken?

De stad is een samenspel van sociale, economische en ecologische factoren, die met elkaar in balans dienen te zijn. Problemen die momenteel urgent worden voor steden zijn een ongezond stedelijk klimaat, onveiligheid, wateroverlast en overlast door verkeer. In steden is ruimte nodig voor verduurzaming en vergroening, maar ruimte is schaars in Nederland. Anderzijds komen er steeds meer kantoor- en fabrieksgebouwen leeg te staan. Welke nieuwe technologieën zijn beschikbaar om hier een oplossing aan te bieden? Het smart city concept biedt hier vele mogelijkheden.

Smart cities zijn gebaseerd op nieuwe technologieën, zoals elektrisch vervoer, straatverlichting met sensoren en mobiele netwerken. Er is echter nog veel onderzoek nodig naar de toepassingsmogelijkheden van deze nieuwe technologieën in de gebouwde omgeving. Dit onderzoek vraagt een samenwerking tussen stadsbewoners, stadsbestuur, onderzoeksinstituten en de bedrijfsleven. Daarnaast dient nieuwe kennis ontwikkeld te worden met betrekking tot stedenbouw en bestuurlijke instrumenten om zowel voor de lokale als globale schaal tot nieuwe oplossingen te komen.

Het is belangrijk dat zoveel mogelijk belanghebbende partijen betrokken hierbij worden en dat de resultaten van het onderzoek zichtbaar en tastbaar worden gemaakt. Zonder gericht onderzoek loopt Nederland als één van de dichtstbevolkte landen ter wereld het risico om aan leefbaarheid in te boeten, zolang problemen als toenemende verdichting, onveiligheid en een ongezond leefmilieu niet aangepakt worden.



INFRASTRUCTUUR & VERVOER: SMART MOBILITY

De logistiek van grondstoffen, producten en personen is het belangrijkste fundament onder de economische ontwikkeling van een samen-leving: Nederland heeft zijn huidige welvaart er grotendeels aan te danken. Kenmerkend voor mobiliteit en logistiek zijn twee verschillende aspecten: enerzijds de modaliteit, zoals auto, trein, schip, vliegtuig of pijp- of kabelleidingen, en anderzijds de onderliggende infrastructuur, zoals wegen, bruggen en tunnels, spoor, water-wegen en havens en luchthavens. Modaliteit en infrastructuur dragen heel verschillende kenmerken, qua investering, levens-duur en innovatiesnelheid. In het afstemmen van ontwikkelingen en beperkingen van beiden schuilt een grote maatschappelijke opgave.

Infrastructuur aanleggen vergt veel planning, grote investeringen en anticiperen op ontwikkelingen voor lange tijdsperiodes, soms langer dan 100 jaar. De structurele eigenschappen van deze infrastructuur zullen door gebruik en externe omstandigheden verouderen, terwijl veilig gebruik gewaarborgd moet worden. Hierdoor is er behoefte aan nieuwe monitoringstechnieken die op elk moment de gezondheidstoestand van een object kunnen weergeven en onderhoud- en vervangingscycli kunnen aansturen. Door de dichtheid van de netwerken zal aanleg, onderhoud en vervanging steeds complexer en duurder worden, terwijl de acceptabele last en barrièrewerking voor de omgeving geringer zal moeten worden.

Dit vraagt om nieuwe processen, contractvormen, tot multifunctioneel ontwerp en nieuwe in-place recycling en upgrading strategieën. Daarnaast veranderen de kenmerken en infrastructurele behoefen van vervoersmodaliteiten snel, terwijl de eisen met betrekking tot veiligheid, geluidshinder en uitstoot vervuiling steeds strenger worden. De interface tussen de modaliteiten en hun infrastructuren wordt ook belangrijker: de uitdaging om goed functionerende multimodale knoop-punten te verwezenlijken. Verder zal de rol van de bestuurder door voortgaande ontwikkelingen op het gebied van sensoring en ICT steeds kleiner worden. Vervoersmiddelen digitaliseren snel, en zullen gaan interacteren met de omgeving.

Duurzame bereikbaarheid in snel verdichtende en qua vervoer dichtslibbende urbane regio's blijft een constante uitdaging. Hierin kunnen nieuwe geavanceerde verkeerssystemen een rol spelen om een optimale reistijd te laten samengaan met maximale veiligheid en geringste hinder. Tenslotte is het noodzaak te streven naar 100% emissieloos transport

INFORMATIE & INTERACTIE: INTELLIGENTIE IN DE BOUW

De bebouwde omgeving bepaalt in belangrijke mate ons gevoel van welzijn. In een wereld van toenemende automatisering neemt het gebruik van robotica en ICT ook in de bouw toe. Dit leidt tot een virtuele infrastructuur die verschillende partijen en processen met elkaar verbindt, en bovenal een enorme hoeveelheid data en informatie produceert. Dit zal de manier van bouwen, de bouwplaats en daaraan gekoppelde processen ingrijpend gaan veranderen.

De digitalisering van de bouw staat nog in de kinderschoenen. Met technologische innovaties en het beschikbaar komen van steeds meer informatie, zal op het gebied van het bouwproces, ketensamenwerking en –integratie nog veel winst te behalen zijn. Ontwikkelingen zoals BIM, 3D-printing, sensors en drones zullen talrijke mogelijkheden bieden voor constructie en duurzaam beheer van onze leefomgeving. De integratie van verschillende informatie systemen en real-time data communi-catie leidt momenteel echter nog tot veel problemen.

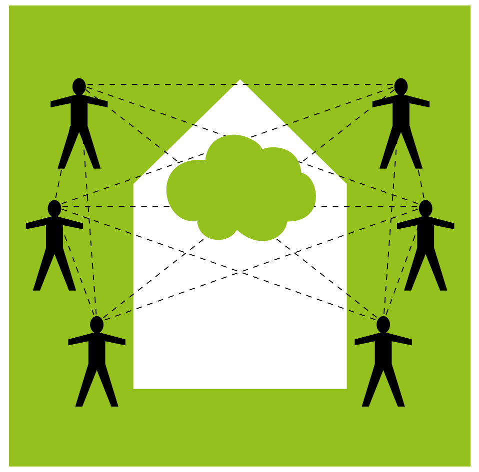
Daarnaast ontstaan nieuwe vraagstukken over de balans tussen openbaar en privé. De beschikbare hoeveelheid data gerelateerd aan de bouw is al enorm, en zal naar verwachting blijven groeien? Welke informatie hebben we nodig, en hoe wordt die informatie gedestilleerd uit data-sets? Welke data zijn er in de toekomst nodig, en kunnen we daar nu al op anticiperen? Hoe gaan we de informatie delen, binnen bouw- en beheerprocessen, met beleidsmakers en eindgebruikers? Data science is daarom bij uitstek een kennisgebied dat de toekomst van de bouw en het beheer van de (openbare) ruimte gaat bepalen.

Momenteel ontbreekt het nog aan informatie en inzicht over de kansen en toepassingen van ICT ten behoeve van bijvoorbeeld het klimaat in gebouwen, comfort, gezondheid, welzijn en bovenal de menselijke interactie met technische systemen in gebouwen. Een sterke kennispositie over de inpassing van systeem innovaties in de gebouwde omgeving en effectieve toepassing van ICT in de bouw, zal de concurrentiepositie van Nederland blijvend kunnen versterken.

Nederland is het resultaat van een eeuwenlang bouwproces, Nederland is het resultaat van maatwerk gedurende vele eeuwen. Er is land gewonnen, er is land verdedigd tegen het water, er zijn steden en dorpen gebouwd, er is infrastructuur gebouwd: van wegen en dijken, van polders en luchthavens. Mensen beleven het land, de ruimte, het (binnen)klimaat van gebouwen, en hebben verbinding met anderen via fietspad, spoor, snelweg, digital highway, water uit de kraan, vuil naar het stort en waterzuivering, elektriciteit voor levensbehoeften en luxe, droge voeten, veilige havens - een greep uit vanzelfsprekendheden die mede mogelijk gemaakt zijn door de bouw en civiele techniek.

De ontwikkeling van de samenleving en de technologie vragen voortdurend aanpassing van de fysieke leefomgeving. Voorspellingen over de gevolgen van klimaatverandering zoals zeespiegelstijging, de noodzakelijke transitie naar decentrale, duurzame energieproductie en de noodzaak tot een gesloten kringloop voor grondstoffen, maakt een versnelde ontwikkeling en toepassing van innovaties in de gebouwde omgeving van groot belang, voor de huidige generaties, en alle die volgen.

Desondanks kampt de bouw met het imago conservatief en versnipperd te zijn. Echter, de constructieve zekerheid van producten van de bouwsector zijn formidabel (voor infrastructurele objecten als waterkeringen is 100 jaar een absoluut minimum), de ontwikkelingen in de afgelopen decennia ten aanzien van energiecomfort en –zuinigheid, nieuwe, slimme bouwmaterialen zijn spectaculair te noemen. De bouwsector is bij uitstek de omgeving waarin de innovaties uit talrijke vakgebieden in geïntegreerde vorm hun uiteindelijke toepassing vinden. Zo heeft bijvoorbeeld geen enkele innovatie zoveel kwaliteitsjaren aan het leven van de mens toegevoegd als adequate sanitatie in zijn leefomgeving. Publieke sanitatie is een goed voorbeeld van een historisch, en 'ongoing', project dat alleen tot stand kon komen door effectieve werking van de gouden driehoek tussen normstellende en faciliterende overheden, voortschrijdende inzichten vanuit onderwijs en wetenschappen, en voortvarende uitvoering door de private sector.



INTEGRATIE & ORGANISATIE: SMART CONSTRUCTION

Opdrachtgeverschap en projectmanagement in de bouw worden in toenemende mate complex. In alle projectfasen, vanaf initiatief en ontwikkeling tot aan realisatie en beheer, zijn multi-disciplinaire, multi-stakeholder en multifunctionele processen geen uitzondering meer. Voor de 'license to operate' zal de bouwsector haar opdrachtgevers, omgeving en ketenpartners meer betrouwbaar en reëler tegemoet moeten treden. Verder is er een beweging richting meer zelfbouw en meer bouw op kleine schaal. Daarnaast wordt de bouwsector meer bipolair, met enkele grote spelers, en vele kleintjes.

Door de economische crisis is een ontwikkeling in gang gezet richting een veel kleinschaligere bouw. Economische groei moet nu gezocht worden in iets anders dan enkel het bouwvolume. Hiervoor zullen onder andere nieuwe markt-partijen en financieringsarrangementen nodig zijn. Er kan gedacht worden aan andere business modellen zoals huren in plaats van kopen, of financiering door middel van crowd funding. Daarnaast wordt transparantie van beleid en besluitvorming steeds belangrijker en wordt in toenemende mate waarde gehecht aan creativiteit en waarde creatie.

De toegenomen complexiteit van het bouwproces leidt tot nieuwe onzekerheden op het gebied van planning, kosten, tijdige voltooiing en uiteindelijke kwaliteit van het bouwwerk. Opdrachtgeverschap en de relatie met opdrachtnemers verandert en risico's verschuiven. Aan de ene kant worden opdrachtgevers en gebruikers ontzorgd; aan de andere kant krijgen stakeholders juist steeds meer zeggenschap in bouwprocessen. Zo ontstaan nieuwe werkvormen, zoals ketensamenwerking en integrale werkwijzen, met een heel scala aan nieuwe management uitdagingen van dien.

Een andere trend is de netwerk benadering ten aanzien van infrastructuur; er worden immer hogere eisen gesteld aan betrouwbaarheid van netwerken en voorzieningen. Verder liggen er grote uitdagingen met betrekking tot onderhoud en beheer. Voortgaand wetenschappelijk onderzoek is nodig naar nieuwe aanbestedings- en contractvormen, regelgeving, juridische kaders en financieringsmodellen. Hoe kan Nederland een gidsland worden op het gebied van lange termijn samenwerking en waarde creatie?

ENERGIE & GRONDSTOFFEN: CIRCULAR ECONOMY

Onze huidige leefwijze legt een onevenredig groot beslag op schaarser wordende grondstoffen, water, ruimte en energie. Deze levenswijze gaat gepaard met belasting van de leefomgeving: CO2 en andere afvalgassen in de lucht – leidend tot klimaatverandering –, vervuiling van oppervlakte- en grondwater, contaminatie van de bodem door storten van afval. Een groot deel van deze milieubelasting wordt veroorzaakt door de bouw. Het realiseren van een toekomst gebaseerd op duurzaam materiaal- en energiegebruik in de bouw is daarom van groot belang voor toekomstige generaties.

De mens legt een steeds groter beslag op eindige hulpbronnen: fossiele energie en grondstoffen. Dit heeft grote impact op zijn leefomgeving. De bouw legt een groot beslag op grondstoffen en energie; zo leidt de productie van cement alleen al tot 5% van de jaarlijkse CO2 –uitstoot. De bouw werkt met gefragmenteerde processen die geen rekening houden met de lange termijn milieubelasting en levensduur en hergebruik van materialen. De implementatie van een circulaire economie zou hier oplossingen kunnen bieden.

In een circulaire economie worden de belasting op het milieu en de kosten van beheer van de gehele levensduur van producten meegenomen en wordt gekeken hoe materialen en energie (eeuwig) hergebruikt kunnen worden met hetzelfde kwaliteitsniveau. Deze circulaire aanpak verschuift de focus van nieuwbouw naar hergebruik en richt zich op een omschakeling naar een bouwsector die geen afval meer produceert. De uitdaging is om voor zeer lange gebruiksperiodes te ontwerpen, met inherent functionele flexibiliteit van de bouwwerken. De implementatie van nieuwe, circulaire processen als de basis voor een duurzame bouw is echter uitermate ingewikkeld.

De mogelijkheden voor het produceren van hernieuwbare energie en duurzame materialen zijn nog maar ten dele bekend. Daarnaast is er ook veel onderzoek nodig op procesniveau: nieuwe werkvormen, aanbestedingsprocedures, business modellen voor levensduur benadering of building with nature. Tenslotte zal het energielandschap veranderen van grootschalige installaties, naar decentrale productie. Kortom, de noodzakelijke energietransitie zal vergaande consequenties hebben voor de bebouwde omgeving.

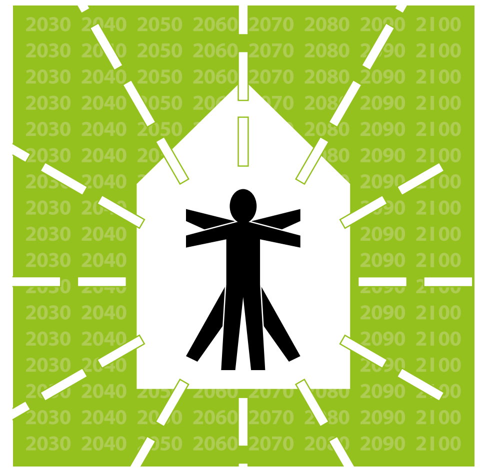
ANTICIPATIE & ADAPTATIE: KLIMAAT

Vooral vanwege economische redenen trekken mensen steeds meer naar steden toe, steden die om dezelfde reden vaak in deltagebieden of aan grote rivieren liggen. Deze gebieden zijn extra kwetsbaar voor extreme weersomstandigheden. Klimaatverandering leidt vooral tot toename van deze extremen: wateroverlast, stormen en tornado's, extreme koude die het openbare leven verlamt, extreme droogtes die sanitatie, watervoorziening en stabiliteit van de ondergrond bedreigen, en periodes van extreme hitte die industriële productieprocessen stilleggen en tot verhoogde sterfte onder ouderen leiden.

Door klimaatverandering zal de frequentie van extreme weersomstandigheden blijven toenemen. Retentie en nuttig gebruik van regenwater wordt steeds relevanter en vraagt om een goede waterplanning van stedelijke gebieden als onderdeel van integraal watermanagement, welke wellicht te koppelen is aan een duurzame energievoorziening. Verder is het de vraag hoe de met wateroverlast gepaard gaande risico's verzekerd gaan worden. Kunnen cruciale installaties of woningen en infrastructuur in zeer overstromingsgevoelige gebieden niet beter worden uitgerust met intrinsiek 'drijfvermogen'?

Hier en daar zou het wellicht zelfs profijtelijk kunnen zijn het land, of alleen de infrastructuur en gebouwen te verhogen. Als Nederlandse steden niets doen aan hun klimaatrobuustheid zullen ze binnen enkele decennia 's zomers een klimaat vergelijkbaar met dat rond de Middellandse Zee hebben, hetgeen grote gevolgen voor de volksgezondheid met zich meebrengt. Het in stedelijk gebieden temperen van temperatuurextremen is van groot belang, en biedt tevens een mogelijkheid om buffers (warmte accu's) te implementeren, waarmee de gevolgen van temperatuur-schommelingen over langere periodes uitgesmeerd kunnen worden en eventueel benut.

Extreme omstandigheden vragen ook om nieuwe ontwerpstrategieën en materialen voor wegen, bruggen en tunnels. Deze dienen robuust en betrouwbaar te blijven functioneren. Dit alles vraagt niet alleen om het vergroten van de voorspelbaarheid van het gedrag van materialen, constructies en systemen, maar ook van het weer en andere natuurfenomenen, zoals aardbevingen en vulkaanuitbarstingen. Zelfs als de vermeende oorzaken van klimaatverandering in de komende decennia volledig kunnen worden weggenomen, dan nog zullen de gevolgen zich lang merkbaar zijn.



INTEGRATIE VAN INNOVATIE: THE FUTURE STARTS NOW

De meeste innovaties uit diverse wetenschappelijke disciplines vinden hun toepassing uiteindelijk in de gebouwde omgeving: in woningen, kantoren, fabrieken, bruggen, wegen, vliegvelden en hun installaties. De hoeveelheid aan ontwikkelde innovaties is enorm. Tegelijkertijd is het mogelijk dat bestaande optimale situaties weg-geïnnoveerd zijn: vervangen door iets nieuws dat niet noodzakelijk beter is. Wie kan dit allemaal overzien? Hoe meet en weeg je het belang van een ontwikkeling alvorens deze grootschalig toegepast is en er langdurig ervaring mee is opgedaan?

Ontwikkelingen die lange termijn voordelen bieden, die zich uitstrekken voorbij de sterfelijkheidhorizon van individuen, kunnen grote impact op de mensheid hebben. Maar de economie van de vrije markt is (nog) niet ingericht op voordelen en cash flows in een verre toekomst. Hoe kun je in het hier en nu bepalen of een technologie of beleidskeuze op zo'n lange termijn voordelen biedt? Verder blijven er talrijke veelbelovende technologieën 'op de plank liggen'. Alleen grootschalige toepassing gedurende langere tijd kan aantonen of een nieuwe technologie echt werkt, wat vervolgens de mogelijkheid geeft tot door- en uitontwikkeling en tot optimalisering van voordelen.

Dit vraagt echter om partijen die grootschalige risico's willen en kunnen dragen, partijen die vooroplopen en sturen. Zijn dat de overheden, internationale verbanden, NGO's?

De uitdagingen van vandaag zijn te groot om alleen maar door technische oplossingen beslecht te kunnen worden. Er zal een zeer breed gedeeld gevoel van noodzaak moeten ontstaan, er zullen snelle resultaten nodig zijn om het momentum te houden en te vergroten.

Er zal sturing moeten plaatsvinden, naar kennisbehoefte, de 'fog of information' over de prestatie van diverse alternatieve innovaties zal moeten optrekken. Innovatie vraagt om toepassing, testen in de praktijk, verwerpen of evolutionair verbeteren. Het vraagt intense samenwerking om technieken en processen verdergaand te integreren en te versimpelen. Dit gebeurt allemaal door mensen: hoe bereid je mensen in onderwijs en inspiratie voor op zo'n gezamenlijke uitdaging?

Daarom heeft het samenwerkingsverband van bouw-faculteiten van de drie Technische Universiteiten in Nederland, 3TU.Bouw, in nauwe afstemming met de bouwsector en de hele bouw gerelateerde onderwijsketen, een 8-tal thema's geagendeerd die richtinggevend zullen zijn voor toekomstig wetenschappelijk en onderzoek. Op basis van deze thema's zijn vragen geformuleerd voor de Nationale Wetenschapsagenda, welke in de volgende pagina's gepresenteerd worden.
De toekomst wordt gebouwd!

Samenstelling op basis van bijdragen medewerkers Technische Universiteit Delft - Architecture & Civil Engineering and Geosciences, Technische Universiteit Eindhoven - Built Environment en Universiteit Twente - Engineering Technology; ondersteund door Bouwend Nederland.

redactie:
Alexander Schmets met **Siebe Bakker**, **Ulrich Knaack** & **Lisa Kuijpers**

FUTURE FORMATS FOR APPLIED RESEARCH

Most current research and development projects deployed at university level are fully embedded within a historical grown academic culture. Well-known are core and fundamental research, free from any 'outside' influences and driven by inspired and ambitious researchers or research programs. Methods of conduct, analysis of results and the results themselves are solidly engrained in peer-reviews, financial systems and academic award systems.

However, we see a growing need for innovation within the built environment industry. Traditionally a craftsmanship world seemingly embedded with many obstacles for this industry to radically develop. Hindered by relatively limited budgets (almost non-existent dedicated innovation budgets), by its nature of being project driven in combination with severe competition regulations and by a generally short term financial outlook. Simultaneously this industry needs radical changes: energy transition, climate change and raw material scarcity are just a few of the global challenges that need to be addressed. And especially these issues are currently investigated within various academic research contexts.

There is a need for a better, more efficient and effective collaboration between industry and academia. In terms of content this is evident. Just as clear are the cultural gaps; different economies, time schedules, hierarchies and management models, even though ambitions and tasks are aligned. There is a need for 'moderating'; to bridge academic knowledge and industry expertise, to facilitate building industry in the transition from craftsmanship to high-tech, and to produce effective 'deliverables' by academic researchers.

Disciplines like 'IT' and 'energy' developed a dedicated culture for innovation, finance of research, and facilitaties for breeding start-ups and 'good ideas'. The built environment industry and the related university world seem mostly dependent on government driven financial programs and formats for innovation and research. One can state that these 'other disciplines' can truly operate globally supported by multinational industries and interests. The built environment, while developing 'global knowledge', is per definition local and depending on regional industries and and smaller economies. It seems clear that one can learn from other experiences and formats. Not to 'copy – paste' directly, but to borrow elements, to adapt and implement those that can improve an 'eco-system' for developing and applying built environment innovations. Obvious 'other' expertise ranges from crowd-funding to venture capitalist funding formats, including the associated 'business-side'. They unveil the need to improve a facilitating role for culture change in industry to optimize and to expand the academic world of research characteristics: fundamental and applied.

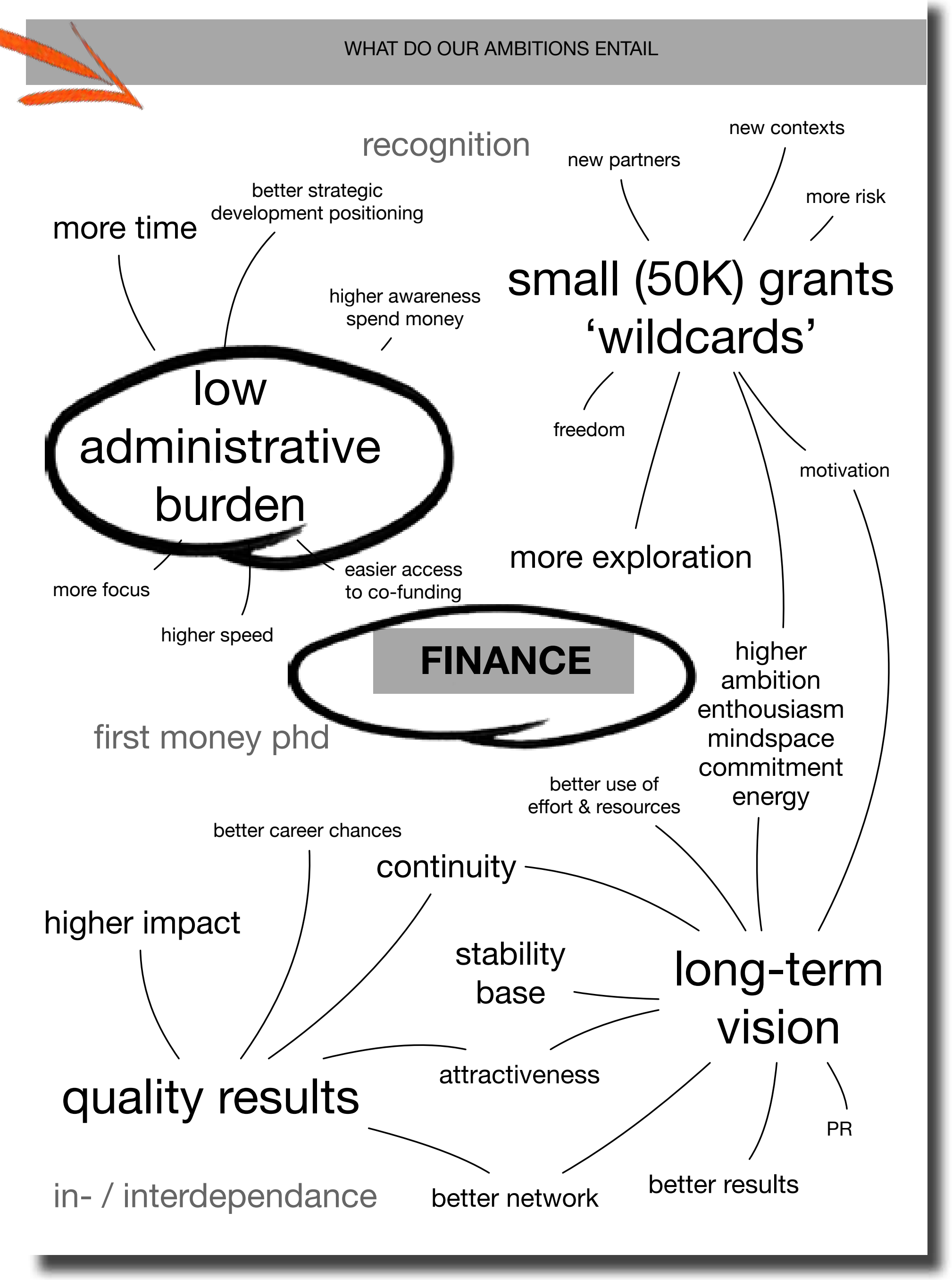
IN A FAST CHANGING WORLD, STARTUPS ARE THE WAY TO EXPLORE NEW IDEAS. WHAT DOES THAT MEAN FOR APPLIED RESEARCH?

IN SESSIONS WITH RESEARCHERS, A VENTURE CAPITALIST, A CROWDFUNDING SPECIALIST AND UNIVERSITY MANAGEMENT, WE RESEARCHED THIS QUESTION.

STARTUP INCUBATOR
- NETWORK
- COACHING
- MENTORS

CROWDFUNDING PROJECTS
- SUPPORTING CROWD
- DIRECT INPUT
- VALORISATION

CONCLUSION: MORE SUPPORT HERE



PROPOSAL | **RESEARCH PERIOD** | **RESULTS**

Moderators
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Finacial Experts
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Nienke Binnendijk – Recycled Island Stichting,
Frank van der Hoeven – Delft University of Technology,
Truus Hordijk – Delft University of Technology, **Tillmann Klein** – Delft University of Technology,
Ramon Knoester – WHIM Architecture, **Sina Mostafavi** – Delft University of Technology,
Kay Oosterman – Zwarts & Jansma Architecten,
Alexander Rosemann – Eindhoven University of Technology,
Pieter Stoutjesdijk – Fabrication Factory, **Martin Tenpierik** – Delft University of Technology,
Michela Turrin – Delft University of Technology,
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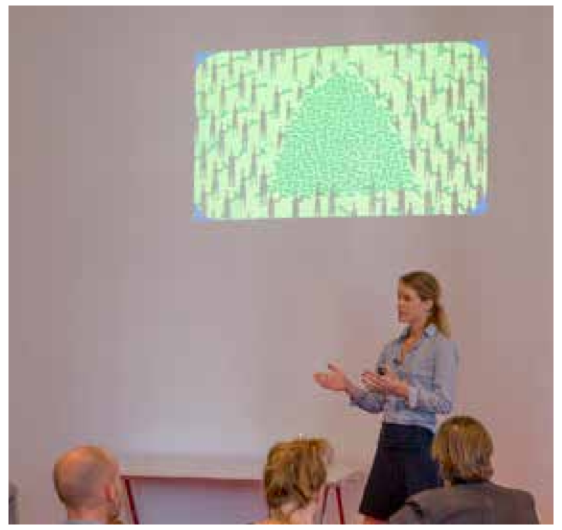

The potential for additive manufacturing (AM) in the built environment can be found in special products with small badge sizes. Using standardized systems is not always desired since almost every building is different. AM can be utilized for a lot of small parts embedded in our façades and especially for the complex parts where everything comes together. Integration of functions that could not be embedded yet is a large potential. Can adapting insulation be printed or can elements be printed on side, to deal with the different tolerances in the built environment?

Along with the quest to find the real application of AM, certification is an issue. Each part is different, caused by a lot of parameters. Although for example steel has the advantage of its strength, it is also unlikely that it will be used in critical parts, because the structural performance is hard to predict. Formwork or models used to make molds can be printed easily, which allows to cast the final products itself. It is likely that till products can be certificated the non critical parts will be printed directly and tested to obtain enough information about their behavior. Such non critical parts can be found all over a façade. The disadvantage of plastic printed products in the built environment is that they do not always have enough strength to be used as structural elements and are not that fire resistant. Next to those material characteristics, the anisotropic behavior, caused by the layered fabrication method, can be a concern. This side effect has to be controlled better to minimize its presence. Or can it be utilized in a beneficial way?

AM Processes

To understand and use AM in a beneficial way the printing technologies have to be well understood. Probably not everything will be printed in future now the hype has come to its end. Now it is time to use it as a supplementary technology next to all other plastic processing technologies. Like very production technology the AM process is divided into certain steps;

a. Make a digital model, which defines the geometry
b. Export the model to a STL file.
c. Generate a G code from the STL file to control the machine.
d. Upload the file to the machine and start the production.
e. Unload the final product, which in some cases will need to go through a post processing process like sanding.

AM allows the production of nearly any geometrical form, but it is important to select the right production process. For every product the parameters will be different and because of that the limitations of the different AM processes can easily become visible.

The most common used materials in Additive Manufacturing are polymers like ABS (Acrylonitrile butadiene styrene), PLA (Polylactic acid), PC (Polycarbonate), Polyamide (Nylon), Nylon 12, Glass filled nylon, Epoxy resin, Wax and Photopolymer resins. Most of the materials are directly related to a certain production technology. For example ABS can be extruded, not be polymerized.

Text and images
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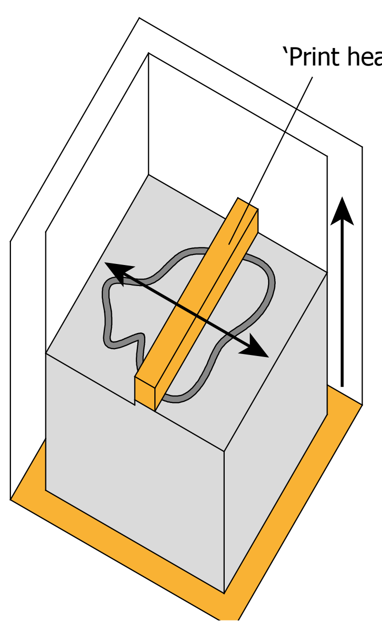
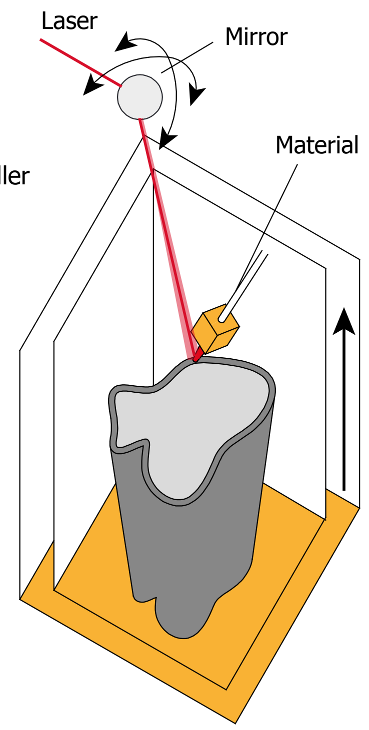
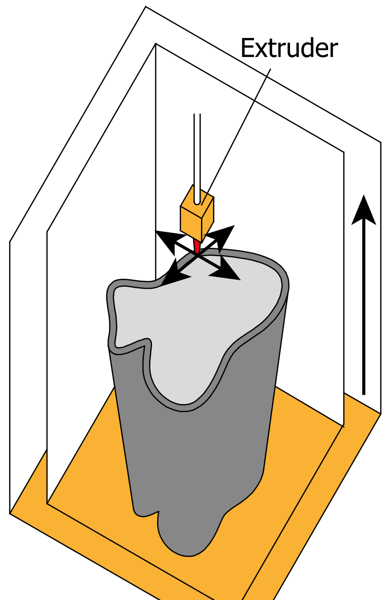


Binder jetting



Directed energy deposition



Material extrusion

Technologies
The AM technologies differ from each other based on the way the bonding process takes place.
All common categories can be used for AM of plastics;

Binder jetting
Binder jetting is a technique that selective depositions a layer of resin to selective bind a layer of powder material.

Directed energy deposition
Directed energy deposition is considered as a complex printing process whereby the material is melted upon deposition with focused thermal energy, for example a laser beam.

Material extrusion
This technology is considered as one of the most utilized techniques for additive manufacturing. The process is based on using heated extruders, which are fed with the filament material used to print the model. The extruders move in the x, y direction while the building plate controls the z direction movement. Some printers have fixed nozzles and a building plate that controls all the directions.

Material jetting
Material jetting is a process that selectively drops droplets of material on top of each other. This could be wax or photopolymers that are hardened directly by use of an UV source.

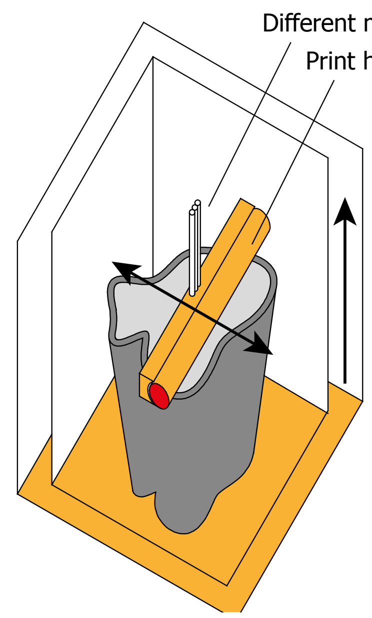
Powder bed fusion
Powder bed fusion involves selective melting and re-solidification of powder beds. When plastic based powder beds are used no additional support materials is needed, since the unbounded powder itself acts as a support material for the printed element.

Sheet lamination
Sheet lamination is a process where prefabricated foils or sheets are used as print material. A knife or milling machine is used to cut the desired form, where after the sheets are attached on top of each other, using glue in case of paper and plastic, while ultrasonic welding is used in case of metals.

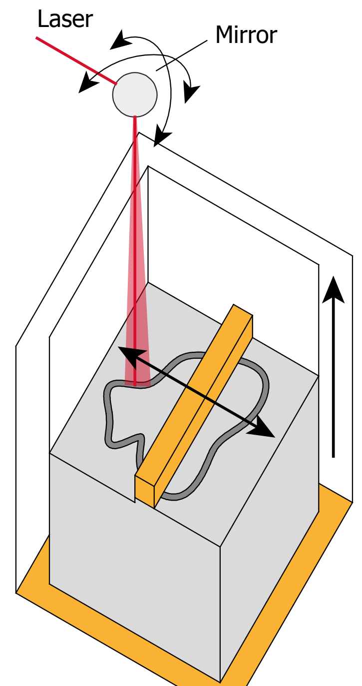
Vat photo polymerisation
Vat photo polymerisation involves the selective solidification of the liquid resin in a vat by use of a light source, for example UV.

	Metals	Ceramics	Polymers	Composites
binder jetting		3DP Inkjet	3DP	3DP
directed energy deposition	DLD DMD EBDM LENS LMD			
material extrusion		DIW FDM Robocasting	FDM FFF	FDM
material jetting			Material Jetting MJM Polyjet	
powder bed fusion	DMSL EBM SLM SLS	SLS	SHS SLS	
sheet lamination			LOM	LOM SDL
vat photo polymerisation			DLP SLA	

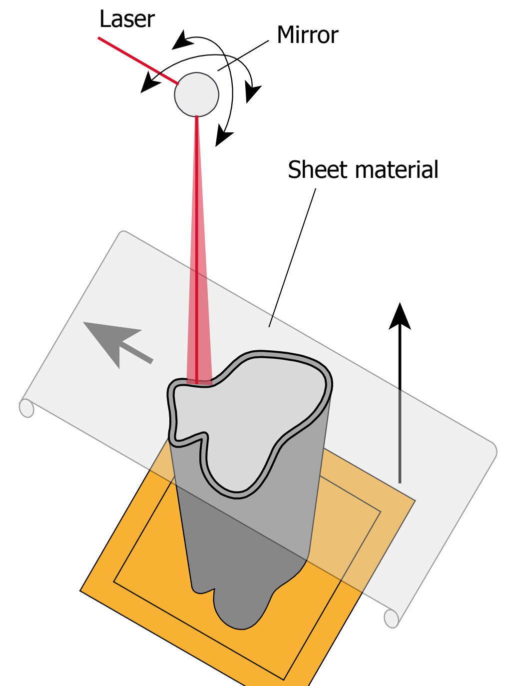
AM can be utilized for a lot of small parts embedded in our façades and especially for the complex parts where everything comes together.



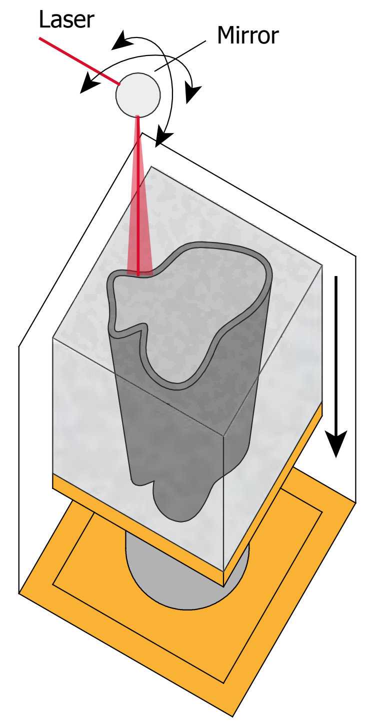
Material jetting



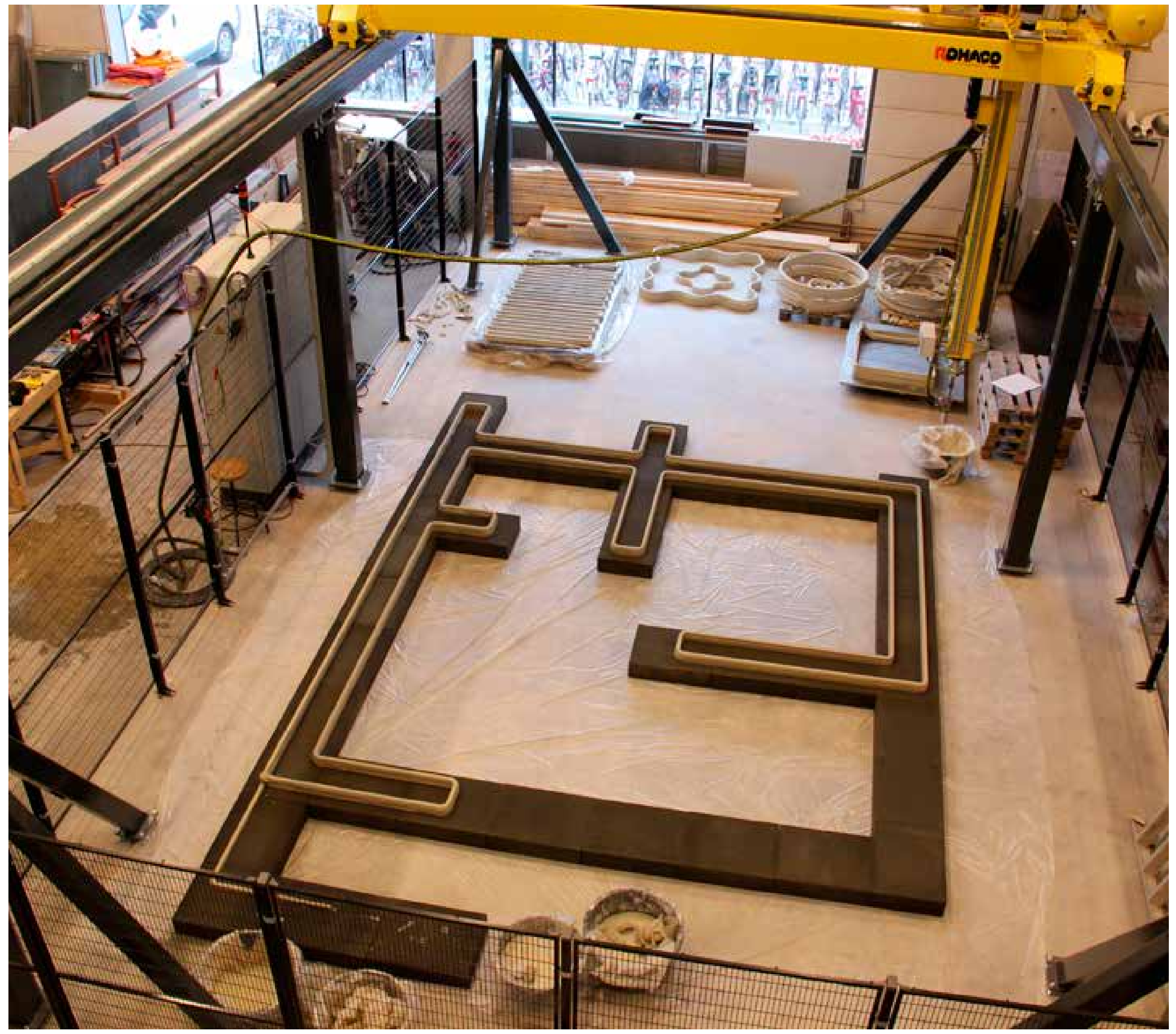
Powder bed fusion



Sheet lamination



Vat photo polymersiation



In steeds meer disciplines vindt 3D printen toepassingen. De meest uiteenlopende producten kunnen met deze techniek worden gemaakt; een steeds breder scala aan printbare materialen is daarvoor voor handen. Hoogwaardige, geometrisch complexe producten zoals machineonderdelen uit gesinterd metaalpoeder winnen terrein. Maar ook lekkernijen van geprinte chocolade en suikerwerk lijken een toekomst te hebben. De mogelijkheid tot mass-customization (het massaal vervaardigen van unieke voorwerpen) vindt haar ultieme toepassing in het 3D printen van medische protheses.

In de bouwwereld wordt de techniek nu zo'n 15 jaar toegepast voor het maken van maquettes, het beoordelen van verbindingen en details, e.d. Sinds een paar jaar wordt voorzichtig de stap gemaakt naar het printen van gebouwen en bouwdelen. Er wordt geëxperimenteerd met het printen van diverse materialen, waaronder staal, kunststof, hout, glas en beton.

Het 3D printen van betonachtige materialen gebeurt op ongeveer een dozijn plaatsen in de wereld. Een aantal bedrijven en een paar universiteiten, onder andere in Italië, Engeland, de VS, China en Nederland, experimenteren ermee. In China zijn al huizen en een meerlaags kantoorgebouw met behulp van deze techniek gerealiseerd. Alhoewel niet bekend is wat in die projecten precies wél en wat niet daadwerkelijk geprint is, zijn dit onmiskenbaar belangrijke eerste stappen naar een toekomst waarin het 3D printen een belangrijke techniek zal zijn voor de realisatie van gebouwen.

Het 3D printen van betonachtige materialen gebeurt op ongeveer een dozijn plaatsen in de wereld.

Het 3DCP project van de TU Eindhoven wordt ondersteund door een groep bedrijven die deze toekomst voor zich ziet. Samen vormen ze een groep waarin de hele maak-keten vertegenwoordigt is: cementleveranciers, betonbedrijf, aannemer, ingenieursbureau. Eén van de bedrijven verkent zelf ook de mogelijkheden van het beton printen.

De 3D beton printer van de TU/e staat in het Pieter van Musschenbroek-laboratorium van de faculteit Bouwkunde. De printer bestaat uit een portaalrobot met vier vrijheidsgraden (x, y, z en rz) en een intern 'printbed' van 9,0 × 4,5 × 2,8 m, aangestuurd door servo-motoren. De machine is voorzien van een Siemens Sinumerik 840 sl motion controller, die werkt op basis van zogenaamde G-Code. Dergelijke controllers worden vaak gebruikt in de CNC-gestuurd boren en frezen. De portaalrobot is via een flexibele slang verbonden met een MTec DuoMix 2000 beton pomp/mixer. De pomp is ook verbonden met de controller waardoor de bewegingen van de robot (snelheid, versnelling, rotatie) gekoppeld kunnen worden aan de toevoer van beton.

Dat het 3D beton printen veel potentie heeft is duidelijk. Maar de vraag hoe deze het beste benut kan worden, is veel minder makkelijk te beantwoorden. Om een stip aan de horizon te kunnen zetten, heeft Tektoniek in samenwerking met Boossting een Design Challenge opgezet. Uitdaging: 'doe een ontwerpvoorstel voor een bouwwerk dat optimaal gebruik maakt van de potenties die 3D-betonprinten lijkt te bieden'. De uiteenlopende resultaten die dit opleverde onderstreept wel hoe breed de mogelijkheden zouden kunnen zijn. Drie projecten werden geselecteerd. Het onderzoeksteam is met de projectteams aan de slag gegaan om te kijken welke eerste stappen gezet konden worden om de concepten te realiseren. Daarbij is geëxperimenteerd met de vorm van de spuitkop, het printen op gekromde ondergrond, uitkragingen, het printen van splines, etc. De techniek is in dat proces een stuk beter onder controle gekregen, de do's and dont's zijn boven water gekomen.

Tegelijkertijd zijn ook de uitdagingen voor de komende jaren naar voren gekomen. In de eerste plaats moet de vormvrijheid – de belofte van 3D printen – gerealiseerd gaan worden. Hiervoor moeten uitkragingen geprint kunnen worden. Dat vraagt ook om een ondersteuningsmateriaal. Verder moet het printmateriaal gekarakteriseerd en geoptimaliseerd worden. Gedacht moet worden aan de relaties tussen viscositeit, groene sterkte en stijfheid, uitgeharde sterkte, uithardingssnelheid, hechting van laag op laag, etc. Voor constructieve toepassingen is de vraag hoe veilig (plastisch) bezwijkgedrag moet worden verkregen, voor de hand liggend.

De uiteenlopende ontwerpvoorstellen die dit opleverde onderstreept hoe breed de mogelijkheden zouden kunnen zijn.

Verschillende voorstellen uit de Tektoniek/ Booosting Design Challenge voorzien ook in het gebruik van meerdere (beton)materialen door elkaar, bijvoorbeeld een isolerend beton op de ene plek en een constructief beton op de andere. Omdat de printkop tijdens het productieproces overal in de constructie minimaal één keer komt, behoort een dergelijke optimalisatie tot de mogelijkheden. Dit is bij uitstek de 'kleurenprinter' die de onderzoeksgroep voor zich ziet: een betonprinter die een element precies zo op kan bouwen dat het op elke plek de eigenschappen bezit die het nodig heeft, ook al kunnen die voor elk opvolgend element totaal anders zijn. En daar wordt aan gewerkt!

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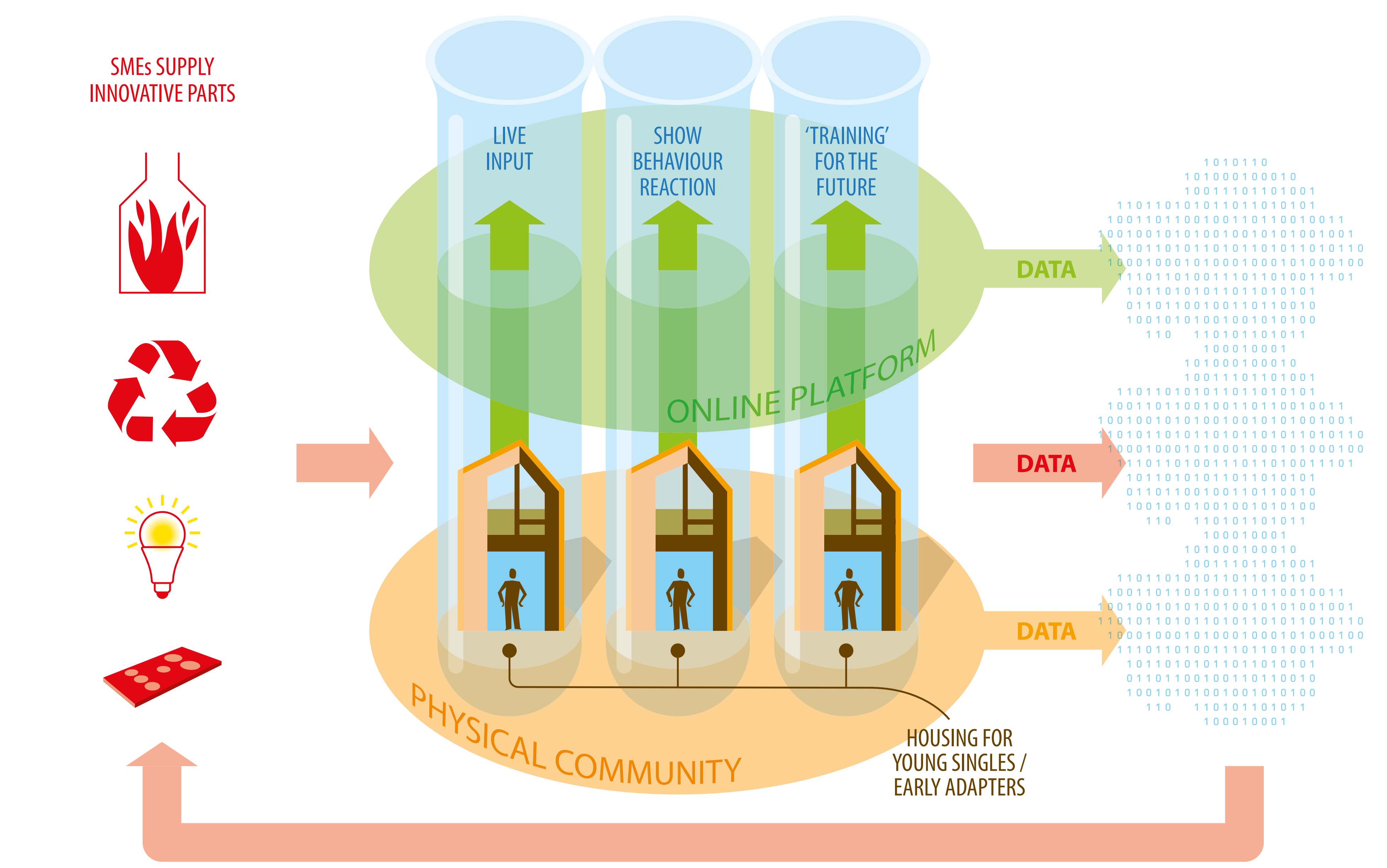
Dr. Ir. **Freek Bos**, Ing. **Cor de Bruijn**

Ballast Nedam, Bekaert, Concrete Valley, CRH, CyBe, SGS Intron, Stichting SKKB, Van Wijnen, Verhoeven Timmerfabriek, Weber Beamix, Witteveen+Bos



What is required from built environment enterprises to comply with the sustainability goals set by COP21 in Paris? Are the goals set by European Union for 2020 for new buildings or renovation of old buildings enough to tackle the built environment's impact on climate change? In order to reach the energy neutral built environment, new and renovated buildings should produce more energy than they consume, to compensate for existing buildings, for which there are no plans to get renovated. Such an approach should produce high margins for the built environment enterprises, either with the ESCO approach, or by higher selling prices, due to the reduced life cycle costs of their buildings. The society would also benefit by actively participating in the energy transition, by enabling energy efficient houses to reach positive energy margins by adapting their energy consuming behavior. This could also be translated to monetary savings. But how can the built environment enterprises to design and built positive energy buildings? Would the design for positive energy built environments in community level be more socially and financially attractive? A strategy towards the design of positive energy built environment has been developed using the Heijmans ONE communities as a case study.

Project scope
In this project, TU/e university researchers and Heijmans N.V. have formed a team, in order to link industry with research for the potential application of research outcomes in built environment development projects. It aimed to develop a strategy for the integration, implementation, operation and maintenance of new technologies and practises in the design of the built environment. An actual Heijmans built environment project, the Heijmans ONE communities, was chosen as a case study to perform applied research. The Heijmans ONE residence is a new product of living developed by Heijmans, aiming at young professionals who earn too much for social housing and too little for the free rental sector. It consists of a small prefabricated, mountable, temporary residence.

Goals and results
One of the two main goals of this assignment was to develop a list of technologies that can be applied in built environment, and a strategy to pave the way towards the goal of the company to design and potentially construct a zero energy, or even positive energy (surplus energy balance), urban environment by 2020. To validate this strategy and especially regarding emerging technologies, the case study was introduced, in order to match the Heijmans ONE with a creative process towards the transition to sustainability. The second main goal was to develop a business plan for the commercialization of the results of the applied research. For this, the idea of a living lab based on the Heijmans ONE residence where innovative technologies would be tested emerged. Ideally, these technologies would modularly attach to the building in a similar way to 'Phonebloks' flexible mobile concept. Following this concept, the "Autarchy Hub" idea evolved, which lead to the design of a centralized neighbourhood level energy service business case and business plan.

One of the main goals was to develop a strategy to pave the way towards the goal of the company to design and potentially construct a zero energy, or even positive energy (surplus energy balance), urban environment by 2020.

Results
In order to accomplish these goals, the milestones set were met:

- A detailed morphological overview of available or potentially available materials and technologies for implementation in the urban environment for district, building, and user level.
- An assessment of materials and technology; based on investment, operational and aintenance costs, if possible.
- A technology selection strategy for optimization of the design of buildings based on typology, functionality and realization criteria of technologies.
- A business plan for the development of a living lab for the Heijmans ONE community.

The successful completion of these milestones has allowed further development of the project's aim and a broader application of the formulated design strategy to other built environment projects. In detail, the following are the most important additional results of the project:

- A business law report for a company producing a neighbourhood level centralized CHP plant.

- The development of the design basics, requirements, criteria, and design optimization for the Heijmans ONE residence, producing 2 scenarios: the "Smart Off-grid Heijmans ONE"and the "Heijmans ONE SmartVille".
- A proposal for the renovation of RM3 Heijmans office complex, using the developed database with assessment of the proposed design scenarios.
- A proposal for the renovation of social housing residences, using the developed Matlab tool and database, with assessment of the proposed design scenarios.
- A detailed component sizing and pricing for the Heijmans ONE off-grid system and connection with two companies to realize the a forementioned project plan.
- Participation, reaching the national finals, in Climate KIC Launchpad NL competition with the 'Autarchy Hub' idea for neighbourhood level (centralized) Energy Service Company.
- A business plan for the development of an energy service/product Heijmans spin-off company called 'Autarchy Hub'.

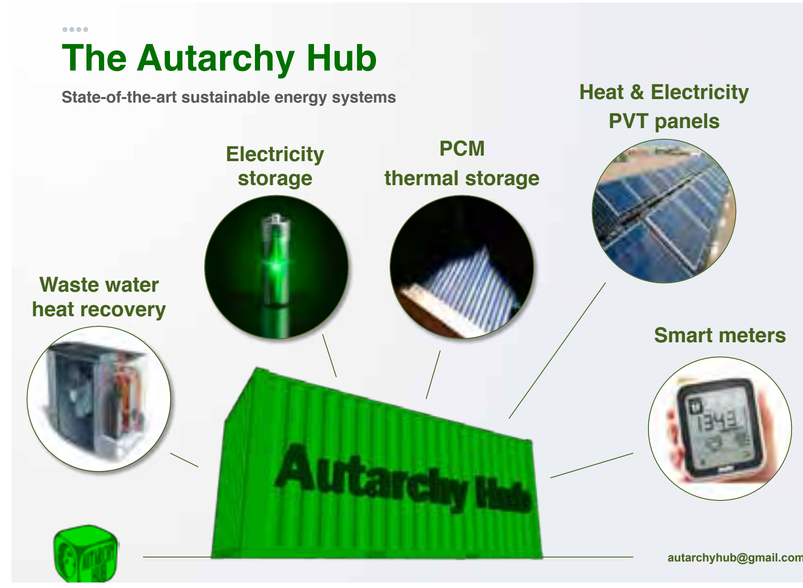
Field study
During the period of this project, the first two Heijmans ONE residences were constructed and placed at Zeeburgereiland, Amsterdam. In one of these residences, different people would stay over the period of a few months, while the other was used for showcasing purposes. Then, following the development of the living lab idea, it was decided to install energy consumption plug load monitoring equipment in one of the two residences.

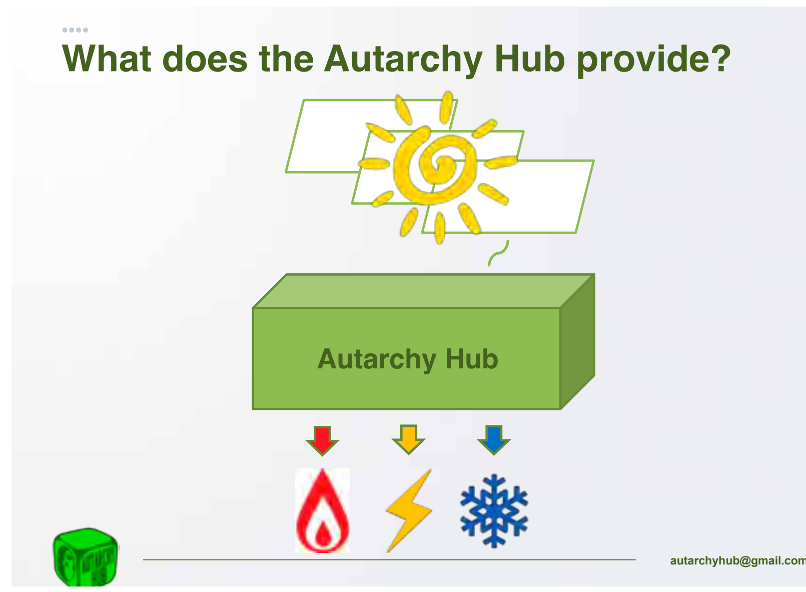
The installation of this measuring equipment allowed us to monitor and understand the energy consumption patterns of the Heijmans ONE and the most energy consuming appliances. In addition, the indoor temperature and humidity conditions were monitored, in order to distinguish the thermal comfort conditions in the residence.

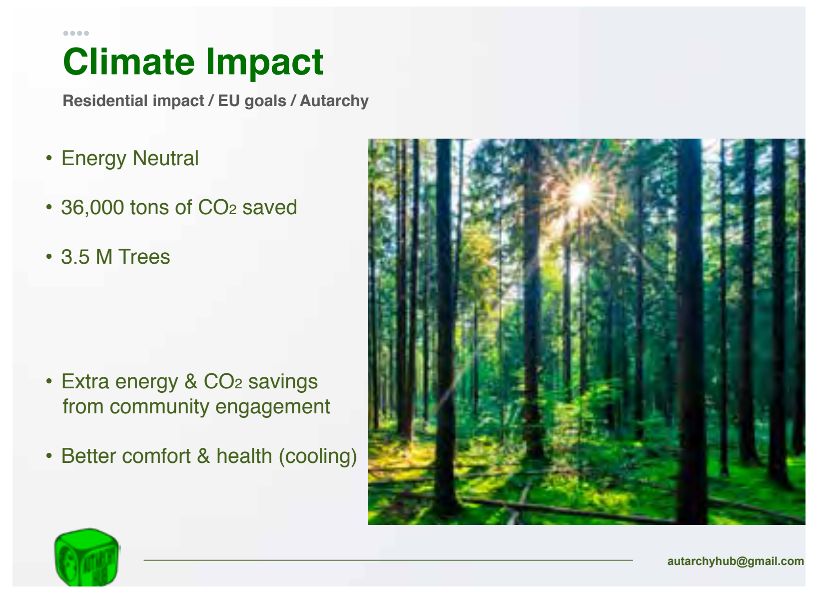
Finally, the measurements were used to validate a building performance simulation TRNSYS model of the Heijmans ONE residence, developed by an MSc graduate in Building Services & Physics in TU/e, for checking the performance of the design tools and in depth optimization of the detailed design.

The process innovation is related to the development of initial design stage building optimization tools giving emphasis in the energy aspects.

Conclusion
The project involved the development of both process and product innovation results. The process innovation is related to the development of initial design stage building optimization tools giving emphasis in the energy aspects. The product innovation is related to the development of the business plans for the living lab and the "Autarchy Hub", to be realized in 2016 in collaboration with TU/e and its Innovation Lab.







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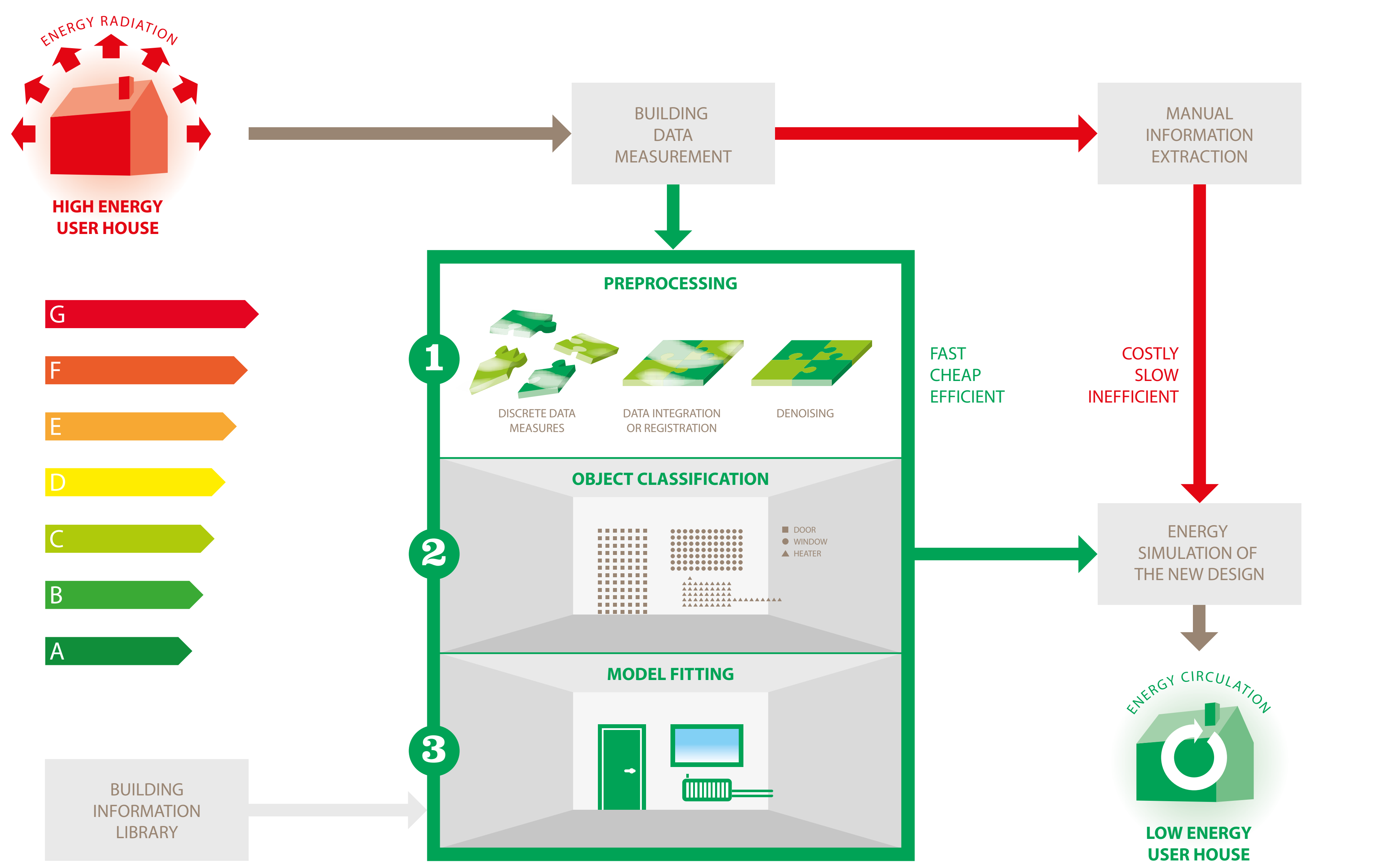
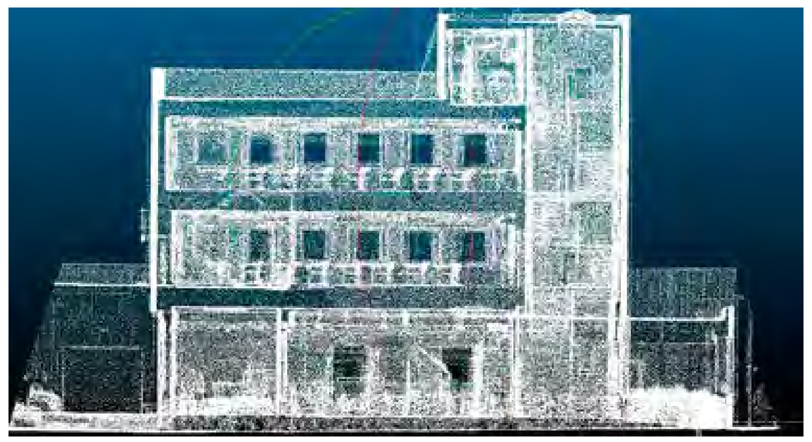
Jordi Guasch Lopez



Renovation of existing buildings is known as an essential stage in reduction of the energy losses. A critical part of this process is simulation of energy usage based on geometric reconstruction of the building. Following many research projects focused on parameterizing the energy usage, various energy modeling methods were developed during the last decade. However qualified simulations highly depend on external geometric information of the building.
On the other hand, by development of the accurate 3D measurement tools such as laser scanners, the industry is highly eager to use this technology for innovative solution. Architectures, engineers and constructors were the early users of laser scanner products. But the application of this technology still does not meet the increasing industrial demands. The automation of 3D information extraction from laser point cloud and object detection tasks are still significant challenges of industry.
The aim of this project is designing a platform through which required geometric information can be efficiently generated to support energy simulation software. Developing a reliable procedure which extracts required information from measured data and delivers them to a standard energy modeling system is the main purpose of the project. Reaching to this point is highly beneficial both in short and long term. Energy labels for existing buildings are an urgent demand of authorities. Having a functional application to speed up energy simulation and energy label generation would be an early achievement of this project. In addition, methodological development of such a system would have a significant contribution in the as-built modeling research field



Expected outcomes

Current renovation procedure for energy efficiency is too slow and expensive and is not covering market demand. One of the bottlenecks is having a reliable 3D as-built model to run the energy simulation. However 3D modeling is a wide field in science with various methods and standards. Energy simulation software, such as Energy plus, requires general geometric information from indoor area of buildings. The coordination of heating zones, dimension and orientation of walls, position and shape of the openings, position and volume of energy sources are quite essential information for a reliable energy simulation. Therefore the expected outcome is an efficient platform which provides such information. Optimization between automation and accuracy for efficient energy simulation is the main target of this platform. Nowadays laser scanners are frequently used to provide dense as-built measurements. However the cost of modeling is often more than the measurement. Following algorithm describes an easy-to-use procedure which leads to creation of input file enriched by the geometric information for Energy Plus software. This procedure is designed to tackle the complexity of dealing with laser data, reducing uncertainty in calculations and avoiding unnecessary details.

The platform and the functional sections

The user can operate the platform through an interface (Figure 1). Push buttons, selection from the list and simple mouse clicks are all user efforts to interact with the program. Users can track the procedure through some illustrations and apply required changes. Functional sections are illustrated in Figure 2 and are explained in following subsections.

File input and floor detection

The Point cloud of a building can be uploaded as a text file to the system. At the beginning the point cloud does not have any structure. In this part histogram matching analysis is used to divide the point cloud to a number of levels. For this aim Z value of all points are used to generate a histogram. Some knowledge based conditions is employed to automate the process. For instance in the histogram, a minimum between two maximums (the ceiling points from previous story and the floor points from the next story) is considered as a clue to draw a division line. Or a condition of at least 3m distance between division lines is also considered to avoid wrong detections. Then the points of different stories are labeled.

This procedure is designed to tackle the complexity of dealing with laser data, reducing uncertainty in calculations and avoiding unnecessary details.

Segmentation of level points

A typical story is composed of a floor, a ceiling and some walls. In the most cases the floor and the ceiling are horizontal objects and the walls and their attached objects (doors and windows) are vertical. In this section, an algorithm is used to differentiate the floor and ceiling points from the rest of the points. The user can select a story to recall corresponding points. Ceiling points and floor points of the selected story are detected and labeled through a plane fitting function.

Wall extraction

The aim of this section is recognition of wall models. This is an essential step because the orientation of walls and their dimensions are very important information for energy simulation. Instead of the common methods which is based on plane detection in 3D space, 3D points

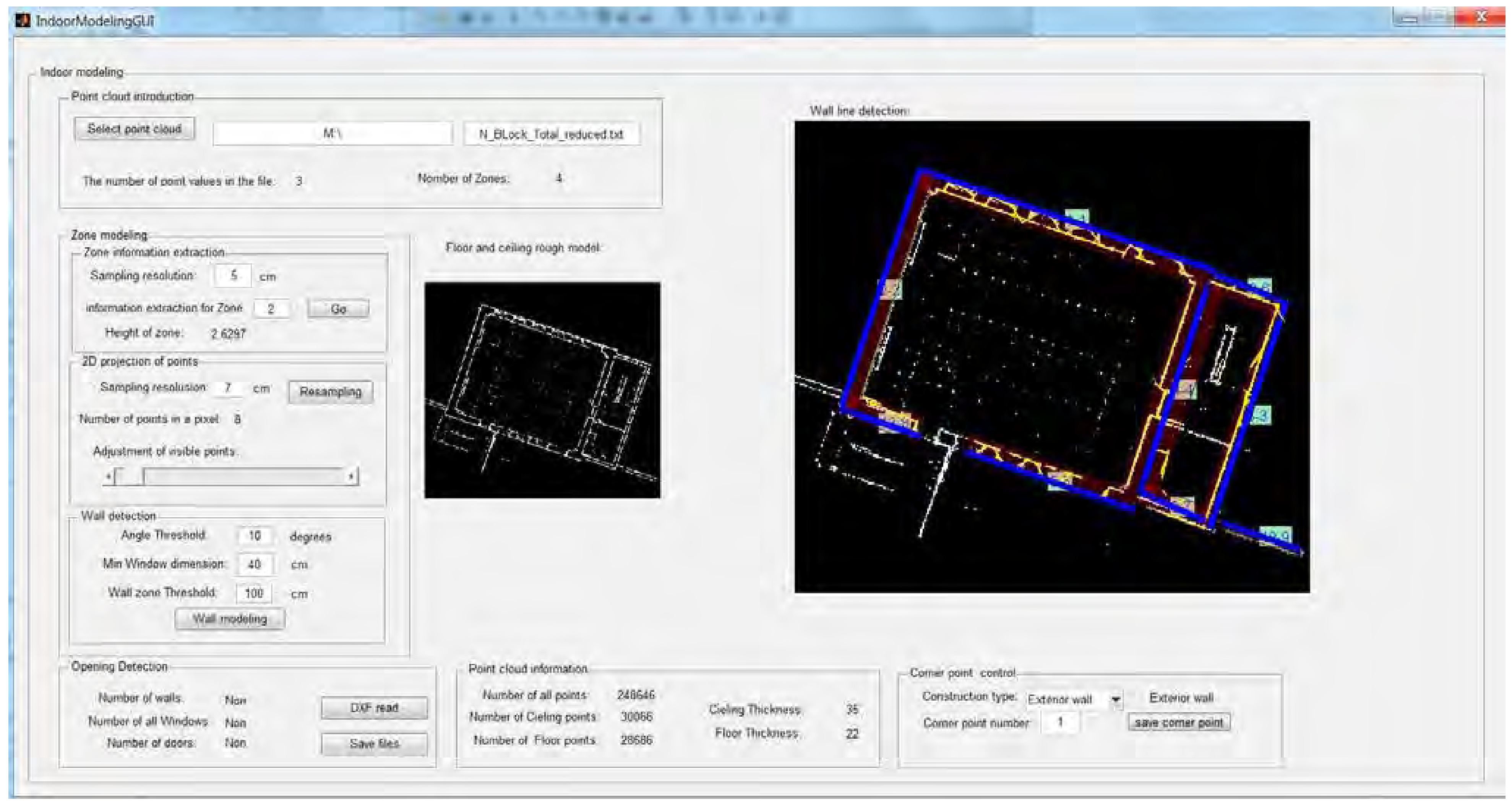


Figure 1: The platform interface

Figure 2: The flowchart of the program.

are projected on XY plane as a main source of wall detection. This strategy brought some computational advantages. After some successive computations (mentioned in the flowchart of figure 2), main walls and their attributes are estimated.

Openings extraction

Detection of empty spaces on the wall is the main clue of automatic window detection. The idea is that laser points are more dense and uniform on wall area. While glass windows are appeared as holes in point cloud. As another clue, windows with curtain or closed doors are appeared as a slight intrusion or extrusion in the dominant wall plane.

Verification and labeling

Extracted information needs to be controlled and verified by the user. For this reason a user-friendly section is designed. The results of automatic object detection are represented to the user through the interface. The user is enabled to apply some corrections with simple efforts such as mouse clicks and selection from a list. This information finally is combined with automatic driven information.

Save in Energy plus format

Verified information has to be transformed to a format which is readable for Energy plus. A sample txt file is used for this aim. Geometric information is added to the end of this file and saved in a separate name.

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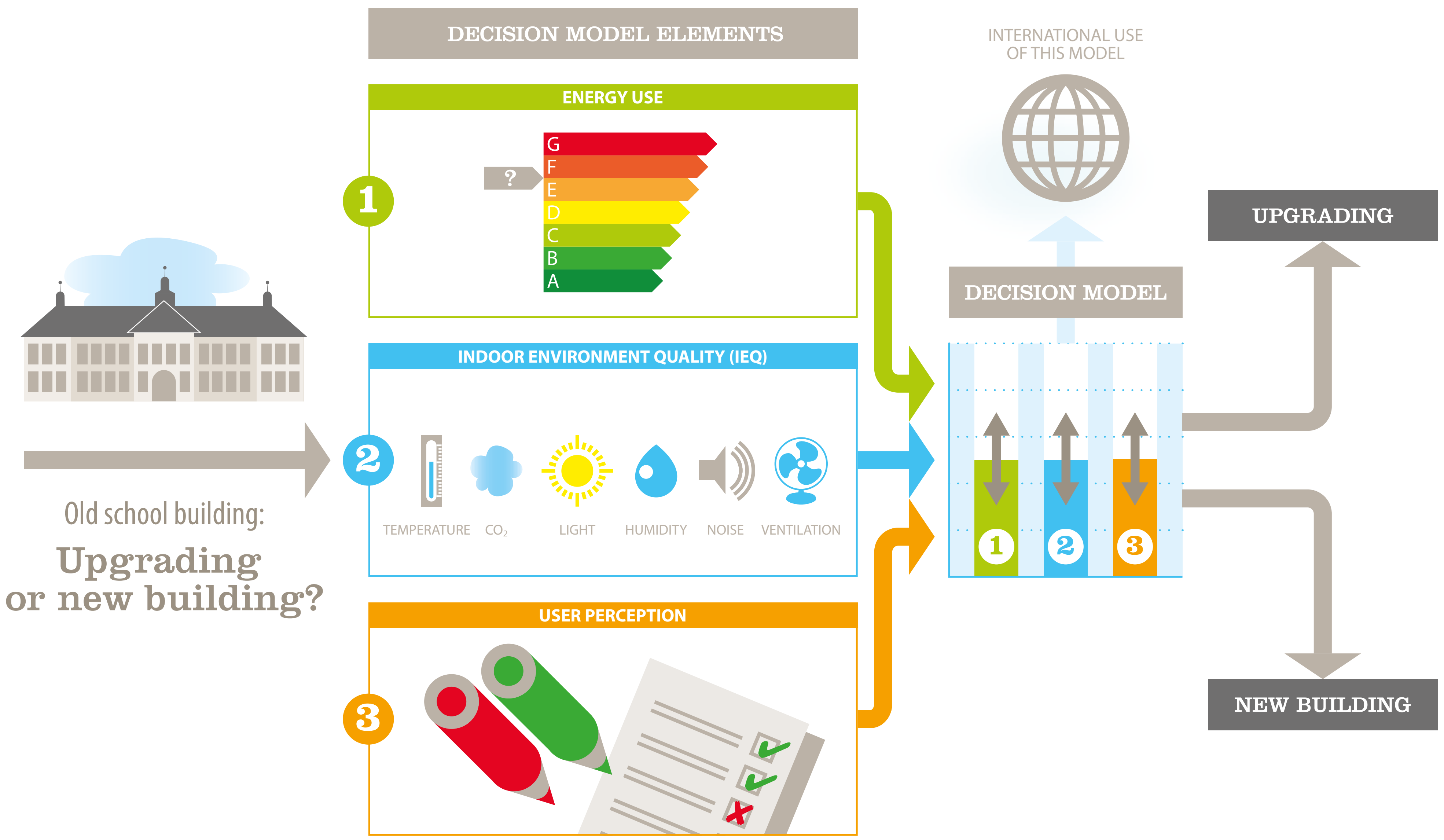
HEALTHY LEARNING ENVIRONMENT PDENG

balancing indoor environment quality, energy use, and costs



The quality of school buildings in the Netherlands is in general not so good, with a very large percentage of them not complying with good practices for the indoor environment. According to RVO (Rijksdienst voor Ondernemend), in about 70% to 80% of the total of Primary and Secondary schools, CO2 concentration levels are much too high. This can cause an increase in health-related issues, which in turn affects the performance from both pupils and teachers. In addition to this problem, schools across the territory also have high energy costs, which represent up to 20% of their fixed costs. Oftentimes, School Boards are faced with important decisions to make regarding the improvement of the quality of the indoor environment in their facilities; it is not a simple and straightforward task, as there are many factors that need to be taken in consideration, such as costs and energy use in the buildings. And of course, all schools do not have the exact same priorities, nor do they face the exact same issues regarding their indoor environment. Therefore, a balance between all the elements mentioned above –i.e. Indoor Environment Quality, energy use and costs- will not be the same for every school. How to achieve this balance and support the schools in their decision making is at the core of this project.

The goal of the project 'Developing a model for the balance of energy use and Indoor Environment Quality in school buildings' is to create a decision support model to help School Boards make informed decisions about actions that they could implement in their facilities to improve the quality of the indoor environment and to reduce their energy consumption.
To achieve this goal, a model was designed using three data flows as input: First, data for the following Indoor Environment Quality parameters: CO2 concentration, indoor temperature, relative humidity, daylight factor and acoustics; Second, data for energy consumption; and third, data about the perceived satisfaction of the users, which was collected by means of questionnaires. By means of two separate Co-Creation sessions, the structure of the model was defined and further refined. The model is divided in four quadrants: Assessment of the current situation, definition of the priorities, selection of recommended actions and display of improvement. An explanation of each of the quadrants is given below.

Too high CO2 concentration levels can cause an increase in health-related issues, which in turn affects the performance from both pupils and teachers.

Assessment of the current situation:
The initial step is to understand the current situation of the school building. In this step, the measurements of Indoor Environment Quality parameters and energy use, together with the results of questionnaires are collected. Next, each individual parameter (CO2 concentration, temperature, relative humidity, lighting and acoustics) is benchmarked to the values of the reference scenario and a 'grade' is given. Currently, the values used in the reference scenario are the ones given in the 'Frisse Scholen' Program of Demands, Class B. It is worth mentioning that the reference scenario is not the most optimal one -although it gives an acceptable basis for this project-, and for this reason a proper benchmark -discussed with and approved by the School Board- would be developed during the implementation of the model.

There are thousands of prospective schools that could benefit from the use of this model and the recommendations it gives.

Definition of the priorities:
The recommended actions that will be presented to the schools are evaluated according to four focus areas: energy savings, indoor environment quality, user satisfaction and costs. However, not all schools have the same priorities or desires; or they might not be fully aware of what their actual priorities or desires are. For this reason, a questionnaire is designed to help School Boards determine the ranking in importance of these four areas.

Selection of recommended actions:
Once the focus areas are ranked according to the desires of the School Board, the Analytic Hierarchy Process is followed to determine which actions are suitable. Applying this process, information is categorized in a hierarchy of both alternatives (actions) and criteria. Subsequently, the information is summarized in order to determine a relative ranking of the applicable solutions.

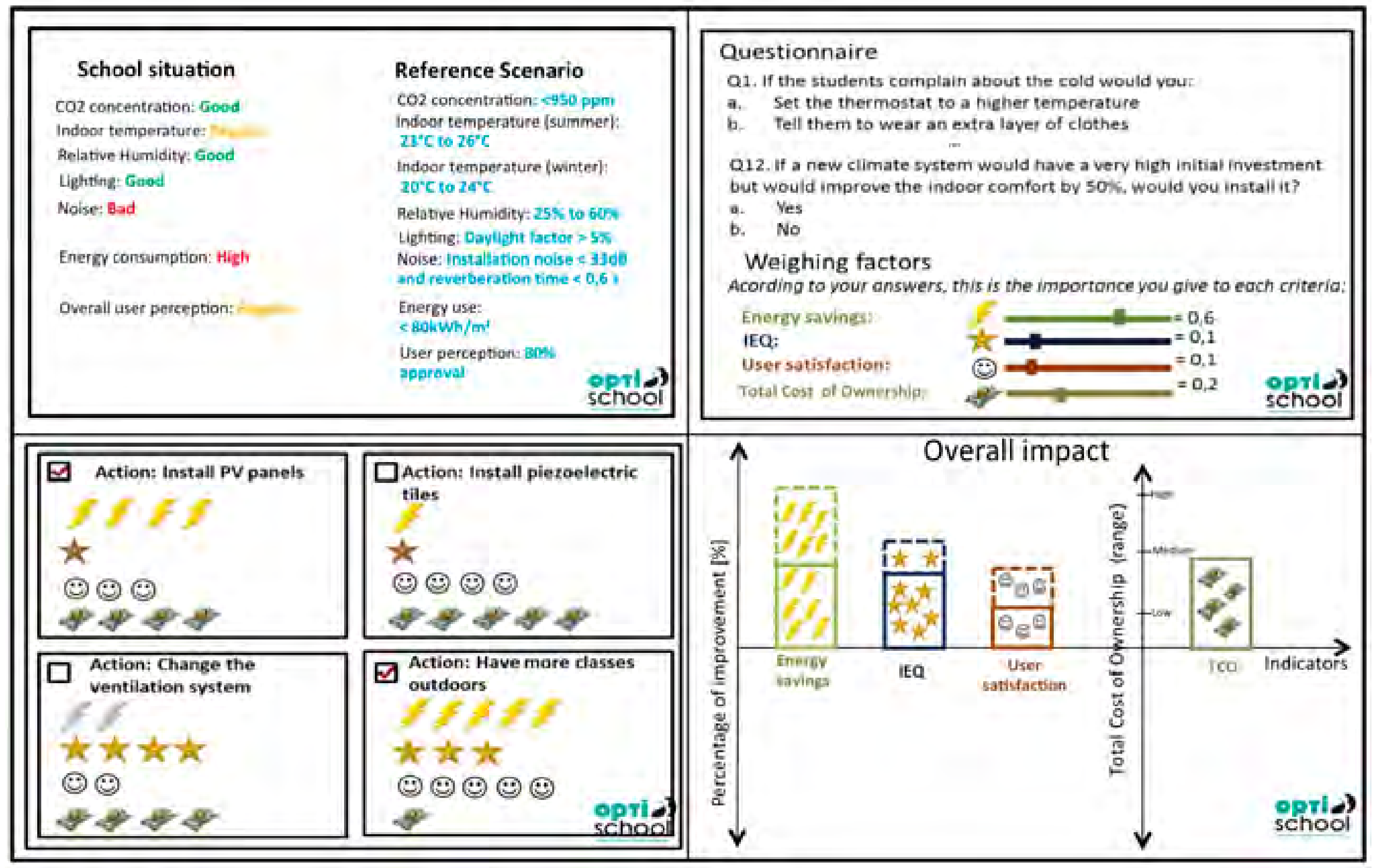


Figure 1. Representation of interface of the model

Display of improvement:
The total contribution of the actions to the improvement of each of the focus areas is shown. A bars diagram is used to indicate how much improvement there is after applying the actions. Figure 1 shows a representation of how the interface of the model could look like.

There are thousands of prospective schools that could benefit from the use of this model and the recommendations it gives. At the moment, there is not a specific tool in the market that can take into account the preferences of the main stakeholders, and propose solutions accordingly. This is one of the strongest points of this solution, and the one that could make it an attractive and well-received tool among the schools. The solutions offered by the tool are based on real-time measurements of the performance of the buildings, and as such, they would tackle the main issues at hand. Furthermore, the solutions (actions) included are backed by the expert knowledge of professionals in the field who were consulted during the development of the model; in this manner, it is possible to assure to the schools that the information given by the tool, is of the highest quality.

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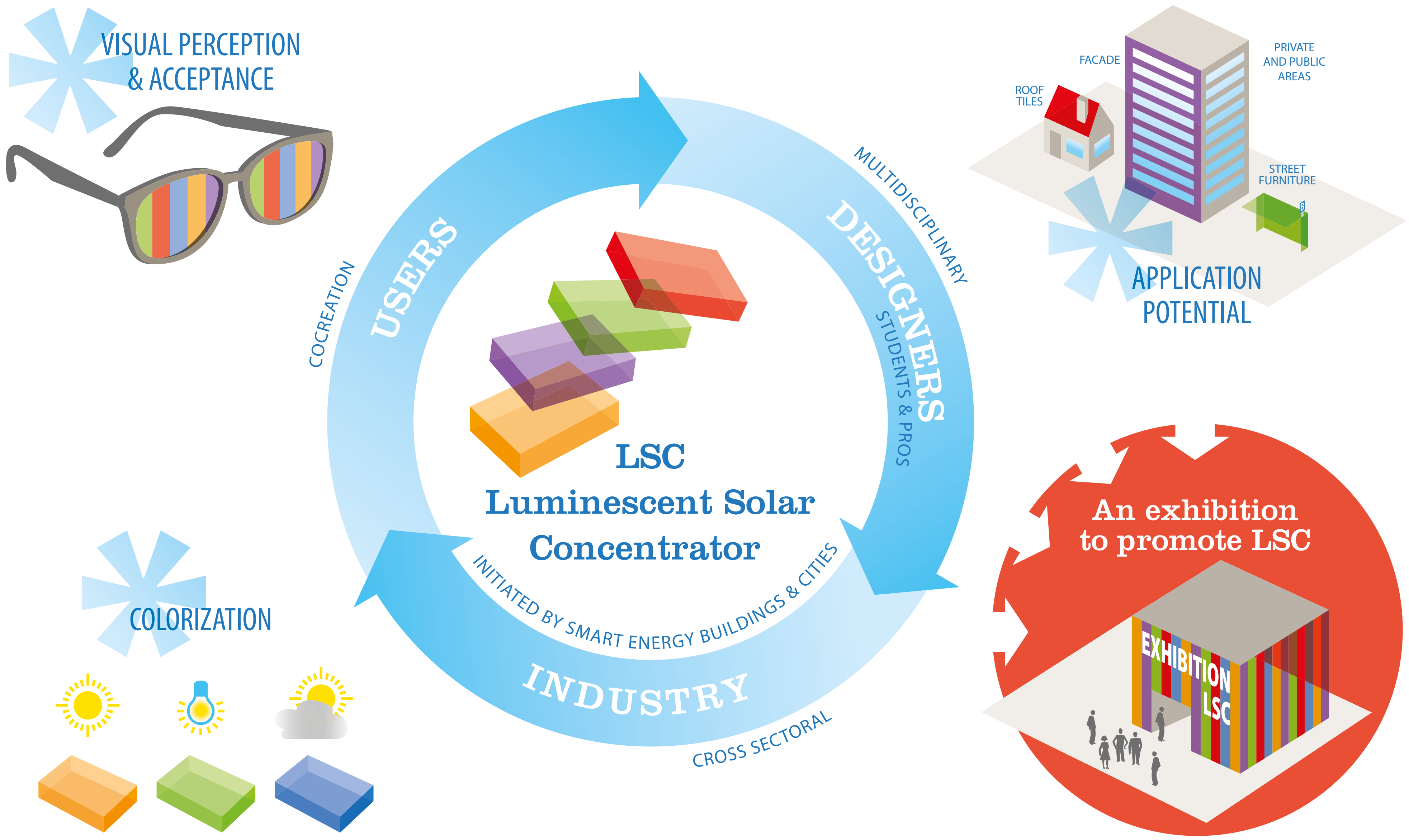
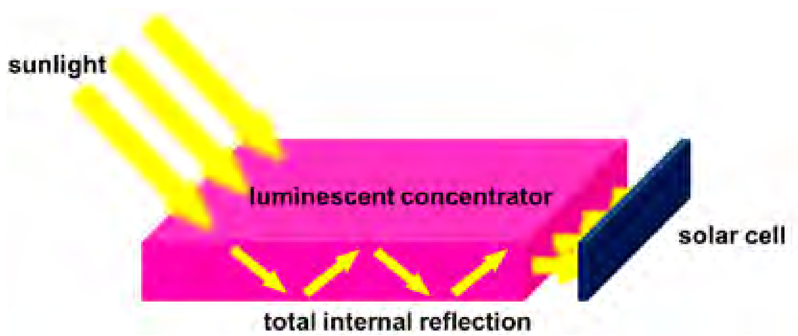
utilizing LSC through design quality and product development



A luminescent solar concentrator (LSC) is a device that has luminescent molecules embedded in a polymeric or glass waveguide to generate electricity from sunlight via a photovoltaic cell attachment. The LSC device can function in diffused light as well as direct light, and may come in a variety of colors, shapes and transparencies. Therefore, the LSCs can be employed both in small and large scale projects, independent on the direction or angle of the surface with respect to the sun. It also promises more freedom for integration in urban environments and design choices compared to the traditional PV systems.
Even though, the LSC offers many advantages over existing technologies, it has not yet been commercialized. To achieve this, proper understanding and exploration of not only technical aspects, but also insights into its presentation, design and appearance is needed.
The aim of this Smart Energy Buildings & Cities (SEB&C) company assignment is to investigate the applicability of the LSC device in the built environment and to create a successful business case for a new product design that utilizes this technology.

The necessity of a paradigm shift emerged towards sustainable and smart cities due to the significant increase in the energy demand of buildings. The challenge is to increase renewable sources in the energy mix while designing aesthetic environments. Therefore, renewable energy technologies that can be well integrated in urban environments represent a great opportunity to help overcome this current challenge.
Smart energy, energy efficiency and use of renewable sources are key aspects to be considered nowadays and many innovative technologies need further exploitation to be commercially viable, such as the luminescent solar concentrator.



Even though, the LSC offers many advantages over existing technologies, it has not yet been commercialized.

The research on solar energy conversion with luminescent solar concentrators (LSCs) was initiated in late 1970s; these first experiments aimed at solar energy conversion with florescent collectors to be used at greenhouses (Weber & Lambe, 1976; Goetzberger & W., 1977). Due to the shift from fossil fuel to renewable sources for energy generation and the emergence of solar energy technologies to improve sustainable development; research on LSC gained importance as it is a promising technology for integrated energy generation solutions in urban spaces.
The working principle of LSC has not been changed from late 70s until now; nevertheless the improvements of luminescent materials, solar cells as well as theoretical studies renewed the interest in the LSC technology. Several configurations with different dyes, mirrors, reflector coating and PV types have been investigated to increase the electrical performance. Furthermore various research groups throughout the world, including TU/e (Debije & Verbunt, 2011), have been investigating the energy performance of the LSC modules in order to create value that is feasible and competitive in the built environment market.
To create value, the product type is as important as the energy performance. This means we should think of designing products benefitting from the appearance of LSC while generating some energy. It was necessary not to see the electricity generation as the main target but an additional value.

Before selecting a product idea for further development, we followed a participatory approach to generate ideas about the possible application areas of the LSC device. Two co-creative workshops and an open innovation survey were executed to gather ideas about the applicability and visual perception of LSC with the participation of the SEB&C trainees, employees of Heijmans, two freelance designers and 83 surveyors.

Looking at the results gathered during this co-creative process, it can be stated that, participants perceive LSC as a technology that will help integrate renewable energy generation in urban areas. Exterior façade cladding, window glazing, public transportation waiting area, shading device and street lighting are some of the examples of application areas proposed by the participants. All the generated ideas gave us guidance to develop design concepts for three different LSC-based products, which have different value propositions for the built environment. One of these proposed design concepts was a small scale urban greenhouse that provides herbs and plants while generating some energy for its own use (lighting and water pumping for irrigation). This concept was called Re(d)Garden which was designed to work as a community garden in urban spaces. This design aimed at creating a social space that can be located at areas lacking vegetation while contributing to renewable energy generation, urban farming and rainwater harvesting to cope with the extreme rainfall events and floods.

The challenge is to increase renewable sources in the energy mix while designing aesthetic environments.

As a result of the explorations, we managed to develop LSC-based product concepts for various market segments. We can say that LSC-based products can be economically feasible with the integration of not energy intensive functions. If the technical performance of the LSC device is improved, we can expect to see LSC-based products in the energy and built environment markets in the near future.

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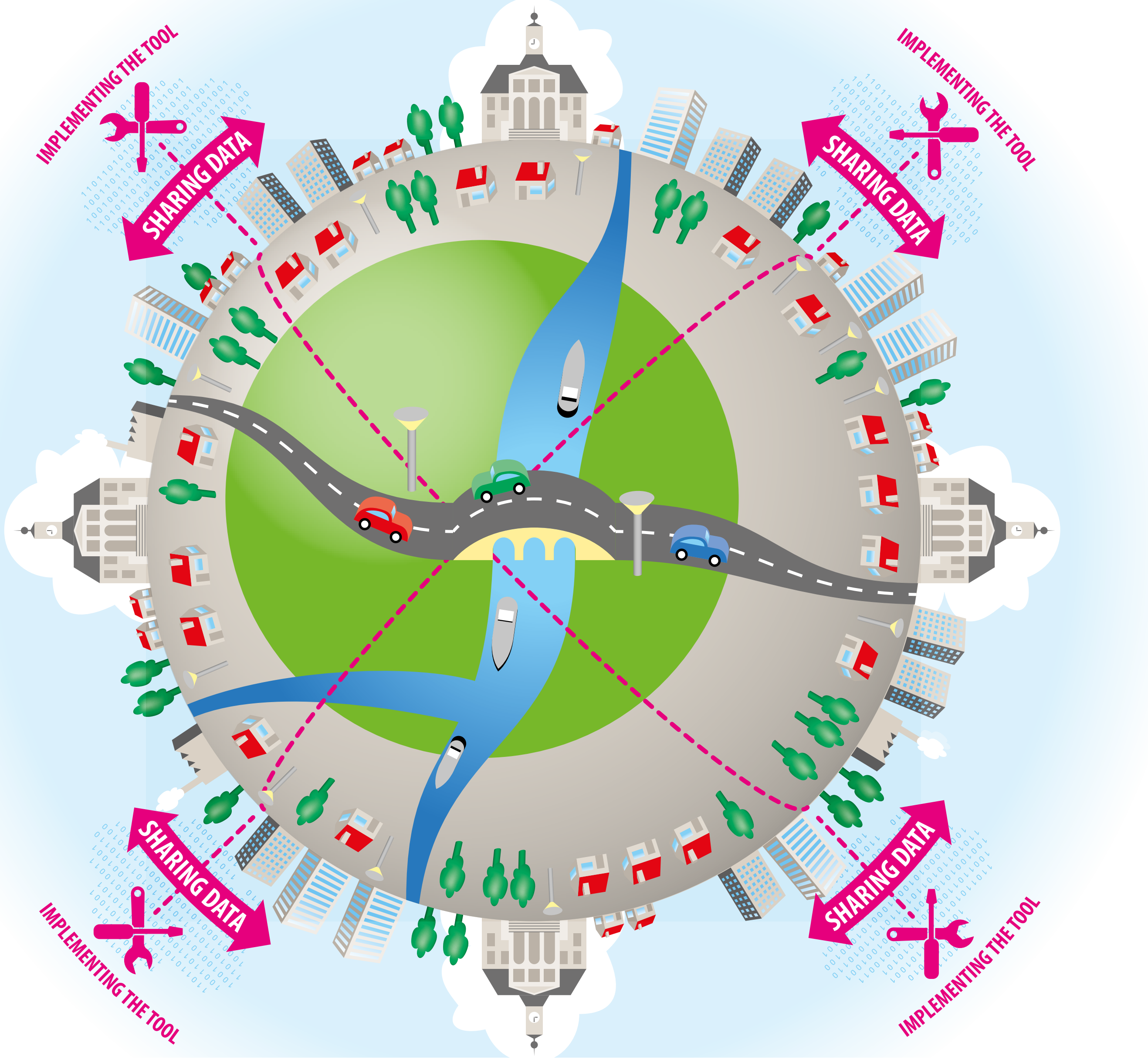
Goal: Interoperability

Context information
The municipality gathers the information from the infrastructure above and underground of a city. The zeros and ones represent the "data" of an asset in the database.

The problem
The unawareness of the potential business and common goals a municipality can have with other organization by being in an invisible capsule that block them from this to happen.

The solution
The solution is sharing information. It doesn't have to be all the information the organization posseses, but only the nesccesary by implementing the tool.

The tool
The database and the Life-cycle cost (LCC) will throw information to qualify performance, resources and interoperability making them work together smoothly.



The existing infrastructure of a significant number of business parks in the Netherlands and beyond is deteriorated. It is therefore not surprising that many municipalities are stuck with areas that are no longer attractive for businesses and that are more and more vacated. All across the Netherlands large efforts are undertaken to revitalize the infrastructure of business parks.
One important aspect during such revitalization efforts is the need to understand the life-cycle costs of the new infrastructure system. Despite this importance much of the current focus of municipal planners lies on understanding the first cost of a revitalization, while little understanding prevails over the financial and ecological effects of a new infrastructure system in the long run, gaining such an understanding is important, however, as, independent of the success of a system, municipalities have to guarantee the sound functioning of an area's infrastructure even in the case that only a few companies are occupying a specific area.
To support municipalities, the goal of this PDEng project is it to develop a Life Cycle Cost Analysis (LCCA) Tool to support municipal planners with gaining a better understanding of the life-cycle costs of a business park. More specifically, the project will focus on the harbors at the Twente Channel, which will start being managed by a new consortium in an integrated way in the near future.

The Company Context

The harbors from the municipalities Hengelo, Almelo, Enschede, Hof van Twente and Lochem form one of the biggest inland harbors in the Netherlands. This inland harbors are an important component in the region as 'logistic centrum' in Northwest Europe.
To achieve the desire to increase the water transport in the region, seems to be necessary to professionalize the management of the harbors at the Twente canal. Therefore, these five municipalities have expressed the desire to unify in a centralized management method of the physical and nautical tasks.

In January 2014 the five municipalities have approved a development plan, which was to lead to the establishment of a cooperative in the short term. The requirements of the development plan are:

- A cooperation based on a feasible management model,
- A central coordination and management of the basic tasks and accountable to the port managers,
- The uniformity / harmonization of some basic tasks and regulations and,
- To perform centrally the basic tasks.

Based on the above mention points, the Gemeenschappelijk Havenbeheer Twentekanalen (GHT) was created. This company has the responsibility, among others, to manage the infrastructure of the Twente canal. The first steps of the GHT are:

- To setting up the organization,
- To design and implement the basic tasks and,
- To develop the cooperation towards a more independent company.

The mission of the GHT is:

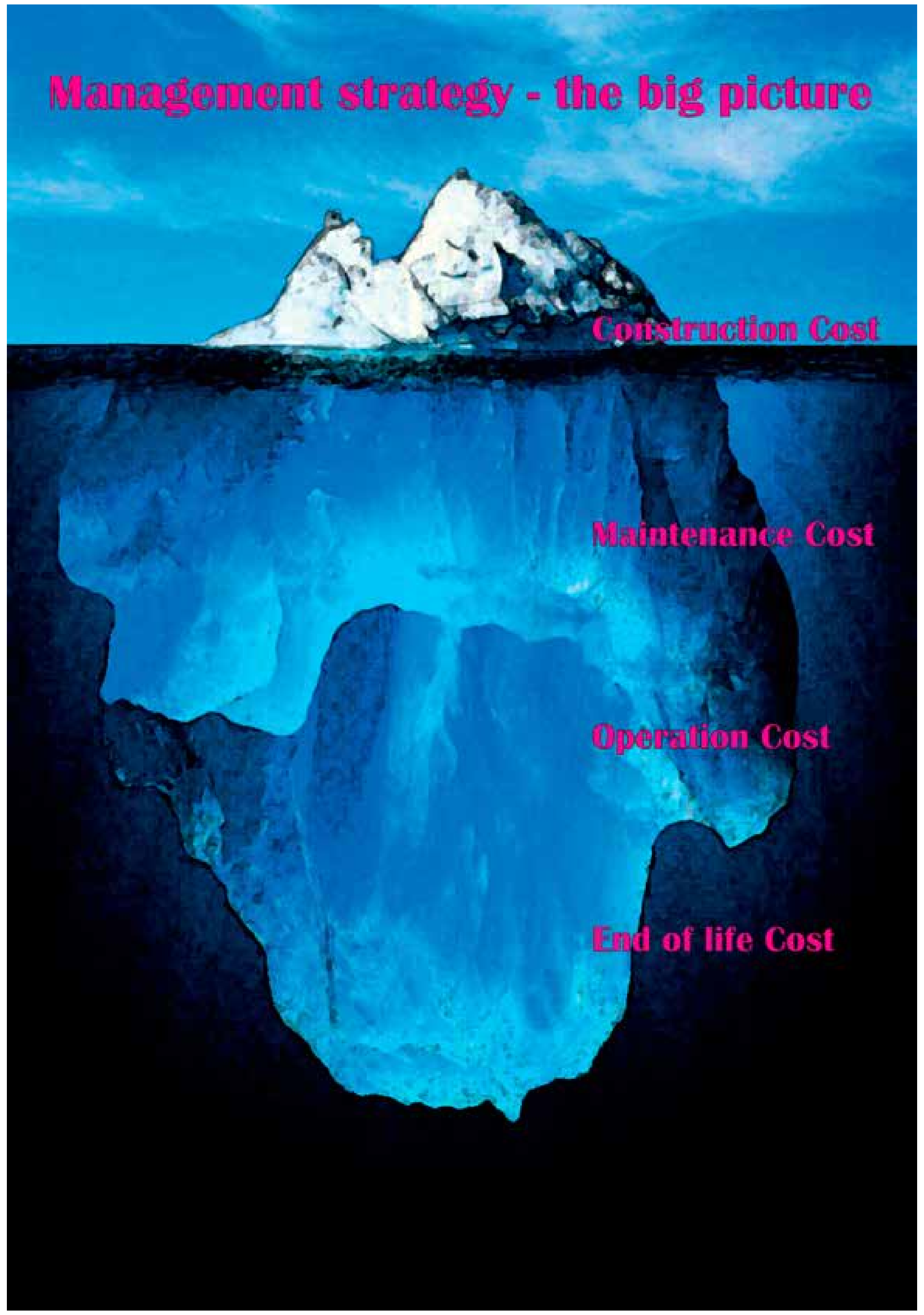
"Through an effective and efficient development of its basic tasks, in a professional and sustainable method, facilitate an optimum accessibility, quality of life and reliability of the inland harbors and the water-related businesses along the Twente Canal"

Amongst others, the GHT is responsible for managing the physical asset and creating the strategic future plans of the channel. From the physical assets point of view, this means that the harbors must be equipped and maintain according to the accessibility and safety required by the users. Therefore, the GHT should ensure the well-maintenance of the quays, quay walls and the soil (bottom) of the harbors. From the strategic point of view, GHT is responsible for the establishment of long-term visions as well as the establishing and monitoring a central budget and accounts.
Under the coordination and management of the port manager are the multi-year programs drawn up. The objective is to ensure proper coordination, timely maintenance of embankments, quay walls and harbor bottoms to ensure effective and efficient implementation of the maintenance and management tasks.
Being GHT a just conformed company, it is essential for them to establish an operational system. Therefore, in order to fulfill their tasks and responsibilities it is important to equip the company with a unified system that manages and controls the ownership and asset maintenance of its different components.

All across the Netherlands large efforts are undertaken to revitalize the infrastructure of business parks.

The PDEng Project

Maintenance in the harbor area is currently done only if an emergency presents itself, meaning it has very short term planning horizons. Given the scarcity of economic resources to be invested in the required processes of maintenance, the tasks of allocating and using the resources by asset managers is a real challenge. The short term operational strategy means that the resources have to be available at the moment they are needed. To be able to react quickly to such scenarios, the asset manager need to have at hand the right and current information about ownership, assets present, their conditions and their capacities. However, their current systems do not support the asset manager in obtaining this information efficiently nor consistently, as asset data is not interconnected nor standardized for the whole Twente Channel.
Therefore, the general objective of this project is to create a LCCA Tool to support GHT in deciding on how to allocate efficiently and effectively resources for managing the harbors infrastructure. The LCCA Tool that is being developed in this project allows planners to determine the sensitivity that asset management variables (e.g. preventive maintenance intervals) have on the costs of those asset such that they are supported in designing appropriate resource allocation strategies. Furthermore, it also enables planners in calculating the cost implications of different long and short term scenarios, and by doing so, determine the most efficient way to allocate resources. As Figure 1 shows, the tool integrates a database, a LCCA method and a decision-making engine based on the asset management requirements of GHT. The database allows incorporating a proper classification of the assets, and in combination with the LCCA method, it allows overlapping the life-cycle cost of each one of the assets at harbor. This allows asset managers to obtain tailored information for making construction and acquisition decisions, renewal and rehabilitation activities, and replacement and disposals tasks.



Little understanding prevails over the financial and ecological effects of a new infrastructure system in the long run

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Gemeenschappelijk Havenbeheer Twentekanalen

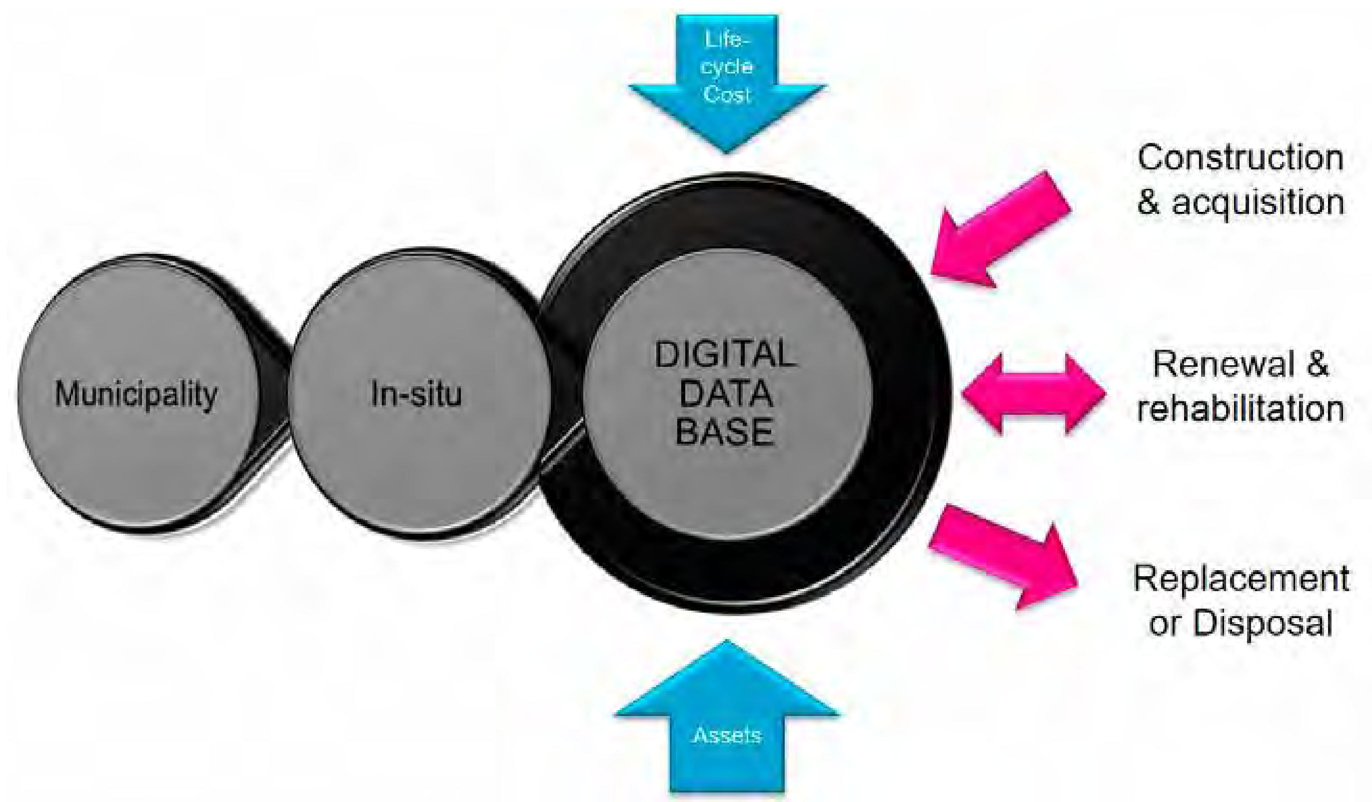

Figure 1. LCCA Tool