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A Flexible, Structured Approach to Commit University Stakeholders to Sustainable Development

Verhoef, Leendert; Graamans, Luuk; Gioutsos, Dean; van Wijk, Ad; Geraedts, Jo; Hellinga, Chris

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ShowHow: A Flexible, Structured Approach to Commit University Stakeholders to Sustainable Development

Leendert Verhoef, Luuk Graamans, Dean Gioutsos, Ad van Wijk, Jo Geraedts and Chris Hellinga

Abstract

This paper presents an alternative approach and preliminary results to developing a sustainable campus by connecting research, education and real estate management. It is coined 'ShowHow': the deployment and display of the knowhow of all stakeholders in a university. The approach is built upon five pillars: (1) *Projects*: the initiation of a variety of projects; (2) *Intensive real estate involvement*: the introduction of sustainability and innovation to all levels of real estate strategy and decision-making processes; (3) *Programmatic themes*: the development of multi-faculty, overarching programmatic themes; (4) *Stakeholder integration*: The involvement of and intense liaison and co-creation with

L. Verhoef (✉) · L. Graamans · D. Gioutsos · C. Hellinga
Delft University of Technology—Green Office, Van den Broekweg 2, 2628, CS Delft, The Netherlands
e-mail: l.a.verhoef@tudelft.nl

L. Graamans
e-mail: l.j.a.graamans@tudelft.nl

D. Gioutsos
e-mail: deangioutsos@gmail.com

C. Hellinga
e-mail: c.hellinga@tudelft.nl

A. van Wijk
Process and Energy Department—3mE, Delft University of Technology, Delft, The Netherlands
e-mail: a.j.m.vanwijk@tudelft.nl

J. Geraedts
Industrial Design Engineering, Delft University of Technology, Delft, The Netherlands
e-mail: J.M.P.Geraedts@tudelft.nl

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real estate, facility management, professors, and students, and (5) *Outreach*: the provision of impetus for regional/national sustainability systems with campus projects. The results are encouraging: In a short period of time, one year, more than 20 projects have been developed, the board of the Real Estate department adopted sustainable development as a key value, three programmatic lines are under construction, personal connections between students, operational and scientific staff were established, and 2020 goals for greening the energy supply will be met in 2017. Additionally, the University also performs a catalyst role for regional sustainable heating transformations. New PhD positions could be established. This approach seems very promising, generating enthusiasm throughout the university. It has elements, typical for technical universities, but the formula may be replicated at other universities in general, by deploying non-technical knowhow, and by including existing local sustainability themes and opportunities.

Keywords
Innovation · Sustainability · Circularity · Real estate management · Campus operations · Student participation

1 Introduction

Universities across the world fulfill a variety of functions in their operation. First and foremost, these reside in scientific and applied research, and education. Simultaneously, they satisfy a range of quite different other complementary functions, from identity formation to stimulating the values that engineers should carry forward into their professional working lives.

An increasingly important challenge for engineers is to acquire (technological) leadership skills and experience in the pursuit of a sustainable society and circular economy. To fulfill these roles, and as an overarching responsibility, universities should set an example for society. Universities can take the first steps towards fulfilling this responsibility, by developing and implementing plans for sustainable campuses.

Delft University of Technology (TU Delft), like other technical universities, addresses fundamental and technical issues through its research and education. Moreover, TU Delft prides itself in fostering students with a pragmatic, critical, and problem-solving oriented attitude.

The campus is like a small city, and is in many aspects representative of the vast challenges faced in society. Moreover, the campus physically connects research, education, staff and students. Hence, it is an ideal environment to define precise, clear targets for sustainable development. Simultaneously, visionary input and practical implementation can be integrated, with a keen eye for innovation.

Many universities have committed to energy reduction goals. TU Delft is committed to 50 % CO_2 emission reductions, 40 % primary energy savings and 25 % sustainable energy generation in 2020, from a 2012 base line. This is no trivial task, considering that university campuses are advanced building and laboratory complexes, housing critical, and often energy-intensive research equipment, and engaging in primary processes where energy consumption is a small part of total expenditure. Additionally, campus management needs to take into account a vision on the future strategic developments of the University (den Heijer 2011).

In many universities, students have taken the lead in change towards sustainability, by opening the dialogue and/or establishing 'Green Offices.' Sometimes this occurred concurrently with pioneering real estate departments. Scientific funding proposals increasingly require practical relevance, and an interdisciplinary approach. In accordance, the TU Delft Green Office initiates and stimulates practice-oriented projects with a strong sustainability perspective and scientific challenges, thus providing new impulses for TU Delft primary processes.

A campus is an interesting playground for researchers, innovative external stakeholders, real estate developers and managers, which can influence the mindset of the future leaders. It can provide a more practical approach for scientists, along with innovative thinking of the real estate developers and direct contact to more innovative suppliers and designers.

The goal of this paper is to present an alternative approach to developing a sustainable campus, by connecting the often isolated spheres of research, education, campus operation and real estate management, and present preliminary results of this approach. The underlying methodology adopted at TU Delft—which is continually being refined—is focused on, with its replication potential for other Universities in mind. The approach has been coined 'ShowHow': the deployment and display of the knowhow of *all* stakeholders in a University.

2 Approach

2.1 Analysis of Other Initiatives

In creating the ShowHow approach, a body of knowledge and approaches towards sustainable universities has been reviewed. A few findings:

In the best practices developed by ISCN members, limited attention is currently being paid to projects utilizing the expertise of the research institute *itself* (ISCN 2014).

The Green Offices are a growing movement throughout the Netherlands, Germany and further across Europe, in which groups of students take the initiative in making their own universities sustainable (RootAbility 2016). These are effective, but face challenges in continuity and serious stakeholder engagement and project realization, depending on the level of resources available, both human and financial, and how the organization is embedded within the University institution.

Other initiatives that have taken place in the past 5 years at TU Delft (The Green Village, Delft Energy Initiative) have shown that visionary, staff-led student-supported systems lead to improved staff contact and involvement, science involvement/connection and stronger results.

From these experiences, a program for sustainability at a technical university campus needs to utilize and employ its own technical knowledge, expertise and innovations and should cover a wide range of activities both managerial as well as research oriented.

2.2 'ShowHow'

The philosophy of the TU Delft Green Office is that a nearby, visible, and innovative implementation of sustainability and circularity is stimulating, and strongly contributes to the greater mission of the university. When engaging in the selection process of projects or technologies to implement at a University campus, one can identify and prioritize areas where home-grown knowhow (generated by the University's own scientists) is used or knowhow of other parties (see Fig. 1). The TU Delft Green Office focuses primarily on those technologies that strongly resonate in staff and department expertise—its own knowhow—and secondarily on external technologies that deliver significant positive impacts on sustainability. Deploying and stimulating TU Delft knowhow outside of the University is mostly called valorization, and outside the Green Office scope.

The approach presented in this paper is in operation for almost one year, and has been developed through research and practice in a *technical* University environment, and therefore the replication potential of the approach may have an implicit bias towards *technology-based* universities.

Where Applied? / Whose KnowHow?	University Campus	Other locations
Own Researchers	ShowHow	Valorization
External Parties	Innovative Partners	Other

Fig. 1 Applying own knowhow on campus sustainability: ShowHow

2.3 The Five Pillars

The approach is built on five pillars as illustrated below, in Fig. 2. These five pillars are a combination of hands-on activities, strategic interventions, thematic programming, networking, and deploying off-campus opportunities.

1. **Pillar 1**: *Projects.* Practical and opportunistic: launch a variety of projects. Develop a portfolio of projects small and large, covering a wide range of circularity topics. Initiate projects that can be executed in limited time by students and (very) large projects requiring significant time investment of specialized staff.
2. **Pillar 2**: *Intensive real estate involvement*. Introduce sustainability and innovation to all levels of the real estate and facility management group's strategic and decision-making processes. Real estate departments are organized to manage large projects, driven financially. A separate strategy is needed to include circularity/sustainability into their processes, for instance in the design, tender and procurement procedures.
3. **Pillar 3**: *Programmatic themes.* Build cross- and multi-disciplinary, faculty-overarching programmatic themes. Since most real estate projects are of limited or temporal value to researchers, overarching, longer lasting research themes should be developed to engage and maintain their interest or to facilitate visionary professors.
4. **Pillar 4**: *Stakeholder integration*. Intensely liaise and co-create with real estate, facility management, professors, employees and students. Because of large differences in culture, language, interest and skills of the stakeholder groups: real estate staff, research staff, and students, no single person can be liaising with all different ones. Therefore a triple-liaison system was set up in the Green

Fig. 2 Five pillars under green office approach. *Source* the authors

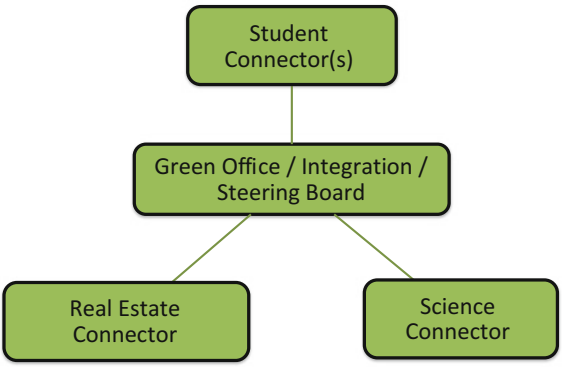

Fig. 3 Triple Liaison approach green office. *Source* the authors

Office, where students, science connectors, and real estate/circularity strategists can interact, see Fig. 3. The Green Office yields the backbone to bridge the gap between facilitating university departments, scientific staff and students.

5. **Pillar 5**: *Outreach*, the university as a catalyst in regional/national sustainability systems. A campus is a large office/laboratory park, with significant streams of energy, materials, and food flowing both in and out. These connections with the outer world can be utilized and developed to stimulate solutions for larger circularity and energy sustainability systems. It is aimed to provide impetus for regional sustainability developments with campus projects.

Pillars 2 and 4 can be seen in many real estate (campus) sustainability programs. Pillars 1, 3, and 5 are more particular and unique to the ShowHow approach.

2.4 Green Office Organization: Students, Staff, and Steering Board

The movement for a dedicated sustainability department at TU Delft, initiated by students in 2013, ultimately led to the formal establishment and resources for the Green Office by the Executive Board starting Jan 2016. It is a formal department in the university organization consisting of University four staff members and five student assistants with a three- member board consisting of:

1. The director of the Real Estate & Facility Management Department (Anja Stokkers)
2. A distinguished professor in the field of sustainability (currently prof. dr. Kornelis Blok, chair Energy System Analysis)
3. The TU Delft Sustainability Program Manager (Chris Hellinga)

3 Results

So far the adoption of the '5 Pillar' approach at TU Delft is successful, with a growing integration of sustainability principles within the organizations responsible for campus projects, management and operations and pathways to merge sustainable campus developments with the prime responsibilities of a university: high-level research and education have appeared to emerge.

The university has received high sustainability rankings (34st overall and and 1st on Sustainable campus transportation on the UI-Greenmetric[1] 2015) and will meet its goals, set by the executive board in 2014 for 'greening' the campus energy use and supply, well before the original target year of 2020.

3.1 Pillar 1: Projects

Over 20 projects have been developed so far. Some find their roots in the real estate department, while the Green Office initiated others, with input from students, and scientists. To name a few:

- Solar PV on the roofs of many faculty buildings, generating more than 1 GWh/year (Fig. 4)
- Purchase of Dutch Wind electricity
- Energy Monitoring
- Real Estate Energy Saving
- Food Collection
- Coffee cup collection
- Student Farming
- Joint Venture Earth, a circularity demonstrating ship, sailing around the north pole

The Delft Energy Monitor (Fig. 5) (www.energymonitor.tudelft.nl) keeps track of energy production and consumption. It has led to a new monitoring project to explore opportunities for monitoring individual appliances (Moorman 2016).

3.2 Pillar 2: Introduction in Real Estate and Facility Management Decisions

At every University, campus development and facility management are complex matters with a plethora of strategies, visions and opinions. The goals of sustainability are clear, but the means to achieve this goal are often debated. The

[1]University of Indonesia Greenmetric ranking 2015, currently with over 400 universities participating, www.greenmetric.ui.ac.id.

Fig. 4 Installation of solar energy on campus buildings. *Source* TU Delft

Fig. 5 Delft University of technology energy monitor website. *Source* TU Delft

implementation of circularity in all campus development is the TU Delft strategy to streamline this debate.

Circularity at TU Delft focuses on Energy, Water, Material and Topsoil. These four aspects are key in minimizing the environmental footprint of the University campus.

- Energy: demand and production of the campus on daily, seasonal and annual basis.
- Water: demand and collection of the campus on daily, seasonal and annual basis.

Fig. 6 Draft circularity commandments. *Source* the authors

- Material: The material which used for the construction and is 'temporarily stored' in the building, during its functional lifespan.
- Topsoil: The natural land and its functionality, which will be subplanted by the new development.

Each project is designed to first reduce the demand for energy, secondly to re-use waste streams as much as possible and finally to meet the remaining demand by sustainable measures. The Green Office has developed Ten 'Commandments' of circularity to be integrated in all future projects, as shown in Fig. 6. An interdisciplinary advisory group is currently evaluating this approach.

Three examples of this pursuit in practice:

I. Future buildings are designed to be energy neutral. The new learning center, is the first and sets an example: a sustainable energy neutral building,[2] achieving BREEAM excellent. Set to be operational in 2017, it deploys know-how from the Architectural Engineering & Technology Department. The design features underground cold-heat storage system, LED illumination, a green roof, and 3D-printed sun blinds. Additionally, it is flexible to facilitate changing use demands.

[2]https://intranet.tudelft.nl/en/direct-links/news/latest-news/article/detail/realisatie-nieuw-onderwijsgebouw-pulse/.

II. Introduction of sustainability and innovation criteria in the purchase processes. A first significant result is the electricity contract for 2017–2018, which will be fully based on Dutch wind energy. This approach will be pursued stimulating innovation.
III. New campus real estate strategy. This strategy is currently being prepared and will involve the construction of new buildings rather than renovations, partly as a financial consideration, but also to realize energetically more attractive buildings, reduction of floor space and improvement of the sustainability of the campus. New questions arise as to the demolition waste handling and re-use, offering new challenges to staff.

Each building or development is unique and should be optimized with regard to its individual program and context. These 'commandments', however, illustrate the primary principles that have to be taken into account in the design for circularity for the future campus. The principles will be converted to a set of requirements and design strategies that enable the real estate department to develop all buildings as sustainable as possible.

3.3 Pillar 3: Programmatic Themes

Criteria for programmatic theme development are:

1. Leading to significant solutions for energy, mobility, materials, and/or facilities
2. Applicable/testable at the campus
3. Cross-or multidisciplinary, relevant because mono-disciplinary themes can be handled with/within one department and need no overarching programming

Demonstration projects can be a meaningful way to connect expert fields, while not interfering with the core expertise and research interests within the respective faculties. The TU Delft Green Office - in collaboration with Department of Industrial Design Engineering - asserts a proactive role, initiating project formulation and consortia formation. The spin-off of these demonstrators should be that powerful and promising project proposals can be submitted on the basis of a portfolio and an existing network.

Various themes have been developed, such as *Geothermal heat* for regional networks (see more details in section 'Pillar 5'), *Green Digital Manufacturing*, and *Advanced* Smart Lighting are emerging as strong cross-disciplinary connectors for stakeholders. A particular paradigm-changing program, the 'Car as a Power Plant' is also described.

a. *Green Digital Manufacturing (GDM)*

Digital Manufacturing (DM, the combination of Digital Design with the Internet of Things and 3D printing) is an example of a technological development that will

result in significant societal changes. A sustainable society requires minimalized, sustainable materials in a circular economy and reduced global fuel demand for the transport of goods. To highlight some environmental challenges around DM (Verhoef 2016):

- The location of the design becomes irrelevant
- Products can be made when they are needed
- Production and application sites are closer together
- Sustainable—locally available organic materials may come within reach
- There may be new options for a circular economy (material recycling)

Connecting DM to sustainability illustrates the role of universities: addressing technical questions, developing sustainable solutions and thinking through the social consequences.

At TU Delft, a number of activities and initiatives are going on in the field of 3D printing. Application areas range from small plastic components, reproduction of old paintings and surface treatments, car parts, up to building facades, bridges, and later even entire buildings. Researchers welcome a comprehensive and multidisciplinary approach/philosophy of this fourth industrial revolution in which common scientific factors and bottom-up approach are important steps. Lastly, but not least: DM is seldom approached integrally with sustainability as first priority.

How does green digital manufacturing answer to the three criteria?

1. This technology will have a major global impact on material and energy consumption. Policy questions will arise—and the TU Delft should be able to assist decision makers in answering these
2. Applicability and testability—in buildings, construction, products, and maintenance, and repair. The wide scope of the technology requires focus and ambitious demonstration projects
3. A strong multidisciplinary challenge, with interfaces in all university departments It is suspected that both fundamental science and applied technology are involved and GDM can be a good bridge between the faculties

b. *Smart lighting by Light Emitting Diodes (LED's)*

Lighting at TU Delft amounts for approximately 25 % of total electricity consumption. Most of the lights are TL-tubes. A large energy saving is possible with no doubts at all on the environmental profile by LED's. Changing all buildings on TU Campus to LED will cost around 2–3 million Euros. It will yield an annual saving on energy and maintenance of around 0.5–0.7 million Euros. Many university campuses already deploy LED's. The consensus is forming: "let's do it!"

When talking to *scientists* on LED-based illumination strategy, they are working on much more than *just* light: Sensing, wireless Internet, colour matching are just a

few ideas. Application areas are wide such as indoor-Google maps and crowd control for example. When talking with *real estate officers*, they see and understand the potential, but have questions and often doubts on the financial and technical feasibility of LED's. When talking with *suppliers* of LED systems and services, they immediately talk about smart lighting, services, and business cases.

LED implementation requires a vision and a future proof program, because it necessitates the connection of ICT with other TUD departments and activities and LED lights last 30,000 h - approaching a building's lifetime. It also needs a hands-on approach, because in many buildings, switching to LED is feasible already.

LED offers new opportunities to building management and is a testing ground for novel features to scientists, not only for lighting, but for other facilities as well. Projects can utilize features of LED's as a *light source,* its *smaller size/lighter weight*, its *reduced energy consumption and DC power requirement*, and the *digital-based electronics* for new ICT systems. Besides these, technological, behavioral and business aspects are of interest.

The applicability area is wide, but research interest is predominantly linked with the electronics and ICT departments, as well industrial design and architecture. Some areas in which electronics researchers are active are: Visible Light communication (10 × higher speed and much lower power consumption than WiFi) and distributed intelligence (individual lights deciding on their illumination levels).

The TU Delft approach is to stimulate application of LED's in all renovation and new-built projects, using a simple decision diagram based on clear questions. In new buildings, one or more of the extra features that LED's offer should be pioneered.

c. *Car as a Power Plant*

One program example of thematic multi-disciplinary programming is the Car as a Power Plant Program (van Wijk and Verhoef 2014). It does not originate from the TU Delft Green Office, but from The Green Village.[3]

The 'Car as a Power Plant' program is based on a strong paradigm-changing vision that: *Fuel cell vehicles can provide efficient and clean transportation, but also clean and efficient electricity production at times when renewable electricity production is not sufficient. And the 'waste' products of heat and water could be utilized as well. In such an integrated transport, energy and water system, hydrogen will become a key energy vector in storing and transporting energy*. It is exemplary and showing the success for the three criteria of programmatic themes:

1. Major impact? Fuel cell electric vehicles such as cars, buses and trucks can provide, when parked—which is more than 90 % of the time—electricity to houses, cities, industry or the electricity grid, producing useful 'waste' products:

[3]The Green Village is a platform for system innovation, located on the TU Delft premises (http://www.thegreenvillage.org).

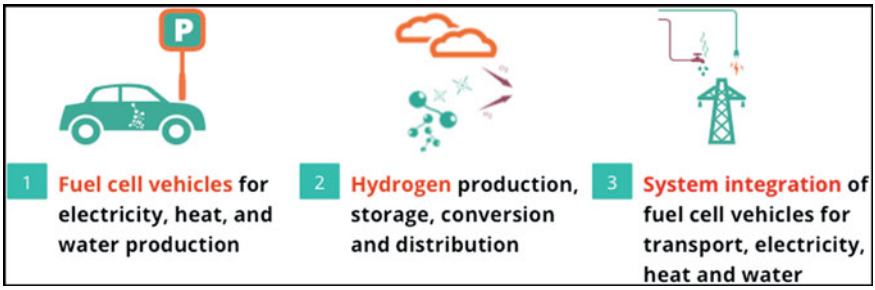

Fig. 7 Program lines car as power plant program. *Source* The Green Village

heat and water. A fuel cell car can power 10–100 European houses and can replace all power plant capacity.
2. Applicable/testable on the campus? The research and innovation program requires a special test bed facility with real life conditions. This test bed facility will be realized on the Green Village, in the heart of the TU Delft campus.
3. Cross-disciplinary. The newness of technology and paradigm change requires technological and systems research. The research and innovation program will encompass the entire energy and transport system, from demand to source with all conversion, storage, distribution, logistics, IT and integration challenges included in 3 program lines are (Fig. 7).

Most importantly, it is successful. Starting with the vision in 2011, now 15 researchers at the TU Delft, several research institutes, and over 40 companies and organizations are connected. Seven research and innovation projects are being executed.

3.4 Pillar 4: Liaising and Co-creation

Trust and dialogue has developed between departments and researchers. Innovative concepts underlying the sustainable TUD Learning Centre Building (under construction) were developed in close collaboration between scientists, the real estate department, the project architect, and external stakeholders.

3.5 Pillar 5: Outreach: University as a Catalyst in Regional/National Sustainability Systems

As an owner and operator of combined heat and power installations and several underground Heat and Cold storage systems, the facility management department is already trading energy with several third parties.

An example of how connecting to the region can provide new insights is the preparation of geothermal heating for the campus. A new smart district heating system is being developed. Part of this development is a deep (2.3 km) geothermal well. New scientific opportunities arise for the Geoscience Faculty. Developing it provides hands-on experience with regulations, financial, and societal aspects.

The foreseen geothermal well will deliver heat at a temperature of 70–75 °C, below the operating temperature of the existing high temperature heating network (100–130 °C). The transition requires campus-wide adjustments of the in-building heating systems and a new heating strategy, reducing the peak demands that supersede the thermal well power. Moreover, the geothermal well competes with the CHP system, which is also operating in the lower temperature range. To manage the complex transition at reasonable investments, next to the well development itself, two parallel projects are started to address (1) the building transitions and (2) an overarching new (model predictive) control approach.

This control approach requires minimizing peak demands, dealing with a new, cascaded building structure, and utilizing the various heating options (gas fired boilers for remaining peak demands, the CHP unit and the geothermal base load) in a cost effective and environmental friendly way. It is termed the Smart Thermal Grid project (Fig. 8), an intensive collaboration between scientists, the real estate department and external parties.

This innovative approach for district heating with practical experience, including organizational and financial aspects, provided a basis for input in the regional discussion the development of provincial heating network, connecting waste heat from the Rotterdam harbor area and new sustainable heat sources (such as geothermal wells) to the heat demand of a major part of the Province of South

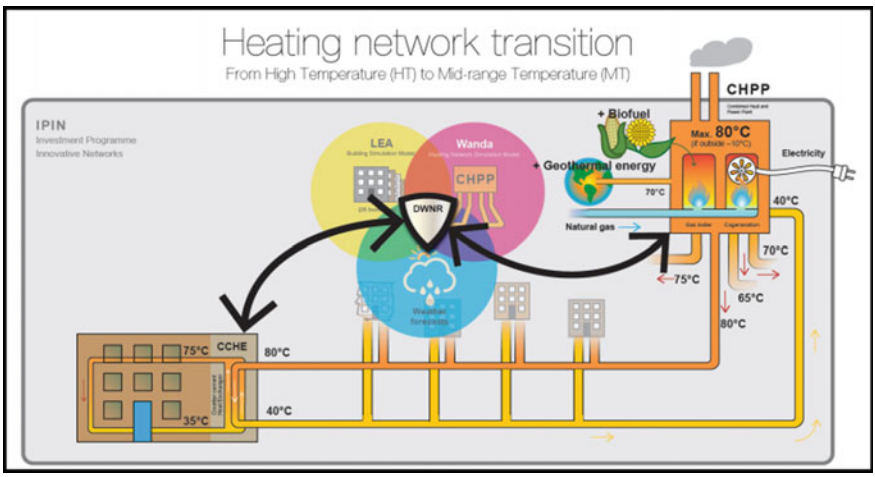

Fig. 8 Campus-wide sustainable heating: from high- to medium-temperature with geothermal heating. *Source* TU Delft

Holland, including Rotterdam, Delft, The Hague, other cities and the energy intensive greenhouse sector.

As a consequence of this engagement the span of the university input has broadened to more general questions surrounding the logics behind regional heating network: To develop a vision on future waste heat availability in the Rotterdam harbor industrial area. A challenge that requires a fundamental evaluation on future energy systems, with, for example waste heat flows accompanying future fuel production and back-up electricity facilities.

This case clearly shows how campus developments can provide an anchor in creating new collaborations and scientific challenges that have impacts well beyond the campus boundaries. Although presented as a Pillar 5 example, it is also based strongly on Pillar 4.

4 Discussion

This ShowHow approach has been in effect for less than a year but has already yielded valuable results. Its impact will become even more visible throughout the coming year. Some observations and considerations:

1. Challenges of the 'Five Pillar' Approach

The 'five pillars' approach seems to be a solid foundation to stimulate sustainability between all stakeholders. Pillars 1, 3, and 5 seem to be powerful ingredients in addition to the pillars 2 and 4. They give visibility, structure, and grip for all of the relevant stakeholders:

- *Pillar 1* has quickly led to visible projects, with increasing participation of the University community.
- *Pillar 3* has identified new and interesting themes and openings for scientific research and innovation, which have enabled the research of numerous new PhD's.
- *Pillar 5* is leading to a wide variety of opportunities, where a university can become a well embedded, catalyzing partner in creating new pathways for sustainability.

The main challenges of the approach lie in the balance between the responsibilities of the Real Estate department in optimally facilitating a demanding academic environment against scientists whose research often is not yet ready for market or perhaps even demonstration. Possible solutions are:

– To identify and involve departments/researchers whose activities are more near-market

– To deploy technologies developed in the past, which are only now becoming ready for market

2. Suggestions for Replication

The '5 Pillar' approach is applicable and replicable at other universities. In essence, it relies on utilizing *all* available resources at that University, with the aim of expediting the process towards sustainable Universities.

The initial success of the '5 Pillar' approach experienced at TU Delft seems to depend on the expertise and in-house knowledge that is created and fostered within it. The required resources for the approach are:

– Student communities
– A real estate department, willing and capable to engage in sustainability
– Scientists/researchers willing to implement their research
– People who are able to connect the various cultures
– Clear overview of local and regional (physical) possibilities and opportunities.

The first four can be developed or acquired anywhere. The fifth is campus-specific; at TU Delft, geothermal and regional heat demand forms an opportunity. Other campuses may have other opportunities such as a dense metropolitan area, an airfield, river water, or solar resources. These opportunities should be identified and explored by each university individually.

This highlights an opportunity for future research, in testing the effectiveness of such an approach at other technical as well as non-technical Universities, to shed light on *how* the '5-pillar' approach works within them.

3. Looking Ahead at the Approach, at the TU Delft Green Office

The real estate department can now rely on a 'sustainability back-office,' with scientific and student support. This has facilitated and strongly enhanced the focus on sustainability for new buildings, renovations and campus-wide developments.

Innovative concepts underlying the sustainable 'Pulse' Learning Centre Building (under construction) were developed in close collaboration between scientists, the real estate department, the project architect and external stakeholders. This is partly a result of the triple-liaison structure, with the Green Office as the proactive and motivated connector to all these stakeholder groups.

A less tangible but equally important result is the newly developed trust and dialogue between departments and researchers. This has allowed for a more centralized and collaborative strategy towards sustainability.

Consequently, the University will meet its goals, set by the executive board in 2014 for greening the campus energy use and supply, well before the original target year of 2020. Together with the high (inter)national rankings this places further impetus on improving performance and discussing the goals.

It is not yet possible to comment on the long-term effectiveness of the approach. Follow up assessment is required in order to gauge the long-term effectiveness and longevity of the approach.

5 Conclusion

The ShowHow approach has been presented, detailing a method for traversing the gap from a general recognition of the importance of sustainable development to a working practice that joins the university's various internal and external stakeholders on the path towards sustainable campuses and University environments.

The initial results of the adoption of the '5 Pillar' approach at TU Delft indicate the successful integration of sustainability principles within the organizations responsible for campus projects, management and operations. Pathways are being formed to merge sustainable campus developments with the prime responsibilities of a university: high-level research and education have appeared to emerge.

Replication of the initial success of the '5 Pillar' approach experienced at TU Delft, at other Universities, is dependent on the expertise and in-house knowledge that is created and fostered within it. This highlights a need for future research, in testing the effectiveness of the approach at other technical and non-technical Universities. Follow up assessment is also required in order to gauge the long-term effectiveness, merit and longevity of the approach in itself.

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Author Biographies

Dr. Leendert Verhoef is Sustainability Innovation Program Developer at TU Delft Green Office. He has a doctorate degree in Physics from Utrecht University and a PhD in Solar Energy. He has worked for more than 30 years in industry, science, government and consulting, mainly on innovation and large-scale introducing of disruptive technologies, and published books about

them. To name a few: SunCities (the first 1000 + homes suburb fully optimized for solar energy); Energy from the Desert (GW solar in desert areas), and Car as Power Plant (replacing all power plants by fuel cell cars). He is skilled in multidisciplinary sustainability innovation management and creativity methods

Ir. Luuk Graamans is a member of the TU Delft Green Office, functioning as its real estate expert and consultant to the TU Delft Sustainability Program. He has graduated as architectural engineer from the TU Delft and is currently continuing his research within the department of Architectural Engineering and Technology. This research focuses on food production in a metropolitan context and its optimisation with regards to energy expenditure. Additionally, he is working as a consultant on the topic of circularity and sustainability in the built environment

D. (Dean) Gioutsos graduated from a Bachelor of Engineering (Civil) at the University of Melbourne in 2011. He is currently completing his final thesis for the MSc. Degree of Sustainable Energy Technology (SET) at Delft University of Technology, working on the topic of cost-optimal configurations of renewable energy and storage technologies for multiple islands not connected to mainland grids. He is concurrently working as Chairman of the TU Delft Green Office Students Board

Professor Ad van Wijk holds the 'Future Energy Systems' chair at TU Delft since 2011, and serves as director for the 'Business in Energy Systems' postgraduate education program at TU Delft. Prior to this position, he was managing director of Ecofys and Econcern for over 25 years. He has directed research and utilisation successfully. Ad van Wijk serves as member of several advisory boards (a.o. Rotterdam Economic Council, Bio-Renewables Business Platform) and has served as a jury member for a.o. the Zayed Future Energy Prize (Abu Dhabi UAE) and the Accenture Innovation Award. At TU Delft he has founded the Green Village and created the "Car-as-Power-Plant" concept

Professor Jo Geraedts holds the "Mechatronic Design" chair at the faculty Industrial Design at TU Delft since 2008. His research focuses on 3D scanning, 3D printing and robotics. One research topic is on the impact of personalized 3D printed products on the digital design process. Next to the TU Delft position he is working for more than 30 years at Océ, a Canon group company. He is involved in the development of digital manufacturing processes and workflow for document and industrial printing. From 2000 to 2013 Jo Geraedts was manager of the Océ Industrial Design department and responsible for product, graphic, user interaction and usability design of hardware and software developments in multidisciplinary teams worldwide

Ir. Chris Hellinga chairs the TU Delft Green Office as the TU Delft Sustainability Program Manager. He graduated as food process engineer from Wageningen University, was process engineer in the Dutch dairy industry and joined the TU Delft bioprocess engineering department for 15 years as scientist. After a period as self-employed entrepreneur, he works since 10 years as scientific advisor and organizer on sustainable energy programs at the TU Delft