THE ROAD TO A SUSTAINABLE FUTURE

Annual Report 2018

Energy Ville

Empowered by KU Leuven, VITO, imec & UHasselt

KU LEUVEN vito imec UHASSELT

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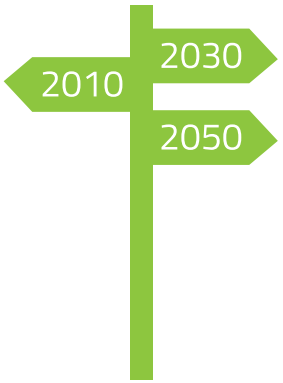


PREFACE

Four questions about the present, past and the future for Ronnie Belmans, CEO of Campus EnergyVille and President of the Operational Steering Committee of EnergyVille and Walter Eevers, President of the Strategic Steering Committee of EnergyVille.

A new year brings new insights. Where does EnergyVille stand today?

Ronnie Belmans: 2018 was an interesting year. First of all, the researchers of imec and UHasselt have officially made their transfer to the Thor Park in Genk. This enables a new dynamic in the EnergyVille collaboration. The operational efficiency got up to speed, the roadmaps have been perfected and the ambitions are clear. The interdisciplinarity between the different research groups is becoming more tangible which results in new insights and projects.

Walter Eevers: Within the energy transition we have more and more strengthened our position as a knowledge institute. The Belgian energy system faces important challenges. To guarantee a reliable, affordable and sustainable energy provision in the future, a balance needs to be found between costs, technology and ecology. Within EnergyVille we wish to provide the parts of the puzzle, lay them on the table and propose solutions based on scientific research. In order to do so we can firmly count on the strong R&D basis of our partner institutions. By combining the research of KU Leuven, VITO, imec and UHasselt we can provide and validate new solutions all over the value chain: from material to system level. This way, we do research on both new technological solutions which can be directly transferred into products or services, and on facts and figures to support policy makers.

What were the key moments of 2018?

Ronnie Belmans: An important moment was of course the opening of EnergyVille 2 and the official move of the researchers of imec and UHasselt. Furthermore, the results of the EFRO/SALK project 'Towards a Sustainable Energy Supply in Cities' were presented and three new projects financed by the energy transition fund: EPOC, BREGILAB and NEPTUNE got green light in July 2018. Technologically, several breakthroughs were announced such as for example imec's solid state batteries, VITO's high performance battery management system, the newly installed systems such as the DC grid for residential appliances and the installation of new state-of-the-art lab equipment which can even better respond to the industry's needs.

Walter Eevers: Also externally we had the honour to welcome new partners or strengthen existing partnerships. We carried out studies for governments and policy makers, validated new technologies in our labs and developed new technologies ourselves, often in collaboration with external partners. Thanks to Fluvius for example we got the opportunity to welcome some of the first Flemish digital meters in our labs and integrate them into our research. This way we support enterprises that wish to develop solutions based on the digital meter. Within our thermal research new partnerships were developed to implement our technologies on large demo sites, such as for example with Ennatuurlijk in Eindhoven. Living labs remain important in 2018. Within the EcoRen and REnnovates project for example, several social housing communities were renovated into nearly energy neutral buildings. All of this without the residents having to move.

To enable the large-scale shift, the energy transition needs to be affordable for everyon. More than ever we have included social components of our projects. We're also partner in a European project to tackle energy poverty. A sustainable transition for everyone, that is our ultimate goal.

Ronnie Belmans: EnergyVille has also grown on European level in 2018. Several new European projects have found their way into our research and several studies were performed to support national and international energy policies.

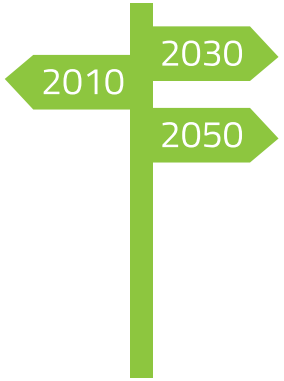
Walter Eevers: I would also mention the growing social interest in the energy transition as an important moment, though indirect for EnergyVille. The awareness has grown that the energy transition brings new opportunities, not only ecologically, but also economically. On individual level we're enhancing the comfort with technology. For youngsters this brings new study or job opportunities. This is key to get everyone along.

What are the future ambitions?

Ronnie Belmans: We have our mind set on the European goals for 2030 and 2050. By 2030, the European Commission wants 40% less greenhouse gas emissions compared to 1990, 32% renewable energy in the total energy mix and an increased efficiency of 32,5%. For 2050 a total decarbonisation of the energy system, including transport, is foreseen. A challenge not to be underestimated, though possible: we have to be ambitious and look for solutions at system level. There is no silver bullet. Neither hydrogen, nor electricity, heat or biogas, etc. will solve all problems encountered. We have to bring the different components that contribute to the energy transition together and verify their interaction and complementarity. That's where the strength of EnergyVille lies. Apart from focussing on certain technologies, we go for a system approach. We have the ambition to keep enforcing this in the future by continuing to integrate new energy vectors into our research agenda.

Walter Eevers: With about 400 employees and PhD students, we continue working on a challenging research programme. We're happy to share that knowledge with our industrial and other partners. The energy transition brings numerous opportunities and new business models. With our expertise and lab infrastructure we wish to support our partners to bring innovative technologies to the market. We believe together we can enhance technology development and valorisation. On the other hand, we'll continue delivering facts and figures to decision makers in order to make the right decisions in an everchanging energy system.

What are the key takeaways in this report?



Ronnie Belmans: In our annual report we proudly present our roadmaps. Instead of solely focusing on our accomplishments in 2018, we would also like to cast some projections on the future. We hope this annual report shines a light on the energy transition and may it make clear that there is a role for everyone in the transition towards a sustainable energy system.

GOVERNANCE @ ENERGYVILLE

STRATEGIC STEERING COMMITTEE

President: Walter Eevers (EnergyVille, VITO)

Members:

- Gerard Govers (KU Leuven)
- Ludo Deferm (imec)
- Paul Van Dun (KU Leuven)
- Marc D'Olieslaeger (UHasselt)
- Luc De Schepper (UHasselt)
- Paul Heremans (imec)
- Bruno Reyntjens (VITO)

OPERATIONAL STEERING COMMITTEE

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- Geert Deconinck (EnergyVille, KU Leuven)
- Giovanni Flamand (EnergyVille, imec)
- Leen Govaerts (EnergyVille, VITO)
- Bert Gysen (EnergyVille, VITO)
- Jef Poortmans (EnergyVIlle, imec)
- Marlies Van Bael (EnergyVille, UHasselt)
- Bart Vermang (EnergyVille, UHasselt)

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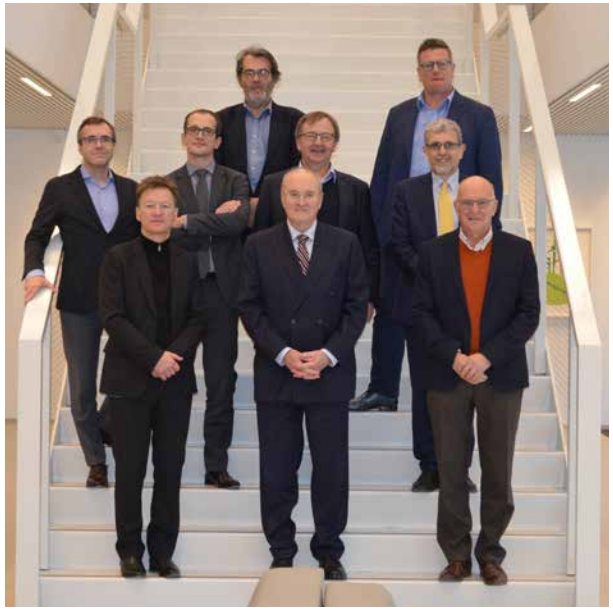

President: Luc Sterckx (KU Leuven)
Secretary: Eszter Voroshazi
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- Wim Boydens (UGent)
- Frederic Dunon (Elia)
- Peter Hermans (Alliander)
- Paul Matthijs (Niko)
- Jan Mertens (Engie Research)
- Jean-Francois Minster (IPVF & Total)
- Alexandre Oudalov (ABB)
- Marc Van Sande (UMICORE)
- Peter Wouters (WTCB)

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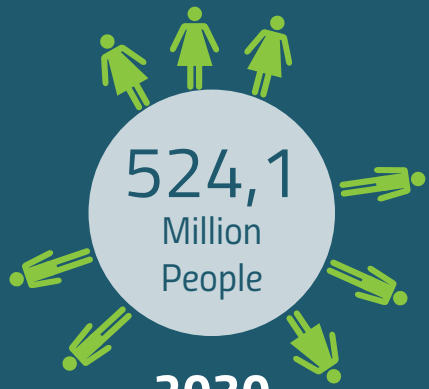
- Luc Peeters (VEA)
- Daniëlle Devogelaer (Federal Planning Bureau)
- Lut Bollen (Flemish Government, Department of Economy, Science and Innovation)
- Wim Dries (City of Genk)
- Leo Van Broeck (Flemish Government Architect, KU Leuven)
- Dörte Fouquet (Becker Buettner Held)
- Wim Martens (Benelux)
- Rutger Huijgens (BP)
- Roberto Zangrandi (European Distribution System Operators' Association for Smart Grids)

2005

2020

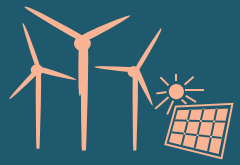


2030

2050

Greenhouse gas emissions compared to 1990

2005	2020	2030	2050
5500 million tons CO_2 equivalent	-20%	>-40%	>-80%



Renewable energy compared to gross final consumption

2005	2020	2030	2050
9%	20%	32%	>55%

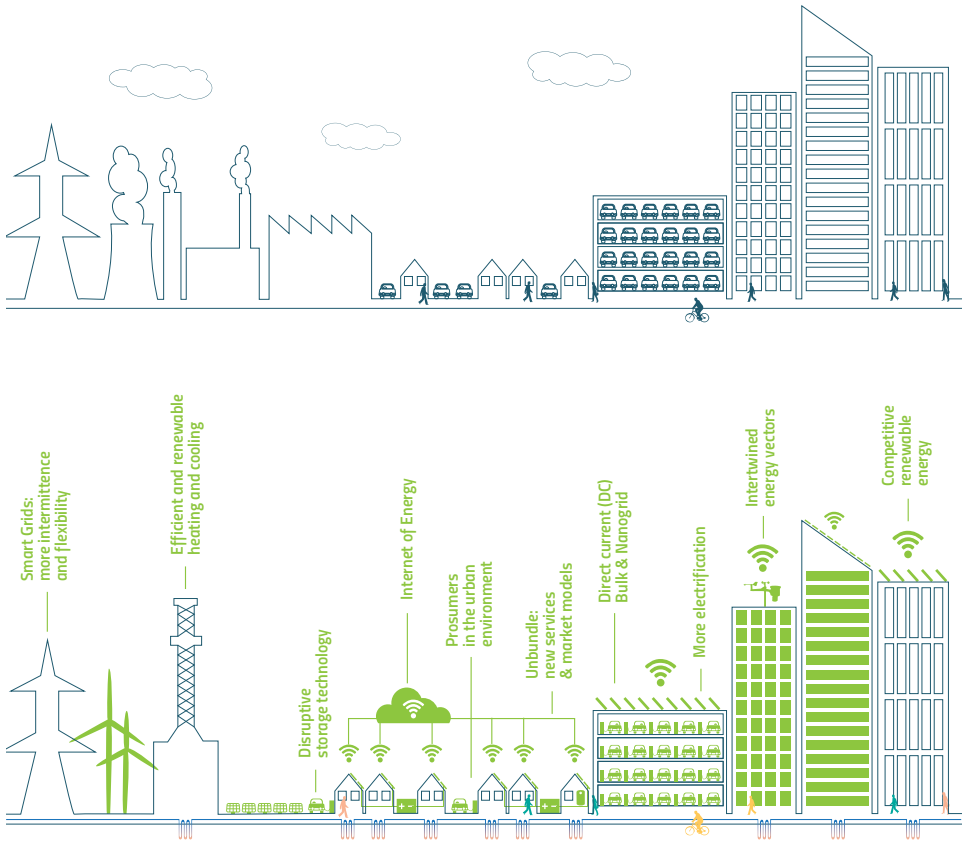
Energy efficiency compared to baseline scenario

2005	2020	2030	2050
Primary energy consumption: 1720 million tons oil equivalent	-20% 20% compared to baseline scenario 13% compared to 2005	-32,5% 32.5% compared to baseline scenario 26% compared to 2005	> 28% compared to 2005

OUR ENERGY SYSTEM IS IN TRANSITION

Energy, in all its forms, plays an important role in our lives. Not only for comfort at home, but also for industrial processes and for transport we need energy. Our energy system in its current form, however, faces important challenges. A glance at some future figures shows that the global energy consumption will increase substantially in the upcoming years. Despite the fact that the efficiency has increased significantly (for instance thanks to more efficient cars, better insulated houses, power stations that achieve higher efficiency, etc.) we will have to use energy more consciously. The integration of sustainable energy in an increasingly urban environment is complex, as space is limited. The opportunities are substantial as new energy technologies offer great local advantages such as less local pollution by cars and heating, less noise etc. The ambitious targets for 2030 and 2050 therefore will help to improve air quality, reduce greenhouse gas emissions, increase end-user comfort, combat energy poverty and achieve economic growth. It will be a transition by everyone, for everyone.

To reduce the energy demand, ensure a continuous energy supply and reduce CO_2 emissions, more energy efficient and flexible applications and technologies need to be introduced. In contrast to the traditional model, not the supply side (central vs. decentralised generation) but the demand side will be at the center. In that way, the consumer is given an even greater role to play.



Eurostat, Trends and projections in Europe 2018, EEA Report No 16/2018

WORKING TOGETHER TOWARDS A SUSTAINABLE ENERGY TRANSITION

EnergyVille supports the energy transition by developing technological solutions such as new battery technologies or innovative solar cells and by developing and offering services such as policy studies, tools or feasibility studies. In both cases, the approach is based on scientific research. We rely on a high-level R&D performed by the researchers from KU Leuven, VITO, imec and UHasselt.

The added value lies in a multidisciplinary system approach. The energy system of the future will not be based on one specific technology, but will be a continuous interaction of various applications, amongst others thermal and electrical. Within EnergyVille we conduct research at all levels, from material to system level and across various energy sources. Therefore, we do not only develop more efficient battery materials for solid-state batteries, but we also look at the role of batteries in the electricity grid. To meet heat demand, we are investigating both thermal networks, where, among other things, residual heat from industrial processes can be used district heating, as well as individual components such as heat delivery substations, thermal storage and control strategy in heat networks. The interaction between heat and electricity is optimized in so-called multi-energy networks, and by interfacing components like heat pumps and Organic Rankine Cycle systems. We develop algorithms and tools to optimally consider different solutions at the building, district and regional level, accounting for the full sustainability from a life cycle perspective.

ENERGYVILLE AS LIVING LAB

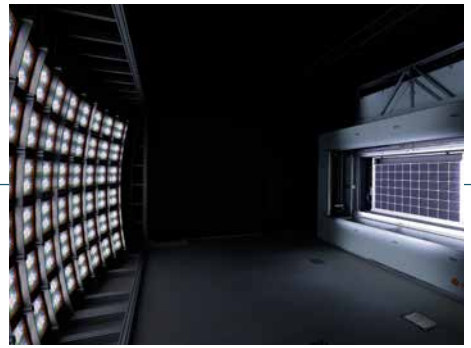
Thanks to our state-of-the-art lab infrastructure, we can extensively test these hardware, software and business models. It creates an ideal environment to experiment with future-oriented energy scenarios, to set up specific simulations and develop new products and services, not only within EnergyVille but also in collaboration with industrial partners. After all, the energy transition also offers many new opportunities for industrial players, service providers and cities. EnergyVille supports them by supplying proven technologies that can be directly inserted into the products and services of their companies and in their city developments.

New technologies are constantly being validated not only within the buildings but also on the entire site. This way, EnergyVille 1, EnergyVille 2 and by extension the entire Thor Park act as a unique living lab.

OUR LAB INFRASTRUCTURE

Thin Film PV Lab

PV Module Lab



PV Reliability Lab

Outdoor Metrology Lab for PV

Battery Testing Lab

Battery Lab

Dry room in the Battery Lab

Indoor Metrology Lab for (Building Integrated) PV

Home Lab

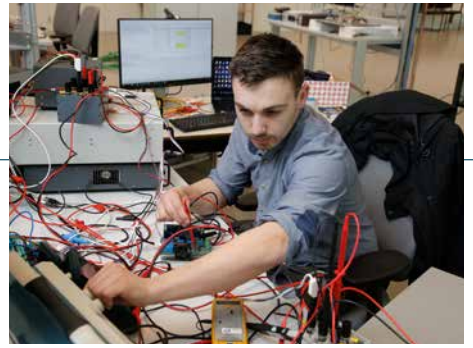
Low Voltage Grid Lab

Thermo Technical Lab

Medium-Voltage Lab

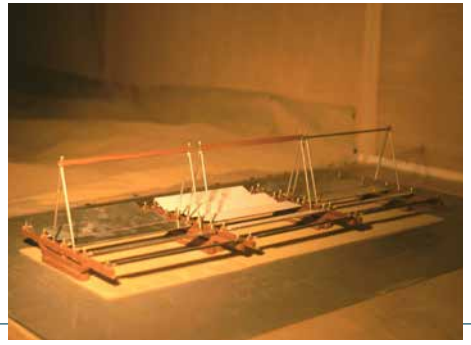
Building Integrated PV Lab

Bipolair DC Lab



Power Electronics Lab

Digital Grid Emulation Lab



Wind Tunnel and Soiling Lab

Silicon Solar Cell Lab

ENERGYVILLE IN 2018

2018

JANUARY

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Cozie and EnergyVille/VITO introduce Homefit, an energy audit tool

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City-zen Virtual Power Plant wins the Green Digital Charter Award 2017

30

Johan Driesen wins Febeliec Energy Award 2017

FEBRUARY

1

Study: new scenarios for energy mix after 2030 for Greenpeace, BBL and IEW

7

Study: reform of the tariff structure of the distribution grid tariffs for VREG, the Flemish regulator of the electricity and gas market

In the context of a future reform of the tariff structure, the Flemish Regulator of the Electricity and Gas Market (VREG) allocated a study on the revision of the tariff structure of the distribution grid tariffs to EnergyVille/VITO. With the results of this study and in collaboration with various stakeholders, the VREG will draw up a new tariff structure.

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Launch Energy and Renovation Check of KBC, scientifically underpinned by EnergyVille

22

Launch TOTEM: new tool to improve the environmental performance of buildings

2018

APRIL

10

imec reaches milestone for next-gen solid-state batteries to power future long-range electrical vehicles

18

Jesus Lago Garcia third place winner in RTE competition on electricity consumption forecast

MAY

31

Official Opening EnergyVille 2

Opening of the second building in which the EnergyVille research collaboration resides, dedicated to technology development for power generation with thin-film solar cells, intelligent PV modules and new battery systems for local energy storage

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Closing Event EFRO/SALK Project: Towards a Sustainable Energy Supply in Cities

EnergyVille provides latest insights in solar cells and modules, battery technologies, advanced heating networks, energy-as-a-service models ... all integrated into a system approach: the multi-energy system of the future

JUNE

26

Punch Powertrain Solar Team optimizes solar race car with the Battery Management System of VITO/ EnergyVille

JULY

9

Launch projects Energy Transition Fund

EnergyVille works on the European electricity grid in NEPTUNE, on a maximal use of solar and wind energy in BREGILAB and on energy system models in EPOC

24

imec, within EnergyVille, Beats Silicon PV with 27.1 Percent Perovskite-Silicon Tandem

AUGUST

30

Project REnnovates shows that rendering districts energy-neutral is technically and economically feasible

SEPTEMBER

2018

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Thor is Happening: we welcome 5000 visitors at Thor Park

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EnergyVille supports the development of the TECHtalent at T2 Campus

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Home Lab EnergyVille is one out of two Test Labs for Digital Energy Meters

2018

OCTOBER

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Punch Powertrain Solar, equipped with EnergyVille/VITO's Battery Management System, wins the Carrera Solar Atacama in Chili

The solar car was equipped with EnergyVille/VITO's Battery Management System, which accurately and in real time indicates how much energy is left in the batteries. In addition, it keeps all battery cells in balance to simultaneously charge or discharge the battery pack, extracting up to 2 percent extra energy. Expressed in time gained, the team won 12 to 14 minutes thanks to the BMS.

NOVEMBER

22

EnergyVille scientific partner of District Heating Antwerp

26-28

International conference IEEE Smart Grids for Smart Cities in Thor Park

DECEMBER

22

Ennatuurlijk and EnergyVille/VITO launch district heating network with smart, self-learning heat controllers in Eindhoven

2019

RESEARCH HIGHLIGHTS

ELECTRICAL STORAGE: THE INDISPENSABLE LINK

Innovative Battery Materials

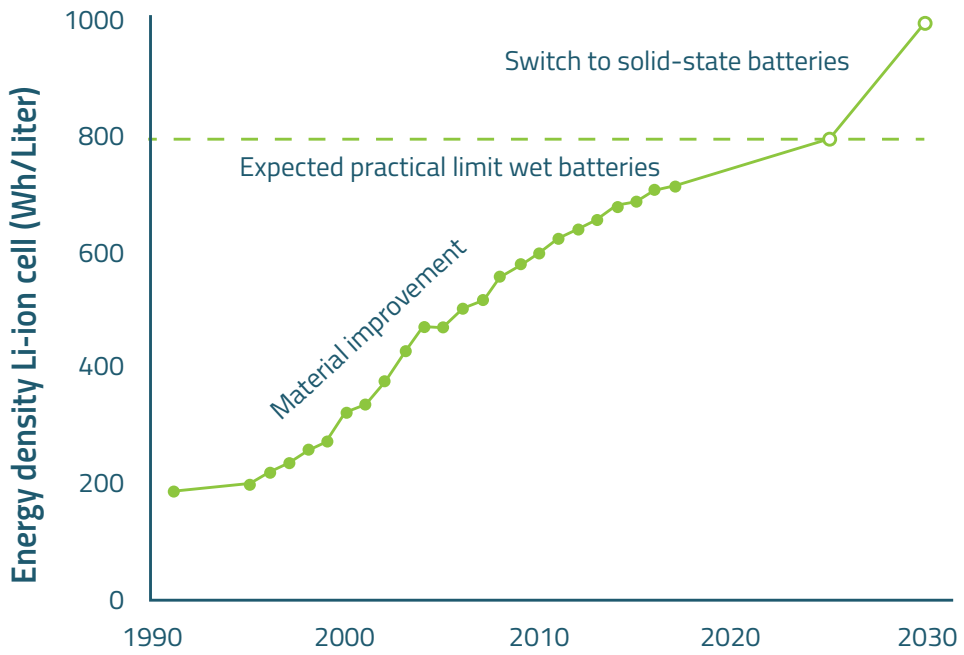
Storage undoubtedly has an important role to play in the energy transition. Not only our transport, but also our daily energy use can become much more sustainable by storing energy in batteries. In order to continuously improve the efficiency, cost and capacity of these batteries, EnergyVille conducts extensive research into new battery materials.

From Wet to Dry Batteries

The most common battery today is the wet lithium-ion battery. These are typically used for electric cars or home batteries to store renewable energy locally. These wet batteries have already undergone an extensive evolution, but gradually reach their limits. **Philippe Vereecken**, scientific director electrochemical storage within EnergyVille/imec and professor at KU Leuven: "As far as performance is concerned, lithium-ion has almost reached its limit. We are confronted with the physical boundaries of the material. In order to ensure that batteries become even more efficient, a breakthrough of other materials and technologies is required. Solid-state batteries can take over to surpass the current limits. Commercialisation of solid-state batteries is on the verge of a breakthrough. We estimate that solid-state will be the standard in electric vehicles by 2030. "

The difference between the wet and solid or solid-state lithium-ion batteries lies in the electrolyte. The ions between the anode and the cathode of a battery flow through the electrolyte. With a wet battery, the electrolyte is liquid, with a solid battery it is dry. This not only ensures that the battery is more compact and has a higher energy density, it also ensures higher safety, because the solid electrolyte is less flammable.

Philippe Vereecken: "The existing solid-state batteries have some serious disadvantages. For example, the charging speed is much lower than that of other batteries, which is problematic for electric vehicles. In addition, factories have to install a completely new production process, which increases the costs. Therefore



we set up a solid integration platform at EnergyVille in Genk, where the existing wet energy toolsets are used for solids. In addition, we have developed a prototype with a charging speed that comes close to conventional batteries: 200Wh/l and charging in 2 hours. Soon we will demonstrate 400Wh/l with the same charging time. And still there is room for improvement."

The Way Towards Lighter and More Sustainable Batteries

Both wet and dry (solid-state) lithium-ion batteries contain heavy metals such as cobalt and nickel. As a result, these batteries are relatively heavy in relation to their energy content per kilogram. The exploitation of these metals, which are relatively rare on earth, requires a great deal of energy and water and is environmentally damaging. That is why VITO and UHasselt are working on the development of more sustainable lithium-sulphur batteries within EnergyVille. Sulphur is the third most common raw material on earth and is often considered as waste, making the price very low. Due to their low weight, lithium-sulphur batteries have the potential to store 5 times more energy per unit weight than the current lithium-ion batteries. First, obstacles such as lifespan and the number of charging cycles have to be improved, after that, first applications are expected in drones and in the long term in many mobile applications.

Sodium-Ion Batteries as an Important Game Changer for Home Batteries

In addition to new technologies for lithium-ion batteries, which are particularly important for compact applications such as electric vehicles, EnergyVille also focuses on new materials such as sodium-ion batteries. "The mechanism behind both materials is practically the same, but there are more natural reserves of sodium, much more than lithium" explains **An Hardy**, professor at UHasselt and connected to EnergyVille. This makes sodium-ion not only more durable, the cost is also lower. "For applications that require more space or require less capacity such as household appliances or home batteries, this can be a great alternative." The next step is to scale up our material, which has great potential to make Na-ion batteries more efficient, in the Battery Lab of EnergyVille 2.

Philippe Vereecken

Scientific director electrochemical storage within EnergyVille/imec and professor at KU Leuven

An Hardy

Professor at EnergyVille/UHasselt

Optimising Existing Batteries

In addition to new materials and technologies for batteries, we are also looking for solutions to optimize existing batteries. An example of this is our **BattSense** technology, a battery management system for mobile and stationary battery packs. The technology is a combination of hardware and software functions that not only continuously monitor the individual battery cells, but also manage the system in such a way that its intrinsic capacity is maximized and its lifespan is extended. The battery management system is a commercially available product already applied in several projects. Furthermore it is optimized for different types of batteries. Therefore the new batteries developed in EnergyVille can be perfectly equipped with the battery management system (BMS).

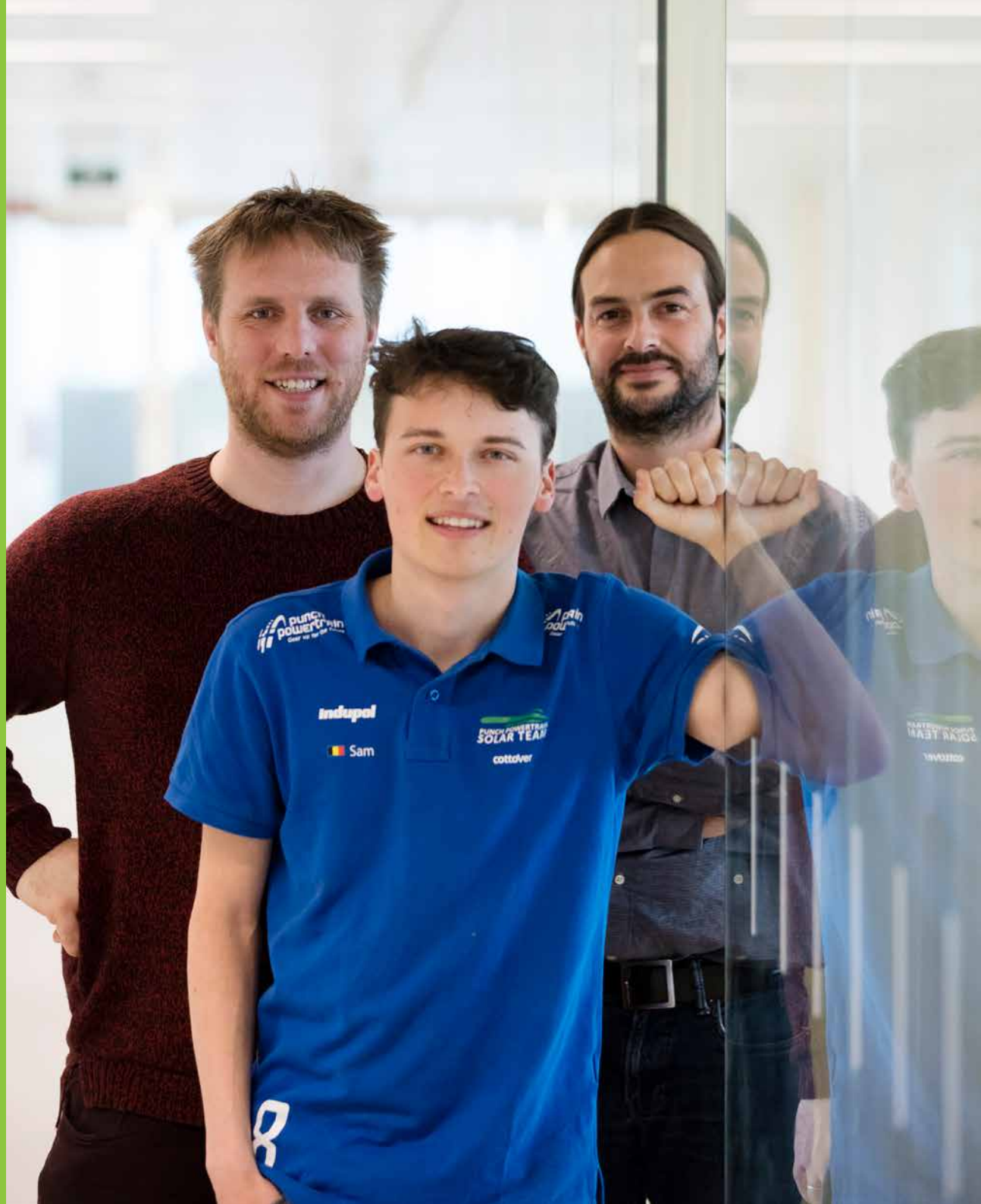
Punch Powertrain Solar Team, with BMS from EnergyVille/ VITO, Wins Carrera Solar Atacama in Chile

In October the Punch Powertrain Solar Team, since 2019 known as the Agoria Solar Team, took part in the Carrera Solar Atacama in Chile, the most extreme race for solar cars. Their solar car was equipped with a battery management system from EnergyVille/ VITO and was the first to cross the finish line in Arica, in northern Chile.

A solar car generates electricity via photovoltaic cells. This power does not only drive the electric motor, but is also stored in the batteries on board - so that the car will not stall in the absence of sunlight. A reliable battery management system is indispensable. "This electrical system monitors and protects the battery so that it does not break down under extreme conditions," says Sam Vanherbergen, engineering student at KU Leuven and responsible for the electric drive of the solar car within the Punch Powertrain Solar Team. "In addition, the BMS accurately and in real time shows how much energy is left in the batteries."

The BMS of the Punch 2 was developed by EnergyVille/VITO. "Our BMS is one of the few available systems that can balance both dynamically and actively," says Geert Jacobs of EnergyVille/VITO. "Thanks to the balancing system, each cell can be recharged or discharged individually. As a result, the intrinsic capacity of the total battery package is maximized. The BMS ensures that all battery cells are kept in balance, while the total battery pack is - simultaneously - charged or discharged. Consequently, thanks to our BMS, all individual battery cells can not only be fully charged, but also drained to the limit."

During a solar car race, details that seem futile at first glance can mean the difference between victory and loss. "With our innovative BMS we can extract up to 2% extra energy from the batteries," says Boudewijn Knooren from EnergyVille/VITO. "Taking into account that a solar car consumes 10% of its battery capacity per hour, you can expect a time saving of 12 to 14 minutes. During the previous World Championship in Australia that was exactly the average time difference between two incoming teams. EnergyVille/VITO will continue to support the Solar Team, already looking forward to the World Solar Challenge in Australia in October 2019."



INNOVATION IN SOLAR TECHNOLOGY

Tandem Cells for Improved Efficiency

Solar panels are now a well-established technology. That does not mean improvements can no longer be made in terms of materials and related efficiency and performance. Silicon cells are traditionally used in solar panels, but this technology gradually reaches its theoretical limit of 29% efficiency. The best reported result for silicon cells is currently 26.7% on a laboratory scale. However, converting this to an industrial process costs a lot of money. Reaching the theoretical limit will therefore not be economical in practice. That is why EnergyVille is looking for alternatives to achieve higher efficiency on the one hand and to set up a cost-efficient industrial process on the other. Tandem cells offer a solution.

Tom Aernouts, Programme Manager PV Perovskite: "With tandem cells we try to combine conventional silicon with another material that is complementary to it. Perovskite cells can offer this complementarity. They capture the blue and green light and efficiently convert it into electricity. At the same time, the red and infrared light can still pass through to the silicon cell, which can then be converted efficiently again. Together they can lead to an improved energy yield, with a theoretical limit of 40%."

After the first promising research results, devices that allow the tandem cells to be scaled up from lab level to real modules of 30 by 30 cm were purchased for EnergyVille 2. "We are the only research centre in Europe that can make tandem modules up to this size," Tom Aernouts explains.

The perovskite cells used for these tandem cells are semi-transparent and can even be flexible. This way they can be used for other applications, for example in windows. In the long term, perovskite cells can be used in buildings alongside the usual silicon technology. But other applications are also possible, such as in vehicles, where perovskite cells can be reapplied into the windows. But alos on other parts tandem cells can provide increased efficiency.

Tom Aernouts: "There is a lot of industrial interest for our technology. We are in contact with companies that are interested in replacing their silicon technology by, or combining it with, our tandem cell technology. "

Tom Aernouts

Programme Manager PV Perovskite at EnergyVille/imec

Towards Custom-Made PV Modules

Not only on cell level but also on module level new opportunities arise for solar power. PV module technologies have improved over the last decade, prices have dropped rapidly and the module efficiency has advanced tremendously. Especially Building Integrated PV (BIPV), which neatly integrates solar modules into building façades or windows, has become a promising (and aesthetically pleasing) technology to get solar panels even more widely implemented. To keep on improving the efficiency, sustainability and applicability of these modules, a lot of innovative research has been done within the EnergyVille cooperation.

Improved Module Efficiency

First aim on the agenda is to keep on improving the efficiency of PV panels. "The **SolSThore** project for example looked into the possibility of woven multi-wire interconnection technologies as a next generation technology for bifacial solar cells. It advances the current interconnection technologies by combining soldering and lamination materials in one woven layer. These modules have now also been installed in the façade of EnergyVille 2 and demonstrate promising results", explains **Eszter Voroshazi** Programme Manager PV modules and systems at EnergyVille/imec. The new interconnection technology will be further developed for industrial-scale production of the fabric and modules with industrial and academic partners, such as for example in the **TWILL BIPV**, an imec icon project.

Eszter Voroshazi

Programme Manager PV modules and systems at EnergyVille/imec

Improved Reliability and Predictability of PV Modules

Next to an improved efficiency, a lot of attention goes to the reliability of PV modules. We mainly look at PID or Potential Induced Degradation, a phenomenon that affects cells of PV modules. In a long string of PV panels in series, a voltage difference arises where sodium floats from the glass to the cells. This can cause damage or lower the efficiency. Possible solutions are using barrier materials or glass without sodium.

Michael Daenen, Associate Professor at EnergyVille/UHasselt: "We conduct reliability studies based on the mission profile of a PV panel. With PID, external factors such as temperature and humidity play a major role, so it is important to consider where a panel will be used (location) and for which application (in an open field, on a roof, integrated into a façade, etc...). This way our reliability studies are even more accurate."

In order to test our silicon and thin film modules, several beyond-the-state-of-the-art characterisation facilities for outdoor and indoor monitoring and energy yield simulations were launched. Eszter Voroshazi: "For outdoor testing EnergyVille has its own BIPV test set-up aimed at testing real-size façade elements in different orientations. This test set-up is the result of a cooperation between building physicists, electrical engineers and PV specialists. It constantly validates different configurations in real-life conditions, which we benchmark with a standard rack-based installation which is designed for high relative accuracy. For indoor testing several climate chambers and a large LED-light-based solar simulator with double side illumination have been installed. All to accurately measure the performance, predict and investigate the failure mechanisms and degradation patterns of solar modules".

To accurately predict the energy yield of solar cells and modules under varying conditions, a detailed energy yield simulation framework has been further developed for bifacial PV systems. It combines optical, thermal and electrical parameters to provide detailed insights on thermal variations in the solar module considering its complex, potentially shaded environment. Last year's addition of the rear irradiance and improved wind models combined with high performance computing approach makes this framework ever more precise and fast. We worked in several industrial and cofunded projects to enable modules designed for a high energy yield, and bifacial PV systems with maximal gains as well as to contribute scenario development for the large-scale deployment of PV in Belgium.

Michael Daenen

Associate Professor at EnergyVille/UHasselt

Towards Custom-Made Technology

Since specialty and integrated PV (e.g. in cars, boats, façades, houses, roads…) solution are essential for distributed electricity generation advanced engineering materials and automation approaches are needed for mass customisation in the PV sector. Eszter Voroshazi explains: "In the PV Module Lab of EnergyVille 2 we started up an automated assembly tool (developed jointly with IPTE) for assembling custom-made BIPV solar modules. This tool can pick up cells and interconnection sheets/foils and assembly custom sized/shaped modules without human interaction."

Possible applications of this kind of custom-made panels were examined in the **PVopMaat** and **Rolling Solar** projects. PVopMaat looked at the integration of PV panels in a custom color, shape and size in building components, for example in roofs, façades or windows. Rolling Solar, in turn, looks at the integration of PV in infrastructure, for example on bikeways or on roadsides. Noise barriers are also a possibility.

Sustainability

Last but not least, the sustainability of PV modules is included in our research. " Together with VITO we kicked off two projects on the environmental impact of PV: **Ecodesign** for PV systems and modules and the **CIRCUSOL** project. The CIRCUSOL project, which started in June 2018, looks into Circular Business Models for the Solar Power Industry. Within the project, business solutions for circular economy in the solar power sector are developed and demonstrated", Eszter explains. "The EnergyVille partnership has been an important facilitator in this matter. The CIRCUSOL project was established thanks to joint forces of the EnergyVille collaboration. It is exactly with this combined expertise we continue to optimise the sustainability of PV panels."

Green Light for BREGILAB Project: Research into the Development of Renewable Energy in the Belgian Electricity Grid

Given the fact that there is a major peak in solar energy around noon, the current injection into the grid must be limited when there is a lot of sun. This is done to prevent overloading the electricity grid. Within BREGILAB, different options are studied to use the generated renewable energy as directly as possible, as this is the cheapest solution. In addition, alternatives are considered, such as an injection limit in combination with storage in batteries, to avoid grid overload with high production of renewable energy.

The BREGILAB project, approved in the framework of the energy transition fund, examines in detail how this can be practically realized at minimal cost for network expansion and batteries. The following topics are studied:

- Design of the electricity grid for maximising the direct consumption of renewable energy with a grid injection limit
- Optimal geographical distribution of the capacity of wind turbines
- Optimal geographical distribution and orientation of solar panels
- Optimal dimensioning and spreading of storage, for instance with batteries
- Use of surplus renewable energy for thermal industrial processes
- Impact of the growth of electric cars and heat pumps on the electricity grid

The BREGILAB project forms an essential element to prepare Belgium for the further roll-out of solar and wind energy in the upcoming decades. The project will be executed under the direction of **Marc Meuris** of EnergyVille/imec, in collaboration with his colleague **Pieter Lodewijks** from EnergyVille/VITO.

In addition to BREGILAB, two other projects submitted by EnergyVille for the Energy Transition Fund were approved: NEPTUNE and EPOC 2030-2050.

Opening EnergyVille 2 – a Unique Lab for Research into Solar Cells and Storage Systems

On 31 May 2018 EnergyVille 2, the second building in which the EnergyVille research collaboration resides, was officially opened. The building is dedicated to technology development for power generation with thin-film solar cells, intelligent PV modules and new battery systems for local energy storage.

In the context of the energy transition and the climate objectives to be achieved, it is essential to make optimal use of storage and make the production of solar energy even more efficient and less expensive. EnergyVille 2 is the second building in which the EnergyVille research collaboration resides. The building is equipped with state-of-the-art research laboratories and office space for about 100 researchers. The opening also announced the official move of part of the PV and battery research of imec and UHasselt. Highlights of this brand-new building are the BIPV set-up (solar panels integrated in the façade), imec's pre-pilot line for thin-film solar cell production and the dry room in the lab where the humidity is kept at 0.6% to ensure a safe way of processing new battery materials into batteries. ▶

SUSTAINABLE HEAT

Currently, little attention is being paid to making heat sustainable, even though our heat demand is responsible for a substantial part of our global CO_2-emissions. Geothermal CHP or cogeneration installations can help making our heat sustainable by at the same time generating electricity and heat based on a deep geothermal source.

Geothermal CHPs for Green Heat

Sarah van Erdeweghe, PhD student at EnergyVille, investigated geothermal CHP installations. "My PhD arose from the question whether geothermal CHPs are profitable in Belgium or similar regions. The challenges for Belgium, and for almost all of North-West Europe, are largely due to the low temperature gradient in the earth. This contrasts strongly with volcanically active areas such as Italy or Iceland. This low temperature gradient leads to high investment costs for the geothermal wells and a relatively low source temperature (100-150 ° C). Earlier doctoral research at VITO/KU Leuven showed that electricity production alone from this deep geothermal source is not cost-effective. In my doctoral research I want to investigate whether this economic feasibility can be improved by the simultaneous production of heat and electricity, starting from a geothermal source at relative low temperature. My research shows that a geothermal CHP installation for generating electricity and supplying heat to a heating network can indeed be economically viable in a Belgian context. "

The question remains what such a CHP plant should look like. Which components are needed and in which configuration? To see which set-up works best in which situation, different configurations were compared. For example, the installation can be connected in series, whereby electricity is first generated via an Organic Rankine Cycle (ORC) and the remaining heat is used as a heat source. In a parallel set-up, electricity and heat are generated in parallel. There are also combinations, such as the preheat-parallel configuration or the HB4 configuration. Which set-up is the best depends on various factors. For example, for heating networks at low temperatures, the series connection is the best. It is also possible to change configurations, for example switching in series when the heat demand is low (in summer) and in parallel when the heat demand is high (in winter). By adjusting the speed of the pumps and fans in a CHP configuration, the electricity production can also be controlled as a function of the heat demand.

"There are currently no commercial geothermal CHP installations in Belgium, mainly because there are only a few heating networks in our country. There is a growing interest in geothermal energy thanks to some unique features; it is a local, sustainable and a renewable energy source of which the energy production does not depend on weather conditions (as opposed to wind and solar energy) and which is therefore predictable and controllable. The expectation is that geothermal CHP installations will be rolled out in the near future. A CHP plant can not only be used with geothermal energy, but also with heat from waste incineration or residual heat from industrial processes", concludes Sarah van Erdeweghe.

Sarah van Erdeweghe

PhD student KU Leuven/VITO at EnergyVille

Thermal Grids for Sustainable Heat

Thermal energy has an important role to play in the energy transition. Thermal networks have great potential, especially in the urban environment. In the past year, projects with district heating were rolled out at various locations. EnergyVille joins these projects, both in Belgium and all over Europe.

Towards Smarter and Efficient District Heating Networks

Fourth generation thermal networks offer great potential to increase the energy efficiency and the share of renewable energy in heating or cooling buildings. These heating networks provide the heat supply of low-energy buildings with low grid losses by using low-temperature heat sources. Residual heat from industrial processes or from geothermal sources can thus be ideally integrated into the network. Moreover, there are fewer heat losses at a lower temperature, which results in a higher efficiency.

District Heating and Cooling (DHC) networks form an important part of the EnergyVille research. In the past year we participated in various projects on smart control of district heating and substations, thermal storage and the possibility of lowering the return temperature in district heating networks.

The most recent project that was started is a heating network with smart, self-learning demand-side management controllers in Eindhoven, in collaboration with **Ennatuurlijk**. **Koen Allaerts**, project coordinator at EnergyVille/VITO: "The **STORM controller** wants to optimise the heat demand of buildings and neighbourhoods in function of the supply in order to use more heat from renewable energy sources or residual heat. The use of waste heat and renewable energy sources is maximized by self-learning algorithms. " In order to make thermal networks more efficient, the STORM controller is also used at pilot sites in Heerlen (NL), Rottne (SE) and the Balmatt site at VITO in Mol (BE). In Heerlen the heating network is controlled with heat from the flooded mine galleries, in Sweden with bio-oil and woodchips, and in Mol deep geothermal heat will be used.

The STORM technology was evaluated within EnergyVille in cooperation with other partners. **Johan Desmedt**, activity coordinator at EnergyVille/VITO: "In Sweden a reduction of 13% of the peak heat production was realised, in warmer months, the STORM controller technology even reached a 50% reduction. Demo tests in Heerlen showed the possibility of connecting extra buildings to the district heating network thanks to the STORM controller technology. Together with its industrial partners EnergyVille wants to enable a big roll-out of this technology towards other network operators and markets."

Towards a Large-Scale Implementation of Heating Networks

And that's not all. Heating networks are in full development and great interest is shown from the industry. EnergyVille is therefore preparing for partnerships with major heat network operators to implement our technology in their networks.

Koen Allaerts

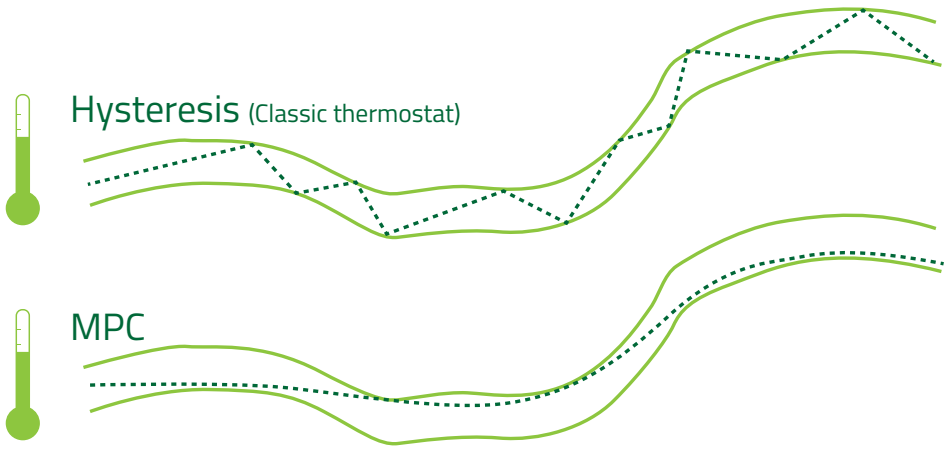
Project coordinator at EnergyVille/VITO

Johan Desmedt

Activity coordinator at EnergyVille/VITO

Model-based Predictive Control (MPC) of Energy Systems in Buildings

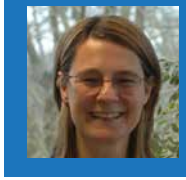
We also look at the building level to see how we can use sustainable heat and cold in buildings as efficiently as possible with the highest possible user comfort. **A Model Predictive Control (MPC)** was developed to enable this. MPC makes a mathematical model of a building and optimally coordinates cooling, heating and ventilation. The model is very detailed and takes weather forecasts and user behaviour into account.



How does it work exactly? **Filip Jorissen**, post-doctoral researcher at KU Leuven/ EnergyVille: "Control techniques for buildings already exist, the best known of which is the ordinary thermostat. The traditional thermostat switches the heating on when the temperature in a home drops below a certain point, and off when the set point is reached. Instead of switching the heating on and off continuously, the MPC will first estimate temperature fluctuations as a result of, for example, the outside temperature or solar radiation and anticipate this by supplying just enough heat or cold. This optimisation not only ensures greater comfort, but also results in energy savings of around 20 to 30%, although the final figure depends on the building in question."

Filip Jorissen defended his PhD entitled "Toolchain for optimum control and design of energy systems in buildings" in 2018, after which he continued his work in the **hybridGEOTABS** project. In this project the MPC approach is tested in real buildings. EnergyVille/KU Leuven is involved in 3 demonstration studies: the Fluvius office building in Dilbeek, the Ter Potterie elderly home in Bruges and the Solarwind office building in Luxembourg. In these demonstration studies, a geothermal drilling field is always combined with concrete core activation and heat pumps. This GEOTABS concept allows very efficient cooling and heating, using renewable heat and cold.

"In the future, MPC can be applied in any building. In 2018 we started a valorisation process from the Thermal Systems Simulations research group (The SySi) in which we want to further roll out our MPC approach, starting with building types with great potential, but ultimately all buildings are eligible. Within this process, first the user-friendliness of the tool is further developed. With an accessible graphical user interface, companies will be able to configure which is the most cost-efficient solution for them, "says Jorissen. EnergyVille 1 is one of the potential candidates to function as a living lab equipped with MPC.



Lieve Helsen

Professor at EnergyVille/KU Leuven

Filip Jorissen

Post-doctoral researcher at EnergyVille/KU Leuven

ELECTRICAL NETWORKS: TOWARDS THE SUPERGRID OF THE FUTURE

Our current electricity grid is facing important challenges. To transport ever larger amounts of electricity, integrate energy from renewable sources into the grid optimally and connect electricity generated by offshore wind farms to the mainland as efficiently as possible, a completely new offshore network is needed, and possibly even a large-scale super grid. HVDC networks, based on high voltage direct current transmission, have an important role to play in this. Integrated HVDC grids will enable a higher share of renewable energy in the coming decades. This technology is essential to bring offshore wind energy to land and to increase interconnection capacity between different countries, in order to enable a single European electricity market. HVDC technology makes it possible to develop an electricity highway based on direct current. To make the transition to HVDC networks, EnergyVille develops the models, tools and the necessary test infrastructure for the control, protection and planning of such systems.

"**PROMOTioN** is an international project that focuses on the deployment of HVDC networks," Professor **Dirk Van Hertem** (EnergyVille/KU Leuven) explains. "Future energy systems need a flexible and large-scale transport of energy. The protection of those networks requires new hardware applications and algorithms. Within PROMOTioN, EnergyVille/KU Leuven takes the lead in the development of these protection strategies". Specifically, this concerns the refinement of protection algorithms and the development of the necessary control algorithms for HVDC converters, methods to guarantee interoperability of protection strategies and the integration of HVDC networks in the cost-benefit analysis. At the same time, pre-standardisation test protocols were developed to test DC security relays.

The **NEPTUNE** project, set up with support from the Energy Transition Fund, also focuses on the development of HVDC networks, specifically for offshore wind. "The development of renewable energy and in particular wind energy has ensured that offshore wind is becoming more cost-effective. The transport of wind energy to the end user therefore becomes more and more important for which traditional AC technology no longer meets all requirements. The NEPTUNE project is investigating how this network can be rolled out, protected and controlled, "says Dirk Van Hertem.

Converters have an important role to play as they bridge the gap between the existing AC network and the DC technology. Within the framework of the **ABB Research Award in Honour of Hubertus von Gruenberg** our research focuses on modelling the converters and their control. "The converters as such provide many opportunities. By visualising all degrees of freedom in detail with new models, unknown possibilities for control are established," professor **Jef Beerten** (EnergyVille/KU Leuven) adds.

"HVDC grids are complex, and in many ways total new, systems. Hence, at EnergyVille, we endorse knowledge reinforcement through junior experts to enable the roll-out of HVDC networks. The **InnoDC** project for example focuses on the training of talented researchers at the beginning of their professional career within this booming sector," explains Jef Beerten. Within this European project, EnergyVille and Elia develop methods to visualise the impact of converters on the DC network. With CG Global tools are developed to define the economically optimal lay-out for wind farms at sea.

Dirk Van Hertem

Professor at EnergyVille/KU Leuven

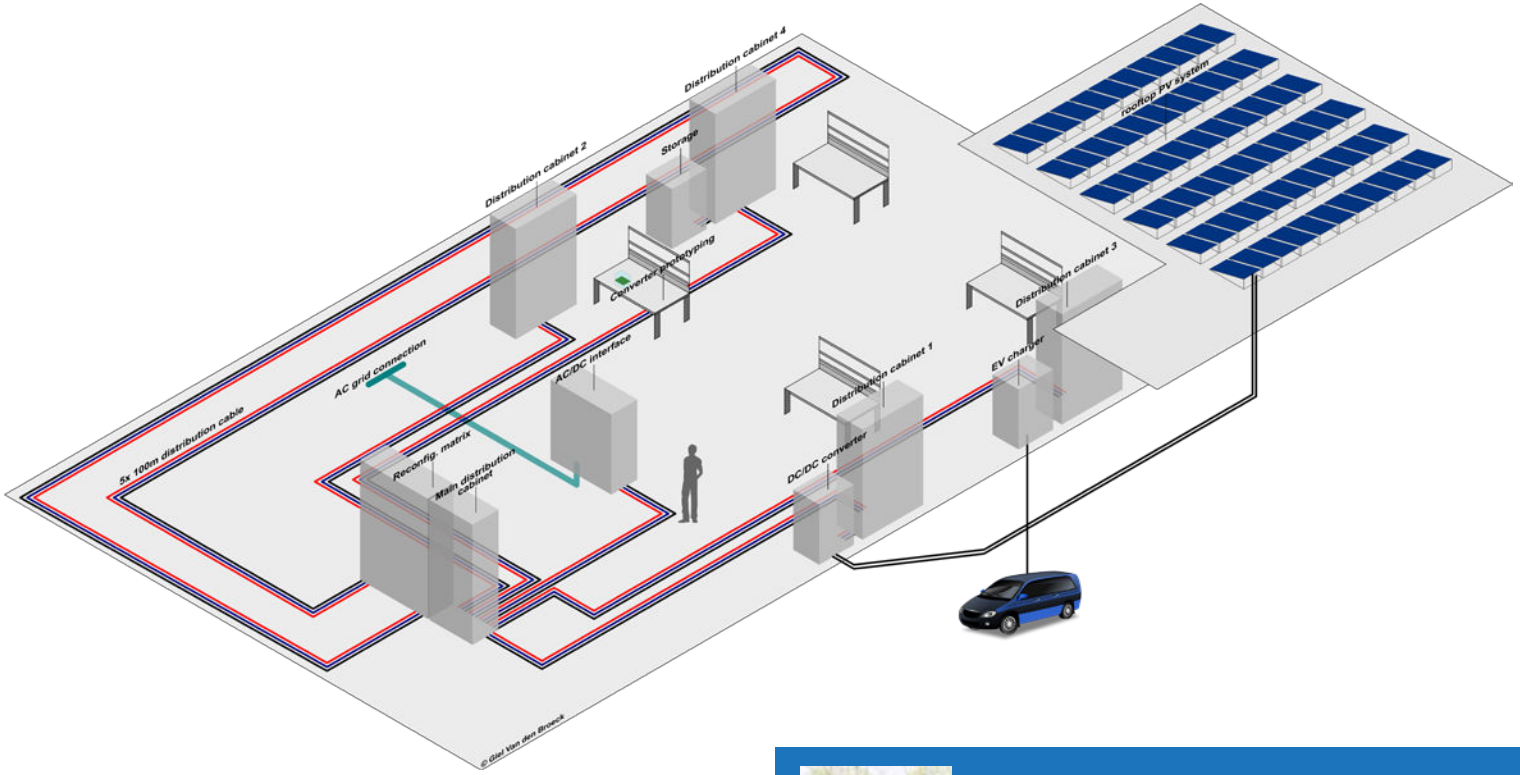
Jef Beerten

Professor at EnergyVille/KU Leuven

From Alternating Current (AC) to Direct Current (DC) in Smart Buildings

Although electricity networks in buildings and districts have been widely equipped with alternating current technology at 50 or 60 Hz for more than a century, the energy transition raises the question whether that is still the best option to go for. The transition to decentralized production, energy-efficient technologies and electrification in heating and transport all contribute to the question whether the current lock-in of AC technology is still justified. EnergyVille investigates low-voltage DC technology and its practical implementation. To do this, a representative bipolar DC nanogrid at building level (as opposed to the wide area microgrids) was set up in the Home Lab of EnergyVille 1. The focus is now on security and managing the DC nanogrid as stable and flexible as possible.

Professor **Johan Driesen** (EnergyVille/KU Leuven): "There is a major potential for bipolar DC nanogrids: both in smart buildings as for public lighting or charging stations for electric vehicles. Electrical sockets in houses will not immediately disappear, but direct current is already often used in smart buildings, for example for the interaction between solar panels and batteries, and for charging electric vehicles. What's missing is standardised components and the necessary safety regulations. Those regulations are now developed in the **ICON BIDC project**. Furthermore, we also have several test installations in our Home Lab with electrical appliances such as an electrical stove or a heat pump on district current.



Johan Driesen

Professor at EnergyVille/KU Leuven

Decision support for Network Operators

To support network operators in optimising the operation and planning of transmission and distribution systems, EnergyVille also offers calculation methods and tools to make proactive decisions and enable optimum integration of all service providers in the market. For example, the **Adrian** project, in collaboration with Fluvius, looked at how a higher share of renewable energy can be integrated into the electricity network. New tools were developed that can quickly and accurately calculate the electrical network.

In that respect, we also look beyond national borders. In an international energy system in which renewable energy sources form a substantial part of electricity generation, it can be more beneficial to trade electricity between different countries. In collaboration with State Grid China, research is being conducted into how transnational network investments can be made. EnergyVille takes the lead on HVDC system development. A concrete realisation within this context is the development of an open source optimisation module for hybrid AC and DC networks: **PowerModelsACDC**.

NEPTUNE Project: Green Light for Ambitious Research Proposal for European Electric Superhighway at Sea

The Energy Transition Fund aims at encouraging and supporting research and development in the field of energy. The Council of Ministers has, in the framework of this fund and on the recommendation of the Minister for Energy, Environment and Sustainable Development Marie Christine Marghem, approved the NEPTUNE project to investigate the development of the future European electrical grid for offshore wind energy.

Such an electrical grid will be rolled out to a large extent using DC technology. Before constructing this grid, a number of challenges have to be addressed. The research proposal of the NEPTUNE project focuses on 3 axes:

- Planning and roll-out of the grid in a cost-effective and reliable way
- Reliable protection to prevent grid outage or component damage due to faults
- Control of the converters to achieve stable grid operation

This way, the NEPTUNE project is an essential element to prepare Belgium for the further roll-out of offshore wind energy in the coming decades.

The development of renewable energy and in particular wind energy has ensured that the cost-effectiveness of this technology has increased, whereas this also leads to increasing sizes of wind parks which are located further away from the existing network. As a result, the transport of wind energy to the end user takes on an increasingly important role, for which the traditional AC or alternating current technology is no longer suitable. In addition to the new developments, the project also contributes to the development of the necessary knowledge in this sector, which already accounts for 15,000 employees in Belgium. The project will be executed under the supervision of Prof. Dirk Van Hertem of EnergyVille/KU Leuven, in collaboration with his colleagues Prof. Jef Beerten and Prof. Erik Delarue.

In addition to NEPTUNE, two other projects EnergyVille submitted for the Energy Transition Fund were approved: EPOC 2030-2050 and BREGILAB.

FLEXIBILITY FOR A BALANCED GRID

Historically, the electricity grid has been designed for top-down distribution, where electricity is generated in large power plants and transported to the end consumer. Thanks to the rise of solar panels, wind turbines and smaller CHPs, end consumers can generate their own electricity and inject it into the grid, which is already happening on a massive scale. This can cause problems for the stability of the electricity grid, since the injection and consumption of electricity on the grid must be the same at all times.

Besides, the transport and distribution capacity of the grid is limited and investments to reinforce the grid are expensive and cannot be done everywhere at the same time. That is why within EnergyVille we look for flexibility of buildings and neighbourhoods, both in electricity and in heating or cooling, to support the stability (balancing) of the grid and postpone reinforcement investments or even eliminate the need for them altogether. Flexibility at system level is already regularly used in the form of demand control or demand response, for example by switching off installations of large industrial users during a contractually defined short period of time. Switching off wind turbines or giving price signals (which can lead to negative prices) when there is too much electricity production can also help. Many problems are, however, situated at the low or medium voltage level, since an increasing amount of houses are equipped with solar panels and heat pumps, since an increasing amount of factory roofs are full of solar panels and since wind turbines are integrated in industrial areas.

Within the **REnnovates** project, EnergyVille/VITO has looked at flexibility on district level. **Chris Caerts**, Activity Coordinator at EnergyVille/VITO: "We use smart algorithms to prepare houses for the energy markets of the future. Buildings should mainly use energy when a lot of self-generated energy is available or when the rates are low, so you need to be able to handle your energy consumption flexibly. In order to do so without giving in on comfort, we ensure that a building predicts its energy demand as accurately as possible during the day and automatically adjusts its consumption. By optimising at district level, we can increase this flexibility (and therefore also increase the cost savings) even further."

This strategy also has advantages for the end user: in the future they can trade their own generated energy in a dynamic flexibility market. "Pilot projects in the Netherlands are already showing successful results," says Chris Caerts. "A lot is already possible on a technical level, but in terms of policy there are still some obstacles to be tackled. In any case, flex trading is the next logical step after demand response at system level. "

Chris Caerts

Activity Coordinator at EnergyVille/VITO

Key to More Flexibility: Data

Instead of a model-based approach, data can also be used to implement flexibility. Especially on household level, where a lot of flexibility is needed to have an effect on the energy market but where there is also a lot of uncertainty due to weather changes, unpredictable user behaviour or diversity of devices, it is more accurate to start from as much data as possible.

Data-driven applications will become increasingly important to control flexibility within the energy system. Professor **Geert Deconinck** from EnergyVille/KU Leuven explains: "Thanks to artificial intelligence and data analytics, devices can increasingly identify and use flexibility themselves. For example, it would be perfectly possible for washing machines to switch on automatically when the electricity prices are low. Ultimately, the end user has more comfort at a lower price while maintaining his privacy, so the benefits are threefold. "

In addition, flexibility at the household level has advantages for multiple parties. For the consumer it means more self-consumption of generated green electricity and a lower invoice. Voltage problems can be avoided or remedied on the electricity grid. Thirdly, aggregators can capitalise on flexibility in the energy market. In the future, the role of the consumer in all of this can become even bigger. In addition to flex trading, peer-to-peer trading (where consumers sell electricity to their neighbour, for instance) is also a promising track. "We currently have a number of projects related to peer-to-peer trading. However, a number of obstacles still need to be tackled, such as scalability, privacy and the economic aspect." says Geert Deconinck.

The EnergyVille 1 building itself also serves as an important source of information. Not just the heating system, but also the solar panels, electric charging points and the lighting are registered in its own platform. This data is also linked to weather forecasts, user patterns and external data from the electricity market. This way we try to map supply and demand in the building as detailed as possible and we try to locate flexibility. Based on that, smart applications or services can then be further developed and tested.

Geert Deconinck

Professor at EnergyVille/KU Leuven

ThermoVault Optimally Utilizes Flexibility of Thermal Appliances

The start-up ThermoVault, affiliated with EnergyVille/KU Leuven and UC Berkeley, addresses the huge potential of flexibility in thermal appliances. Sandro Iacovella, founder of ThermoVault: "Our goal is ambitious: build the biggest decentral energy storage system in the world. We still have a lot of work to do, but we've already reached 1 megawatt of flexibility in households all over Flanders, by means of electrical boilers and heating systems. The upcoming year we hope to enable an even more rapid growth."

Making use of flexibility is simple: everything is done with a small device which can be installed on a boiler or a heating system. On the one hand it controls energy locally by means of smart control without any loss for the end user. On the other hand it also opens up the possibility to function together as a virtual power plant to balance out the transmission grid.

Sandro Iacovella: "Control is currently done nationally, but we're also preparing for control at the level of households and local energy communities. In order to do so we want to include heat pumps, to reduce peak moments and enhance the self-consumption of the energy generated by the end user. Additionally we wish to address flex trading, earlier mentioned in this report. In sum, we wish to optimally use the flexibility of appliances in a dynamic flexibility market. On the primary reserve market of transmission system operator Elia, we can then rapidly respond to frequency deviations."


EnergyVille

POLICY INPUT FOR A SUSTAINABLE ENERGY FUTURE

The increase in distributed renewable energy sources such as solar panels, changes in the consumption pattern of end users and technological developments such as the digital meter pose new challenges for all stakeholders involved in our energy system: end consumers, producers, balance responsible parties, system managers and policy makers. It is essential that technological choices and policy measures for the short and long term are based on scientific data and calculations. Not only local and international governments but also stakeholders and actors in the energy market regularly consult us for scientific input to review and design policies.

For example in 2018 the Flemish Regulator of the Electricity and Gas Market (VREG) commissioned EnergyVille/VITO to conduct a study on the revision of the tariff structure of the electricity distribution tariffs. With the data from this study and in collaboration with various stakeholders, the VREG is now developing a proposal for a new tariff structure.

The official roll-out of the new digital energy meter in Flanders is approaching and will start in 2019. From then on, the utility company Fluvius will no longer install the traditional mechanical energy meters. To prepare companies for this change, EnergyVille offers its labs to test the first versions of the digital meters. Energy suppliers and technology companies active in Flanders and beyond can come to us to test almost the whole range of energy innovation in a realistic setting. This can involve technologies that represent specific energy consumptions or warning devices for energy consumption in the home environment, the smart control of household appliances, but also applications that simulate in a lab setting the efficient consumption of power generated from solar panels.

Given the complexity of the challenges, there is a need for energy models that take into account all aspects of the energy system and how they are related. One application of our energy models is to calculate the most cost-effective way to reduce greenhouse gases taking into account future innovations and policy decisions while at the same time guaranteeing the reliability of the energy supply and keeping the bill of the consumer under control. In 2018, a number of projects submitted by EnergyVille in the context of the Energy Transition Fund were approved. One of them, **EPOC 2030-2050**, is set up as a scientific observatory to support policymakers and stakeholders in the energy transition in Belgium with a view on 2030 and 2050. This project unites 14 Belgian energy-related institutes, together accounting for more than 400 scientists and energy experts from Flanders, Brussels and Wallonia.

At European level as well we are knowledge provider for policy makers and stakeholders. As coordinator of the "**European Topic Centre on Climate Change Mitigation and Energy**" for the European Environment Agency, EnergyVille/VITO plays a key role in analysing and assessing the progress in achieving the European Union's energy and climate goals. Since we are approaching the year 2020, the existing European policy framework will be replaced by the 2030 Climate and Energy Framework and the Energy Union with a view on 2030 and beyond. **Ils Moorkens**, researcher energy & climate change policy at EnergyVille/VITO: 'The EU energy and climate plan raises important questions, such as the status of the 2020 targets and whether the EU and Belgium will meet the greenhouse gas reduction, renewable energy and energy efficiency objectives. We answer these types of questions in collaboration with our European research partners.'

Ils Moorkens

Researcher energy & climate change policy at EnergyVille/VITO

EPOC 2030-2050 Project: Research Institutes Join Forces to Develop Models for a Sustainable and Cost-Effective Energy Future in Belgium

EnergyVille is coordinating the EPOC project, that was approved in the framework of the Energy Transition Fund in 2018 and that will, for the first time, unite 14 Belgian energy related institutes representing more than 400 scientists and energy experts in one research project.

The aim of the EPOC 2030-2050 project is to combine the expertise of the Belgian research community by linking the different energy models, carefully discussing the input data used and applying them to the Belgian context. This will support policy makers in their decisions with respect to the energy future in Belgium towards 2030 and 2050.

The overall approach of the EPOC 2030-2050 project is a first-of-a-kind in the Belgian energy sector, never before have such a wide range of academic partners collaborated in one energy modeling research project. The project is coordinated by EnergyVille, and the participating research institutes are: KU Leuven, VITO, Imec, UHasselt, ICEDD, the Federal Planning Bureau, WaterstofNet, Transport & Mobility Leuven, UGent, UMons, RMI (The Royal Meteorological Institute of Belgium) UCL and ULB.

In addition to EPOC 2030-2050, two other projects EnergyVille submitted for the Energy Transition Fund were approved: NEPTUNE and BREGILAB.

TOWARDS SMART BUILDINGS AND DISTRICTS

Buildings are responsible for approximately 40% of the energy consumption and 36% of the CO_2 emissions in the EU. This is no surprise, as around 35% of EU buildings are over 50 years old. As 90% of existing buildings in the EU will still be inhabited by 2050, improving the energy performance of existing buildings is a major challenge.

EnergyVille supports various stakeholders in the transition towards smart, energy-efficient, low-carbon buildings and cities with innovative software tools and algorithms, both at building, district and city level.

A Smart Readiness Indicator for Buildings

In the European Union, making buildings and neighbourhoods more sustainable and smarter is put high on the agenda. The Energy Performance of Buildings Directive (EPBD) aims to accelerate the large-scale renovation of existing buildings and improve the energy performance of new buildings. The focus is not only on energy efficiency, but also on making buildings themselves smarter. At the request of the European Commission's Directorate-General for Energy, EnergyVille/VITO has - conducted two studies related to setting up a **Smart Readiness Indicator for Buildings**. The impact of the indicator was calculated in the first study. The second study, which is currently ongoing, examines in detail what the indicator should look like and how it can be implemented practically.

Stijn Verbeke, Project Manager Energy and Buildings at EnergyVille/VITO: "The Smart Readiness Indicator provides insight into the technological readiness of a building to be energy efficient, manage that energy efficiency and to interact with its residents and the network . In the first study, the indicator has been tested in the EnergyVille 1 building, which achieved a good score. The tool is currently in full development, but the roll-out in European member states is expected around 2021."

Mapping the Sustainability of Buildings

On behalf of the European Commission, EnergyVille/VITO, together with other partners, has investigated whether the so-called Product Environmental Footprint method (PEF method) can be applied at the level of a complete building. The PEF method was tested on various product groups between 2014 and 2018, including construction-related products such as insulation materials, piping systems for homes, paints, photovoltaic and metal panels. In the **PEF4Buildings** project, it was investigated if this method could also be used to calculate the ecological footprint of an entire building.

Mapping the sustainability of a building is very complex: it is not just about the different building materials themselves, but also about the consequences of the interaction between those different materials at the building level. **Carolin Spirinckx**, Project Manager Smart Energy and Built Environment at EnergyVille/VITO: "The PEF method was tested for two new office buildings, one with an average energy performance built in Belgium and one almost energy neutral building built in Austria. This way differences in geographical context were also included in the study. We mainly focused on methodology and on drafting recommendations for modelling at the building level. It turned out that the different guidelines for individual construction products (the so-called PEFCRs - Product Environmental Footprint Category Rules) are currently not fully aligned with each other. An alignment is recommended to facilitate the use at building level in a scientifically correct way."

It was also demonstrated that a common EU method should be defined to calculate the environmental performance of buildings and that there is a need for a common method for determining environmental criteria. Moreover, it would be good if there was a single benchmark for both the impact related to the materials used at the building level as well as one related to the energy impact.

Then we looked at the assessment of the entire building stock based on PEF. We searched for a method to link the assessment of the environmental performance of individual building products to the assessment of buildings using the PEF method. The drafted recommendation calls for one European PEFCR at the building level with possibly some national annexes. This PECFR can then serve as the basis for all new PEFCRs for building materials. The results of this project are now being used within the European Standardisation Commission (CEN TC 350) to find out how these findings can be integrated into the revision of existing European standards.

Sustainability as a Competitive Advantage

Building materials are currently responsible for 10 to 30% of the environmental impact over the entire life cycle of a typical Belgian home built before 2001. This share is expected to increase in the coming years, since the construction of, and renovation to, low energy, passive, energy-neutral and active buildings will lead to a significant reduction of their energy-related environmental impact.

That is why in 2014 the federal government included the Environmental Product Declaration or so-called EPD in a Royal Decree. The EPD is an information sheet created by the manufacturer of a building product that provides neutral, detailed and quantitative information about the environmental performance of a construction product during its entire lifespan. A manufacturer who wants to make an environmental claim must perform a life cycle assessment, report the results in a B-EPD and have the EPD registered in a central database managed by the federal government.

The great merit of a central database is that by bringing together the B-EPDs of the different materials in a building, an analysis can be made of the environmental performance of a complete building based on specific data from the EPD's. To support the Belgian construction sector in reducing the environmental impact of buildings, the three Belgian regions have developed the **TOTEM** tool in collaboration with universities and engineering firms, including EnergyVille/VITO: Tool to Optimise the Total Environmental impact of Materials.

Carolin Spirinckx, Project Manager Smart Energy and Built Environment at EnergyVille/VITO: "In February 2018, the TOTEM web tool was launched for the general public. All environmental indicators are expressed in a monetary value so that the total result can be expressed in one score. This makes the interpretation of the results easier for the user. For now, the tool still works with generic data, but once the specific B-EPDs from the central federal government database are included, construction professionals and architects can also compare different buildings or building elements based on specific B-EPD data and then choose the most ecological solution. In addition, any Belgian government tender for public buildings will in the future be calculated through TOTEM. "

To make the preparation of the specific B-EPDs accessible for manufacturers of building materials, EnergyVille/VITO and the Belgian Building Materials Manufacturers Association (BMP-PMC) have set up a support program. Having own EPDs not only gives manufacturers a positive differentiation, but also helps them to identify the possibilities for improvement towards sustainable products. This way, manufacturers of building materials can distinguish themselves from the competition, which in addition to the environmental benefits also gives them a competitive advantage.

Carolin Spirinckx

Project Manager Smart Energy and Built Environment at EnergyVille/VITO

Urban Energy Pathfinder, Scenarios for Sustainable Cities and Municipalities

Another tool developed by EnergyVille/VITO that can be used to make buildings and neighbourhoods more sustainable is the **Urban Energy Pathfinder**, which makes scenario analyses possible for citizens, project developers, urban planners, (local) authorities etc. The tool calculates the most optimal measures to make the energy system of a building, street, neighbourhood, municipality or city more sustainable, from a financial and energy technical point of view.

"The Urban Energy Pathfinder provides information about energy consumption, the buildings present, the possibilities for renewable production, heat network trajectories, the expected energy demand, costs and benefits per investment measure etc. It also shows where measures are best applied: at building level or at street or neighbourhood level. The optimal scale level is also investigated in the tool," says **Stijn Verbeke**, Project Manager Energy and Buildings at EnergyVille/VITO.

Stijn Verbeke

Project Manager Energy and Buildings at EnergyVille/VITO


Data based on:
2 adults, 2 children
CO2 Emissions
Ton CO2/year
8.7
9.0
0.3
Electricity Consumption
MWh/year
6.5
After Reduction
4.3
Reference
Primary energy
MWh/year
50.7
Reference
8.7
After Reduction
70%
Renewable
BUILDING
90%
Choose your CO2 reduction ambition level
Powered by
&
vto


Data based on:
500.000 people
CO2 Emissions
kt CO2/year
975
1096
121
Electricity Consumption
GWh/year
826
After Reduction
643
Reference
Primary energy
GWh/year
6741
Reference
1803
After Reduction
50%
Renewable
CITY
90%
Choose your CO2 reduction ambition level
Powered by
&
vto


DISTRICT HEATING
You can significantly reduce the CO2 emissions by connecting buildings to district heating that is supplied with residual heat from the industry
CLOSE


Data based on:
600 people
CO2 Emissions
Ton CO2/year
388
955
567
Electricity Consumption
MWh/year
706
Reference
638
Primary energy
MWh/year
5360
Reference
3105
After Reduction
16%
Renewable
DISTRICT
40%
Choose your CO2 reduction ambition level
Powered by
&
vto

THE ROAD TOWARDS 2030-2050

A continuous series of small and large changes will mark the way to the energy system of 2030, 2050 and beyond. You have already discovered how EnergyVille conducts research on this subject in the previous chapters. But how do we see the energy transition evolving further, both at a social, political and technological level? And what societal role has EnergyVille to play in this? Ronnie Belmans, CEO of EnergyVille and professor at KU Leuven, Bert Gysen, COO of EnergyVille and Unit Manager at VITO, and Jef Poortmans, R&D Strategy Coordinator at EnergyVille and programme director at imec, explain.

FINDING SOLUTIONS ON SYSTEM LEVEL

"The concept of sustainability has taken a central place in the social debate" Ronnie Belmans says. "Technological breakthroughs have steadily found their way into the energy system and climate awareness has grown strongly in society. That is a positive evolution, as social support is desperately needed. In addition, there is also a growing awareness that we must move away from silo approaches on separate technologies and embrace system thinking. Not a single solution will solve the full challenge as the energy issue is a complex question made up of technological options, investment and operational costs, market mechanisms and end-user behavior. We need to take all of these factors into account in order to make the energy system more sustainable as a core part of the battle against climate challenge."

"The added value of EnergyVille lies in the fact that we can investigate technologies at system level," continues Bert Gysen. "We conduct research across the entire value chain of the energy system: from material to system level and across different energy sources. Hence, we do not only offer new technological solutions, but also facts and figures to support policy and vision."

A clear political view can help with this. "By 2030, the European Commission aims for 40% fewer greenhouse gas emissions compared to 1990, 32% renewable energy in the total energy mix and an energy efficiency increase by 32.5%. Full decarbonisation is planned for 2050, "says Ronnie Belmans. With the Clean Energy for All strategy, Europe has set a clear path that can now be developed in detail by the member states. EnergyVille subscribed to this Clean Energy Package from the first moment. We take a decentralised approach rather than a centralised one, and we start from Local Energy Communities with a maximum of renewable energy and local balancing. From there we can construct the energy system in a modular way. In these Local Energy Communities, consumers will play a key role.

The energy transition must be supported by a clear policy, but at the same time be based on scientifically substantiated facts and figures. Bert Gysen: "We are happy to play an important role at European level in supporting the energy policy. That is one of our major achievements in 2018. EnergyVille has grown further from a research collaboration that not only plays in the national league, but also managed to strengthen its position at European level. We are coordinating the European Topic Centre on Climate Change Mitigation and Energy for the European Environment Agency, but also a large number of European projects in which we conduct applied research. In addition, with our partner InnoEnergy we play an important role in the European Battery Alliance, the European initiative to make the EU play a key role in the global battery sector."

"Scientifically based facts and figures are more than ever necessary," confirms Ronnie Belmans. "EnergyVille is a pioneer in the system approach. In addition to testing new technologies, we continue to map the energy transition with scientifically substantiated data. We use energy system models, scientifically developed software models that calculate combinations of technologies and their costs, and identify the most promising future possibilities. Moreover, they enable to estimate the impact of various policy measures. This will remain extremely relevant for the coming years. We already carried out the study "Energy transition: choices and costs" looking at 2020-2030. The EPOC project, in which 14 belgian research institutions are joining forces, looks beyond 2030 and takes into account new developments for a sustainable energy vision by 2050. In addition to electricity, the heat demand and transport in Belgium are also included in the project, in order to obtain an even broader picture. "

EXTENDING OUR LAB INFRASTRUCTURE

Jef Poortmans: "In 2018 we had the honor of opening a series of new labs. We are now ready to work on custom-made (BI)PV modules and have a pilot line to refine the next generation of batteries. In addition, we regard DC as an important driver for the smart buildings of the future and have rolled out a system in our Home Lab to test this accurately, under realistic conditions."

"Our innovative lab infrastructure remains important in the validation process of new technologies. Not only can we test and validate new technologies at material level, we can also deploy them in a larger context. For example, we develop more efficient PV modules, but what makes EnergyVille unique is that we can also extensively test these modules in climate chambers, a solar simulator or even integrate them in a simulated electricity network (hardware in the loop, real time digital simulator). To cover the heat demand, we also investigate heating networks, where residual heat from industrial processes can be used to heat local districts, as well as individual components in heating networks. In other words, our labs are ready for the future."

2019: A YEAR FULL OF CHALLENGES

"In 2019 we want to keep working on technological innovations. We are fully committed to new technologies,advanced test methods, living labs and both experimental and applied research. This all-in close cooperation with the industry, because their input and our collaboration are necessary to make the energy transition possible. Throughout our research, we keep in mind that the energy transition must be affordable and without loss of comfort for end users. The balance between investments needed for new technologies and the idea of an affordable energy transition is a challenge. But being allowed to work on major challenges that can make a difference for society is a dream for scientists." concludes Jef Poortmans.

KEY FIGURES

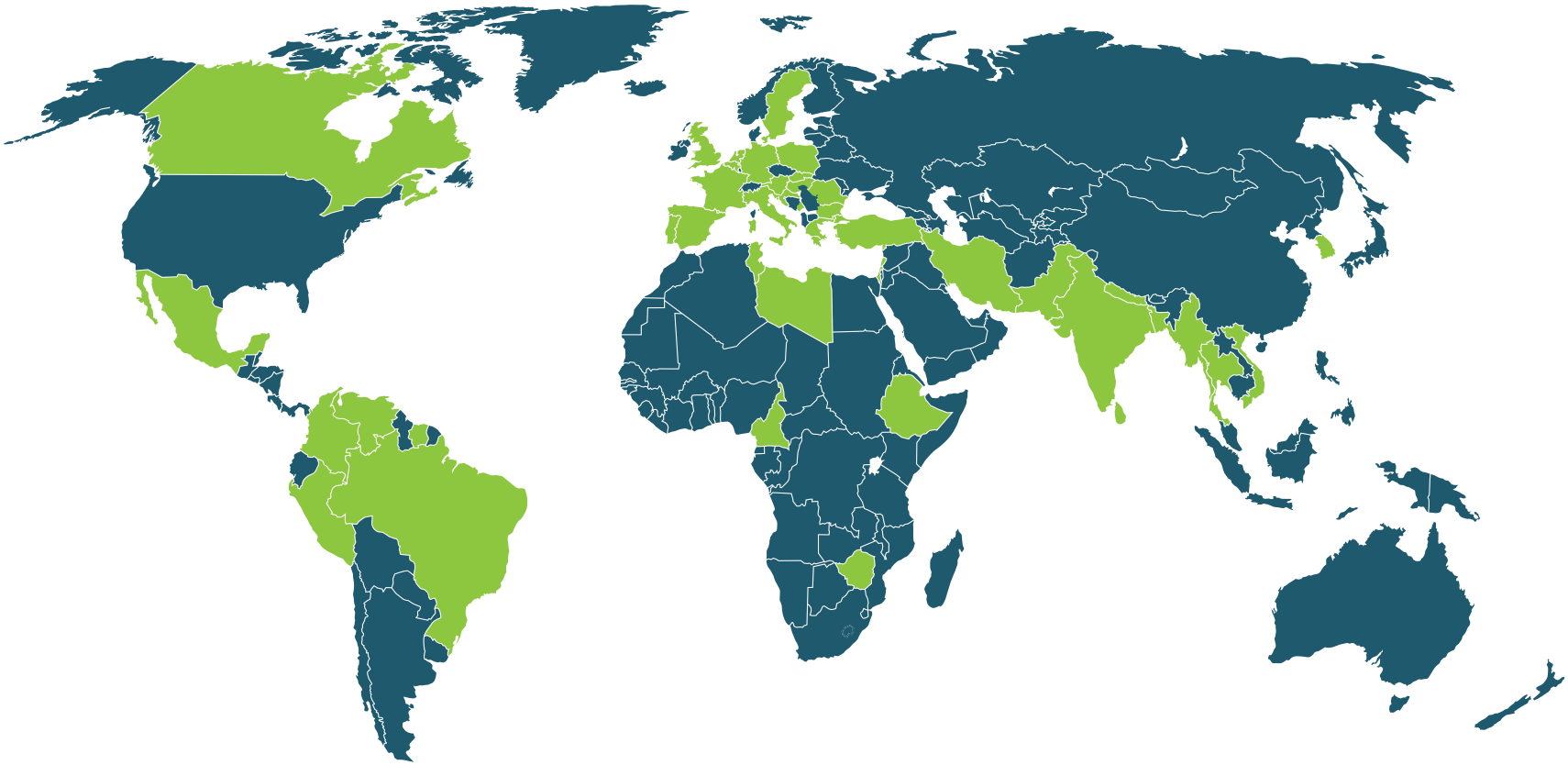
Publications
428

Patents
10

Contracts
222

Press
481

Events
52



PhD students
160

98 + **310** = **408**

KU LEUVEN

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Smart Power Grids (AC/DC)
Building Physics
Energy Conversion &
Thermal Fluid Engineering

vito

Strategies & Markets
Buildings & Districts
Thermal Systems
Electrical Storage

imec

Photovoltaic Research
Solid-state Batteries
Power Devices
Energy Yield Forecasting

UHASSELT

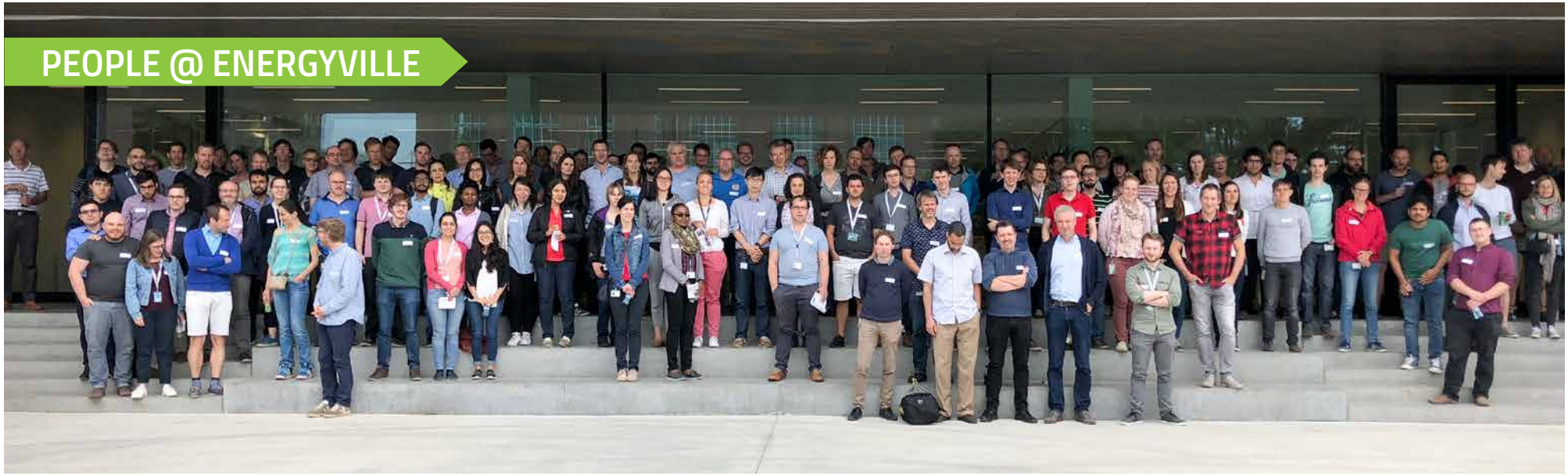
Materials for PV
Materials for Batteries
Thin-film PV
Reliability

2084 ▶ 2538

815 ▶ 996

1190 ▶ 1993

PEOPLE @ ENERGYVILLE



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