



Empowered by KU Leuven, VITO, imec & UHasselt



# ENERGYVILLE ANNUAL REPORT 2021

ANOTHER YEAR OF PUSHING THE FRONTIERS  
OF INNOVATIVE RESEARCH



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## PROLOGUE

### 2021 THROUGH THE LENS OF GERRIT JAN SCHAEFFER



*"We rely on fundamental, applied and industry-driven research – theoretical as well as experimental – not only to explore new energy-related solutions, but also to offer them. From transforming technologies into new products or services, to providing local, national or international policymakers with science-based support. Anything to accelerate the energy transition."*

A new EnergyVille. That is what I found, as I set foot again on EnergyVille's grounds after returning from my time away in the industry. And what a pleasant reunion it was! These last couple of years, EnergyVille has clearly benefited from further professionalisation. New means have been secured. And an array of new people has been gathered. People who – one by one, day after day – display nothing but pure dedication and enthusiasm to and for our common cause: facilitating the energy transition on the back of our research collaboration.

For me, the last year was coloured by countless conversations and inspiring interactions. And there was one highlight that surfaced and re-surfaced over and over again: the extensive scope of activities offered by and at EnergyVille. So, that is where I have decided to step forward and step up: to further join forces to dive deeper into our EnergyVille strategy, and – together with all of these dedicated and enthusiastic people – work on a concrete vision for the next years and decades, up to 2050. That is what I consider to be our calling, here in my new role of General Manager.



Obviously, the foundations necessary for this endeavour have already been laid: the growing amount of knowledge within EnergyVille – in different fields of expertise, stemming from different organisations – is allowing us to research the energy system of the future from all angles, and position its building blocks according to our findings – helping the pieces of the puzzle seamlessly fall into place. And this is an achievement to be proud of – unquestionably so. Because it entails we are substantially and structurally contributing to the energy transition – in Flanders, Belgium, Europe and far beyond – locking our gaze on the future, above and beyond everyday hypes.

Nevertheless, there is more work on our radar.

Firstly, we have reached a stage in the energy transition where it has meanwhile transpired that the solution is not always as simple as straightforwardly replacing current energy sources by renewable energy sources across the board. Especially when it comes to the decarbonisation of important industrial sectors, and the reduction of heavy transport emissions, there still seems to be a missing link. That is why 2021 saw the birth of a new but important eighth EnergyVille research line: Power-to-Molecules. After all, scenario studies from all over the world have shown that critical technologies for decarbonising our energy system might be hidden, right there, in that field of expertise. So, not adding this extra dimension to our EnergyVille research landscape, was simply not an option for us. And we are proud and excited to have done so this past year.

Secondly, as I see it, one of our other opportunities for growth lies in further co-creation and cooperation with both companies and civil society. So, with the 2021 oPEN Thor living lab plans, we already took a determined first step in exactly that direction: our living lab creates an environment for companies to set up real-life and real-time experiments, and test their products or even new market models – all in close consultation with local residents. That, in and of itself, makes for a unique value proposition and turns our home base into a business magnet. Yet, let it be clear: the range of that unique added value stretches far beyond what benefits businesses – it equally covers our organisation and our impact on society at large. Because innovation, you see, is a product of interplay. That is something I am completely convinced of. That is what I want to commit to.

We live in a rapidly changing world. Nevertheless – as will transpire throughout this annual report – the direction in which EnergyVille is headed is clear, and we are adamant to keep on sailing a constant course.



Because – whichever way you look at it, even in a world of change – there are certain matters which simply remain of vital importance, no matter what. Whichever way you look at it, we have to heavily invest in energy conservation. Whichever way you look at it, we have to fix our focus on renewable energy. Whichever way you look at it, we have to be able to smoothly switch gears within our energy system, and we have to be able to do so swiftly and flexibly through smart control of demand and energy storage.

The ways in which EnergyVille, in the course of 2021, concretely committed to each of the above – and more – will become clear throughout this Annual Report.

# ENERGYVILLE: FROM A COAL MINING PAST TO LIVING LABS FOR THE FUTURE

On the exact same grounds which used to generate the “black gold” of the past, today, all eyes are on a completely new sort of energy. Based on the challenges of the future, and with a determined view to facilitate the fulfilment of climate ambitions, a unique living lab for technology, energy and innovation is taking shape in Genk.

## Setting the scene

### From strategic basic research to applied research

Ever since its move to Thor Park in 2016, EnergyVille has been the cradle of an extensive amount of state-of-the-art research – both strategic basic and applied – which, in the course of the years, has been performed in its no less than 18 different multidisciplinary labs.

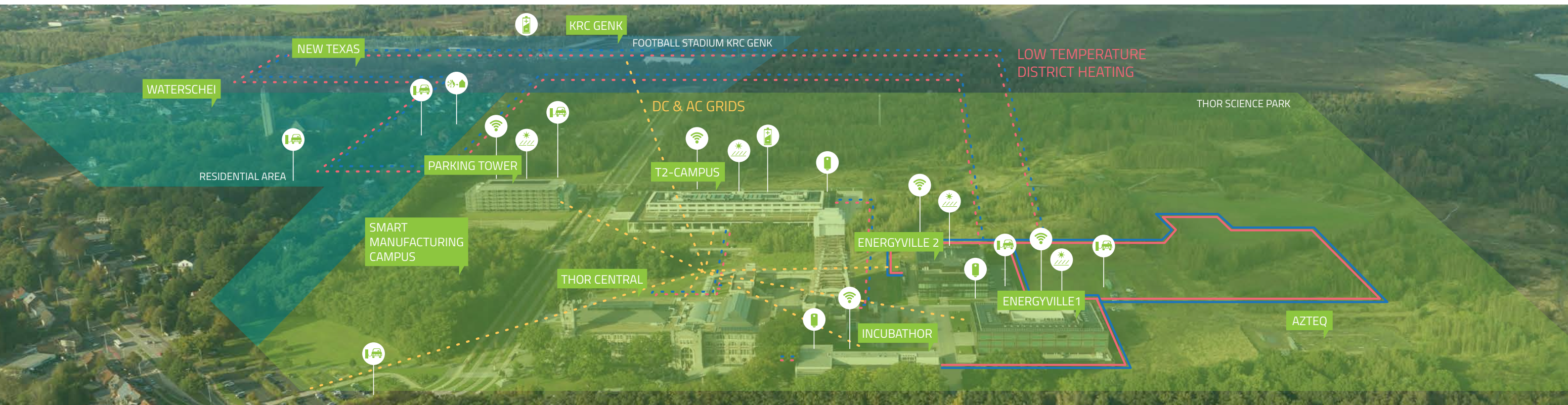
In 2020, we were granted permission to further evolve into Flanders’ first regulatory sandbox for energy, which enabled us to extend our labs and pave the way for a large-scale living lab for open innovation involving end users.

Founded by EnergyVille, NV Thor Park and the City of Genk, and embedded in the activities of its collaborating research partners KU Leuven, VITO, imec and UHasselt, today, the living lab has grown into a unique ecosystem that stretches its wings to include the Thor science and business park, the New Texas social housing estate, the adjacent Waterschei garden district, and the buildings and training complex of KRC Genk.

## The oPEN Thor living lab A unique ecosystem

As such, our top-notch innovation environment has steadily been growing into a vibrant living lab, in which co-creation between scientific partners, industrial players, policymakers, but also citizens takes centre stage, enabling national and European policy ambitions to be put into practice. Furthermore, our extraordinary infrastructure for the energy transition creates a bedding for innovative energy solutions to be developed, tested and brought to the market at an accelerated pace – all in interaction with scientific, industrial and residential stakeholders, every step of the way.

Thus, the former mining site of Waterschei has been transformed into a sustainable business and science park, turning the “black gold” of the past into fertile ground for a unique energy ecosystem – a transformation that can serve as an example for future large-scale projects, both nationally and internationally, and that perfectly symbolises the energy transition that awaits us all.



# 2021: A SMALL SAMPLE OF OUR BIGGEST ACHIEVEMENTS

## WITHIN EACH OF OUR FIELDS OF EXPERTISE

### SOLAR ENERGY

#### Record efficiency for tandem solar cells

Photovoltaic (PV) electric energy generation is the world's fastest growing renewable energy source. At EnergyVille, our PV research – in which we combine the expertise gathered by three of our four collaborating research partners: KU Leuven, imec and UHasselt – is twofold. On the one hand, we focus on improving the efficiency of PV technologies. On the other hand, we tap into its wide range of potential applications.

As such, we have been joining forces with industrial partners to continue research on tandem solar cells. In the future, these cells could achieve efficiencies of 30% or more, which is almost 50% more compared to today's state of the art. Thanks to the application of a perovskite top cell to a bottom cell based on silicon or a polycrystalline semiconductor material, 2021 saw substantial progress in the field of 2- and 4-terminal tandem cells, with efficiencies now ranging from 25% to almost 29%.



#### BIPV (Building Integrated PV) - VIPV (Vehicle Integrated PV) - Agri-PV (Agriculture PV) What's in a name?

BIPV is an innovative type of PV application, and refers to PV systems which have been integrated into a building's envelope elements, such as construction materials, roof tiles and ceramic or glass facades. EnergyVille's thin-film PV systems have great potential for BIPV applications, but can also be used in other applications such as VIPV. Hence, in 2021, we successfully designed, demonstrated and tested the first curved PV-modules for vehicles.

Then, there are also the bifacial solar panels we focus on in our research – solar panels that can capture sunlight on either side. These can be used in agrivoltaic applications, in which growing crops and producing solar energy go hand in hand. In this context, the AgriVoltaics project – an EnergyVille / KU Leuven cooperation – was awarded the Febeliec Energy Award 2021 for its innovative efforts and sustainable results in this field of expertise.



## BATTERY STORAGE

### Solid-state lithium-ion batteries A game changer for electric transport

EnergyVille partners imec and UHasselt are developing technology and materials for new solid-state lithium-ion batteries. The underlying goal? To be able to produce batteries that are less flammable, charge faster, and have both a higher energy density and a longer life span (i.e. more cycles). Here, specialised knowledge of surface functionalisation, mesoporous materials and ordered 3D metal nanostructures is relied upon to develop electrodes and membranes for these solid-state lithium-ion batteries. In 2021, we made substantial progress in increasing the energy density and life span of the demonstrator cells. The aim is now to valorise this progress through further scale-up for solid-state batteries developed for their application in e-mobility. We strongly believe this research of ours will help realise the greater goal of electrifying all land and inland waterway transport of people and goods, and probably also short-distance flights.



### The smart battery cell For safer (dis)charging

EnergyVille / VITO has been working on a new concept for battery management systems (BMS) by introducing electronics directly into the battery cell during cell production. In the course of 2021, continued development on the basis of the existing technology platform took place by further testing and confirming future features. Improved data quality and cell balancing capability are – amongst others – some of the results we booked.

In addition – in consultation with the main stakeholders in the battery value chain – further efforts were made to precisely define the full functionality and corresponding design of the necessary electronics. In this regard, EnergyVille / VITO tries to not only involve as many Flemish parties as possible, but at the same time also realises the intermediate steps in a European context – for example through the Horizon 2020 project NAIMA, or, in collaboration with UHasselt researchers, the Horizon 2020 project Current Direct. A European context in which VITO – through the Batteries European Partnership Association (BEPA) and European Technology and Innovation Platform (ETIP) on Batteries – also helps to define the long-term roadmap for sustainable battery development.

## POWER ELECTRONICS

### More compact power converters Onboard and offboard charging of electric vehicles made easy

EnergyVille partners KU Leuven and imec joined forces to gather an impressive amount of knowledge on electric vehicle charging at both system and circuit level. As such, new converter topologies were proposed and tested with new approaches at both semiconductor and magnetic levels. Using GaN and SiC semiconductors,

we managed to reduce the size of electric vehicle chargers, making it possible to reduce the overall size of powertrains and charging stations. The result? New doors for onboard and offboard charging of electric vehicles have been opened, facilitating their wider use.



## POWER-TO-MOLECULES

### Sustainable molecules

#### A more efficient technology for the electrolysis of water

The production of green hydrogen – with its potential for applications in industry and long-distance air and maritime transport sectors – plays a pivotal role in the energy transition. So, relying on our existing knowledge of electrochemistry, nanomaterials and process development, we are working on technology to produce green hydrogen based on electrolysis in a more efficient way. By combining imec's expertise in solid-state electrolytes, electrode surfaces and process technology at nanoscale with VITO's expertise in membranes, catalysis and system integration, we aspire a turnaround in the development of Membrane Electrode Assemblies (MEA) for Alkaline Water Electrolysis (AWE) technology. And that aspiration is within reach, as the introduction of imec's ultrathin nanomesh material already brought about a fourfold increase in the production rate of hydrogen gas (H<sub>2</sub>) compared to existing electrode technologies. Thus, we soon expect to be able to demonstrate an improvement in efficiency of over 75% compared to today's state of the art of 70%.

Moreover, 2021 saw the birth of two remarkable Power-to-Molecules initiatives.

At the University of Hasselt, the Green Hydrogen Lab was set up, opening its doors for EnergyVille researchers to use the infrastructure to realise innovative breakthroughs in sustainable hydrogen production by conducting materials research with a view to increase Technology Readiness Levels (TRLs) – all in close collaboration with industry.

Furthermore, the Hyve consortium was formed – a consortium in which EnergyVille partners imec and VITO joined forces with industrial pioneers Bekaert, Colruyt Group, DEME and John Cockerill. The consortium partners are pooling their resources for a cost-efficient and sustainable production of hydrogen at gigawatt level, and put Flanders in the driver's seat for the deployment of a hydrogen economy and the transition towards a carbon neutral industry in Europe.

## ENERGY FOR BUILDINGS & DISTRICTS

### A vital cornerstone of the energy system of the future

In the energy system of the future, conventional solutions for reducing the annual energy demand – such as thermal insulation – will obviously play an important role, but they won't suffice in and of themselves. An equally important cornerstone of our future energy system is the active control of various components and buildings itself, so as to dynamically adjust the energy demand to the local energy supply. That is why one of EnergyVille's main themes is the integrated design of buildings and districts, and why the various research projects we are proudly involved in, are manifold: the Horizon 2020 Smart2B Consortium, the Flux50 ICON project DITUR, the Flux50 feasibility study 'Connected Buildings', the Horizon 2020 project AmBIENCE, ... to name but a few.

### oPEN Lab: experimental environments for Positive Energy Neighbourhoods (PENs)

Flowing from our focus on integrated design of buildings and districts, 2021 saw EnergyVille / VITO step into the role of coordinator of the European Green Deal project oPEN Lab – a large-scale undertaking in which technologies, services and social innovations for the implementation of Positive Energy Neighbourhoods are tested and optimised in the setting of three living labs: one in Pamplona, Spain, one in Tartu, Finland and – last but not least – our very own Living Lab in Genk, Belgium. As such, EnergyVille is substantially contributing to making the transition to a climate-neutral infrastructure in urban environments as smooth as possible, as well as offering businesses a lasting testbed for the development of technologies and services – even long after the closing of the oPEN Lab project in the spring of 2026.





## ELECTRICAL NETWORKS

### From LVDC to HVDC DC-grids as the backbone of future energy grids

Both LVDC and HVDC grids will prove to be indispensable parts of the energy system of the future.

That is why, in 2021, we cooperated with Nexans and Imtech to further develop EnergyVille's LVDC lab with innovative cabling – including extensions to basements and outdoor installations – in preparation for the connection of a DC charging infrastructure for electric vehicles and large (outdoor) battery containers.

As for HVDC, our Energy Transition Fund-supported project NEPTUNE – a project coordinated by EnergyVille / KU Leuven – continued throughout 2021 by investigating the dimensioning of HVDC grids. More specifically, the NEPTUNE researchers analysed the interaction between the protection of HVDC networks, the necessary reserves and the reliability of the connected AC networks. They found that these three elements very much influence optimal network design, and – in particular – that for large HVDC networks, with several connections and a large capacity, more selective protection of HVDC networks is very advantageous.

## ENERGY STRATEGIES & MARKETS

### European energy and climate policy Finger on the pulse

In the course of 2021, EnergyVille / VITO further developed its quantitative models, and used them to analyse aspects of the European energy and climate policy and its instruments. In doing so, researchers paid special attention to different forms of support mechanisms for renewable energy, as well as to possible distortions caused by national policies within European cooperation mechanisms. Furthermore, an in-depth analysis of the European CO<sub>2</sub> emission trading system (EU ETS) was carried out in order to investigate the implications of the European Green Deal and the Fit for 55 climate package as proposed by the European Commission in July 2021.

Hence, our people keep on following the progress made by the EU in achieving its climate and energy targets, and provide important insights and knowledge to accelerate the transition to a climate-neutral society – just as we have been doing in previous years.

### Energy and flexibility markets In full swing

Here, in the course of 2021, EnergyVille prioritised delving into future flexibility needs of network operators. There was a specific focus on which products and services would have to be developed in order to sufficiently support congestion management and grid balancing, and on how flexibility markets would best be organised if these services are then to be delivered in a safe and economically efficient way. The analysis of different cooperation models between network operators was one of our central research themes.

Additionally, we researched both explicit flexibility mechanisms (markets) and implicit flexibility mechanisms. The former by developing market concepts and models to integrate several energy carriers and sectors. The latter by developing dynamic distribution grid tariffs to counterbalance peak loads and stimulate better demand and supply management.

Proper attention was given to the vital role played by the end consumer, as technical, economic and regulatory barriers that hinder the valorisation of flexibility were identified, and policy recommendations – on a regional, national and European level – were developed accordingly.







## THERMAL SYSTEMS

### Fifth generation district heating and cooling grids A proven but underutilised concept

Since 2018, the Interreg North-West Europe (NWE) project D2GRIDS – an acronym for “demand driven grids” – has been aiming to accelerate the rolling-out of a proven but so far underutilised concept: fifth generation district heating and cooling, also known as 5GDHC – a highly optimised, demand-driven, self-regulating energy management system for urban areas. The project’s objective is to maximise the share of renewable energy in the local energy loops through an industrialisation of the approach, a standardised technological model, and a clarification of the business model to strengthen the interest of these projects for third party investors. EnergyVille / VITO has been a key project partner in industrialising the 5GDHC concept, as well as in evaluating results booked. In 2021, the consortium’s main outcome was the elaboration on the definition of the five principles of 5GDHC and the conditions for 5GDHC, in which we provided substantial support with our technical expertise on district heating and cooling.

## WITHIN INDUSTRY: THE TRANSFER OF KNOWLEDGE & TECHNOLOGY

EnergyVille is continuously looking to cooperate and cocreate with companies. We do so, because we strongly believe in the added value of giving the industry a clear insight into the energy system of the future as early on as possible. This interplay benefits businesses by giving them the chance to integrate opportunities in their strategy, processes and organisation. Just as it benefits our organisation, and the impact we can have on society at large.

As such, 2021 saw the birth of the Hye consortium, in which EnergyVille partners imec and VITO joined forces with industrial pioneers Bekaert, Colruyt Group, DEME and John Cockerill. Other examples include our manifold cooperation with spearhead cluster Flux50, our framework agreements with ENGIE, Fluvius and Elia, and many more initiatives.



## WITHIN THE DIGITAL WORLD: SHAPING THE DIGITAL FUTURE OF ENERGY

The digitalisation pace of the energy sector is picking up, which is why EnergyVille is seamlessly integrating data into both its research and its day-to-day running.

EnergyVille's SmarThor data platform is a Microsoft Azure-based platform that allows for various external data – market data, sensor data, weather forecasts, etcetera – to be captured, stored, monitored and queried in a simple, standardised manner. Hand in hand

goes the Smart Charging Lab, which integrates the charging stations installed in the EnergyVille parking lot into the SmarThor cloud environment. The integration of a Model Predictive Control (MPC) framework allows for dynamic optimisation of charging sessions according to changed conditions and updated forecasts, ensuring a higher level of comfort for our employees who now no longer need to worry about the optimal charging times of their vehicles.



## WITHIN OUR POOL OF GREAT PEOPLE: AMBITIOUS BUILDERS MAKE BRIGHT IDEAS REAL

For us, investment in our "human capital" is non-negotiable. That is why we put a lot of effort into offering our people all the support they could possibly need. This ranges from overall career development, over initiatives to strengthen the international orientation of our young researchers, to – obviously – all sorts of training: daily on-the-job training, discipline-specific training, interdisciplinary training, cross-disciplinary training and specific STEM training in close cooperation with the T2-Campus through the "Train the Trainer" initiative.

Our efforts pay off. The quality of the work our EnergyVille researchers put out into the world, is clearly reflected in the prizes we have collected over the years, including the three 2021 additions to our collection: the Febeliec Energy Award for our AgriVoltaics project (EnergyVille / KU Leuven), the Sinave Award from the Royal Belgian Society for Electricians (KVBE) won by researcher Willem Leterme (EnergyVille / KU Leuven) for his doctoral research on HVDC cable grids, and the highly regarded 'Laureate in the Class of Technical Sciences' award from the Royal Flemish Academy of Belgium for Science and Art (KVAB) won by Professor Bart Vermang and his team (EnergyVille / UHasselt / imec) for their research into new materials for renewable energy applications.

## WITHIN COMMUNITIES: SUSTAINABLE GROWTH FOR ALL

Broad public support is essential, if we want to bring the energy transition to a successful conclusion for us all. And we believe EnergyVille has an important role to play in stimulating social acceptance of sustainable growth.

First of all, our active involvement in the European Green Deal project oPEN Lab is a prime example: it allows for a framework in which to stimulate public engagement through co-creation sessions with the community of local residents.

Furthermore, it also helps that the province of Limburg is being promoted as an innovative hotspot by bringing important international conferences our way. In October 2021, for example, the Energy Mission Conference took place in Genk, bringing together international decision-makers from the fields of business, policy and knowledge institutions.

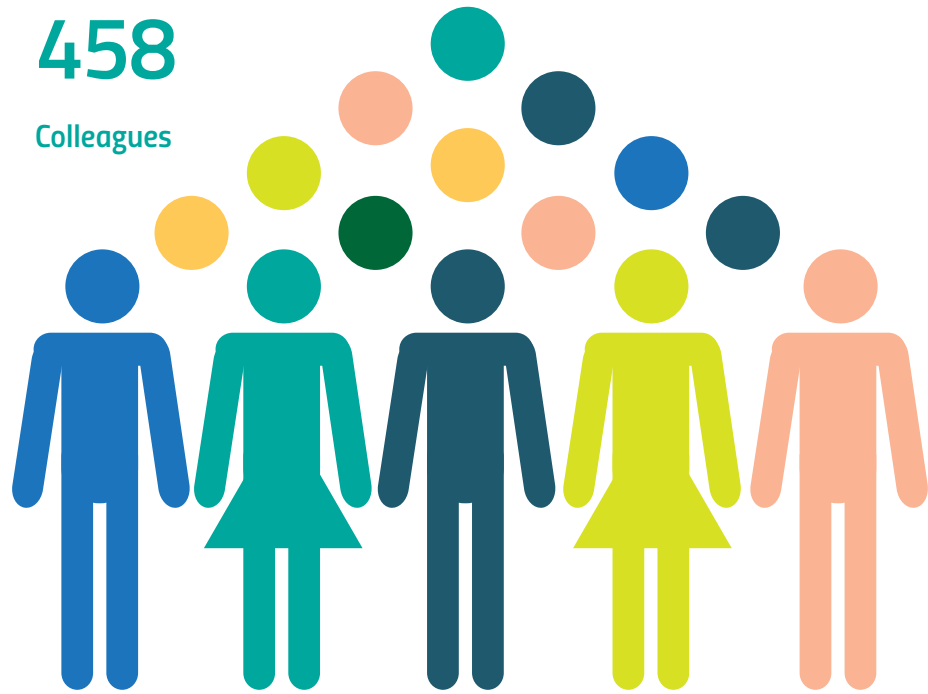
And we go further than that. We don't only share our acquired knowledge with businesses, policy makers and the academic world. We also make a point of interpreting it for the general public by placing great emphasis on science communication – both through national and international fairs and events, and through general outreach. Because we are convinced this broad sharing of our knowledge contributes substantially to the acceptance of technologies by society at large. And let that be indispensable to EnergyVille's goal of facilitating the energy transition that awaits us all.



# ENERGYVILLE IN NUMBERS

458

Colleagues



39

Companies active in our living lab



4

EU research projects granted to two or more EnergyVille partners



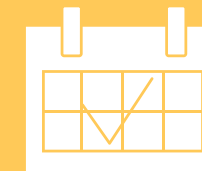
3

Awards



2

International events at Thor Park



22

Events and fairs



349

General outreach



252

Belgian colleagues



78

European colleagues



128

International colleagues



163

PhDs

69

Post-Docs



6

Patents



260

Scientific publications



44

Science Citation Index entries with two or more EnergyVille partners

# EPILOGUE BY GERRIT JAN SCHAEFFER: LOOKING FORWARD WITH A FORWARD-LOOKING APPROACH

As I already stated in the closing paragraph of my prologue, the direction in which EnergyVille is headed is clear, and we are adamant to keep on sailing a constant course – in spite of the rapidly changing world we live in.

Hence, here at EnergyVille, we will keep on looking forward with a forward-looking approach and, in the years that lie ahead of us, continue to dedicate our time and effort to the eight dimensions of our EnergyVille research landscape. Solar energy. Battery storage. Power electronics. Power-to-Molecules. Energy for buildings & districts. Electrical networks. Energy strategies & markets. Thermal systems.

These eight lines of research are crucial building blocks of the energy system of the future, and if they can be positioned correctly, the pieces of the puzzle will seamlessly fall into place. Of that we are convinced. So, we will further define roadmaps. Set up demonstrators – preferably with as many actors as possible. And upgrade our quadruple helix model for innovation to a quintuple helix model for even more innovation by bringing a fifth actor onto stage: the financial sector.

Companies, the academic world, governments, citizens and financial institutions. With those five actors we will cocreate and continue our journey, celebrating the fact that each of them represents a different core concept: value creation, innovation, policy / regulation, justice and risk management. The energy transition plays in each of these five fields, and it is an additional part of our task to see to it that the bigger picture makes sense – for everyone involved.

Because up until this day, EnergyVille has always focused firmly on technology development and policy input. And, obviously, that focus forms the fundament of the energy transition. But what if the best solution theoretically speaking, proves not to be the best option practically speaking?

It has often been said that we must get everyone on board, if we want to turn the energy transition into a success story. I personally prefer a different nuance: if we want to turn the energy transition into a success story, we first and foremost mustn't leave anyone behind!

And it is exactly that nuance that fuels our expanding vision. A vision in which we focus even more on an inclusive future for all by incorporating innovative initiatives, such as the oPEN Thor living lab – places in which real-life and real-time experiments go hand in hand with co-creation sessions and dialogues with the people living there.

*Not leaving anyone behind in a rapidly changing world, that – to me – is the essence of our work. Or to put it differently: a just transition, that is what EnergyVille stands for.*



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