EnergyVille

Shaping Sustainable Energy Research

Empowered by KU Leuven, VITO, imec & UHasselt

EnergyVille is a collaboration between the Belgian research partners KU Leuven, VITO, imec and UHasselt in the fields of **sustainable and intelligent energy systems**. EnergyVille develops technology and knowledge to support public and private stakeholders in the **transition to an energy efficient, decarbonised and sustainable urban environment.**

The unique complementarity of the research partners allows us to integrate **the energy system value chain in its entirety**, ranging from materials and components to the level of entire energy systems, business models and strategies. Our activities are clustered in **six interdisciplinary domains**: photovoltaics, electrical and thermal storage, power control and conversion, electrical and thermal networks, buildings and districts, strategies and markets.

With approximately **400 researchers** and state-of-the-art research facilities, EnergyVille is a top European innovation hub in the energy field. It bundles research, development and training under one roof and collaborates closely with local, regional, national and international partners from industry as well as public authorities.

Buildings and districts

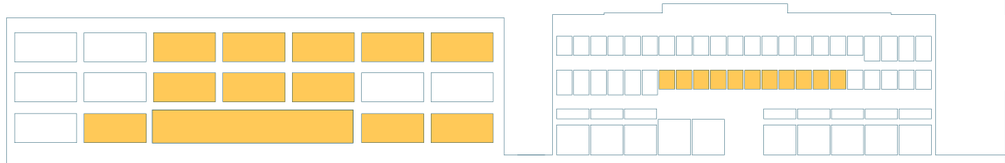
Networks

Power control and conversion

Storage

Solar

Strategies and markets



22 labs

406 Coworkers

165 Doctoral students

42 Countries

Key Figures 2019

Awards **3**

Patents **7**

Expert talks **11**

Press **310**

Events **48**

Publications **297**

Eco-system Thor Park

EnergyVille committees:

Industrial advisory committee (IAC)

Policy advisory committee (PAC)

Operational steering committee

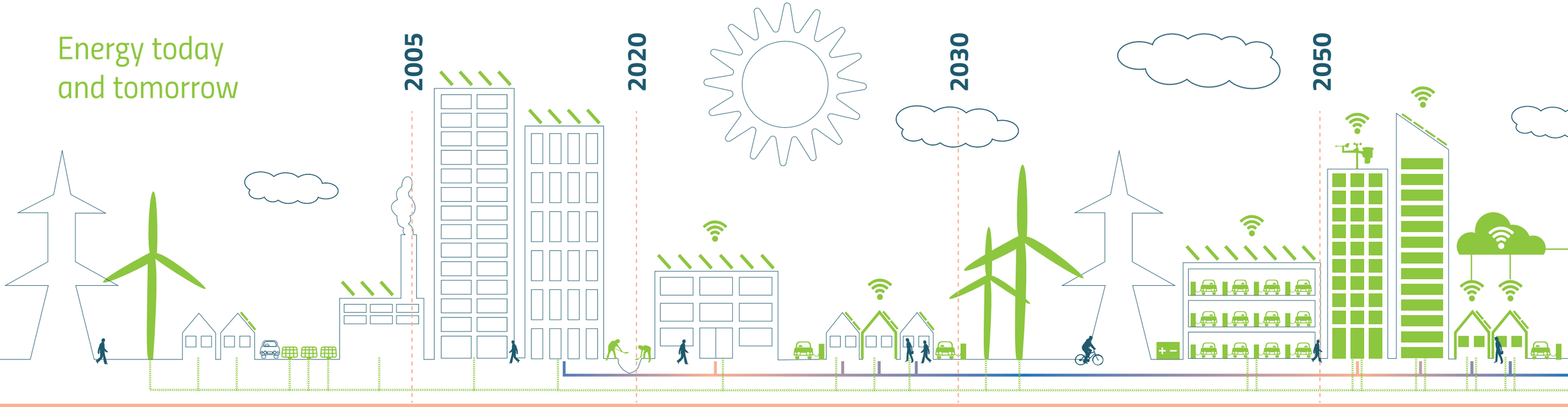
Strategic steering committee

2538 ▶ 3065

996 ▶ 1155

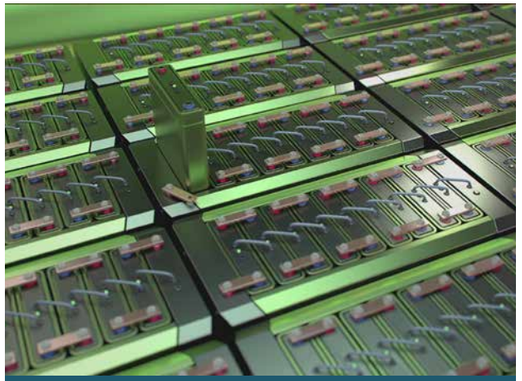
1993 ▶ 3226

Energy today and tomorrow

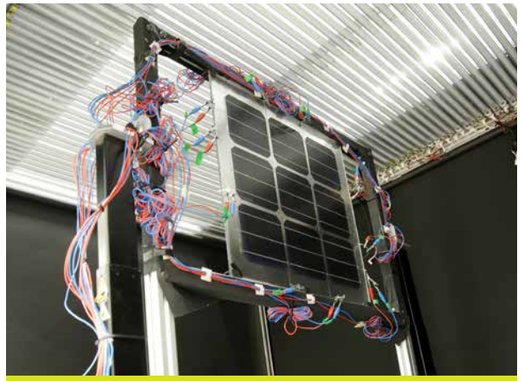


	2005	2020	2030	2050
Greenhouse gas emissions compared to 1990	**5500 million tons CO_2 equivalent**	**-20%**	**>-40%** **-50%-55%**	**>-80%** **-100%**
Renewable energy compared to gross final consumption	**9%**	**20%**	**32%**	**>55%**
Energy efficiency compared to baseline scenario	**Primary energy 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

Research highlights



New battery materials
& technologies



Improving
solar technologies

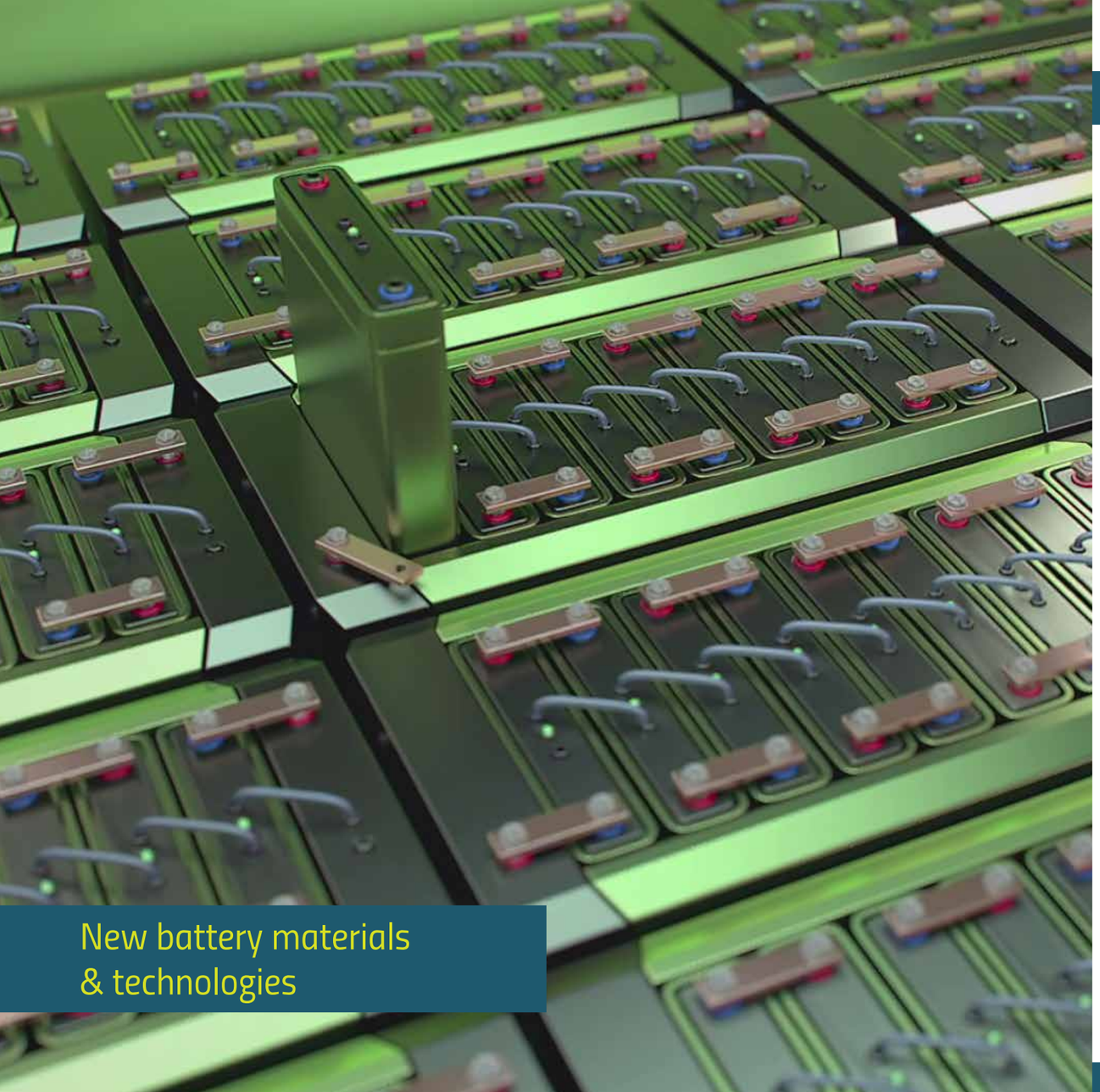
The comeback
of direct current

Digitalisation
of thermal networks

Sustainability
in the built environment

Adding flexibility
to the power system

Developing roadmaps
for the energy transition



New battery materials & technologies

Electrical storage:
game changer in the energy transition

Electrical storage has a key role to play in the energy transition. Not only to bridge the period between generation and consumption of renewable electric energy, but also to improve electricity transmission, extensive research is being carried out for better, safer and more efficient battery technologies. The following battery technologies are being investigated at EnergyVille.

New battery cell structures developed at EnergyVille

Conventional liquid lithium-ion batteries

Liquid Li-ion batteries have been around for quite some time. Though their theoretical performance might be an obstacle in electric vehicles, they have proved themselves in phones, laptops, home batteries, etc.

Advantages:

- High energy density
- Long cycle life (1000-10000 cycles)
- High round-trip efficiency

Drawbacks:

- Safety (thermal runaway)
- Battery Management System (BMS) is required
- Energy density has reached its theoretical limit

Solid-state lithium-ion batteries

To obtain greater autonomy, a shift is underway from liquid Li-ion to solid-state Li-ion batteries. Developments in solid-state batteries will enable electric cars to achieve a driving range that matches and eventually surpasses vehicles with an internal combustion engine. Battery cell roadmaps foresee that cells of 1000Wh/l will be available in 2030.

Solid-state Li-ion batteries?

- Higher density (enabling a trip from Belgium to the South of France without charging)
- Faster charging: **400 Wh/l at a charge rate of 0.5C has been achieved at EnergyVille**
- Safer than liquid Li-ion batteries

Lithium-sulphur batteries

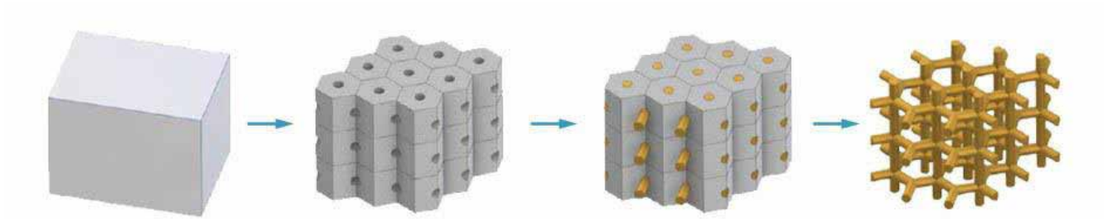
In addition to lithium-ion batteries, EnergyVille is also researching lithium-sulphur batteries, which have greater inherent sustainability. Sulphur is the third most common raw material on earth and is often considered waste, making it inexpensive. Due to their low weight, lithium-sulphur batteries have the potential to store 5 times more energy per unit weight than current lithium-ion batteries. First, obstacles such as lifespan and the number of charging cycles have to be cleared. Initial applications are expected in drones and mobile electronics.

Sodium-ion batteries

Sodium is chemically similar to lithium, but is much more abundant. This potentially makes sodium-ion batteries more sustainable and inexpensive than lithium-ion batteries. Sodium-ion batteries are suitable for stationary storage applications such as home batteries. The further potential of these battery technologies is being investigated at EnergyVille.

Nanomesh

A novel nanomesh material has been developed at EnergyVille that may result in a breakthrough in a variety of sustainable applications. The new nanomesh material is a three-dimensional nanometer-scale (metal) grid structure with highly regular internal dimensions. Thanks to its unique material properties combined with its ease of manufacturing, its wide use is expected in sustainable industrial applications such as more efficient batteries.



Improving battery technologies

In addition to new materials and technologies for batteries, we are also looking for solutions to optimise existing battery technologies. The ultimate aim is to extend their range, lifetime and performance, and increase the charge rate without sacrificing safety. Thus extensive research is being conducted into optimal utilisation schemes for all sorts of batteries. Optimal battery use results in a longer lifespan and a higher return on investment.

An example of this is BattSense technology. This battery management system not only continuously monitors the individual cells within the battery, but also manages the system in such a way that its intrinsic capacity is maximised and its lifespan extended.

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Projects to keep an eye on

SOLiDIFY

Circusol

NAVAIS

NAIMA

COBRA

TEESMAT

SPIDER

EVERLASTING

XL-LION

Improving solar technologies

The Terawatt era: better, more aesthetic and custom-made solar panels

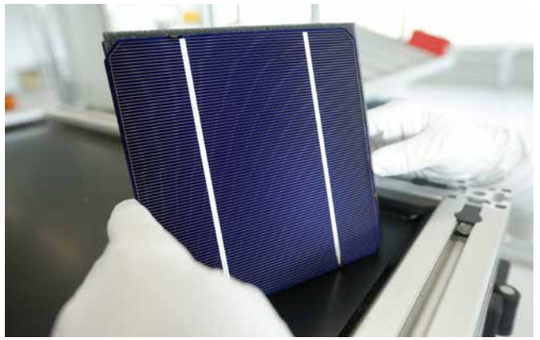
Over the years, solar power has proven its value in the energy transition. Solar technology has rapidly improved, prices have dropped and module efficiency has increased tremendously. To reach the long awaited terawatt era (surpassing the 1 terawatt/hour solar energy threshold), the focus is being placed on improving existing technologies, increasing their flexibility and making them more efficient, more aesthetic and adaptable in size and colour, while, at the same time ensuring the greatest level of sustainability, from cradle to grave.

Greater efficiency due to improved hardware

Bifacial crystalline silicon PV modules

To harvest as much energy as possible, EnergyVille is looking into bifacial crystalline silicon PV modules. Bifacial modules accept light from both sides, making possible their combination with a transparent or reflecting backside of a PV panel. EnergyVille takes these highly efficient bifacial cells as a starting point and combines them with optimised cell metallisation techniques and multi-wire interconnection technologies. This has resulted in a **record-setting efficiency of 23.2%** using bifacial n-pert solar cells.

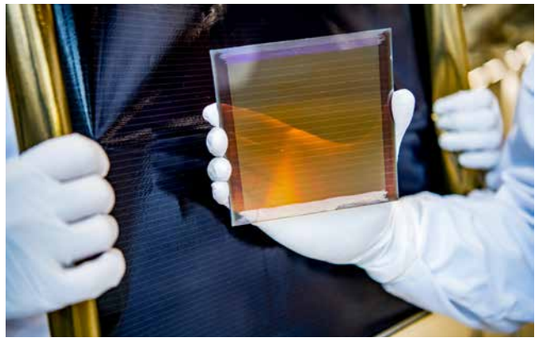
Passivated contacts are the next step in optimising bifacial silicon PV. The first cells are expected in the spring of 2020.

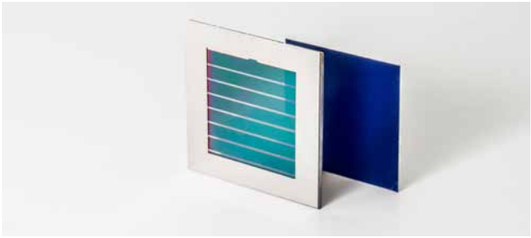


Thin film PV modules

In addition to crystalline silicon solar cells and modules, EnergyVille is also focusing on developing thin film PV cells and modules of inorganic-organic perovskite materials, making it possible to create solar cells with a thickness of **less than 1 micron** (1/100 the diameter of a human hair).

Due to their thinness, these solar cells can be semi-transparent, flexible and adaptable in colour, making them ideal for custom-made panels for surfaces such as windows, cars, building elements, etc.





Tandem cells

Tandem cells combine conventional silicon cells with perovskite (thin film) cells. Together they can improve energy yield, with a **theoretical limit of 40%**.

This technology has already been scaled up from lab level to 30 x 30 cm modules. EnergyVille is the only research centre in Europe able to make tandem modules up to this size.

Increasing PV solar panel sustainability

As we move towards the "terawatt era", EnergyVille is also investigating methods to repair, reuse and recycle PV modules. As the use of PV in electricity production increases, resource efficiency is becoming an increasingly critical factor for the long-term success of the sectors. The circular economy and renewable, clean energy must go hand in hand if we are to be able to safeguard a truly sustainable transition to a carbon-neutral future.

Prediction is key

As the share of PV in the energy system continues to grow, accurately predicting the energy yield of solar cells and modules becomes ever more important. To support PV power plant operators, for example, EnergyVille has developed a **bifacial PV systems simulation framework** that can accurately calculate the energy yield of bifacial PV systems. The new simulation framework guarantees high precision. It not only computes the energy yield of the individual cells and modules based on local and varying meteorological conditions, but also takes into account double-sided illumination and the way this is influenced by module frames, system component geometry, and varying the albedo. A first commercial model will appear on the market in 2020.

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Projects to keep an eye on

POSITIF

TWILL-BIPV

BREGILAB

Lasergraph

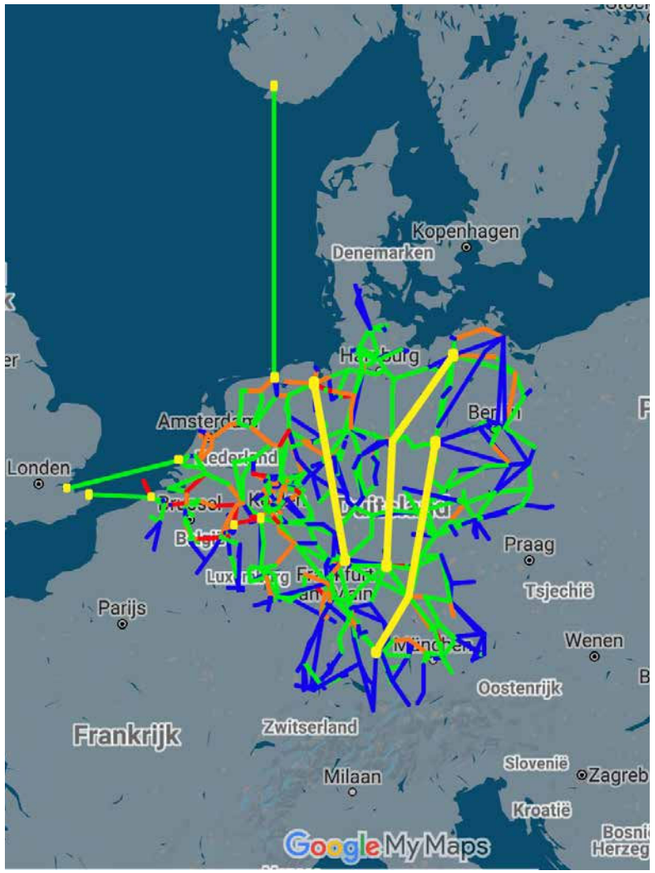
PROCEED

CUSTOM-ART

The comeback of direct current (DC)

Direct current for the power grid of the future

The return of direct current is a key characteristic of the energy transition. Direct current offers a cost-effective, efficient and flexible alternative to standard AC power systems. EnergyVille's research is extensively examining both high and low voltage DC grids, making EnergyVille a key reference in the development of new technologies for the power grid of the future.



The shift to high voltage DC grids

Most of the power grid runs on alternating current (AC) systems. High-voltage direct-current (HVDC) links have proven to be a more cost-effective and flexible means of bulk energy transport. Thus they are a key enabler of the 100% renewables-based power system of future, and essential to realising a sustainable, secure and affordable energy system.

Our focus at EnergyVille is on developing the models and tools to implement an HVDC-based power system, in particular with applications in the area of grid development and operations, the protection of DC grids, and controlling interactions between different converters.

Decision support for grid operators

To support network operators in optimising the operation and planning of transmission and distribution systems, we offer calculation methods and tools to make proactive decisions and enable optimum integration of all service providers in the market. These calculation methods can for instance be used to examine how a higher share of renewable energy can be integrated into the electricity network. The calculations are performed for both local integration and at international level. Our tools make use of detailed models and employ new mathematical techniques to aid the grid operator. Thus we are examining the development of the pan-European power system based on the massive integration of renewables, which depends heavily on the transmission of electricity between different countries. Our tools allow the study of future investment options, including taking into account the flexibility inherent in all types of technology (AC and DC, overhead and underground) in order to provide grid operators with the information they need to make informed investment decisions.

Low voltage DC Grids

DC technology has clear technical advantages in a world dominated by local energy storage systems, batteries, electric vehicles, LED lighting, photovoltaic modules, digital equipment and energy efficient HVAC systems. Introducing DC technology will increase conversion efficiency and power transfer capability while at the same time reducing investment and operational costs.

At EnergyVille we are focusing on bipolar DC nanogrids. These are small-scale distribution networks that can be used in a broad spectrum of applications, such as data centres, mobile applications and commercial buildings. In addition, DC solar home kits can typically be rolled out in regions with no or limited access to the electricity grid. Recently a representative building-level bipolar DC nanogrid was set up in one of the EnergyVille labs in order to further investigate and test this technology.

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Projects to keep an eye on

ICON BIDC

MultiDC

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Neptune

Digitalisation of thermal networks

Accelerating the development of sustainable heat

Heating and cooling in buildings and industry account for a huge part of the EU's energy use. To reach the climate targets, thermal grids, thermal energy storage and optimisation of building installations will have a major role to play in increasing energy efficiency and the share of renewable and residual energy in the urban environment.

Digitalisation for more efficient 4th generation thermal networks

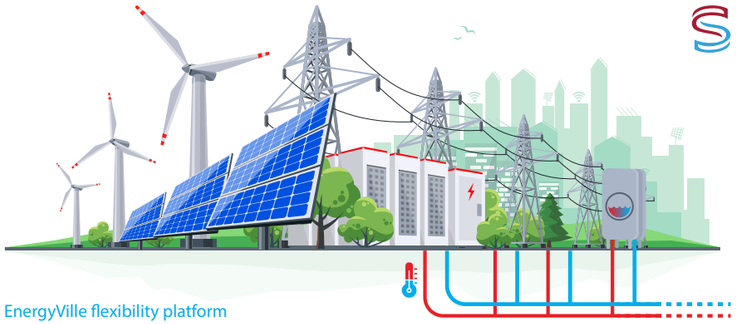
Why 4th generation thermal networks?

A sustainable future energy system requires thermal networks. In contrast to centrally controlled heating installations, 4th generation thermal networks provide heating or cooling for low-energy buildings using low-temperature heat sources. Residual heat from industrial processes or from geothermal sources can be perfectly integrated into the network, resulting in less heat loss, greater efficiency, and a greater share of renewable and residual energy sources.

The role of digitalisation:

To ensure that the comfort needs and energy demand of the consumer are guaranteed at all times, flexibility is needed to deal with uncontrollable or fluctuating heat and cold generation. This flexibility is available in the thermal capacity present in buildings and the networks themselves. Digitalisation can help unlock this potential. The commercially available **STORM District Energy Controller**, for example, optimises the heat demand of buildings or neighbourhoods in function of supply. In order to increase the share of renewable energy sources or residual heat, the use of waste heat and renewable energy sources is maximised by self-learning or model-based algorithms. This not only reduces peak demand, but also ensures comfort and lower costs.

In addition to optimal control, algorithms can also rapidly identify faults, flaws or heat losses in thermal networks. Adding intelligence to substations and/or network controllers allows easy and remote detection of inefficiencies in the system, thereby reducing maintenance and operating costs for service companies as well as network operators. These algorithms for network and building analytics are being developed in the **TEMPO** project.



EnergyVille flexibility platform

Optimal design concepts and routing

Each thermal network design depends on the context it is operating in. In order to obtain thermal network designs with reduced investment and operating costs and increased energy efficiency, optimisation strategies for the routing and network connections in specific geographical locations are indispensable. In the D2Grids project, different thermal network are being designed for five partner pilot sites (Paris-Saclay (FR), Bochum (DE), Brunssum (NL), Glasgow and Nottingham (UK)). For each individual location, optimal characteristics are determined. The thermal networks are based on 5th Generation District Heating and Cooling (5GDHC) technology that make use of ultra-low temperatures.

Thermal storage

EnergyVille is also focusing on thermal energy storage technologies. With thermal storage, heat or cold surpluses are stored to be used later when necessary. This solves the problem of the daily imbalance between the heat demand at household level and the supply of heat from renewable or residual sources. The MATChING project for example is investigating whether Organic Rankine Cycles (ORCs) could be cooled using groundwater from a shallow underground aquifer. Using a specific aquifer means we have a supply of cooling water with a consistent temperature of 11° C, in both summer and winter. Simulation results from the MATChING project indicate that this makes higher ORC output possible. Cooling with groundwater in the summer generates 3-14% more electricity than with air cooling.

Building optimisation: Model Predictive Control (MPC)

Alongside district heating, optimisation at building level also presents interesting optimisation opportunities. Model Predictive Control (MPC) – which uses a mathematical model of a building to optimally coordinate cooling, heating and ventilation – makes it possible to use sustainable heat and cold in buildings as efficiently as possible while improving user comfort. Even weather forecasts and user behaviour can be taken into account to define optimal heating and cooling profiles. Results in energy savings of 20 to 30% are expected, although the final figure depends on the specific building under control. Thanks to generic models, the algorithms are applicable to a broad range of building types. In the context of the H2020 hybridGEOTABS project, demonstration studies are running in the Fluvius and Boydens engineering office building in Dilbeek, the Ter Potterie elderly home in Bruges and the Solarwind office building in Luxembourg. More buildings are likely to follow in the near future.

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Johan Desmedt


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Projects to keep an eye on

hybrid GEOTABS

Interreg North-West Europe D2Grids

STORM District Energy Controller

heatstore

MATChING

TEMPO

Sustainability in the built environment

More sustainable buildings and districts

The built environment is transitioning to a more sustainable future with major environmental, financial and social changes. EnergyVille is developing solutions to optimise the energy performance and environmental impact of buildings and districts: from their design and construction up to and including their operation. The research priorities lie in two areas: the development of next generation construction materials and energy technologies, and decision support algorithms for optimal building and district planning and design.

Next generation energy technologies for buildings: 2019 as a key year with upcoming legislation in the European battery industry

Since batteries are an essential technology in the energy transition, working with industry to regulate and reduce their environmental impact is key. To this end, EnergyVille is involved in various studies in which the sustainability of batteries is assessed by means of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC).

EnergyVille coordinated two studies on the Ecodesign and Energy Labelling of Batteries for the European Commission. The preparatory study laid the foundation for EU-wide rules and minimum mandatory requirements for the energy and environmental performance of batteries. In this study, the Methodology for Ecodesign and Energy-related Products (MEErP) was used to analyse Li-ion battery applications including electric vehicles and energy storage systems. The follow-up study used the Product Environmental Footprint Category Rules (PEFCR), a method developed by the European Commission, for battery types such as sodium ion and sodium nickel chloride.

One of the main findings of the preparatory study was that for Li-ion batteries, cathode active material production had the largest environmental impact among all impact categories from cradle to grave. Another aspect observed was the higher Levelised Cost of Energy (LCOE), a measure of the lifetime costs per lifetime energy production, in battery operated passenger cars versus battery operated trucks. The follow-up studies demonstrated the use of the PEFCR and provided guidance on the challenges and opportunities for its wider application to new and emerging battery types.

Building and district energy performance simulation platform expanded and put to the test in multiple case studies

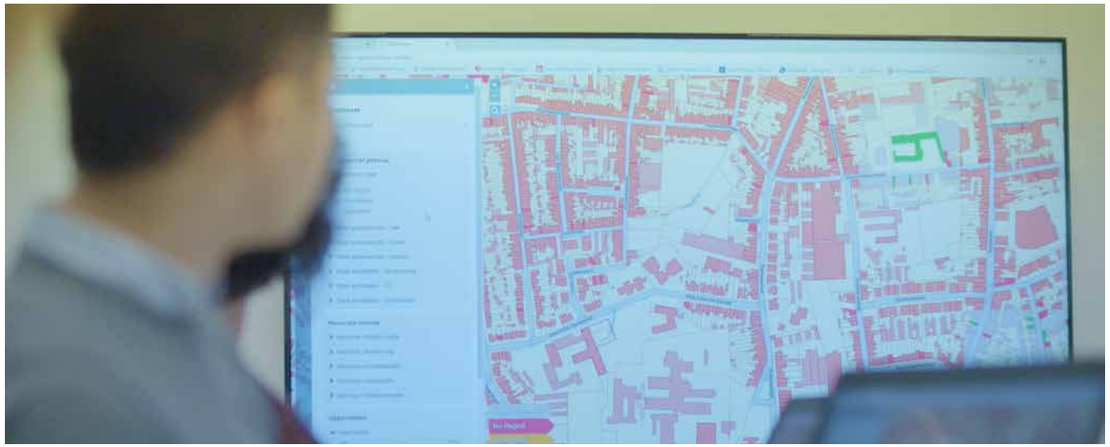
Flexible simulation platform for building and district energy performance assessment

EnergyVille developed a comprehensive simulation platform for building and district energy performance assessment, consisting of multiple toolchains, algorithms and unique data sources. This platform covers multiple scales (ranging from individual technical building systems, through buildings and districts, to connection with the wider energy grids) and multiple performance indicators (energy, comfort, economic and ecological). Due to its modular nature, the simulation platform can be flexibly adapted to the needs of specific clients and applications. One of the key repositories within the simulation platform is a data pool bringing together the available data on buildings in Flanders, including spatial layout, individual building geometry, energy consumption profiles, renewable energy sources and building characteristics.

Urban Energy Pathfinder: tool for private and public decision makers

The Urban Energy Pathfinder is a modular toolkit for district and city energy planning. This toolkit is being developed in close interaction with companies involved in planning, design and construction, and with cities and municipalities in order to tailor the application to their needs and ensure the user-interface presents the most relevant findings in a clear and easy to understand way.

The purpose is to support decision makers such as project developers, contractors, engineering firms and local policy makers in optimal building and district energy planning. The Urban Energy Pathfinder assesses the feasibility of technical interventions (e.g. district heating networks versus building envelope upgrades) and explores their costs and benefits, for new designs as well as district reconversions. Powerful data gathering and data enrichment algorithms automate the process and ensure detailed insights.



Two case studies examining Limburg and Antwerp districts as well as other typical Flemish neighbourhoods

In 2019, the insights of five years of research on urban energy transitions were integrated in our report "The trade-off between urban building stock retrofit, local renewable energy production and the roll-out of fourth generation district heating networks". This comprehensive study, whose sole focus is the Flemish context, analysed nine representative neighbourhoods. The study showed the importance of taking into account the local context when deciding on pathways to energy transition. The layout of the district, the available heat sources and specific heat demand affect the feasibility of district heating grids and the optimal interventions needed to reduce the carbon emissions of a district.

Another analysis case study collaborated with local actors to examine district heating distribution for the Wilrijk and South Antwerp districts.

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Projects to keep an eye on

Interreg North Sea Region ACCESS

EPOC

SPIDER

circusol

NAIMA

Adding flexibility to the power system

Flexibility as a major driver of the energy transition

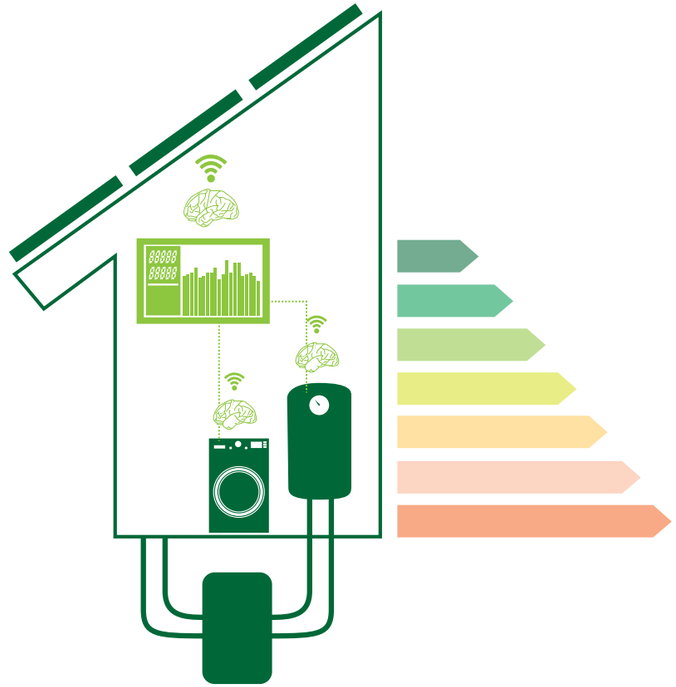
We are currently undergoing an energy transition that is drastically changing how we produce and consume energy. Our electricity grid, for example, has been designed for traditional top-down distribution, with the electricity being generated in large power plants and transported to the end consumer. Thanks to the rise of PV panels, wind turbines and smaller CHPs, end consumers are able to generate their own electricity and inject it into the grid. Similarly, thermal grids have found their way into the energy system to provide sustainable heating and cooling in buildings. For both electric and thermal energy, demand and generation need to be balanced at all times. To improve grid operations and make maximum use of the available sustainable energy sources, flexibility is key at all levels of the power system.

Flexibility at building level

To drastically decrease the climate impact of buildings, efforts on smarter consumption are as important as efforts in reducing consumption.

Renewable sources bring the consumer ever closer to the centre of the electricity system. Thus for example, a prosumer who owns solar panels should be the first to make optimal use of the available self-generated electricity. Similarly, optimising thermal energy consumption at building level (e.g. by means of Model Predictive Control) makes considerable energy savings possible. Making optimal use of locally produced electricity and optimising the consumption of thermal energy are the cheapest and easiest ways to decarbonise our electricity system.

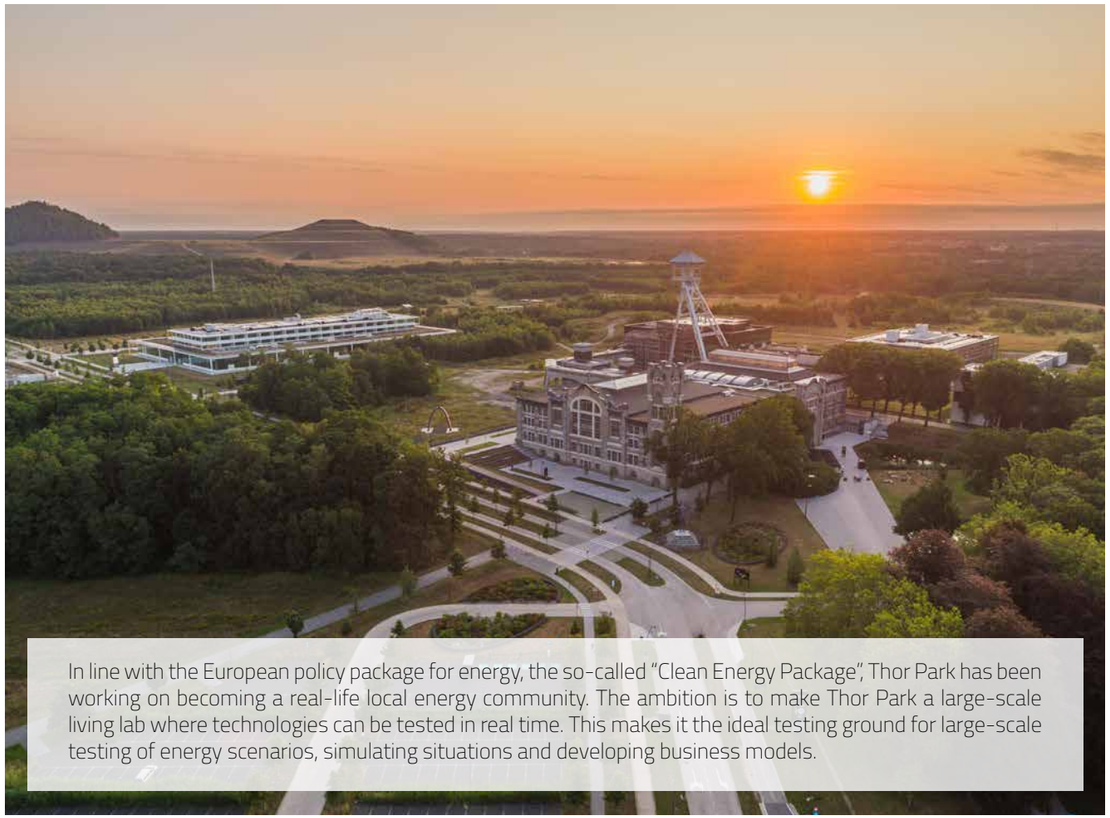
EnergyVille is developing various solutions for smart building control to optimally shift and modulate flexible energy consumption without loss of comfort.



Flexibility in local energy communities

To make optimal use of the available energy, local generation, distribution and consumption are key. Alongside consumption of self-generated energy by the end consumer, local energy communities play a pivotal role in reaching climate targets. In local energy communities, optimisation is done not only at building level, but also at community, district and even city level. Thanks to local coordination, surpluses of both thermal and electric energy at one consumer can be effectively used by another, thereby optimising supply and demand at community level.

Flex trading, where building level consumption plans and flexibility information are automatically and pro-actively shared to make better informed decisions, is the next logical step at system level after demand response.



In line with the European policy package for energy, the so-called "Clean Energy Package", Thor Park has been working on becoming a real-life local energy community. The ambition is to make Thor Park a large-scale living lab where technologies can be tested in real time. This makes it the ideal testing ground for large-scale testing of energy scenarios, simulating situations and developing business models.

Flexibility as a commodity

Evolutions in ICT, e.g. internet of things (IoT), the cloud, artificial intelligence, machine learning and the rise of the connected citizen, are creating new opportunities. Simultaneously they are redefining the role of aggregators in the energy system. Where the traditional energy system was designed top-down, prosumers now take centre stage, requiring new services and market models. IoT makes energy-as-a-service solutions possible in a multi-energy system. In a multi-energy system, different energy vectors (such as electricity, gas, heat, cold,...) interact. Energy-as-a-service makes it possible to automatically find the most sustainable energy source according to availability, demand and costs.

Data have an important role to play in the energy system of the future. The interoperability and privacy of these data will play a pivotal role in the market uptake of new service models. Both are also being investigated at EnergyVille.

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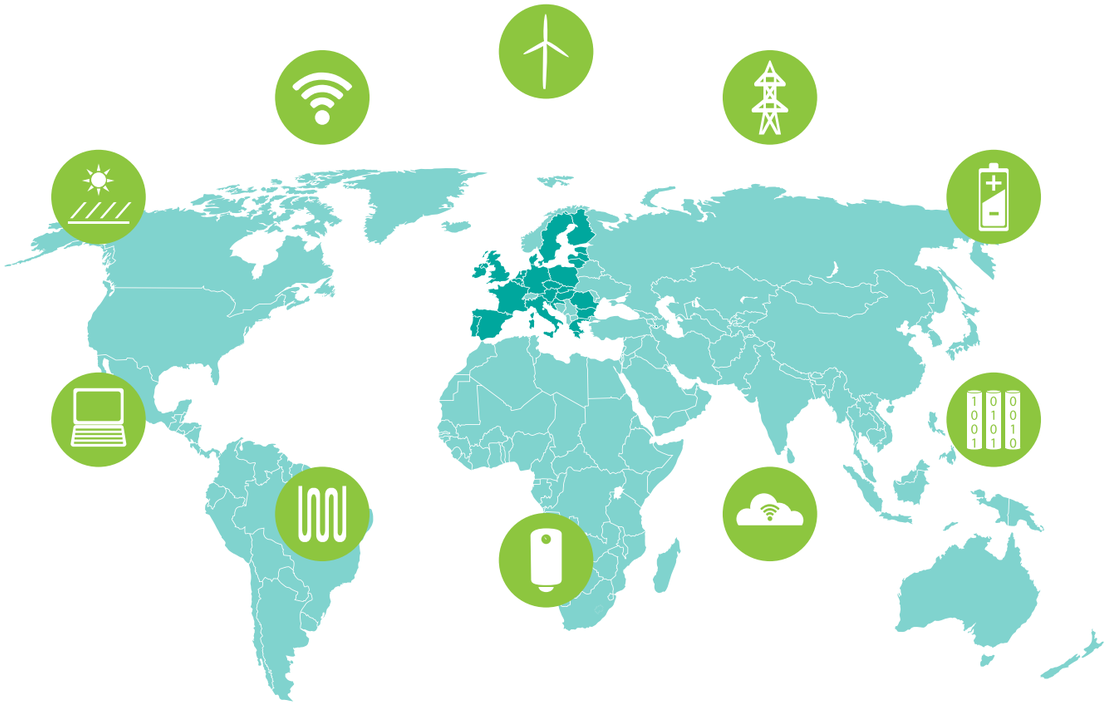
Projects to keep an eye on

ambience · interconnect · ROLECS · EXCESS · PrivateFlex · fhp · snippet · RES4BUILD · Magnitude · coordiNET

Developing roadmaps for the energy transition

Drafting pathways to a decarbonised energy system and economy

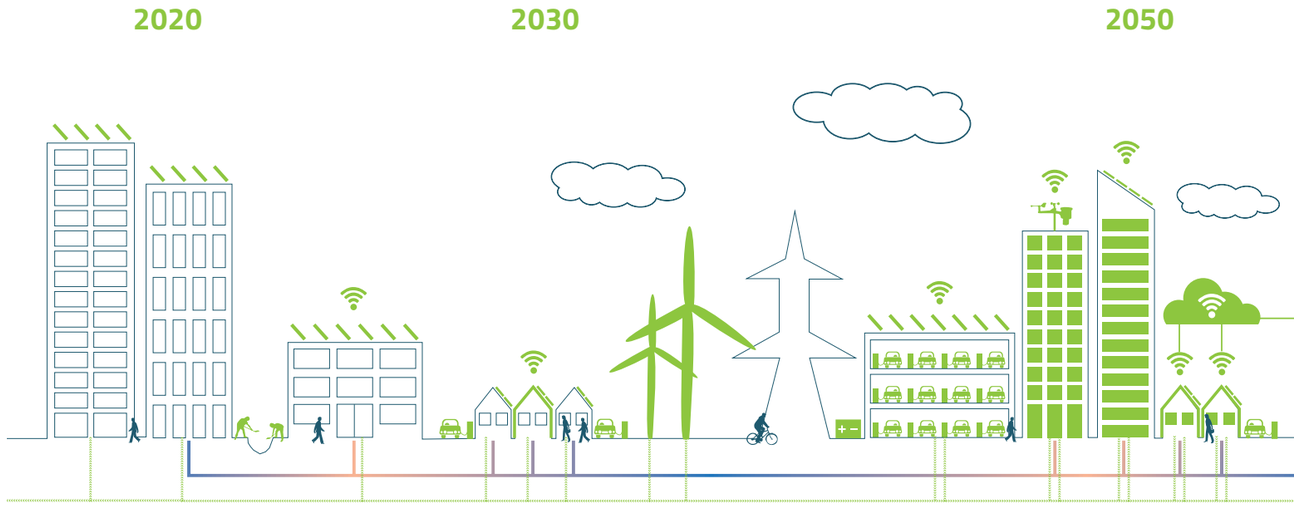
2019 saw a new sense of urgency in the political and public debate on drafting realistic pathways to a decarbonised energy system and economy in Belgium and in Europe. Regarding this process, the newly installed European Commission (EC) is sending clear signals concerning increasing the ambitions, especially regarding 2030, making the Green Deal one of the guiding objectives of the EC in the coming years. EnergyVille's researchers are supporting this process on multiple levels with data analysis, policy evaluation and model applications.



Our policy team is leading the European expert network on climate change mitigation and energy for the European Environment Agency in Copenhagen. This entails gathering and analysing data on greenhouse gas emissions, renewable energy and energy efficiency in support of the implementation of policies resulting in a more sustainable continent. This expertise at EnergyVille is also being called upon by the EC in the on-going review of the National Energy and Climate Plans (NECPs), in which each Member State formulates detailed steps towards the 2030 energy and climate targets, making the NECPs the central policy tool in the coming years.

At the same time, our modelling teams support policy makers, companies and other stakeholders by calculating scenarios to better understand the impact of specific pathways to be taken. The ambitious policy targets set the stage for in-depth modelling studies on how our current energy system can cope with high penetration levels of distributed renewable energy sources at local level. We aim to provide insights concerning which pathways are the most sustainable: environmentally as well as economically. At the other end of the spectrum heavy industries are facing investment decisions that will radically transform their respective sectors. Recently started research projects will analyse the impact of intense electrification of industrial processes and the role of molecules in new and decarbonised industries. These insights will support the fact-based formulation of roadmaps for the transformational challenges ahead.

A much more integrated perspective is needed in order to render our energy system sustainable, across sectors and country borders. Member States can no longer limit their view to individual policies and administrative borders, but will have to work together in order to identify common opportunities and implementation strategies. Cooperation with neighbouring countries is essential, especially for Belgium, a country with heavy industrial clusters and a limited spatial potential for renewable energy sources. EnergyVille has well established relationships with research institutes from neighbouring countries and is actively pursuing collaboration projects to identify win-win situations in the energy transition, ranging from shared electricity generation resources to common future infrastructure needs.



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Projects to keep an eye on

BREGILAB

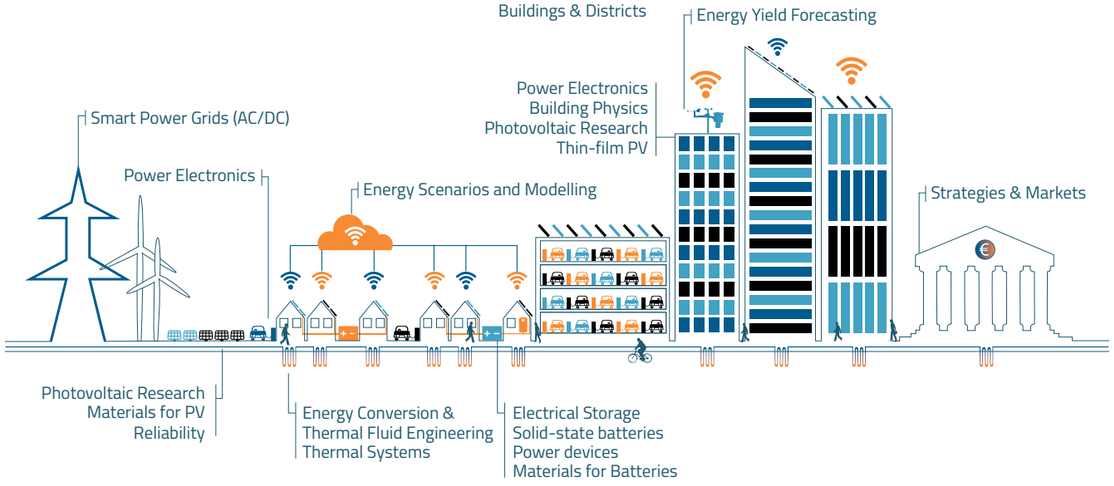
PROCURA

ETC/CME

Join us in the journey to a zero-carbon energy system

In conclusion, many new technologies are being developed that will find their way into the market in the coming years. A continuous series of small and large changes will mark the road to the energy system of 2030, 2050 and beyond. Thus, the transition will continue, bringing with it interesting social, economic and technological opportunities. As researchers, we are very excited to be tackling the challenges we will face in the coming years.

We invite all interested parties – companies, governments and organisations, in Belgium and abroad – to work together on the sustainable energy system of the future. Feel free to contact us and learn more about the opportunities the energy transition has in store for you!



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