Amsterdam University of Applied Sciences

INAUGURAL LECTURE

Positive energy in the city: innovation for a sustainable transition

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Creating Tomorrow

Positive energy in the city:
innovation for a sustainable transition

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Introduction

Summer 2021: A storm front lingers for days over the Ardennes-Eifel, causing severe flooding. In the Netherlands, the Meuse manages to handle the water reasonably well. The Geul overflows, causing major damage in the centre of Valkenburg. In Belgium and Germany, there are hundreds of victims. This is the extreme weather we will see more often (KNMI, 2021). Climate change is no longer something far off. It's already in the neighbourhood, and you know people there, or maybe you even have relatives living there.

The great urgency associated with the energy transition has to do with its role in limiting climate change. The latest report by the Intergovernmental Panel on Climate Change (IPCC) was very clear in its repeated message that human activity is causing global warming. To combat climate change, the United Nations (UN), the European Commission (EC), and the Dutch government have set various targets for the reduction of greenhouse gas emissions. We are not on track to achieve these goals. We have until 2030 to turn things around. So we must act quickly. We are living through two major crises: the climate emergency and the COVID-19 pandemic. At the start of the pandemic in March 2020, due to widespread lockdowns, it seemed that we could continue using less energy and that we would no longer be as mobile as we had been. However, the pandemic did not result in a permanent reduction in greenhouse gas emissions (IEA, 2021a). What this can teach us will become apparent in the years to come.

In this lecture, I will explain the contributions that the Energy and Innovation Group at the Amsterdam University of Applied Sciences (AUAS) is making to the energy transition. This research group is part of the Centre of Applied Research Technology in the Faculty of Technology, and it is affiliated with the Centre of Expertise on Urban Technology. This story is about positive energy districts as a metaphor for an innovative integral approach to the energy transition in cities. The aim is to set the bar high and speed things up.

In Section 1, I explain the role of the energy transition in relation to the climate crisis. In Section 2, I indicate what the solution space is, both in technical terms and in terms of the approach required. I will then zoom in on the urban context in which the AUAS operates, and for which the approach of the European Union

(EU) to positive energy districts is important. In Sections 3 and 4, I set out my vision on the role of innovation and practice-based research, and indicate the specific contributions the research group is making to the energy transition. I will discuss research and education, and our intended impact at a practical level. In this story, I will give examples from our research projects to illustrate my points.[1]

1 Climate change

> *"We share one atmosphere, one climate system. It knows no borders. The true measure of effectiveness of our collective efforts will be the state of its condition. And science will attest to that."* Keynote address by IPCC Chair Hoesung Lee at the ceremonial opening of COP26 Glasgow, 31 October 2021 (Lee, 2021)

The latest report from the IPCC (IPCC, 2021) was very clear:
- It is an incontrovertible fact that human activity is warming up the earth and the climate has already changed in all regions of the world as a result.
- The global surface temperature will continue to rise until the middle of the 21st century under all emission scenarios.
- The temperature increase will be greater than 1.5°C to 2°C in the 21st century if there is no substantial reduction in greenhouse gas emissions in the coming decades.
- In order to limit the rise in global temperatures, CO_2 emissions must be reduced to at least net zero,[2] and other greenhouse gas emissions must also be significantly reduced.

In order to stay below a 1.5°C rise in temperature, the "safe" limit, there is an amount of CO_2 that we can still emit in the coming years. This is the so-called CO_2 budget (Blok & Nieuwlaar, 2020). This is now about 400 gigatonnes (Gt) of CO_2.[3] In 2019, about 43 Gt of CO_2 were emitted meaning that we have 9 more years before we go through the budget (IPCC, 2021). So action is needed quickly. In other words, *the critical decade* lies ahead (Figueres & Rivett-Carnac, 2020, p. 1).

1 A complete list of projects can be found at the back.
2 Net zero means that CO_2 emissions and CO_2 capture are in balance.
3 This is the budget for 1.5°C with a probability of 67% (IPCC, 2021).

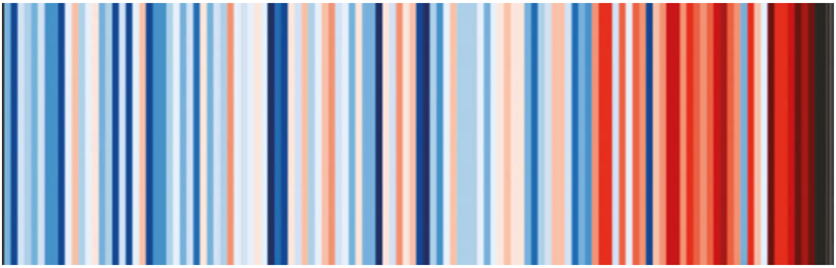

Figure 1. Warming of the Netherlands (1901–2020) represented by what are known as warming stripes: the darker the red, the warmer it is; the darker the blue, the colder, relative to the average (Showyourstripes, n. d.).

Targets for limiting the temperature increase

In order to combat the far-reaching effects of climate change, the UN made specific agreements for the first time in 1997 in the Kyoto Protocol. A breakthrough came with the 2015 Paris Agreement, in which the UN set a goal of limiting global warming to at least 2° C, and preferably 1.5° C (Delbeke & Vis, 2019). At the 26th Global Climate Summit (COP26), which was held in Glasgow in October and November 2021, the urgency was felt, but not enough was achieved to limit global warming to 1.5° C. As UN Secretary-General António Guterres put it: "These are welcome steps, but they are not enough." (UNFCC, 2021a and b)

To make the emission reductions concrete, the European Commission conveyed more-specific targets to its member states. The objectives at the EU level—to achieve a 55% cut in CO_2 emissions by 2030 and to be climate neutral by 2050—are laid down in the Climate Act and the policy proposal *Fit for 55* (EC, 2021a and b).

The Netherlands has elaborated the EU targets for cutting CO_2 emissions with its social partners in the Climate Agreement—a 49% reduction by 2030, and a 95% reduction by 2050—and set these out in the Dutch Climate Act (Klimaatakkoord, 2019).

Many cities have also set their own ambitions and committed to initiatives such as the Covenant of Mayors (Covenant of Mayors, n.d.). Amsterdam has committed to reduce CO_2 emissions by 55% by 2030, and to become a natural-gas-free city by 2040 (Gemeente Amsterdam, 2021).

Current and future greenhouse gas emissions

Measures taken in the context of climate change are often referred to in terms of adaptation and mitigation. Climate adaptation means adapting to the new circumstances and thus trying to limit or absorb the adverse effects of climate change. Climate mitigation is the reduction of emissions. It is clear from the IPCC models that the consequences are significant if greenhouse gas emissions continue to rise, and that major adjustments are still needed for scenarios if we are to keep to a 1.5°C temperature increase (IPCC, 2021).

Figure 2 shows the scenarios modelled by the IPCC for greenhouse gas emissions (in Gt CO_2-equivalents) up to 2050 if we continue with current policies (the purple line up to 2050) and what emissions reductions will be needed to limit the temperature increase to 1.5°C (the lower green line up to 2050). It clearly shows that much more needs to be done than is currently being done or being promised around the world (UNEP, 2021).

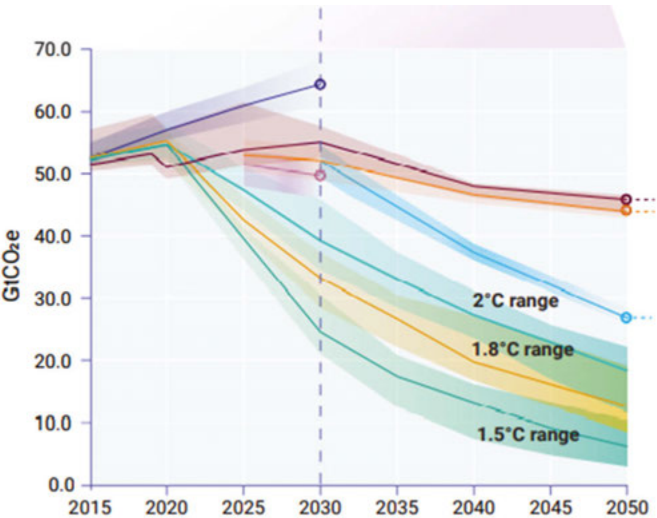

Figure 2. Future greenhouse gas emissions in various scenarios involving rises in temperature: in 2050, purple for current policies, and in blue the + 2°C range, in yellow the + 1.8°C range, and in green the + 1.5°C range (UNEP, 2021, p. xxv).

In the European Union, the 2020 targets were met, and the 2030 targets also seem achievable with current policies. However, the EU also needs to reduce emissions substantially by 2050. For the Netherlands, the picture looks different. The Netherlands only just met the 2020 targets, and it needs to do more by 2030 (PBL, 2021). Amsterdam will not achieve its 2030 goals based on the current measures (Zoelen, 2021).

The role of the energy transition

In order to stay within 1.5°C , major cuts in greenhouse gas emissions are needed in the short term. To do this, we need to know the cause of the emissions. Energy consumption accounted for 65% of total global greenhouse gas emissions in 2019 (Olivier et al., 2020). The remaining emissions come from deforestation and in the form of methane (CH_4) and nitrous oxide (N_2O), which are released mainly in agriculture. CO_2 emissions in the energy sector are caused by the production and combustion of fossil fuels. The energy consumption of the various economic sectors contributes as follows: the energy sector, 36%; industry, 17%; transport, 16%; and buildings, 9%. Cities are responsible for 70% of the world's CO_2 emissions. Transport in cities accounts for 40% of emissions from the transport sector (IEA, 2021a).

The energy system must therefore change drastically from being based on fossil sources to a system with net zero CO_2 emissions. This is what I mean by an energy transition: a change that takes place at several different scales and in multiple domains in society (Geels, 2004; Geels et al., 2017; Grin, 2019). A historical example is the transition from coal to natural gas in the Netherlands in the 1960s and 1970s. This transition not only had an impact on energy supply—it also created a new infrastructure, a major source of income for the government, and led to the emergence of central heating in housing. New companies, products, and habits emerged, and old ones disappeared (Ringelberg 2021). Economist Mariana Mazzucato speaks of a moonshot project that will be needed for this complex transition (Mazzucato, 2021). She believes the government should play a guiding role in this. Mazzucato has helped the European Union shape its innovation policy through "grand challenges" and "missions". A grand challenge is a large and urgent social problem that needs to be solved, such as climate change. The "mission" is the task, such as creating 100 positive energy districts in Europe (as discussed in the next section). Here, a portfolio of projects and bottom-up experiments contributes to innovation across sectors that is aimed at solving the problem.

Apart from climate change as a major driver for making the energy system more sustainable, there have been more reasons to work on an energy transition around the world over the years (Lund, 2014; Blok & Nieuwlaar, 2020; Yergin, 2012; Yergin, 2020; EC 2021):

- a wish to be independent of energy sources from abroad
- the finite nature of fossil fuels
- access to energy, and thus the possibility of economic and social development
- local availability of energy resources
- the cost of energy from fossil fuels and other sources
- the side effects of extraction or use, such as earthquakes, environmental damage, and damage to health.

In the Netherlands we are seeing that, in addition to climate change, the adverse effects of extracting natural gas in Groningen are currently playing an important role in the debate on the energy transition (Klimaatakkoord, 2019). In the case of mobility, the prevention of air pollution is often a major driving force behind the promotion of electric transport in cities (Klimaatakkoord, 2019; IEA, 2021a). In order to bring about change, it is important to understand all the drivers and barriers that may be involved in a transition. In the coming chapters, I will also indicate how we take this systemic approach into account in our research.

2 How do we choose paths towards solutions?

> *"Cities are key to a net-zero emissions future where affordable and sustainable energy is accessible to all."* (IEA, 2021a, p. 9)

The energy transition that is needed will affect everything we do, and will touch all the major emission-producing sectors (energy, industry, transport, and buildings). In the next section, I will indicate the main options, technical and otherwise, for the future energy system. I will then zoom in on the urban context in which the AUAS operates, and for which the EU approach to creating positive energy districts sets a high bar. Under the leadership of the municipality of Amsterdam, we are working on a major international project, ATELIER, in this context. To explain the story, I will use examples from this project and from the activities of other research groups. Finally, I propose an assessment framework that is appropriate to this new challenge.

The stress involved in making choices

To reduce CO_2 emissions in the energy system, three main categories of solution can be distinguished (IPCC, 2018; Blok & Nieuwlaar, 2020):

- savings or efficiency
- the generation of low-CO_2 energy
- the capture, storage, and use of CO_2.

Within the above categories, there are various technologies that contribute to this. Savings include, for example, all forms of insulation—from buildings to pipes in the process industry—but also less consumption as a result of behavioural changes. Efficiency refers to devices and factories that use less energy, for example an electric car, an LED lamp, and a more economical steel plant. Generating low-carbon energy means generating sustainable energy from sources such as the sun, wind, biomass, water, and the earth, but also nuclear energy. And CO_2 capture, storage, and use refers to large installations that release CO_2 (fossil fuel or biomass fired) and can capture and store or reuse the CO_2.

The IPCC has compiled and calculated four "emissions pathways," all of which lead to a global limitation of the temperature increase to 1.5°C (IPCC, 2018). In Figure 3, it can be seen that these paths differ in terms of primary energy consumption[4] and the mix of energy technologies involved: from two paths with increasing savings (S1 and LED), a path with growth and a lot of renewable energy (S2), and a path with a lot of growth and a lot of CO_2 capture, storage, and use (S5).

Previous modelling work has already shown that a 100% renewable energy scenario is also possible around the world with existing technology (Deng et al., 2011; Lund 2014). This clearly indicates that there are still many options, and many choices to be made.

4 Primary energy consumption: the amount of energy required to cover final energy consumption—including the energy lost during extraction, production, and transport of energy (Boer, 2020).

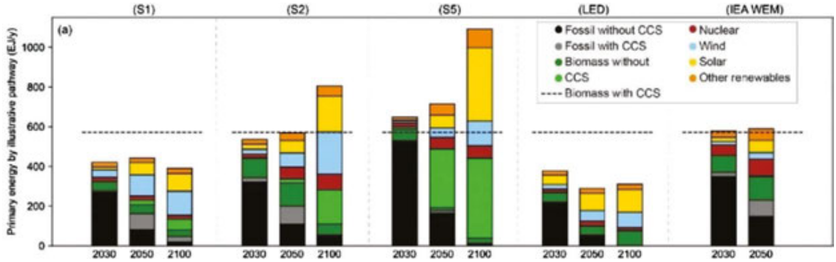

Figure 3. Four emissions pathways from the IPCC report that lead to 1.5°C warming, given the structure of the energy system. From left to right: (S1) savings and renewables, little carbon capture and storage (CCS); (S2) growth and deployment of renewables and CCS; (S5) strong growth in consumption and a delayed decline in emissions, but compensation later on thanks to biomass with CCS; (LED) very high savings and renewable energy; and (IEA WEM) this scenario from the International Energy Agency is for comparison. The dotted line indicates primary energy consumption in 2015 (IPCC, 2018).

The fact that many paths are still available that would lead to enough of a reduction in CO_2 emissions around the world is cause for hope, but that does not mean that all options can be implemented quickly enough in all contexts. This depends, for example, on the local availability of renewable and other energy sources, but especially on political, social, and economic conditions and choices (Lund, 2014). This plethora of possibilities is currently causing governments, companies, and consumers a lot of stress in terms of the choices they have to make - because, when there are many options, everyone wants to choose the best one. That is understandable, but it should not distract us from acting now.

Trias Energetica is a step-by-step plan used in Dutch energy policy to indicate the strategy to be followed to achieve energy-efficient design (Lyssen, 1996; RVO, 2013). The steps proposed under it are:
1. reduce the demand for energy
2. use renewable energy
3. if fossil fuels do have to be used, use them as efficiently as possible.

These steps broadly correspond to the categories indicated by the IPCC, except that in order to meet the reduction targets, fossil fuels can be used only with CO_2 capture, storage and use. In the next section I will discuss in more detail how Trias Energetica can be specifically applied to the new challenges cities are facing.

Figure 4. The Atelier project team visits Schoonschip in Amsterdam, where a smart grid is being tested.

The city

With as much as 70% of the world's CO_2 emissions coming from cities (IEA 2021a), a lot has to change in the urban environment. Cities themselves have also set ambitious targets for this. The urban district is characterised by a cluster of buildings and activity. There is also little unused space. Many people live relatively close to each other and there is a lot of activity going on. As a result, cities attract many people from outside, and there is a constant flow of traffic to and from them. Due to the density of the built environment, there is a high demand for heat. There are also many small consumers of energy, such as houses and cars, and therefore many actors distributed throughout the space. At the same time, in or around a city, such as Amsterdam, there are also larger generators and consumers of energy, such as a power station, a waste-incineration plant, and industry.

In order to achieve significant cuts in CO_2 emissions from cities, the EC has launched the concept of positive energy districts in the Horizon 2020 research and innovation program. These are districts where the generation of renewable energy exceeds energy use and there are no CO_2 emissions. The EC's mission is to create 100 positive energy districts by 2025. All of these initiatives are supported by climate and energy strategies. The EC's Strategic Energy Technology Plan defines a positive energy district as follows:

> "Positive energy districts are energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems, while securing the energy supply and a good life for all in line with social, economic and environmental sustainability." (Urban Europe, 2021)

The concept of a district therefore comprises much more than an assemblage of energy-neutral buildings. It is about an integral concept across sectors. This poses a far-reaching challenge in all possible disciplines.

The definition speaks of managing "an annual local or regional surplus production of renewable energy," and this indicates that it is not about complete self-sufficiency on the part of a given district. Exchange with the larger energy system at the regional, national, and international levels is required if we are to avoid falling into sub-optimal solutions. This optimisation works in complex ways, and many questions have yet to be answered, such as: What is the driving force for the optimisation, who is in control, which scale levels can be efficiently connected, and how can this be done reliably? The optimisation must therefore take into account the technical, economic, legal, social, and environmental dimensions. We also call this system integration (Topsector Energie Systeemintegratie, 2020). The desire for self-sufficiency must therefore be kept in check. At the same time, we as a society must make conscious choices about who and what we want to, and can connect with. This applies just as much to discussions about the origin of biomass as to those about natural gas. Thus the concept of the positive energy district does not stand on its own. The question of how this concept fits into and contributes to the global energy transition is important, and we will investigate it in a project such as ATELIER in the coming years.

Positive energy districts are now gaining attention as a tool for making cities climate-neutral, smart, and inclusive, but not many examples have yet come into being (Vandevyvere, 2020; Bossi et al., 2020). It is not yet clear from the current definition how to delineate positive energy districts and what the benchmark for success is.

Figure 5. Energy exchange by the area with regional and national integration (Vandevyvere, 2020).

Efficiency and renewable electricity

Within an energy-positive area, there are different technical solutions for making the energy system energy-positive. As in the Trias Energetica, energy efficiency and renewable energy are an important part of the energy system, but flexibility and mobility are also part of the picture. In order to give an impression of which techniques might be suitable for an urban positive energy district , I have put them into Figure 6 for the ATELIER project's demonstration district in Amsterdam. This is what is known as a morphological map. The rows show the functions (broken down by savings and by how power is generated), while the columns show the possible technologies (Oskam et al., 2017). It is not an exhaustive list of techniques, but there are already quite a few. This gives us an impression of the stress around making choices that can accompany all these options. The techniques that are framed in black were chosen for the Amsterdam positive energy district. We can already see that this is what they call an "energy concept" that consists of a number of techniques. This is typical of urban environments, where there are many functions to fulfil, in this case, heat, electricity and mobility. As you can see from Figure 6, no fewer than four techniques are used to generate savings at the building level: insulation, balanced ventilation, triple glazing, and management of demand. In what follows, I will explain the four parts of the energy system in a positive energy district in more detail and give you a sense of the state of the art.

Energy efficiency and renewable energy are already referred to as "business as usual"—in other words, they are widely applicable. The efficiency of the built environment in the European Union has improved in recent decades, especially through the application of strict laws and regulations for appliances and in the construction of new buildings (Economidou et al., 2020; Delbeke & Vis, 2019). In the Netherlands, the consumption of natural gas was reduced by almost 30% between 2000 and 2020 (PBL, 2021) through insulation measures, but this is not enough to achieve far-reaching emission reductions needed (Fillipidoou et al., 2017). And so far, the renovation programs have not achieved their goals (Visscher, 2020). So things need to change faster.

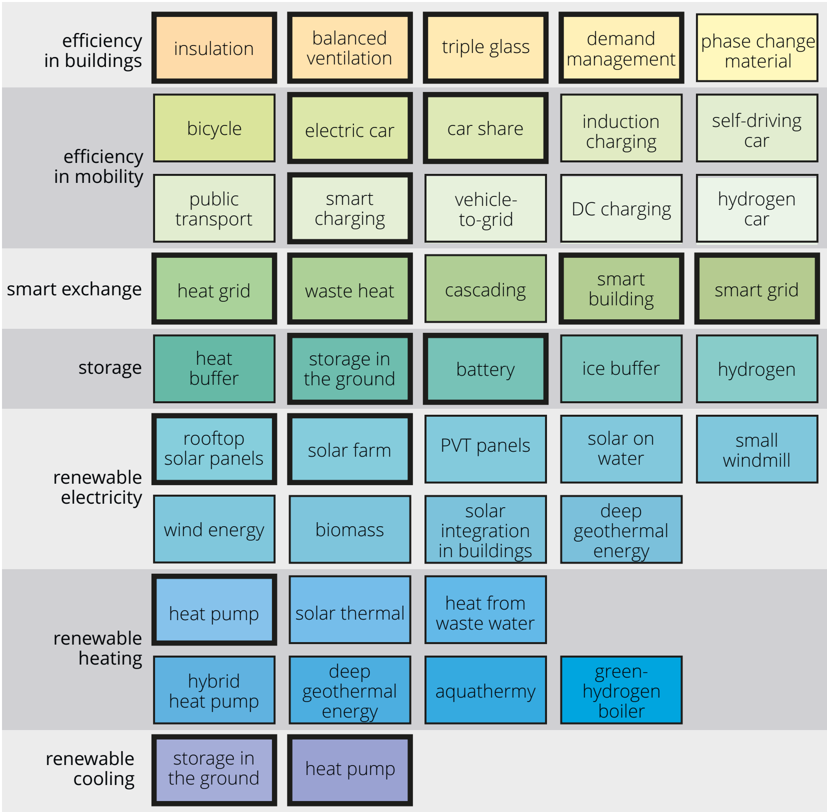

Figure 6. Morphological map drawn up for the positive energy district in Amsterdam, with possible techniques and ordered per function from high technology readiness levels (TRLs) (left) to low TRLs (right) (see section 3); the selected techniques are indicated by the boxes with black lines.

Renewable energy technologies can be applied on a large scale, and there is a good business case for solar and wind power in many locations (Delbeke &

Vis, 2019; Irena, 2021). The sustainability of the electricity sector in the Netherlands has also progressed rapidly since 2015, thanks in part to cost reductions and government support for research, innovation, and investment. Renewable generation covered 11% of electricity needs in 2019 (CBS, n.d).

Sustainable heat

Around the world, and in the Netherlands, the heat sector is lagging behind the electricity sector when it comes to the transition to renewable-energy sources (IEA, 2021c). In 2019, only 7% of the demand for heat in the Netherlands was met with renewable sources (CBS, n.d.). There are many reasons for this. The electricity sector, for example, has only a few major players, and electricity is a product for consumers. It makes no difference where it comes from in terms of its use. (Geels et al., 2017; Ringelberg, 2021). For the built environment, it can generally be said that the system is more complex:

- There are many players who need to take action and who have different interests: aside from municipalities, property owners, and energy and network companies, there are also 7.5 million households.
- Legislation covers several domains and is lagging behind when it comes to the advances required.
- The benchmark technology, the natural-gas boiler, was very cheap for many years and dominates the market completely.
- Far-reaching sustainability measures will require a renovation that affects people in their homes.

There is no silver bullet in this complex transition, and all options should be used where they fit best. We have already seen this in the IPCC's emission pathways (above), and in the morphological map in Figure 6. This applies to a large extent to making the heat supply more sustainable, where major steps are required and where, at the same time, there are a lot of options available.

In addition to savings through insulation, the electric heat pump is an efficient device when it comes to sustainability, because it is two to three times more efficient for heating than a gas boiler. With a heat pump, the production of heat for homes no longer requires gas, but instead uses electricity. In addition to electricity, a heat pump needs another source of energy, such as air, soil, wastewater, or water from a nearby canal or lake. The more stable and the higher the temperature of this source is, the more efficient the heat pump will be (Entrop et al., 2020). If we want to move away from natural gas in the built environment by 2050, as envisaged in the Climate Agreement, the in-home demand for electricity will probably rise, terms of both energy and power, thanks to the use of induction cooking, electric cars, perhaps heat pumps, and solar panels. If we make the transition to a more electricity-based energy system as a matter of policy, the electricity grid in residential areas will have to be considerably reinforced (Entrop et al., 2020; Netbeheer Nederland, 2021). Alternatives to heating with electricity will thus be welcome.

Heat networks could be an alternative. There are many sustainable heat sources that provide so much heat that they are more suitable for the scale of a city or a district than for a house. These sources, such as ground heat, deep geothermal energy, aquathermy, solar thermal or biomass, are also needed for sustainability. These sources can supply heat through a network of pipes in the ground known as a heat grid, which distributes the heat to customers. Large-scale heat networks are quite successful in northern Europe in making the demand for heat more sustainable. The Netherlands is lagging behind in this regard (Bertelsen et al., 2020; Lund et al., 2018). Many cities such as Amsterdam have also included heat networks in their heat-transition plans (Gemeente Amsterdam, 2020). When it comes to actual implementation, however, things are not going so fast, because we have to do with large-scale solutions, for which a large number of players must be on board, and with large investments (PBL, 2021; Heller & Suurenbroek, 2017; Willems et al., 2021).

Residual heat from data centres, of which there are many in Amsterdam, can play an important role locally. Residual heat from data centres can be included in a new type of low-temperature heat network and in an open system, which could be more sustainable and more affordable. In this system, heat is interchangeable, and a supplier is also a buyer. This is also known as a fifth-generation heat network. Despite the benefits, implementation is still coming along slowly (Buffa et al., 2019; Wahlroos et al., 2018). Our research in the Amstel III district in Amsterdam showed that property owners do not yet regard this as a proven technique and are therefore reluctant to put it to use. At the same time, the parties involved are waiting for the new law on heating to give them clarity about what the landscape will look like (Willems et al., 2021; the Rira Amstel III project).

Electric transport

The inclusion of transport in energy-system concepts for the built environment is new. Usually the focus is sector by sector. There is much to be gained in the city by designing the space and the transport system in such a way that people walk, cycle, or use public transport more than they do the car. However, the positive energy district concept considers only electric transport. Electric transport results in a large drop in CO_2 emissions, and in much less local air pollution (Blok & Nieuwlaar, 2020). The Netherlands is one of the world leaders in this connection. Twenty-five percent of new cars sold are electric (IEA, 2021d).

Electric transport does present a number of challenges for the energy system. It requires a whole new charging infrastructure. Also, in the big cities, a lot of people do not have their own driveway where they can charge their car with their own electrical connection. In the Netherlands this is true of about 65% of households, while the figure for Amsterdam is as high as 90%. As a result, cities are faced with the task of solving this in public spaces (Hoed et al., 2019). Also, as indicated above, simultaneous electrification of the heat supply for buildings and of transport puts enormous pressure on low-voltage grids in neighbourhoods (Netbeheer Nederland, 2021). How this will fit in with the growing share of electric cars is an important question for many cities. With ever-larger car batteries and the advent of fast chargers, the demand for, and the supply of, charging stations are still developing strongly. The impact that a greater use of shared and self-driving cars could have should also be investigated through scenario studies.

Flexibility and smart grids

For the positive energy district, there is a major role for flexibility and Information and Communication Technology (ICT) to manage this proactively in the energy system, such as in a smart grid. “Smart grid” is usually a reference to ICT, which is used to manage supply and demand for energy (Netbeheer Nederland, 2008) but I also include energy storage, when using the term smart grid. More and more flexibility in the energy system is needed as renewable sources of electricity such as solar and wind power fluctuate and cannot be managed via matching supply with demand. They are dependent on the weather. For example, we can turn off solar panels whenever they produce too much energy, but the sun does not always shine when the demand for energy is high. This requires flexibility, for example, in the form of energy storage or demand management. Demand management means that devices or factories are switched off and thus require less energy. It is also possible to postpone using equipment until there is less of a burden on the electricity grid. The battery in the car can also provide a solution for this by temporarily storing electricity. Figure 7 makes clear how an electric car, with a standard home charging system, places an extra burden on the evening peak. Charging the car battery with solar energy during the day actually relieves the evening peak by feeding the energy back to the grid. It is also possible to reduce the load on the grid by delaying charging slightly. This is known as smart charging (Bons et al., 2020).

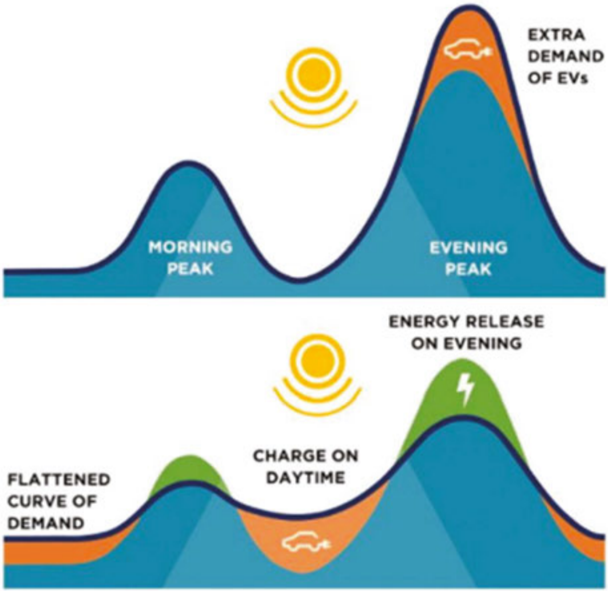

Figure 7. The car as a battery. Top: household electricity consumption in the course of a day (blue), with an additional peak in the evening from charging the electric car (orange); bottom: the car can be charged by solar panels during the day and give off some of the electricity in the evening to reduce the peak (Bons et al., 2020).

In positive energy districts, the idea behind flexibility is primarily to maximise the integration of local renewable energy into the district, and thus limit the burden that networks impose on the outside. This can be done by balancing buildings and functions, for example, not only with electricity but also with heat and cold. It should also give local players and citizens opportunities to influence their energy system (Vandevyvere, 2020).

The ICT concept has been in development for some time, but up to now the conditions for it are lacking on the financial front as well as the legislation and regulations needed to achieve large-scale implementation (IEA, 2021b). The potential of storing and discharging energy from car batteries or in batteries at the neighbourhood scale is generally recognised, but the realisation of that potential is still fraught with uncertainty (Van Bergen et al., 2020; Putrus et al., 2020). In line with the grand challenge of combatting climate change, the big question here is also whether and under what conditions a smart grid can lead to lower CO_2 emissions.

Trias Energetica 3.0

How the components of the energy system in a positive energy district are to be forged into an integrated energy concept depends on the characteristics of a given location, such as:

- How the area is laid out and how much space there is, for example
- How much demand there is for heat, tap water, cold, electricity, and mobility
- How construction has been done (the types of houses, how old they are, and what methods have been used)
- Who the users are, what they need, and what they can offer
- What local renewable energy sources are available
- How energy can be exchanged both within the district and with the surroundings

To go back to the morphological map in Figure 6: instead of heating with a heat pump and waste heat, sustainable heat could, in theory, also come from geothermal energy. That said, it is unclear whether this source could be exploited well enough in Amsterdam. It is already clear, though, that geothermal heat can be harnessed in other places in the Netherlands (Entrop et al., 2020).

As we have seen, getting these systems to fit is a major challenge, not only in cities but also in the rest of the Netherlands. This certainly includes not only the energy supply, but also space for housing, mobility, industry, and agriculture (Kuijers et al., 2018; Alkemade et al., 2018). For the energy challenge, it is important to exploit, in spatial terms, the opportunities urban districts offer to both limit transport and exchange energy. And we must focus in the process on multiple uses for space. For instance, it is not possible to generate, with solar panels on the roof of a high-rise apartment block, the equivalent of the electricity currently being consumed on average by the residents of that block, but this can often be done in the case of row houses (Entrop et al., 2020). For a city such as Amsterdam, which has a lot of high-rise buildings and apartments, doing this is therefore more difficult than for a place such as Almere, which has more single-family homes (CBS StatLine, 2021). However, Amsterdam might benefit from developing or further developing attractive solar panels integrated into façades, so as to use these to generate energy (Sloof et al., 2017).

Positive energy districts are thus a new challenge when it comes to making cities sustainable. Many techniques are possible, but it is not yet clear in every setting which will be most serviceable. To simplify the process of making choices for local and other governments as well as other players, a clear assessment framework is needed to make districts considerably more sustainable. In accordance with the adaptation of the Trias Energetica for energy-neutral buildings (Van den Dobbelsteen, 2008), I propose to add energy exchange specifically within and between sectors in the city. The exchange, storage, and smart use of energy are the “lubricant” for optimising the balance between saving energy and generating it sustainably. This may involve the exchange or storage of heat, of electricity, or even of fuels. The Trias Energetica 3.0 will thus be as shown in Figure 8:

- saving
- the exchange, storage, and smart use of energy
- sustainable generation

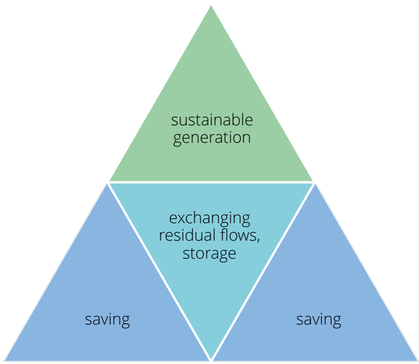

Figure 8. Trias Energetica 3.0, in which residual flows are exchanged, and where storage is shown as an optimisation of the balance between the basis for saving and sustainable generation.

As I mentioned, energy exchange and storage are meant to be optimised. Here, it is important to pay attention to the future use of the area, the spatial aspects, the needs of users, and the objectives for the area. In addition, the larger task should be kept in mind and not only optimised within the district. Because the development of districts entails efforts made over the long term, this is an iterative process that is carried out by the players involved (Willemsen et al., 2021).

3 The role of innovation and applied research in the energy transition

> *"TNG: Clearly one has to constantly be both master and dilettante—it's a different kind of intellectual rigor. DH: And obviously the point is we need to be doing both vertical deep studies and lateral, cross-cutting ones. Interdisciplinarity is risky, but how else are new things going to be nurtured?"* Donna J. Haraway, How Like a Leaf: An Interview with Thyrza Nichols Goodeve (Haraway, 2000, p. 46)

Now that the technical possibilities and the order in which choices can be made for achieving far-reaching reductions in emissions from the Trias Energetica 3.0 are clear, I will discuss the role of practical research in this chapter. In order to clarify what is required for the energy transition in the city, I will first explain the role of innovation in the energy transition on the basis of developments that have taken place over the past decade.

Innovation

The Energy and Innovation research group was founded in 2011. Since then, some innovations have developed faster than others. For example, the decline in the cost of solar cells and wind turbines is such that using them to generate power is the cheapest option in many parts of the world (Irena, n.d.). The cost of batteries is also dropping sharply (ZIegel & Trancik, 2021), and this, together with stringent European emission requirements, has led to a clear decision by the automotive industry in favor of electric passenger cars. This was not foreseen ten years ago (Hoed, 2013; Geels, 2012; Boer, 2020). For example, the Netherlands is now one of the leaders in electric passenger cars thanks to a combination of subsidies and tax breaks for the leasing sector on the one hand and, on the other, municipal policy on charging infrastructure (Wolbertus and Hoed, 2020). As I noted above, there has been less of a change when it comes to supplying heat. There are more and more heat pumps in homes built after 2000, thanks to building regulations, but there has not been such a sharp drop in the price of pumps as there has been for solar and wind energy (IEA, 2021c; Lijzenga et al., 2019).

What can be seen in these trends is how an interplay of developments in technology, market incentives, and/or government regulation leads to breakthroughs. At the same time, it appears to take decades for the technologies associated with the generating power to go from discovery to commercialisation, while producers of consumer products that directly replace a product capture a substantial market share much more quickly (Gross et al., 2018). This has to do with the fact that sustainable generation also requires a system change, as is the case with the rollout of electric cars, for instance (Geels, 2012; Geels et al., 2017; IEA, 2020).

Figure 9. Infrastructure for charging electric cars in public spaces.

In general, the innovation process has to be faster. The role of technology here is important not only in the discovery phase, but also when it comes to scaling up, cutting costs, and execution. Electric cars, and solar and wind energy are serviceable and deployable technologies, but in this sense they are not mature, since technological developments still allow for further efficiency gains and cost reductions (Elia et al., 2021).

The phases through which technologies develop are often presented in terms of technology readiness levels (TRLs), which have also been used in the EU's Horizon 2020 innovation program to assess technologies (EC, 2014). The IEA has extended this scale, which originally went from "TRL 1—basic principles" to "TRL 9—system proven in operational environment," by two levels: TRL 10, which reflects the upscaling and the integration into the energy system that are specifically required for low-carbon technologies, and TRL 11 for a market share corresponding to maturity (IEA, 2020), as shown in Figure 10. According to the IEA, technologies such as solar, wind, and heat pumps are in the early adoption phase (TRL 9 and 10), while grid-integration solutions such as smart charging are in the "large prototypes" phase (TRLs 5 and 6).

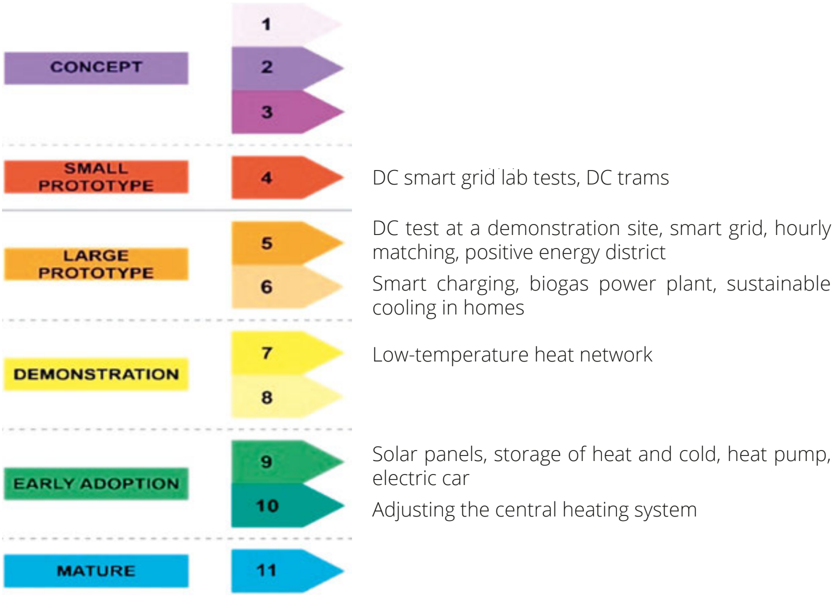

Figure 10. Technology-readiness levels according to the IEA (IEA, 2020) (left) and the technologies that we are working on in projects within the research group (right).

The research group conducts research from the "TRL 4—small prototype" phase, where we develop and test in our own lab, to "TRL 10," where, in demonstration projects, integration into the energy system is still particularly important in the early-adoption phase. I have put the technologies we are working on in the projects on the TRL scale in Figure 10. For example, many of the developments in the field of DC grids are not yet ready for the market (Bianchi et al., 2020). This research is therefore done first in our own research lab (such as in our DC Charging Square and VAP-DC projects). Most of our research takes place outside the lab, at test and demonstration sites with partners in practice and users. For example, the City of Amsterdam is a living lab where research into the rollout of charging infrastructure for electric transport is taking place (in the Future Charging project). The city is also the demonstration site for the positive energy district (in the ATELIER project). And we are researching the energy consumption of our own buildings (the UvA-AUAS Buildings project).

Practically focused research

Practically focused research is characterised by investigating practical questions from the field and working closely with professional practitioners. Challenges in this connection are well articulated in the research vision of the Centre for Applied Research Technology, of which the Energy and Innovation research group is a part:

1. Practically focused interdisciplinary research and thus the combination of research methods from various scientific paradigms
2. Co-creation and/or intense cooperation with different stakeholders
3. The translation of individual and/or exploratory pilots and other projects and sector-based solutions into contributions to the broader transition at the level of systems (Faculteit Techniek, 2021)

I will discuss the first two challenges below. The third challenge, which I will address in the next section, is quite clear when it comes to the task that many of our projects have.

Interdisciplinary research

As the discussion of the system transition and Trias Energetica 3.0 shows, the energy transition requires an interdisciplinary approach. What is needed in the first place is quite basic: that sociologists know the difference between kW (power) and kWh (energy), and that engineers do not regard every consultation with residents as a waste of time because they do not understand engineering concepts. So it starts, in part, with some knowledge of, and with respect for, each other's expertise. These are prerequisites for multidisciplinary work. But beyond that, greater cooperation is needed if we are to meet the new challenges and come up with new solutions. Within the technical disciplines, we see this challenge around electrification in the built environment. Whereas heating systems used to be the domain of mechanical engineers, they are now increasingly the preserve of electricians. This requires interdisciplinary work not only between the technical disciplines, but between all disciplines relevant to the issue. This is already common practice among designers (Oskam et al., 2017). The application of this practice to all domains and issues within the transition is a work in progress. We have a good starting point in the recognition that both societal characteristics and choices on the one hand and, on the other, considerations around efficiency and functionality lead to a different technical design. This has to be reflected in our complex optimisations and mathematical models, in which engineers and modelers, along with sociologists and psychologists, study the entire issue. Up to now, optimisation has been based on costs (Blok & Nieuwlaar, 2020; Lund, 2014). But we must now take into account a combination of criteria, such as emissions-free, fair, and practicable. These terms are still too broadly defined, and a lot of interdisciplinary research will be needed to operationalise them properly. The good news is that a shared mission is a great catalyst for interdisciplinary cooperation (Brown et al., 2015). For example, in the ATELIER project here at AUAS, we are working with a team from various disciplines such as planning, psychology, economics, and physics. For us, too, interdisciplinary work requires that we pay constant attention and listen carefully, both to each other in-house and to our project partners. In order to better prepare future generations, we set up the Positive Energy City minor (secondary specialisation) in 2020 as part of the ATELIER project. Students from all fields of study are welcome.

For the research group, this means that, in addition to more-technical quantitative methods (via sensors, measuring instruments, data analysis, and computer simulations), more-qualitative associated methods such as, stakeholder, market, and user analyses, also play a role in the research. Legislation and regulations often lag behind innovations, and are included in the analysis of the necessary system transition (the Rira Amstel III and VAP-DC projects). In order to solve optimisation problems that have more complex issues, we also use *agent-based models* . These are models that can, for example, simulate the behaviour of drivers of electric cars (agents) with context such as the availability of charging stations, the distance to those stations, and their availability based on data from charging sessions (Hoed et al., 2019). This type of model is used to calculate scenarios for the further rollout of charging infrastructure under shifting circumstances, such as a larger proportion of shared electric cars (the Future Charging project). Especially when it comes to design research, more of these methods will be used to settle on the right intervention. Sometimes the method comes from the research group itself, sometimes it results from cooperation with other research groups within AUAS, and sometimes it emerges from the contributions made by one of the partners in practice or one of the other knowledge institutions in the project.

Cooperation with partners in practice

For the research group, cooperation with partners in practice means that they not only have an important role in the articulation of the question, but also cooperate in carrying out and disseminating the research itself. Our role is often that of researcher-observer-analyst. However, in more design-oriented projects, the interconnectedness of partners is greater and we deliver joint products.

The research groups partners in practice include local and other governments, construction and installation companies, energy companies, network operators, consulting firms, industry associations, civil-society organisations, and other knowledge institutions. There are partners with whom we cooperate on several topics, such as the municipality of Amsterdam, UvA-AUAS Facility Services, and Vattenfall. We are now working intensively with the City of Amsterdam on themes such as positive energy districts (the ATELIER project), charging infrastructure (the Future Charging project), and smart grids (the Flexpower project). UvA-AUAS Facility Services has been working with the research group for several years to make UvA-AUAS's buildings more sustainable. Researchers, lecturers, and students alike, are really keen to work on monitoring and optimising our buildings, under the auspices of the UvA-AUAS Buildings project. By tendering the energy contract in an innovative way, Facility Services has linked the supply of energy to a collaboration with research and education. This has enabled the Centre of Expertise on Urban Technology to establish a strategic partnership with Vattenfall for the next 10 years. Our research group has worked with Vattenfall before, on research into charging infrastructure, and in the Hour Matching project we have been able to extend this cooperation to smart grids.

In this context, we use the term "impact" to indicate that the effects of research on education and professional practice are felt not only later on, but right from the very start of a research project, when shared learning and the creation of value are constantly taking place (Vereniging van Hogescholen, 2018). Interactions with professional practice take place within the projects through cooperation with partners in the field, but also through dissemination to the wider field by means of workshops, conferences, and publications in reports and in professional and academic journals.

In order to be more closely aligned with the needs of the field, the products of our practice-based research also include such items as a dashboard, design guidelines, an assessment framework, and a serious game. They often play not only a knowledge-transfer role but also a role in practice as a process. In the Rira Amstel III project, for example, we drew up an assessment framework together with the project partners and turned it into a serious game. We play these games with both parties involved and with students in order to gain insights into the choices that parties can make individually and collectively, and into which technical systems might be chosen on this basis.

4 How is the research group contributing to the energy transition?

> *"CREATING TOMORROW IN PRACTICE Working together on sustainability, digitization and diversity. It sounds fantastic and it truly is. But what does that really mean? Read here about how we do this in practice."* (HvA, 2021)

The Energy and Innovation research group is contributing to the energy transition. To create an impact, we are researching and designing technological interventions. As I noted in the last section, a lot of technical progress will still be needed to implement existing technologies and thus cut CO_2 emissions to a sufficient degree. There is also the interdisciplinary challenge of this system transition, and we see that in our projects, too. The focus of the research is on the urban context of Amsterdam and the Amsterdam Metropolitan Area. There is a further delineation around positive energy districts as a theme, because we can still make a major contribution to this innovative, challenging theme with practically focused research. This is an overarching theme to which, as we have seen in the preceding section, electric transport, charging infrastructure, smart grids, and the heat transition are all contributing. On all of these topics we also have separate research projects that in themselves are contributing to the energy transition and that do not necessarily themselves have the goal of leading to a positive energy district. In this section I will indicate which projects the research group currently running, and how they affect education. I will highlight here a few different elements regarding the coherence of the themes and how I see things developing in the future.

Without skilled people, it is impossible to fulfil all ambitions. Over the years, my predecessor Robert van de Hoed built a strong team. The Energy and Innovation research group now has 20 members who between them have a wide range of expertise, including in energy engineering, industrial design, architecture, innovation management, and data science. We also have a good mix of experienced project developers, project managers, and subject matter experts. Some team members combine teaching and research and work in one of the Faculty of Technology programs. A dedicated data team ensures the careful storage and management of charging-session data from the municipalities of

Amsterdam, Rotterdam, The Hague, and Utrecht, and by the Amsterdam Metropolitan Area, as well as the careful handling of access to that data.

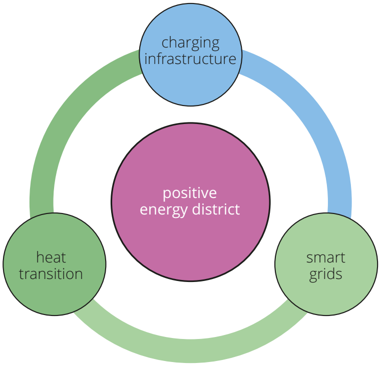

Figure 11. Themes the Energy and Innovation research group is working on.

Within the themes, we strive to accumulate knowledge by carrying out multiple projects in succession. Knowledge of the methods used is also shared among the themes. For example, we work a lot with measured data and simulations. Here we share the team's knowledge and experience, and cooperate with Urban Analytics within the Centre of Expertise on Urban Technology. Knowledge that we produce under the charging-infrastructure, smart-grid, and heat-transition themes can also be used in the overarching positive energy district theme. For example, the Future Charging project contributes to the analyses of mobility in the positive energy district that the ATELIER project is working on.

Positive energy districts

ATELIER, which we mentioned above, is a large European project that is being subsidised under the EU's Horizon 2020 program, and in which Amsterdam and Bilbao are realising positive energy districts. Our research group is involved in monitoring and evaluation, among other things. We also want to learn from the evaluation in order to apply the concept in other districts. In doing so, we are carefully considering all social, spatial, and technical prerequisites. We will thus be working on these analyses for Amsterdam in the months ahead, and we also want to be able to scale them up to other cities and countries. With students and partners, we have already started to research good ways of modelling the system, because there are currently no positive energy district simulation tools available (Belda et al., 2021).

Charging infrastructure

The research on charging infrastructure has a long history within the research group, and is also an important theme in the research we are now doing. The rollout of charging infrastructure in the Netherlands is now in a new phase: the explosive growth of electric transport means that the rollout of charging infrastructure must also take a quantum leap in terms of scale. In the Future Charging project, we are investigating the charging infrastructure of the future, together with 18 partners in practice. The aim is to gain insights, through various simulations, into the effects of future scenarios on the use of charging infrastructure and their impact on the electricity grid and public space. The results of simulations are the starting point for design studies that lead to recommendations for practice. Within the project, we are expanding this knowledge to different sectors, such as logistics and car-sharing, but we are also looking at other charging solutions such as fast chargers.

Smart grids

In order to avoid the unnecessary expansion of the electricity network during the electrification of different sectors, we are exploring different demand-side flexibility options that use various forms of storage. At the moment we are investigating the following options within the research group:

- smart charging of electric cars (in the Flexpower project);
- demand management and storage in buildings (in the Hour Matching project);
- DC grids and charging stations (DC = direct current) linked to storage and solar panels (in the DC Charging Square, VAP-DC, and TS-DC projects). The expectation is that, with DC charging of more cars, charging will be more efficient and easier to control than with the standard AC connections (AC = alternating current). With a DC network in or on a building, there are also many technical challenges to solve, such as possible corrosion.

Heat and cold transition

As indicated earlier, the heat transition in the built environment in the Netherlands is lagging behind. Our research program is thus also focusing in particular on making the heat supply more sustainable. Our current projects are looking at the following challenges:

- making areas and utility buildings more sustainable, for example with residual heat from data centres (the UvA-AUAS Buildings, Hour Matching, and Rira Amstel III projects)
- homes that are ready for the future

- research into the possibilities of saving energy with gas boilers (the Energy Savings project and earning models for adjustments to central-heating systems);
- cooling for homes (the Cold in the City project, and project application under review).

In the future, I expect more-extensive digitisation to play a greater role in the built environment. We will thus be able to use better monitoring, modelling, and forecasting to improve and simplify schemes and guidance. We will also work on this in the research group.

Figure 12. Aerial photo of the AUAS Amstel Campus, with the Jacoba Mulder House, the new location of the Faculty of Technology, in the upper-left corner.

Impact on education

In recent years, the Faculty of Technology has focused on societal-transition themes. Energy transition is one of these. We will do this together at the intersection of education, research, and professional practice (Faculteit Techniek, 2021). The impact on education is important for several reasons:

- to be able to directly incorporate the latest insights from research into relevant teaching modules
- to train students for the energy transition

Lecturer-researchers in the team serve as the hub for bringing in cases and developing new teaching based on the knowledge that is gained from the research projects. Here are some examples of educational development in which the research group is involved:

- the Data Science minor (energy track), the Positive Energy City minor, and the Power minor;[5]
- master Urban Tech
- energy and innovation subjects, and (graduation) projects within the Engineering, Built Environment, and Applied Physics bachelor's programs
- a massive open online course (MOOC), Positive Energy Districts, for professionals
- learning community system-integration data

This way, research is linked to education for students and professionals at various levels.

In the coming years, the cooperation between research, education, and practice in the Faculty of Technology will be strengthened with the development of, and through participation in, Communities of Practice. Here, students work together with teachers, researchers, and practitioners on issues related to the energy transition. In addition, insights find their way to the Centre of Expertise on Urban Technology, which operates on an interdepartmental basis and in close cooperation with partners in practice.

Conclusion

Climate change is forcing an acceleration of the energy transition, which is one of the most important societal issues of the coming decade. A city such as Amsterdam has high ambitions. The Energy and Innovation Group is working on this by researching and designing technological interventions. A positive energy district is a highly innovative intervention. For example, we are examining what is technically possible and whether the extent to which CO_2 emissions are being

5 The Power minor is a collaboration among Tennet, HAN University of Applied Sciences (coordinator), The Hague University of Applied Sciences, and AUAS—see https://www.powerminor.nl

cut is enough. Other interventions we are investigating include smart charging for electric transport, flexibility in the energy system, and sustainable heat. We are doing this in our own lab, both with simulations and on the basis of monitoring in the field, such as in AUAS's buildings, and through demonstration projects in the Amsterdam Metropolitan Area.

As we have seen, there are many technical possibilities. That said, no single technique can result in sufficient cuts in CO_2 emissions. A guide can help stakeholders to reduce the stress involved in making choices. The basis for this is a Trias Energetica 3.0: saving energy to begin with, this then to be combined with sustainable generation and energy exchange and storage. The optimisation comes from social, spatial, and technical considerations. The models and tools we are developing should help our partners in practice to move to a higher TRL.

In addition to the above-mentioned substantive themes, I see three important ways to speed up the energy transition in the coming years, with the research group making contributions through practically oriented research. The first way involves translating individual projects into scalable interventions and keeping the level of ambition high in the coming years. This is already happening in various ongoing projects, but it can be further strengthened by focusing on follow-up projects and further digitisation. The second involves intensifying interdisciplinary cooperation and arriving at a common assessment framework. There is still a lot of research to be done in this area in order to come to a good conceptual framework and to models that do justice to these assessments. The third involves finding enough people with the required knowledge who can work on the transition. For me it is important that the focus of the research group be on the technical domain, which is where our strengths lie. In a word: by developing knowledge and technology together with professionals and students, the research group is contributing to the energy transition of the city.

I am convinced that *"...even at this late hour we still have a choice about our future, and therefore every action we take from this moment forward counts"* (Figueres & Rivett-Carnac, 2020, p.163).

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List of projects being run by the Energy and Innovation research group in 2020 and beyond

ATELIER (AmsTErdam BiLbao cItizen drivEn smaRt cities)

Funding: EU Horizon 2020
Duration: 2019–2024
Partners: City of Amsterdam (NL) (project lead), City of Bilbao (SP), Tecnalia (SP), TNO (NL), Cartif (SP), De Waag Society (NL), Amsterdam University of Applied Sciences (NL), Paul Scherrer Institute (SW), Steinbeis-Europa-Zentrum (GE), City of Budapest (HU), City of Matosinhos (PO), City of Riga (LT), City of Copenhagen (DK), City of Bratislava (SK), City of Krakow (PL), DEUSTOTECH (SP), Cluster Bilbao (SP), IBERDROLA (SP), TELUR (SP), EVE (SP), SPECTRAL (NL), Republica Development VOF (NL), Developer Poppies Location (NL), Amsterdam Institute for Metropolitan Solutions (NL), Waternet (NL), DNV-GL (NL), Greenchoice (NL), Civiesco (IT), Zabala Innovation Consulting (SP), and Fraunhofer ITWM (GE)
Website: smartcity-atelier.eu
Energy and Innovation Team: Mark van Wees (project lead), Karen Williams, Shakila Dhauntal, Rick Wolbertus, and Renée Heller

The ATELIER project is a European project in which Amsterdam and Bilbao are creating a positive energy district (PED). Six cities are going through this process in order to come up with their own plan for a PED. AUAS is coordinating cooperation with other smart-city projects, is contributing to the monitoring and evaluation of the project, and is supporting the dissemination of the results to other European cities. Researchers from the HvA are developing strategies for scaling up and replicating such energy-generating districts. Among other things, we are looking into how the various parties involved can achieve the ambitious goals for the district together, and which technologies are best suited to this. Besides technological solutions, the research group is also looking at new forms of citizen participation, at effective business models, and at the scaling up and rollout of PEDs in other cities. The AUAS team is made up of researchers from several faculties and from the Urban Governance and Social Innovation and the UrbanTech Centres of Expertise. Study materials will be developed based on the insights that are generated, and there will be training and coaching programs for professionals and students. The minor in Positive Energy Cities was developed, in cooperation with the ATELIER project, by the Engineering, Built Environment, Applied Psychology, and Business Administration programs.

Future Charging

Funding: SIA RAAK-Pro

Duration: 2019–2023

Partners: TU Delft, the University of Amsterdam, the Municipalities of Amsterdam, Rotterdam, The Hague, and Utrecht, OverMorgen, Vattenfall, Engie, ParknCharge, ElaadNL, Social Charging, Taxi Centrale Amsterdam, the National Knowledge Platform on Charging Infrastructure, Connekt, Mister Green, Last Mile Solutions, and AUAS (project lead)

Website: https://www.hva.nl/urban-technology/gedeelde-content/contentgroep/future-charging/future-charging.html

Energy and Innovation Team: Rick Wolbertus (project lead), Mylene van der Koogh, Shakila Dhauntal, and Renée Heller

The rollout of charging infrastructure in the Netherlands is now in a new phase: the explosive growth of electric transport means that the rollout of charging infrastructure must also take a quantum leap in terms of scale. In the Future Charging project, AUAS is investigating, together with 18 project partners, the charging infrastructure of the future. The aim is to gain insights, through various simulations, into the effects of future scenarios on the use of charging infrastructure and their impact on the electricity grid and on public space. In this way, the research project is facilitating and accelerating the introduction of electric driving on a large scale. Within the project, we are expanding this knowledge to different sectors, such as logistics and car-sharing, but we are also looking at other charging solutions such as fast chargers. Recently, for example, we have also analysed the effect that the various lockdowns during the COVID-19 pandemic have had on charging patterns. The project is also contributing to analyses of mobility within the Atelier project. AUAS worked on the projects on an interdisciplinary basis with data scientists, technical/business experts, energy experts, designers, and social scientists. Students from the Faculty of Technology work on the project for internships or to earn credit, while those in the Data Science minor work on cases and assignments from the project.

Flexpower

Funding: EU Interegg NSR, and contract research

Duration: 2019–2022

Partners: the municipality of Amsterdam, Liander, Vattenfall, Heijmans, Elaad, and AUAS (project lead)

Website: https://www.hva.nl/urban-technology/gedeelde-content/contentgroep/future-charging/future-charging.html

Energy and Innovation Team: Rick Wolbertus (project lead) and Renée Heller

The Flexpower Amsterdam project is looking into how smart charging can ease the burden on the electricity network. AUAS is looking at whether the speed at which electric cars are charged can be adjusted in accordance with how much energy is available on the electricity grid. Sixty charging stations are equipped with software that allows the charging speed to be changed throughout the day, depending on how many cars are charging at the same time. Charging is faster at quiet moments, and slightly slower during peak times. There is ongoing cooperation with the Urban Analytics research group on data analysis and modelling.

Electric-vehicle charging-session data management

Funding: contract research
Duration: 2014–
Partners: municipalities of Amsterdam, The Hague, Rotterdam, and Utrecht, the Amsterdam Metropolitan Region, and AUAS (project lead)
Energy and Innovation Team: Simone Maase (project lead), Peter Odenhoven, Nico van Bruggen, Mo Hoogeveen, and Freddie van Haaren.

A data-infrastructure system has been set up with servers, protocols, and a dedicated data team that ensures the careful storage and management of charging-session data from the four municipalities and the Amsterdam Metropolitan Region, as well as the careful handling of access to that data by the municipalities themselves and by researchers from within and outside AUAS. This data is currently being used in our research on electric-vehicle charging infrastructure; in the Future Charging, Flexpower, and ATELIER projects; and by students, for instance in the Data Science minor.

Learning Communities system-integration data

Funding: System Integration Programme and Human Capital Agenda of the Energy Top Sector
Duration: 2020–2021
Partners: Hanze University of Applied Sciences (project lead), HAN University of Applied Sciences, TU Delft, AUAS
Energy and Innovation Team: Simone Maase (project lead), Shakila Dhauntal, and Renée Heller

In these learning communities, the central question is how enough technically trained workers can be made available for the energy transition in the near future—people who are able to implement solutions to systemic issues. The subthemes involved are: a) flexibility; b) energy systems and conversion; c) data, modelling, and digitisation; d) smart multi-commodity energy systems. AUAS is taking the lead on the data related to the subthemes.

The Hour Matching project

Funding: TKI Urban Energy: Public-Private Cooperation Subsidy from the RVO
Duration: 2021–2022
Partners: Vattenfall, UvA-AUAS Facility Services, and AUAS (project lead)
Energy and Innovation Team: Peter Quaak (project lead), Samuel de Vries, Hamdi Elsayed, and Renée Heller

It is not only electric cars that can play a role in the balancing of the electricity grid in the future—there are also options for flexibility in the built environment. Energy supplier Vattenfall is experiencing growing demand from large customers to "match" the supply and demand of renewable electricity on an hourly rather than an annual basis. Hourly matching can ensure that more renewable sources are used locally, that fewer cables need to be laid, that fewer back-up systems are needed, and that less energy needs to be purchased at moments when it is expensive. In this project, which we are running with Vattenfall and UvA-AUAS Facility Services, we are investigating options for flexibility on both the demand and the supply side, such as demand management and various forms of storage. The first cases we are looking into involve a number of UvA-AUAS buildings.

The DC Charging Square project

Funding: TKI Urban Energy
Duration: 2018–2022
Partners: Timeshift, Ecotap, and AUAS (project lead)
Energy and Innovation Team: Willem Knol (project lead), Rob Schaacke, Jos Warmerdam, and Shakila Dhauntal

The expectation is that, as more cars are charged with DC, charging will be more efficient and easier to control than with the standard AC connections (AC = alternating current). In this project, a charging station and control strategies for the charging square are being developed, along with a storage system. Tests take place in the lab and at a test site run by one of our partners. In addition, the current laws and regulations for networks and devices are based in large part on the use of AC, and the research we are doing will help when it comes to the drafting of sound standards and regulations. Students from Engineering are working on the project for internships or to earn credit.

VAP-DC

Funding: TKI Urban Energy: Public-Private Cooperation Subsidy from the RVO
Duration: 2020–2022
Partners: ASR (project lead), Kropman, Venema, and AUAS
Energy and Innovation Team: Jos Warmerdam (project lead), Rob Schaacke, and Edward Heath

In the VAP-DC project, we are going to test how the charging square functions when it is connected to solar panels. The technical design of the charging station was made last year, and testing and monitoring will follow. We are developing and testing control strategies and components, first in the controlled environment of our own lab, and then in the field with charging stations and cars. One of the major challenges here is preventing excessive stray currents, which can cause corrosion in the structural supports in buildings. We take measurements in this connection with an extensive network of sensors in the building. The research we are doing here will help when it comes to the drafting of standards and regulations. Students from Engineering are working on the project for internships or to earn credit.

From Traction Network to Smart DC Electricity Network

Funding: TKI Urban Energy: Public-Private Cooperation Subsidy from the RVO
Duration: 2021–2023
Partners: The Hague University of Applied Sciences (project lead), Dynnic, HTM (public-transport operator in The Hague), the municipality of Amsterdam, GVB (public-transport operator in Amsterdam), Witteveen+Bos, DC Opportunities
Energy and Innovation Team: Jos Warmerdam (project lead), Rob Schaacke, and Edward Heath

In the From Traction Network to Smart DC Electricity Network project, we are investigating whether and how the DC supply network for the tram and metro system can be used to support the electricity network. Trams, metros, trains, and trolleys have a separate DC network below or above ground, managed by transport and transport-infrastructure companies. This network has a strong focus on always being able to deliver peak load when a metro or train needs to run. If this network could also be used to support other parts of the electricity supply or separate applications, the public electricity network would not need to be reinforced so quickly in some locations. This requires not only cooperation among parties with different goals and interests, but also regulatory and regulatory-technical development and, as with the previous project, the further development of adequate legislative standards.

Energy savings and revenue models for adjusting central-heating systems

Funding: SIA KIEM
Duration: 2021–2022
Partners: TVVL, Milieu Centraal, Deltares, Energiepaleis, Fedec, and AUAS (project lead)
Energy and Innovation Team: Samuel de Vries (project lead) and Mark van Wees

For heat savings in existing systems, we have just started a project to set natural-gas boilers in homes at lower temperatures and determine the extent of the resulting savings. This project also aims to investigate which types of homes are suitable for low-temperature heating and can thus be switched to a heat pump in the future without any modifications to the delivery system.

Rira Amstel III

Funding: RVO, Top Sector Energy
Duration: 2018–2021
Partners: Equinix, Escoplan, Huygen, Greenvis, VillaVille, AUAS (project lead)
Website: www.rira-project.nl
Energy and Innovation Team: Felia Boerwinkel (project lead), Egbert-Jan van Dijk, and Renée Heller

The Rira Amstel III project is looking into the use of low-temperature heat networks, particularly in renovations and restructuring. The Amstel III area in Amsterdam Zuid-Oost will be used for the case study. In the project, we drew up an assessment framework and turned it into a serious game. We are playing this game with both of the parties involved, and with students, in order to gain insights into the choices that parties can make individually and collectively, and into which technical systems might be chosen on this basis. Students from Engineering and Built Environment did a project or an internship.

The UvA-AUAS Buildings project

Funding: contract research, and project application under review
Duration: 2018–
Partners: AUAS (project lead)
Energy and Innovation Team: Peter Quaak (project lead), Karen Williams

We have been working with UvA-AUAS Facility Services and Housing for several years on making our own buildings more sustainable, for instance through feasibility studies on a heat pump or a low-temperature heat network. We are also working on setting up a comprehensive monitoring plan for energy flows. Sensing and data analysis play a major role here. Researchers, lecturers, and students alike are really keen to work on our buildings. Students from Engineering are working on the project for internships or to earn credit.

Cold in the city

Funding: SIA KIEM, and project application under review
Duration: 2018–
Partners: Klimaatverbond, W/E Adviseurs, Tauw, and AUAS (project lead)
Website: https://www.koelebuurt.nl
Energy and Innovation Team: Froukje de Vries (project lead) and Samuel de Vries

As a result of climate change, heat waves are becoming more and more frequent in the Netherlands. In large cities, the heat-island effect occurs, making temperatures especially high during warm periods. Dutch housing is not designed to cope with this, and people experience health and other problems as a result. We already see that, in heat waves, many people buy an air conditioner. This additional energy consumption is not yet properly accounted for in forecasts of energy consumption in existing dwellings or in our sustainability efforts.
More and more attention is being paid to heat in urban environments. Research has been done mainly on the heat-island effect and on measures to cool outdoor areas. We are working with the Water in and around the City research group to look at heat in the home. We have taken measurements and conducted surveys among residents of various types of home, and we are planning to expand this with a large-scale measurement campaign with various housing corporations and municipal health services.

Renée Heller's CV

Renée Heller, PhD, has been Professor of Energy and Innovation in the Faculty of Technology and in the Urban Technology research program at AUAS since 2020. Before that, she was a senior lecturer in Sustainable Energy Systems within the Engineering program and the Urban Technology research program. At AUAS, she researches heat networks, positive energy districts, the integration of electric transport, solar cells, and heat technologies into the electricity grid, and the integration of solar cells into buildings. She started at AUAS in 2014 as a Project Manager with the Bachelor's of Engineering program, where she was responsible for setting up an integrated study program in Engineering.

Renée studied Physics and General Literature in Utrecht from 1988 to 1995. In Physics, she studied history and the philosophy of science and graduated with a thesis on a method to produce thin amorphous silicon layers for solar

Figure 13. Urgenda Climate March along the Kromme Rijn, on the way to Amelisweerd, on 20 October 2021 (photo credit: Ontmoeting Klimaatmars Urgenda 20 oktober – Vrienden van Amelisweerd).

cells more quickly. In General Literature, she specialised in women's studies, and graduated with a thesis on stories about quantum mechanics in feminist and new-age literature. In her PhD research at Utrecht University from 1995 to 2000, Renée did materials-science research on storing hydrogen in thin metal layers. She then went on to work for Ecofys, an international consultancy firm in energy savings and renewable energy, where she was responsible for the R&D of a spin-off company, Innogrow, that specialises in horticultural greenhouses. The company combined heat pumps, heat buffers, underground heat storage, cooling, and the cogeneration of heat and electricity to create a system that saves energy and increases production. Starting in 2011, she was Unit Manager of the Built Environment and then of the Integrated Energy Systems units. She has carried out many assignments as project leader, including energy systems for residential areas and business parks, mainly on behalf of municipalities and energy companies.

Renée is a member of the Scientific Advisory Board of Milieu Centraal, and is actively involved in the LEVE and Urban Energy platforms.