Uncertainty Reduction in Smart Energy Systems (URSES)

Enabling a rapid transition to a reliable, affordable and sustainable energy system

NWO

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Enabling a rapid transition to a reliable, affordable and sustainable energy system

Partners in URSES and/or URSES+

Universities

- Delft University of Technology
- Eindhoven University of Technology
- Erasmus University Rotterdam
- University of Groningen
- Utrecht University
- University of Twente
- Wageningen University & Research

Electricity companies, utilities & network operators

- Alliander/Liander
- Delta
- Eneco
- ENGIE
- Enexis
- Essent
- GasTerra
- Locomation
- Statkraft
- Stedin
- TenneT
- Waternet

Research institutes/ consulting/knowledge and innovation centres

- Accenture
- CWI (NWO)
- DNV Kema
- DRIFT
- DWA
- E-Bridge
- E-Laad
- Greenspread
- KWR Watercycle Research Institute
- Tauw
- The Green Village
- The Demand Centre (UK)
- VSL (National Metrology Institute)

Private companies

- ABN AMRO
- Amsterdam ArenA
- BAM
- Bellamy BV
- Cofely
- Croonwolter&dros
- DNV-GL
- GPX
- Hytruck
- IBM
- Jedlix
- National Instruments
- NewMotion
- Priva
- Q-Park
- Shell
- Thales

Public partners

- Energiecoöperatie Zuiderlicht U.A.
- Energiek Vasse
- Lochem Energie
- Milieu Centraal
- Noordelijk Lokaal Duurzaam Energie
- Provincie Noord-Holland
- Regio Achterhoek
- Regio Twente
- Stichting SETS
- Urgenda
- Van Gogh Museum

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Preface

Sustainability has become an important topic in modern society. It concerns all kinds of areas from logistics and transportation, to waste management, environment, and energy. Today, our energy system mainly depends on non-sustainable fossil fuels. These are not only exhaustible, but also pollute the environment via greenhouse gas emissions. We need new energy systems, that are reliable in the broadest sense of the word. That is where URSES comes in.

To make our society sustainable, targets have been set for the upcoming years, by various governments, from local to European levels. For energy systems, these will especially have a large effect on the electricity grid. A massive introduction of energy from renewable sources, such as solar and wind energy, will affect the planning of electricity supply. Due to the nature of the weather, this supply becomes uncertain and intermittent, and the possibility of planning becomes limited.

"Due to the nature of the weather, this supply is uncertain and intermittent, and the possibility of planning becomes limited."

Daily uncertainty becomes a reality

When consumers use such renewable resources, they also become small producers. This leads to large amounts of uncertain and decentralised electricity supply. The increasing number of intensively energy-consuming devices, like electric cars and heat pumps, results in even more uncertainty. Hence, the organisation and planning of electricity supply and demand become a challenge and daily uncertainty a reality. In parallel, the role of gas can change, like hydrogen gas becoming an alternative major energy carrier for consumers.

At the same time within the energy domain, similar to other sectors, smart systems are expected to arise. Supported by smart ICT, Smart Energy Systems (SES) will appear, dealing with decentralised, uncertain, renewable electricity production. Several developments have been ongoing to realise the Smart Energy Systems of the future, using existing technologies and approaches. However, it appeared that various substantial and fundamental research questions had to be answered as well. This concerned a wide range of disciplines, including mathematics, social sciences, computer science, electrical engineering, control theory, economics, and innovation sciences.

Three themes

To this end, the **URSES** programme (**U**ncertainty **R**eduction in **S**mart **E**nergy **S**ystems) was created in 2014 with a focus on three themes. The first theme concerned the daily operations and management of the SES with its uncertainties. The second theme dealt with analysing the SES with uncertain states and expanding it. The third theme, in its turn, focused on customers, organisations, institutions and uncertain behaviours.

The URSES programme was able to fund eleven prominent projects. A variety of important research challenges was addressed; from controlling power flows, planning energy storage systems, and embedding energy markets, to designing adaptive user clustering, analysing emerging social practices, and enabling the energy transition. To take a step towards the application of their results, several of the projects were extended via the URSES+ programme.

Joint forces

URSES was a interdisciplinary activity by the NWO domains of Social Sciences and Humanities, Applied and Engineering Sciences, and Science, and was supported by Shell. For URSES+, Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute) and TKI Switch2Smartgrids joined forces with NWO. Both were a counterpart of the general programmes organised by Topsector Energy. URSES and URSES+ addressed the more fundamental research questions, while the application and pilot projects were embedded within the Topsector Energy.

Via cooperation between projects and yearly programme conferences, URSES started building a community of researchers involved in future energy systems. Industrial partners were also connected, via project user committees and programme conferences — which guaranteed relevant research for future applications in smart energy systems.

Steps towards application

A fundamental basis of results has been laid in the URSES and URSES+ programmes. These can be used for further application and development in other projects and activities, as well as for successive fundamental research initiatives. In some cases, several steps have already been taken towards real applications. In addition, the success of URSES and URSES+ programmes has led to new programmes on future energy systems, especially regarding energy system integration.

I want to emphasize once more the importance of social sciences and humanities, and sciences joining forces in future energy research programmes.

The subsequent chapters show the appealing activities and excellent results of the projects in more detail, including the engaging views of several researchers. We hope you will have an inspiring time reading about them.

Han La Poutré

Aim of the programme: Uncertainty Reduction in Smart Energy Systems (URSES)

From generating electricity at home with solar panels, plugging electric cars into the grid to developing improved systems for heat storage systems: there is a demand for more intelligence in the electricity network. Smart energy systems are of great importance for a reliable supply of energy and for keeping electricity from new energy sources affordable. But, actors in the energy systems are facing many uncertainties. Which uncertainties can be distinguished? What are the effects of uncertainties on e.g. users? How can these uncertainties be reduced? Research programme URSES was initiated to provide answers to these urgent questions.

In 2013 a call for research projects in the Uncertainty Reduction in Smart Energy Systems (URSES) research programme was issued. This programme, being part of the NWO theme Sustainable Energy, was a joint initiative of the NWO division for the Social Sciences, NWO division for the Physical Sciences, NWO Technology Foundation and Shell.

Objective

The objective of URSES was to contribute to the reduction of uncertainty for actors in the energy chain by developing science and tools that are needed for smart energy systems (SES). It also aimed to provide insight into the causes, character and effects of these uncertainties from a social and behavioural science perspective. URSES should enable a fast transition to a reliable, affordable and sustainable energy system.

"URSES should enable a fast transition to a reliable, affordable and sustainable energy system."

Application for business and society

A requirement of the research programme was that each project - on behalf of a consortium – had to demonstrate the capacity to combine scientific excellence with a proven ability to make research results applicable for business and societal purposes. Another important objective was to stimulate participation of private or public societal partners within projects, following the conviction that participation of multiple parties strengthens innovation networks in the field of smart energy systems, stimulates demand articulation by private and public organizations and increases the chances of application of research results by users. URSES aimed to initiate collaborations of interdisciplinary research groups from different departments and/or universities.

Budget

The total budget for the programme was 6.5 million euro's. Shell contributed 2 million euros (including 0.4 million euros 'TKI surcharge' to this programme as part of an investment of 20 million euros in the Shell-NWO programme 'Computational sciences for energy research'.

Projects

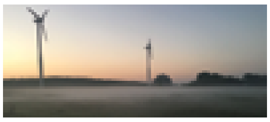
In 2013 eleven projects were rewarded within URSES. These projects and their results are presented on the following pages.

URSES+ – follow-up URSES-projects

In 2016, Shell, Amsterdam Institute for Advanced Metropolitan Solutions (AMS), TKI Switch2SmartGrids (S2SG) and NWO joined forces in the URSES+ programme. This call offered ongoing projects the opportunity to submit an application to further develop their ongoing URSES research towards actual application. The results are presented on pages 32 to 68.

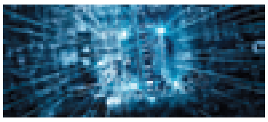
URSES projects 2014

These eleven research projects started at the beginning of 2014.



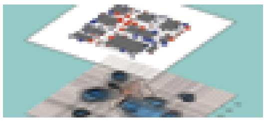
Gaming beyond the Copper Plate: scheduling flexible consumption and decentralised generation within distribution constraints — dr M.M. de Weerdt, TU Delft

Car as Power Plant (CaPP) – Fuel cell cars creating a detachable decentralized multi-modal smart energy system — prof dr ir Z. Lukszo, TU Delft

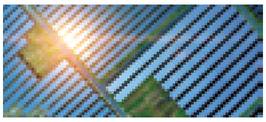


Distributed Intelligence for Smart Power routing and mATCHing (DISPATCH) — dr Phuong Nguyen, Eindhoven University of Technology

Transition Patterns Enabling Smart Energy Systems (TRAPESES) — dr D.A. Loorbach, Erasmus University Rotterdam



Aquifer Thermal Energy Storage Smart Grids (ATES-SG) — dr T. Kevicky, TU Delft

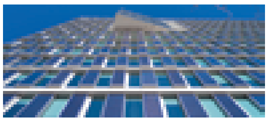


ENergy-Based analysis and control of the grid: dealing with uncertainty and mARKets (ENBARK) — prof dr C. De Persis, University of Groningen

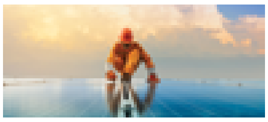
Realizing the smart grid: aligning consumer behaviour with technological opportunities (SMARTER) — prof dr L. Steg, University of Groningen

Emerging Energy Practices in the Smart Grid (Emerging) — prof dr ir G. Spaargaren, Wageningen University & Research

Stable and scalable decentralized power balancing systems using adaptive clustering (STASCADE) — prof dr F.M.T. Brazier, TU Delft



Smart Regimes for Smart Grids (SmaRds) — dr M.J. Arentsen, University of Twente



PMU Supported Frequency-Based Corrective Control of Future Power Systems (PMU) — dr ir M.S.E.E. Popov, TU Delft

Gaming beyond the Copper Plate

Team

- **Dr Mathijs de Weerdt**, project lead, Associate Professor on Algorithms for Planning and Optimization, Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology
- **Dr Matthijs Spaan**, Delft University of Technology
- **Rens Philipsen**, PhD student Delft University of Technology
- **Erwin Walraven**, PhD student Delft University of Technology
- **Dr Germán Morales España**, postdoctoral researcher Delft University of Technology
- **Dr Natalia Romero Lane**, postdoctoral researcher Delft University of Technology

Partners

- Alliander
- Bellamy BV
- Croonwolter&dros
- Delft University of Technology
- E-bridge
- GPX
- Stedin

Lead time

1 October 2014 – 30 September 2018

Full title

Gaming beyond the Copper Plate: scheduling flexible consumption and decentralised generation within distribution constraints.

https://www.tudelft.nl/powerweb/research/urses-projects/gaming-beyond-the-copper-plate-urses

Rationale and questions

The irregular characteristics of renewable energy sources influence electricity prices and consumption. However, costs can be lower if a combination of efficient planning and scheduling algorithms are used.

The researchers in this project developed contributions to planning, auction design and unit commitment under uncertainty. In addition, they looked at better ways of dealing with congestion in capacity-constrained distribution grids.

Results

The researchers proposed a new approach with lower social costs to congestion management, compared to current solutions. The approach relies on algorithms that can efficiently schedule flexible loads of multiple customers within the capacity of the local energy networks. They designed a game to get consumers to share their (planned) use and flexibility within shifting loads. The researchers also developed new planning approaches under incentive constraints. In their analysis, they included decentralised combined heat and power production. These methods were evaluated in simulations based on data from a real case.

Insights & recommendations

➟ A complicating factor for efficient planning is that demand in the distribution network is flexible. However, temporary constraints are acceptable in practice and can be limited. The researchers designed a new algorithm that can tune these limits to improve the distribution of available resources. Experiments show that this approach is the best method to coordinate the network capacity for uncertain, but flexible loads.

➟ The unit commitment problem (UC) in electrical power production stands for a large family of mathematical optimisation problems where the production of a set of electrical generators is coordinated to achieve some common target. This is usually either matching the energy demand at minimum cost or maximise revenues from energy production. There are many methods for UC that do not include wind curtailment. The contribution of the researchers is the inclusion of wind curtailment. This ensures improvements like the reduction of computation time and operational costs.

➟ The researchers developed an alternative scheduling process that represents momentary electricity production on a larger scale. They also provided market design options, combining pricing and market rules.

Mathijs de Weerdt
"This was the first project that I was leading with more than six researchers involved and where we had regular meetings with the user committee. I got much more interested in the field of operations research applied to energy systems. Usually, research contributions consist of papers and sometimes some experimental programming code. We designed new electricity market rules that can lead to a significant reduction in costs and CO_2 and would free up costly reserve generation for system security, especially important in the entry transition."

CaPP

Team

- **Prof Zofia Lukszo**, project lead, Professor in Energy and Industry group, Faculty of Technology, Policy and Management, Delft University of Technology
- **Prof Ad van Wijk**, Associate Professor in Energy Technology Section, Process and Energy, Department of the Mechanical, Maritime and Materials Engineering faculty, Delft University of Technology
- **Prof Bart de Schutter**, Head of Department Delft Center for Systems and Control, Delft University of Technology
- **Farid Alavi,** PhD student Delft University of Technology
- **Vincent Oldenbroek**, PhD student Delft University of Technology
- **Esther Park Lee**, PhD student Delft University of Technology
- **Dr Reinier van der Veen** Delft University of Technology
- **Dr Samira Farahani,** postdoctoral researcher Delft University of Technology

Partners

- BAM
- Delft University of Technology
- Eneco
- GasTerra
- Hytruck
- Q-Park
- Shell
- The Green Village

Lead time

1 September 2014 – 31 October 2018

Full title

Car as Power Plant – Fuel cell cars creating an integrated, efficient, reliable, flexible, clean, multi-modal, and smart transport and energy system.

Rationale and questions

Clean, efficient, reliable, and flexible transport and energy systems are often approached as separate challenges. However, using fuel cell cars as power plants could be a joint answer to these challenges. When parked, fuel cell cars produce electricity from hydrogen – more efficiently than our current electricity system. Additionally, they provide cleaner transportation. The '**Car as Power Plant (CaPP)**' project investigated the feasibility of such an integrated transport and electricity system.

Results

The CaPP-researchers designed a detachable and decentralised multi-modal energy system, composed of interlinked energy carriers. This resulted in three system design concepts that can function as blueprints for future energy and transport systems:

1. the Car as Power plant in Smart City Areas
2. the Car as Hospital Power Plant
3. the Car Park Power Plant

Besides that, the researchers designed a robust Model Predictive Control algorithm for a CaPP-microgrid system to guarantee the power balance condition when dealing with uncertainty. They also worked on several business concepts to explore the economic potential of this microgrid system. This included a modelling and cost-benefit analysis for the Car Park Power Plant case.

Furthermore, the researchers developed a framework accounting for technology, institutions, and actors' perspectives.

Insights & recommendations

➟ When renewable power generation is scarce, a community microgrid with photovoltaic systems, wind turbines, and fuel cell cars can be used to provide vehicle-to-grid power.

➟ Modelling and simulations have shown two things:

1. Price-based contracts can be applied to selling vehicle-to-grid in the wholesale electricity market.
2. Volume-based contracts can be used for balancing the local energy supply and demand in a microgrid. Therefore, fuel cell car owners and vehicle-to-grid coordinators need to work on new agreements and contracts.

The models can provide a base for exploring market strategies and improving performance in a system dependent on vehicle-to-grid.

Zofia Lukszo
"We proved that hydrogen cars could act as a buffer in a sustainable energy system. However, the CaPP project team contributed to broader research into the role of hydrogen in the energy transition. Hydrogen can have a substantial contribution to this transition, as it can not only contribute to the decarbonisation of the energy and mobility sectors, but also to the process industry and built environment."

DISPATCH

Team

- **Dr Phuong Nguyen**, project lead, Associate Professor in the research group Electrical Energy Systems, Eindhoven University of Technology
- **Prof Martha Roggenkamp**, Professor of Energy Law and Director of the Groningen Center of Energy Law, University of Groningen
- **Prof Johann Hurink**, Professor Applied Mathematics, University of Twente
- **Prof Gerard Smit**, Professor Computer Architectures for Embedded Systems, University of Twente
- **Niels Blaauwbroek**, PhD student, Eindhoven University of Technology
- **Maryam Hajighasemi**, PhD student, University of Twente
- **Dirk Kuiken**, PhD student, University of Groningen
- **Dr Shahab Shariat Torbaghan**, postdoctoral researcher, Eindhoven University of Technology
- **Dr Thai Vo**, postdoctoral researcher, Eindhoven University of Technology
- **Dr Thijs van der Klauw**, postdoctoral researcher, University of Twente
- **Dr Heyd Fernandes Más**, postdoctoral researcher, University of Groningen

Partners

- Alliander
- Cofely
- DNV GL
- Eindhoven University of Technology
- Eneco
- Enexis
- Essent
- IBM
- Johan Cruijff ArenA
- Statkraft
- Tennet
- University of Groningen
- University of Twente

Lead time

1 August 2014 – 1 July 2019

Full title

Distributed **I**ntelligence for **S**mart **P**ower routing and m**ATCH**ing

Rationale and questions

The integration of renewable energy sources challenges the electricity system with more uncertainties on all timescales. Also, new demand technologies, such as electric vehicles, make it challenging to guarantee constant stability and reliability. To overcome these challenges, the DISPATCH project team proposed a decentralised interaction between the two separate mechanisms that control the electricity system:

1. Suppliers and large consumers, such as Vattenfall and Essent, trade electricity based on forecasts, resulting in the distri-bution of capacity for the next day. The planning is rough and full of uncertainty, with 15-minute intervals.
2. National and regional grid operators, such as Alliander and Stedin, control the system by keeping the voltage, current and frequency within safe limits. They do this on a much finer time scale: from milliseconds to minutes.

The question DISPATCH worked on was: how to control and balance the power flows in real-time, without involving the market and deploying its flexibility?

Results

The researchers developed a framework that combines the 15-minute schedules of the energy suppliers with the much shorter time schedules of grid operators. It required a multi-disciplinary approach and included: electrical power engineering, advanced control theory, the use of new ICT concepts, and appropriate legal and organisational instruments.

Insights & recommendations

➟ Communication is crucial for providing correct real-time data about control and the balance of power flows. It is the responsibility of national policymakers to make sure that these services become available. They should also create a level playing field in the EU to guarantee comparable conditions.

➟ Future electricity distribution networks require advanced monitoring and control applications (MCAs). The researchers have designed accurate and integrated simulation solutions to evaluate these MCAs.

➟ The ultimate goal is to create a testing environment to verify various so-called 'Distributed Intelligence-based Applications'. To generate an overview of these applications, the researchers developed a conceptual framework.

Dr Phuong Nguyen

"With our multi-disciplinary team, we managed to address different aspects of the development of Smart Energy Systems. DISPATCH was extraordinary in the way that we conducted our research. It laid the foundation for further development in the field, such as grid monitoring capability, implicit versus explicit demand response, or data governance. Being a coordinator of such a large project was special, especially since I had just started my academic career path. I loved the annual project meetings in which we shared our recent findings with involved industry partners."

TRAPESES

Team

- **Prof Derk Loorbach**, project lead, director of DRIFT and Professor of Socio-economic Transitions at the Faculty of Social Science, both at Erasmus University Rotterdam
- **Dr Matthijs Hisschemöller**, Erasmus University Rotterdam
- **Rick Bosman**, PhD student, Erasmus University Rotterdam
- **Antonia Proka**, PhD student Erasmus University Rotterdam
- **Dr Marloes Dignum**, postdoctoral researcher, Delft University of Technology
- **Dr Daniel Scholten**, Delft University of Technology
- **Dr Pieter Jelle Beers**, Erasmus University Rotterdam
- **Ilonka Marselis**, Erasmus University Rotterdam

Partners

- Alliander
- Delft University of Technology
- Erasmus University Rotterdam

Lead time

1 May 2014 – 1 April 2019

Full title

TRAnsition **P**atterns **E**nabling **S**mart **E**nergy **S**ystems

https://drift.eur.nl/nl/projecten/trapeses/

Rationale and questions

The goal of the research project was to develop a better understanding of the dynamics and mechanisms for accelerating the energy transition. In these transitions, disruptive events and technological and social innovations destabilise dominant regimes and the actors involved. This triggers chaotic processes in which new alliances, routines, networks and rules develop. Such transitions cannot be planned top-down, but evolve as involved actors strategise, reconnect, develop and push innovations or resist transformative change. The researchers studied when in such a context emerging niches align with traditional actors such as grid operators, energy companies or policy departments. This 'hybrid transition pattern' is considered socially most desirable: infrastructures and investments are repositioned and based upon new demand, logics and values.

Results

The researchers developed a better analytical, conceptual and empirical understanding of the hybrid transition pathway. This includes insight into the dynamics of destabilisation at the level of regimes. Traditional actors are then forced to reposition because of external pressures, resulting in erosion of previous shared interests and positions. In this context it is possible to distinguish between more proactive and more resisting actor positions, where proactive ones can transform internally and engage with emerging niches. The researchers also explored the dynamics at the niche level in a context of an accelerating energy transition. Not all niches want to scale or align with incumbent actors; a lot of politics and dilemmas surface when alternatives start to mature and threaten the existing regime. Part of this project was based on transdisciplinary research. Some 40 to 50 individuals, representing a large variety of niches (cooperatives, entrepreneurs, change agents) and regime actors (incumbents, banks, ministries), were involved in co-creating a vision for the energy transition. Strategic dialogue with

niche actors (mainly leading energy cooperatives) helped create an emergence and acceleration strategy and a shared ambition for the bottom-up energy movement.

Insights & recommendations

➟ The concept of 'transition space' was developed as a broader term, unpacking the process of destabilisation. During this process actors embedded in a regime context start to diverge, face increasing pressures for transformation and are forced to reposition and reorient. This has implications for internal culture, capacities, as well as business strategy and investments. What tensions and responses arise when proactive incumbents enter this transition space? This was explored through an embedded case study within Alliander and an internal transition management process within the Port Authority of Rotterdam.

➟ Cooperatives should seek to strategise across niches and develop a shared agency to engage more evenly with incumbents.

➟ This collective empowerment and strategising was explored through action research by creating a 'strategic dialogue' with leading actors from the Dutch energy cooperative movement. They identified shared values and developed a shared narrative and quantitative contribution to the energy transition. When it comes to creating shared understanding it showed the value of bringing together individuals to discuss collective futures, rather than representatives to discuss agreements.

➟ A transdisciplinary approach was used to understand the transformative challenges for moving towards sustainable heating in the built environment in Amsterdam. One hundred citizens were mobilised to create public pressure and support for sustainable heat transitions in new area developments. The research uncovered the dynamics that support fossil-based heat and put this issue on the political agenda. It showed institutional lock-in mechanisms and the challenges of introducing more transformative and radical new technologies in new area developments, but also highlighted the need for citizens to work together with professionals to influence technological considerations, economic choice and decision-making.

Derk Loorbach
"The dialogue between Shell, Statkraft, the city of Amsterdam and cooperative Zuiderlicht for a corporate cooperative wind project in Amsterdam, 'Hybrid transition pathway in the making', made TRAPESES followed by ABC special for me. By offering a fresh perspective we were able to use the project to stimulate a community of active organisations and initiatives in the field of the energy transition to think and work differently."

ATES-SG

Team

- **Dr Tamas Keviczky**, project lead, Associate Professor at Delft Center for Systems and Control, Delft University of Technology
- **Prof Theo Olsthoorn**, Parttime professor Geohydrology, Delft University of Technology (CiTG)
- **Dr Jan Kwakkel**, Delft University of Technology (TPM)
- **Dr Martin Bloemendal**, postdoctoral researcher, Delft University of Technology (CiTG)
- **Vahab Rostampour**, PhD student, Delft University of Technology (3mE)
- **Marc Jaxa-Rozen**, PhD student, Delft University of Technology (TPM)

Partners

- Delft University of Technology
- DWA
- KWR
- Priva
- Provincie Noord-Holland
- Tauw
- Waternet

Lead time

1 August 2014 – 30 September 2018

Full title

Aquifer **T**hermal **E**nergy **S**torage **S**mart **G**rids

https://www.tudelft.nl/energy/aquifer-thermal-energy-storage

Rationale and questions

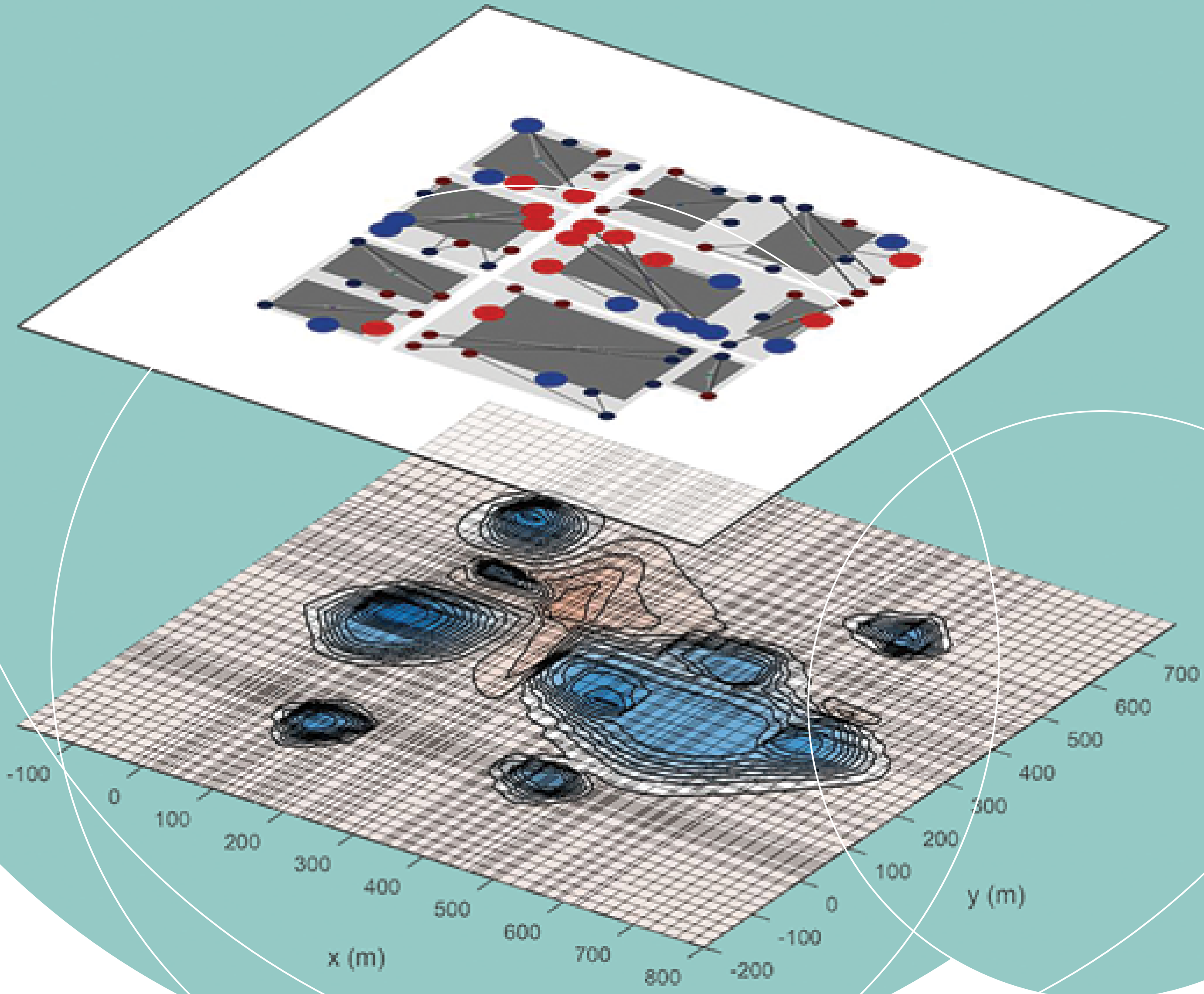
Heating and cooling in buildings account for 25% of the global energy demand. Hence, to mitigate climate change, developing and adopting energy-efficient technologies for buildings is key. An example of such a technology is the Aquifer Thermal Energy Storage (ATES); a popular and competitive geothermal energy technology. The Netherlands is one of the global technological leaders in the field, with ATES systems in close to 10% of new buildings. Unfortunately, the current performance of the technology falls below expectations. This is mainly due to operation and regulation practices, such as spatial planning guidelines. Therefore, the main research goal for the ATES-SG project was to develop improved methods for the planning and operation of ATES systems.

Results

The researchers investigated how ATES control configurations and planning policies affect the adoption of geothermal energy technology in urban areas. Besides that, they questioned how this affects the sustainable use of the subsurface as a resource for thermal storage.

The result is a proof-of-concept for interdependent ATES/building control systems. Using a distributed model-based predictive control (DMPC) approach, this proof-of-concept could improve the current operational performance.

The researchers also developed a toolkit that can model and simulate ATES-systems and predict their behaviour over time. Such predictions can be uncertain, which prompted the design of a robust control framework. By supporting the exchange of information between ATES-systems, the framework led to the Smart Grid technology.



Insights & recommendations

➟ Two case studies have shown that the coordinated operation of ATES systems led to an improvement in specific greenhouse gas emission savings. For the idealised case with 75% and for another case with 38%.

➟ It is possible to achieve significant savings by coordinating among nearby buildings. The developed control framework is an excellent tool or creating a balance between uncertain thermal energy demand and production units in individual buildings.

➟ The researchers obtained insights into the processes that affect energy loss in the sub-surface, and they developed methods and guidelines to limit them. These assessment methods can also be used to optimise well placements and be applied to other cities.

Tamas Keviczky
"For me, as project leader, the chemistry and collaboration that has taken place among different disciplines, struck me. Systems and control theory, geohydrology, and socio-technical policy analysis: it was a pleasure to work with such a diverse group. We have learned a lot from each other, and achieved great results and new insights on the effect of ATES planning policies and how advanced control approaches can make a difference."

ENBARK

Team

- **Prof Claudio De Persis**, project lead, Professor Smart Manufacturing Systems, Engineering and Technology Institute Groningen, University of Groningen
- **Prof Arjan van der Schaft**, Professor of Applied Analysis, Faculty of Science and Engineering, University of Groningen
- **Prof Jacob van der Woude**, Associate Professor for Mathematical System Theory, Delft University of Technology
- **Prof Jacquelien Scherpen**, Professor of Discrete Technology and Production Automation, University of Groningen
- **Mahya Adibi**, PhD student, Delft University of Technology
- **Tjerk Stegink**, PhD student, University of Groningen
- **Dr Nima Monshizadeh Naini**, postdoctoral researcher, University of Groningen
- **Dr Krishna C. Kosaraju**, postdoctoral researcher, University of Groningen

Partners

- DNV-GL
- TenneT

Lead time

16 March 2014 – 31 December 2018

Full title

Energy-based analysis and control of the grid: dealing with uncertainty and markets in an urban environment

Rationale and questions

In the future, it will be a challenge to guarantee stable grid operation and maintain cost-efficiency. Power markets should evolve towards real-time decision making to handle this challenge. A transition that can only be successful when using an automated process.

Results

The ENBARK-researchers developed a machine learning model to analyse power grids and market dynamics. They started with simple models, subsequently extending into more complex ones, describing the market dynamics and usage evolution of the grid. In the last year of research, they showed that usage-driven bidding mechanisms lead to an efficient and stable operation of power grids. On the physical network side, a novel technique was implemented, which preserves information about the original network structure. This modular, energy-based approach has been extended to more complex multi-machine learning models and in several models of micro-grids.

Insights and recommendations

➡ The models shed new light on the problem of micro-grid analysis and control. The ENBARK approach allows for large integrated signal analysis of the coupled micro-grid. This is different from the approach in which frequency dynamics is separated from voltage dynamics and analysed.

➟ The researchers considered real-time price-based bidding mechanisms that look at the interaction between the independent system operator and a group of generators. By using frequency measurements as a feedback signal, they showed that the closed-loop system converges to optimal production allocation, guaranteeing physical grid stability.

➟ The researchers illustrated the applicability of their methodologies by designing voltage controllers for DC converters and DC networks.

Claudio De Persis

"We studied the dynamic pricing of electricity in combination with control of the grid. TenneT tested the models we developed. We had to consider the fact that many consumers are afraid of dynamic pricing. Therefore, we needed the valuable insights of colleague researchers within the social and behavioural sciences."

SMARTER

Team

- **Prof Linda Steg**, project lead, Professor of environmental psychology, University of Groningen

- **Prof Floor Alkemade**, Professor of Economics and Governance of Technological Innovation, Eindhoven University of Technology (till 2015 Utrecht University)

- **Prof Wilfried van Sark**, professor Photovoltaics Integration at the Copernicus Institute of Sustainable Development, Utrecht University

- **Dr Ellen van der Werff**, University of Groningen

- **Mart van der Kam**, PhD student, Utrecht University

- **Annemijn Peters**, PhD student, University of Groningen

Partners

- Delta
- Liander/Alliander
- Stedin
- University of Groningen
- Utrecht University

Lead time

1 April 2014 – 1 October 2018

Full title

Realising the smart grid: aligning consumer behaviour with technological opportunities

https://www.rug.nl/gmw/psychology/research-units/environmental-psychology/projects/sub/sub_1_soc_realizing_the_smart_grid_aligning_consumer_behaviour_with_technological_opportunities

Rationale and questions

The benefits of smart energy systems will only be achieved if consumers use them in a way that is aligned with system reliability, efficiency and sustainability. Scenarios and simulation models should take consumer diversity into account, requiring behavioural models.

Results

The researchers developed evidence-based recommendations for further smart energy system development that:

1. include an accurate model of consumer behaviour;
2. take into account the capacity of the energy system;
3. are location-specific.

The scenarios inform distribution system operators and policymakers where and when changes are most needed and appropriate in energy infrastructure, investments, and incentives.

Insights & recommendations

➠ Photovoltaic energy (PV) and electric vehicles (EV) have an uneven distribution of popularity in the Netherlands. EV's are popular in the Randstad, PV's in rural areas – especially in the north. This difference will have implications for the stability of the electrical grid.

➠ The more people adopt an EV for environmental reasons, the stronger their environmental self-identity. This increases the probability that they will also engage in other sustainable energy behaviours.

➠ Tailored information on charging behaviour positively effect on the motivation of EV drivers to charge with renewable energy. This also counts for financial incentives or automated smart charging.

➟ Charging behaviour varies significantly between neighbourhoods. This implies that the policy for charging infrastructure could be best designed locally.

➟ After installing PV's, people are less likely to believe that it has positive environmental effects. This suggests that it is essential to support people in their intentions to use their PV sustainably.

➟ The researchers found that it is essential to strengthening the environmental motivations to adopt sustainable energy technologies to promote consistent, sustainable behaviour. However, they also found that appeals that emphasise environmental benefits were not successful in promoting this behaviour. It also did not affect the motivation to adopt sustainable energy technologies.

Linda Steg
"The collaboration between researchers with different disciplinary backgrounds and practitioners enabled us to develop novel theories and insights, and to address real-life problems faced by practitioners, such as promoting the adoption and use of sustainable energy technologies."

Emerging Energy Practices in the Smart Grid

Team

- **Prof Gert Spaargaren**, project lead, Professor and Chair of the Environmental Policy Group, Wageningen University & Research
- **Prof Geert Verbong**, Professor and Chair of System Innovations & Sustainability Transitions in the section of Technology Innovation & Society, Eindhoven University of Technology
- **Robin Smale**, PhD student Wageningen University & Research
- **Nick Verkade**, PhD student Wageningen University & Research
- **Dr Sanneke Kloppenburg**, postdoctoral researcher Wageningen University & Research
- **Dr Bas van Vliet**, Associate Professor Environmental Policy, Wageningen University & Research
- **Dr Johanna Höffken**, Assistant Professor Technology, Innovation and Society, Eindhoven University of Technology
- **Dr Marten Boekelo**, postdoctoral researcher Wageningen University & Research

Partners

- Eindhoven University of Technology
- Enexis
- Milieu Centraal
- The Demand Centre (UK)
- Wageningen University & Research

Lead time

1 August 2014 – 31 August 2018

Full title

Emerging Energy Practices in the Smart Grid

https://www.wur.nl/en/project/Emerging-energy-practices-in-the-smart-grid.htm

Rationale and questions

Households and other local actors play an increasing role in the transition to more sustainable energy configurations. This calls for specific knowledge about the social relationships between these users and providers of smart grids. The main idea of the research project was that this could best be studied analysing emerging energy practices in detail.

Results

The project focussed on three case studies in households and neighbourhoods:
1. the production of (solar) energy
2. the planning and monitoring of energy consumption with grid balancing
3. storage of energy

These activities resulted from the exchange between energy technologies and two groups: providers and end-users of household energy.

Insights & recommendations

➡ Generating green energy and monitoring production and use have become standardised for households. These practices allow people to experience and realise an active relationship with

their energy use. However, there are still unpredictabilities when it comes to the timing of energy use. An example is the required reorganisation of household activities: some are easier to change than others.

➟ The researchers proposed a new approach to involve people in the governance of smart grids. Their core idea was to distinguish between practices 'domestic consumption' and 'home energy management' (HEM). It is easier to develop new instruments for the co-governance of smart grids after identifying a set of HEM-practices relevant to overall domestic energy performance.

➟ The project identified the emergence of five organisational modes for energy storage:

1. individual autonomy
2. local energy community
3. smart grid integration
4. virtual energy community
5. power market integration

Also, digital platforms for energy exchange emerged. They function as new intermediaries that reconfigure how people access, sell, and buy energy.

➟ Designers, producers, consumers, and intermediaries have different ideas about sustainability communality and transparency of smart grids. The project developed a game-like workshop to discuss these differences. The outcome showed that householders mainly see energy as an area in which they can take responsibility for the environment.

Gert Spaargaren

"This URSES project was special. It gave us time to reflect on and investigate some of the uncertainties surrounding the energy transition. The project generated relevant insights into the role of households in the process. Mostly, policymakers perceive the behaviour of homeowners as an obstacle and uncertainty. We provided new knowledge for both them and energy companies to engage with households in positive ways. We became aware of the important contribution that social science can make to the energy transition. The project was extended with an URSES+ project. This allowed us to explore and analyse both the new opportunities and the risks generated by energy storage technologies and their related software for households engaging with the energy transition."

STASCADE

Team

- **Prof Frances Brazier**, project lead, Professor and section leader System Science of the Department of Multi-Actor Systems, Delft University of Technology
- **Prof Han La Poutré**, (tenured) Professor of Intelligent Energy Systems, Delft University of Technology and senior researcher at CWI, Amsterdam; research group Intelligent and Autonomous Systems.
- **Dr Martijn Warnier**, Delft University of Technology
- **Dr Michael Kaisers**, CWI Amsterdam
- **Nina Voulis**, PhD student, Delft University of Technology
- **Georgios Methenitis**, PhD student, CWI Amsterdam

Partners

- Alliander
- CWI
- Delft University of Technology
- DNV Kema
- Thales

Lead time

1 October 2014 – mid-2019

Full title

Stable and scalable decentralised power balancing systems using adaptive clustering

https://participatorysystems.tudelft.nl/2015/04/stascade/

Rationale and questions

In the future, there will be a need for stable and scalable approaches to balance energy supply and demand in smart grids. For this reason, the STASCADE project focused on designing dynamic clusters of different types of actors and dedicated market mechanisms.

Results

The researchers first defined various dynamic clusters of consumers and producers to coordinate their local load balancing for varying periods amongst each other. Local load balancing allows for new and more reliable solutions which can be used in combination with external market mechanisms. When clusters are dynamic, they can adapt to changing situations, including network failures. The researchers studied different clusters, consisting of a mix of household and service sector buildings. Within these, they achieved to match local supply and demand by using batteries and demand response. Finally, the researchers proposed different market mechanisms for local clustering balancing and incentive mechanisms.

Insights & recommendations

➜ Urban areas consist of a mix of households and services or utilities, such as offices, shops and schools. However, most urban energy models only consider household load profiles, ignoring other sectors. The researchers showed that including these in the models leads to better estimations of the potential of renewable resource integration in urban areas.

➟ The researchers uncovered three different types of urban areas: residential, business, and mixed. They determined it is essential to match local demand profiles to support the transition of these areas towards sustainable energy generation, transportation, and heating. The shape of a local demand profile can determine how much renewable energy can be used directly and how electric vehicles and electric heating affect a local grid.

➟ The researchers proposed a risk-sharing tax that enables consumers to choose the amount of risk they are willing to accept. It incentivises to decrease demand uncertainty by changing demand behaviour and reduce overall electricity costs.

➟ The researchers proposed market mechanisms, coupled with a Service Level Agreement framework. Producers that depend on renewable sources and may not always be able to guarantee electricity delivery to consumers can use these mechanisms.

➟ The researchers studied the design of market mechanisms that can be used to incentivise uncertain demand response of small-scale users like electric vehicles and households. They can be applied on a local level to entice users to change their demand.

Frances Brazier

"I have good memories about the good and friendly cooperation moments within the project, with the Advisory Council and with the enthusiastic and motivated PhD students. We designed novel solutions and concepts based on fundamental insights for future sustainable energy systems. That was really special. The follow-up of STASCADE is that we continue to work on our techniques in current projects and extend our insights in future projects."

SmaRds

Team

- **Dr Maarten Arentsen**, project lead, Associate Professor energy innovation, University of Twente
- **Prof Michiel Heldeweg**, Professor of Law, Governance & Technology, University of Twente
- **Prof Hans Vedder**, Professor of Economic Law, University of Groningen
- **Imke Lammers**, PhD student, University of Twente
- **Dr Thomas Hoppe**, University of Twente, Technical University Delft
- **Lea Diestelmeier**, PhD student, University of Groningen

Partners

- Energiek Vasse
- Lochem Energie
- Noordelijk Lokaal Duurzaam Energie
- Regio Achterhoek
- Regio Twente
- Stichting SETS
- University of Groningen
- University of Twente

Lead time

1 July 2014 – 15 August 2018

Full title

Smart Regimes for Smart Grids

Rationale and questions

The goal of the SmaRds research project was to analyse the governance and legal implications of accelerating the use of smart grids. New organisational regimes are required to manage the increasing technical complexities of decentralising electricity production and consumption.

The project answered the following questions:

1. Which legal framework enables and incentivises Smart Energy Systems (SES)?
2. How can local governance on the introduction of smart grids be improved?

Results

The project suggested a new approach to law-making, which would follow the speed and flexibility of the current electricity market. It also proposed a new institutional framework for the governance of local smart system development. Furthermore, the researchers suggested an approach to rebalance citizen participation in local decision making on smart grids.

Insights & recommendations

➟ Electricity market regulations that enable and incentivise smart grids should be technology and actor-neutral. Such a legal approach defines system users by their flexibility. They include communication infrastructures dedicated to smart grid purposes and integrate automation for flexibility provision. The researchers point out that these requirements have significant implications for the current legal framework of the electricity market – specifically, incentive schemes, pricing mechanisms, consumer protection frameworks and the role of communication networks.

➟ The project designed an institutional and a process structure to facilitate the introduction of smart grids:

1. The institutional structure shows which changes in institutional arrangements are needed to get to a desired smart grid.
2. The process structure specifies the active participation of actors in different phases of decisionmaking. It also provides tools to increase the acceptance of chosen smart grid designs, and more generally, the effectiveness and efficiency of decision-making processes.

Maarten Arentsen

"I enjoyed the meetings with the science team and the members of the user committee. Theory would meet practice, always with mutually fertile outcomes. In the end this project contributed to revealing decision-making processes and showed the necessary steps on the way to a smart grid."

PMU

Team

- **Dr Marjan Popov**, project lead, Associate Professor Electrical Energy Systems, Delft University of Technology
- **Prof Mart van der Meijden**, Professor Large-scale Sustainable Power Systems, Delft University of Technology/ Innovation Manager at TenneT
- **Matija Nagli**, PhD student, Delft University of Technology
- **Ilya Tyuryukanov**, PhD student, Delft University of Technology
- **Dr Jose Chavez Muro**, postdoctoral researcher, Delft University of Technology

Partners

- Delft University of Technology
- TenneT
- VSL

Lead time

1 August 2014 – 31 December 2019

Full title

PMU Supported Frequency-Based Corrective Control of Future

https://www.tudelft.nl/en/protection-centre/research-projects/urses/

Rationale and questions

Present control and monitoring schemes will not be able to cope with future reliability problems of the grid. Unexpected disturbances and inadequate monitoring will cause failures and blackouts. Currently, phase measurements units (PMU's) are the most accurate and advanced technology available. They provide voltage, current phasor, and frequency information.

The main goal of the PMU-project was to create a wide-area intelligent system, that empowers future energy grids by:

1. providing real-time information,
2. assessing system vulnerability,
3. timely performing corrective control actions.

Results

The researchers designed a new closed-loop corrective control scheme. In existing and future electricity networks, they focused on eliminating frequency instability, cascading interruptions, and catastrophic blackouts. Three interdependent solutions underpin the control scheme:

1. A simulation platform for the design and online validation of closed-loop control algorithms.
2. A monitoring platform for robust frequency estimation and measurement-based algorithms to improve system observability.
3. Automated corrective control.

Insights & recommendations

➟ The developed open-source platform in this project proposes a new communication technique. The advantage of this is that it enables machine-readable data resulting from the synchro-phasors realised in a MATLAB programming environment.

➟ For the first time the, PMU's have been used for high voltage direct current applications, enabling grid observability.

➟ Low-computational complexity makes the algorithm ready for online use in advanced 'System Integrity Protection Schemes'.

➟ Network partitioning algorithms have been developed to prevent the spread of a power outage by isolating parts of the network. Tests confirmed that control zone boundaries could lead to insights and efficient control and protection architectures.

Marjan Popov
"The PMU-project paves the way toward protection and security applications in real-time monitoring by utilising synchro-phasors to increase the reliability and security of electricity supply in future power systems. As a project leader, I enjoyed the research and user committee meetings. They were fulfilled with highly motivated discussions. The follow-up is the on-going big data project 'Resilient Synchro Measurement-based Grid Protection Platform' (ReSident) within NWO's research programme Energy System Integration (ESI-BIDA). In ReSident we use the knowledge and assets obtained from URSES, for real-time disturbance detection and system vulnerability assessment."

The sequel: Uncertainty Reduction in Smart Energy Systems + (URSES+)

Research within the preceding URSES projects uncovered many types of uncertainties in the electricity system. Having distinguished and addressed them, how were these results being translated into practice, of energy suppliers and consumers? Starting from scientific insights URSES+ projects developed possible applications, taking into account technical and economic opportunities and constraints, and behavioural aspects of stakeholders.

The objective of the preceding URSES programme was to contribute to the reduction of uncertainty for actors in the energy chain by developing science and tools needed for smart energy systems (SES). The projects provided insight into the causes, character and effects of these uncertainties, also from a social and behavioural science perspective. URSES should enable a fast transition to a reliable, affordable and sustainable energy system. Therefore, the URSES+ programme was launched to take the research one step further towards application in practice.

Objective

The aim of URSES+ was to develop actual applications of the research results, coming from collaboration between different research disciplines, and with companies. The researchers were asked to look at technical innovations, but also to investigate the social side of the transition to new energy systems.

URSES+ starting

In 2016, Shell, Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute), TKI Switch2SmartGrids (S2SG) and NWO joined forces in the URSES+ programme. Through the involvement of AMS some researchers had the chance to test their potential innovations in the urban context of the Amsterdam metropolitan region.

> “URSES+ researchers were asked to look at technical innovations and to investigate the social side of the transition.”

Budget

The budget available for this call was 1.7 million euro’s. The projects had a maximum duration of two years.

Projects

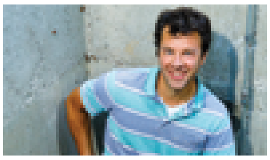
In 2016 eight projects were rewarded. These projects and their results are presented on the following pages, including background interviews with researchers that participated in the projects.

Overview of URSES+ projects in Amsterdam

AMS
AMSTERDAM INSTITUTE FOR
ADVANCED METROPOLITAN SOLUTIONS

URSES+ projects 2016

In 2016, another eight top-up projects, following URSES projects, were awarded funding in a so-called Plus call.


Martin Bloemendal

Aquifer Thermal Energy Storage Smart Grids (ATES-SG+) — prof dr ir T. Keviczky, project lead, TU Delft


Samira Farahani

Modelling and designing 'Car as Power Plant' systems in a real life environment at Shell Technology Centre Amsterdam and at the Amsterdam Arena Stadium (CaPP-Life) — prof dr ir Z. Lukszo, project lead, TU Delft


Thijs van der Klauw

Distributed Intelligence for Smart Power routing and mATCHing 2 – Extension to a case study of Amsterdam ArenA (DISPATCH2) — dr ir P. Nguyen, project lead, Eindhoven University of Technology


Sebastian Trip

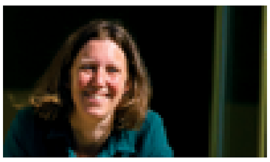
Energy based analysis and control of the grid: dealing with uncertainty and markets in an urban environment (ENBARK+) — prof dr C. de Persis, project lead, University of Groningen


Koos van der Linden

Future-proof Flexible Charging: dealing with uncertain prices and network constraints (FFC) — dr M. M. de Weerdt, project lead, TU Delft


Ellen van der Werff

Smart energy systems in the Amsterdam area: Electric vehicle as gateway to smart and sustainable energy use (SMARTEST) — prof dr E.M. Steg, project lead, University of Groningen


Sanneke Kloppenburg

Storing renewable energy in urban households (StoRe) — prof dr ir G. Spaargaren, project lead, Wageningen University & Research


Matthijs Hisschemöller

Amsterdam Builds the Coalition towards a zero emission built environment (ABC) — prof dr D. Loorbach, project lead, Erasmus University Rotterdam

ATES-SG+

Team

- **Prof Tamas Keviczky**, project lead, Professor at Delft Center for Systems and Control, Delft University of Technology
- **Dr Martin Bloemendal**, postdoctoral researcher, Delft University of Technology
- **Dr Eunice Herrera Santisbon**, postdoctoral researcher, Delft University of Technology
- **Ir Yvo Putter**, research associate, Delft University of Technology

Partners

- Delft University of Technology
- DWA
- KWR Watercycle Research Institute
- Priva
- Provincie Noord-Holland
- Tauw
- Van Gogh Museum
- Waternet

Lead time

1 April 2018 – 31 July 2020

Full title

Aquifer **T**hermal **E**nergy **S**torage **S**mart **G**rids+ (ATES-SG+)

https://www.tudelft.nl/3me/over/afdelingen/delft-center-for-systems-and-control/research/networked-cyber-physical-systems/ates-sg

Follow-up to URSES project

Aquifer **T**hermal **E**nergy **S**torage **S**mart **G**rids (ATES-SG)

Results

The researchers performed a detailed evaluation of the heating, ventilation, and air conditioning (HVAC) system of the Van Gogh Museum. They investigated how to apply Model Predictive Controllers (MPC) to improve the overall operational HVAC energy efficiency and increase the effective use of the aquifer thermal energy storage well.

MPC = Model Predictive Control: a model is used to run experiments in future with different control strategies; the optimal control action to meet a give/certain goal can then be used for the real-life system. Usually this is a centralised approach in which the model solves one objective function to find a global optimum. D-MPC = Distributed MPC, when there are multiple actors, each actor has its own objective function, which the controller tries to optimise.

The project developed a control-oriented grey-box predictive model, suitable for MPC, which models zone air temperature and humidity as a function of outside air conditions, room parameters, occupancy and HVAC components such as the heat pump, peak boiler, and air handling unit (AHU).

A MSc student provided a thesis with an analysis of a predictive control approach to achieve thermal comfort and energy savings by control-ling the indoor temperature and humidity conditions in buildings with the use of mechanical air conditioning systems.

Additionally, a study was performed regarding the possibility of heat transport via the aquifer under the Museumplein.

ATES = Aquifer Thermal Energy Storage
Basic working principle of a ATES-doublet:
in Winter, buildings are heated with a heat pump (HP) which extracts heat that was previously stored in a warm well. This creates cooling capacity that is stored in another well in the subsurface. This cooling capacity is used in Summer to cool the building, by storing the excess heat in the warm well.

Martin Bloemendal, Photo: Bram Saeys©

Important role subsurface in energy transition

The Netherlands has roughly 3,000 Aquifer Thermal Energy Storage/Systems (ATES) installed, and this number will grow significantly. These heat buffers for HVAC-systems in large buildings have a high-profile energysaving potential that can play a crucial role in the energy transition of the Netherlands.

However, it is not everywhere that ATES systems utilise the subsurface optimally. The absence of models and cooperation regarding uncertainties of aquifer characteristics and interaction of neighbouring systems, causes utilisation to remain below earlier prognoses. This is primarily a concern in urban areas, such as Amsterdam, where the underground is crowded, and hydrological and thermal interferences give rise to unwanted and unexpected effects, such as negative mutual interactions between ATES systems.

Testing controllers at Van Gogh Museum

To solve this problem, the URSES ATES-SG project developed algorithms and methods for smart and self-organising ATES systems using Distributed Model-based Predictive Controllers (D-MPC). The project showed proof of concept of these controllers, for maximal and sustainable utilisation of subsurface space. In the URSES+ project ATES-SG+, the controllers were tested, implemented and evaluated at a test site: the Van Gogh Museum at the Museumplein in Amsterdam.

Challenges of modernising large buildings

The researchers studied how the various parts of the museum's HVAC-system, like air handling units, peak boilers and cooling machines, worked together and what could be improved to make better use of its capacity. Tamas Keviczky, Professor Systems and control at TU Delft and project lead for the URSES+ project: "Our original idea was to implement a new controller in the museum. But when we were analysing the modelling of the system, we found that the buildings' management system was composed of different systems that had been developed over the years."

Keviczky explains that this is not uncommon for large buildings that have been redeveloped in different phases: "If you work with multiple parties for a period of 10, 20 years, you will likely end up with a complex system." According to him, this is one of the major challenges of modernising large utility buildings today.

Eventually, the algorithms and simulations showed that there is capacity and space to use the ATES system much more than it is currently being used: an important discovery for the museum. Keviczky: "The Van Gogh Museum were very excited to see that they can minimize their carbon footprint by improving their energy system. On top of that, we gained more awareness of how to better use the ATES systems. Not only at the building level, but also in a network of buildings."

Possibility of heat transport via aquifer Museumplein

Another important part of the ATES-SG+ project was a study regarding the possibility of heat transport via the aquifer under the Museumplein, where the Van Gogh Museum has a heat surplus and the nearby Concertgebouw a heat shortage.

Martin Bloemendal, part-time Assistant Professor Underground thermal energy storage at TU Delft, works on various research projects to develop ATES technology and sustainable subsurface use for renewable heating and cooling systems. He was the leading researcher in this part of the URSES+ project.

“When you are cooling a building, you are storing heat for next winter.”

Bloemendal: “Buildings do not need the same amount of heating as cooling, although that is an important prerequisite for an HVAC-system using ATES. Because when you are cooling a building, you are storing heat for next winter. So, if you do not cool enough, you do not store enough heat for the next winter.”

Due to the high humidity requirements for museums the Van Gogh Museum has a heat surplus. On the other hand, because most concerts are in Winter and evenings, resulting in a much larger heating demand, the Concertgebouw across the street has a heat shortage and little cooling demand. They could make use of that surplus heat from the museum. An earlier study showed that making a piped connection is too expensive and complex. So Bloemendal explored under which conditions it would be possible and efficient to transport the heat through the aquifer from one side to the street to the other. Keviczky: “I think this idea has much potential for implementation in a real-life case, which we unfortunately did not realise within this project.”

Number of systems will grow twenty-fold

Both Bloemendal and Keviczky see many smart project possibilities in using of of HVAC-systems with ATES, for example, for energy flexibility. They are currently putting together various project applications, control strategies and hydraulic optimisations, in which they want to use buildings and HVAC-systems with ATES for flexibility purposes. This is interesting for municipalities, stadiums such as the Amsterdam ArenA and large buildings.

According to Bloemendal, the subsurface will play an important role in the energy transition: “The need to develop smart solutions will grow especially when you see that we already have quite a busy subsurface in various places in the Netherlands.”

CaPP-Life

Team

- **Prof Zofia Lukszo**, project lead, Professor at Energy and Industry group, Faculty of Technology, Policy and Management, Delft University of Technology
- **Prof Ad van Wijk**, Associate Professor in Energy Technology Section, Process and Energy Department of the Mechanical, Maritime and Materials Engineering faculty, Delft University of Technology
- **Dr Samira Farahani**, postdoctoral researcher, Delft University of Technology

Partners

- Amsterdam ArenA
- Delft University of Technology
- Shell

Lead time

1 September 2017 – 31 August 2019

Full title

Modelling and designing "Car as Power Plant" systems in a real-life environment at Shell Technology Centre Amsterdam and at the Amsterdam ArenA Stadium (CaPP-Life)

Follow-up to URSES project

Car as **P**ower **P**lant (CaPP)

Results

To integrate the CaPP-system into the energy micro-grids of the live environment at Shell Technology Centre Amsterdam, the researchers developed three scenarios: all-electric, hydro-electric and combined.

They have conducted the techno-economic analysis for each scenario for two periods: Near-Future (2025 – 2030) and Mid-Century (2040 – 2050). Additionally, they have provided optimal scheduling for energy management and improvement of the operational performance in the designed energy system.

The results of each scenario were mainly compared by their System Levelized Cost of Energy, for which electricity, gas and thermal demands were considered. System Levelized Cost of Energy are the total system costs, divided by the total energy provided by that system. The findings have shown that using electricity and hydrogen as energy carriers can create a more flexible, reliable and cheaper energy system for office buildings. Furthermore, hydrogen can design a reliable energy system, combined with cars as power plants, which are mainly suitable for hourly energy balancing.

The results have also shown that seasonal storage using hydrogen and salt caverns is much cheaper than using large battery storage systems, that the integration of electric vehicles into the electricity network is technically and economically feasible and that they can provide a flexible energy buffer.

Samira Farahani, Photo: Bram Saeys©

Hydrogen as crucial link in sustainable energy system

The URSES project 'Car as Power Plant' (CaPP) investigated the potential impact and feasibility of an integrated system that provides mobility, electricity, heat, and water. The system is based on wind and solar power, converses renewable energy surpluses to hydrogen, stores and distributes this hydrogen, and consists of hydrogen fuel cell electric vehicles.

Subsequently, the URSES+ project CaPP-Life was launched to effectively transfer the theoretical knowledge of CaPP to a real-life environment. The controlled environment of the Shell Technology Centre Amsterdam was used as a test location. Ultimately, it should lead to an application in the public space.

Researcher Samira Farahani explains how she designed different scenarios to compare energy production costs for such an energy system.

Combination of electricity and hydrogen most economical

As Farahani expected, having an all-electric energy system resulted in the highest system-levelized cost due to the high storage costs. The most economical design was the scenario, in which they used a combination of different technologies based on both electricity and hydrogen.

In this system, both battery and hydrogen-based fuel cell electric vehicles provided balancing and backup power. The study has shown that even during peak hours, they only needed less than 150 cars, "which is less than half of the parking capacity of the office," Farahani explains.

She designed an optimal scheduling method for the energy production management of the combined system aimed at minimizing costs and the degradation of the battery and fuel cell used in the vehicle-to-grid mode.

Cost efficiency more important than energy efficiency

Among the different results obtained in this project, for Farahani, the essential finding was showing the importance of flexibility in the choice of energy carriers and technologies. "It should not be either this or that; instead, we have to look at what is available and what gives us the most cost-efficient solution." She also emphasises that "when we are focussing on renewable energy systems, cost efficiency is more important than energy efficiency. We do have an abundance of renewable energy globally, and we do not have to produce it locally. We can import it, just as we do now with gas and oil."

"We do have an abundance of renewable energy in the world."

Infrastructure for fuel cell electric vehicles not yet in place

The idea of using fuel cell electric vehicles for vehicle-to-grid in the CaPP-Life project was a global first, according to Farahani. Nevertheless, unfortunately, there are no organisations that are using the results of her research yet. “In the Netherlands, the required infrastructure for implementing of this project, such as hydrogen fuelling stations, vehicle-to-grid ports, and fuel cell electric vehicles, is not yet in place. Once there are enough hydrogen fuelling stations, there will also be more incentives to buy fuel cell cars; then, we will be able to have pilot projects based on the CaPP concept.”

However, to her relief, the investments in research on large scale solutions for a hydrogen-based energy transition are going quite well. Farahani: “It’s changing in in a positive way. We need probably ten years to get there, but we are moving.” She hopes NWO continues funding these types of projects. “Of course, energy is only is not the only theme, and not all the money can go there. Still, I think it impacts everything. If we can decarbonise and improve our energy system, we will also help the environment, which directly impacts our health, food, water, and the air we breathe. Hence, I think it is worth to considering energy as one of the important topics to be supported by research funding institutes.”

DISPATCH2

Team

- **Dr Phuong Nguyen**, project lead, Associate Professor at Electrical Energy Systems, department of Electrical Engineering, Eindhoven University of Technology
- **Dr Heyd Fernandes Mas**, postdoctoral researcher, University of Groningen
- **Dr Thai Vo**, postdoctoral researcher, Eindhoven University of Technology
- **Dr Thijs van der Klauw**, postdoctoral researcher, University of Twente

Partners

- Alliander
- Amsterdam ArenA
- DNV-GL
- ENGIE
- Locomation
- National Instruments
- University of Groningen
- University of Twente

Lead time

1 January 2017 – 31 December 2018

Full title

Distributed Intelligence for Smart Power routing and mATCHing 2 — Extension to a case study of Amsterdam ArenA

Follow up to URSES project

Distributed Intelligence for Smart Power routing and Matching (DISPATCH)

Results

The researchers have defined different scenarios to properly consider when and how to use the flexibility provided by the Amsterdam ArenA stadium. Simulations showed that the techniques developed in the URSES project could be used in relevant real-world cases.

Thijs van der Klauw, Photo: Bram Saeys©

Potential role event facilities in intelligent energy systems

The integration of intermittent renewable energy sources like wind and solar energy, and new demand-side technologies, such as electric vehicles, challenge the power system. This will make it increasingly difficult to control power flows in real-time and balance supply and demand to always guarantee stability and reliability.

To solve these metropolitan energy supply issues, the URSES project DISPATCH proposed innovative solutions by developing a local flexibility framework for market and network control mechanisms. The framework introduces flexibility to energy and reserve markets, facilitating distribution network operation.

The follow-up URSES+ project DISPATCH2 illustrated this using a practical case study in the Amsterdam ArenA. The researchers focused on how the availability of such a large system user in a dense urban area can be made available for both distribution network operation and system balancing.

Using old electric cars batteries for storage facility

Thijs van der Klauw, junior scientist autonomous systems at TNO, was one of the postdocs involved in DISPATCH2. He clarifies that if you want to use flexibility, you have to onsider what it does to your network locally. “This is what we mean by ‘local flexibility network’. If you simply match demand and supply on a high level with flexibility, using the energy that is available at that moment, it can cause additional peaks in the neighbourhood and congestion in the network on the local level.”

Concerning the energy transition, the Amsterdam ArenA saw challenges but also opportunities ahead. For example, with a storage facility based on old electric cars batteries. “These batteries were no longer suitable for cars but could still function as grid storage. So, within DISPATCH2 we researched the possibilities to apply the techniques we had developed within DISPATCH for a situation like that,” explains Van der Klauw.

“These batteries were no longer suitable for cars but could still function as grid storage.”

Sources claimed surrounding network could become congested

According to the UT researcher, various sources claimed that the ArenA and its surrounding network could become congested. However, simulations led to the conclusion that the network was a lot stronger, and things would not go wrong in the current situation.

Van der Klauw: “Only when electric charging increases, I expect batteries to become a major player. In one of our simulations, we calculated a case in which between 30 or 50% of ArenA visitors would want to use of recharging facilities with their electric car. We saw that the network could become congested at that point, so this has to be considered in the future.”

Use of flexibility faces legal challenges in current arrangements

Another thing that has to be taken into account are the technical possibilities and challenges within the current legislation. The people involved in the DISPATCH2 project from Groningen researched this and came to some interesting conclusions. Van der Klauw: “If the ArenA installs charging stations, they will likely be managed by a third party. If I then connect my electric car there, the question arises: whose flexibility is it? And how do I arrange that legally so that what I make available can still be traded fairly? Who can make money from that, and in what way?” This shows that the use of the flexibility provided by electric vehicles specifically faces several legal challenges in current arrangements.

It is people who must use our solutions

After Van der Klauw finished his postdoc, he started working at TNO. And although he does not work directly on a continuation of DISPATCH2, he is involved in some projects related to the energy transition. “Much of the knowledge I gained in the project still helps me to understand what the actual issues are, what is being researched at the universities and how we link it together.”

Van der Klauw very much enjoyed working on the URSES+ project. “It was fun to look at such a complex problem from different points of view with such a diverse group. I think we learned a lot together.” According to him, the energy transition is not a field that can be captured by one discipline: “We need almost all the different disciplines. From mathematics and physics to chemistry and psychology. Because in the end, it is people who must use our solutions.”

ENBARK+

Team

- **Prof Claudio De Persis**, project lead, Professor Smart Manufacturing Systems, Engineering and Technology Institute Groningen, University of Groningen

- **Prof Jacquelien Scherpen**, sub-project lead, Professor of Discrete Technology and Production Automation at the Faculty of Science and Engineering, University of Groningen

- **Dr Khrishna Kosaraju** postdoctoral researcher, University of Groningen

- **Dr Sebastiaan Trip**, postdoctoral researcher University of Groningen

Partners

- DNV-GL
- University of Groningen

Lead time

1 May 2017 – 18 May 2020

Full title

Energy based analysis and control of the grid: dealing with uncertainty and markets in an urban environment (ENBARK+)

Follow up to URSES project

Energy based analysis and control of the grid: dealing with uncertainty and markets (ENBARK)

Results

The researchers developed a method to adjust existing algorithms keeping the generated powers within capacity limits. They also proposed a broadcasting implementation for distributed algorithms, which permits a more straightforward digital implementation instead of a continuous exchange of information.

The sliding mode control strategy has been adopted to regulate the frequency in the power network while obtaining an economic dispatch. This provides an alternative view of the results within the URSES project.

Another scientific contribution is the development of a control strategy to boost converters within a distribution network. This way, voltages are regulated around their nominal values, to efficient electric vehicle charging.

To achieve both economic efficiency and maintaining proper voltage levels, the researchers have proposed a sliding mode control scheme and a distributed integral control scheme for distribution network microgrids with buck converters. The performance has been demonstrated experimentally.

They also developed a case study of the future parking lot, followed by the proposal of a higher-level controller of a model predictive control type. This provides reference points for converters to obtain optimal coordination among photovoltaic panels, batteries, electric cars, and the external distribution grid while considering external price signals from the market. For the lower-level control of the converters, the researchers compared proportional-integral control and sliding mode control strategies.

Sebastian Trip, Photo: Bram Saeys©

Guarantee stable operation by making existing network smarter

There are still several challenges to guarantee the stable operation of future smart grids in a reliable and cost-efficient manner. Appropriate control strategies have to regard economic considerations that allow producers and consumers to share utilities and costs fairly associated with the generation and consumption of energy.

To resolve this, the URSES project ENBARK developed a new approach for the modelling, analysis, and control of smart grids. These new control and pricing mechanisms were based on energy functions, mostly tailored to high voltage networks. The URSES+ project ENBARK+ continued this approach, emphasising lower voltage resistive networks in an urban environment.

Project incorporated social aspects

Sebastian Trip was one of the postdoc researchers working on the project. “To guarantee the stable operation of the network, you can lay thicker power cables,” Trip explains. “But since that is very expensive, you can also try to use the existing network smarter. And this is what the ENBARK+ project was about, translated to mathematics.”

Trip and his peers developed algorithms that aim at voltage regulation and efficient charging strategies for electric vehicles. They used mathematical frameworks that lend themselves to the integration of dynamic pricing algorithms that allow consideration of economic factors in the control of smart grids. Besides that, ENBARK+ explicitly incorporated social aspects to envision the development of these new and socially acceptable incentives and control mechanisms.

Algorithms taking human behaviour into account too

Trip: “You want your solutions to be socially accepted, in a way they help people to manage a network properly.” That was the reason that the department of Environmental Psychology was closely involved in the project. “That human aspect is always a bit tricky for me as a mathematician and physicist. Behaviour seems so difficult to model. However, it turned out that behavioural scientists do modelling too, describing and predicting actions of people.” He explains how you can, for example, model whether someone is acting altruistically or because of financial incentives. “We have seen that the algorithms have to take this human behaviour into account too, which has led to some nice insights.”

“You want your solutions to be socially accepted, in a way they help people to manage a network properly.”

According to Trip, a logical next step would be to see how the developed algorithms would work in a real environment. “Although the proposed solutions are very general, it is difficult to predict their performance in a real environment. You always have to look at the specific situation. What kind of problems are there? What kind of cables? What kind of cars? And so on.”

Mathematical guarantees that algorithms work

For him, one of the most important results from the project were the specific algorithms and “that we also give mathematical guarantees that these algorithms work. What we have developed does not only apply to one network. In my opinion, this makes our research very strong, or at least different from many other research projects.”

The ENBARK+ project’s combination of economic and energy considerations in a unifying energy-based framework is new in the scientific literature and provides a good starting point on how future smart grids will be operated. And although Trip does not think that there is a company that has just literally implemented the developed algorithms yet, he does think companies are drawing inspiration from it.

Taking general results from ENBARK+ further in new project

Today, Trip is a researcher at the University of Twente, for which he works on a project in Nijmegen. A similar one to ENBARK+, although more specific. “There is a waste incineration plant with a lot of surplus heat and a large solar park. They want to know how to use all that energy as well as possible. I can easily incorporate the general results from ENBARK+, take them further and look at what aspects may or may not have been included at the time. In short: I benefit a lot from the knowledge that I gained during the project .”

FFC

Team

- **Dr Mathijs de Weerdt**, project lead, Associate Professor on Algorithms for Planning and Optimization and section head of the Algorithmics Group, Delft University of Technology

- **Dr Germán Morales España**, postdoctoral researcher, Delft University of Technology

- **Dr Natalia Romero Lane**, postdoctoral researcher, Delft University of Technology

- **Ir Koos van der Linden**, software developer Delft University of Technology

Partners

- Alliander
- Delft University of Technology
- Eneco
- Jedlix
- Liander

Lead time

1 February 2017 – 1 September 2019

Full title

Future-proof **F**lexible **C**harging (FFC): dealing with uncertain prices and network constraints

https://www.tudelft.nl/ewi/over-de-faculteit/afdelingen/software-technology/algorithmics/projects/future-proof-flexible-charging-completed

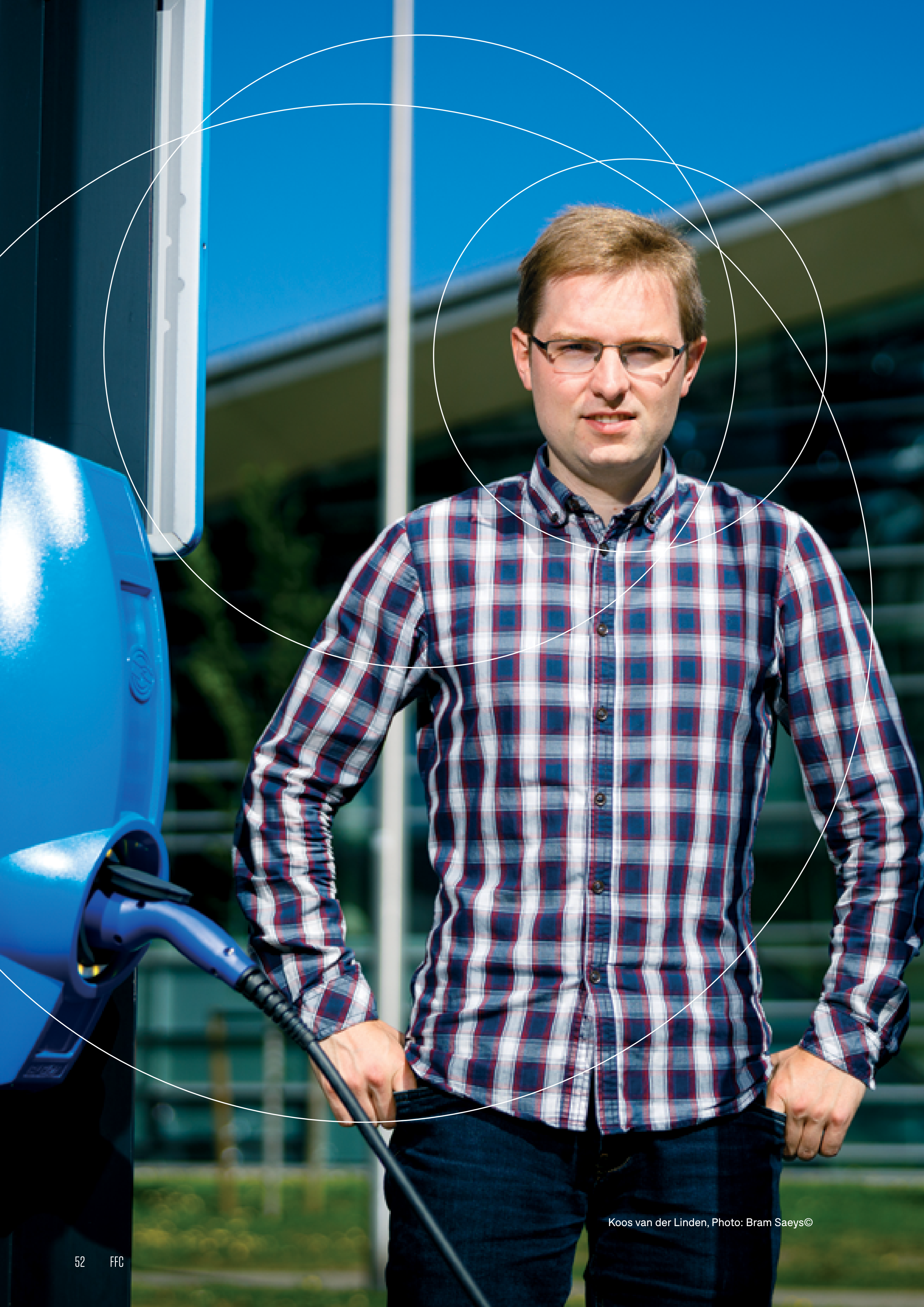
Follow up to URSES project

Gaming beyond the Copper Plate: scheduling flexible consumption and decentralised generation within distribution constraints

Results

The researchers developed some new advanced algorithms for scheduling flexibility under uncertainty. They also realised a benchmarking tool for quantitative analysis of the diverse trading in day-ahead, reserve and imbalance markets.

This scientific contribution used/created a method to control the quality of the data to measure the performance of algorithms with different degrees of uncertainty.



Koos van der Linden, Photo: Bram Saeys©

Flexible charging: how well can we predict the future?

Due to the uncertainty of renewable energy sources, balancing demand and supply in power systems has become a challenge. One of the solutions for settling this imbalance is flexible car charging. However, how can you make this possible and cost-efficient while participating in the existing electricity markets?

To answer this question, TU Delft joined forces with Jedlix, Eneco, Alliander and Liander in 'Future-proof Flexible Charging' (FFC). FFC is a continuation of the URSES project 'Gaming beyond the Copper Plate' in which some advanced algorithms were developed that can efficiently schedule the charging of many EV's in a distribution network.

The necessity of trustworthy benchmarking

In FFC, the researchers developed a realistic simulation environment where they tested the performance of the algorithms. One of the most important things they wanted to measure is how these algorithms would respond to uncertainty.

> "One of the conclusions was that it is difficult to decide which algorithm is the best."

"But in order to do that, you have to have a measure for that uncertainty," explains Koos van der Linden, one of the researchers in FFC and scientific programmer at the Delft University of Technology. "One of the conclusions from the project was that it is difficult to decide which algorithm is the best. It depends on how good the available data is. How well can you predict the future? It has shown the necessity of trustworthy benchmarking."

Compare different solution methods in a fair way

As a result, Van der Linden and his peers developed an open-source toolbox for benchmarking scheduling algorithms considering different energy market designs. The benchmark environment is built so that it can manage the degree of uncertainty within algorithms, to measure its effect. Van der Linden: "The toolbox makes it possible to compare the different solution methods in a good and fair way. This has not yet been done very often in the scientific field."

Last year the FFC researchers organised a workshop for people from the industry to use the toolbox. Van der Linden: "We showed what developments we were working on and asked for feedback on which specific things the participants would adjust or add."

The toolbox is of interest to all large energy consumers who are somewhat flexible in their power consumption, such as owners of charging station infrastructure and grid operators. However, the toolbox could also be of use to analysts informing policies for a stable grid.

A more complex algorithm not always a better algorithm

The FFC project combined diverse expertise, such as electrical engineering, policy and management and mathematics. Van der Linden's background is in computer science, and the electricity market was new to him. "The complexity of planning with uncertainty makes it a fascinating market. Itis just hard to make uncertainty quantifiable and then to plan robustly against it."

From the beginning of the project, Van der Linden and his peers worked to ensure that the complex algorithms would help them solve the problem. That was what they hoped for and what their research proposal was. However, during their research, they discovered that complex (stochastic) algorithms might be better from time to time, but this also comes with disadvantages. And in quite a lot of cases, the simple algorithm is just better or preferable. "A more complex algorithm is not always a better algorithm."

Today Van der Linden works on a project about the planning of train maintenance. Although a very different domain, he still uses the knowledge he gained from the FFC project. "One of the important questions in this project is how can we plan in such a way that we can deal with uncertainty." A very different application, but the same uncertainty.

SMARTEST

Team

- **Prof Linda Steg**, project lead, Professor of environmental psychology, University of Groningen

- **Prof Floor Alkemade**, Professor of Economics and Governance of Technological Innovation, Eindhoven University of Technology

- **Dr Ellen van der Werff**, postdoctoral researcher, University of Groningen

- **Job Harms MSc**, postdoctoral researcher, University of Groningen

- **Dr Önder Nomaler**, postdoctoral researcher, Eindhoven University of Technology

Partners

- ABN AMRO
- Accenture
- Eindhoven University of Technology
- Elaad
- ENGIE
- New Motion
- University of Groningen

Lead time

14 January 2017 – 30 September 2018

Full title

SMARTEST: Smart Energy systems in the Amsterdam area: Electric vehicle as gateway to smart and sustainable energy use

https://www.rug.nl/gmw/psychology/research-units/social-psychology/projects/sub/sub_1_soc_urses_electric_vehicle_as_gateway_to_smart_and_sustainable_energy_use?lang=en

Follow up to URSES project

SMARTER: Realizing the Smart Grid: Aligning consumer behaviour with Technological Opportunities

Results

The researchers have tested and found that how companies aim to reduce their environmental impact, influences the extent to which its employees see themselves as a pro-environmental person. A stronger 'environmental self-identity' is, in turn, related to more pro-environmental behaviour both at work and at home and to stronger acceptability of policies in that area.

In collaboration with the URSES+ ENBARK+ project, the researchers tested how electric vehicles provide flexibility to power offices. The results suggested that interventions targeting environmental self-identity and range-anxiety may somewhat increase how electric vehicles provide to providing this flexibility. Furthermore, the simulation showed that local neighbourhood conditions need to be included in strategies for public charging infrastructure roll-out.

Ellen van der Werff, Photo: Bram Saeys©

Getting a grip on consumers' energy behaviour

To ensure the future stability of the electricity network, consumers need to adopt various smart energy systems, such as electric cars and solar panels. However, the potential of these technologies will only be achieved if these consumers use them in a way that is in line with the system's reliability, efficiency, and sustainability. This requires a large-scale transition to sustainable energy behaviour, such as smart charging.

The URSES project SMARTER aimed to determine which individual factors predict, explain, and influence consumer adoption and usage of these new technologies. The project linked this through the theoretical concept of environmental self-identity: people show more environmentally-friendly behaviour if they consider themselves environmentally-friendly. The follow-up URSES+ project SMARTEST used this knowledge for further research, looking specifically into the use of electric vehicles.

Extra nudge to act even more environmentally-friendly

RUG's associate professor Ellen van der Werff was one of the researchers of both the SMARTER and the SMARTEST project. "In SMARTER, we found that sustainable behaviour depends on the reason why people purchase a sustainable energy technology. For instance, if people buy an electric vehicle for environmental reasons, they consider themselves environmentally-friendly. Subsequently, they are more inclined to use the electric car sustainably, for example, by smart charging."

"A route along which you can give people an extra nudge to act even more environmentally-friendly."

Pursuing this knowledge in SMARTEST, Van der Werff and her peers discovered that more triggers influence how people label themselves environmentally friendly. "For example, if an organisation shows its commitment to sustainability, there is a better chance that their employees are committed to sustainability too. Not only in the workplace but also in their private lifes, for instance by smart charging and using vehicle-to-grid technology". According to Van der Werff, a valuable outcome of the project: "It is a route along which you can give people an extra nudge to act even more environmentally-friendly."

With our data we could predict what people are willing to do

In the project, Van der Werff collaborated with mathematicians from the University of Groningen, who integrated the SMARTEST results in models. "With our data, we could more or less predict what people are willing to do. By putting this into models, we could see what this meant. For example, if you have an office where a certain number of employees have electric cars, can you then supply that office building with electricity from those electric car batteries?"

According to Van der Werff, the next step in SMARTEST would be to test how to propagate sustainable behaviour as a government or organisation, to have the most significant possible impact. “We see, for example, that governments are often a bit hesitant. They do not want to moralise too much, while this research shows that it can help to show what you are doing.”

People are willing to act environmentally-friendly

Over and over again, it has shown that people are willing to act. “But you have to help them. What exactly do they have to do?” illustrates Van der Werff. She gives the example of making a house more sustainable. “Where should you start? How do you find someone who can best insulate your house? Who knows what steps you need to take to get it all done? So, in the end, I do not think the problem is that people do not want to be environmentally-friendly. We have to help them get there.”

StoRE

Team

- **Prof Gert Spaargaren**, project lead, Professor and Chair of the Environmental Policy Group, Wageningen University & Research
- **Dr Marten Boekelo**, postdoctoral researcher, Wageningen University & Research
- **Dr Sanneke Kloppenburg**, postdoctoral researcher, Wageningen University & Research

Partners

- Alliander
- Greenspread
- Wageningen University & Research

Lead time

1 March 2017 – 31 November 2018

Full title

Storing Renewable Energy in Urban Households (StoRE)

Follow up to URSES project

Emerging Energy Practices in the Smart Grid

Results

The researchers have contributed to designing socially robust energy storage models and services by developing recommendations for organisational models and end-user-oriented services and products.

The pilot project in Amsterdam has allowed them to get insight into how households are engaged in new energy practices, such as charging, energy management, and the trading, monitoring and consuming of stored energy. The project has laid bare the uncertainties of participating in distributed storage platforms.

In addition to – and building upon – the research, the team of researchers developed a workshop format for virtual power plants. It could help prosumers think through the possible consequences of various design choices in distributed storage platforms. The workshop has been recognised as a helpful contribution to designing socially robust storage models.

Sanneke Kloppenburg, Photo: Bram Saeys©

How to successfully implement storage in urban regions

Local generation and storage of renewable energy will become essential if we want to meet our future energy consumption needs. One solution could be to create a virtual power plant (VPP) in which households with solar panels and home batteries are connected via a digital platform to trade energy on the energy market. However, to make a home battery interesting for households, technical and social challenges need to be considered. Therefore, the URSES+ StoRe project was launched, in which a team of researchers focused on the social and behavioural aspects of energy storage.

Curious about how participants experience participation in VPP

WUR researcher Sanneke Kloppenburg had already been working on the URSES project 'Emerging Energy Practices in the Smart Grid' when she got the opportunity to apply for an URSES+ follow-up project. "We had researched practices such as self-generating and monitoring of energy, and the joint generation of energy within a cooperative. Storage was something we were also interested in." So, when Kloppenburg and her peers came into contact with the City-zen project in Amsterdam, it was a match. In this EU project, a group of solar panel owners from the same neighbourhood installed home batteries and participated in a VPP that collectively allowed them to trade their stored energy on the energy market. In City-zen Amsterdam and Grenoble combined forces in 20 projects with the aim of carbon neutrality in both cities. "However, the project was predominantly technically oriented without any social scientific dimension. As the batteries had to be installed in people's homes, the City-zen's project leaders were curious about how participants experienced their participation in a VPP."

New home battery and VPP became 'black box'

Kloppenburg and her peers interviewed the 30 City-zen participants about current energy practices, followed by two game-like workshops. Through propositions, they initiated discussions about different goals of VPP's, such as trading, grid balancing or self-consumption. Interesting for the consumer, but also for other stakeholders. "Afterwards cooperatives and municipalities involved in the same kind of projects used the workshops to gain more insights about their participants". For Kloppenburg and her peers, a successful outcome of the StoRE project.

Another outcome was that it became clear throughout the project, that these new storage systems and services need to take the preferences and needs of the households into account. Kloppenburg: "The battery's user interface was very technical and complicated, which gave the participants fewer insights into what was happening to the energy from their solar panels." The new home battery and VPP became a 'black box' in which the 'home-grown' energy disappeared.

Main motivation was always the environment

"Energy management at the household level gets disturbed by a more collective approach, and there is a chance that people will lose their enthusiasm and commitment to sustainability because of that. If there is no transparency about environmental benefits and the way energy flows, there is little to relate to," explains Kloppenburg.

According to the URSES+ researcher, the participants from City-zen were seen as people predominantly interested in financial benefits. "Whereas all our workshops and interviews repeatedly showed they were driven by the desire to contribute to the energy transition. As it turned out, the main motivation was always the environment."

> "As it turned out, the main motivation was always the environment."

"In the workshop, the participants can end up with three or four different VPP's. For example, one in which you mainly go for an individual or collective financial gain, or a more social model," clarifies Kloppenburg, which shows the importance of finding out what kind of people you are dealing with, before creating the entire infrastructure and user interface.

Does energy have to become an exchangeable product?

Currently, Kloppenburg is working on some follow-up projects, such as a new application to further researching VPP's at a European level. "It is an increasingly relevant subject because VPP's provide new ways for citizens to participate in the energy transition actively. But such new decentral energy infrastructures need to be developed and designed also from the perspective of citizens and their motives to participate in it". She adds: "The assumption often seems to be that it is about assigning a certain economic value to energy, so you can then start trading. It makes it a financial matter. But is that what it is all about for people? Does energy have to become an exchangeable product? We should investigate that first."

ABC

Team

- **Prof Derk Loorbach**, project lead, director of DRIFT and Professor of Socio-economic Transitions at the Faculty of Social Science, both at Erasmus University Rotterdam
- **Dr Matthijs Hisschemöller**, postdoctoral researcher, DRIFT/Erasmus University Rotterdam
- **Drs Ilonka Marselis**, DRIFT/Erasmus University Rotterdam

Partners

-
- Alliander DGO
- DRIFT/Erasmus University Rotterdam
- Energiecoöperatie Zuiderlicht U.A.
- Urgenda
- Waternet

Lead time

1 January 2017 – 31 December 2018

Full title

Amsterdam **B**uilds the **C**oalition towards a zero emission built environment (ABC)

https://drift.eur.nl/projects/amsterdam-bouwt-coalitie-abc/

Follow up to URSES project

Transition Patterns Enabling Smart Energy Systems (TRAPESES)

Background

Because of climate change and global warming, centralised energy regimes relying mainly on fossil fuels increasingly encounter opposition. Local governments and residents appear to be willing to undergo a system change. However, uncertainties can still prevent the implementation and scaling potential of the alternatives to fossil fuels. The tension and synergy that arise determine how successful the concerned parties can be in adequately shaping a local energy transition.

Results

Research conducted in the TRAPESES and ABC projects (2014 – 2018) is exemplary of this tension and synergy between two energy paradigms. The researchers within TRAPESES explored how these arise as top-down and bottom-up innovations come together. A consortium comprising DRIFT, Alliander DGO, Waternet, the energy corporation Zuiderlicht and the Urgenda Foundation carried out the ABC project.

ABC is a research project that aims to turn a transition experiment into reality. The project's background was an initiative by the local Amsterdam partners to compete for the tender for a renewable low-temperature heating concept at Centrumeiland, IJburg. The consortium did not win the tender. Still, they decided to to consult with Amsterdam municipality to find another location for realising the ABC project. In this concept, the end-users of a new housing estate were to become the owners of an innovative, low-temperature energy system.

Bottom-up and top-down dynamics

The researchers at DRIFT studied whether the parties representing the niche (i.e. emerging social and technical innovations) would cooperate with parties allied to the existing energy regime, in this case Amsterdam municipality in particular. It was a disappointment for the ABC consortium that this eventually did not materialise. However, it has prompted the researchers – from their front row seats, as it were – to investigate the obstacles encountered towards the energy transition in Amsterdam.

Drawing on ABC's facilitative nature, the first year of the research project focused on identifying constraining factors for productive cooperation between energy cooperatives and local government. The second year of the study focused on how these constraints could be removed and under which circumstances citizens would support the transition to renewable heating in cooperative ownership. Research shows the importance of dialogue between actors and room for adjustment during the process in complex multi-stakeholder processes such as the energy transition.

Three reports delivered by ABC

The ABC project delivered three reports. The first report, 'Het moet niet te avontuurlijk worden' (*It shouldn't become too adventurous*) identifies institutional challenges in the city of Amsterdam for a project like ABC. The second report, 'Daar brandt een vlammetje onder' (*There's a little flame burning underneath*), presents a focus group study on how sustainability-minded residents regard cooperative and sustain-able heat transition. A third report, 'Waar vuur is, is rook' (*Where is fire, there is smoke*), published after the project's closure, discusses a case of municipal decision-making on a high-temperature heating system for a new city district, Amsterdam Sluisbuurt.

- **It shouldn't become too adventurous**
  https://drift.eur.nl/app/uploads/2018/03/ABC-rapport-institutionele-barri%C3%A8res-voor-een-wijkgebonden-warmtevoorziening-in-Amsterdam.pdf
- **There's a little flame burning underneath**
  https://drift.eur.nl/app/uploads/2018/11/Daar-brandt-een-vlammetje-onder_DRIFT.pdf
- **Where is fire, there is smoke**
  https://drift.eur.nl/app/uploads/2019/10/Waar-Vuur-Is-Rapport-Matthijs-Hisschem%C3%B6ller-DEF.pdf

Matthijs Hisschemöller, Photo: Bram Saeys©

Insights and approaches of ABC being used for local initiatives

"Our research pointed out that residents would be susceptible to the proposed transition given the right circumstances", ABC researcher Matthijs Hisschemöller explains. "The pivotal issue here is support from the local government for the already active, enthusiastic residents in drawing up a technical plan and approaching fellow residents."

"Residents would be susceptible to the proposed transition given the right circumstances."

Calling for equal opportunities

Despite all its insights and findings, ABC did not succeed. Because the project was unsuccessful in starting a dialogue with the Amsterdam municipality. Hisschemöller and colleague-researchers observed that the Amsterdam municipality is mainly committed to high-temperature district heating based on fossil fuels' combustion. "Partnerships between local governments and existing energy suppliers impede a bottom-up sustainability transition. A large company can find funding easier compared to a citizens' initiative. National and local governments should ensure a level playing field that enables citizen initiatives, with the goal of providing equal opportunities," explains Hisschemöller. "This is what I am calling for, and it is exactly the kind of network we are building. So we're working on ensuring the continuation of the ABC project."

Demanding space for low temperature heat networks

Although disappointed about the impossibility of realising an ABC estate, the research team still gained a lot from the project. The insights and approaches have been disseminated and used by different organisations to confront local government(s) and demand space and support for low-temperature heat networks.

An example is the Van der Pek neighbourhood in Amsterdam-Noord, where tenants have initiated independent research to consider a low-temperature aqua-thermal system. Hisschemöller: "Even though the municipality, the housing association and Vattenfall have in fact already primarily agreed on the high-temperature network. Furthermore, in April 2020, the Amsterdam court ruled that a passage in the heat plan of the Sluisbuurt – that solar panels do not count for a sustainable heat solution competing with district heating – violates Dutch law. Something that ABC had previously also concluded."

Parties that need each other to make progress

Looking back on the projects, Hisschemöller concludes: “It was both exciting and challenging. And we are still preoccupied with it.” The researcher is now working on a project for the Netherlands Enterprise Agency (RVO). “We are looking into what they call ‘communities of innovative learners’: learning communities in the energy transition. We are trying to bring together the parties who, according to our analysis, will need each other to make progress.”

The second report, Daar brandt een vlammetje onder [Enthusiasm has not dimmed], results from the second year of research. This time, the researchers looked at the issue from the other side: not that of the institution, but that of the residents. The report presents the results of a focus group study into how in the context of climate change and global warming, centralised energy regimes which mainly rely on fossil fuels increasingly encounter opposition. Local governments and residents appear to be willing to undergo a system change. However, countless uncertainties still often impede the implementation and scaling potential of the alternative to fossil fuels: there are many new initiatives at a niche level. The tension and synergy that arise determine how successful the parties concerned can be in adequately implementing a local energy transition.

Co-operation consortium partners opportunity to increase knowledge

An important objective of the URSES+ programme was to stimulate the participation of private and public consortium partners within the projects. To translate the research results to the urban context and to optimally exploit the consortium's potential. How did partners perceive the co-operation within the URSES+ programme? Did the results meet their expectations? Their opinions are presented here.

All partners saw the co-operation as an excellent opportunity to increase their knowledge. They said that they got a fresh look at sustainability and how consumers, companies and grid operators deal with it, and they were content to have obtained insights into the much broader context of the energy transition.

Ewald Breunesse
Photo: Shell International Ltd.

Shell: energy chain on pilot scale

For URSES sponsor Shell, the collaboration with CaPP-Life was a catalyst to carry out plans they already had in the pipeline. **Ewald Breunesse**, Manager Energy Transitions at Shell:

"Our intention already was to investigate how we could run our Shell Technology Centre Amsterdam (STCA) solely based on sun and wind for some time already. Then URSES+ came along, and I said to my colleagues: we have to participate".

Inspired by the URSES+ project, they bought some hydrogen-powered cars for car-sharing on the premises, built a small hydrogen filling station, purchased an electrolyser to split water, and increased the number of solar panels on the roof.

"We completed the energy chain on a pilot scale," explains Breunesse. "CaPP-Life has shown that the cost of building a dual infrastructure, so power lines and hydrogen lines, far outweighs the cost of having and maintaining them. And one of the great results of this project is that now we have become a living lab. We can follow the car-sharing cars, for example, or we research the quality of hydrogen. So, we have built many laboratory tests around this whole project, and we have it all under our management. In the future, economic considerations will determine whether hydrogen-powered cars can be used on a large scale."

Martijn van der Eerden

Liander: important to shift focus to social side too

Consortium partner Liander was working on a pilot project to realise sustainable solutions in city centres when they had the opportunity to collaborate with URSES+ project StoRE. The grid manager is convinced that for large-scale implementation, it is essential to look at more areas than just technology — reason why the Amsterdam project City-zen was such a good fit. The project enabled Liander to gain a good understanding of people's choices and behaviours in the energy transition to anticipate on the future.

Martijn van der Eerden, Asset Management Strategy & Innovation at Liander: "The StoRE researchers were in direct contact with the project participants. Without us, as a large company, being present. This allowed them to create a safe and personal situation and to put the human side in the right place. Therefore, they got everything on the table". According to Van der Eerden, the project has demonstrated in concrete terms that the energy transition is not a purely technical responsibility. He recognises the importance to shift the focus to the social side too.

"StoRE has shown that the world is different from what we think. And as a utility company, we must be prepared for everything we do today to last for the next 40 to 50 years. Besides that, we should be one step ahead of the fact that tomorrow's questions already will have to be resolved now".

Ben van der Stoop

Van Gogh Museum: call for further research

Consortium partner Van Gogh Museum came into contact with ATES-SG+ by chance. The museum had been looking at how they could use their surplus heat and cold with other institutions around the Museumplein, but without success. Then the TU Delft got involved, and the museum had the opportunity to engage in a separate trajectory in the URSES+ research project.

Ben van der Stoop, Senior Advisor Property Management at Van Gogh Museum: "One of the interesting parts of the project was modelling a 3D model of the building. It provided insights into the possibilities of making more, or at a more innovative way, use of our HVAC-system."

The model is very abstract and mathematical, according to Van der Stoop. "They are a kind of mathematically designed building blocks, but without a real connection with reality. Except for the fact that calculations were made and that they were compared with what then emerged in practice in heat and cold flows. What made it difficult was that not all the important data was available at the time."

Van der Stoop explains that nowadays, museum does have access to that data, and he would like to make a call for further research: "Should any other student be interested, we are willing to cooperate. I enjoyed working with the students. There was a nice open atmosphere which made it a great environment to work in."

Conclusion

Results

In this booklet, we have presented the results from URSES and URSES+. Both programmes and their projects have been very successful and form a solid base for future activities. One could think of subsequent fundamental and applied projects, pilots, deployments, and other activities in the field of future energy systems. To realise a sustainable energy system, it is not only the researchers and the governmental bodies who have to take this up. Also, the Topsectors Energy and ICT, companies, private institutions, and associations have their roles and responsibility. In this light, it is a positive development that NWO has continued developing research programs focused on the energy transition. In any way, the research community has become a dedicated community. Researchers from various disciplines can find each other, cooperate actively, and prepare for the next steps in research and development.

Urgency

The urgency to deal with the increasing amount of renewables has become eminent in current times. A good example is to be found in Germany. Our neighbouring country is dealing with complex management and control issues regarding their electricity system, due to the large-scale introduction of PV panels and wind turbines in recent years. However, also in the Netherlands, we are dealing with such types of urgencies. For example, in some regions, generating electricity from renewable sources was delayed deliberately due to network capacity issues. Moreover, because of removing gas as an energy supplier for homes, there has been growing stress on electricity networks. We have an excellent research and development community in our country that needs continuing support from, e.g. national and EU governmental bodies, as well as private funders to keep our energy transition steaming at full speed ahead.

Furthermore, initiatives from industry and the market can lead to innovation and investment. The government could continue setting up incentives and subsidies, and deal with issues like return on investment, the organisation of a future energy system, and system responsibilities.

Outlook

Finally, areas of current research address various topics, and we foresee more activities in the future. One example is the consideration of integrating multiple energy systems, like electricity and hydrogen. Another example is the energy system with a nested subsystems structure - private, local microgrids, and distribution, transmission, and combined networks.

Other important issues are:
- dealing with e-vehicles and e-mobility
- storing heat and cold as energy buffers for seasonal changes
- achieving reliability in handling supply and demand or congestion in future electricity systems.

The latter have to be at the same high level as we have seen in the past.

“Besides these technical challenges, the social, legal, and political approaches are indispensable.”

ICT will play an increasing role, together with cybersecurity and privacy issues, besides the enormous opportunities for artificial intelligence and big data usage. In addition to these technical challenges, the social, legal, and political approaches are indispensable. This concerns e.g. the acceptance of future technologies by users, the proper transition and innovation paths towards sustainability with multi-actor decision making, appropriate business models and (returns on) investments, and furthering the awareness of people to tackle all these points.

A lot has been done already, but there is still a lot to do. Now it is time to go ahead and establish our desired sustainability. Not only because of the various national and international treaties on this, but because we want it, and it is necessary.

Han La Poutré

Colophon

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