Book of abstracts

Including programme

Smart Energy Hubs Conference

SAXION UNIVERSITY OF APPLIED SCIENCES

UNIVERSITY OF TWENTE.

1st Conference on Smart Energy Hubs
20 November 2024

Book of abstracts

Saxion University of Applied Sciences
Research group Sustainable Energy Systems
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Preface and welcome

With great pleasure we welcome you to the first conference on Smart Energy Hubs in the Netherlands, which takes place on November 20, 2024 at Connect-U in Enschede. The conference is organised by Saxion University of Applied Sciences, University of Twente and Oost-NL. We look forward to meeting speakers and visitors from academia, industry and municipalities from the Netherlands and countries around us.

The conference is focussed on the solution framework of Smart Energy Hubs which is still relatively new. There is a continuous need for the exchange of knowledge and experiences from practice surrounding the development and implementation of the solutions. In addition, there is a need for a better understanding of the scope of the solution framework and what can be expected in the future in terms of new solutions and applications, e.g. the use of Multi-Commodity Smart Grids to achieve the conversion of electrical energy into heat, sustainable fuels and chemical building blocks. This also requires new insights and developments from science.

The conference offers the opportunity to learn these new developments and to participate in the exchange of scientific knowledge (by researchers) and practical experience (by professionals). The purpose is that participants will gain new knowledge and experience about the current state of the art and updates about the latest developments (also internationally) in the field of smart energy hubs. There will be approximately 150 participants (including speakers and audience).

Target groups for the conference are: researchers (university, university of applied sciences, TO2 institutes), industry experts, representatives of municipalities, companies and consultancy firms. The main language during the conference is English, especially for speakers and visitors from abroad.

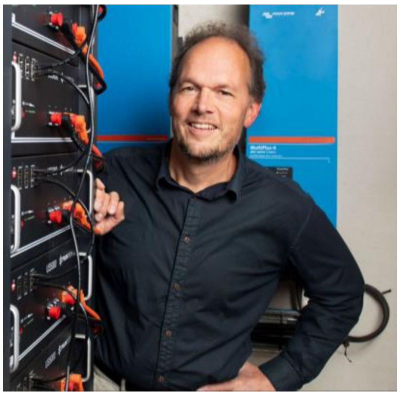
We wish all our guests, speakers and visitors an inspiring conference!

Richard van Leeuwen, lector Sustainable Energy Systems, Saxion hogeschool, conference chair
Yashar Hajimolana, ass. Professor energy system integration, University of Twente, conference co-chair
Robert-Niels van Droffelaar, Oost-NL Smart Energy Hub program
Caroline Lettinga and Tanja Vreugdenhil, conference support team.

Contents

Organising committee

Dr. ir. Richard van Leeuwen, Professor Sustainable Energy Systems at Saxion University of Applied Sciences, conference chair.



With his research group he performs applied research in the fields of energy system integration, smart energy systems, bio-energy and hydrogen technology and applications. Research projects in the field of smart energy hubs include MOOI EIGEN, MOOI new energy control business park, Horizon 2020 Serene and Learning Community System Integration. Within the energy flexibility lab, researchers and students work together on investigating the role and control of flexibility options to balance energy networks, with state of the art hardware and digital twin simulation facilities. He also leads Saxion's focus expertise area on Circular Innovation and Energy transition in which 12 research groups participate.

Dr. ir. Yashar Hajimolana, ass. Professor in Energy Systems Integration at University of Twente, conference vice chair.

Yashar Hajimolana is an assistant professor in Energy Systems Integration at the University of Twente, part of the Thermal and Fluid Engineering Department. His work focuses on sustainable energy solutions including energy hubs and hydrogen integration to drive decarbonisation in industrial and transportation sectors. His approach integrates multi-energy carriers and sector coupling, exploring how these elements dynamically interact to enhance the adaptability, flexibility and efficiency of energy systems. He applies his expertise on reversible fuel cell systems to applications like grid balancing and Power-to-X production, advancing energy storage and conversion technologies that support the transition to low-carbon infrastructures.

Robert-Niels van Droffelaar MSc, Sr. Business Developer Energy at Oost-NL , conference co-organiser.

Robert-Niels van Droffelaar is core team member of Connectr Energy Innovation, partner in the project MOOI EIGEN. Oost NL co-develops and manages the living lab for smart energy hubs in East Netherlands together with the provinces of Gelderland and Overijssel. The living lab currently supports 10 energy hubs in the region. With the approach 'learning through realizing energy hubs' the program accelerates the development of energy hubs. Practical knowledge is shared, tooling is being developed on the themes Legal, Technological, Financial and Organisational.

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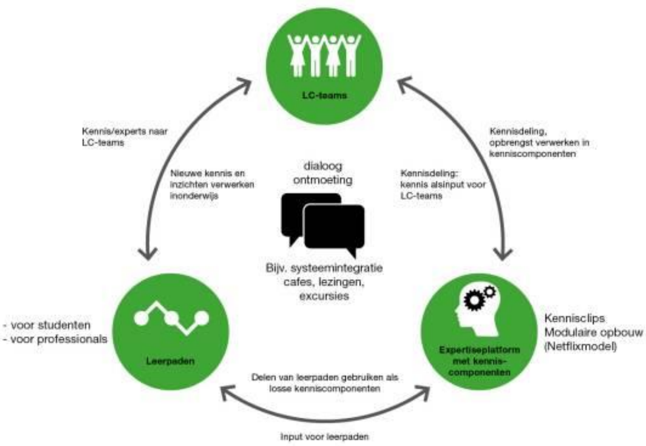


Nationale Learning Community Systeem Integratie
https://topsectorenergie.nl/nl/projecten/learning-communities-systeemintegratie/

Programme

08:30 – 09:00		**Registration and coffee/tea**	**Main entrance**
09:00 – 10:15		**Plenary opening session**	**Plenary hall 1st floor**
09:00 – 09:10	**Professor Richard van Leeuwen and assistant Professor Yashar Hajimolana:** welcome and logistics guides for the conference		
Plenary keynotes:	**Perspectives on Smart Energy Hubs – chaired by Prof. Richard van Leeuwen**		
09:10 – 09:25	**Pavol Bauer, Professor DC Systems, Energy Conversion & Storage, TU-Delft**: Energy Hubs – basic building block for energy transition		
09:25 – 09:35	**Jorian Bakker, senior policy advisor Climate and Energy, Dutch ministry for climate and green growth**: Dutch government policies on development of Smart Energy Hubs		
09:35 – 09:45	**Marjolein Bot, director of program on energy system integration, Topsector Energy**: Topsector energy working program Smart Energy Hubs		
09:45 – 09:55	**Bart van der Laan, program manager energy flexibility, Alliander**: Impact of Smart Energy Hubs for DSO's		
09:55 – 10:15	**Questions and debate**		
10:15 – 10:30		**Short break**	**Main hall**
10:30 – 12:00		**Parallel session 1 - 3**	
Session 1 – Chaired by Richard van Leeuwen - Room1		**Session 2 – Chaired by Cihan Gercek - Room 2**	**Session 3 – Chaired by Lisanne Havinga - Room 3**
Local and regional energy planning, spatial and infrastructural aspects of Smart Energy Hubs		**Preventing and solving congestion on medium/low voltage networks**	**Smart Energy Hubs solutions framework and applications**
Session keynote Sebastian Thiede: Towards decarbonisation of manufacturing industry		**Session keynote Edmund Schaefer**: Sizing energy storage while considering financial, environmental and grid peak reduction objectives: a neighbourhood case	**Session keynote Michiel van Dam**: Scaling smart energy hubs: the slippery slope to success
Joris Knigge and Jeroen Janissen: The energy transition in urban planning and development; towards an integral approach		**Shalika Walker**: Predictive control and energy flexibility for buildings	**Jeike Wallinga**: Development of industrial estate energy hubs: Accelerating the energy transition through effective interventions of local government
Timo te Velde: Smart Energy Hubs at the Municipality of Enschede - Lessons Learned from Practice		**Hans Meerman**: Tackling grid congestion by connecting neighbours	**Willem Wijnen**: Smart Change Management in Smart Energy Hubs
Rick Stratingh: Solutions for grid congestions on business parks: Groningen Stroomt Door		**Aditya Pappu**: Flexibility sizing for Energy Communities under Dynamic Grid Constraints	**Sjoerd Doumen**: Making Energy Hubs Even Smarter by Providing Trade Between Energy Hubs and Communities
Shamsoddin Ghiami: Investigate electricity consumption reduction potential during winter using PVT		**Hans Schokker**: RAAK MKB Project NOWATT	**Michel Chatelin**: Unlocking the Full Potential of Energy Hubs with Programmable Energy
12:00 – 12:45		**Lunch and networking**	**Main hall**
12:45 – 13:00		**Formal opening of Saxion Energy Flexibility lab**	**Plenary hall 1st floor**

13:00 – 14:30	**Parallel session 4 - 6**	
Session 4 – Chaired by Edmund Schaefer - Room1	**Session 5 – Chaired by Fenna van de Watering - Room 2**	**Session 6 – Chaired by Robert-Niels van Droffelaar - Room 3**
Cyber secure and interoperable ICT-systems and device interfaces for monitoring and control of Smart Energy Hubs	**Hydrogen integration in Smart Energy Hubs**	**East Netherlands Smart Energy Hubs pilot program**
Session keynote Gerwin Hoogsteen: Rethinking interaction for a resilient and cyber-secure system	**Session keynote Benno Aalderink**: Developments and outlook for decentral hydrogen integration in the Netherlands	Session organised by **Oost-NL** about experiences and lessons learned from the pilot Smart Energy Hub projects
Dwijasish Das: DC Wind Energy Hubs for a sustainable future	**Monika Sharevska**: Renewable energy system with hydrogen production and methanol storage for efficient electricity supply-demand balancing	**Robert-Niels van Droffelaar**: Program and learnings (focus on organisation) **Wouter Heres**: Smart Energy Hub Broeklanden
Deepak Tunuguntla: Explainable AI/ML forecasting models	**Lauro Oliveira**: Renewable hydrogen hubs in the Netherlands: assessing the feasibility of hydrogen production technologies integration	**Rutger Beekman**: Smart Energy Hub Almelo & A1 Deventer (focus on tools) **Thomas Pesiwarissa**: Smart Energy Hub Lorenz (focus on EMS)
Eyuel Debebe Ayele: IECON: IoT edge computing for carbon Neutral communities	**Richard van Leeuwen**: The energy system in Twente and the role of underground hydrogen storage	Panel discussion
14:30 – 14:45	**Short Break**	**Main hall**
14:45 – 16:15	**Parallel session 7 - 9**	
Session 7 – Chaired by Abhishek Singh - Room1	**Session 8 - Chaired by Johann Hurink - Room 2**	**Session 9 – Chaired by Miloš Bunda - Room 3**
Multi-commodity smart grids, sector coupling and power to X.	**Smart charging in Energy Hubs**	**MOOI EIGEN: new and open tools for Smart Energy Hub projects**
Session keynote Daniël Bakker: Exploration of potential grid capacity reduction for multi-commodity smart energy hubs in three industrial areas in the Netherlands	**Session keynote Cihan Gercek**: Grid design and grid aware EV charging	**Session keynote Attila Németh and Natalia Kuznetsova**: A framework for a social cost-benefit analysis for energy hubs
Maja Sharevska: Optimization of design and operation of an energy hub using different strategies	**Andreas Ligtvoet**: Charging Energy Hubs - cooperating to electrify logistics	Stage 1: steward ownership of the future security of supply **Joey Willemse and Robin Schipper**: Bottom-up development of shared responsibility using a participation framework **Vincent Kamphuis**: developing future local energy vision using a Plan & Design tool suite
Pepijn van den Bent: Realized and Operational Smart Energy Project Thermen Soesterberg and Heat Central Groenpoort (for district heating/cooling)	**Ali Saklaoui**: Coordinated Optimization of Logistics Electric Fleet and Energy Management System of Constrained Energy Hub	Stage 2: translating local energy vision into an actual design using **Vincent Kamphuis**: Plan & Design tool suite **Gerwin Hoogsteen**: energy system simulations using Demkit **Pelle van den Heuvel**: legal framework **Timo van Ingen**: tender strategy
Juan López: Developing Digital Twins for Industrial Microgrids: The Ecofactorij Case Study	**Tim van 't Wel**: Energy Hubs for High Power Charging of Zero Emission Logistics	Stage 3: realizing the Energy Hub **Vincent Kamphuis**: development of a shared SCADA/EMS system for local matching of supply and demand
Ewoud Vos: SynergyS: a market-based approach for multi-commodity energy hubs	**Jim Kienhuis**: The effects of the location of Energy Storage in Low-voltage Grids	Stage 4: asset management and exploitation of the Energy Hub **Miloš Bunda**: the exploitation entity
16:15 – 16:30	**Short Break**	**Main hall**
16:30 – 17:00	**Plenary closing session**	**Plenary hall 1st floor**
16:30 – 16:45	Take aways from organising chairs and session chairs, moderated by **Robert-Niels van Droffelaar**	
16:45 – 16:55	Best presentation award ceremony by **ass. Professor Yashar Hajimolana**	
16:55 – 17:00	Closing by **Professor Richard van Leeuwen**	
17:00 – 17:30	**Networking and drinks**	**Main hall**

Editorial: It all comes together in a Smart Energy Hub

Dr.ir. Yashar Hajimolana and Dr.ir. Richard van Leeuwen

In response to the Paris Climate Agreement and supportive policies in the Netherlands, Dutch regions and cities are targeting ambitious 2030 and 2050 to achieve carbon-neutral energy systems. With favourable tax policies driving the adoption of renewable energy, a range of actors — including industries, businesses, municipalities, energy cooperatives, and households — are increasingly investing in sustainable energy sources like solar PV and wind turbines, as well as electrification technologies such as heat pumps and electric vehicles. However, this rapid transition is challenging the existing electrical infrastructure. Local electricity networks, especially low-voltage grids, are frequently congested due to overload in energy demand and generation surpluses. This results in creating bottlenecks that could slow progress in sustainability.

Smart Energy Hubs (SEHs) represent a strategic approach to address environmental goals as well as grid capacity issues without the need for extensive physical upgrades, enhance energy security, and promote economic and social equity. These hubs combine renewable energy generation, storage, and advanced energy management to maximize the use of sustainable resources locally, mitigating grid congestion, providing a flexible, resilient solution for communities.

Advantages and Goals of Smart Energy Hubs

Reduction in CO_2 Emissions and Fossil Fuel Dependence

SEHs optimize local energy use by integrating renewable sources such as solar, wind, and biomass with storage technologies, which enables communities to minimize reliance on fossil fuels. SEHs manage the generation, storage, and usage of renewable resources, using real-time data and forecasting to align energy supply with energy demand. This strategic energy flow minimizes waste and curtails the need for supplemental, carbon-intensive power from the grid.
By creating local pathways to carbon neutrality, SEHs support national and international climate goals, like the Paris Climate Agreement, from the ground up. Communities can decarbonize independently of slower national progress, creating faster and tailored pathways toward sustainability.

Reduction in Infrastructure and Maintenance Costs

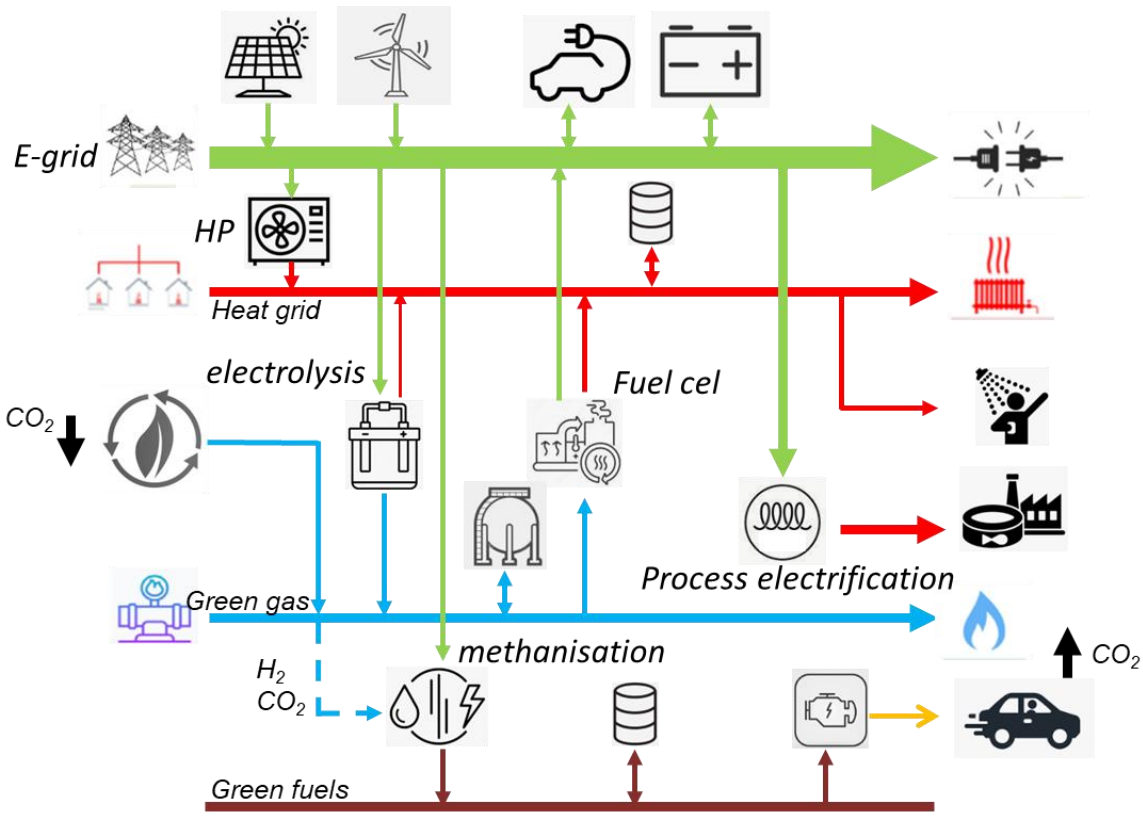
One significant challenge with renewable integration is its impact on grid infrastructure, which is often unprepared for increased demand and supply variability. SEHs help mitigate this issue by creating self-sufficient energy ecosystems that rely less on extensive infrastructure modifications. By storing excess energy and balancing loads, SEHs prevent overloading in low and medium-voltage networks, avoiding congestion. This reduces the need for costly grid reinforcements and maintenance, saving municipalities and utilities millions. SEHs can adjust local demand dynamically, helping balance energy flow to the grid and reducing peak demand, which lowers stress on the infrastructure.

Promoting Socially Equitable Energy Transition

SEHs support energy transition by encouraging the active participation of local businesses, organizations, and residents. Local stakeholders can invest in and manage SEHs, creating opportunities for community-driven energy solutions. This involvement gives residents a sense of control over their energy use, aligning energy solutions with local needs. Community ownership models, like cooperatives, allow residents to benefit from lower costs and revenue-sharing. This socially equitable framework not only empowers communities but also attracts local investments that can be reinvested in other community projects.

Improved Energy Efficiency through Multi-Energy Integration

SEHs combine multiple energy carriers, such as electricity, heat, and gas, to optimize the local production, storage, and consumption of energy. The schematic below shows a future fully integrated energy system that could become reality on the local, regional and national level. By creating systems that can store heat or convert surplus electricity into thermal energy (for heating) or hydrogen (for fuel), SEHs capture and recover energy that would otherwise be lost. This system-wide optimization can significantly lower overall energy use and improve sustainability. SEHs use real-time analytics and advanced energy management systems to coordinate energy flows, minimizing losses due to excess generation or inefficient transmission.



Enhanced Flexibility and Resilience of Local Energy Systems

SEHs build resilience by integrating multiple energy types, which makes local systems more adaptable to fluctuations in demand or unexpected disruptions. This diversity creates a buffer that helps communities maintain functionality during grid disruptions. SEHs are equipped to provide backup power, demand response, and ancillary services, helping to stabilize the grid during critical moments and ensuring reliability. This capability is especially important for critical facilities.

Supporting Innovation and Economic Growth

SEHs stimulate local economies by creating new opportunities in clean energy production, storage, and technology development. This localized approach to the energy transition encourages economic development and attracts green investments. As SEHs are developed, they generate jobs in construction, engineering, operations, and maintenance. Additionally, ongoing training programs to support SEH initiatives help build a skilled workforce equipped to manage next-generation energy systems. By fostering a need for localized, resilient energy solutions, SEHs drive innovation in areas such as storage technologies, Energy management systems, grid management software, and smart home integration. This continuous cycle of innovation and deployment contributes to a robust green economy.

Facilitating the Shift to a Decentralized Energy System

SEHs are an essential component of the shift from centralized to decentralized energy systems. By enabling local energy production, utilization and storage, SEHs allow communities to be less reliant on central energy grids, which are vulnerable to systemic failures or disruptions. This approach makes it feasible for communities to implement peer-to-peer energy trading, where households or businesses can sell excess energy to neighbours or other community members. This fosters a more resilient, autonomous energy system that better meets local demand.

Complexity and Bottlenecks in Developing Energy Hubs

While energy hubs offer a promising solution for sustainable energy transition, implementing them in practice presents numerous complexities and challenges that require innovative approaches beyond traditional methods. Several key bottlenecks must be addressed to make energy hubs effective and scalable:

Greater Community Involvement in Planning

Unlike conventional energy projects, energy hubs rely heavily on bottom-up input from a diverse set of local stakeholders, including community members, businesses, and local government entities. Achieving a functional energy hub necessitates not only the technical infrastructure but also a commitment from these stakeholders to participate actively. The goal of “securing local sustainable energy” may not hold the same importance for every stakeholder, so establishing common objectives and ensuring all parties feel ownership is essential.

Long-term Energy Demand Forecasting

For energy hubs to function effectively, they must be developed with a clear understanding of future local energy demands, often looking several years or even decades ahead. However, most organizations—particularly companies—typically focus on short-term planning, often only one to two years ahead, for their energy usage and sustainability targets. Adapting to a longer planning horizon is essential for supporting the infrastructure, investment, and strategic coordination that energy hubs demand. Unlike short-term energy adjustments, energy hubs involve capital-intensive components such as energy storage and conversion technologies, renewable energy generation installations, and grid modifications. These elements require significant investment and long-term commitment, which is only feasible if future demand is anticipated accurately. This shift in perspective calls for a deeper engagement with data-driven forecasting, including factors like population growth, urban development, and evolving energy technologies.

Understanding Technical and Economic Interdependencies

Creating a successful energy hub involves aligning the economic interests and technical requirements of all participants. In practice, establishing theses frameworks is challenging due to several dynamic parameters such as energy prices, fluctuation of renewable energy sources and demand of energy, and stakeholder priorities which can shift over time. Therefore, effective energy hubs, must incorporate revenue-sharing structures that are able to adapt to these dynamic changes.

Efficient Asset Management for Scalability

Optimizing energy hubs operationally relies on effective asset management practices. This includes strategically managing resources, forecasting demand, and planning for future expansion. For energy hubs to scale effectively, operators must focus on maintaining energy efficiency and maximizing return on investment, a challenging task given the unique configuration and dependencies within each hub.

Coordination and Organizational Structure

Coordinating the different actors in an energy hub and establishing efficient operational practices require a new form of collaboration. Unlike traditional energy systems where roles are well defined, energy hubs demand flexibility, a high level of interdependency, and often, non-traditional partnerships. Setting up such an organizational structure can be labour-intensive and requires continuous alignment of priorities.

Legal and Regulatory Frameworks

The current regulatory framework is often not tailored to accommodate the collaborative, decentralized, and flexible nature of energy hubs. Policies around market regulation, cooperation, and operational coordination within energy hubs evolve slowly, and there is a need for adaptable legislation to support the planning, development, and management of these systems. Delays in regulatory adaptation can slow down the deployment of energy hubs and dissuade potential stakeholders.

Public Acceptance

Public support and understanding are critical for the successful implementation of energy hubs. Resistance to new energy infrastructure, whether due to a lack of information or perceived disruption, can significantly delay or derail projects. Outreach efforts that clearly communicate the environmental, economic, and community benefits of energy hubs are essential to build trust and foster acceptance.

Technical Challenges

Developing energy hubs presents a range of technical challenges, each crucial to ensuring reliable, efficient, and scalable operations. A major hurdle is integrating these hubs with existing power grids, which often lack the capacity to handle the fluctuating input from renewable sources like solar and wind. Ensuring grid stability requires advanced management tools and predictive algorithms that dynamically balance supply and demand to prevent overload. Storage solutions add another layer of complexity; while batteries can temporarily store excess power, they are costly and often limited in capacity. Data management also poses a significant challenge as energy hubs depend on real-time data for optimizing energy flows. Efficiently gathering, processing, and analysing this data across multiple devices requires robust computational resources. Using IoT and edge computing can streamline data handling, while AI and machine learning further enhance forecasting and maintenance needs. Additionally, managing demand response is crucial to balancing the load, as renewable sources fluctuate. Demand response programs and dynamic pricing models can help adjust consumption patterns, reducing grid strain during peak periods.

Interoperability among diverse technologies within the energy hub is key to smooth integration, especially since each system may follow different communication protocols. Securing the energy hub infrastructure from cyber threats is also essential, given the risks posed by increasingly networked systems. Optimizing renewable energy use is another complex task. The variable nature of sources like solar and wind means energy hubs must employ forecasting tools and hybrid systems to maintain consistent output. Cost management is equally challenging, as the initial capital investment and ongoing maintenance can be high. Through a mix of innovative storage, real-time data management, interoperability, and security strategies, energy hubs can overcome these technical challenges to provide sustainable, localized energy solutions that serve community needs effectively.

This book aims to situate the Dutch SEHs framework within the broader landscape, identifying potential solutions for common challenges in the transition to sustainable energy. The specific contributions of this book include:

- Local and regional energy planning spatial and infrastructure of Smart Energy Hubs

This session focuses on embedding SEHs into local and regional energy planning, exploring the spatial and infrastructure aspects that shape urban energy systems. Topics include transitioning manufacturing industries towards decarbonization, integrating energy transitions into urban development, and practical insights from Enschede’s implementation of SEHs. Also highlighted are case studies such as De Waterlaat industrial park and winter energy reduction using photovoltaic-thermal (PVT) systems, showing real-world applications of SEHs.

- Preventing and solving congestion on medium/low voltage networks

As energy demand and renewable energy generation grow, managing congestion in low and medium voltage networks becomes essential. This session covers strategies for monitoring and controlling grid loads, such as using smart meters, local pricing, and neighbour collaboration to prevent congestion. It also includes discussions on flexibility sizing for energy communities and energy storage strategies that balance financial, environmental, and grid peak reduction goals.

- Smart Energy Hubs solutions frameworks and applications

Scaling SEHs requires effective strategies and frameworks, including interventions by local governments, change management, and programmable energy tools. This session addresses challenges and solutions for scaling SEHs, with topics covering industrial estate hubs, change management for effective SEH implementation, and enabling energy trading between hubs and communities to maximize the benefits of SEHs.

- Cyber secure and interoperable ICT-systems and device interfaces for monitoring and control of Smart Energy Hubs

Smart Energy Hubs rely heavily on ICT systems for monitoring, control, and security. This session delves into creating cyber-secure and resilient ICT interfaces. Topics include resilient system interactions, the potential of DC wind energy hubs, explainable AI/ML forecasting models, and the use of IoT edge computing in achieving carbon neutrality. Each of these solutions plays a role in ensuring robust, secure, and efficient energy systems.

- Hydrogen integration in Smart Energy Hubs

Hydrogen's potential as a clean energy source makes it a key component in SEHs. This session explores decentralized hydrogen production, renewable hydrogen hubs in the Netherlands, and the integration of hydrogen and methanol storage systems for efficient balancing of energy supply and demand. Additionally, the role of underground storage in Twente's energy system offers insights into optimizing storage and supply within SEHs.

- East Netherlands Smart Energy Hubs pilot program

The East Netherlands Smart Energy Hubs pilot program highlights innovative applications and real-world testing of SEHs. This program serves as a model for how regional pilot projects can inform scalable solutions across other areas, using lessons learned to improve energy management, sustainability, and grid resilience.

- Multi-commodity smart grids, sector coupling and power to X

This session focuses on the synergy between different energy sectors within SEHs. It examines strategies for reducing grid capacity needs in industrial areas and optimizing energy hub design through multi-commodity smart grids. Case studies include Thermen Soesterberg and Heat Central Groenpoort, as well as digital twin technology applications like the Ecofactorij microgrid, demonstrating sector coupling for district heating, cooling, and industrial energy management.

- Smart charging in Energy Hubs

Electrifying logistics and vehicle fleets requires efficient charging solutions within SEHs. This session presents methods for grid-aware EV charging, coordinated fleet management, and energy hub designs that support high-power charging. By focusing on grid design and smart charging, SEHs can further support sustainable transportation networks while managing demand on local grids.

- MOOI EIGEN: new and open tools for Smart Energy Hub projects

Effective SEH deployment requires open tools and frameworks to analyse costs and benefits. This session introduces tools for social cost-benefit analysis, providing a framework to assess SEH projects' economic and social impacts. These tools can help guide decision-making, optimize SEH design, and encourage adoption across regions and communities.

Session 1: Local and regional energy planning, spatial and infrastructural aspects of Smart Energy Hubs

Towards decarbonisation of manufacturing industry

Dr.ir. Sebastian Thiede, s.thiede@utwente.nl, University of Twente

Industrial value chains play a crucial role in context of global greenhouse gas emissions. Different strategies are possible at different scales – from machine over factory to supply chain level - and need to be combined towards decarbonization of the sector. Energy efficiency and energy substitution are of major importance.

The presentation will give an overview of current challenges and outlines key strategies for improvement. Besides some general background, specific examples will be given to illustrate impact and technology pathways towards decarbonization.

Specific attention will be paid on digital supported technologies, methods and tools and their potential contributions.

Energy transition in urban planning and development; towards an integral approach

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1. L. Mol, 2. N. Vink, 3. J. Janissen, 4. S. Winkel, 5. J. Knigge
Antea Group (1, 2, 3, 4, 5)

In the Netherlands the energy transition is progressing. More and more sustainable energy production is being realised, more sites are being developed to exploit solar and wind energy (on and offshore) and isolation and reduction of energy usage is being undertaken by companies. This also leads to more and more problems with the development and realisation of energy infrastructures. Electricity networks are not equipped to accommodate new bi-directional flows of electricity and do not have enough or sufficient capacity and any given time and place. Urban planning and development (the development of the build environment) increasingly comes to these problems in day-to-day practice.

This presentation sets the stage towards an integral approach from an urban planning and development perspective. When parties and actors have the ambitions to realise programs for housing, work and mobility in certain designated areas; how do we tackle in an early stage the issues and aspects with regard to the implementation of sustainable energy systems? What aspects of production, transport and distribution, storage and usage we have to consider in this stage of urban development and what kind of consequences do we have to apply in designing an urban development.

This presentation combines the point of view of urban planning with the practical lessons Antea Group learned in feasibility studies for municipalities and industries for commercial and industrial area development for smart energy hubs. Also lessons from different approaches on the smart energy hubs from a study form TU Delft will be presented. The presentation invites the audience to discuss the lessons from the urban development perspective as well as the technical and economic feasibility perspective on smart energy hubs.

Smart Energy Hubs at the municipality of Enschede – lessons learned from practice

Timo te Velde MSc, t.tevelde@enschede.nl, Municipality of Enschede
1. T. te Velde, 2. M. Morskieft, 3. P. Spijker, 4. D. van den Berg
Municipality of Enschede (1, 2, 3), VU University Amsterdam (4)

The municipality of Enschede is currently working on two projects centred around Smart Energy Hubs (SEH). Namely at 1) business park de Marssteden and 2) at business park Kennispark and sports park Twente Village. In this summary we outline some of the lessons learned.

De Marssteden

At De Marssteden, the main purpose of the SEH is to allow businesses to expand their operations and to increase the park's amount of renewable energy (solar PV). The electricity grid at de Marssteden is currently at or near its maximum capacity, restricting further growth. The aim of the SEH is therefore to create extra capacity.

Kennispark & Twente Village

Similar to the SEH at de Marssteden, the energy hub at Kennispark will be used to increase the available grid capacity. However, what sets this SEH apart from the first is the inclusion of a planned solar parking installation and battery at nearby sports park Twente Village.

Even though these projects have potential, there are several challenges that still need to be overcome. These can be grouped in three main areas. Some, but not all, are;
1) Contracts and management: Currently it is unclear which management construction can be best used at an SEH. In addition to this, the necessary group contract has not yet been made available by grid operators. This causes uncertainty, leading to a lower level of interest for the SEH.

2) Investment and ownership: This is probably the most significant barrier. Businesses typically avoid investments with payback periods exceeding 5 to 7 years and the SEH's payback time is longer than that. Moreover, many companies do not perceive ownership of the problem that is addressed with the SEH. Stating that this is the net operator's responsibility. Additionally, businesses are reluctant to give their autonomy, which often is a requirement for joining a collective such as an SEH.

3) Data: The currently available 15-minute usage data is insufficient. For efficient operation of the SEH, second data is necessary. This requires new measurement equipment, for which another investment is necessary. Also, who will be the owner of this data still has to be determined.

Solutions for grid congestions on business parks: Groningen Stroomt Door

Rick Stratingh MSc, r.g.stratingh@pl.hanze.nl, ENTRANCE, Hanze
1. R.G. Stratingh, 2. R. Kappert, 3. F. Pierie, 4. M. van der Laan
ENTRANCE (1, 2, 3, 4)

The Netherlands, including Groningen, is transitioning its energy generation and consumption towards sustainability and electrification, driven by the Climate Agreement and the Regional Energy Strategy. As simultaneous electricity consumption increases and more sustainable electricity is supplied to the grid, the risk of grid congestion rises, given the mismatch between demand and supply. Grid congestion hampers business growth and sustainability, putting pressure on the business climate. This research aims to prevent grid congestion from hindering the development of business parks in the region and to enable companies to continue expanding and becoming more sustainable.

Within this project, a methodology has been developed that involves assessing the growth potential of individual companies through site visits. This is done by analyzing business activities, future plans, and energy-saving opportunities, and linking these to energy profiles of grid operators. Additionally, scenarios are developed at the area level to explore, from a system integration perspective, how various energy generation, storage, and demand response technologies can be combined to free up capacity on the electricity grid.

A case study at a business park in Groningen shows that an integrated application of wind energy, solar energy, battery storage, and smart control can create space for new businesses. An initial cost-benefit analysis suggests that by keeping a large part of energy production and consumption local, a payback period of 12 years is achievable. However, practical implementation of such solutions faces challenges, such as the need for a group connection agreement (TO) and regulatory limitations regarding wind energy.

This research provides valuable insights for policymakers, grid operators, and entrepreneurs on how business parks can continue to grow sustainably within the constraints of the current electricity grid.

Investigate electricity consumption reduction potential during winter using PVT

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Utilization of Solar Photovoltaic Thermal (PVT) collectors present an economically beneficial approach that improves electricity generation and heat energy utilization. The PVT system's electrical efficiency enhancement emanates from the lower PV panel temperature while the heat generation in the panel is used for working fluid's temperature increment. The dual functionality of this system would bring benefit in the context of Ultra-Low Temperature District Heating and Cooling (ULTDHC) networks, where the demand for efficient low-temperature energy is vital. The incorporation of PVT systems would enormously enhance energy management in tightly packed districts with high energy consumption through providing decentralized and renewable sources of energy.

In this study, we utilized TRNSYS simulation software to dynamically model a district network that integrates PVT collectors with horizontal ground heat exchangers. The proposed configuration would allow efficient usage of thermal energy, with the heat generated by PVT panels directed towards Domestic Hot Water (DHW) supply and moderating the energy demand for space heating, reducing the reliance on the network. The study hypothesizes that PVT-ULTDHC network integration would result in higher overall combined efficiency compared to the conventional Photovoltaic (PV) and Solar Heating (SH) systems of equivalent area. The electrical self-reliance of the district is also expected to improve as the PVT would offset electricity demand while contributing to heating energy management. The thermal performance of the network would also be maintained without being compromised by electricity generation.

This research emphasizes the PVT system potential as a prominent component in future district networks, capable of supplying sustainable energy with improved energy efficiency in densely populated urban environments with diverse thermal energy demand pattern.

Session 2: Preventing and solving congestion on medium/low voltage networks

Sizing energy storage while considering financial, environmental and grid peak reduction objectives: a neighbourhood case

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The electricity grid is becoming increasingly strained due to the integration of (local) renewable energy sources and electrical loads such as heat pumps and electrical vehicles. As a result, more flexibility in low voltage grids is required to balance production and demand peaks. This flexibility can be provided in different ways, whereby we focus on using Energy Storage Systems (ESS).

ESS has the potential to add a significant amount of flexibility to low voltage grids, thereby potentially reducing the dependence on the national grid, leading to a reduction of upstream grid congestion. Furthermore, an ESS has one or more control objectives, which can include financial or CO2 minimization as well as peak shaving to name a few. Using these objectives to create operational ESS profiles while considering actual ESS technologies can lead to finding realistic ESS requirements when sizing.

In this presentation, we explain the results of our investigation into sizing an ESS for a neighbourhood use case with a static grid limit while considering the effect of operating the ESS with different control objectives. We therefore give insight into what flexibility should be provided by an ESS to both achieve an objective while ensuring that grid limits are not exceeded. In the investigation, we use the 'ESSKit' tool to size the ESS based on input power profiles, while considering the operational control of the ESS and different ESS technologies. The advantage of 'ESSKit' is that any operational control scheme for an ESS can be used when sizing ESS while at the same time considering grid limits. We examine the difference in ESS sizing as well as differences in how the ESS is operated.

Predictive control and energy flexibility for buildings

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In the future, a building will need to use anticipatory control systems to enhance energy efficiency and leverage its energy flexibility, driven by self-generation, energy buffering, and scarcity. It is estimated that more than 20% of energy consumption in buildings can be saved, and peak loads on the electricity grid can be reduced. This control should rely not only on real-time data from traditional building-related HVAC control systems but also on weather forecasts and predictions based on historical data from electrical systems, solar panels, and battery systems. This approach allows for more informed actions within these anticipatory control systems. For this purpose, a new open-structure generation of Building Management Systems (BMS) is needed.

Kropman has been developing its own Building Management System, InsiteSuite for 30 years, which has been very successful in the market and now aims to upgrade this system. In addition, new functional modules will be developed and integrated to enable energy demand forecasting and adaptive control of thermal comfort and energy flexibility through model predictive control (MPC) with self-learning capabilities.

As an example of the development, a smart charging case study and a heating demand shifting case study has been carried out. The results of the two case studies will be discussed during the presentation. This also improves energy flexibility by limiting peak loads in the electrical infrastructure. It's crucial to offer integration options with existing systems without needing a complete replacement, ensuring a circular approach for BMS that allows reuse of existing field equipment.

Tackling grid congestion by connecting neighbours

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The case:

TPN West is an industrial cluster within the municipality of Nijmegen, including a transport company, an overhauling company, a manufacturer of heavy-duty vehicles, and two companies with a large number of solar panels. All of them require an expansion of their electricity connection. This extension is not possible due to transport-capacity limitations at two levels: DSO and TSO. These congestion bottlenecks were not fully known at the start of this endeavour. This is our adventure.

The process:

During the process the municipality became aware of their impact on grid congestion. In fact, most participating stakeholders did (both regarding governmental policies and economic activities). The core players (entrepreneurs, DSO and municipality) all recognized the importance of availability of electricity to maintain and develop economic activity in this zone. This facilitated an attitude amongst several entrepreneurs that collaboration was essential. These players who did not consider (any) governmental organisation sufficiently reliable and knowledgeable to tackle this challenge. They preferred to take it on themselves.

During this project three separate but intertwined processes have been identified:

Grief cycle:

From electricity capacity shortage to openness among the stakeholders to possibilities and interests of each other.

System engineering:

From explorations of (improper) solutions to technical preconditions for who effective partnerships might be feasible (grid configuration, instantaneous power, willingness).

System thinking:

A successful approach requires systems thinking, by an area director, to ensure the system design remains synchronous with developments beyond the scope of this specific cluster (i.e. H2backbone, shipping, nearby industries, national legislation developments).

Core results:

Identification of grid bottlenecks, identification of cable-neighbours. Identification of compatibility in energy related operation of the stakeholders and the attitude shift of the stakeholders to find a mutual beneficial solution. Genuine connections between stakeholders from different sectors.

Flexibility sizing for energy communities under dynamic grid constraints

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There has been an increasing proliferation of Distributed Energy Resources (DERs) coupled with an increasing adoption of electric devices such as electric vehicles (EVs) and heat pumps. However, the existing grid infrastructure cannot handle the increasing energy flow leading to congestion on the main grid and the increasing implementation of dynamic grid constraints. Another effect of the increasing electrification is the emergence of energy communities (ECs). Due to DERs and high-power electrical devices in an EC, the EC's power behaviour can lead to congestion in the main grid. This implies that, soon, grid operators will look to bring ECs under their congestion management scheme by applying dynamic grid constraints on their power behaviour.

The DSO can make the existing grid constraint stricter and tell the EC to reduce its power input or output during specific hours of the day. Such a power curtailment order may solve congestion on the main grid but lead to a comfort loss for the prosumers of the EC. However, ECs can invest in flexibility to alter their power behaviour to adhere to the new grid constraints while minimizing their comfort loss and the financial price of the installed flexibility.

In this presentation, we present a methodology to calculate the amount and financial price of the flexibility that ECs require to adhere to a dynamic (stricter) grid constraint while minimizing comfort loss. Specifically, we use the case of an EC with 24 houses called Aardehuizen under the influence of a Capacity Limitation Contract (CBC). CBCs represent one example of a mechanism for implementing a dynamic grid constraint. We vary the strictness level of the constraint and calculate the imbalance profile for each strictness level, assuming the EC initially has no ESS (zero flexibility). The imbalance profile is input into a novel ESS sizing tool called ESSKit to output the ESS specifications required to minimize the imbalance profile i.e. comfort loss. Our methodology results in the ESS specifications that represent the best compromise between comfort minimization and the financial price of the ESS under the application of a range of grid constraints.

RAAK MKB Project NOWATT

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NOWATT is deploying AI to accelerate the energy transition and combat grid congestion, by making neighbourhoods more energy neutral. From this practical question, based on the Trias Energetica 2.0, we and a broad group of SME partners, we have identified research questions that contribute to this. AI can be used to inform people (influencing behaviour) or to (automatically) take action (smart balancing, controlling appliances), both at the level of an individual home and at the level of a neighbourhood. Underlying this, we are investigating whether AI can be used to profile homes (and residents); such a profile provides a basis for personalized advice and helps to plan measures at the neighbourhood level.

The SME partners involved are divided into 3 groups:

1. SENSE (measuring energy generation and consumption, collecting data at the level of an installation, a home, a neighbourhood),

2. THINK (reasoning with AI based on available data) and

3. ACT (informing/influencing people, controlling devices).

In this way, we can do this at the level of a house, but also at the level of a neighbourhood, perform analyses, calculate scenarios and take concrete measures. The solutions that NOWATT is developing or continuing to develop focus on comprehensible informing people (residents, coaches, housing corporations, municipalities) and on automatically steering to make the neighbourhood more energy neutral, for example by making choices about when to charge a car is charged, when the washing machine turns on, or an optimal strategy for deploying a neighbourhood battery.

Session 3: Smart Energy Hubs solutions framework and applications

Scaling smart energy hubs: the slippery slope to success

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Smart energy hubs have a lot of technical potential but need more to grow as a concept than an energetically sound model.

Getting a single pilot working with a lot of effort, subsidy and customisation is nice, but what barriers and solution directions do we as grid operators see to make energy hubs a large-scale success?

In my presentation, some real-life examples and directions we support will be shown. I will also mention some examples of social factors that play an important role in this seemingly technical adventure.

Development of industrial estate energy hubs: Accelerating the energy transition through effective interventions of local government

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The project aim is to accelerate the energy transition through enabling public institutions, and in particular municipalities, to timely facilitate the needs of existing industrial estates in their transition. The investments in transition are viewed as an important KPI to measure acceleration. The project applies a broad view, where energy hubs can be part of the solution.

The objective is to identify information and competences that municipalities currently have, need or want to develop for addressing the energy transition. Through literature review, desk research, interviews and workshops insight has been gained in enabling and blocking factors, seen from perspective of municipalities, provinces, environment agencies, park management and firms. Based upon these factors municipalities involved in the research are guided to develop their own plan/strategy to organize access to information and competences adequately.

The following preliminary conclusions have been drawn.

First, grid congestion is high on the agenda and municipalities feel a constraining effect of legislation and dependence on business owners and grid operators. The cooperation with these organizations is – from the governmental side – not result-oriented enough, amongst others because a framework for long-term development is lacking and there is limited organizational capacity. Second, the access to information is inadequate, enhancing above effect. Moreover, the effectiveness from the government side is often person-centred, forming a severe risk for continuity.

A management guide is being developed, which will comprise tools to sharpen focus by building on concrete projects with transparent benefits for entrepreneurs (business case) and society (value case). It stresses the importance and approach to knowledge building: finance, financial-legal, technical, cooperation constructions, and risk management. Particular attention is given to building competence in municipalities facing constraints of limited staff capacity: How to make sharp and well-founded choices for what information and competences the municipality wants to have in-house and what is outsourced or gained from network partners.

Smart change management in Smart Energy Hubs

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Our energy system is changing. This transformation is not only due to the use of different resources but also involves changes in our infrastructure and energy processes. We are shifting from “how I did it in the past” to “how will we do it together in the future.” Many variables in the system are evolving; from centralized to decentralized, individual to collective, always available to collective optimization, competition to community, facilitation to entrepreneurship, etc. The challenge is how to transition from today’s individual principles to tomorrow’s solutions collectively. In the new context of scarcity, opportunities arise for companies in business parks that can effectively manage these changes. A result-oriented approach has emerged from experiences across various business parks in recent years.

One and a half years ago, the municipality of Enschede, in collaboration with the business sector, took a step towards a sustainable future by establishing the Smart Energy Hub Marssteden at the De Marssteden business park in Enschede. Simultaneously, the municipality of Wierden took a similar step for the De Elsmoat - De Vonder business park.

These projects have demonstrated the importance of smart technologies, sustainable energy solutions, and a strong community for the success of a hub. One and a half years ago, bind was commissioned by these municipalities and the province to take effective steps towards a Smart Energy Hub. It is not only a technical-systemic challenge but also a social- organizational one. Our approach focuses on giving both aspects the necessary attention to ensure that we can always achieve our ultimate goal of providing sufficient energy.

This involves engaging and motivating the right potential participants for a Smart Energy Hub. It is about creating a strong organizational structure, fostering trust between companies and trust from companies towards the advisor and government, to work on the necessary additions to the energy system through projects. The assets developed from these projects can be exploited from a strong foundation.

We have learned many lessons and adapted our approach across various business parks, gaining insights.

Making energy hubs even smarter by providing trade between energy hubs and communities

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Congestion within the energy grid is becoming an increasingly significant challenge for businesses, particularly as they expand operations or transition to more sustainable energy sources. This congestion restricts their ability to access and utilize energy efficiently. To address this, new capacity-based contracts have been introduced, enabling greater connectivity to the grid. However, these contracts often require the management and control of energy assets and frequently necessitate the addition of batteries or generators. The associated costs can be particularly high in most industrial areas, where congestion is not a daily occurrence, making such investments less economically viable.

Simultaneously, there is often an excess of renewable energy generated from sources like photovoltaic panels and wind, which cannot be easily sold or traded directly with other consumers. This results in a missed opportunity to optimize the use of available renewable energy and reduce dependence on traditional power sources. ENTRNCE is currently developing a platform for the Port of Amsterdam that facilitates the management required for capacity-based contracts and provides a peer-to-peer (P2P) marketplace for the direct trade of excess energy between businesses.

However, based on experiences with P2P markets within cooperatives, three key issues have been identified that could impact the success of such a combined management and P2P market. These challenges include low energy prices, oversaturation of energy supply, limited flexibility in energy consumption, and a potential lack of social trust in the system. Addressing these concerns is crucial to ensuring that the energy market operates effectively and that all participants benefit from the transition to a more sustainable and decentralized energy system.

One potential solution to these challenges is to bring industrial areas, neighbourhoods, and municipal buildings together within an exchange platform. This would create a more dynamic and interconnected energy market, enabling seamless energy trading among different entities and fostering a more resilient and flexible energy system.

Unlocking the full potential of energy hubs with programmable energy

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To fully realize the potential of Energy Hubs, the 2 Tokens Foundation proposes adopting Programmable Energy as a core strategy to adhere to essential guiding principles that ensure Energy Hubs are effective, inclusive, and resilient.

Key Principles:

Digitization & Flexible Asset Management: Programmable Energy enables digitizing assets, allowing for efficient resource management and fractionalized ownership and promoting broader market participation. Decentralized Operations & Local Empowerment: By leveraging Programmable Energy, Energy Hubs can empower local stakeholders to engage directly in transactions and decisions, reducing reliance on central authorities and fostering a more autonomous energy community. Transparency & Trust-Building: Programmable Energy ensures transparent, tamper-proof records of all transactions, which are crucial for building trust, ensuring accountability, and simplifying the tracking of energy flows.

Liquidity & Accessibility: Implementing Programmable Energy makes it easier for participants to invest in and trade assets, lowering barriers to entry and encouraging smaller investors and local communities to participate. Programmability & Interconnectivity: Programmable Energy supports customizable functions and interconnected systems, enhancing the collaboration, scalability, and effectiveness of Energy Hubs. Incentivization & Stakeholder Engagement: Systems powered by Programmable Energy can reward sustainable behaviours and actively involve participants in decision-making, aligning individual actions with collective sustainability goals.

Michel Chatelin will introduce Programmable Energy, a concept pioneered by Jos Roling, highlighting how it enhances flexibility, efficiency, and integration of Energy Hubs into our Energy Systems. Tokenization is critical to implementing Programmable Energy. Tokens represent assets digitally, facilitate decentralized operations, ensure transparency, provide liquidity, allow for programmability, and incentivize stakeholder engagement.

Session 4: Cyber secure and interoperable ICT-systems and device interfaces for monitoring and control of Smart Energy Hubs

Rethinking interaction for a resilient and cyber-secure system

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The energy transition is slowing down in the Netherlands due to grid congestion, which cannot be resolved in the short term. Next to this, in order to decarbonize our energy system, more flexibility is needed to match the demand and production. Both problems can be resolved through coordination using ICT. However, this introduces a new dependency that may jeopardize energy security.

We present an outlook for the required research and innovation for the next 10 years to develop the next generation cooperative energy management systems to support the Energy Transition.

Firstly, we argue that the grid is the backbone to which all devices are connected and hence are jointly responsible for its stability. Therefore, open interfaces and regulation is required to create an open ecosystem and avoid silo thinking.

Secondly, we argue that future Energy Management Systems need to be formed around fully distributed networks to ensure resilience against single points of failure. Furthermore, together with open interfaces and standards, this will lead to a better scalable approach where devices work on a “plug-and-play” basis in the IT domain, analogous to connecting it to the power grid using a socket.

Thirdly, power and energy are merging due to a reduction in abundant fuel and therefore available power. Instead, power will be linked to the availability of renewables and distribution capacity. Therefore more localized control and management at shorter timescales is unavoidable to ensure a reliable system. This will require the investigation of asynchronous approaches and markets as opposed to the current heavily synchronized design.

Lastly, cyber-security for the Smart Grid is more than just classical IT-based solutions. Instead, utilization of the physical process of the power grid is a strength that can be utilized to detect anomalies and malicious behaviour using digital twins.

DC Wind Energy Hubs for a sustainable Future

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As global trends are seeing a shift towards renewable energy sources, there is an increased importance on sources like wind energy. Conventional power systems rely mostly on AC power and thus the grids have been designed primarily to support AC infrastructure. However, with the increase in renewable energy infrastructure in the grid, researchers are eyeing at DC grids as a more suitable option. Various factors like improved control on power flow, higher power transfer, lesser transmission losses have made HVDC transmission and an overall HVDC grid a highly promising solution for the future.

One common problem with the use of DC at high power is the lack of power electronic devices that operate at very high voltage and current levels. However, recent advancements in technologies like silicon-carbide (SiC) and gallium nitride (GaN) have allowed researchers to venture out into the possibility of having 15 kV and 20 kV power electronic switches. Such advancements are bound to assist higher injection of DC technologies into the grid. In this current scenario, a DC based wind power generation system is being envisioned where the conventional back-to-back converter is replaced with a rectifier and a dual active bridge converter.

The envisioned system will be better suited for offshore applications due to reduction in size and weight. Moreover, direct power injection into the HVDC grid will ensure lesser power conversion stages and hence a reduction in losses. The system is being tested for operation feasibility with electrolyser. With proper control of the power, the system can be replicated to form energy hubs interfacing wind power generation to the HVDC grid with option to store energy in the form of hydrogen.

The presentation will guide the audience through the various technological advancements that project a promising future for HVDC renewable energy hubs. An overview will be presented on the various technological challenges, stability issues and control problems that will be encountered at the device and system level. It will also showcase some of our endeavours in the area, share some results and our future direction of research.

Explainable AI/ML forecasting models

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The rising demand for electricity and the integration of renewable energy sources require reliable and explainable forecasting models for effective grid management. Given the recent advances in time series forecasting, this study evaluates a variety of methods ranging from classical machine and deep learning to hybrid models. These include Transformer-based solutions like PatchTST and hybrid models like CNN-XGBoost and LSTM-XGBoost.

Besides delving into relevant aspects such as model performance, we also explore the utilisation of explainability techniques like SHAP and Maximum Mean Discrepancy (MMD). As a result, Facebook's own additive model, prophet, excelled in short-term forecasts (15 minutes to 1 hour), while PatchTST consistently performed well for longer horizons (≥6 hours), demonstrating its utility for long-term planning.

On the other hand, in contrast, hybrid models such as CNN-XGBoost and LSTM-XGBoost showed improved forecasting performance over XGBoost, with CNN-XGBoost outperforming LSTM-XGBoost marginally. Furthermore, the inclusion of relevant weather features improved model accuracy. Besides model predictions, SHAP and MMD provided explainable insights into the decision-making process of these models, revealing that model performance fluctuates when forecasting over different periods.

Overall, our study highlights the need for tailored model selection based on forecasting horizons and data constraints, while also exploring innovative tools for enhancing the interpretability of complex models in energy forecasting. In future, we aim to focus on refining these models and expanding the interpretability frameworks, particularly for Transformer-based solutions.

SUSTENANCE: IoT edge computing for carbon neutral communities

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The SUSTENANCE project addresses the critical need for efficient, real-time energy management systems within carbon-neutral communities. Funded by the European Union's Horizon 2020 research and innovation program, this project introduces a transformative IoT architecture designed to support sustainable energy management.

A key innovation within SUSTENANCE is the development of the IECON IoT protocol, which leverages advanced IoT Edge Computing to create a decentralized platform for intelligent energy control. The protocol employs Eclipse MQTT SparkPlug B to ensure secure, interoperable data exchange. This modular design is suitable for microgrids and energy management systems (EMS), making it adaptable to various applications and supporting advanced IoT research.

The project's innovative framework integrates DERA and SGAM reference architectures, enabling standardized and interoperable energy data exchange. It has been successfully deployed and operational for two years, providing real-time energy system insights through technical dashboards and mobile apps, empowering users to make informed energy use decisions.

Key outcomes of the SUSTENANCE project include the development of "energy islands" powered by local renewables, exemplified by the Vriendenerf housing community. This initiative has elevated energy system efficiency and resilience, highlighting the need for a robust platform to manage decentralized SCADA systems and enhance decision-making at the edge.

SUSTENANCE's real-world implementation demonstrates its effectiveness in addressing climate change through sustainable energy solutions. By promoting high-resolution local data processing and intuitive user interfaces, the project fosters enhanced user engagement and informed decision-making. The integration of robust security protocols ensures reliable and efficient data exchange, protecting against cyber threats.

Keywords: IoT Edge Computing, Carbon Neutral Communities, Sustainable Energy Management, SCADA, Realtime Energy Systems, Eclipse MQTT SparkPlug B, DERA, SGAM, Horizon 2020.

Session 5: Hydrogen integration in Smart Energy Hubs

Decentralized hydrogen production via methane plasmolysis

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In the future energy system, there is an obvious need to convert electrical energy into molecules, both for cost effective energy storage and transportation and for feedstock applications. Hydrogen will play an important role in this, although the exact field of applications is still heavily debated.

Traditionally, low carbon Hydrogen is associated with electrolysis, but there are some alternative ways. One technology that is gaining traction is methane pyrolysis, use plasma technology. Several suppliers are testing pilot installations, in which methane is decomposed into Hydrogen and solid Carbon.

This conversion technology has several advantages and disadvantages compared to electrolysis. In this presentation, we dive a bit deeper into possible applications of methane plasmolysis and how this could relate to decentral hydrogen use cases.

Renewable energy system with hydrogen production and methanol storage for efficient electricity supply-demand balancing

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The increasing reliance on renewable energy sources presents significant challenges in balancing supply and demand due to their intermittent nature. To address this issue, an innovative energy system has been developed to ensure flexible and efficient energy management.

The system stores electricity when renewable energy supply exceeds demand and generates electricity when the demand surpasses the renewable generation. Energy is stored by producing hydrogen and methanol. Through electrolysis, water is split into hydrogen and oxygen, which is stored for future use. Methanol is synthesized by combining hydrogen with CO2, effectively capturing carbon.

Electricity is generated in a supercritical gas turbine powered by methanol, with the stored oxygen from the electrolysis serving as the oxidizer. The combustion products, H2O and CO2, are captured and stored for reuse in fuel production. The results present the electricity stored and the electricity generated over a year based on a defined renewable electricity generation profile and electricity demand profile, alongside the corresponding mass changes in the storage tanks.

Key benefits of the system include zero pollutant emissions, 100% carbon recovery, high efficiency, compactness, fast response times, operational flexibility, and its contribution to a circular economy.

Renewable Hydrogen Hubs in the Netherlands: Assessing the feasibility of hydrogen production technologies integration

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The transition to a carbon-neutral future requires green hydrogen as a key solution for decarbonizing energy intensive industries. In countries with energy matrices heavily dependent on natural gas, such as the Netherlands, shifting to cleaner alternatives poses challenges in reducing emissions while maintaining industrial productivity. This study presents a zero-emission hydrogen hub integrating Proton Exchange Membrane (PEM) electrolysis, Solid Oxide Electrolysis Cells (SOEC), and Autothermal Reforming (ATR). The hub enhances the reliability, efficiency, and economic feasibility of large-scale hydrogen production by combining the strengths of each technology.

PEM electrolysis offers flexibility by allowing hydrogen production to fluctuate with electricity prices, stabilizing the grid, and leveraging low-cost renewable energy. SOEC technology benefits from heat recovery from ATR, enabling efficient hydrogen production from renewable electricity. ATR, a mature and cost-effective technology, processes biogas into hydrogen while capturing carbon. The process is further optimized by utilizing oxygen-enriched air from the electrolysers, improving efficiency.

This research assesses the feasibility of the integrated hydrogen hub in the Netherlands. A dynamic, quasistatic model is being developed in Python to simulate and optimize the hub's performance across different locations, considering factors such as energy demand and renewable resource availability.

The project demonstrates the practical and economic viability of large-scale green hydrogen production and its role in decarbonizing energy-intensive industries. Supported by Roger Energy and the RegioDeal fund, it highlights the potential for hydrogen hubs to reduce carbon emissions and support renewable energy adoption.

The energy system in Twente and the role of underground storage

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Twente has empty salt caverns and gas fields in which energy can be stored. Storage of sustainable energy is necessary to better match the difference in supply and demand over time. In the winter the demand for heat is large, while in the summer the supply of sustainable energy is large, for example from solar energy. To gain insight into what underground storage in Twente can contribute to the energy transition, this was investigated in a RAAK public project. This research highlights one part of this project focused on the energy system in Twente. The contribution of underground storage for the current situation and scenarios for 2030 and 2050 for the Twente RES region have been investigated.

For the energy units electricity, heat (80 °C), heat industry (200 °C), green gas, natural gas and transport fuels and hydrogen, supply and demand have been investigated for 2021, 2030 and 2050. Annual numbers of usage and supply determined, and in addition, user profiles were set up based on average daily consumption. No need for large-scale energy storage is foreseen for 2021 and 2030. For 2050, there is a need for storage within electricity and hydrogen supply chain. It appears that there will then be surplus of electricity for a lower continuous period in the summer. This surplus of electricity can be converted to hydrogen, this hydrogen can be used directly for fulfilling the hydrogen demand or converted for electricity production.

Two scenarios were analysed for the use of hydrogen. For these two scenarios, the required hydrogen storage and the consequences for the import and export of hydrogen and electricity from the Twente region to and from the national grid were analysed.

The presentation will be about the backgrounds of the concept, the context and modelling approach, important assumptions and shows the results of the two scenarios. Also, the outlook for using the underground will be discussed and follow-up research that is still necessary.

Session 6: East Netherlands Smart Energy Hubs pilot program

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OOST NL

Oost NL co-develops and manages the living lab for smart energy hubs in East Netherlands together with the provinces of Gelderland and Overijssel. The living lab currently supports 10 energy hubs in the region. With the approach ‘learning through realizing energy hubs’ the program accelerates the development of energy hubs. Practical knowledge is shared, tooling is being developed on the themes Legal, Technological, Financial and Organisational.

SEH Broeklanden

SEH Broeklanden has been benefitting from the learnings from SEH Hessenpoort and therefor has rapidly developed over the past year. *Wouter Heres*, process director, will share his learnings and experiences in the development and will focus on how parts of the development, focused on data, can be accelerated.

SEH XL Business Park Almelo and A1 Bedrijvenpark Deventer

Process director *Rutger Beekman* has been involved in the development of two hubs within the living lab in East Netherlands and will amongst others provide insight into the steps that were taken to get the Enexis GTO pilot contract signed at XL Business Park in Almelo.

SEH Lorentz III Harderwijk

Process director *Thomas Pesiwarissa* will share his experiences on the development of the energy hub in Harderwijk and how to work with stakeholders and when to involve them or not. Joram van de Doodewaard, student at University of Twente and intern at Oost NL, will share the current development of a standardized document to support energy hubs in selecting the right Energy Management System.

Session 7: Multi-commodity smart grids, sector coupling and power to X

Exploration of potential grid capacity reduction for multi-commodity smart energy hubs in three industrial areas in the Netherlands

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We explored whether smart combinations of sustainable energy generation, energy conversion and energy storage can reduce the required electricity grid connection in industrial areas. This is a pressing research question given the rapidly increasing severity and scope of grid congestion issues.

We developed and applied a quick scan to identify three industrial areas in the province of Utrecht suitable for the application of an integrated, area-specific approach. The heart of the exploration was a model study with transient simulation of energy flows and assessment of costs and emissions. To collect information and data, we organized workshops with local stakeholders, and supplemented this by public data. We considered three fictitious variants of the energy system for each industrial area:

- Power-to-X energy system (PtX-ES): future smart energy system with mutual exchange of available energy, diversification of energy carriers and smart control, thereby maximizing local energy se and minimizing grid consumption;
- Electrified energy system (E-ES, future refence): energy system with smart electrification of business processes and logistics, supplemented by local production of green electricity;
- Fossil fuel energy system (FF-ES, historic reference): energy system where fossil fuels are utilized for transport and other business processes, supplemented by electricity from the grid and without local sustainable production of electricity.

The approach for sketching the design of the energy systems, referred to as the PtX approach, was based on earlier research by KWR on integrated, area-specific energy systems. The local developments and plans shared during the workshops were explicitly included in the PtX-ES and E-ES.

The E-ES requires a 6 to 8 times larger connection to the electricity grid than the FF-ES. The PtX-ES requires a 3 to 5 times larger grid capacity than the FF-ES. The PtX-ES thus yields significant advantages in terms of the required grid capacity. Moreover, the higher investments required for the PtX-ES in terms of CAPEX and cooperation between local stakeholders, result in lower total costs of ownership and emissions than the E-ES.

Optimization of design and operation of an energy hub using different strategies

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1. Maja Sharevska, 2. Monika Sharevska, 3. G. Hoogstreen, 4. J. Hurink, 5, G. Brem,
6. Y. Hajimolana. University of Twente (1,2,3,4,5,6)

The slow upgrade of the existing electricity infrastructure fails to keep up with the growing adoption of distributed renewable energy sources and the increasing electricity demand. Multi-energy systems that can locally balance the demand and supply have the potential to increase the share of distributed renewables without overloading the grid. However, the design and operation of these energy systems is a challenge that requires a strong framework – the Energy Hub concept.

This study aims to compare different strategies for optimization of the design and operation of an energy hub that has to cover the local demand for heat and electricity while minimizing energy use and power peaks. The energy hub design is comprehensive and consists of selection of technology, structuring and sizing. The operation variables of the energy hub are the operating power of each component. The results show that integrated optimization of the design and operation of the energy hub has to be performed to expoit the benefits of energy hubs fully.

Realized and operational smart energy project Thermen Soesterberg and Heat Central Groenpoort (for district heating/cooling)

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In 2023/2024 we realized two smart energy projects which are operational and serviced.

Most comprehensive project Thermen Soesterberg 'one of the largest wellness complexes' of The Netherlands. Other project is Groenpoort focused on Power to Heat and flex control of heat generation based on optimal sustainability and grid congestion (Flex Ato constraints).

Flex management of large components of the total energy system consisting of:

- Heat pump and large-scale thermal buffering (Power to Heat), creating flexibility in the timing of heat generation;
- Own PV generation;
- Load infrastructure EV vehicles;
- Control Electric saunas.

Based on demand forecasts and congestion restrictions (limited grid capacity), the entire energy system is managed digitally in real time and electricity is purchased directly on the Electricity markets. Where possible, value is also created by trading on the imbalance market.

Linthorst is an integral service provider:

- Energy system design, realisation and maintenance;
- Supplier of industrial heat pump technology;
- Smart grid software management;
- Electricity supplier for the client (permit holder) and congestion service provider for grid operator (CSP).

Developing Digital Twins for industrial microgrids: the Ecofactorij case study

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This works presents a study on developing a Digital Twin (DT) framework for industrial microgrids, using the Ecofactorij industrial complex in Apeldoorn, the Netherlands, as a case study. The DT concept is explored as a virtual representation of physical systems, leveraging real-time data from sensors to model, simulate, and optimize industrial microgrids. The Ecofactorij, with its interconnected companies and diverse energy assets like photovoltaic plants, batteries, electric vehicle chargers, and heat pumps, serves as an ideal test-bed for this framework.

The study identifies the need for a DT framework that addresses challenges in modelling, simulation, and forecasting systems within industrial microgrids. The proposed DT framework for the Ecofactorij focuses on three main functionalities: modelling and parameter estimation, real-time state estimation, and "what-if" scenario analysis. These functions aim to improve situational awareness, estimate system parameters, and enhance decision-making processes.

A key feature of this DT framework is its adaptability and reproducibility. The DT influences the physical system through a bidirectional interaction, focusing on the ability of the industrial microgrid to avoid congestion at the point of common coupling and maximize self-sufficiency. The architecture of the DT is built using a microservice approach with Docker containers, ensuring modularity, scalability, and ease of maintenance. A graphical user interface (GUI) is also being developed to provide stakeholders with real-time insights, allowing for effective monitoring and decision-making.

A detailed architecture is presented, establishing the functionalities and relationships between specific components and algorithms used by the DT, such as data error correction, regression analysis, state estimation, forecasting, and scenario generation. In conclusion, this study not only contributes to the theoretical framework of DTs but also offers practical insights and solutions for real-world applications in industrial microgrids, highlighting the potential of DTs in driving innovation and achieving energy management excellence.

SynergyS: a market-based approach for multi-commodity energy hubs

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The SynergyS project aims to develop and assess a smart control system for multi-commodity energy systems (SMCES). The consortium, including a broad range of partners from different sectors, believes a SMCES is better able to incorporate new energy sources in the energy system. The partners are Hanze, TU Delft, University of Groningen, TNO, D4, Groningen Seaports, Emerson, Gain Automation Technology, Energy21, and Enshore.

The project is supported by an Energy Innovation NL (topsector energie) subsidy by the Ministry of Economic Affairs.

Groningen Seaports (Eemshaven, Chemical Park Delfzijl) and Leeuwarden are used as case studies for respectively an industrial and residential cluster. Using a market-based approach new local energy markets have been developed complementing the existing national wholesale markets. Agents exchange energy using optimized bidding strategies, resulting in better utilization of the assets in their portfolio. Using a combination of digital twins and physical assets from two field labs (ENTRANCE, The Green Village) performance of the SMCES is assessed.

In this talk the smart multi-commodity energy system is presented, as well as some first results of the assessment. Finally an outlook is given how the market-based approach can benefit the development of energy hubs.

Session 8: Smart charging in Energy Hubs

Grid design and grid aware EV charging

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This abstract demonstrates the importance of grid-aware EV charging and its benefits for society, as well as its role in the grid design for DSO. With close collaboration between CPOs and Dutch DSOs, the firm capacity is lowered and the non-firm capacity introduced, down to a 0 kW level for short intervals. This is very important for enabling a better use of the grid, both the low-voltage grid and the feeding HV/MV-grid. As a conclusion, Liander (Dutch DSO) has made a policy framework for its grid design to take into account grid-aware charging for public charging poles. Despite many regulatory challenges, the potential in grid aware home-charging would be a game changer for the energy transition.

Potential

About 3,75 million BEV and 1,6 million charging points are forecasted in Liander's region. That means approximately 14 charging poles per secondary substation in 2050, with an expected peak power of 240 kW simultaneously. That is more than half of Liander's average secondary substation capacity at this moment. Grid aware charging could result in more clients and charging poles to be connected.

Gains at LV grid

For secondary substations, day-ahead capacity forecasting of the each distribution transformer leads to the non-firm available capacity and is communicated to CPOs per charging pole. In case of absence of a communication signal, the agreed firm power will be leading. An optimal firm capacity of 3.5 kW is taken, not causing significant discomfort at customers, giving a significant amount of power reduction for the LV grid design. Our analysis indicates that these power limitations will only occur a limited time: only some winter evenings during 2-4 peak hours approximately . With a 3.5 kW firm capacity, potentially 4 more charging poles or 15 houses can be connected to the grid per distribution transformer. Details about these design principles as well as our results will be mentioned in our full paper. We will also indicate what is the potential gain if home-charging would be grid-aware for an average LV grid.

Potential gains at MV grid

For HV/MV-substation level, the pre-requirements and advantages will be discussed.

Charging Energy Hubs – cooperating to electrify logistics

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Nationaal Kennisplatvorm Laadinfrastructuur (NKL)

Charging Energy Hubs (CEH) is a Dutch National Growth Fund programme to expedite the roll out of charging infrastructure by stimulating the cooperation of players in the Dutch logistics networks as well as players in energy infrastructure construction and services. By promoting a fast roll out of these hubs, the programme aims to support Dutch industry while furthering the need of grid operators (and society) to combat congestion. It does so by investigating different use cases that can serve as a guide or blueprint for other locations in the Netherlands and abroad.

In this presentation, we will highlight the use cases that focus on private, public and private-public charging locations. As the programme just started, we will describe the planned projects and the elements that make these plans interesting cases of smart energy hubs. Whether it is the integration of fleet management in energy management systems, the novel use of charging hardware or the connection of several industrial partners through DC-grids.

Coordinated optimisation of logistics electric fleet and energy management system of constrained energy hub

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The electricity network has reached its transport capacity limits in various areas in the Netherlands. With the electrification of various sectors, the imminent challenge of granting connections and capacity to users becomes ever critical. The concept of energy hubs, where neighbouring prosumers collaborate to optimize the available capacity, poses itself as a short-term alternative for grid reinforcement.

This study presents a coordinated optimization approach enabling a smooth transition into an electric fleet for logistics companies, taking part of an energy hub, while respecting the grid's limited capacity and taking into account uncertainties arising from load and generation profiles. The last-mile deliveries of the logistic company are depicted by the Electric Vehicle Routing Problem formulation, and the partheno-genetic algorithm is implemented to solve it, where the parameters of interest are fed to the energy management system that minimizes the overall energy costs at the energy hub while incorporating day-ahead market prices. The intermittency of renewable generation and load demand is tackled by adopting the model predictive control (MPC) framework, providing a corrective mechanism that ensures that the overarching objective of the system is met while respecting the grid's limitation.

Three charging strategies at the hub are investigated: dynamic charging, direct charging and delayed overnight charging. The results demonstrate the mitigation of the grid's connection capacity while attaining savings with the proposed dynamic charging strategy, ranging between 11.5% and 52% compared to the delayed overnight charging and direct charging strategies.

Energy Hubs for high power charging of zero emission logistics

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The goal of the Charging Energy Hubs (CEH) project is is to set up a blueprint for developing a flexible / grid-aware (charging) energy hub in order to lower the costs of flexibility and the integration of zero emission logistics into the electricity grid. Issues to be solved in the project are: operating high power charging infrastructure with limited grid capacity, non-standardized interfaces to the assets (storage, generators, ...) and the coupling with complex energy, balancing and congestion markets.

The CEH consortium will develop three truck charging facilities. One private, one public and one private/public charging location covering multiple sites.

Initially, an overview of the stakeholders and the interaction between the stakeholders will be provided for the different charging facilities. Reviewing both the internal CEH-stakeholders like asset owners, CPO's, service companies, Energy Management Systems Providers etc., as external stakeholders like the energy market, grid system operators, mobility planners, etc.

To meet the project goals, the CEH will be developed with standard, where possible open, components and protocols. This way of standardization is not only focusing on software protocols, but also at standardisation of the architecture, the market approach, the energy management algorithms and the mobility planning interactions. All with the mindset to provide a reference implementation for scaling up these HUBS and keeping the charging energy hubs flexible and able to adjust for specific needs of the customer and/or the location in regards to logistical planning and the local energy balance.

Finally, the CEH project will evaluate and validate the system in three different truck charging facilities, before scaling up.

Tim van 't Wel and Winifred Roggekamp are both working at ElaadNL. ElaadNL is a knowledge and testing institute with knowledge about charging of electrical vehicles (cars, trucks, construction vehicles). ElaadNL focusses on outlooks on the market, standardization of the (charging) interface.

Optimisation of location of energy storage in grids

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Grid congestion is an ever-growing problem in the Netherlands. Rising energy prices and growing climate ambitions are accelerating the electrification of heating, transportation and industrial processes. This increased electricity demand, coupled with the integration of more and more intermittent renewable energy sources (RES) causes synchronized peak loads and grid congestion issues forcing system operators to reinforce the grid. However, the demand for electricity transport capacity outpaces these grid reinforcement efforts, hindering the construction of essential infrastructure, RES integration and electrification of industry. Energy storage systems (ESSs) could reduce the need for grid reinforcement, but the effects of ESS distribution remain unclear.

This presentation investigates the impact of ESS distribution on Dutch low-voltage grids and their reinforcement requirements. Various scenarios with different siting and sizing of ESSs, controlled to reduce grid stress, were simulated in both consumption-dominated and generation-dominated cases.

For almost all placement and sizing scenarios, simulations show that ESSs reduce voltage deviation, line loading and transformer loading, reducing the need for cable and transformer reinforcements to varying extents. ESSs placed near prosumer households show superior overall results. ESSs also offer the ability to match electricity production and consumption which is not offered by traditional grid reinforcement.

Beyond the technical aspects, socio-economic analysis shows that without ESS, the financial burden of grid upgrades would fall on all users, potentially leading to an unfair distribution of costs. Home-ESS, especially when financed by overproducers of photovoltaic (PV) energy, can distribute costs more fairly. Phasing out the Dutch net-metering policy could encourage prosumers to invest in home-ESS to enhance self-consumption.

Session 9: MOOI EIGEN: new and open tools for Smart Energy Hub projects

A framework for a social cost-benefit analysis for energy hubs

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The energy transition is a complex process that should result in a sustainable and reliable energy system. The current energy system is based on the principle of centrally generated energy by using mainly fossil energy sources. The sharp increase in the use of renewable (sustainable) energy creates problems on the existing power grid. The problem with solar power projects is the shortage of available feed-in capacity. Moreover, economic growth is causing a shortage in supply capacity in several areas in the Netherlands. As a result, new companies cannot be connected to the grid or existing companies cannot get additional capacity.

In this context, energy hubs can be a solution to strengthen and innovate the central energy system at a local (regional/decentralised) level. Several initiatives have emerged around energy hubs at regional business parks. Here, central government, provinces, municipalities, grid operators, business clusters, educational institutions, civil society organisations and other stakeholders are working together on this concept at different levels. When deploying and operating energy hubs at business parks, the need arises to investigate not only their technological and process aspects, but also their societal impact.

In this presentation we will present a framework with the possible societal benefits of energy hubs situated on regional business parks. This framework is based on two workshops and substantiated using literature. In this framework, (1) the possible elements of an energy hub are described, followed by (2) the possible effects and side effects, translating to (3) a list of possible societal benefits.

This framework can be used at the start of the development of an energy hub as a checklist to determine whether certain effects and benefits are relevant for the energy hub to be developed. This information can be used to increase the possible societal value of the energy hub. It can also be used to determine which stakeholders that benefit from an energy hub can or should be involved in the development of the energy hub.

A novel, multi-stage approach for developing energy hubs

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The current structure of our energy supply system, which was initiated in 1998 when Energy Markets were separated from infrastructure, is coming to a standstill if we don't provide alternative solutions. A very promising development concerns (Smart) Energy Hubs, in which a local demand for energy is locally matched with a local supply of energy as much as possible, relieving the regional and national grids. This however requires a paradigm shift, in which local entrepreneurs must organize themselves to play a significant role in the local energy provision.

We present a framework for a multi-stage approach for the development of Energy Hubs and show you some tools we have been working on as part of the MOOI EIGEN initiative, including an outlook for further development, research and development, especially for the tools for simulation and analysis (a Plan & Design tool suite) and an advanced control system that is to be used for maintaining the system balance locally, while respecting the physical boundaries of the local, regional and national infrastructure.

List of attendees is available at your request.