

Book of abstracts

Including programme

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3rd Conference on Smart Energy Hubs
4 November 2026

Book of abstracts

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Preface and welcome

We are delighted to welcome you to the 3rd International Smart Energy Hubs Conference, taking place on 4 November 2026 at the U-Park Hotel in Enschede. Building on the success and lessons of the first two editions, the conference has developed into a meeting place where researchers, industry, public authorities, municipalities and other professionals come together to exchange knowledge and practical experience on the development of Smart Energy Hubs.

This year's theme, "Resilient Energy Hubs: (em)powering Europe's energy future!", reflects an important next step in this development. The energy transition is increasingly taking place in an environment shaped by grid congestion, rapid electrification, variable renewable generation, changing energy markets, cybersecurity challenges and the need for stronger cooperation between different actors. Smart Energy Hubs therefore need to do more than balancing local generation and demand. They need to become resilient energy systems that can adapt to changing technical, economic, regulatory and societal conditions while continuing to provide reliable, affordable and sustainable energy.

Resilience is not achieved through technology alone. It requires an integrated perspective connecting energy infrastructure, flexibility, storage, multi-commodity energy systems, Energy Management Systems, digitalisation and cybersecurity with viable business models, appropriate governance, regulation and active participation of companies, municipalities and citizens. The transition from individual pilots towards scalable and replicable solutions therefore depends on bringing these different perspectives together.

The 2026 programme reflects this broad perspective. Through keynote contributions, a plenary debate and thematic sessions, the conference brings together scientific advances and lessons from implementation. Topics range from system integration, multi-commodity energy management and industrial electrification to energy markets, governance, cybersecurity, grid congestion and the role of citizens and communities. Together, these contributions explore not only how Energy Hubs can be designed and operated, but also how they can become robust and scalable building blocks of Europe's future energy system.

An important strength of this conference remains the connection between research and practice. Smart Energy Hubs are evolving rapidly, and their successful implementation requires knowledge to move in both directions: scientific developments need to respond to real-world challenges, while experiences from pilots and operational projects should inform the next generation of research, policy and solutions. The conference provides a platform for exactly this exchange. We therefore encourage you not only to listen to the presentations, but also to exchange experiences, challenge ideas, make new connections and explore opportunities for collaboration. We hope that the discussions and encounters throughout the day will contribute to moving Smart Energy Hubs from promising concepts and individual projects towards resilient, integrated and widely applicable energy solutions. We wish all our participants, speakers, session chairs, partners and guests an inspiring and productive conference.

Prof. Richard van Leeuwen, chair
Dr. Yashar Hajimolana, co-Chair
Robert-Niels van Droffelaar, co-organiser

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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 energy control business park, MOOI Flexpower and Learning Communities on energy hubs. Within the energy flexibility lab, researchers and students work together on investigating the role of control of flexibility options to balance energy networks, with state-of-the-art hardware and digital twin simulation facilities. Within Saxion, 12 research groups participate in the expertise area “Circular Innovation and Energy transition”.



Dr. ir. Yashar Hajimolana, Assistant 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, conferenceco-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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Programme

8:30-09:00	**Registration and coffee/tea**	**Main entrance**
09:00-10:45	**Plenary opening session**	**Room C1 + C2**
09:00-09:05	**Opening: Marc Leeuw, senior project manager Energy & Smart Energy Hubs program, Oost-NL**	
09:05-09:15	**Prof. Richard van Leeuwen and ass. Prof. Yashar Hajimolana**: introduction "Resilient energy hubs: (em)powering Europe's energy future!"	
Plenary keynote speeches:		**Room C1 + C2**
09:15-09:30	**Sara Gustafsson: Professor Environmental Technology and Management, Linköping University, Sweden**	
	Governing resilience: the role of municipalities in energy hubs	
09:30-09:45	**Simone van der Burg: Professor resilient democracy, Saxion, The Netherlands**	
	Resilient for whom? Citizens as actors in energy hubs	
09:45-10:00	**Q&A between Sara, Simone and audience**	
Plenary keynote debate:	**Moderated by Serge Santoo, Energy Innovation NL**	**Room C1 + C2**
10:00-10.45	Role of energy markets in resilient energy hubs **Machiel Mulder, Professor energy economics, Rijkuniversiteit Groningen, the Netherlands** Cyber security cornerstones of resilient energy hubs **Roland van Rijswijk-Deij, Professor network security, University of Twente, the Netherlands** Vision and challenges for energy resilience by the Dutch ministry **Marjolein van Splunder, Coordinating policy advisor energy innovation, Dutch ministry of economic affairs, the Netherlands** Governing resilience: the role of municipalities in energy hubs **Sara Gustafsson, Professor Environmental Technology and Management, Linköping University, Sweden** Resilient for whom? Citizens as actors in energy hubs **Simone van der Burg, Professor resilient democracy, Saxion, The Netherlands**	
10:45-11:15	**Break**	**Meeting Lounge and Restaurant**
11:15–12:15 Parallel Session 1 - 5		
Session 1: The role of people, governance and organisation for energy communities and energy hubs Chaired by: Annemarije Kooijman Associate professor governance of energy transition, Saxion University of Applied Sciences, the Netherlands		**Room C3**
Keertana Subramani: The Art of the Deal: Polycentric support and Institutional design of Group transport agreements.		
Rick Wolbertus: Learning Communities as Enablers for Energy Hubs: Bridging Hard and Soft Relations in the Dutch Energy Transition.		
Aidana Tleuken: Networks, Awareness, and Resource exchange in Hubs for Circularity using Agent-Based Approach.		
Session 2: Industrial electrification as part of energy hubs		**Room C4**
Chaired by: Mina Shahi Professor of Thermal Conversion & Storage at University of Twente, the Netherlands		
Sylke Angenent: Feasibility of Behind-the-Meter Wind Energy for Energy-Intensive Manufacturing Sites.		
Merlijn Siffels: The Value of Industrial Energy Flexibility in Energy Hubs.		
Kirill Resnikow: Economic viability of thermal flexibilization of agricultural anaerobic digesters under intermittent Power-to-Gas plant operation.		
Gijsbert Korevaar: Zeotropic hydrocarbon refrigerants in high-temperature heat pumps: digital twin development and experimental validation.		
Session 3: Viable business models for resilient energy hubs		**Room C5**
Chaired by: Wytze van der Gaast Professor economic questions of energy transition, Hanze University of Applied Sciences, the Netherlands		
Rogier Pennings: Who Pays What in an Energy Hub? A Transparent Financial Settlement Model for Industrial Parks Under Grid Congestion.		
Rolf Bastiaanssen: Local Energy Price and the Local Levelised Cost of Energy: A framework for benchmarking energy supply models.		
Ahmad Abdolhosseini: Requirements for Viable Business Models for Smart Multi-Commodity Energy Hubs (SMCEH).		
Elaheh Shadkam: Resilience You Can Size and Price: What a Rule-Based Solar–Battery–Hydrogen Hub Costs, and What It Should Sell		
Session 4: Risk management policies for resilient energy hubs		**Room C6**
Chaired by: Marjolein van Splunder Coordinating policy advisor energy innovation, Dutch ministry of economic affairs, the Netherlands		
Rein Boshuisen: Who Carries Which Risk in an Energy Hub? Allocating Responsibility Across Shared Assets and Interdependencies		
Linde Kapinga: Unlocking Congestion Management with Closed Distribution Systems: An Agent-Based Exploration of the Interplay Between Technology, Markets, and Policy		
Joke Westra: Anticipate and Mitigate: A Comprehensive Risk Framework for Maturing Energy Hubs		
Leon van den Beemt: The City Energy Bill; providing city-level policy makers with the economic narrative needed to support their e-hub strategy.		
Session 5: Multi-commodity energy control in practice: lessons learned from MOOI Energy Control Business Park		**Room C1+C2**
Chaired by: Gerwin Hoogsteen Assistant Professor Smart Grids, University of Twente, the Netherlands		
Gerwin Hoogsteen: Introduction to Ecofactorij & Issues		
Pieter Zeilstra: Scalable MLOps Architecture for Large-Scale Energy Forecasting in Industrial Microgrids.		
Jacco Reuling: Design and use of EMS		
Tayyab Ali: Design and deployment RT simulation		
Rick Dijkstra: The social impact, acceptance and possibilities		

12:15 -13:15	**Lunch and networking**	**Meeting Lounge and Restaurant**
13:15–14:15 Parallel Session 6 - 9		**Room C3**
Session 6: Citizens as actors in resilient energy hubs		
Chaired by: Simone van der Burg Professor resilient democracy, Saxion University of Applied Sciences, the Netherlands		
Bram Reinders: From Consumers to Co-Creators: Citizens as Actors in Resilient Positive Energy Districts		
Dorothy Iseghohi: Evaluating the Spatial and Societal Feasibility of Local Thermal Storage: A GIS and Energy System Approach.		
Jeroen Boerkamps: How a Locally Owned Wind Farm Unlocks a Multi-Stakeholder Energy Community.		
Ferdi Hummelink: Energy communities as actors in resilient energy hubs.		
Session 7: Multi commodity Energy Management Systems and resilience in practice		**Room C4**
Chaired by: Bart Homan Lead researcher smart energy, Saxion University of Applied Sciences, the Netherlands		
Trung Nguyen: NegoFlex: Unlocking Flexibility Behind Building Energy Management Systems for Congestion Management.		
Samuel de Vries: FLEXED: A multi-asset Home Energy Management System with hierarchical district coordination for grid congestion management.		
Albert Molderink: Making It Bankable: How We Turn Flexibility Technology into Real Smart Energy Hubs.		
Rick Stratingh: Assessing the Role of Hydrogen in Managing Grid Congestion on Zernike Campus		
Session 8: Power quality aspects of smart charging and industrial area energy hubs		**Room C5**
Chaired by: Jan Geurts van Kessel Cluster manager system integration and flexibility, HAN University of Applied Sciences, the Netherlands		
Jan Geurts van Kessel: explaining relevance of power quality for resilient distribution grids		
Rick Poulussen (Enexis): oscilation sources within distribution grids		
Carolien Kattenbelt: contribution of PV inverters to power quality		
Wrap-up and Q&A		
Session 9: East Netherlands Smart Energy Hub pilot program		**Room C6**
Chaired by: Robert-Niels van Droffelaar Senior business developer, Oost-NL, the Netherlands		
Rutger Beekman, Justin Pagden: Netbewust Energiedelen, outcomes of the implementation in two Hubs in East Netherlands		
Sabina van Driel: Beyond the EMS: Emerging Cross-European Lessons on What It Takes to Build a Smart Energy Hub.		
14:15-14:45	**Break**	**Meeting Lounge and Restaurant**
14:45–15:45 Parallel Session 10 - 13		
Session 10: Optimising for robust local resilience on a congested grid		**Room C3**
Chaired by: Roland van Rijswijk-Deij Professor network security, University of Twente, the Netherlands		
Rutger Kersjes: Leveraging Open Data in the Design and Validation of Energy Management Systems for Energy Hubs.		
Tayyab Ali: BESS-Supported Industrial Electrification for Resilient Operation Under Grid Congestion: A Spray-Drying Case Study		
Hugo Schönbeck: The Missing Layer: A Neutral Custodian for Secure and Fair Local Grid Steering in Community Energy Hubs.		
Daphne Piket: Identifying Robust Flexibility Investment Decisions for Grid Congestion.		
Session 11: Municipal district heating integration for energy hubs		Room C4
Chaired by: Hinnerk Willenbrink research lead municipal heat planning, Fachhochschule Münster, Germany		
Patrick Wesseler: F|Heat.connect – Scalable and Modular Approaches for Digital Heat Network Planning Using Geospatial Optimization		
Femke Janssen: District heating to shift seasonal energy consumption and reduce the strain on the electricity grid.		
Aulia Tirtamarina: Stakeholder Mapping and Financial Modelling for District Heating Expansion and Integration in Urban Energy Hubs: Findings from the RODEO Project.		
Linda van Bouwel: methodology for exploring heat grids as part of business parks energy hubs		
Session 12: Setting up Regional Ecosystems FOR Multiple-Energy Resilient Systems: Lessons Learned		**Room C5**
Chaired by: Armin Zegwaard Project manager energy transition, New Energy Coalition Groningen, the Netherlands		
Armin Zegwaard: Introduction to REFORMERS		
Bart Kaas: Multi-Commodity Systems and Innovative Technologies		
Armin Zegwaard: Interactive Session with audience		
Wrap-up and Q&A		
Session 13: DSO/TSO developments on congestion control and resilient smart energy hub integration		**Room C6**
Chaired by: Bart van der Laan Program manager flexible energy consumption, Alliander, the Netherlands		
Edmund Schaefer: Creating an energy hub by integrating flexibility into an existing solar park: A Dutch techno-economic case study.		
Joost Kieftenbeld: Collective Energy Management for Grid-Congested Business Parks: Implementing C-EMS under a Group Transport Agreement.		
Ferdi Kozukara: Beyond grid access: the financial and qualitative impact of a group transport agreement and the value drivers that shape it.		
Haike van de Vegte: From Grid-Constrained Area Development to Smart Energy Hubs		
15:45:16:15	**Break**	**Meeting Lounge and Restaurant**
16:15-16:45	**Plenary closing session**	**Room C1 + C2**
16:15-16.30	**Take aways from organising chairs and session chairs, moderated by: Robert-Niels van Droffelaar**	
16:30-16:40	Best presentation award ceremony by: **Professor Yashar Hajimolana**	
16:40-16:45	**Closing by: Professor Richard van Leeuwen**	
16:45-17:45	**Networking and drinks**	**Meeting Lounge**
9:00 - 17:30	**Live Podcast Recording**	**M2**

Resilient Energy Hubs: (em)powering Europe's energy future!

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

Smart Energy Hubs (SEHs) have emerged as a practical response to a rapidly changing energy system: growing electrification, increasing shares of renewable generation, persistent grid congestion, and the need to coordinate energy locally across sectors and actors. The first editions of this conference showed that energy hubs can move beyond isolated technical solutions. They can combine generation, storage, conversion and flexible demand; connect electricity with heat, mobility and molecules; and create a shared framework in which companies, communities, municipalities, grid operators and knowledge institutions can act together.

In 2026, the discussion moves one step further, from making Smart Energy Hubs robust and repeatable to asking how they can contribute to a resilient energy system. Resilience means more than keeping an energy system operating during a technical disturbance. It is the capacity to anticipate, absorb and adapt to changes in grid capacity, energy prices, renewable production, demand, cyber threats, regulation, investment conditions and societal expectations. A resilient energy hub therefore needs technical flexibility, but also viable economics, trusted digital infrastructure, clear governance and an active role for the people and organisations that depend on it.

Takeaways from 2025

Last year's conference focused on unlocking robust, decarbonized energy systems through Smart Energy Hubs. The discussions showed that the field is maturing from individual pilots towards integrated local energy systems. Multi-commodity approaches demonstrated the value of coordinating electricity, heat, hydrogen and other energy carriers rather than optimising them separately. Energy Management Systems, forecasting, digital twins and flexible assets increasingly became part of operational strategies for managing congestion and matching local supply and demand.

At the same time, the 2025 contributions made clear that technology alone does not determine whether an energy hub succeeds. Spatial planning, contracts, financing, regulation, data sharing, cybersecurity, stakeholder organisation and community participation all shape what can be implemented in practice. Experiences from business parks, municipalities, regional programmes and research projects highlighted a recurring lesson: Smart Energy Hubs work best when physical infrastructure, digital intelligence, viable business models and governance are developed together.

Taken together, 2025 moved the conversation from proving that Smart Energy Hubs can work towards understanding how they can be made robust and scalable. That provides the bridge to 2026. As energy hubs become more deeply embedded in local and regional energy systems, the central question is no longer only how to optimise them under expected conditions, but how they continue to function and create value when conditions change.

Resilient Energy Hubs: (em)powering Europe's energy future!

Resilience requires us to look at Smart Energy Hubs as socio-technical systems. On the technical side, flexible demand, storage, smart charging, multi-commodity conversion and advanced Energy Management Systems can help hubs respond to changing grid and market conditions. Digitalisation enables forecasting, coordination and faster decision-making, but it also makes cybersecurity, data quality, interoperability and control architecture essential parts of energy-system resilience.

On the economic and institutional side, resilient hubs need market arrangements and business models that reward flexibility and make collective investments viable. Municipalities and regional authorities have an important role in spatial planning and local coordination, while national policy and regulation determine the room available for collective solutions.

Resilience also raises a fundamental question: resilient for whom? Citizens, companies and communities are not merely end users of energy hubs; they are actors whose participation, trust, ownership and ability to adapt influence whether local energy systems remain effective over time.

This broader perspective is especially relevant for Europe. The energy transition must advance while grids are constrained, industries electrify, heating and mobility become increasingly connected to electricity, and energy security and affordability remain central concerns. Smart Energy Hubs can become an important building block in this transition by using local flexibility intelligently, integrating different energy carriers and connecting technical innovation with markets, governance and society. The ambition for 2026 is therefore not simply to make energy hubs smarter, but to make them resilient enough to support Europe's energy future.

What you'll find in this year's programme

1. The role of people, governance and organisation for energy communities and energy hubs
Explores how governance, organisation, local institutions and collaboration shape energy communities and hubs, and how responsibilities can be aligned across citizens, companies and public authorities.

2. Industrial electrification energy hubs
Focuses on the opportunities and challenges of industrial electrification and the role of energy hubs in integrating flexible industrial demand with local generation, storage and grid constraints.

3. Viable business models for resilient energy hubs
Examines how energy-market design, price signals, flexibility mechanisms and business models can support resilient operation and investment in local energy systems.

4. Risk management policies for resilient energy hubs
Discusses the policy and regulatory conditions needed for resilient local energy systems and the barriers that must be addressed as energy hubs move from pilots towards wider deployment.

5. Multi-commodity energy control in practice: lessons learned from MOOI Energy Control Business Park
Shows how integrated design and development approaches, advanced modelling, and AI-applications for smart control, contribute to energy balance and energy storage business cases for Ecofactorij business park.

6, Citizens as actors in resilient energy hubs:
Places citizens at the centre of the resilience discussion, considering participation, ownership, trust, fairness and the ways local communities can actively shape energy hub development.

7. Multi commodity Energy Management Systems and resilience in practice
Shows how multi-commodity EMS approaches can coordinate electricity, heat, storage, conversion and flexible demand, translating integrated system concepts into resilient operation in practice.

8. Power quality aspects of smart charging and industrial area energy hubs
Connects flexibility with power-system performance, addressing how smart charging and industrial energy-hub operation interact with power quality and local network conditions.

9. East Netherlands Smart Energy Hub pilot program
Brings lessons from regional implementation into the conference, showing how pilots in East Netherlands are turning energy-hub concepts into practical solutions and transferable experience.

10. Optimising for robust local resilience on a congested grid
Addresses fundamental conditions for increasingly digital and interconnected energy hubs, including secure communication, control, data exchange and operational continuity.

11. Municipal district heating integration for energy hubs
Explores the connection between municipal heat planning and energy hubs, highlighting how district heating can be integrated with electricity, flexibility and local spatial planning.

12. Setting up Regional Ecosystems FOR Multiple-Energy Resilient Systems: Lessons Learned
Shares experiences from Smart Energy Hub development in the Northern Netherlands, connecting regional programmes, implementation practice and lessons for replication.

13. DSO/TSO developments on congestion control and resilient smart energy hub integration
Examines how developments by distribution and transmission system operators can enable energy hubs to contribute to congestion management while remaining reliably integrated with the wider energy system.

Plenary Keynote Speakers



Serge Santoo is responsible for Community & Impact at Energy Innovation NL, where he works on strengthening the connections between innovation, policy and practice in the energy transition.

His focus is on bringing together energy professionals from industry, government and research, turning knowledge and innovation into collaboration, implementation and impact.

Within the System Integration programme, Serge works on complex challenges that require collaboration across technologies, sectors and organisations. This includes the development of smart and integrated energy systems, where flexibility, local energy solutions and Smart Energy Hubs play an increasingly important role. With a background in communication sciences, innovation management and business administration, Serge approaches innovation not only as a technological challenge, but also as an organisational and societal one. His starting point is that successful innovation requires trust: in the solution, in the process and in the people involved. Community building and stakeholder engagement are therefore essential to move from promising innovations to solutions that can be implemented and scaled.



Simone van der Burg is trained as a philosopher. In the fall of 2025 she started as professor of Resilient Democracy at Saxion University of Applied Sciences. Her aim is to make democracy more resilient by strengthening the capacity of government and society to collaboratively attend to the grand climate challenges of our time.

Deliberative dialogue, citizen participation, democratic innovation and civic technology are key terms summarizing the interest of her research group. Prior to this, she was Head of Programme and team leader at Waag Futurelab (the institute responsible for developing the original Fairphone), which is a cultural institute in Amsterdam specialized in design research that aims to align digital technology with human (public) values.

Earlier she worked as assistant professor and PI, at WUR and RadboudUMC, and focused on responsible innovation of medical technologies (new genomics, newborn screening) and digital agriculture. She was leader of the commons collective at the Amsterdam Economic Board and served in the ethics committee of Cogem, which advises the government about genetic modification, and she was co-founder of the international Journal of Responsible Innovation. Her full list of publications can be found at: https://www.researchgate.net/profile/Simone-Van-Der-Burg-3?ev=hdr_xprf



Sara Gustafsson is an Associate Professor in Environmental technology and management, and her expertise is sustainable city development with focus on the role of municipalities and how they can act as arenas where

different actors can collaborate to meet the challenges of sustainable development. Sara has also worked with standardized environmental management systems and how these are implemented in municipalities.

Collaboration with the surrounding society has always been an important component in Sara's research and teaching. She has followed several Swedish municipalities' strategic environmental and sustainability management efforts over more than 15 years and have thereby build up a broad network. Sara has also led a university central project on incentives for research collaboration to encourage and reward researchers and research environments that collaborate with the surrounding society.

While the earlier research mainly dealt with organisations' internal sustainability management, the common theme for Sara's later research projects is actor collaboration related to development and implementation of sustainability strategies. Sara has been the coordinator of a research programme called Sustainable Norrköping (2010-2013), which had a triple helix approach to actor collaboration. This was further developed in another project (HEKSA, 2010 2012) for which Sara was the project leader.



At present Sara is involved in two research projects of which one deals with the sustainability perspective when building the "sustainable city" in which spatial planners and contractors need to collaborate. The other project deals with the potential of expanding the district cooling grids.



Marjolein van Splunder is a policy advisor for the energy transition at the ministry of Economic Affairs and Climate Policy, with a specific focus on innovation. She has a background in journalism and anthropology, which provided the foundation for her technical and analytical understanding of societal dynamics and public-private governance. Previously a consultant at PwC, she advised multinationals on complex organizational and strategic challenges. Marjolein now focuses on translating intricate system challenges into actionable policy, mission-driven innovation programmes and effective multi-stakeholder collaboration.

Machiel Mulder is Professor of Energy Economics and director of the Centre for Energy Business and Economics Research at the faculty of Economics and Business of the University of Groningen. He is also programme director of the energy programme of the University of Groningen Business School. He has extensively published on the fields of energy economics, energy markets and energy policy.



Roland van Rijswijk-Deij is full professor of Data-driven Internet Security. His research interests lie in improving the security, resilience and robustness of (inter)networked systems, including the "mainstream Internet" as well as industrial control systems. He also has a strong interest in safeguarding the digital autonomy of Dutch and European society in a changing geopolitical landscape. His interest in the energy system is both personal and professional: he's an avid hobbyist that cobbled together an energy management system for his own house, at the same time he cares about cybersecurity of the larger energy system. Roland is involved in FLECS, a Dutch initiative that aims to guarantee the cybersecurity of large offshore wind farms.

Session 1:

The role of people, governance and organisation for energy communities and energy hubs

Chair: Annemarije Kooijman

The Art of the Deal: Polycentric support and Institutional design of Group transport agreements

Keertana Subramani
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Group transport agreements— multiple firms sharing electricity capacity rights— are an emerging institutional form for managing grid congestion in the Netherlands. There is, however, substantial variation in how quickly hubs progress to a signed Group Transport Agreement (GTO). Existing literature lacks a) a comparative case study of operational GTOs b) an account of why variation in formation speed occurs, and c) what institutional rules can help hubs sustain. This study analyses GTOs through the Institutional Analysis and Development (IAD) and Transaction Cost Economics (TCE) frameworks. The evidence is a near-census of operational GTOs in the Netherlands: nine hubs holding a standard or customized GTO. We collected data from 25 semi-structured interviews and extracted notarial deeds of incorporation for the 9 hubs. Four conditions — DSO posture, TSO compliance, asset specificity (hold-up exposure)— were analysed using fuzzy-set qualitative comparative analysis (fsQCA), with the outcome measured as elapsed time from origin to GTO signing.The same data is also coded against IAD's eight design principles for an institutional design audit.

Among the 9 GTOs studied, formation time varies more than six-fold, from 8 to 54 months. DSO posture is the sharpest discriminator and the only condition approaching necessity for fast formation: the two hubs whose DSO resisted or deferred the arrangement are the slowest cases, while hubs with a committed DSO cluster at the fast end. Low asset specificity is necessary but not sufficient for fast formation— where members carried no hold-up exposure but lacked a willing DSO, formation was among the slowest observed. The sufficient path combines a supportive DSO with low hold-up exposure, combined with TSO non-interference or early clearance when involved. Hubs signing pilot or bespoke instruments formed roughly twice as fast as those negotiating standard-track agreements, indicating that contractual stringency itself carries a coordination cost. Formation speed is therefore governed primarily by the grid-operator relationship and secondly by the flexibility of the agreement. The design audit shows a gap between constitutional and operational level rules: at the constitutional level, while the legal basis for the formation of the GTO is now established, polycentric governance coordination is lacking. At the operational level, rights to organise and collective-choice arrangements are well developed, but proportional cost allocation, monitoring and graduated sanctions are only partially specified; sanctions are warning- and expulsion-based rather than graduated, conflict resolution rests on good faith, monitoring is delegated to heterogenous third-party providers, and capacity-allocation rules under congestion constraints are rarely defined. Overall, there's a need for coordinated multi-level governance to speed up hub formation, and clear operational design rules and standards on capacity allocation, monitoring, enforcement, conflict resolution and cost-benefit sharing to make hubs sustain the long run.

Learning Communities as Enablers for Energy Hubs: Bridging Hard and Soft Relations in the Dutch Energy Transition

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The Dutch government is promoting local energy systems and energy hubs (e-hubs) to relieve short-term grid congestion and accelerate the wider energy transition. The potential of e-hubs is considered substantial, yet practical knowledge on how to develop them successfully remains fragmented and frequently fails to reach the stakeholders who could benefit from it. Learning Communities (LCs) — transdisciplinary, meso-level collaborations connecting researchers, educators, students, and professionals across organizational boundaries — are increasingly positioned as a mechanism to bundle, enrich, and apply this fragmented knowledge in practice.

However, transdisciplinary collaboration is inherently complex: alongside formal, visible ("hard") structures, its success depends heavily on participants' expectations, perceptions, and interests ("soft" characteristics), which, left unaddressed, can hinder collaboration and innovation, particularly where power asymmetries exist between large and small organizations. Practical methods for organizing such collaboration remain scarce, and whether LCs currently fulfil their potential as enablers of e-hub development is unclear. This study investigates the current and desired relationships between LCs and e-hubs across the Netherlands, aiming to identify actionable building blocks for strengthening LCs as enablers of e-hub development.

A three-phase research design is applied. Phase 1 maps the existing landscape through desk research and AI-assisted screening of approximately 1,200 potential e-hub locations across the four "energy hub families" (built environment, mobility, business parks, and Cluster 6 industries). It aims to give an overview of active energy hubs and their engagement with learning communities. Phase 2 deploys a structured survey among identified e-hub initiatives, combining closed questions on satisfaction with current LC involvement and open questions on underlying motivations and perceived barriers, enabling comparison across the four families. Phase 3 convenes a multi-stakeholder workshop — combining appreciative inquiry, anonymous prioritization, and case-based reflection — to validate, deepen, and translate the phase 1–2 findings into a practical guide for both LCs and e-hubs. The study delivers a database and visual network map of existing LC–eHub relations differentiated by family, an empirically grounded account of satisfaction levels, motivations, and barriers shaping these relationships, and a co-developed, practice-ready guide outlining concrete steps to expand, deepen, and diversify LC–eHub collaboration.

The study addresses a documented gap in practical methods for organizing cross-boundary collaboration in the energy domain, offering findings directly relevant to policymakers shaping support structures for e-hubs, to LC coordinators seeking to demonstrate value to practice partners, and to e-hub initiatives navigating an unfamiliar collaborative landscape. The research contributes the first systematic, families-based empirical mapping of LC–eHub relations in the Netherlands, combining a transferable methodology for assessing hard and soft dimensions of transdisciplinary energy collaborations with a validated, practitioner-oriented guide to strengthen Learning Communities as enablers of the energy hub transition.

Networks, Awareness, and Resource exchange in Hubs for Circularity using Agent-Based Approach

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Hubs for Circularity (H4C) connect industry, communities, policymakers and researchers to develop urban and rural industrial symbiosis through exchanges of energy, water and materials. By supporting cooperation around surplus heat, shared infrastructure and resource exchanges, H4C contribute to industrial decarbonisation and more efficient resource use. Their expansion depends on attracting new participants to join industrial symbiosis activities.

Building on an earlier social network analysis, this study develops an agent-based model to examine how the hubs expand and how interventions affect adoption. The model uses communication and resource-exchange networks from four H4C in the Basque Country, Germany, the Netherlands and Türkiye. It follows new industrial and community participants through two stages: becoming aware of symbiosis opportunities and adopting them by establishing exchanges. Behavioural, institutional and infrastructural friction factors are informed by surveys among project partners and a project deliverable. We compare the effects of these frictions, different ways of connecting newcomers to the network, and support from brokers who help participants find partners. We also identify which existing actors attract the most newcomers and compare scenarios that reduce different groups of frictions.

The simulations show a persistent gap between widespread awareness and more limited adoption across the four hubs. Frictions affecting adoption have a stronger effect on final uptake than those affecting awareness, highlighting the importance of helping participants establish exchanges once they know about the opportunities. Connecting newcomers to highly connected actors or to actors linking different parts of the network produces similar adoption outcomes. Brokers, however, improve adoption when participants struggle to find suitable partners on their own. Their contribution therefore depends on the difficulties participants face in finding partners. The analysis also reveals distinct stakeholder roles: research organisations often act as knowledge brokers, while established industrial actors attract new participants and become anchors for resource exchange. Intervention scenarios show that reducing barriers and increasing participants' capacity to pursue partnerships can improve adoption. However, combining several programmes produces less than the sum of their separate gains when engagement capacity remains constrained. This shortfall disappears when all scenarios, including the baseline, allow the same number of partnership attempts.

These findings suggest that hub managers should prioritise barriers to establishing exchanges, direct brokerage support towards participants who struggle to find partners, and ensure sufficient capacity to pursue opportunities. For policymakers, they highlight the need to align support programmes with the practical capacity available to develop partnerships. The study explains how stakeholder networks, implementation barriers and engagement capacity jointly shape industrial symbiosis adoption, with practical lessons for hubs developing surplus heat exchange, shared energy infrastructure and other forms of energy symbiosis.

Session 2:

Industrial electrification as part of energy hubs

Chair: Mina Shahi

Feasibility of Behind-the-Meter Wind Energy for Energy-Intensive Manufacturing Sites

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Industrial electrification and increasing grid congestion are driving energy-intensive industries to explore local renewable energy generation. For manufacturing plants, behind-the-meter wind (with additional solar) either combined with energy storage can reduce dependency on the electricity grid, improve energy security, and contribute to decarbonization targets. However, the deployment of wind, solar and storage energy at industrial sites is often constrained by spatial planning regulations, environmental restrictions, and uncertainties regarding technical and economic performance. This work presents an integrated three-phase framework to assess the feasibility of behind-the-meter wind energy for industrial sites.

Real world examples are omitted in the abstract but can be shown during presentations for inspiration!

The first phase evaluates the spatial and policy feasibility of wind turbines through a permitting and constraints assessment, including national and regional policies, zoning regulations, environmental impacts, Natura 2000 areas, infrastructure constraints, and external safety requirements. The second phase develops a preliminary business case for one or more turbines by assessing investment requirements, utilization scenarios, financial risks, and economic performance indicators such as cash flows and payback periods under different technical and policy scenarios. This phase serves as a decision gate to determine whether further technical optimization is justified. The third phase assesses the technical and energetic feasibility of the most promising scenarios by analyzing electricity consumption profiles, matching on-site demand with wind or solar production, and evaluating behind-the-meter integration, grid limitations, and the potential role of flexibility and storage solutions.

The first phase typically reveals substantial differences between potential locations. Generally, sites with sufficient available space for a utility-scale wind turbine on the premises or within a radius of a few kilometers, combined with the possibility to partially feed surplus electricity back into the grid, are considered more promising for further analysis. In contrast, locations constrained by strict height limitations, for example due to the proximity of residential areas, radar stations, obstacle limitation surfaces for aviation or other height-restricting factors, may still be suitable for microturbines or smaller second-hand turbines. Similarly, sites affected by nearby planned developments, conflicting land uses or other spatial constraints are typically associated with higher permitting risks and a less favorable business case and are therefore less attractive for further development within the framework. The second phase will determine the degree to which locally generated wind and solar energy can directly supply industrial electricity demand and establish the optimal turbine configuration, solar field dimensions and required storage power and capacity. It also delivers input for phase 3, setting up a business case model.

The preliminary results demonstrate that the feasibility of behind-the-meter wind is highly site-specific and that non-technical constraints can be equally influential as technical and economic considerations. Beyond direct financial returns, behind-the-meter wind energy and flexibility solutions may create significant value by enabling factories to electrify processes and expand

operations despite grid congestion. As a result, the business case should not be evaluated solely by conventional economic metrics. Initial economic analyses indicate that, although smaller behind-the-meter wind turbines can be financially viable under certain conditions, the relatively high development and investment costs generally make larger turbines or multiple-turbine configurations more attractive. Their economic performance, however, depends on the connected factory being able to directly consume a substantial share of the electricity generated. The proposed three-phase framework provides industrial stakeholders with a practical methodology to systematically identify, assess, and prioritize local wind energy opportunities under increasingly constrained electricity network conditions. The resulting business case forms a robust basis for investment decisions and for progressing towards detailed design, permitting, and project realization.

The Value of Industrial Energy Flexibility in Energy Hubs

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The increasing electrification of industrial processes and decentralized generation creates problems such as congestion for existing power grid infrastructure. In the Netherlands grid congestion has become a major bottleneck limiting industries in expanding operations due to inadequate transmission capacity. While industrial energy flexibility and demand response (DR) are recognized as essential technologies for balancing large grids, there remains a gap in research regarding their specific role in smaller, local industrial energy hubs. The objective of this research is to quantify the potential of industrial energy flexibility in mitigating grid congestion and increasing the uptake of local renewable energy sources (RES) using the Urk industrial area as a case study. An energy system model was developed using Python for Power System Analysis (PyPSA) to simulate. The study modeled energy system scenarios for 2025, 2030, and 2040, considering the energy demand, RES generation, and grid transmission requirements of the Urk industrial area at an hourly resolution across six historical weather years. Evaluating the cost-optimal installed capacity of wind and solar together with DSR strategies for utilizing the inherent flexible capacity of the industrial area, focusing on the thermal inertia of freezer warehouses, hot water buffers, and smart charging for electric vehicles (EVs). The results demonstrate that Demand-side management substantially improves the energy system. The 2025 scenario of the model shows that implementing DR increased the share of RES in the total electricity supply from 62.3% to 73.7%, while also reducing the curtailment of wind and solar by 40% and 20% respectively. The thermal inertia of freezer warehouses provided the largest flexibility opportunity at 312 MWh(th). For the 2040 scenario, using RES and incorporating DR strategies reduced peak grid transmission requirements by 33%, dropping from 34.3 MW(e) to 22.8 MW(e). Furthermore, a greenfield analysis showed that up to 5.7 MW(e) of current transmission capacity can be made available through the implementation of DR in combination with RES generation, highlighting how industrial flexibility can alleviate grid congestion. For the system level benefits to be achieved it is important to consider all the necessary stakeholders. The findings of this research show that for the wind turbine operators physical coupling to the local industrial grid is discouraged by high curtailment rates, high initial infrastructure costs, and subsidy losses. This study demonstrates that DSM is an effective strategy for mitigating grid congestion and facilitating the uptake of RES in industrial energy hubs. By quantifying the local potential of inherent industrial flexibility through a case study, this work provides a practical basis for network operators, policymakers, RES operators, and industries to build a modern energy system.

Economic viability of thermal flexibilization of agricultural anaerobic digesters under intermittent Power-to-Gas plant operation

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Power-to-Gas systems in biogas plants complement volatile renewable energy systems by converting surplus electricity into an energy carrier suitable for long-term storage. Heat integration and sales support the economic performance especially for catalytic high-temperature technologies, but thermal storage is required to assure supply to the anaerobic degradation process in intermittent operation. This can be achieved by thermally flexibilizing the digesters avoiding additional heat storage. This study evaluates such thermal flexibilization in Power-to-Gas applications by comparing its total costs with various conventional constant-temperature alternatives. Detailed simulations of typical agricultural biogas facilities and intermittent Power-to-Gas plant operation provided data for the techno-economic assessment. The results indicate that thermal flexibilization is viable between 4,000 and 8,000 annual full-load hours of Power-to-Gas system operation. The relative economic improvement over the closest constant-temperature alternative is at least 5.7% and 6.6% for manure- and energy-crop-based biogas plants, respectively, even at low methane prices. If the influence of temperature on biogas production is neglected, thermal flexibilization becomes non-viable at 8,000 annual full-load hours. While savings in internal methane consumption alone are sufficient for a competitive thermal flexibilization in energy-crop-based biogas plants, manure-intensive facilities may require additional measures in the absence of waste-heat revenues, with necessity depending on Power-to-Gas plant configuration. In future intermittently operated catalytic Power-to-Gas plants, conventional waste-heat integration can reduce synthetic methane production costs by 8% and 5% for manure- and energy-crop-based biogas plants, respectively. Thermal flexibilization can provide further cost reductions of 2% and 1%, respectively.

Zeotropic hydrocarbon refrigerants in high-temperature heat pumps: digital twin development and experimental validation

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High-temperature heat pumps are expected to play an important role in the decarbonisation of industries, buildings and district heating systems. Recent studies have shown that zeotropic refrigerant mixtures may improve heat pump performance through better temperature matching during evaporation and condensation. Despite this potential, most research has focused on theoretical analyses, simulations, or laboratory-scale experiments. Experimental validation under representative operating conditions remains limited, particularly for natural refrigerant mixtures and higher-capacity heat pump systems. In our Energy Transition Lab at RDM Campus Rotterdam and with several research programmes, we aim to address this knowledge gap by investigating the behaviour, stability and controllability of natural zeotropic hydrocarbon refrigerants in high-temperature heat pumps. The project combines thermodynamic modelling, experimental research and digital twin development in a joint effort between industry and knowledge institutes. A laboratory-scale heat exchanger test rig and a 50-100 kWth heat pump prototype are being developed to evaluate refrigerant performance under realistic operating conditions.

A central element of the project is the development of a digital twin that represents the dynamic behaviour of the heat pump system. The digital twin is used to analyse system performance, evaluate control strategies and investigate the implications of temperature glide on heat transfer and system operation. Particular attention is given to the development of control concepts for systems without a fixed evaporation or condensation temperature, since conventional control approaches are not directly applicable to zeotropic refrigerants. The experimental programme focuses on three key research questions: (i) the influence of temperature glide on heat transfer performance, (ii) the stability of refrigerant mixtures and potential composition shifts within the cycle, and (iii) the interaction between refrigerant mixtures, lubricant oil and system control. Experimental observations are used to calibrate and validate the digital twin and associated design models.

The presentation will discuss the project methodology, the role of digital twins in the development of advanced heat pump systems, and initial insights into the practical application of natural zeotropic refrigerant mixtures. The work contributes to the development of design and control methodologies for next-generation high-temperature heat pumps and provides knowledge that may support the integration of efficient thermal energy systems within future smart energy hubs.

Session 3:

Viable business models for resilient energy hubs

Chair: Wytze van der Gaast

Who Pays What in an Energy Hub? A Transparent Financial Settlement Model for Industrial Parks Under Grid Congestion

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Grid congestion is slowing industrial growth and electrification on Dutch industrial parks. Energy hubs — where companies share grid capacity, generation, storage, and flexibility — offer a way forward, but getting companies to actually commit takes more than sound engineering. Even when the hub-level business case is solid, projects stall on one question: how do we divide the costs fairly? Without a defensible answer, intent never turns into signature. Existing hub initiatives often defer this question, eroding trust between participants and stalling the process. The objective of this work is to turn energy hub participation into a defensible investment decision by making financial settlement transparent and traceable, so participants know where they stand before committing.

We developed a financial settlement model commissioned by PVB, which has also been made publicly available. The model rests on six principles:

- Cost causation: participants pay for what they actually use, so a participant who does not use the battery does not pay for it.
- Cost transparency: every participant has insight into the build-up of their own bill.
- Non-discriminatory: every company applies the same calculation rules, regardless of size or influence.
- Cost-covering: all actual costs are settled, including any margin.
- Affordable: we use a cost-plus model rather than a market mechanism.
- Accessible and committed: the financial threshold to join is low enough to be reachable but high enough to demand serious commitment.

In the application at the Kempisch Bedrijvenpark (KBP) , participants could model their own business case before committing, and internal approvals moved faster because the cost split was defensible inside their own organisations. Lead time from concept agreement to signature shortened and renegotiation was reduced. Energy hubs rarely fail on engineering. They fail because the cost-allocation question is raised too late and participants withdraw the moment the numbers appear on the table. Treating settlement as a design choice from day one, rather than as legal cleanup at the end, changes the conversion rate from interest to signature. This contribution offers industrial parks, municipalities, and network operators a tested and publicly available model to answer the cost-allocation question that decides whether an energy hub becomes real. The model can be adopted as-is, the principles scale across configurations, and the KBP application is directly usable as a reference for comparable initiatives.

Local Energy Price and the Local Levelised Cost of Energy: A framework for benchmarking energy supply models

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The energy transition is accelerating diverse energy supply models—ranging from conventional grids and behind-the-meter systems to community energy and local flexibility markets—each with distinct capital stacks, operating models, and tax treatments. However, public-sector strategic energy planning in Europe primarily evaluates energy through macro-economic lenses using uniform pricing. This obscures the economic reality and cost-competitiveness experienced by local consumers. To address this gap, this paper introduces the Local Energy Price (LEP) framework for benchmarking alternative energy supply models serving a defined local demand boundary.

LEP is operationalized through the Local Levelised Cost of Energy (LLCOE), which measures the discounted lifetime net supply cost per unit of electricity delivered. Building upon traditional LCOE, LLCOE evaluates the complete local configuration by incorporating technology, network, financing, governance, fiscal conditions, and revenue streams within the demand boundary, all unified into a standardized metric (€/kWh). A diagnostic framework integrating Multi-Level Governance and the PEST model structures pathway price components across political, economic, social, and technical domains and niche, regime, and landscape levels. The approach is demonstrated through European urban case studies comparing conventional grid supply, behind-the-meter solar–storage, and district/community aggregation.

Results illustrate that pathway price structures and local energy price vary substantially, with a significnat attribution of local arrangements, financing conditions, and policy design. Ultimately, the LEP framework provides policymakers, investors, and local energy actors with a decision-oriented tool to assess the economic attractiveness of decentralized supply models and identify targeted interventions to optimize local energy prices.

Requirements for Viable Business Models for Smart Multi-Commodity

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Smart Multi-Commodity Energy Hubs (SMCEHs) offer a promising approach for integrating local energy generation, storage, flexible demand and energy conversion while supporting grid-congestion mitigation, sector coupling and more efficient use of energy infrastructure. However, technical feasibility alone does not guarantee successful implementation. The viability of SMCEH business models is also shaped by political, economic, social, technological, environmental and legal conditions, many of which remain uncertain or context-dependent within the Dutch energy system. This study developed a whole-system methodology to identify these external conditions and translate them into measurable requirements for assessing SMCEH business-model viability.

A structured PESTEL analysis was conducted using Dutch energy-hub studies, regulatory and policy documents, sector reports and relevant literature. Factors were classified across the six PESTEL dimensions and assessed according to their nature, directional influence on viability and supporting evidence. The analysis resulted in a hierarchical framework comprising 28 high-level PESTEL factors, consolidating detailed sub-factors together with their underlying sources, representing the principal external conditions affecting SMCEH development and operation. These include regulatory and congestion-management conditions, financing and cost-allocation mechanisms, stakeholder participation and coordination, energy-management and interoperability requirements, environmental performance, and contractual and legal arrangements. Their distribution across the six dimensions is markedly uneven: legal and economic conditions together account for roughly half of the identified sub-factors, followed by technological requirements, while purely political conditions are the least numerous. The large majority of factors are structural or context-dependent rather than transient, indicating that they are persistent characteristics of the Dutch energy system rather than temporary frictions, and only a minority act in a consistently positive or negative direction. The resulting framework demonstrates that viability depends on a combination of regulatory, organisational, financial and technical conditions rather than on technological capability alone.

To support quantitative prioritisation, the identified factors are currently being evaluated using the Best-Worst Method (BWM), which prioritises them while maintaining a formal consistency assessment. Preliminary findings indicate that regulatory and congestion-management conditions, financing and cost-allocation mechanisms, and stakeholder coordination are among the most influential conditions affecting SMCEH viability. The quantified requirements are linked to representative SMCEH configurations based on established Dutch energy-hub archetypes and incorporated into technical and economic assessment, with sensitivity analysis identifying threshold conditions under which an SMCEH business model becomes more or less viable. By integrating PESTEL analysis, quantitative prioritisation and energy-system assessment, the resulting framework offers a reproducible pathway for translating broad external uncertainties into actionable requirements for Smart Energy Hub development, policy design and investment decision-making. The conference presentation will report the final prioritisation results and

discuss the conditions that most strongly affect the viability of Smart Multi-Commodity Energy Hubs in the Dutch context.

Resilience You Can Size and Price: What a Rule-Based Solar–Battery–Hydrogen Hub Costs, and What It Should Sell

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Resilience in an energy hub is easy to claim and hard to specify: how many hours of autonomy, for which loads, at what cost, and underwritten by whom. Nearly 400 energy hub initiatives are registered in the Netherlands, yet only dozens are active or in realisation, while grid connection queues run to several years and group transport agreements leave unresolved how participants allocate capacity and risk. Sizing studies optimise components against fixed demand; feasibility studies price concepts. Neither directly tells a developer what to build, what level of resilience to promise, or what maintaining that promise costs. These questions are examined in a completed case: a multifunctional redevelopment in Amsterdam (≈10,000 m^2) designed to operate without a grid connection, representing the limiting case of a resilient hub. A rule-based energy management model combines hierarchical dispatch (direct solar, then battery, then hydrogen) with demand-side control of heating, cooling, ventilation and lighting based on temperature, humidity, occupancy and time of day. Four segments totalling 1,592 m^2 (museum, restaurant, office and dwelling) were simulated hourly over 8,760 steps using 1,764 kWp of PV, a 1,800 kWh battery (92%), a 500 kW electrolyser (72%) and a 500 kW fuel cell (55%).

Relative to an uncontrolled baseline of 1,063 MWh per year, demand-side rules reduced demand by 81.1% under sustained-warm conditions but only 25.8% under sustained-cold conditions, showing that control is least effective when the hub is most stressed. In the annual islanded-system run, 1,421 MWh was supplied with no unmet hours, of which 435 MWh came directly from solar, 235 MWh from the battery and 751 MWh from hydrogen. Hydrogen dependency ceased to improve materially once battery capacity exceeded approximately 1,000–1,250 kWh, leaving about 550 kWh of the specified battery without additional resilience benefit in the simulated cases. Hydrogen showed the opposite pattern: days with unmet demand fell from 140 per year at 5,000 kg of modelled storage to zero at 35,000 kg, with diminishing returns beyond approximately 20,000 kg. The 35,000 kg value is a simulation upper bound, not a demonstrated site-feasible storage configuration, and requires separate assessment of storage technology, footprint, safety, permitting and logistics. Delivering that 751 MWh through the fuel cell consumes about 41 t of hydrogen annually on a lower-heating-value basis. Full on-site regeneration would require roughly 1.9 GWh of electrolyser input, exceeding the annual PV yield, so approximately 18–22 t must be externally supplied; the hourly solar record was taken from another project and does not correspond to the specified array, which bounds this estimate. At €10–13.7/kg delivered, hydrogen-derived electricity costs about €0.55–0.75/kWh versus approximately €0.175/kWh for Dutch business electricity. The results show that battery and hydrogen are complements rather than substitutes, that hydrogen capacity represents a service-level choice rather than a single optimum, and that full autonomy introduces recurring commodity exposure alongside capital investment. Resilience should therefore be treated as a measurable and priceable service in the energy-hub business case.

Session 4:

Risk management policies for resilient energy hubs

Chair: Marjolein van Splunder

Who Carries Which Risk in an Energy Hub? Allocating Responsibility Across Shared Assets and Interdependencies

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Energy hubs on Dutch industrial parks are increasingly used to work around grid congestion, but attention focuses mainly on engineering. A question that is just as decisive in practice for whether a hub succeeds or fails receives far less attention: who carries which risk? The moment participants become dependent on each other for capacity, generation, or flexibility, risk questions emerge that need to be addressed both contractually and in governance. If they are not made explicit, parties withdraw or the investment is never made. The objective of this work is to put this question on the agenda by sharing two recurring risk cases from practice, illustrating how many different aspects need to be considered before hubs in these configurations can move forward. We analysed two cases encountered in our projects.

In the first case, a participant contributes a CHP unit as back-up for the hub, while that installation will rarely run for the hub itself. How do you determine the compensation for standby, who is liable if the CHP fails at the moment the hub needs it, and what happens if the owner decides to leave the hub or decommission the CHP?

In the second case, the hub's generation depends on a single party, a biodigester (generator), leaving the other participants reluctant to invest because they do not want to carry that dependency risk.

Both cases show that risk allocation cannot be reduced to a single contractual clause. A wide range of arrangements comes into play — from standby fees and replacement obligations to exit clauses, liability allocation in case of non-delivery, and governance arrangements that prevent one party from collapsing the entire structure. Our practical experience shows that explicitly naming dependencies is what makes these discussions possible in the first place. In our experience, this is what allows participants to justify their risk position internally and become willing to invest despite the mutual dependency. Energy hubs do not get stuck on engineering, but on the question of who carries the risk if something goes wrong and on the willingness to help each other. This contribution offers industrial parks, municipalities, and hub initiatives concrete examples and discussion points to make the risk question discussable, with cases directly recognisable for comparable situations across the Netherlands.

Unlocking Congestion Management with Closed Distribution Systems: An Agent-Based Exploration of the Interplay Between Technology, Markets, and Policy

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Although more than 140 Closed Distribution Systems (CDSs) operate alongside the public electricity grid, their private operation and internal transport agreements make their participation in congestion management fundamentally different from conventional grid users. Under the Dutch Energy Act (2026), these systems are expected to facilitate participation in congestion management. This study combines policy analysis, stakeholder interviews, and Agent Based Modelling to investigate how Closed Distribution Systems can contribute to public grid congestion management under different operational and market strategies.

A Technology–Market–Policy framework, informed by policy analysis and stakeholder interviews, was integrated with an agent-based model based on The Green Box, an innovative Cleantech Campus in Hengelo. The model represents multiple market participants operating in redispatch and intraday electricity markets and simulates one year of operation under different congestion scenarios, market strategies, and energy management system capabilities.

The simulations show that CDSs can provide meaningful flexibility when predictive energy management and clear communication between internal and external stakeholders are in place. The Green Box could have provided flexibility equivalent to approximately 2% of all redispatch requests on GOPACS during the simulated year. However, increased participation in congestion markets introduced trade-offs between internal optimisation and external market incentives, increasing the risk of transport agreement violations and conflict.

Unlocking flexibility for congestion management requires not only technical capabilities, but also clearer governance arrangements and standardised communication and control protocols. Although this research focuses on Closed Distribution Systems, the identified trade-offs and governance lessons are relevant for a broader range of decentralised energy hubs participating in flexibility markets.

Anticipate and Mitigate: A Comprehensive Risk Framework for Maturing Energy Hubs

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As the maturity of multi-commodity energy hubs (MCEHs) in the Netherlands progresses, there is a corresponding need to deeply understand and manage the complex risks involved in their establishment and operation. Awareness of safety hazards during installation and operation, as well as realization risks associated with the initiation and launch phases, has grown steadily. This growing familiarity is visible in recent reports such as Verkenning veiligheid van energiehubs NIPV and active knowledge-sharing platforms such as Oost-NL Smart Energy Hubs and Kennisplatform Energiehubs. Existing risk assessments for energy hubs are fragmented and predominantly focused on risks in initiation and development up to the initial realization (including organizational challenges and permitting). As such, a structured framework that supports risk identification throughout the full lifecycle of an energy hub is relevant as MCEHs are maturing.

This contribution presents a risk categorization framework tailored for energy hubs, adapting the 6 phase-MCEHs framework, by Jenks et al. 2025, to aid the continued development of multi-commodity systems within the Dutch context. This risk categorisation was created drawing on (i) a review of contemporary reports, (ii) an expert workshop, utilising the regional expertise and experience of the participants, and (iii) by applying a root cause analysis to identified dangers. Our methodology enables the systematic identification of risks across the development, utilisation and expansion of MCEHs.

Within the proposed framework, these risks are categorized into four distinct dimensions: organizational, legal, technological, and financial. We discuss each dimension and identify challenges requiring specific domains of expertise to effectively navigate, mitigate, or eliminate entirely. Our results show that the dominant risk category shifts per phase; for instance, technological risks dominate the utilisation phases, while organisational risks peak as hubs mature from exploration to realisation.

Ultimately, this structured categorisation serves as a strategic tool for project developers, policymakers, and engineers to proactively address vulnerabilities, ensuring the safe, resilient, and successful deployment of future energy hubs.

The City Energy Bill; providing city-level policy makers with the economic narrative needed to support their e-hub strategy.

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Most cities in Europe do not know what they spend on energy on a yearly basis, yet they are expected to lead a local energy transition that requires billions of euros of investments. As the energy transition is moving from formulating goals and strategy on a (supra)national level to execution on the local level, cities and municipalities across Europe are stepping up to take the lead in the local energy transition. Within cities and municipalities this means that a major shift is happening, they are moving from scattered energy pilots and programs to fully integrated Local Energy Action Plans (LEAPs). This shift requires internal and external buy-in. Despite the clear evidence of its positive impact on the climate, the energy transition is often wrongfully framed to be a cost, rather than an investment with a strong economic ROI. To mobilize stakeholders, a new economic narrative is needed, and the opportunity needs to be clear. This narrative starts from the status quo, the City Energy Bill.

In our work with cities across Europe like Dordrecht, Ghent and Antwerp it has become clear that insights into the city energy bill are crucial for proper investment planning. An average European city spends hundreds of millions of euros a year on energy, a number that is expected to increase rapidly in the coming years. However, with the right investments, cities can develop a local energy system that is not just green, but also equitable, affordable and resilient. The City Energy Bill combines credible publicly accessible databases with statistics and benchmarks from renowned research organizations (e.g. TNO, VITO, etc.) to create accurate policy level insights into the city energy spending. Where available, additional non-public data can be added to further increase the accuracy of the model. It covers the total city energy bill, a break-down into the main asset lines (industry, municipal, residential), scenario's, market trends, and more. Starting from the current energy bill, it allows policymakers to calculate the economic impact of investment scenario's, such as accelerating the roll-out of e-hubs in the local area. With the City Energy Bill, we are reframing narrative of the local energy transition from a cost to an economic opportunity. This new economic narrative can be used to gather support for local energy investments. The audience will walk away from this session with a new perspective on the economic opportunity of the local energy transition, and the narrative that supports it.

Session 5:

Multi-commodity energy control in practice: lessons learned from MOOI Energy Control Business Park

Chair: Gerwin Hoogsteen

Multi-commodity energy control in practice: lessons learned from MOOI Energy Control Businesspark Ecofactorij

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The Ecofactorij is a business park in the eastern Netherlands, comprising 25 companies including offices, cold storage, transportation and car-parts manufacturing. It operates in a self-owned, local distribution grid with a common shared connection at a transformer station to the main DSO grid. Due to grid congestion in the eastern Netherlands, the grid capacity has been limited to 12.5 MVA, which is problematic for expansion plans and electrification efforts of the companies as exceeding this limit can have severe consequences: from fines up to disconnection.

In the MOOI – Energy Control Businesspark Ecofactorij (ECBE) project, researchers from different engineering and social disciplines have worked together with the companies to explore possibilities, using digital twin technologies to make better use of existing assets and existing flexibility to optimize their use of the limited grid capacity. In this session we present findings from four main areas of research within the project.

Pieter Zeilsta (Saxion UAS, Ambient Intelligence) - Scalable MLOps Architecture for Large-Scale Energy Forecasting in Industrial Microgrids

This part of the project aims to develop and evaluate a scalable Machine Learning Operations (MLOps) architecture for large-scale energy forecasting in industrial microgrids, addressing the gap between forecasting model development and reliable operational deployment. Here, we present the results, which indicate that large-scale energy forecasting should be addressed as a system-level MLOps challenge rather than solely as a model development problem.

Jacco Reuling (University of Twente, Computer Architecture for Embedded Systems) - Making battery flexibility work under grid constraints

A battery at a congested business park can serve two goals: it can earn money on the energy market, but it may also be needed to keep the local grid within its capacity limit. So how much of that battery can we safely use, and what happens when our prediction of tomorrow turns out to be wrong? We built an augmented digital twin so that we could safely experiment with this. In this environment, we tested a layered energy-management approach that combines forecast-based planning with real-time grid protection. The experiments show why forecasting or fast control are insufficient on their own.

Tayyab Ali (Saxion UAS, Sustainable Energy Systems) – Design and deployment of a real-time simulation of the Ecofactorij

Practical tests are difficult at the Ecofactorij, as these would potentially disrupt the operations of the companies. Therefore, a real-time simulation of the Ecofactorij is created using an OPAL-RT Hardware In the Loop simulator, which enables the researchers to evaluate the effect of using the control algorithms and additional measures, without risking disruptions to the normal operations of the companies, before real validation tests can be conducted at Ecofactorij. Here, we present how the real-time simulation was constructed and how it was used to test the EMS.

Rick van Dijk (Saxion UAS, Sustainable Areas and Soil Transitions) - Understanding the societal impact of smart energy hubs

An important part of the project was to look at the societal impact of the proposed technical solutions. The main question was, what can we learn from the Ecofactorij case, about the way positive societal impact of a smart energy hub can be improved. Here, we present what the impacts of a SEH are, who are the beneficiaries and what can be done to improve the societal impact.

Session 6:

Citizens as actors in resilient energy hubs

Chair: Simone van der Burg

From Consumers to Co-Creators: Citizens as Actors in Resilient Positive Energy Districts

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Positive Energy Districts (PEDs) bring together local renewable energy, energy efficiency, storage, flexibility and energy sharing at neighbourhood level. But a PED is not only about technology. It is about people and how they can actively participate in their local energy system. Citizens can become producers of energy, provide flexibility, share energy and take part in decisions about their neighbourhood. This paper looks at how citizens can play this active role in resilient energy hubs, using the development of the new village centre of Aadorp in the Netherlands as a real-life case. In Aadorp, new and existing homes, a new community centre and the local energy system are being considered as part of one integrated PED. An important part of the approach is the use of a Local Digital Twin (LDT). Through the work of twinlink.eu, we explore how an LDT can bring together spatial, energy and community data and, more importantly, make this information useful and understandable for citizens. Different scenarios can then be explored together, rather than presenting residents with a technical solution after most decisions have already been made.

The Aadorp case shows that the role of citizens becomes more important when we move from individual energy solutions towards a shared neighbourhood energy system. Decisions about solar energy, storage, flexibility, energy sharing and local infrastructure affect the whole community and cannot be made by technology providers or municipalities alone. A Local Digital Twin can help create a common picture of the neighbourhood, showing what is technically possible and what different choices could mean for energy use, costs, comfort and the local environment. At the same time, citizens bring local knowledge, priorities and ideas that can improve these scenarios. This creates a continuous interaction between the digital model and the real community. Our work therefore looks at a PED as both a technical and a community system. The main lesson from Aadorp and the twinlink.eu work is that digital twins can help citizens become part of designing and developing their future energy system. In this way, citizens are not simply the end-users of an energy hub, but become co-creators and active actors in making their neighbourhood energy system more resilient.

Evaluating the Spatial and Societal Feasibility of Local Thermal Storage: A GIS and Energy System Approach

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In the Netherlands, the transition towards a low-carbon energy system by 2050 is accelerating the deployment of renewable energy technologies and the electrification of heating. Collective heating networks and decentralised electricity generation are driving this transition. As the heating sector electrifies and renewable electricity generation becomes more variable, shifts in electricity demand and supply can strain the electricity grid and cause congestion. These capacity bottlenecks challenge grid operators and municipal energy planners. Therefore, solutions are needed to provide flexibility and reduce peak electricity demand. Thermal Energy Storage (TES) is recognised as a flexibility option to balance fluctuations in heat supply and demand, buffer excess heat, and relieve electricity-grid congestion. TES is a site- and context-specific infrastructure; its placement depends on geology, geography, land availability, heat network connections, existing energy systems, and governance regulations.

Current research and municipal plans on TES focus on technical and economic dimensions, leaving a gap in the spatial information required for decision-making. To address this, the research evaluates the spatial feasibility of local Thermal Energy Storage (TES) using Geographic Information Systems (GIS) to analyse the criteria for locating potential sites. This study employs a comparative case study of two locations. First, the Municipality of Apeldoorn, which is developing a Warmterotonde (Heat Roundabout) to heat approximately 50,000 buildings. Secondly, Enschede Energie, a local energy cooperative facing financial losses from grid congestion and seeking to convert surplus solar electricity into seasonal heat storage for Enschede South.

Using a GIS-based Multi-Criteria Analysis (MCA) methodology and qualitative interviews, the research will identify and analyse TES spatial planning criteria and evaluate suitable locations across the two sites. It will also assess societal feasibility and municipal policy implications. Although empirical and quantitative results are still being developed within the ongoing study framework, the expected outcome and primary contribution are a Spatial Multi-Criteria Decision-Making (MCDM) framework designed to support municipalities and energy infrastructure planners in evaluating potential TES locations. The MCDM framework integrates technical and spatial constraints, available spatial datasets, and stakeholder-ranked criteria.

How a locally owned wind farm unlocks a multi-stakeholder energy community

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Wind farm Egchelse Heide (five wind turbines, 21 MW) was initiated by three farmers in Egchel in the municipality of Peel & Maas in the North of Limburg, The Netherlands. Together with local energy cooperative Peel Energie, Aelmans Adviesgroep and GreenTrust Consultancy the windfarm was realized in 2021. Even before grid congestion the wind farm wanted to boost the energy transition by supplying 75% of residential electricity consumption in the municipality. But it strives at making the municipality energy self-sufficient: local energy generation that residents can participate in and revenues that flow back into the community. Now that grid congestion hinders societal and industry development the wind farm's ambitions have only grown in relevance since sharing grid assets has become the key. Together with several stakeholders the wind farm is working on the realization of energy hub Peel & Maas.

The objective is to design a multi-commodity energy hub that combines renewable energy generation with local industry and society in an optimal way from technical, legal, financial and organizational perspective. This requires deep stakeholder involvement and dealing with all kinds of limitations, such as spatial constraints. In addition, managing the changing grid, regulatory (e.g. Energiewet), technical and financial context is key.

So far the wind farm with grid connection and charging station (the most affordable in the Netherlands!) has been realised. Instantly, plans were made to expand in a modular way, combining cable pooling and direct line solutions as enabled by the Energy Law (2026).

Phase 1 focuses on cable pooling of:

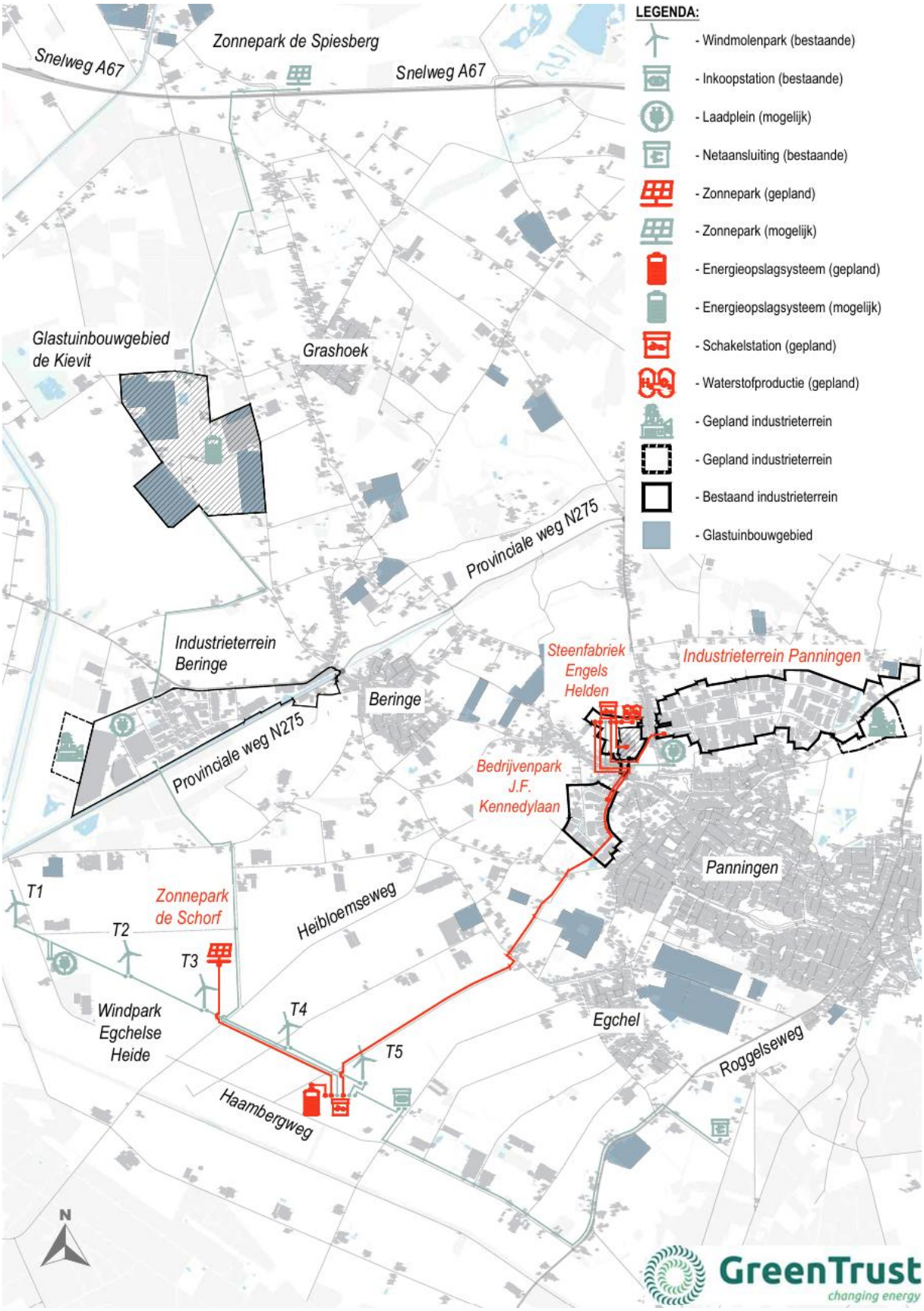
- Modular realisation of BESS 10-21 MW and 20-90MWh in 2028.
- Renewably sourced 2,5-5 MW electrolyser operational at nearby brick factory Engels in 2027, replacing natural gas and a grid connection that was not timely available.
- Cable pooling with solar farm "De Schorf" 41 MWp in 2028. Fully permitted but also without a grid connection in time.

Phase 2 entails:

- Connecting greenhouse horticulture "De Kievit" where electricity will be used for lighting, heat pumps replacing natural gas for Combined Heat and Power and required CO2 for plants to grow will be generated by combining with a planned manure digester that will produce green gas and CO2 for the greenhouses.
- Sourcing industrial zone "Beringe" and a heavy mobility charging station with renewable electricity.
- Sourcing industrial zone "Panningen" and a heavy mobility charging station with renewable electricity. In addition, contributing to connecting the expansion of the industrial zone that due to grid congestion until 2034 has come to a standstill.

When the plan succeeds, it combines wind, solar, battery, electrolyser, heat pumps, charging stations and industry on one grid connection, and facilitate green gas production and CO2 transportation.

The phase 1 parties are now drafting a cable pooling agreement that will be further extended with direct lines. The presentation will explain the challenges involved and the solutions found.



Energy communities as actors in resilient energy hubs

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In the European Green Deal and the Dutch Energy Act (Energiewet) energy communities are viewed as a fundamental actor in shaping the energy transition from the bottom up, driven by citizens. This policy stems from a clear foundation and need; for many years now citizens, usually organized within an energy cooperative, have been working toward a local energy model in which citizens own energy production (via solar and wind) and are given the opportunity to supply energy to their members at a price they set themselves. They also feel a shared responsibility for solving the problem of grid congestion and, if well-organized, can collectively provide substantial grid services to grid operators.

There are many positive side effects; local and cooperative generation and distribution of renewable energy boosts the local economy and restores energy to its status as a collective and, moreover, non-profit-driven good; one that is not decided upon by (international and anonymous) shareholders but through direct democracy; for example, every citizen can have a say in what energy prices are set and how any revenues are allocated. An example of the latter is the creation of an energy fund from which other local projects, such as greening the residential environment, can be subsidized.

Every municipality in the Netherlands now has its own energy cooperative. On a national scale, there is close collaboration and knowledge sharing through the umbrella cooperative EnergieSamen. Several cooperatives are at the forefront of the Local4Local project, which has been experimenting since April 2026 with energy sharing; that is, generating, distributing, and simultaneously supplying energy to members within the energy community at a price they set themselves. Thanks to a legal exemption (under the so-called Dutch “Experimentation Scheme”), they have the legal leeway to also make (price) agreements with grid operators to reduce grid congestion in residential neighborhoods. The first pilot projects on this topic are currently being conducted with grid operators Enexis and Stedin.

Session 7:

Multi commodity Energy Management Systems and resilience in practice

Chair: Bart Homan

NegoFlex: Unlocking Flexibility Behind Building Energy Management

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Grid congestion delays new connections in Dutch distribution networks, while network reinforcement remains slow and costly. This makes demand-side flexibility essential. Commercial buildings equipped with Building Energy Management Systems (BEMS) possess significant flexibility in HVAC, thermal mass, and on-site generation, yet rarely participate. Owners are concerned about penalties and comfort complaints, and Congestion Service Providers (CSPs) lack reliable information about the flexibility buildings can provide. To address this gap, we developed NegoFlex, an agent-based framework that enables automatic negotiation of flexibility between buildings and a CSP. Each building agent derives a feasible flexibility envelope from its BEMS forecast and comfort constraints, tagging each offer with a confidence indicator—the probability it can deliver within those constraints. Offers are limited to ensure the CSP's reliability target (0.90) and are priced using cost-neutral, cost-plus, or revenue-sharing strategies. The CSP aggregates offers using a bounded concession protocol aligned with USEF and GOPACS, assuming delivery risk and shielding buildings from penalties. We simulated a congestion event for three heterogeneous commercial buildings under energy prices either aligned (0.20 €/kWh) or conflicting (−0.10 €/kWh) with congestion relief.

In every simulated scenario, NegoFlex successfully procured and delivered 1,770 kWh (88.5% of the 2,000-kWh requested), achieving a mean offer confidence of 0.956 (minimum 0.945). The available volume was constrained by feasibility and reliability rather than price, so the pricing strategy primarily determined how the congestion value was distributed. With aligned prices, cost-neutral pricing cleared at 0.05 €/kWh, leaving the CSP with €230.10. Under conflicting prices, cost-plus pricing cleared at 0.17 €/kWh, resulting in only €17.70 for the CSP. On average, buildings remained within ±1 °C of setpoint for 83.3% of event hours, with violations ranging from 0% to 33.3% of hours outside the comfort band.

Analysis of real building data shows a total consumption of 144.5 MWh and peak monthly consumption of 16,474 kWh in January. Monthly indoor temperature averages remained within 19.4 to 21.7 °C, despite outdoor temperatures ranging from −7.0 to 34.1 °C. The floor heating and cooling system operated 76% of the time, demonstrating the potential to shift HVAC load.

Comfort-band compliance averaged 70.1% across all hours, but varied widely across zones, from 15.1% to 90.6%. NegoFlex and its simulator are fully developed and ready for deployment. AIMZ is preparing two commercial buildings for pilot testing, with integration currently pending. In conclusion, NegoFlex demonstrates that confidence-qualified offers enable risk-free flexibility for building owners. It shifts the industry focus from theoretical capacity envelopes to actionable, automated flexibility that operates alongside existing BEMS.

FLEXED: A multi-asset Home Energy Management System with hierarchical district coordination for grid congestion management

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Residential electrification increases the need to coordinate heat pumps, batteries and photovoltaic (PV) generation to reduce household electricity costs and manage grid congestion. Existing Home Energy Management Systems (HEMS) often rely on device-specific integrations, limiting interoperability and coordination across homes.

FLEXED is an interoperable, multi-asset HEMS developed by TNO, BeNext and Seita. It combines the S2 flexibility protocol, the RealEstateCore ontology, automatically calibrated thermal RC models and the open-source FlexMeasures platform. A Customer Energy Manager optimises household assets against prices and forecasts within comfort and technical constraints. A District Energy Manager coordinates household plans through price signals and capacity limits, including temporary restrictions communicated through OpenADR 3.

Household simulations used a well-insulated Dutch apartment with a ground-source heat pump, underfloor heating and PV. Across four tariff scenarios, projected heating-season electricity cost savings relative to the measured baseline without a battery were 6.4% with limited price variation and 7.8–15.3% with dynamic electricity prices and/or network tariffs. Adding a 10 kWh battery increased savings to 15.2–21.6% in the more variable tariff scenarios, while savings remained 6.4% with limited price variation. These estimates were extrapolated from twelve simulated winter days and excluded battery investment costs and degradation.

In fourteen-day simulations of ten apartments, independent household price optimisation produced coincident peaks of 34.7 kW with batteries and 11.3 kW without batteries. District coordination kept demand close to an 8 kW group limit. Exceedances were limited to one quarter-hour by 0.09 kW with batteries and two quarter-hours by up to 0.6 kW without batteries. Coordination increased electricity costs by €0.42 and €0.17 per dwelling per day, respectively, compared with uncoordinated household optimisation, and increased mainly shallow comfort-band deviations. Temporary capacity restrictions were met in all tested contract configurations, although demand peaks shifted outside the restriction periods.

The results demonstrate how interoperable, hierarchical control can support residential Smart Energy Hubs while exposing trade-offs between household savings, comfort and shared grid capacity. They also show that independent price optimisation can create coincident demand peaks, particularly with batteries. The simulations assumed perfect forecasts and excluded domestic hot-water production. Field validation and evaluation beyond the winter period are needed to establish practical performance.

Making It Bankable: How We Turn Flexibility Technology into Real Smart Energy Hubs

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Medium- and low-voltage grids increasingly face congestion and limited connection capacity. Electrification is accelerating through heat pumps, electric vehicle charging and distributed generation. At the same time, large multi-commodity installations such as hotels and district heating networks must manage electricity, heat and gas together. Congestion-mitigating technologies, storage and flexible steering of heat pumps, combined heat and power (CHP) units and EV chargers are technically mature. Yet many of these solutions remain unbuilt because a viable business case is missing. Single-purpose flexibility measures rarely earn back their investment on one revenue stream alone, and the value of relieving grid congestion is not yet priced consistently in current energy market design. This contribution presents the practitioner perspective of an energy service provider. We start from a concrete customer challenge and design one integral solution. It covers both the installation itself and the surrounding grid constraints — congestion and limited connection capacity — using congestion mitigators, storage and coordinated steering of heat pumps, CHPs and EV chargers. This is orchestrated by a self-developed multi-commodity energy management system (EMS) spanning electricity, heat and gas. Rather than presenting a research plan, we share operational experience from realized large-scale installations, including hotels and district heating networks. Here, a value-stacking approach combines multiple revenue streams — day-ahead and intraday electricity trading, congestion and capacity-limitation services, and avoided or deferred grid reinforcement — into one multi-asset business case per site.

Results from these implementations show that stacking value streams across a portfolio of flexible assets can turn business cases that are unprofitable on a single service into commercially viable propositions. This simultaneously relieves pressure on the local grid and enables continued electrification of heat and transport at sites that would otherwise be capacity constrained. At the same time, current energy market products and regulation only partly reward this stacked value. We identify where market design still limits the size and bankability of these business cases. These findings show that solving grid congestion on medium- and low-voltage networks, integrating district heating and building HVAC, and deploying energy management, smart charging and demand-side management for energy hubs cannot be separated from the underlying business case. Technical solutions only scale once they are also commercially viable. Our contribution is a market-based perspective, complementary to ongoing research. It shows how a value-stacking, multi-asset, multi-commodity business case is the decisive factor that turns technically available flexibility solutions into smart energy hubs that are actually built — closing the gap between proven technology and its real-world adoption.

Assessing Hydrogen Flexibility for Grid Congestion Management on Zernike Campus

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Grid congestion limits expansion of business parks, electrification of processes and sustainable energy development in the Netherlands. Business park Zernike Campus Groningen houses university facilities of the University of Groningen and the Hanze University of Applied Sciences, next to research laboratories, data centres, and other commercial activities. Zernike Campus faces similar challenges as electricity demand continues to grow while grid capacity remains constrained. Goal of this research is to see what role hydrogen could play at Zernike Campus in addressing its challenges.

The first results of an ongoing assessment of hydrogen-based flexibility options for improving the resilience of the campus energy system are presented. Analysis of campus energy data reveals a highly structured demand profile with pronounced daily and weekly peaks. Most of the electricity consumption is associated with research-related activities, resulting in specific demand characteristics that strongly influence congestion mitigation options and flexibility requirements. The analysis identifies several recurring peak-demand periods that may restrict future campus development under current grid constraints.

To evaluate potential hydrogen applications, the energy model PowerNodes has been refined using operational data from the Entrance field-lab fuel cell experiments complementary to model data. Comparing measured fuel-cell performance with conventional steady-state modelling approaches shows that real-world system behaviour can differ significantly from simplified assumptions commonly used in optimization models. These findings demonstrate the importance of incorporating experimental performance characteristics when assessing the contribution of hydrogen technologies to congestion management and system resilience.

Using Zernike Campus as a case study, the presentation discusses how detailed demand analysis and experimentally validated component models improve understanding of hydrogen's potential role in supporting resilient local energy systems. The results provide practical insights for campus operators, grid operators, and other stakeholders seeking to balance electrification ambitions with increasing pressure on electricity infrastructure.

Session 8:

Power quality aspects of smart charging and industrial area energy hubs

Chair: Jan Geurts van Kessel
Workshop

Session 9:

East Netherlands Smart Energy Hub pilot program

Chair: Robert-Niels van Droffelaar

Grid-Conscious Energy Sharing: From Individual Energy Risks to Collective Solutions

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Businesses face three simultaneous energy market challenges: volatile wholesale prices, shrinking grid access due to congestion and limited contracted transport capacity (GTV), and opaque, fragmented supplier margins. Traditional responses, such as fixed-price contracts, capacity requests, and price comparison, buy off these risks rather than actively managing them, and they address each company individually rather than the shared problem at business-park level.

This session introduces grid-conscious energy sharing as a low-threshold entry point into a local energy collective, built on three principles: local generation, local transport within available grid capacity, and local cooperation through a shared, transparent service provider. Participants trade through a platform based on a dynamic EPEX Day Ahead contract, sharing locally generated electricity at an agreed settlement price whenever production and consumption coincide, while surpluses are sold to the market. Two sharing variants are outlined: one where generators retain the profile risk of surplus power, and one where the collective absorbs it, the latter giving consumers the strongest incentive to shift demand toward periods of local generation.

By actively managing these risks together, grid-conscious energy sharing offers participating companies long-term price certainty, continued grid access, cost transparency, and a basis for joint investment in generation, storage, and charging infrastructure, while strengthening local economic resilience through local ownership and reduced exposure to international energy markets.

This session outlines the theoretical framework of grid-conscious energy sharing and examines how to put it into practice through real-life pilot examples. Our question to you as audience is, ‘how can we speed up the adoption of this new model in the Netherlands and EU’?

Beyond the EMS: Emerging Cross-European Lessons on What It Takes to Build a Smart Energy Hub

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Business parks are increasingly confronted with grid congestion, growing electrification needs and the challenge of integrating locally generated renewable energy. Energy Management Systems (EMS) can provide the technical core for coordinating generation, consumption, storage and flexibility at local level. However, the emerging experience of the Interreg North-West Europe project GEMS - Green Energy Management Systems for Business Parks - shows that successful implementation depends on the ecosystem around that technical core. GEMS works with six pilot cases across five European countries, covering different energy systems, organisational structures and regional contexts. This provides a unique opportunity to compare what enables or constrains the development of smart energy hubs in practice. Rather than focusing primarily on whether the technology works, this contribution asks: what does it actually take to move from a technically promising concept to an operational and replicable smart energy hub? The session presents emerging cross-case lessons from the six GEMS pilots using a PEST framework covering political, economic, social and technological dimensions. The analysis draws on pilot implementation experience, structured exchanges between project partners and comparative reflection across the different national and regional contexts.

The central emerging lesson from GEMS is that a smart energy hub cannot be replicated simply by copying an EMS solution. The EMS may be the technical core, but successful implementation depends on the capacity to align policy, business models, stakeholder organisation, data and legal arrangements around a specific local energy system. By comparing six distinct European implementation contexts, the session provides practical insights for business parks, regional intermediaries and policymakers seeking to move from isolated pilots towards wider deployment of smart energy hubs.

Session 10:

Optimising for robust local resilience on a congested grid

Chair: Roland van Rijswijk-Deij

Leveraging Open Data in the Design and Validation of Energy Management Systems for Energy Hubs

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As is the case for many locations in the Netherlands, grid congestion is a big challenge for future developments in the Twentekanaal business park in Hengelo. To reduce the impact of this grid congestion, a battery energy storage system (BESS) was considered for the site. This required an investigation into the optimal placement of the BESS in the existing power grid and into a potential energy management strategy to operate the system. Two challenges that are deeply intertwined and require knowledge on existing and future grid infrastructure, consumers and distributed generators. A proper design of an energy management system (EMS) relies heavily on the availability of data. Data on physical assets in the grid and data on the utilization of those assets. To manage this complex system with many different stakeholders, a design workflow was developed based on (semi) open data platforms to fill the many gaps that exist in the data on energy consumption and generation.

The key design choice in this workflow is to access and utilize unique identifier codes for buildings and businesses and to match them with example load profiles provided in open datasets from DSO's. The parameters that change between projects or potential future scenarios remain as inputs to the algorithm. For example, the size of a company in the considered site is required to scale the open load profiles. On the generation side, the presence and approximate size of existing rooftop PV systems can be identified from satellite data. The generation profile of these systems can be modelled using historical irradiation profiles from the PVGIS dataset. One remaining challenge is to tie the generation and consumption profiles together geographically. This requires data on the cables and transformers in the local electricity grid, but the availability of this data depends heavily on the policies of DSO's. While estimates can be made when aggregating different connections in the grid, the results will be more valuable when the data is available.

The presented approach provides an example on how open data sources can be leveraged to fill gaps and gain a better understanding of the potential value of flexibility in an early stage. Allowing for fast and repeatable generation of initial case studies and enabling a more effective analysis on energy management strategies and asset acquisitions, as envisioned by GEMS – short for Green Energy Management Systems in business parks – an European project helping industrial hubs adopt smart, scalable energy solutions.

BESS-Supported Industrial Electrification for Resilient Operation Under Grid Congestion: A Spray-Drying Case Study

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Grid congestion has emerged as a major barrier to industrial electrification. While electrification can significantly reduce greenhouse gas emissions, it often increases peak electricity demand beyond the available grid capacity. This creates a need for flexible solutions that enable industrial facilities to decarbonize while maintaining reliable operation under constrained network conditions. This study investigates how battery energy storage system (BESS) can enhance local resilience and reduce dependence on grid reinforcement in the electrification of an industrial spray-drying process in the Netherlands.

The study evaluates a fully electrified process configuration combining heat recovery, mechanical vapour recompression (MVR), a transcritical CO_2 heat pump, and an electric boiler for start-up steam production. Instead of upgrading the existing 4 MW grid connection to a 10 MW firm connection, the proposed solution integrates a BESS operating with 4 MW firm and 5 MW non-firm grid access. Battery dispatch is optimized using a deterministic linear-programming model that minimizes electricity costs while supporting congestion management and maintaining operational reliability. Simulations were performed using a 308-day industrial dataset with a 10-minute resolution.

Results show that full electrification eliminates direct CO_2 emissions, reducing emissions from 5,494 tonnes to zero while supplying 33,283 MWh of process heat and 6,124 MWh of steam annually. The optimized 1.56 MW / 5.45 MWh BESS limits peak grid imports to 5 MW despite the electrified process requiring substantially higher electrical demand than the existing operation. The system exhibits only 0.0615 MWh of congestion-violation energy over the entire simulation period, demonstrating robust operation under constrained grid conditions. Compared with a conventional 10 MW grid-expansion pathway, the BESS-supported solution reduces total annual costs while maintaining full decarbonization. The resulting total annual cost is only 1.69% above the current factory operation, compared with 5.88% for the grid-expansion alternative.

The findings demonstrate that flexibility technologies can improve local energy resilience by enabling industrial electrification without requiring extensive grid reinforcement. Battery-supported operation provides a cost-effective pathway to full decarbonization while reducing dependency on scarce grid capacity. The study contributes practical insights for industries, grid operators, and policymakers seeking resilient strategies to accelerate industrial electrification in congested electricity networks.

The Missing Layer: A Neutral Custodian for Secure and Fair Local Grid Steering in Community Energy Hubs

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Electricity demand is becoming electronic and fast: heat pumps, EV chargers and home batteries now react within seconds to prices. The difficulty is not that these devices are smart, but that they all follow the same national signals — the day-ahead price, and from 2029 a nationwide time-dependent grid tariff. This erodes the natural diversity of load on which the low-voltage grid was designed, producing synchronised peaks precisely where capacity is scarcest, while actual local grid conditions remain largely unmeasured. In short, we increasingly steer local networks without local insight.

No party is currently responsible for translating national signals into locally safe coordination. Grid operators can measure and physically control, but must not become market makers, creating a role conflict and competition risk; markets have local blind spots and let flexibility value drain away from the communities that produce it. This work defines and designs a neutral coordination, registry and settlement layer — a "custodian" — positioned between grid operators and energy communities.

The approach is an institutional and architectural design grounded in existing Dutch practice: real-time measurement already emerging in industrial energy hubs, forthcoming open-data forecasting for the low-voltage grid, the 2029 tariff reform, and contractual grid access under Article 15a of the EU Electricity Market Directive. A strict separation of roles is central: the custodian occupies only the coordination, allocation and settlement layer, while physical safety, emergency islanding and the last line of defence remain with the grid operator and local control. Into this design two security principles are integrated: horizontal decoupling — disconnectable "holons" or circles that can island so that a single fault or cyberattack does not cascade nationwide (a recoverable brown-out rather than an irreversible black-out) — and vertical decoupling — separating operational (OT) from administrative (IT) layers with store-and-forward logging, so that kilowatt-hours keep flowing during a cyber incident and are reconciled afterwards.

The design shows that one instrument can address four questions at once: the physical (relieving low-voltage congestion), the institutional (preserving role purity), the distributional (keeping flexibility value local and reinforcing local ownership), and the security question (resilience to attack, framed on Borsboom's argument that the energy transition is a power shift and therefore never safe, and Middendorp's account of vital infrastructure as a strategic target). The custodian makes vertical decoupling an engineered process rather than an empty "settle later" promise, and gives horizontal decoupling its governance: which rights apply in which circle, who may island, and how reconnection is settled.

The contribution is a policy-ready "third way" between internalising coordination inside the grid operator and leaving it to the market — the only route that answers the physical, institutional, distributional and security questions together. The neutral coordination role is today assigned to no one; it must be named, mandated, and embedded in the tariff code change and in the ongoing standardisation of energy communities before regional pricing becomes reality.

Identifying Robust Flexibility Investment Decisions for Grid Congestion

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Electrification and renewable generation are straining the Dutch electricity system: demand for transport capacity already exceeds what network expansion can accommodate, causing congestion. Expanding the grid towards 2050 without the use of flexibility would be extremely costly, spatially infeasible, and impossible given the pace at which network expansion can be realised. Flexibility technologies such as batteries and hydrogen systems are therefore an essential part of network planning. Deciding where and how much to invest in these technologies can be done through energy system optimisation, which creates a single cost-optimal solution. However, this solution is just one of many possible solutions of near-identical cost, some of which may better reflect real-world considerations that total system cost minimisation alone does not capture. This is a form of uncertainty that a single optimal solution does not reveal.

For Stedin, a Dutch distribution system operator, we have developed a methodology to address this uncertainty and identify robust flexibility investment decisions for grid congestion. Its novel aspect is combining Modelling to Generate Alternatives (MGA), which generates many near-optimal system configurations rather than relying on a single optimum, with statistical testing. This combination shows not only whether a planning decision is robust across these configurations, but also why. It links that robustness statistically to specific properties of the underlying network, such as its structure or demand pressure. The aim is to make these findings transferable beyond the specific substations studied. This means similar investment decisions elsewhere in the network do not require the full analysis to be repeated. We have applied this methodology to Stedin's high- and medium-voltage grid, where flexibility technologies and network expansion are optimised simultaneously. This has generated 113 near-optimal configurations that we have used to identify robust investments: those justified across nearly all of them, and those only made in some. The results have shown that the location of flexibility investment is generally more robust than the choice of technology deployed there, and that flexibility and grid expansion typically substitute for each other at the substation level. The same robustness-testing logic is expected to be relevant to other flexibility investment decisions relevant to Smart Energy Hubs, such as assessing multi-carrier energy hub integration for greenhouses, a question being explored within the SPROUT project.

Session 11:

Municipal district heating integration for energy hubs

Chair: Hinnerk Willenbrink

F|Heat.connect – Scalable and Modular Approaches for Digital Heat Network Planning Using Geospatial Optimization

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Background and Context: The transition toward climate-neutral energy systems requires efficient and scalable planning approaches for district heating networks, particularly in regions where fossil-based heat supply remains dominant. However, the technical complexity and extensive data requirements involved in network planning make these projects costly and time-consuming. As a result, municipalities are often reluctant to engage in district heating planning during early project stages.

Gap and Objective: Existing tools primarily support detailed engineering design, while accessible solutions for early-stage, data-driven configuration and evaluation of district heating networks remain limited. The objective of this work is to develop a modular framework for geospatially informed pre-planning and optimization of district heating network layouts.

Methodology: Building on the open-source platform F|Heat, the project F|Heat.connect extends functionality within a Python-based QGIS environment. The framework integrates heterogeneous geospatial datasets with domain-specific engineering knowledge to support early-stage system design.

A scalable network generation method is implemented to derive district heating topologies from spatial demand and infrastructure data. The architecture is modular, separating data processing, network generation, and techno-economic evaluation to ensure adaptability across different regional contexts.

Network routing is formulated as a geospatial cost minimization problem, where pipeline paths are computed based on construction costs derived from surface characteristics, infrastructure constraints, OpenStreetMap data, and remote sensing inputs.

Results: The framework produces geospatial outputs in QGIS-compatible GPKG format and structured numerical data exportable to Excel. These outputs include network topology, system sizing, cost estimates, heat demand distribution, load profiles, and renewable heat supply potentials such as solar thermal and geothermal sources.

Discussion / Implications: The use of cost-informed geospatial routing enables a more spatially constrained representation of infrastructure development than purely distance-based approaches, particularly in heterogeneous urban and rural environments.

Conclusion and Contribution: F|Heat.connect provides a workflow for rapid generation and evaluation of district heating network configurations based on open geodata and optimization methods. The main contribution lies in enabling early-stage comparative analysis of alternative system layouts within a unified spatial framework.

District heating to shift seasonal energy consumption and reduce the strain on the electricity grid

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The energy transition is accelerating the electrification of multiple sectors, e.g. heating sector, mobility and industry. While this supports decarbonization, it also increases the stress on the electricity grid, contributing to congestion, while simultaneously the integration of renewable energy sources gets hindered by the imbalance between production and demand, hourly and seasonally. District heating systems can play a role in alleviating these challenges by enabling energy system integration between heat and electricity, facilitating the use of alternative renewable heat sources and reducing the peak electricity demand.

The MOOI Joule4Joule (J4J) project develops methodologies to support the design and operation of district heating systems as part of local energy hubs in the built environment to alleviate the pressure from the electricity grid. A key gap in current practice is that system design, operation and infrastructure investment decisions are typically evaluated separately between the commodities. This limits the ability to asses the impact of flexibility options of sector coupling.

In J4J a workflow is developed based on the techno-economic optimization framework of MESIDO, an open source codebase to optimize district heating networks in the draft design phase, that integrates evaluation of investment decisions (CAPEX) and operational strategies (OPEX). The framework is updated to represent the interactions between electricity and heat systems, including (de)centralized assets like heat pumps and heat and electricity storages, allowing for analysis of how district heating networks can shift or reduce electricity demand peaks. It supports the assessment of local energy utilization strategies.

The methodology is applied to real-world case studies, including neighbourhood developments where detailed configurations and operational strategies are explored. Initial results indicate that integrating thermal storage and flexible operation of heat pumps can significantly reduce peak electricity demand by shifting loads over time, while increasing the utilization of local heat and electricity sources and reducing the utilization of peak producers.

The findings demonstrate that integrated modelling of district heating and electricity systems is essential to quantify the role of heat networks in mitigating grid congestion by capturing the interactions between assets and energy carriers. The approach enables stakeholders to make informed decisions on infrastructure investments that account for both local energy system performance and the constraints of the electricity grid.

In conclusion, the approach provides a structured method to evaluate how district heating contributes to a more flexible and resilient energy system. It supports the design of smart energy hubs that reduce pressure on the electricity grid while facilitating the integration of renewables, thereby contributing to a cost-effective and robust energy transition.

Stakeholder Mapping and Financial Modelling for District Heating Expansion and Integration in Urban Energy Hubs: Findings from the RODEO Project

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Smart energy hubs are becoming central to the urban energy transition, enabling integrated management of electricity, heating, cooling and energy storage. Within these hubs, District Heating and Cooling (DHC) is increasingly recognised as an important component for decarbonising city areas. Yet many DHC networks in North-West Europe remain in early development stage and face barriers that are now primarily financial, organisational and regulatory rather than technical.

The RODEO project (Rolling Out District Heating and Cooling Extensively to Home Owners) investigates how four pilot cities - Assen (the Netherlands), Dunkerque (France), Dublin (Ireland), and Oostende (Belgium) - can strengthen their capacity to roll out DHC networks. Each city is in a different stage of development, while all still rely predominantly on natural gas for heating. Through an iterative process of pilot engagement, workshops, literature review, and expert validation, the project identifies a shared set of constraints shaping DHC deployment: trust in public institutions, coordination among diverse stakeholders, investment risks and affordability for end users.

To address these challenges, the project developed two complementary instruments. A comprehensive stakeholder map outlines the strategic landscape and interdependencies that influence project success. In parallel, a review of 41 existing modelling tools revealed a critical absence of user-friendly DH financially robust tools, motivating the development of a tailored financial modelling architecture. This architecture enables transparent assessment of investment needs, tariff structures and long-term viability, providing municipalities with a practical decision-support tool.

Together, these insights and tools support the accelerated integration of DHC within emerging smart energy hubs across North-West Europe, enabling cities to progress from technical feasibility to financially viable, socially accepted and strategically coordinated heating transitions.

MOOI ABLE: a methodology for exploring heat grids as part of business parks energy hubs

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Business parks offer significant opportunities for collective heat exchange and low-temperature district heating networks. However, the development of such networks often stalls during the initial exploration phase due to the lack of company-specific energy data, the cost of feasibility studies, and uncertainty about what the greatest opportunities are. Consequently, many potentially viable projects never progress beyond the first assessment.

Within the MOOI ABLE project, TNO, Saxion and consortium partners are developing a digital methodology to support the exploration of industrial area heat grids through the Potential scan.

Potential scan combines thermal demand, waste heat availability, spatial information, and optional local data to identify for industrial parks where collective heat exchange is technically promising. The methodology provides municipalities, park managers, engineering consultants, and companies with an accessible starting point for stakeholder engagement and helps prioritize locations for more detailed technical and economic assessments. The Potential Scan uses standardized electricity demand, gas consumption, heating demand, cooling demand, and recoverable waste heat at company level using publicly available business classifications (SBI codes) combined with validated datasets. Rather than relying on confidential company information, the tool generates normalized temporal demand and supply profiles, including relevant temperature levels for heat exchange.

The presentation will introduce the methodology and demonstrate its application using a business park pilot within the MOOI ABLE project. It will discuss the workflow, the role of standardized datasets in reducing uncertainty during the early planning phase, and the opportunities and limitations of data-driven screening for business parks heat grids.

Session 12:

Setting up Regional Ecosystems FOR Multiple-Energy Resilient Systems: Lessons Learned

Chair: Armin Zegwaard

Setting up Regional Ecosystems FOR Multiple-Energy Resilient Systems: Lessons Learned

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Europe's energy transition faces major challenges, including grid congestion, renewable energy integration, and the decarbonisation of industry and the built environment. Conventional energy systems treat electricity, heat, and gas separately, limiting flexibility and reducing opportunities for system-wide optimisation. Addressing these challenges requires integrated, decentralised energy systems that connect multiple energy carriers, technologies, and stakeholders.

The Horizon Europe project REFORMERS (Regional Ecosystems FOR Multiple-Energy Resilient Systems) addresses this need through the development of Renewable Energy Valleys (REVs): regional energy ecosystems that integrate electricity, heat, green gas, and hydrogen within a single multi-commodity energy system. By linking generation, storage, conversion, and consumption, REVs enhance flexibility, improve resource utilisation, and strengthen regional energy resilience.

REFORMERS is a five-year, €20 million project involving 28 partners from 10 European countries. Its flagship Renewable Energy Valley is being developed in the Boekelermeer industrial area in North Holland, the Netherlands. The project combines innovative technologies, including Carbon Capture, Utilisation and Storage (CCUS), hydrogen technologies, advanced energy management solutions, and new governance models. A key feature is its regional approach and strong collaboration among industry, government, knowledge institutions, distribution system operator, and local communities, ensuring that technological innovation is accompanied by organisational and societal innovation.

Following two years of preparation and system design, the project entered its implementation phase. Key technologies are now being deployed, while stakeholder collaboration structures are being formalised. In addition to demonstrating innovative technologies, REFORMERS is generating practical insights into the development of integrated multi-energy systems. Emerging results include lessons learned from innovation deployed across the project, the development of a station Energy Management System to optimise energy flows and flexibility in the valley, and a holistic methodology for planning and implementing Renewable Energy Valleys. Alongside the innovations being demonstrated, REFORMERS is developing a digital twin, stakeholder engagement approaches, impact assessment frameworks, and policy recommendations to support the replication of the Renewable Energy Valley model across six Replication Valleys in Europe.

The session will share early implementation experiences, technical and organisational challenges, and emerging results on technology integration, Station Energy Management System development, and a holistic methodology for the design and implementation of Renewable Energy Valleys. By demonstrating the technical and organisational feasibility of integrated multi-commodity energy systems, REFORMERS contributes directly to REPowerEU objectives and provides a scalable model for regions seeking to accelerate the transition towards climate neutrality.

Session 13:

DSO/TSO developments on congestion control and resilient smart energy hub integration

Chair: Bart van der Laan

Creating an energy hub by integrating flexibility into an existing solar park: A Dutch techno-economic case study

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Integrating renewables and electrified loads such as EV chargers has led to electricity grid congestion in countries such as the Netherlands. Operators are upgrading these grids to provide more energy flexibility, and for many companies requiring new or larger grid connections further integration of renewables and loads is delayed until these upgrades are complete. However, more flexibility can be provided without upgrading the grid. Concurrently, operators of renewables such as solar parks see their business models shifting due to the increase of negative-price periods over the last few years. There is an opportunity for these operators to increase the amount of flexibility they provide by creating an energy hub through the integration of new (control) systems. However, the effects of creating an energy hub are case-specific and often unknown.

This paper investigates the techno-economic effects of integrating different flexibility options (including energy storage) into an existing microgrid in order to create an all-electric energy hub. The goal is to show operators the effects so they can make informed investment decisions in the future. To achieve this goal, we conduct a simulation study of the solar park Noordmanshoek, the Netherlands. We simulate microgrid behaviour using a Python-based energy flow model with integrated Gurobi optimiser and rolling horizon strategy, which maximises EPEX SPOT income while considering the cost of storage degradation for a calendar year. In this study, we investigate control strategies with no storage degradation, with optimistic degradation (i.e., high lifetime and low storage CapEx) and with conservative degradation (i.e., low lifetime and high CapEx). Per control strategy, we examine four scenarios which do or do not allow energy import from the connected grid and curtailment.

Preliminary results show that even when controlling towards a financial objective, selecting storage sizes between 0.5 and 1 MWh (no degradation strategy), 1.25 and 1.75 MWh (optimistic degradation strategy) and 1.25 and 2.5 MWh (conservative degradation strategy) leads to the highest connected grid peak reductions per scenario. The largest peak reductions (between 16.1 and 19.7%) occur when allowing curtailment and cycling the storage optimistically. Also, allowing import lowers peak reductions, and if storage is allowed to import, storage sizes between 4.5 and 5.5 MWh lead to between 1.2% and 18.2% peak increases. Finally, using the optimistic degradation strategy while also allowing curtailment and import creates the largest profits, and increasing storage size does not lead to higher profitability. Also, certain situations lead to a reduced income, due to the storage cycling even when the marginal cost is low (no degradation strategy) or there not being enough moments where market profits are higher than degradation costs (conservative degradation strategy).

We conclude that a microgrid which allows curtailment and has a storage size between 1.25 and 1.75 MWh, cycled optimistically, is profitable, while connected grid peaks are also reduced. Furthermore, we conclude that allowing import from the connected grid does not increase profitability or lower peaks, and should be avoided. Generally, we conclude that operating storage can be both profitable and aid in reducing grid congestion.

Collective Energy Management for Grid-Congested Business Parks: Implementing C-EMS under a Group Transport Agreement

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Grid congestion has become a structural barrier to economic and sustainable development in the Netherlands. The accelerating electrification of industry, mobility, and the built environment is outpacing the reinforcement capacity of network operators, leaving large parts of the high and medium-voltage grids saturated and inaccessible for new or larger grid connections. Many of the congested areas are not expected to see additional transport capacity until 2033–2036 or later.

A multitude of approaches are possible to tackle the problem of congestion, of which the Group Transport Agreement (Groeptransportovereenkomst, GTO) is one. The GTO provides a regulatory mechanism enabling multiple connected parties with a large grid connection (grootverbruikaansluiting) to share a single contracted group transport capacity (GGTV). However, a GTO transfers compliance responsibility for the GGTV from the network operator to a collective of participants. To ensure the boundaries of GTO are respected, a Collective Energy Management System (C-EMS) is necessary to monitor the energy usages and production over multiple grid connections and automatically control flexible assets. While the GTO is a promising solution, there is a significant gap in practical, case-based knowledge on the implementation and challenges that manifest in real-world business park deployments and how they can be effectively resolved.

Repowered has implemented a C-EMS on 2 business parks, namely Smart Energy Hub ECHT Zeewolde and the Energy Hub EC Boekelermeer. The energy usage and production of 3 GTO's is monitored, and flexible assets are steered automatically to ensure the boundaries of the GTO's are not exceeded. We would like to share our experience in setting up these C-EMS and discuss challenges that we still face in relieving congestion on the grid with a GTO.

Beyond grid access: the financial and qualitative impact of a group transport agreement and the value drivers that shape it

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In the Netherlands, a Group Transport Agreement (GTO) is typically adopted as a response to grid congestion rather than as an investment decision. Municipalities, business parks and area developers use the instrument to secure access to network capacity needed for electrification and growth. As a result, the financial implications of a GTO are rarely assessed explicitly. Network tariffs with and without a GTO are seldom compared, while battery storage is often treated solely as a connection-related expense rather than as a potential revenue-generating asset.

This perspective is becoming increasingly relevant. From 1 January 2027, Dutch grid operators will be required to offer a GTO, while network tariffs are expected to rise substantially. Therefore, we investigated whether a GTO generates a business case and identified the key factors that determine its value. We developed an hourly techno-economic model based on metered load profiles and published network tariffs and applied it to an anonymised mixed-use energy hub. The model distinguishes between contracted capacity and measured peak demand, the two tariff components affected by a GTO, and explicitly simulates operational decisions. In each hour, battery storage is dispatched before flexible demand is curtailed. Four configurations are evaluated: a reference case without a hub, a GTO without operational intervention, active demand curtailment, and a GTO combined with battery storage.

The results reveal three key insights. First, a GTO can deliver financial benefits even without operational changes. A large share of the savings originates from the non-coincidence of participating users' peak demands. Additional savings can be achieved by reducing contracted capacity, although this requires curtailment of flexible demand.

Second, the impact of curtailment is often underestimated. While the curtailed energy volume may appear negligible on an annual basis, the practical consequences can be significant. Electric vehicles of a company that cannot charge on site are typically charged elsewhere at higher electricity prices, while publicly accessible charging infrastructure may lose charging revenue. Metrics such as the longest uninterrupted charging outage or the costs shifted to users therefore provide a more meaningful assessment than curtailed energy alone.

Third, battery storage should not be considered solely as a cost. Flexibility market revenues substantially affect both project economics and optimal battery sizing. The most valuable battery is not necessarily the one that maximises peak shaving, but the one that balances peak reduction with market participation. Because flexibility revenues vary throughout the year, this trade-off should be assessed monthly rather than through a single annual utilisation factor. The analysis further shows that beyond a certain level of flexibility revenue, maintaining additional contracted capacity can create more value than minimising it, which is counter to the original policy objective of the GTO.

The main contribution of this model is to reframe the GTO as both an access instrument and a tariff optimisation decision with its own economic return. The presented methodology identifies the drivers of this value and highlights the trade-offs that determine whether an energy hub is economically attractive.

From Grid-Constrained Area Development to Smart Energy Hubs
An Integrated Area-Based Decision-Making Methodology for Energy System Planning

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Across the Netherlands and many European regions, grid congestion has become a major barrier to economic development, industrial decarbonization, housing construction and energy transition ambitions. Area development projects are increasingly delayed because electricity infrastructure can no longer accommodate expected demand growth. At the same time, flexibility options, local generation, storage, heat networks, hydrogen applications and innovative contractual arrangements are often assessed separately by individual stakeholders. This paper presents an integrated area-based methodology that supports Smart Energy Hub development by combining spatial planning, customer demand, grid information, flexibility options, energy carriers and stakeholder objectives into a single decision-making framework.

The methodology consists of four modules. First, Area Scoping and Shared Fact Base establishes a common understanding of the area, stakeholders, development plans and network constraints. Second, an Integrated Energy Area Model combines electricity demand, renewable generation, heating needs, storage opportunities, hydrogen options, smart charging infrastructure and expected grid developments. Third, Scenario Analysis and Optimization compares collective and individual solutions, including flexibility contracts, group transport agreements, batteries, thermal solutions, hydrogen and conventional grid reinforcement. Finally, Decision-Making and Stakeholder Alignment translates technical outcomes into decision-ready information for municipalities, developers, businesses and network operators.

Initial experiences from business parks, industrial clusters and port environments such as the Amsterdam Port region indicate that technology alone is insufficient. Successful Smart Energy Hub development depends on governance structures, data availability, stakeholder alignment and clear decision-making processes. Pilot projects demonstrate that collective approaches can often unlock considerably more capacity and development potential than isolated investments by individual participants. Future research will focus on validating the methodology through additional pilot projects, integrating AI-supported optimization techniques and exploring digital twin applications for area-level energy system planning.

SMART ENERGY HUBS CONFERENCE



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