CINELDI

Centre for intelligent electricity distribution

# Annual report 2021

As we move to an increasingly electrified society, we need to generate more electric power and develop a stable and vast electric grid. Sustainability targets cannot be met unless the distribution system undergoes this necessary transformation.

CINELDI's main objective is to develop new concepts, technologies and solutions that will enable the cost-effective realisation of a future, flexible and robust electricity distribution system. In addition, these innovations will contribute to a more sustainable energy system by increasing the use of renewable energy sources and facilitating a more efficient power and energy use.

Following the roll-out of the Advance Meter Infrastructure in 2019, CINELDI began researching new, optimal technologies in the fields of electric power and ICT, with the goal of achieving a sustainable distribution system. Research activities place a particular emphasis on new and emerging topics like microgrids and utilising load/generation flexibility as well as cyber security. CINELDI's research comprises the fields of power engineering, cybernetics, information technology and communication technology. It also incorporates social sciences in order to understand the real-life applications of these technologies.

The R&D results will be integrated into stakeholder guidelines and recommendations for a holistic transition to a smarter and more flexible distribution system in Norway. Our innovations aim to considerably reduce total distribution system costs, and leverage business opportunities for technology providers, in both national and international markets. In addition, CINELDI focuses on increasing our research partners' knowledge, strengthening education, and establishing international collaboration within our fields of research.

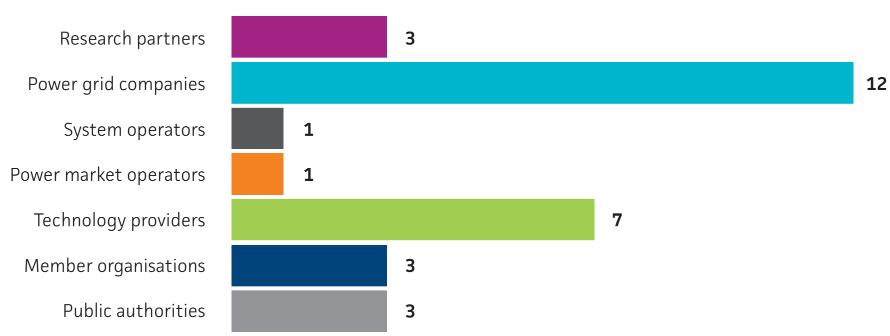
# Contents

# By numbers

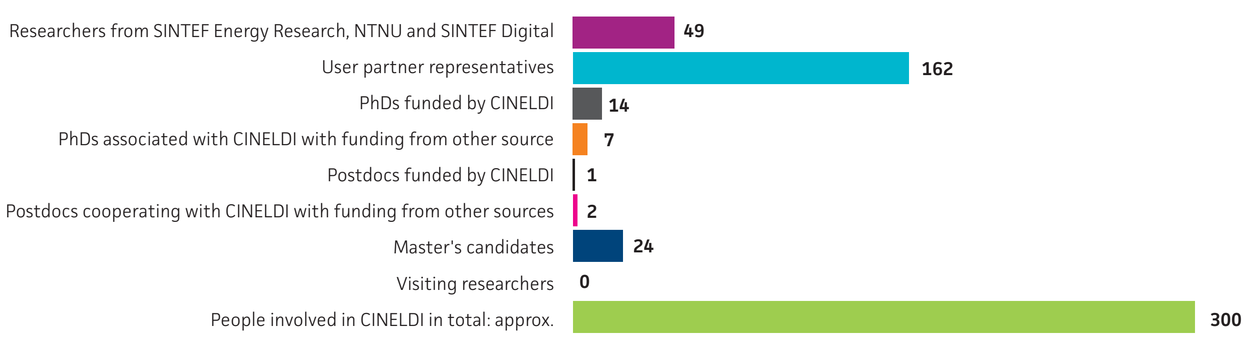
**30**
partners

**369**
MNOK

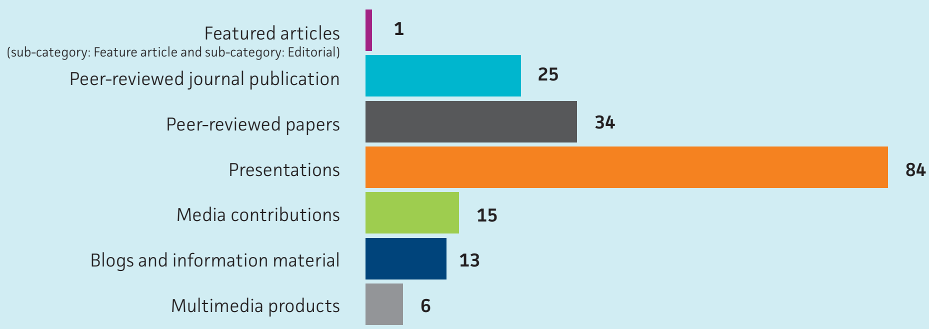
## Partners




## People 2021



## Communication and dissemination 2021

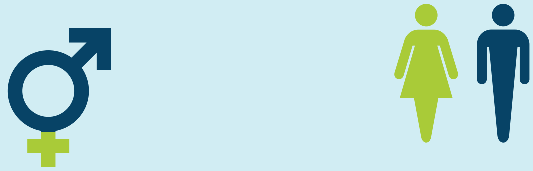



## Gender balance

Executive board:
73% men, 27% women

PhD/Postdoc:
63% men, 37% women

Master's students:
57% men, 43% women



Researchers:
75% men, 25% women

Centre management:
50% men, 50% women

# How long can we live without electricity?

**With soaring energy prices in Europe, electricity was a hotly debated topic by the end of 2021. But what if there was no guarantee that electricity was available at all? Could security of supply – knowing that your electrical outlets will be powered – be even more important than the price?**

Norway's continuity of supply is measured at over 99.98%. This is an impressive figure, considering the power system's scope and complexity. However, even though this is a good result, losing power for even a few minutes can have dire consequences. For example, institutions that provide essential services, such as hospitals, rely so much on security of supply that they have emergency generators to be used in the event of an outage. Power outages can also result in prolonged interruptions in factories, as the production line must be restarted completely. These are only a few examples demonstrating why the development of smart grids is becoming more and more important.

The transition to a low-emission society will also involve a more pluralistic energy mix, including the increased utilisation of both wind and solar power. In addition, more end users will become *prosumers*, which means that they produce some of their own power from, for example, solar panels. However, producing enough electricity at the correct voltage can be a challenge for prosumers. For example, Norwegians cannot rely solely on solar panels to meet their power needs in the winter. Therefore, most end users will still need to supplement their self-produced electricity with a secure supply from the national grid, to ensure that they always have power.

## Heavy grid loads for short periods

According to NVE, Norway is the only Nordic country to have increased its electricity consumption in the last few years. While the lion's share of that increase is from industry, Norwegian households and a general economic growth have played a significant role in this development. The increased consumption has given grid companies few challenges in the short term, since grid systems are built to have a good capacity. However, while the total capacity is sufficient, the current grid still faces local challenges. Electricity consumption has increased unexpectedly in some areas, putting a larger strain on the grid. This strain will increase as society continues to electrify.

While Norwegian households have not significantly increased their electrical consumption over the last few years, power peaks have increased. This means that there are periods throughout the day where we use a lot more electricity, which puts a higher strain on the grid. Dimensioning the grid to be able to meet these peak loads is both technologically challenging and expensive. Therefore, instead of engineering a new expensive grid to cover the capacity needs in the few hours of the year where it could be overloaded, grid companies hope for consumers to collaborate with them on a smarter use of the grid.

## New challenges in an electrified society

Electrification is a key part of the efforts to decarbonise society and mitigate global warming. However, the climate changes that have already happened are posing challenges to our power system. Stresses from the weather or other external events, such as trees falling on power lines, are the biggest causes of faults and power outages. As more extreme

weather events continue to happen, we risk more and longer power outages.

The second challenge to the security of supply is the digitalisation of the power system. Digitalisation involves the fusion of power grids and computer infrastructure to make a *cyber-physical system*. These systems make cybersecurity crucial for the electric grid because a cyberattack could shut down the power supply. Stopping or recovering from a cyberattack require completely different skill sets than clearing and repairing a power line. Therefore, we need secure and alternative solutions to maintain the security of supply.

There is a positive public consensus on the topic of the electrification of society, which involves new and increased electricity consumption and more electricity production from renewable sources. However, there is potentially an insufficient understanding of the consequences of these changes for the power system and security of supply. These challenges also present possibilities: by using new technology and adopting more flexible solutions, we can continue to maintain a high security of supply in the future.

## What's to come in CINELDI?

In 2021, CINELDI passed our midterm evaluation by the Research Council of Norway. As a part of this process, an international panel held digital evaluation meetings and wrote a report on the centre's accomplishments so far.

A midterm evaluation is a very useful and timely tool for evaluating our own strategies, research plans and achievements. After receiving the report, we prioritized talking to all our partners, both separately and in different groupings, to ensure that we are on the right track before starting the last centre period 2022-2024.

For this reason, we will implement a new structure of work packages from 2022 and onwards, while continuing our work on all the same research topics.

This annual report that you are reading is all about the research and dissemination carried out by CINELDI in 2021. This year, our three first PhD students defended their thesis, which was a big milestone for the research centre.

We would like to thank all our partners for their contributions to our many exciting results and innovations, as well as to the strategic discussions on the centre's research plans for the CINELDI's final three years.

*Gerd Kjølle & Sigurd Kvistad*

## Gerd Kjølle

Dr. Gerd H. Kjølle is the CINELDI Centre Director and Chief Scientist at SINTEF Energy Research.

She holds a PhD in Electric Power Engineering from NTNU and has more than 30 years of R&D experience from the electric power sector. Her main fields of expertise are power system reliability and security of electricity supply.

Her work has resulted in solutions for grid operators and energy regulators, foundations for handbooks, decision support tools, guidelines of good practice, as well as standards and regulations of grid companies. She has also contributed to educating and recruiting numerous candidates to the electric power sector.

## Sigurd Kvistad

Sigurd Kvistad is the CINELDI Chairman of the Board, and head of the Operational Control department at Elvia. Kvistad is also the Chairman of the board in the Norwegian Smart Grid Centre.

Through more than 30 years in the electricity grid sector, he has been responsible for contractor operations, development projects, grid planning and grid operation.

As the project owner of several ongoing projects at Elvia, Kvistad has taken part in many R&D projects within Smart Grids throughout his career. Kvistad also takes part in different fora in the electricity grid sector related to the future grid as well as regulation of the grid companies.

# Vision, mission and goals

### VISION

CINELDI develops the electricity grid of the future.

### MISSION

CINELDI works towards digitalising and modernising the electricity distribution grid to ensure higher efficiency, flexibility, and resilience.

### GOAL

CINELDI enables and facilitates a cost-efficient realisation of the future flexible and robust electricity distribution grid.

**Robust grid:** a grid that safeguards the security of electricity supply (energy availability, power capacity, reliability of supply and voltage quality) as well as safety, privacy and cyber security.

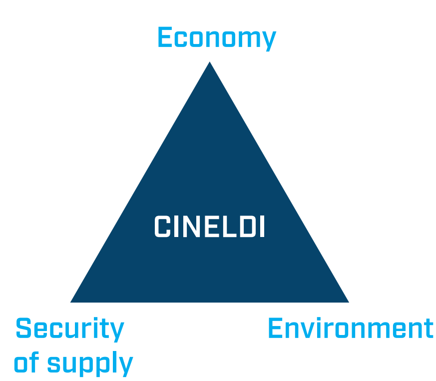
## Realising the mission

By acting as a national hub for long-term research and innovation within the field of intelligent electricity distribution, we bring together innovative stake-holders with the common task of developing and implementing new technologies, work processes and solutions. The end goal is to develop the electricity grid of the future.

In CINELDI, we are equipped to tackle this challenge with our unique combination of academic resources, computer modelling, and simulation facilities. Through the National Smart Grid Laboratory infrastructure, as well as pilots and demos, we integrate involvement from industry partners, using the physical grid owned by the distribution system operators (DSOs) and transmission system operators (TSOs) as living labs.

## Reaching the goals: The energy trilemma

One of the main reasons for transforming today's ageing and passive electricity grid into an active, flexible, robust and intelligent grid – a *smart grid* – is to lay the foundation for reaching national and international energy and climate goals.



However, *creating* the smart grid is not the main challenge. The main challenge is to do it in an affordable way, while showing consideration for the environment and ensuring a high security of supply. We call this the *energy trilemma*.

**Economy**

With our research and innovation, we shall enable a cost-efficient realisation of the future flexible and robust electricity distribution grid, while minimizing strain on society. This will in turn reduce the total distribution system costs compared to the "business as usual"- solutions, by reducing both operational (OPEX) and investment costs (CAPEX).

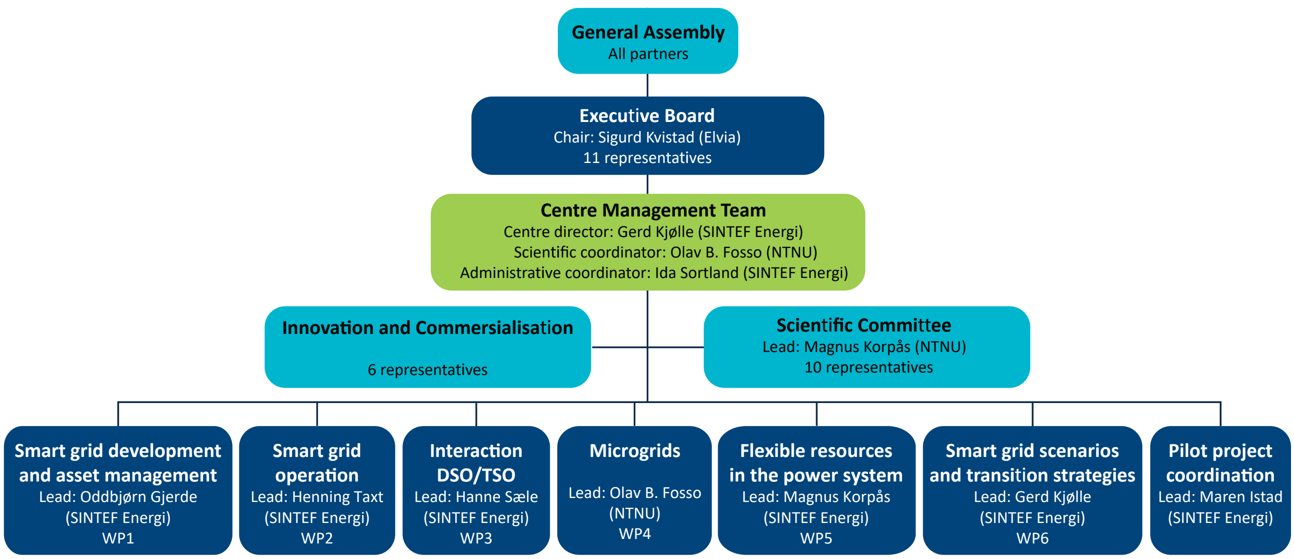
**Environment**

Our work paves the way for increased distributed generation from renewable energy sources, further electrification of transport, and a more efficient use of electric power and energy.

**Security of electricity supply**

We develop the knowledge and methods needed to ensure the security of electricity supply. We do this by focusing on energy availability, power capacity, reliability of supply and voltage quality – as well as cybersecurity, safety and privacy – as important aspects of developing the electricity grid of the future.

# Organisation




## Scientific Committee (SC)

The Scientific Committee (SC) is a platform for dialogue between CINELDI and key international partners. The SC discusses matters regarding the Centre's direction, lab activities, scientific ambition, and international relevance of research.

The SC meets twice a year: once in the spring and once in the autumn. The spring meeting focuses on ongoing research and collaboration, while the autumn meeting looks at the next year's work plan.

A SC meeting was planned as part of the CINELDI conference in the spring of 2021, but it was cancelled due to Covid-19. Instead, a digital meeting was arranged in both the spring and autumn.

The WP leaders and Centre Management participate in all SC meetings to ensure close contact between the researchers and international advisors.

**The purpose of the SC is to:**

- Provide advice on the research being carried out in CINELDI, as well as emerging research topics, and input to plans,
- Contribute to coordinate research and laboratory activities between participating institutions,
- Identify new areas of collaboration and contribute to organizing and coordinating international research proposals.

The SC was expanded in 2021 and has the following members

- Professor Magnus Korpås, the Norwegian University of Science and Technology (NTNU), Norway (Leader)
- Reader Ivana Kockar, University of Strathclyde, UK
- Associate professor Mattia Marinelli, the Technical University of Denmark (DTU), Denmark
- Professor Fabrizio Pilo, the University of Cagliari, Italy
- Director Angel Diaz, Tecnalia, Spain
- Professor Bruce Mork, Michigan Technological University, USA
- Research Professor Kari Mäki, VTT Technical Research Centre of Finland, Finland
- Professor Anne Remke, the University of Münster, Germany
- Professor Madeleine Gibescu, Utrecht University, The Netherlands
- Scientist Marialaura di Somma, ENEA, Italy

Several SC members are involved in international research related to CINELDI, such as participation in EERA JP Smart Grids, EU projects, researcher exchanges and PhD exchanges. Unfortunately, planned visits from SC members were still not possible in 2021 due to Covid-19.

## Partners

Building the smart, flexible, robust grid of tomorrow in a cost-effective way requires a huge effort from all aspects of the industry: from authorities setting the industry's framework conditions, to DSOs and TSOs operating the grid within that framework, and everyone in between. In CINELDI, we are proud to have active partners, putting in hard work and dedication towards our joint goals.

Having partners representing all areas of the industry gives us a strong platform to develop the future grid.

The twelve DSO partners in CINELDI cover about two thirds of the total Norwegian end users. The national knowledge building by this range of companies has the potential to significantly impact the power sector. Furthermore, if most of these partners utilise CINELDI results to establish a more cost-efficient and flexible grid, they can impact society at large.

However, to truly realise our vision, more areas than those covered by our research need to be developed, such as regulation of the DSOs and the TSOs. For this reason, it is crucial that the public authorities DSB, NVE and the Norwegian Communications Authority are partners in CINELDI.

## Research partners

SINTEF Energy Research

Norwegian University of Science and Technology (NTNU)

SINTEF Digital

## Power Grid Companies

Agder Energi Nett

BKK Nett

Elvia

Fagne AS

Linea

Elinett AS

Linja AS

Lnett AS

Arva AS

Norgesnett

Lede AS

Tensio TN AS

## System Operators

Statnett

## Power Market Operators

Nodes

## Technology Providers

ABB AS

Aidon

Disruptive Technologies

Embriq

Smartgrid Services Cluster

Prediktor

Heimdall Power AS

## Member Organizations

Energy Norway

KraftCERT

The Norwegian Smart Grid Centre

## Public Authorities

Directorate for Civil Protection and Emergency Planning (DSB)

The Norwegian Water Resources and Energy Directorate (NVE)

Norwegian Communications Authority

## Welcome to our new partner

We are thrilled to welcome a new partner to our Consortium in 2021: Heimdall Power AS.

Heimdall Power is a technology provider, developing both hardware and software to monitor power grid capacity, energy flows, rerouting and fault detection. The hardware they use is comprised of intelligent sensors called Power Neurons.

In 2022, Heimdall Power will lead a new CINELDI large-scale pilot project, wherein many neurons will be installed in CINELDI partners' grids. While previous pilot projects have verified that the technology works, this pilot will explore the *value* of grid monitoring at such a large scale.

## Cooperation between partners

One of the keys to success in CINELDI is partner cooperation and knowledge sharing. Thanks to our multidisciplinary research platform (which you can read more about on page 18), the R&D partners cooperate closely in all work packages (WPs).

The partners are tightly integrated in CINELDI's work process. For example, representatives from the whole centre are involved in idea generation, activity selection, planning and reviews. Partners are involved through discussion of new ideas at workshops, as well as dedicated expert groups within each WP. The WPs actively use the expert groups every year when they develop their work plans.

As part of the midterm evaluation, the centre management had separate meetings with all the partners over the course of 2021. These meetings were held to get feedback on the cooperation so far, plan for how individual partners could contribute going forward, and receive input on the strategy for 2022-2024.

Pilot projects also represent an area for cooperation between the different R&D partners and user partners. You can read more about our pilot projects in this report.

## Meeting points

In April, we replaced our annual CINELDI Conference with a one-day online meeting between the partners, due to the Covid-19 pandemic. It was a success, with 110 attendees. In addition to being a venue for presenting results from our pilot projects and research activities, we had fruitful discussions between partners and researchers during a session of presenting and getting feedback on our newest innovation: a checklist for evaluating results (see page 59). We also hosted several online meetings, workshops, and seminars throughout the year.

We find that the webinar is a great format for disseminating results to the partners in the CINELDI Consortium. As no travelling is involved, we can use this format to facilitate numerous meetings for presenting and discussing projects and results. In 2021, we held ten webinars for the Consortium, wherein we presented our latest research progress. Both CINELDI WP leaders, scientists and partners presented during these webinars.

And finally, after two years of waiting, we were able to host a physical two-day meeting for the Consortium in November 2021. With over 70 participants, the main theme was innovation and encouraging mobility between the partners. As part of the event, our PhD candidates, postdoc researchers and technology partners presented themselves through a poster session, stands and a panel debate. We understand how important these physical meetings – spending time together over two days, with the opportunity for in-depth face-to-face conversations – are to building a strong Consortium.

*Pictures from Consortium meeting in November.*


# Research and innovation strategy

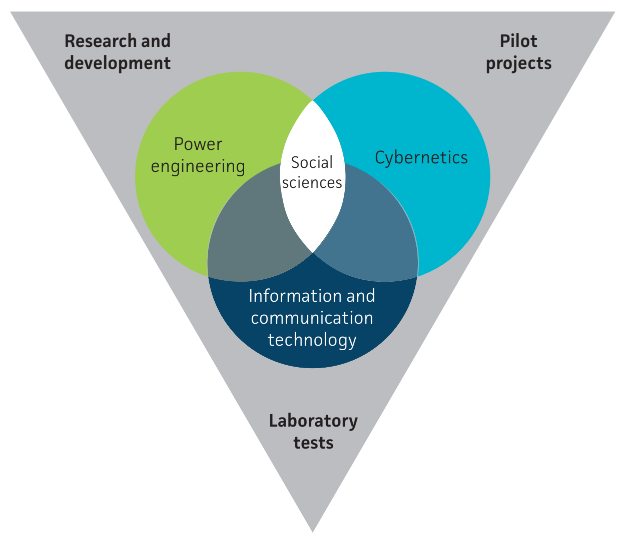
## Research

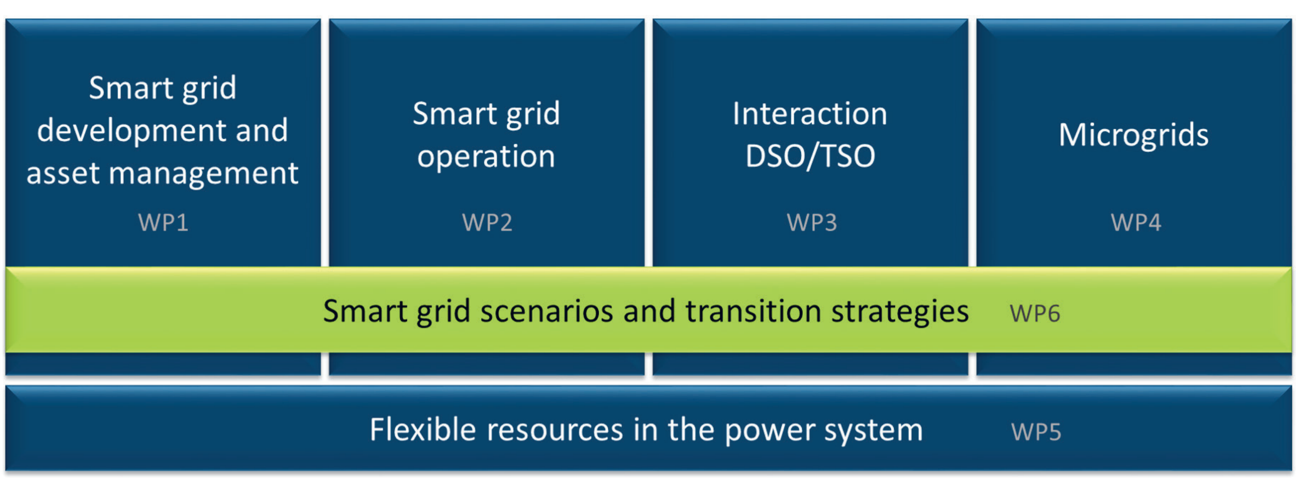
The research activities are designed to meet CINELDI's main goal of a cost-efficient realization of the future flexible and robust electricity grid. Our research is performed across four main disciplines: *electric power engineering, cybernetics, information technology,* and *communication technology*. These are further supported by social sciences in order to analyze social economics and consumer behavior related to flexibility.

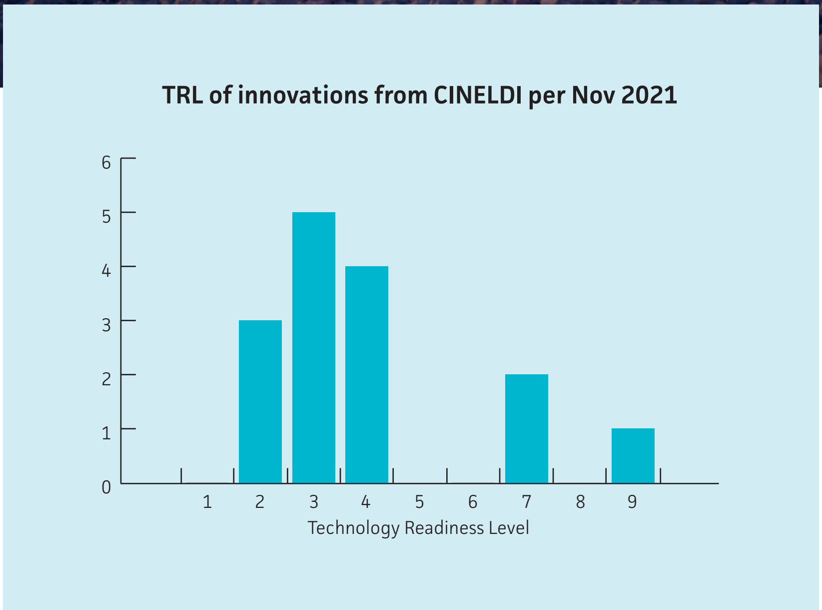
The research activities are organized in six research areas, represented by the six WPs. The WPs reflect the main aspects of power system operation and management. This ensures that each WP addresses research questions that are highly relevant to both industry and society. Furthermore, it enables academic partners to work in close collaboration across the disciplines. It also facilitates interaction and communication between partners from research and industry alike.

## Multidisciplinary research platform

CINELDI's research is based on a multidisciplinary platform consisting of three pillars: *research and development, laboratory tests* and *pilot projects*. Through basic and applied research, CINELDI's researchers provide in-depth knowledge, methods, and tools





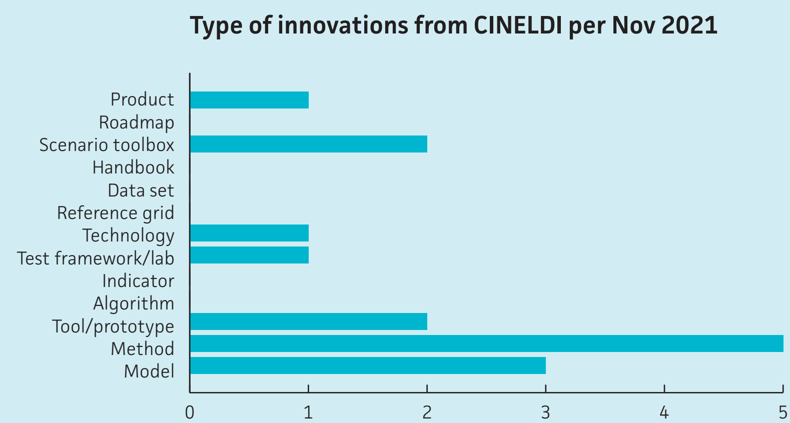

that are then tested in laboratories, simulated environments, and small-scale field pilots (living labs).

Active utilisation of use-case methodology and research infrastructure is an important part of both the research strategy and the multidisciplinary research platform. By using the Norwegian Smart Grid laboratory and living labs hosted by user partners and laboratory tests, we integrate active involvement from the industry partners into our research activities.

## Innovation

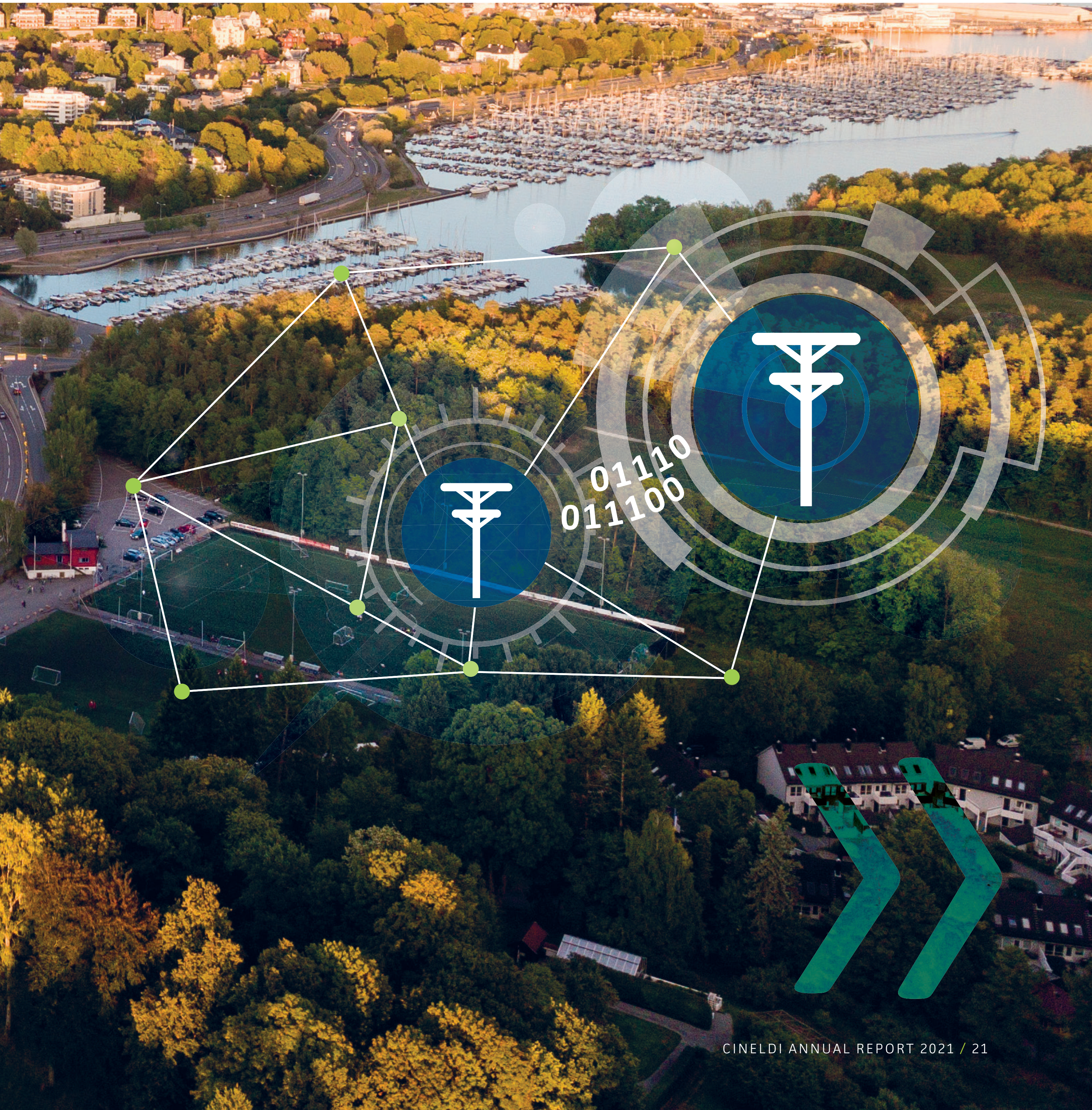
Innovation is a key factor to succeeding with CINELDI and the centre targets system innovation for the electricity distribution system. We define innovations as something *new* that is *useful* and *being utilised*, so that it can create value for society.

CINELDI's activities are positioned on a scale from targeted basic research and demonstration to novel technology and business opportunities.




Through working with user partners, CINELDI identifies new business opportunities and turns pilot projects into new spin-off projects across the whole value chain, both nationally and internationally. Through this cooperation, we build capacity so that we can succeed in Horizon Europe projects with higher TRL (5-9).

# Smart grid development and asset management **(WP1)**



Our primary objective in WP1 is to develop the decision-support methodologies and tools needed for optimal planning and asset management in a smart grid. These methodologies and tools will make the grid more efficient through a better utilisation of both existing and new infrastructure, more target-oriented investments, and better risk control.

In 2021, we have conducted further work on elaborating and concretising the previously developed methodology for active distribution grid planning. The work comprises several case studies, and supports the common CINELDI focus on flexibility.

Due to the ongoing digitalisation of the power system, cyber risks need to be included more broadly in risk analyses. To improve current approaches to risk analysis, an interview study of several DSOs and sectorial organisations has been carried out. This has established an understanding of current practices as well as current and envisioned future needs for improvements and support. A tool for reliability calculations has also been proposed.

## Active distribution grid planning

The traditional passive framework for distribution grid planning is being augmented to handle future challenges, such as variabilities and uncertainties due to variable distributed generation. Further development will also aim to take advantage of emerging opportunities in the distribution grid, such as new active grid operation technologies.

The objective in 2021 has been to describe the methodology more concretely, so that it can be implemented as part of the framework.

A comprehensive overview of options for planning active distribution grids is provided, including:

1. Active measures that should be considered, and how they can be represented in planning studies,
2. Methods for load and generation modelling, including uncertainty,
3. Methods and tools for techno-economic analysis and assessment of risk, and
4. Methodology for optimising and ranking solutions.

For each option, requirements and recommendations for the planning methodology are given. Based on this overview, a roadmap for implementing the framework and methodology is suggested, with steps that can be taken for putting new methodology into practice.

The practical application of the methodology has been tested in a pilot area with new energy solutions. Load and generation models from FME ZEN are incorporated, along with a model for the optimal operation of neighbourhood batteries, time series power flow analyses, and a tool for optimal grid planning. This is all illustrated in Figure 1.

In this case, due to the district heating supply, photovoltaic (PV) generation became the dimensioning factor for the distribution grid. Calculations of the cost of losses were adjusted to account for the effect of local PV generation. Neighbourhood batteries turned out not to be cost-effective, but this result will depend on the grid company's policy for allowing the temporary overload of transformers.

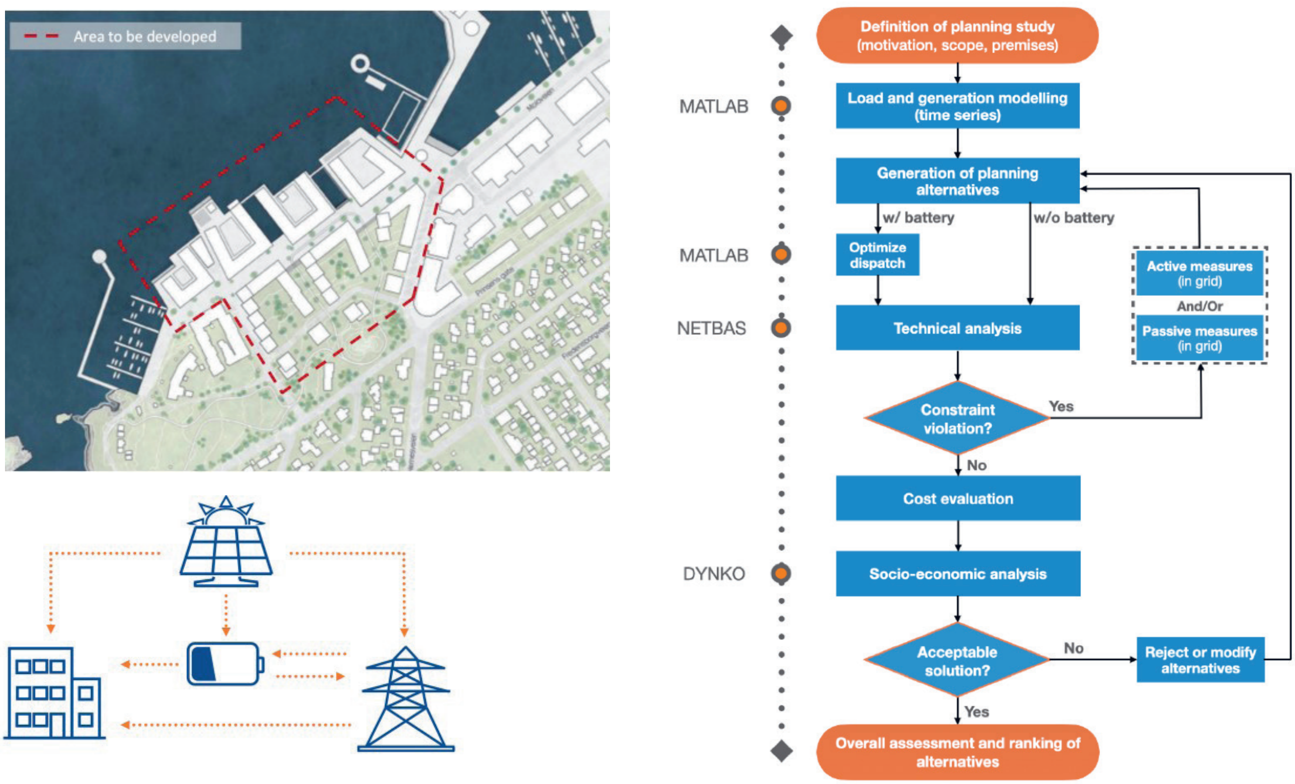



*Figure 1*

## Security of supply in cyber-physical power systems

Power technology and digital technology is interconnected at various levels throughout the whole grid. Digital components rely on electric power to operate, and the electric power system is becoming increasingly dependent on the functioning of digital technology. It is crucial to understand these interdependencies, and they need to be considered in future risk analyses.

An existing framework for vulnerability analysis was modified to enable a combined analysis, which included both power and cyber aspects. This was done to keep a holistic system perspective, as well as to build a common understanding across these domains. In 2021, we have been focusing on identifying success criteria for risk assessments in the future power system, and evaluating gaps in existing methods.

In addition, a PhD candidate has worked on a simulation tool for evaluating the reliability of cyber-physical distribution systems. As with grid planning and vulnerability evaluation, the increasing use of renewable energy resources, flexible resources and ICT components in the distribution system requires modification of reliability calculations. The new components are included in the proposed tool, and the distribution system is considered as an active grid with regards to power system reliability. The tool package is developed in Python and includes ICT components, flexible resources, and distributed generation. This is illustrated in Figure 2.

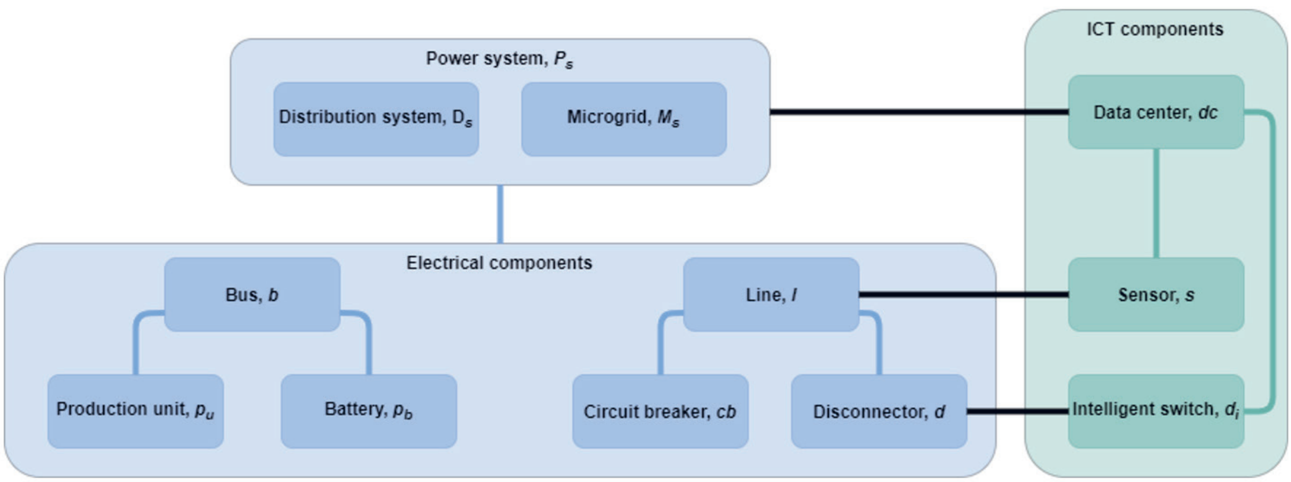



*Figure 2*

# Smart grid operation (WP2)

WP2 develops and tests a set of new concepts and solutions that make optimal use of new emerging control and monitoring technologies. These technologies can exploit extensive, real-time monitoring between all assets, grid customers and flexible resources.

The expected impact is a more flexible operation of the distribution grid. This will in turn contribute to cost reductions, enhanced energy efficiency, and improved system reliability and security, as well as standardised solutions.

As more distributed generation is integrated into the electricity grid, DSOs and TSOs must adapt new ICT solutions to coordinate the activation of resources like solar and wind power for reactive power. Some of the technology that is needed to do this has been developed, but further testing is necessary.

In WP2, we use the National Smart Grid Laboratory to set up testbeds and perform case studies. This is so that we can test scenarios that are too difficult to test in regular pilot projects, due to system security. The different activities in WP2 help us to build competence in joint lab work that covers both cyber security and power issues, which are important aspects due to the increasing integration of power technology and ICT. It is vital to improve our understanding of the issue of cyber security and how it relates to measurement data, as we expect an increasing degree of autonomy and self-healing in the future grid.

## Testbed for advanced distribution management system (ADMS)

We have developed a laboratory testbed, which integrates volt-var optimization function with the SCADA system, and presents the possibility of integrating state estimation functions that utilise ADMS measurements. The main objective is to validate the benefits of advanced network operation functions and characterise the need for ICT infrastructure. Assessing cyber security threats is also an important part of this research.

The testbed is being built step-by-step, offering grid operators a mini platform that replicates the future integrated grid operations centre. It enables grid operators to test customised advanced distribution management functions in a controlled environment. In 2021, we successfully performed the first full-scale implementation of a testbed for ADMS. This was done for the use case of TSO-DSO reactive power management in the National Smart Grid Laboratory. We also increased the number of distributed energy resources and flexibility resources in the test system by using models developed in WP5 and other projects related to CINELDI.

## Workshop on ground faults

A highlight of 2021 was our workshop on ground faults, with representatives from grid and tech companies as well as from the authorities. During this workshop, we were able to discuss and assess important challenges related to ground faults, which is a common issue for all the participants. Among these challenges is the dependency on actions from end customers to repair faults themselves.

Through this workshop, we were able to discuss how we can work around existing issues moving forward. The nationwide implementation of smart meters has proven to be an effective tool to indicate ground faults. In most cases, the customers often have the necessary tools to handle ground faults. What the grid companies must now focus on is aiding in the use of this equipment and communicating this assistance to the end customers.

It is also critically necessary to develop technology that can ensure accurate diagnostics of the ground faults. In this case, CINELDI will be able to focus our research activity on an issue that is still quite present with customers that have a larger electrical need. This is a great example of how CINELDI's research can be applied by our industry partners, to ensure more efficient treatment of issues that impact end customers directly.

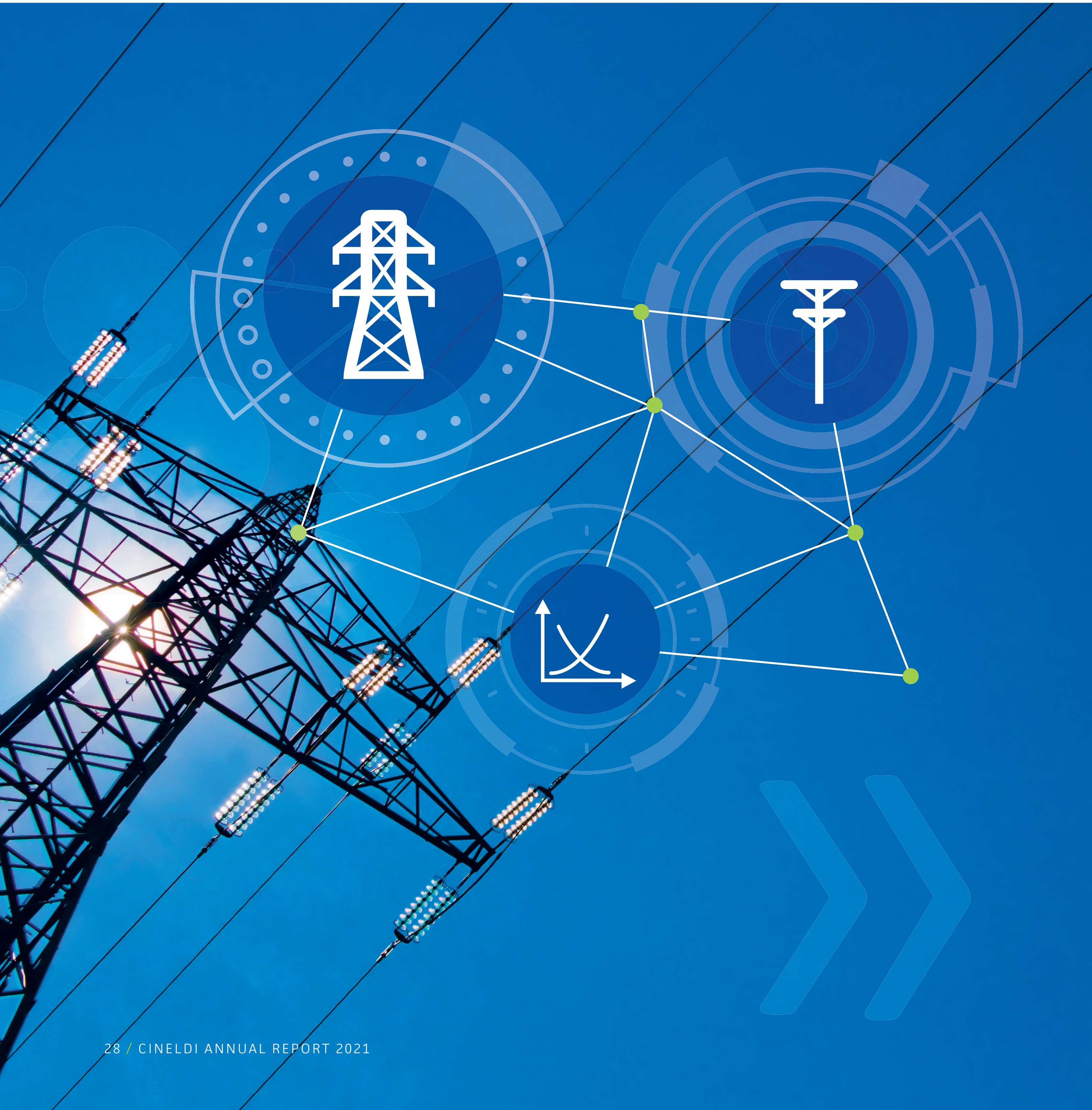
## Tool-assisted threat modelling for smart grid cyber security

When transitioning to a digitalised smart grid, cyber security becomes a major concern for grid operators. For instance, a cyberattack might wipe out the electric supply of entire regions. A conference paper, based on the thesis by one of our master's student's, assessed this very issue.

A framework for cyber security in smart grids was developed. The project also presented an overview of possible threats to the future grid and developed a model for identifying threats. This model is easily applied, with an intuitive user interface. In this way, it can be a useful tool for different actors as the future flexible smart grid becomes a reality.

The framework was successfully demonstrated in a laboratory test. A total of 355 threats where identified, and some of these will be the basis of future analysis.

# Interaction DSO/TSO **(WP3)**



Through WP3, CINELDI develops concepts and solutions for utilising flexible resources in different market products and ancillary services. We do this to increase observability between the distribution and transmission systems, and to develop business models regarding the utilisation of customer flexibility.

## Utilising flexible resources in ancillary services

Coordination between TSOs and DSOs is essential for ensuring that flexibility resources in distribution grids remain available for system balancing purposes, without inducing unmanageable local congestions that could affect the local grid. An optimal mix of flexibility resources can be obtained through a holistic approach that considers technical, market and environmental aspects. To get an overview of how flexibility can be utilised, we have developed use cases that focus on voltage control, congestion management and balancing.

## Future ancillary services, where flexible resources are used

In cooperation with WP2, the coordinated TSO-DSO reactive power management use case has been tested in the National Smart Grid laboratory. This use case focuses on the challenges in near real-time grid models, as well as data exchanges between TSO and DSO control centres.

A test system for operational coordination between TSO-DSO control centres is implemented in the laboratory by using the relevant communication protocols, control centre functions and power system grids. The test system is used to investigate the impact that different levels of DSO grid models have on the

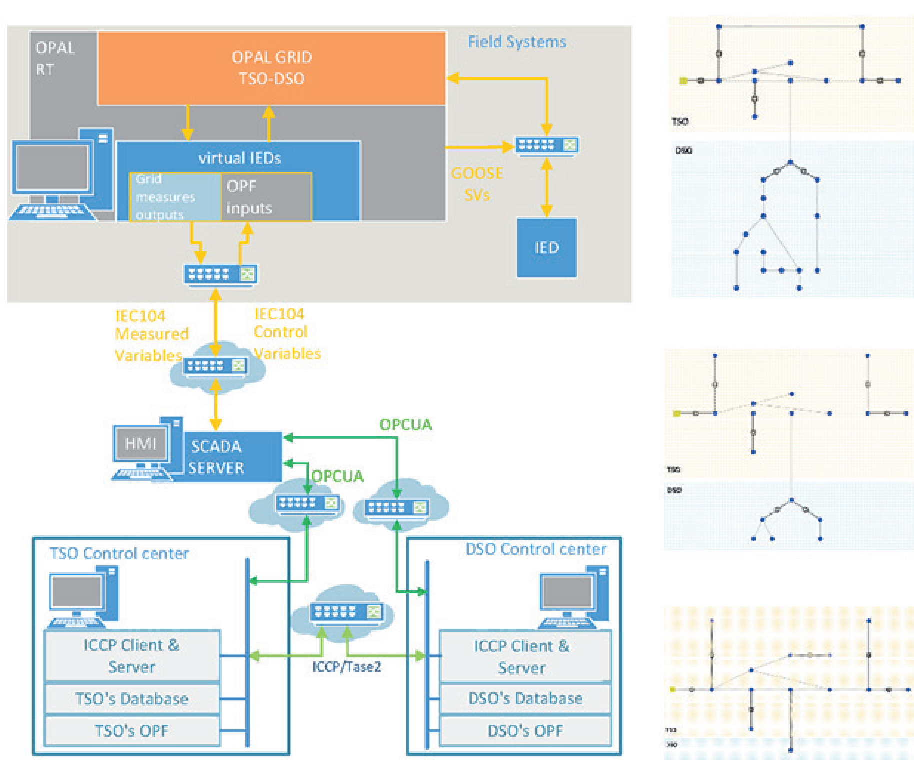



*Figure 1 The architecture of the laboratory setup (left). Full DSO grid model (top), technologically clustered DSO grid model (middle), DSO grid model as a P-Q bus (bottom)*

TSO control centre for TSO-DSO coordinated reactive power management. The testbed, with our laboratory setup, is presented in Figure 1.

The necessary parts of the inter-control centre communication protocol (ICCP) have been implemented for communication between the TSO and DSO control centres. In addition, grid models with different levels of detail have been transferred using a subset of the Common Grid Model Exchange Standard Common Information Model (CGMES CIM) profile.

A realistic ICCP is implemented in a laboratory environment. The physical grid is simulated in a real-time simulator, while optimal setpoints are communicated between the control centres and the simulated assets by using the IEC 60870-5-104 standard. Three equivalent grid models of the DSO grid are compared for TSO operations. This is presented in the Figure 1.

Some of the significant results from this research suggest that the DSO equivalent grid models should be developed with a tailored approach for the dynamics considered in specific cases. This should be done to avoid performance degradation. Use of the Common Grid Model (CGM) for exchanging different levels of DSO equivalent grids has proven its adequacy for this type of operational coordination.

## Identification of TSO and DSO ancillary services, activation priority and their value

A literature review has been performed to identify the basic ancillary services that TSOs and DSOs require for the safe and efficient operation of the power system. Based on this review, the service priorities are categorised as *security of supply*, *operational efficiency*, and *portfolio optimisation*. This is illustrated in figure 2.

One type of flexibility resource can provide multiple services. A classic example is a battery storage system

| **Priority** | **TSO services** | **DSO services** |
|---|---|---|
| Secuarity of supply | Controlled islanding | Controlled islanding |
| | Redundancy (N -1) support | Redundancy (N -1) support |
| | Black start | Power quality support (Voltage level, Flicker control)? |
| | Fast Containment Reserves (FCR-N, FCR-D) | |
| | Inertia | |
| Operational efficiency | Congestion management | Congestion management |
| | Voltage control | Voltage control |
| | Grid losses | Grid losses |
| | Fast restoration reserves (FRR), Replacement Reserves (RR) | |
| Portfolio optimization | Balancing | |

*Figure 2 Prioritizing of ancillary services*

(BESS), which provides congestion management by peak shaving, voltage control by absorbing excess PV generation, and a non-wired alternative to increase the PV hosting capacity of the distribution grid, as well as providing Frequency Containment Reserves (FCR) and Frequency Restoration Reserves (FRR). Similarly, a grid-connected PV inverter can provide voltage control through reactive power control, as well as harmonic damping and flicker control as a power quality support for DSO. WP3 will further investigate the details about this in our future work.

## Pilot project – Fast Frequency Reserves

A pilot project showing how a flexibility resource can be utilised in an ancillary service was performed at Skagerak Energilab by Lede. In this pilot project, the Battery Energy Storage System (BESS) was evaluated for offering Fast Frequency Reserve (FFR) services to Statnett (read more on page 45).

## Mapping of barriers and potential for flexibility

A feasibility study was performed in cooperation with WP1 and Energy Norway in order to map barriers and potentials for Norwegian DSOs to utilise flexibility in the operation and management of the grid.

Seven Norwegian DSOs were interviewed in the first tertiary of 2021. The objectives of these interviews were to map the incentives and barriers in relation to the utilisation of flexibility in planning and operation of the distribution grid, as well as to get an update on the status of this process. The report and policy document were published at the Smart Grid conference in November of 2021.

In summary, the main identified barriers were related to the four C's at the DSOs, as presented in Figure 3.

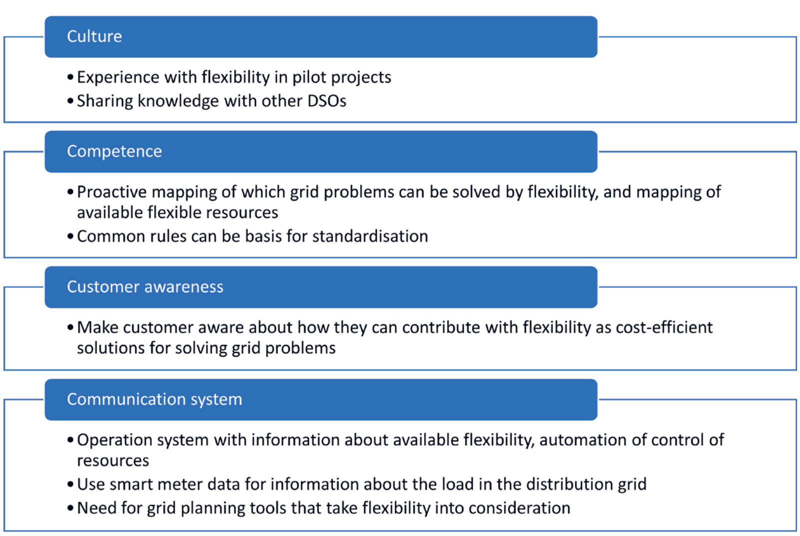



*Figure 3 Barriers related to the 4 C's at DSOs*

# Microgrids (WP4)

The objective of WP4 is to develop concepts, technologies, and models for microgrids and their interaction with the distribution system. The expected impact is a contribution to the cost-efficient and robust integration of microgrids with the distribution grid. We also aim to contribute to the integration of more distributed and renewable energy resources (DER) into the system. Microgrids within CINELDI have focused on both grid-connected and isolated modes. The activities in 2021 have in large part been connected to the joint flexibility studies conducted. The focus has also changed a bit, where the grid-connected operation has been more addressed and the integration of Local Energy Communities (LEC) has been strengthened.

## Education in WP4

WP4 has two PhD candidates funded by CINELDI. One of these is working on microgrid protection from the perspective of communication and use of 5G technologies, while the other is in our task on ancillary services and energy routers. The candidates have been progressing well, and the candidate on ancillary services defended their thesis in 2021. This thesis was supported by publications in a prestigious journal.

To strengthen the activities within WP4, externally funded PhD candidates and postdoc researchers have been recruited to work with topics related to microgrids. The external resources have made it possible to work on a broader scope, and to build a more solid foundation for the work within WP4 Microgrids.

One PhD candidate and one postdoc researcher are working with dynamic interaction in systems with high penetration of Power Electronic Converters. Both positions are funded by NTNU.

One PhD candidate has been working on planning in systems with distributed intermittent resources and storage devices, with funding from SINTEF Energy Research and The Research Council of Norway. This candidate submitted his thesis in December 2021. This thesis was also supported by impressive journal publications.

A postdoc researcher funded by an in-kind project has been working on the planning and operation of microgrid systems.

In addition to PhD candidates and postdoc researchers, a close collaboration with master's students at NTNU has been a priority in WP4. These collaborations provide interesting and challenging research activities within microgrids.

## International collaboration

International collaboration is an important activity to build a strong research center. WP4 has had several fruitful international collaborations with institutions, such as Shanghai Jiao Tong (China), Aalborg University (Denmark), IMDEA (Spain), Universidad Tecnica de Pereira (Colombia).

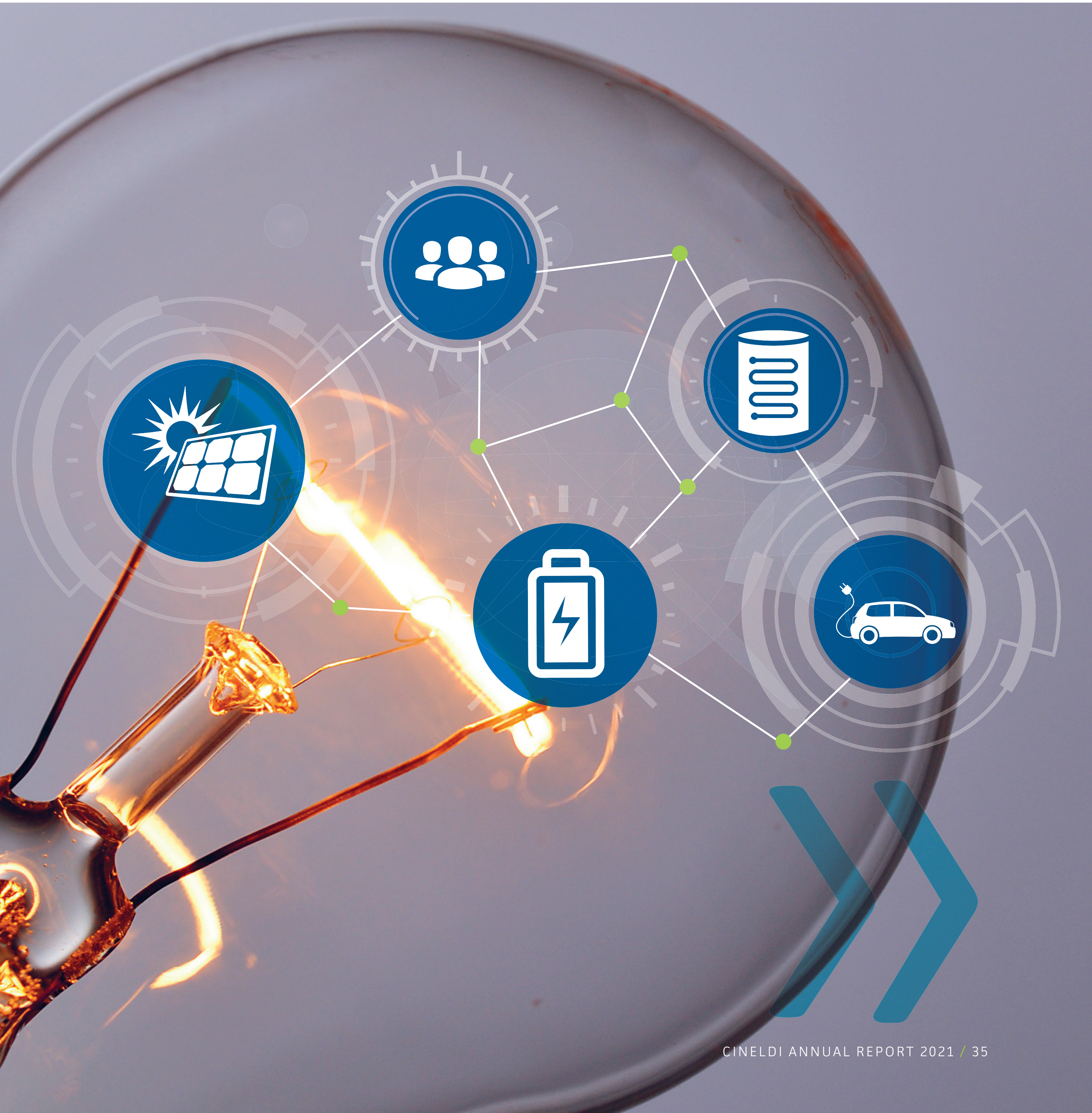
## Dissemination and publications

There were many conference and journal papers published in 2021 related to WP4, from researchers, PhD candidates and postdoc researchers alike. A total of four IEEE journal publications were accepted.


## The future of WP4

With the stronger focus on the grid-connected modes, we realized that many of the activities in WP4 overlap with WP1 and WP2. After the midway evaluation of CINELDI in 2020, it was concluded that gathering the WPs' resources would strengthen the activities of the centre. This is also because several researchers were involved in more than one of these three WPs. WP4 has essentially been merged with WP2. None of the activities have been disbanded, but we now focus on how to maximize the output from FME CINELDI by the end of 2024.

# Flexible resources in the power system (WP5)



The overall objective of WP5 is to develop models and strategies for the cost-effective integration of flexible resources in smart distribution grids. We expect this to improve the efficiency of system operations when utilising flexibility as an important asset, and thereby become a realistic alternative to grid investments, and serve flexibility to the transmission level.

In 2021, we continued the collaboration with the other work packages on the topic of flexibility, with respect to planning (WP1), operation (WP2), TSO-DSO integration (WP3) and microgrids development (WP4). We experienced an all-time high interest for CINELDI among NTNU students, resulting in 14 master's theses that were linked to this work package alone. Some topics of the theses included:

- Flexible charging of Electrical Vehicles (EVs) and Vehicle-to-everything (V2X) in distribution grids,
- Utilisation of energy storage for wind and solar integration,
- Flexibility market development,
- Flexibility from water boilers,
- Load forecasting using machine learning (ML), and
- Flexibility provision from Zero Emission Neighbourhoods (ZEN).

A total of eight PhD candidates and postdoc researchers were linked to WP5 in 2021, including in-kind positions and collaborating positions financed outside CINELDI. Overall, 2021 was a very active year with regards to research and dissemination. Here are some highlights from this past year.

## Operation model for a Zero Emission Building with emission compensation

The goal of this research has been to identify the value of flexibility for buildings in a long-term operational setting, considering longer periods – anywhere from days to months – and uncertainty. The model was developed by Kasper Thorvaldsen as part of his PhD project. The presented work was published in *Elsevier Applied Energy*.

The primary objective of Zero Emission Buildings (ZEBs) is to achieve net-zero emissions within the buildings' lifetime. To achieve this goal, accurate cost-effective emission compensation is needed during the operational phase. We aim to capture the long-term economic impact of emission compensation for a ZEB throughout its operation. We first developed an operational strategy for a building, with emission compensation using Stochastic Dynamic Programming for energy storage optimisation. We then compared the operational strategy with the strategy from a case conducted in Norway and Denmark. We found that emission compensation has a significant impact on the local energy system operation. For example, a penalty cost of €10 per kg resulted in zero net emissions from the building, leading to a total cost increase of five percent.

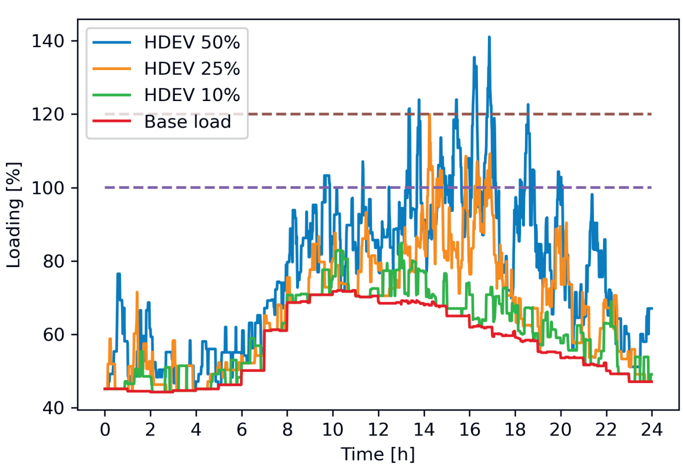
This model is of high value for both grid operators and building or neighborhood developers. This is because the results provide direct estimates of the value of flexibility from end users with local emission targets.

## Charging profiles for heavy-duty electric vehicles

This was the result of a master's thesis written by Kyrre Kirkbakk Fjær at NTNU's Department of Electric Power Engineering. The results were later published at the IEEE *SEST scientific conference*.

The background of the study is that the upcoming heavy-duty electric vehicles (HDEVs) are expected to have a charging power of 100-1600 kW. Therefore, a transition to HDEVs can present challenges to the power grid. To plan for this, grid owners need to be aware of how these new loads can impact their grids.

We aim to create load profiles of a high-power charging station for HDEVs, to be used in power flow analyses. A case study for a relevant Norwegian area was set up. We evaluated the impacts of HDEV charging and how changes in mandatory breaks for drivers influenced the distribution of load in the grid through a typical day.




*Transformer loading in a Norwegian transit area with increasing share of heavy-duty electric vehicles*

We found that HDEV charging causes overloading issues when a share of EVs is in the 25-50% range. By increasing mandatory breaks for HDEV drivers, we can reduce these charging peaks significantly. The results show how important it is to model new loads on a detailed level in order to foresee grid issues and to evaluate different mitigation strategies.

## Quantification of electric water heater flexibility potential in Norway

This is part of a large portfolio of research activities at SINTEF concerning the feasibility of water heaters as flexible loads in Norway. The study has been published in *Elsevier Energy*.

The aim of the study was to provide a way for DSOs and TSOs to obtain an overview of how flexibility from water heaters can potentially contribute to different grid services. For example, it is crucial to be able to predict – and counteract – potential rebound effects. DSOs must be able to characterise the impact, as they are responsible for the voltage quality of power delivery and the lifespan of network components may shorten due to overloading.

The paper proposes parameters for characterising flexibility activation on electric water heaters (EWHs). The flexibility potentials are then computed considering smart activation methods for the Norwegian scenario. The proposed parameters are rebound: *percentage, delay, ramp rates, second peak distance, activation error, flexible power, and temperature deviation.*

Four scenarios based on a Norwegian context, with different levels of flexible power and activation time, were developed to quantify the flexibility potentials and the parameters. The highest average flexible power potential was 53.9%, which happened at eight o'clock in the morning and lasted for 61 minutes.

EWHs' flexibility activation can serve as FCR at peak demand hours, with high ramp-up and ramp-down rates of 48.5 and 23.8 percent per minute. It can also function as FRR during non-peak hours.

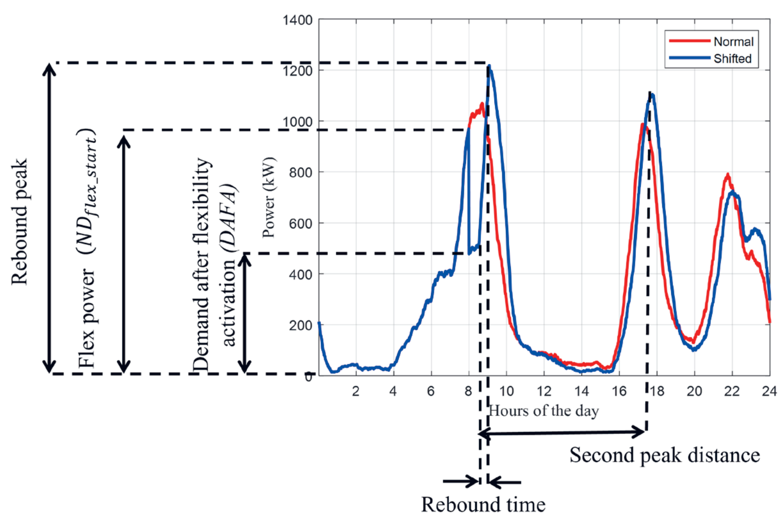
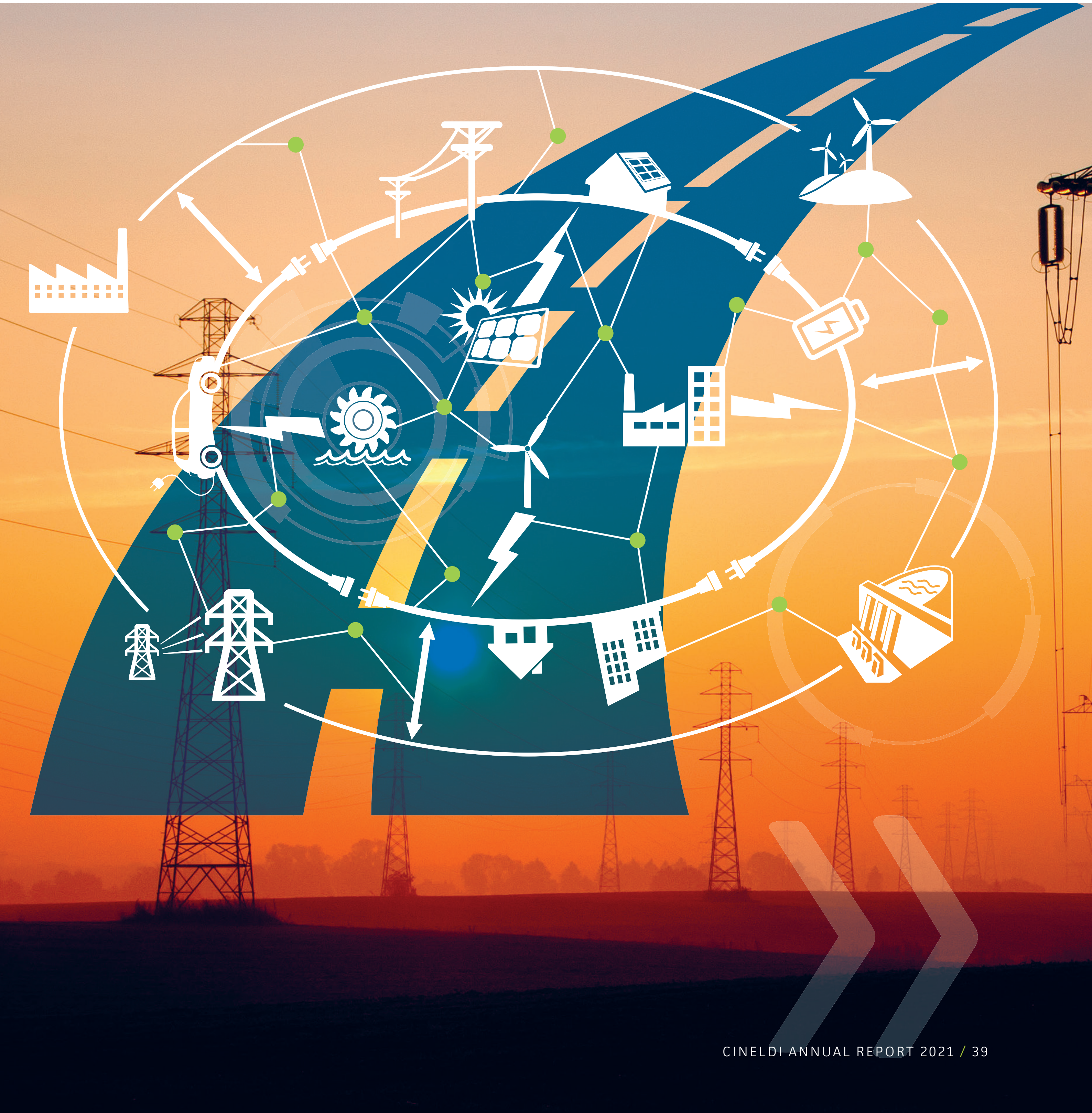



*Illustration of the rebound effect of a water heater.*

# Smart grid scenarios and transition strategies (WP6)



Industry requires a robust strategy in order to make a cost-efficient transition to a flexible, intelligent and secure grid. In WP6, we develop scenarios for the future electricity distribution grid. These scenarios serve as a basis for research in the other WPs, as well as for the development of guidelines and recommendations for transitioning to the future grid.

To support the transition strategy, WP6 has developed reference grids that represent real Norwegian distribution grids. International test grid data sets are typically made for academic purposes, and for verifying and validating new methods. However, they are often not suitable for studying realistic problems. Therefore, it is important to establish reference grid data sets that are representative of Norwegian distribution grids.

Our goal is to establish stylised grids that represent different operating conditions and voltage levels. Reference grids enable technologies, scenarios, and challenges to be tested in realistic environments. They may be used for comparison purposes, as well as for quantifying the socio-economic costs of the future grid in relation to investments, operation, power supply interruptions and electrical losses in different scenarios. Moreover, reference grids may be used to show the effect of new technologies and solutions, as well as quantify benefits and potentials to save costs. In CINELDI, reference grids will be used to perform and test different cases in order to support the development of the transition strategy.

We aim to make the reference grid data sets available to be accessed by other researchers, so that they can test their own methods and techniques, and compare their results. This creates a basis for evaluating both methods and results. The reference grid can also visualise appropriate measures for integrating new elements – such as distributed renewable power generation, charging stations for electrical vehicles, and new types of electricity consumption – and for dealing with any challenges that might occur. This enables more fundamental analyses, as well as analyses of new problems in the future grid.

A basic medium voltage (MV) distribution grid data set is established, based on data from a real MV distribution grid in Norway. This data is anonymised and adapted to establish the reference grid data set. In CINELDI, we have started using the data set to study methods and concepts developed for more flexible consumption, power production and energy storage. The basic reference grid data set is further extended to produce a data set that is relevant for a case study on flexibility. For this purpose, new elements are integrated in the reference grid (as shown in Figure 1) in order to simulate many of the issues that we expect to be dominant in the future distribution system:

- Local energy systems/communities with PV power production, charging for Electrical Vehicles, local storage, etc.,
- Large storage units like batteries,
- Power intensive charging stations for electrical vehicles defined by number of charging points and total capacity,
- Electric ferry charging points for different needs, governed by the ferry timetable,
- Wind farms with intermittent power production.

In addition, the grid has alternative supplies from back-up feeders.

The ongoing flexibility case aims to support the research question of how, where and when flexibility is the right solution to ensuring a cost-efficient and robust grid. This reference grid data set will be further extended and adapted for case studies in order to perform overall analyses about the impact on security of electricity supply. It will also be used to investigate socio-economic coherency and the justification of transition paths.

During the period 2022-2024, security of supply will be the main research subject in CINELDI. In this work, the reference grid will be an important tool for testing different strategies in order to ensure security of supply. It has already been well received by our partners, as well as other actors that are connected to CINELDI. Moving forward, we wish to make this an accepted system at both a national and international level.

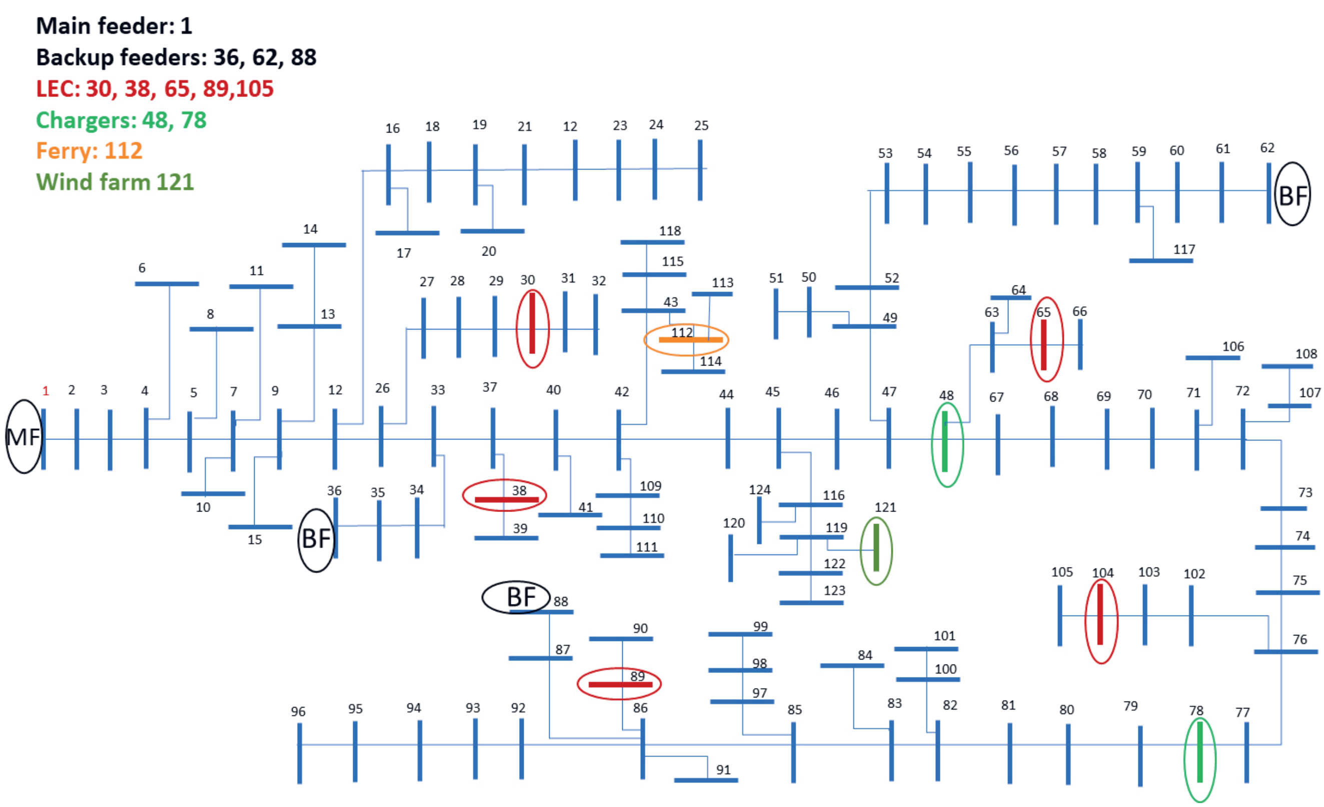



*Figure 1. CINELDI 124 bus MV distribution reference grid for flexibility studies.*

# Pilot projects

Through our pilot projects, we test and verify new research results, technologies, and solutions for the future intelligent electricity distribution system in real environments. Pilot projects can contribute to system innovations, as well as aid in the establishment of standardised and cost-effective solutions for the future distribution grid. In addition, pilot projects will contribute to the transition strategy of WP6 (see page 40). The projects are organised into four priority areas: *application of AMR/grid data, flexibility, fault handling and self-healing and sensing and digital monitoring*.

CINELDI partners are involved in approximately 25 pilot projects. These range from testing new technologies and algorithms, to testing new tariffs and flexibility markets. Some pilot projects have already been finalised, and their results put into practice through our innovations. There is also a large potential for more innovations to result from the ongoing pilots, as well as new spin-off projects in the years to come.

In 2021, it was important that the remaining pilot projects be initiated, as CINELDI is heading into its final three years as an FME. This was particularly the case for pilot projects that require data to be collected from the power grid, to ensure that enough data was gathered to perform the required analyses. For example, we started working on a large-scale research pilot project with our new partner, Heimdall Power, which aims to test their neurons at a system scale.

In addition, some pilot projects were finalised in 2021. The dissemination and reporting activities for these projects will continue in 2022.

As CINELDI moves into our last three years, we are shifting our focus in our pilot projects. We will be working to identify and create more innovations by facilitating the implementation of pilot project results, such as new work processes, methods and technologies, in the everyday work of the CINELDI partners.

Over the course of 2021, five pilot project expert meetings and additional webinars were held to share developments from the projects. A priority in dissemination activities moving forward is to communicate pilot project results to more partners than the ones directly involved in the project, to enable them to implement results and innovations themselves.

## Overview of pilot projects in CINELDI

The status and the number of pilot projects in the four priority areas is shown below:

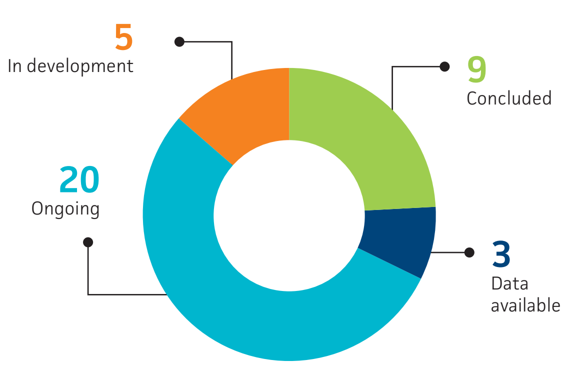
**Application of AMR/grid data**

- Smart meters in the Smart Grid Lab - Aidon - (2)
- Risk-based distribution network planning - Agder Energi Nett - Agder Energi Nett - (11)
- Predicting peak load in secondary substations - Agder Energi Nett - Agder Energi Nett - (12)
- Probabilistic planning methodology - Norgesnett - (22)
- Development area Molobyen - Arva - (26)
- Data Driven Failure Risk Assessment for Predicting maintenance - Elvia - (27) *Finalised*

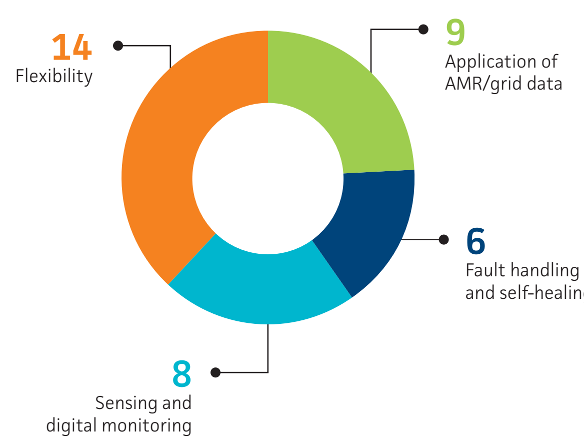
**Fault handling and self-healing**

- New relay concept - Elvia - (1)
- Automated recoupling in smart secondary substation - Lnett - (7) *Finalised*

**Count of Pilot projects**




**Count of Pilot projects**



- Faster fault location - Elvia - (14)
- An algorithm for self-healing - Lede - (18)
- Fault indicators - Lede - (19)
- Fault handling and self-healing - Elvia - (24)

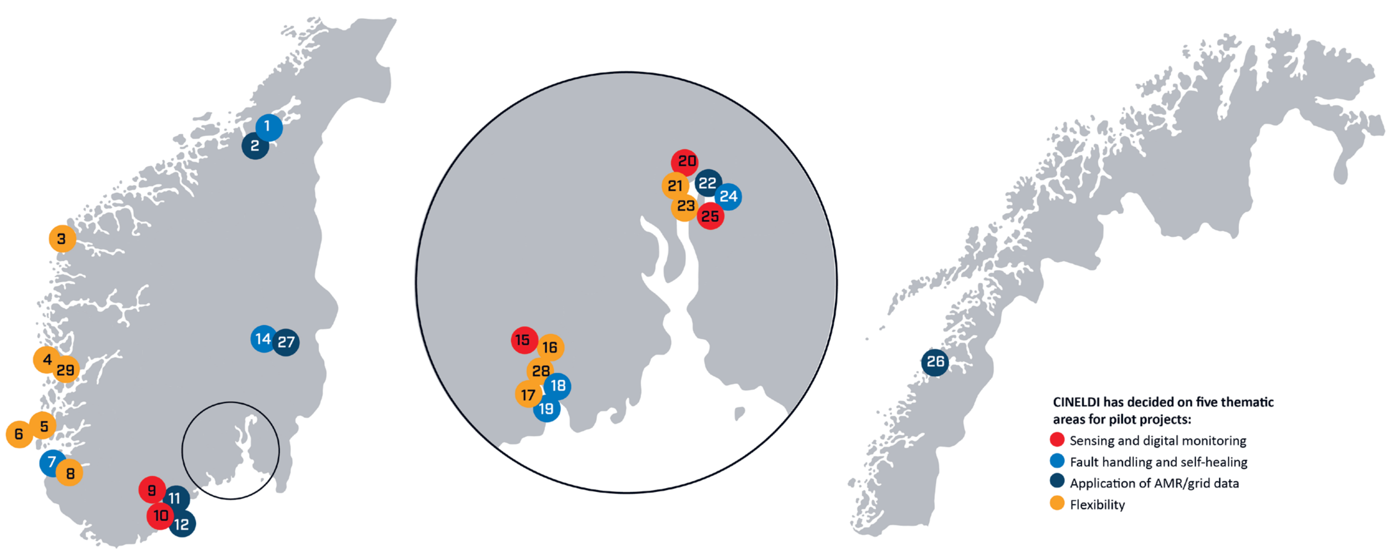
**Flexibility**

- NODES flexibility platform - Linja - (3)
- Batteries as voltage support Two - BKK Nett - (4)
- Flexibility marked - Fagne - (5)
- Utsira: An islanded grid on an island - Fagne - (6)
- Batteries as voltage support- Lnett - (8)
- Optimisation of local balancing with battery - Lede - (16)
- Transition to and from island mode - Lede - (17) *Finalised*
- Active homes - Elvia - (21) *Finalised*
- iFleks - Statnett - (23)
- Fast Frequency Reserve - Lede - (28) *Finalised*
- Energy management in BKK Nett - BKK Nett - (29)

**Sensing and digital monitoring**

- Machine learning in grid inspection - Agder Energi Nett - (9)
- Digital Inspection - Agder Energi Nett - (10)
- Digital Inspection - ABB Electrification - (15) *Finalised*
- Smart Cable Guard - Elvia - (20) *Finalised*
- Digital Inspection - Elvia - (25) *Finalised*

You can read a full description of each pilot project at: https://www.sintef.no/projectweb/cineldi/pilot-projects-in-cineldi/




*Overview of the CINELDI's pilot projects and their location.*

# Fast frequency reserves: From pilot projects to commercial operation

Skagerak Arena is not only one of Norway's largest football stadiums, but it is also home to an intricate renewable energy system, consisting of solar panels and a 1MWh battery. In the summer of 2021, CINELDI tested the possibilities for this infrastructure to provide FFR. This mechanism will ensure a more stable power supply as more intermittent power sources are incorporated into the national energy mix, such as wind and solar power.

The battery system at Skagerak Arena has functioned as an energy storage, and an alternative power source for companies, housing, and schools nearby the stadium, since 2019. Together with the grid company Lede, CINELDI tested the battery to ensure that it could be utilised commercially as frequency support. The test was successful, and the battery is now an integrated part of the local power supply.

**Signe Marie Oland (Project leader at Lede)**
*This project will facilitate the possibility for more intermittent renewable energy from solar and wind power. The battery has a great ability to deliver energy almost instantaneously. A service like this is easily combined with other primary sources in the battery. We stack services in a prioritized order, based on necessity or seasonal factors. The result is a more efficient utilisation of the battery, which in turn makes different business models more sustainable.*

**Gerd Kjølle (Centre director at CINELDI)**
*FFR functions as a power response, which is activated after about one second if the frequency sinks below a certain level. In comparison, it takes hydropower about seven or eight seconds to regulate the frequency. The battery kicks in at about 49 Hz. We rarely see the frequency reach this level, but this may happen more frequently in the future, due to increased power export and use of wind power. When this happens, solutions like this battery will be crucial to maintain the security of supply.*

# Innovation

Innovation is a key factor for success with CINELDI. We focus on the research-driven innovation chain, from “blue skies research” to pilot projects and testing at a lower TRL.

However, revolutionary technologies and methodologies mean very little if no one is willing to put them to use, if they’re too expensive, or if regulations prevent them from being applied. Therefore, we target system innovations for the electricity distribution system.

An important part of our innovation activity is making our results available to be used by our partners to introduce new or improved work processes, methods or models.

At the end of 2021, CINELDI had around 100 scientific results. We have also identified 20 innovations so far, five of which were identified in 2021. These innovations will contribute to reducing investment costs (CAPEX), as well as costs related to the operation and maintenance (OPEX) of the electricity grid.

They may also lead to improvements to the qualitative aspects of grid operation, such as improved security of supply, and increased cyber security and personnel safety.

We also expect several of our innovations to leverage business opportunities for technology providers in both Norwegian and international markets.

## CINELDI's innovations

**Scenarios for the future electricity distribution grid**

To better understand the complexity of the future distribution grid, we identified and structured the driving forces for distribution system innovation. Based on these driving forces, we developed a repository of about 100 mini scenarios.

Using a two-dimensional system of coordinates, we have built four plausible scenarios for Norwegian electricity distribution grids in 2040. The horizontal axis describes the grid costumers and the degree to which they contribute flexibility. The vertical axis describes the degree of digitalisation and automation of the grid and grid management. This enables us to prepare for an uncertain future.

FACTS

TRL: 3

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

**Checklist for evaluation of results**

Long-term knowledge building research is mostly conducted in lower TRL projects, while pilot projects typically produce results that are higher on the TRL scale. However, turning research into innovation requires work in multiple areas. CINELDI has developed a checklist that considers a research result's target groups, benefits, and sustainability contributions. It can also be used to evaluate what is needed before results can be applied as innovations. Moreover, the checklist provides insight to potential barriers and suggests barrier-reducing measures, and maps possibilities for further research and spin-off projects.

FACTS

TRL: 5

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

**Comprehensive classifications and characterizations of flexible resources**
Power system flexibility is essential for coping with the uncertainty and variability of power generated from PV sources and the wind. Based on an extensive literature review, a unified definition, characterization, and classification of flexibility resources was proposed in paper. The paper showcases how the clear characterization of flexibility resources can be used to map different ancillary service needs to the relevant group of flexibility resources.

FACTS

TRL: 2
Target group
- DSO/TSO
- Researchers and consultants
- Educators

**Planning framework for active distribution grids**
The long-term planning frameworks currently used by electricity distribution grid companies are not designed to account for more variability and new uncertainties due to e.g. variable distributed generation. The solution? An adaptation and extension of the traditional grid planning framework in the Norwegian handbook on power system planning and the active distribution grid planning framework by CIGRE WG C6.19., among other innovative elements like more detailed modelling of the variability. This allows for active grid measures and related technologies to be considered consistently along with traditional measures in distribution system development, which may lead to cost reduction.

FACTS

TRL: 4
Target group
- DSOs/TSOs
- Researchers and consultants
- Educators

**Method for cybersecurity risk analysis customized to smart grids**

Smart grids are socio-technical systems characterised by complexity, interdisciplinarity and dynamics, introducing new risks that have not previously been dealt with. To improve decision making in this complex system, we need an efficient risk analysis.

We have developed a new method that provides an easy-to-understand risk picture. The method will improve our understanding of the effects of power grid digitalisation on cybersecurity, and provide decision support for managing reliability of power supply and cybersecurity. This in turn improves the security of supply. The approach is based on parts of the "CORAS" method for risk analysis.

FACTS

TRL: 7

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Researchers and consultants
- Educators

**State estimation algorithm for monitoring distribution grids**

Power system state estimators play a critical role in modern power grids. However, state estimation cannot be easily achieved in smart grids. Therefore, we have developed a simultaneous input and state estimation method (SISE) to estimate the states of a partially known system with system-wide unknown inputs. The method can be used for several purposes: to prevent system-wide failures or blackouts, tune power system stabilizers, or to improve the reliability of system models utilised for dynamic security assessment (DSA), and to design state estimator-based fault detectors.

FACTS

TRL: 2

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants
- Educators

**Concept for delayed integrity check of PMU measurements**

Future power system operation is expected to rely on the use of synchrophasor measurements (PMU). The IEC 61850 standard defines communication protocols for electrical substations, including synchrophasor measurement transmission. However, it does not properly address cyber security, leaving this critical infrastructure highly vulnerable to cyberattacks. We have developed a novel mechanism for a delayed integrity check of synchrophasor measurements. The solution manages to detect when integrity is compromised, without adding any overhead or delay to the time-critical synchrophasor transmission itself.

**FACTS**

TRL: 3

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants

**Real-time power hardware-in-the loop microgrid simulation platform**

Microgrids contain distributed generators, energy storage systems, controllers and passive loads, wherein the components and controllers have different characteristics. Therefore, the interaction of all these devices and their controllers results in very complex systems where the dynamic performance may be unpredictable. To test the closed loop interaction of these devices, we have installed a power hardware-in-the-loop (P-HIL) simulation facility at the Norwegian National Smart Grid Laboratory. P-HIL is a virtual simulated system and actual hardware coupled together using a real-time simulator plus a power amplifier. This approach offers high flexibility, which can extend the test coverage compared to a prototype or even full-scale testing.

**FACTS**

TRL: 7

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants
- Educators

**Virtual Oscillator Control**

Synchronisation in island electrical grids dominated by power electronics is a challenge due to the absence of a grid reference to follow, lack of inertia sources and the usual lack of communication among the units. A new technique for synchronisation of Voltage Source Converters in microgrids has been developed. The technique was successful in cases where the conventional droop controller failed. The results provide convincing evidence for the adoption of a more complex controller as the Virtual Oscillator Control in island grids will naturally be more vulnerable to voltage distortions.

FACTS

TRL: 3

Target group

- Technology providers
- Researchers and consultants
- Educators

**Energy storage and RES representation in multi-period optimal power flow**

The optimal operation of a distribution system with energy storage can be formulated as a multi-period optimal power flow (MPOPF). The challenge is to decide when to charge and discharge the storage, taking into account grid constraints , wind and PV uncertainties. We have developed a method for storage valuation inspired by optimization principles from hydropower scheduling, including the energy storage model in MPOPF, together with stochastic wind and PV. This is relevant for DSOs facing new challenges when planning and operating their grid, such as increasing amounts of prosumers with PV and batteries and increasing amounts of medium-scaled distributed generation, such as smaller wind farms and solar PV farms.

FACTS

TRL: 4

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

**BATTPOWER Toolbox: memory-efficient and high-performance multi-period AC-optimal power flow solver (AC OPF)**

Energy storage and flexible demand makes AC OPF computations very challenging to solve, and computation time is an issue when using commercial or free optimisation solvers. Our solution is to derive a tailor-made optimisation solver for the problem, utilising the structure of the underlying mathematical formulation of the system. This innovation is relevant for DSOs facing new challenges in the planning and operation of their grid, e.g. increased amounts of medium-scaled distributed generators.

FACTS

TRL: 4

Target group

- DSOs/TSOs
- Technology providers
- Market operators
- Researchers and consultants
- Educators

**SDP model for operation planning of flexible resources in buildings**

When considering future long-term operational costs, it can be crucial to include the future impact of current decision-making within building energy system scheduling. We have made a long-term operational model inspired by water value calculation in hydropower. This captures the future impact of current decision-making through the use of non-linear cost curves. The model can be further developed into a practical operational tool for scheduling of building energy systems.

FACTS

TRL: 3

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

**Method for analysing communication failures in smart grids**

The power system's high dependency on ICT establishes new interdependencies and vulnerabilities that need to be properly analysed. We have developed a novel dependability analysis method that combines Stochastic Activity Network (SAN) modelling and numerical analysis. The method application returns a set of metrics that assess the impact of ICT architecture vulnerabilities, cyber-physical system interdependencies, and dependencies on environmental conditions on Wide Area Measurement Systems (WAMS) data accuracy. The software represents a valuable tool for assessing ICT architecture capability to reliably deliver data for correct monitoring.

FACTS

TRL: 3

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants

**Data-driven flexibility model for shiftable atomic loads**

Modelling flexibility can be a difficult task, especially when it involves the considerations of user habits. Appliances such as dishwashers, washing machines and tumble dryers are sources of flexibility, as the frequency of use and the selected program during operation can vary greatly. We have developed a data-driven model that utilises statistical data and other previously available time series measurements to extract the required features in the calculation of the expected flexibility potential as well as rebound effects after activation. Network operators may use it in their operation and/or long-term plans.

FACTS

TRL: 4

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators



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**Method for cost-benefit analyses of batteries in distribution grids**

Batteries can be deployed at strategic locations in the grid, and perform active and reactive power control to achieve a better utilisation of the grid as an alternative to reinforcements. We have established a general framework suited for grid planning incorporating batteries. The proposed methodology is the first step towards a holistic planning approach for grids, where batteries can help mitigate congestions and other problems.

FACTS

TRL: 7

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Researchers and consultants
- Educators

**Driving forces and mini scenarios for the future distribution grid**

The interaction between various technological, regulatory and social factors add complexity to the future electricity grid that needs to be addressed in a holistic and coordinated way in order to support the system innovation. To better understand the complexity of the future Norwegian distribution grid, the driving forces for system innovation have been identified and structured. Based on the driving forces, a repository of 109 mini scenarios have been developed. The driving forces and mini scenarios can be used as input to strategic processes such as grid development, competence building, R&D strategy, etc.

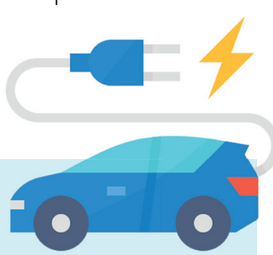
FACTS

TRL: 2

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

**EV power share charging system**
Charging electric cars in an area can cause major power surges both locally and in the grid. A system incorporating POWER SHARE means that power for charging can be regulated dynamically, based either on a maximum value for the respective circuit or on input signals that regulate the maximum value for all cars. With the power share solution, it will be possible to control the maximum load either statically, by setting a fixed maximum value, or dynamically, based on other consumption for the same master fuse, data from smart transformers, or the requirements in the network in general, based on the published ACOPF algorithm.



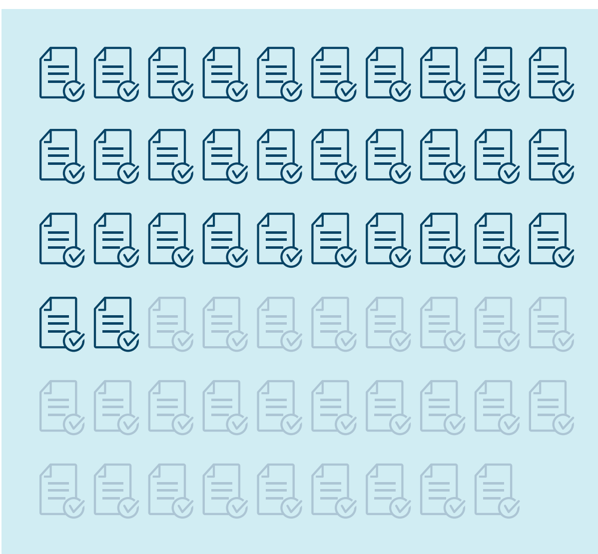
**FACTS**

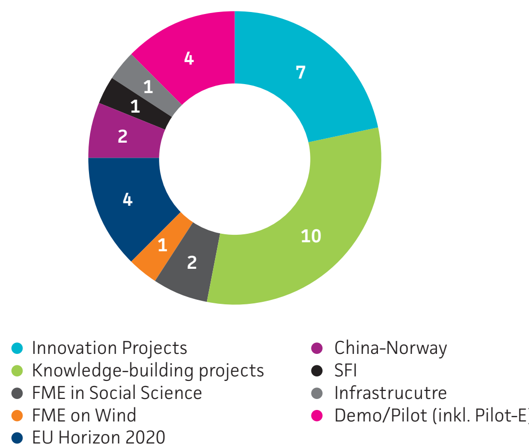
TRL: 9
Target group
- DSOs/TSOs
- Technology providers
- Researchers and consultants

# Spin-off projects

CINELDI actively contributes to applications for spin-off projects that contribute to building the electricity grid of the future. Between 2017 and 2021, 60 CINELDI-supported applications were submitted. By 15 December 2021, 59 had been evaluated and 32 were granted.

Most of the new knowledge-building projects (KSP/ RCN) and EU Horizon 2020 projects are integrated as in-kind-projects in CINELDI. We also cooperate closely with a few demo projects and innovation projects, typically funded by Enova and the Research Council of Norway.





# A stronger connection between research and application

As an FME, we are expected to contribute to innovation and value creation. One of our innovations from 2021 was a “meta innovation”– a checklist for turning results into innovations. The goal is to facilitate a better connection between scientific results and their real-world application.

By the end of 2021, CINELDI had produced more than a hundred different results. These results varied from a scenario toolbox and new algorithms, to improvements to services or work processes. Our checklist assesses the substance of the result and asks the question: what is its potential for further utilisation? It can also be used to identify target user groups, benefits, data needs, barriers, and so on.

The checklist enables us to identify the actual value of the results regarding their innovation or value creation. This facilitates the implementation of the results and can contribute to cost-benefit analyses and upscaling from pilot projects.

Our user partners and target groups vary from DSOs to technology providers, market operators, and consultancy and member organizations. During a webinar for the Consortium on 21 April, we introduced the checklist to the partners in a group work session and demonstrated its use with selected CINELDI results. The partners have responded positively to the checklist and its usefulness in the process of turning research results into applicable innovations for everyday use.

Going forward, our senior research scientists will use this checklist when reporting their results. This will enable them to pinpoint barriers to the result’s use and adjust accordingly.

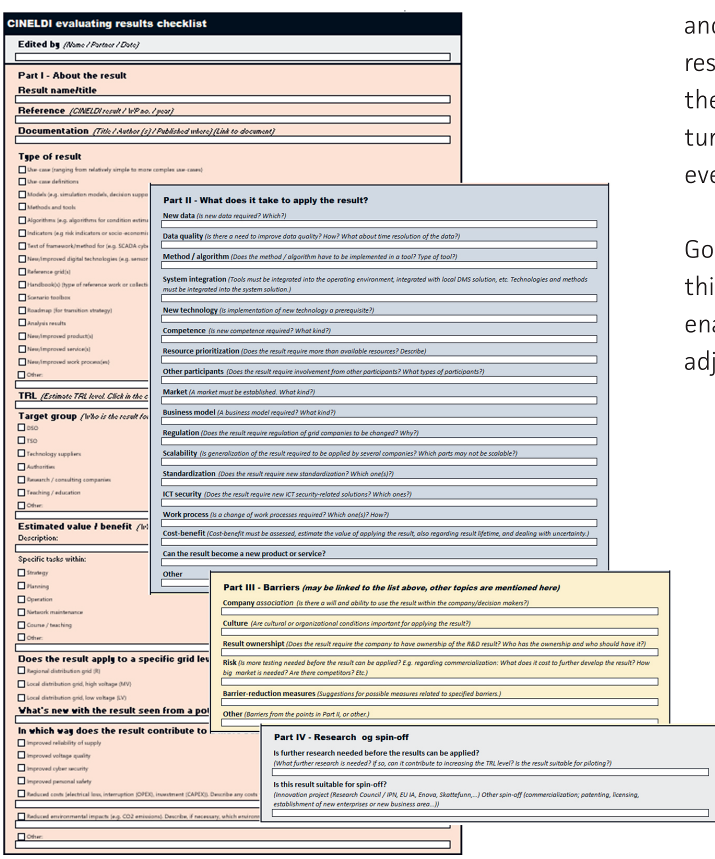



*Illustration of the checklist for evaluation of results*

# International cooperation

We aim to establish CINELDI as an international reference project in the field of flexible, intelligent, robust, and cost-efficient electricity distribution grids for the future.

To do that, we cooperate with leading international smart grid scientists, projects, research institutions and universities. Our own research scientists also actively participate with keynotes, as well as organizing and participating in panel debates at international conferences, such as *IEEE ISGT Europe, CIRED* and *AMC e-Energy*. In addition, senior researchers from CINELDI have acted as opponents of several PhD dissertations in France, Australia, India and Denmark.

We are collaborating with the University of Cagliari on a Norwegian case study, which uses the SPREAD tool to plan active distribution grids. This was presented at a webinar for the consortium. We collaborate with MIT on markets for renewable energy and in the IEA Wind Task.

The EU Horizon 2020 (EU-H2020) project *FlexPlan* conducted a joint workshop with CINELDI, facilitated by our partner Energy Norway. This workshop ensured that methods and tools developed in Europe, through the FlexPlan project, are made known to the Norwegian grid companies. Discussions and input from Norwegian actors at the workshop will ensure that future case studies planned in FlexPlan will be applicable to the Norwegian power system. In addition, postdoc researcher Ida Marie Henriksen participated in the IEA User Task *Social License to Automate* as part of WP5.

Typically, several guest scientists, associate professors and international PhD candidates visit us for longer periods throughout the year. However, due to Covid-19, all planned visits were cancelled or delayed until 2022. We will work towards resuming these researcher exchanges in 2022.

## EU cooperation in CINELDI

CINELDI has collaborated with several EU H2020 projects in 2021. The FlexPlan project involves several work packages in CINELDI (WP1, WP2, WP3, WP6). WP6 also collaborates with the research project *PAN-T-ERA*, while WP3 and WP5 collaborates with *eNeuron*. In addition, CINELDI has collaborated with the ERA-Net project *HONOR*. CINELDI also contributed to several applications to the Horizon Europe programme in 2021.

CINELDI collaborates with EERA (European Energy Research Alliance), through the projects *JP Smartgrids, SP Transmission* and *SP Energy Storage*. Furthermore, there was a collaboration to host the board meeting of EERA JP Smartgrid in connection with the CINELDI conference in Trondheim in 2020 and 2021, which would also feature some conference contributions from EERA. As the conference was cancelled both years, and because the conference in 2022 will be limited to Norwegian attendees, we now work towards hosting this meeting during the CINELDI conference 2023.

## India-Norway and China-Norway cooperation

CINELDI collaborates with the *ROME* project, which is funded as part of the India-Norway program. ROME deals with the planning and operation of microgrids. Furthermore, CINELDI collaborates with the China-Norway projects *ChiNo-ZEN* and *KeyTech-NeVe-ChiNo* (the latter via the KSP project *FuChar*).

# Recruitment

CINELDI wishes to congratulate our first three PhD candidates on successfully defending their theses. This is an important milestone for the whole centre.

CINELDI had 13 active PhD candidates and one postdoc researcher in 2021. In addition, there are eight PhD students and postdoc researchers associated with CINELDI, funded by other sources, including two industrial PhDs. These positions encompass all the disciplines covered by the Centre.

The PhD candidates actively participate in the WPs, and regularly present their results to the partners through webinars. During the CINELDI Days in November, the PhDs presented their work to our partners in a poster session. This further facilitated discussions between the PhDs and the partners on the projects and results so far.

In addition to the three completed PhDs, several candidates are now approaching completion. There were also one PhD candidate and one Postdoc researcher who began their CINELDI journey during 2021. As we are coming close to the eight years of CINELDI, our last PhD candidate will begin in 2022.

Master's theses are an important contribution to CINELDI. By the end of 2021, a total of 107 master's students had written their theses on CINELDI projects, with 24 graduating in 2021. The master's students contribute to CINELDI's research, and are potential future researchers and PhD candidates for CINELDI and our industrial partners.

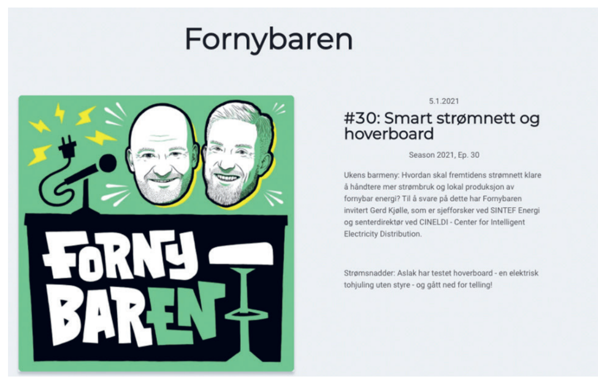
# Communications

Communication is vital for increasing the impact of the research and innovation activities in CINELDI. In CINELDI, communication between partners, key stakeholders and the public is a core activity.

Since 2016, our main communication channels have been the CINELDI website and newsletter, the SINTEF blog, and various media outlets.

## Traditional media and events

In 2021, CINELDI was featured in eight news stories in highly relevant industry media. The financial newspaper *E24* also published an op-ed, wherein CINELDI's Centre Director Gerd Kjølle and Scientific Coordinator Olav Fosso discussed how flexibility and smart grids can lower the costs of electrification. This op-ed represented an important milestone in CINELDI's goal to become more visible in the public discourse on energy and electrification.




Krister Sørbø/VG

**Slik kan kostnadene for den elektriske klimakuren krympes**

Skal vi unngå at morgendagens strømnett blir unødvendig dyrt, vil vi trenge alt fra batterier hjemme hos solkraftentusiastene til energilagre i form av industriell vanndamp.

**Gerd Kjølle** Sjefforsker, Sintef/forskningssenteret FME Cineldi
og
**Olav B. Fosso** Professor, NTNU/ forskningssenteret FME Cineldi

Publisert: 5. juli 2021

In January, Centre Director Gerd Kjølle was interviewed on Energy Norway's podcast *Fornybaren* on the topic of how we can adapt the grid to more distributed, renewable energy production and higher demands for electricity.

Later in the year she was invited to speak at Agder Energi's event "Fleksibelt kraftsystem som nøkkel til det grønne skiftet" during Arendalsuka, Norway's largest political festival. This contributed to solidifying CINELDI as a trusted advisor and expert on electrification and smart grids.

CINELDI was invited to speak at several industry conferences, including *Nettkonferansen* and *Smart-Grid-konferansen*, as well as a seminar on Cyber Security hosted by the the Norwegian Smartgrid Centre.

## Digital communication activities

**Social media**

Twitter was CINELDI's only social media platform from 2016 to 2020. However, after noticing that LinkedIn has become a relevant and efficient channel for communicating science and technology, we established a LinkedIn page for CINELDI in 2021. The page has increased our total social media following from 153 followers at the end of 2020, to 428 by December 2021.

From LinkedIn's analytics tool, we can see that our followers are highly relevant to CINELDI, with research being the top category, closely followed by utilities (water, electricity etc), higher education and oil & energy.

Our followers' engagement with our content has also increased, from 156 engagements to 622 engagements.

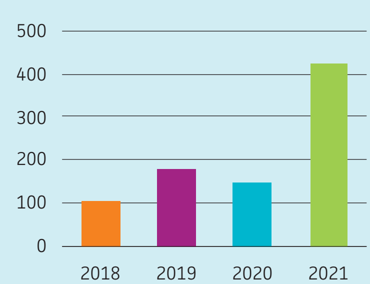
**Blog posts**

Research scientists in CINELDI are encouraged to write blog posts about their work throughout the year. Most of our blog posts summarise project results or scientific publications, and are targeted at different groups, such as private industry or governmental decision makers. Other blog posts are aimed at fellow researchers working with smart grids and related fields.

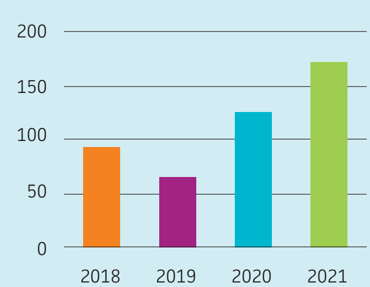
We are very pleased to see an increase in overall blog views, from 8,422 in 2020 to 12,900 in 2021.

The best performing blog post was a post on how households can use smarter power consumption to reduce their electricity bill. The post was called *Bruk strømmen smartere for å redusere strømregninga*. It was read 1,409 times with an average reading time of more than five minutes.

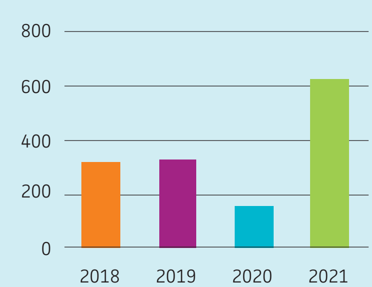
**Social media followers**




**Newsletter followers**




**Social media engagement**




**Website**
Cineldi.no had 3,628 page views in 2021. The website's primary objective is to provide information about the centre and its research, as well as associated activities and events. The website is regularly updated with research results, new innovations, and upcoming events. In 2021, a significant effort was also made to update the pilot project presentation on the website.

**Newsletters**
In 2021, we continued to send regular newsletters, with a total of three sent out over the course of the year. The newsletter has gained 48 new subscribers, resulting in a total of 172 subscribers.

**Webinars**
Webinars has become a useful activity for CINELDI. It enables frequent meetings with our partners and allows the partners to engage more with the centre. We hosted 10 webinars throughout 2021, with participants from both CINELDI partners and other actors from grid companies, technology providers and academia. It proved to be a valuable addition to our communication activities, with a satisfactory number of attendees overall.

# Appendix

## Personell

### Key researchers

| Name | Institution | Main research area |
|---|---|---|
| Irina Oleinikova | NTNU | Interaction DSO/TSO |
| Kjell Sand | NTNU | Smart grid development and asset management |
| Magnus Korpås | NTNU | Flexible resources in the power system |
| Olav B. Fosso | NTNU | Centre Management |
| Poul Einar Heegaard | NTNU | Smart grid operation |
| Sule Yildirim Yayilgan | NTNU | Smart grid development and asset management |
| Thomas Sagvold Haugan | NTNU | Smart grid operation |
| Ida Fuchs | NTNU | Centre Management |
| Borgaonkar Ravishankar | SINTEF Digital | Smart grid operation |
| Geir Mathisen | SINTEF Digital | Smart grid operation |
| Giancarlo Marafioti | SINTEF Digital | Microgrids |
| Henrik Lundqvist | SINTEF Digital | Interaction DSO/TSO |
| Inger Anne Tøndel | SINTEF Digital | Smart grid development and asset management |
| Johannes Phiilip Maree | SINTEF Digital | Microgrids |
| Kristoffer Nyborg Gregertsen | SINTEF Digital | Interaction DSO/TSO |
| Martin Gilje Jaatun | SINTEF Digital | Smart grid operation |
| Sture Holmstrøm | SINTEF Digital | Centre Management |
| Synne Fossøy | SINTEF Digital | Flexible resources in the power system |
| Lars Flå | SINTEF Digital | Smart grid operation |
| GencerErdogan | SINTEF Digital | Smart grid development and asset management |
| Shukun Tokas | SINTEF Digital | Smart grid development and asset management |
| Kjersti Berg | SINTEF Energi | Microgrids |
| Maren Brubæk | SINTEF Energi | Microgrids |
| Merkebu Zenebe Degefa | SINTEF Energi | Smart grid operation |
| Michele Garau | SINTEF Energi | Smart grid development and asset management |
| Oddbjørn Gjerde | SINTEF Energi | Smart grid development and asset management |
| Eirik Haugen | SINTEF Energi | Smart grid scenarios and transition strategies |
| Maren Istad | SINTEF Energi | Centre Management |
| Sigurd Hofsmo Jakobsen | SINTEF Energi | Smart grid scenarios and transition strategies |
| Gerd Kjølle | SINTEF Energi | Smart grid scenarios and transition strategies |
| Jonatan Klemets | SINTEF Energi | Smart grid operation |
| Venkatachalam Lakshmanan | SINTEF Energi | Flexible resources in the power system |

| Name | Institution | Main research area |
| --- | --- | --- |
| Kjell Ljøkelsøy | SINTEF Energi | Smart grid operation |
| Markus Löschenbrand | SINTEF Energi | Flexible resources in the power system |
| Andrei Z Morch | SINTEF Energi | Interaction DSO/TSO |
| Santiago Sanchez-Acevedo | SINTEF Energi | Smart grid operation |
| Eivind Solvang | SINTEF Energi | Smart grid development and asset management |
| Iver Bakken Sperstad | SINTEF Energi | Smart grid development and asset management |
| Hanne Sæle | SINTEF Energi | Interaction DSO/TSO |
| Henning Taxt | SINTEF Energi | Smart grid operation |
| Raymundo E Torres-Olguin | SINTEF Energi | Microgrids |
| Bendik NybakkTorsæter | SINTEF Energi | Smart grid development and asset management |
| Tesfaye Amare Zerihun | SINTEF Energi | Smart grid operation |
| Rubi Rana | SINTEF Energi | Microgrids |
| Bjørnar Fjelldal | SINTEF Energi | Microgrids |
| Erlend Sandø Kiel | SINTEF Energi | Smart grid scenarios and transition strategies |
| Håkon Toftaker | SINTEF Energi | Smart grid scenarios and transition strategies |
| Berkehagen Daniel | SINTEF Energi | Smart grid development and asset management |
| Susanne Sandell | SINTEF Energi | Flexible resources in the power system |

### Postdoctoral researchers with financial support from the Centre budget

| Name | Nationality | Period | Sex M/F | Topic |
| --- | --- | --- | --- | --- |
| Ida Marie Henriksen | Norge | 06.04.2020-01.05.2024 | F | The role of intermediaries in demand response service |

### Postdoctoral researchers working on projects in the centre with financial support from other sources

| Name | Funding | Nationality | Period | Sex M/F | Topic |
| --- | --- | --- | --- | --- | --- |
| Chendan Li | NTNU - SO | Norwegian | 01/2019 - 01/2021 | F | Methods and tools for stability assessment of microgrid systems dominated by Power Electronic converters. |
| Soumya Das | ROME-project - Indnor | India | 02/2020 - 02/2022 | M | Integrated methods and tools for planning and operation of Microgrids |

**PhD students with financial support from the Centre budget**

| Name | Nationality | Period | Sex M/F | Topic | Completed |
|---|---|---|---|---|---|
| Mohammad Ali Abooshabab | Iran | 08.2017-08.2021 | M | Distributed and hierarchical dynamic state estimation for smart distribution grids | x |
| Fredrik T.B.W Göthner | Norway | 08.2017-11.2021 | M | Smart power control in microgrids with modern power converters | x |
| Ingvild Fjellså | Norway | 03.2017-06.2022 | F | Understanding mechanisms and incentives for motivating user flexibility | |
| Güray Kara | Turkey | 06.2017-01.2022 | M | Techno-economic optimization for analysing consumer flexibility and related market structures | x |
| Fredrik Bakkevig Haugli | Norway | 09.2017-01.2022 | M | Distributed and centralized control to support smart grid operation with high quality in a cost-efficient way | |
| Romina Muka | Albania | 01.2018-07.2021 | F | Self-Healing and Autonomous Smart Grid Operation | |
| Kalpanie Mendis | Sri Lanka | 01.2018-06.2023 | F | 5G for Low-Latency, Secure, and Dependable Communication Services for Fault Handling in Micro Grids | |
| Kasper Thorvaldsen | Norway | 09.2018-08.2022 | M | The value of buildings' energy flexibility in the power market | |
| Stine Fleischer Myhre | Norway | 08.2019-07.2022 | F | Risk and vulnerability in the future intelligent electricity distribution system | |
| Maciej Grebla | Poland | 11.2019-05.2020 | M | Power system protection in microgrids | |
| Outi Pitkänen | Finland | 04.2020-04.2023 | F | Integrating consumer (end-user) knowledge in demand-response technology and service design | |
| Emil Dimanchev | Bulgaria | 08.2020-07.2023 | M | Utilization of electric vehicle storage flexibility in modern power grids | |

| Name | Nationality | Period | Sex M/F | Topic | Completed |
|---|---|---|---|---|---|
| Natasa Gajic | Serbia | 05.2021-05.2025 | F | Methods for assessment of the cyber-physical security of smart grid operations in the presence of large-scale and controllable DER | |
| Dung-Bai Yen | Taiwan | 09.2021-09.2024 | M | Trasition pathways for smart distribution grids in view of market designs, regulation and other incentives | |

**PhD students working on projects in the centre with financial support from other sources**

| Name | Funding | Nationality | Period | Sex M/F | Topic | Completed |
|---|---|---|---|---|---|---|
| Salman Zaferanlouei | NTNU | Iran | 2016-2020 | M | Integration of electric vehicles into power distribution systems | x |
| Sjur Føyen | NTNU - SO | Norwegian | 2018-2022 | M | Methods and tools for stability assessment of microgrid systems dominated by Power Electronic converters. | |
| Per Aaslid | SINTEF - PhD | Norwegian | 2018-2022 | M | Optimal coordination of distributed flexible resources | |
| Tesfaye Amare Zerihun | NTNU, IE | Ethiopia | 2015-2020 | M | Quantitative Modelling of Digital Ecosystems (Case study: smart distribution grid) | x |
| Charles Mawutor Adhra | KPN ProSmart | Ghana | 2015-2020 | M | Communication Networks for Protection Systems in Smart Transmission Grids | x |
| Mostafa Barani | RSO-TSO Energi, NTNU Project Number: 81770920 | Iran | 2018-2021 | M | Reliability Studies in Information and Communication Technology (ICT)-dominated Power Systems | |
| Matthias Hofmann | Statnett/ NFR (Industry PhD) | German | 2018-2021 | M | Flexible demand as an alternative to investments in the transmission grid | |

| Name | Funding | Nationality | Period | Sex M/F | Topic | Completed |
|---|---|---|---|---|---|---|
| Sigurd Bjarghov | NTNU | Norge | 2018-2022 | M | Consumer-centric electricity market design integration peer-to-peer and flxibility markets | |
| Kjersti Berge | FINE | Norge | 2021-2023 | F | Integration of Local Energy Communities into the Norwegian Electricity Distribution System | |
| Aurora Flataaker | FuChar | Norge | 2021-2023 | F | Long-term grid planning considering the electricity demand and flexibility potential of electric transport | |

**Master thesis in 2021**

| Name | Sex M/F | Topic |
|---|---|---|
| Amanda Njøten and Stine Morberg Larsen | F/F | Resource allocation and pricing for residential flexibility services (coop with NTRANS) |
| Annvor Teigen and Anders Grøttås | F/M | Flexibility Solutions in Distribution Networks. Case Study Utsira |
| Daniel Bolstad | M | Load forecasting using Elhub Data and Machine Learning - A New Era? |
| Erik Seeger Bjørnerem | M | Utnyttelse av fleksibilitet i kraftmarkeder dominert av fornybare energikilder: Modellering og optimalisering |
| Erlend Øye | M | A Practical Application of an Active Distribution Grid Planning Framework in Relation to a Pilot Area for New Energy Solutions |
| Frida Bratlie | F | Flexibility market development for Utsira Island |
| Henrik Waterloo | M | Assessing local flexibility resources in Zero Energy Buildings - Household appliances and domestic hot water |
| Ida Langseth | F | V2X services for increasing utilization of flexibility in EV charging infrastructure (Coop with KPN FuChar) |
| Ine Ingebrigtsen Svendsen | F | Characterization of electrical flexibility of water boilers |
| Jacob Wang | M | Long-term Peak Power and Energy Forecasting in Norwegian Electricity Grids |
| Jostein Johansen Lyngen | M | Optimal planning and operation of micro grid |

| Name | Sex M/F | Topic |
|---|---|---|
| Kyrre Kirkbakk Fjær | M | Optimal integration of high-power charging infrastructure for electric transport in the Norwegian distribution grid |
| Lars Halvdan Flå | M | Threat Modeling Framework for Smart Grids |
| Malin Kaaløy | F | Assessing local flexibility resources in a Zero Emission neighbourhood - Heat demand (Coop with FME ZEN) |
| Maria Claire Westad | F | Assessing local flexibility resources in a Zero Emission neighbourhood for DSOs - Electric vehicles |
| Matias Kraft Vistnes | M | Modelling and studies of mutual dependency in a combined electrical power and ICT network |
| Oda Skeie | F | Converter control strategy for seamless interconnection of microgrids in a multigrid-configuration |
| Ole Andreas Sloth | M | Time series forecasting of consumption load to estimate flexibility |
| Sanna Løfqvist and Mari Langås | F/F | Cybersecurity Preparedness Exercises in Smart Grid: Collaboration with Suppliers During Incident Response |
| Synnøve Hovden | F | Energy management of microgrids |
| Viljar Stensaker Stave | M | Optimal utilization of grid capacity for connection of new renewable power plants |

## Statement of account

*(All figures in 1000 NOK)*

| FUNDING | Amount | in-kind | Sum |
|---|---|---|---|
| The Research Council | 20454 | | 20454 |
| The Host Institution SINTEF Energi | | 2025 | 2025 |
| **Research Partners** | | | |
| NTNU | | 1348 | 1348 |
| SINTEF Digial | | 1200 | 1200 |
| **Enterprise partners** | | | |
| DSOs | 6850 | 10473,1 | 17323,1 |
| TSOs | 500 | 164 | 664 |
| Vendors | 300 | 3385 | 3685 |
| Member organizations | 200 | 435 | 635 |
| **Public partners** | | | |
| Authorities | 300 | 70 | 370 |
| **sum** | **28604** | **19100,1** | **47704,1** |

| COSTS | | | |
|---|---|---|---|
| The Host Institution SINTEF Energi | 16140 | 2025 | 18165 |
| Research Partners | 12464 | 2548 | 15012 |
| Enterprise partners | | 14457,1 | 14457,1 |
| Public partners | | 70 | 70 |
| **Sum** | | | **47704,1** |

## CINELDI Dissemination and communication 2021

### Peer reviewed journal publications


1. A Robust Circuit and Controller Parameters Identification Method of Grid-Connected Voltage Source Converters Using Vector Fitting Algorithm. IEEE Journal of Emerging and Selected Topics in Power Electronics 2021. Zhou, Weihua; Torres Olguin, Raymundo E.; Göthner, Fredrik T. B. W.; Beerten, Jef; Zadeh, Mehdi; Wang, Yanbo; Chen, Zhe
2. A stochastic operational planning model for a zero emission building with emission compensation. Applied Energy 2021 ;Volum 302. Thorvaldsen, Kasper Emil; Korpås, Magnus; Lindberg, Karen Byskov; Farahmand, Hossein
3. A Systematic Mapping Study on Approaches for AI-Supported Security Risk Assessment. Computer Software and Applications Conference 2021 s. 755-760. Erdogan, Gencer; Garcia-Ceja, Enrique; Hugo, Åsmund Pedersen; Nguyen, Phu Hong; Sen, Sagar
4. A Systematic Mapping Study on Cyber Security Indicator Data. Electronics 2021 ;Volum 10.(9). Meland, Per Håkon; Tokas, Shukun; Erdogan, Gencer; Bernsmed, Karin; Omerovic, Aida
5. A Temporal Neural Network Model for Probabilistic Multi-Period Forecasting of Distributed Energy Resources. IEEE Access 2021 ;Volum 9. s. 147029-147041. Loschenbrand, Markus
6. A two-level over-voltage control strategy in distribution networks with high PV penetration. International Journal of Electrical Power & Energy Systems (IJEPE) 2021. Emarati, Mohammadreza; Barani, Mostafa; Farahmand, Hossein; Aghaei, Jamshid; Crespo del Granado, Pedro
7. Apparent Impedance-Based Adaptive Controller for Improved Stability of Droop-Controlled Microgrid. IEEE transactions on power electronics, 2021. Göthner, Fredrik T. B. W.; Torres Olguin, Raymundo E.; Roldan-Pérez, Javier; Rygg, Atle; Midtgård, Ole-Morten
8. BATTPOWER Toolbox: Memory-Efficient and High-Performance Multi-Period AC Optimal Power Flow Solver. IEEE Transactions on Power Systems, Volume 36, Issue 5, 2021. Zaferanlouei, Salman; Farahmand, Hossein; Vadlamudi, Vijay Venu; Korpås, Magnus
9. Comprehensive classifications and characterizations of power system flexibility resources. Elseiver, Electric Power Systems Research (EPSR), Vol 194, May 2021. Degefa, Merkebu Zenebe; Sperstad, Iver Bakken; Sæle, Hanne
10. Developments and Challenges in Local Electricity Markets: A Coprehensive Review. IEEE Access, Volume 9, 2021. Bjarghov, Sigurd; Löschenbrand, Markus; Ibn Saif, A.U.N.; Pedrero, Raquel Alonso; Pfeiffer, Christian; Khadem, Shafiuzzaman K.; Rabelhofer, Marion; Revheim, Frida Huglen; Farahmand, Hossein
11. Economic evaluation of operation strategies for battery systems in football stadiums: A Norwegian case study. Journal of Energy Storage, Vol 34. Berg, Kjersti; Resch, Matthias Johannes; Weniger, Thaddäus; Simonsen, Stig
12. Electric vehicle charging and end-user motivation for flexibility: a case study from Norway. Energy, Sustainability and Society, Volume 11, Article number: 44, 2021. Henriksen, I. M., Throndsen, W., Ryghaug, M., & Skjølsvold, T. M.
13. Electric water heater flexibility potential and activation impact in system operator perspective – Norwegian scenario case study. Energy, Volume 236, 2021. Lakshmanan, Venkatachalam; Sæle, Hanne; Degefa, Merkebu Zenebe
14. Flexibility poverty: 'locked-in' flexibility practices and electricity use among students. Energy Sources, Part B: Economics, Planning and Policy, 2021. Fjellså, Ingvild Firman; Ryghaug, Marianne; Skjølsvold, Tomas Moe
15. Flexibility-Enhancing Charging Station to Support the Integration of Electric Vehicles. World Electric Vehicle Journal, 12(2), 53, 2021. Ilieva, Iliana; Bremdal, Bernt
16. Harmonic Virtual Impedance Design for Optimal Management of Power Quality in Microgrids. IEEE Transactions on Power Electronics, Volume 36, Issue 9, 2021. Göthner, Fredrik T. B. W.; Roldan-Pérez, Javier; Torres Olguin, Raymundo E.; Midtgård, Ole-Morten
17. Impact of local electricity markets and peer-to-peer trading on low-voltage grid operations. Applied Energy, Vol. 301, Nov 2021. Dynge, Marthe Fogstad; Crespo del Granado, Pedro; Hashemipour, Seyed Nasar; Korpås, Magnus
18. Improving Smart Grid Security through 5G Enabled IoT and Edge Computing. Wiley Journal on SPECIAL ISSUE of

Concurrency and Computation on SECURE MOBILE CLOUD COMPUTING, 2021. Borgaonkar, Ravishankar Bhaskarrao; Tøndel, Inger Anne; Degefa, Merkebu Zenebe; JAATUN, Martin Gilje
19. Justice aspects of flexible household electricity consumption in future smart energy systems. Environmental Innovation and Societal Transitions 2021 ;Volum 38. s.98-109. Fjellså, Ingvild Firman; Silvast, Antti; Skjølsvold, Tomas Moe
20. Long-term Value of Flexibility from Flexible Assets in Building Operation. IEEE Transactions on Sustainable Energy. Thorvaldsen, Kasper Emil; Farahmand, Hossein; Korpås, Magnus
21. Reduced-Order Model of Distributed Generators with Internal Loops and Virtual Impedance. IEEE Transactions on Smart Grid, 2021. Göthner, Fredrik T. B. W.; Roldan-Pérez, Javier; Torres Olguin, Raymundo E.; Midtgård, Ole-Morten
22. Simultaneous input & state estimation, singular filtering and stability. Elsevier, Automatica, vol 137, 2022. Abooshahab, Mohammad Ali; Alyaseen, Mohammed M.J.; Bitmead, Robert R.; Hovd, Morten
23. Social license to automate: A critical review of emerging approaches to electricity demand management. Energy Research & Social Science, Vol. 80, Oct 2021. Adams, Sophie; Kuch, Declan; Diamond, Lisa; Fröhlich, Peter; Henriksen, Ida Marie; Kattzeff, Cecilia; Ryghaug, Marianne; Yilmaz, Selin
24. The Impact of Uncertainty and Time Structure on Optimal Flexibility Scheduling in Active Distribution Networks. IEEE Transactions on Smart Grid, Vol. 9, 2021. Kara, Güray; Pisciella, Paolo; Tomasgard, Asgeir; Farahmand, Hossein
25. Utilizing Local Flexibility Resources to Mitigate Grid Challenges at Electric Vehicle Charging Stations. Energies, Vol. 14, Iss. 12, 2021. Ilieva, Iliana; Bremdal, Bernt

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1. A Norwegian Case Study on Battery Storage as Alternative to Grid Reinforcement. IEEE Madrid PowerTech. IEEE, ISBN 978-1-6654-3597-0, 2021. Brubæk, Maren Refsnes; Korpås, Magnus
2. A Testbed for Advanced Distribution Management Systems: Assessment of Cybersecurity. IEEE PES Innovative Smart Grid Technologies Conference Europe - ISGT Europe. IEEE, ISBN 978-1-6654-4875-8, 2021. Degefa, Merkebu Zenebe; Acevedo, Santiago Sanchez; Borgaonkar, Ravishankar
3. Agent-Based Analysis of Spatial Flexibility in EV Charging Demand at Public Fast Charging Stations. IEEE Madrid PowerTech. IEEE, ISBN 978-1-6654-3597-0, 2021. Garau, Michele; Torsæter, Bendik Nybakk
4. Ancillary services from a residential community - a Norwegian case study. International Conference on Smart Energy Systems and Technologies - SEST. IEEE, ISBN 978-1-7281-7660-4, 2021. Rana, Rubi; Berg, Kjersti; Brubæk, Maren Refsnes; Fosso, Olav B.
5. Battery Degradation-Aware Congestion Management in Local Flexibility Markets. IEEE Madrid PowerTech. IEEE, ISBN 978-1-6654-3597-0. s. 1-6, 2021. Bjarghov, Sigurd; Kalantar-Neyestanaki, Mohsen; Cherkaoui, Rachid; Farahmand, Hossein
6. Charging Profile Generation Tool for Grid Planning and Flexibility Assessment of EV Fleets. International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe - EEEIC / I&CPS Europe. IEEE, ISBN 978-1-6654-3613-7, 2021. Lakshmanan, Venkatachalam; Torsæter, Bendik Nybakk; Sæle, Hanne; Hjelkrem, Odd Andre
7. Coordinated Voltage Support with Reactive Power from High-power Charging Stations for Evs. IEEE Madrid PowerTech. IEEE, ISBN 978-1-6654-3597-0, 2021. Rana, Rubi; Torsæter, Bendik Nybakk
8. Co-simulation and Discrete Event Simulation for Reliability Assessment of Power System and ICT. 5th International Conference on System Reliability and Safety (ICSRS). IEEE, ISBN 978-1-6654-0049-7. s. 66-73, 2021. Garau, Michele; Muka, Romina; Heegaard, Poul Einar; Helvik, Bjarne Emil
9. Development of Smart Grid Standards in View of Energy System Functionalities. 6th International Conference on Smart and Sustainable Technologies - SpliTech. IEEE, ISBN 978-953-290-112-2, 2021. Mutule, Anna; Antoskova, Irina; Papadimitriou, Christina; Efthymiou, Venizelos; Morch, Andrei
10. Distributed H_∞ Filtering for Linear and Nonlinear Systems. IEEE Conference on Control Technology and

Applications (CCTA). IEEE conference proceedings, ISBN 978-1-6654-3643-4, 2021. Abooshahab, Mohammad Ali; Hovd, Morten
11. Effect of 5G communication service failure on placement of Intelligent Electronic Devices in Smart Distribution Grids. IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids - SmartGridComm. IEEE, ISBN 978-1-6654-1502-6. s. 308-314, 2021. Muka, Romina; Garau, Michele; Heegaard, Poul E.
12. EMS2aaS: A Dockerized framework for remote EMS deployment. International Conference on Smart Energy Systems and Technologies - SEST. IEEE, ISBN 978-1-7281-7660-4, 2021. Marafioti, Giancarlo; Fossøy, Synne; Maree, Johannes Philippus; Sperstad, Iver Bakken
13. Experience from Norwegian Intelligent Electricity Distribution pilot projects. CIRED 2021 - The 26th International Conference and Exhibition on Electricity Distribution. Institution of Engineering and Technology (IET), ISBN 978-1-83953-591-8. s. 3339-3343, 2021. Sæle, Hanne; Istad, Maren Kristine; Oland, Signe Marie; Kjerpeset, Sven Arild; Johansen, Regine; Hagen, Hallstein; Hansen, Kristian Finborud; Nesse, Leif E.
14. Generating scenarios from probabilistic short-term load forecasts via non-linear Bayesian regression. International Conference on Smart Energy Systems and Technologies - SEST. IEEE, ISBN 978-1-7281-7660-4, 2021. Löschenbrand, Markus; Gros, Sebastien; Lakshmanan, Venkatachalam
15. Genetic Algorithm for Placement of IEDs for Fault Location in Smart Distribution Grids. The 26th International Conference and Exhibition on Electricity Distribution. Institution of Engineering and Technology (IET), ISBN 978-1-83953-591-8. s. 1639-1643, 2021. Muka, Romina; Garau, Michele; Heegaard, Poul E.
16. Heavy-duty electric vehicle charging profile generation method for grid impact analysis. International Conference on Smart Energy Systems and Technologies - SEST. IEEE, ISBN 978-1-7281-7660-4, 2021. Fjær, Kyrre Kirkbakk; Lakshmanan, Venkatachalam; Torsæter, Bendik Nybakk; Korpås, Magnus
17. Hunting Dependencies: Using Bow-Tie for Combined Analysis of Power and Cyber Security. 2nd International Conference on Societal Automation - SA. IEEE, ISBN 978-1-7281-9690-9, 2021. Tøndel, Inger Anne; Vefsnmo, Hanne; Gjerde, Oddbjørn; Johannessen, Frode; Frøystad, Christian
18. Implementing the Clean Energy Package: Best Practices and Overcoming Barriers. The 26th International Conference and Exhibition on Electricity Distribution. Institution of Engineering and Technology (IET), ISBN 978-1-83953-591-8. s. 3249-3253, 2021. Morch, Andrei Z; Papadimitriou, Christina; Efthymiou, Venizelos; Mutule, Anna; Berg, Kjersti
19. Intent-based Network Management and Orchestration for Smart Distribution Grids. 28th International Conference on Telecommunications. IEEE, ISBN 978-1-6654-1376-3. s. 114-119, 2021. Mehmood, Kashif; Mendis, Handunneththi V. Kalpanie; Kralevska, Katina; Heegaard, Poul Einar
20. Low-complexity Risk-averse MPC for EMS. IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids - Smart-GridComm. IEEE, ISBN 978-1-6654-1502-6, 2021. Maree, Johannes Philippus; Gros, Sebastien; Lakshmanan, Venkatachalam
21. Modelling framework for study of distributed and centralized smart grid system services. IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids - SmartGridComm. IEEE, ISBN 978-1-6654-1502-6, 2021. Haugli, Fredrik Bakkevig; Heegaard, Poul Einar
22. MPC-based Voltage Control with Reactive Power from High-Power Charging Stations for Evs. IEEE Madrid PowerTech. IEEE, ISBN 978-1-6654-3597-0, 2021. Klemets, Jonatan Ralf Axel; Torsæter, Bendik Nybakk
23. Operational Valuation for Energy Storage under Multi-stage Price Uncertainties. IEEE Conference on Decision and Control, 2021. Xu, Bolun; Botterud, Audun; Korpås, Magnus
24. Optimal Sensor Placement for Partially Known Power System Dynamic Estimation. IEEE PES Innovative Smart Grid Technologies Conference Europe - ISGT Europe. IEEE, ISBN 978-1-6654-4875-8, 2021. Abooshahab, Mohammad Ali; Hovd, Morten; Valmorbida, Giorgio
25. Optimal Utilisation of Grid Capacity for Connection of New Renewable Power Plants in Norway. International Conference on Smart Energy Systems and Technologies - SEST. IEEE, ISBN 978-1-7281-7660-4. s. 1-6, 2021. Stave, Viljar Stensaker; Dynge, Marthe Fogstad; Farahmand, Hossein; Korpås, Magnus; Cali, Umit

26. Optimisation model with degradation for a battery energy storage system at an EV fast charging station. IEEE Madrid PowerTech. IEEE, ISBN 978-1-6654-3597-0, 2021. Haugen, Eirik; Berg, Kjersti; Torsæter, Bendik Nybakk; Korpås, Magnus
27. Power Unavailability Reduction in Distribution Grid Fault Management with Entropy Minimization. 5th International Conference on System Reliability and Safety (ICSRS). IEEE, ISBN 978-1-6654-0049-7. s. 32-41, 2021. Garau, Michele; Helvik, Bjarne Emil
28. Research and Innovation Supporting Energy Transition: Challenges for Wider Participation of Lagging Countries. IEEE Madrid PowerTech. IEEE, ISBN 978-1-6654-3597-0, 2021. Mutule, Anna; Antoskova, Irina; Efthymiou, Venizelos; Papadimitriou, Christina; Morch, Andrei Z
29. Review of Grid Interconnection Requirements and Synchronization Controllers for Dispersed Minigrids. IEEE PES/IAS PowerAfrica. IEEE, ISBN 978-1-6654-0311-5, 2021. Degefa, Merkebu Zenebe; Klemets, Jonatan Ralf Axel; D'Arco, Salvatore; Sekhar, P.C.; Gupta, Amit
30. Saving Nine Without Stitching in Time: Integrity Check After-the-fact. 2nd International Conference on Societal Automation (SA). IEEE, ISBN 978-1-7281-9690-9, 2021. Gudmestad, Racin; Houmb, Siv Hilde; Jaatun, Martin Gilje
31. Scenarios for the future electricity distribution grid. The 26th International Conference and Exhibition on Electricity Distribution. Institution of Engineering and Technology (IET), ISBN 978-1-83953-591-8. s. 3259-3263, 2021. Kjølle, Gerd Hovin; Sand, Kjell; Gramme, Eivind
32. Tool-assisted Threat Modeling for Smart Grid Cyber Security. International Conference on Cyber Situational Awareness, Data Analytics and Assessment (CyberSA): Cyber Science - Trustworthy and Transparent Artificial Intelligence. IEEE conference proceedings, ISBN 978-1-6654-2529-2, 2021. Flå, Lars; Borgaonkar, Ravishankar Bhaskarrao; Tøndel, Inger Anne; JAATUN, Martin Gilje
33. Transient Performance Modelling of 5G Slicing with Mixed Numerologies for Smart Grid Traffic. IEEE 26th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD). IEEE, ISBN 978-1-6654-1779-2. s. 1-7, 2021. Mendis, Handunneththi V. Kalpanie; Heegaard, Poul Einar; Casares-Giner, Vicente; Li, Frank Yong; Kralevska, Katina
34. With a Little Help from Your Friends: Collaboration With Vendors During Smart Grid Incident Response Exercises. European Interdisciplinary Cybersecurity Conference (EICC). Association for Computing Machinery (ACM), ISBN 978-1-4503-9049-1. s. 46-53, 2021. Langås, Mari; Løfqvist, Sanna; Katt, Basel; Haugan, Thomas Sagvold; Jaatun, Martin Gilje

**Presentations**

1. Grid Interconnection of largely dispersed minigrids. IEEE PES INNOVATIVE SMART GRID TECHNOLOGIES CONFERENCE EUROPE. Degefa, Merkebu Zenebe; Endegnanew, Atsede Gualu; Ranjan, Abhishek; Perumalla, Chandrasekhar; D'Arco, Salvatore; Garces Ruiz, Alejandro; Kotsampopoulos, Panos
2. A Systematic Mapping Study on Approaches for AI-Supported Security Risk Assessment. IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC). Erdogan, Gencer
3. Agent-Based Analysis of Spatial Flexibility in EV Charging Demand at Public Fast Charging Stations. IEEE Madrid PowerTech. Garau, Michele
4. Alternative forretningsmodeller for fleksibilitet - for bedre utnyttelse av strømnettet. Nettkonferansen 2021. Sæle, Hanne
5. Batterier som en del av et klimavennlig energisystem. NTNU Kveld. Magnus Korpås
6. Battery Degradation-Aware Congestion Management in Local Flexibility Markets. IEEE Madrid PowerTech. Bjarghov, Sigurd; Kalantar-Neyestanaki, Mohsen; Cherkaoui, Rachid; Farahmand, Hossein
7. Behov for kunnskap om samspill mellom komponenter og system i fremtidens system. Workshop om primærkomponenter. Kjølle, Gerd Hovin
8. Charging Profile Generation Tool for Grid Planning and Flexibility Assessment of EV Fleets. IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe - EEEIC / I&CPS Europe. Lakshmanan, Venkatachalam
9. CINELDI - Forskning relevant for Strømnettutvalget. Møte med Strømnettutvalget. Kjølle, Gerd Hovin; Gjerde, Oddbjørn; Sperstad, Iver Bakken; Istad, Maren Kristine

10. CINELDI activities on flexibility and grid planning: Classification, characterization, barriers and potential as seen from a Norwegian perspective. DiPoFlex workshop. Hanne Sæle
11. CINELDI: Den fleksible forbrukeren. HydroCen Fagutvalg. Hanne Sæle
12. Contribution to webinar "Pilot Society and the Energy Transition: The co-shaping of innovation, participation and politics". Pilot Society and the Energy Transition: The co-shaping of innovation, participation and politics. Istad, Maren Kristine
13. Coordinated Voltage Support with Reactive Power from High-power Charging Stations for EVs. IEEE Madrid Power-Tech. Rana, Rubi
14. Den fleksible forbrukerens rolle i fremtidens miljøvennlige energisystem. Eksperter i Team. Hanne Sæle
15. Digitalisering medfører endret risikobilde – hvordan bør sikkerheten håndteres?. Smartgridkonferansen 2021. Inger Anne Tøndel
16. Digitaliserte og integrerte energisystemer - Forsknings-agenda. Strategimøte Digitaliserte og integrerte energisystemer. Gerd Kjølle
17. Disturbance and State Estimation in Partially Known Power Networks. The 3rd IEEE Conference on Control Technology and Applications (CCTA 2019). Abooshahab, Mohammad Ali; Hovd, Morten; Bitmead, Robert R.
18. Electricity Markets with high RES shares – Price formation and cost recovery. WinGrid Scientific Workshop on Power System Balancing and Operation with Large Shares of Wind Power. Korpås, Magnus
19. Elektrifiseringens utfordringer løses gjennom tverrfaglig samarbeid. Energiforskningskonferansen, Norges forskningsråd. Gerd Kjølle
20. Er fleksibilitet alltid et godt alternativ til nettutbygging?. Fagseminar om fleksibilitet i distribusjonsnettet. Sperstad, Iver Bakken
21. Experience form Norwegian intelligent electricity distribution pilot projects. CIRED 2021. Sæle, Hanne; Istad, Maren Kristine; Oland, Signe Marie; Kjerpeset, Sven Arild; Johansen, Regine; Hagen, Hallstein; Hansen, Kristian Finborud; Nesse, Leif E.
22. Experiences from CINELDI WP3. ISGAN Workshop on "Flexibility for Resilience" Annex 6. Hanne Sæle
23. Fleksibelt kraftsystem som nøkkelen til det grønne skiftet – i et forskningsperspektiv. Arendalsuka, Agder Energo. Kjølle, Gerd Hovin
24. Fleksibilitet i CINELD. Heimdall Power kundesamling. Istad, Maren Kristine
25. Fleksibilitet, elbil-lading og v2g: Erfaringer fra CINELDI. FME NTRANS Workshop om samfunnsverdien av lokal fleksibilitet. Magnus Korpås
26. Fleksibilitetsressurser og hvordan de kan benyttes i systemtjenester. DiPoFlex workshop. Hanne Sæle
27. Fremtidens kraftnett. Fagdag Energi, Grønn omstilling. Gerd Kjølle
28. Grid Interconnection of largely dispersed minigrids. ISGT-EUROPE 2021. Degefa, Merkebu Zenebe; Endegnanew, Atsede Gualu; Ranjan, Abhishek; Perumalla, Chandrasekhar; D'Arco, Salvatore; Garces Ruiz, Alejandro; Kotsampopoulos, Panos
29. Heavy-duty electric vehicle charging profile generation method for grid impact analysis. International Conference on Smart Energy Systems and Technologies - SEST. Fjær, Kyrre Kirkbakk
30. How to ensure the security of electricity supply in light of climate change and the transition to the future Smart Grid. Women in Power Engineering Session. Gerd Kjølle
31. Hunting Dependencies: Using Bow-Tie for Combined Analysis of Power and Cyber Security Using Bow-Tie for Combined Analysis of Power and Cyber Security. 2020 2nd International Conference on Societal Automation (SA). Inger Anne Tøndel, Hanne Vefsnmo, Oddbjørn Gjerde, Frode Johannessen, Christian Frøystad
32. Hvilken rolle kan batterier spille i kraftsystem framover?. #Klimafrokost om batterier som klimaløsning og del av kraftsystemet. Magnus Korpås
33. Hvordan velge riktige løsninger for solenergi i distribusjonsnettet? Forenklet regneeksempel på samfunnsøkonomisk kost/nytte. Solar Energy Webinar - Integrasjon av solcelleanlegg i det elektriske distribusjons-nettet. Sperstad, Iver Bakken
34. Implications of delays in fleet turnover policy implementations. Implications of delays in fleet turnover policy implementations. Qorbani, Davood; Dimanchev, Emil; Korpås, Magnus

35. Linking Local and European Emission Targets - A Capacity Expansion Study. IEA WIND Task 25 Design and operation of energy systems with large amounts of variable generation. 31st Research Meeting. Magnus Korpås
36. Local Electricity Market: Impact to low-volage operations, Scalability of P2P, and new marketplaces. Energy Transition Conference 2021. Crespo del Granado, Pedro; Korpås, Magnus; Hashemipour, Naser; Dynge, Marthe Fogstad
37. MPC-based Voltage Control with Reactive Power from High-Power Charging Stations for EVs. 2021. IEEE Madrid PowerTech. Klemets, Jonatan Ralf Axel
38. On the profitability of market participants in decarbonized power systems. MIT Applied Energy Conf. Korpås, Magnus; Tarel, Guillaume; Botterud, Audun
39. Optimal grid integration of aggregated EV charging interfaces with large demand. AEIT-Automotive 2021 - Panel 1: The future of distribution system with e-mobility. Torsæter, Bendik Nybakk
40. Optimal grid integration of high-power charging infrastructure for EVs. CIRED 2021 - Round Table 3: Distribution Planning and E-Mobility. Torsæter, Bendik Nybakk
41. Optimal Sensor Placement for Partially Known Power System Dynamic Estimation. IEEE PES ISGT Europe 2021. Abooshahab, Mohammad Ali; Hovd, Morten
42. Optimisation model with degradation for a battery energy storage system at an EV fast charging station. IEEE Madrid PowerTech. Haugen, Eirik
43. Prisen på batterier faller hurtig. Hvilken rolle kan batterier spille i kraftsystem framover?. #Klimafrokost. Magnus Korpås
44. Rammeverk for nettplanlegging med aktive tiltak. Smartgridkonferansen. Sperstad, Iver Bakken
45. Sammenhengen mellom cybersikkerhet og forsynings-sikkerhet: Er vi klare til å håndtere den økte avhengigheten mellom kraft og IKT?. Cybersikkerhet i kraftsystemet (arrangert av Smartgridsenteret). Inger Anne Tøndel, Oddbjørn Gjerde
46. Scenarios for the future electricity distribution grid. CIRED 2021. Kjølle, Gerd Hovin
47. Security of electricity supply in the future intelligent and integrated power system. Centre for Natural hazards and Disaster Science (CNDS), Uppsala University. Seminar: Vulnerability of the electrical grid and interdependent critical infrastructures to extraordinary disruptive events. Gerd Kjølle
48. .Task 25 Webinar - Design and Operation of Energy Systems with Large Amounts of Variable Generation: The Market Challenge. Task 25 Webinar - Design and Operation of Energy Systems with Large Amounts of Variable Generation. Korpås, Magnus; Holttinen, Hannele
49. Today's distribution grid planning approaches, gap analysis, and roadmap. FlexPlan/CINELDI (DiPOflex) workshop. Sperstad, Iver Bakken
50. Tool-assisted Threat Modeling for Smart Grid Cyber Security. IEEE/Cyber Security 2021. L Flaa, R Borgaonkar, IA Tøndel & MG Jaatun
51. TradeRES - 1st Public Workshop. Introduction to Open Discussion. EU project TradeRES - 1st Public Workshop. Magnus Korpås
52. Utfordringer og forskningsbehov for kraftbransjen innen cybersikkerhet. Fagseminar om cybersikkerhet i kraftsektoren. Gerd Kjølle

**Report/Thesis**

1. Interconnection Protocols for Minigrids. SINTEF Energi. Perumalla, Chandrasekhar; Taxt, Henning; Degefa, Merkebu Zenebe
2. Mulighetsstudie om bruk av fleksibilitetsressurser hos nettselskap. CINELDI/Energi Norge. Kristian Wang Høiem, Vivi Mathiesen, Iver Bakken Sperstad, Hanne Sæle
3. Ny nettleiemodell for norske husholdninger. SINTEF Energi (2021:01468). Sæle, Hanne; Aasen, Marianne
4. Reference minigrids and minigrids controllers for rural India. SINTEF Energi. Perumalla, Chandrasekhar; Degefa, Merkebu Zenebe; Klemets, Jonatan Ralf Axel
5. Modelling Approaches for Local Energy Community (2021:01005). SINTEF Energi (2021:01005). Rana, Rubi; Degefa, Merkebu Zenebe; Berg, Kjersti; Löschenbrand, Markus

**Featured article/Op-ed**

1. Slik kan kostnadene for den elektriske klimakuren krympes. e24. Kjølle, Gerd Hovin; Fosso, Olav Bjarte

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**CINELDI – Centre for intelligent electricity distribution**

CINELDI is a Centre for Environment-friendly Energy Research (FME). The objective of the FME-scheme is to establish time- limited research centres which conduct concentrated, focused and long-term research of high international calibre.


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CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

The Research Council of Norway