

Data Intelligence for Clean Energy

The Imperative of Data-Driven Solutions
for a Reliable Clean Energy System

THE AUGMENTED INFRASTRUCTURE PART IV



ARDIAN

Foreword

This study provides a digital and data-centric perspective on the energy transition of the electricity system and the wider European energy sector. It has been developed in cooperation with Compass Lexecon, an economic consultancy focusing amongst other things on energy market analysis, energy market design and regulation: www.compasslexecon.com

The energy sector is undergoing an unprecedented transformation. First, due to the shifts from traditional energy sources to cleaner and more decentralized alternatives. Second, because of the electrification of the end usage in transport, industry and heating, which will double the share of electricity in total energy demand according to EU estimates.

In this context, "clean energy transition" refers to the move away from fossil fuels and the adoption of renewable and clean energy sources. These considerations around carbon reduction are part of a broader effort to ensure security of energy supply and affordability.

Within the scope of this study, "data intelligence" refers to the use of data and data solutions to support decision-making, optimization, creation, and automation.

The study focuses on the role of innovative digital and data-driven solutions in the transformation of the electricity sector, acknowledging that this sector also sustains and hence impacts a great part of the economy (notably industry, heating, and transportation). Although necessary for the energy transition, this study does not aim at being exhaustive on the financing, technological progress, and project development considerations of the transition. These aspects are alluded to in this study to the degree that they are related to the overall challenges and solutions.

The study aims at providing both a new perspective into the challenges and opportunities for digital solutions along the electricity sector value chain, and to illustrate these issues through concrete case studies showing the crucial role of these technologies for shaping the energy landscape of tomorrow.

Glossary

Term	Definition
BESS	Battery Energy Storage System
BRP	Balancing Responsible Party
CCMD	Consumer-Centric Market Design
CCS	Carbon Capture and Storage
CFE	Carbon-free Energy
CHP	Combined Heat and Power
DSO	Distribution System Operator
DSR	Demand Side Response
EV	Electric Vehicles
GoO	Guarantees of Origin
IEA	International Energy Agency
IoT	Internet of Things

Term	Definition
MW/GW/TW	Megawatt/Gigawatt/Terawatt
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
PMS	Power Management System
PPA	Power Purchase Agreement
PV	Photovoltaic
RES	Renewable Energy Sources
RTE	Réseau de Transport d'Électricité
SCADA	Supervisory Control and Data Acquisition
TSO	Transmission System Operator
VPP	Virtual Power Plants

Editorial

Achieving affordable, secure and clean energy systems has been widely acknowledged as a key priority by governments, businesses and households around the globe. Beyond public statements, the main evidence of this acknowledgement is the significant resources dedicated to the energy transition supported by recent policies such as the Inflation Reduction Act in the US and REPowerEU in the European Union, both setting unprecedented targets for the clean energy transition.

In light of this, if we turn our eyes to growth, over 80% of global new additions of electricity production capacity are renewable, providing good reasons to be optimistic as to the decarbonization of energy¹.

Yet, as of today, only 23% of our energy system is electrified², and within the electrified portion, only 22% is renewable³. Hence, there are still substantial hurdles and barriers across the energy value chain which must be faced and overcome.

- How to deploy renewable capacity at scale while still managing the balance of the grid?
- How to maximize the efficiency of renewable resources and mitigate their intrinsic intermittency?
- How to empower consumers to reduce energy consumption or to mainly consume electricity when is cheap?

At Ardian, we believe data intelligence will play a crucial role, acting as the key enabler and catalyst of the energy transition, coordinating and aligning the different players involved and allowing them to exchange data, generate insights, and feed these insights to control systems that put them into action.

On the supply side, data intelligence is already a key enabler in the deployment of new renewable generation, and it will support the scale-up of firm and flexible capacity, while mitigating the respective challenges arising from these. On the demand side, data intelligence will facilitate the electrification efforts and unlock the untapped potential of decentralized flexibility, also supporting the rising needs of shifting customers' behavior. Finally, on the networks side, it will enable energy infrastructures to effectively manage the increasing clean capacity, avoiding physical constraints which might limit the pace of the transition.

The energy sector is undergoing a profound transformation and data intelligence is the accelerating force at the heart of it. At Ardian, we truly believe that embracing a digital culture and utilizing the power of data will be pivotal in solving one of the most challenging problems faced by societies and economies today. We are convinced that data-driven solutions will optimize and integrate energy systems, allowing them to become "augmented" and finally overcome the impediments between production, transmission, distribution and consumption.

After an era of overconsumption and waste, the future of energy shall be characterized by sobriety, security and sustainability. Technology and data driven solutions can be the backbone of this critical revolution.



Mathias Burghardt

Member of the Executive Committee, in charge of Technology Development and Head of Infrastructure, Ardian

Summary

- 1. A 'day in the life' in a clean energy system**
- 2. Throughout the value chain, the vision and the path to a clean electricity system**
 1. Supply: Unleash renewable generation
 2. Demand: Electrify and unlock the potential of decentralization
 3. Networks: Enable flexibility and efficiency
- 3. The policy support: towards a smart regulation**
- 4. Conclusion**



1.

A 'day in the life' in a clean energy system



Vision: A clean energy system, facilitated by digitalization

'A day in the life' – a short story on how digital technologies will shape our life in a clean electricity system

It is early September in a quite distant future. Meet John and Alice, two stakeholders in the energy sector, living a day in their life in the Germany of the future.

The day starts as any other day but, in hindsight, several technologies contribute to bringing to the world of Alice and John clean, secure and affordable energy.

Walking through this day shows how a future electricity system may look like and how it will affect, although mostly in hindsight, their everyday life.



John, a responsible system user



John lives in a house in a village close to Berlin



John works as a production engineer in an ammonia production plant



Like tens of millions of Europeans, he has an electric car, and his house is heated by a heat pump



Together with his neighbors, he co-owns their own small electricity network, called microgrid, with PV and wind assets to sustain their own needs



He has a main supplier for his electricity demand. On top of that, John has also contracted with a counterparty, called a flexibility broker, to sell the electricity surplus



Alice, working at the transmission network operator



Alice works in the control center of the German transmission system operator, in charge of transporting the energy from the production facilities to the end users



Her job is to look after the stability of the electricity network



On a daily basis, she monitors the system and procures services from power plants and other market players when needed



She is in close exchange with other system operators

'A day in the life'

One usual morning

Day start



7:00 am

It is morning. Everyone gets ready for work

John

- It is still dark outside. John gets up, showers, and cooks his breakfast.
- Since prices are still high before sunrise and as John wants to optimize his finances, John's smart house system sources the electricity directly from his electric car battery, which he had charged the night before.

Alice

- Alice has a long shift today. She is already at work.
- Her monitoring dashboard shows that **heat pumps reduced production** based on the price signal and consumer preferences as they prepare to go to work.



11:05 am

John discusses electricity procurement at work

John

- John receives a push notification on his cell phone to re-charge his electric vehicle, because the sun is shining, and his electric vehicle battery is below 50%.
- He has a meeting at his company. They plan to improve electricity procurement for their battery. Two options exist:
 - a. a long-term procurement contract where each MWh is sold to them at the same price, or
 - b. a flexible contract for which the price of the MWh evolves and depends on the market demand and supply
- John argues in favor of the flexible contract, because by running flexibly, they could **offer flexibility services to the grid operator and reduce the energy bill**. They could also **profit from hours of low electricity market prices**, when renewable production is high.
- At times where they do not use the battery, an optimized dispatch engine could be in charge of automatically analyzing data signals coming from the market to decide on the best energy usage option.

'A day in the life'

A challenging afternoon with a power line outage



4:25 pm

Clouds move in front of the sun, the wind picks up

John

- John tracks in his app that the neighborhood's microgrid now uses the power from the wind turbine nearby.
- For a short time, the microgrid generated surplus electricity which was **automatically sold on to the electricity market**, thanks to **automated transactions through an aggregator**.
- John gets notified that his flexibility broker turned inactive, because supply from connected countries is currently comparatively cheap.

Alice

- As the wind picked up, the **monitoring system** suggests that more electricity can now be transmitted via the interconnector lines from France.
- Alice **validates the suggestions from artificial intelligence** that prepares the network for the change in flows and **cross-border trade picks up** automatically.
- Prices decrease because of this market integration.



2:15 pm

A power line outage occurs

Alice

- Alice's network reacts automatically through digital tools by isolating the local network where the outage occurred.
- Alice recognizes however that the grid is still not fully stable. She activates the reserve which is a virtual powerplant (VPP): a combination of several assets that can act as a single electricity source. As a result, a steel smelter and a set of smaller decentralized assets reduce automatically production in exchange for a compensation.
- The power system continues to operate smoothly. Before leaving for home, Alice relies on the network digital twin, a perfect digital replica of the physical electricity network, to prepare for the night and test different evolutions of the network.

'A day in the life'

A windy evening



9:45 pm

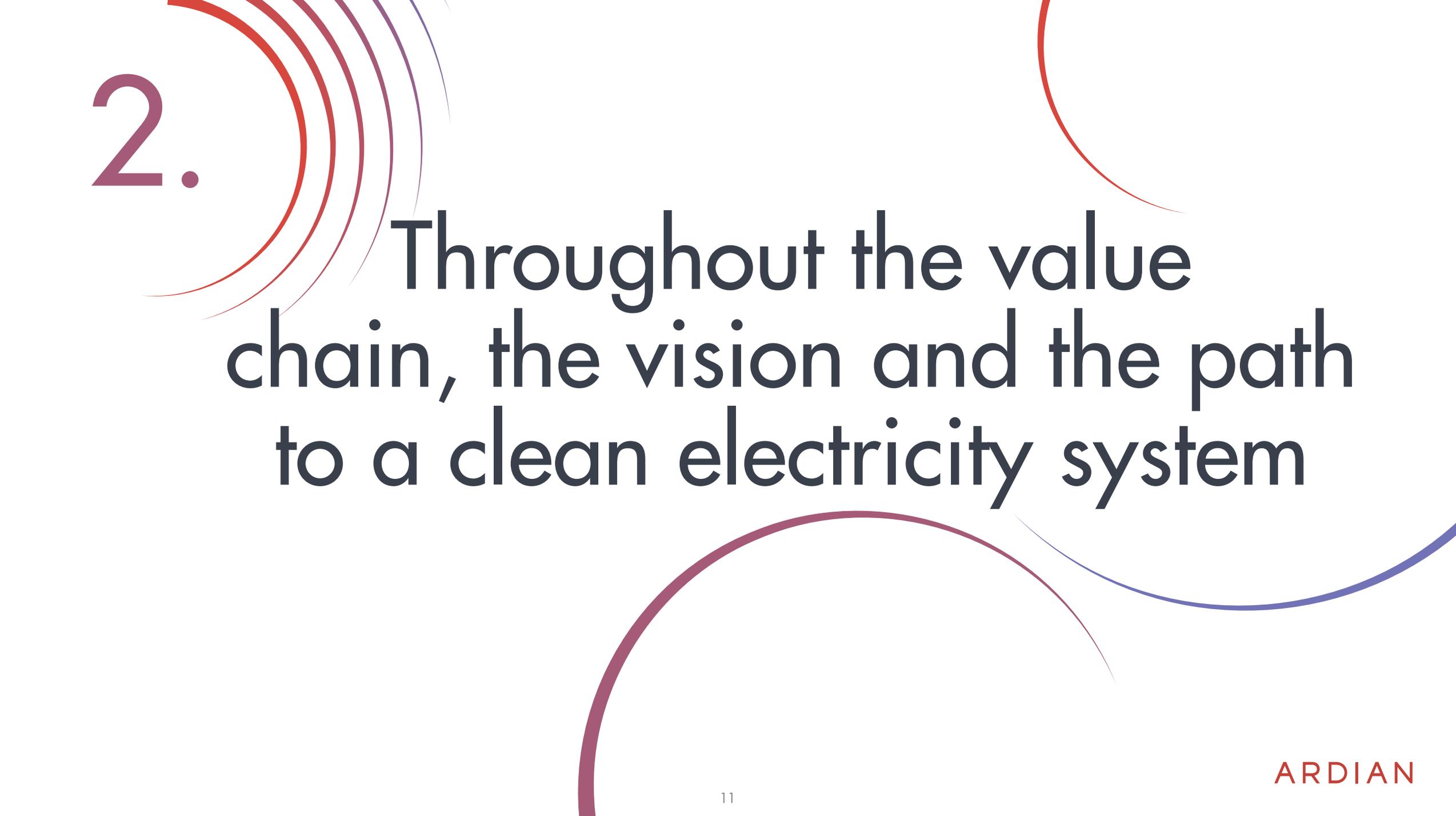
In the evening, there are strong winds out at sea

John

- John has been at home for a while now.
- He watches a documentary about offshore wind in the Baltic Sea. There, it states that engineers visually inspect wind turbines by **using drones** instead of site visits **when their data analysis predicts a malfunction.**
- That reminds John of the contracting options for the battery supply discussed earlier at work. He recalls that the operator **offered to combine** offshore wind with other RES sources across Europe to **ensure 24/7 RES electricity delivery.**

Alice

- Whilst a colleague has taken over for the night shift, electricity production out at sea is so high that the wind farm started its **co-located battery.** This allows to store energy and avoids curtailment of excess production given the network limitations.
- In addition, excess electricity is exported to Poland through a connection to a neighboring Polish wind park. This **hybrid interconnector connecting two wind farms and two countries** was funded by private investors and contributes to the optimal use of the wind resource.



2.

Throughout the value chain, the vision and the path to a clean electricity system

The clean electricity system is a paradigm shift from the fossil-based system

Grids connecting new types of generation assets

The incumbent network was optimized for central generation assets.

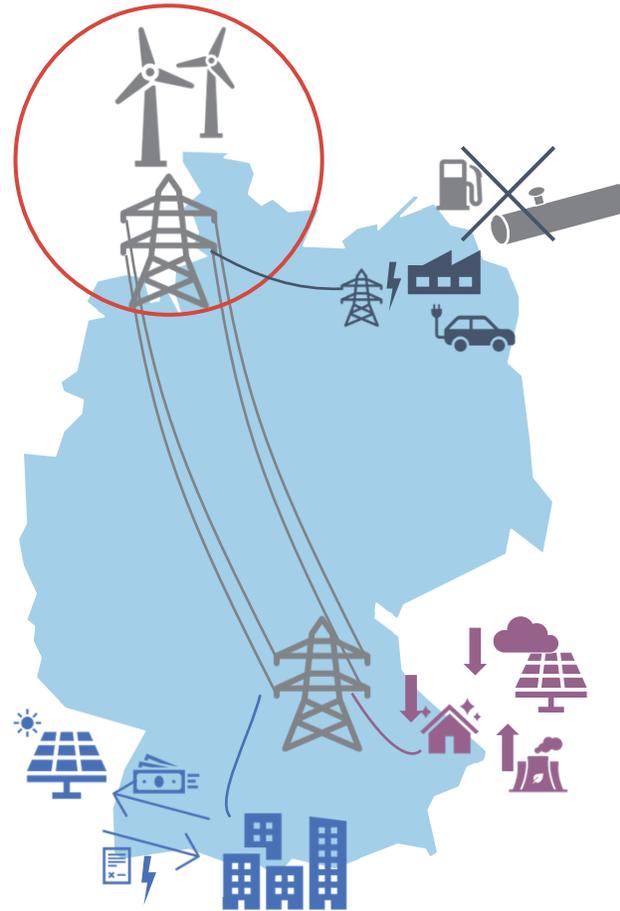
In the future, weather conditions will dictate the generation location, because renewable energy sources will be the basis of many energy mixes.

The system is thus shifting from a centralized production to a fundamentally decentralized production.

Supply-Demand matching

New markets and products will emerge, because the generation and consumption players will evaluate electricity provision differently to the past.

Demand will ask for 24/7 clean energy and will also be more adaptive to what the system is able to supply.



Additional electricity demand

The full clean energy transition leads to significantly increased demand for electricity. Electricity will become the main energy carrier for many economies, whether directly or indirectly through green hydrogen. It will be coupled to additional sectors, including mobility, heating, and industry.

Flexibility supporting variable generation

Many renewable energy sources generate electricity when weather conditions allow it. This is what we refer to by "intermittency".

To mitigate for this intermittency, stakeholders on the supply and demand side will need to provide flexibility services to the system.

The transition to a clean energy system comes with a number of challenges addressable by digital solutions



Increasing clean electrification of more and more sectors (mobility, industry, and buildings), directly linked to the clean energy transition of these sectors, creates new supply constraints to meet this growing demand, but also opportunities for optimization. **Digitalization allows real-time monitoring and steering of connected appliances (such as EVs and heat pumps), as well as building more complex business models relying on optimization and statistics.**

c. +50% EU electricity demand in 2050 compared to today¹



Flexibility needs: Switching from stable and predictable sources of energy to a more weather-dependent generation pattern calls for additional flexibility solutions to adequately meet the demand. **Automation of dispatch and streamlined markets can unleash substantial participation of demand response and decentralized flexibility resources.**

EU flexibility need by 2030 corresponding to 24% of today's power demand²



Network bottlenecks: With new renewable energy sources and electricity uses, rising demand for grid connection will likely create grid bottlenecks and congestion. **Digital solutions shall contribute to get more out of existing networks and to anticipate and manage congestion.**

+84% required investments in the EU grid from today to 2030³



Complexity and coordination: There used to be only a few hundred power generators in the EU power system.⁶ Within the next decade, decentralized energy sources will lead to millions of market participants and microtransactions. **Data-driven solutions could enable real-time coordination and managing the increasing complexity of the power system.**

c. 40m EV charging points by 2040 in the EU, compared to below 3m today⁴



Business models and financing: RES variability, the associated impact on market prices, and the increase in interest rates will affect the bankability of new projects. **Approaches leveraging data intelligence and portfolio optimization will be key to maximize value.**

2x more hours with negative power prices in first half 2023 vs. 2022 in Germany⁵

Still, recent events highlight the need to reconcile clean energy transition with energy security and affordability

On top of the climate emergency, **the Ukraine war has made the energy transition even more urgent.**

The challenge of the transition is to reconcile the three dimensions of the energy trilemma: to guarantee citizens and businesses clean, affordable and reliable energy.

The Covid-19 crisis and Ukraine war have highlighted the vulnerabilities of the European energy system, which was relying heavily on imported fossil fuels. Indeed, the EU imported 89% of its natural gas in 2022. During that year, imports from Russia were reduced from nearly 40% to 10% of total import volume and substituted mostly by Liquid Natural Gas (LNG) from the USA.

As a matter of fact, the significant increase in energy prices associated with the war in Ukraine has put security of supply and competitiveness back on top of the policy agenda. Forward contract prices had quadrupled for major European regions such as France and Germany over the course of 2022.

These recent constraints coupled with the increase in interest rates put increasing pressure on the business case and financing of clean technologies:

- The Covid-19 related supply chain issues can delay or hamper the risk return profile of investments and have increased the cost for certain technologies putting a stop to the continuous decrease in equipment cost.
- Investments in LNG have partly cannibalized investment in renewable assets.

This calls for innovative business and regulatory approaches to keep up with the pace of investment required.

This means higher share of **local RES instead of imported fossil energy**.
And **sufficient flexible and firm generation** on the system.

Energy security

Energy Trilemma

Environmental sustainability

Affordability

This means achieving **RES-buildout** and **electrification** targets, in order to decarbonize.

This means **optimizing the use of existing assets**, as well as customers reducing their electricity bill by providing **flexibility**.

This report describes how digitalization can solve challenges in supply, demand and networks to accelerate the clean energy transition

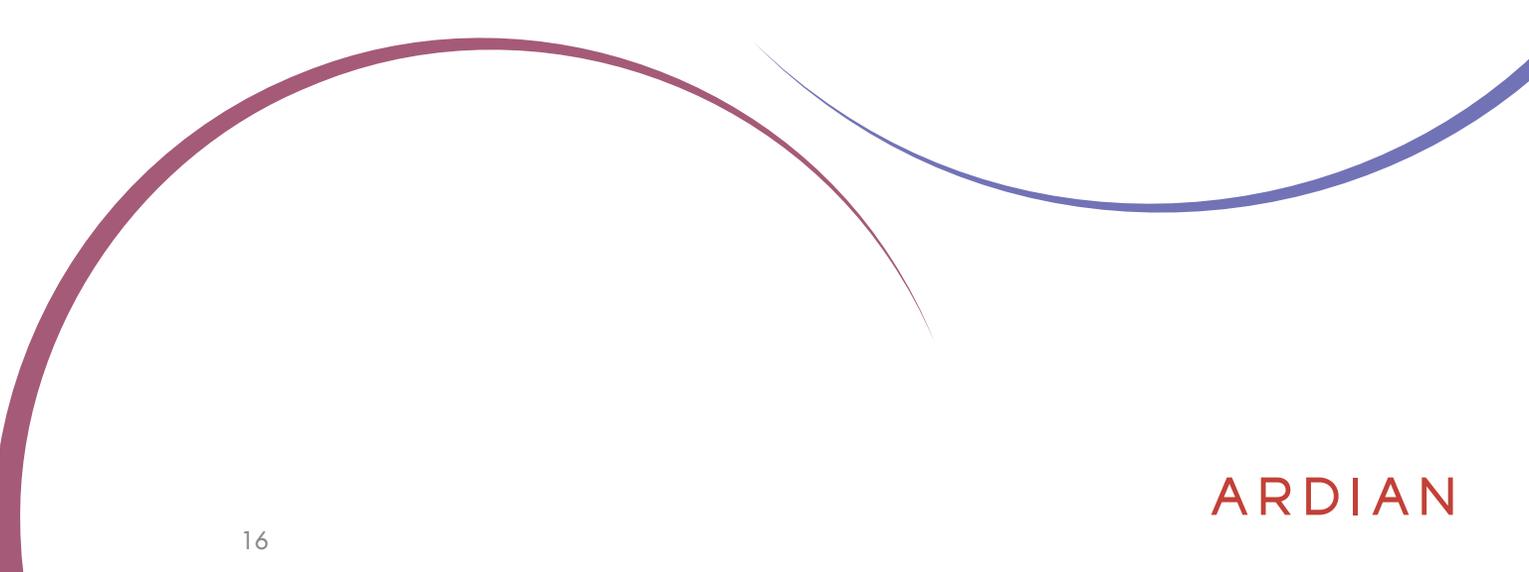
Value Chain	Objective
Supply (every market participant that generates or stores electricity)	<ul style="list-style-type: none">• Achieve sufficient clean generation buildout• Ensure large-scale firm and flexible capacity
Demand (every market participant that uses electricity)	<ul style="list-style-type: none">• Unlock the potential of decentralized flexibility• Incentivizing clean energy sourcing and supply-demand matching in real time
Networks	<ul style="list-style-type: none">• Ensure networks have enough hosting capacity• Develop charging, metering, smart home and other networks

The next slides analyze a **number of use cases**, demonstrating how digital tools can contribute **in practice** to the transition to a clean energy system



2.1

Supply: Unleash renewable generation



The path to a clean, cost-effective and reliable supply is already underway

Objectives

Scaling up clean energy supply

The next phase of the clean energy transition will require massive development of renewable energy sources as well as other clean energy technologies and supporting networks.

CO2 emissions in the electricity sector are planned to be cut by 24% between 2021 and 2030 in the EU27 countries - the largest projected decrease among all sectors.

Increasing coordination of firm and flexible capacity to ensure 24/7 clean energy

Resources: Optimizing scarce grid connections and land

Operations: Optimizing renewable asset operations to reduce costs and improve output

Go-to-market: Addressing **renewable price cannibalization risks**

Optimizing dispatch and **coordination across various clean energy and flexibility sources**

Case Studies

EMS and AGR-AM Asset co-location to optimize scarce resource use is made easier with digitalization



Greenbyte and Ardian RES remote O&M reduces downtime and labor needs in hazardous and remote areas



Ardian Tracking, forecasting & portfolio management of RES allows to create new products with lower risk profiles and higher market value



EnergyPool Flexibility and RES aggregation can be provided in virtual power plants with minimal transaction costs



Deployment of renewables must accelerate to achieve policy targets

To reach the clean energy transition targets set by the industry and public authorities, a faster **build-out of clean energy assets** will be required.

The REPowerEU¹ Plan targets 69% of RES in the electricity capacity mix by 2030. Hence, about 300GW of additional solar and wind capacity is needed in the next 5 years in order to reach decarbonization targets.

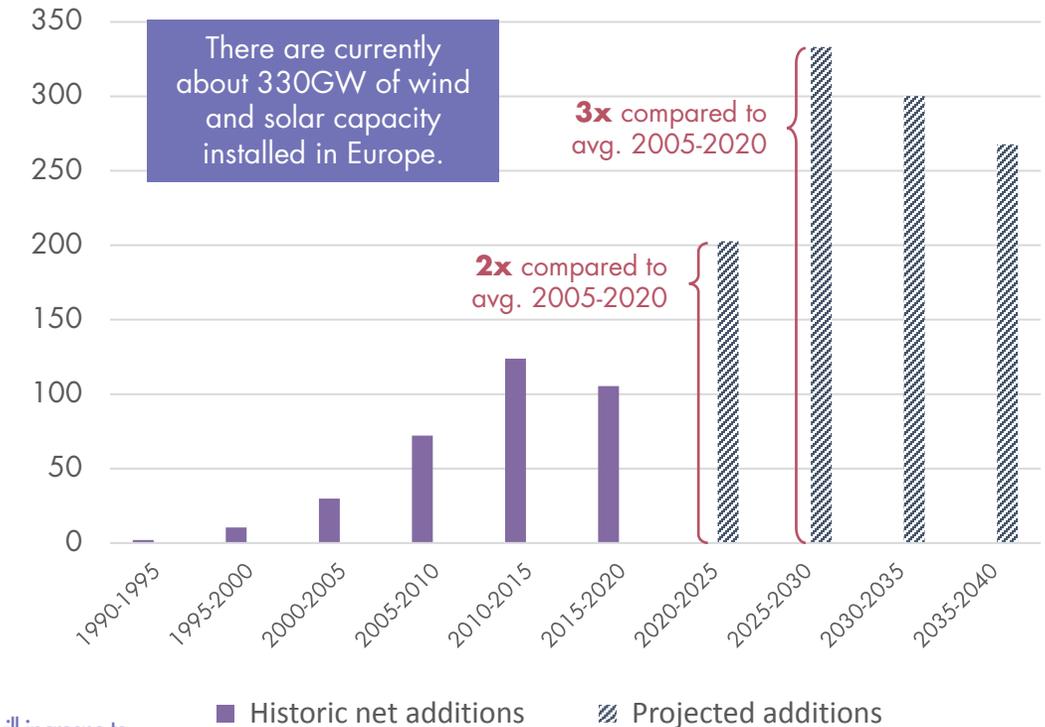
However, it is becoming more challenging to develop new RES projects - particularly in **densely-populated and network-constrained countries**. According to a recent report from McKinsey², 9 percent of available land in Germany is suitable for wind and less than 1 percent of land in Italy is suitable without limitations for solar PV.

Scarcity of suitable sites, new regulations on biodiversity as well as network connections make development of new projects more challenging.

At the same time, supply chain constraints and permitting processes lead to long lead-times for project commissioning.

In this context, digital solutions can **facilitate RES planning** and help to make the best-possible use of **scarce land and network capacities**.

Historic and required solar and wind capacity additions to reach decarbonization targets (in GW)³



"We have moved from an addition of 3GW [RES] a year to an average of 4GW in 2022 and will increase to 6 GW from 2026." "We are now in a phase of accelerated growth and investment"³

Catherine MacGregor
Chief Executive Officer, Engie

Note: [1] In May 2022, the European Commission introduced the REPowerEU Plan in response to the energy market turmoil following Russia's invasion of Ukraine. The plan aims to reduce Europe's dependency on fossil fuel imports from Russia and accelerates the transition to a clean energy system.

Source: [2] Land: A crucial resource for the energy transition (McKinsey 2023). [3] Compass Lexecon based on reference model for projections that incorporate RES policy targets, Eurostat (2017) for data until 2015 and IEA (2020) for 2020 data. [3] Engie (2023)

CASE STUDY: Increased utilization of congested grid connection and land

How digitalization supports co-location of clean energy generation

EMS and AGR-AM, respectively the Italian and Spanish management companies of Ardan renewable assets, started thinking about how **data-driven tools could support the co-location of clean technologies behind a grid access point**. This allows for a more efficient use of the scarce and costly grid connections and land.

AGR-AM is hybridizing brownfield projects in Spain, by adding PV plants to existing wind sites, to maximize the grid connection utilization.

AGR-AM expects that the hybridized assets in Burgos (Spain) will **increase the installed capacity by 50% and generated electricity by c.27%**.

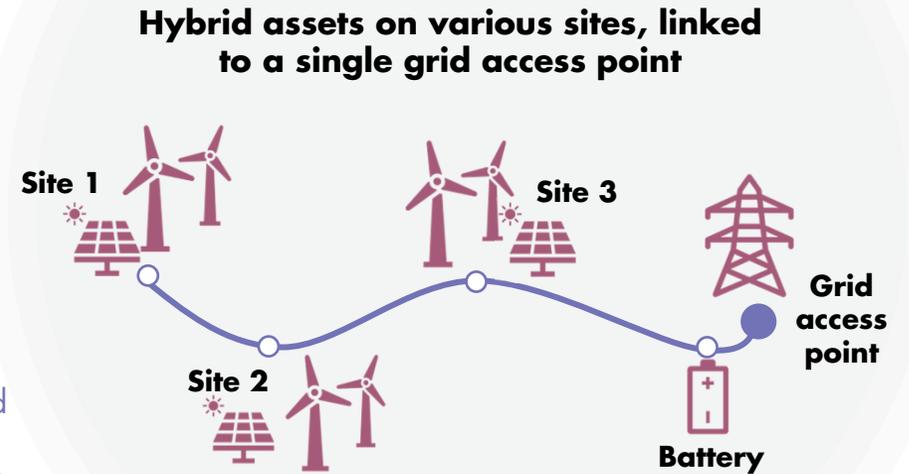
EMS is currently developing the first hybrid project in Italy (Sicily), co-locating greenfield wind, solar and BESS assets behind one single costly grid access point.

Digital tools are critical to properly analyze opportunities for co-located assets and further monitor the project once commissioned.

The ability to differentiate between all co-located assets is essential for remote O&M applications (as further explained in the following case study), as well as for distinguishing contracted assets from merchant ones.

The energy management system (the digital tool) managing the connection to the grid is the real enabler of all the co-located generation assets as it will:

- monitor the generation profile of each asset,
- manage grid curtailment inputs,
- forecast short term production,
- control generation output for each asset in an automated way, and
- match generation profiles during design phases.



“The connection permit is the perpetual asset. Hence, to maximize the long-term value of the connection capacity, the co-location of different technologies will enable to maximize the load factor.”

Santiago Varela Ullastres
Chief Executive Officer, AGR-AM

High interest rate environment and value chain constraints create a more challenging environment for investment into renewables

Variable RES technologies have seen **unprecedented cost decreases** since 2000.

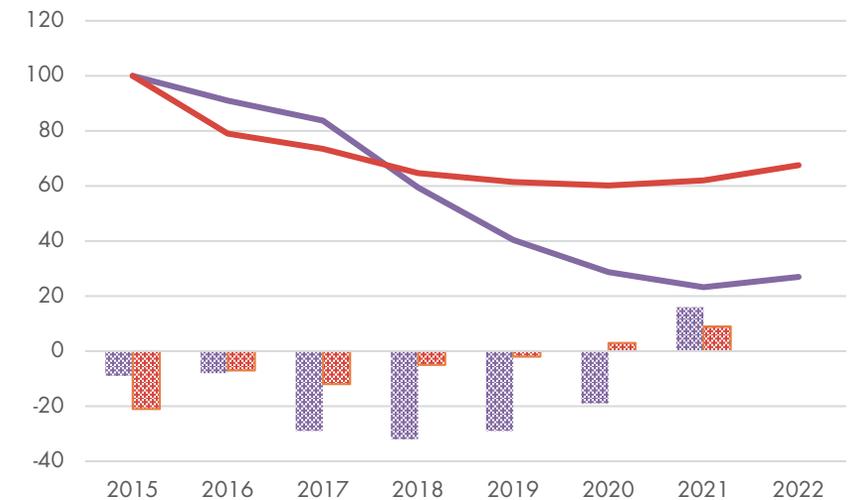
- Technological improvements, economies of scale and low interest rates have driven down investment costs for RES significantly.
- As an illustration, the global average of levelized cost of energy for solar PV decreased by 89% between 2010 and 2022, and by 69% for onshore wind¹.

However, costs increased again slightly since 2021 following the post-Covid recovery, putting the downward trend to a halt.

- Supply chain tensions due to rapid Covid-19 recovery, rising commodity prices, and labor shortages, are also pushing costs up.

To continue sustaining viable business cases for RES, a **key focus of investors and operators is to optimize operations, maximize output and reduce operating expenses.**

Cost index of wind turbines and solar PV (% for change, indexed value for prices)²



"Future investments in renewables require ever closer monitoring of risks and revenues. Through active portfolio management, we can leverage the benefits each individual asset brings to our portfolio."

Marion Calcine

Chief Investment Officer Infrastructure & Senior Managing Director, Ardian

Source: Compass Lexecon analysis based on [1] IRENA Renewable Power Generation Costs In 2022 (IRENA (2023)) and [2] IEA (2022a and 2022b), incl. earlier version thereof

CASE STUDY: Optimizing renewable energy operations

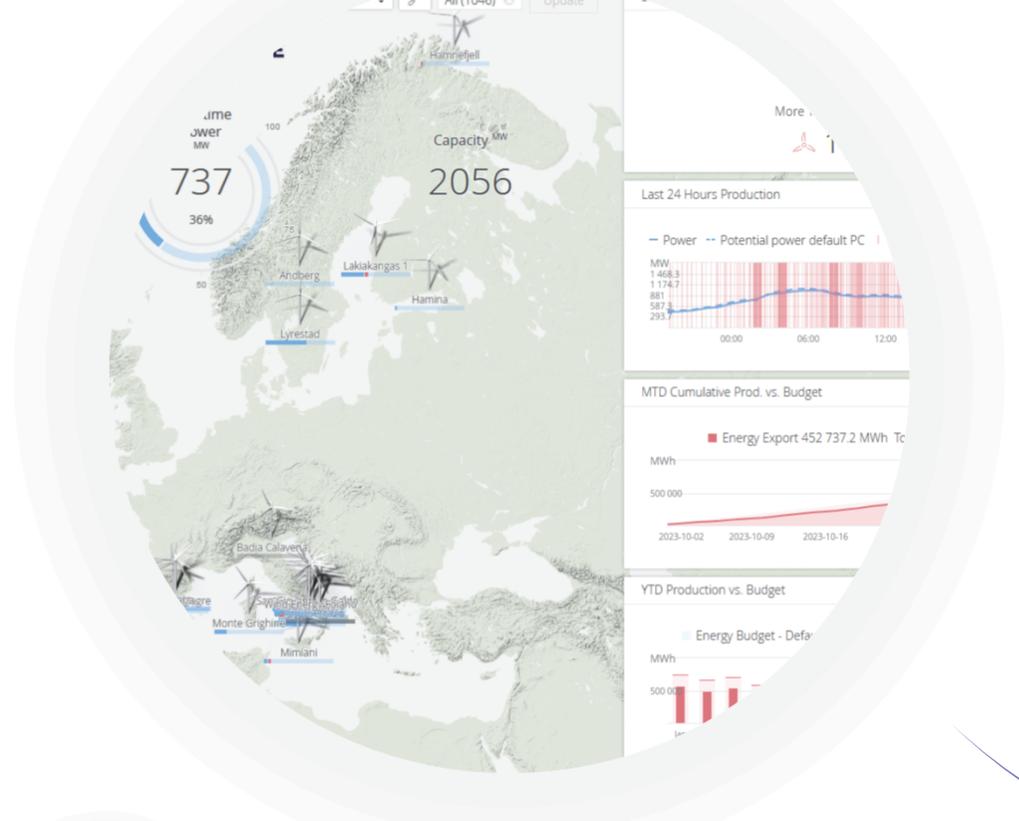
How digitalization helps to increase generation and reduce O&M cost

The collaboration between Greenbyte and Ardian demonstrates **how RES costs can be further reduced through optimizing O&M with digital tools.**

- Greenbyte by Power Factors is a 2nd level SCADA system that interprets up to 5,000+ signals from various RES assets' sensors. It maps and analyzes them in a standardized format.
- Ardian has connected the Greenbyte system to all its distributed generation assets to indicate when a malfunction is detected on an asset so that management teams acting locally can further investigate and resolve the incident.

The application of such smart monitoring and remote-control systems reduces operational costs and downtime and **increases production thanks to overall improvement of operations efficiency.**

- Remote monitoring grants real-time visibility of **standardized and consistent data across a distributed and diverse asset portfolio.**
- Malfunctions can be detected in real time and identified in remote locations. On average, Greenbyte has been able to reduce lost production caused by component malfunctions by 12% across 4GWs of renewable energy where prediction services are utilized.
- Another area with large potential for improvement is production forecasting. Forecasts are based on meteorological satellite data, which can be combined with real-time data from the asset. **Improvements to production forecasting reduces balancing costs, improves energy sales and maintenance planning.**



"Early detection of downtime on our generation portfolio thanks to GreenByte allows us to quickly intervene remotely or physically on site to restore operations. This has improved overall wind farm availability quite significantly."

Lorenzo Nastasi

Business Development Manager, EMS



"Greenbyte allows us to speak the same language and rely on harmonized data across our portfolio. Thanks to this, we can then run automatic performance analysis across our portfolio through our Opta platform."

Pauline Thomson

Director & Head of Data Science, Ardian

More renewables leads to cannibalization risk which can be mitigated by data intelligence

The “cannibalization”, i.e. the decreasing market value of RES with increasing RES penetration is a growing issue, leading to less profitable business cases for renewable assets compared with fossil fuel powered production assets.

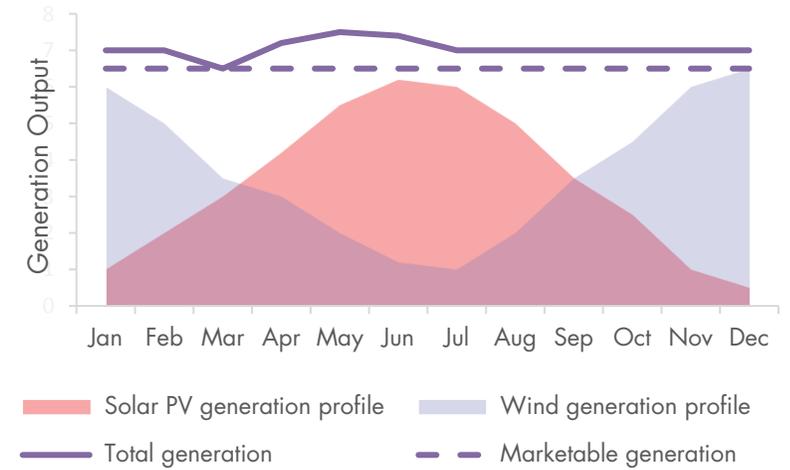
- During times of high feed-in from renewables (e.g. during high winds), market prices go down as a direct consequence of this increase in supply.
- This reduces the captured market prices by RES and therefore their market value. Price cannibalization increases with RES penetration, and can be partially mitigated with the deployment of flexible capacity.
- This is coupled with a lower predictability of the amount of power to be generated by renewable assets on the day ahead market, as it inherently depends on the accuracy of weather forecasts.

This had led in certain markets to **negative electricity prices**, when renewable assets produce heavily. Such was the case in Finland in May 2023 as a surge in hydroelectric power due to heavy rainfall meant that the production supplied on the grid was no longer remunerated.

Smart portfolio management can help reduce RES variability and cannibalization risk and allow for more structured ways to sell electricity.

- **Long-term contracts** such as Power Purchase Agreements (PPA), fixing the price of energy sold over the long term between a supplier and an off-taker. PPA also support revenue predictability of merchant RES assets.
- But the creation of **premium-value PPAs**, such as baseload PPAs or demand-shaped PPAs requires sophisticated forecasting and portfolio management approaches.

Stylized example of creating a portfolio of different assets to leverage portfolio effects



“Improving production forecasts for renewable assets using predictive models is key but accuracy still remains a challenge. One of the best mitigants is likely the portfolio effect, i.e. leveraging from a mix of different technologies in various locations with complementary production profiles.”

Simone Tonon
Managing Director - Renewables, Ardian

Source: SMARD.de
Note: [1] This effect depends on weather patterns. For PV, it is therefore stronger in summer

CASE STUDY: Using data for portfolio construction

How data intelligence supports converting intermittent production and volatile electricity prices into stable returns for investors

Ardian has developed Opta, an in-house renewable energy management platform to optimize a portfolio of more than 2.5GW of RES generation and storage assets.

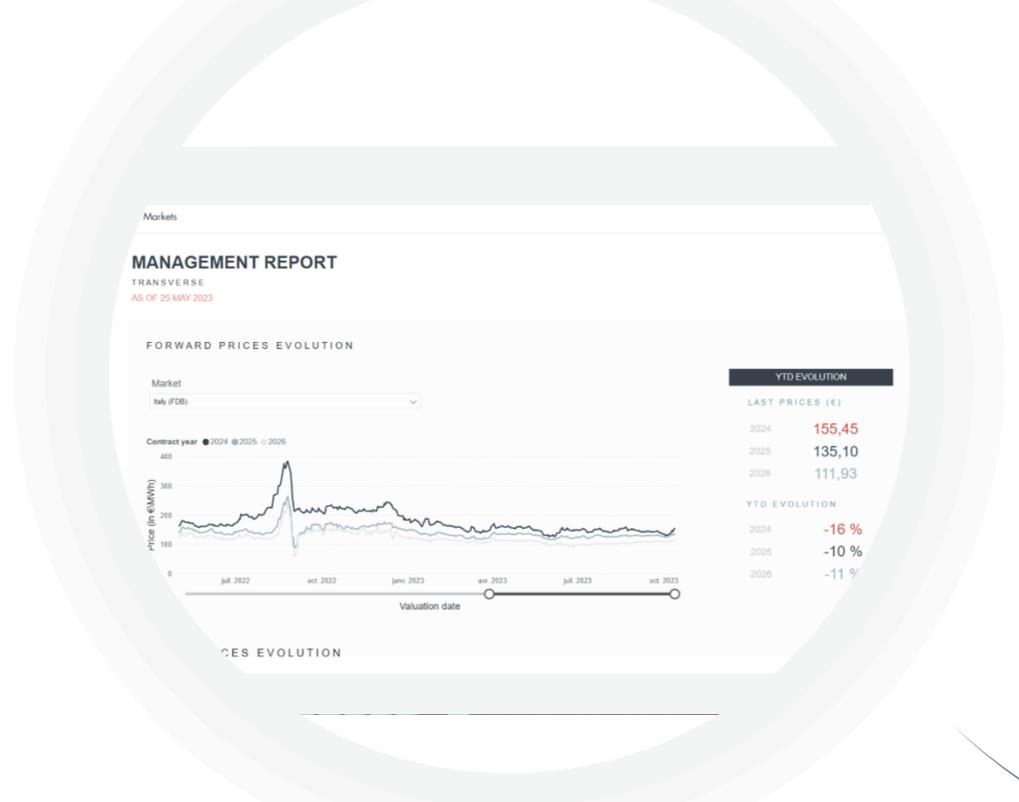
Through Opta, Ardian monitors the operations and the go-to-market strategy across the portfolio, allowing calculation of historic and expected operational and financial performance.

On operations, Opta allows to capture upsides from operational improvements through an intelligent alerting system. It also leverages the large amount of data from Ardian portfolio to produce benchmarks, as well as progressively building smart recommendations.

When it comes to risk management and portfolio optimization, data intelligence allows to diversify risk and to explore opportunities to create premium value products:

- The analysis of correlations allows to leverage the portfolio effect to diversify risk and hold revenue streams steady. This improves the overall value of the portfolio.
- By combining assets, new premium value products, in particular PPAs, can be created that achieve better captured market prices and increased benefits for the consumer compared to selling the generated electricity from each asset separately.
- This in turn increases the liquidity of the PPA market and thereby decreases the counterparty risk, a benefit to both suppliers and consumers.

Ardian now also leverages Opta to analyze potential new investments, both in terms of operational deep dive and risk management.



“Digital tools help assessing if we can take baseload risk thanks to portfolio diversification, which is key to attract all types of customers. Renewable electricity at cheaper prices with stable production is also key to fuel electrolyzers producing hydrogen.”

Marion Calcine

Chief Investment Officer Infrastructure & Senior Managing Director, Ardian



“Optimizing profits on energy sale now goes hand in hand with a proper modelling of how the assets produce and how their respective productions behave in relation with one another.”

Skander Kamoun

Senior Data Scientist, Ardian

More renewables in the system drives higher intermittency and increases the need for storage and flexibility resources

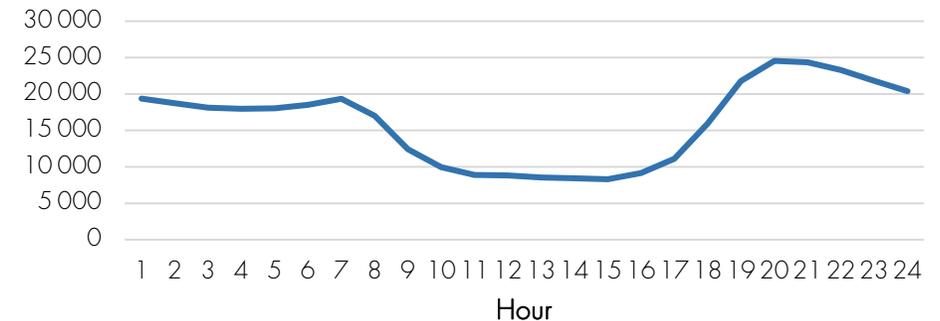
RES generation and electricity demand are not naturally aligned as weather conditions drive RES generation.

- Residual electricity demand, demand not covered by RES generation, typically arises in the morning and evening hours when electricity consumption is high, but PV generation is low.
- This leads to a rising demand for daily and weekly flexibility, depending on the generation mix and weather conditions.
- Additionally, seasonal flexibility will also be needed to deal with RES generation deficits in the winter when demand is the highest.

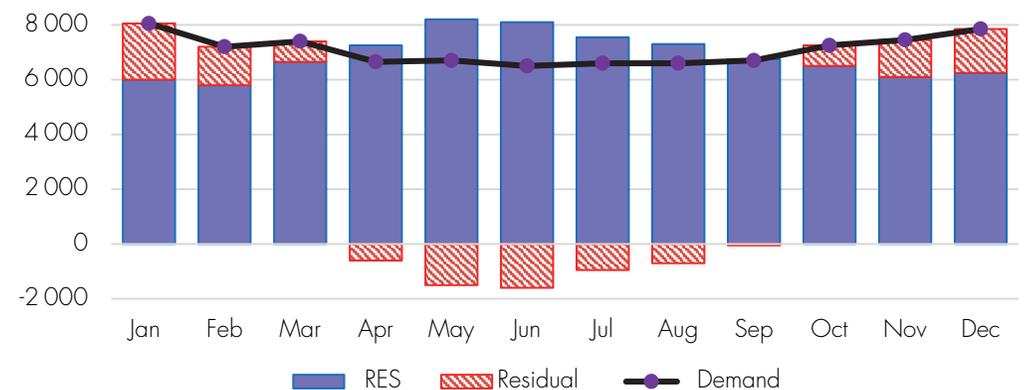
The growing flexibility needs can be partly addressed thanks to the complementary generation profiles of different PV and wind assets, but a mix of other technological solutions are needed including:

- **Flexible interconnection**, which can connect different areas, such that demand and renewable production even out better.
- **Dispatchable capacities**, which can produce electricity flexibly when needed.
- **Storage**, which can also provide a range of ancillary services to the grid including inertia services as grid inertia also drops with higher renewable energy.
- **Demand side response** to balance the grid by acting on the demand side and shifting part of the demand to off-peak times.

Example for need for daily flexibility – Residual electricity demand, i.e. Duck Curve (in MW)



Example for seasonal flexibility need (in GWh)



Note: The lower figure shows the difference in the estimated monthly renewable energy production and demand for Austria in 2030. RES include hydro, biomass, wind, PV and battery.
Source: Upper figure: IEA (2019), lower figure Compass Lexecon analysis based on E-Control (2022)

CASE STUDY: Flexibility through Virtual Power Plants

How data intelligence enables distributed flexibility

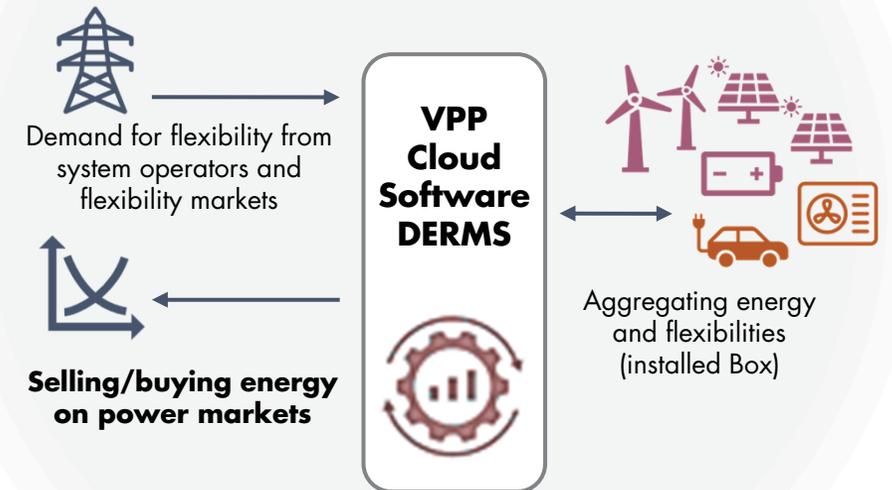
EnergyPool supports the **aggregation and monetization of flexible and RES assets through its Virtual Power Plants (VPPs).**

- Energy Pool's VPP is a virtual network aggregating and centrally controlling small-scale RES, demand side response (DSR) assets and storage systems. It provides an access point for power market participation and offering flexibility services to system operators.
- The impact from participating in VPPs may be an electricity consumption bill reduction of up to 15% while effectively eradicating most transaction costs for small assets.

Digitalization is the critical enabler for such VPP solutions, as well as interoperability of communication protocols and data quality.

- VPPs leverage digital solutions for live remote monitoring, optimization and steering.
- Energy Pool's VPP solution is based on a two-layer system of digital hardware and software: the onsite Box telecontrol solution (Flex-Box) ensures reliable communication, and the Distributed Energy Resources Management System (DERMS) optimizes operations across various assets from a control centre (see illustration).
- At the same time, interoperability of communication protocols are needed to collect and use high-quality and standardized data. Only then, the VPP cloud software DERMS can effectively produce forecasts, manage and monetize the assets through market access.

Exemplary set-up of EnergyPool's Virtual Power Plants



DERMS: Distributed Energy Resources Management System
Box: Onsite installation for power management



"The overarching aim of the portfolio of flexibility sources and RES coming together in the VPP is to allow market access, mutualize risks, increase value and share it with our clients. The VPP gives all consumers and producers the opportunity to benefit from participation in power and flexibility markets."

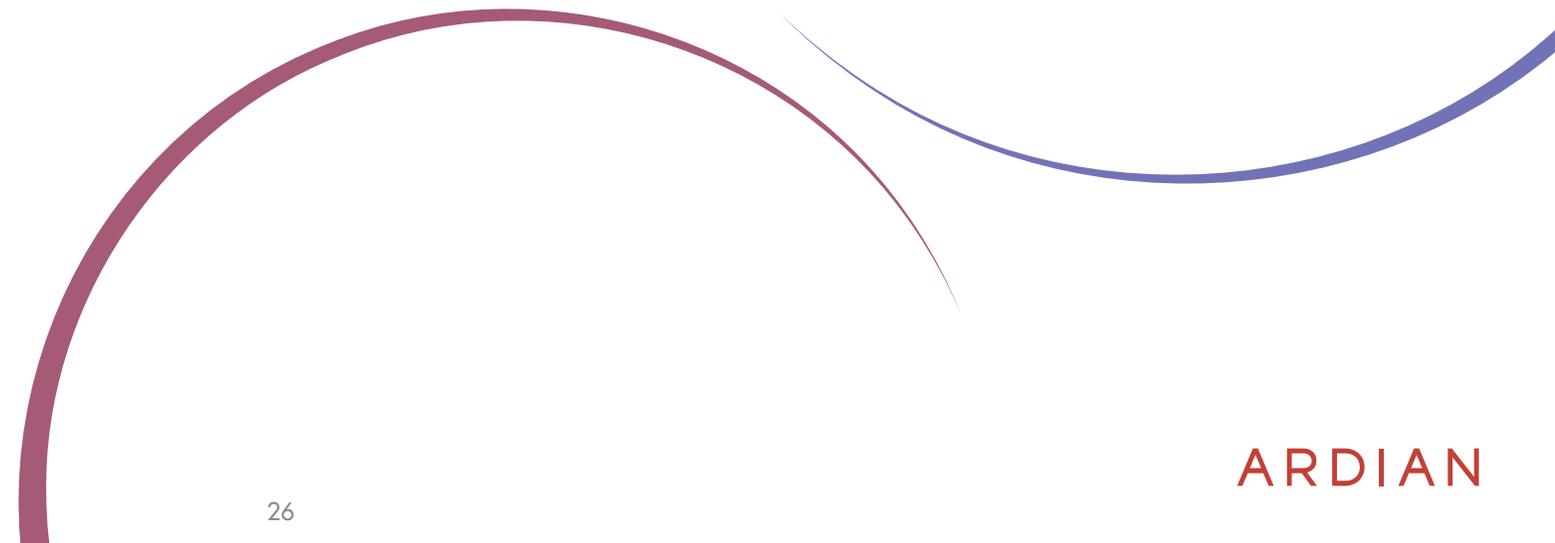
Sylvie Tarnai

Chief Strategy Officer, Energy Pool



2.2

Demand: Electrify and unlock the potential of decentralization



Decarbonization of end-use sectors (transport, industry and buildings) will increase demand of electricity

Overall, **total energy demand is expected to decrease through changes in processes including energy efficiency measures and fuel switching.**

In parallel, **electricity demand will increase significantly by 2050** through both direct and indirect electrification:

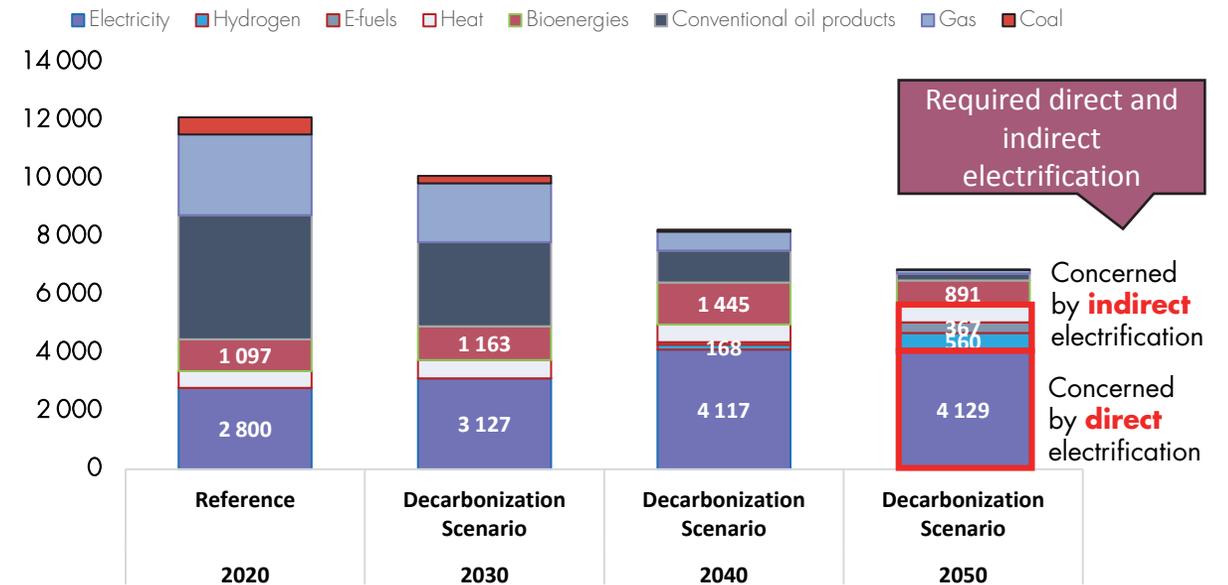
- Direct electrification means that processes switch to electricity from another energy carrier.
- Indirect electrification means that electricity is used to process the final consumed energy carrier.

By 2050, about **60% of end-uses will need to be directly electrified, compared to 23% in 2020.**

Other clean energy carriers would include hydrogen, e-fuels, in turn requiring electricity for their production, as well as bio-energies and small amounts of fossil fuels, with emissions being compensated by CCS or other means of carbon sequestration.

21% of end-uses would be concerned by indirect electrification by 2050.

Projected decarbonization scenario of energy carrier demand in the EU to achieve net-zero by 2050 (in TWh)



"In order to achieve net zero ambitions in 2050, energy efficiency should play a critical role to moderate total energy demand whilst substantial electrification of end-uses will increase electricity demand."

Fabien Roques

Executive Vice President, Compass Lexecon

Source: Compass Lexecon (2020).

Note: The depicted scenario is in line with the EU decarbonization targets. Depending on the assumptions taken, projections may be different

The path to unlocking demand potential with digital solutions and case studies to illustrate with real world examples

Objectives

Unlocking demand-side flexibility

Automation of dispatch and streamlined market can unleash substantial participation of demand response and decentralized flexibility resources.

Enabling clean energy sourcing, matching consumption and production with high granularitiy

Unlocking the flexibility potential of newly electrified sectors (mobility, heat, H2 etc.)

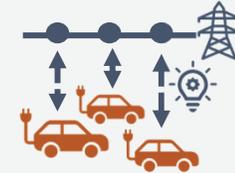
Fostering active participation of flexibility assets, minimizing transaction costs

Enabling peer-to-peer trading for all consumers and energy communities

Enabling 24/7 clean energy sourcing for industrials

Case Studies

EV Cars
Smart and bi-directional EV charging integrates EV batteries into the electricity system



H2 Green Steel
Hydrogen storage providing flexibility services



Elia
Consumer-centric market design uses digital solutions to enable consumers to actively participate in the electricity market

Google
Innovative procurement approaches that are supported by digitalization



Electrification of transport and heating provides new flexible resources which can be leveraged through digitalization

The number of **new flexible connected assets** in the electricity system will expand to an **unprecedented extent**.

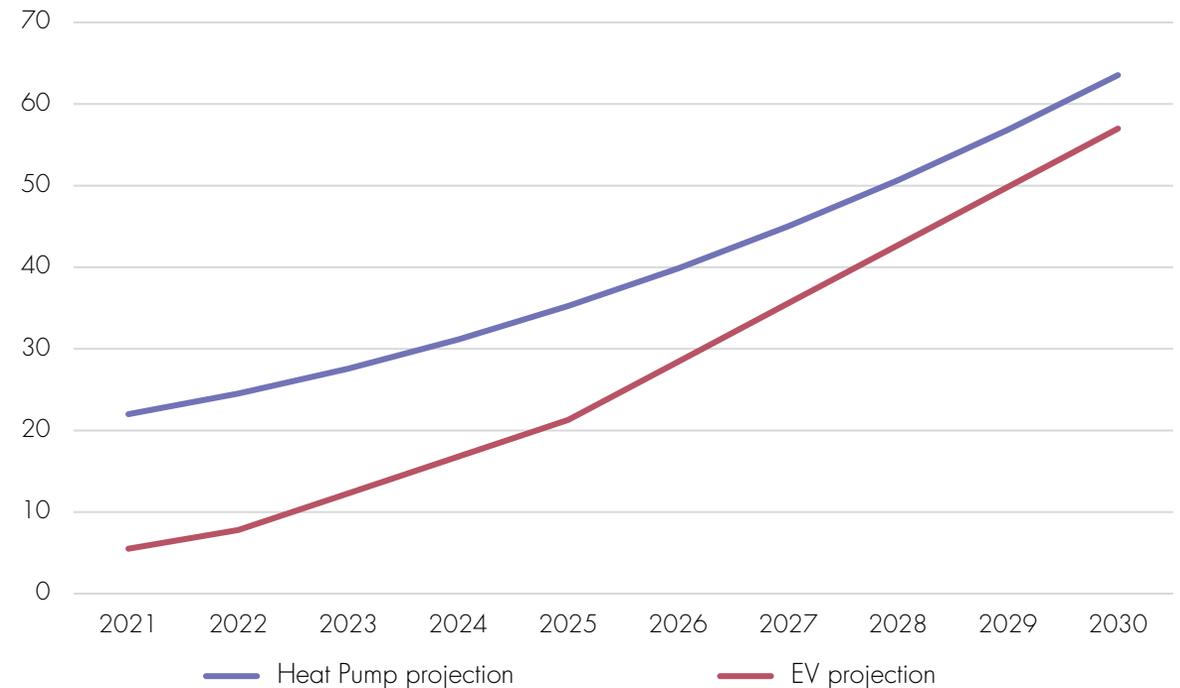
In Europe, heat pumps are expected to increase to about c.60 million by 2030 against c.20 million today. The number of deployed electric vehicles in Europe should also increase at a pace to reach a total of more than 50 million in 2030.

These **new loads on the system are** not only new demands, but could **offer new sources of flexibility**:

- Electrified end-uses and industrial sites can provide substantial decentralized flexibility as they are also de facto storage facilities with the ability to dispatch energy.

However, the **complexity** of monetizing such flexibility through markets and the associated **transaction costs may be prohibitive for business cases**, unless handled through automation.

Expected increase in EVs and heat pumps in Europe (in millions of installed assets)



Source: Heat pump projection is based on EHPA (2023) for historical data and IEA (2022c) for projected new installations. EV projection is based on linear interpolation from IEA (2023b) projected EV stock. Linear interpolation for both heat pumps and EVs is assumed for yearly installation values between 2021 and 2025 and between 2025 and 2030

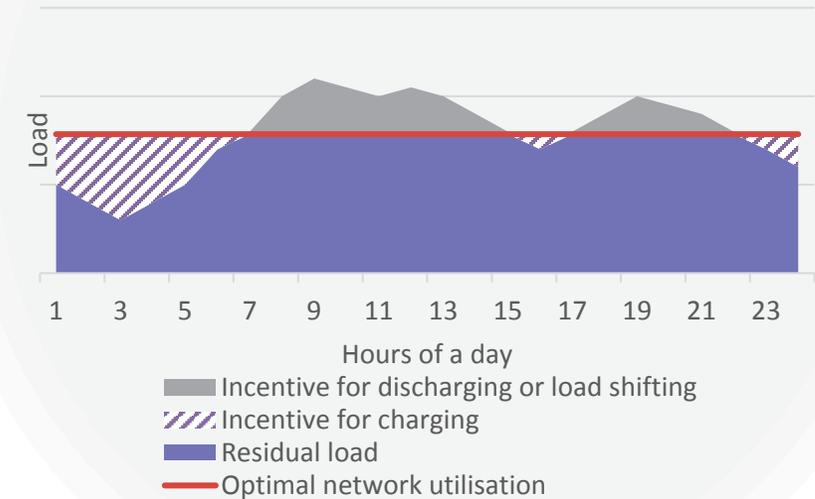
CASE STUDY: Unlocking the flexibility potential of EV batteries

How data intelligence facilitates charging optimization and manages microtransactions

Digitalization allows for smart charging and bidirectional charging.

- Smart charging means that the EV is charged in accordance with economic incentives, e.g. when electricity prices are low, when additional electricity consumption is remunerated because of balancing needs, or when RES production peaks must be absorbed (see figure to the right).
- To limit transaction costs which could be massive, because charging behavior can be adjusted each minute throughout the day, the economic incentive signals are processed by digital tools – sometimes through full automation.
- Bidirectional charging, also known as vehicle-to-grid, is similar to smart charging but further allows for discharging the battery into the grid or into the home energy management system.
- Smart and bidirectional charging solutions buffer variable RES feed-in by contributing flexibility to the system or conducting arbitrage on the energy market.
- EVs can further alleviate network constraints by offering the flexibility to the local network operator. This would require local flexibility marketplaces or comparable solutions.
- The optimization of the use and charging of EV batteries requires real-time signals and smart control solutions. This can only be done through digitalization, e.g. Data intelligence that facilitates optimization and manages microtransactions.

Schematic potential for smart charging in a given day



“The exponential need of EV Charging Station represent a real challenge for grids but also an opportunity. Solutions like “vehicle-to-grid”, stationary storage requested to limit connection cost for ultra-fast chargers, and smart energy management will offer new perspectives of value creation and new services to the grid that GreenYellow is actively exploring.”

Philippe Houins

Group General Manager, GreenYellow

Potential for demand flexibility is substantial but does need encouragement through an updated regulatory framework

Unlocking demand side flexibility is essential to complement **flexible powerplants and centralized electricity storage** in Europe. Upward flexibility implies generating additional electricity or consuming less, while downward flexibility is the opposite.

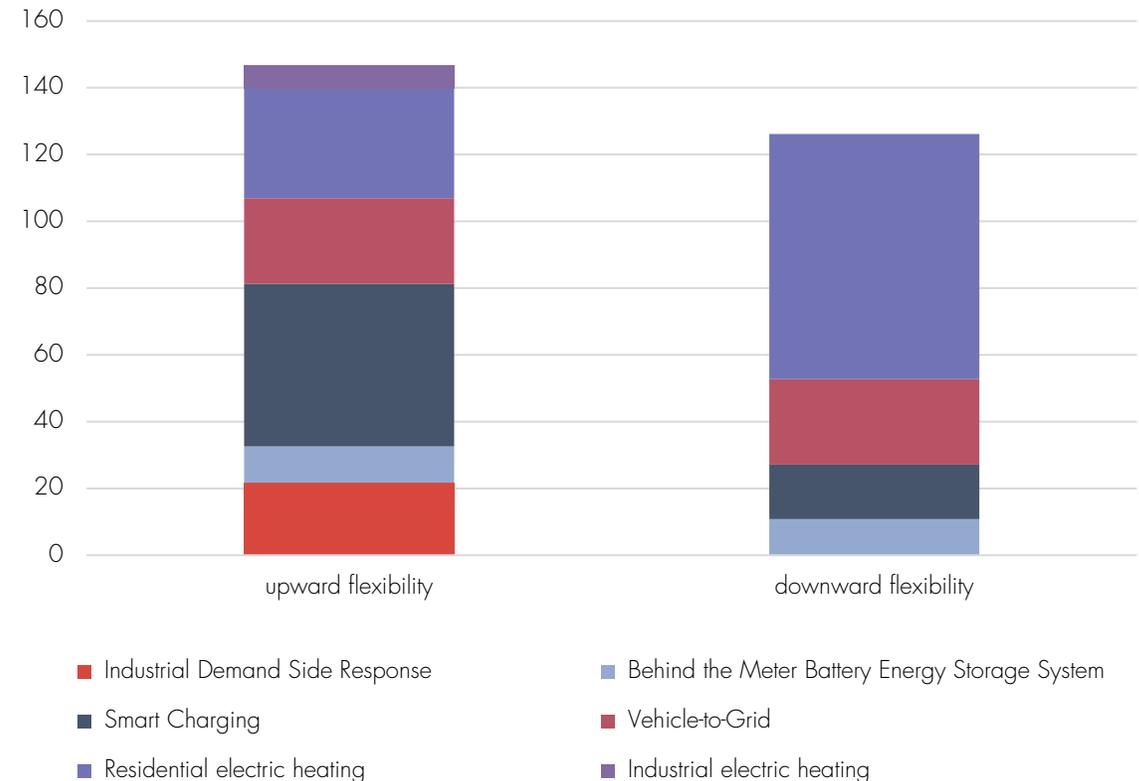
- Flexibility from smart charging is estimated to be the largest source of upward Demand Side Response with c. 49GW.
- Residential electric heating (c. 74GW) may provide more than half of the total available downward flexibility.

To unlock this potential, **behavioral and regulatory challenges** need to be overcome, on top of digitalization. Demand has historically been relatively inelastic.

Encouraging demand responsiveness of small consumers implies a paradigmatic shift.

This requires to revisit the regulatory framework, to reduce barriers to market access for small players and costs of microtransactions as further explored in section 3.

Estimation of available decentralized flexibilities in Europe in the year 2030 (in GW)¹



CASE STUDY: Flexibility through Hydrogen facilities

How data-driven processes enable demand-side response

H2 Green Steel will produce **green steel in Sweden by using a Direct Reduced Iron (DRI) process with green hydrogen.** It targets **95% lower CO2 emissions compared to traditional steel production.**

- Instead of exporting iron ore and green energy separately, H2 Green Steel aims to export an energy-intensive product. Energy will amount to a third of total costs.
- H2 Green Steel expects to optimize energy use and costs through a) purchasing electricity when it's cheap (price arbitrage) and b) creating revenues as a flexibility provider to the Swedish grid (by providing the grid with downward flexibility – e.g. by taking off load from the grid when needed).

Data driven models and automation are the critical enablers for the successful operations of the plant and energy optimization strategy.

- H2 Green steel relies on in-house machine learning models to predict the next day price on the day ahead electricity market as well as the frequency needs in the grid to optimize H2 production planning and ancillary services provision. It can do so without interrupting the iron production process by leveraging its H2-storage facility.

H2 Green Steel targets to generate c. 20m€ in revenues and a 5% to 15% reduction in energy costs thanks to its data-driven energy strategy.



"We will act as counterweight to volatility and smooth the peak curve for the grid. Overtime, more and more large-scale energy consumers like us will have pure economical incentives to balance the grid."

Olof Hernel

Chief Digital Officer, H2 Green Steel

CASE STUDY: Consumer-centric market design (CCMD)

How digitalization can work hand-in-hand with market incentives to foster customer engagement

Digitalization will need to leverage efficient market signals to provide incentives for consumer participation, and to optimize demand flexibility:

- The current market design has several barriers which prevent the active participation of small flexibility assets: it is complex, time-consuming, costly, and often requires additional layers of hardware. These hurdles often outweigh the benefits of consumer engagement.
- Elia's proposed CCMD aims to address these barriers, by placing consumers at its heart, giving them the full freedom to choose services from different providers at appliance level, and allowing the decentralized peer-to-peer exchange of energy.
- The CCMD's goal is to unlock active demand participation and flexibility whilst facilitating innovative business models and services (see right figure). In other words, the CCMD will foster competition 'behind the meter'.
- [The Elia adequacy & flexibility study for Belgium for the period 2024-2034](#) quantifies the yearly value for the Belgian society of unlocking new flexibility from the end user as being up to m€205-m€438/year in the lead-up to 2034.
- The CCMD is a customer-oriented **market design that leverages the embedded connectivity of digital appliances**, rather than costly dedicated hardware and meters that are currently needed.

Elia CCMD services and added value



"Consumer participation is a fundamental EU right and a no-regret pathway in the energy transition, yet still needs to be implemented in practice. Elia is taking action to remove the remaining barriers to demand-side flexibility and make the market truly consumer-centric."

James Matthys-Donnadieu
Chief Customers, Markets & Systems Officer, Elia

Unleashing the power of Demand Side Response would benefit the whole power system including consumers

Scaling up DSR into power systems does not only enhance reliability, but also benefits **end-consumers by reducing system costs.**

In addition, other benefits of DSR include price stability and overall lower levels during peak hours.

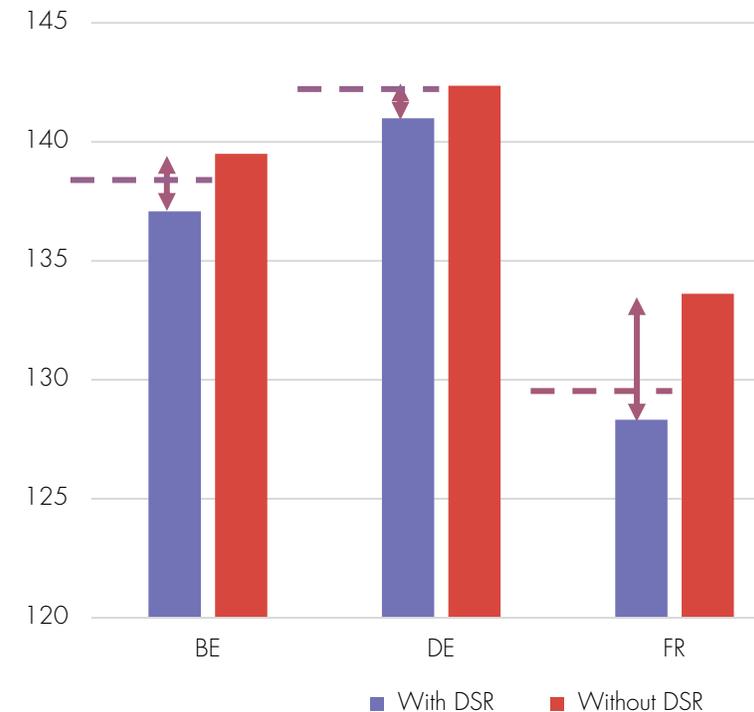
- Peak prices tend to be lower thanks to the displacement of costly generation sources (in the modelled case, thermal plants).
- Price volatility tends to be lower during peak hours.
- The incorporation of DSR further creates direct monetary benefits from selling energy and flexibility.

DSR will tend to reduce wholesale prices, to a greater or lesser extent **across countries.**

- Compass Lexecon modelling shows reductions of power prices in the top 50 hours of up to 5.3€/MWh (see right figure), assuming an additional 10GW of demand response.

DSR will also be a key element to reduce carbon emissions as the share of fossil fuel in the energy mix tends to be greater during peak hours.

Simulation of power prices with and without DSR, for the average top 50 power price hours in 2030 (in €/MWh)



There is growing demand from both corporate and residential consumers to source firm clean energy

Many corporate and residential users want better control and knowledge on the source of their electricity supply, to actively contribute to the energy transition.

At the corporate level, **24/7 clean energy** refers to an innovative energy procurement approach that allows **to access clean electricity continuously to match consumption.**

- This requires a tracking system to ensure electricity is sourced from clean energy sources and consumed in the same hour it is generated.
- 24/7 clean energy sourcing for corporates contribute to clean energy transition efforts and foster countries' security of supply by reducing national reliance on fossil fuels.

At the residential level, **initiatives fostering peer-to-peer trading and energy communities** are emerging to empower consumers.

- Local exchanges of energy require now digital solutions both to track and enable financial flows as well as to manage local energy networks.

However, the real time matching of clean supply sources with demand comes with **operational and tracking challenges** – which can be addressed through **advanced forecast, optimization and certification.**



But matching consumption and production with fine temporal and geographical granularity requires advanced optimization, forecasting and tracking tools.

CASE STUDY: 24/7 clean energy sourcing for industrials

How digitalization supports supply-demand matching, forecasting and tracking

A number of corporate initiatives such as Google's approach demonstrate **how digital solutions support efficient 24/7 clean energy procurement for industrials**, in a cost-effective manner.

Google takes an active role in the energy transition and is committed to operate all its data centers and offices on 24/7 clean energy by 2030.

Google initiated innovative clean energy procurement models building on a portfolio of resources (including wind, solar and batteries) tailored to match Google's hourly electricity demand (see right figure).

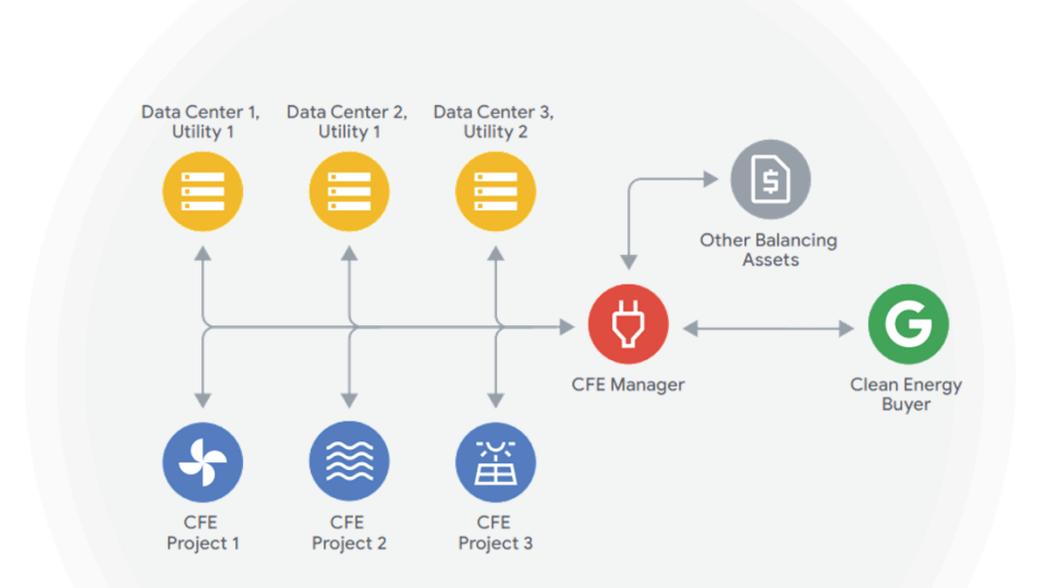
24/7 clean energy procurement is made possible and cost-efficient by a **combination of optimization tools, machine learning forecasts and digital registries** for tracking the origin of electricity used.

The clean energy procurement is guided by a Google optimization model, which solves for the least-cost portfolio of clean resources that matches Google's forecasted data center load on an hourly basis.

Forecasts going into the model include anticipated growth in Google's electricity demand, as well as expected RES generation profiles. For instance, Google partnered with DeepMind, for applying machine learning algorithms that predict and optimize wind power output.

Google also uses machine learning to minimize the carbon intensity and cost of its applications by shifting data center workload across time and locations.

To effectively track clean-energy generation, Google has partnered with various digital registries around the world (e.g. APX, I-REC, M-RETS, FlexiDAO).



CFE Manager model: The CFE Manager designs, supported by Google digital capability, a portfolio of resources (including wind, solar and batteries) tailored to match Google's facilities hourly electricity demand. The CFE Manager takes responsibility for retail energy supply to the demand facilities and contracts with a portfolio of CFE generators. Google has already executed the CFE Manager in some countries. The first such agreement in Europe was signed with French utility ENGIE for Germany. Under the agreement, Google purchases electricity from a portfolio of 23 renewable projects in five German states including solar and wind.



"Not long ago, it was hard to imagine 24/7 carbon-free electricity supply. It is now within reach thanks to the intelligence and data enabled by digital solutions."

Marc Oman

Principal, Energy & Infrastructure, Google



2.3

Networks: Enable flexibility and efficiency



Network challenges addressed with digital solutions and case studies to illustrate with real world examples

Objectives

Ensure timely deployment of electricity networks to integrate new assets and connect different zones

Maximize efficiency of the existing networks and manage congestions

Optimize network planning and new investments

Leverage decentralized solutions facilitating local supply-demand matching

Develop smart charging, metering, appliances and other networks at the consumer level

Optimize behind-the-meter asset management and coordination

Case Studies

Siemens, Enel and General Electric
Smart grid solutions
to optimize grid efficiency



WindGrid
Data intelligence for
planning of offshore wind interconnectors



GreenYellow
Efficient grid connectivity through
home energy management and microgrids



Renewables drive higher grid costs which can be reduced using digital solutions to optimize network transit capacity

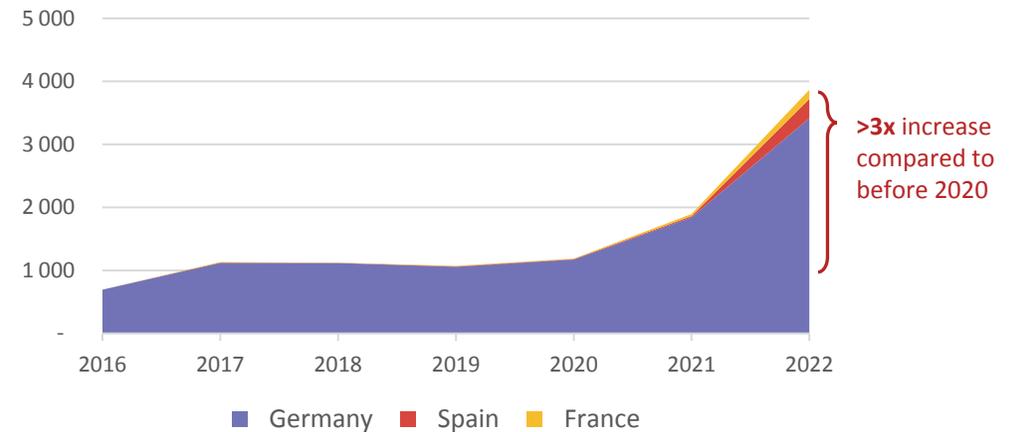
Structural grid constraints are increasing in Europe.

- The existing grid was designed to match demand with supply in different locations, based on legacy centralized assets.
- Electrification of end-uses and new RES investment require new/upgraded connections and transmission line reinforcements.
- The large increase in network investment needs stretches network operators operational and financing capabilities of network operators.

Optimizing network operations through digital solutions can contribute to reducing congestion and connection bottlenecks.

- Peaks in the network flows occur rarely such that lines utilization is often only at 20-30% overall. This leaves a substantial scope to spread the load and optimize the utilization of existing grids.
- When the grid's capacity is congested because of too high inflows of supply, grid operators need to curtail the energy, which means that power generation is 'lost' and renewable assets are not operated at their maximum output capacity.
- In Germany for example, about 5% of potential renewable generation was curtailed in the first quarter of 2023, amounting to €775m. and 6 TWh of curtailment.

Transmission grid congestion costs in several EU countries (mEUR)



"With increased renewable capacity, curtailments will be important, in particular in areas such as South of Italy. Grid management supported by wider set of real time data available to grid operators, will allow for optimal grid saturation in a dynamic mode and allow dispatch of more renewable capacity."

Simone Tonon

Managing Director - Renewables, Ardian



"Last winter, the only thing people could talk about was where to get more electricity. Now we are thinking hard about how to limit production. We have gone from one extreme to another."

Jukka Ruusunen

President & CEO, Fingrid

Source: Compass Lexecon analysis based BNetzA (2023); figure based on Entso-E (2023).
Quote from Jukka Ruusunen to Finish public broadcaster Yle

CASE STUDY:

Digital solutions for grids

How data intelligence maximizes efficiency of grid operations

Smart grid solutions and load management can help the networks to cope with the evolving demand patterns by **making better use of existing electricity network**.

Smart grid solutions allow a **continuous live monitoring, simulation and forecasting of the condition of the network** that can be enhanced by artificial intelligence. Network operators can use granular and real-time data to reduce the reliance on static parameters and safety margins. With dynamic line rating optimizing grid utilization based on ambient data, up to 30% more electricity can be transmitted.

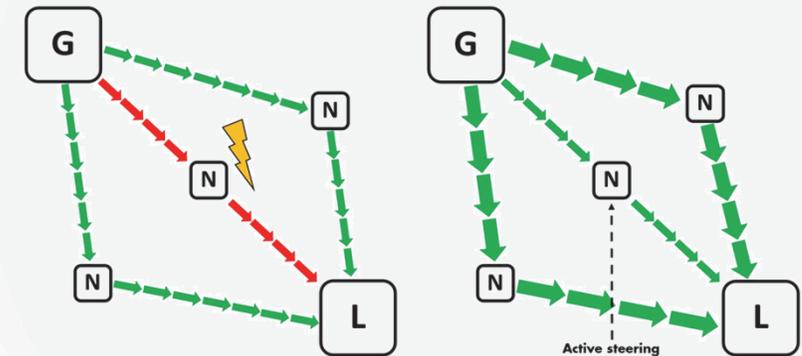
Digitalization allows **active steering of power flows and connected assets**. Many points in the network can be reached in more than one way which will also provide **quicker restoration times and improved resilience**, e.g. by real-time fault localization.

Estimations are that innovative technologies and **active steering of the distribution grid can double the throughput of the grid**.

A smoother operation of grids through a more active steering of power flows could reduce network losses by up to 20%.

Progressive deployment of grid digitalization over the last 20 years has allowed the largest distribution network operator in Italy to improve its System Average Interruption Duration Index (SAIDI) value by more than 60%, mainly due to remote control and automation of the grid.

Example for Active steering of power flows on the grid



The flow through a network is often limited by its weakest line; by actively steering power flows – a bit like road traffic management – more power can flow through the grid



“Without digital grid solutions, system operators have to revert to conservatism: Build more, connect less, curtail more, or accept more outages.”

Joshua Wong
General Manager, Grid Orchestration



“No grid, no glory – without the grid, the energy transition will not be successful.”

Ben Gemsjäger
Head of Distribution Grid and Microgrid Studies, Siemens

Explosion of grid connected assets drives complexity to manage grids

Operating interdependent networks at different geographic levels (from local to European) creates new challenges for network operators.

Networks interplay with a growing number of stakeholders, including decentralized RES producers, storage, EV charging, and smart home equipment.

This implies increased complexity of operations in real time as well as coordination of planning processes.

To manage this **increasing system complexity, data-management and digital optimization solutions play a growing role.**

For instance, communities fostering local matching between supply and demand can in some periods reduce demand on the transmission network.

But they can also create new challenges both within such communities to optimize operations and with the interface with the network.

Selection of expected development of connected assets

Timeline	EV charging	Decentralized generation	Various devices & applications
From hundreds in 2000-2010...	Very few EV charging points	Limited	No IoT installed devices
...to a few millions in 2011-2020...	< 3 million EV charging points¹	12m European citizens producing electricity in 2015	n.a.
...to billions in the future.	40 million EV charging points estimated by 2040¹	112m European citizens producing electricity by 2030²	30bn IoT devices worldwide in 2027³

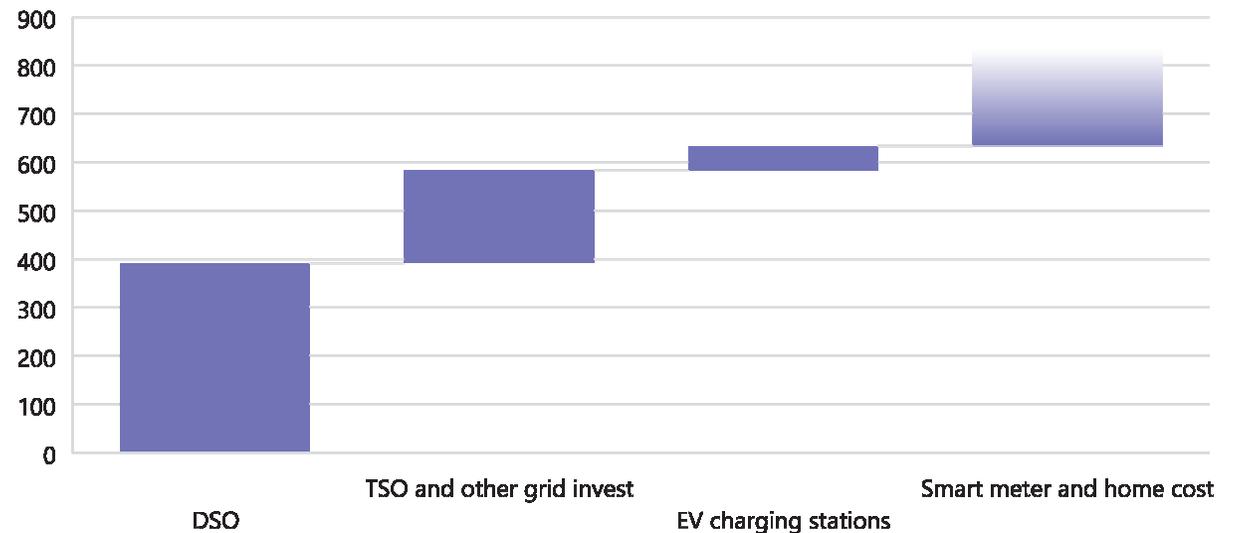
Substantial investments in grids are needed and digital solutions can support network expansion

The **transmission and distribution electricity grids need to expand significantly**. New connections are needed to integrate RES assets in remote areas and electrified assets. New power lines and reinforcements are also needed to reinforce the system resilience.

The **costs for grid expansion in Europe have been estimated at c.€600bn** until 2030, which is a significant increase from previous investment levels. And among these, €170bn would go to digitalization.

However, the transmission network **development could take more than 15 years**. The investments are not only expensive, but face multiple challenges, such as labour shortages, long planning cycles, etc.

Cumulative expected grid and data exchange infrastructure investment in 2021 to 2030 (in bn EUR)



To achieve the needed expansion and digitalization, investment is crucial. From 2021 to 2022, we saw an 8% increase in investment. However, we need to increase the annual investment by 84% from now until 2050

Source: DSO investment costs are based on Deloitte, E.DSO, Eurelectric 2021. They include investments into EU and UK DSO grids. TSO and other grid investments are based on European Commission expected investments of €584bn., net of DSO investments. Exact cost projections exclude UK DSO costs as DSO cost and would include an equivalent amount to TSO and other grid investments. EV charging station investments are separate from investments for EV charging stations into the DSO grid. They are based on the EV Masterplan by ACEA Auto. Smart meter and smart home investments are further needed, but investments until 2030 have not been quantified.

CASE STUDY:

Microgrids and on-site optimization

How microgrids create both new opportunities and challenges for system operations

Digitalization can contribute to **efficient grid connectivity through home energy management and microgrids**. This helps to optimize local production and consumption, to reduce supply cost and pressure on the public network.

For instance, GreenYellow contributes to making decentralized energy systems a reality for corporates. It does so by **facilitating physical and digital connectivity across assets**, and by implementing **microgrid building blocks**.

As a first step, GreenYellow has launched EasyVision in 2019, which is a software tool that allows real-time supervision of electricity consumption and technical parameters of key equipments. The software currently monitors, controls and optimizes, consumption of over 3 000 buildings. By the meantime, GreenYellow allows corporate to produce green energy on their facilities with solar solutions, behind the meter, interfaced with their energy need.

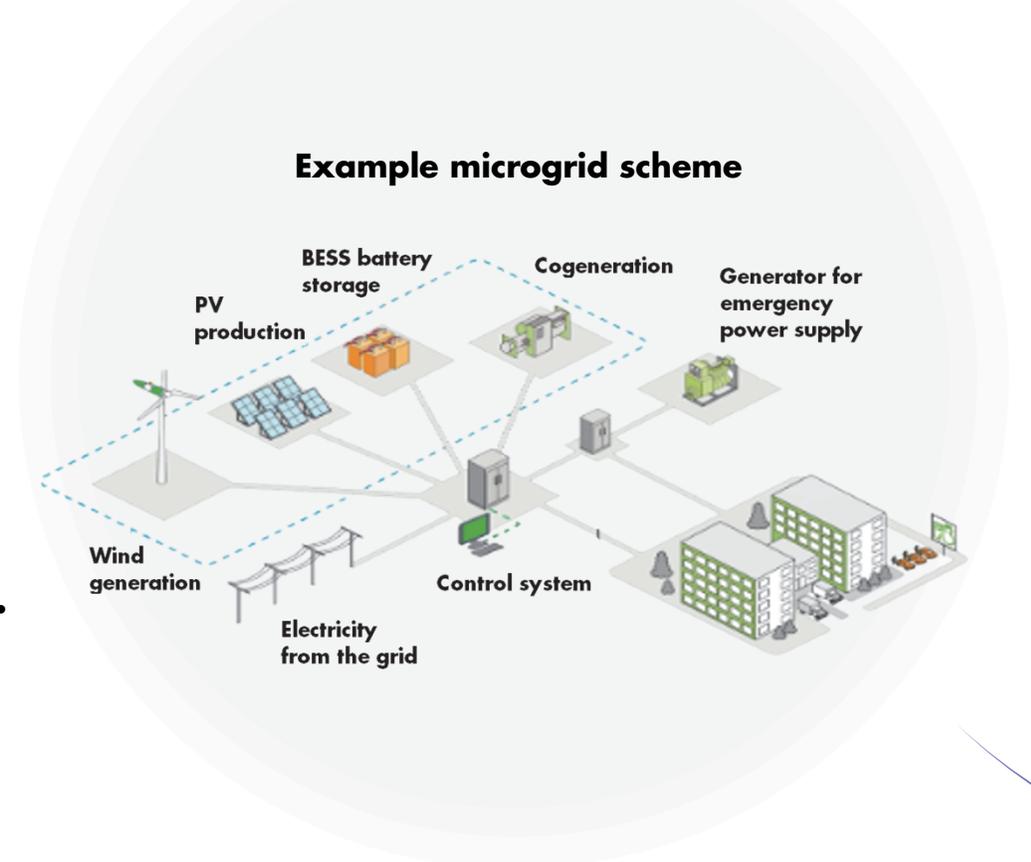
Thereby, energy efficiency and procurement can be optimized behind the meter, limiting the reliance on the public network.

The ultimate goal are microgrids, which are small networks of electricity users with a local source of supply that are usually attached to a centralized national grid but can function independently.

Microgrids require **advanced data management and optimization tools** and **complement centralized networks** to foster energy independence and reduce carbon emissions.

Microgrids require advanced data management and real-time optimization solutions across various types of network, generation and consumption assets.

Delivered as a service, microgrid solutions provide customers with all the benefits of a microgrid while removing the related (investment) risks, challenges and substantial upfront investment.



"As public networks get more and more congested, we need microgrids to make sure that the consumption load curve fits on-site production. Digital supervision tools like EasyVision will be key to ensure that all assets and appliances work together and that our customers can extract the maximum from them – the lowest carbon emission at the lowest price."

Philippe Houins
Group General Manager, GreenYellow

CASE STUDY: Planning of hybrid offshore wind interconnectors

How data intelligence supports risk assessment and investment decisions

The use of digital simulation and optimization tools can contribute to optimize the planning of complex hybrid interconnector projects, using advanced power grid and market models to project revenues across a range of network configurations and scenarios:

For example, WindGrid aims to develop merchant offshore interconnectors, notably hybrid interconnectors that combine offshore power production and grid infrastructure.

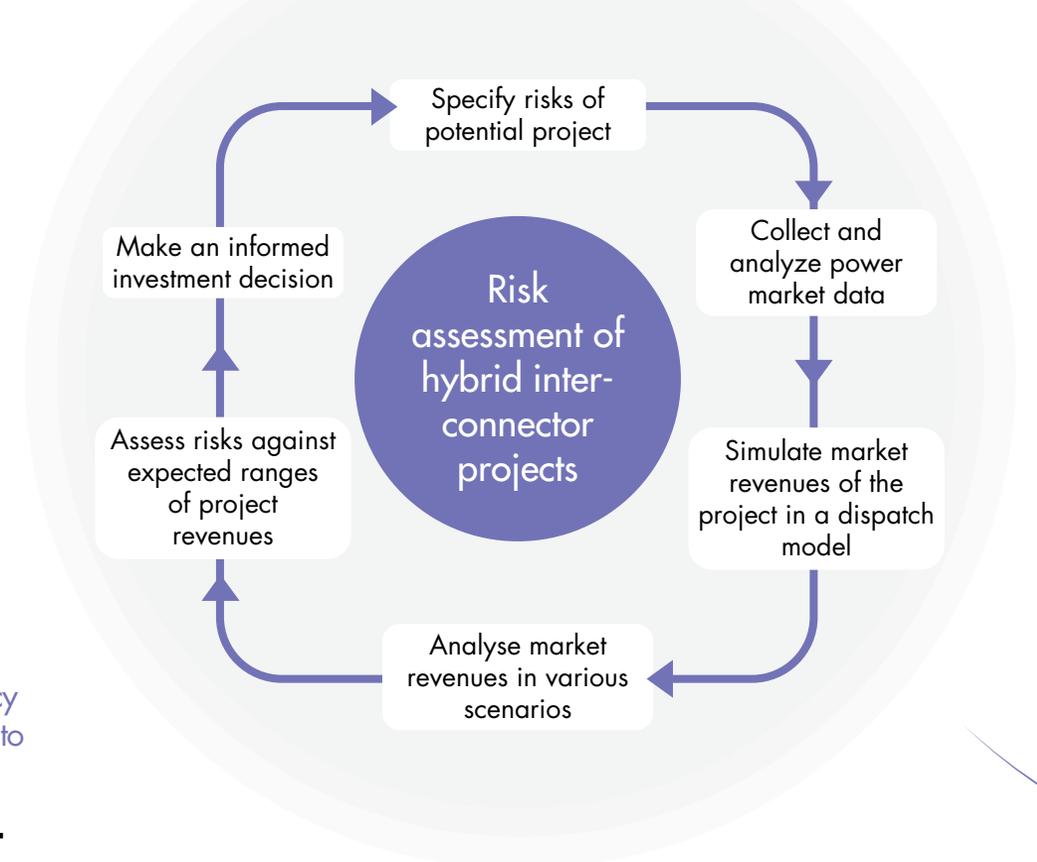
Hybrid interconnectors can reduce the need for onshore grid infrastructure and increase efficiency of power flows. The business case thus requires complex modelling using large amounts of data to simulate different possible configurations with types of costs and benefits.

WindGrid has been developing its project pipeline with the support of Compass Lexecon European electricity market model which simulates the functioning of the power grid and EU market:

Offshore wind infrastructure projects are exposed to substantial market and regulatory risks including the future development of interconnectors, generation fleets and market zones.

In order to assess the impact of different risks and uncertainties, substantial amounts of data and network configurations need to be tested.

The recent developments of advanced power system databases and simulation tools provide critical intelligence support to market participants to optimize their portfolios in the context of growing power system complexity and to make more informed business case assessments.



“Given the highly uncertain future energy market environment, long-term planning and execution of investments are risky. Modelling revenue streams of potential hybrid interconnector projects based on market data helps us to assess project risks and make an informed investment decision.”

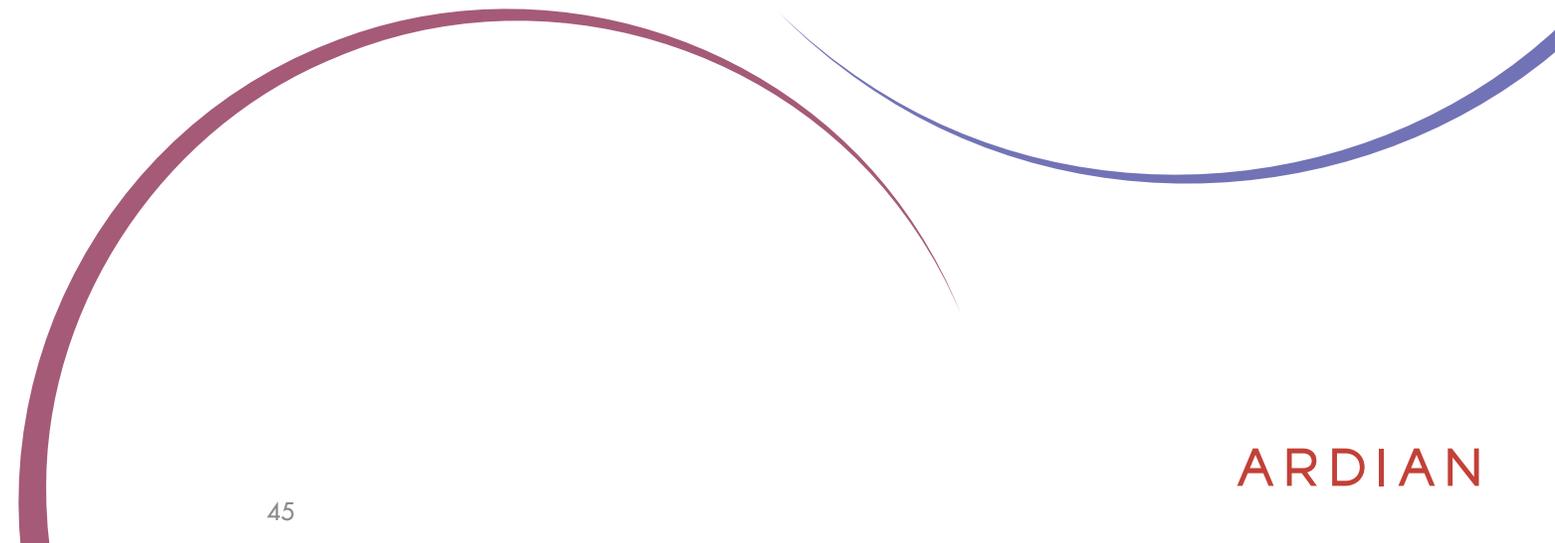
Thomas Köbinger

Lead Market Development & Project Origination, WindGrid



3.

The policy support: towards a smart regulation



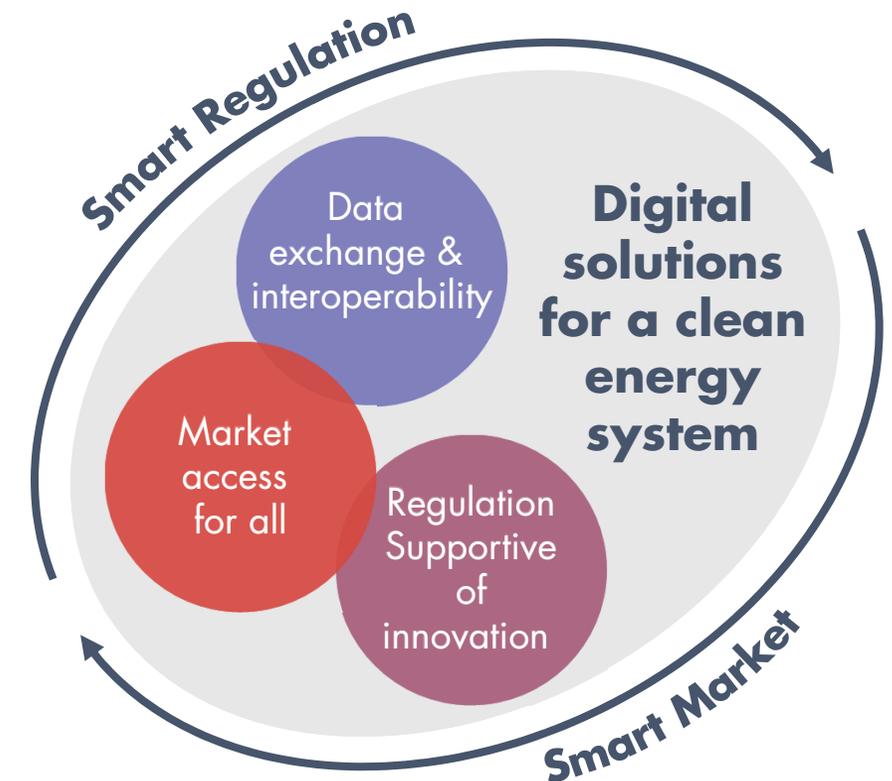
Three critical contributions from policy and regulation are needed for digital solutions to unfold their full potential

The deployment of digital solutions which are a critical enabler for the transition to a clean energy system requires policy action to address some of the shortcomings of the existing market and regulatory framework.

This is because the deployment of innovative digital solutions and the associated business models currently face a range of **regulatory and market hurdles**.

In a successful “whole system approach” where digital solutions can **unfold their full potential**, market design and regulation have to go hand in hand with the evolution of digital businesses, ensuring an adequate set-up for:

- 1 A **framework** enabling standardized and secure **data exchange, communication and interoperability**
- 2 **Market access for all** to facilitate consumer engagement and direct trading between peers
- 3 **Regulatory evolutions fostering innovation**, including incentives for the investments required to support digital solutions and adaptive frameworks in line with quickly evolving business models



1 A framework enabling standardized and secure data exchange, communication and interoperability

Data exchange transparency and reliability are the foundation of a seamless interaction of consumers with the energy system they are part of.

Key issues:

Obtaining and sharing data safely between different stakeholders and policy makers can prove challenging due to a **lack of compatible and reliable frameworks, standards and communication protocols.**

Recommendations:

- To facilitate interoperability, policymakers should push the development of **cyber security protocols, principles for AI, reference data structures, data-exchange standards and harmonized standards across borders.**
- As a one-size-fits all approach may not always be suitable, a **minimum set of interoperability requirements** can help to develop standards, while maintaining competition and innovation.
- With the Internet as a key prerequisite for communication and interoperability, policymakers need to ensure **that the quality of the digital network is fit** for smooth and reliable data exchange.
- The regulatory **approach to data cyber security should be balanced** to ensure data privacy as well as enable the benefits of data sharing.
- The design and establishment of cyber security frameworks should be accompanied with transparent communication of associated risks and benefits to **promote social acceptance and support for smart technologies.**



"In a digital energy world, there will be many sources of data and many systems that need to integrate. Today, it is challenging to obtain the data and to integrate the systems because standardization is lacking."

Jonas Corné

Former CEO & Co-founder of Greenbyte,
Senior Advisor for Ardian on Digital

2

Market access for all to facilitate consumer engagement and direct trading between peers

Digitalization requires a shift in market design which was predominantly conceived for centralized generation assets to a more granular market open to the participation of decentralized parties.

Key issues:

The current market design includes several **barriers which discourage active consumer engagement**: access is often made complex, time-consuming and costly, and requires intermediaries and additional hardware. In addition, **missing markets and frameworks** do not adequately value demand-side response services and externalities.

Recommendations:

Regulators should ensure:

- **That market entry and participation are facilitated for all entities involved in digital business models**, by revising rules for market participation or enabling demand aggregation (including for PPAs).
- **That power markets are supportive of innovative business models**. For example, by ensuring **efficient price signals** as required for demand side response, or by **incorporating missing markets** to properly value smart solutions and allow trading between peers.
- **A standardized framework and definition for all products**, including Guarantees of Origin (time-stamped, with consistent tracking and sufficient granularity).



"Grid operators should open up a harmonized set of APIs for flexibility, thereby favoring new types of aggregators and push for interoperability along the value chain. People are usually lost from the many standards and grid operators are best positioned to give direction for this."

Laurent Schmitt
President, Digital4Grids

Regulatory evolutions fostering innovation and digital solutions

As technologies and business models are quickly evolving, regulation needs to be adaptative and support innovation, striking the right balance between competition and regulation, and providing incentives for innovation and digital solutions.

Key issues:

In the EU, regulatory frameworks for network operators tend to **favour CAPEX over OPEX**, i.e. foster **conventional network over digital solutions**.

Recommendations:

- Regulators may revise the **regulatory approach for capital and operating expenditures**, to better account for operational benefits from digital optimization technologies as in the case of smart grids. For instance, **output-based or TOTEX regulation** can provide opportunities and incentives to optimize the choice of CAPEX light digital solutions and technologies that maximize system efficiency.
- The decision tools and processes used by regulators such as **costs benefit analyzes need to evolve** to include a **whole system perspective** and include the **value of often non-monetized benefits**. **Otherwise, increased capacity will always be favored to increased flexibility**.
- More generally, a **specific process to support innovative approaches** can be put in place e.g. through **regulatory sandboxes to test and learn on limited scopes before scaling**.

4.

Conclusion

Data intelligence is the cornerstone to the clean energy equation

To succeed in the clean energy transition which is paramount in our collective fight against climate change, several changes in our energy system, some of which we already anticipate today, need to happen.

The massive upcoming expansion of Renewable Energy Sources will lead to more frequent shortfalls in electricity prices, a phenomenon often referred to as the self-cannibalization of renewables. Newly electrified sectors will need to mitigate intermittency coming from a more weather-dependent production and provide flexibility. Electricity networks will see the emergence of new forms of supply, more decentralized than today, and demand, more adaptive than today. With a larger and more diverse pool of market participants, the energy landscape becomes more complex. Efficient and effective coordination will become a major challenge.

All along the value chain, data intelligence and digitalization will be essential to address these changes. They will help to optimize the production of existing assets, manage and minimize the exposure to market risk and hence decrease the cost of capital for renewable assets. On a macro perspective, they will allow to master the increasing complexity of modern and clean energy grids and to properly integrate the various types of assets coming on the network.

Beyond resolving issues, data and digital solutions create new opportunities. Through enabling innovative market designs, the conception of new products and the granular matching of demand with local and clean energy generation, these technologies open new perspectives in the more global and challenging context of the fight against climate change.

Sources [1/4]

ACEA (2022): European EV Charging Infrastructure Masterplan March 2022. Available online at: <https://www.acea.auto/files/Research-Whitepaper-A-European-EV-Charging-Infrastructure-Masterplan.pdf>.

Bundesnetzagentur (2023): Quartalsbericht Q1 2023. Available online at: https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/Versorgungssicherheit/Engpassmanagement/QuartalszahlenQ1in2023.pdf?__blob=publicationFile&v=1.

Compass Lexecon (2020): Sustainable paths for Eu increased climate and energy ambition. Available online at: <https://www.enelfoundation.org/all-news/news/2020/09/sustainable-paths-for-eu-increased-climate-and-energy-ambition>

Deloitte, E.DSO, Eurelectric (2021): Connecting the dots: Distribution grid investment to power the energy transition. Available online at: <https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/energy-resources/deloitte-ch-en-eurelectric-connecting-the-dots-study.pdf>.

E-Control (2022): Monitoring Report Versorgungssicherheit Strom 2022. Berichtsjahr 2021/2022. Available online at: <https://www.e-control.at/documents/1785851/1811582/Monitoring-Report-Versorgungssicherheit-Strom-2022.pdf>.

EdF (2019): Flexibility is the foundation for our energy future. Available online at: <https://www.edfenergy.com/large-business/talk-power/blogs/flexibility-energy-future>

EEA (2023): Projected future emissions. Available online at: <https://climate-energy.eea.europa.eu/topics/climate-change-mitigation/projected-future-emissions/data>.

Sources [2/4]

Elia (2023): Adequacy and flexibility study for Belgium for the period 2024-2034. Available online at: https://issuu.com/eliagroup/docs/adequacy_flexibility_study_for_belgium_2024-203?fr=sOTBhNDYxOTUwMTY.

Engie (2023): Catherine MacGregor: "I am calling for a Europe-wide energy policy". Available online at: <https://www.engie.com/en/news/interview-echos-catherine-macgregor>

Entso-E (2023): Entso-E transparency platform. Available online at: <https://transparency.entsoe.eu/>.

Eurelectric (2023a): Eurelectric Power Barometer 2023. Available online at: <https://powerbarometer.eurelectric.org/>.

Eurelectric (2023b): Electricity market design. Available online at: <https://cdn.eurelectric.org/media/6448/market-design-flagship-final-h-0706B927.pdf>.

European Commission (2022): Flexibility requirements and the role of storage in future European power systems. Available online at: <https://publications.jrc.ec.europa.eu/repository/handle/JRC130519>.

European Council (2023): Infografik – Woher stammt das Gas der EU?. Available online at: <https://www.consilium.europa.eu/de/infographics/eu-gas-supply/>

Eurostat (2017): Energy from renewable sources. Available online at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Energy_from_renewable_sources.

Eurostat (2023): Energy production and imports. Available online at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_production_and_imports.

Sources [3/4]

EU - U.S. Trade and Technology Council (2022): TTC WG2 Report of the Industry Workshop on pre-normative recommendations for smart charging and vehicle-to-grid integration. Available online at: https://futurium.ec.europa.eu/system/files/2022-12/TTC-WG2-Report-Stakeholders-Workshop-E-mobility_2022.pdf.

Friends of the Earth Europe (2016): Potential for citizen-produced electricity in the EU. Available online at: https://www.foeeurope.org/sites/default/files/renewable_energy/2016/foee-potential-energy-citizens-eu-260916.pdf.

Google (2022): A new clean energy purchasing model to drive decarbonization. Available online at: <https://cloud.google.com/blog/topics/sustainability/a-new-clean-energy-purchasing-model-to-drive-decarbonization?hl=en>

IEA (2019): The California Duck Curve. Available online at: <https://www.iea.org/data-and-statistics/charts/the-california-duck-curve>.

IEA (2020): Installed capacity in the European Union, 2000-2010, and projections up to 2040 in the Stated Policies Scenario. Available online at: <https://www.iea.org/data-and-statistics/charts/installed-capacity-in-the-european-union-2000-2010-and-projections-up-to-2040-in-the-stated-policies-scenario>.

IEA (2022a): Technology cost trends and key material prices for a solar PV module, 2017-2022. Available online at: <https://www.iea.org/data-and-statistics/charts/technology-cost-trends-and-key-material-prices-for-a-solar-pv-module-2017-2022>.

Sources [4/4]

IEA (2022b): Technology cost trends and key material prices for wind turbine, 2017-2022. Available online at: <https://www.iea.org/data-and-statistics/charts/technology-cost-trends-and-key-material-prices-for-wind-turbine-2017-2022>.

IEA (2022c): Annual heat pump installations in the European Union, 2021-2023. Available online at: <https://www.iea.org/data-and-statistics/charts/annual-heat-pump-installations-in-the-european-union-2021-2030>

IEA (2023a): Electricity Market Report – Update 2023. Available online at: <https://www.iea.org/reports/electricity-market-report-update-2023/executive-summary>.

IEA (2023b): Global EV Data Explorer. Available online at: <https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer>

IRENA (2023a): Renewable Capacity Highlights. Available online at: https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2023/Mar/IRENA_RE_Capacity_Highlights_2023.pdf?rev=a4a69a28b3a444f1b4ff02f6a6664bb4&hash=553011612FECB16B409DA315652AB9ED

IRENA (2023b): Renewable Power Generation Costs in 2022. Available online at: https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2023/Aug/IRENA_Renewable_power_generation_costs_in_2022.pdf?rev=cccb713bf8294cc5bec3f870e1fa15c2.

Schneider Electric (2023): EcoStruxure Microgrid Flex Available online at: https://centuriontechnologies.com/wp-content/uploads/EcoStruxure-Microgrid-Flex-June-22-2023-Centurion-Tech-LLC_Webinar.pdf

SmartEn (2022): Demand-side flexibility in the EU: Quantification of benefits in 2030. Available online at: https://smarten.eu/wp-content/uploads/2022/09/SmartEN-DSF-benefits-2030-Report_DIGITAL.pdf.

Statista (2023): Number of Internet of Things (IoT) connected devices worldwide from 2019 to 2023, with forecasts from 2022 to 2030. Available online at: <https://www.statista.com/statistics/1183457/iot-connected-devices-worldwide/>.



ARDIAN

Published in November 2023