Case Study

E.ON:

Building a New AI-Powered Energy World

Image credit: NASA

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This case study was written by Pal Boza, INSEAD GEMBA '14, and Theodoros Evgeniou, Professor of Decision Sciences and Technology Management at INSEAD. It is intended to be used as a basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation.

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Extra teaching materials are available at https://publishing.insead.edu/case/eon

"Every economy is built with three general purposes: communication, energy and mobility. We have seen revolutionary shifts in all these sectors. There is a layer entering those purposes which I call the "data layer". This is where artificial intelligence kicks in. It is fundamental."

Karsten Wildberger, Chief Operating Officer – Commercial (COO-C) and Board Member, E.ON

Business with Purpose: Energy, Technology and the Planet

The energy sector has played a dominant role in the economy and society for centuries. But rising energy consumption is putting the planet at risk, notably in the form of climate change. Today, global energy consumption is 10 times higher than it was 100 years ago (Exhibit 1); per capita consumption more than doubled in the same period. According to the International Energy Agency (IEA), energy consumption will rise by more than 25% between 2020 and 2040.[1]

In 2019, seven of the top 10 companies on the *Fortune Global 500* list were from the energy sector, which continues to evolve in terms of technical progress and in response to society's expectations.[2]Technological changes (such as renewable energy, small-scale commercial generation and electric vehicles) lead to innovative business models. Societal expectations related to CO^2 and other emissions are pushing companies to adopt carbon-neutral strategies. "Carbon pledges" have been made by Facebook[3], Google[4], Apple[5] and Amazon.[6] Microsoft[7] has committed to remove more carbon from the environment than it emits by 2030.

The energy sector is directly responsible - through the production of electricity and heat - for 45% of global CO_2emissions.[8] Indirectly it has a major impact on emissions from industrial, residential, transport and other sectors. The energy transition aims to meet the increasing global demand for energy (Exhibit 2) in a way that is sustainable and efficient.

Green electricity may be part of the solution, and as Matthew Timms, E.ON's Chief Digital & Technology Officer describes *"many people like the idea that electrification is transforming the world"* as electricity provides a constantly increasing share of our energy consumption. Since 2000, global electricity consumption has increased by 75% and is expected to rise by a further 60% by 2040.[9] Around 85% of the increase comes from developing economies, China being the largest and India the third-largest electricity markets in the world. E-mobility, electric heating/cooling and electrification[10] will push up global demand for electricity.

Liberalization of the energy market has de-coupled the traditional business model involving generation/distribution/sales, changing the competitive environment. Recent decades have seen the 'democratization' of energy in Europe. As the energy transition moves up the agenda, utility suppliers have come under pressure to provide new innovative services.

This contrasts with the last century when electric power was a relatively safe business. High barriers to entry and heavy regulation made it possible for utilities to operate as natural monopolies. *"This is probably the reason why utilities have also a more traditional culture"* explains Juan Bernabé Moreno, E.ON's Chief Data Officer.

In the traditional value chain, electricity is generated by a small number of utilities requiring very large capital investments, mainly from fossil fuels (gas, coal, etc.) and nuclear energy. The transmission system delivers high voltage over long distances from a few power plants to the distribution network. The distribution system delivers low voltage electricity to end-customers. Retail energy companies purchase electricity and sell it to customers, with the task of metering and billing. Energy and data flow to the end customer, the last link in the value chain.[11]

The New World of Energy

> *"Historically the energy system was based on large centrally managed power plants. You needed at least a billion euro to participate in the energy generation business. In contrast, today you can participate with one solar panel, and you contribute to the electricity system."*
>
> Karsten Wildberger, COO-C and Board Member, E.ON

"The energy system of the twentieth century was founded on burning fossil fuels and splitting atoms. But this system is reaching its limits."[12] With the 'fourth industrial revolution', energy is on its way to having further socioeconomic significance. This involves a transition from a centralized, monopolistic and fossil-fuel system to a decentralized, sustainable system in which energy and an increasing volume of data flow both ways along the value chain as consumers increasingly become producers ("prosumers").

The volume of data generated along the value chain has exploded in the past decade (Exhibit 9). Take the example of smart meters, which collect energy consumption data from consumers. For one million consumers, 35 billion data records are generated, equivalent to 2900 Tb of data annually.[13] Using this data, artificial intelligence (AI) can forecast network load, consumption habits, predict consumption patterns for each consumer, and optimise peer-to-peer trading between prosumers. However, smart meters also evoke threats to personal privacy. In the Netherlands, for example, the roll-out of smart meters was delayed by privacy issues such as predicting consumption patterns related to religion (e.g., Ramadan).[14]

As the boundaries of the traditional regulated electricity system expand, cities in the future could be independent of the national grid, generating, storing and consuming electricity through their own micro-grids. In 2017 there were already 1,800 micro-grids worldwide (mostly in North America), with a generation capacity of more than 20 gigawatts.[15]

Decentralized renewables and electric cars are changing consumption patterns in a way that could disrupt the value chain if not managed properly. In 2019, there were 7 million electric vehicles globally; 250 million are expected by 2030.[16] When electric cars are not in use, the electricity stored in their battery could be returned to the grid at peak demand periods, thus providing flexibility through intelligent technology and data-driven optimisation.

For example, in California, solar energy provides a significant part of the electricity supply. Since January 2020, every new-built home in California must be equipped with enough solar panels to satisfy its electricity needs.[17] However, solar panels do not generate energy at peak demand hours, whereas e-vehicles provide the equivalent of $12.8 bn to $15.4 bn of stationary electricity storage investment in California alone.[18]

This is just one example of how the power sector is being disrupted by innovation (renewables) and how data-intensive technologies such as AI offer opportunities for new businesses/solutions that transform the way energy is generated, stored, transmitted, bought and sold by a global network of millions of prosumers of all sizes. Wildberger notes:

> *"The future of the energy sector will be more networked, driven more by software and AI. The value will be created by providing technology-enabled energy solutions and infrastructure to our consumers."*

The Renewables Revolution

Thanks to renewable sources, electricity may be the fuel of the future – a relatively cheap alternative in a decarbonised world. The energy produced by solar and wind was 60 times higher in 2019 (1.857 TWh) than in 2000 (32 TWh). In 2019 alone, the size of new-built solar photovoltaic projects globally was equivalent to 200,000 football fields.[19] Largely as a consequence of technological improvements (Exhibit 3), between 2010 and 2018 the levelized cost[20] of electricity from renewables declined by 77% for solar and 35% for onshore wind[21] to $51/MWh and $47/MWh respectively,[22] bringing generating costs to a level comparable with fossil fuels. Today, wind generates 5% and solar 2% of the global electricity supply – but they are anticipated to account for a much greater share in the future.

However, renewables create new challenges because the supply is dependent on the weather, which is uncertain and uncontrollable. Onsite and microgeneration (e.g. rooftop solar panels) disrupt the existing system as the power grid is dimensioned for large-scale remote production. Now with two-way direction, steering and optimization for future investments in grid gets more important and leads to higher costs. Digitalization and specifically AI can help reduce these costs and speed up deployment of renewable energy sources, as Karsten Wildberger points out: *"The future energy world will be decarbonised. The question is how fast can it happen and how can this be orchestrated with digitalisation?"*

If "AI is the new electricity", as many claim, what about using AI *for* the new electricity world?

New Technological Challenges

> *"Current AI tools lead to more accurate predictions and better decision making. Hence, the cost of prediction will be cheaper. This will increase efficiency, reduce costs, and improve the customer experience."*
>
> Karsten Wildberger, COO-C and Board Member, E.ON

When electricity is distributed through the grid, the supply must be equal to demand at all times. Renewable energy sources such as wind and solar can only generate electricity in certain conditions (e.g., daylight, windy weather) – so they can rarely match demand. Not being able to store intermittent energy and variability in generation creates challenges for generators, utilities and the energy markets, making it essential to retain costly "buffers" for power generation (e.g. gas-fired power plants) and storage (e.g. electric batteries, pumped hydro storage) on stand-by to balance demand when there is an unexpected change in output. This requires the ability to rapidly determine how much electricity should be produced, by which generator, and at what time (Exhibit 4). Such decisions can be optimized by a combination of more efficient electricity trading and better forecasting of supply (e.g. wind or solar power) and demand (e.g. household consumption).

AI can be an efficient tool as the importance of this optimisation will increase in the future with higher penetration of variable renewable sources, probably leading to increased electricity prices and price volatility (Exhibit 5). Maintenance spending in the network can also be reduced by using algorithms to make more accurate decisions about the maintenance or replacement of equipment. Indeed, AI may prove to be the missing 'piece of the puzzle' for the transformation of how the world produces, buys, sells, and consumes energy – and with far-reaching implications for our economy and the planet. Getting there will require technological as well as major business innovations. This is where the E.ON journey starts.

E.ON's AI Journey

E.ON, a German electric utility company quoted on the DAX and DJ Stoxx 50, had more than 70,000 employees and revenues of €41.48 bn in 2019 (Exhibit 6). It was created in 2000 as the result of the merger of VEBA[23] and VIAG,[24] two state-controlled industrial groups. Over the last decade, E.ON has committed to transform and adapt to meet customers and society's needs, using its existing know-how and developing new capabilities.

> *"Ten years ago we were not really considered a customer-centric company. A customer was only a connection point for us and we operated in a quasi-monopolistic structure. We were too expensive and too slow in an increasingly competitive market environment."*
>
> Jan Niclas Brandt, Vice President, Market Excellence, E.ON

Having spun off conventional generation (Uniper) in 2016, E.ON committed to become an enabler of the energy transition. In March 2018, it announced the acquisition of energy utility Innogy as part of a €43 bn deal swap with RWE, another German electric utility. E.ON received Innogy's retail and distribution business, while RWE took over E.ON's industrial renewable portfolio. From being an industrial generator (of fossil fuel and renewables), distributor and energy retailer, E.ON streamlined its portfolio to become an enabler of connectivity through the distribution network and a sustainable energy solution provider for industry, local municipalities and end customers.

> *"E.ON has fundamentally changed its business model. We are moving from a system-centric (i.e., asset-heavy project business with high complexity but long-term stable cash flows) to a more decentralized business model (i.e., a wide range of models from small-scale PV systems to large-scale city supply solutions) built to support the transition to a decentralized and sustainable energy system."*
>
> Jan Niclas Brandt

The Energy Networks business plays a crucial role in making the transition of the energy system work. E.ON invested more than €1,655m (2019) in modernizing the energy distribution system and today operates 1.7m km distribution lines and 500,000 connected assets. It also invested €724 million in the Customer Solutions business, ranging from city-scale solutions, industrial solutions and electric vehicle charging infrastructure, to private home solutions, thereby enabling its customers to take an active role in the energy transition. With around 350 heat networks, 32,000 industrial and commercial sites, as well as 50 million energy retail customers in 15 countries, E.ON generated EBIT of €3,235 million in 2019.

Following the integration of Innogy, E.ON committed to preserving the climate and creating a future worth living in for generations to come. In the new energy world, digitalization and AI have an important role in a radically different competitive landscape.

Building a Digital Business: Getting it Off the Ground

> *"What kind of decisions can I make based on data? What is the data model of this industry? How would I rebuild E.ON or the energy industry by applying the data model? Those are the questions we are basically trying to answer."*
>
> Karsten Wildberger, COO-C and Board Member, E.ON

Along with the new business model, E.ON is building its digital and data capabilities. Its vision is to develop a culture of data – where data drives the business and AI is used to answer fundamental questions and solve problems – while advancing the energy transition.

Different experts were brought in the organisation from outside into key positions. A dedicated structure was created, led by a new Chief Digital Officer, Matthew Timms. The new digitalisation unit was centrally located in the company structure, with a specially allocated budget and mandate to operate globally.

> *"There was a strong impetus from the board that digital transformation is a key for the next years. This set the frame for the organization to build capabilities and drive initiatives, combined with a programme of 'Big Tickets' focusing on value pools across the company."*
>
> Matthew Timms, CDO and CTO, CEO EDT GmbH, E.ON

In April 2016, Juan Bernabé Moreno was appointed as Chief Data Officer at E.ON. He has previously worked at Telefonica, a major telecommunication company, being in charge of building AI solutions internally. He explained:

> *"Right before joining E.ON, Matthew Timms warned me: 'E.ON has not been focusing on data for some time, so we need to catch up.' I knew this was going to be a tough journey because of the traditional focus on assets and infrastructure and the cultural gap, but at the same time, the opportunity to drive impact was really appealing."*

Big Ticket Projects for People to Talk About

They started by identifying "big ticket" items– transformational digitalization projects that created measurable value. Some, such as implementing AI-based predictive maintenance for wind turbines, had been identified by external consultants. Most relied on data and AI components provided by the central data team. Projects with the shortest time-to-market and highest impact were realised first. There was a huge emphasis on visibility, as Moreno affirmed:

> *"When I joined E.ON, AI was a very abstract concept. My obsession was to make it tangible for everyone in the company, highlighting the benefits and the potential. So I started presenting at several internal events. Eight weeks after joining the company, I took the audience to a wind park in Texas to show AI-based wake management in action using Google Earth... and people started talking about it."*

As the value became apparent, the central data team was solicited by different parts of the organisation. A mechanism was needed to scale up efforts in order to be able to satisfy demand and maximise the value creation potential of AI. In May 2018, the board gave its approval to a transformational programme called Data.ON, defining a set of strategic priorities and focus areas to develop specific activities, outcomes and measurable results. At the core were "data evangelization" and "data readiness".

Data Evangelization

> *"If you look at reality based on data, it might be different from what people believe. We have to challenge beliefs to adopt AI."*
>
> Victoria Ossadnik, CEO, E.ON Energie Deutschland

The purpose of the data evangelisation activities was to increase data literacy in the company. Events were organised to show the status of ongoing projects. A "Data Visualisation Day" was held where companies like Tableau and PowerBI were invited to present, pitch, and coach employees to compete on a challenge. Attendees learned how to visualise and interact with data from inside and outside the company.[25]

Data.ON hubs were organised to foster cooperation between the business units and the central data team. There were demos of existing projects and exchanges on technology, best practice, data management and privacy-related issues.[26] By the end of 2019, more than 1,000 employees were involved in the Data.ON community, over 45 projects had been documented and shared, and the visualisation community had over 100 members (Exhibit 7).

"Establishing partnerships with academia and the corporate sector clearly helps to build capabilities inside the company. This is especially true in the field of AI."

Michel Thomas, Head of Strategic Partnerships. E.ON

Initially, data science and engineering courses were organised by the company for data-literate employees. After thorough analysis, Udacity was commissioned to provide 11 nano-degrees for 3-6 months (in machine learning, computer vision, and deep reinforcement learning). Free courses from Udacity (20 courses), Coursera (30 courses) and Google helped to bridge the gap with the nano-degrees. A "Dat-A-Cademy" platform was set up to enable data experts to keep developing their skills. Data evangelisation was a useful tool for "getting people on board" within the company. Similar efforts were made to attract talent from outside.[27]

Attracting Talent

"The energy business is today clearly much more interesting than compared to 10 years ago. I think that from an industry that was seen as old and very conservative, we are now doing things that are relevant for many people across industries."

Johan Mörnstam, Senior Vice President, Energy Networks Europe

At first, hiring was difficult as the energy sector was not perceived as a great place to work (compared to Silicon Valley-type companies). However, AI had the potential to fundamentally influence the energy transition and E.ON was clearly pushing this agenda, as Karsten Wildberger emphasized: "We are on the cusp of the next energy transition and we wrote the E.ON story[28] to give people a purpose."

As the team grew and projects started to show results, hiring got easier, although data professionals were in demand and attracting talent was still challenging. By the end of 2018, the central team numbered more than 50 data professionals (from 10 when the unit was set up in Q2 2017). In parallel to the central team, each regional and business unit brought in their own data professionals (in energy economics, retail, solutions, etc.), boosting the community. The complexity of AI systems required employees with highly specialised profiles in multiple disciplines: advanced statistics, mathematics, machine learning, software development, deep domain knowledge, visualisation, data storytelling and communication skills.[29]

Data Readiness: Building on data at E.ON

"The limiting factor of AI is data. Hence, we focused on getting all the data assets in the company "ready" so that we can harness the potential value. Our obsession has been to make data first class citizens."

Juan Bernabé Moreno, E.ON Chief Data Officer

At E.ON, a large organisation with complex structures and processes and a relatively underdeveloped data culture, few employees understood the potential size of the opportunity. For example, there were contracts where the ownership of internal data had been given to different providers without a clear business rationale. A poor understanding of data privacy regulations meant that projects were often halted or deemed unfeasible "because of GDPR" (General Data Protection Regulation rules), whereas GDPR rules were in fact respected.[30]Sometimes, several initiatives were started simultaneously in different parts of the organisation in an attempt to solve the same problem – without coordination or understanding how value was generated.[31]

Different data maturity frameworks (Exhibit 8) were studied to determine the starting point of the roadmap:

> *"We looked at existing maturity frameworks and we realized that the way they were structured, collecting data and analysing the situations was not suitable for E.ON, because they were not scalable. They did not take into account the change management elements. So this is why we developed our own framework."*
>
> Romina Medici, Data Management Specialist

To measure the evolution of the company's data culture, the maturity levels of people, processes, technology, execution, data management and governance had to be identified. Within the Data.ON programme, data readiness had a clear goal: to change the way the organisation thought about and handled data. Three core areas were formulated to achieve this[32]:

- Implement a standard mechanism to identify, describe and catalogue all data sources (owned and acquired) across the organisation.
- Establish "lite" tool-supported data governance (who can access what, with what purpose, and remain GDPR-compliant).
- Standardise a secure infrastructure, where all data is centrally stored and managed while integrating distributed data sources.

A data governance platform was implemented for internal and external data. Information on data governance was integrated into the meta-data management tool, defining roles, responsibilities and processes to create transparency about data sources. Predefined data domains (e.g. customer data) were allocated to "data owners", who were responsible for data quality and answering related questions, and supported by technical and business "data stewards" (Exhibit 9).

> *"We have different levels of data readiness across the different countries. For instance, at E.ON Romania we have a dedicated data owner for each data type, so we have 100% coverage there."*
>
> Romina Medici, Data Management Specialist

The central data team's approach was to help business people understand the challenges related to data readiness and data governance. Workshops were organised across the different units to demonstrate how improved data quality created value.

How Value is Created with AI

> *"How to start with AI? First, pick a pet project where you think you perfectly understand the business. Secondly, you need to talk to people from different background and bring them together. I brought IT and business people with me for 3-4 hours, and at the end there were a lot of cool ideas on how to reduce costs."*
>
> Victoria Ossadnik, CEO, E.ON Energie Deutschland

The value creation pools were grouped around five different themes:

- Smart assets and networks: predictive maintenance, local balancing, intelligent inspection and network monitoring
- Sales and service: growth hacking, base management and next-gen customer service
- New AI-enabled customer-facing products: disaggregation, photovoltaic analytics, optimum and future energy home
- AI-assisted energy economics: network zone balancing, short-term yield prediction, smart hedging
- Renewables: dynamic yield optimisation, predictive analytics for wind turbines, autonomous assets inspection.

AI Project Prioritization Processes

From the beginning, business units cooperated to define potential projects. A "gating process" was established to prioritize AI projects based on the following criteria:

- What is the value creation potential, and is it possible to measure it?
- Can the project be generalised? Is it a project that solves a problem for a specific business unit, or can it be scaled to company level?
- Can previous project elements be reused to shorten the time to market, to show value quickly?
- Is there an important "sponsor" in the company behind the project? Can it help in the "data evangelisation" process?

The aim was to have a strong commitment and clear understanding. However, as Juan Bernabé Moreno put it, "If necessary, we should be able to fail fast and move on."

First, a prototype would typically be built with offline data to show that the solution could really be created. Once the prototype approved, together with the business unit the pilot phase delivered an 'industrial pilot' based on real data and a real business context that had to deliver value. Limitations of the pilots tended to be technical and hence were later made more robust without the business units noticing it, but being "very transparent". Finally, the solution was made into a product and rolled out.

"Once we have it implemented end to end, the algorithm does what it is supposed to do, but you are by far not done: you need to change the business process where the AI insights need to be consumed. Experts know more than what you captured with the algorithm; also they are not used to use them. This is a micro change management issue. We tried to overcome this by building trust with the user and making sure they were always in control and not the algorithm."

Juan Bernabé Moreno, Chief Data Officer

What's the Value of Data Readiness

The aim of data readiness was to "datafy" the whole value chain and thus enhance value creation based on data. Data readiness would increase productivity and efficiency with handling data, and enhance compliance with GDPR. It provided "options" to build new technologies such as AI that leveraged the data layer, although it was difficult to estimate the value of an "option" because it enabled future prospects based on, for instance, a net present value calculation.

"We do 'value workshops' with people from the business units where we help them understand the value of data quality and calculate what the impact would be for them. We end up with user stories and impact calculations at the end of these workshops."

Romina Medici, Data Management Specialist

There was clearly value for the organisation but the board and the data team were looking for further evidence in support of data readiness to answer the question: 'Why are we doing this?' They wanted data to be used for evidence-based decision making but needed to show that data readiness created value. What were the arguments in its favour, for example what options would it enable? And what KPIs could be used to measure these?

Building on the previous work of the data team, in March 2019 a dedicated project was created with four workstreams to support data readiness:

- Data governance: Working with local business units to develop a global data governance framework; finalize an aligned approach for E.ON data license management
- Metadata management: Roll out the metadata management tool to additional countries; develop related best practice, tutorials and e-learning
- Data modelling: Analyze the current data models for energy networks, compare them, and create a draft for a consolidated model
- Data quality and mastery: Analyze data quality, challenges, technologies and needs; develop a global concept of data quality to support business units.

The data team sought to benchmark the organisation in terms of data maturity. Different levels of readiness necessitated different types of action, but how could they know that it was "data ready" and how could the data maturity model be used to describe a data mature organisation? (Exhibit 4)

Investing in AI for Energy Trading

> "For us, value is very much created through risk mitigation."
>
> Giorgio Cortiana, Head of E.ON Adv. Analytics- – Energy Intelligence

An early challenge for the trading unit was to reduce balancing costs of the variable renewable energy sources (wind, solar). Because the production of variable renewable energy sources is uncertain, there are deviations between the forecasted generation and the actual production, which needs to be balanced in a short amount of time. The greater the imbalance, the more the need for emergency generators, and the higher the costs. When an imbalance occurred, market mechanisms (trading) were used to adjust to unforeseen changes in power production and consumption.[33]

The risk of commercialisation of renewables was reduced through:

- Use of AI to improve the accuracy of the renewable assets infeed predictions
- Prediction of production facilities shut-down (a day ahead), for example as a result of transmission network congestion
- Prediction of price trends for intraday trading (When should a position be adjusted – now? in half an hour?)
- Prediction of the nationwide surplus/imbalance in the energy network (e.g. predict the balance of energy sector in Germany, Exhibit 12)

These aimed to reduce the inherent risk of commercialising renewable energy sources and reach the maximum value creation potential when exploited together, possibly linked to trading robots.

Scaling up AI: The Road Ahead

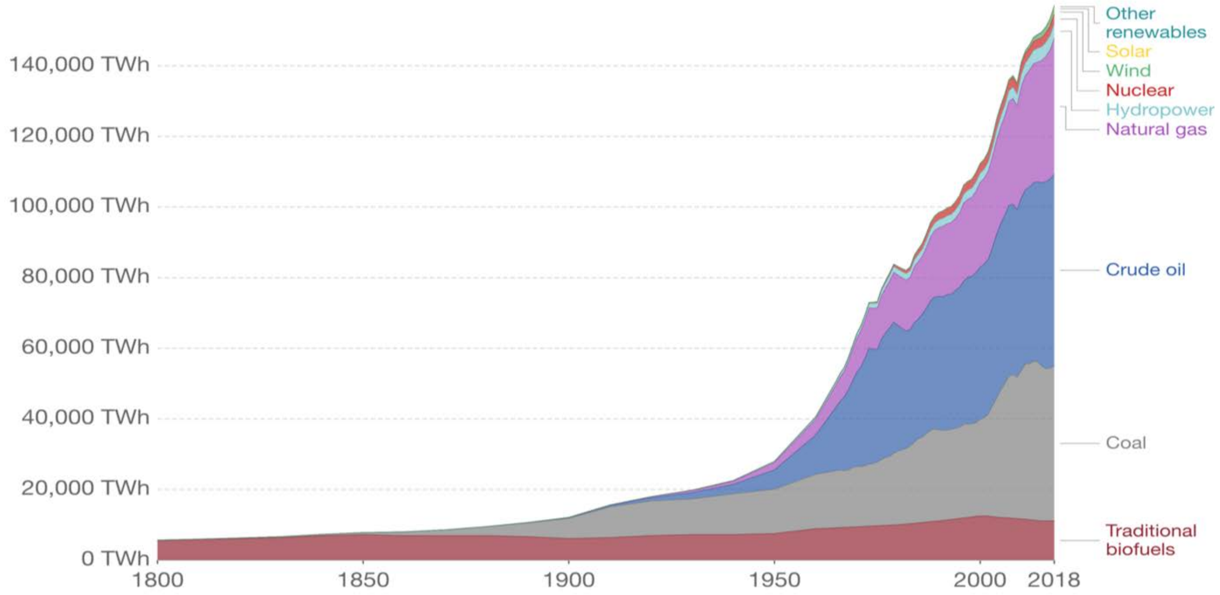
> *"We still need to get more focused, be faster and get better at creating a tangible business case. We also need to continue developing capabilities across the broad organization to change the system."*
>
> Karsten Wildberger, COO-C

E.ON has engaged in demonstrating how data is transforming the energy world and how data and AI play an indisputable role in the energy transition.[34] The vision for the future was to have "embedded", "scaled" and "disruptive" AI. "Embedded" meant to have AI integrated in all new solutions and applications. "Scaled" AI referred to the scaling up of the technology to organisational level as a widely accepted tool to create value. "Disruptive" AI was aimed at supporting new business models that can fundamentally change the way of doing business and creating value in the energy sector.

> *"How will value be created in the future? By combining our assets, infrastructure and solutions with technology, AI and software to create new solutions and revenue streams."*
>
> Matthew Timms, E.ON CDO and CTO, CEO EDT GmbH

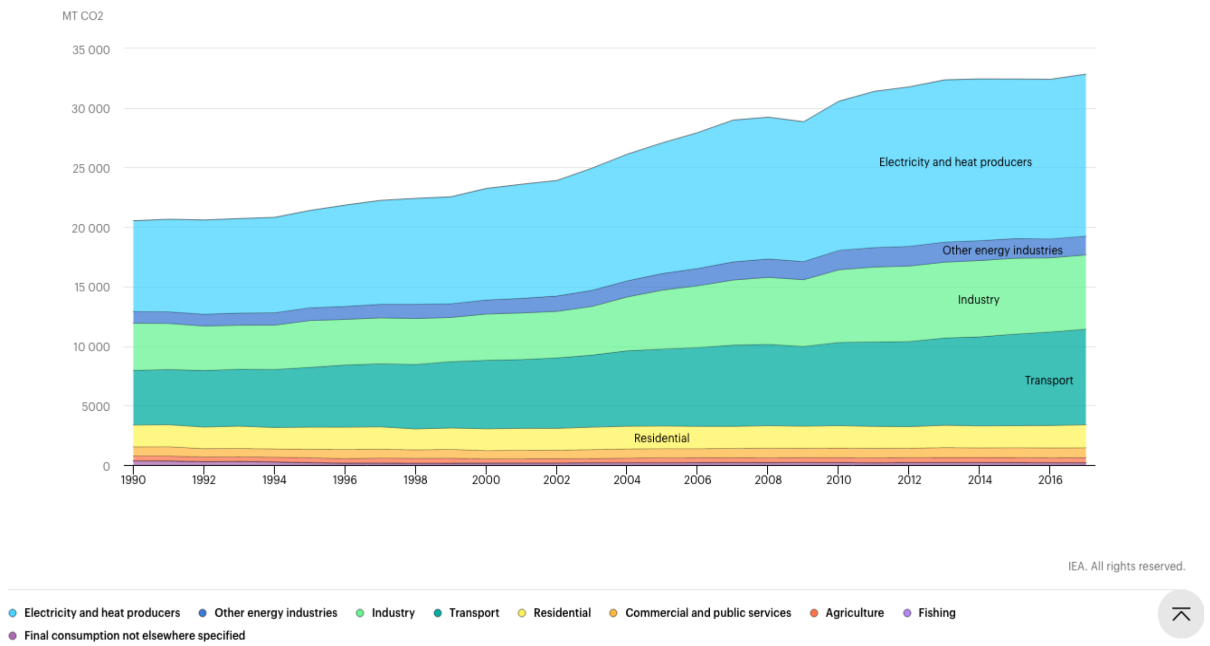
Besides scaling up, there was the question of how to finance the "enabler" data infrastructure and activities across the organisation. Initially, the central data team was financed from a centrally allocated budget. Over time it was transferred to the IT and Digital business function unit (EDT GmbH), and had to finance its own operations in line with the initial aim to bring AI closer to the business and push for commercial utilisation. The new focus was on "real life" use-cases and the cost of the tool supporting this had to borne by users. Thus, the business units became 'clients' of the IT and Digital Unit, which was henceforth dependent on them for revenues from those. The challenge remains for the organisation: How can AI be leveraged to create value and what is the proper way to finance an "enabler" infrastructure?

Exhibit 1
Global Primary Energy Consumption



Source: Our world in data - Accessed on the 26 March 2020 at https://ourworldindata.org/energy

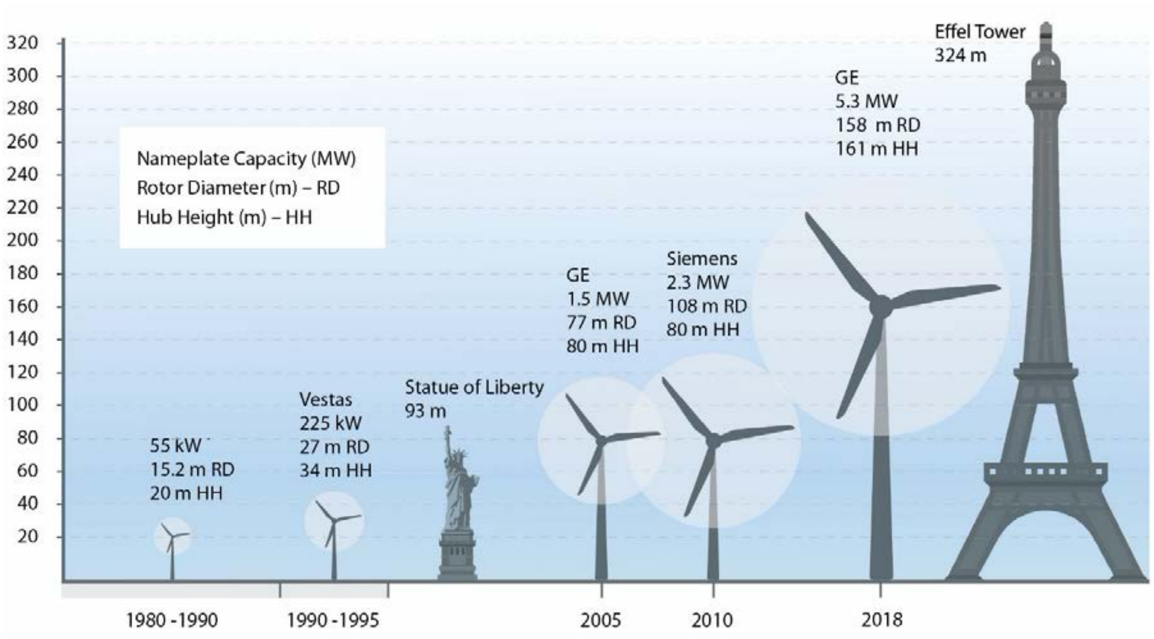
Exhibit 2
CO² Emissions by Sector (worldwide) 1990-2017



Source: International Energy Agency

Exhibit 3

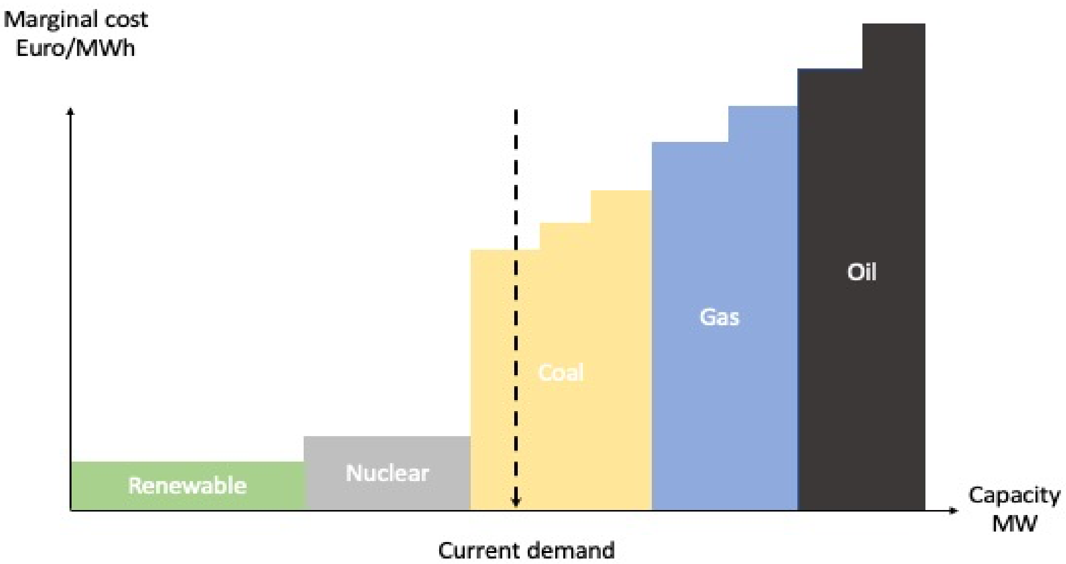
Growth of Wind Turbine Size 1980-2018



Source: Results of IEA Wind TCP Workshop on a Grand Vision for Wind Energy Technology
Accessed on the 26 March 2020 at https://www.nrel.gov/docs/fy19osti/72437.pdf

Exhibit 4

Merit Order Ranking of Electrical Generation

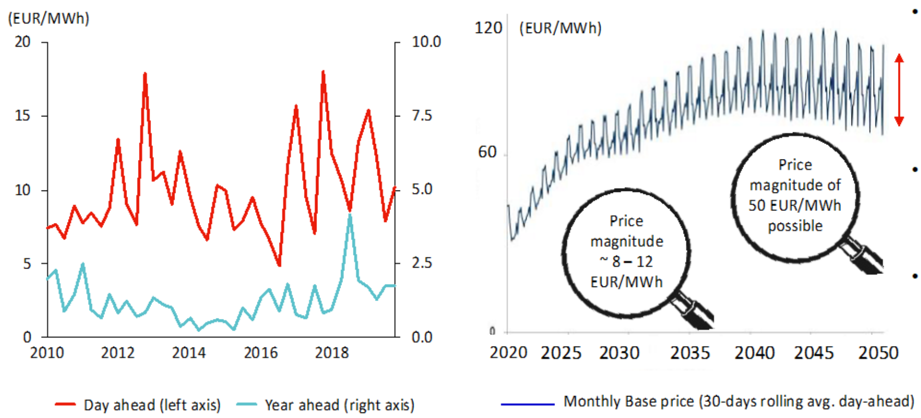


Source: https://medium.com/electricitymap/using-machine-learning-to-estimate-the-hourly-marginal-carbon-intensity-of-electricity-49eade43b421

The power price is determined by the "merit order" – the order in which power stations provide power to the electricity market. The demand for electricity defines the capacity needed on the market. Offers by the power stations with the lowest costs (hence cheapest) will be accepted first to provide capacity for the market.

Exhibit 5

German Power Price Volatility (historic and forecast)



- The volatility of spot and forward prices has increased in recent years and will continue in parallel with the rising share of RES
- The day ahead market for power is much more volatile than the forward market
- Summer-winter seasonality from temperature in winter and lower electricity prices in summer

Source: European Energy Exchange (EEX), Energy BrainPool

Exhibit 6

E.ON Financial Figures 2018-19

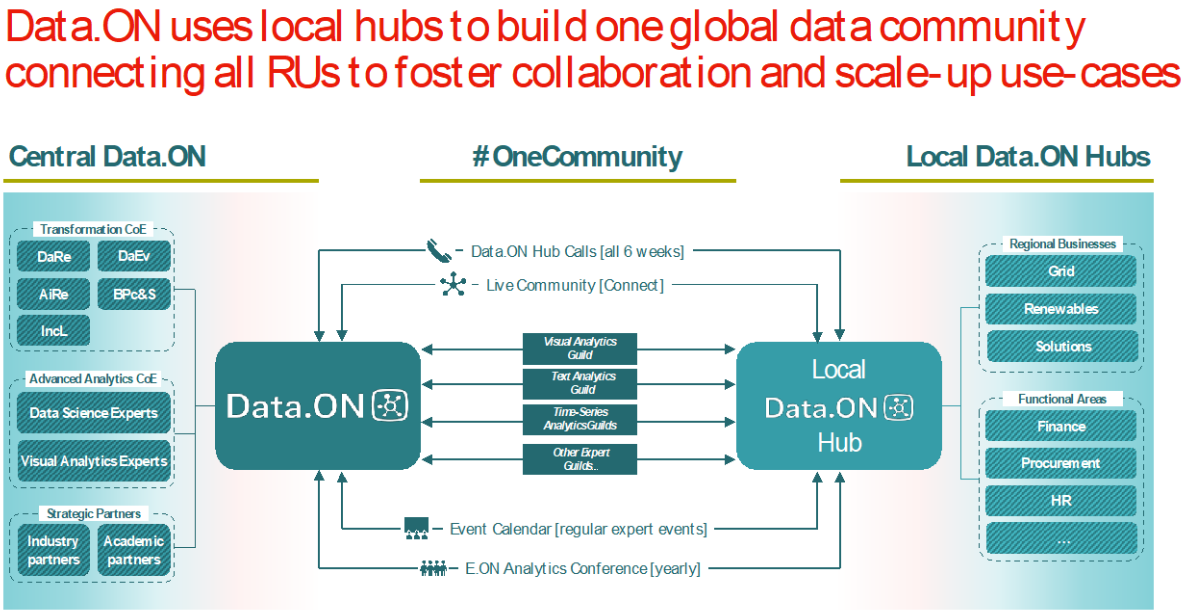
€ m	FY 2018	FY 2019	% YoY
Sales	30,084	41,484	+38
EBITDA[1]	4,840	5,558	+15
EBIT[1]	2,989	3,235	+8
Adjusted Net Income[1]	1,505	1,536	+2
OCFbIT	4,087	4,407	+8
Investments	3,523	5,492	+56
Economic Net Debt[2]	-16,580	-39,430	-138

1. Adjusted for non operating effects 2. Economic Net Debt as per 31 Dec 2019 and 31 Dec 2018; Economic Net Det definition takes into account the decommissioning provisions calculated with a real discount rate of 0.0% as opposed to IFRS AROs; bonds issued by innogy are recorded at their nominal value: the amount in the consolidated balance sheets is €2.5 bn higher

Source: E.ON

Exhibit 7

Data.ON Global Data Community at E.ON



Source: E.ON

Exhibit 8

Stanford Data Governance Maturity Model

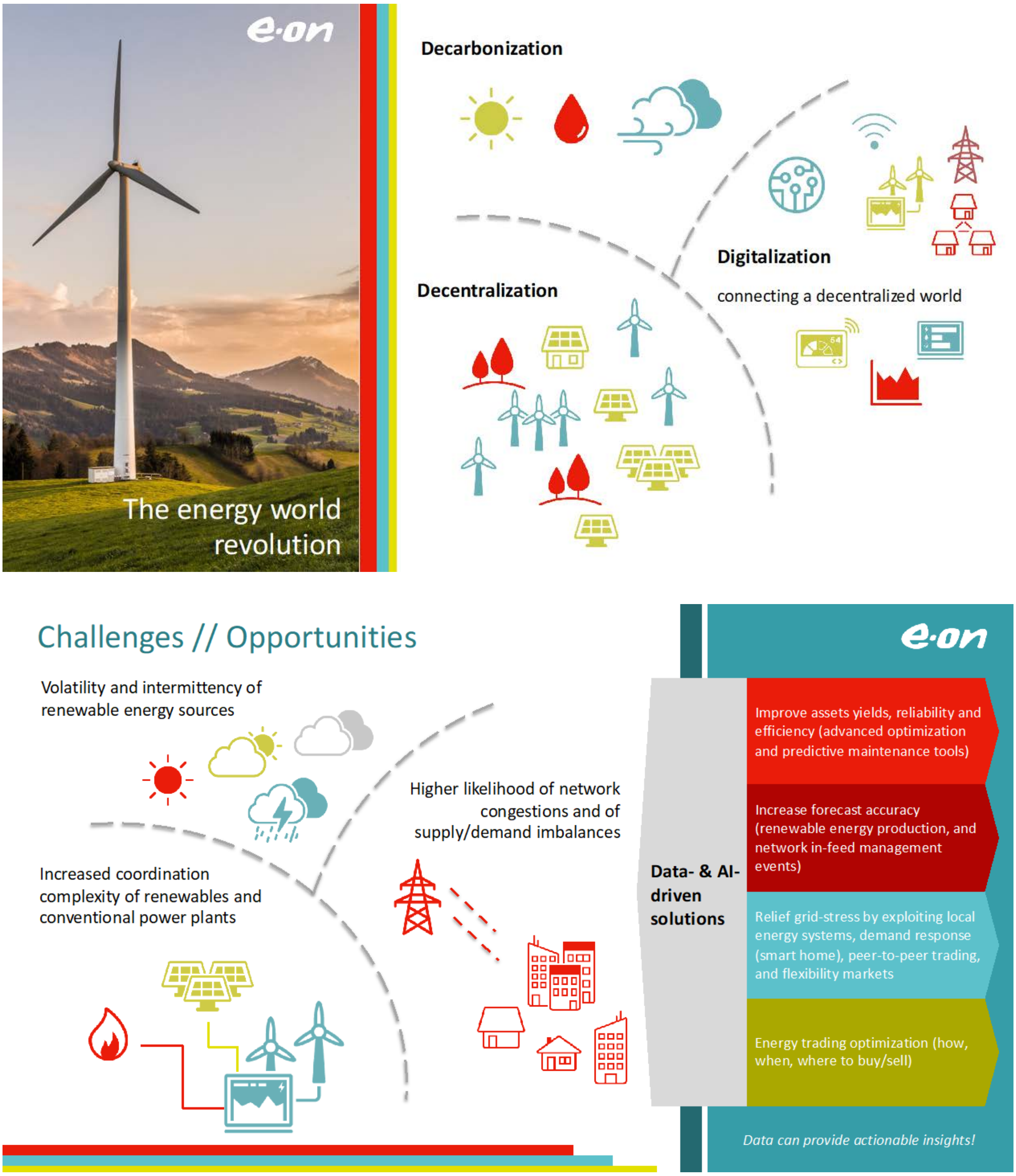
Data Governance Maturity Model Guiding Questions for each Component-Dimension			
Foundational	People	Policies	Capabilities
Awareness	What awareness do people have about the their role within the data governance program?	What awareness is there of data governance policies, standards and best practices?	What awareness is there of data governance enabling capabilities that have been purchased or developed?
Formalization	How developed is the data governance organization and which roles are filled to support data governance activities?	To what degree are data governance policies formally defined, implemented and enforced?	How developed is the toolset that supports data governance activities and how consistently is that toolset utilized?
Metadata	What level of cross functional participation is there in the development and maintenance of metadata?	To what degree are metadata creation and maintenance policies formally defined, implemented and enforced?	What capabilities are in place to actively manage metadata at various levels of maturity?

Project	People	Policies	Capabilities
Stewardship	To what degree have stewardship roles been defined and filled?	To what degree are stewardship policies defined, implemented and enforced?	What capabilities are implemented to support the effective stewardship?
Data Quality	To what degrees have data quality competencies developed?	To what degree are data quality policies defined, implemented and enforced?	What capabilities are implemented to support the production and maintenance of high quality data?
Master Data	To what degree has a formal master data management organization been developed and assigned consistent responsibilities across data domains?	To what degree are master data policies defined, implemented and enforced?	What capabilities are available and implemented to actively master and provision master data?

Source: https://www.lightsondata.com/data-governance-maturity-models-stanford/ (accessed on 3 March 2020)

Exhibit 9

Data in the Energy Sector Revolution



"The energy industry is very assets heavy. More and more assets are getting connected using various IoT technologies, which opens new possibilities for obtaining information in a near real time manner about the status and the condition of the asset. The flow of data can be used to automate decisions to optimize efficiency, to maximize the profit provided we can commercialize the flexibility of the asset, to detect indicators for potential functioning issues and apply predictive maintenance routines, to assess the criticality of potential failures before they happen and trigger triaging procedures, to optimize the workforce planning, to plan and optimize spare parts stock, etc. In general, no matter if we are talking about an industrial size CHP, a heating pump, a solar panel, a substation in a grid, a mid-voltage cable, a mobility charging station, etc., IoT and data analytics substantially transforming the whole assets management lifecycle"

Exhibit 10

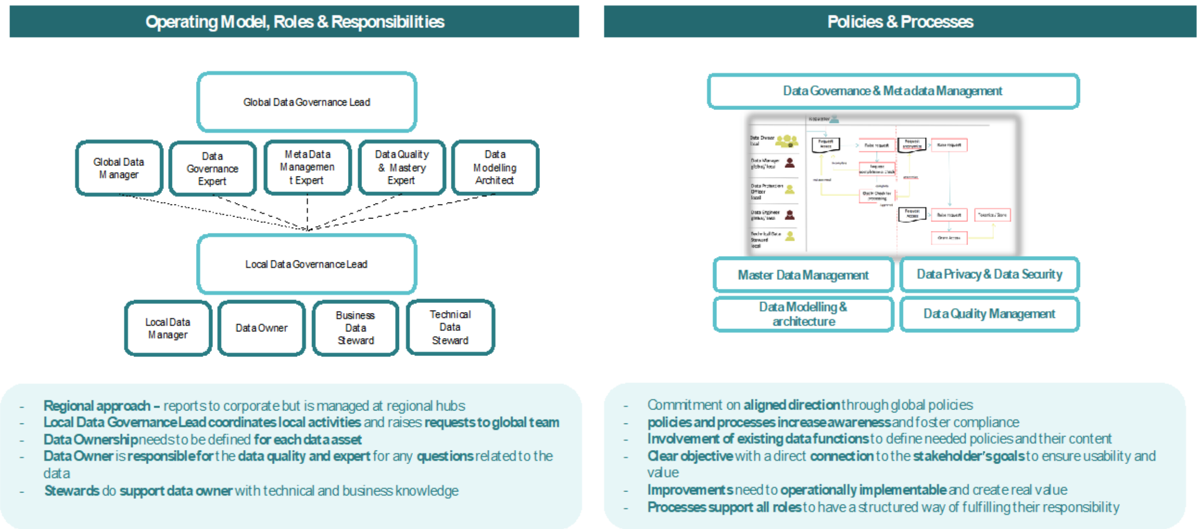
Data Readiness Programme at E.ON

"Data is at the core of any industry. Machine Learning has positioned as a unique tool enabling companies to learn from this data. The quality of the decisions that can be inferred with Machine Learning techniques highly depend on the quality and availability of the data used to train algorithms. As a matter of fact, data scientists spend up to 70% of their time finding and curating data. But where is data coming from? Typically, data is generated within all kinds of IT applications and systems. The variety and complexity that we typically find in any big company strongly compromises a comprehensive data management. Data remains locked down into applications and we don't know which data is available where, how to access these data sources, who looks after quality and consistency, which systems are master, which slaves, etc.

Putting in place a proper data management and data governance is essential to move from an application centric to a data centric paradigm, where data has been "liberated" from applications and where quality, availability, lineage and all aspects around have the data "ready" has been already taken care of, so that data scientists can focus on just harnessing the value with algorithms. That's what we started implemented in 2018 within what we call our Data Readiness programme."

Exhibit 11

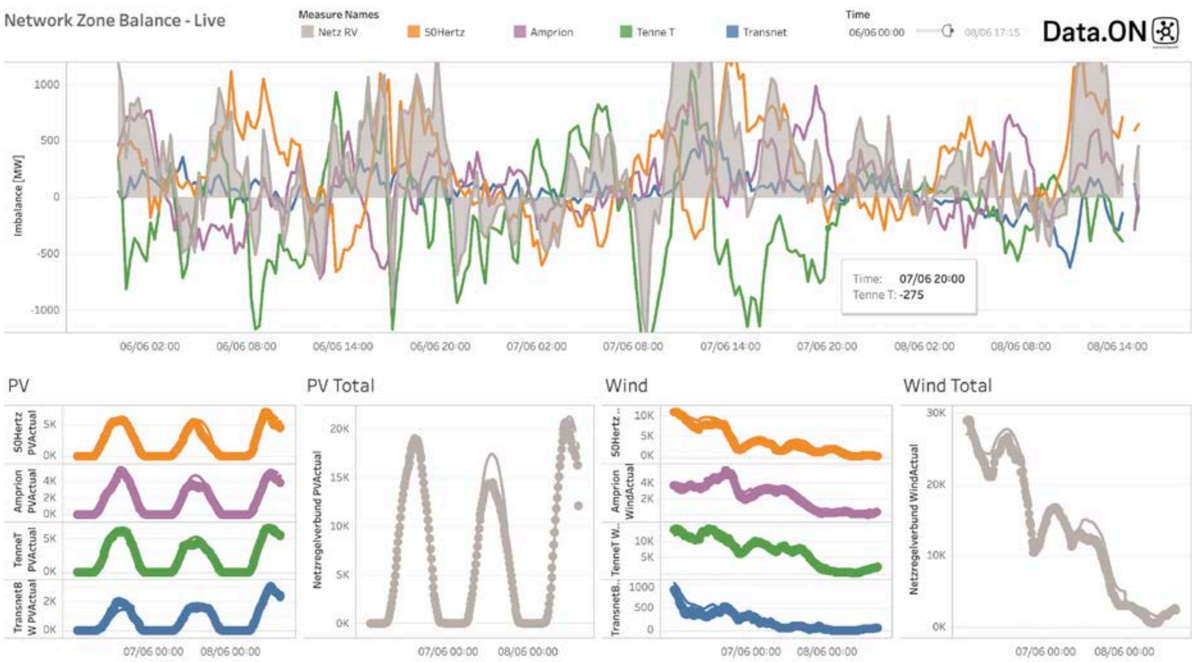
Operating Model to Support Data Readiness at E.ON



Source: E.ON

Exhibit 12

Power System Balance in Germany



Source: regelleistung.net and German TSO transparency pages.

"The power system balance (Germany-wide and for the different Transmission System Operator areas). The volatility of the renewable energy resources (PV/Wind) increases power transmission networks stress, by generating imbalances between demand and generation which need to be compensated for, and that can increase the volatility of the energy markets.

Endnotes

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