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CXO INSIGHTS

CXO TECH BRIEF FOR THE ENERGY & UTILITIES INDUSTRY

1. SECTORAL EXEC SUMMARY

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THE ENERGY & UTILITIES (EU) SECTOR IS ON THE EDGE OF A NEW ERA, DRIVEN BY A GLOBAL QUEST FOR CARBON NEUTRAL YET RELIABLE ENERGY

The industry is currently facing a paradigm shift: market players must **meet the growing demand** while dealing with **an evolving energy mix** and an **aging** and sometimes **inefficient infrastructure.**

1. SECTORAL EXEC SUMMARY

7 CORE CHALLENGES OF THE EU INDUSTRY

1. **Making the industry carbon neutral** by accelerating the energy transition

   Global energy-related CO_2 emissions were at around **33Gt** in 2019 (-8% est. in 2020 due to the Covid-19 pandemic) [1]

2. **Rising demand for energy,** mainly driven by Asia

   By 2040, the worldwide energy consumption is expected to increase **by 25%** [2]

3. **Growing dependency on new resources** leading to geopolitical tensions

   Global cobalt consumption increased by **30%** in 5 years [3]

4. **Blurred boundaries between traditional players and mobility players**

   Tesla's valuation was **4x higher** compared to Exxon Mobil's as of mid Jan 2021

5. **Fluctuating prices**

   19% drop in the price of EV Li-ion batteries and stationary storage costs in 2019 [2]

6. **Aging infrastructure to be maintained**

   Average age of the electricity transmission infrastructure in the US is **40 years** [4]

7. **Growing and complex decommissioning needs** for diverse infrastructures

   <1% of the global cumulative mass of installed solar panels has been decommissioned [5]

SPECIFIC CHALLENGES TO BE FACED BY INDUSTRY SEGMENTS

OIL & GAS

- **Energy transition leading to a major upheaval for oil & gas companies,** forcing the latter to adjust their business models following 3 scenarios:
  - Extending the value chain
  - Changing or diversifying activities
  - Focusing as a pure player
- **Lack of standardized operations during the exploration and extraction stages,** due to the uniqueness of natural fields and boreholes
- **High environmental impacts, mainly during the extraction phase and due to aging assets** (30-40 years old)

NUCLEAR

- **A segment that is mainly operated by state agencies and is highly regulated**, with strong entry barriers for private players, thereby limiting disruptive innovation at the heart of the value chain
- **Greater supply flexibility required by energy regulators** due to changes in the energy mix, making it challenging for nuclear players to meet the fluctuating needs (baseload vs. flexibility)
- **A complex asset deconstruction process** and long infrastructure lifespan (~60 years)

RENEWABLES

- **Operational excellence as a must-have** to support rapid expansion
- **24/7 energy availability to meet customer demand,** whatever the source of supply: solar, wind, biomethane, etc.
- **Preparing for and initiating the decommissioning and recycling of the first infrastructure that was set up more than 20 years ago** (e.g., service life of wind turbines = 25 years)

THESE CHANGES GENERATE NEW VALUE-ADDED OPPORTUNITIES, OFTEN THROUGH NEW TECHNOLOGIES, WHICH NEED TO BE SEIZED BY BOTH INCUMBENTS AND NEW ENTRANTS

(1) International Energy Agency
(2) World Energy Markets Observatory, Capgemini
(3) BRMG
(4) Marsh & McLennan
(5) International Renewable Energy Agency

1. SECTORAL EXEC SUMMARY

EU PLAYERS ARE CAPITALIZING ON DIGITAL PARTNERSHIPS FOR RESEARCH & DEVELOPMENT, INNOVATION AND FOR OFFERING NEW SERVICES TO THEIR CUSTOMERS

OIL & GAS

bp ✖ Microsoft

Unlock **co-innovation, bring Cloud** capabilities to bp operations and achieve Microsoft's **environmental ambitions** for 2025

NUCLEAR

EDF ✖ Capgemini ✖ Dassault systemes

Enable the **digital transformation** of EDF's nuclear engineering division and that of its ecosystem

RENEWABLES

Tepco ✖ Sky specs

Deliver solutions for **autonomous drone inspections, blade asset management software**, and **predictive maintenance** planning

AN OVERALL INTEREST IN NEW TECHNOLOGIES, WHICH STILL NEEDS TO BE SCALED UP BASED ON DATA CENTRICITY, TO ACT AS A COMPETITIVE ADVANTAGE

- **Capitalize on supercomputers** already deployed for exploration purposes
- **Standardize exploration** processes and methods by capitalizing on shared databases (e.g., government-regulated image database in Norway)
- **Leverage large amounts of data** collected
- **Deploy Cloud** computing power and services
- **Progressively integrate digital capabilities at the heart of the business model** to go beyond the mere use of new tech "gadgets"
- **Enable infrastructure modelling** and **dynamic asset monitoring**
- **Achieve technological resilience and security by design** (closed systems)
- **Build a digital strategy** to tackle an overall low technological maturity
- **Structure a reliable data chain**, relying on data-driven consciousness
- **Enable high value-added and personalized customer services** based on the behavioral knowledge derived from data

FIRST TECHNOLOGICAL TRENDS TO BE SEIZED

IOT MASS DEPLOYMENT

+40% IoT endpoints installed globally since 2018 for the utilities industry (#1 segment worldwide)[7]

+26% IoT endpoints used for electricity smart metering in Western Europe[7]

DIGITAL OPERATIONS

+500% estimated increase on addressable market for digital oil and gas solutions over the next 5 years[8]

$150Bn Estimated savings for oil producers if they implement digital services[8]

HIGH CYBER RISKS

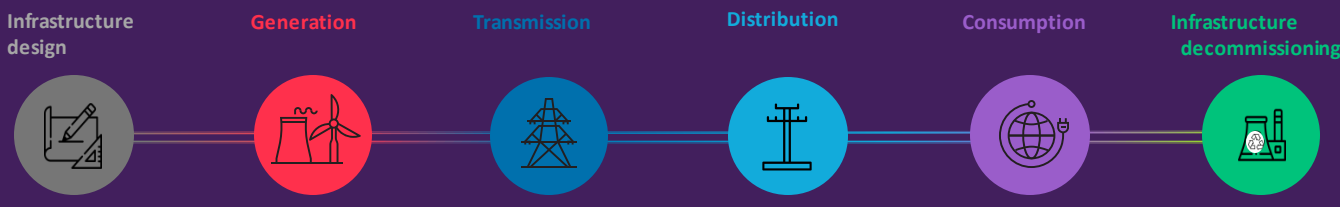
$150,000 - median cost of a cyber event[9]

#1 The energy sector is the most at risk in terms of cyber attacks[9]

75% ENERGY PLAYERS POSITIVE ABOUT SUSTAINABLE TECH ADOPTION FOR NEXT YEAR[10]
KEY SUCCESS FACTORS: CUSTOMER READINESS FOR NEW TECH AND ACCESS TO PARTNERS FOR R&D

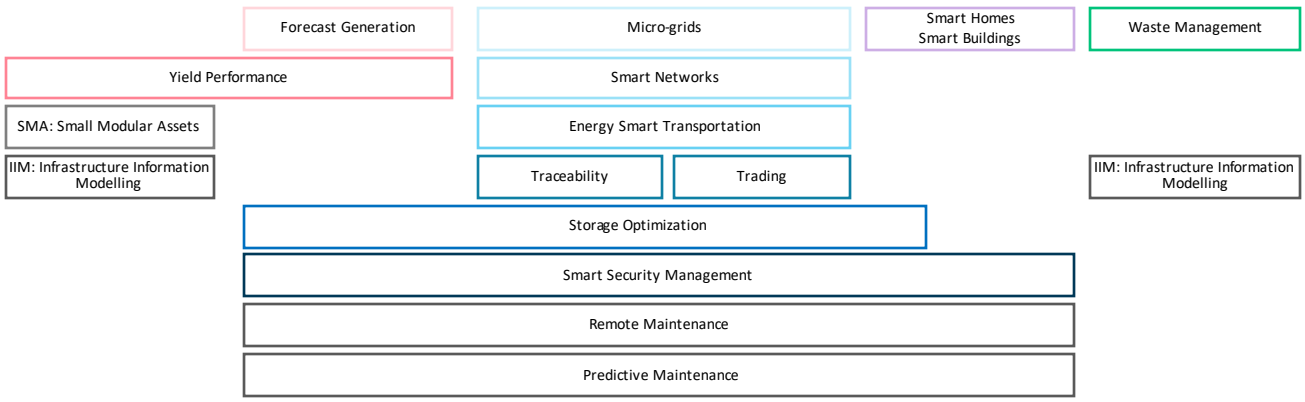
(7) Gartner
(8) Barclays
(9) Hiscox Cyber Readiness Report 2020
(10) EIT InnoEnergy study

2.1 HOW IS THE VALUE CHAIN DISRUPTED BY TECH?



CHALLENGES

Optimization and security by design	Production matching demand	Omnichannel resilience and accessibility	New services adapted to end-user needs	Upcycling of decommissioned assets



~50
power nuclear reactors are still being constructed globally in 2021 (1)

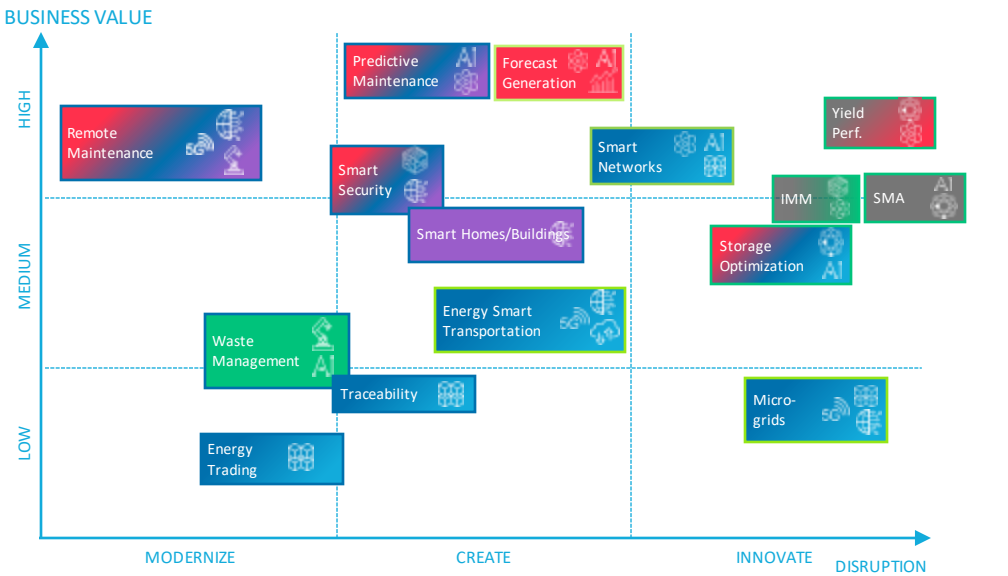
50%
of renewables in the European power generation mix by 2025 (2)

13%
of the population did not have access to electricity globally in 2019 (2)

-1.5%
Decrease in Customer satisfaction with gas and electricity services in the US in 2020 (3)

200 to 400
reactors are likely to be decommissioned globally by 2040 (4)

2.2 FOCUS ON TECH DELIVERY MATURITY & BUSINESS VALUE



Value chain positioning:

Design	Generation	Transmission	Distribution	Consumption	Decom

Timeframe — Now (1-3 years) — New (3-5 years) — Next (< 5 years)

AI / Machine Learning · 5G Network · Blockchain · Data Analytics · Cloud / Edge · IoT
Augmented Reality · Quantum · Digital Twins · Virtual Reality · Robotics · Nanotechnologies

TAKEAWAYS FROM TECHNOLOGY ROADMAPS

From a technology perspective, we identify 3 groups:

- **Must-have technologies:** IOT, AI and data analytics, specially to address efficiency and predictability stakes and to speed up the energy transition
- **Future must have technologies:** Quantum to accelerate data exploitation and nanotech to improve productivity. The use of digital twins or augmented reality to support asset optimization
- **Enabling technologies:** 5G, Cloud and Edge to facilitate mass data transfers; Blockchain to improve traceability and network security

(1) World Energy Outlook (2020)
(2) International Energy Agency, 2020 report
(3) ACSI Energy Utilities report 2019-2020
(4) Enerypost.eu

3. FOCUS ON VALUE CHAIN BLOCKS ALONG WITH USE CASES

INFRASTRUCTURE DESIGN

EU invested €998 million in energy infrastructure projects in October 2020 (1)

Better designed infrastructure to improve their lifespan and their ability to cope with physical and digital attacks

Quantum, digital twins and nanotech

- **Stakes and why now:** the optimization of the energy production and distribution phases starts at the time of designing the physical assets. Moreover, resilience and security by design are must-haves for the energy sector given that infrastructure such as nuclear power plants are subject to a growing number of threats. Engineering efficient infrastructure also requires agility, which can be enabled by designing multi-layer assets as an assembly of smaller composites. As such, Small Modular Reactors have seen the light of day in the nuclear field to decomplexify financial and regulatory aspects.
- **How tech can help**: new technologies such as digital twins can facilitate the management of infrastructure modeling and help organizations better anticipate asset lifecycle
- **Example of emerging use cases:**
  - Digital twins are used to optimize the construction, operation and maintenance of energy assets, systems, and production processes.

GENERATION

Renewables account for 95% of the increase in total power capacity through 2025 (2)

Supporting the scale-up of renewable energy production is today's biggest challenge

AI, IOT, quantum and nanotech

- **Stakes and why now:** the energy sector is facing increasing pressure to produce more, faster and more extensively, while at the same time decreasing their environmental impact. In addition, customers require more flexibility around the desired energy mix. To meet these expectations, it is crucial for energy producers to enhance production predictability, reliability and efficiency, while scaling up clean energy production.
- **How tech can help**: it can bring demand and production into line, with precision, by leveraging large amounts of data and AI capabilities, and increase production efficiency
- **Examples of emerging use cases:**
  - **Better predictability of renewable energy** production based on weather reports through meteorological sensors
  - **New optimized storage systems** to help maintain the balance between energy supply and demand

TRANSMISSION

DISTRIBUTION

Average age of the electricity transmission infrastructure in the US = 40 y/o (3)

Rising demand for decentralized and uninterrupted access to clean energy

Blockchain, 5G, edge computing, IOT, AI

- **Stakes and why now:** 24/7 energy availability for customers represents a challenge for energy suppliers. Power networks must balance multi-channel production and the increasing demand for renewable energy. This requires flexibility at all levels of the distribution chain: energy storage, adaptable supply, transmission grids and decentralized delivery points. The main challenge is to avoid energy intermittency.
- **How tech can help:** AI (including machine learning) makes it easier to anticipate and manage peak loads and save energy by adjusting the energy flow across transmission networks. Other technologies such as Blockchain, 5G and Edge computing will enable a more transparent, secured and decentralized distribution chain
- **Examples of emerging use cases:**
  - **Smart grids** leveraging big data and analytics at different points of the energy grid for more efficient management
  - **Micro grids,** local and independent energy networks to provide modular clean energy access and supply reliability

(1) Europa.eu (2) International Energy Agency, 2020 report (3) Marsh & McLennan

3. FOCUS ON VALUE CHAIN BLOCKS ALONG WITH USE CASES

CONSUMPTION

63 million American homes will qualify as "smart homes" by 2022 (1)

The urge to reduce energy consumption and the fall in IOT prices are factors that have made the smart homes market highly competitive

IoT, 5G, AR and 3D printing

- **Stakes and why now:** smart homes / smart buildings are nothing new. For the past 20 years, various connected objects and digital services have been deployed to enhance consumer experience. These smart technologies have evolved significantly to provide customers with more detailed monitoring of their energy consumption and related spending.
- **How tech can help:** it can facilitate secure data collection, monitoring and exchange in real time to forecast energy spending and enable smart automated energy supply.
- **Example of emerging use cases:** install IOT devices to track and analyze energy consumption in real time in smart homes and smart buildings, and better manage energy consumption.

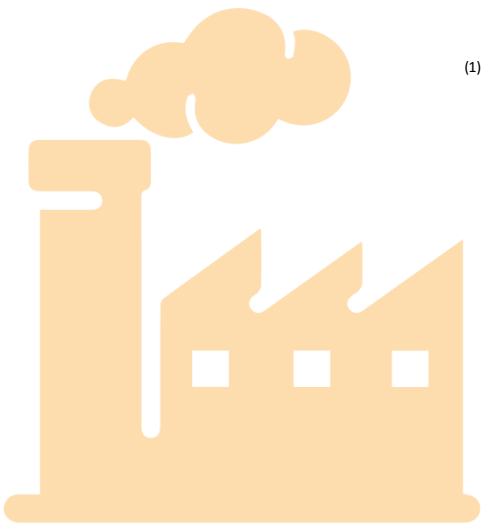
INFRASTRUCTURE DECOMMISSIONING

34,000 wind turbines in Europe are now 15 years or older (2)

Increasing number of products to be decommissioned and decommissioning triggers: regulation (nuclear), efficiency (renewables), etc.

IoT, digital twins, data analytics

- **Stakes and why now:** aging infrastructure and the complexity of the asset deconstruction process make it indispensable for energy players to seize the decommissioning challenge. The deconstruction is triggered by the age threshold of a given infrastructure or when its efficiency is not satisfactory enough. Deconstruction applies to wind turbines, offshore platforms, nuclear reactors, pipelines, etc.
- **How tech can help:** the use of disruptive tech allows the optimization of product lifecycle management and helps better anticipate infrastructure decommissioning, for instance, thanks to digital twins or dynamic monitoring of aging assets.
- **Example of emerging use cases:** IoT coupled with data analytics allows visual and real-time monitoring of asset aging parameters, therefore anticipating the most relevant timeframe to initiate the deconstruction process.



(1) IOT Business News (2) Wind Europe, November 2020

4. FOCUS ON USE CASES AND ASSOCIATED TECHNOLOGIES

YIELD PERFORMANCE

INFRASTRUCTURE DESIGN

GENERATION

- **Nano-composites** (carbon nano-tubes – CNT) for **lighter and stronger rotor blades**, anticorrosion protection through nano-coating for powertrains, etc.
  - Support impact-friction resistance, super hydrophobicity, and high damping ratio
  - Turbine blades are up to eight times tougher and several times lighter than standard carbon fiber
- **Innovative materials** such as perovskites
  - Offer better efficiency in the conversion of light to electric power and sometimes at a lower cost than existing technologies
  - However, crystals dissolve easily and cannot handle humid conditions, and therefore, need to be protected from moisture through encapsulation
- **Quantum Computing** is used to model physical properties for next generation material

- **Players:**

Saule Technologies Solaronix Oxford pv

MARKET TECHNO IMPACT

Market and techno rationale:

- Although many new players propose innovative materials that can help produce energy more efficiently, the technology still needs to be improved (theoretical efficiency of crystalline silicon cells does not exceed 30%)

TECHNOLOGIES NANO TECHNOLOGY QUANTUM

Why now

- It is crucial to find ways to boost the efficiency of clean energy production, to help meet the growing demand
- The next step for organizations is to find sponsors to scale up the adoption of such technologies (accelerate the research, manufacturing and commercialization phases)

FORECAST GENERATION

GENERATION

- **Intelligent exploration:**
  - Sensors coupled with data analytics to examine ground composition and reduce exploratory drilling samples
  - Quantum computing to optimize the positioning of oil sites and solar/wind power farms based on advanced geological calculations
- **Demand forecasting:**
  - Multi-model data to predict energy demand trends and take production-related decisions accordingly
- **Production forecasting:**
  - Meteorological sensors coupled with aggregated historical and real-time data to adapt renewable energy production based on weather trends
  - Quantum computing for complex calculations to improve weather predictability for solar, water and wind sources

5G as an enabler → makes it possible to collect and process large volumes of information to anticipate and take relevant decisions

- **Players:**

Steady sun

MARKET TECHNO IMPACT

Market and techno rationale:

- Several tech solutions are being deployed in the market (the most mature market segment is demand forecasting using the multi-data model)
- This can help organizations to carry out the proactive management of their production processes and increase efficiency

TECHNOLOGIES 5G QUANTUM IOT PREDICTIVE ANALYTICS AI/MACHINE LEARNING

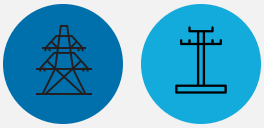
Why now

- The growing demand for energy requires a better ability to predict demand upstream and accordingly adapt production downstream

4. FOCUS ON USE CASES AND ASSOCIATED TECHNOLOGIES

STORAGE OPTIMIZATION

GENERATION



TRANSMISSION/DISTRIBUTION

There are several types of storage systems (battery, supercapacitors, CAES, hydrogen, etc.) depending on different use cases. New technologies can enable the scalability of these systems:

- **IOT sensors and AI** are used to ensure inventory and storage optimization based on demand forecasting (mainly for oil and gas containers)
- **Machine learning** is deployed to reduce the testing time of energy storage devices, specifically for supercapacitors (testing time reduced by nearly 96%)
- **Nanomaterials to optimize storage, for instance:**
  - Optimized Li-ion batteries through nanostructured electrodes, flexible load management in power grids
  - Highly porous, nanoparticle-based smart material capable of storing hydrogen in a solid state
- **Quantum calculations** used for the simulation of complex molecules using high-performance computing (HPC) technologies, in order to discover more economical and efficient adsorbents
- **Players:**

Total

H_2 GO$_{power}$

MARKET TECHNO IMPACT

Market and techno rationale:

- Storage systems can significantly reduce the flow of carbon emissions into the market (using batteries in the short term, hydrogen in the long term) and act as a critical enabler for large-scale and intermittent renewable energy generation

TECHNOLOGIES

IOT

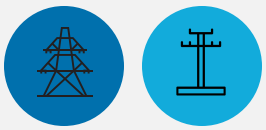
NANO TECHNOLOGY

AI/MACHINE LEARNING

Why now

- The large-scale integration of renewable energy is being deployed globally
- Storage systems are key to mitigate the inherent intermittency of renewable energy sources (RES), and to achieve secure and stable grid operations

SMART NETWORKS



TRANSMISSION/DISTRIBUTION

A smart network is an electricity network offering real-time data that can help utility providers carry out demand-based power generation and distribution. These networks are operated based on several pieces of technology:

- **Smart meters and big data** are applied at different nodes of the grid to allow an **optimal and exhaustive management of the network** (identifying weak points, reinforcing the grid accordingly and reducing the risk of blackouts)
- **IOT** platform and **blockchain** are used to better control and monitor **the battery-equipped devices** connected to the grids to:
  1. Adjust the energy distribution
  2. Guarantee electricity delivery
- **Quantum Computing** to optimize the power grid, handling real-time fluctuations of power usage, anticipating short- and long-term demand, and harnessing energy from a growing list of renewable sources as needed
- **Players:**

Motion werk

MARKET TECHNO IMPACT

Market and techno rationale:

- Many players operating in the market are offering new solutions to improve grid efficiency with significant proven benefits for the sector

TECHNOLOGIES

IOT

QUANTUM

AI/MACHINE LEARNING

BLOCKCHAIN

Why now

- Smart networks play a key role in reducing electricity consumption while meeting the needs of corporations as well as citizens
- They are therefore becoming more and more vital in many areas where energy optimization is critical: production, transport, distribution, etc.

4. FOCUS ON USE CASES AND ASSOCIATED TECHNOLOGIES

SMART SECURITY MANAGEMENT

GENERATION

TRANSMISSION/DISTRIBUTION

Employee safety

- Sensors implemented to monitor parameters such as vibration / temperature / moisture / pressure helping prevent accidents, increase safety and reduce the required manpower on site
- Robotics to perform interventions in dangerous environments and ensure employee safety
- Smart materials to protect employees on nuclear sites (coveralls, protective clothing)

Asset and site security

- Digital twins to assess the consequences of a changing environment on production thanks to digital and real-time simulations of a plant
- Drones / smart cameras coupled with AI to monitor and secure sites and to ensure compliance with standards (especially on nuclear or oil sites with high security stakes)

Cybersecurity

- AI to improve the detection of phishing attacks and prevent data breaches/leakage

- **Players:**

Red marlin Sentryo

MARKET TECHNO IMPACT

Market and techno rationale:

- In the nuclear and oil sectors in particular, security is a major stake that is already tackled by organizations using mature technologies (sensors, smart cameras, etc.)
- Although security management does not provide direct business value, it can limit risks of negative impacts on the company's reputation and loss of property or value

TECHNOLOGIES IOT 5G ROBOTICS AUGMENTED REALITY AI/MACHINE LEARNING

Why now

- Operational technology security has become a priority at the board level
- Many players are not yet prepared to face future hybrid threats, combining physical and virtual attacks

SMART HOMES / BUILDINGS

CONSUMPTION

- **IOT in smart homes and smart buildings** to:
  - Collect and analyze energy usage in real time to optimize energy consumption, save on annual utility bills and comply with regulatory requirements
  - Send maintenance-related data to reduce manual interventions, thereby saving time and energy
- **Private 5G networks** to ensure coverage and allow energy access, even at isolated sites
- **Carbon nanotubes, nano-coated light metals, polymer-composites** for lightweight construction
- **Electrochromic windows, connected devices and integrated energy management systems** generating data that can be used to reduce heating, cooling or lighting in underutilized zones
- **Players:**

Beebryte Covea Wattio

MARKET TECHNO IMPACT

Market and techno rationale:

- New technologies (IOT devices to a large extent) are already widely deployed in smart homes/buildings, often used for real-time data collection
- The next priority is to develop and test new business models engaging professional and domestic customers to play an active role in the energy transition: how to switch from a monitoring-oriented model to an adaptive building energy system?

TECHNOLOGIES IOT 5G AI/MACHINE LEARNING NANO TECHNOLOGY

Why now

- Smart homes establish a direct interface between energy providers and B2C/B2B customers, allowing both sides to benefit from high value data and services
- All metrics related to energy flows across the grid can be analyzed to identify potential improvements and savings for end customers

Capgemini invent

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