Capgemini engineering

THE SOFTWARIZATION OF ENERGY

The need for decentralized software platforms to manage future distributed energy grids

CONTENTS

TRENDS

#1: Asset type

The diversity of assets to be considered on the grid (mainly in the distribution grid) is increasing in terms of :

- Distributed energy:
  - Solar (generation)
  - Wind (generation)
  - Hydrogen (generation and storage)
- Batteries (generation and storage)
- Methane (generation and storage)
- Heat pumps
- Electrical vehicle (chargers and mobile batteries)

#2: Huge increase of asset numbers

These new types of assets are going to be deployed at a very large scale. In comparison, where utilities have been used to managing tens of thousands of assets from an automation standpoint, we are talking about millions of them in this new era.

#3: Mobility, a new paradigm

Electrical vehicles, in addition to being a new asset type, are also introducing a new pattern on the grid. As a result, utilities must balance the grid more quickly and at a lower level to include a higher number of variable assets and forecast consumption and storage.

#4: New type of services

T&D operators, with the paradigm shift and the set of new consumption patterns, must deal with various new services:

- Beyond the meter: Manage end customer production/consumption (prosumer)
- Reinforce load/demand real-time balance
- Flexibility, demand-response, storage, capacity management
- Energy-as-a-service, due to mobility paradigm
- Peer-to-peer: Edge mediation between end customers
- Connected microgrid or community that could be operated by utilities

#5: Increasing number of stakeholders involved in grid management, in addition to regulators, electric system operators, and sometimes asset owners

The number of participants involved in the management of the distribution grid is increasing:

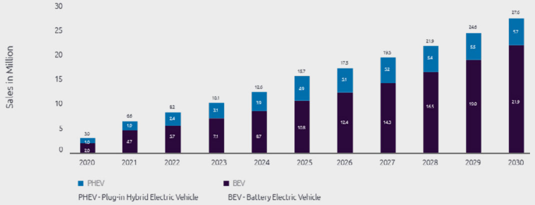
- Renewables operators, prosumers
- Virtual power plant provider (both in terms of flexibility and asset optimization)
- Public network microgrids (communities, campus, hospitals) connected to the grid

In addition, there are higher expectations on the delivery of energy:

- Increase network resilience:
  - Against frequent, recurring climatic events (e.g., wildfires, flooding, hurricanes)
  - Secure criticality of energy availability due to the extension of the usage (SAIDI, SAIFI)
- Deliver more efficiently:
  - Optimize network design by limiting the number of connections (copper saving)
  - Increase performance (never-ending requirement)
- Improve flexibility:
  - To manage intermittency of renewables due to their increased proportion in the energy mix
  - Be more agile in implementing new/ evolution use cases/ services
  - Shortening deployment at scale on the edge
- Secure reliability in a new network architecture:
  - From centralized to decentralized generation
  - From one-way to two-way flow
  - Guarantee the level of service (geopolitical tensions, autonomy)
  - Strengthen cybersecurity

Figure 1

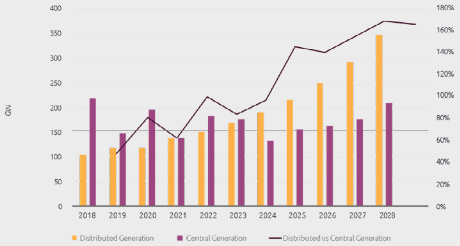
Global EV Car Sales (Mn)



Source: Global EV Outlook 2022 IEA

Figure 2

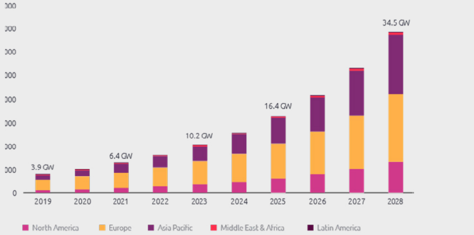
Global annual revenue from distributed energy resources (DER)



Source: Navigant Research

Figure 3

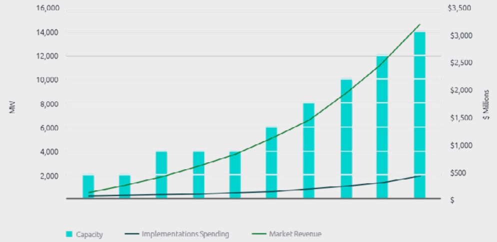
Global VPP Capacity Market Forecasts: 2019-2028



Source: Navigant Research

Figure 4

Annual Total VPP Capacity, Implementation Spending and Market Revenue



Source: Navigant Research

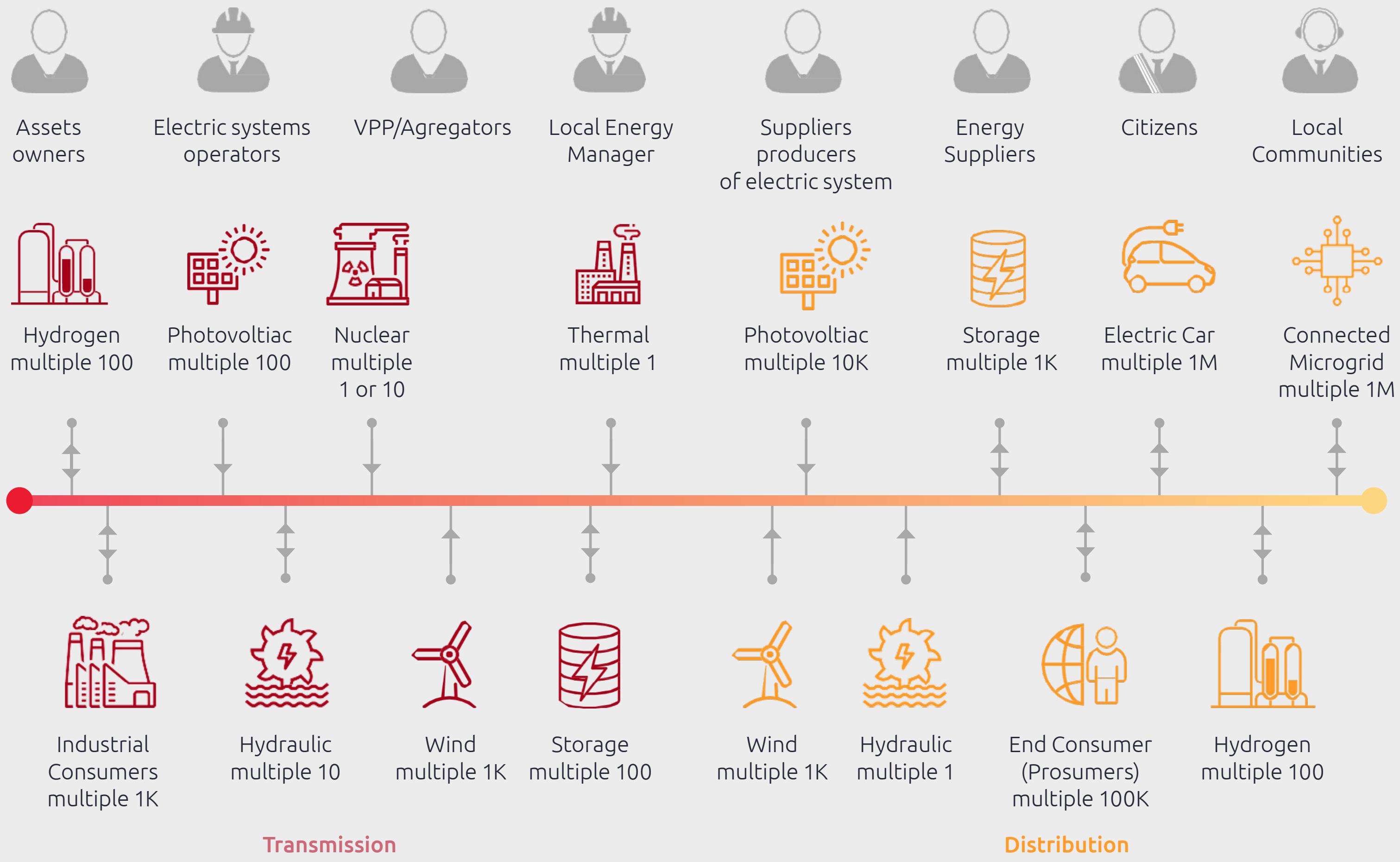
CONSTRAINTS AND CHALLENGES

To tackle ongoing trends:

- Each country has its specifics, but regulatory bodies have to change regulation on various domains:
  - Today's DSO on the grid is based on HW assets and does not recognize the value of software enough
  - Modernize the market structure to enhance the aggregator role and create more room to play
  - TSO/DSO boundary to be reviewed, each of them having to take a joint responsibility in demand/response forecasting and supervision
  - Capacity markets and new services to be supported under the responsibility of T&D operators
- Sustainability generates a pressure on resource consumption; both raw material and energy itself (new non "technical losses" corresponding to the management of the grid).
- Intermittent energy generation has to be optimized without degrading service quality, which, as a consequence, needs a near real-time modelling in terms of impact assessment and allocation management (real-time balancing at the end)

Figure 5

Utility Transformation: Distributed Energy Resources



- Utilities:
  - Have to shift their mindset to embrace the digital transformation both in terms of technology shift and short project lifecycle
  - Have to take into account its legacy and determine its strategy with high-pressure short-term milestones (energy shortage that increases pressure on DER connection)
  - Need to embrace new services as already stated
  - Have to invest in grid modernization at a moment when auto consumption and microgrids could decrease energy transiting, and, as a result, compensation; more investment and less compensation, causing a financial effect
  - Need to take into account more and more data for managing the grid (e.g., weather patterns, auction
  - Outcomes, flexibility connections, DER profiles) and getting value out of data
  - Must consider for the mid-term, network convergence triggered by new energy mix and Power-to-X/Xto-Power services

CHANGE PATH

Due to these trends highly impacting the management of the distribution grid, utilities' transformation is on a radical change path.

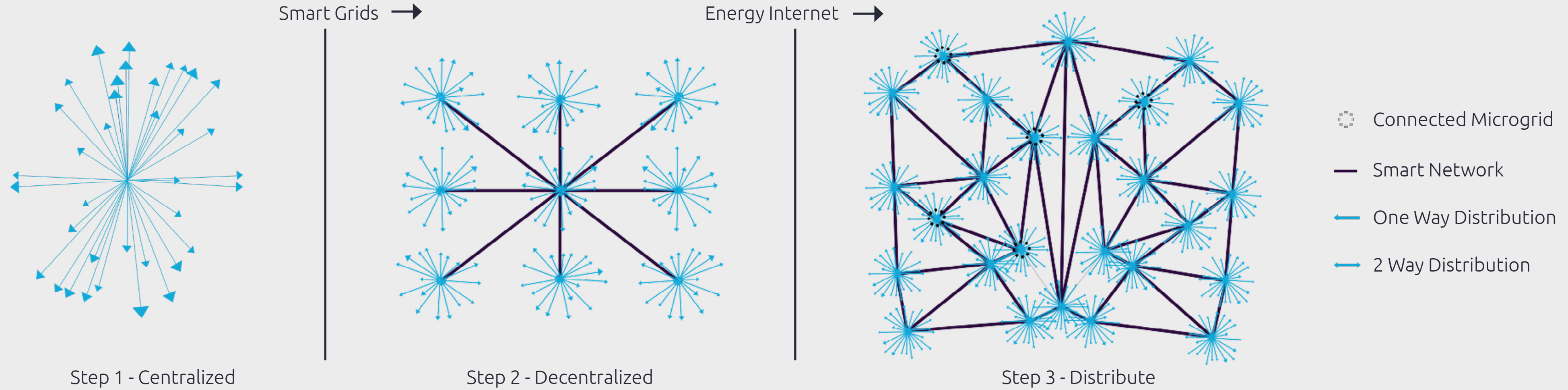
In the past, utilities managed everything centrally:

- Production was centralized
- Distribution network was one way
- End-users were consumers
- Storage was almost non-existent
- Production was permanently connected to the grid
- Many, if not most, activities were done manually

Today, the distribution network is decentralized which leads to:

- Production is hybrid and scattered across the territory
- Distribution network works both ways
- End-users are prosumers, using or injecting on the grid energy they produce
- Storage is taking an important room
- Production and storage assets are sometimes disconnected from the grid
- Some assets start to be mobile in their connection to the grid
- Almost all high- and medium-voltage grids will be automated rapidly

Figure 6
Decentralization of Distribution Network



Tomorrow, a distributed network will be the norm:

- Huge increase of small size storage (V2G, P2G, and battery)
- Production and storage assets will go on and off the grid
- Off-grid systems can run independently from the grid
- Automation of low-voltage grid will be mandatory
- Near real-time management of the grid will be needed with complex and changing pattern to manage (intermittency and decentralization)
- The complexity of the management of the grid will require a high level of automation (still under the supervision of humans)
- Network convergence (electric, gas, heating, cooling, hydrogen)

As a result, the technology and solutions need to evolve tremendously as the pressure to move to more sustainable and decarbonized energy is becoming higher.

This not only encompasses utilities, but also their entire provider ecosystem. The latter could evolve with this paradigm shift with new entrants.

In addition, this change will have to be deployed at scale.

Since it is focusing on a medium/low-voltage networks, it increases the magnitude of the effort to be performed and will require the appropriate strategy and execution. Each utility will have its own based on constraint, regulation, and unique priorities with the software toolset needed to manage such deployment.

As a result, CAPEX are expected to double; and the share of software will grow from 15% of the modernization cost to about 35%, due to the distribution grid.

SOLUTIONS

In order to address these future needs, DSOs will have to put in place a highly distributed management

system based on multiple levels of nodes, each of which will require its own level of automation and selfdecision making mechanisms. Introducing here the well-known smart grid concept at a high level:

At the end, each of the nodes will have:

- Its own level of decision making, including part or the majority of smart grid components above
- ML/AI/rule-based type of algorithms in order to be able to manage the complexity of network topology, market, or technical rules
- Will require a high level of OT/IT integration

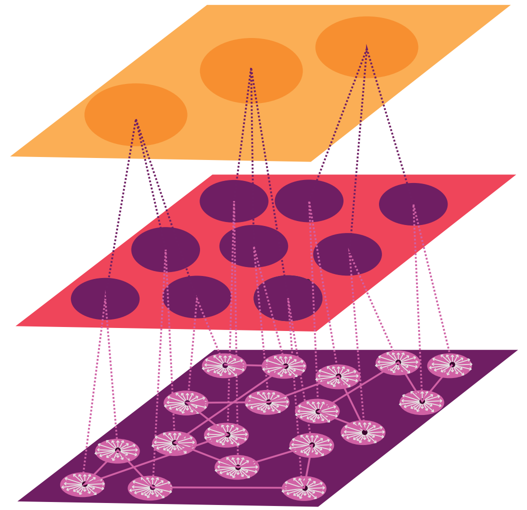
To make this development easier, a common software platform architecture has to be designed and implemented to develop and connect new functions (two stakeholders exchanging data through an intelligent and automated platform).

The overall node configuration will be subject to changes over time, depending on the state of the distribution grid and its topology evolution.

Figure 7

Distributed software platform to manage future distribution energy grid

- Central Nodes (Management, supervision, market)
- Group of substations management
- Substation and connected micro grid management



As a result, in order to manage such infrastructure at scale:

- A set of central software platforms will still be required to:
  - Coordinate and supervise all these nodes
  - Provide a mediation layer for aggregators and other market stakeholders to interface them for energy grid management
  - Ensure overall (cyber)security of the system
- A software factory to manage both the development and the administration of all those components
- The development/deployment cycle will need to be heavily shortened compared to existing cycles

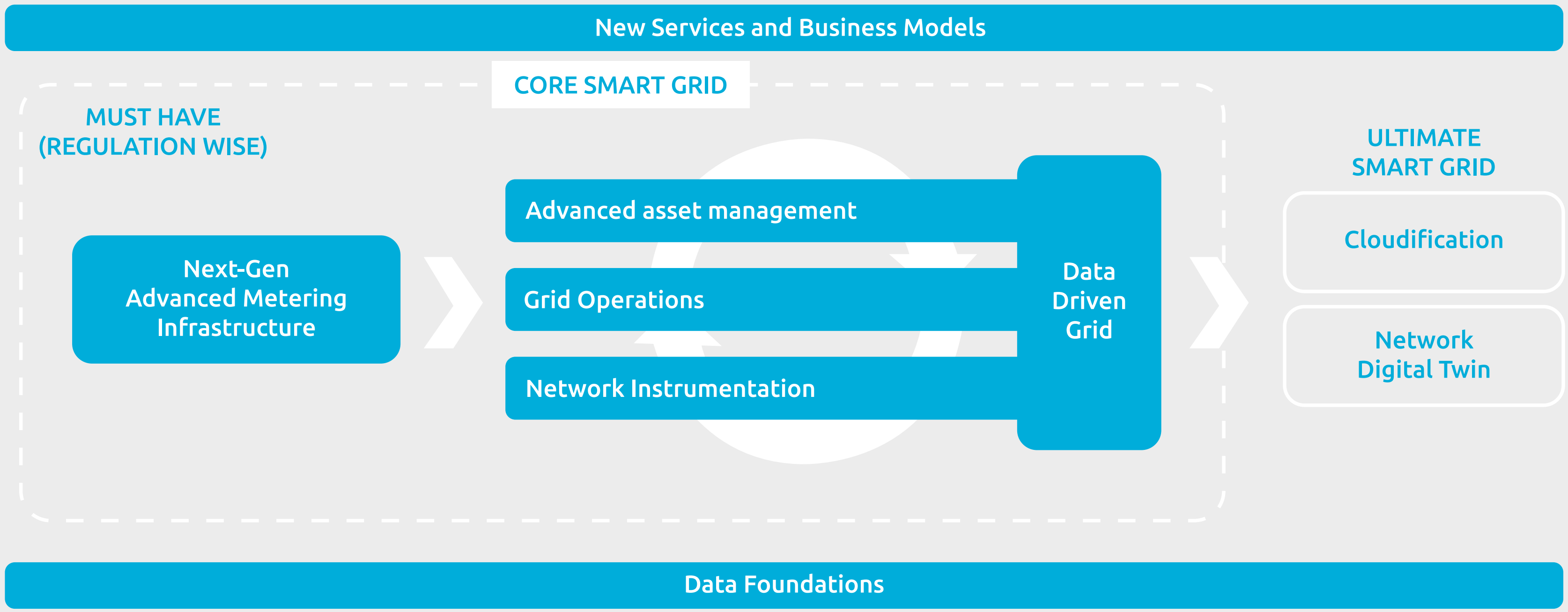
This platform approach will strengthen resiliency and efficiency by its flexible distributed management. Overall sustainability due to this additional level overlay will be an attention point.

This will require digitalization of the grid in all its dimensions: planning, forecasting, simulation and management, taking into account the vast variety of devices and its tremendous numbers.

IMPACTS

Figure 8

Capgemini Smart Grid Framework



Based on Capgemini Smart Grid framework, all components will be impacted:

- Smart metering: merger and full integration of this early program in a single infrastructure from an edge and a communication standpoint,
- Network instrumentation: deployment at scale of IoT devices and implementation of edge compute (down to low voltage),
- Grid operations: full integration of DERs in a decentralized way of management in addition to connecting a wide range of new stakeholder to get from and send to data.
- Advanced asset management: from asset planning with high level of simulation to determine best solutions to operations,
- Data-driven grid: transversal aggregation of the additional data tsunami (smart meter being the first "wave") to get value out of the data and create new services ()

This will need to standardize (externally and internally) and harmonize (internally) all data model between these various silos.

DISTRIBUTED SOFTWARE PLATFORM REQUIRED TO MANAGE FUTURE DISTRIBUTED ENERGY GRID

Software platform:

Software platforms are becoming utilities' key asset to support the digital transformation like all other markets. This is a radical change in the current value chain and its way to operate

Edge:

Edge compute capabilities are a must in transmission and distribution transformation as the new grid complexity and associated response time can no longer be managed by a centralized architecture

Smart assets:

Any asset will have to become connected, smart, and automated with embedded OT/IT integration and will have to be delivered with its digital twin (middle term)

Multi-level management:

Flexibility of grid node management is needed (moving from one to many control rooms) to optimize compute balancing requirements

Cloud technology:

Cloud-based technology will best fit the need. Not cloud first, but cloud-only. Using hyperscalers systems and/or services will raise the need for sovereignty and privacy

We are moving from an energy transportation and distribution grid to a distributed (production and consumption) energy system. The grid will become the backbone enabler of the (complex) energy system.

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