CLOUD BASED SUBSTATIONS

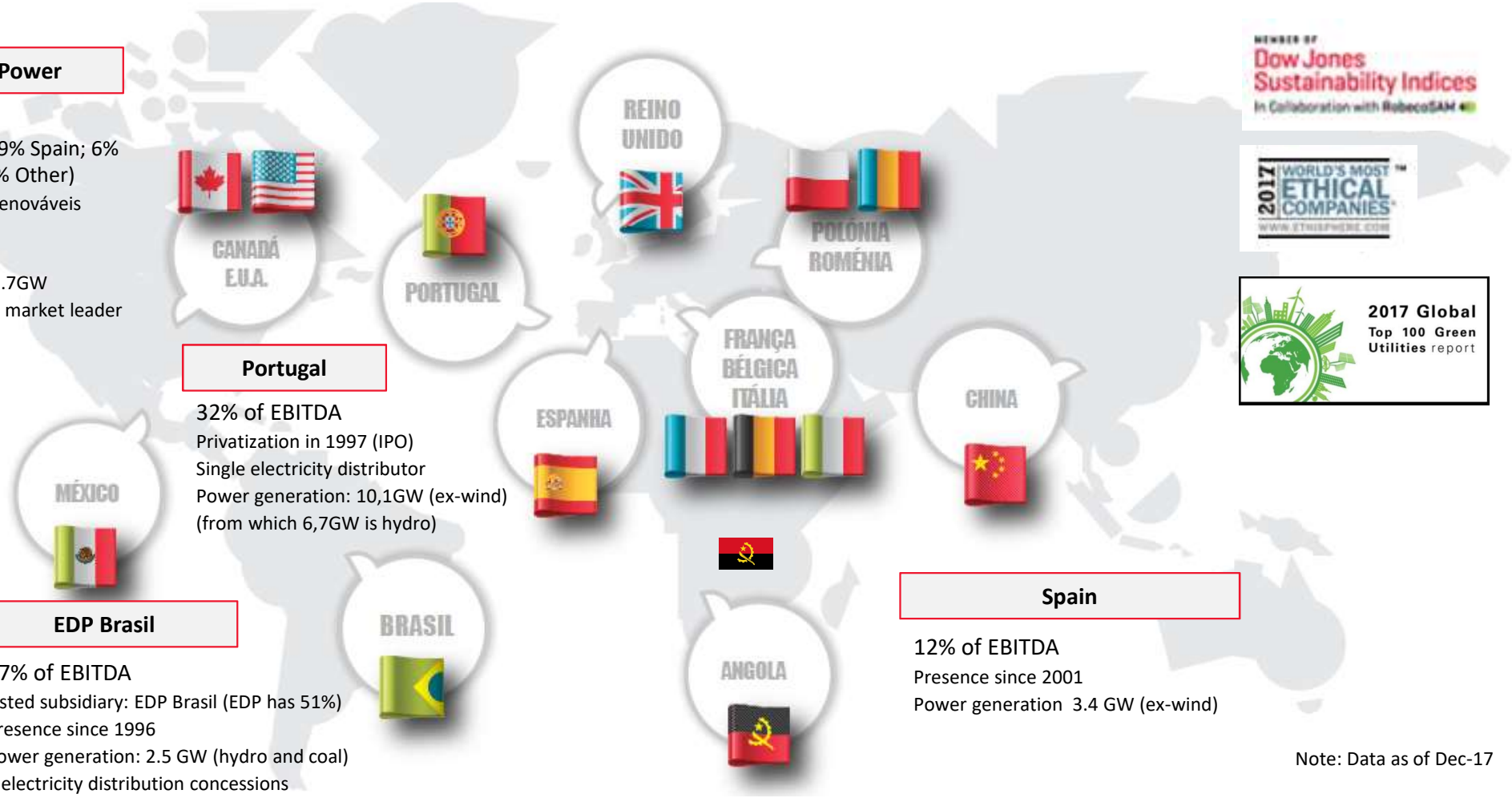
EDP Distribuição’s vision on Clouds and Edge Computing

November 2019

AGENDA

1. **EDP in brief**
2. Energy Transition and Digitalization
3. CLOUD Concepts and key technologies
4. Substation Cloudification Potential
5. Strategy, Culture and new ways of working

EDP Group has grown from a local integrated incumbent utility to a global energy player with business operations in 14 countries



Wind & Solar Power

39% of EBITDA
(17% North America; 9% Spain; 6% Portugal; 2% Brazil; 6% Other)
Listed subsidiary: EDP Renováveis (EDP has 82,6%)
IPO in Jun-08
Wind & Solar Power: 10.7GW
A worldwide renewable market leader

Portugal

32% of EBITDA
Privatization in 1997 (IPO)
Single electricity distributor
Power generation: 10,1GW (ex-wind) (from which 6,7GW is hydro)

EDP Brasil

17% of EBITDA
Listed subsidiary: EDP Brasil (EDP has 51%)
Presence since 1996
Power generation: 2.5 GW (hydro and coal)
2 electricity distribution concessions
5 transmission lines (under construction)

Spain

12% of EBITDA
Presence since 2001
Power generation 3.4 GW (ex-wind)

Member of Dow Jones Sustainability Indices In Collaboration with RobecoSAM

2017 World's Most Ethical Companies

2017 Global Top 100 Green Utilities report

Note: Data as of Dec-17

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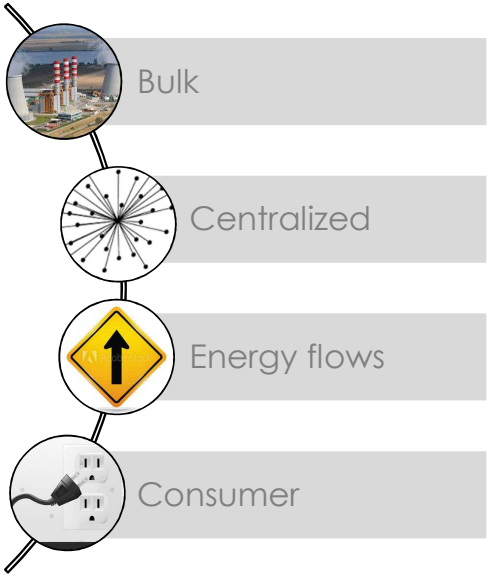
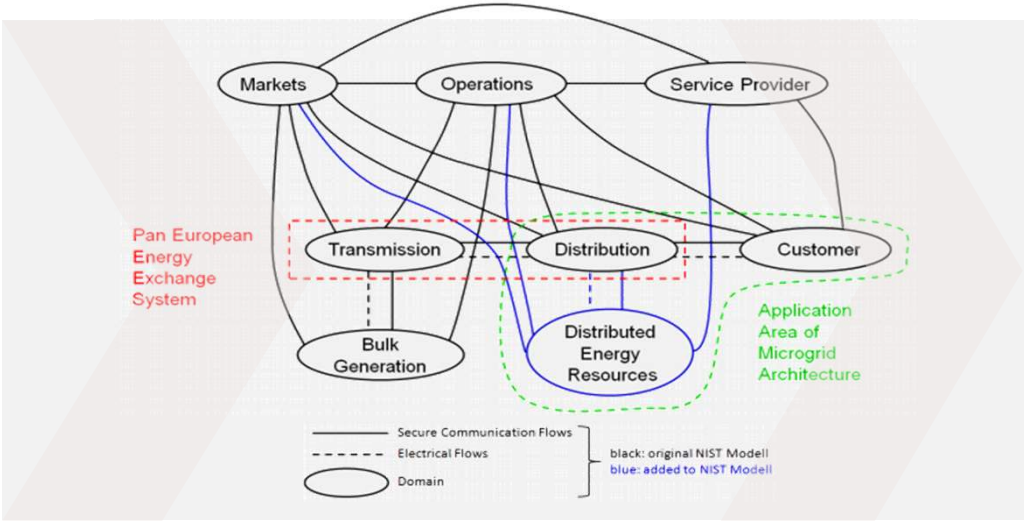
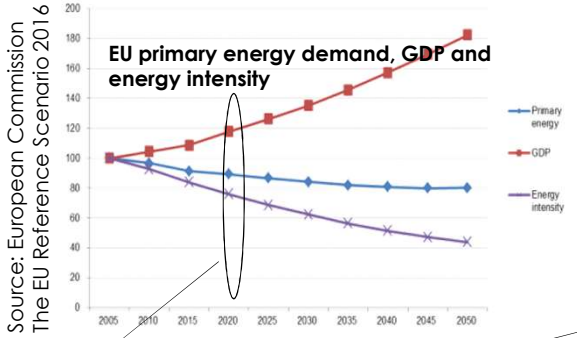
The path to a secure, affordable, competitive and sustainable energy is being supported by a profound System transformation

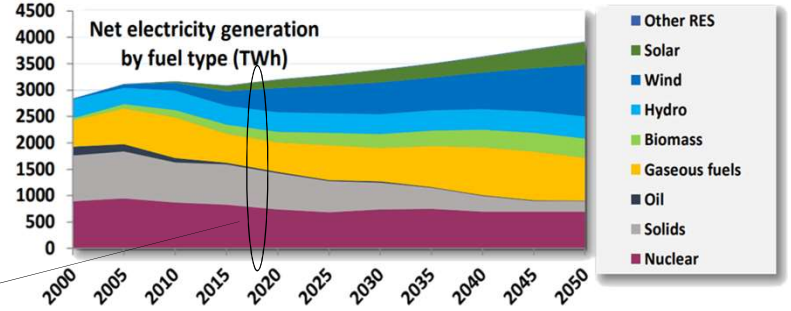




CEN/CENELEC/ETSI Smart Grid conceptual model

Source: European Commission
The EU Reference Scenario 2016





Continuous efficiency gains and innovative market models strongly depend on digitalization and Servitization

edp distribuição

Digitalization untaps fundamental capabilities, such as small scale and variable renewables, flexibility and smart demand response

"The Energy Internet"
Connectivity and electrification are required to transform the way electricity is supplied and consumed

Aggregators …. etc

Real time Flexibility Management

Virtual power plants

Business Models

Digital Enablers

IoT / 5G / NFV / SDN

Risk and resilience frameworks

Cloud Computing / Edge Computing

Big Data / AI / Analytics

Cyber & Physical security / Trust technologies

Example I

1/3 Global
Energy Consumption

Real-time data control can capture 10% of efficiency

Billions of participating connected appliances by 2040

Buildings Efficiency (>>> Millions)

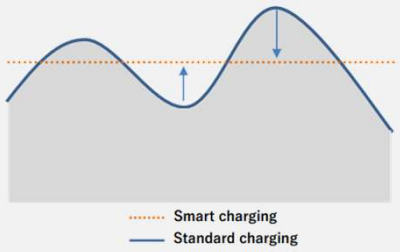
- PV / Storage
- Demand response
- Smart Thermostats
- Occupancy sensors
- Remote adaptive control
- Flexibility management
- Smart appliances

Example II

Estimates point to a reduction of 40% of peak demand from EV can be achieved by smart charging

Electric vehicle (EV) Smart Charging (>> Millions)

- Smart Charging
- EV2G
- EV2Home



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Digitalization core technologies are key to smart grids and energy sustainability, security and decarbonization

The dynamic and permanent balance between supply and demand in an atomized control and at scale, mediated by market participants implies:

- An all-connected data environment;
- Massive and distributed processing and decision making;
- Core ICT technologies, Big Data and AI

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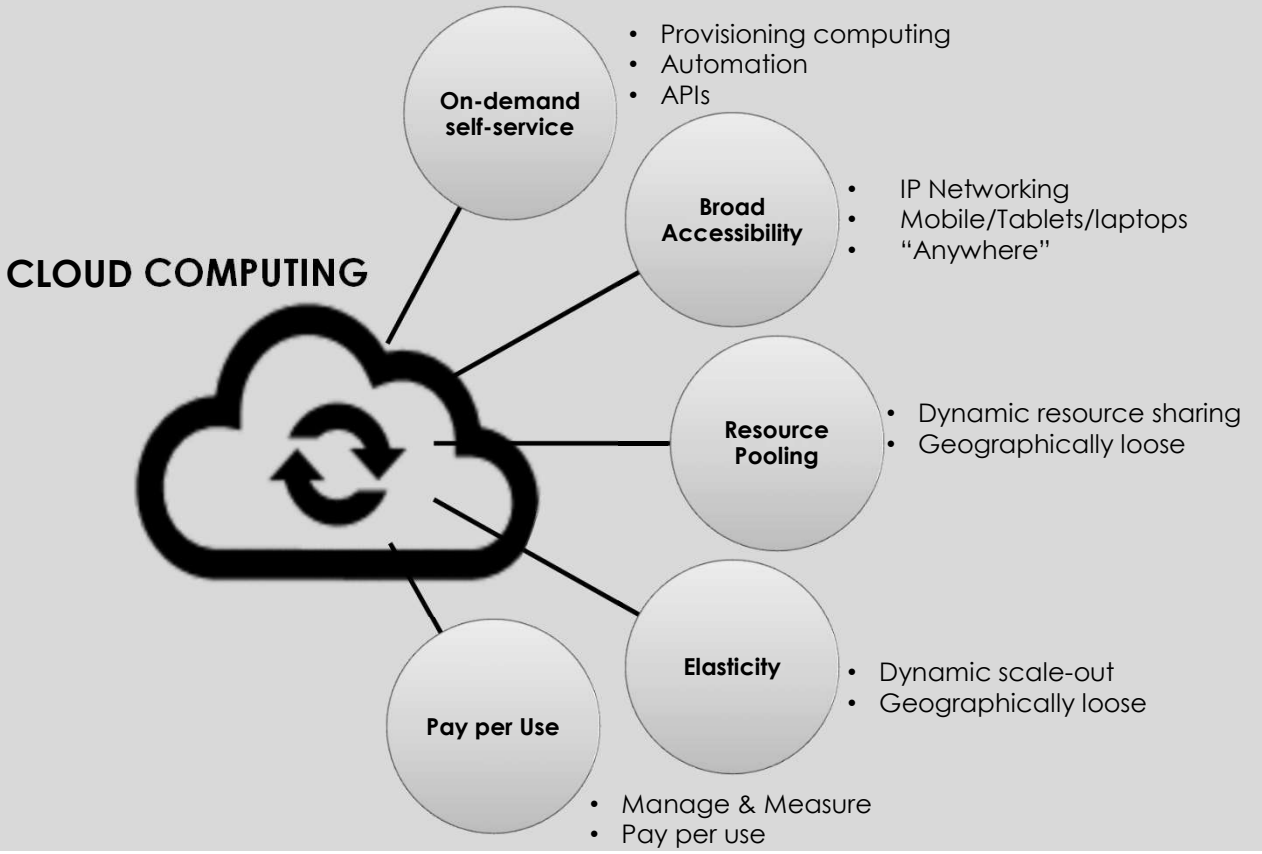
Digitalization at scale requires flexible, evolutive and efficient computing resources as offered by Cloud technologies

DIDITALIZATION COMPUTE REQUIREMENTS

- **Ubiquitous,**
- **Convenience**
- **On-demand**
- **Scalability**
- **Agility/Speed**
- **Efficient**
- **Composable**



CLOUD entails three key enabling technologies ….

Virtualization

- Resource abstraction
- Efficiency
- Scalability
- Reusability
- Geographic reach

- Reliability

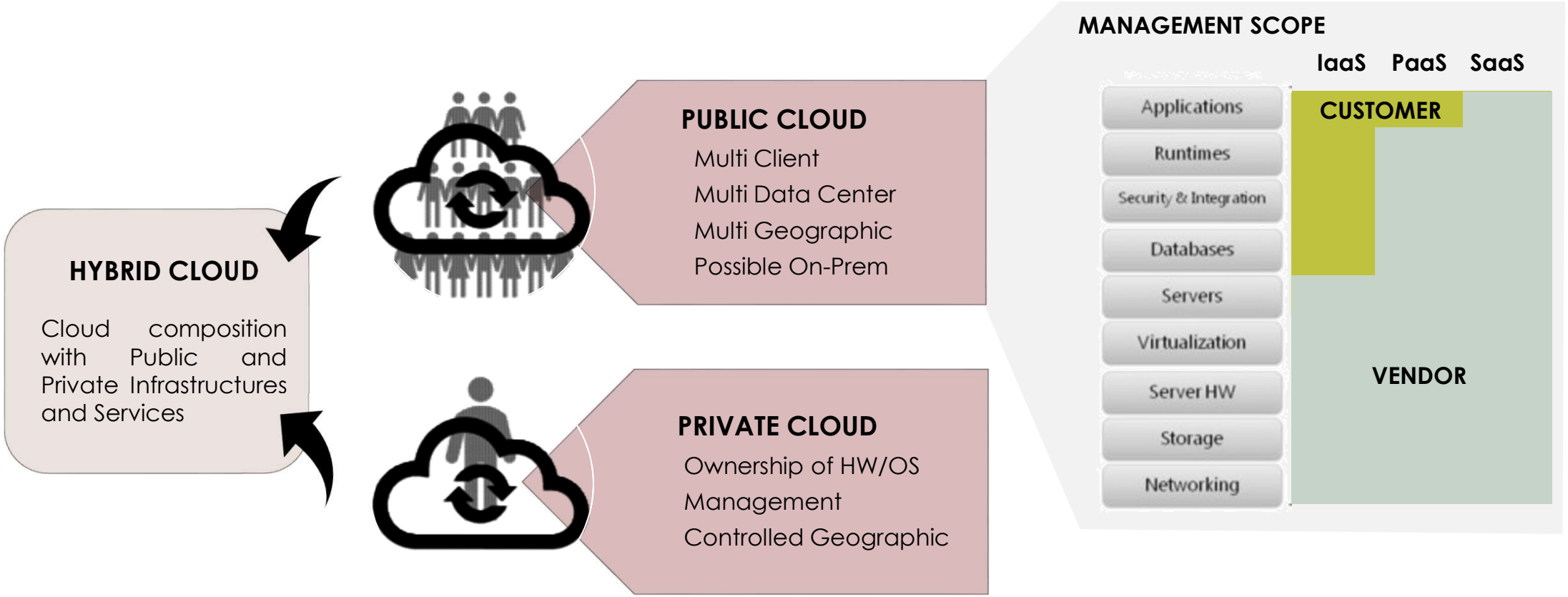
CONNECTIVITY

- IP Networking
- VPNs
- Wired/Wireless
- Pervasiveness
- High Bandwidth

SOA

- APIs
- Ease of Interfacing
- Hide Logic
- On demand services
- Flexibility
- Reuse

The ownership, location and management of CLOUD resources define their deployment models, namely Public, Private and Multi-Clouds



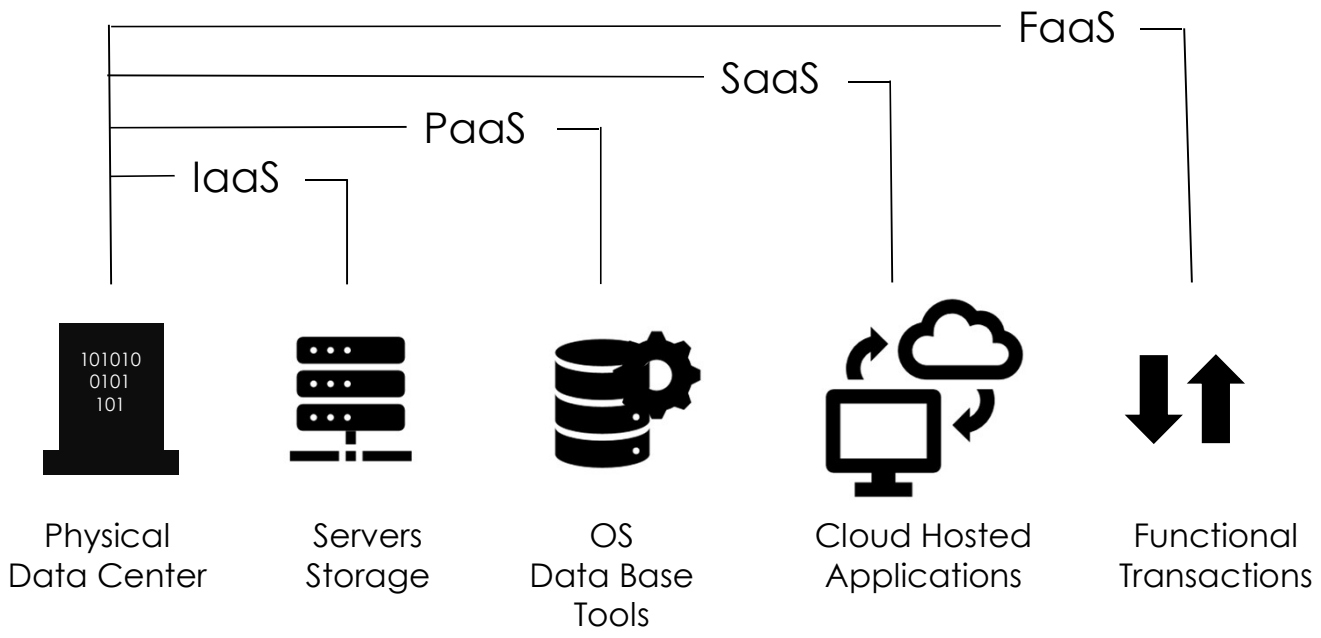
CLOUD Services vary on composition and scope, from low level Computing resources to Applications (Software) and Functions (Serverless)

(IaaS) Infrastructure-as-a-service
Servers
Storage

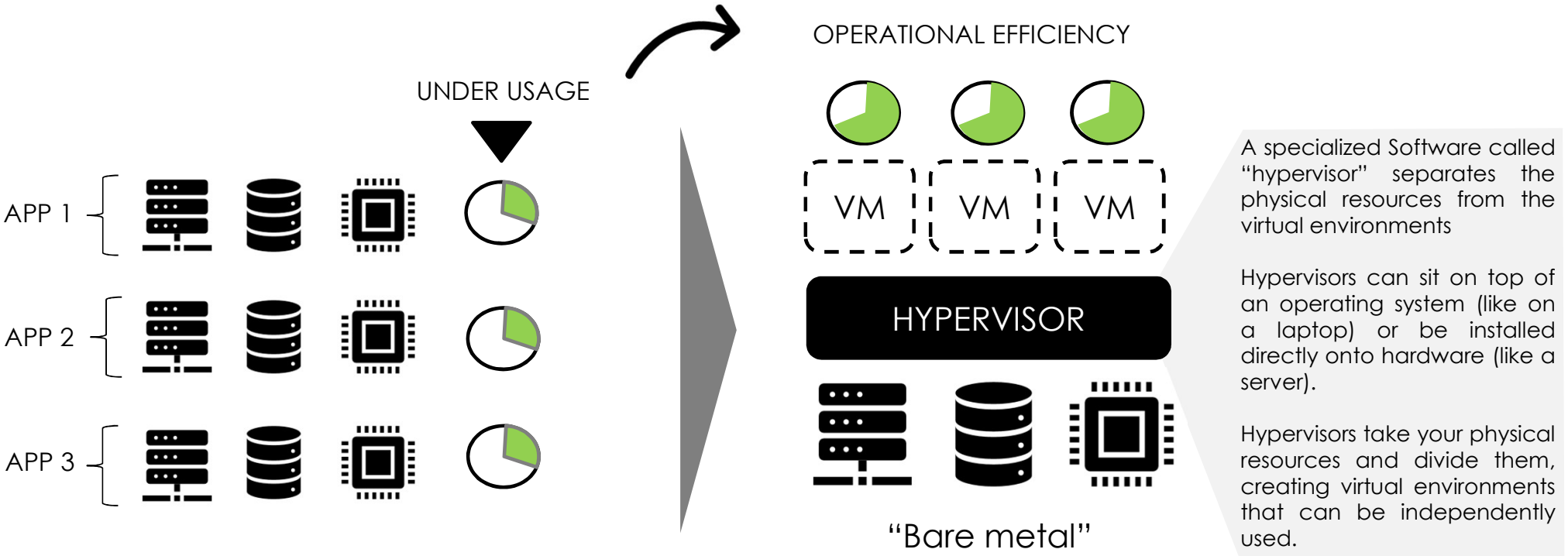
(PaaS) Platform-as-a-Service
Operating OS
Development tools

(SaaS) Software-as-a-Service
Applications
Access through network

(FaaS) Function-as-a-Service
Functions
Serverless



Cloud concept has virtualization has one of it's core pillars



A specialized Software called "hypervisor" separates the physical resources from the virtual environments

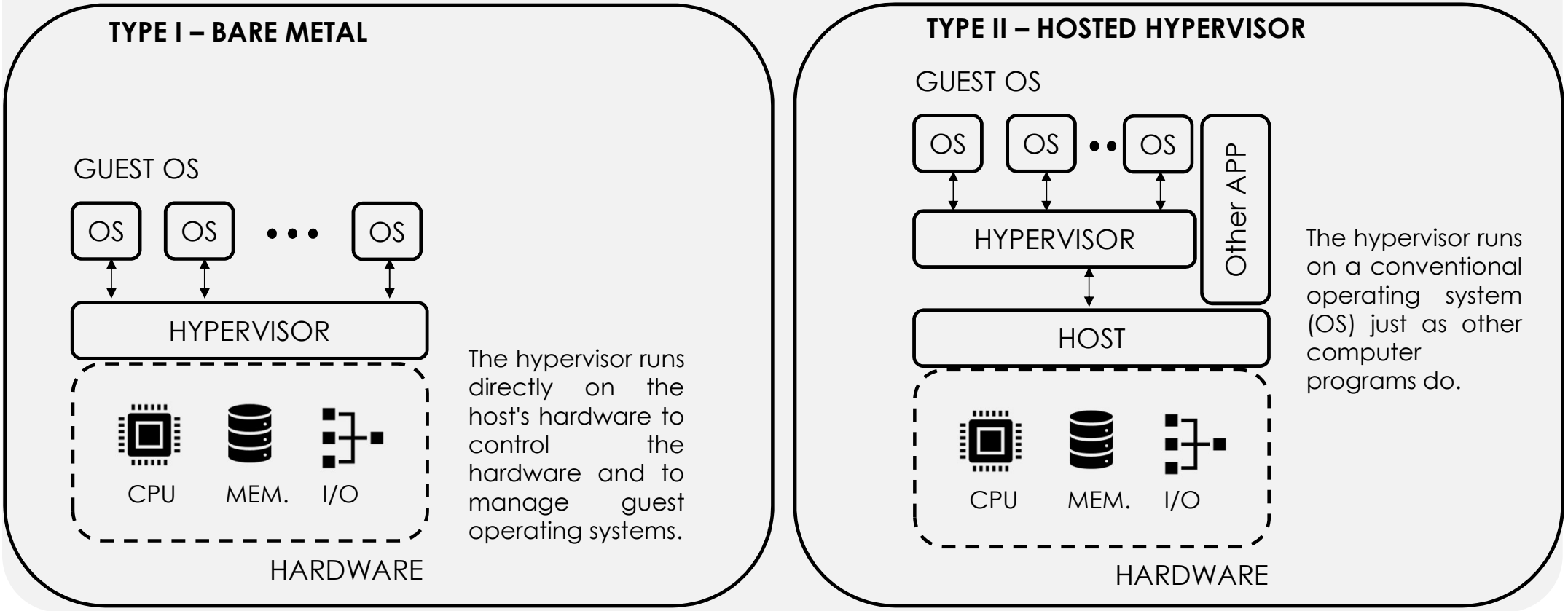
Hypervisors can sit on top of an operating system (like on a laptop) or be installed directly onto hardware (like a server).

Hypervisors take your physical resources and divide them, creating virtual environments that can be independently used.

- Expanding hardware capabilities
- Efforts to control costs and to simplify through consolidation of servers
- The effort to control and manage large multiprocessor and cluster installations
- The ability to run OS-dependent applications in different hardware or OS environments

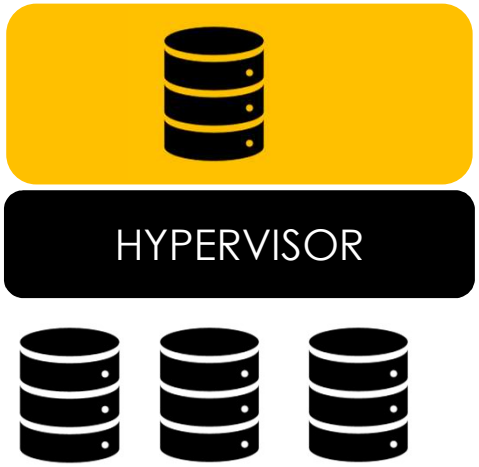
The fundamental role of the hypervisor in virtualization

HYPERVISOR ISOLATES HOST MACHINE RESOURCES AND PROCESSES, CONTROLLING ACCESS FROM OS CLIENTS WITHIN A VIRTUAL INSTANCES



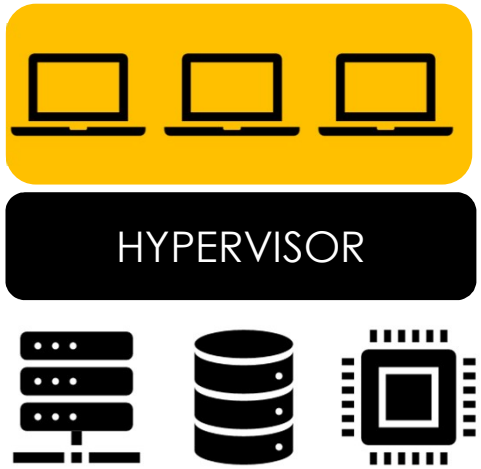
Virtualization can be applied in different domains …

"DATA"



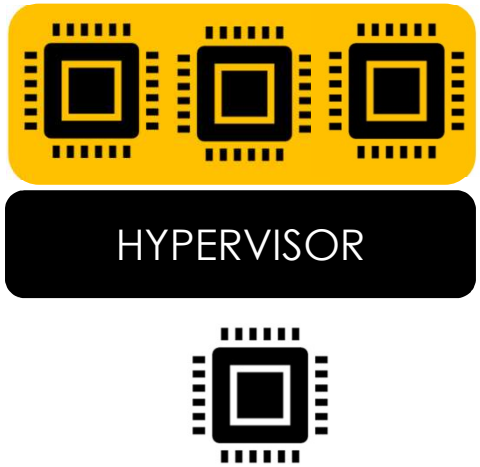
Data virtualization integrates data from disparate sources without copying or moving the data, thus giving users a single virtual layer that spans multiple applications, formats, and physical locations. This means faster, easier access to data.

"DESKTOP"



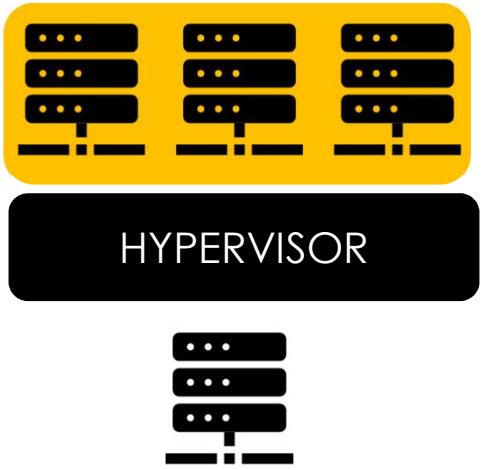
Desktop virtualization is the creation of a virtual computer environment that runs in a HOST server and is then delivered remotely to the user's device.

"VIRTUAL MACHINE"



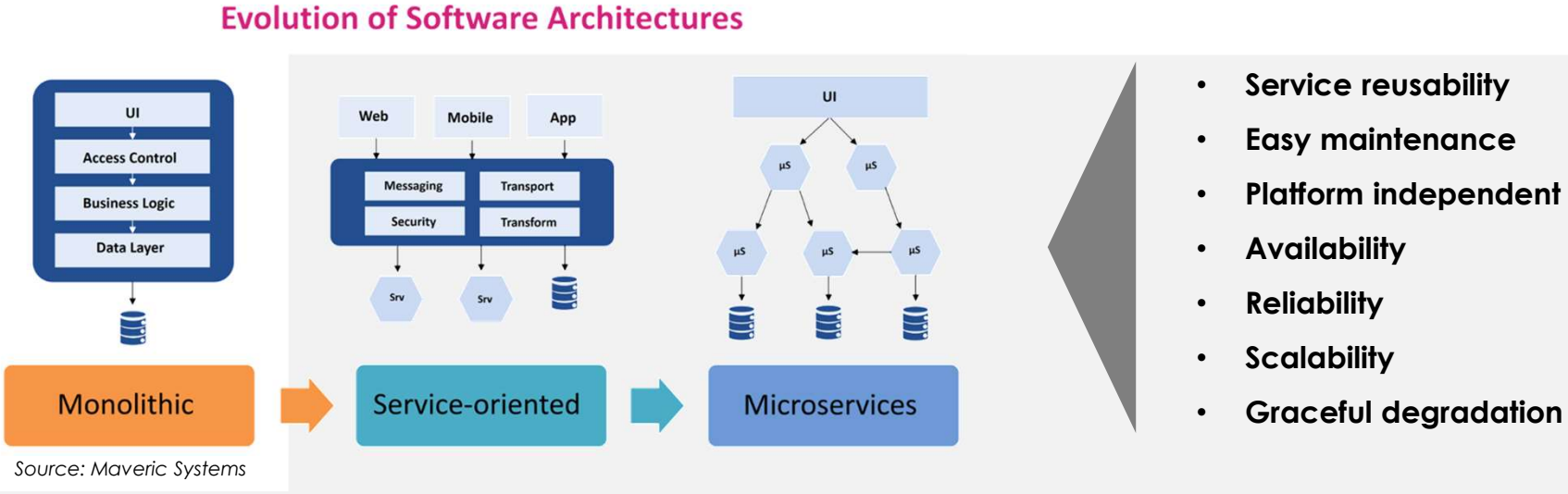
Servers are computers designed to process a high volume of specific tasks. Virtualizing partitions a physical server into multiple smaller, virtual servers, improving utilization

"NETWORK"



Network virtualization is defined by the ability to create logical, virtual networks that are decoupled from the underlying network hardware, virtualizing L2-3 services like switching and routing, and L4-7 including firewalling and load-balancing

The benefits of software “contentorization” and inherent scalability is further enhanced by SOA and Microservices architecture

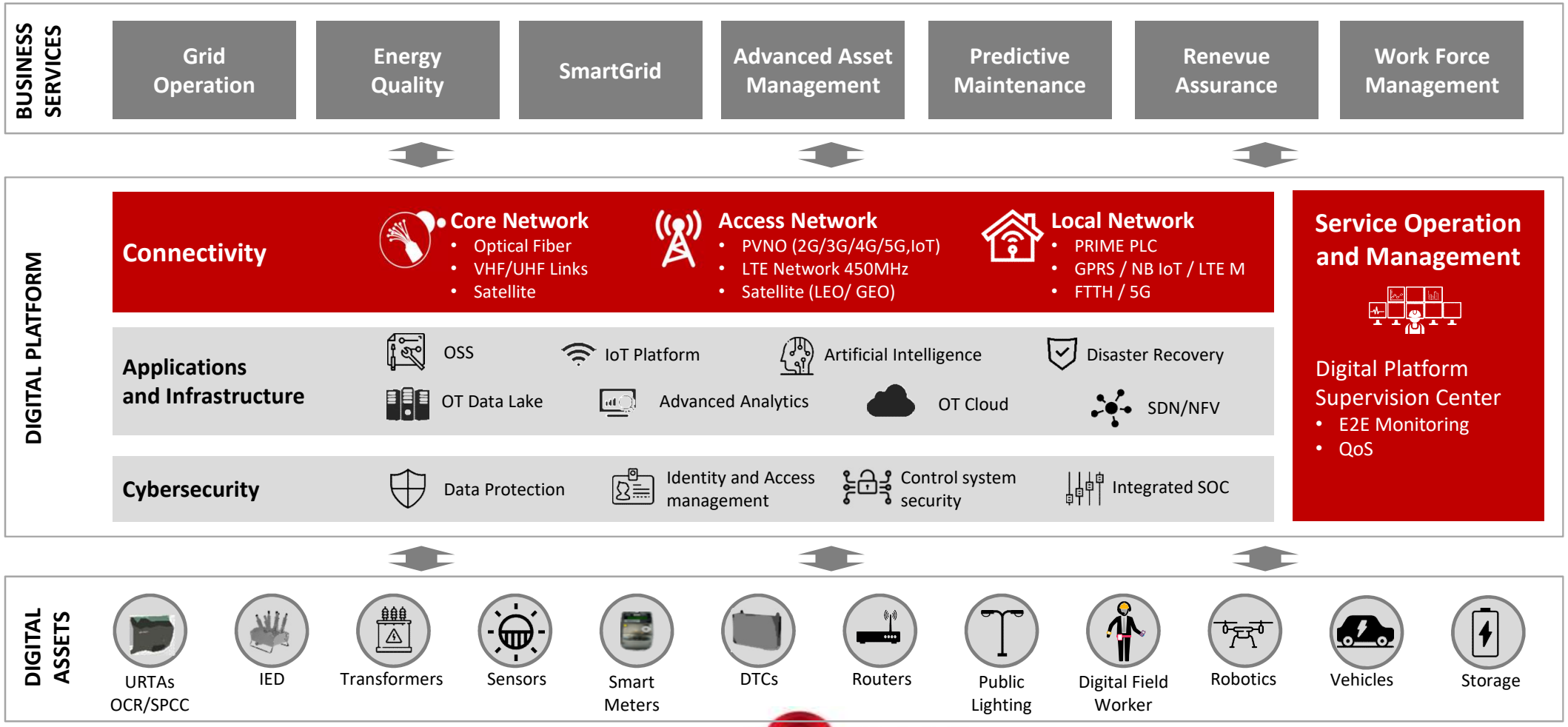


Source: Maveric Systems

- **Service reusability**
- **Easy maintenance**
- **Platform independent**
- **Availability**
- **Reliability**
- **Scalability**
- **Graceful degradation**

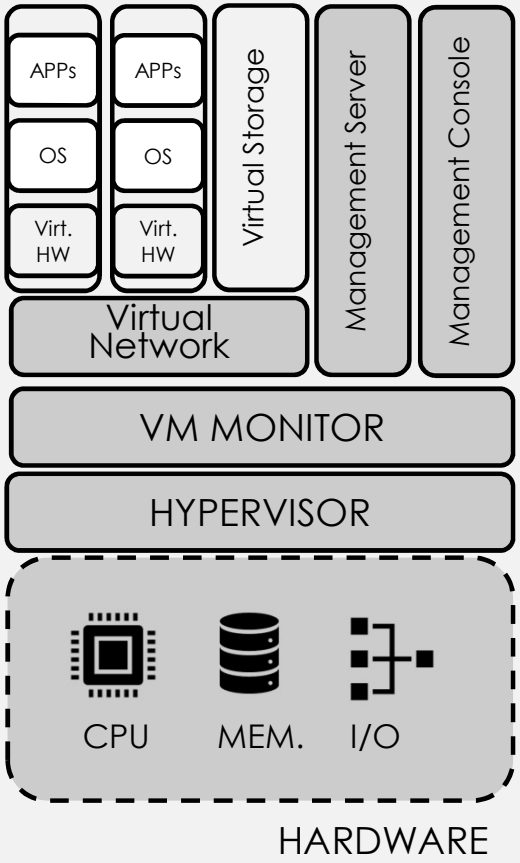
Loose coupling: Services are designed as self-contained components, maintain relationships that minimize dependencies on other services.
Abstraction: A service is completely defined by service contracts hiding their logic
Reusability: Services can be reused more effectively, thus reducing development time and the associated costs.
Autonomy: Services have control over the logic they encapsulate
Discoverability: Services are defined by description documents
Composability: Using services as building blocks, sophisticated and complex operations can be implemented

Private and Public networks support pervasive connectivity, enabling the evolution of DATA driven processes required by Grid Digitalization



Clouds and Virtualization bring and undebatable advantages to security but also come with increased security risks that must be taken into account

CONPONENTS OF VIRTUALIZATION



A complex mix of software components at different levels of the computing architecture, each with its own administrator privileges, enlarges the attack surface.

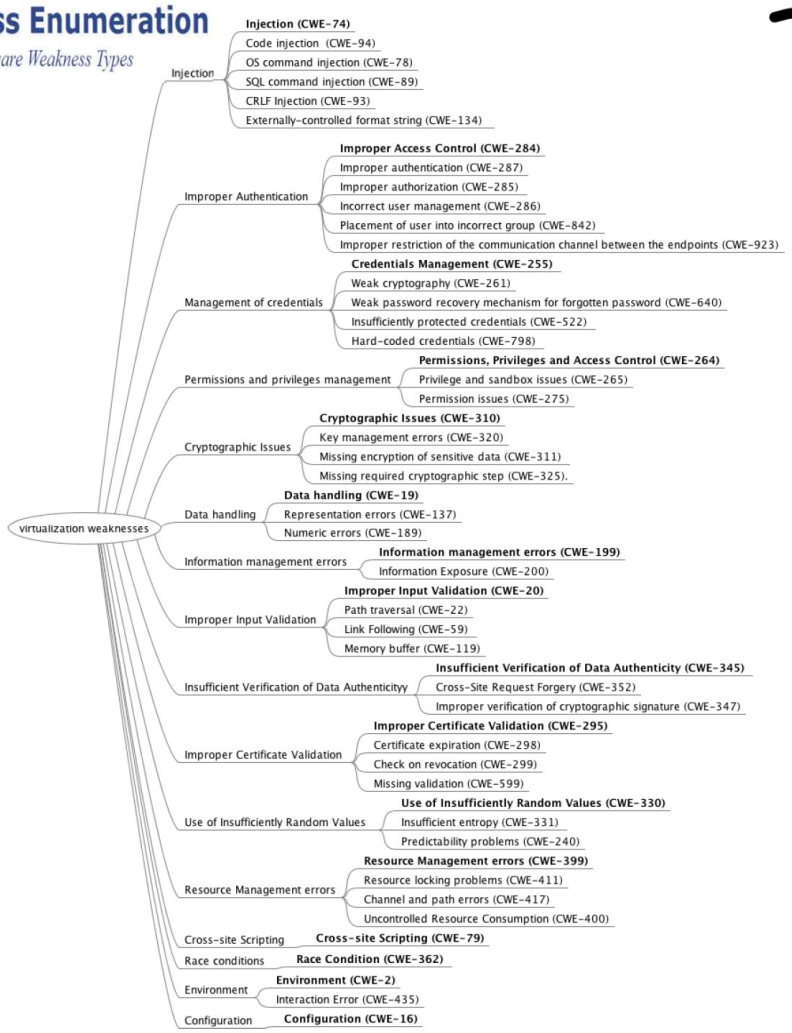
Promote a Risk Management Framework (ISO 27001), assessing Threats, Risks and mitigation techniques and practices, ENISA as the European Lighthouse

Existing standards and recommended frameworks enable risk management and security controls, with open scrutiny and sharing for effective action

Common Weakness Enumeration
A Community-Developed List of Software Weakness Types

Categorized Data Base of know weaknesses (SW Architecture, Coding, Implementation, …)

US DHS / CISA



Common Vulnerability and Exposures (CVE) by System Component

- Guest and Host OS
- Containers
- Hypervisor / Management SW
- Virtual Networks
- Virtual Storage

Share and Mitigate

enisa

ISACA

CSA cloud security alliance®

ISO

(ISC)²

EE-ISAC

NIST National Institute of Standards and Technology

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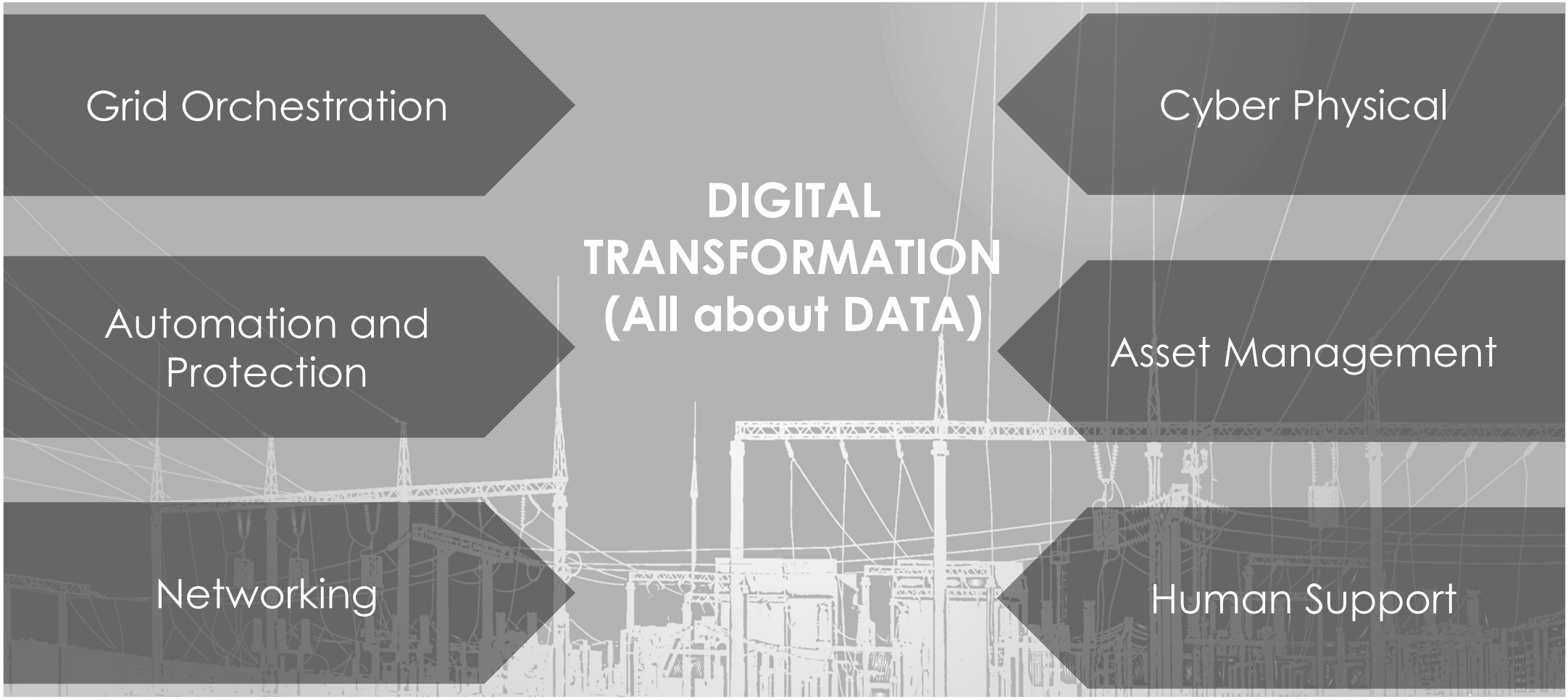
Envisioning the present and future Digital context of a Substation through possible functional families



Envisioning the present and future Digital context of a Substation through possible functional families – **GRID OCHESTRATION**

Grid Orchestration

Smart Grids will comprise new distributed "intelligence" multi agent systems, supporting Islanding, self-healing and concepts requiring:

- Power flow and state estimation can be called and computed in high performance environments
- Fault Location Identification and System Restoration (FLISR)
- Load and Generation Forecast
- Self-healing automation can be further improved by configuration ….AI / ML

Automation and Protection

Remote Control

Physical Awareness

Asset Management

Human Support

DIGITAL TRANSFORMATION

Envisioning the present and future Digital context of a Substation through possible functional families – **Automation & Protection**

Envisioning the present and future Digital context of a Substation through possible functional families – **Networking**

Grid Orchestration

Automation and Protection

Networking

With server virtualization, with connectivity required between workloads, network virtualization contributes to flexibility and improved DR mechanism:

- Virtualize Network Functions
- Mobility of workloads and networks
- Avoid external dedicated HW
- Management and configuration across platform
- Simplify installation and cabling

Envisioning the present and future Digital context of a Substation through possible functional families – Cyber Physical

Envisioning the present and future Digital context of a Substation through possible functional families – ASSET MANAGEMENT

Advanced Asset management and "Digital Twins" technology will require an increased sensorization of assets and their physical contexts:

- Asset "all data" logging (functional, security, …)
- Complementary Sensors
- Local atomized connectivity and authorization of devices
- Edge processing (Data cleansing, ML, AI)

Grid Orchestration

DIGITAL TRANSFORMATION

Physical Awarness

Automation and Protection

Asset Management

Remote Control

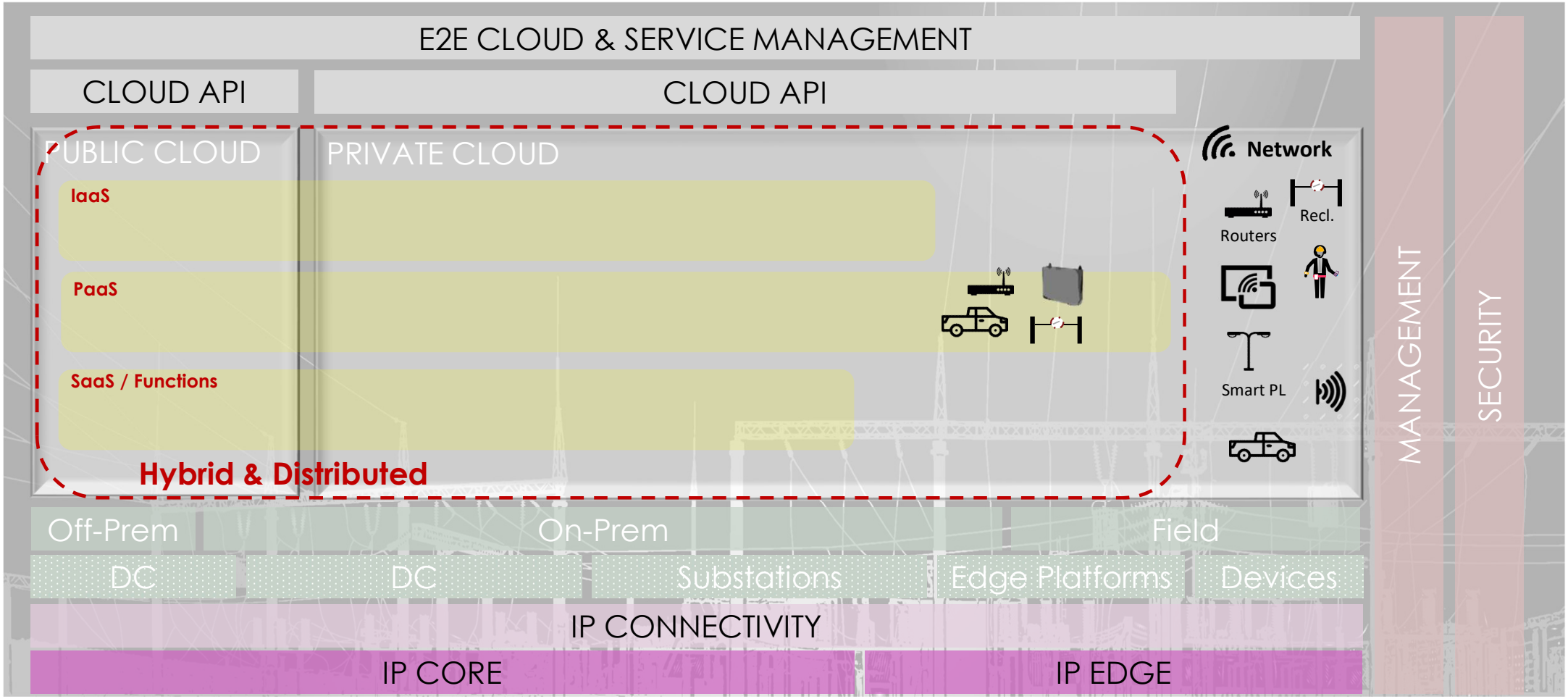
Human Support

Envisioning the present and future Digital context of a Substation through possible functional families – HUMAN SUPPORT

Human intervention can benefit from advance on key supporting information:

- Augmented reality regarding technical diagnose and intervention
- Reinforced security environment by fencing intervention context
- Personal health and security by monitoring wearable sensors and other behaviour patterns

CLOUD technology can leverage the Smart Grid digital transformation, offering a fluid, agile and scalable architecture, from Core to Edge



Cloud Substation clusters will be orchestrated as a distributed Cloud, constrained by capacity of core IP networks and delay requirements

ILLUSTRATIVE

CORE CLOUD

High Performance Backbone
Geographical constrain on delay

- Host local High performance app (IED)
- Video Analytics
- Host Backup instances of other S.
- IoT GW & Data …
- ADMS in decentralized mode
- ….

Substation Perimeter

High Performance Backbone
(Sub 5 ms RTT)

High Performance
WAN

Miscellaneous Connectivity
Technologies

Fit for Purpose

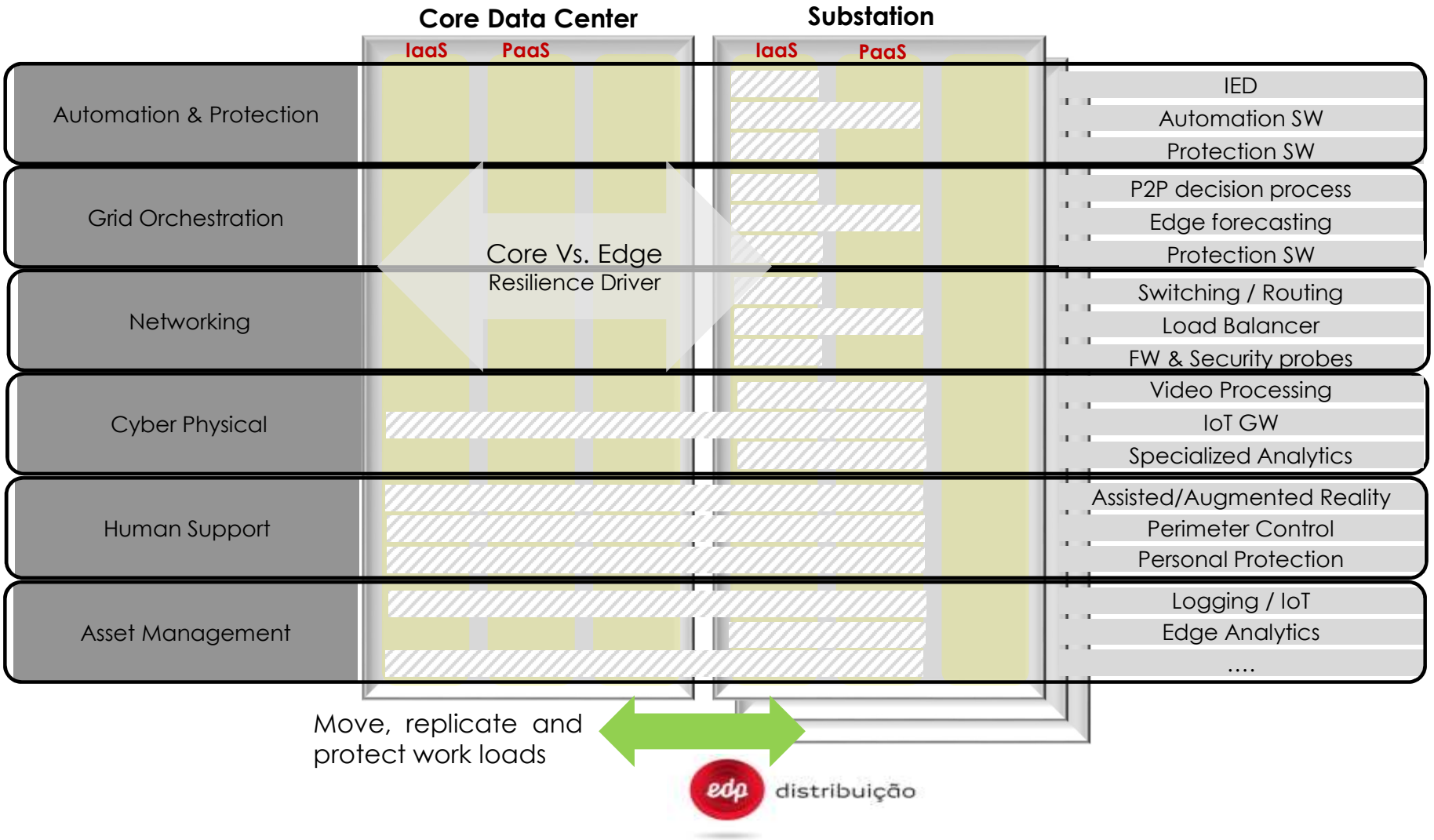
High / Low Performance
Access WAN
(NB-IoT, CAT-M, 5G, LoRa, …)

EDP Distribuição

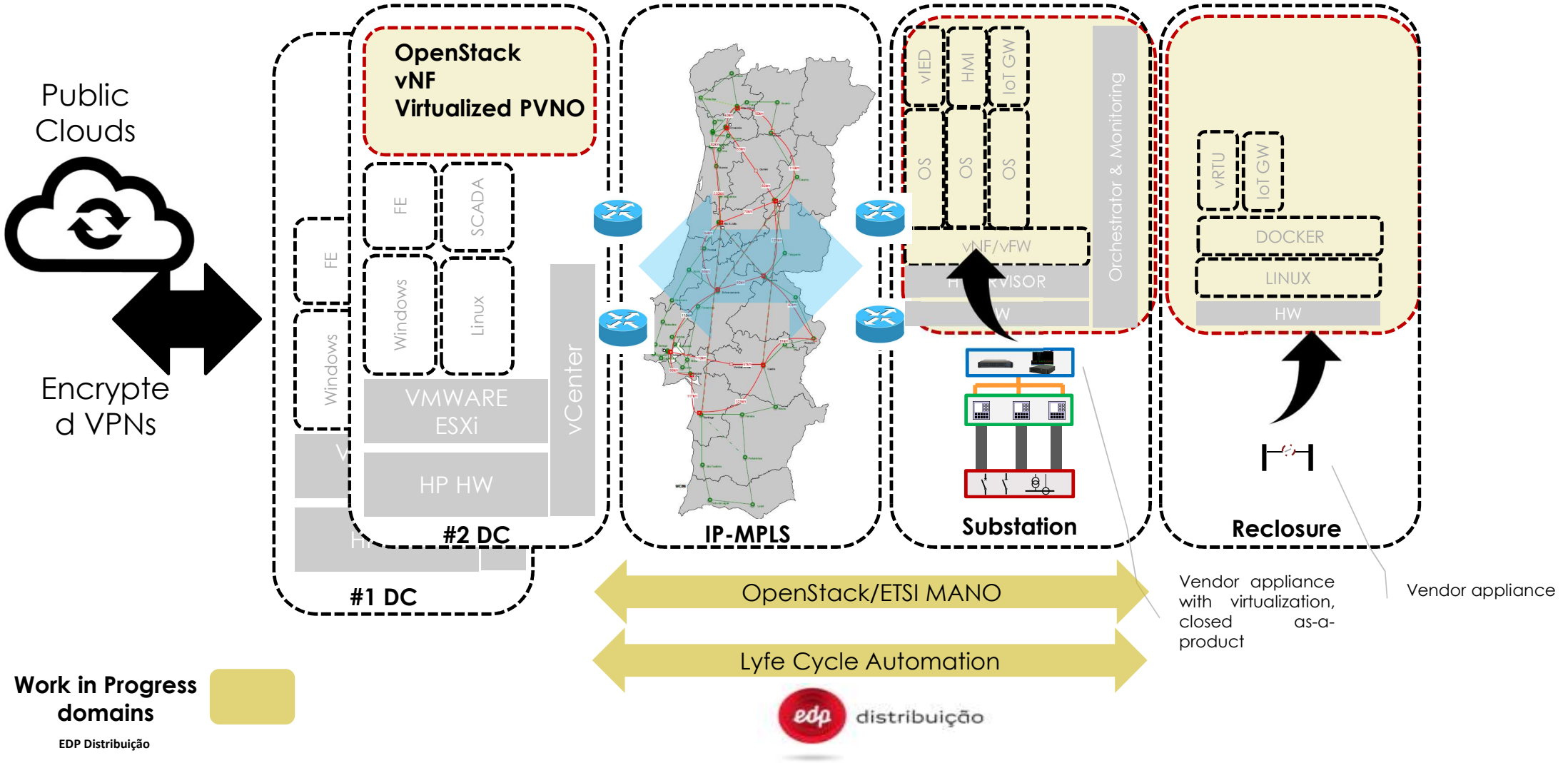
Substation Perimeter

edp distribuição

CLOUD technology can leverage the Smart Grid digital transformation, offering a fluid, agile and scalable platform, from Core to Edge

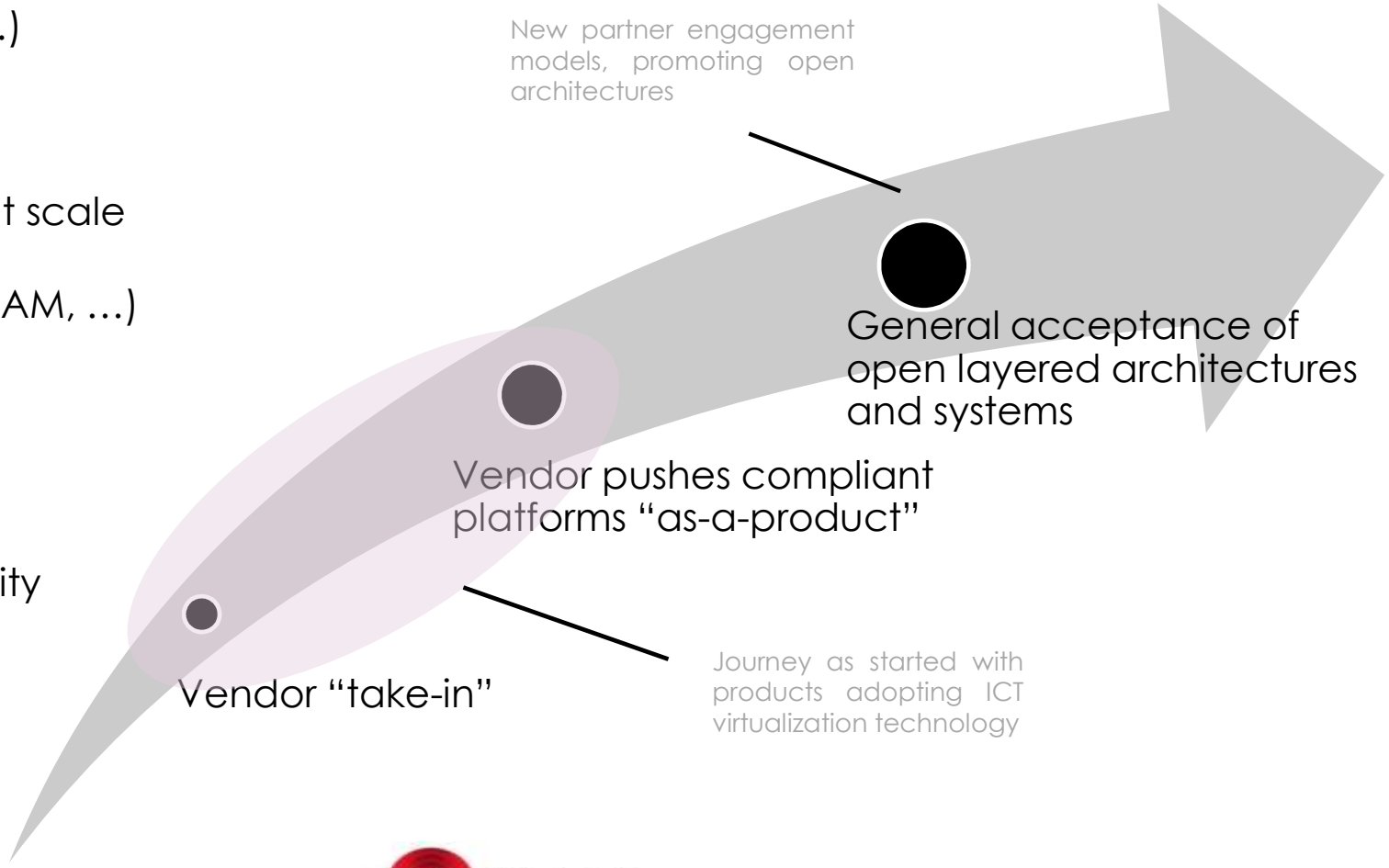


“As-is” and the new developments from Cloud and Virtualization perspective …



The “CLOUD journey” tackles hidden benefits and will require holistic approach and reference vendor participation and buy-in

- Agility (deploy, Change, …)
- No Single-point-of-failure
- Environment automation at scale
- Compliance (App, RBAC, IAM, …)
- Patching
- Decouple HW / SW
- Horizontal/Vertical scalability
- …



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Digital acceleration motivated EDP X project, sponsored by EDP's CEO, tackling Strategy, Projects and Culture, fostering and retaining skills

GLOBAL OVERVIEW *ON DIGITAL, IT AND OT*

DIGITAL ROADMAPS, BIG BETS & KPIs

NUGGETS BANK & FINANCIALS

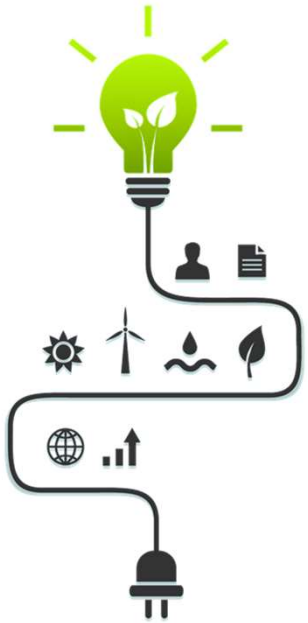
DIGITAL BOOST *> 3 - 9 MONTHS*

DIGITAL mVP *> ~3 MONTHS*

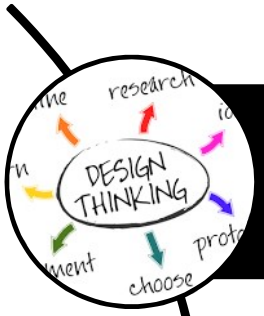
DIGITAL QUICK WIN *> ~2 WEEKS*

- **NEW WAYS OF WORKING** *> AGILE / DESIGN THINKING*
- **COLLABORATIVE WORK** *> VIRTUAL COMMUNITIES*
- **AWARENESS / COMMUNICATION / TRAINING_**

Engaging Digital stakeholders and embracing new roles, moving into the "Hands-on" domain is crucial to the innovation "New Normal" paradigm



"Playing the game" and work dynamics are key to attracting, developing and retaining digital talent



New Ways of Work

- Ideate & Create
- Test / Fail

New Players

- Disruptors
- Start-ups

Engage and Contribute

- Specialized forums
- Open source

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EUTC

EE-ISAC

amazon web services

LFENERGY

openstack.

OPEN Compute Project

CSA cloud security alliance®

CLOUD is a Pillar for the Digital Utility Transformation

GET ENGAGED ON OPEN FRAMEWORKS

DIGITAL TRANSFORMATIONS ARE RARELY PRODUCT DRIVEN

DE-VERTICALIZE CONCEPTS, OPENING LAYERS DO INNOVATION AND COMPETITION

CONTINUOS TRANSFORMATION REQUIRES LIVING AND ADAPTATIVE ARCHITECTURES

IN-HOUSE KNOW-HOW FUELS AND SUSTAIN YOUR SUCCESS

COMPOSE AND SOURCE TO YOUR BEST FIT

a better energy, a better future, a better world