

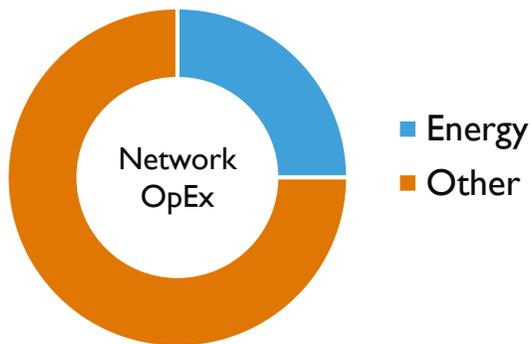
# GREEN TECHNOLOGIES FOR 5/6G SERVICE-BASED ARCHITECTURES

CHIARA LOMBARDO



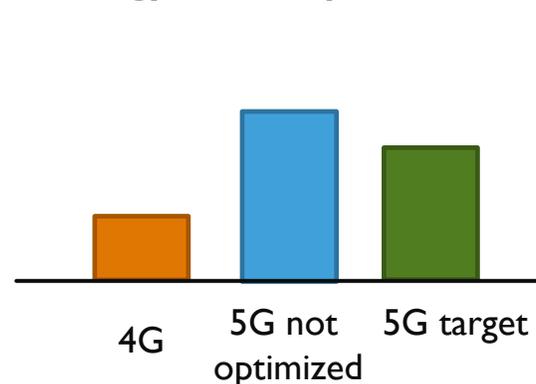
# CONTEXT

- 5/6G and edge computing are intrinsically **distributed and pervasive** by design.
- Relevant **increase of computing resources** and associated infrastructure **OpEx and CapEx**, and, consequently, their carbon footprint and energy requirements.

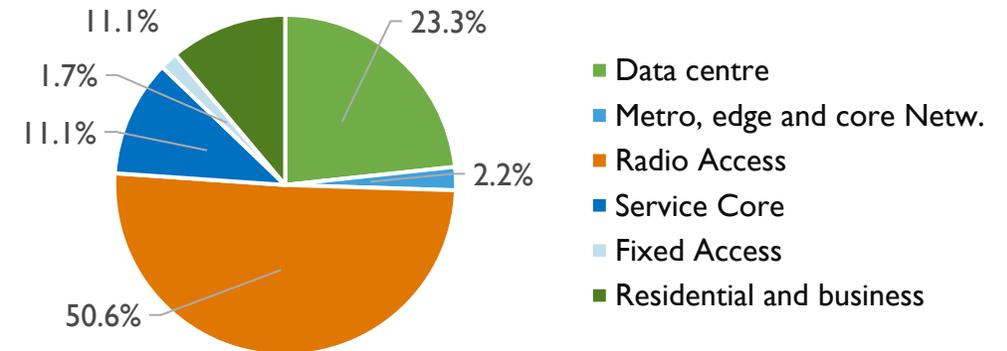


[1]

Energy Consumption Level



[1]



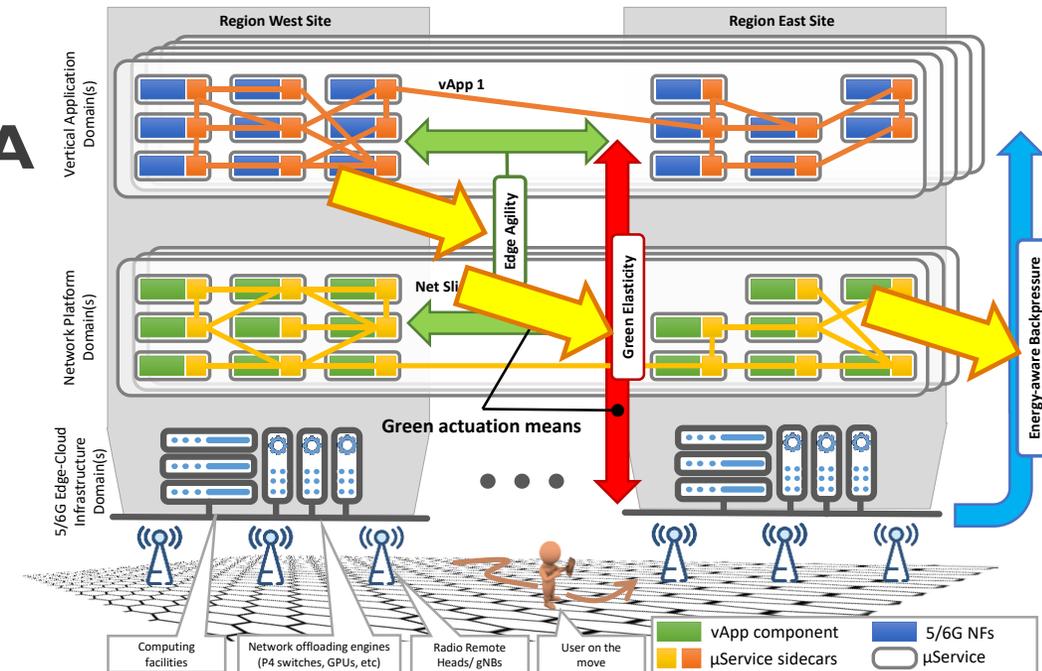
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[1] "Energy Efficiency: an Overview," GSMA Future Networks, 8th May 2019. URL: <https://www.gsma.com/futurenetworks/wiki/energy-efficiency-2/>.

[2] Lorincz J, Capone A, Wu J. Greener, Energy-Efficient and Sustainable Networks: State-Of-The-Art and New Trends. Sensors. 2019; vol. 19, no. 22:4864. <https://doi.org/10.3390/s19224864>

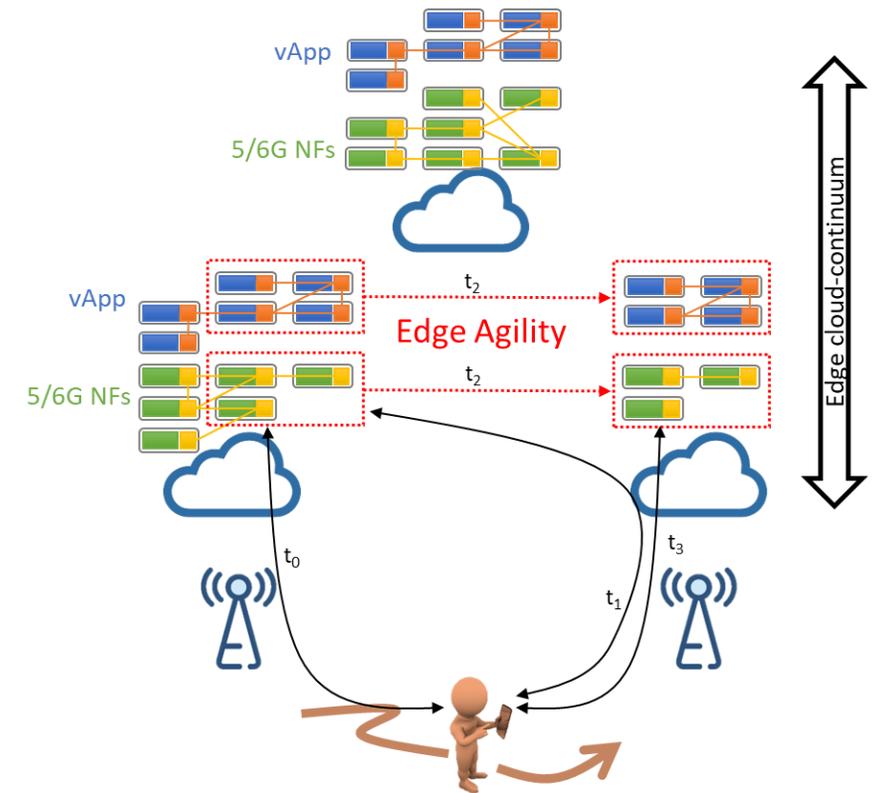
# THE 6GREEN PROJECT

- Objective: promote energy efficiency across the whole **5/6G value-chain**, and enable **5/6G networks and vertical applications** to reduce their carbon footprint by a factor of 10 or more.
- How? Exploit and extend state-of-the-art **cloud-native technologies and the B5G SBA** with new cross-domain enablers to:
  - boost the global ecosystem flexibility, scalability and sustainability
  - enable all the 5/6G stakeholders reducing their carbon footprint by becoming integral parts of a win-win green-economy business.



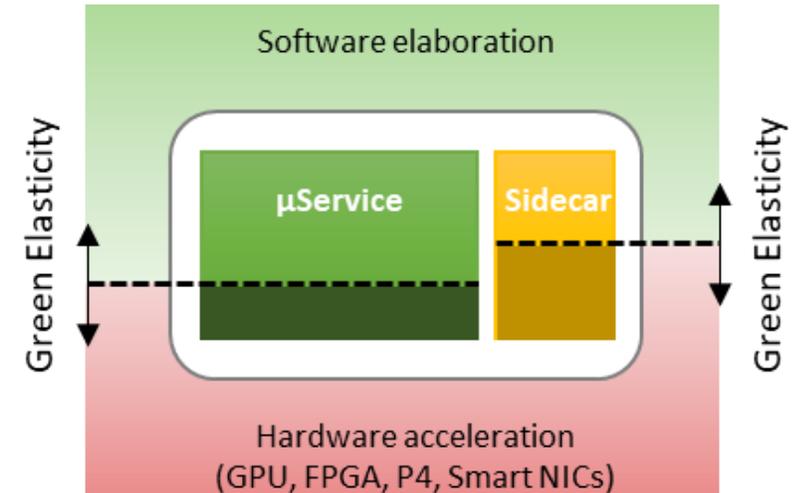
# GROUND-BREAKING INNOVATIONS – EDGE AGILITY

- Roughly, a sort of handover procedure for SBA/application side. Provide **smart, fast, and automated horizontal scalability** to vertical application and related slices **across the 5/6G edge-cloud continuum**.
- **Workload redistribution** according to user or infrastructure-driven events, (e.g., user mobility, seamless workload replacement/migrations, etc.). **Opportunistically** move the **latency budget** between connectivity and computing.
- Enable the **5/6G SBA** to **autonomously proacting/reacting** to UE handovers or policy-driven events by triggering joint management operations on slice network functions and on the vertical application. Control plane integration to assure **seamless operations** through suitable procedures based on cloud-native service-mesh routing.
- Management operations will permit to rapidly **“scale to zero”** the footprint of the slice/vertical application in all not used continuum areas, and to quickly resume the operating capacity when needed.



# GROUND-BREAKING INNOVATIONS – GREEN ELASTICITY

- Dynamically and adaptively provide **energy-aware hardware-assisted acceleration** to network functions and vertical applications to enable **smart vertical scalability** across the three domains of 5/6G environments.
- Rely on **hardware acceleration engines**, which exhibit low power-consumption dependency against their usage, to **lower processing latency** with respect to pure software artefacts and **reduce consumption** by exploiting **standby/low power** modes joint with optimal configurations/deployments.
- Dynamically distributing the time-varying, end-to-end latency budgets of vertical applications **across the domains**, while **holistically optimizing** the **trade-off** between the energy/carbon footprint and the performance of network and application artefacts.

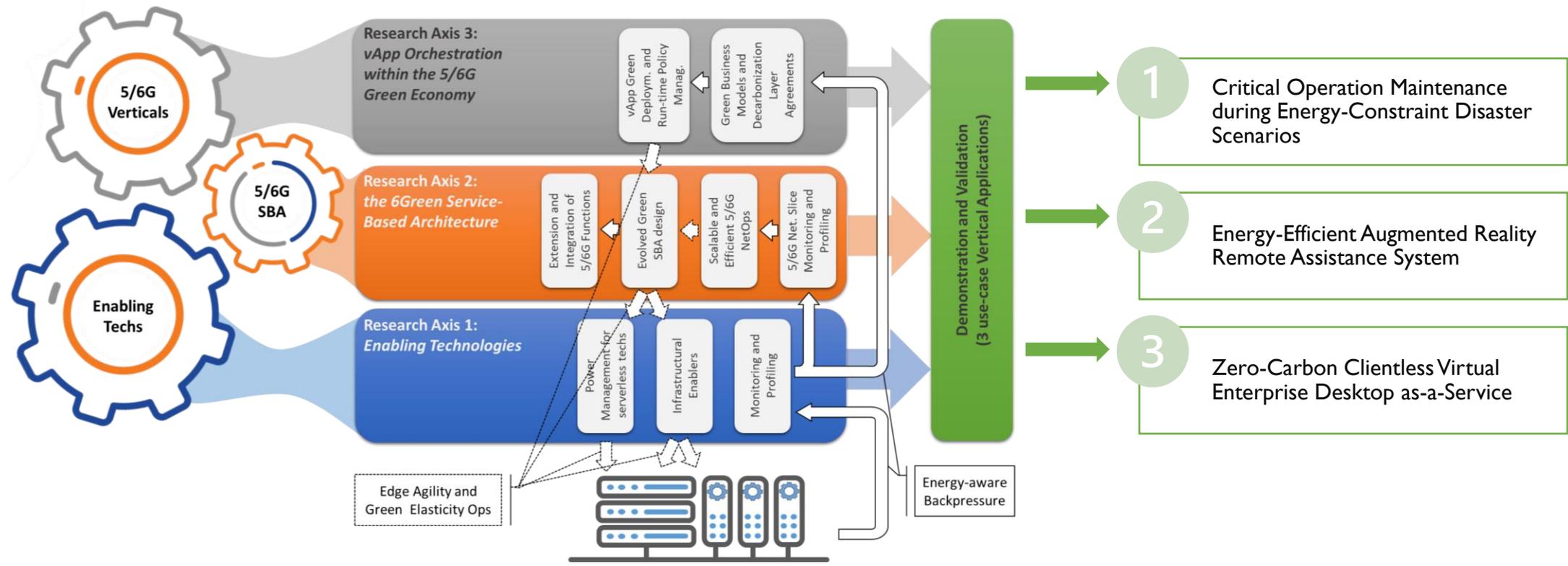


# GROUND-BREAKING INNOVATIONS – ENERGY-AWARE BACKPRESSURE



- A set of **cross-domain** observability **mechanisms and analytics** to evaluate the energy and the carbon footprint that a vertical application, a slice, or the overall 5/6G network **induce onto the edge-cloud infrastructure**.
- To reach a **holistic green ecosystem** and to make all the stakeholders aware of the footprint they induce, 6Green aims to suitably **process, infer, and expose** this information at both the 5/6G SBA and vertical application (and their network slices) levels.
- Hardware-level **energy consumption metrics** will be collected by explicitly considering renewable energy contribution and will be **divided/mapped onto each hosted tenant** through **adaptive AI-driven analytics**.
- **SBA extension** to acquire these energy consumption metrics, and to further **classify and expose** them to the accountable vertical.

# METHODOLOGY



# RA #1: GREEN ENABLING TECHNOLOGIES FOR CLOUD-NATIVE SERVICES



- Optimize the execution environment of microservices and their mesh interconnectivity and network-related functions, to make them intrinsically **more elastic and agile** in heterogeneous serverless environments.
- P4-enabled NICs and switches, eBPF/XDP, and DPDK-accelerated SW switches, etc. will be exposed to microservices and sidecars as programmable offloading engines, and seamlessly integrated into the **6Green cloud-native VIM** to leverage the work of microservices sidecars and of containers networking.
- Map the **energy consumption** arising from the main hardware components of servers (i.e., CPUs, memory, disks, network I/O) to the hosted containers/pods.
- Support run-time policies and long-term optimizations for adaptive power management in serverless environments.

## RA #2: THE 6GREEN SERVICE-BASED ARCHITECTURE



- Evolution of the 5/6G SBA towards the 6Green “Edge Agility,” “Green Elasticity,” and “Energy-aware Backpressure” paradigms.
- Exploit the new capabilities to realize extremely **efficient network slices**, and to **autonomically drive their lifecycle management** according to vertical applications’ **run-time requirements** and feedback.
- Innovative extensions of both the 5G SBA architecture and single NFs, managing the **lifecycle** of **deployed software components** and reserved resources in the **5/6G continuum**, and abstracting them to the **vertical stakeholders** (by means of the AF).
- Suitably map the **Energy-aware Backpressure KPIs** across the various domain layers (i.e., per platform, per slice, per application).
- **Reinforce** platform awareness to optimize the **placement** and the **configuration of microservices** across the continuum to correctly serve moving UEs, to exploit the availability of **renewable energy sources**, to meet the workload according to the dynamic requirements expressed by the stakeholders, etc.

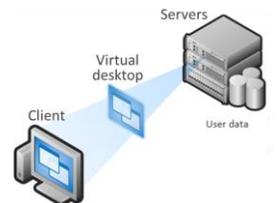
## RA #3: VERTICAL APPLICATION ORCHESTRATION WITHIN THE 5/6G GREEN ECONOMY



- Showcase the mutual benefits related to a **win-win approach** based on the optimization of energy consumption, carbon footprint, and OpEx to **all members of the ecosystem**.
- **Extend agreements** between Telecom Operators and Vertical Stakeholders **to include carbon footprint and energy consumption** and/or requirements induced to the network.
- Define **economic incentives** to motivate upper stakeholders to acquire and use resources as-a-Service.
- Provide the **algorithms, policies, and run-time optimization** mechanisms driving **Day-0/I/2** lifecycle operations to reduce the energy consumption ascribable to the vertical applications.
- Use information retrieved during Day-0 and Day-I operations to **feed the analytics algorithms** of Action 2.d and **synthesize** them in specific **green KPIs** to be exposed to the verticals.

# 6GREEN USE-CASES

- Use-Case #1: Critical Operation Maintenance during Energy-Constraint Disaster Scenarios
  - Evaluation of the consequences of a **disaster** for the infrastructure essential for the functioning of a society and economy), and identification of countermeasures to preserve **stability** and **reduce negative impact** for society and economy.
- Use-Case #2: Energy-Efficient Augmented Reality Remote Assistance System
  - Evolution of a **Remote Visual Assistance** from a remote optimization tool for manufacturers towards a **key solution** for verticals to get closer to **carbon neutrality**, with AR features to collect live data and share it remotely to improve energy-efficiency.
- Use-Case #3: Zero-Carbon Clientless Virtual Enterprise Desktop as-a-Service
  - **Shift** most DaaS tasks from clients to servers to provide native 5/6G benefits such as security, slice integration with the private enterprise network infrastructure, and reduce **GHG emissions**.



# 6GREEN AT A GLANCE



- Project grant No.: 101096925
- Start Date: 1 Jan. 2023
- End Date: 31 Dec. 2025
- Call Topic ID: HORIZON-JU-SNS-2022-STREAM-A-01-04
- Consortium: 15 partners
- Estimated Project Cost: €6,449,531.25
- Requested EU Contribution: €5,996,896.00
- Project Coordinator: CNIT
  - Coordinating Person: Roberto Bruschi
  - Technical Manager: Chiara Lombardo
  - Administrative Manager: Riccardo Rapuzzi

Part. No	Participant organisation name	Short Name	Type	Country
1	CONSORZIO NAZIONALE INTERUNIVERSITARIO PER LE TELECOMUNICAZIONI	CNIT	RI	
2	ATOS IT SOLUTIONS AND SERVICES IBERIA SL	ATOS	LI	
3	ERICSSON TELECOMUNICAZIONI SPA	TEI	LI	
4	TELENOR ASA	TNOR	TO	
5	TELEFONICA INVESTIGACION Y DESARROLLO SA	TID	TO	
6	TELECOM ITALIA SPA	TIM	TO	
7	ORANGE ROMANIA SA	ORO	TO	
8	GIOUMPI TEK MELETI SCHEDIASMOS YLOPOIISI KAI POLISI ERGON PLIROFORIKIS ETAIREIA PERIORISMENIS EFTHYNIS	UBITECH	SME	
9	ATHONET SRL	ATH	SME	
10	INTERNET INSTITUTE, COMMUNICATIONS SOLUTIONS AND CONSULTING LTD	ININ	SME	
11	OCULAVIS GMBH	OCULAVIS	SME	
12	INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS	ICCS	RI	
13	EURECOM	EURECOM	RI	
14	CONSIGLIO NAZIONALE DELLE RICERCHE	CNR	RI	
15	SMILE	SMILE	SI	