ARGE Conference 2024
Milan   26-27 Sept.

Smart Homes: Opportunities, Challenges, and the Future of Living

Proff. Andrea G. Mainini and T. Poli

Department of *Architecture, Built environment and Construction engineering Department*

POLITECNICO
MILANO 1863

DABC

What is a House?

What is a House?

A house is a machine for living in.

— LE CORBUSIER

What is a House?

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The Villa Savoye by Le Corbusier, image by End User (CC BY-ND 2.0)

What is a Home?

What is a House?

A house is a machine for living in.
— LE CORBUSIER

The Villa Savoye by Le Corbusier, image by End User (CC BY-ND 2.0)

What is a Home?

home: |hōm| - n.
a place where one lives;
an environment affording
security and happiness; a
valued place considered a
refuge or place of origin.

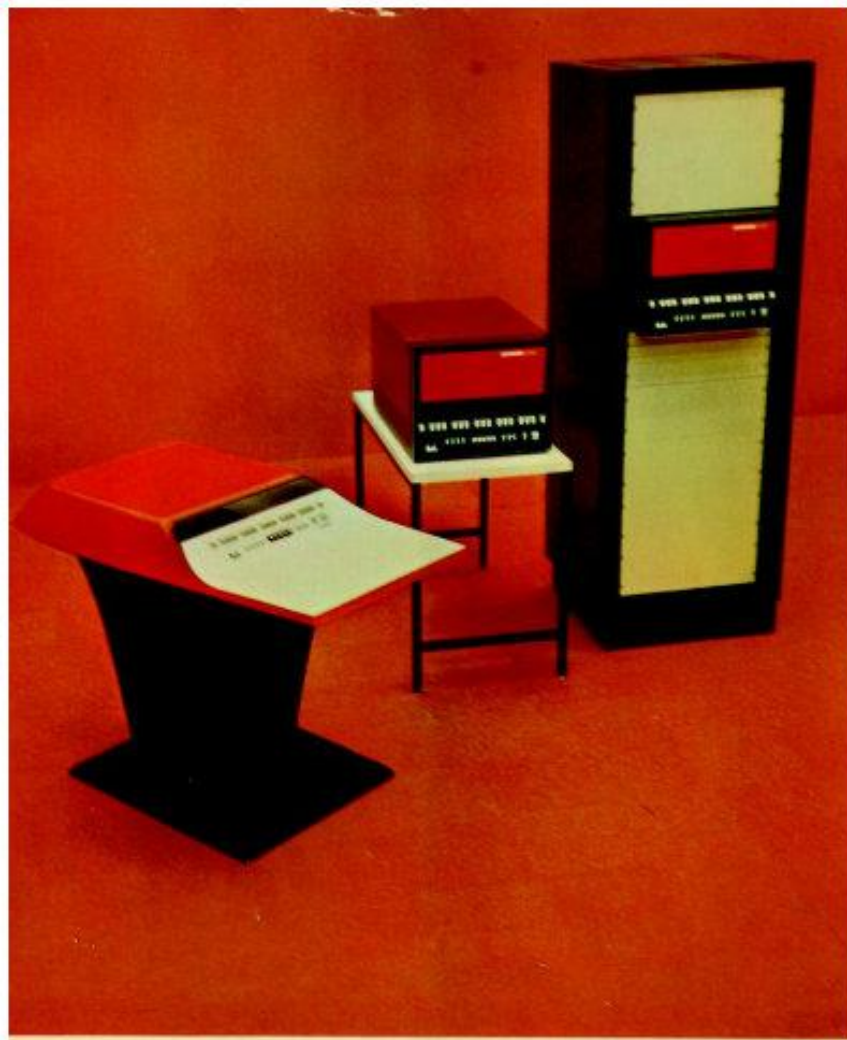# Which kind of Smartness are we searching for?

THE CLAPPER®

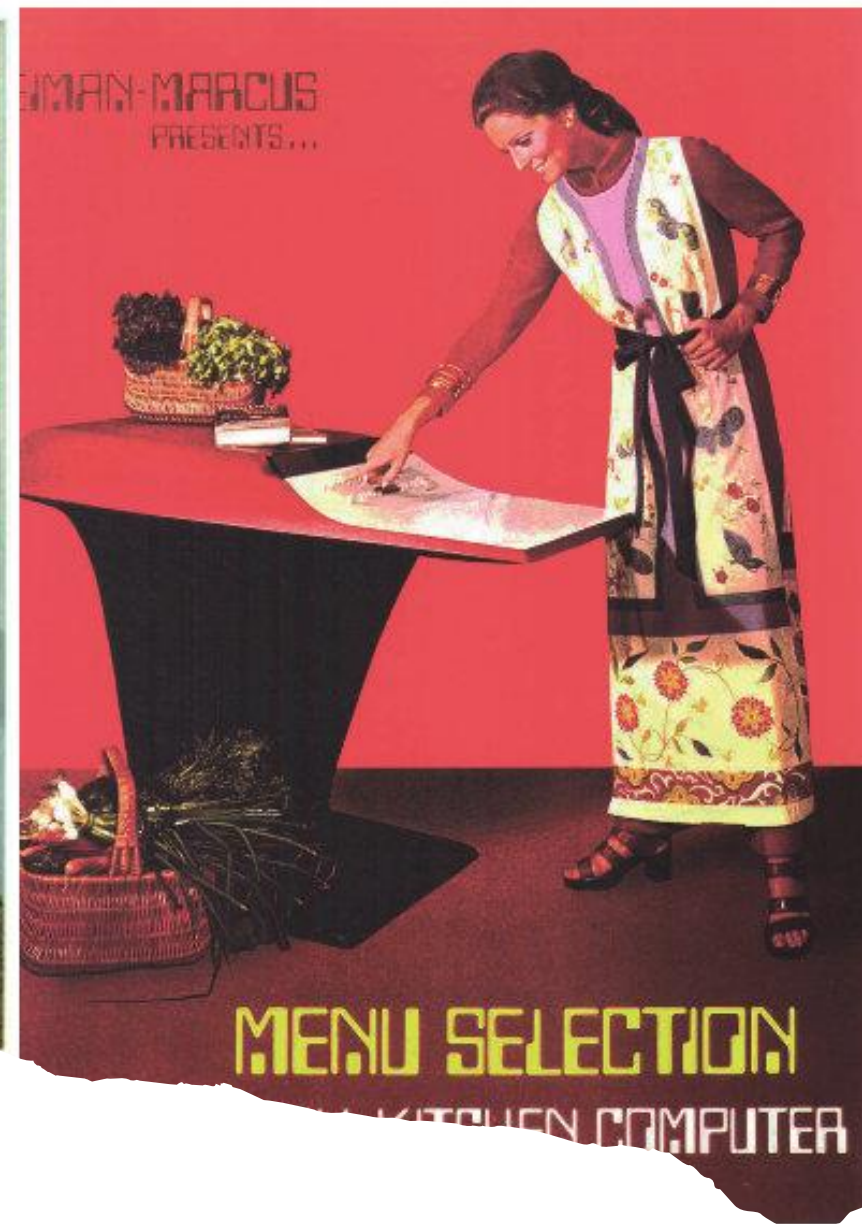CLAP ON! CLAP OFF!

THE CLAPPER®
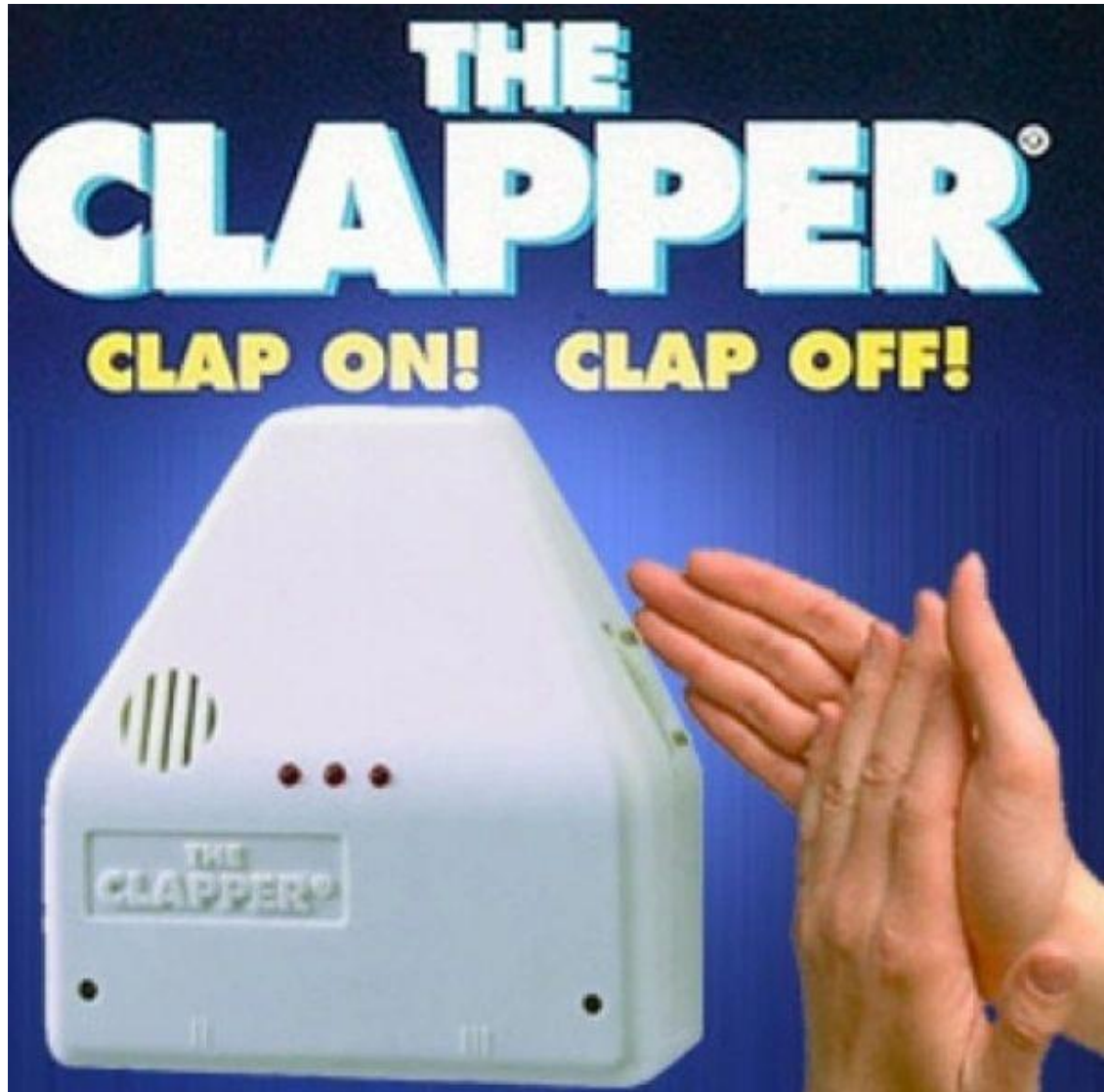
X10 home automation system

Reddit r/homeautomation

Me…In the 80's

Honeywell Kitchen Computer

[The device nobody Bought – Pinterest]

https://historyofinformation.com/detail.php?entryid=1052

ECHO IV - 1966
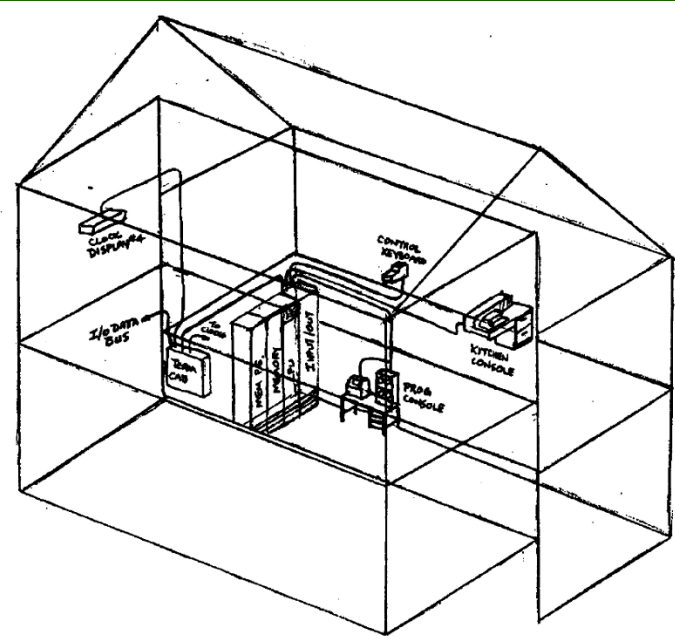
ECHO- IV SYSTEM DIAGRAM

DID YOU KNOW?

In **1966**, Westinghouse engineer **Jim Sutherland** created the **ECHO IV**, which was the first true home automation device, controlling temperature and appliances, and allowing for inputting and later retrieval of shopping lists, recipes, and other family memos.
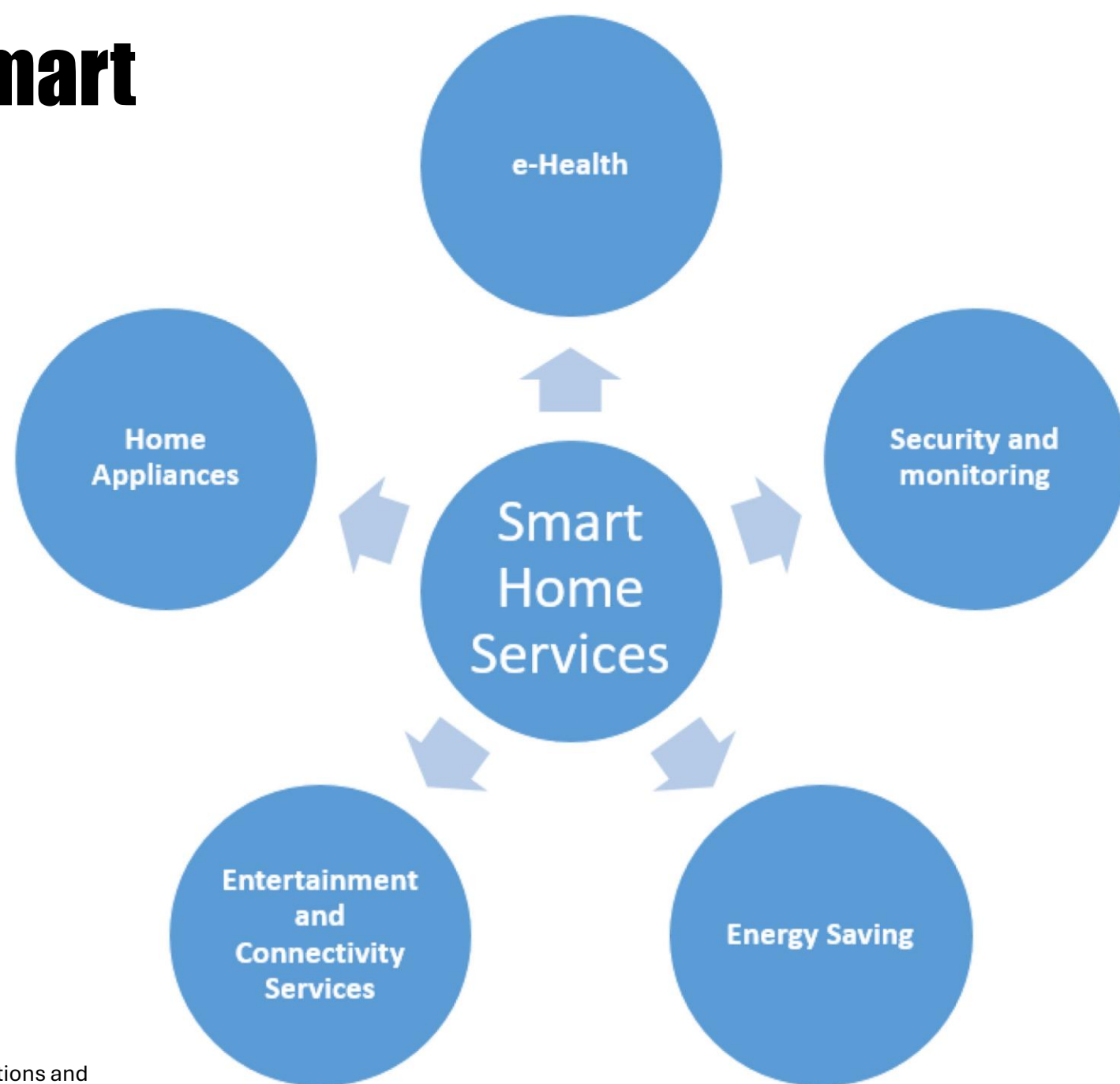
THE BUSINESS AS IS TODAY
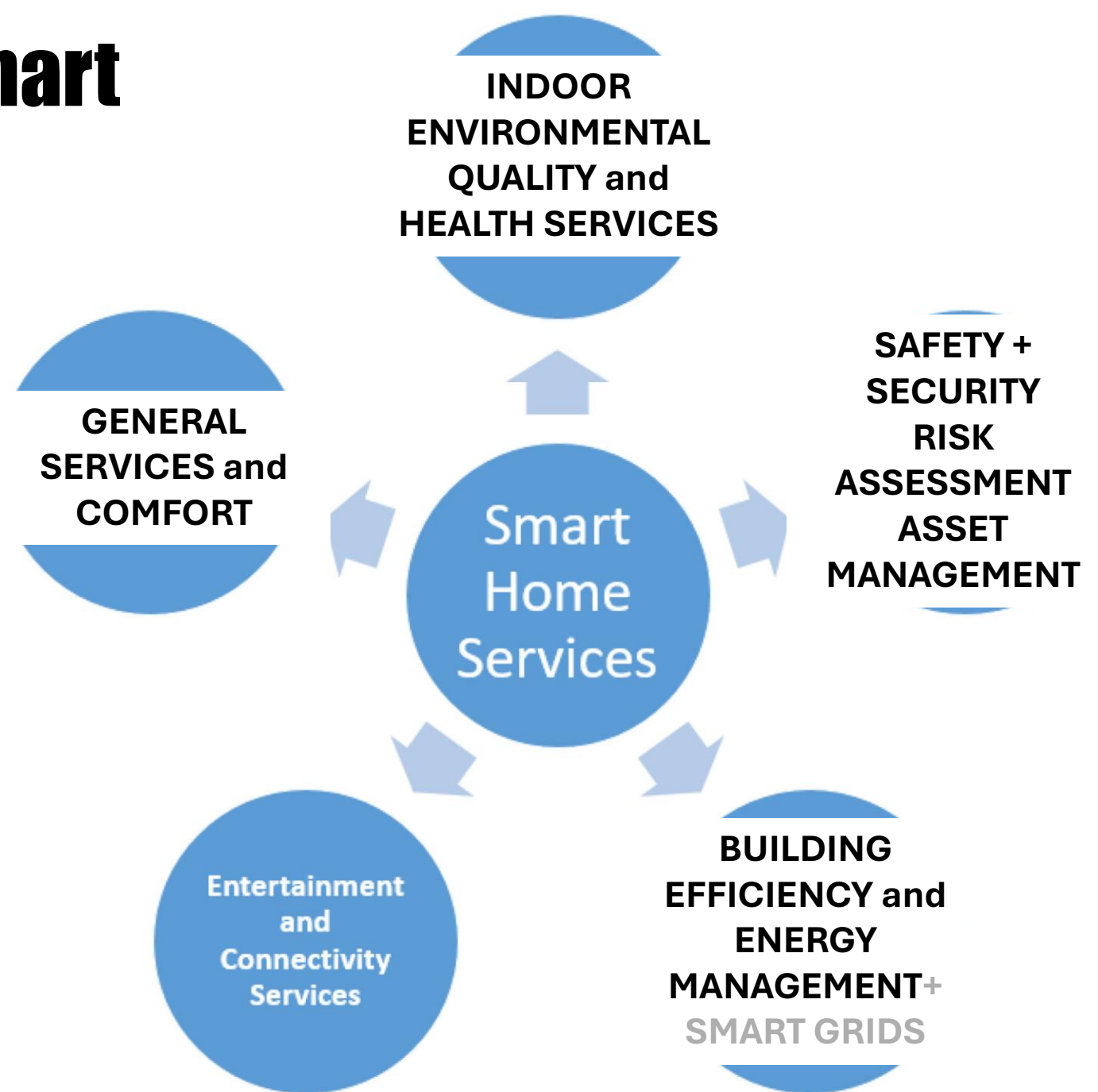
Which is the definition of a Smart Home?

«A home equipped with appliances that can be **controlled remotely** using a device connected to the **internet**»
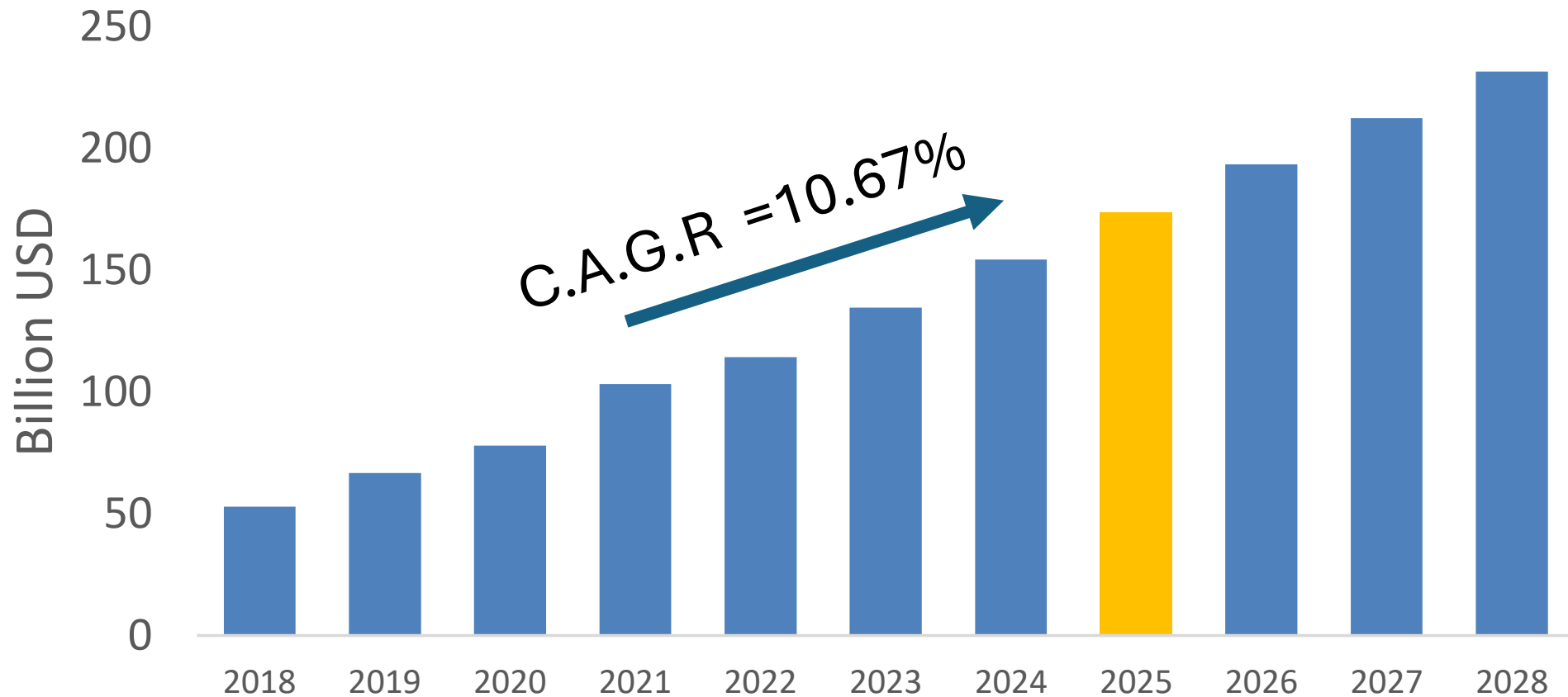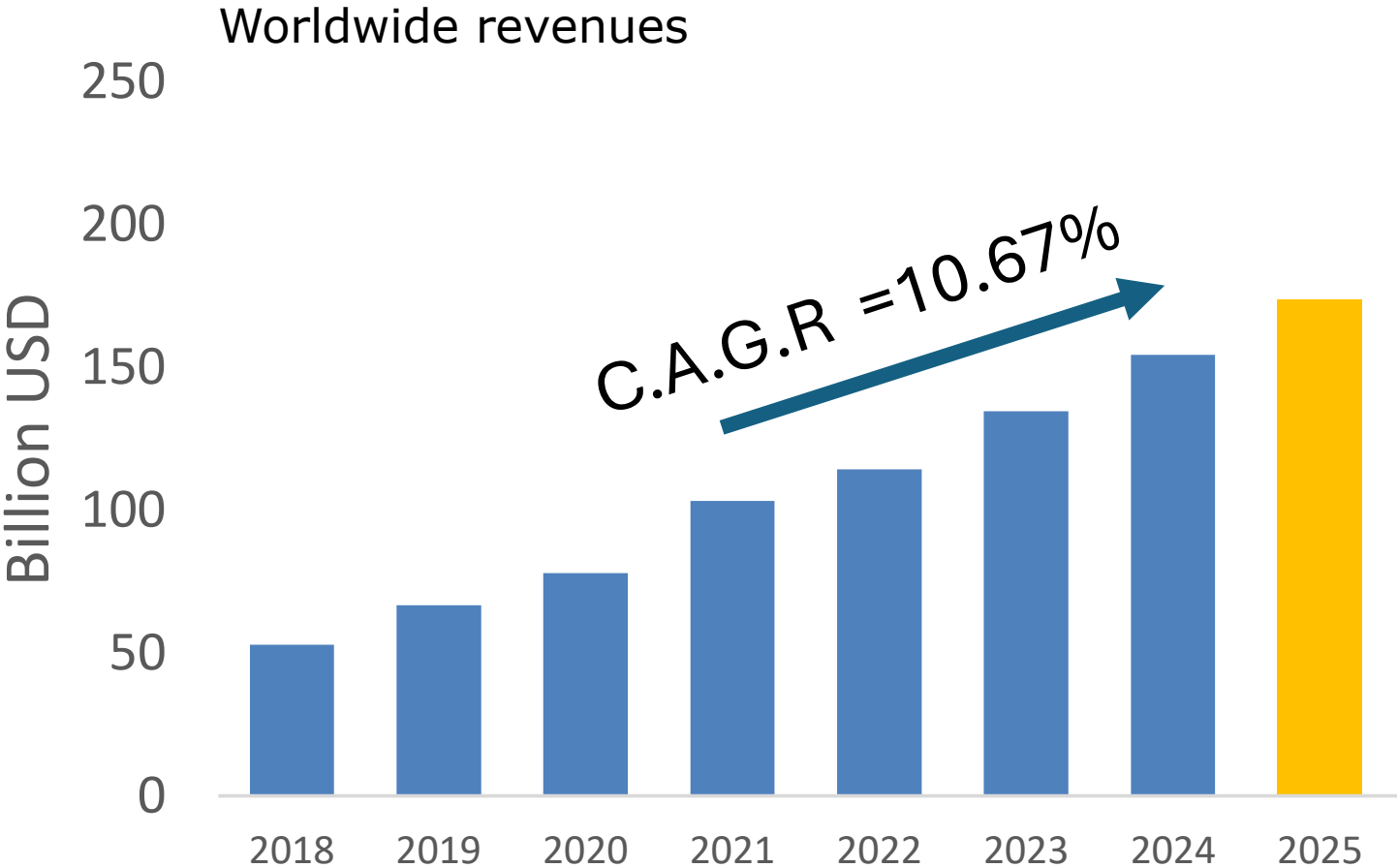
Which are the Main smart home services

Source: Dede G. et Al. Evaluation of end user requirements for Smart Home applications and services based on a decision support system,

Which are the Main smart home services

INDOOR ENVIRONMENTAL QUALITY and HEALTH SERVICES

SAFETY + SECURITY RISK ASSESSMENT ASSET MANAGEMENT

GENERAL SERVICES and COMFORT

Smart Home Services

Entertainment and Connectivity Services

BUILDING EFFICIENCY and ENERGY MANAGEMENT+ SMART GRIDS

THE MARKET

Household penetration will be 18.9% in 2024 and is expected to hit 33.2% by 2028.

*STATISTA 2024

THE MARKET

Worldwide revenues

Billion USD

C.A.G.R =10.67%

2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028

REVENUES SHARE

Energy Management	7%
Comfort & Lighting	9%
Home Entertainment	10%
Security	**15%**
Control & Connectivity	21%
Smart Appliances	38%

Biggest Player Worldwide: USA, China

Biggest Player in Europe: Germany

Household penetration will be 18.9% in 2024 and is expected to hit 33.2% by 2028.

*STATISTA 2024

TRENDS

Connected security systems, smart appliances, and customizable smart lighting. **Focus on home security** and energy savings.

Emphasis on **sustainability and energy efficiency** with smart thermostats, energy monitoring devices, and solar panels. Growing interest in smart solutions for **elderly independent living**.

Driven by urbanization and a growing middle class, with a focus on **convenience and comfort**. Rising demand for smart entertainment systems, robotic vacuums, and smart kitchen appliances.

MAIN COMPONENTS OF A SMART HOME

- Smart locks

- Voice assistants

- Smart security systems

- Smart Thermostats, Lighting, window opening

- Connected appliances
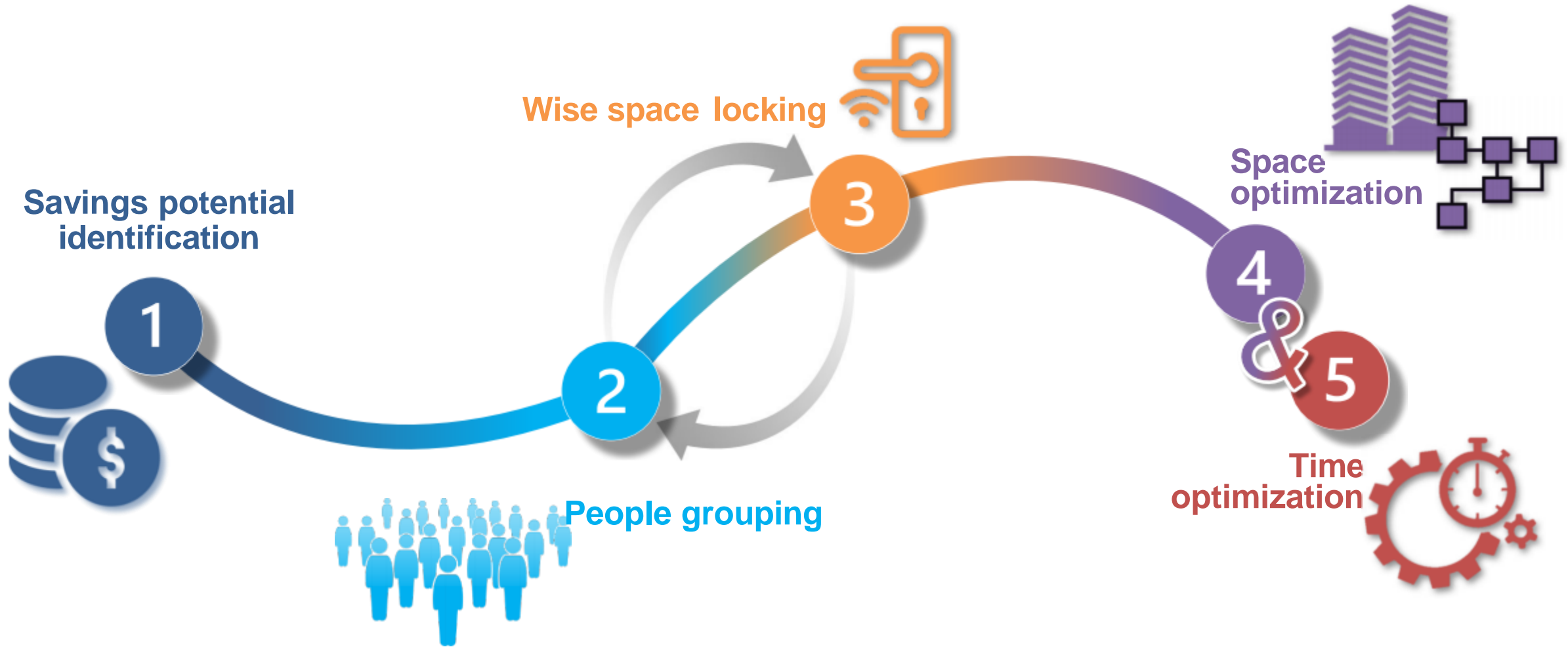
MAIN COMPONENTS OF A SMART HOME

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Smart Home Opportunities

OPPORTUNITIES

- Smart locks

- Voice assistants

- Smart security systems

- Smart Thermostats, Lighting, window opening

- Connected appliances

Remote management via app and AI Driven automation

Natural Language Processing

Facial Recognition and Bio + Real time monitoring and AI driven Predictive security

Machine Learning for energy optimization and data analytics

Real time and remote monitoring – Link with BIM

FROM SMART LOCK TO WISE LOCK

Savings potential identification

Wise space locking

People grouping

Space optimization

Time optimization

1

2

3

4 & 5

OPPORTUNITIES

- Smart locks → Remote management via app and AI Driven automation

- Voice assistants → Natural Language Processing

- Smart security systems → Facial Recognition and Bio + Real time monitoring and AI driven Predictive security

- Smart Thermostats, Lighting, window opening → Machine Learning for energy optimization and data analytics

- Connected appliances → Real time and remote monitoring – Link with BIM

LIVING LAB IEQ DASHBOARD @DABC
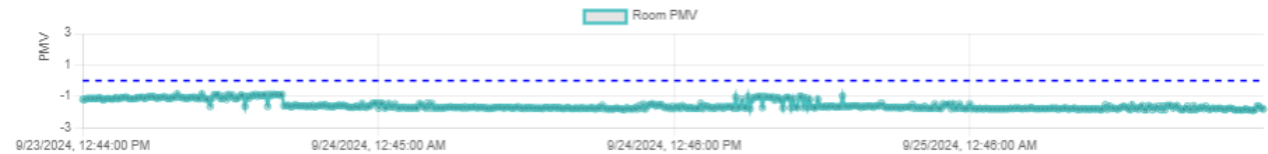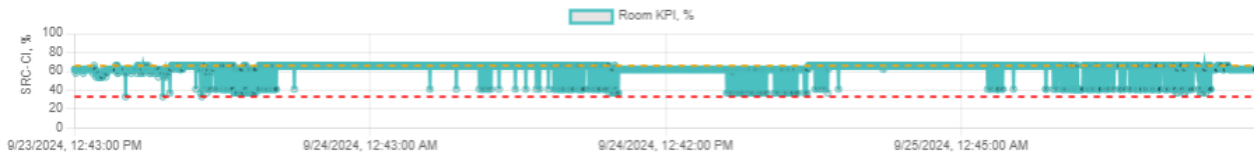
Current Room KPI (SRC-CI): 62% ⓘ
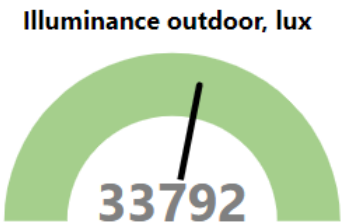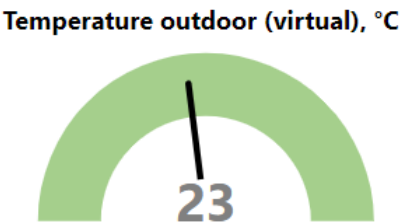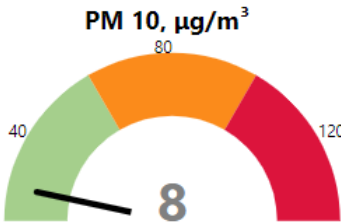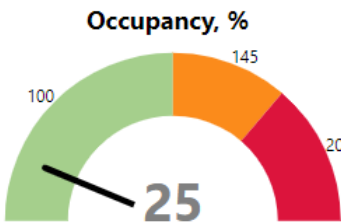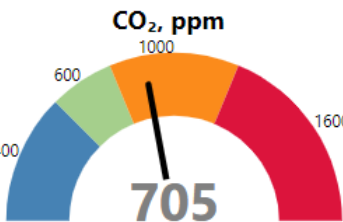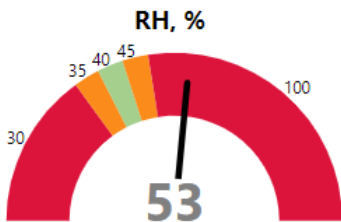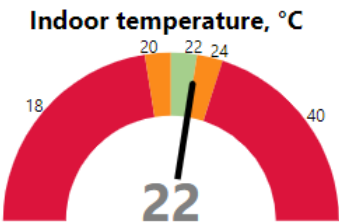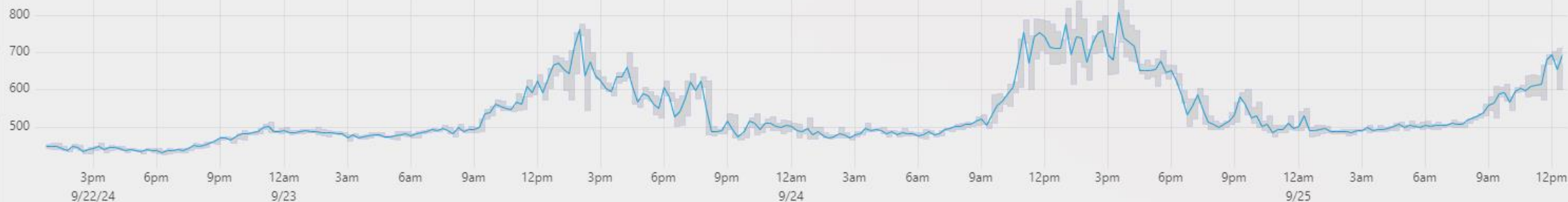
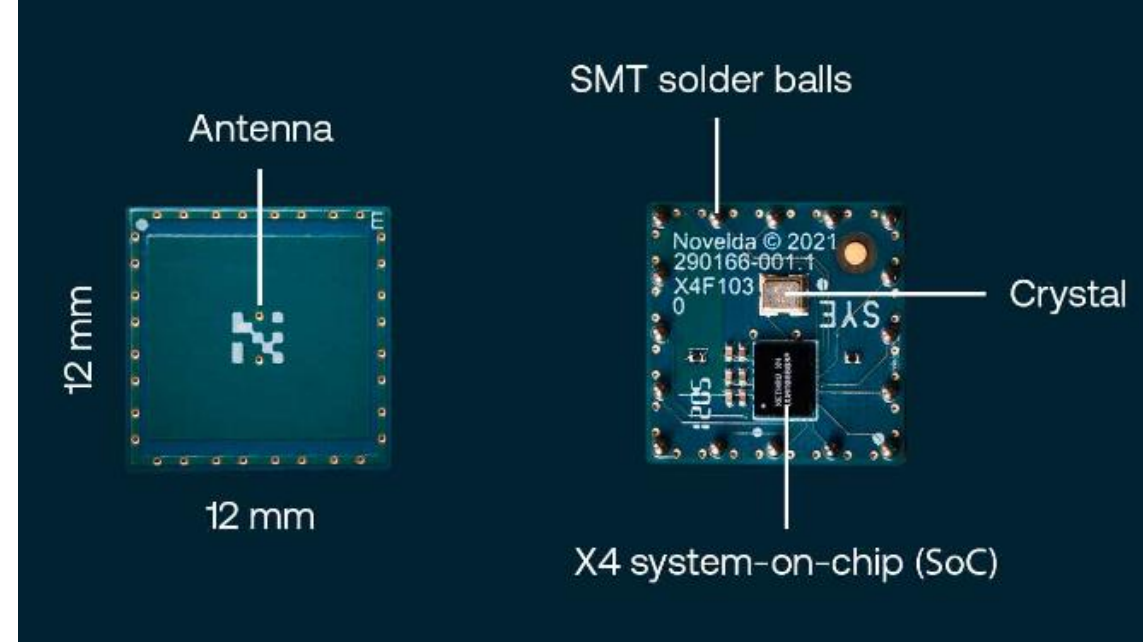©SEEDLAB @DABC @POLIMI

OPPORTUNITIES

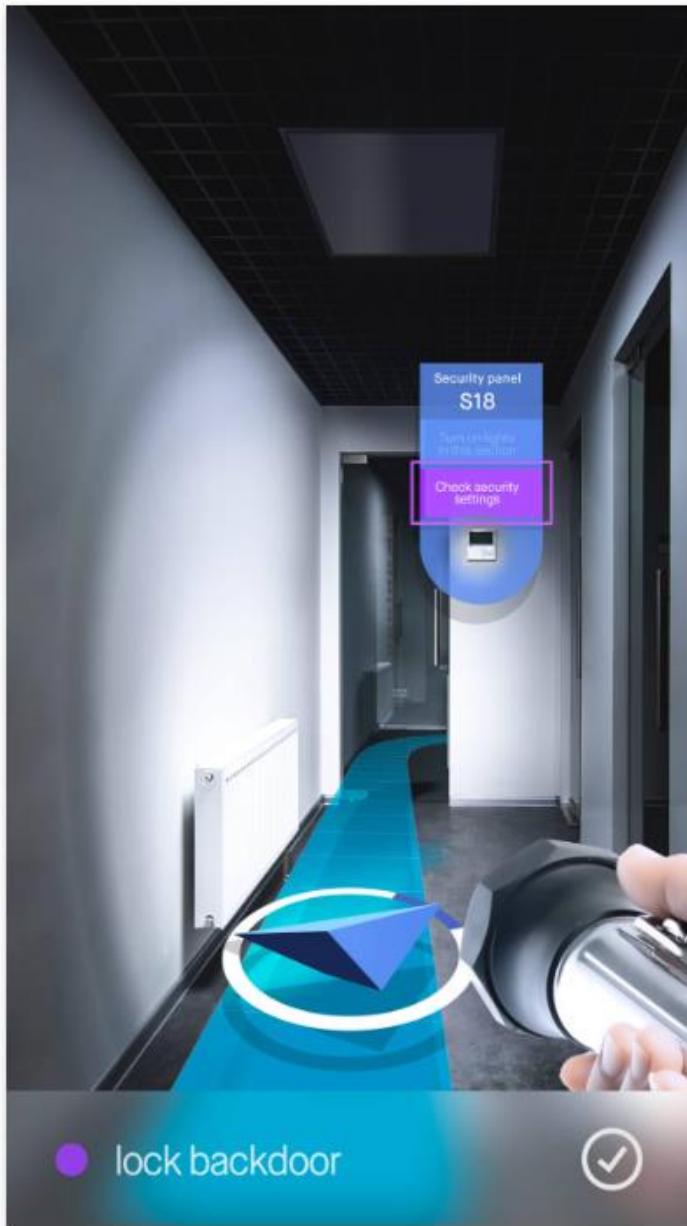https://www.aqara.com/ FP2 Radars Sensor
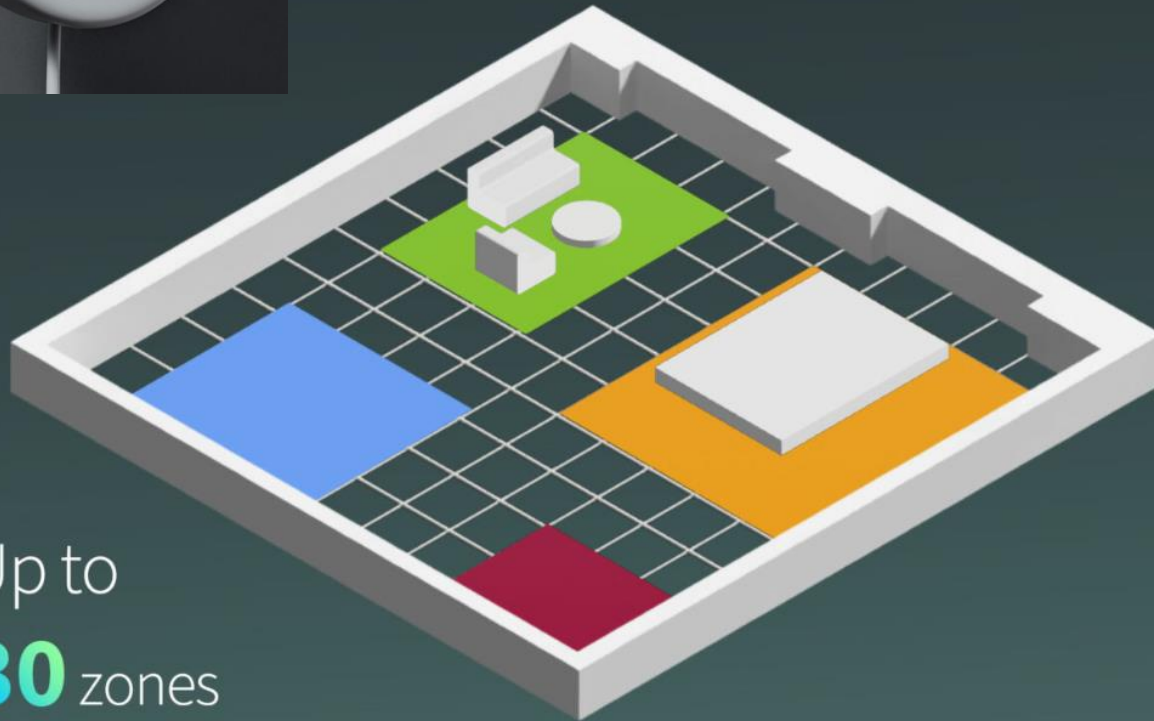
Up to **30** zones
320 cells

NOVELDA UWB Occupancy Sensor – Novelda.com
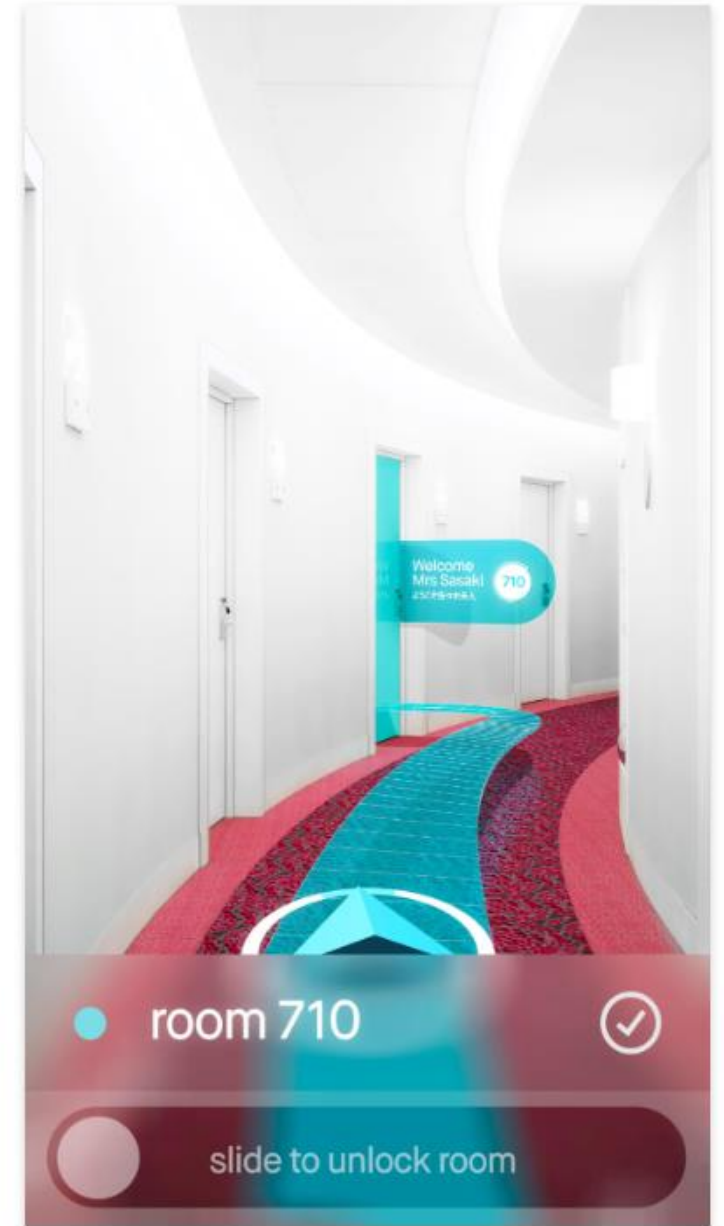Up to 3.5 m radius for detection

- Frequencies: 30-300 GHz (1-10 mm wavelengths).
- High resolution and precision for detailed detection.

Security

Warehouse

Hotel

www.tangar.io

CHALLENGES

Security and vulnerability [cybersecurity -> Passwords updates and SW updates]

Data privacy -> GDPR and compliance

(i.e. personal data and user position)

Cost Benefits and affordable solution

Interfaces and Complexity -> Crossing the chasm

OPPORTUNITIES (and Challenges)

International Journal of Human-Computer Studies

Volume 147, March 2021, 102571

Older adults' perspectives of smart home technology: Are we developing the technology that older people want?

Abir Ghorayeb [1], Rob Comber [2], Rachael Gooberman-Hill [1]

Share of population that are aged 65 years and older in European countries in 2023

European Union average   21.3 %

OPPORTUNITIES (and Challenges)

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ELSEVIER

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Share of population that are aged 65 years and older in European countries in 2023

European Union average   21.3 %

- Gradual adoption & customization
- **User control over Data and Privacy**
- **Non-Intrusive**, aesthetic sensor Design
- Prefer sharing data with Professionals
- **Balance automation with User Interaction**
- Include social and engagement features (gamification)
- Promote indipendence
- **Ensure trust, reliability, and Data Security**

OPPORTUNITIES (and Challenges)

Has set the following key targets for the construction sector by 2030:

- **60% reduction in emissions**

- 14% reduction in final energy

- 18% reduction in energy use for heating and cooling

- **Doubling** of the building renovation (from 1.5 to 3%) **rate.**

OPPORTUNITIES (and Challenges)

European Performance of Building Directive (EPBD) aims to introduce additional constraints regarding new constructions and renovations

"ZERO EMISSION BUILDINGS"

OPPORTUNITIES (and Challenges)

- Reformed Energy Performance Certificates (EPC)

- Defines the concept of Zero emission building

- Introduces the Mandatory Minimum Energy Performance Standards (MEPS)

REVISED EPBD PUBLISHED

European Commission

OPPORTUNITIES (and Challenges)

- Analyses show that **the smartness component is currently only partially considered** in the main sustainability certification mechanisms for buildings.

- This highlights the need to create a dedicated indicator like the **Smart Readiness Indicator**, which is still not widely adopted in Italy and Europe.

[Osservatorio Smart Building Politecnico di Milano]

	SMARTNESS	SOCIAL	ENERGY
LEED	🟡	🟡	🟢
WELL	🔴	🟢	🟡
fitwel	🔴	🟢	🟡
BREEAM	🔴	🟡	🟢
GRESB	🔴	🟡	🟢
EPD	🔴	🔴	🟢

SRI - SMART READINESS INDICATOR

REGULATION (EU) 2020/2155 of 14 October 2020

Purpose: Rates and **communicates** the smart readiness of buildings to stakeholders like planners and operators.

*"Premises 13) The smart readiness indicator should allow to highlight the additional benefits from advanced smart technologies for building owners and users, for instance in terms of energy savings and preparedness to climate change, or in **terms of more inclusiveness and accessibility, comfort and well-being**."*

SRI - SMART READINESS INDICATOR

REGULATION (EU) 2020/2155 of 14 October 2020

Purpose: Rates and **communicates** the smart readiness of buildings to stakeholders like planners and operators.

*"Article 4.1 The methodology for calculating the smart readiness indicator shall be based on the assessment of smart-ready services present or planned at design stage in a building or building unit, and of **smart-ready services that are considered relevant for that building or building unit**."*

SRI

ONE SINGLE SCORE CLASSIFIES THE BUILDING'S SMART READINESS

SRI

	Energy savings and operation		Respond to user needs			Respond to needs of the grid
	Energy savings	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Energy flexibility & storage
Heating			16%	10%	20%	11,4%	
Domestic hot water				10%		11,4%	
Cooling			16%	10%	20%	11,4%	
Controlled ventilation			16%	10%	20%	11,4%	
Lighting			16%	10%	20%		
Electricity				10%		11,4%	
Dynamic Envelope	5%	5%	16%	10%	20%	11,4%	
EV Charging				10%		11,4%	5%
Monitoring & Control	20%	20%	20%	20%		20%	20%

STEP 1:
FIXED WEIGHTS

STEP 2:
EQUAL WEIGHTS

STEP 3:
ENERGY BALANCE WEIGHTS (depend on climate zone)

SRI

SRI

Matrix showing SRI scores by domain and impact criterion, aggregate scores per impact criterion and the overall SRI score

IMPACTS

DOMAINS	Energy efficiency	Maintenance and fault protection	Comfort	Convenience	Health and well-being	Information to occupants	Energy flexibility & storage	SRI
Total	**39%**	**18%**	**60%**	**71%**	**48%**	**59%**	**0%**	**42%**
Heating	32%	18%	62%	55%	24%	74%	0%	
Sanitary hot water	17%	0%	45%	70%	67%	83%	0%	
Cooling	65%	51%	78%	72%	61%	55%	0%	
Controlled ventilation	41%	0%	55%	60%	34%	44%	0%	
Lighting	85%	14%	90%	100%	83%	15%	0%	
Dynamic building envelope	10%	0%	31%	56%	22%	46%	0%	
Electricity	10%	0%	-	-	-	68%	0%	
Electric vehicle charging	_	38%	-	82%	-	84%	0%	
Monitoring and control	52%	43%	62%	72%	45%	64%	0%	

The future of smart Homes

SMART HOME

SMARTNESS e HUMAN IN THE LOOP

From   To

To   From

SMART BUILDING

SMART USER

ADVANTAGES AND DISADVANTAGES

Adaptability: Encourages an _iterative design_ based on user _testing and feedback_.

Innovation: Directly addresses user problems and needs.

Human Touch: _Puts users at the center_, emphasising empathy and understanding of their experiences.

Subjectivity: User preferences may not always align with the overall project goals.

Representativeness: Difficulty in capturing the varied needs of a diverse user population – Baseline definition

Scalability: Scaling the user-centered approach requires robust methodologies and resources.

HUMAN in THE LOOP

AI personal assistants

ANALISYS AND OPTIMIZATION

DATA STORAGE

ENERGY SAVING BEHAVIOURAL MODELs

SYSTEMS

INDOOR

OUTDOOR

- - - SENSE and LEARN
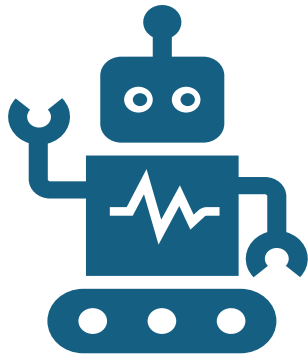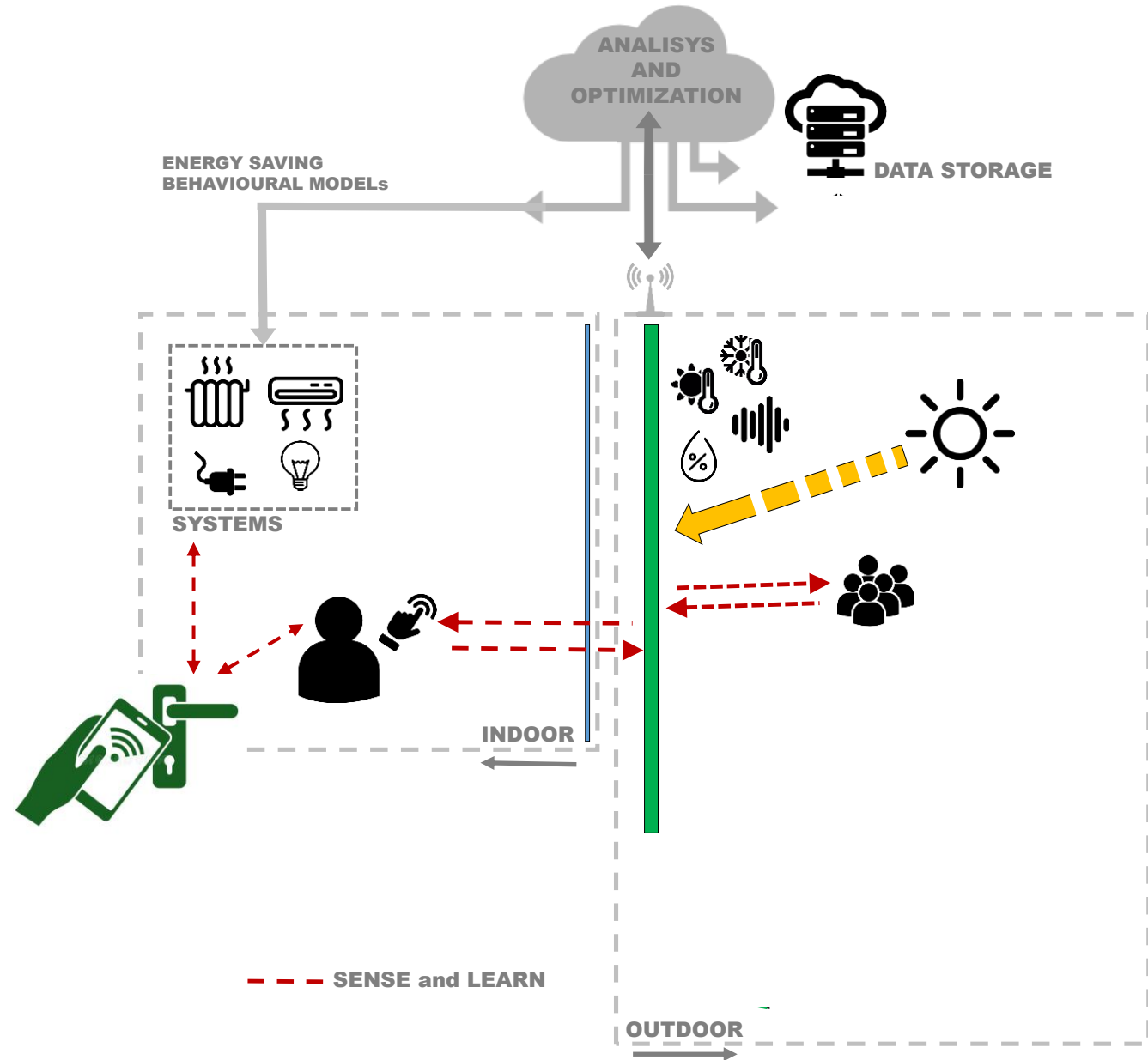
HUMAN in THE LOOP

5G and connectivity

FACT

SWEDISH TELECOM GIANT ERICSSON PREDICTED THAT **5G INTERNET** WILL COVER UP TO **65%** OF THE WORLD'S POPULATION BY THE END OF **2025**.

ANALISYS AND OPTIMIZATION

DATA STORAGE

ENERGY SAVING BEHAVIOURAL MODELs

SYSTEMS

INDOOR

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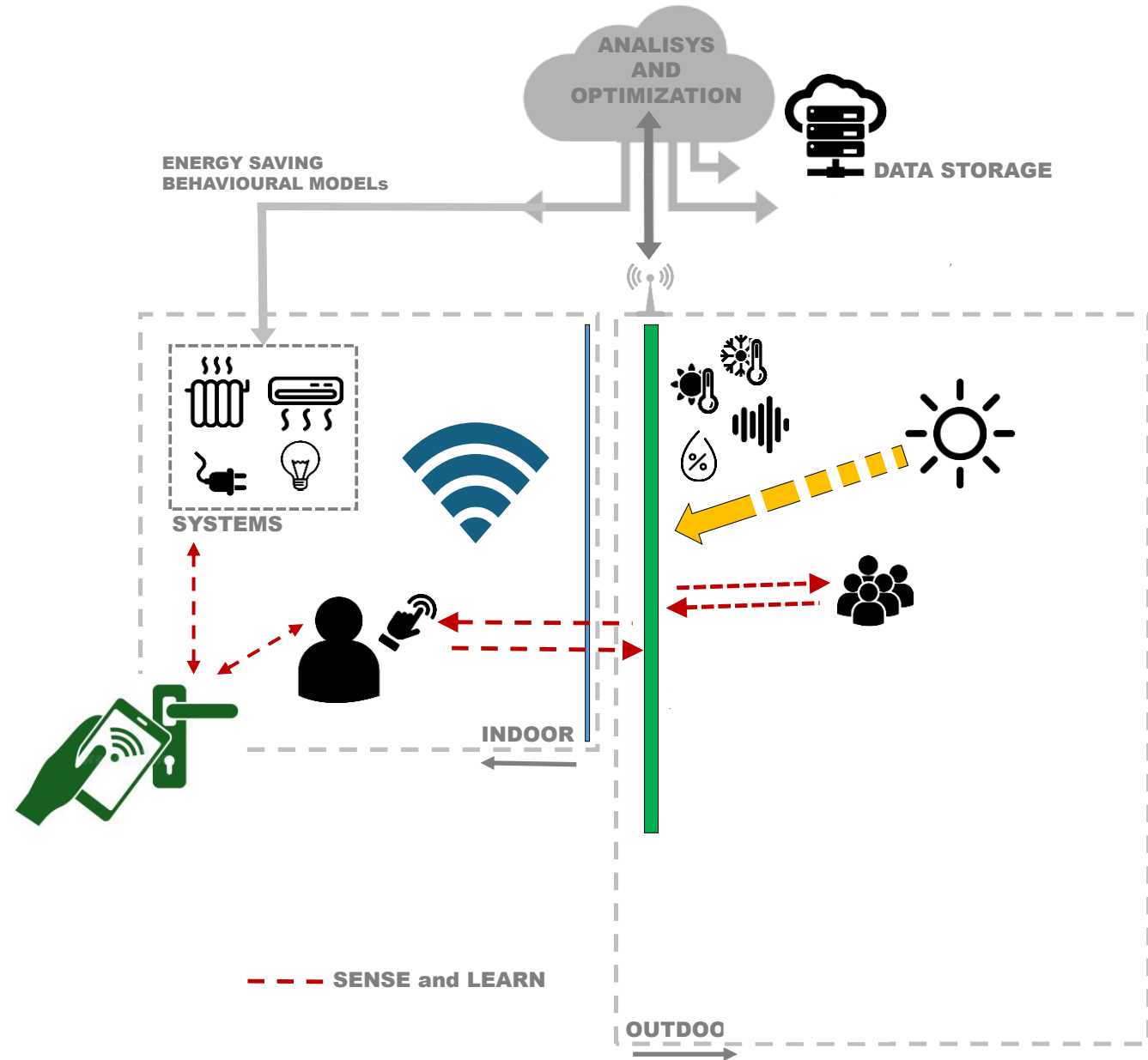
HUMAN in THE LOOP

Smart cities -> Smart homes in a urban smart city

+ Grid and Micro Grid

ANALISYS AND OPTIMIZATION

ENERGY SAVING BEHAVIOURAL MODELs

DATA STORAGE

CITY

SYSTEMS

INDOOR

OUTDOOR

- - - SENSE and LEARN
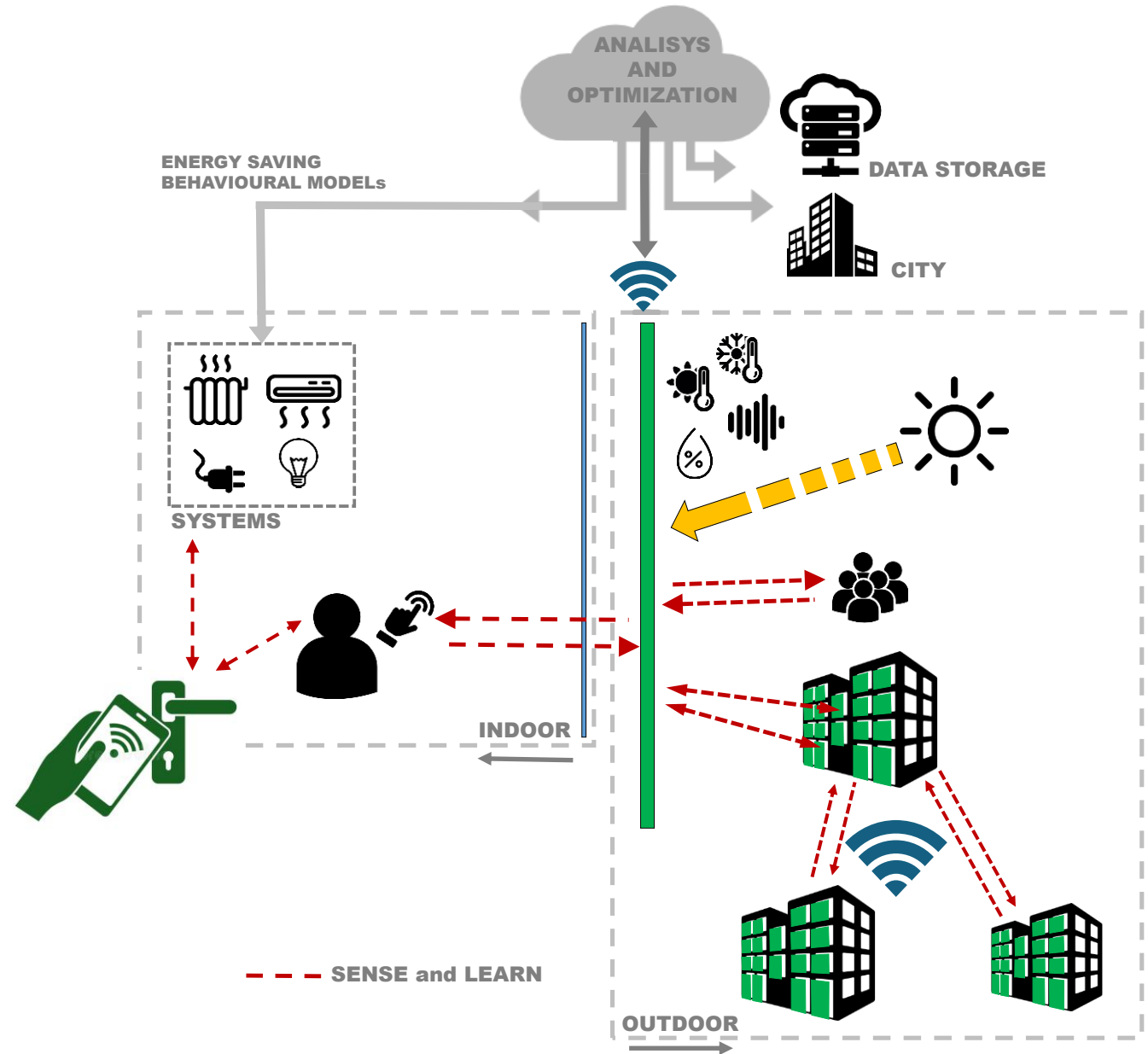
Other Trends

Touchless Tech: Contactless controls reduce germ exposure and increase hygiene.

Health Tech: Smart sensors and purifiers enhance home health and air quality.

High-Speed Connection: Mesh Wi-Fi ensures reliable, whole-home internet coverage.

Home Office: Innovations support remote work with improved focus and connectivity.
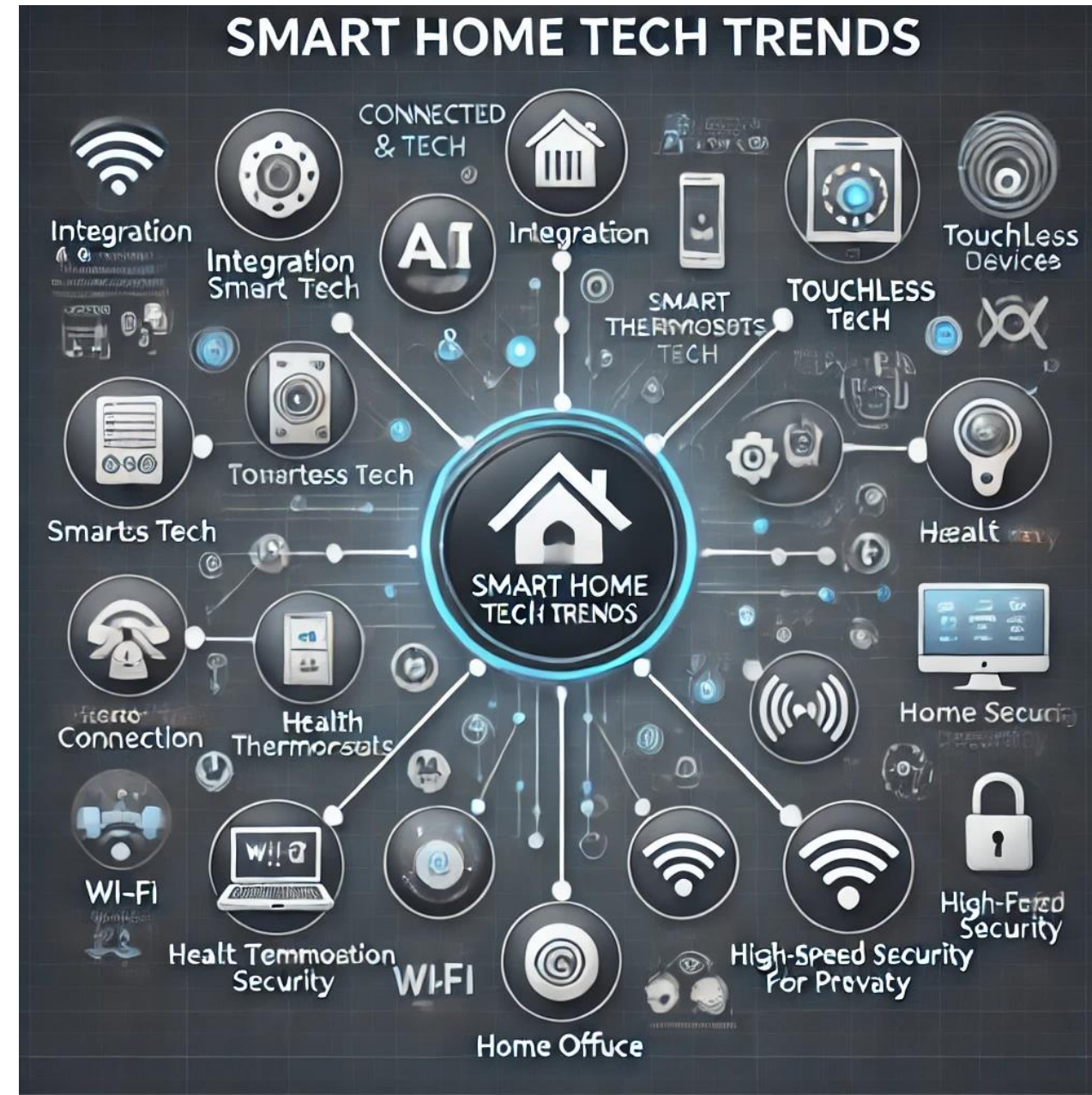
IN ITALY*

- Only **9% of people** in Italy are aware of what a smart building is and are unfamiliar with the potential benefits.
- **Thermostats** are the most recognized smart technology among users.
- **85%** have interacted with at least one smart technology.
- Most interactions were with **stand-alone devices**, not integrated into a structured, system-wide approach.

*Osservatorio smartbuilding Politecnico di Milano
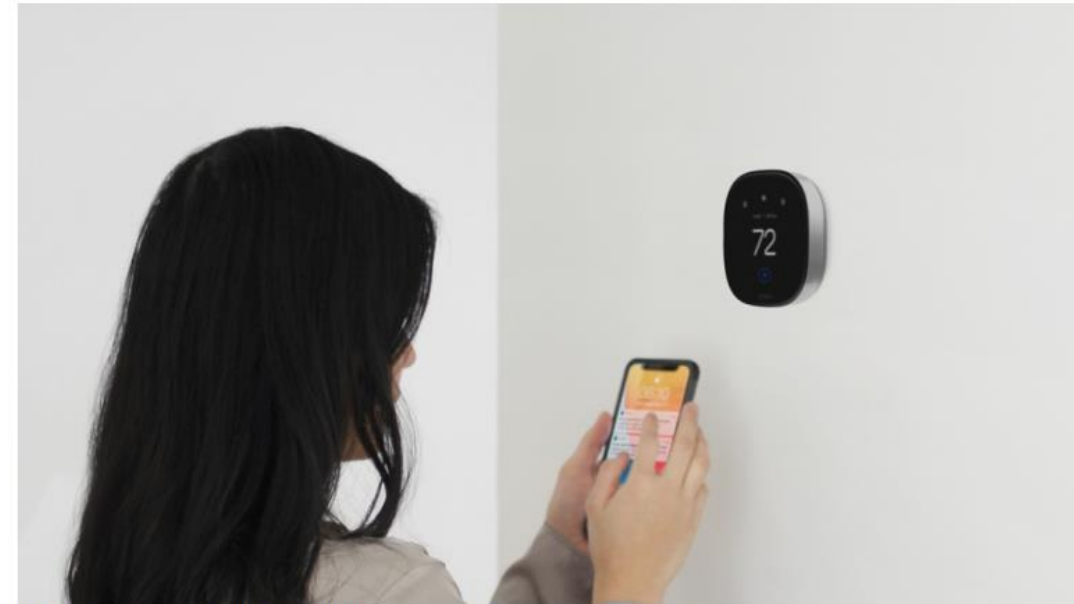
Ecobee Smart Thermostat (Credit: Ecobee)

SimpliSafe Home Security System (Credit: Zlata Ivelva)

TAKE AWAY

- Highlight the **return on investment** and financial benefits of smart home systems.

- Emphasize **simplicity**; benefits should be clear and immediately understandable to users.

- Smart home users prioritize **privacy, trust, usability**, and overall utility of the systems.

- Customers value convenience, efficiency, and connectivity through **automation, security, and energy-saving technologies**.

- Explore the integration of emerging technologies like microcontrollers, **5G, and AI** to enhance smart home capabilities.

- Potential growth in developing systems to aid and support **elderly** residents, addressing safety and independence.

- Stay updated with **new regulations** on energy efficiency, which drive the adoption of smarter, more sustainable technologies.

THANK YOU!

Prof. Andrea Giovanni Mainini

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Architecture, Built environment and Construction engineering Department - Politecnico di Milano

LinkedIN:AgMainini

ADD ME TO YOUR CONTACTS

DISCUSSION: THE SMART HOME MARKET ON THE EUROPEAN CONTINENT HAS BEEN DEVELOPING SIGNIFICANTLY SLOWER COMPARED WITH USA AND UK. WHY?*

Regulatory Hurdles

Strict Data Privacy Laws

General Data Protection Regulation (**GDPR**)

Diverse Certification Requirements

Varying standards across countries

Legal Barriers

Complex compliance processes

*A tentative scheme

DISCUSSION: THE SMART HOME MARKET ON THE EUROPEAN CONTINENT HAS BEEN DEVELOPING SIGNIFICANTLY SLOWER COMPARED WITH USA AND UK. WHY?*

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EU DATA ACT

An european strategy for data usage

The added value is in the data

---

*A tentative scheme

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EU DATA ACT
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The added value is in the data

Market Fragmentation

Multiple Countries

Different **languages**, **cultures**, **regulations**

Challenges in Unified Strategy

Complicates **marketing** and **sales**

Need for **multilingual support** Increased development costs and **complexity**

*A tentative scheme

DISCUSSION: THE SMART HOME MARKET ON THE EUROPEAN CONTINENT HAS BEEN DEVELOPING SIGNIFICANTLY SLOWER COMPARED WITH USA AND UK. WHY? *

Cultural attitudes toward privacy

Higher concern for **privacy** and **data security**

Skepticism toward data-collecting devices

Economic disparities

Variations in **disposable income**

Limited investment in **non-essential technologies**

*A tentative scheme

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Infrastructure "inconsistencies"

Variability in **broadband availability???**

*A tentative scheme