Digital Twins @ the Edge: sustainable technologies for global sustainability

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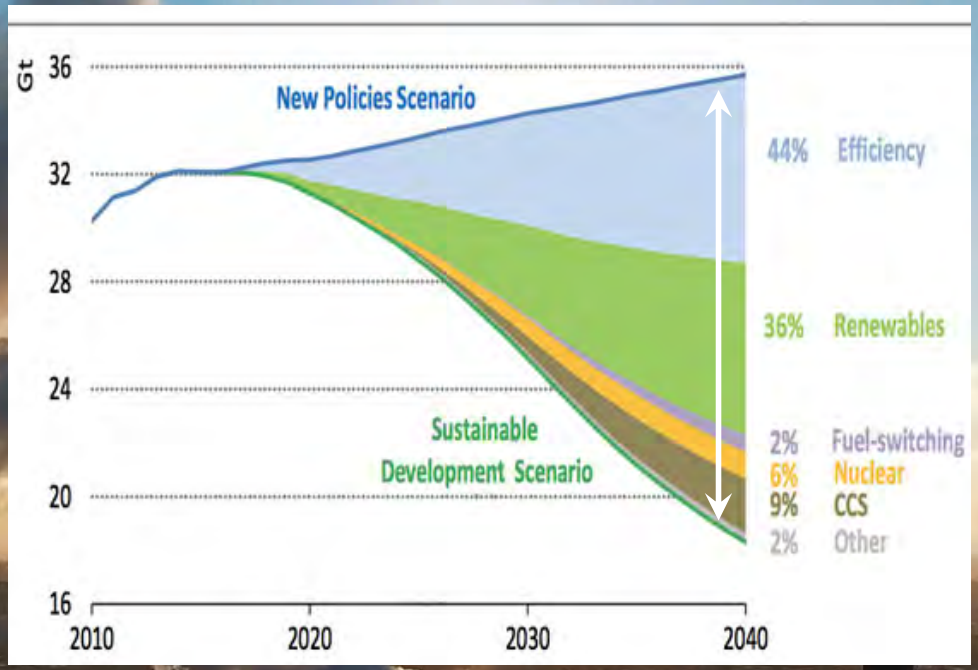
Outline

- Gaps to sustainability
- Emerging technologies for sustainability
  - ❑ Internet of Things: Edge
  - ❑ Digital Twins: Edge-to-Cloud
    - ➢ Digital twins of systems-of-systems: examples and merits
- Perspective

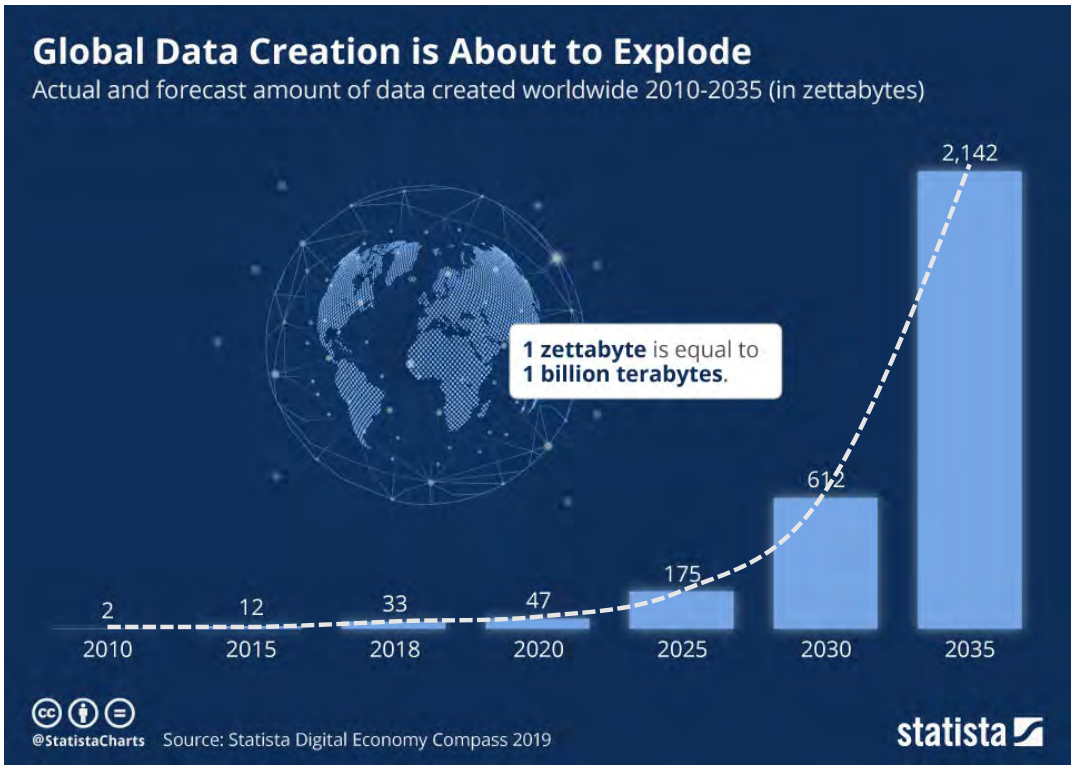
There is an **enormous gap** between **what we need to do** and what we're **actually doing** to prevent dangerous levels of climate change.



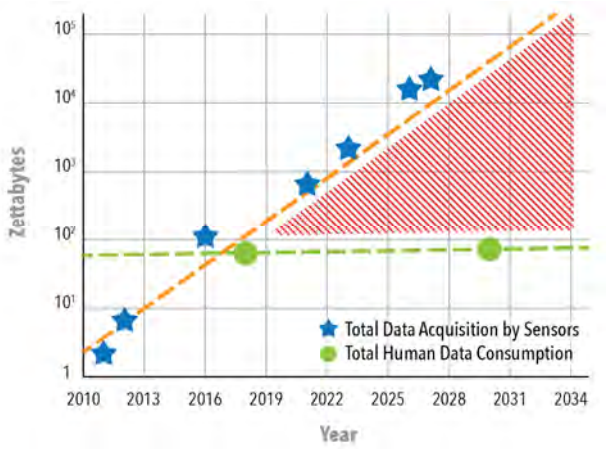
2018 **#EmissionsGap** Report

UN environment

Gap: energy crisis in the Zettabyte and IoT Era



Global Data via IoT Sensors



+ 1 trillion IoT devices by 2035
with annual growth >20% (© ARM)

A sustainable IoT for sustainable applications…

- Technology and environmental sustainability: **mutually exclusive?** Until now digital innovation and sustainability have been disconnected.
- Today's advancements in IoT sensor technologies and wireless connectivity, two concepts of digital innovation and sustainability: **mutually reinforcing**.

→ **pivot to (i) more energy-efficient practices, (ii) use resources more responsibly and (iii) organize processes in ways that reduce waste.**

Sustainable IoT deployment

I. **Massive reduction** of IoT sensory node **power** by ~1000x

II. **Massive reduction** in **data** proliferation

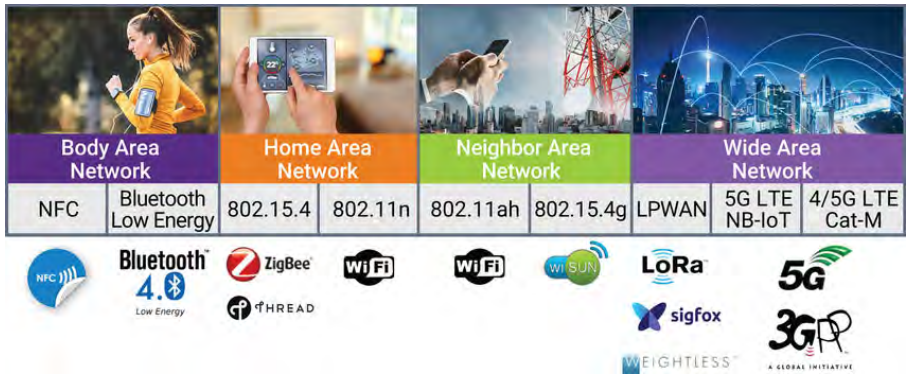
BOTH possible?!

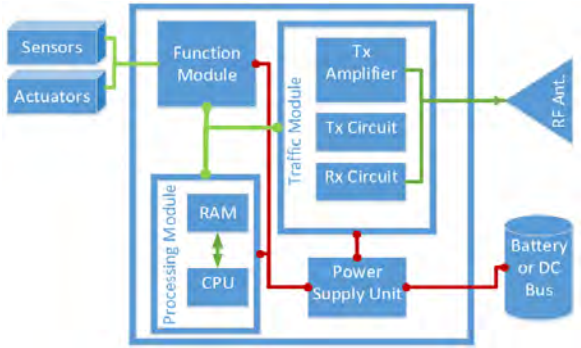
Incremental reduction of IoT sensory node power with traditional technologies

Industrial IoT node size and power consumption: mm^3 to cm^3 with 100's uW to 10's mW.

Silicon = only solution for all IoT Node Devices?

- Sensing
- Processing
- Communications



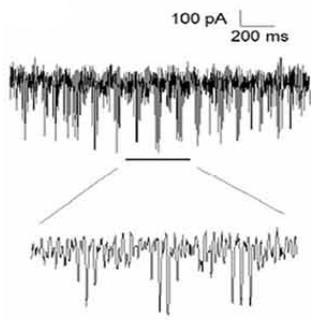


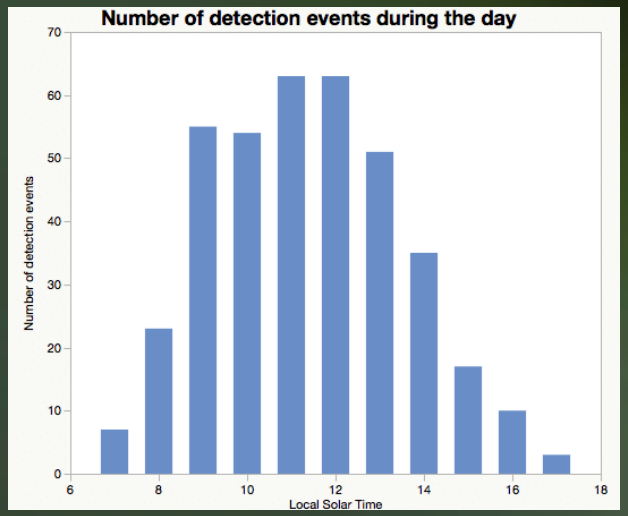
Energy problems @ node level:

- **No digital data reduction**
- **Expensive ADC and digital processing**
- **Expensive data communication**

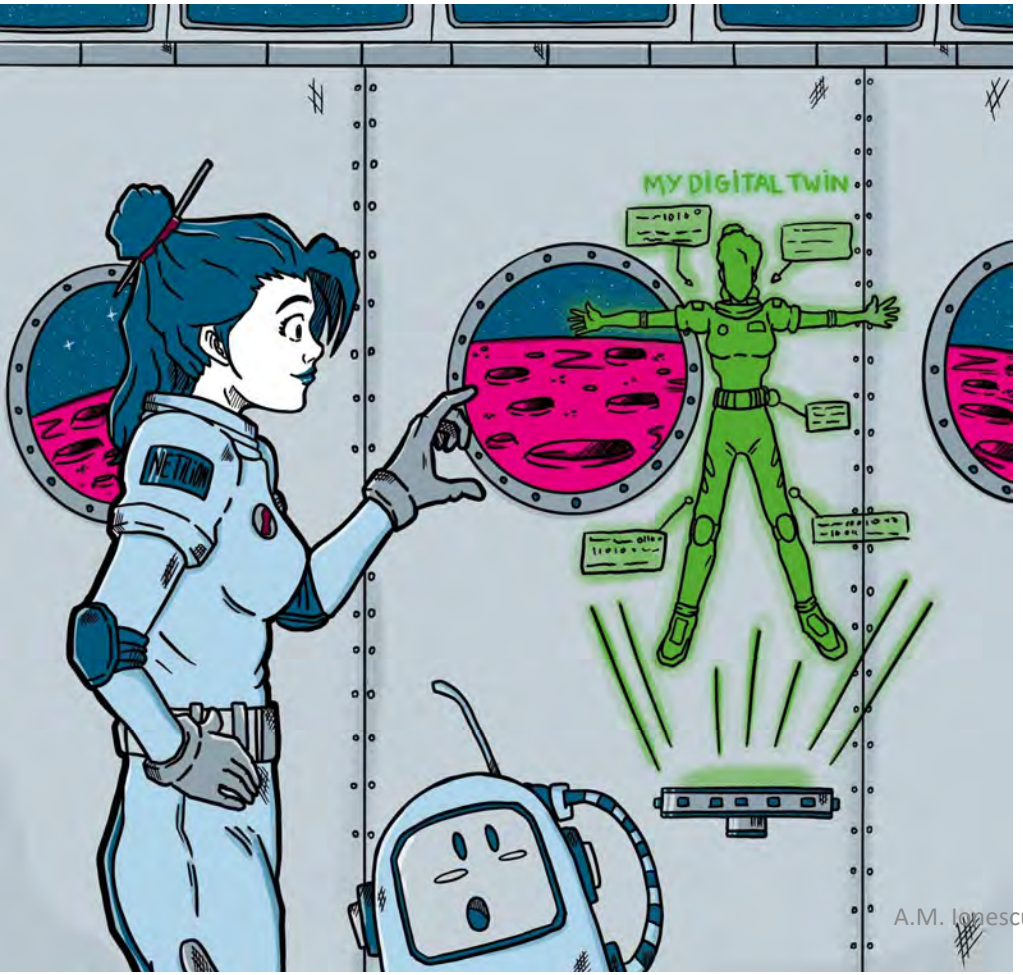
Massive reduction in IoT data proliferation

- **Paradigm change: bio-inspiration on the Edge**
- no digital, no ADC → time-domain **spikes**
- no sensed bits transmitted → **event/tasks**





Digital Twins as mainstream technology for digitalisation

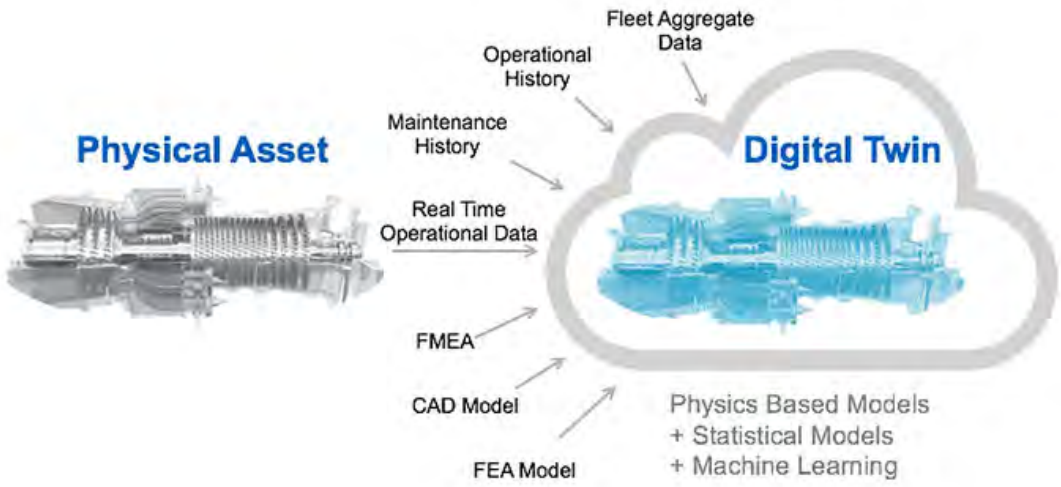


- **digital replica** of an object or a process in the physical world…

One source of truth…

Three main purposes to implement a DT:

- A **PRODUCT Digital Twin** – to guarantee reliable design in product development and improvements.
- A **PRODUCTION Digital Twin** – to improve production planning and manufacturing.
- A **PERFORMANCE Digital Twin** – to capture, analyse and act on data while an asset is in operation.



Key components:

- **MODEL**
- **TIME SERIES DATA**
- **UNIQUE IDENTIFIER**
- **MONITORING CAPABILITY**

Expected benefits

- Enhances **efficiency and productivity**:
  - ❑ Using digital twins, businesses no longer need to fully experiment with physical objects to improve processes.
  - ❑ Don't need to halt ongoing processes and can simply run simulations in the lab to understand the risks and benefits
- Reduces product **quality** issues:
  - ❑ Digital twins simulate different "what-if" real-world scenarios
- Lowers **maintenance** costs:
  - ❑ Digital twins predict maintenance failures via simulation models that capture information about various risk factors
  - ❑ They save costs, improve equipment reliability, reduce downtime, and extend the equipment life span.
- Improves employee **training**:
  - ❑ Employees can be also trained to handle equipment that isn't physically close or is too costly to be given hands-on training.
  - ❑ Digital twins can recreate real-life hazardous situations to train employees.

- **What about Digital Twins and Sustainability?**

Can Digital Twins Transform Cities Environment in a more Sustainable way?

- **City = A complex case of systems-of-systems, the DT needs to incorporate the data from the physical twin in real time to model real-world processes.**
- Recent developments in sensors, wireless communications, and processors enabled Smart Cities Digital Twins.

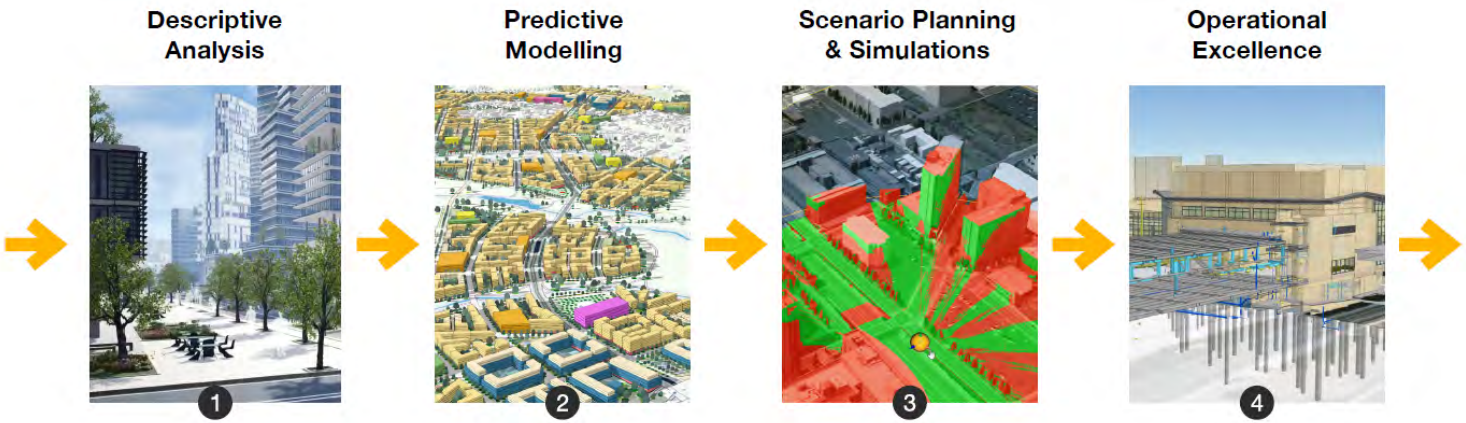
How digital twins can make smart cities better

Monitoring of multiple physical assets

- The smart city a digital twin continuously collects information from the built environment: sensors, drones and mobile devices for **up-to-the-second picture.**
- An urban digital twin will be receiving data from sources including vehicles, buildings, infrastructure and individuals. Key: data captured by smart city **Internet of Things (IoT) and additionally augmented by the use of artificial intelligence (AI).**

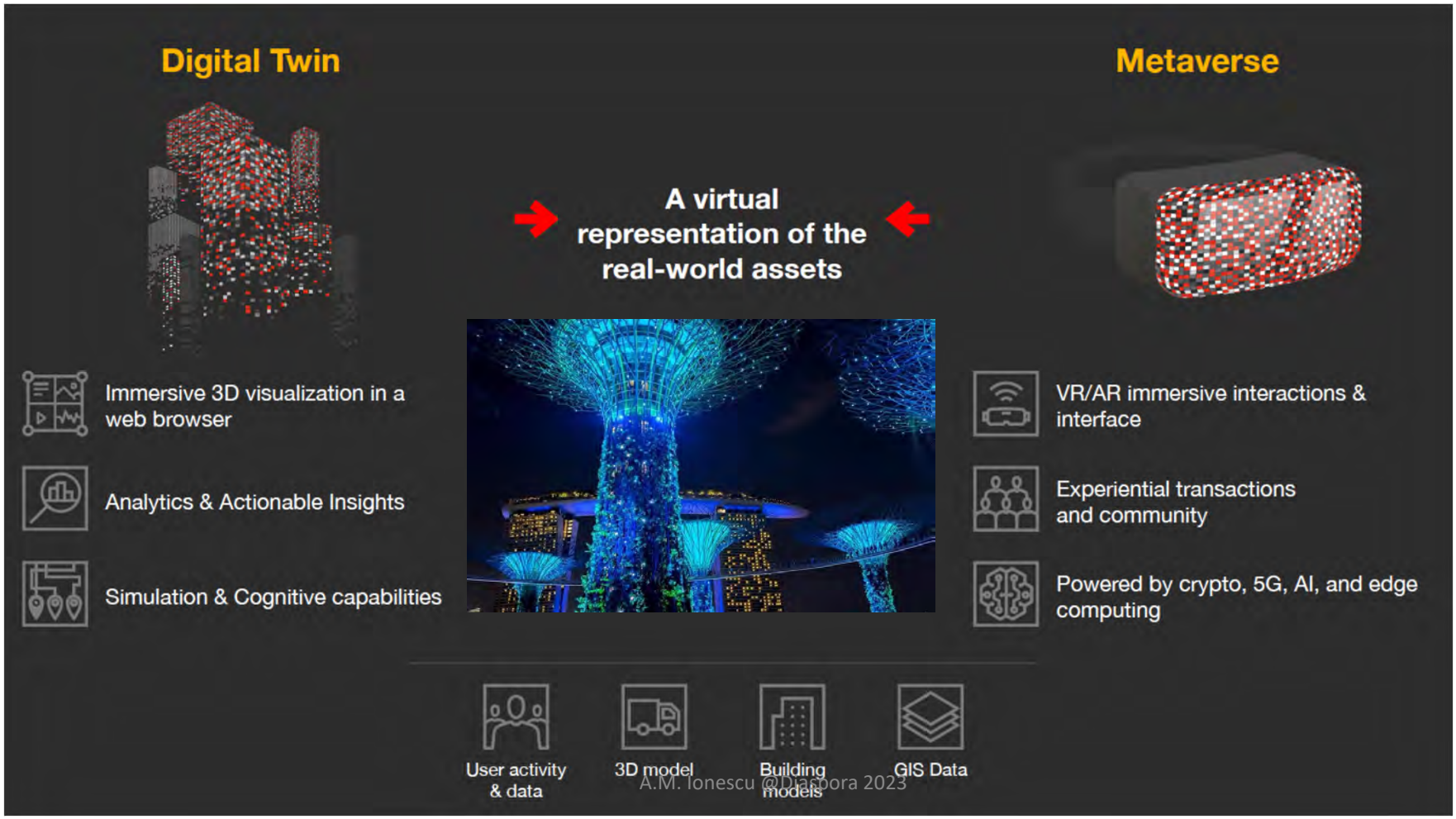
Strategy accelerator

- The digital twin is **a "strategy accelerator" that** enables public sector organisations to identify insights and connections more effectively, and **drives better solutions with more confidence**.
- **Examples**: Cities including Singapore, Sydney and Amaravati, are already using digital twins to enable smart development.



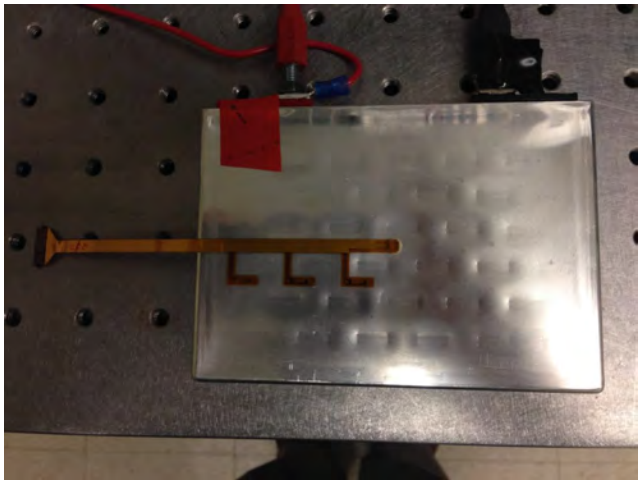
Source: PWC.

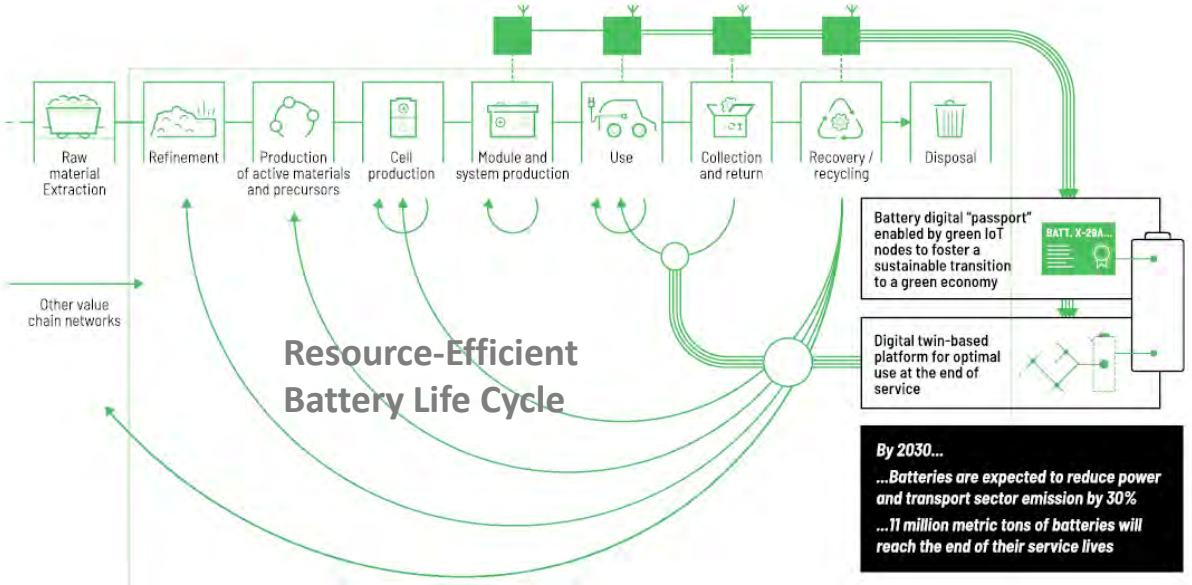
Digital twins and the metaverse for smart cities



Digital twins of smart batteries

- https://www.ge.com/news/reports/scientists-built-a-digital-twin-of-a-car-battery-to-make-it-last-longer
- shrink the battery size, shave production expenses by 15%, all while maintaining long-term reliability and life.



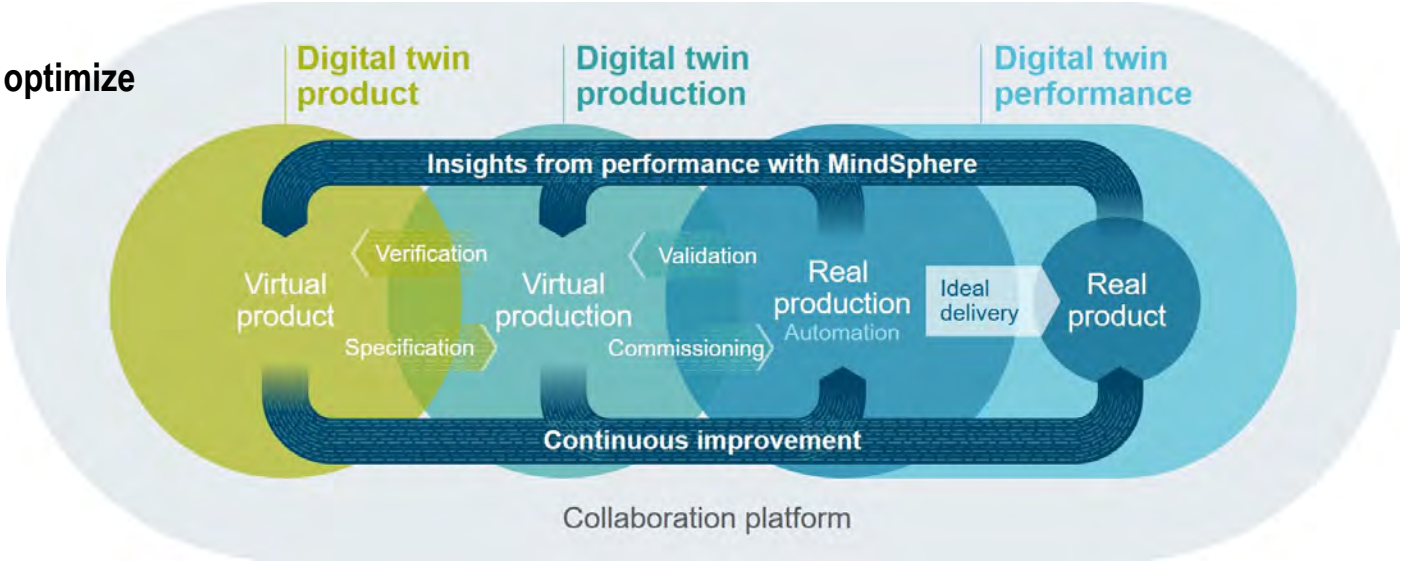


Digital twins of performance

Siemens manufacturers implement the **in conjunction with IIoT** to eliminate the unknowns and make near real-time production optimization decisions.

The **performance twin** involves capturing and sending back live performance data of the production line and of product itself, at a customer location. This **near real-time data** allows engineers to determine if the production line and product behave as they were intended. If not, this information will quickly drive **actionable insights** and informed decision making back into the product and production line design.

Closing the loop to optimize decision making



Digital Twins of All Humans

- Reactive healthcare is unsustainable
- Digital twins will apply to people too
- Towards a more sustainable Personalized, Preventive and Participatory (P3) Healthcare

The missing link…

… for breaking barriers between Medical Knowledge Creation and Medical Knowledge Application

… for creating the triangle Citizen – Human Avatar – Clinical Professional

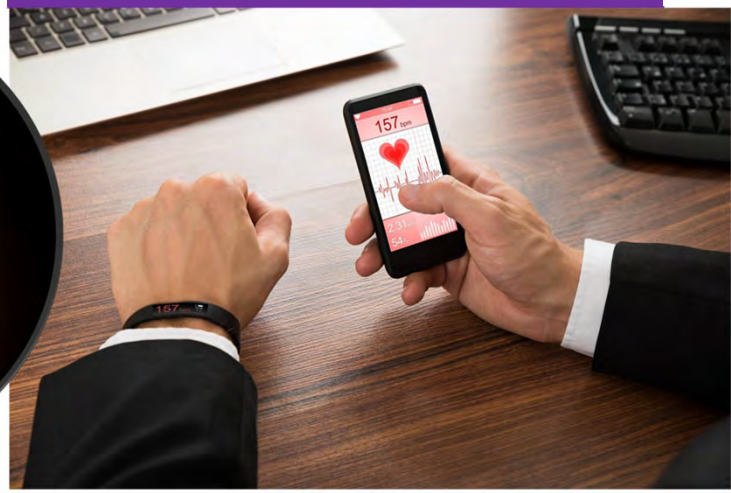
… for a sustainable healthcare in 21st Century

Re-thinking the future of P3 healthcare with DT

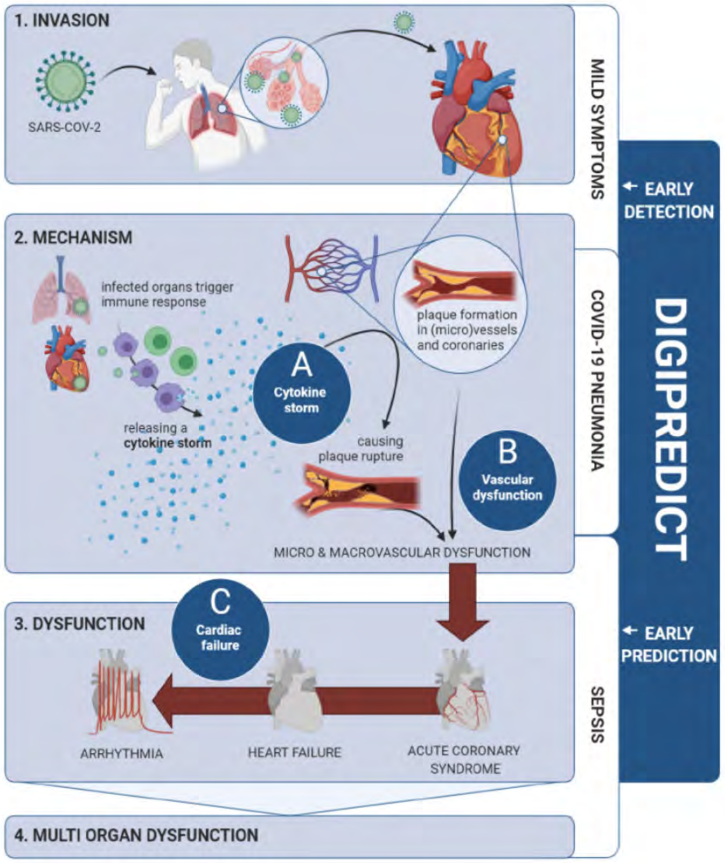
- What's the real opportunity for future Digital Twins in P3 healthcare?

The value of being sick

The value of NOT being sick = healthy?

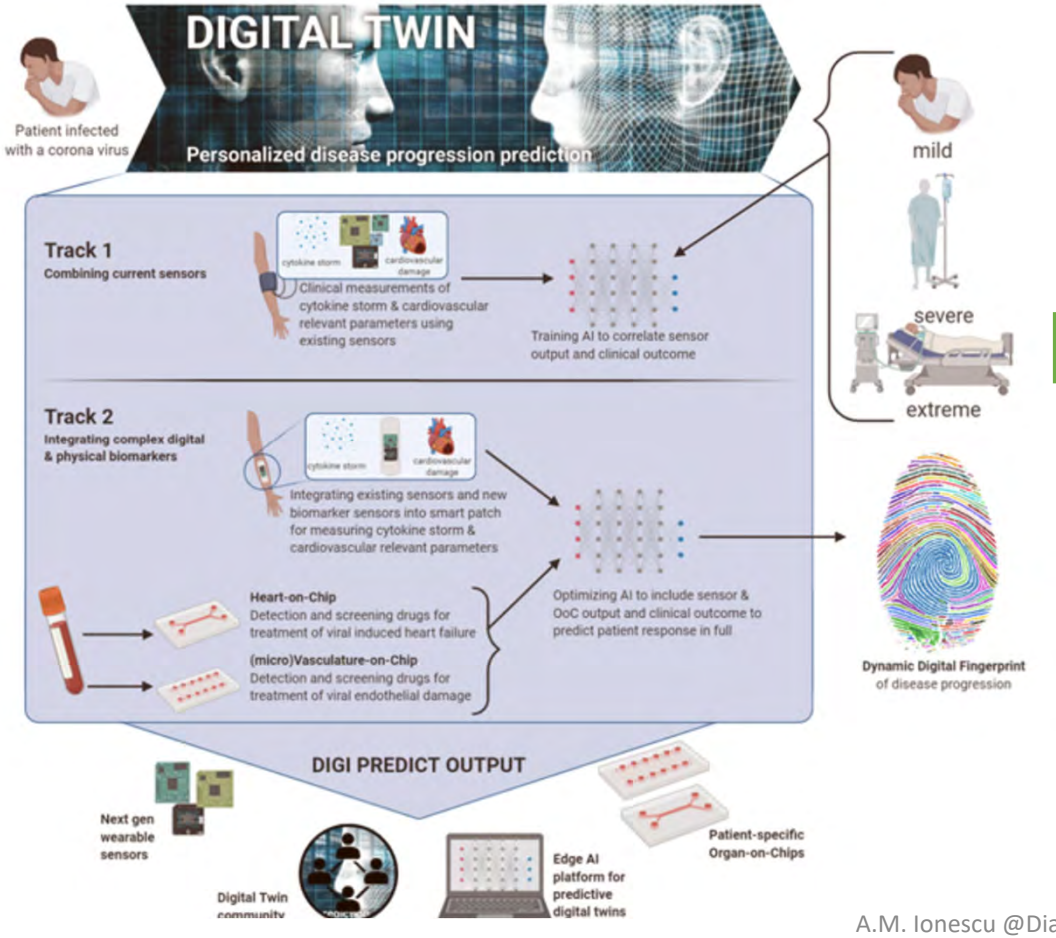


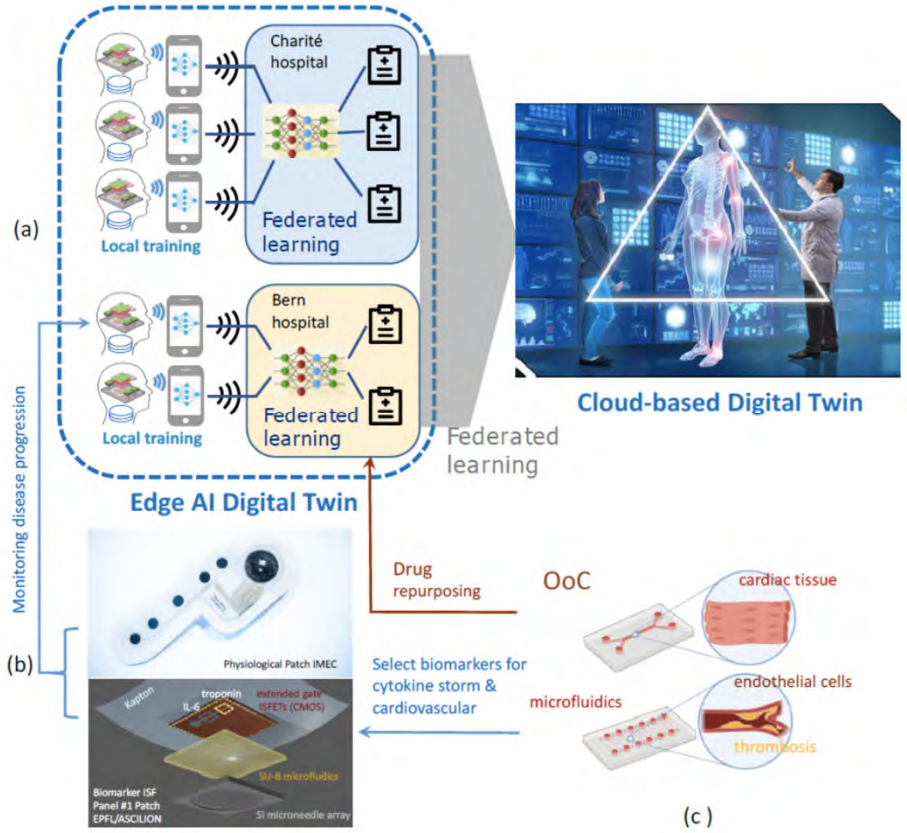
DIGIPREDICT FET Proactive: Digital Twins @ the Edge



- **Early detection**: High risk COVID-19 patients can be early identified from **Digital Fingerprints**
- **Personalized therapy**: Supportive therapy and referral decisions can be personalized to patients with highest need.
- **A new Digital Twin tool for P3 Healthcare**: empowers citizens and medical doctors with a new assistive and predictive healtcare tool.
- Build a **Digital Twin community** in Europe.

The DIGIPREDICT concept

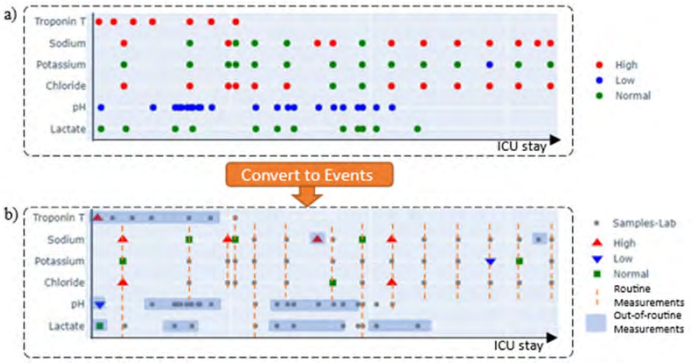




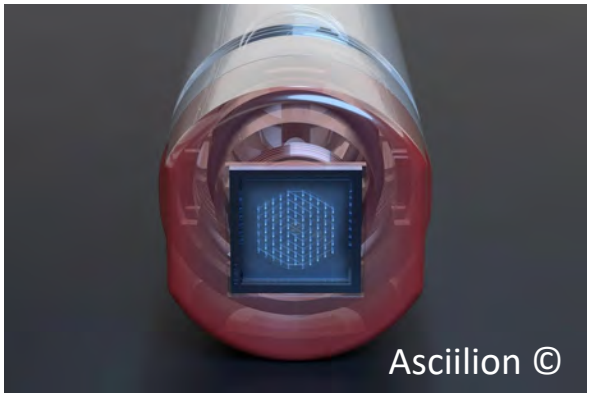
DIGIPREDICT biomarker smart patch

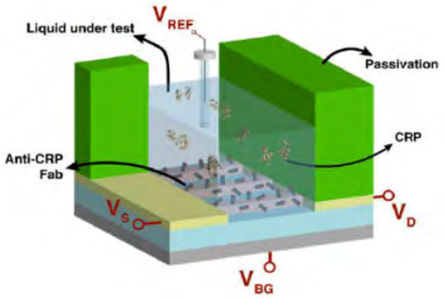
Develop **sensors co-integrated with MEMS needle arrays for collecting ISF and detecting biomarkers** for cytokine storm :

- Multimodal sensing: inflammation proteins
- Dynamics of change/monitoring
- Near real-time monitoring
- Wirelessly connected
- ML algorithm & visualisation interface

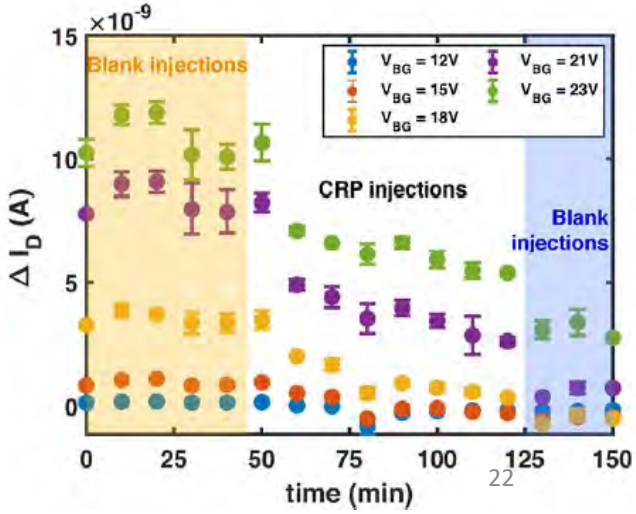


CRP detection: EPFL + CEA-LETI + Xsensio SA





L. Capua et al., IEDM, 2021.

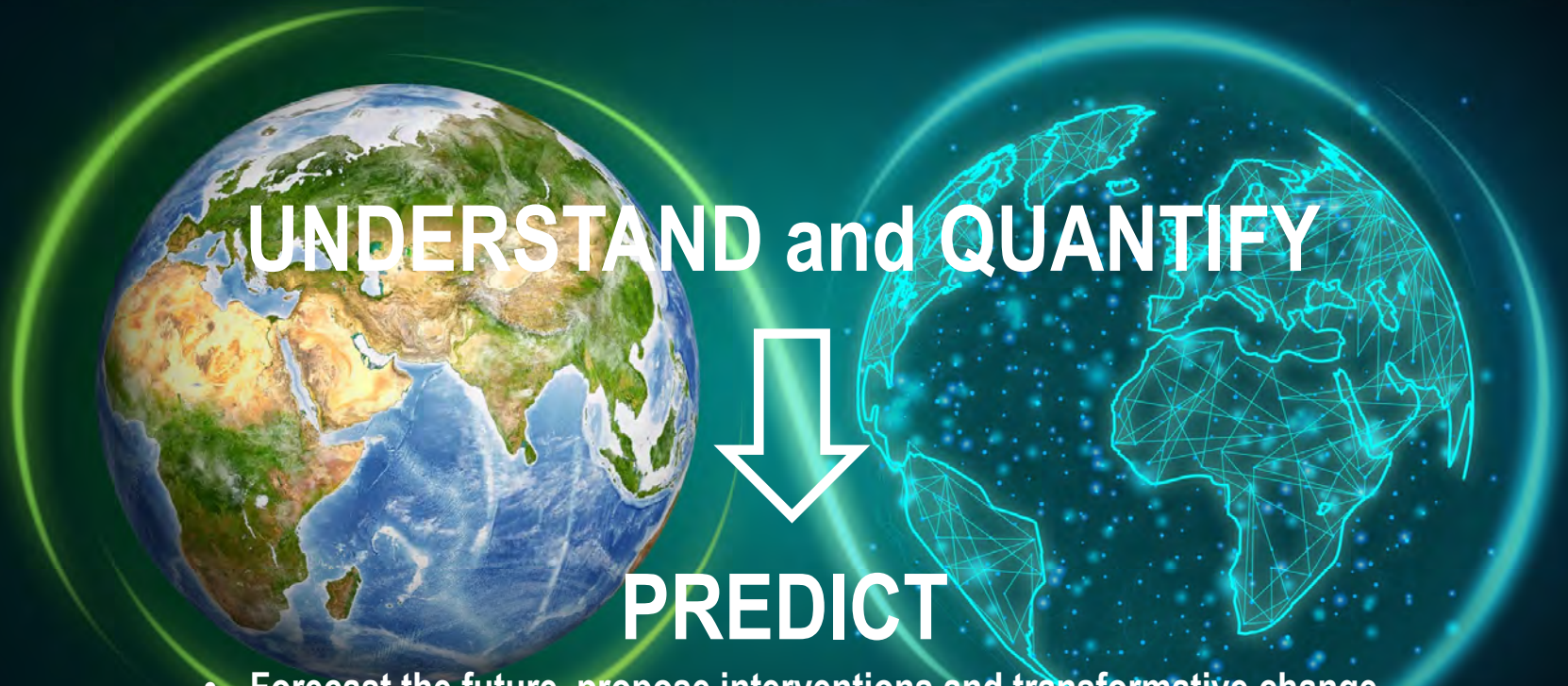


Next generation wearables: real-time sensing of stress hormone in biofluids

Sheibani et al. Extended gate field-effect-transistor for sensing cortisol stress hormone. Commun Mater 2, 10 (2021)

Overcoming sustainability challenges with digital twins

https://global.royalhaskoningdhv.com

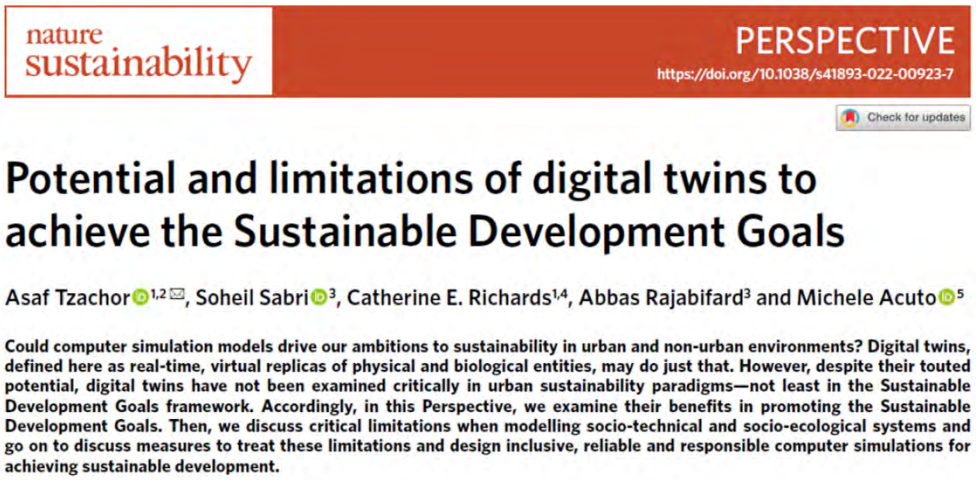


- Forecast the future, propose interventions and transformative change.
- Across the lifecycle of the asset, process, system or organization.

Perspective: Sustainable Development Goals

- Possible **only with**
  two key digitalization components:

  IoT/Edge AI and Digital Twins!
- Sustainable chips & software



nature sustainability

PERSPECTIVE

https://doi.org/10.1038/s41893-022-00923-7

Check for updates

Potential and limitations of digital twins to achieve the Sustainable Development Goals

Asaf Tzachor[1,2], Soheil Sabri[3], Catherine E. Richards[1,4], Abbas Rajabifard[3] and Michele Acuto[5]

Could computer simulation models drive our ambitions to sustainability in urban and non-urban environments? Digital twins, defined here as real-time, virtual replicas of physical and biological entities, may do just that. However, despite their touted potential, digital twins have not been examined critically in urban sustainability paradigms—not least in the Sustainable Development Goals framework. Accordingly, in this Perspective, we examine their benefits in promoting the Sustainable Development Goals. Then, we discuss critical limitations when modelling socio-technical and socio-ecological systems and go on to discuss measures to treat these limitations and design inclusive, reliable and responsible computer simulations for achieving sustainable development.