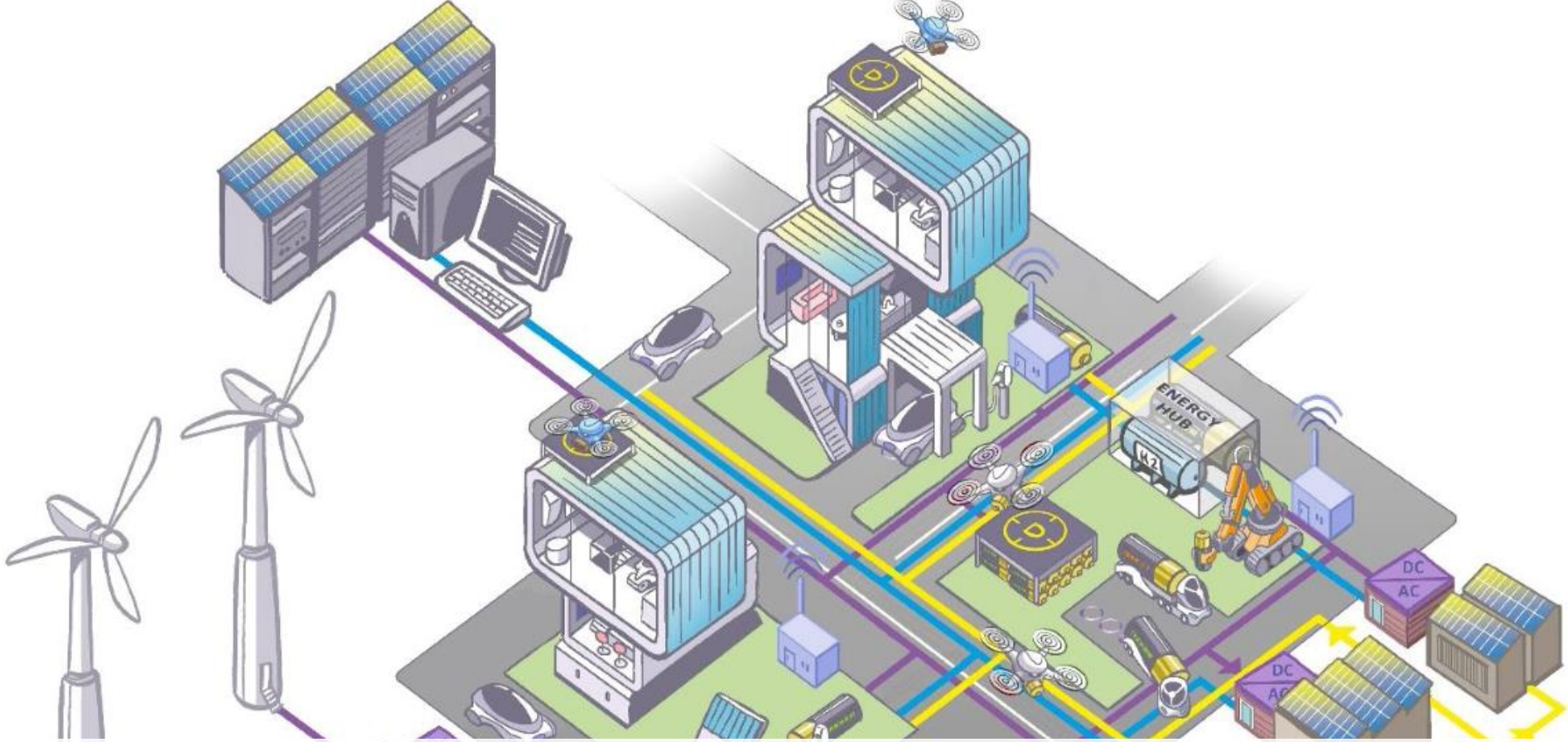


Digital Energy

Gravitation Programme 2023

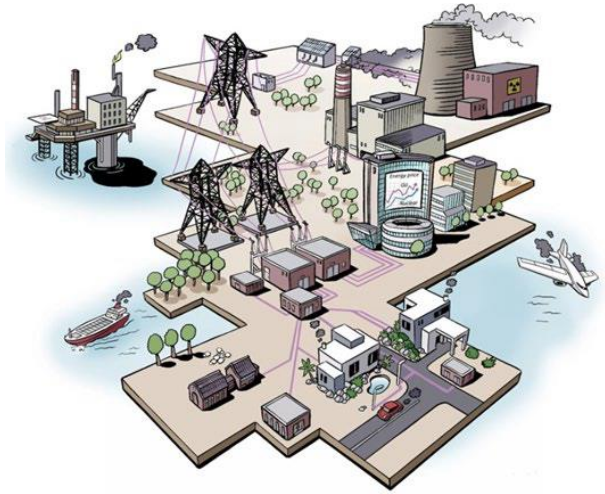
Prof.dr. Pavol Bauer

TU Delft Delft University of Technology

Introduction

Future energy system

- Analogue energy system:
  - Impact global warming
    - Renewable energy sources
    - Electrification of society
  - Relying on unstable supply
  - Highly susceptible to disasters
    - Natural hazards
    - Cyber-attacks



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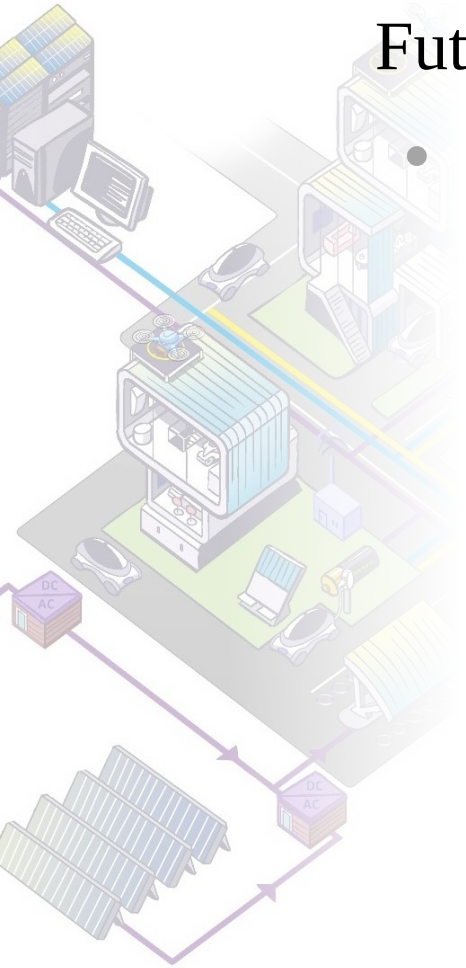
Introduction

Future energy system



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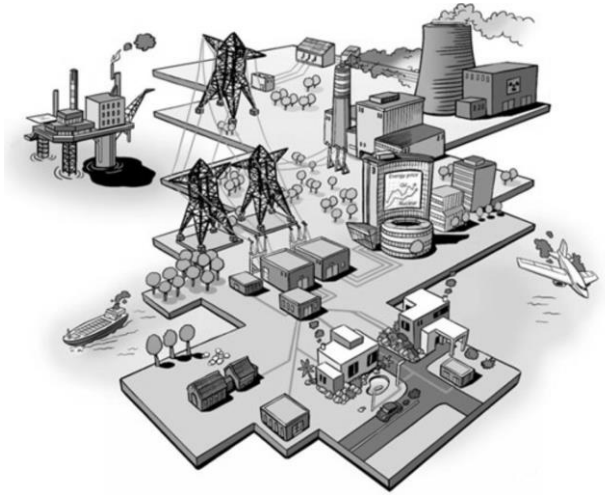
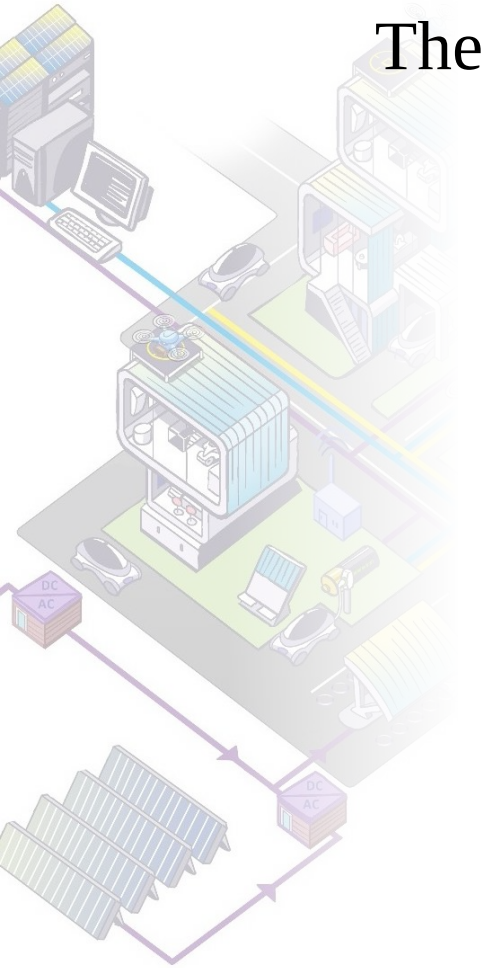
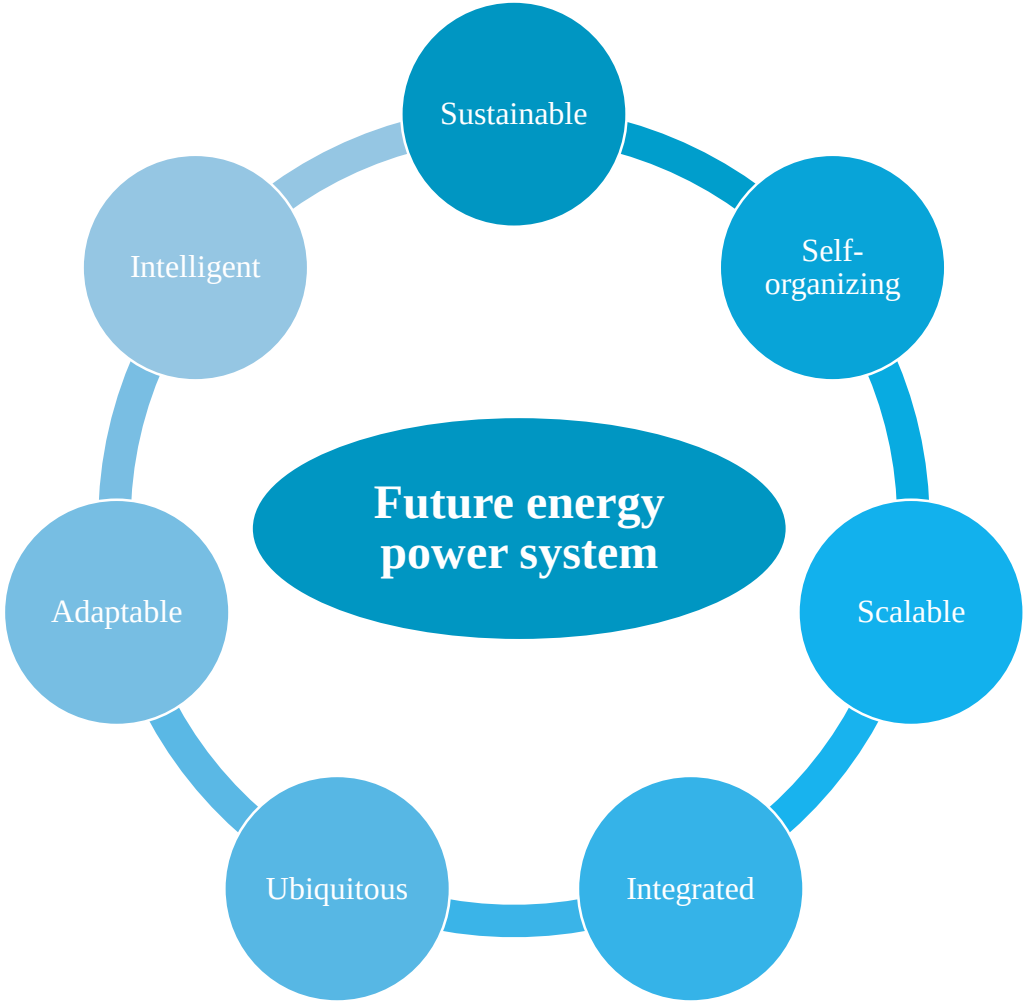


- Future energy framework:
  - Facilitate easy, fair, and efficient
    - Energy generation
    - Energy consumption
    - Energy storage
  - Decentralised flexible operation
    - Peer-to-peer energy trading
    - Modular power systems
    - Intelligent control

Introduction

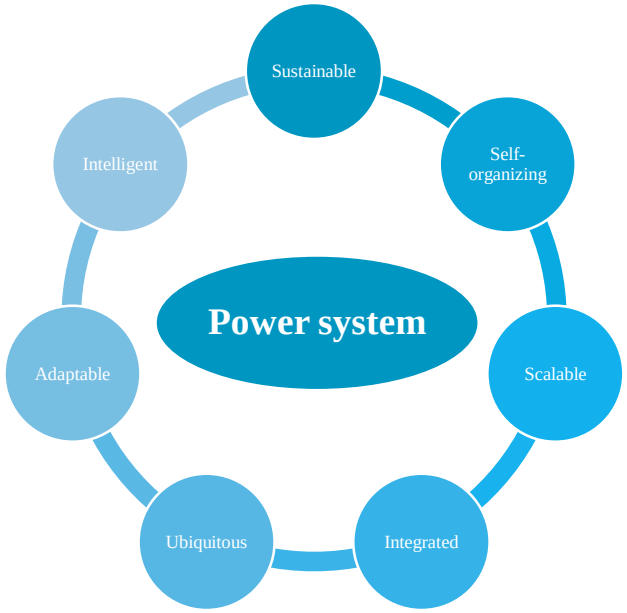
The digital energy framework





Introduction

The digital energy framework



- Digital energy framework:
  - Decentralised exchange of energy
    - Inclusive, affordable, secure and fair system
    - Local energy supply/demand balancing
    - Peer-to-peer energy trading
  - Internet resemblance

https://www.dnv.com/power-renewables/themes/digitalization/index.html

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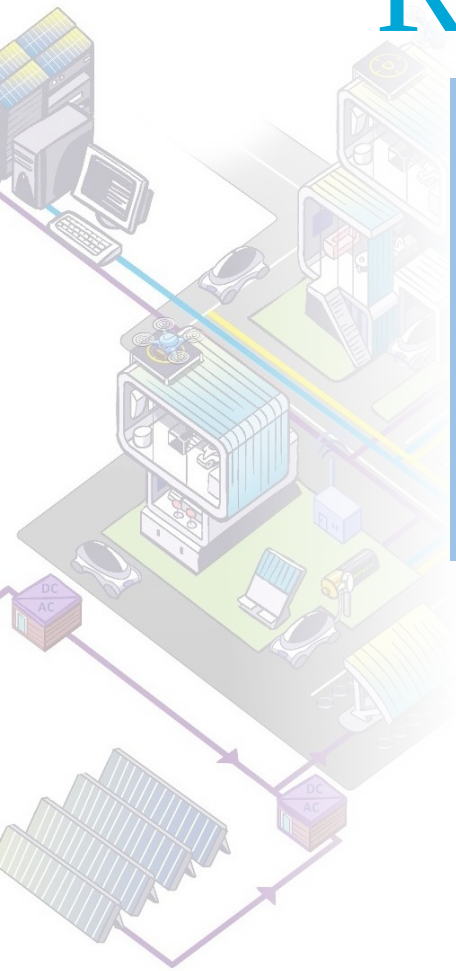
Research question



How do we create a sustainable, self-organizing, scalable, integrated and ubiquitous digital energy system that can adapt to various technological, organizational and societal constraints?

- Framework:
  - Inclusiveness
  - Resilience
  - Fairness
  - Affordability
  - Preparedness
- Flexibility:
  - Disconnect *physical layer* - *service layer*

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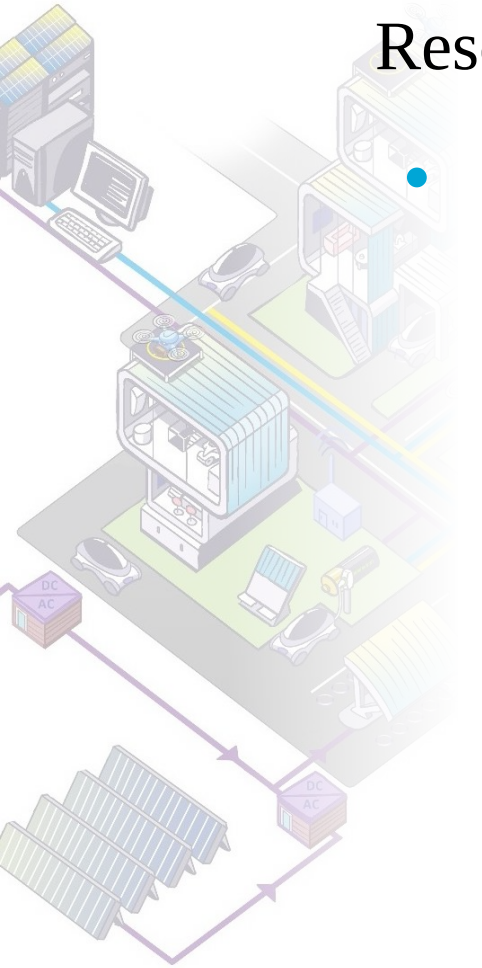
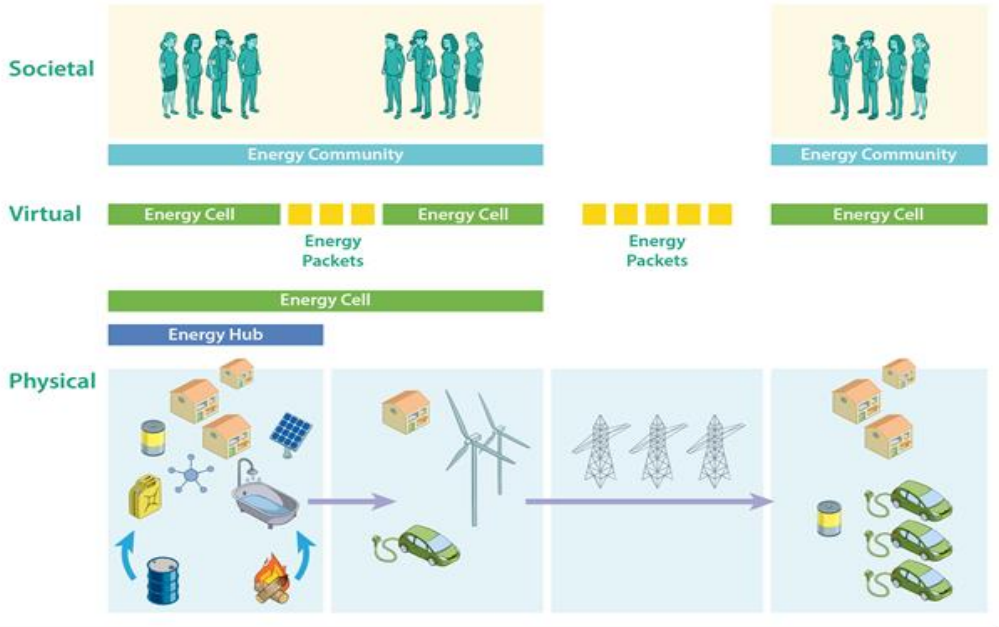
Research proposal

Research program

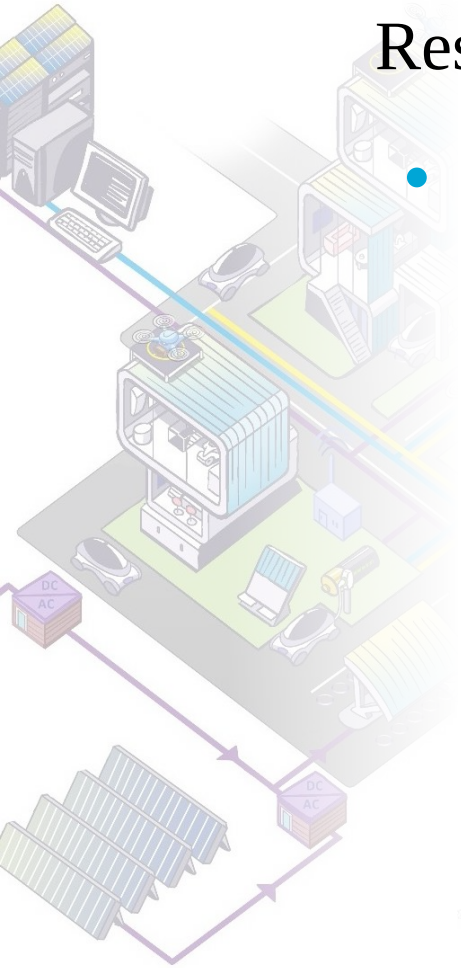


- Digital energy concept:
  - Energy cells
  - Energy conversion hubs
  - Energy packets
  - Virtualisation
  - Energy communities



Research program

Research program



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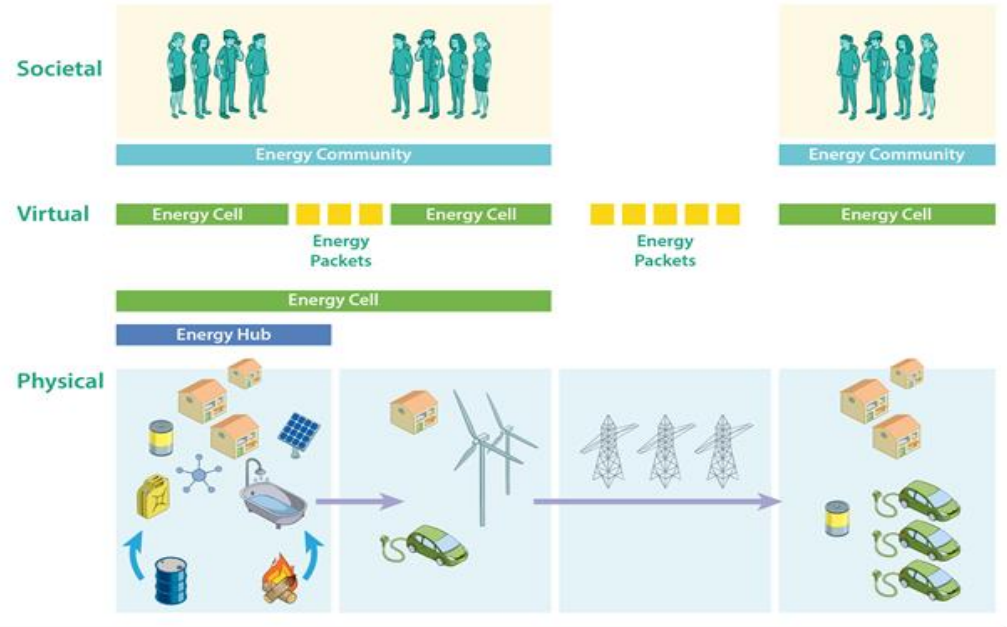
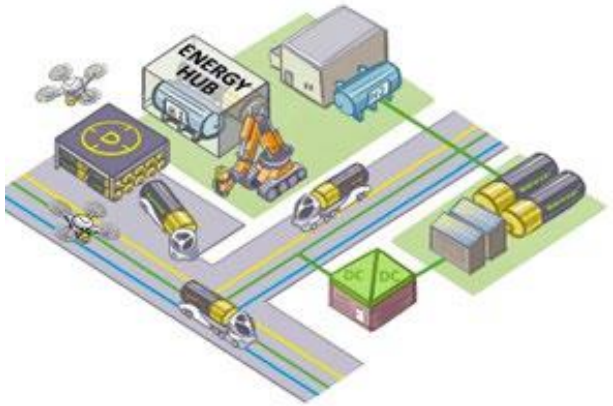
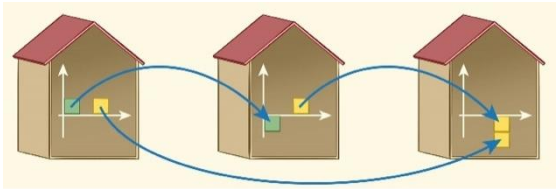
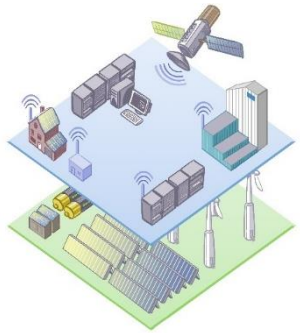
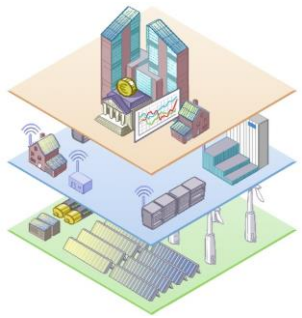
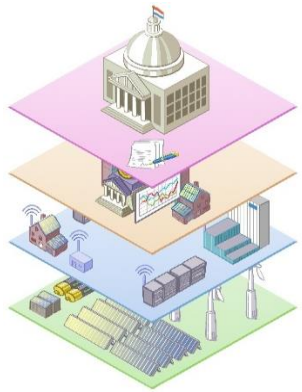




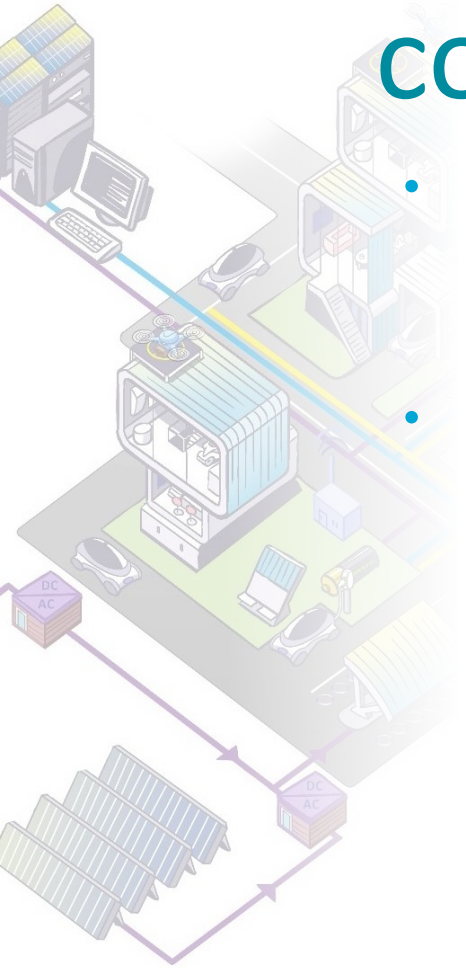


Research aspects

4 aspects

WP1	WP2	WP3	WP4
Intelligent Hardware	Planning and operation	Market, transition and risks	Social acceptance and energy communities
• Flexible solar • Modular energy conversion • Intelligent energy storage • Power routing	• Virtualisation of energy assets • Planning and coordination	• Advanced network models • Market mechanisms • Cyber risk and resilience • Technology and institutions	• Legal challenges • Ethical challenges • Behaviour challenges • Societal challenges
			

Intelligent hardware for generation, conversion, storage, and transport



- Ambition:
  - intelligent hardware that enables and facilitates the physical formation of digital energy concepts (energy cells, energy conversion hubs, virtualization, energy communities).
  - Design and development of intelligent components.
  - Combine digital- and novel power technologies structure for the emerging electrical energy system will dominated by power electronics

- Scientific challenges:
  - **Flexible solar based energy generation**
    - Reconfigurable, intelligent PV module
    - Shade-resilient PV modules
  - **Modular and flexible energy conversion**
    - Scalable, adaptable, robust, reliable, cost-effective, flexible ac/dc energy conversion.
    - Novel converter topologies, the utilization of new semiconductor devices, and innovative control strategies
    - Partially rated power flow controllers with implemented methods will guarantee resilience and reliability and allow (inter-)cell power flow optimization
    - Reliability models and data of power electronics, predictive maintenance
    - Advanced converter control algorithms will provide the necessary flexibility to operate in different scenarios of faults and disturbances.
  - **Intelligent integrated storage systems**
    - intelligent and reconfigurable storage packs with AI-empowered battery management systems; electricity used for heat storage (heat pumps) and hot water for local community; business model for storage, markets and regulatory structures
    - Integral approach for short and long term (seasonal) storage. Flexible and adaptive coordination methods within energy cells and energy conversion hubs. .
    - Flexible and portable storage connection – storage on demand. This “storage on wheels” or “storage with wings” will offer flexibility and deliver storage in packages (digital energy) with fast reaction time and create a new way of “wireless or cableless” energy transfers
  - **Power Routing**
    - Flexible dc Interlinks and parallel ac/dc links works in a decentralized manner. Concept of re-configurable power router with control of energy flow.
    - Dc link technologies that will revolutionize the exchange of energy between grids by drastically improving redundancy, flexibility and efficiency.

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Research consortium

- Research consortium:
  - 6 research organisations
  - 5 universities
  - 14 research groups

TU Delft Delft University of Technology · TU/e Eindhoven University of Technology · University of Twente. · rijksuniversiteit groningen · Utrecht University · CWI

- State of the art facilities:
  - Electrical Sustainable Power Lab
  - RTDS Laboratory
  - Power Electronics Lab
  - Power Quality Laboratory

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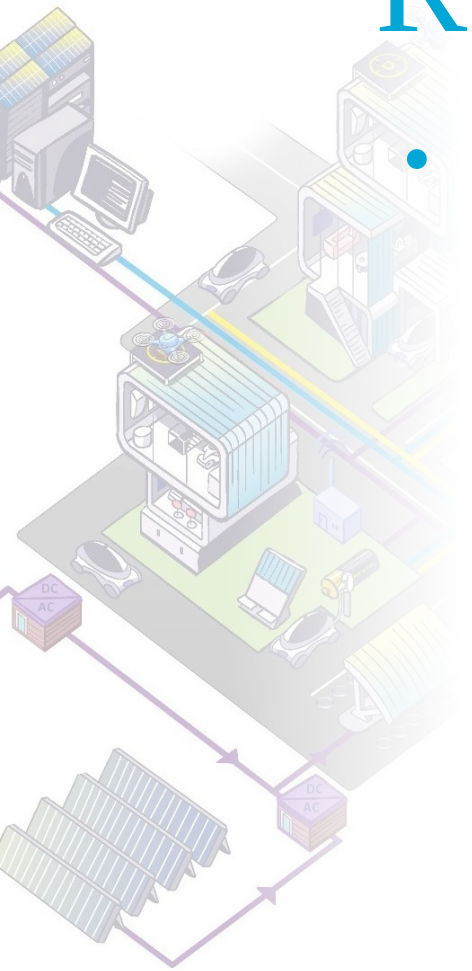
Research team



- Team:
  - Principal investigators
    - Prof. P. Bauer - TUD
    - Prof. F. Alkemade - TU/e
    - Prof. J. Hurink - UT
    - Prof. P. Palensky - TUD
    - Prof. B Zwart - CWI & TU/e
    - Prof. J. Mifsud Bonnici - RUG
  - 44 Senior researches
  -

	WP1	**WP2**	**WP3**	**WP4**
PhDs	10	11	12	11
Postdocs	5	4	4	1
Visitors	3	3	3	3

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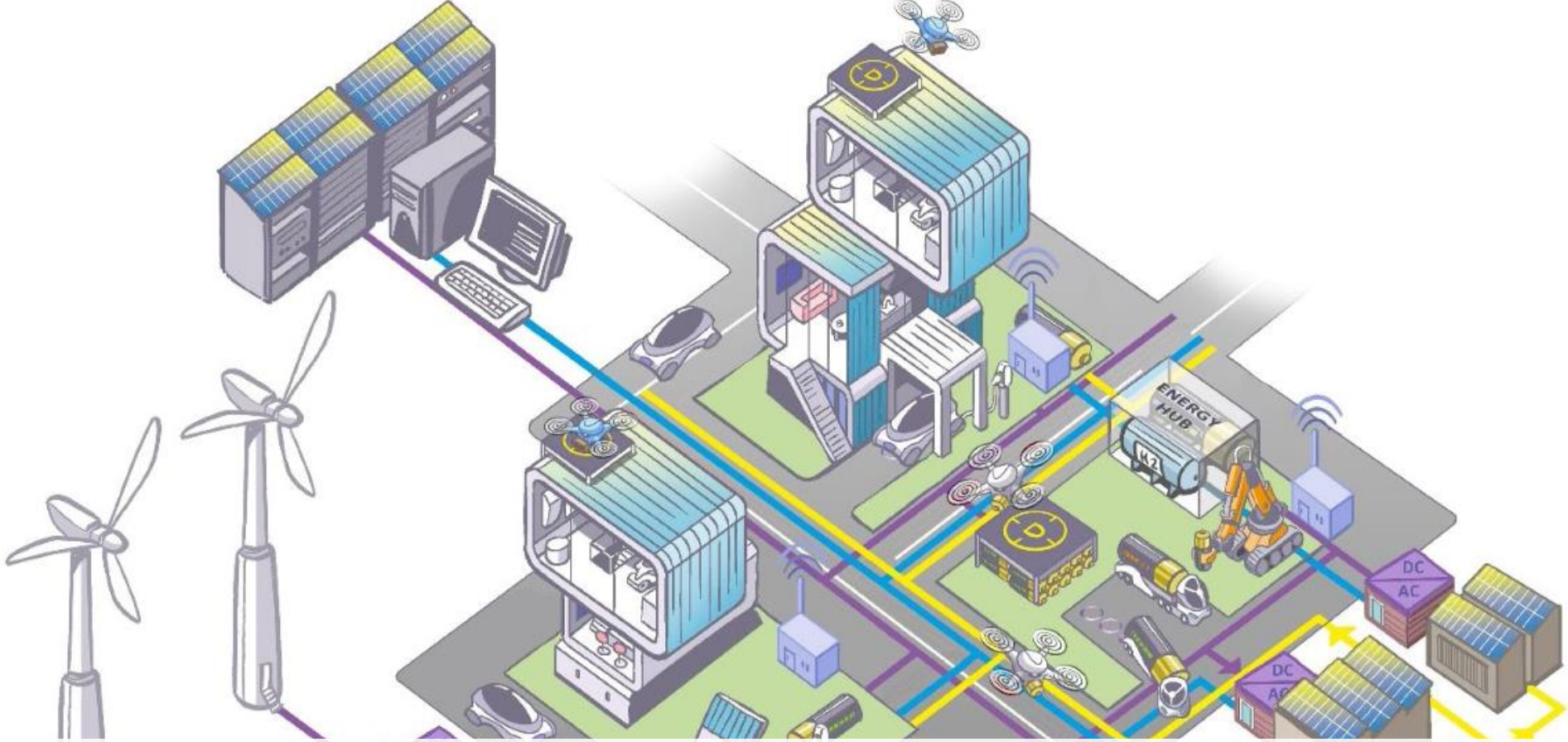

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