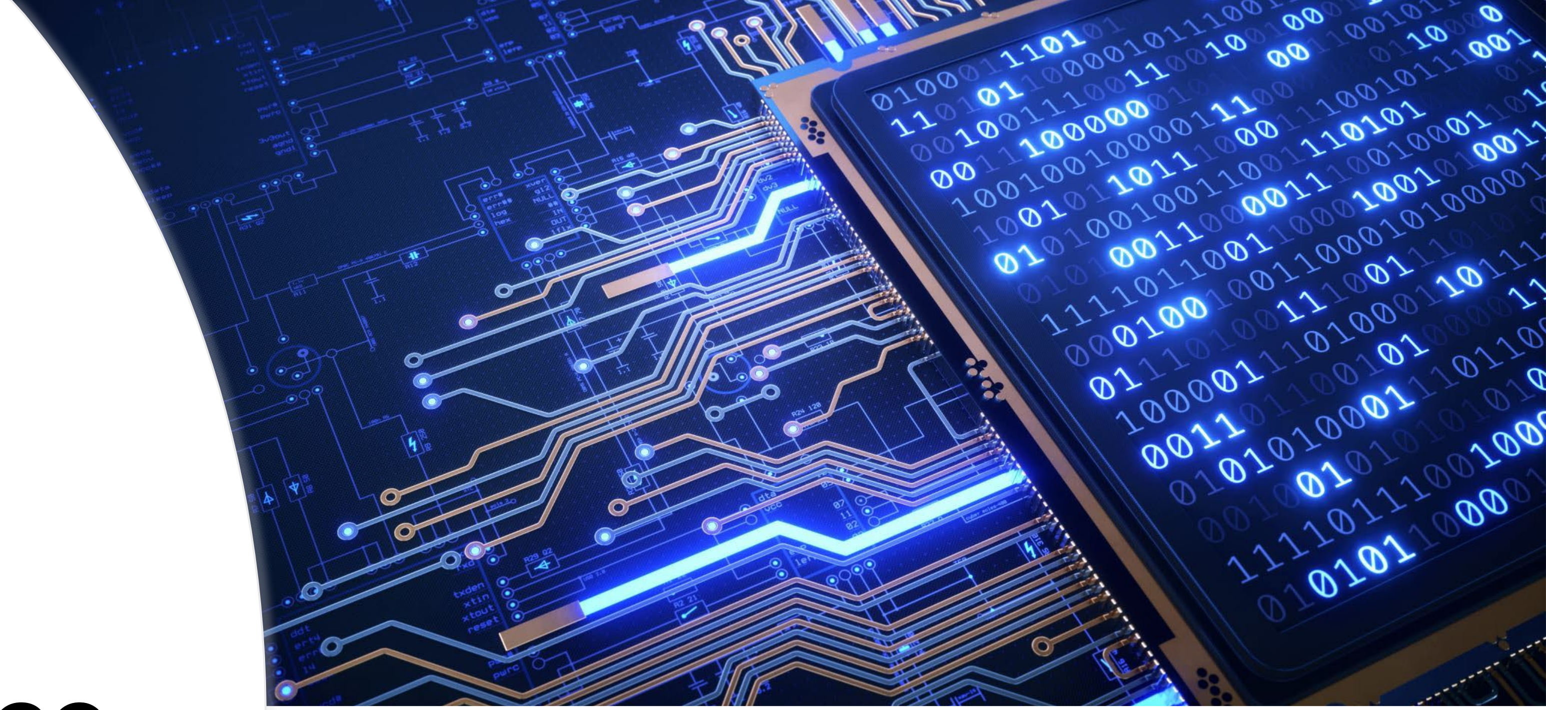
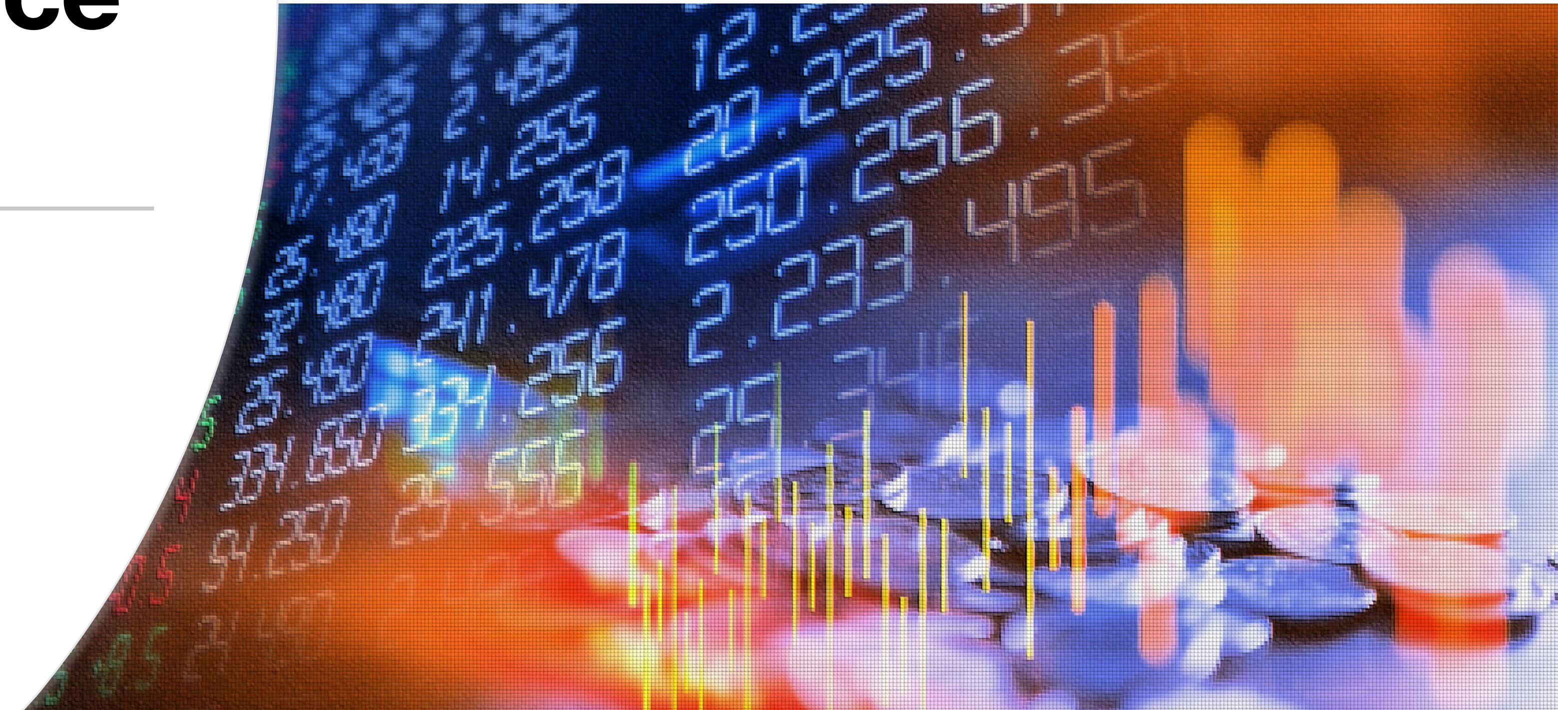
Regional Conference on Energy Resilience through Decentralized Power Plants and Smart Grid Integration

15 September 2022

Emerging 4IR technologies and trends for enhancing resilience of smart grids





Prof Z.Y. Dong

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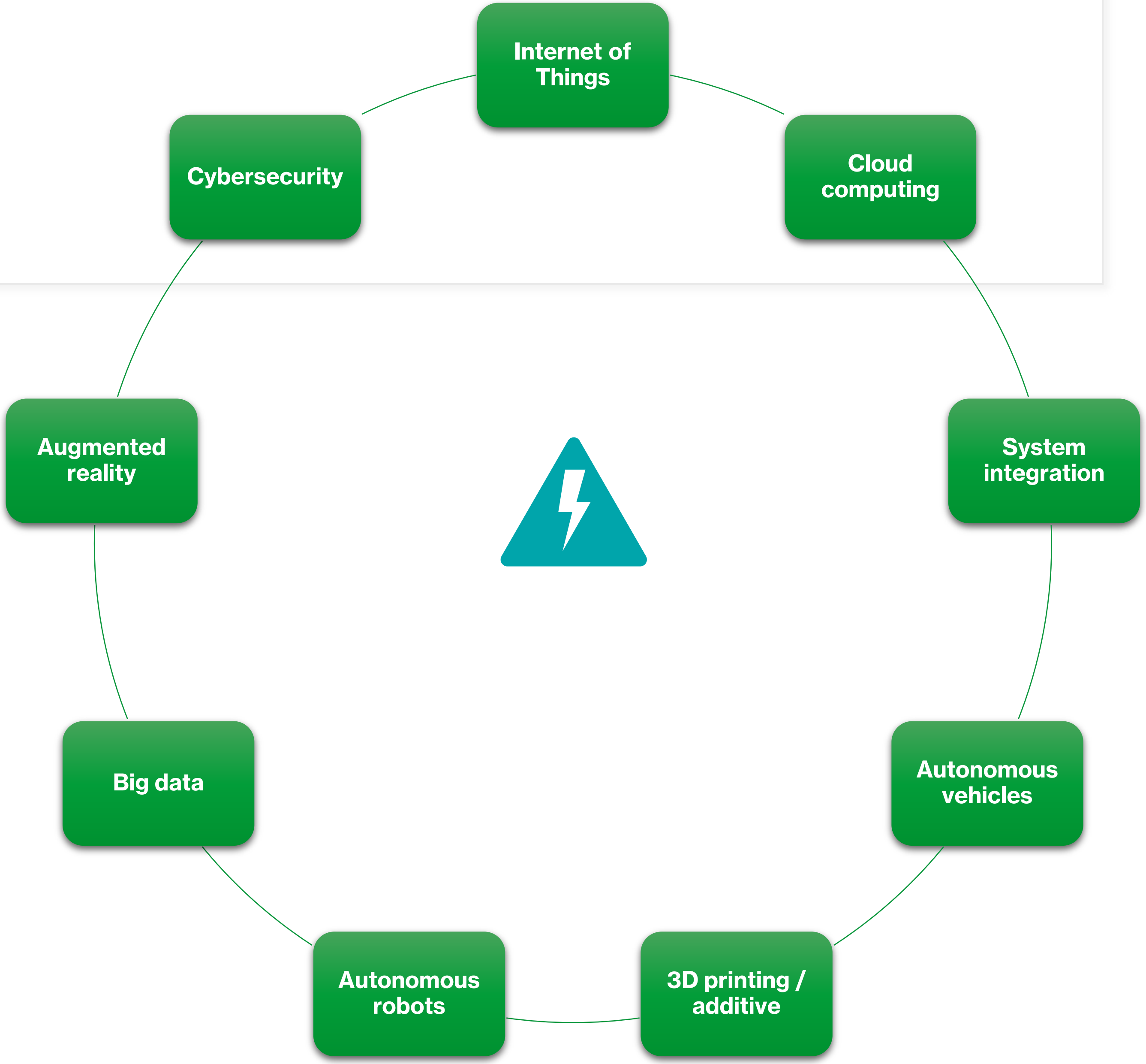
4IR

IEEE highlighted 4IR technologies

These technologies have been used by the power industry

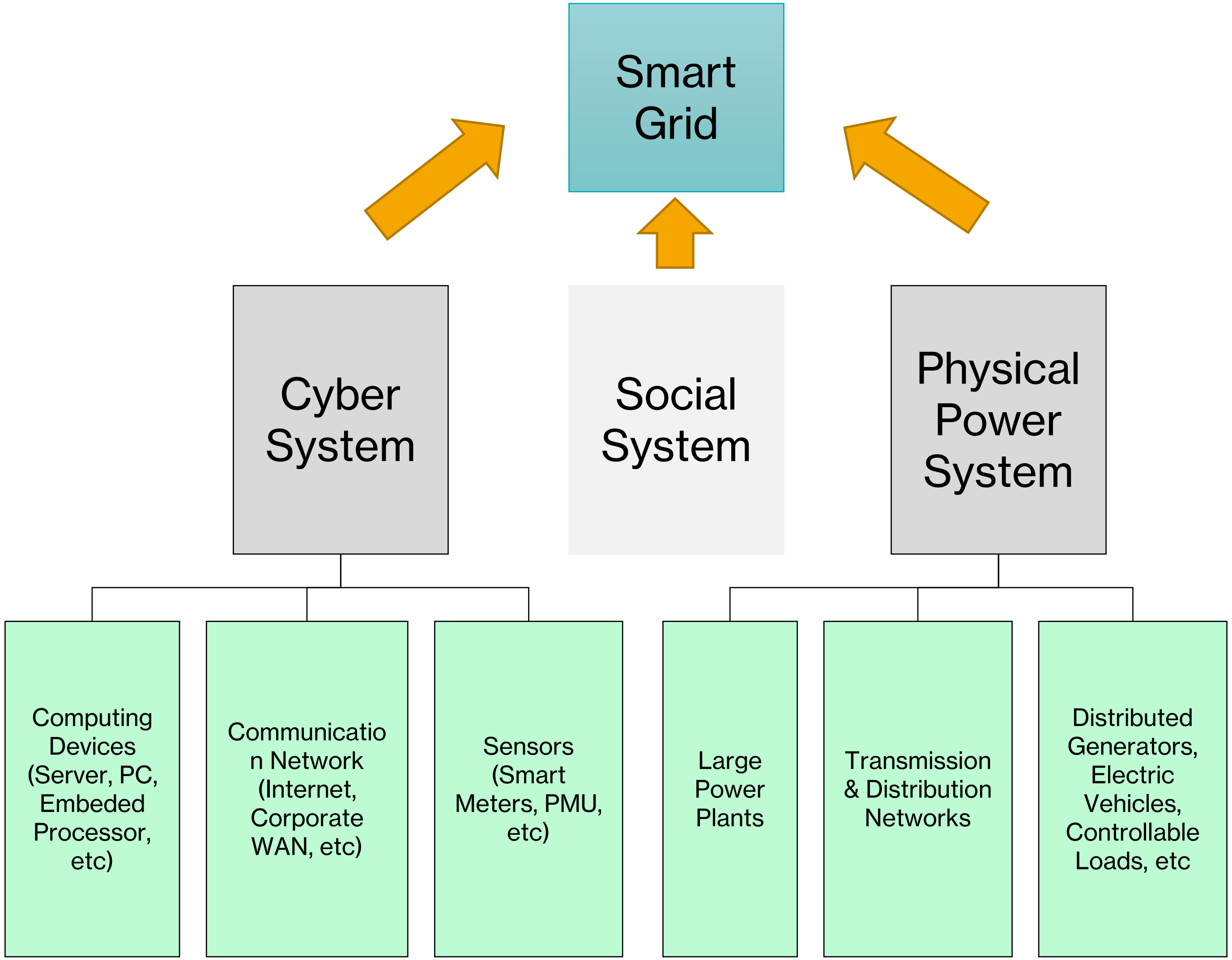
more 4IR technologies will be employed contributing to the zero-emission target from the main emission sectors



Source: https://innovate.ieee.org/innovation-spotlight-ieee-fueling-fourth-industrial-revolution/

Syber-physical-social-Power System

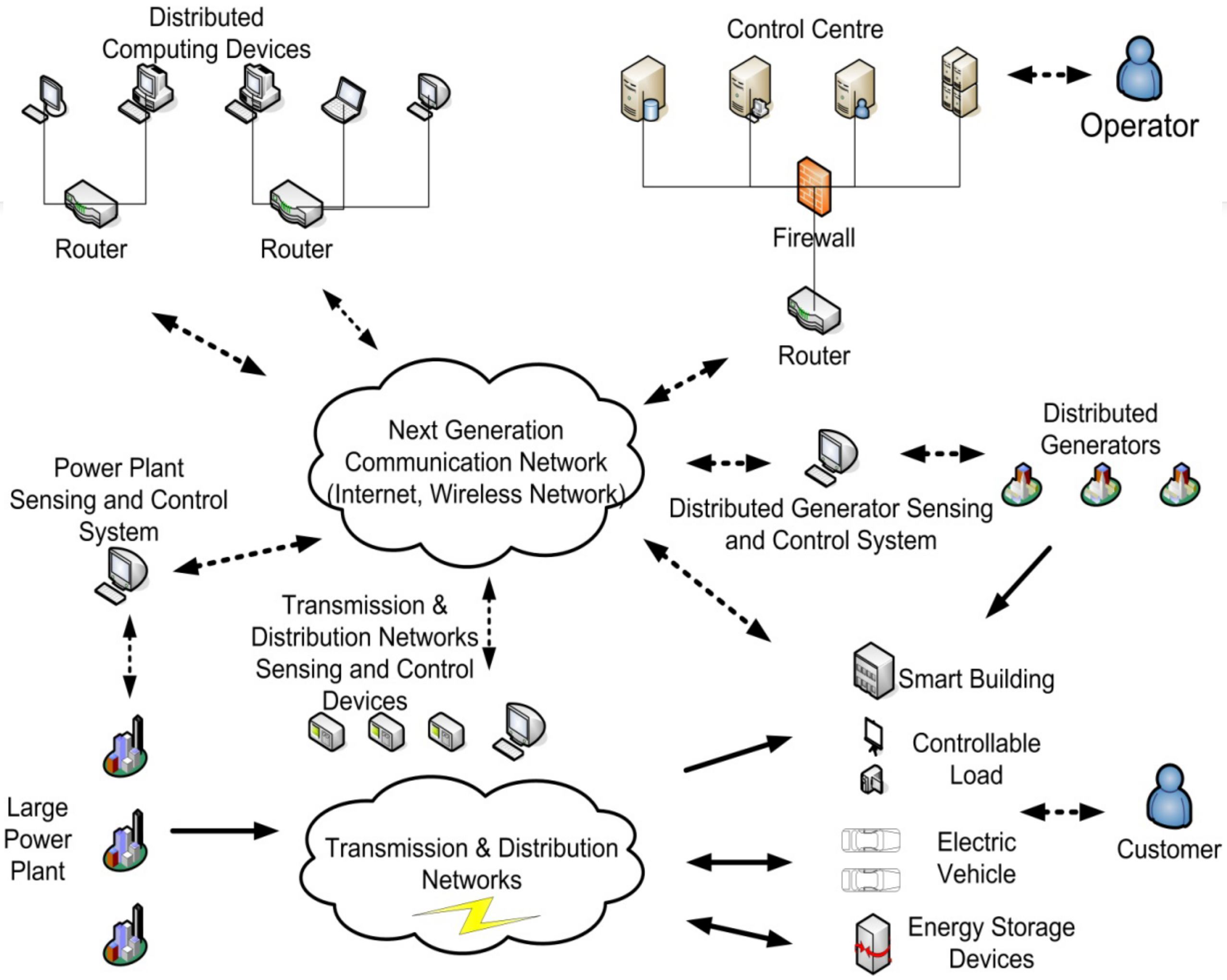
- A SPSP grid is an integration of the physical (power) system, cyber (ICT) system, and social system (policy, prosumers etc)
- The cyber system can be divided into three components:
  - computing,
  - communication and
  - Sensing
- Increasing impact from the social system as well



Cyber Technologies in a Smart Grid

- Advanced cyber technologies play a vital role in smart grid implementations.

- A smart grid relies on sensing, communication and computing systems to collect, transfer and process information.



Carbon Emissions and Neutrality

- Carbon neutrality targets

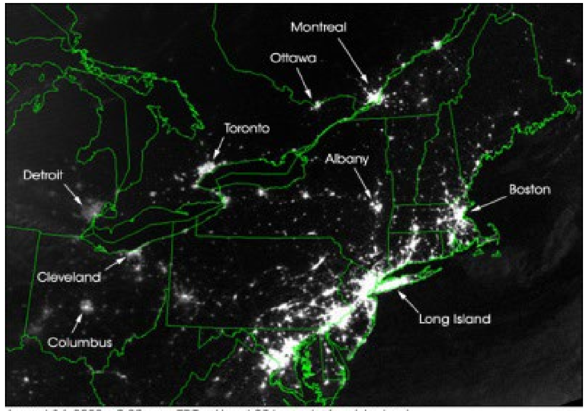
China	2060
Singapore	2050-2100
Australia	2050-2100
Japan	2050
European Union	2050
USA	2050
India	2070

Source: Race to Net Zero: Carbon Neutral Goals by Country

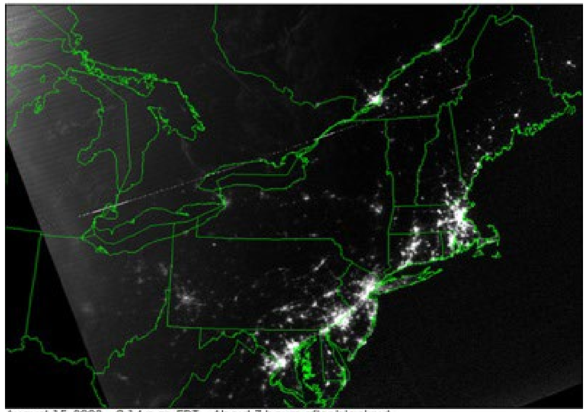
Evolution of Smart Power Grids

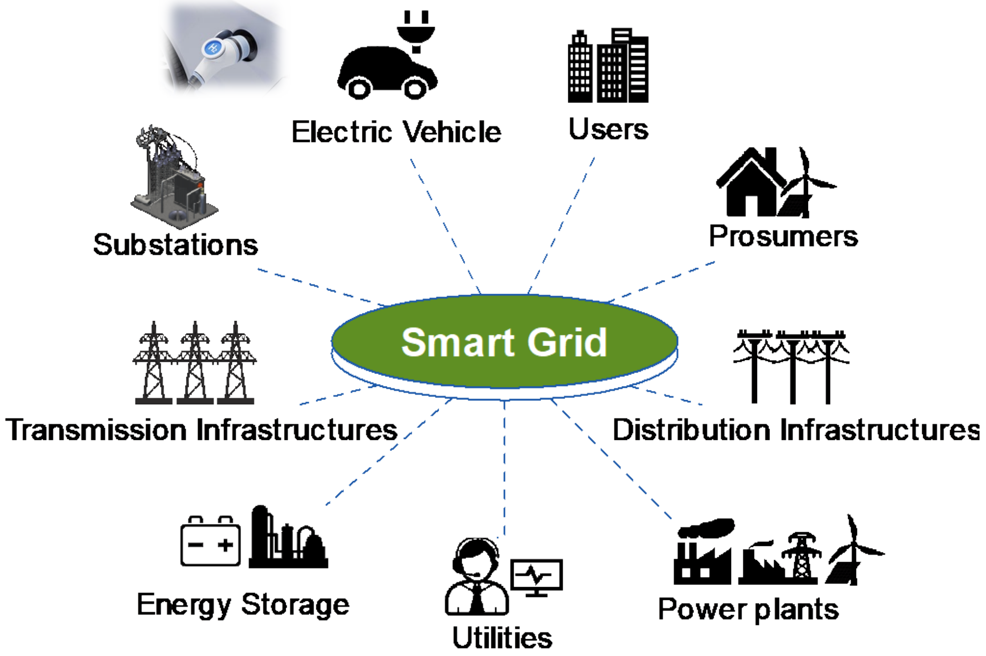
Power system/smart/future grid – monitoring, measurement, modelling, control, security, telecommunications, power, computing, electronics, computing, regulation, situational awareness … …

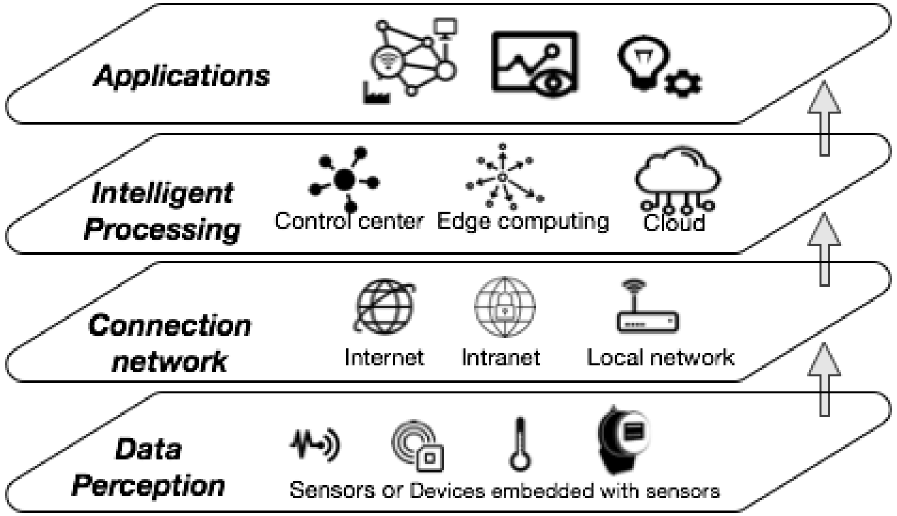
Power grid → Smart grid → Multi Energy → IoT & Digitalisation



August 14, 2003 • 9:29 p.m. EDT • About 20 hours before blackout


August 15, 2003 • 9:14 p.m. EDT • About 7 hours after blackout



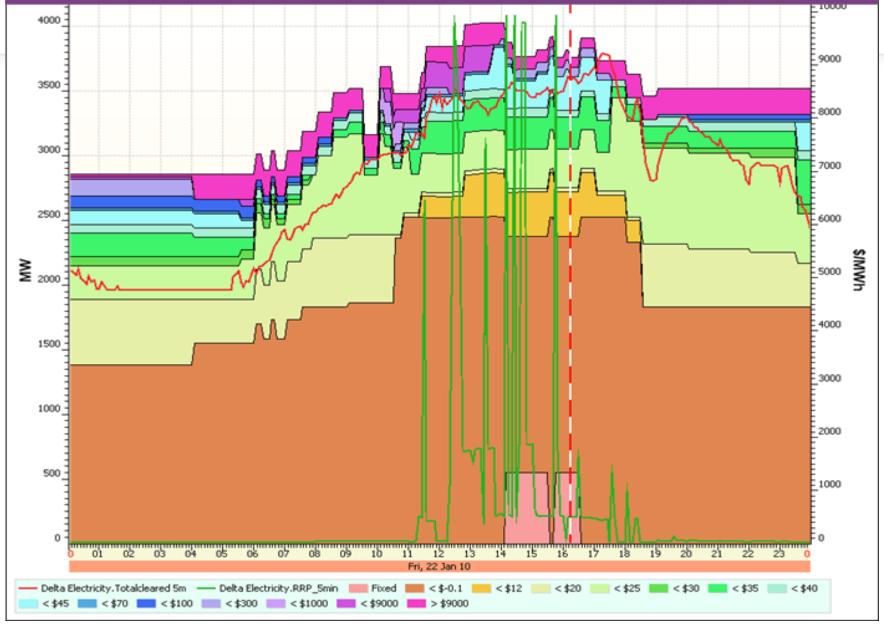


Assets and Disasters

- probabilistic modelling, abnormal prediction, contingency assessment, risk management, stability, resilience

- Disaster
- System Failure
- Market Failure

Volatility of the electricity market during natural disaster



Extreme Disaster

⇩

Power System Component Failures

⇩

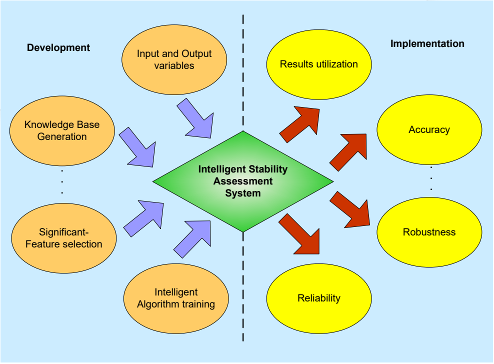
Large Disturbances to Power System

⇩

Power System loses stability

⇩

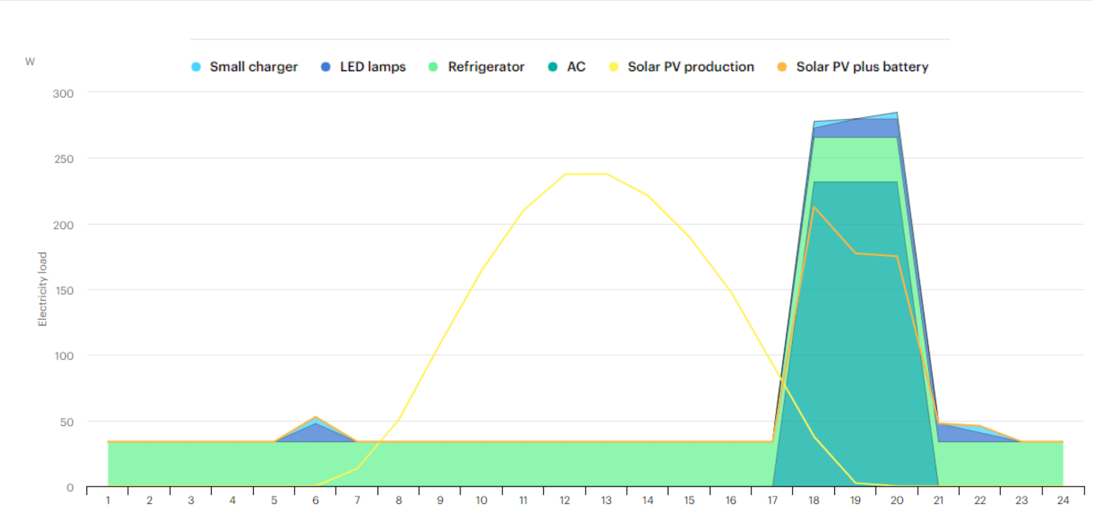
Blackouts



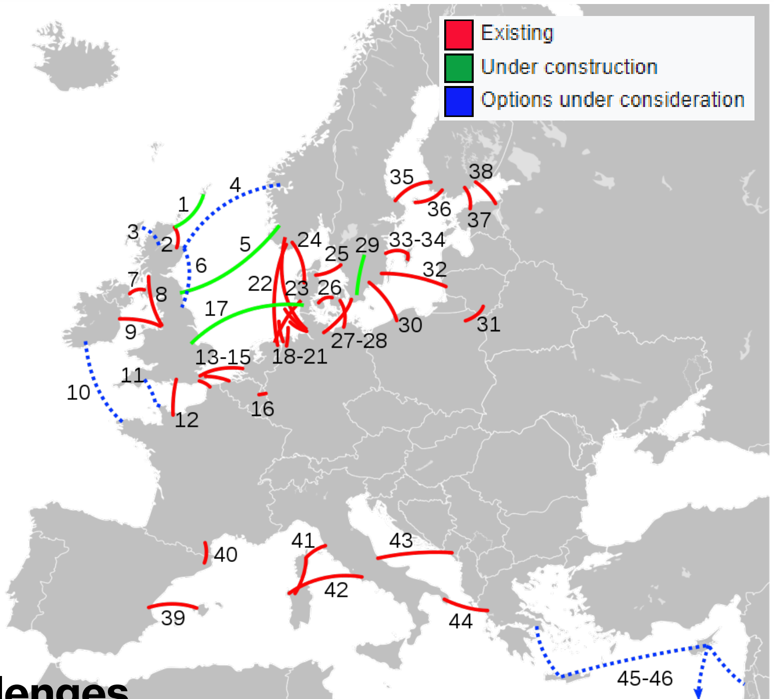
Wednesday 15 June 2022 – "AEMO announced the suspension because a confluence of events has made it impossible to continue operating the spot market while ensuring a secure and reliable supply of electricity for consumers." - AEMO

Renewable & HVDC

- Intermittency
- Firming
- Reliability
- Cost



Source:
IEA, example of daily load profile for solar PV production relative to electricity demand in 2050



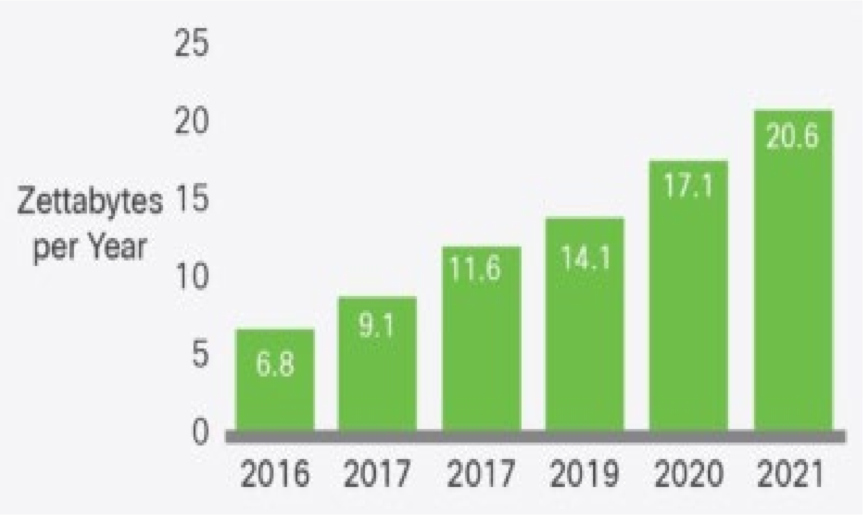
HVDC Main challenges

Large fault current, no nature zero crossing of current, need fast switching and be able to absorb energy at the time of switching→ very fast (2-10ms) operation with parallel paths with auxiliary circuits for current commutation and energy absorption

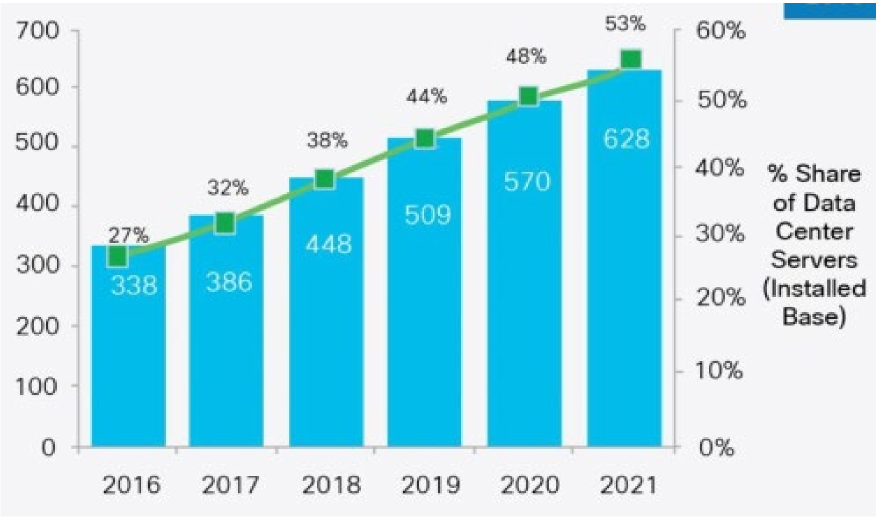
Demand - Urbane load growth (Data centre & EV)

- Global data center traffic has increased **3 times** over the past 5 years, and will grow 3-fold over the next 5 years.
- Hyperscale data centers has increased **1.8 times** over the past 5 years.

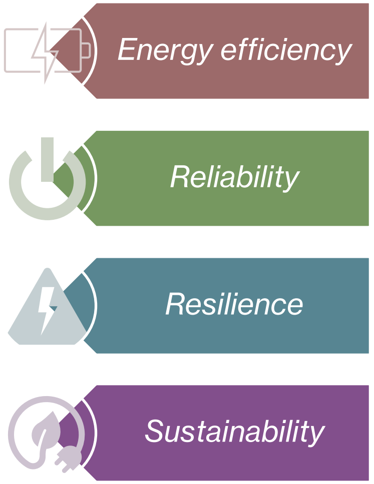
Global data center traffic growth



Global hyperscale data center growth



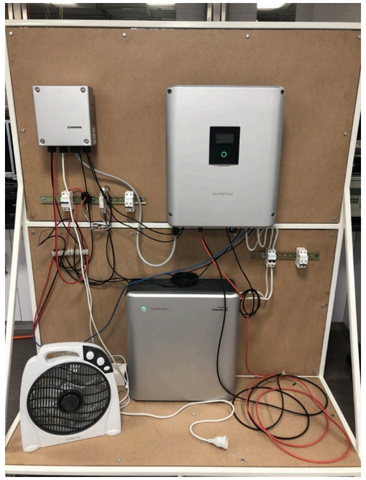
Challenges and Grid Impact

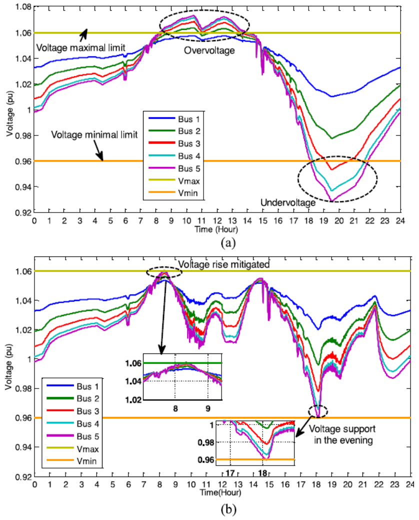


Source: Cisco Global Cloud Index: Forecast and Methodology, 2016–2021

Demand Side Applications of 4IR

- Consumers vs Prosumers
- Grid connected vs Off grid
- Micro-grid
- Community Resources: Battery, RE and EV
- DER
- VPP
- Sharing and circular economy
- Environmental sustainability awareness





Green Transportation

Major emitter together with power generation sector

Interdependence between Power Grid and Transportation Network/infrastructure

Rapid change → grid impact

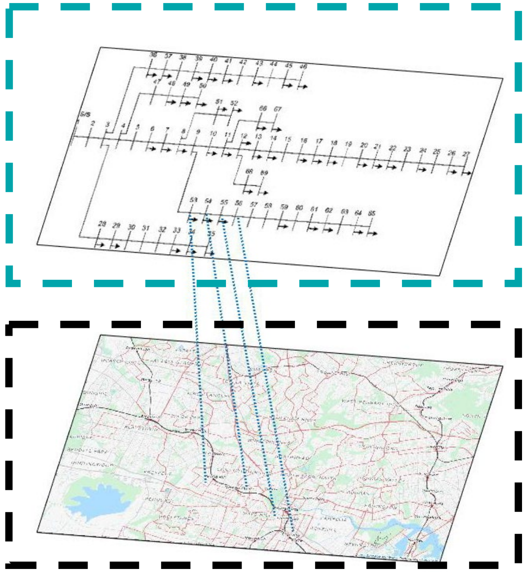
Availability of charging infrastructure, grid support and EV uptake

Policy and regulations

Safety: battery & H2

Data acquisition and preprocessing

Distribution network

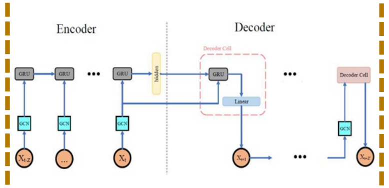


Transportation network

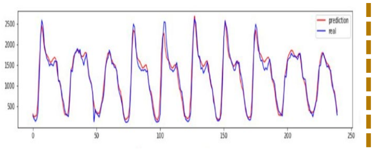
1.Missing data imputation by matrix factorization

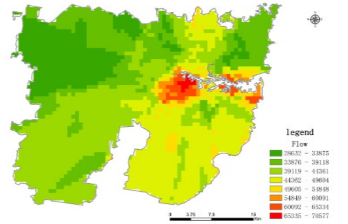
Demand prediction

2. Multi-graph convolutional network for traffic flow prediction

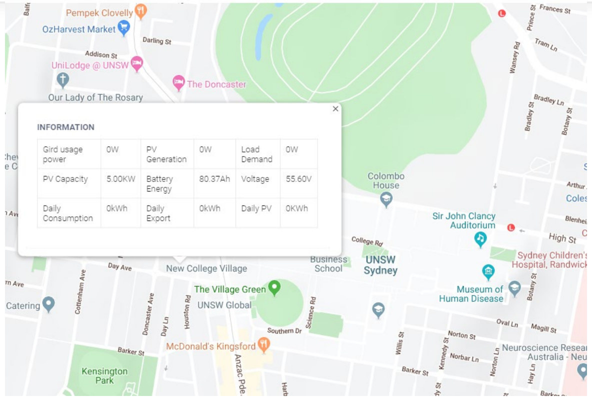


Prediction





Next generation ICT and cyber system



Monitoring & Control vs cyber security

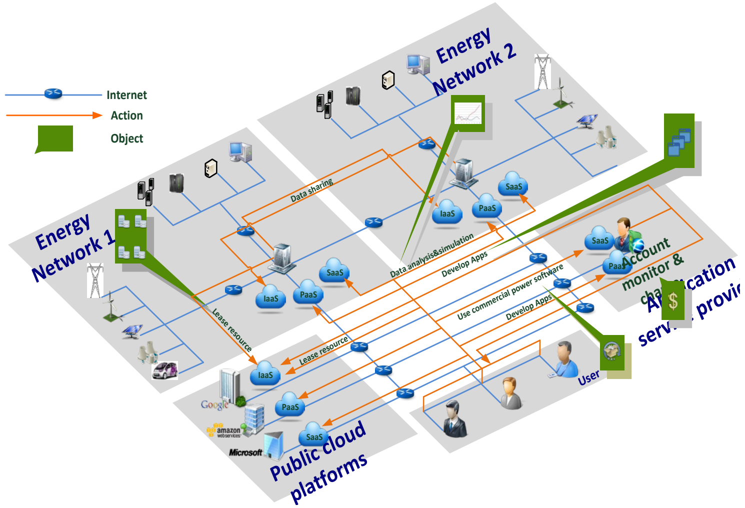
Cyber – Physical – Social interaction/interdependence

AI, data analytics and data privacy/security

Communications system cost, latency, coverage

Beyond AMI

Digital Twin & Metaverse



ICT & Market

AI, Blockchain & NFT

Energy Market and Peer to Peer Trading

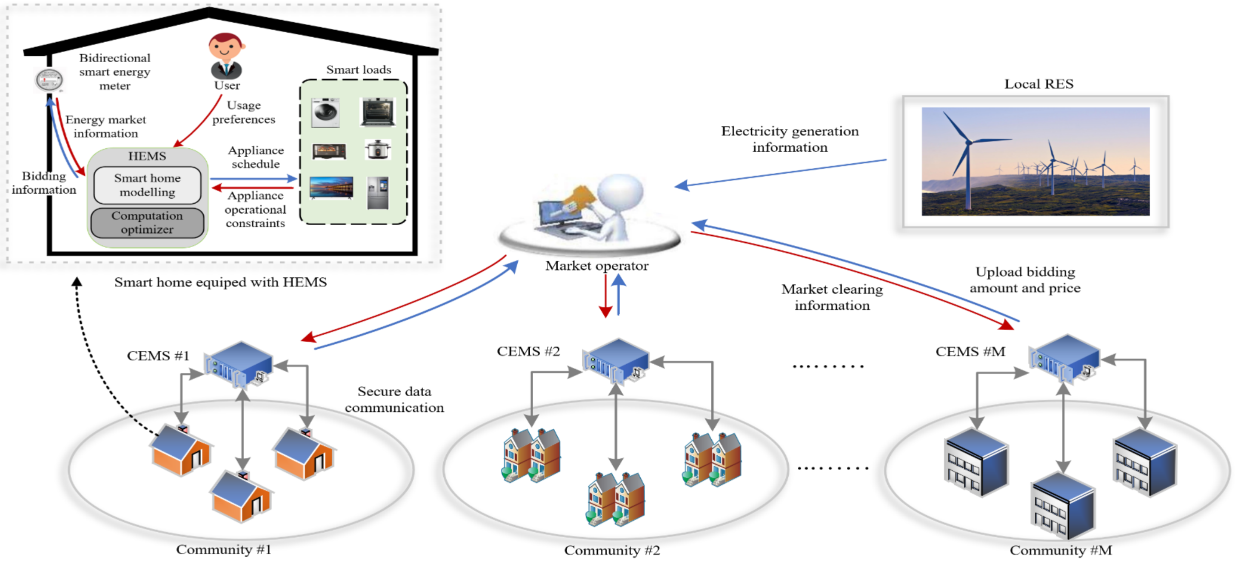
Consumers and prosumers

Gentailers

DERs and community battery

Sharing economy

ESG, carbon credit & GH2 credit

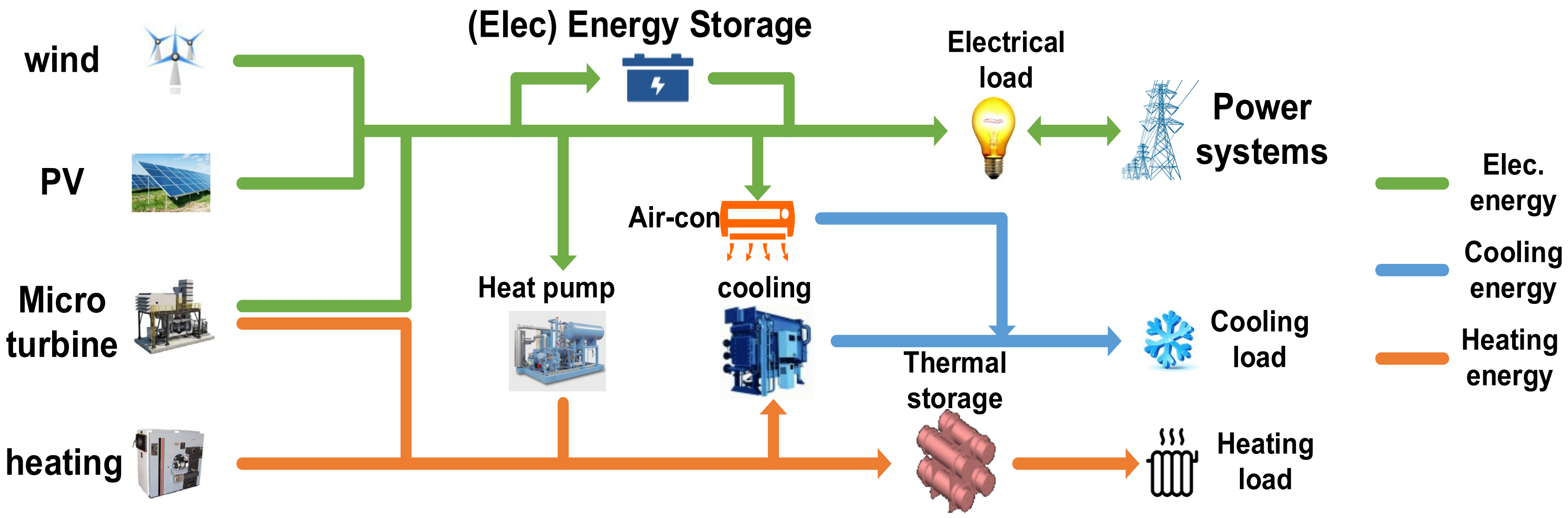


- Facilitate users to trade renewable energy in a peer-to-peer manner
- Use Paillier cryptosystem to enable secure customer bids
- Privacy-preserving energy market clearing mechanism based on the Paillier cryptosystem encrypted customer bidding data

Source: R. Deng, F. Luo, Z.Y. Dong, et al., “Privacy preserving renewable energy trading system for residential communities,” International Journal of Power and Energy Systems

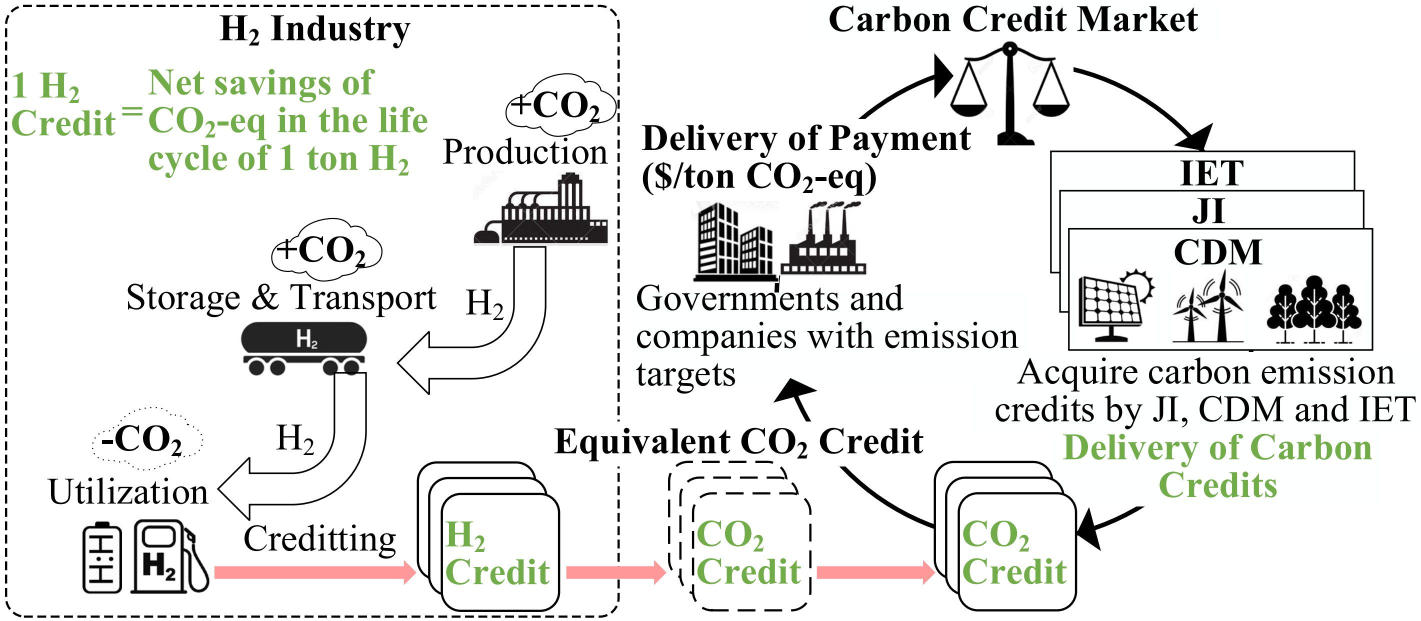
Sustainability and Implementation

Sustainability in operations and planning



Green Hydrogen Credit/Trading

- **Significant levels of new investment are needed to successfully commercialise and scale a global green H_2 industry.** To meet the estimates of providing up to 18% of the world's final energy demand by 2050, global annual investments of between US $20 to $25 billion are needed for a total investment of about $280 billion by 2030.
- **Key challenges regarding the delivery and storage of H_2 are yet to be tackled** (e.g., the delivery/storage cost, weight and volume of H_2 storage systems, storage efficiency and safety), in order to scale up the H_2 industry. Presently, H_2 is transported from the site of production to the utilization sites mainly through pipeline, over the road in cryogenic liquid tanker trucks or gaseous tube trailers, by rail or barge.
- **Costs and technical requirements for storage and long-distance transportation are major obstacles** for international trading and wider adoption of green H_2 for global carbon natural objectives.



Z. Y. Dong, J. Yang, L. Yu, R. Daiyan and R. Amal, "A Green Hydrogen Credit Framework for International Green Hydrogen Trading Towards A Carbon Neutral Future", *International Journal of Hydrogen Energy,* accepted for publication, Oct 2021.

Conclusions

- 4IR technologies provide effective tools for power grid revolution and resilience
- Rapid grow of uptake of BESS, EV and GH2 created potential impact on the existing grid while creating opportunities, both from physical system and through financial market
- Public awareness /community engagement is key to sustainability
- AI & ICT technologies provides better services while data security/privacy is a dominant concern
- Emerging tool and platforms (ESG, NFT, GH2 credit) lacks behind the development
- Growing uncertainties requires more energy security measures

Acknowledgement

- Team members and research partners
- Funding support from research grants and industrial projects

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CAFEA Smart City