BUSINESS NETWORK INNOVATION

Ecosystem of **energy transition** players driven by **business perspective**

Bridge between ENTSO-E and start-ups, citizen initiatives, opinion leaders, institutions, energy businesses

Over **130 members**: Tesla, GE, Utrecht University, ESA, Ampacimon

Webinars and luncheons: Storage, Dynamic Line Rating, Artificial Intelligence, Common grid model and energy data architecture...

Join today #InnovationENTSO-E

www.entsoe.eu/research-and-innovation/business-coalition/

BUSINESS NETWORK INNOVATION

500+

Attendants altogether in previous webinars

400+

Followers on Social Media

1500+

Watched webinars on YouTube

esa | business applications

European Network of Transmission System Operators for Electricity

entsoe

Why need a cooperation?

ROLE OF POWER NETWORKS INCREASED

Networks need:

- More sector coupling
- More flexibility
- More innovation
- More digitalization

SPACE TECHNOLOGY CAN HELP

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European Network of Transmission System Operators for Electricity entsoe

Feasibility study for

Space-based services for distributed energy networks (smart-grids)

Levels of opportunities:

Commercial & Residential

- Demand response
- Predict peaks in consumption
- Smart homes & factories
- Electric vehicle integration

Transmission & Distribution

- Communication services
- Early warnings for possible outages
- IoT services for smartgrid management

Virtual Power Plants

- Remote control
- Production & load forecasting

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Feasibility study for

Space-based services for distributed energy networks (smart-grids)

Timeline

2018 Q3

Preparation for tender

2019 Q2

Start work on feasibility study

2019 Q4

Feasibility study ready

ARTIFICIAL INTELLIGENCE

The AI boom is happening all over the world, and it's accelerating quickly

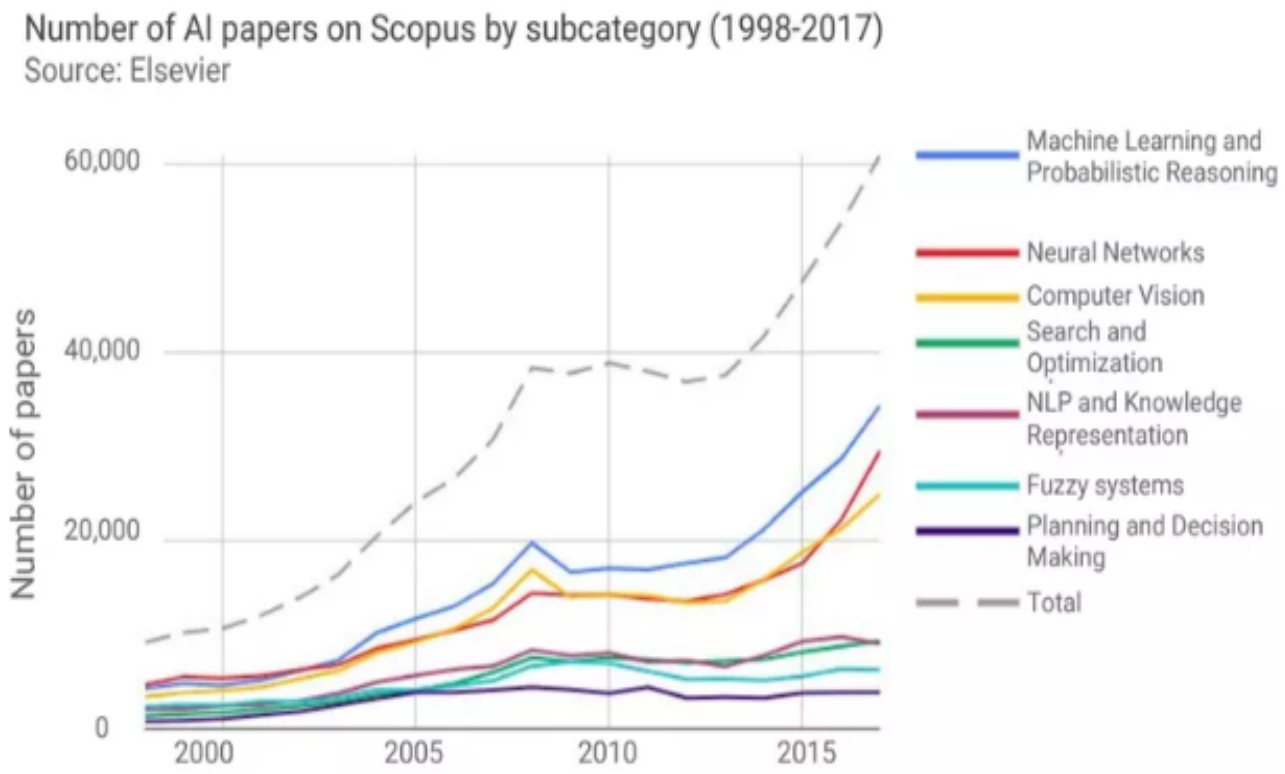
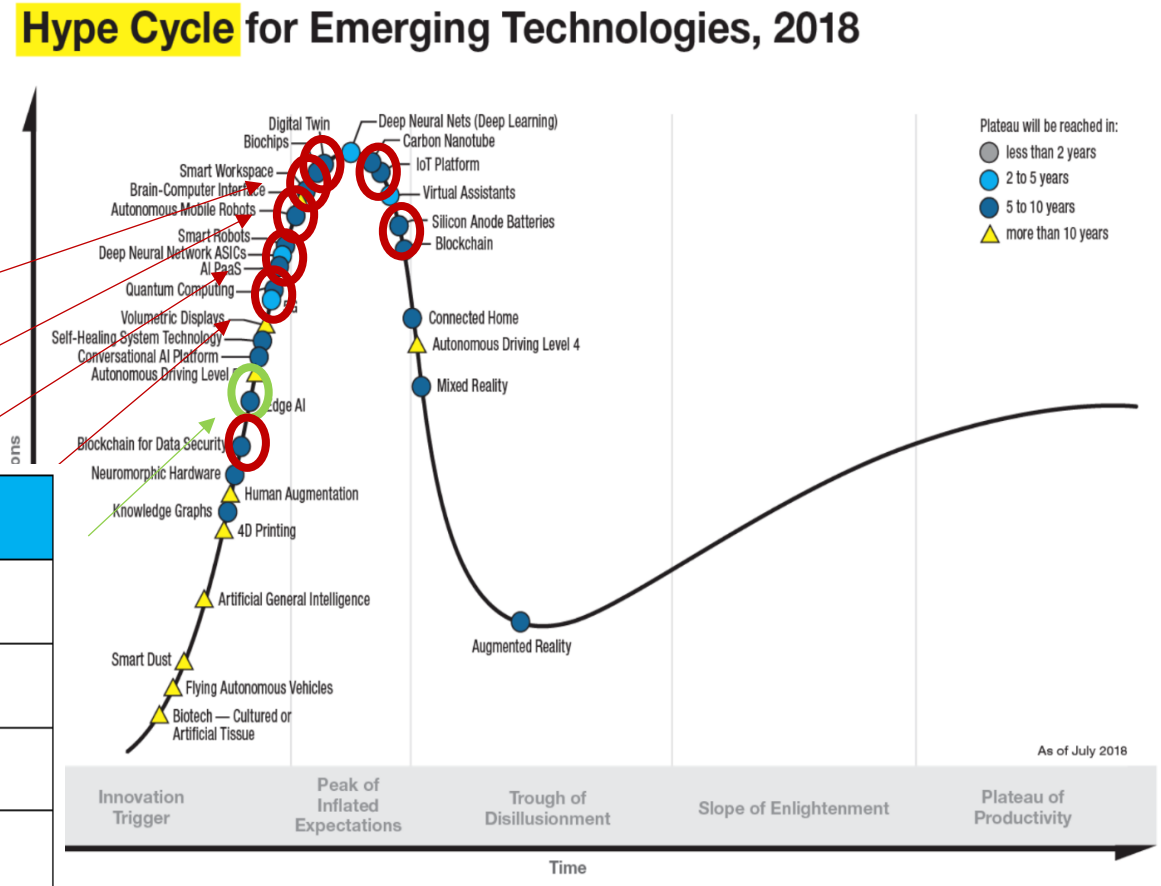


Image: AI Index Report 2018

Digital technologies prioritization

- ENTSO-E has identified 30 relevant technologies within the Gartner Hype Cycle and has run an internal consultation to get insights on the priority.
- The TOP10 digital technologies (predominantly in the zone of Innovation trigger or on Peak of inflated expectations):

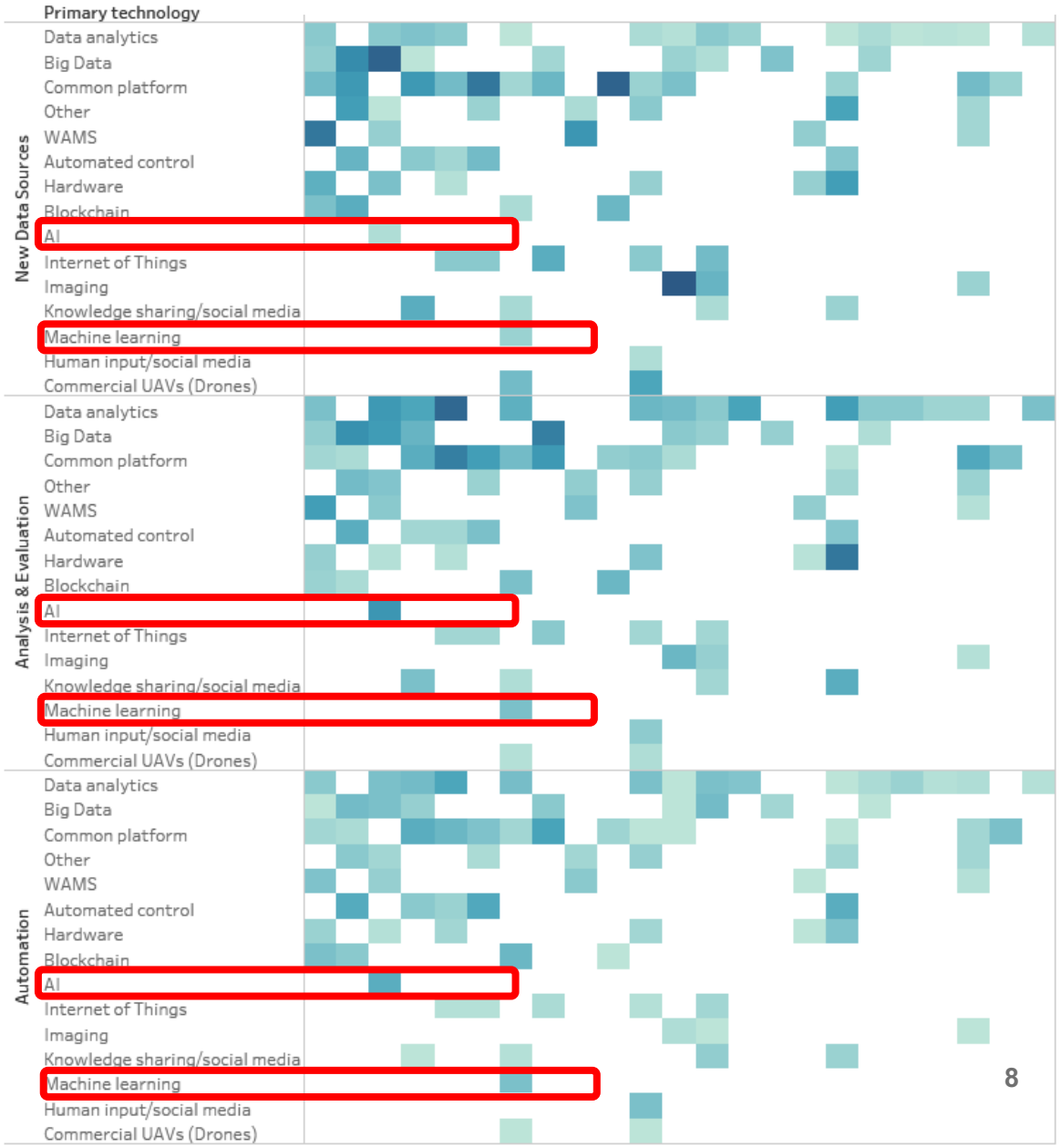


TOP 10 Digital technologies for the power system	
1. Artificial Intelligence	6. Distributed ledger technologies
2. Machine learning	7. Software Defined Security
3. Digital Twin	8. Smart robots
4. Internet of things	9. Edge computing
5. 5G	10. Cloud computing

INTELLIGENCE IN TSO BUSINESS:
State of art

- Only a few TSOs applies AI related technology to their processes
- In all the digitalization processes: new data sources, analysis and evaluation of data, automation
- Artificial intelligence and Machine learning, not yet cognitive computing or deep learning

Application of Digital Technologies
(17 TSOs sample)



AI Opportunities for TSOs

Power system operations

- fault location
- risk assessment

Pattern generation and forecast

- demand
- wind
- flexibility

Asset management

- identification of replacement and upgrading
- image analysis (captured from drones)

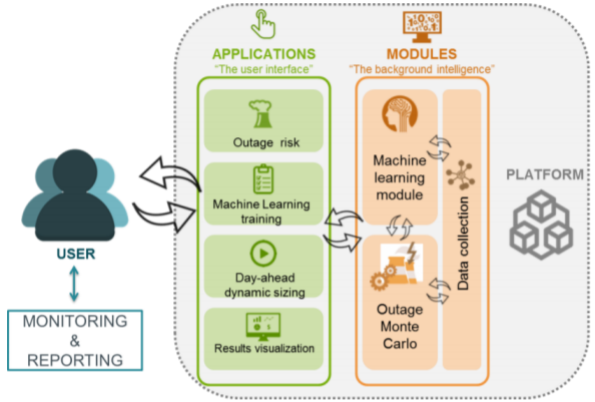
Market algorithms

- new algorithms for balancing

Innovation is key

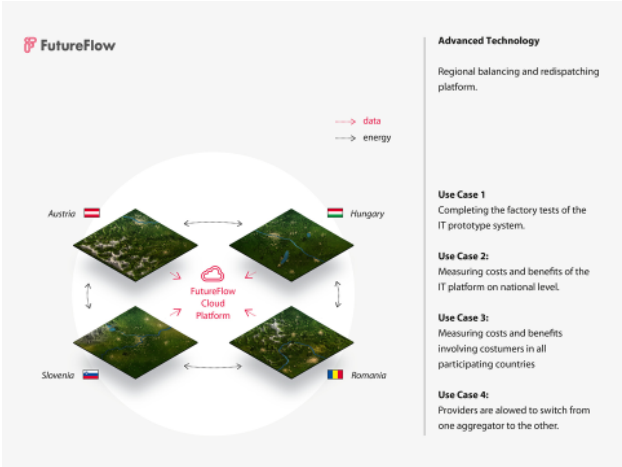
DYNAMIC DIMENSIONING OF THE FRR NEEDS

Forecasting method to size the balancing reserve needs dynamically close to real time.



FUTURE FLOW

Design of e-Trading solutions for electricity balancing

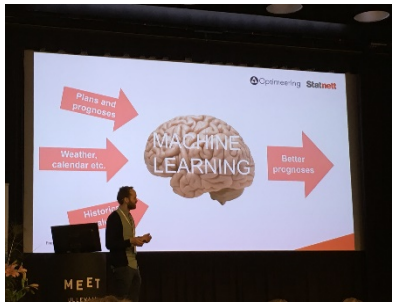


GARPUR

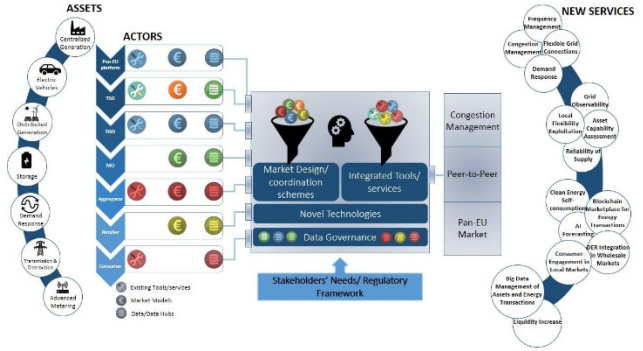
Machine learning for probabilistic analysis

IMPALA

Imbalance Prediction with Advanced Learning Algorithm



INTERRFACE PROJECT



Demonstrate an Artificial-Intelligence-based advanced forecasting tool

ENTSO-E UPCOMING CONFERENCES

INNOGRID2020+

the innovative power conference

May 13-14 2019 • Brussels

Connecting physics and digits: Power Platforms on the rise


APG
AUSTRIAN POWER GRID
WE KEEP IT GOING
TenneT
Taking power further
SONI
elering
GENERATING OPPORTUNITIES
LANDSNET
Transelectrica
ESO EAD
VORARLBERGER
ÜBERTRAGUNGSNETZ
GmbH
amprion
ΜΕΠΣΟ
nationalgrid
ΔΣΜΚ
RED ELÉCTRICA
DE ESPAÑA
Terna
EMC
OST
ADMHE
swissgrid
TenneT
Taking power further
ČEPS, a.s.
FINGRID
LITGRID
SVENSKA
KRAFTNÄT
NOSBiH
НОСБиХ
50hertz
Powering a world in progress
HOPS
Statnett
Rte
Le réseau
de transport
d'électricité
creos
ELES
TRANSNET BW
MAVIR
HUNGARIAN INDEPENDENT
TRANSMISSION OPERATOR COMPANY LTD.
PSE
elia
ENERGINET
AST
Slovenská elektrizačná
prenosová sústava, a. s.
SP ENERGY
NETWORKS
REN
Redes Energéticas Nacionais
entsoe
EIRGRID
sse
Scottish Hydro
CGES
CRNOGORSKI
ELEKTROPRENOSNI
SISTEM
TEİAŞ

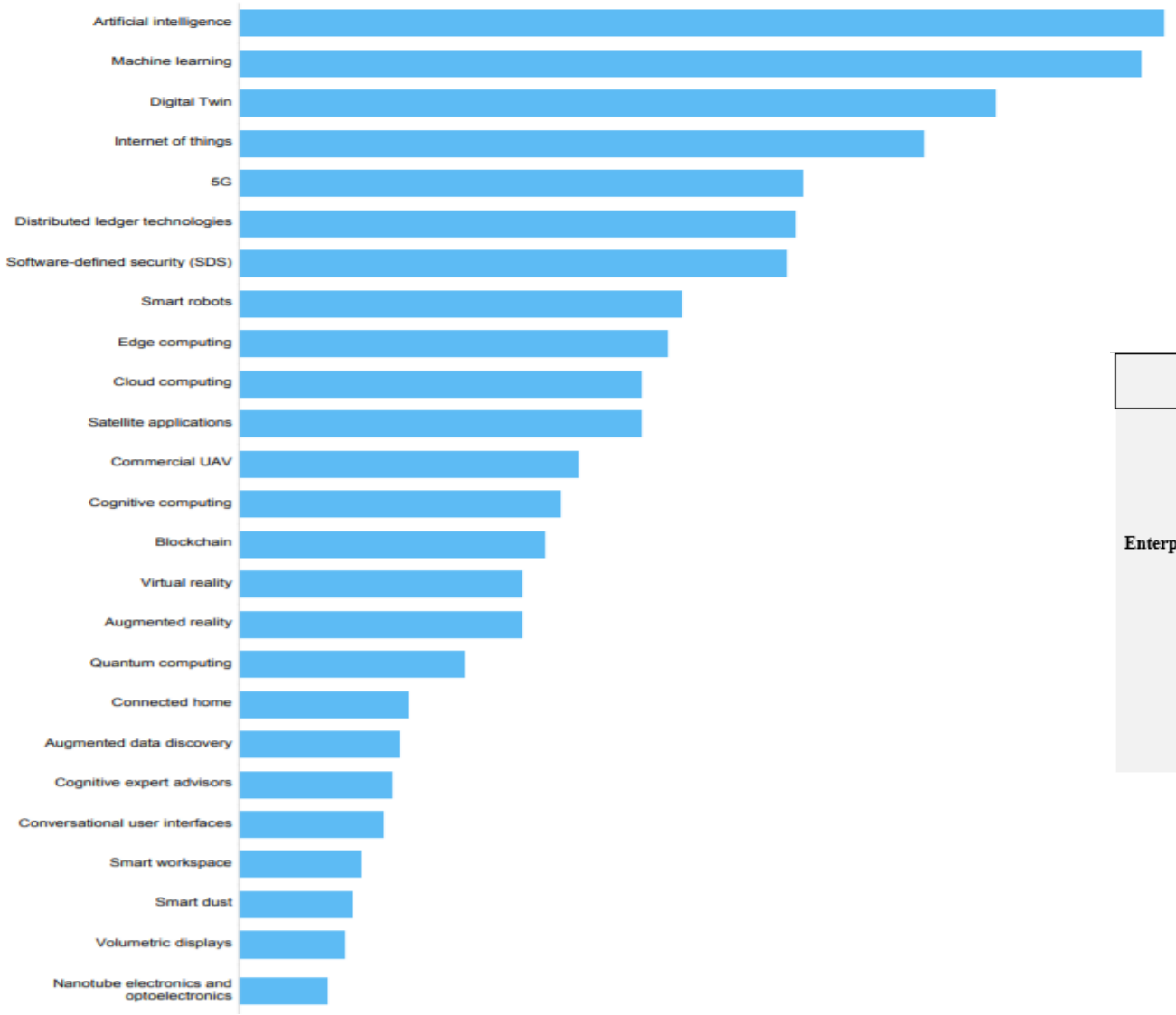
Background for AI

The power system of the future requires artificial intelligence

Virtualization	•Virtual reality •Augmented reality •Digital twin •Human Augmentation
Data exchange	•Augmented data discovery •Enterprise taxonomy and ontology management
Cybersecurity	•Software-defined security (SDS)
Intelligence	•Artificial Intelligence •Cognitive computing •Machine learning •Deep learning
Robots and automation	•Smart Robots •Commercial UAVs (Drones) •Autonomous vehicles
Data management	•Distributed ledger •Blockchain

Computing	•Nanotube electronics a •Optoelectronics •Edge computing •Cloud computing
Connectivity	•Connected home •Smart workspace •Internet of Things
Interfaces	•Conversational user interfaces •Virtual assistants •Cognitive expert advisors •Volumetric displays •Brain-computer interface
Communication	•5G •Satellite
Manufacturing	•4D printing •Smart dust

Digital technologies prioritization



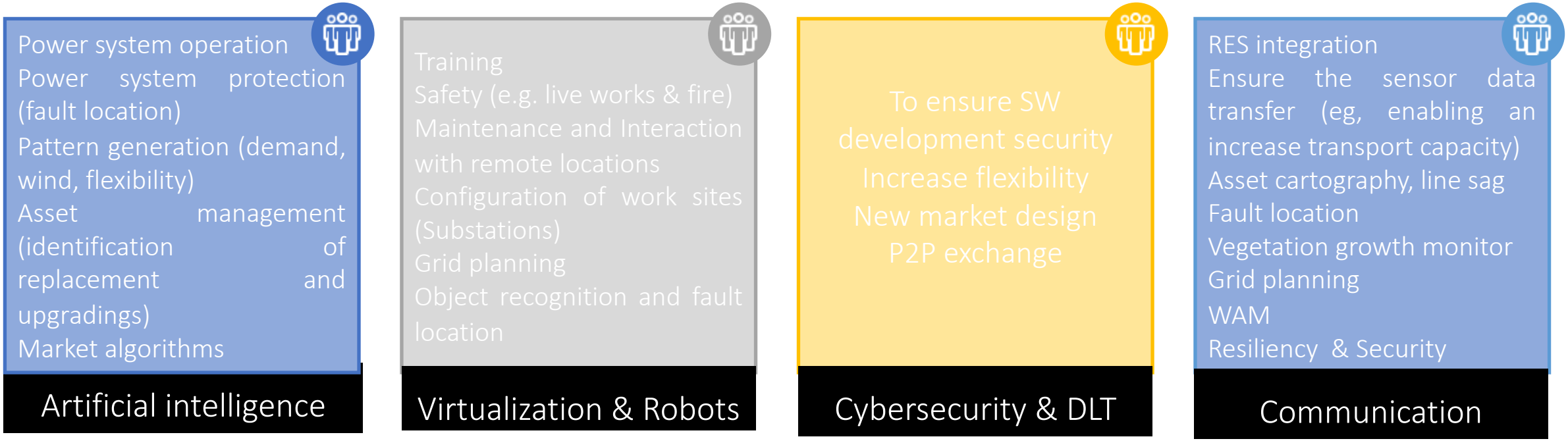
Results of the survey on technologies ranking

- Innovation hub expert opinion of the following TSOs

Technology	spread (st.dev)
Virtual Reality	5,9
Augmented reality	5,0
Digital Twin	5,8
Human Augmentation	3,7
Augmented data discovery	5,5
Enterprise taxonomy and ontology management	1,8
Software defined Security (SDS)	6,3
Artificial Intelligence	5,8
Cognitive computing	6,0
Machine learing	5,4
Smart robots	6,8
Commercial UAV	5,0
Autonomous vehicles	3,3
Distributed ledgers technologies	7,1
Blockchain	6,8

Quantum computing	5,1
Nanotubes electronics and optoelectronics	4,5
Neuromorphic hardware	4,5
Edge computing	6,9
Cloud computing	5,6
Connected home	5,6
Smart workspace	4,9
Internet of things	6,6
Conversational user interfaces	4,1
Cognitive experts advisors	4,3
Volumetric displays	4,2
Brain-computer interface	0,0
5G	7,0
Satellite applications	4,5
4D printing	1,5
Smart Dust	4,6

Key applications: Power system operation, fault location, Training, pattern identification and market algorithms



TECHS	TECH	TECH	TECH
Artificial intelligence	Virtual reality	Software-defined security (SDS)	5G
Cognitive computing	Augmented reality	DLT	Satelliltes
Machine learning	Digital twin	Blockchain	
Deep learning			

AI & ELECTRICITY:

SATELLITE TECHNOLOGIES AND SMART GRID

24 APRIL 2019

WEBINAR BY

BUSINESS NETWORK INNOVATION

WITH

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Space services in energy & case studies

Davide.Coppola@esa.int

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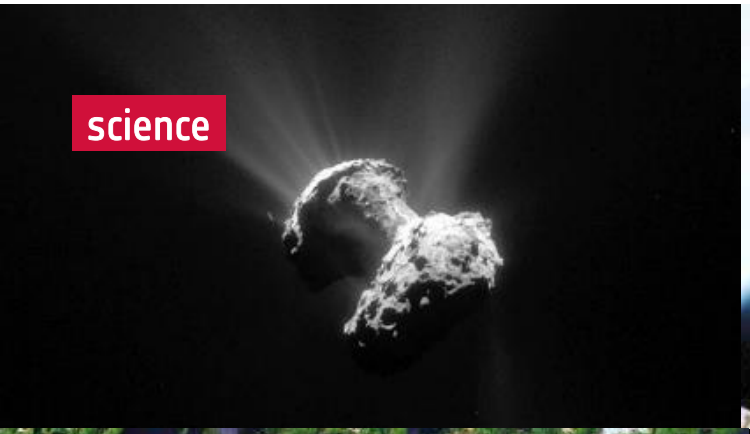
ESA facts and figures

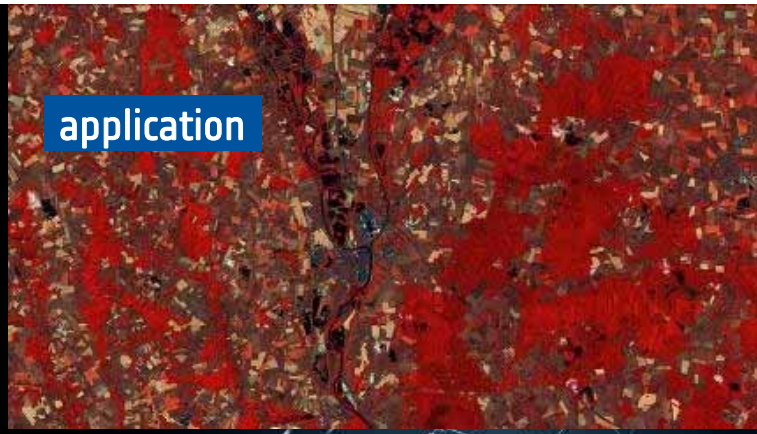
- Over 50 years of experience
- 22 Member States
- Eight sites/facilities in Europe, about 2300 staff
- 5.75 billion Euro budget (2017)
- Over 80 satellites designed, tested and operated in flight

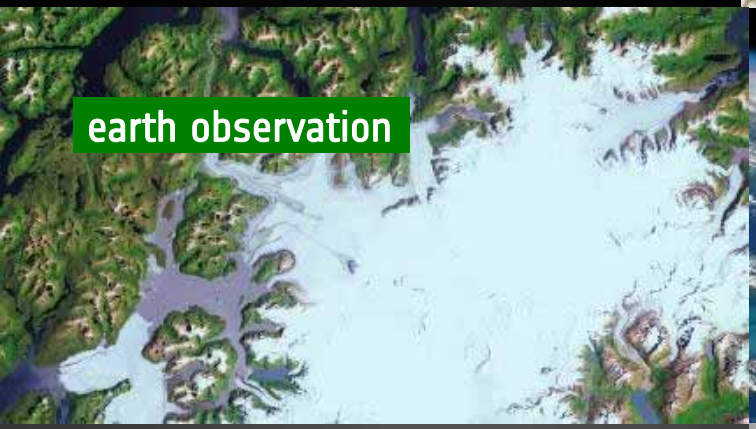
"To provide for and promote, for exclusively peaceful purposes, cooperation among European states in space research and technology and their space applications."

Article 2 of ESA Convention


science

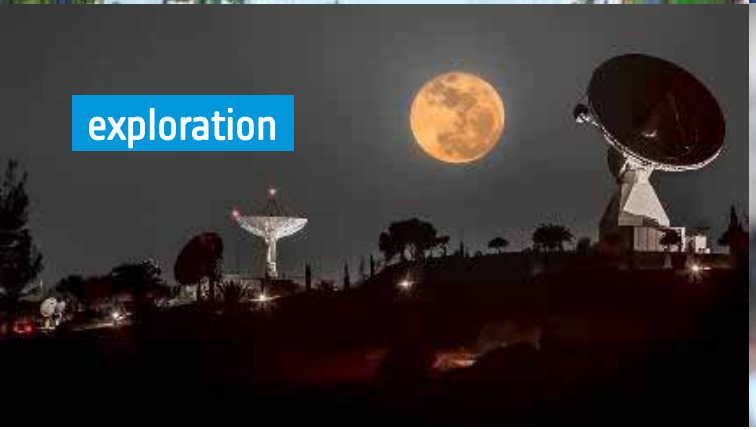

human spaceflight


application


earth observation


space transportation


navigation


exploration


technology


telecommunication

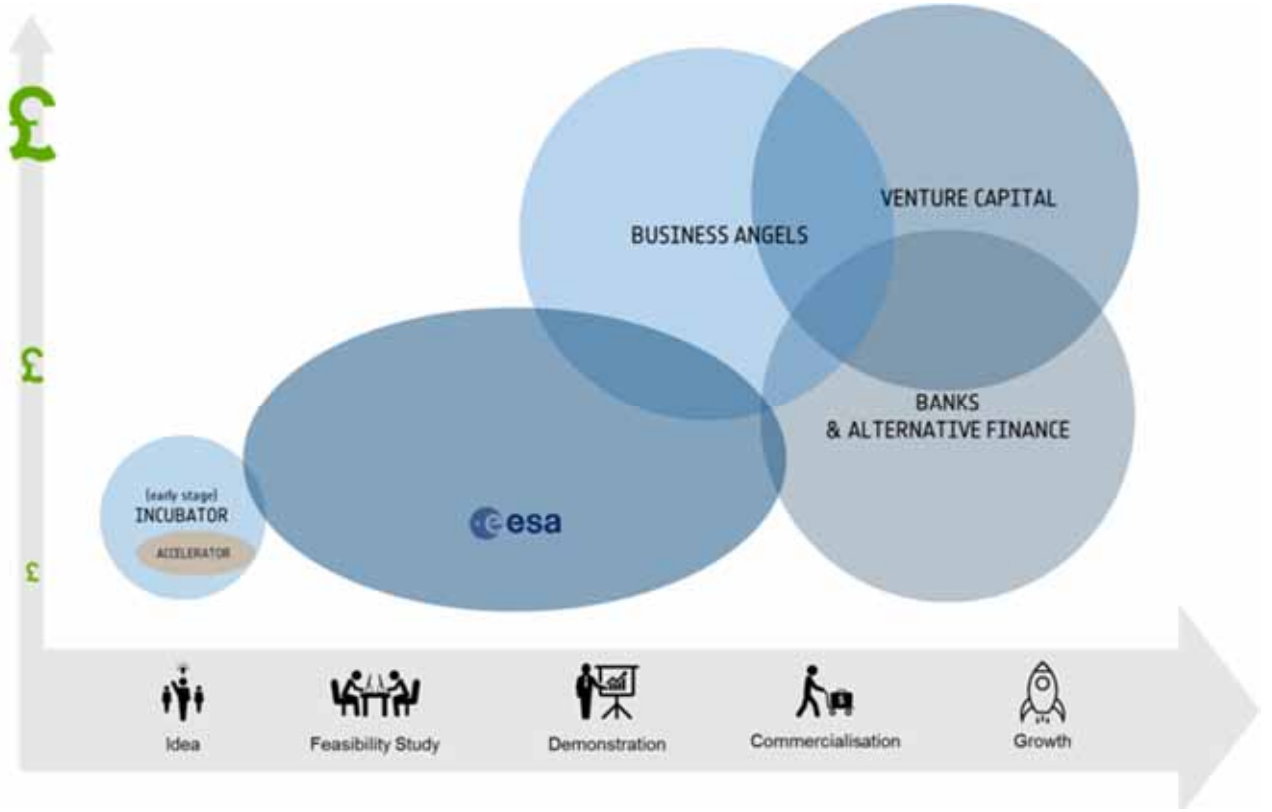
➔ WHAT FOR?

Could you be leveraging Space technology and data for the benefit of life on Earth?

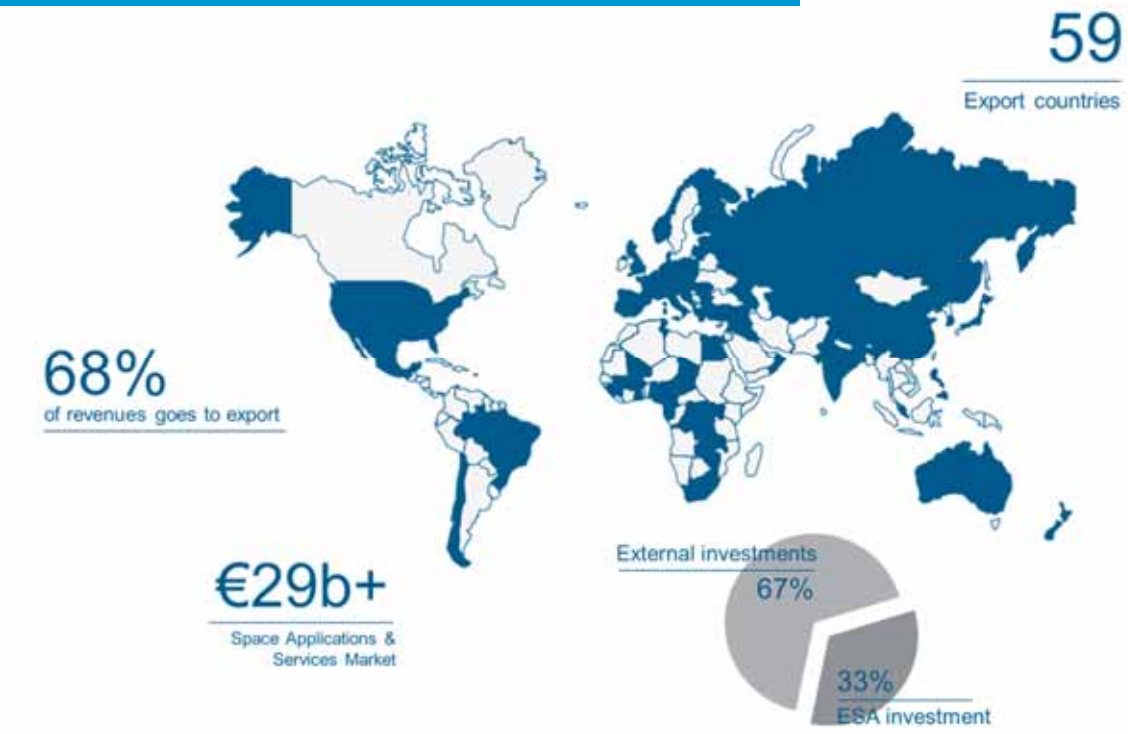
→ GEARED TOWARDS SUSTAINABILITY

User Demand → **Feasibility Study** → **Demo** → **Operational Service**

- FINANCIAL SUPPORT
- TECHNICAL & BUSINESS EXPERTISE
- ESA BRANDING & PROMOTION
- NETWORK & PARTNERSHIP BUILDING



➔ WHAT FOR?



*Socio-economic assessment of 60 out of 320 projects (September 2016)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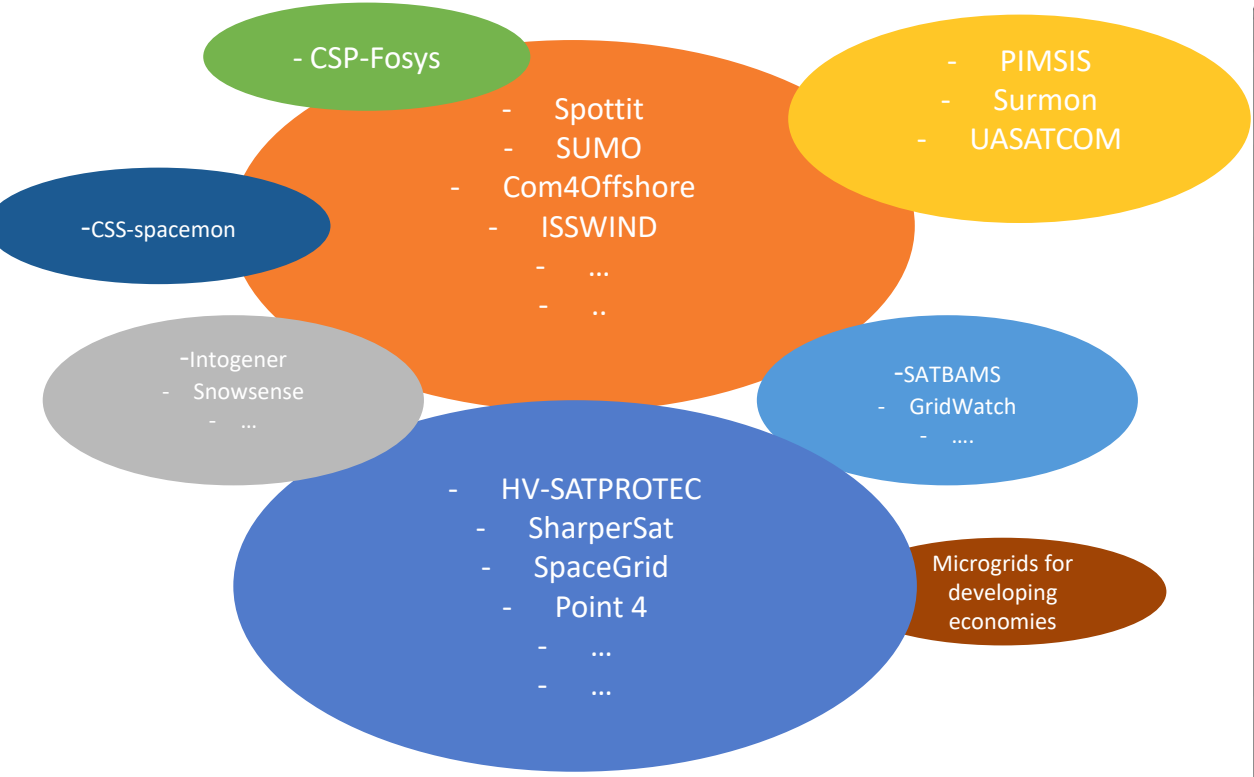
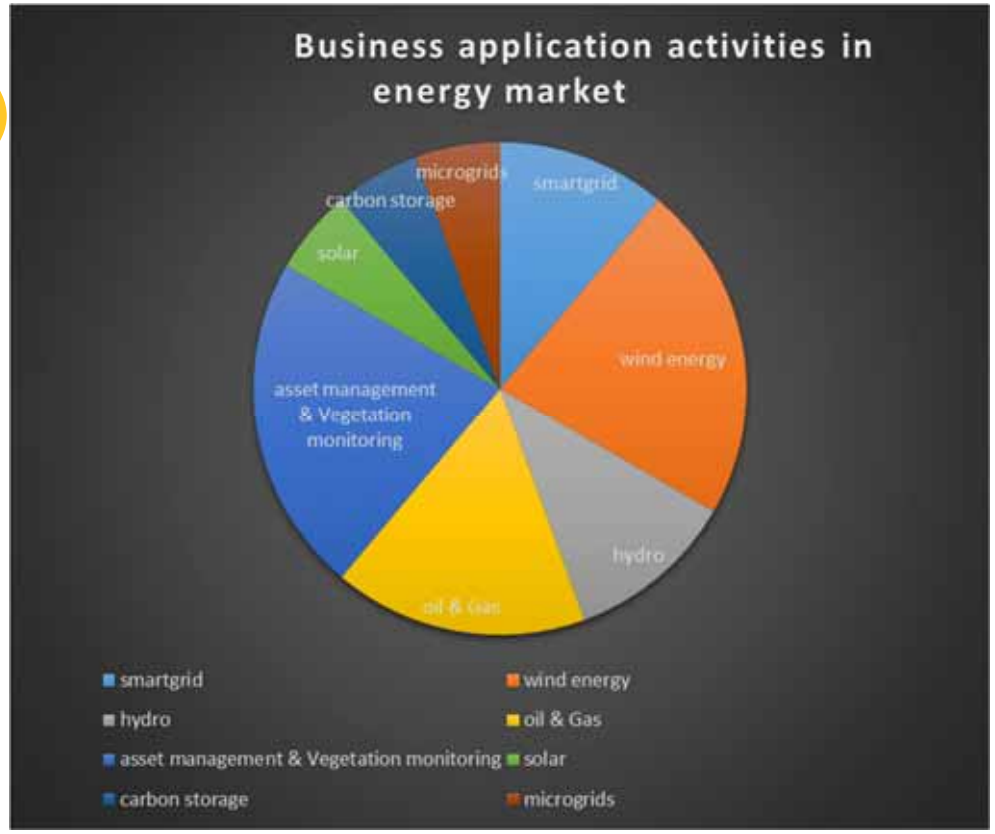
ESA BUSINESS APPLICATIONS AND ENERGY
European Space Agency

ESA Business Applications

→ Project examples

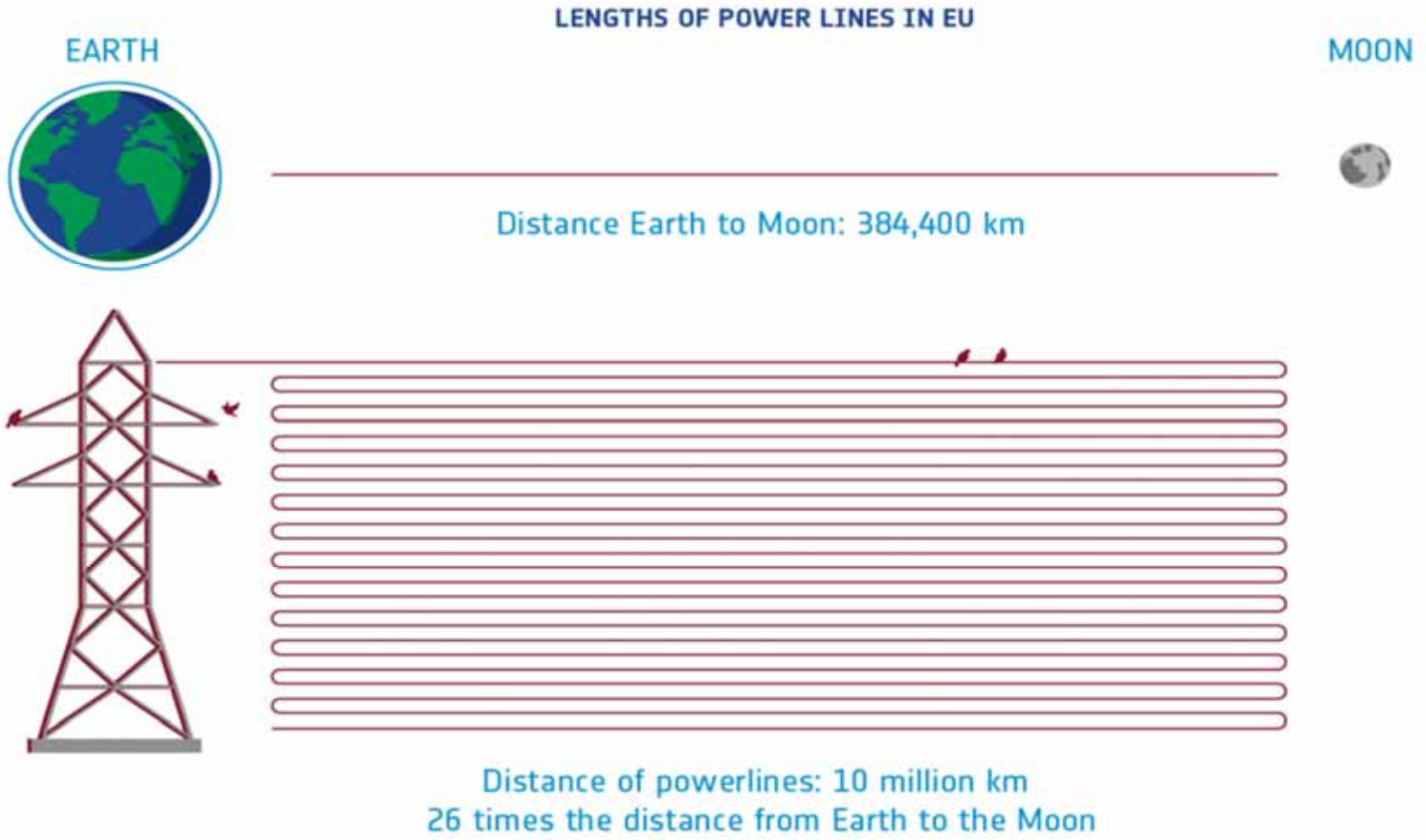




Energy critical infrastructure monitoring

→ WHY DOES SPACE DATA MATTER?

An overview of localised conditions and changes throughout vast land areas or cities over time is vital in the continuous maintenance and operation of these services. This is only possible as a result of satellite technology.



Vegetation monitoring

→ WHY DOES SPACE DATA MATTER?

Earth Observation optical and Earth Observation SAR data provide information on: tree species & height estimation, determination of the position of trees with respect to power lines. By knowing the tree specie and environmental condition (including weather), a prediction of vegetation growth can be modelled.

RENEWABLE ENERGY

→ WHY DOES SPACE DATA MATTER?

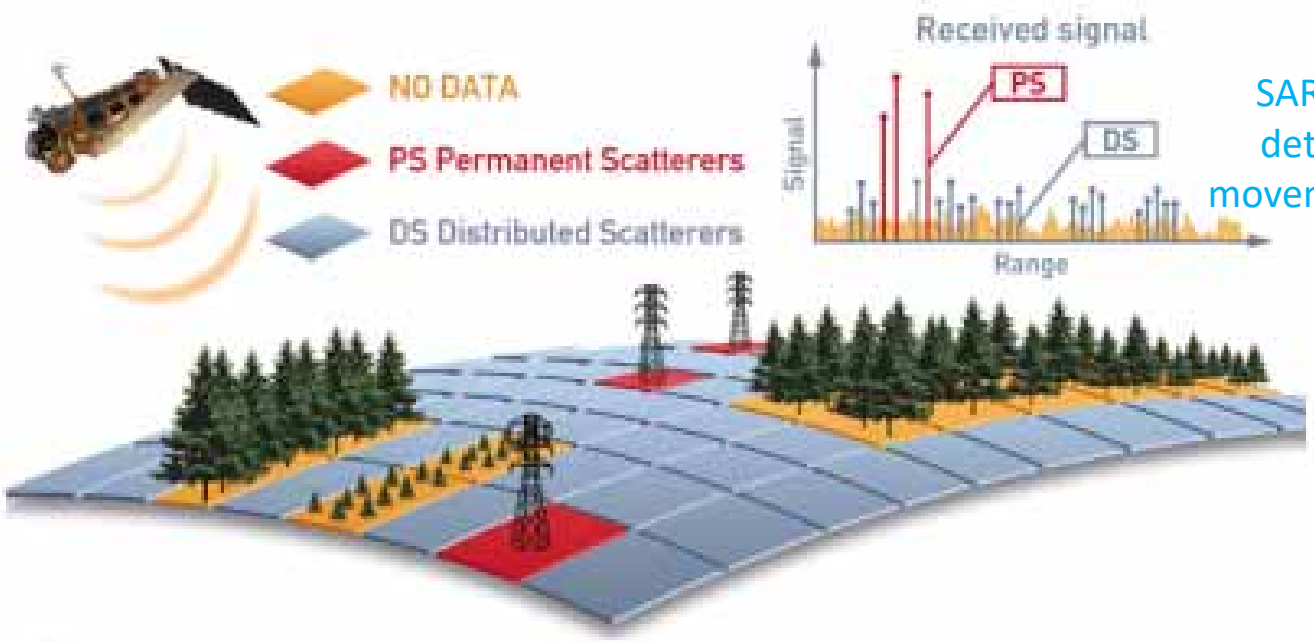
The weather plays a huge role in the level of energy produced from renewable sources. This is where Earth orbiting satellite data can be utilised for maximum effect. Highly accurate weather forecasting will help solar, wind and hydro energy output predictions.

Pylon movements and ground displacement

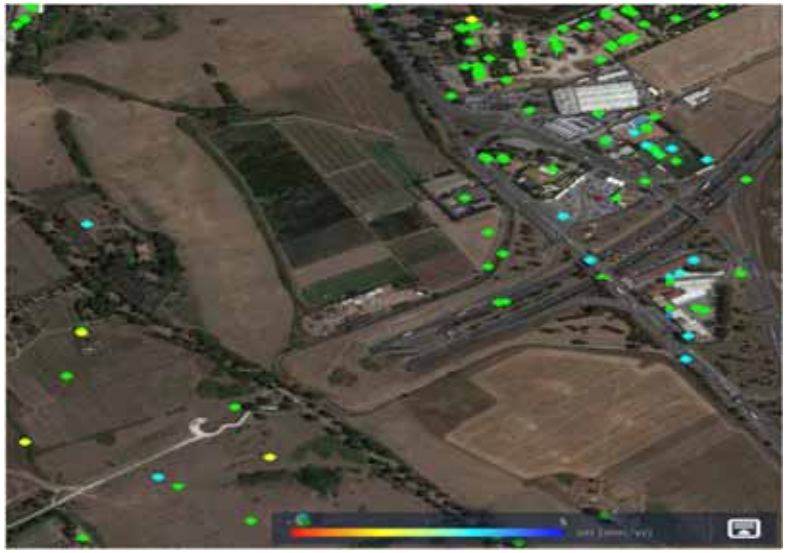
Distribution tower collapsed because of the wind *Credit: GridWatch IAP project https://business.esa.int/projects/gridwatch*

Pylon movements and ground displacement

→ GridWatch: project example



SAR images are used for the detection of small and slow movements of pylons and ground



Displacement map using satellite SAR data

Credit: GridWatch IAP project
https://business.esa.int/projects/gridwatch

SPACE-BASED SERVICES FOR DISTRIBUTED ENERGY NETWORKS [SMART-GRIDS]

ESA'S FUNDED INVITATION TO TENDER

➔ SPACE-BASED SERVICES FOR DISTRIBUTED ENERGY NETWORKS

Objectives

- Assess **technical** feasibility and **economic** viability of **space** based applications for ***Smart*Grid** and **electricity grid maintenance & operations**
- Get **anchor customers commitment** towards services implementation and **sustainable operation**.
- Define a **roadmap** for services **implementation** and **demonstration** (potentially through a follow-up ESA co-funded project).

Invitation to tender closed in March 2019, evaluation on-going

KEY AREAS OF INTEREST

- **Smart Grids**: demand and response management, integration of electric vehicles into the electricity grid, home automation, virtual power plants and industrial microgrid management, etc.
- **Electricity grid maintenance:** conductivity and hot spot measurements, vegetation and infrastructure monitoring, weather event impacts on energy infrastructure and supply, assessment of building electrical consumption, use of satellite communication for utilities, etc.
- **Technology enablers**: Data analytics & big data, artificial intelligence, internet of (nano-) things, cybersecurity, 5G, etc.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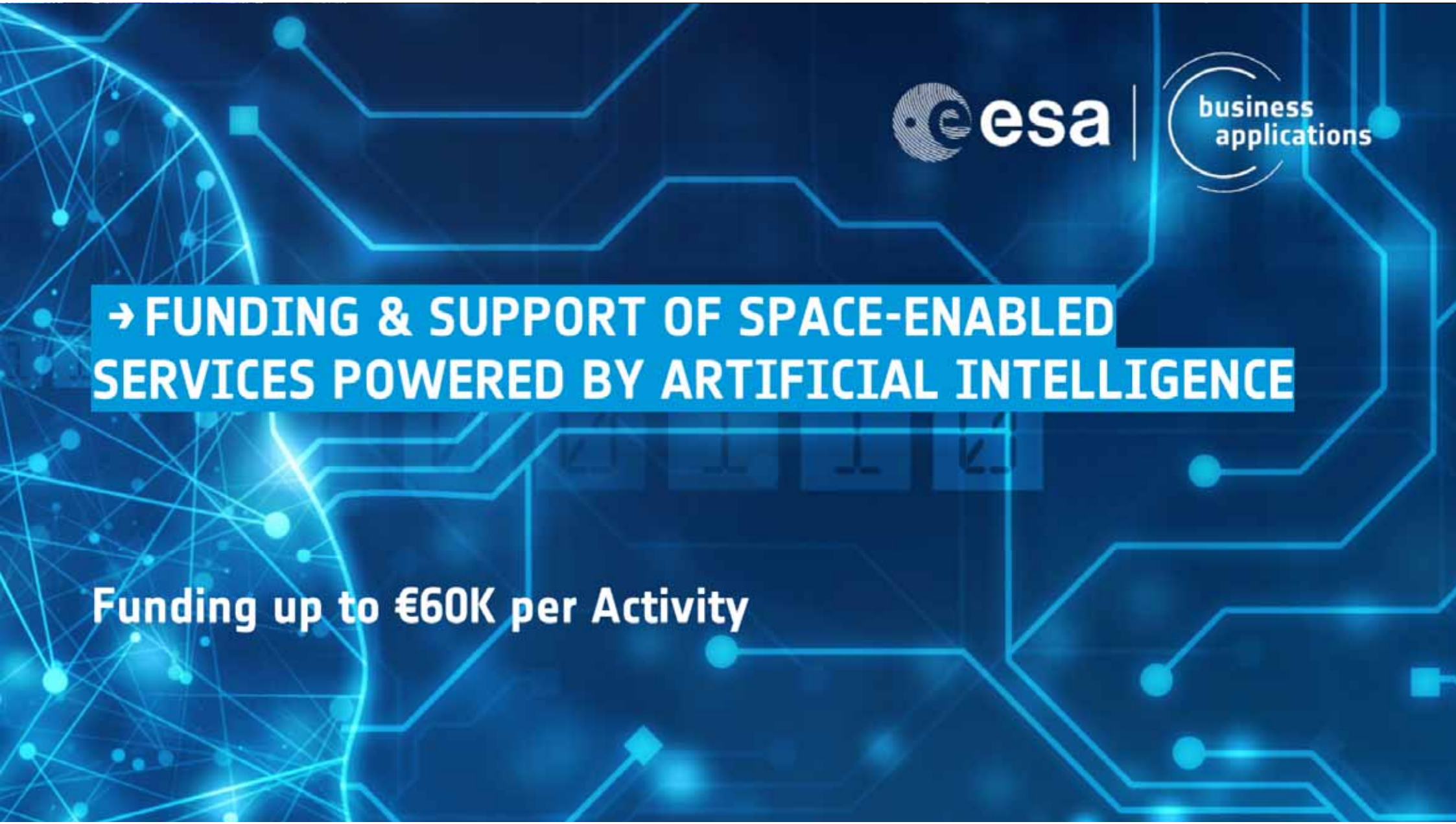
➔ WHAT'S NEXT?
European Space Agency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→ FUNDING & SUPPORT OF SPACE-ENABLED SERVICES POWERED BY ARTIFICIAL INTELLIGENCE
Funding up to €60K per Activity

AI ESA KICK START CALL

- The European Space Agency is offering **technical support** and **funding** to companies developing innovative and **commercial products** and services combining **Artificial Intelligence with space technology**.

- To find out more: https://business.esa.int/funding/invitation-to-tender/artificial-intelligence-kick-start

AI kick start

6 months duration

up to **€60K ESA funding** (75% ESA co-funding)

Develop business case for commercially viable services

- **Customer Engagement**
- **Technical Feasibility Assessment**
- **Commercial Viability Assessment**

➔ EXAMPLES OF AREAS OF INTEREST

Retail : customer behaviour, customer journeys and shopping experiences, etc.

Electric Utility: match energy supply to energy demand, energy renewable prediction, understand energy thefts, etc.

Social good: AI to make an impact on issues faced by societies.

Healthcare : Leveraging aggregated medical and social data to better manage costs, forecasting, etc.

Manufacturing, Transport and Logistics: supply and demand planning, sales lead identification and price optimization, etc.


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→ FUNDING & SUPPORT OF SPACE-BASED SERVICES FOR CYBER SECURITY
Funding up to €200K per Activity
Opens: End of August 2019

CYBER SECURITY AND SPACE-BASED SERVICES
CALL FOR TENDERS

- Investigate **new services and solutions** in support of cyber security
  - **enabled by Space** (SatCom, SatNav, SatEO)
  - and/or **enhancing end-to-end cyber security** of **Space based applications**

- For the following domains
  - Transport (maritime, land, air, incl. autonomous vehicles)
  - Critical Infrastructures
  - Energy
  - FinTech – financial services
  - Public Safety

- Targeting cyber security **prevention, protection, detection and response activities**

- Solutions combining space with innovative technologies such as **AI-ML, IoT, QKD,** etc., are encouraged

- Feasibility Study Objectives

- Assess **technical** feasibility and **economic** viability of **space** based services for cybersecurity
- Get **anchor customers commitment** towards services implementation and **sustainable operation,** and validate **value proposition**.
- Define a **roadmap** for services **implementation** and **demonstration** (potentially through a follow-up ESA co-funded project).

EMSA
enisa
EUROPEAN DEFENCE AGENCY
EDSO
EUROCONTROL
unicri

€ 200K, 100% funded,
duration 12 months
Tender to be issued on
22 August 2019
x parallel contracts

More information to come soon on :
https://business.esa.int/funding/invitation-to-tender/cyber-security-and-space-based-services

→ THANK YOU!

Davide.Coppola@esa.int

UCL

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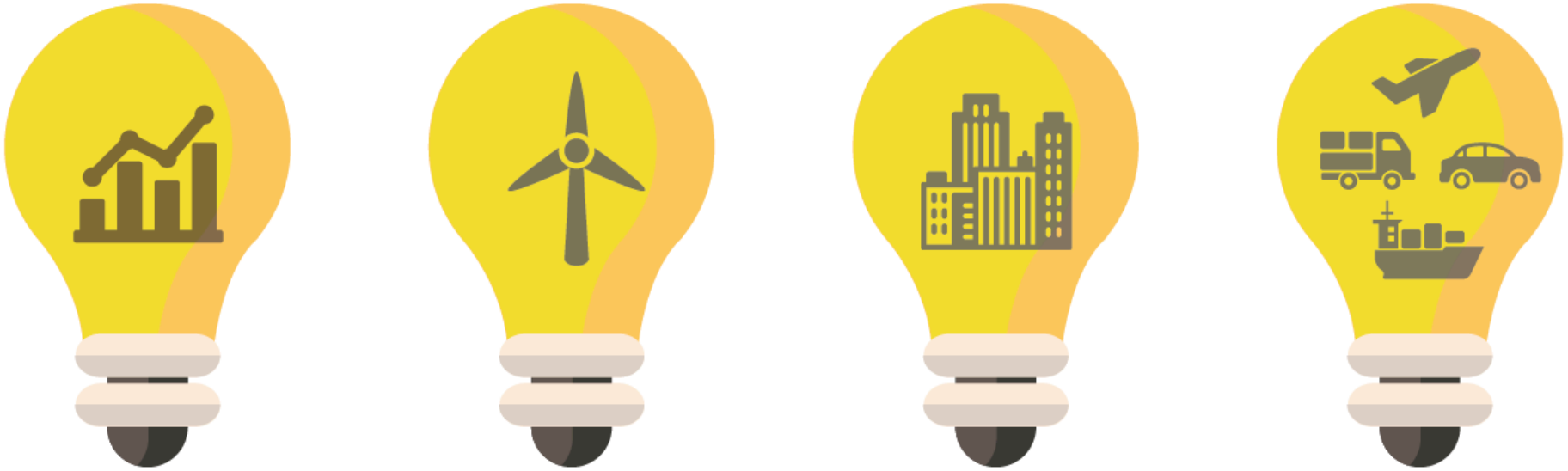
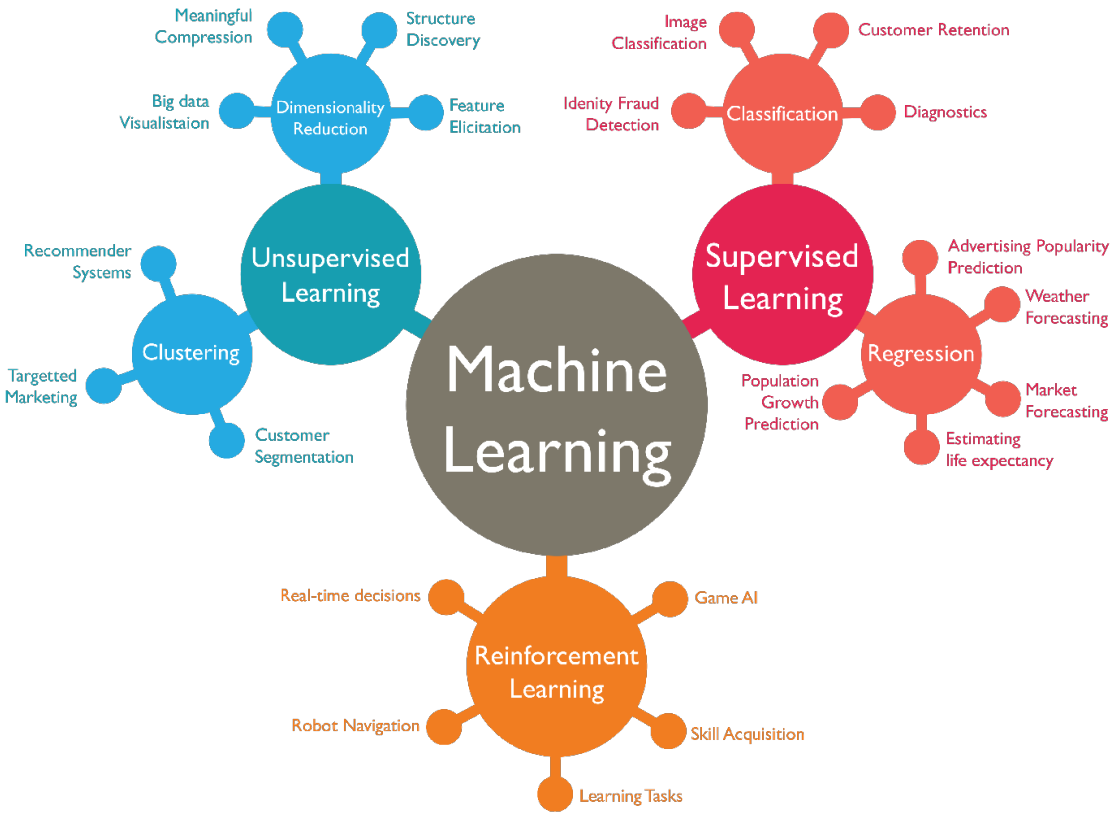
Energy and Artificial Intelligence

Dr. Aidan O'Sullivan
Head of Energy and AI Research Group



Machine Learning and AI Landscape



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Supervised Learning

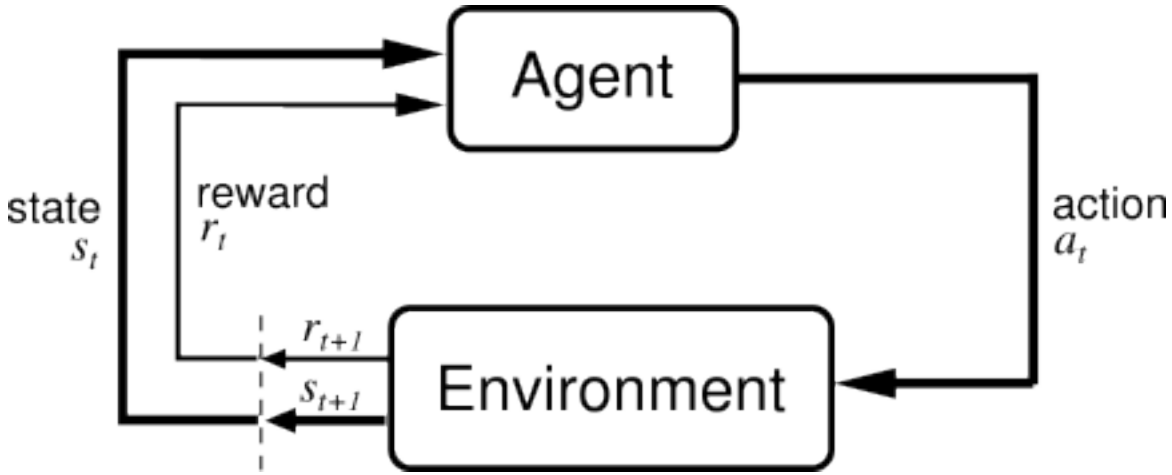
- Most of the value created by machine learning has been through supervised learning

- Mapping from input to output, lots of labelled data

Dog

Reinforcement Learning

- A different kind of problem set up



- Intelligent behavior in complex dynamic environments

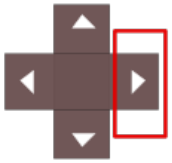
Reinforcement Learning

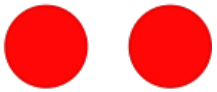
State
S_t

Agent

Reward
R_t

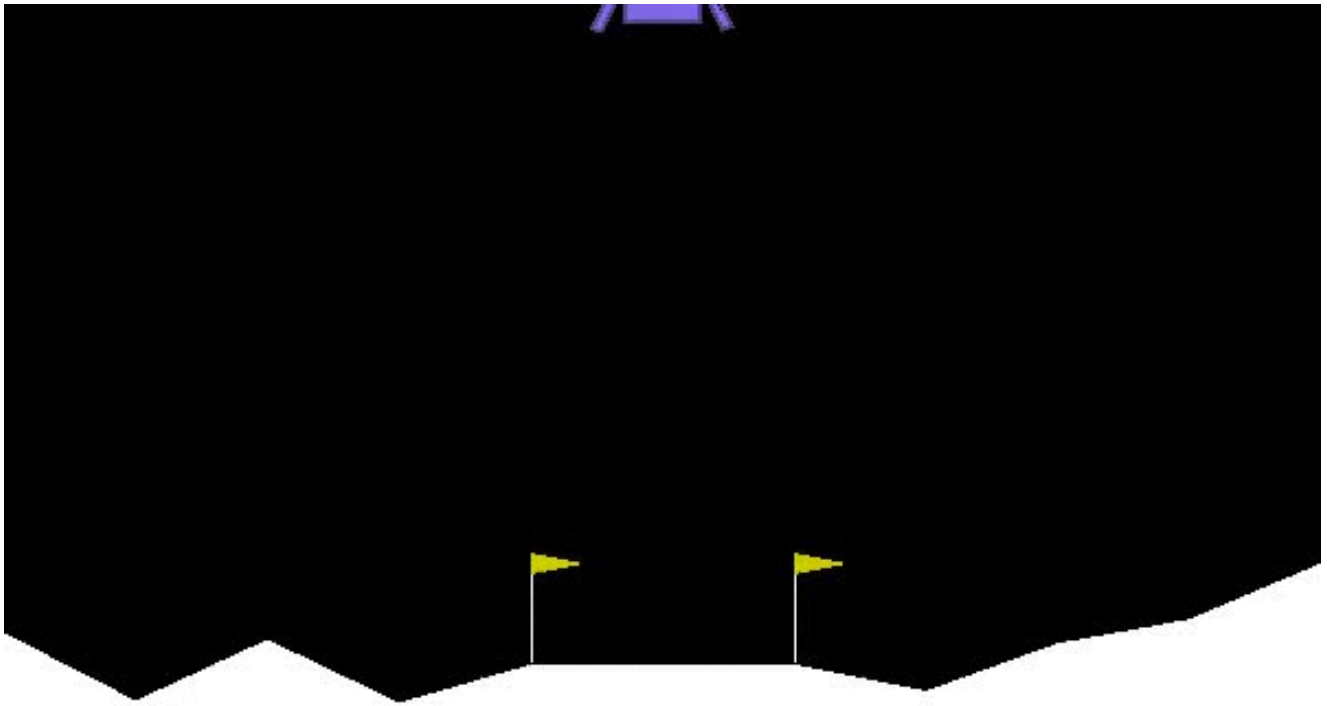
Environment



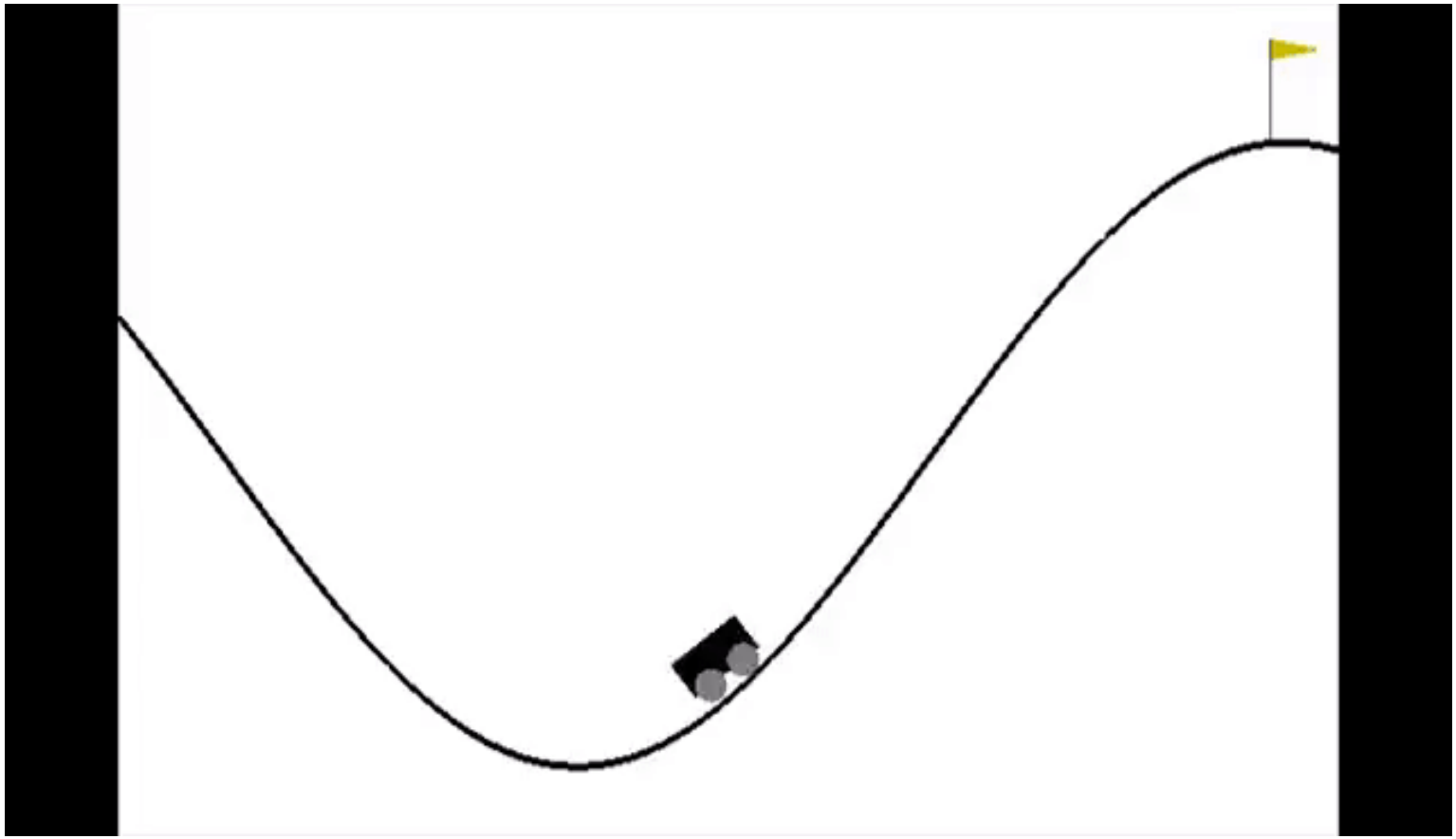


Action
A_t

Reinforcement Learning Classics: Lunar Lander

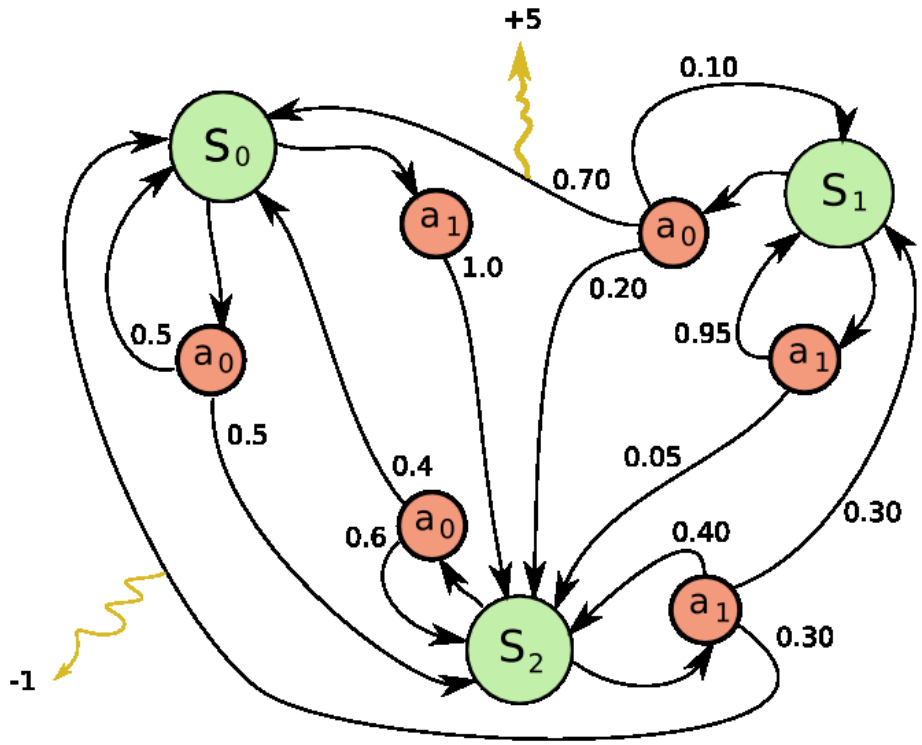


Reinforcement Learning Classics: Hill Climb



Reinforcement Learning Classics: Cartpole

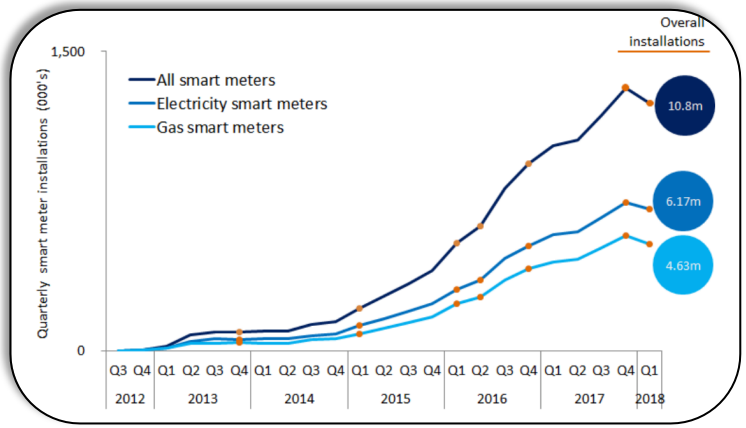
Reinforcement Learning: States + Actions MDP

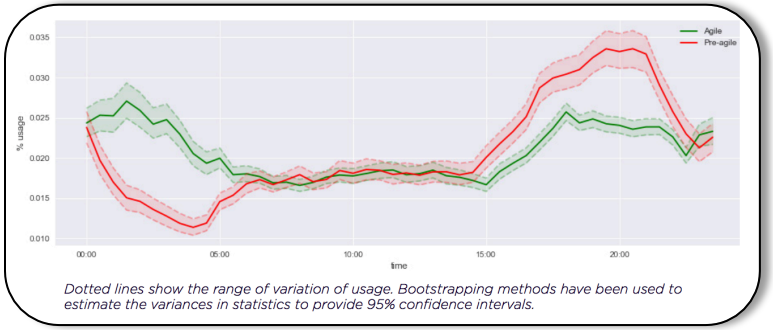


Enabling AI in The Energy Sector

- Progress and development in RL opens up new applications
- However:
  - AI requires data
  - Need to be able to simulate environment, realistically
  - A well defined reward function
- Currently `narrow AI'
  - Can train algorithms for specific tasks and decision making
  - Potential to exceed human performance
- A more open energy system enables greater innovation
- These elements are starting to come together

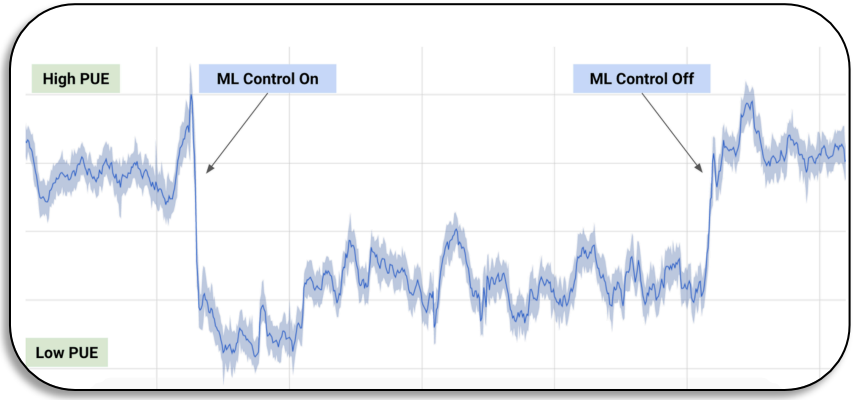
Examples





Dotted lines show the range of variation of usage. Bootstrapping methods have been used to estimate the variances in statistics to provide 95% confidence intervals.

octopus energy



UCL ENERGY INSTITUTE

Research taking place in the UCL Energy and Artificial Intelligence group

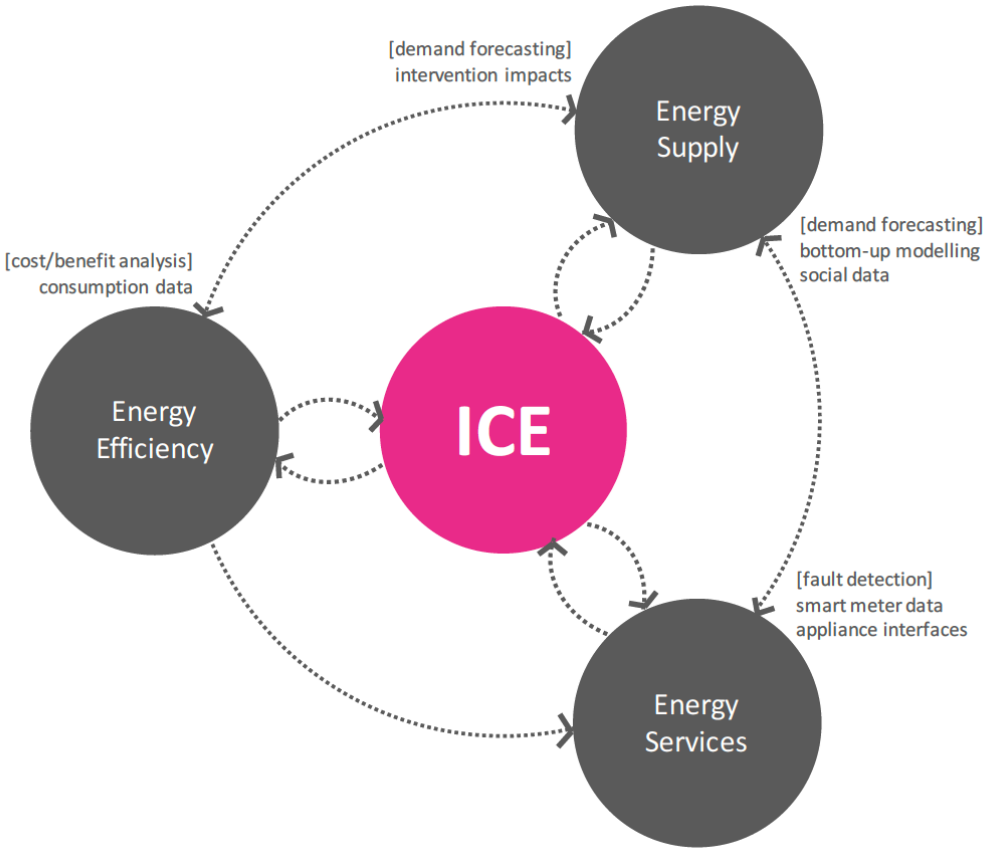
UCL ENERGY INSTITUTE


igloo.energy
Energy for the Connected Generation.

UCL Energy Institute - Igloo Collaboration

- Data driven decision making platform
- New **business model** for an energy provider
- Not based on volume of electricity sold – sustainability
- Offer smart energy products and services based on data unique to the customer

UCL Energy Institute - Igloo Collaboration



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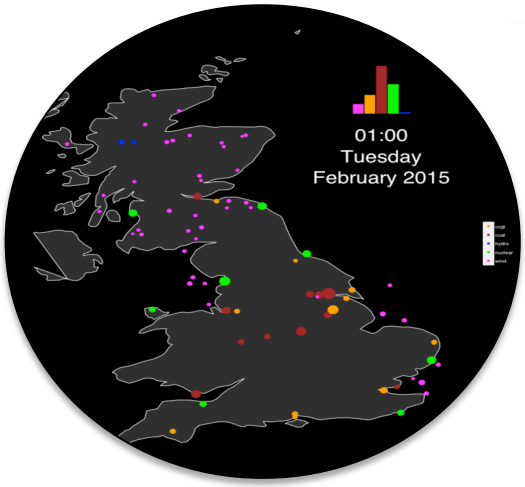
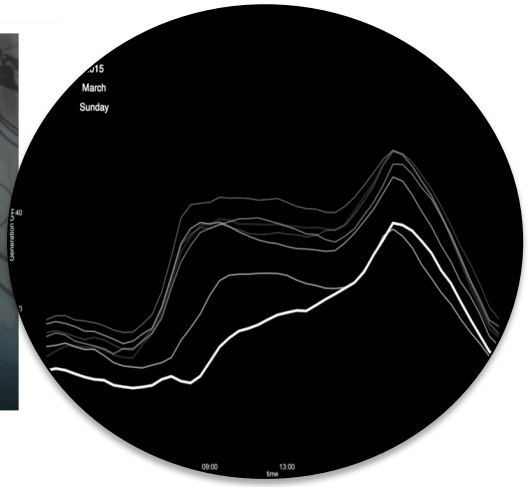
The Management of the Electric Grid





BRIEF

Report: Extreme weather power outages rising in US

- Grid – The most complex machine ever built
- Deals with incredible levels of variability
- Becoming more uncertain – Ideal Application for AI

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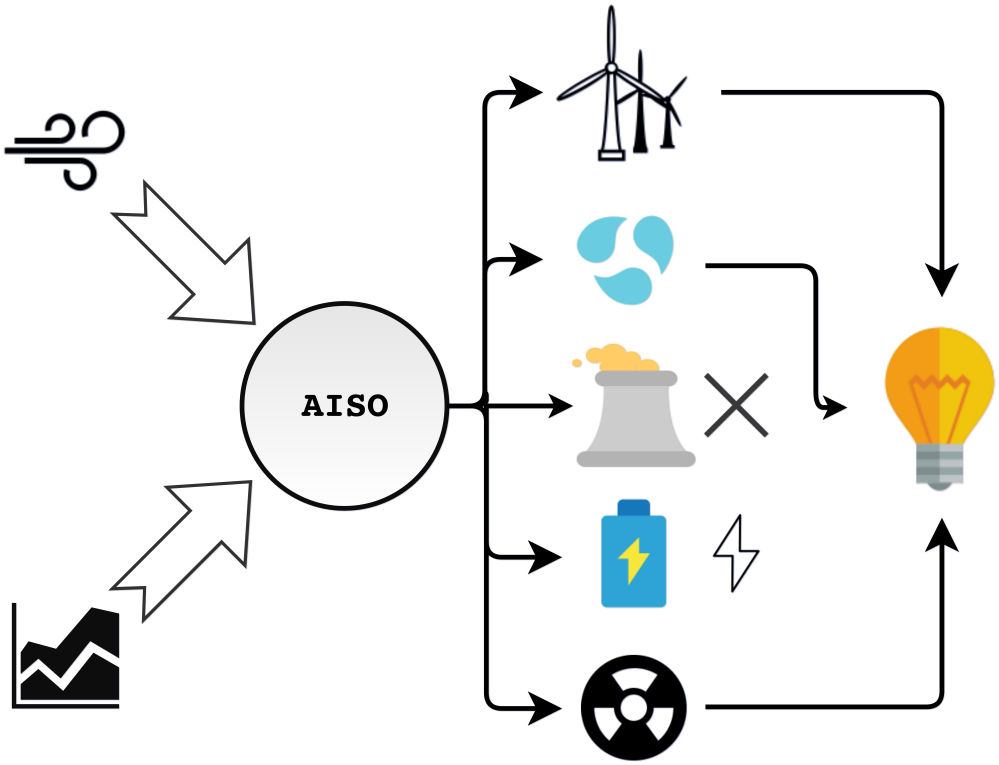
AISO

- Artificial Intelligence System Operator
- Schedule generation more optimally using reinforcement learning to minimize the cost of imbalance
- Highly complex non-linear problem ideally suited to AI
- Fast decision making ability
- Suited to stochastic environments (renewables penetration)

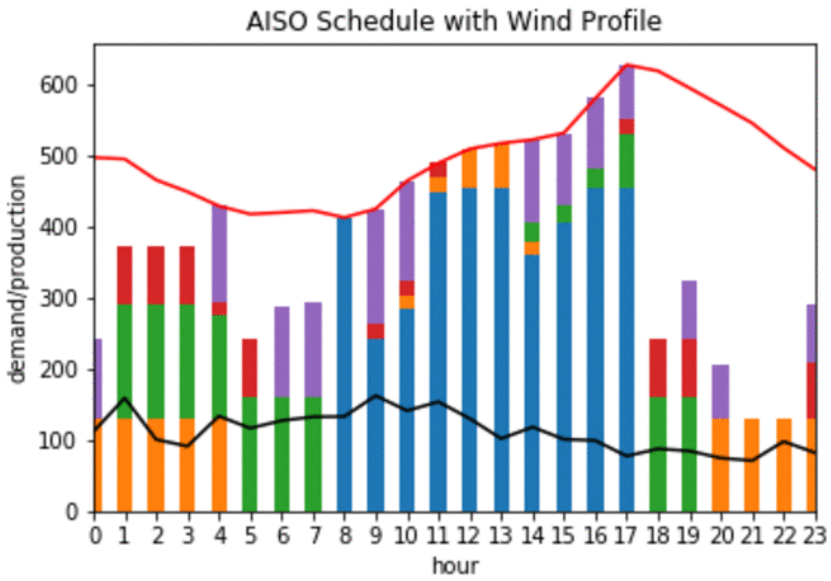
AISO - Structure

- Takes wind and load forecasts and state of the grid as input, outputs a generation schedule

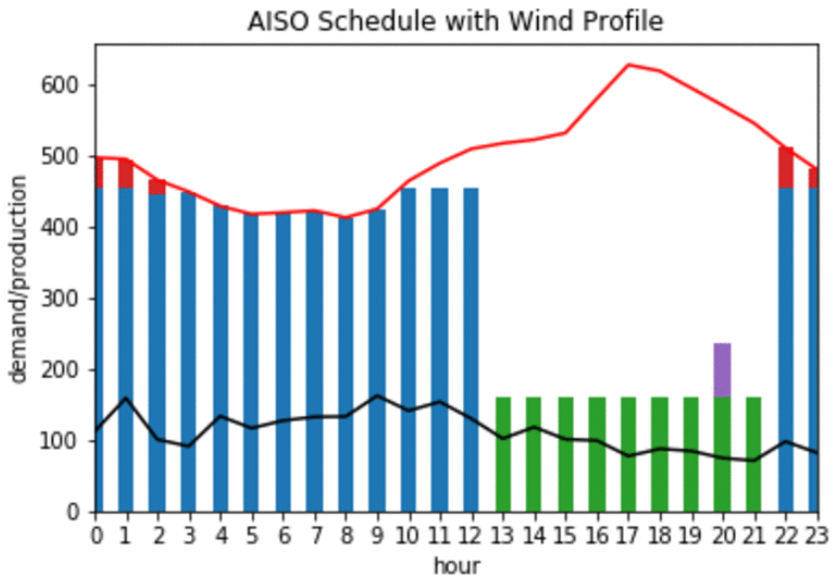


AISO – Learning

Training (trial and error)



Testing (best known policy)



patrick.demars.14@ucl.ac.uk

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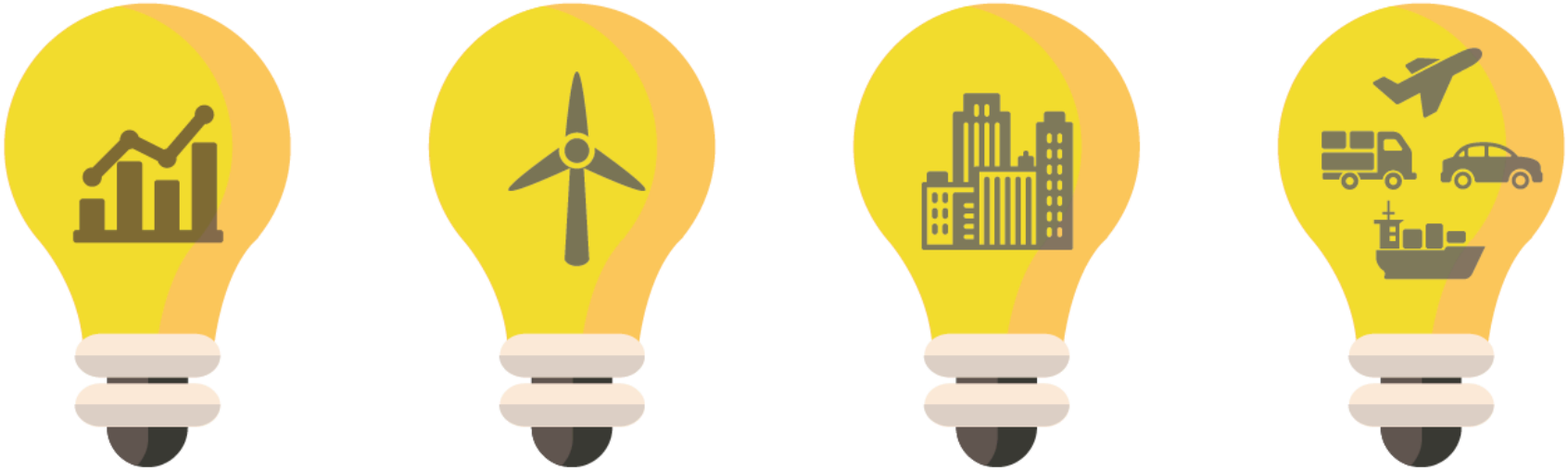
AISO - Applications

- Optimisation of transmission network (centralised system operator)
- Grid simulation studies: investigating the impact of storage
- Distribution system operation
- Microgrid operation
- Short-term balancing/emergency control

Energy Systems and Data Analytics MSc.



- Key skills gap in energy sector for machine learning expertise + energy systems
- First programme of its its kind - launched 2018

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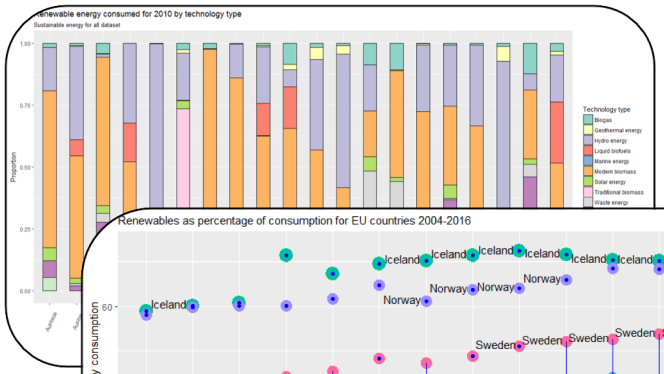
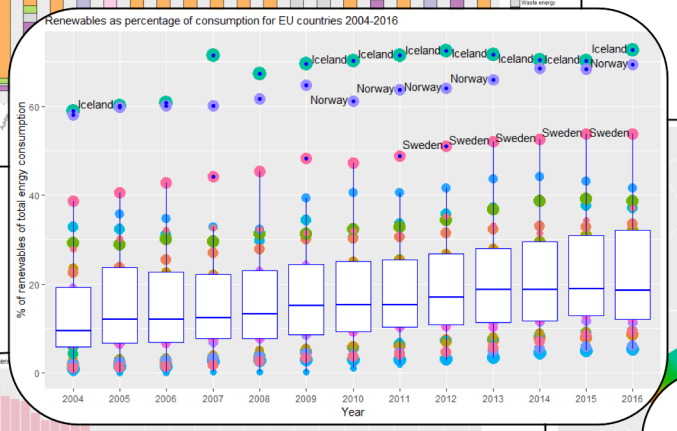
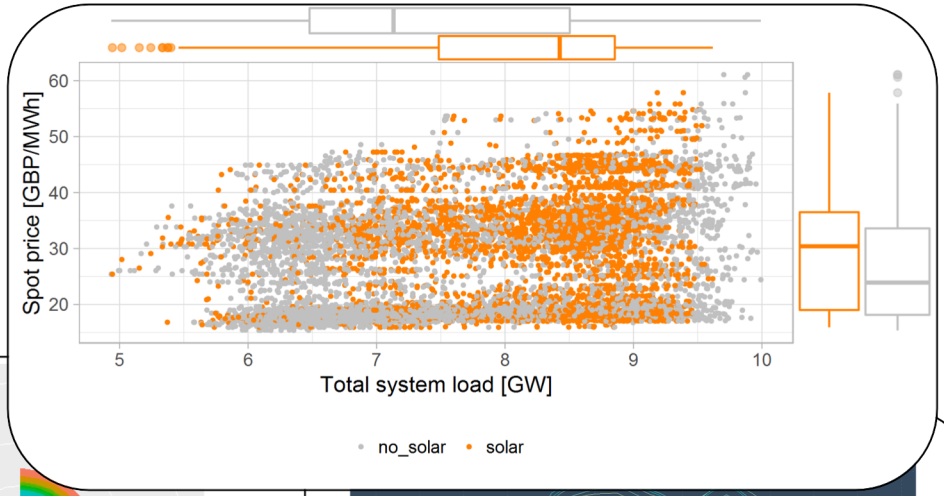
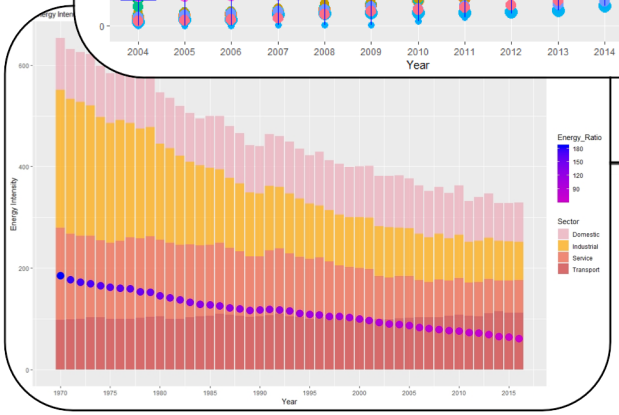
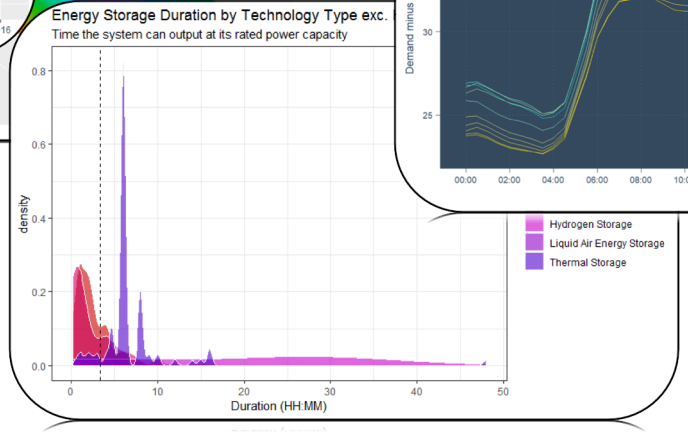
Our Students – Energy Data Analysts of the Future

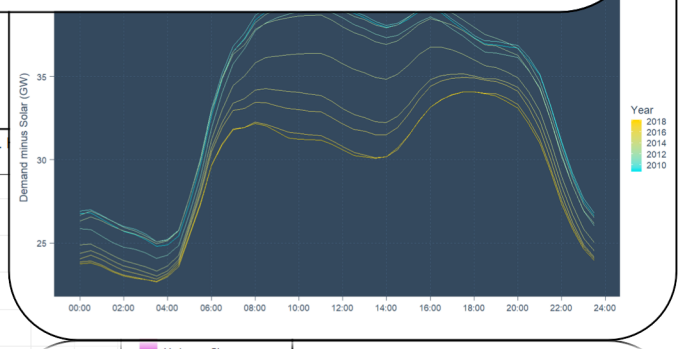












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Conclusion

- Progress in the field of reinforcement learning has been significant in the last 2-3 years
- Well suited to a number of applications in energy sector
- Research into AI and Energy underfunded relatively
- Opportunity for new business models and paradigms
- AI requires data, these resources need to be **freely** available
- Talent shortage enabling use of AI in the energy system
- More Open Data

More Info

- More information on Energy and AI group here:

  https://www.ucl.ac.uk/bartlett/energy/ai

- More information on Energy Systems and Data Analytics MSc. here:

  https://www.ucl.ac.uk/bartlett/energy/programmes/energy-systems-and-data-analytics-msc

Thank You

aidan.osullivan@ucl.ac.uk

UCL ENERGY INSTITUTE

26/04/2019

ENTSOE WEBINAR ON AI

Assisting control room operators with Artificial Intelligence

Antoine Marot – RTE R&D

01

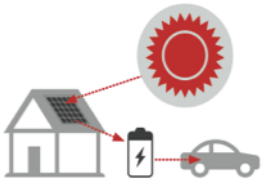
Rethinking control room Human-Machine Interfaces

Control rooms full of human operators…

Quite a congested working environment !

… with rising complexity in the system

Many new actors & scales



Grid optimization & hybridization

Digital world

Distributed Automata

What about one more screen … ?

AND TOMORROW ?

Yes, it is about thinking of a whole new interface …

… But it is first a question of **strategic information management**

ACTUAL SOURCES OF INSPIRATION

Personal assistant (Jarvis!)

Help you **plan** & make **suggestions**

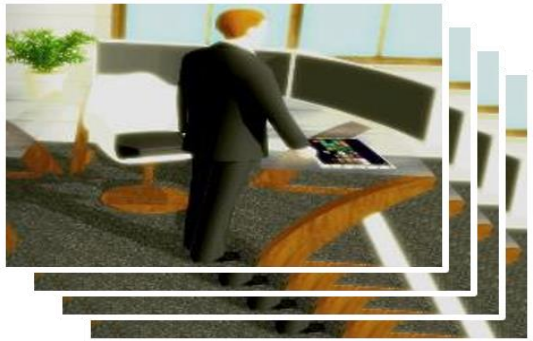
Autonomous vehicle

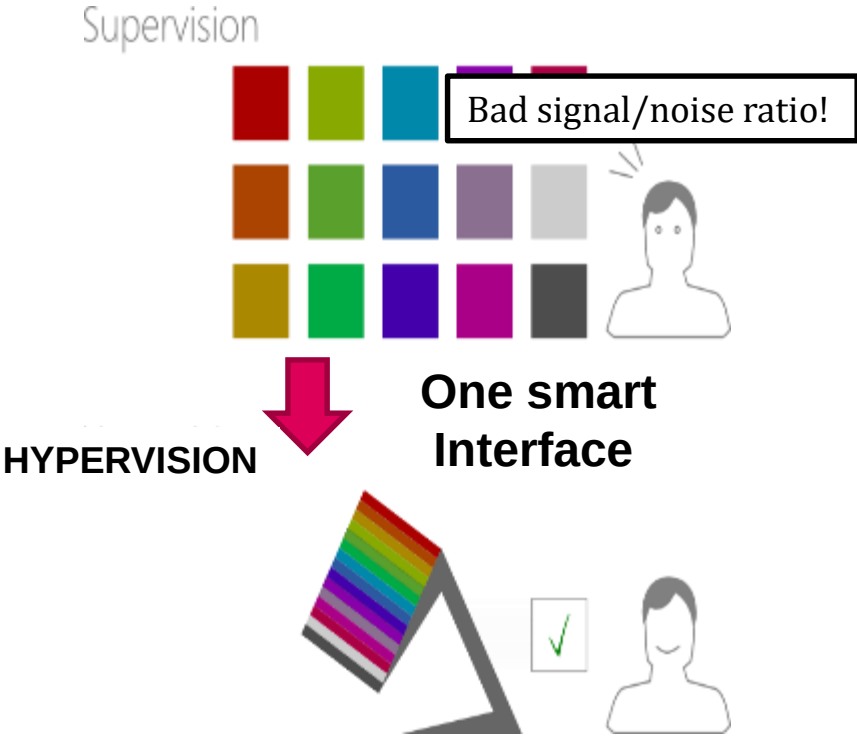
Find your way and **pilot**

VS

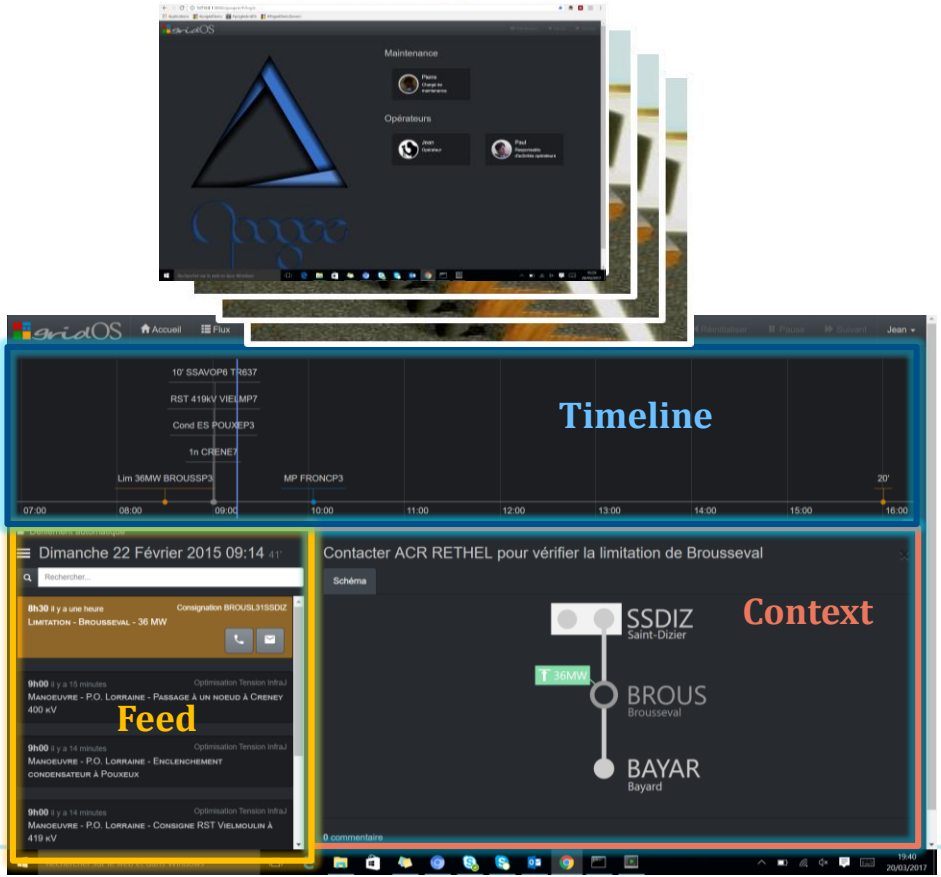
plan your journey, **navigate** & coordinate

OUR PROJECT : APOGEE (2014 – TODAY)





OUR PROJECT : APOGEE (2014 – TODAY)

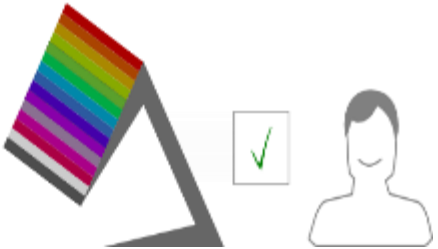


Supervision

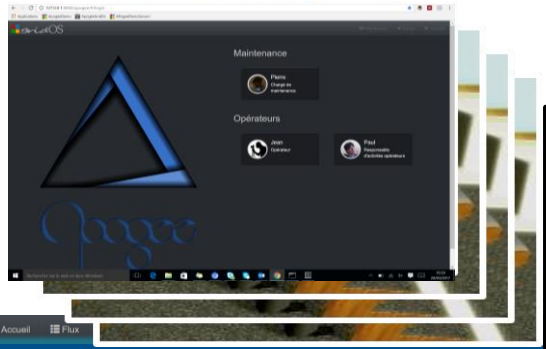
Bad signal/noise ratio!

HYPERVISION

One smart Interface



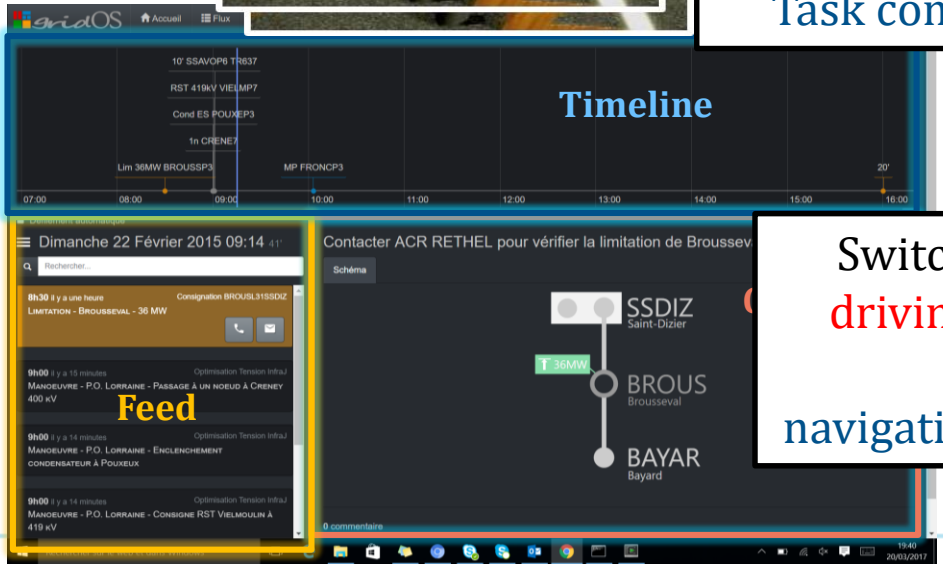
OUR PROJECT : APOGEE (2014 – TODAY)



Supervision

Change the focus from
Alarm monitoring
to
Task completion !

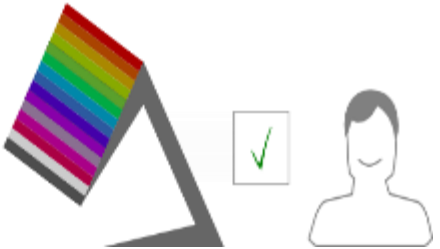
Bad signal/noise ratio!



HYPERVISION

One smart Interface

Switch from
driving mode
to
navigation mode !



DEMO ONLINE & OPEN-SOURCED FRAMEWORK

LFENERGY

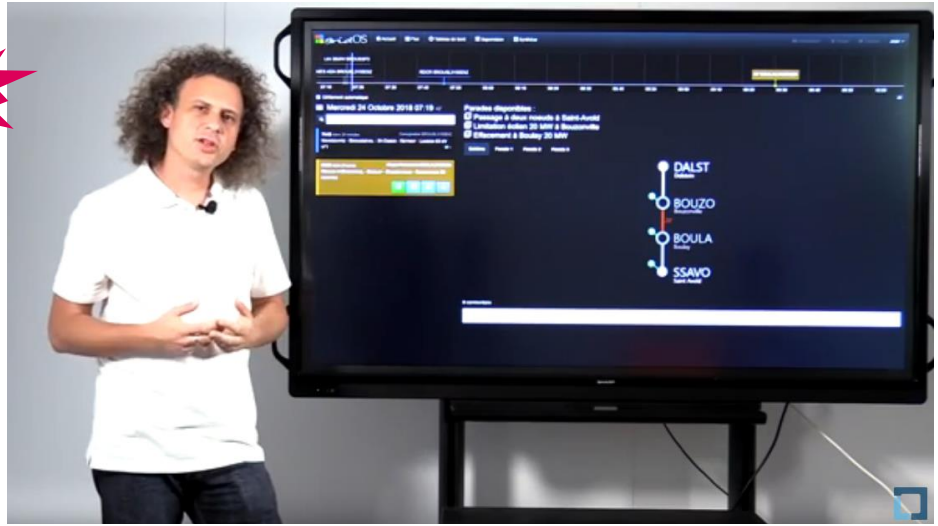
Linux Fondation Initiative

New

https://www.lfenergy.org/projects/

LFENERGY OPERATORFABRIC

LFENERGY POWSYBL



https://www.youtube.com/watch?v=sXdCrXrWtlI

The HMI framework has been industrialized and is now open-sourced!

Next: How can AI deliver relevant information and suggestions ?

Rte Le réseau de l'intelligence électrique

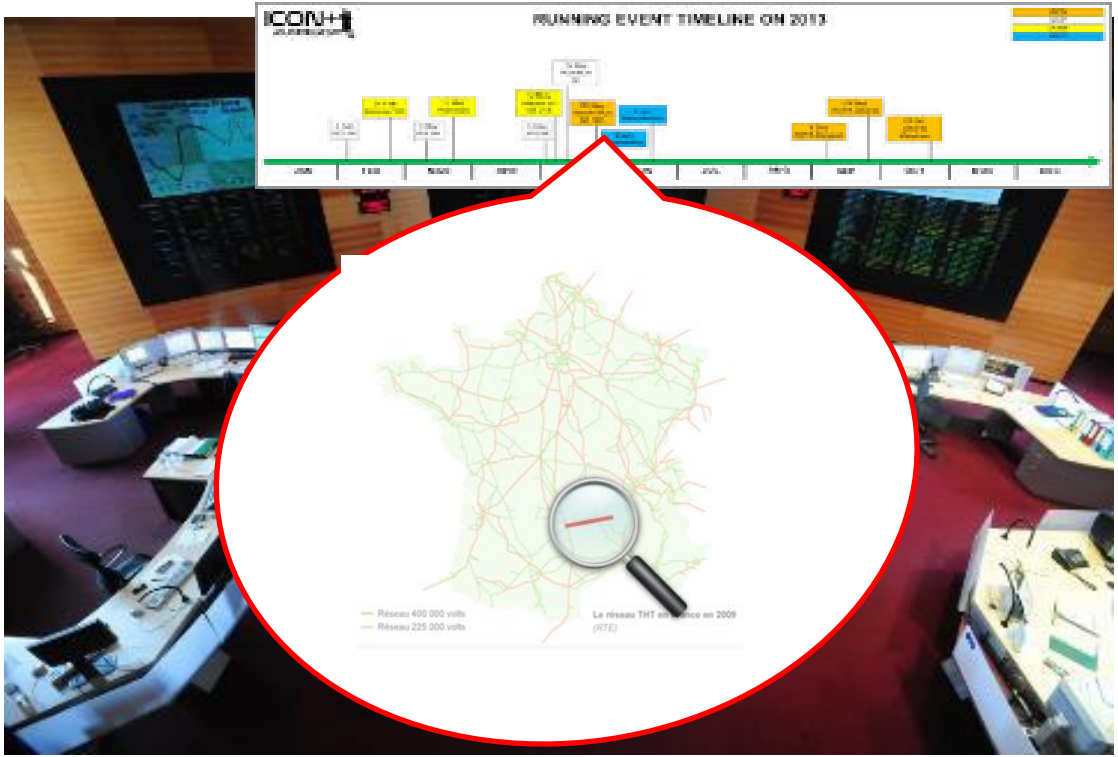
02

Problem statement
One day in control rooms

1 DAY IN CONTROL ROOM

How can we help our operator:

- Anticipate and assess risks
- Makes sense of a situation
- Speed up his remedial action search



INTEGRATION IN REAL TIME OPERATIONAL PROCESS

Typical problem solving and decision making task

Problem identification

Solution search

Decision making

CURRENT REAL TIME OPERATIONAL PROCESS

Grid states Generation
= Forecast * contingencies

Simulator

Constraints to deal with

Unsecure grid detection

Operator Tactic

Simulator

Candidate solutions

Action space search

Validation by simulation

Optimization for best compromise

Selected Tactics

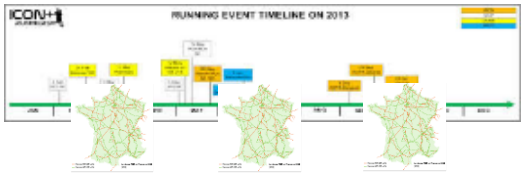
Decision

CURRENT REAL TIME OPERATIONAL PROCESS

Limitations of solely using physical model

- **Risk assessment in depth**
  - High computational tome
  - Hard uncertainty modeling
  - High dependance on data availability
  - Lots of irrelevant information in results

- **Quick and deep remedial action search**
  - High computational time
  - No suggestions over known remedial actions
  - Lots of irrelevant information in results



Physical models don't use any memory of past operations to filter what is irrelevant and accelerate screening
=> AI will help us learn from our system operations and complement physical models

03

One key element: Learning!

BUILDING PRIOR KNOWLEDGE

Deep Blue

Expert System

Machine Learning

Alpha Go

Expert Systems (top-down) vs Machine Learning (bottom-up):

deduction induction

Expertize Formalization with symbolic and logical rules is hard

- Especially the most intuitive concepts

Learning approach to let the machine :

- makes its own representations
- infer rules from observations
- capture field constraints

⇒ More relevant, scalable, modular, maintainable

But sometimes less interpretable with questionable robustness

Introduce Machine Learning for power grid real-time operations

BUILDING PRIOR KNOWLEDGE

Deep Blue

Expert System

Machine Learning

Alpha Go

Expert Systems (top-down) vs Machine Learning (bottom-up):

deduction induction

Expertize Formalization with symbolic and logical rules is hard

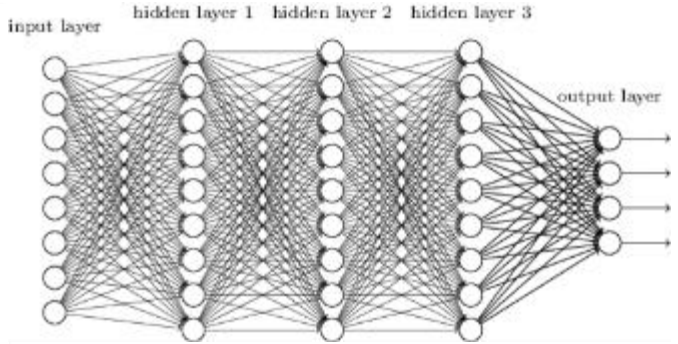
- Especially the most intuitive concepts

Learning approach to let the machine :

A key catalyst:

the advent of Deep Learning with Neural networks

=> powerful and flexible models for end-to-end learning

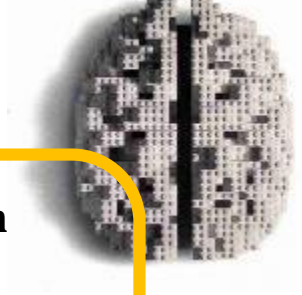


Introduce Machine Learning for power grid real-time operations

04

AI in Apogee for system operations

ARTIFICIAL INTELLIGENCE IN APOGEE



Data

- Generation
- Labelling
- Capitalization

Representation

- Modeling
- Contextualization
- Visualization

Learning

- Imitation
- Simulation

Adaptation

- Exploration
- Reinforcement
- Transfer

3 PHDs:

- Deep Learning Methods for Flows in Power Grid (2015 - INRIA – Isabelle Guyon)
- Interactive and interpretable Machine Learning with expert users (2019 - LORIA – L. Boudjeloud)
- Learning to Run a Power Grid with Reinforcement Learning (2018 - INRIA – Isabelle Guyon)

05

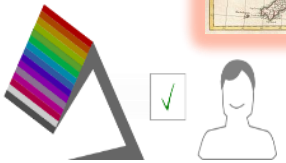
Works & illustrations

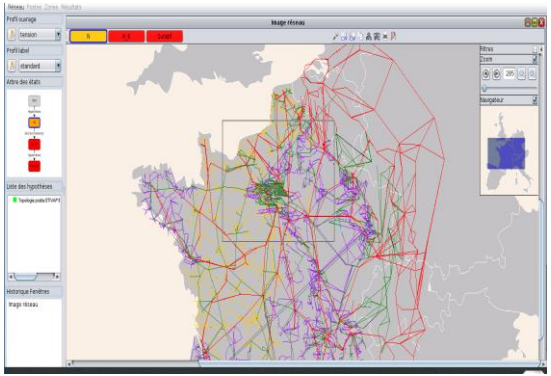
The Map

FUTURE HMI WITH TASK SPECIFIC INFORMATION

Supervision

Hypervision





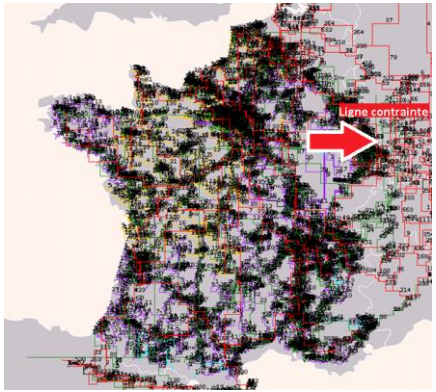
Interactive navigation in the full picture

Static but focused representation

Within new HMI, we'd like to **bring relevant focused representation to a task without having to launch your study tool** to understand what this is about

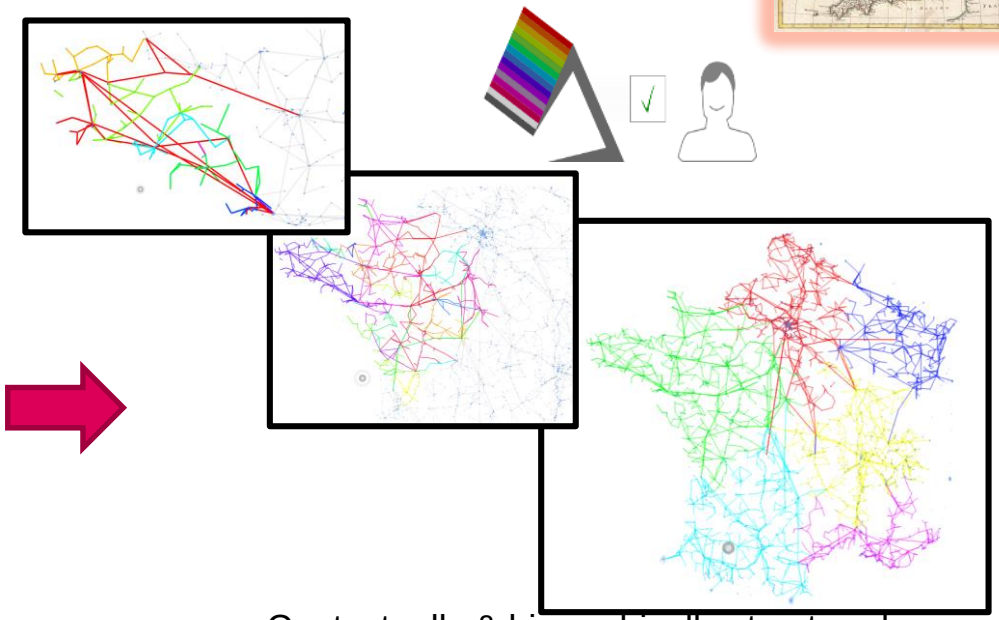
FUTURE HMI WITH TASK SPECIFIC INFORMATION

Supervision



Full Detailed Picture

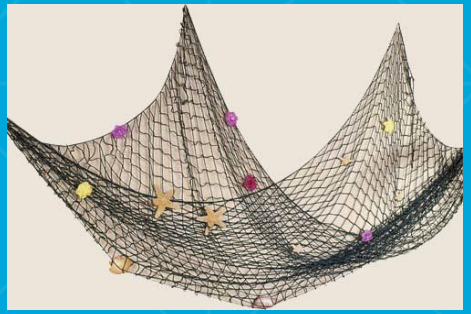
Hypervision



Contextually & hierarchically structured map

Within new HMI, we'd like to **bring relevant focused representation to a task without having to launch your study tool** to understand what this is about

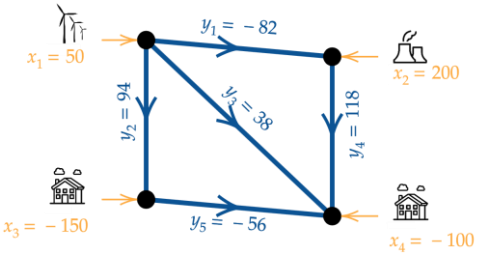
05



Works & illustrations

The Net

NEURAL NETS FOR PREDICTING FLOWS



3 Approaches to compute the load flow

$$\begin{cases} \text{Minimiser } F(\langle X \rangle) \\ g_i(\langle X \rangle) \le 0 \\ h_j(\langle X \rangle) = 0 \\ \langle X \rangle = \langle X_1, \ldots\ldots\ldots\ldots, X_n \rangle \end{cases}$$

Physical Model & solver:
Usual solver & Explicit optimization formulation

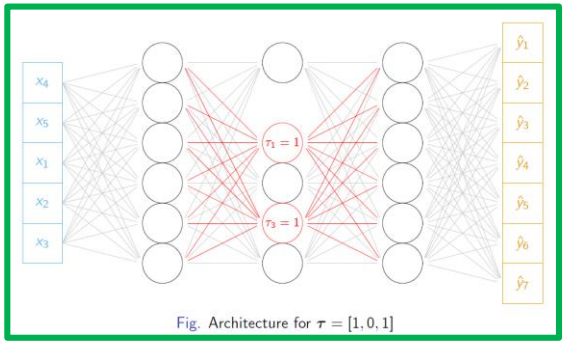
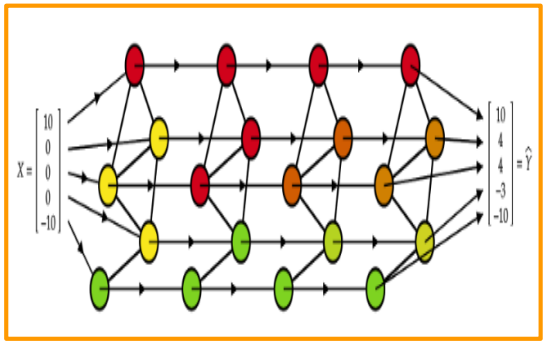


Fig. Architecture for $\tau = [1, 0, 1]$

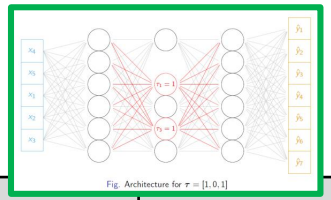
Leap Net:
Neural Net & Solver imitation

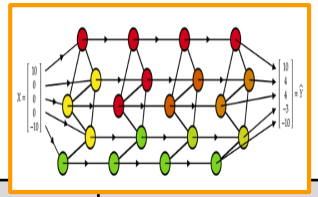


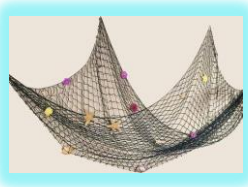
Grid Net:
Graph Neural Solver

Load Flow Benchmark Table

$$\begin{cases} \text{Minimiser } F(\langle X \rangle) \\ g_i(\langle X \rangle) \le 0 \\ h_j(\langle X \rangle) = 0 \\ \langle X \rangle = \langle X_1, \ldots\ldots\ldots\ldots, X_n \rangle \end{cases}$$







	Hades2 Newton Raphson solver	**LEAP net** Less than 2% accuracy loss	**Graph Neural Solver**
Based on physical equations	Yes	No	Inspired
Computation time on French Grid	100 ms	500x faster	2x faster (=> 100x ?) (at least its first implementation..)
Ability to predict around operating conditions for a given grid	Yes (-)	Yes (+)	Yes
Ability to predict on deeply different grid operations or on new grids	Yes (+)	No	Yes (-)

You have a **tradeoff** between accuracy and physical guarantees, accounting for conditions of operations, computational speed, and generalization.

=> Variety of load flows to choose for your specific application

05

Connecting the dots In operational processes

INTEGRATION IN REAL TIME OPERATIONAL PROCESS

Typical problem solving and decision making task

Problem identification

Solution search

Decision making

TODAY'S REAL TIME PROCESS

Grid states Generation
= Forecast * contingencies

Simulator

Constraints to deal with

Unsecure grid detection

Operator Tactic

Simulator

Candidate solutions

Action space search

Validation by simulation

Optimization for best compromise

Selected Tactics

Decision

INTEGRATION IN REAL TIME OPERATIONAL PROCESS

Grid states Generation
= Forecast * contingencies

Learnt Leap Net

Constraints to deal with

Operator strategies

Learnt Strategies

Generated Strategies

Learnt Graph Neural Solver

Candidate solutions

Validation by simulation

Optimization for best compromise

Selected Strategies

Unsecure grid detection

Action space search

Decision

INTEGRATION IN REAL TIME OPERATIONAL PROCESS

Grid states Generation
= Futur * variability

Learnt Proxy Load flow

Constraints to deal with

Operator strategies

Learnt Strategies

Generated Strategies

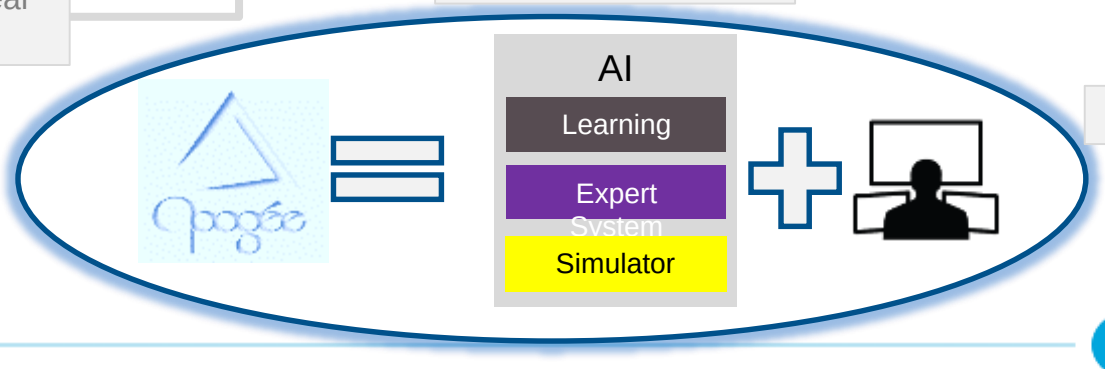
Learnt Proxy Load flow

Validation by simulation

Optimization for best compromise

Selected Strategies

A human-machine collaboration



APOGÉE: ASSISTANT FOR CONTROL ROOM OPERATORS

Apogée

Supervision

Hypervision

gridOS

Cortana. Siri amazon echo Google now Facebook M

Apogée

A **personnal assistant** for the operator

OUR AI PROJECT TEAM

Apogee RTE researchers:

- Antoine Marot, Research Project Supervisor
- Rémy Clément, « Learning voltage control »
- Vincent Barbesant, « Forecasting grid states », control room manager previously

Managers:

- Pauline Gambier-Morel, Apogee Project manager,
- Patrick Panciatici, R&D scientific advisor

PHDs:

- Benjamin Donnot, «Deep Learning Methods for Flows in Power Grid », ending with INRIA
  - Co-advised by Isabelle Guyon and Marc Shoenauer
- Balthazar Donnot, « Learning to Run a Power Grid with Reinforcement Learning », beginning with INRIA. Data Challenge to come as well !
- Laure Crochepierre, « Interactive Machine Learning with expert users », beginning with LORIA

Master Thesis:

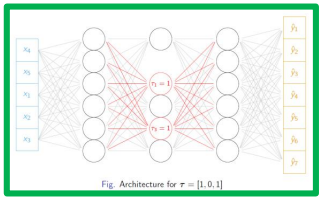
- Antoine Rosin, « Event detection and labelling in energy systems », 2018 with DTU

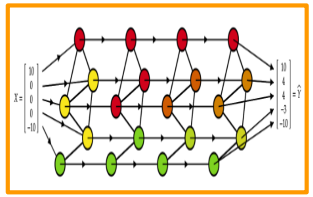
OUR REFERENCES

Our related work:

Accepted papers

- **IERP 2017:** Introducing Machine Learning for power system operation support
- **ESANN 2018:** Fast Power System Security Analysis with Guided Dropout
- **IJCNN 2018:** Anticipating contingengies in power grids using fast neural net screening
- **ISGT Europe 2018:** Optimization of computational budget for power system risk assessment
- **ISGT Europe 2018:** Guided machine learning for power grid segmentation
- **MedPower 2018:** Expert System for topological remedial action discovery in smart grids
- **ESANN 2019:** Leap Net for power grid perturbations





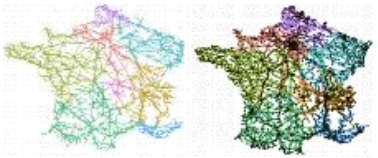


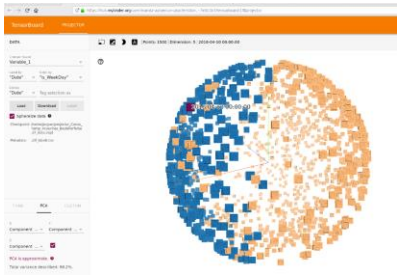
Fig. 7. Comparison of a) our French power grid segmentation with b) historical RTE regional segmentation.

In review for **2019:**

- IJCNN 2019: Graph Neural Solvers for Power Systems
- IJCNN 2019: Semi-supervised labelling, Towards an Extended Expert Approch

Upcoming Challenge:

- Learning to Run a Power Network, IJCNN 2019, start on May 5th



Related Projects:

- The Itesla European project to learn security rules at scale
- The GARPUR European project to define a new security framework under uncertainties

Thank You
For your attention !

antoine.marot@rte-france.com