JEMIMA
Japan Electric Measuring Instruments Manufacturers' Association

JEMIMA Special Talk

SICE2022 SICE ANNUAL CONFERENCE | September 6-9, 2022 Kumamoto-Jo Hall, Kumamoto, Japan

"Automation" from the Perspective of an Energy Management System

Professor Yoshiharu Amano,
Waseda University
September 7th 16:45-17:45
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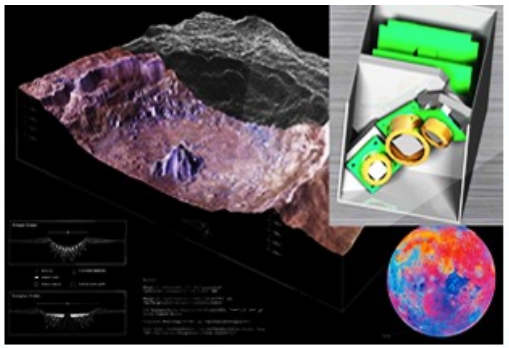
Self-introduction

Yoshiharu AMANO, Dr. Eng., Professor,
Faculty of Science and Engineering, Waseda University

Director: **IONL-WISE**(Industrial Open-Network Lab, WISE)
Director: **RIPES-ACROSS**(Research Institute for Power and Energy Systems,
Advanced Collaborative Research Organization for Smart Society)
2022- Advisor, **JEITA** Control & Energy Management Committee-WG1, RENKEI control
2019-2021 Chair: **JEMIMA FEMS**(IEC 63376) committee, TC65/JWG14, 17 expert
2008.4 - **Professor, Waseda University**
2008.3 - 2008.12
Visiting Professor, École polytechnique fédérale de Lausanne, Switzerland
2002.4 - 2008.3
Associate Professor, Waseda University
2000.4 - 2002.3
Assistant Professor, RISE (**R**esearch **I**nstitute for **S**cience and **E**ngineering), **Waseda University**

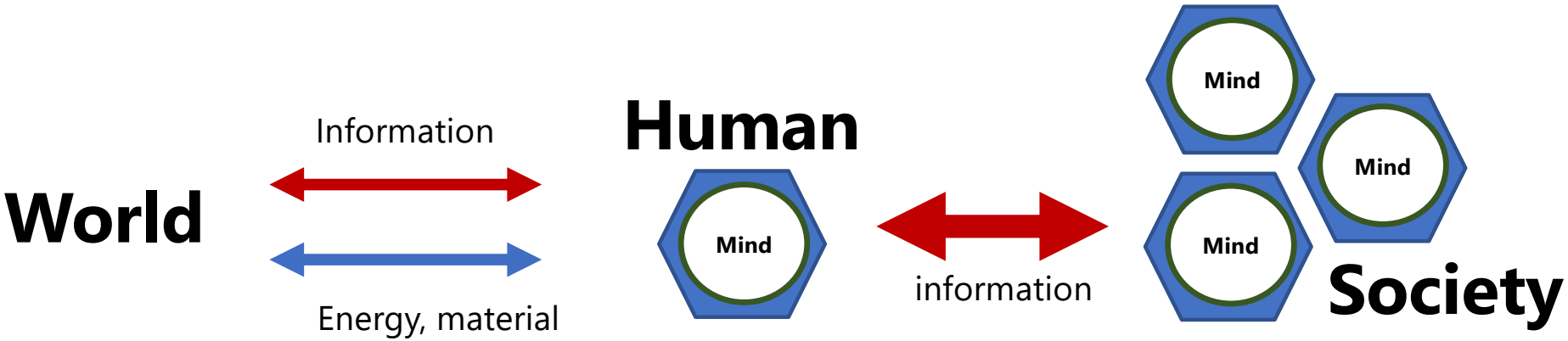


Amano Laboratory, Waseda Univ.

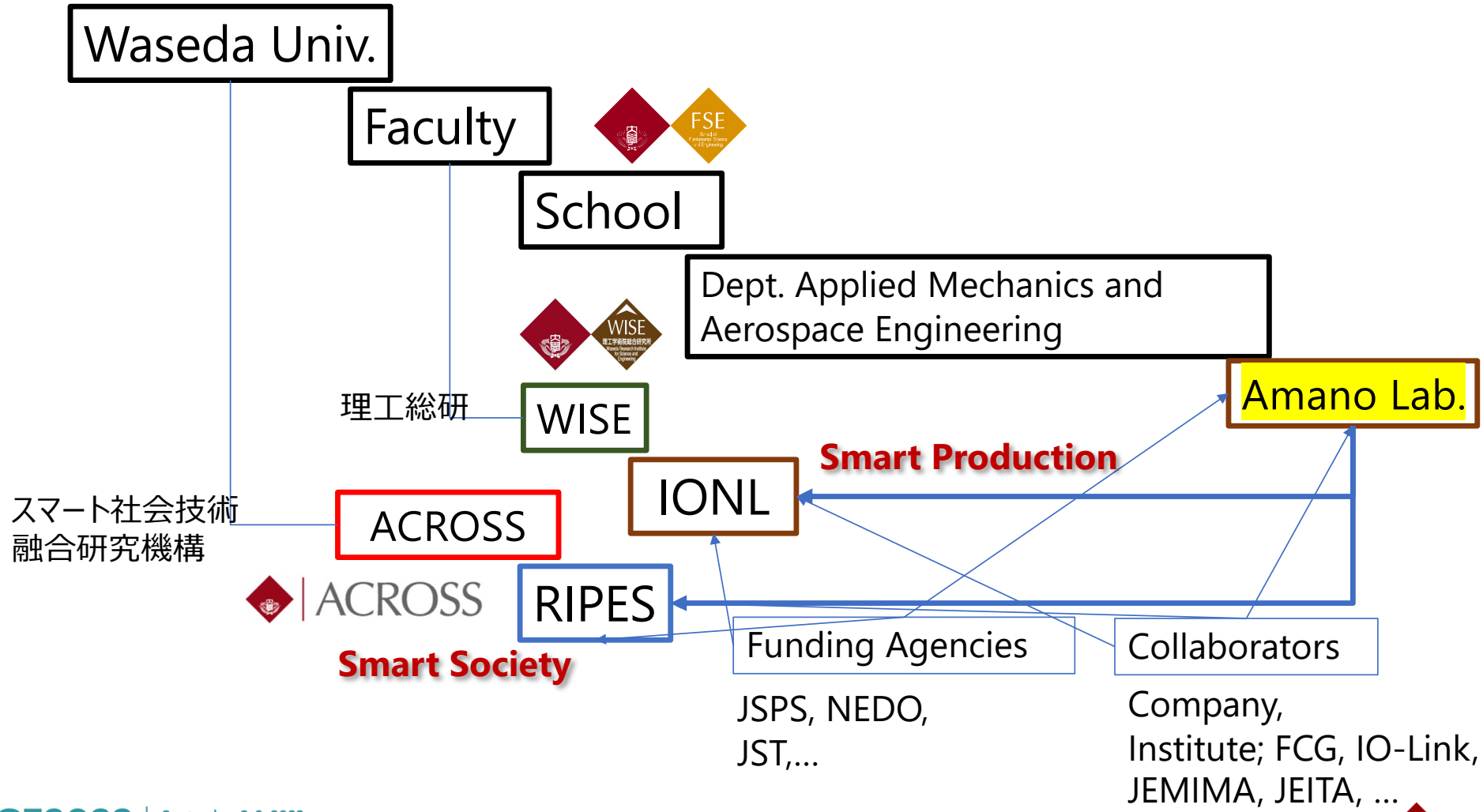
School of Fundamental Science and Engineering

Engineering is a knowledge system that **evolves technology**

Learn from Society and develop technology for Society



Organization

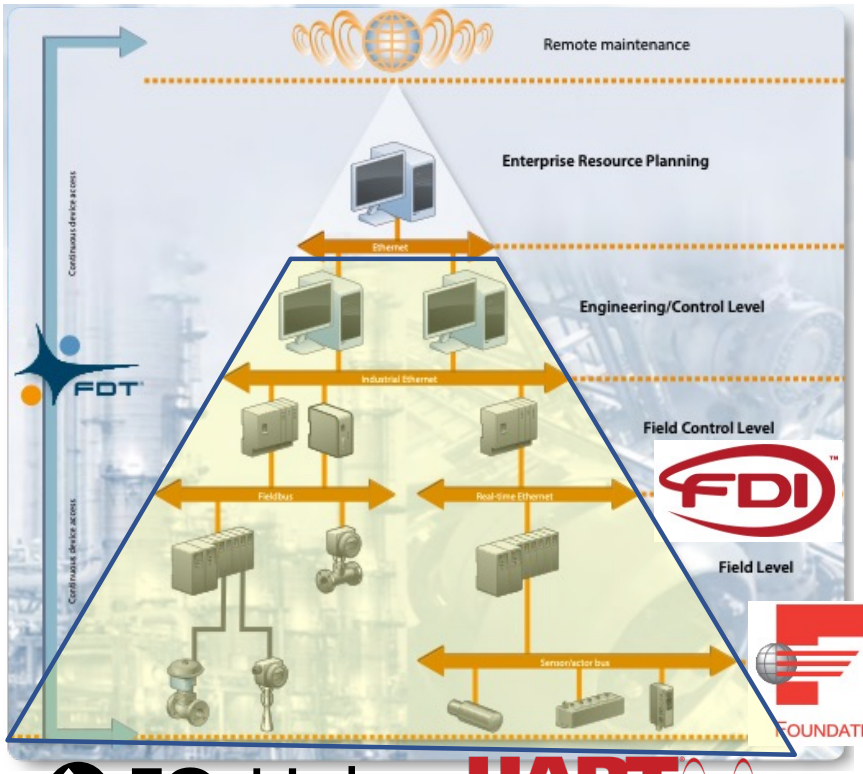


IONL: Industrial Open-Network Lab.

Founded in 2003
Target：Process Automation，Factory Automation

- Field information: Hierarchy from field to manufacturing execution system (MES) (ISA 95 model, Level 0 to 3)
- Holding technical seminars (every month to three months)

- **IONL**
  - FCG section
    - FieldComm Group™ Connecting the World of Process Automation
  - IO-Link section
    - IO-Link
  - FDT section
    - FDT GROUP Empowering the Intelligent Enterprise



Contents

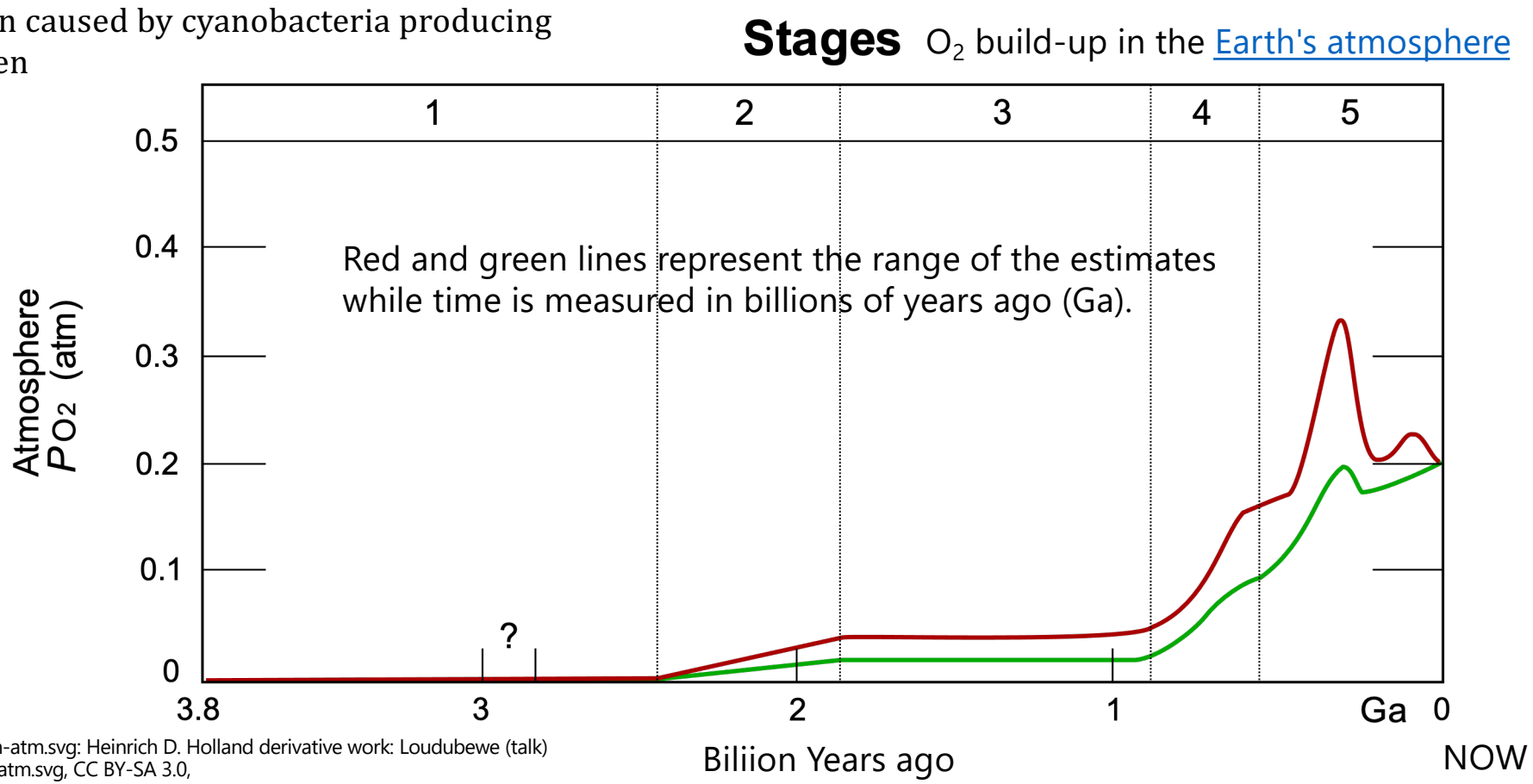
- Challenges to overcome
- Energy Management System
- Automation is a measure of evolution of technology
- Summary

Challenges to overcome in society

- Develop Sustainable Society
  - Climate Change due to GHG;
    - Human activity
    - Re-build energy system
  - Optimization of system **configuration**

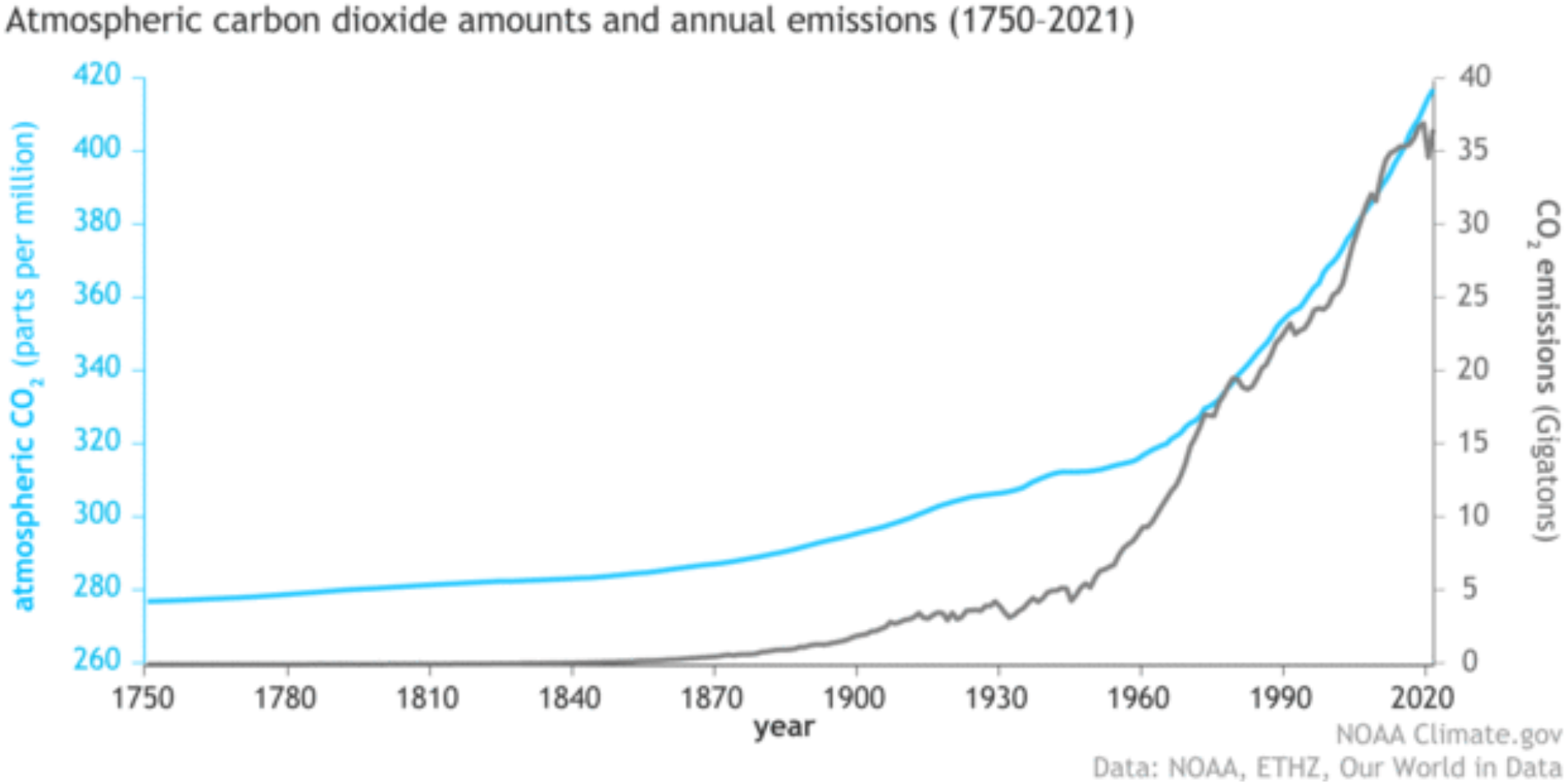
Activity of life changed our environment

Great Oxidation Event; The event is inferred to have been caused by cyanobacteria producing the oxygen



By Oxygenation-atm.svg: Heinrich D. Holland derivative work: Loudubewe (talk) - Oxygenation-atm.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=12776502

we put more carbon dioxide into the atmosphere than natural processes can remove



https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

Global human-made mass exceeds all living biomass

On average, for each person on the globe, anthropogenic **mass** equal to more than his or her **bodyweight** is produced **every week**.

4 Gt

8 Gt

Animals ..... 4 Gt
Plastics ..... 8 Gt

900 Gt

11,00 Gt

Trees and shrubs ..... 900 Gt
Buildings and infrastructure ....1,100 Gt

Source: Elhacham, E., Ben-Uri, L., Grozovski, J. *et al.* Global human-made mass exceeds all living biomass. *Nature* **588,** 442–444 (2020). https://doi.org/10.1038/s41586-020-3010-5

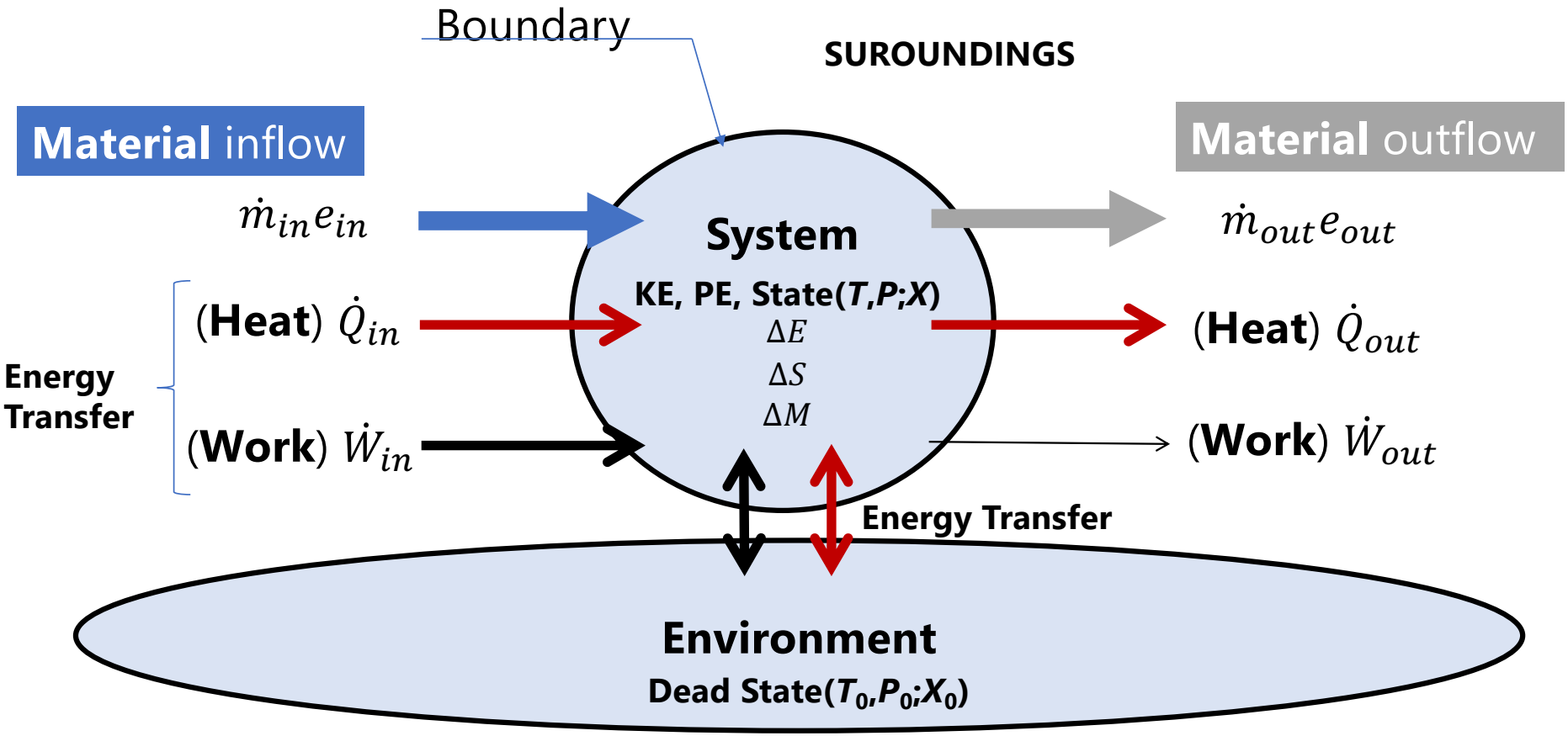
Sustainable Energy System

- Human productive activities on earth involve the use of energy.

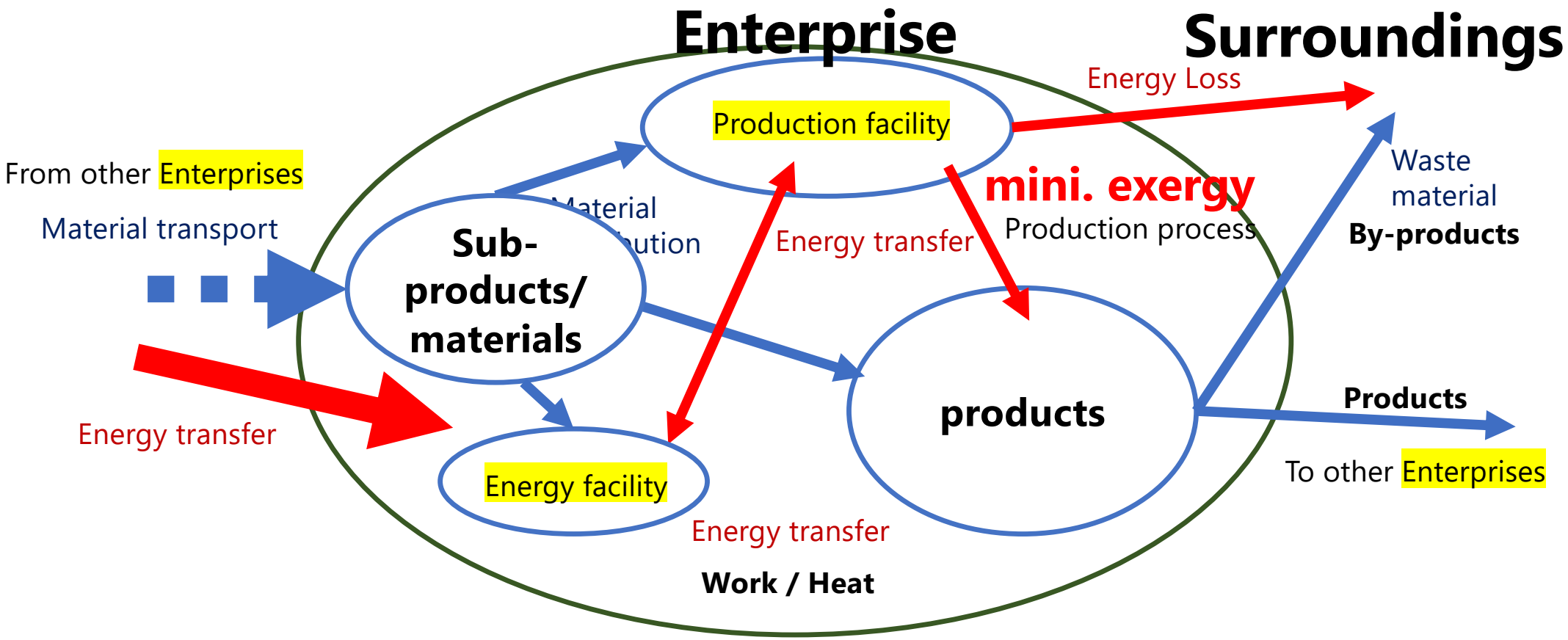
Manipulating resources (**energy and material**) changes the world

Thermodynamics

Thermodynamic perspective



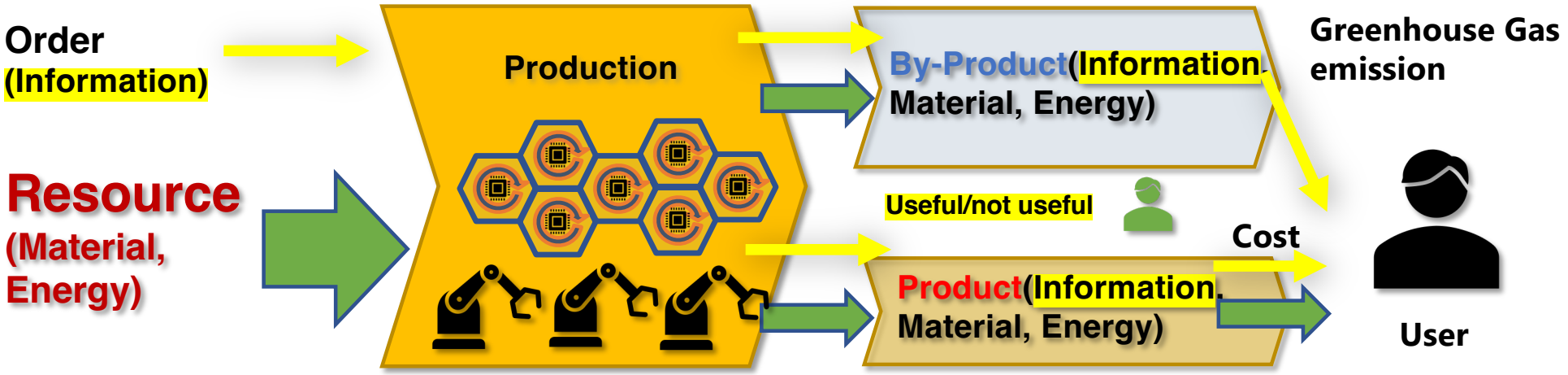
Thermodynamic perspective on production



Production Process

Information flow along with **material/energy** flow in Industrial facility

From "linear" material flow to "closed loop" in order to recycling finite resource



Leaner process of production

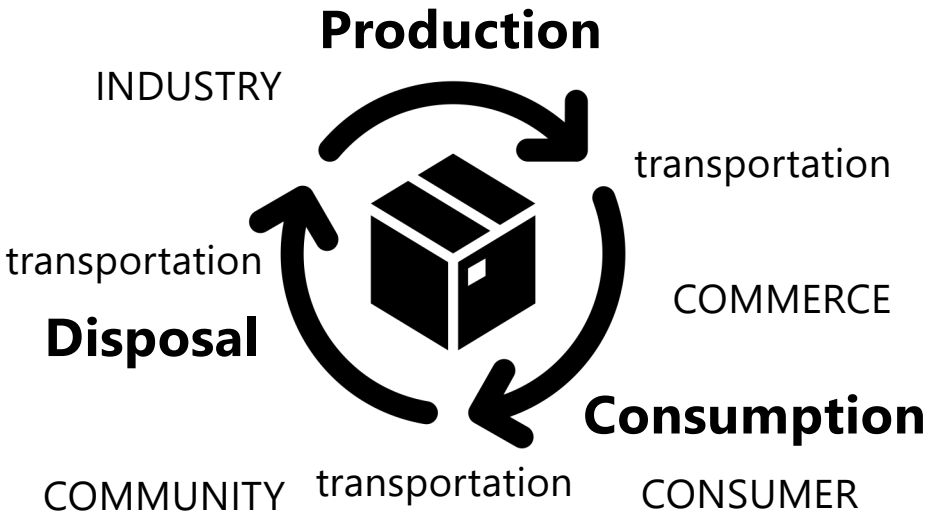
Change entire lifecycle of production system

Goal; Change lifecycle of products, from design to production, consumption and disposal.

Sustainable

Circular material flow, including by-products

How can we achieve the goal?



Change entire lifecycle of production system

Long period; **Planning**

How to design a (large) energy system?

System optimisation for investment

Regarding future: forecasting, but still **uncertain**

Setting an **Ideal goal**

Short period; **EMS**

Responding quickly

How to operate a (complicated) energy system?

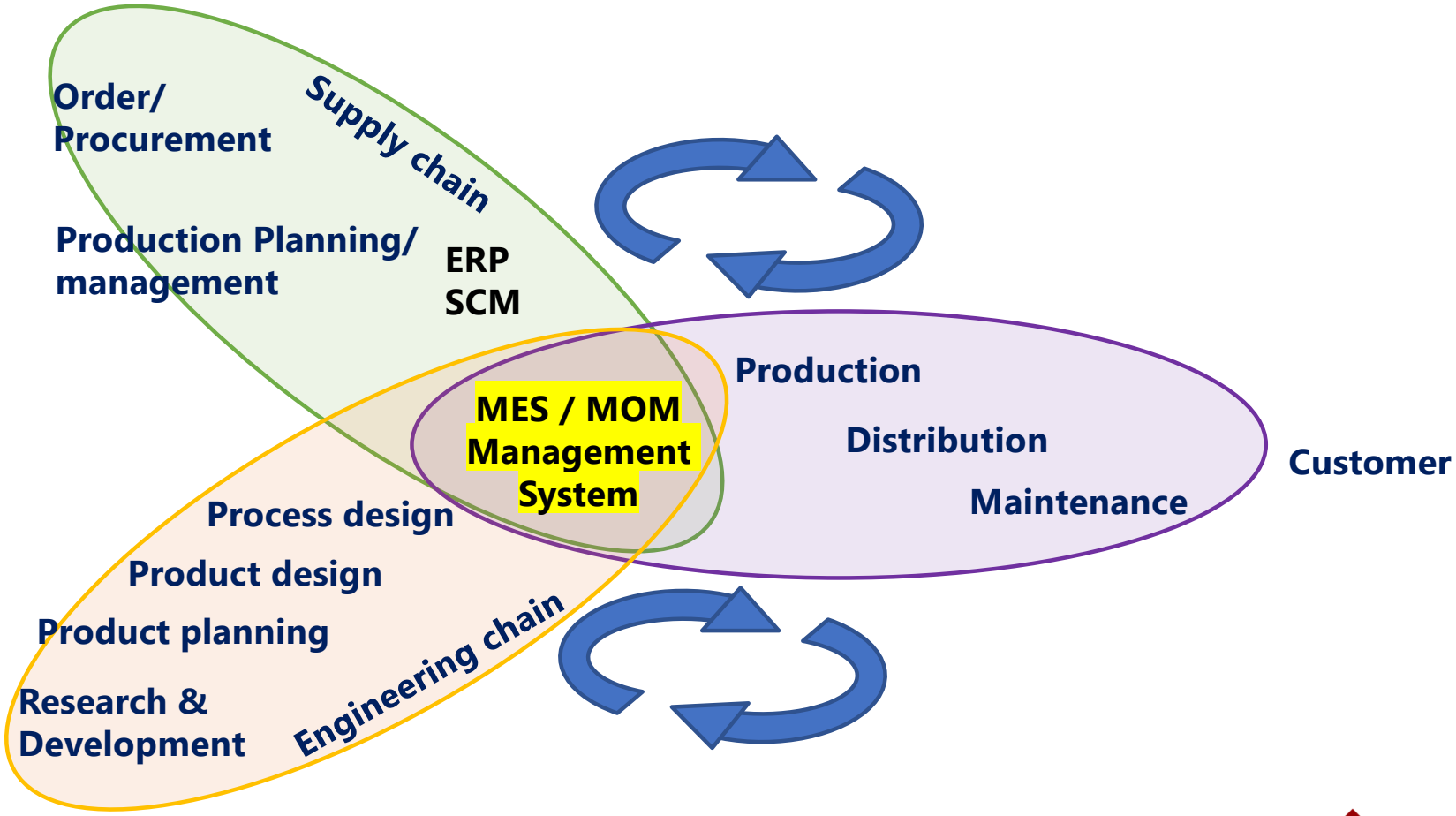
System optimisation for operation

Regarding future: **uncertain** change

Forecasting

Solution for DX, but…

Design large-scale complex systems while considering **optimal operation**



Sustainable Society and EMS?

- Major changes in energy systems configuration are inevitable
  - From fossil fuel to renewable resource
- The system is large and very complicated
  - Systematic approach

Set up an **ideal energy system** and actively **commit** to its realization.

Develop **optimal operation** mechanisms for energy facilities.

EMS can contribute to transition to sustainable energy system with optimal operation.

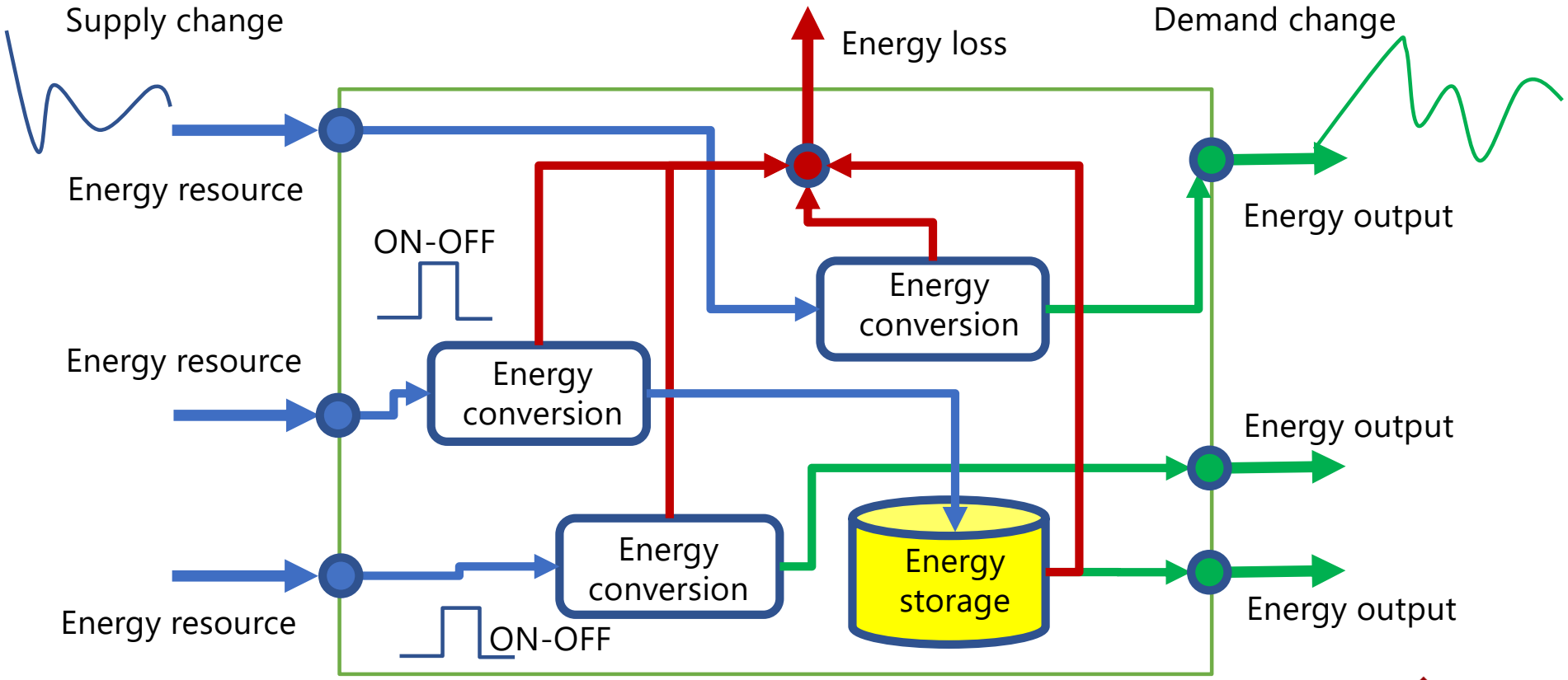
Energy Management System

- Example of EMS
  - **Development of optimal operation model for demand side energy resources corresponding to demand response**
- What is **Energy Management System**?
  - General definition by EnMS, ISO 50000 series
  - Fundamental functions for EMS
  - How can we classify the system; Automation Levels

Energy system design

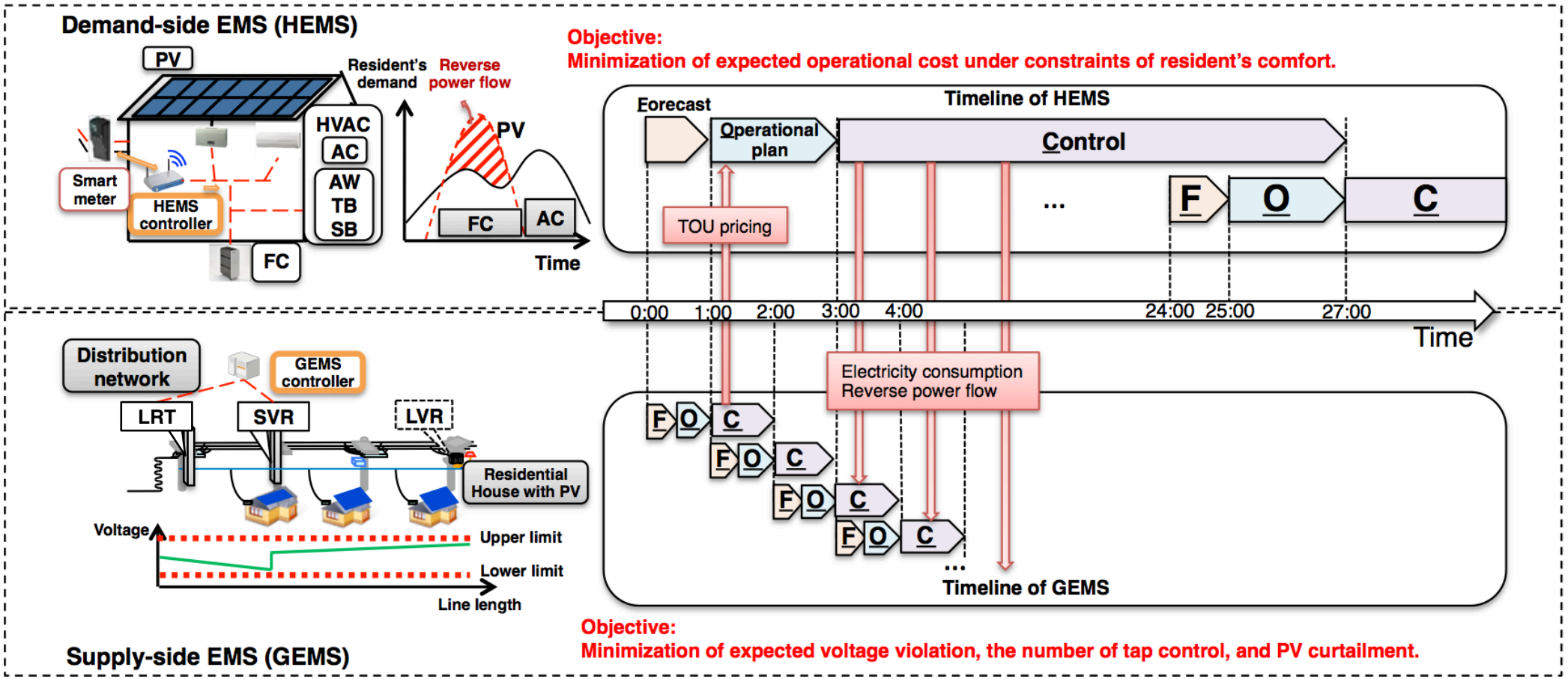
Desing **optimal** system configuration to meet demand/supply change

>>> Most simple configuration

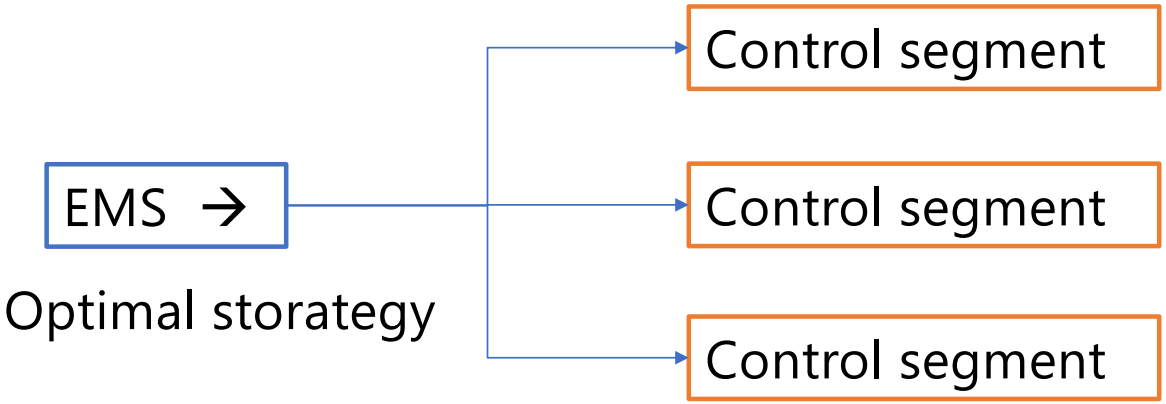


Optimal operation with uncertainty: MPC

Energy demand **uncertainty**



EMS delivers optimal strategy to contlloers



When and Which facility?

ON-OFF/start-stop

Set-point value

Which operation mode? (objectives: CO2 emission min.?, Low cost op?)

Mixed-Interger Programing model (MIP model)

デマンドレスポンスに対する需要家側エネルギー資源の最適運用モデルの開発

*1 Yusuke Shiga, Akira Yoshida, Yoshiharu Amano, Impact for CO2 Emission Reduction by Ice Storage Tank in District Cooling System Using Variable Renewable Energy, Proceedings of ECOS 2022, Copenhagen, 2022.
*2 Akira Yoshida, Yoshiharu Amano, Multi-horizon Forecasting and Operational Planning Method of Energy Storage Under a Demand Response, Proceedings of ECOS 2022, Copenhagen, 2022.

Development of optimal operation model for demand side energy resources corresponding to demand response

Application: Water Distribution System and District Heating and Cooling System

ACROSS Dr. Akira YOSHIDA and Yoshiharu AMANO
AMANO LAB, Waseda Univ.

Objective

- Develop and evaluate an optimisation model for **virtual power plant (VPP)** that can be easily applied to arbitrary plants to generate arbitrary power profiles

  - ✓ **Digitalization** by a method for estimating the **connection relationship between entities based on diagrams and texts in reports by AI**
  - ✓ **Data-driven model identification; Estimation** of **physical models** from process variables based on conservation laws
  - ✓ **Time-series forecasting** with **quantiles** as exogenous variables
  - ✓ Application of **annealing technology** to solve large-scale problems that cannot be solved by existing mixed-integer linear programming (MIP) solvers; inspired by **quantum computation**

FUJITSU

Application for a Virtual Power Plant (VPP)

Aggregator

- Limited profitability and opportunity: **10 EUR/kW** for DR at most.
- No **control system** modifications due to limited budget.
- Plant operators have supply **responsibilities**.
- **Retrofitting** the Information system to the existing control system would be suitable.

Given specification

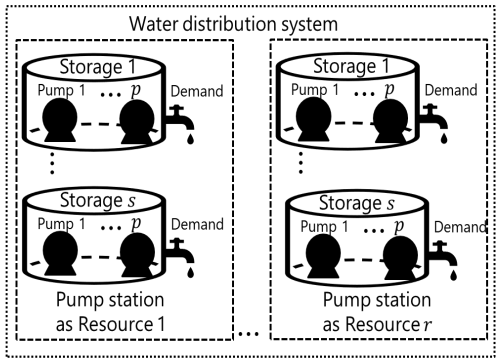
Process variable → Estimate inclusion relations and connections → Correlation analysis → Timeseries forecasting → Optimal scheduling

Issues	Automatic recognition of "text" meaning on schematic diagrams	Criticism of predictions against the mean	Propose operational strategy under uncertainty	Soft constraints require computing power
Solutions	Regular expression	Gray box modelling for energy and mass IO balance	Quantile forecasting	Soft-constrained quadratic unconstrained binary optimization	Quantum-inspired annealing which is hardware solver

A Virtual Power Plant for Demand Response

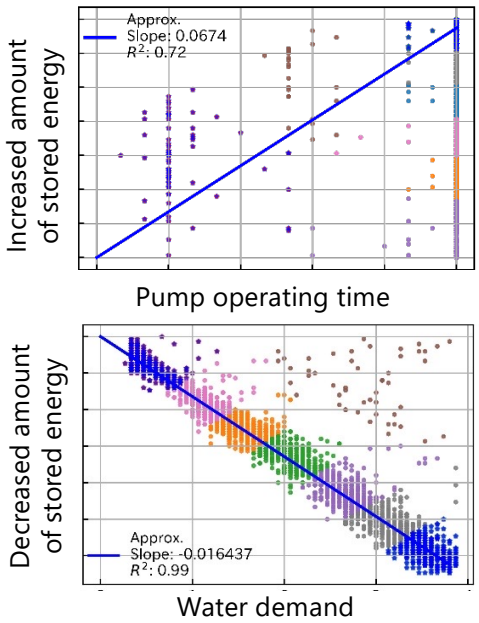
Process variable → Estimate inclusion relations and connections → Correlation analysis → Timeseries forecasting → Optimal scheduling

Water distribution*2



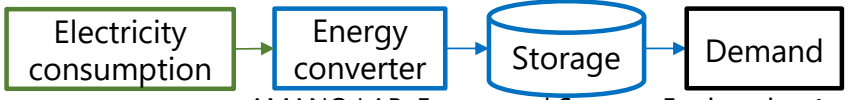
Estimate relations of entities

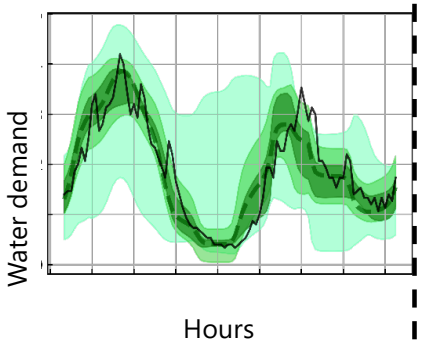
Model the system from limited information



Estimate stored energy and rates

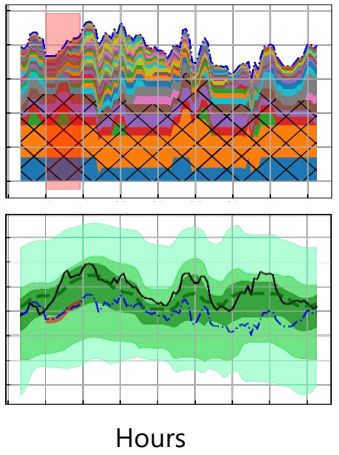
Describe different processes as a common abstracted model





Forecast quantile

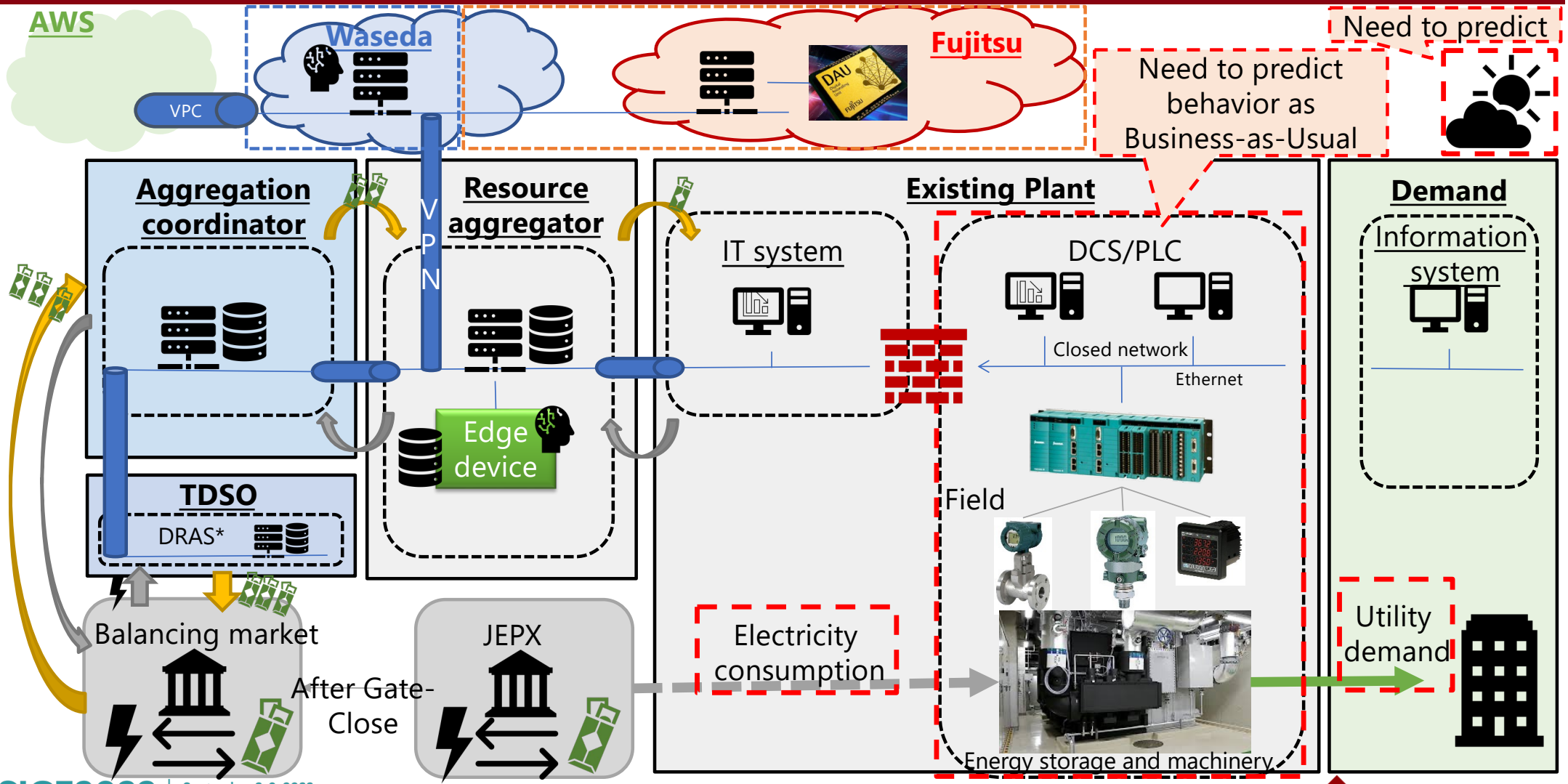
Quantify uncertainty of forecast by quantiles



Optimal on/off status of pumps

Decision support under uncertainty

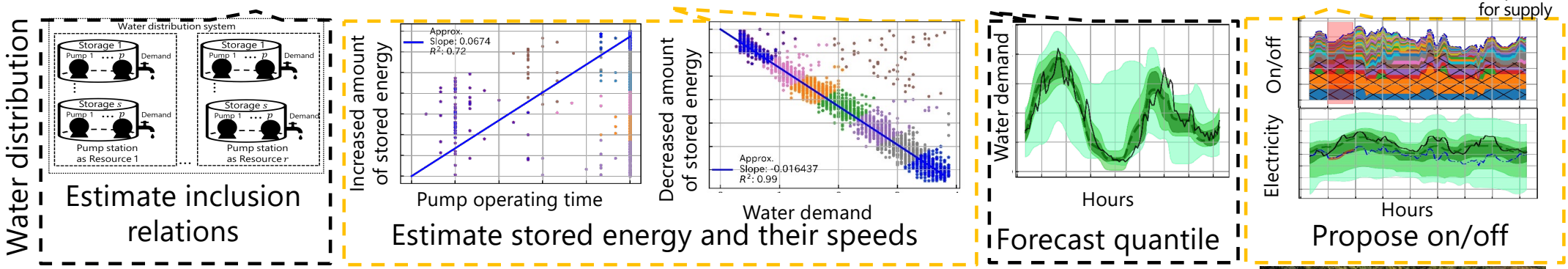
DR Overview: data, electricity, cash flow



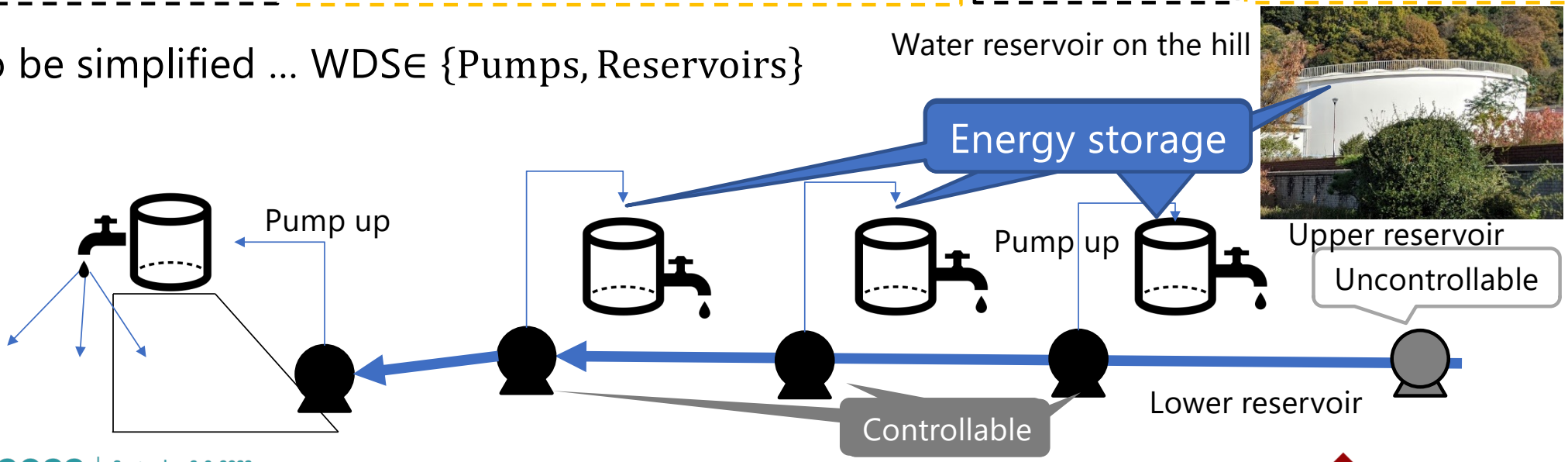
*DRAS: Demand Response Application Server

Apply to Water Distribution System (WDS) as an example

Process variable → Estimate inclusion relations and connections → Correlation analysis → Timeseries forecasting → Optimal scheduling → Responsible for supply

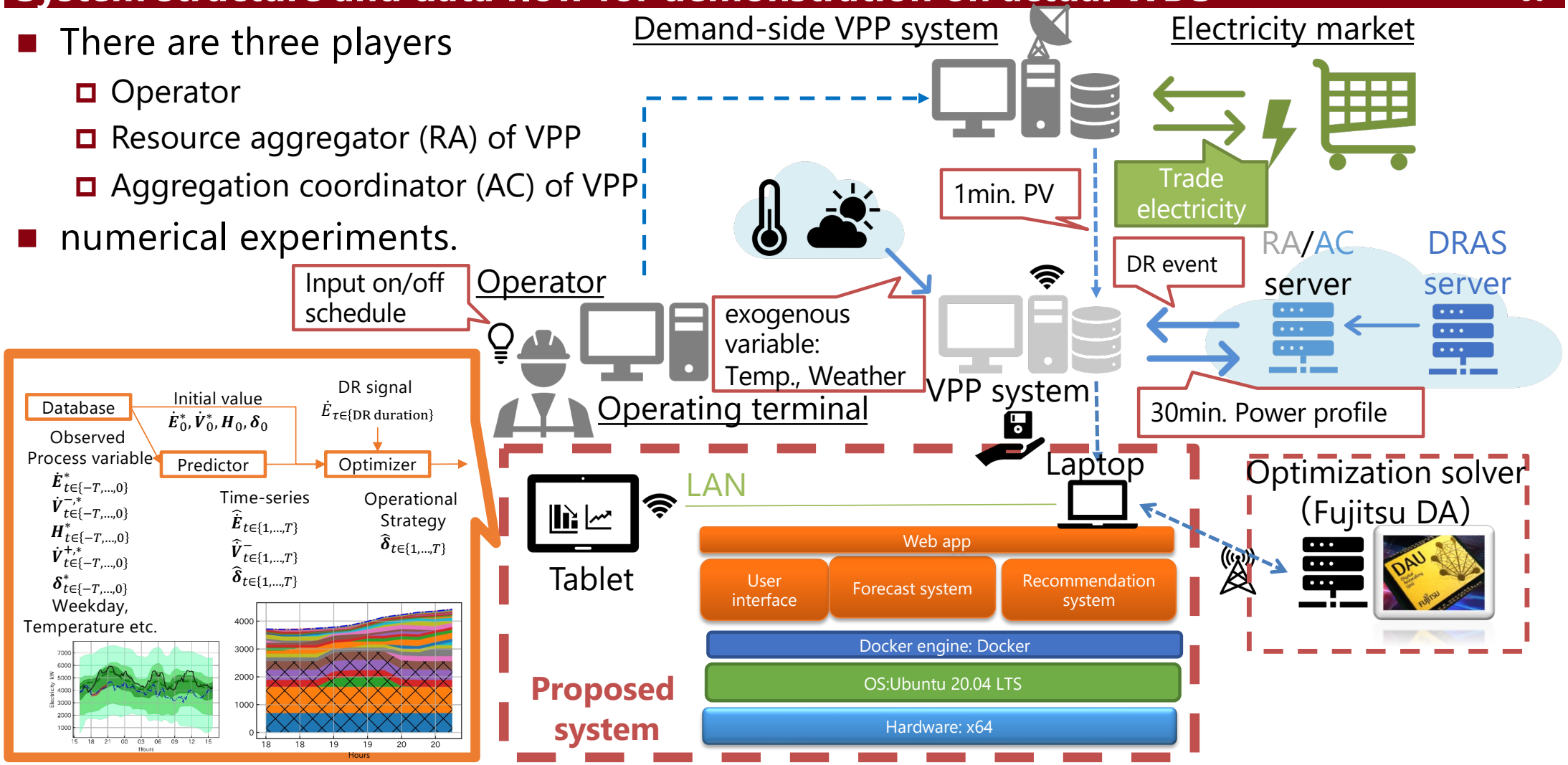


- To be simplified … WDS$\in$ {Pumps, Reservoirs}



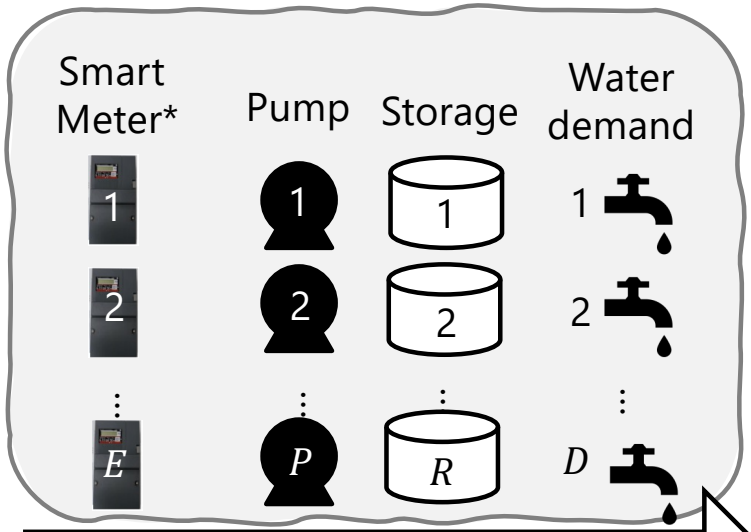
System structure and data flow for demonstration on actual WDS

- There are three players
  - Operator
  - Resource aggregator (RA) of VPP
  - Aggregation coordinator (AC) of VPP
- numerical experiments.

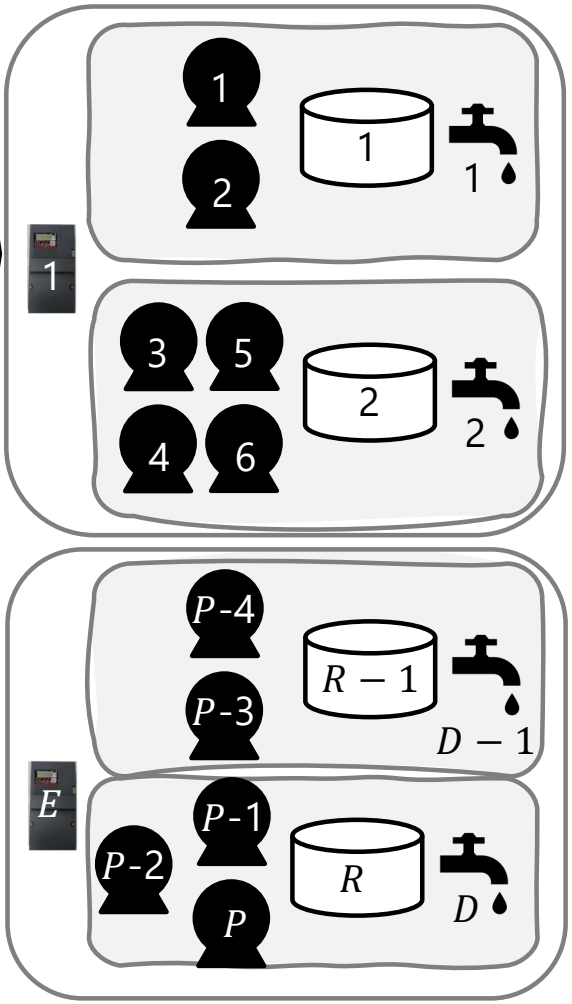


Tag name tells us…

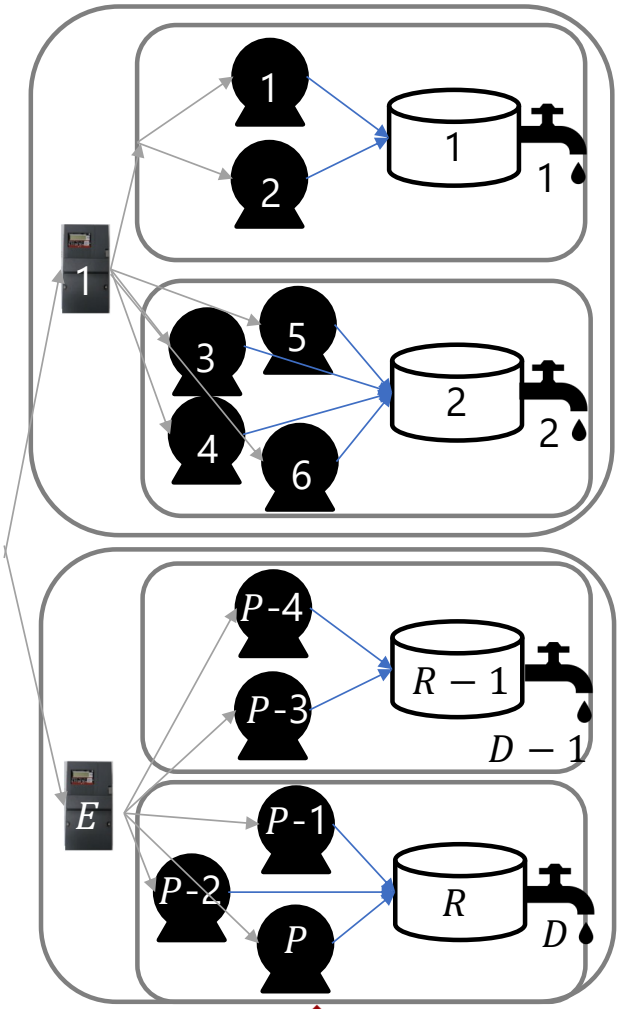
Fragmented content



relation of **inclusion**

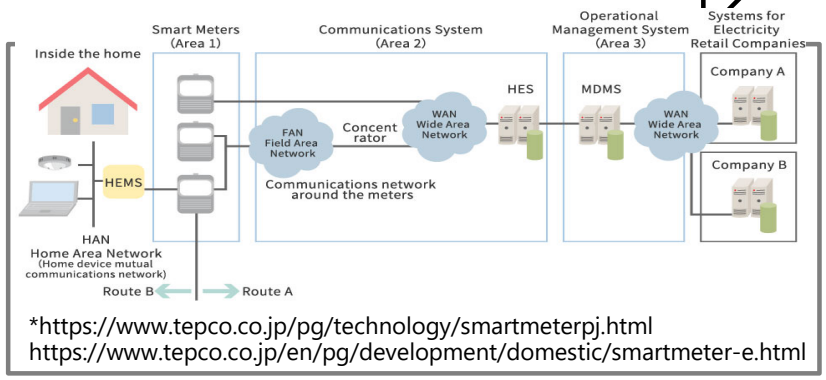


Connection



WDS

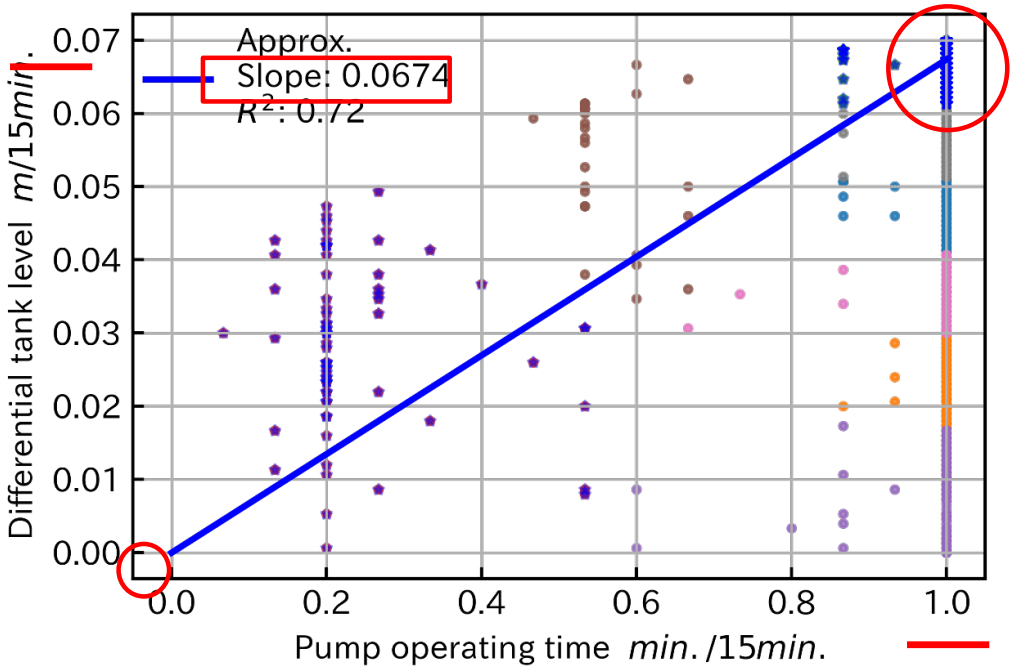
Regular expressions ^(.*?)hoge(.*?)$



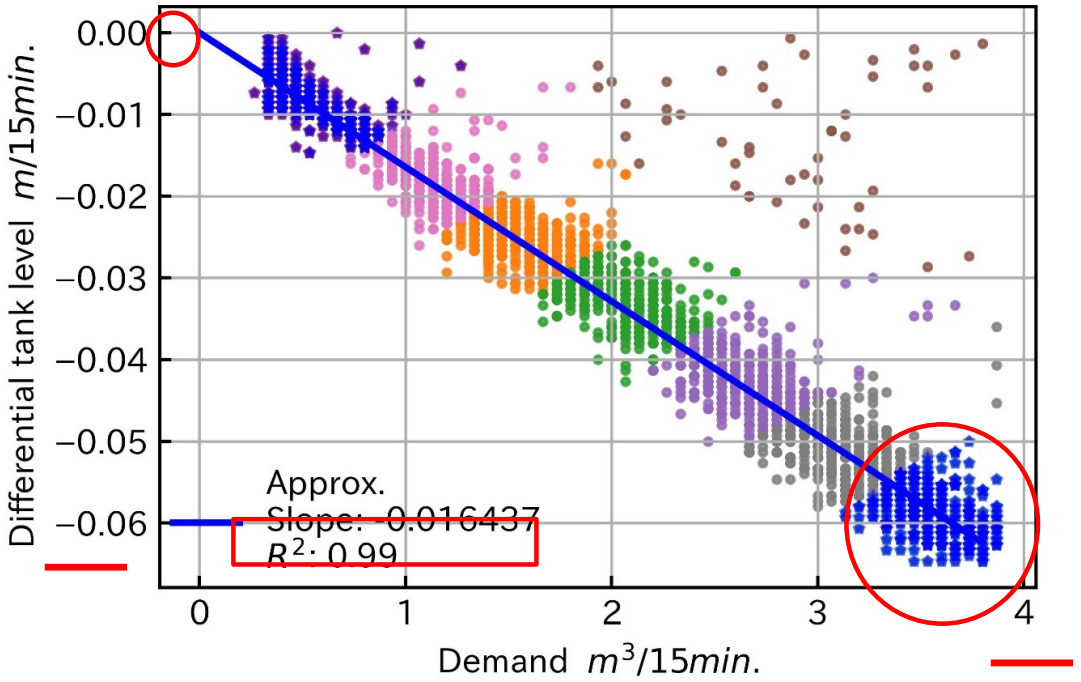
*https://www.tepco.co.jp/pg/technology/smartmeterpj.html
https://www.tepco.co.jp/en/pg/development/domestic/smartmeter-e.html

Identify I/O relationship

- K-means clustering to classify operating points.
  - Up to 8 clusters in this study
- Connect origin and blue clusters



which means that the water level rises 0.07 m when the pump operates for 15 minutes.



which means that the water level falls 0.06 m when the 4 m^3/15min of water demand is occurred.

Dataflow of PV forecasting

Training phase

Database

Observed Process variable
$\dot{E}^*$
$\dot{V}^{-,*}$
H^*
$\dot{V}^{+,*}$
δ^*
Weekday, Temperature etc.

Machine learning modeler

Trained model

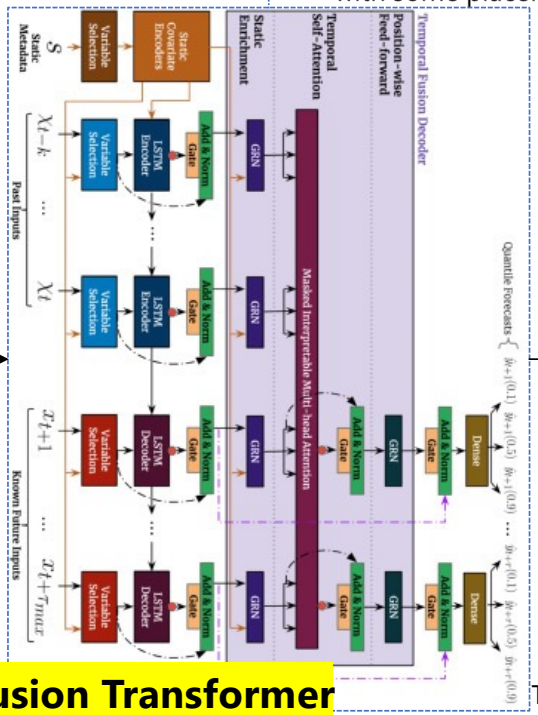
Given conditions

Optimization modeler

Optimization model with some placeholders

Input X

Observed Process variable
$\dot{E}^*_{t\in\{-T,\dots,0\}}$
$\dot{V}^{-,*}_{t\in\{-T,\dots,0\}}$
$H^*_{t\in\{-T,\dots,0\}}$
$\dot{V}^{+,*}_{t\in\{-T,\dots,0\}}$
$\delta^*_{t\in\{-T,\dots,0\}}$
Weekday, Temperature etc.



Output Y

Time-series
$\dot{E}^*_{t\in\{1,\dots,T\}}$
$\dot{V}^{-*}_{t\in\{1,\dots,T\}}$
$\delta^*_{t\in\{1,\dots,T\}}$

Temporal Fusion Transformer

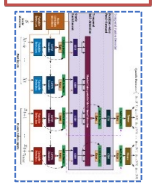
Forecasting phase

Database

Observed Process variable
$\dot{E}^*_{t\in\{-T,\dots,0\}}$
$\dot{V}^{-,*}_{t\in\{-T,\dots,0\}}$
$H^*_{t\in\{-T,\dots,0\}}$
$\dot{V}^{+,*}_{t\in\{-T,\dots,0\}}$
$\delta^*_{t\in\{-T,\dots,0\}}$
Weekday, Temperature etc.

Initial value
$\dot{E}^*_0, \dot{V}^*_0, H_0, \delta_0$

Predictor

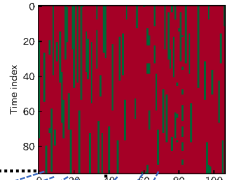


Time-series
$\hat{\dot{E}}_{t\in\{1,\dots,T\}}$
$\hat{\dot{V}}^{-}_{t\in\{1,\dots,T\}}$
$\hat{\delta}_{t\in\{1,\dots,T\}}$

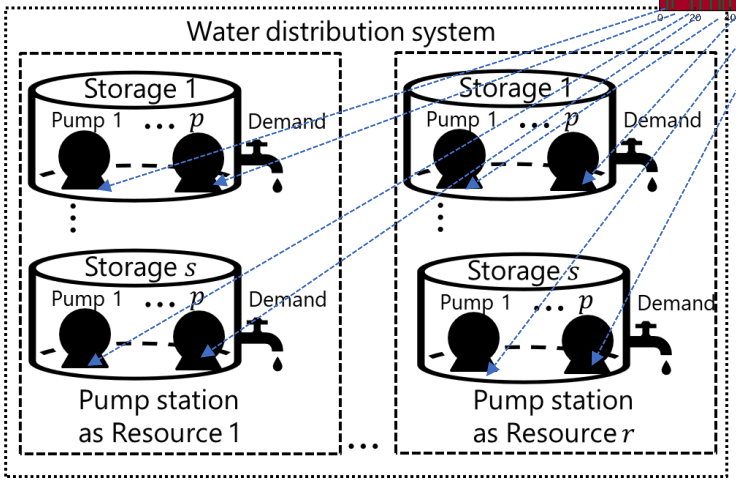
DR signal
$\dot{E}_{\tau\in\{\text{DR duration}\}}$

Optimizer

Operational Strategy
$\hat{\delta}_{t\in\{1,\dots,T\}}$



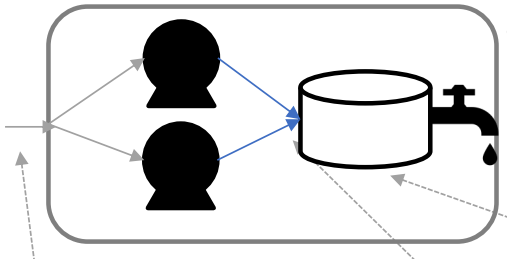
ON/OFF

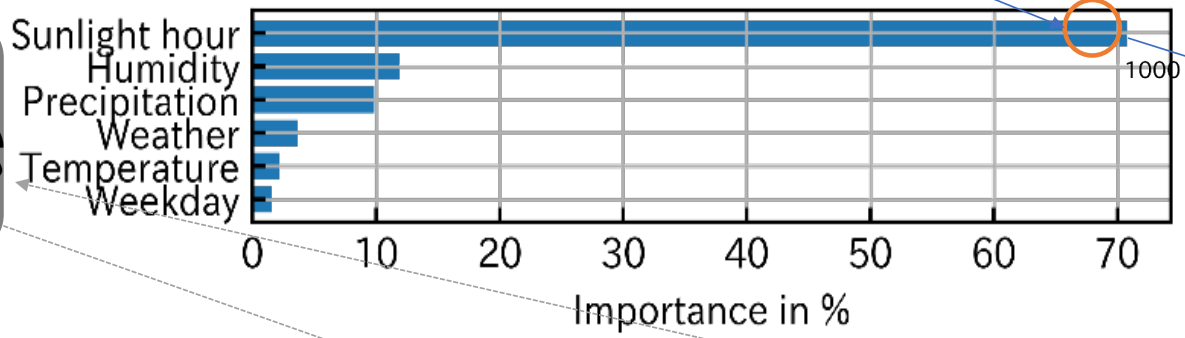


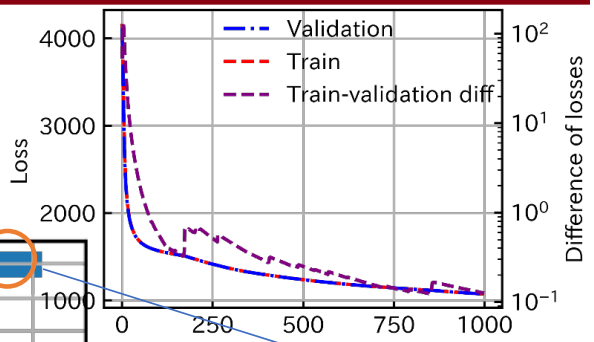
Temporal Fusion Transformer for interpretable multi-horizon time series forecasting, Int. J. forecasting, 2021

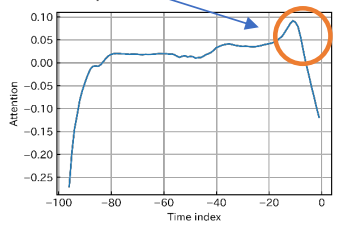
Quantile forecasting for multivariable multi-horizon timeseries

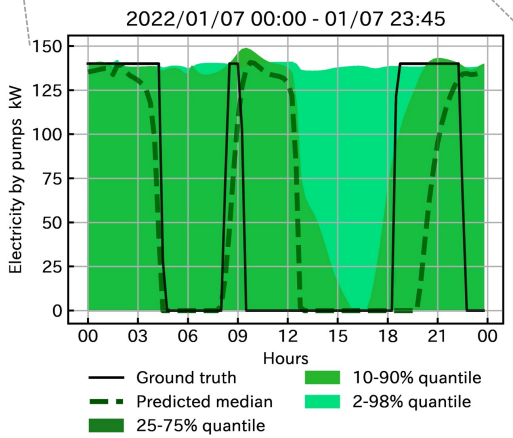
- Estimate connection
  - Describing inclusions around a reservoir from the tag name
- Multi-horizon forecasting

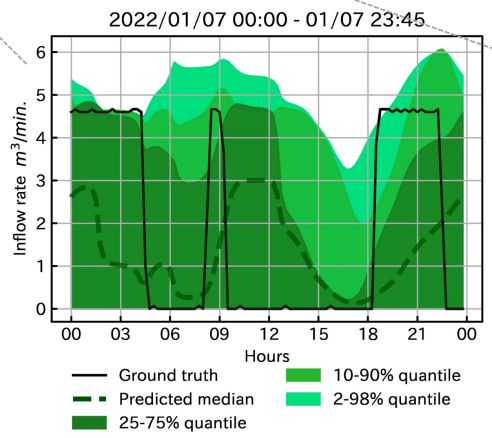


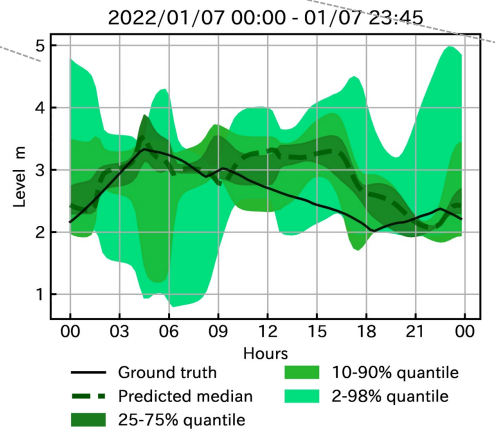


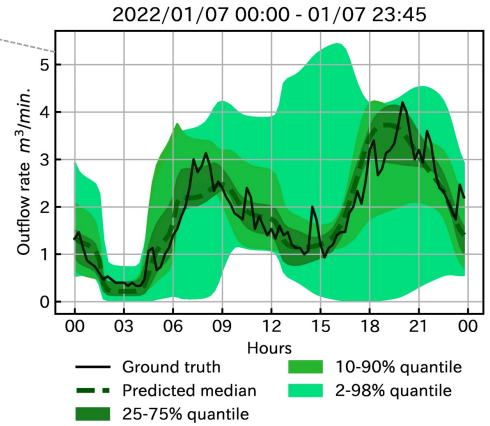












Operational planning problem by MIP

- $\delta^* = \underset{\boldsymbol{\delta}}{\operatorname{argmin}} \rho_1 \Sigma_{rspt} \left(\delta_{rspt} \overline{\dot{E}}_p \right)$
  - $+\rho_2 \Sigma_{rsp,t\in\{2,\ldots,T\}} \gamma_p \left(\delta_{rspt} - \delta_{rsp,t-1} \right)^2$
  - $+\Sigma_{tq} \left[\rho_{3,q} \left\{ \hat{\dot{E}}_{rtq} - \Sigma_{rsp} \left(\delta_{rspt} \overline{\dot{E}}_p \right) \right\}^2 \right]$
  - $+\Sigma_{rtq} \left[\rho_{4,q} \left\{ \hat{\dot{E}}_{stq} - \Sigma_{sp} \left(\delta_{rspt} \overline{\dot{E}}_p \right) \right\}^2 \right]$
  - $+\rho_{5,q} \Sigma_{rst} \left(\hat{H}_{rstq} - h_{rst} \right)^2$
  - $+\rho_6 \Sigma_{rt} \left(\Sigma_{sp} \delta_{rspt} \right)^2$
  - $+\rho_7 \Sigma_{rsp} \left(\Sigma_t \delta_{rspt} - \frac{\Sigma_{st} \delta_{rspt}}{\#p_s} \right)^2$

- s.t.
  - $\Sigma_{rsp} \delta_{rspt} \overline{\dot{E}}_p \le \overline{\dot{E}}_r$
  - $\underline{H}_{rs} \le h_{rst} \le \overline{H}_{rs}$
  - $\begin{cases} h_{rst} = H_{rs,t=0} + \delta_{rspt} \eta^+_{rsp} \Delta t - \hat{D}_{rst} \eta^-_{rsp} \Delta t & \text{if } t = 1 \\ h_{rst} = h_{rs,t-1} + \delta_{rspt} \eta^+_{rsp} \Delta t - \hat{D}_{rst} \eta^-_{rsp} \Delta t & \text{otherwise} \end{cases}$
  - $\dot{E}^{Base}_\tau - 1.1 \dot{E}^{DR}_\tau \le \Sigma_{rsp} \delta_{rsp\tau} \overline{\dot{E}}_p \le \dot{E}^{Base}_\tau - 0.9 \dot{E}^{DR}_\tau$
  - $\min\left(\hat{h}_{rstq}, \underline{H}_{rs} \right) \le h_{rst} \quad \forall t$ except for τ

- Feature of this formulation
  - Decision variables are binary
  - Objective terms work as constraints that can be violate
  - The weights of each term need to be adjusted in a heuristic way

Operational planning problem by MIP

- $\delta^* = \underset{\boldsymbol{\delta}}{\operatorname{argmin}}\ \rho_1 \Sigma_{rspt}\left(\delta_{rspt}\overline{\dot{E}}_p\right)$ — Electricity consumption
  - $+\rho_2 \Sigma_{rsp,t\in\{2,\dots,T\}}\gamma_p\left(\delta_{rspt}-\delta_{rsp,t-1}\right)^2$ — Suppress hunting
  - $+\Sigma_{tq}\left[\rho_{3,q}\left\{\hat{\dot{E}}_{rtq}-\Sigma_{rsp}\left(\delta_{rspt}\overline{\dot{E}}_p\right)\right\}\right]^2$ — Deviation from the forecasted electricity consumption per pump station
  - $+\Sigma_{rtq}\left[\rho_{4,q}\left\{\hat{\dot{E}}_{stq}-\Sigma_{sp}\left(\delta_{rspt}\overline{\dot{E}}_p\right)\right\}\right]^2$ — Deviation from the forecasted electricity consumption per water storage group
  - $+\rho_{5,q}\Sigma_{rst}\left(\hat{H}_{rstq}-h_{rst}\right)^2$ — Deviation from forecasted water level H
  - $+\rho_6\Sigma_{rt}\left(\Sigma_{sp}\delta_{rspt}\right)^2$
  - $+\rho_7\Sigma_{rsp}\left(\Sigma_t\delta_{rspt}-\frac{\Sigma_{st}\delta_{rspt}}{\#p_s}\right)^2$ — #operating pumps multiplied per water storage group

Deviation of pump operating time from average operating time per water storage group

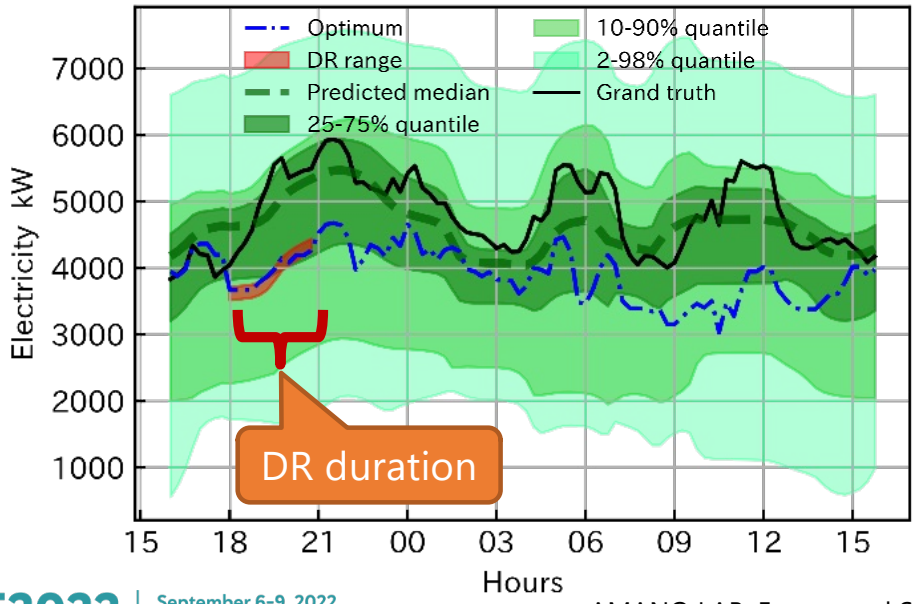
- s.t.
  - $\Sigma_{rsp}\delta_{rspt}\overline{\dot{E}}_p \le \overline{\dot{E}}_r$ — Contracted power
  - $\underline{H}_{rs} \le h_{rst} \le \overline{H}_{rs}$ — Operable range of water level
  - $\begin{cases} h_{rst} = H_{rs,t=0} + \delta_{rspt}\eta^+_{rsp}\Delta t - \hat{D}_{rst}\eta^-_{rsp}\Delta t & \text{if } t=1 \\ h_{rst} = h_{rs,t-1} + \delta_{rspt}\eta^+_{rsp}\Delta t - \hat{D}_{rst}\eta^-_{rsp}\Delta t & \text{otherwise} \end{cases}$ — balancing of water level
  - $\dot{E}^{Base}_\tau - 1.1\dot{E}^{DR}_\tau \le \Sigma_{rsp}\delta_{rspt}\overline{\dot{E}}_p \le \dot{E}^{Base}_\tau - 0.9\dot{E}^{DR}_\tau$ — DR should be ±10%
  - $\min\left(\hat{h}_{rstq}, \underline{H}_{rs}\right) \le h_{rst}\quad \forall t \text{ except for } \tau$ — Constraint of water level

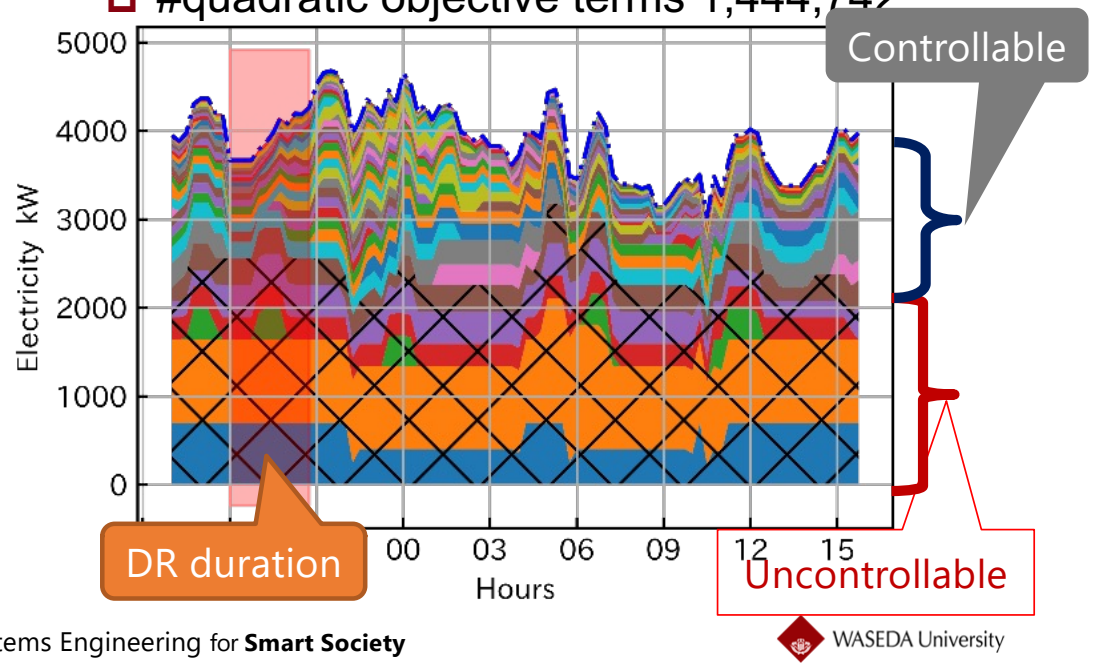
Feature of this formulation

- Decision variable is only binary
- Objective terms work as constraints that can be violate
- The weights of each term need to be adjusted in an heuristic way

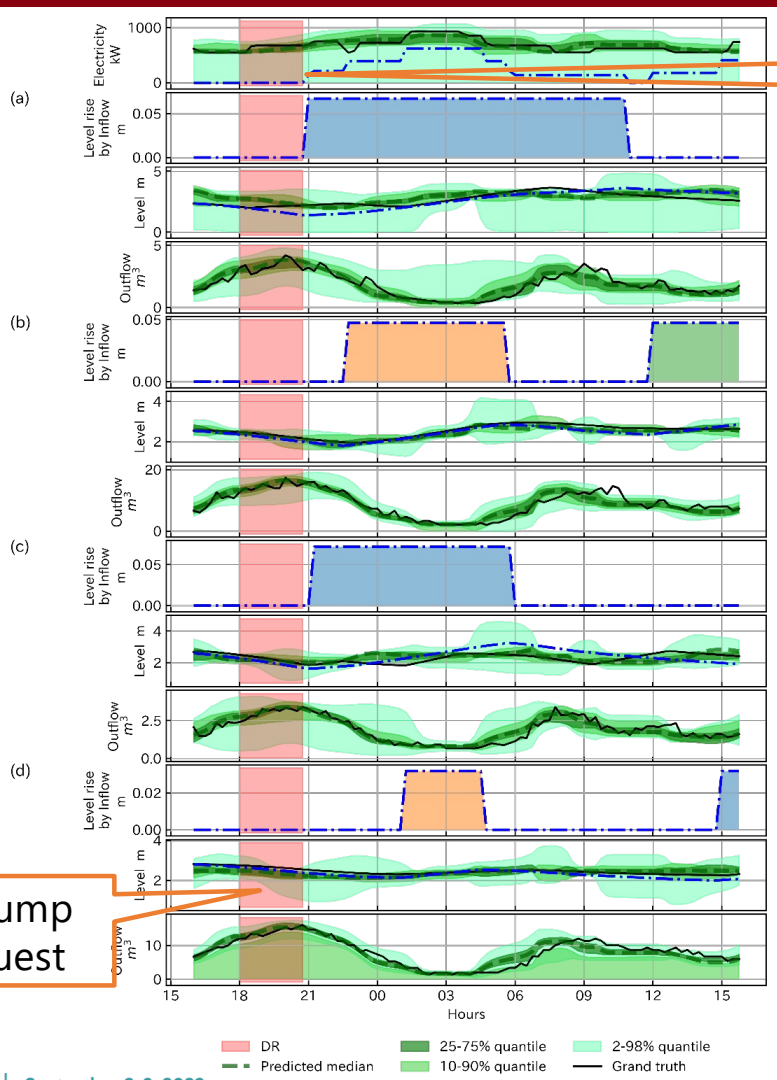
1 MW downtrend DR result optimized by Gurobi

- Incentive-based DR specification
  - 1 MW curtailment
  - Three hours
  - ±10% success criteria
- Difficult to solve; problem size is too large
  - 0.25 hr time step
  - #107 / 129 controllable pumps
  - #20 smart meters, #40 reservoirs
  - #binary decision variables 10,272
  - #quadratic objective terms 1,444,742

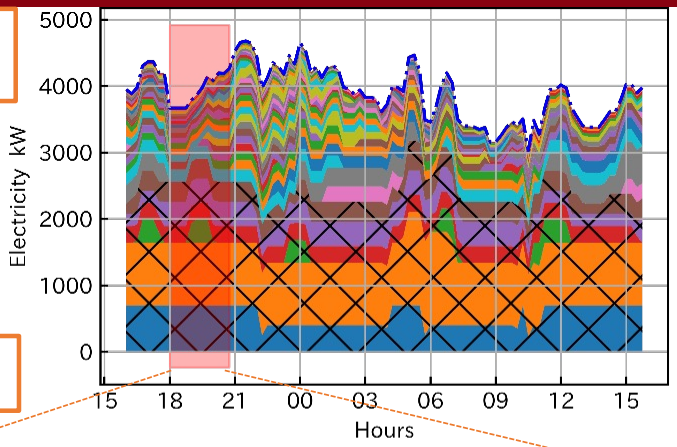




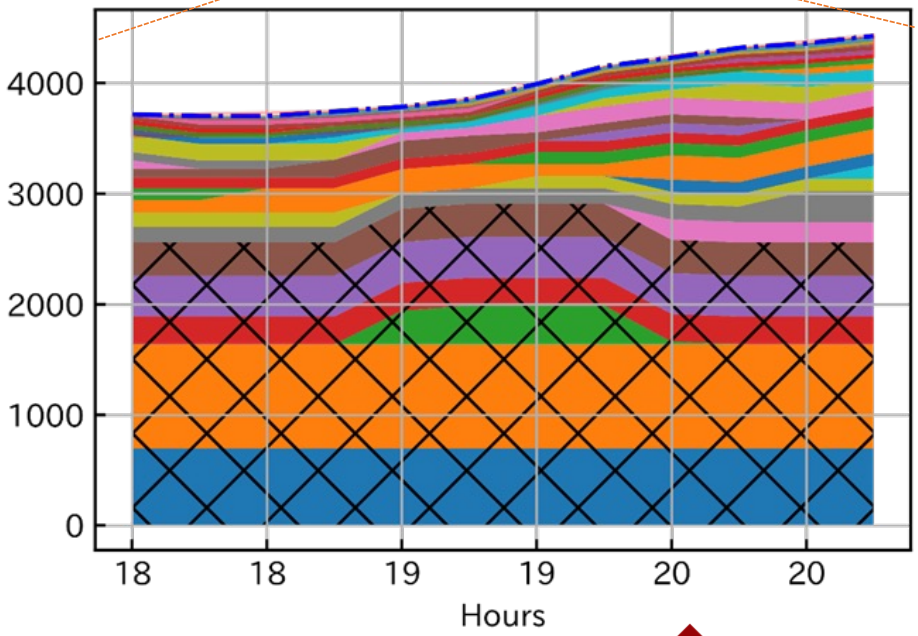
Breakdown of profiles: A reservoir



BAU 700kW
→DR 0KW



Load balancing



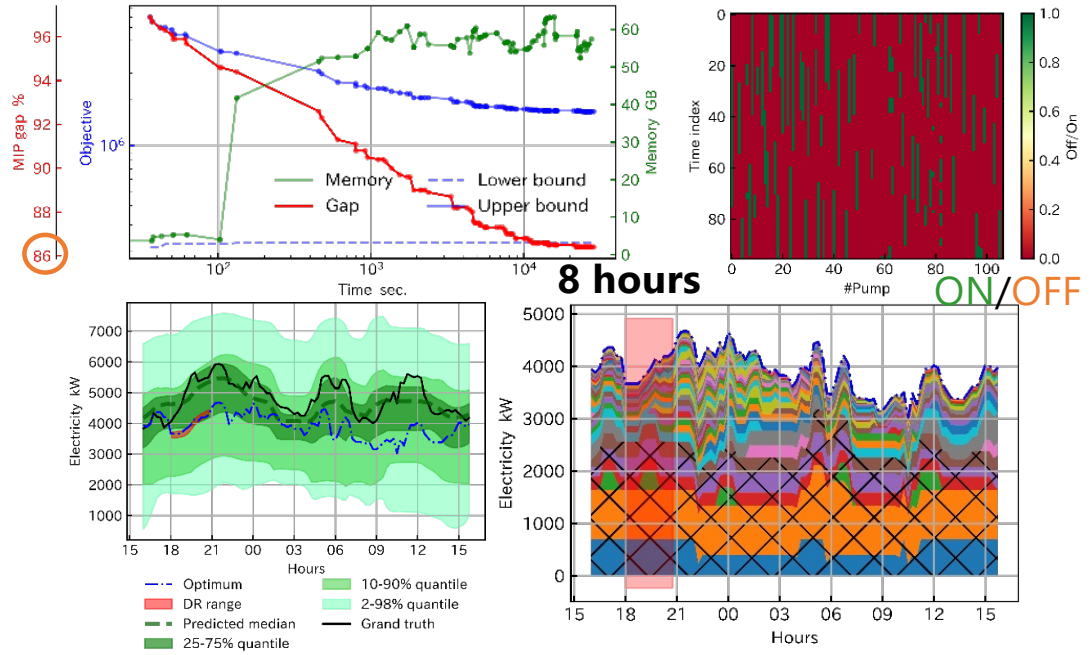
Stopped pump
by DR request

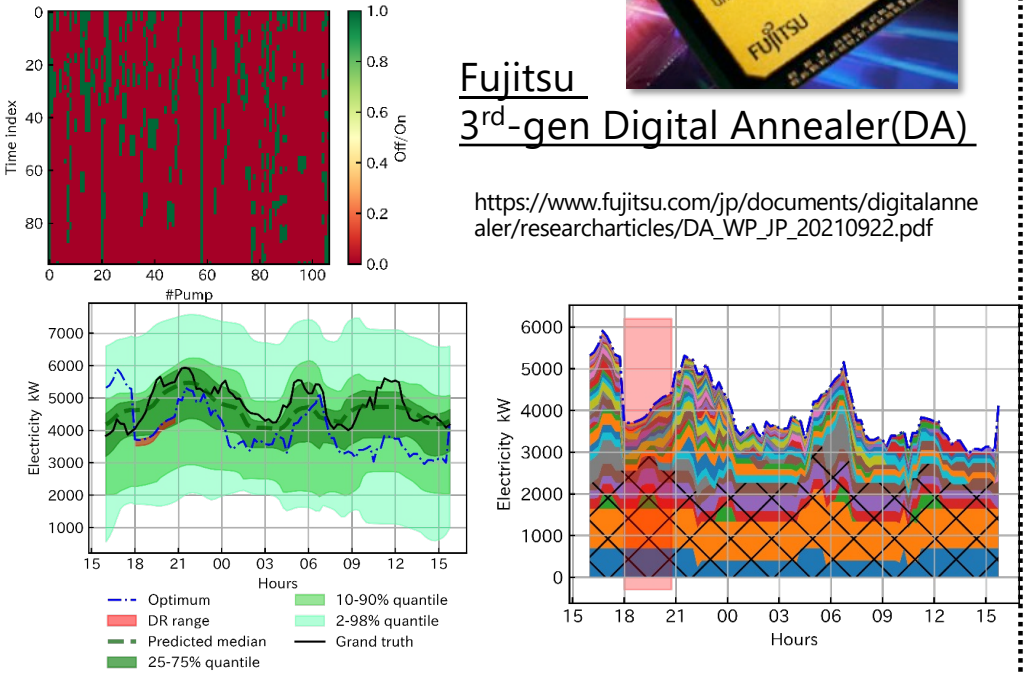
Annealing solver can solve with 60 seconds.

- Operational planning by MIP solver
  - With **86%** MIP-gap, Gurobi took **8 hours**
- **Quadratic Unconstrained Binary Optimization**(QUBO) solved in **1 minutes.**
  - up to 100,000 variables

Convert to **QUBO**

General MIP solver, Gurobi





Fujitsu
3rd-gen Digital Annealer(DA)

https://www.fujitsu.com/jp/documents/digitalannealer/researcharticles/DA_WP_JP_20210922.pdf

SUMMARY

- Developed and evaluated an **optimization model** for **virtual power plant (VPP)**
  - A method for estimating the connection relationship between entities by text mining method
  - Input-output relationship modeling of elements based on process variables (PV)
  - Time-series forecasting with quantiles as exogenous variables
  - Annealing technology for quantizing and solving problems that cannot be solved by existing mixed-integer linear programming solvers
  - Methodology for Discretizing Continuous Variables to Formulate Binary Optimization Problems

Analytics tools are ready for modeling the **energy management problem.**

Large-scale combinatorial optimization can be solved with a special hardware!

Management system model can be formulated as optimization problems

Optimization approach is promising for

designing large, complicated system and
operating the system

Variety of modeling/formulating theories are available; from **MIP** to **QUBO**

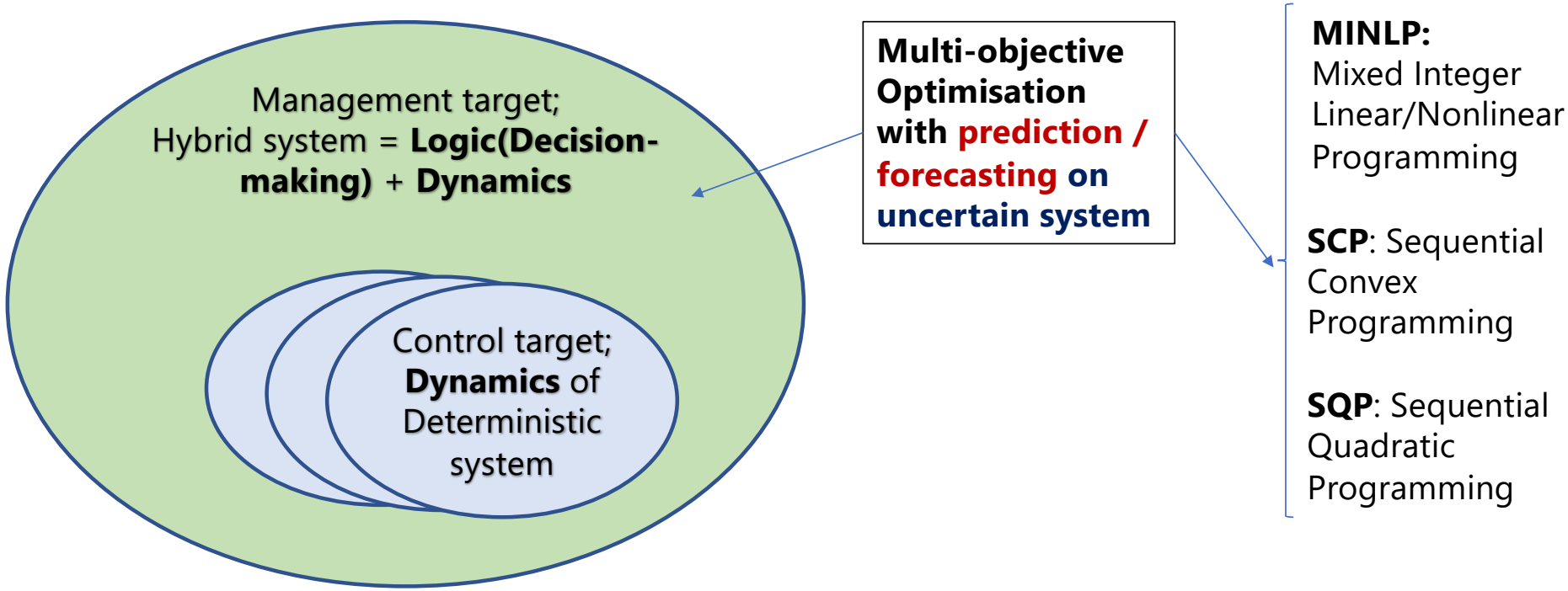
Any question? Ask to the expert: Dr. Akira Yoshida by e-mail; a.yoshida@aoni.waseda.jp

Energy Management System

- Example of Energy Management System
  - **Large-scale hierarchical optimisation of resource aggregation for Demand Response / VPP**
- **What is Energy Management System(EMS)?**
  - **Management and Control**
  - **Definition of EMS in ISO, IEC**
  - **Fundamental functions for EMS**
  - **How can we classify the system; Automation Levels**

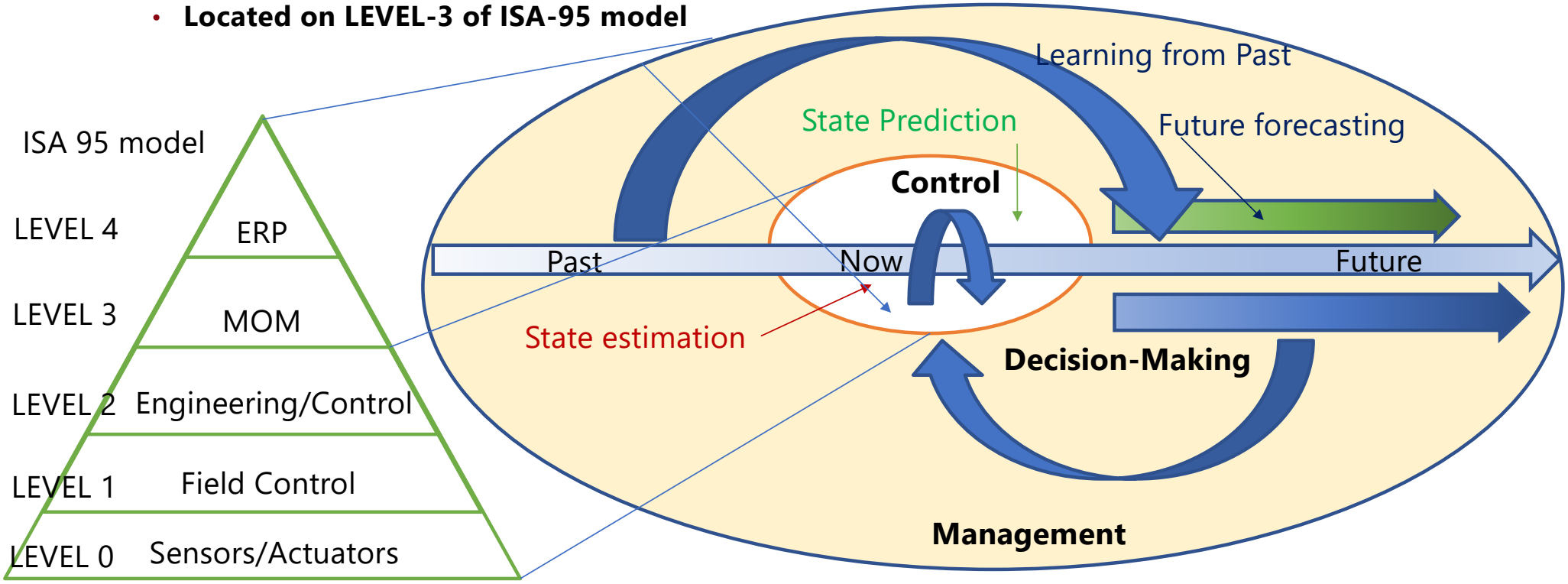
Management and Control

- **Control**; automatic regulation of dynamic behavior of systems
- **Management**; automatization of decision-making activity with **prediction / forecasting** on **uncertain system**; system of systems



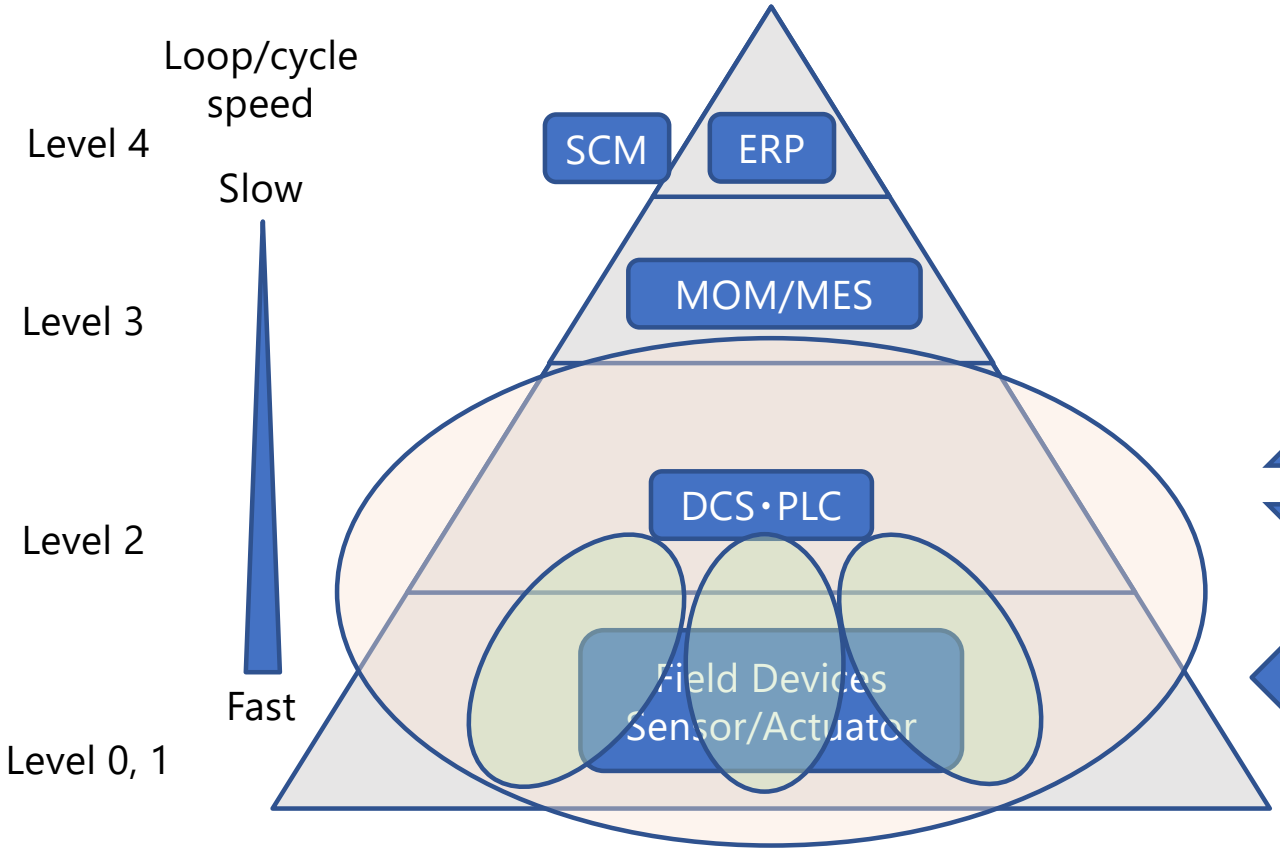
Management and Control

- Objectives ; **manage** the system to achieve **goals**
  - **Represent** Plant; Identification of the target system's behavior model
  - **Configure** system including feedback loop;
  - Management system is composed of functions of sensing/analysis/optimization and instruction
    - **Located on LEVEL-3 of ISA-95 model**



ISA95, Enterprise-Control System Integration

International Society of Automation



ERP: Enterprise Resource Planning
SCM: Supply Chain Management
MOM: Manufacturing Operations Management
MES: Manufacturing Execution System
DCS: Distributed Control System
PLC: Programming Logic Controller

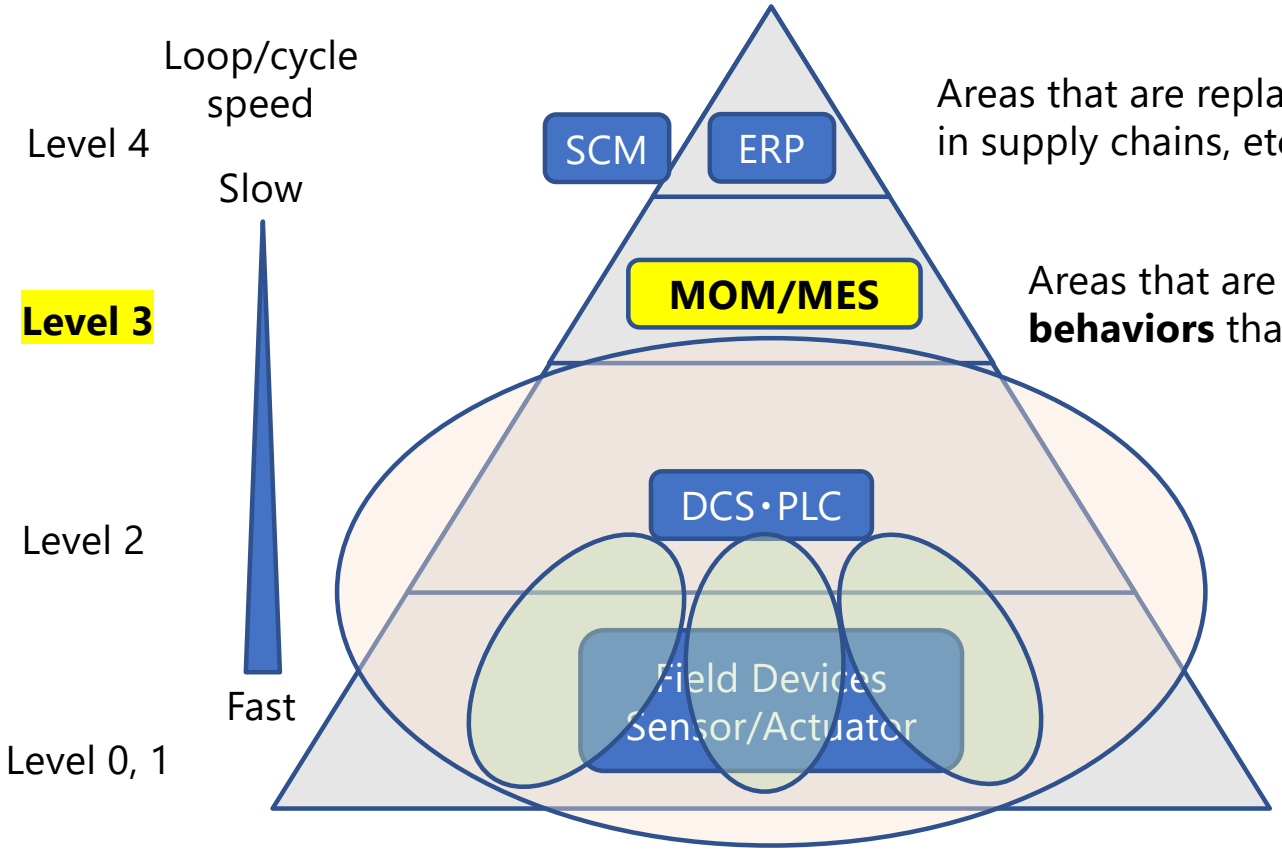
It makes sense to establish data connectivity between each level through a common database hub.

It is reasonable to share the data that spans the segments within each level as data after connecting with the Gateway.

MOM/MES

International Society of Automation

ISA95, Enterprise-Control System Integration



Areas that are replacing **human activities and behaviors** in supply chains, etc.

Areas that are **substituting human activities** and **behaviors** that connect the field and the head office

Areas where sufficient technology exists for **automation**

https://blog.lnsresearch.com/whats-the-difference-between-mom-mes

Definition of EMS from ISO, IEC

- **management system**

set of interrelated or interacting elements of an organization to establish **policies** and **objectives** and **processes** to achieve those objectives

From ISO 50001:2018 Energy management systems — Requirements with guidance for use

- **energy management system**

control system designed to **monitor** the environment and the **use of energy** in a facility and to **adjust the parameters** of local control loops to conserve energy while maintaining a suitable environment

From ISO 16818:2008(en)

- **energy management**

process for **monitoring**, **analysis**, **reporting** and **improvement** of energy efficiency

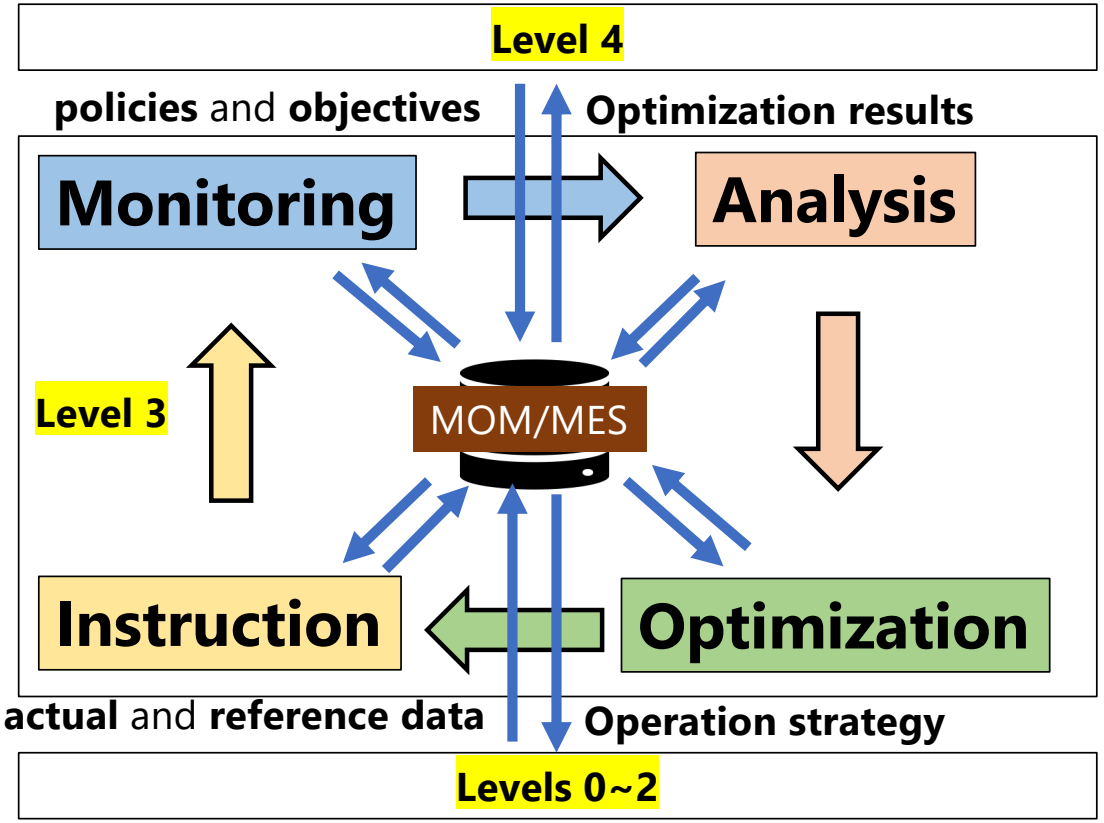
From ISO/IEC TS 22237-7:2018(en)

Fundamental functions for EMS

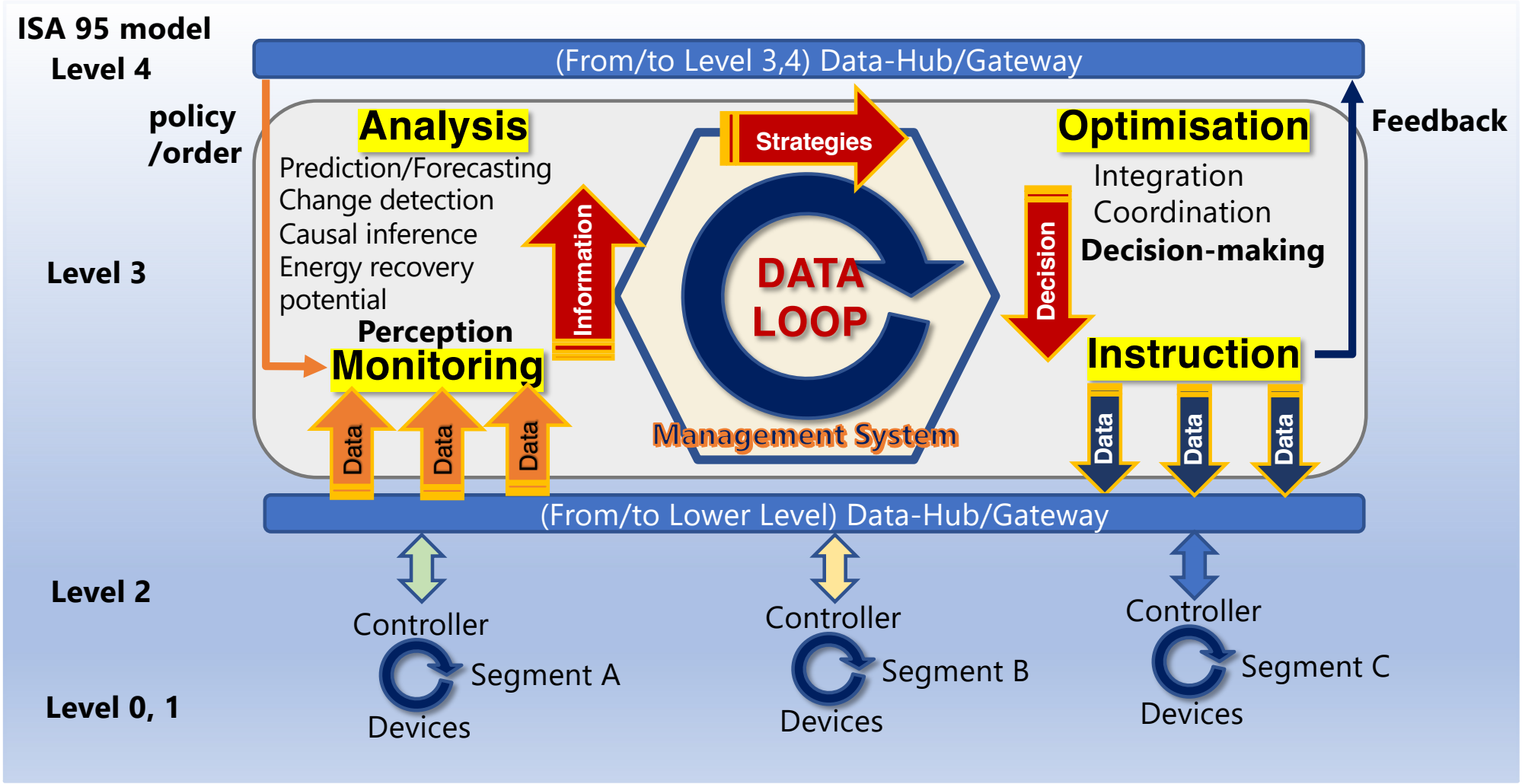
- Idea for **IEC 63376 FEMS**

Modified from ISO/IEC TS 22237-7:2018 "process for **monitoring**, **analysis**, **reporting** and **improvement** of energy efficiency"

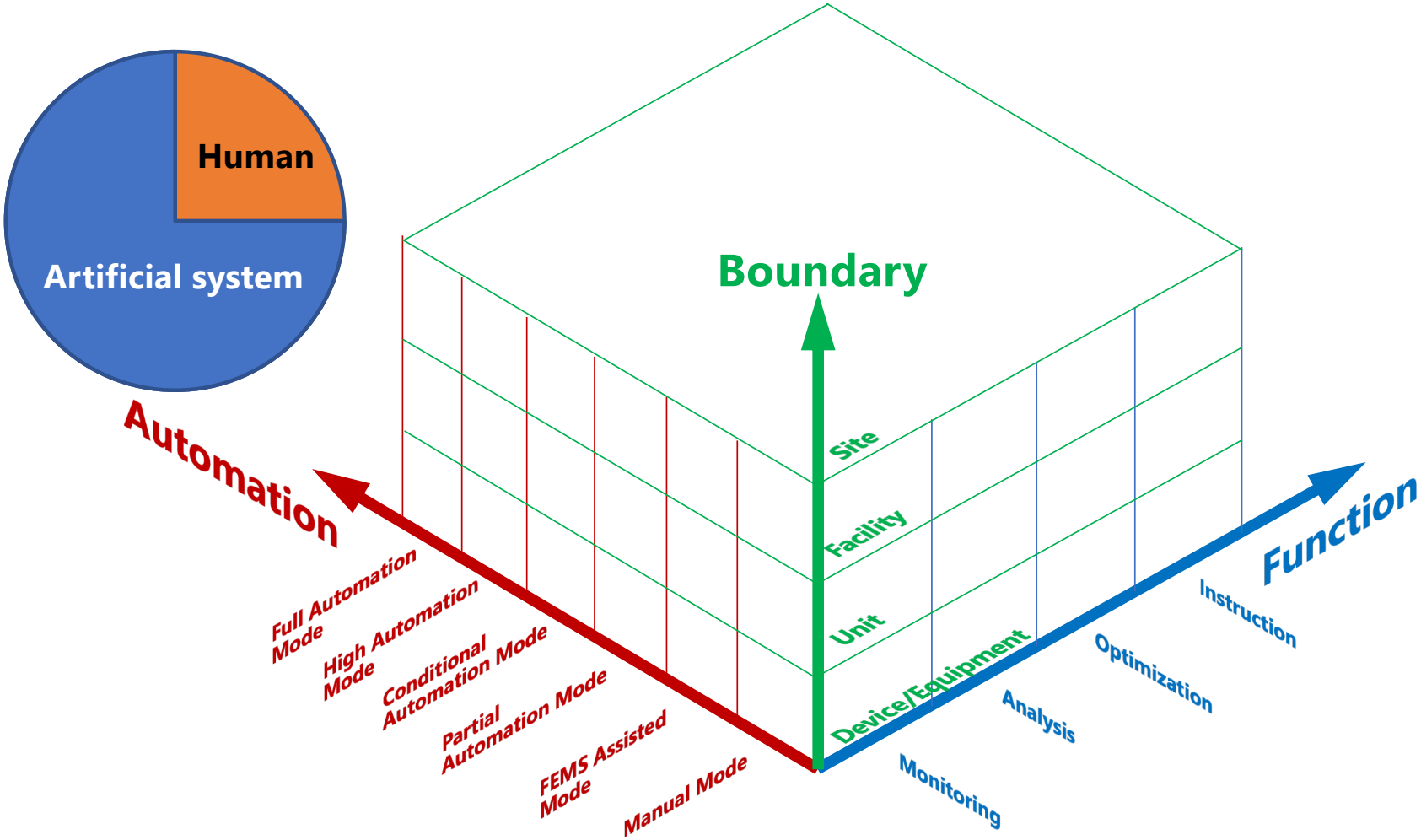
the "**loop**" suggests **continuous activity**



Design of Management System



Automation level in EMS



Evolution of Technology

Automation and technology???

Evolution of Technology

automatic | adjective **1** (of a device or process) working by itself with little or no direct human control

automation; late 19th century (with reference to a theory that living organisms act in a purely mechanical way): irregular formation from automatic + -ation.
The current sense dates from the 1940s.
Oxford Dictionary of English

Evolution of Technology

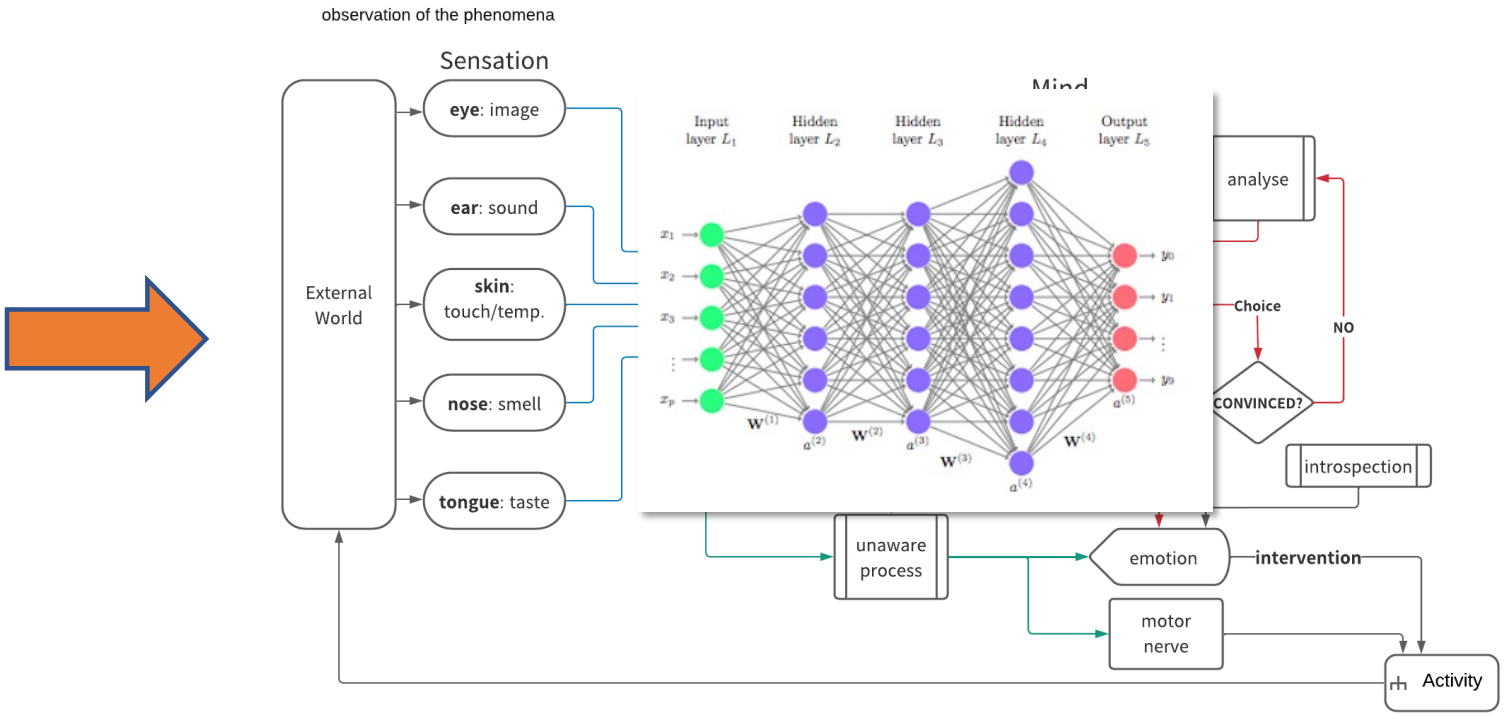
- What is **Technology**?
  - **Engineering** is a knowledge system that **evolves technology**

    - **Technology** is a knowledge system that *realize* **accountable function**

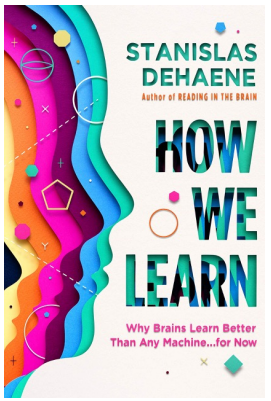
    - The evolution of technology manifests itself as the **extension/expansion** of boundary of **automation**

Mechanism of human recognition of the world

- How can we **perceive** the external world as it is, without biases?

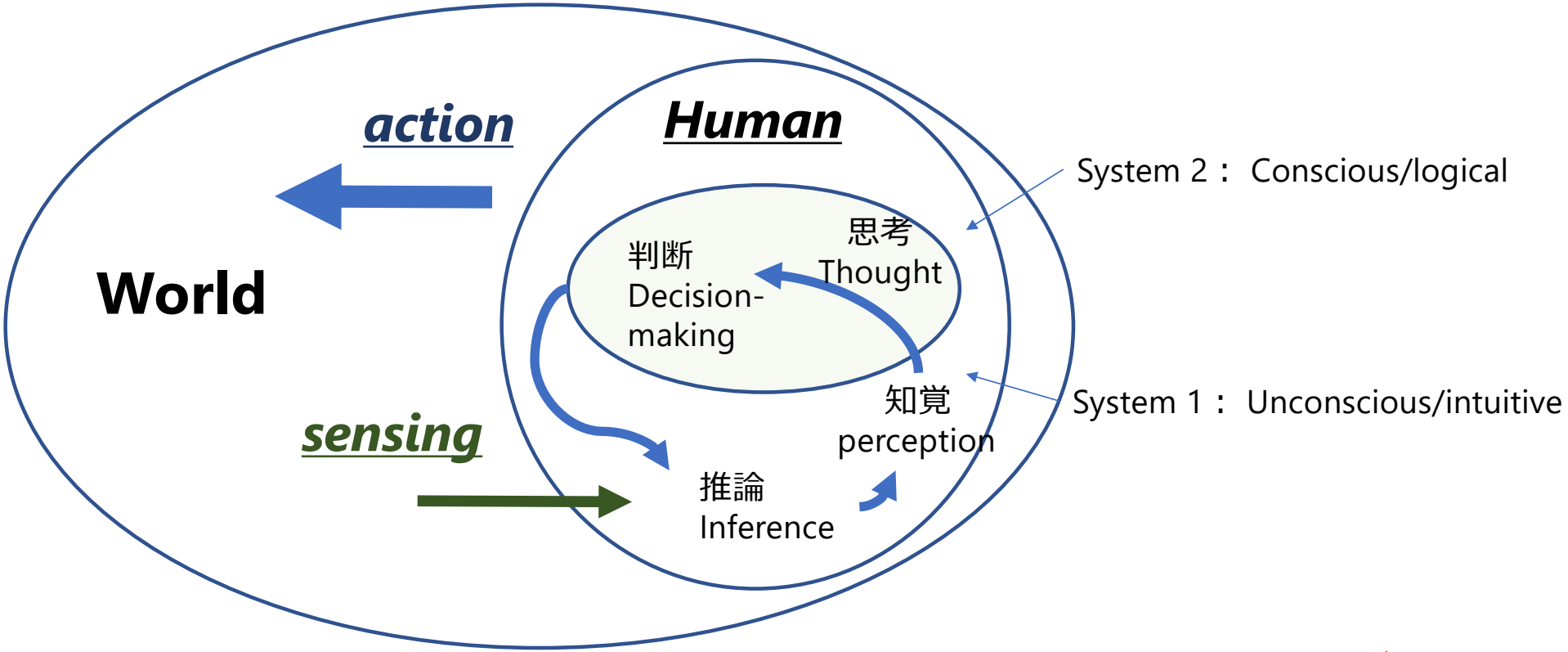


based on



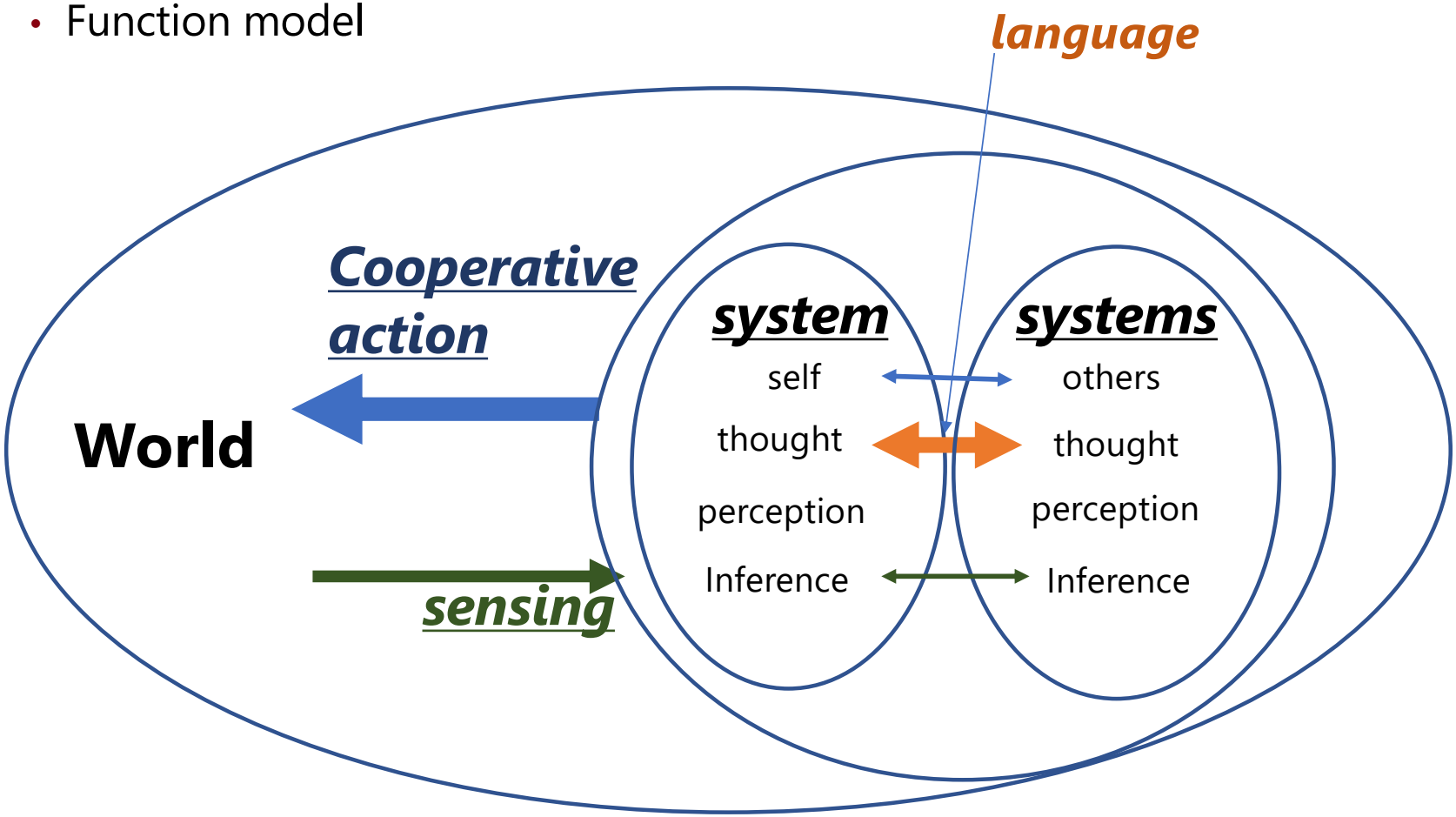
Evolution of Technology

- Human activity inside and outside
  - How can we **perceive** the external world?
  - How can we **know** the external world as it is, without biases?



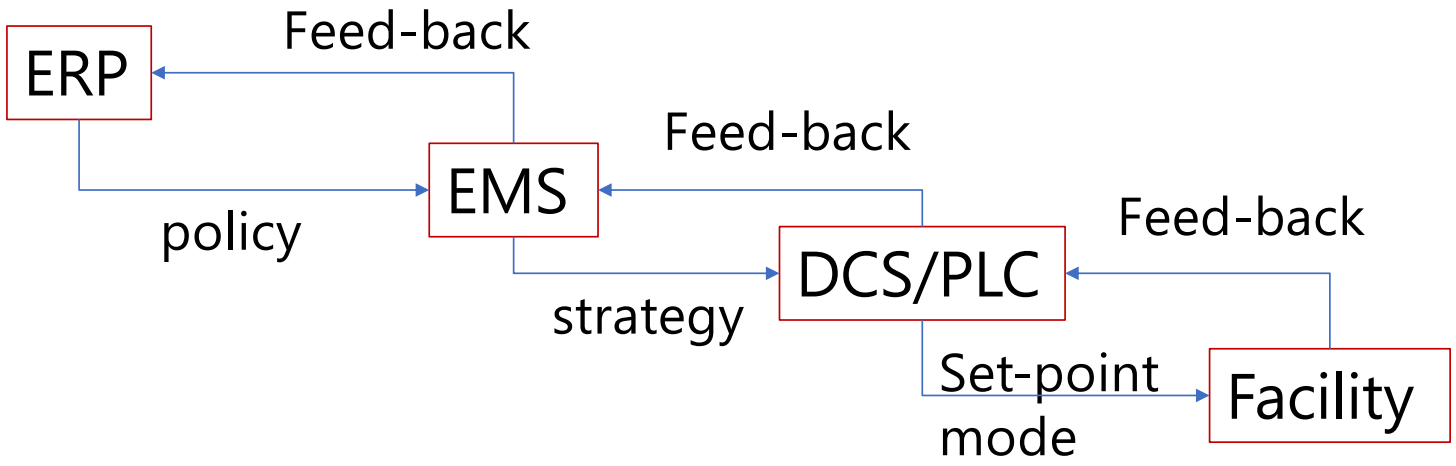
Evolution of Technology

- Social activity and the social system
  - Function model

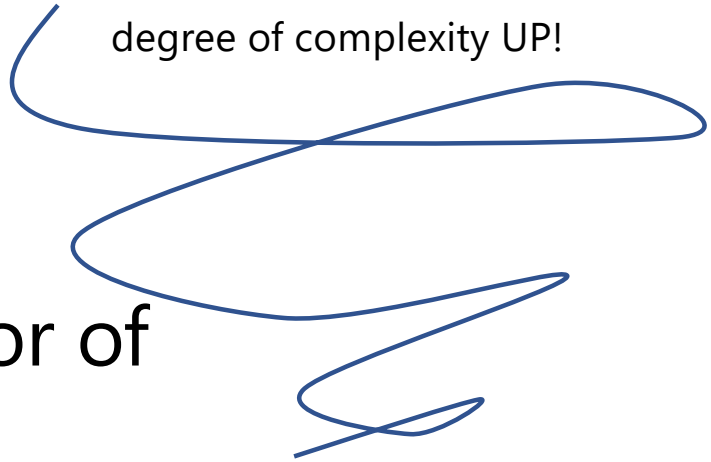


Management system

- Management system, above the control system, should have capability of **recognition of external world (set of facilities relevant to energy)** and **decision-making** functions based on policy.



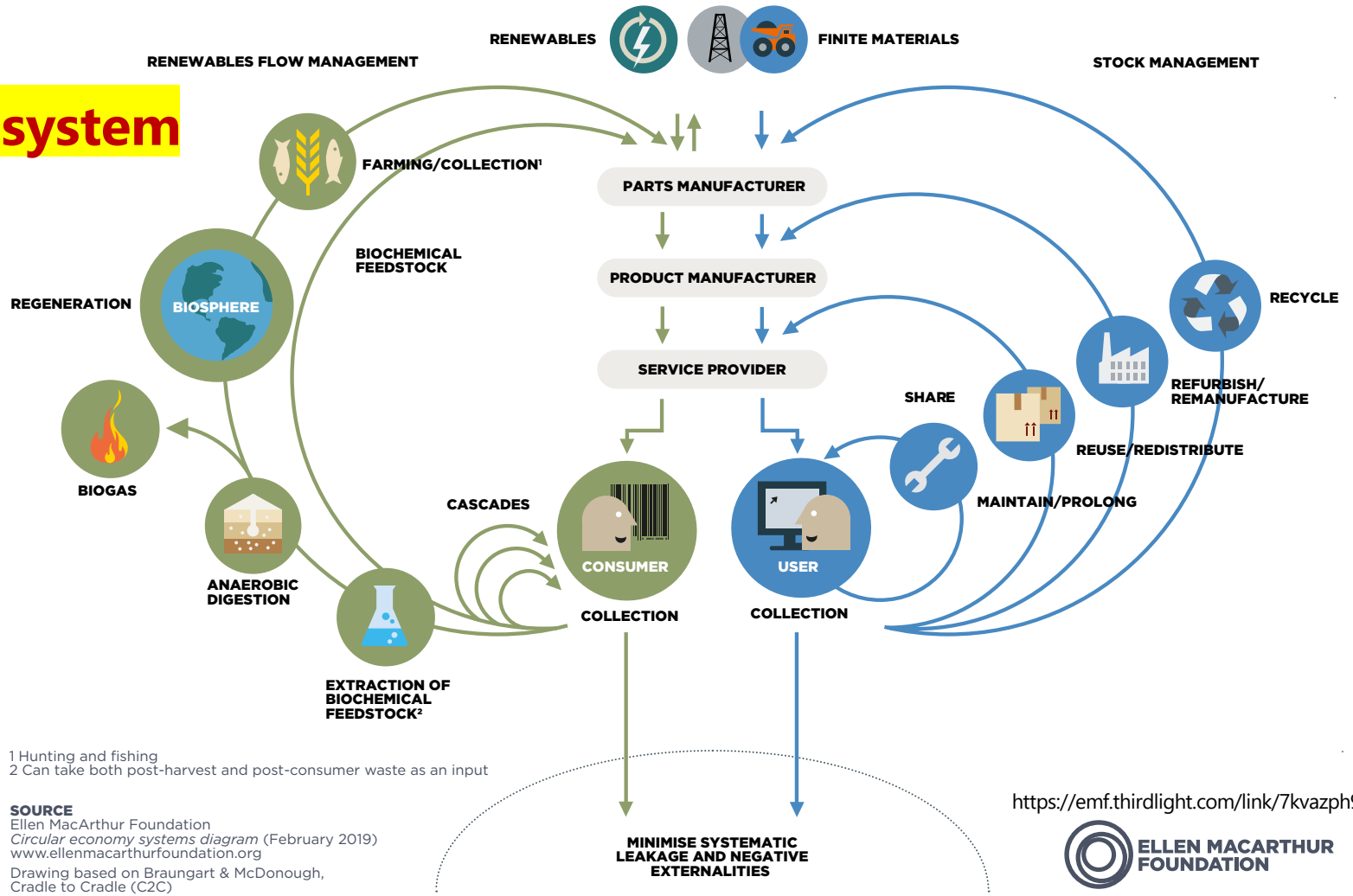
Evaluate your system from the perspective of
Evolution of **Technology.**



Automation level is the key indicator of
the **Evolution** of the **Technology.**

Technology for Sustainability

ecosystem



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input

SOURCE
Ellen MacArthur Foundation
Circular economy systems diagram (February 2019)
www.ellenmacarthurfoundation.org
Drawing based on Braungart & McDonough, Cradle to Cradle (C2C)

https://emf.thirdlight.com/link/7kvazph93afk-owveai/@/preview/1?o

ELLEN MACARTHUR FOUNDATION

Summary

- **Optimization** is the key technology to **design** and **operate** a large/complicated system
- To build an artificial system in **society**
  - **Organize the system as an ecosystem**
  - Set **broader boundaries** and prepare **data(information) flows** with all stakeholders to enable them to participate
    - System that **circulates energy** + **matter** + **data(information)** at every level
  - If we understand the inner/outer mechanism of our **mind**, **management system** will evolve.

Thank you for your attention.