ITU/FAO Workshop on
"Digital Agriculture at Scale: Sustainable Food System with IoT and AI"
(Seongnam, Korea (Republic of), 24 August 2022)

# Digital Twin for Smart Livestock Farming


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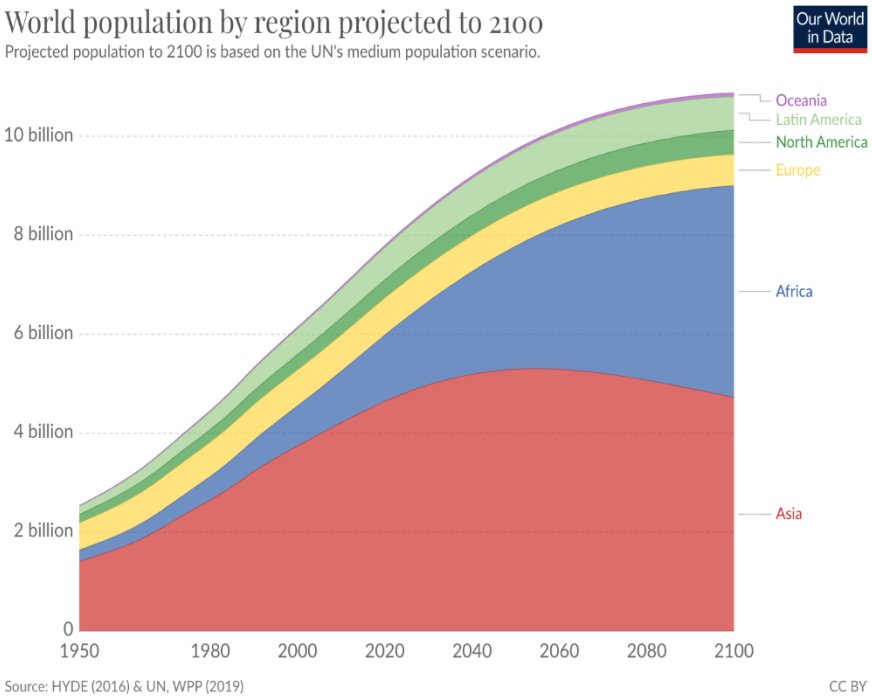
# Today's Agriculture

## Sustainable food security
## against explosive growth of the population and environmental pollution



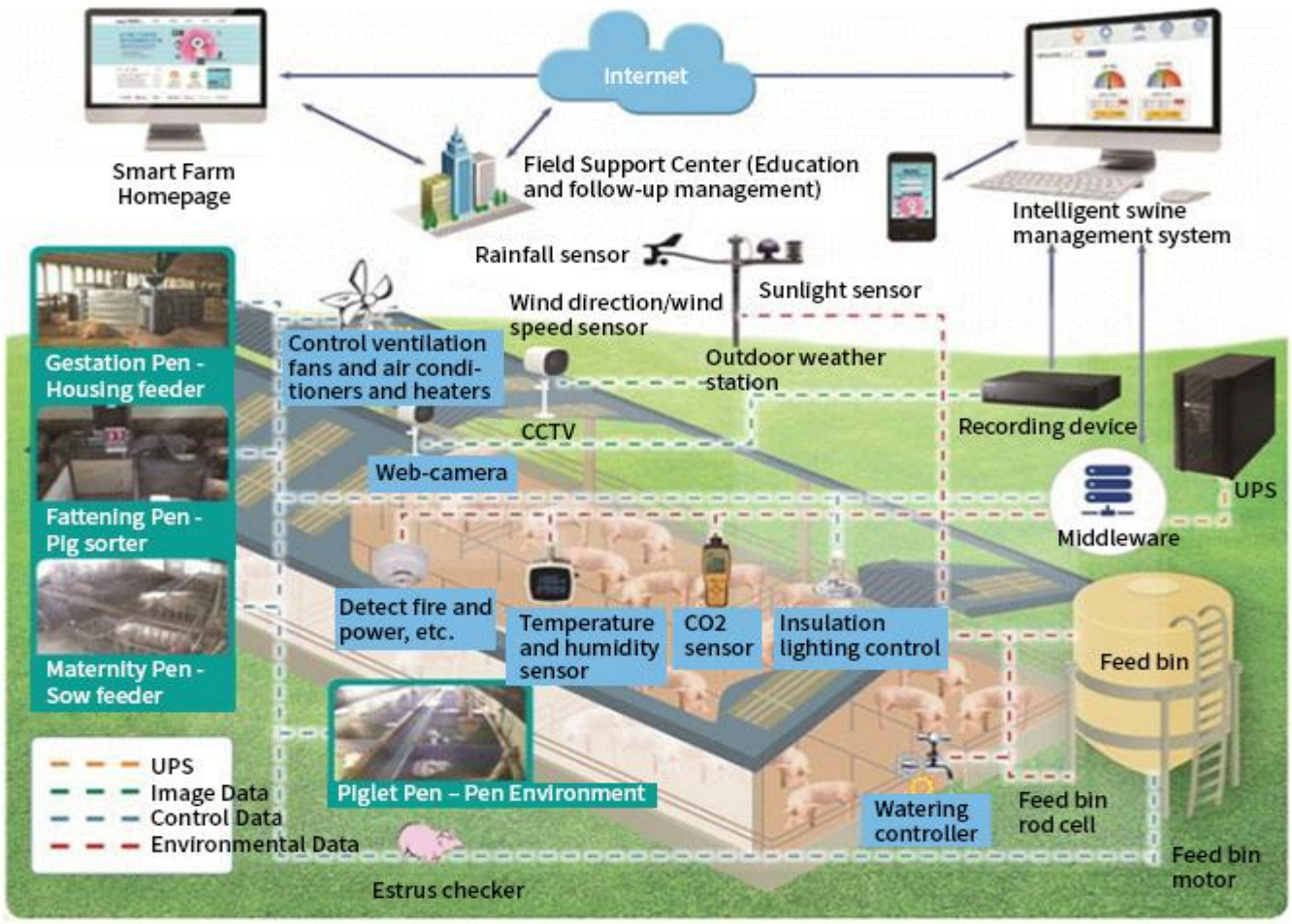

**구제역 피해현황** 자료: 농림축산식품부

| | 살처분 마릿수 | 재정 소요액 |
|---|---|---|
| 2000년 | 2천마리 | 2725억원 |
| 2002년 | 16만마리 | 1058억원 |
| 2010~2011년 | 354만마리 | 2조8695억원 |
| 2014~2015년 | 17만마리 | 655억원 |
| 2016년 | 3만3천마리 | 59억원 |
| 합계 | 390만5천마리 | 3조3192억원 |

**Agriculture is no more traditional primary industry mainly depending on labor.**
**Being evolved through digitalization using ICT**
**for securing food and high-tech future industry**

# Today's Livestock Farming

# ICT Convergence for Livestock Farming




Source: http://www.mafra.go.kr/english/1495/subview.do

# Digital Twin (DT)

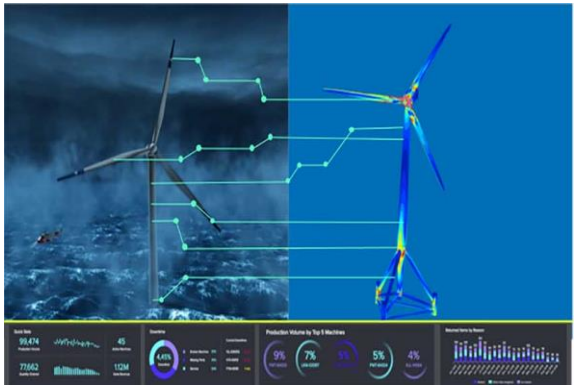
A **digital twin** is a digital representation of a real-world entity or system.
The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. **(Gartner)**

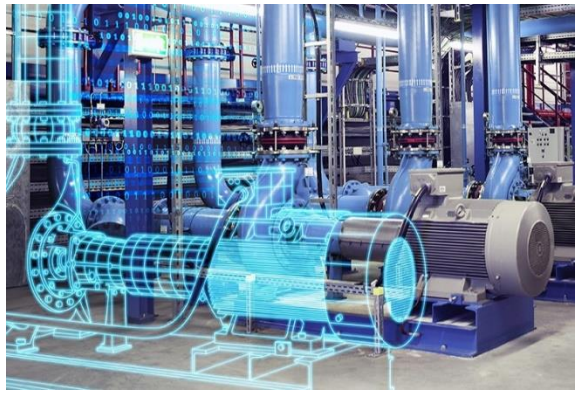
A **digital twin** is a virtual representation that serves as the real-time digital counterpart of a physical object or process. **(Wikipedia)**

A **digital twin** is a virtual model designed to accurately reflect a physical object. **(IBM)**

GlobeNewswire

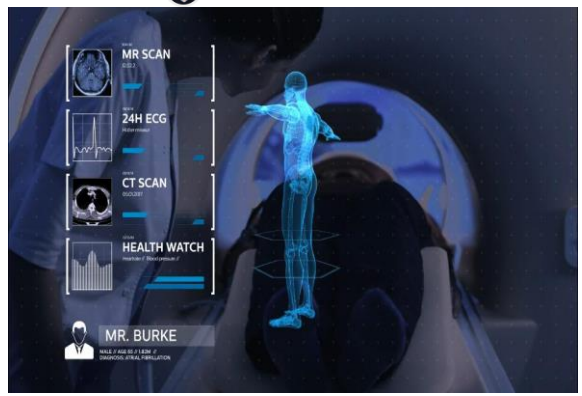
**Digital Twin Market to reach USD 165.8 Billion with 41.8% CAGR by 2030 | MDC Research**





**New digital twin of the immune system will make precision medicine a reality**

By **Iain Robertson** on 20th May 2022

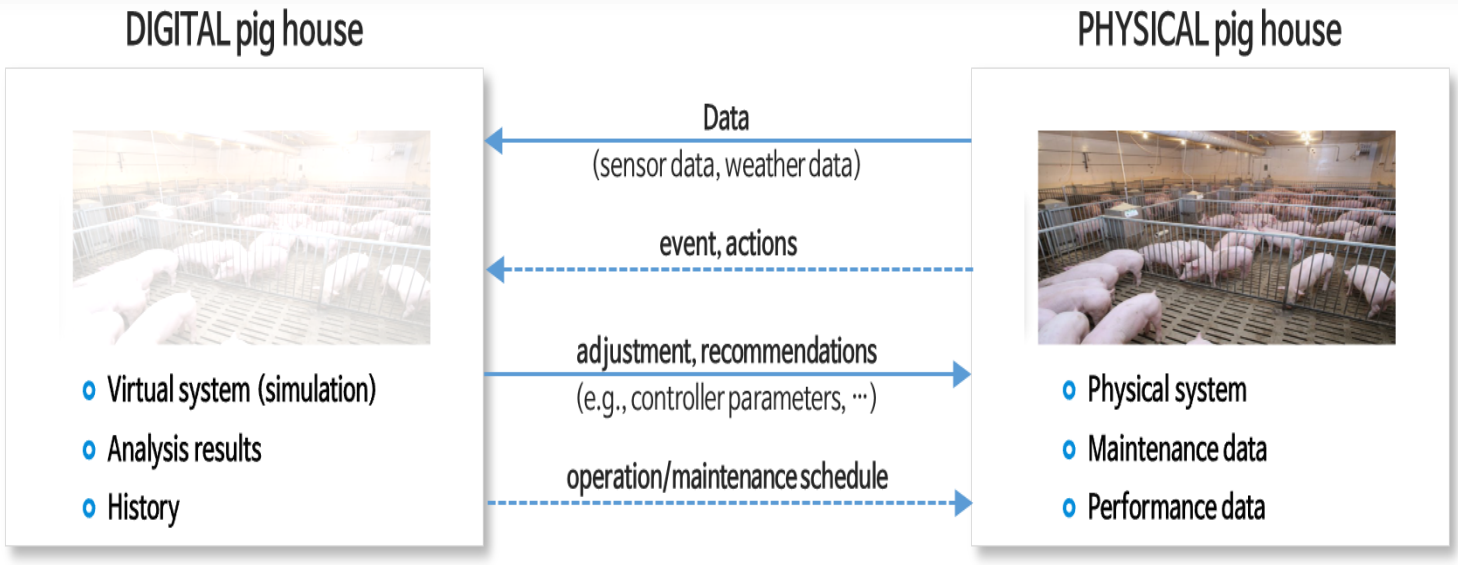


# DT in Livestock

## The role of DT in livestock farming

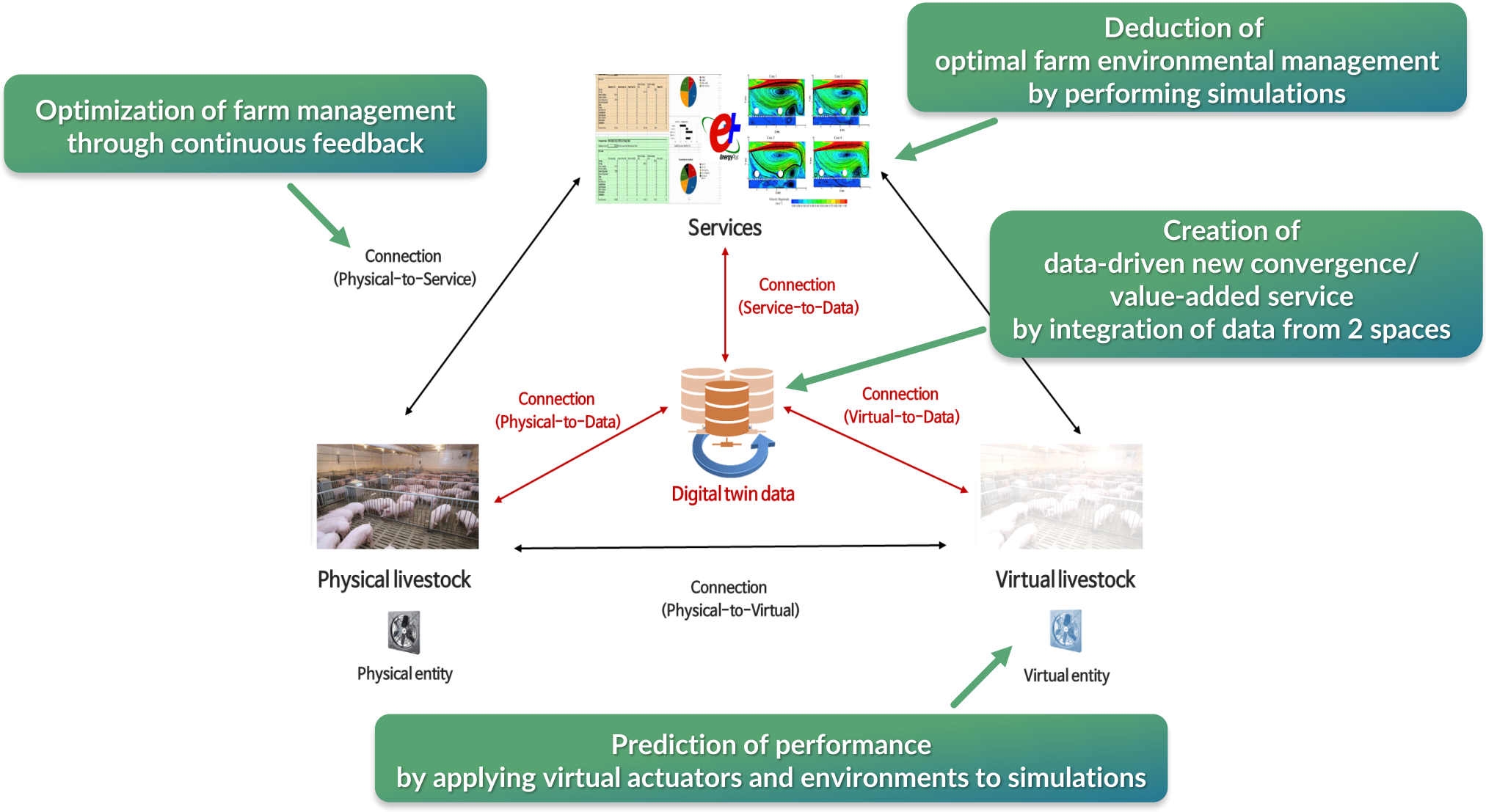
A **service platform** which can maximize productivity and efficiency of farm management by constructing virtual farm in a digital space and interworking data and control between physical and digital spaces.

Then, it performs a variety of simulations for environment and growth control and manages farm according to simulation results



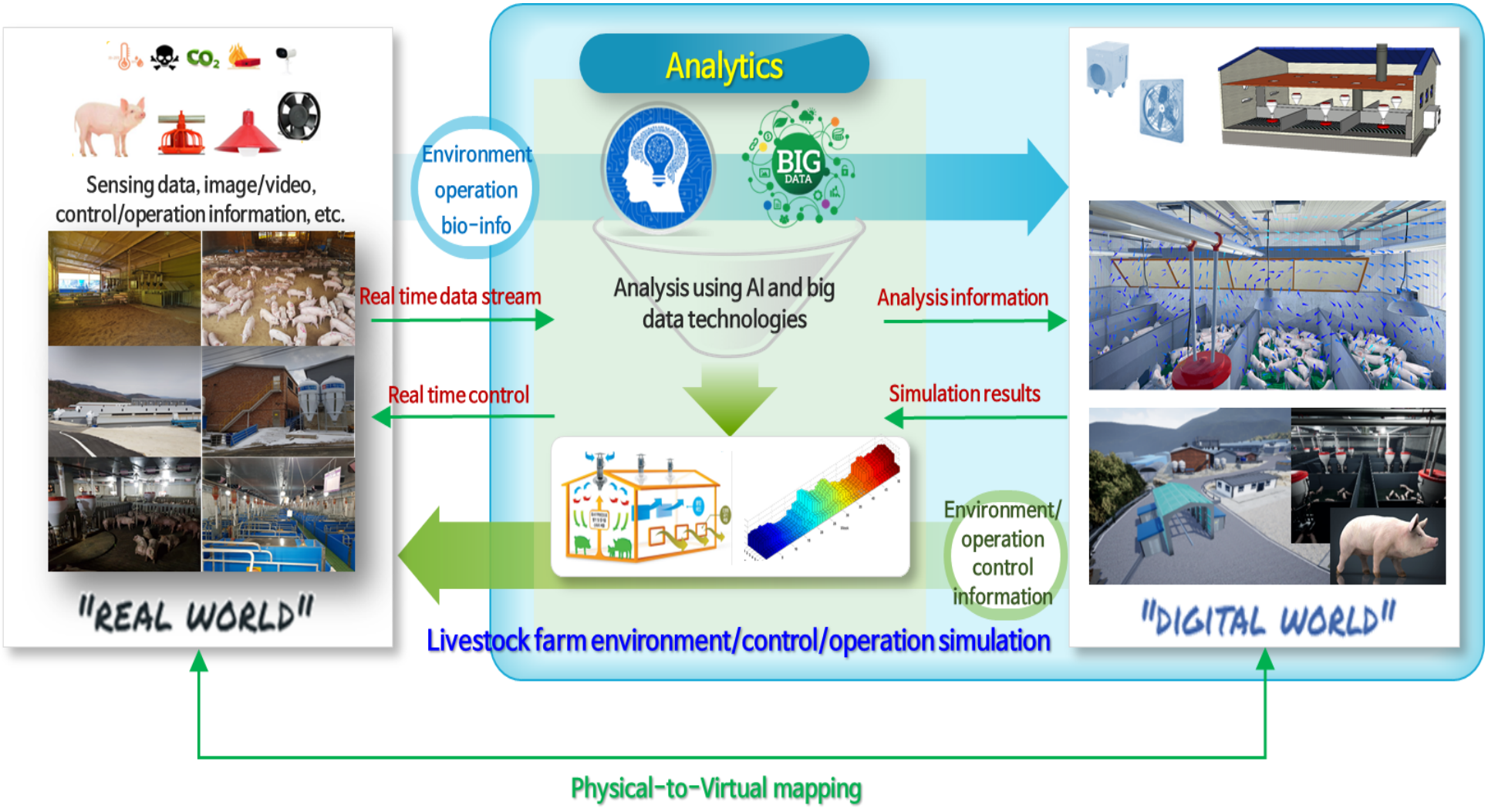

Interaction between Physical & Digital space in livestock farming

# DT in Livestock

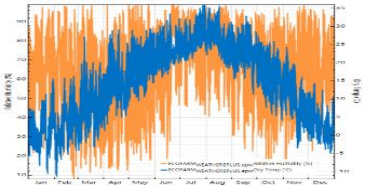



Reference: “5-dimension DT model” - Digital Twin Driven Smart Manufacturing (Academic Press, 2019)

# Concept of DT for Livestock Farming



# DT Scenario #1 – virtual objects, locations



Temperature/humidity,
wind direction/speed, solar radiation, etc.

DB

Livestock Simulations

Virtual DB

Simulators

SIM environments

SIM control

SIM feedback

P2V control

P2V mapping

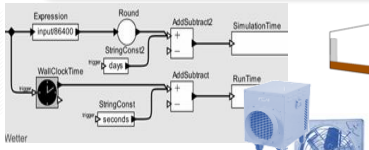
Real objects

Virtual objects

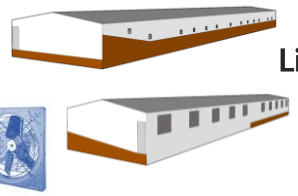
Livestock energy analysis
(virtual objects, locations, etc.)

Livestock farm energy simulation

IDF authoring tools



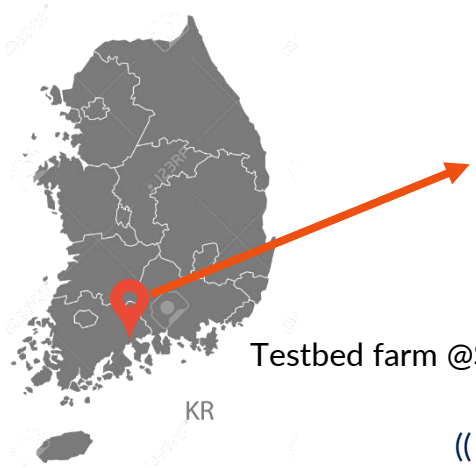
VO control logic



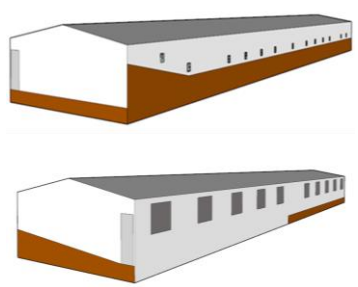
Livestock facility modeling

# DT Scenario #1 – virtual objects, locations

## Energy analysis using DT – ventilation fans




Testbed farm @Suncheon

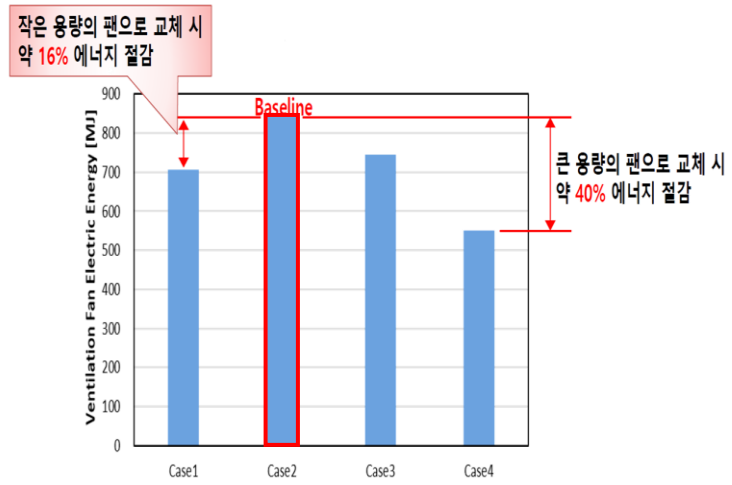



(( Ventilation fan profile ))

| Model | Power consumption | Air volume ($CMH$) | Design Flow Rate ($m^3/s$) | Fan Pressure Rise ($PA$) |
|---|---|---|---|---|
| SLF-350A4-6 | 102 W | 3400 | 0.94 | 108 |
| SLF-500A4-6 | 535 W | 8500 | 2.36 | 227 |
| SLF-730A6-5 | 660 W | 12600 | 3.50 | 189 |
| SLF-960A6-3 | 670 W | 19550 | 5.43 | 123 |
| SLF-300D2-6 | 255 W | 3568 | 1.00 | 257 |
| SLF-500D4-6 | 418 W | 8500 | 2.36 | 177 |

(( Ventilation fan combinations for simulation ))

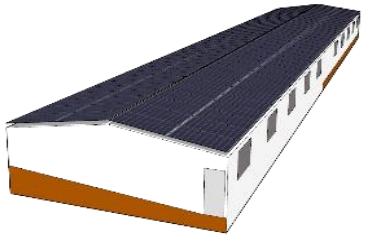
| | Fan combination | ea | Total CFM |
|---|---|---|---|
| Case #1 | SLF-350A4-6 (15ea), SLF-300D2-6 (10ea) | 25 | 51000 |
| Case #2 | SLF-500A4-6 (6ea), SLF-500D4-6 (4ea) | 10 | 50000 |
| Case #3 | SLF-730A6-5 (4ea), SLF-500D4-6 (4ea) | 8 | 49600 |
| Case #4 | SLF-960A6-3 (4ea), SLF-300D2-6 (2ea) | 6 | 50000 |




Energy consumption per case

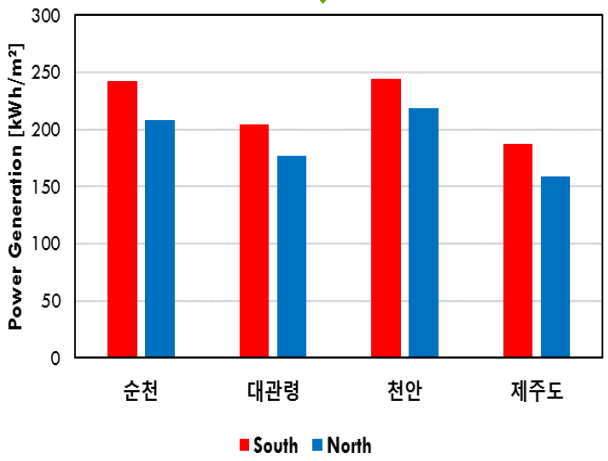
# DT Scenario #1 – virtual objects, locations

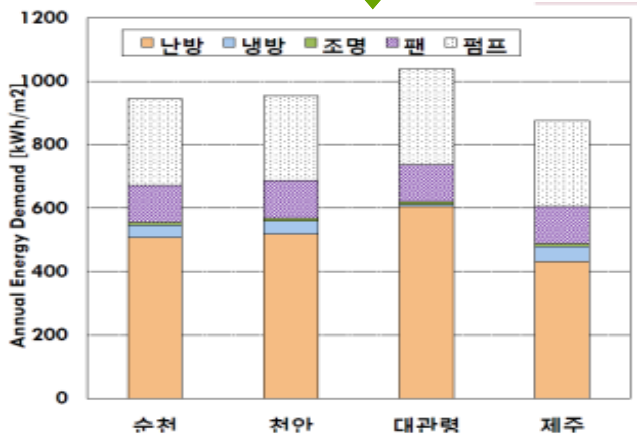
## Energy analysis using DT – solar panels and locations




How much renewable energy can be generated if the roof is equipped with solar panels?

How much do I pay for electricity bills if I built pig house in other places?



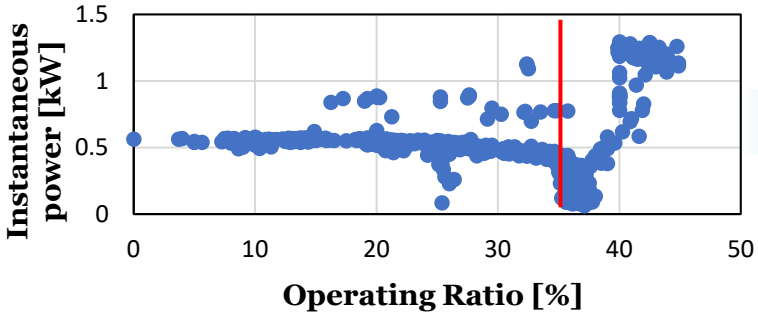



# DT Scenario #2 – fan operation strategy

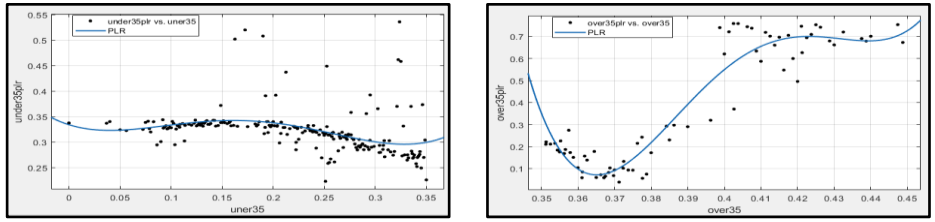
## Energy analysis using DT – optimal fan operation strategy

Define ventilation fan energy model using measured data

Verification of fan energy model through physical-to-virtual interworking and model update

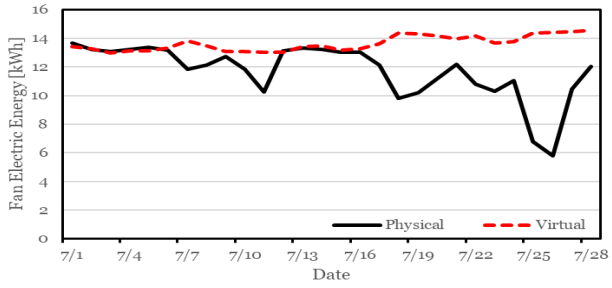



Measurement of fan energy consumption
(2022.5.25 ~ 6.30)



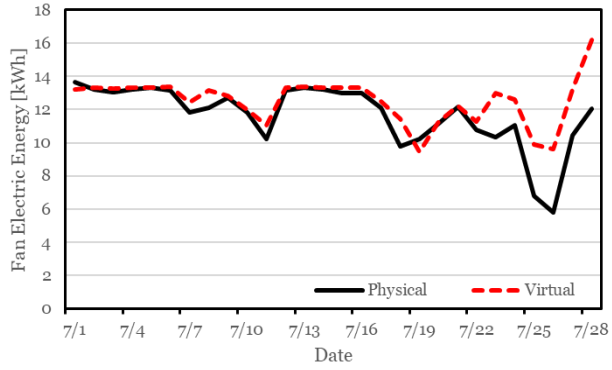

Define an initial fan energy model (part load ratio) for simulations
(based on operation ratio = 35%)

$$f_{pl} = c_1 + c_2 \cdot f_{flow} + c_3 \cdot f_{flow}^2 + c_4 \cdot f_{flow}^3 + c_5 \cdot f_{flow}^4$$




Verification of an initial energy model

Energy model update

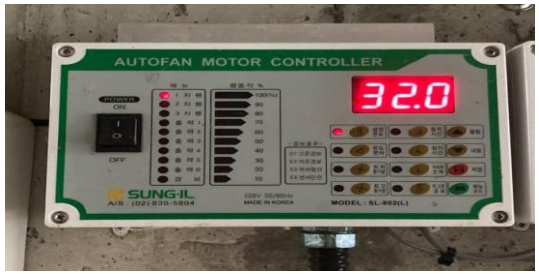


# DT Scenario #2 – fan operation strategy

## Energy analysis using DT – optimal fan operation strategy

Define ventilation fan operation algorithm

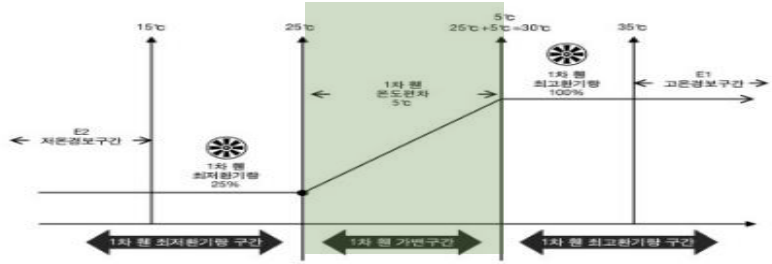
Deduction of input values which can minimize energy consumption




Input values for fan controller

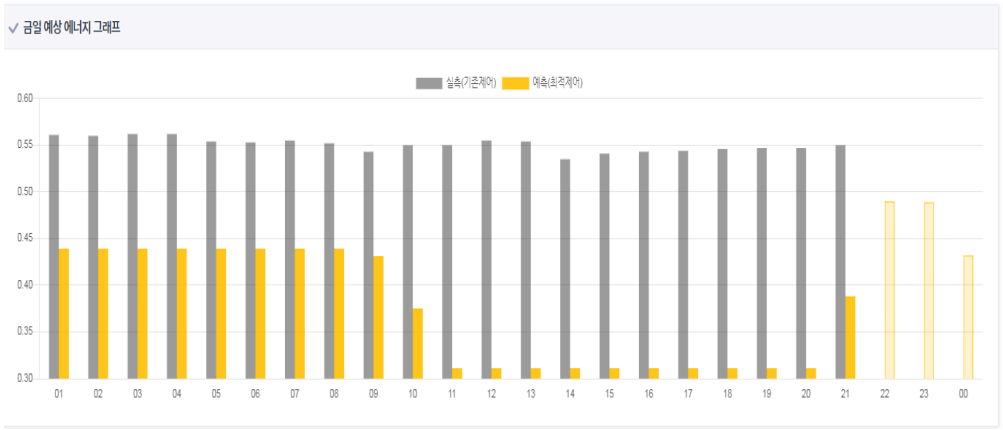
① Min. temperature ② Allow. temperature

③ Max. ventilation ratio ④ Min. ventilation ratio




Ventilation fan control logic

Performs simulations using 4 input parameters and compares energy consumption. Select one set.




```
Step        = 0.5;

Parameter{                  //highest fan flow
Name        = highflow;
Min         = 0.3;
Ini         = 0.3;
Max         = 0.5;
Step        = 0.05;
}
Parameter{                  //setpoint
Name        = set;
Min         = 26;
Ini         = 27;
Max         = 28;
Step        = 0.5;
}
Parameter{                  //lowest fan flow
Name        = lowflow;
Min         = 0;
Ini         = 0;
Max         = 0.2;
Step        = 0.05;
```

# DT Scenario #2 – fan operation strategy

PHYSICAL ⇄ VIRTUAL

Farm building model, weather data, fan operation history, electricity usage, indoor environment data, etc.

Fan energy model/update

Weather cast,
Electricity usage (pred)/indoor temperature(measure)

Additional input from farm management (experience)

GenOpt

Fan control configurations

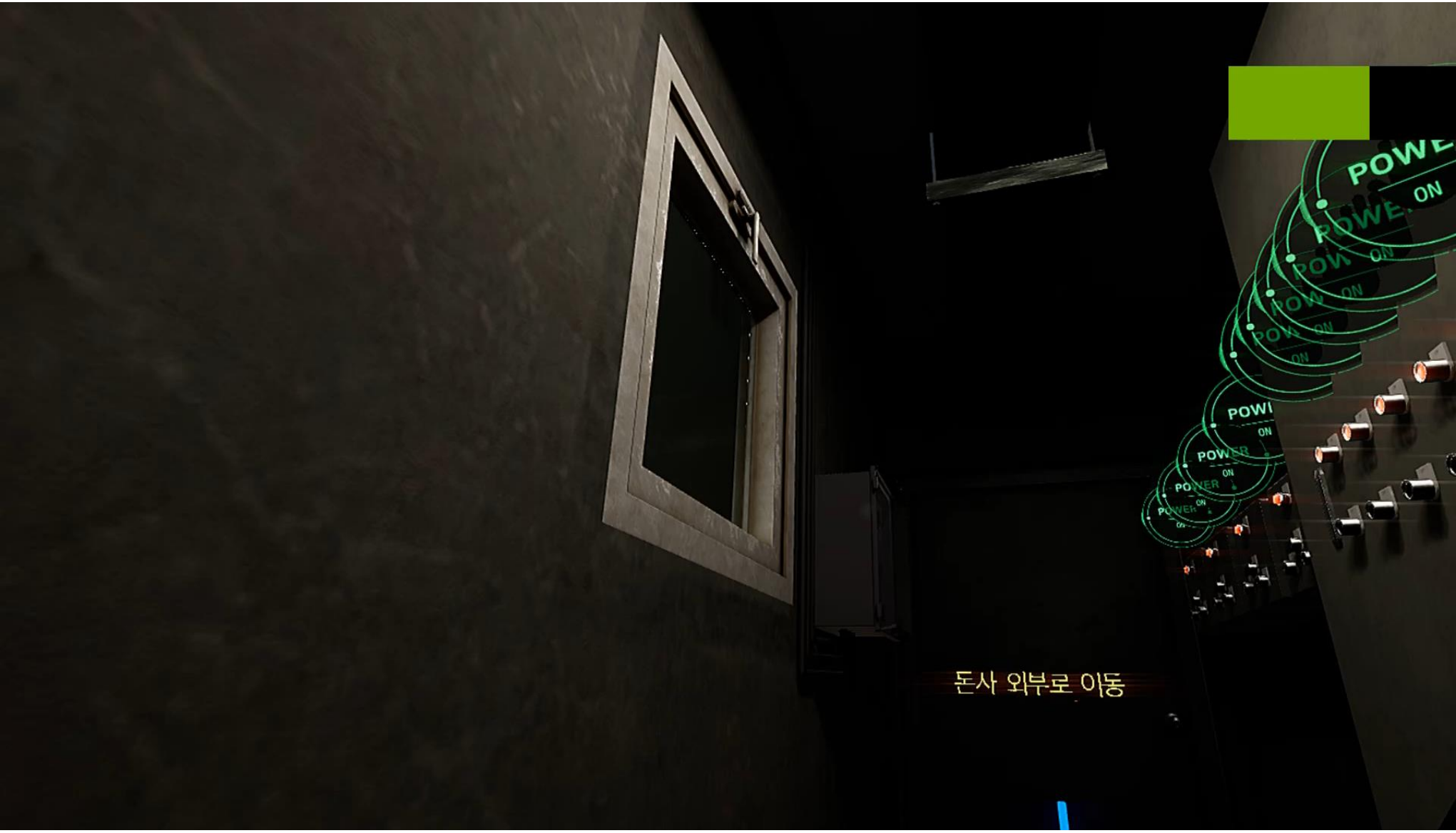
```
Start date: 2020-01-10
End date: 2020-01-30
Update frequency: 7

Operation rule{
00:00       0.45
02:00       0.32
04:00       0.34
…
22:00       0.55
}
```

Fan operation

Fan operation strategy

# DT Scenario #3 – visualization



# DT Technical Advancement in Agriculture

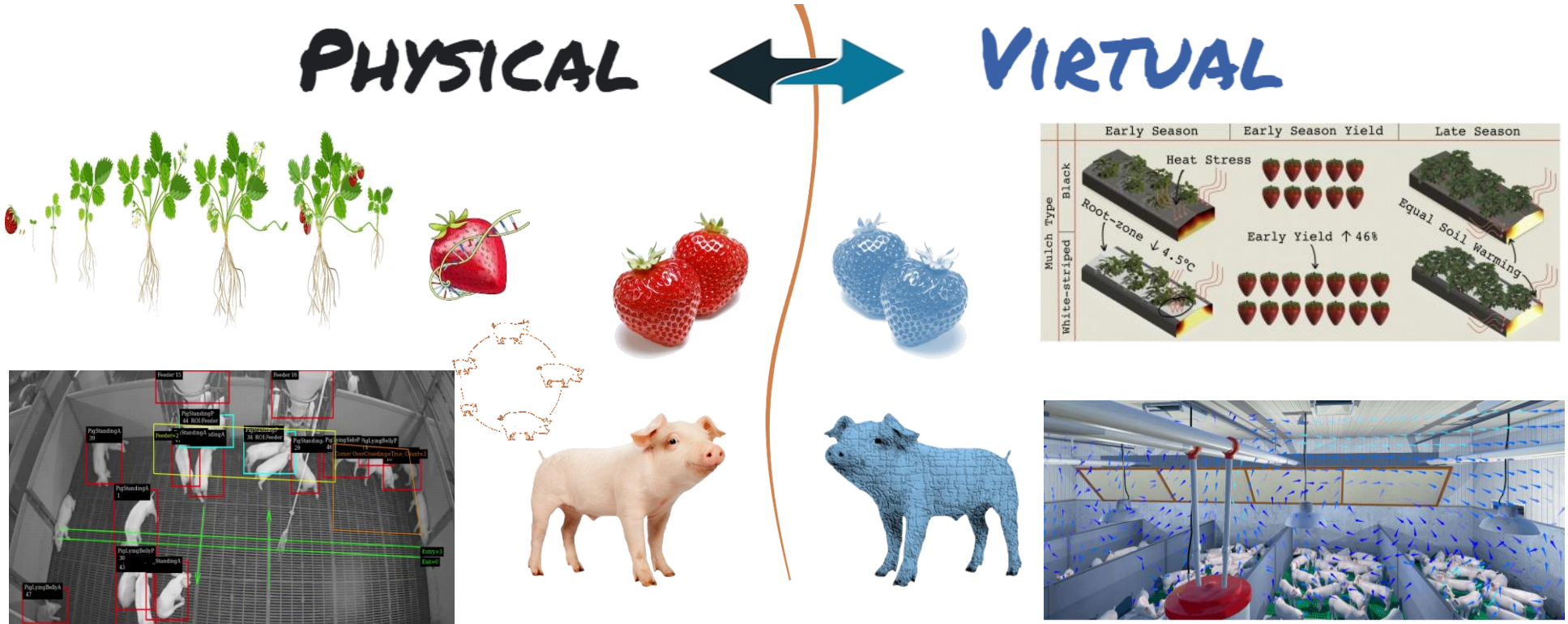
| Step | | Characterestics | Core technologies |
|---|---|---|---|
| 1 | **Preliminary DT** | Initial DT stage<br>Visualization of physical space, presentation<br>Static monitoring of physical space | ▪ 2D/3D Visualization of farm facilities, products, environments<br>▪ Data collection/management/monitoring of farm<br>▪ Real-time farm control and tracking |
| 2 | **Vanilla DT** | Simulation in virtual space & control physical space (Static control) | ▪ Physical-to-virtual farm data interacting<br>▪ Farm environment simulations (energy, air-flow, etc.)<br>▪ Real-time actuators error detection/error correction |
| 3 | **Interactive DT** | Interaction between physical-virtual spaces<br>Repeatable simulations & control physical space (Dynamic control) | ▪ Real-time farm object image analysis<br>▪ Livestock behavior detection/recognition<br>▪ Error correction for autonomous farm management |
| 4 | **Adaptive DT** | Intelligent interaction between physical-virtual spaces<br>Repeatable simulations & optimize physical space (Intelligent control) | ▪ Unmanned robot control<br>▪ Intelligence for agriculture production/distribution/consumption<br>▪ Detection/prediction/intelligent control of animal disease |
| 5 | **Vital DT** | Digitalization and modeling of seed/dielectric<br>Life-cycle simulation of living objects | ▪ Digital dielectric modeling<br>▪ Dielectric information production, marker, presentation<br>▪ Dielectric nutritional requirement per growth steps |

# Considerations for DT Applications

**What is the main purpose of DT adaptation?** – Increase outputs, enhance environments, etc.

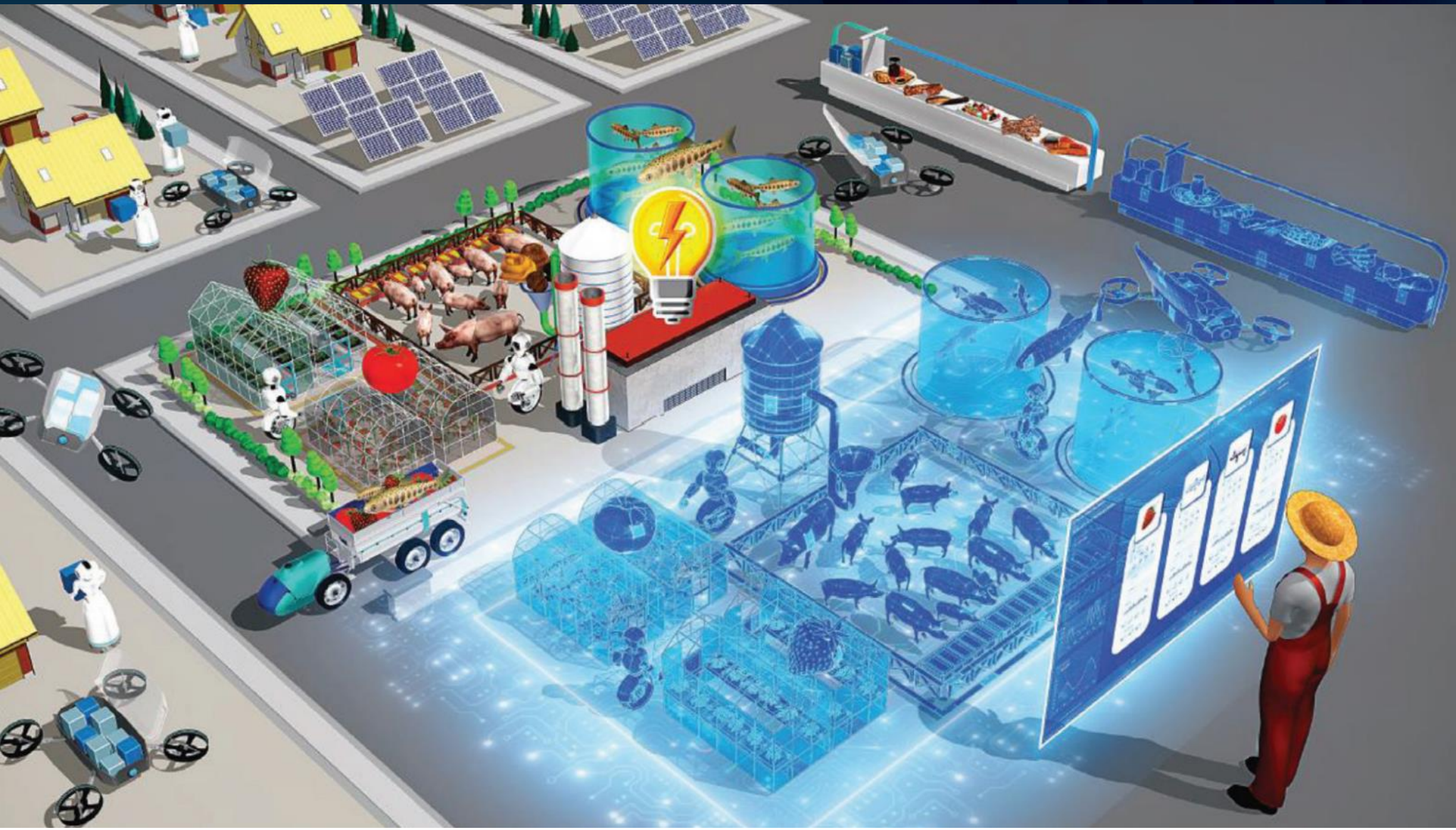
**How living objects (plant, animal) can be virtualized in digital space?**

**Interaction/synchronization between real & digital space** - why, what, when, and how frequently



# Conclusion…

**Concept of**
**environmental recognition production technology**



Reference: “Road toward Intelligent information society” – Technology development map 2035 (ETRI, 2020.06.30)

# Thank You

## Q&A

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