International Workshop on Food Energy Water Nexus

Developing Intelligent System Dynamic Management Instruments on Water-Food-Energy Nexus toward Sustainable Green Economy in Response to Urbanization - Taiwan

PI: Prof. Fi-John Chang
Presenter: Prof. Huu-Sheng Lur
Co-PIs: Prof. Chih-Hao Fan
Prof. Ming-Che Hu
Prof. Tai-Lin Huang

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Outline

- **Introduction**
  - WFE Nexus crisis
  - WFE Nexus in Taiwan

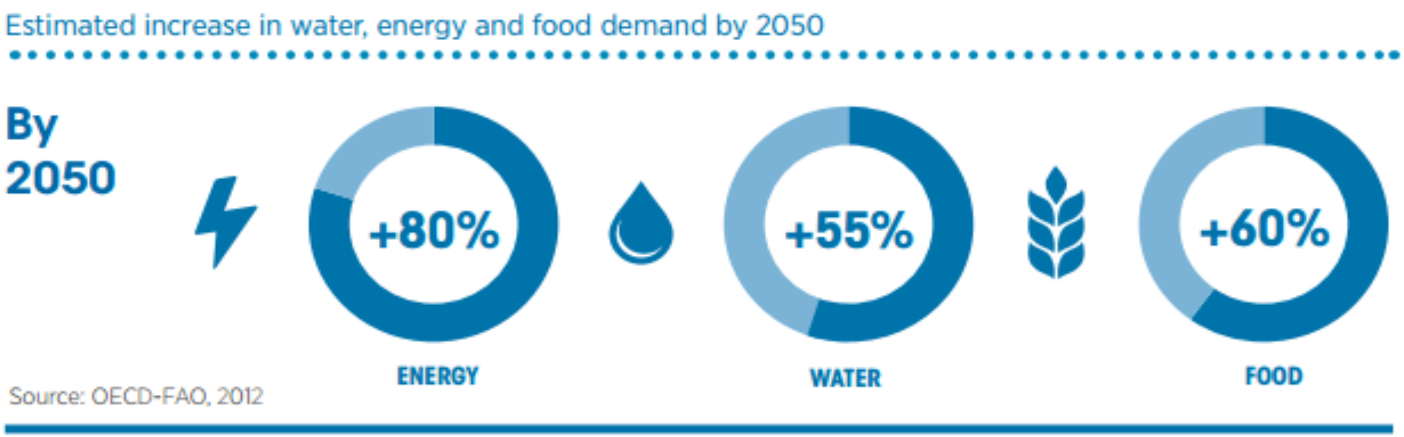
- **WFE Nexus and Resource Analysis Tools**
  - The Importance of WFE Nexus Research
  - Introducing Two Important WFE Nexus Models

- **Intelligent System Dynamic Management on WFE Nexus - Taiwan**

Introduction

Rapid economic growth, expanding populations and increasing prosperity is driving up demands for energy, water and food.

By 2050, the demand for energy will nearly double while demands for water and food are estimated to increase by over 50%.



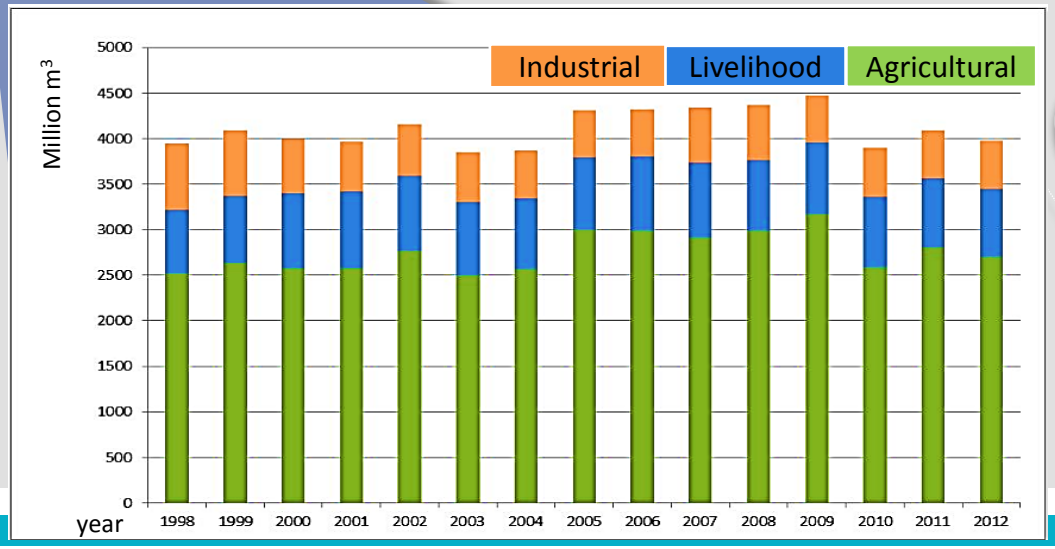
Resources: Planet Under Pressure

WFE Complexity in Taiwan

Water-Food in Taiwan

Main Food production areas

The proportion of water use



Climate change

- Water supply is reduced
- Water vulnerability is increased
- Water quality is deteriorated

Flood and dry periods

- Heavy rainfall in summer
- Dry in winter

Water distribution/allocation

- livelihood
- Agriculture
- Industry

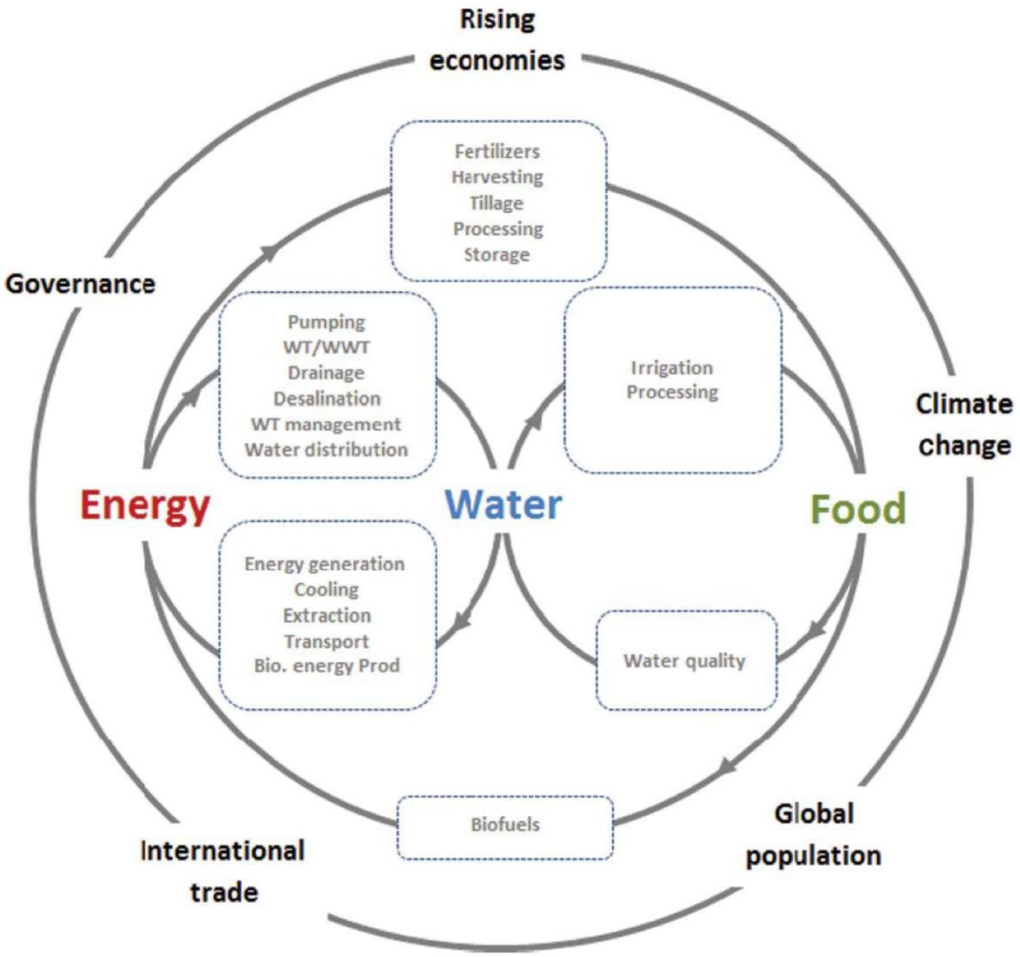
Future management

- Smart water management and allocation
- Develop precision farming
- ……
- ➔ **Smart tools are needed!**

WFE Nexus
and
Resource Analysis Tools

I. Importance of WFE Nexus Approach

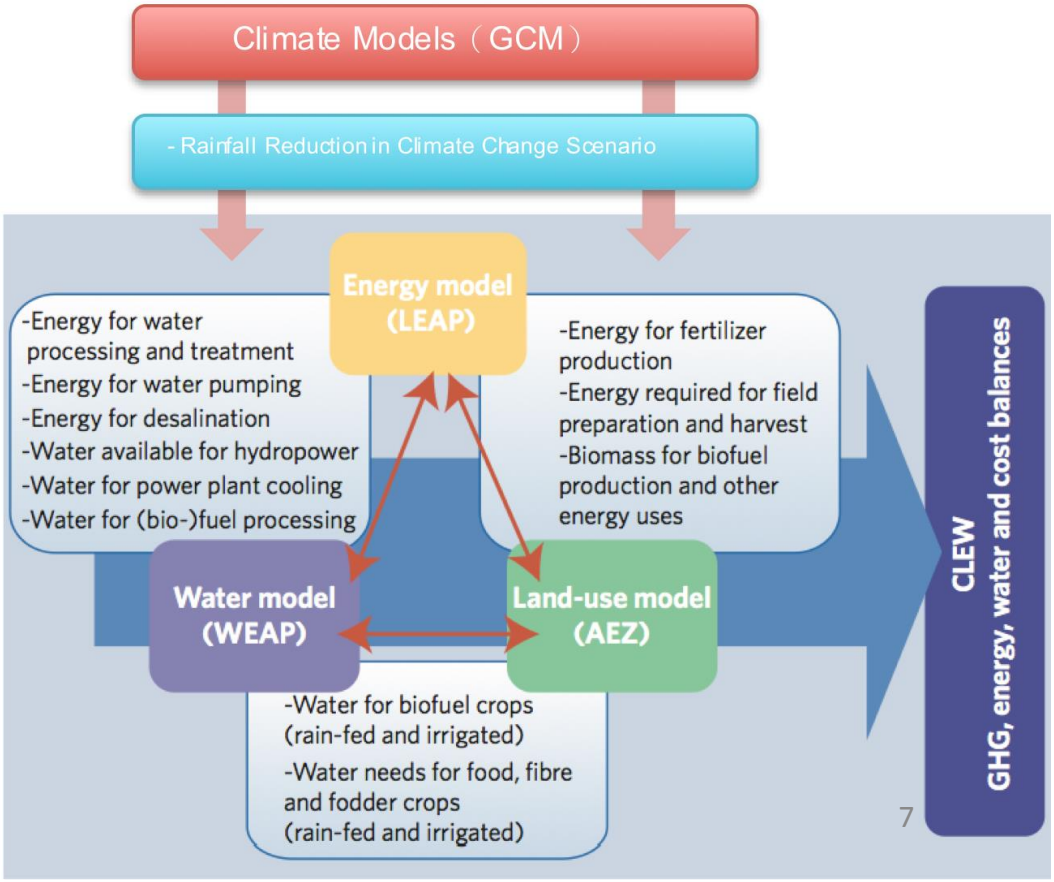
- **The allocation/use of each WFE resource often affects the demand/supply of the other two WFE resources.**
- **Lack of integrated resources assessment and holistic decision-making has an inclination toward inefficient use/squander, and even causes severe impacts on environment and climate.**



II. Introducing Two Important WFE Nexus Models

A. CLEW (Climate, Land-use, Energy and Water Framework)

- **Integrate assessment on the significance of resources interrelation and interaction with climate, land-use, energy and water systems + the application on socio-economic development**



Schematic CLEW Framework

- **Features of the CLEW Framework**

Advantages:

- Identify resource interactions
- Establish scales and data-exchange among various modules
- Lower costs and more efficient for users to operate
- Modules can be run under either integrated or individual

Limitation (so far):

- Unable to quantify and value impacts on ecosystem services when resources conditions change

CLEW models applied in various cases show one consistent tendency:

- Carry "sustainable development" as a national goal
- Adopt integrated WFE Nexus as a resource management strategy
- Greenhouse gas mitigation costs becomes much less than either "business as usual" (i.e. without any changes) , or by sectors' efforts individually

B. WEF Nexus Tool 2.0

- **Mainly integrate two data interfaces to establish a national scenario-based model**
  - **Local characteristics data**
  - **Components from users' expected scenarios**

1. **Understand resource conditions**
2. **Identify future goals and setup designated indices & environmental requirements under scenario-based models.**
3. **(Re-)arrange priority/weight of indices to achieve the most efficient resources management.**

- **Establish scenario models as needed to compare the consequences according to users' requirements for different indices.**

Structure of WEF Nexus Tool 2.0

Local Characteristic Data

- Local Yields
- Water Requirements
- Import Data
- Local Availability
- Energy Requirements
- Other

WEF Nexus Tool 2.0

The Resource Management Strategy Guiding Tool

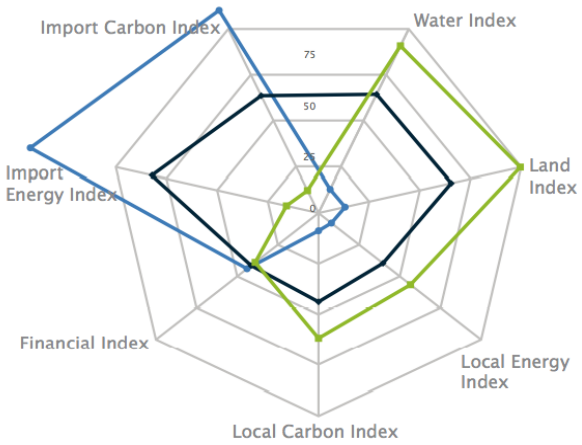
wefnexustool.org

Scenario Components

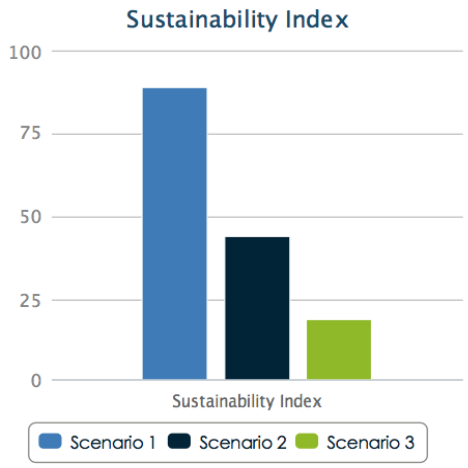
- Food Self-Sufficiencies
- Water Sources & Amounts
- Energy Sources & Amounts
- Sources of Import Countries

Scenario Resource Requirements

Resource Indices



Sustainability Indices



Intelligent System Dynamic Management on WFE Nexus - Taiwan

Our Ideas about WFE Nexus :

** We plan to make a comprehensive comparison of WFE nexus management between urbanized and non-urbanized basins to evaluate the impacts of urbanization on the WFE nexus, with a consideration of the scalability and transferability of methodology during modeling and platform construction.

The novelty of our project consists of:

- develop a nexus-based interactive platform for synergy-based resources allocation
- integrate techniques to optimize benefits and target indicators through cross-sectoral resources allocation
- design scenarios in response to possible future conditions of WFE nexus.

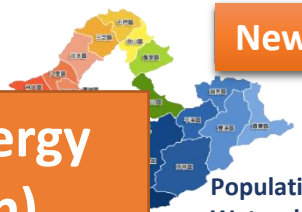
Study area - Taiwan

Danshui River Basin (Urban)

Highest demand in water and energy
Low food Production (12.5 million)

Population: 2130 K
Water demand: 440 K t
Paddy output: 4744 Kg/ha
Energy used: 241,34KM w

Taipei City



New Taipei City

Population: 3970 K
Water demand: 1370K t/day
Paddy output: 5351 Kg/ha
Energy used: 477,25 KM w

Taoyuan City

Population: 370 K
Water demand: 150 K t/day
Energy used: 42,41 KM w

Keelung City

ZhuoShui River Basin (Rural)

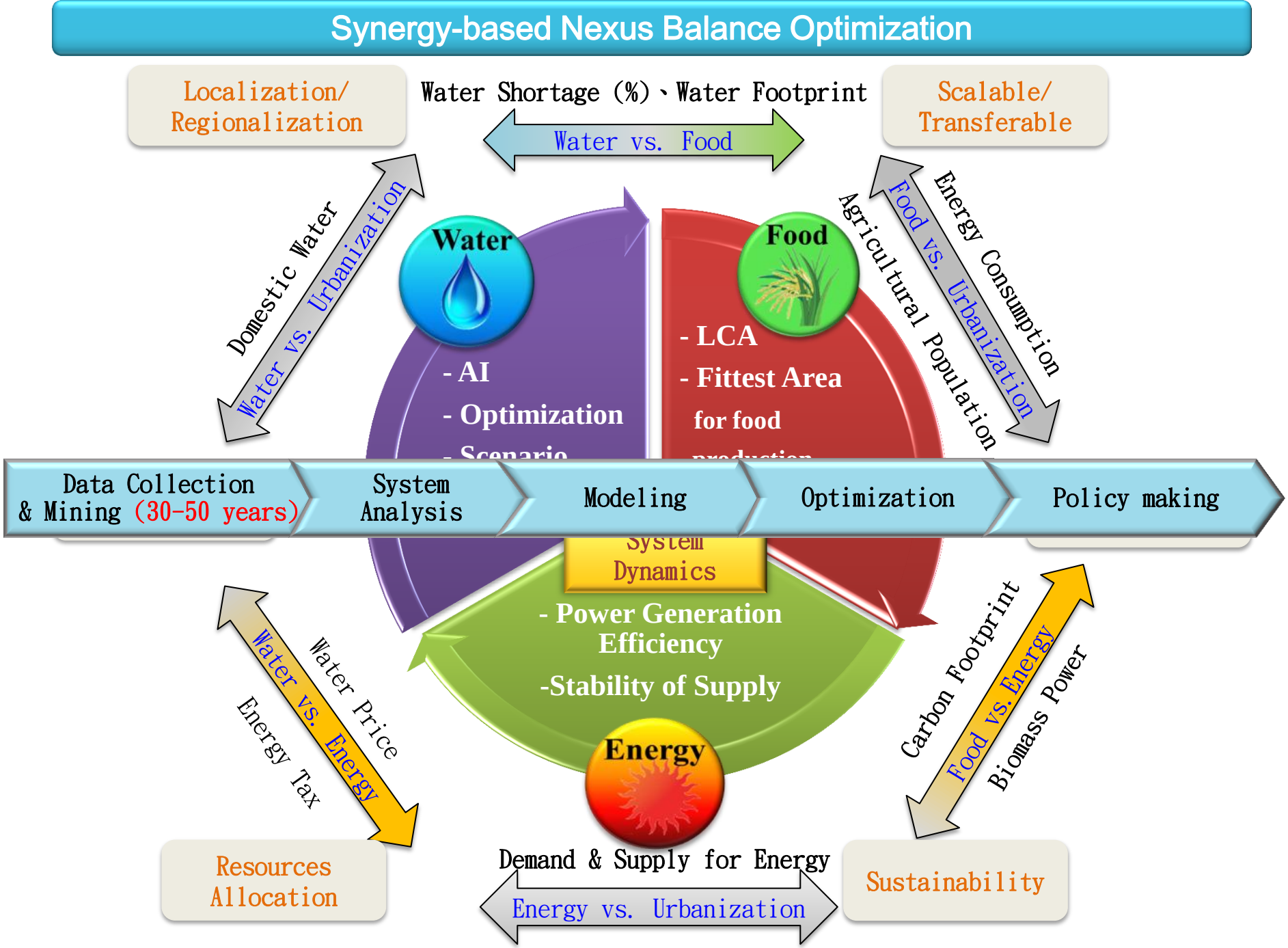
Relative low demand in water and energy
Highest food production (2 million)

Yunlin City

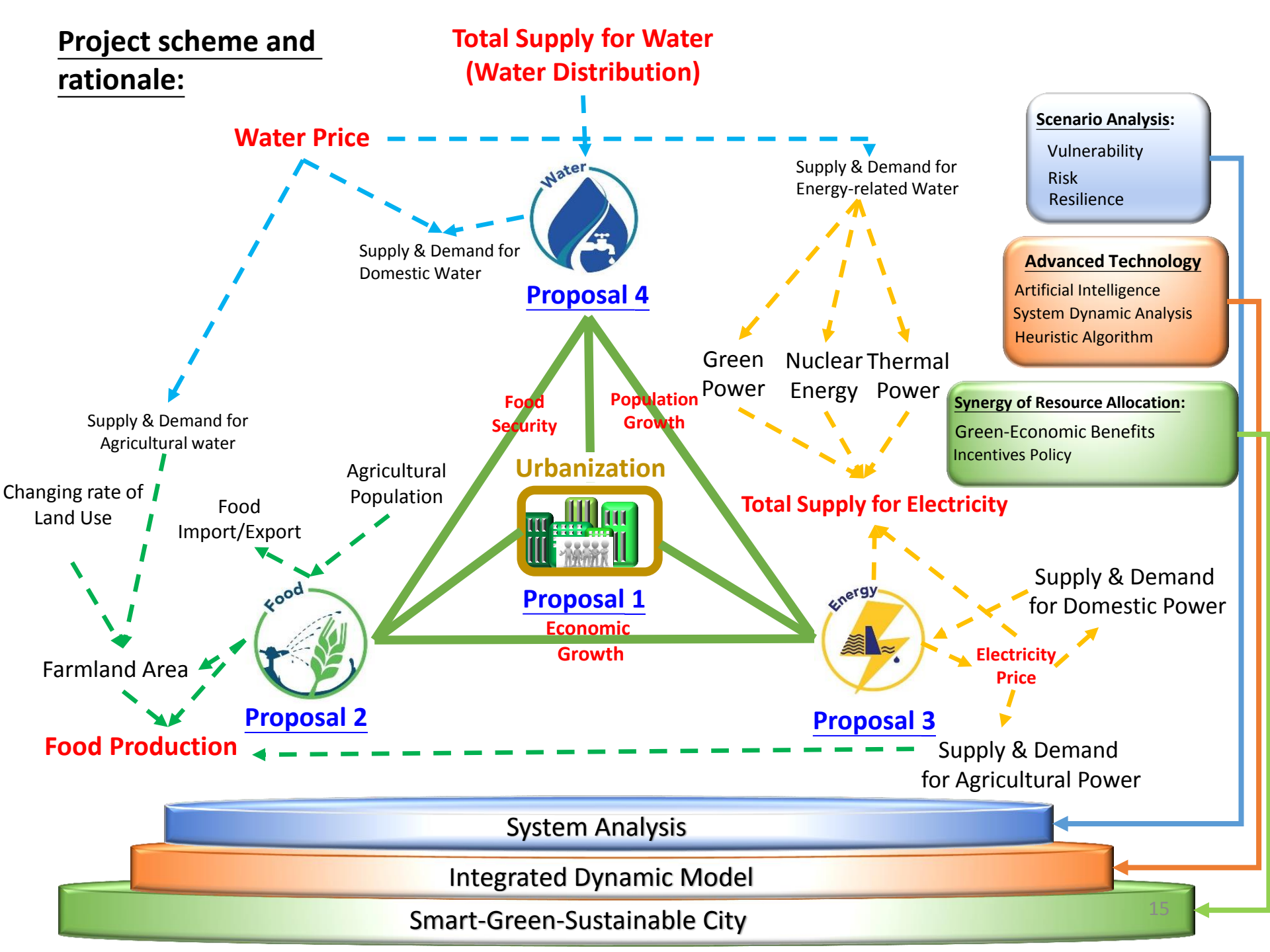
Population: 700 K
Water demand: 280 K t/day
Paddy output: 7017 Kg/ha
Energy used: 79,58 KM w

Changhua City

Population:1280 K
Water demand: 360 K t/day
Paddy output: 6429 Kg/ha
Energy used: 141,54 KM w


Synergy-based Nexus Balance Optimization
Localization/ Regionalization
Water Shortage (%)、Water Footprint
Water vs. Food
Scalable/ Transferable
Domestic Water
Water vs. Urbanization
Agricultural Population
Food vs. Urbanization
Energy Consumption
Water
Food
- AI
- Optimization
- Scenario
- LCA
- Fittest Area for food production
Data Collection & Mining (30-50 years)
System Analysis
Modeling
Optimization
Policy making
System Dynamics
- Power Generation Efficiency
-Stability of Supply
Energy
Water Price
Water vs. Energy
Energy Tax
Carbon Footprint
Food vs. Energy
Biomass Power
Resources Allocation
Demand & Supply for Energy
Energy vs. Urbanization
Sustainability

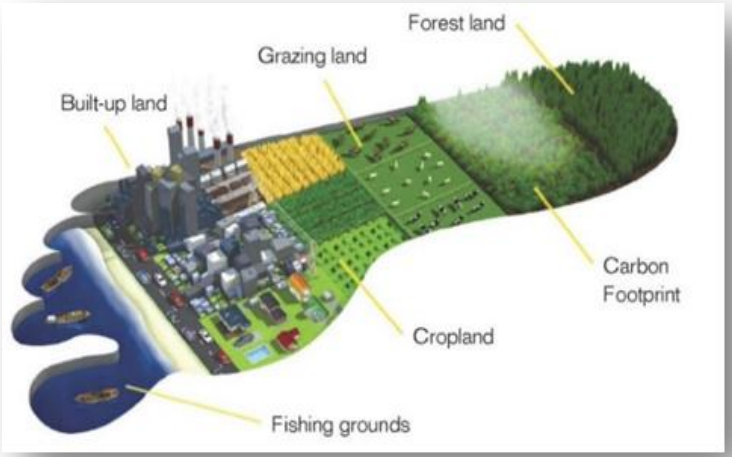
Project scheme and rationale:

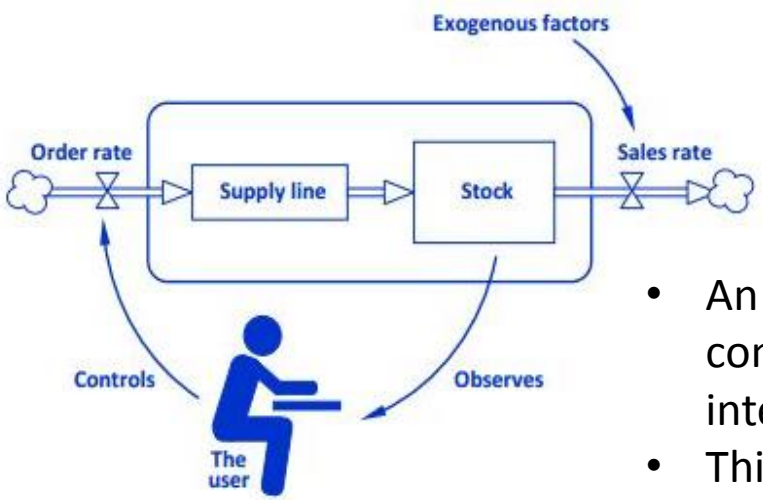


Development and application of an urban system dynamic model under WFE nexus (subproject 1-Urbanization)

Ecological footprint

It can explore the connections between WFE and land-use, then can assess the influence of WFE chains on urbanization development.





System Dynamics (SD)

- An approach to understand the nonlinear behavior of complex systems over time by using stocks, flows, internal feedback loops and time delays.
- This sub-project is expected to adopt/develop a system dynamic model with the use of software including Ventana Vensim DSS, NetLogo and AnyLogic.

THE DYNAMIC CHANGES IN FOOD PRODUCTION BETWEEN WATER AND ENERGY (SUBPROJECT 2-FOOD)

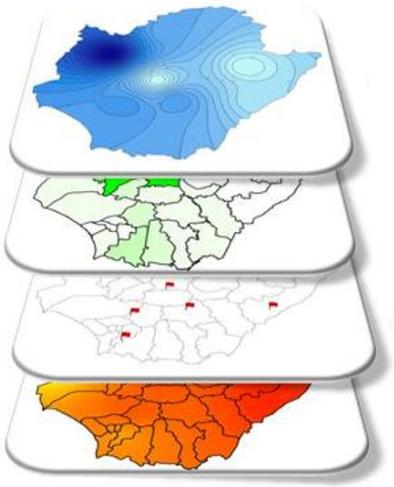
- **Adopt "Life Cycle Assessment" for the relationship among the food (rice) production, water and energy consumptions; and to investigate environmental impacts on WFE Nexus.**
- **Choose two different urbanized river basins, and analyze the rice-growing, water resources and energy of both basins based on a long-term (30 – 50 years) database.**

Life cycle assessment
(GE Healthcare)

Planning of Sustainable Production Areas

(Subproject 2-Food)

Suitable crop production zones in the Zhuoshui River Basin: integrates factors such as *soil properties, climate suitability and the minimum energy production consumption,* which will be used to plan/identify the optimum sustainable food production area.

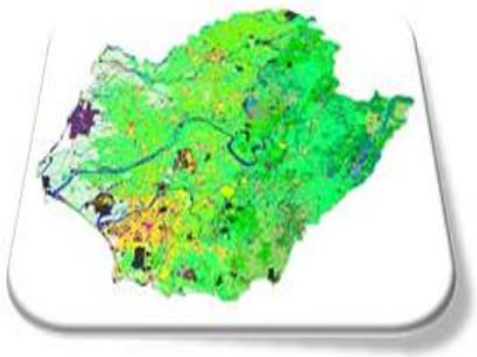


Low energy consumption in food production

Water supply adaption

Climate – smart cropping

Soil properties

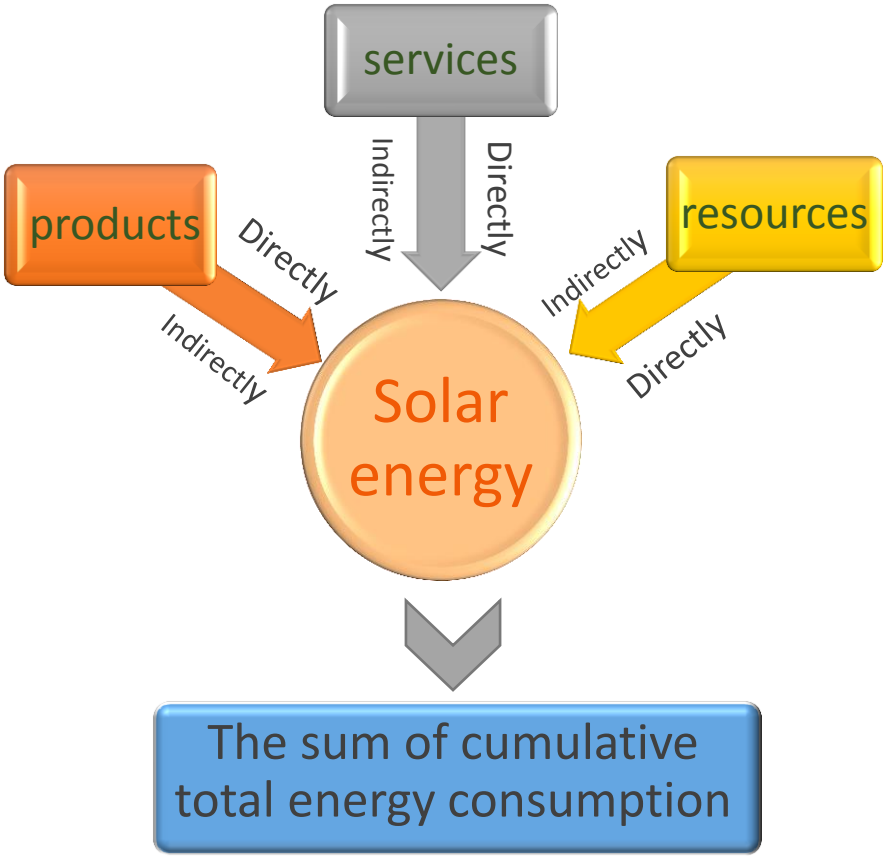


Planning the most suitable sustainable food (rice, corn and soybean) production areas.

Energy Consumption of Water Supply and Management (Subproject 3-Energy)

Analysis of energy consumption

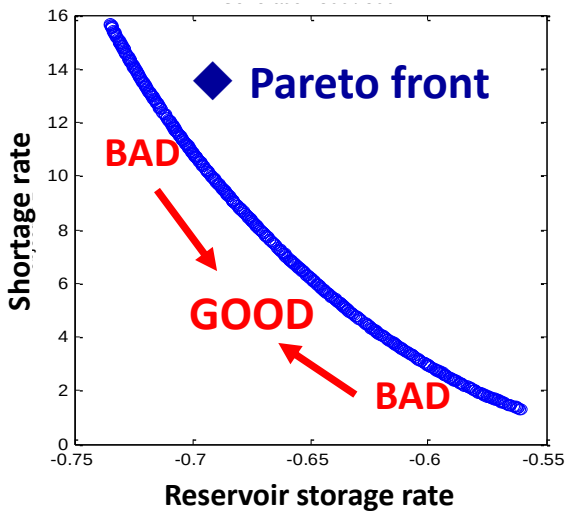
- **Estimate the energy consumption of two systems (water supply and food production), and then use "Energy Analysis" to analyze energy consumption in water supply and food production systems.**
- **Build a hydro-electric mathematical planning model to simulate river inflow, reservoir operation and the state of water supply, and then calculate the amount of hydropower potential.**



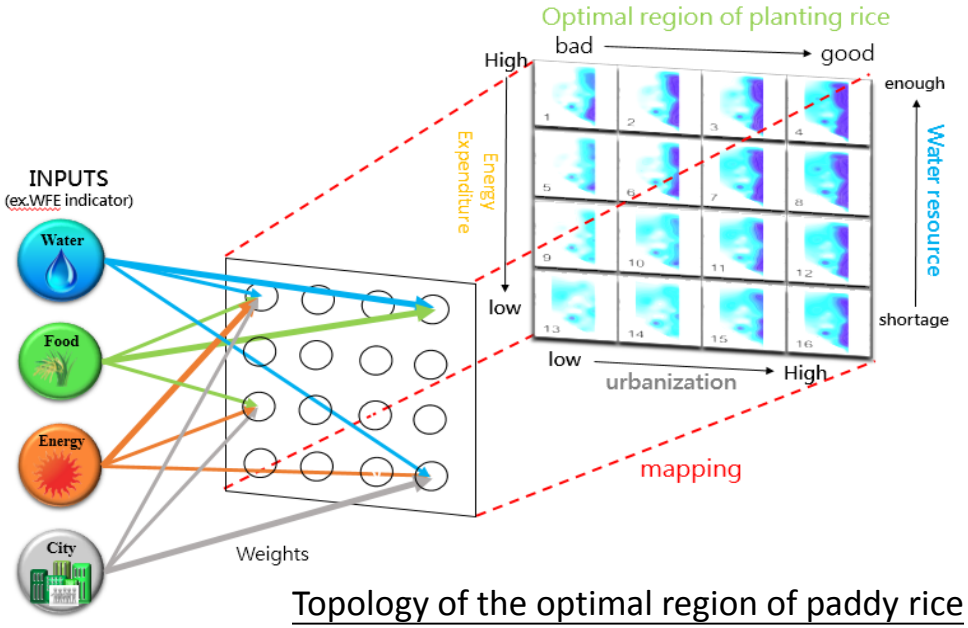
Optimizing the water allocation system for WFE Nexus under urbanization (Subproject 4-Water)

SOM (self-organizing map)

One of the distinguishing characteristics of the SOM is the development of topological structures that provide a meaningful map to present the clusters of input variables. (e.g. utilization of water resources and power sources).



Pareto front of the water allocation system



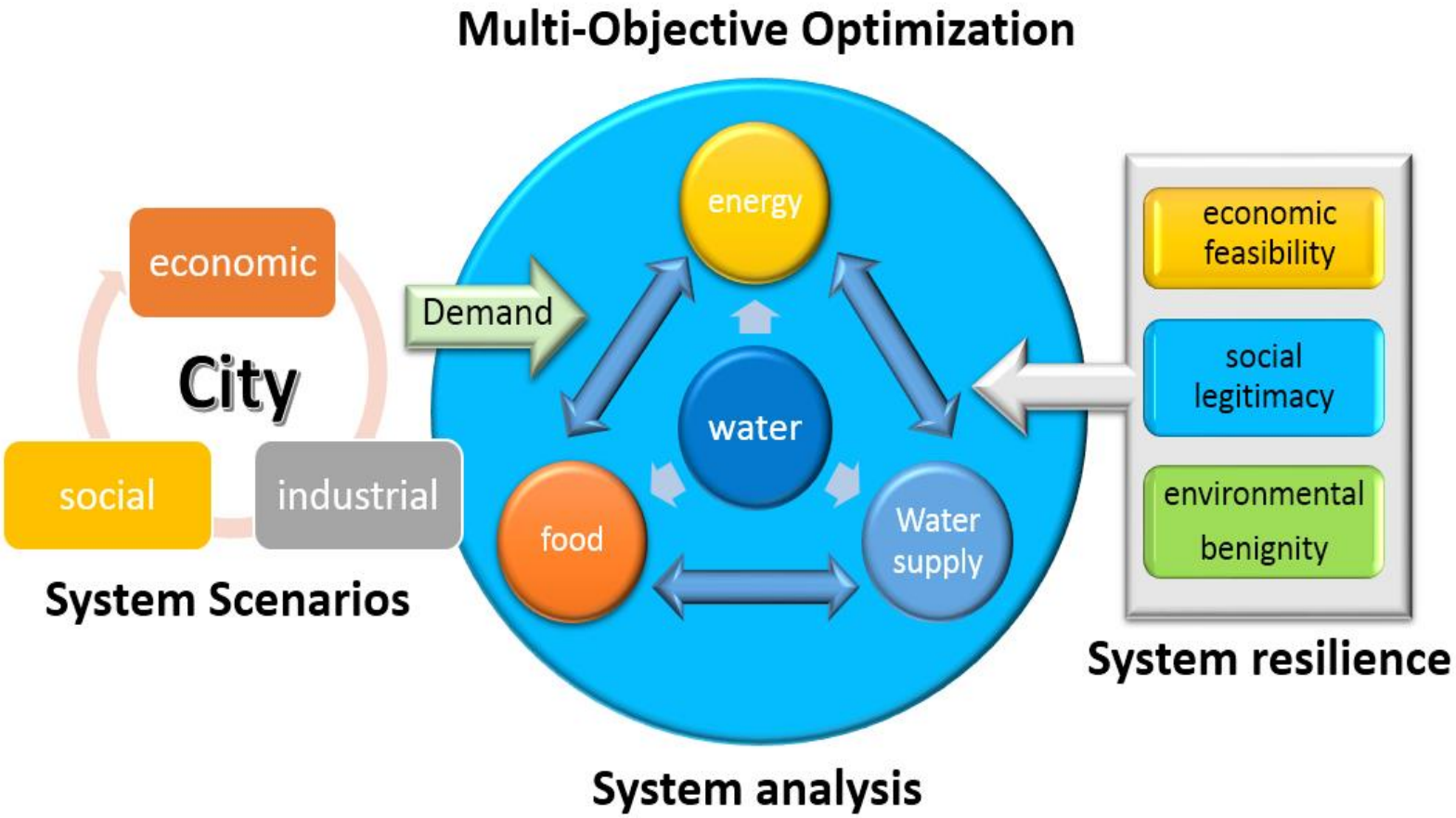
Topology of the optimal region of paddy rice

Non-dominated Sorting Genetic Algorithm-II (NSGA-II)

NSGA-II is a popular non-domination based genetic algorithm for multi-objective optimization.

In this research, we use the algorithm to optimize the water allocation with the strategy searching from the Pareto front in order to balance the WFE nexus.

Optimizing the water allocation system for WFE Nexus under urbanization (Subproject 4-Water)



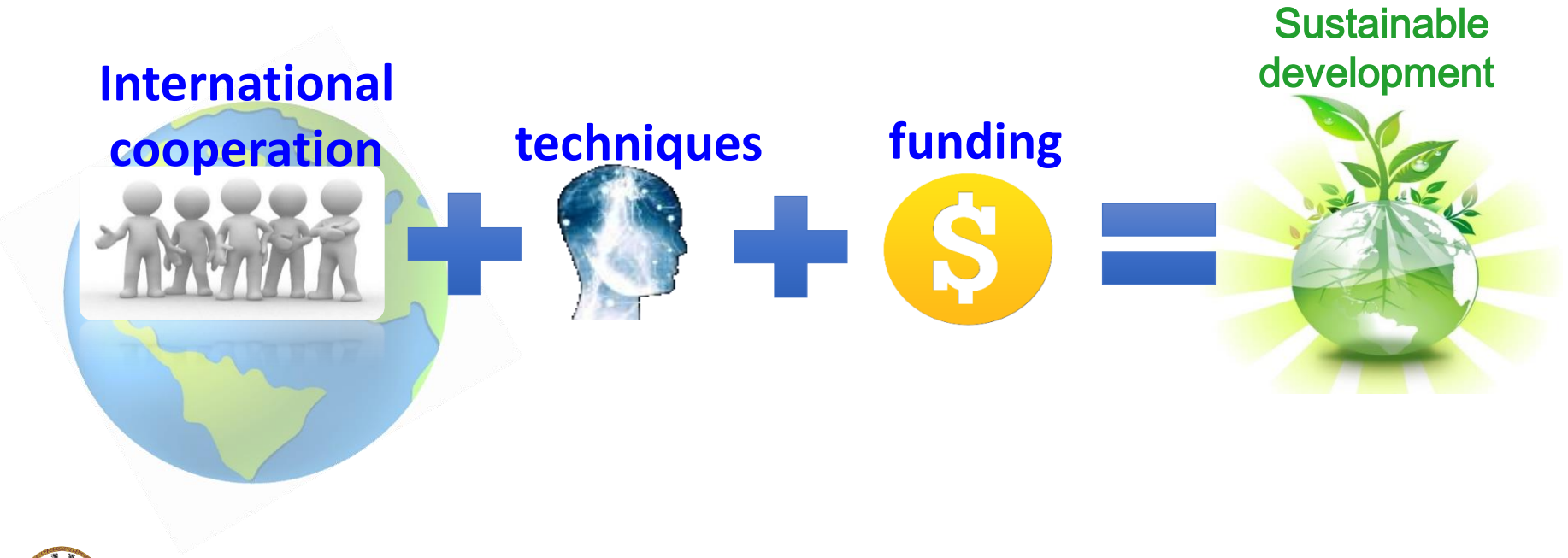
Expected results

- Propose the analytical methodology of WFE Nexus and provide integrated solutions with characteristics for Taiwan.
  - Integrate the factors of urbanization and identify the interactions of W-F-E.
  - Identify the goals for Taiwan, i.e. management of resources distribution, to make the best synergy among WFE nexus.
  - By international knowledge/experience exchanges, enhance domestic research capacity & technology development capability.
  - Through international cooperation, we will share experiences with partners for the promotion of global sustainable development.
  - Develop a comprehensive support for national policies.

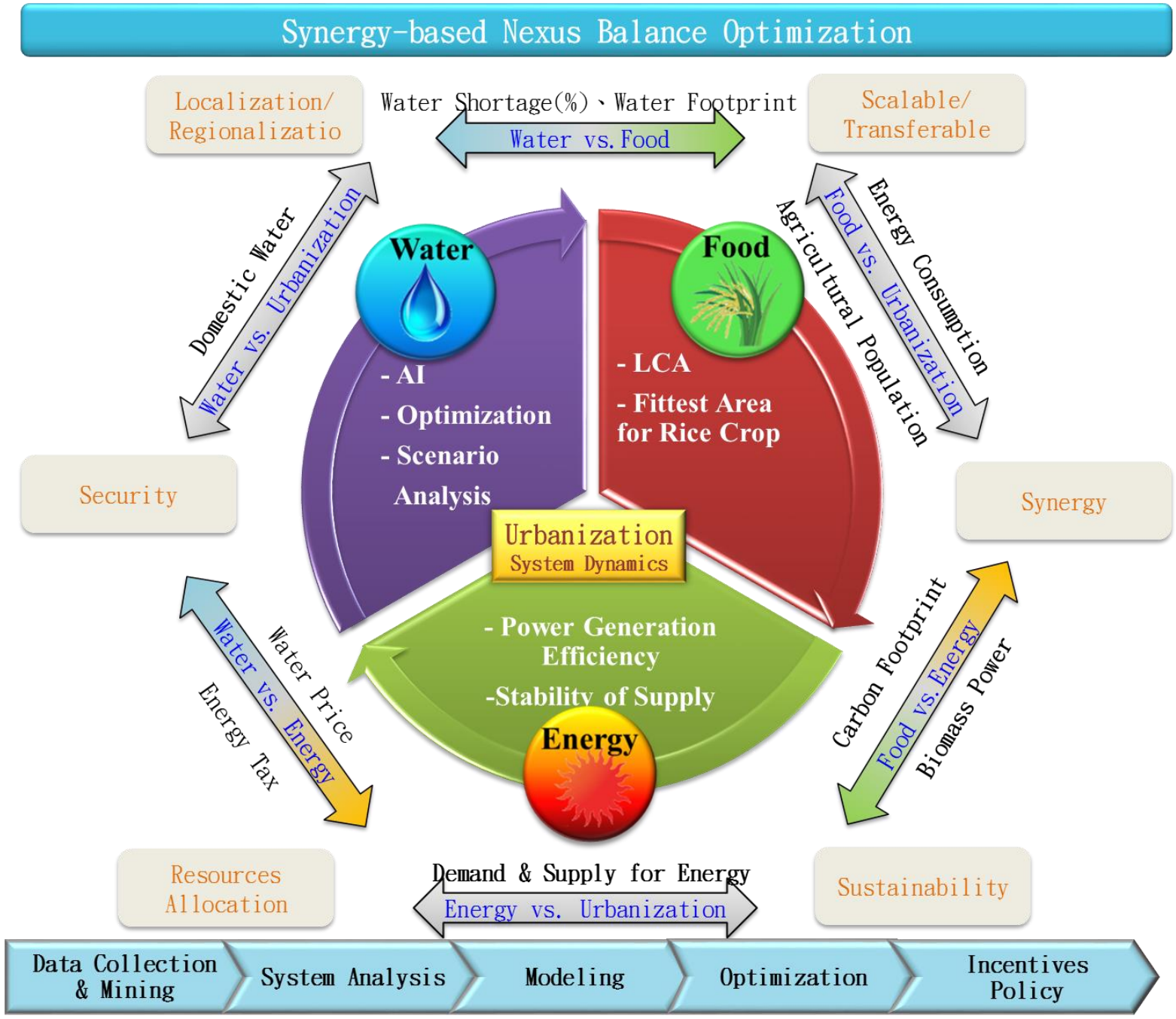
Collaborative Research Action (CRA) of Belmont Forum

We are looking for partnership in:

- Pursuing the **transboundary cooperation on WFE nexus research**
- Proposing a more **comprehensive adaptation strategy** for WFE issues with different perspectives in different countries.



Thanks for Your Attention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