CONSTRUCTING A TAIWAN'S ENERGY SECURITY ANALYSIS OF LIQUEFIED NATURE GAS BY SYSTEM DYNAMIC MODEL

Kuei-Lan (Kelly) Chou

Green Energy and Environment Research Laboratories
Industrial Technology Research Institute(ITRI), Taiwan

Current and Future Challenges to Energy Security

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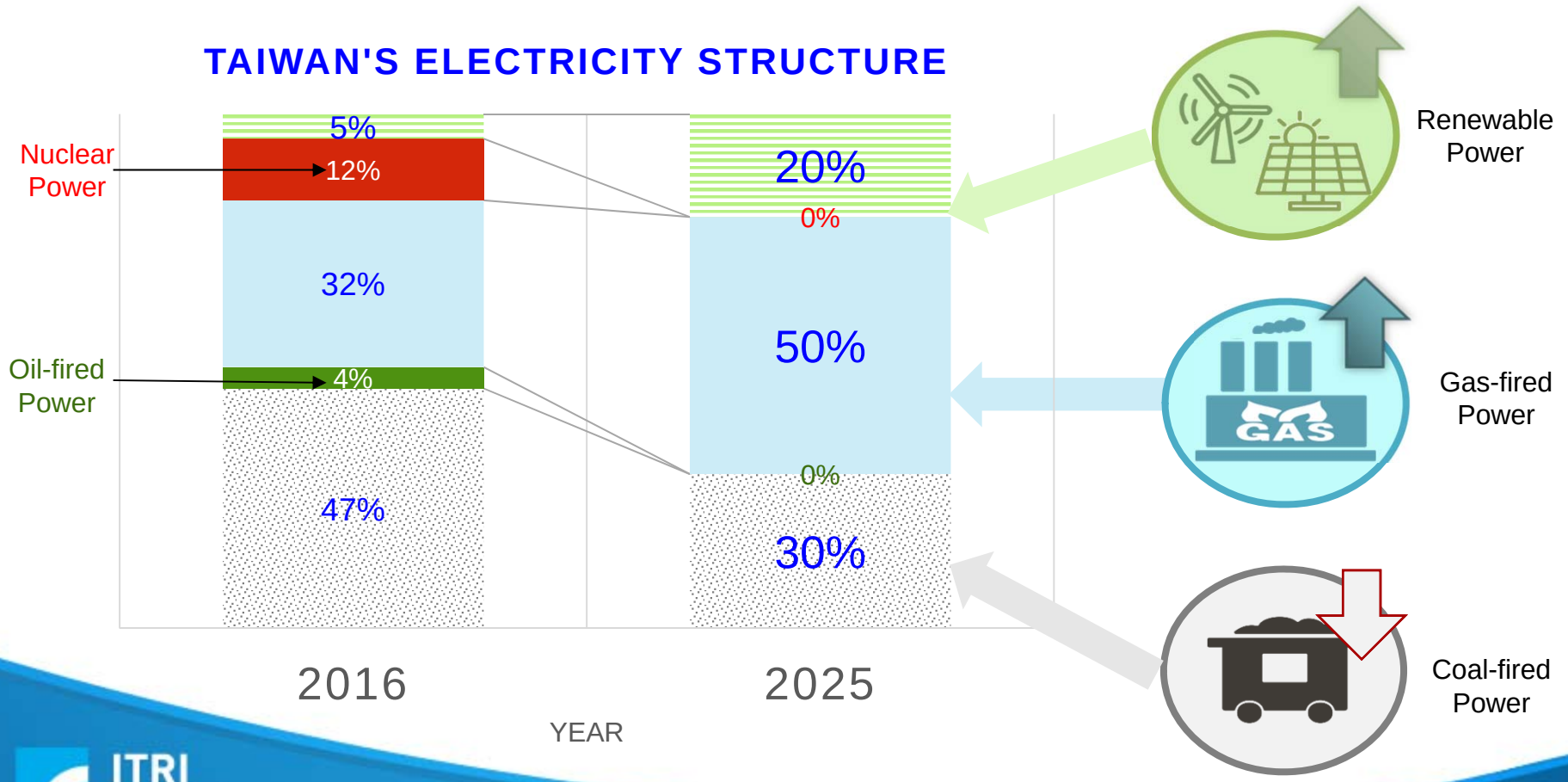
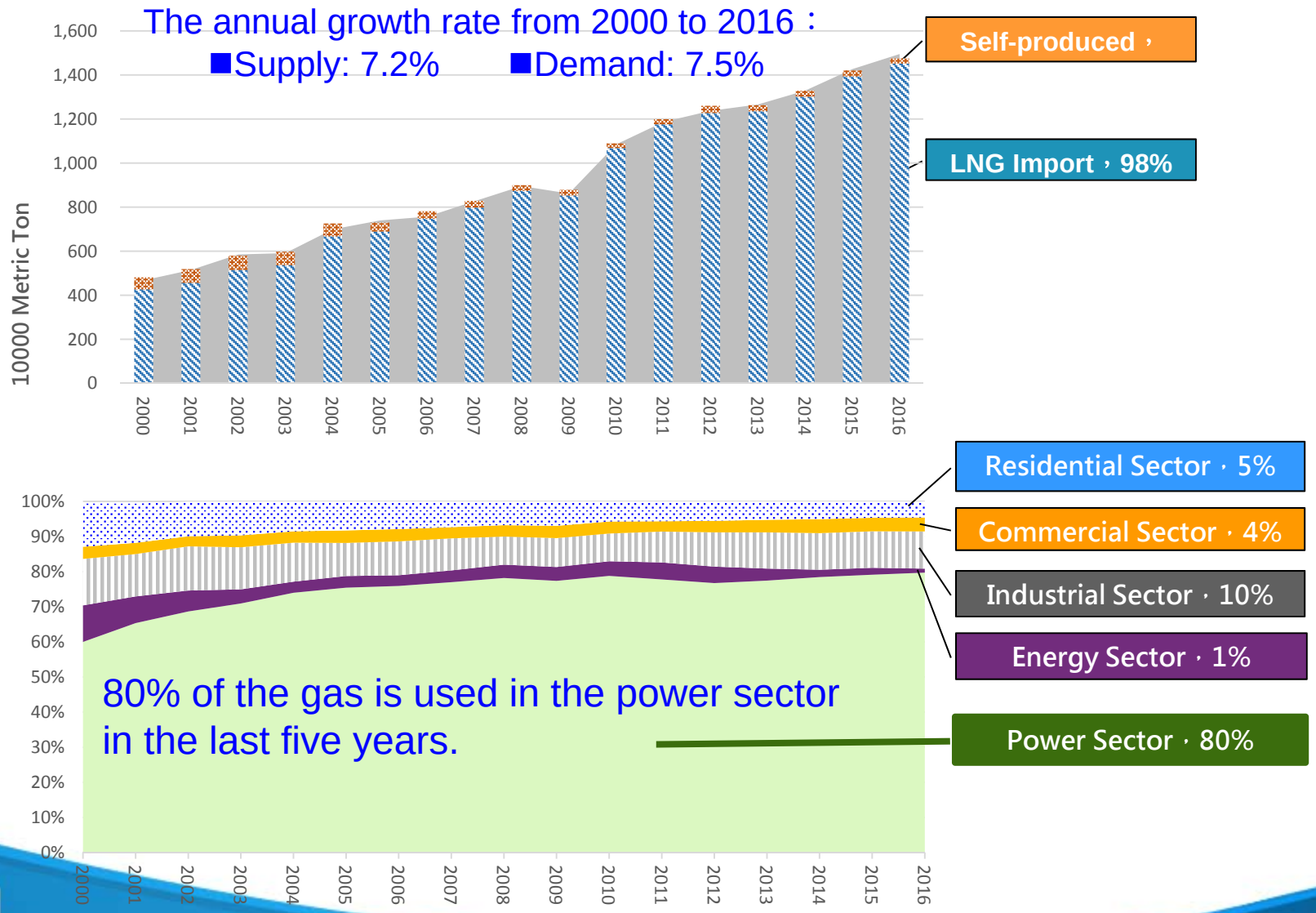
The goal of Taiwan's energy policy

- Non-nuclear homeland and low-carbon economic development.
- Establishing a new national electricity structure by 2025.



The role of liquefied natural gas(LNG) in Taiwan



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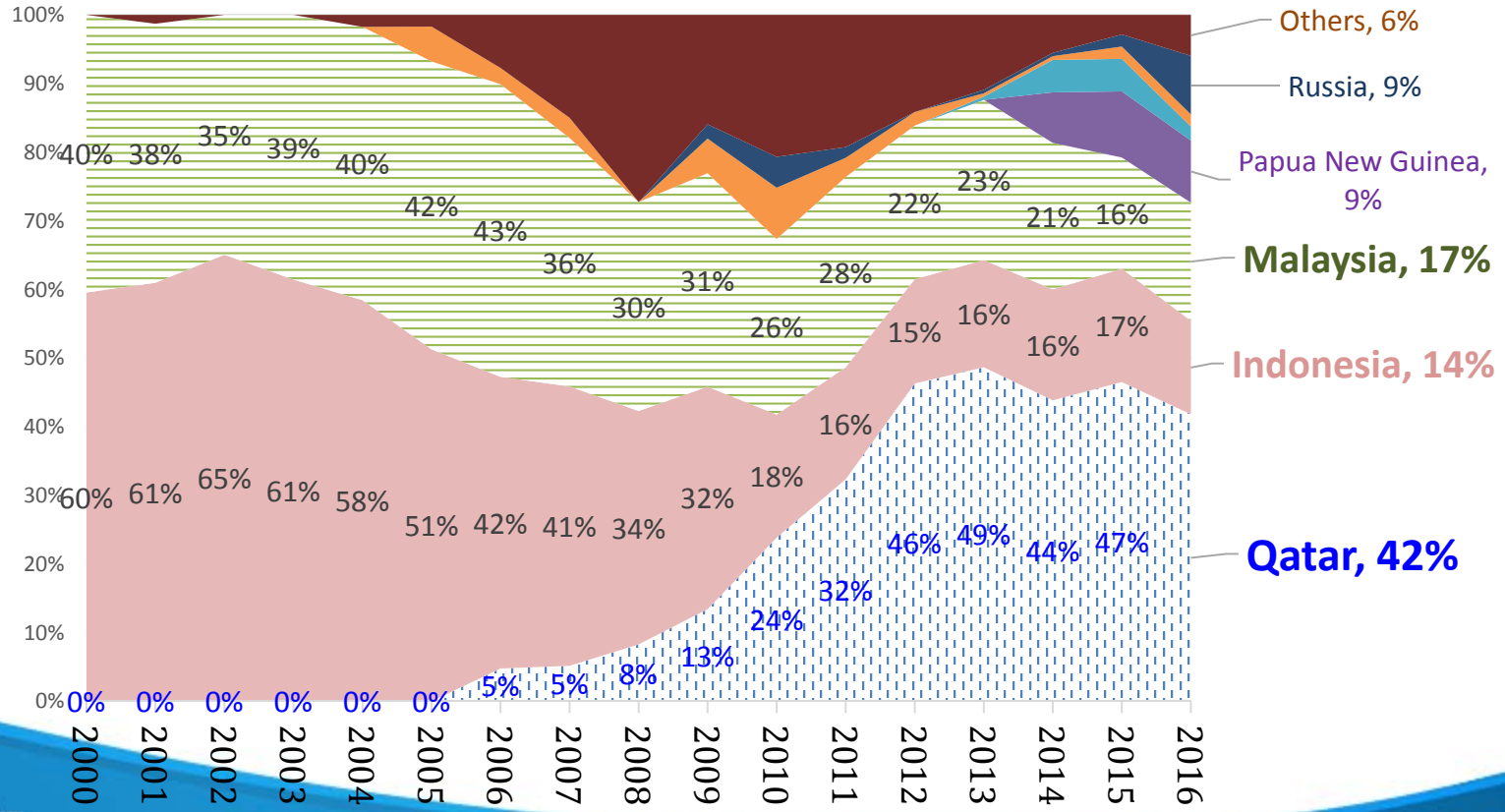
The import source of liquefied natural gas in Taiwan

- Before 2005, the LNG import was dominated by Indonesia and Malaysia, nearly accounting for 93%.
- After 2005, the source of import from Qatar is gradually expanding and accounts for 42% in 2016.
- Since 2014, Taiwan's import source moved towards more diversity, joined Russia and Papua New Guinea.



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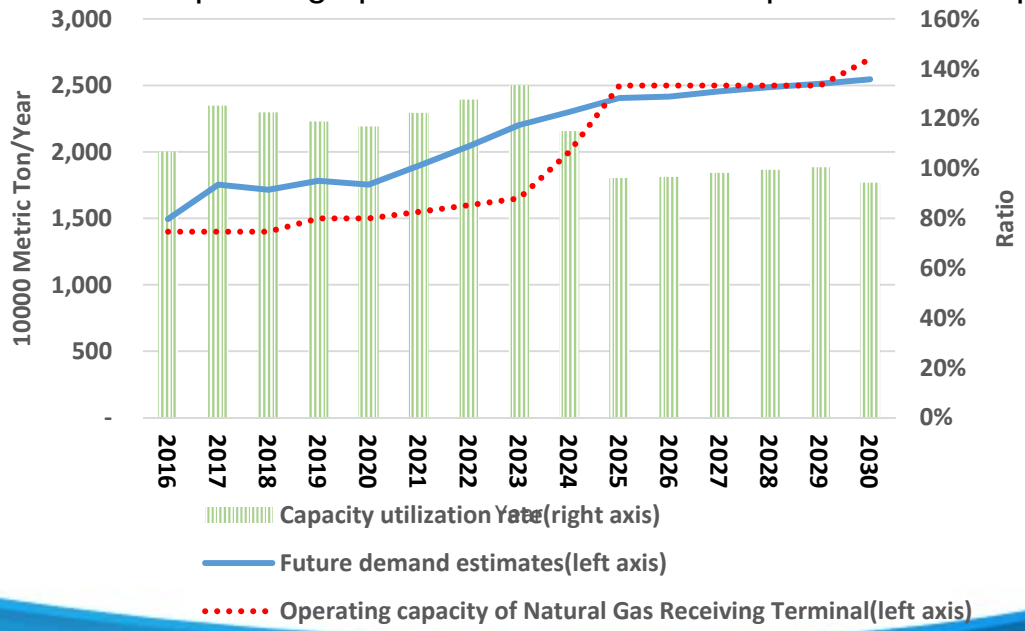
The problems of Taiwan's energy security

Challenge :

- ✓ Renewable energy power is intermittent and needs sufficient reserve margin to maintain a stable power supply.
- ✓ For resolving the power gap of nuclear power phasing out and supporting renewable energy power reserve margin, Taiwan Power Company will construct a lot of new advanced gas-fired power since 2020.

Vulnerability :

- ✓ The capacity utilization ratio of natural gas receiving station has been more than 100% until new storage capacities completed in 2025.
- ✓ Before new storage capacity completed, mitigating the vulnerability of interruption is to increase the shipping cycle of import, which means speeding up the flow rate to make up the lack of capacity stock.



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The meaning of energy security analysis

Cherp and Jewell(2014) propose a different concept of energy security as

“low vulnerability of vital energy system”.

The analysis of energy security should address three questions:

Security for whom?

Security for which values?

Security from what threats?

The aim of this study is to construct an analysis of energy security for supporting policy-making by addressing the aforementioned three questions.

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The methods of energy security analysis

- Indicator is a prevailing method for measuring energy security.
- There are two types of energy security indicator, which present different mode and meanings.
- Comparing the two type of energy security indicator as follow:

This study use the ***system dynamic model*** as a research method.

	Simplified	systemic
Temporal	Static	Dynamic
Spatial	Assembled	Integrated with interaction
Functional	Outcome-based indicators	Evaluated-based indicators
	ex-post	ex-ante
Meaning	Measuring the current state of energy supply chain	Assessing the potential risks and vulnerability of energy system
	Short -term warning tool	Long - term hedging strategy planning tool
Advantage	Simple and Easily communication	Clarification of causality brings meaningful dialogue
Disadvantage	Incomplete thinking may convey contradictory messages	Complex on data collection and model operation

The introduction of system dynamic model

- In 1956, system dynamic(SD) was created by Jay W. Forrester.
- **The main characteristics as follow:**
  - ✓ To analyze the dynamic behavior of complex systems.
  - ✓ Qualitative visualization ：A feedback causality of influential factors are represented in SD as a causal-loop diagram(CLD).
  - ✓ Quantitative analysis：The CLD is formulated the equations to simulate the value of all stocks and flows (stock-flow diagram, SFD)over time under certain conditions and assumptions.
- **The steps of building a SD as follow:**

The basic starting point for solving the problem is the system structure analysis.

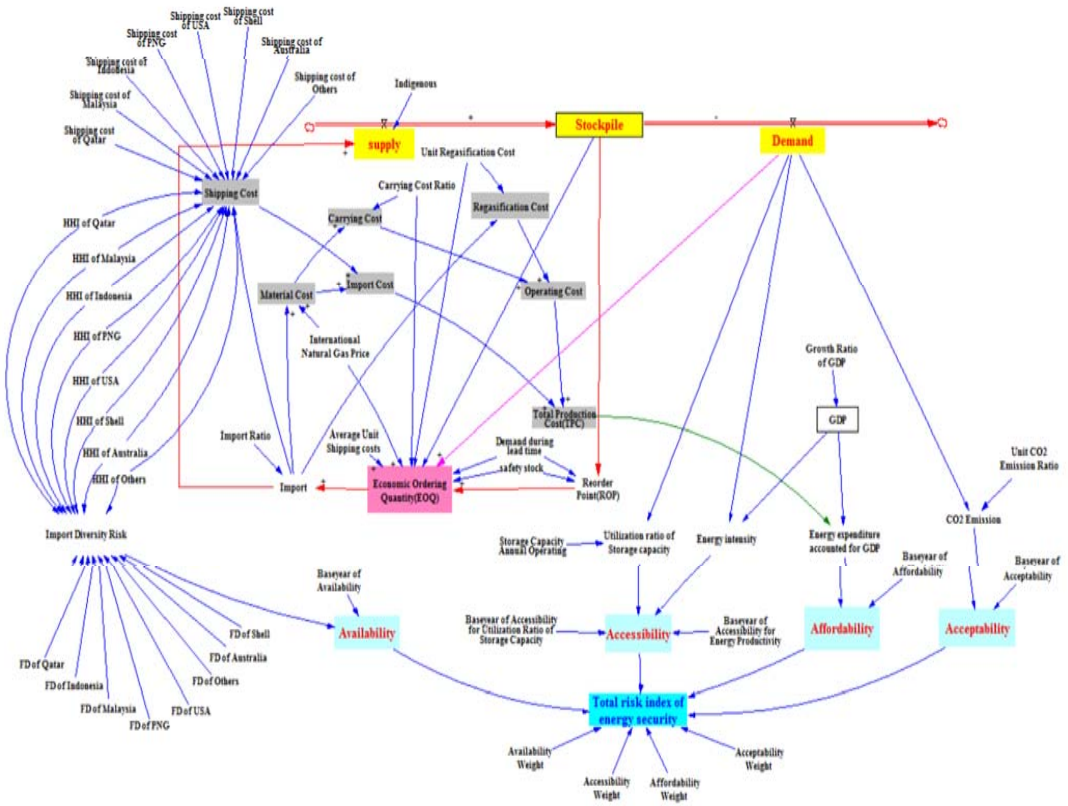
The assumptions in this study

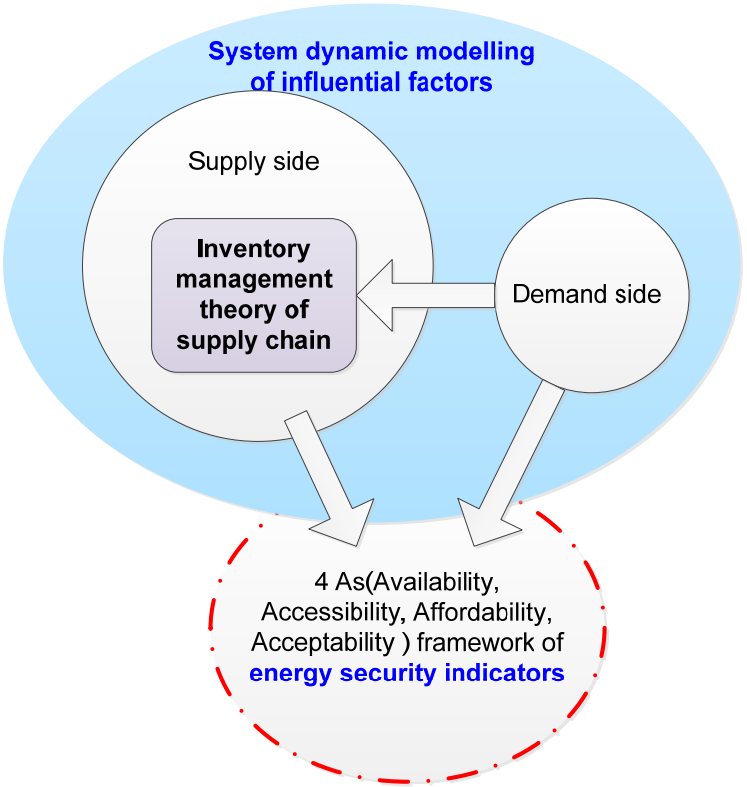
- The annual growth rate from 2016 to 2030 in Taiwan：
  - ✓ Natural gas demand : 3.3%
  - ✓ GDP：4.1%
- Regulative natural gas safety stock：

  The average daily sales in the previous six years are multiplied by 15 days.
- Demand during lead time：

  The average daily sales in the previous six years are multiplied by 9 days.
- Import natural gas price forecast was referred to the World Bank report.
- Inventory holding costs：5% of the purchase cost
- Cost of regasification： US$0.35/Mcf
- Shipping cost：(including LNG tankers and operating costs) US$0.7~1/Mcf

The construction of SD model in this study





The innovations of this study ：

- System dynamic model is joined with energy security indicators to Assess the potential risks and vulnerability of energy system.
- The reaction of supply chain is triggered by demand side.
- Introducing inventory management theory of the supply chain to establish systematic thinking of economic efficiency principle.

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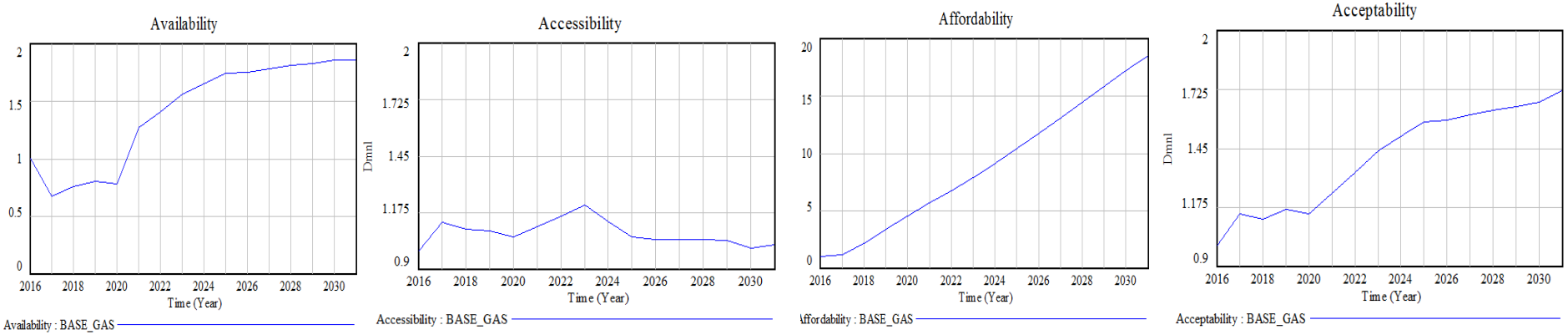
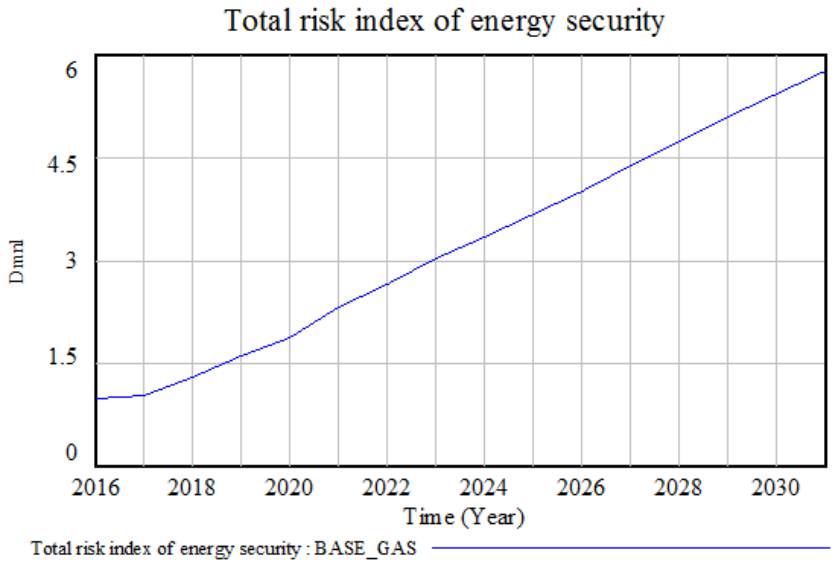
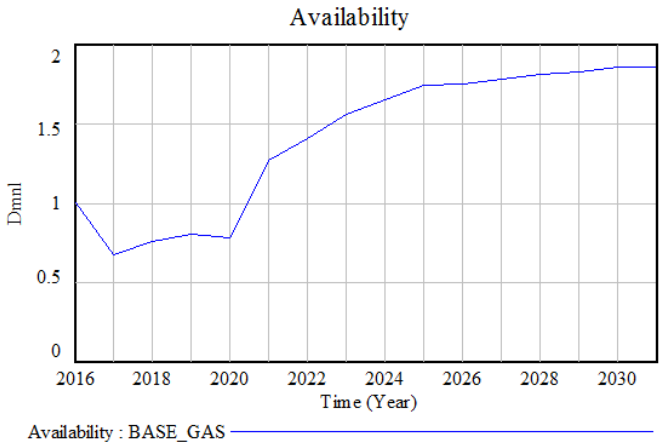
The LNG energy security index of Taiwan



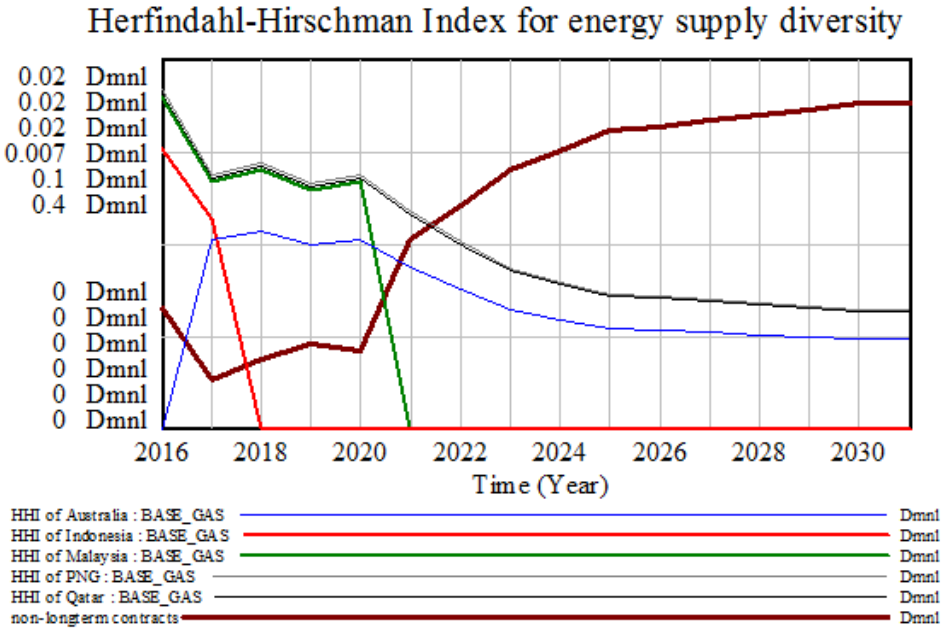


- Since 2020, LNG risk index of Taiwan have been soared in the BAU (business as usual) scenario.
- There are two main reasons.
  - ✓ *Taiwan's Long-term contracts with Malaysia and Indonesia will expire by 2020.*
  - ✓ For non-nuclear homeland and low carbon economy, *Taiwan increase a lot of natural gas power generation since 2020.*

The variety of availability risk index



- Availability risk index measures ***the vulnerability of obtaining resources.***
- The long-term contracts between Taiwan and Indonesia and Malaysia will expire in 2018 and 2020 respectively.
- In BAU scenario, the proportion of long-term contracts accounted for total imports will decline from 80% to 40 ~ 50%
- Since 98% of Taiwan's natural gas imports, Taiwan needs to *early plan diversification of long-term contracts of LNG*.



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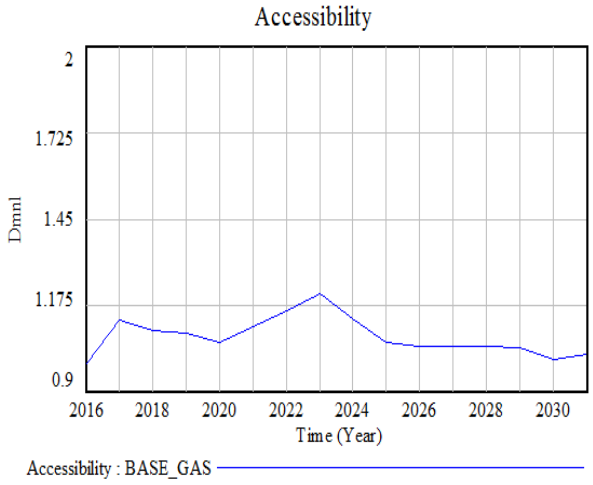
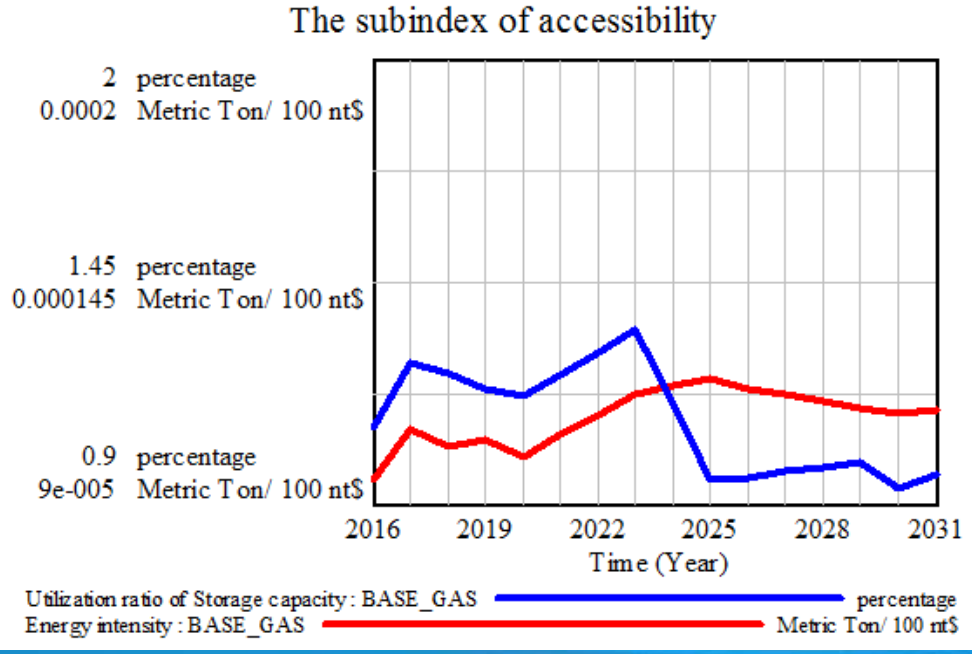
The variety of accessibility risk index



- Accessibility risk index measures ***the vulnerability of convection from supply to demand***.
- In BAU scenario, the utilization ratio(Demand/storage capacity) is more than 100% by 2023, *which means LNG storage capacity is not enough to meet demand growth until 2023 because new storage capacity will be completed*.
- The energy intensity index(Energy/GDP) will be upward because Taiwan increases a lot of natural gas power generation since 2021, which *means LNG will become an c development*.



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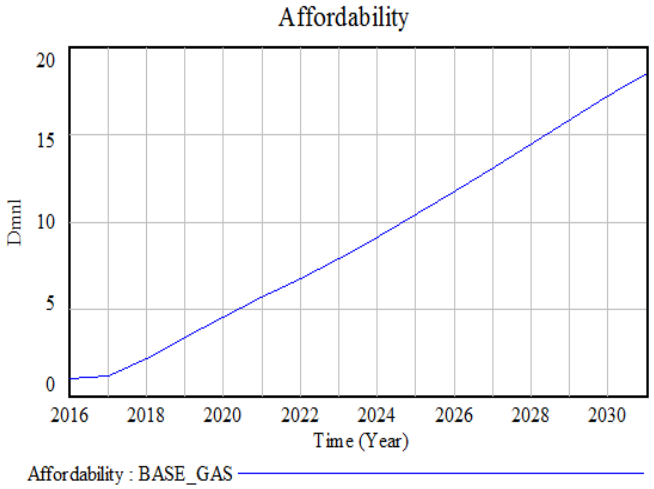
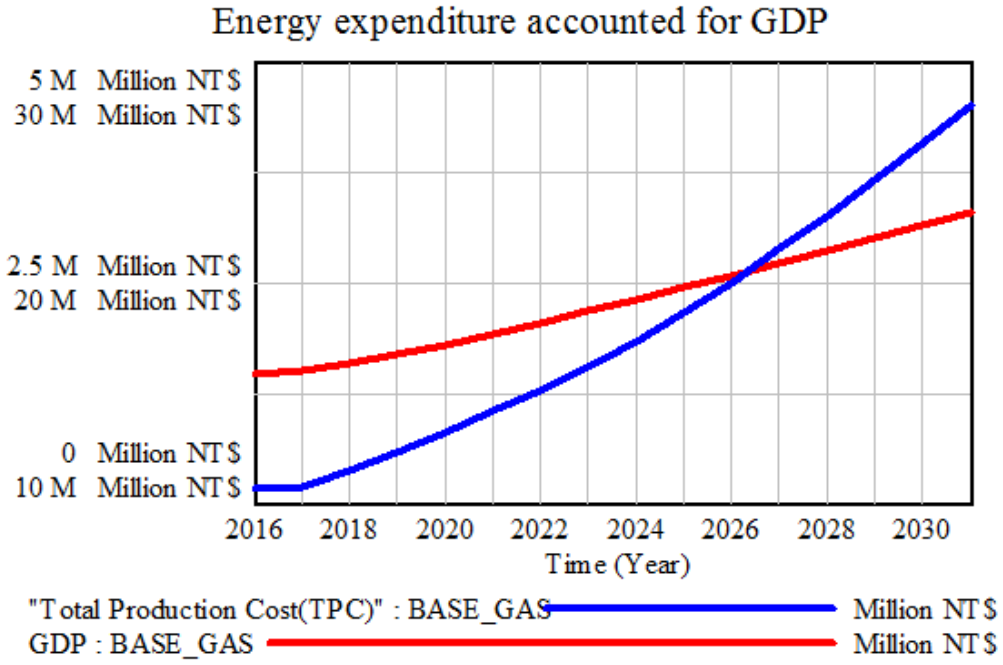
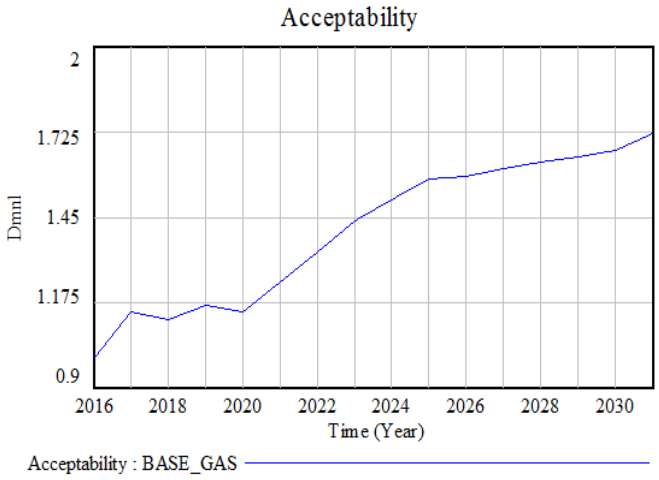
The variety of affordability risk index



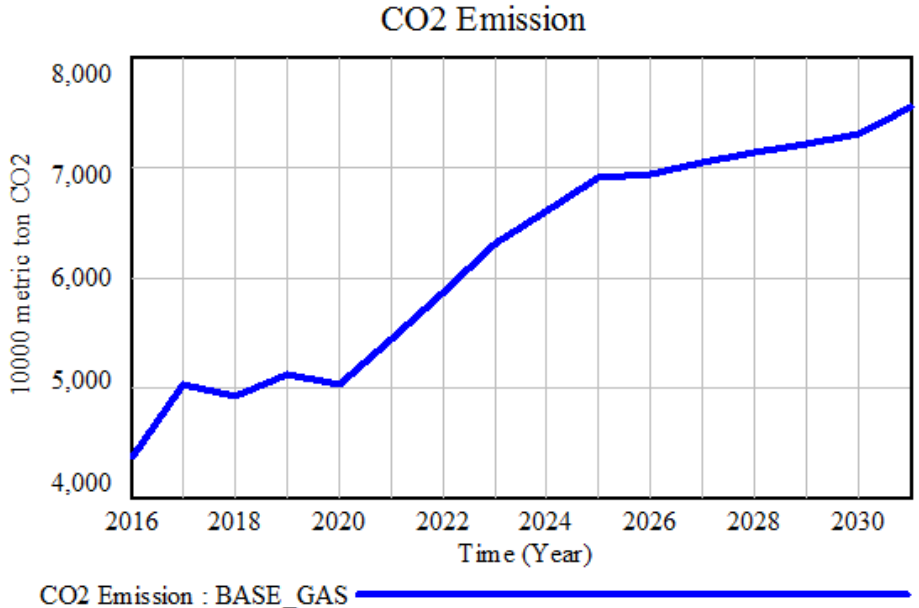
- Affordability risk index measures ***the vulnerability of economic loading***.
- A large amount of natural gas power generation results in a rapid increase in production costs, including import cost, carrying cost and regasification cost.
- *The increase of production costs may have feedback impacts on price and GDP, which need to further study*.



The variety of acceptability risk index



- Acceptability risk index measures ***the vulnerability of environmental loading***.
- It is obvious that a rapid increase in CO_2 emission of natural gas because of a large of natural gas power generation since 2020.
- Environmental impacts of fossil fuel substitution need a comprehensive measurement to avoid misleading of one-sided viewpoint, which imply that *the acceptability index of LNG needs to integrate with index of other energy*.



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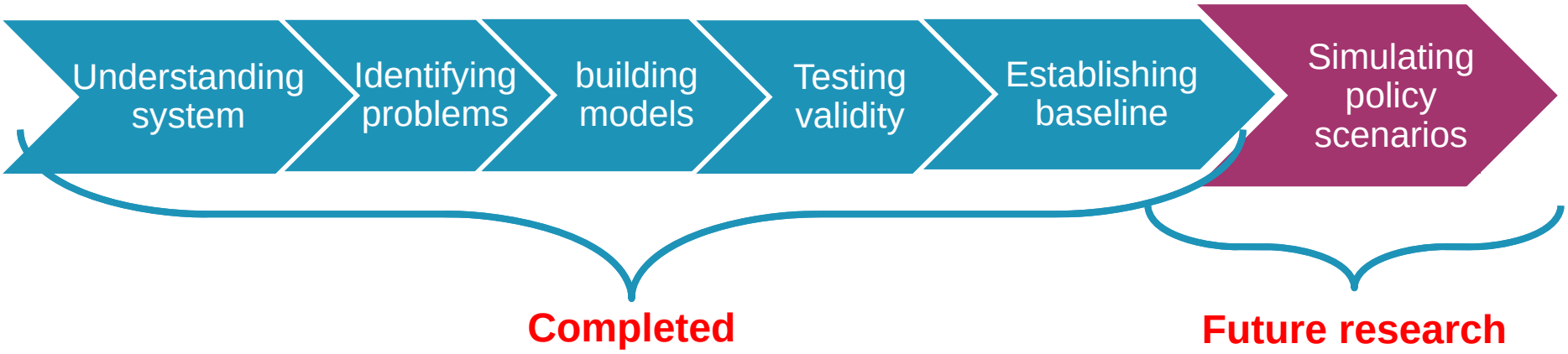
The main contributions of this study

- This study integrated the inventory management theory into the system dynamic model and constructed the nonlinear feedback logic between the influential factors for exploring the systematic causal relationship and evaluating the impact on the national energy security.
- A state of the art analysis method connected risk indicators of energy security with system dynamic model.
- This study focuses on an ex-ante strategy analysis, which is different from the energy security review of ex-post key performance indicators (KPIs) by static linearity aggregative method.

The future research……



(1)Firstly, planning national long-term energy security strategies.

(2)Secondly, simulating policy scenarios and assessing the potential vulnerability and impacts on the energy security.

Thank you for your attention!

Contact information:
Kuei-Lan Chou
E-mail: kelly@itri.org.tw

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