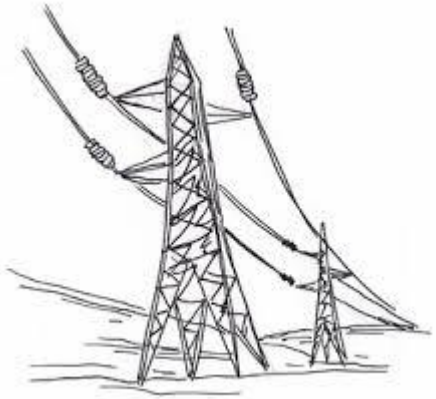

Optimization of the Electricity Grid: Long-Term Planning for 2030-2050

BMI's 9th Annual Conference

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Under the supervision of: Prof. Itai Sened and Prof. Asher Tishler

Tel Aviv University

May 2024

What are we going to talk about?

- Background: the changes of the 21st electricity markets.
- The electricity network.
- Research objectives and contribution.
- Our model and methods.
- Case study: Israel's electricity market.
- Summary.

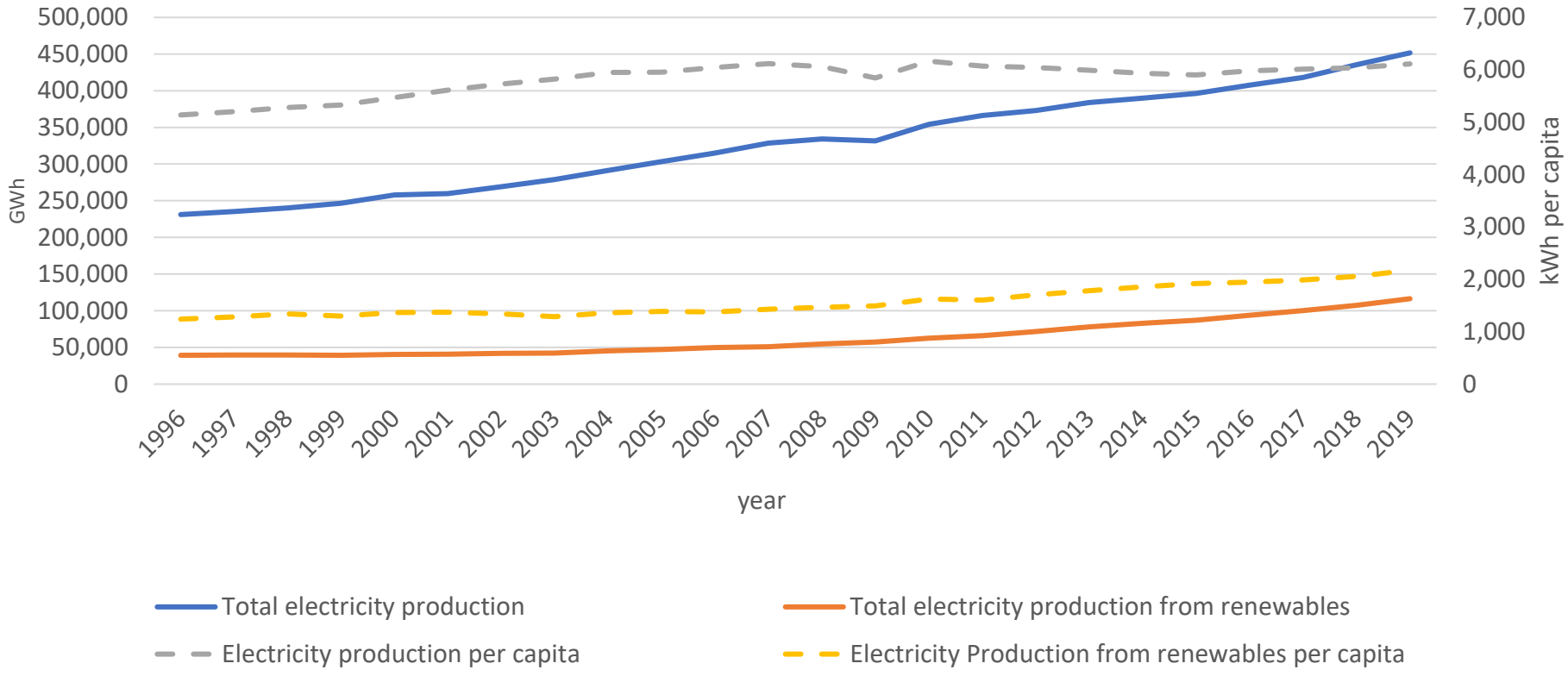
Background

- As part of the global mission to mitigate global warming and its consequences, many countries have pledged to promote policies aiming at low-carbon economy by 2050.
- The energy sector's transition towards renewable energy poses major challenges.
- The war in Ukraine led to a significant energy crisis, amplifying calls for an accelerated energy transition.
- The year 2021 saw record-breaking growth in renewable energy installations with a total capacity surpassing 314 gigawatts (GW), providing more than 10% of the global electricity supply.

Background

- The transition to de-carbonate electricity production based on renewable energy requires optimal planning of the future electricity network as a preliminary step towards renewable energy implementation on a large scale.
- This research provides an economic model for planning the optimal layout of the electricity network in Israel, based on an evolving capacity mix (natural gas, solar energy, other), population growth, the location of new settlements and industrial areas, and the demand for electricity in the years 2030-2050.
- The model employs linear programming to provide feasible solutions for minimizing the costs of the future electricity network.

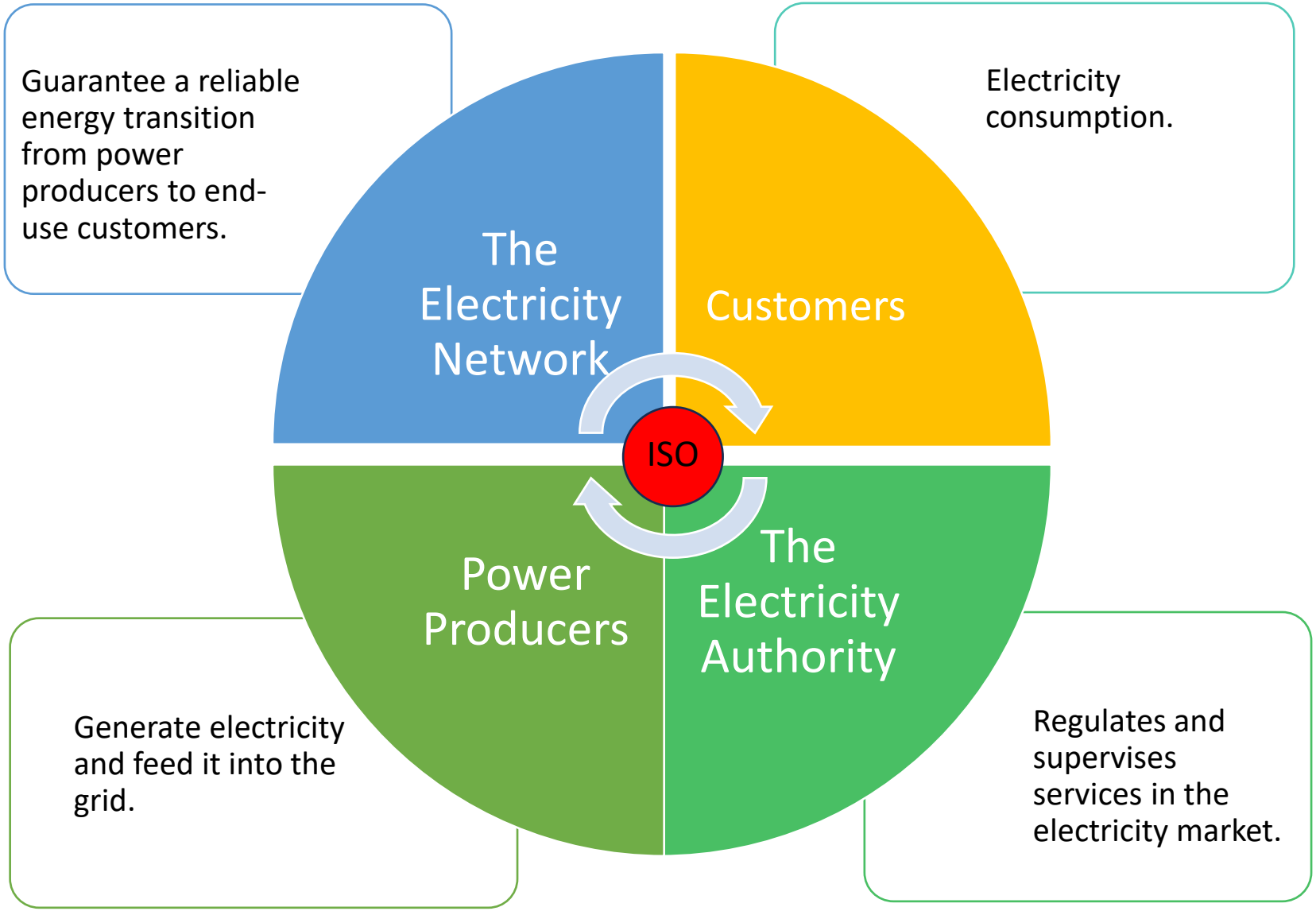
Trends in total electricity production and electricity production by renewables



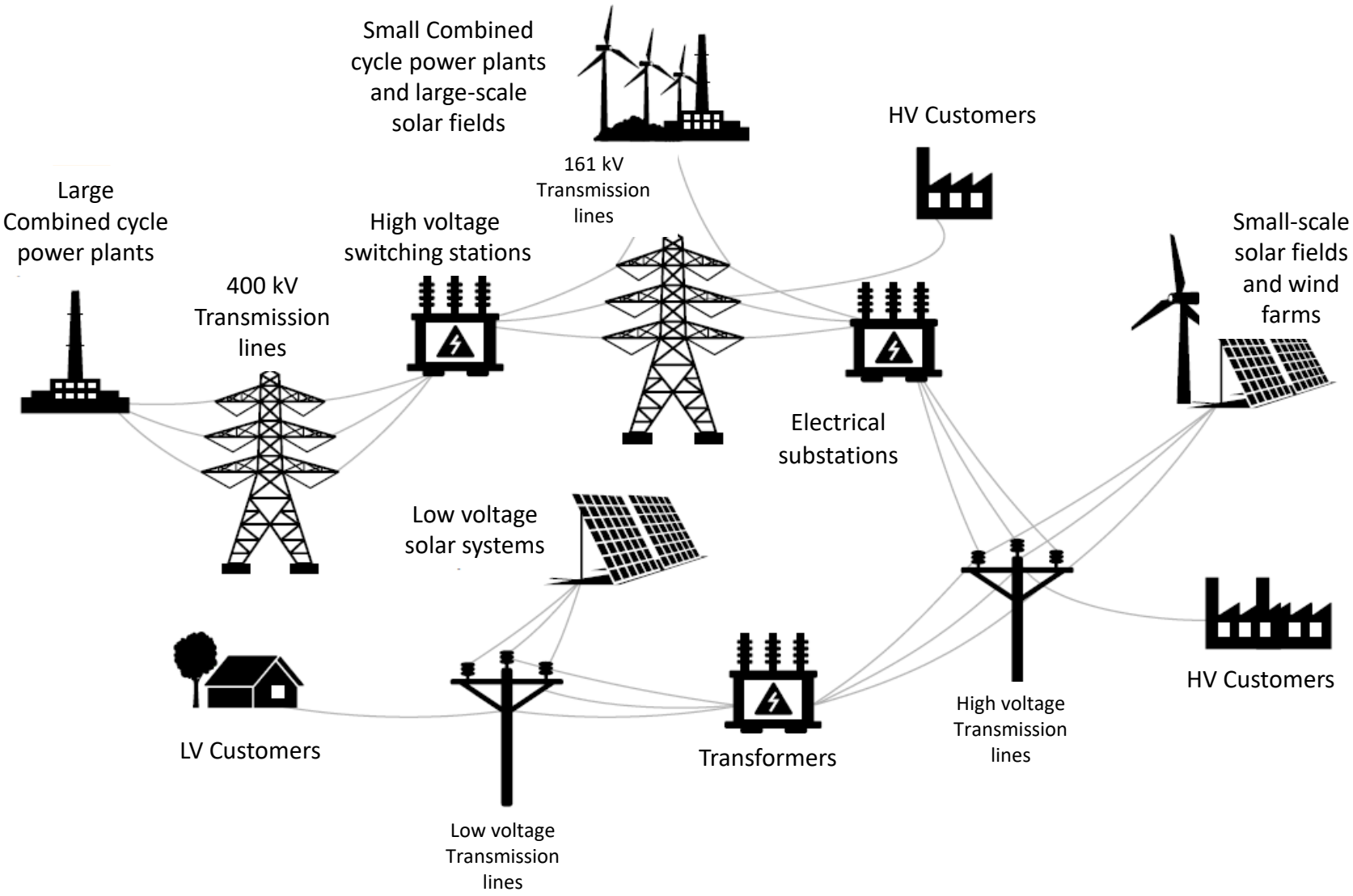
Author's calculations. Based on data from IEA.

* Renewable energy sources include hydropower, wind, solar, geothermal, tidal, and biomass energies.

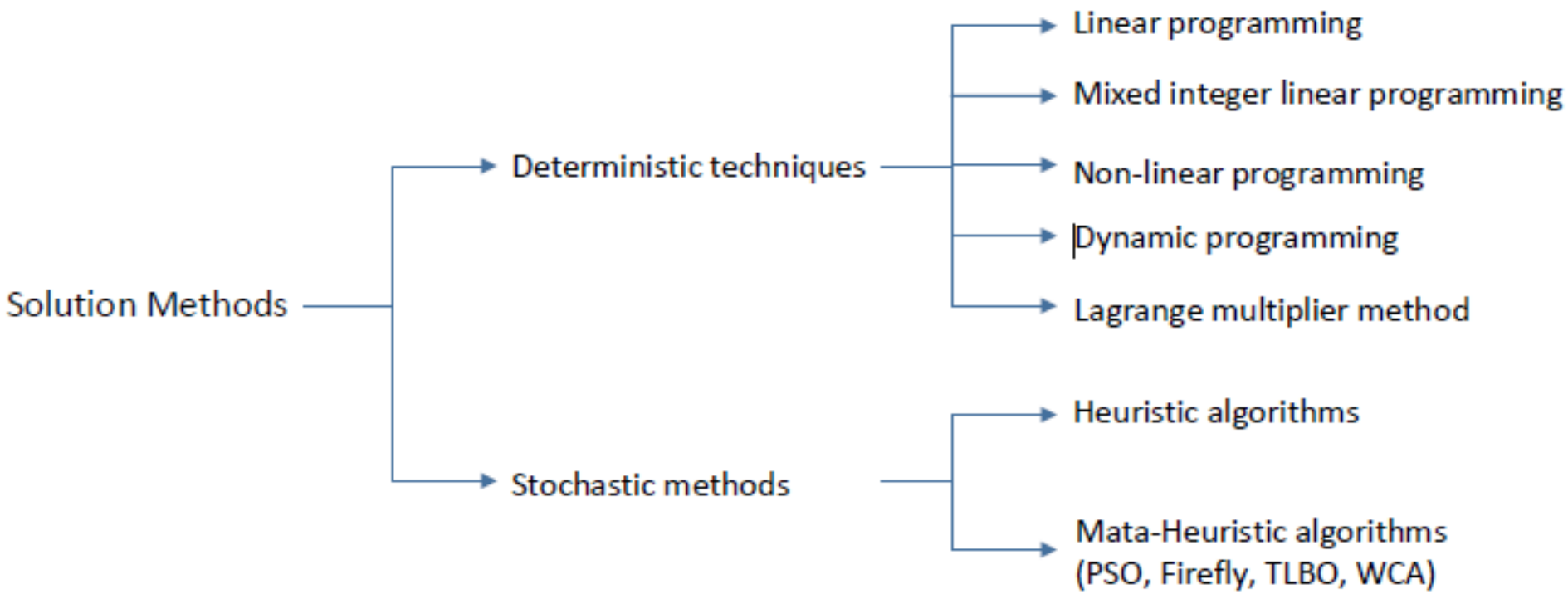
Electricity Market: Key Players



The structure of a typical power grid



Methods for solving transmission optimization problems



Source: Liaquat, Zia, and Benbouzid (2021).

Two-stage optimization models

Milstein and Tishler (2012), Chao and Wilson (2020), Gomes and Saraiva (2020), Milstein et. al. (2022)

Electricity Network Optimization (capacity mix is predetermined)

IPPs determine and build their optimal generating capacity

Equilibrium generation levels and prices

Research Objectives

1. The main objective of this study is to provide a linear programming model for the optimization of the electricity network in Israel during 2030-2050; and
2. To provide feasible optimal solutions for the Israeli case for 2030-2050.

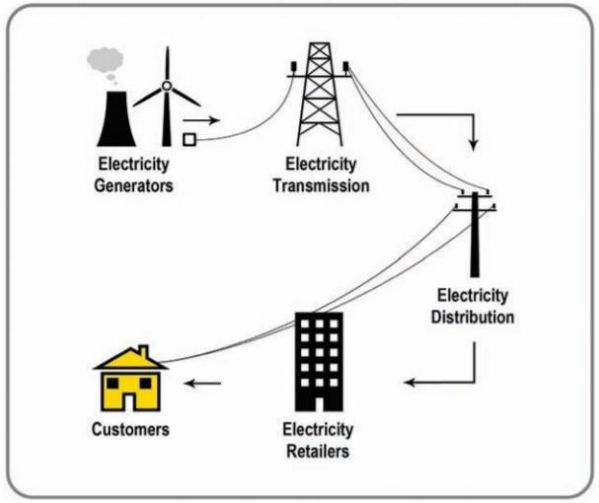
A centralized electricity market managed by an independent system operator

A decentralized electricity market coordinated by an independent system operator

A decentralized wholesale electricity market that includes microgrids

Research Contribution

1. This study provides an economic model for the optimization of the electricity network by solving a linear programming optimization problem.
2. Using Israel as a case study, I will provide feasible solutions for minimizing the costs of future electricity networks for 2030-2050.
3. The model would provide new insights on the integration of microgrids and their effects in future planning of electricity networks.



Research Methodology

- Assess the development and geographic location of the population, spatial distribution of electricity demand (such as new settlements, and new industrial areas) in Israel in 2030-2050.
- Estimate the costs of the various technologies currently available for extra high and high voltage network.
- Estimate the peak demand for electricity, the optimal capacity mix, and the optimal electricity production quantities in 2030-2050.
- The model will account for electricity production by various consumers as well as for the increase in demand due to the penetration of electric vehicles into the market.
- Use a linear programming model that will minimize the costs of establishing and operating the electricity grid in Israel in 2030-2050, subject to land limitations, technological barriers, regulatory barriers, design constraints, population changes, location (and changes) of new/existing settlements and industrial areas, and more.
- Provide solutions for several scenarios for Israel's electricity market.

The Model

Establishing an optimal transmission network at minimal cost.

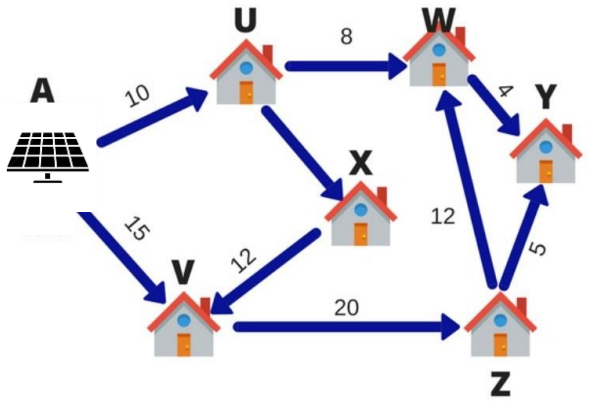
Optimization Problem

Constraints

- Land limitations.
- Technological barriers (the system reliability, storage solutions).
- Regulatory barriers.
- Circuit constraints.
- Design constraints.
- Population growth.
- Location and size of new settlements.
- Location and size of new industrial areas.

Optimal transmission network

Feasible Solutions



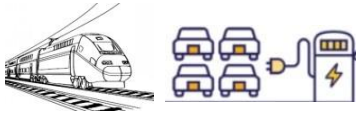
A Long-term Model based on Five-Year Action Plans

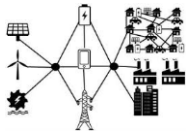
Demographic growth





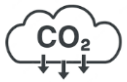
Design aspects

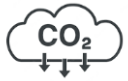



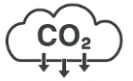


2030 → 2035 → 2040 → 2045 → 2050

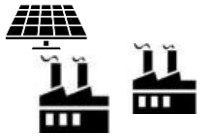
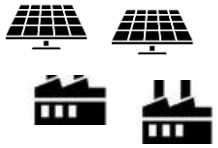
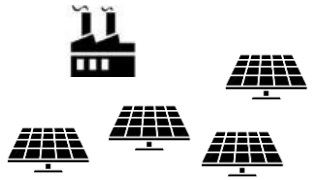
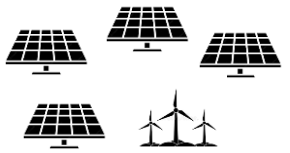
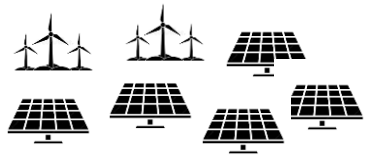
De-carbonization







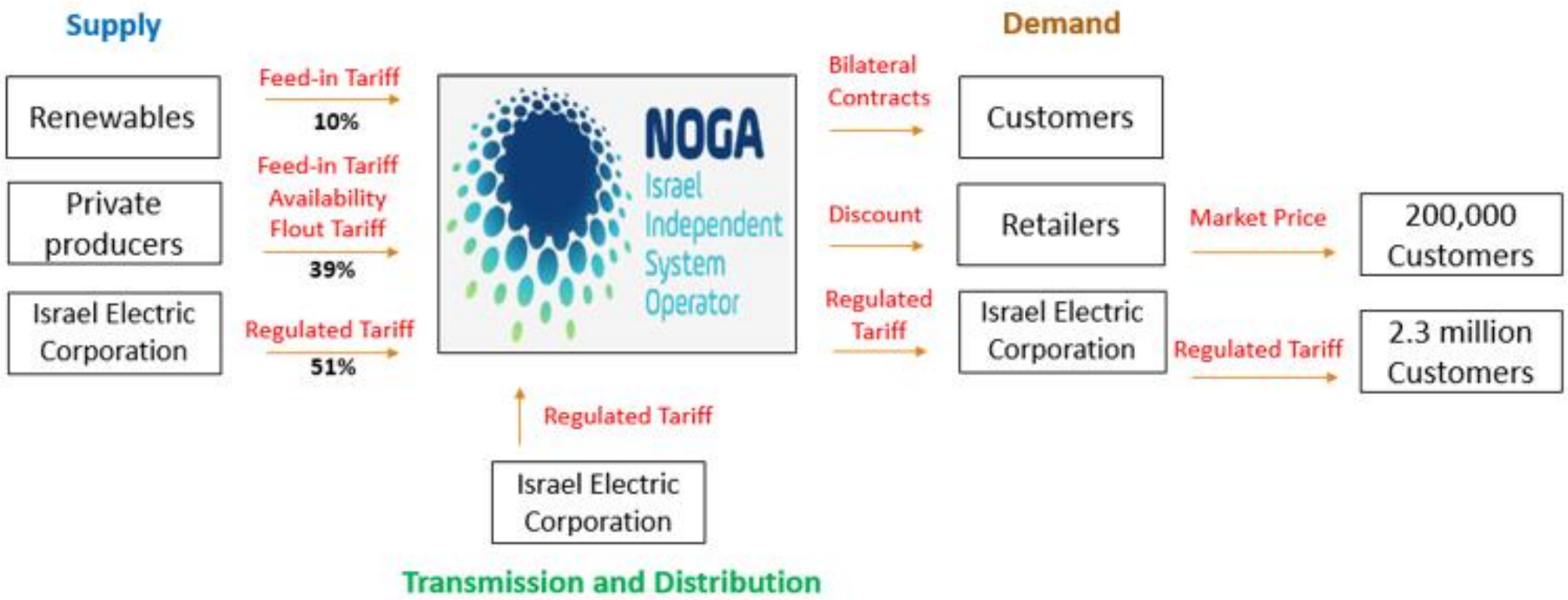
Technological improvements

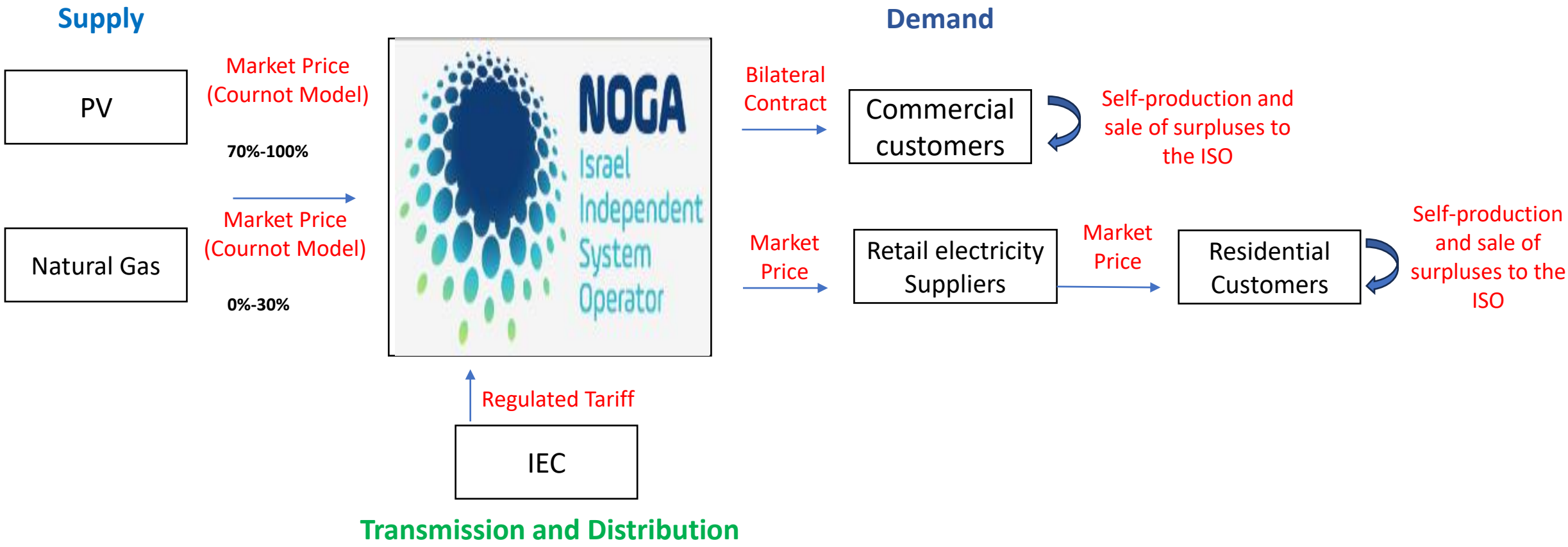
Why Israel?

- Israel has recently begun to reform its electricity market.
- Israel's 2023-2030 transmission development plan total budget exceeds 17 billion NIS but lacks long-term planning beyond 2030.
- Israel has the unique characteristics of an 'Electricity Island'.
- The Israeli case study contributes to the literature on macro-grid transmission network design.

The Israeli Electricity Market, 2023



Israel's Electricity Market in 2050 (a reasonable scenario)



Summary

- Transmission network design is a complex process that requires integration of many factors.
- This study uses linear programming to optimize the future electricity network.
- The model provides a framework for a multi-period optimization of transmission networks.
- Applying the model for Israel's electricity market, using three scenarios for Israel's electricity market that should attempt to achieve a zero-carbon competitive market by 2050.
- Integrating "islands" in the model that are likely to provide all their electricity needs and, possibly, stay disconnected from the country's main electricity transmission network (identify the main characteristics of these islands).

Thank you
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