

PyPSA-KR: An open-source energy system modelling of Korean electricity network

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Research Overview

- This study aims to **introduce the PyPSA model to Korea** for the first time by developing **PyPSA-KR** and conducting an in-depth analysis of Korean energy system.
- PyPSA is an **open-source energy system model** which is useful for regional grid analysis and optimization due to its high spatial and temporal resolution
- Derive Korean **renewable energy potential** and **power system** by PyPSA-KR and validate with real-world data
- This research presents a systematic approach to **expanding renewable energy and optimal capacity**, contributing to the national long-term energy strategy

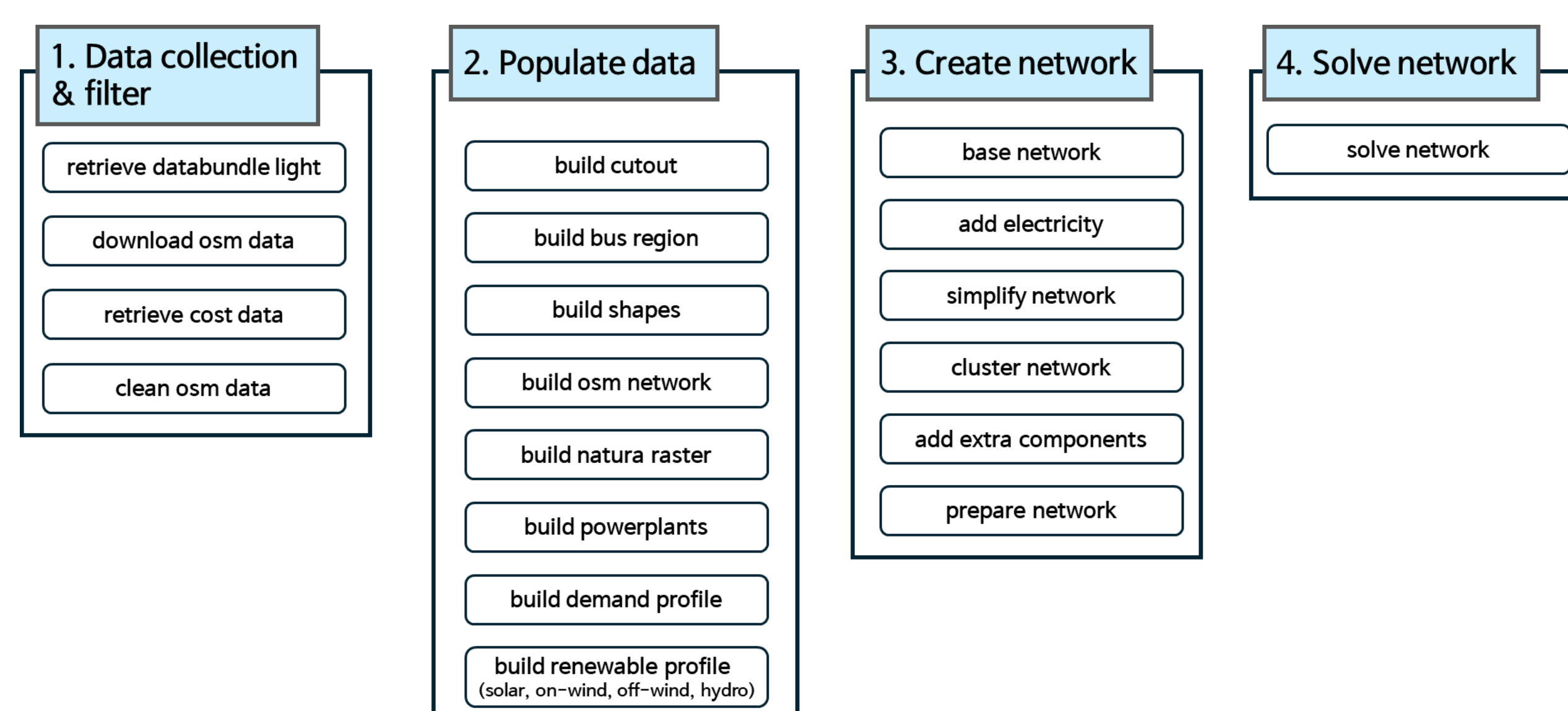
Status quo of modelling work in Korea

- Most of the energy models studied in Korea are **Integrated Assessment Models**
 - ⇒ Useful for scenario-based analysis of overall energy systems
 - But, not suitable for addressing detailed elements of the power system
- Difficulty in modelling **new ESS technologies and renewable energy variability**
- Therefore, this study proposes the PyPSA model

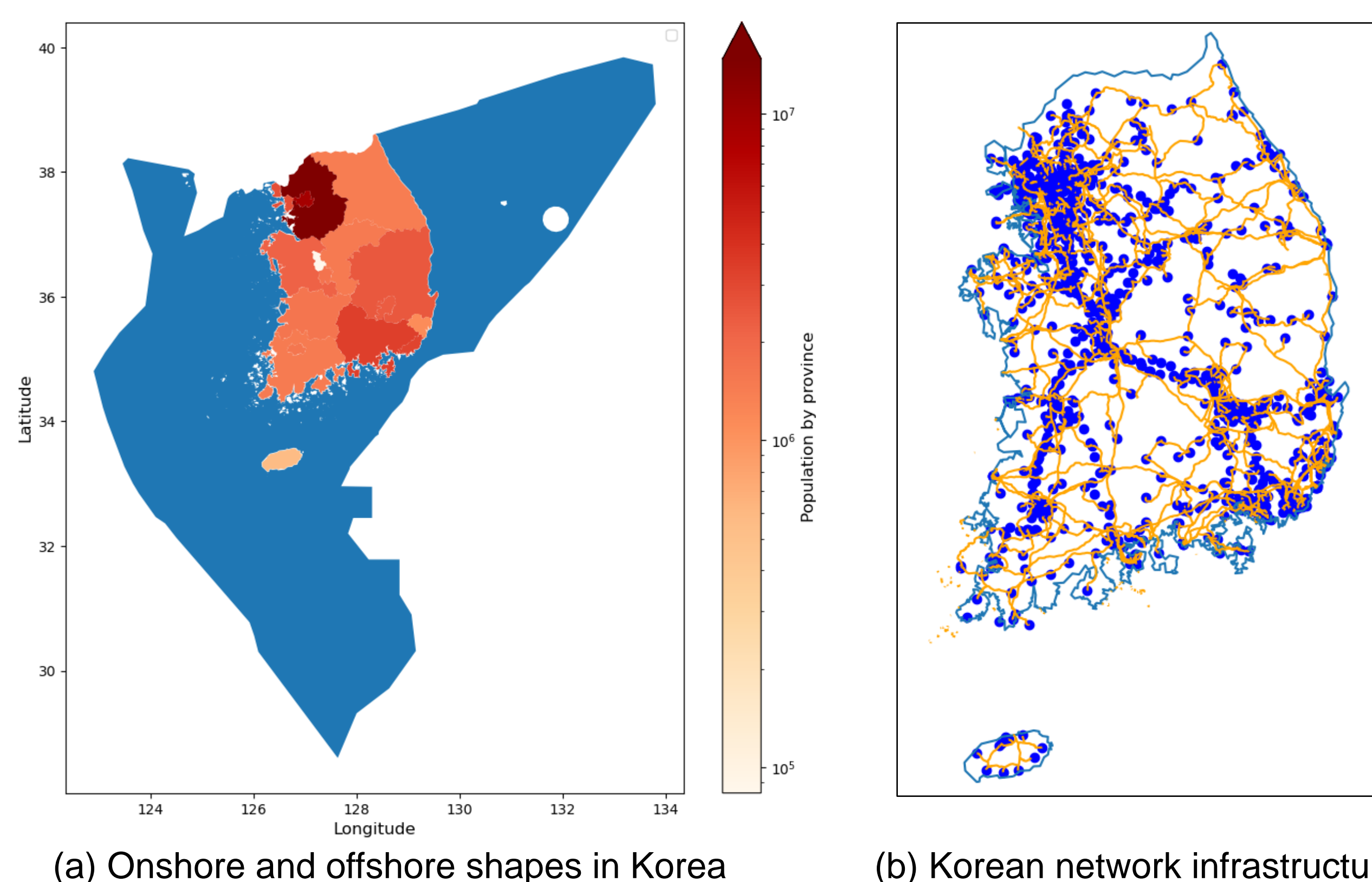
Model	Description	Spatial resolution	Temporal resolution	Approach	Free and open-source
TIMES	An optimization energy planning model that represents energy systems, focusing on technology and policy analysis.	Local to Global	day, night and peak hours for 4 seasons	Bottom-up	limited
GCAM	An integrated assessment model that links energy, water, land, and climate systems to assess the implications of policy decisions.	National to Global	Annual	Bottom-up	✓
LEAP	A scenario-based energy modeling tool that is used for integrated resource planning and climate change mitigation assessment.	Local to Global	Hourly	Hybrid	limited
PLEXOS	A power market simulation software used for modeling electricity markets and generation optimization.	National to Local	Hourly	Bottom-up	limited
PyPSA	An open-source tool for simulating and optimizing energy systems.	Local to Global	Hourly	Bottom-up	✓

Workflow of PyPSA-KR

- PyPSA-KR utilizes a modular approach, using **'snakemake' rules** that break down complex tasks into manageable sub-tasks ⇒ **increases usability and clarity**
- The workflow is divided into four steps. Data collection & filter → Populate database → Create networks → Solve & Optimize networks

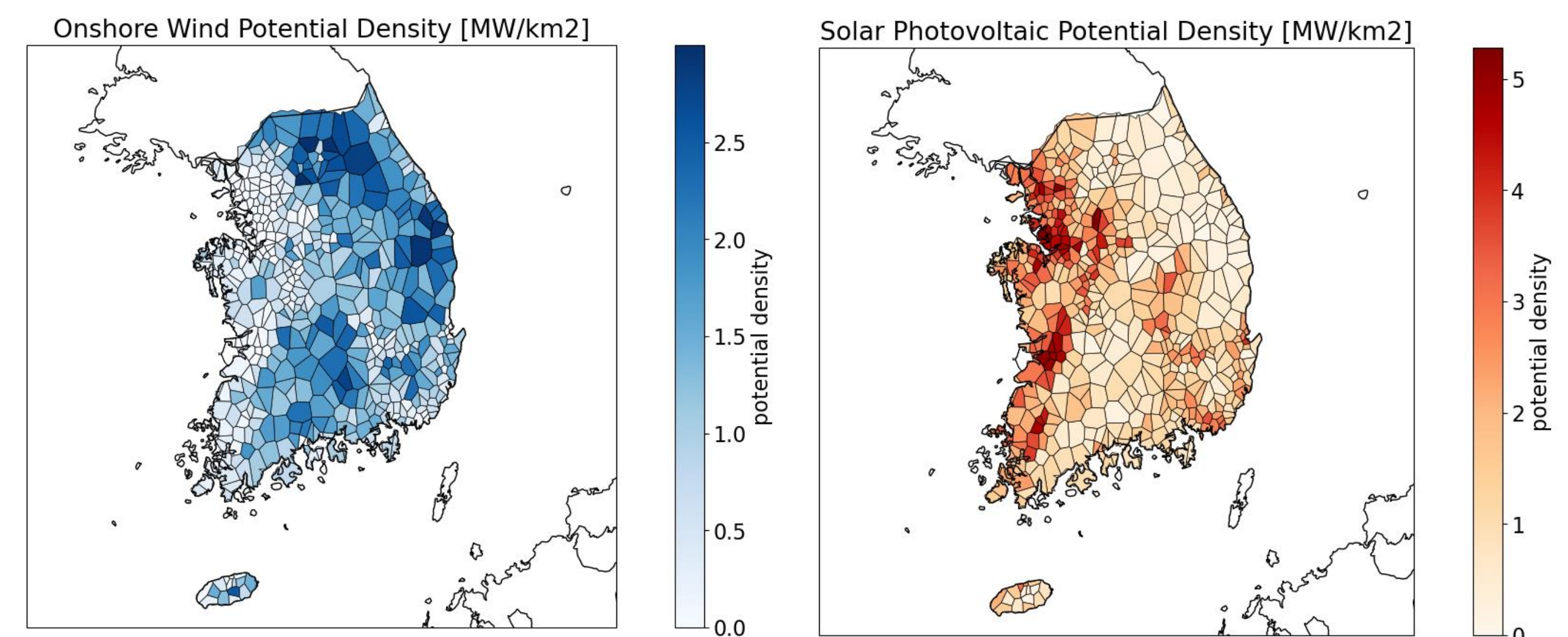


- Generates the network based on Korean onshore and offshore shapes with **GIS datasets** and **assigns ID** to the buses



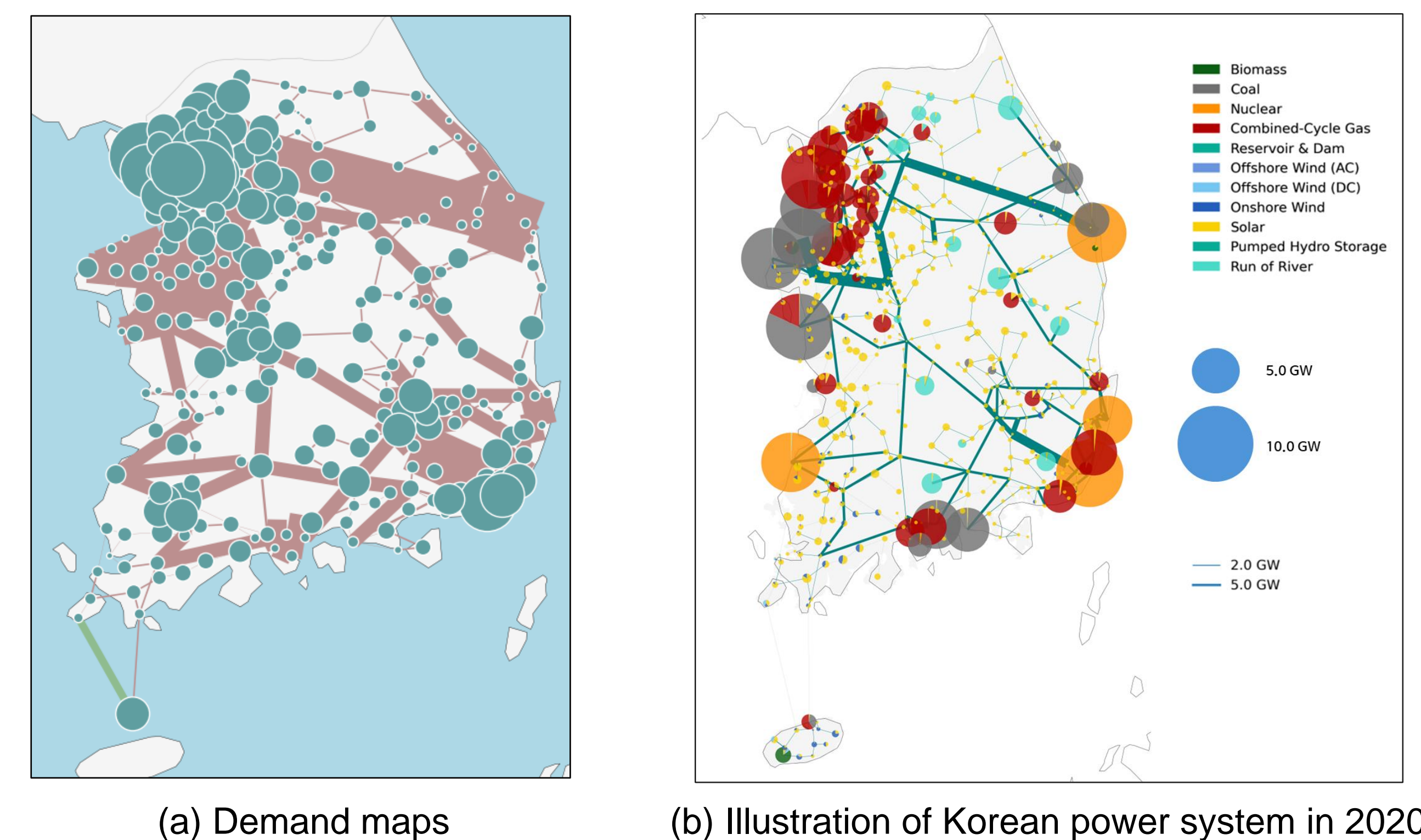
Potential renewable energy

- Potential renewable energy is calculated for each node using the **'Atlite'** climate package (**'ERAS' dataset** was used in this model)



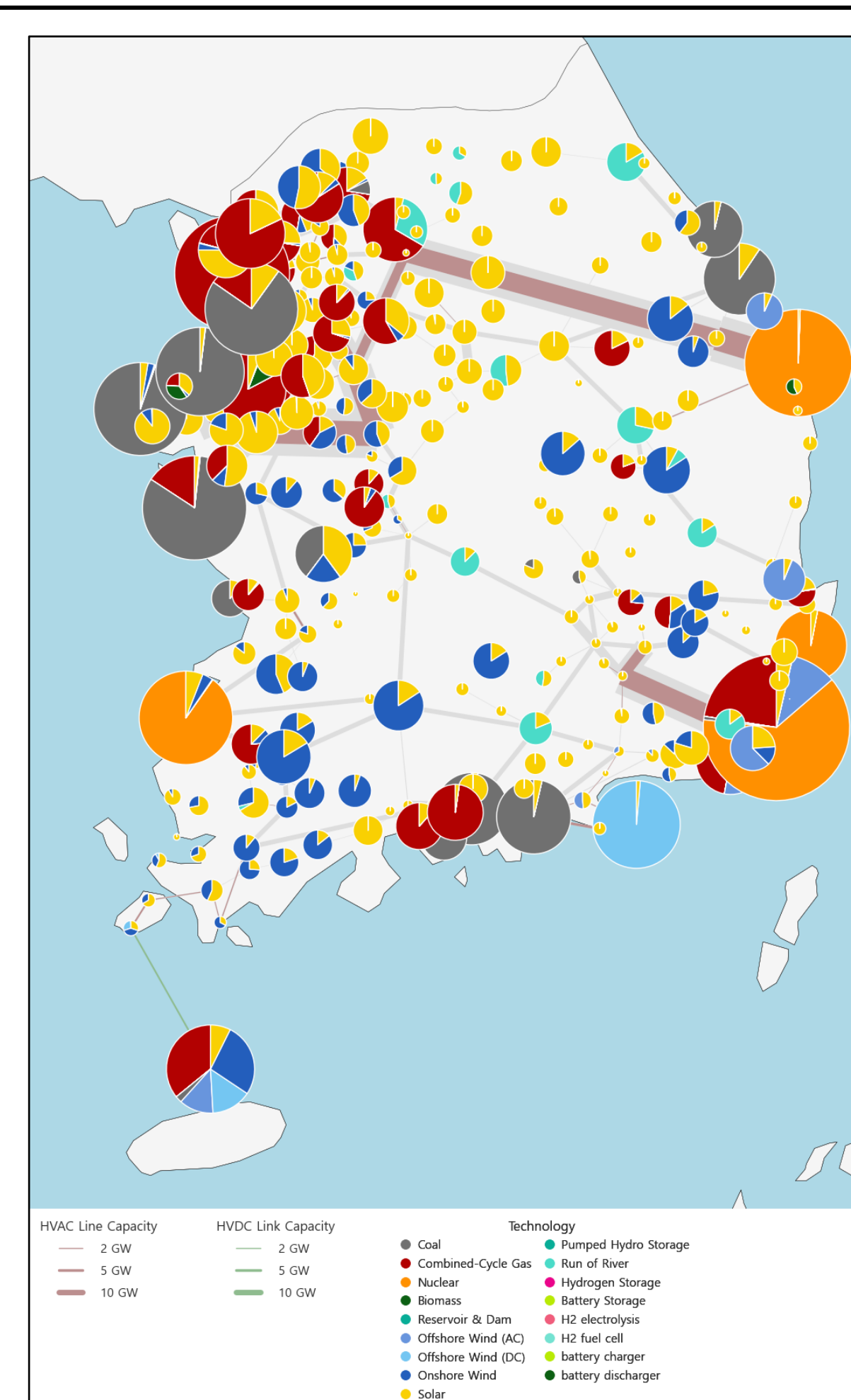
Transmission network

- (a) Shows the **demand map in Korea** and the size of the circles represents the electricity demand of each Bus.
 - Transmission lines are represented by lines connecting the nodes and the **thickness indicates the transmission capacity** of the power grid (thicker lines representing higher capacity)
- (b) **Illustrates the Korean power system**. It shows the distribution and capacity of power plants, as well as the clustered power grid structure (256 Bus-2Hour)
 - Size of the circles represents the generation capacity of power plants, and the colors indicate different energy sources



Optimized Results for 2036

- Rural areas are suitable for local solar generation, promoting **regional energy independence** and reducing **transmission losses**
- Offshore wind farms should be expanded in the **southern sea regions and southeastern coast** due to high wind potential
- Additional transmission infrastructure is needed **between the east coast and inland** with high concentrations of power plants to improve power distribution and grid stability



Summary & Policy Implications

- PyPSA-KR model and framework were developed to support the energy transition challenge in Korean power system
- A key advantage of this model is the ability to easily interpret and understand the research results through visualization
- Future studies will focus on various future challenges like ESS (Li-B, H₂) mix, the impact of carbon tax, and simulations for carbon neutrality goals and strategies
- As PyPSA is an open-source model, its adoption provides valuable insights for students and researchers in Korea