Documento: Personal

PyPSA-AR

Open-Source Model for the Argentine Power System

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Supported by

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Main objectives

01 Calibrated & Reproducible PyPSA Model

Develop and deliver a rigorously validated model of Argentina's Interconnected Power System (SADI) — fully reproducible and version-controlled. A fully open-source, publicly documented tool — enabling independent validation and academic collaboration

02 Long-Term Energy Planning

Provide a robust analytical platform to support scenario analysis, capacity planning, and long-term energy system foresight.

03 Full Technology Coverage

Integrate and standardize all the information of the Argentine electricity system – demand, conventional thermal generation, hydroelectric, nuclear, wind, solar, pumped and electric transport – in a single model.

04 Create a local PyPSA Team

Bring together analysts, programmers and modelers and create a local team to learn PyPSA. The local development of PyPSA-AR in Argentina by local researchers provides confidence in the local academic and research community, promoting its dissemination in the environment.

Challenges

Technical Audit of the PyPSA-Earth Framework for Argentina: *No Usable Baseline Existed*

- ***PyPSA-AR Team found Argentina's PyPSA-Earth data critically insufficient: 11% transformer coverage,*** *zero impedances on all lines, European conductor types assigned to Argentine 500 kV infrastructure, outdated generation capacity data and generalist demand data.*

Reproducible Pipeline for the 500 kV Physical Network: *Everything Built from Scratch*

- *The entire pipeline — from raw file parsing to optimization —* ***was designed, coded, tested and validated as original work.*** *Each of the 9 milestones in this report represented a difficulty that had to be solved before the next one could begin.*
- *8 chained scripts transform raw PSS/E and GeoSADI files into a fully functional PyPSA Network*

Identification & Adoption of Official Argentine Datasets: *Heterogeneous and non-aligned data sources*

- ***Integrate multiple official datasets (PSS/E, CAMMESA, GeoSADI, ENARGAS, ATB/NREL)*** *that differed in: Naming conventions, Granularity, file formats, sizes, and update frequencies.*

Expert-Driven Curation of network topology and generation unit clean up: *Curated dictionaries were built manually*

- ***Manual dictionaries were crafted to match the Electrical substations and the lines between both data sources.*** *Also, manually resolving dozens of unresolved generator mappings.*
- ***Cleaning, filtering, and validating a very large hourly dataset (~580 MB) outside GitHub****.*

Power, demand and economics: *aggregation and spatial assignment, marginal costs and efficiency assignment gaps*

- ***Some technologies lacked CAMMESA marginal cost coverage****.* ***Efficiencies and heat rates*** *incorporated*
- ***Energy Demand Manual aggregation and allocation*** *to 500 kV buses was required, hourly and by province.*
- *Only a subset of buses carries load after aggregation, which had to be* ***validated against system totals and peaks.***

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Milestones – a summary

I — Technical Audit of the PyPSA-Earth Framework for Argentina

Run of the full PyPSA-Earth pipeline configured for Argentina and systematically audited every output against official CAMMESA data (GeoSADI).

II — Identification & Adoption of Official Argentine Datasets

Official CAMMESA power flow case (PSS/E — ver2526pid.raw) and Official GIS database for Argentina's power grid (GeoSADI — CAMMESA)

III — Reproducible Pipeline for the 500 kV Physical Network

8 chained scripts transform raw PSS/E and GeoSADI files into a fully functional PyPSA Network object. Every step is version-controlled in GitHub.

IV — Expert-Driven Curation of Geographical and Topological Data

Automated matching alone was insufficient. Curated dictionaries were built manually, reviewed against official unifilars, and version-controlled in Git.

V — Network Mapping of 604 Power Generation Units

Connecting generators to the model and Resolving naming conflicts

VI — Node-Level Hourly Demand, Generation Profiles & Marginal Costs

Hourly demand profile for each 500 kV node and hourly generation availability profiles were built; and Variable production costs assigned per generation unit.

VII — End-to-End Georeferenced Verification in QGIS

GeoPackages (.gpkg) were exported at multiple pipeline stages, enabling visual QA that cannot be caught through tabular validation alone.

VIII — Successful Deployment of the Optimization Model

A linear DC Optimal Power Flow (OPF) executed over the complete Argentine 500 kV network using real 2024 operational data

MILESTONE I

Technical Audit of the PyPSA-Earth Framework for Argentina

Before building anything, we ran the full PyPSA-Earth pipeline configured for Argentina and systematically audited every output against official CAMMESA data (GeoSADI).

11%

Transformer Coverage

125 modeled vs 1,132 real

r = x = 0

No Electrical Impedances

All 500 kV lines — zero physics

+22%

Line Length Overestimated

65,016 km vs 53,129 km real

Decision: Build the model from scratch using official Argentine data sources (PSS/E + GeoSADI) instead of OpenStreetMap.

Result: First open-source power system model for Argentina built on physically consistent, **CAMMESA-validated data.**

MILESTONE II

Identification & Adoption of Official Argentine Datasets

PSS/E — ver2526pid.raw

Official CAMMESA power flow case

- All +13.2 kV buses with type, area and voltage
- Transmission lines: real r, x, b impedances in per-unit (Sbase = 100 MVA)
- Thermal ratings in MVA for every branch
- Series compensators explicitly modeled
- Transformers (2W and 3W) with impedances
- Verified electrical topology (official load flow case)

GeoSADI — CAMMESA

Official GIS database for Argentina's power grid

- 1,332 transmission line geometries (WKT format)
- 1,132 transformer records with substation coordinates
- 436 power generation plants with location and capacity
- Unique element names matching PSS/E naming conventions
- Publicly available via CAMMESA's ArcGIS portal

Result: Combined, these two sources enabled a model with real electrical physics — previously unavailable in any open-source implementation for Argentina.

First Version – 500 kV network

01 Real Data

To work, from scratch, with real information from the Argentine System, considering both its network topology and its georeferenced characteristics. **The 500 kV Network is the backbone of the SADI, where the most relevant power flows and dispatch decisions for energy planning are concentrated.**

02 Small and manageable System

Be able to load information, make changes, and run a model that is simple enough and can keep an orderly record of the steps and results of the model.

MILESTONE III

Reproducible Pipeline for the 500 kV Physical Network

Result: 8 chained scripts transform raw PSS/E and GeoSADI files into a fully functional PyPSA Network object. **Every step is version-controlled in GitHub.**

01–04	**Parse PSS/E**	Extract buses, lines, transformers and secondary buses from the .raw file
05	**Coord Matching**	Geospatial match: PSS/E bus names → GeoSADI substation coordinates
06	**Geometry Matching**	Assign WKT line geometry from GeoSADI to each transmission branch
07	**Topology Validation**	Automated check: connectivity, isolated buses, busbar coupler fusion (17 buses merged)
08	**Build Network**	Construct PyPSA Network object with real impedances, ratings, and AR–Brazil interconnection

344 Buses

103 Active Lines

300 Transformer Station

1 Connected Component

0 Isolated Buses

AR-Brazil Link Included

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MILESTONE IV

Expert-Driven Curation of Geographical and Topological Data

Automated matching alone was insufficient. ***The following curated dictionaries were built manually, reviewed against official single-line diagrams, and version-controlled in Git.***

buses_PSSE_vs_geosadi.xlsx

95 verified coordinates

Manual verification of GPS coordinates for every 500 kV bus. Each bus was cross-checked between the PSS/E name and the GeoSADI substation record.

manual_line_mappings.csv

23 manual line assignments

For 23 transmission lines where automated geospatial matching failed, **the correct PSS/E → GeoSADI association was resolved manually.**

conflicts_psse_cammesa.csv

77 naming conflicts resolved

Discrepancies between PSS/E unit names and CAMMESA dispatch groups (GRUPOs) were resolved manually — including 22 exclusions and 18 irresolvable conflicts — by reviewing single-line diagrams of each plant.

Result: These files are the sole source of truth for matching between data systems — they ensure the model geometry accurately reflects real-world infrastructure.

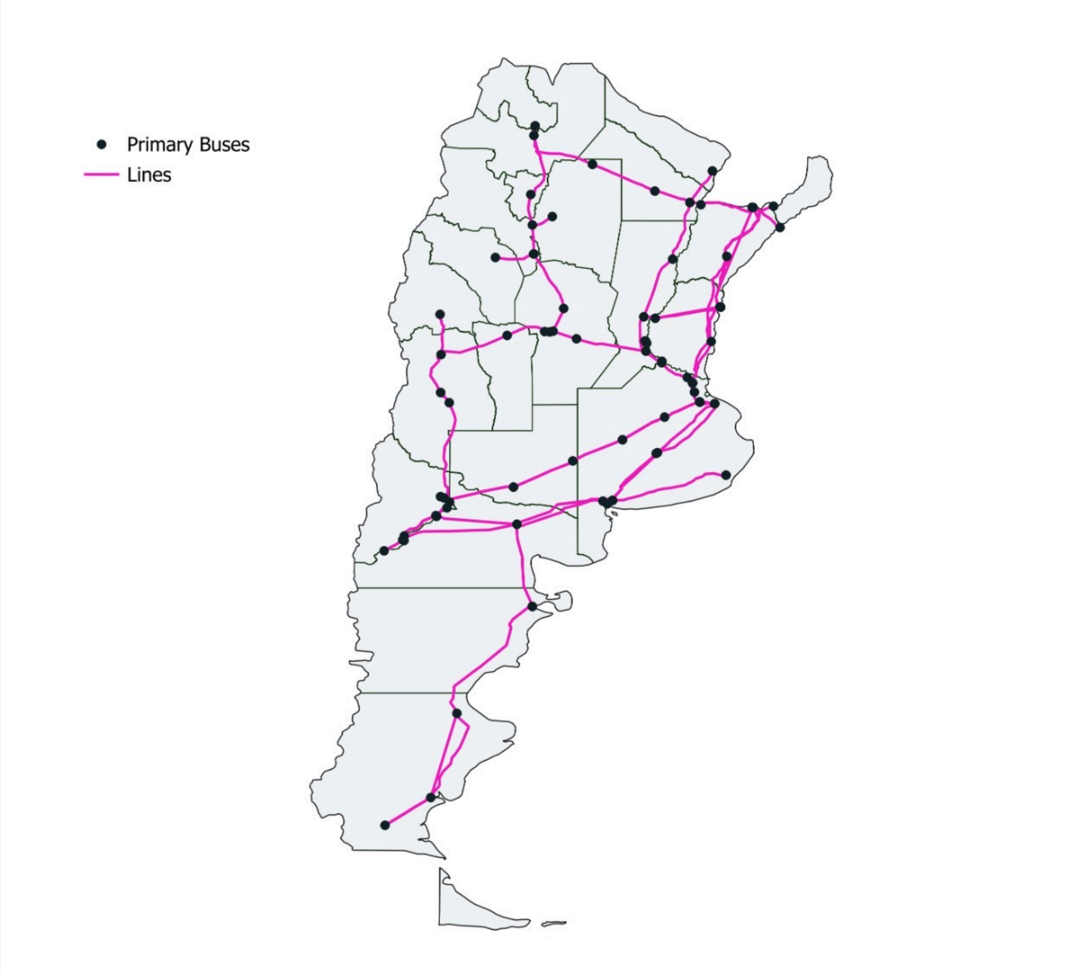
500 kV Network — PyPSA Model

95
Primary buses (500 kV)

249
Secondary buses

103
Active lines

300
Transformers stations



1 connected component · 0 isolated buses · AR–Brazil interconnection included

MILESTONE V

Network Mapping of 626 Power Generation Units

Connecting generators to the model

A dedicated pipeline was built to link each PSS/E generation unit to its correct 500 kV node. **Units connected below 500 kV (at 220, 132 kV, etc.) required topological traversal — walking up the transformer chain until reaching a 500 kV bus.**

Resolving naming conflicts

PSS/E names and CAMMESA dispatch groups (GRUPOs) do not always match. **77 conflicts were resolved manually by reviewing single-line diagrams for each plant**. p_nom was calculated as the 95th percentile of hourly available capacity (POT_DISP) from CAMMESA 2024 data.

626
Generation units in the model

~39,873 MW
Total installed capacity

77
Naming conflicts resolved manually

~91%
SADI capacity coverage

Result: 91% SADI capacity coverage

MILESTONE VI

Node-Level Hourly Demand, Generation Profiles & Marginal Costs

Demand Matrix — 2024

72 buses × 8,784 hours

Hourly demand profile for each 500 kV node, built from CAMMESA's transformer-level consumption data. Peak demand: 27,439 MW on 01/02/2024 at 14:00.

Generation Availability Profiles

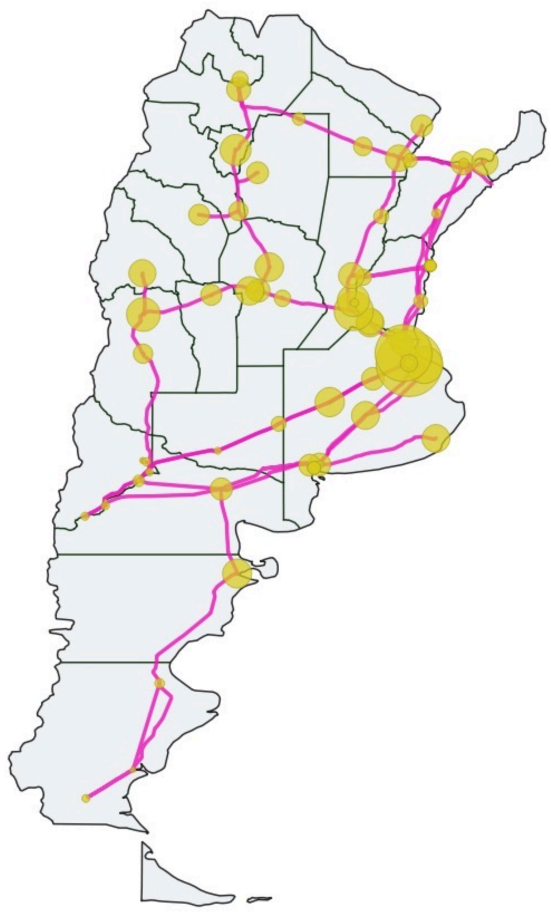
p_max_pu — 8,784 hourly values per unit

Hourly generation availability profiles were built for each of the 604 units across all 8,784 hours of 2024, based on real operational data reported by CAMMESA.

Marginal Cost Assignment

433 units with real 2024 costs

Variable production costs (CVP) sourced from CAMMESA's official data, assigned per generation unit in USD/MWh.



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MILESTONE VII

End-to-End Georeferenced Verification in QGIS

GeoPackages (.gpkg) were exported at multiple pipeline stages, enabling visual QA that cannot be caught through tabular validation alone.

Pipeline step 07b

500 kV Network

Buses, lines, and transformer connections — used to verify topological correctness and detect mismatched coordinates

Pipeline step 10b

Generation–Load Balance

Nodal generation capacity vs. demand by bus — used to detect nodes with implausible generation-to-load ratios

Pipeline step 12b

Power Plant Locations

All 604 generation units with their assigned 500 kV connection bus — used to catch misrouted or geographically implausible mappings

Pipeline step 21

Network Clusters

K=10, K=20, K=50 spatial aggregations of the network — exported for scenario analysis and presentation of results

Result: Visual inspection in QGIS was the only method capable of detecting geospatial matching errors — a critical quality-assurance step that no automated test can fully replace.

MILESTONE VIII

Successful Deployment of the Optimization Model

Result: For the first time, a linear DC Optimal Power Flow (OPF) was executed over the complete Argentine 500 kV network using real 2024 operational data — integrating all milestones into a single functional model.

Solver

HiGHS (open-source linear solver)
via PyPSA n.optimize

Objective

Minimize total generation cost
subject to DC network constraints

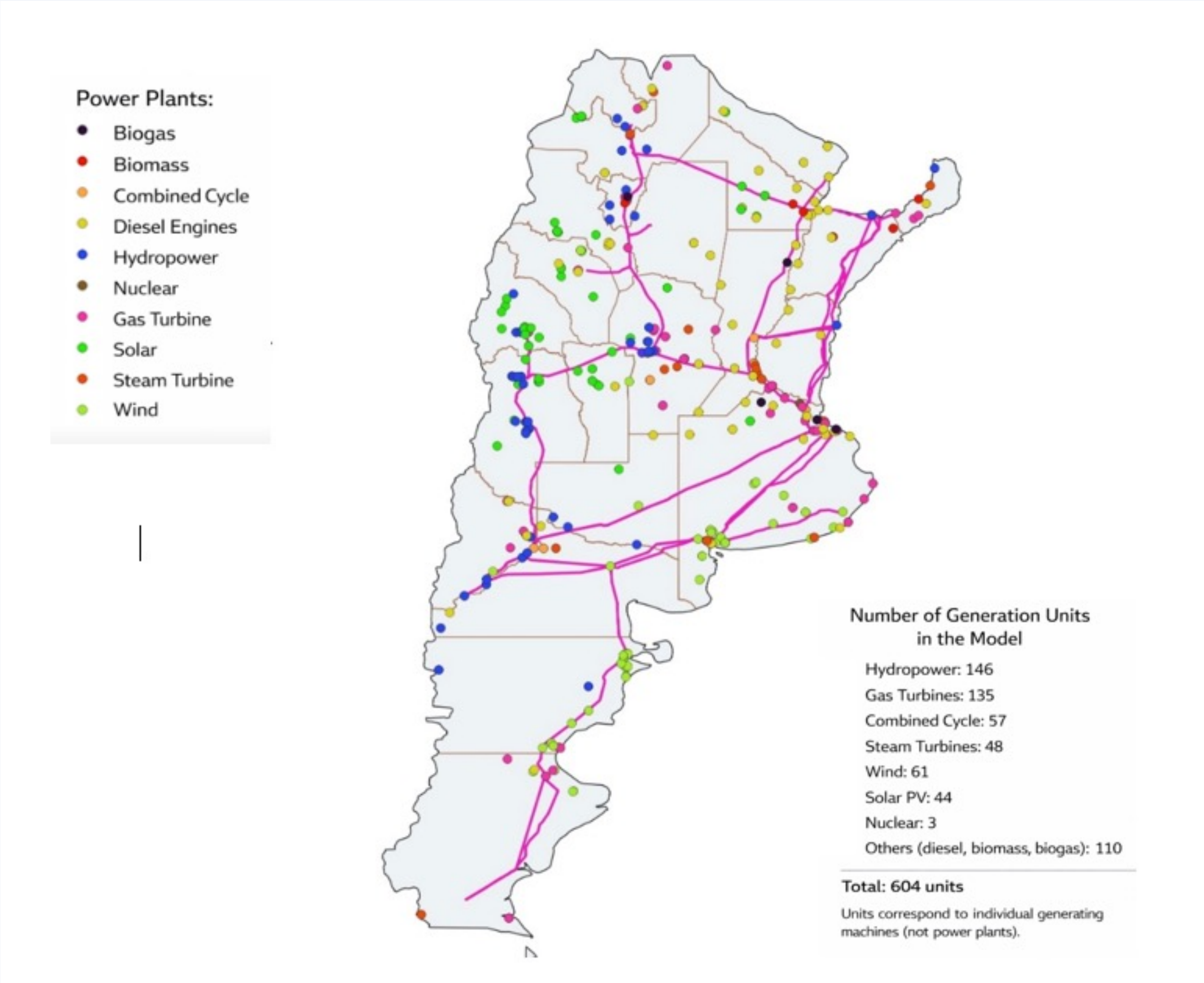
Time Horizon

Up to 8,784 hours (full year 2024)
with configurable chunking

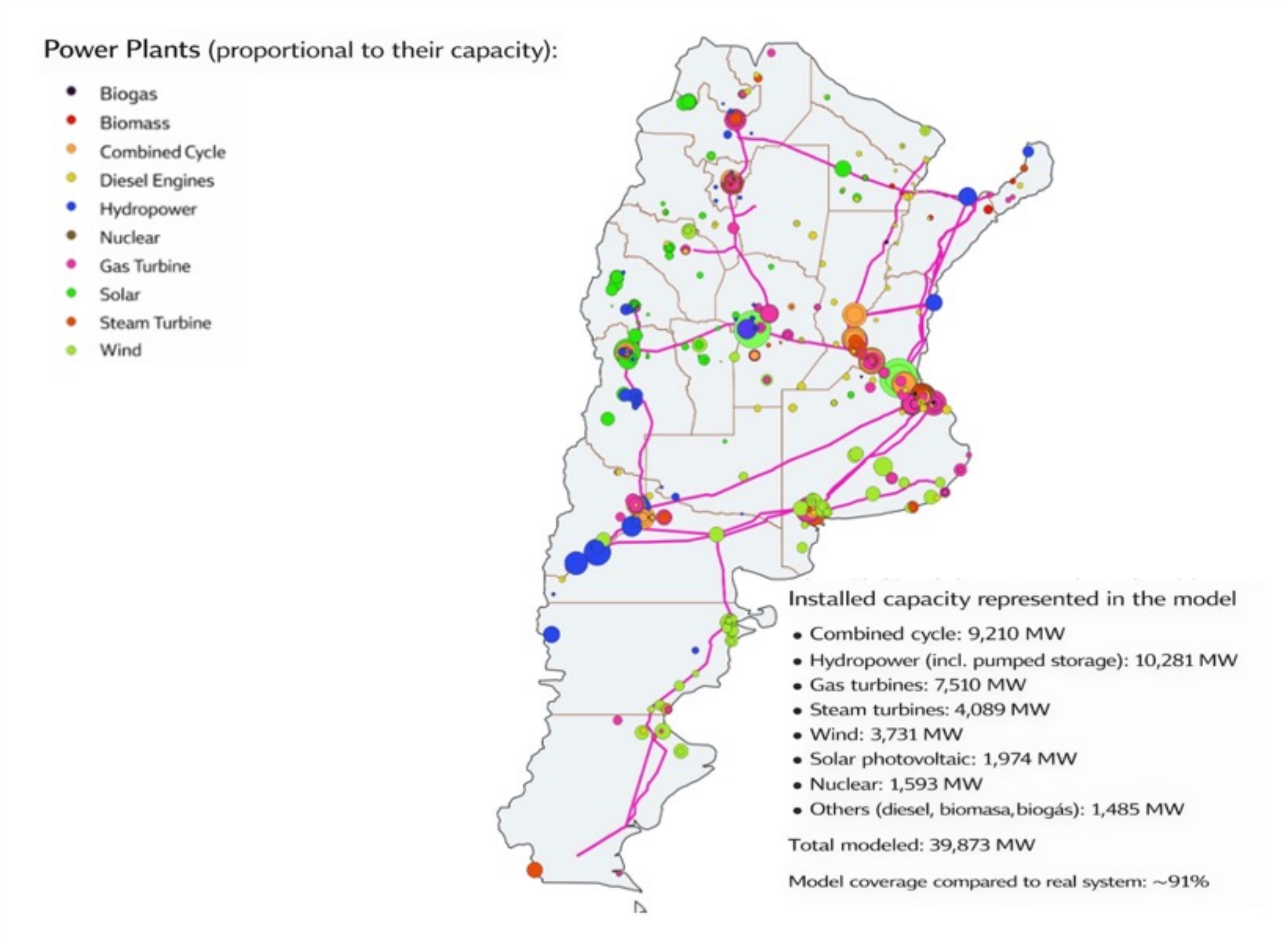
Output

.nc file with hourly dispatch
per unit and flow per line

625 Generation Units Mapped to the Network



~91% of SADI Installed Capacity Represented (39,873 MW)



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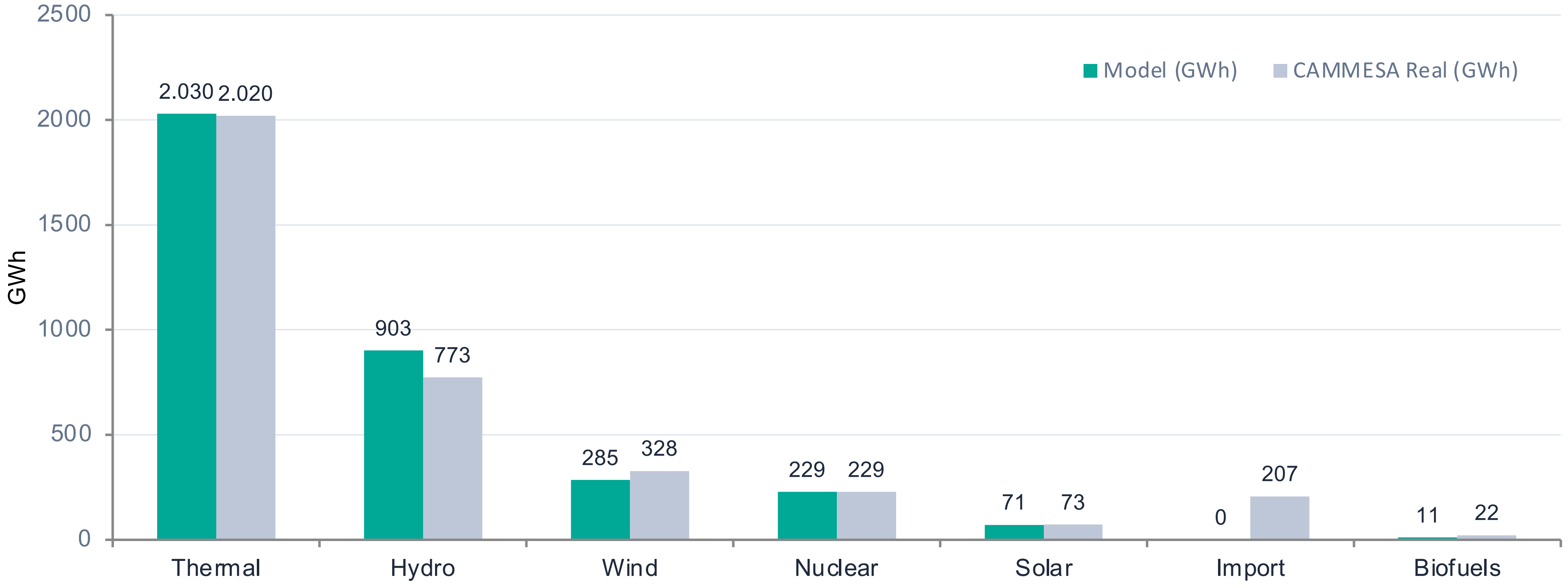
Model Validation — Dispatch Comparison vs. CAMMESA 2024 (Feb 1-7, 2024)

Model total: 3,531 GWh vs. CAMMESA real: 3,653 GWh → 96.7% capture rate | Nuclear 100% · Solar 97.6% · Thermal 100%



Note: Import from Brazil = 0 because thermal units have lower marginal cost in the current model. Adding seasonal fuel constraints in future versions will allow the interconnection to play an active role in dispatch.
Period includes 2024 annual demand peak: Feb 1st at 14:00 hs (27,439 MW)

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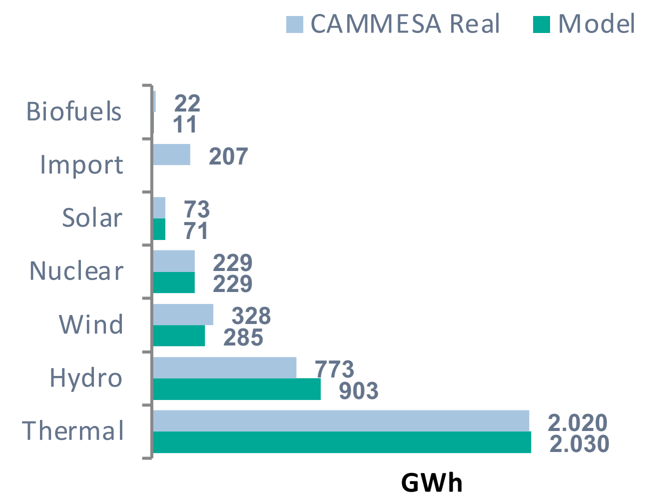
Outcome: Successful Deployment of the Model

A linear DC Optimal Power Flow (OPF) executed over the complete Argentine 500 kV network -

Snapshot Feb 1–7, 2024 (week including 27,439 MW annual peak)



Note: Brazil import = 0 in the model because thermal units have lower marginal cost. Adding seasonal fuel constraints in future versions will activate the interconnection.

Model total: 3,531 GWh vs. CAMMESA real: 3,653 GWh → **96.7% capture rate**

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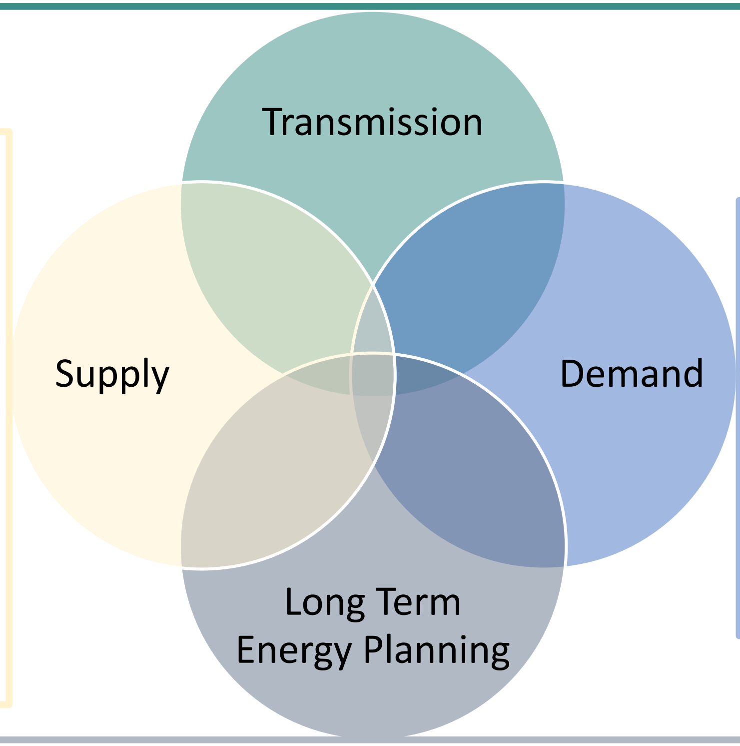
Transmission model was built from original PSS/E data with:
real impedances, series compensation, complex Transformers, Argentina–Brazil interconnection and simplified for large-scale optimization.

Real CAMMESA unit-level data:

- installed capacity,
- hourly availability,
- marginal costs and thermal efficiencies
- economically and physically realistic dispatch

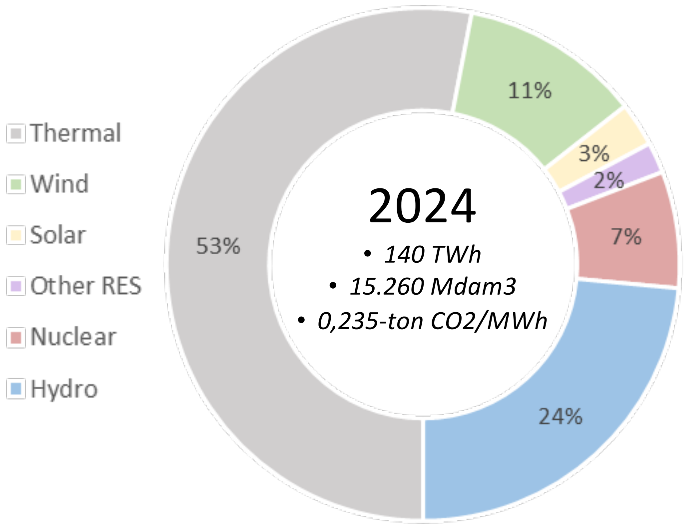


Full hourly and spatial resolution for 2024

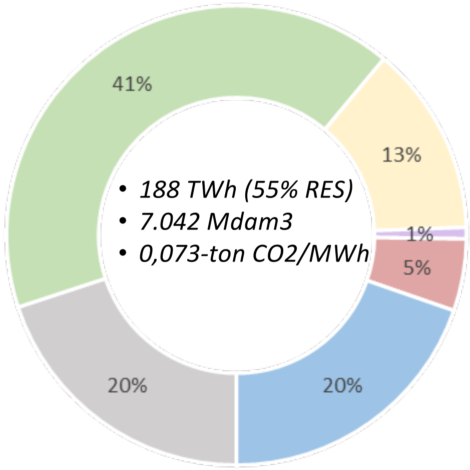
- mapped to the transmission grid
- validated against observed peaks and annual energy

Policy-ready long-term scenarios with transparent outputs on:
additional capacity, demand pathways, investments, costs, fuel consumption and CO_2 emissions.

Key results - First validated scenarios 2035 – 30 regional clusters

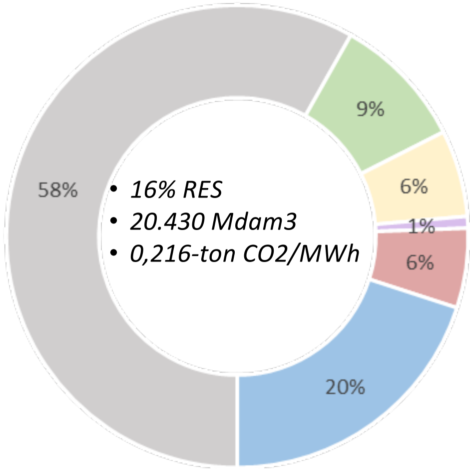


2035 BAU



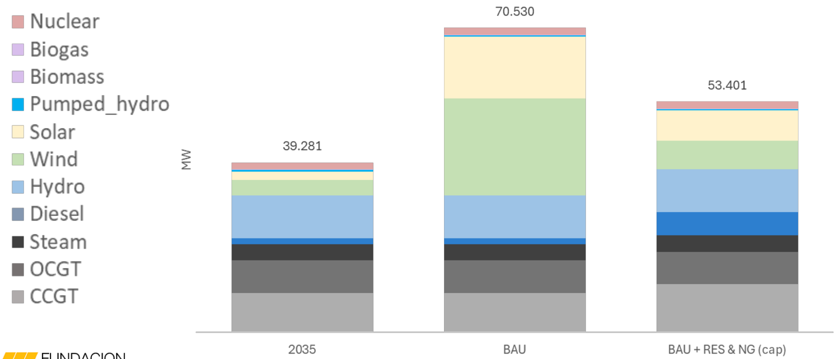
- Demand: +3% CAGR
- No caps and capacity limit

2035 BAU + RES&NG (cap)



- Demand: +3% CAGR
- Solar up to 5.000 MW
- Wind up to 3.000 MW
- NG consumption up to 60 Mm^3/day

Installed capacity



- *Bottle Necks identified and new capacity required to solve by cluster.*
- *Additional lines required to meet new demand.*
- *Optimal generation mix under different climate policies and technologies*
- *CO_2 emissions reduction with additional GW of renewables.*
- *System-wide cost for different climate target.*
- *Fuel savings through renewables*

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Next Steps

01 Full National Grid (132 – 500 kV)

Extend the model scope from the 500 kV backbone to the full national network — 132, 220 and 330/345 kV — enabling regional and inter-regional transmission analysis.

02 Operational Constraints — Refinement

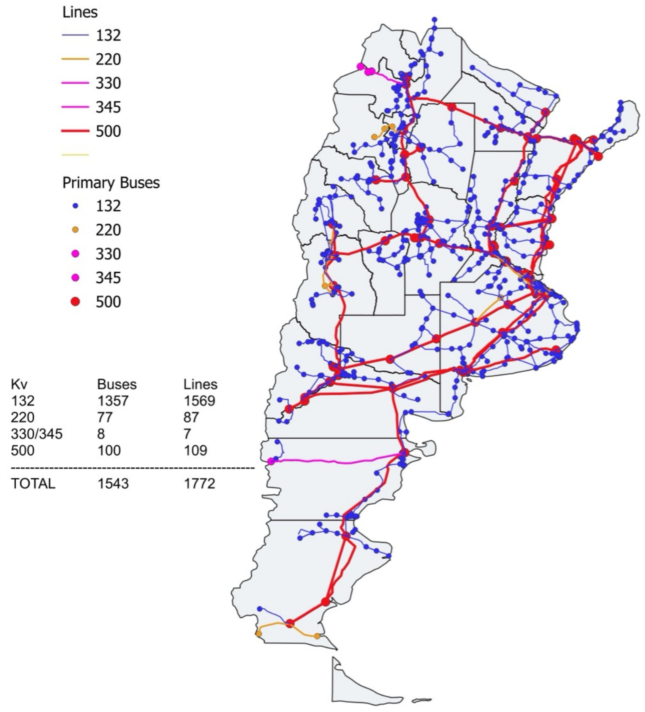
Built on top of the extended model: fuel constraints, seasonal availability, reservoir hydropower dispatch, ramp-rate limits and dual-fuel thermal — for a realistic dispatch under operational reality.

03 Future Works

Additional robust Argentina Energy System coverage: Coupling with natural gas network, regional integration, demand side management analysis, energy transition pathways.

FULL NATIONAL GRID (132 – 500 kV)

Scope of the next phase



1,543 buses · 1,772 lines · 4 voltage levels

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Thank you very much

FTDT Team

Access: github.com/FTDT-PyPSA/PyPSA-AR

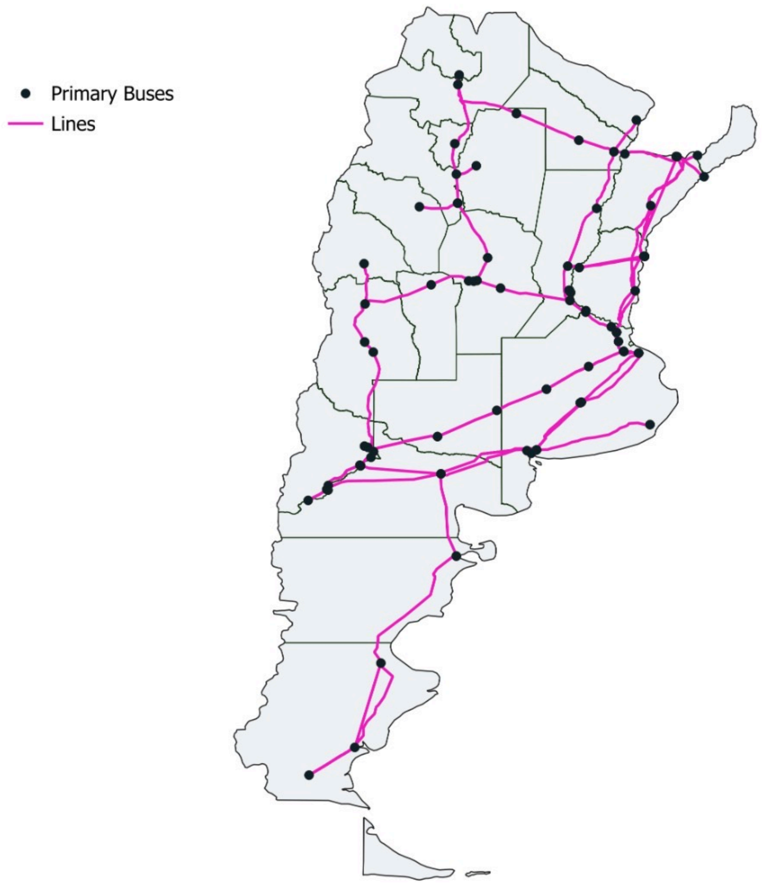
ANNEX I — Network 500 kV: PyPSA Model

95
Primary buses (500 kV)

249
Secondary buses

103
Active lines

300
Transformers stations



1 connected component · 0 isolated buses · AR–Brazil interconnection included

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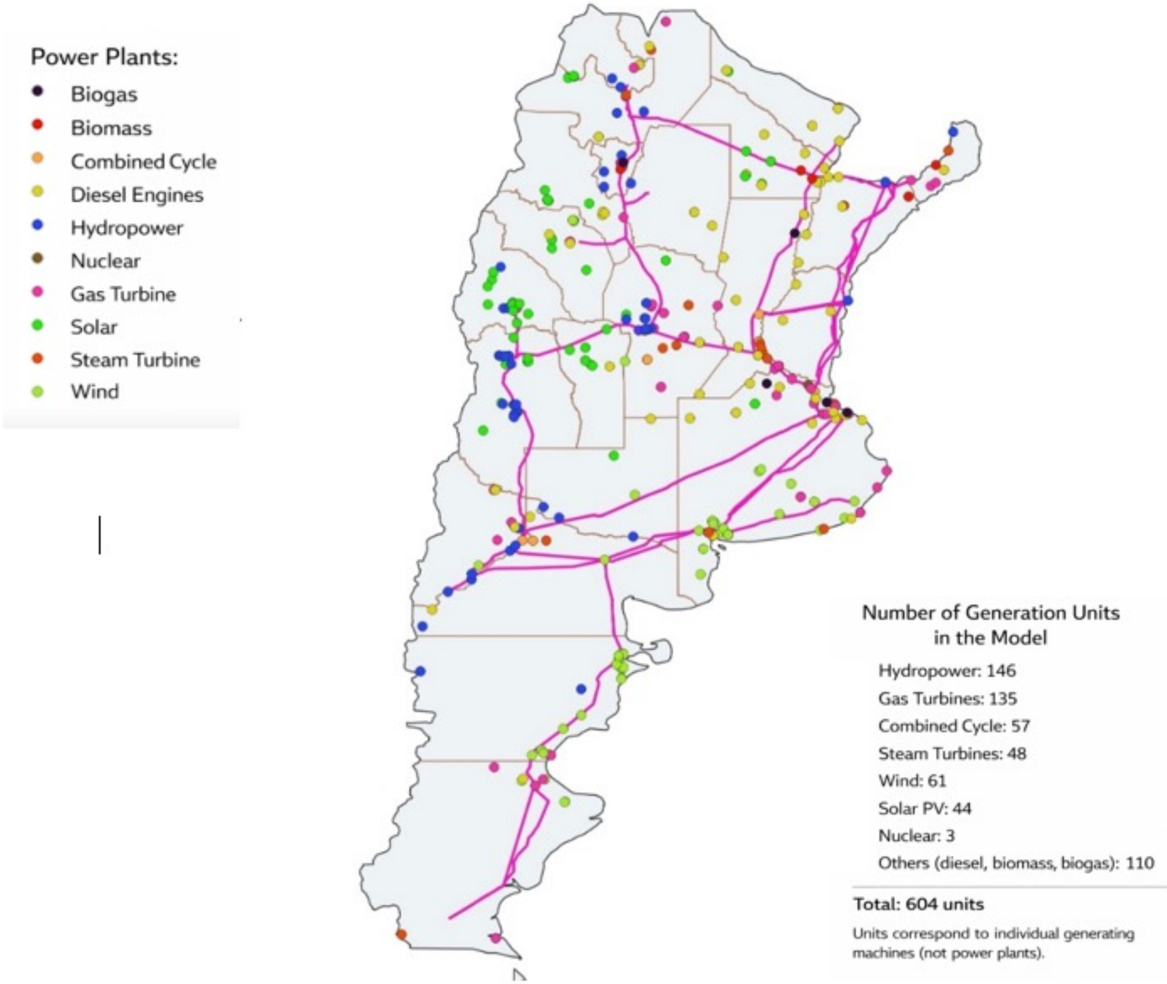
ANNEX II — 626 Grid Power Units



ANNEX III — ~91% total SADI capacity (39.873 MW)