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REGIONAL TRAINING ON COMPREHENSIVE ENERGY AND CLIMATE ANALYSIS BASED ON THE MODEL

Electricity demand projections and demand-supply balance implications (2023–2030)

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JNKE SECCA modeling project

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Title & Objectives.

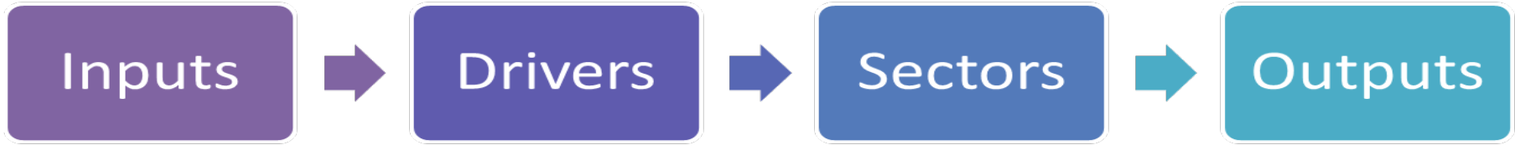
ELECTRICITY DEMAND PROJECTIONS and DEMAND–SUPPLY BALANCE IMPLICATIONS (2023–2030).

Objectives

- Assess medium-term electricity demand under uncertainty.
- Compare alternative demand trajectories using scenario analysis.
- Inform demand–supply balance discussions and planning decisions.

Modelling Tool Overview.

- Projection-based electricity demand model.
- Annual time resolution (2023–2030).
- Sectoral coverage:
  - Residential
  - Public sector
  - Industrial & commercial
  - Irrigation and pumping
- Demand driven by macroeconomic indicators and elasticities
- Scenario-based approach to reflect uncertainty



Inputs & Key Assumptions

- Population growth based on national statistics.
- GDP per capita growth as main residential demand driver.
- Sector-specific demand elasticities applied.
- Explicit treatment of irrigation and industrial activity.
- Energy efficiency and demand-side measures included.

Analyzed Cases / Scenarios.

Three demand projection scenarios were analyzed:

Conservative scenario

- Lower economic growth assumptions
- Higher impact of energy efficiency measures
- Represents a lower-bound demand trajectory

Base scenario

- Central reference case
- Reflects current macroeconomic and sectoral trends
- Higher impact of energy efficiency measures
- Used as the main comparison benchmark

Accelerated scenario

- Higher economic growth and faster electrification
- Higher impact of energy efficiency measures
- Stronger industrial and irrigation demand growth
- Represents an upper-bound demand trajectory

Scenarios reflect uncertainty in future demand evolution rather than point forecasts.

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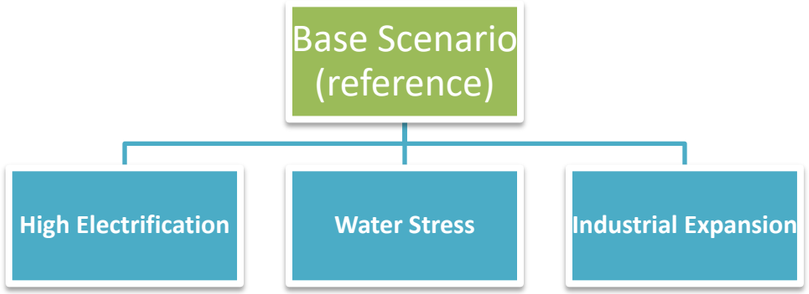
Analyzed Cases / Scenarios.

Sector	Conservative ↓	Base	Accelerated ↑
Residential	0.80	0.90	0.95
Public sector	1.20	1.30	1.35
Industrial & Commercial	0.95	1.10	1.20
Irrigation and pumps	0.85	0.90	1.05
Other heavy activities	0.70	0.80	0.90



- Elasticity values increase progressively from the conservative to the accelerated scenario.
- Higher responsiveness is assumed for industry and irrigation, while residential demand remains moderately elastic across all scenarios. –
- This structure ensures realistic demand growth and avoids excessive projections

All structural experiments are derived from the Base scenario to test system sensitivities under different stress conditions.

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Analyzed Cases / Scenarios Quantitative Summary.

Macroeconomic drivers (2030).

Indicator	Conservative	Base	Accelerated
Population (million)	**~8.0**	**~8.1**	**~8.2**
GDP per capita growth (%)	**7.2**	**8.7**	**9.8**

Analyzed Cases / Scenarios Quantitative Summary.

Key demand elasticities.

Sector	Conservative	Base	Accelerated
Residential	0.80	0.90	0.95
Public sector	1.20	1.30	1.35
Industrial & Commercial	0.95	1.10	1.20
Irrigation and pumps	0.85	0.90	1.05
Other heavy activities	0.70	0.80	0.90

Analyzed Cases / Scenarios Quantitative Summary.

Total electricity demand.

Year	Conservative (TWh)	Base (TWh)	Accelerated (TWh)
2025	23.8	24.6	25.5
2030	**24.7**	**27.8**	**31.5**

Analyzed Cases / Scenarios
Monthly Demand Profile.

Monthly total electricity demand (2030).

Month	Conservative (TWh)	Base (TWh)	Accelerated (TWh)
January	1,9	2,2	2,4
February	1,9	2,1	2,4
March	1,8	2,0	2,2
April	1,8	2,0	2,3
May	1,9	2,1	2,4
June	2,1	2,4	2,8
July	2,2	2,5	2,9
August	2,2	2,5	2,9
September	2,1	2,4	2,7
October	1,9	2,2	2,4
November	2,0	2,2	2,5
December	2,0	2,2	2,5
Total	**23,9**	**26,8**	**30,5**

Analyzed Cases / Scenarios
Hourly Demand Profile.

Hourly electricity demand — representative peak day (2030).

Hour	Conservative (GW)	Base (GW)	Accelerated (GW)
1	2,5	2,9	3,3
2	2,4	2,7	3,1
3	2,4	2,7	3,1
4	2,4	2,7	3,1
5	2,2	2,5	2,9
6	2,1	2,3	2,7
7	2,8	3,1	3,4
8	3,2	3,5	3,9
9	3,1	3,4	3,8
10	3,0	3,3	3,6
11	2,8	3,1	3,4
12	2,7	2,9	3,2
13	2,7	2,9	3,2
14	2,9	3,2	3,4
15	2,9	3,1	3,4
16	3,0	3,3	3,6
17	3,3	3,6	4,0
18	3,8	4,2	4,6
19	3,6	4,0	4,5
20	3,0	3,3	3,8
21	2,9	3,2	3,7
22	2,8	3,2	3,7
23	2,6	2,9	3,4
24	2,6	2,9	3,4
Peak	**3,8**	**4,2**	**4,6**

Motivation for Additional Experiments

🔍 Why additional experiments?

- Sensitivity to demand changes
- Electrification stress test
- Supply adequacy evaluation
- Long-term planning risks

What do they reveal?

- Structural vulnerabilities
- Demand growth drivers
- Supply–demand risks
- Policy trade-offs

⚠ Key insight

The experiments help identify structural vulnerabilities and policy trade-offs in the power system.

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Scenario Assumptions & Sensitivities.

Key sources of uncertainty reflected in the scenarios:

Economic growth (GDP per capita)

- Different GDPP growth paths applied across scenarios.
- Main driver of divergence in residential electricity demand.

Demand-side measures

- Different uptake rates of energy efficiency measures.
- Stronger impact in the conservative scenario
- Gradual and realistic implementation assumed.

Sectoral elasticities

- Elasticities adjusted for industry and irrigation sectors
- Higher elasticities in the accelerated scenario
- Reflect different demand responsiveness assumptions

Sectoral activity assumptions

- Explicit sensitivity for irrigation and industrial activity
- Sectoral growth assumptions drive upper and lower demand bounds.

Sensitivity analysis helps illustrate the impact of uncertainty on electricity demand projections.

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Additional Model Experiments

Experimental Design

(All experiments based on Base scenario)

Experiment	Parameter modified	Magnitude
High Electrification	Residential & Public elasticity	↑
Water Stress	Irrigation index	+15%
Industrial Acceleration	Industry index	+15%

Additional Model Experiments

Experiment 1 Results

(All experiments based on Base scenario)

- Residential demand ↑ **10.2%**
  (+0.49 TWh million)
- Public demand ↑ **1.2%**
- Total demand ↑ **2.2%**
  (+0.54 TWh million)
- Estimated peak load impact: **+5–6%**

Additional Model Experiments

Experiment 2 Results (Water Stress)

(All experiments based on Base scenario)

Irrigation Δ2030

+4.45 TWh (+59% vs Base)

Seasonal effect

- Significant increase in summer demand
- Higher pumping load during irrigation season
- Increased stress on peak capacity

Total demand Δ

+4.45 TWh by 2030

≈ +18% total system demand

Additional Model Experiments

Experiment 3 – Industrial Push Results

(All experiments based on Base scenario)

Industrial Δ2030

+4.13 TWh (+57% vs Base)

Heavy industry Δ2030

+0.41 TWh (+41% vs Base)

Total demand Δ

+4.5 TWh ≈ +18% system demand by 2030

System Impact

- Significant increase in baseload demand
- Higher capacity requirement
- Increased transmission losses
- Need for additional generation investment

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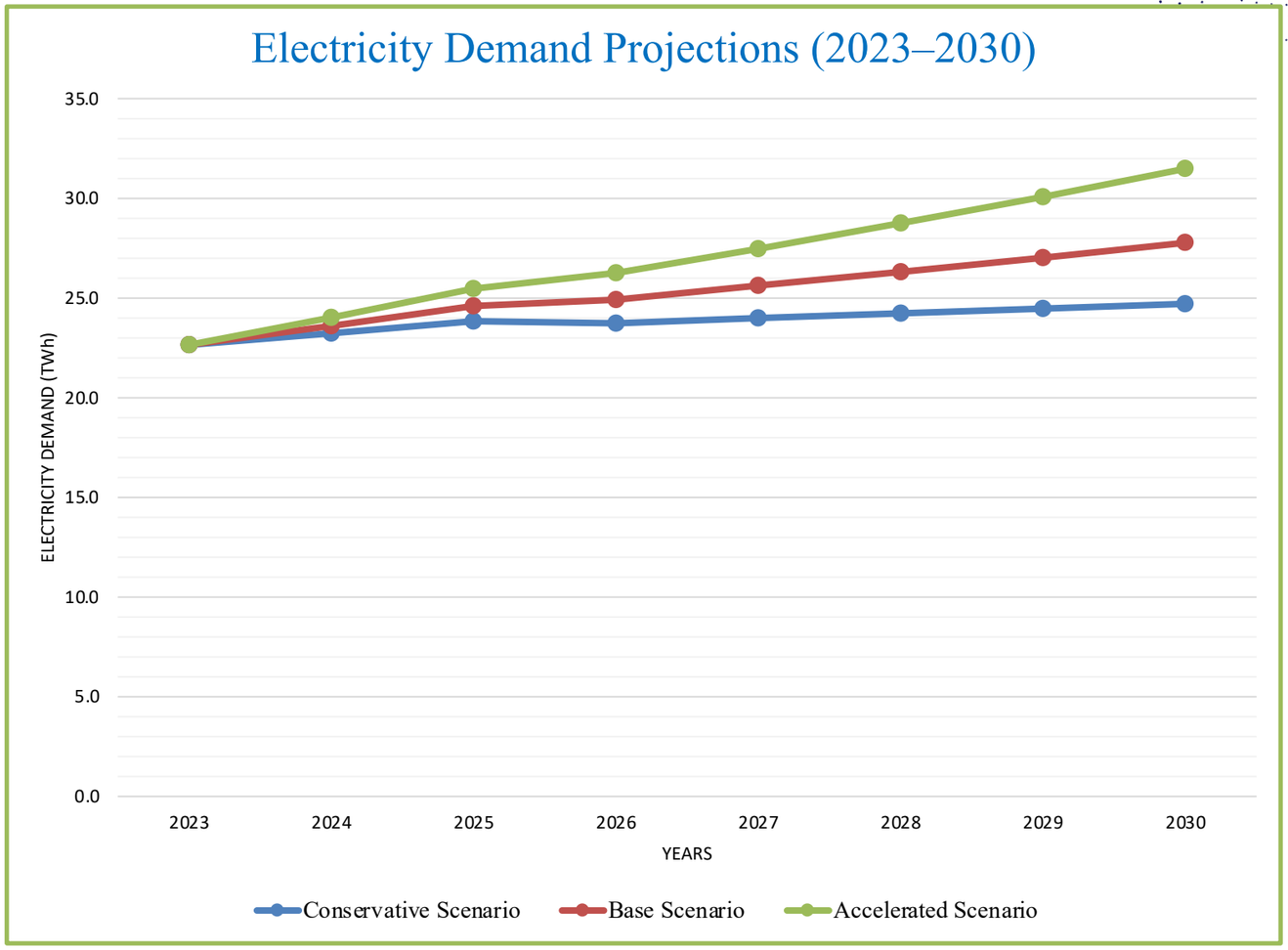
Total electricity demand projections (2023–2030).

- Electricity demand increases steadily across all scenarios
- 2030 demand range spans from a conservative to an accelerated trajectory
- Differences between scenarios reflect macroeconomic and sectoral uncertainty

Scenario-based projections provide a realistic demand range rather than a single forecast.



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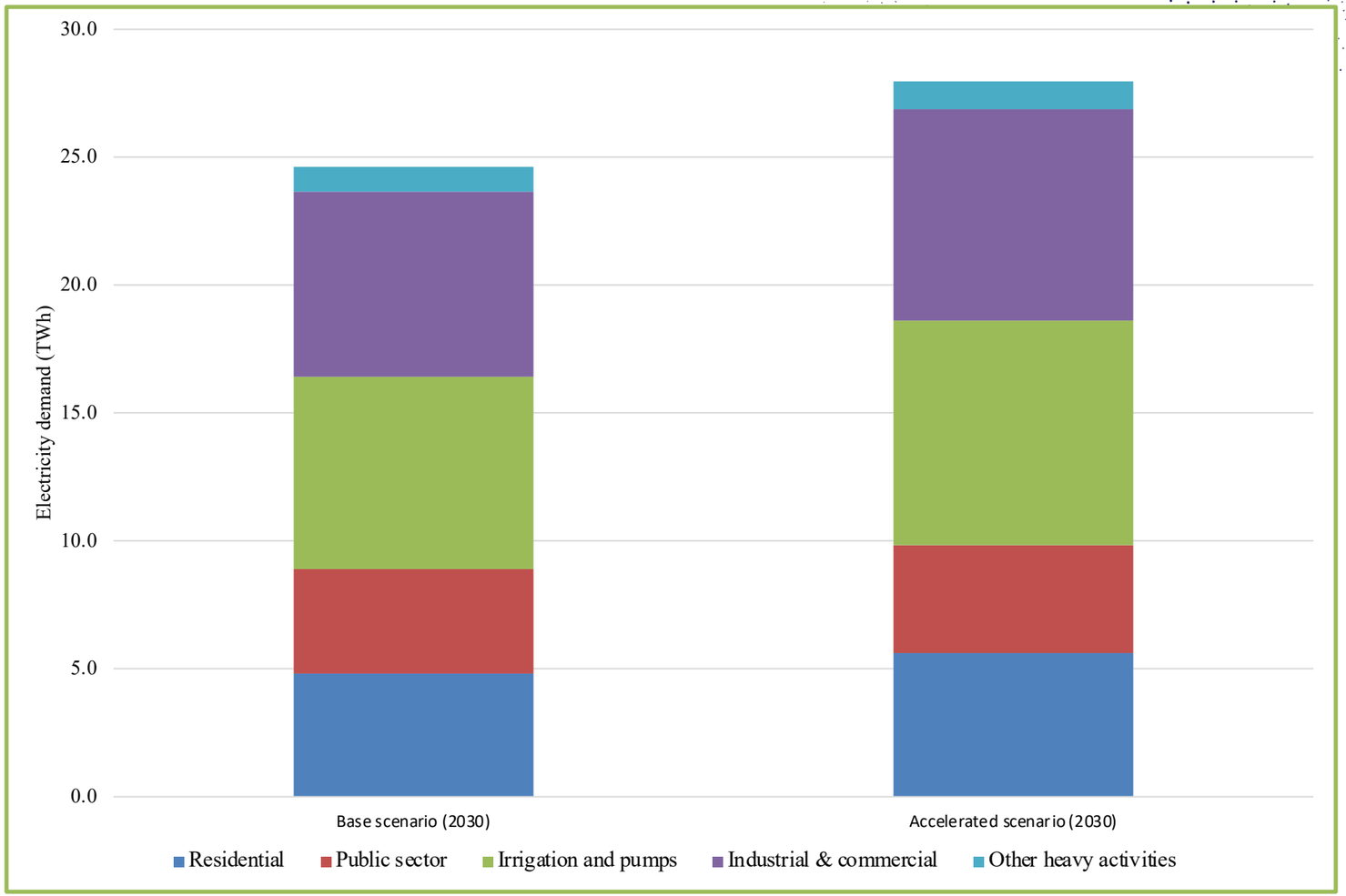
Sectoral electricity demand structure in 2030.

- Industrial and commercial demand drives the upper-bound scenario
- Irrigation demand shows strong sensitivity to activity assumptions
- Residential demand remains relatively stable across scenarios
- Sectoral composition highlights diversification of demand drivers

Scenario-based projections provide a realistic demand range rather than a single forecast.



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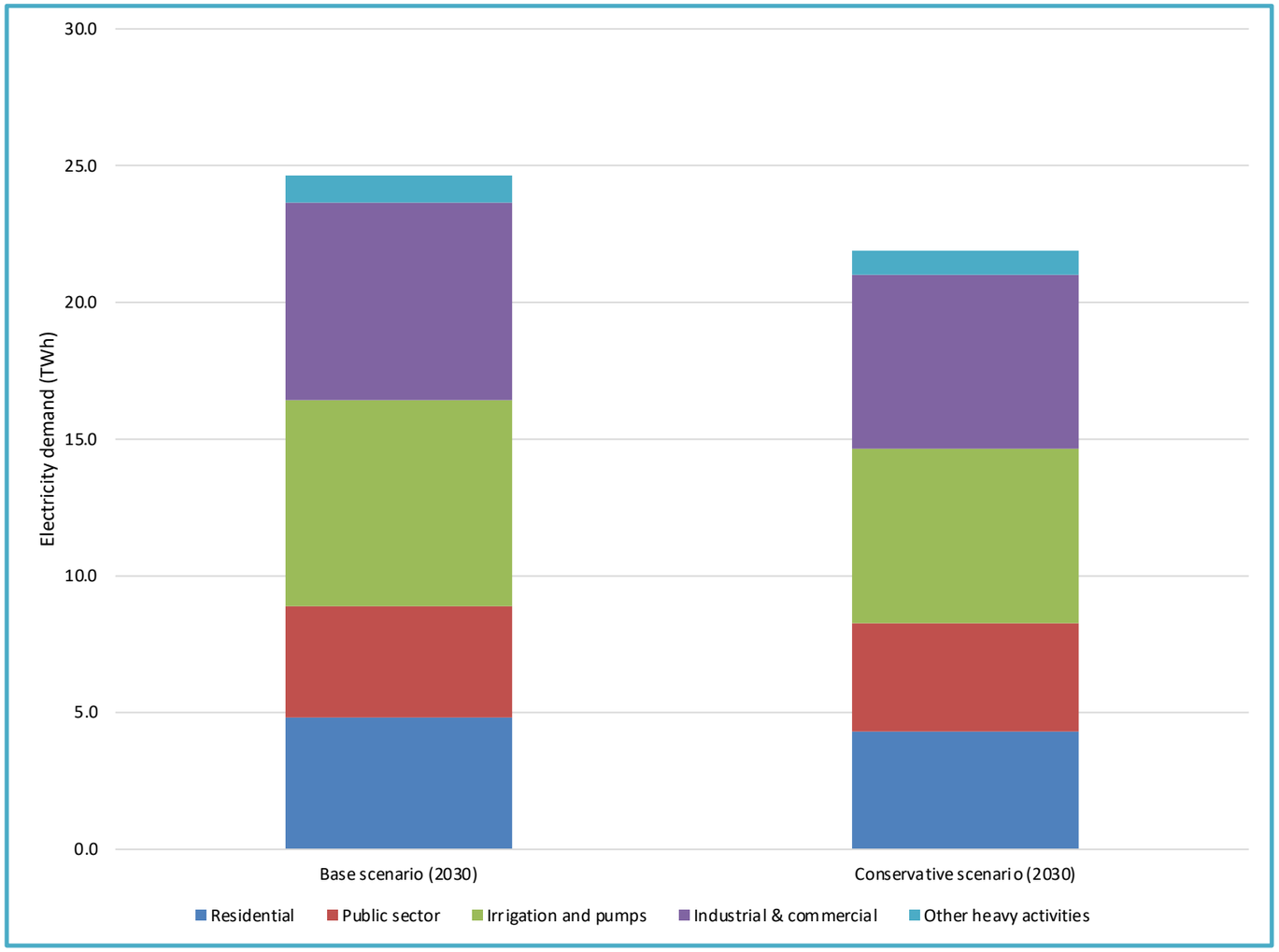
Sectoral electricity demand structure in 2030.



Sectoral Demand Comparison: Base vs Conservative (2030)

- **Residential:** 4.8 → 4.3 TWh
- **Public sector:** 4.1 → 4.0 TWh
- **Irrigation and pumps:** 7.5 → 6.4 TWh
- **Industrial & commercial:** 7.2 → 6.4 TWh
- **Other heavy activities:** 1.0 → 0.9 TWh

Values shown in TWh; differences reflect scenario assumptions.

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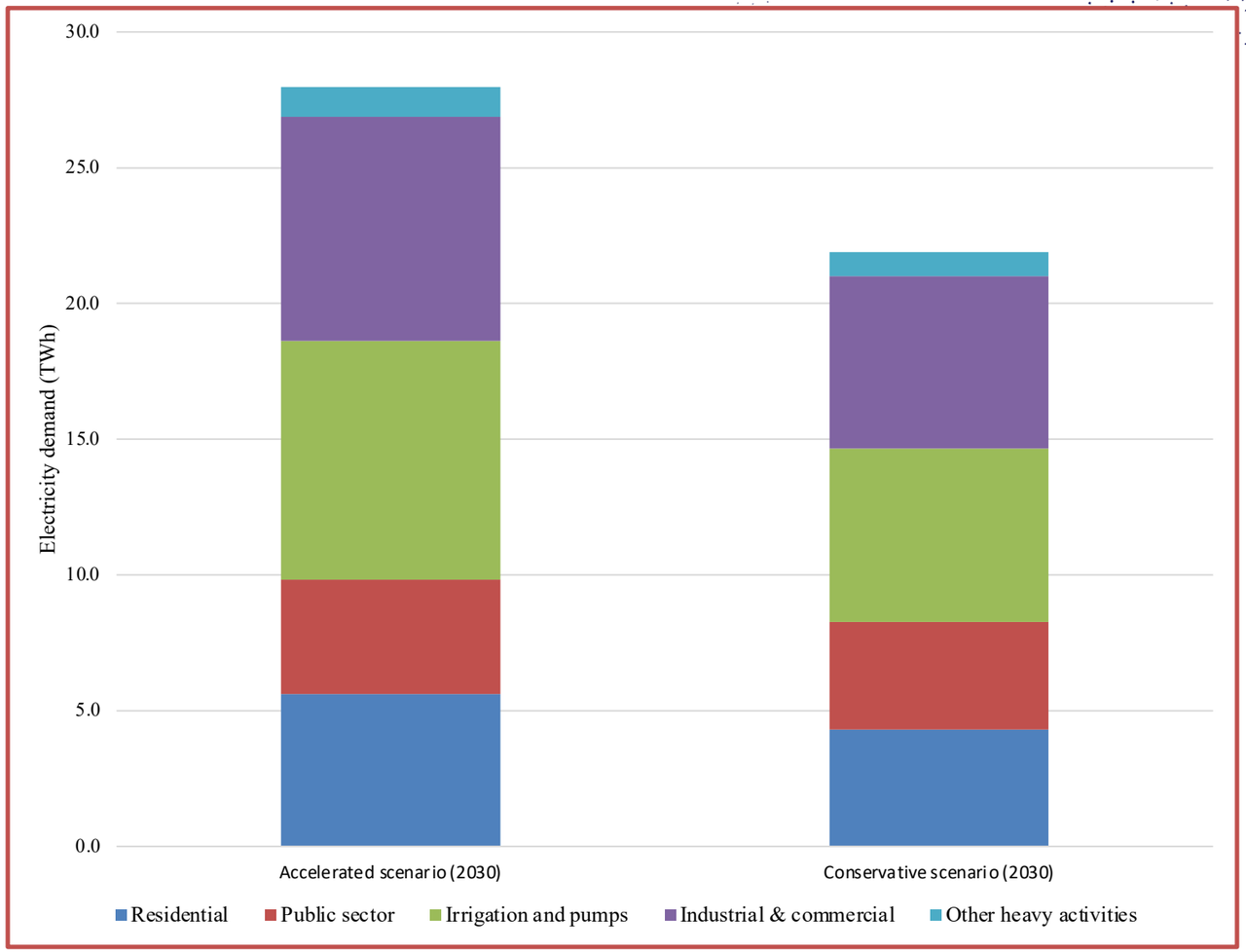
Sectoral electricity demand structure in 2030.

Sectoral Demand Comparison: Accelerated vs Conservative (2030)

- **Residential:** 5.6 → 4.3 TWh
- **Public sector:** 4.2 → 4.0 TWh
- **Irrigation and pumps:** 8.8 → 6.4 TWh
- **Industrial & commercial:** 8.3 → 6.4 TWh
- **Other heavy activities:** 1.1 → 0.9 TWh

Values shown in TWh; differences reflect scenario assumptions.



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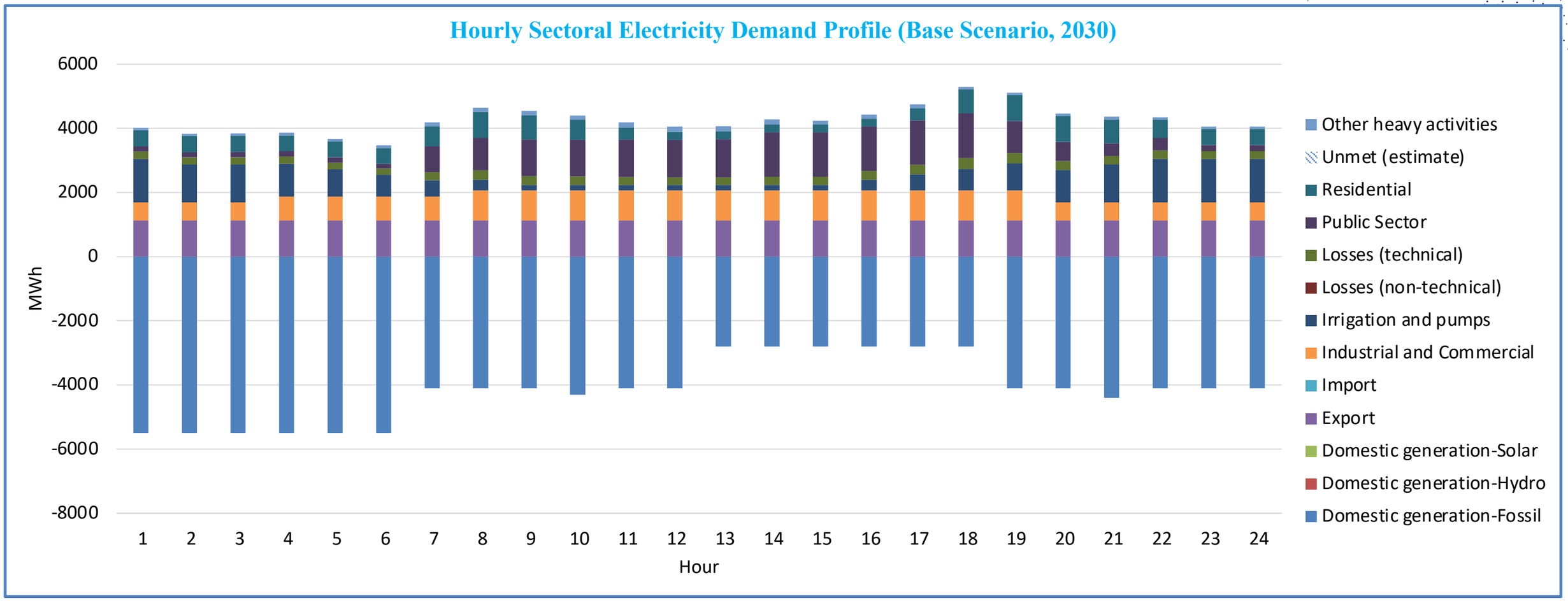
Sectoral electricity demand structure in 2030.



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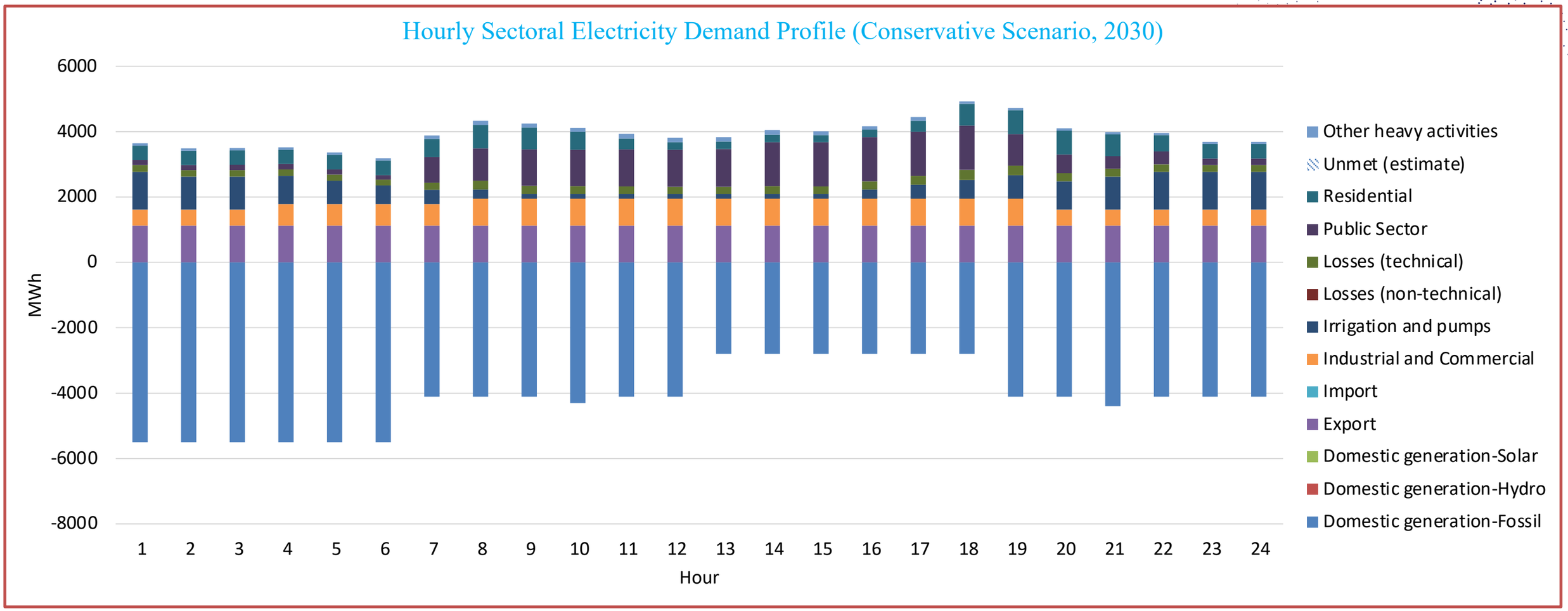

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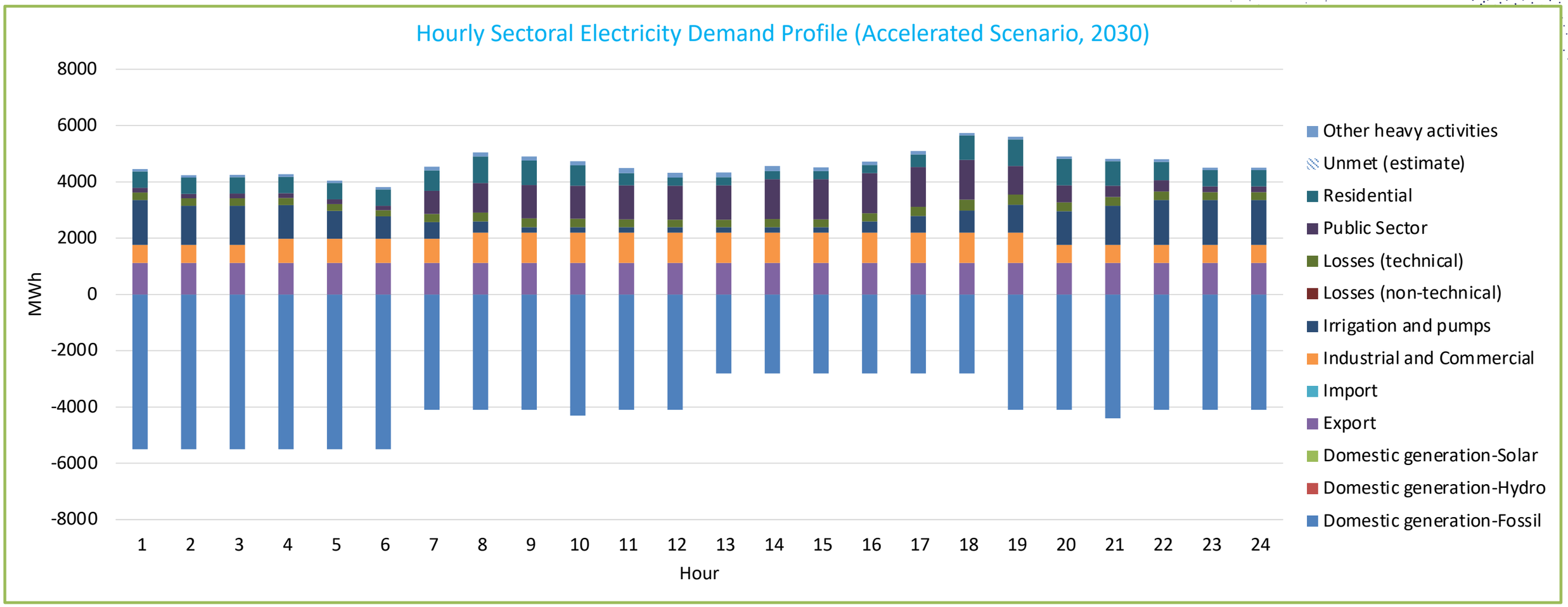

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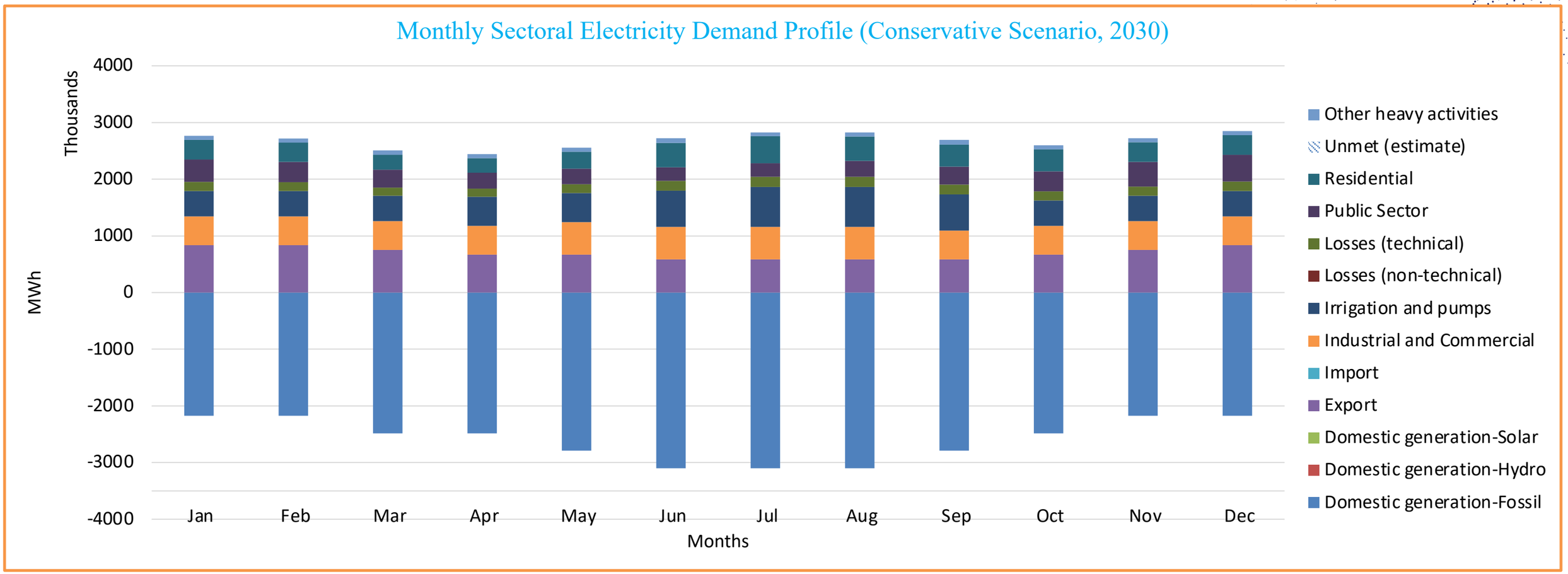

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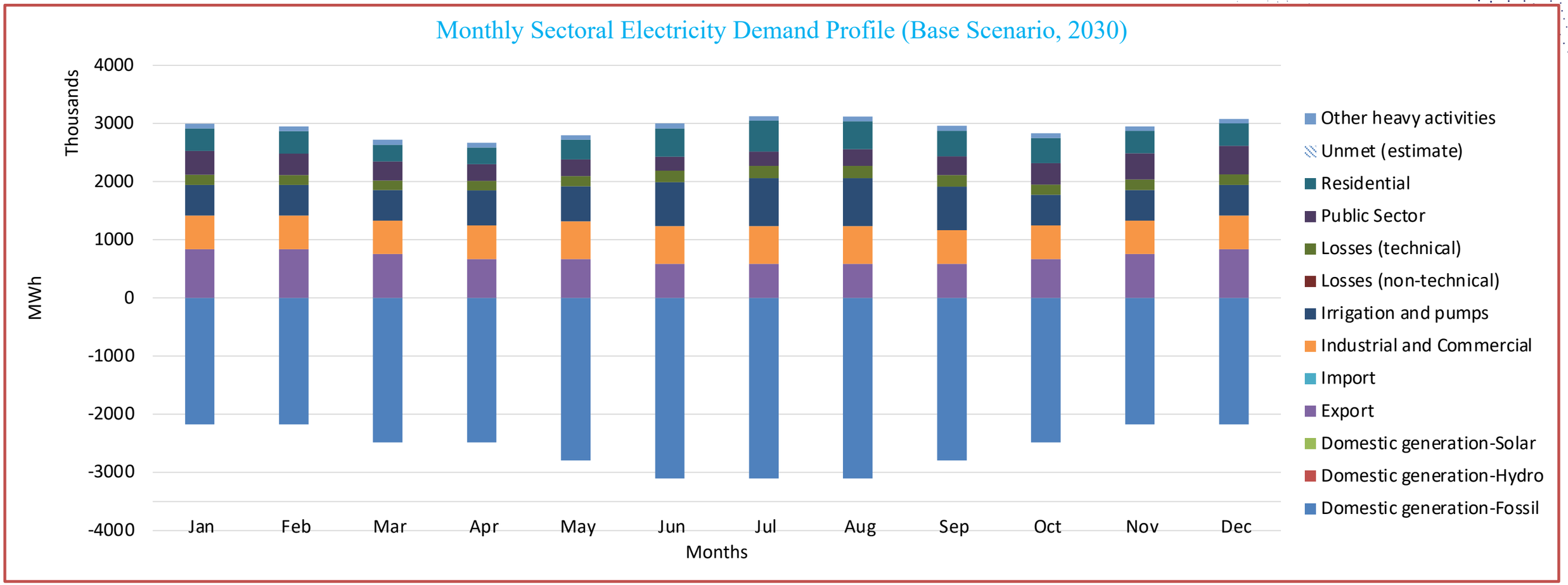

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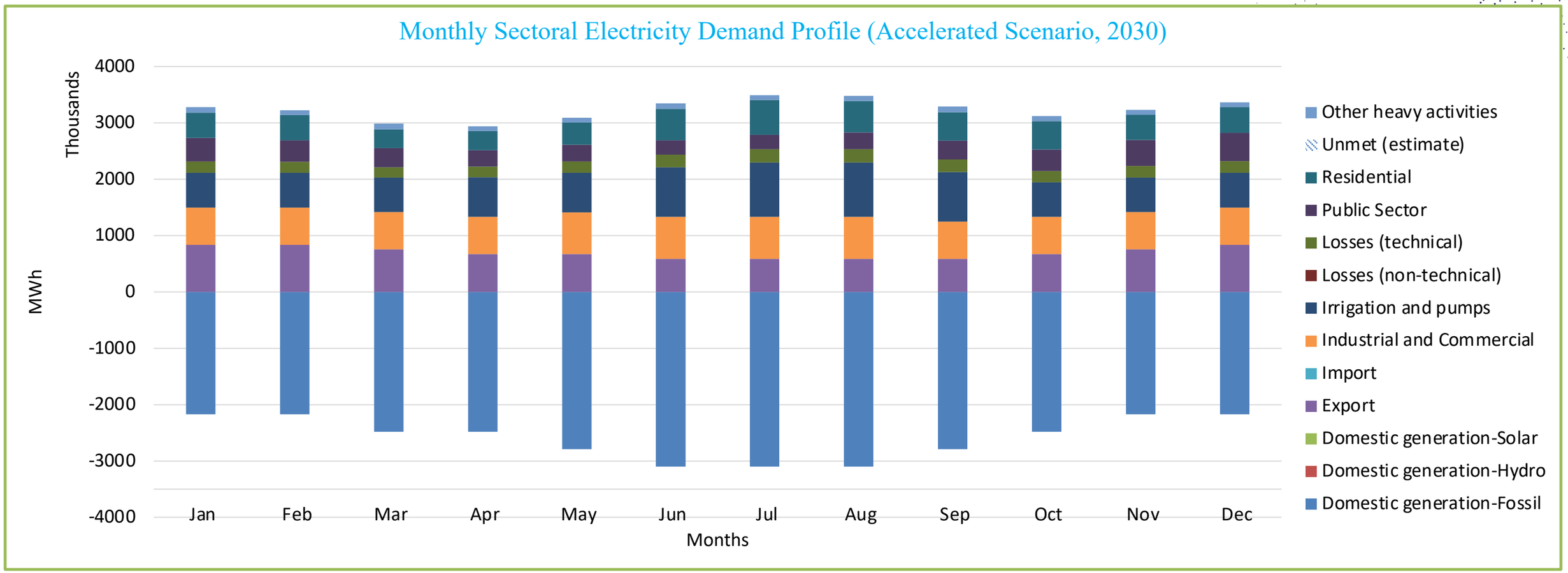
Sectoral electricity demand structure in 2030.



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Key Insights from the Demand Projections.

- GDP growth and industrial activity are dominant demand drivers.
- Residential demand contributes to stability, not volatility.
- Accelerated scenario remains plausible and non-excessive.
- Scenario-based approach avoids overconfidence in single outcomes.

Scenario-based analysis supports more robust planning under uncertainty.

Key Insights from the Demand Projections.

Total electricity demand (2030).

- **Conservative:** ~24.7 TWh
- **Base:** ~27.8 TWh
- **Accelerated:** ~31.5 TWh
- **Scenario spread:** ±(31.5–24.7)/27.8 ≈ 20-25%

All values derived from Annual Projections module, consistent across scenarios.

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Key Insights from the Demand Projections.

Average annual demand growth (2023–2030).

- **Conservative: ~4.8 %/year**
- **Base: ~5.6 %/year**
- **Accelerated: ~6.6 %/year**

All values derived from Annual Projections module, consistent across scenarios.

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Key Insights from the Demand Projections.

Sectoral contribution to total demand (2030, Base).

- **Industrial & Commercial:** ~34–36 %
- **Irrigation and pumps:** ~28–30 %
- **Residential:** ~22–24 %
- **Public sector:** ~12–14 %
- **Other heavy activities:** ~2–3 %

All values derived from Annual Projections module, consistent across scenarios.

Key Insights from the Demand Projections.

Demand drivers sensitivity.

- **GDP per capita elasticity (Residential):** 0.9
- **Industrial elasticity:** 1.1
- **Irrigation elasticity:** 0.9
- **Public sector elasticity:** 1.3

All values derived from Annual Projections module, consistent across scenarios.

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Key Insights from the Demand Projections.

Seasonal variability (Accelerated scenario).

- **Peak month demand:** +18–22 % above annual average.
- **Minimum month demand:** −12–15 % below annual average.
- **Peak driven by:** irrigation + residential cooling load.

All values derived from Annual Projections module, consistent across scenarios.

Key Insights from the Demand Projections.

Intra-day variability (2030).

- **Peak hour load:** ~1.4–1.6 × off-peak hour
- **Peak hours:** 18:00–21:00
- **Minimum load:** 02:00–05:00

All values derived from Annual Projections module, consistent across scenarios.

Demand–supply balance implications.

Demand–supply balance (2030).

Scenario	Demand (TWh)	Fossil Supply (TWh)	Balance* (TWh)
Conservative	24,7	31	6,3
Base	27,8	31	3,2
Accelerated	31,5	31	-0,5

Note: Supply includes domestic fossil generation only; renewables, imports and storage not included.

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Balance Under Structural Experiments (2030)

Case	Demand (TWh)	Fossil Supply (TWh)	Balance (TWh)
Base	27,8	31	3,2
High Electrification	28,4	31	2,6
Water Stress	32,6	31	-1,6
Industrial Push	32,7	31	-1,7

Note: Balance = Fossil Supply – Demand

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Investment Program & Cost Profile (2026–2030)

(in millions of USD rounded)

Measure	Sector	2026	2027	2028	2029	2030
M2	Off-Grid SPPs	3.1	4.1	5.6	7.8	10.6
M4	Tertiary	19.2	26.4	36.0	49.2	66.0
M5	Tertiary	41.9	46.1	50.7	55.8	61.1
M6	Tertiary	8.5	8.5	8.5	8.5	8.5

* The investment program shows a gradual increase in capital requirements, reaching approximately 146 million USD annually by 2030.
* The largest contribution comes from tertiary sector modernization measures (M4–M5), while distributed Off-Grid solar deployment (M2) provides a growing decentralized component of the investment strategy.
* The cumulative investment over 2026–2030 amounts to approximately 526 million USD.

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Investment vs Adequacy Trade-Off (2030)

System Challenge

- Structural stress scenarios create **a deficit of ~1.6–1.7 TWh**
- Required firm capacity: **≈ 250–300 MW**
- Estimated supply-side CAPEX: **200–250 million USD**

Demand-Side Investment Program (2026–2030)

- Annual investment in 2030: **~146 million USD**
- Cumulative investment (5 years): **~526 million USD**

Main components:

- Tertiary modernization (M4–M5)
- Off-Grid solar deployment (M2)
- Efficiency support measures (M6)

Strategic Comparison

Option	Investment Scale	System Effect
New firm capacity	200–250 M USD	Eliminates deficit directly
Demand-side program	526 M USD (5 years)	Reduces structural growth & long-term risk

Demand-side measures reduce long-term system risks, while new firm capacity provides immediate adequacy.

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Demand–supply balance implications.

- Demand uncertainty has implications for capacity planning.
- Scenario range supports flexible investment strategies
- Risk of under- or over-investment can be reduced. through phased planning.
- Results provide inputs for supply-side and adequacy analysis.

Demand projections inform planning decisions under uncertainty.

Conclusions & Next Steps.

Conclusions.

- Electricity demand projections are realistic and internally consistent.
- Scenario analysis provides a credible demand range.
- Results support informed demand–supply balance discussions.

Next steps.

- Integration with supply-side modelling
- Stress-testing policy and investment options
- Preparation of a consolidated analytical report

Scenario-based demand projections support robust and transparent energy planning.

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Backup: Key Elasticities (Appendix).

Key elasticities applied in the demand projections

- Sector-specific demand elasticities applied across all scenarios
- Elasticity values reflect internationally observed ranges
- Higher elasticities assumed for industry and irrigation sectors
- Residential demand shows moderate elasticity to income growth
- Elasticities adjusted across scenarios to reflect uncertainty

Sector	Conservative ↓	Base	Accelerated ↑
Residential	0.80	0.90	0.95
Public sector	1.20	1.30	1.35
Industry & commercial	0.95	1.10	1.20
Irrigation & pumps	0.85	0.90	1.05

Elasticity values are varied to test sensitivity and are not intended as precise forecasts.

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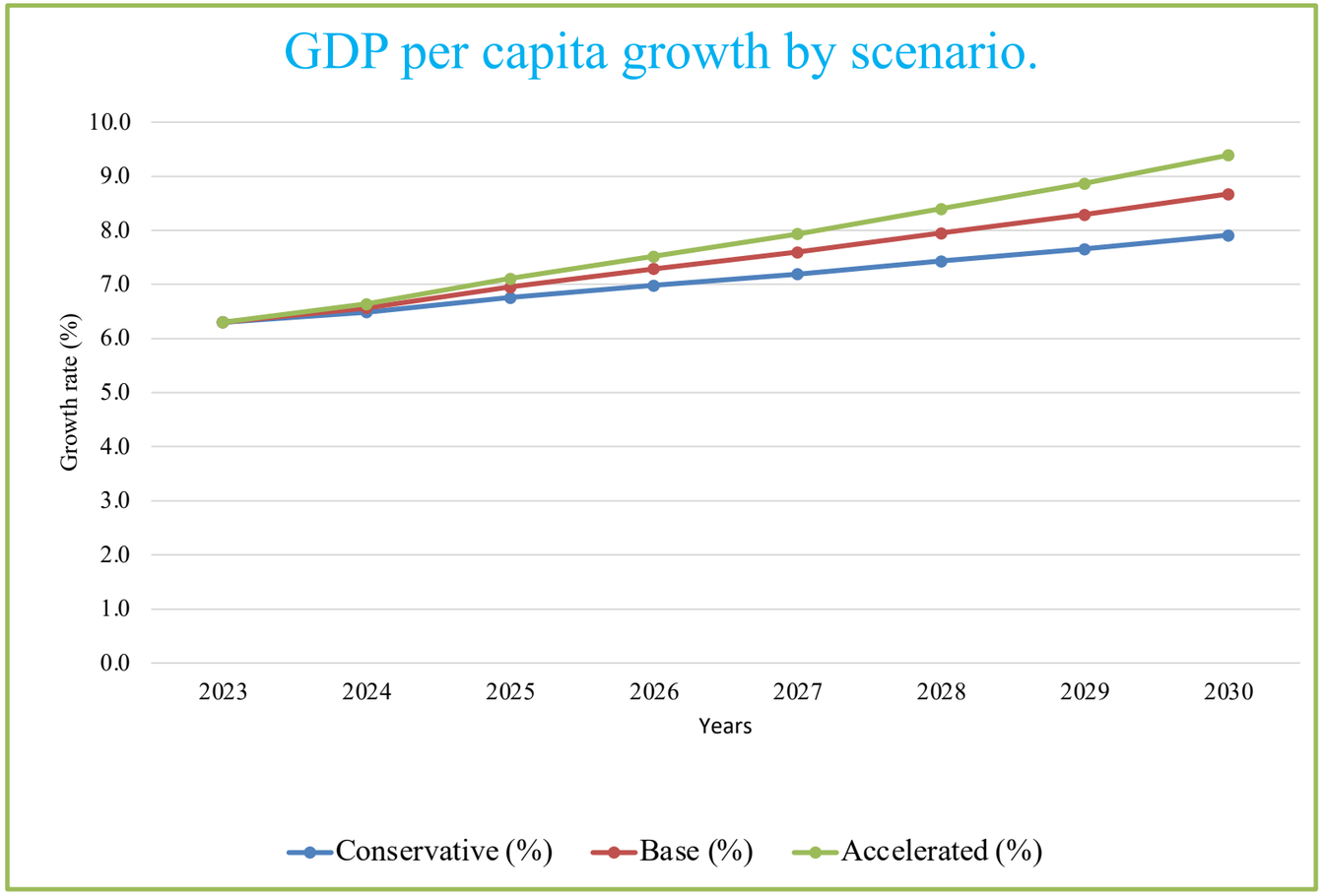
Backup: Macroeconomic Assumptions (Appendix).

Macroeconomic assumptions by scenario.

- Population growth based on official national statistics
- GDP per capita growth paths differ across scenarios
- Conservative scenario assumes lower economic growth
- Base scenario reflects continuation of recent trends
- Accelerated scenario assumes higher growth and faster electrification

Macroeconomic assumptions are used to illustrate uncertainty rather than predict exact outcomes.



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