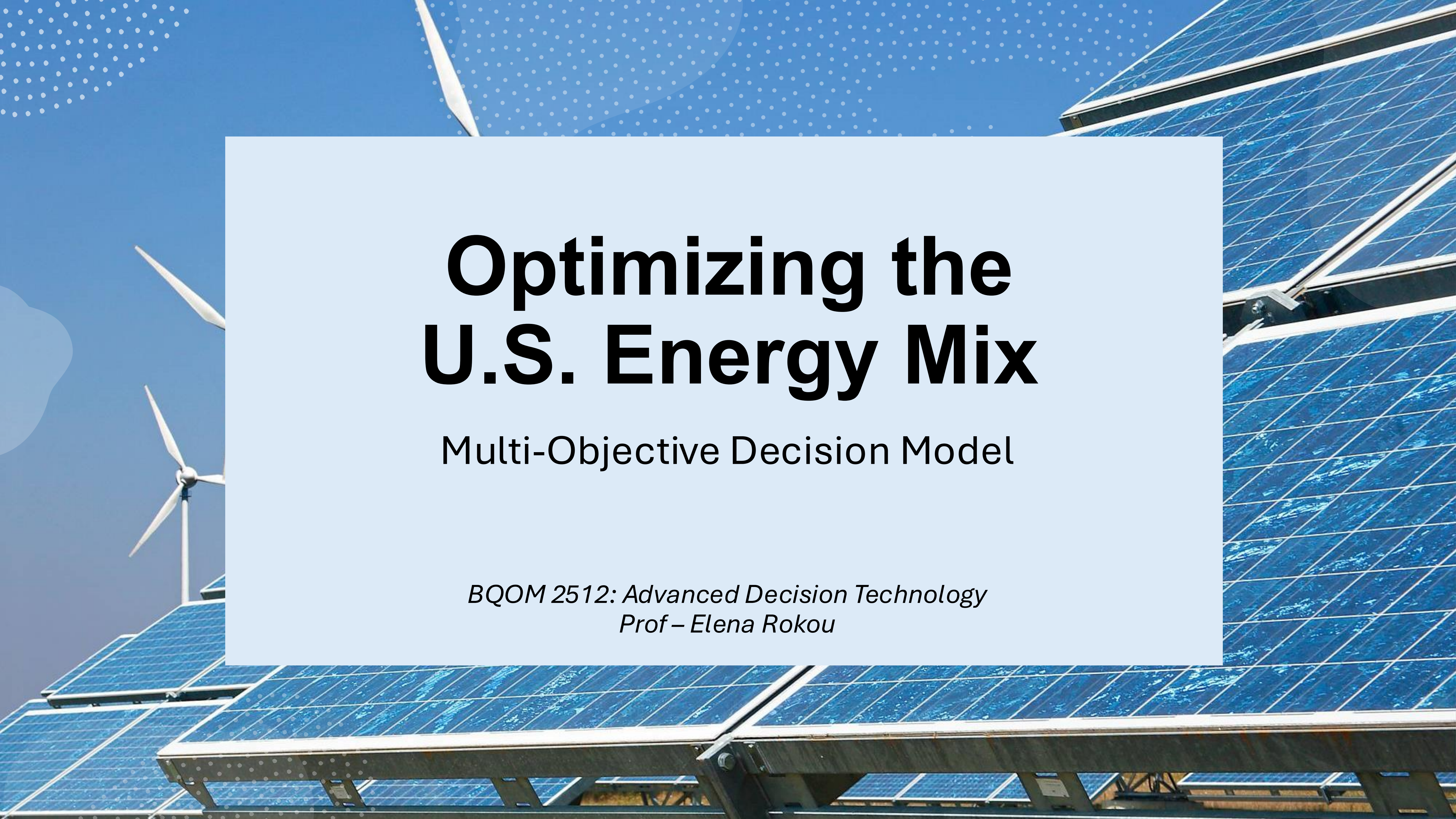


Optimizing the U.S. Energy Mix

Multi-Objective Decision Model

BQOM 2512: Advanced Decision Technology
Prof – Elena Rokou

Team Introduction

Azure Hsiao
MS Marketing & Business Analytics

Revati Wankhede
MS Management & Business Analytics

Timothy Liu
MS Marketing & Business Analytics

Today's Agenda

1. Project Case

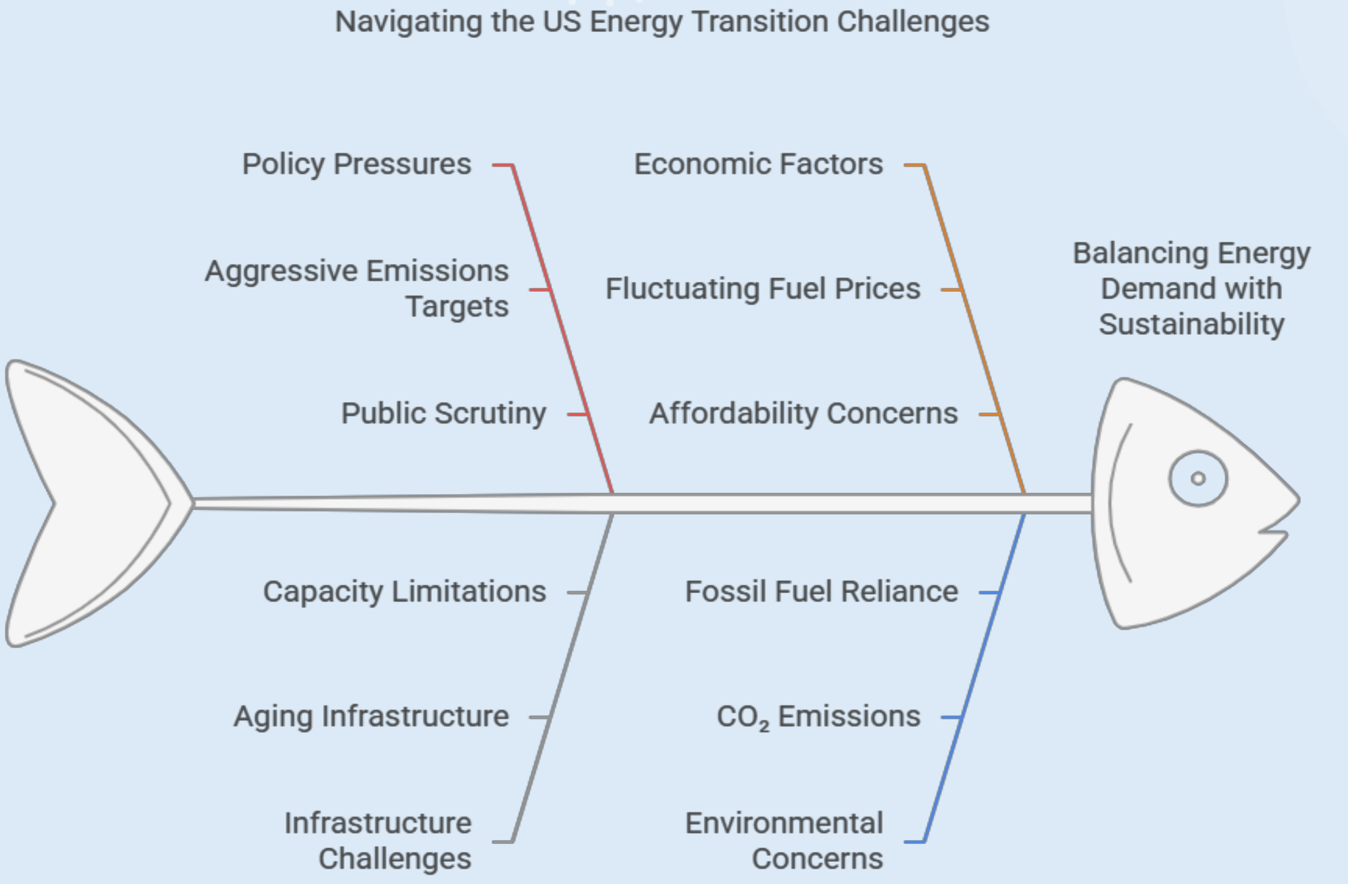
2. Methodology

3. Insights

4. Recommended Next Steps

Energy Landscape in the US

- The U.S. must meet a 1000 MWh electricity demand while balancing cost, reliability, and sustainability.
- Strict CO_2 caps (≤100 metric tons/year) and capacity constraints add pressure on planning.
- Utilities face volatile fuel costs, infrastructure challenges, and growing scrutiny of traditional energy sources.



Energy Landscape - Challenges

How do we strike the right balance between cost and reliability while staying within environmental and capacity limits?

- Instead of optimizing for just **cost** or **reliability**, we apply a **Pareto-based multi-objective approach**
- This method explores trade-offs to identify the **most balanced and practical energy mix**
- The goal is to support **real-world decision-making**—not rely on idealized assumptions

Problem Statement

The United States plans to meet a projected electricity demand of 1000 MWh using four generation sources: Solar, Wind, Nuclear, and Fossil. Each source differs in cost and reliability and is constrained by generation capacity and environmental policy. The goal is to determine the optimal mix that:

- **Minimizes total cost**
- **Maximizes overall reliability**

Subject to:

- A **CO_2 emissions cap** of 100 metric tons per year
- Source capacity limits
- Total generation must meet demand

Methodology - Pareto Multi-objective

- **Objective:**
Determine the optimal mix of energy sources (Solar, Wind, Nuclear, Fossil) to meet **1000 MWh demand**

- **Goals:**
  Minimize total generation **cost**
  Maximize overall **reliability**

- **Constraints:**
  Emissions cap: **≤ 100 metric tons CO_2/year**

- **Source capacity** limits

- **Total generation** must equal **1000 MWh**

Decision Variables

S: MWh from Solar
W: MWh from Wind
N: MWh from Nuclear
F: MWh from Fossil

Constraints

Total generation meets demand:
$S+W+N+F=1000$

Source capacity limits:
$0 \le S \le 400$, $0 \le W \le 400$, $0 \le N \le 300$, $0 \le F \le 1000$

CO_2 emissions constraint (hard cap):
$0.40F \le 100$

$S, W, N, F, d1^-, d1^+, d2^-, d2^+, d3^-, d3^+ \ge 0$

Objectives:

Objective 1: Minimize Total Cost
$Cost=50S+52W+100N+40F$

Objective 2: Maximize Reliability
$Reliability= 0.25S+0.35W+0.95N+0.90F / 1000$

Single Objective Results – Minimizing Cost

Source	DV	Cost ($/MWh)	Emission (tons/MWh)	Reliability (%)		Max Gen (MWh)
Solar (S)	400	50	0	25%		400
Wind (W)	350	52	0	35%	<=	400
Nuclear (N)	0	100	0	95%		300
Fossil (F)	250	40	0.4	90%		1000
Actual Amount	1000	48200	100	45%		
Limit	1000	Min	100	Max		
	=		<=			

- **Cost: 48,200 ($/MWh)**
- **Reliability: 45%**

- Due to the emissions constraint, the model limits fossil fuel usage to 250 MWh, even though it is cheap and reliable.

Single Objective Results – Maximizing Reliability

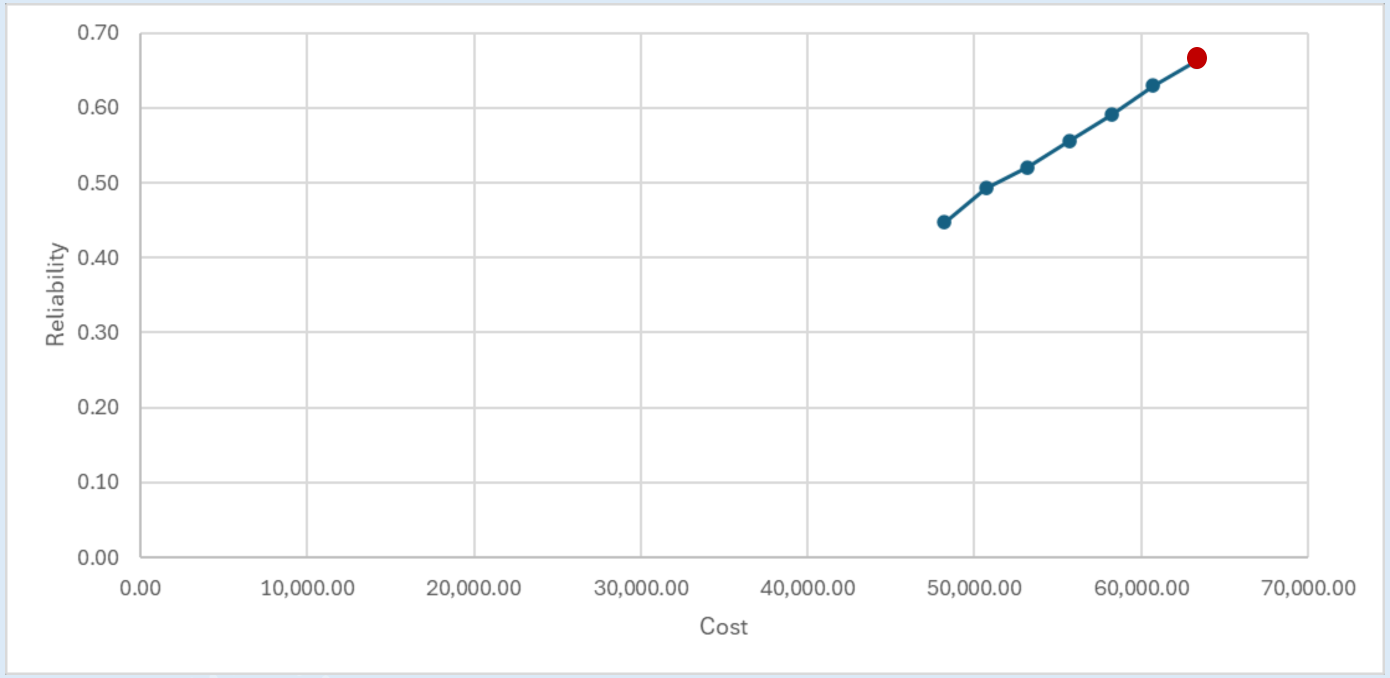
Source	DV	Cost ($/MWh)	Emission (tons/MWh)	Reliability (%)		Max Gen (MWh)
Solar (S)	50	50	0	25%	<=	400
Wind (W)	400	52	0	35%		400
Nuclear (N)	300	100	0	95%		300
Fossil (F)	250	40	0.4	90%		1000
Actual Amount	1000	63300	100	66%		
Limit	1000	Min	100	Max		
	=		<=			

- **Cost: 63,300 ($/MWh)**
- **Reliability: 66%**

- To increase reliability, the model leans more on **nuclear energy**, which is **expensive but highly reliable**.

Pareto: Trade-off Analysis

- For each point, we solve the model again using **constraint adjustment**, generating a set of **non-dominated solutions**



Cost	Reliability
48,200.00	0.45
50,700.00	0.49
53,200.00	0.52
55,700.00	0.56
58,200.00	0.59
60,700.00	0.63
63,300.00	0.66

Recommendations

- When reliability drops below 90%, it's not just a number. It means blackouts, disruptions, and real-world consequences for families, hospitals, and businesses.
- To build a grid that's both resilient and responsible, we must rethink limits, unlock cleaner firm power, and adapt our planning in real time.

Problems	Recommendations
Current 100 t CO_2 cap holds fleet reliability at ~66 %, well below the 90 % target.	Raise the CO_2 cap to enable greater fossil fuel use, boosting firm generation and improving reliability.
Baseload gap: existing 300 MWh nuclear ceiling limits zero-carbon, high-reliability supply.	Invest in nuclear generation, raising the maximum generation limit.
Reliability penalty for staying under the cap: grid lacks clean-firm resources that can replace fossil peakers.	Invest in complementary "clean-firm" solutions: long-duration storage and demand response.

Next Steps

Policy Analysis → CO_2 Cap Adjustment → Nuclear Capacity Roadmap → Expanded ESG Scorecard → Clean-Firm Pilot Programs → Tool Roll-out

- **Policy Analysis → CO_2 Cap Adjustment:** Reassess the 100 t CO_2 cap based on system reliability needs; explore how raising the cap could enable limited fossil generation to prevent blackouts.
- **Nuclear Roadmap:** Evaluate options to raise the 300 MWh nuclear ceiling via uprates or SMR deployment to expand carbon-free, high-reliability baseload.
- **Expanded ESG Scorecard → Clean-Firm Pilots:** Integrate broader sustainability metrics (land, water, waste, jobs); launch long-duration storage and demand-response pilots to increase reliability without added emissions.
- **Tool Roll-out:** Launch a cloud-based tool that helps DOE and EIA teams re-optimize the generation plan every quarter—adjusting to real-world shifts in prices, emissions limits, and available technologies.

Questions

Appendix

Data Sources:

- 2025 Sustainable Energy in America Factbook
- U.S. Renewable Energy Factsheet | Center for Sustainable Systems
- Electric power sector CO_2 emissions drop as generation mix shifts from coal to natural gas - U.S. Energy Information Administration (EIA)
- Nuclear Energy Factsheet | Center for Sustainable Systems
- Cost of electricity by source - Wikipedia
- 2019 Electricity ATB - Natural Gas Plants