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Evaluating CHP as a Boiler Replacement Option

U.S. EPA CHP Partnership

Jay Weist, Director, Business Development

Webinar Tuesday April 30, 2013

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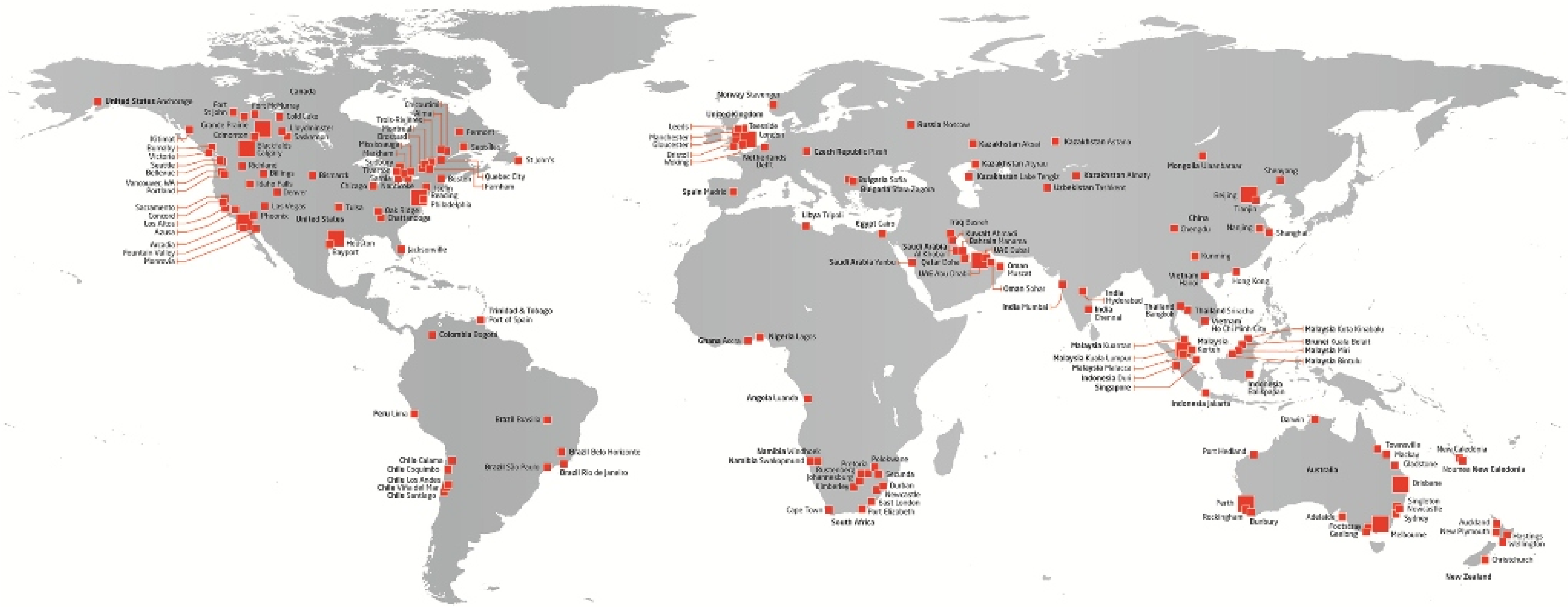

Revenue
FY '12 - $7.7 Bn

Power Hydrocarbons Mining Metals Infrastructure Environment Minerals Chemicals

Project Delivery Diagram

	1 IDENTIFY	2 EVALUATE	3 DEFINE	4 EXECUTE	5 OPERATE
CUSTOMER GOALS	*Establish preliminary scope and business strategy*	*Establish development options and execution strategy*	*Finalize scope and execution plan*	*Detail and construct asset*	*Operate, maintain and improve asset*
		Select concept	Sanction	Start-up	
OUR SERVICES	• Pre-feasibility screening studies • Business model development	• Feasibility studies • Conceptual design • Cost estimating • Contract planning	• Preliminary Engineering (FEED) • Cost estimating • Execution planning	• Detailed Engineering • EPCM • PMC	• Brownfield projects • Portfolio delivery • Asset management • Business improvement • Operations and maintenance support
	CORE BUSINESS				
OUR BUSINESS LINES	***Select*** ...brings real world experience into the front-end, value adding phases to maximise investment return and underlying confidence		***Deliver*** ...converts the highest potential value options identified at the *Select* phase, into fully defined and successfully executed projects.		***Improve*** ...supports and improves customers' assets throughout operating lifecycle

Delivering profitable sustainability EcoNomics™

...profitably embeds environmental, social, and financial sustainability into project delivery across the asset lifecycle

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Why CHP?

Value Proposition

- Invest in continued coal fired plant with Air Quality Control System
  - Higher O&M costs over existing ops
  - Increased maintenance cost for existing equipment
  - No return on invested capital
  - Risk of escalating coal costs
  - Risks of future exposure to new regulations
- Invest in gas fired CHP Option
  - Lower O&M
  - Leverage CHP for producing electricity to supplement plant load or sell excess
  - Natural gas price stability in the 3-5 year horizon
  - Possible higher return on investment and/or lower O&M costs through external electricity sales and improved plant profitability

Developing Market – Additional Value

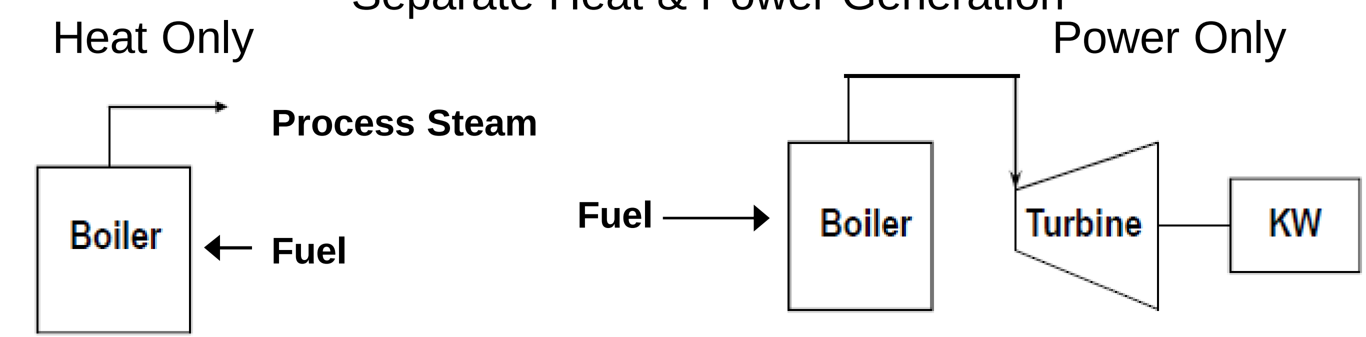
- Considerations with Existing Operations
  - Corporate sustainability compliance implementation plans alignment
  - Site expansion and increasing steam demands
- Economic and Operational Benefits
  - Enabling System Resiliency in Energy Infrastructure
  - CHP during grid outages – “Island Mode”
    - Continued operations
    - Avoided shutdown costs
  - Hedge against rising electricity costs
  - Avoided costs of new regulations (coal, oil fired boilers)
- Environmental Benefits
  - Reduced GHGs emissions and other criteria air pollutants, hazardous air toxics, solid waste (coal, oil fired boilers), wastewater
  - Increased energy output per unit of fuel consumption with significantly improved energy conversion efficiency

CHP vs. No CHP Performance

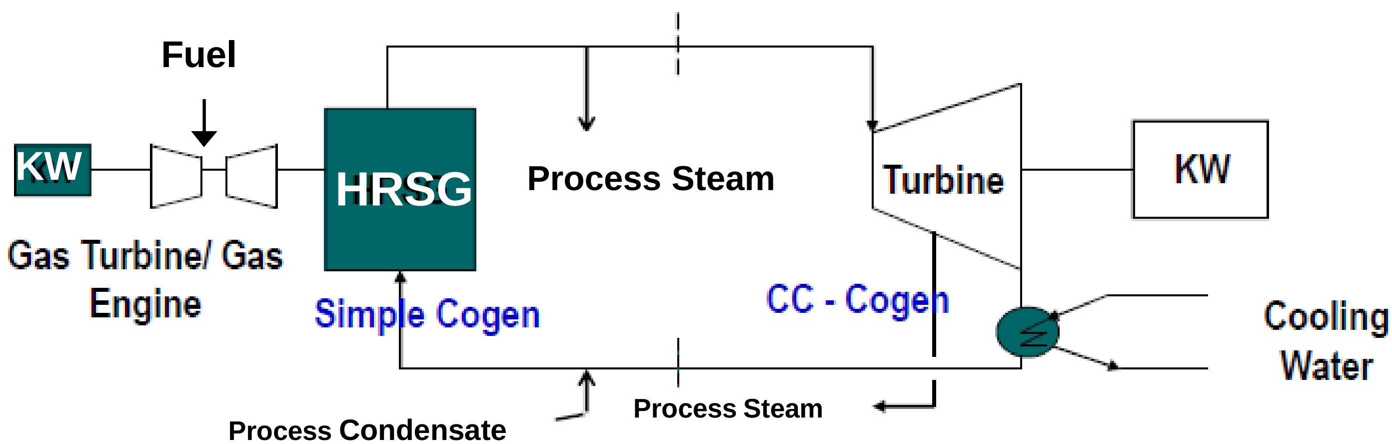
Fuel Use Efficiency (HHV)

- Heat Only: 80-90%
- Power Only (Blr & Turb): 30-40%
- Separate Heat & Power: 50-65%
- CHP: 80-90%

Separate Heat & Power Generation



Combined Heat & Power (CHP)
(Gas Turbine / Gas Engine and HRSG with or without STG)



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CHP Plants

Site Design Conditions & Analysis

Site Design Conditions

- **Objective**: Determine benefits of CHP with respect to various non-CHP options firing coal or gas.
- **Facilities**: Primarily Industrial or large Institutional facilities
- **Power Generation**: 3.5 – 200 MW
- **Steam Generation**: 20 – 900 kpph,
- **Steam Conditions**: 150 psig/saturated and 600 psig/750 F.
- **Redundancy**: None on Power. N-1 on Steam with Aux Boilers for steam Supply.
- **Fuel**: Natural Gas for Gas Turbine / HRSG. Dual Fuel for back up Aux Boiler.
- **Prime Mover**: Gas Turbines in 3.5 – 85 MW range
- **Grid Support**: Yes with full back up.

Site Design Conditions

- **Power Purchase / Sales**: Could be either Power Short or Power Long. All excess power is sold to grid.
- **Emission Compliance**: Post Combustion Emission Controls to comply with Environmental regulations
- **Power Turndown**: About 50 percent based on OEM's design for emission compliance load (ECL).
- **Operational Flexibility**: Designed to meet the steam demand at varying power demands above ECL.
- **CHP Scope**: Includes all equipment & systems for the CHP. All utilities are terminated at the CHP boundary.
- **Costs**: Includes both Capex & Opex
- **Economic Inputs**: Assumed data, can be changed based on project specific requirements

Configuration Options

- **Gas Turbine Models**: Seven (7) discrete gas turbine models with nominal ratings of:
  - 3.5 MW - Solar Centaur 40
  - 10 MW - Solar Mars 100
  - 15 MW - Solar Titan 130
  - 20 MW - Solar Titan 250 (DLN)
  - 45 MW - GE LM 6000PF (DLN)
  - 65 MW - Rolls Royce Trent 60 ISI (WI)
  - 85 MW - GE 7EA (DLN)
- **Configuration Options**: Three (3) configurations in each group with supplemental firing in HRSG to match various Thermal to Power Demand ratios (TPR)
  - Simple CHP – Gas Turbine + HRSG **(High TPR)**
  - CC CHP with BP Steam Turbine **(Moderate TPR)**
  - CC CHP with Cond/Extraction Steam Turbine **(Low TPR)**

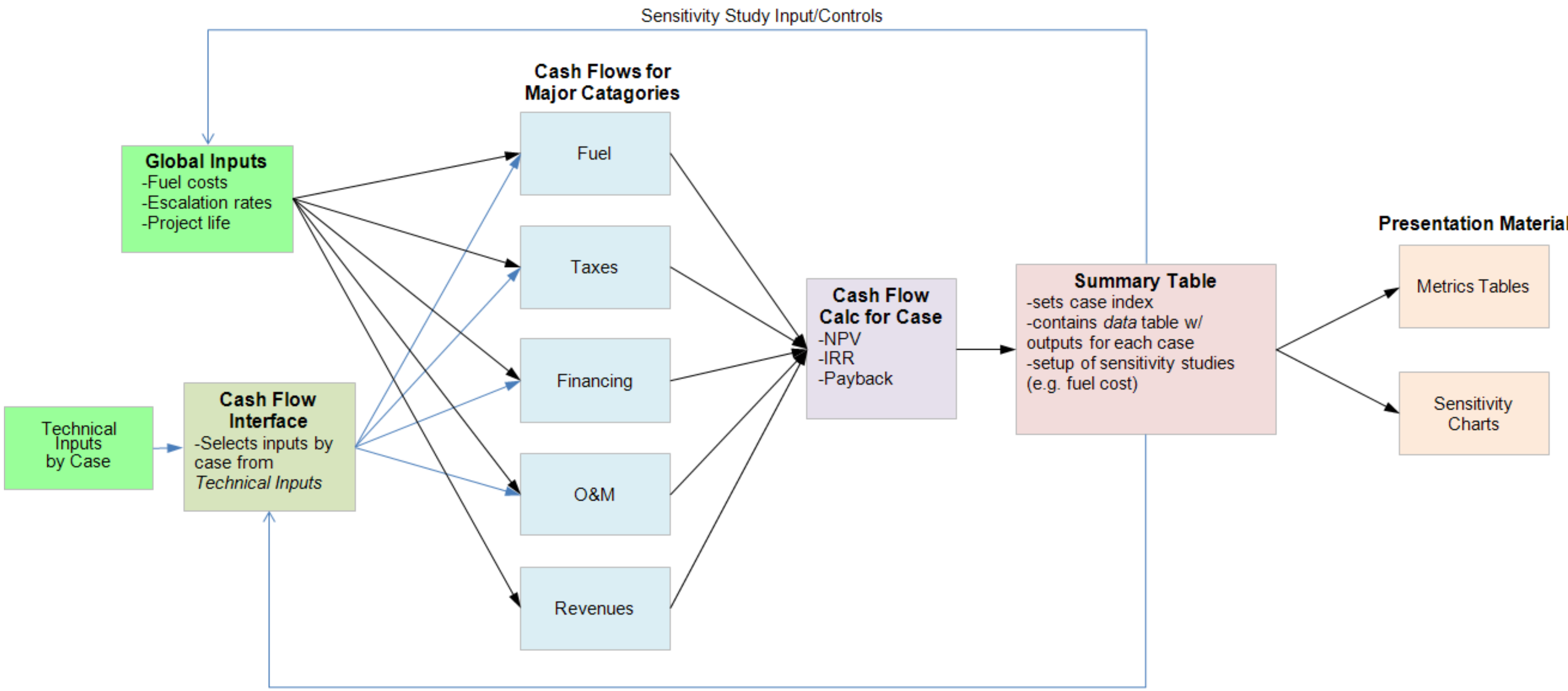
Screening Approach

- **Study Cases**: Four Cases to include three non-CHP and one CHP configurations.
  - No CHP Base: Coal Fired Boiler or Current Operations
  - No CHP Option - 1: Fuel Switching on Existing Boilers
  - No CHP Option - 2: Replace Coal Boilers by Gas Package Boilers
  - CHP Option: Gas Turbine or Reciprocating Engine based system
- **Capex Basis**: Based on PEACE Model / In-house data base, EPCM, Gulf Coast basis, 2013 Dollars.
- **Opex**: Utility Costs are assumed and can be changed in the model. Other Non utility O&M costs are based on in-house data base.
- **Economic Comparison**: Based on Net Present Value (NPV) approach while considering Simple Payback, and IRR.

Analysis Considerations

- **Additional Data included in the Screening Model**
  - Min and Max steam generations for each Options
  - Gas Turbine Attributes
  - Minimum Fuel Gas Pressure requirements
  - Project Completion Schedule
  - Utility Consumptions
  - Power Import / Export amount (Normal & during Outage)
  - CO_2 reduction CHP vs. No CHP with coal (No credit for displaced Electricity)
  - Fuel Chargeable to Power (FCP)
  - FCP Heat Rates
  - Thermal to Power Demand and Electricity to Gas Price ratios (for sensitivity analysis)

Block Flow Diagram for Economic Model



Summary Observations

- CHP provides between **40 – 60% energy cost savings**
- CHP FCP Heat Rate can be as low as **3,800 Btu/kWh – HHV.** This is far better than the most advanced CC Plant (HR 6,200 – 6,500) or modern Coal Plants (8,500 – 9,000) Btu/kWhr - HHV.
- CHP Capex is **higher** than the Air Quality Control, Fuel Switching, or Replacement Boiler costs, but the Opex is **lower** in energy costs and will pay back the additional investment.
- CHP provides environmental benefits in **significant reduction of CO2 emissions and other criteria air pollutants** and depending on location possible additional monetized value.

Case Study 1

8 MW CHP (Small scale)

Current Facility Energy Demands

Power Demands and Costs

- 8,334 kW Annual Average (2012 Data)
- 73 million KWH Yearly Consumption (2012), about 38.5% (28.1 million kWh purchased, rest self generated.
- $72/ MW-hr Power Purchase Price (7.2 cents/kW-hr)

Steam Demands

- 144,000 lbs/hr – Average (2012 Data)
- 160,000 lbs/hr – Winter Peak / 90,000 pph - Minimum
- 600 psig / 700F Steam Generation (180/50/80 psig usage pressure)

Fuel

- Coal ($3.79 / MMBtu - HHV)
- Natural Gas ($4.50 / MMBtu-HHV)

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Additional Energy Supply Scenarios

New Packaged Boiler w/ BP Steam Turbine

- Steam produced by Aux Boiler at 600 psig / 700 deg
- BP STG produces power (2 MW) and exhaust steam sent to process users

Solar Centaur 50 Gas Turbine w/ HRSG and BP STG

- Gas Turbine and BP STG produce electricity
- Steam generated by HRSG and Auxiliary Boiler. Process steam supplied from STG Exhaust .

Solar Taurus 70 Gas Turbine w/ HRSG Only

- Gas Turbine produces electricity and process steam generated by HRSG and Auxiliary Boiler.

Solar Mars 100 Gas Turbine w/ HRSG Only

- Gas Turbine produces electricity and process steam generated by HRSG.

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Revised CHP Options

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4 Gas Turbine CHP options sized for 85,000 lbs/hr of steam and various power production levels

Solar Turbines
A Caterpillar Company

Centaur 50	Taurus 70	Mars 100	Titan 250
6 MW	7.5 MW	11 MW	20 MW

Must run auxiliary boiler during normal operation to meet steam demand (Centaur 50, Taurus 70)

Titan 250: Revised to Simple CHP

1 Additional Gas Boiler w/STG CHP option also evaluated

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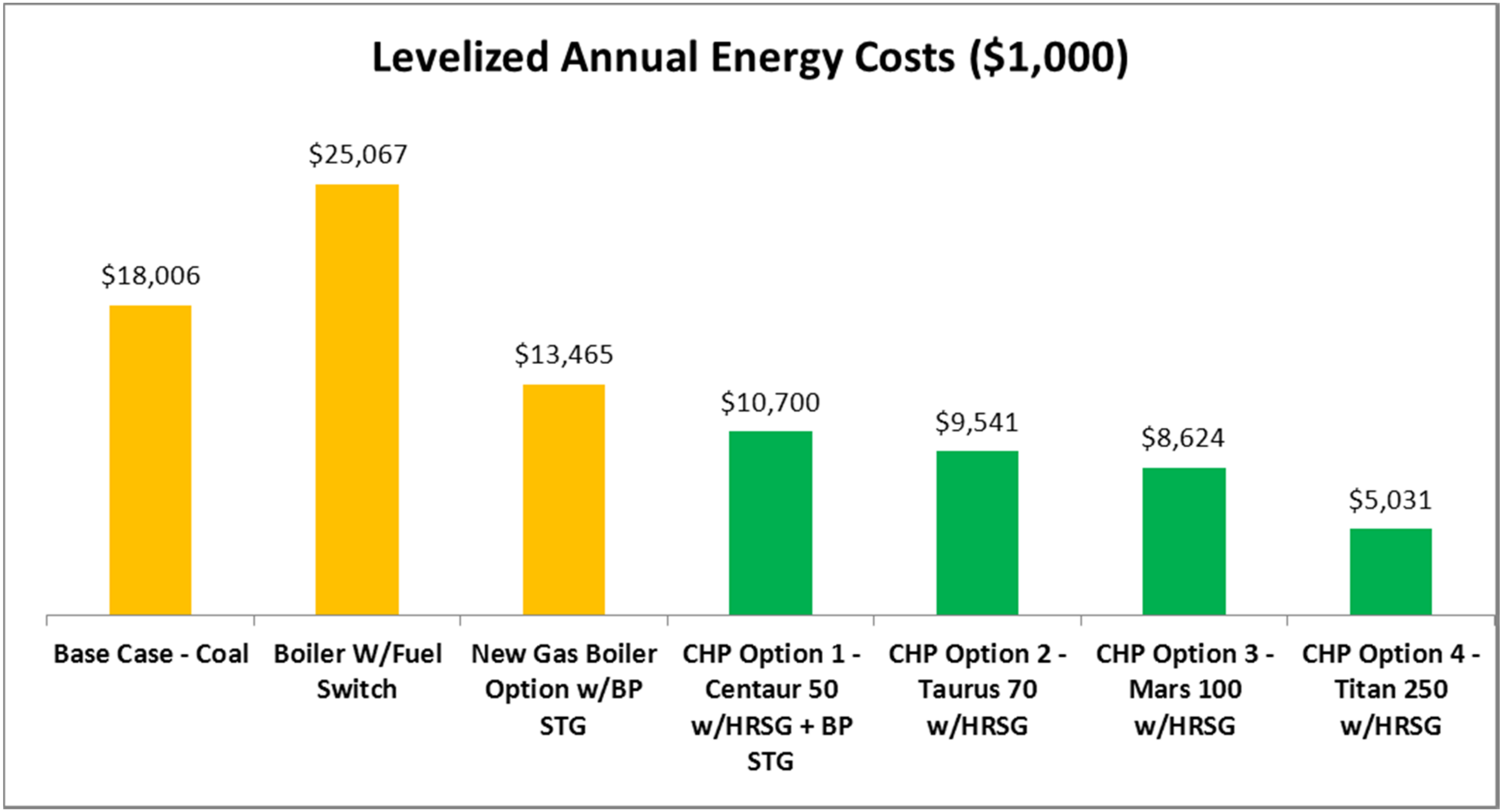
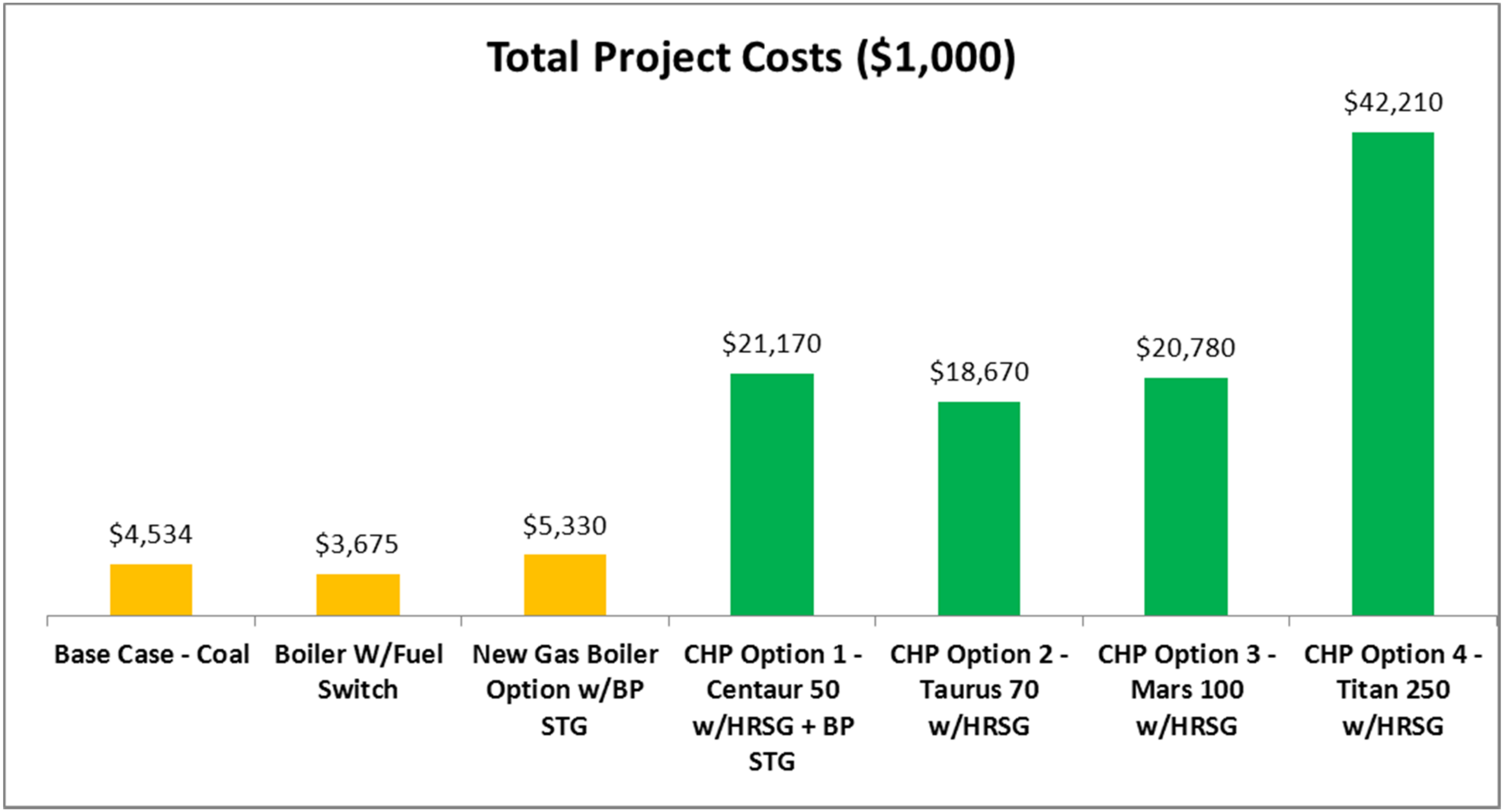
Screening Analysis Results



Annual Energy Cost: CHP Option 4 has the lowest annual energy cost compared to the other options. Energy Cost is offset by sale of excess or production of electricity for the larger CHP Option.

Screening Analysis Results



Capex: **However, nothing comes free.** The Gas Turbine CHP will cost between $14 – $38 million dollars more than the non GT CHP configurations. **The higher delta for the GT based CHP also provides lowest energy cost**. The GT CHP Capex includes 100% capacity back up NG Aux Boiler

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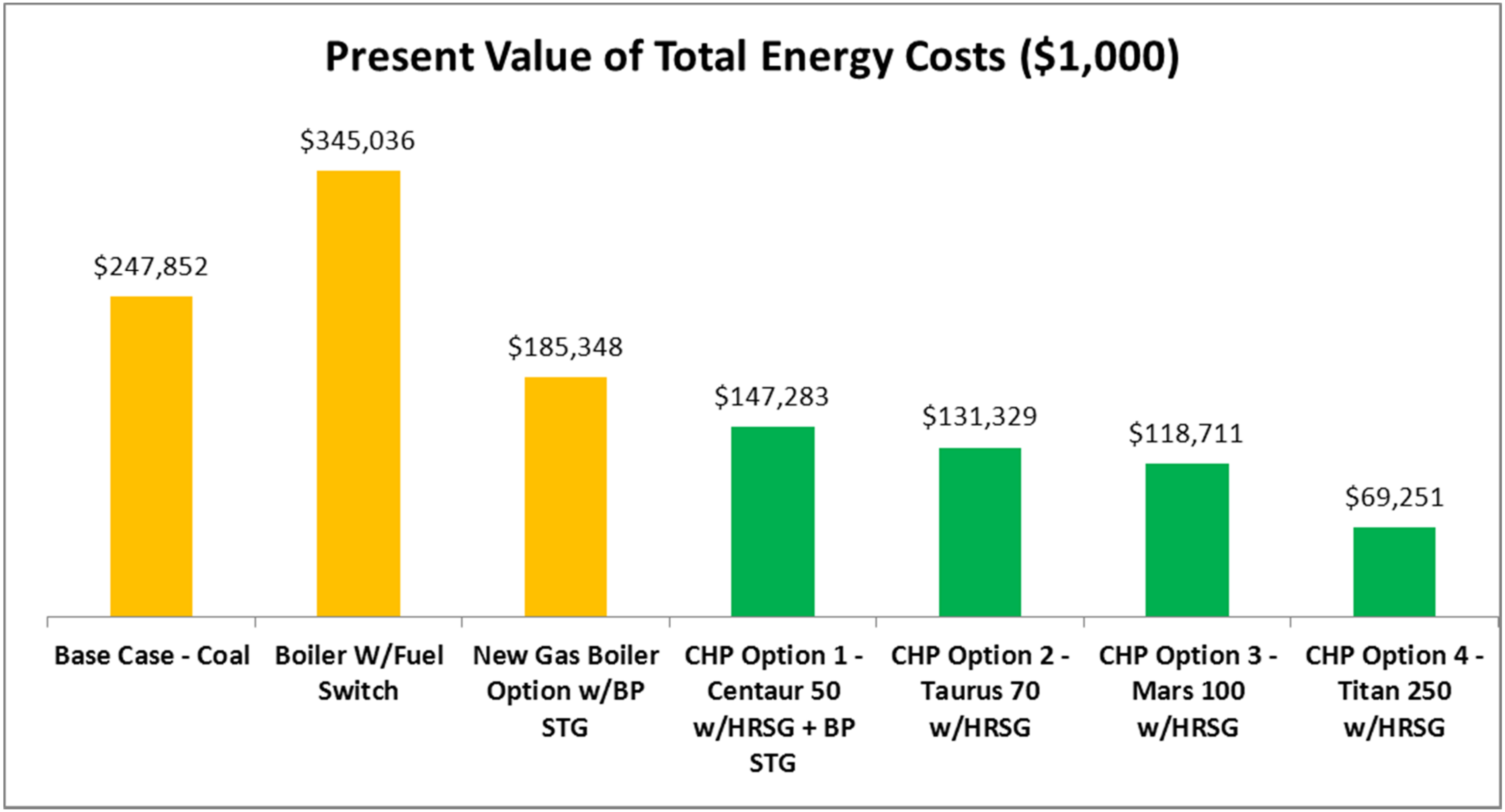
Screening Analysis Results



NPV of Energy Cost: The larger CHP option has lowest NPV of energy cost compared to the other options. Energy Cost is offset by sale of excess or production of electricity for the larger CHP Option.

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Screening Analysis Results

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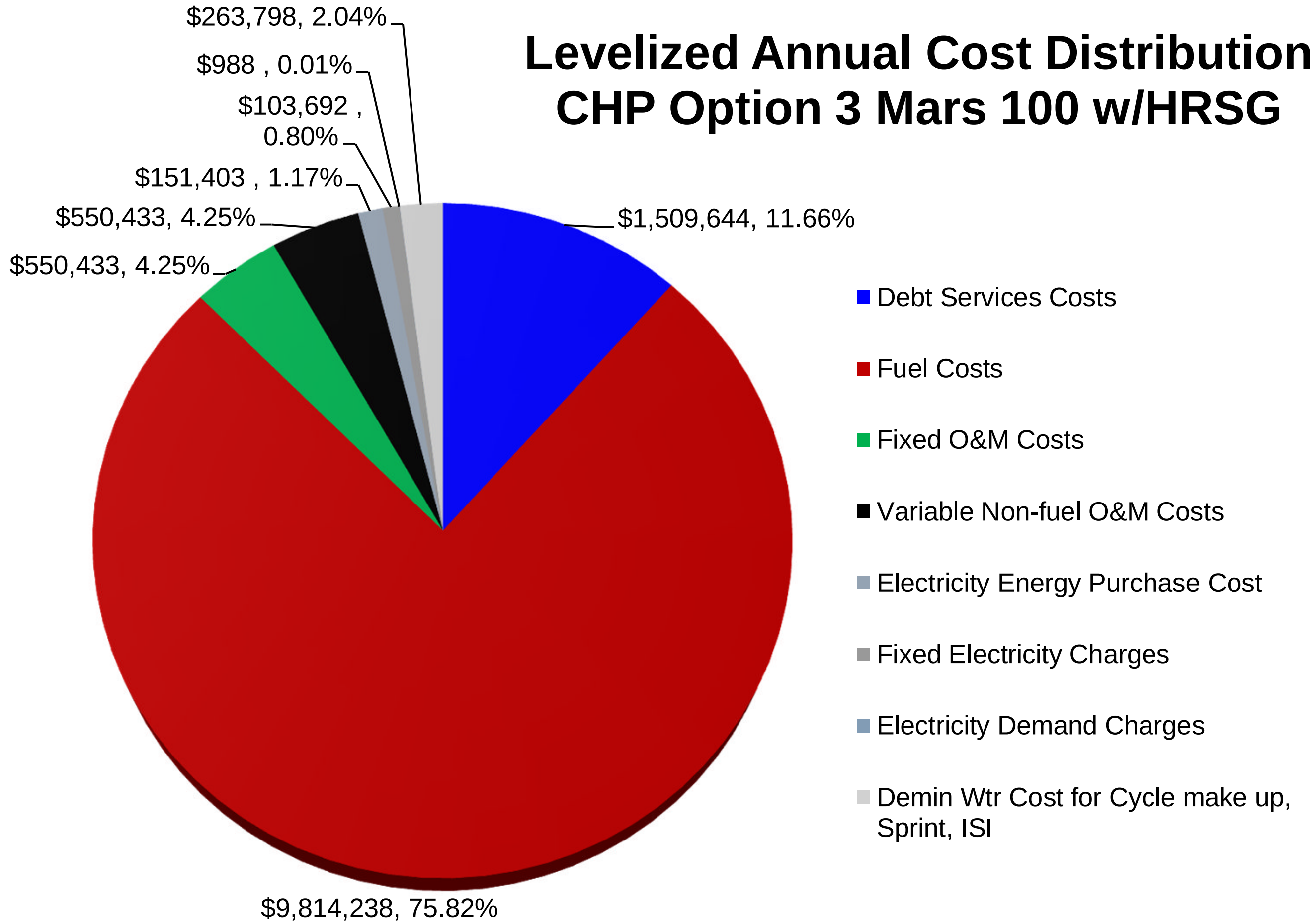

Larger CHP Annual Cost Distribution: The fuel cost has the highest contribution (~76%) of total costs followed by the Capex (~12%). **Lower natural gas cost will make the CHP option much more attractive.**

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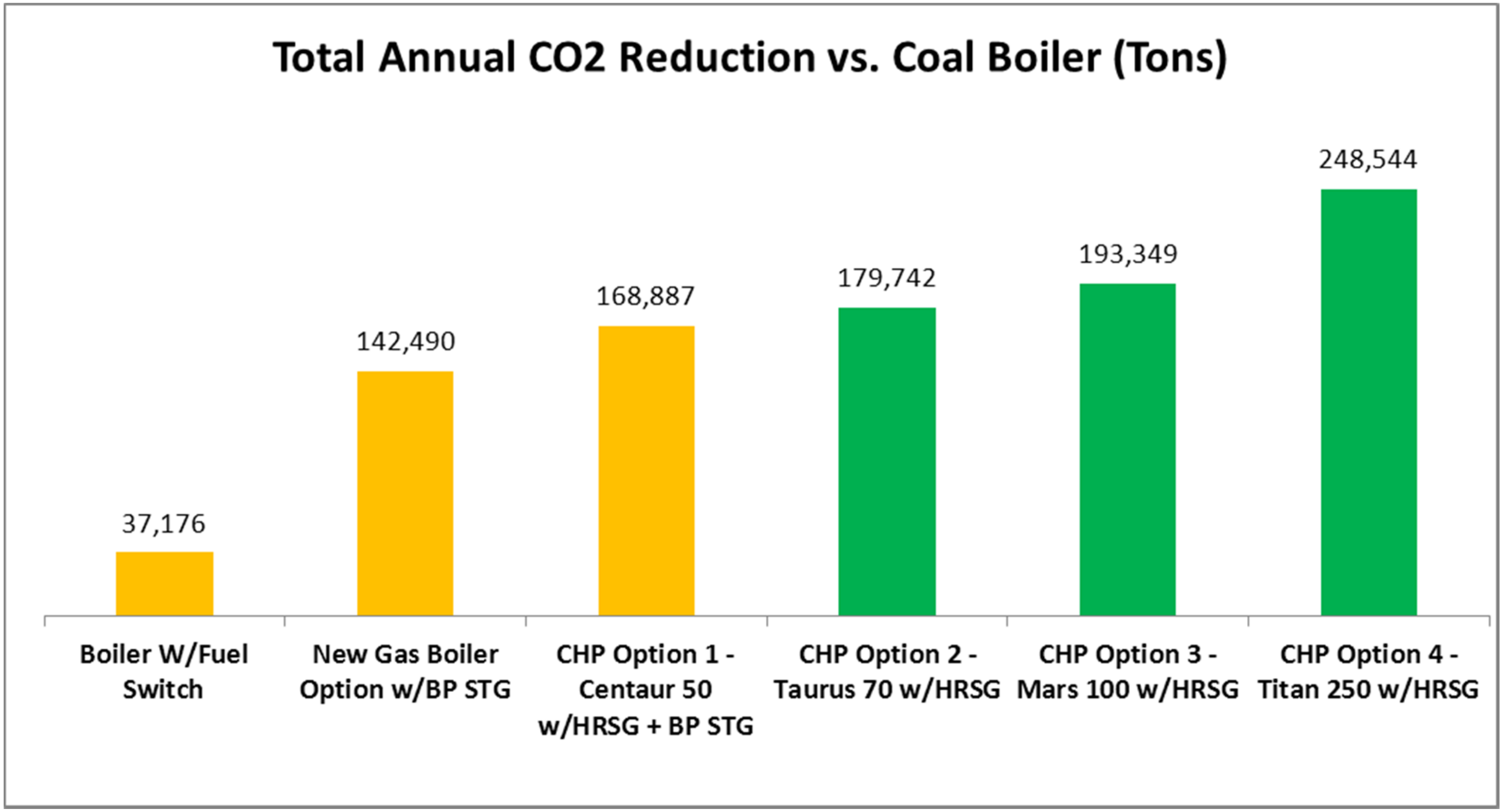
Annual CO2 Reduction



Annual CO_2 Reduction: The CO_2 reduction shown above are with respect to the Base Case (Coal Boiler w/AQCS). This includes the impact of displaced generation from existing utility coal plant (HR assumed 9,500 Btu/kWh).

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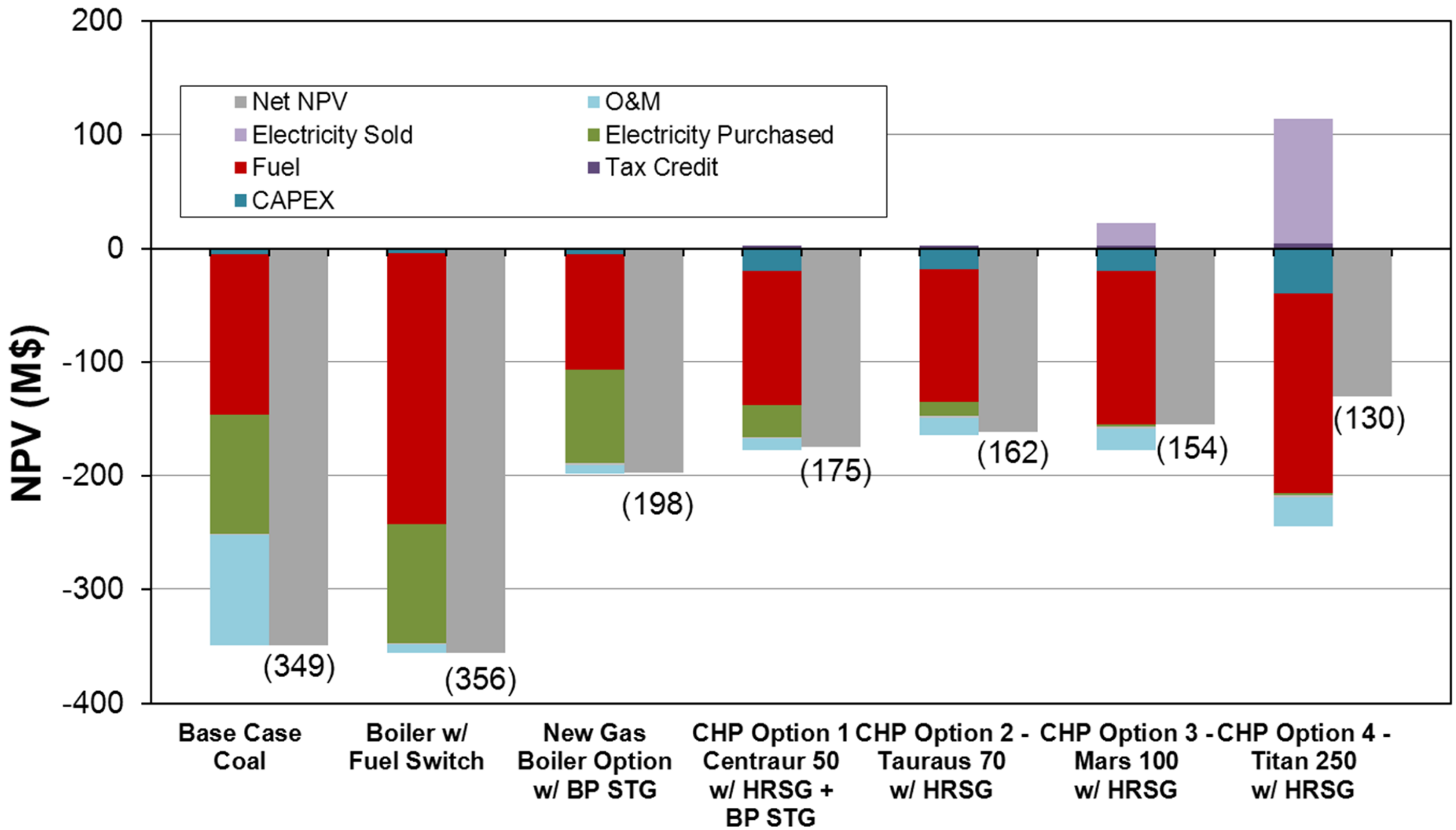
Screening Analysis Results



NPV: The Net NPV most positive for Option 4 with the larger CHP due to excess electricity sales. Base case and boiler fuel switch impacted by purchase electricity.

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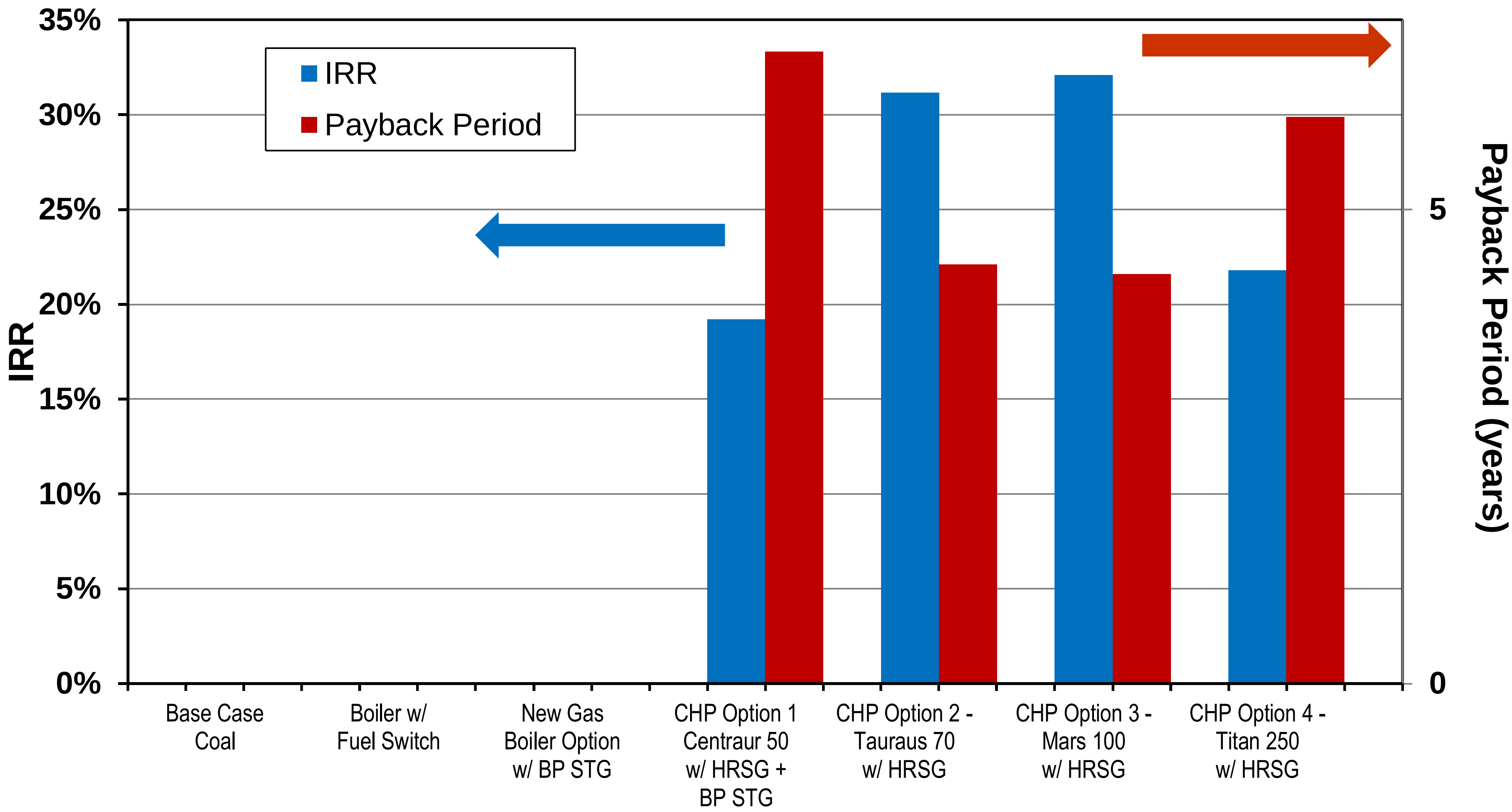
Payback Period and IRR with Respect to Package Boilers



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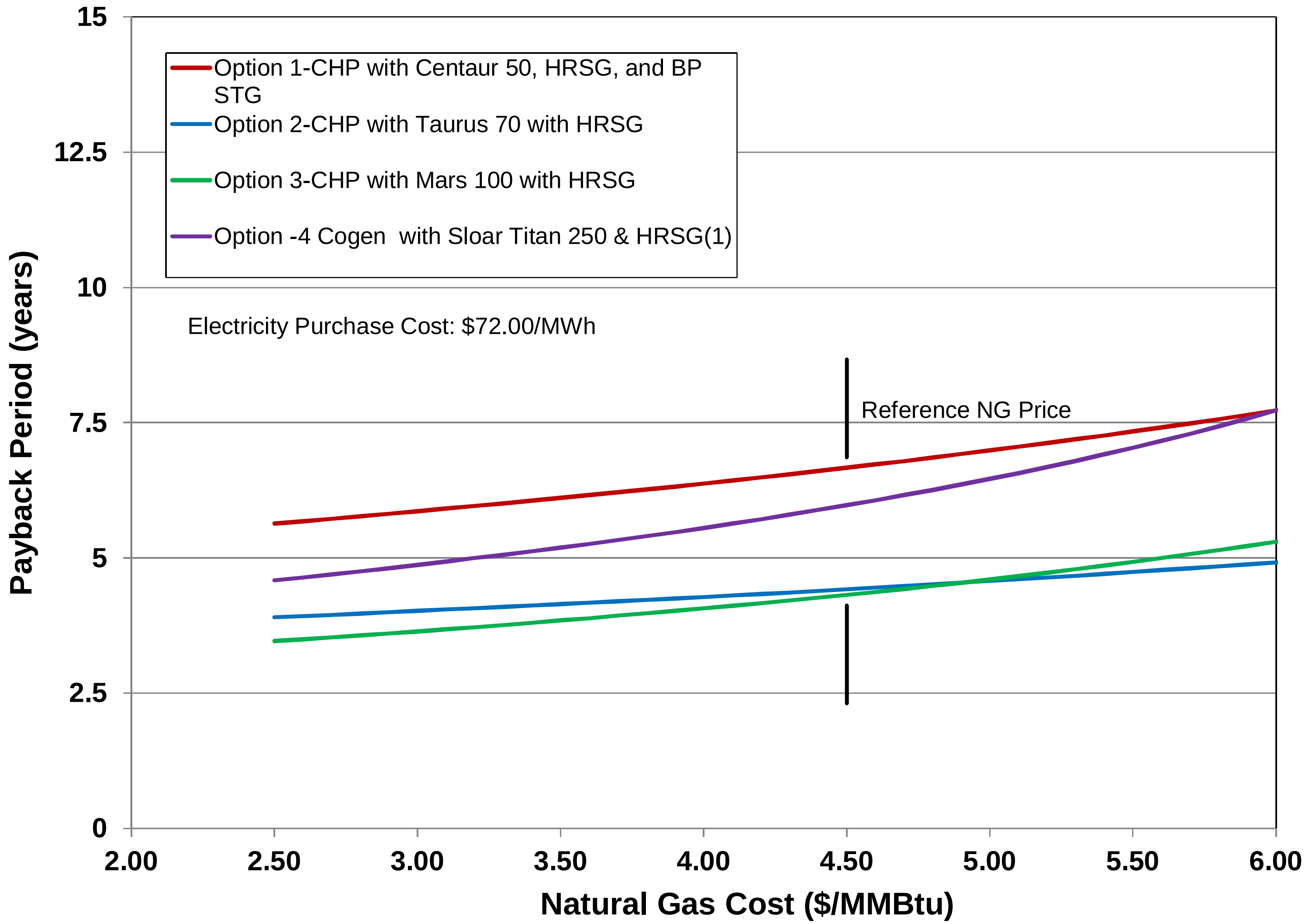
Payback Period Sensitivity to Natural Gas Costs



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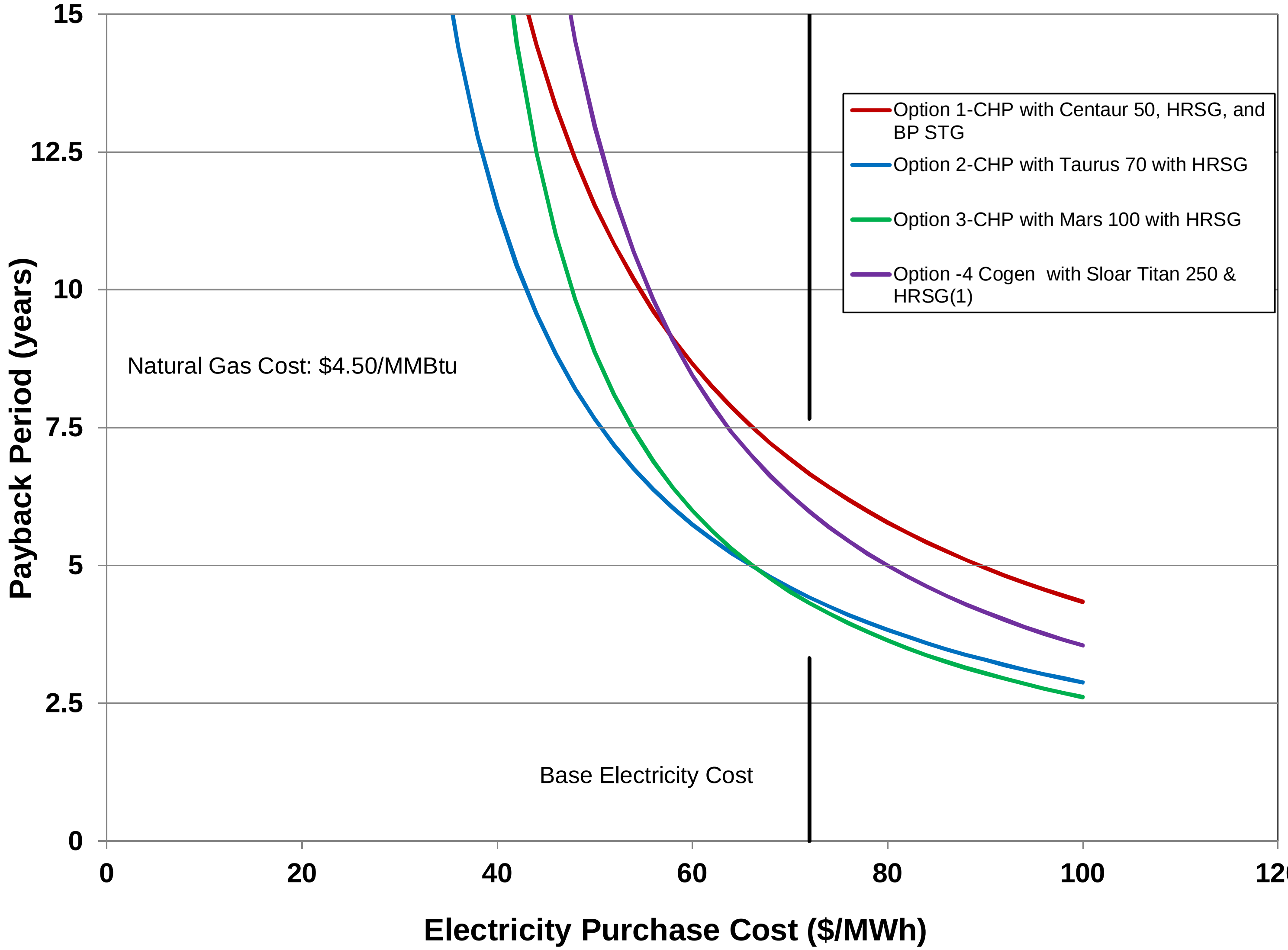
Payback Period Sensitivity to Electricity Purchase Costs



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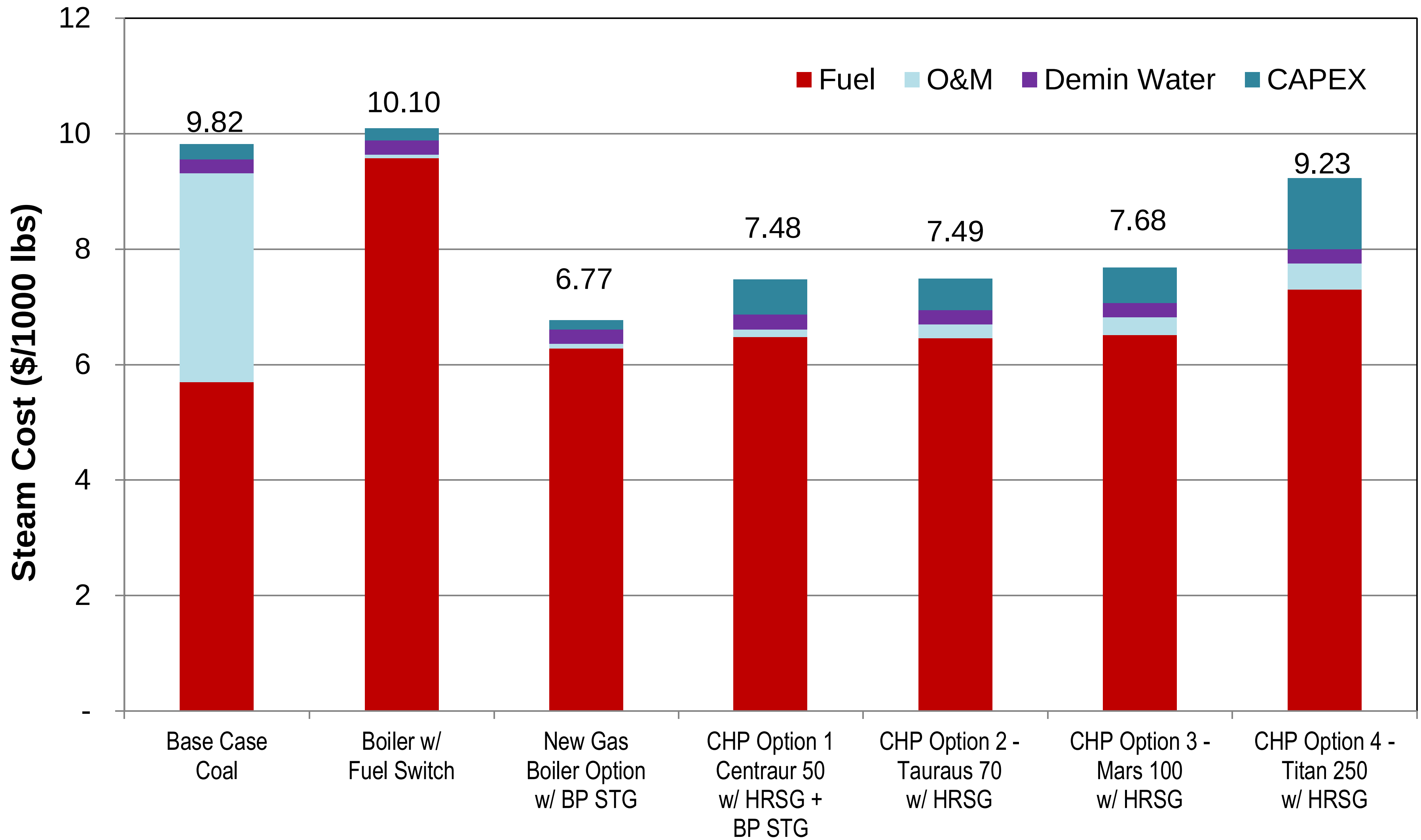
Financial Analysis Basis & Results
Steam Costs



Based on Steam Plant Cost Percentage of 30%.

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Financial Analysis Basis & Results
Annual Average Electricity Costs

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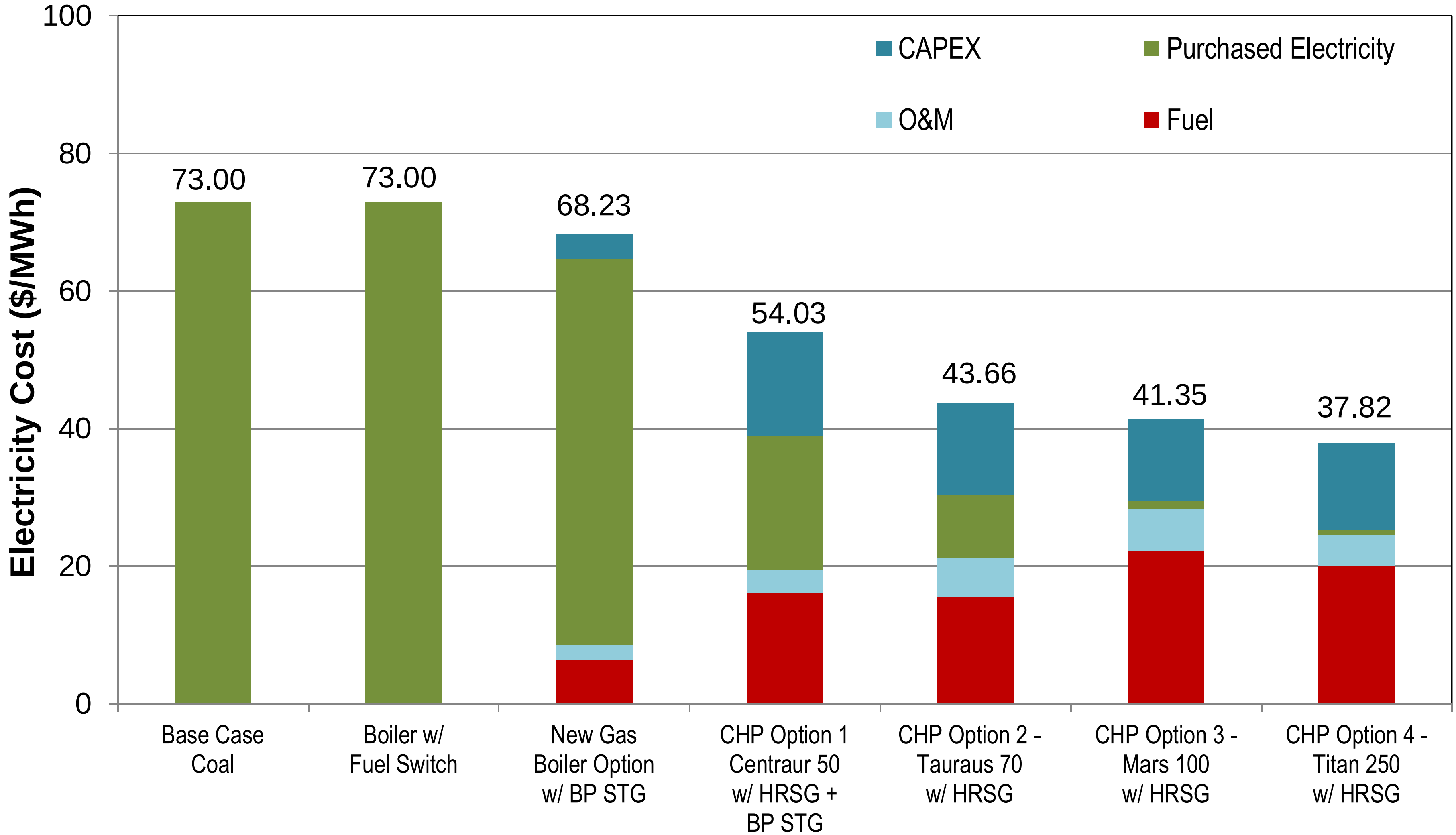

Based on Steam Plant Cost Percentage of 30%.

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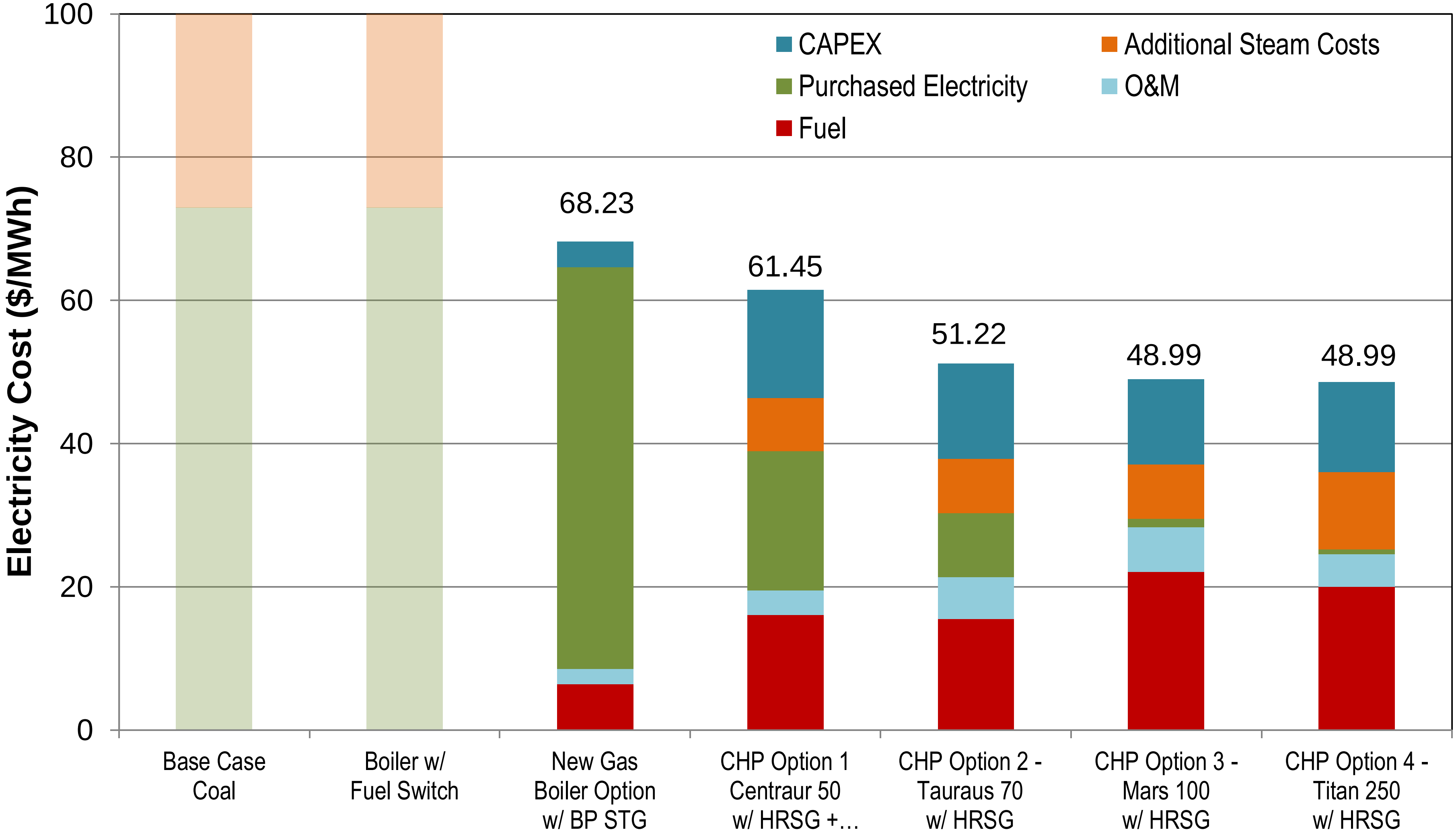
Breakdown of First Year Electricity Costs with Steam Cost Fixed to $6.77/ 1,000 lbs



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Case Study 2

40 MW CHP (Medium Scale)

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Current Facility Energy Demands

Power Demands

- 41,750 kW Average
- 56,000 kW Max (Summer) / 27,500 kW Min
- 259.62 million KWH Yearly Consumption (5 year avg)
- $55.2 / MW-hr ($0.0552/kW-hr)

Steam Demands

- 202,500 lbs/hr - Average
- 320,000 lbs/hr – Winter Peak / 85,000 pph - Summer
- 130 - 150 psig / Saturated

Fuel

- Coal ($3.21 / MMBtu)
- Natural Gas ($4.94 / MMBTU)

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CHP Options

11 CHP options evaluated to meet facility energy needs

4 Gas Turbine Models Analyzed (20 – 85 MW range)

Solar Titan 250 GE LM6000PF RR Trent 60 GE 7EA

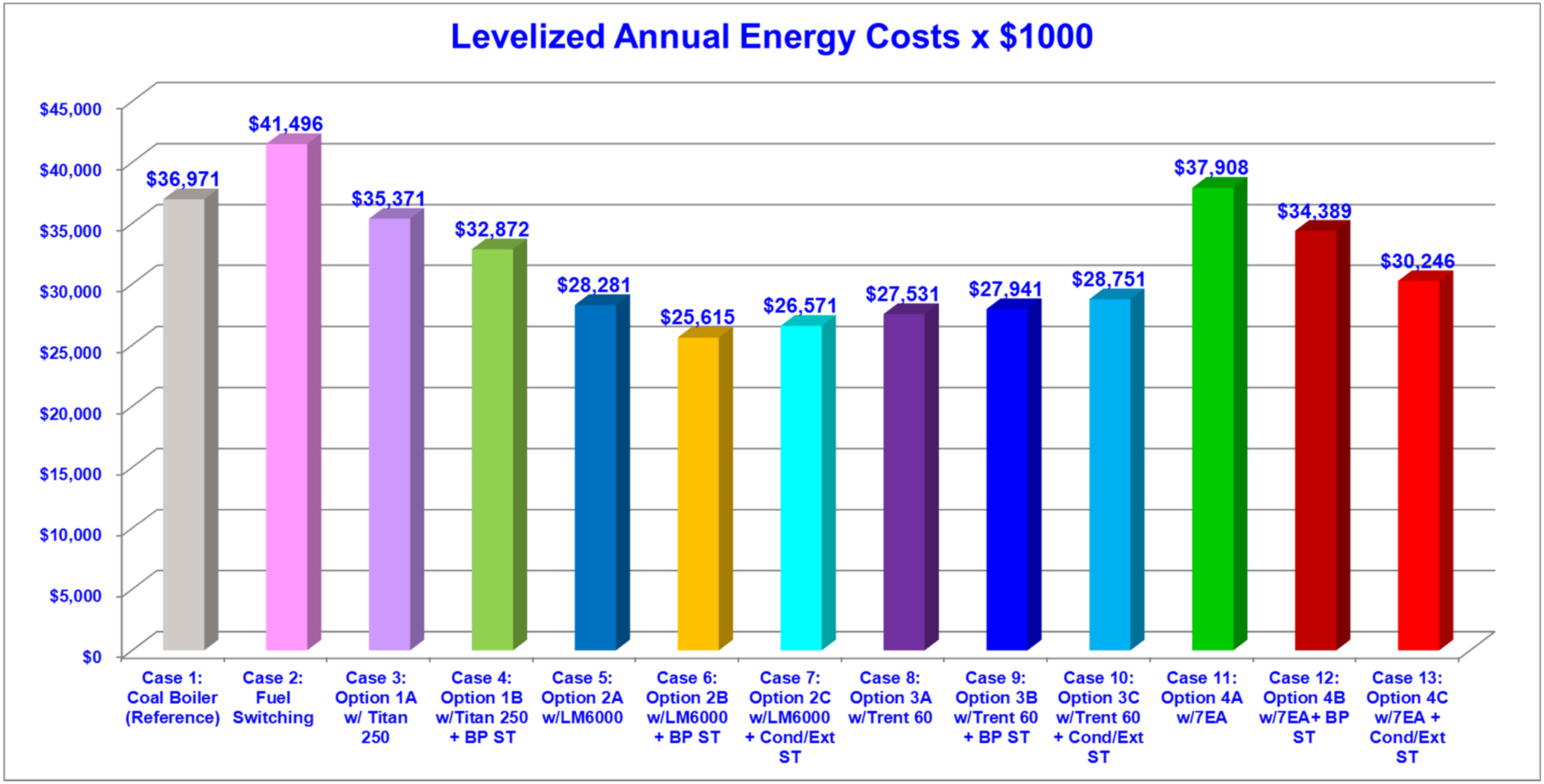
20 – 30 MW
(Solar- Power Short)

79 – 198 MW
(GE 7EA- Power Long)

2 or 3 Configuration Options per Gas Turbine Generator

- **Simple CHP**: Gas Turbine with HRSG (All Options)
- **CC CHP -1**: Gas Turbine with Back Pressure (BP) Steam Turbine (All Options)
- **CC CHP - 2**: Gas Turbine with Condensing/Extraction Steam Turbine (All Options except Solar Titan 250)

Screening Analysis Results



Annual Energy Cost: Most CHP options have lower annual energy cost compared to the Non-CHP options. Energy Cost is offset by sale of excess or production of electricity when applicable and can be about 30% lower than the Non-CHP option in some CHP configurations.

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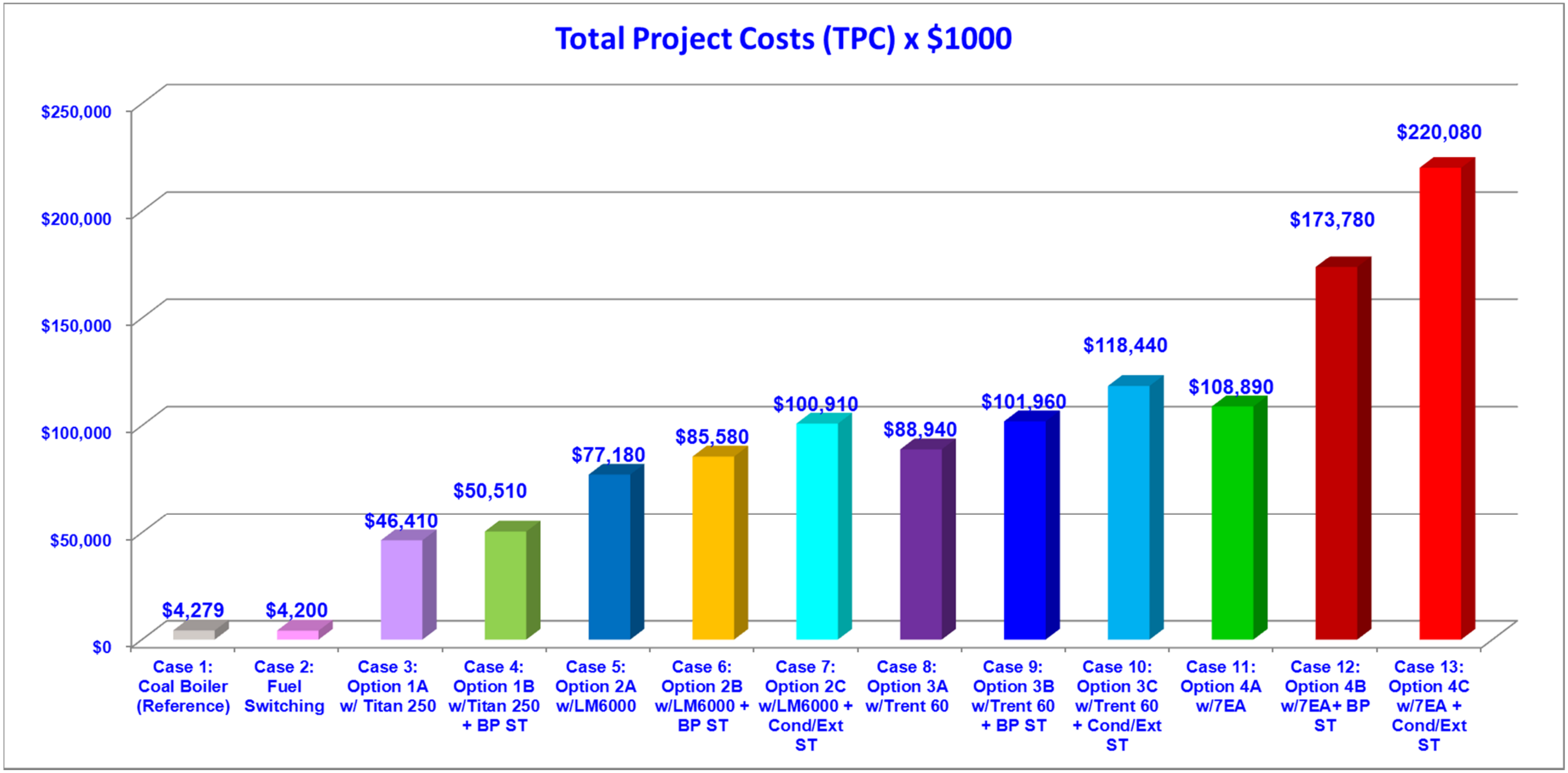
Screening Analysis Results



Capex: **However, nothing comes free.** The CHP will cost between $40 – $216 million dollars more than the no CHP options depending on the configuration. **The higher delta is for larger CHP that also typically provides larger energy cost reduction**.

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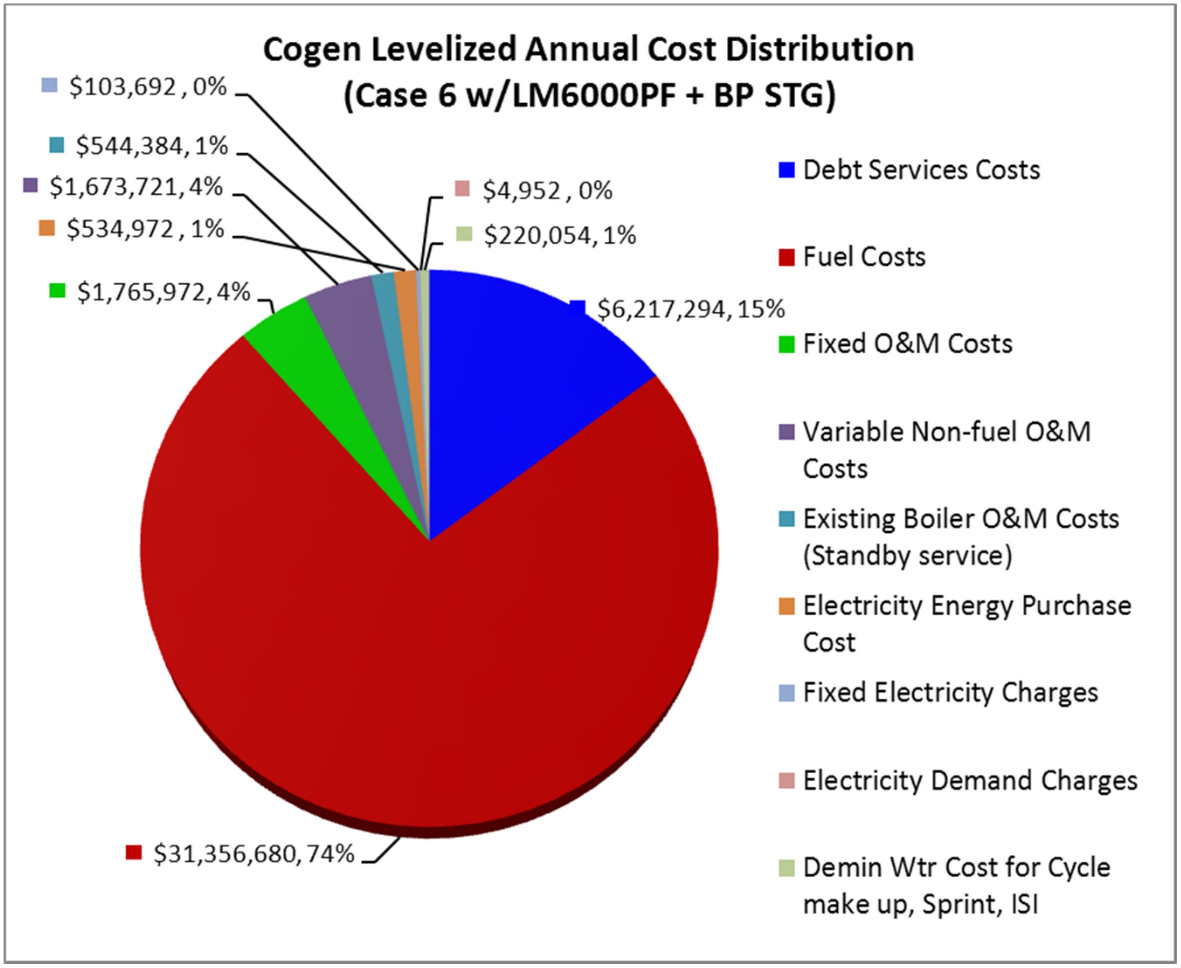
Screening Analysis Results



CHP Annual Cost Distribution: Shown for the lowest Energy Cost configuration only (Case 6). The fuel cost has the highest contribution (~74%) of total costs followed by the Capex (~15%). **Lower natural gas cost will make the CHP option much more attractive.**

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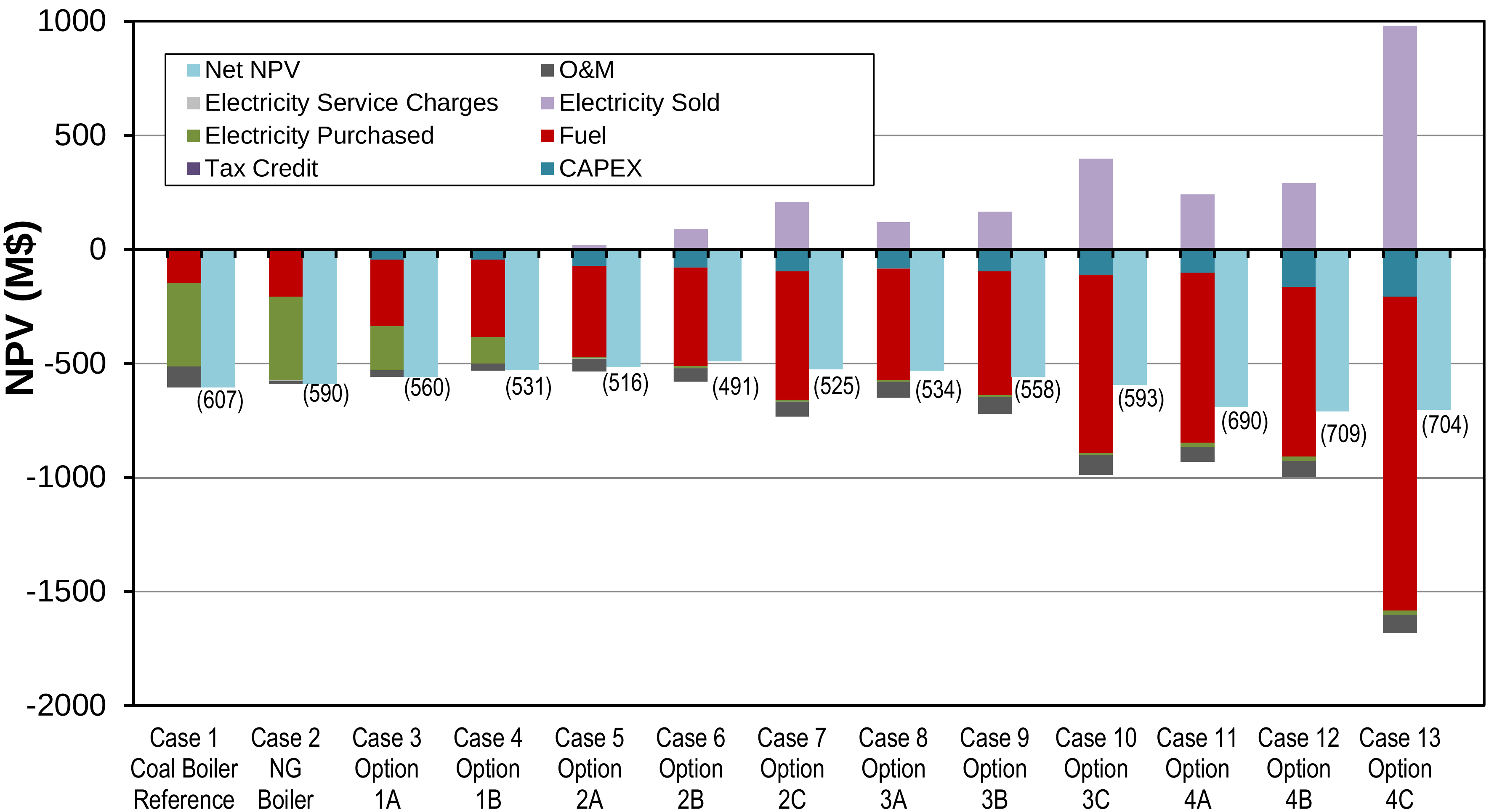
Screening Analysis Results



NPV: The Net NPV is lowest for LM6000 w/ back pressure steam turbine (Option 2B) Options 1B, 2A, 2C and 3A also had low NPVs. **Therefore, these five CHP options are suggested for detailed analysis in a next step.**

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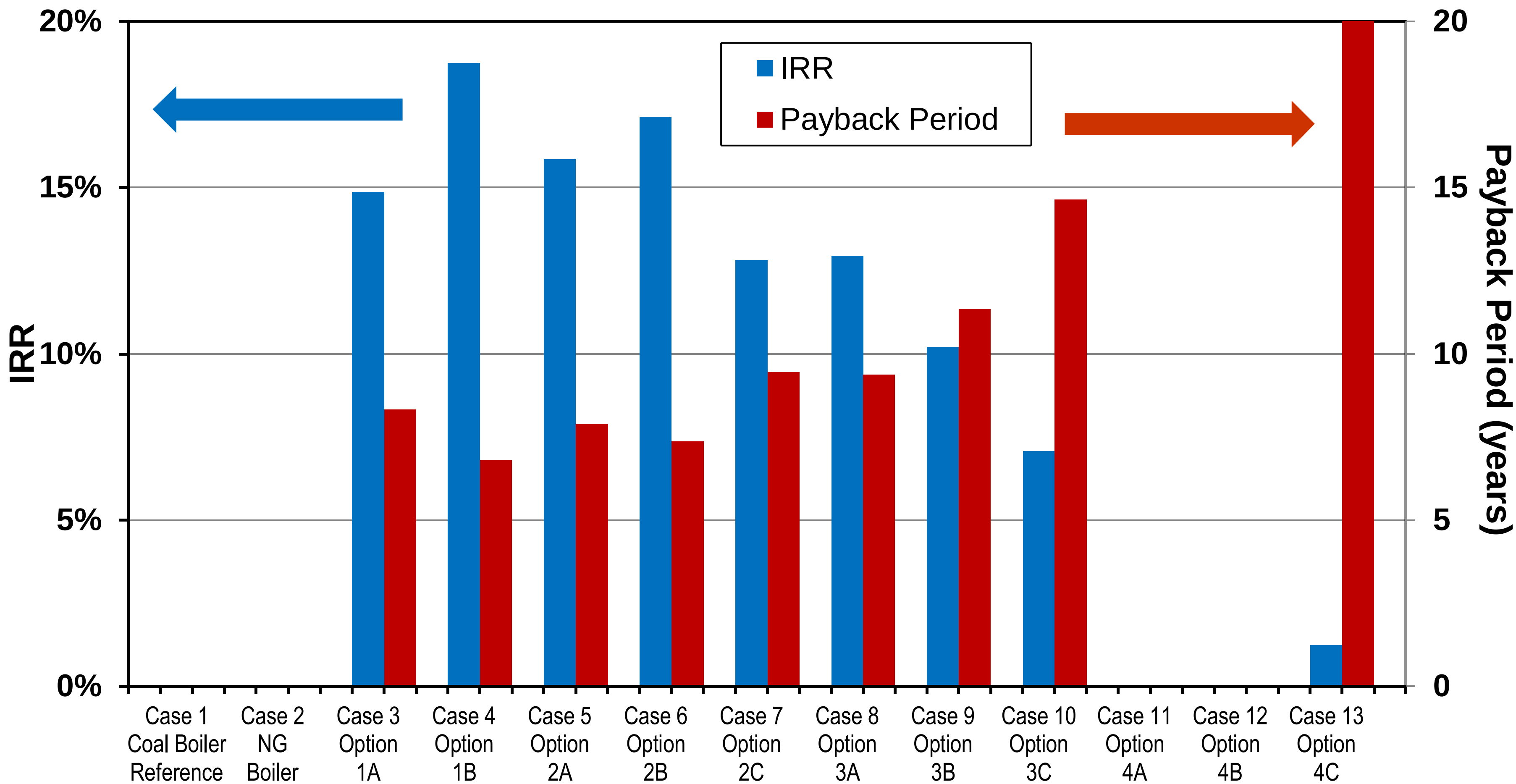
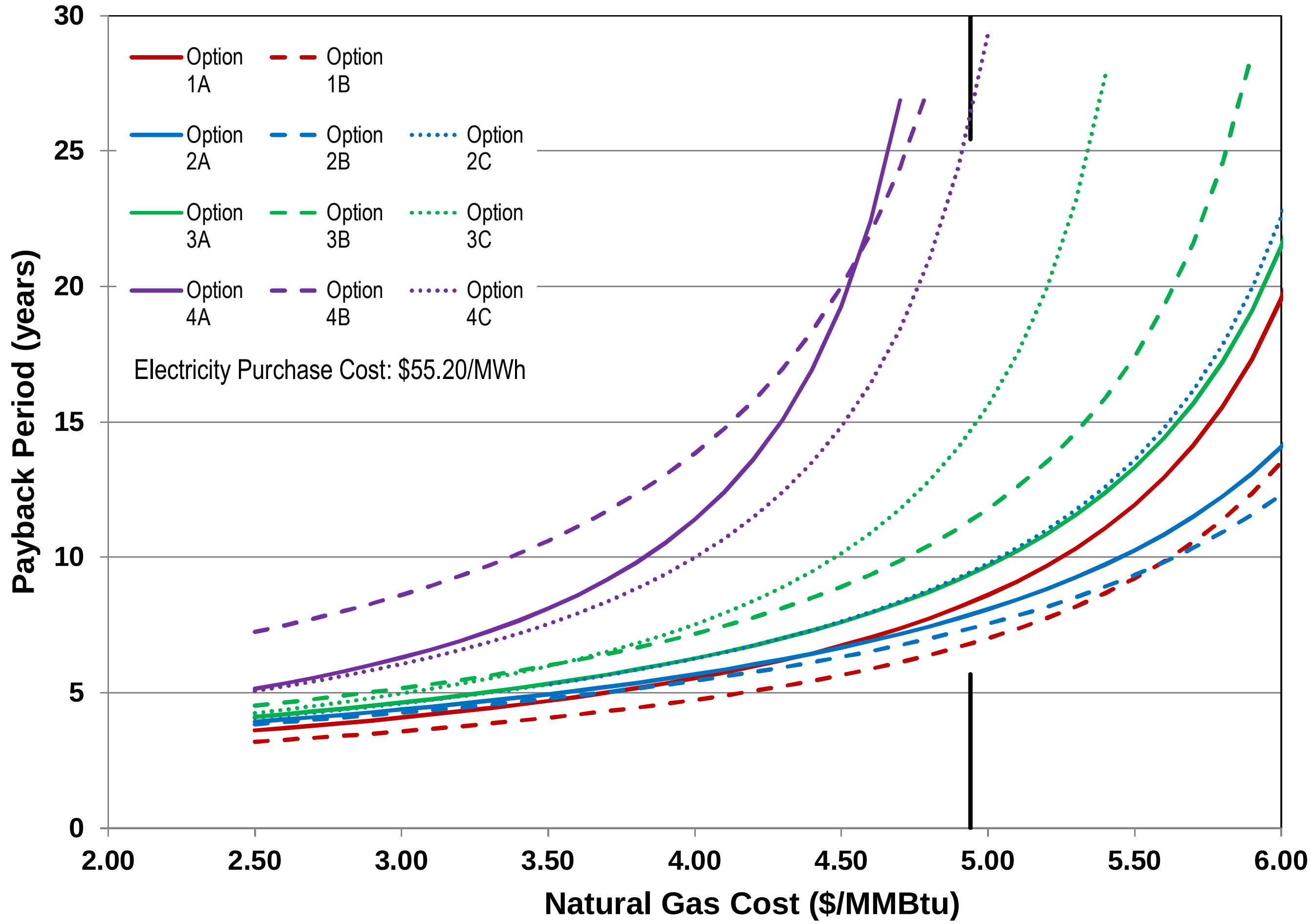
Financial Analysis Results
IRR and Payback Period

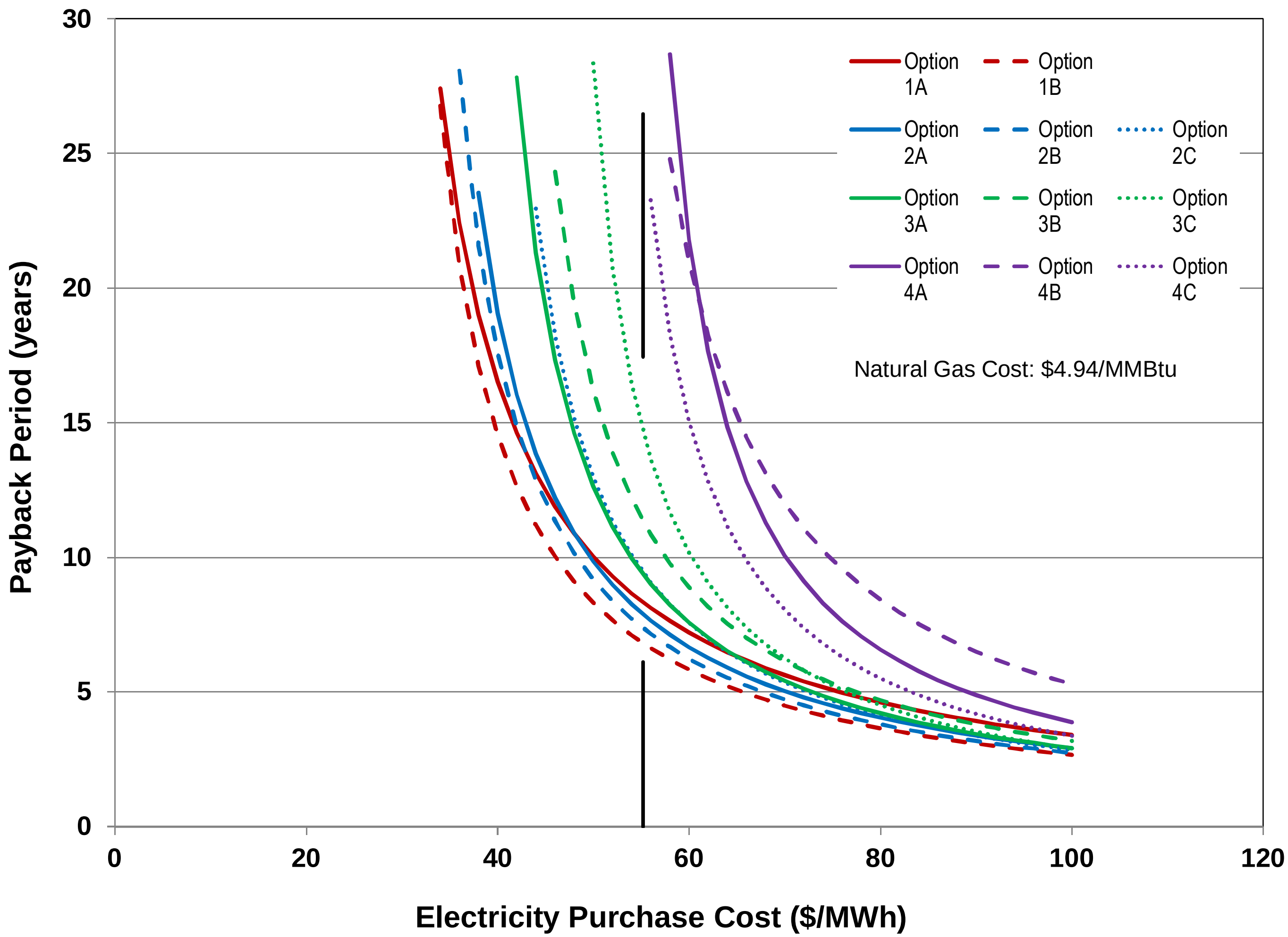


Financial Analysis Basis & Results
Natural Gas Cost Sensitivity



Note: Payback calculated with respect to Coal Case (Reference)

Financial Analysis Basis & Results
Electricity Purchase Cost Sensitivity



Note: Payback calculated with respect to Coal Case (Reference)

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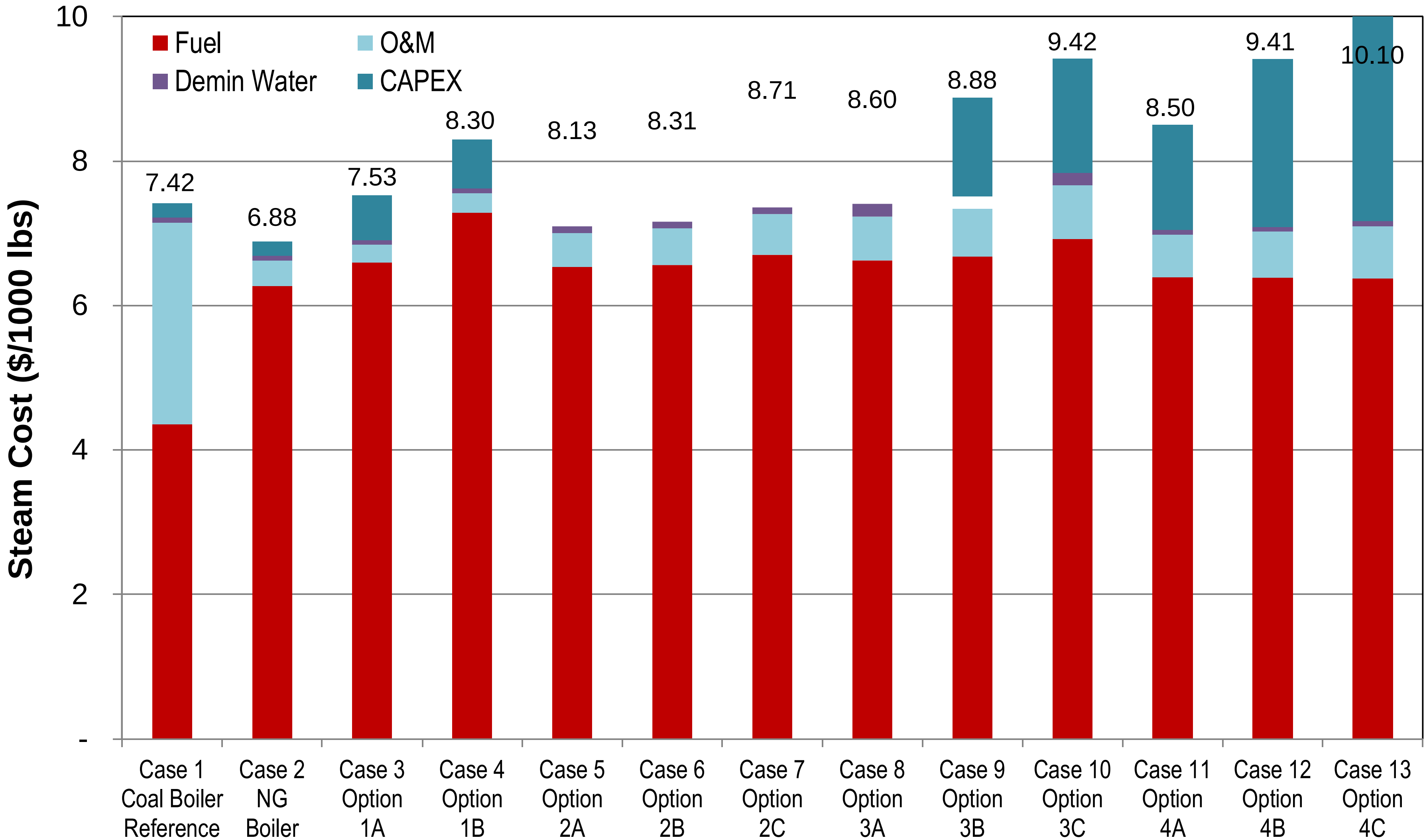
Financial Analysis Basis & Results
Steam Costs



Based on Steam Plant Cost Percentage of 30%.

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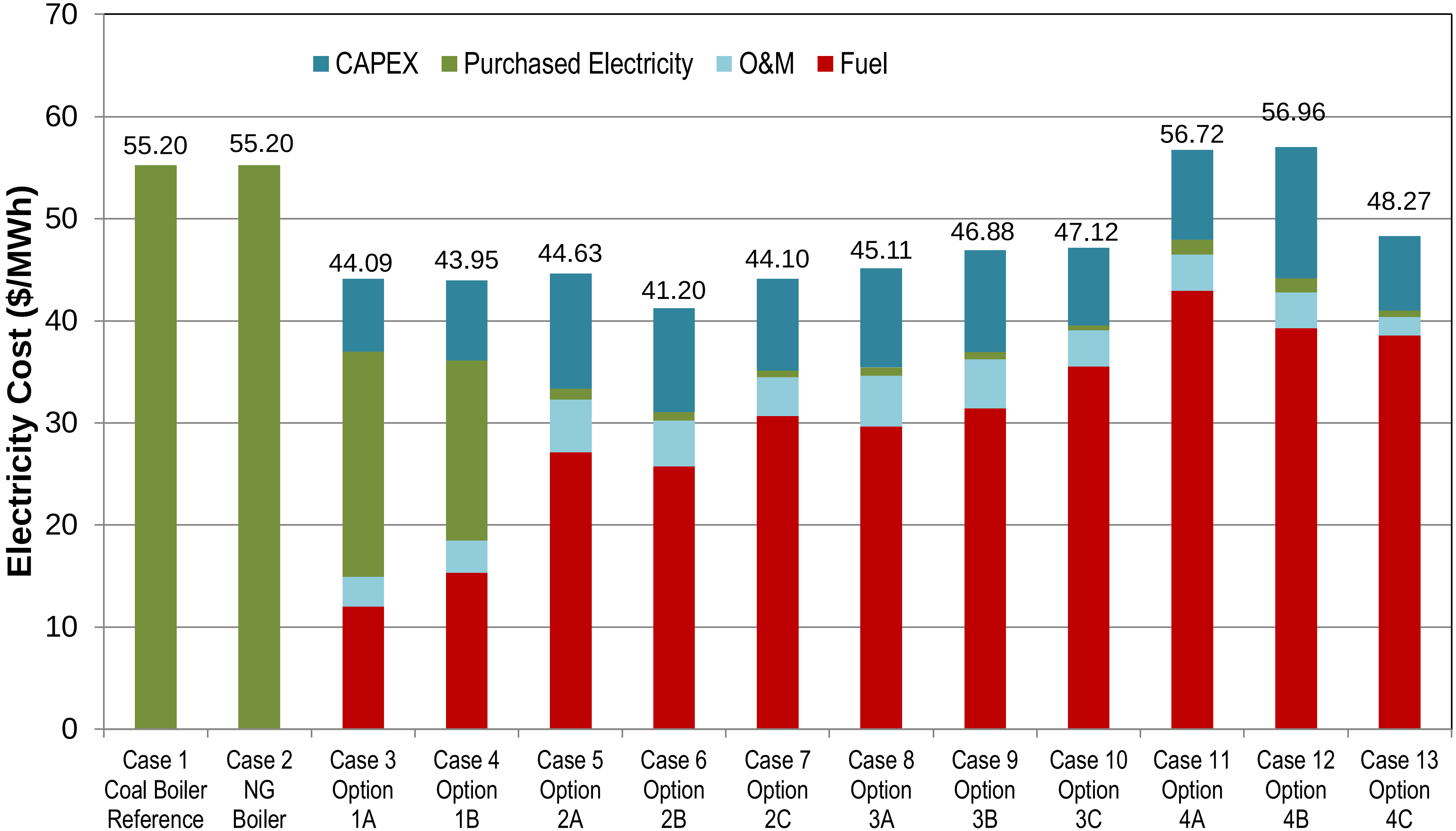
Financial Analysis Basis & Results
Annual Average Electricity Costs



Based on Steam Plant Cost Percentage of 30%.

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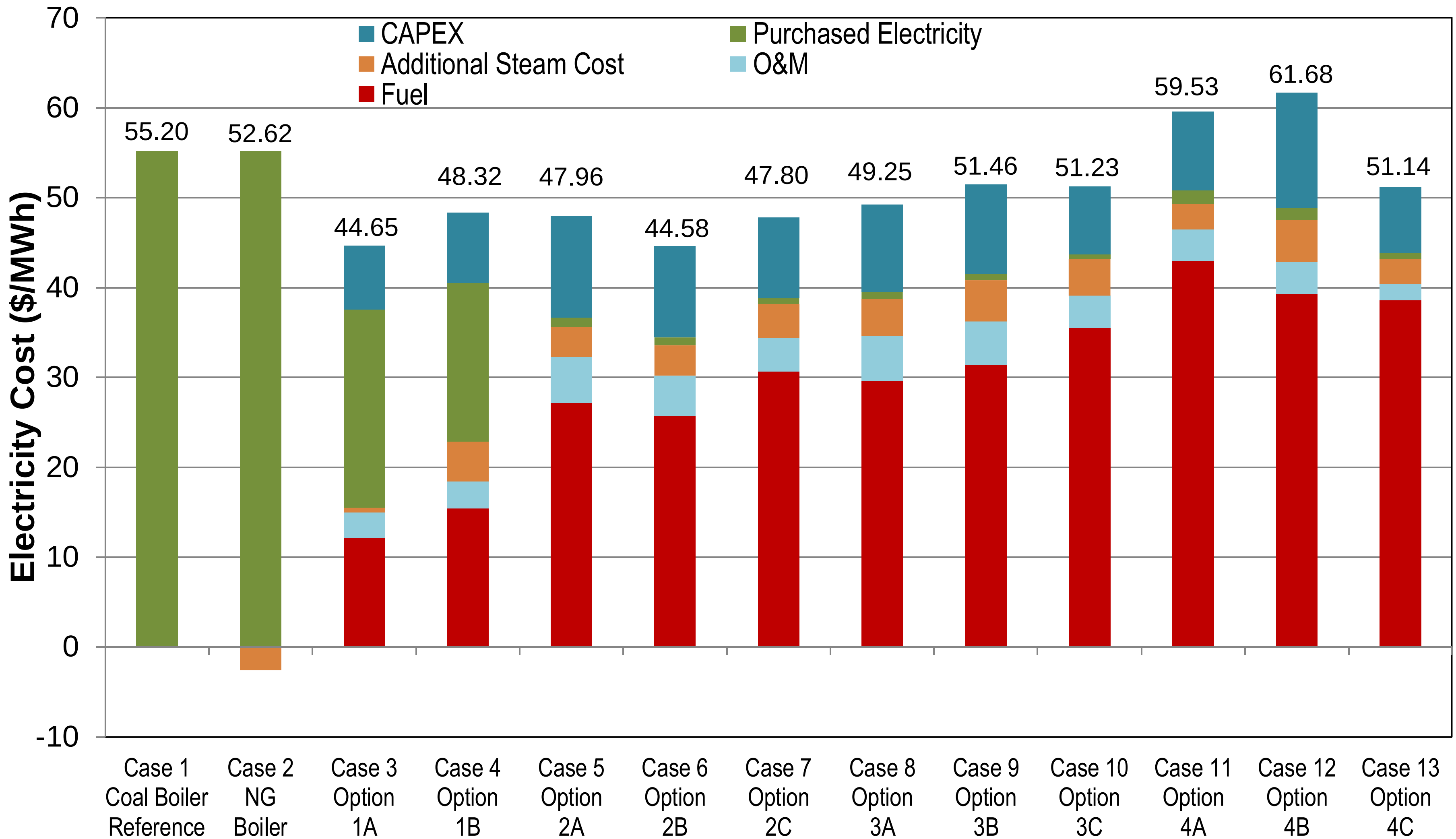
Financial Analysis Basis & Results
Annual Average Electricity Costs



Based on Fixed Steam Price of $7.42/1000 lbs

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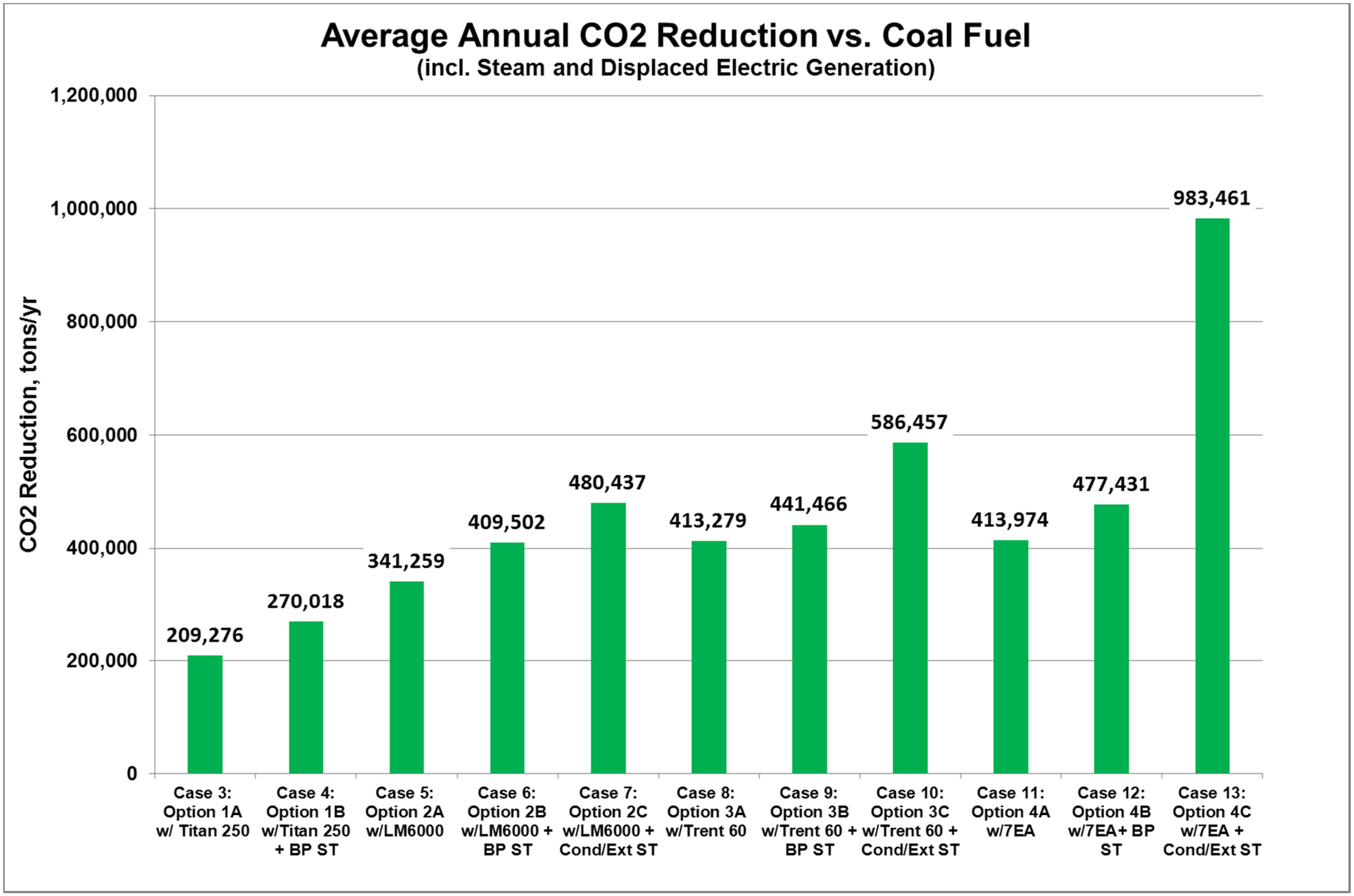
CO2 Emissions Reduction



Displaced electric generation assumed to be Coal Plants with a heat rate of 9,500 BTU/kW-hr HHV.
Assumed CO2 displacement of 2 lbs/kW-hr.

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