Economics of Competing CCS Plants

NATIONAL ENERGY TECHNOLOGY LABORATORY

Kirk LaBarbara
NETL Research General Engineer

Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY

Sub-Activity 11 – Economics of Competing CCS Plants

- Economics of 4 auxiliary plant CCS configurations will be compared against the economics of direct integration, where capture load is provided by parasitic load on the main unit, using PROMOD and PSFM GT:
  - Base plant configuration is a Natural Gas Combined Cycle (NGCC) plant
  - Auxiliary plant for supporting CCS operations, can be Direct Integration, Biomass, Solar, or Grid Support
- This sub-activity will improve the understanding of the best configuration and business pathways that can enable deployment and dispatch of CCS greenfield NGCC Plants with CCS

Economics of Competing CCS Plants

NATIONAL ENERGY TECHNOLOGY LABORATORY

Modeling

- ERCOT 2035 – IHS 2022
- Multiple CCS plant configurations

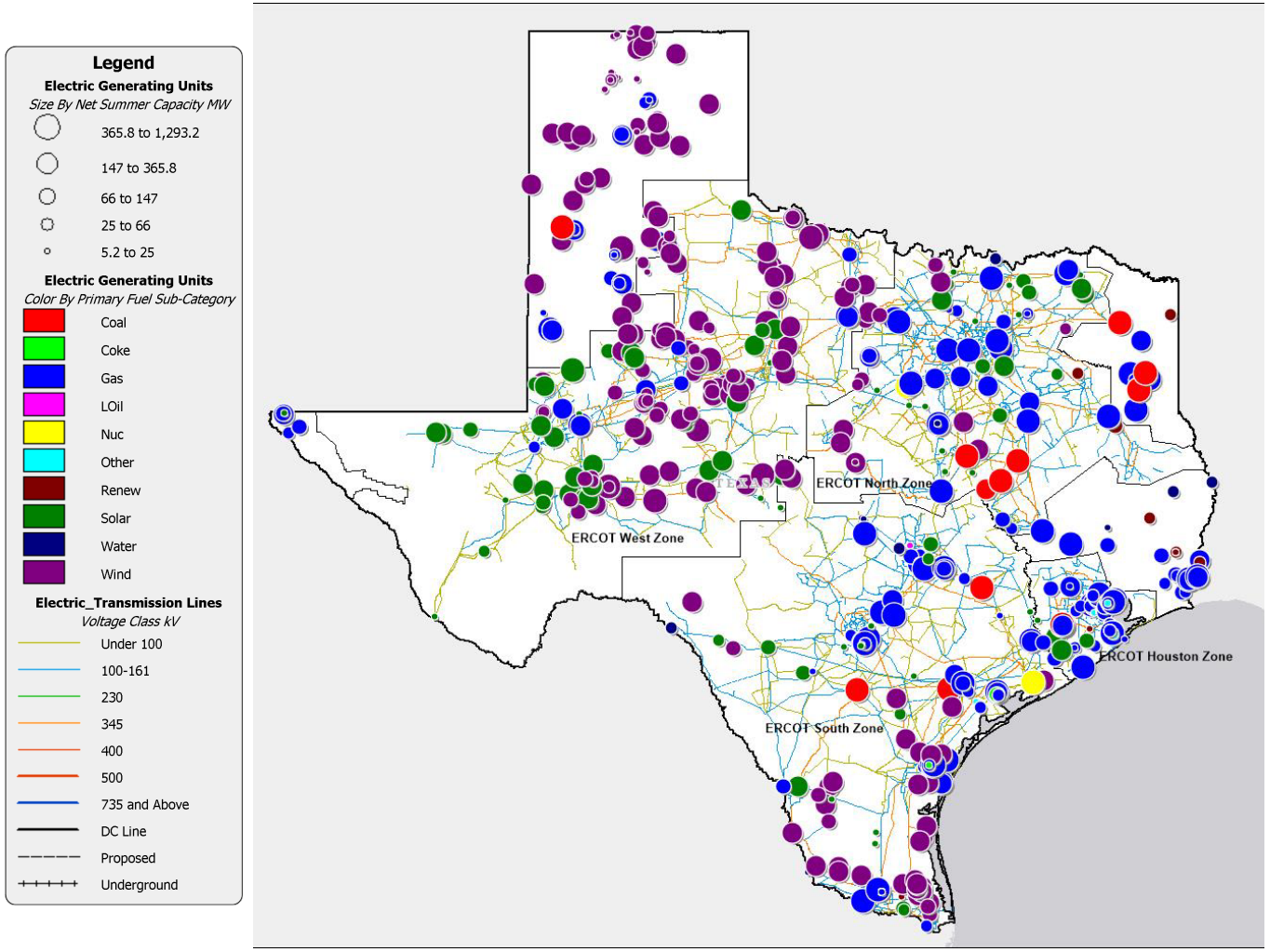
PROMOD

- ERCOT Economic Dispatch
- CCS plant performance, dispatch, and economic results

PSFM-GT

- Plant cost performance data
- Plant internal rate of return

PROMOD Dispatch Modeling



ERCOT 2022 Hitachi Energy Velocity suite Mapping Utility

- Hitachi Energy PROMOD is a Security Constrained Unit Commitment and Economic Dispatch Model
- PROMOD is used to simulate Hourly unit dispatch, zonal and nodal hourly Locational Marginal Pricing (LMP), Transmission congestion, renewable generation and curtailment, and environmental impact.
- Simulation ready data, provided by Hitachi Energy, contains detailed models of regional generation and transmission systems, updated from publicly available and industry sources, and available forecasts.

Scenario Set-up

- Region: ERCOT
  - The ERCOT region was updated to 2035 using the July 2022 IHS predictions
  - ERCOT transmission zone for NGCC plant deployment was chosen based on selection criteria
- Multiple plant configurations were tested against each other, comparing unit dispatch and economic performance
- Hitachi PROMOD Security Constrained Economic Dispatch model was used to run multiple scenarios with a single NGCC plant with carbon capture system in a region in a 2035 configuration of the electric system
- Plant economics were analyzed using PSFM-GT based on PROMOD Unit Performance results

IHS ERCOT

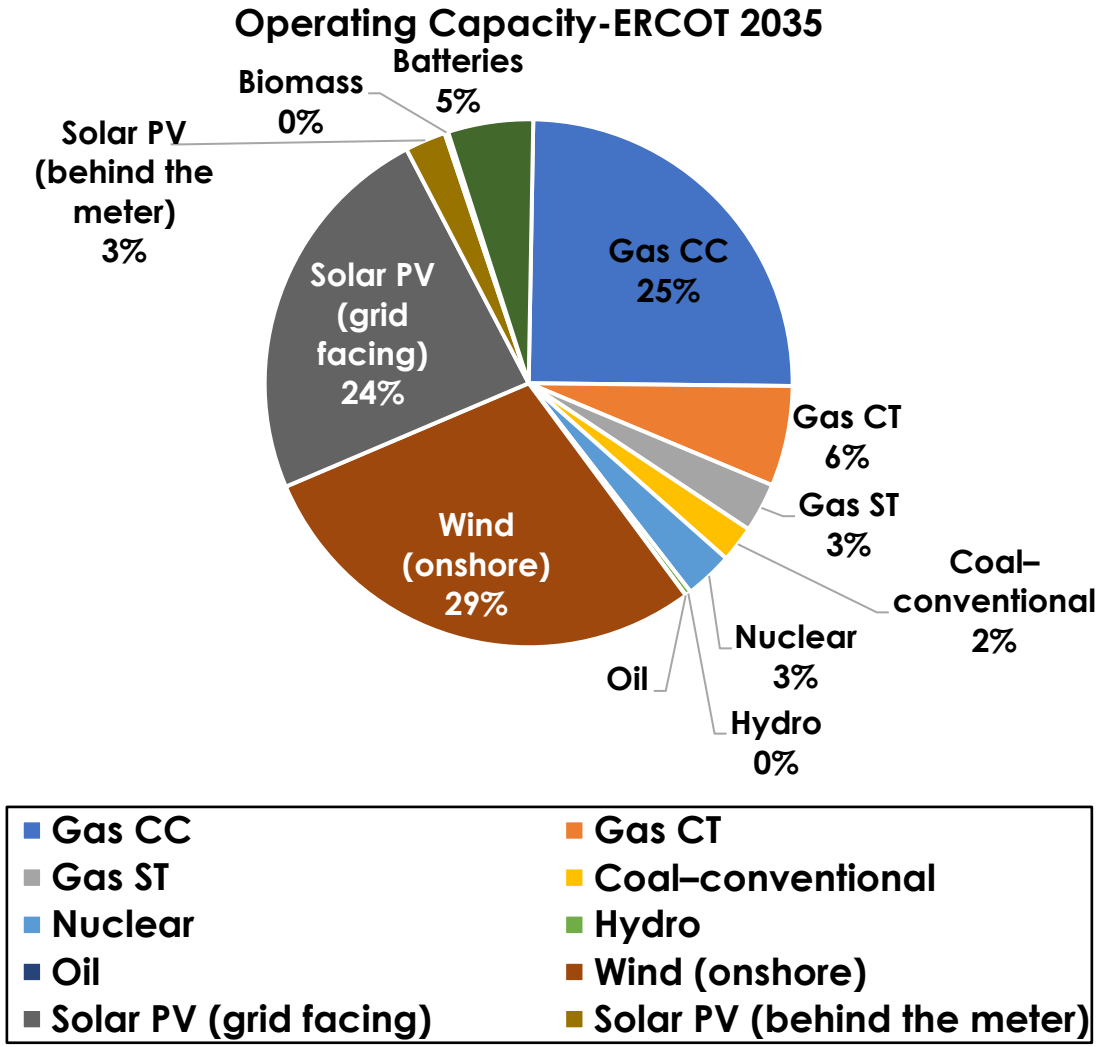
Scenario capacity expansion details

- Existing PROMOD model Updated using July 2022 IHS ERCOT Scenario
- IHS ERCOT from Long Term Market outlook including Capacity expansions planning model through 2050
- IHS model Assumes $10/Ton Carbon tax beginning in 2030, escalating to $17/Tonne by 2035, and $45/Tonne by 2050
- IHS planning forecast model assumes more support is needed to make CCS Viable, and does not deploy it in its planning forecast case
- IHS Fuel pricing forecasts, demand forecasts, Capacity additions and retirements added to Update existing PROMOD model for 2035 Scenario run date

IHS ERCOT

ERCOT-IHS				
Operating capacity (MW) summer year	2019	Capacity percentage	2035	Capacity percentage
Gas CC	33,784	34%	44,517	25%
Gas CT	6,441	6%	10,993	6%
Gas ST	11,794	12%	5,394	3%
Coal–conventional	14,201	14%	3,970	2%
Nuclear	5,150	5%	5,268	3%
Hydro	602	1%	629	0%
Oil	44.7	0%	27	0%
Wind (onshore)	24,797	25%	51,393	29%
Solar PV (grid facing)	2,289	2%	42,475	24%
Solar PV (behind the meter)	483	0%	4,475	3%
Biomass	289	0%	394	0%
Batteries	64	0%	9,329	5%
Total Operating Capacity (MW)	**99,939**	-	**178,863**	-
Energy Demand (GWh)	**383,802**	-	**485,643**	-
Peak Demand (MW)	**74,820**	-	**94,444**	-

2019–2035 ERCOT projected 58% carbon footprint reduction (based on average ERCOT emissions and IHS generation predictions)



NGCC with CCS Baseline Plant

Plant	NGCC with CCS
Type	NETL Plant B32B.97
NGCC Plant Capacity	919 MW
Capture Load	45 MW
CO_2 Capture Rate	97 %
Heat Rate	7.045 MMBtu/MWh
Emission	• NO_X: 0.022 lb/MWh • CO_2: 23 lb/MWh
Costs (Fixed O&M)*	$43.00/kW-Year
Costs (Variable O&M)*	$0.97/MWh
Costs (Fuel)	$4.55/MMBtu

* Values adjusted from NETL Bituminous Baseline to match USoA modeling practices

Plant CCS Incentives

- 45Q incentives under the 2022 IRA increase from $50 to $85/tonne of CO_2 for CO_2 captured from industrial and power generation facilities and stored in saline geologic formations
- Plants are eligible to claim 45Q for **12 years**
- Plant 45Q revenue integration into PROMOD
  - Storage 45Q Incentive: $85/tonne
  - 119-135 lb/MWh CO_2 emissions w/97% capture
  - $27-$31/MWh fuel and VOM price reduction
  - $4.44/MMBtu plant operating cost reduction
  - $4.44/MMBtu reduction in Fuel cost to the modeled CCS plant

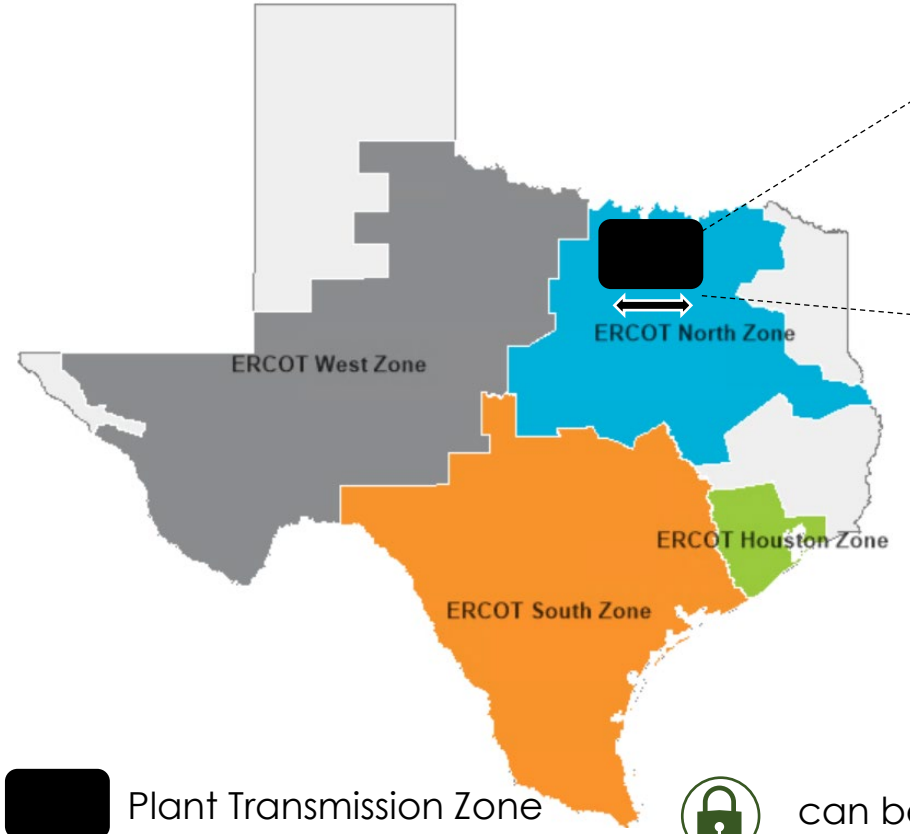
Auxiliary CCS Example Plant Configuration

NATIONAL ENERGY TECHNOLOGY LABORATORY

PROMOD Model (ERCOT Transmission Zones)

Selected NGCC Plant

Updated PROMOD Model (ERCOT Transmission Zones + Plant Transmission Zone)



Plant Transmission Zone

Transmission Link

Plant Transmission Zone

Plant Capture Load

CCS Plant

CCS Plant

To Grid

Main NGCC Unit

Carbon Capture Auxiliary Unit

CC Auxiliary Unit can be NGCC or Biomass or PV Solar or Grid

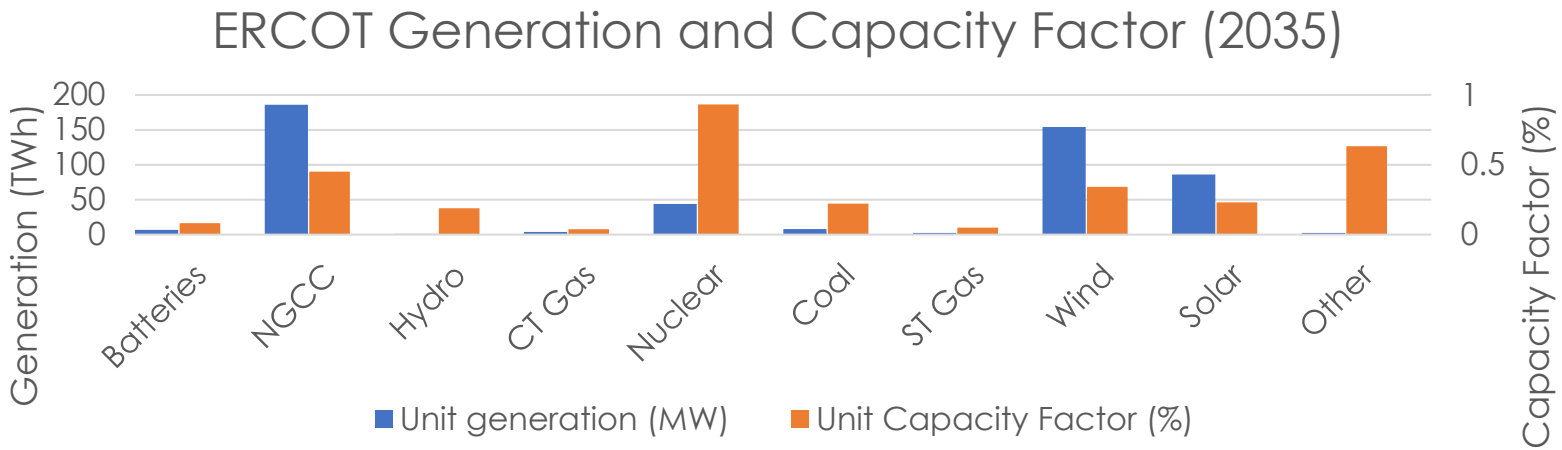
Plant Configurations

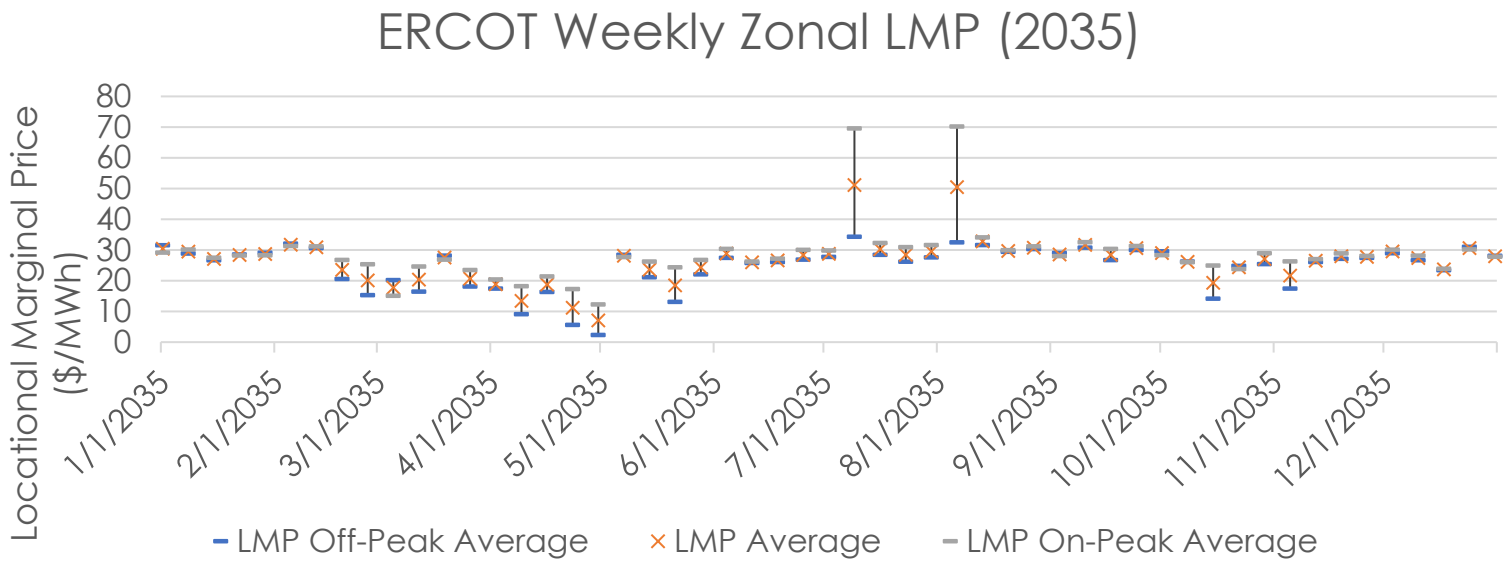
Configurations	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Auxiliary Plant Configuration	Direct Integration	Direct Integration	Biomass Auxiliary	Solar Auxiliary	Grid Support Auxiliary
Plant Size	873 MW	873 MW	992 MW	992 MW	992 MW
Carbon Capture	Always on	Dispatchable	Dispatchable	Dispatchable	Dispatchable
- Capture load	n/a	45 MW	45 MW	115 MW	115 MW
- Capture load support	n/a	n/a	45 MW Biomass plant (additional 70 MW steam load)	115 MW Solar PV plant with makeup energy from grid	Energy from grid

Plant Cost Accounting

- Plant 2 (direct integration) dispatchable costs are accounted for in Main Plant.
  - Plant VOM: $0
  - Plant FOM: $0
  - Plant Fuel cost $0
- Plant 3 (Biomass): Source EIA AEO 2022
  - TOC: $4,525/KW
  - Plant VOM: $5/MWh
  - Plant FOM: $131/Kw-year
  - Plant Fuel cost Biomass cost projection
  - Must Run: Yes
- Plant 4 (Solar): Source IHS summer 2022
  - TOC: $667/KW
  - Plant VOM: $1.08/MWh*
  - Plant FOM: $10/Kw-year
  - Must Run: Yes

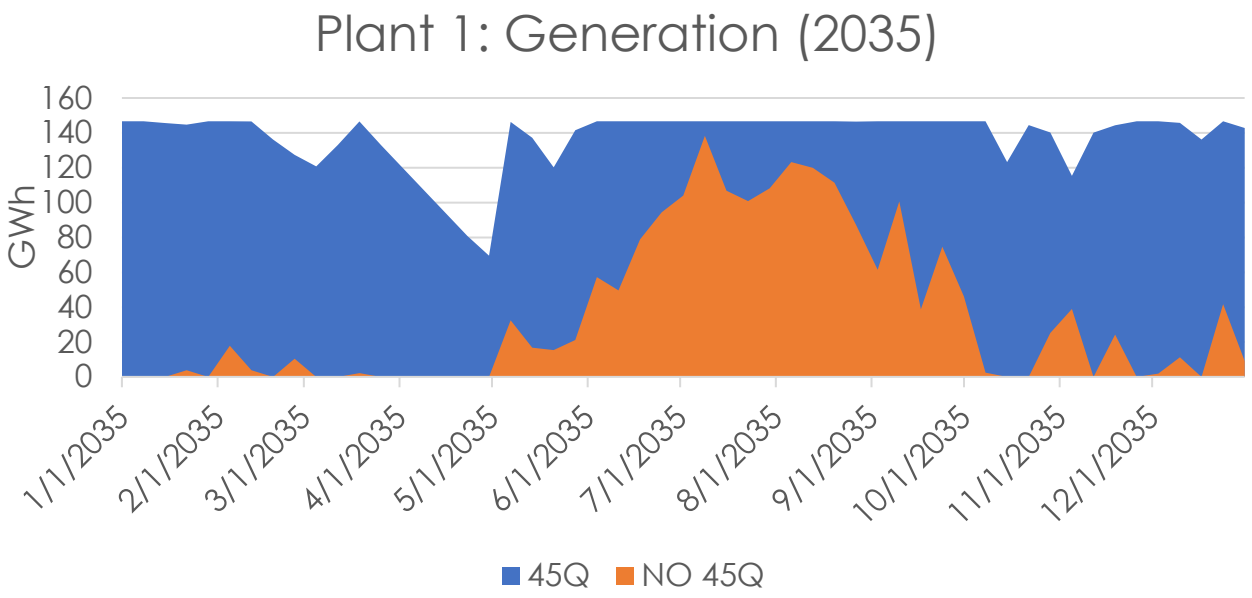
ERCOT System Dispatch Results

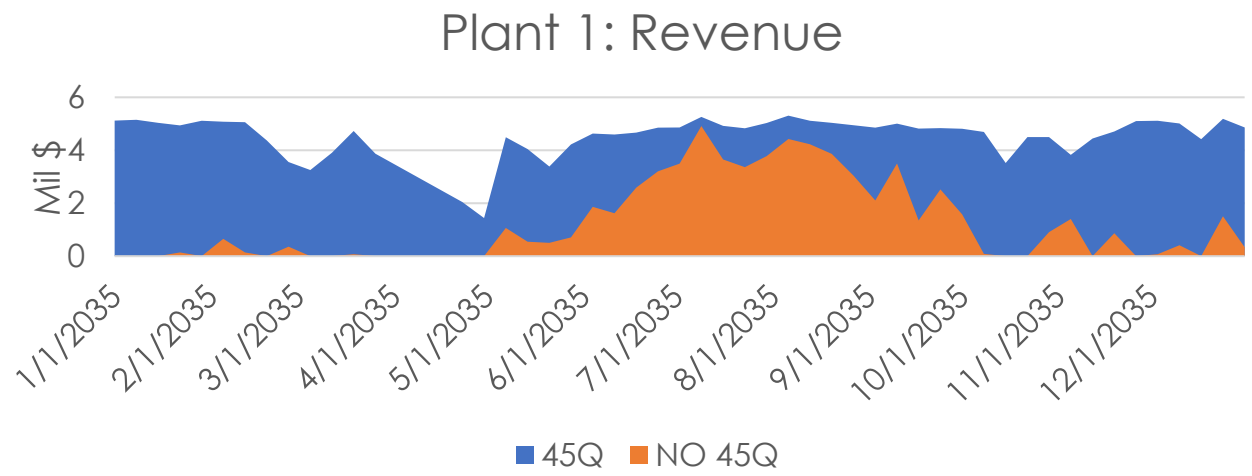




- The IHS 2035 ERCOT system sees low average system LMP most of the year.
- The system is supported by a large renewable capacity providing 48% of the total generation for the year.
- NGCC units provide 37% of the total generation for the year.

Plant 1: 45Q comparison



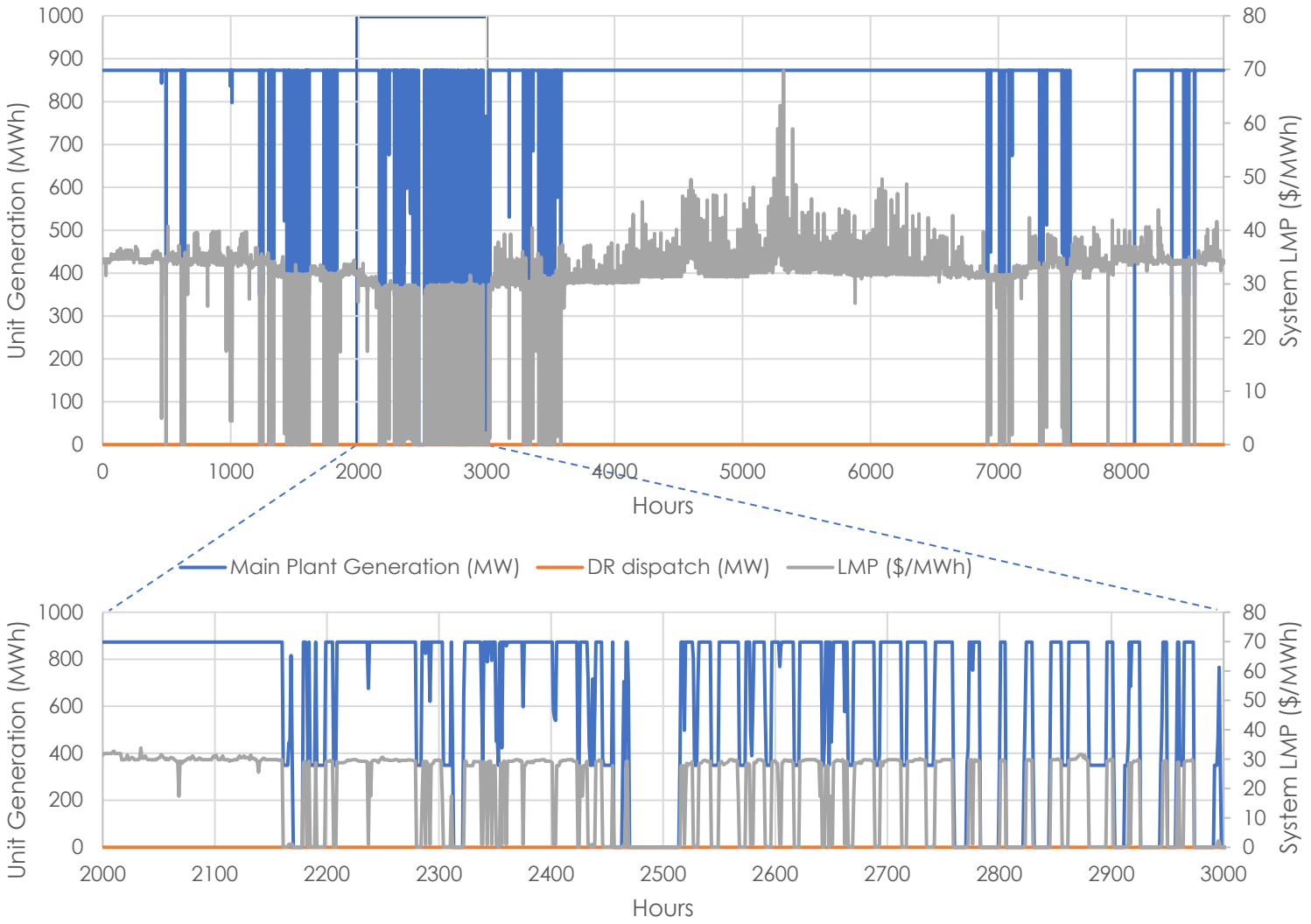


- The addition of the 45Q Revenue reduces the Plant Fuel cost from an average of $4.62/MMBTU to $0.21/MMBtu
- Dispatch cost reduction due to lower fuel prices drastically increases plant operation, from 24.5% CF, during mostly summer months, to 87.9% CF running the whole year.
- Plant revenues reflect the increased run time, showing greatly increased revenue during times outside the summer peak.

Dispatch Results: Plant 1

Plant 1	Main Unit	Aux Unit	Total
Plant size (MW)	873	45	873
HR (MMBtu/MWh)	7.045	-	7.045
CO_2 (Lbs/MMBtu)	115	-	112
Captured CO_2 (Lbs/MMBtu)	-	-	109
Emitted CO_2 (Lbs/MMBtu)	-	-	3.2
NOx (Lbs/MMBtu)	0.004	0	0.02
Variable O&M ($/MWh)	$0.97	0	$0.97
Fixed O&M ($/KW-Year)	$43	0	$43
45Q ($/MMBtu)	-	-	$4.44
CCS Dispatch Threshold ($/MWh)	-	-	$606
TOC ($/KW)	$2063	$0	$2063
Unit Generation (GWh)	-	-	6729.5
Unit Capacity Factor (%)	-	-	87%
Hours Online	-	-	7,944
Makeup Energy (GWh)	-	-	0
Makeup Energy Cost ($)	-	-	$0

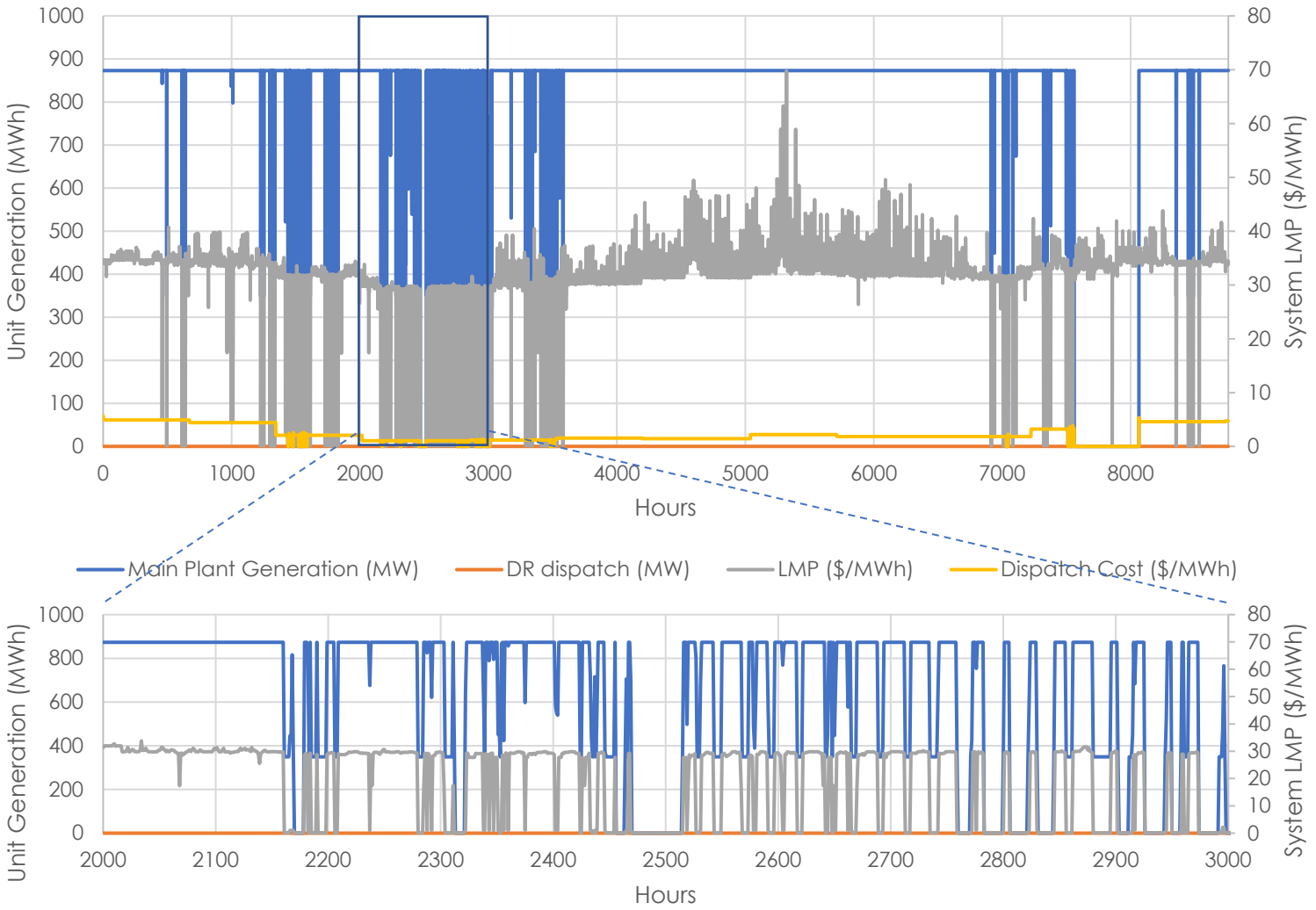
Direct CCS Integration: Non-Dispatchable



Dispatch Results: Plant 2

Plant 2	Main Unit	Aux Unit	Total
Plant size (MW)	873	45	873
HR (MMBtu/MWh)	7.045	-	7.045
CO_2 (Lbs/MMBtu)	115	-	112
Captured CO_2 (Lbs/MMBtu)	-	-	109
Emitted CO_2 (Lbs/MMBtu)	-	-	3.2
NOx (Lbs/MMBtu)	0.004	0	0.02
Variable O&M ($/MWh)	$0.97	0	$0.97
Fixed O&M ($/KW-Year)	$43	0	$43
45Q ($/MMBtu)	-	-	$4.44
CCS Dispatch Threshold ($/MWh)	-	-	$606
TOC ($/KW)	$2063	$0	$2063
Unit Generation (GWh)	-	-	6729.5
Unit Capacity Factor (%)	-	-	87%
Hours Online	-	-	7944
Makeup Energy (GWh)	-	-	0
Makeup Energy Cost ($)	-	-	$0

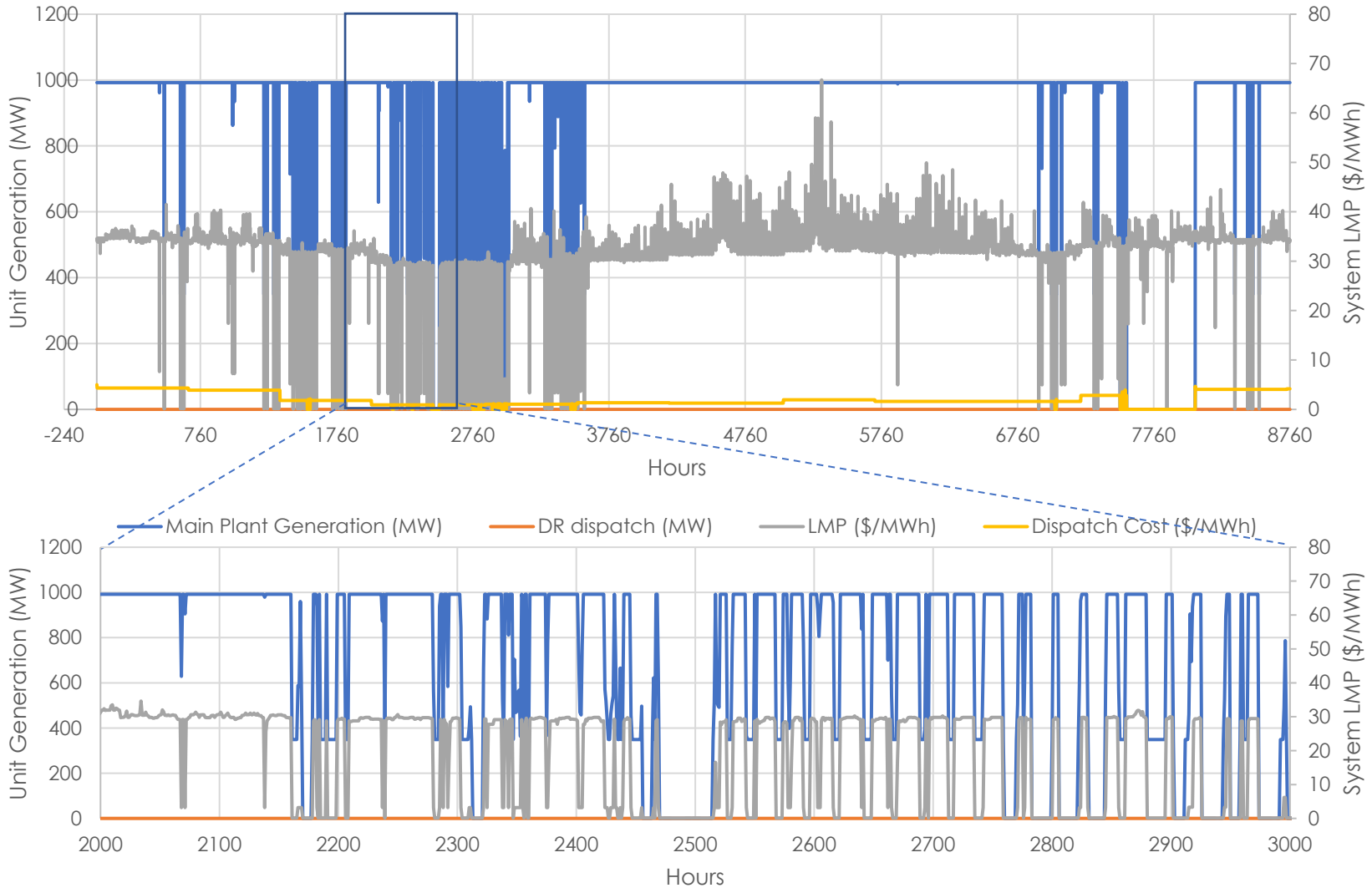
Direct CCS Integration: Dispatchable



Dispatch Results: Plant 3

Plant 3	Main Unit	Aux Unit	Total
Plant size (MW)	992	45(115)	
HR (MMBtu/MWh)	6.196	13.5	6.196 (34.5)
CO_2 (Lbs/MMBtu)	119	208	171.5378
Captured CO_2 (Lbs/MMBtu)			166.39
Emitted CO_2 (Lbs/MMBtu)			5.15
NOx (Lbs/MMBtu)	0.001	0.0009	0.001227
Variable O&M ($/MWh)	0.004	0.08	0.024207
Fixed O&M ($/KW-Year)	$0.85	$5.00	$1.47
45Q ($/MMBtu)	$37.92	$131.00	$54.05
CCS Dispatch Threshold ($/MWh)			$6.42
TOC ($/KW)			$876.50
Plant size (MW)	$1,815.00	$3,740.00	$2,333.57
Unit Generation (GWh)	-	-	7628.8
Unit Capacity Factor (%)	-	-	87%
Hours Online	-	-	7980
Makeup Energy (GWh)	-	-	$0
Makeup Energy Cost ($)	-	-	$0

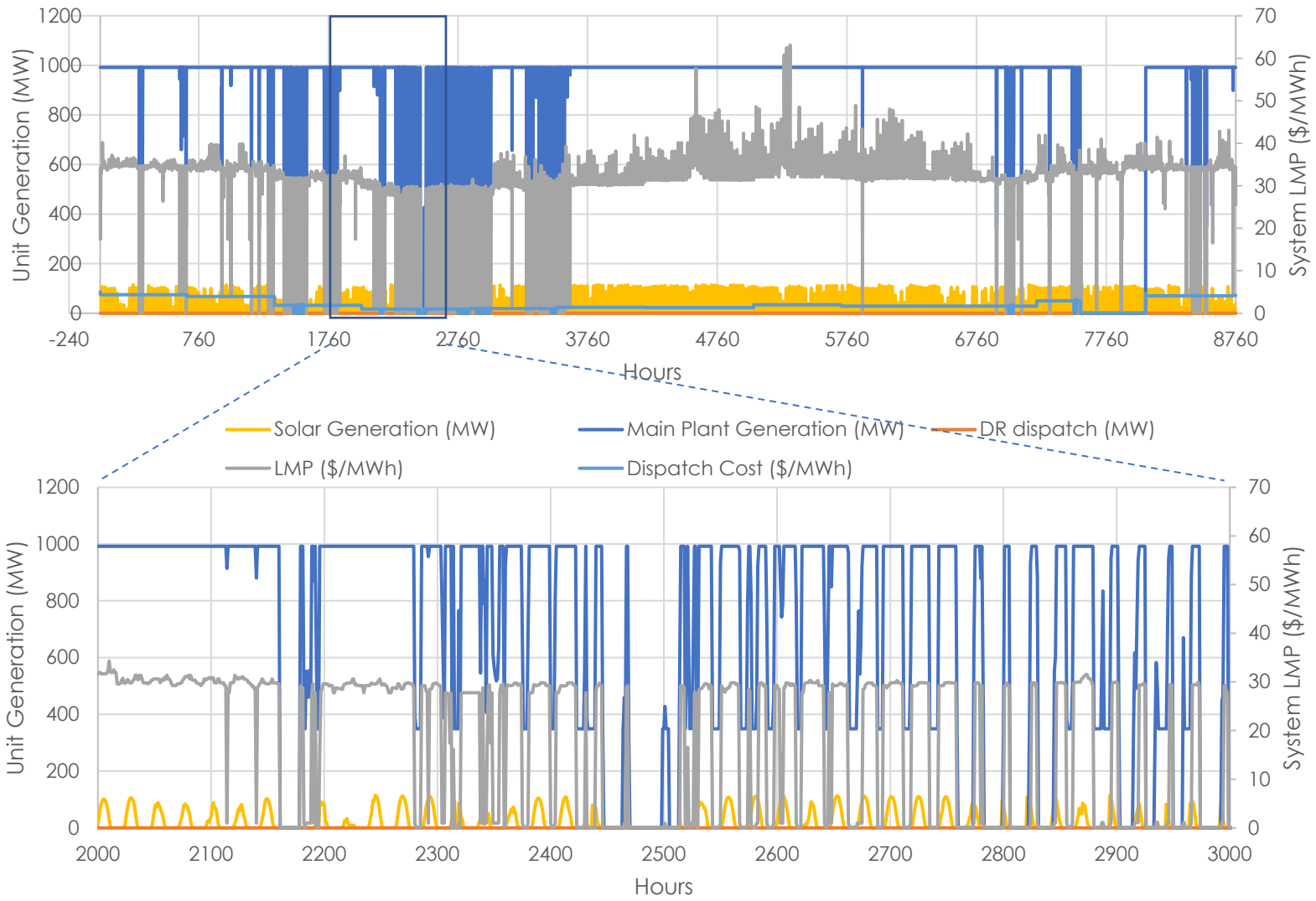
Biomass Auxiliary Unit



Dispatch Results: Plant 4

Plant 4	Main Unit	Aux Unit	Total
Plant size (MW)	992	115	992
HR (MMBtu/MWh)	6.196	-	6.196
CO_2 (Lbs/MMBtu)	119		119
Captured CO_2 (Lbs/MMBtu)			115.43
Emitted CO_2 (Lbs/MMBtu)			3.57
SO_2 (Lbs/MMBtu)	0.001		0.001
NOx (Lbs/MMBtu)	0.004		0.004
Variable O&M ($/MWh)	$0.85	$1.08	$0.90
Fixed O&M ($/KW-Year)	$37.92	$10	$39.08
45Q ($/MMBtu)			$4.44
CCS Dispatch Threshold ($/MWh)			$237.31
TOC ($/KW)	$1,815	$667	$1,892
Unit Generation (GWh)	-	-	7631.7
Unit Capacity Factor (%)	-	-	87%
Hours Online	-	-	7965
Makeup Energy (GWh)	-	-	783
Makeup Energy Cost ($)	-	-	$21,647,000

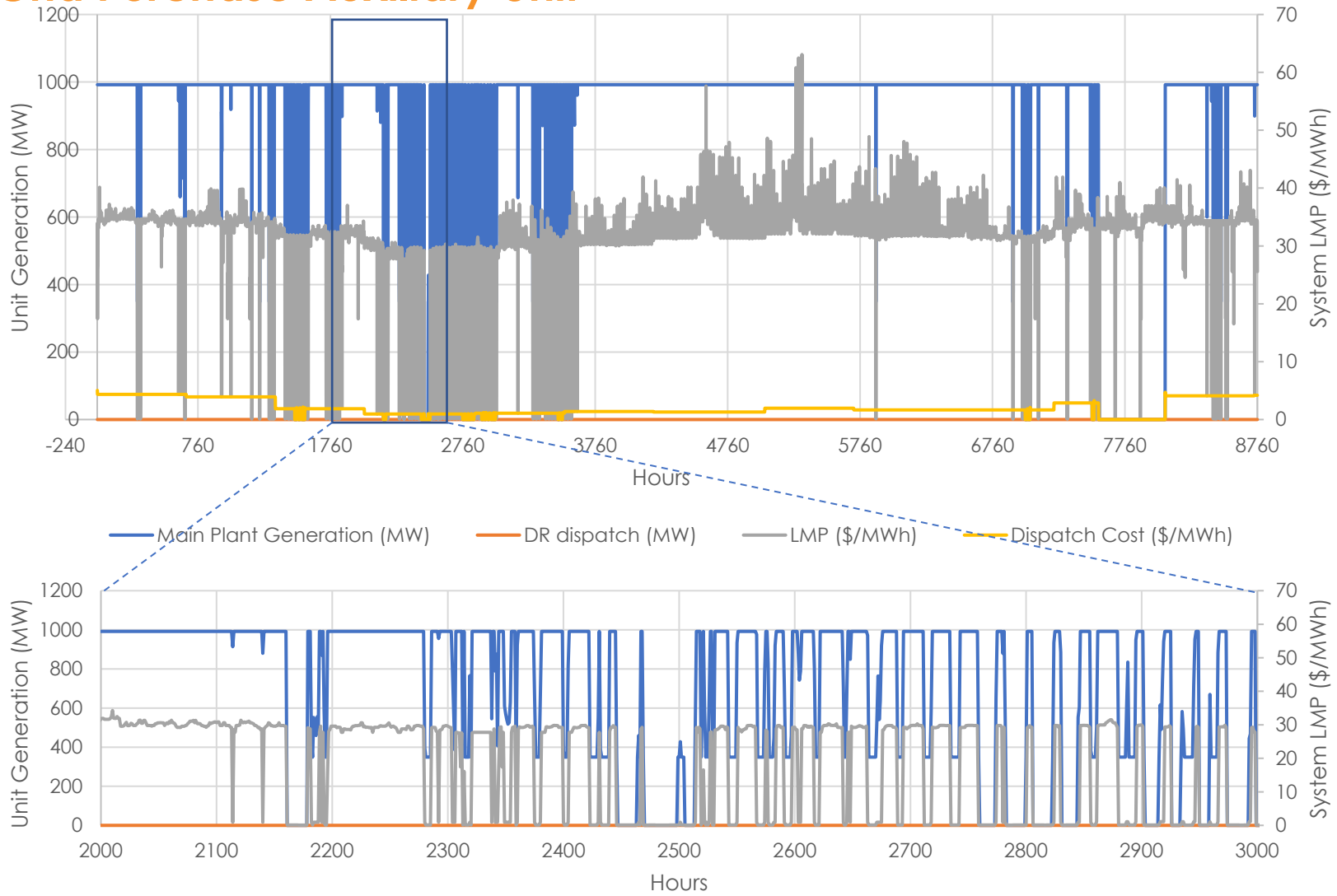
Solar Auxiliary Unit



Dispatch Results: Plant 5

Plant 5	Main Unit	Aux Unit	Total
Plant size (MW)	992	115	992
HR (MMBtu/MWh)	6.196	-	6.196
CO_2 (Lbs/MMBtu)	119	-	119
Captured CO_2 (Lbs/MMBtu)	-	-	115.43
Emitted CO_2 (Lbs/MMBtu)	-	-	3.57
SO_2 (Lbs/MMBtu)	0.001	-	0.001
NOx (Lbs/MMBtu)	0.004	-	0.004
Variable O&M ($/MWh)	$0.85	-	$0.85
Fixed O&M ($/KW-Year)	$37.92	-	$37.92
45Q ($/MMBtu)	-	-	$4.44
CCS Dispatch Threshold ($/MWh)	-	-	$237.31
TOC ($/KW)	$1,815	-	$1,815
Unit Generation (GWh)	-	-	7436.5
Unit Capacity Factor (%)	-	-	85%
Hours Online	-	-	7790
Makeup Energy (GWh)	-	-	895.5
Makeup Energy Cost ($)	-	-	$28,604,000

Grid Purchase Auxiliary Unit



Unit Cashflow analysis

Overview and Setup

- Power System Financial Model – Grid Technologies (PSFM-GT): provides a financial evaluation of user-defined technologies.
- Table shows Model financial input calculations for all 5 units
- Unit specific inputs come from PROMOD model dispatch results

Category	Attribute	Value	Source
Market	Monthly operational capacity	100%	Default
	Months capacity provided	12	Default
Financial	Return on Equity	10%	Default
	Debt financing	55%	Default
	Federal Tax	21%	Default
	State Tax	0% (Texas)	Default
	MACRS	20 years	Default
	ITCs/PTCs	Unused	-
	Construction period	2 years	Assumption
Financial	Life of Technology = Study period	30 years	BBR4: B31B, NGCC w/capture
	Escalation rate	2%	Default

Unit Cashflow analysis

Normal Unit Dispatch Results Input

Attribute	NGCC Plant	Wind Plant	Solar Plant
Project capacity (MW)	1097	244.5	382
Outlay per unit capacity ($/KW)	$970	$1,278	$667
Heat Rate (BTU/KWh)	6,720	-	-
Variable O&M Costs ($/KWh)	$0.0017	$0.0000	$0.0000
Fixed O&M Costs ($/KW-year)	$26.00	$42.00	$19.00
Annual Energy Capacity Factor	62.50%	47.80%	23.50%
Energy or Fuel Charge ($/KWh)	$0.032	$0.028	$0.030
Fuel Costs ($/MMBtu)	$4.56	-	-

Attribute	NGCC Plant	Wind Plant	Solar Plant
Internal Rate of Return (IRR)	Infeasable	6.51%	13.58%
Net Present Value (NPV)	($712,355,652)	($35,074,926)	$21,972,092
After Tax Weighted Average Cost of Capital (ATWACC)	6.50%	6.50%	6.50%
Financially Feasible?	No	Yes	Yes
Profitable?	Yes	No	Yes

- Solar Plant only plant feasible and profitable Without carbon tax

Unit Cashflow analysis

CCS Unit Dispatch Results Input

Attribute	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Project capacity (MW)	873	873	992	992	992
Outlay per unit capacity ($/KW)	$2,063	$2,063	$2,333	$1,892	$1,815
Heat Rate (BTU/KWh)	7,045	7,045	6,196	6,196	6,196
Variable O&M Costs ($/KWh)	$0.0041	$0.0041	$0.0042	$0.0037	$0.0036
Fixed O&M Costs ($/KW-year)	$54.07	$54.07	$63.69	$48.72	$47.56
Annual Energy Capacity Factor	87.90%	87.90%	92.30%	87.80%	87.96%
45Q Tax Credit ($/MMBtu)	$4.44	$4.44	$6.42	$4.44	$4.44
Energy or Fuel Charge ($/KWh)	$0.032	$0.032	$0.032	$0.032	$0.032
Fuel Costs ($/MMBtu)	$0.21	$0.21	$0.74	$0.71	$0.85

- Unit Fuel costs include makeup energy purchased from the grid to support capture for plants 4 and 5

Unit Cashflow analysis

Results

Attribute	Plant 1: Direct Integration	Plant 2: Direct Integration	Plant 3: Biomass	Plant 4: Solar PV	Plant 5: Grid Purchase
Internal Rate of Return (IRR)	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible
Net Present Value (NPV)	($620,449,747)	($620,449,747)	($1,245,801,244)	($710,660,483)	($704,384,187)
After Tax Weighted Average Cost of Capital (ATWACC)	6.70%	6.70%	6.70%	6.70%	6.70%
Financially Feasible?	No	No	No	No	No
Profitable?	No	No	No	No	No

Takeaways:

- Projects are financially infeasible even with 45Q credits under current assumptions.
- Additional revenue sources are needed to make the project profitable at ROE=10%.

Greenfield Plant W/CCS

No 45Q sunset

- Plant 2: Direct integration CCS
- Assumptions:
  - Plant is able to claim 45Q credit for full 30 years
- Project does not satisfy 10% IRR requirement in Base scenario

Attribute	Plant 1
Project capacity (MW)	873
Outlay per unit capacity ($/KW)	$2,063
Heat Rate (BTU/KWh)	7,045
Variable O&M Costs ($/KWh)	$0.0041
Fixed O&M Costs ($/KW-year)	$54.07
Annual Energy Capacity Factor	87.90%
45Q Tax Credit ($/MMBtu)	$4.44
Energy or Fuel Charge ($/KWh)	$0.032

Attribute	Brownfield Plant Plant
Internal Rate of Return (IRR)	6.93%
Net Present Value (NPV)	($276,054,814)
After Tax Weighted Average Cost of Capital (ATWACC)	6.70%
Financially Feasible?	Yes
Profitable?	No

Brownfield Plant W/CCS

Dispatch results and Financial Analysis

- NETL B32 BR 97 Plant retrofit case
- Assumptions:
  - Retrofit 20 year old NGCC plant
  - Fully paid capital costs
  - 15 year life of project after retrofits
- Project does not satisfy 10% IRR requirement in Base scenario

Attribute	Brownfield Plant
Project capacity (MW)	867
Outlay per unit capacity ($/KW)	$987
Heat Rate (BTU/KWh)	7,091
Variable O&M Costs ($/KWh)	$0.0041
Fixed O&M Costs ($/KW-year)	$54.07
Annual Energy Capacity Factor	83.50%
Energy or Fuel Charge ($/KWh)	$0.033
Fuel Costs ($/MMBtu)	$0.28

Attribute	Brownfield Plant Plant
Internal Rate of Return (IRR)	8.17%
Net Present Value (NPV)	($25,198,726)
After Tax Weighted Average Cost of Capital (ATWACC)	6.70%
Financially Feasible?	Yes
Profitable?	No

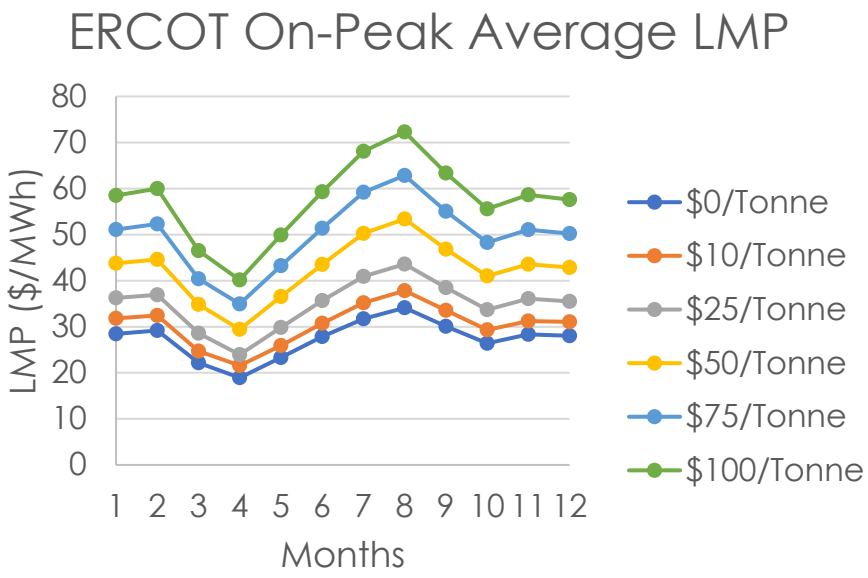
Plant dispatch Results Takeaways

- Lower system LMP in the 2035 IHS ERCOT system is driven by a large percentage of renewable generation
- The 45Q incentive changes the dispatch cost of plants by reducing fuel cost to an average $0.21/MMBtu, low enough to raise plant CF to 88%
- 45Q incentive claimable for only 12 years
- Despite running at a high CF, all plants remain at a negative NPV in the modeled system, and will require additional revenue streams
- Retrofit NGCC plant with Parasitic load supplying capture load has the Best NPV, Greenfield NGCC with integrated capture and the solar Auxiliary plant being the next closest

Carbon Tax Sensitivities

Scenario Results

- 5 Carbon tax scenarios were run using PROMOD to add CO2 emissions costs on all thermal units in the model
  - $10/Tonne, $25/Tonne, $50/Tonne, $75/Tonne, and $100/Tonne
  - Plants:
    - Greenfield NGCC W/ Direct Integration
    - Brownfield NGCC W/ Direct Integration Retrofit
    - Unabated NGCC Unit
    - Wind Plant
    - Solar Plant



- Carbon Tax increases Thermal unit Dispatch costs, increasing System LMP

Carbon Tax Sensitivities

Wind Plant

- 244 MW Wind plant
- NPV Breakeven point is at $12/Tonne CO2

Attribute	Carbon Tax: $10/Tonne	Carbon Tax: $25/Tonne	Carbon Tax: $50/Tonne	Carbon Tax: $75/Tonne	Carbon Tax: $100/Tonne
Internal Rate of Return (IRR)	9.65%	12.99%	19.55%	27.01%	35.83%
Net Present Value (NPV)	($3,453,429)	$28,717,217	$87,501,839	$145,763,488	$203,949,270
After Tax Weighted Average Cost of Capital (ATWACC)	6.70%	6.70%	6.70%	6.70%	6.70%
Financially Feasible?	No	Yes	Yes	Yes	Yes
Profitable?	No	Yes	Yes	Yes	Yes

Carbon Tax Sensitivities

Solar Plant

- 382 MW Solar Plant
- Solar plant Financially viable in all carbon tax scenarios

Attribute	Carbon Tax: $10/Tonne	Carbon Tax: $25/Tonne	Carbon Tax: $50/Tonne	Carbon Tax: $75/Tonne	Carbon Tax: $100/Tonne
Internal Rate of Return (IRR)	17.85%	22.73%	32.27%	43.30%	56.57%
Net Present Value (NPV)	$47,593,248	$75,864,101	$126,285,514	$176,003,205	$225,625,619
After Tax Weighted Average Cost of Capital (ATWACC)	6.50%	6.70%	6.70%	6.70%	6.70%
Financially Feasible?	Yes	Yes	Yes	Yes	Yes
Profitable?	Yes	Yes	Yes	Yes	Yes

Carbon Tax Sensitivities

NGCC Plant

- Plant BETL B32A
- NPV Break Even point is at $48/Tonne CO2

Attribute	Carbon Tax: $10/Tonne	Carbon Tax: $25/Tonne	Carbon Tax: $50/Tonne	Carbon Tax: $75/Tonne	Carbon Tax: $100/Tonne
Internal Rate of Return (IRR)	0.99%	6.37%	16.31%	29.04%	47.79%
Net Present Value (NPV)	($475,114,483)	($178,122,784)	$263,065,642	$670,176,486	$1,077,566,946
After Tax Weighted Average Cost of Capital (ATWACC)	6.70%	6.70%	6.70%	6.70%	6.70%
Financially Feasible?	No	No	Yes	No	No
Profitable?	No	No	Yes	No	No

Carbon Tax Sensitivities

Greenfield NGCC W/ CCS Plant

- Plant 2: B32B.97
- NPV Breakeven point is at $40/Tonne CO2

Attribute	Carbon Tax: $10/Tonne	Carbon Tax: $25/Tonne	Carbon Tax: $50/Tonne	Carbon Tax: $75/Tonne	Carbon Tax: $100/Tonne
Internal Rate of Return (IRR)	Infeasible	Infeasible	13.11%	20.58%	27.95%
Net Present Value (NPV)	($607,699,406)	($303,703,501)	$165,429,565	$607,786,628	$1,047,600,094
After Tax Weighted Average Cost of Capital (ATWACC)	6.70%	6.70%	6.70%	6.70%	6.70%
Financially Feasible?	No	No	Yes	Yes	Yes
Profitable?	No	No	Yes	Yes	Yes

Carbon Tax Sensitivities

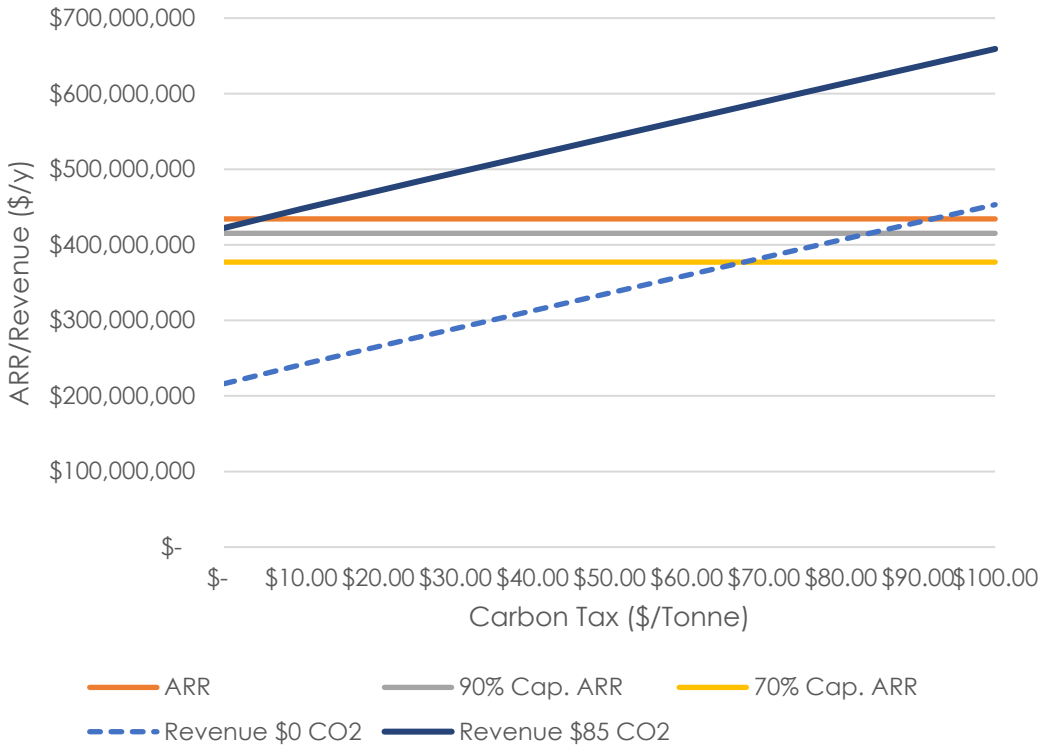
Brownfield NGCC W/CCS Plant

- NETL B32BR.97 NGCC Retrofit case
- Plant financially viable in all carbon tax scenarios

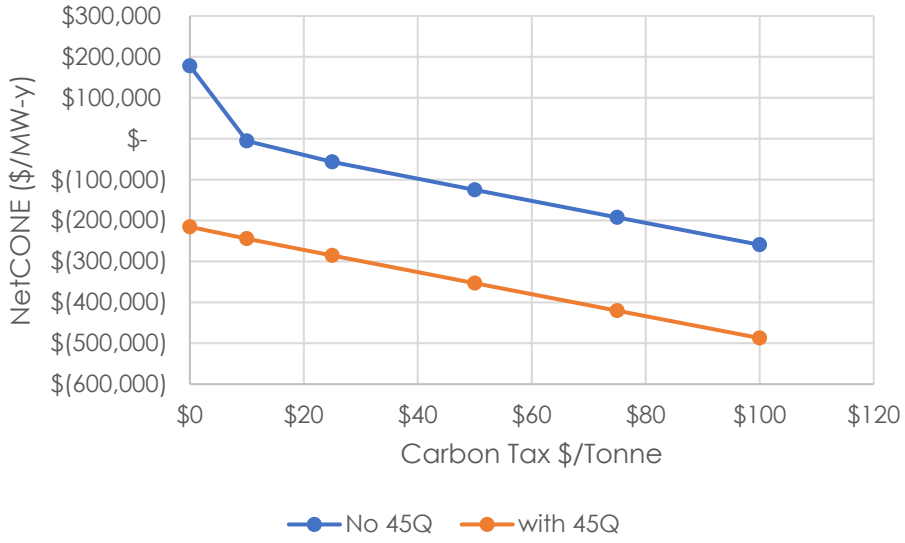
Attribute	Carbon Tax: $10/Tonne	Carbon Tax: $25/Tonne	Carbon Tax: $50/Tonne	Carbon Tax: $75/Tonne	Carbon Tax: $100/Tonne
Internal Rate of Return (IRR)	17.16%	27.63%	45.05%	64.35%	88.18%
Net Present Value (NPV)	$110,977,944	$300,149,129	$611,466,532	$905,135,640	$1,204,623,747
After Tax Weighted Average Cost of Capital (ATWACC)	6.70%	6.70%	6.70%	6.70%	6.70%
Financially Feasible?	Yes	Yes	Yes	Yes	Yes
Profitable?	Yes	Yes	Yes	Yes	Yes

ARR and NET CONE

Greenfield NGCC plant w/ Direct integration CCS

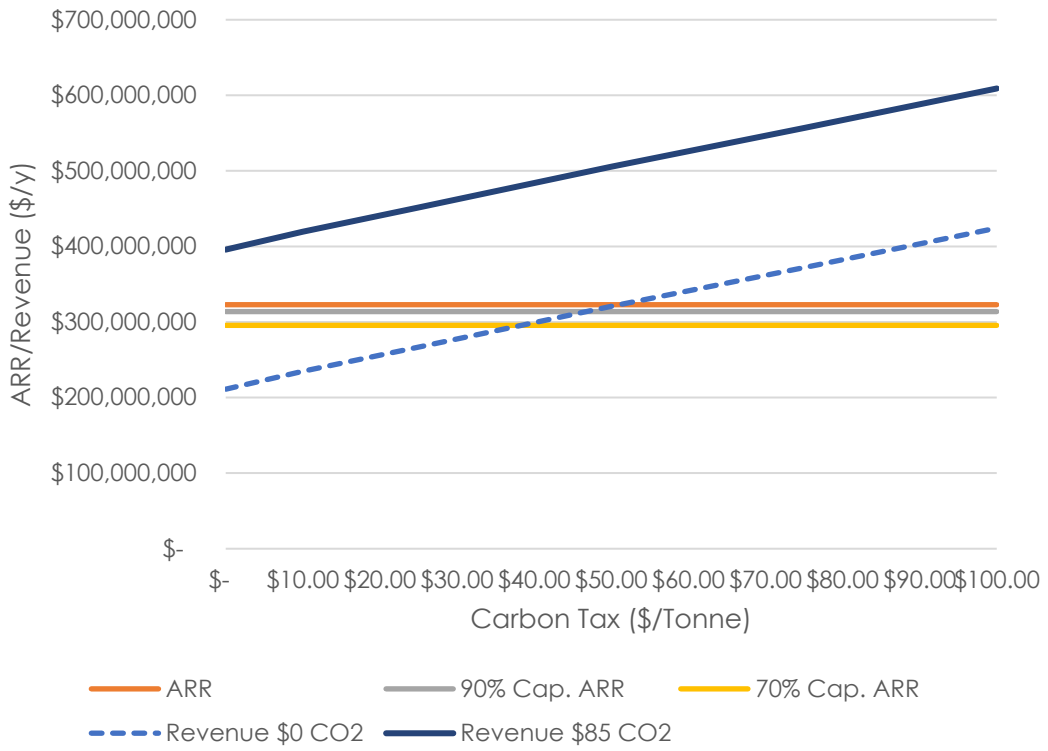


- Greenfield Plant needs ~$10 Million/year in additional revenue while taking 45Q with no Carbon tax, and $210 Million/year in additional revenue without 45Q.

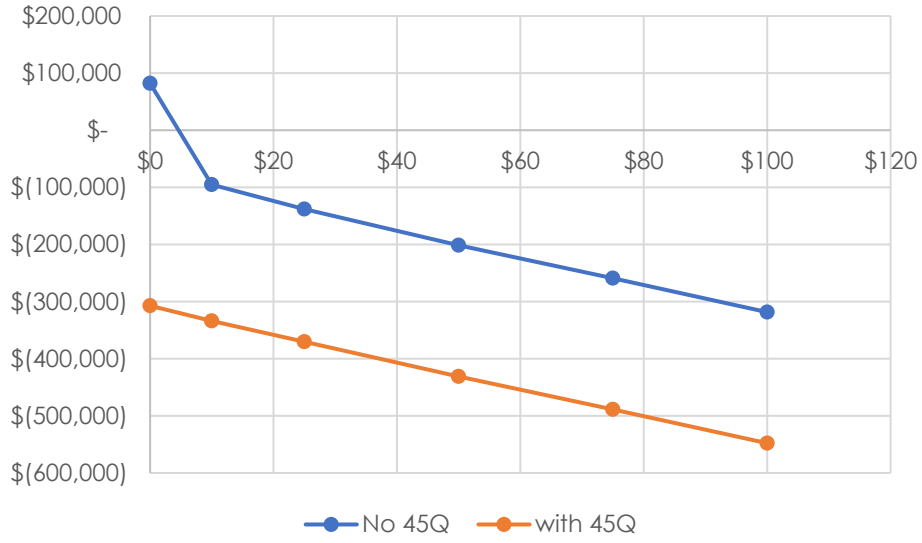


ARR and NET CONE

Brownfield NGCC plant w/ Direct integration CCS



- Brownfield Plant exceeds revenue requirements while taking 45Q with no Carbon tax, and needs additional $103 Million/year in additional revenue without 45Q.



Plant Financial analysis sensitivities takeaways

- Carbon tax scenarios increase zonal LMP, enabling plants to hit a breakeven point due to increased plant energy revenue while captured CO2 reduces additional costs of carbon emissions

Conclusions

- High renewable penetration in the modeled system result in low system LMP, averaging $27/MWh
- 45Q revenue inadequate to sustain CCS units in low LMP system
- Greenfield plant requires additional revenue during 45Q eligibility and beyond.
- Brownfield plant meets revenue requirement during 45Q eligibility, but require additional revenue after 45Q expiration.
- Greenfield plant becomes profitable at $50/tonne scenario, with average system LMP of $42/MWh
- Brownfield plant becomes profitable at $10/tonne scenario, with average system LMP of $30/MWh

Potential Future Work

- Potential additional revenue Streams
  - Capacity markets
  - Renewable Energy Credits for Biomass and Solar auxiliary units
- Future Capacity expansion scenarios. Factoring in 2022 IRA effects
- Additional Plant Configurations

Project Team Contacts

Name	Email
Chris Nichols	Chris.Nichols@netl.doe.gov
Justin Adder	Justin.Adder@netl.doe.gov
John Brewer	John.Brewer@netl.doe.gov
Kirk LaBarbara	Kirk.labarbara@netl.doe.gov
Arun Iyengar	Arun.Iyengar@netl.doe.gov
Marija Prica	Marija.Prica@netl.doe.gov
Ben Turner	Benjamin.Turner@netl.doe.gov
Nick Messina	Nicholas.Messina@netl.doe.gov

Questions?

VISIT US AT: **www.NETL.DOE.gov**

@NETL_DOE

@NETL_DOE

@NationalEnergyTechnologyLaboratory

CONTACT:
Chris Nichols
Chris.Nichols@netl.doe.gov