

Competitiveness of US Gas Turbine Manufacturers

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Submitted to:

Gas Turbine Association

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EXECUTIVE SUMMARY

GTA believes that expanded government-sponsored research on improved gas turbine technology will lead to more American jobs going forward, increased American global competitiveness, and potential greenhouse gas reductions in the power sector.

ICF International ("ICF") was retained by the Gas Turbine Association ("GTA") to assess the impacts of sponsored research on the competitiveness of US-based gas turbine manufacturers. The analysis estimates economy-wide impacts both in terms of the direct as well as the secondary (i.e., indirect and induced) American jobs supported. This analysis also quantifies the effect that the research and development (R&D) funding will have on American competitiveness by providing projections of gas turbine construction by US-based companies over the next twenty-five years.

To assess American job impacts, the study utilized the economic impact modeling software, IMPLAN. IMPLAN is used by many government agencies and other companies to quantify jobs and economic impacts. To assess the effect on US-based turbine competitiveness, ICF utilized its Integrated Planning Model (IPM®), which is a widely-used model that analyzes power markets and projects forward energy pricing, as well as capacity additions and retirements. In performing the analysis, ICF relied exclusively on publicly available data and information – primarily from the Department of Energy's (DOE's) Energy Information Administration (EIA) and guidance from the Gas Turbine Association committee. While this analysis only shows the effect on the US market for new power generation, the results could be extrapolated to the broader worldwide market.[1]

Background

United States-based manufacturers currently have a large share of the gas turbine and combined cycle marketplace. With the expansion of European manufacturers to the US, the only other major producer of heavy frame gas turbines currently selling turbines in the US is Japan.[2] Due to the Fukushima disaster, the Japanese government is funding large research and development efforts into improving combined cycle efficiencies as one of the alternatives to decreased usage of nuclear power in their country. This study attempts to show that without an expansion of US government funding in natural gas-fired turbine research and development, US-based manufacturers will lose the competitive advantage that they have long held over foreign manufacturers in the US domestic electricity market.

[1] Lowering operational costs is a great concern in many of the power markets outside the US. As many of these markets have higher delivered natural gas prices compared to the US, efficiency improvements in natural gas–fired combined cycles technology plays an even greater role in turbine selection. Thus, results from this study may provide key insights on the projected competiveness of US-based manufacturers in non-US markets.

[2] Siemens opened a turbine manufacturing facility in the US in 2011, and Alstom opened a facility in 2010.

Overview of Results

This study forecasts that foreign manufacturers will gain a large share of the US market for new electric generating capacity over the next twenty-five years unless US manufacturers develop new advanced natural gas–fired combined cycles (NGCC). One way the US-based gas turbine manufacturers can maintain their competitive advantage is by expanding research and development investment programs and by producing a series of highly efficient combined cycles.

This study also forecasts an increase in US jobs in construction and operation for the associated new capacity expansion. If advanced US-based NGCC efficiency targets are not met and foreign manufacturers meet theirs, fewer jobs will be supported in the US economy over the next twenty-five years as turbine manufacturing is increasingly done offshore. Finally, this study will show that developing high-efficiency NGCC in the US will also lead to slower growth in anthropogenic carbon dioxide (CO_2). As the expected US NGCCs will be more efficient than their foreign competitors, they will produce less CO_2 as well.

Technology Competitiveness Retention

In the US electricity market today, turbines built by US-based manufacturers make up over 80% of the operating NGCCs. Non-US based manufacturers make up the balance, with European and Japanese manufacturers having the largest segment of this category.[3]

In the Foreign government investment case, without the increased US government R&D spending, and the advanced NGCC technologies that come with it, US-based manufacturers are projected to become much less competitive relative to foreign manufacturers. As seen below in Exhibit ES-1, by 2037 in the Foreign government investment case, the share of the NGCC market filled by US-based manufacturers is projected to drop to 42% from 84% today. Meanwhile, the share of the market occupied by foreign manufacturers increases to 58%, growing by over 220 GW from its current position. This growth is due to the better economics achieved from the new series of advanced foreign NGCCs and thus pushing any new capacity based on the current state-of-the-art US-based NGCCs out of the market.

[3] With the opening of Siemens and Alstom manufacturing plants in the US (2011 and 2010 respectively), ICF assumes going forward that units produced by these companies are US-built and count toward the US-based total market share.

Exhibit ES-1

Projected Combined Cycle Build Out

CCs	Actual as of 2013		2037 - Foreign government investment Case		2037 – Enhanced US investment Case	
	MW	%	MW	%	MW	% of Total
US	191,100	84%	191,900	42%	327,745	72%
Non-US	35,196	16%	262,432	58%	128,371	28%
Total	**226,296**	**100%**	**454,333**	**100%**	**456,115**	**100%**

Source: Ventyx and IPM output

In contrast, in the Enhanced US investment case, with the assumed benefit from enhanced R&D funding, the 67% efficient NGCC is assumed to be available in 2027 and is forecast to compete economically and beat the best foreign built machines. As a result, in the Enhanced US investment case, US-based manufacturers are projected to retain their competitive advantage, maintaining roughly 70% market share, and adding almost 140 GW of new CC capacity by 2037.

Expected Impact on Jobs Supported in the US Economy

The other important impact of the continued competitiveness in US-based turbine manufacturing is its impact on jobs in the US economy. While both scenarios are expected to produce many new jobs in the American economy, the Enhanced US investment case is projected to support over 35,000 (around 20%) more jobs by 2030. Despite both cases producing similar amounts of total NGCC capacity, the significant increase in American jobs in the Enhanced US investment case is due to the projected domestic manufacturing jobs created. This can be seen below in Exhibit ES-2, which shows total yearly jobs supported in a given year by the expenditures associated with the forecasted capacity expansion.

Exhibit ES-2

Projected Jobs Impact on the US Economy

Select Years	Foreign government investment Case	Enhanced US investment Case	Delta
2020	26,000	23,000	-3,000
2030	16,5000	203,000	38,000
2035	172,000	208,000	36,000
Annual Average	90,000	102,000	12,000

Source: IMPLAN output

Both cases will create a significant amount of engineering, procurement and construction (EPC) jobs, needed for the construction of the new combined cycle capacity. However, in the Foreign government investment case, a large amount of gas turbines are assumed to be manufactured in a foreign country and shipped to the US. The associated manufacturing jobs will not be created in the US market. In other words, in the Enhanced US investment case, US-manufactured advanced gas turbines will be built at home, supporting an incremental 36,000 manufacturing jobs per year by 2030.[4]

Expected Impact on Carbon Emissions

In both cases, the majority of the capacity expansion in the US power market is projected to be from new and highly-efficient combined cycles. Thus, over the next twenty-five years, US power sector CO_2 emissions are projected to grow slower than energy demand (1.0% vs 1.1%). In other words, the new fleet of projected combined cycles, which emit low amounts of CO_2 compared with today's technology, will lower the rate of growth of emissions of the entire US generation fleet.[5] Additionally, as can be seen below in Exhibit ES-3, CO_2 emissions grow at an even slower rate in the Enhanced US investment case than in the Foreign government investment case. This is because the advanced NGCCs produced by US-based manufacturers will be more efficient, producing fewer tons of CO_2 per megawatt-hour of energy produced than those manufactured by their Foreign competitors.

Exhibit ES-3
Projected CO_2 Emissions in the Power Sector (Million Short Tons)

	Foreign government investment Case	Enhanced US investment Case	US - Foreign government investment Case Delta
2015	2,099	2,099	0
2020	2,164	2,166	2
2025	2,308	2,313	5
2030	2,412	2,409	-2
2037	2,597	2,577	-20
2015-2037 Growth Rate	**1.0%**	**0.9%**	

Source: IPM output

Summary of Methodology

In order to develop projections of the effects on American jobs and US-based manufacturer competitiveness that expanded government R&D funding would have, ICF analyzed two scenarios defined by GTA:

1) A reference case ("Foreign government investment" case), which reflects a future where there is minimal funding support from the US government for US original equipment manufacturers (OEMs) and where foreign manufacturers gain a competitive advantage in terms of both capital cost and gas turbine efficiency through strong government

[4] The 36,000 jobs represent the differences in jobs supported between the two cases analyzed for the year 2030. The year 2030 represents the peak year difference.
[5] Based on EIA's AEO we assume a 1.1% energy growth rate over the study's time horizon. While new power plants are being built, the new NGCC has a lower CO2 emission rate (e.g. 1000 lb/MWh v. 1500 lb/MWh) than the average power plant, thus slowing the CO2 growth rate.

funding.[6] This case assumes no development beyond the current state-of-the-art technology for the US-manufactured gas turbines.[7]

2) An "Enhanced US investment" case, which reflects the future brought about by the expansion of US-government funding in gas turbine R&D. This case assumes that there will be enough funding to support the development of advanced gas turbines in the US with increasing efficiency targets.

These cases assume that the rollout of advanced gas turbine and NGCC technologies follow the dates shown in Exhibit ES-4 below. Under the Foreign government investment case, only the foreign NGCCs will be available (shown below, in red). In the Enhanced US investment case, both the foreign NGCCs as well as advanced US-based NGCCs will be available (shown below, in green).

Exhibit ES-4
Rollout Timeline of Advanced Combined Cycles

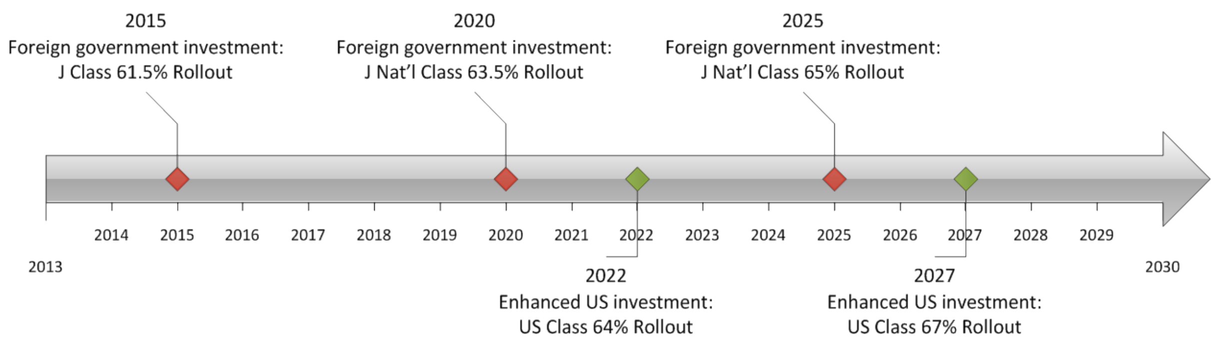


Exhibit ES-5 shows the assumptions regarding each of these technologies. The most important characteristic distinguishing the different CCs is the efficiency of the units. The assumed newer foreign units surpass all current American CCs, reaching 65% efficiency by 2025. In order to maintain the competitiveness of US-based manufacturers, government R&D spending is expected to be at sufficient levels in the Enhanced US investment case such that a 67% efficiency target by 2027 for an NGCC can be achieved. In contrast, most CCs operating in the US today function at around 56% efficiency.[8]

[6] Among foreign manufacturers in the gas turbine sector, the Japanese have the clearest and most aggressive business plan for turbine development. As such we use their technology goals as a proxy for all foreign competitors. The Japanese plan also has the most impressive performance targets. As such using their targets potentially represents a case with the strongest penetration of foreign based machines in the US market.

[7] Most key assumptions underlying this analysis are based on EIA's assumptions in its Annual Energy Outlook, 2012. The AEO is a forward looking projection of various parts of the US economy including the electricity market. Underlying assumptions on prime movers such as the NGCC include improvements in cost over time, as well as, but to a limited degree, improvements in heat rate performance. While these assumptions may not reflect the most advanced NGCC machines currently available by US-based manufacturers, these assumptions serve as a consistent platform by which new assumptions on future performance can be measured.

[8] Inland Empire Energy Center is the most efficient NGCC in the US fleet at 60% based on GE's H-technology and came on-line in 2009. However, it is the only one of its kind currently operating in the US.

Assumptions on technology levels and rollout dates were developed based on conversations with the Gas Turbine Association committee.[9]

Exhibit ES-5
Assumed Characteristics of Advanced Combined Cycles

Combined Cycle Technology Types	Country of Origin	Funding Case	Online Year	Efficiency (%)	Heat Rate (Btu/kWh), HHV	Capital Cost (2010$/kW)
J Class NGCC 61.5	Foreign	Foreign government investment Case	2015	61.5%	6,281	$1,028
J National Class NGCC - 63.5	Foreign	Foreign government investment Case	2020	63.5%	6,084	$1,083
J National Class NGCC - 65	Foreign	Foreign government investment Case	2025	65.0%	5,943	$1,143
US Class NGCC - 64	US-based	Enhanced US investment Case	2022	64.0%	6,036	$1,113
US Class NGCC - 67	US-based	Enhanced US investment Case	2027	67.0%	5,766	$1,193

Summary of Major Assumptions

A summary of this study's major assumptions are presented below in Exhibit ES-6. In this analysis, public-sourced data was used to develop most assumptions. Assumptions for peak demand and energy were taken from the NERC ES&D. Construction costs, natural gas and coal commodity pricing and other major assumptions were taken from the Energy Information Administration's (EIA) Annual Energy Outlook. The AB32 California Carbon allowance price was developed from forwards traded on the open market. The RGGI carbon price is derived from a publicly-available document from the Regional Greenhouse Gas Initiative. Further details on assumptions can be found in Chapter 5.

[9] New foreign efficiency assumptions were based on Japanese technology referenced in the article "*Test Results of the World's First 1,600 C J-series Gas Turbine,"* Satoshi Hada, et al, March 2012.

Exhibit ES-6
Summary of Assumptions

	Units	2015	2020	2030	Average 2015-2037
Summer Peak Demand	MW	814,823	868,453	981,582	1.3%
Net Energy For Load	GWh	4,171,254	4,438,538	4,930,905	1.1%
Advanced NGCC	Nominal $/kW	$1,188	$1,233	$1,326	$1,260
Single Unit IGCC with CCS	Nominal $/kW	$6,295	$6,521	$6,808	$6,618
Advanced Simple Cycle CT	Nominal $/kW	$786	$808	$839	$820
Henry Hub Natural Gas Price	Nominal $/MMBtu	$4.21	$4.97	$8.45	$6.32
Eastern Interior Medium Sulfur (Bituminous) Minemouth Coal Price	Nominal $/ Short ton	$62.70	$71.25	$97.07	$80.49
Total Cumulative Firm Builds[10]	MW	4,948	4,948	4,948	
AB32 - California Carbon Allowance (CCA)	Nominal $/Ton	$18.02	$26.02	$54.25	$36.15
RGGI CO2	Nominal $/Ton	$7.20	$10.77	$13.78	$11.42

Conclusion

Foreign manufacturers will gain a large share of the US market for new electric generating capacity over the next twenty-five years unless US-based manufacturers develop new advanced natural gas–fired combined cycles (NGCC). Without advanced US-based gas turbines, foreign manufacturers are poised to increase their share of the NGCC market from 6% to 53% by 2037. However, with sufficient R&D investment, US-based manufacturers will maintain their competitiveness and market share. In the near-term, efficient foreign NGCCs will be the primary units built. In the long-term, the highly efficient US Class 67% will displace the foreign models, allowing US-based manufacturers to maintain their current market share, of about 60% of the total US market.

Similar to the capacity build out, the Foreign government investment case produces more jobs and more tax revenue in the near-term. After the roll out of advanced US-manufactured NGCCs, the Enhanced US investment case supports many more jobs. This study shows that, on an average annual basis, as well as overall during the timeframe, the Enhanced US investment case produces more jobs, higher GDP (value added), more industry activity, and higher tax revenue for federal, state, and local governments.

As most new builds projected between now and 2037 are to be clean and highly-efficient combined cycles, both cases gradually lessen the amount of CO_2 emitted by the US generation fleet. Since the advanced US-based combined cycles are cleaner than the best foreign units, the Enhanced US investment case is also slightly cleaner in terms of CO_2 emissions.

[10] No new firm builds are projected past 2015, and as a result the number remains constant across the study's time horizon.

Finally, while not a focus of this report, advanced gas turbine technology can be a key driver to the successful integration of wind power into the power grid. A number of papers have reported on the challenges that integrating large amounts of variable wind can present to system power operators and planners.[11,12] Gas turbines are one of the better prime movers to compensate for the high degree of wind variability due to their high ramp up rates compared to other base load types such as coal and nuclear. Advanced gas turbines are now closing in on 40 MW/min ramp up times.[13]

[11] Nova Scotia Power, "*Challenges of Large Scale Wind Integration in Nova Scotia*," January 2013.
[12] California Independent System Operator, *" Resource Adequacy and Flexible Capacity Procurement Joint Parties' Proposa*l", October 2012.
[13] General Electric, *" 7F 5-Series Gas Turbine Fact Sheet*", September 2012.

CHAPTER ONE
OVERVIEW OF THE TWO CASES

GTA believes that expanded government-sponsored research on improved gas turbine technology will lead to more American jobs going forward, increased American global competitiveness, and potential greenhouse gas reductions in the power sector.

ICF International ("ICF") was retained by the Gas Turbine Association ("GTA") to assess the impacts of sponsored research on the competitiveness of US-based gas turbine manufacturers. The analysis estimates economy-wide impacts both in terms of the direct as well as the secondary (i.e., indirect and induced) American jobs supported. This analysis also quantifies the effect that the research and development (R&D) funding will have on American competitiveness by providing projections of gas turbine construction by US-based companies over the next twenty-five years.

1.0 Description of Cases

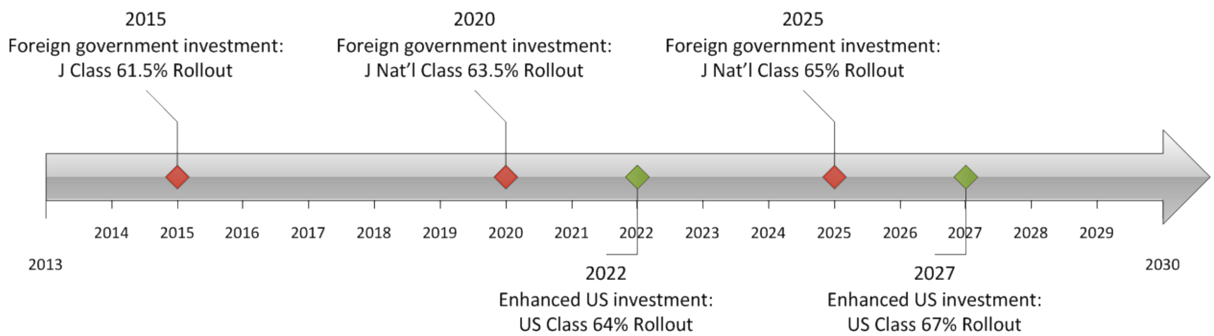
In order to quantify the effects on American jobs and US-based turbine manufacturer competitiveness that enhanced government research and development (R&D) funding would lead to, ICF analyzed two scenarios defined by GTA:

1) A reference case ("Foreign government investment case"), which would reflect the future where there is no funding support from the US government for US original equipment manufacturers (OEMs) and where foreign manufacturers gain a competitive advantage in terms of both capital cost and gas turbine efficiency.
2) An "Enhanced US investment" case, which would reflect the future brought about by the institution of US-government funded gas turbine R&D. This case assumes that there will be enough funding to support the development of advanced gas turbines in the US, such that US OEMs maintain their competitive balance with foreign OEMs over the next twenty-five years.

The analysis looked at the impacts of R&D funding on two factors: job creation and market share of future additions as a proxy for competitiveness. The differences in these two factors between the scenarios quantify the impacts of the R&D funding, given the assumptions used for this analysis. To assess the effect on US-based turbine competitiveness, ICF utilized its Integrated Planning Model (IPM®), which is a widely-used model that analyzes electric power markets and projects forward energy pricing, as well as capacity additions and retirements. ICF used the economic impact modeling software IMPLAN to conduct the job and impact analysis. IMPLAN provides detailed industry information for 440 sectors roughly aligned with 4-digit NAICS (North American Industry Classification System) industry codes.

These cases assume that the availability of advanced gas turbine and combined cycle (NGCC) technologies follow the schedule shown in Exhibit 1-1 below. Under the Foreign government investment case, only the foreign NGCCs will be available (shown below, in red). In the Enhanced US investment case, both the foreign NGCCs as well as advanced US-manufactured NGCCs will be available (shown below, in green).

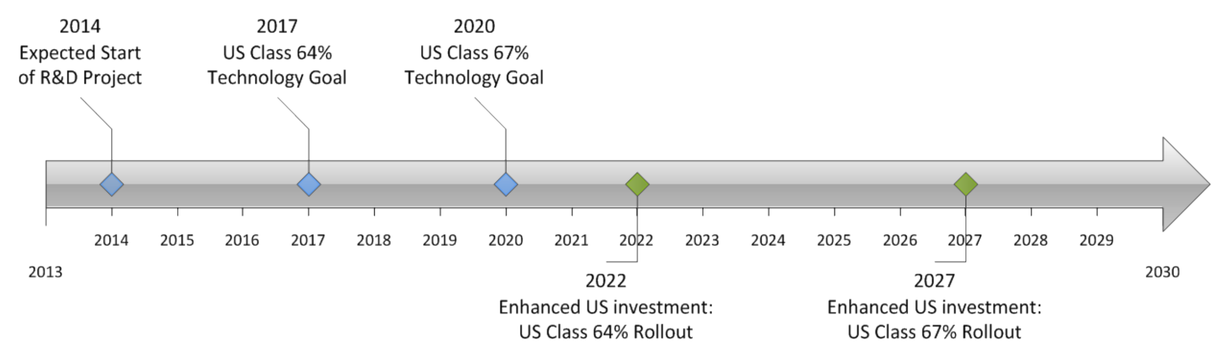
Exhibit 1-1
Rollout Timeline of Advanced Combined Cycles



1.1 Goals of Research and Development Program

The schedule of the assumed government-funded R&D program was designated as starting in 2014 and lasting seven years, until 2020, with funding levels at $50 million per year. This schedule was developed with the guidance of the Gas Turbine Association. As shown below in Exhibit 1-2, this R&D is projected to achieve the goal of a NGCC with 64% efficiency by 2017 and with 67% efficiency by 2020. The process of achieving commercial manufacturing ability and unit delivery is expected to take five to seven years from the time the goal is achieved, resulting in a 2022 on-line date for the US Class 64% and 2027 for the US Class 67% NGCCs.

Exhibit 1-2
Development Timeline of Advanced US-Based Combined Cycles



1.2 Description of the Technologies

Both cases assume that advanced and highly-efficient natural gas combined cycles will come on-line in the next two years. The foreign J Class, which starts at 61.5% efficiency, is projected to be available by 2015.[14]

Exhibit 1-3 shows the assumptions regarding each of the advanced NGCC technologies. The most important characteristic distinguishing the different NGCCs is the efficiency of the unit. The assumed newer foreign units surpass all current American NGCCs, reaching 65% efficiency by 2025. In order to maintain the competitiveness of American manufacturers, government R&D spending is expected to produce a 67% efficiency NGCC by 2027. In contrast, most NGCCs operating in the US today operate at around 56% efficiency.

Exhibit 1-3
Assumed Characteristics of Existing and Advanced Combined Cycles

Combined Cycle Technology Types	Country of Origin	Funding Case	Online Year	Efficiency (%)	Heat Rate (Btu/kWh), HHV	Capital Cost (2010$/kW)
Conventional NGCC (F-Tech)[1]	US-based	Foreign government investment Case	current	56.0%	7,050	$978
Advanced NGCC (H-Tech)[1]	US-based	Foreign government investment Case	current	60.0%	6,430	$1,003
J Class NGCC 61.5[2]	Foreign	Foreign government investment Case	2015	61.5%	6,281	$1,028
J National Class NGCC - 63.5[2]	Foreign	Foreign government investment Case	2020	63.5%	6,084	$1,083
J National Class NGCC – 65[3]	Foreign	Foreign government investment Case	2025	65.0%	5,943	$1,143
US Class NGCC - 64[3]	US-based	Enhanced US investment Case	2022	64.0%	6,036	$1,113
US Class NGCC - 67[3]	US-based	Enhanced US investment Case	2027	67.0%	5,766	$1,193

Sources: 1) – EIA's AEO 2012, 2) "Test Results of the World's First 1600 FC J-Series Gas Turbine, 3)guidance from GTA.

1.3 Current market mix of gas turbine technology

Nearly 70% of current domestic installed capacity is 56% efficient "F-Tech" NGCCs shown in Exhibit 1-4. These were installed en masse in the late 90s and early 2000s; currently there are nearly 160 GW of F-tech level combined cycles. The remaining capacity is comprised of older vintage units and the more advanced "G-Tech" and "H-tech" units. Historically, foreign manufacturers such as Siemens and Mitsubishi have had the most success exporting F-tech and G-tech NGCCs machines, respectively, to the US.

[14] "*Test Results of the World's First 1600 C J-Series Gas Turbine"*, Satoshi Hada, et. al., Mitsubishi Heavy Industries Technical Review, March 2012.

Exhibit 1-4
Technology Breakdown of US Combined Cycle Fleet

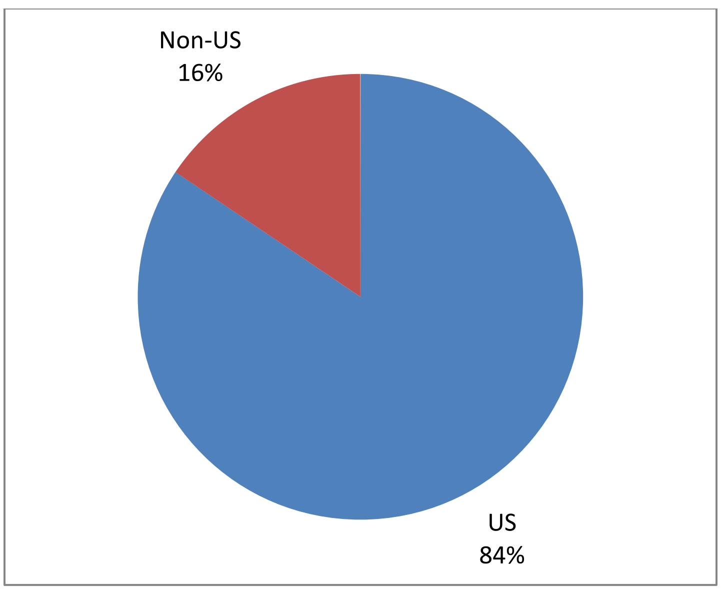
NGCCs	Efficiency %	Today	
		MW	% of Total
E-Tech and Older Units	<50%	46,463	21%
Conventional NGCC (F-Tech)	56%	158,682	70%
Advanced NGCC (G/H-Tech)	58%-60%	21,152	9%
Total		**226,296**	**100%**

Source: Ventyx

Current market mix of combined cycles by place of origin

The current mixture of natural gas combined cycles is comprised of units manufactured in the US, Europe and Japan. As can be seen below in Exhibit 1-5, US based manufacturers currently have the largest share of the US NGCC market.

Exhibit 1-5
Region of Origin for US Combined Cycles



Source: Ventyx

Siemens and Alstom recently opened new advanced manufacturing facilities in the US and it appears will now produce these gas turbines for the US market.[15] This study assumes that, going forward, these manufacturers will be considered US-based, as they will use American labor in their manufacturing.

[15] Siemens has been producing gas turbines domestically as it acquired Westinghouse in 1997.

Summary of Major Assumptions

A summary of this study's major assumptions are presented below in Exhibit 1-6. In this analysis, public-sourced data was used to develop most assumptions. Assumptions for peak demand and energy were taken from the NERC ES&D. Construction costs, natural gas and coal commodity pricing and other major assumptions were taken from the Energy Information Administration's (EIA) Annual Energy Outlook. The AB32 California Carbon allowance price was developed from forwards traded on the open market. The RGGI carbon price is derived from a publicly-available document from the Regional Greenhouse Gas Initiative. For further details on these and other key assumptions, please refer to the Appendix.

Exhibit 1-6
Summary of Assumptions

	Units	2015	2020	2030	Average 2015-2037
Summer Peak Demand	MW	814,823	868,453	981,582	1.3%
Net Energy For Load	GWh	4,171,254	4,438,538	4,930,905	1.1%
Advanced NGCC	Nominal $/kW	$1,188	$1,233	$1,326	$1,260
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Henry Hub Natural Gas Price	Nominal $/MMBtu	$4.21	$4.97	$8.45	$6.32
Eastern Interior Medium Sulfur (Bituminous) Minemouth Coal Price	Nominal $/ Short ton	$62.70	$71.25	$97.07	$80.49
Total Cumulative Firm Builds	MW	4,948	4,948	4,948	
AB32 - California Carbon Allowance (CCA)	Nominal $/Ton	$18.02	$26.02	$54.25	$36.15
RGGI CO_2	Nominal $/Ton	$7.20	$10.77	$13.78	$11.42

CHAPTER TWO
TECHNOLOGY COMPETITIVENESS RESULTS

Section 2 presents the results of the competitiveness analysis for the foreign government investment and the Enhanced US investment cases. This study forecasts that foreign manufacturers will gain a large share of the US market for new electric generating capacity over the next twenty-five years unless US manufacturers develop new advanced natural gas–fired combined cycles (NGCC). One way the US-based gas turbine manufacturers can maintain their competitive advantage is by producing a series of efficient combined cycles based on expanding research and development investment programs.

ICF developed the projections of market penetration using the power market model IPM and based on assumptions selected by GTA, including projections from public sources. Detailed descriptions of the modeling methodology and key assumptions are in the appendix of this report.

2.0 Projected NGCC buildout in both cases

In both the Foreign government investment and the Enhanced US investment cases, a similar amount of NGCCs are projected to be built between 2015 and 2037. However, the amount built by foreign manufacturers versus US-based manufacturers varies significantly between the cases, as can be seen below in Exhibit 2-1. Currently, domestically manufactured NGCCs make up around 84% of the US market, and foreign manufactured NGCCs only make up 16%. By 2037, unless the advanced US-based NGCCs are developed, the foreign market share is projected to climb to 58%, while the domestic share will drop to only 42%. However, in the Enhanced US investment case, US-manufacturers maintain their competitiveness, holding their market share over 70% by 2037. The market penetration of foreign NGCCs, while increased over today's levels, only climbs to 28% of the total.

Exhibit 2-1
Total Cumulative Buildout of NGCCs by Year by Case (GW)

CCs	Actual as of 2013		2037 - Foreign government investment Case		2037 – Enhanced US investment Case	
	MW	%	MW	%	MW	% of Total
US	191,100	84%	191,900	42%	327,745	72%
Non-US	35,196	16%	262,432	58%	128,371	28%
Total	**226,296**	**100%**	**454,333**	**100%**	**456,115**	**100%**

Source: Ventyx and IPM output

As can be seen below in Exhibit 2-2, in 2015 for the Foreign government investment case, the US market is projected to add roughly 5 GW of the most efficient available combined cycle, the J Class 61.5%. Thereafter, over the next five years, nearly 20 GW of this NGCC class is projected to come online. In 2020, a more advanced NGCC, the J National Class 63.5% unit is assumed to become available. It slowly begins to expand its market penetration over the next five years, until the most efficient foreign unit becomes available in 2025, the J National Class 65%. Between 2025 and 2030, market demand growth is strong enough that both the 63.5% and 65% NGCCs are built at high levels.[16] After 2030, when the technologies are expected to be commercially mature, the 65% NGCC further expands its market share. From 2030 through the end of the study, nearly 12 GW per year of J Class 65% NGCC are added.

Exhibit 2-2
Total Cumulative Buildout of NGCCs by Year by Case (GW)

Prime Mover	Foreign government investment Case				Enhanced US investment Case			
	2015	2020	2030	2037	2015	2020	2030	2037
Conventional NGCC (F-Tech)	0	0	0	0	0	0	0	0
Advanced NGCC (H-Tech)	0	0	0	1	0	0	0	0
J Class NGCC 61.5	5	19	30	34	5	19	20	23
J National Class NGCC - 63.5	0	2	42	86	0	1	36	42
J National Class NGCC - 65	0	0	24	108	0	0	28	28
US Class NGCC - 64	-	-	-	-	0	0	0	0
US Class NGCC - 67	-	-	-	-	0	0	14	137
Total	**5**	**21**	**96**	**228**	**5**	**20**	**98**	**231**

Source: IPM output

In the near-term, between 2015 and 2020, the Enhanced US investment case has a similar build-out. Only in later years, after the rollout of advanced US-manufactured NGCCs, does the Enhanced US investment case significantly differ from the Foreign government investment case. Since the most advanced NGCC, the US Class 67%, does not become available until 2027, there are slightly fewer GW of NGCC built in the 2025 to 2027 period than in the Foreign government investment case. The J class 65% is still projected to be added in the 2025-2030 time period, but the advanced 67% US NGCC begins to erode the foreign market share as soon as it becomes available. From 2030 onward, nearly 18 GW, on average, of US 67% NGCCs are projected to be built per year. While there is a construction cost premium for the more advanced CC, its higher energy margin outweighs its cost premium when compared to less advanced machines.

As can be seen below in Exhibit 2-3, the share of the US market represented by “F-tech” NGCCs falls by 2037 in both cases from 70% of the market to 35%, even as it stays flat on a MW basis. In the Foreign government investment case, this short fall is picked up by the three foreign NGCCs, with the largest market share being represented by the J National Class 65%. In the Enhanced US investment case, due to the increased competitiveness of US gas turbines, over 30% of the market is US Class 67%, and only 6% is the J National Class 65%. While F-techs are available to be built, the model projects that none will be built because of their lower efficiency relative to the more advanced foreign and US-based NGCCs assumed to become available. Results would change if the technology was offered at stronger discounts to those assumed in the modeling analysis.

[16] ICF assumes that limitations on manufacturers’ production ability will limit the production of each new combined cycle to 5 GW per year until 2030. This is loosely based on a historical analysis of the market penetration of NGCC technology over the last twenty years. After 2030, this constraint on production of a certain NGCC series is completely relaxed.

Exhibit 2-3
Market Share of NGCCs by Case (GW)[17]

NGCCs	Efficiency %	Today		2037 Foreign government investment		2037 Enhanced US investment	
		MW	% of Total	MW	% of Total	MW	% of Total
E-Tech and Older Units	50%	46,463	21%	46,463	10%	45,225	10%
Conventional NGCC (F-Tech)	56%	158,682	70%	158,682	35%	158,682	35%
Advanced NGCC (G/H-Tech)	58%-60%	21,152	9%	21,952	5%	21,552	5%
J Class NGCC 61.5	62%	0	0%	34,007	7%	22,933	5%
J National Class NGCC - 63.5	64%	0	0%	85,539	19%	42,352	9%
J National Class NGCC - 65	65%	0	0%	107,691	24%	27,890	6%
US Class NGCC - 64	64%	0	0%	0	0%	0	0%
US Class NGCC - 67	67%	0	0%	0	0%	137,482	30%
Total		**226,296**	**100%**	**454,333**	**100%**	**456,115**	**100%**

Source: Ventyx and IPM output

2.1 Projected Buildout of Other Prime Movers

Over the 2015-2037 time period, the analysis forecasts additions of other types of generating units as well, mainly to meet capacity demand needs or various state and regional renewable portfolio standards (RPS). The build-out of prime movers other than NGCCs in both cases is very similar. Both cases add around 410 GW of new capacity, over half of which are combined cycles. As can be seen below in Exhibit 2-4, the simple cycle combustion turbine (CT) is the second-most numerous power plant projected to be built, behind the combined cycle.

[17] We have not imposed a technical or economic life on combined cycle operation. Thus some existing combined cycles (at the beginning of the study) will have an implied commercial life of over 40 years by the end of the study. To the extent that this assumption is too optimistic, more advanced combined cycles/simple cycle gas turbines will be built to replace the gap.

Exhibit 2-4
Cumulative US Economic Buildout by Prime Mover by Year (GW)

Prime Mover	Foreign government investment Case				Enhanced US investment Case			
	2015	2020	2030	2037	2015	2020	2030	2037
Combined Cycle	5	21	96	228	5	20	98	231
Coal	0	0	0	0	0	0	0	0
Simple Cycle CT	23	69	116	120	23	69	115	119
Nuclear	0	0	0	0	0	0	0	0
Renewable (Inc. Hydro)	20	31	43	60	20	32	43	60
Other	0	1	1	2	0	1	1	2
Total	**48**	**123**	**256**	**410**	**48**	**122**	**258**	**411**

Source: IPM output

In the near-term, from 2015-2020, nearly 70 GW of capacity of simple cycle CT are projected to be added. These units are the cheapest and most reliable way to meet necessary reserve margins, as they require very little energy revenue to have a positive return on investment. In the long-term, as energy margins grow, advanced NGCCs are the more economic choice relative to the simple cycle CT in many regions of the country and thus there is very little need for additional simple cycle CTs to be built.

2.2 Total Capacity in the US

In both 2015 and 2037, the total projected US capacity is very similar in both the Foreign government investment and the Enhanced US investment case. As stated in earlier sections, the major difference between the two cases is in the type of combined cycles being built. As can be seen below in Exhibit 2-5, the total capacity in the US is projected to grow from 1,052 GW in 2015 to 1,332 GW by 2037, which is driven in large part by the assumed peak demand growth rate.

Exhibit 2-5
Total US Capacity (GW)

Prime Mover	Foreign government investment Case				Enhanced US investment Case			
	2015	2020	2030	2037	2015	2020	2030	2037
Combined Cycle	229	246	323	454	229	246	323	456
Coal	268	236	227	222	268	237	227	222
Simple Cycle CT & Oil/Gas Steam	247	292	335	339	247	292	334	338
Nuclear	103	106	106	69	103	106	106	69
Renewable (Inc. Hydro)	174	186	199	215	174	186	199	215
Other	31	31	31	32	31	31	31	32
Total	**1,052**	**1,099**	**1,220**	**1,332**	**1,052**	**1,098**	**1,220**	**1,332**

Source: IPM output

Despite the increase in capacity over the 2015 to 2037 time period, coal and nuclear capacities decrease due to both economic and technical life retirements. In both cases, combined cycles are the primary sources of replacements for these retiring units.

2.3 Summary of Retirements

Between 2015 and 2037, 90 GW of coal is projected to retire. This capacity is a combination of those units that have announced they will retire and are considered "firm," and those that are projected to retire due to the economic pressures of meeting environmental measures in the face of relatively low natural gas prices and low electric demand growth.[18] Many oil/gas steam units also retire due to less favorable power market economics.

Exhibit 2-6
Cumulative US Retirements (GW)

Prime Mover	Foreign government investment Case				Enhanced US investment Case			
	2015	2020	2030	2037	2015	2020	2030	2037
Coal	50	77	85	90	50	76	85	90
Nuclear	3	3	6	46	3	3	6	46
Oil/Gas	23	24	27	27	24	24	27	27
Total	**76**	**104**	**118**	**163**	**76**	**103**	**118**	**163**

Source: Ventyx and IPM output

Most projected nuclear retirements are "firm." This study assumes that nuclear units will retire after the expiration of a 20-year license extension, at which point the units will be 60 years old. Many nuclear units will reach this age between 2030 and 2037, which is why the number of retirements increases so dramatically in the last few years of the study.

2.4 New Combined Cycle Generation

The electricity generation from the new NGCC units is largely reflective of the build out seen in Section 2.0. As the more efficient NGCCs come on-line, they gradually supplant the less efficient units, namely older coal and F-tech NGCC units. Both cases build a similar amount of new NGCC capacity, which generates roughly the same amount, producing around 1,750 TWh by 2037. The major difference between the cases is which unit generates the most, the J National Class 65% or the US Class 67%. In the Foreign government investment case, the J National Class 65% is the largest single generator, producing 50% of TWh by 2037. In the Enhanced US investment case, the more efficient 67% NGCC produces nearly 63% of all TWh by 2037.

[18] The major driver of coal retirements are upcoming environmental policies, specifically the Mercury and Air Toxics Standards (MATS). All environmental assumptions for the modeling analysis can be found in the appendix.

Exhibit 2-7
US Economic Build Combined Cycle Generation Post 2015 (TWh)

Prime Mover	Foreign government investment Case				Enhanced US investment Case			
	2015	2020	2030	2037	2015	2020	2030	2037
Conventional NGCC (F-Tech)	0	0	0	0	0	0	0	0
Advanced NGCC (H-Tech)	0	3	3	2	0	0	0	1
J Class NGCC 61.5	38	155	231	199	38	154	153	128
J National Class NGCC - 63.5	0	13	335	677	0	10	291	322
J National Class NGCC - 65	0	0	194	867	0	0	225	224
US Class NGCC - 64	-	-	-	-	0	0	0	0
US Class NGCC - 67	-	-	-	-	0	0	112	1,106
Total	**38**	**171**	**763**	**1,746**	**38**	**164**	**780**	**1,782**

Source: IPM output

The new units operate at a very high capacity factors, as they are the most efficient units in the market. In 2015, the J Class 61.5% units start to displace existing NGCCs on the dispatch stack. Over time, as more and more efficient NGCCs come on-line, they displace ever more of the existing NGCC fleet as well as some of the earlier NGCC builds on the dispatch stack. For example, the utilization of the J Class 61.5% NGCC is projected to fall from a high of 92% in 2015 to 64% in 2037.

2.5 Total Generation of all Prime Movers

As can be seen below in Exhibit 2-8, NGCCs increase from providing around 30% of US generation in 2015 to over 46% of total US generation by 2037. In both cases, the advanced and highly-efficient NGCCs provide nearly all the incremental generation needed between now and 2037.

Exhibit 2-8
Total US Generation (TWh)

Prime Mover	Foreign government investment Case				Enhanced US investment Case			
	2015	2020	2030	2037	2015	2020	2030	2037
Combined Cycle	1,262	1,427	1,818	2,529	1,262	1,424	1,817	2,536
Coal	1,418	1,403	1,544	1,513	1,418	1,406	1,546	1,509
Simple Cycle CT & Oil/Gas Steam	129	154	110	87	129	155	110	86
Nuclear	782	814	807	527	782	815	807	527
Renewable (Inc. Hydro)	559	593	638	692	559	593	638	692
Other	96	96	98	100	96	96	98	100
Total	**4,245**	**4,489**	**5,014**	**5,448**	**4,245**	**4,489**	**5,015**	**5,451**

Source: IPM output

As discussed in Section 2.1, while simple cycle CTs are projected to be the second-most numerous new build in the US, they do not provide a great deal of generation. They are primarily built to meet resource adequacy requirements.

Even though coal capacity is expected to fall by nearly 90 GW by 2037, generation from coal facilities holds relatively steady from 2015 onward. Most of the coal units that retire are older, inefficient units that operate at a relatively low capacity factor. As that coal capacity retires, coal generation at the remaining units is actually projected to increase, as the cleanest and most efficient units are the ones that remain. As many coal units retire and coal demand drops, an increasing fuel price difference between coal and gas will develop, giving the remaining coal units a price advantage. However, even while holding steady on a TWh basis, coal generation share percentage falls from providing 33% of total generation in 2015 (slightly more than NGCCs) to only around a quarter of total generation by 2037.

Nuclear generation decreases from nearly 800 TWh in 2015 to 500 TWh in 2037, as the older units are forced to retire due to the expiration of their operating licenses. The units that remain operate at high capacity factors, due to the low variable operating costs of these units.

CHAPTER THREE
PROJECTED CO_2 EMISSION IMPACTS OF R&D SPENDING

In both cases, the majority of capacity expansion in the US power markets is projected to be new and highly-efficient combined cycles. Thus, over the next twenty-five years, US power sector CO_2 emissions are projected to grow slower than energy demand (1.0% vs 1.1%). In other words, the new fleet of projected combined cycles, which emit low amounts of CO_2 compared with today's technology, will lower the rate of growth of emissions of the entire US generation fleet. Additionally, as can be seen below in Exhibit 3-1, CO_2 emissions grow at an even slower rate in the Enhanced US investment case than in the Foreign government investment case. This is because the advanced NGCCs produced by US-based manufacturers will be more efficient, producing fewer tons of CO_2 per megawatt-hour of energy produced than those manufactured by their foreign competitors.

Exhibit 3-1

Projected CO_2 Emissions in the Power Sector (Million Short Tons)

	Foreign government investment Case	Enhanced US investment Case	US - Foreign government investment Case Delta
2015	2,099	2,099	0
2020	2,164	2,166	2
2025	2,308	2,313	5
2030	2,412	2,409	-2
2037	2,597	2,577	-20

Source: IPM output

CHAPTER FOUR
JOBS IMPACT RESULTS

The following discussion provides the results of the IMPLAN-based modeling of the two natural gas combined cycle cases—the Foreign government investment case and the Enhanced US investment case. Results favored the Foreign government investment case in the early years (i.e., up to 2024) and significantly favored the Enhanced US investment case in the latter years (i.e., 2025-3036). This significant increase is driven by US-based manufacturers producing new gas turbines domestically, rather than in a foreign country.

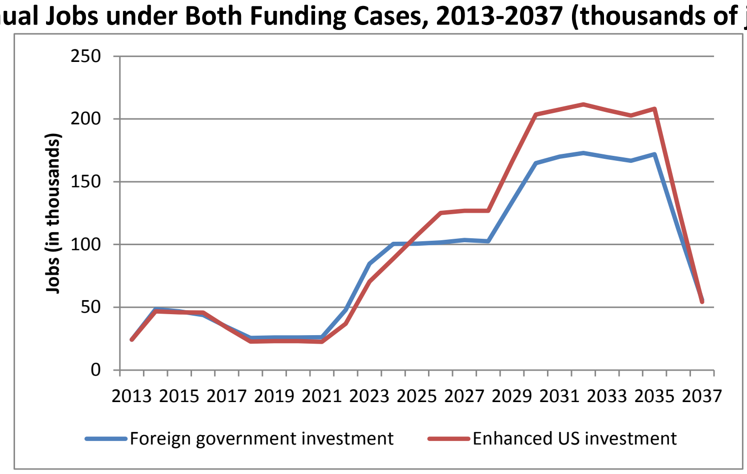
On average, the Enhanced US investment case produced more jobs, higher GDP (value added), more industry activity,[19] and higher tax revenue for federal, state, and local governments. The results presented below provide further details for each of the metrics, which are presented in annual terms.

4.0 Employment Impacts

Over the 25 years of investments covered by this analysis, the Enhanced US investment case generates an average of roughly 12,000 more jobs in a given year than the Foreign government investment case.

As seen in Exhibit 4-1 below, the number of jobs generated by the Foreign government investment case initially exceeds the number of jobs generated by the Enhanced US investment case. Five years after the final investment in research and development (R&D), the difference (jobs created under the Enhanced US investment case minus those created under the Foreign government investment case) becomes positive in 2025. The difference in jobs generated by the two cases peaks at 39,000 jobs in 2032, favoring the Enhanced US investment case. This is due to the increased competitiveness of US-based manufacturers building advanced NGCCs and thus maintaining market share.

Exhibit 4-1
Annual Jobs under Both Funding Cases, 2013-2037 (thousands of jobs)



Source: IMPLAN output

[19] Industry activity represents the value of an industry's total output increase due to the modeled scenario (in billions of constant dollars).

Exhibit 4-2 shows the annual employment figures for 2020, 2030, and 2035 under the two Funding cases from Exhibit 4-1, and presents the annual difference between the cases. As shown, the Enhanced US investment case generates slightly fewer jobs in the early years as a direct result of the slightly lower funding in those years, but generates significantly more jobs in the out-years, which also corresponds to the higher funding levels and secondary impacts associated with the R&D spending. In 2030 and 2035, the number of annual jobs created is higher under the Enhanced US investment case by roughly 20%. This is because many more manufacturing jobs can be supported in the domestic economy due to the increased competitiveness of US-based gas turbine manufacturers.

Exhibit 4-2
Annual Job Impacts and Delta for US and Foreign government investment cases, 2020, 2030, and 2035 (thousands of jobs)

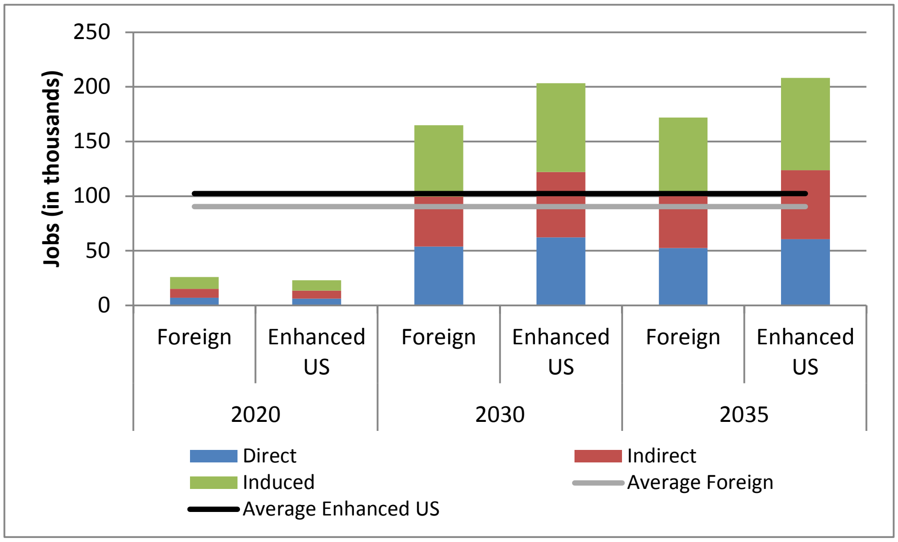
	Foreign government investment case	Enhanced US investment case	Delta
2020	26	23	-3
2030	165	203	39
2035	172	208	36
Average	**90**	**102**	**12**

Source: IMPLAN output

Exhibit 4-3 below presents the direct, indirect, and induced jobs in 2020, 2030, and 2035 for the two funding cases, and compares these to the average number of annual jobs with the average annual number of jobs produced by both cases. The breakout of direct, indirect, and induced[20] jobs also highlights the significant quantity of jobs that are created by indirect and induced expenses (i.e., the "multiplier effect"). The Enhanced US investment case has a stronger multiplier than the Foreign government investment case in 2020, 2030 and 2035. For example, in 2035, the Enhanced US investment case creates an additional 3.4 jobs per direct job whereas the Foreign government investment case only creates 3.3 jobs per direct job.

[20] Direct jobs are those that are directly attributable to the investments in the industry, such as manufacturing jobs. Indirect jobs are those that indirectly result from the direct jobs, such as industries that supply materials to the direct industries. Induced jobs are those that result from the spending of consumers whose jobs fall in the first two categories, such as service industries that cater to employees. For further definition, please refer to the glossary.

Exhibit 4-3
Jobs Impacts – 2020, 2030, 2035 (thousands of jobs)



Source: IMPLAN output

Exhibit 4-4 presents the industry-specific impacts under the two funding cases for 2030. In general, jobs created in most sectors under the Enhanced US investment case are of similar magnitude as those created under the Foreign government investment case. The construction sector, which produces around 15% of total jobs in both cases, does not vary too much between cases. The Turbine and Turbine Generator Set Units Manufacturing sector, however, benefits greatly under the Enhanced US investment case —a result of the significant investments in R&D and US-based manufacturers producing advanced NGCCs. This results in over 5,000 more jobs supported in the Enhanced US investment case.

Exhibit 4-4
Job Impacts by Sector, 2030 (thousands of jobs)

Sector	Foreign government investment case	Enhanced US investment case	Delta
Construction of new nonresidential manufacturing structures	28	26	2
Securities, commodity contracts, investments, and related activities	14	13	1
Food services and drinking places	11	9	2
Architectural, engineering, and related services	10	9	1
Electric power generation, transmission, and distribution	9	8	1
Turbine and turbine generator set units manufacturing	7	2	5
Employment services	6	4	2
Real estate establishments	6	5	1
Maintenance and repair construction of nonresidential structures	6	5	1
Wholesale trade businesses	4	3	1
Total employment in top 10 sectors	**101**	**84**	**17**

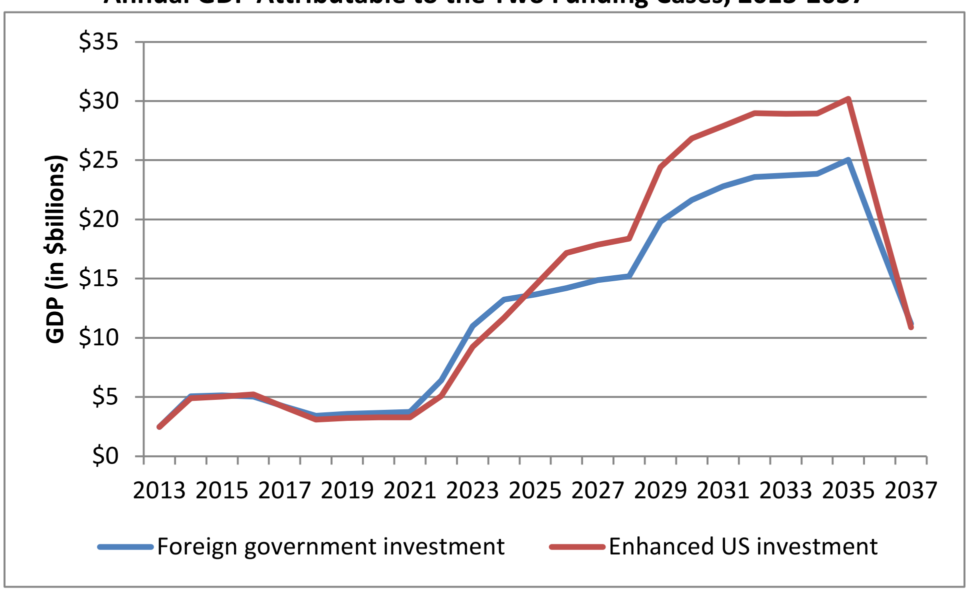
Source: IMPLAN output

Jobs in the construction sector, as well as the Electric Power Generation, Transmission, and Distribution sector and Turbine Manufacturing sector, are an effect of direct funding to the industry—that is, investments went directly to these industries. Jobs in food services and drinking places and real estate establishments are generated by induced effects. The remaining categories are predominantly a result of indirect project expenses.

4.1 Gross Domestic Product (Value Added) Impacts

GDP is the value added associated with the portion of a product or service that was created within the country. As with jobs, the GDP under both scenarios are similar until 2025, at which point the GDP under the Enhanced US investment case is significantly greater than under the Foreign government investment case. Over the 25-year period of investments (2013-2037), the GDP under the Enhanced US investment case averages $1.7 billion more per year than the GDP under the Foreign government investment case. In 2032, the difference in GDP between the US and Foreign government investment cases peaks at $5.4 billion, favoring the Enhanced US investment case.

Exhibit 4-5
Annual GDP Attributable to the Two Funding Cases, 2013-2037



Source: IMPLAN output

Exhibit 4-6 presents the GDP results for the years 2020, 2030, and 2035 and the per-annum average for the two cases, as well as the difference between them. Once again, the Enhanced US investment case generates a lower level of GDP in the near-term (i.e., 2020) than the Foreign government investment case, but generates a significantly higher level of GDP in the out-years (i.e., 2030 and 2035). In 2030 and 2035, the Enhanced US investment case results in roughly $5.2 billion more GDP than the Foreign government investment case – a result of increased output from US-based manufacturing of NGCC turbines.

Exhibit 4-6

GDP Impacts and Delta for US and Foreign government investment cases, 2020, 2030, and 2035 (in $billions)

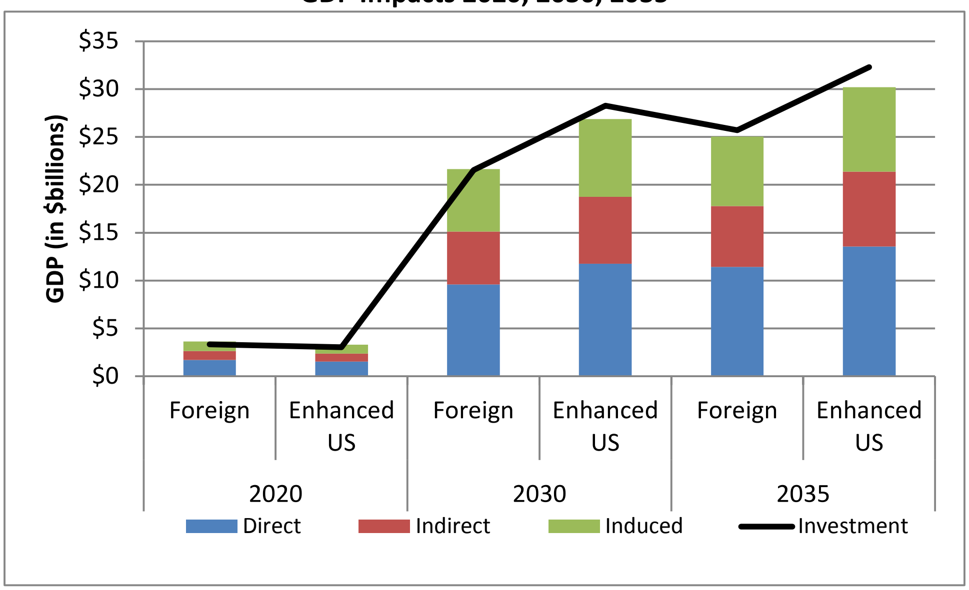
	Foreign government investment case	Enhanced US investment case	Delta
2020	3.6	3.3	-0.4
2030	21.6	26.9	5.2
2035	25.0	30.2	5.2
Average	**12.6**	**14.2**	**1.7**

Source: IMPLAN output

As shown in the exhibit below, the GDP impacts —including direct, indirect, and induced GDP—are roughly equivalent to the value of the annual investment for both cases in 2020, and are slightly below the value of the annual investments for both cases in 2030 and 2035. The GDP is higher under the Enhanced US investment case than under the Foreign government investment case by roughly $5 billion in both 2030 and 2035 because of the increased investment in US manufacturing as advanced US-developed NGCCs are being built in increasing numbers.

Exhibit 4-7

GDP Impacts 2020, 2030, 2035



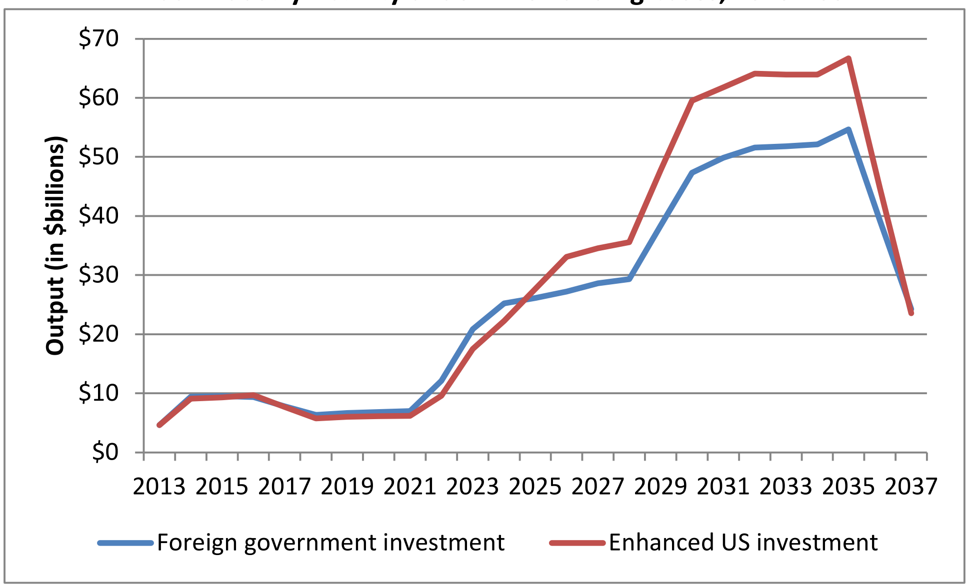
Source: IMPLAN output

The GDP multipliers under the two Funding Scenarios in 2020, 2030, and 2035 are similar. The multipliers ranged from 2.1 to 2.3, being smallest in 2020 and largest in 2030. In other words, $1 of products or services made in the country as a direct result of the initial funding results in at least double that in total GDP in these scenario years under both scenarios.

4.2 Industry Activity (Output) Impacts

On average, total industry activity is greater under the Enhanced US investment case than under the Foreign government investment case by roughly $3.8 billion per year. As has been the trend with other metrics, the Foreign government investment case creates more industry activity in the years leading up to 2025 than does the Enhanced US investment case; industry activity is higher under the Enhanced US investment case after 2025. The greatest difference in industry activity between the two cases, similar to other metrics previously discussed, occurs in 2032, where output under the Enhanced US investment case exceeds output under the Foreign government investment case by $12.5 billion. The major driver of difference between the two cases is the development of advanced and highly efficient gas turbines by US-based manufacturers, which leads to more investment in domestic manufacturing.

Exhibit 4-8
Annual Industry Activity under Two Funding Cases, 2013-2037



Source: IMPLAN output

In 2020, the Enhanced US investment case generates roughly $0.7 billion less in industry activity than the Foreign government investment case. By 2035, however, the difference in annual industry activity between the two cases exceeds $12 billion, favoring the Enhanced US investment case. The Enhanced US investment case results in significantly more output on average, although, as shown below, this does not occur each year.

Exhibit 4-9

Industry Activity Impacts and Delta for US and Foreign government investment Cases, 2020, 2030, and 2035 (in $billions)

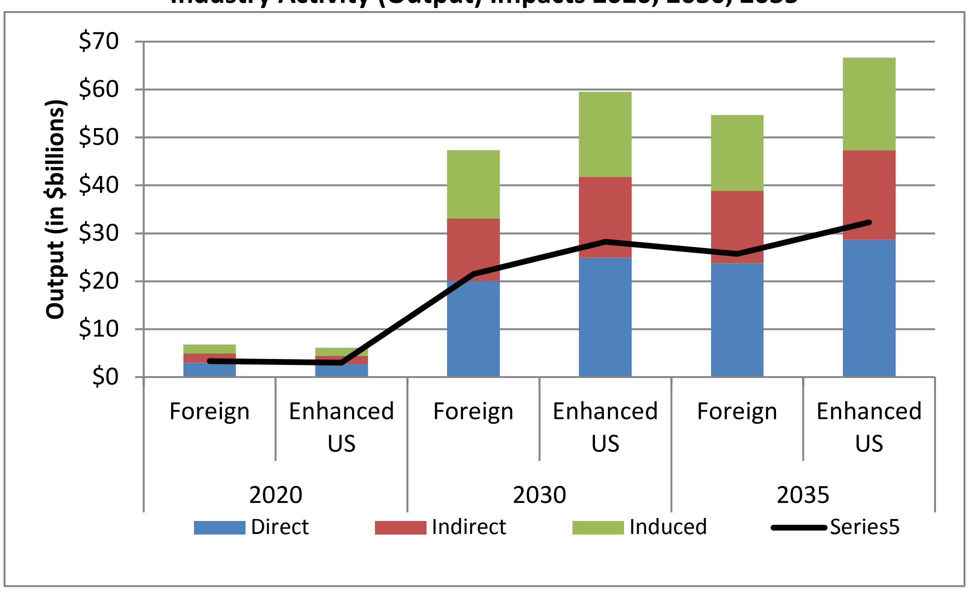
	Foreign government investment	Enhanced US investment case	Delta
2020	6.8	6.1	-0.7
2030	47.3	59.5	12.2
2035	54.7	66.7	12.0
Average	**25.8**	**29.6**	**3.8**

Source: IMPLAN output

As shown in the exhibit below, total industry activity significantly exceeds the value of annual investments under each case. For each of the two cases in both 2030 and 2035, the total industry activity is roughly twice the value of annual investments. The industry activity that is a direct effect of expenses is roughly 95 to 100 percent of initial expenses—the small difference accounting for the amount "leaking out" of the economy. The output multipliers for each Funding case in 2020, 2030, and 2035 range from 2.2 to 2.4; in each year, the multiplier under the Enhanced US investment case is similar to the multiplier under the Foreign government investment case. Together, industry activity resulting from indirect and non-related induced spending accounts for over half of the total output from annual expenditures. Or, in other words, a $1 investment into the economy leads to slightly more than $2 of total industry activity.

Exhibit 4-10

Industry Activity (Output) Impacts 2020, 2030, 2035



Source: IMPLAN output

As has been the trend with other metrics, both funding cases affect the same industries similarly, except for the Turbine and turbine Generator Set Units Manufacturing sector. As shown in Exhibit 4-11 below, the output in this sector in 2030 is roughly $4 billion greater under the Enhanced US investment case than under the Foreign government investment case, a result of direct expenses in R&D. While the industry activity generated under the Foreign government investment case is less than under the Enhanced US investment case, outputs based on the Foreign case often lag by only a small amount.

Exhibit 4-11

Industry Activity (Output) by Top 10 Sectors Impacted by Investments, 2030 (in $billions)

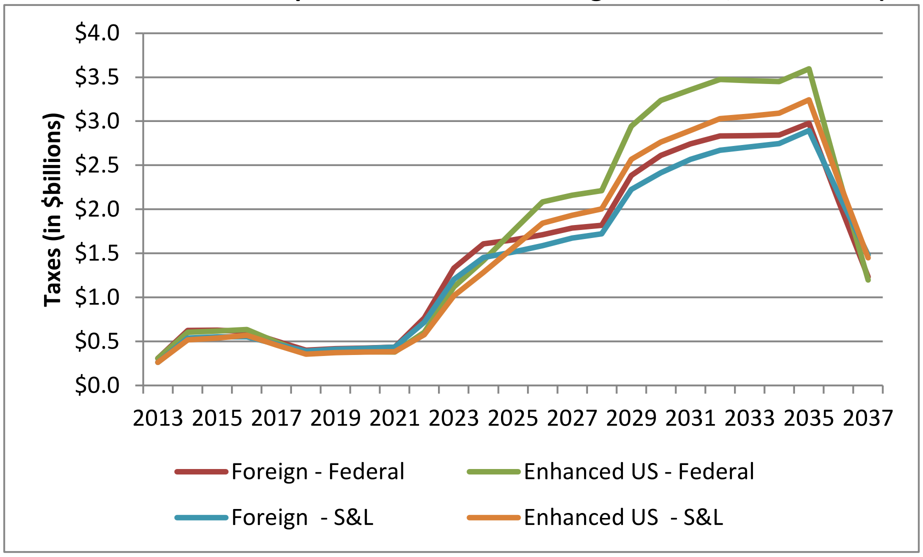
Sector	Foreign government investment	Enhanced US investment case	Delta
Electric power generation, transmission, and distribution	10.9	11.4	0.4
Turbine and turbine generator set units manufacturing	1.7	5.7	4.0
Construction of new nonresidential manufacturing structures	3.1	3.4	0.3
Securities, commodity contracts, investments, and related activities	2.9	3.2	0.3
Architectural, engineering, and related services	1.6	1.9	0.2
Real estate establishments	1.1	1.4	0.3
Wholesale trade businesses	0.8	1.0	0.3
Food services and drinking places	0.8	0.9	0.2
Maintenance and repair construction of nonresidential structures	0.7	0.8	0.1
Employment services	0.3	0.4	0.1
Total output from top 10 sectors	**23.9**	**30.0**	**6.1**

Source: IMPLAN output

4.3 Tax Revenue Impacts

Over the 25-year period (2013-2037), investments (i.e., industry activity) for the Enhanced US investment case generate an average of $1.7 billion per year in federal taxes and $1.5 billion per year in state and local taxes. The Enhanced US investment case generates $0.2 billion more per year in federal taxes and $0.1 billion more per year in state and local taxes than the Foreign government investment case (Exhibit 4-12).

Exhibit 4-12
Federal and State & Local Tax Impacts Under Two Funding Scenarios, 2013-2037 (in $billions)



Source: IMPLAN output

Exhibits 4-13 and 4-14 present the federal, state, and local tax impacts for the years 2020, 2030, and 2035 for each of the two cases. As has been the case with other metrics, the Foreign government investment case produces more federal, state, and local tax revenue in 2020, but the Enhanced US investment case generates significantly more tax revenue in 2030 and 2035. In 2030, the Enhanced US investment case generates roughly $0.6 billion more federal tax revenue and $0.3 billion more state and local tax revenue.

Exhibit 4-13
Federal Tax Impacts and Delta for US and Japan Cases,
2020, 2030, and 2035 (in $billions)

	Foreign government investment	Enhanced US investment case	Delta
2020	0.4	0.4	0.0
2030	2.6	3.2	0.6
2035	3.0	3.6	0.6
Average	**1.5**	**1.7**	**0.2**

Source: IMPLAN output

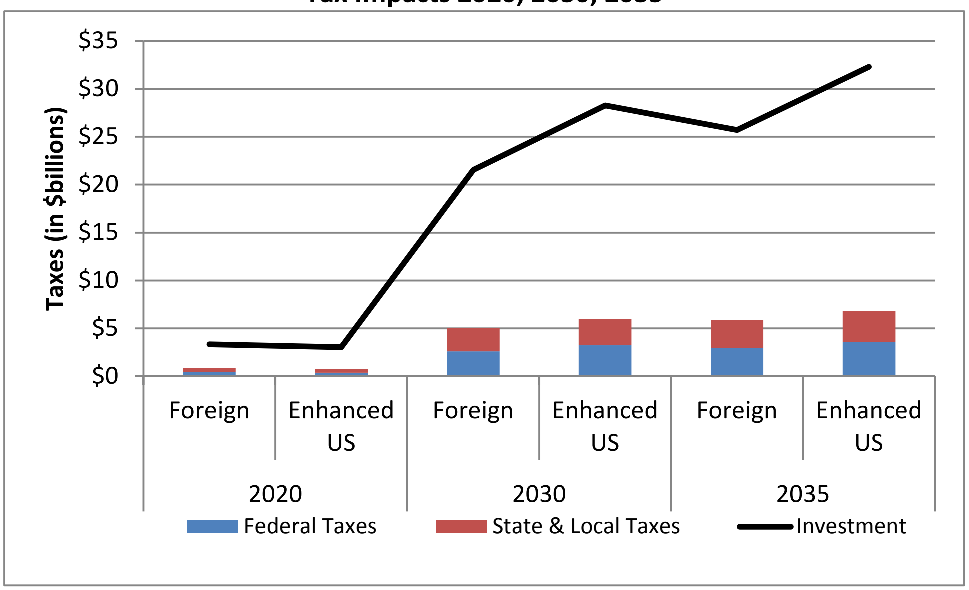
Exhibit 4-14
State & Local Tax Impacts and Delta for US and Foreign cases, 2020, 2030, and 2035 (in $billions)

	Foreign government investment	Enhanced US investment case	Delta
2020	0.4	0.4	0.0
2030	2.4	2.8	0.3
2035	2.9	3.2	0.3
Average	**1.4**	**1.5**	**0.1**

Source: IMPLAN output

As shown in the exhibit below, the public sector recovers roughly 20% of all activity made into the industry through federal, state, and local taxes. Although the value of all taxes is slightly higher for the Enhanced US investment cases for 2030 and 2035 than for the Foreign government investment case for the respective years, the difference generally corresponds with the difference between the value of industry activity in each case.

Exhibit 4-15
Tax Impacts 2020, 2030, 2035



Source: IMPLAN output

CHAPTER FIVE
APPENDIX – MAJOR ASSUMPTIONS

In this appendix, we summarize select key assumptions underlying both the Foreign government investment case and the Enhanced US investment case. For a more complete view of assumptions, please reference the detailed assumptions spreadsheets sent to GTA earlier in the process. As discussed earlier, all assumptions were developed based on public data sources and with the guidance of GTA.

Demand Growth

Exhibit 5-1 summarizes our assumptions on peak and energy demand. Peak demand and energy growth demand was taken from the North American Electric Reliability Association (NERC) Electricity Supply & Demand (ES&D) report, which was released in December 2012. National figures are shown for illustrative purposes. For modeling purposes, sub-NERC regional data was implemented.

Exhibit 5-1
Assumed Energy and Peak Demand Growth

Year	Net Energy For Load (GWh)	Summer Peak Demand (MWs)
2010	4,016,137	776,528
2011	3,981,149	789,490
2012	4,018,691	784,778
2013	4,077,261	786,170
2014	4,117,354	801,249
2015	4,171,254	814,823
2016	4,236,737	827,411
2017	4,284,991	837,899
2018	4,332,903	847,005
2019	4,382,668	856,761
2020	4,438,538	868,453
2021	4,451,392	879,275
2022	4,502,371	888,660
2023	4,553,832	899,776
2024	4,605,880	911,031
2025	4,658,524	922,428
2026	4,711,769	933,966
2027	4,765,623	945,649
2028	4,820,092	957,478
2029	4,875,184	969,456
2030	4,930,905	981,582
2031	4,987,264	993,861
2032	5,044,266	1,006,293
2012-2022 Growth Rate	**1.1%**	**1.3%**

Natural Gas Pricing

ICF utilized the Energy Information Agency's (EIA) 2012 Annual Energy Outlook (AEO) to develop its assumed Henry Hub natural gas price stream. As IPM uses the Henry Hub natural gas pricing point in its modeling, ICF utilized the AEO West South Central pricing point and used a historical percentage difference between it and Henry Hub to calculate a going forward Henry Hub price.

Exhibit 5-2
Assumed Natural Gas Pricing (Nominal $/MMBtu)

Year	AEO West South Central	Estimated Henry Hub
2013	4.46	3.97
2014	4.51	4.03
2015	4.73	4.21
2016	4.77	4.25
2017	4.90	4.37
2018	5.03	4.49
2019	5.28	4.71
2020	5.57	4.97
2021	5.94	5.30
2022	6.36	5.67
2023	6.77	6.04
2024	7.12	6.35
2025	7.51	6.70
2026	7.89	7.03
2027	8.29	7.39
2028	8.64	7.70
2029	9.06	8.07
2030	9.48	8.45
2031	9.91	8.84
2032	10.41	9.28
Average 2013-2032	**6.83**	**6.09**

Coal Pricing

Exhibit 5-3 summarizes ICF's assumed minemouth coal prices for two major coal basins: Eastern Interior Medium Sulfur (a bituminous coal) and Powder River Basin (a sub-bituminous coal). These coal prices were taken from the 2012 AEO Coal Report. Coal prices delivered to plants vary by source, location, and transportation options. Transportation costs were also based on this AEO report.

Exhibit 5-3
Assumed Minemouth Coal Pricing (Nominal $/short ton)

Year	Eastern Interior Medium Sulfur (Bituminous)	Wyoming, Powder River Basin Low Sulfur (Sub-Bituminous)
2013	61.10	14.61
2014	63.30	15.77
2015	62.70	16.96
2016	62.40	17.73
2017	64.22	18.59
2018	66.48	19.51
2019	68.63	20.38
2020	71.25	21.39
2021	73.92	22.41
2022	76.35	23.63
2023	78.82	25.09
2024	80.98	26.51
2025	83.29	27.89
2026	85.70	29.35
2027	88.18	30.89
2028	90.87	32.47
2029	94.22	34.05
2030	97.07	35.77
2031	100.07	37.42
2032	103.64	39.01
Average 2013-2032	**78.66**	**25.47**

New Unit Characteristics and Capital Costs

For both our new unit characteristics and capital cost assumptions, ICF used the data found in the 2012 AEO, which were originally developed by EIA in its report, "Updated Capital Cost Estimates for Electricity Generation Plants," released in November 2010. The efficiencies and heat rates of the five types of advanced NGCCs was based on assumed combined cycle development program, developed in discussion with GTA. Additionally, the capital cost assumption for Advanced PC with CCS was modified from EIA data based on GTA guidance.

Exhibit 5-4
Assumed New Unit Characteristics

Combined Cycle Technology Types	Funding Case	Online Year	Efficiency (%)	Heat Rate (Btu/kWh), HHV	Initial Capital Cost (2010$/kW)	Fixed O&M Cost (2010$/kW)	Variable O&M Cost (2010$/MWh)
Single Unit Advanced PC with CCS	-	2015	-	12,000	$4,000	$76.62	$9.05
Single Unit IGCC with CCS	-	2015	-	10,700	$5,348	$69.30	$8.04
Conventional NGCC	-	2015	-	7,050	$978	$14.39	$3.43
Advanced NGCC	-	2015	-	6,430	$1,003	$14.62	$3.11
J Class NGCC 61.5	Foriegn	2015	61.5%	6,281	$1,028	$14.62	$3.11
J National Class NGCC - 63.5	Foreign	2020	63.5%	6,084	$1,083	$14.62	$3.11
J National Class NGCC - 65	Foreign	2025	65.0%	5,943	$1,143	$14.62	$3.11
US Class NGCC - 64	US	2022	64.0%	6,036	$1,113	$14.62	$3.11
US Class NGCC - 67	US	2027	67.0%	5,766	$1,193	$14.62	$3.11
Conventional Simple Cycle CT	-	2015	-	10,850	$974	$6.98	$14.70
Advanced Simple Cycle CT	-	2015	-	9,750	$665	$6.70	$9.87
Dual Unit Nuclear	-	2015	-	10,000	$5,335	$88.75	$2.04
Onshore Wind	-	2015	-	N/A	$2,438	$28.07	$0.00
Offshore Wind	-	2015	-	N/A	$5,975	$53.33	$0.00
Large Photovoltaic	-	2015	-	N/A	$4,755	$16.70	$0.00

The change in capital costs over time was developed from the 2012 AEO Assumptions, Table 8.10. For the five new NGCC units, capital costs were developed based on a "Value-Added" analysis in which the value-added over the "Advanced NGCC" unit option from the AEO was calculated, in terms of $/kW. It was assumed that 50% of the Value-Added would be of sufficient incentive for the manufacturer to produce this new unit. This process was performed for five new NGCC.

Exhibit 5-5

Assumed Overnight Capital Costs of New Combined Cycles (Nominal $/kW)

Year	Conventional NGCC	Advanced NGCC	J Class NGCC 61.5	J National Class NGCC - 63.5	J National Class NGCC - 65	US Class NGCC - 64	US Class NGCC - 67
2012	$1,028	$1,054					
2015	$1,161	$1,188	$1,216				
2016	$1,174	$1,197	$1,226				
2020	$1,224	$1,233	$1,265	$1,335			
2022	$1,251	$1,256	$1,289	$1,363		$1,404	
2025	$1,292	$1,289	$1,325	$1,405	$1,492	$1,448	
2027	$1,307	$1,296	$1,334	$1,418	$1,509	$1,464	$1,586
2030	$1,326	$1,303	$1,344	$1,434	$1,532	$1,483	$1,614
2035	$1,348	$1,309	$1,355	$1,457	$1,568	$1,513	$1,661

The change in capital costs over time was not provided in the AEO report for Wind or Solar units. For these units, the trend for the conventional simple cycle combustion turbine was used.

Exhibit 5-6

Assumed Overnight Capital Costs of Selected New Units (Nominal $/kW)

Year	Single Unit Advanced PC with CCS	Single Unit IGCC with CCS	Conventional Simple Cycle CT	Advanced Simple Cycle CT	Dual Unit Nuclear	Onshore Wind	Offshore Wind	Large Photovoltaic
2012	$4,203	$5,619	$1,023	$699	$5,605	$2,561	$6,277	$4,996
2015	$4,707	$6,295	$1,156	$786	$6,184	$2,882	$7,064	$5,621
2016	$4,742	$6,344	$1,169	$791	$6,169	$2,898	$7,106	$5,655
2020	$4,875	$6,521	$1,220	$808	$6,059	$2,959	$7,255	$5,773
2022	$4,951	$6,624	$1,247	$821	$6,133	$3,005	$7,370	$5,864
2025	$5,058	$6,768	$1,288	$839	$6,231	$3,070	$7,530	$5,992
2027	$5,077	$6,795	$1,302	$840	$6,271	$3,075	$7,544	$6,003
2030	$5,087	$6,808	$1,321	$839	$6,309	$3,070	$7,533	$5,993
2035	$5,070	$6,789	$1,342	$836	$6,329	$3,058	$7,505	$5,971

Firm Builds

ICF used the Ventyx power plant database to develop its firm build assumptions. Ventyx is a subscription-based service which tracks unit-level data. Exhibit 5-7 presents a US-wide summary of projected firm builds for the 2013-2017 time period. Units are considered firm if they are under construction, in testing, or undergoing site preparation.

Exhibit 5-7
Assumed Firm Builds (MW)

Type	2013	2014	2015	2016	2017	Total (2013-2017)
Biomass	469	320	56			845
Coal	1,107		600			1,707
Geothermal	118	72				190
Hydro	250	213	140	20	4	626
Landfill Gas	139		30			169
Combined Cycle	3,902	4,082	1,800	624		10,408
Combustion Turbine	3,385		690			4,075
Nuclear	119		1,270	1,117	2,234	4,740
Other	43		210			253
Solar	3,215	1,127	152	150		4,644
Wind	2,784					2,784
Total	**15,530**	**5,814**	**4,948**	**1,911**	**2,238**	**30,440**

Environmental Regulations

Exhibit 5-8 summarize ICF's assumptions on environmental programs and their dates of inception. The Mercury and Air Toxics Standard (MATS) will have the strongest impact on the coal fleet, leading to many retirements. The New Source Performance Standards (NSPS) will limit construction of new generation units to only those that emit CO_2 at the levels of a combined cycle. This will effectively ban new coal unless it is equipped with carbon capture and storage (CCS).

Exhibit 5-8
Assumed Environmental Regulations

Regulation	Timing
SO_2 and NO_x (CAIR/CAIR II)	2013
Air Toxics (HAPS/MATS)	2016
CO_2 (RGGI)	2013
CO_2 (AB32)	2013
NSPS	2014

Exhibit 5-9 summarizes ICF's assumptions for two CO_2 policies: the AB32 California Carbon Allowance Program (AB32) and the Regional Greenhouse Gas Initiative (RGGI). The pricing for AB32 in 2013 and 2014 are forward prices from NYMEX, averaged from one month of trade dates (Jan 1, 2013 to Feb 1, 2013). Going forward, we assume a 5% annual growth in pricing, which is consistent with the growth in floor price assumed by the California Air Resources Board (CARB). The pricing for RGGI, which affects most Northeastern states, is taken from a study commissioned by RGGI itself, which can be found at http://www.rggi.org/docs/ProgramReview/February11/Results_91_Cap_Bank_MR.xls.

Exhibit 5-9
Assumed CO_2 Pricing (Nominal$/ton)

Year	AB32 - California Carbon Allowance (CCA)	RGGI CO_2
2013	15.77	2.00
2014	16.74	6.65
2015	18.02	7.20
2016	19.39	7.81
2017	20.87	8.47
2018	22.46	9.16
2019	24.17	9.95
2020	26.02	10.77
2021	28.00	11.04
2022	30.14	11.31
2023	32.43	11.59
2024	34.91	11.88
2025	37.57	12.18
2026	40.43	12.49
2027	43.52	12.80
2028	46.84	13.12
2029	50.41	13.45
2030	54.25	13.78
2031	58.39	14.13
2032	62.84	14.48
Average 2013-2032	**34.16**	**10.71**

Limitations on CC Build Out

ICF assumes that limitations on manufacturers' production ability will limit the production of each new combined cycle to 5 GW per year until 2030. This is loosely based on a historical analysis of the market penetration of NGCC technology over the last twenty years. After 2030, this constraint on production of a certain NGCC series is completely relaxed.

CHAPTER SIX
MODELING METHODOLOGY

IPM

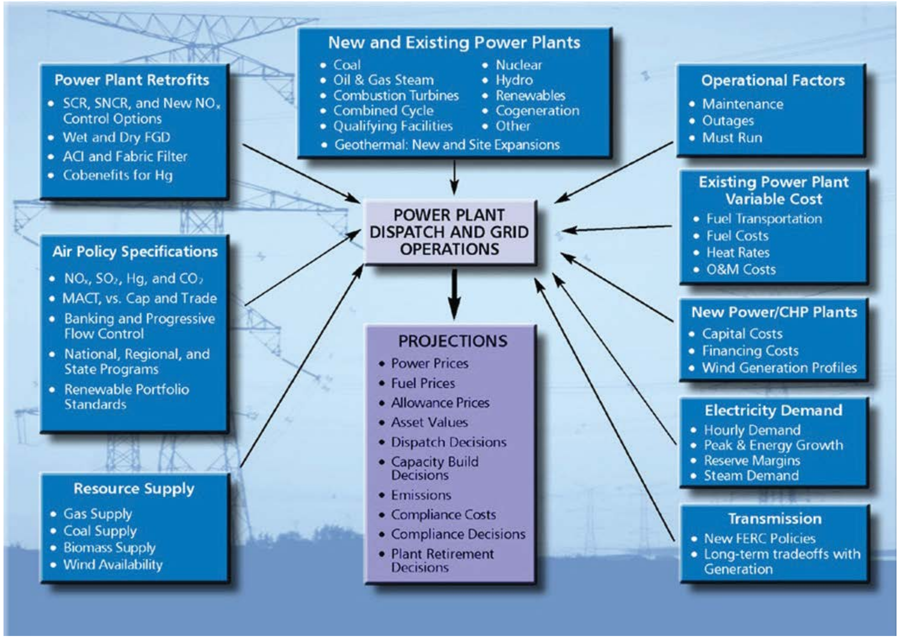
IPM® analyzes wholesale power markets and assesses competitive market prices of electrical energy, based on an analysis of supply and demand fundamentals (see diagram below). IPM® projects zonal wholesale market power prices, power plant dispatch, fuel consumption and prices, interregional transmission flows, environmental emissions and associated costs, capacity expansion and retirements, and retrofits based on an analysis of the engineering economic fundamentals. The model does not extrapolate from historical conditions, but rather provides a least-cost optimization projection for a given set of future conditions that determine how the industry will function (i.e., new demand, new power plant costs, new fuel market conditions, new environmental regulations, etc.). The optimization routine has dynamic effects (i.e., it looks ahead at future years and simultaneously evaluates decisions over a specified time horizon). All major factors affecting wholesale electricity prices are explicitly modeled, including detailed modeling of existing and planned units, with careful consideration of fuel prices, environmental allowance and compliance costs, transmission constraints, and operating constraints.

Based on the supply/demand balance in the context of the various factors discussed above, IPM® projects hourly spot prices of electric energy within a larger wholesale power market. IPM® also projects an annual “pure” capacity price.

IPM models the entire North American power system with more than 100 zonal markets. The benefit of this greater geographic scope and granularity is that the model covers the entire market, the details of the national environmental regulations, and transmission congestion across major interfaces. This also allows for properly capturing coal and natural gas usage.

A graphic representation of the IPM power market model is shown below in Exhibit 6-1 in terms of inputs and outputs.

Exhibit 6-1
IPM Modeling Structure



IMPLAN

ICF used the economic impact modeling software IMPLAN to conduct the job and impact analysis. IMPLAN is created and maintained by the Minnesota IMPLAN Group (MIG). IMPLAN provides detailed industry information for 440 sectors roughly aligned with 4-digit NAICS (North American Industry Classification System) industry codes. This level of detail allows the analysis to be more precise both in terms of the inputs (which drives the multipliers) and in the sense that the output results are at a higher granularity and thus we are better able to understand the sector-specific implications.

IMPLAN is considered a static model because the impacts calculated for any scenario estimate the indirect and induced impacts for that year. For projects that span more than one year, such as the proposed seven-year scenario for this project, impacts can be assessed annually and job impacts can be reported in annual job-years. For this analysis, we analyzed the annual impact associated with each year of technology development program funding (2013 – 2037). The model uses multipliers to trace and calculate the flow of dollars from the industries that originate the impact to supplier industries. These multipliers are thus coefficients that "describe the response of the economy to a stimulus (a change in demand or production)." Three types of multipliers are used in IMPLAN:

- Direct – represents the impacts (e.g., employment or output changes) due to the investments that result in final demand changes, such as investments in gas turbine infrastructure

- Indirect – represents the impacts due to the industry inter-linkages caused by the iteration of industries purchasing from industries, brought about by the changes in final demands.
- Induced – represents the impacts on all local industries due to consumers' consumption expenditures arising from the new household incomes that are generated by the direct and indirect effects of the final demand changes.

The total impact is the sum of the multiple rounds of secondary indirect and induced impacts that remain in the region (as opposed to "leaking out" to other countries by way of exports/imports). IMPLAN then uses this total impact to calculate subsequent impacts such as total jobs created and tax impacts.

CHAPTER SEVEN
GLOSSARY

Executive Summary, Chapters 1-3 - Competitiveness

AB32: California's state-level carbon policy.

Advanced PC: Advanced pulverized coal. Pulverized fed plants are the typical form of coal firing in the US.

Capacity Factor: The ratio of the actual output of a power plant over a period of time and its potential output if it had operated at full capacity the entire time.

British thermal unit (Btu): The quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit.

Capacity: A measure of output from a power plant, commonly expressed in megawatts (MW).

Capital Costs: A measure of the total cost of construction of a power plant that Includes the engineering and procurement costs, owner's costs, and interest during construction costs.

Carbon dioxide (CO_2): A colorless, odorless, non-poisonous gas that is a normal part of Earth's atmosphere. Carbon dioxide is a product of fossil-fuel combustion as well as other processes.

CCS: Carbon capture and storage.

Energy: The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Electrical energy is usually measured in kilowatthours, while heat energy is usually measured in British thermal units (Btu).

Generation: The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in kilowatthours.

Gigawatt (GW): One billion watts or one thousand megawatts.

Gigawatthour (GWh): One billion watt-hours

Greenhouse gases: Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface.

Heat Rate: An expression of the conversion efficiency of a thermal power plant or engine, as heat input per unit of work output. The units for this study are Btu/kWh.

Hg: Mercury.

Henry Hub: Henry Hub is the typical pricing index used when expressing the cost of natural gas.

IGCC: Integrated gasification combined cycle. Typically used with coal as a feedstock, the fuel is gasified and then fed through a combined cycle.

MATS: Mercury and Air Toxics Standards. Often used interchangeably with the term HAPS (Hazardous Air Pollutants).

Megawatt (MW): One million watts of electricity.

Megawatt-hour (MWh): One million watt-hours

Minemouth: The price of a fuel, typically coal, at its source, prior to the addition of any transportation charges.

MMBtu: One million British Thermal Units

NGCC: Natural gas combined cycle, a popular power generation technology since the early 1990s typically fired with natural gas. The combined cycle combines two thermodynamic cycles: the brayton cycle and the rankine cycle.

Nitrogen oxides (NOx): Compounds of nitrogen and oxygen produced by the burning of fossil fuels.

NSPS: New Source Performance Standards.

Oil/Gas Steam: Typically an older generator which runs on oil or natural gas that uses only a steam rankine cycle to produce energy.

Overnight Capital Costs: A measure of construction costs that estimates the cost at which a plant could be constructed assuming the entire process from planning to completion could be finished in one day. This measure thus does not include short-term financing costs.

PRB: The Powder River Basin region is located in and around the State of Wyoming and is the source of low sulfur sub-bituminous coal.

Regional Greenhouse Gas Initiative (RGGI): A 10-state regional CO_2 policy, centered in the Northeastern US.

Simple Cycle CT: Combustion turbine. A generator typically fired with natural gas. The CT uses one thermodynamic cycle: the brayton cycle.

Sulfur dioxide (SO_2): A toxic, irritating, colorless gas soluble in water, alcohol, and ether. Used as a chemical intermediate, in paper pulping and ore refining, and as a solvent.

Watt (W): The unit of electrical power equal to one ampere under a pressure of one volt. A Watt is equal to 1/746 horse power.

Watt-hour (Wh): The electrical energy unit of measure equal to one watt of power supplied to, or taken from, an electric circuit steadily for one hour.

Chapter 4 - Jobs / IMPLAN

Three types of multipliers are used in IMPLAN:

- Direct – represents the impacts (e.g., employment or output changes) due to the investments that result in final demand changes, such as investments in gas turbine infrastructure
- Indirect – represents the impacts due to the industry inter-linkages caused by the iteration of industries purchasing from industries, brought about by the changes in final demands.
- Induced – represents the impacts on all local industries due to consumers' consumption expenditures arising from the new household incomes that are generated by the direct and indirect effects of the final demand changes.

Result Options –

- *Industry Activity / Output* – represents the value of an industry's total output increase due to the modeled scenario (in billions of constant dollars).

- *Employment* – represents the jobs created by industry, based on the output per worker and output impacts for each industry.

- *Total Value Added* – is the "catch-all" for payments made by individual industry sectors to workers, interests, profits, and indirect business taxes.

- *Labor Income* – is part of the value added, and consists of all forms of employment income. Consistent with I/O terminology, IMPLAN defines this as the sum of the employee compensation and proprietor's income.

    - *Employee Compensation* – represents the total payroll costs (including benefits) of each industry sector. These results will show the positive impacts on wages and salaries of workers due to any brownfields cleanup and redevelopment.

    - *Proprietor's Income* – the other component of labor income, consists of payments received by self-employed persons as income. This includes payments received by doctors, lawyers, and other private business owners.

- *Other Property Type Income* – another part of value added consisting of payments for rents to individuals on properties, royalties from contracts, and dividends paid by corporations, as well as corporate profits.

- *Indirect Business Taxes* – third and final component of total value added, consists of excise taxes, property taxes, fees, licenses, and sales taxes paid by businesses.

- *Tax Impact* – breakdown of taxes collected by the federal, state and local government institutions from different economic agents. Includes corporate taxes, household income taxes, and other indirect business taxes.[21]

[21] The tax impacts are not part of the GDP accounting framework used for the other impacts. These are calculated in IMPLAN using standard assumptions about tax rates.

CHAPTER EIGHT
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