NGNP-HTGR Assisted Conventional Processes Jobs Creation and Energy Security Report

FINAL REPORT

February 2011

Prepared By:

URS Corporation, Denver, CO 80237
Power, Infrastructure, Federal, Industrial & Commercial

Prepared For:

Idaho National Laboratory

The INL is a U.S. Department of Energy National Laboratory
Operated by Battelle Energy Alliance

NGNP-HTGR Assisted Conventional Processes Jobs Creation and Energy Security Report

FINAL REPORT

February 2011

Report Authors:

Chris Cunningham, Senior Engineer

Navroze Amaria, Project Manager

REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	02/21/2011	All	Final Issue

TABLE OF CONTENTS

Table 1. List of Acronyms

ASU	Air Separation Unit
bbl	barrel
BLS	Bureau of Labor Statistics
BOE	Barrel of Oil Equivalent
BTU	British Thermal Units
Ctdc	Cost Total Depreciable Cost
DW&B	Direct Wages and Benefits
EIA	Energy Information Agency
G&A	General and Administrative
FTE	Full Time Equivalent
HTGR	High Temperature Gas Cooled Nuclear Reactor
HTSE	High Temperature Steam Electrolysis
lb	Pound
MMXXX	Millions of XXX
MW&B	Maintenance Wages and Benefits
NGNP	Next Generation Nuclear Plant
O&M	Operations and Maintenance
SCF	Standard Cubic Feet
SCFD	Standard Cubic Feet per Day
SNG	Substitute Natural Gas
SOW	Scope of Work
TIC	Total Installed Cost
USGS	United States Geological Survey
$M	Millions of US Dollars

1. INTRODUCTION

1.1. Purpose of Report

This report provides an estimate of the jobs created and impact on the energy security as a result of the integration of the HTGR with various Commercial Industrial Processes. The report was prepared by URS in response to the INL SOW-8688, "Impact of HTGR - Integrated Processes on jobs and Energy Security".

This report helps to fulfill a two-fold purpose:

- To establish a baseline estimate of the jobs created and market impacts for the life cycle of various industrial processes.
- To provide a tool to address changes in the baseline as the processes are refined.

It must be stressed that these baseline estimates are functions of the level of definition of the technologies, not just with respect to technical maturity, but also with respect to life cycle costs.

1.2. Industrial Processes Investigated

The following Integrated Processes are included in the analysis:

- TEV 666
    - Natural Gas to Ammonia
    - HTSE: Gas to Ammonia (Combustion)
    - HTSE: Gas to Ammonia (ASU)
- TEV 667
    - Natural Gas to Methanol to Gasoline
    - Coal to Methanol to Gasoline
- TEV 671
    - Coal to Substitute Natural Gas
- TEV 672
    - Coal to Liquids
    - Gas to Liquids
- TEV 674

  - Power Production
- TEV 693
  - Hydrogen Production
- TEV 704
  - Steam Assisted Gravity Drainage

1.3. Analysis and Boundaries

This report considers the jobs created and US energy security impact for the lifecycle of the conventional portion of the HTGR integrated processes as well as the HTGR itself, and the HTGR in a power-CoGen configuration.

2. JOBS CREATION ANALYSIS METHODS

In order to segregate the jobs creation periods into distinct phases, the following was utilized, in chronological order to cover the life cycle:

- Engineering: Engineering Labor
- Fabrication: The Fabrication of Capital Items
- Manufacturing: Construction Bulk Materials
- Construction: Direct and Indirect
- Operations: Plant Operations and Support, Maintenance
- Decommissioning: Direct and Indirect

Each life cycle phase has its own method and metrics applied to calculate the jobs created. Each phase has some overlap when transitioning from one to another and in some cases occurs concurrently in a periodic manner (as in the case of the manufacture of replacement or maintenance items, installed on a periodic basis) in some cases, there may be several methods devised to calculate the same item. When possible, more than one method is employed to estimate the jobs created.

Most of the assumptions around the total jobs created for a life cycle are based on the INL provided capital costs as described in Table 2. The Total Installed Cost (TIC) is obtained from the TEVs, less the TIC of the nuclear (HTGR) portion of the plant. These values are taken directly from the respective INL prepared TEVs.

Table 2. Capital Costs Established for Each Case.

	Installed Equipment Cost	Uninstalled Equipment Cost	Engineering	Contingency	TIC with Contingency
		Based on Installation Factor of 3.5	10% of Installed Equip. Cost	18% of installed Equip. and Eng.	
	$M	$M	$M	$M	$M
HTGR Only	932	266	93	N/A*	1,025*
HTGR in CoGen**	1092	312	109	32	1,233
Natural Gas to Ammonia	1,359	388	136	269	1,764
HTSE: Gas to Ammonia (Combustion)	2,107	602	211	417	2,735
HTSE: Gas to Ammonia (ASU)	2,031	580	203	402	2,636
Natural Gas to Methanol to Gasoline	1,385	396	138	274	1,797
Coal to Methanol to Gasoline	5,194	1,484	519	1,028	6,742
Coal to Substitute Natural Gas	2,081	595	208	412	2,701
Coal to Liquids	4,153	1,187	415	822	5,391
Gas to Liquids	1,437	411	144	285	1,865
Power Production	160	46	16	32	208
Hydrogen Production	303	86	30	60	393
Steam Assisted Gravity Drainage	786	225	79	156	1,021

**Contingency not included in the HTGR only case as it was not specifically identified in the TEVs. It is assumed that the contingency is contained within the overall TIC.*

*** Contingency is applied to the power production portion only.*

Industrial processes are assumed Nth of a kind.

The following is a complete discussion of the methods employed for each job creation phase. For the sake of continuity, all wages and costs are provided in 2009 US dollars.

2.1. Engineering: Engineering Labor

For the Engineering phase job creation period, the cost of the engineering was based on a percent of the equipment cost (In general, this was 10% of the un-installed cost). This value was then divided by an aggregate estimate of the cost of engineering labor per hour. This is then divided among the total period of time allotted in the TEV for the Engineering effort to determine the jobs per year. A percentage of the contingency is distributed to the engineering, based on the fraction it contributes to the total installed cost.

Engineering jobs include the range of engineering disciplines; Chemical, Electrical, Mechanical, Civil and Structural Engineers etc. This period also includes designers of all disciplines, drafters, administration, and management.

For the sake of this analysis, a value of $107/hour (Table 3) was used to determine the total engineering hours expended for the project. This represents a 70/30 split of wages to benefits[1] and an estimated 1.5 overhead and profit multiplier.

Table 3. Engineering Cost Buildup

Wages	$50/hour
Benefits	$21/hour
Total Compensation from above	$71/hour
Overhead	$36/hour
Total	$107/hour

2.2. Fabrication: The Fabrication of Capital Items and Equipment

For the Fabrication period, the bare equipment cost was used to determine the total worker-hours required to fabricate the capital items. For the purpose of the analysis, the metric[7] of 1 FTE-yr for every $250,000 of purchased equipment was utilized. A percentage of the contingency is distributed to the fabrication, based on the fraction it contributes to the total installed cost.

In some instances, the Fabrication period extends through the Operations period as there is a significant capital investment in replacement of items such as failed pieces of equipment, catalyst or membranes.

2.3. Construction: Direct and Indirect

For the Construction period, the installation cost (TIC minus the Bare Equipment Cost) can be used to determine the total hours associated with the construction labor. The installation cost is a mix of direct labor, indirect labor, tools, and equipment. It is convenient and customary to reduce this cost to an “all in” labor rate (Table 4). Using this rate, the total number of direct labor hours expended can be calculated. Typical examples of jobs created during this phase include welders, pipefitters, instrumentation technicians, electricians, and general construction laborers. A percentage of the contingency is distributed to the construction, based on the fraction it contributes to the total installed cost. Additional jobs are created in the indirect category at the rate of ~0.1 support hours per direct hour.

Table 4. Buildup to "All-In" Construction Labor Rate

Average "mixed" journeyman rate	\$30/hr
Benefits, burdens & premium pay to standard 60 hours per week	\$15/hr
Training, craft incentives & per diem	\$10/hr
Indirect costs including clean-up, welder qualifications, small tools & consumables, scaffolding, construction equipment, temporary facilities, subcontractor supervision & staff (including field, local & office staff, field office expenses, per diem, travel), package policy insurance and subcontractor G&A and fee.	\$45/hr
Total “All In” Rate	\$100/hr

It must also be acknowledged that there are jobs created in the production of raw materials. For the permanent plant equipment, it is assumed that the metric prescribed in 2.2 accounts for this raw material. The only remaining capital items are bulk construction materials (concrete, structural steel, pipe, fill material). For the purposes of the study, the following metrics[a] are employed:

- 70% of the installation cost is due to field labor (described above)
- 30% of the installation cost is due to bulk materials

As the true distribution of bulk materials in each process are not known at this level of cost estimate and the definition of the type or quantity of each bulk is not known, an order of magnitude assumption has been made to describe the distributions. It is an important distinction as there may be significant differences in the distribution between the various technologies, as well as the labor fractions of each type of material, but that is far beyond this level of cost definition and should have little impact on the overall lifecycle jobs. The distribution of the bulk materials as a fraction of the total bulks, fraction of TIC, and their labor contributions to the overall TIC can be seen in Table 5. The aggregate fraction of labor cost associated with the cost of the bulks is ~9%. For the purpose of the analysis, the overall compensation rate is \$50 per hour.

[a] Representative of a cross section of similarly sized Industrial Process Facilities, internal URS metrics.

Table 5. Bulk Material Distributions

Material Account	Earthwork	Concrete	Structures (steel)	Piping
% of Bulks	7%	8%	17%	69%
% of TIC	0.47%	0.52%	1.16%	4.65%
% of material account cost due to labor	3%	5%	10%	10%
% of total bulks cost due to labor	0.207%	0.386%	1.707%	7%
%of TIC as Material Production Labor	0.0140%	0.0261%	0.1155%	0.4652%

2.4. Operations: Plant Operations and Support

For the Operations period, not all categories are represented in each of the cases. However, at a minimum, direct and indirect costs are included in all cases.

2.4.1. Conventional Processes

Several metrics were identified to determine the relationship between the process and the required production support (or at least the cost of that support). These metrics are functions of capital cost, capacity, number of units in the process, and phase. Examples of these calculations can be found in common references including *Product and Process Design Principles: Synthesis, Analysis, and Evaluation*[3], Seider-Seader-Lewin (capital cost, capacity, # of units and phase), *Petroleum Engineering Handbook*[4] (capital cost), and *Perry's Chemical Engineering Handbook*[5] (production rate, # of units, degree of complexity). For comparison, three (3) methods of calculating the Operations and Maintenance Jobs have been selected.

1. Utilize the Operations and Maintenance costs established in the TEVs and use the labor rate to calculate total FTEs.
2. Utilize an algorithm developed by Seider-Seader-Lewin, based on TIC, number of units and capacity.
3. Utilize Energy Information Agency (EIA) and Bureau of Labor Statistics (BLS) data to establish staffing levels normalized by throughput for typical refineries. Adjust with factors to allow for more or less complex processes.

Using approach 1 from above, the TEVs have utilized a factored approach to determine the operating cost (and therefore the required staffing). This operating cost has been utilized to calculate the required staffing, based on an aggregate rate of $50/hour. The TIC, O&M factors[b], plant throughput rate[c] and the resulting O&M cost are given below in Table 6.

2.4.2. HTGR only and HTGR in CoGen

In general, there is sufficient literature to determine the number of jobs created during the operations period for a conventional nuclear reactor coupled to a power generation process. Based on several sources[7, 8], the high side of this metric varies between 0.4 and 0.7 employees per megawatt. However a study conducted by Dominion Energy and Bechtel Power Corporation[9], estimated that a 4 module, 600MWt per module plant would require approximately 241-300 employees. This scheme yields approximately 1144 MWe, reducing the employee per MW metric to

[b] Based on INL Provided Operations and Maintenance Factors.

[c] Throughput rate is based on inlet rates for process that have primarily solid feed stocks (coal), and outlet rates for those that are primarily vapor feed stocks (gas to liquids).

approximately 0.21 to 0.26 employees per MWe. This analysis was conducted for the Westinghouse AP1000, 3rd Generation reactor, and may be a better fit than older 1st and 2nd generation reactors that other metrics may be based on.

These metrics of course include resources required to operate and maintain both the reactor as well as the power generation cycles. For the purpose of the analysis, it will be assumed that the number of jobs identified for the power production process (TEV 764) identified in the parent report will be deducted directly from the estimated jobs created. This will reduce the results by approximately 23 FTEs (0.084 FTEs per MWe). Using the range of 0.7 to 0.21 FTEs per MWe and removing the FTEs from the power generation results in a final metric range of 0.62 to 0.13 FTEs per MWe.

Table 6. Primary Inputs to Operations Jobs Calculations

Process	TIC with Contingency	Plant Rate	Operating Cost per Year	Maintenance Cost per Year
			1.15% of TIC	3.0% of TIC
	$M	tons/day	$M/Year	$M/Year
HTGR Only	1,025	-		
Natural Gas to Ammonia	1,764	6,718	16	41
HTSE: Gas to Ammonia (Combustion)	2,735	6,718	24	63
HTSE: Gas to Ammonia (ASU)	2,636	6,718	23	61
Natural Gas to Methanol to Gasoline	1,797	4,864	16	42
Coal to Methanol to Gasoline	6,742	11,845	60	156
Coal to Substitute Natural Gas	2,701	3,864	24	62
Coal to Liquids	5,391	9,520	48	125
Gas to Liquids	1,865	8,894	17	43
Power Production*	208	16,157	2	5
Hydrogen Production	393	6,387	3	9
Steam Assisted Gravity Drainage	1,021	9,408	9	24

*Based on Boiler Feedwater rate - Hybrid Powercycle, Hysys stream 33

For the second method (from the list of 3 above), the Seider-Seader-Lewin algorithm for determining the number of operations and maintenance personnel was used. This method does not make references to sources of information, so is used as-is for comparison purposes only and can be found in the “Calculation-Results” section for each case.

Consistent with approach 3 above, actual operating and staffing data was obtained by referencing US workforce volumes in the refining industry as determined by the BLS vs. EIA production data. This allowed the determination of “number of employees per unit of production per year” basis. See Table 7 for the data set used to determine the metric. In this case, the metric is calculated by dividing the average number of workers in a calendar year by the total production on a daily basis for that calendar year to establish a normalized employee per unit of daily production basis. For the study, an average value of 0.0454 FTEs per ton per day was selected.

The 0.0454 FTEs per ton per day refers to refining only and is used as a reference point. The numbers of jobs generated by the other processes are then compared to the number of jobs for a refinery of the same capacity. In the calculation, a typical refinery would have a complexity of one (1), with the processes analyzed having complexities relative to that. On the Input Sheet, the “Complexity Relative to Refinery” cell is set to one (1) at this time. It could be altered to reflect a more or less complex plant. This is used more as a check against a known set of data. Each process can be seen as more or less complex, relative to a typical refinery. For the sake of future analysis, the complexity can be estimated qualitatively and compared to other methods of calculating the operations staffing. As this would not likely extrapolate well to Power Generation Cycles, it is not included for that analysis.

Table 7. Average Annual U.S. Refinery Inputs, and Employment Workforce, 1987-1994

	Total Refining thousand bbls/day[6]	Yearly Average of Employees (thousands)[10]	Employees per thousand bbl/day	Employees per ton/day
Inputs				
1987	19584	125	6.4	0.051
1988	20256	121	6.0	0.047
1989	20401	117	5.7	0.046
1990	20602	118	5.7	0.045
1991	20731	122	5.9	0.047
1992	20905	119	5.7	0.045
1993	21355	112	5.3	0.042
1994	21428	109	5.1	0.040
Average Charge Capacity				
1987	23158	125	5.4	0.043
1988	23525	121	5.1	0.041
1989	23357	117	5.0	0.040
1990	23475	118	5.0	0.040
1991	23692	122	5.1	0.041
1992	23504	119	5.1	0.040
1993	23243	112	4.8	0.038
1994	23301	109	4.7	0.037

Other jobs created in this phase, but broken out as a separate activity are any jobs created from significant capital replacements. These are fabricated items such as the replacement of the HTSE cells. HTSE cells are considered to be a fabricated item, requiring an appreciable amount of labor per unit to produce (on par with all other fabricated items). These are relatively insignificant compared to other jobs created during this phase and are included in the “Calculation and Results” section as “Operations Capital Fabrication” and not shown here. In the case of catalyst, where most of the cost is in the material, the jobs created for this is assumed to be insignificant and not included. The technologies that included HTSE cell replacements are; Gas to Ammonia (combustion and ASU), Coal to SNG and Hydrogen Production.

2.5. Decommissioning

The jobs created during the decommissioning phase are assumed to be similar in nature to jobs created in the construction phase. That is, the same wage rates and methodology used to calculate the number of jobs created in the construction phase is applied to the decommissioning phase. The cost of the decommissioning period was not directly given in the TEVs, but instead was estimated to be a “wash” with the salvage value of the equipment. Salvage value is typically estimated at approximately 10% of TIC[4], so this value was used to determine the total jobs created.

2.6. Direct, Indirect and Induced Effects

Part of the economic benefit of the various processes can be found in the relationship between the direct, indirect and induced effects of the investment. The direct benefits are captured in the analysis above. For the sake of the analysis, the following assumptions are made:

- For every direct job created, 1.4 indirect jobs are created from induced spending
- For every direct and indirect job created, there is an additional induced effect, creating an additional 0.8 jobs.

Therefore, through each phase a total of 2.2 incremental jobs are created for each direct job[11].

3. ENERGY SECURITY ANALYSIS METHODS

3.1. Impact on Imported Hydrocarbons

In general, the most significant impact with respect to the importation of hydrocarbons is when it is practical for a product of one of the conventional processes to act as a direct substitute for an imported one. Even in the event there is not a straightforward relationship, it is reasonable that one energy source can substitute for another. This generalization of course does not account for the thermal efficiency of the end user (hydrogen cell, versus an internal combustion engine), but for the sake of the analysis, this will be the assumption. Table 8 illustrates the assumed aggregate specific BTU content of the various product streams.

Table 8. Heating Values of the Various Conventional Process Products.

	BTU/lb
Coal	12,000
Substitute Natural Gas	24,000
Gasoline	20,000
LPG	20,000
CTL/GTL - Liquids	20,000
Hydrogen	60,000
Bitumen	18,000

For the sake of convenience, the various case outputs can be converted into a Barrel of Oil Equivalent (BOE). Using a basis for energy content of 5,800,000 BTU/BOE, the product streams can be compared to an average barrel of oil, imported or domestic.

3.2. Impact on Jobs for Overseas Suppliers

It is acknowledged that if there are incremental sources of energy domestically that result in the production of new domestic jobs and a reduction in the importing of non-domestic sources of energy, there may be a net reduction in non-domestic job growth. At this point in the analysis, it will be assumed that there is a net reduction in overseas jobs growth that is a direct 1:1 relationship to those held domestically for the production of oil and gas. Table 9 illustrates the number of domestic oil and gas production jobs, normalized to the production during that period. As BLS data for oil and gas production is grouped together for both oil and gas, the total BOEs produced is considered. This is based on the USGS metric of 6000 cubic feet of natural gas per BOE[12].

Table 9. Domestic Jobs per Unit of Domestic BOE Production

	Crude Oil Production	Natural Gas Production		Total Oil and Gas Production	Yearly Average of Employees	Normalized Employees
	bbls/day	MMSCFD	BOE/day	BOE	Thousands	Employees per mBOE production
1987	8,348,981	55,179	9,196,438	17,545,419	402	22.88
1988	8,161,981	57,532	9,588,701	17,750,682	400	22.52
1989	7,613,077	57,738	9,623,025	17,236,102	381	22.08
1990	7,355,307	58,966	9,827,681	17,182,988	395	22.97
1991	7,416,545	59,589	9,931,556	17,348,101	394	22.68
1992	7,190,773	60,636	10,106,050	17,296,822	352	20.37
1993	6,846,666	62,262	10,377,005	17,223,671	349	20.29
1994	6,661,578	64,605	10,767,446	17,429,024	337	19.31

4. RESULTS OF ANALYSIS: JOBS CREATED

Table 10 is a summary of the jobs created for each process, by job creation period. For example, Coal to Substitute Natural Gas creates on average approximately 1317 FTE jobs per year for the duration of the life cycle of 36 years, directly attributed to the process. Most of these jobs are operations jobs with a life cycle of 30 years. Using the metric established in section 2.6, this may also result in additional 2.2 indirectly generated jobs per directly generated job (2356, or another 2897 FTEs).

For the sake of understanding the number of jobs created per year, the duration of each phase is important. These durations are consistent with the assumptions used for the economic analysis completed in the TEVs. These durations do not necessarily represent a realistic schedule, but were chosen for consistency in developing pricing and cost. Since the jobs created are based on a total cost of Engineering, Equipment Fabrication, Construction, and Decommissioning, the total number of jobs are independent of the duration. In some cases, the assumed Engineering, Fabrication, or Construction durations may need to be modified in order to understand the true FTEs per year and the lifecycle average.

The complete detail of the inputs, calculations and the results can be found attached.

- 2009 – 2012 (Three Years) Engineering
- 2011 – 2012 (One Year) Fabrication
- 2011 – 2014 (Three Years) Construction and Bulks Manufacturing
- 2014 – 2044 (Thirty Years) Operations
- 2044 – 2045 (One Year) Decommissioning

The complete set of inputs, outputs, and results can be found in the appendix, the results of which are summarized in Table 10.

Table 10. Summary of FTEs per Year, Per Phase

		Engineering	Fabrication	Construction	Bulk Materials Manufacturing	Operations	Operations Capital Fabrication	Decommissioning	Total Lifecycle Average
-	HTGR Only	140	1065	548	58	113	0	361	389
-	HTGR In Cogen	168	1281	659	69	136	0	435	467
TEV 666	Natural Gas to Ammonia	240	1553	1000	105	150	0	622	669
TEV 666	HTSE: Gas to Ammonia (Combustion)	372	2842	1461	154	233	1	964	1088
TEV 666	HTSE: Gas to Ammonia (ASU)	358	2739	1408	148	225	1	929	1049
TEV 667	Natural Gas to Methanol to Gasoline	244	1868	960	101	153	0	634	717
TEV 667	Coal to Methanol to Gasoline	917	7005	3602	379	574	0	2377	2689
TEV 671	Coal to Substitute Natural Gas	367	2807	1443	152	230	1	952	1074
TEV 672	Coal to Liquids	733	5602	2880	303	459	0	1901	2150
TEV 672	Gas to Liquids	254	1938	997	105	159	0	658	744
TEV 674	Power Production	28	216	111	12	23	0	73	79
TEV 693	Hydrogen Production	53	408	210	22	33	0	139	156
TEV 704	Steam Assisted Gravity Drainage	139	1060	545	57	87	0	360	407

These results represent the average per year FTEs employed in each of the phases, for the duration of each phase. For example, TEV 671 shows 2807 FTEs per year for the Fabrication period. This implies that there are 2807 FTEs on average during the one (1) year Fabrication period. If the capital cost remains the same and the duration extended, the average per year FTEs will decrease, but of course the duration is now longer. The “Total Life Cycle Average” is the total yearly FTEs, averaged over the lifecycle of the projects, in these cases, 36 years.

For the sake of comparison, the results of the three different methods described for the determination of the operations and maintenance jobs are shown in

Table 11, along with the average and standard deviation in the values. For the case of the HTGR and HTGR in CoGen, the TEV O&M Cost method is compared to the high and low ranges. These results are found in Table 12.

It is important to understand the limitations of the various methods of calculating the Operations period FTEs. As much of the determination of “complexity” and “number of significant units” may largely be subjective, the variability in the results is not surprising. The Seider-Seader and Lewin method is quantized based on capacity and is not a smooth function, making it somewhat limited. A strict analysis of the true number of units, the actual train philosophy, even the location of the facility would allow more precision in this determination.

Table 11. Comparison of the Three Methods of Estimating the Operations and Maintenance FTEs for the Conventional Processes

		Operations (TEV O&M Cost)	Operations (Seider-Seader-Lewin)	Operations (BLS Data Metric)	Average	Standard Deviation
TEV 666	Natural Gas to Ammonia	150	283	305	246	84
TEV 666	HTSE: Gas to Ammonia (Combustion)	233	278	305	272	36
TEV 666	HTSE: Gas to Ammonia (ASU)	225	274	305	268	40
TEV 667	Natural Gas to Methanol to Gasoline	153	193	221	189	34
TEV 667	Coal to Methanol to Gasoline	574	746	537	619	111
TEV 671	Coal to Substitute Natural Gas	230	369	175	258	100
TEV 672	Coal to Liquids	459	482	432	458	25
TEV 672	Gas to Liquids	159	195	403	253	132
TEV 674	Power Production	23	80	Not Used	51	40
TEV 693	Hydrogen Production	33	88	290	137	135
TEV 704	Steam Assisted Gravity Drainage	87	114	610	270	294

Table 12: Comparison of the Three Methods of Estimating the Operations and Maintenance FTEs for the Conventional Processes in the HTGR cases.

		Operations (TEV O&M Cost)	Dominion/Bechtel Study (Low)	Dominion/Bechtel Study (High)	Average	Standard Deviation
-	HTGR Only	113	36	170	106	67
-	HTGR In Cogen	136	58	195	129	69

5. RESULTS OF ANALYSIS: ENERGY SECURITY

There are two elements that will be investigated for the analysis:

- Determine the potential reduction in oil imports
- Determine the corresponding decrease in non-domestic oil and gas production jobs

In addition, energy security will be considered with respect to investigating the application of the HTGR in general, as well as it's conjunction with a CoGen process.

5.1. Potential Reduction in Oil Imports

Table 13 illustrates the potential net reduction in oil imports on an BOE basis per process, and the reduction in energy imports on an BOE per ton of process product. While it is reasonable to continue with the assumption that the analysis based on a BTU and BOE basis is acceptable, it is important to understand that due to infrastructure limitations (i.e. hydrogen storage and distribution). Some options may be a more direct comparison and substitution than others.

Table 13. Potential Reduction in Energy Imports per Process, on an Oil Equivalent Barrel Basis

TEV #	Process	Total MMBTUs/day	Total BOEs	BOEs per Ton of Product
			Bbls/day	BOEs/ton
TEV 666	Natural Gas to Ammonia	-	-	-
TEV 666	HTSE: Gas to Ammonia (Combustion)	-	-	-
TEV 666	HTSE: Gas to Ammonia (ASU)	-	-	-
TEV 667	Natural Gas to Methanol to Gasoline	191,016	32,934	7
TEV 667	Coal to Methanol to Gasoline	329,325	56,780	7
TEV 671	Coal to Substitute Natural Gas	154,944	26,714	8
TEV 672	Coal to Liquids	247,788	42,722	7
TEV 672	Gas to Liquids	249,280	42,979	7
TEV 693	Hydrogen Production	766,440	132,145	21
TEV 704	Steam Assisted Gravity Drainage	338,688	58,394	6

Making these substitutions, the various technologies can be compared to the current and projected energy importation on a BOE basis. Assuming a 2009 import basis of 11.7 MMBOE per day and a total consumption of 18.7 MMBOE, the percentage each facility represents of each is shown. Also shown is the number of facilities required to satisfy 20% of total domestic demand (2009).

Table 14. Potential fraction of domestic market represented by various technologies and number of plants required to satisfy 20% of domestic usage (2009)

TEV#	Process	Total OEBs	Fraction of Imported Oil	Fraction of All Domestic Usage	Number of plants required to meet 20% of domestic consumption (2009)
		bbls	%	%	#
666	Natural Gas to Ammonia	-	-	-	-
666	HTSE: Gas to Ammonia (Combustion)	-	-	-	-
666	HTSE: Gas to Ammonia (ASU)	-	-	-	-
667	Natural Gas to Methanol to Gasoline	32,934	0.28%	0.18%	114
667	Coal to Methanol to Gasoline	56,780	0.49%	0.30%	66
671	Coal to Substitute Natural Gas	26,714	0.23%	0.14%	140
672	Coal to Liquids	42,722	0.37%	0.23%	88
672	Gas to Liquids	42,979	0.37%	0.23%	87
693	Hydrogen Production	132,145	1.13%	0.71%	28
704	Steam Assisted Gravity Drainage	58,394	0.50%	0.31%	64

5.2. Potential Decrease in Overseas Oil and Gas Production Jobs

Based on the above BOE reduction in imports, there may be a corresponding reduction in overseas jobs developed. This potential reduction is based on BLS data for total US workers employed in oil and gas extraction, normalized to a yearly FTE per thousand BOE. The assumption at this point is that non-domestic oil production workers have similar normalized productivity on a worldwide scale as their US conterparts. Table 15, “Total Overseas Jobs Reduction” illustrates that potential reduction based on an average 21.6 yearly FTEs per thousand BOE, taken from Table 9.

Table 15. Potential decrease in overseas oil and gas oil and gas production oil and gas production jobs based on reduced energy imports.

TEV #	Process	Total BOEs	Total Overseas Jobs Reduction
		bbls/day	FTEs per year
666	Natural Gas to Ammonia	-	-
666	HTSE: Gas to Ammonia (Combustion)	-	-
666	HTSE: Gas to Ammonia (ASU)	-	-
667	Natural Gas to Methanol to Gasoline	32,934	713
667	Coal to Methanol to Gasoline	56,780	1,229
671	Coal to Substitute Natural Gas	26,714	578
672	Coal to Liquids	42,722	925
672	Gas to Liquids	42,979	930
693	Hydrogen Production	132,145	2,860
704	Steam Assisted Gravity Drainage	58,394	1,264

5.3. HTGR and HTGR in CoGen

By inspection, it is expected that the energy security derived from the development of the HTGR lies in the coupling of the HTGR with a conventional process that allows the displacement of imported liquid hydrocarbons and not necessarily directly attributable to the HTGR itself. It could be argued that nuclear derived power of any confirmation (HTGR, BWR, PWR, etc.) improves domestic energy security. However, as petroleum liquids presently make up less than 1% of fossil fuel derived electric generation[13]; the opportunity to displace imported liquid hydrocarbons is limited.

There is potential to displace imported natural gas however. Presently, approximately one third of fossil fuel derived electric generation is from natural gas. Approximately 15% of natural gas consumed within the US is imported[14] (chiefly from Mexico and Canada). Natural gas power generation is in general increasing[15] (doubling from 1996 to 2007) much faster than coal (up 12% between 1996 and 2007). It is likely that the total natural gas net generation will be ~1,000,000 thousand-MW-hours in 2010. Assuming 15% of this power is generated via imported natural gas and that a single 600 MWt / 274 MWe unit produces 2400 thousand-MWe-hours per year, it would take approximately 416 units to displace the entire imported natural gas volume, assuming of course that the fraction of total imported gas extends to the fraction of implored gas used in power generation. There may be less energy security advantages to displacing natural gas imports, but it is noted here regardless.

6. REFERENCES

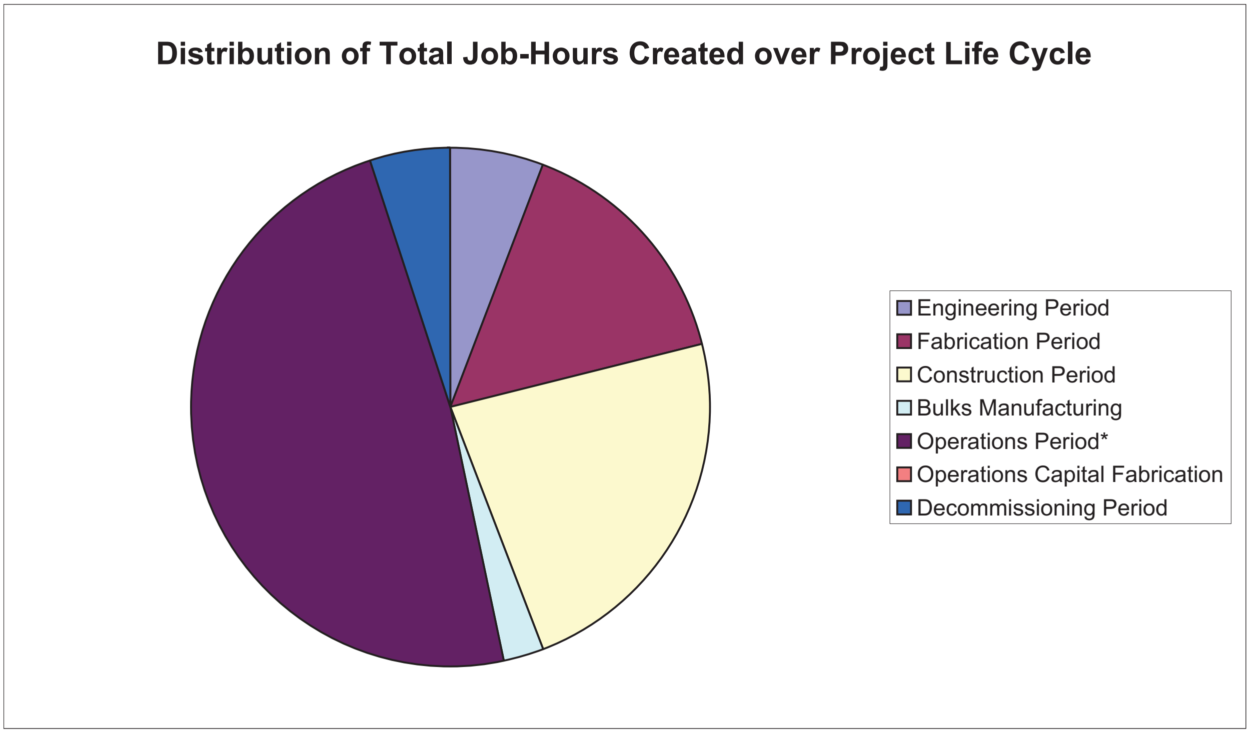
1. http://www.bls.gov/news.release/ecec.nr0.htm BLS Employer Costs for Employee Compensation news release, accessed June, 2010
2. INL Supplied Metric: Document comments via Email, 9/23/2010
3. Seider, Seader, Lewin: *Product and Process Design Principles*, 2nd Edition, 2003
4. H.B. Bradley, *Petroleum Engineering Handbook,* First Edition, 1987
5. Perry et. Al, Perry's Chemical Engineering Handbook
6. The Energy Information Administration, Petroleum Supply Annual, 1987-1994
7. Http://www.nei.org/keyissues/reliableandaffordableenergy/factsheets/nuclearpowerplantcontributions/ - Accessed August 2010
8. http://thisweekinnuclear.com/?p=1019 - Accessed August 2010
9. *Study of Potential sites for the Deployment of New Nuclear Power Plants in the United States* – By dominion energy for US DOE, September 2002
10. Bureau of Labor Statistics Data extraction for SIC type 322910 "Petroleum Refining"
11. Report on Economic, Employment and Environmental Benefits of Renewed U.S. Investment in Nuclear Energy, 2008, Oxford Economics,
12. http://energy.cr.usgs.gov/WEcont/world/woutsum.pdf, accessed June, 2010
13. http://www.eia.doe.gov/cneaf/electricity/epm/tablees1a.html - Accessed August 2010
14. http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_m.htm - Accessed August 2010
15. http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html - Accessed August 2010

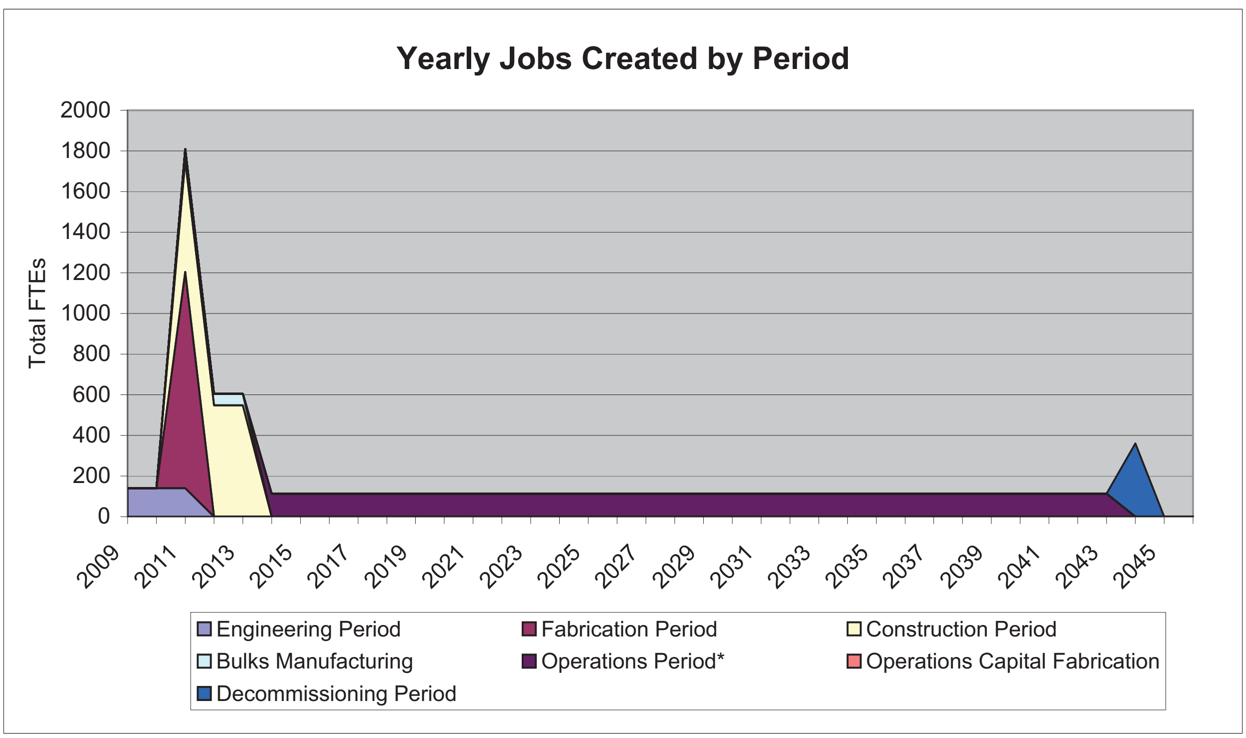
APPENDIX A

JOBS CREATION CHARTS

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

- HTGR Only

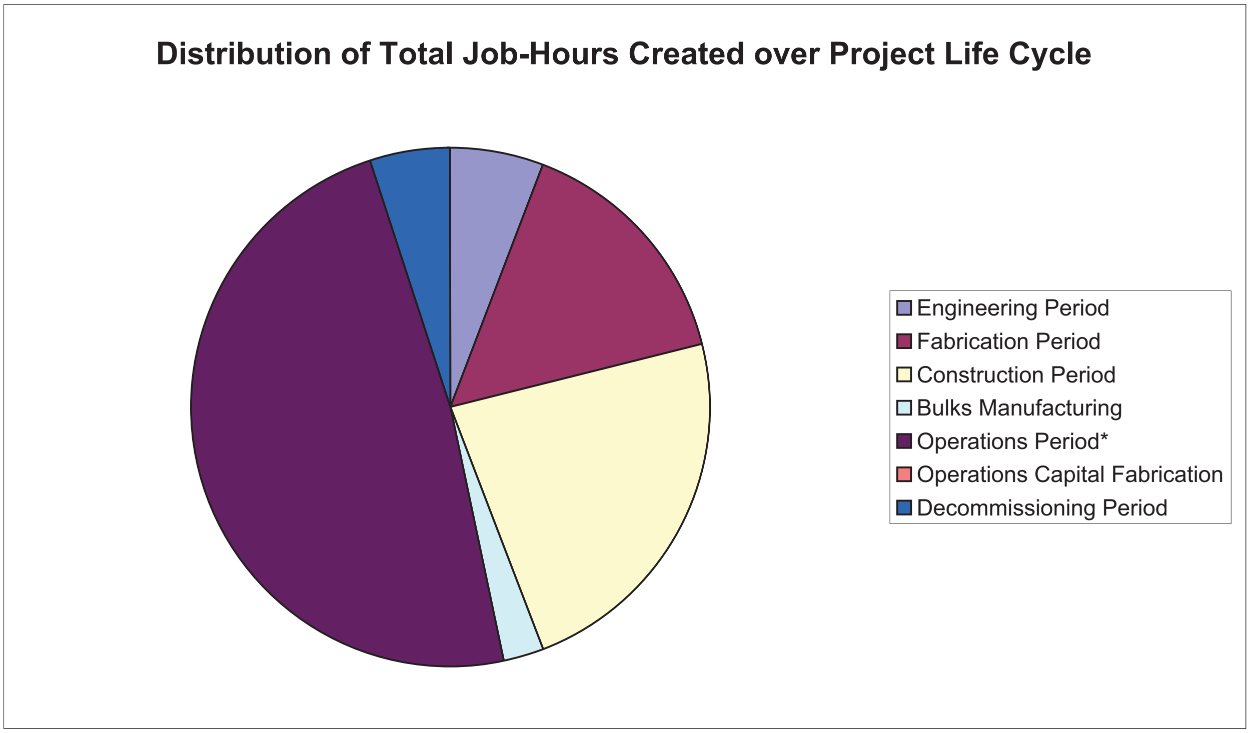


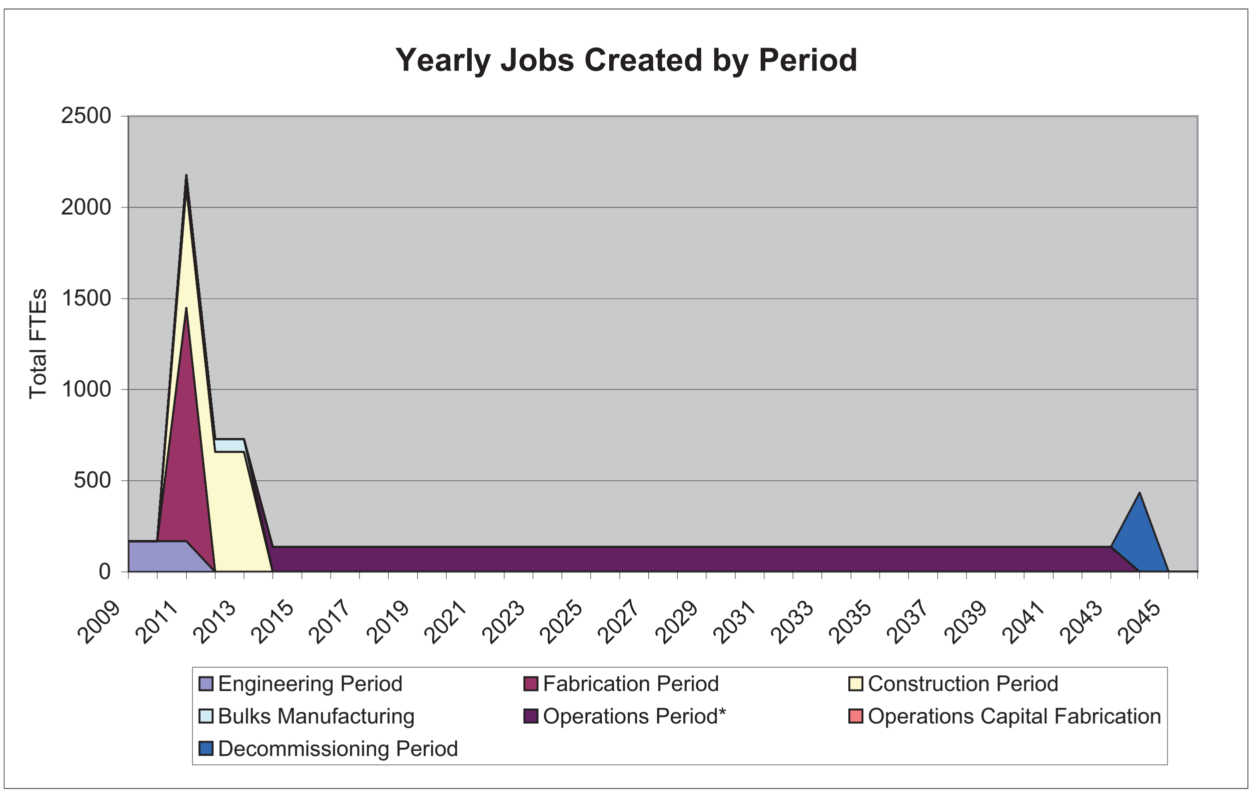


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

- HTGR in Cogen

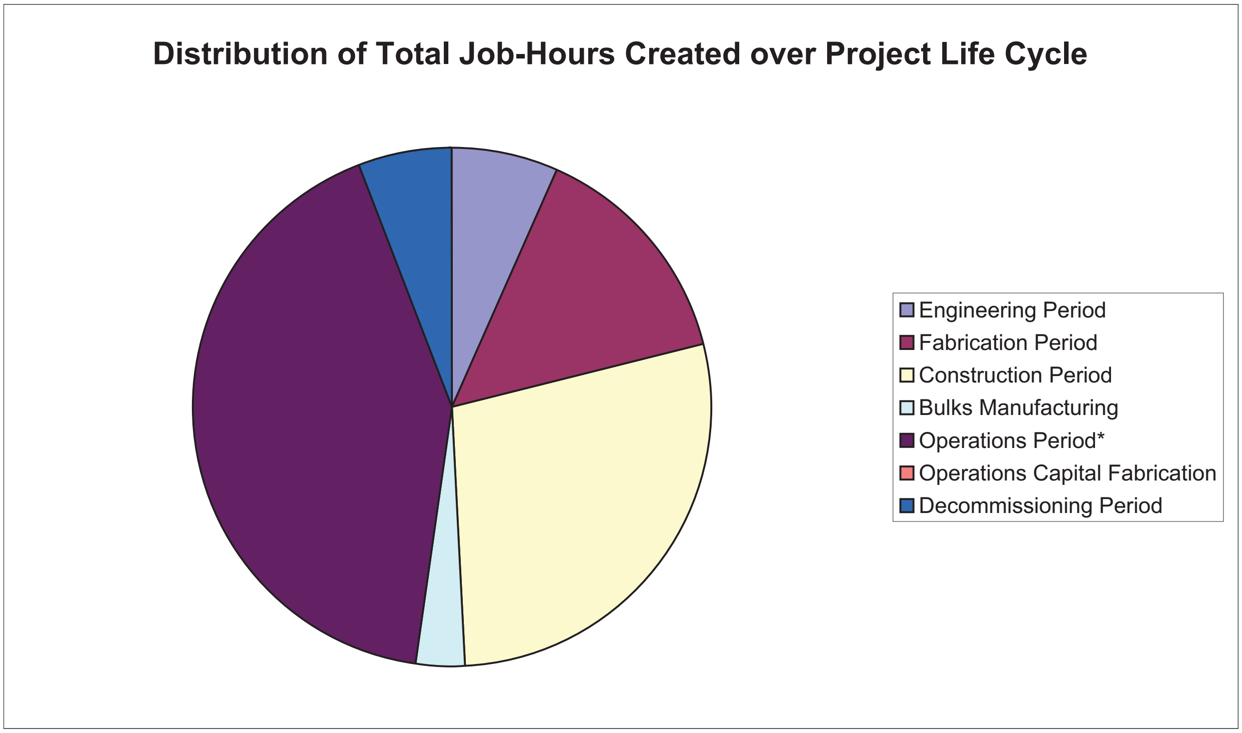


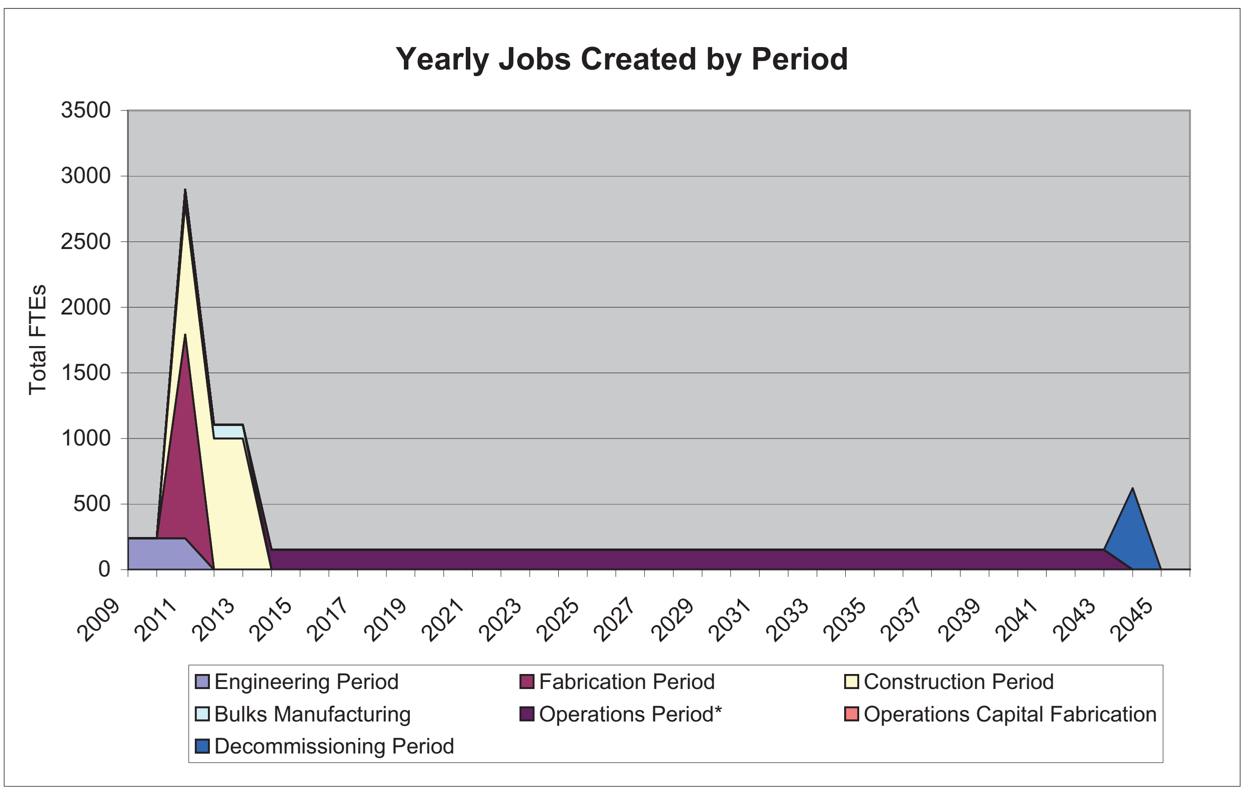


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

666 Natural Gas to Ammonia

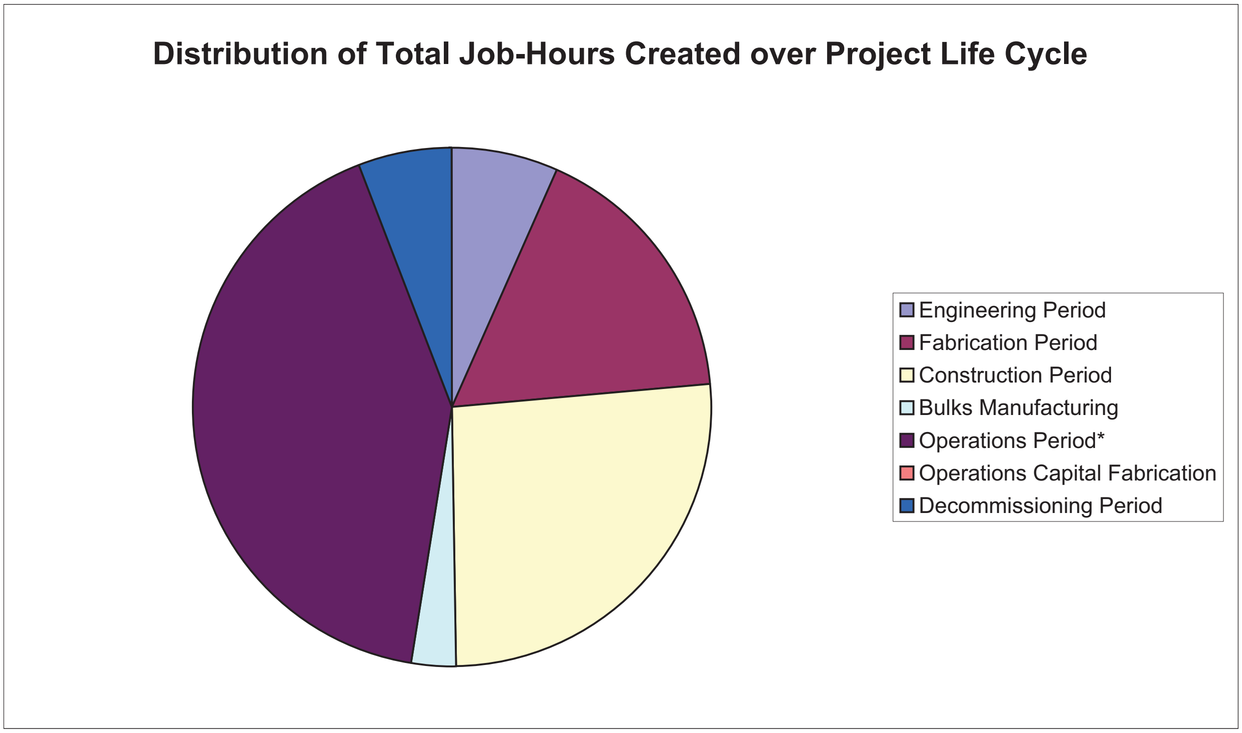


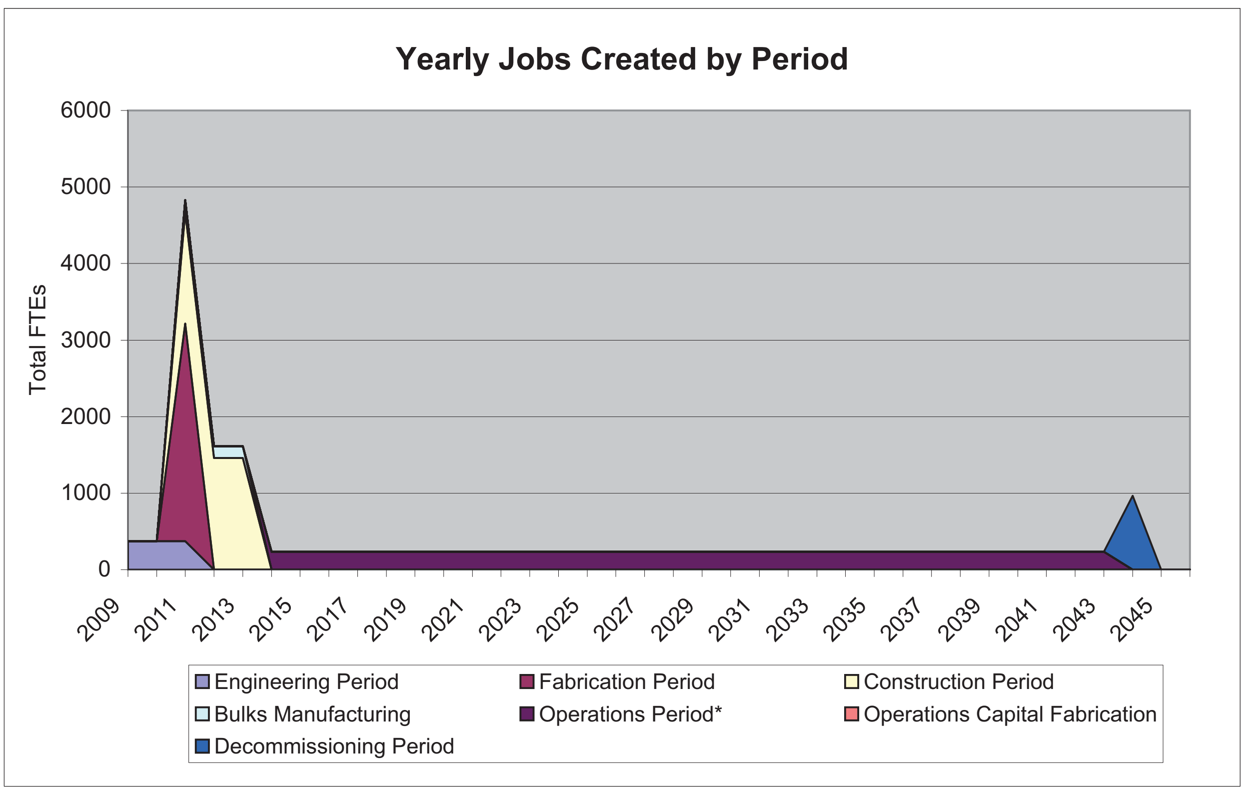


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

666 Gas to Ammonia (Combust)

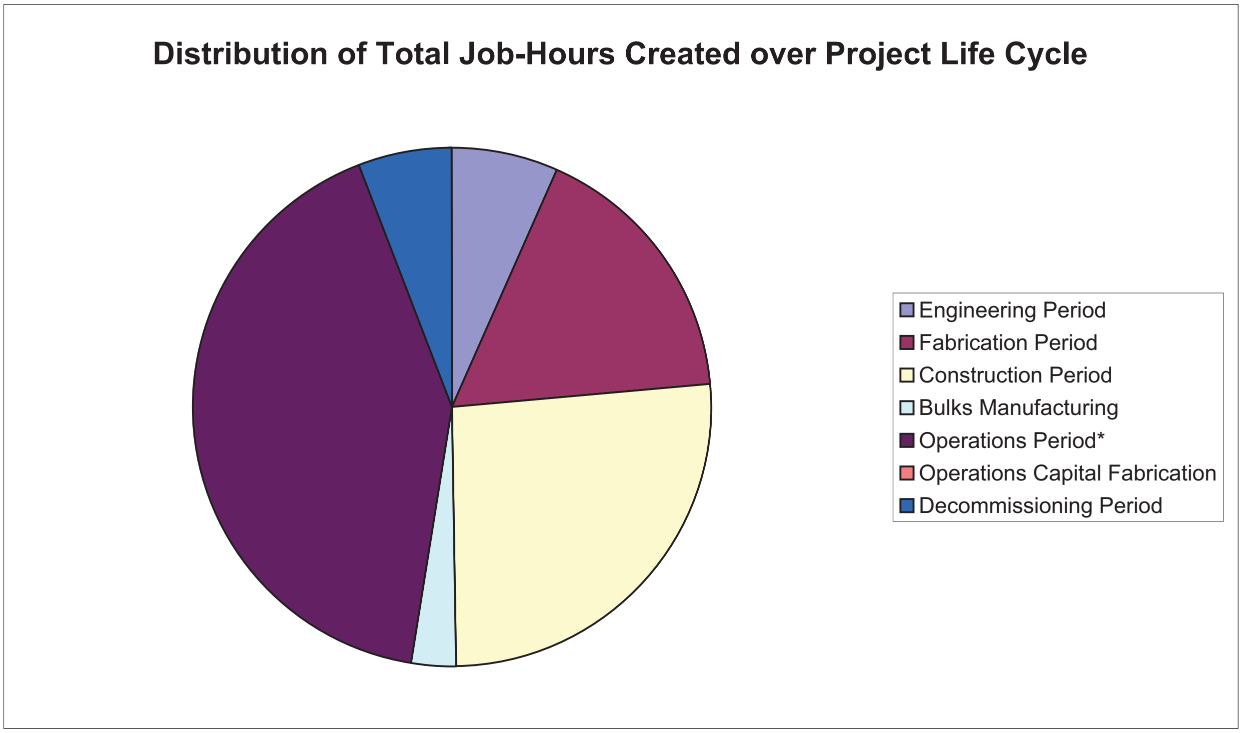


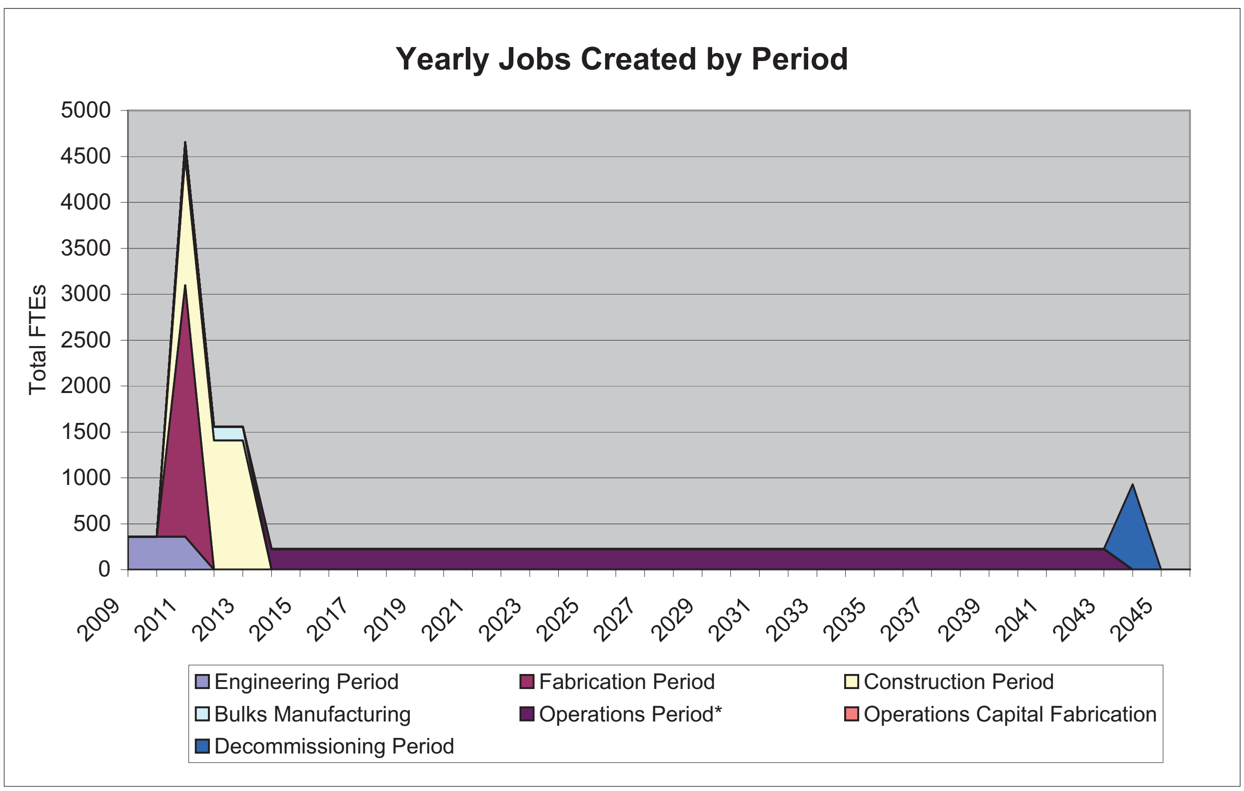


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

666 Gas to Ammonia (ASU)

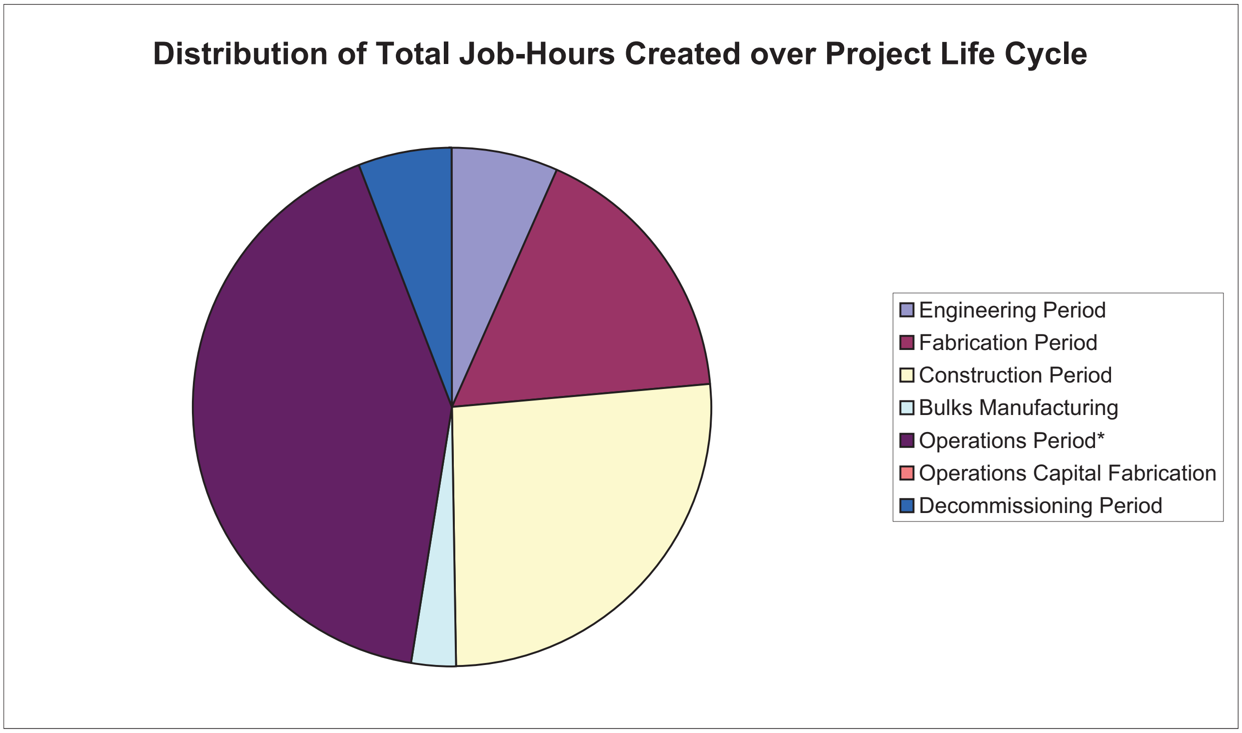


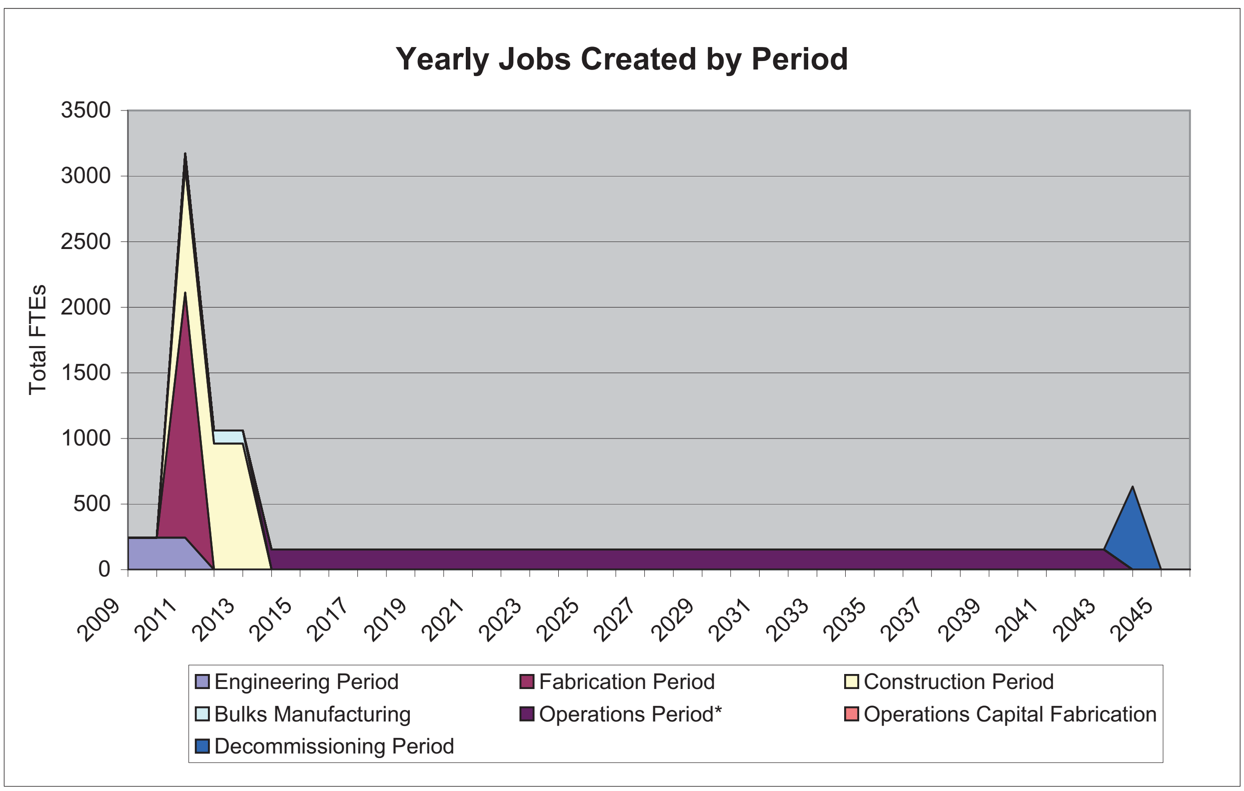


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

667 Natural Gas to Meth to Gasoline

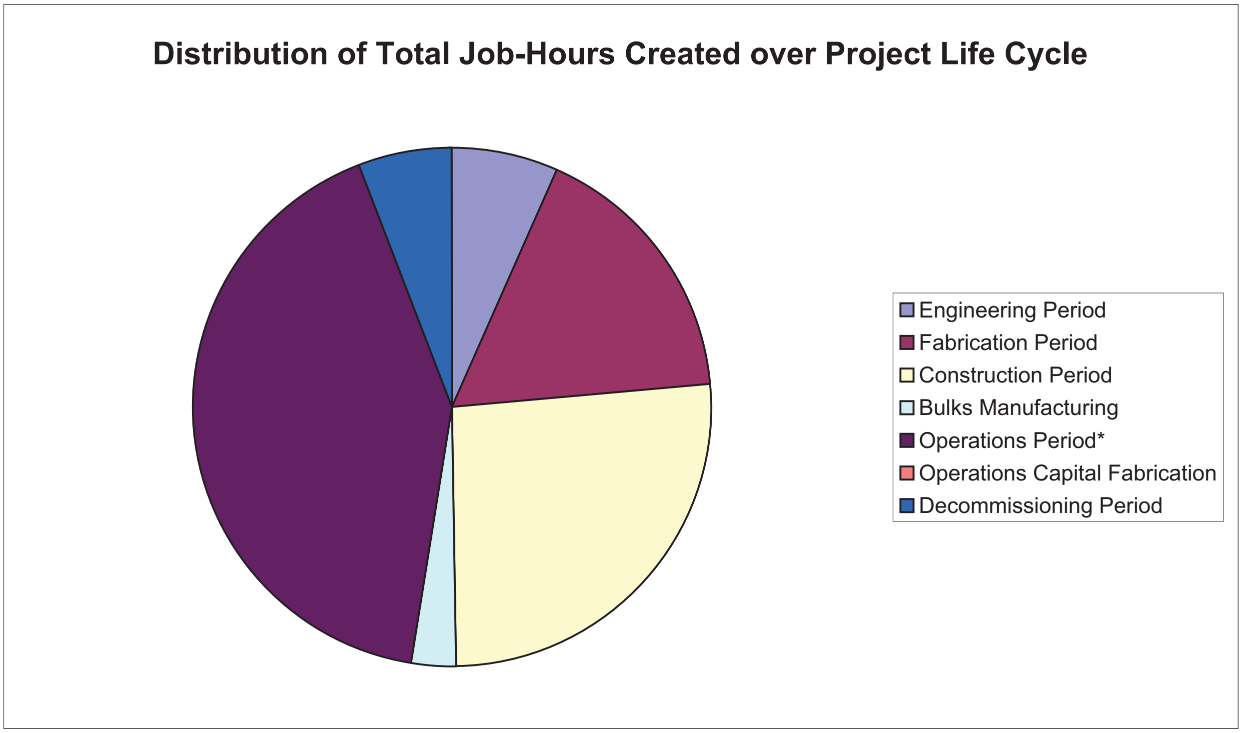


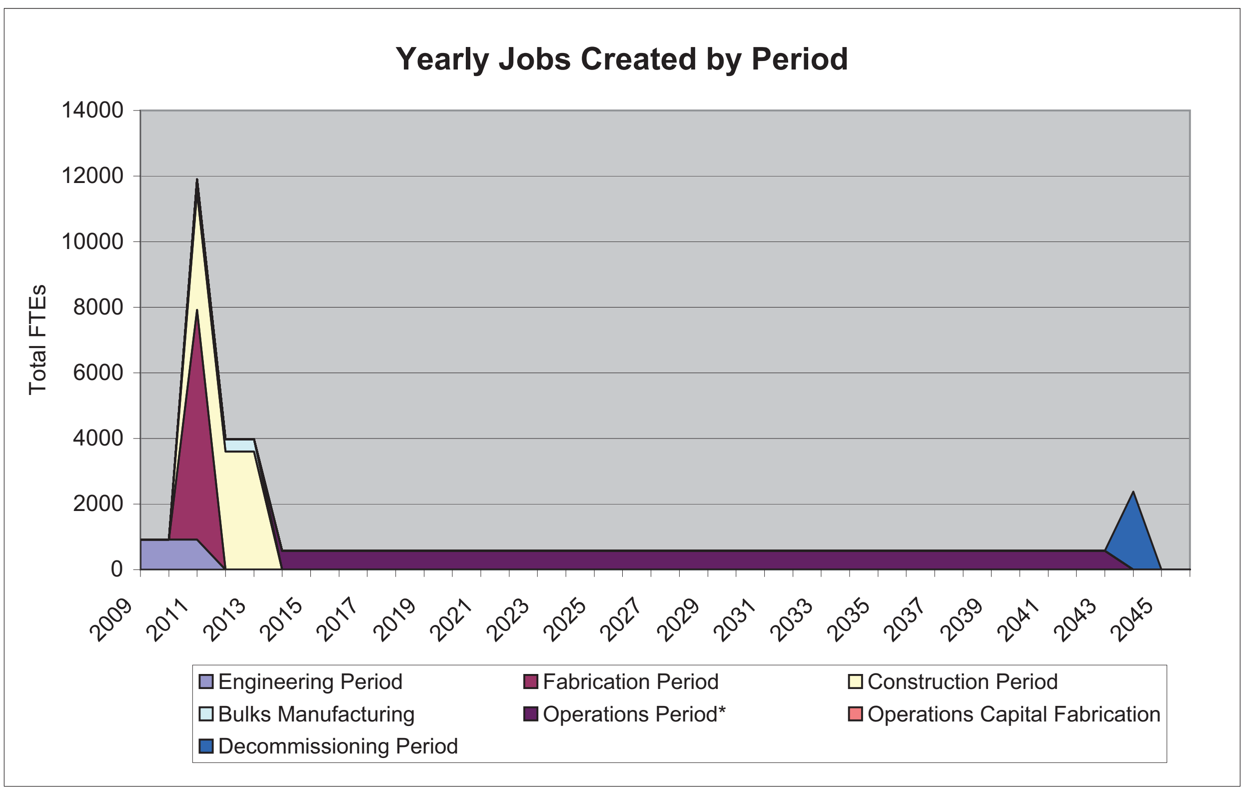


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

667 Coal to Methanol to Gasoline

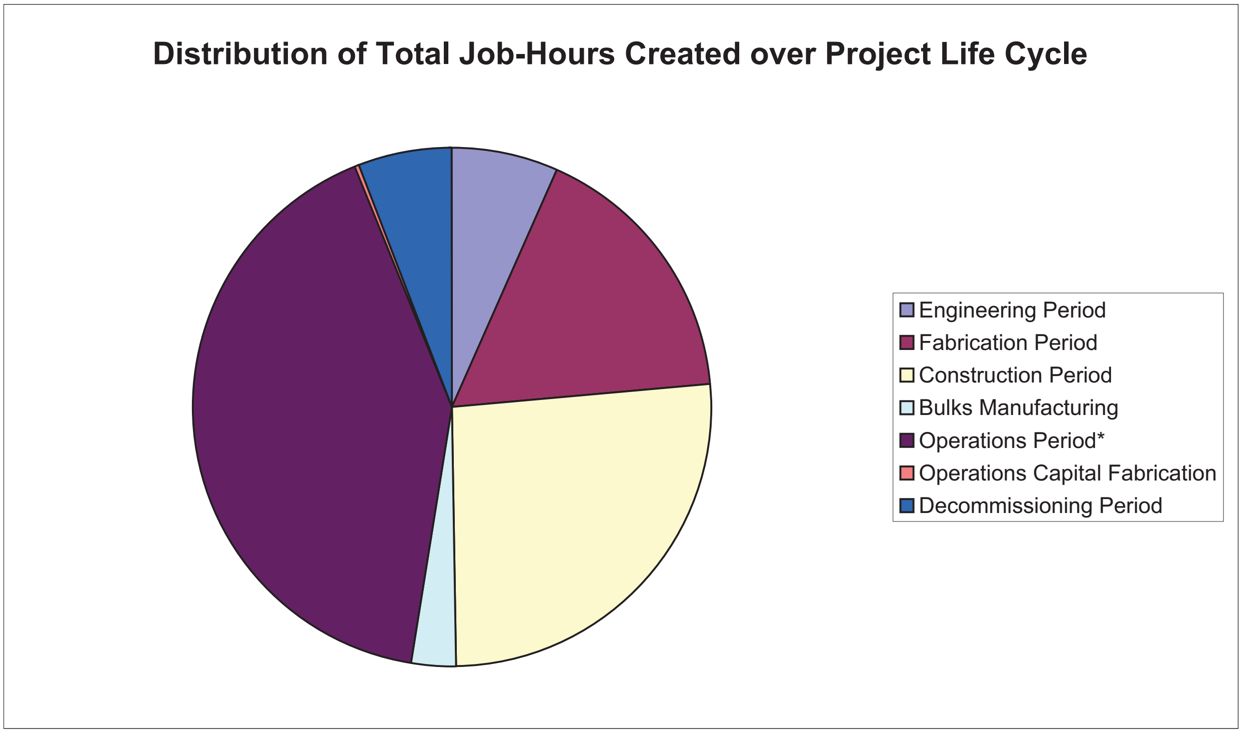


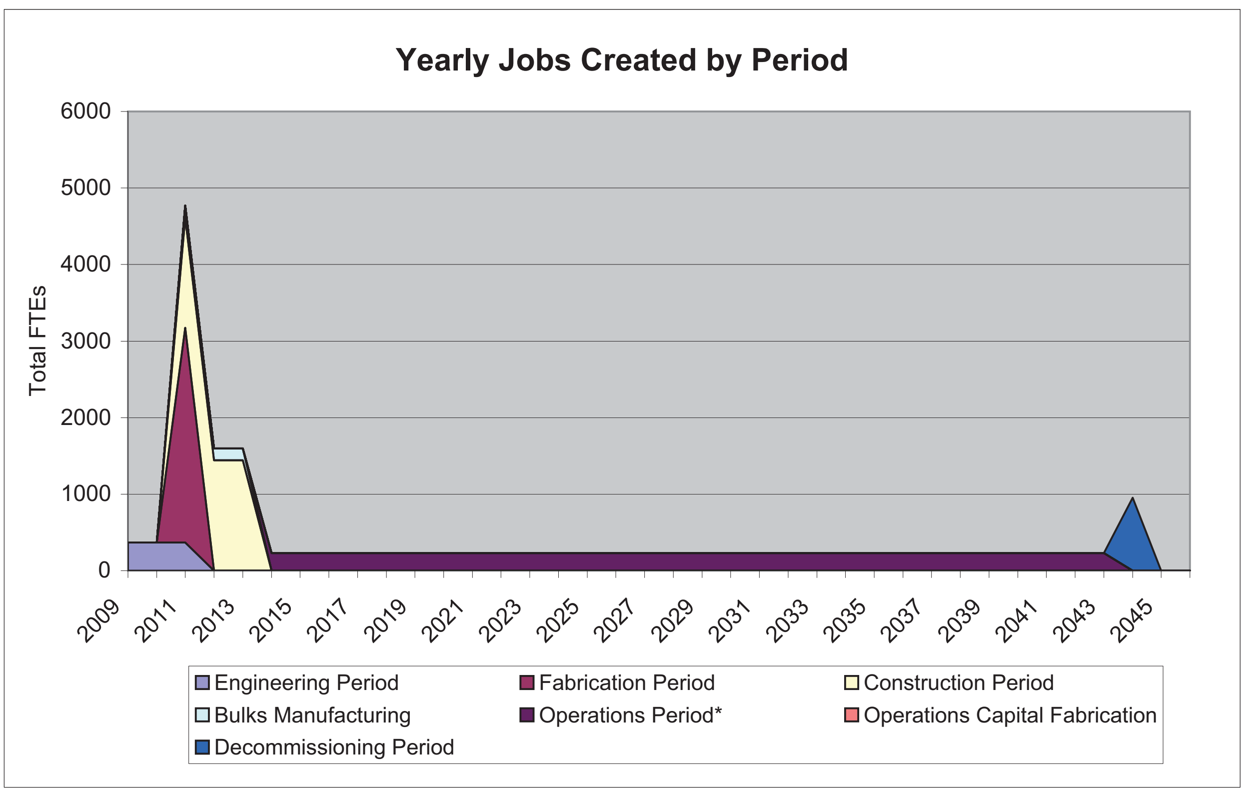


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

671 Coal to Substitute Natural Gas

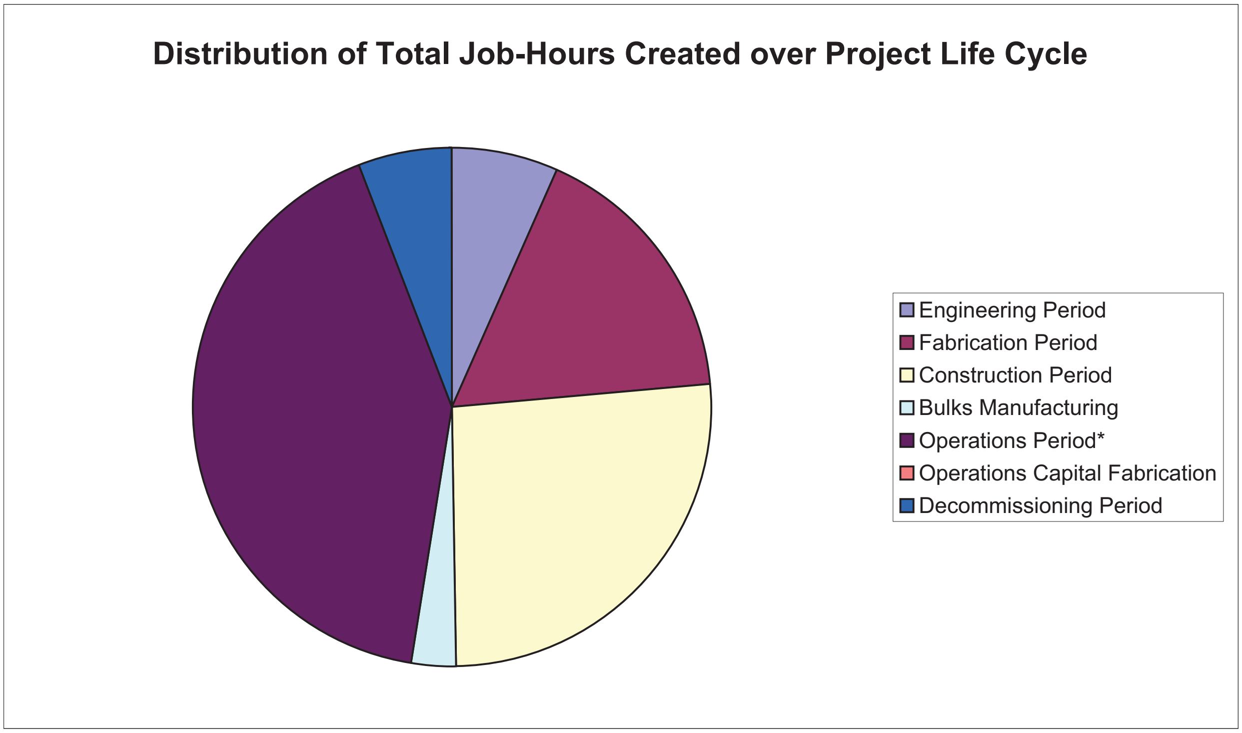


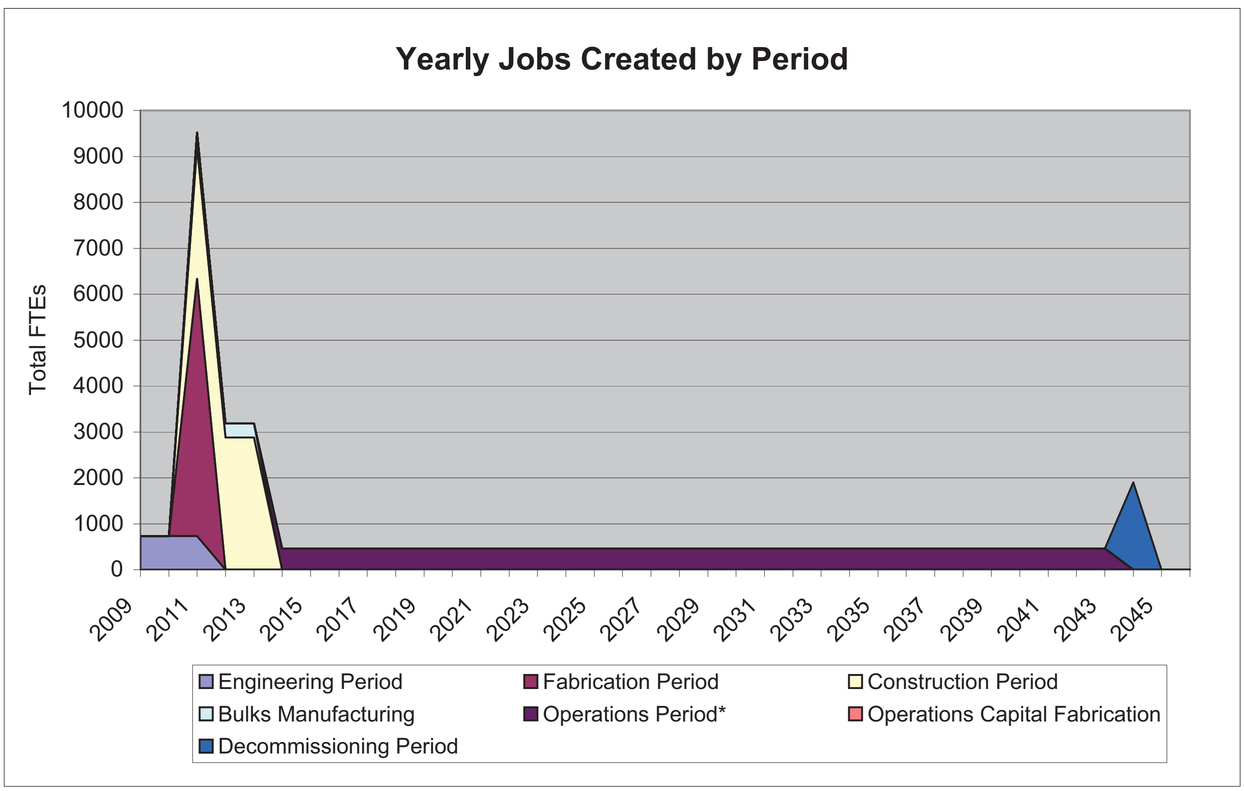


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

672 Coal to Liquids

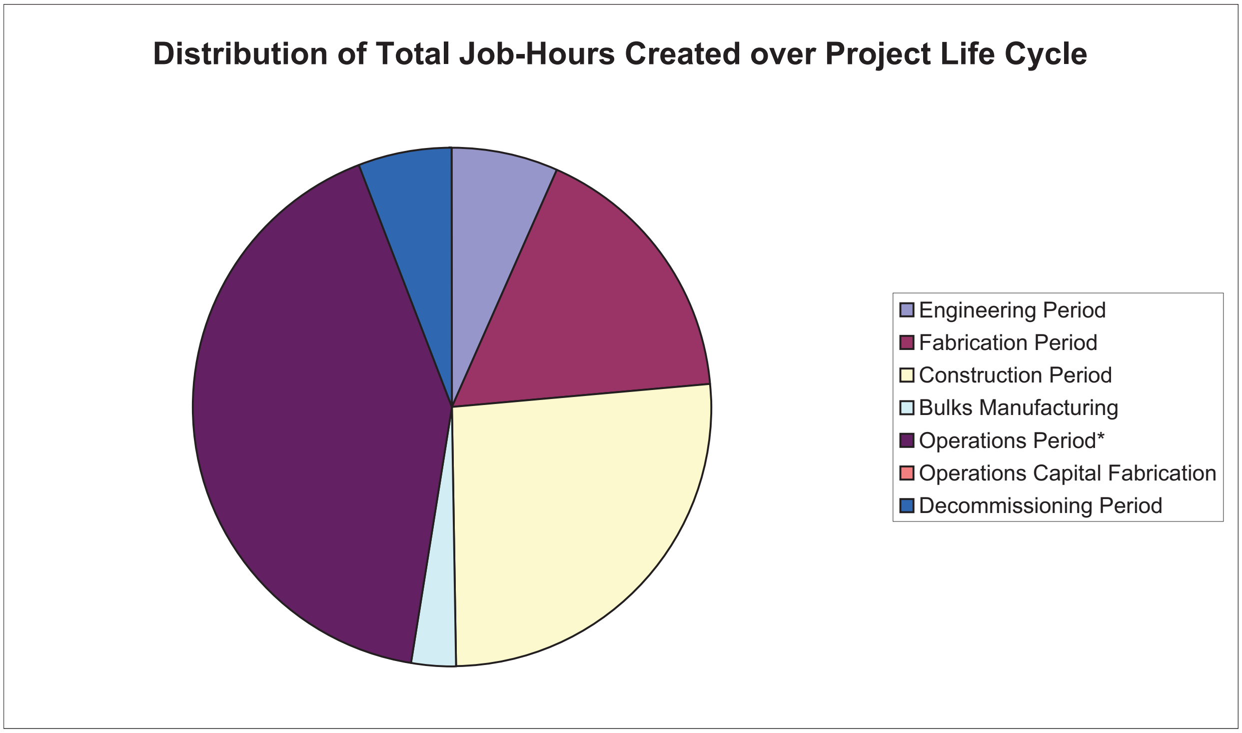


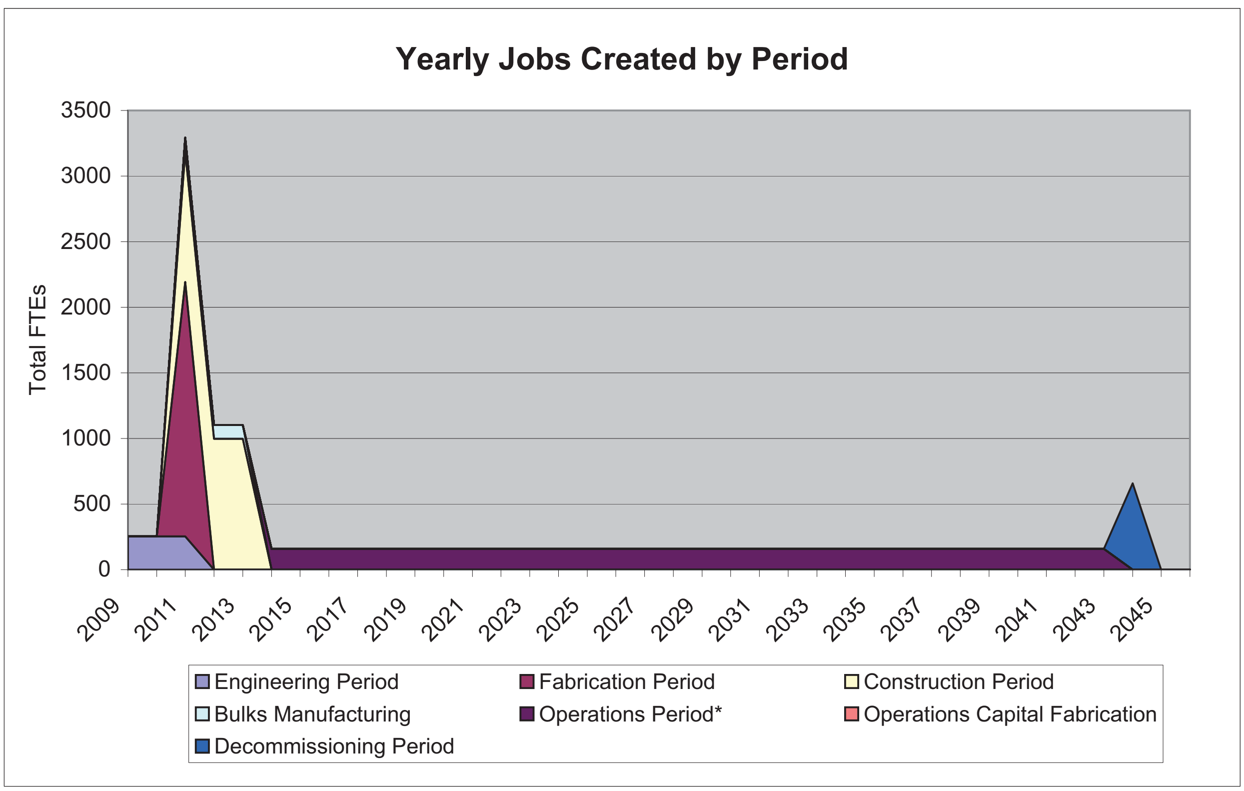


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

672 Gas to Liquids

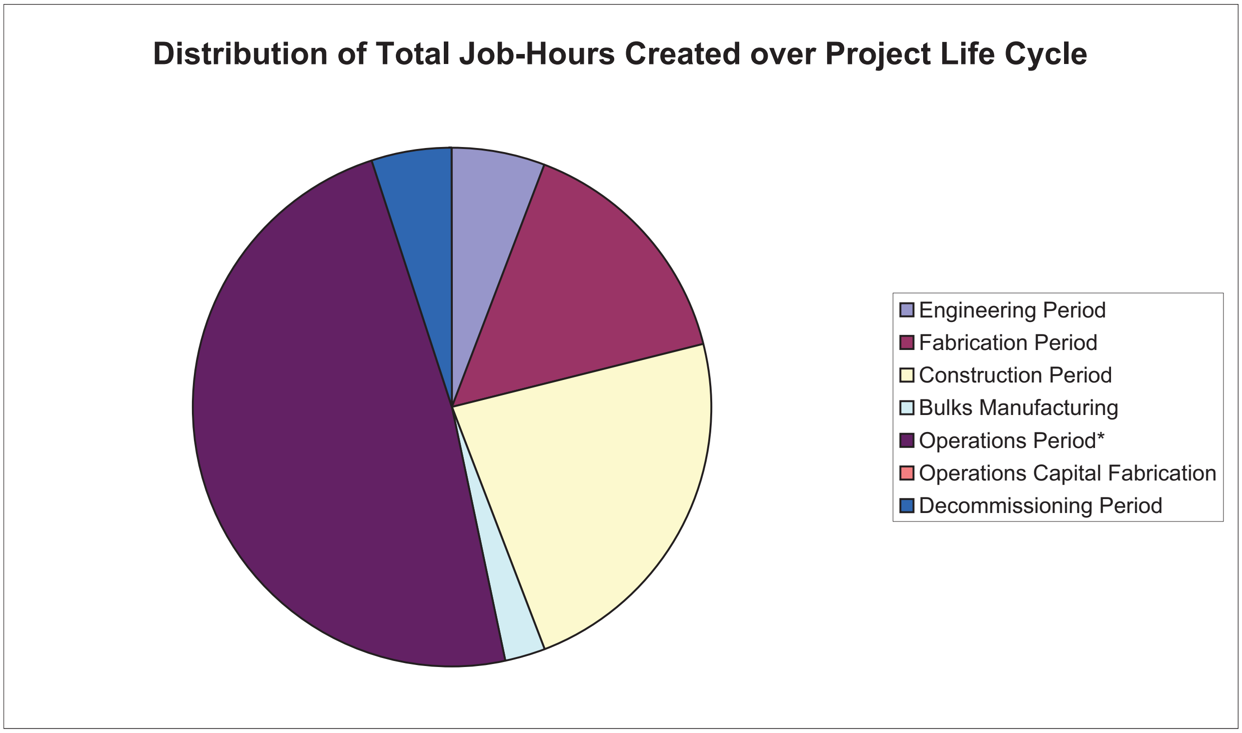


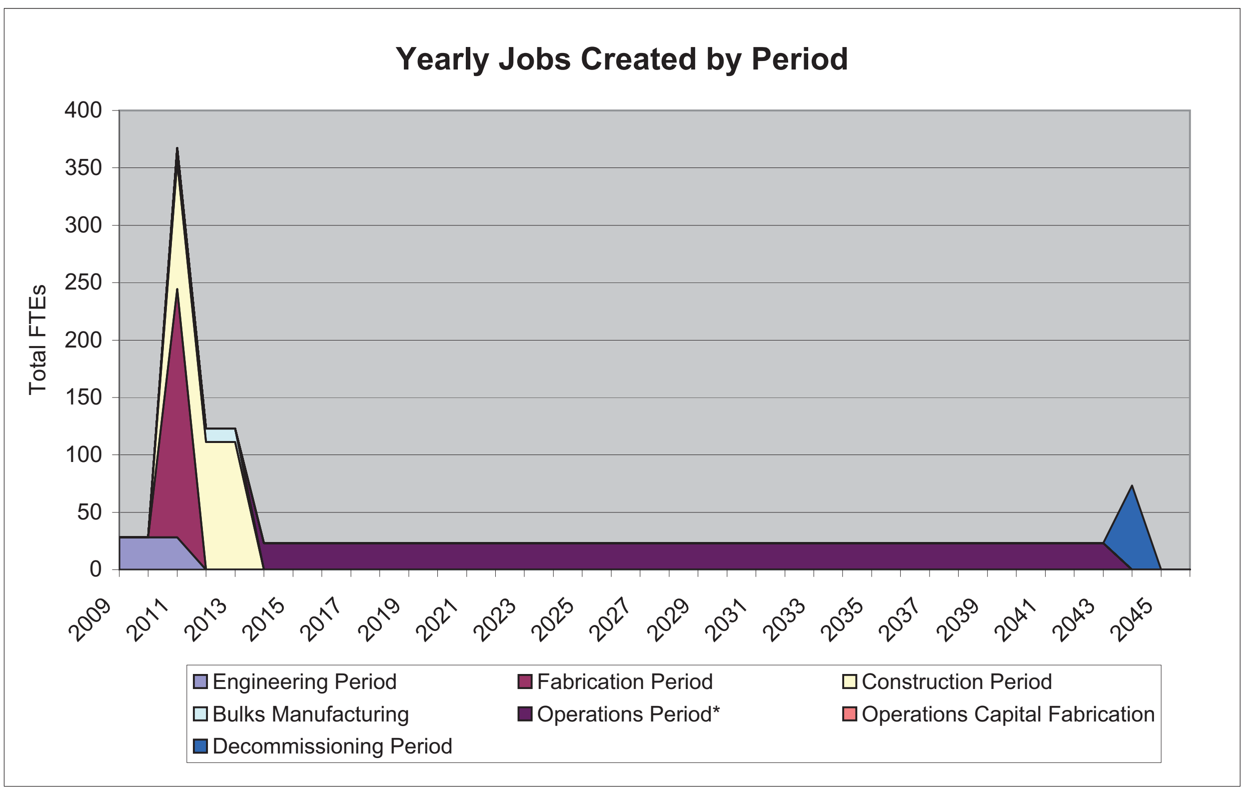


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

674 Average Combine Rankine/Brayton

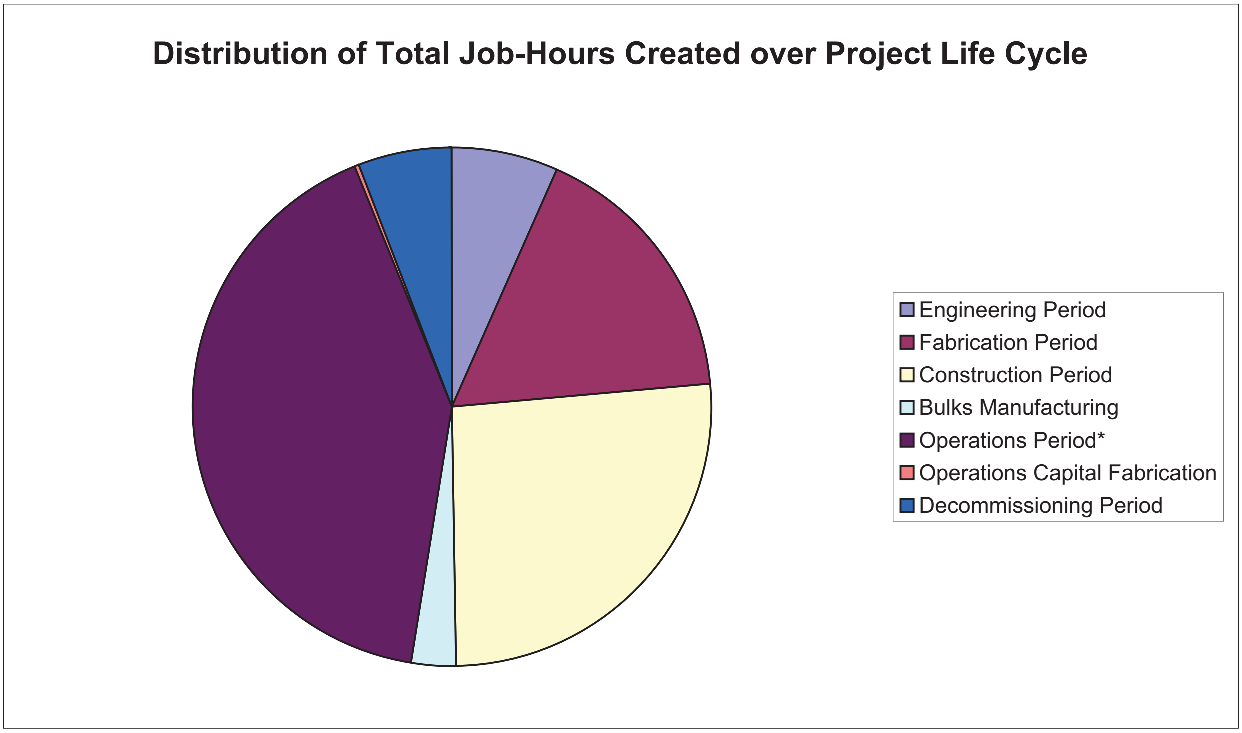


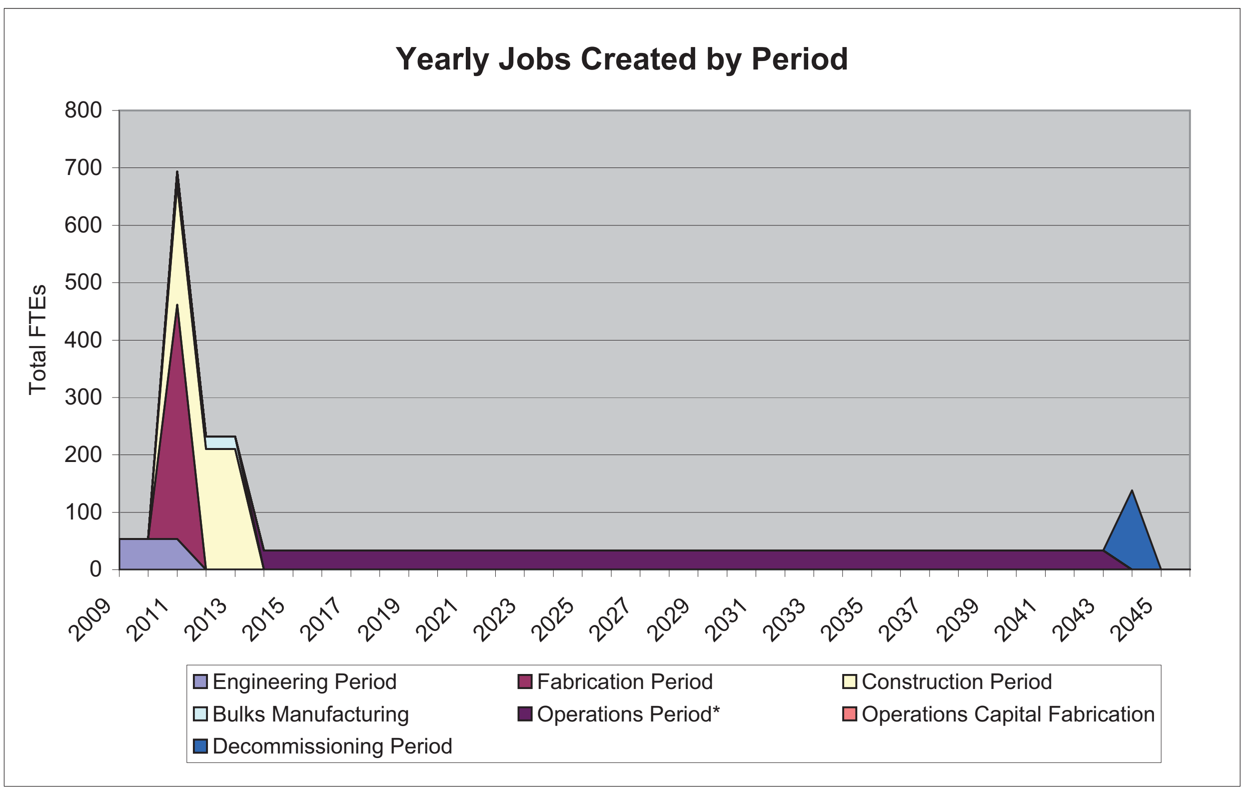


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

693 Hydrogen Production

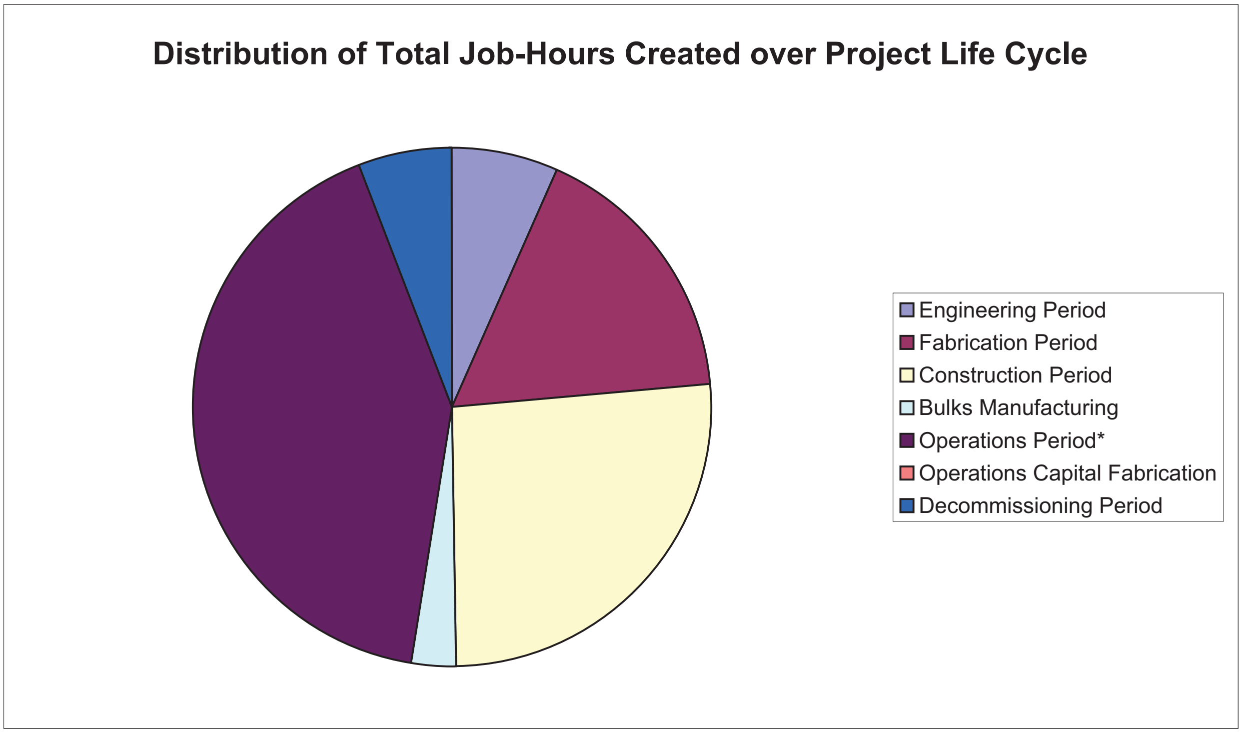


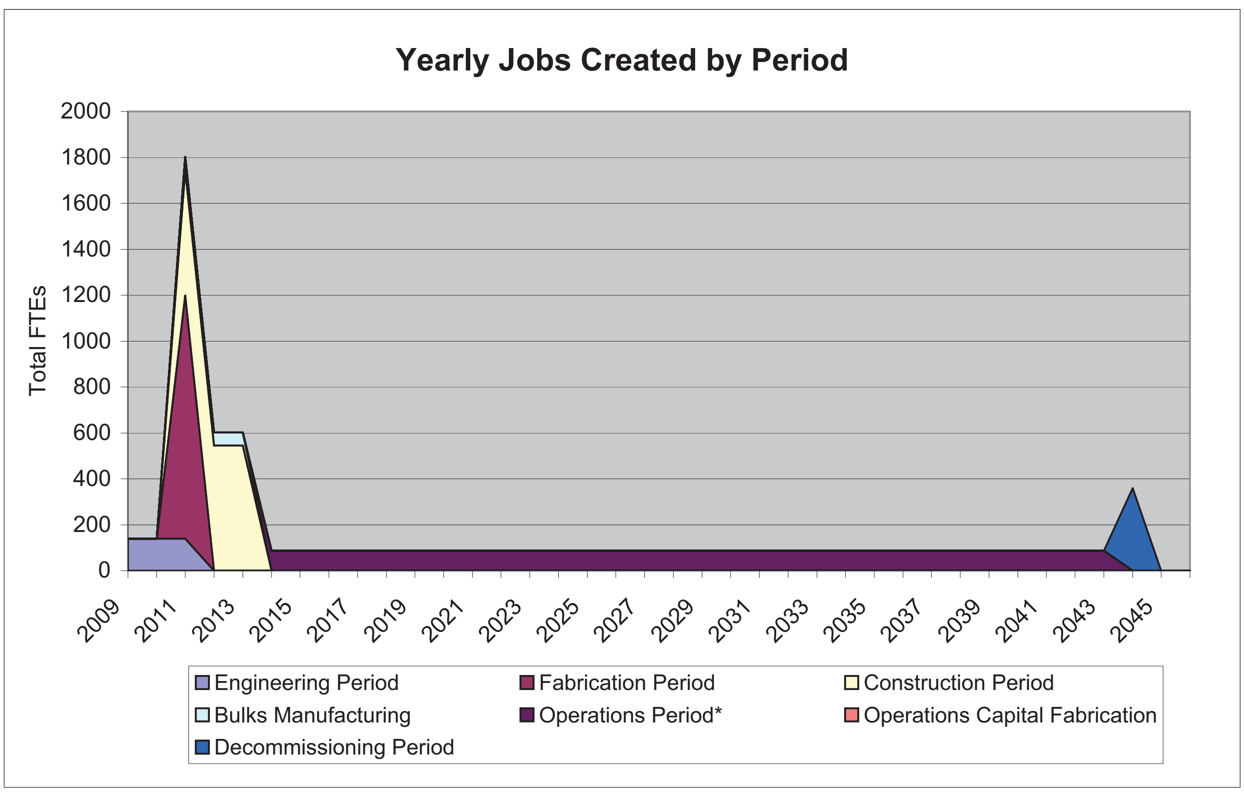


*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

704 Steam Assisted Gravity Drainage





*Determined by TEV Provided Op Cost

APPENDIX B

JOBS CREATION TOOL: INPUT AND RESULTS SHEETS

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	-
Case Name	HTGR Only

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 266,233,766	
Instalation Cost	$	$ 665,584,416	(70% Construction Labor, 30% Bulks)
Total Installed Cost	$	$ 1,025,000,000	
Engineering Cost	$	$ 93,181,818	
Operation Costs	$/yr	$ 11,787,500	
Cost Of Decommissioning	$	$ 102,500,000	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	MWe	274	
# of Major Units		-	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Dominion Energy and Bechtel Power Corporation Study

	Low Side	High Side
FTEs per MWe	0.13	0.62
Total Operations Period	36	170

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year	
Operators Per Shift	0	Set to zero for purpose of report
# Shifts	0	
Salaried Operations Positions	0	
Laboratory Positions	0	
Technical Assistance	0	
Maintenance Positions	0	
Engineering	0	
Total Operations Period	0	

Comparison Of Jobs Creation Methods	TEV Provided Op Cost	Study Low-Side.	Study High-Side	Manual Method
Total Operations and Maint. FTEs per Year	113	36	170	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	870,858	140
Fabrication Period	2,215,065	1,065
Construction Period	5,125,000	548
Bulk Materials Manufacturing	359,416	58
Operations Period*	7,072,500	113
Operations Capital Fabrication	-	-
Decommissioning Period	1,127,500	361
Total/Average	16,770,339	389

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	-
Case Name	HTGR in Cogen

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 320,274,751	
Instalation Cost	$	$ 800,686,879	(70% Construction Labor, 30% Bulks)
Total Installed Cost	$	$ 1,233,026,060	
Engineering Cost	$	$ 112,064,430	
Operation Costs	$/yr	$ 14,179,800	
Cost Of Decommissioning	$	$ 123,302,606	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	MWe	274	
# of Major Units		-	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline

	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Dominion Energy and Bechtel Power Corporation Study

	Low Side	High Side
FTEs per MWe	0.21	0.71
Total Operations Period	58	195

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods	TEV Provided Op Cost	Study Low-Side.	Study High-Side	Manual Method
Total Operations and Maint. FTEs per Year	136	58	195	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	1,047,331	168
Fabrication Period	2,664,686	1,281
Construction Period	6,165,289	659
Bulk Materials Manufacturing	432,371	69
Operations Period*	8,507,880	136
Operations Capital Fabrication	-	-
Decommissioning Period	1,356,329	435
Total/Average	20,173,885	467

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	666
Case Name	Natural Gas to Ammonia

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 388,362,484	
Instalation Cost	$	$ 1,215,819,242	
Total Installed Cost	$	$ 1,764,330,763	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 160,149,037	
Operation Costs	$/yr	$ 15,631,590	
Cost Of Decommissioning	$	$ 176,433,076	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline

	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year
Total Operations hours (DW&B)		374,400	180.0
Salaried Operations Positions	15% of DW&B	56,160	27.0
Laboratory Positions		2,080	1.0
Tech Assistance		2,080	1.0
Maintenance (MW&B)	0.35% of Ctdc	123,503	59.4
Engineering	25% of MW&B	30,876	14.8
Total Operations Period			283.2

<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	150	283	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	1,496,720	240
Fabrication Period	3,231,176	1,553
Construction Period	9,361,808	1,000
Bulk Materials Manufacturing	656,542	105
Operations Period*	9,378,954	150
Operations Capital Fabrication	-	-
Decommissioning Period	1,940,764	622
Total/Average	26,065,964	669

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	666
Case Name	Gas to Ammonia (Combust)

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 710,460,433	
Instalation Cost	$	$ 1,776,151,084	
Total Installed Cost	$	$ 2,734,855,486	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 248,243,970	
Operation Costs	$/yr	$ 24,230,230	
Cost Of Decommissioning	$	$ 273,485,549	
Operational Capital Cost	$/year	$ 11,646,491	HTSE Cell Replacements From Table 17

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline

	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year
Total Operations hours (DW&B)		374,400	180.0
Salaried Operations Positions	15% of DW&B	56,160	27.0
Laboratory Positions		2,080	1.0
Tech Assistance		2,080	1.0
Maintenance (MW&B)	0.35% of Ctdc	191,440	92.0
Engineering	25% of MW&B	47,860	23.0
Total Operations Period			324.0

<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods

	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	233	324	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	2,320,037	372
Fabrication Period	5,911,031	2,842
Construction Period	13,676,363	1,461
Bulk Materials Manufacturing	959,122	154
Operations Period*	14,538,138	233
Operations Capital Fabrication	96,899	1
Decommissioning Period	3,008,341	964
Total/Average	40,509,930	1,088

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	666
Case Name	Gas to Ammonia (ASU)

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 684,832,177	
Instalation Cost	$	$ 1,712,080,443	
Total Installed Cost	$	$ 2,636,201,750	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 239,289,129	
Operation Costs	$/yr	$ 23,356,179	
Cost Of Decommissioning	$	$ 263,620,175	
Operational Capital Cost	$/year	$ 9,870,809	HTSE Cell Replacements from Table 18

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline

	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year	
Total Operations hours (DW&B)		374,400	180.0	
Salaried Operations Positions	15% of DW&B	56,160	27.0	
Laboratory Positions		2,080	1.0	
Tech Assistance		2,080	1.0	
Maintenance (MW&B)	0.35% of Ctdc	184,534	88.7	<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.
Engineering	25% of MW&B	46,134	22.2	
Total Operations Period			319.9	

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods

	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	225	320	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	2,236,347	358
Fabrication Period	5,697,804	2,739
Construction Period	13,183,019	1,408
Bulk Materials Manufacturing	924,523	148
Operations Period*	14,013,707	225
Operations Capital Fabrication	82,125	1
Decommissioning Period	2,899,822	929
Total/Average	39,037,348	1,049

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(gray)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	667
Case Name	Natural Gas to Meth to Gasoline

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 466,902,100	
Instalation Cost	$	$ 1,167,255,250	
Total Installed Cost	$	$ 1,797,298,923	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 163,141,571	
Operation Costs	$/yr	$ 15,923,681	
Cost Of Decommissioning	$	$ 179,729,892	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline

	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor		2
Operators Per Shift		36
# Shifts		5

		Total Hrs/Year	Jobs/Year	
Total Operations hours (DW&B)		374,400	180.0	
Salaried Operations Positions	15% of DW&B	56,160	27.0	
Laboratory Positions		2,080	1.0	
Tech Assistance		2,080	1.0	
Maintenance (MW&B)	0.35% of Ctdc	125,811	60.5	<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.
Engineering	25% of MW&B	31,453	15.1	
Total Operations Period			284.6	

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods

	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	153	285	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	1,524,688	244
Fabrication Period	3,884,625	1,868
Construction Period	8,987,865	960
Bulk Materials Manufacturing	630,318	101
Operations Period*	9,554,208	153
Operations Capital Fabrication	-	-
Decommissioning Period	1,977,029	634
Total/Average	26,558,734	717

*Determined by TEV Provided Op Cost

NGNP-HTGR Assisted Conventional Processes
Jobs Creation Calculation

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	667
Case Name	Coal to Methanol to Gasoline

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$1,751,338,456	
Instalation Cost	$	$4,378,346,139	
Total Installed Cost	$	$6,741,624,671	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 611,940,076	
Operation Costs	$/yr	$ 59,729,340	
Cost Of Decommissioning	$	$ 674,162,467	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline

	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year	
Total Operations hours (DW&B)		374,400	180.0	
Salaried Operations Positions	15% of DW&B	56,160	27.0	
Laboratory Positions		2,080	1.0	
Tech Assistance		2,080	1.0	
Maintenance (MW&B)	0.35% of Ctdc	471,914	226.9	<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.
Engineering	25% of MW&B	117,978	56.7	
Total Operations Period			492.6	

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods

	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	574	493	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	5,719,066	917
Fabrication Period	14,571,136	7,005
Construction Period	33,713,265	3,602
Bulk Materials Manufacturing	2,364,307	379
Operations Period*	35,837,604	574
Operations Capital Fabrication	-	-
Decommissioning Period	7,415,787	2,377
Total/Average	99,621,166	2,689

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(gray)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	671
Case Name	Coal to Substitute Natural Gas

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 701,785,092	
Instalation Cost	$	$ 1,754,462,730	
Total Installed Cost	$	$ 2,701,460,517	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 245,212,695	
Operation Costs	$/yr	$ 23,934,357	
Cost Of Decommissioning	$	$ 270,146,052	
Operational Capital Cost	$/year	$ 16,128,887	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline

	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year	
Total Operations hours (DW&B)		374,400	180.0	
Salaried Operations Positions	15% of DW&B	56,160	27.0	
Laboratory Positions		2,080	1.0	
Tech Assistance		2,080	1.0	
Maintenance (MW&B)	0.35% of Ctdc	189,102	90.9	<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.
Engineering	25% of MW&B	47,276	22.7	
Total Operations Period			322.6	

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year	
Operators Per Shift	0	Set to zero for purpose of report
# Shifts	0	
Salaried Operations Positions	0	
Laboratory Positions	0	
Technical Assistance	0	
Maintenance Positions	0	
Engineering	0	
Total Operations Period	0	

Comparison Of Jobs Creation Methods	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	230	323	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	2,291,707	367
Fabrication Period	5,838,852	2,807
Construction Period	13,509,363	1,443
Bulk Materials Manufacturing	947,410	152
Operations Period*	14,360,614	230
Operations Capital Fabrication	134,192	1
Decommissioning Period	2,971,607	952
Total/Average	40,053,746	1,074

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	672
Case Name	Coal to Liquids

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$1,400,425,057	
Instalation Cost	$	$3,501,062,642	
Total Installed Cost	$	$5,390,814,140	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 489,326,442	
Operation Costs	$/yr	$ 47,761,450	
Cost Of Decommissioning	$	$ 539,081,414	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year	
Total Operations hours (DW&B)		374,400	180.0	
Salaried Operations Positions	15% of DW&B	56,160	27.0	
Laboratory Positions		2,080	1.0	
Tech Assistance		2,080	1.0	
Maintenance (MW&B)	0.35% of Ctdc	377,357	181.4	<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.
Engineering	25% of MW&B	94,339	45.4	
Total Operations Period			435.8	

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	459	436	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	4,573,144	733
Fabrication Period	11,651,536	5,602
Construction Period	26,958,182	2,880
Bulk Materials Manufacturing	1,890,574	303
Operations Period*	28,656,870	459
Operations Capital Fabrication	-	-
Decommissioning Period	5,929,896	1,901
Total/Average	79,660,203	2,150

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV	672
Case Name	Gas to Liquids

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 484,534,539	
Instalation Cost	$	$ 1,211,336,347	
Total Installed Cost	$	$ 1,865,173,456	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 169,302,571	
Operation Costs	$/yr	$ 16,525,034	
Cost Of Decommissioning	$	$ 186,517,346	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year
Total Operations hours (DW&B)		374,400	180.0
Salaried Operations Positions	15% of DW&B	56,160	27.0
Laboratory Positions		2,080	1.0
Tech Assistance		2,080	1.0
Maintenance (MW&B)	0.35% of Ctdc	130,562	62.8
Engineering	25% of MW&B	32,641	15.7
Total Operations Period			287.5

<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	159	287	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	1,582,267	254
Fabrication Period	4,031,327	1,938
Construction Period	9,327,290	997
Bulk Materials Manufacturing	654,122	105
Operations Period*	9,915,021	159
Operations Capital Fabrication	-	-
Decommissioning Period	2,051,691	658
Total/Average	27,561,717	744

*Determined by TEV Provided Op Cost

Input Sheet

User Input Required	(yellow)
Calculated Value	(grey)
Default Value, but can be altered if required	(blue)

Case Information

TEV	674
Case Name	Average Combine Rankine/Brayton

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 54,040,985	
Instalation Cost	$	$ 135,102,463	
Total Installed Cost	$	$ 208,026,060	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 18,882,612	
Operation Costs	$/yr	$ 2,392,300	
Cost Of Decommissioning	$	$ 20,802,606	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year	
Total Operations hours (DW&B)		374,400	180.0	
Salaried Operations Positions	15% of DW&B	56,160	27.0	
Laboratory Positions		2,080	1.0	
Tech Assistance		2,080	1.0	
Maintenance (MW&B)	0.35% of Ctdc	14,562	7.0	<--3.5% in method captures all maint cost, of which 10% is assumed to be labor.
Engineering	25% of MW&B	3,640	1.8	
Total Operations Period			217.8	

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods

	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	23	218	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	176,473	28
Fabrication Period	449,621	216
Construction Period	1,040,289	111
Bulk Materials Manufacturing	72,955	12
Operations Period*	1,435,380	23
Operations Capital Fabrication	-	-
Decommissioning Period	228,829	73
Total/Average	3,403,547	79

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(grey)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV		693
Case Name		Hydrogen Production

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 102,058,949	
Instalation Cost	$	$ 255,147,372	
Total Installed Cost	$	$ 392,867,024	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 35,660,703	
Operation Costs	$/yr	$ 3,480,717	
Cost Of Decommissioning	$	$ 39,286,702	
Operational Capital Cost	$/year	$ 2,714,310	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year	
Total Operations hours (DW&B)		374,400	180.0	
Salaried Operations Positions	15% of DW&B	56,160	27.0	
Laboratory Positions		2,080	1.0	
Tech Assistance		2,080	1.0	
Maintenance (MW&B)	0.35% of Ctdc	27,501	13.2	<--3.5% in method captures all maint
Engineering	25% of MW&B	6,875	3.3	cost, of which 10% is assumed to be
Total Operations Period			225.5	labor.

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year	
Operators Per Shift	0	
# Shifts	0	
Salaried Operations Positions	0	
Laboratory Positions	0	Set to zero for purpose of report
Technical Assistance	0	
Maintenance Positions	0	
Engineering	0	
Total Operations Period	0	

Comparison Of Jobs Creation Methods	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	BLS Data Metric	Manual Method
Total Operations and Maint. FTEs per Year	33	226	305	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	333,278	53
Fabrication Period	849,130	408
Construction Period	1,964,635	210
Bulk Materials Manufacturing	137,780	22
Operations Period*	2,088,430	33
Operations Capital Fabrication	22,583	0
Decommissioning Period	432,154	139
Total/Average	5,827,989	156

*Determined by TEV Provided Op Cost

Input Sheet

(yellow)	User Input Required
(gray)	Calculated Value
(blue)	Default Value, but can be altered if required

Case Information

TEV		704	
Case Name		Steam Assisted Gravity Drainage	

INPUT: From TEVs
Includes weighted distribution of contingency

			Comments
Bare Equipment Cost	$	$ 265,109,608	
Instalation Cost	$	$ 662,774,021	
Total Installed Cost	$	$ 1,020,516,319	(70% Construction Labor, 30% Bulks)
Engineering Cost	$	$ 92,632,691	
Operation Costs	$/yr	$ 9,041,554	
Cost Of Decommissioning	$	$ 102,051,632	
Operational Capital Cost	$/year	$ -	

Plant Operations Information

Plant Design Throughput	tons/day	6718	
# of Major Units		18	Based on Flowsheet and Cost Estimate
Complexity Relative to Refinery (1=same complexity)		1.00	
Continuous or Batch		Continuous	
Phase		Fluids	Fluids, Solids-Fluids, Solids
Operations Jobs Calc Method for Display of Final Results		TEV Provided Op Cost	Set to "TEV Provided Cost" for purpose of report

Project Timeline

	Start	Finish	Duration Years
Engineering Period	2009	2012	3
Fabrication Period	2011	2012	1
Construction Period	2011	2014	3
Operations Period	2014	2044	30
Operations Capital Fabrication	2014	2044	30
Decommissioning Period	2044	2045	1

Hourly Rates

Engineering	$/hr	107
Fabrication	$/hr	50
All in Construction Rate	$/hr	100
Operations Production	$/hr	50
Decommissioning	$/hr	100

Hours Per Year

Engineering Period	hours	2080
Fabrication Period	hours	2080
Construction Period	hours	3120
Operations Period	hours	2080
Decommissioning	hours	3120

Other Variables

Fabrication Labor Metric (by INL)		250,000	$ Equipment Sales/FTE-yr
Indirect Jobs per Direct Construction	-	0.1	
Indirect Jobs per Direct Decommissioning	-	0.1	

Calulation and Results Sheet

Seider, Seader and Lewin Method of determining Operations Jobs

Capacity Factor	2
Operators Per Shift	36
# Shifts	5

		Total Hrs/Year	Jobs/Year	
Total Operations hours (DW&B)		374,400	180.0	
Salaried Operations Positions	15% of DW&B	56,160	27.0	
Laboratory Positions		2,080	1.0	
Tech Assistance		2,080	1.0	
Maintenance (MW&B)	0.35% of Ctdc	71,436	34.3	captures all maint cost,
Engineering	25% of MW&B	17,859	8.6	of which 10% is
Total Operations Period			251.9	assumed to be labor.

BLS Data Metric for Determining Operations Jobs

Total Operations Staff per ton/day		0.04536
Total Operations Period	633,830	304.7

Manual Input: Section to allow an intuitive input and comparison to the calculation methods

	Jobs/Year
Operators Per Shift	0
# Shifts	0
Salaried Operations Positions	0
Laboratory Positions	0
Technical Assistance	0
Maintenance Positions	0
Engineering	0
Total Operations Period	0

Set to zero for purpose of report

Comparison Of Jobs Creation Methods	TEV Provided Op Cost	Seider-Seader-Lewin Calc.	Manual Method
Total Operations and Maint. FTEs per Year	87	252	-

OUTPUT: Total Labor Hours and Jobs/Year	Total Life Cycle Labor Hours	Jobs/Year
Engineering Period	865,726	139
Fabrication Period	2,205,712	1,060
Construction Period	5,103,360	545
Bulk Materials Manufacturing	357,898	57
Operations Period*	5,424,933	87
Operations Capital Fabrication	-	-
Decommissioning Period	1,122,568	360
Total/Average	15,080,197	407

*Determined by TEV Provided Op Cost