Engineering and Economics of the USGS Circum-Arctic Oil and Gas Resource Appraisal (CARA) Project

By Mahendra K. Verma[1], Loring P. (Red) White[2], and Donald L. Gautier[3]

Open-File Report 2008-1193

U.S. Department of the Interior
U.S. Geological Survey

[1]USGS, Central Region, P.O. Box 25046, MS 939, Denver, CO 80225
[2]USGS, 1321 Cortlandt Street, Houston, TX 77008
[3]USGS, Western Region, 345 Middlefield Road, Menlo Park, CA 94025

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:
Verma, M.K., White, L.P., and Gautier, D.L., 2008, Engineering and economics of the USGS circum-arctic oil and gas resource appraisal (CARA) project: U.S. Geological Survey Open-File Report 2008-1193, 17 p.

Introduction

This Open-File report contains illustrative materials, in the form of PowerPoint slides, used for an oral presentation given at the Fourth U.S. Geological Survey Workshop on Reserve Growth of petroleum resources held on March 10-11, 2008. The presentation focused on engineering and economic aspects of the Circum-Arctic Oil and Gas Resource Appraisal (CARA) project, with a special emphasis on the costs related to the development of hypothetical oil and gas fields of different sizes and reservoir characteristics in the North Danmarkshavn Basin off the northeast coast of Greenland.

The individual PowerPoint slides highlight the topics being addressed in an abbreviated format; they are discussed below, and are amplified with additional text as appropriate. Also included in this report are the summary results of a typical “run” to generate the necessary capital and operating costs for the development of an offshore oil field off the northeast coast of Greenland; the data are displayed in MS Excel format generated using Questor software (IHS Energy, Inc.).

Content of Slides

Slide 1. – Overall objective of CARA project and the general approach to estimating resource development costs are presented.

Slide 2. – Additional engineering and economic considerations relative to estimating resource development costs are listed. Application of Questor (IHS Energy, Inc.), as an integral part of the resource development study is introduced. Questor generates the following three main parameters that are used to develop resource cost (unit curves) – production profile, capital expenditure (CAPEX), and operating expenditure (OPEX).

Slide 3. – It is pointed out that Questor is directly linked to a large IHS database, which is the source for all the geologic, reservoir, production, and cost data. It also emphasizes that, due to lack of cost data for the Arctic region, some of the costs in Questor's output need to be adjusted to adequately address the unique operating conditions and ice management concerns that impact resource development in the Arctic region. Following are few examples of cost adjustments, made in consultation with the technical group of IHS Energy, Inc.:

1. Drilling rig: (a) consider the option and added expense of using a 'fourth generation' drilling rig, (b) change the floating bare rig unit cost by 10 percent, (c) change the transportation cost by 10 percent, (d) increase the number of drilling days by 15 percent to allow for the extra expense of site preparation, (e) add logging days equal to the number of wells expected to be drilled, and (f) make the cost of Design and Project Management approximately equal to 10 percent of the total drilling cost.
2. Topsides (oil processing facility on top of floating vessel): increase the material cost by 25 percent.
3. Booster pumps: (a) install a pump capable of sustaining a flow of oil for approximately every 200 km or more as defined by the onshore oil booster pump scheme, (b) add the cost of cable at the rate of $100/m, (c) calculate the number of days for cable installation by dividing the length of the pipe in km by 4, and introduce the cable installation cost (possibly $200,000/day), and (d) make the Design and Project Management Cost equal to 10 percent of the total cost.
4. Ice management: use the 'special item' in the Field/Project cost under the 'Offshore' tab of the Total Operating Cost Summary for adding possibly as much as $500,000,000 per year.
5. Pipelines: (a) insulate all offshore pipes in water depths of more than 200 m, (b) bury pipes where water depths are less than 200 m to avoid scouring by ice berg, and (c) insulate onshore pipe.

Slide 4. – The main types of data needed for input to Questor are listed. Some of the data are readily available, such as reserve volume, reservoir depth, water depth, and distance to shore. Other parameters are calculated from engineering correlations, such as peak field production, gas-oil ratio equation, pressure gradient, and well productivity. In addition, Questor prompts the user to choose a procurement strategy whereby appropriate regions are selected for front-end engineering design (FEED); engineering, procurement, and construction (EPC); and associated cost data.

Slide 5. – A schematic diagram of essential facilities for the drilling, production processing, and transport of crude oil, specific to an offshore field is presented. Questor helps design field development that includes drilling rigs/equipment items; subsea well completion, oil production, and processing facilities (both offshore and offshore); pipelines to transfer the oil from offshore to an export terminal; and booster pumps. With respect to fields off the northeast coast of Greenland, oil processing and transport to market would include the following stages: (a) oil processing offshore with partial stabilization of oil, (b) oil transportation via pipelines to the onshore facility at Flade Budgt where oil is fully stabilized, (c) oil transportation via a subsea pipeline running along the coast to the oil Storage and Export Terminal located at Angmagssalik, and (d) oil tankers are used to transport oil from the Oil Storage and Export Terminal to the New York port for distribution.

Slide 6. – Use of Questor results to estimate resource development costs is described, and the five principal variables –recoverable hydrocarbon volume, well productivity, reservoir/drilling depth, water depth, and distance to shore – that affect the CAPEX and OPEX are listed. The need to apply these variables in a number of different “runs” is emphasized in order to develop statistical cost functions.

Slide 7. – The reports resulting from the use of Questor software are described, and a typical custom report is presented for one development scenario. The report includes, in tabular form, a Summary of all the input data, a Combined Investment and Production Profile, a Combined Cost (CAPEX) Summary and Total Operating Cost Summary.

The PowerPoint slides given below are followed by an Excel spreadsheet. This spreadsheet constitutes a custom report for one of the runs, giving the project summary and combined investment and production profiles, and investment and operating costs.

Engineering and Economics
of the
USGS Circum-Arctic Oil and Gas Resource Appraisal
(CARA)

By

Mahendra K. Verma

Loring P. (Red) White

Donald L. Gautier

Fourth U.S. Geological Survey Workshop on Reserve Growth

March 10-11, 2008

Denver, Colorado

Study Objective

- The objective of the CARA project is to assess the Arctic region for its hydrocarbon resource volume and its development cost by integrating geologic, engineering and economic (cost) data.
  - Geology defines the hydrocarbon volume of a resource.
  - Engineering looks at the development strategy.
  - Economics (or unit cost curves) defines the value of a resource development.

Engineering and Economics

- Hydrocarbon volume along with the following reservoir/engineering and cost data are required for the development of resource cost (unit) curves:
  - Production Profile
  - Capital Expenditure (CAPEX)
  - Operating Expenditure (OPEX)
- Questor (IHS Inc.) is a tool that generates these above parameters for various field development scenarios.

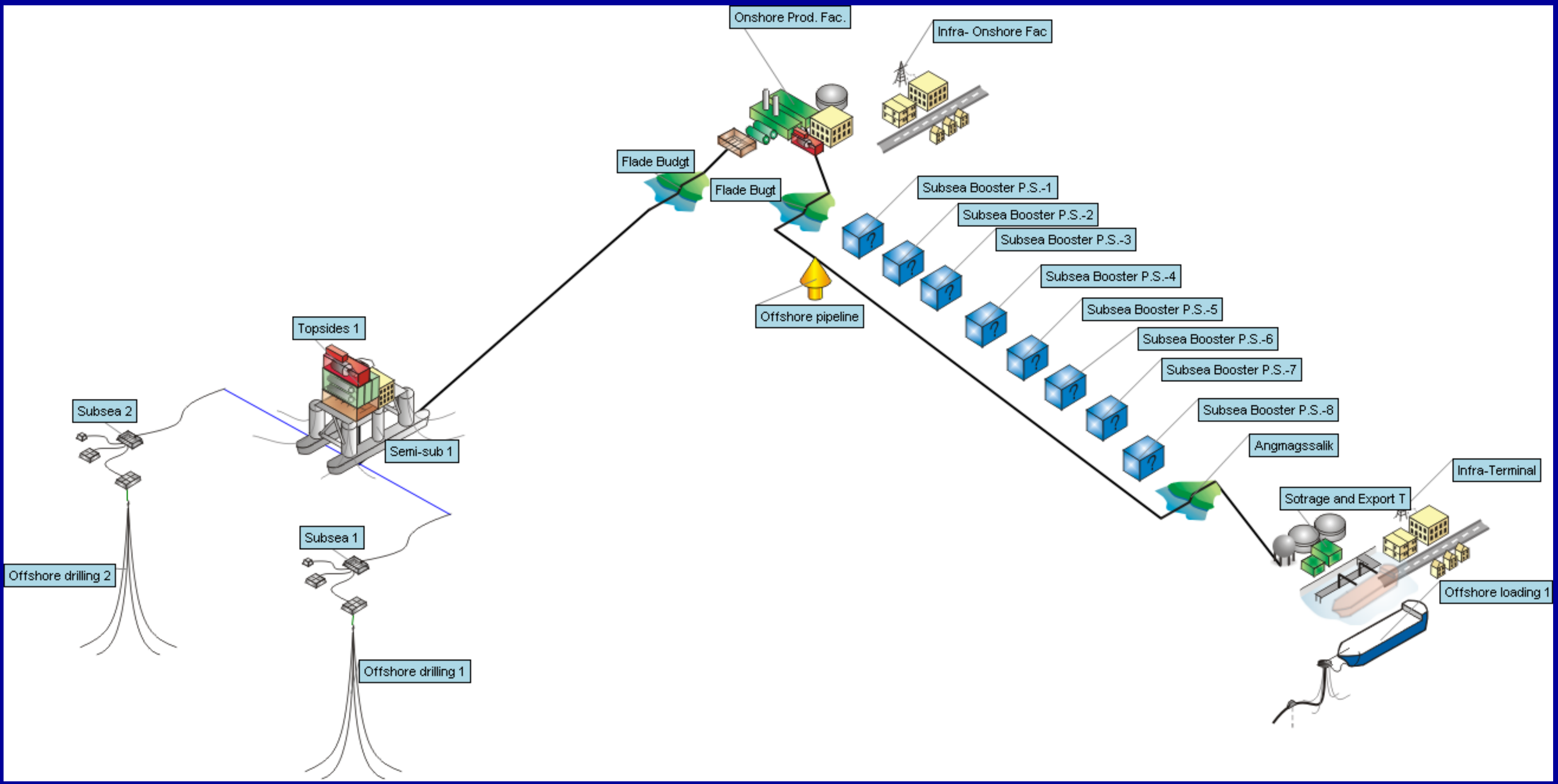
Questor's link to a database and policy decisions for better estimates of cost

- Questor has a direct link to a large database with geologic, reservoir, production and cost data from various countries/regions around the world.
- In consultation with IHS technical support group, certain costs in the Questor were added/increased to account for harsh operating conditions and ice management in the Arctic region.

Questor and its Input

- The following parameters are required as an input to Questor:
  - Reserve volume
  - Reservoir depth
  - Reservoir pressure
  - Solution gas-oil ratio
  - Water depth
  - Fluid gravity
  - Estimated ultimate recovery per well
  - Average well productivity
  - Distance to shore

A schematic of the facility design for an offshore oil field



How Questor results are to be used to develop resource cost curves?

- Make a number of runs with Questor using a range of values for each of the following variables:
  - Reserve volume
  - Well productivity
  - Reservoir/drilling depth
  - Water depth
  - Distance to shore
- Use results from the runs to develop statistical cost functions.

Results from Questor

- Questor allows printing of either detailed or custom reports.
  - Detailed report: giving details of CAPEX and OPEX, and a report could be up to 100s of pages long.
  - Custom report: giving Summary sheet, CAPEX and OPEX, making it easier for a review.

  A typical custom report in Excel format is presented separately.

OFFSHORE PROJECT SUMMARY

Project name	NEG_MKV_OIL_RUN_27B
Country	North America Average
Region	North America
Basin	Arctic Ocean Region Average

Procurement strategy		Currency	Rate/$	Procurement strategy		Currency	Rate/$
Offshore	North Atlantic Ocean Regi	$	1.00	Onshore	North America Average	$	1.00
Contingency	N. North Sea (Norway)	NOK	5.78	Contingency	N. America	US$	1.00
Equipment	N. North Sea (Norway)	NOK	5.78	Equipment	Western Europe	US$	1.00
Materials	N. North Sea (Norway)	NOK	5.78	Materials	Western Europe	US$	1.00
Fabrication	S. E. Asia	US$	1.00	Prefabrication	Asia	US$	1.00
Linepipe	N. North Sea (Norway)	NOK	5.78	Linepipe	Eastern Europe	US$	1.00
Installation	N. North Sea (U.K.)	£	0.50	Construction	Western Europe	US$	1.00
Design & PM	N. North Sea (Norway)	NOK	5.78	Design & PM	Western Europe	US$	1.00
Opex	N. North Sea (Norway)	NOK	5.78	Certification	Western Europe	US$	1.00
Certification	N. North Sea (Norway)	NOK	5.78	Opex	Western Europe	US$	1.00
Freight	N. North Sea (U.K.)	£	0.50				

Technical database		Technical database	
Offshore	N. North Sea (Norway)	Onshore	N. America

Unit set	Oilfield
Development type	Oil
Development concept	Semi-submersible + Subsea tie-back

Overall input

Design oil production flowrate	220.00	Mbbl/day	Reserves	1000.00	MMbbl
Design associated gas flowrate	205.00	MMscf/day	Water depth	450.00	m
Water injection capacity factor	1.20		Reservoir depth	2950.00	m
Design water injection flowrate	264.00	Mbbl/day	Reservoir pressure	4120.00	psia
Design gas injection rate	205.00	MMscf/day	Reservoir length	14.10	km
Gas oil ratio	931.00	scf/bbl	Reservoir width	7.07	km
Design factor	1.10				

Fluid characteristics

Oil density @ STP	35.00	°API	H2S content	10.00	ppm
CO2 content	1.00	%	Gas molecular weight	30.10	

Production profile characteristics

Plateau rate	200.00	Mbbl/day	Years to plateau	3.00	year
Productivity	50.00	MMbbl/well	Plateau duration	7.00	year
Peak well flow	10.00	Mbbl/day	Field life	21.00	year
Maximum drilling stepout	3.00	km	Onstream days	350.00	day

Export methods

Oil export method	offshore loading		Gas export method	inject into reservoir	
Distance to delivery point	1.00	km	Distance to delivery point	0.00	km

Number of wells

Production wells	20	Gas injection wells	7
Water injection wells	8		

Field level miscellaneous data

Distance to operations base	120.00	km
Distance to delivery point	120.00	km
Maximum drilling stepout	3.00	km
Maximum ambient temperature	2.00	°C

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	NEG_MKV_OIL_RUN_27B	boe/bbl Oil	1.		
Currency (millions $)	US Dollars	boe/bbl Condensate	0.8	Capital cost	13,185.23
		boe/Mscf Gas	0.17	Cost/boe	13.19

Lifecycle cost	37,034.89	E & A cost	0.	Drilling cost	2,775.37
Cost/boe	37.03	Cost/boe	0.	Cost/boe	2.78
Facilities cost	10,409.86	Operating cost	22,549.45	Decommission cost	1,300.21
Cost/boe	10.41	Cost/boe	22.55	Cost/boe	1.3

Design production	
77.	71.69

Year	EXPLORATION & APPRAISAL				PROD. DRILLING		CAPITAL COSTS			OPERATING COSTS			DECOMM.	PRODUCTION		
	Seismic	Expl.	Well test	Apprsl.	Tangible	Intangible	Facilities	Pipelines	Other facilities	Fixed OPEX	Tariffs	Mods	Abandnmt	Oil MMbbl/yr	Cond. MMbbl/yr	Gas Bscf/yr
TOTAL	0.00	0.00	0.00	0.00	384.97	2,390.40	3,236.89	6,864.42	308.55	20,473.31	2,076.14	0.00	1,300.21	1,000.00	0.00	0.00
1					11.94	82.01	296.63									
2					45.41	77.32	528.95	1,092.81								
3					74.47	192.70	531.73	3,524.86								
4					78.28	387.07	1,448.42	870.82								
5					78.28	592.95	197.92	543.72	79.95							
6					66.35	592.95	233.24	566.38	187.89							
7					28.97	367.81		265.83	40.71							
8					1.27	97.59				880.32	36.33			17.50		
9										881.94	72.66			35.00		
10										883.55	109.00			52.50		
11										1,099.71	145.33			70.00		
12										885.36	145.33			70.00		
13										910.01	145.33			70.00		
14										885.17	145.33			70.00		
15										1,198.49	145.33			70.00		
16										885.17	145.33			70.00		
17										1,472.91	145.33			70.00		
18										909.60	136.10			65.55		
19										1,098.55	119.19			57.41		
20										883.36	104.38			50.28		
21										882.77	91.41			44.03		
22										882.45	80.05			38.56		
23										1,219.99	70.11			33.77		
24										881.43	61.39			29.57		
25										881.09	53.77			25.90		
26										880.80	47.09			22.68		
27										1,090.33	41.24			19.86		
28										880.31	36.11			17.39		
29													1,300.21			

COMBINED COST SUMMARY

Project	NEG_MKV_OIL_RUN_27B	Currency	US Dollars
Location	North America		
Development type	Oil		

Sub total	11,339,191,000	Procurement strategy: Offshore	North Atlantic Ocean Region
Contingency	1,846,024,000	Procurement strategy: Onshore	North America Average
Grand total	13,185,215,000		

Cost centre	Grand total	Equipment	Materials	Fabrication	Prefabrication	Installation/Construction	H.U. & C.	Design	Project management	Ins. & cert.	Contingency
Topsides 1	576,644,000	162,665,000	76,183,000	52,315,000		0	16,230,000	153,727,000	38,139,000	24,963,000	52,422,000
Semi-sub 1	786,599,000	562,413,000	19,826,000	2,992,000		8,832,000	4,620,000	12,882,000	12,720,000	31,214,000	131,100,000
Offshore pipeline 2	37,561,000		2,778,000			26,017,000		616,000	1,696,000	1,555,000	4,899,000
Offshore pipeline 1	412,162,000		185,611,000			134,190,000		5,677,000	15,858,000	17,066,000	53,760,000
Offshore pipeline 3	6,405,489,000		3,392,620,000			1,733,349,000		47,173,000	131,610,000	265,238,000	835,499,000
Offshore loading 1	340,752,000	172,563,000	16,805,000			17,330,000		17,100,000	46,640,000	13,522,000	56,792,000
Offshore drilling 1	1,433,580,000	94,758,000	62,142,000			837,422,000		50,160,000	93,280,000	56,888,000	238,930,000
Offshore drilling 2	1,341,780,000	90,046,000	58,583,000			780,660,000		47,424,000	88,192,000	53,245,000	223,630,000
Subsea 1	276,260,000	73,178,000	32,392,000			95,485,000		11,924,000	6,275,000	10,963,000	46,043,000
Subsea 2	270,186,000	66,424,000	28,363,000			100,603,000		12,472,000	6,572,000	10,721,000	45,031,000
Subsea Booster P.S.	38,569,000	24,051,000	1,395,000	7,000		4,028,000		1,368,000	2,544,000	1,670,000	3,506,000
Subsea Booster P.S.	38,569,000	24,051,000	1,395,000	7,000		4,028,000		1,368,000	2,544,000	1,670,000	3,506,000
Subsea Booster P.S.	38,569,000	24,051,000	1,395,000	7,000		4,028,000		1,368,000	2,544,000	1,670,000	3,506,000
Subsea Booster P.S.	38,569,000	24,051,000	1,395,000	7,000		4,028,000		1,368,000	2,544,000	1,670,000	3,506,000
Subsea Booster P.S.	38,569,000	24,051,000	1,395,000	7,000		4,028,000		1,368,000	2,544,000	1,670,000	3,506,000
Subsea Booster P.S.	38,569,000	24,051,000	1,395,000	7,000		4,028,000		1,368,000	2,544,000	1,670,000	3,506,000
Subsea Booster P.S.	38,569,000	24,051,000	1,395,000	7,000		4,028,000		1,368,000	2,544,000	1,670,000	3,506,000
Subsea Booster P.S.	38,569,000	24,051,000	1,395,000	7,000		4,028,000		1,368,000	2,544,000	1,670,000	3,506,000
Onshore Prod. Fac.	238,798,000	36,882,000	28,523,000		12,284,000	86,817,000		25,200,000	13,872,000	4,072,000	31,148,000
Sotrage and Export T	516,633,000	35,727,000	59,074,000		13,222,000	230,280,000		65,894,000	36,240,000	8,809,000	67,387,000
Onshore pipeline 1	3,071,000		1,001,000			1,084,000		245,000	288,000	52,000	401,000
Onshore pipeline 3	3,071,000		1,001,000			1,084,000		245,000	288,000	52,000	401,000
Onshore pipeline 2	3,071,000		1,001,000			1,084,000		245,000	288,000	52,000	401,000
Infra- Onshore Fac	115,503,000		86,506,000					5,314,000	6,648,000	1,969,000	15,066,000
Infra-Terminal	115,503,000		86,506,000					5,314,000	6,648,000	1,969,000	15,066,000
TOTALS	13,185,215,000	1,487,064,000	4,150,075,000	55,363,000	25,506,000	4,086,461,000	20,850,000	472,556,000	525,606,000	515,710,000	1,846,024,000

Total operating cost summary

		Totals	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21
Grand total operating cost	$	**22,549,433,000**	**916,653,000**	**954,602,000**	**992,552,000**	**1,245,043,000**	**1,030,684,000**	**1,055,339,000**	**1,030,499,000**	**1,343,818,000**	**1,030,499,000**	**1,618,236,000**	**1,045,700,000**	**1,217,739,000**	**987,731,000**	**974,181,000**	**962,502,000**	**1,290,089,000**	**942,828,000**	**934,863,000**	**927,888,000**	**1,131,565,000**	**916,422,000**
Direct costs																							
Operating personnel costs	$	1,506,645,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000	71,745,000
Inspection & maintenance costs	$	2,877,593,000	112,055,000	112,055,000	112,055,000	115,710,000	112,223,000	131,163,000	112,055,000	115,710,000	112,055,000	564,213,000	131,163,000	115,710,000	112,055,000	112,055,000	112,223,000	134,818,000	112,055,000	112,055,000	112,055,000	112,055,000	112,055,000
Logistics & consumables costs	$	477,695,000	20,285,000	21,716,000	23,148,000	24,577,000	24,577,000	24,577,000	24,577,000	24,577,000	24,577,000	24,577,000	24,214,000	23,547,000	22,967,000	22,454,000	22,006,000	21,615,000	21,270,000	20,971,000	20,711,000	20,476,000	20,276,000
Well costs	$	958,857,000	0	0	0	161,379,000	0	0	0	237,360,000	0	0	0	161,379,000	0	0	0	237,360,000	0	0	0	161,379,000	0
Insurance costs	$	1,303,449,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000	62,069,000
Direct costs total	$	7,124,239,000	266,154,000	267,585,000	269,017,000	435,480,000	270,614,000	289,554,000	270,446,000	511,461,000	270,446,000	722,604,000	289,191,000	434,450,000	268,836,000	268,323,000	268,043,000	527,607,000	267,139,000	266,840,000	266,580,000	427,724,000	266,145,000
Field/ project costs	$	13,349,071,000	614,167,000	614,353,000	614,538,000	664,234,000	614,741,000	620,456,000	614,724,000	687,028,000	614,724,000	750,303,000	620,409,000	664,100,000	614,515,000	614,448,000	614,407,000	692,377,000	614,295,000	614,257,000	614,223,000	662,606,000	614,166,000
Tariff costs	$	2,076,123,000	36,332,000	72,664,000	108,997,000	145,329,000	145,329,000	145,329,000	145,329,000	145,329,000	145,329,000	145,329,000	136,100,000	119,189,000	104,380,000	91,410,000	80,052,000	70,105,000	61,394,000	53,766,000	47,085,000	41,235,000	36,111,000