Prepared by

Sargent & Lundy Consulting

55 East Monroe Street
Chicago, Illinois 60603-5780

FINAL

New Asset Development Milestone Schedules

Prepared for

Alberta Electric System Operator

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CONTRIBUTORS

Prepared by:	Patrick S. Daou *Consultant*	Michael Samluk *Project Controls Specialist*
Reviewed and Approved by:	Sang H. Gang *Project Manager*	July 2, 2018 Date

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TABLES AND FIGURES

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ACRONYMS AND ABBREVIATIONS

Term	Definition or Clarification
AESO	Alberta Electric System Operator
BMS	Burner Management System
BOP	Balance of plant
CONE	Cost of New Entry
CTG	Combustion turbine generator
DCS	Distributed Control System
FEED	Front End Engineer Design
GSU	Generator step-up (transformer)
GWC	General Work Contract
HRSG	Heat recovery steam generator
ISD	In-service date
LNTP	Limited notice to proceed
MLS	multiple lump sum (contracting scheme)
NTP	Notice to proceed
OEM	Original equipment manufacturer
PO	Purchase order
POI	Point of Interconnection
PRV	Pressure reducing valve
S&L	Sargent & Lundy LLC
SCR	selective catalytic reduction (unit)
STG	Steam turbine generator
UAT	Unit auxiliary transformer

1. INTRODUCTION

Sargent & Lundy LLC (S&L) was contracted by the Alberta Electric System Operator (AESO) to develop milestone schedules for reference technologies anticipated to participate in the Alberta capacity market. The AESO's capacity market model requires that generators bid capacity into the market three years in advance of the anticipated capacity need with the first rebalancing auction occurring 18 months before the in-service date (ISD), and the second rebalancing auction three months before the ISD. The report is intended to provide insight to the AESO in determining whether new or retrofitted generators who submit an application to participate in the capacity market will be able to meet their committed capacity on time. The AESO, as part of the Comprehensive Market Design 2 Proposal, has already outlined a number of general prequalification requirements for new assets to be allowed to participate in the capacity market. Included in the prequalification requirements is submittal of a project timeline as well as major milestone list and dates. S&L's scope includes development of key milestone schedules and risk considerations over the course of design and construction of simple-cycle, combined-cycle, coal-to-gas conversion, wind, and battery energy storage system projects. Schedules and delay risks during the development phase of a project are not included in this scope. The task durations are representative of a typical project for each reference technology.

The simple-cycle and combined-cycle reference technologies chosen are based on the Cost of New Entry (CONE) study performed by the AESO. The coal-to-gas conversion, wind, and battery energy storage technologies (see Table 1-1) were chosen by S&L based on upcoming projects in the AESO interconnection queue as well as a general survey of recently announced or completed projects.

Table 1-1 — Milestone Schedule Reference Technologies

Technology	Configuration	Capacity (MW)
Simple-Cycle Combustion Turbine	2 x 0 GE LM6000	106
Combined-Cycle Gas Turbine	1 x 1 Siemens 8000H	421
Coal-to-Gas Conversion	Tangentially Fired Pulverized Coal Boiler	350
Wind	50 x 3 MW Turbines	150
Battery Energy Storage	10 MW / 40 MWh (4 x 2.5 MW Battery Banks with 4-hour storage)	10

Source: Capacities listed are at ISO conditions. 15°C / 60% RH / 1.013 bar

2. MILESTONE SCHEDULES AND DELAY RISKS

2.1 SIMPLE-CYCLE COMBUSTION TURBINE PROJECTS

As part of the CONE study effort, the AESO performed a survey of recent and upcoming simple-cycle combustion turbine developments as shown in Table 2-1. Using the method of revealed preferences, the AESO determined that the GE LM6000PF was an appropriate reference technology for simple-cycle units.

Table 2-1 — Recently Built and Planned Combustion Turbines in Alberta

Turbine Model	Turbine Type	Capacity Installed Since 2008 (MW)	Number Installed and Permitted Since 2008
GE LM6000	Aero	719	15
Siemens SGT6-5000F	Frame	600	3
GE LMS100	Aero	200	2
Rolls-Royce Trent 60	Aero	198	3
GE 7EA	Frame	177	2
Wärtsilä 18V50SG	Reciprocating	94	5
Caterpillar-G16CM34	Reciprocating	65	10
Solar Turbines Inc-Titan 130	Aero	30	2
Cummins C2000 N6C	Reciprocating	20	10
Jenbacher JGS 620	Reciprocating	18	6
Wärtsilä 20V34SG	Reciprocating	9	1

Source: Ventyx's Energy Velocity Suite and S&P Global in February 2018. Includes units built since 2008 and units that are under construction or permitted.

The GE LM6000PF is an aeroderivative-type combustion turbine with an approximate capacity of 53 MW at ISO conditions when operated as a simple-cycle unit. Aside from the combustion turbine itself, the construction of a new simple-cycle facility requires, as a minimum, the installation of an exhaust stack, control system, emission controls, electrical equipment, and foundations. Each of these items comprises many different tasks, each with a different level of impact on the project schedule if it is delayed.

2.1.1 Simple-Cycle Combustion Turbine Milestone Schedule

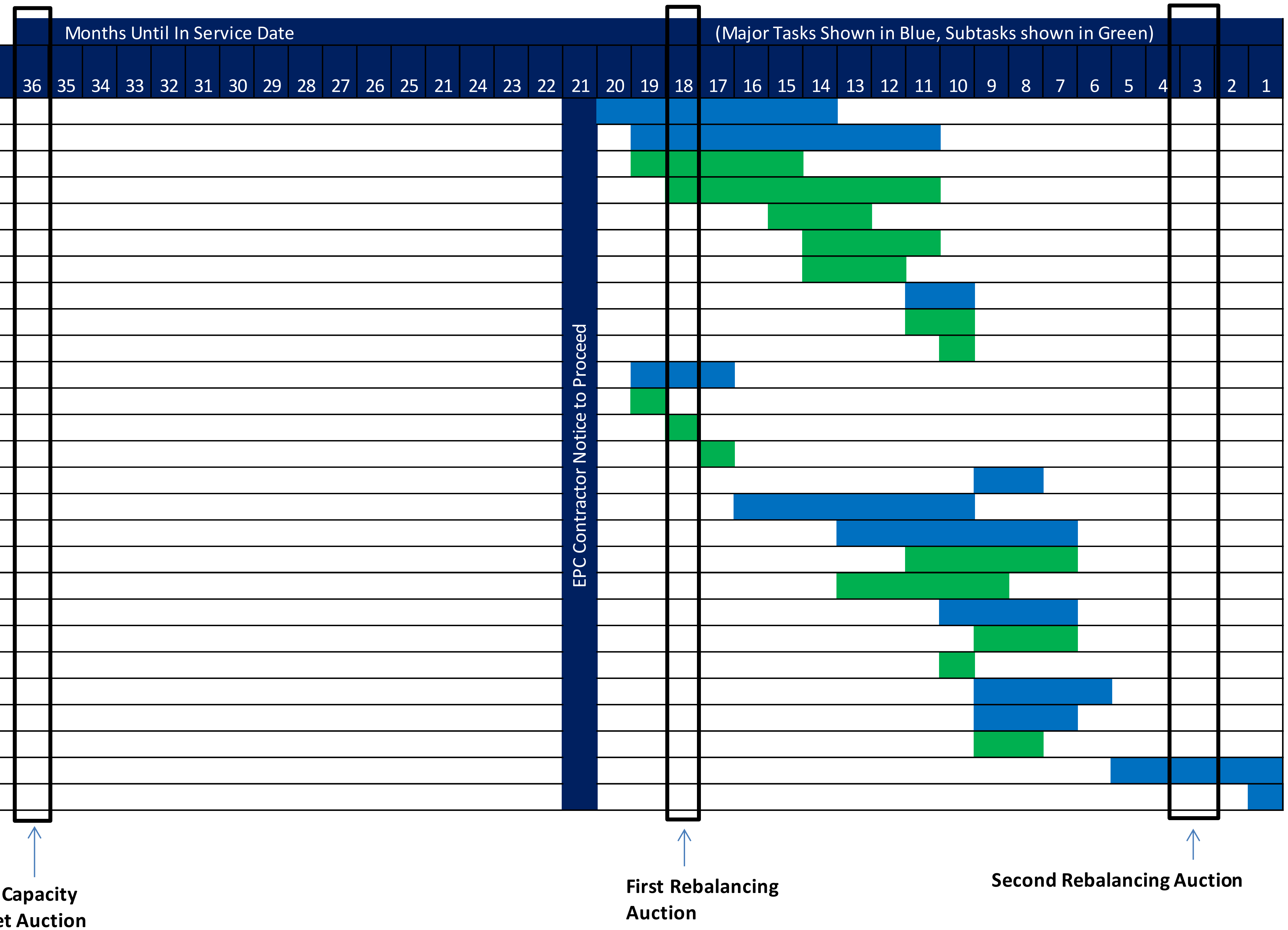
The proposed simple-cycle facility would include two GE LM6000PF aeroderivative combustion turbine generators (CTGs) arranged in a 2x0 configuration. The CTG would be designed for single-fuel operation with only dry low-NOx burners for emissions controls as proposed by the AESO for the CONE analysis. No evaporative cooling for power augmentation is included. The facility is assumed to be installed on a suitable greenfield site that does not require atypical site work. The following tasks are assumed to be performed by the developer before the EPC contractor's notice to proceed (NTP):

- Site Selection and Land Acquisition
- CTG Selection and Procurement
- Mass and Water Balances
- Environmental Impact Assessments
- Site Permitting
- Gas and Electrical Interconnection Process

The development tasks identified typically occur in parallel. Any delays in completion of the tasks are non-recoverable in the project schedule as these tasks must be completed prior to any associated subsequent tasks beginning. Presented in Figure 2-1 is a representative milestone EPC schedule from the EPC contractor's NTP to the ISD.

Figure 2-1 — Simple-Cycle Milestone Schedule

Task	Description	Duration (months)
A	Equipment Specification Development & Award	7
B	Detailed Engineering	9
B.1	P&IDs	5
B.2	Piping Isometrics	8
B.3	Single Line Diagram	3
B.4	Master Schematic Diagrams	4
B.5	Foundation Drawings	3
C	Major Foundation Erection	2
C.1	CTG Foundation	2
C.2	Aux. Equipment Foundations	1
D	Civil & Underground Sitework	3
D.1	Site Grading & Drainage	1
D.2	Underground Piping	1
D.3	Roads	1
E	Field Erected Tanks	2
F	Distributed Control System (From PO to Delivery)	7
G	Mechanical Balance of Plant	7
G.1	Piping Installation	5
G.2	Equipment Installation	5
H	Electrical Balance of Plant	4
H.1	Cable Installation	3
H.2	Equipment Installation	1
I	Combustion Turbine Generator Installation	4
J	Project Substation	3
J.1	Major Transformer Installation	2
K	Start-up & Commissioning	5
L	Project Completion	--



2.1.2 Simple-Cycle Combustion Turbine Milestone Risks and Mitigations

Task A – Equipment Specification Development & Award

The EPC contractor is responsible for all equipment not procured by the developer. Award of larger, long-lead-time items in a timely manner is critical for the project to maintain schedule. The developer and EPC contractor typically have performed enough engineering through the limited notice to proceed (LNTP) to allow the EPC contractor to prepare an equipment specification for major equipment. Delays in award of major contracts can push detailed engineering due to lack of information as well as construction if the delivery of equipment is delayed. Items such as large transformers can have minimum lead times of 12 months from contract award to delivery. The AESO could monitor the progress of the purchase orders (POs) for the following major components:

- Transformers – Generator Step-Up (GSU), Unit Auxiliary Transformer (UAT)
- Tanks
- Water Treatment
- Distributed Control System (DCS)

Smaller equipment, mechanical balance-of-plant (BOP) commodities, and electrical BOP commodities, while important, are awarded after completion of detailed engineering and have shorter lead times.

Task B – Detailed Engineering

During the detailed engineering phase of the project, the EPC contractor prepares construction drawings for the project including foundations, piping, steel, wiring, and equipment installation drawings. In addition to drawings, the contractor will prepare a detailed bill of materials for piping, electrical, instrumentation, civil, and structural commodities. The drawings listed below are considered major construction documents. Commodities are not procured and erection plans are not prepared until the documents listed below are released for construction:

- General Arrangement Drawings
- Equipment Arrangement Drawings
- Piping & Instrumentation Diagrams
- CTG Foundation Drawings
- Underground Ductbank Drawings
- Ductwork and Ductwork Support Steel Drawings

- Transformer Foundation Drawings

The list of documents above is not all-inclusive, but delays in these documents can have significant impacts on the schedule as each of these items has many BOP tasks dependent upon completion of the item.

Task C – Major Foundation Erection

Before the erection and installation of any major equipment, the foundations must be completed. All things held equal, a delay in completion of a foundation translates to an equivalent delay in the erection of the associated equipment. While there are many foundations that must be completed, the foundations listed below are ones for equipment that, if delayed, can have a particularly significant domino effect on subsequent tasks. For example, if the heat recovery steam generator (HRSG) foundation completion is delayed, then not only is erection of the HRSG delayed, but completion of steam piping and ductwork is also delayed, both of which are major tasks.

- CTG Foundation
- Transformer Foundation
- Ductwork Support Steel Foundations
- Stack Foundation

Completion of the above tasks can be identified visually by visiting the project site. Each major foundation will also have a concrete compressive strength test (break test) performed. This test is required by code for all structural concrete.

Task D – Civil & Underground Site Work

Initial site work performed by the contractor will include site grading, compacting, and backfilling as needed to prepare for the installation of the equipment foundations. This initial site work may also include trenching in preparation for installation of underground piping and cables, which will be backfilled later on in the project.

Completion of the above tasks can be identified visually by visiting the project site. In addition, before the work is performed, the contractor typically is required to get permits from the local authority for site development. These permits will require submission of site plans and grading drawings.

Task E – Field-Erected Tanks

Erection of any field-erected tanks is an important task but independent of the majority of the other construction tasks. The field-erected tanks have minimal interface with piping and are unlikely to cause delays to the completion of the project.

Completion of the field-erected tanks can be identified visually. In addition, EPC contractors will typically subcontract this scope of work to a tank specialist. Award of the subcontractor is an item that the AESO could monitor. The field-erected tanks, though important, are not typically critical path items because the tanks can be erected independently from the remainder of the project.

Task F – Distributed Control System

The DCS for a simple-cycle unit is fairly straightforward due to the simplicity of the installation. Simple-cycle units can be controlled locally or remotely depending on the installation purpose. The DCS is developed by a specialty subcontractor to the EPC contractor on most projects. An operable DCS system is critical to successful control and operation of the unit. A DCS system with go through a factory acceptance test (FAT) before being shipped to the project site for final installation. This is typically a test the EPC contractor, Developer, and other relevant parties attend in person to ensure that the DCS system will operate correctly.

Task G – Mechanical Balance of Plant Fabrication & Installation

Mechanical BOP work includes the installation of auxiliary equipment such as lube oil skids, water treatment, service water pumps, and potable water systems. In addition to equipment installation all piping and pipe supports will be performed as part of the mechanical BOP work.

Task H – Electrical Balance of Plant Fabrication & Installation

Electrical BOP work includes the installation of auxiliary equipment such as miscellaneous transformers, panels, and breakers. In addition to equipment installation, all cable tray routing, instrument installation, and cable terminations will be performed as part of the electrical BOP work.

Task I – Combustion Turbine Generator Installation

The combustion turbine is the core of a simple-cycle unit and the most critical part of the installation. The installation of the CTG can begin once the CTG foundation is completed. The list below summarizes, at a high level, the tasks required to complete the installation of a CTG. In general, these tasks are listed in the order in which they should be completed.

- Gas Turbine
- Lube Oil System
- Exhaust Diffuser
- Inlet Duct and Silencer
- Filter House
- Generator
- Transformers

In most cases, these tasks are supervised by a representative from the original equipment manufacturer (OEM) with a detailed schedule laid out for the installation. With the exception of the generator, a task cannot be completed unless the task predecessor is completed. The generator is installed separately from the combustion turbine and can be done at any time during the CTG installation. A delay in completion of the CTG installation is usually a direct delay on the project completion as the CTG is the core component of a simple-cycle unit.

Task J – Project Substation

Installation of the transformers is a fairly simple task with minimal risk. In many cases, the plant substation where the transformers are located is subcontracted to a specialty contractor. The substation is built independently of the remainder of the plant, so delays to the substation completion will not typically impact completion of other tasks in the schedule although they can still impact the overall project completion if the delays are significant.

Task K – Start-Up & Commissioning

Start-up and commissioning is the final critical step in the construction of a power plant. For a simple-cycle unit, there is a limited amount of equipment aside from the CTG that requires commissioning. The commissioning of the CTG and CTG auxiliaries are supervised by the OEM, which reduces the risk of issues during commissioning. The remainder of the equipment that requires commissioning is auxiliary equipment such as small pumps, electrical panels, etc.

2.1.3 Simple-Cycle Critical Path Milestones

The critical path identified in the project schedule is unique to each project. For a simple-cycle project, the critical path items are typically foundations and the CTG delivery. Intermediate tasks associated with major foundation erection include the following:

- Excavation
- Rebar Placement
- Concrete Pour

Delays in all the items identified above can be recovered by increasing manpower. Intermediate tasks associated with the CTG delivery include the following:

- Purchase Order Placement
- Rotor Fabrication
- CTG Blade Fabrication
- Factory Acceptance Testing

The CTG can be recovered through an expediting effort with the OEM. The specifics of this effort depend on where the delay is in the OEM fabrication of the CTG.

2.2 COMBINED-CYCLE PROJECTS

As part of the CONE study effort, the AESO performed a survey of recent and upcoming combined-cycle combustion turbine developments. Using the method of revealed preferences, the AESO determined that the Siemens SGT6-8000H was an appropriate reference technology for combined-cycle units.

Table 2-2 — Recently Built and Planned Combined Cycles in Alberta

Turbine Model	Turbine Type	Capacity Installed Since 2008 (MW)	Number Installed and Permitted Since 2008
Mitsubishi M501G1	Frame	851	1
Mitsubishi 501J	Frame	1,060	2
Siemens SGT6-8000H	Frame	510	2
Siemens SGT6-5000F	Frame	350	3

Source: Ventyx's Energy Velocity Suite and S&P Global in February 2018; includes units built since 2008 and units that are under construction or permitted.

2.2.1 Combined-Cycle Milestone Schedule

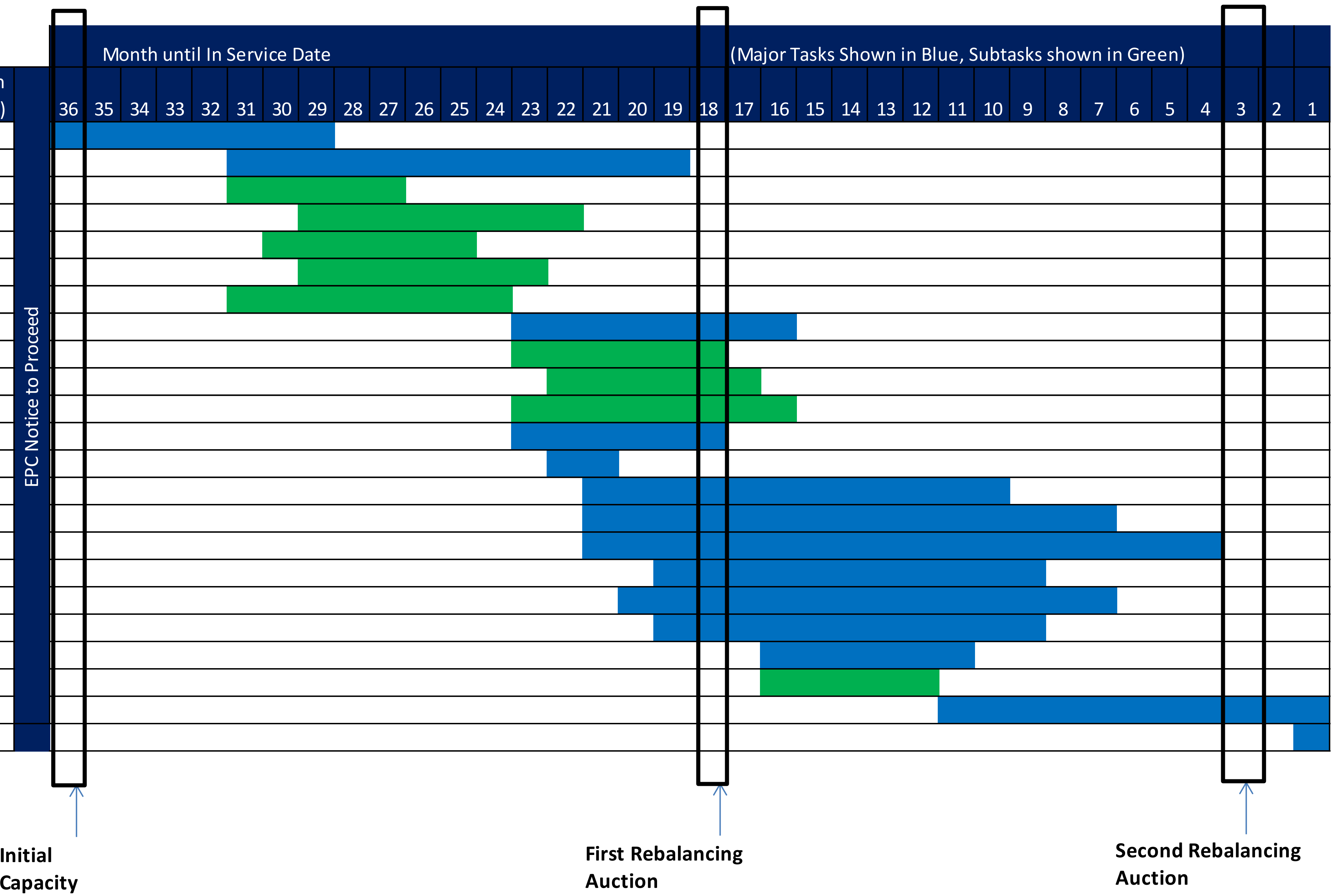
The proposed combined-cycle facility would include one Siemens SGT6-8000H combustion turbine generator (CTG) arranged in a 1x1 configuration with a HRSG and a steam turbine generator (STG). The CTG would be designed for single fuel operation with only selective catalytic reduction (SCR) and dry low-NOx burners for emissions controls as proposed by the AESO for the CONE analysis. The facility would also use a wet cooling tower. The facility is assumed to be installed on a suitable greenfield site that does not require atypical site work. The following tasks are assumed to be performed by the developer before the EPC contractor NTP:

- Site Selection and Land Acquisition
- CTG, HRSG, and STG Procurement
- Mass and Water Balances
- Environmental Impact Assessments
- Site Permitting
- Gas and Electrical Interconnection Process

The development tasks identified typically occur in parallel. Any delays in completion of the tasks are non-recoverable in the project schedule as these tasks must be completed prior to any associated subsequent tasks beginning. Presented in Figure 2-2 is a representative milestone EPC schedule from NTP to the ISD.

Figure 2-2 — Combined Cycle Milestone Schedule

Task	Description	Duration (months)
A	Equipment Specification Development & Award	8
B	Detailed Engineering	13
B.1	P&IDs	5
B.2	Piping Isometrics	8
B.3	Single Line Diagram	6
B.4	Master Schematic Diagrams	7
B.5	Foundation Drawings	8
C	Major Foundation Erection	8
C.1	CTG Foundation	6
C.2	HRSG Foundation	6
C.3	STG Foundation	8
D	Civil & Underground Sitework	8
E	Field Erected Tanks	2
F	Distributed Control System (PO to Delivery)	12
G	Mechanical Balance of Plant	15
H	Electrical Balance of Plant	18
I	HRSG Erection & Installation	11
J	Steam Turbine Generator and Condenser Installation	14
K	Combustion Turbine Generator Installation	11
L	Project Substation	6
L.1	Major Transformer Installation	5
M	Start-up & Commissioning	11
N	Project Completion	--



2.2.2 Combined Cycle Milestone Risks and Mitigations

Task A – Equipment Specification Development & Award

The EPC contractor is responsible for all equipment not procured by the developer. Award of larger, long-lead-time items in a timely manner is critical for the project to maintain schedule. The developer and EPC contractor typically have performed enough engineering through the LNTP to allow the EPC contractor to prepare an equipment specification for major equipment. Delays in award of major contracts can push engineering and construction. Items such as large transformers can have minimum lead times of 12 months from contract award to delivery. The AESO could monitor the progress of the contracts for the following major components:

- Condenser
- Cooling Tower
- Transformers (GSU, UAT)
- Pumps (boiler feed pumps, circulating water pumps)
- Steam Bypass Valves
- DCS

Smaller equipment, mechanical BOP commodities, and electrical BOP commodities, while important, are awarded after completion of detailed engineering and have shorter lead times.

Task B – Detailed Engineering

During the detailed engineering phase of the project, the EPC contractor prepares construction drawings for the project including foundations, piping, steel, and equipment installation drawings. In addition to drawings, the contractor will prepare a detailed bill of materials for piping, electrical, instrumentation, civil, and structural commodities. The drawings listed below are considered major construction documents. Commodities are not procured and erection plans are not prepared until the documents listed below are released for construction:

- General Arrangement Drawings
- Equipment Arrangement Drawings
- Piping & Instrumentation Diagrams
- CTG Foundation Drawings
- HRSG Foundation Drawings
- Underground Ductbank Drawings

- Ductwork and Ductwork Support Steel Drawings
- Transformer Foundation Drawings

The list of documents above is not all inclusive, but delays in these documents can have significant impacts on the schedule as each of these items has many BOP plant tasks dependent upon completion of the item.

Task C – Major Foundation Erection

Before the erection and installation of any major equipment installation, the foundations must be completed. All things held equal, a delay in completion of a foundation translates to an equivalent delay in the erection of the associated equipment. While there are many foundations that must be completed, the foundations listed below are ones for equipment that, if delayed, can have a particularly significant domino effect on subsequent tasks. For example, if the HRSG foundation completion is delayed, then not only is erection of the HRSG delayed but completion of steam piping and ductwork is also delayed, both of which are major tasks.

- CTG Foundation
- HRSG Foundation
- Cooling Tower Foundation
- STG Foundation (including STG pedestal)
- Transformer Foundation
- Ductwork Support Steel Foundations

Completion of the above tasks can be identified visually by visiting the project site. Each major foundation will also have a concrete compressive strength test (break test) performed. This test is required by code for all structural concrete. Documentation regarding completion of these tests can be requested to confirm completion of the foundations.

Task D – Civil & Underground Site Work

Initial site work performed by the contractor will include site grading, compacting, and backfilling as needed to prepare for the installation of the equipment foundations. This initial site work may also include trenching in preparation for installation of underground piping and cables, which will be backfilled later on in the project.

Completion of the above tasks can be identified visually by visiting the project site. In addition, before the work is performed, the contractor typically is required to get permits from the local authority for site development. These permits will require submission of site plans and grading drawings.

Task E – Field-Erected Tanks

Erection of any field-erected tanks is an important task but independent of the majority of the other construction tasks. The field-erected tanks have minimal interface with piping and instrumentation and are unlikely to cause delays to the completion of the project.

Completion of the field-erected tanks can be identified visually. In addition, EPC contractors will typically subcontract this scope of work to a tank specialist. Award of the subcontractor is an item which the AESO could monitor. The field-erected tanks, though important, do not typically cause delays in project completion as the tanks can be erected independently from the remainder of the project.

Task F – Distributed Control System

The DCS for a combined-cycle project is more complex than that of a simple-cycle installation. The DCS system in a combined-cycle project must incorporate the control logic for the combustion turbine as well as the logic for the steam cycle operation. On most projects, the DCS is developed by a specialty subcontractor to the EPC contractor. An operable DCS system is critical to successful control and operation of the unit. A DCS system with go through a factory acceptance test (FAT) before being shipped to the project site for final installation. This is typically a test the EPC contractor, Developer, and other relevant parties attend in person to ensure that the DCS system will operate correctly.

Task G – Mechanical Balance of Plant Fabrication & Installation

Mechanical BOP work includes the installation of auxiliary equipment such as lube oil skids, water treatment, service water pumps, and potable water systems. In addition to equipment installation, all piping and pipe supports will be performed as part of the mechanical BOP work.

Task H – Electrical Balance of Plant Fabrication & Installation

Electrical BOP work includes the installation of auxiliary equipment such as miscellaneous transformers, panels, and breakers. In addition to equipment installation, all cable tray routing, instrument installation, and cable terminations will be performed as part of the electrical BOP work.

Task I – HRSG Erection & Installation

The erection of the HRSG is a major undertaking for the contractor. The HRSG components are categorized at a high level as pressure parts and non-pressure parts. Pressure parts are generally any components of the HRSG that are exposed to steam or water. Non-pressure parts are generally any components of the HRSG exposed to CTG exhaust gas.

Pressure parts include the following:

- Modules (tube bundles)
- Steam drum
- Evaporator piping
- Economizer piping
- Attemperator piping
- Steam piping
- Feedwater piping

Non-pressure parts include the following:

- SCR casing
- SCR catalyst
- HRSG outlet ductwork

The above list is not all inclusive but identifies major parts of the HRSG erection and installation. A delay in any of the listed items has a direct impact on the completion time of the HRSG. The erection of a HRSG requires many crane lifts due to the large size of the HRSG. Construction progress of the HRSG can be tracked using a lift plan as all large lifts will typically have designated dates to be performed. Each day a lift is delayed is one additional day added to the completion of the HRSG.

Task J – Steam Turbine Generator and Condenser Erection & Installation

The installation of the STG and condenser can begin once the STG foundation is completed. The list below summarizes, at a high level, the tasks required to complete the installation of an STG. In general, the following tasks are listed in the order in which they should be completed.

- Base Plates
- Bearing Pedestals
- STG Auxiliaries
- High Pressure (HP) Turbine
- Intermediate Pressure (IP) Turbine

- Low Pressure (LP) Turbine
- Interconnecting Piping
- Steam Valves
- Rotor Alignment & Balancing
- Thermal Insulation
- Turbine Enclosure, Platforming, & Electrical
- Generator

With the exception of the generator, a task cannot be completed unless the task predecessor is completed. The generator is installed separately from the steam turbine and can be done at any time during the STG installation.

Task K – Combustion Turbine Generator Erection & Installation

The installation of the CTG can begin once the CTG foundation is completed. The list below summarizes, at a high level, the tasks required to complete the installation of a CTG. In general, the following tasks are listed in the order in which they should be completed.

- Gas Turbine
- Lube Oil System
- Exhaust Diffuser
- Inlet Duct & Silencer
- Filter House
- Generator
- Transformers

With the exception of the generator, a task cannot be completed unless the task predecessor is completed. The generator is installed separately from the combustion turbine and can be done at any time during the CTG installation.

Task L – Project Substation

In many cases, the plant substation is subcontracted to a specialty contractor. The substation is built independently of the remainder of the plant so delays to the substation completion will not impact completion of other tasks in the schedule although they can still impact the overall project completion if the delays are significant.

Task M - Start-Up & Commissioning

Start-up and commissioning is the final critical step in the construction of a power plant. For a combined-cycle unit, this is a significant undertaking due to the amount of equipment required for the steam cycle. The commissioning of the CTG and CTG auxiliaries are supervised by the OEM, which reduces the risk of issues during commissioning. This also holds true for the STG. The tasks listed below are typically supervised by the CTG and STG OEMs:

- CTG Lube Oil Flush
- STG Lube Oil Flush
- STG Steam Blow
- CTG First Fire
- STG Load Test

The remainder of the equipment requires an experienced staff to successfully commission the equipment. OEMs of pumps, valves, instrumentation, etc. will provide start-up and commissioning guidelines but unless contracted to do so will not provide onsite start-up support. Below is a sample list of tasks that are performed during start-up and commissioning:

- Steam Blow & Chemical Clean HRSG
- Pump alignment
- Instrument loop checks
- Motor checks

2.2.3 Combined-Cycle Critical Path Milestones

The critical path identified in the project schedule is unique to each project. For a combined-cycle project, the critical path is typically the delivery and erection of the HRSG. Intermediate tasks associated with HRSG erection include the following:

- Setting the HRSG Modules
- Setting the SCR
- Erecting Platforms and Support Steel
- Setting the Steam Drum
- Pressure Part Welding
- Installation of Instrumentation and Wiring

Delays in all the items identified above can be recovered by increasing manpower.

2.3 COAL-TO-GAS CONVERSION PROJECTS

2.3.1 Coal-to-Gas Conversion Milestone Schedule

Coal-to-gas conversions are unique projects with no standard designs or contracting schemes. The proposed conversion project would be for a tangentially fired, pulverized-coal boiler with a capacity of approximately 350 MW. This is similar in size and configuration to the proposed and current coal-to-gas conversion projects in Alberta. These projects are typically performed in multiple phases using a multiple lump sum (MLS) contracting scheme. There are typically three phases in a coal-to-gas conversion:

- Phase 1: Front End Engineering Design (FEED)
- Phase 2: Detailed Engineering
- Phase 3: Construction

The uniqueness of each plant and coal-to-gas conversions makes turnkey EPC projects difficult because the contractor being brought in would not have any familiarity with the station and its specific needs relative to the project. The schedule outlined below assumes the following tasks are performed during Phase 1:

- The Owner of a coal-fired generating station performs a feasibility study to determine whether the conversion would be profitable.
- The Owner contracts an engineering firm to perform the FEED work. Due to the uniqueness of coal-to-gas conversions, no two projects are the same. Input from the Owner and plant staff is critical for successful project completion. The FEED study includes heat balances, environmental impact assessments, and permitting as required.
- As part of the FEED work, the Owner contracts with the boiler OEM or similar firm who can design the modifications to the boiler and prepare specifications for equipment procurement.
- The Owner, using input from the boiler OEM and FEED work, contracts with a local natural gas supplier and arranges for installation of a gas pipeline to the gas metering station located on site.
- The Owner or the engineering firm performing the FEED work will perform any environmental assessments and permitting modifications as necessary for the project.

Presented in Figure 2-3 is a representative milestone coal-to-gas conversion EPC schedule from NTP to the ISD.

Figure 2-3 — Coal-to-Gas Conversion Milestone Schedule

Task	Description	Duration (months)
A	Design Criteria	1
B	Equipment Procurement & Delivery	17
B.1	Forced Draft, Induced Draft, & Primary Air Fans	11
B.2	ESV & PRV Skids	8
B.3	Boiler Combustion Equipment	13
C	Mechanical Engineering Design	13
C.1	Natural Gas Pipe Routing	5
C.2	Equipment Calculations	5
C.3	P&IDs	4
C.4	Demolition Drawings	2
D	Electrical Engineering Design	13
D.1	Instrument List & Datasheets	3
D.2	I/O List	3
D.3	Logic Diagrams	2
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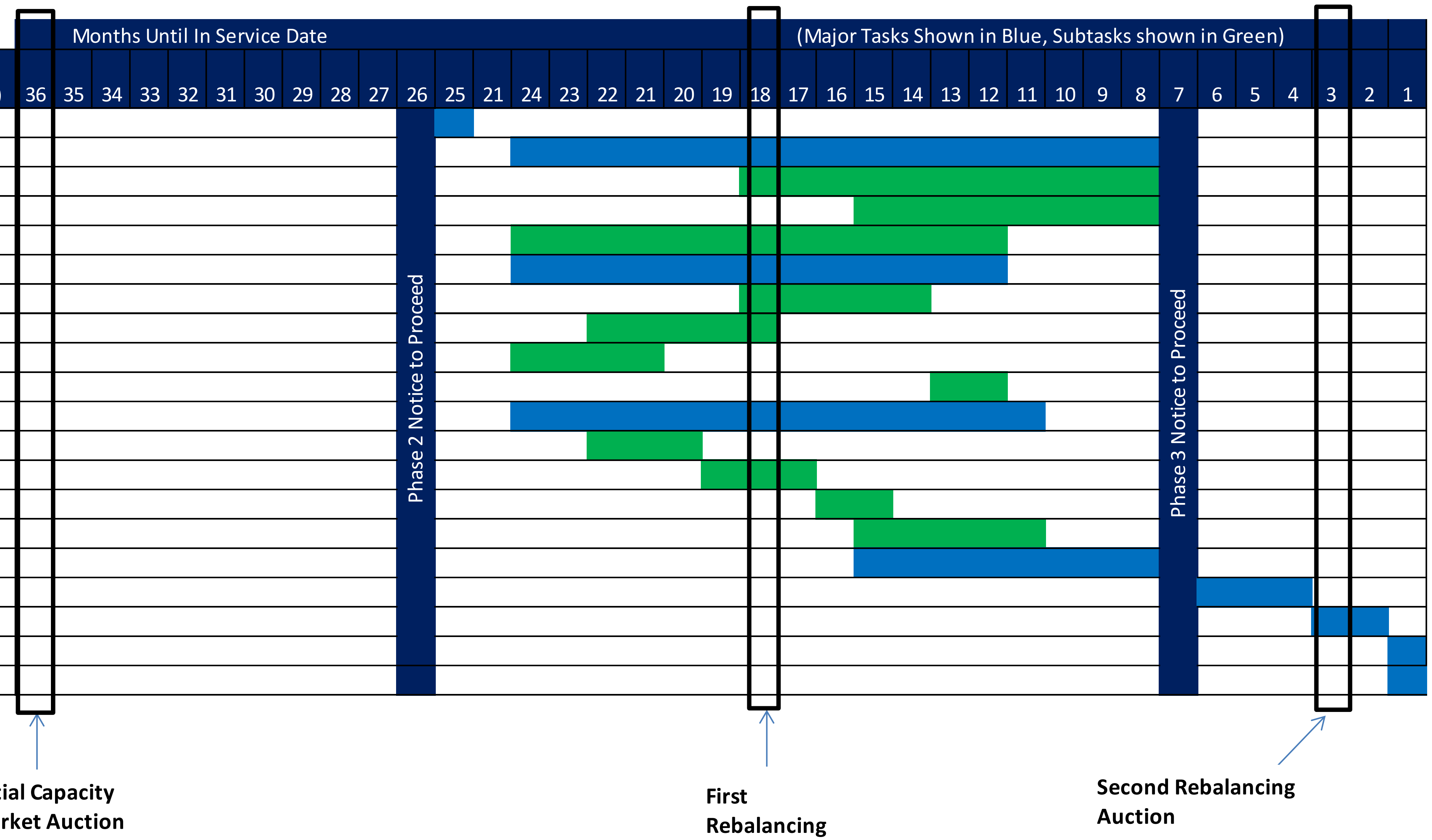
E	Prepare & Award General Work Contract	9
F	Metering Station, PRV Station, & Underground Piping Installation	3
G	Plant Outage	2
H	Start-up & System Tuning	1
I	Project Completion	--



2.3.2 Coal-to-Gas Conversion Milestone Risks and Mitigations

Task A – Design Criteria

The design criteria are developed by the engineering contractor awarded the Phase 2 design work using direct input from the Owner along with the results of the FEED work in Phase 1. Sound design criteria are required to ensure that all the project requirements are met once the detailed design work is completed. General practice is to begin detailed engineering only after the design criteria are completed for the mechanical, electrical, structural, and civil scopes of work.

Task B – Equipment Procurement & Delivery

In a MLS contracting scheme, specifications are prepared by the Owner's engineer during Phase 2 of the project for procurement by the Owner. A separate contract is prepared and awarded to each equipment supplier, and the procurement is managed by the Owner with technical support from the Owner's engineer. Delays in award of major contracts can push engineering due to lack of information, which can roll into construction delays if the general work contract award is delayed due to lack of construction-ready drawings.

The AESO could monitor the progress of the POs for the following major components:

- Forced Draft, Induced Draft, and Primary Air Fans
- Structural Steel
- Emergency Shutoff Valve (ESV) and Pressure Reducing Valve (PRV) Skids
- Boiler Conversion Equipment (ignitors, valves, etc.)
- Distributed Control System (DCS) and Burner Management System (BMS) modifications

Smaller equipment, mechanical BOP commodities, and electrical BOP commodities, while important, are awarded after completion of detailed engineering and have shorter lead times. These items may be given to the General Work Contract (GWC) contractor for procurement if sufficient information is available for the GWC to procure the equipment without additional engineering.

Task C – Mechanical Engineering Design

During the detailed engineering phase of the project, the Owner's engineer will prepare construction drawings for the project for use by the GWC contractor. In addition to drawings, the Owner's engineer will prepare a detailed bill of materials for commodities. The construction drawings and bill of materials issued to the GWC contractor contain enough detail such that the GWC contractor is not required to perform any design engineering. At the Owner's discretion, smaller items such as small bore piping may be left to the GWC contractor for routing in accordance with a generic specification issued by the Owner's engineer. The drawings listed below are considered major construction documents. Commodities are not procured and erection plans are not prepared until the documents listed below are released for construction:

- General Arrangement Drawings
- Equipment Arrangement Drawings
- Piping & Instrumentation Diagrams
- Large Bore Isometrics
- Small Bore Isometrics
- Underground Pipe Routing
- Mechanical Balance of Plant Modifications
- Mechanical Demolition Drawings

The list of documents above is not all inclusive, but delays in these documents can have significant impacts on schedule as each of these items has many BOP tasks dependent upon completion of the item.

Task D – Electrical Engineering Design

Electrical detailed design is similar to the mechanical detailed design discussed above. Commodities are not procured and erection plans are not prepared until the documents listed below are released for construction

- Electrical Equipment Arrangement Drawings
- Single Line Diagrams
- Cable Tray Drawings
- I/O Lists
- Logic Diagrams
- Wiring & Termination Drawings

The list of documents above is not all inclusive but delays in these documents can have significant impacts on schedule as each of these items has many BOP tasks dependent upon completion of the item.

Task E – Prepare & Award General Work Contract

Timely award of the GWC is critical to the completion of the project. The contractor awarded the GWC is responsible for the installation of the equipment procured by the Owner along with any commodities included in the GWC. To provide accurate pricing and schedules, the GWC contractor will require that the finalized construction drawings and bill of materials be included in the technical specification issued with the GWC. Award of the GWC contract is the beginning of Phase 3 of a coal-to-gas conversion project.

Task F – Metering Station, PRV, & Underground Piping Installation

The metering station, PRV skid, and underground piping installation begin along the plant fence line. On the upstream side of the metering station, the natural gas supplier still has ownership of the natural gas. Downstream of the metering station, the natural gas ownership is transferred to the Owner. The natural gas is then put through a PRV skid to bring the pressure down to the design pressure of the project. A pipeline is installed, typically underground, from the outlet of the PRV station to the boiler house. Installation of all three is performed by the GWC contractor. The pipeline upstream of the metering station is installed in accordance with the agreement between the Owner and natural gas supplier. Typically, this pipeline is installed by the natural gas supplier or by a different contractor hired by the Owner.

Task G – Plant Outage

The maximum amount of work is performed before the plant outage to minimize the outage duration. The work left to be performed during the outage is work that requires the disconnection of plant services, boiler modifications, or equipment demolition.

The most critical scope of work the GWC contractor will perform during the outage is the boiler modification. This includes installing new ignitors and burners, removing the old ignitors and burners, disconnecting coal piping, and reinforcing the boiler if needed.

The BOP modifications include installation of piping and pipe supports, electrical cables and wiring, instrumentation, miscellaneous foundations, platforms, and demolition of existing equipment. All BOP work is performed by the GWC contractor with the exception of fire protection work, DCS modifications, and BMS modifications. These items are handled by specialty contractors who are managed by the Owner’s procurement.

Task J – Start-up & System Tuning

With the unique aspects of a coal-to-gas conversion, start-up and system tuning is a critical part of the project. The boiler is now operating under new system conditions, which require equipment and instrument setpoints to be changed accordingly. After the conversion, major plant systems such as FGDs and pulse jet fabric filters are no longer required. Pumps, compressors, and instruments that provided air or water to decommissioned systems must be adjusted or decommissioned accordingly. In addition, plant setpoints such as flue gas monitoring pressures need to be adjusted in the DCS to ensure the plant continues to operate safely in the new configuration.

2.3.3 Coal-to-Gas Conversion Critical Path Milestones

The critical path for a coal-to-gas project is anything that may delay the start of the outage. Typically, the two tasks that may cause this to happen are (1) equipment procurement and delivery and (2) preparation and award of the general work contract.

Equipment procurement and delivery have the following intermediate milestone tasks:

- Forced Draft Fan PO & Delivery
- Induced Draft Fan PO & Delivery
- Structural Steel PO & Delivery
- DCS & BMS PO & Delivery
- Combustion Equipment PO & Delivery

Delays in equipment procurement and delivery can be recovered through an expediting effort with the various OEMs. The specifics of this effort would depend on where the delay is in the OEM schedule.

Preparation and award of the general work contract have the following intermediate milestone tasks:

- Specification Issued for Bid
- Project Site Walkdown & Meeting with Bidders
- General Work Contract Award

Delays in issuing of the specification can be recovered through increased manpower by the preparer of the specification. Any delays in the remaining tasks associated with the award of the general work contract are unlikely to be recoverable as to do so would require the bidders to use additional resources to expedite their bidding process.

2.4 WIND PROJECTS

Sargent & Lundy conducted a brief survey of the current AESO transmission connection project list to determine the appropriate size for a reference wind project. As of May 2018, there are 66 major projects being reported by the AESO with an average capacity of approximately 143 MW. Individual wind turbines available in today's market range in capacity from 1.5 MW to 3.6 MW. For this report, we have chosen to use a 150-MW wind project consisting of 3-MW turbines as the reference wind project. A wind turbine model is not specified because construction of different OEM models is similar enough to not have a significant impact on project schedule.

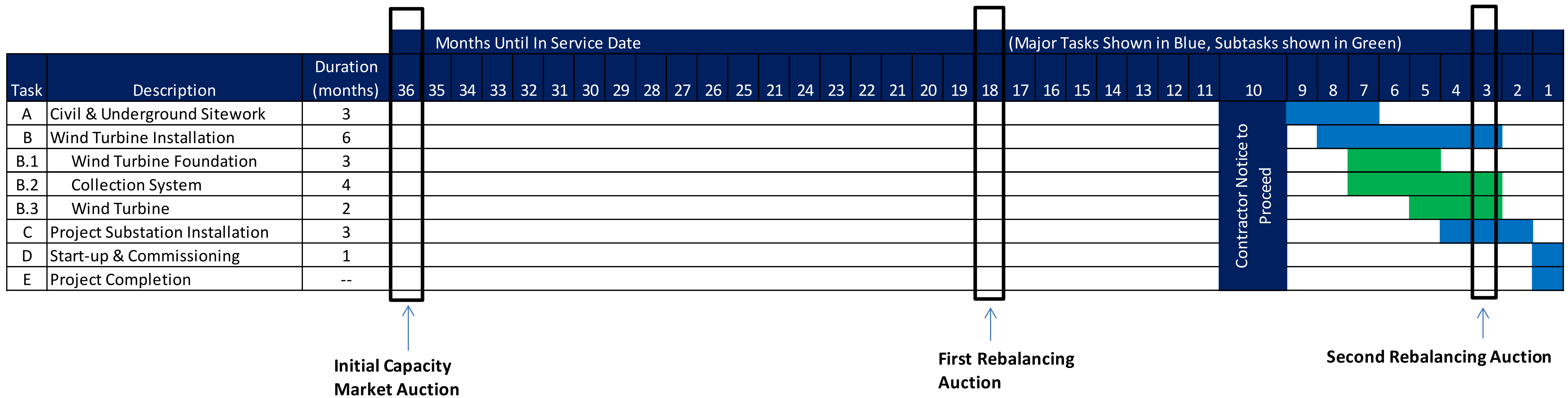
2.4.1 Wind Project Milestone Schedule

The proposed wind project would consist of 50 wind turbines, each with a capacity of 3 MW, installed on spread footing foundations. Electrical cabling for the collection system would be run underground to the site substation from which the power would be transmitted to the grid. The facility is assumed to be installed on a suitable greenfield site that does not require atypical site work. The following tasks are assumed to be performed by the developer before the EPC contractor's NTP:

- Site Selection & Acquisition
- Wind Resource Assessment & Micro-siting
- Wind Turbine Selection & Procurement
- Environmental Impact Assessments
- Site Permitting
- Electrical Interconnection Process

The development tasks identified typically occur in parallel. Any delays in completion of the tasks are non-recoverable in the project schedule as these tasks must be completed before any associated subsequent tasks can begin. Presented in Figure 2-4 is a representative milestone EPC schedule from NTP to the ISD.

Figure 2-4 — Wind Turbine Milestone Schedule



2.4.2 Wind Project Milestone Risks and Mitigations

Task A – Civil & Underground Site Work

Initial site work performed by the contractor will include site grading, compacting, backfilling, and excavation as needed to prepare for the installation of the wind turbine foundations. This work will be performed immediately after the contractor mobilizes to the project site. This may also include trenching in preparation for installation of underground cables for the collection system, which will be backfilled later on in the project.

Completion of the above tasks can be identified visually by visiting the project site. In addition, before the work is performed, the contractor typically is required to get permits from the local authority for site development. These permits will require submission of site plans and grading drawings.

Task B – Wind Turbine Installation

Before the erection and installation of wind turbine equipment, the foundations must be completed. All things held equal, a delay in completion of a foundation translates to an equivalent delay in the erection of the associated equipment. For wind turbine projects, wind turbines are erected independently of each other as soon as a given wind turbine's foundation is available. The wind turbine installation typically consists of three components:

- Tower
- Nacelle
- Rotor & Blades

The major auxiliary equipment for each turbine such as the gearbox and generator are housed within the nacelle.

The collection system is a series of underground cables and pad-mounted transformers that transport the generated electricity from each turbine to the project substation.

Aside from the wind turbine foundations, there are a limited number of smaller foundations that are required for the project. These smaller foundations are typically for pad-mounted transformers and other substation equipment.

Task C – Project Substation Installation

The Project substation receives power delivered from the collection system circuits that connect the wind turbines in parallel and delivers that power to the Point of Interconnection (POI). Protection and Control of the substation is provided via high-voltage circuit breakers and microprocessor relaying.

Task D – Start-up & Commissioning

Start-up and commissioning is performed on each wind turbine. This effort includes the testing of generator and auxiliary equipment located in each wind turbine nacelle and the testing of equipment installed in the project substation.

2.4.3 Wind Project Critical Path Milestones

The schedule for a wind project is linear, putting most of the tasks on the critical path. Aside from the substation, which can be installed separately from the wind turbines, the work must be performed in the following sequence:

- Foundation Excavation
- Foundation Rebar Installation
- Foundation Concrete Pour
- Wind Turbine Tower Erection
- Wind Turbine Rotor Installation
- Wind Turbine Start-up & Commissioning

Delays in the tasks identified are typically recoverable by increasing manpower to expedite installation of each wind turbine or by installing more wind turbines in parallel.

2.5 BATTERY ENERGY STORAGE SYSTEM PROJECTS

Sargent & Lundy conducted a brief survey of the current AESO connection project list to determine the appropriate size for a reference battery energy storage system (BESS). BESS is still a developing technology with limited development to date. As of May 2018, there are two major BESS projects being reported by the AESO with capacities of 30 MW and 40 MW. BESS is highly modular in nature; thus for this report, we have chosen to use a 10 MW BESS facility with a 4-hour duration rating.

2.5.1 BESS Project Milestone Schedule

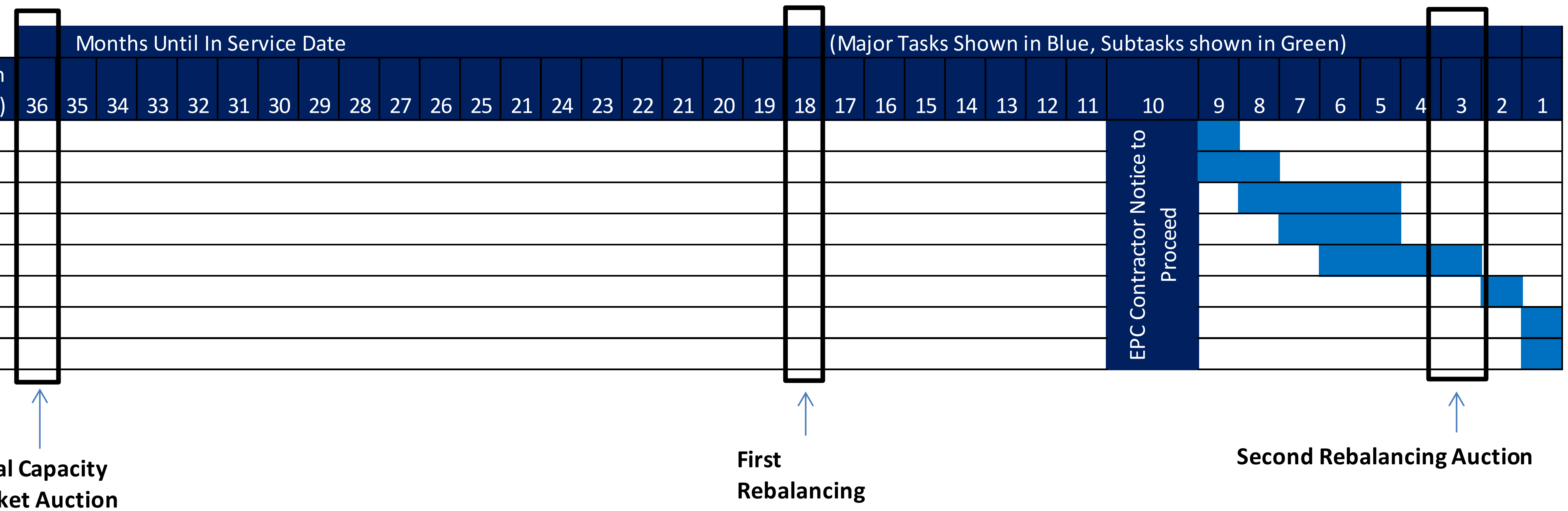
The proposed BESS facility would consist of four 2.5-MW strings of batteries that would connect directly via DC disconnect switches and cables to inverters and pad-mounted step-up transformers. The batteries are lithium ion rack mounted and are contained in a standard ISO container. The inverters are installed outside of the battery container in a separate weather-proof enclosure. Each 2.5-MW string of batteries would have one inverter and one step-up transformer. The facility is assumed to be installed at an existing generation site where the existing interconnection equipment can be used to make the grid connection. The following tasks are assumed to be performed by the developer before the EPC contractor’s NTP:

- Environmental Impact Assessments
- Site Permitting
- Electrical Interconnection Process
- Battery sizing
- BESS Applications – Revenue Stream Identification

The development tasks identified typically occur in parallel. Any delays in completion of the tasks are non-recoverable in the project schedule as these tasks must be completed before any associated subsequent tasks can begin. Presented in Figure 2-5 is a representative milestone EPC schedule from NTP to the ISD.

Figure 2-5 — BESS Milestone Schedule

Task	Description	Duration (months)
A	Equipment Specification Development & Award	1
B	Detailed Engineering	2
C	Battery Procurement	4
D	Power Control System & Transformers Procurement	3
E	ISO Containers Fabrication & Delivery	4
F	Site Construction	1
G	Start-up & Commissioning	1
H	Project Completion	--



2.5.2 BESS Project Milestone Risks and Mitigations

Task A – Equipment Specification Development & Award

For a BESS system, a developer will need to contract with a BESS OEM and an EPC contractor for construction, startup, and commissioning. With the site development completed upfront, contract finalization typically takes one month to complete. The project developer should have signed contracts to document completion of the contracting phase and the beginning of the engineering and permitting work.

Task B – Detailed Engineering

The engineering phase of the project is where the site and equipment drawings are developed. By the end of the two-month period, the project should have site drawings issued for construction and equipment drawings issued for procurement.

Task C – Battery Procurement

Battery lead times are typically 16 weeks. During periods of high demand, this time can increase significantly for Tier 1 products. Upon request, the developer should be able to provide documentation such as a project schedule showing the procurement status of the batteries.

Task D – Power Control System & Transformers Procurement

Procurement of control systems and transformers ranges from 12 to 16 weeks depending on the size of the BESS.

Task E – ISO Containers

ISO containers are standardized and generally come in 8’ x 20’ or 8’x 40’ sizes. Lead time can be up to 12 weeks for standard containers. If the developer chooses to use concrete containers, the lead time can increase to 20 weeks, which includes engineering, design, and construction of the containers.

Task F – Site Construction

Site construction typically takes one month for a 10-MW BESS system. Filling an 8’ x 40’ container typically takes one to two days.

Task G – Commissioning

Commissioning consists of testing and tuning the batteries, transformers, instrumentation, HVAC, and control systems to ensure reliable operation. For a 10-MW BESS system, commissioning typically takes two weeks to complete if no major issues arise.

2.5.3 BESS Project Critical Path Milestones

For a BESS project, battery procurement is typically the critical path for project completion. The demand for high-quality batteries can significantly increase the procurement time of the batteries. The following intermediate tasks are associated with the battery procurement:

- Purchase Order Placement
- Battery Fabrication
- Factory Acceptance Testing

A delay in battery procurement can be recovered through an expediting effort with the OEM. The specifics of this effort will depend on where the delay is in the OEM fabrication.