4 DEVELOPMENT AND PRODUCTION SCENARIOS

Possible Canadian and Newfoundland benefits are predicated on the specifics of the construction and operations processes. Following a thorough evaluation of potential development concepts, two economically and technically feasible production alternatives have been identified and further examined in the context of potential Canada-Newfoundland Benefits. Both of these are FPFs: a steel semi-submersible solution and a ship-shaped FPSO solution. This chapter describes the construction and operations processes with respect to each of these solutions on a comparative basis. The work components that have been examined include:

- hull fabrication (with turret fabrication and assembly taken as a separate component for the FPSO option);
- topsides module fabrication and assembly;
- on-shore/at-shore hook-up;
- offshore installation;
- production drilling;
- subsea fabrication and installation; and
- operations/production.

Major sub-contract packages for the construction and fabrication work associated with the White Rose development will be tendered and awarded either by Husky Oil or White Rose major contractors. Depending on the procurement philosophy, these packages may also include various arrangements for leasing of major equipment required, for instance, for subsea installation and production drilling, or for long-term operations and maintenance. The above categories of work will create both labour and infrastructure demands regardless of which production option is selected.

Within this and succeeding sections, references will be made to the National Occupation Classification, or NOC. This is a systematic taxonomy of occupations in the Canadian labour market intended for use in compiling, analyzing and communicating information about occupations based on a four digit construct. First published in 1993, it replaces the previous occupation classification system known as the Canadian Classification and Dictionary of Occupations, or CCDO, and better reflects many of the occupational changes that have occurred in recent decades. As an example specific to this study, offshore petroleum exploration and production activities are, as a result of the NOC, well defined in terms of category and skill level.
4.1 Steel Semi-Submersible with Detached Storage

4.1.1 Description

A steel semi-submersible production unit consists of a large deck connected to submerged steel pontoons by widely-separated water surface-piercing steel columns. The pontoons provide buoyancy to support platform weight, the columns provide floating stability and structural strength, and the deck supports the production, process, accommodation and marine facilities.

The steel semi-submersible is a stable platform with low vertical motions that allow for production operations in rough seas and extreme environments. Station keeping systems for semi-submersibles are considered to be robust and highly reliable. Having evolved over 35 years based on mobile offshore drilling units (MODUs), this production option represents a hull based on mature, proven technology.

A semi-submersible for White Rose, equivalent to a fourth-generation design, would have a length of approximately 100 m, a width of approximately 70 m and a process capacity of approximately 15,000 m$^3$ per day. Deck load capacity would be approximately 10,000 t. Although moored for normal production, the semi-submersible would be able to disconnect its moorings in an emergency. Propulsion systems allow the platform to move off location, and also assist in transportation.

Detached oil storage in the form of a storage tanker is an integral part of a semi-submersible production option. The storage tanker would be moored approximately 2 km away from the semi-submersible platform and would have weather-vaning capability, allowing it to respond to wind, wave and tidal conditions.

4.1.2 Hull Fabrication

The main construction activities include hull fabrication and outfitting. The hull is commonly built in sub-assembled components. Steel material delivered to the shipyard is normally shot blasted and painted with primer before cutting and forming. Panels, webs, girders and other small components are usually prefabricated before being included in the sub-assembled structures. Mechanical components and other outfitting materials are delivered to the shipyard in sequence to allow extensive pre-outfitting during the fabrication of sub-assemblies. The completed subassembly structures, which may weigh up to 500 t each, are delivered to the hull assembly area.

The lower hull sections (pontoons and lower column sections) may be fabricated in a single dry dock. Alternatively, they can be built in two dry docks, and then launched and mated at a wet dock. The columns are completed at the wet dock after mating.
4.2 Floating Production, Storage and Offloading Facility

4.2.1 Description

FPSOs are also referred to as monohull or "ship-shaped" offshore production platform solutions. They range in length from 200 to 300 m and are typically in the order of 45 m in width. Storage capacities vary from 50,000 to 159,000 m³ (up to a million barrels). Designed to stay on location in severe weather conditions, these vessels feature a turret that allows the vessel to "weathervane" without restriction. A heading control system ensures optimum orientation to wind and waves, while providing the best operating environment for the process system and crew. Based on the example of Terra Nova that has a lightship weight of 42,000 t, an FPSO is comprised of 76 percent steel (32,000 t) and 26 percent pipe, cable and miscellaneous equipment (10,000 t) (Terra Nova Project 2000).

An FPSO hull features multiple segregated oil storage tanks. Double-sided or double-hulled structures and wing tanks provide segregated water ballast within the cargo area. The vessel is moored to the seabed with mooring lines distributed out from the turret. The turret is arranged with tubes for guiding flexible production and injection risers and service umbilicals. Production fluids pass through the flexible risers via the turret manifolds into a multi-path swivel. These risers also provide the means for gas and water injection used to maintain required pressure levels within the reservoir. From the swivel, the fluids enter the process system, and following separation, the crude is transferred to the oil storage tanks. The type of FPSO turret typically considered for harsh environments (in this case the Grand Banks) allows the vessel to disconnect from its risers and moorings in the event of an emergency. Offloading crude from an FPSO is generally direct to shuttle tankers off the stern of the vessel by means of a flexible offloading hose.

4.2.2 Hull Fabrication

The hull and topsides of an FPSO are typically built in separate facilities. In accordance with modern shipbuilding methods, the hull will be constructed in "blocks" that have a specific size and tonnage limit. These blocks are fabricated separately and welded into position after they have been prepared and painted. Prefabrication of the blocks starts with the cutting and marking of steel plates using optically or numerically controlled thermal cutting tools.

The cut and marked plates are palletized and transported to a subassembly shop for manufacturing of webs, ribs and floor, which in turn are fitted into panels. Panels are flat structural pieces consisting of one or more plates joined together and stiffened by profiles. The blocks are built up from the panels.

The lower turret (the cylindrical structure that allows the vessel to weathervane) is the first piece of equipment to enter the dry dock, and the blocks are added in sequence around it.
When completed, the hull can receive the topsides modules, skid-mounted facilities and other deck-mounted equipment. The lifting, hook-up and commissioning of the topsides can be done at the hull fabrication yard or, alternatively, the FPSO, outfitted with all marine systems, can make its way under its own or vessel assisted power, to a separate hook-up site. Prior to sailing, the FPSO will be required to undergo sea-trials and inclination testing as prescribed by maritime authorities.

4.3 Floating Production, Storage and Offloading Facility Turret

Internal turret mooring systems allow FPSOs to remain on location permanently, even in very harsh environmental conditions. Disconnectable internal mooring systems are used where offshore fields may be subjected to harsh conditions and allow the vessel to be disconnected from its moorings to avoid severe weather and sea conditions, and icebergs. The FPSO turret is a highly specialized fabrication limited to only a handful of companies world-wide.

The turret provides the interface between the subsea facilities and the topsides. All fluids and information communication systems pass through the turret, including well fluids, injection water and gas, and the electrical connections and controls for the subsea systems. For example, the turret designed for the Terra Nova Development consists of the following components:

- Upper Turret: supports the manifold deck for the production, test, gas injection and water injection manifolds, and the swivel deck, where the multi-path swivel is located along with pigging facilities and various system cabinets and packages. This portion of the turret assembly was installed at the hook-up site.
- Lower Turret: carries the riser piping from the disconnect buoy to the upper turret and also contains the bearing system to transfer mooring loads and allow weathervaning. It features mooring winches used to secure the disconnect buoy to the lower turret. This portion of the turret was installed at the FPSO fabrication yard, and is integral to the vessel.
- Riser Buoy: the riser buoy (also known as riser connector, spider buoy or disconnect buoy) is integral to the disconnect/reconnect operation of the FPSO. The vessel mooring chains and production risers are permanently connected to the buoy. The riser buoy was installed on the offshore field prior to locating the FPSO. Retrieval of the buoy secures the vessel into its permanent position.

The Terra Nova turret in its entirety weighs approximately 4,000 t and has an overall height of 70 m. The disconnect portion of the turret (the spider buoy) has a 20-m diameter (Terra Nova Project 2000). It is anticipated that a White Rose FPSO would require a smaller turret.
4.4 Topsides Fabrication and Assembly

4.4.1 Semi-Submersible Topsides

The topsides for a steel semi-submersible would weigh approximately 10,000 t and consist of several assemblies, including skid-mounted packages and modules weighing up to 2,000 t. A structural deck of approximately 5,000 t is required to support the topsides. Depending upon schedule constraints, topsides production and living quarters facilities may be constructed at one or more sites or at the same site as the hull structure.

If the topsides are built at a different site than the hull structure, they and the deck structure are usually constructed as a complete unit and then mated to the hull. To accomplish this, the hull is relocated to a suitable nearshore location, moored in sheltered waters, and ballasted down to a mating draught. The entire topsides and deck structure are towed to the nearshore location on a barge small enough to allow the structure to be floated between the columns of the hull. The hull is then deballasted with the deck structure positioned over the columns. Landing devices take the structure’s load off the barge. Final alignment, mating preparation and welding precede final deballasting and removal of the barge.

If the topsides facilities are built at the same site as the hull structure, the hull, deck, and topsides components can be assembled in one shipyard with a large drydock facility.

During construction of the production facility, special emphasis must be placed on:

- maintaining weight and dimensional control during construction;
- scheduling construction activities to ensure coordinated delivery of subassemblies to the erection site; and
- quality control of welding procedures and materials assembly operations to ensure structural integrity and dimensional accuracy.

Topside production equipment is integrated into the deck as much as possible. This minimizes the need to package the equipment into separate structural modules on top of the deck. Accordingly, most of the outfitting is completed during the construction of the sub-assembled components.

A semi-submersible presents additional options for module fabrication. The living quarters together with the helideck are usually fabricated and installed as separate modules for these production options. Additionally, cranes and boat stations can also be regarded as “modules”, and therefore bid and fabricated separately from the remainder of the platform.
4.4.2 Floating Production, Storage and Offloading Facility Topsides

Topsides facilities for an FPSO are generally fabricated in what are commonly called modules, skids, or pre-assembled units (PAUs). They range considerably in size and weight, and perform a wide variety of functions including:

- separation/compression;
- water injection;
- produced water/glycol;
- power generation;
- utility; and
- flare system.

Modules for FPSOs are typically limited to 20-m lengths, based on the vessel’s beam of 45 m.

With either production scenario, modules are unlikely to exceed 2,000 t. A range of much smaller PAUs is possible, however, this will also lead to greater cost, and a more complex hook-up phase, imposing specific demands on schedule.

Preliminary engineering indicates that the typical maximum topsides weight for the White Rose FPSO is in the order of 8000 t.

With an FPSO, the accommodations and helideck are regarded as integral to marine operations and, therefore, are built as part of the hull in preparation for sea trials and inclination testing prior to certification by maritime regulatory authorities.

The accommodations for a floating platform, whether FPSO or semi-submersible, will be sized for an operations and marine crew of between 45 and 50 persons, depending on operating philosophy.

4.5 On-shore/At-shore Hook-up and Commissioning

This term describes the installation, testing and commissioning of topsides modules at a designated hook-up site. The site will have to provide sufficient water depth at quayside to permit the vessel to be moored. The hook-up site will also require substantial industrial infrastructure to support the physical and technical work associated with this stage of construction.

A semi-submersible hull would likely be towed to the hook-up site. An FPSO would typically reach the site under its own power after passing sea trials at its point of origin.
The hook-up and commissioning process requires a well-coordinated plan that involves substantial input from the hook-up technical team, the hull fabricator, module fabricators and equipment vendors and suppliers.

### 4.6 Offshore Installation

In a generic context, offshore installation of a production vessel begins with setting out and embedding the anchors or piles at the installation site using anchor handling vessels and additional support vessels. Depending upon seabed conditions at the installation site, a remote-operated vehicle (ROV) is employed to accurately place drag anchors on the bottom, or a crane or construction/lay vessel is deployed to install steel anchor piles or suction anchors.

Survey vessels perform pre-installation surveys to confirm that installation areas and mooring line laydown corridors are free of debris and suitable for installation. Subsea positioning is then performed using hydro-acoustical and global positioning systems.

Both semi-submersible and FPSO solutions employ chain mooring legs. Typically, 9 to 12 legs are employed. The moorings are designed to hold the vessel on site unaided by thrusters. When the moorings have been installed, the production vessel locates to the installation site, while stand-by vessels patrol surface buoys. Anchor handling vessels are employed to retrieve the temporary pendant buoys and recover the mooring pendants. ROVs are employed to secure wire leads (messenger lines) to the chain moorings, and the chains are then recovered through mooring hawser pipes located in the vertical legs of the semi-submersible, or in the case of an FPSO, the turret.

### 4.7 Development Drilling and Workover/Intervention

With both the semi-submersible and FPSO production scenarios, drilling, well completion and workovers will be performed using a semi-submersible MODU.

Workover, as defined by C-NOPB regulations in respect of a development well, means any operation that requires the removal of the christmas tree. This term generally refers to maintenance and re-drilling of existing wells based on an evolving picture of well and reservoir characteristics and performance derived from information gathering conducted through the production drilling and operations stages. Typical well intervention activities include those initiated to increase productivity, reduce water production, repair mechanical damage, etc.

A typical MODU crew can be characterized by the skills and demands shown in Table 4.7-1. This crewing example forms the basis for labour projections provided in Section 6.7.
### Table 4.7-1 MODU Crew

<table>
<thead>
<tr>
<th>Position</th>
<th>NOC</th>
<th>Qty.</th>
<th>Position</th>
<th>NOC</th>
<th>Qty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior Toolpusher</td>
<td>9232</td>
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<td>Deck Hands</td>
<td>7433</td>
<td>4</td>
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<tr>
<td>Toolpusher</td>
<td>8222</td>
<td>1</td>
<td>Food Preparation</td>
<td>6641</td>
<td>12</td>
</tr>
<tr>
<td>Driller</td>
<td>8232</td>
<td>2</td>
<td>Cleaners / Stewards</td>
<td>6661</td>
<td>4</td>
</tr>
<tr>
<td>Assistant Driller</td>
<td>8232</td>
<td>2</td>
<td>Medic</td>
<td>3234</td>
<td>1</td>
</tr>
<tr>
<td>Lead Roustabout</td>
<td>8615</td>
<td>2</td>
<td>Mud Logging</td>
<td>8232</td>
<td>6</td>
</tr>
<tr>
<td>Roustabout</td>
<td>8615</td>
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<td>Well Drilling</td>
<td>8232</td>
<td>3</td>
</tr>
<tr>
<td>Floormen</td>
<td>8615</td>
<td>6</td>
<td>Directional Drilling</td>
<td>8232</td>
<td>2</td>
</tr>
<tr>
<td>Storemen</td>
<td>8615</td>
<td>1</td>
<td>Crane Operator</td>
<td>7371</td>
<td>1</td>
</tr>
<tr>
<td>Lead Maintenance</td>
<td>2232</td>
<td>1</td>
<td>Radio Operator</td>
<td>1475</td>
<td>2</td>
</tr>
<tr>
<td>Mechanical Technician</td>
<td>2232</td>
<td>3</td>
<td>Ballast Control Operator</td>
<td>7434</td>
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<tr>
<td>Electrical Technician</td>
<td>7242</td>
<td>2</td>
<td>Engineer</td>
<td>2100</td>
<td>1</td>
</tr>
<tr>
<td>Instrumentation Technician</td>
<td>2243</td>
<td>2</td>
<td>Geologist</td>
<td>2100</td>
<td>1</td>
</tr>
<tr>
<td>Deck Officers</td>
<td>2273</td>
<td>2</td>
<td>Operator’s Representative</td>
<td>2100</td>
<td>1</td>
</tr>
<tr>
<td>Marine Crew</td>
<td>7434</td>
<td>4</td>
<td>Forecasters</td>
<td>2114</td>
<td>2</td>
</tr>
</tbody>
</table>

### 4.8 Subsea Fabrication and Installation

Subsea facilities typically consist of:

- wellheads and christmas trees arranged in clusters or subsea templates;
- production/injection/control manifolds; and,
- flowlines connected to flexible risers which terminate on-board the production platform (at the loading porch on a semi-submersible or at the riser buoy for an FPSO). White Rose concept engineering studies suggest that up to 18 to 25 wells may be required, just less than half of them injection wells.

The subsea wellhead supports critical well casings and the production tubing that extends from the reservoir producing zones to the mudline, and serves as a conduit for all well fluids. A subsea component known as a christmas tree (due to the characteristic grouping of valves that control the flow of well fluids) is connected to each wellhead. Besides controlling the fluid flow, the christmas tree permits access to the well bore for workover operations. The wellheads and christmas trees are protected from ice scouring by locating them in glory holes or excavations, and are installed from a semi-submersible unit or vessel with the assistance of ROVs.
The individual wellheads and christmas trees may either be arranged in clusters or are integrated into structures called templates. The latter are seabed support structures that feature well slots to accommodate the subsea wellheads and trees or tie-in of satellite wells. A manifold, containing the piping arrangement for guiding and controlling the flow of fluid from the subsea wells to the flowlines, may either be installed as a separate component or integrated on each template. These also distribute injection fluids to the appropriate injection wells. Based on the experience of Terra Nova, the templates to be fabricated for White Rose may weigh up to 20 t.

Various methodologies have been studied for protecting wellheads and subsea equipment from iceberg scouring. Caisson wellheads were developed in the 1980s, whereby the wellhead and the lower master valves were located below the scour depth, offering a high level of safety in areas where drilled wells were subject to ocean floor hazards. Given the limited amount of space inside the caisson, special slimline tree valves with vertically-oriented actuators were developed. Another method is the glory hole, where a conventional subsea tree is placed in a deep excavation dredged in the sea floor.

The Terra Nova development opted to install the wellheads and subsea trees using templates. The entire assembly is installed in 10-m deep glory holes, including the manifold assembly. Another option would be to install the wellheads and trees (only) in cased glory holes or in subsea excavations without templates, and manifold on the seafloor immediately adjacent. This method reduces offshore excavation to a minimum and may simplify workovers on individual wells. Jumper flowlines are used to connect manifolds to the subsea trees.

Typically, templates, manifolds, flowlines and risers are installed from construction lay/diving support vessels. Flexible flowlines are installed between the production vessel and the drill centres, and deliver well fluids from the satellite templates or manifolds. These flowlines can be trenched into the seabed or insulated and laid simultaneously from the multi-purpose construction vessel. Risers, flanged to the flowlines at the seabed and secured with concrete riser bases (each weighing from 100 to 150 t), are suspended from the vessel in catenary or “lazy wave” configurations to accommodate vertical and lateral environmentally-induced vessel motions. The risers are flexible pipes that carry the oil to the production vessel and transport injection and control fluids to the subsea wells. Risers are made up of layers of different composition and thickness, each serving a specific function, and typically range in diameter from 125 to 300 mm in diameter.

Divers and/or ROVs will be employed for hook-up of the various components.

A portion of the subsea work occurs on-shore, after fabrication but prior to installation. This is designed to avert the huge cost of testing and rework offshore. Factory acceptance and systems integration testing involves the assembly and testing of production trees, template and manifold elements, the pull-in heads of the actual flowlines and umbilicals, and the subsea control system used to monitor well performance and control remote actuation of the subsea valves. Due to the sensitivity of the control system to
contamination, facilities for integration testing are often indoors, where a high level of cleanliness can be assured. The equipment providing hydraulic fluid for testing must also meet specific criteria demands, and the labour force must be highly trained and familiar with procedures pertaining to this aspect of the work.

4.9 Production and Operations

4.9.1 Vessel Operations

The total crew required to maintain and operate a floating production facility ranges world-wide from 35 to 60 persons, depending upon owner operating strategies and the field environment and individual facility requirements. A recent study by CAPP put the crew estimate for an FPSO operating on the Grand Banks at approximately 50 persons.

A typical crew would be characterized by the skills and demands shown in Table 4.9-1. This crewing example forms the basis for labour projections provided in Section 6.9.

Table 4.9-1 Vessel Crew

<table>
<thead>
<tr>
<th>Position</th>
<th>NOC</th>
<th>Qty.</th>
<th>Position</th>
<th>NOC</th>
<th>Qty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore Installation Manager OIM</td>
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<td>Mechanical Technicians</td>
<td>2232</td>
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<tr>
<td>Deck Officers</td>
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<td>Pipefitters</td>
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<td>Able Bodied Seamen</td>
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<td>Welders</td>
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<tr>
<td>Shift Supervisors</td>
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<td>2</td>
<td>Radio Operators</td>
<td>1475</td>
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<tr>
<td>Control Room Personnel</td>
<td>7434</td>
<td>2</td>
<td>Weather Forecasts</td>
<td>2114</td>
<td>2</td>
</tr>
<tr>
<td>Operators</td>
<td>9232</td>
<td>4</td>
<td>Crane operator</td>
<td>7371</td>
<td>1</td>
</tr>
<tr>
<td>Process Operators</td>
<td>9232</td>
<td>1</td>
<td>Logistics Technicians</td>
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</tr>
<tr>
<td>General Maintenance Supervisor</td>
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<td>Maintenance Crew</td>
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<tr>
<td>Instrumentation Supervisor</td>
<td>2243</td>
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<td>Food Service</td>
<td>6641</td>
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<td>Mechanical Supervisor</td>
<td>8222</td>
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<td>Cleaners / Stewards</td>
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<td>Laundry</td>
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<td>Medic</td>
<td>3234</td>
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</tbody>
</table>
4.9.2 Oil Transport

As explained previously, a semi-submersible production facility would require a separate storage tanker but an FPSO has inherent storage by virtue of its hull. Either production option, however, will require the services of shuttle tankers to transport the oil to market or transshipment facilities. These would be in the 80,000 to 120,000 dead weight tonnage (DWT) range, probably with dynamic positioning capability. They would meet the appropriate class requirements for operations in ice-prone waters.

4.9.3 Marine Support Facilities

During pre-production drilling, and throughout the life of the FPF, life safety operations assistance and re-supply will require standby and supply vessel support. The supply vessels will provide everything to the field, from drill casings and fluids to food and equipment, and will be equipped with anchor handling capabilities. These will be leased on the world market rather than purpose-built specifically for White Rose operations. The functions of the support vessels include:

- stand-by duty;
- ice management;
- oil spill response;
- cargo and consumable re-supply;
- anchor handling;
- tug assistance;
- towing; and
- environmental monitoring.

Helicopter support for the field (drilling and operations crew changes) will be contracted. Primary and back-up helicopter service will be required on a 24-hour a day basis, with provision for passenger handling, flight following services and first response capability.

Supply base facilities will also be contracted to support both drilling and production. An industrial park site will be required with warehouse facilities of up to 4,000 m² for drilling services and in the vicinity of 7,500 m² for exterior storage and handling of drill casings. Additional space will be required for mud and cement storage, laydown yard, various bunker and explosives storage, bulking material and receiving. Husky Oil will examine the potential for synergies with existing operations for the provision of these services.