Transforming offshore field developments with Pivotree™

An innovative technology solution for fast, cost effective, and low footprint projects

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Agenda

1. MCD Analysis
2. Concept Select
3. Pivotree Comparison
4. Conclusion
5. Questions

Introduction

Oil & Gas (O&G) powers the global economy.

Exploration and production activities account for approximately 5.3% of global GDP.[1]

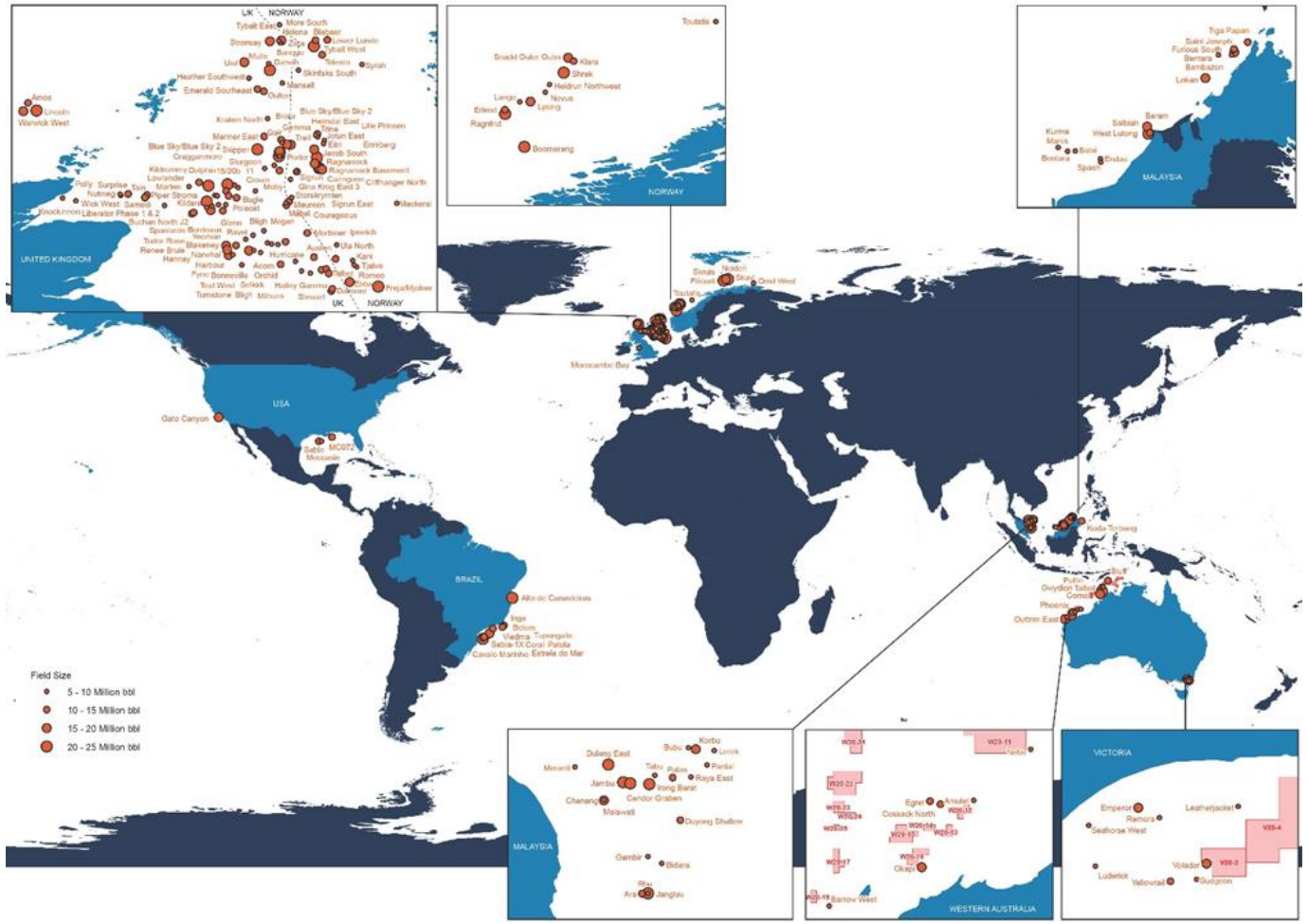
In the United States alone, O&G employs an estimated 2.3 million people directly, and over 10 million indirectly.[2]

The transition to renewables is behind schedule[3] and underfunded to the tune of USD$2.5 trillion per year to 2050.[4]

There will be a greater reliance on hydrocarbons for longer than envisaged by aggressive decarbonisation scenarios (BP, 2023) (IEA, 2021).[5]

The energy industry has focussed on exploiting the largest, most economically produced oil fields. Few easily extracted large hydrocarbon accumulations remain.

However, many discovered resource opportunities, previously deemed sub-economic, exist around the globe, ranging from one million barrels to as much as 25 million barrels.



Global map of stranded fields, less than 25MMbbls, more than 20kms from a host facility (Source: Rystad Dataset)

Field Development

The pivotal importance of the **Concept Select** phase

Conventional Oil and Gas Field Development

An oil and gas development is conducted over several discrete phases, segmented as short duration, high CAPEX activities followed by long duration, revenue generative operations, before decommissioning and abandonment.

In Australia, the shortest path timeline from being awarded title to an offshore area into exploration, making a discovery and being able to produce (including regulatory approvals) is estimated as **five years**.

While decision making occurs over the entire lifecycle of the field the largest number of decisions with the largest impacts on project success, happens during **Concept Select** or "Select" phase: a relatively short but intense period of the development.

During Concept Select the attributes (unique characteristics) of the field are assessed and the solution space for developing the field – the feasible alternatives – is established.

A desirable outcome of the activity is several feasible development "Concepts" that can be compared for schedule, risk, and cost.

Field Development Concepts

- There are many feasible concepts, of either open or proprietary design, that can be built to exploit a field, though all can be fit into a few generalised categories:
- Fixed: a permanently installed facility that is attached to the seabed,
- Floating: a permanently moored or disconnectable floating facility; or,
- Subsea Tie-Back: a subsea well, flowline and umbilical connecting a remote reservoir to another fixed or floating facility.

Fixed	Floating	Subsea Tie-Back
Platform with Steel Frame Jacket	Ship Shaped FPSO with Mooring	XTs with Flowline / Umbilical
Gravity Base Structure	Sevan Shaped FPSO with Mooring	XTs with Flowline / Control Buoy
Mono-Column Platform	FPSO with Dynamic Positioning	XTs with Flowline / Subsea Tanks
Conductor Supported Platform	Production Barge with Mooring	XTs with Flowline / Subsea Boosting
Jackup Rig (MOPU)	Spar / Cell Spar Platform	
Compliant Tower Platform	Semi-Submersible (MOPU)	
Tension Leg Platform	Control Buoy	
	Drillship (Converted to MOPU)	

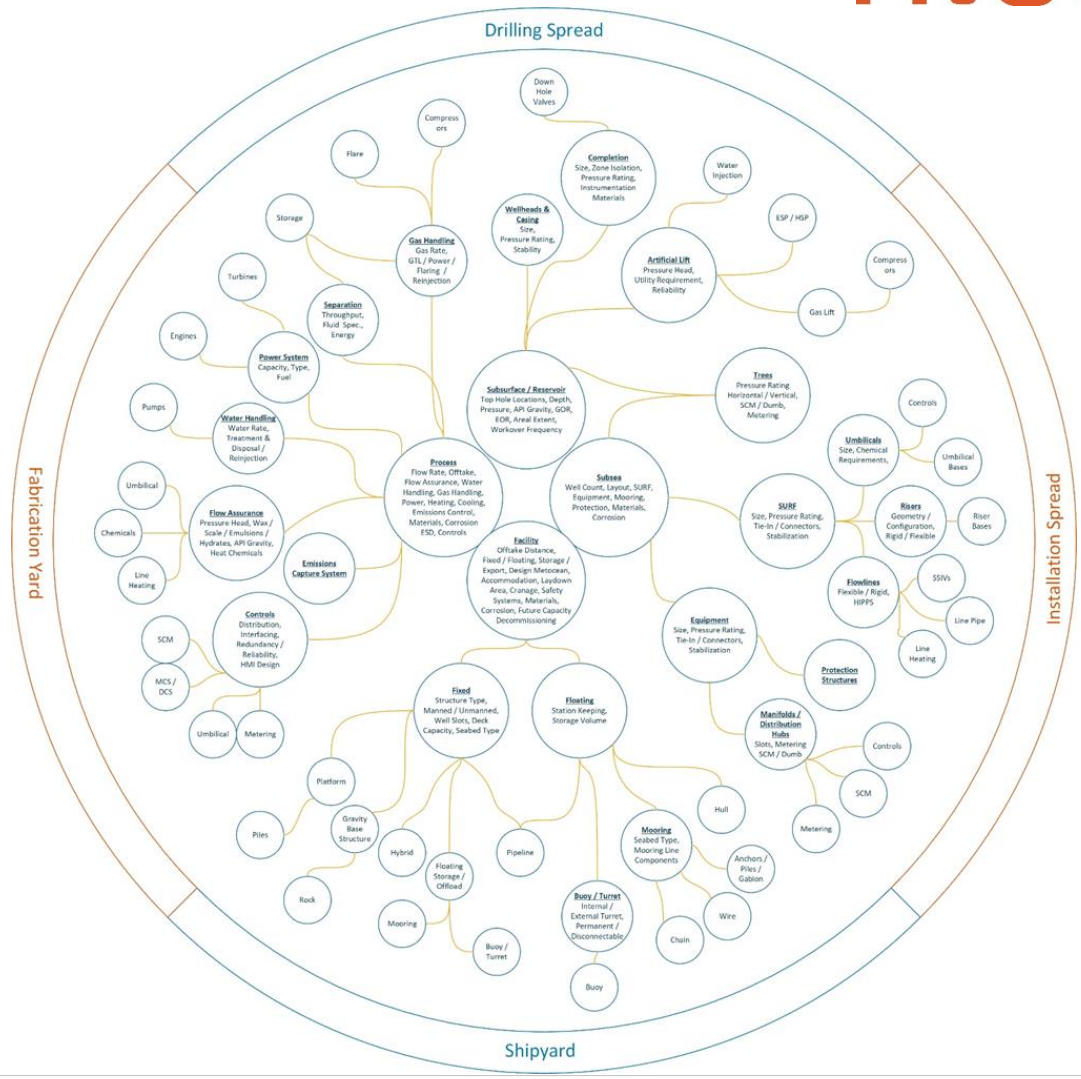
Categorised list of conventional development “Concepts”

Development Concept Attributes

Facility Type	Well Count	Trees	Mobile	Storage	Water Depth	Station Keeping	Production Export
Platform with Steel Frame Jacket	Multiple	Dry	No	No	500	Piles	Pipeline
Gravity Base Structure	Multiple	Dry	No	Yes	300	Mass	Shuttle Tanker
Mono-Column Platform	Multiple	Dry	No	No	70	Piles	Pipeline
Conductor Supported Platform	3 or 4	Dry	No	No	70	Wells	Pipeline
Jackup Rig (MOPU)	Multiple	Dry	Yes	No	110	Legs	FSO
Compliant Tower Platform	Multiple	Dry	No	No	500	Piles	Pipeline
Tension Leg Platform	Multiple	Dry	No	No	>1000	Tendons	Pipeline
Ship Shaped FPSO with Mooring	Multiple	Wet	Yes	Yes	>1000	Anchors	Shuttle Tanker
FPSO with Dynamic Positioning	Multiple	Wet	Yes	Yes	>1000	DP	Shuttle Tanker
Production Barge with Mooring	Multiple	Wet	Yes	No	50	Anchors	FSO
Spar / Cell Spar Platform	Multiple	Wet	No	Yes	>1000	Tendons	Shuttle Tanker
Semi-Submersible (MOPU)	Multiple	Wet	No	No	>1000	Anchors	Shuttle Tanker
Control Buoy	Multiple	Wet	No	No	>1000	Tendons	Pipeline
Drillship (Converted to MOPU)	Multiple	Wet	Yes	Yes	>1000	Anchors	Shuttle Tanker
XTs with Flowline & Umbilical	Multiple	Wet	No	No	>1000	Well	Flowline
XTs with Flowline & Control Buoy	Multiple	Wet	No	No	>1000	Well	Flowline
XTs with Flowline & Tanks	Multiple	Wet	No	No	>1000	Well	Flowline
XTs with Flowline & Boosting	Multiple	Wet	No	No	>1000	Well	Flowline

Concept Select Framework

- Operators need to determine:
  - Drilling Spread
  - Fabrication Yard Works
  - Installation Spread
  - Shipyard Works
- They do so by considering:
  - Subsurface / Reservoir
  - Process
  - Subsea
  - Facility
- Ultimately the sum of all decisions affects the choice of these four scopes that can deliver a production-ready field.



Multiple-Criteria Decision Analysis

Application to decision making in offshore oil and gas development

Multiple-Criteria Decision Analysis (MCDA)

- MCDA is a structured decision-making tool that allows comparative analysis of several options according to their attributes with rankings against weighted decision criteria, removing individual bias.
- MCDA can be applied to develop a set of economic scenarios with the costs of different development concepts compared over the lifecycle phases from Drilling to Abandonment and the Net Present Value (NPV) and Internal Rate of Return (IRR) calculated against a range of oil prices, and operating expenditures.

- In offshore O&G development, factors can include:
  - safety
  - environmental impact
  - operability
  - maintainability
  - time to deploy
  - water depth
  - independence, and
  - abandonment burden

MCDA for Concept Select in Field Development

- In the context of a Concept Select activity, MCDA allows operators determine the “optimal” solution,, by using quantitative and qualitative metrics, weighted according to their preferences, to rank the attributes of different development concepts.
- Vastly different project attributes including risk, time, environmental impact, tax regime, social license to operate, cost, or legal jurisdiction can be compared using this method.
- Setting decision preferences by the application of weightings is a critical step in the MCDA process.
- Numerical weights are assigned to each criterion to reflect their relative importance (priority) in the decision.
- Weightings should be relatable back to the organisation’s strategy and goals, and/or mission, vision, and values.

$$Overall\ Ranking = \sum_{Criteria} \left(\sum_{Sub-Criteria} \frac{Sub-Criteria}{Rank} \cdot \frac{Sub-Criteria}{Weighting} \right) \cdot \frac{Criteria}{Weighting}$$

MCDA Ranking Formula

Introducing Pivotree

An Innovative Field Development Concept

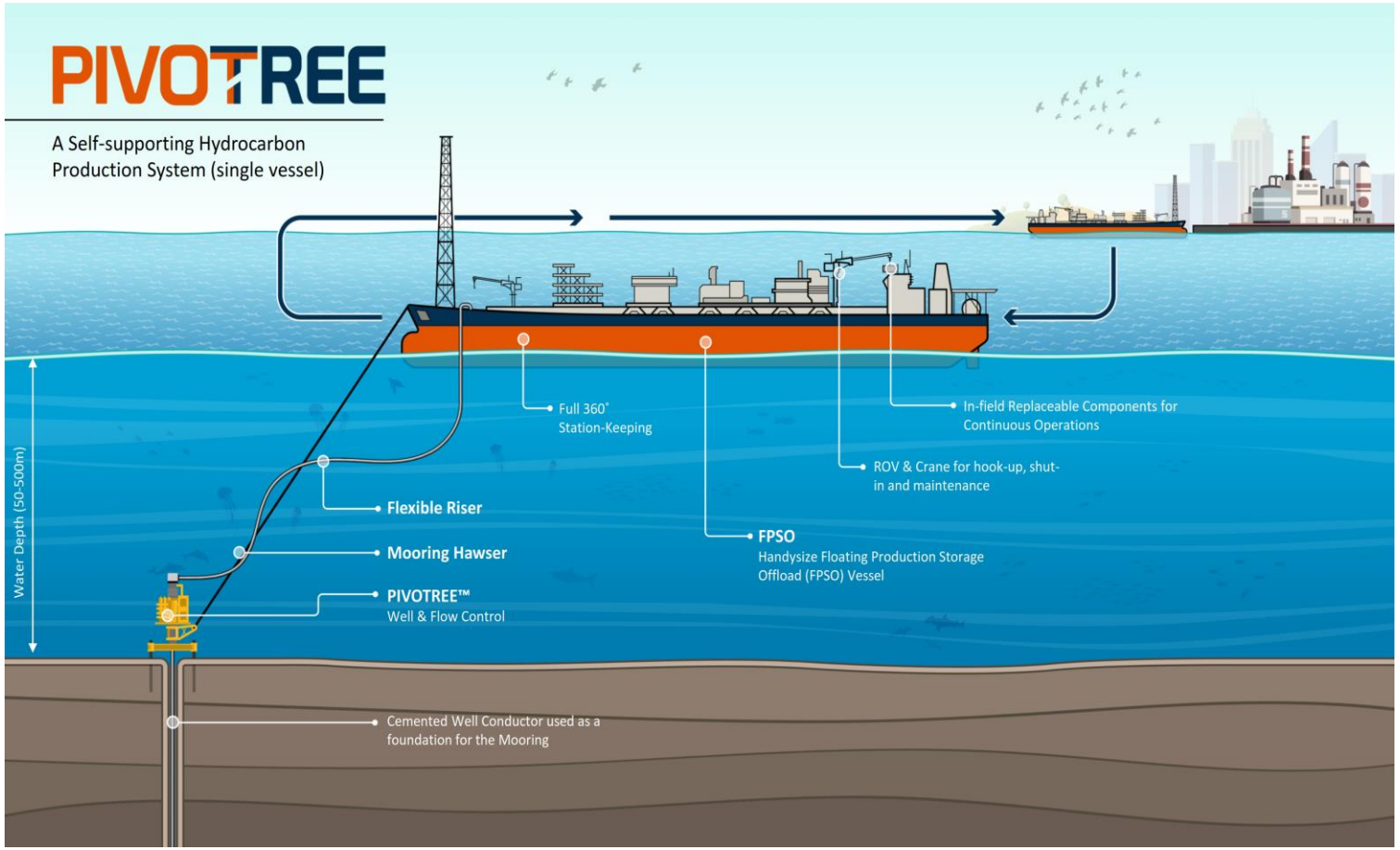
The Concept

A floating, field development concept for predominantly liquids-based hydrocarbon reservoirs that are too small to support a standalone development, but too far from existing facilities to tie back or in water too deep for a low-cost fixed platform.

The concept comprises two elements:

1) The Pivotree™: a modified subsea Xmas Tree (XT) provides the pressure containing, flow control system for the well and hosts the flexible riser and swivel assembly mounted to the upper tree block mandrel with a wellhead connector. Below the XT, the Mooring Permanent Guide Base (MPGB) is welded to the surface casing, providing a 360° rotational mooring.

2) The FPSO: supporting surface separation and processing facilities that are modularised components as would be used in any floating offshore production facility. The FPSO will integrate a ROV, and crane(s) sized to allow for recovery of the replaceable sub-components on the Pivotree™.



Design Considerations

- Selecting the Pivotree concept means that the Installation phase of the lifecycle is eliminated: once the well is drilled and completed, the FPSO can self-install the flexible riser and swivel assembly upon entering the field, and no additional equipment or construction spreads are required to start production.
- Gas and water handling are key decisions to be made during Concept Select that when improperly sized can bring a premature end to production.
- All safety and safeguarding systems will be built into the design in accordance with the requirements of the regulations and applicable codes and standards.
- Anticipating that both zero flaring of associated gas, and emissions control will become key requirements of new field developments in many jurisdictions, the FPSO process will be designed to integrate process equipment to meet both requirements.
- For emissions control integration of a flue gas capture system to capture engine and process emissions will be integrated into the redeployment scope of the FPSO's base vessel.
- Associated gas produced with the well fluids will be utilised primarily for fuel.

System Advantages

- Through the design process of the Pivotree concept choices have been made to minimise the capital expenditure required to produce a single well, that preclude other options from being implemented.
- In the Construct phase, the scope of supply of the Pivotree concept is significantly reduced with a knock-on effect reducing CAPEX and schedule.
- The base case for the FPSO is a redeployment of existing tanker tonnage and the use of a Single Point Mooring (SPM) using the ships existing bow equipment means that there is no lengthy shipyard scope for structural modifications of the hull to accommodate either an internal or external turret.
- The shipyard scope is reduced to the repair, rectification or replacement of marine, power, and utility systems, and the integration of the comparatively small process topsides.
- In terms of comparison with other development concepts, only the minimum facilities platforms compare in CAPEX terms, noting that their water depth and weather limitations restrict their applicability.
- The installation phase demands intricate planning and logistics to transport, install, and connect the various subcomponents. This process is resource-intensive and a significant contributor to the CAPEX required for conventional developments.
- In contrast, Pivotree is a single subsea structure, installed by the drilling spread when the well is completed, obviating the need for a separate installation spread and reducing the time to first oil. Any concept requiring activity in the installation phase is automatically more expensive than a Pivotree solution.
- Pivotree is peerless in terms of abandonment liability. There are no other elements of the production system to be decommissioned and the FPSO and Pivotree XT can be reused.
- The system is designed to be reusable over multiple oil fields, supporting a 15-year design life.

A Hypothetical Case Study

Informing “Concept Select” for a Marginal Field using MCDA

The Scenario: A Hypothetical Marginal Field

- Evaluation of development concepts for an offshore field with P50 of 9MMbbls of reserves, that is 50kms from offtake, in 380m of water, producing liquid hydrocarbons with no associated gas.
- An MCDA worksheet is created using the Concept Select Framework
- Management set the following weightings: Safety (20%), Environment (20%), Technical (15%), Societal Impact (15%), Abandonment Risk (20%), and Cost (10%)
- Each of the major criteria have several sub-criteria for ranking purposes, each having weightings of their own.
- A rank (score) is assigned to all criteria and sub-criteria for the development concept based on the attributes (characteristics) of the project.

Preliminary Work		
Preliminary Works Documents		**Additional Information**
1	Cost Estimate	Analysis of DRILELX, CAPEX, OPEX and ABEX Costs.
2	Competitor Analysis	Comparison of attributes, capability, and additional assets required for production.
3		

Multi-Criteria Decision Analysis			
Criteria 1 - Safety		**Input Document**	**Ranking Criteria**
1	Potential Loss of Life	Complex Facilities, Extensive Facilities	5 = Lowest PLL, 1 = Highest PLL
2	Risk Assessment	HAZID for Option	5 = Least Unmitigated Risk, 1 = Most Unmitigated Risk

Criteria 2 - Environment		**Input Document**	**Ranking Criteria**
1	Environmental Risk Assessment	HAZID for Option	5 = Least Unmitigated Risk, 1 = Most Unmitigated Risk
2	Marine Impact	EA for Option	5 = Lowest Impact, 1 = Highest Impact
3	Seabed Disturbance	EA for Option	5 = Lowest Impact, 1 = Highest Impact
4	Hydrocarbon Discharge	EA for Option	5 = Lowest Release Probability, 1 = Highest Release Probability
5	Other Pollutant Discharge / Emission	EA for Option	5 = Lowest Release Probability, 1 = Highest Release Probability
6	Energy Usage	Schedule Estimate	5 = Lowest Duration, 1 = Highest Duration
7	Resource Usage	Resources by Activity	5 = Lowest Resource Usage, 1 = Highest Resource Usage

Criteria 3 - Technical		**Input Document**	**Ranking Criteria**
1	Ease of Execution	WBS, Special Conditions	5 = Most Feasible, 1 = Least Feasible
2	Risk Assessment	HAZID for Option	5 = Least Unmitigated Risk, 1 = Most Unmitigated Risk

Criteria 4 - Societal Impact		**Input Document**	**Ranking Criteria**
1	Fishery Impact	EA for Option, Stakeholder Input	5 = Lowest Impact, 1 = Highest Impact
2	Employment / Regional Development	WBS Activities, Stakeholder Input	5 = Most Positive Impact, 1 = Least Positive Impact
3	Community Impact	Stakeholder Engagement	5 = Most Positive Impact, 1 = Least Positive Impact

Criteria 5 - Abandonment Risk		**Input Document**	**Ranking Criteria**
1	Volume of Equipment	Asset Register	5 = Lowest Install Base, 1 = Highest Install Base
2	External Intervention / Support	Asset Register, Installation Procedures	5 = Lowest Spread Requirement, 1 = Highest Spread Requirement
2	Waste Disposal	Asset Register, Installation Procedures	5 = Lowest Waste Burden, 1 = Highest Waste Burden

Criteria 6 - Cost		**Input Document**	**Ranking Criteria**
1	Cost	Cost Estimate	5 = Lowest Estimate Cost, 1 = Highest Estimate Cost

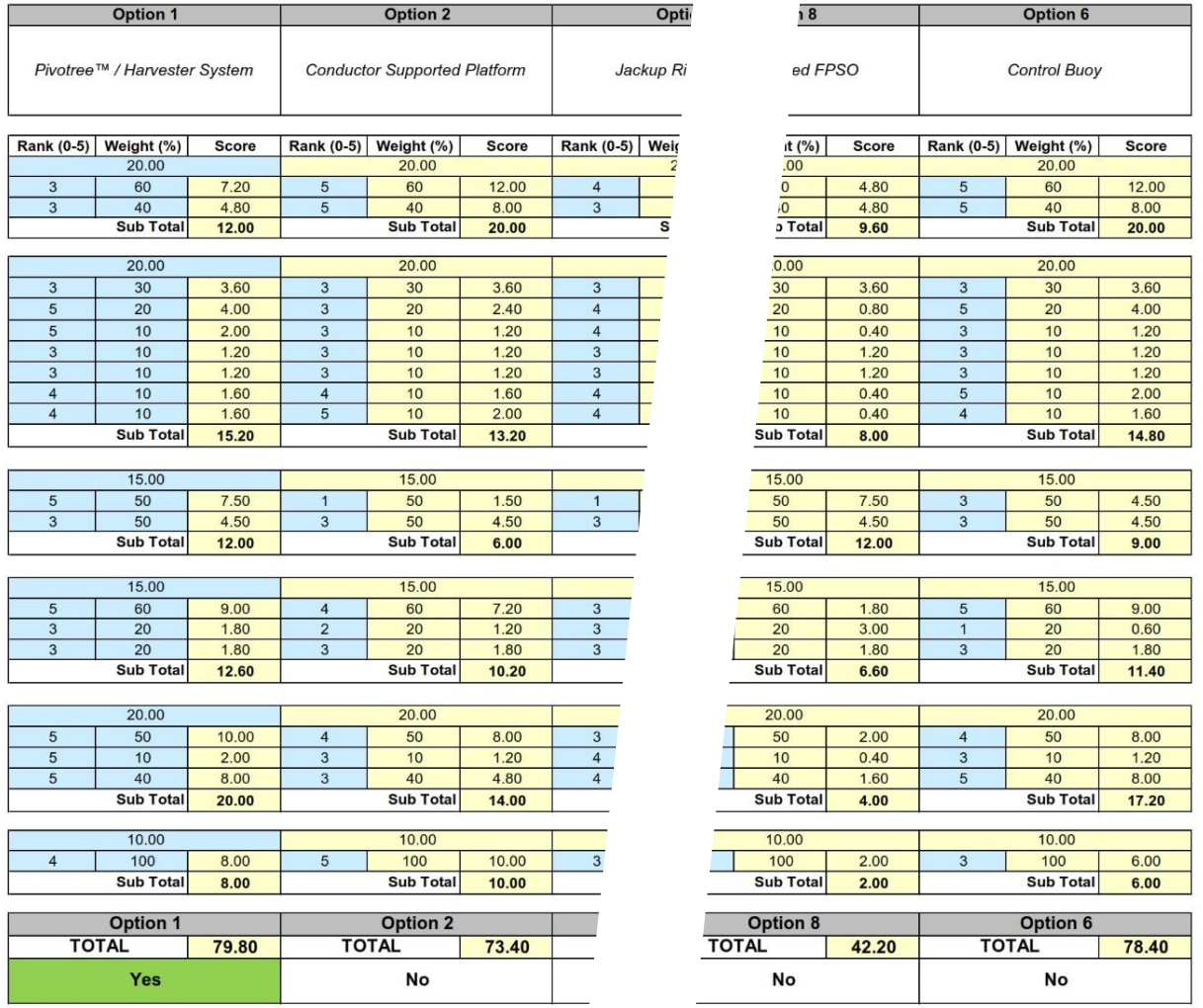
The Process

- Following the definition of the ranking system a multi-discipline team compares each sub-criteria for all options according to the defined ranking criteria.
- Preliminary work documents serve as inputs for the decision-making team to understand the scope and what is proposed by each of the options / solutions.
- Options are each considered against each other, line-by-line, and a score assigned to each option for each sub-criterion.
- Certain options have attributes that make them inherently unfeasible, resulting in a low score for that sub-criterion.
- Critical sub-criteria with a heavy weighting have a larger effect on the score for the option.

Option	Constructability	Availability of Construction Spreads	Quantity of Equipment to be Installed	Suitable for Water Depth
Pivotree™ System	Installed with well	Drilling Rig	None	Yes
Conductor Supported Platform	Simple, commonly used methods.	Construction Vessel	Small	No
Jack-up Rig (MOPU)	Simple, commonly used methods.	Construction Vessel, SURF Vessel	Medium	No
Mono-Column Platform	Simple, commonly used methods.	Construction Vessel, Crane Vessel, Barge	Small	No
Platform with Jacket	Complex but well-known methods	Construction Vessel, Crane Vessel, Barge	Large	Yes
Turret Moored FPSO	Complex but well-known methods	Construction Vessel, Towing Support	Large	Yes
Control Buoy	Simple, commonly used methods.	Construction Vessel	Small	Yes

The Analysis

- Capital cost and installation cost are not assessed as part of the ranking of this sub-criterion as it is considered elsewhere in the decision process.
- A worksheet is completed using an Excel sheet to capture and calculate values against each criterion for each of the decision options.
- In the scenario, both the Conductor Supported Platform option and the Control Buoy option had relatively close scores to the Pivotree™ option however feasibility reduced the score for the Conductor Supported Platform, and the assessment of the Control Buoy option was generally ranked lower across all criteria except safety (the Control Buoy is unmanned).



Option 1	Option 2	Opti	8	Option 6
Pivotree™ / Harvester System	*Conductor Supported Platform*	*Jackup Ri*	*ed FPSO*	*Control Buoy*

Rank (0-5)	Weight (%)	Score	Rank (0-5)	Weight (%)	Score	Rank (0-5)	Wei	t (%)	Score	Rank (0-5)	Weight (%)	Score
	20.00			20.00			2	.00			20.00	
3	60	7.20	5	60	12.00	4		0	4.80	5	60	12.00
3	40	4.80	5	40	8.00	3		0	4.80	5	40	8.00
	Sub Total	12.00		Sub Total	20.00		S	Total	9.60		Sub Total	20.00
	20.00			20.00				0.00			20.00	
3	30	3.60	3	30	3.60	3		30	3.60	3	30	3.60
5	20	4.00	3	20	2.40	4		20	0.80	5	20	4.00
5	10	2.00	3	10	1.20	4		10	0.40	3	10	1.20
3	10	1.20	3	10	1.20	3		10	1.20	3	10	1.20
3	10	1.20	3	10	1.20	3		10	1.20	3	10	1.20
4	10	1.60	4	10	1.60	4		10	0.40	5	10	2.00
4	10	1.60	5	10	2.00	4		10	0.40	4	10	1.60
	Sub Total	15.20		Sub Total	13.20			Sub Total	8.00		Sub Total	14.80
	15.00			15.00				15.00			15.00	
5	50	7.50	1	50	1.50	1		50	7.50	3	50	4.50
3	50	4.50	3	50	4.50	3		50	4.50	3	50	4.50
	Sub Total	12.00		Sub Total	6.00			Sub Total	12.00		Sub Total	9.00
	15.00			15.00				15.00			15.00	
5	60	9.00	4	60	7.20	3		60	1.80	5	60	9.00
3	20	1.80	2	20	1.20	3		20	3.00	1	20	0.60
3	20	1.80	3	20	1.80	3		20	1.80	3	20	1.80
	Sub Total	12.60		Sub Total	10.20			Sub Total	6.60		Sub Total	11.40
	20.00			20.00				20.00			20.00	
5	50	10.00	4	50	8.00	3		50	2.00	4	50	8.00
5	10	2.00	3	10	1.20	4		10	0.40	3	10	1.20
5	40	8.00	3	40	4.80	4		40	1.60	5	40	8.00
	Sub Total	20.00		Sub Total	14.00			Sub Total	4.00		Sub Total	17.20
	10.00			10.00				10.00			10.00	
4	100	8.00	5	100	10.00	3		100	2.00	3	100	6.00
	Sub Total	8.00		Sub Total	10.00			Sub Total	2.00		Sub Total	6.00

Option 1		Option 2			Option 8		Option 6	
TOTAL	79.80	TOTAL	73.40		TOTAL	42.20	TOTAL	78.40
Yes		No			No		No	

Summary

Key points to take away

Summary

- The global energy landscape is undergoing significant changes, characterized by a growing need for hydrocarbons and the transition to renewables.
- Selection of the most suitable (optimal) concept is a trade-off of a multitude of field attributes, including reservoir characteristics, location particulars, technical requirements, and flow assurance.
- Pivotree™ is a flexible development concept that suits a wide range of field attributes and supports high mooring loads to combat storm conditions in the offshore environment. The Handysize FPSO is disconnectable from the Mooring PGB and is self-supporting, needing no additional vessels to assist with mooring or disconnection, or to perform intervention work.
- An illustrative MCDA exercise was completed for an example field that underscores the suitability of the system.
- This paper underscores the transformative impact of the Pivotree™ concept as a low-cost, small footprint, high reliability, and safe option for offshore oil field developments.
- The Pivotree™ concept offers an efficient, sustainable, and versatile solution, addressing the industry's need for rapidly deployable facilities that can provide a route to market for the global pool of stranded discovered resource opportunities in an evolving energy landscape.

Thank you!

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