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# SUMMARY REPORT
# Offshore Circular Economy

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# REFERENCES

Guidelines, Rules & Regulations

| Ref No | Code | Title |
|---|---|---|
| | ISO 14009 | Environmental Management |
| | DNV-CG-0156 | Conversion of ships |
| | ISO/TC 323 | Circular Economy |

Other sources

| Ref No | Author | Title |
|---|---|---|
| A1 | IMCA | IMCA Code of practice sustainability |
| A2 | EU | EU Green deal, Circular economy Action Plan |
| A3 | Rederiforfundet | Konjuktur rapport, Rederiforbundet mars 2021 |
| A4 | DNV | Energy Transition Outlook 2021 |
| A5 | Ellen Macarthur | Ellen Macarthur Foundation for Circular Economy |
| A6 | Stortinget | Meld. ST. 10 (2020-2021) Grønnere og smartere – morgendagens maritime næring |
| A7 | SSI | Exploring shipping's transition to a circular economy |
| A8 | UNEP FI | Financing Circularity: Demystifying Finance for the Circular Economy |
| A9 | Rystad Energy | Offshore vessel owners need stronger medicine to survive |
| A10 | Vard | ZeroCoaster Project |
| A11 | Linstad Et. Al SINTEF | Reduction of maritime GHG emissions and the potential role of e-fuels |
| A12 | IEA | Global Energy Review 2021 |

# FOREWORD

This report is made as a result from the work carried out under the Green Shipping Programme (GSP) phase 5. GSP is a public-private partnership with aim to advance the Norwegian value creation of green maritime solutions. The programs's vision:

"Develop and strengthen Norway's ability to establish the world's most efficient and environmentally-friendly shipping".

This pilot project was listed in 2020 as a potential project for high value creation for a subject with currently little knowledge in shipping, i.e., the potential of circular economy. The aftermath of COVID-19 and the insecurity in the offshore market also proved to be timely and relevant for the start-up of the project. The massive overcapacity in the market have led to a situation where a relatively young fleet of offshore ships are laid up. This fleet will not be competitive when newbuilding activities start up again with a mature zero emission technology. The project aims to put light on the subject of circular economy and the environmental gains by applying the current offshore fleet as a practical example.

The purpose of the project is to document and prove the economy of conversion to a new market including the environmental gains. This can be done by mapping the opportunities of reusing offshore ships into new segments by evaluation of criteria's within market, economy, functional, technical and safety.

Participants in the Pilot Project:

A total of 9 companies have joined the work with this pilot. We are grateful to the contribution from these, which have made this pilot project a success.

Norges Rederiforbund Norwegian Shipowners' Association

Sjøfartsdirektoratet Norwegian Maritime Authority

BREVIK engineering

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Eksfin NO EXPORT FINANCE Norway

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# SUMMARY

The possibilities within circular economy and its economic potential are barely uncovered, but still through our focus on reuse by conversion we can document economic and environmental gain competitive to a newbuild. In addition, results show how this strategy is accelerating the maritime shift to zero emission.

Our study has explored and assessed 14 different markets considering commercial framework, technical & functional requirements, operational profiles and carbon footprint. Both qualitative and quantitative evaluation have been done to segregate the different markets and their fit to meet circular economy.
The current fleet of offshore vessels have been developed into a PIVOT database to evaluate the volume and fit for circular economy. This database reveals their principal particulars and class notation, which are important to match with potential future markets. A calculation tool for carbon footprint have been developed to verify the environmental gain of circular economy. The tool is simplified to capture the main principals related to conversion and newbuild segregated into steel, electrical installation and ship outfitting as well as emission during operation.

The environmental calculation shows that a zero-emission vessel will always result in a lower carbon footprint, however that is only possible when the technology is available in about 10+ years. When zero emission vessels become available the initial carbon footprint during newbuilding is governing, and reuse becomes even more important as well as use of renewable energy during construction. The operational profile and type of conversion governs the sensitivity of how competitive circular economy is regarding the environmental gain. A vessel primarily operating in transit will be penalized by operational emissions and will most likely not be competitive. Similarly, a vessel with extensive conversion scope will also imply a high initial carbon footprint and will eventually loose against a more efficient vessel.

The cost of circular economy must be better or meet the financial requirements in order to be realized. Long term contracts and financing institutes who value carbon footprint needs to be established before large scale circular economy can become attractive. A secondary driver is the uncertainty of selecting future ready technology and the cost of CO2, which with current scenarios mainly drive additional cost to the project without necessarily improving the overall carbon footprint.

One emerging strategy show that the penalties and barriers seen in environmental and economic gain can be overcome by applying a model, which is currently new to the maritime industry. The strategy synergies can be maximized also when collaborating with other industries seeing the same issue mainly due to the energy shift.

Our findings show that conversion of a PSV with electromechanical propulsion with a modular design of power with 15% emission reduction, then later with a zero emission module is economical and environmental competitive to a zero emission vessel built in 2030. This will at large be applicable for vessels mainly operating with low average MCR and minor conversions. Acceleration of circular economy will be attractive where authorities and operators/cargo owners approach the opportunities and incentives listed below:

| | |
|---|---|
| 1. REWARD | •Financing of projects for circular economy<br>•Reduction of CO2 Fee or Pawn Scheme for «stranded asset» |
| 2. CARBON FOOTPRINT | •Operator should find a way to favorize carbon footprint in tenders<br>•Means such as Hull and lifetime extension of equipment |
| 3. LONG TERM CONTRACT | •The uncertainty in investing in a «old» commodity weigh high for banks<br>•Collaboration between operators to improve ship utilization |

# 1. CURRENT FRAMEWORK FOR CIRUCLAR ECONOMY

## 1.1 What is Circular Economy?

The Ellen MacArthur Foundation coined the most well-known definition of an Circular Economy:

“An industrial economy that is restorative or regenerative by intention and design”

The definition reshapes a linear model into a circular model, by closing the cycle and keeping resources in it. This Framework is aligned to the EU Green Deal’s Transition to a Circular Economy Statement by 2050, ref /A2/

The current use of circular economy is represented at the lower levels such as actions to extend the lifespan of products and its parts by recycling and recovering.

The target of circular economy is to level up to the higher degree of circular economy which imposes a different set of strategies. This pilot project has taken the potential assents from R9 to R3. To exemplify the circular economy, we may approach the known types:

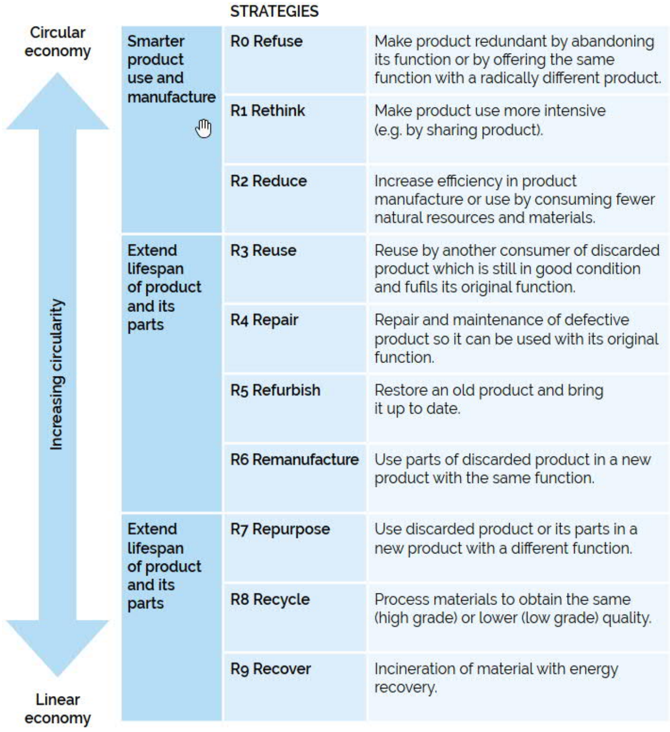


Figure 1-1: Ellen MacArthur – Circular Economy, ref /A1

R9 - Waste management
Advanced recycling onboard ship may involve the classic segregation of different types of waste such as paper, organic, metallic and others. Care is taken to ensure these wastes are separated, stored and handled to a proper recycling center.

R8 - Beaching & condemnation
Many ships have from a historic perspective been sent to low-cost countries for disassembly and recycled to a low level. Mainly high-cost materials are re-used, and waste not considered as a value is being disposed. However, this is changing with high degree value creation in modern and to the purpose recycling yards, but with economic incentives.

R7 - Modularity of cranes and equipment
As some modern ship operators see the opportunity or designers provide flexibility, we find examples of vessels with high level of flexibility or utilization due to the fact of modularization. This can be removable cranes and equipment which is used only when needed, providing the high degree of utilization and minimized degree of stranded cost of non-used equipment.

## 1.2 Current Incentives favoring Circular economy

EU Circular Economy Action plan:
The adoption of the new EU Circular Economy Action Plan in 2020 created a stronger basis for legislative and non-legislative measures. One of the main blocks of the EU Green Deal, the Action Plan, is aimed at initiatives along the entire lifecycle of products, taking into consideration product design, and aiming to ensure that resources used are kept in the EU economy for as long as possible (European Commission, 2020). Connected to the action plan, the United Nations Environmental Programme Finance Imitative (UNEP FI) have detailed out strategies and actions that will finance and accelerate the circular economy transition. Reference is made to Financing Circularity: Demystifying Finance for the Circular Economy /A8/. These results are still strategies in the making and not applied yet for the market to use.

Innovation Norway:
There are possibilities to receive incentives for recycling of ships, both offshore and short sea market. It should be noted that this may only attract lower level of circular economy as described in Figure 1-1: Ellen MacArthur – Circular Economy, ref /A1 and described under recycling in section 4.1. The process and Economic compensation can be applied from the following link: Offshore vessels

The target group is Norwegian-registered companies that have ships in petroleum activities in the North Sea area, or ships that have been laid up within the Norwegian baseline for the past twelve months. In addition, the following criteria are set.

- The ship cannot exclusively use fossil fuels as an energy source after rebuilding
- Assessment of the climate and environmental impact of the investment compared to the same vessel before investment
- Account and calculation of the climate and environmental costs, or additional costs compared to similarly smaller climate and environmental investments that would have been carried out without the subsidy.

A maximum of 60% of the eligible cost may be financed, depending on business size and qualifications for the application in general.

## 1.3 Experience with circular economy in the Maritime Industry

As the focus of circular economy is to elevate the focus of reducing the carbon footprint, this report will only mention projects applying the strategy of Reuse/retrofit. The alternative decisions by selling the vessel will not reduce the carbon footprint for a significant value, as mentioned in section 1.1 What is Circular Economy?

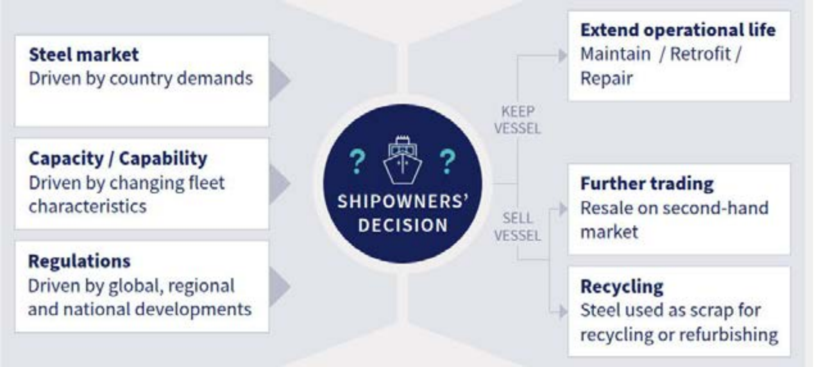


Figure 1-2: Shipowners' Dilemma ©2Bhonest /A7/

The shipping industry is familiar with the concept of conversions, and there are numerous examples, from classical examples of converting oil tankers to shuttle tankers, oil tankers to FPSOs, lengthening of vessels (e.g., Peter Wessel) while widening of vessels is rare. There are many minor conversions and less major conversions. For offshore vessels the situation is different.

Only a few offshore vessels have been converted so far. Mainly due to cost and favorable conditions in current market. Our review of the market and stakeholders show to diversified situations and motivations for the conversions. Minor conversions related to hybridization are not included in the evaluation. We have interviewed shipowners, operators, yards and technology owners in order to capture the holistic perspective. From our findings of total 18 conversion projects (fleet of about 10 000 vessels) the distribution is favoring the Wind market.

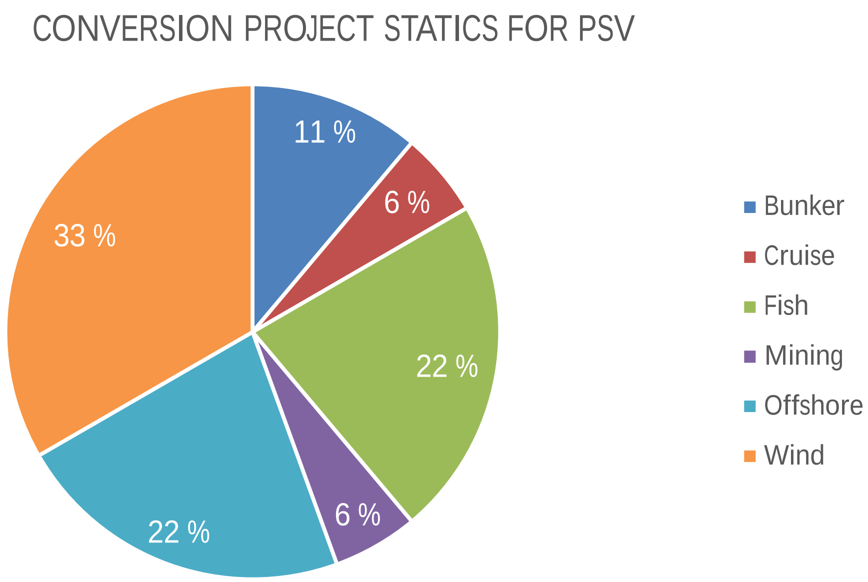


Figure 1-3: Distribution of Converted Vessels in Market

The main motivation behind the conversion depends on the market it is planned to convert to, but mainly price and time to market were the chosen motives. When looking at the profitability of the conversion, they vary depending on which stakeholder in the value chain that are asked. This makes it difficult to derive statistics with confidence

In general, we were surprised that no more vessels have been converted or documented when more than 1000 vessels have ben in lay up over this period. Better date could improve our statistics related to studies of conversions for us to understand the barriers that have driven the conclusion to not finance the project. Also, a trend to highlight is the high level of modularized concepts being realized compared to fully integrated solutions.

For barriers, please see ch.4.1

# 2. MARKET BASIS

The first work package, WP1, focused on market and fleet analysis. We defined and segregated both market segments and the OSV fleet. A total of twelve markets were defined to be used as a basis to understand the variation, were as four markets were considered as “hot” but only two markets have been exemplified to understand the decision space for circular economy. These two markets are considered as outer edges within carbon footprint and economic feasibility. The remaining markets can be situated in between these outer edges. The complete list can be found in APPENDIX C MARKET HOTLIST.

Table 2-1: Four markets selected for deeper evaluation

| Vessel Type / Market | Conversion Type | CO2 due to conversion | KPI | Energy Profile | Average MCR | CO2 emission ton/day |
|---|---|---|---|---|---|---|
| Service Operation Vessel<br><br>Offshore Wind | Minor Conversion | 967 ton | SPS, DP, crew comfort,<br>w2w, | Standby/ DP | 20 % | 13,1 |
| Live fish carrier/De-lice<br><br>Sea Farming | Major Conversion | 8100 ton | Pump capacity<br>Tank Capacity<br>Stability | Transit | 60 % | 21,9 |
| H2 / HN3 Bunker<br><br>Tanker/ Bunker vessel | Major Conversion | 4800 ton | Cargo Capacity<br>Manoeuvring<br>Power for Cargo Handling<br>Stability | Mixed | 35 % | 17,9 |
| Recovery vessel<br><br>Ocean plastic recycling | Minor Conversion | 625 ton | Diesel electric<br>Deck space | Mixed | 30 % | 9,8 |

For all twelve markets and vessel types the following have been evaluated:

- Market type and Vessel type
- Conversion type, Added steel due to conversion (undisclosed)
- Key Performance Indicators,
- Energy profile (reference is made to APPENDIX A ENERGY PROFILES, Operational Profile, Average MCR, Installed Effect
- New build price (undisclosed)
- CO2 emission

The attractiveness is mainly driven by meeting KPI, High Newbuild Cost, Minor Conversion and Standby Energy Profile. This does not necessarily exclude major conversions which have already been experienced.

# 3. FLEET BASIS

## 3.1 Vessels in Lay-up

The project vision is to utilize the available fleet which is not in use or not attractive for the current market to avoid lower level of circular economy, i.e., scrapping. In Norway this corresponds to over 100 ships, while worldwide up to about 1000 ships. The graph in Figure 3-1 taken from the Norwegian ship association business cycle report 2021, published in March 2021 /A3/. It should be emphasized that the conversion candidates do not only include vessels laid up but also vessels on poor contracts, so the total number of relevant candidates exceeds the number of ships laid up! The prognosis in the end of 2021 suggest that 2021 is a year of big change including scrapping and sale which is ongoing.

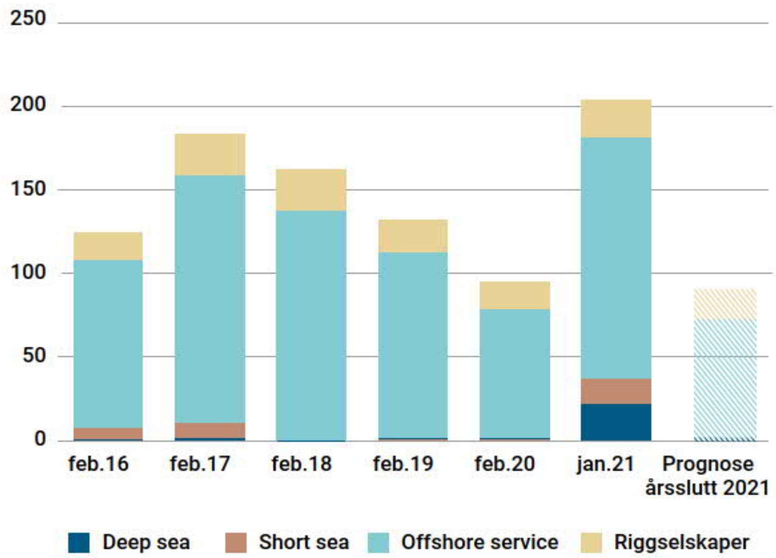


Figure 3-1: Ships in Lay-up – Norwegian Sector – Norwegian Ship Association 2021

To better understand the fleet characteristics, further analysis had to be made by analyzing the fleet database. With this data available, the path to enabling circular economy may be shorter.

A dilemma arising during the discussions are whether the laid-up vessels or the vessels in operation are the correct candidates to circular economy. A successful conversion is mainly seen by low cost and low risk projects combined with long term contract. As shown in the next section a possible segregation can be found as described in Table 3-1. Deck area and Diesel Electric (DE) versus Diesel Mechanic (DM) are characteristics that affects the secondhand value while deadweight and age are less important. Diesel Mechanic is not ideal for hybridization and may be more likely candidates for scrapping but may still be relevant as a standby vessel with HVO biofuel.

Table 3-1: PSV Categorization

| Category | 2nd Hand Value | Deck Area | DWT | Power System | DESIGN TYPE | AGE |
|---|---|---|---|---|---|---|
| A | HIGH | 1000 | 5000 | DE | UT 776, VS 485, VARD 1 06 | 2008-2014 |
| B | MEDIUM | 850 | 4000 | DE | VARD 1 08, Hav Yard 832, PX 121 | 2008-2014 |
| C | LOW | 700 | 3000 | DM | VS 470, UT 755 | 2004-2010 |

## 3.2 PSV database and distribution

A pivot database has been developed to categorize the OSV (offshore supply vessel) fleet in Northern Europe including PSV (platform supply vessel), AHT (Anchor handling tug) and AHTS (Anchor handling tug supply). Key characteristics such as power type and age of vessel have been usedin Figure 3-2 to Figure 3-5 to indicate the potential for circular economy.

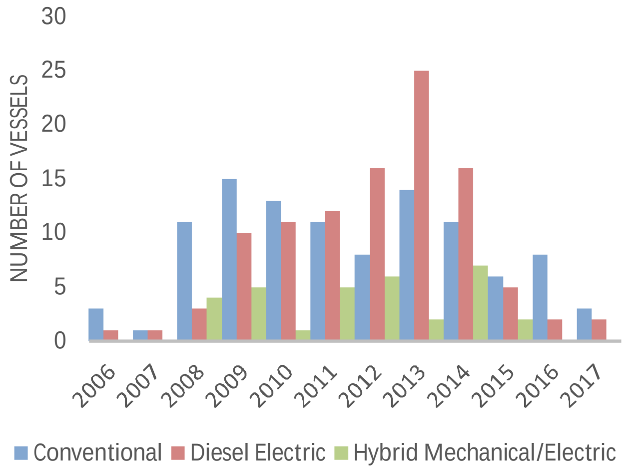


Figure 3-2: Power type - History

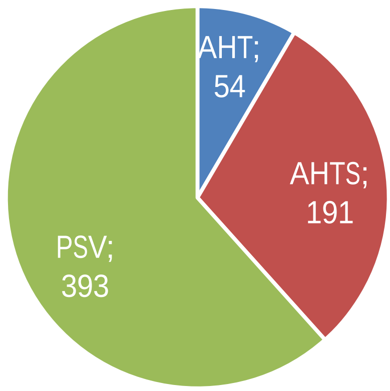


Figure 3-3: Vessel Type - total

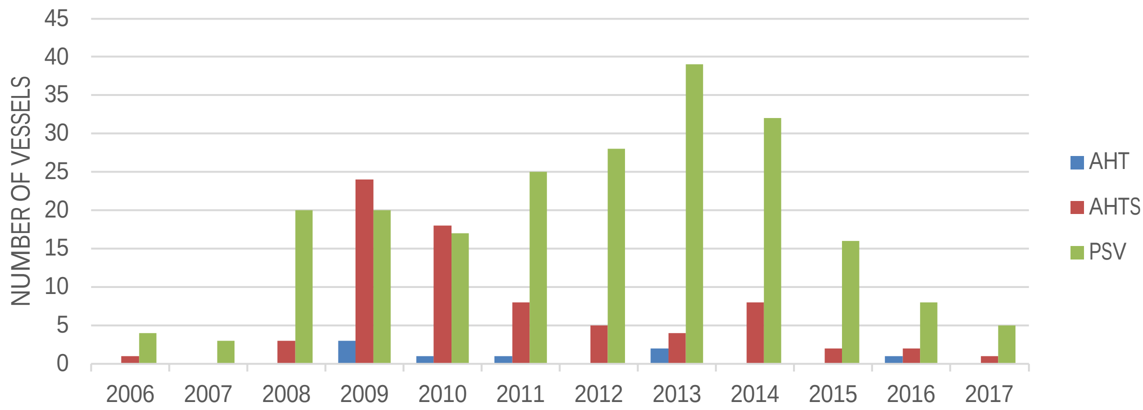


Figure 3-4: Vessel Type – History

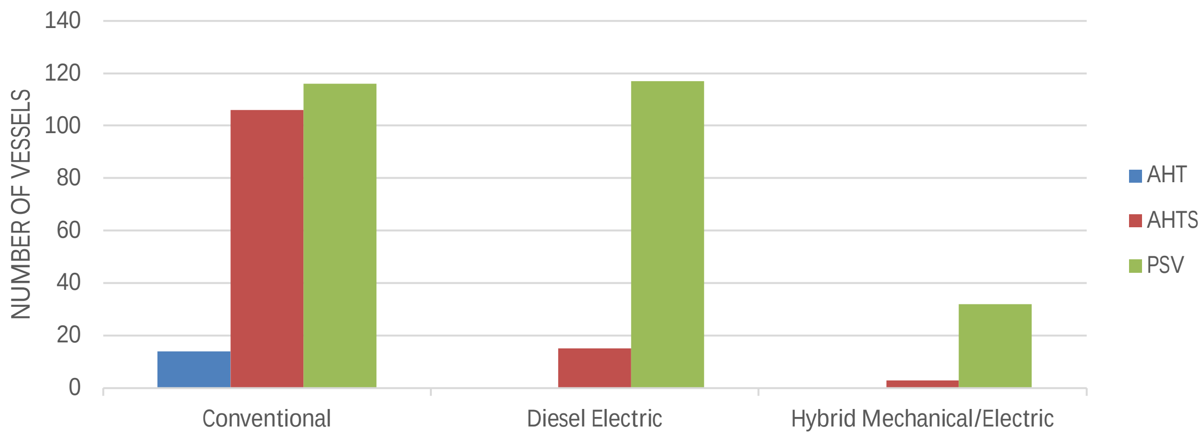


Figure 3-5: Power Type – Total

# 4. TECHNICAL AND ECONOMICAL BARRIERRS AND OPPORTUNITIES

What can prevent us from succeeding and what needs to be in place? As part of the process to create awareness of the technological and economic situation related to circular economy a HAZID process was performed to develop an overview of the key issues and possibilities. The workshop purpose was to identify barriers and opportunities, categorize them within subject, quantify their risk and consequence, and finally propose mitigating actions or incentives. Focus was reduced to four promising markets and cases:

- Offshore wind: Service Offshore Vessel for Wind
- Fish farming: Live Fish carrier
- Waste handling: Plastic collecting and recycling vessel
- Bunkering logistics: Fuel and Energy Bunker vessel

A summary of key findings is elaborated in section 4.1 Technical barriers and opportunities. The complete list can be found in APPENDIX D CONVERSION HAZID WORKSHOP.

## 4.1 Technical barriers and opportunities

Technical barriers may be related to the difference between the vessel at hand and the requested vessel specifications for the new market. Opportunities may be related to the ease of the conversion but also to other aspects where even technical aspects may become economical. A few key elements are:

- Vessel characteristic properties
- Scope of conversions, rules and regulations
- Standardization of equipment and ship function
- Vessel condition
- Unmature and emerging zero emission technology
- Vessel specification requirements
- SPS code in particular for Wind service market. (Offshore vessel rebuilding)
- Market high expectations favor newbuilding – no incentives to utilize existing tonnage.
- Lack of acknowledgement and regulation to take the total carbon footprint into account.

Vessel characteristics properties:
Firstly, we are focusing on PSV and AHT(S) vessels and they have a set of vessel characteristics properties, which need to be understood as they may be both a barrier but also an opportunity towards the new market. Examples are: Large deck area with good strength, low freeboard, modern ships, good maneuvering capabilities and good station keeping with dynamic positioning (DP), diesel-electric machinery, firefighting systems, crane, remotely operated vehicle on board, good seakeeping capabilities, good pumping capacity, high deadweight capacity, helideck, good accommodation capacity with high standard, excess power for additional equipment, good and advanced tank capacity for chemicals, hydraulic capacity, N2 equipment, oil contingency equipment, etc. Not all vessels have the same equipment on board, but these characteristic properties may be useful for different purposes fitting to promising markets. Imagine that the large open deck area is good for modularization of whatever, e.g., accommodation, hospital, hotel, workshops, cranes, gangways, equipment, waste collection and processing, event scenes, tanks, etc.

Scope of conversions, rules and regulations:
One of the key drivers of conversion costs are the implications when the changes done have a reverse effect on already integrated expensive equipment or ship arrangements. Making the seemingly straight forward conversion to a complex job. This complexity and uncertainty are usually of main economic risks.

This risk must either be avoided, meaning only approach conversions with the category "minor conversion" or challenged, meaning working for a compromise in performance or waiver from authorities for a dispensation. Avoiding this issue will reduce the potential of circular economy and utilization of the OSV fleet. Definitions of conversions are given by DNV-CG-0156 *Conversion of ships* as well as in MARPOL listed in Table 4-1. The class guideline is a good starting point for considering any change relevant.

Table 4-1 Levels of conversions

| | |
|---|---|
| minor conversion = alteration (CG-0156) | Change that does not affect the basic character or structure of the ship to which it is applied. This is typically a limited change to the ship's structure, equipment or functions, such as change of components, change of local structure, change of draught or change of class notations not affecting ship's purpose/type |
| Major conversion (MARPOL) = conversion (CG-0156) | Change that substantially alters the main dimensions (L, B, D), watertight subdivision, carrying capacity, engine power or ship type. Increased draught is normally not regarded as a conversion. However, precaution should be taken if the increase in draught is major |

The costs and time are likely much higher for major conversion than minor conversion. Conversions relate to various disciplines such as:

- global and local strength and structural arrangement
- stability, damage stability and collision zones
- load line
- fire safety
- machinery
- electrical installations and instrumentation
- lifesaving appliances and fire safety
- crew accommodation

Elements affecting this could be increased draught, length, breadth, depth, change of freeboard deck, bow height requirements, installed equipment, change of cargo and need for more crew onboard. It is also a question if it is related to mobilization by temporary installation and single voyage where exemptions can be made. It is not easy to understand the necessary changes required, and planning is essential also together with class but may conflict with time to market. Possibly through this process not-essential requirements may be identified and be discussed with other stakeholders like the flag to reduce the conversion risk. A guide for conversions may be established towards specific markets based on conversions from PSV/AHT/AHTS.

In case a high number of service personnel is needed on board a Special Purpose Ships (SPS), or for industrial personnel (IP) sleeping onboard but working elsewhere, the 2008 SPS code is essential. IMO is working on a new IP code, which is expected to align with the SPS code. The latest SPS code distinguish between crew and special personnel. MSC.418(97) relates to more than 12 IP on board suggesting SPS as a standard. The SPS class notation visualizes that the vessel is approved to these requirements and relates also to MSC.408(96) which distinguish between ships carrying up to 60 personnel on board, between 60 and 240 and above 240 on board relating to subdivision, damage stability, fire protection etc. This needs to be considered early if relevant and may be a major barrier. Old vessels with old SPS with less than 12 people on board may be misleading towards opportunities, so clear understanding of the SPS code is necessary.

Turning a PSV into a cargo ship as oil tanker or bulk carrier may have severe consequences, e.g., requirements to double side and double bottom arrangement. This is also a major barrier.

Opportunity may be related also to onboard equipment which are no longer needed. This may be sold, and the sales value may be significant if the existing vessel have many stainless-steel tanks, which are not needed. However, what is the best opportunity overall needs to be considered.

Standardization of equipment and ship function:
The strategy of standardization and modularity is not new and have been explored by many industries, but with low success in the maritime industry, until now. The application of digital ship and intelligent logistic or "Big Data" uncover the potential if applied correctly. One of the key points for modularity is however time to market to avoid losing opportunities.

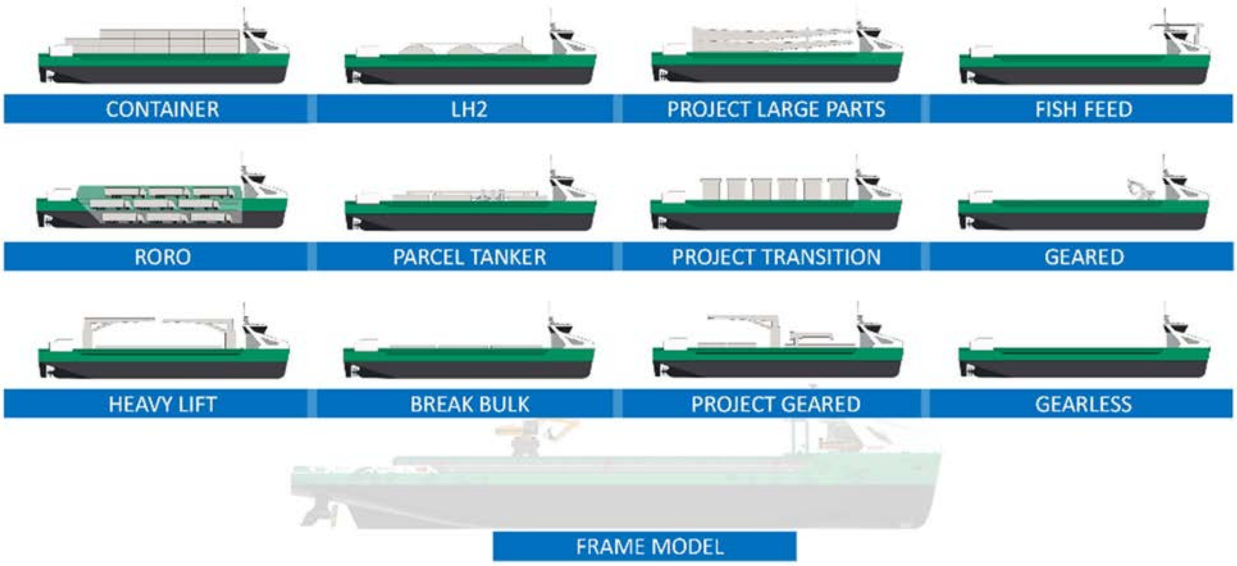


Figure 4-1: Standardization of Ship function –Vard © ZeroCoaster

As the illustration above indicate; the utilization of one vessel for many transport problems, will have the potential to reduce the lifecycle cost, reduce the carbon footprint and improve the circular economy.

The definition of a module and standardization are typically divided in the following categories:

- Slot Modularity: Common Frame model, Limited interface allow for upgrade, but not interchanges between slots.
- Bus Modularity: Common Frame model, Different modules, but with common interface
- Sectional Modularity: No frame model, different modules and with a common interface.

The level of modularity applied today are slot modularity, such as cranes or deck equipment that can be upgraded or removed. These are examples already applied today which help to reduce cost and increase utilization.

An example of standard equipment related to existing rules are offshore gangway installation – walk2work (w2w) and walk2workready which are class notations also associated with the standard DNV-ST-0358 *Offshore gangways*. This has been used lately towards the wind turbine industry where minor conversions of PSVs are already seen. This market is expected to need 100 more vessels from 2021 to 2025 according to Rystad Energy report dated 18th March 2021 /A9/. Using newbuildings here imply a significant initial carbon footprint compared to conversions which is difficult to defend from a $CO_2$ perspective, although the operator of the wind turbine farms may only consider the annual operational CO2 and forget about the initial footprint of the newbuilding itself. As annual emission goes down to zero the newbuilding accounts for everything!

Vessel condition:
Vessel condition relates to both hull and machinery. A vessel is normally designed for 20-25 years lifetime. A main issue is related to the belief that age, i.e., building year, is the only key factor representing the condition. This may not be supported by experience through surveys, which primary concern is safety. The concern for the owner may however also be maintenance costs. Regarding hull surveys the main elements related to safety and maintenance are corrosion, cracking, dents and overloading. Corrosion and cracking are degradation mechanism related to age but also to other parameters. Corrosion is related to especially coating break down and coating quality and time spent in warm areas or heated tanks. Stainless steel tanks do not corrode! Newer ships tend to have better coating standards and many of these PSVs operate in colder climates, so corrosion may not be a significant issue even after 20 years. Cracking is related to harsh wave environment, which is relevant for these vessels, but they are again relatively new. Small vessels have also much fewer cracking issues than larger vessels and these PSVs spend also relative much time in port. Cracking may not be an issue for these vessels also after 20 years. Overloading and dents from wave loading are generally also not an issue for these small vessels with easy dimensioning design loads. Hence, the survey experience for these vessels is mainly good even for the older vessels and looking at the age may be misleading or irrelevant for the hull!

For the machinery there are two main types of engines, diesel electric and diesel mechanical engines. The propulsion system may also differ from single fixed shaft/propeller more common for transit to pods with increased maneuverability. The systems also have different performance in terms of fuel efficiency.

There are different approaches to consider the condition of the hull and engine including:

- Condition assessment program (CAP) for hull and machinery
- Sensor monitoring of hull and machinery for condition monitoring
- Condition monitoring by digital twins

Condition monitoring program (CAP) already exist for oil carrying vessels of age above 15 years following requirements by oil majors. This is an additional survey program to rate ships from poor to good and where a rating better than class minimum acceptable standard would be required for oil majors. This can easily also be applied to an offshore vessel, and would require less efforts, so a CAP light may be introduced! Such an activity was just done on a 39-year-old oil barge with assigned rating above class minimum, so the concern was towards the age, but the condition was good, and the contract was renewed.

Hull stress monitoring is a well-established discipline with DNV rules for hull monitoring updated regularly last 30 years associated with the class notation HMON and with Light Structures AS in Oslo as a world leading supplier with many approved systems. Other class societies have similar rules and notations. These systems are used for monitoring development of cracking and overloading to assess the condition versus safety and maintenance needs. A few sensors may be used to monitor the general condition, which may be enough.

Digital twins for condition monitoring resulting in inspection programs are already in the DNV rules associated with the class notation FMS(NUM) and FMS(SENS) for hind cast based numerical twin and HMON based sensor twin, respectively. These digital twins bring life to the design models and replace design assumptions with encountered wave data or sensor data to provide inspection program for critical details even far from sensors. It is intended especially for offshore units, navy, coast guard, ferries, ocean fish farms and floating offshore wind turbines, basically assets allowing for finding an optimum and more

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cost-effective inspection regime than the IMO/IACS interpretated stringent regime. Other class societies have similar rules and class notations. Similar may be done for machinery and for machinery condition monitoring are acceptable for all ships.

Some simplified digital twins may also be used to demonstrate good conditions of a specific vessels or versus the entire fleet with much less efforts pinpointing vessels with relatively high or low utilization. It is believed that these offshore ships will be rated as relatively good, so this could be established for the whole offshore fleet of about 10 000 vessels.

The purpose of these approaches is typically:

- Enhanced safety; alarm for unexpected events
- Transparency; demonstrate performance to your stakeholders
- Quick root cause analysis and confirmation of mitigation measures
- Save costs; optimized inspection and operability
- Demonstrate fit for purpose; redeployment/lifetime extension
- Reduced risk of loss of life (in the utmost consequence)
- Reduced risk of discharges with damage to nature and the environment, and subsequent economic costs of clean-up
- Reduced risk of financial losses for the owner and insurance company due to the need for repairs, loss of trade and possible loss of the hull
- Reduced risk of loss of reputation for the charterer if they are linked to emissions/pollution (cf. Exxon Valdez)

Once the condition of the hull is known, it will be easier to assess the residual life and the possibilities for a lifetime extension. By utilizing the lifetime potential of the hull, one will be able to defer the costs associated with scrapping and subsequent new construction. At the societal level, this will contribute to better resource utilization and reduced emissions.

The machinery and propulsion can be rated versus their condition and emissions in similar ways.

Unmature and emerging Zero emission Technology:
One of the main drivers to progress the circular economy is the risk of stranded asset and technology. Never before have the industry been at this turning-point that will drastically change the perception of what is competitive and what is not. An indication of the availability of fuel technology is shown in the graph in Figure 4-2. It basically states that these technologies will not be available from a technological and infra structures point of view (the latter not considered by the figure) for another decade. A newbuilding will therefore not be significantly better than an existing vessel. For a new building it is however a matter of becoming ready at least and the class notation Fuel Ready is already covered by the rules (similar for other class societies than DNV).

It should be emphasized that ammonia is highly toxic, and toxic zones from ventilation system (ventilating possible leakage) may be as high as 25 meters horizontally and with ventilation outlet 6 meters above deck. This may make this fuel less relevant for smaller vessels without exemptions or rule adaptions.

LNG as a fuel is not mentioned in Figure 4-2 as this is an intermediate solution expected to last until about 2040. Although the CO2 emissions are better than fossil fuel LNG fuel is certainly still representing emission of CO2.

What is not evident from the below Figure 4-2 is that biodiesel is an alternative which have varying properties (https://ebb-eu.org/about-biodiesel/) and may be associated with moderate (65%) to high reduction (90%) of CO2 emissions from the whole production and infrastructure chain not frequently studied holistically. B7 is used a lot on petrol stations in Europe and implies 7% bio diesel blend from mainly FAME. The most common bio diesel is actually FAME(Fatty Acid Methyl Ester)/RME from fat of plants, e.g., rapeseed, soya, palm oil. This is a bio diesel which is associated with relatively high CO2 emission; hence this may not be the best choice. An alternative is HVO(Hydrotreated Vegetable Oil ) B100 bio diesel which is 100% bio diesel based on animal fat and hydrogenated vegetable oil. The HVO blend may not be 100% depending on what the engine can handle. HVO B100 is however associated with low CO2 emission. HVO is expensive, and FAME is inexpensive and also sour potentially requiring significant changes to the engine. Hence existing engines may need minor conversion to use high % blend or pure biodiesel, where HVO is preferred from a CO2 point of view. .

Wind assistant propulsion systems is another technology emerging quicker and already ordered for newbuildings and contributing to lower the fuel consumption in transit by 5-20%. There are already rules and standards for these sail systems related to the WAPS class notation (other class societies may have similar rules and class notations). SC Connector claims 25% fuel savings and may sail up to 9 knots without propeller being used in favorable conditions. This is understood to have received ENOVA funding (Norges største seilskip satt i drift (mtlogistikk.no) ).

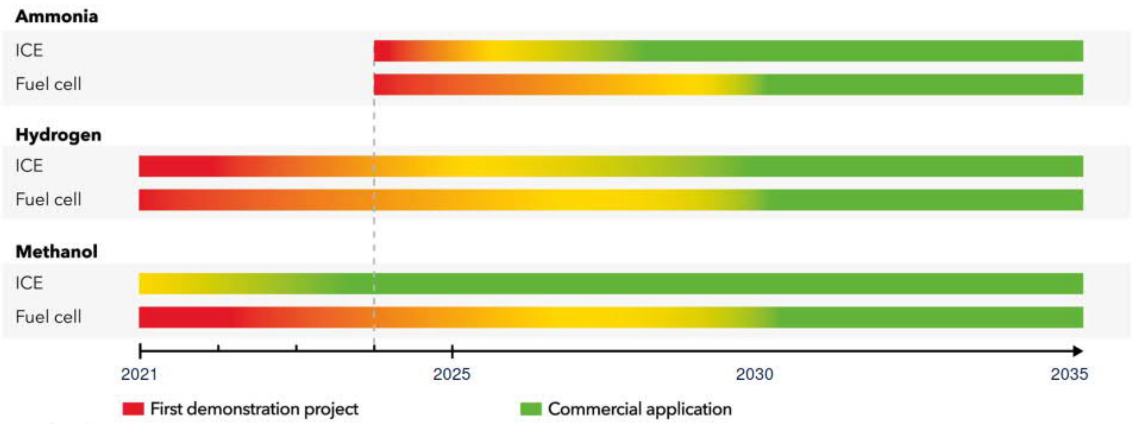


Figure 4-2: Fuel technology development – DNV © ETO 2021

There are in principle two directions, either electromechanical propulsion or mechanical with a combustion engine. It would be speculative to state which solution is best, but from a risk perspective it makes sense to utilize a modularity which maximize the possibility of replacement without penalty of major conversion.

Vessel specification requirements:
Vessel specification requirements comes from the need in the new market. The wind market is maybe a bit special where the current owner may also be the new owner after the conversion, so a conversion does not imply a sale and the requirements may be clearer. For most other new markets, the vessel will be sold for conversion to a new owner in a quite different market. The challenge is to know and match the needs of the demander in the new marked with the suppliers (offshore shipping company) already available specifications. The gap reveals the conversion scope, but compromises may be made. Maybe the vessel is not ideal, but conversions of OSVs may be a good way to test out new technology for new markets waiting for low or zero emission technology to become available.

Green Shipping Programme represents a meeting place between different stakeholders, like merchandise owners and ship owners. However, the opportunities are limited by the lack of clear specification requirements in different new markets. One way is to make guidelines for such requirements for specific markets as also proposed under conversion scope related to rules and regulations. Another option is to arrange forum where stakeholders in the new market meet to specify more generic requirements to what is absolute requirements and what is secondary preferred requirements.

## 4.2 Economic barriers and opportunities

Contract length/profitability/margin and ship financing:
Financing a shipping business require a solid and risk-free business idea, predictability in revenue, cash flow and end of life value. These elements are tangible for most newbuild. However, a conversion project has statically more difficulty in meeting these high valued financial elements with current market mechanics.

Financing carbon footprint/cost rating of carbon footprint:
Currently there are very few and available methods and standards in how the reduction of carbon footprint can be supported economically. There are also few standards defining the correct calculation method and assumptions that will result in a carbon account. Legislators and authorities need to take actions to form a common framework for the industry to effectively apply the business or use cases.

Governmental Incentives and support scheme through Enova or others may be the only alternative to overcome this barrier in the short term. Rebuilding of existing vessels at Norwegian shipyards, to be supported both by attractive financial loans and by direct support, is desirable. In terms of potential CO2 reduction compared with other measures supported like batteries and others, we see a greater potential, demonstrated in Figure 6-4. The already established schemes available from the government may support pilot projects, but robustness is missing in the regulatory basis to achieve systematic approach to circular economy.

Attractiveness for Operators and tendering requirements → rating and sustainability report:
In this context implementation of well-to-wake requirements for operators hiring vessels and utilizing existing tonnage appears to be the most effective way to support circular economy. In the transition period the next ten (10) years whereby zero emission technology is neither available, mature, nor is the infrastructure for alternative fuels built, it will make sense to support those parties who take an overall approach for their business.

High scores within established and acknowledged ESG rating schemes should also be given higher incentive reward.


Figure 4-3: Alternative rating schemes to be used in reporting/tenders

Financing an old vessel and circular economy → Leasing of modules/equipment:
The financing institutes are currently valuing the basic economic mechanics of a shipping project. These are rewarded for projects that can show to an improved environmental gain, but there is currently little knowledge from banks in how circular economy affect the economics and cashflow for a shipowner. To maximize the circular economy, these effects should be accounted for and relayed to the factors of financings.

CO2 taxonomy and cost of Carbon (operational):
The taxonomy is currently setting the limitation to operational carbon, released during the project realization and operation. These fees and taxes are planned implemented as defined in Table 5-2. The rate of change to CO2 cost is unknown for each year but is expected to increase considerably and will definitely help to motivate in the use of zero emission energy solutions for ships. In relation to the technology roadmap Figure 4-2 and fuel cost of zero emission energy, timing of the implementation is the key factor for success. The economical evaluation in Figure 6-6 shows the effect of C02 cost and energy cost.

Unlocking zero emission energy rely on the global ability to develop renewable energy (currently 30% of total energy production) and make it commercially available and abundant. Reference is made to ref /A12/.

As an example, one should review the Norwegian Shipowners' Association and their proposal for a worldwide CO tax scheme on the fuel, which will be applied similar for all ships. Likewise, this tax dedicates funding to research to zero emissions for ships and the maritime industry.

Value of recycled material & equipment:
Steel is the main driver for the ship recycling market. Due to an inherent demand for scrap steel a robust market for second-hand machinery and equipment is observed. One other observation is the highest prices are obtained in south Asia.


Figure 4-4: Recycling prices development ©2BHonest 2021

The old steel is re-rolled and does not required to reach its melting point such as new steel plates. As the steel used for shipbuilding is certified and classification, steel plates are considered as high quality. The value of steel is attractive and may lead the shipowner to choose recycling over re-use. Reference is made to Figure 1-2.

The shift towards vessels that operate on zero or low emission fuels and technologies will impact these decisions. This basis increase the need to address and reduce CO2 emissions at other stages of the lifecycle compared to 29% recycling, which is the current rate of recycling of the ship fleet.

Combining the global fleet figures with the average age of ships results in the conclusion that the current ship recycling capacity will not be able to process the increasing number of ships to be recycled. This market mechanism may change attractiveness towards re-use instead of recycling. Reference is made to /A7/.

# 5. QUANTITATIVE EVALUATION

## 5.1 Method

The applied method use the information and Key Performance Indicators collected by the different work packages. The description in below paragraph and illustration in Figure 5-1: Quantitative assessment of Circular economy for offshore ships show the intended function and correlation between work packages. Market possibilities are quantified by analyzing the data as specified in section 2, MARKET BASIS. This data provides the reference operational cost, capital cost and carbon footprint for a newbuild.

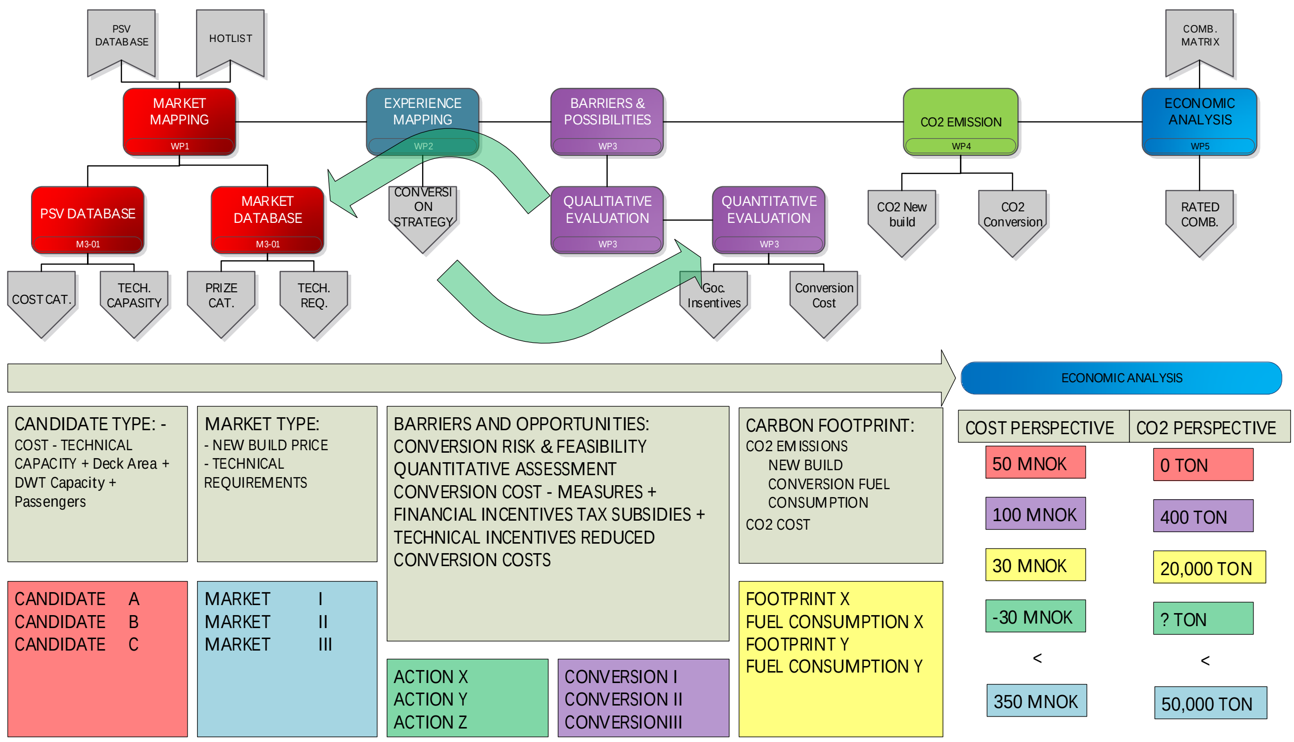


Figure 5-1: Quantitative assessment of Circular economy for offshore ships

Data from PSV database provides the operational cost of existing vessel, entering in a new transport solution. The database also provides estimated 2nd hand value and class notation gap compared to the newbuild.

Barriers and opportunities are defined and quantified in economical (€) and environmental (ton $CO_2$) calculations. These are again explained and exemplified in section 6.3 Scenarios. The list of barriers and opportunities can be found in APPENDIX D CONVERSION HAZID WORKSHOP.

$CO_2$ and cost (OPEX and CAPEX) are then evaluated separately and compared to existing and future solutions. These numbers may vary depending on the actual cost of PSV and conversion cost, however, the calculation gives a good indication on the tendency and feasibility by implementing circular economy.

## 5.2 Environmental Calculations

Carbon footprint calculations are done by using an inhouse excel tool and collected information from market and OSV database. The overall $CO_2$ from produced material will vary depend on location, type of material and dominant power supply available. However, in this report the following assumptions are made:

Table 5-1: $CO_2$ emission from operation and construction

| Category | Steel | Electronics | Other | MGO | LNG |
|---|---|---|---|---|---|
| Ton $CO_2$/ Ton | 3 | 34 | 13 | 3,2 | 2,2 |

The fractions of material selection are refined from actual building projects, while the operational consumptions are derived from the OSV database. As a simplification it is assumed that a new build, built for purpose will at minimum have 15% less fuel consumption than a current PSV. Some time in the future it may have 50% or even 100% reduced $CO_2$ emission related to fuel consumption.

Besides the initial carbon footprint from a newbuilding, it is however critical to understand the operational profile in the new market as transit and standby operations have very different fuel consumption.

When the operational emissions go towards zero in the future, the only thing that matters is the initial carbon footprint for a conversion or a newbuilding. In the future it will then be much more focus on reuse. Maybe it is not a good idea to design current ship hulls to 20 years.

## 5.3 Financial Calculations

The financial calculations are performed by using the assumptions in the table below. These assumptions define the possible scenarios of operational cost and financial cost. Cost of financing is not accounted for as there are uncertainties in how the banks will leverage the use of circular economy vs. zero emission vessel.

The operational costs are heavily dependent on cost of bio fuel vs electricity. The expectations are that the cost of electricity will rise as the demand will grow faster than the supply.

Table 5-2: Various Operational Cost (€/ton)

<table>
<tr><th>Category</th><th>CO2</th><th>MGO</th><th>LNG</th><th>NH3</th><th>CH2</th></tr>
<tr><td>2021</td><td>59</td><td>600</td><td>380</td><td>800</td><td>3500</td></tr>
<tr><td>2030</td><td>200</td><td colspan="2" rowspan="2">Cost of fossil-based energy carriers are assumed to maintain the cost</td><td colspan="2" rowspan="2">Cost of zero emission-based energy carriers are assumed to be reduced as the continued investment grow</td></tr>
<tr><td>2050</td><td>200</td></tr>
</table>

Table 5-3: Economic Assumptions

| Category | $CO_2$ |
|---|---|
| Payback time Converted Vessel | 20 |
| Payback time modules | 12 |

# 6. CASE STUDY

## 6.1 Selected Markets & Conversion Candidates

For the case study we have selected two well-known markets where we have both data from previous conversions, representing two different markets in terms of attractiveness and scope of conversion. With reflection to the Key Performance indicators, which evaluate the functional and regulative performance a selected vessel should meet to minimize the technical and commercial risk. The newbuild price is defined at a qualitative level for the purpose of comparison. An actual sensitivity analysis has been done to verify if the ships are meeting the market expectations.

Table 6-1: Selected Cases for exemplification

| Vessel Type | Conversion Type | CO2 due to conversion | KPI | Energy Profile | Operational Load | Newbuild Prize | CO2 emission ton/day |
|---|---|---|---|---|---|---|---|
| Service Operation Vessel | Minor Conversion | 967 ton | SPS, DP, crew comfort, w2w, | Standby/ DP | Transit: 20% Port: 20% Maneuvering; 60% | High | 13,1 |
| Live fish carrier | Major Conversion | 8100 ton | Pump capacity Tank Capacity Stability | Transit | Transit: 55% Cargo Operation: 20% Maneuvering; 5% Stand-by: 20% | Medium | 21,9 |

For selecting and defining a candidate we have based on a generic description and settled a price which is represent a typical PSV in the 2nd hand market. Designs and age of vessel may vary but will in general have a diesel electric energy and propulsion system.

Table 6-2: Basis for selected generic PSV

| Category | 2nd Hand Value | Deck Area | DWT | Power System | DESIGN TYPE | AGE |
|---|---|---|---|---|---|---|
| A | 15 m€ | 1000 | 5000 | DE | UT 776, VS 485, VARD 1 06 | 2012-2014 |

For the service operation vessel, we would prefer a vessel which fulfils the minimum requirements as following:

- Crew Capacity of 75
- SPS Code compliant class notation(Unless regulation waiver and support recommendations are implemented)
- DP Class
- Deck Area above 900 $m^2$

For a vessel intended for live fish transport, we would prefer a vessel of following characteristics:

- Maximum dwt capacity
- Minimum gross tonnage
- Minimum fuel cost and installed power

## 6.2 Conversion type

The scope of conversion can be related to different subject depending on the focus area. For the yard and ship owner, which purchase and perform the work, may relate to the total cost of conversion. While designer and class society may correlate this to the technical magnitude of conversion, which affect applicable rules and complexity of conversion. This report will focus on the economical perspective in order to elaborate on the sensitivity to carbon footprint and economic feasibility. To distinguish the technical and commercial risk one may refer to “Major” and “Minor” conversions.

Major Conversion

- Scope of Work: Integrated steel work, arrangement changes, changes to watertight arrangements and installed power.
- Design & Engineering: Complete review of existing document list for class approval, revised stability and inclining test, structural
- Rules & regulations: Have to comply with new and updated rules of when the vessel intend to operate from. New class notations are to be applied

Minor Conversion

- Scope of Work: Modular changes, exterior updates or new equipment and upgrades
- Design & Engineering: Minor interface work, structural, piping or electrical of little significance.
- Rules & regulations: Can base the requirements on rules dated to when the vessel was built. Will continue with existing class notation.

## 6.3 Scenarios

The case study has compared two different extremities that affect the carbon footprint, which is major conversion and minor conversion. The energy profile is also noted to correlate with the operational carbon emission. These are represented by SOV and a Live Fish Carrier, with four (4) different scenarios in Figure 6-1.

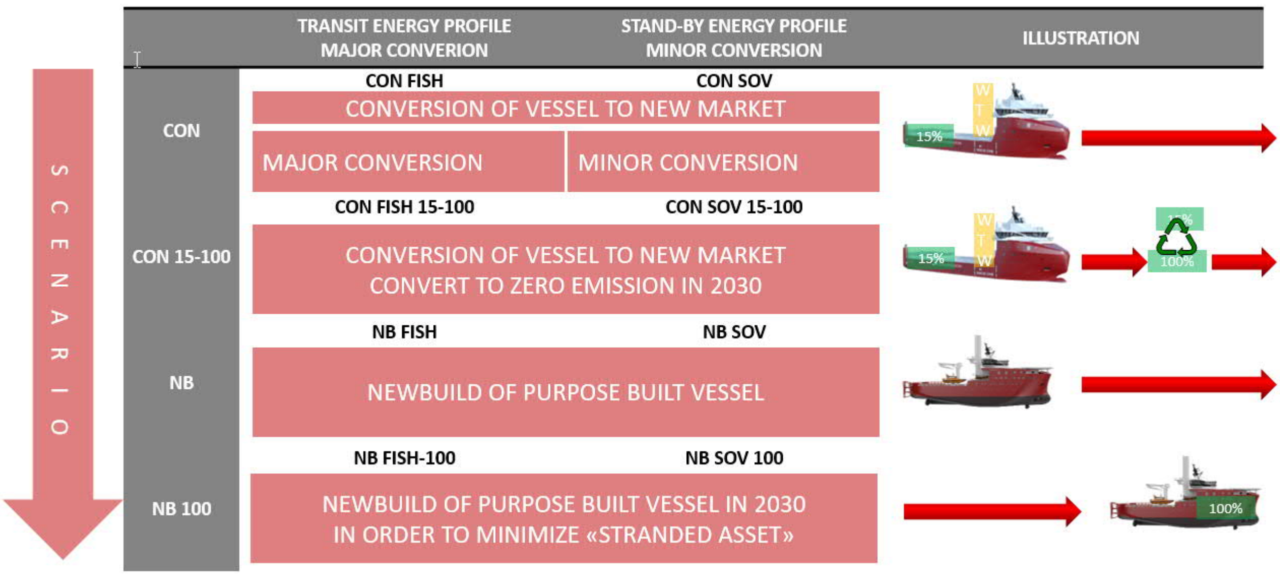


Figure 6-1: Quantitative Scenario

A traditional conversion is denoted as "CON", which implies utilizing the current technology for low emission or traditional conversion scope without modular and circular economy as a strategy. This scenario can be compared to previous conversions already done within wind and fish industry.

A conversion with intension of modular power and modular function is denoted as "CON 15-100", which also implies that we expect the vessel to embrace a circular economy strategy in the way the technology and modules are designed. This can be done by preparing the vessel for a bus modularity as explained in section 4.1 Technical barriers and opportunities.

A traditional newbuild is denoted as "NB", which will represent a vessel in terms of cost and performance optimized for the intended the operation. Compared to a conversion this vessel will have a higher CAPEX, but an improved revenue.

A developed scenario in line with DNV ETO technology prediction is the "NB 100". Zero emission ships will be commercially available and competitive also for ocean going vessel in 2030+. This scenario is developed to compare the environmental and commercial difference.

## 6.4 Analysis of Economy and Carbon Footprint

Carbon Footprint:
The main driver for carbon footprint will depend on the operational profile, the fraction of material and what type of energy that has been used to produce the ships. This statement may come clear for most readers and can be presented as following in the graphs in Figure 6-2:

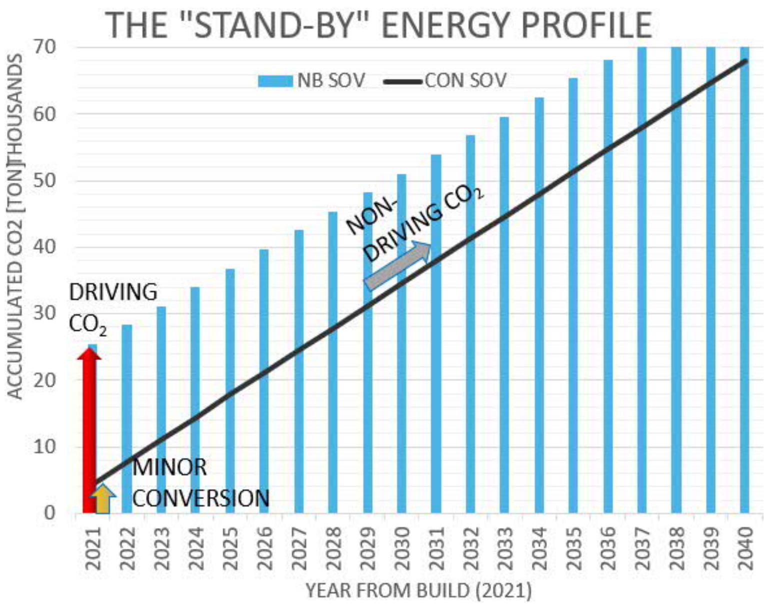


Figure 6-2: Carbon Footprint - Conversion vs. New build – Minor Conversion

The graph illustrates two scenarios, New build (blue) and conversion (black line). X-axis represent time, while Y-axis represent the accumulated $CO_2$ from operation and construction. The driving factor of carbon footprint is illustrated with a red arrow, which in this case is the carbon footprint from newbuild.

The purpose of this comparison is to see when in the future the line crosses the columns of newbuild.

A major conversion will reduce this threshold, while a minor conversion will extend the point of intersection. The same perception may be derived from the operational profile. A vessel that uses a lot of fuel or energy will in comparison with a vessel using less have the benefit of reduced carbon foot print.

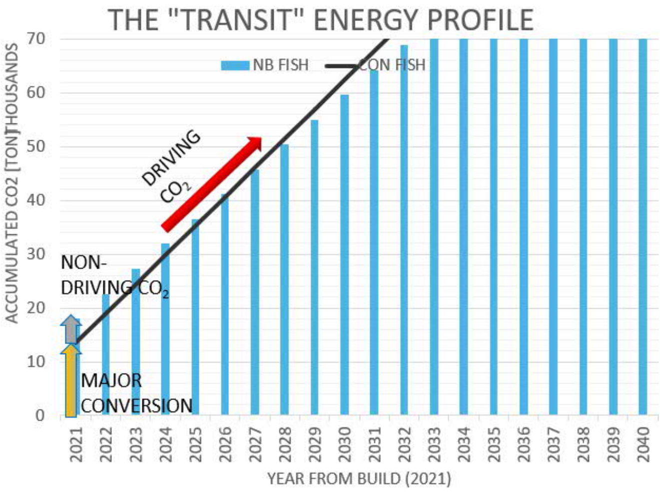


Figure 6-3: Carbon Footprint - Conversion vs. New build – Major Conversion

The graph illustrates two scenarios, New build (blue) and conversion (black line). X-axis represent time, while Y-axis represent the accumulated $CO_2$ from operation and construction. The driving factor of carbon footprint is illustrated with a red arrow, which in this case is the operational CO2 from converted vessel.

- A converted vessel will be competitive with a newbuild in terms of carbon footprint if one considers operational profile with low MCR and a conversion scope with minimum carbon release.

The similar results can be derived from comparing a zero-emission vessel in 2029 to a conversion with a modular approach and utilizing circular economy. The zero-emission module should be strategically installed when technology is commercially available and competitive to the fossil fuel.

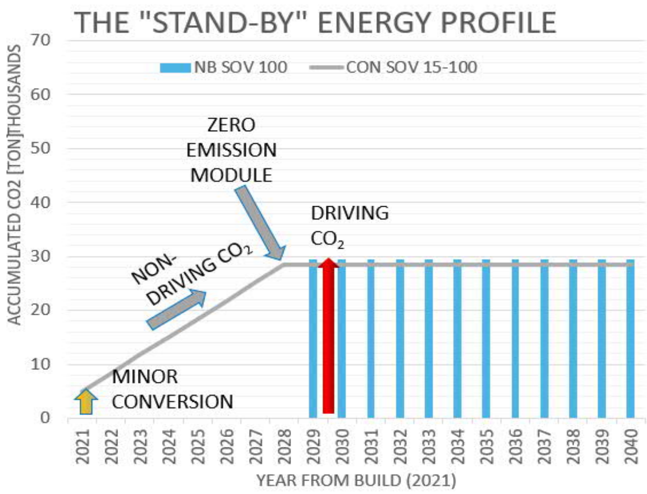


Figure 6-4: Carbon Footprint - Zero Emission – Conversion vs. New build – Minor Conversion

The graph illustrates two scenarios, New build (blue) and conversion (black line). X-axis represent time, while Y-axis represent the accumulated $CO_2$ from operation and construction. The driving factor of carbon footprint is illustrated with a red arrow, which in this case is the carbon footprint from newbuild.

In the scenario compared to a newbuild delivered in 2029 with zero-emission technology it will only be vessels with minor conversion and low average MCR (reference is made to APPENDIX A ENERGY PROFILES that will be competitive to a newbuild.

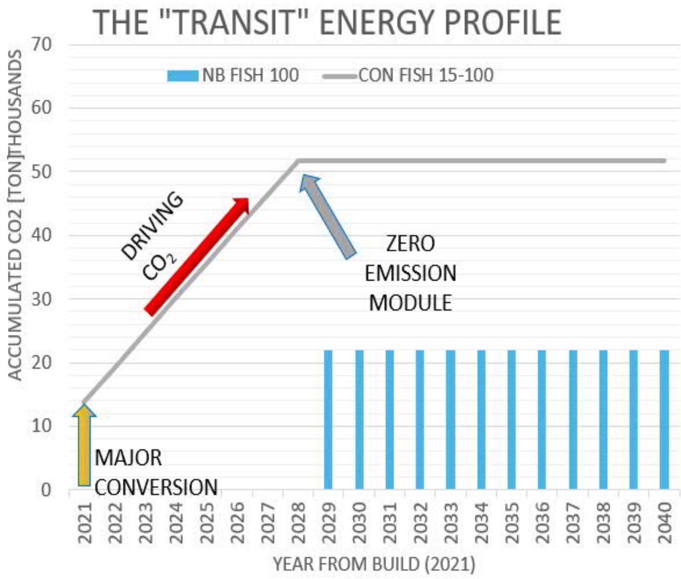


Figure 6-5: Carbon Footprint - Zero Emission – Conversion vs. New build – Major Conversion

- Newbuild will always be best at fuel costs
- If conversion is to be competitive, it must have the ability to change the energy type
- "Transit Case" is less suitable for conversion without incentives.

Economical Evaluation:
From an operational point of view, a competitive zero-emission vessel will be more competitive than a converted vessel if optimized to the planned function. This may not always be the case but serve as a conservative comparison. Three vessels are considered as none zero-emission, but the modular concept have the opportunity to switch. This opportunity may allow for a strategy to follow the most competitive fuel path at any time in the lifetime.

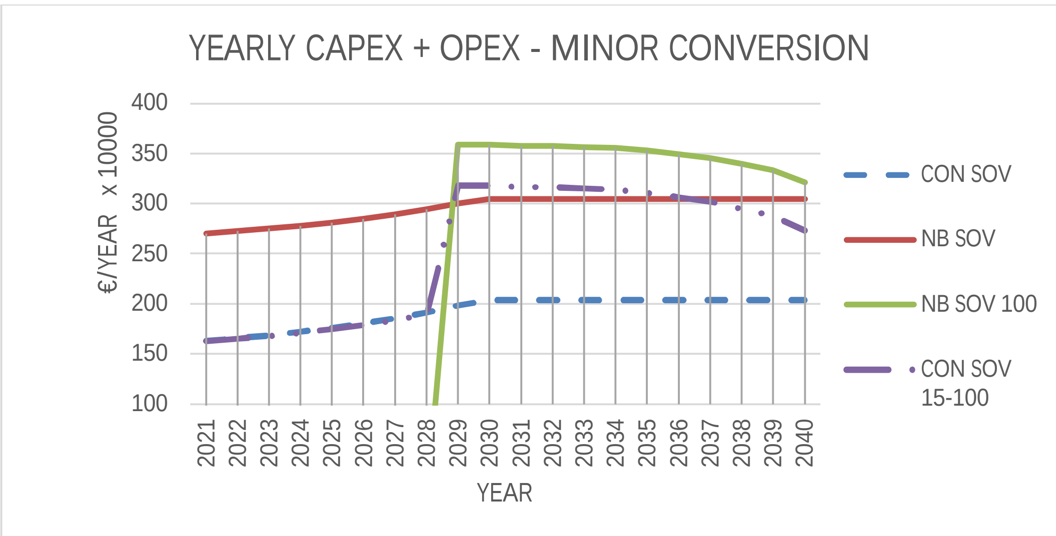


Figure 6-6: Economical evaluation - Conversion vs. New build – Minor Conversion

The graph illustrates four scenarios, New build (red) and conversion (blue dashed), zero emission (green) and conversion with modular power (purple dashed).The X-axis represent time, while Y-axis represent the yearly cost in Euro. The cost include capital cost with a down payment according to Table 5-3: Economic Assumptions and operational cost according to Table 5-2: Various Operational Cost (€/ton).

CO2 tax will drive the operational cost for all scenarios, while switching or using zero-emission will possible reduce the cost.

Including the investments cost reveals that a newbuild built in 2030 will be more competitive after some years than a newbuild built with fossil fuel. Considering also conversion vessels, these seem to be a logical solution, given a financial solution for 20 year.

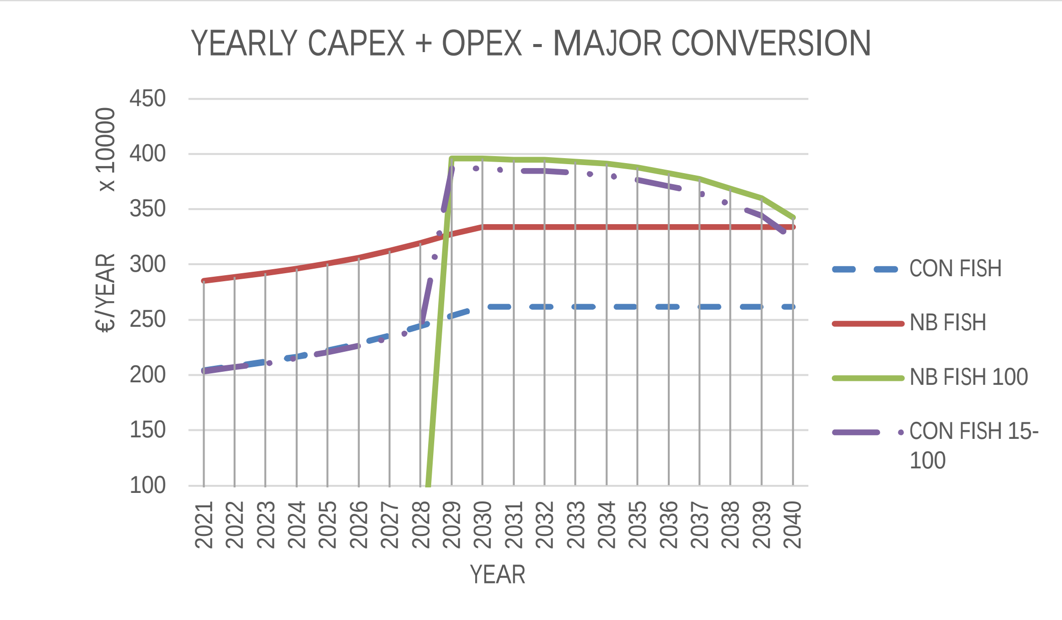


Figure 6-7: Economical evaluation - Conversion vs. New build – Major Conversion

From the economical evaluation for a vessel in transit operation, sensitivity to operational cost

## 6.5 Sensitivity to Carbon Cost, PSV Cost and Energy Cost

The economical evaluation and scenarios have been assessed with sensitivity to CO2 tax, cost of PSV, and zero emission energy cost. A offensive change to CO2 (increase of 67%) tax will make zero emissions vessels more competitive to conversion and reduce the likelihood of increased circular economy. As where in contrary modest CO2 tax will favorize circular economy project or newbuild without zero emission energy.. Reference is made to Figure 6-8 and Figure 6-9.

Change of PSV investment cost will have minor effect to the variation compared to other parameters such as CO2 tax and energy/fuel cost. However, will affect the margins and economy of marginal projects with low TC cost and high conversion cost/operational cost.

Reduction of the fuel cost, in this case ammonia will lead to more attractiveness for zero emission new-build. The cost is theoretically reduced by 60%, which shows the ability to compete against fossil fueled ship. Reference is made to Figure 6-11.

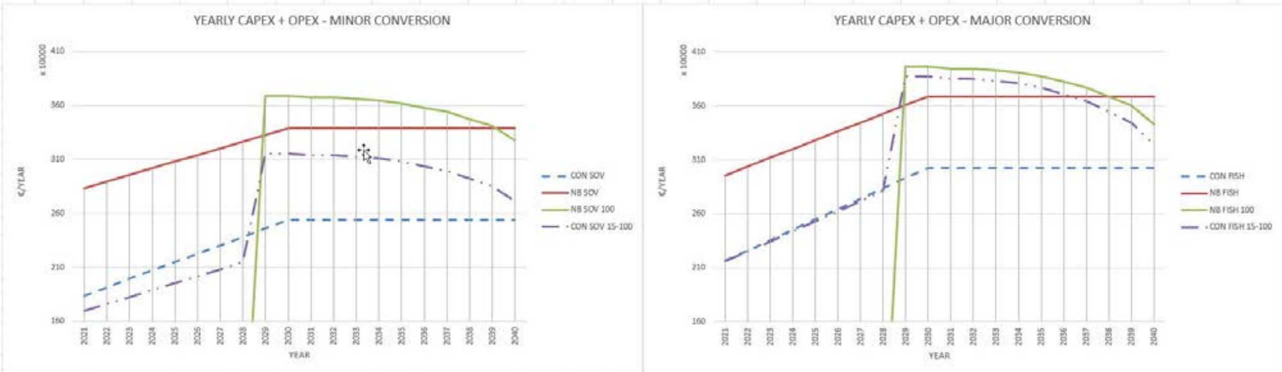


Figure 6-8: CO2 Cost of 300€/ton

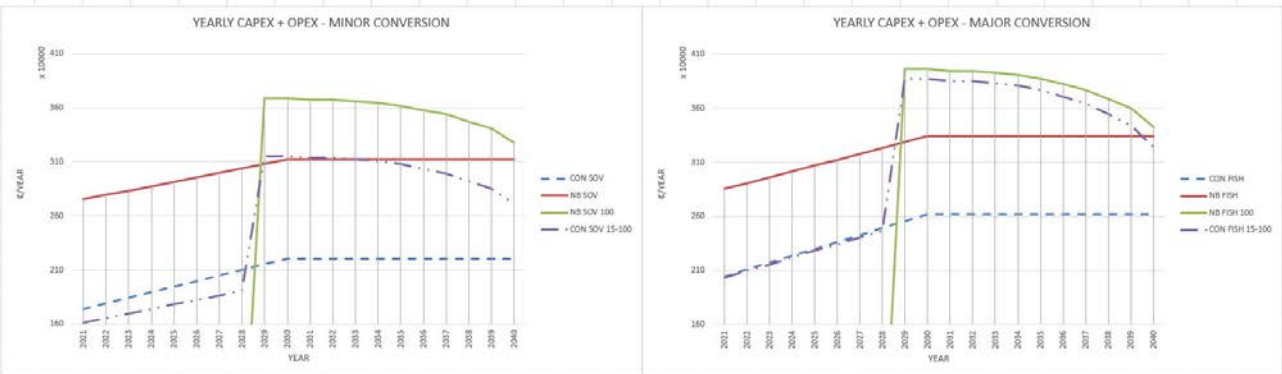


Figure 6-9: CO2 cost of 200 €/ton

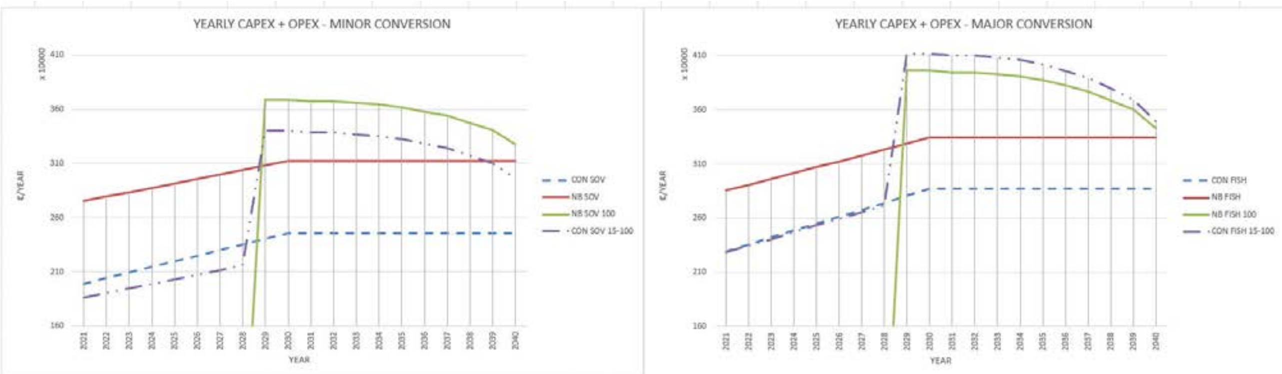


Figure 6-10: PSV cost of 1 500 k€

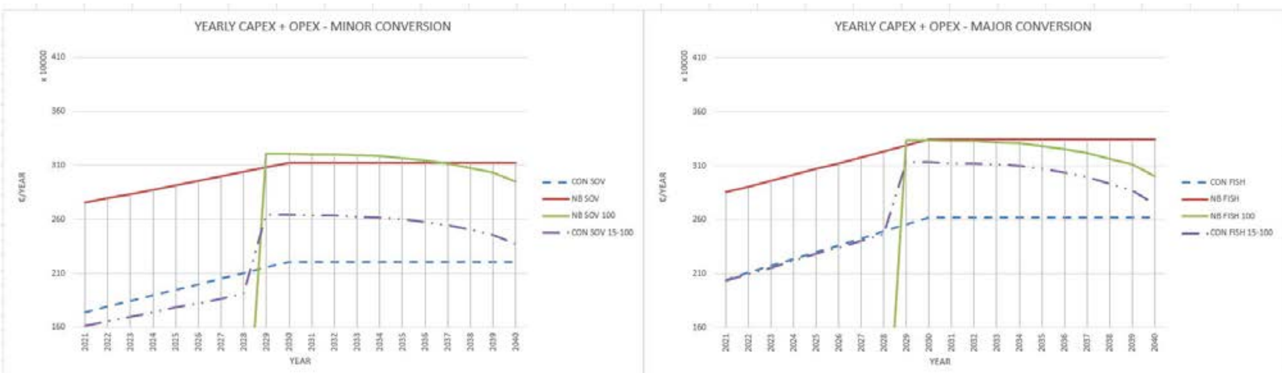


Figure 6-11: Reduced cost of zero emission energy (-60% for ammonia compared today)

# 7. STRATEGY FOR CIRCULAR ECONOMY

From the basis of environmental calculations and economical calculations we have developed a roadmap or strategy to illustrate a potential solution to maximize the circular economy for offshore ships. The proposal has the purpose to take into consideration the barriers and opportunities described in section 4 TECHNICAL and ECONOMICAL BARRIERRS and OPPORTUNITIES.

To maximize the potential of circular economy in offshore one has to have a product that can be shared with other industries. This will improve the product utilization and reduce the lifecycle cost. If the product adopts a high degree of modularity the platform or module can be reused as its original purpose or be remanufactured to a new market.

Other advantage points are to maximize the lifetime of the product or modules and apply standardization that allow upgrades and repairs, which will improve its competitiveness in a competing market.

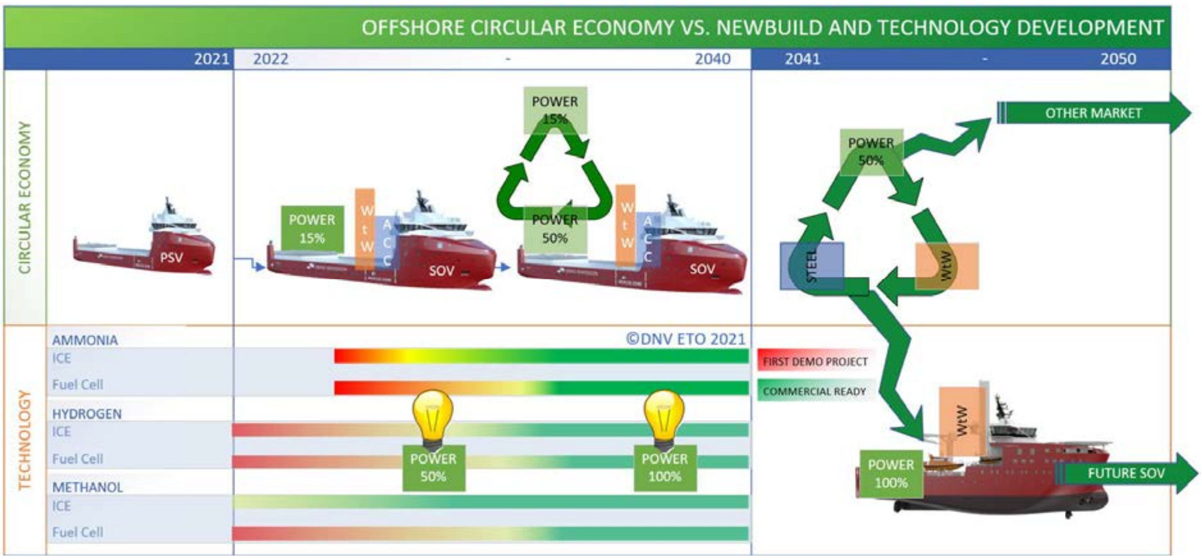


Figure 7-1: Offshore circular Economy Strategy – Vard Engineering Brevik

In the event of complete use or end of life for the product, a lower level of circular economy can always be adopted such as re-circulation.

A ship owner should during the ship operation phase plan a strategic approach to the technology shift. This will give the business model an economical and environmental edge. An economical edge by using the commercial pricing scenario of energy to become competitive in terms of operational cost. An environmental edge by showing to a minimal carbon footprint for the same function and work as a newbuild. From the results of this project and the proposed incentives we believe this information can change the mindset and attract projects with low or reduced carbon footprint in the future:

| | |
|---|---|
| 1. REWARD | •Financing of projects for circular economy<br>•Reduction of CO2 Fee or Pawn Scheme for «stranded asset» |
| 2. CARBON FOOTPRINT | •Operator should find a way to favorize carbon footprint in tenders<br>•Means such as Hull and lifetime extension of equipment |
| 3. LONG TERM CONTRACT | •The uncertainty in investing in a «old» commodity weigh high for banks<br>•Collaboration between operators to improve ship utilization? |

# 8. FUTURE WORK

Future studies should qualify the carbon footprint calculator with reference to ISO 14067 and also explore the other twelve markets not exemplified in this report in order to fully document the potential of circular economy for OSVs.

Necessity of SPS code for vessels carrying less than 100 people. – Statistical approach on incidents and accidents whereby SPS Code has been important to avoid fatality or escalation of an accident. Hypothesis to be studied; SPS code for vessels have not contributed to increased safety for vessel with less than 100 people aboard having double hull. The environmental impact of the SPS code requirement has not been proportional in terms of the total CO2 emission consequence nor contributed to effective shipbuilding.

A economical analysis on how circular economy can be financed and accelerated. Development of financing model or incentives where the purpose of lifting the level of circular economy from recycling to re-use and refuse as mentioned in Figure 1-1: Ellen MacArthur – Circular Economy, ref /A1.

# APPENDIX A ENERGY PROFILES

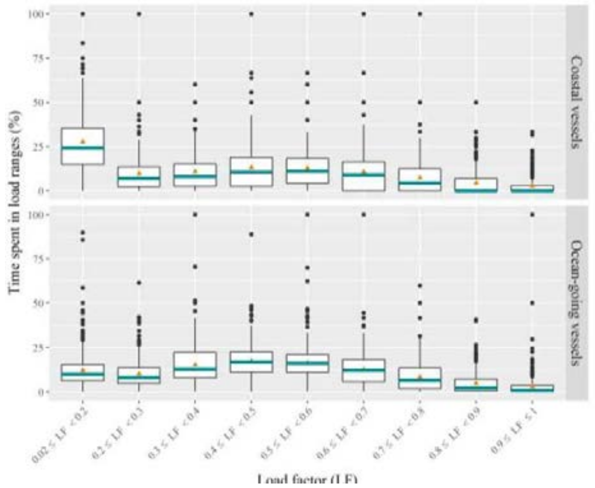

Figure 8-1: General Cargo Ships

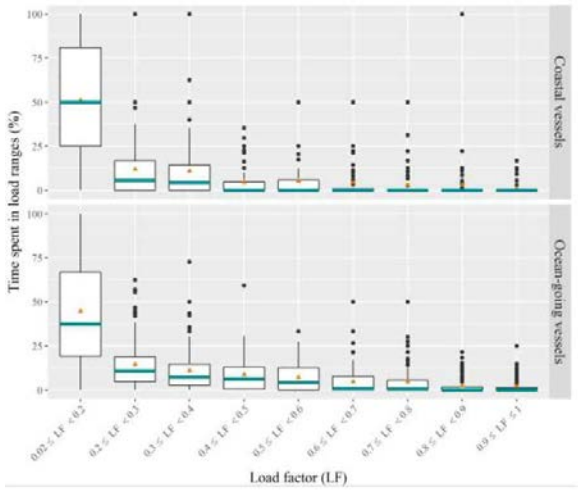

Figure 8-2: Offshore Vessels

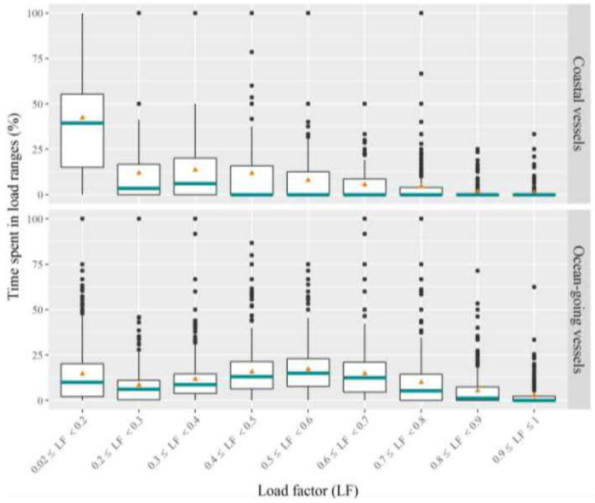

Figure 8-3: Tanker & Bunker Vessels

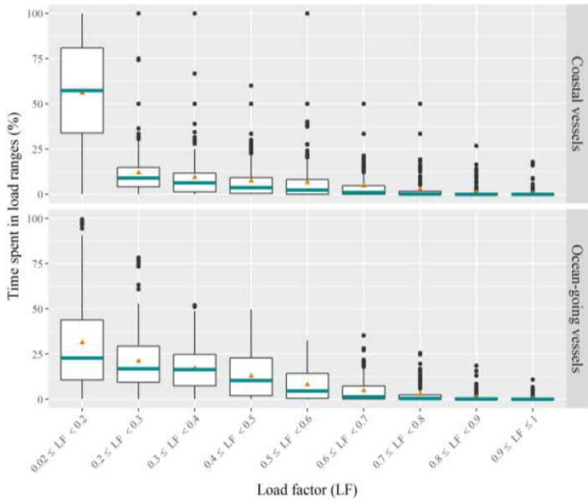

Figure 8-4: Passenger Vessels

# APPENDIX B LIST OF FIGURES & TABLES

## B1 LIST OF FIGURES



## B2 LIST OF TABLES

# APPENDIX C MARKET HOTLIST

| # | Market | Vessel Type | Conversion Type | KPI | Energy Profile | Average Operational Load | AverageMCR | Installed/Applied Effect kW | Average CO2 emission tonnes/day |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Offshore Wind | Service Operation Vessel | Minor Conversion | SPS, DP, crew comfort, w2w, | Standby | Transit: 20%<br>Port: 20%<br>Manouvering; 60% | 20 % | 4500 | 13,1 |
| 2 | Offshore Wind | Installation vessel | Minor Conversion | Crane capacity<br>DP<br>Significant wave height | Standby | | | | 0,0 |
| 3 | Seafarming | Live fish carrier/De-lice | Major Conversion | Pump capacity<br>Tank Capacity<br>Stability | Transit | Transit: 55%<br>Cargo Operation: 20%<br>Manouvering; 5%<br>Stand-by: 20% | 60 % | 2500 | 21,9 |
| 4 | Seafarming | Serviceskip | Minor Conversion | Crane capacity<br>Deck Area | Standby | | | | 0,0 |
| 5 | Seafarming | Trawler | Major Conversion | Bollard Pull<br>Space for Factory<br>Space for Storage of frozen fish | Transit | | | | 0,0 |

| # | Market | Vessel Type | Conversion Type | KPI | Energy Profile | Average Operational Load | AverageMCR | Installed/Applied Effect kW | Average CO2 emission tonnes/day |
|---|---|---|---|---|---|---|---|---|---|
| 6 | Seafarming | Fish Feed | Major Conversion | DWT Capacity<br>Crane<br>DP | Transit | | | | 0,0 |
| 7 | Tank/Bunker | LNG Bunker | Minor Conversion | Cargo Capacity<br>Manouvering<br>Power for Cargo Handling<br>Stability | Standby | Transit: 20%<br>Cargo Operation: 20%<br>Manouvering; 5%<br>Stand-by: 55% | | | 0,0 |
| 8 | Tank/Bunker | CO2 Carrier | Minor Conversion | Cargo Capacity<br>Manouvering<br>Power for Cargo Handling<br>Stability | Transit | Transit: 20%<br>Cargo Operation: 20%<br>Manouvering; 5%<br>Stand-by: 55% | | | 0,0 |
| 9 | Tank/Bunker | H2 / HN3 Bunker | Minor Conversion | Cargo Capacity<br>Manouvering<br>Power for Cargo Handling<br>Stability | Standby | Transit: 20%<br>Cargo Operation: 20%<br>Manouvering; 5%<br>Stand-by: 55% | 35 % | 3500 | 17,9 |
| 10 | Cruise | Cruise / Expedition | Major Conversion | Ice Class<br>Comfort/Noise | Transit | Transit: 69%<br>Port: 28%<br>Manouvering; 17% | | | 0,0 |

| # | Market | Vessel Type | Conversion Type | KPI | Energy Profile | Average Operational Load | AverageMCR | Installed/Applied Effect kW | Average CO2 emission tonnes/day |
|---|---|---|---|---|---|---|---|---|---|
| 11 | Cargo transport | General Bulk Ship | Major Conversion | DWT Capacity<br>Fuel economy | Transit | Transit: 55%<br>Cargo Operation: 20%<br>Manouvering; 5%<br>Stand-by: 20% | 70 % | 1800 | 18,4 |
| 12 | Cargo transport | Reefer | Major Conversion | DWT Capacity<br>Speed<br>Power for Refrigiators | Transit | Transit: 55%<br>Cargo Operation: 20%<br>Manouvering; 5%<br>Stand-by: 20% | | | 0,0 |
| 13 | Ocean plastic | Recovery vessel | Minor Conversion | Diesel electric<br>Deckspace | Standby | Transit: 5%<br>Port: 40%<br>Cargo Operation: 10%<br>Manouvering: 25%<br>Stand-by: 20% | 30 % | 4500 | 9,8 |

# APPENDIX D CONVERSION HAZID WORKSHOP

| ID | Barriers & Opportunities | Subject | Subject Description | Existing Experience WP2 | Rating | Commercial Incentives | Technical Incentives |
|---|---|---|---|---|---|---|---|
| Node 1C: Offshore Wind: Service operation vessel | | | | | | | |
| 1.1 | Opportunity | Profitability | Financing | Purchase or leasing of walkway and including a mobilization fee prior to start up. | High | Financial incentives for conversion to Wind market is expected to be effective. | Standardization |
| 1.2 | Barrier | contract type | financing, time to market | Short contract (modularized) | Medium | | |
| 1.3 | Opportunity | modularization | High modularization reduce risk, allow for mobilization, cost sharing of equipment | A tendency is purpose built vessel for long contracts | Low | Leasing of equipment, | Difficult to standardize, too many parameters currently today |
| 1.4 | Opportunity | Capital Cost and lifetime | New build price is relatively high compared with other categories | | Medium | | condition monitoring of hull for lifetime documentation |
| 1.5 | Barrier | Conversion Cost | Cost for converting existing vessel to given new operation | cargo to passenger-->major conversion? | High | Can the value of reduced carbon footprint be valued by Government --> CO2 TAX - currently no fund is effective to handle this | |

| ID | Barriers & Opportunities | Subject | Subject Description | Existing Experience WP2 | Rating | Commercial Incentives | Technical Incentives |
|---|---|---|---|---|---|---|---|
| | | | | | | kind of "cost sharing" | |
| 1.6 | Opportunity | Conversion SOW | Accommodation module, offshore crane, w2w, SPS class<br>Minor Conversion | SPS - Wind market.<br>Light SPS upgrade for some vessels.<br>Norman energy -> Full SPS<br>Short period contracts makes it challenging to achieve full SPS for some vessels. Easier for a larger vessel due to stability<br>- integration of W2W bridge require risky cabling work | Medium | Cost of CO2 | - Can waiver to operate outside rules be given? |
| 1.7 | Opportunity | Technical capability | The ability of an existing vessel to adapt to new technical / class requirements | favourable class notations such as SPS is important | Medium | Financial incentives to motivate for modification and procurement of required equipment. | Class notation, Ship capacity (DWT, deck area, etc<br>Better Equipment |
| 1.8 | Opportunity | Energy profile | Fuel cost, taxonomy, CO2 emission, Average operational load | Not received yard or operator experience info on this specific issue. Further investigation to be done. | High | | |

| ID | Barriers & Opportunities | Subject | Subject Description | Existing Experience WP2 | Rating | Commercial Incentives | Technical Incentives |
|---|---|---|---|---|---|---|---|
| 1.9 | Opportunity | New fuel technology and infrastructure | Ability to implement new fuel technology and required infrastructure | Same as above | High | Financial incentives to facilitate implementation of new fuel and refuelling infrastructure | |
| Node 2C: Live Fish carrier | | | | | | | |
| 2.1 | Opportunity | Profitability | Financing | Difficult to answer as the project was hit by the Covid-19 situation. Both price and delivery time became a challenge. A positive result was achieved, but it would have been much better in a normal situation without Covid-19. | Low | | |
| 2.2 | Opportunity | contract type | | Time to market is the main reason so far for these projects | Medium | | |
| 2.3 | Barrier | modularization | | There are examples but with limited tank capacity (for lice removal), but not for Live Fish Carrier | Low | | Not possible? |
| 2.4 | | Capital Cost | | There are examples from Aquaship: 3000 m3. | Medium | | |
| 2.5 | | Conversion Cost | | major conversion | High | | |

| ID | Barriers & Opportunities | Subject | Subject Description | Existing Experience WP2 | Rating | Commercial Incentives | Technical Incentives |
|---|---|---|---|---|---|---|---|
| 2.6 | Barrier | Conversion SOW | Important to remove equipment to place space for tanks and pumps. Assume no changes to machinery and cabeling | Change from PSV to Cargoship introduced limitng factors as height of tank. Removal of equipment not required for new operation. Longitudinal strength became an issue when removing existing configuration under deck.<br>Classification society response was slow. Time-consuming evolution of applicable rules etc.<br>Reduced value of NOK became an economical challenge and Covid-19 was a general obstacle. | Medium | | Cement tanks?<br>Crane capacity |
| 2.7 | Opportunity | Regulatory | | Currently no limitation for commercial application<br>Domestic rules & Regulation | Medium | | |
| 2.8 | | Technical capability | | DP capability is needed | Medium | | |
| 2.9 | Opportunity | Energy profile | Fuel cost, taxonomy, CO2 emission, Average operational load | Transit profile, unknown energy profile related to cargo handling | Low | | |
| 2.10 | Opportunity | New fuel technology and infrastructure | Use of battery and hybrid | Experience remains to be identified for this specific area. | Low | Enova will bring full support to the converted candidate market | Develop required infrastructure |

| ID | Barriers & Opportunities | Subject | Subject Description | Existing Experience WP2 | Rating | Commercial Incentives | Technical Incentives |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Node 3c: Ocean plastic recovery vessel | | | | | | | |
| 3.1 | Barrier | Profitability | CO2 savings from recycled waste not included in emissions calculation. Overall operation is CO2 negative. Further savings from installed battery. | | Medium | Enova support of conversion to other market | The ability to recirculate more than 40% of plastic is needed to make the project commercial |
| 3.2 | Barrier | contract type | Possibilty of branding sustainability | Governmental and voluntair organization<br>- Missing commercial partner | Medium | Length of contract is important to reduce risk (development bank or FN)<br>- need predictability<br>- unclear scalability of Business | |
| 3.3 | Opportunity | modularization | Recovery module | Relatively simple and low. Plug and play. Can also continue as PSV after contract | High | What is possible to develop realted to modularization | |

| ID | Barriers & Opportunities | Subject | Subject Description | Existing Experience WP2 | Rating | Commercial Incentives | Technical Incentives |
|---|---|---|---|---|---|---|---|
| | | | | | | to standardize solution and reduce cost in the value chain | |
| 3.4 | Barrier | Capital Cost | | Cost of modules is the main driver of conversion | Medium | | |
| 3.5 | | Conversion Cost | | low, minor modifications, additional power and auxiliary systems | High | | |
| 3.6 | Opportunity | Conversion SOW | | Conidered as minor conversion | Low | | |
| 3.7 | Barrier | Regulatory | Operation in national water not allowed --> Convert to different flag | | Low | | |
| 3.8 | Opportunity | Technical capability | Deck area, diesel electric propulsion, crane capacity | | High | | |
| 3.9 | Opportunity | Energy profile | Fuel cost, taxonomy, CO2 emission, Average operational load | Standby Profile : Very close to PSV operational profile | Medium | Can negative CO2 be accounted for and valued? | |
| 3.10 | Opportunity | New fuel technology and infrastructure | | Standby profile may be attractive for installed and hybrid power | Medium | Enova support for energy conversion | |
| Node 4c: Hydrogen/ammonia carrier | | | | | | | |
| 4.1 | Barrier | Profitability | Cost of Energy | Cost of Energy is currently high and may be subsidised by Government.<br>Profiabilty is mainly driven by scale of volume carried. | Medium | Require govermental incentives and program before business is started. | |

| ID | Barriers & Opportunities | Subject | Subject Description | Existing Experience WP2 | Rating | Commercial Incentives | Technical Incentives |
|---|---|---|---|---|---|---|---|
| 4.2 | Barrier | contract type | Comodity value | Comodity is sold on the market by the ship-owner | Medium | Currently limited buyers, require value chain project development - this may change within 4 years also due to Grean Deal (EU) | |
| 4.3 | Barrier | modularization | Compressed Hydrogen Liquid Hydrogen | | Low | | |
| 4.4 | Barrier | Capital Cost | | 50% of cost may be covered | Medium | Enova support of conversion to other market | |
| 4.5 | Barrier | Conversion Cost | | Compressed; Low Cost Liquid; High Cost | High | | |
| 4.6 | Barrier | Conversion SOW | | Compressed: Minor Conversion Liquid: Major Conversion | Medium | | favourable class notations |
| 4.7 | Barrier | Regulatory | | Low with containers on deck Low for ammonia, but challenges with handling of leakage and ventialtion High if work is needed below deck (compressed) | Low | | Rules and regulations needs to be be developed consusly to avoid added cost. |
| 4.8 | Barrier | Technical capability | | Can transport 60ton (compressed hydrogen) Safety sones due to toxisity Limited volume capacity compared to newbuild | Medium | | LFL notation --> nitrogen system |

| ID | Barriers & Opportunities | Subject | Subject Description | Existing Experience WP2 | Rating | Commercial Incentives | Technical Incentives |
|---|---|---|---|---|---|---|---|
| 4.9 | Barrier | Energy profile | Fuel cost, taxonomy, $CO_2$ emission, Average operational load | Transit profile, unkown energy profile related to cargo handling | Low | | |
| 4.10 | Barrier | New fuel technology and infrastructure | | | Low | | |

# APPENDIX E PROJECT APPLIED METHODOLGY