Tender Reference 16-03633

Provision of Service to Identify Green Ferry Options that are Technically Feasible in Local Context

Summary Report

submitted to

The Environmental Protection Department
The HKSAR Government

by

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Introduction

SR1. In recent decades, attention on the impact of shipping and port activities on air pollution and climate change has escalated at the international, national and city levels, leading to various new and enhanced control measures to mitigate these environmental impacts. The International Maritime Organization (IMO), for example, has progressively tightened the global cap for the sulphur content of marine fuel used by all ships, from 4.5 per cent to 3.5 per cent in 2012, and further to 0.5 per cent effective from 1 January 2020.

SR2. Hong Kong has responded proactively to this trend by capping the sulphur content of locally supplied marine light diesel (MLD) at 0.05 per cent since April 2014, and requiring ocean-going vessels (OGVs) to mandatorily switch to marine fuel with sulphur content not exceeding 0.5 per cent while berthing since July 2015. The latter could be extended in the near future to vessels plying in Hong Kong waters, in order to co-ordinate with China's domestic emission control area (DECA) implementation plan and its compliant fuel requirements in the Pearl River Delta (PRD) starting in 2019.

SR3. In response to the more stringent emission standards and regulations, as well as the growing need and desire to combat air pollution and climate change, green technologies for vessels, including those applicable to ferries, have also advanced speedily in the past decades. While green technologies have demonstrated tremendous potential and effectiveness in emission abatement, successful uptake and implementation of these technologies is not always guaranteed. This is often due to the presence of different technological, operational, commercial, and institutional barriers, and the lack of drivers, infrastructure, regulations, and incentive.

Objectives

SR4. In the 2017 Policy Address, former Chief Executive Leung Chun-ying stated that the Government "is exploring technologies that can improve the fuel efficiency and environmental effectiveness of local ferries." In light of this, the main objectives of the Study are:

(a) to assess the technical feasibility of various common green ferry technologies worldwide in the local context, taking into account the current operational characteristics of the local ferries;

(b) to appraise the environmental benefits and cost implications of the recommended green ferry technologies; and

(c) to evaluate the need for a pilot scheme before full implementation of the recommended green ferry technologies.

Ferry operation in Hong Kong

SR5. According to the Special Conditions of Contract (SCC), local passenger ferries defined in this Study include the in-harbour routes, outlying island routes, and cross-boundary routes to Macau and the PRD ports.

SR6. The market share of ferry (in-harbour and outlying island routes) is very low compared to other major public transport modes. It remained at 1.1 per cent in 2015 with an average of 134,000 passengers every day, serving as a complementary mode of transport in Hong Kong. As at end 2015, there were altogether 14 franchised and licensed ferry operators running 21 regular passenger ferry services. (Table 1) There were also 2 dangerous goods vehicular ferry services and 2 special services at the harbour and to the new towns and outlying islands, but these services were not covered in this Study.

SR7. Two operators are providing cross-boundary passenger ferry services between Hong Kong and Macau. (Table 2) Services between Hong Kong and PRD ports are run by a number of operators, providing connection to destinations such as Doumen, Gaoming, Humen, Jiangmen, Lianhuashan, Nansha, Shekou, Shenzhen, Shunde, Zhongshan, Zhuhai, as well as Shenzhen Airport in Fuyong.

SR8. Other than the passenger ferry services described above, there are also kaito ferry services that provide transport connection between destinations in the relatively remote locations in Hong Kong, and where regular public transport services are lacking. In 2015, there were 14 kaito routes served with regular services, and another 56 on-demand kaito routes, with 89 kaitos in service. Kaito ferry services were not covered in the scope of this Study.

SR9. Ferry services are operated by the private sector on commercial principles in Hong Kong. Ferry operators either enter into a franchise agreement or a licence agreement with the HKSAR Government with respect to the provision of ferry services, according to section 6 or section 28 of the Ferry Services Ordinance (Cap. 104). All the operating details including the route, the timetable, the fares and vessel allocation specified in the schedules of services of franchised and licensed ferry services are approved by the Transport Department.

SR10. Unlike all the above, the ferry companies that operate cross-boundary ferry services do not enter into any franchise or licence agreement with the Hong Kong Special Administrative Region (HKSAR) Government regarding the provision of services. Their operations are purely commercial, and they have full autonomy in fare and time table adjustment.

Initial technical and environmental assessment

SR11. Green technologies that are applicable to ferries, both newbuilds and in-use ferries, for reducing exhaust and greenhouse gas emissions, especially those being used in environmentally advanced places such as North America and the European Union, were identified. These technologies include (a) liquefied natural gas (LNG), (b) compressed natural gas (CNG), (c) battery-powered propulsion, (d) hybrid propulsion, (e) diesel-electric propulsion, (f) dual fuel engines, (g) light-weight materials, (h) scrubbers, and (i) fuel cell technology.

SR12. Eight criteria were selected for the technical feasibility assessment in the local context, including (a) readiness of the technology, (b) supporting infrastructure, (c) technical capacity, (d) human resources, (e) financial resources, (f) institutional capacity, (g) time frame, and (h) risks and challenges.

SR13. In addition, five criteria were chosen to provide a preliminary environmental assessment of the identified green ferry technologies, based largely on international experience. These criteria are (a) emission, (b) fuel reduction, (c) fuel economy, (d) noise level, and (e) waste.

SR14. All the identified green ferry technologies were scored according to a three-point scale. Technical feasibility and environmental performance are given an equal weighting (50 per cent each) in the overall score.

SR15. Assessment results show that *on technical and environmental ground*, battery-powered propulsion (75 points), light-weight materials (66 points), hybrid propulsion (65 points), and diesel-electric propulsion (61 points) are the high-scoring technologies. Low scoring technologies (between 45 points and 51 points) either require supporting infrastructure for fuel storage, supply and bunkering, technical capability, human resources support, and institutional capacity, which are all lacking in Hong Kong at the moment, or perform not as well as others in environmental improvements. (Table 3)

Recommendation based on local ferry operation characteristics

SR16. While battery-powered propulsion, light-weight materials, hybrid propulsion, and diesel-electric propulsion stand out after initial assessment based on technical and environmental considerations, it does not mean that all four technologies should be implemented in Hong Kong. Rather, the most suitable technology or combination of technologies should be identified according to the characteristics and demand of local ferry services.

SR17. Therefore, a thorough assessment of Hong Kong's ferry services was carried out, with due consideration of several key features of operation that would influence the selection of the most feasible green technologies for local ferries. These features include (a) vessel size and capacity, (b) vessel speed, (c) sailing distance, (d) berthing time, and (e) fleet age.

SR18. It was found that:

- Ferries operating in-harbour routes are sailing shorter distance (pier-to-pier) at a lower speed, and the berthing time is relatively short;
- Ferries operating outlying island routes are sailing medium distance at varying speeds (slow speed in restriction zones, and higher speed outside these zones), and berthing time is longer;
- Ferries operating services to Macau are sailing long distance at high speed, except in speed restriction zones, and berthing time is relatively short;
- Ferries operating services to the PRD ports are sailing long distance at high speed, except in speed restriction zones, but berthing time is on average longer due to less frequent sailings; and
- Given the average age of the in-use ferry fleet is well over 20 years, and some vessels are built in the late 1950s and 1960s, most operators suggested during interviews that building new vessels with green technologies is preferred over retrofitting these technologies with the current ferries.

SR19. With all the assessments and considerations undertaken as explained in the previous paragraphs, several recommendations are made.

SR20. Newbuilds versus retrofitting: first and foremost, it is recommended ***new vessels should be designed and built, instead of retrofitting in-use ferries***. This is the best option after taking into account the old fleet age (over 20 years) and hence little space and flexibility to retrofit, and the need to optimise payload capacity and service conditions.

SR21. Ship construction materials: it is also recommended that ***light-weight materials, such as carbon fibre composite or aluminium alloy, should be considered for newbuilds due to its fuel saving potential***. Fuel saving benefits will be highest for ferries serving long distance, high-speed routes (e.g. outlying island ferries, Macau ferries and PRD ferries), but the frequent in-harbour routes will also benefit.

SR22. Propulsion system: to optimise the opportunity of designing and building new vessels, and to achieve additional environmental benefits, it is highly recommended that propulsion systems other than conventional diesel engine should be considered. Based on the Study's findings, electric ferries and hybrid electric ferries built with carbon fibre composite are recommended for specific routes below:

- In-harbour routes: it is recommended that ***for ferries running the in-harbour routes, a battery-powered propulsion system should be considered***.

  (a) Electric ferry is the best choice, as short-distance in-harbour routes have lower energy requirement per sailing, which will minimise the power and battery requirements of the on-board electric system. Frequent services will also maximise savings in fuel consumption and other operating costs.

  (b) Charging requirement could be satisfied by both overnight charging at ferry piers, supplemented by quick charging arrangement during berthing time for these short distances, in-harbour routes. As such, shore-side charging facilities have to be built at the berthing locations.

  (c) It is suggested that new vessels should be built, rather than retrofitting in-use ferries, with light-weight materials, so that under a similar operation environment (such as same speed profile) power requirement of the vessels could be further reduced.

  (d) For the propulsion system, it is suggested that the vessels could be driven by two electric motors, using both lithium battery packs and supercapacitor for energy storage. Potentially, fuel cell technologies could also be considered as a secondary source of power for contingency.

- Outlying island routes: it is recommended that ***for ferries operating the outlying island routes, a hybrid propulsion system that combines electric generators and diesel engines in CODLOD configuration (using either electric or diesel mode) should be considered.***

  (a) Hybrid ferry is considered the most suitable for outlying island routes, given the longer sailing distance at a higher speed and higher power requirement for propulsion.

  (b) Vessels to be built with light-weight materials and driven by both a diesel engine and an electric motor in CODLOD configuration. They are designed to operate in either diesel or battery mode.

  (c) At constant, high-speed environment outside the Victoria Harbour, diesel engine

will take over as prime mover.

(d) Electric motor will be the prime mover during low speed (in speed control zones) and varying engine loads environments (like maneuvering) in the harbour to achieve zero emission, eliminating smoke and air pollution nuisance to the public near the shore.

(e) The design of a hybrid propulsion system can be tailor-made and optimised to cater for the charging of batteries to suit operational profiles, including vessel speed, engine loading, and berthing time, and hence overnight charging at ferry piers is not required.

(f) Hybrid ferries would reduce fuel consumption and enhance energy efficiency. Fuel savings, air pollution and noise reduction benefits could be maximised under operation at low speed in battery mode.

SR23. Other considerations:

- For ferries operating the cross-boundary routes, hybrid propulsion once again is considered the most suitable technology to achieve fuel savings and emissions reduction from the technical and environmental perspectives. However, the decision to switch to green ferries or not should rest with the commercial operators as a business decision.

- For kaito ferry services, the scale of operation is rather small and only a handful kaito ferry services are regular. It is therefore suggested that the application of green technologies to kaito ferries is of low priority at the moment given the limited potential to scale, and should be considered on a case-by-case basis.

- Other than the hybrid electric propulsion system that is recommended for the outlying island routes, there are other hybrid propulsion systems that should be monitored for the medium to long term. For example, gas-electric hybrid propulsion could be considered an option when LNG supplies to Hong Kong would become more secured.

- Diesel-electric propulsion scored very well in the integrated assessment and is considered a feasible green ferry technology for Hong Kong on technical ground. However, the environmental performance of diesel-electric ferry is out-performed by electric ferries for the in-harbour routes or hybrid electric ferries for the outlying island routes.

SR24. Pilot scheme: it is premature at this juncture to require ferry operators to replace all existing ferries in Hong Kong with the recommended technologies, as so far there are only a limited number of green ferries operating in Asia. ***It is recommended that a pilot scheme is essential*** for testing green ferries in local operation, confirming their local suitability, before scaling up the application in the longer term.

Environmental benefits of the recommended options

SR25. Air pollution reduction: if all the ferries operating the seven in-harbour routes are replaced by electric ferries, the biggest environmental benefit would be the achievement of ***zero emission of air pollutants from these ferries in the Victoria Harbour***. It is estimated that SO_2, NO_X, PM_{10}, $PM_{2.5}$, HC and CO will be reduced by 1.3 tonnes, 79.4 tonnes, 1.6 tonnes, 1.5 tonnes, 1.1 tonnes, and 14.3 tonnes, respectively. By replacing all outlying island ferries with hybrid electric ferries, it is estimated that an additional 8.2 tonnes of SO_2, 485.9 tonnes

of NO_X, 9.2 tonnes of PM_{10}, 8.4 tonnes of $PM_{2.5}$, 6.8 tonnes of HC, and 87.1 tonnes of CO will be reduced.

SR26. Air quality improvement: using electric ferries for the in-harbour routes and hybrid electric ferries for the outlying island routes will bring notable improvement in air quality in Victoria Harbour and the nearby areas. It is anticipated that both SO_2 and NO_X concentration levels will be lowered quite significantly, especially the portion contributed by the outlying island ferry operation. Also, air quality improvement will be more noticeable during high air pollution days with weak or no wind, as a major source of air pollution in the harbour area will be eliminated.

SR27. Greenhouse gas reduction: it is estimated that full implementation of all the recommended green ferry options in Hong Kong will result in a total reduction of 30,139 tonnes of CO_2, 0.8 tonnes of N_2O, and 2.9 tonnes of CH_4 in the base year (year 2015), which is equivalent to a reduction of 30,458 tonnes of CO_2-e (CO_2-equivalent).

SR28. Fuel savings and fuel economy: if all the ferries running the in-harbour routes and the outlying island routes are replaced by electric ferries and hybrid ferries, respectively, it is estimated that 11.4 million liter of MLD will be saved, representing a 33.3 per cent fuel reduction relative to the baseline. Other than leading to air pollution and greenhouse gas reduction, fuel savings will also bring down the cost of operation.

SR29. Noise pollution reduction: hybrid ferries, and in particular electric ferries will offer a much more quiet environment for both passengers and crew members. International and local examples suggest a noise level range from below 60 decibels (dB) to 70 decibels for electric and hybrid ferries, compared to 80 to 90 dB for diesel ferries.

SR30. Waste reduction and other environmental considerations: less lubricating oil will be consumed with a hybrid electric propulsion system relative to a diesel drive, and most lubricating oil consumption will be eliminated with an all-electric system due to the largely reduced number of parts that require lubrication. With electric ferries and hybrid ferries, there will be greater need to properly handle waste batteries.

Financial evaluation of the recommended options

SR31. With the advice provided by overseas ship architects, ship builders, technology providers and other experts in green ferry technologies, the main cost items related to designing, building and operating one electric ferry with carbon fibre composite (ship specifications similar to the in-use ferries carrying about 525 passengers) for the in-harbour routes are as follows:

- Cost of one electric ferry: HKD 75 million
- Cost of shore-side automated mooring and induction charging facilities: HKD 17.5 million
- Annual maintenance cost: HKD 5 million every 6 years for battery replacement
- Electricity tariff: HKD 0.9 million per year, based on non-residential tariff rate

SR32. On the other hand, the cost of designing and constructing a hybrid electric ferry with carbon fibre composite (ship specifications similar to the in-use high-speed ferries carrying about 500 passengers) for the outlying island routes is estimated at HKD 100 million. It is assumed

that there will be a 30 per cent saving in fuel cost due to reduced consumption of MLD.

SR33. As ferry operators have already indicated during interviews that the huge financial outlay for building a green ferry is unbearable under the current financial and operational environment, it is suggested that a new business model should be considered that would facilitate the implementation of green ferries in Hong Kong, ensure a sustainable business for the operators, and create an optimised regulatory regime managed by the Government that would deliver high quality ferry services to passengers.

Pilot scheme

SR34. It is strongly recommended that the Government should take a progressive and pragmatic approach in introducing the recommended green ferry technologies in Hong Kong, and a pilot scheme should be carried out as the first step to provide a testing ground for the chosen technologies and to gain valuable experience before full-scale implementation in the future. Reasons to conduct a pilot scheme include:

- To establish a proven example and to build up confidence among the operators and also the passengers in the domestic applications of green ferry technologies;
- To conduct trial before full implementation in order to minimise the risk of technical failure and to optimise ship and system design;
- To identify unforeseen problems and opportunities; and
- To monitor and quantify the benefits of the chosen technologies..

SR35. The major tasks to be covered under the pilot scheme should include, but not limited to, (a) securing government funding, (b) drawing up vessel specifications, (c) studying the feasibility of installing charging facility at the existing piers, (d) preparing and inviting tenders, (e) preparing detailed design and construction of ferries and charging facilities, (f) classification approvals, (g) commissioning of ferries, and (h) testing, monitoring, data analysis and evaluation. Some of the tasks listed above could take place at the same time to streamline the process. It is expected that the pilot scheme will take 4 to 5 years to complete.

SR36. The entire pilot scheme can be divided into three stages – pre-pilot stage, pilot stage, and post-pilot stage.

SR37. The pre-pilot stage would cover all the preparation work prior to the design, construction, commissioning and operation of the new green ferries, and other supporting infrastructure. A cross-bureau working group should be set up to work out the implementation programme of the pilot scheme, including (a) the identification of service routes and ferry operators to take part in the pilot scheme, (b) the scope and terms of the trial, (c) financial arrangements during the trial period, (d) ferry operational schedule, (e) maintenance support and arrangement, (f) ownership of the ferries after the trial, and (g) charging facilities requirement.

SR38. The pilot stage includes the design, construction, commissioning and operation of the green ferries, and other supporting infrastructure such as shore-side charging facilities. It should also pay attention to classification approval, as well as the monitoring of technical, environmental and financial performance of the trial operation of green ferries, and the collection of relevant data. Cross-sector task forces, including representatives from the relevant government bureaux and departments, as well as external experts with relevant

professional knowledge in naval architecture, ship building, class approval, ferry operation, and other ancillary technical support, should be set up to provide special expertise that is required for the completion of the tasks.

SR39. The main task during the post-pilot stage is to summarise and consolidate the data and information collected during the pilot stage, and to provide a full assessment of the effectiveness of the pilot scheme in terms of technical feasibility, environmental benefits and financial performance. An assessment report will be submitted to the Government with a recommendation about full implementation of green ferry technologies for the in-harbour and outlying island routes. If the recommendation is positive, the working group should also prepare a roadmap and a timetable for full implementation.

Conclusion

SR40. It is concluded that switching from diesel-powered ferries to new electric ferries for the in-harbour routes and to new hybrid electric ferries for the outlying island routes, both built with light-weight materials such as carbon fibre composite, are technically feasible and environmentally desirable. Full implementation of these recommendations will contribute significantly to an "emission-free" Victoria Harbour in the long term. The precious experience obtained from the pilot scheme would also contribute to the greening of other fleets in Hong Kong, including the government fleet.

Table 1 Franchised and Licensed Passenger Ferry Services in Hong Kong, 2015

	Operator	Route
Franchised	The "Star" Ferry Company Limited	Central ↔ Tsim Sha Tsui
Franchised	The "Star" Ferry Company Limited	Wan Chai ↔ Tsim Sha Tsui
Licensed	Chuen Kee Ferry Limited	Aberdeen ↔ Sok Kwu Wan (Via Mo Tat)
Licensed	Coral Sea Ferry Service Company Limited	Sai Wan Ho ↔ Sam Ka Tsuen
Licensed	Coral Sea Ferry Service Company Limited	Sai Wan Ho ↔ Kwun Tong
Licensed	Discovery Bay Transportation Services Limited	Central ↔ Discovery Bay
Licensed	Fortune Ferry Company Limited	North Point ↔ Kwun Tong
Licensed	Fortune Ferry Company Limited	Tuen Mun → Tung Chung → Sha Lo Wan → Tai O
Licensed	Hong Kong & Kowloon Ferry Limited	Central ↔ Peng Chau (including special departure between Peng Chau and Hei Ling Chau)
Licensed	Islands Ferry Company Limited	Central ↔ Yung Shue Wan
Licensed	Maris Ferry Service Limited	Aberdeen ↔ Cheung Chau
Licensed	New World First Ferry Services Limited	Central ↔ Cheung Chau
Licensed	New World First Ferry Services Limited	Central ↔ Mui Wo
Licensed	New World First Ferry Services Limited	Peng Chau → Mui Wo → Chi Ma Wan → Cheung Chau
Licensed	New World First Ferry Services Limited	North Point ↔ Hung Hom
Licensed	New World First Ferry Services Limited	North Point ↔ Kowloon City
Licensed	Park Island Transport Company Limited	Ma Wan ↔ Tsuen Wan
Licensed	Park Island Transport Company Limited	Ma Wan ↔ Central
Licensed	Peng Chau Kai To Limited	Discovery Bay ↔ Mui Wo
Licensed	Tsui Wah Ferry Service (H.K.) Limited	Aberdeen → Pak Kok Tsuen → Yung Shue Wan
Licensed	Winnertex Limited	Central ↔ Sok Kwu Wan

Source: Transport Department

Table 2 Passenger Ferry Services between Hong Kong and Macau, 2015

Operator	Route
TurboJET	Hong Kong Macau Ferry Terminal ↔ Outer Harbour Ferry Terminal
TurboJET	Hong Kong Macau Ferry Terminal ↔ Taipa Ferry Terminal
TurboJET	China Ferry Terminal ↔ Outer Harbour Ferry Terminal
TurboJET	Hong Kong International Airport (SkyPier) ↔ Outer Harbour Ferry Terminal
Cotai Water Jet	Hong Kong Macau Ferry Terminal ↔ Outer Harbour Ferry Terminal
Cotai Water Jet	Hong Kong Macau Ferry Terminal ↔ Taipa Ferry Terminal
Cotai Water Jet	China Ferry Terminal ↔ Outer Harbour Ferry Terminal
Cotai Water Jet	China Ferry Terminal ↔ Taipa Ferry Terminal
Cotai Water Jet	Hong Kong International Airport (SkyPier) ↔ Outer Harbour Ferry Terminal
Cotai Water Jet	Hong Kong International Airport (SkyPier) ↔ Taipa Ferry Terminal

Sources: TurboJET and Cotai Water Jet

Table 3 Summary Table: Technical and Environmental Assessment of Green Ferry Technologies

3-point scale (3-2-1-0) / (high-medium-low-nil)	LNG	CNG	Battery powered	Hybrid	Diesel-electric	Dual fuel	Light-weight materials	Scrubber	Fuel cell
TECHNICAL FEASIBILITY									
Readiness of the technology	●●○	●○○	●●○	●●○	●●○	●●○	●●●	●●○	●○○
Supporting infrastructure	○○○	○○○	●●○	●●●	●●●	○○○	●●●	●●●	○○○
Technical capacity	○○○	○○○	●●○	●●○	●●○	●○○	●●○	●●○	○○○
Human resources	○○○	○○○	●○○	●●○	●●○	○○○	●●○	●●○	○○○
Financial resources	●●○	●○○	●●○	●●○	●●○	●●○	●●○	●●○	●○○
Institutional capacity	●○○	○○○	●●○	●●○	●●○	●○○	●●○	●●○	○○○
Time frame	●○○	●○○	●●○	●●○	●●●	●●○	●●●	●●●	○○○
Risks and challenges	●○○	●○○	●●○	●●○	●●○	●○○	●●○	●●○	●○○
Subtotal of Technical Feasibility (max. 24)	***7***	***4***	***15***	***17***	***18***	***9***	***19***	***18***	***3***
ENVIRONMENTAL CONSIDERATIONS									
Emission	●●○	●●○	●●●	●●○	●○○	●●○	●●○	●○○	●●●
Fuel reduction	●●●	●●●	●●●	●●○	●●○	●●○	●●○	○○○	●●●
Fuel efficiency	●●○	●●○	●●●	●●○	●○○	●●○	●○○	●○○	●●●
Noise level	●●○	●●○	●●●	●●○	●○○	●○○	●○○	○○○	●●●
Waste	●●○	●●○	●○○	●○○	●●○	●●○	●●○	●○○	●○○
Subtotal of Environmental Considerations (max. 15)	***11***	***11***	***13***	***9***	***7***	***9***	***8***	***3***	***13***
INTEGRATED ASSESSMENT (Technical Feasibility + Environmental Considerations)	**LNG**	**CNG**	**Battery powered**	**Hybrid**	**Diesel-electric**	**Dual fuel**	**Light-weight materials**	**Scrubber**	**Fuel cell**
Weighted Score of Technical Feasibility (max. 50)	***14.6***	***8.3***	***31.3***	***35.4***	***37.5***	***18.8***	***39.6***	***37.5***	***6.3***
Weighted Score of Environmental Considerations (max. 50)	***36.7***	***36.7***	***43.3***	***30.0***	***23.3***	***30.0***	***26.7***	***10.0***	***43.3***
TOTAL SCORE (max. 100)	**51**	**45**	**75**	**65**	**61**	**49**	**66**	**48**	**50**
Ranking	5	9	1	3	4	7	2	8	6

●●● = High potential ●●○ = Medium potential ●○○ = Low potential ○○○ = Absence of potential