ELEMENT: EUROPEAN TIDAL ENERGY IMPACT ANALYSIS REPORT

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Contents

EXECUTIVE SUMMARY

This report provides insight on the socio-economic impact of tidal turbines on Europe. There are 3 main themes that are addressed:

1. The European socio-economic impact;
2. The European tidal turbine potential;
3. The European local content impact.

Theme 1 confirms that tidal energy deployment has mostly major positive socio-economic impact. This section compares two tidal energy projects, one in the UK (EnFAIT in the Shetland Islands) and one in France (ELEMENT in the Étel estuary). These projects show no negative or neutral effects on identified socio-economic factors, moreover, none are expected for Europe. In fact, tidal energy only brings minor to major positive effects. The most positive impacts can be seen in the socio-economic areas below:

- Employment and businesses and
- Effects on the regulatory framework.

Moreover, if a tidal energy project is coupled with a Renewable Energy Community (REC), then major positive effects are also expected for:

- Standard of living / housing conditions / vulnerable groups;
- Educational change;
- Social cohesion;
- Perception of the sea as a tidal energy resource.

Indeed, the benefits to the socio-economic landscape are three times more important when including an energy community in a project that installs tidal energy. The local acceptance of this renewable source will therefore be increased, and its energy will be used more efficiently and cost-effectively thanks to the educational change and awareness-raising a REC can foster.

Theme 2 identifies the countries in Europe that have the highest potential to install tidal turbines at their coast and in their estuaries or rivers. Out of a selection of 18 countries, the highest potential is seen in UK, France, Norway and Italy. The methodology used open-source data which is unfortunately scarce and has low granularity. If tidal and river speed data was more freely available, the identification of countries for this specific technology could be confirmed and potentially enlarged. If the speed and depth data was also available per specific coast, estuary and river, the identification would be able to pin-point specific high-capacity sites.

Finally, Theme 3 includes a local content study for France, UK, Italy and Norway that shows the direct, indirect and induced FTE (full-time equivalent) and GVA (gross value added) created per MW (megawatt) installed in each country and for high (100%), medium (% used in ELEMENT deliverable D12.3) and low (50%) local content scenarios. The study confirms that there are extra jobs and GVA to be created by deploying tidal projects in these countries. The study is focused on small-scale demonstrator projects that currently require high CAPEX and OPEX. It does not consider large GW (gigawatt) deployment, which would reduce expenditure per MW. Once the technology is mature, costs will be reduced, and this will diminish the direct, indirect and induced FTE and GVA impact per MW installed, although the overall positive impact of installing GW of tidal power would be significantly increased.

In the study's low scenario, per MW of small-scale, early-stage technology, the results on the local content show:

- During the development and construction phase, an increase of up to:
    - 47.4 FTE:
        - 14 direct,
        - 14.1 indirect,
        - 19.3 induced, and
    - 13.7 million € of GVA:
        - 1.5 direct,
        - 4.5 indirect,
        - 7.7 induced, and then
- During the operational and maintenance phase:
    - 2.9 FTE:
        - 0.8 direct,
        - 1 indirect,
        - 1.2 induced, and
    - 0.9 million € of GVA yearly:
        - 0.1 direct,
        - 0.3 indirect, and
        - 0.5 induced.

As can be seen, there are higher impacts in indirect and induced FTE and GVA than there are in direct FTE and GVA results. The direct results refer to the first-line business-sector that is directly involved in the construction and/or operational phases of the tidal energy projects. The indirect jobs are a second-line support used by the first line business-sector to finalise the construction and/or operational work. This is generally done through business-to-business (B2B) contracts. Finally, the induced jobs reflect general employment in the country that is created by the leisure and living costs of both first- and second-lines' business-sectors' employees.

Furthermore, when considering the local content impact, as the ELEMENT and EnFAIT projects have shown in Theme 2, even when goods and services are produced outside of the country where the tidal project is located, the supply chain companies are in Europe and therefore contribute to a full European local content distribution. The job and GVA creation therefore continue to positively impact Europe even when the tidal project's supply chain is not completely local. This explains why a 100% local content scenario has been considered in the study: these high scenario results can be seen as an indication of the impact to the European employment and business impact. These figures are:

- During the development and construction phase, an increase of up to:
    - 94.8 FTE:
        - 28 direct,
        - 28.2 indirect,
        - 38.6 induced, and
    - 27.4 million € of GVA:
        - 3.1 direct,
        - 8.9 indirect,
        - 15.4 induced, and then
- During the operational and maintenance phase:
    - 6.0 FTE:
        - 1.6 direct,
        - 1.9 indirect,
        - 2.4 induced, and
    - 1.7 million € of GVA yearly:
        - 0.2 direct,
        - 0.5 indirect, and
        - 1.0 induced.

INTRODUCTION

A Funding Grant was awarded from the European Union's Horizon 2020 research and innovation programme to develop and validate an innovative tidal turbine control system, using the tidal turbine itself as a sensor, to deliver a step change improvement in the performance. This will demonstrate Effective Lifetime Extension in the Marine Environment for Tidal Energy (ELEMENT), driving the EU tidal energy sector to commercial reality. This was in response to the call LC-SC3-RES-11-2018: Developing solutions to reduce the cost and increase performance of renewable technologies.

This document pertains to work package 12 (WP12) that is focused on the socio-economic impact assessment of tidal energy and is led by IDETA. As per the ELEMENT Grant Agreement, the objectives of WP12 are to:

- Assess the socio-economic impacts of the tidal industry at the regional and national level in France.
- Conduct a French market analysis, covering: potential sites, policy advisory framework, consenting, recommended route to market.
- Conduct a supply chain analysis in France, covering: potential suppliers, local content assessment, ports assessment, development of a dedicated tool to assess the local content for a tidal array, recommended targets.
- Identify and assess the potential impact of up to ten tidal, estuary and run-of-river energy sites in France.
- Extrapolate findings to assess the wider potential socio-economic impact of the tidal energy industry, with a focus on European industry and local communities.

Within WP12, there are multiple tasks. This document is associated to task 12.4 (T12.4) that refers to the "European Impact Analysis" and consists in the analysis of the socio-economic impact of tidal energy in Europe. It is led by IDETA with the support of INNOSEA, NOVA, GUINARD and OREC.

This European Impact Analysis Report is divided into 3 main themes:

- Theme 1 summarises the socio-economic appraisal results between the ELEMENT project in the Étel estuary in France and the EnFAIT project in the Shetland Bluemull Sound in the UK. It also includes the results per socio-economic topic for Europe.
- Theme 2 highlights European countries where there is a potential for tidal or run-of-river energy deployment.
- Theme 3 provides a local content study that provides the job and GVA creation per installed MW of tidal energy project deployed in the European countries identified in Theme 2.

THEME 1: EUROPEAN SOCIO-ECONOMIC IMPACT

Theme 1 Introduction

The ELEMENT project exploits synergies with another ongoing European Union's Horizon 2020 tidal energy project called EnFAIT – Enabling Future Arrays in Tidal. The EnFAIT Funding Grant was awarded from the European Union's Horizon 2020 research and innovation programme in January 2017 to continuously improve operations and maintenance of an array of tidal turbines in Shetland, Scotland, to drive tidal energy towards competing on a commercial basis with alternative renewable sources of energy. This was in response to the call LCE-15-2016: Scaling up in the ocean energy sector to arrays to generate significant learning through demonstration of cost-effective tidal arrays.

The ELEMENT deliverable 12.2 used the same socio-economic classification and appraisal system as the EnFAIT project's deliverable 8.9 with the aim of streamlining the community impact assessment. At this stage in ELEMENT deliverable 12.4, the assessment done in D12.2 is compared against the EnFAIT results to highlight the differences and similarities between both projects, which are based in different countries. The ELEMENT project's regional assessment focuses on the Étel estuary communities in Brittany, France, while the EnFAIT project focuses on communities in the Shetland Islands in Scotland, United Kingdom. There is about 1,500 km between the two locations. Below figures 1 and 2 show the maps of the two project's test sites, copied from deliverable 4.1 published by FEM (France Energies Marines) for the ELEMENT project.

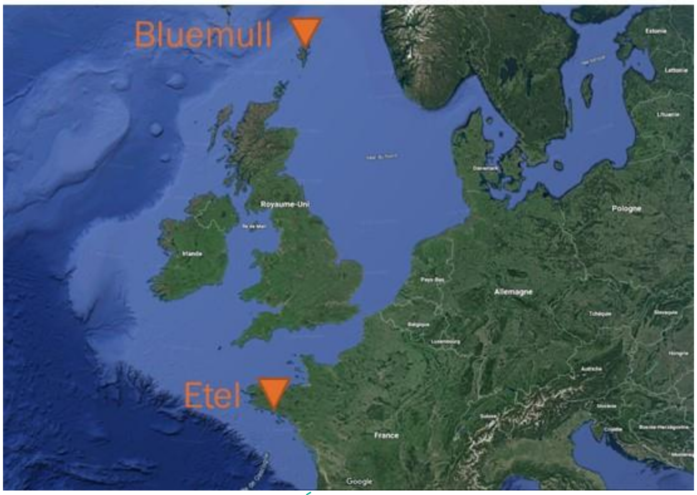

Figure 1 – Locations of the two test sites: the Étel estuary for ELEMENT and Bluemull sound for EnFAIT

Figure 2 – Closer look on location and tidal turbine (NOVA M100 in Bluemull) and (NOVA RE50 in Étel).

An initial environmental and socio-economic appraisal of the effects of tidal energy was completed as part of the EnFAIT project as deliverable 8.9 by RSK at a UK and EU level in 2018. A final appraisal will be completed at the end of the EnFAIT project to note any changes.

The ELEMENT deliverable 12.2 used the same socio-economic model as the above-mentioned EnFAIT deliverable to appraise the effects of tidal energy in the region around the Étel estuary. This chapter of ELEMENT deliverable 12.4 will now observe the differences between the appraisal results at the UK, French and European level by comparing the ELEMENT results with the above-mentioned EnFAIT results.

The appraisal categorises the potential effects by using a visual classification.

- Major positive effect: ✓✓
- Minor positive effect: ✓
- Neutral effect: 0
- Minor negative effect: X
- Major negative effect: XX
- Uncertain effect: ?

Below Table 1 summarises the expected results for the ELEMENT project's Étel region as well as the EnFAIT project's Shetland Islands. The results show no negative socio-economic effects. On the contrary, the effects are all positive with a major positive effect on employment and business. In addition, should the tidal energy be produced for a Renewable Energy Community (REC), extra positive impact would be felt, as shown in the table by the "+✓" symbols in the ELEMENT column. Although the EnFAIT project did not consider at its start the impact for a REC, this current ELEMENT report already includes the extra positive impact that would also be felt in Shetland or in Europe in general if a REC was created with the tidal energy. This is shown in the table by the symbol "(+✓)".

Appraisal date	**May-2021**	**Dec-2018**	**Dec-2018**
Project	ELEMENT	EnFAIT	EnFAIT
Appraised region	Étel, France	Shetland, UK	Europe
Socio-economic topics			
Demographics	✓	✓	✓
Standard of living / housing conditions / vulnerable groups	✓+✓	0(+✓)	✓(+✓)
Educational change	✓+✓	✓(+✓)	✓(+✓)
Social cohesion	✓+✓	0(+✓)	✓(+✓)
Perception of the sea as a tidal energy resource	✓+✓	✓(+✓)	✓(+✓)
Recreational and tourism activities	✓	0	0
Employment and business	✓✓	✓✓	✓✓
Industrial strategy and rural regeneration	✓	✓	✓
Commercial shipping and navigation	✓	0	?
Effects on the regulatory framework	✓	✓✓	✓✓

Table 1 – Summary of EnFAIT and ELEMENT socio-economic appraisal results

The explanation for the results of each topic is further explored below in sub-sections for each region. Extracts from previous reports are included unedited below, with comments from May 2022 added in *[square brackets]*. These sub-sections also provide an updated discussion of the current May 2022 socio-economic situation in Europe.

Demographics

ELEMENT D12.2 publication on demographics 2021 Étel, France ✓

The development of new technology has the potential to increase the offer of new skilled local jobs. This is interesting for the Belz commune that continues to increase in population year after year. So far, the employment impact from the ELEMENT project has been limited to CHBS as direct project partner. Moreover, the future test of the tidal turbine within Work Package 10 is temporary. Indeed, the turbine will be decommissioned after the estuary test phase. During WP10, IDETA will note the local impact to the workforce, economic growth through expansion of the supply chain, construction or maintenance, as well as any population migration flows.

EnFAIT D8.9 publication on demographics 2018 Shetland, UK ✓

The continuing out-migration of young and qualified people from Shetland to the Scottish mainland and other parts of the UK is of concern to stakeholders.

The development of new technology has the potential to reduce out-migration through the provision of skilled local jobs. The direct employment impact has been relatively limited to date, however, future expansion of this and other tidal sites in Shetland will lead to increased opportunities for skilled local employment for building and servicing tidal energy projects.

The project has stimulated economic growth and skilled employment amongst local businesses through the expansion of the supply chain. For example, revenue from the array has helped Shetland Composites to expand its premises and workforce. To date, over 50% of project spend has gone to companies in Shetland or Orkney and over 30 local companies have been involved in the project. The capital spend on Shetland-based companies through the supply chain is expected to encourage people to stay in Shetland.

Summary: At a project-level, the effects on demographics are positive as the development of new technology and increased capital spend will encourage people to stay in Shetland.

EnFAIT D8.9 publication on demographics 2018 Europe ✓

Summary: At an EU-Level the effects on demographics are also positive as the technology is particularly suited to rural and remote areas that may be experiencing a similar demographic trend of out-migration *[as explained for Shetland]*.

ELEMENT D12.4 review on demographics ✓

The French results of May-2021 and the Shetland and European results of Dec-2018 are identical and continue to be true in May-2022. The development of new technologies still contributes to offer new skilled jobs and thus supporting the working population & their families to stay in the regions where these technologies are deployed. This is especially important in cases when the technology is deployed in remote rural areas with out-migration issues. For Shetland, the latest direct employment impact to date includes two full time NOVA employees in Shetland and a broad local supply chain including blades, vessels, engineering, environmental and logistic services. Future expansion of this and other tidal sites in Shetland will lead to increased opportunities for skilled local employment for building and servicing tidal energy projects.

Standard of living / housing conditions / vulnerable groups

ELEMENT D12.2 publication on Standard of living / housing conditions / vulnerable groups 2021 Étel, France ✓+✓

Nearly 39% of Belz households, and 30% of Étel ones, use electricity for their heating needs. If the Levelized Cost of Energy (LCOE) of tidal projects continues to diminish with projects such as EnFAIT and ELEMENT, and by consequence the price of the tidal energy can be sold at a cheaper price than the actual market or EDF prices, then this would increase the communities' consumption power, by allowing the unspent money in being used for other expenditures or in heating needs, therefore increasing standard of living. Such an increase can also benefit housing conditions should the consumer decide to spend money on improving the energy efficiency of its household, either by replacing appliances and lightbulbs for less energy-consuming ones or by isolating their houses and hence reducing their heating needs. There are multiple ways the tidal electricity, for general power and/or heating, can be sold. This can be through a specialised contract with a green energy provider such as "Enercoop", or by creating a Renewable Energy Community (refer to the REC study within document D12.2).

The "Enercoop" provider is active all over France. It is a citizen association that aims to provide 100% green energy to consumers. In April 2021, according to their website https://www.enercoop.fr/nos-cooperatives/bretagne, in Brittany, there were 32 producers generating 52 MWh/year and 10,000 consumers linked to "Enercoop Bretagne". The Guinard Energies Nouvelles' tidal turbine mentioned in the tidal energy statistics was one of these producers from February 2019 until the end of their project in 2020. This turbine was installed in the Étel estuary.

In parallel, the creation of a REC can help provide tidal energy at an attractive price to vulnerable groups. Indeed, RECs are community-based and in some cases led by local authorities who wish to offer cheap green electricity to people in need.

In addition, by providing the grid with decentralised electricity, consumers can be less impacted by any power cuts from the central generation network. This increase in electricity resilience ensures consumers are not disrupted by power outages, thus creating a better comfort of living.

EnFAIT D8.9 publication on standard of living / housing conditions / vulnerable groups 2018 Shetland, UK 0(+✓)

Local people refer to the 'Shetland price factor' as goods and services are transported to the archipelago from the Scottish mainland. Transport involves using a ferry from the Scottish mainland to Sumburgh, and then road transport and ferries between islands to reach their destination. Costs gradually increase the further away the consumer is from the source of the product. This price factor contributes to the high cost of living in Shetland compared with mainland Scotland and other parts of the UK.

Shetland has an average fuel poverty rate of 43%. Fuel poverty is higher amongst those living in the North Isles, and among elderly people over the age of 60; 68% of whom are estimated to be living in fuel poverty. Shetland has a cold climate and experiences high wind speeds, resulting in homes requiring heating throughout most of the year. High wind speeds contribute to the wind chill effect and exploits cracks and gaps in houses, reducing indoor temperatures and lowering energy efficiency. Outside of Lerwick, electricity or oil is used as the heating fuel. There is a district heating scheme in Lerwick linked to an energy from waste plant; there is no public gas distribution system on Shetland.

If the energy generated by the tidal array were to be provided at a cheaper price to households, then this could increase standards of living and housing conditions as people would have more money available for other items, apart from heating. This would also contribute towards a reduction in fuel poverty. However, due to the way in which the UK energy market is regulated it is not possible to use public infrastructure (SSE's cabling network) to provide households with cheaper energy.

The provision of low-carbon energy is aligned with SIC's strategy to improve the energy efficiency of residential properties and businesses. The aim is to increase energy generation from renewable energy sources whilst improving the way in which energy is consumed. SIC's grants are currently being used to insulate homes and increase the quality of windows which improves housing condition. However, this initiative lies outside the scope of the EnFAIT Project.

Building on the results of the community engagement activities completed during preparation of the Initial ESEA Report, NOVA is considering additional ways that the project can be used to more directly support vulnerable groups.

Summary: At a project-level, there will be no noticeable effects on the current standard of living or housing conditions.

EnFAIT D8.9 publication on standard of living / housing conditions / vulnerable groups 2018 Europe ✓(+✓)

At an EU-level, tidal arrays have the potential to generate positive effects to the standard of living and housing conditions if the cost of energy to the household or business consumer decreases, although this does depend on extent to which tidal energy is cheaper.

ELEMENT D12.4 review on standard of living / housing conditions / vulnerable groups ✓+✓

When green electricity is produced locally, it contributes to providing competitive energy prices and increasing the region's energy resilience. This is particularly needed in the 2022 socio-economic climate where the European population has been confronted with unprecedented high energy prices. As stated by the European Commission on 8-Apr-2022 in the "Quarterly electricity market report"[1]:

"The quarterly electricity market report points out that after the dramatic, pandemic-related fall in 2020, EU consumption in the last quarter of 2021 rose back to levels seen in the same period of 2019. This post-covid rise in demand has driven electricity prices to unprecedented highs. The European Power Benchmark averaged 194 €/MWh in Q4 2021 – equivalent to 400% higher than Q4 2020 and an 85% increase from Q3 2021."

Moreover, the recent Russian invasion of Ukraine has further increased already high energy prices. The war has also highlighted the need for Europe to secure its energy supply locally in Europe. For example, around 40% of the European import of natural gas comes from Russia[2]. This demonstrates that Europe needs to increase its energy resiliency by using indigenous energy sources, and thus being less impacted by non-European production. As the October 2021 recommendations from the European Commission state in "Tackling rising energy prices: a toolbox for action and support"[3], one of the structural medium-term measures to reduce energy prices is to "step up investments in renewable energy".

The EnFAIT 2018 assessment did not consider the potential of creating a Renewable Energy Community (REC) to further confirm better energy efficiency and lower energy prices. As the EC's "Tackling rising energy prices: a toolbox for action and support" also confirms, another structural

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[1] https://ec.europa.eu/info/news/quarterly-market-reports-highlight-unprecedented-gas-and-power-prices-eu-q4-2021-2022-apr-08_en
[2] https://www.consilium.europa.eu/en/policies/energy-prices/
[3] https://op.europa.eu/en/publication-detail/-/publication/a6651e1b-3089-11ec-bd8e-01aa75ed71a1/language-en/format-PDF

medium-term measure to reduce energy prices is to "Further boost the role of consumers in the energy market, by empowering them to switch suppliers, receive advice about how to reduce energy consumption and bills, generate their own electricity, and join energy communities".

To conclude, now more than ever, once the LCOE of tidal energy is sufficiently low – thanks to projects like ELEMENT and EnFAIT – this new renewable energy source will be able to support households and companies in providing competitive energy prices that will contribute to increasing the standard of living, including vulnerable groups, and through a domino-effect allowing money to be saved and then redistributed to improve, for example, housing conditions. Not only will tidal energy prices become more competitive with conventional energy prices, but this tidal energy will also be available consistently at known periods of the day, every day of every year, and thus allow consumers to easily synchronise their electricity needs with production. This synchronisation will reduce costs further since it is cheaper to consume energy at the same time as it is produced locally. Combining this with the creation of RECs that share tidal energy and raise-awareness on better energy management (by saving energy and avoiding energy wastage), these RECs will further intensify the positive effect of this new renewable energy source on the standard of living.

Educational change

ELEMENT D12.2 publication on educational change 2021 Étel, France ✓+✓

Children, students and households can receive ecology lessons, energy efficiency coaching and participate in tidal turbine site visits to allow them to be more conscious of energy and ecology issues. This could be translated by age-groups into below educational topics:

- For young children, renewable energy sources, including tidal, could be an eye-opener on environmental and ecological topics.

- For secondary school children, the interest can be increased by enabling practical discussions on environmental and ecological topics to build future citizens. It can also attract children into considering related professions in these topics through the study of mechanical and electrical engineering, environmental sciences, management or other related courses.

- For university students, the theme can be part of focused research on tidal power and renewable energies as well as the continued pursuit of building a career in related opportunities.

- For households, the subject allows them to take part in the green energy transition, increase their energy efficiency and reduce their CO_2 emissions. In the case of the creation of a REC, the participants would also be more aware of when to consume efficiently. This is because by using the tidal energy when it is produced, the participants will increase their green energy self-consumption rate, thus increasing their self-coverage rate as well as reducing their electricity bill.

EnFAIT D8.9 publication on educational change 2018 Shetland, UK ✓+✓

Stakeholder engagement found that young people in Shetland who choose to enter into further education studies are increasingly focusing on creative media and similar types of courses, rather than vocational and practical courses that Shetland needs, such as mechanics and engineering. Shetland presently relies on people from the mainland to provide a range of technical services. For example, SIC recently purchased a fleet of electric cars which local garages were initially (the issue has since been rectified) unable to service or fit replacement parts due to a lack of knowledge of this type of new technology.

The project has raised awareness about renewable energy technology amongst young people in schools. Raising awareness of a new technology contributes to the development of society and is a positive effect arising from the project. The development of new technology in Shetland could inspire more young people to study mechanical and electrical engineering, environmental sciences, and practical courses, which will benefit the local economy and could stimulate further technological investment.

Summary: At a project *[and an EU]*-level, the effects are positive as knowledge of the project's technology could inspire young people to follow engineering and science-based courses.

EnFAIT D8.9 publication on educational change 2018 Europe ✓+✓

Summary: At *[a project and]* an EU-level, the effects are positive as knowledge of the project's technology could inspire young people to follow engineering and science-based courses.

ELEMENT D12.4 review on educational change ✓+✓

If the 2018 assessment had considered the creation of an energy community, it would also have added an extra positive effect to educational change. The 2022 review therefore observes that the impact on education is identical in Shetland, in Étel and in Europe in general, with a positive impact in general and an extra positive impact if a REC is animated.

Social cohesion

ELEMENT D12.2 publication on social cohesion 2021 Étel, France ✓+✓

The Work Package 12 tasks related to local community engagement should increase social cohesion. This will be monitored and shared in the ELEMENT project.

As touched on during the above-mentioned Standard of Living topic, renewable energy can be provided to a community through the Renewable Energy Community (REC) model. Such a model would become a citizen activity and enhance community spirit. It allows a group of people to join together with the single goal of acting towards a greener ecological world. The community can then also consider other activities that can contribute to energy efficiency, reduction in carbon generation, reduction in waste and other ecological awareness.

In parallel, green-energy providers like Enercoop also have a potential for social cohesion because these associations are led by citizens. For example, Enercoop is a cooperative society of collective interest (SCIC or société cooperative d'intérêt collectif in French). Enercoop Bretagne is comprised of 4020 members who bring capital for renewable projects. Moreover, 24 communities work with Enercoop Bretagne towards the energy transition.

EnFAIT D8.9 publication on social cohesion 2018 Shetland, UK 0(+✓)

The project has the potential to enhance Shetland's already very strong local identity and increase social cohesion as they are host to a world-first, demonstrator tidal energy project. However, interactions with local people during preparation of the Initial ESEA Report indicate that locals are not generally motivated by the 'world-first' factor, and instead understandably focus on more immediate concerns such as the high cost of living and electricity in Shetland and economic development. If the scale of the tidal array were to expand in the future and contribute a significant quantity of renewable energy and economic development to Shetland, then this perception could change.

Summary: At a project-level the effects of the tidal array on social cohesion are neutral.

EnFAIT D8.9 publication on social cohesion 2018 Europe ✓(+✓)

Summary: Effects at an EU-level are unknown though they could be positive in other locations *[compared to Shetland]*, particularly if the tidal array were to contribute a significant quantity of renewable energy or economic impact.

ELEMENT D12.4 review on social cohesion ✓+✓

If the 2018 assessment had considered the creation of an energy community, it would also have added an extra positive effect to social cohesion. The 2022 review therefore considers that the impact on social cohesion is identical in Shetland, in Étel and in Europe in general, with a positive impact in general and an extra positive impact if a REC is animated.

Moreover, since 2018, the EnFAIT project and NOVA's tidal array in Bluemull Sound have been frequently mentioned in the local Shetland news. Shetlanders have been made more aware of tidal energy in these 4 last years. They know that tidal energy is powering local homes and businesses. NOVA's deployment in Mar-2021 of an electric vehicle charging point at Cullivoe harbour has further benefitted the local community who now has its first EV charge point in Yell Island, and which is powered by tidal energy – an event which achieved worldwide coverage. These recent events have had a positive impact on social cohesion.

Perception of the sea as a tidal energy resource

ELEMENT D12.2 publication on Perception of the sea as a tidal energy resource 2021 Étel, France ✓+✓

GUINARD has in the past deployed two of their tidal turbines in the Étel estuary. The ELEMENT project will also test a NOVA turbine at the site. These projects have and should continue to raise awareness that estuaries, as well as coastal and river waterways, can generate energy by harnessing the tide and water speed. The future local community engagement activities will include ways to disseminate this information further to the region and local communities.

In addition, the creation of a tidal REC would highlight this perception even more because the REC participants would be directly aware that the estuary current is generating their green electricity.

EnFAIT D8.9 publication on perception of the sea as a tidal energy resource 2018 Shetland, UK ✓(+✓)

The project has raised awareness associated with the potential for the sea to provide energy through tidal arrays. Based upon local stakeholder perceptions gathered during preparation of the Initial ESEA Report, the coastal and marine environment is increasingly seen as a reliable source of renewable energy, in addition to a resource for fishing and vessel navigation.

Summary: At a project *[and EU-]*level, the tidal array is enabling people to view the sea as a source of tidal energy and this change in perception is a minor positive effect.

EnFAIT D8.9 publication on perception of the sea as a tidal energy resource 2018 Europe ✓(+✓)

Knowledge of the project is being disseminated throughout the EU, through the EnFAIT website, regular press releases, presentations and other communication tools. This is raising awareness across Europe about the potential for tidal energy to contribute towards future low-carbon energy generation.

Summary: At a *[project and]* EU-level, the tidal array is enabling people to view the sea as a source of tidal energy and this change in perception is a minor positive effect.

ELEMENT D12.4 review on perception of the sea as a tidal energy resource ✓+✓

If the 2018 assessment had considered the creation of an energy community, it would also have added an extra positive effect to the perception of the community on the perception of the sea as an energy source. The 2022 review therefore considers that the impact is identical in Shetland, in Étel and in Europe in general, with a positive impact in general and an extra positive impact if a REC is animated.

The impact assessment results in 2018 for Shetland and Europe remain identical for Étel in 2021. The inhabitants of the regions involved in the projects are aware that the sea is a tidal energy resource. Both Shetland and Brittany are territories with significant potential for tidal energy.

Recreational and tourism activities

ELEMENT D12.2 publication on recreational and tourism activities 2021 Étel, France ✓

Tidal turbines can be placed underwater and therefore have no visual impact on the scenery, to the contrary of wind turbines, for example. This should remove barriers in the construction of this type of renewable energy source, compared to wind or solar that are more visible.

In addition, tidal turbines do not induce noise that propagates in the air and therefore do not create any acoustic problems for local residents in the case of installations close to the coast such as gulfs and estuaries. Moreover, IDETA suggests placing an information board close to the tidal turbine in order to stimulate the site as an attraction point for locals and tourists.

EnFAIT D8.9 publication on recreational and tourism activities 2018 Shetland, UK 0

As the tidal array is submerged, there is no visual or landscape impact from the turbines.

In the future if visitor resources were to be established at Cullivoe Pier, tourists would be able to learn about this new type of technology and understand how the tidal array is being operated.

A large proportion of Shetland's visitors are nature tourists, motivated to travel to Shetland by a combination of natural scenic beauty, coastal wildlife and the rugged landscape. These types of visitors are likely to be interested in new types of renewable energy technology. Based on the feedback from the ESEA Survey, NOVA is considering options for developing visitor resources at the site.

Summary: At a project *[and EU]*-level, the tidal array is not having any effect on recreational and tourism activities. The future construction of a visitor resource would attract people to visit the site and learn about this new type of renewable energy technology.

EnFAIT D8.9 publication on recreational and tourism activities 2018 Europe 0

At a *[project and]* EU-level, the tidal array is not having any effect on recreational and tourism activities. The future construction of a visitor resource would attract people to visit the site and learn about this new type of renewable energy technology.

ELEMENT D12.4 review on recreational and tourism activities ✓

The Étel impact assessment on the topic of tourism and recreational activities took the view that the deployment of tidal turbines, that are unseen and unheard, has a positive impact on the environment compared to other energy sources such as wind turbines, or even conventional energy production using nuclear or gas. As such, it was assessed that the impact of tidal energy on tourism and recreational activities was positive.

Moreover, another positive outcome on tourism is the news of tidal turbine deployments in coastal locations. The publicity of the deployment indirectly makes publicity on the location where it is deployed. People who know about tidal energy projects therefore consider the projects' coastal and idyllic locations as the potential site for their future vacation.

A third positive tourist effect can be harnessed by setting up a local notice board, or even a demonstrator in a dedicated office. This would enable interested foreigners to visit the site for leisure or business. These visitors would potentially eat, drink and sleep in the region, thus increasing local restaurants and hotels' income. The visitors could also envisage visiting other local tourist and recreational activity sites.

In addition, an electric vehicle charging point has been installed connected to the array in Shetland, allowing visitors to charge their cars using tidal power. This development gained widespread publicity in the international media and has proven to be a popular local attraction, bringing tourists to the site.

To conclude, by taking the 2021 Étel approach, the Shetland and Europe impact assessment would also have been positive.

Employment and business

ELEMENT D12.2 publication on employment and business 2021 Étel, France ✓✓

In general, employment in the tidal energy sector can be promoted by sharing the related job opportunities available in the tidal business as well as in the supply chain. Professionals can be invited to speak on the subject in job forums. This is particularly relevant in Étel and Belz that have an unemployment rate of 10.3% and 11.6% respectively.

In parallel, INNOSEA's deliverable 12.3 on French site assessment shares data on the job content and how different businesses can support the capital expenditure (CAPEX) and operational expenditure (OPEX) of tidal energy development projects. In addition, other businesses can be impacted indirectly by these tidal projects. Below table 2 provides a summary of the businesses expected to see an increase in activity. This reflects a major positive effect on employment and business activities.

Businesses by economic centre (NACE codes)	Employment estimation
C25 – Manufacture of fabricated metal products, except machinery and equipment	14% of CAPEX
C27 – Manufacture of electrical equipment	14% of CAPEX
C28 – Manufacture of machinery and equipment	28% of CAPEX
C33 – Repair and installation of machinery and equipment	49% of OPEX
D35 – Electricity, gas, steam and air conditioning supply	1% of CAPEX & 1% of OPEX
F42 – Civil engineering	5% of CAPEX
F43 – Specialised construction activities	Indirect
H49 – Land transport and transport via pipelines	Indirect
H50 – Water transport	16% of CAPEX & 50% of OPEX & Indirect
H51 – Air transport	Indirect
H52 – Warehousing and support activities for transportation	Indirect
I55 – Accommodation	Indirect
I56 – Food and beverage service activities	Indirect
J58 – Publishing activities	Indirect
J62 – Computer programming, consultancy and related activities	Indirect
J63 – Information service activities	Indirect
K64 – Financial service activities, except insurance and pension funding	8% of CAPEX
K65 – Insurance, reinsurance and pension funding, except compulsory social security	Indirect
L68 – Real estate activities	Indirect
M71 – Architectural and engineering activities; technical testing and analysis	14% of CAPEX
N79 – Travel agency, tour operator and other reservation service and related activities	Indirect
N81 – Services to buildings and landscape activities	Indirect

Table 2 – Impact of tidal business on French employment

EnFAIT D8.9 publication on employment and business 2018 Shetland, UK ✓✓

In the first 18 months of the EnFAIT project, NOVA's supply chain has been 100% from within the EU, 84% from Scotland and 60% from the Highlands and Islands region. Businesses that have been involved in the supply chain have significantly benefitted from the project. For example, Fred Gibson of Shetland Composites (who manufacture the turbine blades) has been able to continue his business operations, and the additional business revenue has contributed to his decision to expand the workforce and construct a new warehouse facility. His role as a supplier has also increased his technical knowledge of turbine blade manufacture which has already led to new exports and will benefit his business in the future both with NOVA, and other clients.

If energy generated from the tidal array is provided to other users of Cullivoe Pier through a "private wire", micro-grid network at cheaper rates than grid electricity, this will benefit other pier users through reduced expenditure on energy. NOVA is considering options for supplying local consumers with electricity from the tidal array.

Summary: At a project *[and EU]*-level, the tidal array has a positive effect on employment and business.

EnFAIT D8.9 publication on employment and business 2018 Europe ✓✓

Summary: At a *[project and]* EU-level, the tidal array has a positive effect on employment and business.

ELEMENT D12.4 review on employment and business ✓✓

The impact of tidal energy on employment and business has been in both projects extremely positive. This major positive effect continues to be a reality for the two projects. Both projects have a supply chain that comes from Europe and therefore positively impacts the European employment and businesses.

For ELEMENT, the supply chain so far has positively impacted the following 8 European countries (EU in bold):

- **Belgium**,
- **France**,
- **Germany**,
- **Ireland**,
- **Netherlands**,
- Norway,
- **Sweden**, and
- UK.

For EnFAIT, the supply chain positively impacts the below 20 European countries (EU in bold):

- **Austria**,
- **Belgium**,
- **Bulgaria**,
- **Czech Republic**,
- **Denmark**,
- **Estonia**,
- **Finland**,
- **France**,
- **Germany**,
- **Greece**,
- **Ireland**,
- **Italy**,
- **Luxembourg**,
- **Netherlands**,
- **Poland**,
- **Romania**,
- **Slovakia**,
- **Spain**,
- **Sweden**, and
- UK.

Industrial strategy and rural regeneration

ELEMENT D12.2 publication on industrial strategy and rural regeneration 2021 Étel, France ✓

CHBS located in Belz is working directly on the ELEMENT project. They proactively onboarded as project partners to this European Union's Horizon 2020 research and innovation programme and lead specific tasks and deliverables in the project. Their engagement in the project is increasing their network as well as supporting their future business needs.

In addition to providing jobs and work experience to the unemployed, as mentioned in the above employment and business topic, there are no other special needs to regenerate the area of Étel and Belz. Both communes have a good standard of living and a low poverty rate. The Étel commune is a densely populated small tourist location, prone to regular tourists staying in second homes. As for the Belz commune, it is a prospering community. Nevertheless, both communes can benefit from the decentralised electricity source produced by tidal that provides electricity resilience against central power outages and from diversifying the local economy.

Brittany, with an important deficit in terms of energy production and a high tidal current resource potential, has a real interest in developing decentralized units of marine renewable energy.

EnFAIT D8.9 publication on industrial strategy and rural regeneration 2018 Shetland, UK ✓

NOVA has recently completed the fabrication of their new workshop in Edinburgh. This is an example of how the project has resulted in regeneration where an old warehouse built in the 1970s is stripped down and upgraded to support NOVA's future activities, as the company moves away from a research and development model into a business growth and operational and maintenance phase. The new workshop provides improved facilities, more space and is designed to support multiple turbine maintenance activities simultaneously.

In addition, supplier Shetland Composites has expanded their business and headcount in Shetland; just one of over 30 local suppliers benefiting from the project.

The project is a good example of pan-European cooperation, where European companies are at the leading edge of the development of new, low-carbon technologies.

If the commerciality of the tidal array is demonstrated by EnFAIT and the tidal array scales up, then NOVA would create a maintenance hub in Shetland and the project could contribute towards rebalancing the UK economy, where economic activity is boosted in the outer reaches of the UK, rather than being solely focused on London and Edinburgh. Development of new investment areas outside of major cities could create 'hotspots' of economic growth to occur, particularly in remote areas such as Shetland.

Summary: At a project *[and EU]*-level, the tidal array has a minor positive effect on UK industrial strategy and rural regeneration. The effects would be greater if the commerciality of the technology is demonstrated and the tidal array is scaled-up in the future.

EnFAIT D8.9 publication on industrial strategy and rural regeneration 2018 Europe ✓

Summary: At a *[project and]* EU-level, the tidal array has a minor positive effect on UK industrial strategy and rural regeneration. The effects would be greater if the commerciality of the technology is demonstrated and the tidal array is scaled-up in the future.

ELEMENT D12.4 review on industrial strategy and rural regeneration ✓

The positive impact of tidal energy on local industrial strategy and rural regeneration remains in 2022. NOVA recently conducted their first full turbine service operation entirely in Shetland, forging the way for a future Shetland tidal energy maintenance hub which would bring increased economic benefits to the local economy.

Commercial shipping and navigation

ELEMENT D12.2 publication on commercial shipping and navigation 2021 Étel, France ✓

In order to receive consent by the local authorities, the RE50 tidal turbine that will be installed in Étel has to be placed in an area that will not interfere with navigation. This would be the case with any tidal project deployed in France. Moreover, NOVA has created two sizes of turbines (RE50 and M100) to potentially place the turbines in sufficiently deep waterbeds and still enable boats to pass above them.

EnFAIT D8.9 publication on commercial shipping and navigation 2018 Shetland, UK 0

The depth of the turbine blades is sufficiently below the sea surface to allow the safe passage of vessels.

There is a potential for subsea cables to cross areas used for lobster pots and the collection of other types of crustaceans, or for anchorage. However, this is not a problem when stakeholders are adequately consulted to ensure that cables are appropriately located, such as in the Bluemull Sound.

If the scale of the tidal array at Cullivoe were to increase in the future, consultation with fishermen and other stakeholders will be required to ensure that there remains no interference with fishing or navigation.

Summary: At a project-level there are no effect on commercial shipping and navigation.

EnFAIT D8.9 publication on commercial shipping and navigation 2018 Europe ?

Summary: Potential effects would need to be considered on a case-by-case basis at an EU-Level.

ELEMENT D12.4 review on commercial shipping and navigation ✓

The 2021 Étel viewpoint to assess the navigation impact as slightly positive was that the deployment of tidal turbines in water navigation paths can coexist with the existing commercial or private ships. The waterbed and the water can therefore both benefit the community by being a means of energy supply and of travel route at the same time. Both activities can coexist together. By considering this topic in this light, the Shetland and European impact assessment results are also positive.

Effects on the regulatory framework

ELEMENT D12.2 publication on effects on the regulatory framework 2021 Étel, France ✓

Brittany is supportive of tidal energy projects, as can be confirmed by the previously shared statistics in section 1 of D12.2. The Brittany and Normandy coasts are considered to have high currents and be great prospects for tidal energy, however water speed data is not readily available for estuaries and rivers. It is therefore useful for local authorities to consent to research and development projects that experience tidal energy generation on estuary and run-of-river sites in order to promote even further tidal energy and reap the previously mentioned benefits to local communities. The Étel estuary has already received regulatory consent for tidal projects in the past with Guinard Energies Nouvelles and in the future with ELEMENT and further Guinard Energies Nouvelles projects.

EnFAIT D8.9 publication on effects on the regulatory framework 2018 Shetland, UK ✓✓

Small-scale energy suppliers face market barriers to entry in the UK. For example, existing regulations fail to fully recognise the potential benefits of distributed, small-scale generation, such as: reduced network losses; improved local grid balancing services; and increased resilience of remote networks. Recent UK policy developments include: the removal of feed-in tariffs (FITs) for small scale renewable generators; the closure of the Renewable Obligation (RO); the focus of the remaining Contract for Difference (CfD) support mechanism on very large-scale projects; and the denial of Seed Enterprise Investment Scheme (SEIS) tax relief to companies that generate electricity. This has created a “perfect storm”, leading to the collapse of the UK small-scale, low carbon energy market.

Consequently, small-scale project developers are forced to either: cede the UK market to large-scale competitors and move overseas, cease all activities (as many have done), or focus on the “behind the meter” market, selling directly to consumers to offset their electricity consumption. There is currently no route to market for new low carbon energy generating technologies in the UK, which has had a chilling, adverse effect on investment.

Energy policy in Scotland is not a devolved function and remains seated in Westminster, which has a variety of priorities, including: delivering Brexit; driving down energy bills; and developing large-scale energy projects. Ongoing large energy projects typically use imported energy generating technologies such as nuclear (the 3,200 MW Hinkley Point C project which is based upon French technology) and GW generation-scale offshore wind that utilises turbines imported from Denmark and Germany.

Tidal stream energy is a predictable source of low-carbon energy that does not require large capital investment, or a long-time frame from the start of construction until the point of energy generation. NOVA recently deployed batteries at the Shetland array to create the world’s first baseload tidal power plant; supplying controllable, flexible renewable energy to the Shetland grid. However, developers of small-scale renewable energy projects face a significant challenge in addressing the current regulatory and market conditions in the UK. A key challenge is convincing the UK government to reinstate revenue support for emerging energy technologies. This used to be offered by the FIT and RO schemes, which spurred a wave of innovation and investment in the UK energy generation sector. Within the CfD framework, the focus is on reducing the cost of energy to consumers, with a push for renewable energy to be deployed at the lowest possible cost. The CfD scheme favours established renewable energy technologies imported from overseas, such as offshore wind, rather than smaller-scale, emerging, home-grown technologies that which be the export opportunities of the future but need to be fostered to grow. *[The re-introduction of tidal energy to the UK CFD mechanism in 2021 is discussed below.]*

Summary: The tidal array has highlighted the need for existing UK government policy to be adjusted so that structural market conditions in the UK favour the future development of innovative, small-scale, low-carbon energy technologies.

EnFAIT D8.9 publication on effects on the regulatory framework 2018 Europe ✓✓

Summary: At an EU-level, the tidal array has demonstrated the value of project investments such as EnFAIT that sow the seeds of the low carbon technologies of the future, and that would not have taken place without EU support.

ELEMENT D12.4 review on effects on the regulatory framework ✓✓

Although the French location is already open to projects such as ELEMENT, it is true that in general, there is still a need to receive support from the government or the EU to deploy innovative renewable energy sources. The aid can be financial as well as promotional to foster low LCOE installations through multiple research and development activities. It is only by lowering the LCOE that tidal energy will be sufficiently competitive to be selected as a source of green energy. Moreover, even if the LCOE is low, it is imperative that the European population grasps how essential it is to produce renewable energy locally. The unprecedented energy prices since Q4-2021 that continued to increase drastically in Q1-2022 are not alone sufficient to raise awareness that local green energy can be a solution. It may be enough for some to consider installing solar panels on their rooftop, but not enough for the general population to know about tidal energy. It is vital that governments and Europe promote tidal energy as a reality in appropriate locations: such incentives will have a major positive impact on tidal energy deployment throughout Europe’s coasts, estuaries and rivers. In fact, since the EnFAIT D8.9 publication in 2018, the UK re-introduced support for tidal energy via the Contract for Difference (CfD) mechanism. This shows progress on how the UK government supports the cost of energy to UK consumers in the medium term. By doing this, it allows tidal energy to be competitive with other energy sources, thus supporting the tidal energy industry in deploying new installations. However, the CfD isn’t designed to support innovative technologies and is oriented towards lower LCOE solutions. The UK FIT and RO schemes would have been a more appropriate solution for supporting an emerging renewable energy technology like tidal power, as they have proven to be previously with great success for wind and solar energy.

Theme 1 Conclusion

The conclusion of the 2022 review of the socio-economic impact assessment results for Shetland and Europe in 2018 and Étel in 2021 is that tidal energy will bring positive social and economic benefits. Below table 3 summaries the review's outcome and is sorted from major to minor positive impacts.

2022 Reviews of socio-economic impact assessment topics	Conclusion
Employment and business	✓✓
Effects on the regulatory framework	✓✓
Standard of living / housing conditions / vulnerable groups	✓+✓
Educational change	✓+✓
Social cohesion	✓+✓
Perception of the sea as a tidal energy resource	✓+✓
Demographics	✓
Recreational and tourism activities	✓
Industrial strategy and rural regeneration	✓
Commercial shipping and navigation	✓

Table 3 – Conclusion of the comparison of ELEMENT and EnFAIT socio-economic appraisal results

In all socio-economic topics, there are no negative or neutral impacts. As the table shows, there is 60% of major positive impact and 40% of minor positive impact in elaborating a tidal energy project combined with an energy community. Without including a REC, the major positive impact reduces to 20% while the minor positive impact increases to 80%. This demonstrates that the benefits to the socio-economic framework are three times more important when including an energy community in a project that installs tidal energy. The local acceptance of the renewable source will therefore be increased, and its energy will be used more efficiently and cost-effectively thanks to the educational change a REC fosters.

THEME 2: EUROPEAN TIDAL TURBINE POTENTIAL

Theme 2 Introduction

This section of the report identifies potential high energy capacity sites for the deployment in European coasts, estuaries and rivers of underwater turbines. When referring to tidal energy, the term “tidal” pertains to the tide that is available in the ocean, the coast and estuaries. However, underwater turbines such as those created by NOVA or GUINARD can potentially also be installed in rivers where the tide is no longer applicable but is replaced by the rivers’ currents.

In rivers, the water flows in a single direction, which means that an underwater turbine will need to rotate one way only.

At the coast and in estuaries, the water flows in two directions due to the tide, and consequently the underwater turbines are required to withstand and capture this two-way stream. This also means that underwater turbines that are designed for the tide (i.e., tidal turbines) can also be used in rivers. As such, when identifying potential sites for tidal turbine deployment, it is relevant to consider both tidal and run-of-river energy capacity.

Theme 2 Methodology

To identify potential tidal or run-of-river energy project locations, it is essential to know the water currents’ speeds. However, this type of information is rarely available publicly.

There are high-level global maps of the tidal flow, such as the open-source Tidemap found on maps.tidetech.org[4]. This type of map visualises in red the quickest sea currents (refer to below figure 3).

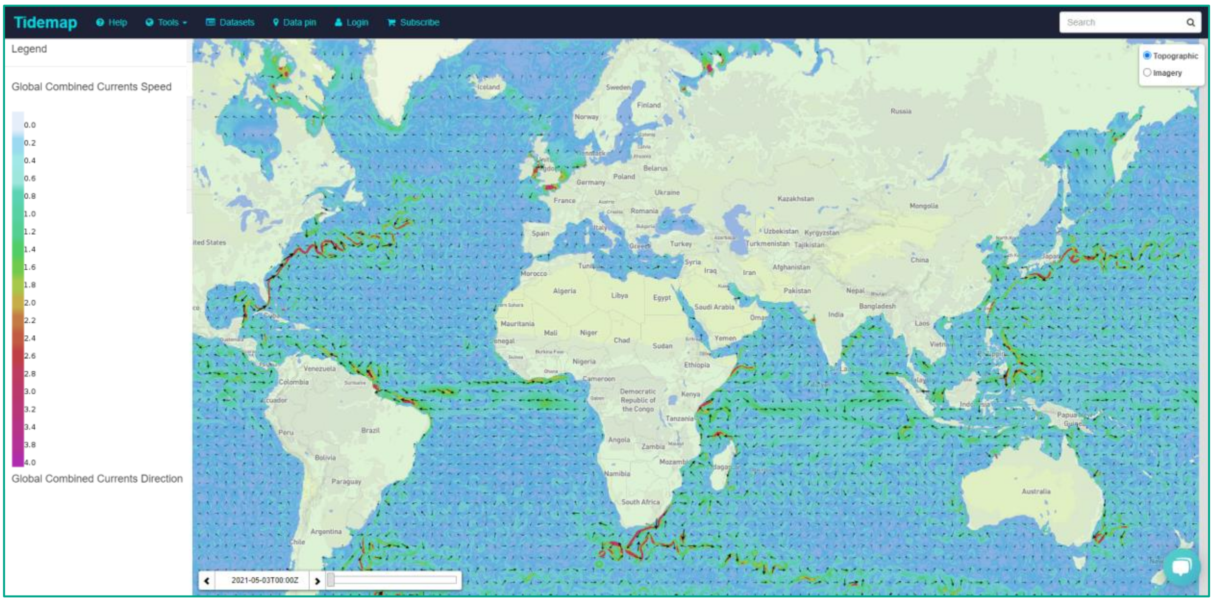


Figure 3 – Tidemap’s global combined current speed on 3-May-2021 0:00Z

[4] https://maps.tidetech.org/?workspace=public&layer=combined_currents&baseLayer=Topographic

However, Tidemap does not identify the estuary tidal flow nor the river currents, and it is not sufficiently granular to provide coastal current speeds between islands or up close. As an example, although there is a confirmed high current speed at Cullivoe in Shetland, where the EnFAIT project's tidal array is located, Tidemap is not detailed enough to show it on the map (see figure 4).

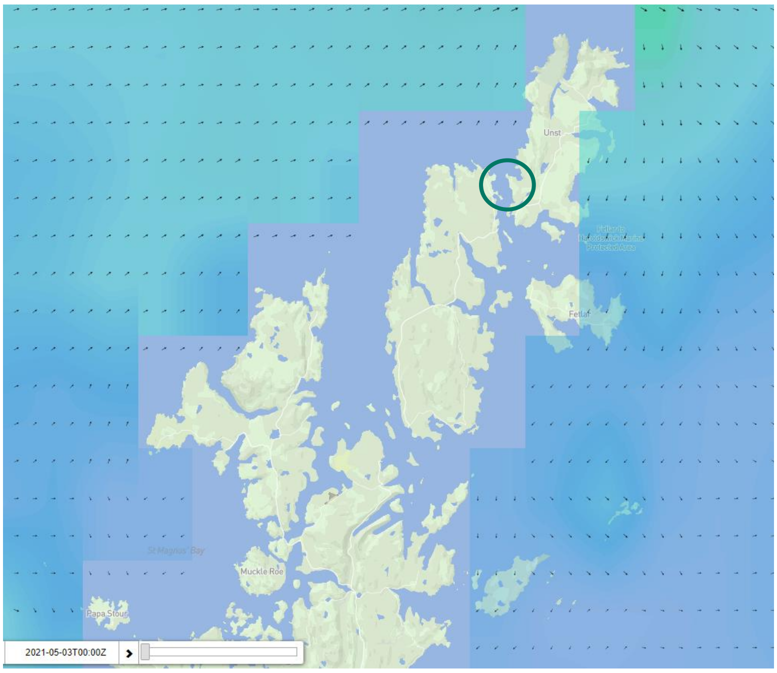


Figure 4 – Tidemap's global combined current speed at Cullivoe on 3-May-2021 0:00Z

Another more complete open-source data source on the internet that supports the identification of potential tidal and run-of-river energy capacity locations is the Aqua-RET project's website[5], funded with support from the European Commission (EU Lifelong Learning Programme Agreement no LLP/LdV/TOI/2009/IRL – 515). As the site mentions, "Aquatic Renewable Energy Technologies (Aqua-RET) is an e-learning tool promoting aquatic renewable technologies. The tool will show you how these technologies work, where and how they fit into the landscape, and how they benefit the economy." The Aqua-RET source provides two useful maps that highlight the potential locations to deploy underwater turbines:

1. The "tidal stream resource distribution" map (below refer to figure 5) pin-points coastal locations with high, medium and low potential for kinetic energy capacity. Aqua-RET's explanation of this type of technology is the following:

   "Tidal stream technologies generate electricity using the flow of water created by the tides and accelerated by coastal topography. As is the case with early-stage wind and wave technologies, a number of tidal stream concepts have been, and continue to be, proposed. Most are based on rotating rotors, either horizontal or vertical-axis."

[5] https://www.aquaret.com/

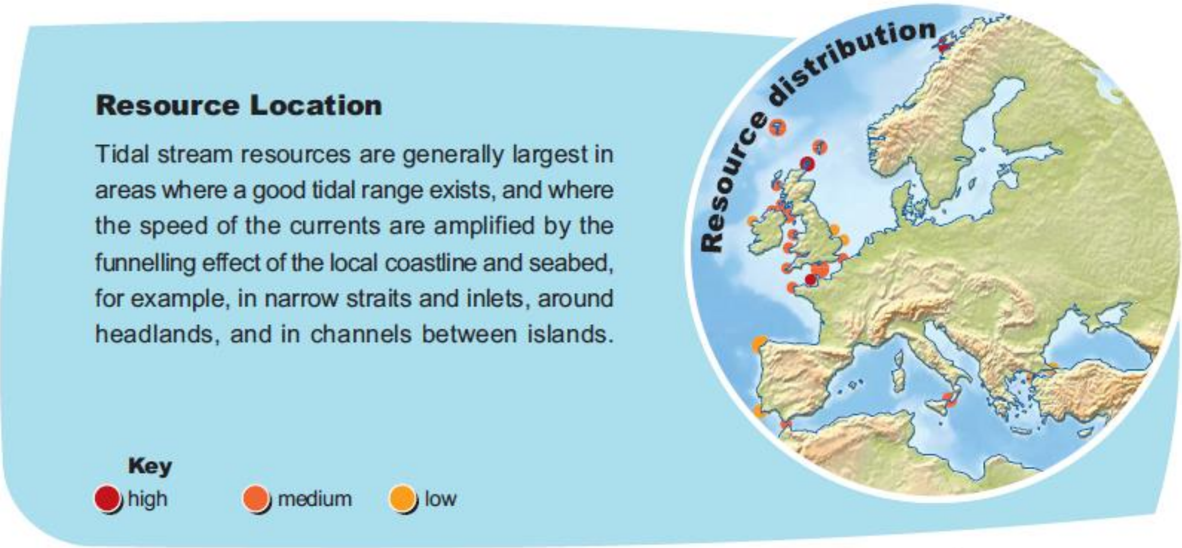


Figure 5 – Aqua-RET's tidal stream resource distribution

2. The "run-of-river resource distribution" map colour-codes countries to reflect a high, medium, low or very low potential of energy capacity related to run-of-river technology. Aqua-RET mentions that "Run-of-river hydro power is used to describe hydroelectric power generation where there is little to no water storage." The Aqua-RET map considers the potential by grouping weir type plants, diversion plants, and kinetic energy devices such as underwater turbines, as well as oscillating hydrofoils, and venturi devices.

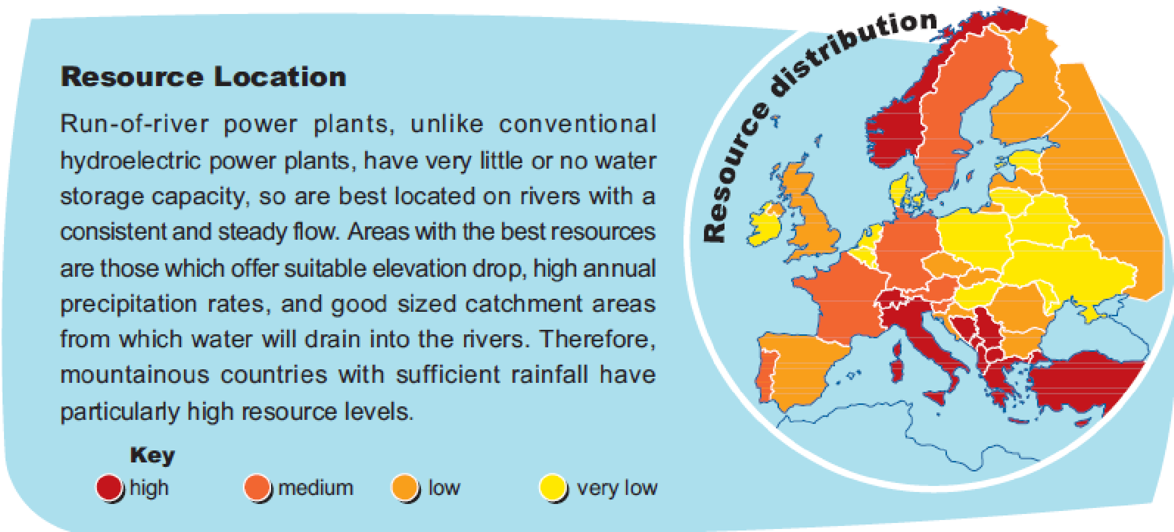


Figure 6 – Aqua-RET's run-of-river resource distribution

Both Aqua-RET maps can therefore be combined to identify countries with coastal, estuary and run-of-river kinetic energy capacity. The maps do not, however, mark the exact place on a river or estuary where an underwater turbine would yield the best energy. It also does not clarify the locations or capacity for run-of-river turbines specifically. Only local site visits with current speed and depth measurements would provide such specific resource identification.

Nevertheless, by using Aqua-RET's tidal and run-of-river maps and translating the maps' key results with a weighted score, this report estimates the countries where tidal and run-of-river energy capacity is most likely to be high.

For Aqua-RET's coastal tidal stream resource distribution map, each country's points on the map are translated into a score which is then added together:

- A score of 3 for points colour coded as high,
- A score of 2 for points coded as medium, and
- A score of 0 for points coded as low.

For the run-of-river resource distribution map, each country has a single Aqua-RET colour code based on all the run-of-river technologies that could yield energy, not just underwater turbines. This was translated into:

- A score of 6 for countries colour coded as high,
- A score of 3 for countries coded as medium, and
- A score of 0 for countries coded as low or very low.

The scores for run-of-river are higher than tidal stream: 6 versus 3 for high results and 3 versus 2 for medium results. This is because the run-of-river Aqua-RET results are provided for a country as a whole, while as the tidal stream Aqua-RET results pin-point locations within a country. A country can therefore have multiple tidal stream results (France has 1 high and 3 medium), but only one result for run-of-river (medium for France). It is therefore assumed that the run-of-river results would include multiple estuary or river locations, hence why the score is higher than for the already multiple scores for tidal results.

The tidal stream and run-of-river scores are then combined to identify the potential for underwater turbine deployment in the countries studied by Aqua-RET.

The European Countries with Tidal Turbine Potential

Based on above-mentioned methodology used on Aqua-RET's maps, the below table 4 first lists all the countries analysed by Aqua-RET and summarises Aqua-RET's identified energy capacity results.

Country	Tidal stream resource distribution	Run-of-River resource distribution
Austria	-	Medium
Cyprus	-	High
Czechia	-	Low
Finland	-	Low
France	High (x1) + Medium (x3)	Medium
Germany	-	Medium
Greece	-	High
Ireland	Low (x1)	Very low
Italy	Medium (x1)	High
Latvia	-	Low
Norway (non-EU)	High (x1)	High
Portugal	Low (x2)	Medium
Slovakia	-	Low
Spain	Medium (x1) + Low (x1)	Low
Sweden	-	Medium
Switzerland (non-EU)	-	High
Turkey (non-EU)	Low (x1)	High
UK (non-EU)	High (x1) + Medium (x11) + Low (x2)	Low

Table 4 – Summary of Aqua-RET's tidal stream and run-of-river energy capacity results

The results are then translated into scores and combined to determine the countries with a potential to deploy underwater turbines as reflected in table 5.

Country	Tidal stream resource distribution	Run-of-River resource distribution	Underwater turbine deployment score
UK (non-EU)	3 (x1) + 2 (x11) + 0 (x2)	0	25
France	3 (x1) + 2 (x3)	3	12
Norway (non-EU)	3 (x1)	6	9
Italy	2 (x1)	6	8
Cyprus	0	6	6
Greece	0	6	6
Switzerland (non-EU)	0	6	6
Turkey (non-EU)	0 (x1)	6	6
Austria	0	3	3
Germany	0	3	3
Portugal	0 (x2)	3	3
Sweden	0	3	3
Spain	2 (x1) + 0 (x1)	0	2
Czechia	0	0	0
Finland	0	0	0
Ireland	0 (x1)	0	0
Latvia	0	0	0
Slovakia	0	0	0

Table 5 – Translation of Aqua-RET's results into underwater turbine deployment scores

From the listed 18 countries, 4 have a total score above 6 and have been selected in this report as the countries with the highest potential. The four countries are:

1. UK (highest score with 25),
2. France (score of 12),
3. Norway (score of 9) and
4. Italy (score of 8).

As such, according to the hypothesis and methodology used, these 4 identified countries should have a high potential to deploy a tidal turbine at their coasts or in their estuaries or rivers.

Theme 2 Conclusion

There is not sufficient open-source data to identify all the European countries where tidal turbines could be deployed, let alone identify the specific location at the coast, in an estuary and in a river. The available data can however be used to indicate promising countries where the potential should be high. Four countries were identified in Theme 2: the UK, France, Norway and Italy. The tidal energy that could be produced in these four identified countries could also benefit the energy supply in the neighbouring European countries due to the interlink grid network that is already in place in Europe for energy import and export.

THEME 3: EUROPEAN LOCAL CONTENT IMPACT

Theme 3 Introduction

The ELEMENT partner INNOSEA studied to what extent French businesses can be impacted by a tidal energy project in ELEMENT deliverable D12.3. For D12.4 Theme 3, INNOSEA has studied similarly the local job content of tidal energy projects in the 4 countries identified as having the highest tidal energy potential as seen in Theme 2 of this report: UK, France, Norway and Italy.

By identifying the business-sectors impacted by tidal energy projects, the study provides the following results for the 4 countries:

- The gross value added (GVA) per 1MW of installed tidal energy capacity projects, and
- The number of expected direct, indirect and induced jobs per 1MW of installed tidal energy capacity projects.

The GVA is an economic indicator evaluating net output of goods and services produced (mathematically corresponding to the difference between gross output and intermediate consumption).

Direct jobs refer to jobs created within the first-line business-sector that is directly involved in the construction and/or operational phase of the tidal energy projects. The indirect jobs are a second-line support used by the first line business-sector to finalise the construction and/or operational work. This is generally done through business-to-business (B2B) contracts. Finally, the induced jobs reflect general employment created by the unrelated expenditure (ex: leisure & living costs) of the first- and second-lines' business-sectors' employees.

Theme 3 Methodology

The first step of the methodology is defining the input tables that are used for the study. There are two types of input tables. Those that are determined specifically by the tidal energy project and those that are widely accepted socio-economic matrices. There are 5 tidal energy project input tables and 2 socio-economic matrices.

Tidal energy project input tables

The tidal-project input table (below table 6) is composed of the:

- Installed capacity fixed at a benchmark of 1 MW,
- Current capital expenditure (CAPEX) per kW for early-stage, small-scale projects,
- Current operational expenditure (OPEX) per kW for early-stage, small-scale projects, and
- Foreign exchange rate to convert USD to EUR for the socio-economic matrices.

The CAPEX and OPEX figures are currently high for small-scale tidal projects but should reduce in time as the technology matures. With lower figures, the study shows lower FTE and GVA results. Moreover, the same CAPEX and OPEX figures have been taken for all countries of the study while, in reality, the expenditure will be different in each country. These assumptions and hypotheses have been taken in the current study to allow a short-term view on small-scale tidal energy projects.

Parameter	Values	Unit
Installed capacity	1000	kW
CAPEX	7580	€/kW
OPEX	505	€/kW/year
€/$ conversion rate	0.82	€/$

Table 6 – Tidal-project input table

The business-sector input table (below table 7) reflects the business-sectors that are affected by a tidal energy project. The businesses are listed by their European statistical classification of economic activities (also known as the NACE code, derived from the French "**N**omenclature Générale des **A**ctivités économiques dans les **C**ommunautés **E**uropéennes").

Business-sector	NACE Code
Architectural and engineering activities; technical testing and analysis	M71
Manufacture of machinery and equipment	C28
Manufacture of electrical equipment	C27
Manufacture of fabricated metal products, except machinery and equipment	C25
Water transport	H50
Construction	F42
Financial service activities, except insurance and pension funding	K64
Electricity, gas, steam and air conditioning supply	D35
Repair and installation of machinery and equipment	C33

Table 7 – Business-sector input table

The national share input table (below table 8) reflects the national share distribution that impacts the identified NACE codes. The ELEMENT partners defined in D12.3 the extent to which the French business-sector is expected to be impacted by a French tidal energy project. This percentage considers that certain goods and services will be produced by foreign businesses, i.e. outside of France. This percentage may also be similar in other countries however this study has not analysed in detail if this is true for UK, Norway or Italy particularly. As such, the table also considers a 100% national share distribution that reflects that there is no importation and that all the goods and services are produced in the country. This would provide a high scenario for local content. The table also provides a low scenario where 50% of the goods and services are from the national share and therefore 50% is foreign.

Business-sector	NACE Code	D12.3 National Share Distribution	High National Share Distribution	Low National Share Distribution
Architectural and engineering activities; technical testing and analysis	M71	70%	100%	50%
Manufacture of machinery and equipment	C28	70%	100%	50%
Manufacture of electrical equipment	C27	50%	100%	50%
Manufacture of fabricated metal products, except machinery and equipment	C25	50%	100%	50%
Water transport	H50	80%	100%	50%
Construction	F42	80%	100%	50%
Financial service activities, except insurance and pension funding	K64	30%	100%	50%
Electricity, gas, steam and air conditioning supply	D35	100%	100%	50%
Repair and installation of machinery and equipment	C33	70%	100%	50%

Table 8 – National share input table

The CAPEX input table (below table 9) provides the percentage of the capital expenditure that is distributed to the identified NACE codes during the development and construction phase. Refer to D12.3 for background information.

Business-sector	NACE Code	100% CAPEX Distribution
Architectural and engineering activities; technical testing and analysis	M71	14%
Manufacture of machinery and equipment	C28	28%
Manufacture of electrical equipment	C27	14%
Manufacture of fabricated metal products, except machinery and equipment	C25	14%
Water transport	H50	16%
Construction	F42	5%
Financial service activities, except insurance and pension funding	K64	8%
Electricity, gas, steam and air conditioning supply	D35	1%

Table 9 – CAPEX input table

The OPEX input table (below table 10) provides the percentage of the operational expenditure that is distributed to the identified NACE codes during the operational and maintenance phase. Refer to D12.3 for background information.

Business-sector	NACE Code	100% OPEX Distribution
Water transport	H50	50%
Electricity, gas, steam and air conditioning supply	D35	1%
Repair and installation of machinery and equipment	C33	49%

Table 10 – OPEX input table

Socio-economic input tables

The Business-to-Business (B2B) input tables provide the exchanges between business sectors. It states for each sector the monetary value in millions of dollars it produces through goods and services for its own sector as well as for other sectors. By using this matrix one can assess the impact of a project in term of GVA. These matrices are available online[6] and the data is specific per country.

The socio-economic accounts (SEA) input table delivers per country:

- The number of employees per sector,
- The mean salary per sector and
- the value added per sector.

The number of employees per sector is used to assess the number of jobs created by a project, and ratios between mean salaries and added value are used to calculate induced impact.

Combining the input tables

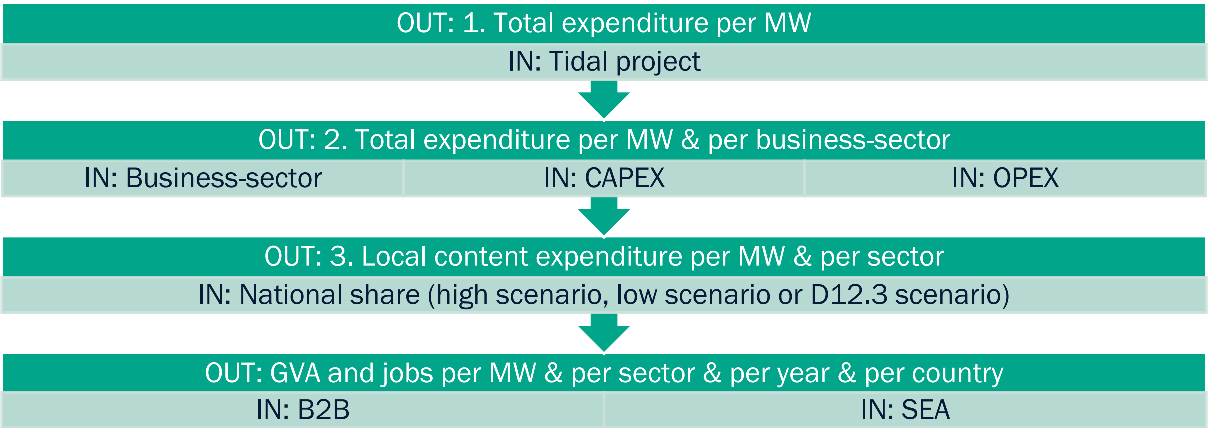
The following graph shows the different input tables (IN) used to define the different level of local content results (OUT). By combining, at different stages, these input tables, the study defines consequently:

1. The total expenditure per MW installed,
2. The total expenditure per MW and business-sector,
3. The total expenditure per MW and business-sector based on the 3 national share distribution scenarios:

    - High scenario with 100% local content,
    - Low scenario with 50% local content and,
    - D12.3 scenario with the percentages of local content defined in D12.3 for a French project,

4. The GVA and jobs per year for the 4 identified countries (France, UK, Norway and Italy) that have the highest tidal energy potential. The results reflect the high, low and D12.3 scenarios.

[6] https://www.rug.nl/ggdc/valuechain/wiod/?lang=en Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), "An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production", Review of International Economics., 23: 575–605



Graph 1 – Process flow of the methodology, including input tables (IN) and results (OUT) per stage

The results are given for the development and construction phase as well as the operational and maintenance phase.

- The development and construction results are reflected for the total duration of the development and construction phase altogether. It is not reflected per year. This was decided in order to provide the FTE and GVA figures for the whole capital expenditure (CAPEX) in total. If a project takes 2 years in this phase then the results should be divided by 2 to show the FTE and GVA results per year. This stage of a small-scale tidal energy project is assumed to take 2 to 3 years.

- The operational and maintenance results are reflected as annual results during the lifetime of a project. This stage of a small-scale tidal energy project is assumed to take 20 years.

As explained above, the study shares 3 local content scenario results: low, D12.3 and high. It is important to note that each country will have a local content that is different due to the available businesses in the country. Moreover, even with the needed business in the country, the project developers may end up choosing a foreign business due to pricing or quality reasons, for example. Indeed, as the ELEMENT and EnFAIT projects show, the supply chain is rarely 100% local. However, it is useful to keep the high scenario of 100% local content because it provides an indication of the FTE and GVA opportunity for Europe as a whole. As the ELEMENT and EnFAIT projects show, the supply chain for these projects have remained within Europe, therefore providing a 100% European content.

Expected Jobs per Country

The result of the study that show the extra jobs that would be created in the 4 selected countries are reflected by high, low and D12.3 local content scenarios in the following table 11. The table first displays the jobs that are created in the development and construction phase due to the total CAPEX input and then later on annually during the operational and maintenance phase due to the OPEX input. The results are split by direct, indirect and induced jobs.

This table also highlights the results that stand-out by colour-coding them. In yellow, the table shows the lowest results that are far from the other results. It reflects that Norway has the lowest results, while the other 3 countries (France, UK and Italy) have quite similar results. The highest results are often seen for the UK, except for the operational indirect jobs that are higher in Italy.

Country	Local content scenario	CAPEX direct jobs (FTE/MW)	CAPEX indirect jobs (FTE/MW)	CAPEX induced jobs (FTE/MW)	Total CAPEX jobs (FTE/MW)	OPEX direct jobs (FTE/MW/year)	OPEX indirect jobs (FTE/MW/year)	OPEX induced jobs (FTE/MW/year)	Total OPEX jobs (FTE/MW/year)
France	Low	15.2	15.9	17.9	49.0	0.7	1.1	1.1	2.9
UK	Low	15.3	15.8	28.2	59.3	0.7	1.2	1.8	3.7
Norway	Low	10.9	8.9	6.9	26.7	0.7	0.5	0.4	1.6
Italy	Low	14.6	15.6	24.3	54.5	1	1	1.5	3.5
Average	Low	14	14.1	19.3	47.4	0.8	1	1.2	2.9
France	D12.3	18.8	21.1	22.8	62.7	1	1.7	1.6	4.3
UK	D12.3	18.9	20.8	36.2	75.9	1	1.8	2.7	5.5
Norway	D12.3	13.9	11.6	8.8	34.3	1.1	0.8	0.6	2.5
Italy	D12.3	18.1	20.7	30.7	69.5	1.5	1.6	2.3	5.4
Average	D12.3	17.4	18.6	24.6	60.6	1.2	1.5	1.8	4.4
France	High	30.3	31.9	35.7	97.9	1.4	2.2	2.2	5.8
UK	High	30.6	31.6	56.4	118.6	1.4	2.4	3.6	7.4
Norway	High	21.8	17.9	13.8	53.5	1.5	1	0.8	3.3
Italy	High	29.3	31.2	48.6	109.1	2.1	2.1	3.1	7.3
Average	High	28	28.2	38.6	94.8	1.6	1.9	2.4	6

Table 11 – Extra jobs created by a tidal energy project

The results demonstrate in the D12.3 local content scenario that per installed MW, a tidal energy project would generate up to 18.9 FTE (13.9 FTE for Norway) in direct jobs due to the CAPEX stage and then 1 to 1.5 FTE directly each year after. In the high scenario, the new direct jobs would be of up to 30.6 FTE (minimum 21.8 FTE in Norway) while the low scenario would still create maximum 15.3 FTE (10.9 FTE in Norway). The results also show the important increase in indirect and induced jobs that range from minimum 8.9 indirect and 6.9 induced FTE in the low scenario in Norway up to 31.6 indirect and 56.4 induced FTE in the high scenario in the UK. All these FTE increases are to be considered per MW installed for small-scale projects that would be deployed in the current early stages of the industry. The total job-increase in the CAPEX years can go up to 118.6 FTE and then 7.4 FTE yearly per deployed MW for UK.

The lower number of jobs created per MW for Norway can be explained by the lower ratio of Norway in the SEA input table. Indeed, for the identified business-sectors, the number of Norwegian employees per output (in USD millions) has a lower ratio compared to the 3 other countries. This is shown below in table 12. This can be due to the maturity of the supply chain with, for example, a greater automation in the manufacturing process, or due to more efficient working methodology. It is also potentially due to the higher cost of living and consequently the higher wages that employees receive. We have assumed the same cost for projects in each country: in reality, costs are likely to vary between countries in a way that reduces the differences observed between countries. For example, higher project CAPEX in Norway would result in more jobs in the CAPEX phase.

	Ratio number of employees per output (USD millions)				Ranking			
NACE	France	UK	Norway	Italy	France	UK	Norway	Italy
C25	4.64	4.72	3.31	4.29	2	1	4	3
C27	2.90	3.48	2.39	3.37	3	1	4	2
C28	3.42	3.31	1.59	3.00	1	2	4	3
C33	3.85	4.27	2.72	4.85	3	2	4	1
D35	0.97	0.76	1.10	0.76	2	4	1	4
F42	4.04	2.75	2.54	3.38	1	3	4	2
H50	0.73	0.41	2.13	1.94	3	4	1	2
K64	2.72	2.15	1.27	3.05	2	3	4	1
M71	4.07	4.98	2.66	2.12	2	1	3	4
Mean	**3.04**	**2.98**	**2.19**	**2.97**	**1**	**2**	**4**	**3**

Table 12 – Ratio of number of jobs per output (USD millions) and ranking

Expected GVA per Country

The results of the study that show the extra gross value added (GVA) that would be created in the 4 selected countries are reflected by high, low and D12.3 local content scenarios in below table 13. These results are relatively similar for the 4 countries and reflect a general GVA increase trend. No results standout from the others.

Country	Local content scenario	CAPEX direct GVA (m€/ MW)	CAPEX indirect GVA (m€/ MW)	CAPEX induced GVA (m€/ MW)	Total CAPEX GVA (m€/ MW)	OPEX direct GVA (m€/ MW/ year)	OPEX indirect GVA (m€/ MW/ year)	OPEX induced GVA (m€/ MW/ year)	Total OPEX GVA (m€/ MW/ year)
France	Low	1.3	4.1	7.3	12.7	0.1	0.2	0.4	0.7
UK	Low	1.7	4.8	8.7	15.2	0.1	0.3	0.6	1.0
Norway	Low	1.6	4.4	6.5	12.5	0.1	0.3	0.4	0.8
Italy	Low	1.5	4.5	8.3	14.3	0.1	0.3	0.5	0.9
Average	Low	1.5	4.5	7.7	13.7	0.1	0.3	0.5	0.9
France	D12.3	1.6	5.2	9.3	16.1	0.1	0.4	0.7	1.2
UK	D12.3	2.2	6.1	11.3	19.6	0.2	0.5	0.8	1.5
Norway	D12.3	2	5.6	8.2	15.8	0.1	0.4	0.6	1.1
Italy	D12.3	1.8	5.7	10.5	18.0	0.1	0.4	0.8	1.3
Average	D12.3	1.9	5.7	9.8	17.4	0.1	0.4	0.7	1.3
France	High	2.7	8.2	14.6	25.5	0.1	0.5	0.9	1.5
UK	High	3.4	9.6	17.5	30.5	0.2	0.6	1.1	1.9
Norway	High	3.3	8.8	13	25.1	0.2	0.5	0.8	1.5
Italy	High	3	9	16.5	28.5	0.2	0.5	1	1.7
Average	High	3.1	8.9	15.4	27.4	0.2	0.5	1.0	1.7

Table 13 – Extra GVA created by a tidal energy project

All these amounts are per MW installed of small-scale early-stage projects. In all cases, the results show an important increase in GVA during the CAPEX years ranging from 12.5 million € at the lowest end (low scenario in Norway split between 1.6 direct, 4.4 indirect and 6.5 induced GVA) to 30.5 million € at the highest end (high scenario in the UK split by 3.4 direct, 9.6 indirect and 17.5 induced GVA). In the OPEX years, the lowest GVA outcome starts at 700.000 € per year (low scenario for France split at 100.000 direct, 200.000 indirect and 400.000 induced) and ends at 1.9 million € per year (highest scenario in the UK with 200.000 direct, 600.000 indirect and 1.1 million induced GVA).

Theme 3 Conclusion

INNOSEA's local content study confirms that there are extra jobs and extra GVA to be created by deploying small-scale early-stage tidal projects in France, UK, Italy and Norway. Moreover, as noted in the 2022 review in Theme 1's subsection on employment and business, both EnFAIT and ELEMENT projects have shown that although there are goods and services that are produced outside of the country where the tidal project is located, the foreign countries involved are in Europe and therefore contribute to a full European local content distribution. The job and GVA creation therefore continue to positively impact Europe as a whole even when the tidal project's supply chain is not completely local.

Per installed MW, if the local content remains completely in the business-sector of the country or Europe (high local content scenario), then the average total expected local content creation will be:

- During the development and construction phase, an increase of up to:
  - 94.8 FTE:
    - 28 direct,
    - 28.2 indirect,
    - 38.6 induced, and
  - 27.4 million € of GVA:
    - 3.1 direct,
    - 8.9 indirect,
    - 15.4 induced, and then
- During the operational and maintenance phase:
  - 6.0 FTE:
    - 1.6 direct,
    - 1.9 indirect,
    - 2.4 induced, and
  - 1.7 million € of GVA yearly:
    - 0.2 direct,
    - 0.5 indirect, and
    - 1.0 induced.

In the medium scenario that uses the D12.3 local content distribution, the average impact continues to remain high with, per installed MW, up to:

- During the development and construction phase, an increase of up to:
  - 60.6 FTE:
    - 17.4 direct,
    - 18.6 indirect,
    - 24.6 induced, and
  - 17.4 million € of GVA:
    - 1.9 direct,
    - 5.7 indirect,
    - 9.8 induced, and then

- During the operational and maintenance phase:
    - 4.4 FTE:
        - 1.2 direct,
        - 1.5 indirect,
        - 1.8 induced, and
    - 1.3 million € of GVA yearly:
        - 0.1 direct,
        - 0.4 indirect, and
        - 0.7 induced.

Even in a low scenario with only 50% of local content, the average impact continues to be positive:

- During the development and construction phase, an increase of up to:
    - 47.4 FTE:
        - 14 direct,
        - 14.05 indirect,
        - 19.3 induced, and
    - 13.7 million € of GVA:
        - 1.5 direct,
        - 4.5 indirect,
        - 7.7 induced, and then
- During the operational and maintenance phase:
    - 2.9 FTE:
        - 0.8 direct,
        - 1 indirect,
        - 1.2 induced, and
    - 0.9 million € of GVA yearly:
        - 0.1 direct,
        - 0.3 indirect, and
        - 0.5 induced.

Except for Norway, the <u>induced</u> FTE figures are higher than the direct figures by an average of:

- 16% during CAPEX years and 37% during OPEX years for France;
- 46% during CAPEX years and 62% during OPEX years for the UK;
- 40% during CAPEX years and 33% during OPEX years for Italy.

Moreover, the difference between indirect and direct is still high for the UK and Italy with 43% and 35% higher in CAPEX years and 33% and 32% higher in OPEX years respectively.

For Norway, the <u>induced</u> FTE figures are lower than the direct figures by an average of:

- -58% during CAPEX years and -82% during OPEX years.

In all countries, the <u>induced</u> GVA figures are 75% to 82% higher than direct figures in CAPEX years and 78% to 83% higher in OPEX years, even for Norway (who has the smallest difference). The indirect figures stay higher for the UK and Italy versus direct GVA figures, from 32% to 43%.

This study and its results therefore reflect that it is imperative to take into account the indirect and induced consequences since it is there that the most value is to be had.

CONCLUSION

The main conclusion of D12.4 is extremely positive based on the 3 themes that have been addressed.

Theme 1 confirms the great positive impact of tidal energy projects on the socio-economic topics that have been assessed in 2018 for the EnFAIT project in the Shetland Islands, UK, and in 2021 for the ELEMENT project in the Étel estuary, France. The assessment also considers that these positive impacts continue to be true in 2022 and are in some cases even more important due to the COVID pandemic crisis, the environmental and economic changes and the war in Ukraine that have opened Europe’s eyes to the fact that energy supply needs to be more secure, local and green.

Theme 2 identified four countries with notable tidal and run-of-river energy potential within Europe: France, Italy, Norway and UK. The tidal energy produced in these four countries could also help support the needs of other European countries through the European electricity’s grid interlinks. Moreover, there is still more to learn on the tidal energy capacity potential which may find extra countries and specifically pertinent sites for tidal device deployment.

Finally, Theme 3 confirms that in average per installed small-scale, early-stage tidal energy project in a medium local content scenario, per MW, the 4 identified high-potential countries would create 64 FTE (60.6 the development and construction years, then 4.4 to remain there after) and 17.4 million € of GVA in the CAPEX years followed by 1.3 million € annually during OPEX years. Even in a low scenario, the FTE and GVA generation is important, and as confirmed by the ELEMENT and EnFAIT projects, the content that is not local remains in Europe. The impact therefore stays positive for Europe as a whole.

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