marinerg-i

Marine Renewable Energy Infrastructure

Date: 09/11/2018

Report number: D6.1

Report on all RI costs and revenues

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Public

This project has received funding from the European Union's H2020 Programme for research, technological development and demonstration under grant agreement No. 739550

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Document Information

Version	Date	Description			
		Responsible	Authors	Reviewed by	Approved by
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Abbreviations

CRL	Commercial Readiness Level
MRE	Marine Renewable Energy
MRL	Manufacturing Readiness Level
R&D	Research and Development
ORE	Offshore Renewable Energy
TPL	Technology Performance Level
TRL	Technology Readiness Level

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1. Introduction

The Ocean Energy Strategic Roadmap [1], in line with European Policy towards de-carbonization and independence of the energy sector, has envisioned that ocean energy could meet 10% of European Union's power demand by 2050. Europe is, at present, at the forefront of ocean energy development, due to access to good resource sites, and more importantly a strong focus in Research and Development. Offshore wind energy, although only a small percentage of the total wind energy deployment (3% of total wind) [2], represents a sector with great potential for growth in the short to medium term. Globally, about 35 GW could be achieved by 2020 [2]. Looking further ahead, between 64 and 86 GW could be reached by 2030 just in Europe, with a great contribution of floating systems [3], up to 370 GW by 2045 [4].

Marine renewable energy technologies are still at an early stage of development, with only a few concepts undergoing tests at full-scale array levels. Wave energy, in particular, has yet to achieve a design consensus, with new concepts routinely being proposed [5]. Early stage support is key in order to advance the sector towards commercialization. Offshore wind energy is at a more mature level, as wind turbines are an extension of the onshore counterparts. However, foundation systems – especially floating solutions, are one of the major areas of research and innovation, along with drive train and blade innovations [4].

The existence of R&D centres and testing facilities is of great importance in advancing technology from concept to a commercial solution. As such, access to testing infrastructures allows for local technology to be more easily advanced. The existence of testing infrastructures in the UK, Ireland and Denmark, in conjunction with policies supporting R&D and early-deployment, has led these countries to being initial focal points of development of offshore renewable energy (ORE). Furthermore, most of these testing infrastructures are associated with research institutions, and many technologies have been a product of this research.

As technology advances, more specialized testing is required, and lack of suitable testing infrastructure can delay innovation. Access to foreign research centres may be hindered by high costs of relocating personnel and equipment, and bureaucratic access procedures. In this line, initiatives such as MaRINET and MaRINET2 have had a positive impact in the sector by removing these barriers to testing.

Building on the success of MaRINET and MaRINET2, MARINERG-i proposes to become the leading internationally distributed infrastructure in the Offshore Renewable Energy (ORE) sector. However, in order to develop a strong business case, the current status of the Research Infrastructures must be studied. This includes surveying the existing facilities and their capabilities, understanding the costs associated with managing and operating such facilities, and identifying the current and future needs of the sector.

This deliverable provides an overview of the existing infrastructures and their associated costs, using data provided by selected infrastructures.

2. Research Infrastructures types

2.1. Technology development

In order to develop an ORE market that is competitive in the broader energy sector, the technology adopted needs to be developed, tested and optimised into a final product. This is achievable through an interactive process of testing, in which efficiencies, costs and processes are optimized [6]. The technology development cycle of ORE is similar to that of other technologies, following the pattern of:

1. Technology Research
2. Application Demonstrator
3. Industrial Prototype
4. Marketable Product [7].

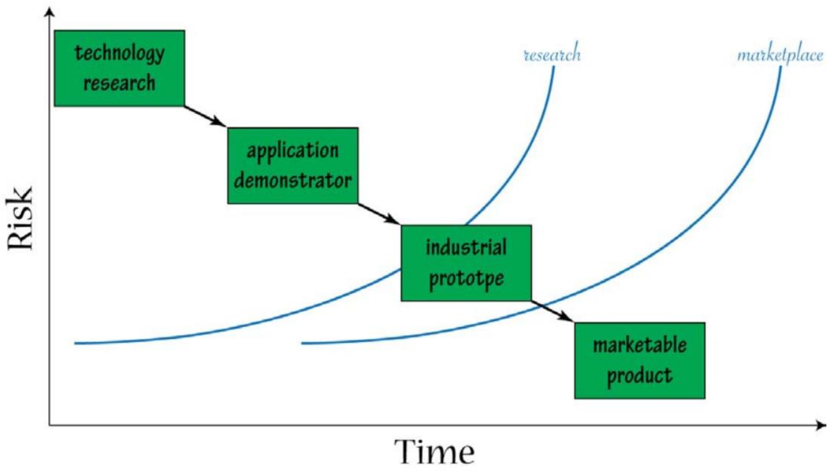

Figure 2:1 Technology development cycle [7]

These different phases can be used to establish metrics to assess the level of development and maturity of a technology or component, which in turn can be an important factor for decision making.

A common indicator is the Technology Readiness Level (TRL). This indicator was first developed by NASA but was expanded to cover other areas of technology such as energy by the U.S. Department of Energy. However, with the development of the ocean energy sector, the DOE TRL's classification[1] was found to be unclear to distinguish within the highest TRLs and new interpretations have been adapted for the sector by the Waveplam project [8], ESBi [9] and the European Commission[2] for the Horizon 2020 projects.

[1] Available at http://www1.eere.energy.gov/water/hydrokinetic/usingDB.aspx

[2] Available at https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

Furthermore, other classifications have also been utilized in order to detail technology advancement towards a marketable product, including the Technology Performance Levels (TPL), assessing performance instead of readiness; the Manufacturing Readiness Levels (MRL), assessing the readiness of the associated supply chain, which may be a limiting factor on the technology readiness; and the Commercial Readiness Levels (CRL), which start progressing after TRL 8 and go beyond the TRL scale, to address the business elements of product development.

The following table outlines the TRL classifications.

Table 1: TRL definitions

TRL	Definition
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Advancing from TRL 1 to TRL 9 will require substantial testing but, depending on the stage of development of the technology, the testing setup and infrastructure will differ. The table below details the typical infrastructure required at different TRLs.

Table 2: Infrastructure requirements based on TRL [10]–[12]

TRL	Infrastructure requirements	Typical Scale
TRL 1	No specialized infrastructure required	
TRL 2	Modelling Capabilities; Small scale testing: University laboratory	1:100 – 1:25
TRL 3	Modelling Capabilities; Small scale testing: University laboratory	1:100 – 1:25
TRL 4	Small scale testing: Industrial scale laboratory	1:25+
TRL 5	Small scale testing: Industrial scale laboratory; Benign test site	1:15 – 1:4
TRL 6	Benign test site	1:4+
TRL 7	Exposed test site	1:2+
TRL 8	Exposed test site	1:1
TRL 9	Commercial site	1:1 scale array

Following the MaRINET and MaRINET2 approach, the Research Infrastructures have been classified into 4 main categories:

- Small Lab (TRL 1 - 3)
- Large Lab (TRL 3 - 5)
- Medium-Scale Site (TRL 5 – 6)
- Large-Scale Site (TRL 7 – 9)

For low TRLs (1-3), which require numerical modelling, the only infrastructure requirement is in terms of computational analysis. The outputs of numerical modelling are produced at a fraction of the cost of physical model testing. Physical model testing can also be performed at low TRLs, in order to validate numerical modelling, with small scale models (1:100-1:25).

The path to TRL 9 is not always straightforward – companies that have tried to reach it too fast, by skipping to utility full scale devices for the first trials, typically fail. A well-planned, step by step, technology development strategy is needed – different TRLs correspond to the testing and validation of different aspects of the technology, from basic operation validation to power performance, and including survivability of structure, moorings and PTO. A stepped approach allows the developer to evaluate these different aspects, at a smaller, but also cheaper scale, in the most cost-effective way. As the prototype costs increase from a few thousands of euros at lab scale to around 10-30 million for a full-scale demonstrator.

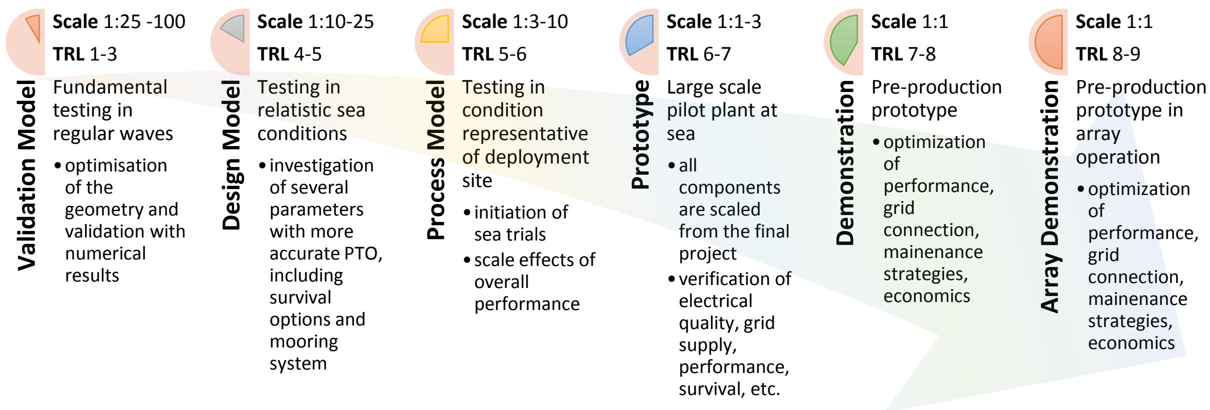

Figure 2:2 Progressive Development Plan steps

The costs associated with development of a technology through the different TRLs are presented on Table 3. These include all the costs related with research, testing and fabrication of devices, but as the TRL increases, costs related with testing infrastructure represent a high proportion of the total research cost.

Table 3: Costs and time associated with advancing technology through TRLs [13]

TRL	Typical Cost (M€)	Development time (yr)
TRL 1	0.01	0.05
TRL 2	0.04	0.3
TRL 3	0.42	0.7
TRL 4	0.83	1
TRL 5	2.5	1.5
TRL 6	4.2	1.5
TRL 7	8.3	2
TRL 8	12.5	2
TRL 9	24.9	3

2.2. E-infrastructures

A separate type of infrastructure that is covered under MARINERG-i are e-infrastructures.

E-infrastructures refer to data resources and technology which are required to support research activities. The research activities performed under MARINERG-i presuppose the generation of large quantities of data, which must be stored, processed and enabled to be shared.

Several e-infrastructures, associated with Research Infrastructures or projects dedicated to marine science, are available across Europe. These make use of databases and web-services and cover a wide range of topics [14].

From the user-needs consultation presented in D3.1, the requirements for e-infrastructures foreseen in the MARINERG-i network are:

- Open information on facilities capabilities and availability
- Access to virtual services, connection to other e-infrastructures and general use of common formats for interoperability
- Long-term data storage
- Standardization of analysis tools and instrumentation
- Platform for coordination of research activities
- Platform for education and training programs
- Security of data exchange and storage, especially guaranteeing IP protection [15]

3. Methodology

The work conducted in this project profiling infrastructures and e-infrastructures as well as existing networks such as MaRINET and MaRINET2, have helped identify which are relevant for inclusion in the MARINERG-i distributed infrastructure.

Cost and revenue information for Research Infrastructures are, in some cases, publicly available through financial statements, whether for the infrastructure itself or of the entire organization responsible (e.g. university). However, these correspond to high level information focused in ascertaining the sustainability of said infrastructures.

In order to have detailed information on cost structures, access rates and revenues, a questionnaire was sent to the infrastructures subscribed for MARINERG-i communications. The questionnaire can be found in Appendix 1. The response rate to the questionnaire was very low, so the information was completed using cost data available through the MaRINET2 project. *Figure 3:1* shows the distribution of the infrastructures sampled.

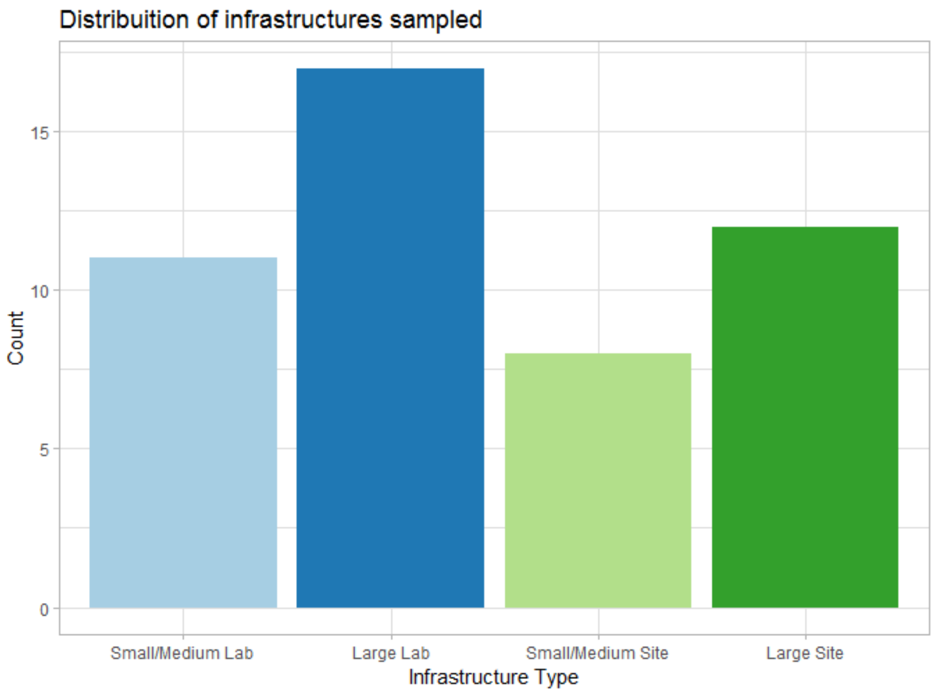

Figure 3:1 Distribution of infrastructures sampled

4. Research Infrastructures costs

The costs associated with Research Infrastructures vary depending on the size and type of the infrastructure, the scope of the research, whether the infrastructure is part of a large institution, as well as the geographical location.

The costs associated with Research Infrastructures can be separated into:

- Construction,
- Commissioning,
- Operation and
- Decommissioning

In the following sections, these costs are analysed for the different infrastructure types:

- Small Lab
- Large Lab
- Medium-Scale Site
- Large-Scale Site
- E-infrastructure

4.1. Investment Costs

The investment costs of a new facility include:

- Permits needed for land/sea use
- Project management
- Civil construction cost (e.g., buildings)
- Plant and machinery
- Other equipment

Existing facilities may also have investment costs, due to upgrades. These costs are considered investment costs, as they are one of a kind, and are typically planned according to needs, and budgeted in advance (3-5 years).

Civil construction work has a higher impact on large lab facilities. While the equipment used is very specific and costly, the buildings needed to house such equipment is also quite large. Civil construction associated with scale sites can also be high, especially in those that are grid connected.

However, plant and machinery costs are the most relevant cost centres. The equipment needed to simulate marine environments is highly specific. Many early testing facilities used custom designs produced in the laboratory, with unique costs associated. More recent facilities use state-of-the-art equipment. The total equipment used is proportional to the complexity of environments simulated.

The equipment necessary to generate waves, currents and wind channels also needs drive and control systems. These are generation systems that are either pre-computed or generated in real time. As such, information technology (hardware and software, off-the-shelf and custom-made) is likely to be a costly component of a large Research Infrastructure [16].

Table 4: Typical investments costs for different infrastructures

	Small Lab	Large Lab	Medium-Scale Site	Large-Scale Site
Total Investment Costs	~3-5 Million	~ 4-15 Million	~ 1–8 Million	~ 40 Million
Permits needed for land/sea use			~3%	~3%
Project management	~5-20%	~5-20%	~5-20%	~5-20%
Civil construction cost (e.g., buildings)	~50-60%	~30-50%	~10%	~5-10%
Plant and machinery	~20-30%	~45-55%	~55%	~70%
Other equipment	~5%	~1%	~5%	~1%

The investment costs associated with e-infrastructures are between 315 and 553 €/core, accounting for cores, associated storage, and other investment costs. Accounting for depreciation costs, the annual CAPEX is between 63-109 €/core [17].

4.2. Operational Costs

Operational costs relate to all the recurring costs that affect the day-to-day operations of a facility. These costs can be separated into two different categories:

- Management
- Research and Operation

Depending on the size of facilities, these costs can range from a few thousand euros per year, to a few millions. For the different facilities, typical ranges are:

- Small Lab: 5 k€ - 700 k€
- Large Lab: 85 k€ - 3.5 M€
- Medium-Scale Site: 30 k€ - 1 M€
- Large-Scale Site: 100 k€ - 1.5 M€

4.2.1. Management Costs

Management costs refer to the day-to-day cost of running any institution. These can be harder to assess if the Research Infrastructure is part of bigger organization such as a University, or if the institution provides several different types of services.

Costs associated with rent or leasing of buildings, utilities, cleaning services, legal fees, and management activities can be estimated on the basis of utilization of the Research Infrastructure within the context of the entire organization.

In general, management costs are:

- Rent costs

- Non-research Personnel costs
- General Utilities
- Insurance and other administrative costs

For facilities integrated in a university or higher education institution, rent costs are non-existent or negligible. Administrative personnel costs and other administrative costs are the most relevant cost centres.

4.2.2. Research and Operation Costs

Operating costs are costs that are incurred directly for running the Research Infrastructure. These include:

- Personnel working directly within the Research Infrastructure;
- Rents or leases associated with the Research Infrastructure;
- Maintenance, replacement and calibration of equipment;
- Consumables and equipment hire required for research;
- Utilities that are supplied to the infrastructure;
- Other fees including insurance and certification.

Infrastructure operating costs can be very significant: for large research facilities, a "rule of thumb" is that the annual cost of operations is about 10% of the total construction cost.

Information technology costs (including software, computing services, data distribution and archiving) also need to be considered in some detail, especially for data-oriented infrastructures and e-infrastructures.

Personnel costs vary from country to country, as they relate to the cost of living and typical wages (as well as contracting policies). They also vary depending on the seniority and experience of the person employed.

However, direct personnel associated with labs include:

- General and commercial managers
- Research staff
- Mechanical Technicians
- Instrumentation Technicians
- Quality Systems and Project Engineering
- IT technicians

Direct personnel associated with scale testing sites include:

- General and commercial managers
- Operations manager
- Test engineers
- Technical managers
- Data technicians

Figure 4:1 shows the breakdown of operational costs for physical infrastructures, aggregated from surveys to infrastructures and MaRINET2 data. *Figure 4:2* shows the ranges for each cost centre.

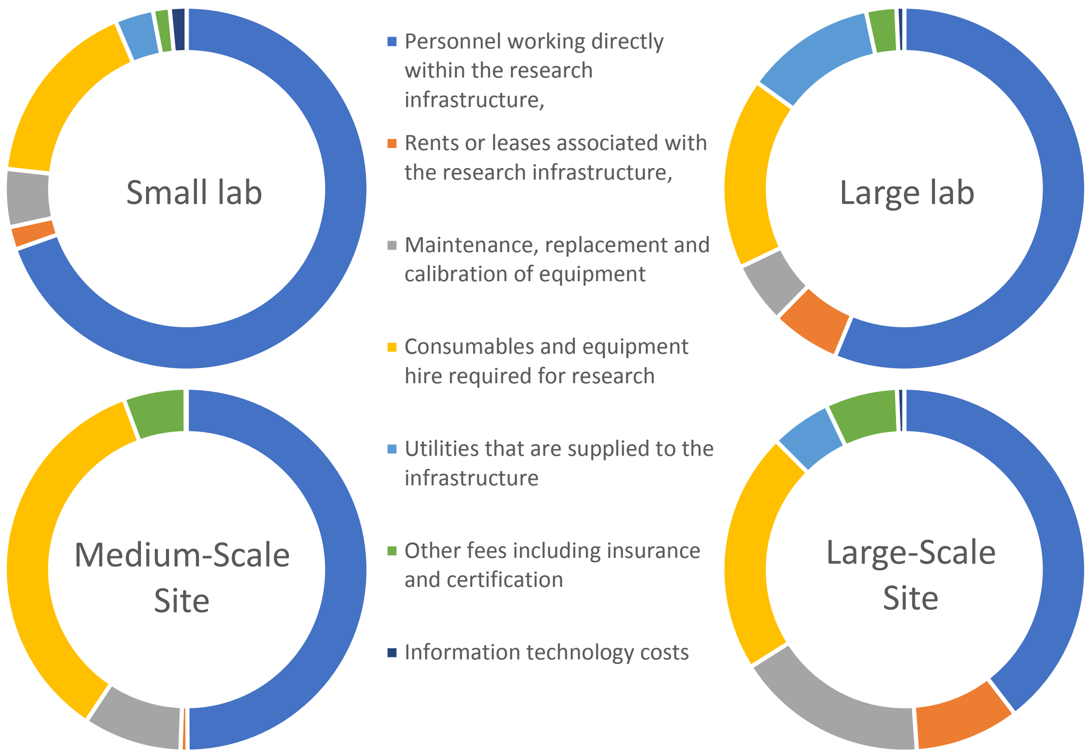

Figure 4:1: Operational costs breakdown by type of infrastructure

Personnel costs represent a high proportion of the operational costs, especially in labs, with the contribution to total operating costs decreasing as the infrastructure size increases. The majority of these costs are related to research personnel, with facilities managers and test engineers representing the bulk of the cost. Depending on the size of the facility, the number of test engineers employed can range from 2 to 8.

Consumables and equipment hire are the second highest contributor to the operational costs, followed by maintenance and calibration costs.

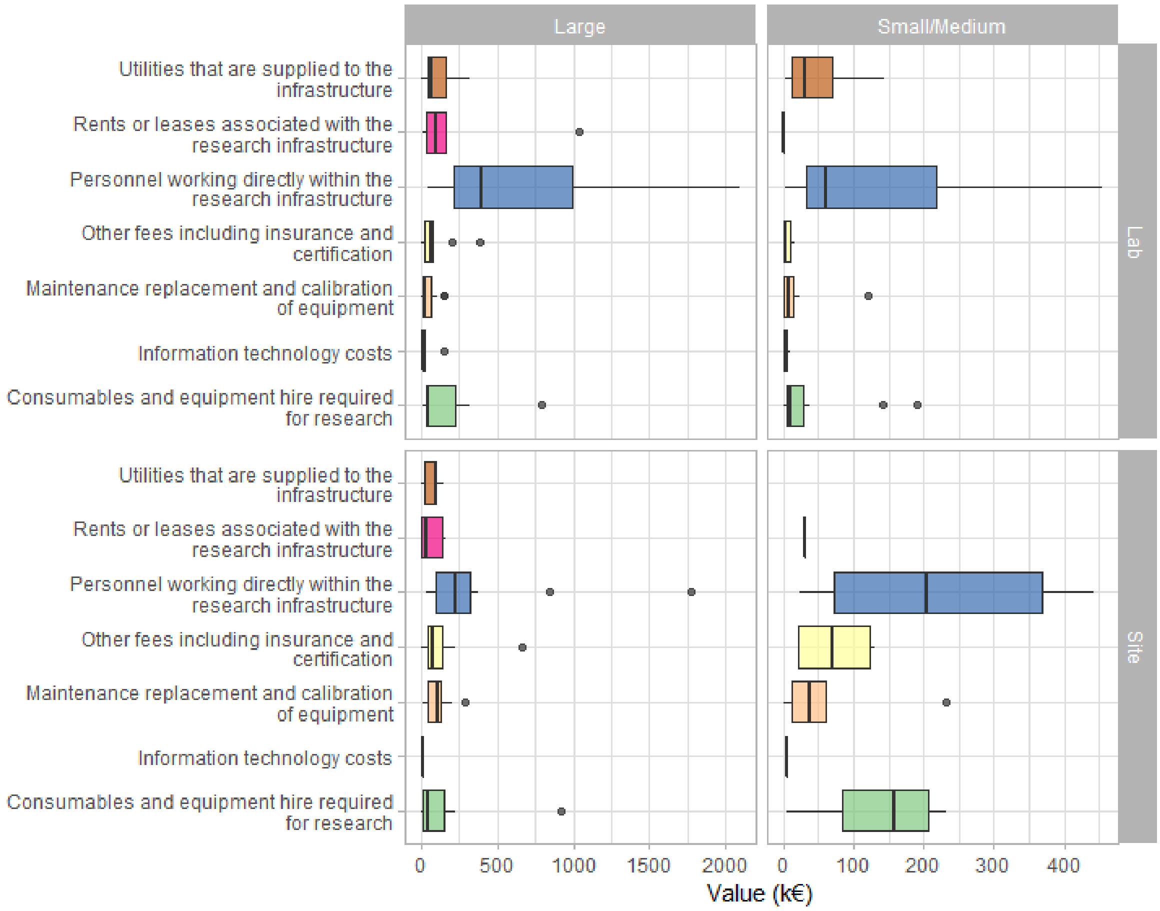

Figure 4:2 Operational cost ranges by infrastructure type and cost centre

Computing costs associated with labs are small compared to other costs (c. 1%). It is possible that not all computing costs were reported in the surveys. However, these costs are of course larger for e-infrastructures. The total costs associated with running e-infrastructures have been estimated to be, on average, between 0.03€/core. hour and 0.05€/core. hour for high performance computing, and between 0.04€/core. hour and 0.08€/core. hour for high throughput computing. The assumptions for these values include costs with software (c. 5.3%), direct and indirect personnel costs (c. 81.4%), site costs (c. 2.1%) and electricity (c. 11.1%) [17].

With a growing utilization of Research Infrastructures, and the use of more specialized sensors, the requirements for data storage and analysis will increase, leading to an increase in the associated storage and computing costs. Depending on the complexity of the analysis, CFD modelling will require dedicated computing workstations, which will also drive the costs up.

4.3. Decommissioning Costs

Decommissioning of a Research Infrastructure should always be considered as part of its lifecycle. These include the costs of disposing of sensitive and hazardous materials, either through recycling or dedicated disposable. There may also be recuperation of funds through the shutting down of existing infrastructures.

5. Research Infrastructures revenue sources

The development and operation of Research Infrastructures and e-infrastructures can be financed through different methods, contingent on the needs and type of organization responsible for the facility.

For a Research Infrastructure, the types of funding and revenue employed include:

- Grants:
  - for design studies and planning of construction or collaboration
  - for investing in equipment or databases
  - for operational costs of maintaining the operation in the long term
  - for phasing-out the Research Infrastructure (when relevant)
- Funded Research
- Public Funding
- Private Investments
- Payment for services rendered and access charges
- Debt funding
- Other Funding

While grants and public funding are a critical and fundamental source of financing for Research Infrastructures, new forms of financing are being adopted, such as zero-interest debt, venture capital and technology transfer funds.

Public sources of funding have seen some budgetary cuts, especially in European countries affected by the recent economic crisis, which have translated in lower amounts available and more constrained access conditions. This means that other sources are sought. Securing private sources also has challenges, as grant-type funds are less common, as well as zero-interest funding [18].

The funding of R&D across Europe, according to funding sources (public vs. private) is presented on the figures below.

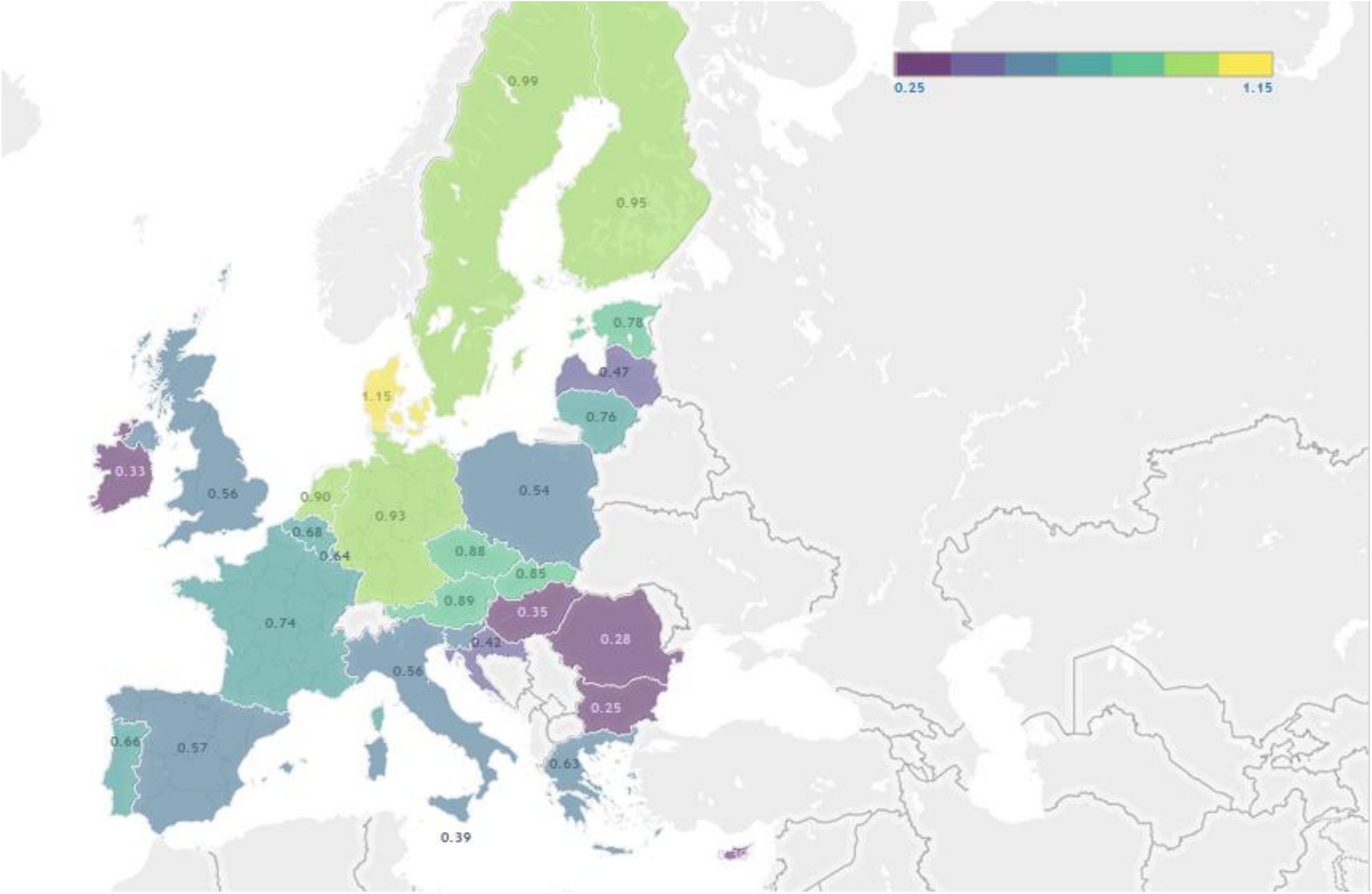

Figure 5:1: Public (government and higher education) R&D Expenditure as % of GDP (2015) [19]

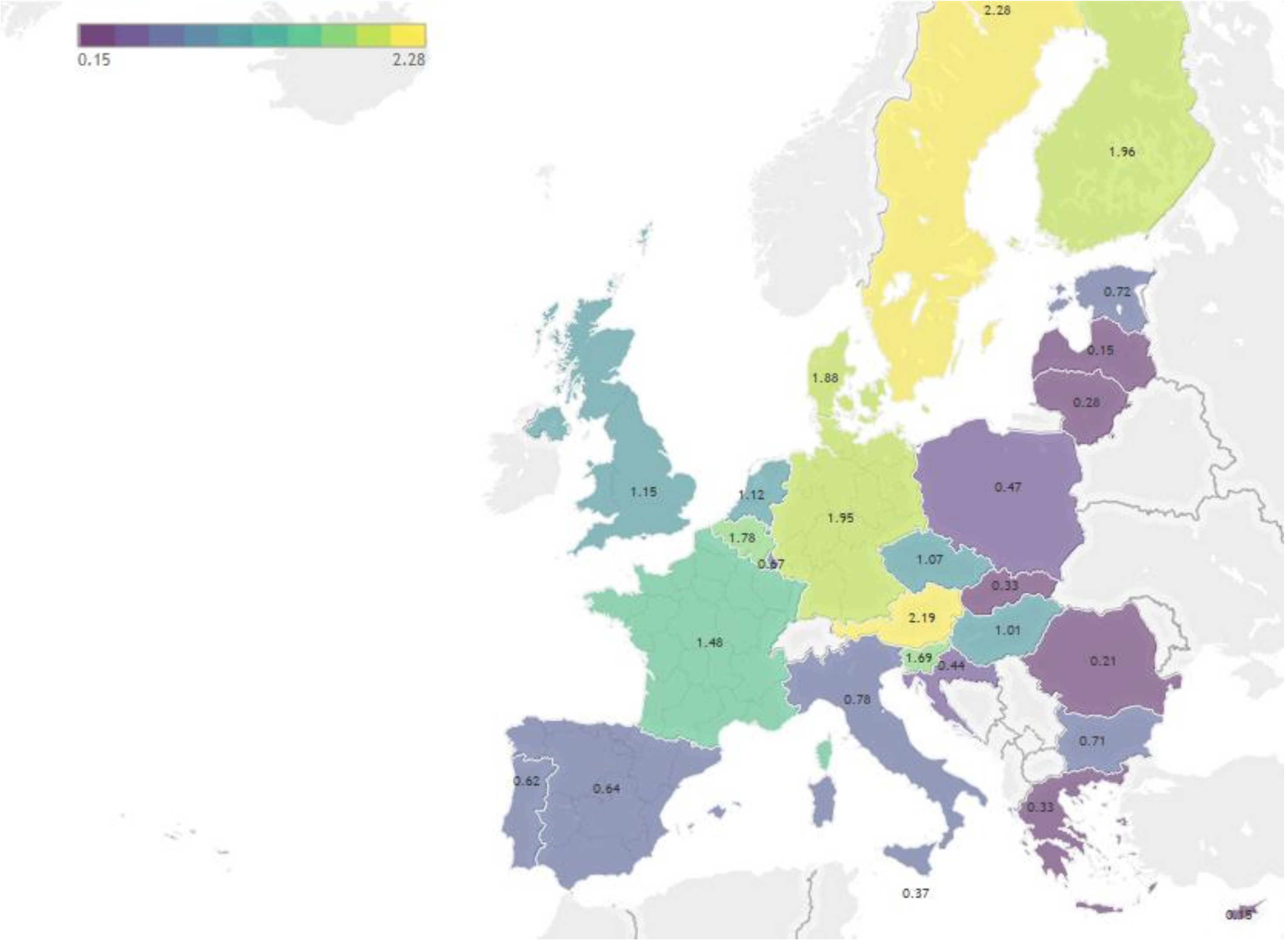

Figure 5:2: Private (including Private Non Profit) R&D Expenditure as % of GDP (2015) [20]

An overview of available funding streams at European and national level is available in project deliverable 6.2 [21].

For the surveyed infrastructures, the typical financing is described in the following graph, separating funded research, public funding, services to academia and services to industry.

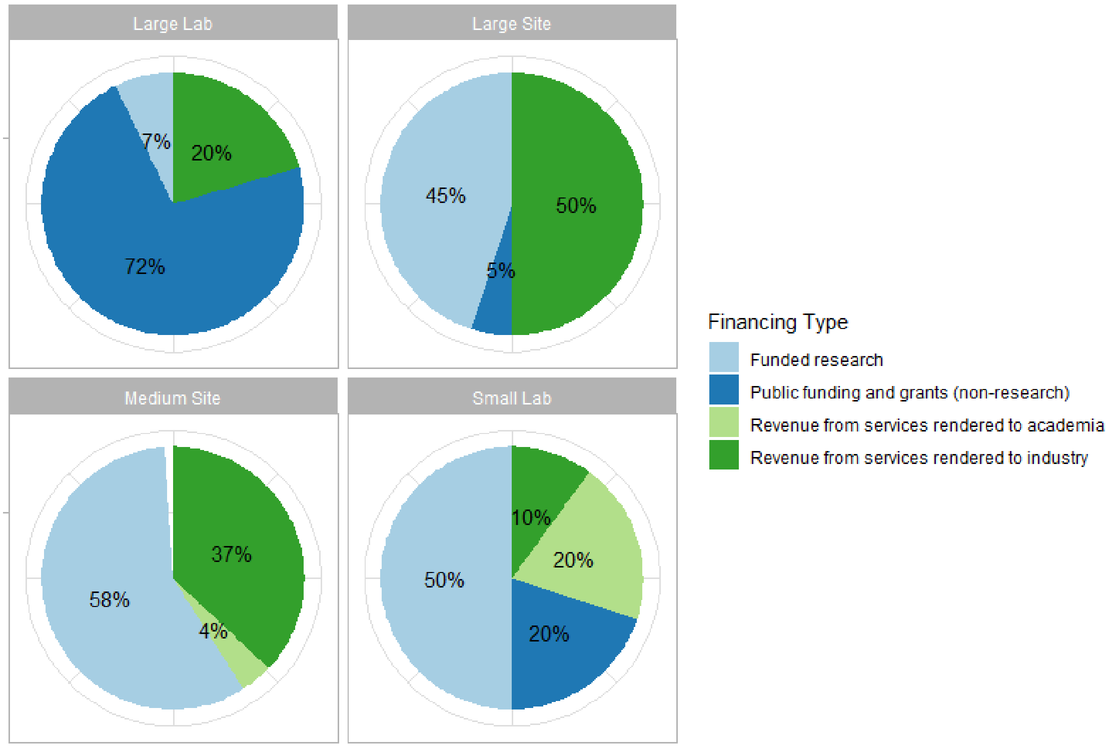

Figure 5:3 Financing breakdown by infrastructure type

5.1. Grants

Grants are a critical and fundamental source of financing for Research Infrastructures [18]. However, grants to establish the Research Infrastructure rather than directly for research are less common.

There are European funds, under Horizon2020 target towards Research Infrastructures. The actions under this objective aim at developing European Research Infrastructures for 2020 and beyond, fostering their innovation potential and human capital as well as reinforcing European Research Infrastructure policy.

Three groups of activities will be supported to enable excellent science in Europe:

- Implementation and operation of the Research Infrastructures listed on the ESFRI Roadmap;
- Integration of national facilities into European networks;

- Further deployment and development of Information and Communication Technology based e-infrastructures [22].

At each national node, the agencies responsible for distribution of funds allocated to innovation and research may have specific grants towards for planning, construction, upgrade or operation of Research Infrastructures and e-infrastructures.

5.2. Funded research

Funded research refers to specific projects, collaborative or not, with allocated funds. These projects can be:

- Collaborative research projects, such as EU projects
- PhD scholarships
- Post-doctoral grants
- Other scholarships and grants

The funding available may cover, under direct costs:

- Personnel costs of research fellows
- Equipment costs to be used in the research activity
- Training costs and participation in conferences
- Travel allowance for research fellows

With the exception of collaborative research, this funding can be tied to the research fellow, to be used in any facility of choice,

Some of the funding will also cover indirect costs, as a percentage of the direct costs, in order to cover for expenses related with:

- Non-research staff
- Infrastructure rent or lease
- Utilities
- Insurance and other administrative costs

From the point of view of the infrastructures, the source of financing of visiting fellows is irrelevant for the balancing sheets. However, for in-house staff, the availability of research funds for staff is important, as these represent one of the highest operational costs.

5.3. Other Public Funding

Public institutions, being research centres or higher education institutions, are at least partly publicly funded. In the majority of cases, there is allocation within the state budget for research and higher education institutions, with ministries for science, higher education or equivalents being responsible for the allocation of this budget. In some countries, there may be allocations also at regional level.

The allocation of public funding is subject to the will of the governing bodies in funding research activities, and its distribution may be dependent on national scoring of facilities. The distribution of these funds is usually administered by innovation or science and technology agencies.

These funds are used to cover the running expenses of the institutions; acquisition of resources or licensing of access to resources; support the development of Research Infrastructures; and knowledge and cultural dissemination activities and training activities.

Other sources of public funding, such as zero-interest debt, venture capital and technology transfer funds are becoming increasingly more common, Examples include the financing instruments offered by the European Investment Bank or, at regional level, the Scottish Investment Bank. These give an entrepreneurial approach to science research, and are a good solution for fields with industrial application. Zero-interest debt are debt instruments that while requiring recipients to pay back the full amount of contribution, have no interest rate associated, unlike normal debt financing. Venture capital is small value high-risk investments, usually in start-ups and pre-seed phase companies. Interest rates are usually high, with lenders taking equity positions. InnovFin SME Venture Capital is an example of this type of instrument. Technology Transfer funds are applied on IP rights of early research and are directed to academia that wish to transform their research into a marketable product [18].

The European Investment Bank Group has a track record of co-financing of Research Infrastructures such as CERN, the European Space Observatory and the European Synchrotron Radiation Facility, and to a lesser extent the direct financing of infrastructures for innovation and commercialisation projects.

5.4. Private Investment, services rendered and access charges

Another funding source is the rendering of services and access to the infrastructure. The revenue from these is calculated with basis of the operating costs for the duration of the testing, and the amortization of the initial investments. Tests can range from a few days in small labs, to a week basis in larger labs and scaled test sites, to months in large scale sites.

The determination of access costs is of particular interest for MARINERG-i as the management of infrastructure access will be one of the key services provided by the distributed Research Infrastructure. However, depending on the business model and legal framework adopted by MARINERG-i, the determination of access fees may still lie with the individual Research Infrastructures, with a small mark-up for administrative fees added. If any upgrade is to be carried out or new facilities financed through the MARINERG-i distributed infrastructure, the framework adopted for determining access fees can be adapted from the practise of existing infrastructures. The details of the financial framework are available in deliverable 6.4 [23], and the business model is presented in deliverable 8.2 [24].

However, these access fees can vary widely in value and time unit. Furthermore, different pricing has been reported, depending on the type of client. Small and large labs can have as base time unit days or weeks, depending on the type of equipment and service. The costs range from a few thousand euros/day to a few thousand euros per week. For testing sites, the time-frame needed for testing is longer, so it is common to use a monthly base unit, although for medium scale sites it can be possible to contract in terms of weeks. The costs in these cases can range from a few thousand euros/month to a few hundred thousand euros/month. A small mark-up will likely be added to these prices for commercial clients.

Charges for e-infrastructures can be harder to establish, as it would require determining which fraction of each CPU hour was used [25]. Charges associated to data storage and management will be easier to establish, by determining the data amount generated, and the storage time required.

5.5. Debt funding

Access to debt funding is more common in private institutions, in order to raise capital, to ensure liquidity or invest in equipment. This debt tends to be short-term, and planned around payments expected from services rendered. The use of debt financing is also tied with the business model adopted by the institutions.

Public institutions may also access debt financing; however, generally debt financing is discouraged as it can conflict with societal goals of research institutions. Furthermore, the private financial sector may have high interest rates that are not compatible with research that has a non-product output.

5.6. Other revenue sources

Other revenue sources include charitable donations, licensing revenues and patent sales.

Charitable donations are typical in public institutions, namely those providing services in higher education. These donations can be used for specific purposes, such as funding scholarships and fellowships, or to be used more generally by the institution.

6. Conclusions

The construction and operation of Research Infrastructures have associated costs. The construction of new infrastructures requires high initial costs, as new facilities and new equipment must be purchased. However, establishing a distributed network of Research Infrastructures such as MARINERG-i would primarily require operational costs, as it will incorporate existing facilities. Their primary initial and ongoing outgoings would be the cost of ongoing work in standardisation, harmonisation, and quality assurance of procedures and data, as well as costs associated with establishing and maintaining the e-infrastructure [26]. Long-term; however, these procedures will enable the distributed infrastructure to operate more efficiently, as well as the individual infrastructures.

Regarding the costs associated with the distributed infrastructure, there will be management costs associated with the different nodes, related with physical location(s), consumables, communication, outreach and marketing; personnel costs associated with management, national coordinators, advisory members and consultants needed; and operational costs related with access procedures, training, certification, and other activities of the infrastructure.
However, construction and operational costs must be financed in order to ensure its financial sustainability.

Some of the revenue streams available for Research Infrastructures can be achieved through lobbying and application to funds as is the case of public funds in the national science budgets, funded research and other grants.

Services rendered by the Research Infrastructures, including the access to the facilities by academia and industry can represent between 20% and 50% of the financing. The pricing associated with this access, referred as access fees, is often calculated on the basis of the initial investment of the infrastructure, through amortization, the subsequent upgrades made, and the operational costs associated with the infrastructure, including administrative ones. Determining how the access fees are calculated, and what is included can inform the distributed infrastructure on how to manage the access to the participating infrastructures and how to articulate the business model with any possible future upgrades to the infrastructure. The financial model and sustainability project for MARINERG-i will be outlined in project deliverable 6.4 due in November 2018.

Bibliography

[1] Ocean Energy Forum, 'Ocean Energy Strategic Roadmap: Building Ocean Energy for Europe', Ocean Energy Forum, 2016.

[2] T. Telsnig, C. Vázquez Hernández, A. Villalba Pradas, European Commission, and Joint Research Centre, 'JRC wind energy status report : market, technology and regulatory aspects of wind energy: 2016 edition', Joint Research Centre, 2017.

[3] BVG Associates, 'Unleashing Europe's offshore wind potential: A new resource assessment', WindEurope, Jun. 2017.

[4] IRENA, 'Innovation Outlook: Offshore Wind', International Renewable Energy Agency, Abu Dhabi, United Arab Emirates, 2016.

[5] D. Magagna, A. Uihlein, R. Monfardini, European Commission, and Joint Research Centre, *JRC ocean energy status report technology, market and economic aspects of ocean energy in Europe: 2016 edition.* Luxembourg: Publications Office, 2016.

[6] A. MacGillivray, H. Jeffrey, and R. Wallace, 'The importance of iteration and deployment in technology development: A study of the impact on wave and tidal stream energy research, development and innovation', *Energy Policy*, vol. 87, pp. 542–552, Dec. 2015.

[7] D. F. Beck, 'Technology development life cycle processes', Sandia National Laboratories, Albuquerque, New Mexico, SAND2013-3933, May 2013.

[8] HMRC, 'State of the Art Analysis : A Cautiously Optimistic Review of the Technical Status of Wave Energy Technology', WAVEPLAM, 2009.

[9] ESBI, 'Supply Chain Study for WestWave', 2011.

[10] D. McAuley, 'Marine Renewable Energy Infrastructure Analysis', 2014.

[11] D. Noble, T. Davey, T. Bruce, H. Smith, P. Kaklis, and A. Robinson, 'Characterisation of current generation in the FloWave facility', in *Proceedings of the 11th European Wave and Tidal Energy Conference*, 2015.

[12] HMRC, 'OCEAN ENERGY: Development & Evaluation Protocol. Part 1: Wave Power', HMRC, Sep. 2003.

[13] J. Weber and J. Roberts, 'Cost, time and risk assessment of different wave energy converter technology development trajectories', in *Proceedings of the Twelfth European Wave and Tidal Energy Conference*, University College Cork, Ireland, 2017, pp. 725\hyphen 1–725\hyphen 8.

[14] C. Maisondieu, 'ORE e-Infrastructures User-needs Profile and Integration with Existing e-Infrastructures', MARINERG-i, Project Deliverable D3.2, 2018.

[15] C. Maisondieu, 'ORE e-Infrastructures End-users requirements profiles', MARINERG-i, Project Deliverable D3.1, 2018.

[16] OECD Global Science Forum, 'Large Research Infrastructures : Report on Roadmapping of Large Research Infrastructures (2008) and Report on Establishing Large International Research Infrastructures: Issues and Options (2010)', OECD, 2010.

[17] Cohen, Sandra, Karagiannis, Fotis, Courcoubetis, Costas, Iqbal, Kashif, Andreozzi, Sergio, and Heikkurinen, Matti, 'Computing e-Infrastructure cost estimation and analysis - Pricing and Business models', e-FISCAL, Project Deliverable D2.3, 2013.

[18] A. Verbeek and L. Busato, 'Access-to-finance for Research and Technology Organisations (RTOs) and their academic and industrial partners', European Investment Bank, Luxembourg, Mar. 2017.

[19] EUROSTAT, ‘Public (government and higher education) R&D expenditure as % of GDP’, *RIO Indic. Theme Investment– Sect. Perform.*, 2017.

[20] EUROSTAT, ‘Private sector expenditure on R&D’, *RIO Indic. Theme Investment– Sect. Perform. Sect. Priv. Sect. Priv. Non Profit PNP*, 2017.

[21] M. Silva, T. Simas, R. Sebastian, and J. Cândido, ‘Report on Funding streams’, MARINERG-i, Project Deliverable D6.2, 2018.

[22] European Commission, ‘Research Infrastructures - Horizon 2020 - European Commission’, *Horizon 2020*. [Online]. Available: /programmes/horizon2020/en/area/research-infrastructures. [Accessed: 19-Sep-2017].

[23] ‘Financial model & Sustainability projection’, MARINERG-i, Project Deliverable D6.4, 2018.

[24] ‘Final Business Model’, MARINERG-i, Project Deliverable D8.2, 2018.

[25] ‘Placing a price-tag on e-infrastructure’, *Science Node*. [Online]. Available: https://sciencenode.org/feature/placing-price-tag-e-infrastructure.php. [Accessed: 20-Sep-2017].

[26] Academy of Finland, ‘National criteria for research infrastructures’, 2017.

Appendix 1: Infrastructure questionnaire: Costs and revenues

Introduction

MARINERG-i proposes to become the leading internationally distributed testing infrastructure in the MRE sector. Please refer to the MARINERG-i website for an overview of the project and its objectives. (http://www.MARINERG-i.eu/).

In order to develop a strong business case, the current status of the Research Infrastructures must be studied. This includes surveying the existing facilities and their capabilities, understanding the costs associated with managing and operating such facilities, and identifying the current and future needs of the sector.

This questionnaire aims to gather information on cost structure and financing of existing offshore renewable energy testing facilities. The information obtained through the questionnaires will be aggregated, analysed and compiled into a report (D6.1) that summarises the overall cost and revenue structure of the various facilities. Several questions in this questionnaire will ask about specific costs and services prices. While detailed information is always welcomed and will enhance the analysis, we do not require in-depth detail, but estimates within the same order of magnitude. This report will be a primary source for use in developing the overall financial model for the MARINERG-i distributed testing infrastructure.

If there are any questions about the questionnaire, please contact Marta Silva at marta@wavec.org.

1. Infrastructure classification

This section aims to profile the infrastructure, in terms of size, operating framework, and the existing equipment.

1.1. How would you classify your infrastructure?

The classification below follows the MaRINET and MaRINET2 characterization.

- Small labs conduct design validation and optimization testing at small scale (1:25 – 1:100).
- Large labs conduct performance verification and component testing and monitoring at medium scale (1:10 – 1:25).
- Medium-scale sites are benign sea or equivalent environments for medium scale (1:2 – 1:10) prototype or sub-system testing.
- Large-scale sites are open sea sites for full and large-scale testing (1:1 – 1:2) of devices.

☐ Small Lab ☐ Large Lab ☐ Medium-Scale Site ☐ Large-Scale Site

☐ Other: ____

1.2. To which sectors do you provide services to?

Select all that apply.

☐ Wave Energy ☐ Tidal Stream Energy ☐ Offshore Wind

☐ Other Sectors: ____________________

1.3. Is the infrastructure part of a larger organization (e.g., university)?

☐ Yes ☐ No

1.3.1. If yes, please describe the nature of the legal relationship to the parent body. E.g. constituent part, wholly owned subsidiary, Service Level Agreement etc.

____

____

1.4. What equipment/facilities are available at your infrastructure?

Available equipment and facilities are those that are operational for internal and external use. If part of MaRINET2, or similar programme that allows third-party access, please indicate.

	Equipment	Third party access? (Y/N)
☐	Wave Tank	
☐	Current flume	
☐	Wind tunnel	
☐	Open sea testing site	
☐	Full scale testing site	
☐	Material testing facility	
☐	Electrical component testing facility	
☐	Other:	

2. Investment costs

The section aims to gather information on typical costs of setting up facilities, upgrading, and how they relate to access costs

2.1. Are initial investment costs accounted for when determining access costs?

☐ Yes ☐ No

2.1.1. If yes, how are the initial investment costs factored in the access costs?

☐ % of initial costs Rough estimate: ____________________

☐ Other Rough estimate: ____________________

2.2. What was the total initial investment for the facility?

This includes permits, project management, land acquisition costs, civil construction, machinery and other equipment.

If not in Euros, please indicate currency.

If exact values are not available (or you do not wish to disclose), can you please indicate order of magnitude (~100€, ~1000€, ~M€, etc).

____

2.2.1. Year of payment of costs detailed above (for conversion into EUR_{2018})?

____

2.2.2. Concerning the initial investment for the facility, how were the values distributed across the categories below

Cost Item	% of total
Permits needed for land/sea use	
Project management	
Civil construction cost (e.g., buildings)	
Plant and machinery	
Other equipment	
Other costs	

2.3. What timeframe was envisioned to amortize the initial investment costs?

☐ Within 3 years
☐ 3 to 5 years
☐ 5 to 10 years
☐ 10 to 15 years
☐ 15 to 20 years
☐ Over 20 years

2.3.1. What is the expected percentage return on investment during that timeframe?

____

2.4. Can you provide base costs for the plant and machinery equipment directly used for R&D and services?

Equipment	Cost (per unit)

Add more lines as needed

2.5. Is there any budget for or estimation of expenses related with infrastructure upgrade (i.e., expenses with acquiring new equipment or construction of new facilities, not regular maintenance or repair)?

☐ Yes ☐ No

2.5.1. If yes, how much and within what time frame (budget for 1 year, 5 years, etc...)

If possible, specify the upgrades foreseen. If no specification of upgrades is available (or confidential), please indicate as all upgrades.

Upgrade purposes: *(i.e., what for)*	Value: *(i.e., how much)*	Time frame: *(i.e., when)*

2.5.2. How is the infrastructure upgrades budget determined?

☐ Budgeted as needed	Rough estimate (€):	____________
☐ % Budget set for upgrade work	Rough estimate (%):	____________
☐ % of revenues generated	Rough estimate (%):	____________
☐ Other:	Specify:	____________

2.6. Are access costs updated to account for upgrade costs?

☐ Yes ☐ No

2.6.1. If yes, how are the initial investment costs factored in the access costs?

☐	% Budget set for upgrade work	Rough estimate (%):	____________
☐	% of revenues generated	Rough estimate (%):	____________
☐	Other:	Specify:	____________

3. Running costs

This section aims to understand how running costs for the infrastructure are structured – especially in fixed and administrative costs, and costs directly related with running research activities, and how it translates into access costs.

3.1. Are running costs accounted for when determining access costs?

☐ Yes ☐ No

3.1.1. What is the total value of running costs?

____

3.1.2. If yes, how are the initial investment costs factored in the access costs?

☐ % of running costs Rough estimate: ________________

☐ Expenses associated with the activity/work + fixed rate Rough estimate: ________________

☐ Other Rough estimate: ________________

3.2. What is the personnel distribution within your institution?

Category	Number	Base salary (month)	Administrative [y/n]	Research [y/n]
Manager				
Mechanical Technician				
Instrumentation Technician				
Test engineer				
IT and Data technicians				

Add more lines as needed, adapt categories as needed

3.3. Are there personnel contracted only when the infrastructure is in use?

☐ Yes ☐ No

3.3.1. If Yes, can you specify category, number and base salary

Category	Number	Base rate	Rate time-frame (day, week, month)

3.4. How are the management/administrative (i.e., not research related) costs distributed across the categories below?

If answering with values on column 1, the % on column 3 is not required

Cost Item	Cost per year	% of total running costs	% of administrative costs
Rent			
Non-research personnel			
Utilities *(not directly related to research)*[1]			
Insurance			
Other administrative costs			

[1] *If distinction between research and non-research utilities costs are not available please indicate total amount below.*

3.5. How are research costs distributed across the categories below?

If answering with values on column 1, the % on column 3 is not required

Cost Item	Cost per year	% of total running costs	% of research costs
Consumables			
Research personnel			
Maintenance, replacement and calibration of equipment			
Utilities *(only directly related to research)*[2]			
Information technology costs			
Other research costs			

[2] *If distinction between research and non-research utilities costs are not available please indicate total amount here, and do not report it on the table above.*

4. Revenue stream

The section aims to gather information on how infrastructures ensure financial stability and what services are provided.

4.1. What services do you provide? For each service, can you also indicate the typical selling price, the typical duration and the utilization rate over the year?

Service	Time basis (day, week, month)	Selling price per time unit	Utilization rate over the year (%)

Add more lines as needed

4.2. Is there a difference in service pricing between clients from industry or academia?

☐ Yes ☐ No

4.2.1. If yes, how does pricing differ?

____

____

____

____

____

4.2.2. What is the typical breakdown of financing of the infrastructure

Amount	% of total	Financing type
		Revenue from services rendered to industry
		Revenue from services rendered to academia
		Funded research
		Public funding and grants (non-research)
		Private investments
		Debt financing
		Other financing

5. Market and Future Business Development

This section aims to understand the future vision of the infrastructure in terms of business opportunities.

5.1. Is there an active infrastructure promotion program?

☐ Yes ☐ No

5.1.1. If yes, how is it financed?

☐ Budgeted as needed
☐ % Budget set for promotion program Rough estimate: ____________
☐ % of revenues generated Rough estimate: ____________
☐ Other: Specify: ____________

5.2. Have you identified business opportunities for developing new infrastructure services?

☐ Yes ☐ No

5.2.1. If yes, across which sectors?

Select all that apply.

☐ Wave Energy ☐ Tidal Stream Energy ☐ Offshore Wind

☐ Other Sectors: ______________________________

5.2.2. Can you specify these?

____
____
____
____
____