Gardens & Landscapes
The Strength of the Tide in the Tagus Estuary
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DOI 10.2478/glp-2021-0002

 Gardens and Landscapes, Sciendo, nr 7 (2021), pp. 5-17. URL: <https://content.sciendo.com/view/journals/glp/glp-overview.xml>
ABSTRACT

In the context of the history of science and technology, the article explores the use of tide force in the Tagus estuary, more precisely in the municipality of Seixal, from the tide mills in the early modern period to the project of the hydraulic motor in the nineteenth century. The historical knowledge of practices and devices for the intelligent use of water in Seixal is an invitation to current reflection on the use of clean and renewable energies.

Keywords: water devices, tide mills, hydraulic motors, Tagus estuary, Seixal.

ARTICLE
Introduction

Given the problems arising from climate change and the fact that water and energy are increasingly scarce resources, revisiting the past and recovering sustainable technologies for water and clean energy, gained momentum. Considering the growth of the occupation of Lisbon and the significant increase in occupation of the south left bank of the Tagus River, it is urgent to enhance the memory of the estuary, and its economic potential, while enhancing its identity and developing a circular and sustainable. The history of the Tagus estuary area, mainly the Municipality of Seixal, conveys an example of a balanced dynamic between economic goals with the landscape, respecting the natural environment. Throughout history, knowledge on the water theme in Portugal is quite rich and of great reference, especially when analyzing the sustainability of old systems, considered intelligent and advanced for the time and still applied in various scales of water management. Such expertise in hydraulic innovations was essential for developing current water systems.

Historiography of technology has paid attention to the use of water as a source for energy production. It has been addressed by the history of technology, mainly by Terry Reynolds who wrote the seminal book *Stronger than a hundred men* (1983) and Jeremy Black's *The Power of Knowledge* (2014). Moreover, historians of Antiquity and medievalists have covered the importance of mills for irrigation and economy in general, such as Andrew Wilson's

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Machine, Power and the Ancient Economy (2002) and John Langdon's *Mills in the Medieval Economy* (2004). In Portugal, water mills have been studied by the fields of history of economy, ethnography and also some medievalists. Sousa Viterbo, who has written the most important dictionaries on architects and also of gardeners, dedicated also to the first publication of archaeological industry (VITERBO 1896). From the perspective of ethnography, Oliveira, Galhano and Pereira produced the most important survey of water devices (OLIVEIRA, GALHANO and PEREIRA 1983). Specifically, on the case-study of Seixal, municipal historians have covered the Seixal tide mills (NABAIS 1982, 1986). Moreover, some works have been produced in the last decades, covering the analysis of unpublished documentation from Medieval times (SILVEIRA 2009, 2017).

Focusing of the Seixal tide mills, this paper argues that in the nineteenth century, famous engineers understood the importance of using the tides' strength to produce clean energy. They proposed to use the tides' strength through hydraulic motors. Moreover, I argue that this knowledge stems from local expertise developed during the early modern period and that it should be rescued in current times due to climate changes.

To unfold my argument, I divided this paper into two parts. The first covers the history of tide mills in the Tagus estuary during the early modern period and the second the projects' proposals to take advantage of the tides' strength by using hydraulic motors. Furthermore, I conclude with some ideas on how to resume these old solutions to cope with current challenges.

The importance of tide mills in early modern Portugal

"Apart from the use of the sail to propel boats by the wind, the water mill represents the earliest human application of a natural force to do mechanical work. It is therefore of major importance in the history of technological development. Besides transforming the process of milling grain into flour, it is also the remote ancestor of many other kinds of industrial machine which apply waterpower to either rotary or reciprocating linear motion. It has also been something of a *cause célèbre* in the history of classical and medieval technology, having for many years been used as an illustration of the technological under-development of the ancient world." (WILSON 2002: 10-11).

In the sixteenth century, Western Europe had greater growth and invested substantially in capital goods that increased productivity. Water mills were crucial and were used for activities universally carried out, that is, grinding and building more than a man could achieve. Despite the high investment cost, and the necessary consistent skill in construction and operation, the mills saved a lot of manual labor. The efficiency of the system in the grain milling process was a considerable advance in the production of staple foods in pre-industrial Europe. These facts demonstrate that the theme of technology involving water, has always been in constant development and evolution, with the creation of new solutions aimed at meeting the increasing needs of a population that became increasingly urban and industrial and therefore required not only the access to the common and essential good, water, but also the energy that water has the great potential to produce. For example, water mills and windmills were also widely used for the manufacture of paper, pressing oilseeds or sugar cane.

Diversity in the application of energy generated by water was considered a central feature since antiquity. The European Atlantic coast witnessed the development of tide mills throughout the Middle Ages. The ocean in question contemplates great variation in heights between tides, which made the undertakings feasible, always located together on the seafront and on flat and flooded terrains. The oldest recorded tide mill to date is in Northern

Ireland and is dated to the seventh century. It was discovered due to archaeological excavations undertaken in 1999 near the medieval monastery of Nendrum, in Strangford Lough, where two samples of tide mills with horizontal rotation and boilers were found, dated between 619 and 788 AD (SILVEIRA 2009).

Tide mills arise in response to the geographic characteristics of some regions. When the location was in low coastal areas, which were too wide or too deep, in addition to the slow pace of the waters, making it impossible to intercept the water or the action of damming, through bridges or dams to which mills were associated, it was necessary another kind of solution. Thus, the water wheel inserted in a tide mill appears to solve this problem in the medieval period. Tide mills can take many forms. Probably the first specimens were only moored or in moored boats. That way when the tide goes up, the wheels are pushed in one direction and then, when the tide goes down, in the opposite direction. However, it is possible that the implantation of tide mills that came to be more widely applied was the one with a more complex format. Thus, gates were used to dam tide water installed in their own buildings, located at the mouth of a river, stream or bay (REYNOLDS 1983: 66-68).

In general, the tide mills are made up of the building that incorporates the devices, the boiler that holds the water, the dike that delimits it, and finally, the gate that allows controlling the flow of water in the boiler (SILVEIRA 2009: 591). They worked as follows: when the tide filled, the gates were opened for water to enter, and before the tide started to go down, the gates were closed, thus damming the water, creating large reservoirs. It is noted that the movement of opening and closing of the gates was made by the force of the water, which pushed the gates. Subsequently, the water from these reservoirs was then released through a mill, passing through the blades of the water wheel. With the backwater, the millers could already start the milling process. These artisans opened one or several existing channels in the mill's basement, allowing the water accumulated in the boiler to be released with considerable pressure on the wheels. Thus the grinding wheels came into operation. Such a process could take place twice a day, according to the two daily cycles of the tide. In some cases, gears transmitted the energy of the hydraulic wheels to the grinding wheels so that the grinding process could begin (SILVEIRA 2009: 591).

Tide mills had a greater installation complexity compared to conventional water mills. Added to this fact, these structures depended on the times and particularities of the tide, which changed with the seasons, cycles of the moon, and changed from one day to another, thus restricting the time of use of this hydraulic structure. Moreover, they relied on local expertise as artisans had to know very well the environment to take advantage of tides. Despite this, tide mills were a smart alternative in places where conventional mills could not be implemented, adding the advantage of never freezing, being predictable and being able to function every day of the year.

In the early modern Portugal, not only water mills but also tide mills fostered optimization of energy production. In view of the favorable and strategic geographical conditions, Portugal has one of the highest concentrations of tide mills in the world. The water mills were introduced in the current Portuguese territory by the Romans as the material traces found prove. They spread on a large scale in the following centuries, in the Middle Ages, under the influence of lay and religious lords. The investment in hydraulic mills is associated with the emancipation and exodus of peasants and with the expansion of agricultural areas. The hydraulic mills are found from north to south of the country. To the north it is possible to mention the hydrographic basin of Rio Ave with a high number of mills. In the south, the tide mills of the Tagus River Estuary stand out, since the choice for the construction of these structures is specific – between the ocean and the rivers, in low and swampy geographical areas, where the action of the tides is very strong. These structures were incorporated the landscape since the 13th century, reached their peak two centuries later and continued to be built until the nineteenth century.

As for the tide mills, which use the same technology, but with a specific geography, little is known about the reality

of the beginning of their construction in Portugal. Reynolds states that in Portuguese territory, the first records of tide mills date back to the thirteenth century (REYNOLDS 1983: 66-68).

Fig. 1. Alcântara mill represented in panoramic tiles panel of eighteenth century.

According to the records of the Tagus estuary, tide mills can be traced in the thirteenth and fourteenth centuries, such as the Alcântara mill, the one in São Julião do Tojal, in addition to the building in Montijo dated 1386, but possibly mentioned in 1305 as a watermill owned by the Church of Santa Marinha do Outeiro (SILVEIRA 2009).

On the left bank, the lands south of the Tagus have excellent characteristics for the construction of tide mills, that is, a landscape that mixes the waters of the river and the Atlantic and where the tide acts strongly. The riverbank of Seixal, which runs from Ponta dos Corvos, also known as the Alfeite peninsula, passing through Corroios, Amora, Paio Pires, and reaching the left bank of the Coina river, was used in the milling industry powered by energy from tide. Geography was perfect for the installation of these structures, that is, low altitude, flooded by the Tagus creeks and a variety of nooks that made the construction of small dams more agile. Seixal's landscape is demarcated by the Seixal bay, mainly by its riverfront, the Tagus estuary and the Atlantic beaches. These delimit the morphology and contour of the margins. The geographic framework of Seixal has a great ally, which is its proximity to Lisbon, which has greatly guided the occupation and exploration of the territory, influencing the forms of property division, uses and the flow of agricultural products to the capital. Still, the existence of several water courses that permeate the county, represent not only important ways of connection, but also provide resources to be exploited economically, such as the fishing culture (SILVA 2008: 60).

The hydrology of the municipality of Seixal is conditioned by the Tagus River estuary, where the many water lines that cut through the landscape flow directly or indirectly through the Coina River or the Seixal bay. Except for the Coina River, a tributary of the Tagus, the remaining water lines flow into Seixal Bay. The hydrographic network is formed by five main hydrographic basins: Vala da Queimada de Milhaços, Vala de Santa Marta, Vala Quinta da Princesa, Rio Judeu and Rio Coina (CAMS 2017: 102). The riverfront facing the Mar da Palha and bathed by the streams of the Judeu and Coina Rivers, provides gentle slopes with extensive areas of marsh, subject to the tide regime. It is in this context of landscape that the Seixal tide mills are inserted. Since the fourteenth century, this area has been favored by the royal house, religious orders and nobility, with productive and recreational farms.

The Maritime Expansion favored the triumph of the tide mills, since there were also shipyards established for shipbuilding and other various activities related to the river, such as salt exploration, fishing, in addition to produc-

Fig. 3. Tide mills in the Tagus River estuary. Map by the author.

These structures were in constant technological evolution as they responded to local needs, which required new solutions, from the use of local raw materials (stone, lime) to adaptations in the mill system. Some innovations were based on existing technology appropriated by local expertise. Experiments were carried out on the site by local artisans, who probably did not consult the hydraulic treatises already circulating in Portugal.

The technology used adapts and reinvents itself to cope with the local geographic challenges, which are so unique and that are only fully understood by men and artisans are perfectly aware of the site conditions. Thus becoming the only ones able to build these types of structures in wetlands as Seixal's marshes.

At the time when engineers became the harbingers of progress, Major Jorge Higgs (1818-?) and other foreign engineers, inspired by the tide mills, envisioned the potential of hydraulic motors to create an alternative to electricity and the steam engine.

Taking advantage of the tide strength: hydraulic engines for Seixal - Tagus Estuary

The tide mills south of the Tagus had their splendor between the thirteenth and nineteenth centuries when they faced a sharp decline in the mid-twentieth century. The cause was the modernization of the large motor-milling sectors, which surpassed the production of traditional mills. Industrial mills, which started to use electricity or combustion engines, completely changed the dynamics and functioning of hydraulic mills. Many were deactivated, abandoned, and are currently in ruins. The steam engine revolutionized the technical, social and cultural practices

developed over many centuries. Engines need energy. However, the clean, local, and natural energy based on tide movements and force, produced until then by tide mills, was not enough.

Mills tried to adapt and reinvent themselves due to the Industrial Revolution. There were adaptations seeking to increase the number of rotations of the grinding wheels, or improvements such as the metal cogwheel, but nothing was enough, and profit, the dictator of the moment, did not allow these structures to remain in the industrial economic situation.

Despite everything, the valuable contribution of the tide mills and the use of clean energy that employed the forces of nature, fostered attempts to expand energy production based on water in the Seixal waterland. Nineteenth-century engineers focused on the study of harnessing the ebb and flow of tides with hydraulic energy to drive turbines and produce electricity.

In the beginning of the nineteenth century, an article about tide-powered machines was included in the *Collection of Instructions on Agriculture, Arts and Industry*, published in 1832. This collection was linked to the Session Programs of the Royal Academy of Sciences of Lisbon from the years 1810, 1829, 1830 and 1831. In this edition, proposals are made for improvements of tide mills, aiming at more adequate and advantageous processes, in addition to providing instructions for the construction of these industrial structures (NABAIS 1986: 91).

The most relevant and innovative project was presented by Major Jorge Higgs, called Seixal Hydraulic Engine, intending to take advantage of the ebb and flow effect of the tides (flood and ebb) and not just the ebb as it used to happen. In 1850 and 1851, he commanded the Vale de Zebro Naval Detachment (NABAIS 1986: 93). Between 1825 and 1829 he was included in the Alentejo Regiment. In 1850, he is mentioned in the *Book of Registration of Settlements of Officers and Squares of the 1st Battalion of Infantry Regiment*. In 1870, he appears in the list of Infantry captains¹.

Fig. 4. Location of the manufacturing industry proposed by Jorge Higgs. Map by the author.

1 GERMIL Project. Master or Enrollment Books and Salary Books were created by the Law of July 7, 1763. Military Historical Archive. Quotas PT/AHM/G/LM/A/07/02/0611 and PT/AHM/G/LM/B-06/53/0039.

He intended to use hydraulic energy in the milling of cereals, rice husking or any other demand arising from the industry. He aimed to create an efficient, clean model, logically taking advantage of the geophysical configurations of Seixal, specifically the area called Ponto dos Corvos or Rio Judeu. The major's project intended to create a large natural boiler in the bay of Seixal, corresponding to the estuary of the Judeu River, damming the water, connecting Ponta dos Corvos to the current parish of Seixal, and using a floodgate and turbines.

On August 3, 1864, before proposing the hydraulic motor, Major Jorge Higgs registered a patent for an electro-hydraulic regulator, which had its operation based on the joint action of electricity and tides (NABAIS 1986: 93). The project of a company based on the hydraulic motor was approved in 1873 (by government concession referred to in the letter of law dated April 24, 1873), but it was not carried out, despite being considered an important technological contribution to that day. For a better understanding, three publications about the Seixal Hydraulic Engine are presented chronologically. The proposal by Higgs, which was debated for three decades (from 1864 to the end of the nineteenth century), followed by publications by engineers Theophilo Seyrig and Pedro Romano Folque.

Thus, in 1879 Major Jorge Higgs published the *Memoria Descritiva e Historia Documentada do Motor Hydraulico – Seixal* (*Descriptive Memory and Documented History of the Hydraulic Motor – Seixal*).

In the descriptive memory, Jorge Higgs assumes that a driving force is the mandatory element in the manufacturing industry, as well as properties at the interface with watercourses. He shrewdly quotes Alfred Maulde and Wibart², steam engine makers in Paris, as they state that hydraulic motors should always be preferred when there is a flow at their disposal. The major emphasizes that steam engines need fuel, skilled technical personnel, lubricating materials, ongoing boiler repairs, valves and screws. Therefore, are to be avoided if there is another energy source at disposal. He also states that his proposal aims to take advantage of the best possible location, the strength, the ebb and flow of the tides, and of narrowing the space for the passage of water by the simplest, easiest and most economical way, and thus providing the current at a convenient speed (HIGGS 1879: 3). Its publication covers the following topics: *Cost and Charges for the two Engines, Steam and Hydraulic; Characteristic Fact and Historical Part*.

Fig. 5. Jorge Higgs's publication on the Seixal Hydraulic Motor.

Subsequently it carefully addresses the cost and charges of the two engines, steam and hydraulic. He makes a comparison and concludes that the savings in the hydraulic motor compared to the steam, corresponds to 46% on its cost, and 22% on the relative profit. In the next topic, which he calls *Facto Característico* (characteristic fact), Higgs presents the advantages of the hydraulic motor already perceived in France and America, French and American flours were associated with the use of natural elements. He affirms that in the Seine River and in the rivers of America there were hydraulic mills in great quantity, and he questions why Portugal is unable to achieve their success and be that competitive.

The *Parte Histórica* (historical part), records the ten-year struggle to obtain the concession according to a letter of law of April 24, 1873, and the preparation of the project in accordance with the aforementioned law. It fiercely criticizes the radical modification of the system proposed by the Consulting Board of Public Works and Mines, which reduced investment to one fifth

2 Alfred Maulde, Geibel & Wibart were manufacturers of high-speed letterpresses and presses in Paris in the nineteenth century. Also cited in the Jornal Politécnico Alemão in 1873 as having tried and tested a vertical boiler. More in: Grothe, H. (1873). *Allgemeine deutsche polytechnische Zeitung*. Verlag von Julius Springer: Berlin.

* A água está representada em baixa-mar d'águas vivas. ** As rodas hydraulicas trabalharão sempre no mesmo sentido. O trabalho das mós terá em todas as phases a velocidade normal.

Fig. 6. Illustration of the Jorge Higgs Project showing how the proposed dam would work. Higgs, 1879.

of the initial amount, based on the report by Dutchman João Waldorp. Higgs believes this report is fraught with errors and inconsistent arguments. On June 3, 1875, Higgs sent a letter to the Board requesting the review of Waldorp's report by Portuguese engineers. However, the Board denied the request, ignoring the considerations presented and excluded Portuguese engineering from the process, a fact that Higgs considered a coup.

The German engineer Theophilo Seyrig (1843-1923) published the *Memoria Descritiva sobre a Instalação de Motores Hydraulicos para o Aproveitamento da Força das Marés no Tejo* (*Descriptive Memory on the establishment of hydraulic motors to take advantage of tides' strength in Tagus River*) in 1883.

Seyrig was a bridge builder and together with Gustave Eiffel, he founded *Eiffel et Cie*. He made the D. Luís bridge that connects the city of Porto to Vila Nova de Gaia (1986). A few years after Higgs' proposal, he presents a new project with a very robust foundation and with the necessary improvements.

He claims that there are advantages to using the force of the tide, as there is no risk of seasonal variations, droughts, or even lack of fuel, or even wars. He adds the benefits that Bahia do Seixal offer regarding communication, that is, transportation of raw materials and production flow, concluding that Seixal has all the favorable conditions to become a first-class industrial center.

Fig. 7. The Seixal Hydraulic Motor. *Diário Ilustrado* n.540, 1874.

Fig. 8. Publication by Seyrig on the Seixal Hydraulic Motor.

Seyrig claims that Seixal hydraulic motors could be used for different purposes: milling, preaching, ice making, rice husking, oil making, pasta and barley pasta, cable, rope and cord making, sawing marble and wood, spraying lime phosphates, wood putty manufacturing paper, electroplating, as well as own production of electricity. The engineer, due to his experience in other European countries, envisions new market demands that did not yet exist in Portugal.

The description of the project covers the construction of a landfill near the Seixal Village, a dam with movable gates, a series of chambers designed to receive the hydraulic motors turbines with vertical axis, and a floodgate to allow boats to enter and exit at any time from the Seixal bay. Although he was proposing a new industry, he was committed with keeping the functioning of the five extant tide mills. In his project, he explains when the flood-gates should be closed or opened, when the turbines should be working, and how to optimize the use of the tide flow and its reflux with the hydraulic motor. This is a great difference from early modern use of tides' strength as they could only take advantage of one of tide's movement rather than two.

He presents the project to establish the company, following different phases. He also calculates the income that could be achieved with this industry. He also demonstrates the entire calculation of the available motor force, demonstrating the effectiveness of the proposed hydraulic motor and the immediate application to grinding. Moreover, he envisions that energy could be sold. He makes a comparison with the force obtained by the steam, and like Higgs, he proves that the annual expenses with steam engines would be higher than those foreseen for hydraulic engines. Seyrig concludes that Seixal Bay has the potential to produce energy through the use of hydraulic motors as no other in Portugal. Moreover, he emphasizes that projects have already been made, and besides requiring some improvements, they are totally feasible and could ensure the foundation of an industrial company of the most remunerative and auspicious (SEYRIG 1883: 12-13).

Although his project was not implemented, the idea of taking advantage of Seixal tides' strength was resumed by other engineers. The famous Portuguese engineer Pedro Romano Folque (1848-1922) wrote the *Aproveitamento da Força das Marés no Seixal* (*Harnessing the Strength of the Tides in Seixal*) in 1885. Therefore, I argue that the force of the tides in Seixal Bay has definitely left the exclusive universe of milling artisans and emerged into the minds of engineers.

The engineer Pedro Romano Folque was Director of Public Works for the District of Lisbon and was the author, as an example, of the Agricultural and Forestry Charter of Portugal of 1910. He developed extensive research on mills, flours, wheat. He criticizes Portuguese reality and emphasizes that it could take more advantage of its natural resources. Therefore, a dam should be built in Seixal. Moreover, he considers that the Portuguese industry backwards is due to charcoal imports (FOLQUE 1885: 3).

Fig. 9. Tide Mill of Corroios and the Waterland of Seixal. Photograph by the author, 2020.

Folque credited Jorge Higgs for pioneering the concept of exploiting the hydraulic motor in Seixal, extolling his more than twenty-year struggle against the reluctance and hesitation of capitalists who questioned the viability of this monumental work. He mentions that Higgs' idea was very well appreciated by the notorious Dutch engineer Pieterszen³ (1819-1874) and by the respectable Portuguese engineer José Victorino Damasio. Folque states that the first project was carried out with the support of Ellicott and Baron of Kessler. Then, and after analysis by the Consulting Board of Public Works and Mines, it was reviewed by engineer Candido de Moraes (1841-1895). A little later the project was subject to update by Theophilo Seyrig and the Portuguese engineer Joaquim Pires de Sousa Gomes (1836-?). Therefore, Folque considers that the Seyrig project clarified any doubts about the feasibility of the project seeking to establish hydraulic motors in Seixal Bay. There was no reason to continue to delay its implementation.

Moreover, he adds that there was a deficit of cereals to feed the Portuguese population in parallel with the difficulty of farmers to sell their wheat. He claims that in 1881 foreign wheat was imported and paid high fees. Thus, Folque claims for the establishment of a company to take advantage of the hydraulic motor in Seixal with the installation of a large wheat milling industry for the production of flour by the modern process of cylinders. This should be associated with an important bread factory, functioning by mechanical processes. The aforementioned investments would be a condition for the prosperity of national agriculture and for the good of less privileged classes.

Given the above, the question naturally arises as to what might have happened had the hydraulic engine projects

Fig. 10. Publication by Folque on the Seixal Hydraulic Motor.

been implemented in the Tagus estuary. The projects carried out to establish the hydraulic motor in Seixal involved relevant engineers on the national as well as international scene. Although none of the projects presented have been implemented, they are historically of the greatest importance as they prove the real intelligent use of water in Seixal, completely interiorized by early modern artisans but only understood by some in the nineteenth century. The same kind of minds that today advocate the use of clean and sustainable energy. The current state of the planet allows us to confidently say that Higgs, Seyrig and Folque were right. Unfortunately, sometimes techno-scientific lucidity is not enough to guide political will.

New ways

Seixal geography and its history related to water and energy stem from the balanced relation between man and nature. This balance was lost in the nineteenth century onwards due to the new demands of the capitalist atmosphere.

Rethinking the forms of production regarding the use of non-renewable resources is indispensable. Thus, new doors are opened in the field of science, technology, energy, which can be explored in the context of the Tagus estuary, particularly in the Seixal waterland, a territory that still has great potential and many opportunities.

In addition to the unique landscape presented by rivers and seas, riverside fronts, such as that of Seixal, may be a

3 Willem Cornelis van der Waeyen Pieterszen (1819-1874). Dutch architect and structural engineer, superintendent of public works, known as the architect of the city of The Hague. See more in: A.J. van der Aa (1877) *Biographisch woordenboek der Nederlanden*. Deel 20. Haarlem, J. J. Van Brederode.

key point in the positive transformation of urban scenarios that dialogue positively with the natural environment. In this sense, Seixal has the advantage of still having areas of pine forest and natural environment belonging to the National Ecological Reserve (REN). From the point of view of spatial planning, it is essential to understand that the water element, and its courses, in addition to enhancing the natural environment and the morphological identity must be considered as a structural component, delimiting areas, generating articulations and transposing barriers. This lays behind Seixal Waterland.

Data reveals that 90% of energy use in Portugal depends on fossil fuels and, therefore, are non-renewable (oil, coal, natural gas), imported from other countries. The movement of the tides is a practically inexhaustible source of energy. If in Portugal, during historical times, the energy of the tides was used for the mills, today, there is no news of the use of this “clean” energy. The energy from tide forces is free, renewable, cyclical, constant and predictable, and we can count on them every day of the year. This does not happen with other non-polluting energies, such as solar and wind power. Therefore, Seixal’s history can be a lesson for the future as a balance between ecology, economy and culture aiming at environmental sustainability stands as our common desire.

ACKNOWLEDGEMENTS

The authors acknowledge the Portuguese Science and Technology Foundation for funding of the project HORTO AQUAM SALUTAREM, PTDC/HAR-HIS/28627/2017.

REFERENCES

- BAVEL, Bas Van; BURINGH, Eltjo and DIJKMAN, Jessica. 2017. *Mills, cranes, and the great divergence: the use of immovable capital goods in western Europe and the Middle East, ninth to sixteenth century*. The Economic History Review.
- BLACK, Jeremy. 2014. *The Power of Knowledge - How Information and Technology Made the Modern World*. London: Yale University Press.
- CARTA AMBIENTAL DO MUNICÍPIO DO SEIXAL – CAMS. (2017) *Metodologia, Caracterização e Diagnóstico*. Seixal: Câmara Municipal do Seixal.
- EDGERTON, David. 2011. *The Shock of the Old: Technology and Global History since 1900*. Oxford: Oxford University Press.
- FOLQUE, Pedro Romano. 1885. *Aproveitamento da Força das Marés no Seixal – Rápida Análise da Questão*. Lisboa: Typographia Mattos Moreira.
- HIGGS, Jorge. 1879. *Memoria Descritiva e Historia Documentada do Motor Hydraulico – Seixal*. Lisboa: Imprensa de J. G. de Sousa Neves.
- LANGDON, John. 2004. *Mills in the Medieval Economy: England 1300-1540*. Oxford: Oxford University Press.
- NABAIS, António J. C. Maia. 1982. *História do Concelho do Seixal*. Seixal: Câmara Municipal do Seixal.
- NABAIS, António J. C. Maia. 1986. *História do Concelho do Seixal. Património industrial – moinhos de maré*. Seixal: Câmara Municipal do Seixal.
- OLIVEIRA, Ernesto Veiga De; GALHANO, Fernando; PEREIRA, Benjamim. 1983. *Tecnologia tradicional portuguesa: sistemas de moagem*. Lisboa: INIC, Centro de Estudos de Etnologia.
- REYNOLDS, Terry S. 1983. *Stronger than a Hundred Men: A History of the Vertical Water Wheel*. Baltimore: Johns Hopkins University Press.
- RODRIGUES, Ana D., MERLOS ROMERO, Magdalena. 2020. Noras, Norias and Technology-of-Use. In: D. Rodrigues, A. & Toribio Marín C. (Eds.) *The History of Water Management in the Iberian Peninsula*. (Trends in the History of Science). Birkhäuser, Cham. https://doi.org/10.1007/978-3-030-34061-2_7
- SANTOS, João Rafael Marques. 2018. *Espaços de Mediação Infraestrutural: Interpretação e Projecto na Produção do Urbano no Território Metropolitano de Lisboa*. Lisboa: Área Metropolitana de Lisboa
- SEYRIG, Theophilo. 1883. *Memoria Descritiva sobre a Instalação de Motores Hydraulicos para o Aproveitamento da Força das Marés no Tejo*. Lisboa: Imprensa

Nacional.

SILVEIRA, Ana Cláudia. 2009. *Novos Contributos para o Estudo dos Moinhos de maré no Estuário do Tejo: empreendimentos e protagonista (século XIII- XVI)*. Lisboa: Caleidoscópio.

SILVEIRA, Ana Cláudia. 2017. *Alcântara: a medieval tide mill in the periphery of Lisbon (13th to 18th centuries)*. Lisboa: Câmara Municipal de Lisboa.

VITERBO, Sousa. 1896. *Arqueologia Industrial Portuguesa: os Moinhos*. O *Arqueólogo Português*, volume II, n. 8-9. Lisboa: Imprensa Nacional.

WILSON, Andrew. 2002. Machines, power and the ancient economy. In *Journal of Roman Studies* 92:1-32.