Offshore wind energy in Greece:
Estimating the socio-economic impact

MEDITERRANEAN PROGRAMME

Alma Economics

A project funded by EEA Grants

ELIAMEP | Policy Paper # 81/2021

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Abstract

Offshore wind energy can play a key role in helping Greece become carbon neutral by 2050. Alma Economics was commissioned by ELIAMEP to explore the socio-economic value that can be generated from floating offshore wind farms in the Greek seas. We develop a Cost Benefit Analysis (CBA) framework which incorporates investment, environmental, social, and economic costs and benefits that can flow from a hypothetical offshore farm to (i) the international community, (ii) Greek society, and (iii) host communities. Our framework explores the welfare gains from reduced CO_2 emissions, as well as the welfare losses to local communities and visitors as a result of visual disamenity and environmental effects. The location of the farm directly influences investment costs, as well as the impact on host communities. Location is instrumental in determining whether the benefits from the investment outweigh the costs at the global and national level. Crucially, at the local level, welfare losses to residents highlight the need for providing compensation to local communities in the region where the farm is installed. Key findings from this research and the accompanying CBA framework will support evidence-based decision making about future investments in offshore wind power in Greece.

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Executive summary

Investing in renewable energy is critical if Greece is to meet its 2050 target of net zero carbon emissions. With current discussions focusing on exploiting the country's offshore wind potential, the relevant legislative framework (to be published in 2021) is expected to promote investment in offshore wind energy in the country.

The newly developed floating offshore wind technology is ideally suited to the deep waters of the Greek seas. A hypothetical floating offshore wind farm of 495MW energy capacity located at an average 10km distance from the shore and 250m water depth is expected to require an investment of almost €1 billion over its lifetime. This farm can create around 2million MWh annually over 25 years, covering around 4% of Greece's annual energy demand and reducing CO_2 emissions by 1.5 million tonnes.

The purpose of this study is to quantify the social impact of offshore wind farms. To this end, we develop a Cost Benefit Analysis (CBA) framework that links investment costs (including construction, operation, maintenance and decommissioning costs) to the economic, social and environmental benefits from offshore wind power. Our CBA framework explores benefits at the global and national level as well as for local communities and visitors to the region where the farm will be built.

Our research suggests that investing in offshore wind power in Greece will create substantial global gains through enabling a reduction in CO_2 emissions by replacing energy from conventional sources.

As long as appropriate compensation mechanisms are put in place, offshore wind power can also be beneficial for local communities, which can often be resistant to developments in their area due to the visual disamenity associated with wind farms and the risk of negative impacts on the local environment. In our hypothetical scenario, we estimate the annual welfare loss – and hence required compensation – to local residents to be around €2,500 per person. This compensation could take the form of private compensation, such as provision of energy at lower prices, or public compensation, such as the provision of local public goods (infrastructure development, or maintenance of cultural heritage). A more in-depth study is necessary to determine the best compensation mechanisms.

1. Introduction

The offshore wind industry in Europe has been up-and-coming and is expected to grow more in the following decade. Although Greece has yet to exploit its sizeable offshore wind potential, floating offshore wind projects could be developed in Greek waters soon. Alma Economics was commissioned by ELIAMEP to carry out a social impact study, exploring the social value that can be generated from investing in offshore wind energy in Greece. The study provides evidence on the social gains and losses from the installation of wind energy farms in Greece.

A Cost Benefit Analysis (CBA) framework is developed to appraise the value such an investment can generate from an international, national and local perspective. It is informed by findings from a thorough desk-based evidence review of social impact studies and business cases on similar investments in renewable energy. We also explore engineering and environmental studies that evidence the links from offshore wind technologies to the creation of public benefits. In addition, our framework draws from expert judgements collected from engaging with a group of key stakeholders in renewable energy and offshore wind farms in Greece and internationally.[1]

The framework goes beyond the identification of costs associated with the investment and resulting economic benefits and cost savings. It assesses wider costs and benefits globally and accruing to Greek society and the local communities hosting wind energy farms. Hard-to-measure social benefits are quantified to support judgements regarding the social impact of investments in floating offshore wind farms. Monetising the value of social benefits allows their comparison with costs, and the calculation of the net social benefits flowing from the investment. Additionally, we explore qualitative evidence about unquantifiable benefits that might be generated by the investment, as well as the geopolitical implications that it is likely to have.

We identify costs and benefits flowing from a central scenario, assuming a hypothetical floating offshore wind project will be built in the Greek seas. The energy capacity of this hypothetical farm will be 455 MW (including 33 turbines of 15MW capacity). It also assumes that the farm will be located at 10 km far from the shore and at 250m water depth. The energy produced will replace conventional energy generated by oil (50%) and by gas (50%).

This report summarises our approach to exploring the impact of this hypothetical investment as well as key findings. It is organised in the following chapters: (i) **Background**, discussing the current and future energy production in Greece as well as evidence from previous socio-economic studies on offshore wind investments; (ii) **Case study – hypothetical investment**, presenting the central scenario about a hypothetical offshore wind farm in Greece; (iii) **Analysis of benefits from the hypothetical investment**, summarising evidence on the quantified and non-quantified benefits from the investment; (iv) **Key findings**, discussing key results on costs and benefits from our CBA framework; (v) **Sensitivity analysis**, exploring changes in the observed costs and benefits under different assumptions and scenarios; and (vi) **Conclusion**, pulling together key messages, identifying limitations, and setting the framework for future work.

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[1] Our study benefited greatly from the advisory role of Multiconsult, our Norwegian partner specialising in offshore wind energy. Their expert advice provides valuable insights into the sector's technology and social impact, feeding into our modelling and analysis.

2. Background

This section discusses the current energy production in Greece and the country's future prospects in producing renewable and green energy. The second part of this section considers evidence on costs and benefits from international offshore wind investments.

Energy production in Greece

According to evidence from the Independent Power Transmission Operator S.A. (IPTO) (2021), Greece produced and imported 4,206GWh of electricity in March 2021. 32% of this electricity was produced by natural gas, 15% by lignite, 7% by hydropower, and 33% by other renewable energy sources. The current renewable energy sources in Greece include hydroelectric, wind, solar, and geothermal power, as well as biomass and waste (Institute of Energy for South-East Europe, 2020). The same study remarks that the contribution of renewable energy resources to the Greek gross final energy consumption doubled during the period between 2006 and 2017. This increase can be attributed to the rapid growth of Greece's solar and wind power investments and the decrease in energy demand in the previous decade.

While the share of renewables in the Greek energy mix increased, the intermittency of their output remains a problem. These technologies depend on weather conditions (e.g., sunshine and wind speed), meaning that non-appropriate atmospheric conditions could lead to unpredictable shortfalls in the supply of power. Unexpected variations in energy outputs require using other energy sources, such as lignite, natural gas or hydropower, to compensate for shortfalls in energy production. However, the energy produced by lignite is accompanied by CO_2 emissions, which does not allow Greece to meet the EU goal of zero carbon emissions by 2050. In addition, with natural gas being imported, its use increases the country's energy dependency.[2]

Another solution to potential shortfalls is storage so that energy from renewable sources is available when demand exceeds supply. In 2020, members of the European Parliament suggested that new battery technologies, thermal storage, or green hydrogen[3] can be used to store energy from renewable sources and achieve smooth and sufficient supply.[4]

According to the 2019 Greek Energy and Climate Plan, the storage of energy from renewable sources requires converting electricity into renewable gas (the so-called green hydrogen) which can be used as a fuel in the energy mix (Ministry of the Environment and Energy, 2019). In May 2021, a group of Greek companies submitted the "White Dragon" to the EU and the Greek government – an 8 billion € proposal for developing a green hydrogen project in Greece. The aim of the proposal is to replace lignite power plants by 2028 and use renewable energy sources for hydrogen production via electrolysis.[5]

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[2] Energy press, 2021, "Panagiotakis: With the abandonment of lignite, the country's energy dependence increases". Available at: https://energypress.gr/news/panagiotakis-me-tin-egkataleipsi-toy-ligniti-ayxanei-i-energeiaki-exartisi-tis-horas

[3] Green hydrogen is hydrogen created by renewable energy instead of fossil fuels. See Jason Deign, 2020. "So, What Exactly Is Green Hydrogen?". Available at: https://www.greentechmedia.com/articles/read/green-hydrogen-explained

[4] Press release, European Parliament, 2020, "Boost energy storage in the EU to help spur decarbonisation". Available at: https://www.europarl.europa.eu/news/en/press-room/20200706IPR82726/boost-energy-storage-in-the-eu-to-help-spur-decarbonisation

[5] Kathimerini, 2021. "The "White Dragon" proposal for hydrogen projects has been submitted". Available at:

Renewable energy sources in island Greece

Mainland Greece belongs to the southern part of the Balkan peninsula. The country has approximately 6,000 islands and islets.[6] There are Greek islands (the so-called non-interconnected islands), whose electricity distribution network is not connected to the mainland network. The Independent Power Transmission Operator has been working on enhancing the interconnection of the Cyclades (a group of islands in the South Aegean) to the mainland system. So far, the connection of Syros, Paros, Mykonos, and Tinos islands to the mainland has been completed.[7] However, there are still 29 islands with autonomous electrical systems. Most of them produce electricity through a combination of renewable energy sources and oil power plants.[8]

According to the Institute of Energy for South-East Europe (2020), the share of renewable energy sources in the energy production mix of the non-interconnected islands is 21%. There are concerns that this share will not increase if, for instance, there is no investment in installing and operating renewable energy sources and storage systems. However, such investments will only materialise, if the interconnection to the mainland proves economically disadvantageous.

There are two noteworthy cases of islands where renewable energy sources are currently in use or will be used in the future to cover local electricity needs. According to the European Commission (Directorate General for Energy et al., 2020), Tilos, a Dodecanese Island in the south-eastern Aegean Sea, is an energy self-sufficient island. Tilos' hybrid energy system is based on wind and solar power, as well as storage, comprising an onshore wind turbine, a photovoltaic park, and a battery for energy storage (Notton et al., 2017). Astypalaia, also a Dodecanese Island, will become "Smart Green" and energy self-sufficient in the following years. Apart from the use of electric private and public transportation, a hybrid energy system based on renewable energy sources will be installed in the island over the following six years.[9]

Wind power in Greece

Greece is exploiting its wind potential by establishing onshore wind farms in island regions, including Crete, Euboea (or Evia) and the Aegean Islands.[10] Currently, the country has onshore wind farms of 4GW capacity, covering 12% of the electricity demand (Ministry of the Environment and Energy, 2019).

According to Greece's National Energy and Climate Plan (Ministry of the Environment and Energy, 2019), Greece will have to install 7GW of wind energy capacity by 2030 to meet its environmental targets. The potential for wind energy in Greece is huge, especially for offshore wind energy, which could even help islands achieve self-sufficiency.

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https://www.kathimerini.gr/economy/561362950/katatethike-i-protasi-white-dragon-gia-ta-erga-ydrogonoy/

[6] Visit Greece. Islands. Available at: https://www.visitgreece.gr/islands/

[7] IPTO, "Cyclades Interconnection". Available at: https://www.admie.gr/en/node/3185

[8] Regulatory Authority for Energy (RAE), "Non-Interconnected Islands". Available at: https://www.rae.gr/non-interconnected-islands/?lang=en

[9] Kathimerini. 2021. "Astypalaia is turning green". Available at: https://www.ekathimerini.com/economy/1161873/astypalaia-is-turning-green/

[10] RAE GeoPortal. Available at: https://geo.rae.gr/

In summer 2021, the Greek government will publish the legislative and regulatory framework for offshore wind power in Greece.[11] The publication of the legislation follows a public consultation conducted jointly by the Hellenic Wind Association (ELETAEN) and the Norwegian Wind Energy Association NORWEA to explore legal and strategic planning issues associated with the development of offshore wind farms in Greece.[12]

It should be noted that there are considerable concerns about community acceptance of onshore wind farms. An indicative example is the case of the Cyclades, where residents protest against the installation of onshore wind farms, expressing their concerns about the impact of such an investment on both the island landscape, biodiversity and tourism.[13] This is not a Greek phenomenon. According to Kaldellis et al. (2016), the "Not in my Backyard" movement expresses social opposition to onshore wind farms (due to noise and visual disamenity) internationally. The study highlights that it is too early to conclude on whether offshore wind farms are socially accepted, although the location is bound to influence public reactions.

International offshore wind farms

The first offshore wind farm was constructed in Denmark in 1991. The farm was built in 2-5 meters of water depth, including 11 wind turbines that provided energy power to more than 2,000 households.[14] Numerous investments in offshore wind farms followed in the last three decades. Denmark, the UK, Germany, China, and the Netherlands are leading offshore wind markets, including many operational offshore wind farms and several others currently under development.[15] Europe has 25GW of installed offshore wind energy capacity, covering 3% of its electricity demand in 2020 (Wind Europe, 2021).

The first offshore wind farm in the US, constructed in 2016, has a capacity of 150 MW and generates electricity for 17,000 households.[16] Due to the performance of the first farm and the prospective wind capacity in the country, more offshore wind farms are expected to operate from 2021 onwards (Carr-Harris and Lang, 2019).

China has also been exploiting its offshore wind potential in the previous decade (Chen, 2011). By the end of 2019, China represented 23% of the global offshore wind energy capacity.[17] In 2020, 3GW of new offshore wind installations took place in China;[18] an

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[11] Wind Europe. 2021. "Offshore wind is coming to Greece". Available at: https://windeurope.org/newsroom/news/offshore-wind-is-coming-to-greece/

[12] ELETAEN. 2020. "Necessary legislative adjustments to promote offshore wind energy in Greece". Available at: https://eletaen.gr/necessary-legislative-adjustments-offshore-wind-energy-greece/

[13] Kathimerini. 2017. "Opinion: Tourism and wind turbines in the Cyclades". Available at: https://www.kathimerini.gr/economy/local/900167/apopsi-toyrismos-kai-anemogennitries-stis-kyklades/; also, Proto Thema. 2019. "Wind farms: They "generate" tension in the Cyclades - What do the municipalities support, what do the companies reply?" Available at: https://www.protothema.gr/greece/article/875770/aiolika-parka-paragoun-edasi-stis-kuklades-ti-upostirizoun-oi-dimoi-ti-apadoun-oi-etaireies/

[14] Tom Ewing. 2019. "Offshore Wind – A Brief History". Available at: https://www.marinetechnologynews.com/news/offshore-brief-history-590397

[15] GlobalData Energy. 2021. "China to add significant offshore wind power capacity every year during 2023–2030". Available at: https://www.power-technology.com/comment/china-offshore-wind-power/

[16] Orsted. "Our offshore wind projects in the U.S." Available at: https://us.orsted.com/wind-projects

[17] See note 14.

[18] Global Associations Platform Hub. 2021. "China installed half of new global offshore wind capacity during 2020 in record year". Available at: https://gwec.net/china-installed-half-of-new-global-offshore-wind-capacity-during-2020-in-record-year/

additional 52GW of offshore wind power capacity is expected to be installed by 2030.[19]

Currently operating wind farms mainly use fixed-bottom wind turbines. This suggests that the wind turbine is based on a platform connected to the seabed at a water depth of up to 50m (Hanania et al., 2015). For water depths above 50m, fixed-bottom foundations are no longer economically viable. In this case, floating offshore wind turbines are used, which are attached to the seabed by mooring lines (Zountouridou et al., 2015). Due to the water depth in the Mediterranean Sea, an offshore wind investment in Greece would probably require a floating foundation.

The first floating wind farm in Europe, namely the Hywind Scotland, started operating in 2017 and has a total capacity of 30MW (5 turbines of 6MW capacity).[20] In Portugal, the 25MW Windfloat Atlantic farm, constructed in 100m of water off the coast of Portugal, is expected to provide power to more than 60,000 households per year. According to a report by Wind Europe (2019), more investments in floating farms are expected, including the Hywind Tampen in Norway, an 88MW wind farm, which will start operating in 2022.

Costs and benefits of offshore wind power

Offshore wind power is expected to boom even more over in the following years. In this context, there is growing literature exploring the economic viability of offshore wind farms, as well as the costs and benefits from offshore wind farms compared to other ways of energy production – for example, onshore farms and fossil fuel-based plants.

A well-cited study by Snyder and Kaiser (2009) explores the costs and ecological impact of a hypothetical offshore wind power farm in the US in comparison to onshore and conventional electricity production. The authors develop a model to calculate investment costs as a function of the technical characteristics of the farm, including the energy capacity of each turbine, distance from shore, water depth, and years of construction. They find that investing in offshore wind energy can be more expensive than investing in onshore wind. An offshore wind farm is shown to generate both ecological benefits (including reductions in greenhouse gas emissions) and disbenefits (for example, adverse effects for birds, mammals, and fish). However, it is argued that the negative environmental impact can be mitigated with new technologies and strategic selection of the farm's location.

More recent studies explore the offshore wind potential in Asia. Nian et al. (2019) focus on the costs and benefits of an offshore wind farm in a region in Southeast Asia with unfavourable climatic conditions. The authors calculate the lifecycle costs of offshore wind power and the carbon footprint of farms in different locations in Southeast Asia. They suggest that improvements in offshore wind power technology can reduce investment costs and improve the load factor of offshore wind power, thus maximising the economic advantages of this kind of investment.

Multiconsult (2019) conducts a Cost Benefit Analysis (CBA) of the Hywind Tampen, the offshore wind farm that will start operating in Norway in 2022 to provide electricity to two gas and oil drilling platforms. The CBA model includes costs associated with the operation and maintenance of the farm, as well as the financial capital required for the investment. It also includes the decommissioning expenditure of the farm. It quantifies the benefits from reduced

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[19] See note 14.

[20] Equinor. "Hywind Scotland". Available at: https://www.equinor.com/en/what-we-do/floating-wind/hywind-scotland.html

CO_2 and NO_x emissions, as wells as the costs of natural gas (assuming that the gas required for the platforms to operate can be sold in the market). Comparing costs with benefits, the authors conclude that the total net present value of the investment (that is, total benefits minus total costs) can range between negative values (that is, -€220 million) and positive values (€96 million). The total value of the project depends on its lifetime, the discount rate, and the trajectory of carbon price. The authors also discuss the knowledge and innovation externalities that such an investment can create and delve into the ripple effects of investing in offshore wind power. These include contributing to Norway's GDP by €905 million to €1 billion and creating 8,000 to 15,000 full-time equivalent (FTE) jobs, depending on the Norwegian share in the supply market.[21]

A study by the Universidad de las Palmas de Gran Canaria (2018), funded by Equinor, explores the economic effects of a 200MW offshore wind farm in the Canary Islands. Based on an input-output model, the authors argue that the farm can mainly be constructed in Spain, leading to the creation of up to around 4,000 FTE jobs.

The case of Greece

There is limited literature on the costs and benefits of offshore wind farms in Greece. A study by Zountouridou et al. (2015) explores the feasibility of offshore wind farms in the deep waters of the Mediterranean Sea. In particular, she discusses an investment in a floating offshore wind farm of 12MW capacity installed at 540m water depth and 15km from the shore of Santorini (an island in the eastern Mediterranean Sea). The farm is assumed to replace energy produced by oil-based plants. The benefits of this investment are explored, including savings from reduced CO_2 emissions and oil imports. The study also sheds light into gains in welfare flowing from a cleaner environment. It is emphasised that the offshore wind technologies in the Mediterranean differ from those in the Northern countries, as the Mediterranean Sea has deeper waters.

A more recent study by Spyridonidou et al. (2020) identifies potential locations for offshore wind farms in Greece and estimates the investment costs for the different areas. According to the authors, the selection of sites for installing offshore farms will depend on: (i) legislation around National Territorial Waters, (ii) wind velocity, (iii) water depth, (iv) military zones, (v) seismic hazard zones, (vi) underwater cables, (vii) distance from ports, and (viii) distance from high voltage electricity grid. The authors identify 16 possible offshore wind projects in different locations in Greece and calculate their investment costs and strategic value. The implementation of 12 offshore wind projects is able to generate socio-economic benefits using only 60% of the total investment capital.

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[21] The Full Time Equivalent (FTE) is a unit of measurement equal to the number of hours of a full-time employee.

3. Approach to appraising the social impact of investing in offshore wind energy

This section presents the CBA framework designed to estimate the social value of investing in offshore wind energy in Greece. It also discusses our approach to developing a central scenario that outlines the technical characteristics of a floating offshore wind farm, which can be built in the Greek seas considering the unique characteristics of the Greek setting. Finally, it sets out our approach to identifying the costs from such an investment.

Cost Benefit Analysis approach

A CBA framework is developed to link the costs of investing in a floating offshore wind farm in Greece to the economic, social and environmental benefits that can flow from this investment. Costs and benefits are identified compared to a counterfactual ('business as usual') scenario assuming that energy is produced in Greece using conventional methods and sources in the absence of the investment. Benefits from the investment are considered at the global level, as well as for Greek society and local communities.

The framework captures both direct costs (i.e., investment-related costs) and indirect costs (costs due to visual disamenity or environmental impact), as well as tangible and intangible benefits flowing from the investment. Tangible benefits (for example, cost savings due to less oil and gas imports) are quantified and monetised based on avoided costs or market values. Intangible benefits, such as gains from improved air quality, are monetised using evidence from the international literature on people's preferences and willingness to pay for such goods. Qualitative evidence is reviewed and taken into account regarding those effects that cannot be quantified.

Future costs and benefits are discounted to identify their present value through considering the time value of money (based on the assumption that people prefer to receive benefits now rather than in the future). In lack of evidence specific to Greece, we assume that the social discount rate is 3.5%, following best practice outlined in the UK HM Treasury's guidance on policy appraisal and evaluation.[22] We calculate and aggregate the present value of costs and benefits throughout the years of the investment to identify the Net Present Value (NPV) and the Benefit to Cost Ratio (BCR) of investing in an offshore wind energy farm.

Counterfactual ('Business as Usual') scenario

A core feature of the CBA methodology is that costs and benefits from the investment are identified compared to a counterfactual, or "business as usual", scenario – this being the situation where there is no investment in offshore wind power.

We assume that in the absence of the investment in offshore wind power, energy will be produced from conventional sources – in particular, a mix of half natural gas and half oil. Natural gas is included in the counterfactual scenario as a key energy source, as it takes over 32% of the Greek energy mix. Oil is included as many Greek islands are dependent on

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[22] HM Treasury. "The Green Book – Central Government Guidance on Appraisal and Evaluation". Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938046/The_Green_Book_2020.pdf

oil power plants that produce tonnes of CO_2 and remain a significant environmental burden. We do not consider energy produced from lignite in the counterfactual, as Greece is committed to stop using this source by 2028, earlier than the assumed commissioning year of the hypothetical offshore wind farm.

Our CBA framework considers the avoided cost from reductions in the use of natural gas and oil that would be used to produce the energy in the absence of the floating offshore wind farm.

At the international level, the amount of natural gas and oil that would have been used to create the energy now produced by the offshore farm will be no longer extracted, meaning that the total extraction costs of natural gas and oil will be reduced. Extraction costs include exploration and lifting costs. Exploration costs are related to finding hydrocarbons and can include expenses for geological studies and drilling costs.[23] Lifting costs involve expenses associated with bringing hydrocarbons to the surface, including completing and equipping wells, related equipment, labour costs etc.[24]

At the national level, the amount of natural gas and oil that would have been used to produce the energy now created in the offshore farm will be no longer imported, thus reducing the energy imports of Greece. Our CBA framework considers the purchase costs of the natural gas and oil units, using projections of the Brent Spot Price (price per oil barrel), as well as the price of natural gas per mmBtu estimated by the US Energy Information Administration (EIA) to calculate the avoided costs at the national level.[25]

Producing energy from natural gas and oil is associated with CO_2 emissions. Our model estimates the tonnes of emissions that would be generated by the two sources producing energy in the absence of the offshore wind investment. Based on a study by Kaldellis and Apostolou (2017), we use the life cycle greenhouse emission factors, which are calculated based on the global warming potential per unit of energy produced through lifecycle assessment.[26] The lifecycle greenhouse gas emissions of electricity generated by natural gas and oil are 450gCO_2/KWh and 840gCO_2/KWh, respectively.

Case study of a hypothetical floating offshore wind energy farm

Based on our evidence review and discussions with key stakeholders and sector experts, we develop a central scenario outlining an investment in a hypothetical offshore wind energy farm that can be built in Greece. This scenario includes the following components:

(i) **Investment timeframe**: The timeframe of the hypothetical farm spans from Year 1 (assumed to be 2025) to Year 36 (that is, 2060). According to sector experts, it

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[23] Aublinger. 2014. "How much does it cost to produce 1,000 cubic feet of gas?". Available at: https://seekingalpha.com/article/2707555-how-much-does-it-cost-to-produce-1000-cubic-feet-of-gas

[24] European Commission. INSPIRE. "Extraction of crude petroleum and natural gas". Available at: https://inspire.ec.europa.eu/codelist/EconomicActivityNACEValue/B.06

[25] US Energy Information Administration. Annual Energy Outlook 2021. Available at: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=1-AEO2021&cases=ref2021&sourcekey=0

[26] The life cycle assessment covers the full time of the source, from extraction until waste management (United States Environmental Protection Agency (EPA). "Lifecycle analysis of greenhouse gas emissions under the Renewable Fuel Standard". Available at: https://www.epa.gov/renewable-fuel-standard-program/lifecycle-analysis-greenhouse-gas-emissions-under-renewable-fuel).

is challenging to specify the exact time required to construct the farm. That said, stakeholders suggest that it is reasonable to assume that planning and constructing the farm will take around eight years while the decommissioning process will last for three years. Based on recent evidence by Spyridonidou et al. (2020), we assume that the farm will be operational for 25 years.

(ii) **Investment size**: We assume that the farm will have a capacity of 495 MW in total, including 33 offshore wind turbines of 15MW. In addition to this assumption in our central scenario, the CBA framework allows for exploring costs and benefits from farms with different levels of capacity and/or numbers of turbines. The results considering different capacity levels are presented in the Chapter Sensitivity Analysis.

(iii) **Offshore wind technology type**: According to Zountouridou et al. (2015), there are different technologies for offshore wind foundations, including monopiles, gravity, tripods, jackets, and floating turbines. For deeper waters, such as those of the Mediterranean Sea, floating offshore wind technology is required, as it can be installed at a water depth of 100-900m. Based on this evidence, we assume that the Greek offshore wind farm will include floating turbines. Additionally, we assume that the average power output produced by a wind turbine (that is, the turbine capacity factor) is equal to 57% of its maximum power capability (Kaldellis and Kapsali, 2013). The degradation factor of one turbine is equal to 0.7% (Zountouridou et al., 2015).

(iv) **Location**: According to insights from key stakeholders, it is feasible to build a farm 6 to 12km from the shore. In addition, given the deep Mediterranean waters, we assume that the farm will be located at waters of between 200 and 400m depth. The central scenario assumes that the farm will be located 10km away from the shore and at 250m water depth.

Table 1.   **Assumptions and parameters**

Assumptions	
Development and construction of the farm (years)	8
Operation (years)	25
Decommissioning (years)	3
Parameters	
Distance from the shore (km)	10
Water depth (m)	250
Capacity of one turbine (MW)	15
Total capacity installed (MW)	495

Wind turbine installation capacity factor (%)	57%
Degradation factor (%)	0.7%

Costs of constructing, operating and maintaining the farm

Investing in an offshore wind farm in Greece comprises capital costs covering the development, consenting and construction process (CAPEX), operational and maintenance costs (OPEX) and decommissioning costs (DECEX).

CAPEX includes all costs occurring before the commercial start date of the farm. Such costs include costs linked to development and project management (development and consenting services, environmental, geological and hydrographical surveys), installing the wind turbines, support and installation costs, and grid connection (BVG associates, 2019). According to Maienza et al. (2020), OPEX includes all costs associated with the farm operation and maintenance, along with any other costs that occur after the commissioning date of the farm. DECEX involves all costs related to decommissioning and site area clearance.

CAPEX

The CAPEX of our hypothetical farm depends on the Final Investment Decision (FID) year as well as the commissioning year. We assume that preparatory work for the farm will start in 2025 and the FID will be taken in 2030. The farm will be ready to operate in 2032 and will eventually start operating in 2033.

We use a combination of best available evidence in the existing literature to calculate the CAPEX of the farm in our central scenario. According to Wood Mackenzie (2021), the CAPEX of offshore wind farms reduces with time as new floating offshore technologies are made available.[27] The authors estimate that the CAPEX per MW of a floating offshore farm will range between $2.6 to 4 million in the period between 2025 and 2030. Based on this evidence, we assume that the CAPEX/MW in 2025 will be $4million (that is, €3.3 million).

To calculate the CAPEX of our hypothetical farm for 2032 (that is, the commissioning year), we use evidence from a study looking into the costs of Hywind Tampen over time (Multiconsult, 2019). The Hywind Tampen is an 88MW wind farm comprising 11 Hywind floating platforms located at 260-300 meters water depth and at 140km from the shore.[28] We use annual cost estimates from this study to calculate trends in CAPEX/MW over time. We then apply the average annual rate of change to the €3.3 million figure for 2025. According to our calculations, the CAPEX/MW for a farm with the same characteristics as the Hywind Tampen will be €1.8 million in 2032.

Ng and Ran (2016) and Spyridonidou et al. (2020) use a rule of thumb to calculate CAPEX/MW for farms with different characteristics – in particular, distance from the shore and water depth. According to this rule of thumb, 10% increase in water depth or distance

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[27] Wood Mackenzie. 2021. "Floating offshore could be largest frontier for wind power in Asia Pacific". Available at: https://www.woodmac.com/press-releases/floating-offshore-could-be-largest-frontier-for-wind-power-in-asia-pacific/

[28] Hywind Tampen will not be connected to the mainland grid. Therefore, the authors in the Multiconsult study use segmentation analysis to identify transmission costs and exclude them from CAPEX. For our analysis, we take total CAPEX (including transmission costs), as the hypothetical farm will be connected to the main grid.

from the shore will increase the investment cost by 1% (including costs related to grid connection and support structure). We apply this rule of thumb to the 2032 CAPEX/MW estimate for the Hywind Tampen farm to arrive at estimates for our hypothetical farm – assuming 10km distance from the shore and 250 meters water depth. Following this approach, the CAPEX/MW is calculated at €1.6 million/MW in 2032.

Based on insights from sector experts, we assume that 10% of CAPEX occurs during the first 5 years of the investment (during the development and consenting process). The remaining 90% of the CAPEX occurs in the following 3 years, during which the farm will be constructed.

OPEX

To estimate the OPEX per MW of our farm, we use evidence from the literature that establishes a relationship between CAPEX and OPEX. Following Spyridonidou et al. (2020), we assume that annual OPEX per MW for Hywind floating wind farms is equal to 3% of CAPEX per MW.

Therefore, OPEX is estimated at 0.05 million €/MW per year. The OPEX is evenly split throughout the 25 operational years of the farm.

DECEX

According to Spyridonidou et al. (2020) and the guide to an offshore wind farm by Catapult,[29] DECEX is approximately equal to 2% of the total investment costs. Based on this evidence, we estimate that the DECEX for the hypothetical offshore wind farm will be equal to €28 million, which is evenly split across the 3 decommissioning years.

Table 2. Costs (CAPEX, OPEX DECEX)

CAPEX per MW	€1.6 million
OPEX per MW	€0.05 million
DECEX per MW	€0.1 million

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[29] Catapult. Wind farm costs. Available at: https://guidetoanoffshorewindfarm.com/wind-farm-costs

4. Analysis of benefits and disbenefits

Our model estimates a range of economic, social, and environmental benefits that will be generated from the offshore wind farm at the global, national and local level. This chapter discusses evidence from the literature and engagement with sector experts that was used in Chapter 5 to explore the impact of the hypothetical offshore wind farm. In particular, the following section presents (i) our approach to quantifying benefits and disbenefits from investing in offshore wind power and (ii) qualitative benefits identified through our literature review and engagement with sector experts.

Quantifiable impact

Benefits

The benefits will start materialising as soon as the offshore wind farm starts operating. The first step to estimate the benefits that such an investment will accrue to society is to calculate the energy that the offshore wind farm can produce.

In line with Zountouridou et al. (2015), and to estimate the energy (in MWh) produced in the first year of operation, we consider the number of turbines of the farm, the capacity of each turbine, the annual operating hours, and the installation capacity of one turbine. Based on these factors, we expect that, in the first year of operation, energy of 2.5 TWh will be produced, covering around 4% of Greece's annual energy demand (Independent Power Transmission Operator S.A 2021).

After this first year, we assume that the wind turbines are degrading by 0.7% annually (Zountouridou et al., 2015). This means that the energy produced in the second year of the farm's operation will decrease by 0.7% compared to the first year.

Welfare gains from reductions in CO_2 emissions

Crucially, **renewable energy** investments generate gains in welfare as a result of reductions in CO_2 emissions. Since wind energy from the hypothetical farm is assumed to replace energy produced by oil and natural gas, the investment will result in reductions in CO_2 emissions generated by producing the same amount of energy from hydrocarbons (that is, natural gas and oil).

Our framework calculates gains in welfare from cleaner air, using the social value of CO_2 estimated by the Department for Business, Energy and Industrial Strategy (BEIS, 2019). BEIS currently uses a market-based approach to estimate the social value of carbon, based on future prices of allowances under the European Union Emissions Trading System (EU-ETS).[30]

It is estimated that in 2025 (Year 1 in our case study), the carbon value will be equal to 35.41£/tonne. It is also assumed that this value will remain stable at 84.61$/tonne after 2030, due to uncertainties in forecasting carbon prices and challenges in specifying the energy mix

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[30] Previously, BEIS estimated the value of carbon (known as Shadow Price of Carbon (SPC)) based on the lifetime damage costs associated with the environmental impact of greenhouse gas emissions, which is known as the Social Cost of Carbon (SCC). However, this approach is no longer used in the UK, as it incorporates considerable uncertainty. UK Government. 2013. "Carbon valuation". Available at: https://www.gov.uk/government/collections/carbon-valuation--2

in the long-term. In line with this approach, we assume that after 5 years following commissioning, the CO_2 value will remain stable at 84.61£/tonne.

According to BEIS, these estimates capture the value society attaches to reducing CO_2 emissions. To arrive at estimates of individual values, we divide the values per tonne estimated by BEIS (2019) by the global population. It follows that gains in welfare from reduced carbon emissions will be larger at the global level compared to the national level.

Welfare losses

Impact on population (aesthetics and noise)

Local communities are usually opposed to offshore wind farms due to their impact on the landscape and the noise they create. Although there is evidence that an offshore wind farm located several kilometres from the shore might not be visible and its noise can be covered by the sound of the sea (Kaldellis et al., 2016), there might still be an impact on the local population.

To quantify this impact, we estimate the costs to residents in coastal areas generated from wind farms located at different distances from the shore, based on Krueger et al. (2011). The benefits (or disbenefits) of an investment can be estimated by measuring the public's willingness to pay to accept (or avoid) them (Alberini et al., 2018). A common approach to quantifying effects to which monetary values cannot be applied involves asking policy and intervention beneficiaries to define their willingness to pay (WTP) or accept (WTA) the effects of this policy or intervention. Krueger et al. (2011) use a state preference model to estimate losses in welfare from an offshore wind farm to the local population at different distances from the shore. The authors reveal that an offshore wind farm can create welfare losses as a result of visual disamenity, as well as a negative influence on fisheries and marine traffic.

It is important to highlight that there is nothing universal or fixed about visual disamenity costs: in simple terms, while at this moment in time the average person views them as visually unappealing, tastes change and evolve – and it is definitely possible that as wind turbines become more ubiquitous fewer people see them as a visual blight to their surrounding environment, reducing the associated social costs.

Under our hypothetical scenario, we assume that the local communities impacted by this investment will reside on an island of around 4,000 households, that is 10,000 residents. Based on stakeholder inputs, it is reasonable to assume that welfare losses from visual disamenity will start from the 2nd year of the farm construction and will last for 5 years (as a result of residents being used to the farm).

Impact on tourism

There is mixed evidence on the impact of offshore wind farms on tourism. In particular, there is evidence that in England and Wales, tourism was not affected by investments in offshore wind farms (Welsh Government, 2014). Another study by Carr-Harris and Lang (2019) finds that installing an offshore wind farm affected the number of tourists in a US resort positively. A study by Westerberg et al. (2013) argues that an offshore wind farm will not affect tourism if it is located at a 12 km distance from the shore or a 5km distance from the shore accompanied by environmental policies and interventions promoting recreational activities for visitors.

We adopt a pessimistic approach assuming that an offshore wind farm affects tourism negatively. In line with Westerberg et al. (2015), we capture this impact using the value of

compensation to attract tourists to the region, including investment in recreational activities to attract visitors to coasts with wind farms. Based on different WTA values for farms located at different distances from the shore, we calculate average changes in WTA for distances between 5-8km and 8-12 km, respectively.

We assume that 50,000 tourists impacted by our hypothetical investment are visiting the island close to which the wind farm will be built. We also assume that the impact on tourism will arise in the 2nd year of the farm construction and will last until the last year of decommissioning.

Environmental impact

Impact on fauna (avian species, benthos, marine mammals, fish)

Offshore wind farms can have negative consequences for the local environment, such as harming birds and marine life. To quantify the effect of offshore investments on the local environment, the existing literature considers individuals' willingness to pay to protect fauna and flora from wind turbines.

According to Kaldellis et al. (2016), an offshore wind turbine can kill around 16 birds per year, meaning that an investment in 33 turbines is likely to cause 530 deaths of birds annually. Other potential effects include birds' displacement and impact on birds' population movements and migratory routes.

Regarding the negative impact on marine mammals, Snyder and Kaiser (2009) highlight that the noise while building the farm and wind turbines operate can affect the sensitive hearing of marine mammals. Additionally, constructing the farm can cause the displacement of fish in the maritime region. Construction noise might also affect marine mammals, although its impact remains unclear. Electric and magnetic fields created by the underwater cables might also affect the navigation and migration of fish.

Based on a recent study by Kim et al. (2019), we calculate the cost of impact on fauna using the willingness of the local communities on an island in the Southern Aegean Sea to pay for protecting birds, benthos, marine mammals and fish from the adverse effects of an offshore wind farm. We assume that the impact of the farm on fauna will start to materialise in the first year of the farm construction and will last until the final decommissioning year.

CO_2 emissions throughout the lifetime of the farm

According to Nian et al. (2019), an offshore wind farm generates CO_2 emissions throughout its lifetime. Kaldellis et al. (2016) highlight that 80% of total greenhouse gas emissions from the farm will be generated during the farm construction phase. 5-20% will be produced during the operation phase, while minor emissions will be generated throughout the decommissioning phase.

Based on this evidence, we assume that 15% of emissions are generated throughout the operation and maintenance phase and 5% during the decommissioning phase.

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Unquantifiable impact

Security of energy supply and system adequacy

Offshore wind power contributes to the security of energy supply,[31] as it helps Greece become independent of oil imports and fossil fuel reserves (Zountouridou et al., 2015). Nonetheless, by relying solely on energy produced by offshore wind power, the power system is likely to struggle to meet the peak energy demand as wind energy depends on weather conditions. According to sector experts, the variability in wind energy supply and the increasing peak energy demand call for the Greek energy generation system to also rely on other resources – in particular, natural gas. The uncertainty associated with wind energy poses barriers to system adequacy.[32] An alternative way to face the challenge of unstable wind energy production is energy storage and the generation of green hydrogen.

Threat to marine traffic

According to sector experts, offshore wind farms impact negatively marine traffic. There is criticism that offshore wind farms can also influence navigation safety. The site selection of the farm will play an important role in mitigating this risk (Snyder and Kaiser, 2009). According to Spyridonidou et al. (2020), farms should be located 5km away from the navigation routes connecting Greek islands to each other and the mainland.

Impact on fisheries

There is mixed evidence on the impact of offshore wind farms on commercial fisheries. On the one hand, Snyder and Kaiser (2009) suggest that offshore wind farms can serve as fish aggregating devices (FADs), positively impacting fisheries. On the other hand, the European Platform (2021) describe the conflicts between offshore wind farms and commercial fisheries in the North Sea, Baltic Sea and Eastern Atlantic. This conflict mainly occurs in countries with strong fishing industries.

The same study by the European Platform (2021) shows that the presence of offshore wind farms can cause accidental damage to fishing vessels or gear. Conversely, fishing methods, such as bottom trawling, might destroy the subsea cables. Additionally, the construction and operation of offshore wind farms might lead to the displacement of or reductions in fish populations, as well as to fishers' exclusion from their traditional fishing areas. As a result, small-scale fisheries might not be able to tackle the new challenges and costs generated by offshore wind farms.

Geopolitics

Moving towards renewable energy sources is expected to reshape geopolitics (Global Commission on the Geopolitics of Energy Transformation, 2019). According to Vakulchuk et al. (2020), the sustainability and natural replenishment of renewable energy sources can promote international security and peace. Furthermore, becoming less reliant on energy

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[31] According to the US Energy Information Administration, security of supply is defined as "the uninterrupted availability of energy sources at an affordable price". Available at: https://www.iea.org/topics/energy-security

[32] According to the European Project Wind Energy - The Facts, system adequacy is defined as "the way in which the power system can match the evolution in electricity demand." Available at: https://www.wind-energy-the-facts.org/security-of-supply-and-system-adequacy.html

imports, countries with renewable energy potential will benefit from this energy transition.

In particular, energy geopolitics in the eastern Mediterranean have sparked heated debate lately. The literature focuses mostly on the energy geopolitics of hydrocarbons in the region, which are deemed the main drivers of diplomatic problems among eastern Mediterranean counties, and particularly between Greece and Turkey.[33] A study by the Oxford Institute for Energy Studies (2021) suggests that potential benefits from the exploitation of the newly discovered hydrocarbons in the Eastern Mediterranean will arise under specific conditions. Differently put, energy security and stability will be established only if Eastern Mediterranean countries resolve their differences fuelled by boundary disputes and regional competition.

Lately, the effects of offshore wind energy on geopolitics have inspired a growing body of literature and increasing international discussion. Consultation with sector experts brought forth that investing in offshore wind power energy will be a "game-changer", contributing to the peace and security in the Mediterranean region. This investment could also generate further geopolitical benefits, as it could help create links with other countries via exports of wind energy. More on the geopolitics of offshore wind energy can be found at the Winds of Change Geopolitical Study, summarising research carried out as part of the current project.

Contribution to GDP and job creation

Investment in offshore wind farms is associated with both direct and indirect employment creation (Zountouridou et al., 2015). In particular, the installation of offshore turbines produces direct and short-term jobs, while operation and maintenance require long-term employment. This type of projects can also help establish other activities such as engineering and education.

According to Multiconsult (2019), an investment in an 88MW capacity farm can contribute to Norway's GDP by €175 to 350 million and create 1,550 to 3,000 full-time equivalent (FTEs) jobs. Assuming that Greece will import resources but will also use its supply chain as Norway, an investment in 495 MW capacity can contribute to Greece's GDP by €985 to €1970 million and create 8,700 to 16,900 FTEs. Ripple effects, such as the investment's contribution to GDP, are not considered in our CBA framework as GDP changes arising from investing in offshore wind energy or continuing using conventional energy will not provide additional information for our analysis. Additionally, while employment effects from the investment can be substantial locally, the investment is not expected to change employment rates at the national level in the long run.

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[33] Pier Paolo Raimondi. 2020. "The new energy geopolitics of "East Med"". Available at: https://aspeniaonline.it/the-new-energy-geopolitics-of-east-med/

The socio-economic impact of offshore wind energy in Greece

5. Key findings

One of the most significant benefits of investing in an offshore wind farm is reducing CO_2 emissions. Welfare gains from a cleaner environment are high at the **global level** and outweigh any potential costs. At the **national level**, the costs outweigh the benefits of the investment, highlighting that while this investment might not be economically efficient for Greece, it will help the country meet its global commitment to climate change action.

Welfare losses will always exceed gains for **local communities and visitors** as a result of the negative impact of building offshore wind farms on the environment and quality of life in the area. This research suggests that environmental policies should be developed to accompany an investment in offshore wind power production and some of form of compensation should be provided to residents and visitors.

International perspective

Table 3 summarises the cost of investing in our hypothetical farm, as well as avoided costs and welfare gains and losses at the international level.

Investment costs include the expenses for designing, constructing, operating and maintaining the farm (that is, CAPEX, OPEX and DECEX). Avoided costs from the investment include the savings in costs from exploration and extraction as wind energy power replaces energy produced by natural gas and oil.

We find that investing in offshore wind farms in Greece can create substantial benefits for the global community. This is mainly by generating welfare gains from reduced CO_2 emissions due to reduced energy production from natural gas and oil unit farms. We also consider the welfare losses from lifetime CO_2 emissions from the offshore wind farm, deducing the social cost from the overall welfare gains. Welfare losses from visual disamenity, the impact on tourism, and the impact on fauna are also considered.

The discounted net value of total benefits at the international level is €715 million. According to findings from the CBA framework, investing €1 in offshore wind energy will generate €1.6 throughout the lifetime of the project at the global level.

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Table 3. International perspective

Costs	
CAPEX	€811 million
OPEX	€608 million
DECEX	€29 million
Total costs	€1.4 billion
Present value of total costs	€994 million
Avoided costs	
Natural gas – exploration and extraction costs	€86 million
Oil – exploration and extraction costs	€289 million
Total avoided costs	€374 million
Present value of total avoided costs	€196 million
Welfare gains	
Welfare gains from clean environment	€3 billion
Present value of total welfare gains	€1.6 billion
Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€101 million
Total welfare losses	€180million
Present value of total welfare losses	€118 million
Net Present Value	€715 million
Benefit-Cost ratio of the investment	1.6

National perspective

At the national level, we estimate that an investment of €994 million in a 495MW offshore wind farm in Greece can potentially generate €783 million savings from replacing conventional energy. It will also create €2 million in welfare gains to the Greek society over its lifetime.

The investment will also result in indirect costs from causing visual disamenity, impacting tourism, and creating environmental effects (estimated at €43 million in total). The Benefit to Cost Ratio of this investment is calculated at 0.8, meaning that the costs of this scenario will outweigh its related benefits. The net present value of the project is estimated at - €252 million.

Table 4.   National perspective

Costs	
CAPEX	€811 million
OPEX	€608 million
DECEX	€29 million
Total costs	€1.4 billion
Present value of total costs	€994 million
Avoided costs	
Cost of buying natural gas	€282 million
Cost of buying oil	€1.2 billion
Total avoided costs	€1.5 billion
Present value of total avoided costs	€783 million
Welfare gains	
Welfare gains from clean environment	€3.8 million
Present value of total welfare gains	€2 million
Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€111,000
Total welfare losses	€80 million
Present value of total welfare losses	€43 million

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Net Present Value	-€252 million
Benefit-Cost ratio of the investment	0.8

Local perspective

We consider costs and benefits to local communities and visitors to the island close to which the offshore wind farm will be built. The welfare losses that the local community is expected to experience far outweigh gains in welfare from reduced CO_2 emissions. The latter are calculated at €2,000 in total for around 4,000 households on the island.

The welfare losses include the cost due to visual disamenity, the impact on tourism and fauna, as well as social costs from lifetime CO_2 emissions of the offshore wind farm. The net present value that the investment will generate at the local level is estimated at -€43 million.

Table 5.   Local perspective

Welfare gains	
Welfare gains from clean environment	€4,000
Present value of total welfare gains	€2,000
Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses because of impact on fauna	€986 million
Social cost of lifetime CO_2 emissions of the offshore wind farm	€116
Total welfare losses	€80 million
Present value of total welfare losses	€43 million
Net Present Value	-€43 million
Benefit-Cost ratio of the investment	0

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6. Sensitivity analysis

Different farm capacity

The energy capacity of an offshore wind farm directly affects the amount of energy produced, and consequently, the amount of conventional energy replaced by wind power. This replacement further influences the amount of reduced CO_2 emissions and the social gains from a cleaner atmosphere. At the international level, increasing the farm's energy capacity increases the net present value that it generates. The farm's energy capacity affects the welfare gains and avoided costs as well as the investment cost, slightly increasing the Benefit to Cost Ratio.

At the national level, increasing the farm's energy capacity leads to decreases in net present value but increases in the Benefit to Cost Ratio. This implies that there might be a need for investments in high-capacity farms.

At the local level, the net present value changes slightly, as we assume that the local community's welfare gains and losses due to visual disamenity, impact on tourism and impact on fauna do not depend on the energy capacity but its existence and location.

Table 6. Different farm capacity

International perspective		
	Capacity of 255MW	Capacity of 455MW	Capacity of 1005MW
Net Present Value	€348 million	€715 million	€1.5 billion
Benefit-Cost Ratio	1.6	1.6	1.7

National perspective		
	Capacity of 255MW	Capacity of 455MW	Capacity of 1005MW
Net Present Value	-€151 million	-€252 million	-€468 million
Benefit-Cost Ratio	0.7	0.8	0.8

Local perspective		
	Capacity of 255MW	Capacity of 455MW	Capacity of 1005MW
Net Present Value	-€43 million	-€43 million	-€43 million
Benefit-Cost Ratio	0	0	0

Changes in the energy mix

In our central scenario, we assume that wind energy will replace 50% of energy produced by oil and 50% of energy produced by natural gas.

We alter this assumption to examine two alternative scenarios under which (i) wind power replaces energy by natural gas only, and (ii) wind energy replaces energy by oil only. Natural gas is cheaper, and its CO_2 emission factor is lower compared to oil. This means that, in the example where the counterfactual is natural gas, the net present value and benefit to cost ratio at both the international and national level are lower compared to our central scenario and the scenario where the counterfactual is oil. At the local level, changes in net present value are negligible. In the scenario where the counterfactual is oil, both the net present value and the benefit to cost ratio are positive and higher than our central scenario at the international and national level.

Table 7. Changes in the energy mix

International perspective			
	Natural gas	**Oil & Natural gas**	**Oil**
Net Present Value	€116 million	€715 million	€1.3 billion
Benefit-Cost Ratio	1.1	1.6	2.2

National perspective			
	Natural gas	**Oil & Natural gas**	**Oil**
Net Present Value	-€741 million	-€252 million	€237 million
Benefit-Cost Ratio	0.3	0.8	1.2

Local perspective			
	Natural gas	**Oil & Natural gas**	**Oil**
Net Present Value	-€43 million	-€43 million	-€43 million
Benefit-Cost Ratio	0	0	0

Changes in water depth and distance from the shore

Changing the location of the farm can directly affect the investment cost and welfare losses for international, national and local communities. Increasing the water depth of the farm will lead to proportionate increases in investment costs. On the other hand, increasing the distance from the shore will increase the investment cost proportionately, but it will decrease the impact on tourism and the cost due to visual disamenity.

We examine two indicative scenarios assuming different locations, and we compare the results to our central scenario (distance from the shore 10km, and water depth 250m). In the first scenario, the depth gets the maximum value it can, which is 400m, and the distance from the shore equals to 6km. The increase in depth results in rises in the investment cost, while the minimum distance from the shore will decrease the investment cost but increase

welfare losses.

The second scenario assumes that the depth gets the minimum value of 200m, and the distance from the shore is 12km. The decrease in water depth will reduce the investment cost, while the increase in distance from the shore will increase it. Increased distance from the shore reduces welfare losses for local communities.

At the international level, the net present value and benefit to cost ratio decrease compared to our central scenario. Contrastingly, both the net present value and benefit to cost ratio increase in the second scenario. The net present value is equal to €762 million, and the benefit to cost ratio is equal to 1.7, meaning that investing €1 in a farm at a 12km distance from the shore and at 200m water depth will generate €1.7 in social value throughout its lifetime.

At the local level, the net present value generated by the farm is reduced compared to our central scenario, while in the second scenario, it increases. The net present value in the second scenario will still be negative, but it is lower (at an absolute value) than in the first example. This means that local communities will have to deal with losses from the offshore wind farm, irrespective of its location.

Table 8. Changes in geographical characteristics

International perspective			
	Maximum depth & minimum distance	**Central scenario**	**Minimum depth & maximum distance**
Net Present Value	€600 million	€715 million	€762 million
Benefit-Cost Ratio	1.5	1.6	1.7

National perspective			
	Maximum depth & minimum distance	**Central scenario**	**Minimum depth & maximum distance**
Net Present Value	-€368 million	-€252 million	-€206 million
Benefit-Cost Ratio	0.7	0.8	0.8

Local perspective			
	Maximum depth & minimum distance	**Central scenario**	**Minimum depth & maximum distance**
Net Present Value	-€102 million	-€43 million	-€15 million
Benefit-Cost Ratio	0	0	0

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Tourism

Another factor that plays an important role in the economic efficiency of the farm is the number of tourists visiting the island close to which the wind farm will be located.

If the wind farm is located at a 10km distance from the shore and if more than 900,000 tourists visit the region from which the farm is visible, then the costs will start outweighing the benefits even at the global level.

If the offshore wind farm is located between 6km and 12km distance from the shore, the costs will start outweighing the global benefits if 400,000 and 2,600,000 tourists visit the region, respectively.

If the wind farm is located close to a region with no tourists and residents, then the location is no longer linked to any welfare losses. Under this scenario, investing €1 in the farm generates €1.7 at the global level.

Changes in multiple parameters

As part of the sensitivity analysis, we develop two scenarios with different parameters related to the location of the farm and the energy produced in the counterfactual scenario. Under the first scenario, the farm is located at 400m water depth and at a 6km distance from the shore, and the wind energy replaces energy generated by natural gas. The second scenario assumes a farm located at 200m water depth and 12km distance from the shore. In this scenario, wind energy replaces energy produced by oil.

In the first scenario, the net present value and the Benefit to Cost Ratio get the lowest values at all levels. In the second scenario, the most optimistic one, the net present value and the Benefit to Cost Ratio reach their highest values. At the international level, the net present value equals €1.4 billion, and the Benefit to Cost Ratio is 2.3. At the national level, benefits outweigh costs. At the local level, although the net present value is still negative, it is lower in absolute terms than in the pessimistic and the central scenario.

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Table 9. Changes in multiple parameters

International perspective

	Natural gas, maximum depth & minimum distance	Central scenario	Oil, minimum depth & maximum distance
Net Present Value	€326,000	€715 million	€1.4 billion
Benefit-Cost Ratio	1.0	1.6	2.3

National perspective

	Natural gas, maximum depth & minimum distance	Central scenario	Oil, minimum depth & maximum distance
Net Present Value	-€857 million	-€252 million	€282 million
Benefit-Cost Ratio	0.3	0.8	1.3

Local perspective

	Natural gas, maximum depth & minimum distance	Central scenario	Oil, minimum depth & maximum distance
Net Present Value	-€102 million	-€43 million	-€15 million
Benefit-Cost Ratio	0	0	0

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7. Conclusions

In this study, we examine the socio-economic benefits of investing in an offshore wind farm in Greece, considering, among other issues, (i) the energy capacity of the farm, (ii) specific parameters relating to its location, and (iii) the type of energy that will be replaced by wind power.

We first calculate the results for our central scenario that assumes that a farm with an energy capacity of 495MW will be built at a 10km distance from the shore and 250m water depth. Under our central scenario, it is assumed that wind energy will replace energy produced by a mix of hydrocarbons – in particular, half oil and half natural gas.

From an international perspective, investing in offshore wind energy is expected to create substantial benefits that will outweigh the relevant costs. We find that the investment can generate net social value of €715 million, with €1.7 being produced for every €1 being invested in the farm. The welfare gains for the international community due to reductions in CO_2 emissions strongly outweigh the costs and welfare losses from the investment. The location of the farm is an important determinant of its impact, as it affects the investment cost and the welfare losses that the farm can generate for local populations and visitors.

From a national perspective, the results vary materially across different scenarios depending on the location of the farm and the energy source offshore wind power will be replacing. Under all scenarios, the substantial reduction in CO_2 emissions will be critical in enabling Greece to contribute to global efforts against climate change.

Finally, a critical conclusion from our research is that investing in offshore wind energy can create benefits for local communities through the provision of either private compensation (e.g., energy at lower prices), or public compensation, such as the provision of local public goods (e.g., infrastructure development, or maintenance of cultural heritage). In our hypothetical scenario, we estimate the annual welfare loss due to the visual disamenity associated with wind farms and the risk of negative impacts on the local environment – and hence required annual compensation to local residents to be around €2,500 per individual.

Limitations

There are several limitations that should be considered when interpreting the results of this study. First, due to the scarce evidence on the potential socio-economic benefits of an offshore wind investment in Greece, we used evidence from the international literature to develop our model. Gaps in existing evidence were addressed through engaging with key stakeholders and sector experts in Greece and internationally. Second, because of data limitations, we assume that certain parameters in our CBA framework remain constant over time, which is highly unlikely.

Future research

This analysis provides high-level answers to critical questions related to investing in wind energy in Greece. The findings from our CBA framework will contribute to the public debate around wind energy in Greece and lay the foundations for future advocacy of policies and regulations that will enable green investments at a national level. We expect this report to be a valuable tool for raising awareness regarding the benefits of investing in offshore wind

among policy makers, local communities, and wider audiences in Greece. Our findings will also help prioritise policies that can create an amenable environment for similar investments.

This report is accompanied by a CBA model, an easy-to-use Excel tool, which can be easily adapted and updated with new data. The tool can be of use in the future and act as a reference point for forthcoming research on renewable energy investments in Greece.

8. Bibliography

Alberini, A., Bigano, A., Ščasný, M., Zvěřinová, I., 2018. Preferences for Energy Efficiency vs. Renewables: What Is the Willingness to Pay to Reduce CO2 Emissions? Ecol. Econ. 144, 171–185. https://doi.org/10.1016/j.ecolecon.2017.08.009

BEIS, 2019. Updated short-term traded carbon values used for modelling purposes 2018. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794188/2018-short-term-traded-carbon-values-for-modelling-purposes.pdf

BVG associates, 2019. Guide to an offshore wind farm. Updated and extended. Available at: https://www.thecrownestate.co.uk/media/2861/guide-to-offshore-wind-farm-2019.pdf

Carr-Harris, A., Lang, C., 2019. Sustainability and tourism: the effect of the United States' first offshore wind farm on the vacation rental market. Resour. Energy Econ. 57, 51–67. https://doi.org/10.1016/j.reseneeco.2019.04.003

Welsh Government, 2014. Study into the Potential Economic Impact of Wind Farms and Associated Grid Infrastructure on the Welsh Tourism Sector. Available at: https://gov.wales/sites/default/files/publications/2019-06/potential-economic-impact-of-wind-farms-on-welsh-tourism_0.pdf

Chen, J., 2011. Development of offshore wind power in China. Renew. Sustain. Energy Rev. - RENEW SUSTAIN ENERGY REV 15. https://doi.org/10.1016/j.rser.2011.07.053

European Commission. Directorate General for Energy., Guidehouse Netherlands B.V., SWECO., 2020. Study on the offshore grid potential in the Mediterranean region: final report. Publications Office, LU. Available at: https://data.europa.eu/doi/10.2833/742284

European MSP Platform, 2021. Conflict fiche 5: Offshore wind and commercial fisheries. Available at: https://www.msp-platform.eu/sites/default/files/sector/pdf/5_offshore_wind_fisheries.pdf

Global Commission on the Geopolitics of Energy Transformation, 2019. A new world: the geopolitics of the energy transformation. Available at: http://geopoliticsofrenewables.org/assets/geopolitics/Reports/wp-content/uploads/2019/01/Global_commission_renewable_energy_2019.pdf

Hanania, J., Stenhouse, K., Donev, J., 2015. Offshore wind turbine. Available at: https://energyeducation.ca/encyclopedia/Offshore_wind_turbine

Independent Power Transmission Operator S.A. (IPTO), 2021. Monthly energy report. Available at: https://www.admie.gr/sites/default/files/attached-files/type-file/2021/04/Energy_Report_202103_v1.pdf

Institute of Energy for South-East Europe, 2020. The Greek Energy Sector - Annual Report 2020. Available at: https://www.iene.eu/articlefiles/greek%20energy%20sector%20study%202020_eng%201.pdf

Kaldellis, J., Apostolou, D., 2017. Life cycle energy and carbon footprint of Offshore Wind Energy. Comparison With Onshore Counterpart. Renew. Energy 108. https://doi.org/10.1016/j.renene.2017.02.039

Kaldellis, J.K., Apostolou, D., Kapsali, M., Kondili, E., 2016. Environmental and social

footprint of offshore wind energy. Comparison with onshore counterpart. Renew. Energy 92, 543–556. https://doi.org/10.1016/j.renene.2016.02.018

Kaldellis, J.K., Kapsali, M., 2013. Shifting towards offshore wind energy—Recent activity and future development. Energy Policy 53, 136–148. https://doi.org/10.1016/j.enpol.2012.10.032

Kim, H.-J., Kim, J.-H., Yoo, S.-H., 2019. Social acceptance of offshore wind energy development in South Korea: Results from a choice experiment survey. Renew. Sustain. Energy Rev. 113, 109253. https://doi.org/10.1016/j.rser.2019.109253

Krueger, A.D., Parsons, G., Firestone, J., 2011. Valuing the Visual Disamenity of Offshore Wind Power Projects at Varying Distances from the Shore: An Application on the Delaware Shoreline. Land Econ. 87. http://dx.doi.org/10.3368/le.87.2.268

Maienza, C., Avossa, A.M., Ricciardelli, F., Coiro, D., Troise, G., Georgakis, C.T., 2020. A life cycle cost model for floating offshore wind farms. Appl. Energy 266, 114716. https://doi.org/10.1016/j.apenergy.2020.114716

Ministry of the Environment and Energy, 2019. National Energy and Climate Plan. Available at: https://ec.europa.eu/energy/sites/ener/files/el_final_necp_main_en.pdf

Multiconsult, 2019. Hywind Tampen - Samfunnsmessige ringvirkninger. Available at: https://www.equinor.com/content/dam/statoil/documents/impact-assessment/hywind-tampen/equinor-multiconsult-2019-hywind-tampen-samfunnsmessige-ringvirkninger.pdf

Ng, C., Ran, L., 2016. Offshore wind farms: technologies, design and operation. Available at: https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=4438749

Nian, V., Liu, Y., Zhong, S., 2019. Life cycle cost-benefit analysis of offshore wind energy under the climatic conditions in Southeast Asia – Setting the bottom-line for deployment. Appl. Energy 233–234, 1003–1014. https://doi.org/10.1016/j.apenergy.2018.10.042

Notton, G., Nivet, M.-L., Zafirakis, D., Motte, F., Voyant, C., Fouilloy, A., 2017. Tilos, the first autonomous renewable green island in Mediterranean: A Horizon 2020 project, in: 2017 15th International Conference on Electrical Machines, Drives and Power Systems (ELMA). Presented at the 2017 15th International Conference on Electrical Machines, Drives and Power Systems (ELMA), pp. 102–105. https://doi.org/10.1109/ELMA.2017.7955410

Snyder, B., Kaiser, M.J., 2009. Ecological and economic cost-benefit analysis of offshore wind energy. Renew. Energy 34, 1567–1578. https://doi.org/10.1016/j.renene.2008.11.015

Spyridonidou, S., Vagiona, D.G., Loukogeorgaki, E., 2020. Strategic Planning of Offshore Wind Farms in Greece. Sustainability 2020, 12(3), 905. https://doi.org/10.3390/su12030905

The Oxford Institute for Energy Studies, 2021. The Geopolicits of Energy: Out with the old, in with the new? Available at: https://www.oxfordenergy.org/wpcms/wp-content/uploads/2021/02/OEF-126.pdf

Universidad de las Palmas de Gran Canaria, 2018. Economic effects of a 200 MW off-shore floating wind farm in the Canary Islands.

Vakulchuk, R., Overland, I., Scholten, D., 2020. Renewable energy and geopolitics: A review. Renew. Sustain. Energy Rev. 122, 109547. https://doi.org/10.1016/j.rser.2019.109547

Westerberg, V., Jacobsen, J.B., Lifran, R., 2015. Offshore wind farms in Southern Europe – Determining tourist preference and social acceptance. Energy Res. Soc. Sci. 10, 165–179. https://doi.org/10.1016/j.erss.2015.07.005

The socio-economic impact of offshore wind energy in Greece

Westerberg, V., Jacobsen, J.B., Lifran, R., 2013. The case for offshore wind farms, artificial reefs and sustainable tourism in the French mediterranean. Tour. Manag. 34, 172–183. https://doi.org/10.1016/j.tourman.2012.04.008

Wind Europe, 2021. Wind energy in Europe - 2020 Statistics and the outlook for 2021-2025. Available at: https://windeurope.org/intelligence-platform/product/wind-energy-in-europe-in-2020-trends-and-statistics/

Wind Europe, 2019. Financing and investment trends The European wind industry in 2019. Available at: https://windeurope.org/wp-content/uploads/files/about-wind/reports/Financing-and-Investment-Trends-2019.pdf

Zountouridou, E.I., Kiokes, G.C., Chakalis, S., Georgilakis, P.S., Hatziargyriou, N.D., 2015. Offshore floating wind parks in the deep waters of Mediterranean Sea. Renew. Sustain. Energy Rev. 51, 433–448. https://doi.org/10.1016/j.rser.2015.06.027

9. Appendix

Sensitivity analysis - Tables

Capacity of 255MW

Table 10. International perspective

Costs	
CAPEX	€418 million
OPEX	€313 million
DECEX	€15 million
Total costs	€746 million
Present value of total costs	€512 million

Avoided costs	
Natural gas – exploration and extraction costs	€44 million
Oil – exploration and extraction costs	€149 million
Total avoided costs	€193 million
Present value of total avoided costs	€101 million

Welfare gains	
Welfare gains from clean environment	€1.6 billion
Present value of total welfare gains	€840 million

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€52 million
Total welfare losses	€131 million
Present value of total welfare losses	€81 million
Net Present Value	€348 million
Benefit-Cost ratio of the investment	1.6

Table 11. National perspective

Costs	
CAPEX	€418 million
OPEX	€313 million
DECEX	€15 million
Total costs	€746 million
Present value of total costs	€512 million

Avoided costs	
Cost of buying natural gas	€145 million
Cost of buying oil	€634 million
Total avoided costs	€779 million
Present value of total avoided costs	€403 million

Welfare gains	
Welfare gains from clean environment	€2 million
Present value of total welfare gains	€1 million

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€57,000
Total welfare losses	€80 million
Present value of total welfare losses	€43 million

Net Present Value	-€151 million
Benefit-Cost ratio of the investment	0.7

Table 12. Local perspective

Welfare gains	
Welfare gains from clean environment	€2,000
Present value of total welfare gains	€1,000
Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€60
Total welfare losses	€79 million
Present value of total welfare losses	€43 million
Net Present Value	-€43 million
Benefit-Cost ratio of the investment	0

The socio-economic impact of offshore wind energy in Greece

Capacity of 1005MW

Table 13. International perspective

Costs	
CAPEX	€1.6 billion
OPEX	€1.2 billion
DECEX	€59 million
Total costs	€3 billion
Present value of total costs	€2 billion

Avoided costs	
Natural gas – exploration and extraction costs	€174 million
Oil – exploration and extraction costs	€586 million
Total avoided costs	€760 million
Present value of total avoided costs	€400 million

Welfare gains	
Welfare gains from clean environment	€6.3 billion
Present value of total welfare gains	€3.3 billion

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€204 million
Total welfare losses	€284 million
Present value of total welfare losses	€195 million
Net Present Value	€1.5 billion
Benefit-Cost ratio of the investment	1.7

The socio-economic impact of offshore wind energy in Greece

Table 14. National perspective

Costs	
CAPEX	€1.6 billion
OPEX	€1.2 billion
DECEX	€59 million
Total costs	€3 billion
Present value of total costs	€2 million

Avoided costs	
Cost of buying natural gas	€572 million
Cost of buying oil	€2.5 billion
Total avoided costs	€3 billion
Present value of total avoided costs	€1.6 billion

Welfare gains	
Welfare gains from clean environment	€7.9 million
Present value of total welfare gains	€4.1 million

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€226,000
Total welfare losses	€80 million
Present value of total welfare losses	€43 million
Net Present Value	-€468 million
Benefit-Cost ratio of the investment	0.8

The socio-economic impact of offshore wind energy in Greece

Table 15. Local perspective

Welfare gains	
Welfare gains from clean environment	€8,100
Present value of total welfare gains	€4,300
Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€235
Total welfare losses	€79 million
Present value of total welfare losses	€43 million
Net Present Value	-€43 million
Benefit-Cost ratio of the investment	0

The socio-economic impact of offshore wind energy in Greece

Natural gas as counterfactual

Table 16. International perspective

Costs	
CAPEX	€811 million
OPEX	€608 million
DECEX	€29 million
Total costs	€1.4 billion
Present value of total costs	€994 million

Avoided costs	
Natural gas – exploration and extraction costs	€171 million
Oil – exploration and extraction costs	€0
Total avoided costs	€17 million
Present value of total avoided costs	€90 million

Welfare gains	
Welfare gains from clean environment	€2.2 billion
Present value of total welfare gains	€1.1 billion

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€101 million
Total welfare losses	€180 million
Present value of total welfare losses	€118 million
Net Present Value	€116 million
Benefit-Cost ratio of the investment	1.1

Table 17. National perspective

Costs	
CAPEX	€811 million
OPEX	€608 million
DECEX	€29 million
Total costs	€1.4 billion
Present value of total costs	€994 million

Avoided costs	
Cost of buying natural gas	€563 million
Cost of buying oil	€0
Total avoided costs	€563 million
Present value of total avoided costs	€295 million

Welfare gains	
Welfare gains from clean environment	€2.7 million
Present value of total welfare gains	€1.4 million

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€111,000
Total welfare losses	€80 million
Present value of total welfare losses	€43 million

Net Present Value	-€741 million
Benefit-Cost ratio of the investment	0.3

Table 18. Local perspective

Welfare gains	
Welfare gains from clean environment	€2,800
Present value of total welfare gains	€1,400

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€116
Total welfare losses	€79 million
Present value of total welfare losses	€43 million
Net Present Value	-€43 million
Benefit-Cost ratio of the investment	0

The socio-economic impact of offshore wind energy in Greece

Oil as counterfactual

Table 19. International perspective

Costs	
CAPEX	€811 million
OPEX	€608 million
DECEX	€29 million
Total costs	€1.4 billion
Present value of total costs	€994 million

Avoided costs	
Natural gas – exploration and extraction costs	€0
Oil – exploration and extraction costs	€577 million
Total avoided costs	€577 million
Present value of total avoided costs	€303 million

Welfare gains	
Welfare gains from clean environment	€4 billion
Present value of total welfare gains	€2.1 billion

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€101 million
Total welfare losses	€180 million
Present value of total welfare losses	€118 million
Net Present Value	€1.3 billion
Benefit-Cost ratio of the investment	2.2

Table 20. National perspective

Costs	
CAPEX	€811 million
OPEX	€608 million
DECEX	€29 million
Total costs	€1.4 billion
Present value of total costs	€994 million

Avoided costs	
Cost of buying natural gas	€0
Cost of buying oil	€2.5 billion
Total avoided costs	€2.5 billion
Present value of total avoided costs	€1.2 billion

Welfare gains	
Welfare gains from clean environment	€5 million
Present value of total welfare gains	€2.6 million

Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€111,000
Total welfare losses	€80 million
Present value of total welfare losses	€43 million

Net Present Value	€237 million
Benefit-Cost ratio of the investment	1.2

The socio-economic impact of offshore wind energy in Greece

Table 21.   Local perspective

Welfare gains	
Welfare gains from clean environment	€5,200
Present value of total welfare gains	€2,800
Welfare losses	
Cost due to visual disamenity	€550,000
Impact on tourism	€78 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO$_2$ emissions of the offshore wind farm	€116
Total welfare losses	€79 million
Present value of total welfare losses	€43 million
Net Present Value	-€43 million
Benefit-Cost ratio of the investment	0

The socio-economic impact of offshore wind energy in Greece

Maximum depth & minimum distance

Table 22. International perspective

Costs	
CAPEX	€857 million
OPEX	€643 million
DECEX	€31 million
Total costs	€1.5 billion
Present value of total costs	€1 billion

Avoided costs	
Natural gas – exploration and extraction costs	€86 million
Oil – exploration and extraction costs	€289 million
Total avoided costs	€374 million
Present value of total avoided costs	€196 million

Welfare gains	
Welfare gains from clean environment	€3.1 billion
Present value of total welfare gains	€1.6 billion

Welfare losses	
Cost due to visual disamenity	€1.1 million
Impact on tourism	€187 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€101 million
Total welfare losses	€290 million
Present value of total welfare losses	€177 million

Net Present Value	€600 million
Benefit-Cost ratio of the investment	1.5

Table 23. National perspective

Costs	
CAPEX	€857 million
OPEX	€643 million
DECEX	€31 million
Total costs	€1.5 billion
Present value of total costs	€1 billion

Avoided costs	
Cost of buying natural gas	€282 million
Cost of buying oil	€1.2 billion
Total avoided costs	€1.5 billion
Present value of total avoided costs	€783 million

Welfare gains	
Welfare gains from clean environment	€3.9 million
Present value of total welfare gains	€2 million

Welfare losses	
Cost due to visual disamenity	€1.1 million
Impact on tourism	€187 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€111,000
Total welfare losses	€189 million
Present value of total welfare losses	€102 million

Net Present Value	-€368 million
Benefit-Cost ratio of the investment	0.7

Table 24. Local perspective

Welfare gains	
Welfare gains from clean environment	€4,000
Present value of total welfare gains	€2,100

Welfare losses	
Cost due to visual disamenity	€1.1 million
Impact on tourism	€187 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€116
Total welfare losses	€189 million
Present value of total welfare losses	€102 million
Net Present Value	-€102 million
Benefit-Cost ratio of the investment	0

The socio-economic impact of offshore wind energy in Greece

Minimum depth & maximum distance

Table 25. International perspective

Costs	
CAPEX	€796 million
OPEX	€597 million
DECEX	€28 million
Total costs	€1.4 billion
Present value of total costs	€976 million

Avoided costs	
Natural gas – exploration and extraction costs	€86 million
Oil – exploration and extraction costs	€289 million
Total avoided costs	€374 million
Present value of total avoided costs	€196 million

Welfare gains	
Welfare gains from clean environment	€3.1 billion
Present value of total welfare gains	€1.6 billion

Welfare losses	
Cost due to visual disamenity	€488,000
Impact on tourism	€26 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€101 million
Total welfare losses	€128 million
Present value of total welfare losses	€90 million
Net Present Value	€762 million
Benefit-Cost ratio of the investment	1.7

The socio-economic impact of offshore wind energy in Greece

Table 26. National perspective

Costs	
CAPEX	€796 million
OPEX	€597 million
DECEX	€28 million
Total costs	€1.4 billion
Present value of total costs	€976 million

Avoided costs	
Cost of buying natural gas	€282 million
Cost of buying oil	€1.2 billion
Total avoided costs	€1.5 billion
Present value of total avoided costs	€783 million

Welfare gains	
Welfare gains from clean environment	€3.9 million
Present value of total welfare gains	€2 million

Welfare losses	
Cost due to visual disamenity	€488,000
Impact on tourism	€26 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€111,000
Total welfare losses	€28 million
Present value of total welfare losses	€15 million

Net Present Value	-€206 million
Benefit-Cost ratio of the investment	0.8

The socio-economic impact of offshore wind energy in Greece

Table 27. Local perspective

Welfare gains	
Welfare gains from clean environment	€4,000
Present value of total welfare gains	€2,100
Welfare losses	
Cost due to visual disamenity	€488,000
Impact on tourism	€26 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€116
Total welfare losses	€28 million
Present value of total welfare losses	€15 million
Net Present Value	-€15 million
Benefit-Cost ratio of the investment	0

The socio-economic impact of offshore wind energy in Greece

Natural gas as counterfactual, maximum depth & minimum distance

Table 28. International perspective

Costs	
CAPEX	€857 million
OPEX	€643 million
DECEX	€31 million
Total costs	€1.5 billion
Present value of total costs	€1 billion

Avoided costs	
Natural gas – exploration and extraction costs	€171 million
Oil – exploration and extraction costs	€0
Total avoided costs	€171 million
Present value of total avoided costs	€90 million

Welfare gains	
Welfare gains from clean environment	€2.1 billion
Present value of total welfare gains	€1.1 billion

Welfare losses	
Cost due to visual disamenity	€1.1 million
Impact on tourism	€187 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€101 million
Total welfare losses	€290 million
Present value of total welfare losses	€177 million
Net Present Value	€325 million
Benefit-Cost ratio of the investment	1

Table 29. National perspective

Costs	
CAPEX	€857 million
OPEX	€643 million
DECEX	€31 million
Total costs	€1.5 billion
Present value of total costs	€1 billion
Avoided costs	
Cost of buying natural gas	€563 million
Cost of buying oil	€0
Total avoided costs	€563 billion
Present value of total avoided costs	€295 million
Welfare gains	
Welfare gains from clean environment	€2.7 million
Present value of total welfare gains	€1.4 million
Welfare losses	
Cost due to visual disamenity	€1.1 million
Impact on tourism	€187 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€111,000
Total welfare losses	€189 million
Present value of total welfare losses	€102 million
Net Present Value	-€857 million
Benefit-Cost ratio of the investment	0.3

The socio-economic impact of offshore wind energy in Greece

Table 30. **Local perspective**

Welfare gains	
Welfare gains from clean environment	€2,800
Present value of total welfare gains	€1,400

Welfare losses	
Cost due to visual disamenity	€1.1 million
Impact on tourism	€187 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO$_2$ emissions of the offshore wind farm	€116
Total welfare losses	€189 million
Present value of total welfare losses	€102 million
Net Present Value	-€102 million
Benefit-Cost ratio of the investment	0

Oil as counterfactual, minimum depth & maximum distance

Table 31. International perspective

Costs	
CAPEX	€796 million
OPEX	€597 million
DECEX	€28 million
Total costs	€1.4 billion
Present value of total costs	€976 million

Avoided costs	
Natural gas – exploration and extraction costs	€0
Oil – exploration and extraction costs	€577 million
Total avoided costs	€577 million
Present value of total avoided costs	€303 million

Welfare gains	
Welfare gains from clean environment	€4 billion
Present value of total welfare gains	€2.1 billion

Welfare losses	
Cost due to visual disamenity	€488,000
Impact on tourism	€26 million
Welfare losses because of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of offshore wind farm	€101 million
Total welfare losses	€128 million
Present value of total welfare losses	€90 million
Net Present Value	€1.3 billion
Benefit-Cost ratio of the investment	2.3

The socio-economic impact of offshore wind energy in Greece

Table 32. National perspective

Costs	
CAPEX	€796 million
OPEX	€597 million
DECEX	€28 million
Total costs	€1.4 billion
Present value of total costs	€976 million

Avoided costs	
Cost of buying natural gas	€0
Cost of buying oil	€2.5 billion
Total avoided costs	€2.5 billion
Present value of total avoided costs	€1.2 billion

Welfare gains	
Welfare gains from clean environment	€5 million
Present value of total welfare gains	€2.7 million

Welfare losses	
Cost due to visual disamenity	€488,000
Impact on tourism	€26 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO_2 emissions of the offshore wind farm	€111,000
Total welfare losses	€28 million
Present value of total welfare losses	€15 million

Net Present Value	€283 million
Benefit-Cost ratio of the investment	1.3

Table 33. Local perspective

Welfare gains	
Welfare gains from clean environment	€5,200
Present value of total welfare gains	€2,800

Welfare losses	
Cost due to visual disamenity	€488,000
Impact on tourism	€26 million
Welfare losses as a result of impact on fauna	€986,000
Social cost of lifetime CO$_2$ emissions of the offshore wind farm	€116
Total welfare losses	€28 million
Present value of total welfare losses	€15 million
Net Present Value	-€15 million
Benefit-Cost ratio of the investment	0