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Socio-techno-economic-environmental investigation of scenarios-based combination sources of green energy system - A case study in Spain

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ABSTRACT

The importance of development, generation, enhancement, and integration of renewable energy sources into the current energy network is excellent; however, the successful implementation of these technologies highly relies on the appropriate regulations, type of application, and the careful consideration of social-economic-technical-environmental analysis. In this research, the PRISMI Plus toolkit, which has been proven as a powerful toolkit in PRISMI projects for islands, the dataset provided by the municipality, and the update of the Sustainable Energy Action Plan were utilized for effective techno-economic analysis, comparing the flexibility of renewable energy systems including photovoltaic and wind turbines and planning of renewable energy scenarios of "Onda" town, in eastern Spain. The examined scenarios consist of a baseline scenario, a 50 % share scenario, and a 100 % share scenario. The baseline scenario entails no change in emissions or new installations of renewable energy resources. In contrast, the 50 % share and 100 % reduction in emissions are achieved through the installation of suitable-sized renewable energy sources, respectively. In scenarios 2 and 3, Electric Vehicles (EVs) are considered to be restricted to smart charging functionality only, and no Vehicle-To-Grid (V2G) is allowed. Based on the techno-socio-economic assessment, the second scenario has a more extensive technical capability to investment ratio compared to the other scenarios. Therefore, the 50 % share scenario is considered more worthwhile. This hypothetical situation has the potential to decrease energy costs by as much as 10 %, diminish relying on fossil fuels for electricity production, confine Greenhouse Gas (GHG) emissions, generate employment opportunities at the local level, and guide the municipality towards the ideals of a sustainable and energy self-sufficient city. Although similar research has been done for other cities, the novelty of this research is in the health consideration.

1. Introduction

According to the definition by the United Nations, climate change denotes enduring alterations in temperatures and weather patterns. Since the 18th century, human actions, including the combustion of fossil fuels such as coal, oil, and gas, have been the primary catalyst for climate change (United Nations What Is Climate Change). Climate change is inextricably linked to water shortage (Nations) also can cause water resources to become increasingly unpredictable, contaminated, or both (Water and Climate Change United Nations). In addition, it has the potential to destabilize the electricity network, stress infrastructure, and endanger human lives (EPA Climate Change Impacts on Energy). Although the impacts of climate change are global in scope (United nations Climate Change), some European countries like Spain are highly vulnerable to climate change (United nationes Spain Progress on Achieving SDG 6) and its consequences. Spain, which is one of the largest countries in Europe, has undergone significant economic growth since 1995, surpassing the average growth rate of Europe, which leads to experiencing societal expansion and a substantial rise in population and results in an escalating emission of greenhouse gases (GHGs) and subsequent climate change ramifications (Vargas-Amelin and Pindado, 2014). Climate change, population growth, increasing energy requirements, and water shortage in Spain necessitate a strong focus on the significance of strategic planning, legislation, and the development of suitable energy supply systems to meet the present and future electricity and water requirements (Kyriakopoulos and Arabatzis, 2016;

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Streimikiene et al., 2022). In this regard, we are trying to investigate the capability and benefits of using renewable resources to manage the increasing population and climate change consequences in Onda city, in southeast Spain.

Regarding the current pollution emission caused by fossil fuel consumption for power generation and aligned with SDGs, the utilization of renewable sources is of significant importance (Sharadga et al., 2020). However, utilizing these kinds of resources requires three primary considerations: comprehensiveness, investigation on different scales, environmental consideration, and social acceptance. The mentioned items mean that the proposed system solves several problems at the same time, the environmental considerations have been carefully evaluated, and it has social acceptance. While particular research has demonstrated the potential for more efficient systems by combining solar energy with hydrogen systems or other power-generating systems (Sameti and Haghighat, 2019) based on existing infrastructures, our study concentrates explicitly on wind and solar energy (Ahmadian et al., 2020). The utilization of solar and wind power, alongside the necessity to adhere to technical and design specifications, can be impacted by statistical methodologies for predicting energy generation, energy storage, and energy management based on energy consumption while also considering financial, social, and environmental criteria. A variety of studies have been conducted on subjects that, from a broader perspective, could contribute to the objective of attaining a more sustainable energy system and a society that is not dependent on fossil fuels.

Researchers have looked at a variety of topics related to solar and wind energy. Mardani et al. conducted a study where they utilized particle-based linear models to predict the attenuation of solar energy in Tehran (Mardani et al., 2024). In another investigation, Mallahi et al. conducted an in-depth review of cleaning techniques for solar PV panels. Their research showcased the advancements made in current cleaning methods, providing valuable insights into this field (Mallahi et al., 2023). In the field of wind energy, Mehrpooya et al. developed a novel integrated process configuration to produce hydrogen chloride by using the power of geothermal and wind energy resources (Mehrpooya et al., 2021). Isaza et al. conducted a study to evaluate the effects of higher concentrations of particulate matter (PM) on photovoltaic (PV) energy generation in New South Wales (NSW) during the bushfire season from November 2019 to January 2020 (Isaza et al., 2023). In another work, Esmaeilion et al. conducted the design, analysis, and optimization process of a novel poly-generation system that utilizes solar and wind energy (Esmaeilion et al., 2022). Shoeibi et al. examined a cogeneration cycle of PV/T waste heat on freshwater linked with a solar still system (Shahin et al., 2023). In previous studies, researchers have extensively examined the integration of renewable energy sources for water production. Maleki et al. conducted a study where they optimized a hybrid system that combined solar, wind, and hydrogen for desalination, with a focus on achieving cost-effectiveness (Maleki et al., 2016). On the other hand, Jabari et al. explored a trigeneration system that utilized biogas for electricity, cooling, and water production, with an emphasis on understanding how climatic conditions affect desalination efficiency (Jabari et al., 2019). However, there are also limitations associated with it. The study conducted by Hachicha et al. revealed a notable decrease in solar PV efficiency in the UAE due to the presence of dust particles (Hachicha et al., 2019). In another study, Khani et al. improved the efficiency and reduced costs of a solar-based multi-generation system through parameter optimization (Khani et al., 2021). As a means of guiding the most effective ecological planning processes, Roshan et al. utilized spatial analysis to classify Iran's bioclimatic areas. This method can benefit both energy efficiency strategy development and building siting (Roshan et al., 2022). In a separate study, Shahverdian et al. presented a strategy for city-specific BIPV/T system installation selection that takes economic, environmental, and energy considerations into account (Shahverdian et al., 2022). Dehghani-Sanij et al. studied a novel wind tower model and concluded that the proposed system poses easy installation and efficiency and is more applicable in developing countries (Dehghani-Sanij et al., 2022; Dehghani-sanij et al., 2015). Khani et al. developed a conceptual modular wind tower with wet surfaces. Their results showed that the A modular wind tower might reduce the ambient temperature by ten degrees Celsius in general (Rezakhani et al., 2017). Assareh et al. improved the efficiency of wind turbines by utilizing proportional and integral controllers for adjusting turbine generator torque (Assareh and Biglari, 2015). Although in the design of wind turbines and towers, in which wind speed forecasts are the result of daily average wind speed changes (Sailor et al., 2000), Sharadga et al. proved that utilizing the neural networks is more accurate for predicting PV output power (Sharadga et al., 2020). Ataei et al. discussed the feasibility of incorporating a tiny wind turbine into a comprehensive system alongside employing the HOMER VR enhancement, a solar energy plant, and a diesel power plant. They found out that a combination 75 kW diesel power source, 21 kW solar power system, 75 kW wind power generator, 50 power storage system, and a converter with 20 kW capacity was more economical (Ataei et al., 2015). Nasiri et al. analyzed a randomized decentralized method to investigate the advantage of ESSs on the regional-local MES market. They showed that by using multi-stage energy storage, the cost of daily operations at a local and regional scale is reduced by almost 7 % and 1.7 %, respectively (Nasiri et al., 2020). In addition to the mentioned technical and statistical studies, we are trying to focus on energy management and socio-economic-environmental analysis, which, without them, projects cannot be sustainable in a long-term manner. In this regard, we will first analyze the study undertaken on demand response and then explore the concerns pertaining to environmental and social studies.

Alipour et al. addressed the basis planning of customers in industry and commerce with cogeneration facilities, traditional power plants, and heat-only units. In this research, we aim to meet the electricity and heat needs of customers at the lowest cost. The results showed that the total profit increased with the implementation of the DR program (Alipour et al., 2014). Oskouei et al. investigated a system for power sharing with DRs for homes in order to lower the demand during peak loads. They showed that their suggested strategy is an efficient way to lower power usage and demand during peak loads (Zare Oskouei et al., 2020). Hemmati et al. addressed the multi-objective optimization analysis of heat and power-based microgrids (MG) with thermal energy storage (TES) and DR programs. Their proposed system can reduce the operation cost and emissions by 3 % and 10.28 %, respectively (Hemmati et al., 2021).

Ahmadian et al. investigated the connection of wind-distributed generations (WDGs) to grid-connected vehicles (V2G) by plug-in electric vehicles (PEVs). Their simulation results showed that the storage capacity of PEVs increases with the increase in their number (Hoseinzadeh et al., 2024). Hoseinzadeh et al. investigated the PRISMI Plus method in Procida Island to achieve the goal of a system characterized by a minimal carbon footprint and a significant reliance on renewable energy sources. Three scenarios have been considered for 2030, including Low, moderate, and elevated levels of use of sustainable energy sources in the designed systems; the outcomes showed that the amount of production power in the scenarios of low, medium, and high penetration coefficient of renewable energies is 0.18, 14.5 and 34.57 GWh/year respectively (Hoseinzadeh et al., 2024, 2022). Also, they simulated the financial and technological use of energy systems, including photovoltaic panels/wind turbines/fuel cells/electrolyzers, and hydrogen storage to meet the energy demand of 2 MW of Catania city in the Mediterranean weather of the island of Sicily in Italy by the HOMER software. The results showed that an expenditure of 4.85 million Euros is required for capital costs to meet the 2 MW requirement of the region, with a return on investment (ROI) during the estimated 25-year lifespan of the project is 2.59 million Euros (Hoseinzadeh and Astiaso Garcia, 2022).

Energy consumption and the GHG emissions in Europe an important topics and attracted a lot of attention. However, using renewable energy may have pros and cons and it is important to find the best percentage of renewable energy resources in whole energy consumption that can provide the most benefits for society, including, financial, economic, and environmental (de Santoli et al., 2017). This is the first time that such research has been conducted for Onda City. This research conducted a thorough analysis and comparison of possibilities for Onda City, taking into account social, technical, economic, and environmental factors in order to provide a complete and comprehensive perspective. In addition to that calculations have been done regarding some aspects like human life, that did not consider in previous research.

The items to be examined encompass the necessary electricity, the output power of the proposed systems under various scenarios, the cost of output for the proposed systems under different scenarios, the generation of jobs both upstream and downstream, environmental consideration and its effects on water usage. Although addressing emissions is likely to encompass addressing climate change, global warming, and environmental concerns simultaneously, it could have other positive effects and yield co-benefits for public health (Gavurova et al., 2021). GHG emissions have a detrimental impact on the health potential of a population, which can be shown by measured reductions in disability-adjusted life years (DALYs). Studies conducted by Woodcock et al. and Kwan et al. provide evidence that implementing approaches like reducing motor vehicle usage and promoting the use of lower-emission systems can have positive health effects in terms of DALYs (Eckelman et al., 2020; Kwan et al., 2017). This health indicator was calculated based on the number of individuals per 1000 population who are experiencing poor health due to a given reason. The DALYs indicator quantifies the disparity in the number of years spent in good health by a group of people in comparison to a benchmark. DALYs are quantitative indicators that combine the number of years lost due to early death with the corresponding number of years lived suffering from disability or sickness (WHO Disability-Adjusted Life Years (DALYs)).

2. Material and method

2.1. Analysis toolkit

In order to conduct a thorough analysis, we have combined the implementation of the PRISMI PLUS toolbox, conducted a thorough examination of the feasibility, and performed a comprehensive comparative analysis of the Onda Municipality. The study provides access to both the materials that govern Onda's strategic energy planning initiatives (European Commission Guidebook), as well as the simulation, pre-processing, and post-processing tools. The present and forthcoming energy scenarios have been constructed and evaluated using data on the regional renewable energy capability European Commission Photovoltaic Geographical Information System (PVGIS). Specifically, the programmer's simulation tool (EnergyPLAN model) has been utilized to examine cutting-edge energy production methods. The PRISMI PLUS website provides a comprehensive explanation of the approach, along with definitions and descriptions of the tools involved. These tools encompass pre-processing ones, namely, wind velocity and outcome power calculators, solar energy tools, and a modelling tool called the EnergyPLAN model. Additionally, a post-processing tool is also available on the website.

2.2. Description of approaches

PRISMI focuses on facilitating the transformation of the Mediterranean Islands toward autonomous, cleaner, and secure low-carbon energy systems. It achieves this goal through the development of an integrated toolkit. This toolkit is designed to assess and map the local potential of Renewable Energy Sources (RES), facilitating their effective integration into new energy systems. The PRISMI PLUS methodology is elaborately delineated in Fig. 1, which depicts the step-by-step diagram for utilizing the PRISMI PLUS tools and the recommended grand strategy. Projecting the energy requirements of the regional municipality of Onda yielded as much subdivision-specific information as feasible regarding energy vectors utilized and the data available regarding electricity, heating, and transportation consumption.

2.2.1. Feasibility of renewable power supply

The information on the possibility of locally accessible Renewable Energy Sources (RES) is gathered in a format suitable for examination, with the aim of offering a structured outline for future investigation and implementation. The utilization of solar resources is facilitated by the specialized tools provided by the "Renewables. ninja" web during this stage of the process, as it exclusively focuses on renewable energy sources (Department of Development and Planning).

2.2.2. Addressing the disparity between energy demands and available energy sources

Energy demand can be determined using the previous usage of the energy in the city. Still, for available energy sources and analysis of the scenarios, we take into account technologies that make use of the renewable energy sources available in the area and are practical for implementation in the local municipality. Onda Municipality has identified several technologies, including photovoltaic (PV), Wind Turbines (WT), and Electric Vehicles (EVs).

2.2.3. Different storylines

The examination of energy system development is conducted by analyzing three different storylines. The investigation will provide a concise overview of the various sources of energy, current energy demands, and the mechanisms that are currently available. These factors will serve as the foundation for developing the corresponding scenarios.

3. Case study examined - Onda municipality

Onda is a municipality located in the eastern region of Spain. The site is situated in the province of Castellón, which is a constituent element of

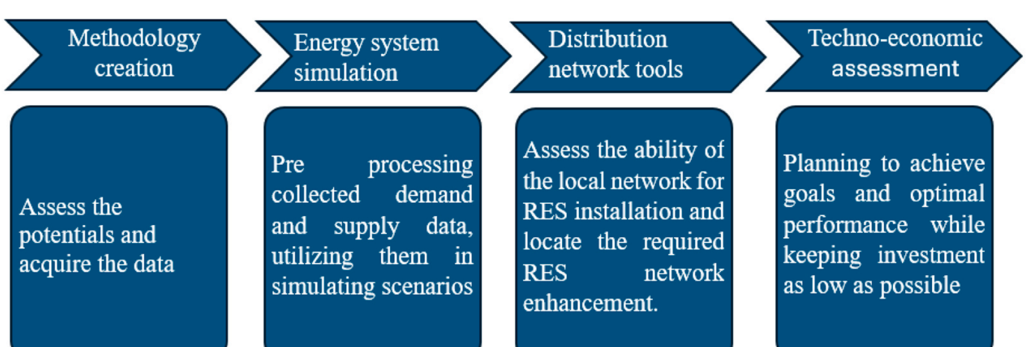

Fig. 1. An outline of the PRISMI PLUS methodology.

the autonomous community of Valencia. The population in 2019 was 24.859. The overall electricity demand and fuel consumption in this city, as provided by the Onda Municipality, is shown in Table 1. In the context of the heating industry, there is a lack of information regarding the utilization of HPs; therefore, neither the baseline nor the subsequent scenarios take into consideration this technology. Regarding the transport demand, 594 MWh/y are related to the Fleet for Public Transportation. In contrast, the remaining diesel consumption and the whole petrol consumption are related to the Municipal Fleet (both cars and motorbikes).

3.1. The potential of renewable resources in Onda city

After conducting a thorough survey of the RES in the area, it can be concluded that the capability of solar irradiation to provide energy is exceptionally high. The yearly solar irradiance levels are estimated to be around 1900 kWh/m2. Fig. 2 and Fig. 3 illustrate the hourly solar radiation and wind speed, respectively, that show the potential of renewable energy providing in Onda City. The raw data time series for these variables were obtained from the web program "Renewables.ninja" (Renewables.ninja Data Time Series).

4. Division of scenarios

The segmentation of scenarios constitutes the fourth stage of the PRISMI PLUS approach. An analysis of the power supply development for the city of Onda was conducted using three distinct scenarios. The initial scenario takes into account the electrical usage of the entire region, as supplied by Onda Municipality. Since no additional investments or installations are taken into account, this scenario serves as the baseline. The second scenario considers a 50 % reduction in total emission, which is aimed at installing appropriate sizes of PV, WT, and electrifying city vehicles (i.e., cars and bikes). The third scenario aims to achieve a 100 % reduction in total emissions through the installation of PV and WT of suitable scale, in addition to the electrification of the municipal and public transportation fleets. The results of this research only indicate the first phase of investigations to create scientific and research guidelines for future research. For example, this research shows that the ideal participation percentage is not 100 %, and percentages close to 50 should be examined more.

In scenarios two and three, EVs are solely permitted to utilize clever charging capabilities; vehicle-to-grid (V2G) is not permitted. Subsequent deliberations will be provided in light of the year 2030. Fig. 4 illustrates the variation in electricity demand across the three scenarios as a result of the increasing electrification of demands, whereas Table 2 details the installed PV and WT capacities for each scenario. Notably, when calculating the WT potential for scenario 2, both the overall cost and imported electricity quantities were simultaneously minimized. The ratios of WT and PV were utilized for the last scenario.

The municipality of Onda supplied every annual data point required for the computations. However, the hourly distribution of Onda was computed by normalizing a reference scenario based on Onda inhabitants.

5. Results of modelling and discussion

The subsequent section provides an overview of the simulation outcomes. The RES (renewable energy source) proportion is illustrated in Fig. 5, and the assortment of RES utilized in each scenario is tabulated below. It is essential to highlight that the approach utilized to determine an appropriate value for WT was to minimize the quantity of imported electricity while minimizing the overall cost. The second scenario was executed using this approach, while the third scenario utilized an equivalent ratio of PV to WT.

Table 3 details the RES that was implemented for each investigated scenario.

Furthermore, Fig. 6 illustrates the proportion of RES in the overall electricity production, taking into account the historical levels of energy generation.

The percentages of RES in electrical supply exhibit significant variety. The subsequent Fig. 7 and 8 illustrate the mean monthly output power of PV and WT systems for the analyzed scenarios 2 and 3.

Table 1
Consumption details.

Electricity	Diesel for heating	Diesel for transport	Petrol for transport	Value	Unit of measure
5450	99.05	1010	153	99.05	MWh/y

5.1. Socio-economic feasibility of proposed solutions

Table 4 contains the input data pertaining to the costs of PV and WT technology for each of the three scenarios.

5.2. Socioeconomic metric for analyzing full-time equivalent jobs

The rapid development of RES, in particular solar and wind power, has already driven the prices per kW of installed PV systems and wind turbines to fall drastically over the last ten years. The specific trend is likely to continue, but the percentage of secondary jobs is far more fascinating, such as those for installation and engineering, as well as O&M.

Similarly, in Fig. 9, a distinction is made between work jobs that are located upstream and those that are located downstream. The focus is mainly on the bulk of occupations that are located within the region and are directly related to the implementation of PV technology. The creation of a novel regional economy by means of transitioning to renewable energy sources is contingent upon the specific case study being researched.

A crucial social element that recent studies examine is the quantity of newly generated employment opportunities associated with the photovoltaic (PV) and wind turbine (WT) business (Renewables.ninja Data Time Series). The introduction of PV and WT systems in Onda municipality will generate a demand for more employment opportunities, namely in areas such as system management, installation, maintenance, and administrative duties. It is essential to highlight that O&M occupations will remain consistent during the upcoming 25-year timeframe, with engineering and installation employment opportunities in the fields of engineering and installation resuming within the repowering phase (as determined by the dynamics established during this analysis). Fig. 10 displays the quantity of full-time equivalent (FTEs) positions in every examined scenario about 2030. When analyzing data for the last year of the study (2030), it is crucial to take into account the FTEs Within the framework of the changing energy landscape. This includes considering the annual rates of installation for solar and wind power.

5.3. Environmental considerations

5.3.1. Decreasing the release of greenhouse gases (GHG) into the atmosphere

Because some fossil fuels that are currently used to make energy are replaced, greenhouse gas emissions are cut down a lot. The GHG emissions for each situation that was looked into are shown in Fig. 11.

The transition from fossil fuels to renewable energy sources for electricity generation significantly reduces greenhouse gas (GHG) emissions. In particular, scenario 3, which assumes the use of 100 % renewable energy, results in zero GHG emissions. This shift is crucial for mitigating climate change and achieving sustainability goals.

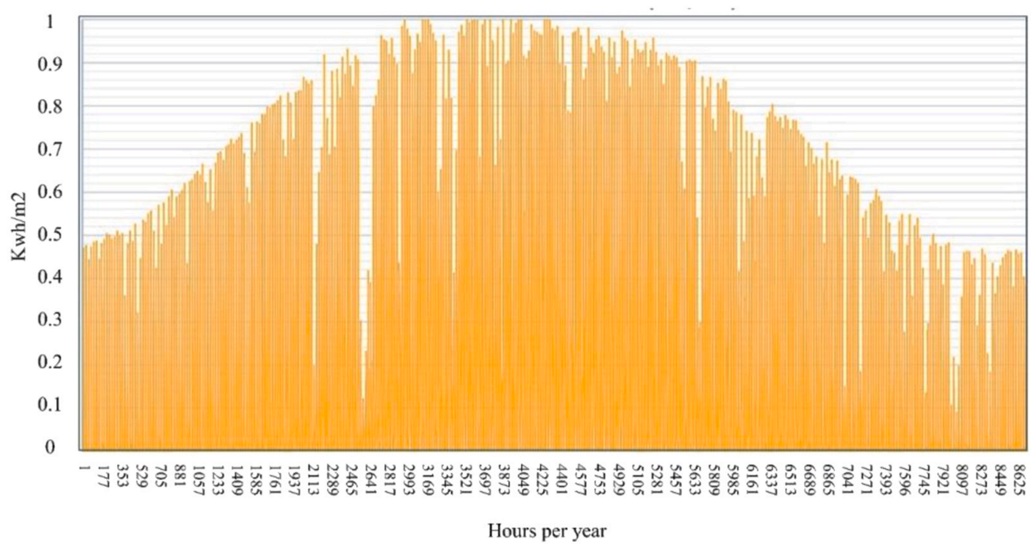

Fig. 2. Horizontal sun irradiation (kW/m2) in Onda (Renewables.ninja Data Time Series).

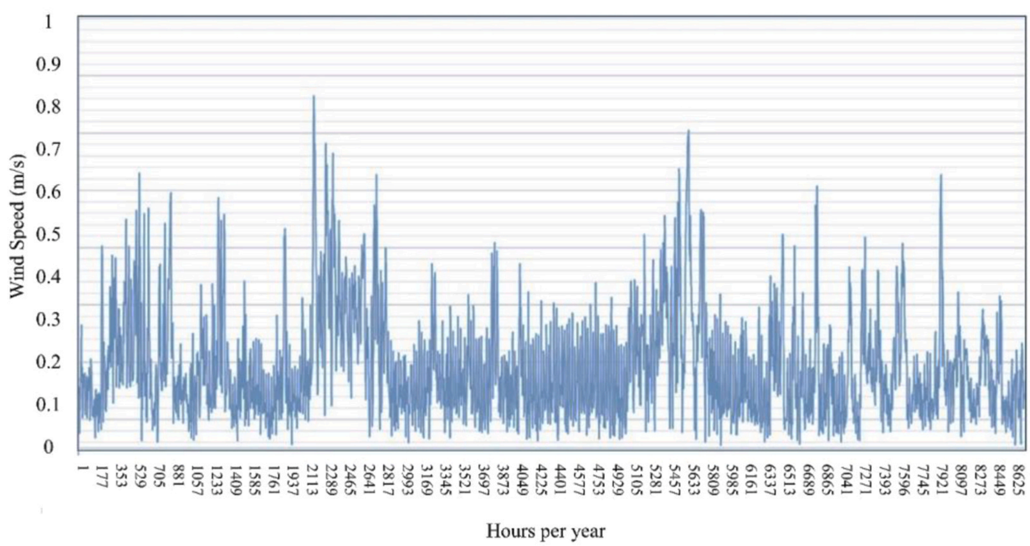

Fig. 3. Wind speed hourly distribution in Onda (Renewables.ninja Data Time Series).

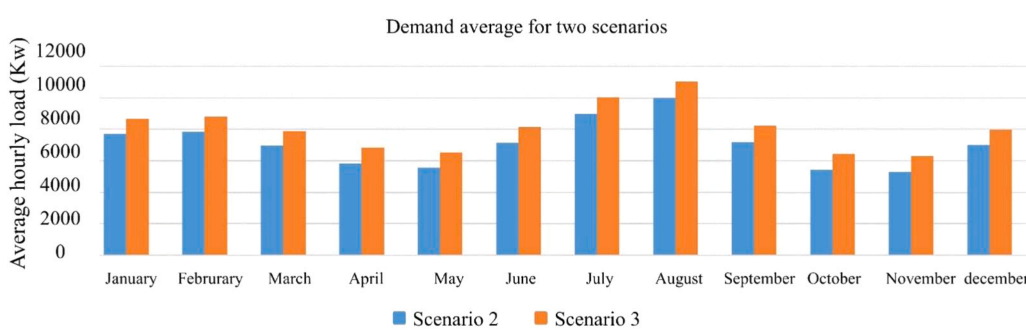

Fig. 4. The month basis mean load requirement of Onda City in 2030 for scenarios 2 and 3.

5.4. Health considerations

Although in line with earlier studies on the prevalence of diseases in Spain, the research in 2022 revealed that smoking and unhealthy eating habits, along with environmental factors, significantly contributed to the overall illness burden (WHO Disability-Adjusted Life Years (DALYs)). Gavurava et al. proved that the GHG emissions with DALY in Spain are highly correlated (Gavurova et al., 2021), which shows a severe impact of environmental factors on DALY in Spain. DALY (Disability-Adjusted Life Year) measures the overall burden of disease,

Table 2
Data regarding the prospective energy systems in Onda.

	Scenario 1	Scenario 2	Scenario 3
PV mounted capacity [kWp]	0	1100	2400
WT mounted capacity [kWp]	0	501	667

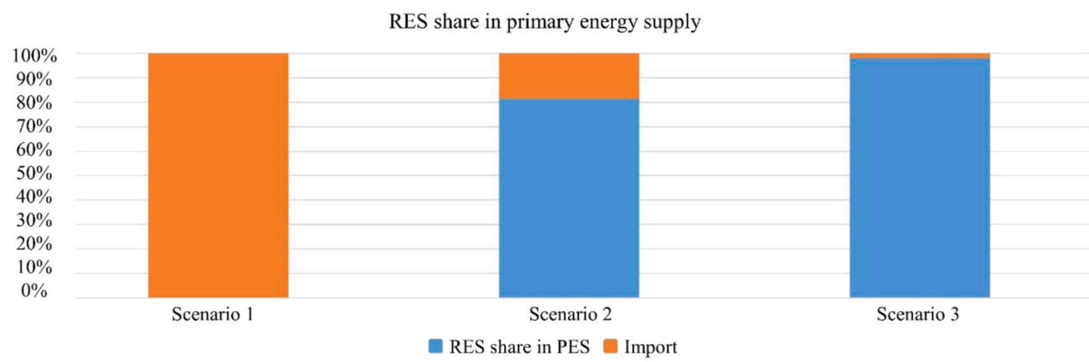

Fig. 5. Renewable energy sources' proportion.

Table 3
Simulation outcomes of RES power generation.

	PV supply	WT supply	Unit
First Scenario	0	0	GWh per year
Second Scenario	2.03	1.02	GWh per year
Third Scenario	4.43	1.38	GWh per year

combining years lost due to premature death and years lived with disability. LLY (Life Lost Years) specifically quantifies the years of life lost due to premature mortality and DLL (Disability-Adjusted Life Lost) measures the years of healthy life lost due to disability, adjusted for severity. These metrics help assess and prioritize public health efforts by quantifying the impact of diseases and injuries on populations.

Therefore, it can be concluded that reducing GHG emissions could lead to DALY reduction. Based on the data provided by WHO, almost 50.27 % of DALY in Spain in 2019 is related to years lived with disability (YLDs) and the rest is related to years of life lost due to premature mortality (YLLs) WHO Disease Burden). Therefore, it can be concluded that a 50 % reduction in GHGs leads to an almost 50 % reduction in YLDs and a 50 % reduction in YLLs. Based on Eqs. (1) and (2) and considering the total DALY for Spain (provided by WHO), population of Spain (46 million), population of Onda (24,859), and with assumption of uniform distribution of DALY (considering this idea that, inhalation of polluted air with GHGs, have uniform effects on whole population in reducing life expectancy), reduction of GHGs of second scenario may leads to 0.13 of year increase in human life expectancy in Onda city.

$$DALY = YLL + YLD \tag{1}$$

$$YLL = number\ of\ depth \times years\ lost\ for\ death \tag{2}$$

5.5. Effects on water usage

Based on the provided information by the European Wind Energy Association, the typical water usage for coal power plants, gas-based electricity generation facilities, and nuclear energy facilities is 1.9, 0.7, and 2.7 m^3/MWh (Koulouri and Jacopo, 2014). Considering the current renewable energy sources in Onda city, which is almost zero, and the average participation percentage of each of the non-renewable sources in energy production in Spain, which are shown in Fig. 12, calculation of water usage reduction can be conducted using Eqs. (1) and (2).

$$Water\ usage\ reduction = \sum R_i \times W_i \tag{3}$$

$$R = electricity\ generation\ by\ nonrenewable\ source \times participation\ in\ electricity\ generation \tag{4}$$

In this equation, R is the non-renewable energy source generation, and W is the water usage related to each electricity generation source. Based on the previous results indicated in Table 2, the total electricity generation of proposed renewable energy sources in the second scenario is 3.06 GWh per year. So, based on average values, the participation of

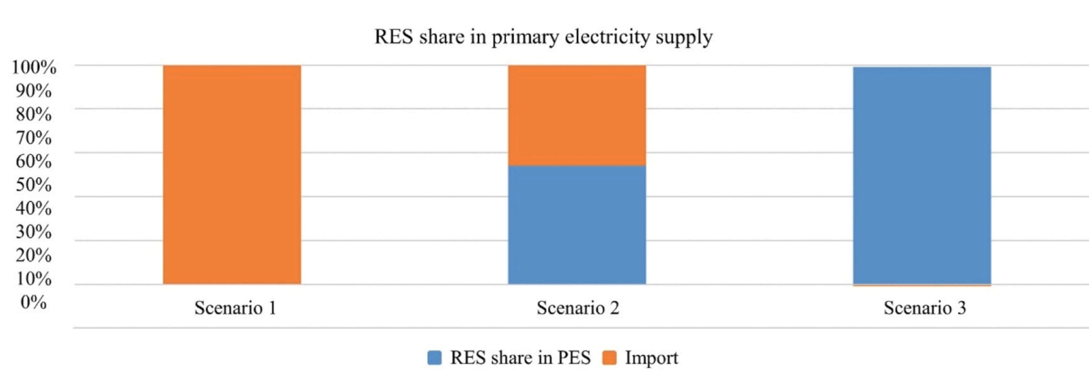

Fig. 6. RES contributes to the generation of electric power.

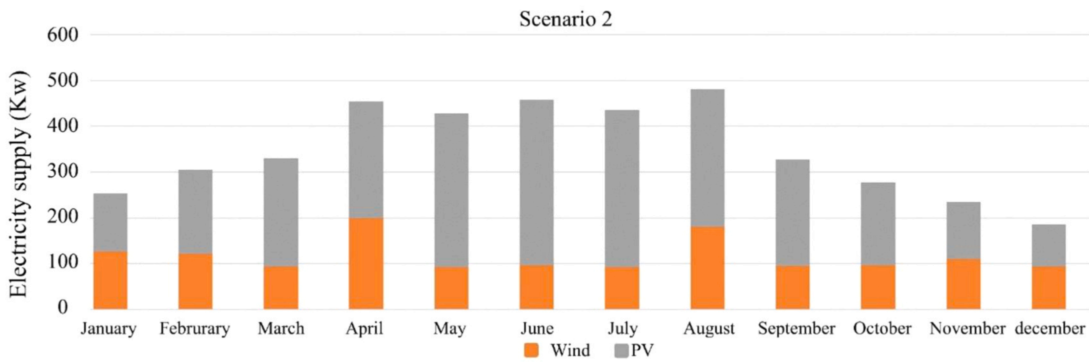

Fig. 7. Mean electricity generation values of PV and WT systems in the second scenario.

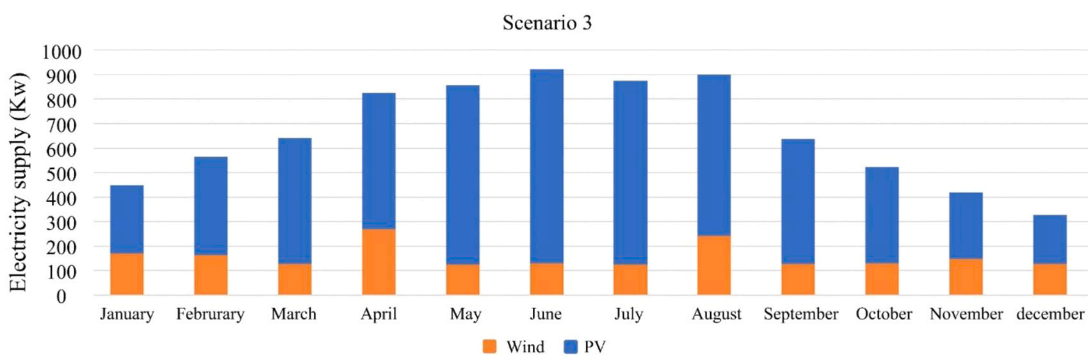

Fig. 8. Mean electricity generation values of PV and WT systems in the third scenario.

fossil fuels, gas and nuclear sources are 0.3672, 1.4688 and 0.6426 GWh per year, respectively. Therefore, utilizing Eq. 1, the total water usage reduction related to using scenario 2 can be calculated as:

$$\textit{Water usage reduction} = 1.9 \times 1000 \times 0.3672 + 0.7 \times 1000 \times 1.4688 + 2.7 \times 1000 \times 1.2362$$

As a result, the total water usage reduction per year is 5063.58 m^3.

6. Suggestions for the development strategy

The initial findings derived from the current investigation validate that Onda possesses a noteworthy capacity for solar and wind energy that remains predominantly underutilized. Very intriguing indications of what can be accomplished through comprehensive energy strategy and the application of tools such as those created by the PRISMI and PRISMI PLUS initiatives are provided by the presented scenarios and calculations. Therefore, the following prospective recommendations regarding Onda's development strategy can be derived from the aforementioned findings:

- development of a comprehensive utilizing strategy for the incorporation of PV systems onto the rooftops of public and residential structures (with potential funding from national and/or local governments);
- implementation of a specific regulation in new construction permits for the indicated incorporation;
- identify critical areas for the installation of wind farms;
- enhancing public consciousness, disseminating informational campaigns, and promoting events to encourage the implementation of energy efficiency methods and the utilization of EVs;
- encourage the development and modernization of the technical and physical facilities needed for the launch of EVs equipped to deliver adaptable services to the network, and consider offering incentives for this process.

7. Conclusions

The present study employs the scenario strategy for energy systems simulation to evaluate future possibilities for Onda Municipality. Furthermore, the EnergyPLAN model has been recognized as the primary modelling instrument for modelling energy simulations due to its user-friendly interface and demonstrated effectiveness in previous research studies. The methodology employed encompasses the depiction of the case study and input information, the presentation of modelling outcomes in the presence of discussion, the assessment of the techno-socio-economic viability of implemented solutions, and the examination of possible environmental implications. Each energy scenario examined the diversifying of RES output to meet the associated energy demands. This study has found intriguing measures and subsequently put forward as recommendations for the formulation of long-term energy strategy papers.

To summarize, this study has shown the potential to enhance the incorporation of regionally accessible types of green power, including solar and wind energy, and the methods to accomplish this goal. Furthermore, the analysis has examined the necessity of transitioning to sustainable transportation to eliminate emissions. It emphasizes that EVs offer a compelling possibility as they may also provide flexible services to the energy grid, potentially eliminating the requirement for extensive energy storage facilities. This energy transition has the potential to guide the Municipality towards the vision of a sustainable and energy-independent city while also generating new job possibilities at the local level. It places the customers at the center of the energy shift.

Table 4
Primary data to conduct an assessment of techno-economics.

2030	Funding	O&M	Lifespan
PV [Thousand Euros per K/W]	1.07	1 %	35
WT [Thousand Euros per K/W]	0.99	3.2 %	27

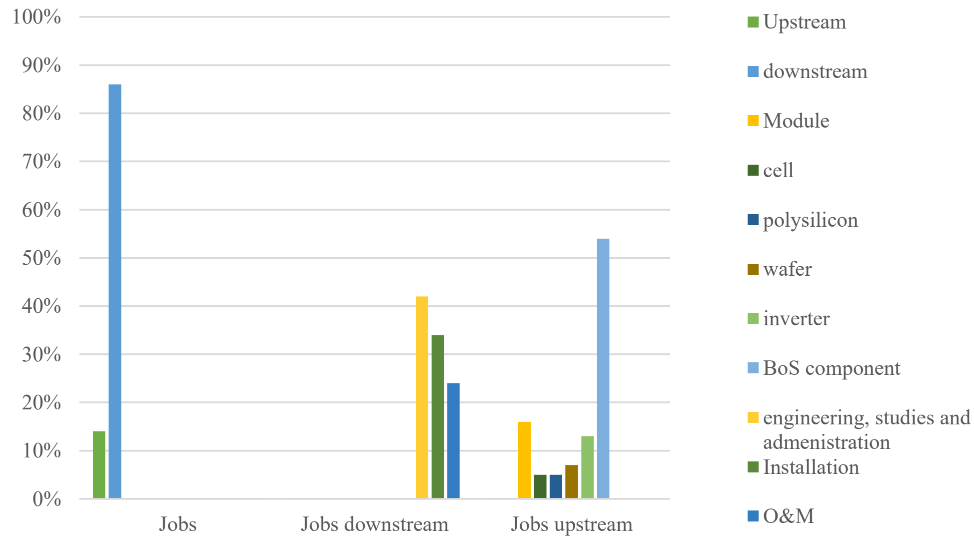

Fig. 9. Upstream and downstream jobs in solar PV technology (Department of Development and Planning).

Importantly, the renewable energy sources proposed in the second scenario have the potential to generate 3.06 GWh of electricity each year, resulting in a significant reduction of 5063.58 m^3 in water usage annually. This substantial decrease in water consumption is due to the decreased dependence on fossil fuels, gas, and nuclear power sources. Thus, the future energy strategy of the region of Ragusa should be centered around several fundamental notions and principles, which include:

●analyses the possibility of enabling V2G services to provide additional grid flexibility through demand response schemes;

●analyses the electricity reliability throughout the city and the whole region in order to avoid relying on renewables curtailment;

●A thorough investigation was designed to include more sustainable energy sources into the area's energy grid in order to stabilize the availability of electricity and reduce the need for storage facilities for energy.

Author statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript.

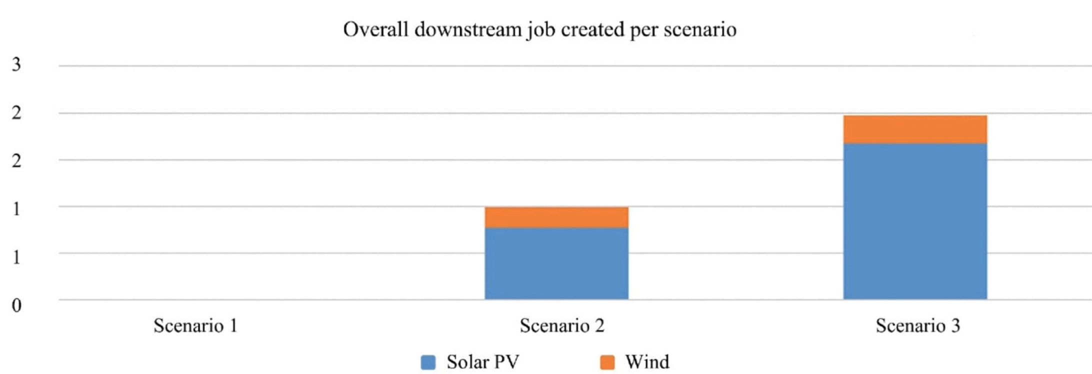

Fig. 10. The projected job positions created in various scenarios for Onda Municipality.

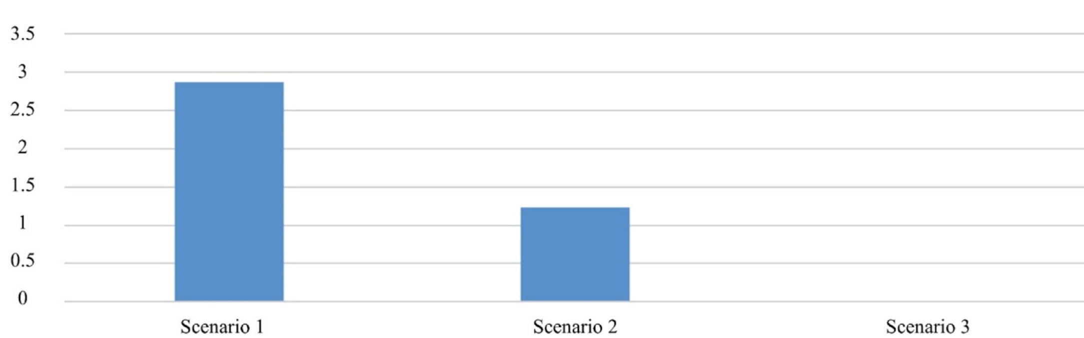

Fig. 11. Evaluation of greenhouse gas (GHG) emissions for all scenarios in comparison to the GHG emissions in the base year.

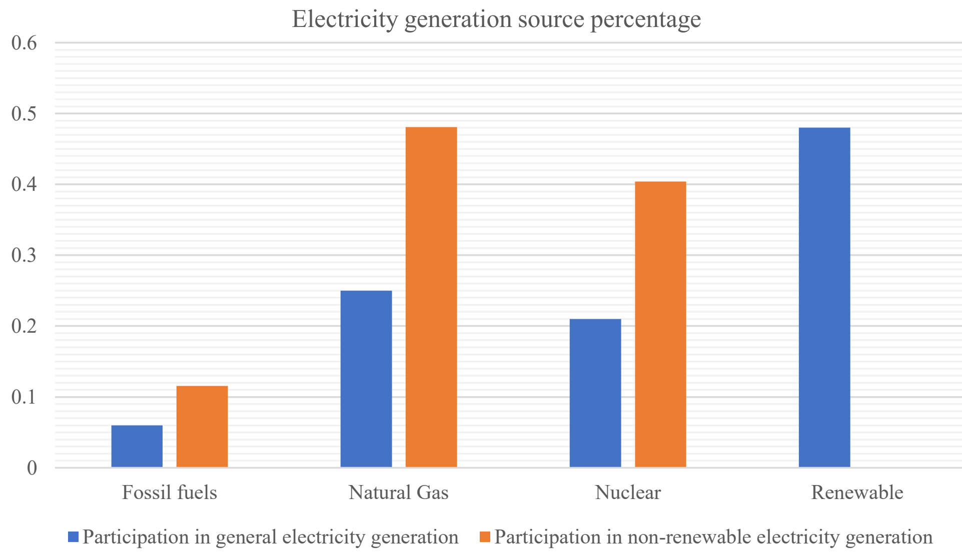

Fig. 12. Participation of electricity generation sources in general and renewable generation in Spain (Koulouri and Jacopo, 2014).

CRediT authorship contribution statement

Davide Astiaso Garcia: Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing. **Benedetto Nastasi:** Writing – review & editing, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization, Data curation, Investigation. **Siamak Hoseinzadeh:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Daniele Groppi:** Validation, Software, Resources, Methodology, Formal analysis, Data curation, Conceptualization, Investigation, Visualization, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Ahmadian, A., Asadpour, M., Mazouz, A., Alhameli, F., Mohammadi-ivatloo, B., Elkamel, A., 2020. Techno-economic evaluation of PEVs energy storage capability in wind distributed generations planning. Sustain. Cities Soc. *56*, 102117 https://doi.org/10.1016/j.scs.2020.102117.

Alipour, M., Zare, K., Mohammadi-Ivatloo, B., 2014. Short-term scheduling of combined heat and power generation units in the presence of demand response programs. Energy *71*, 289–301. https://doi.org/10.1016/j.energy.2014.04.059.

Assareh, E., Biglari, M., 2015. A novel approach to capture the maximum power from variable speed wind turbines using PI controller, RBF neural network and GSA evolutionary algorithm. Renew. Sustain. Energy Rev. *51*, 1023–1037. https://doi.org/10.1016/j.rser.2015.07.034.

Ataei, A., Mojtaba, B., Nedaei, M., Assareh, E., Choi, J.-K., Yoo, C., Adaramola, M., 2015. Techno-economic feasibility study of autonomous hybrid wind and solar power systems for rural areas in Iran, a case study in moheydar village. Environ. Prog. Sustain. Energy *34*. https://doi.org/10.1002/ep.12121.

de Santoli, L., Lo Basso, G., Nastasi, B., 2017. Innovative Hybrid CHP systems for high temperature heating plant in existing buildings. Energy Procedia 133, 207–218. https://doi.org/10.1016/j.egypro.2017.09.392. ISSN 1876-6102.

Dehghani-sanij, A.R., Soltani, M., Raahemifar, K., 2015. A new design of wind tower for passive ventilation in buildings to reduce energy consumption in windy regions. Renew. Sustain. Energy Rev. *42*, 182–195. https://doi.org/10.1016/j.rser.2014.10.018.

Dehghani-Sanij, A.R., Al-Haq, A., Bastian, J., Luehr, G., Nathwani, J., Dusseault, M.B., Leonenko, Y., 2022. Assessment of Current Developments and Future Prospects of Wind Energy in Canada. Sustain. Energy Technol. Assess. *50*, 101819 https://doi.org/10.1016/j.seta.2021.101819.

Department of Development and Planning, A.U. EnergyPLAN: Introduction. Available online: https://www.energyplan.eu/.

Eckelman, M.J., Huang, K., Lagasse, R., Senay, E., Dubrow, R., Sherman, J.D., 2020. Health care pollution and public health damage in The United States: an update. Health Aff. *39*, 2071–2079. https://doi.org/10.1377/hlthaff.2020.01247.

EPA Climate Change Impacts on EnergyAvailable online: https://www.epa.gov/climateimpacts/climate-change-impacts-energy#:~:text=The energy sector is the, pose safety risks to people..

Esmaeilion, Farbod, Soltani, Majid, Nathwani, Jatin, Al-Haq, Armughan, 2022. Design, analysis, and optimization of a novel poly-generation system powered by solar and wind energy. Desalination 543 https://doi.org/116119. 10.1016/j.desal.2022.116119.

European Commission Guidebook 'How to Develop a Sustainable Energy and Climate Action 447 Plan (SECAP) Available online: https://e3p.jrc.ec.europa.eu.

European Commission Photovoltaic Geographical Information System (PVGIS) Available online: https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html..

Gavurova, B., Rigelsky, M., Ivankova, V., 2021. Greenhouse gas emissions and health in the countries of the European Union. Front. Public Heal. *9*.

Hachicha, A.A., Al-Sawafta, I., Said, Z., 2019. Impact of Dust on the Performance of Solar Photovoltaic (PV) Systems under United Arab Emirates Weather Conditions. Renew. Energy *141*, 287–297. https://doi.org/10.1016/j.renene.2019.04.004.

Hemmati, M., Mirzaei, M.A., Abapour, M., Zare, K., Mohammadi-ivatloo, B., Mehrjerdi, H., Marzband, M., 2021. Economic-environmental analysis of combined heat and power-based reconfigurable microgrid integrated with multiple energy storage and demand response program. Sustain. Cities Soc. *69*, 102790 https://doi.org/10.1016/j.scs.2021.102790.

Hoseinzadeh, S., Astiaso Garcia, D., 2022. Techno-economic assessment of hybrid energy flexibility systems for islands' decarbonization: a case study in Italy. Sustain. Energy Technol. Assess. *51*, 101929 https://doi.org/10.1016/j.seta.2021.101929.

Hoseinzadeh, S., Groppi, D., Nastasi, B., Bruschi, D., Astiaso Garcia, D., 2024. D. Designing highshare 50% and 100% renewable energy scenarios for Ragusa by sustainable energy toolkit application. Sustain. Energy Technol. Assess. 63, 103645 https://doi.org/10.1016/j.seta.2024.103645.

Hoseinzadeh, S., Groppi, D., Sferra, A.S., Di Matteo, U., Astiaso Garcia, D., 2022. The PRISMI plus toolkit application to a grid-connected Mediterranean Island. Energies *15*.

Isaza, A., Kay, M., Evans, J.P., Prasad, A., Bremner, S., 2023. Air quality impacts on rooftop photovoltaic energy production during the 2019–2020 Australian bushfires season. Sol. Energy 257, 240–248. https://doi.org/10.1016/j.solener.2023.04.014.

Jabari, F., Ghaebi, H., Mohammadi-ivatloo, B., Mohammadpourfard, M., 2019. Design, worst case study, and sensitivity analysis of a net-zero energy building for

sustainable urban development. Sustain. Cities Soc. *54*, 101991 https://doi.org/10.1016/j.scs.2019.101991.
Khani, L., Jabari, F., Mohammadpourfard, M., Mohammadi-ivatloo, B., 2021. Design, evaluation, and optimization of an efficient solar-based multi-generation system with an energy storage option for iran's summer peak demand. Energy Convers. Manag. *242*, 114324 https://doi.org/10.1016/j.enconman.2021.114324.
Koulouri, A.; Jacopo, M. Saving Water with Wind Energy. 2014, 20.
Kwan, S.C., Tainio, M., Woodcock, J., Sutan, R., Hashim, J.H., 2017. The carbon savings and health co-benefits from the introduction of mass rapid transit system in greater Kuala Lumpur, Malaysia. J. Transp. Heal. *6*, 187–200. https://doi.org/10.1016/j.jth.2017.06.006.
Kyriakopoulos, G.L., Arabatzis, G., 2016. Electrical energy storage systems in electricity generation: energy policies, innovative technologies, and regulatory regimes. Renew. Sustain. Energy Rev. *56*, 1044–1067. https://doi.org/10.1016/j.rser.2015.12.046.
Maleki, A., Pourfayaz, F., Ahmadi, M.H., 2016. Design of a cost-effective wind/photovoltaic/hydrogen energy system for supplying a desalination unit by a heuristic approach. Sol. Energy *139*, 666–675. https://doi.org/10.1016/j.solener.2016.09.028.
Mallahi, M.N.A., Assad, M.E.H., Rejeb, O., Delnava, H., Asaad, S., Tan, Y.C., 2023. A review on cleaning techniques of solar photovoltaic panels. AIP Conf. Proc. https://doi.org/10.1063/5.0165208.
Mardani, M., Hoseinzadeh, S., Garcia, D.A., 2024. Developing particle-based models to predict solar energy attenuation using long-term daily remote and local measurements. J. Clean. Prod. *434*, 139690 https://doi.org/10.1016/j.jclepro.2023.139690.
Mehrpooya, M., Ghorbani, B., Khalili, M., 2021. A new developed integrated process configuration for production of hydrogen chloride using geothermal and wind energy resources. Sustain. Energy Technol. Assess. 45, 101173 https://doi.org/10.1016/j.seta.2021.101173.
Nasiri, N., Sadeghi Yazdankhah, A., Mirzaei, M.A., Loni, A., Mohammadi-Ivatloo, B., Zare, K., Marzband, M., 2020. A Bi-Level market-clearing for coordinated regional-local multi-carrier systems in presence of energy storage technologies. Sustain. Cities Soc. *63*, 102439 https://doi.org/10.1016/j.scs.2020.102439.
Nations, U. Water – at the Center of the Climate Crisis Available online: https://www.un.org/en/climatechange/science/climate-issues/water.
Renewables.ninja Data Time SeriesAvailable online: https://www.renewables.ninja..
Rezakhani, M., Bahadori, S., Dehghani-sanij, M., 2017. A. Experimental investigation of a modular wind tower in hot and dry regions. Energy Sustain. Dev. *39*, 21–28. https://doi.org/10.1016/j.esd.2017.03.003.
Roshan, G., Moghbel, M., Taleghani, M., 2022. Spatial analysis of bioclimatic patterns over iranian cities as an important step in sustainable development. Sustain. Cities Soc. *83*, 103939 https://doi.org/10.1016/j.scs.2022.103939.
Sailor, D.J., Hu, T., Li, X., Rosen, J.N., 2000. A neural network approach to local downscaling of GCM output for assessing wind power implications of climate change. Renew. Energy *19*, 359–378. https://doi.org/10.1016/S0960-1481(99)00056-7.
Sameti, M., Haghighat, F., 2019. Hybrid solar and heat-driven district cooling system: optimal integration and control strategy. Sol. Energy *183*, 260–275. https://doi.org/10.1016/j.solener.2019.03.034.
Shahin, Shoeibi, Saemian, Mohammad, Khiadani, Mehdi, Kargarsharifabad, Hadi, Ali Agha Mirjalily d, Seyed, 2023. Influence of PV/T waste heat on water productivity and electricity generation of solar stills using heat pipes and thermoelectric generator: An experimental study and environmental analysis. **2023** Energy Convers. Manag. *276*, 116504. https://doi.org/10.1016/j.enconman.2022.116504.
Shahverdian, M.H., Sedayevatan, S., Latif Damavandi, S., Sohani, A., Sayyaadi, H., 2022. A road map to detect the foremost 3E potential areas for installation of PV FaçAde Technology Using Multi-Criteria Decision Making. Sustainability *14*.
Sharadga, H., Hajimirza, S., Balog, R.S., 2020. Time series forecasting of solar power generation for large-scale photovoltaic plants. Renew. Energy *150*, 797–807. https://doi.org/10.1016/j.renene.2019.12.131.
Streimikiene, D., Kyriakopoulos, G., Lekavicius, V., Pažėraitė, 2022. A. How to support sustainable energy consumption in households? Acta Montan. Slov. (*27*), 479–490. https://doi.org/10.46544/AMS.v27i2.15.
United nationes Spain Progress on Achieving SDG 6Available online: https://sdgs.un.org/basic-page/spain-34140..
United nations Climate Change Available online: https://www.un.org/en/global-issues/climate-change#:~:text=From shifting weather patterns that,be more difficult and costly..
United Nations What Is Climate Change?Available online: https://www.un.org/en/climatechange/what-is-climate-change..
Vargas-Amelin, E., Pindado, P., 2014. The challenge of climate change in spain: water resources, agriculture and land. J. Hydrol. *518*, 243–249. https://doi.org/10.1016/j.jhydrol.2013.11.035.
Water and Climate Change United NationsAvailable online: https://www.unwater.org/water-facts/water-and-climate-change..
WHO Disability-Adjusted Life Years (DALYs) Available online: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158#:~:text=Definition%3A-, One DALY represents the loss of the equivalent of one,health condition in a population..
WHO Disease Burden Available online: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/global-health-estimates-leading-causes-of-dalys..
Zare Oskouei, M., Mohammadi-Ivatloo, B., Abapour, M., Anvari-Moghaddam, A., Mehrjerdi, H., 2020. Practical implementation of residential load management system by considering vehicle-for-power transfer: profit analysis. Sustain. Cities Soc. *60*, 102144 https://doi.org/10.1016/j.scs.2020.102144.