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The Socio-Economic Impact of Decarbonising Geographical Islands' Energy Systems

Nkiru Lilian Agu[a*], Gobind Pillai[a], Dana Abi Ghanem[a], Stergios Vakalis[b], Tracey Crosbie[a], Dias Haralambopoulos[b], and Xihui Haviour Chen[c]

[a]Centre for Sustainable Engineering, Teesside University, Middlesbrough, TS1 3BA, UK.
[b]Department of Environment, University of the Aegean, GR - 81100 Mytilini, Greece.
[c]Keele Business School, Keele University, UK

ABSTRACT

The impact of the transition to energy autonomy on eight geographical island's local economies, through maximising renewable energy generation and storage, is assessed. The different sectors and activities that impact employment and income generation in the local economies of each of the islands are identified. An empirical assessment approach based on the Keynesian Income Multiplier (KIM) is developed and applied using Analytical Hierarchy Process (AHP). Data for AHP was collated through interviews with local experts and stakeholders on each island. Gender, employment, and wage data was used to calculate the impact of renewable energy system (RES) autonomy on male and female waged employment within the islands' economic sectors. The analysis conducted showed that the induced local economic impact per unit of electrical energy due to the proposed RES autonomy in all sectors for male waged employment for all islands, exceeds its unit cost or Levelised Cost of Energy (LCOE). For female waged employment, the profits from per unit of electrical energy generated exceeded the LCOE for the tourism sectors of La Graciosa, Aran Islands, Majorca and three other sectors in Gotland (health & social work, services, and education). The local economic impact from decarbonisation and 100% energy autonomy is significantly influenced by how the income from this renewable energy is recirculated within the island's economic sectors, especially tourism. The findings suggest that strategies for community ownership and training local people to manage renewable energy facilities is necessary to maximise the benefits of the transition to energy autonomy on local communities.

Keywords

Socio-Economic Impact;
Decarbonisation;
Geographical Islands;
Renewable Energy;
Keynesian Income Multiplier

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1. Introduction

Geographical islands suffer significant energy challenges. Some Islands with mainland connections are highly dependent on the mainland energy market, making the transmission of energy costly and inefficient. While some other non-interconnected islands with remote communities, generate energy with non-renewable sources that are harmful to the environment such as diesel generators. If grid connection exists between an island and the mainland, those islands are highly dependent on imported energy. This affects energy security and increases the energy cost on geographically dispersed islands, which are up to 400% higher than those on the mainland [1, 2].

*Corresponding author – e-mail: n.agu@tees.ac.uk

Abbreviations

AHP	Analytical hierarchy process
GWh	Giga Watt hour
GHG	Greenhouse gas
GRLI	Gender representation in labour income
$GRLI_m$	Gender representation in labour income for an island
ICT	Information and communication technology
ICTSF	Information and communication technology scale up factor
$ICTSF_m$	Information and communication technology scale up factor for an island
KIM	Keynesian income multiplier
$KIM_{n,m}$	The KIM for a specific sector in an island
kWh	kilo Watt hour
LCOE	Levelised cost of energy
$LCOE_m$	Levelised cost of energy for an island
LES	Local economic stimulus
MPC	Marginal propensity to consume.
MWh	Mega Watt hour
RE	Renewable energy
REACT	Renewable Energy for sustainable island Communities
RES	Renewable energy system
RET	Renewable energy technology
SCADA	Supervisory control and data acquisition
SEI	Sustainable energy infrastructure
$SEI_{n,m}$	Sustainable energy infrastructure for a specific sector in an island

The high cost of energy, instability, and insecurity in supply increases the vulnerability of island communities to power outages, adversely affecting residents' welfare [3]. A self-sustainable energy strategy based on renewable energy sources with energy storage, on non-interconnected islands with outlying communities, could potentially alleviate energy poverty and insecurity while helping to reduce Green House Gas (GHG) emissions. In that perspective, energy independence can be achieved on these islands by optimally exploiting locally available clean energy resources with an integration of energy storage and the full participation of the community in demand side management and demand response (DR) [3, 4].

Some existing studies [5–7], implied that energy autonomy based on renewable energy sources could result in positive benefits for remote island communities. These benefits could include direct employment opportunities in areas such as installations, operations, and maintenance. It could also be as direct financial rewards through increased tax base in hosting island communities, generation of extra income for landowners and other island activities that benefit from reduced energy cost. Other benefits could be the fostering of social bonds and the creation of a broader community development [7]. In addition, they also implied that energy autonomy with increased energy conversion efficiency and reduced energy demand can also lead to improved living standards, resulting from lower energy costs due to decentralised energy sources. Finally, that better health arising from reduced GHG emissions could also be achieved when it is exclusively based on renewable energy sources.

At a country level, there is also a suggestion that renewable energy systems (RES) on geographical islands provide economic benefits from saved fuel – oil purchases and carbon levies [5]. However, the investment in RES facilities and decarbonisation processes necessary for energy autonomy involves high costs [8]. To justify these costs, it is necessary to measure the socio-economic impact of such investment. There is a widespread belief that because of limited financial resources for expanding renewable energy in isolated island communities and some developing regions, that prioritizing climate mitigation might lead to a significant trade-off in other crucial infrastructures, potentially reducing overall economic development prospects. Yuni et al., (2023) [9] investigated the impact of renewable electricity production and consumption in Africa and concluded that it does not only mitigate climate change but could also contribute marginally to the economic growth and development of African countries.

Many have argued that renewable energy/smart grid projects impact significantly on electricity consumers' behaviour patterns, culture, and lifestyle [10–13]. Earlier studies have conducted impact assessments of RES on geographical regions, using different approaches to conduct a post installation assessment of the socio-economic benefits of the local community energy projects, and most of these studies utilised more than 12 months of data collected from local businesses and services [14–16]. However, there is a lack of empirical evidence for assessing the socio-economic benefits of community energy projects, pre-installation [17–18].

Therefore, to provide empirical evidence for these impacts, this paper will answer the following research questions using an econometrical impact assessment methodology: (i) What impact will the decarbonisation of geographical islands and the transition to 100% energy autonomy have on the main economic sectors of the islands? (ii) How will the decarbonisation and 100% autonomy of these islands' energy systems effect positive socio-economic changes through the local employment and income benefits, taking account of gender equality in income distribution. This will be done focusing on case study scenarios for 8 different geographical islands.

The aim of this study is to investigate the propensity of enabling the decarbonisation and 100% autonomy of geographical islands' energy systems to effect positive socio-economic change through the benefits it procures on local employment and income distributions using a gender aware approach. For geographical islands, RES projects require estimations or forecasts of their local economic effects for scenario analysis. As far as the authors are aware, no studies have used methods for assessing the socio-economic impacts of self-sustaining energy system projects based on hypothetical future scenarios of RES installation and smart grid technologies. Quantitative socio-economic impact assessments have always been post-installation.

Autonomous energy systems must manage their own generation and energy demand in real time. In a conventional electrical power system, the operation and control role include energy scheduling and accounting, generation dispatch and control, transmission security management, monitoring and maintaining power quality, frequency, and voltage at the distribution level etc [19]. RES technologies like solar and wind are inherently variable due to the nature of the resource and therefore unlike a diesel generator which can manage its own voltage and frequency, will need active real time management as in a fully-fledged electrical power system. To manage the energy infrastructures in real time autonomous energy systems will need an Information and Communication Technology (ICT) platform. The size and scale of tasks to be managed by the ICT system would be variable and depend on the size of the RES, the consumer demand and distribution it must manage. The recent development in artificial intelligence (AI) methods enabling automation of processes and management of vast datasets [20] has enhanced the ability of the ICT platforms to control and manage energy systems in real time. Therefore, ICT platform has been given special attention in the decarbonisation of islands in this study.

In this study, we propose a novel approach to analyse the self-sufficient energy production technologies proposed for eight EU islands and explore the socio-economic impacts they will have on the islands' main economic sectors as well as the local economy. The proposed method will assess the induced effects of renewable energy on the economy and various activities influencing male and female waged employment and income generation in local economies. It will attempt to capture the economic benefits from the investments (i.e., the RES infrastructures and the ICT platform), through an approach that is based on the Keynesian income multiplier (KIM) using Analytical Hierarchy Process (AHP) method, and levelised cost of energy (LCOE). Eight geographical islands of different sizes have been used as case studies to demonstrate the utility of the proposed approach. The islands are La Graciosa, Canary Islands, Spain; San Pietro Island, Italy; Inishmore, the Aran Islands, Ireland; Gotland, Sweden; Lesbos, Greece; Isle of Wight, UK; Majorca, Spain; and Reunion, an island in the Indian Ocean that is an overseas department and region of France.

The remainder of the paper is structured as follows; section 2 methodology, section 3 results, and discussions, section 4 conclusion and recommendations and finally section 5 limitations and future scope.

2. Methodology

A detailed explanation of the steps for the proposed empirical approach for assessing the impact that decarbonisation and 100% energy autonomy will have on islands is presented in this section. Section 2.1 introduces the case study islands with their key characteristics listed in Table 1. In section 2.2, the islands' energy scenarios based on previous studies are presented with references for more information on the selection processes. Section 2.3, reviews the common approaches to socio-economic impact assessment, discusses the economic multiplier concepts and KIM as well as defines the assumptions made for the analysis. Lastly, section 2.4 discusses the proposed empirical approach which involves four main elements to be considered in the assessment.

2.1 Case Study Islands

Eight geographical islands which are in different climatic zones with different underlying energy system requirements and population densities provide the case studies in this research. Depending on their environmental characteristics and national regulatory policies, the islands have different energy generation potentials for different RES technologies. As part of their work in the REACT project [21, 22] identified renewable energy mix scenarios (and electricity storage – where needed) for each island to attain energy autonomy.

Socio-economic impacts are the outcome of the interaction between the characteristics of the project and development actions and the characteristics of the 'host' environment [23]. The development action is the RES facility (for 100% electricity autonomy), and the 'host' environment is the local economy composed of the different business/service sectors active in the economy. In terms of Marginal Propensities to Consume (MPCs), the strength of different sectors in instigating re-spending varies from island to island. This variation in MPCs should be captured by the new method of assessment proposed.

Table 1, columns 2–4 show the key characteristics of each of the islands. Take La Graciosa as one example. It is a volcanic island in the Canary Islands of Spain with an area of 29 km^2. It has two population centres, Caleta del Sebo and Pedro Barba. In 2018, the population registered was 734 inhabitants, of which 730 were for Caleta del Sebo. Its electricity consumption, as recorded in 2017 by Fenie Energia, the electricity retailer in Spain, was 1,861 MWh. The major economic sectors in La Graciosa are tourism and fishing.

2.2 RES Scenario Selection

Typically, developing energy plans involves several stages: (i) conducting an initial study to comprehend the present state of the energy system across various energy sectors (electricity, heat, and transportation), (ii) forecasting future requirements within these sectors, (iii) identifying local energy resources and acknowledging practical limitations, (iv) creating and optimizing energy scenarios that meet these demands [24]. The Horizon 2020 REACT project evaluated the renewable

Table1: REACT islands summary information.

Island	Population	Area (km^2)	Economic Sectors	Electricity Demand	Energy Scenario	LCOE (€/kWh)
La Graciosa, Canary Island (Spain)	734	29	Tourism, Fishing, Services, Food processing, Health and social, Education, Arts and Craft.	1,861 MWh	PV – 0.5 MWp	0.12
San Pietro, Sardinia (Italy)	6173	51	Tourism, Agriculture, Fishing, Construction, Manufacturing, Services, Health and Social Work, Education.	15,776 MWh	PV – 4.3 MWp	0.11
Inis Mor, Aran Island (Ireland)	762	31	Tourism, Fishing, Education, Construction, Services, Manufacturing and Health & social work.	1,855 MWh	Wind – 2.22 MW PV – 0.12 MWp Storage – 0.3 kWh Thermal – 0.09 kWh Heat pump – 1.77 MW	0.10
Gotland (Sweden)	59,249	3,183	Tourism, Agriculture, Food processing, Mining, Construction, Education, Services, Manufacturing, Health & Social Work.	984 GWh	Wind – 310 MW	0.12
Lesvos Prefecture (Greece)	86,436	1,633	Agriculture, Tourism, Manufacturing, ICT, Construction, Industry, Services (financial, property, public administration, entertainment), Education.	335 GWh	PV – 30 MWp Storage – 80 MWp	0.31
Isle of Wight (UK)	141,000	384	Tourism, Agriculture, Fishing, ICT, Services, Manufacturing, Food processing, Health & Social Work, Arts & Crafts, Education, Construction.	545.8 GWh	Wind – 20 MW PV – 30 MWp	0.11
Majorca Island (Spain)	880,113	3,640	Tourism, Agriculture, Fishing, Manufacturing, Food processing, Services, Health and Social Work, Education, Arts and Crafts.	4,569.3 GWh	Wind – 187 MW PV – 405 MWp	0.12
Reunion Island (France)	866,506	2,512	Tourism, Agriculture, Fishing, Manufacturing, Food processing, ICT, Construction, Services, Health and Social Work, Education, Arts & Crafts.	2,745 GWh	PV – 100 MWp Storage – 50 MWh	0.12

energy sources potentials of the various installation sites, and based on the findings, created energy systems scenarios as in [21, 22]. The RE resources potential data facilitated the energy system infrastructural planning. Those scenarios which were identified in [22] as the most technically favourable for each island (shown in column 5 of Table1) were selected for this study. For details of the multicriteria analysis that was conducted, and the assumptions used, readers are directed to [21, 22]. For example, the 100% RES energy autonomy scenario best suited for La Graciosa based on previous research [22] was a solar capacity of 0.5 MWp at LCOE (Levelised cost of energy) of 0.12€/kWh, which is shown in columns 5 and 6 of Table 1.

2.3 Empirical Socio-economic Impact Assessment

Investment in most community energy projects involve high costs, therefore, an overall economic impact assessment is required to ascertain a balance of capital investment in its economic gain. For a project's continuous improvement, there is a critical need to measure its economic impact on the geographical region because it links performance to the principles of sustainability [25]. The assessment of economic impact is an intrinsically complex multi-dimensional process that is usually challenging as it involves two principal approaches. The first approach involves the measurement of renewable energy technologies (RET) impact on jobs in RE industry and its upstream industries measured in sectoral employment known as a gross employment impact. The second is the RET impact on all economic-wide employment known as net employment impact which gives information about the changes in employment throughout the entire economic sectors. The economy-wide employment impact assessment helps to determine whether there is a net employment effect with an increased RET utilisation through support policy measures [26]. These net employment effects include all effects of RE use i.e., (positive or negative) direct, indirect, and induced effects.

In measuring the local economic impacts of community energy projects, it is important to distinguish between direct, indirect, and induced effects. Direct effects are the employment opportunities created for local employees at the RET facilities. Indirect effects are jobs in industries supplying the services to the RET facilities in the local area such as manufacturing, construction, and installation industries. Additionally, induced economic effects are those that affect employment on all other island economic sectors such as fishing, tourism, farming etc, through prices and income basically on consumption and production or investment [7, 26 – 28]

For this research, the following assumptions were made for the socio-economic impact analysis.

1. In terms of direct effects, the impact of 100% RES autonomy negatively impacts on employment in the conventional energy sector on the island. It is assumed that the new local employment created by the RES installation would offer a vis-a-vis replacement for employment lost in the conventional energy sector. This is reasonable as employees in the conventional energy sector are familiar with the electrical power systems on the island [17, 29].
2. In terms of indirect effects, San Pietro, Aran Isles and La Graciosa have fewer inhabitants and fewer industries that can sub-contract elements of the installation of the RES facility. The construction of the RES facility will be sub-contracted and will be a one-off economic influx happening in one snapshot of time rather than being continuous. For these reasons the indirect effects of the construction of these facilities on these islands are not explored in detail in this paper.
3. Induced effects are the primary means by which renewable energy based autonomous systems on geographical islands bring about positive socio-economic changes in island communities. Therefore, they are the most important focus of the socio-economic impact assessments of the implementation of the renewable energy systems on geographical islands.

There are several indicators by which economic impact assessment is expressed, but almost all use the multiplier concept. Economic Base Multiplier, Input-output and Keynesian Income Multiplier (KIM) are techniques/models commonly employed in the analysis of the impact of the additional income and employment in the local economy generated by a major new project [23]. KIM, which is an economic causality deduced theoretically by J. M. Keynes, states that an increase in spending (private consumption expenditures, investment expenditures, or government expenditures) will cause an increase in the total Gross Domestic Product (GDP), proportionately greater than the original change in income. The value of the multiplier depends on the Marginal Propensity to Consume (MPC) [30], which is the change in total consumption caused by a change in total income as represented in Equation (1). KIM is based on money re-spent in the economy and measures how consumer spending changes with a change in income, mathematically represented as in Equation (2):

$$MPC = \Delta C / \Delta Y \quad (1)$$

where Y is Income, and C is Consumption.
Therefore, KIM can be written as in Equation (2):

$$KIM = 1 / \left(1 - MPC\right) \quad (2)$$

The marginal propensity to consume (MPC) measures how consumer spending changes with income. For example, an individual receives a year-end bonus of \$800 and spends \$400 on goods and services. The MPC is ΔC/ΔY = 400/800 = 0.5.

KIM states that an increase in production leads to a rise in income and consequently, an increase in spending. The value of MPC allows us to calculate the size of the multiplier using the formula as shown in Equation (2) 1/(1 – MPC) = 1/(1 – 0.5) = 2 for the example.

In estimating the impacts on the local economy, the KIM can be tailored to focus on the local economic product, such as New Economic Foundation's Local Multiplier 3 (LM3) [31]. The NEF LM3 is a tool used to measure the multiplier effect of money re-spent within a local economy. It gives an indication of how the first 3 rounds of spending of an income generated in a local area, impacts its local economy by maximising social, economic, and environmental benefits. LM3 was developed from Keynesian Multiplier which has been used for decades to measure how income that enters an economy is re-distributed within it. However, as explained by Sacks [31], LM3 needs 9 to 12 months' worth of data from local businesses and services after the installation of the RES facility to calculate its socio-economic impact on the local economy. In this study, geographical islands' pre-installed projects are investigated. Hence, there was a need to estimate or forecast the induced effects of hypothetical RES scenarios, so a new method was developed based on the KIM technique.

2.4 Proposed Empirical Approach for Socio-economic Impact Analysis

The proposed method focuses on capturing the induced effects of RES technology and 100% energy autonomy. The four main elements considered in the approach are:

- Capturing sectoral MPCs using Analytical Hierarch Process (AHP).
- Capturing effects of capital investments based on LCOE.
- Capturing decarbonisation and 100% energy autonomy.
- Capturing gender income differentials.

2.4.1. Capturing Sectoral MPCs Using Analytical Hierarch Process (AHP)

We sought the help of expert stakeholders on each island to capture their economic sector information. Their opinions were processed using the AHP method with the aid of an online software (AHP Priority Calculator) that converted these opinions into numeric weights. AHP is a multicriteria decision-making tool that relies on a heterogeneous data-based model building approach to calculate the weights of a given set of criteria [32]. For a detailed mathematical model of AHP, including calculation of relative weights and a consistency index please see [33]. The AHP method recognises that, though there can be several criteria, their magnitudes will differ. Therefore, weights are assigned to the criteria, and their alternatives are evaluated. It derives priorities among criteria and alternatives in a multicriteria decision-making problem [34]. Considering the MPCs for different sectors as Criteria, AHP can arrive at the sector MPCs by ranking them using pair-wise comparisons. The main steps in AHP are as follows:

- Decompose the decision-making problem into a hierarchy.
- Make pair-wise comparisons and establish priorities among the elements in the hierarchy.
- Synthesise judgments (weights for sector MPCs).
- Evaluate and check the consistency of judgements.

Meetings were arranged with eight experts each one representing a case study island to obtain relevant information on the local economy. These experts are the members of REACT project team and have detailed knowledge of the local economy of the islands. The socio-economic assessment approach was explained to them, and the economic sectors specific to their respective islands were outlined and discussed. The experts then completed pair-wise comparison of these sectors

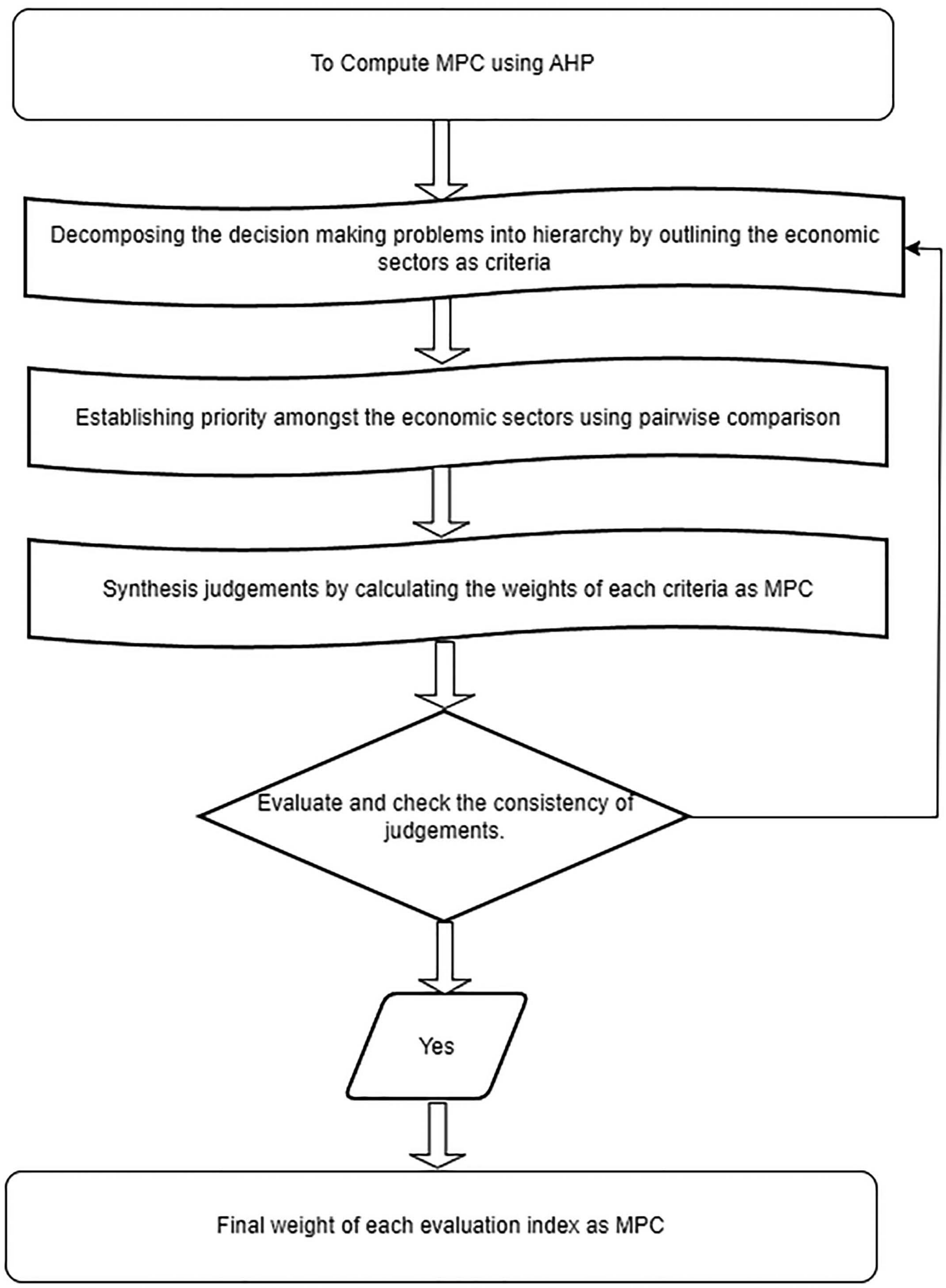

Figure 1: Flowchart of AHP steps

based on their knowledge of the relative strength of the relevant local economic sectors in the island using the AHP priority calculator. The software tool also checked for consistency in the comparison and then assigned weights to the economic sectors considered finally as the MPCs of the islands economic sectors. With these MPCs, the KIM of each sector was calculated using Equation (2).

2.4.2. Capturing Effects of Capital Investments Based on LCOE

The LCOE for a generator is calculated based on its energy over its operational lifetime and life-cycle costs. A central concept in financial analysis is that money received today is more valuable than money received in the future. A real interest rate on the investment normally represents the price for waiting and was used in this study. Equation (3) details a basic LCOE that can be used, including the time value of money in determining costs and production [35].

$$LCOE = \frac{Investment\ Cost + \sum_{t=1}^{n} \frac{Total\ annual\ cost\ at\ year\ t}{(1 + interest\ rate)^t}}{\sum_{t=1}^{n} \frac{Annual\ electricity\ generation}{(1 + interest\ rate)^t}} \tag{3}$$

where t is a given year in the technology's lifetime, and n is technology's total lifetime in years.

A technology's investment cost is the total cost to construct it, while the total annual cost can include fuel, operations, and maintenance costs. In Equation (3), the total annual costs and the annual electricity generation are discounted to their present values for each year to make them comparable. For this study, LCOE values for the energy scenarios considered had been calculated as part of the REACT project and is available along with details of different parameter values considered in [36].

2.4.3. Capturing Decarbonisation and 100% Energy Autonomy

The energy from RES is the economic stimulus that induces positive socio-economic benefits under 100% energy autonomy. Recent literature suggests that mainland electricity companies would be better off transferring the RES facility ownership and energy generated from it to the community at no cost [5, 37–38]. This is because significant transmission losses occur during energy importation from the mainland to the geographical islands. A transfer of ownership to the community will redirect RES energy's cost, which corresponds to the LCOE, back into the local economy resulting in positive socio-economic benefits to the island community.

In Greece, it is a legislative requirement that RES generating companies return a total of that 3% of their yearly income to the local communities as a subsidy, including 1% for electricity bill subsidisation, 1.7% for municipality local environmental projects, and 0.3% for the green fund [39]. The 3% reciprocal payment means that we can assume 3% of the LCOE is recirculated per unit of energy generated in the local economy. Thus, we may assume that the entire LCOE is recirculated or that only a proportion of the LCOE is recirculated. If a proportion is recirculated, it means that the impacts must be scaled down by that proportion. As that is quite straightforward and easy to do, this paper will focus on the 100% LCOE re-spent situation, with an example of 3% LCOE re-spent for Lesvos.

Based on each of the island's recorded annual energy demand and the energy generated annually by the RES technologies under the hypothetical scenarios selected (column 5 of Table 1), the Office of Statistics databases can then be used to determine whether the RES facility's size needs to be scaled up for 100% energy autonomy. However, as construction and other costs are almost a linear function of the RES facility's size, the LCOE for the scenarios – even if they need to be scaled up – would roughly be the same. In this context, it is to be clarified that, it is assumed that assumptions and considerations made in [22] retain validity for scaling up. While it is possible to generate more optimal RES designs for meeting the annual energy demand than what is available via scaling up, this has not been attempted as the focus of the article is to demonstrate the utility of the socio-economic impact forecasting methodology and not RES system design and optimisation.

For enabling the decarbonisation and 100% energy autonomy of geographical islands' they need autonomous energy systems based on renewable energy sources, storage, intelligent monitoring techniques, and advanced energy management techniques. An ICT (Information and Communications Technology) platform is needed for optimised energy dispatching using intelligent monitoring and advanced energy management. The platform needs to integrate algorithms to plan and manage the RES and storage assets by developing a holistic cooperative energy management and demand response (DR) system at the community level on geographical islands. Some of the benefits of energy storage optimisation are, utilising local renewable generation, taking advantage of variable energy prices, responding to custom demand increase/decrease requests, or utilising end-user flexibility in electric load.

Such an ICT platform while integral for autonomous energy management, also adds a cost of between 10% and 50% to the lifetime cost of the RES configurations selected on the geographical islands. This means an increase in the LCOE by a factor between 1.1 and 1.5 based on cost figures observed in the literature [40]. We call this an ICT scale-up factor. Owing to uncertainties around the complexities of the ICT platform, we have considered an ICT scale-up factor of 1.2 for individual scenario analysis. A sensitivity analysis of ICT factors ranging from 1.1 to 1.5 is then performed to evaluate the impact of ICT costs on social and economic benefits.

2.4.4. Capturing Gender Income Differentials

As there is a focus on technology and policies to drive sustainability in the energy transition to RES, it is also important to ensure that there are equal economic opportunities and employment accessibility across gender, and the benefits this might have will be equitably distributed. Adopting a gender aware approach to assessing the impacts and benefits of sustainable energy interventions is crucial to ensure that women's contributions – their skills and perspectives – are represented. Increasing women's engagement will expand the available talent pool for the renewables sector. Other benefits of furthering gender diversity include the varied views women bring to the workplace. Studies have shown that women tend to be more collaborative at work [41]. Whilst increasing the representation of women has shown improved business performance [42].

Labour force participation and wage equality are the two principal parameters related to gender impact on waged employment that will be relevant for socio-economic impact assessment in this paper. Table 2 lists the values of these parameters for the geographical islands that are available from national and international sources [43]. We assume that the national impact is reflected in the islands unless specific sector data is available. Gotland was the only case study island where specific sector data was available [44]. Table 3 shows Gotland's sectoral labour force participation and the

Table 2: Gender impact on waged employment parameters values among the geographical islands.

Geographical Island	Labour force participation (%)			Wage equality score (1-7)	Wage equality	Gender representation F/M in labour income
	F	M	F/M ratio (1)	F/M	F/M ratio (2)	= (1) × (2)
La Graciosa, Canary Island (Spain)	69.2	79.1	0.88	4.18	0.60	0.53
San Pietro, Sardinia (Italy)	56.5	75.1	0.75	3.73	0.53	0.40
Inishmore Aran Island (Ireland)	67.6	79.5	0.85	4.83	0.69	0.59
Gotland (Sweden)	81.3	85	0.96	4.88	0.70	0.67
Lesvos Prefecture (Greece)	60.6	76.7	0.79	4.36	0.62	0.49
Isle of Wight (UK)	73.6	82.4	0.89	4.65	0.66	0.59
Majorca Island (Spain)	69.2	79.1	0.88	4.18	0.60	0.53
Reunion Island (France)	68.3	75.4	0.91	4.02	0.57	0.52

Note: F for female, M for male.

Table 3: Sectoral labour force participation in Gotland Island

Industry sector	Numbers employed		F/M ratio	Gender representation F/M in labour income
	F	M		
Farming, forestry, hunting, fishing	360	1269	0.28	0.19
Manufacturing and extraction	352	1314	0.27	0.18
Energy supply; environmental activities	53	182	0.29	0.20
Construction	194	2290	0.08	0.06
Sales	1226	1369	0.90	0.60
Transport and warehousing	251	878	0.29	0.19
Hotels and restaurants	651	585	1.11	0.75
Information and communication	100	233	0.43	0.29
Finance	345	299	1.15	0.77
Real estate	152	306	0.50	0.33
Business services	799	1018	0.78	0.53
Government and military	1856	1360	1.36	0.91
Education	2159	752	2.87	1.92
Health and welfare; social services	4010	1050	3.82	2.56
Cultural and personal services	848	816	1.04	0.70

gender representation Female to Male (F/M) in labour income using the national wage equality ratio. The Gender Representation F/M in Labour Income (GRLI) parameter values are considered for socio-economic impact analysis.

The induced local economic impact per unit of energy due to the new autonomous sustainable energy infrastructure (SEI) on a particular sector in a particular island, can be calculated using Equation (4) as follows:

$$SEI_{n,m} = LCOE_m \times ICTSF_m \times KIM_{n,m} \tag{4}$$

where n indicates the sector concerned, m indicates the island concerned, $LCOE_m$ is the Levelized Cost of Energy for the island, $ICTSF_m$ is the ICT scale up factor for the island, and $KIM_{n,m}$ is the KIM for the sector on the island.

The impact on female waged employment can be calculated by multiplying the Equation (4) by the GRLI for the islands.

$$SEI_{n,m}\left(F\right) = LCOE_m \times ICTSF_m \times KIM_{n,m} \times GRLI_m \tag{5}$$

where $GRLI$ is the Gender Representation in Labour Income ratio for the island concerned.

It can be seen from equations 4 and 5 that the higher the LCOE or ICTSF, the better the local economic impact (SEI). This is a feature of Keynesian economics. As can be seen from equation 2, KIM (or the impact on local economy) will always be greater than one as MPCs are always less than 1. As mentioned in sec 2.4. (C.), LCOE is income. Therefore, it is only natural that SEI gets higher with higher LCOE and any multiplication of it by factors like ICTSF. In terms of policy this translates to higher the spend in the economy, higher the circulation of that spend in the local economy and therefore higher the local economic impact.

3. Results and Discussion

The basic description of the islands and their key characteristics have been captured in Table 1. The data available for GRLI in Table 2 collated from different national and international sources may have skewed some of the results of these analyses if they are not entirely representative.

3.1 La Graciosa, Spain

The key characteristics and preferred energy scenario of this island is as shown in Table 1. Due to the size and low population of the island, specialist contractors from outside the local economy will be required to construct and install the RES facility. The construction phase does not produce direct employment effect as stated in assumption 1, but the operation phase which involves PV plant maintenance and the management of the local control centre will only offer a vis-à-vis replacement of conventional energy sectors. There is a temporary increase in the local cash flow due to the slight increase in population during site development and plant construction which lasts for just the duration of the installation. It is difficult to predict how the land for the site will be arranged at this juncture. As such, the impact of any land purchasing or land leasing arrangements have not been factored into the study.

With respect to the indirect employment effects, because there are not many industries on the island, elements of the installation cannot be sub-contracted. Therefore, the construction phase will only result in more hours and higher wages which are temporary for those locally on land and marine transportation.

In terms of calculating the induced effects, the new approach described in section 4 using AHP was used. Table 4 shows the economic sectors in the local economy highlighted by the local economy expert, the MPC and the corresponding KIMs for those sectors. Tourism is the economic sector with the highest potential for realising positive economic benefits in the local economy via re-spent income. The second largest economic sector is the service sector, followed by the fishing sector.

Using Equations (4) and (5), the induced local economic impact per unit of energy due to the new autonomous renewable energy infrastructure (SEI) and the impact on female waged employment were calculated. The ICT scale-up factor was considered to be 1.2, and the GRLI was taken from Table 2. As seen in Table 1, the LCOE for the RES scenario selected was €0.12/kWh. Table 4 also shows the induced local economic impact per unit of energy for La Graciosa. Column 4 shows the

Table 4: Economic Sectors, MPC, KIM, and the induced local economic impact per unit of electrical energy for La Graciosa, Spain.

Economic Sectors	MPC	KIM	SEI	SEI (F)
Tourism	0.45	1.82	0.26	0.14
Fishing	0.14	1.16	0.17	0.09
Food processing	0.1	1.11	0.16	0.08
Services	0.21	1.27	0.18	0.10
Health & Social Work	0.04	1.04	0.15	0.08
Education	0.03	1.03	0.15	0.08
Arts & Crafts	0.02	1.02	0.15	0.08

impact on male waged employment and column 5 on female waged employment.

The profits from one unit of electrical energy are more than its unit cost (LCOE of €0.12/kWh) for all sectors in male waged employment (SEI). Meanwhile, tourism is the only sector in which the profit from one unit of energy exceeds its unit cost in terms of female waged employment.

The data available for GRLI may have skewed some of the results. Municipalities and councils managing the local economy can control the impact potential of re-spend by each economic sector and devise plans for how income from the sales of energy is to be shared to affect growth and improvements in target sectors. Without such action plans, the local economic impact of different sectors will remain the same. Only the size of the economy would increase based on the share of energy income offered to the community.

3.2. San Pietro, Italy

Due to its low population density, only the induced employment effect of assumption 3 applies here as in the case of La Graciosa. Table 5 shows the economic sectors of the island, the MPCs, and their corresponding KIM. Tourism also has the highest potential for realising positive economic benefits in the local economy via re-spending income. This is followed by the manufacturing sector and the education sector. Local manufacturers produce non-ferrous metals, refined petroleum, processed foods, wine, textiles, leather, and wood products and, as such, they create indirect rather than direct employment impacts.

Table 5: Economic sectors, MPC, KIM, and the induced local economic impact per unit of electrical energy for San Pietro, Italy.

Economic Sectors	MPC	KIM	SEI	SEI (F)
Tourism	0.44	1.79	0.24	0.09
Agriculture	0.03	1.03	0.14	0.05
Fishing	0.09	1.10	0.15	0.06
Manufacturing	0.14	1.16	0.15	0.06
Construction	0.04	1.04	0.14	0.05
Services	0.07	1.08	0.14	0.06
Education	0.11	1.12	0.15	0.06
Health & Social Work	0.09	1.10	0.15	0.06

Table 5 also shows the induced local economic impact per unit of energy for San Pietro. Column 4 shows the impact on male waged employment and column 5 on female waged employment. The profits from one unit of energy are more than its unit cost (LCOE of €0.11/kWh) for all sectors in male waged employment. In contrast, there are no sectors in which the profit from one unit of energy exceeds its unit cost for female wage earners.

3.3. Aran Islands, Ireland

This island group consists of Inis Mor, Inis Meain, and Inis Oirr, but the RES facility is to be sited in Inis Mor. Its key characteristics and preferred energy scenario are as shown in Table 1. The energy scenario mix was necessary to achieve 100% energy autonomy. Wind, PV, and Heat pump technologies have a similar lifetime. However, electrical, and thermal storage have less than that and will most likely cause a major re-installation midpoint of the operational lifetime of the RES facility. The population density of the island is equally low and requires specialist contractors from outside the local economy for the installation of the RES facility.

Table 6 illustrates the economic sectors on the island as highlighted by the expert stakeholders, MPCs, the corresponding KIM for the sectors, and the induced local economic impact per unit of energy. Tourism is yet again the top on the list for the potential for realising

Table 6: Economic sectors, MPC, KIM, and the induced local economic impact per unit of electrical energy and thermal energy for Aran Isles, Ireland.

			Per unit of electrical energy		Per unit of thermal energy	
Economic Sectors	MPC	KIM	SEI	SEI (F)	SEI	SEI (F)
Tourism	0.41	1.70	0.24	0.14	0.15	0.09
Fishing	0.09	1.10	0.16	0.09	0.10	0.06
Education	0.14	1.16	0.17	0.10	0.10	0.06
Construction	0.03	1.03	0.15	0.09	0.09	0.05
Services	0.15	1.18	0.17	0.10	0.10	0.06
Health & Social Work	0.14	1.16	0.17	0.10	0.10	0.06
Manufacturing	0.03	1.03	0.15	0.09	0.09	0.05

positive economic benefits in the local economy via re-spent of income, followed by the services and education sectors. There is manufacturing on the islands, but it is for souvenirs and small items for the tourism market. As such, has potential for induced impacts rather than direct employment impacts.

The profits from one unit of electrical energy are more than its unit cost (LCOE of €0.10/kWh) for all sectors in male waged employment. Meanwhile, tourism is the only sector where the profit from one unit of energy is more than its unit cost in female waged employment.

The case for Aran Isles is the same as the two previously discussed islands in terms of management of the impact potential of re-spent to affect growth and improvement in the target sectors. Furthermore, the induced effect based on heat pumps and thermal storage was calculated by replacing LCOE with LCOH (levelised cost of heat) in Equations (4) and (5) at LCOH of €0.072/kWh (see Table 6). The profits from one unit of electrical thermal are more than its unit cost for all sectors in male waged employment. Meanwhile, the only sectors where the profit from one unit of energy is more than its unit cost in female waged employment is tourism.

3.4. Gotland Island, Sweden

Key characteristics of Gotland are as shown in Tables 1 and 3. Due to the large population of the island, there is a possibility of specialist sub-contractors from within the local economy as plant/site sub-contractors. To create direct and indirect employment opportunities in the construction phase of wind technology, the main machinery must be manufactured outside of the local economy. Therefore, because of an increase in population, the local cash flow will temporarily increase, but will only last for the duration of the installation. Prediction of the land lease is premature at this point, but community ownership is recommended. The analysis of the induced effect is conducted, and the results are summarised in Table 7.

Table 7 also demonstrates the induced local economic impact per unit of energy for Gotland. The profits from one unit of energy are more than its unit cost (LCOE 0f €0.12/kWh) for all sectors in male waged employment, the tourism, health & social work, services, and education sectors in female waged employment. The advantage for Gotland was that sectoral GRLI data was available, unlike other islands.

3.5. Lesbos, Greece

The island's key characteristic and energy scenario is as shown in Table 1, so as with Gotland, there will be some subcontractors from the local economy for the construction phase as well as contractors from outside the local economy. Both factors will result in a temporary increase in local cash flow that lasts for the duration of the construction project. There are, therefore, temporary direct and indirect employment effect opportunities in the construction phase but none in the maintenance phase as it is a replacement of energy roles from conventional to RES technologies. PV technology has a lifespan of over 20 years, while electrical storage has a lifespan of only half as long. So, it is likely that a major re-installation of the storage element of the RES facility would happen near the midpoint of the operational lifetime of the facility. As a result of the skill development from the operation of the RES facility, those employed at the facility may play an important role in re-installing storage elements. However, this might not translate to additional income for the economy as they are already employed at the facility.

Table 8 shows the economic sectors in the local economy, the MPCs, and the corresponding KIMs for the sectors. Unlike other islands, public administration is the economic sector with the highest potential for realising positive economic benefits in the local economy via re-spent income. This is followed by the tourism sector and the property management sector. The SEI and the impact on female wage employment are calculated using Equations (4) and (5), with 1.2 as the ICT scale-up factor, LCOE of €0.31/kWh, and GRLI from Table 2.

Table 7: Economic sectors, MPC, KIM, and the induced local economic impact per unit of electrical energy for Gotland Island, Sweden

Economic Sectors	MPC	KIM	SEI	GRLI	SEI (F)
Agriculture	0.24	1.31	0.19	0.28	0.05
Tourism	0.29	1.41	0.20	1.11	0.23
Construction	0.08	1.09	0.16	0.08	0.01
Mining	0.03	1.03	0.15	0.27	0.04
Manufacturing	0.03	1.03	0.15	0.27	0.04
Health & social Work	0.12	1.14	0.16	3.82	0.63
Services	0.16	1.19	0.17	0.78	0.13
Education	0.03	1.03	0.15	2.87	0.43
Fishing	0.03	1.03	0.15	0.28	0.04

Table 8: Economic sectors, MPC, KIM, the induced local economic impact per unit of energy, and LES for Lesvos, Greece

Economic Sectors	MPC	KIM	SEI	SEI (F)	LES (€)
Agriculture	0.06	1.07	0.40	0.20	31,692
Industry	0.06	1.07	0.40	0.20	38,969
Manufacturing	0.04	1.04	0.39	0.19	19,645
Construction	0.05	1.05	0.39	0.19	17,862
Trade, Tourism	0.26	1.34	0.50	0.24	135,584
ITC	0.02	1.02	0.38	0.19	12,094
Financial	0.03	1.03	0.38	0.19	16,108
Property Management	0.13	1.14	0.42	0.21	87,522
Science	0.03	1.03	0.38	0.19	17,597
Public Administration	0.3	1.44	0.54	0.26	192,267
Entertainment	0.03	1.03	0.38	0.19	17,011

Note: LES is local economic stimulus.

Table 8 also shows the values of the calculated local economic stimuli per unit of energy for each sector. The sectors still reflect the highest local economic stimuli are public administration and trade/tourism.

We also observed that the profits from one unit of energy are more than its unit cost for all sectors in male waged employment. Meanwhile, there are no sectors where the profit from one unit of energy more than its unit cost in female waged employment.

Greece requires 3% reciprocal payments to the community for RES facilities. The fixed percentage of 3% reciprocal payments makes it possible to directly quantify the economic stimulus injected into the local economy, unlike that for other pilot islands. This local economic stimulus (LES) for different sectors can be quantified by the Equation (6) and the calculations are included in Table 8:

$$LES = \frac{Installation\,cost \times KIM_n}{Yrs\,of\ operation} + Annual\,reciprocal\ payments \tag{6}$$

3.6. Isle of Wight Island, UK

The annual energy demand for Isle of Wight and the estimated population is shown In Table 1. Due to its large population, sub-contractors from the local economy will be required for the sub-contract part of the PV plant and wind farm construction. Some external specialist contractors will be required to manufacture some specialist machinery. There will also be an increased cash flow from a greater number of hours put into the land and marine transportation due to these RES activities. While all these measures will increase local cash flow temporarily during construction, they will not necessarily have any lasting effects on employment in the local economy as with the other islands included in this study.

Table 9: Economic sectors, MPC, KIM, and the induced local economic impact per unit of energy for Isle of Wight, UK

Economic Sectors	MPC	KIM	SEI	SEI (F)
Agriculture	0.04	1.04	0.14	0.08
Tourism	0.2	1.25	0.17	0.10
Fishing	0.02	1.02	0.13	0.08
Manufacturing	0.11	1.12	0.15	0.09
Construction	0.07	1.08	0.14	0.08
Services	0.21	1.27	0.17	0.10
Food processing	0.03	1.03	0.14	0.08
Health & Social Work	0.21	1.27	0.17	0.10
Education	0.11	1.12	0.15	0.09
ICT	0.02	1.02	0.13	0.08
Arts & Crafts	0.02	1.02	0.13	0.08

Table 9 presents the economic sectors, MPCs, and KIM for the corresponding sectors. As compared to other islands, health and social work and services are the economic sectors with the greatest potential to generate positive economic benefits through re-investment of income. This is followed by the tourism industry.

Table 9 also shows the induced local economic impact per unit of energy for the Isle of Wight given LCOE of €0.11/kWh, ICT scale-up of 1.2 and GRLI from Table 2. In all sectors of male waged employment, the profits from one unit of energy exceed its unit cost. As for female waged employment, there are no sectors where the profit from one unit of energy exceeds its unit cost.

3.7. Majorca Island, Spain

As shown in Table 1, with a population of nearly 900,000, it is likely that the same direct and indirect employment effects will be achieved here as in case of the Isle of Wight. A mix of solar and wind energy without storage is recommended for this island at a LCOE of €0.12/kWh. The induced effects analysis is conducted based on the proposed AHP method. Table 1 shows the economic sectors, MPC, and the corresponding KIM for the sectors. The induced local economic impact per unit of energy (SEI) is calculated using Equations (4) and (5),

Table 10: Economic sectors, MPC and KIM of Majorca Island, Spain

Economic Sectors	MPC	KIM	SEI	SEI(F)
Tourism	0.43	1.75	0.25	0.13
Agriculture	0.17	1.21	0.17	0.09
Fishing	0.02	1.02	0.15	0.08
Manufacturing	0.09	1.1	0.16	0.08
Services	0.09	1.1	0.16	0.08
Food Processing	0.08	1.09	0.16	0.08
Health & Social Work	0.02	1.02	0.15	0.08
Arts & Crafts	0.08	1.09	0.16	0.08
Education	0.02	1.02	0.15	0.08

and it is captured in Table 10, with Column 3 showing the impact on male waged employment and column 4 on female waged employment.

The profit from one unit of energy is more than its unit cost for all sectors in male waged employment. Meanwhile, tourism is the only sector where the profit from one unit of energy is more than its unit cost in female waged employment.

3.8. La Reunion Island, France

Similar to Lesvos Island, due to the size and population of the island (see Table 1), La Reunion's RES scenarios would have to be scaled up to achieve 100% energy autonomy. As mentioned earlier, because construction and other costs are almost a linear function of the RES facility's size, the LCOE for the scenarios even under 100% energy autonomy would be the same provided the same ratio of solar capacity to storage capacity is maintained. The population of nearly 870,000 in La Reunion means that its local economy is quite large. It is possible that specialist sub-contractors within the local economy can sub-contract part of the plant/site construction.

Due to this energy mix, there are direct and indirect employment effect opportunities from the increase in population during the site development and construction phase, as both sub-contractors within the local economy and external specialist contractors from outside the local economy bring about an increase in local cash flow within the economy. As previously stated, it will be difficult to predict how the land for the site will be arranged, therefore, the impact of any land purchasing or leasing arrangements have not been factored into the study. For the operation phase, employment lost in the conventional energy sector, given the ease of training, can be offered a vis-a-vis replacement via roles created by the following activities: maintenance of the PV plant, management of the local control centre for REACT's ICT solution including billing and keeping records.

Table 11: Economic sectors, MPC, KIM, and the induced local economic impact per unit of energy for La Reunion Island, France

Economic Sectors	MPC	KIM	SEI	SEI (F)
Agriculture	0.04	1.04	0.15	0.08
Tourism	0.07	1.08	0.16	0.08
Fishing	0.01	1.01	0.15	0.08
Manufacturing	0.02	1.02	0.15	0.08
Construction	0.22	1.28	0.18	0.10
Services	0.10	1.11	0.16	0.08
Food Processing	0.02	1.02	0.15	0.08
Health & Social Work	0.25	1.33	0.19	0.10
Education	0.21	1.27	0.18	0.10
ICT	0.04	1.04	0.15	0.08
Arts & Crafts	0.02	1.02	0.15	0.08

Given the lifespan of PV technology and electrical storage, it is likely that a major re-installation of the storage element of the RES facility will occur near the midpoint of its operational life. As a result of the skill building gained from operating the RES facility, those employed at the facility may play an important role in the re-installation of storage elements. This may, however, not result in increased income for the economy since they are already employed at the facility.

For analysis of induced effects, a method based on AHP is proposed as previously. Table 11 shows the economic sectors, MPC, KIM and the induced local economic impact per unit of energy for La Reunion given LCOE of €0.12/kWh, ICT scale-up of 1.2 and GRLI from Table 2.

For all sectors of male waged employment, the profits from one unit of energy exceed its unit cost. As a result, there are no sectors in which the profit from one unit of energy exceeds its unit cost for female wage earners.

3.9. Sensitivity Analysis of the Impact of ICT Solution Costs.

A sensitivity analysis was performed to holistically understand the impact of the ICT costs. As tourism was a sector with high induced socio-economic impact across all the islands, it was the economic sector selected for use in the analysis. Table 12 presents the population, KIM for the tourism sector, the LCOE, the Gender Representation in Labour Income ratio (GRLI), and the induced local economic impact per unit of energy due to the new autonomous renewable energy infrastructure on

Table 12: Sensitivity analysis of the impact of ICT scale-up factor on the tourism sector

Island	Population	KIM	LCOE	GRLI	SEI (F) for different values of ICTSF				
					1.1	1.2	1.3	1.4	1.5
La Graciosa (Spain)	734	1.82	0.12	0.53	**0.13**	**0.14**	**0.15**	**0.16**	**0.17**
San Pietro (Italy)	6,173	1.79	0.11	0.40	0.09	0.09	0.10	0.11	**0.12**
The Aran Islands (Ireland)	712	1.70	0.10	0.59	**0.11**	**0.12**	**0.13**	**0.14**	**0.15**
Gotland (Sweden)	59,249	1.41	0.12	1.11	**0.21**	**0.23**	**0.24**	**0.26**	**0.28**
Lesbos (Greece)	86,436	1.34	0.31	0.49	0.22	0.24	0.26	0.28	**0.31**
Isle of Wight (UK)	141,000	1.25	0.11	0.59	0.09	0.10	0.11	0.11	**0.12**
Majorca (Spain)	880,113	1.75	0.12	0.53	0.12	**0.13**	**0.14**	**0.16**	**0.17**
Reunion (France)	866,506	1.08	0.12	0.52	0.07	0.08	0.09	0.09	0.10

female waged employment (SEI(F)). The cells highlighted in bold indicate that the SEI(F) is higher than the LCOE, indicating a profit.

The value of the ICT scale-up factor will depend on the size of the RES installation, which is determined by the population. Lower populations may face higher ICT scale-up costs owing to the relatively smaller size of the RES installation. While, in theory, a higher ICT scale-up factor can produce higher induced benefits, especially for female waged employment as it increases the per-unit energy costs, this is not necessarily beneficial since the community must bear the negative effects. Therefore, increasing the per-unit energy costs is never beneficial. This might be in the form of a lower ownership share of the RES facility for the community or lower reciprocal payments depending on the conditions and agreements between the local community and the electricity utility.

4. Conclusion and Recommendations

This paper has introduced a new approach of assessing the socio-economic impact of self-sustaining energy system projects that are based on hypothetical future scenarios of RES installation. The Keynesian Income Multiplier has been used to investigate the induced effects of RES technologies on the economy and the various activities that influence employment as well as income generation on eight geographical islands. The proposed approach involves the use of AHP to capture the sectoral MPCs for selected energy scenarios. The analysis conducted shows that the induced local economic impact per unit of electricity energy due to proposed RES based autonomy in all economic sectors for male waged employment, exceeds its unit cost or LCOE. But for female waged employment, the profits from per unit of electrical energy generated exceeded the LCOE for tourism sector in La Graciosa, Aran Islands, Majorca and three other sectors in Gotland (health & social work, services, and education).

It therefore shows that based on empirical formulation, the islands' main source of income comes from tourism, and the income from RES technologies redistributed within it will positively impact the islands' local economy. It is imperative that a holistic approach of RES based autonomy and decarbonisation with detailed examination of all high-income sectors on each island, including their facilities be developed. This ensures that direct benefit from the RE income and the RES development does not affect the sectors adversely. These sector facilities should be prioritized due to their significant economic impact on employment on the islands.

The gender aware approach has also shown the importance of closing the gender pay gap and the need to foster gender equity in all economic sectors to have a broader socio-economic benefit.

Based on literature and this study's analysis, it is recommended to give community the ownership of the RES facility as well as support the local workforce with skills development and training to maximise benefits to the local economy. This is because community ownership of energy projects can play a pivotal role in fostering sustained economic growth within the local area through the multiplier effect of the income earned from local business development, job creation, revenue generation and other community investments due to the RET installation. This could promote public awareness of clean energy project development, and thereby reduce public resistance to any RE plant prior to construction in remote island communities [18, 45].

5. Limitations and Further Scope

For forecast of socio-economic impacts, expert opinions are the main sources of data identified in this work for smaller geographical islands. We were unable to identify alternative sources for MPCs including literature. MPCs being highly sensitive to expert knowledge is a constraint with the approach that has been developed and demonstrated in this work. The use of the AHP provides a structured approach to capture expert opinion and translate them into MPC values. Future work will investigate means to mitigate the sensitivity of MPCs to expert opinion.

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