Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 159 (2019) 249–254

Energy Procedia

www.elsevier.com/locate/procedia

Applied Energy Symposium and Forum, Renewable Energy Integration with Mini/Microgrids, REM 2018, 29–30 September 2018, Rhodes, Greece

Public perception of sustainable energy innovation: A case study from Tilos, Greece

Phedeas Stephanides[a,b]*, Konstantinos J. Chalvatzis[a,b], Xin Li[a,b], Nikos Mantzaris[c], Michalis Prodromou[c], Christiana Papapostolou[d], Dimitris Zafirakis[e]

[a]*Norwich Business School, University of East Anglia, Norwich NR4 7TJ, UK*
[b]*Tyndall Centre for Climate Change Research, University of East Anglia, Norwich NR4 7TJ, UK*
[c]*WWF Greece, 21 Lembessi Str., 11743 Athens, Greece*
[d]*Optimisation of Production Systems Lab., Mechanical Engineering Dept., Uni. of West Attica, 250 Thivon & P.Ralli Str. 12244 Athens, Greece*
[e]*Soft Energy Applications Lab, Mechanical Engineering Dept.,Uni. of West Attica, 250 Thivon & P.Ralli Str. 12244 Athens, Greece*

Abstract

Renewable and smart grid technologies play a key role in delivering a sustainable energy future for non-interconnected islands. In this context, societal acceptance of proposed interventions manifests itself as a major determinant of planned transitions. With extant scholarship on public acceptability of sustainable energy technologies focusing on local opposition to wind farms, this paper presents timely survey data from the island of Tilos to provide a better understanding of energy-users' perceptions vis-à-vis novel smart island proposals. Against stultifying narratives highlighting the lack of community acceptance for local interventions, we uncover: a) the widespread acceptance of sustainable and smart energy solutions, and b) the willingness of a large proportion of locals to play their part, as engaged energy prosumers, in a green energy transition. In turn, these findings form the basis for future academic and technical interventions on the island, and inform broader conclusions on public engagement around energy.

Selection and peer-review under responsibility of the scientific committee of the Applied Energy Symposium and Forum, Renewable Energy Integration with Mini/Microgrids, REM 2018.

Keywords: public perception; smart grids; renewable energy; islands; TILOS

1. Introduction

The cost of sustaining the energy supply status quo in islands across the globe is significant in financial, social, and environmental terms [1]. Subsequently, many islands have transformed into laboratories where optimised energy

* Corresponding author. Tel.: +44-789-107-0350. *E-mail address:* p.stephanides@uea.ac.uk

Selection and peer-review under responsibility of the scientific committee of the Applied Energy Symposium and Forum, Renewable Energy Integration with Mini/Microgrids, REM 2018.
10.1016/j.egypro.2018.12.058

systems are developed and tested [1-4]. To this end, and although attention has customarily been placed on the optimum sizing of centralised RES plants [5-6], the concept of the green or smart grid that lately emerges has also attracted the attention of researchers [7-9]. Specifically, practitioners in the field have put forth a myriad of suggestions and plans such as continental interconnections, smart microgrid solutions, end-user efficiency measures, RES microgeneration, prototype energy storage solutions, and the establishment of energy cooperatives [4; 10-14].

Nonetheless, emerging research has uncovered a series of hindrances to green or smart energy transitions. Amongst others, international experience documents local public opposition towards promoted technological innovations as a major determinant of planned transitions [15-19]. For instance, whilst recent research in Greece points to exceptionally high levels of acceptability for RES applications [19-24], research across Europe consistently highlights a sharp disparity between generally favourable attitudes to energy developments and acceptance of planned developments by those groups residing close to proposed project sites [25-26]. In this light, social scientists have developed a multitude of conceptual frameworks explaining local social acceptance. For instance, the '*NIMBY'* (not in my backyard) response has been put forth as a construct explaining how locals frequently oppose bearing the visual, social, economic or environmental costs of having energy-related infrastructures in their near vicinity – irrespective of the fact that society might enjoy the general idea of such infrastructures from a distance [24-28]. Furthermore, scholars in the field have conceptualized and empirically validated how personal, contextual, project-specific and place-related factors shape local acceptance of energy-related interventions [29-33].

While scores of papers have studied social acceptance of energy innovations [29-33], research continues to suffer on an empirical level. Internationally, literature exploring local energy acceptability has overwhelmingly focused on local opposition to single wind energy projects [32-34]. Consequently, and with some notable exceptions [35-37], it has relatively little to say about support to smart and green grid developments that involve, amongst others: a) a redefinition of end-users from passive consumers to managers of their consumption and active *'co-providers'* or *'prosumers'*, and b) automated demand-side management (DSM) mechanisms aiming to achieve a balance between electricity supply and demand. This tendency is reflected in research on non-interconnected Greek islands. While recent studies and interventions move significantly beyond renewable energy production [4; 11], they apply implicit and unfounded assumptions about the willingness of locals to live in and be part of green energy systems.

2. A case-study from Tilos, Greece

Against this backdrop, this study investigates the levels of social acceptability for novel sustainable energy applications, using as a case-study the representative example of Tilos, Greece. Alongside exemplifying the problematic status-quo of energy supply for non-interconnected islands, Tilos has recently gained international recognition as the Mediterranean epicenter of experimentation with autonomous smart grid technologies [4]. Our basic aim is to investigate the degree of acceptability of the TILOS-H2020 project. This involves the installation of a 800kWe wind turbine, a 160kW PV park, a battery storage unit, smart meters and DSM devices [4]. Additionally, given growing interest in consumer engagement with micro-generation and energy efficiency [1; 3-4], we pay special attention to the willingness of locals to become an active part of an energy transition.

Specifically, a questionnaire was administered to collect information about the people from the people. The survey was distributed, from door-to-door, between October and November 2016 and its focus moves significantly beyond typical technical and economic assessments of island-mode energy innovations [1-12; 38]. This paper draws on responses from a representative sample of 226 inhabitants that is capable of informing a statistically significant view of local perceptions of sustainable energy technologies, with a ± 3% error margin at the 95% confidence level – see the "sample-to-population" ratio adopted in similar studies [19; 27]. Drawing on past research experience [e.g. 16; 19; 27], each questionnaire had a number of closed-type questions. These focused on: a) public attitudes towards the planned installations, b) the willingness of locals to partake in a green energy transition, c) the role of adverse energy supply conditions on the island in shaping public attitudes towards green energy, and d) personal and demographic attributes that might influence energy-related behaviours and perceptions. The collected data was subsequently analysed using standard descriptive statistical tools and significance tests. During this analysis, the research team consistently uncovered distinct types of energy-users sharing similar opinions and experiences across all questions. As such, an analytical novelty of this research is the application of the *two-step clustering* technique that helped validate homogeneous groups of cases where this grouping was not previously known.

3. Results and discussion

According to the results obtained from across the entire sample, the inhabitants of Tilos are overwhelmingly supportive of renewable and sustainable energy technologies – having, as one of their main aims to become autonomous in terms of energy. It is indicative that a majority of respondents (82%) have an overall positive view of sustainable energy technologies, with only 1% of respondents reporting their objection to such energy innovations (Fig.1a). Importantly, and against international experience suggesting a disparity between generally favourable attitudes to energy developments and acceptance of planned developments by those groups residing close to proposed project sites [e.g. 25-27], the islanders believe, in their statistically significant majority, that an ideal energy supply future for their island is mostly based on renewables. This is in line with recent survey findings from the central Peloponnesus region (Greece) where ongoing exposure to both a problematic energy supply status-quo and emerging RES projects stimulates higher levels of acceptance for green energy technologies [19]. Specifically, as Fig.1b highlights, up to 43% of respondents wish a complete shift from the present fossil fuel based system to a local micro-grid that is fully supplied by renewables. Moreover, an additional 16% of respondents believe that most energy on the island should be provided through an optimised system that mostly comprises of renewable energy and storage technologies such as those implemented by the TILOS project in the Livadia area (Fig.1b).

The prevalence of positive attitudes towards sustainable energy technologies is further validated by responses to questions focusing explicitly on the TILOS project. Whilst data was collected prior to the experimental installation of the technologies on the island, 45% of respondents had a largely positive understanding of the project – with only a negligible 2% of locals citing any doubts (Fig.1c). The prospects of a) ensuring a secure and green energy supply and economic growth at the regional level, and b) of achieving cost and energy savings at the household level via exploitation of smart meter feedback were among the main reasons cited by those providing a positive evaluation of the TILOS intervention. Most respondents (43%; $n_{\text{-sample}}$: 102) treated the intervention as an important step towards energy security; as a panacea to the frequent power outages experienced on the island (Fig.1d).

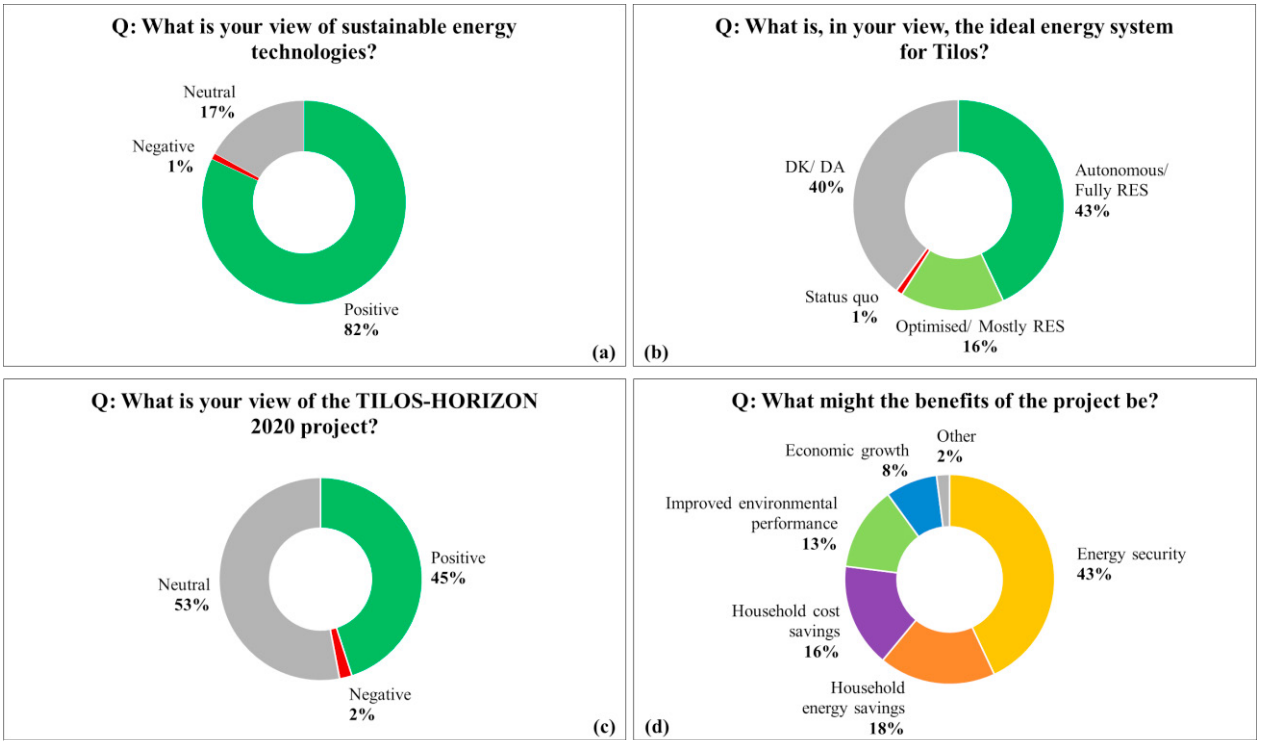

Figure 1: Public acceptability of sustainable energy solutions.

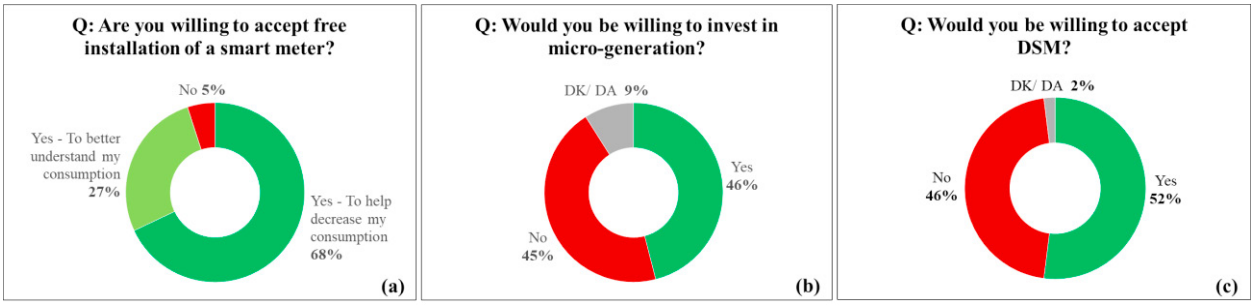

Figure 2: Public acceptability of engaged role in a green energy transition for Tilos.

The aforementioned positive attitude towards a sustainable energy transition is further supported by the willingness of most survey respondents to play an active role in the local energy system, either in terms of better management of their personal energy use or through acceptance of their potential role as energy co-providers. First, we recorded an overwhelmingly positive attitude towards the installation of smart meters, with up to 95% of respondents willing to accept free installation of smart meters in their home – most of whom were driven by a strong desire to reduce their overall energy consumption for either economic or environmental reasons (Fig. 2a). Moreover, with novel infrastructural projects demanding far more than passive consent for construction, the fact that most respondents are willing to either invest in their own micro-RES technologies (46%), or to accept DSM (52%) is reassuring (Fig.2b-c).

Nonetheless, and as Fig.2b-c highlights, relatively large proportions of the sample were unwilling to play an active part in the planned energy transition. For instance, up to 45% of respondents were not willing to invest in their own micro-generation technologies – almost universally attributing this to the allegedly prohibitive costs involved in installing such technologies at the home in the wake of suspended state subsidies. Furthermore, 46% of respondents were unwilling to accept DSM of their devices – claiming that this would act out to the detriment of their respective energy user experiences. This near equal split between respondents supporting and opposing these energy technologies is further reflected in the findings of the *two-step cluster analysis* performed (see Table 1).

Table 1. Two-step cluster analysis of findings (*Silhouette measure of cohesion and separation: Good; 82% of cases*).

	Cluster	1: Potential green energy consumers (46.2%)	2: Potential green energy prosumers (53.8%)
Predictor Inputs (In order of importance)	Willingness to install micro-RES	Importance= 1.00 Most frequent category: No (100%)	Importance= 1.00 Most frequent category: Yes (100%)
	Evaluation of current power supply	Importance= 0.50 Most frequent category: Adequate (65.1%)	Importance= 0.50 Most frequent category: Inadequate (52%)
	Willingness to accept external control	Importance= 0.18 Most frequent category: No (67.4%)	Importance= 0.18 Most frequent category: Yes (72.0%)
	Age	Importance= 0.10 Most frequent category: 41-60 years old (65%)	Importance= 0.10 Most frequent category: 41-60 years old (50%)
	No. of devices damaged by system imbalances	Importance= 0.09 Mean: 0.56	Importance= 0.09 Mean: 0.80
	Perception of sustainable energy	Importance= 0.07 Most frequent category: Positive (86.0%)	Importance= 0.07 Most frequent category: Positive (98.0%)
	Ideal energy system for the future	Importance= 0.03 Most frequent category: Do not know (46.5%)	Importance= 0.03 Most frequent category: 100% RES (50.0%)
	Willingness to "green" consumption	Importance= 0.02 Most frequent category: Yes (53.5%)	Importance= 0.02 Most frequent category: Yes (62.0%)
	Gender	Importance= 0.02 Most frequent category: Male (58.1%)	Importance= 0.02 Most frequent category: Female (58.0%)
	Willingness to change habits	Importance= 0.01 Most frequent category: Yes (81.4%)	Importance= 0.01 Most frequent category: Yes (86.0%)

Specifically, Table 1 reveals two distinct natural groupings of locals. On the one hand, *'potential green energy consumers'* constitute a group of predominantly male, middle-aged locals who are both supportive of sustainable

energy technologies and willing to "green" their personal consumption. Nonetheless, these individuals: a) are unwilling to accept DSM and prosumption practices, and b) remain largely uncertain of what an "ideal" energy future for Tilos might entail. On the other hand, *'potential green energy prosumers'* constitutes a group of primarily female, middle-aged locals who are more radically "green". They are willing to "green" their personal energy consumption and are supportive of both large-scale energy innovations and of technologies such as micro-RES and DSM. From information available at the time of data collection, it appears that personal experiences and interpretations of energy supply exercise a pivotal influence on the desired societal role within a sustainable energy transition, ranking as the second most influential input in our model. Confirming the importance of energy security for islands [cf. 8], prospective *prosumers* felt that the energy supply status quo of Tilos was far more problematic than prospective green *consumers* – arguing that a green transition cannot solely rely upon centralised interventions.

4. Conclusions

Whilst public opposition has been widely discussed as a barrier to sustainable energy interventions [17-21], the findings presented in this paper largely challenge extant scholarship. According to the survey findings, local public attitudes towards renewable and smart energy technologies are largely supportive of the green energy transition initiated through the TILOS project, with most of the respondents recognizing the possible benefits of transitioning to a sustainable energy system. Nonetheless, broad acceptability of such technologies does not equate to universal, unconditional acceptance of all long-term interventions put forth by the research consortium. This holds particularly true for possible interventions such as RES micro-generation and DSM that involve the active involvement of the consumer, where there we recorded nearly equal levels of support and opposition to such proposals.

In this light, we put forth the core argument that there are two statistically validated clusters of locals: a) those supportive of a green energy transition but largely unwilling to actively support this, and b) those who are willing to take a far more active role in this transition by becoming involved energy prosumers themselves. As part of this narrative, we also put forth the core hypothesis that subjective experiences and evaluations of the energy-supply status quo influence the type of acceptance to green energy solutions. In simpler terms, we suggest that the more an individual perceives to have been exposed to the problematic elements of energy supply in non-interconnected islands, the more likely (s)he is to accept an energy prosumer role in the future. However, to fully corroborate this hypothesis, further research is necessary. Specifically, with extant scholarship on public perceptions of sustainable energy technologies suggesting that a diverse array of personal, contextual, project-specific and place-related factors influence levels of public acceptability [25-32], the research team also intends to administer a second questionnaire survey on the island of Tilos. This will focus on: a) the determinants of public acceptability, and b) the impacts first-hand experience of the project might have had on the local population and their attitudes. By further quantifying and qualifying support to the TILOS intervention, further work of the authors in this field is dedicated to developing a 360° snapshot of public perception of sustainable energy solutions. This will in turn inform a socio-technical, best-practice model seeking to transfer our experience to other non-interconnected islands in Greece and beyond.

Acknowledgements

The specific study has been funded under the project TILOS (Horizon 2020 Low Carbon Energy Local / small-scale storage LCE-08- 2014). This project has received funding from the European Union & Horizon 2020 research and innovation programme under Grant Agreement No 646529.

References

[1] Haeder H. *EU Islands: Towards a Sustainable Energy Future*. Eurelectric; 2012. 63p.

[2] Praene JP, David M, Sinama F et al. Renewable energy: Progressing towards a net zero energy island, the case of Reunion Island. *Renew Sustain Energ Rev* 2012;16:426-42.

[3] Sperling K. How does a pioneer community energy project succeed in practice? The case of the Samso Renewable Energy Island. *Renew Sustain Energ Rev* 2017;71:884-97.

[4] Notton G, Nivet ML, Zafirakis D et al. Tilos, the first autonomous renewable green island in Mediterranean: A Horizon 2020 project. *ELMA 15th International Conference*, 2017; 102-5.
[5] Kaldellis JK, Zafirakis D, Kondili E. Optimum sizing of PV-energy storage systems for autonomous small islands. *JEPE* 2010;32:24-36.
[6] Papaefthymiou SV, Papathanassiou SA. Optimum sizing of wind-pumped-storage hybrid power stations in island systems. *Renew Energy* 2014;64:187-96.
[7] Zafirakis D, Chalvatzis KJ. Wind energy and natural gas-based energy storage to promote energy security and lower emissions in island regions. *Fuel* 2014;l115:203-19.
[8] Chalvatzis KJ, Ioannidis A. Energy supply security in southern Europe and Ireland. *Energy Procedia* 2017;105:2916-22.
[9] Ioannidis A, Chalvatzis KJ. Energy supply sustainability for Island Nations: A study on 8 Global Islands. *Energy Procedia* 2017;142:3028-34.
[10] Eftymiopoulos I, Komninos K, Florou A. *Smart Islands Projects and Strategies: A documentation of smart projects and strategies implemented by 35 European islands and showcased during the 1st Smart Islands Forum, 21-22 June 2016, Athens, Greece*. Athens: Friedrich-Ebert-Stiftung.
[11] Jørgensen JM, Sørensen SH, Behnke K et al. Ecogrid EU: A prototype for European smart grids. In *Power and Energy Society General Meeting,* 2011; 1-7.
[12] Vourdoubas J. Description and Assessment of a Small Renewable Energy Community in the Island of Crete, Greece. *OJEE* 2017;6(3):97-111.
[13] Hills JM, Michalena E, Chalvatzis KJ. Innovative technology in the Pacific: Building resilience for vulnerable communities. *Technol Forecast Soc Change* 2018;12916-26.
[14] Malekpoor H, Chalvatzis K, Mishra N et al. Integrated grey relational analysis and multi objective grey linear programming for sustainable electricity generation planning. *Ann Oper Res* 2017;1-29.
[15] Cohen JJ, Reichl J, Schmidthaler M. Re-focussing research efforts on the public acceptance of energy infrastructure: A critical review. *Energy* 2014;76:4-9.
[16] Devine-Wright P. Reconsidering public acceptance of renewable energy technologies: A critical review. In: Grubb M, Jamasb T, Pollitt M, editors. *Delivering a low carbon electricity system*. London: Cambridge University Press: 2008.
[17] Schweizer-Ries P. Energy sustainable communities: Environmental-psychological investigations. *Energy Policy* 2008;36:4126-35.
[18] Wustenhagen R, Wolsink M, Boter M. Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy* 2007;35:2683-91.
[19] Kaldellis JK, Kapsali M, Katsanou E. Renewable energy applications in Greece: what is the public attitude? *Energy Policy* 2012;42:37-48.
[20] Kaldellis JK, Kapsali, M, Kaldelli E, Katsanou E. Comparing recent views of public attitude on wind energy, photovoltaic and small hydro applications. *Renew Energy* 2013;52:197-208.
[21] Petrakopoulou F. The social perspective on the renewable energy autonomy of geographically isolated communities: Evidence from a Mediterranean island. *Sustainability* 2017;9:327-34.
[22] Tsantopoulos G, Arabatzis G, Tampakis S. Public attitudes towards photovoltaic developments: Case study from Greece. *Energy Policy* 2014;71:94-106.
[23] Zografakis N, Sifaki E, Pagalou M et al. Assessment of public acceptance and willingness to pay for renewable energy sources in Crete. *Renew Sustain Energ Rev* 2010;14:1088-95.
[24] Kaldellis JK. Social attitude towards wind energy applications in Greece. *Energy Policy* 2005:33:595-602.
[25] Wustenhagen R, Wolsink M, Boter M. Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy* 2007;35:2683-91.
[26] Burningham K. Using the lamguage of NIMBY: A topic for research, not an activity for researchers. *Local Environment* 2000;5:55-67.
[27] Kaldellis JK, Kavadias KA. Evaluation of Greek wind parks visual impact: The public attitude. *Fresen Environ Bull 2004*;12(4):326-37.
[28] Huijts NMA, Molin EJE, Steg L. Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renew Sustain Energ Rev* 2012;16:525-31.
[29] Devine-Wright P. Rethniking NIMBYism: The role of place attachment and place identity in explaining space-protective action. *J Community Appl Soc Psychol 2009*;19:426-41.
[30] Sardianou E, Genoudi P. Which factors affect the willingness of consumers to adopt renewable energies? Renewable Energy 2013;57(1):1-4.
[31] Steg L, Perlaviciute G, Werff E. Understanding the human dimensions of a sustainable energy transition. *Front Psychol* 2015;6:805-21.
[32] Devine-Wright P, Howes Y. Disruption to place attachment and the protection of restorative environments: A wind energy case study. *J Environ Psychol* 2010;30:271-80.
[33] Firestone J, Kempton W. Public opinion about large offshore wind power: Underlying factors. *Energy Policy* 2007;35(3):1584-98.
[34] Kontogianni A, Tourkolias c, Skourtos M. Renewables portfolio, individual preference and social values towards RES technologies. *Energy Policy* 2013;55:467-76.
[35] Mengolini A, Vasiljevska J. *The social dimension of smart grids: Consumer, community, society*. Luxembourg: Publications Office of the European Union; 2013.
[36] Spence A, Demski C, Butler C et al. Public perceptions of demand-side management and a smarter energy future. *Nat Clim Chang* 2015;5(1):550-5.
[37] Wolsink M. The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources. *Renew Sust Energ Rev* 2012;16:822-35.
[38] Li X, Chalvatzis KJ, Stephanides P. Innovative Energy Islands: Life-Cycle Cost-Benefit Analysis for Battery Energy Storage. *Sustainability* 2018;10:3371; doi:10.3390/su10103371.