

Diffusion of Solar PV Energy

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Solar photovoltaic energy (solar PV) is considered a very attractive solution among renewable energy sources (RES), especially for households. According to the most recent IEA report on renewables, the growth of renewable power capacity at the world level has reached another record in 2021, driven by solar photovoltaic energy; solar PV alone has accounted for more than half of all renewable power expansion in 2021, followed by wind and hydropower.

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1. Background

The continuing increase in per-capita energy demand, coupled with the planet's increasing population, is bringing critical threats to both the fight against global climate change and energy security issues. The COVID-19 pandemic and the consequent lockdown periods all over the world have emphasized the importance of secure, stable, and resilient electricity networks ^[1].

The process of decarbonization, which is the progressive shift from fossil fuels to renewable energy technologies, requires on one hand a rapid growth of renewables, namely solar photovoltaic and wind power, and on the other hand an optimization of the role of natural gas as a transition medium ^[2].

Solar photovoltaic energy (solar PV) is considered a very attractive solution among renewable energy sources (RES), especially for households. According to the most recent IEA report on renewables ^[3], the growth of renewable power capacity at the world level has reached another record in 2021, driven by solar photovoltaic energy; solar PV alone has accounted for more than half of all renewable power expansion in 2021, followed by wind and hydropower.

Despite this rapid growth, some key challenges and market barriers remain and hinder a faster RES diffusion process. As highlighted by ^[4], social acceptance and political feasibility are crucial elements for low-carbon transitions. The diffusion of renewable energy technologies is a complex process that involves multiple agents, with the interaction of firms and economic agents, public and private institutions, and final consumers (see, for instance, ^{[5][6]}). All these subjects may have different needs and expectations, different attitudes towards change, and respond to different economic and social incentives.

Focusing on PV adoption, a study on Switzerland aiming to explain the differences in PV growth at the subnational level ^[7] showed that solar PV is more spread in areas with higher technoscientific knowledge, higher education institutions, and widespread innovation activity. Moreover, the critical role of local authorities, dedicated citizens, and energy companies has been highlighted for its ability to accelerate the uptake of this technology through locally based strategies.

A recent analysis of barriers and enablers for PV installation in ^[8] identified economic, information, and administrative barriers, while enablers included subsidies, climate change concerns, as well as the opportunity to earn money. The analysis especially focused on the importance of the use of nonresidential buildings to strengthen the diffusion process. A meta-analysis of studies on residential PV adoption in ^[9] suggested that measures should focus on enhancing the perception of benefits.

However, many other aspects may be accounted for when dealing with the diffusion of a renewable energy such as PV. For example, a study on Greece by ^[10] highlighted the role of technological and demographic changes, in combination with climatic factors, to explain the differences among regions in terms of energy conservation and emissions reduction. The work by ^[11] took a broader perspective, considering European countries, and assessed the sustainability of rooftop PV systems by taking into consideration the different solar potential of countries as well as the variety of electricity mix throughout Europe. The results of such analysis show that PV systems may be a viable solution for the future, but this

depends on location and the local electricity mix. A more technical assessment on the sustainability and performance of PV systems comparing five different technologies, conducted by [12], confirmed that overall, these technologies proved to be sustainable and environmentally friendly. As a general observation, these studies suggest that PV diffusion is characterized by many sources of heterogeneities, resulting from natural, technological, economic, social, and behavioral specificities.

Bearing in mind the multifaceted nature of a transition to PV systems and the multiplicity of agents and factors involved, in this entry researchers focus on the diffusion of solar PV in the United Kingdom, one of the top ten countries in terms of solar PV cumulative installed capacity according to the IEA-PVPS 2020 report [13].

Compared with standard public data on energy diffusion, typically available only in a highly aggregated form, the UK case is of tantamount importance for the understanding of RES diffusion patterns, in view of the availability of highly disaggregated data, with time-granular (i.e., monthly) information on both installed capacity and number of installations of solar PV from January 2010 to November 2021, concerning three different and largely heterogeneous market categories: residential, commercial, and utility (i.e., licensed electricity suppliers).

2. Modelling the Diffusion of RES: A Short Review

The mathematical modelling of the temporal trends of diffusion processes has proved valuable in many applied sciences [14]. Innovation diffusion models, extensively used after the seminal work of [15], have also proved critically useful for describing and forecasting the growth of an energy source over the years, considering it as a technology that must be accepted in a market.

For recent reviews on the applications of innovation diffusion models for renewable energy technologies see [16][17]. Among the studies using innovation diffusion models for energy markets, [18] proposed an innovative application of the so-called Generalized Bass model (GBM) [19] to energy diffusions, whereby the GBM—thanks to the inclusion of suitable shock terms—was used as a diagnostic tool for describing the impact that external shocks (from, e.g., a war, a price shock or wave of policy incentives) exerted on diffusion trends.

In [20], the GBM was applied to yearly time series of national solar PV capacity in eleven countries up to 2006, finding that public incentives had a key role in stimulating the growth of this technology. A recent cross-country study on 26 countries by [21] has updated the findings of [20] by including the dramatic incentive-triggered adoption waves since 2007. Both these works exploited the ability of the GBM to capture the effect of policy interventions and ad hoc incentives in driving the diffusion of solar energy. In [21], the important role of the GBM as a parsimonious tool to capture the impact of “structured” shocks, i.e., shocks characterized by a precise pattern—as it might be the case of a policy intervention aiming to incentivize a market—on diffusions was noted. Structured shocks have a fully different nature compared, e.g., to standard stochastic perturbations. A complementary perspective based on the use of innovation diffusion models was proposed in [22][23], trying to understand the adoption of solar PV at the household level. In particular, the analysis proposed in [23] suggested that information from the media should explain more about investment criteria, feed-in tariffs (FIT), and environmental attributes.

References

1. Heffron, R.J.; Körner, M.F.; Schöpf, M.; Wagner, J.; Weibelzahl, M. The role of flexibility in the light of the COVID-19 pandemic and beyond: Contributing to a sustainable and resilient energy future in Europe. *Renew. Sustain. Energy Rev.* 2021, 140, 110743.
2. Bessi, A.; Guidolin, M.; Manfredi, P. The role of gas on future perspectives of renewable energy diffusion: Bridging technology or lock-in? *Renew. Sustain. Energy Rev.* 2021, 152, 111673.
3. IEA, Renewables. 2021. Available online: <https://www.iea.org/reports/renewables-2021> (accessed on 21 January 2022).
4. Geels, F.W.; McMeekin, A.; Pfluger, B. Socio-technical scenarios as a methodological tool to explore social and political feasibility in low-carbon transitions: Bridging computer models and the multi-level perspective in UK electricity generation (2010–2050). *Technol. Forecast. Soc. Chang.* 2020, 151, 119258.
5. Geels, F.W. Disruption and low-carbon system transformation: Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. *Energy Res. Soc. Sci.* 2018, 37, 224–231.

6. Sovacool, B.K.; Hess, D.J.; Amir, S.; Geels, F.W.; Hirsh, R.; Medina, L.R.; Yearley, S. Sociotechnical agendas: Reviewing future directions for energy and climate research. *Energy Res. Soc. Sci.* 2020, 70, 101617.
7. Hirt, L.F.; Sahakian, M.; Trutnevyte, E. What socio-technical regimes foster solar energy champions? Analyzing uneven photovoltaic diffusion at a subnational level in Switzerland. *Energy Res. Soc. Sci.* 2021, 74, 101976.
8. Reindl, K.; Palm, J. Installing PV: Barriers and enablers experienced by non-residential property owners. *Renew. Sustain. Energy Rev.* 2021, 141, 110829.
9. Schulte, E.; Scheller, F.; Sloot, D.; Bruckner, T. A meta-analysis of residential PV adoption: The important role of perceived benefits, intentions and antecedents in solar energy acceptance. *Energy Res. Soc. Sci.* 2022, 84, 102339.
10. Martinopoulos, G.; Tsalikis, G. Diffusion and adoption of solar energy conversion systems—The case of Greece. *Energy* 2018, 144, 800–807.
11. Martinopoulos, G. Are rooftop photovoltaic systems a sustainable solution for Europe? A life cycle impact assessment and cost analysis. *Appl. Energy* 2020, 257, 114035.
12. Peng, J.; Lu, L.; Yang, H. Review on life cycle assessment of energy payback and greenhouse gas emission of solar photovoltaic systems. *Renew. Sustain. Energy Rev.* 2013, 19, 255–274.
13. IEA-PVPS (2021), Snapshot of Global PV Markets 2021. Available online: <https://iea-pvps.org/snapshot-reports/snapshot-2021/> (accessed on 21 January 2022).
14. Rogers, E.M. *Diffusion of Innovations*, 4th ed.; Simon and Schuster: New York, NY, USA, 2010.
15. Bass, F.M. A new product growth for model consumer durables. *Manag. Sci.* 1969, 15, 215–227.
16. Rao, K.U.; Kishore, V.V.N. A review of technology diffusion models with special reference to renewable energy technologies. *Renew. Sustain. Energy Rev.* 2010, 14, 1070–1078.
17. Petropoulos, F.; Apiletti, D.; Assimakopoulos, V.; Babai, M.Z.; Barrow, D.K.; Taieb, S.B.; Bergmeir, C.; Bessa, R.J.; Bijaik, J.; Boylan, J.E.; et al. Forecasting: Theory and practice. *Int. J. Forecast.* 2022, in press.
18. Guseo, R.; Dalla Valle, A.; Guidolin, M. World Oil Depletion Models: Price effects compared with strategic or technological interventions. *Technol. Forecast. Soc. Chang.* 2007, 74, 452–469.
19. Bass, F.M.; Krishnan, T.V.; Jain, D.C. Why the Bass model fits without decision variables. *Market. Sci.* 1994, 13, 203–223.
20. Guidolin, M.; Mortarino, C. Cross-country diffusion of photovoltaic systems: Modelling choices and forecasts for national adoption patterns. *Technol. Forecast. Soc. Chang.* 2010, 77, 279–296.
21. Bunea, A.M.; Della Posta, P.; Guidolin, M.; Manfredi, P. What do adoption patterns of solar panels observed so far tell about governments' incentive? Insights from diffusion models. *Technol. Forecast. Soc.* 2020, 160, 120240.
22. Islam, T.; Meade, N. The impact of attribute preferences on adoption timing: The case of photo-voltaic (PV) solar cells for household electricity generation. *Energy Policy* 2013, 55, 521–530.
23. Islam, T. Household level innovation diffusion model of photo-voltaic (PV) solar cells from stated preference data. *Energy Policy* 2014, 65, 340–350.

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