Supplementary material

Contents

1 PV incentivizing policies

Policies incentivizing PV adoption have been enacted in many countries:

- Italy - [1] presents a general evaluation of the national support framework. It describes several policy measures such net-metering programme (so-called "Scambio sul Posto"), the feed-in-premium programme (so-called "Ritiro Dedicato"), and "SEU" (plants that produce electricity for local or own consumption, "Sistemi Efficienti di Utenza"). It describes each policy, identifies the eligibility, the market control and the evaluation.
- Australia - [2] reports that there are two schemes available for households to help with the adoption of solar panels: the small-scale Renewable Energy Scheme and the feed-in-tariff (FiT). The former are designed to reduce the up-front costs of solar panels, while the FiT has been designed to decrease the payback period. The FiT differs among states and territories and it has been cut substantially since the market has matured and the costs of panels decreased.
- Sweden - [3] describes the changes in the policy support framework for PV panels in Sweden. She reports that in the period July 2009 - Nov 2011 households could get subsidies for 60% of the installation cost, including material and labor costs. Such a subsidy has been reduced to 45%, 35% and 20% of installation cost in the period Nov. 2011–Jan. 2013, Feb. 2013–Dec. 2014, and 1 January 2015 onwards, respectively. Since 2015 subsidies can only be applied for if the system costs are less than 3700 EUR excluding VAT/kWp.
- Austria - [4] propose a comparison between Italy and Austria, two countries with contrasting state support for PV investments in terms of amount and duration. Italy introduced the financing program "Conto Energia" in 2005, which lasted until July 2013, and there was no cap during the funding period. In Austria, households could apply only once a year for limited PV funds. Austrian financial support was moderate (FiT, Capital Subsidy) compared to the very generous support mix in Italy (FiT, Capital Subsidy, Net-Metering, Tax regulation mechanism). Italy granted FiT for a period of 20 years, whereas Austria only for 10–13 years. Moreover, in Italy PV investors benefited by a subsidy grant to the initial investment for up to 70% of the eligible, while in Austria such a grant covered only 30–40%.
- Germany - [5] reports the Federal Government's Renewable Energy Act (EEG) as the main renewable energy policy in Germany, together with a number of smaller regional and local support programs, such as tax incentives and soft loans. The EEG gives renewable energy sources priority access to the grid and obliges distribution network operators to purchase electricity from renewable energy plant

operators in return for fixed remuneration (a feed-in-tariff), differentiated by technology, capacity and other plant factors.

- US - [6] investigate whether incentives granted in US have been effective, and to what extent they influenced the growth in solar PV capacity. They report that US state governments have played a large role in incentivizing the use of renewable power sources, and solar power in particular. They established solar electricity generation goals and mandates, and offered generous financial incentives in the form of rebates, tax credits, and tax exemptions, that lowered the cost of installing solar PV system by as much as 50%.
- China - [7] investigate market dynamics, innovation, and transition in China's solar PV industry. They report that since 2009 the Chinese government has drafted a number of supportive policies to narrow the gap between the PV industries in China and the more advanced countries and achieve emissions reductions. The enacted policies at national level are subsidies according to installed capacity or initial investment (2009–2013) and subsidies for electricity generation (after 2013). The policies enacted by provincial and municipal governments mainly focused on support for distributed PV power generation. These policies comprised a power generation subsidy (the specific instruments include feed-in tariffs and net metering) and subsidies according to the initial installed capacity. In addition, some provinces in central China have enacted PV technology policies for poverty alleviation.
- India - https://www.iea.org/reports/unlocking-the-economic-potential-of-rooftop-solar-pv-in-india?utm_campaign=IEA+newsletters&utm_source=SendGrid&utm_medium=Email

2 The survey

2.1 Attributes selection in previous choice experiment studies on PV and BS adoption

The studies which used the choice experiment approach selected attributes as follows.

- [8] characterized alternatives using upfront cost, level of grid independence, payback period, ownership of system (owned by customer, owned by customer from electricity company, leased from electricity company), and panel aesthetics.
- [9] performed a choice experiment in six Mediterranean countries using, instead of attributes, images of PV installations with different technologies.
- [10][10] performed also a choice experiment in South Korea but with reference small-scale solar photovoltaic power plants, ranging from 30 to 150 kW.
- [11] and [2][2] used the following attributes: purchasing price rebate, Feed-in Tariff (FiT), guaranteed length for a FiT, and interest free loan.
- [12] identified their scenarios by the colour of solar panel, the origin of the manufacturers of the solar panel, the reduction in electricity cost over 20 years, and the purchase premium (rebate, e-car raffle, free e-bike).

Differently from these studies, we considered the choice to buy not only the PV panel but possibly also a BS system.

- [13] performed a choice experiment investigating the choice of a BS only, using the following attributes: size, cost, payback period, design, warranty, ease of use, safety.
- [14], on the contrary, examine the choice of the bundle PV+BS in conjunction with the acquisition of an EV.

2.2 Sample representativeness in previous choice experiment studies on PV and BS adoption

- Although using a relatively simple format consisting in ranking four images, [9] were able to collect 100 interviews for each of the six Mediterranean countries analyzed, using a convenience sample methodology and acknowledging the limited representativeness due to budget and time constraints.

- [8] succeeded in collecting data from 1018 participants selected from a commercially sourced panel in New Zealand, but they do not provide a discussion on its representativeness.
- [11] collected 1131 responses, comprising respondents who live in a house, owning it or not, and respondents who live in an apartment. The sample is deemed representative in terms of gender and income, but overrepresented in terms of education.
- [12] used data from 408 respondents, considered representative of the Swiss population in terms of language but not in terms of gender, age, and education (sampled homeowners have a higher education than the average Swiss homeowner).

2.3 Our sample

We report in Table S1 the descriptive statistics of our sample, specifying the socio-economic characteristics of the respondents, their level of information and self-assessed and objective knowledge of PV, BS and EV, their EV purchase intention and social interaction.

Table S1: Descriptive statistics of the sample

Socio-economic characteristics of the respondents

Gender	Women: 23.23%; Men: 76.77%
Age	Under 30 years of age: 87.7%; over 30 years of age: 12.3%
Region of residence	Calabria: 1.3%; Croazia: 0.6%; Emilia Romagna: 1.3%; Friuli Venezia Giulia: 63.9%; Lazio: 1.3%; Lombardia: 4.5%; Puglia: 1.9%; Sicilia: 3.2%; Sardegna: 0.6%; Trentino Alto Adige: 0.6%; Veneto: 20.6%
Educational level	High school diploma: 73.55%; University degree: 19.35%; PhD: 7.10%
Profession	Student: 79.35%; Employed: 16.77%; Retired: 1.29%; Other: 2.58%
What is the (net) family income?	Up to € 30,000: 38.71%; €30,000-€70,000: 45.16%; €70,000-€100,000: 11.61%; over €100,000: 4.52%
Type of dwelling	Apartment: 49.03%; single-family house: 50.97%
Do you own a photovoltaic system?	No: 70.89%; Yes: 29.11%
Do you have a storage system?	No: 96.77%; Yes:3.23%
Do you own an electric car?	No: 95.48%; Yes: 4.52%

Information, self-assessed knowledge, purchase intention and social interaction

What is your level of knowledge of photovoltaic systems? (From 1: low to 10: high)	2: 7.1%; 3: 9.0%; 4: 7.1%; 5: 9.0%; 6: 18.1%; 7: 15.48%; 8: 16.13%; 9: 7.10%; 10: 10.97%
How did you come up with the idea of buying a PV?	Informing from the websites: 17.65% Speaking with friends/acquaintances/relatives who had already purchased it: 17.65% At the suggestion of promoters: 64.71%
What is your level of knowledge of storage systems? (From 1: low to 10: high)	1: 13.55%; 2: 10.32%; 3: 9.03%; 4: 11.61%; 5: 8.39%; 6: 13.55%; 7: 14.84%; 8: 7.10%; 9: 4.52%; 10: 7.10%
How did you come up with the idea of buying a BSS?	Informing from the websites: 50% At the suggestion of promoters: 50%
How did you come up with the idea of buying an EV?	Informing from the websites: 40% Speaking with friends/acquaintances/relatives who had already purchased it: 20% At the suggestion of promoters: 40%
What is your level of knowledge of the electric car? (From 1: low to 10: high)	1: 1.29%; 2: 3.23%; 3: 6.45%; 4: 10.97%; 5: 12.26%; 6: 11.61%; 7: 16.77%; 8: 18.06%; 9: 12.90%; 10: 6.45%

How likely (0% to 100%) do you think the next car you buy will be electric? (From 0: 0% to 10: 100%)	0: 7.10%; 1: 9.68% 2: 10.32%; 3: 10.97%; 4: 5.81%; 5: 11.61%; 6: 10.97%; 7: 12.26%; 8: 9.68%; 9: 7.74%; 10: 3.87%
What is your source of information on PV and BS prices?	friends/acquaintances/relatives: 21% promoters: 12.4% websites: 67.6%
How often do you talk with friends/acquaintances/relatives of PV and BSS?	No: 17.1% Seldom: 49.5% At least ones a week: 7.6% At least ones a month: 25,7%
With how many acquaintances do you talk of PV and BSS each month?	None: 4.6% N° 1-3: 57.5%; N° 4-6: 23%; N° 6 and over: 14.9%

Objective knowledge

In your opinion, how much does a 5 kW photovoltaic system cost (list price including VAT)?	Less than €7000: 14.29%; from €7000 to €12,000: 61.90%; from €12,000 to €20,000: 11.43%; I do not know: 12.38%
How much does it cost, in your opinion, a storage battery for the home photovoltaic system of 13.5 kWh (list price including VAT)?	From €3000 to €6000: 29.52%; from €6000 to €10,000: 32.38%; from €12,000 to €20,000: 10.48%; I do not know: 27.62%
Considering the same model, how much in your opinion does an electric car cost compared to a petrol one (list price including VAT)?	It is about €5000 more expensive: 41.90%; it is about €10,000 more expensive: 34.29%; it is about €20,000 more expensive: 9.52%; they have the same cost: 14.29%

Table S2 reports the levels used in our survey to define the attributes characterizing our choice alternatives: PV price, inclusive of the inverter (€/kW), PV guarantee (in years), BS price (€/kWh), BS guarantee (in years), BS brand (Tesla Powerwall or other brands) and percentage of tax relief on the total investment costs.

Table S2: Attributes' levels

	PV price (€1,000)	PV Warranty (years)	Tax deduction (%)	BS price (€1,000)	BS Warranty (years)	BS Brand
PV	1.4; 1.6; 1.7; 1.8; 2	15; 20; 25	25; 50; 75; 110			
PV + BS	1.4; 1.6; 1.7; 1.8; 2	15; 20; 25	25; 50; 75; 110	0.75; 0.8; 0.85; 0.9; 1	10; 12; 15	Non Tesla Powerwall; Tesla Powerwall

3 Model assumptions

With regards to BEV ownership, [15] estimated that ownership level in 2030 will be equal to 24%, with the evolution in the 2016-2030 period illustrated in Figure S2. The level of PV knowledge is drawn from our survey. It represents the self-assessed PV knowledge. Coded from 1 (low) to 10 (high) the respondents declare on average a good level of knowledge, equal to 6.3. Tested with specific questions about the market prices of PV systems, those who declared to have an above-average PV knowledge provided to a large majority (76%) a correct answer. The same test applied to BS knowledge showed that the self-declared and the actual knowledge of BS systems is lower than that of PV (average knowledge equal to 5 and 56% of those who declared to have an above-average BS knowledge provided a correct answer).

The trend of residential PV prices, illustrated in Figure S1, is based on the following sources:

- Portale Energia: a website dedicated to document the prices of the main energy sources (https://www.portaleenergia.com/costo-fotovoltaico-6-kw/
- Rinnovabili.it: a website collecting data on the environmental sustainability (https://www.rinnovabili.it/energia/fotovoltaico/fotovoltaico-2020-prezzi/)
- Le previsioni dei Prezzi dei pannelli fotovoltaici per il 2021 - Pannelli Solari Prezzi
- ANIE Rinnovabili: the association that within ANIE Federation brings together companies operating in the renewable electricity sector, representing the entire supply chain: from technology and plant manufacturers to service providers and energy producers.
- Solar Price Index (pvxchange.com): an online magazine that publishes a current price index on the development of wholesale prices of solar modules, differentiating between the main technologies available on the market.
- [16] reports energy transformation pathways with specific reference to solar PV and investigates deployment, investment, technology, grid integration and socio-economic aspects.

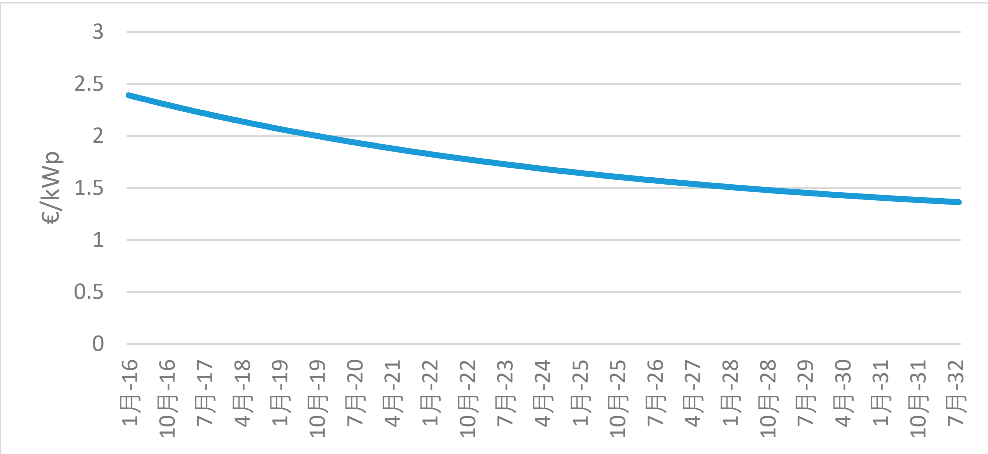

Figure S1 – Evolution of residential PV price in Italy

The trend of BEV ownership rates, illustrated in Figure S2, is based on [15] who provide a simulation of the potential uptake of electric vehicles in Italy up to the year 2030, as a base for transport and energy planning by public and private decision makers. We develop a hybrid model, integrating an agent-based approach for the demand module and a system dynamics approach for the supply module. The demand module is parametrized with data derived from a stated-choice survey to car user (N = 1521), representative of the Italian population. The supply module interacts with the demand module and incorporates the available data on the evolution of battery production costs. Because of the characteristics of the stated choice data, the model is parametrized with data relative to the small-to-medium sized car segment only, and does not include PHEVs. Word-of-mouth and advertisement induce a growing number of potential buyers to include BEVs in their choice set. Car buyers choose between the two propulsion systems based on the relative utility. We estimate that in the period 2019-2030 BEVs will gradually overtake conventional vehicles (CVs) in Italy. In terms of annual registrations, the share of BEVs will be equal to that of CVs in April 2026. By the end of 2030, BEVs will represent more than 90% of new sales. A total fleet of more than 7 million BEVs will be on the Italian roads by 2030, i.e. about a fifth of the Italian car fleet. Scenario analysis lead us to conclude that BEV subsidies are important but that they are likely sub-optimal.

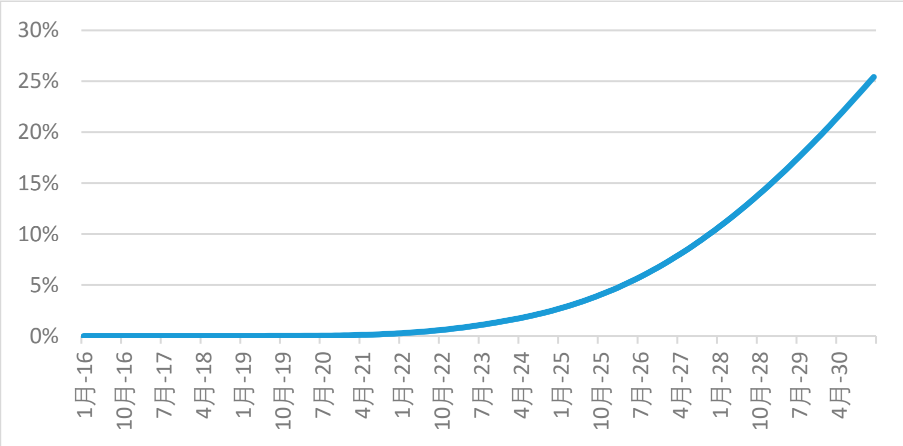

Figure S2 – Percentage of BEVs in the Italian car fleet in the period 2016-2030

The trend of residential BS prices, illustrated in Figure S3 is based on the following sources:

- [17] reports costs and markets to 2030 of electricity storage and renewables.
- Solar Choice: a website that publishes monthly their Home Battery Storage Price Index. (https://www.solarchoice.net.au/blog/battery-storage-price/)
- Clear Energy Reviews compares the main available home battery systems: Home solar battery systems - Comparison and costs — Clean Energy Reviews
- RSE-ANIE Libro Bianco 3.0 sui sistemi di accumulo (Libro Bianco 3.0 sui sistemi di accumulo - Energia (anie.it))

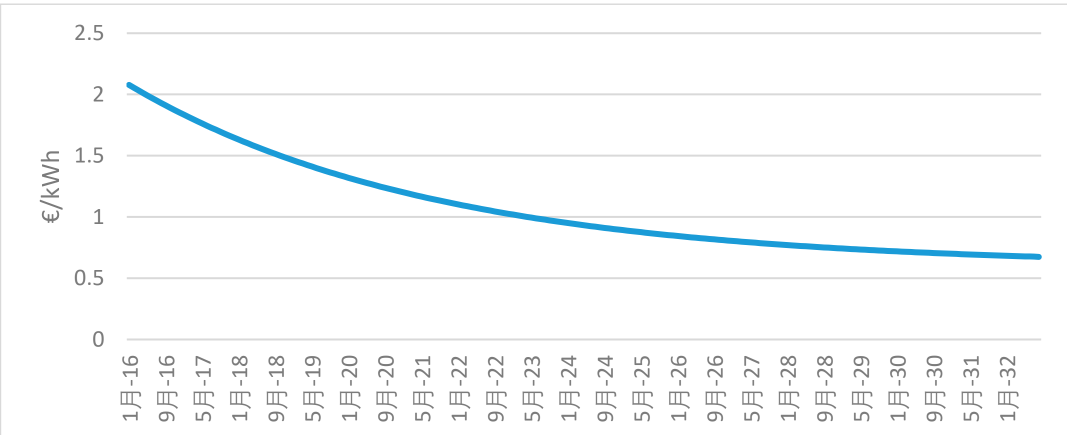

Figure S3 – Evolution of residential BS price in Italy

Table S3 - Assumptions on socio-economic characteristics of the Italian population

Socio-demographics	Distribution at the national level
Age	Under 30: 15% of the Italian population over 18 years of age [18]
Education	89% with a high-school diploma; 11% with a university degree [18]
BEV ownership	Actual ownership level in 2016 and 2019 equal to 0% and 0.03%, respectively.
PV knowledge	Coded 1 (low)-10 (high): 2 (7%), 3 (9%), 4 (7%), 5 (9%), 6 (18%), 7 (16%), 8 (16%), 9 (7%), 10 (11%)

Table S4: Assumptions on social interaction

Word-of-mouth channel (21%)	Frequency of social contact/month: 0 (17%), 0.2 (50%), 1 (26%), 4 (8%) Number of social interactions/month: 0 (5%), 2 (57%), 5 (20%), 7 (18%)
Promoters channel (79%)	Frequency of social contact/month: zero (17%), 0.2 (50%), 1 (26%), 4 (8%)

4 Econometric results

We report in Table S5 the estimates of the attributes parameters obtained differentiating between the utility function of the current PV owner and non-PV owners.

Table S5 – Utility coefficients of PV and non-PV homeowners

Attributes	Non-PV homeowners coefficients	PV homeowners coefficients
asc_grid	-0.113 (0.476)	-0.131 (0.476)
asc_PV	-0.65*** (0.201)	-0.753*** (0.201)
asc_PVBS		
fiscal	0.031*** (0.004)	0.036*** (0.004)
price	-1.072*** (0.22)	-1.242*** (0.22)
warranty	0.074*** (0.011)	0.086*** (0.011)
brand	0.28** (0.134)	0.324** (0.134)

5 Validation of ABM

[19] distinguish between six types of validation: conceptual, internal, external, cross model, data, and security. Conceptual validity refers to the adequacy of the underlying concepts in characterizing the real world. Internal validity refers to the correctness of the computer code. External validity refers to the adequacy and accuracy of the computational model in matching real world data. Cross-model validation [20] is the degree to which two models match. Data validity concerns data accuracy and adequacy for addressing the issue of concern. Security refers to the issue of providing adequate safeguards or assurances against tampering with the model.

[21] integrates such concepts by outlining four validation steps: grounding, calibrating, verifying, and harmonizing. Grounding of a model involves discussing why the model is reasonable, what its limitations and scope conditions are. Calibration consists in an iterative process in which one or more model characteristics are altered to ensure that the model output matches reality. Verification consists in comparing the results of the model with those obtained by other models. Harmonization aim at demonstrating that the assumptions made in the model adequately correspond to the real world.

[22] focused on economic theory and examined three important approaches for ABMs applied to economic issues: indirect calibration, the Werker-Brenner approach, and the history-friendly approach. Indirect calibration is an approach where empirical validation is conducted at an aggregate level by focusing on stylized facts or statistical regularities. The Werker-Brenner approach hinges around the concept of “abduction”, a process that seeks to describe and explain empirical facts in terms of their underlying structures. The history-friendly approach seeks to bring modelling in line with the empirical evidence.

[23] distinguish between micro-face, macro-face, empirical input, and empirical output validation. Micro-face validation is the process of making sure that the mechanisms and properties of the model “on face” correspond to real-world mechanisms and properties. Macro-face validation checks whether the aggregate patterns of the model “on face” correspond to real world patterns. In both type of validations, no data are directly compared to the model (an additional level of validation can be gained by having experts review the model “on face”). Empirical input validation is the process of ascertaining that the data being input into the model are accurate

and bear a correspondence to the real world, while empirical output validation involves comparing the output of the implemented model with the real world.

6 Data for calibration

Based on ISTAT census 2001 in Italy there are 9,280,041 buildings, where 1 or 2 families live, 6,541,746 and 2,738,295 respectively; and 1,971,914 buildings host 3 or more families. The number of photovoltaic installation is with less than 20 kW in 2019 is equal to 811 thousand, so that is 8.75% of the houses are equipped with a PV system [24]. It is possible to calibrate the model only from 2016 onwards since, although rooftop PV were a well-established product, BS were not available in the market. The iconic Powerwall, the rechargeable lithium-ion battery stationary energy storage products manufactured by Tesla, Inc., was announced in 2015. In October 2016, Tesla communicated that nearly 300 MWh of Tesla batteries had been deployed in 18 countries. The Powerwall 2 was unveiled in October 2016. To date, BSS is offered by many brands including Sonnen, LG, Varta and ZCS Pylontech. The available real world observations on PV installations are drawn from the Gestore dei Servizi Elettrici (Manager of the electric services) reports.

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