ABSTRACT

This paper aims at proposing a methodological approach to identify the minimal contents for a future solar photovoltaic (PV) roadmap in Argentina, focusing on the actions required to reach a high penetration scenario until 2030. Argentina has been facing energy supply shortages caused by a combination of increasing in energy demand and government inability to meet the additional demand on time with the available resources (mainly fossil fuels). Although versatile and scalable, Solar PV technology has been receiving low incentives from Argentinean government. Two literature’s perspectives - the functional perspective of technological innovation systems and prospective studies (mainly normative scenarios and roadmaps as a planning tool) – were applied to set the proposed high penetration scenario up to 2030. Stakeholders and expert’s visions, global path of technology and a local prospective study made by local experts in 2012 were used to validate the proposed scenario. As main results, a way to build a future solar photovoltaic scenario in urban and suburban areas is described; minimal contents that can orient a local roadmap construction are defined, and the necessary improvements of solar PV framework in Argentina (both regulatory and promotion aspects) are pointed out.

Key words: solar photovoltaic, high penetration scenario, Roadmap, technology diffusion.
1. INTRODUCTION

Argentina has been facing energy supply shortages caused by a combination of sharp increasing in energy demand and government inability to meet the additional demand on time\(^1\). Furthermore, the electricity mix has tended to be highly dependent on fossil fuels, impacting on both environment and trade balance.

Renewable energy technologies\(^2\) may address these two problems contributing to energy sustainability. For more than 16 years this issue has been in the policy agenda in Argentina. Nevertheless, the effectiveness of instruments adopted by local authorities to support renewable energies should be questioned for at least two reasons: First, the penetration of renewable energy in the local electricity matrix has been very low – just 1% of installed capacity in 2013 (CAMMESA, 2014). Second, the Argentinean framework to support renewable energy adoption has not been able to articulate all sides of technology deployment (R&D&D, market management, financing, etc.).

Argentinean approach for renewable energies support has been favoring large and centralized plants integrated to the grid and mature technologies (e.g. wind power). Distributed generation has not been promoted, despite the advantages of early adoption of technologies like solar photovoltaic (PV) (e.g. to improve electric power service in areas which do not have reliable power supply and delay medium–term maintenance and upgrade investments)\(^3\). Since December of 2015 a new administration took office and changes in policies can be expected, according to recent decisions in the Energy Ministry – eg. a secretary for renewable energy has been appointed and new laws has been implemented.

The current Argentinean energy planning does not embrace solar PV technology and studies on renewable energy do not bring evidences that solar PV will take a relevant role in the future electricity matrix. This occurs despite of the evidence of a great solar generation potential in the country when compared to those of has been leaders in the deployment of this technology. Thus, countries such as Germany or Italy have a solar radiation of about 900-1200 kWh/m\(^2\) and 1400-1700 kWh/m\(^2\), respectively, while most of Argentinean territories rose to 1400-2500kWh/m\(^2\).

This scenario underlines the need of planning tools that can guide local government to adopt this energy source in a scale that could contribute to reach more ambitious targets in installed

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\(^1\) As an example, according to information provided by a local newspaper, in the last summer hundreds of people were affected by power outages. Just in the month of February over 550,000 people per day suffered by power cuts in the State of Buenos Aires. Available on: http://www.lanacion.com.ar/1871941-cortes-programados-luz-edesur-edenor-energia

\(^2\) Regarding this paper subject, we will not include large hydropower (above 30 MW) as a form of renewable source of energy.

\(^3\) Indeed, grid-connected PV systems have had a worldwide accelerated growth in last decade – global installed capacity increased from 3.7 GW installed in 2004 to 139 GW in 2013 (REN21, 2014). Technology diffusion has accelerated costs reduction of the PV technologies – as cumulative volume of production increased twice, and price was reduced by 22% (IRENA, 2012).
capacity or energy consumption when it comes to renewable technologies. Thus, this paper aims at:

- Proposing a methodological approach to identify the minimal contents that a future roadmap for solar PV in Argentina should include, focusing on the actions required to reach a high penetration scenario until 2030; and

- Pointing out the aspects that must be improved at national policy framework to support adoption of solar PV in Argentina.

International experiences on roadmaps development are taken into account, along with the theoretical framework of functions in technology innovation systems (TIS)\(^4\). Both of them intend to accelerate the diffusion of a specific technology upon a previous decision or consensus.

The paper is organized in three parts including this introduction. Second section highlights some aspects of literature and the methodology we based on which we aim to construct a pathway of high penetration of solar PV in Argentina until 2030. Third section presents the results of application of suggested outlines in our methodological approach. Finally, conclusions remark the main findings resulted of methodology application.

### 2. METHODOLOGY

#### a. Literature survey

This paper is based on two approaches: (i) roadmaps as an orientation for technological planning\(^5\), and (ii) functions in innovation systems as a guide to policy actions.

#### i. Roadmap as an orientation to technological planning

A careful planning process requires the employment (in a long-term perspective) of limited resources to achieve the highest priorities. Studies on scenarios building contribute to that process. These studies are addressed from two main approaches: forecasting and backcasting. While first one deals with the question of what *could* happen (strategic scenarios), backcasting is related to what *should* happen (normative scenarios). The last one assumes a desirable visions of future – based on a consensus, suggesting required pathways to reach such futures (Vergragt & Quist, 2011).

Backcasting process entails a reflexive and iterative methodology that involves experts, stakeholders and policymakers in order to develop a shared vision that will work as a guide to influence actors and networks who will adopt that vision (Vergragt & Quist, 2011). Roadmaps can

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\(^4\) For the purpose of this paper, TIS is understood as a network of actors that develop and implement a specific technology, within their institutional context (Carlsson & Stankiewicz, 1991).

\(^5\) Although technological roadmaps were originally used in private sector, they were also applied to orient the formulation of technology and innovation policy (Londo et. Al, 2013).
be considered future studies that follow this concept. Roadmap process works as an important communication tool among different participants involved in its development (Lee, Kim & Phaal, 2012). Bringing together participants with different profiles increases understanding about the functioning, advantages and disadvantages of a given technology (expert opinions), and engages actors that will eventually support and deploy it (i.e. policymakers and stakeholders).

**ii. Functions in innovation systems as conceptual framework to policy actions**

Deployment of renewable energy technologies faces different types of barriers (institutional, economic, technical and cultural) (Kemp, 1997; Johnson & Jacobsson, 2000; Bergek & Jacobsson, 2003). A set of “functions in innovation systems”, that would speed up technology diffusion, have been proposed (Johnson, 1998; Jacobsson & Bergek, 2004; Jacobsson, Andersson & Bångens, 2004; Bergek, Hekkert & Jacobsson, 2008; Bergek et al., 2008; Bergek, Jacobsson & Sanden, 2008; Jacobsson & Bergek, 2011). The functions range from knowledge development and diffusion to legitimation and development of positive externalities.

Based on this set of functions, governments should be able to identify those barriers that block the formation and development of innovation systems and take action (through adoption of policies) to overcome such obstacles. Authors like del Rio & Bleda (2012), Jänicke (2012) and Lizuka (2014), for instance, have applied functional perspective in innovation system to analyze policies effects on triggering or blocking renewable energy technologies diffusion process (“virtuous” or “vicious” circles). Del Rio & Bleda (2012), in particular, have identified the innovation mechanisms that could be boosted by renewable electricity instruments (specifically feed-in tariffs –FIT–, quotas with tradable green certificates –TGCs–and bidding/tendering schemes), contributing to fulfillment of TIS functions and interactions between mechanisms and functions. These findings are taken as a framework for this research, since they corroborate the need of adopting different types of policy instruments to influence successful functioning of TIS.

**b. Methodological approach**

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6 Authors such as Kostoff & Schaller (2001) y Lee, Kim, & Phaal (2012) take the roadmap definition proposed by Galvin (1998): “Roadmaps provide an extended look at the future of a chosen field of inquiry drawn from the collective knowledge and imagination of the groups and individuals driving change in that field. Roadmaps include statements of theories and trends, the formulation of models, identification of linkages among and within the sciences, identification of discontinuities and knowledge voids, and interpretation of investigations and experiments... Roadmaps communicate visions, attract resources from business and government, stimulate investigations, and monitor progress. They become the inventory of possibilities for a particular field...”

7 In the latest proposals from this authors, the following functions has been considered: i) Knowledge development and diffusion; ii) Entrepreneurial experimentation; iii) Influence on the direction of search; iv) Resource mobilization; v) Market formation; vi) Legitimation; and vii) Development of positive external economies (Bergek, Hekkert & Jacobsson, 2008; Bergek et al., 2008; Jacobsson & Bergek, 2011).
Guides prepared by IEA (2010, 2014b) consider five elements for a successful roadmap: i. Goals, ii. Milestones, iii. Gaps and barriers, iv. Action items, and v. Priorities and timelines. Following these elements and the structure described by Kostoff and Schaller (2001) – a technological roadmap should include a retrospective and a prospective component. Hence, we suggest the following steps to build a high deployment scenario in Argentina:

(i) **Establishing initial conditions** such as type of roadmap, panel composition and pathway desired.
   a) Experts, stakeholders and policymakers from different backgrounds should be included in the panel;
   A high level of penetration should be defined, taking as a reference either a governmental goal for technology diffusion or a local prospective study, which includes projections for solar PV technology in the country.

(ii) **Developing a retrospective component** (strong emphasis on barriers analysis):
   a) Based on international experience, data of existing barriers ought to be collected, focusing (but not limited to) on those which are critical for incipient markets and have to be taken into account in short-term. The panel attendants should evaluate significance level of identified barriers and other possible bottlenecks.
   b) An evaluation should be made of barriers’ relative significance.

(iii) **Developing a prospective component**:
   a) Scoped variables (milestones) ought to be identified to be included in desired pathway, based on barriers analysis and revision of solar PV roadmaps published overseas.
   b) Actions, priorities and timelines should be proposed for each scoped variable in order to achieve the desired high deployment pathway.

3. RESULTS AND DISCUSSION
   a. Establishing initial conditions

A combination of action-based and pathway-based technology roadmaps was taken as a reference, according to taxonomical approach suggested by Geum & Park (2013).

Interviews to 17 experts – policymakers and stakeholders from heterogeneous institutions – were conducted between October 2012 and May 2013 for the panel composition: first round was a face-to-face interview and the second one was by email. A multiple-choice questionnaire – like in Delphi method (Godet, 2000) – and chi-square distribution were applied to analyze interviewees’ answers. Interviews were carried out individually or as a group (when they belonged to the same workgroup). The interviewees were classified considering the level they could eventually take part

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8 Barriers analysis, usually included in TRMs, has been recognized in literature (i.e. McDowall & Eames, 2006) as one of the strengths of the TRMs in comparison with other future studies.
in a roadmap process in Argentina.

In order to analyze their answers, the panel was distributed in two sets (Table 1): i) those who could influence or take part in technology diffusion process (Sample S, stakeholders and policymakers); and ii) those who have had in-depth experience in technology deployment (Sample E, experts).

**TABLE 1. List of Interviewees divided into two samples**

<table>
<thead>
<tr>
<th>Sample S</th>
<th>Sample E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three members from Renewable Energies Policy Committee at Secretary of Energy</td>
<td>A secretary from Argentine Renewable Energy Chamber who is also a solar energy firm owner</td>
</tr>
<tr>
<td>Three representatives from Planning and Forecast Committee at Secretary of Energy</td>
<td>A coordinator from Solar PV Commission at the Argentine Electro technical Association (AEA)</td>
</tr>
<tr>
<td>A member from the group which is in charge of energy policies at Ministry of Science and Technology</td>
<td>A researcher from one of the former national groups on solar research</td>
</tr>
<tr>
<td>A renewable energy advisor from Ministry of Science and Technology</td>
<td>A researcher from a Spanish university</td>
</tr>
<tr>
<td>A director from National Regulatory Agency</td>
<td>Three international experts in solar PV with knowledge and/or expertise in Argentina</td>
</tr>
<tr>
<td>A director and two members from the group which are in charge of new technologies areas at two national energy distribution companies</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: research data, 2015

Concerning the high deployment pathway desired, there were no targets or estimates for solar PV diffusion published by local government agencies that could be taken as a reference, though a local prospective study led by private sector was issued in 2012 (CEARE et al., 2012) and updated in 2014. This prospective study developed twelve normative scenarios for the electricity generation in Argentina taking into account bulk energy generation technologies - i.e. fossil, nuclear and renewable. Six of these scenarios included solar PV, and two out of these were chosen

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9 The Secretary of Energy foresees 9% of contributions by all the renewable sources until 2030, without discriminating the share of solar PV, but assigning wind and small hydro a leading position.
as a reference\textsuperscript{10}. Table 2 presents the cumulative installed capacity proposed until 2030, obtained as the average of the values presented by these two scenarios: a total of 4.574 MW installed capacity from solar PV has been projected, which will represent 8% of the total installed capacity by 2030. This is a minor fraction of the technical potential of both centralized and distributed renewable energy generation; 100% of renewable electricity for Argentina has been already proposed in recent scenarios where distributed PV generation alone is even higher than this figure.

### Table 2. Cumulative installed capacity from solar PV until 2030.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cumulative installed capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>16.3</td>
</tr>
<tr>
<td>2015</td>
<td>308</td>
</tr>
<tr>
<td>2018</td>
<td>550</td>
</tr>
<tr>
<td>2020</td>
<td>755</td>
</tr>
<tr>
<td>2023</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td></td>
</tr>
</tbody>
</table>

\textbf{Source:} research data, 2015

\textbf{b. Developing a retrospective component: Barriers analysis}

Table 3 summarizes different types of barriers related to solar PV technology deployment faced by countries.

### Table 3. Barriers faced by countries in the deployment of solar PV technology

<table>
<thead>
<tr>
<th>Type of Barrier</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Related to grid faults that may increase with incorporation of distributed PV. There are issues such as complex management of bi-directional power flows and reactive power; and lack of infrastructures to properly support introduction of decentralized generation because they have been built to dispatch electricity produced by large centralized power plants.</td>
</tr>
<tr>
<td>Economic</td>
<td>Related to financial constraints, such as lack of financial options suitable for solar PV technology (i.e. high capital expenditure, long payback periods) and support schemes for technology deployment.</td>
</tr>
<tr>
<td>Institutional</td>
<td>These include barriers such as limited institutional understanding of technology; incomplete legal framework to support renewable energy systems or even to enable connection of PV systems to the grid; insufficient skilled personnel on PV projects management and installation; long lead times for capacity allocation; and a limited training capacity.</td>
</tr>
</tbody>
</table>

\textsuperscript{10} These scenarios were chosen because they include solar PV technology in projections until 2030 and final capital investments required to accomplish them were similar to those did not consider the solar PV in projections. In addition, there is no other local study, public or private, in which solar PV technology plays a significant role.
The relevance of barriers presented in Table 3 depends on market stage reached by technology. Given the deployment level of solar PV technology in Argentina, seven barriers – related to incipient markets – were presented to interviewees (which suggested five more).

Inspired by the approach proposed by Zhang, Shen, & Chan (2012), interviewees were asked to categorize barriers through a Likert’s scale and, after that, a mean score was calculated (see Figure 1). Given the different profiles of panel composition attendants (experts, policymakers and stakeholders, corresponding to Sample S and E in Table 1), Mann–Whitney U test was applied. Only 12 responses (six from each sample) were analyzed because of either a consensus among participants of an interview group (see Table 1) or absence of opinion of some interviewees.

**FIGURE 1.** Barriers and levels of importance assigned by the interviewees

*Source:* research data, 2015

Developing a prospective component:

(i) **Scoped variables to be included in the desired pathway (milestones)**

Three steps were followed to select the scoped variables to be included in the desired
pathway:

(i) Identification of barriers with highest rank in barriers analysis, considering both the opinions and significance levels given by interviewees and the learning from the international experience.

(ii) Identification of variables from international roadmaps – focused on solar PV technology or that have included the technology in their projections –, which were not included in the barrier analysis.

(iii) Selection of variables that could trigger specific TIS functions and be developed in a roadmap for solar PV.

Tables 4 and 5 presents the scoped variables resulted from these steps and the function that were associated to each one.

TABLE 4. Scoped variables identified based on barrier analysis

<table>
<thead>
<tr>
<th>Scoped variable</th>
<th>TIS function related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical regulation for distributed PV projects grid access</td>
<td>- Market Formation</td>
</tr>
<tr>
<td>Administrative procedures and financial systems suited to PV conditions</td>
<td>- Resource Mobilization</td>
</tr>
<tr>
<td>Tariff regulation and instruments to promote distributed PV projects and creation of niche markets</td>
<td>- Resource Mobilization</td>
</tr>
<tr>
<td>Distributed PV projects as a priority on political agenda</td>
<td>- Guidance of the search</td>
</tr>
<tr>
<td>Training programs on PV projects management and installation</td>
<td>- Resource Mobilization</td>
</tr>
<tr>
<td>Adoption of technologies that will enable increase of PV projects</td>
<td>- Entrepreneurial experimentatoin</td>
</tr>
<tr>
<td></td>
<td>- Market Formation</td>
</tr>
</tbody>
</table>

Source: research data, 2015
TABLE 5. Scoped variables identified based on roadmap analysis

<table>
<thead>
<tr>
<th>Scoped variable</th>
<th>TIS function related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local manufacturing and links along the value chain</td>
<td>- Guidance of the search</td>
</tr>
<tr>
<td></td>
<td>- Resource Mobilization</td>
</tr>
<tr>
<td></td>
<td>- Market Formation</td>
</tr>
<tr>
<td></td>
<td>- Legitimation</td>
</tr>
<tr>
<td>R&amp;D&amp;D financing</td>
<td>- Knowledge development and diffusion</td>
</tr>
<tr>
<td></td>
<td>- Influence on the direction of search</td>
</tr>
<tr>
<td></td>
<td>- Entrepreneurial experimentation</td>
</tr>
<tr>
<td></td>
<td>- Resource Mobilization</td>
</tr>
<tr>
<td>Technology competitiveness (grid parity)</td>
<td>- Market Formation</td>
</tr>
</tbody>
</table>

Source: research data, 2015

i. Actions, priorities and timelines

The pathway was drawn (Figure 2) considering the desired high deployment pathway and scoped variables analyzed above (2.3). Timelines for each scoped variable and effort level required in the moment the variable would take place were also taken in account.

FIGURE 2. Pathway for high solar PV deployment until 2030 in Argentina

Source: research data, 2015
Technical regulation for distributed PV projects’ grid access

No regulation to enable grid access of distributed PV projects in urban and suburban areas was available in Argentina by the time of the interviews – the ENRE (National Regulatory Entity for Electricity) had to evaluate project by project. The absence of a proper technical regulation and standardization is a critical barrier to technology deployment since the utilities (responsible for management and maintenance of distribution grid) may refuse to connect distributed PV projects. The working group on regulation of grid access for distributed PV led by the AEA is an important milestone, but we consider the outcomes have to be presented by AEA as soon as possible in order to guide the formulation of a regulation for PV connection before 2017. This process must not be postponed further if the goal is to achieve the desired pathway in Argentina.

Tariff regulation and other incentives to promote distributed PV projects

The Law 26.190/2006 (Regime to support the Use of Renewable Energy for Electricity Production) was the turning point for promotion of renewable energy in Argentina, specially regarding integration to national grid\(^1\). According to Law 26.190/2006, 8% of electricity demand must be supplied by renewable energy until 2016. In order to accomplish this goal, Secretary of Energy set in 2006 two instruments as an attempt to foster the adoption of renewable energy:

(i) a subsidy on electricity price for wholesale market and public services\(^2\) – Energy sources (encompasses by Law 26.190/2006 )\(^3\) would receive an additional income on market price of (Argentinean pesos) 0.015/kWh for 10 years (since the data of installation), except in case of solar PV (0.09/kWh for 15 years);

(ii) two financial instruments – one to delay the payment of the Value Added Tax (for 10 years) and other to accelerate depreciation of capital assets.

These instruments were not enforced since it was realized they did not provide enough incentives. In consequence, Secretary of Energy launched two new instruments:

a. GENREN tender process - a bidding scheme implemented in 2009 by ENARSA (Energía Argentina Sociedad Anónima), a State-owned company, wherewith select projects of renewable

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1 Before that, there was just Law 25.019/1998 (National Regime of Wind and Solar Energy), which enabled connection of wind and solar energy to the grid.
2 Two types of consumers can be distinguished in Argentina: large customers and tariff customers (divided in residential or commercial); and two associated markets: an Electrical wholesale market and a spot market.
3 It includes: wind, solar (thermal and photovoltaic), geothermal, tidal, small hydropower (below 30MW), biomass, landfill gas, sewage treatment plant gas and biogases.
energy are benefited by a 15 years’ contract and feed-in-tariff scheme. In 2010, 895 MW of installed capacity of renewable energy were allocated through this mechanism (754 MW for wind power, 110 MW for biomass, 10 MW for small hydro, and 20 MW for solar PV)\(^\text{14}\). Large solar PV has been marginally supported under GENREN tender process, representing just 2.2% of granted installed capacity (equivalent to the 20 MW, although only 8 MW were reported by CAMMESA by the end of 2013).

b. Administrative resolution (Res.108/2011) from Secretary of Energy, conceived to be a more flexible instrument than GENREN tender process: the contract for renewable energy projects under this resolution also last 15 years, but payment for energy production are calculated by the Secretary of Energy based on costs and revenues. Results of Res.108/2011 are not available yet.

It should be noticed all these instruments were focused on large plants and, even more important, on distributed PV projects in urban and suburban areas, as well as distributed generation of any electricity source, were not envisaged in the Argentinean framework. IRESUD consortium\(^\text{15}\), a public demonstration and a field trial projects, was the first initiative to promote distributed solar PV Argentina. However, although IRESUD consortium and some efforts from local authorities and other preliminary activities related to distributed solar PV, adoption of this energy source is incipient and requires a proper framework. A proposal to set both technical and tariff regulatory frameworks for distributed solar PV in Argentina was also included in IRESUD consortium goals, but a regulation proposal as well as a specific law for distributed generation are still being elaborated. There is also a lack of regulatory framework and technical institutions for the assessment of key technologies, even though local capabilities have been developed both for space and terrestrial applications in CNEA.

Related to tariff regulation, it should be noted the average price of electricity in the country was significantly lower in the last decade compared to the average price from the countries that stand out in adoption of renewable energy technologies\(^\text{16}\), given mainly to Argentinean subsidy policy, which added another obstacle to distributed solar PV deployment. In face of that, we point out – for the proposed high penetration scenario for solar PV – actions regarding regulation (technical and tariff) carried on until now by the IRESUD must continue. We also recommend it take specific steps in order to support distributed solar PV deployment:

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\(^\text{15}\) The initiative was carried out in 2011 by Ministry of Science, Technology and Productive Innovation (MINCyT), co-funding by Argentine Sectorial Fund (FONARSEC) and developed under a local public-private consortium (IRESUD). A follow-up project IRESUD II, including demand side management and smart grids, started in late 2015 in Centenario, a small city in Neuquen Province.

\(^\text{16}\) While in Germany, for instance, electricity price for medium size household consumers during the first semester of 2013 was around US$380 MWh, in Argentina the wholesale electricity price during the same period was US$80 MWh. Prices calculated according to http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Electricity_and_natural_gas_price_statistics and http://portalweb.cammesa.com/memnet1/Pages/descargas.aspx, respectively. Since January 2015 subsidies are being removed both for power generation and consumers.
(i) settlement of a proper tariff regulation as soon as possible, which must include new definitions and incentives to support the technology adoption in the country;
(ii) update, gradual reduction and final elimination of the incentives as the technology improves and reaches competitiveness (see next variable).

Based on international experience, we argue it would be necessary to combine tariff instruments with incentives to investment, especially in the early years of proposed scenario (Figure 2, above), considering high initial costs of solar PV technology in Argentina could be a relevant barrier as we discuss below.

Grid parity and creation of market niches

Grid parity was the selected variable to analyze technology competitiveness on both wholesale and retail market, considering this is a critical issue to Argentina moves toward higher levels of installed capacity\(^\text{17}\). At pathway outlined in Figure 2, we proposed different grid parities would be achieved between 2020 and 2024, period when highest concentration of interviewee’s answers was observed. As show in Figure 2, before achieving grid parities, it is necessary to develop some important variables to overcome the barriers identified in Figure 1. One of them is creation of market niches, since order to increase its competitiveness the technology depends on a protected space for its successful deployment\(^\text{18}\).

So, it would be necessary to manage different market niches to trigger diffusion and increase penetration of PV in Argentina, starting by demonstration and trial projects (e.g. pilot projects) and stepping forward to wider adoption. The following guidelines should be considered:

Early stage (up to 2020): implementation of solar PV at urban level (which would reduce distribution costs and postpone investments in transmission lines) should be prioritized vis à vis adoption of large plants (considering the incorporation of solar PV has been done through them) from beginning of proposed scenario. Since technical and tariff regulations will be still on elaboration, urban diffusion of solar PV may be limited to demonstration and trial projects at least until 2017 (see Figure 2) – for instance those installed in public facilities (as has been done by IRESUD consortium).

Later stage (beyond 2020): once a proper regulatory framework has been settled, solar PV could also be included in government housing programs and adopted by utilities for ancillary services; and as soon as the technology learning process speeds up, participation of investors/commercial and householder consumers (“prosumers”) would increase as well.

\(^{17}\) Grid Parity is a common measure for evaluation of solar PV competitiveness compared to other electricity sources and depends on different local aspects, such as local technology cost, place conditions where projects are carried out and electricity tariff - which in turn depends on PV project scale (Bazilian et al., 2013). Thus, grid parity should be considered regarding wholesale, residential or commercial tariff respectively.

\(^{18}\) According to Stamboulis & Tsoutsos (2002), identification of proper market niches should enhance learning spaces for new renewable energies technologies in main energy systems. For solar technology, market niches could be created based on its advantages – i.e. the distributed generation - over those of the other technologies available.
Distributed PV projects as a priority on political agenda

The Argentinean energy planning does not indicate any prospect to include solar PV in the national electricity matrix.

Lack of political will to promote PV projects was one of barriers identified by interviewees and considered to have a certain level of importance\(^{19}\). Some of interviewees argued the political will does exist, pointing out the latter actions taken by the government (i.e. GENREN program and Res. 108) as evidences. Other interviewees, mainly those from Sample E, agreed on instruments implemented by Secretary of Energy are not enough to promote a high level of PV penetration since they encourage adoption of renewable technologies sources that have already achieved higher levels of adoption (i.e. wind technology). Overall, interviewees claim for both to include a specific goal for solar PV technology in the national energy planning and to set the technology as a priority at the political agenda.

For a high penetration scenario, we consider the national energy planning has to incorporate a specific goal for solar PV while technology diffusion does not take off in Argentina. A goal for solar PV was not adopted before 2016 as all initiatives that had been taken by Secretary of Energy were focused on achieving the goal of 8% for the whole of renewable sources established by the Law 26.190. In 2016 a new Law (Law 27.191) updated targets for renewable energy and the implementation is calling for differentiated auctioneers and regimes for each renewable technology. The new target, 20 % supplied by renewable sources before the end 2025, is in line with the scenario put forward in this paper.

Administrative procedures and financial systems suited to PV conditions

According to interviewees, support programs adopted in Argentina and local financial system do not embrace all characteristics of projects on solar PV technology. Thus, if a high penetration of solar PV is desired, it will be necessary to adjust the local financial systems and to improve the permitting procedures process related to the PV projects\(^{20}\).

Lack of financing sources is the barrier which interviewees’ opinions were highly lined up with literature, especially concerning to economic barriers (see Table 3). Therefore, we consider the following elements are necessary for the whole period covered by the proposed scenario and afterwards:

\(^{19}\) It is also the only case in which it has not been possible to reject the null hypothesis when the Mann-Whitney U test was calculated at the .05 level.

\(^{20}\) IRENA (2014b) remarks the importance of institutional feasibility related to institutional and human capacity required to implement and monitor interventions. Moreover, studies have shown the number of transactions might be higher in PV distributed generations schemes (Richter, 2012), requiring more efficiency in administrative procedures.
The joint effort from both government and financial institutions. The first manage support instruments and the last ones would finance selected projects under these instruments. Notwithstanding, financial ones do not know particularities of new energy technologies, which currently has made it necessary to search for external funding.

The settlement of standardized and coordinated administrative procedures at different government levels (national, regional and local) to speed up the time that is currently being taking to allocate new installed capacity in renewable energy – which will affect solar PV. For instance, the time taken to allocate new capacity during tendering processes (GENREN and Administrative Resolution number 108, see section 2) exceeds the time required by investors to keep their plans in Argentina with a reasonable level of risk.

Adoption of technologies that will enable the grid access of PV projects

In addition to amount of solar PV foreseen in the proposed high penetration scenario, other intermittent sources will be integrated to Argentinean grid until 2030- like wind energy, which might have a higher contribution to the electric matrix than that of solar PV. Thus, we consider it will be necessary to adapt and reinforce the current Argentinean electricity system to support introduction of meaningful amount of renewable energy sources, as incorporation of intermittent energy sources to electricity system is highly dependent on the conditions of local grids.

Technologies like bidirectional metering, interconnections, demand-side response and distributed storage should be progressively adopted until 2030, as the percentage of solar PV in energy production along with other intermittent sources increases. According to one interviewee, the Secretary of Energy is analyzing the implementation of these technologies. Since no official results regarding this analysis were published, we assume the process of evaluation and selection that is still carrying on by Secretary of Energy needs to be enhanced in order to implement the deployment of selected technologies.

Local manufacturing and links along the solar PV value chain

Our proposed scenario assumes Argentina should take an active position in local process of technology manufacturing - at least in some parts of solar PV value chain\textsuperscript{21}.

\textsuperscript{21} We take the position that the increase of local solar PV installed capacity through components imports may concentrate employment and tax revenue and R&D capacity and technical innovation abroad, limiting the benefits of incorporation of a new technology in Argentina. On the other hand, deployment of a local industry could enhance social acceptance of technology, since the country would be benefitted by the local and international trade of both components and technologies (Huo et al., 2011).
Regarding local solar PV system manufacturing, we consider the best opportunities for Argentina in short term are in BOS - upstream and downstream links –since those have a high local content. Empirical studies have shown the production of solar PV module has one global price and may not be impacted by national initiatives, while cost reduction in BOS is mostly local and highly dependent on local capabilities and learning processes (see for instance Shum & Watanabe, 2008). Moreover, it is expected the participation of BOS components in total cost of solar PV systems increases as long as module cost reduction continues.  

Besides the focus on BOS components, we consider the creation of local capacity for manufacturing of modules should also be encouraged if the high penetration scenario takes place. In this regard, the contract signed by PSE (an Argentinean utility company from the San Juan province) and SCHMID Group to build a 70 MW PV plant – fully integrated from ingot to module – should be considered as a first step. The country should adopt concrete measures of industrial policy to create local manufacture capacity in modules since relying entirely on technology import is not the best alternative to a developing country with instable economy. In this sense, it is important that national agencies that are responsible for the homologation of technologies have the ability to discern about aspects to be accredited, either for imported or national components – e.g. aging test. It requires efforts not only from the point of view of the administrative procedures, but in the training of the personnel that are part of such organs.
Financing of Research, Development and Demonstration

If a high penetration pathway upon a scenario that also aims at implementing local manufacturing of PV systems is desired, it would be crucial to reduce its costs to reach grid parity\(^{23}\). Thus, based on interviews and analysis of international roadmaps (those mentioned in Table 5), we suggest the following guidelines should be considered on a local R&D&D agenda for solar PV:

Focusing on – but not limiting to –implementing of specific programs to support local development of BOS components (hard and soft), especially in the early stages of solar PV deployment, which implies to prioritize demonstrative and trial projects, amplifying initiatives such as IRESUD consortium. In order to increase technology visibility and penetration, these projects should aim at adapting the technology to Argentinean context, besides analyzing technology operational features, enabling the incorporation of solar PV to local distribution grids and also the identification of new markets applications for solar PV in the country. We point out the financing of demonstrative and trial projects should take at least one decade: period required to deploy new competences and skills and create networks related to the technology (Smith & Raven, 2012).

Financing research projects on module technologies, focusing on technologies of first and second generation, as a mean to keep local capabilities updated and competitive\(^{24}\).

Financing technologies that will enable introduction of solar PV in urban and suburban areas and increase safety and reliability (i.e. those related to smart grid concept): communication, metering, storage, among others technologies).

Financing training programs at different levels and formats (workshops, undergraduate & graduate programs, etc.) to meet the increasing demand for skilled people in solar PV technology in case of higher penetration\(^{25}\).

Although MINCyT lead the financing of these kind of initiatives until now, implementing funds exclusively addressed to solar PV technology, it will be crucial to coordinate efforts with other ministries and governmental agencies, such as Ministry of Energy in order to ramp up the scale of deployment. This is particularly important for urban and suburban distributed generation, since IRESUD will have installed less than 1 MW by the end of 2017.

\(^{23}\) Data on BOS local costs are not available. However, based on the results from IRESUD project, interviewees estimate local cost for BOS components in Argentina is up to ten times higher than current cost in countries that were pioneers technology adoption.

\(^{24}\) According to IRENA (2012), PV cell technologies are usually classified into three categories, depending on the basic material used and their level of commercial maturity: first generation (fully commercial) uses wafer-based crystalline silicon (c-Si) technology; second-generation (early market deployment) are based on thin-film PV technologies; third generation (not yet widely commercialized) includes technologies such as concentrating PV (CPV), organic PV cells, and novel concepts under development.

\(^{25}\) According to interviewees, local demand for skilled personnel has been supplying because of limited number of local solar PV projects, but if technology penetration increases, Argentina might not be able to face the lack of personnel on time.
CONCLUSIONS

Solar PV technology has been outlined as a technology that may have an important contribution to diversification of the Argentinian electricity matrix and to minimize local energy problems. Thus, this paper proposes a methodology to identify the minimal content of a solar PV roadmap in Argentina, identifying the main variables for a high pathway proposal (e.g. technical and tariff regulation, grid parity and creation of market niches, R&D&D financing, local value chain).

Milestones, actions and timelines have been analyzed to depict a possible high penetration scenario, using functions in technological innovation systems to validate the proposed pathway. The following improvements on Argentina solar PV framework were suggested in order to achieve 8% of contribution of solar PV to the electricity matrix in 2030:

Address, first and foremost, institutional changes to reduce technical and tariff regulation’s constraints, improve administrative procedures and financial conditions to solar PV.

Ensure political priority for solar PV projects within R&D&D and energy agendas. Initiatives like IRESUD Consortium must be enlarged and the R&D&D strategy for solar PV must be aligned to energy planning goals elaborated by Secretary of Energy, which nowadays does not set any target to solar PV technology. Setting specific goals for solar PV is mandatory to achieve a high penetration pathway.

Promote local manufacturing of different components along the solar PV value chain to avoid high dependency on technology import and also to generate and improve local absorptive capacities. Argentina is able to follow several technology options (e.g. different levels of integration among production chains). Notwithstanding, the country should focus on BOS components - both on manufacturing and R&D&D - in order to reduce local costs and increase solar PV competitiveness, which may attract new investors (i.e. prosumers), enabling additional power generation.

Consider aspects that may be neglected in the beginning of the deployment, for not being considered central, but that could become a bottleneck as installed capacity in solar PV increases in the country – eg. Training of technical personnel and adoption of technologies that will enable the augmenting of the number of projects in solar PV.

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