# Advancing the policy design and regulatory framework for renewable energies in **Latin America and the Caribbean** for grid-scale and distributed generation

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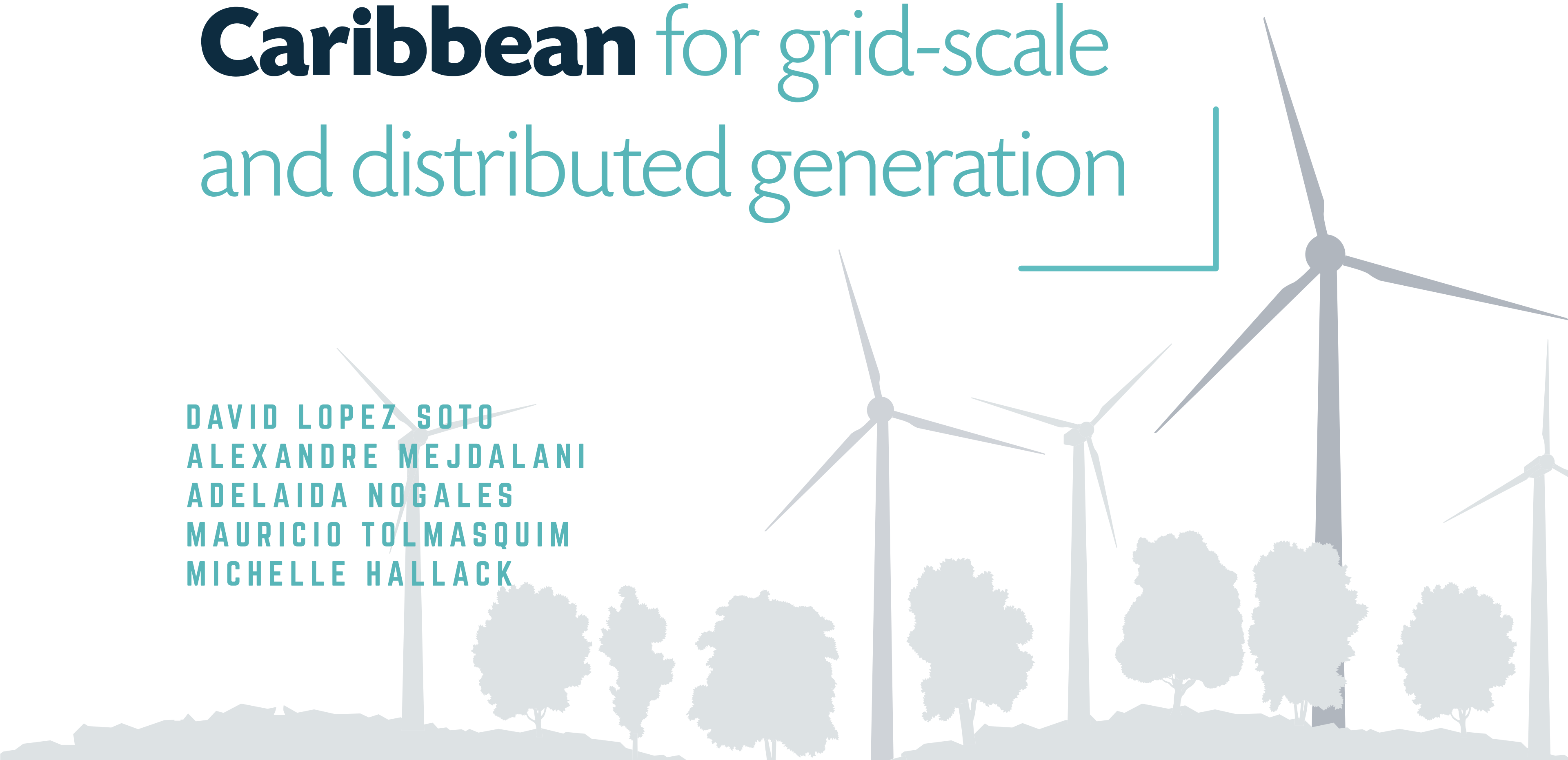


# Contents

# Introduction[1]

The Latin America and the Caribbean (LAC) region holds a comfortable leading place in terms of the share of renewables in the electricity generation matrix, mainly due to the share of hydropower generation, which accounts for 46% of total power generation in 2017 (OLADE, 2018). Despite the share of renewable in the generation mix decreased by 8.2% from 2000 to 2016, the generation output of renewables increased by 51%, in absolute terms, during the same period. This has been a consequence of the decrease of renewables costs and the result of many policies applied in the LAC region. Different kind of policies have been proposed and experienced in the past years on how to stimulate and incentive the private participation on renewable generation, such as non-pricing (quotas and obligations) and pricing instruments for both large and small scale of production (IRENA, IEA, and REN21 2018). However, even if the increase of renewables output was substantial, it is necessary to intensify the LAC efforts in order to achieve decarbonization goals.

When talking about the contrast between distributed and large-scale solutions, we need to consider the scale economy of generation and the network costs associated to the different choices. On the one hand, we have traditional business models with large-scale generators (combining different technologies, with various sources, and providing different services) and extensive networks (transmission and distribution). On the other hand, distributed generation (DG) resources are mounted near the consumption unit. Households, small businesses or small communities can own DG resources to self-provide part of the electricity consumed by the user. This includes new business models and change in the use of networks (transmission and distribution).

In LAC market designs, the risks of the investment in the first case are frequently (but not exclusively) shared among users, which cannot decide whether to take the risk, using centralized mechanisms to ensure the economic viability of the project (such as power purchase agreements obligations). In comparison, the decision to invest in DG is much more decentralized, being part of a self-optimization and self-risk bearing.

Due to these economic differences between grid-scale and distributed renewable investments, the contracts designed to accommodate each option, how agents are rewarded and how the risks are shared among users vary. The policies and tools designed to incentivize each option promote different outcomes, with different economic values. In this monograph, we study incentive mechanisms for both grid-scale (large and medium scale generation) and DG (small scale generation installed at the main consumption unit) in LAC.

1. Thank you very much Katherine Antonio, Enrique Chueca, Tomas Serebrisky and the two blind reviews for all the useful comments.

# Incentives for grid-scale renewables

Different mechanisms can be used to contract new power generation supply at the grid level, as listed by (Kreycik, Couture, & Cory, 2011): (a) competitive solicitations, (b) renewable auctions, (c) feed-in tariffs and (d) bilateral contracts. While (a) and (b) involve a bidding process, (c) is an incentive price mechanism and (d) a direct contract of generation capacity between agents which terms do not include the system operator. The use of these mechanisms depends on the market design of each country.

Some countries have observed, during the last years, non-subsidized renewable generation participating in wholesale markets. Examples exist in Australia, the U.S., and Europe, where markets are mature and electricity prices are high enough to make renewable generation (mainly wind) profitable. Nevertheless, regulatory barriers do still exist for the full participation of renewables, as warned by the FERC or the European Commission.

The investment in a new power generation facility has features of a highly specific asset (Riordan & Williamson, 1985). The high uncertainty involved in the transaction between both parties – the generation capacity constructor and the energy and power buyer – can create incentives for agents to play opportunistically (Goldberg, 1976; Riordan & Williamson, 1985; Williamson, 1976). In this sense, the high transaction costs would make agents ask for guarantees such as long-term contracts or/and well-functioning competitive markets[2].

Two main types of mechanisms can be used to contract supply and capacity in the long term: renewable auctions[3] and bilateral agreements between generators and energy buyers (that can be a large consumer, a commercialization company or a distribution company). While the first one is based on organized and harmonized contracts, the second allows for heterogeneities.

In LAC, the electricity market designs are strongly associated with long-term contracts and/or vertical integration. In both cases, the long-term power purchase agreements have been the most used mechanism to incentivize renewables, and recently most of them are granted through auctions procedures.

2. Most of the final consumers (such as residential) are not used to signing long-term contracts. Retailers frequently took these risks: on the one hand, these risks were mitigated by vertical integration of some utilities (which are both retailers and generators); on the other hand, until recently, consumers had no supply choices and had to buy the electricity from the only existing supplier, as is still happening in most of LAC. However, the abatement in the costs of DG technologies is giving final consumers the opportunity to decrease their dependence on the traditional supplier and/or their dependence on the grid; therefore, increasing the uncertainty of the traditional setup.

3. Renewable auctions can also be settled by bilateral contracts such as Power Purchase Agreements

# 2.1. AUCTIONS: LAC'S FAVORITE TOOL FOR RENEWABLES

The importance of the auction process for the introduction of renewable energies is impressive. By 2017, up to 84 countries worldwide had made use of auction mechanisms to promote new generation of renewable sources (REN21, 2018). In LAC, as shown in Figure 1, 10 countries in the region have implemented at least one type of renewable auction policy for new supply of energy up to 2017. In order, these programs were first implemented in Brazil (2005)[4], Honduras (2007), Uruguay (2008), Jamaica (2008), Peru (2008) and Argentina (2009).

4. The first auction for new supply of energy in Brazil was held in December of 2005 (A-5). It was not an specific renewable auction, but it contracted renewable energy such as 3 biomass plants (Costa Pinto (56 MW), Quirinopolis (40 MW), Interlagos (40 MW)) and 7 new hydropower plants (Baguari (140 MW), Passo de São João (77 MW), São José (51 MW), Simplício (337 MW), Retiro Baixo (82 MW), Foz do Rio Claro (68 MW) and Paulistas (52 MW)) The first Alternative Energy Auction was held in 2007. Although the auction aimed at contracting energy from small hydroelectric plants, biomass thermoelectric and wind energy, the event contracted only projects for the first two sources. The first auction to contract wind generation was held in 2009.

**Figure 1.** Map of countries in LAC with a renewable auction process, 2017



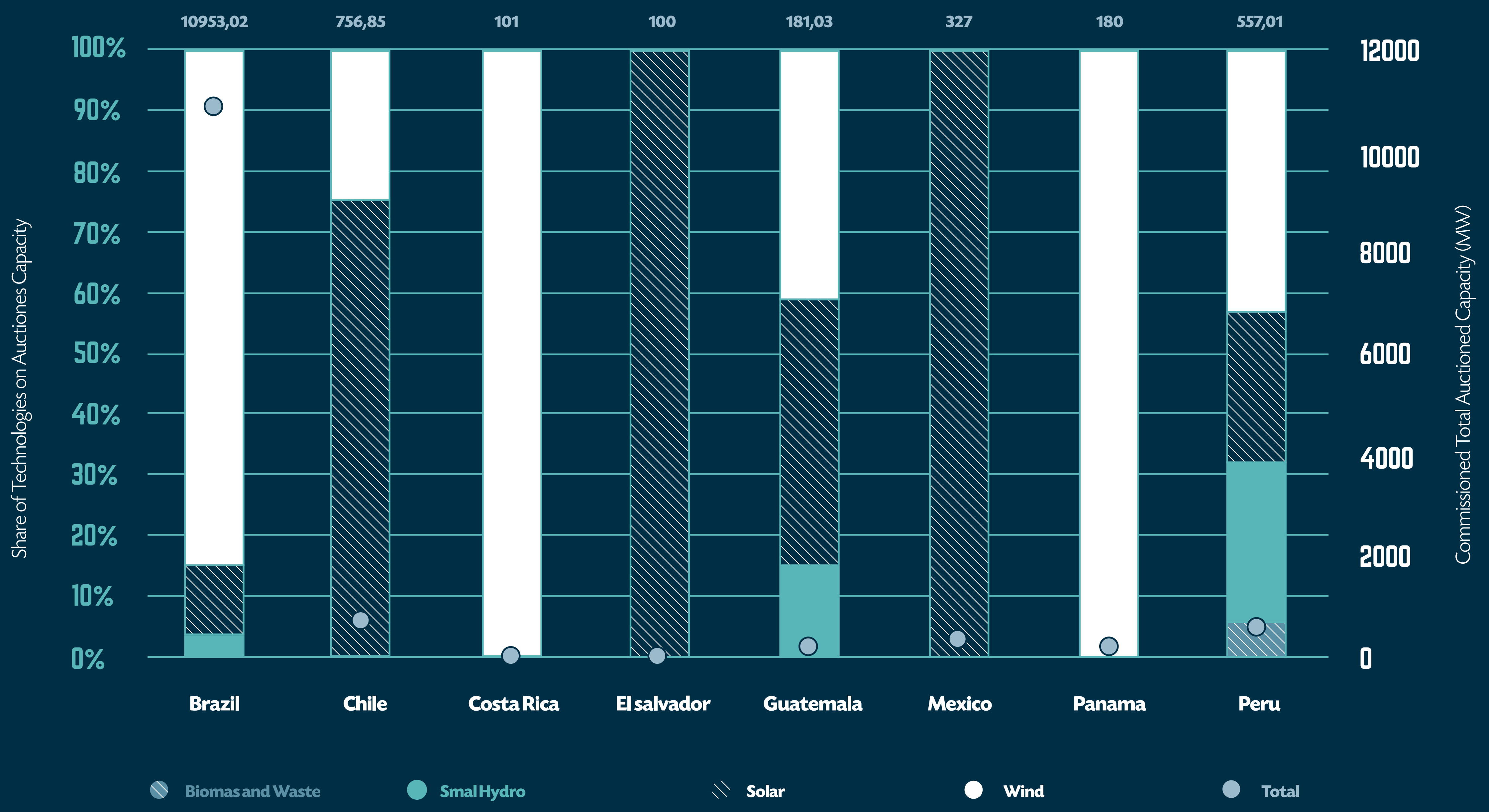
Source: Own elaboration using data from (IRENA, IEA, and REN21, 2018)

From 2009 to 2017, renewable auctions commissioned 13.1GW to the grid in 8 countries in LAC region (Figure 2) using 4 generation technologies: Biomass and waste (0.5%), small hydro (4 %), solar (19%), and wind (76.5%). This represents approximately 10.6% of regional added capacity and 34.3% of the added non-conventional renewable capacity.

Moreover, 564 winning projects are yet to be commissioned[5], accounting 28.1 GW new generation capacity in Argentina (4.1 GW) Brazil (9.1 GW), Chile[6] (3.5 GW), El Salvador (0.2 GW), Guatemala (0.1 GW), Mexico (7.9 GW), Panama (2.6 GW) and Peru (0.6 GW).

Currently, renewable auctions are widely used in the LAC region to contract both existing and new generation capacity form different technologies, as will be further discussed in Section 0.

**Figure 2.** Commissioned renewable capacity auctioned between 2009 and 2018, by source and country




Source: Own elaboration using Bloomberg New Energy Finance Data

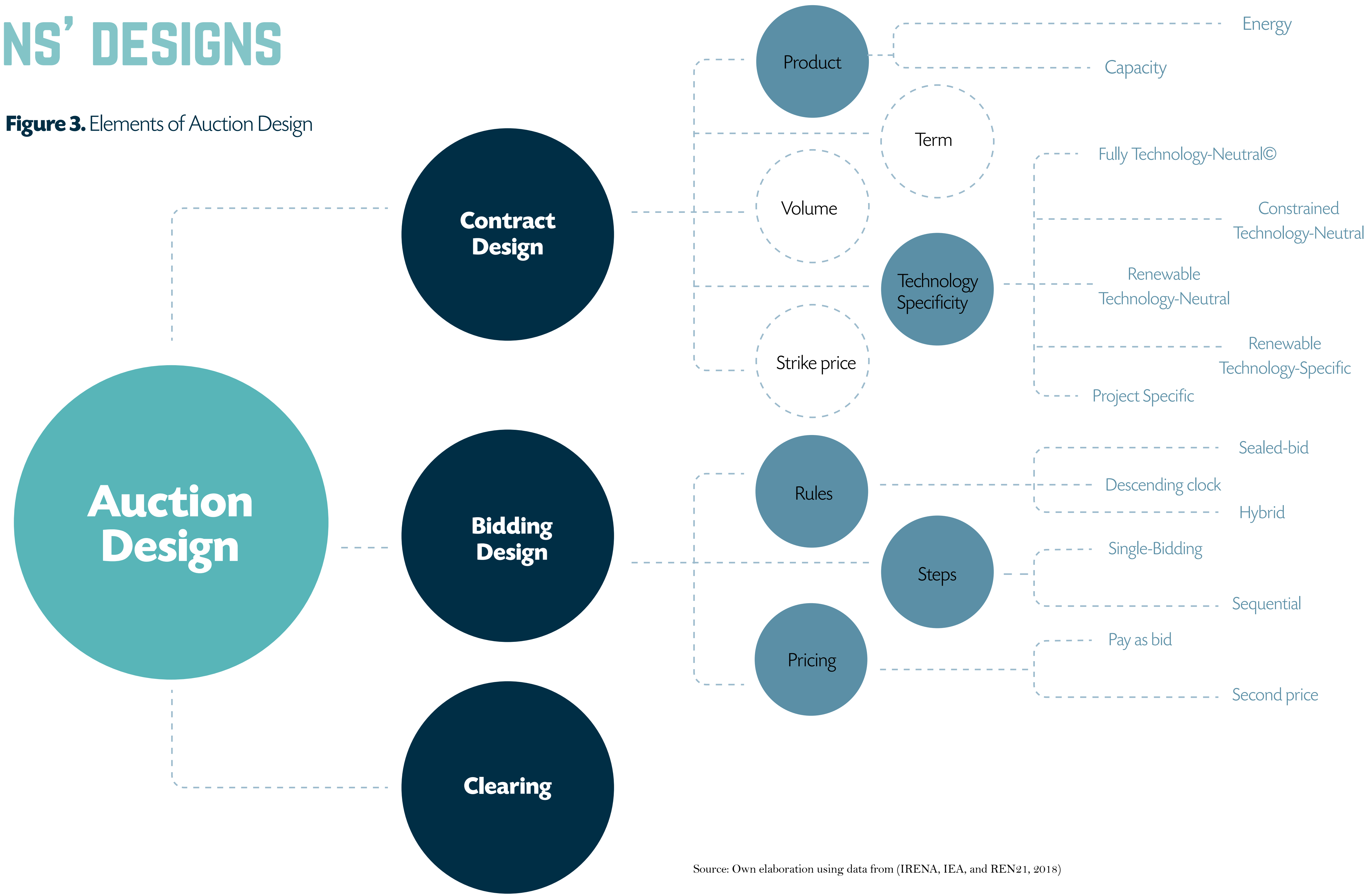
5. These projects are in different phases of the commissioning process: construction, financing and planning.

6. Chile uses a "technology neutral" auction mechanism. The result we present here contains only renewable projects.

## 2.2. The auctions' designs

The auction design is a complex set of policy decisions that concerns different parts of the auction mechanism. Auctions are usually run and designed by a government or by a regulator or system operator acting as the government's agent. Figure 3 summarizes the decisions a policy-maker should be aware of when designing an auction mechanism. It is important to notice that the design of an auction can affect the attractiveness of the bidding, the transparency and information disclosure, the contracted price and other aftermaths of the process. In our scheme[7], we divide the auction design into 3 groups: (1) the contract design, (2) the bidding design, and (3) the clearing mechanism.

**Figure 3.** Elements of Auction Design




Source: Own elaboration using data from (IRENA, IEA, and REN21, 2018)

7. The scheme has been developed based on (C. Vazquez et al., 2002) and (Maurer & Barroso, 2011).

(1) The contract design includes the definition of the product that will be contracted, the contract period, the volume that will be contracted, the definition of any technological constraint, and the price strike (if existent).

It is necessary to define the product to be contracted by the auction. We may divide the product into two types: (i) energy contracts and (ii) capacity contracts. In the case of energy contracts, the buyer is buying an amount of energy that will be received in the future (it is a kind of forward contract, as explained by Vazquez, 2011). As for energy contracts, it is common practice to include a take-or-pay clause that assures the payment to the generator even if there is no consumption. In energy contracts, no further remuneration is expected to be received (besides what is specified in the agreement signed in the auction).

On the other hand, capacity contracts, as explained by (Vazquez, Rivier, & Pérez-Arriaga et al., 2002), is the adoption "of an explicit remuneration for the installed capacity [8] as an economic signal intended to augment the volume of installed and available generation. In theory, capacity payments would attract new investment, resulting in lower (and more stable) market prices, with this price reduction being compensated by the capacity payment itself" (Vazquez et al., 2002, p. 350). In this case, besides the capacity payment, the generator may receive the payment of the energy if it is dispatched.

The contract term specifies how long the agreement will be in-force. Long-term contracts offer greater regulatory certainty to investors, minimizing the likelihood that their remuneration would be challenged in the future even if the market and policy landscapes change (IRENA & CEM, 2015). The average time of contracts in LAC is 20 years.

The decision about the volume to be auctioned is also a critical point in the auction's design that should consider the capacity of the market. The quantity of installed capacity or electricity generation that is going to be acquire through the auction can influence the level of competition. In markets with a limited number of project developers auctioning a large volume in one auction might lead to lack of competition.

The technology specificity defines which technologies can offer the contracted product. While a branch of literature split it into two types – neutral or specific – the technological classification of auctions can be better described by a continuous schematic, from neutral to project-specific:

## A. A FULLY TECHNOLOGY-NEUTRAL

**A fully technology-neutral** (or all encompassing) permits bidders to participate in the auction supplying energy or capacity independently of the technology. An advantage of this auction type is to maximize competition between technologies to achieve a lower price. A fully technology-neutral design is quite challenging to promote since several elements in the design of the auction may affect, such as the definition of generation firmness (in the case of capacity auctions), or the definition of the period that the plant will enter in operation. Besides the challenge of designing a technology-neutral auction, another important difficulty associated with

8. Actually, firm capacity that is the generation capacity available during a certain period.

the efficacy of technology-neutral auctions is the inability of this tool to assure the promotion of renewables.

## B. A CONSTRAINED TECHNOLOGY-NEUTRAL

A constrained technology-neutral auction may include both fossil and renewable technologies, but legally excluding certain technologies, even if their levelized costs are competitive. These auctions, for instance, can exclude high-emission plants, such as Heavy Fuel Oil (HFO) and Coal, but allowing other fossil fuel plants, such as Natural Gas and Liquefied Petroleum Gas (LPG) to compete with renewables.

## C. A RENEWABLE TECHNOLOGY-NEUTRAL

A renewable technology-neutral is an auction in which fossil fuel plants are excluded, and renewable solutions compete for the lowest price that meets the demanded energy.

## D. A RENEWABLE TECHNOLOGY-SPECIFIC

A renewable technology-specific auction is one of the most common auction designs in the LAC region. Under this scheme, each round tenders one (or more) technology-specific project(s) (such as Solar Photovoltaic, Wind, CSP and Small Hydro). One advantage of this scheme is to promote one specific technology, such as wind in Brazil (since 2007). One disadvantage is the possible lack of attractiveness or high prices.

## E. A PROJECT-SPECIFIC AUCTION

A project-specific auction implies bidding for a particular project. This scheme requires less effort to the bidders as a great part of the project details, such as site, grid connection or procurement, are already defined.

The contract should also specify a strike price, which is the price the generator is going to receive for the electricity provided. This allows the generator to stabilize its revenues at a pre-agreed level (the Strike Price) for the duration of the contract. If the market price is below the strike price, the generator is paid the difference and if the market price is above the strike price, the generator pays the difference.

(2) The second element when designing an electricity auction is the bidding design. The bidding process defines the rules by which the auctioneer receives the offers and defines the winning bids. The most commonly used designs are (i) sealed-bid auction, in which all bid information is provided to the auctioneer beforehand and the participants bid simultaneously with no information about other bids; (ii) descending clock auction, an iterative process in which bids are made in a succession of rounds with descending prices; and (iii) hybrid auctions, in which the tender is performed in sequential phases of sealed-bid and descending clock auctions, or vice-versa.

Regarding the pricing scheme, there are two main approaches: (i) the pay-as-bid pricing, in which the remuneration is determined by the winning bid; or (ii) second price, in which the winning bids receives the second lowest offered price.

(3) Finally, the selection of the clearing mechanism is also part of the auction design, though as it should not directly affect the auction result, the simpler its design the better. The selection of the clearing is especially important when generators' bids are bulky and indivisible, which implies that an exact match between supply and demand is not always possible. However, in the case of renewable energies, their relatively modular nature (wind turbines, solar panels, etc.) makes it much easier to adjust the project size than it would be for conventional generators (IRENA & CEM, 2015).

# 2.3. Regional policy mapping

Currently, 10 countries in LAC have implemented renewable auctions for generation capacity (Table 1) based on in-force laws. These auctions are used to contract both existing (less frequently) and new capacity generation from different technological sources, such as small hydro, biomass, wind, solar and geothermal (only one plant in Mexico).

## Table 1. Auction policies in LAC Countries

| **Country** | Argentina | Belize | Brazil | Chile | Costa Rica | El Salvador | Guatemala | Mexico | Panama | Peru |
|---|---|---|---|---|---|---|---|---|---|---|
| **Auction Regulation** | 2015 | 2013 | 2007/2015 | 2008/2013 | 2012 | 2013 | 2012 | 2015 | 2011 (wind)<br>2013 (solar) | 2009 |
| **Number of Rounds (to Dec. 2017)** | 3 | 1 (Firm capacity and Energy) | Capacity: 9<br>Energy: 13 | 4 | 1 | 3 | 2 | 3 | 3 | 4 |
| **Total Capacity Auctioned[9] (GW)** | 4.18 | 2 | 23.12 | 4.3 | 0.41[10] | 0.3 | 0.87[11] | 8.23 | 0.52[12] | 1.203[13] |
| **Technology Type[14]** | Specific | Specific and Neutral | Specific and Neutral | Neutral | Specific | Specific | Specific | Specific | Specific | Specific |
| **Auctioned Technologies** | Biomass<br>Wind<br>Solar | Biomass<br>Small Hydro<br>Solar | Biomass<br>Small Hydro<br>Wind<br>Solar<br>Biofuel | Solar<br>Wind | Wind<br>Small Hydro | Biogas<br>Small Hydro<br>Solar | Biofuel<br>Biomass<br>Small Hydro<br>Solar<br>Wind | Wind<br>Solar<br>Geothermal | Wind<br>Solar | Small Hydro<br>Solar<br>Biomass<br>Wind |
| **Standard Contractual Lenght (years)** | 20 | 15 | Existing: 15<br>New: 20-30 | 25 | 20 | 15 | 15 | 15 (project)<br>20 (Certificates) | 15 | 20 |

9. Bloomberg New Energy Finance data
10. Climatescope 2017
11. 0.3 GW of new capacity
12. A 0.77 GW project was abandoned
13. 1.16 GW of new capacity
14. As legally informed

The auction design varies among LAC countries. In Table 1, we have considered three different auction features regarding auction design: technology specificity (i.e. the diversity of technologies that can compete), allowed technologies (i.e. technologies specified as eligible for bidding), and contractual length.

1. Regarding the technology specificity, the auction can be renewable technology-neutral or renewable technology-specific. As explained in the previous section, renewable technology-neutral auctions limit the participation of specific fossil fuel technologies. Technology-neutral auctions promote competition among different technologies and allows minimizing costs, as favor the more mature and cost-competitive technologies (IRENA & CEM, 2015). Therefore, with technology-neutral auctions there is risk of under deployment of a specific renewable technology. On the contrary, the advantage of technology-specific auctions is to promote the deployment of a technology therefore reducing its price. In the LAC region, only Belize (for firm capacity) and Chile adopted an auction with a high level of technology neutrality.

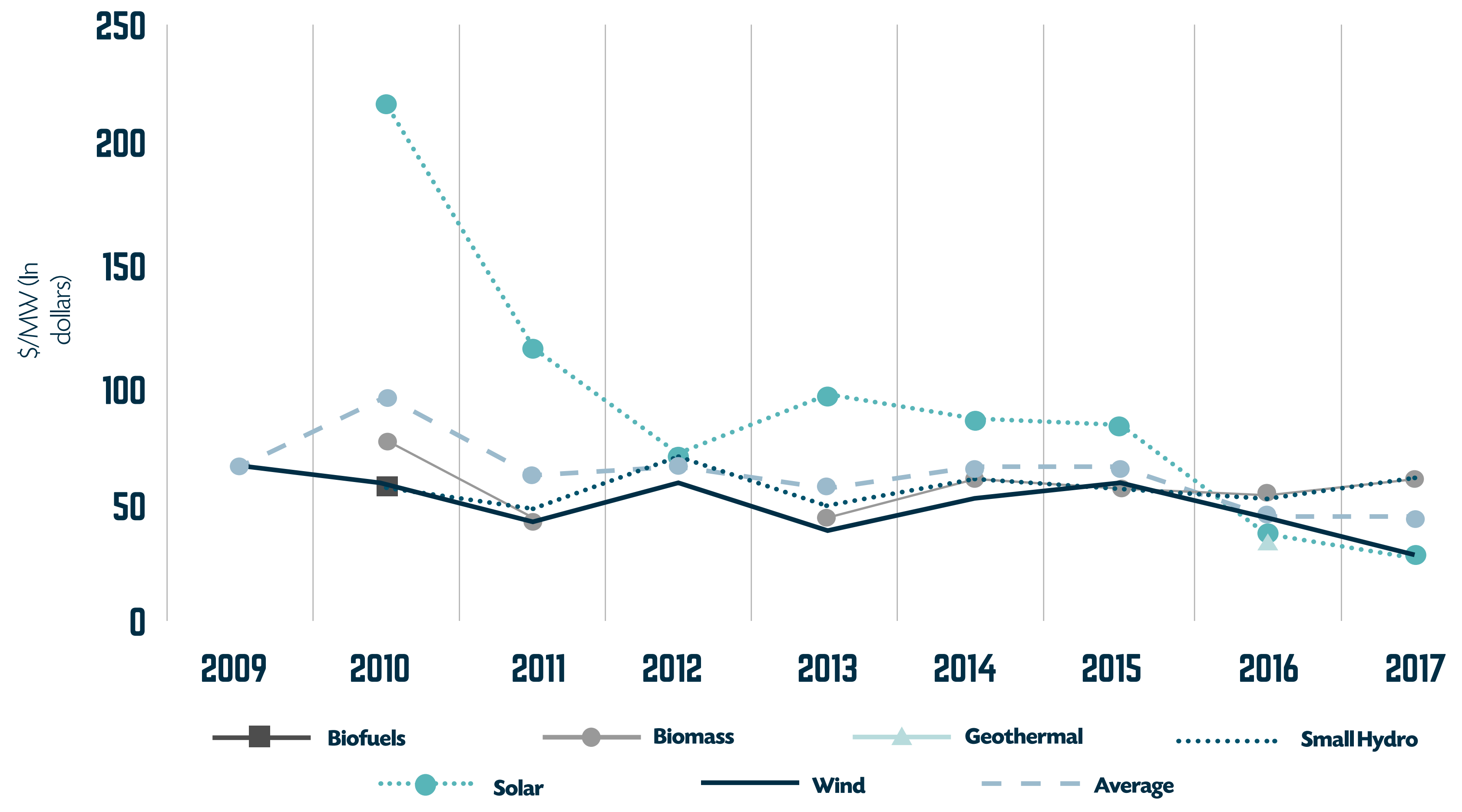
2. The technologies specified as eligible for bidding also varies across countries. The election of which technologies will be incentivized depends on factors, such as (i) power generation capabilities (such as weather conditions), (ii) national firms' capacity to provide technologies (or part of it), (iii) political factors, or (iv) the security of the system. In general, solar and wind technologies are the most common to be eligible, followed by biomass and small hydro plants.

3. Another feature of the auction we have considered is the duration of auctioned contracts. Most countries use a fixed standard contractual length, except for Brazil, which divides it by technology. The minimum duration is 15 years (Belize, El Salvador, Guatemala, Mexico and Panama) and the maximum is 30 years (Brazil).

# 2.4. Auctions' results

Comparing the results of the auction, Figure 4 shows the average bidding prices of new capacity auctions by technology in the LAC region. The average price dropped considerably (32.9%) from 2009 to 2017, especially for solar projects which decreased 86.9% from 2010 to 2017.

**Figure 4.** Average bidding prices of auctioned new generation capacity in LAC




Source: Own elaboration using Bloomberg Data
Note: Green labels indicate the number of projects auctioned in the year
Note [2]: Project values are in constant dollars, (2009 = 100)

Overall, the set of auction design presented in Table 1 can be described by the following set of similarities among them:

- Long term contract (from 15 to 30 years);
- Technology-specific auctions for power contracting (except Chile);
- The vast use of Solar (except Costa Rica) and Wind (expect El Salvador and Belize).

As regard to long-term contracts, (Hochberg & Poudineh, 2018) highlight that long-term contracts facilitate project financing and reduce the cost of capital, as they assure investors with long-term revenue streams. Long-term contracts can create ex-ante incentives for agents to commit to new investments. However, in cases of lack of institutional stability, technological disruption, or financial constraints, the risk of contract default can increase introducing uncertainty to the agreement.

In relation to the technology-specificity of the auctions, we have seen that in the LAC region technology-specific auctions are preferred. This kind of auctions bring some simplification to the process, but also some implementation risks (IRENA, 2017). On the one hand, technology-specific auctions reveal information on the cost of a single technology while technology neutral auctions benefit the most cost-effective technology. Moreover, if competition for a specific technology is low, then the bidding process can result in under-contraction of power. In these cases, technology-neutral auctions have an advantage on the provision of power.

# [15]Incentives for distributed generation: Net metering designs

Net metering (NM) policies have been widely used as a mechanism to incentivize the adoption of DG resources, especially by small consumers like households and small businesses. The most general definition of a NM policy is the permit given to utility-connected consumers to offset their consumption by inputting self-generated electricity surplus into the network and generating credits that can be used afterward (Darghouth, Barbose, & Wiser, 2011). Even though the general definition is straightforward, the design of NM policies varies across countries. For instance, a policymaker should decide elements like the objective of the policy (promote the adoption of DG systems or guarantee the financial sustainability of utilities), the compensation scheme (by energy or in cash), the minimal technical requirements of an installation to guarantee the quality of DG, the rate at which credits are exchanged with the network, and the financial mechanisms (if there are any) and how to fund them, among other decisions. Thus, many countries – including LAC – implement different set-ups of NM policies that can produce a comprehensive set of incentives, challenges, and outcomes.

Overall, the most common technology used to perform NM with the grid is the Solar Photovoltaic (PV) system, by which users generate energy while there is sunlight available. Even with the globally rapidly decrease in PV equipment prices and maintenance costs and an increase in generation efficiency, the adoption of DG technologies still encounters many constraints (Candelise, Winskel, & Gross, 2013). These limitations may have different sources, such as household's budget constraints, complicated or unattractive financing mechanisms, lack of knowledge about DG and NM, the lack of local technical capacity to assist installation, or a regulatory prohibition.

In LAC, 17 countries have adopted policies to introduce NM by 2018, with different stages of implementation (as pilot, regional, sectorial or national projects). Each adopting country has its settings of prior rules and socioeconomic characteristics, which affect the outcome of NM policies. Hence, the goal of this study is to explore the heterogeneity of NM policies adopted in the LAC region and the incentives they provide for the adoption of DG systems.

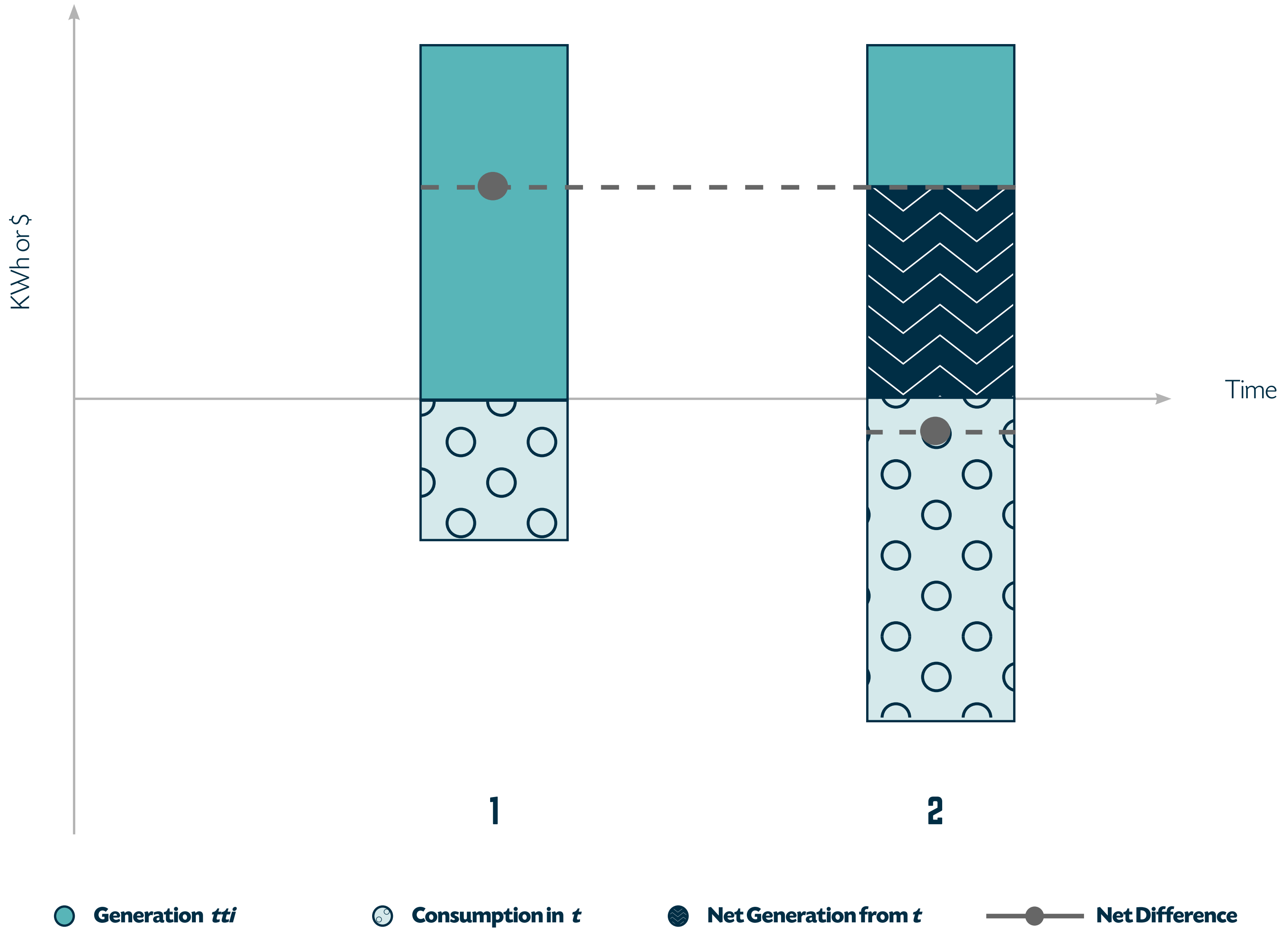
15. This section was first published as two separated Technical Notes: Implementing Net Metering Policies in Latin America and the Caribbean: Design, Incentives and Best Practices, and The Impact of Net Metering Policy Design on the Adoption Rate of Solar Photovoltaic Systems: A Simulation Using Calibrated Data from Brazil.

# 3.1. Designing a Net Metering Policy

The NM scheme is an intertemporal offset of self-generated energy for future use. The basic concept is that a household energy surplus in t can be converted in cumulative credits – measured in energy (kWh) or monetary units – which can be used anytime between *t+1* and *t+n*, with n being the maximum accumulation period (that can be indefinite). The accumulation of credits is not accounted only by period, but also by the accumulated product. (IRENA, IEA, & REN, 2018) splits it into two schemes: NM, in which the offset occurs in energetic terms, and Net Billing, in which the compensation is monetary. However, most of the technical literature commonly uses the term NM for both schemes.

In a simplified scheme, Figure 5 exemplifies the working of a NM policy by offsetting the accumulated credit (energy or money) in period 1 to the consumption in period 2. The period between periods 1 and 2 can be, theoretically, as short as the policymaker wishes. For instance, assume that period 1 is the consumption of energy during off-peak demand with high generation conditions (an average house at noon), and period 2 is a peak demand with low-to-nothing generation conditions (*i.e.* 7 P.M. in the summer). The surplus of generation in period 1 is transported to period 2. At the end of period 2, the net energy consumption to be charged is almost entirely compensated by the self-generation. In this case, the compensation rate (the ratio between generated energy and energy-equivalent credits) is equal to one, meaning that every unit of energy injected in the grid as a surplus can later be consumed.

**Figure 5.** 2-periods NM accumulation




Source: Own elaboration.
Note: Considering no hourly tariff and Compensation Rate equal to 1

## 3.1.1. Benefits and challenges of a net metering policy

The NM policy should be viewed from at least three different perspectives: the regulator, the utility, and the consumer decision process. The benefits desired by all players are different and should be considered differently, even though the decision taken by one affects the other.

On the one hand, consumer benefits are restricted to recover the project investment, and a legally defined monetary surplus. Moreover, consumers may also be guided by environmental concerns that may influence household behavior. Even if the rate of return of a distributed system is negative, some consumers may be willing to pay it, in order to satisfy their environmental beliefs. However, we cannot assess how much consumers are willing to disburse for it.

In the case of a monetary surplus, in some situations it can mean: higher (i) energy consumption, (ii) savings or (iii) non-electricity goods consumption. With NM policies, these benefits can be achieved by (a) reducing the utility bill, (b) receiving a monetary payment for energy inputted to the grid, or (c) levelling energy costs over time (if there is an hourly tariff combined with a NM policy).

On the other hand, utilities, while having less control over the decision process, are affected directly by it. The provision of NM services may directly affect the revenue recovery of the company and the profitability of future investments. The services provided by the utility might experience distortions, which would require the recovery of investments to assure the operation and the remuneration of services by the imposed tariffs. As a result, some costs must be paid by some party, in the form of a loss to the utility, a charge to users (generators or not), or a direct public subsidy.

The regulator's decision process is more complex, involving the coordination of energy self-generators with the utility and the wholesale market. The rules designed by regulators must keep goals clear. Overall, the adoption of NM policies concerns the different objectives of regulators: (1) to promote intermittent technologies in order to develop them further, thus reducing their marginal cost of generation, (2) to incentivize the residential installation of DG systems, and (3) to avoid distortions in the tariff structure.

The expansion of DG capacity in the grid may create a challenge to tariff design, especially concerning the revenue requirement of utilities to pay for investments and operation (Castaneda, Jimenez, Zapata, Franco, & Dyner, 2017; Felder & Athawale, 2014). The incorporation of on-grid DG capacity distorts the tariff structure that balances users and utilities requirements. One role of the regulator is to implement the rules to re-organize it and diminish the risks of contractual default caused by tariff distortions (Picciariello, Reneses, Frias, & Söder, 2015). On the one hand, tariffs must assure that utility investments are paid in the long run and that operational costs are covered in the short term. On the other hand, tariffs should create signals for network users to make decisions and to guarantee the firmness provision of the service. However, in a context where users are becoming more heterogeneous in how they use the network services, distorted signals to users can create revenue problems for utilities.

This scenario might lead to a re-distribution of network costs among users, as (Felder & Athawale, 2014) and (Khalilpour & Vassallo, 2015) point out, and lead to a "death spiral" of network distribution. The death spiral occurs when the tariff design recovers the revenue loss of DG penetration by re-distributing the costs among all the consumers. The higher tariff would increase the net benefit of DG installations and lead to a higher adoption rate of these systems, returning to a point where costs need to be re-distributed indefinitely. In this sense, utilities providing network services would bear most of the risk from cost reallocation.

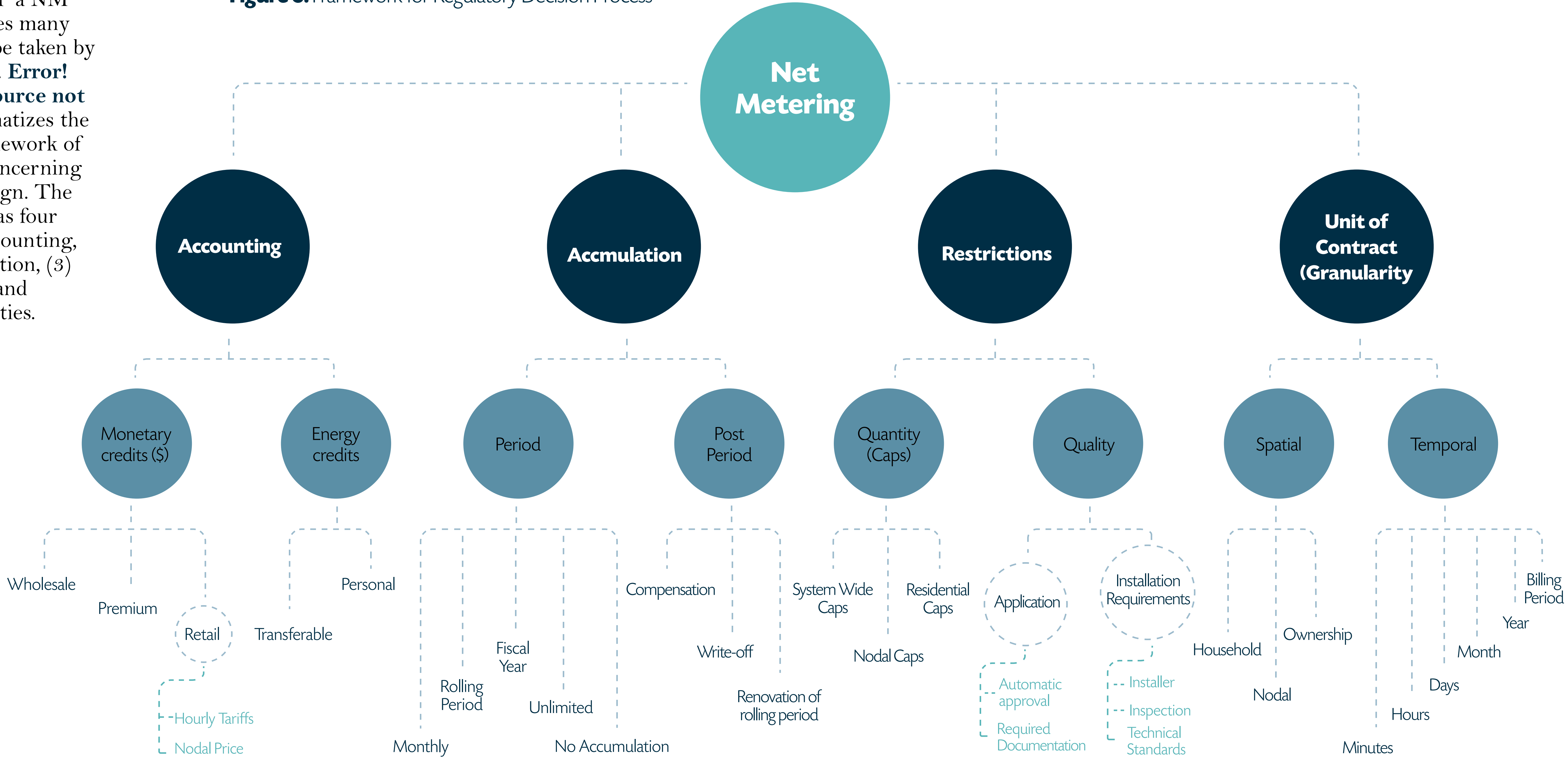
Nonetheless, as highlighted by (Laws et al., 2017), the death spiral is only a threat in certain conditions, such as a high adoption rate combined with a high utility cost, the possibility of community generation, and the pricing structure of NM. Their model shows that the wholesale price should remunerate the distributed energy rather than the retail tariff. This would reduce the acquisition costs for utilities and diminish the need for revenue recovery. Besides, a demand charge (related to the peak demand of the period) separated from the energy charge would also be a better price signal: the energy charge for PV users would be lower while still paying for needed investments.

16. In opposition with off-grid Distributed Generation capacity.

## 3.1.2. Policy-design decisions

The design of a NM policy involves many decisions to be taken by the regulator. **Error! Reference source not found.** schematizes the decision framework of regulators concerning NM rule design. The framework has four parts: (1) Accounting, (2) Accumulation, (3) Restrictions and (4) Granularities.

**Figure 6.** Framework for Regulatory Decision Process




Source: Own elaboration.

Regarding the **accounting**, regulators must define what the DG and the network trade between each other. They can trade (a) energy credits or (b) monetary units. Energy credits compensate users for the generated energy surplus, measured in kWh. This credit can be a full compensation – 1 kWh of surplus equals 1 kWh of credit – or compensated at a different rate (greater-than or smaller-than 1). If NM is accounted in energy credits, regulators should define if credits are personal and can be used only by the generator, or if they can be traded among users and virtually transferred.

The second possibility is to accumulate monetary credits. In this case, the prosumer[17] receives credits as a monetary equivalent of the generation surplus. If NM is accounted in monetary credits (also called Net Billing), then regulators need to define the price at which that energy is going to be traded with the grid, including the existence of any transaction fee, service fee, or premium rate. The most common trading rates used are: (a) retail rate (which includes generation, distribution, and transmission tariffs), (b) wholesale generation rate (which reduces the financial disbursement of utilities, but creates less incentives for prosumers), and (c) premium rate (which compensates surplus with a premium, for instance, 1.15 kWh credits for each 1 kWh of generated surplus). Nonetheless, rate schemes are not limited to these three. It can also compensate using hourly tariffs, flexibility price, or nodal prices, for example, or even a combination of different tariffs, such as a two-part compensation rate (compensating energy plus flexible availability)[18].

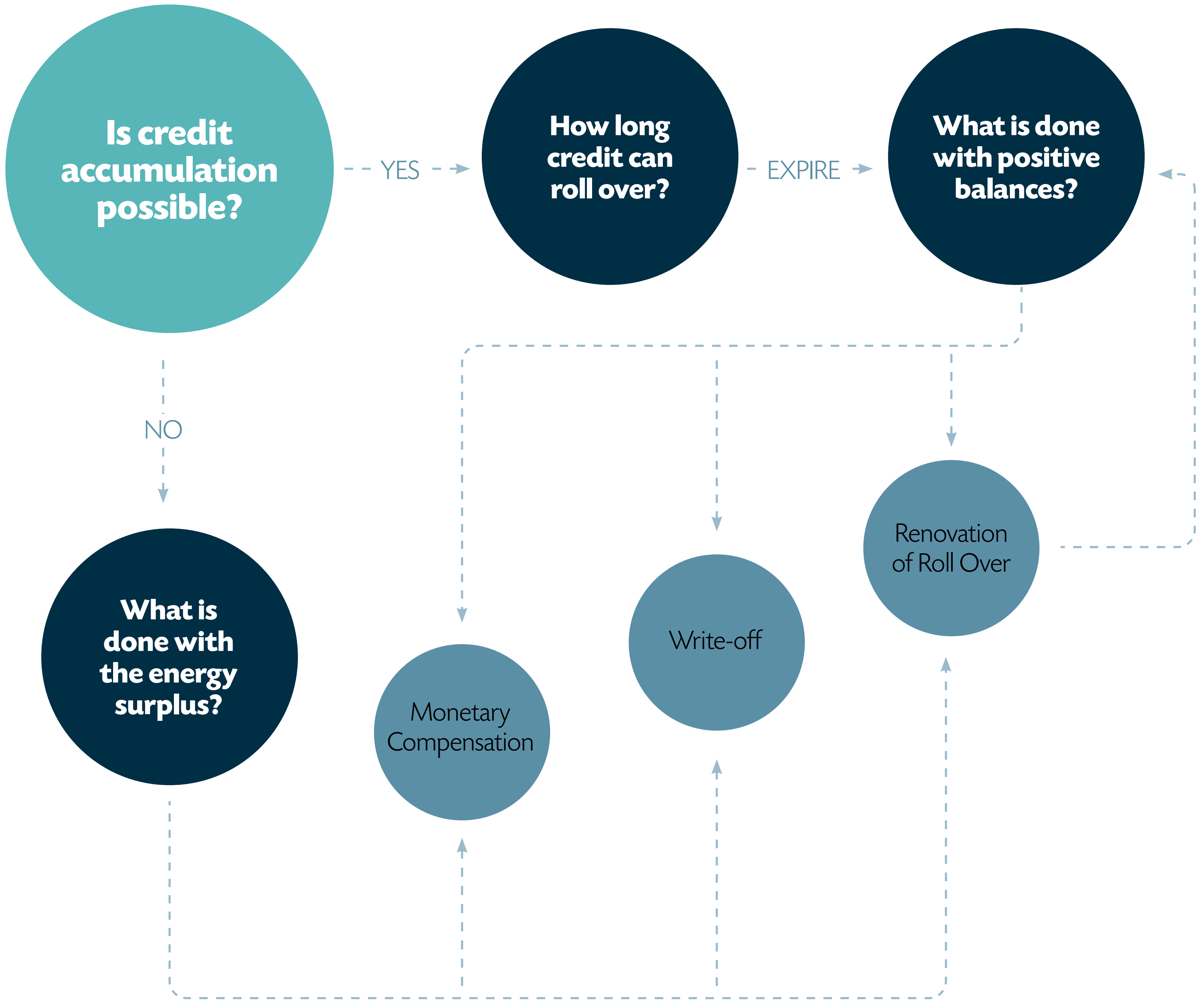
Then, the regulator must define the **accumulation** rules. They are summarized in Figure 7. First, the regulator defines if accumulation is possible. If yes, then she must define the accumulation period or the number of billing periods (e.g.: monthly, fiscal year, through a rolling period, unlimited) in which credits (energetic or monetary) can be used. After the accumulation period credit expires, rules must define the next steps. Three situations are possible: (i) a monetary compensation of credits (also known as a "cashback scheme"[19]), (ii) the renovation of the roll over period, or (iii) balance writes-off (and utilities convert it from liability into current asset on the balance sheet).

17. An agent that combines both consumer and self-producer roles.

18. For instance, in the United States – where NM rules are defined by each State –, the policy adopted in the District of Columbia has two price sets. For installations up to 100 kW, the retail tariff is applied, and from 100 kW to 1 MW of installed capacity, the generation price is used to compensate users. This is an example of a rate differentiation that can be used as a NM pricing policy.

19. Notice that rules can also define voluntary cashback, in which users can demand the money from the credits before the expiration. This situation has two sides: it increases the financial liquidity of prosumers and can incentivize the adoption of PV systems, but it also decreases the financial liquidity of utilities (or another responsible agents).

**Figure 7.** Accumulation rule decision process




Source: Own elaboration.

The third level of decision concerns installation restrictions, which can be divided into two categories: Quantity, or capacity restriction, and Quality, or technical restriction. NM rules can permit unlimited capacity installation or limit it to some degree. On the one hand, unlimited capacity installation may force a rapid increase in DG capacity into the grid, creating coordination problems between utility investments and DG. On the other hand, unlimited capacity can incentivize the adoption of DG systems if monetary compensation is possible since adopters can experience financial gains from increasing the installed capacity. The restriction levels can be set at residential, transmission node, or system wide. For example, a higher density of DG systems connected to a single node might create a local frequency balancing issue if not restricted.

Quality restriction refers specifically to the technical procedures used by the regulator (or any other designated party, such as the utility company) to assure that the DG system is stable, secure and reliable. As part of these procedures, the application for the installation can be automatically approved (mostly for small installations) or may require the submission of specific documentation. There are also installation requirements in order to guarantee that the installers have the necessary experience and resources, that the installation is completed following all the required technical standards and the required inspections are carried out in a timely manner. Rigid quality restrictions can increase installation and operation costs, making DG systems less attractive to potential adopters.

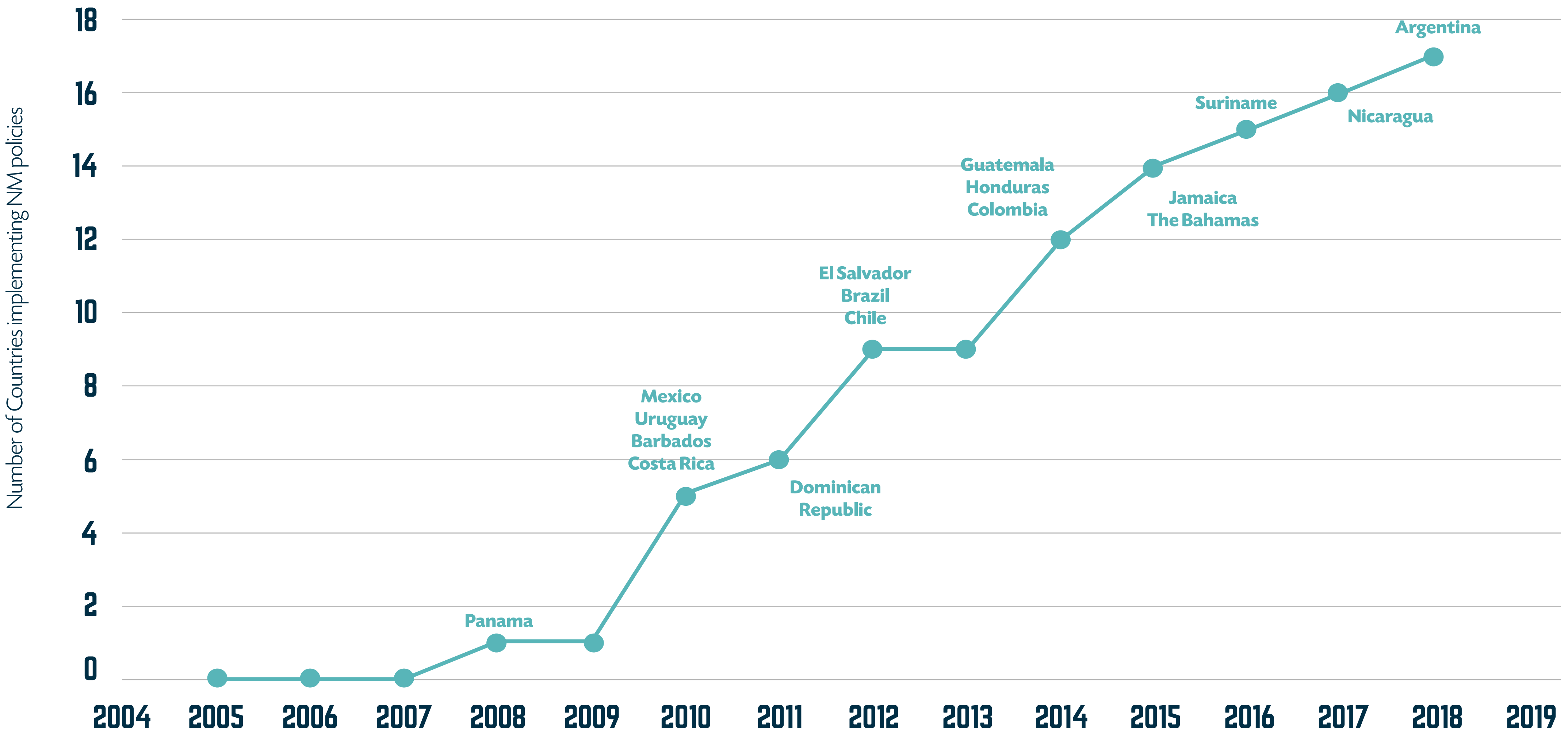
The net balance resolution or **granularity** must be specified in both spatial and temporal terms. Temporal granularity can be understood as the cycle in which the consumption and generation balancing operation is calculated. Thus, it can be calculated at the end of a time unit (i.e. minutes, hours, days, months or year) or at the end of the billing cycle or fiscal year. After this, the credit balance is accounted.

Spatial granularity refers to the level of balancing aggregation between distributed generators, which can be as small as a single individual (with many facilities), a single household facility, or even multiple individuals aggregated in a net energy balancing group. A less disaggregated level, such as nodal aggregation, would allow the formation of neighborhood balancing aggregators, which can increase the attractiveness of installation by sharing operational costs among users, or competing in the wholesale market with a higher flexibility than single users. Lastly, an ownership-based spatial granularity would further increase the possible geographical disaggregation of the balancing operation allowing users with non-contiguous DG facilities, located in different places, to balance virtual energy across the network.

# 3.2. Net metering policies in the LAC region

Currently, NM and Net Billing policies are one of the main mechanisms to incentivize the adoption of DG in the LAC region. From 2008 to 2018 (July), 17 countries adopted one national policy to implement NM (Figure 8). Of these countries, Jamaica and The Bahamas implemented pilot projects prior to the actual implementation, four countries[20] updated regulations during the period, and one country (Argentina) unified regional programs of NM into a national regulation. Of these countries with NM laws in-force, 10 refer to the policy as "Net Metering,"[21] four use the term "Net Billing,"[22] and one (Mexico) uses both terms interchangeably. Terms are not related with the accounting unit (energy or cash).

**Figure 8.** Timeline of NM Policies adoption in the LAC region




Source: Own elaboration based on BNEF, IEA/IRENA, Energy Laws in LAC countries.

20. Panama (2012), Brazil (2014), Guatemala (2014), Colombia (2018).
21. Panama, Uruguay, Costa Rica, Dominican Republic, El Salvador, Brazil, Guatemala, Honduras, Colombia, and Argentina.
22. Barbados, Chile, Jamaica, and the Bahamas.

## 3.2.1. Accounting and accumulation

First, rules must define the product to be traded in a NM scheme, or the accounting unit, and how accumulated credits can be transposed to be used in the future. In terms of accounting, 10 countries adopt monetary credit accumulation, four countries adopt energetic credit accumulation, and one country (Costa Rica) offers two types of contract, the "Simple," with a monthly rollover of energetic credits, and the "Complete," with yearly monetary compensation[23]. The countries adopting only one type of accumulation scheme are:

- *Energetic accumulation:* Uruguay, Brazil, Suriname, Guatemala, and The Bahamas;
- *Monetary accumulation:* Panama, Mexico, Barbados, Dominican Republic, El Salvador, Nicaragua, Chile, Honduras, Colombia, Jamaica, Argentina, and Brazil (for hourly-rates).

The *accumulation periods* in each country vary from one billing period to five years to no-specific definition. The list of countries is summarized in Table 2 according to the accumulation period, the accumulation units, and the aftermath of credits after expired. Eight countries adopt cashback policies, allowing users to convert credits in monetary earnings after the accumulation period limit, and only three countries write-off the credits.

23. The "complete" modality started in 2015.

### Table 2. Accumulation units and periods in LAC

| Country | Accumulation Period | | Accumulation Unit | After Expiration |
|---|---|---|---|---|
| Uruguay | 0 | Months | Energetic | Cashback |
| Dominican Republic | 1 | Billing period | Monetary | Cashback |
| Jamaica | 1 | Months | Monetary | Write-Off |
| The Bahamas | 1 | Billing year | Energetic | Cashback |
| Barbados | 3 | Months | Monetary | Cashback |
| Argentina | 6 | Months | Monetary | Cashback |
| Panama | 12 | Months | Monetary | Cashback |
| Mexico | 12 | Months | Monetary | Cashback |
| Costa Rica | 12 | Months | Hybrid[24] | Cashback |
| Suriname | 12 | Months | Energetic | Cashback |
| Nicaragua | 12 | Financial year | Monetary | Cashback |
| Chile | 12 | Months | Monetary | Write-Off |
| Brazil | 60 | Months | Energetic/Monetary[25] | Write-Off |
| El Salvador | Indefinite | | Monetary | NA |
| Guatemala | Indefinite | | Energetic | NA |
| Honduras | Indefinite | | Monetary | NA |
| Colombia | Indefinite | | Monetary | NA |

Source: Own elaboration.

In Guatemala, distributed generators can choose to "sell" surplus energy in two markets. They can sell directly to the distribution company, receiving energetic credits with indefinite accumulation period. Alternatively, they can choose to sell to the wholesale market, where they are paid the wholesale price. Both options are not mutually exclusive and can be used simultaneously. For instance, a distributer can generate enough energy to (1) satisfy current consumption, (2) smooth future consumption by offsetting energy credits within the distribution network, and (3) sell the over generation credits on the wholesale market. However, the technical specifications that need to be followed to receive the authorization to sell energy directly to the wholesale market can be constraining to users.

24. Hybrid means that Costa Rica offers two types of contracts with different accumulation units, Energetic and Monetary, which cannot be mixed, contrary to what is done in Brazil.

25. In Brazil, a mixed accumulation unit is used when the consumer adopts the hourly tariff. Accumulation is done by tariff block using energetic units but can be converted from one to another block using monetary units.

## 3.2 .2. Quantitative and qualitative restrictions on installation

Table 3 displays the quantitative and qualitative restrictions adopted by NM policies in the LAC region. Overall, almost every country in the region (except for Barbados, Argentina, Costa Rica, Colombia, and El Salvador) adopts a DG capacity cap at the residential level. This cap varies from 100 kW in Uruguay, Jamaica and The Bahamas, to 5 MW in Brazil. In Barbados, the restriction is imposed system-wide, and DG cannot surpass 10% of the total country capacity. In Costa Rica, new installations should reach a maximum of 15% of the previous year's demand. In Colombia, the restriction is applied at the distribution network level, imposing caps on the substations and transformers, which connect the DG (15% of capacity and 50% of demand). Other countries, like Nicaragua and Suriname set annual electricity consumption as a cap for annual electricity generation.

On the qualitative side, countries define the technical installation requirements and who is responsible for authorizing new installations. Four countries adopt licensed installation. Once licensed installers complete the installation of certified equipment, DG can enroll in NM. In addition, 12 countries require distribution authorization to certify that proposed installations fulfill regulatory requirements and to inspect if installed equipment is reliable in order to participate in NM.

All countries in the LAC region with Residential NM policies in-force adopt it at a household level with a monthly billing period. Thus, alternative organizations, like the aggregation of users and a shorter billing period, are not possible.

26. In Suriname, the annual generated output should be smaller than the annual consumption.

27. In Nicaragua, installations are divided into (i) low voltage: unlimited in power, but limited to the annual energy demand of the consumer, and (ii) medium voltage: up to 5 MW.

### Table 3. Qualitative and Quantitative Restrictions in LAC's NM Policies

| Country | Maximum Installed Capacity Allowed (kW) | | | | Installation Technical Authorization |
|---|---|---|---|---|---|
| | System Wide | Nodal | Distribution | Residential | |
| Uruguay | - | - | - | 100 | Licensed Installation |
| Jamaica | - | - | - | 100 | Licensed Installation |
| The Bahamas | - | - | - | 100 | Distribution Company |
| Dominican Republic | - | - | - | 1000 | Licensed Installation |
| Barbados | 10% of Total Capacity | - | - | - | Distribution Company |
| Argentina | - | - | - | - | Distribution Company |
| Panama | - | - | - | 500 | Distribution Company |
| Mexico | - | - | - | 500 | Distribution Company |
| Chile | - | - | - | 2000 | Licensed Installation |
| Costa Rica | 15% of Yearly Demand | - | - | - | Distribution Company |
| Suriname | | | | -[26] | Distribution Company |
| Nicaragua | | | - | 5000[27] | Distribution Company |
| Brazil | - | - | - | 5000 | Distribution Company |
| Honduras | - | - | - | 250 | Distribution Company |
| Colombia | - | - | 15% of Substation Capacity<br>50% of Substation Demand | - | Distribution Company |
| Guatemala | - | - | - | 5000 | Distribution Company |
| El Salvador | - | - | - | - | Distribution Company |

Source: Own elaboration.

# 3.3. Net Metering incentives and policy implications

Here we focus on consumer-side incentives generated by a NM policy. We chose PV installation in Mexico as an example. In our study, we assume that a household chooses the optimal size of the DG installation and consumption as a response to system variables like tariff, interest rates, and other policy rules. Thus, the household is assumed to be a risk-averse investor that maximizes the Net Present Value (NPV) of the DG system. We employ a basic set-up (Annex 1 – Calibration of NPV Model, for the numbers used in the calibration) and simulated marginal changes (upwards and downwards) with ceteris paribus. Then, we make a cost-benefit analysis of a Solar PV System project calculating the NPV[28], and check whether the project is viable for the average consumption of 2.6 kWh/day. Figure 9 shows the NPV behavior for each set of variables.

In **Error! Reference source not found.**, we summarize the variables that have been analyzed in the case study and might affect the decision process of PV adopters. We compare the benefits of generation with the costs of consumption over the whole project period.

28. The NPV after installing the DG system, which is equal to the NPV of the self-generation minus the consumption:

$$\Delta NPV = NPV_{Gen} - NPV_{Con} = \sum \frac{p_{kWh}(G_t(S) \cdot N_{rate} - C_t(1+tax)) - p_{fixed}(1+tax) - M_t(S) - F_t(S)}{(1+\pi_t)(1+i_t)^t}$$

Where, $C_t$ is the consumption in kWh in the period t; $p_{kWh}$ and $p_{fixed}$ are the variable and fixed tariffs, respectively; $N_{rate}$ is the net metering rate, tax is the tax over the bill; $\pi_t$ is the inflation rate in t; $i_t$ is the interest rate in t; S is the installed capacity; $G_t(S)$ is the self-generation in kWh ; $M_t(S)$ is the yearly operational and maintenance cost; and $F^t(S)$ is the payment to pay the initial capital investment in t.

### Table 4. Variables affecting the consumers' adoption behavior

| Variable | Unit |
|---|---|
| Tariff Level | $/kWh |
| NM Rate | % over credit |
| Cashback Scheme | Binary: Yes or No |
| Lending Interest Rate | % per year |
| Payment Periods | Years |
| Consumption Level | kWh |
| Installed Capacity | kWp |
| Capacity Factor | % of potential output |

The **tariff level** has a positive effect on the viability of PV with NM policies. This occurs as a combination of two complementary effects. First, an increase in the tariff level decreases the NPV of consumption, which means that energy bought from the network is more expensive. Second, assuming the NM Rate is calculated over the retail price (as is the norm in almost every NM experience), the increase in tariff level increases the remuneration of the energy load to the network. Thus, the net present difference (between two sates: with and without PV) increases (and turns positive) with a higher tariff.

However, the retail tariff used to remunerate energy sold by DG can also have different trading terms. The **NM Rate** is calculated as a multiplier factor of the retail tariff. If greater than one, the generation is remunerated by a premium tariff. For instance, a factor of 1.1 implies that the price of DG energy is 10% higher than the price of consumption. In some cases, the NM premium is not calculated directly over the retail tariff, but over wholesale costs. This is the case of Jamaica, where the premium is defined as 15% over the price of oil-based generation displaced by DG production. These schemes are more volatile to decisions taken on the wholesale market. On the other hand, the NM Rate can also be smaller than one. In this case, the benefits of selling energy are lower than the costs of buying it from the grid. This scheme creates less friction between users' needs from the network and the revenue requirements of utilities; however, it can slow the rate of adoption in different setups. In the case of Mexico, for example, even a NM Rate of 0.8 represents a net benefit and can still be profitable. Nevertheless, the profitability is also sensitive to the level of household consumption.

A higher **consumption level** increases the present costs of electricity in a situation without PV installation, making PV Systems more profitable. Similarly, greater **installed capacity** increases the energy output of the system, which increases the NPV of generation if all energy can be sold to the network. However, returns on installed capacity vary from region to region and over time. Different regions have different irradiation intensities and period of sunlight, and improvements in technology may reduce the losses and increase the energy output by increasing the capacity factor.

When installing new systems of distributed energy, the cost of acquiring the system is an important variable. In our model, the cost is influenced by four variables: capital costs, operational costs, lending interest rate, and payment period. Capital and operational costs increase the cost of acquiring and maintaining the system properly working, while the lending interest rate affects the cost of financing DG equipment installation. The cost of acquiring a DG system increases if the **lending interest rate** increases. The **payment period** affects the duration of the project. Projects with higher payment periods decrease the cost over time than projects with shorter payment periods. For instance, in the case study, projects with payment periods shorter than four years are not profitable since the NPV of the DG system is negative, while projects above five years are only profitable with cashback schemes.

Cashback schemes are attractive to the adoption of DG systems because they remove the NPV of Generation ceiling, allowing users to make monetary gains. However, this scheme can lead to some problems if the adoption rate is high, such as (i) over generation during peak periods, (ii) nodal unbalances, (iii) distortion in the equilibrium between investments and utility revenue requirements. Conversely, schemes without cashback can impose a lower adoption rate.

**Figure 9.** Sensitivity Test to Policy, Consumer, Financial and Exogenous Variables

## Policy Setup Variables

## Exogenous Variable

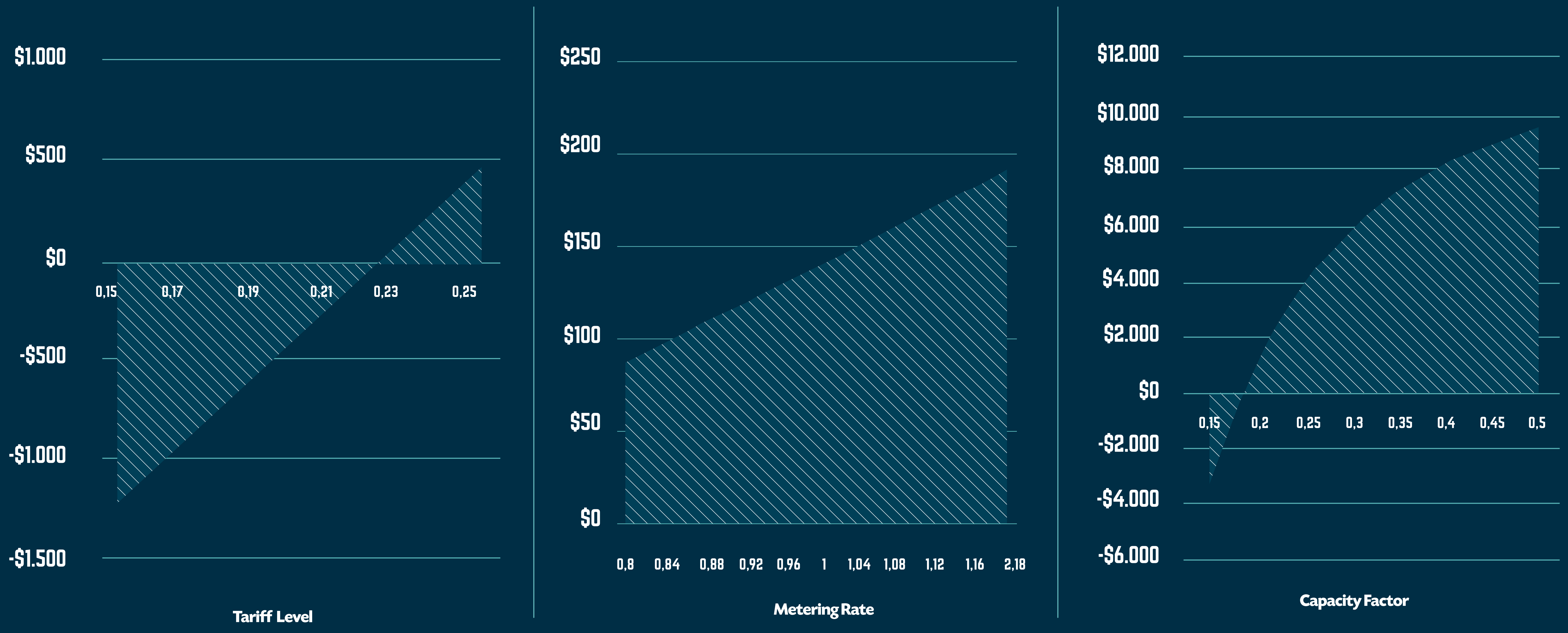
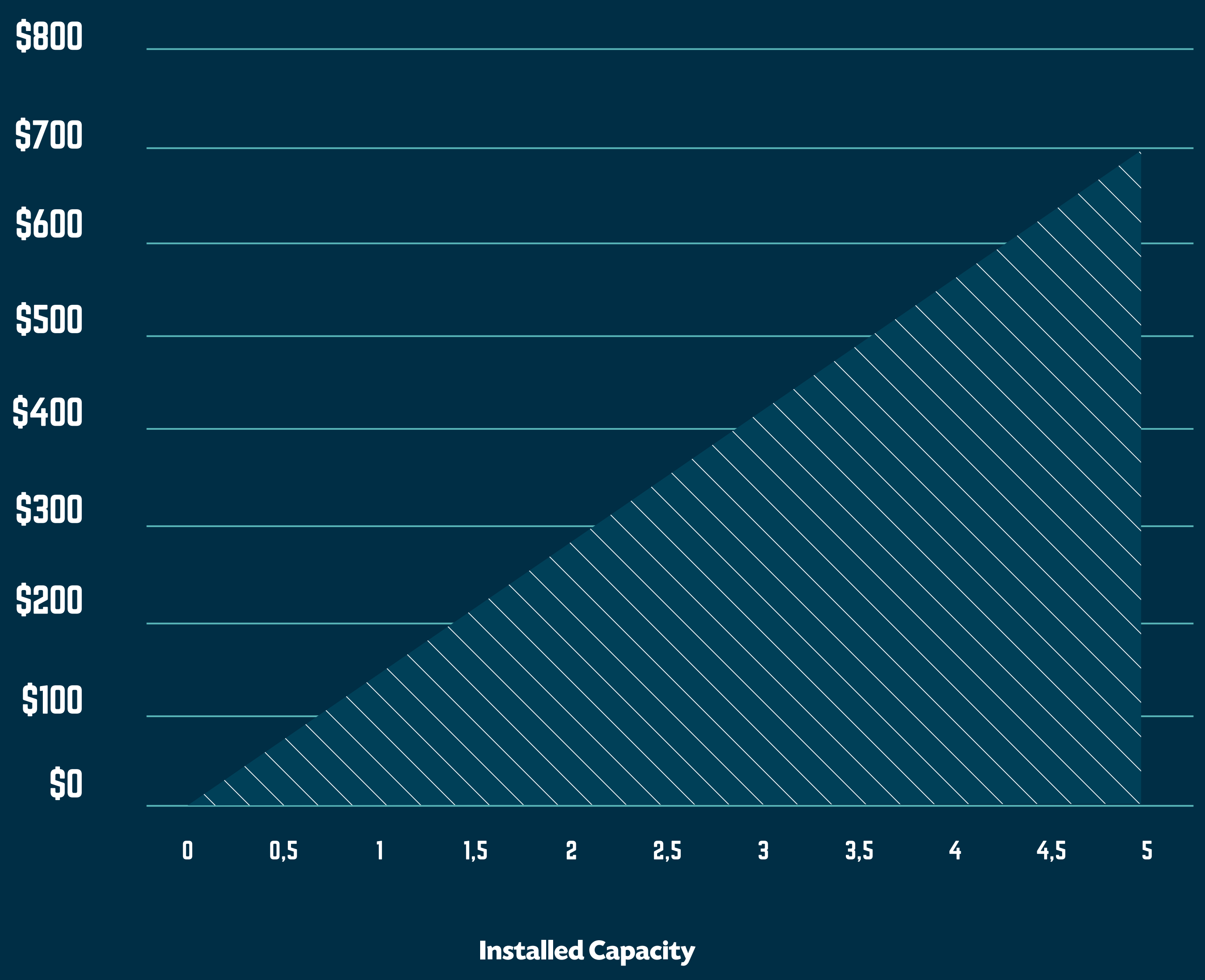


**Figure 9.** Sensitivity Test to Policy, Consumer, Financial and Exogenous Variables

## Consumer Decision Variables



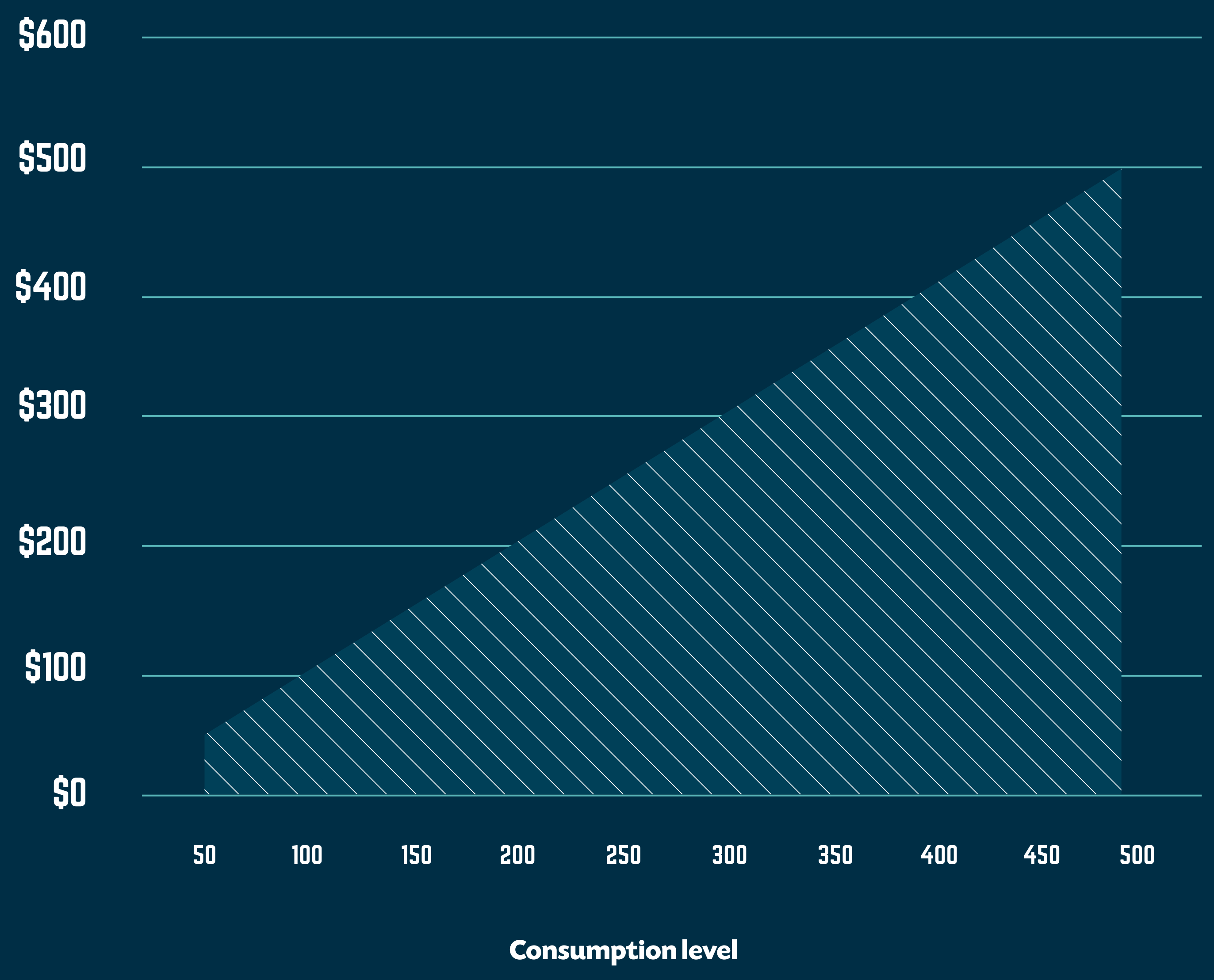
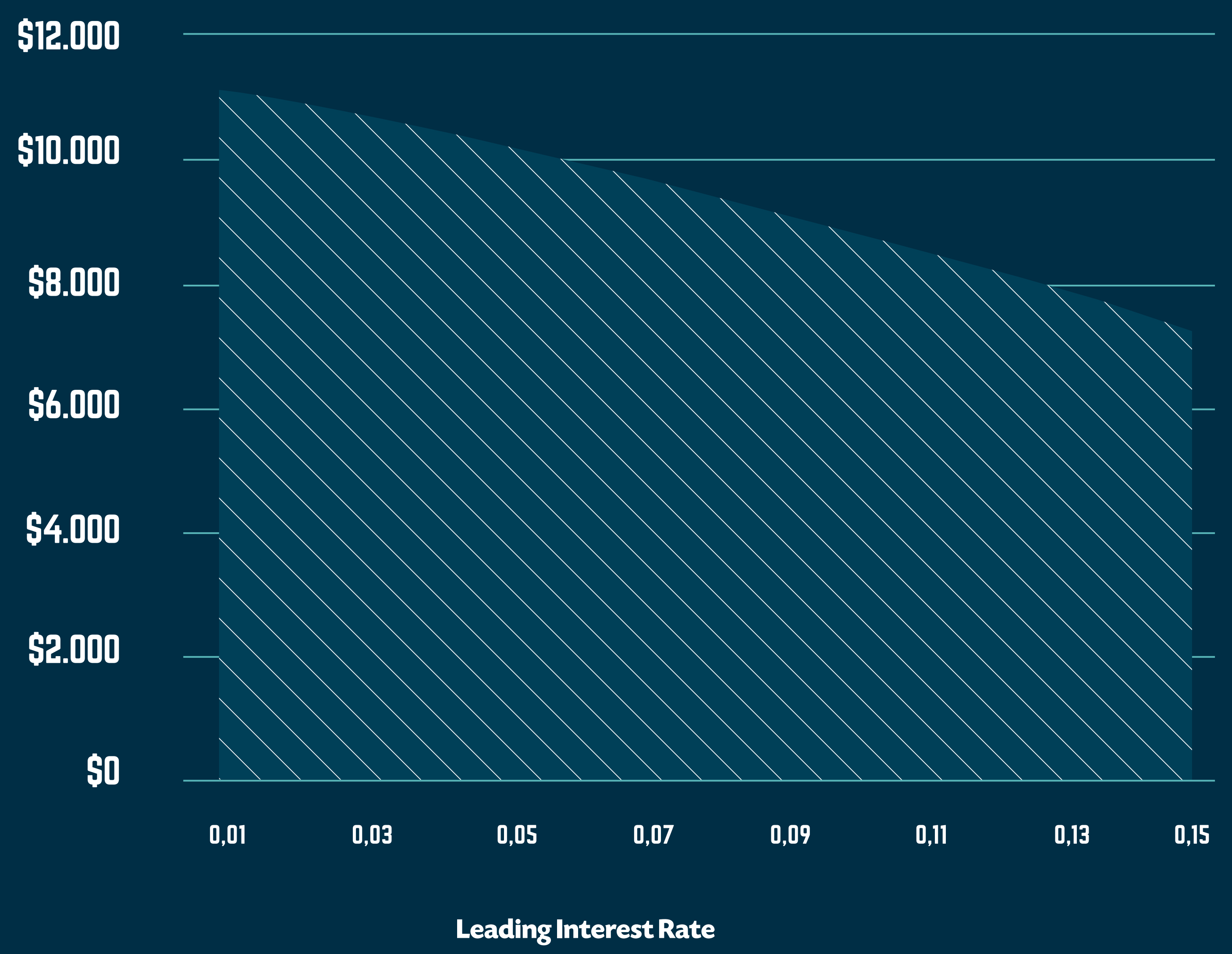
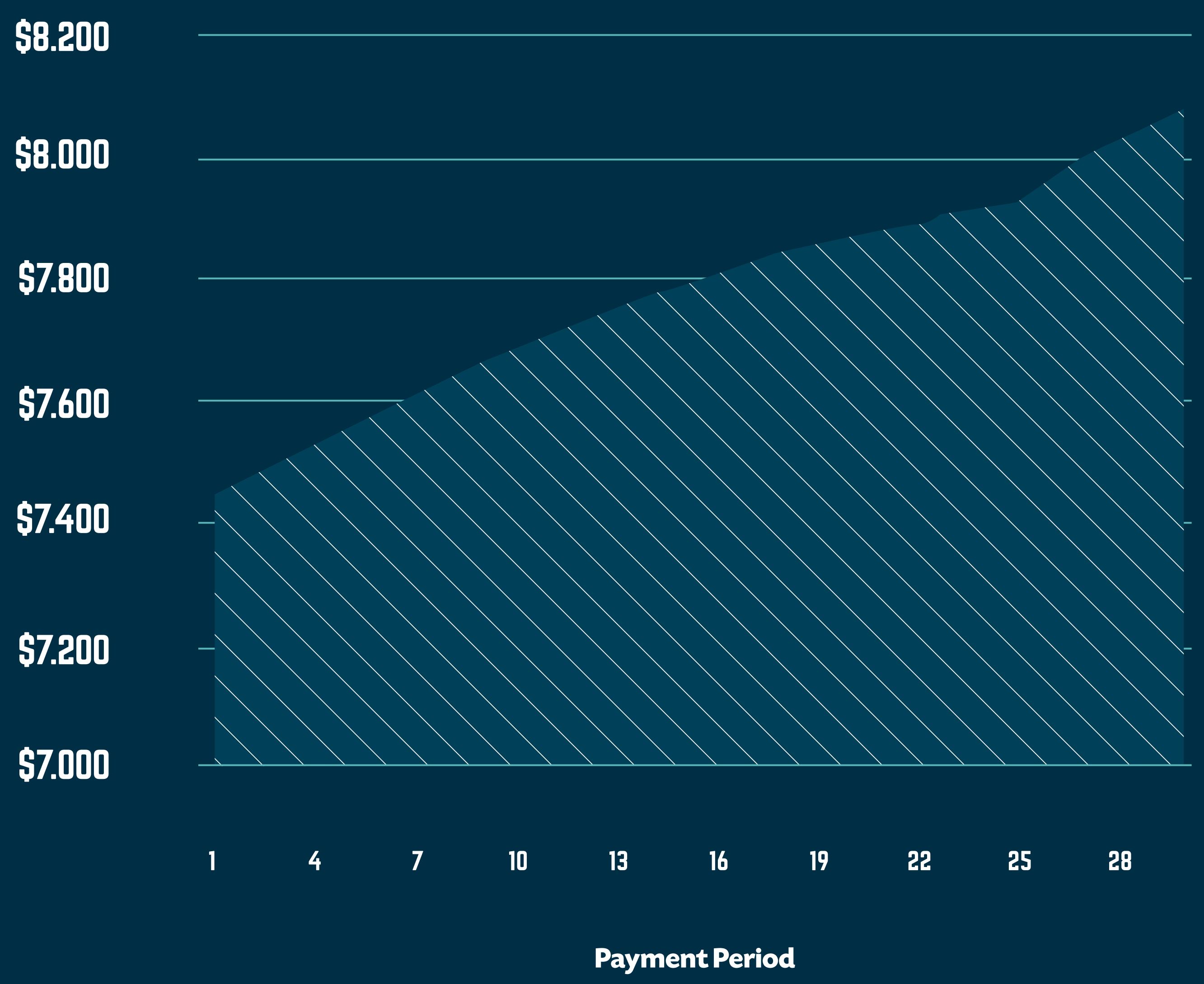



**Figure 9.** Sensitivity Test to Policy, Consumer, Financial and Exogenous Variables

## Financial Variables



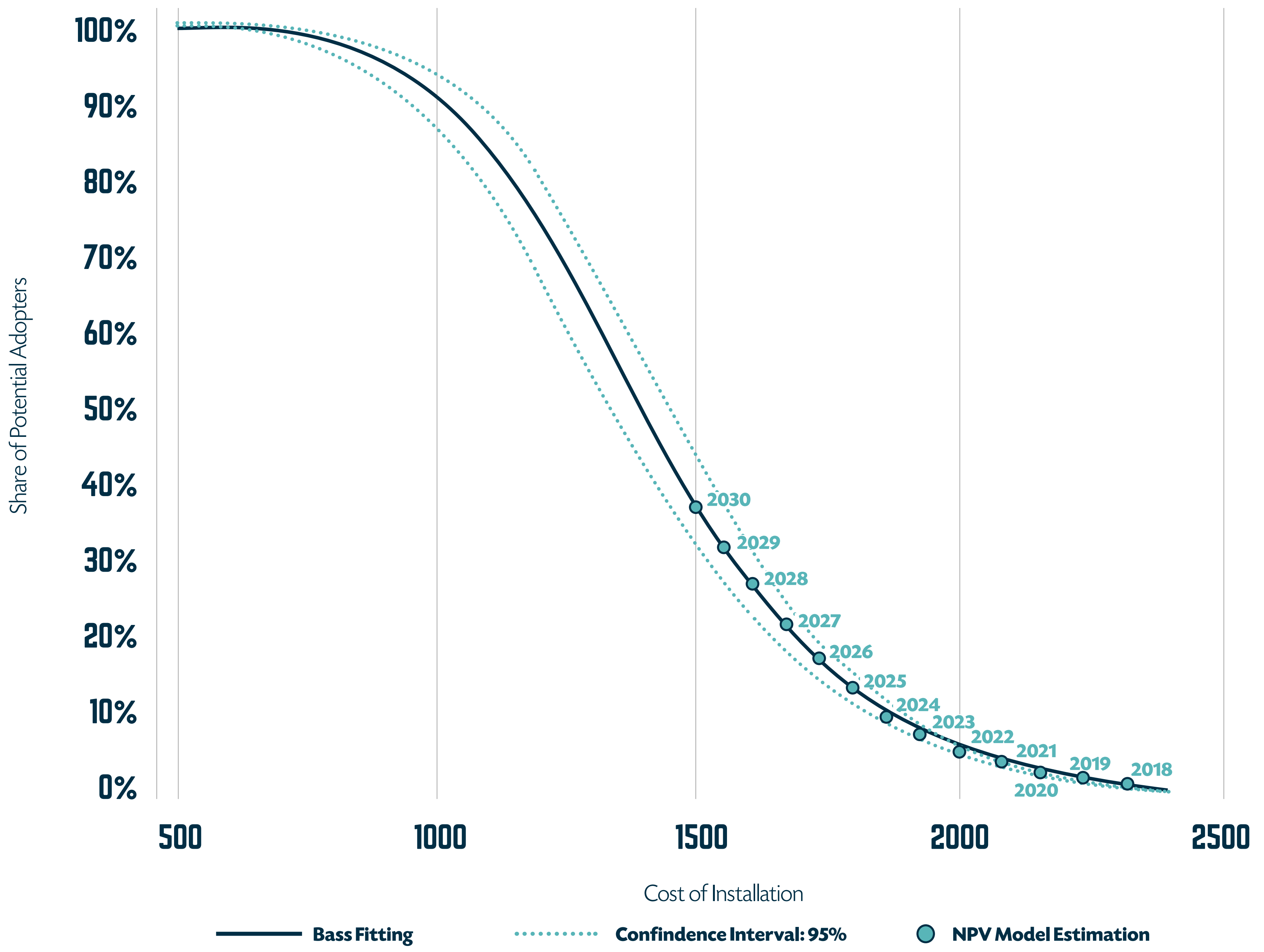



Of course, many factors can affect the adoption rate of DG systems, including non-monetary factors like environmental concerns. Overall, looking at only the economic value of DG projects in NM Schemes, Table 5 summarizes the incentives created by each variable design related to the DG adoption rate. The interaction of each variable design, of course, creates different outputs and depends on the magnitude of the individual effect.

## TABLE 5. SUMMARY OF VARIABLE EFFECTS

| Key Simulated Variable | Effect on DG Adoption Rate |
|---|---|
| Tariff Level (↑) | + |
| NM Rate (↑) | + |
| Cashback Scheme (Yes) | + |
| Lending Interest Rate (↑) | - |
| Payment Periods (↑) | + |
| Consumption Level (↑) | + |
| Needed Installed Capacity (↑) | + |
| Capacity Factor (↑) | + |

**Figure 10.** Results of the Bass Model Fitting Related to the cost level, 3.6% cost-reduction




In a previous IDB publication, (Mejdalani, Lopez & Hallack, 2018) simulate the potential incentive of a NM policy on the adoption rate of solar PV systems in Brazil using a project viability model and a technology diffusion model (Bass, 1969). The results show that under the current policy, technology and financing set up, the market for adoption of PV in Brazil can reach around 40% of technically viable consumers up to 2030 if cost decreasing follows the pattern expected by NREL (2017) of 3.6% per year (Figure 10).

Similarly, (Gonzalez, 2018) develops a NPV Model to assess the viability of Zero Energy Buildings in Colombia, while (Hancevic, Nuñez, & Rosellon, 2017) provide a similar study focused on distributed PV to Mexican residential sector. Their contribution shows that the high capacity factor of PV generation in Mexico may increase household's welfare due to significant annual savings.

# Concluding remarks

How to stimulate private investment in renewable generation has been challenging policymakers in the past years. Different policies have been proposed and experienced worldwide, such as non-pricing (quotas and obligations) and pricing instruments. Although LAC has witnessed a relevant increase in renewable generation, it is necessary to intensify the efforts in order to achieve decarbonization goals. From all different mechanisms that can be used to contract new power generation supply at the grid level (competitive solicitations, renewable auctions, feed-in tariffs and bilateral contracts), LAC has been implementing renewable auctions.

These auctions have shared some common similarities: i) long-term contracts (from 15 to 30 years), ii) technology-specific energy auctions for power contracting, and iii) the vast use of solar and wind. From 2009 to 2017, renewable energy auctions commissioned 13.3GW to the grid in just eight countries in the LAC region. Besides, 564 winning projects are yet to be commissioned, accounting 28.1 GW new generation capacity. Moreover, the average bidding price of new capacity auctions dropped considerably (32.9%) from 2009 to 2017, especially for solar projects which decreased 86.9% from 2010 to 2017.

NM has been a successful policy to promote the adoption of DG resources, especially Solar PV. However, the design of this policy is very heterogeneous among countries and many experiences have proved successful in adopting and implementing NM policies. In LAC, 15 countries have NM policies in-force, with different policy-settings.

We have performed a sensitivity analysis of the variables that affect the decision of a household when deciding the optimal size of the DG installation and consumption. First, an increment of the tariffs or the NM rate makes the installation of PV capacity more attractive under NM policies, as the remuneration of the generation injected to the network increases. Second, cashback schemes are more attractive for adopters than the write-off credits. Third, a higher consumption level makes PV systems more profitable since it increases the expenditures in electricity from the network. Similarly, greater installed capacity increases the energy output of the system, which increases the NPV of generation if all energy can be sold to the network. Finally, the cost of acquiring a DG system is correlated with the lending interest rate, while higher payment periods decrease the cost over time.

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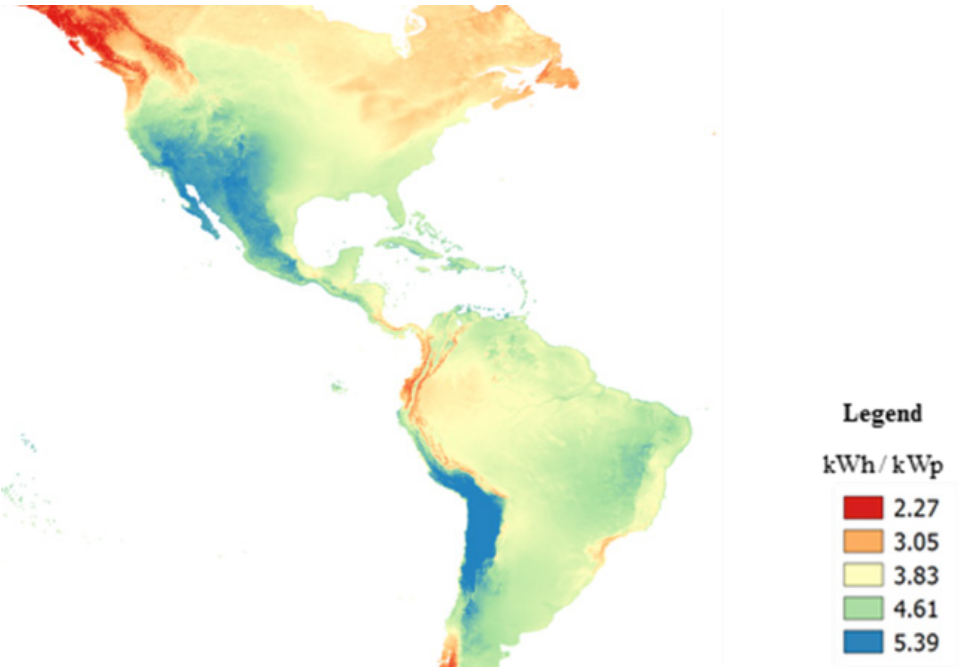
# **Annex 1.** Calibration of NPV Model

| Category | Variable | Mexico (2017) |
|---|---|---|
| **Regulators** | Tariff Level | 0.23 USD/kWh |
| | NM Rate | 100% |
| | Cashback Scheme | Yes |
| | Accumulation Period | 1 Year |
| | Accumulation Credit | Cash |
| | Lending Interest Rate | 7.75%r |
| | Payment Periods | 25 Years |
| **Consumers** | Consumption Level | 130 kWh/Month |
| | Installed Capacity | 4.6 kW |
| **Exogenous** | Inflation Rate | 5% |
| | Real Discount Rate | 2.75% |
| | Capital Cost of DG | 965 USD/kW |
| | Operational Cost of DG | 30 USD/year (USA) |
| | Depreciation Rate of DG | 5%/year |
| | Capacity Factor | % of potential output |

# **Annex 2.** Generation Capabilities in LAC: Wind and Solar

Figures 2 and 3 show the potentialities of power generation using Solar PV and Wind technologies. Many countries in the region have a high solar generation potential, in particular the north of Mexico and the Andean Region. On the other hand, the wind generation is more focalized on the south of Argentina and Chile, with some smaller regions of high potentiality in the Pacific coast of Central America, Bolivia, and the northeast of Brazil.

**Figure 11.** Solar Photovoltaic Electricity Output in the Americas, 2018



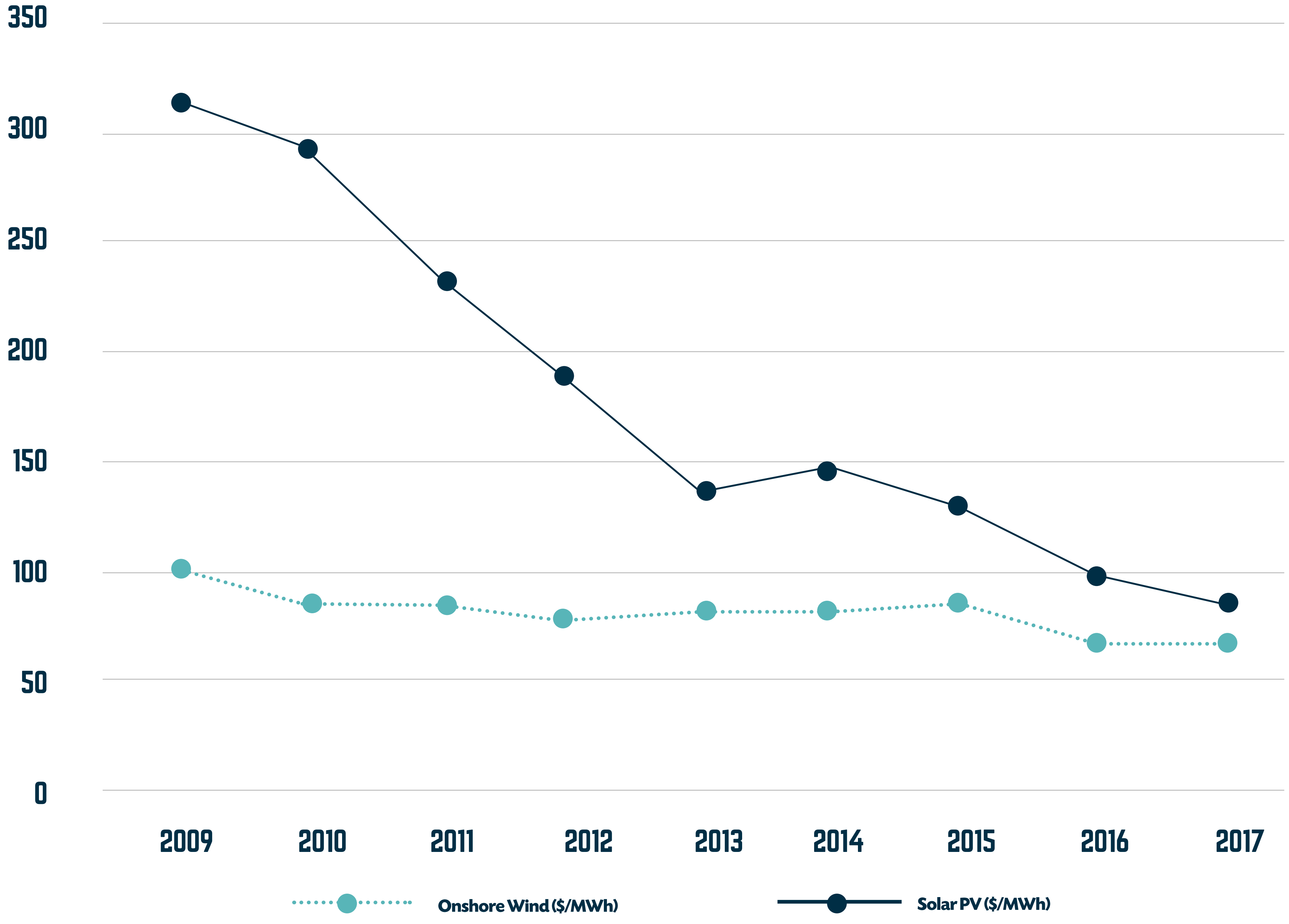

Source: Own elaboration using Solargis GIS data (The World Bank, 2018)

**Figure 12.** Figure 12. Wind Power Density in LAC, 2018 (in W/m2)

Source: Source: The World Bank (2018)

Even though the potential for solar generation is higher in most part of the region compared to wind generation, the cost of solar PV and wind projects can explain why the number of solar projects increased throughout the years and the bidding price rapidly dropped from 2009 to 2017. As shown in Figure 14, the levelized cost of energy (LCOE) of solar generation rapidly decreased while wind generation cost remained at the floor level in the period.

**Figure 13.** Cost reduction in renewable generation of Solar and Wind, 2009-2017




Source: Own elaboration based on Bloomberg New Energy Finance

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