Solving Mexico's Electricity Subsidy and Energy Poverty Granting Solar Bonuses for PV Solar Rooftops.

Daniel Chacon-Anaya[1]

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[1] Energy Director; Iniciativa Climatica de Mexico, A.C.

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The "Solar Bonus" program aims to refocus the present and highly regressive residential electricity subsidy towards providing part of the funds that residents require to install solar PV rooftops with enough capacity to supply their present power needs. At the same time, users can get a discount from their power bills as was promised during the campaign to gain support for the energy reform. Additionally, the new rules allow residential users to sell to the grid any surplus volume of electricity they generate. The rationale is that homes with a solar rooftop will no longer require a subsidy and, furthermore, will make a profit by supplying clean energy to the grid at a cost lower than CFE's unsubsidized electricity prices. According to the World Bank, Mexico has one of the most complex tariff and subsidy structures in the world[2]

Under the new rules regarding distributed generation, small generators under 500 kW skip the cumbersome permitting process, and can be interconnected to the grid by presenting simple paperwork. However, the present highly subsidized tariffs deter PV adoption; residents prefer to continue under the subsidy umbrella instead of disbursing a significant upfront cost for installing PV rooftops.

The purpose of the solar bonus is to lower the cost of the solar rooftop in order to break the subsidy barrier to reach parity between present residential tariffs and PV technology costs. Users will be able to afford to install PV by paying monthly installments equivalent to the present tariffs rate minus a sizable discount, leaving their subsidy dependency. In turn, the State will use the freed subsidy to finance other pressing needs in the country. Additionally, the program could include several energy efficiency measures to optimize investments in solar rooftops and improve the houses' energy performance.

Distributed generation by residential solar rooftops offers the unique opportunity to solve at least four pressing problems that Mexico faces: (1) a gigantic subsidy, estimated to be 6.2 billion USD/yr for 2017 (1 USD = 19 MXP), for residential electricity that is very expensive to public finances, and very regressive favoring the higher income population; (2) energy poverty that affects a very significant proportion of the population that cannot aspire to a better living standard because electricity is very expensive even with the highly subsidized tariffs[3] [4]; (3) shortage of mitigation opportunities in the electricity sector to comply with Mexico's INDCs (now NDCs) committed under the Paris agreement[5]; (4) save capital investments in centralized electricity generation, transmission and distribution by democratizing energy as citizens are able to participate as electricity suppliers for their own use and for selling electricity to the grid.

The "Solar Bonus" program uses the electricity subsidy as a tool to solve the four problems in a very substantial way:

- Fully deployed, this program (scenario DG1.2-70) will install, on 70% of Mexico's homes, 25.1 million rooftops with a total capacity of 27.1 GW in a 15-year time span, allowing residences to

[2] Komives, Kristin et al; Residential Electricity Subsidy in Mexico; World Bank; 2009; Available at: http://elibrary.worldbank.org/doi/abs/10.1596/978-0-8213-7884-7. [Consulted on: 04/25/2016]

[3] World Energy Council; Average Electricity Consumption per Electrified Household; 2015. Available at: https://www.wec-indicators.enerdata.eu/household-electricity-use.html

[4] Garcia, Rigoberto; Pobreza Energetica en America Latina; CEPAL-United Nations; 2014. Available at www.cepal.org/es/publicaciones/36661-pobreza-energetica-america-latina

[5] Chacon, Daniel; Opportunities to Mitigate GHG in the Electricity Sector; Magazine Energia a Debate; Number 74, May-June; 2016. Available at: http://energiaadebate.com/energia-a-debate-no-74-mayo-junio-de-2016/. [(Consulted on: 05/06/2016)]

generate their own electricity without any subsidy. These figures are comparable with other efforts at the international level[6] [7] [8] [9].

- It will free around 67,495 million MXP, equivalent to three billion dollars, per year, to be used in much needed and under-budgeted social programs
- Save 23.6 million tons of CO2 eq. per year (considering a factor of 498 kg CO2eq/MWh) helping Mexico to comply with the NDCs.
- Save and/or delay investments in generation and transmission, and avoid loses in transmission.
- Allow people to enjoy better living standards by effectively lowering electricity cost by taking advantage of decreasing PV technology prices.
- Open a new business avenue worth 527,966 billion MXP equivalent to 27.7 billion USD. This amount is equivalent to 0.20% of GDP with new value chains and creating at least 200,000 jobs.
- It will provide people with the opportunity of an additional income by selling electricity to the grid.
- Save around 200,000 oil barrels per day[10]

[6] Schwabe, Paul; Zhou Ella; Sprint 2: Distributed Generation of Power and Heat; NREL; 2015

[7] Channell, Jason, et al: Energy Darwinism; Citi GPS; 2013

[8] Clean Technica. March 19, 2015. "China's National Energy Administration: 17.8 GW Of New Solar PV In 2015 (~20% Increase)" Available at: http://cleantechnica.com/2015/03/19/chinas-national-energy-administration-17-8-gw-new-solar-pv-2015/

[9] Decentralised Energy. 15/04/2016. "Meeting india's energy goals with decentralized technologies" Available at: http://www.decentralized-energy.com/articles/print/volume-17/issue-2/features/meeting-india-s-energy-goals-with-decentralized-technologies.html

[10] (4) US Energy Information Administration; How Much coal, natural gas, or petroleum is used to generate a kilowatthour of electricity?; October 2015. Disponible en: https://www.eia.gov/tools/faqs/faq.cfm?id=667&t=6

Part 1: The Solar Bonus Program

Sector Context

The Energy Reform and the Clean Energy Goals

Mexico's energy reform has opened up the electricity, oil and gas sectors to private investment under differentiated approaches. In the case of oil and gas, the whole value chain has been opened up for private investment. In the case of electricity, private investment is fully allowed in power generation and commercialization, and partially allowed in transmission and distribution. The energy transition to a decarbonized electricity grid has been largely benefited by the window of opportunity opened by the energy reform.

Mexico's approach to meeting its GHG mitigation goals has evolved, by separate ways, into a two-prong public policy: on one side, goals have been established for all the economic sectors and expressed in avoided tons of CO_2eq emissions. These goals are specifically stated in the Climate Change General Law (CCGL) passed in 2012, echoed in the Climate Change Special Program (PECC) published in April 2014, and finally established in the INDCs published in March 2015. However, the goals do not necessarily coincide, because different approaches, baselines and dates have been used to define them. It can be said, in a practical way, that the goals with a higher hierarchy are the more recently published which correspond to the INDCs.

The Secretariat of Environment and Natural Resources (SEMARNAT) published Mexico's INDCs in March 2015[11], establishing a non-conditional goal of 22% GHG reduction by 2030 against a newly defined business as usual (BAU) baseline. The following table shows the different goals:

Table 1.1 – Evolution of Mitigation Commitments

Policy Instrument	2020	2030	2050
CCGL and PECC (2012 and 2014 respectively)	30% conditioned and referenced to a baseline[12]. Non-binding		50% regarding year 2000's emissions[13]. Non-binding up to now
INDC (2015)		22% non-conditioned and referenced to a baseline[14]. Binding in terms of Paris Agreement	

Source: D. Chacon with data from SEMARNAT

On the other side, it is worth highlighting that one important ingredient in the constitutional changes conductive to the energy reform was the mandatory obligation to achieve a certain percentage of clean energy within the electricity mix. The constitutional mandate was further detailed in the so called secondary laws comprising the Electricity Industry Law (EIL), passed by Congress in August 2014, and the Energy Transition Law ETL, passed by Congress in December 2015.

[11] SEMARNAT, Contribución Prevista y Determinada a Nivel Nacional de México, 2015

[12] This goal most probably will not be considered achievable as it was fully conditioned to non-existent international support in terms of financing and technology transferring

[13] Most probably be regarded as valid as it coincides with Mexico's 2°C path

[14] The 2030 baseline is different than the 2020's

Emissions goals have been assigned to the electricity sector, but indirectly addressed as percentages of power generated by clean energy feed in to the electricity mix. These goals were first designated as indicative goals in the now derogated Law for the Use of Renewable Energy and the Financing of the Energy Transition (LUREFET), passed in 2008 and replaced in 2015 by the ETL. The CCGL echoed and reworded LUREFET's goal, keeping its indicative nature.

The EIL establishes the obligation for qualified users and electricity providers to comply, under substantial fines, with certain percentages -not specified in EIL- of clean energy, while the ETL establishes the compulsory national goals of 25% clean energy by 2018, 30% by 2021, and 35% by 2024. The combination of both laws is the basis for a sound scheme and route to greening the grid. EIL and ETL have resulted in very effective legal instruments for Mexico's power sector decarbonization.

As stated earlier, Mexico has two sets of mitigation goals, one expressed as GHG reductions involving all emitting sectors including electricity generation, and the other expressed in percentages of clean energy within the electricity mix pertaining only to the electricity sector.

The Electricity sector estimated contribution to GHG emissions, future trends and drivers of growth.

According to SEMARNAT, baseline emissions by 2030 will total 973 MtonCO_2eq. A 22% reduction means total emissions of 762 MtonCO_2eq by the same year, namely 211 MtonCO_2eq less than BAU. The intended contribution of the electricity generation sector to these INDCs means that this sector shall reduce its emissions by 2030 from an expected BAU of 202 MtonCO_2eq, to 139 MtonCO_2eq, namely, 63 MtonCO_2eq less. As the power sector is the second largest GHG emitter, just behind the transport sector, its contribution to the INDCs is substantive[15].

The electricity sector's annual growth rate is in the order of 3.5% to 4% for the next 15 years driven by a forecasted GDP of 4%[16]. Data from the National Electricity System Development Program (PRODESEN) pointed out that in 2013, the National Electricity System (NES) had a capacity of 64,131 MW and generated 297,095 GWh. In 2014, the capacity grew to 65,452 MW and the generation was 301,462 GWh, an increase of 2.1 and 1.5% respectively. The electricity mix was 79.6% from fossil sources and the balance from clean energies[17]. SEMARNAT's INDC estimates that in 2013, GHG emissions from the electricity generation sector were 127 Gton CO_2eq[18].

PRODESEN estimates that the additional capacity to 2029 will be 59,986 MW, almost doubling present capacity; 54.2% of the new energy will be clean and the balance will be fossil. Generation by 2029 is projected in 568,000 GWh/yr way above the present 301,462 GWh/yr. Adjustment to 2030 considering a growth rate of 3.5% results in 587,880 GWh.

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[15] INECC, 2015. "México's INDC". Avaliable at: http://www.gob.mx/inecc/acciones-y-programas/contribuciones-previstas-y-determinadas-a-nivel-nacional-indc-s-por-sus-siglas-en-ingles-17371 [Consulted on: 04/20/2016]

[16] SENER, Mexico 2015. "National Electricity System Development Program (PRODESEN) 2015". Available at: http://www.gob.mx/cms/uploads/attachment/file/54139/PRODESEN_FINAL_INTEGRADO_04_agosto_Indice_OK.pdf [Consulted on: 04/20/2016]

[17] According to LIE's clean energies definition which includes nuclear, big hydroelectric, and efficient co-generation among others. ETL limit the designation of any other technology as clean to CO_2eq emission lower than 100 kg/ MWh. Available at: http://cdn.reformaenergetica.gob.mx/2-ley-de-la-industria-electrica.pdf [Consulted on: 04/20/2016]

[18] INECC, 2015. "México's INDC" Supra Note 4.

PRODESEN -which includes the national clean energy goals- and INDC, only fit together if very ambitious emission factors are met, even at the level of BAU estimates. In fact, putting together an energy generation level of 587,880 GWh/yr in 2030, and BAU emissions of the electricity sector of 202 MtonCO_2eq by the same year, results in an emission factor of 0.343 tonCO_2eq/MWh for the whole electricity sector. Even further, the mitigation goal of 139 MtonCO_2eq means, by itself, an emission factor of 0.236 tonCO_2eq/MWh. In comparison, combined cycle with gas turbine (CCGT) has an emission factor of around 0.370 tonCO_2eq/MWh[19]. Resulting emission factors are even tougher to reach considering that the projected clean energy penetration by 2030 will be slightly above 37% according to PRODESEN, while balance, 63% will be mostly CCGT[20].

Estimates by PricewaterhouseCoopers (PwC)[21] point out that a realistic mitigation potential of PRODESEN's electricity mix by 2029 could be in the order of 46 MtonCO_2eq below BAU, which is around 17 MtonCO_2eq short of INDC estimates for the electricity sector. Additionally, Mexico's unconditional mitigation goal for 2030 aims at the 3°C path. In the near future, if Mexico elevates its ambition and aims at the 2°C path in an unconditional way, the gap between PRODESEN and INDCs will widen to approximately 74 MtonCO_2eq/yr[22].

Existing policies aimed at encouraging or requiring GHG emissions reductions in the sector.

The constitutional energy reform and the secondary laws have set the stage for a sound deployment of clean energies, and more specifically, renewable energy. The compulsory goals, together with the clean energy certificates (CECs) and significant fines for defaulters, have created high expectations among investors as the recent tenders showed with world record-breaking proposals for supplying clean energy and CECs to CFE as the company needs to comply with ETL's compulsory goals.

However, even when the present policies do foster clean energies, they are not sufficient to ensure Mexico's compliance with its INDC. As it can be seen, the only way to address the gap between PRODESEN and INDC will be engaging additional opportunities of mitigation beyond the stated clean energy goals for the electricity mix. For this purpose, the next best option to cut emissions in the electricity sector will be though a massive deployment of distributed generation in the country's cities and communities.

The new policy framework for distributed generation represents a great opportunity to grasp the benefits of this relatively new way to generate electricity, democratizing, at the same time, the production and use of energy. Distributed generation can help to alleviate the so called "energy poverty" which is a pressing social problem in Mexico.

Key barriers for climate goals in the electricity sector

Barriers to the mitigation goals can be broken down by economic sectors. In the specific case of the electricity sector, the key barriers are the inertial use of fossil fuels as most of the electricity generation is produced by fossil fuels. A long history of investments in fossil fuel exploitation, distribution and use to generate electricity has built an extensive infrastructure to handle and use coal, bunker oil, and natural

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[19] Spath, Pamela L. and Mann, Margaret K.; Life Cycle Assessment of a Natural Gas Combined Cycle Power Generation System; NREL; 2000

[20] Ibídem 15

[21] PwC; *Estudio sobre las Inversiones Necesarias para que México Cumpla con sus Metas de Energías Limpias*; October 2015. Available at http://www.pwc.com/mx/es/industrias/energia/archivo/20151018-gp-cespedes.pdf. [Consulted on: 05/01/2016]

[22] Ibídem 4

gas. Bunker oil is being replaced by natural gas, in a very aggressive way, taking advantage of its lower cost and lower carbon footprint; however, if Mexico's INDC is going to be met, natural gas will not be sufficient to reach the 2030 goal committed to UNFCC. New energy investments need to be forwarded to clean energy projects specifically to solar and wind, which are demonstrating that they are cheaper than the fossil fuels alternatives.

In the residential electricity sector, a key barrier is the electricity subsidy. The subsidy, while primarily intended to make electricity affordable to the whole population, is, indirectly, a subsidy to fossil fuels as 80.32% of the electricity supplied to the domestic sector is generated by fossil fuels[23]. In fact, the subsidy could be thought as a way to reduce the price of fuel for to generation plants, which is one of the major electricity cost components.

Contrary to other countries with real electricity prices, cheap subsidized electricity in most of Mexico's homes inhibit the deployment of solar rooftops as PV technology does not reach parity with residential tariffs. There is only a subsector where parity has been reach. However, this subsector constitutes just a small portion of the residential sector as it will be explained ahead in this document.

Program Description

Understanding Mexico's residential electricity subsidy

Mexico's residential electricity subsidy hovered around 100,000 million Mexican pesos (MXP) in 2014, equivalent to 5.0 billion USD per year[24] as can be seen in Figure 1.1[25] [26]. Despite its huge amount, the residential subsidy continuous to grow, as during 2014, 2015 and 2016 there were 2% price rebates and no upward adjustments per inflation whose rate is estimated at 2.5% per year. If one adds these numbers, it is probable that the subsidy is now 10% to 15% higher than in 2014.

According to the World Bank, Mexico has one of the most complex tariff and subsidy structures in the world[27]. As a response to persistent inflation, Mexico's government introduced electricity subsidies in 1973. Previously, the country's residential sector was charged by the same single tariff (Tariff 1). After 1973, the system was converted to a three increasing blocks tariff with subsidized rates for the first two blocks.[28]

[23] SENER. Reporte de Avance de Energias Renovables, Mexico 2016. Available at: http://www.gob.mx/cms/uploads/attachment/file/177519/Reporte_Avance_Energ_as_Limpias_1er_sem_2016_VFinal_28122016.pdf

[24] Considering an exchange rate of 17 MXP per one USD. Based on the national trend in the first trimester of 2016. Data available at: http://www.sat.gob.mx/informacion_fiscal/tablas_indicadores/Paginas/tipo_cambio.aspx [Consulted on: 05/01/2016]

[25] Figures for 2015 and 2016 subsidies are not available.

[26] There is another subsidy for crops irrigation, that amounts to 13,000 million MXP, not included in this proposal. Conditions of this subsidy are worst that the residential subsidy and require a separated analysis and proposal.

[27] Ibídem 1

[28] Ibid. P. 10.

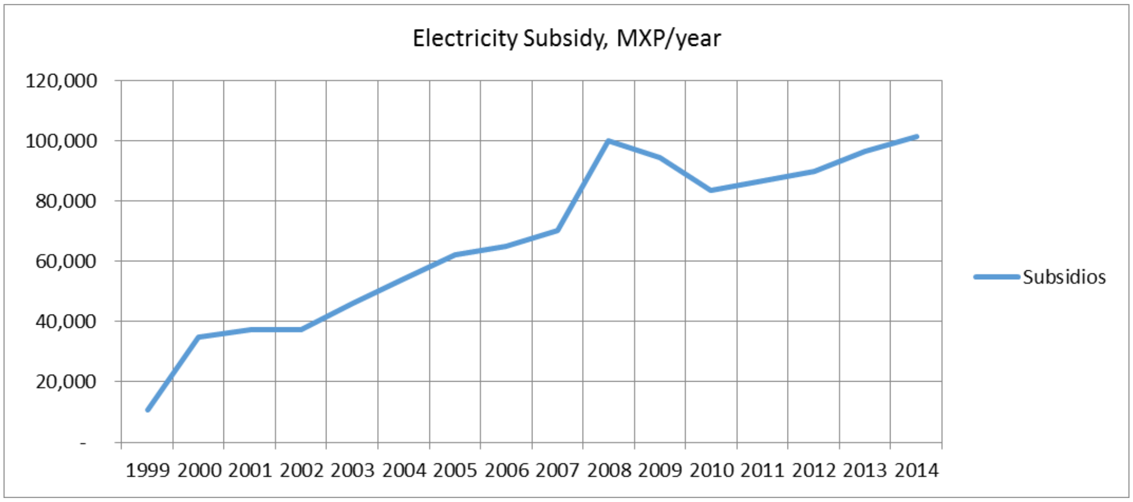

Figure 1.1 – Electricity Subsidy Evolution
Source: Tercer Informe de Gobierno 2014-2015. Anexo estadístico. PP: 540-544. Presidencia de la República. México 2015.

Tariff 1A was introduced for the first time in 1974 and applied to areas with more than 4 months of average temperatures above 25°C. Later, beginning in 1988, a set of incremental tariffs (Tariff 1B > 28 °C; 1C > 30 °C, 1D > 31 °C, 1E > 32 °C, 1F > 33 °C) were introduced to grant increasing subsidies to hotter temperatures zones. In 2002, a special regime was introduced for all tariff groups under the denomination of High Consumption Residential (HCR), which penalizes excessive consumption above differentiated limits. The number of HCR users nowadays range between 400,000 and 450,000, a very small amount compared to an estimated 36 million subsidized domestic consumers. HCR's demand is around 5% of the total residential demand.[29]

The World Bank pointed out that the electricity subsidy for residences is very regressive because it favors the wealthy more than those people belonging to the lower percentiles of household income. Climate depending tariff groups from 1A to 1F are the most regressive. While the bottom three-income deciles account for about 21% of total subsidies, the top three income deciles account for 38%. Worse than that: more than one-quarter of total subsidies go to the top income decile alone. The hottest tariff group, 1F, is the most highly subsidized customer group.[30]

Figure 1.2 depicts the residential tariff evolution. It can be seen that cost (blue line) had a uniform increasing trend mostly due to inflation adjustment before 2013. The gray line represents total increasing electricity cost due to more costly fuel and other cost components. The yellow line shows the government's contribution, or subsidy, to compensate for the increasing cost.

CFE makes sure that users are aware of the subsidy by breaking down the electricity bill to show the subsidized amount and adding the legend: "*Government Contribution*".

[29] Energy Regulatory Commission, 2015. "Reporte Mensual de Estadísticas del Sector Eléctrico" Available at: http://www.cre.gob.mx/documento/3045.pdf. [Consulted on: 04/25/2016]
[30] World Bank, 2009. Supra Note 11.

From the graph, it is evident that there is a policy trend to keep tariffs flas as much as possible recognizing the political cost of raising them.

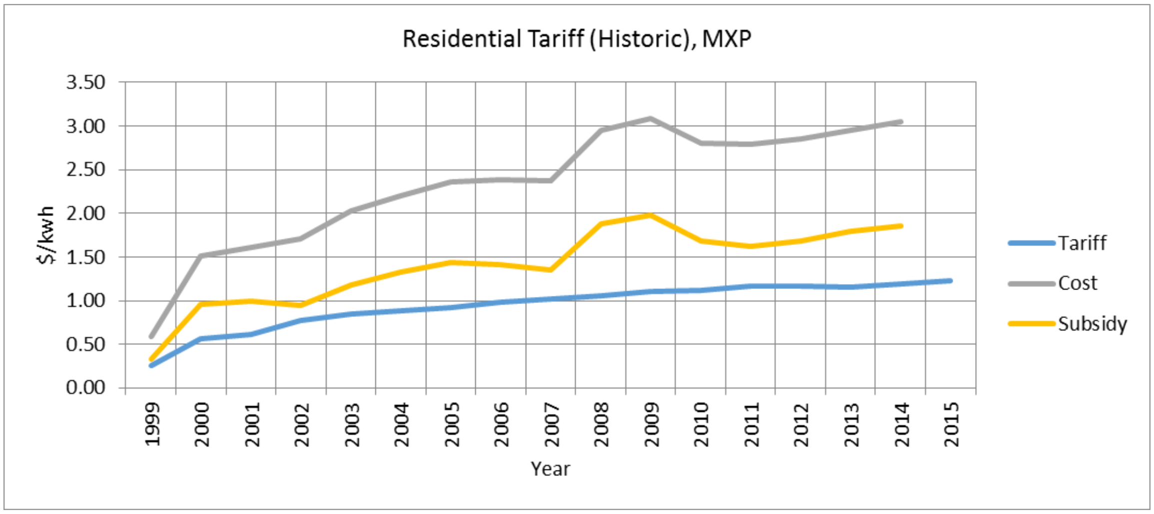

Figure 1.2 – Residential Tariff Evolution

Source: Tercer Informe de Gobierno 2014-2015. Anexo estadístico. PP: 540-544. Presidencia de la República. México 2015.

Objective of the Program

As an answer to alleviating the electricity subsidy, and to seek more mitigation opportunities, it is proposed to refocus the subsidy for residences to provide households with solar rooftops at a significant scale so the subsidy will be no longer needed. This will benefit the Mexican state, home residents, and the environment.

The "Solar Bonus" program aims to refocus the present residential electricity subsidy towards providing part of the funds that residents require to install solar rooftops with enough capacity to supply their present power needs and generate an additional volume of electricity to sell to the grid. The rationale is that homes with a solar rooftop will be self-sufficient (in net terms) and no longer require a subsidy and, furthermore, will supply clean energy to the grid -at a cost lower than CFE's unsubsidized electricity prices- and earn an income.

The following narrative will be focused on describing the characteristics, needs and benefits of a DG scenario consisting in providing solar rooftops to 70% of the country's houses in a period of 15 years. The generation capacity for each house depends on the tariff group where is located but, in all cases, will be between 1.1 and 1.2 times the house's historical needs (to facilitate the description, this scenario will be designated as DG1.2-70). The 70% figure is an estimate assuming that the remaining 30% of the country's homes have some kind of obstacle to installing the PV modules, and that the future PV technology will remain as for today not being able to provide solutions for most of the foreseen obstacles during the 15-year period.

Scenario DG1.2-70 means that 25.1 million rooftops and an overall capacity of 27.1 GW will be added to the electricity national system after a 15-year implementation period. Avoided CO_2eq emissions will be in the range of 23.5 million tons per year of CO_2 eq. If the rooftops were deployed in steady increments, the installation rate would be 1.6 million per year and the annual added capacity would be 1.8 GW. However, is probable that the real rate of deployment will follow an exponential path with the installation of a small number of rooftops at the beginning to allow for the capacity building of all the actors, the setting up of value chains, and the further reduction of solar PV technology cost.

The figures discussed above are comparable with other efforts at the international level. For example, according to the National Renewable Energy Laboratories (NREL), in the U.S. the annual rate of DG installation was 1.3 GW in 2014. NREL also predicted 2.0 GW would be installed in 2015 and close to 3.0 in 2016[31]. Germany installed 7 GW per year during 2009, 2010 and 2011, adding 21 GW in three a year-period, mostly DG under a feed-in-tariff scheme (FiT)[32]. It is estimated that China installed around 2 GW of DG in 2014, out of 15 GW total for solar. China also applies a FiT scheme for PV solar[33]. India set the goal to achieve 40 GW of solar rooftops by 2022[34], meaning installing 6.6 GW per year.

Subsidy Transfer Mechanism

Transferring funds from the subsidy to solar bonus has two key aspects: (1) In theory, putting together the annual subsidy during a certain number of years (from 8 to 15) depending on the official volume of the subsidy, will generate enough capital to entirely pay solar rooftops for the 36 million houses; (2) In practice, such a transfer is not possible due to a number of physical constrains. Therefore, the mechanism requires spreading the program over a reasonable period to allow the Treasury Secretariat (Hacienda) to begin providing solar bonuses to houses entering the program, and, at the same time, continue providing subsidies to those pending to enter. To simultaneously implement both requirements, the government needs to share the financial burden by enrolling users in the funding effort. Users will contribute with part of the cost of the solar rooftop. However, this contribution must be limited to the users' financial capacity as it will be explained below.

Aside of enrolling users, the program also requires a start-up or bridge fund that "primes the process pump". This fund is worth around 25% of the program's total cost and is entirely repayable by the avoided subsidy in a period shorter than the program itself. The proposal assumes that this funds will be provided by an international loan, probably a concessional one.

Each time a house enters the program, a portion of the subsidy is avoided. The cumulative nature of the avoided subsidy for the subsequent years will provide the necessary funds for the solar bonus of the next solar rooftop and so on. Figure 1.3 shows a simplification of the revolving mechanism assuming a steady program implementation for 15 years.

[31] Ibídem 5

[32] Ibídem 6

[33] Ibídem 7

[34] Ibídem 8

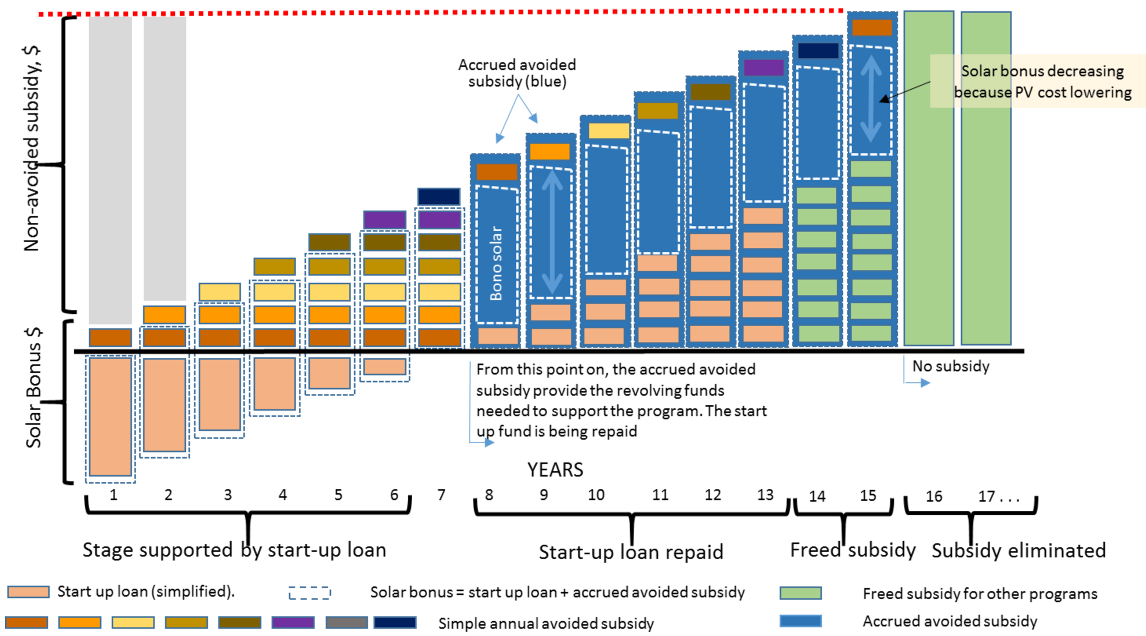

Figure 3. – Solar Bonus Deployment Mechanism
Source: D. Chacon

It can be seen, in Figure 1.3, that during the first 6 or 7 seven years, a decreasing start-up fund is required to provide the solar bonus. At year 7 or 8, the accumulated avoided subsidy is the funding source for the solar bonus for the next 6 or 7 years. At years 14 and 15, there is a surplus amount of money freed to be used in other pressing national needs. At year 16, the whole electricity subsidy is no longer needed. Solar rooftops installed during the program's first year will remain operational at least 10 years more once the program ends. The graph also shows the effect of the decreasing cost of PV technology over the solar bonus. The solar panels are every year 10% cheaper than the year before. The subsidy is freed at a faster pace because of the diminishing solar PV costs.

Depending on the subsidy's official volume and the timing, users will pay around 30 to 40% of the cost of their rooftops via a soft commercial "soft" loan with around 10% interest rate and 10-year period. A fundamental assumption is that the monthly repayment for the soft loan should be 15-20% below the present electricity bill if the proposal is to be acceptable to users. Users will no longer pay for the electrons, as they are provided by the PV modules, they will just pay for the soft loan. At the end, the State will pay only a portion of the cost of the solar rooftops and not the total cost. Figure 1.4 shows schematically the contributions from the users and government.

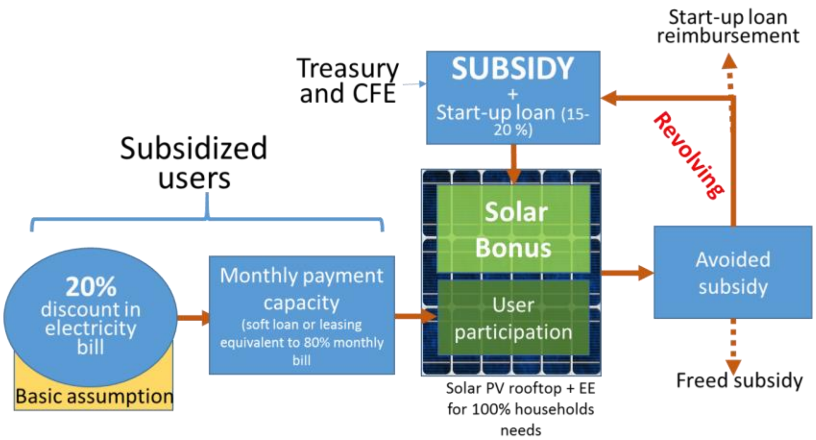

Figure 1.4 – Government and users' contributions
Source: D. Chacon

Recapping, this proposal aims to break the subsidy barrier to reach parity between residential tariff and PV technology costs. The purpose of the solar bonus is to lower the cost of the solar rooftop so users are financially capable of installing PV at the present tariff rate leaving their subsidy dependency. In turn, the State will use the freed subsidy to finance other pressing needs in the country. Additionally, the program could include several energy efficiency measures to optimize investments in solar rooftops and improve the houses' energy performance.

Policy and regulation framework

DG deployment to eliminate the subsidy requires a policy framework that, in its major part, is already in place in the secondary legislation. However, this policy framework has no strategic considerations for DG and the electricity subsidy. As strategic considerations are absent in the legislation and political framework, it is necessary to create political will by demonstrating that DG has unquestionable benefits for all stakeholders.

Distributed generation is a concept barely known by Mexicans even when it has been incorporated in regulations since 2007. Fortunately, the energy reform came to foster DG as the new regulation mandates non-discriminated access and payment for surplus energy fed to the grid. However, one must say that even when the whole new regulatory framework is very favorable, it lacks a strategic approach by omitting to establish a goal and roadmap. This deficiency forces us to think, in creative ways, in how to use the present regulatory framework to leverage DG for massive deployment that adds to Mexico's opportunities to reach the Paris commitments, eliminate subsidies, and improve Mexicans' quality of life.

In fact, EIL deals very thoroughly with the fundamentals and details of the electricity market, emphasizing the trade of energy and ancillary services at an industrial scale in a very prescriptive way full of command and control measures. It also profusely aims to foster small-scale generation, especially distributed generation, but more in a promotional and non-prescriptive manner leaving the field open to voluntary interventions. It is fair to say that even when DG is well addressed by EIL, the law did not fully recognize the strategic aspect of distributed generation. Additionally, the EIL neither explicitly addresses one pressing reality of Mexico's electricity system: the largest electricity subsidy to residences and crop irrigation among OECD countries.

The lack of strategic goals and roadmap for DG, despite the peripheral measures to foster it, together with the difficulties to specifically recognize and prescribe solutions for the electricity subsidy, leave both issues devoid of the strong support that could encourage economic agents to spontaneously innovate and invest in this field. Also, there was the risk that regulations, norms and criteria for massive DG deployment, being a practically new field and market, could have unintended consequences, derailing intentions to foster DG as expressed in the secondary legislation, being counterproductive for DG, and squandering the opportunity to deal with the subsidy in a strategic manner.

On the other hand, even when the ETL does not have a strategic approach to DG, and also lacks any prescriptive measures leaving the topics of DG and subsidy open to voluntary interventions, this law leaves an open door to further developing such a strategic approach. In effect, ETL's article 10 and transitory article 18, mandate SENER to demonstrate to the Treasury Secretariat that DG could be an instrument to alleviate the subsidy situation (benefiting the Mexican State), while users are benefited and the electricity sector's carbon footprint is reduced at the same time. ETL does not mention the word "subsidy", because it is not considered as such by the fiscal authority, but implicitly refers to it.

To comply with ETL's transitory article 18, SENER commissioned a preliminary subsidy with the Center for Economic Investigation and Teaching (CIDE), National Autonomous University of Mexico (UNAM), the National Polytechnic Institute (IPN), the US National Renewable Energy Laboratories (NREL), and several NGOs including Iniciativa Climatica de Mexico (ICM). The study, finished in December 23th, demonstrates that DG will significantly reduce the need for the subsidy by empowering households to produce their own energy through installing PV rooftops. The study also confirms a reduction in the electricity sector's carbon footprint. Benefits to users is left to a pending subsequent study which should address the mechanism to transfer the DG benefits for the State to the users.

Fortunately, regulators and policy makers are gradually aware of the strategic importance of DG, and have being careful to tailor the new regulations as to foster DG even when there is no mandated strategy goals and roadmap. This favorable environment has allowed DG to be envisioned as the ideal tool to solve the electricity subsidy at the lowest possible social and political costs[35].

For example, regarding interconnection rules, there is a vast experience in the country regarding distributed generation as, since 2007 and up to the energy reform, there were and are a growing number of interconnected rooftops belonging to HCR users. As the rooftops remained connected to the grid, incoming and outgoing electricity was netted at the same tariff. Any surplus electricity was accounted in an energy bank lasting a year. At the end of the calendar year, if the accrued energy was not used, the account returned to zero. After the energy reform, surplus energy shall be paid periodically to the user.

Controversy has arisen in the definition of the payment for the electricity provided when solar PV modules are not generating and for the surplus energy when they are. Opinions ranged from keeping the netting scheme at tariff prices, and paying surplus energy at tariff or local marginal costs, or eliminating the netting scheme and charging and paying following hourly rates using two meters. Fortunately, a final decision was made favoring net metering at tariff prices, as this scheme has demonstrated that it fosters distributed generation development. Hourly rates, requiring a two-meter system, are considered very complicated under present conditions and a deterrent for distributed generation deployment. The program proposed in this document will be favored by net metering at tariff prices and surplus payment at a favorable rate.

[35] Recent increases to gasoline prices due to the elimination of the subsidy, unleashed strong protests and riots

Financial mechanisms

As described before, two financial mechanisms are required for the program: commercial loans for users, and an institutional loan acting as a "start-up" or "bridge loan" to fund the initial investment.

As for today, PV technology projects at the residential level are not financed by specific loan schemes comparable to other durable consume consumer goods like cars, houses or other appliances. In fact, the scarce loans for domestic PV are managed as general credit with interest rates comparable with credit cards. There are no specific considerations about the bankability of the technology and its proper value. Commercial loans have been preliminarily discussed with the Mexico's Bank Association (MBA) about the possibility for a specific credit line that concedes specific conditions akin with the nature of PV application in houses namely: high duration, low risk, productive life-span, ensured repayment, and other. As it is expected, the potential volume of credits fostered by the solar bonus program makes this proposal very attractive for the banking industry. The full deployment of the program could mean one of the largest chunks of loans in Mexico's credit history. Besides, it is anticipated that the program will also have a guarantee mechanism that will lessen the risk for the banks.

The "start-up loan" could be provided by national or international banks, at Hacienda's convenience. It will be repaid by savings resulting from the avoided subsidy. IDB and other international financing institutions have expressed an interest in financing the program. This is the natural field for the Green Climate Fund.

It is anticipated that both financial mechanisms will be easier in the future as PV technology will be cheaper.

As the program can be implemented in stages and in different places at the same time or in a sequential manner, it could be possible to manage each intervention as a separate subprogram with its own financial mechanisms.

Relevance, feasibility and risk

The Solar Bonus proposal is relevant in a country-wide scale for the following reasons:

- Provides an additional route to supplement mitigation options helping the country to fulfill its climate change commitments
- Democratizes energy by empowering a significant portion of residential users to be energy self-sufficient and allowing them to profit from selling electricity to the grid
- Opens a new economic avenue with job creation and value chain development for PV technology.
- Saves valuable resources for the nation's electricity system by eliminating or delaying new investments in generation and transmission, decongesting distribution networks, lessening transmission losses, saving hydrocarbons and gas reserves, and saving water by avoiding investments in thermal plants.
- Improves the well-being of electricity plants' neighboring communities by avoiding local pollutants emissions.

Solar Bonus is a feasible program as:

- Solar PV has demonstrated itself to be a mature technology for electricity generation. Up to now, around 300 solar PV gigawatts have been installed in the world. This is equivalent to almost six times Mexico's whole electrical capacity. This amount is likely to be duplicated by 2020 as many countries are actively engaged in raising their solar PV capacity.
- The program is based on redirecting funds that are already committed to pay for the subsidy, be as CFE debt or fiscal funds. In 2016, 30,000 million MXP were earmarked to help CFE to recover part of the subsidy. In 2017, Congress earmarked 43,300 million MXP for the same purpose, recognizing that the subsidy real size is larger.
- Social acceptance for the program can be achieved by granting users 15 – 20% discount in their electricity bills, together by offering full ownership of solar rooftops in a defined timeframe.
- The program would be very appealing to the general public because there is raising awareness about environment protection and energy poverty issues. People empowerment is another appealing factor very favored by the general public.
- Government participation by granting the solar bonus (through the start-up loan and the avoided subsidy re-investment) is a clear financial additionality and a strong signal to ensure the program's integrity. Funds' concessionality level would be reasonably low.
- The start-up loan repayment is fully guaranteed by funds recovered from the avoided subsidy as was shown in Figure 1.3.

The Solar Bonus program's potential risks can be classified in several categories as follows:

- Economic risk. – The nature of the program is, by its own nature, granular. Funds will be spent in a gradual fashion. The degree and speed of deployment are totally controllable. So, there are no big investments that need to be done in advance and risk being stranded if the program fails. If by any chance, some of the program's assumptions are wrong, the process can be modified or closed down in a very opportune way. PV components supply is guaranteed as the global solar PV penetration is driving PV modules production up in an exponential way. Up to 300 GW of installed solar PV with a well-documented cost downward trend guarantees that the program's capital cost will not be overrun during the program implementation.
- Technological risk. – Solar PV is a mature technology that is more efficient and cost-effective every day. The only limit to growing PV penetration is the grid capacity at the distribution circuit level. The program's gradual implementation will grant time to the distributor (CFE) to improve the infrastructure step by step in order to allow increasing penetration. It is assumed that being a government program, CFE will be requested to prioritize improvements to the grid at a sustaining pace.
- Implementation risk. – Distributed generation deployment has resulted in challenges in several locations around the world. Conflicts have arisen because utilities lower their sales, at the same time as having to deal with net metering mandates. In Mexico's case, subsidy accountability could introduce some conflict, and distribution costs will also present some challenges. In the Institutional Framework section, an implementation proposal will be discussed that looks to solve these potential risks.

- Social risk. – Recent elimination of the gasoline subsidy sparked social discontent in the country. Although a deeper analysis is necessary to fully understand the reasons behind the social unrest, one of the probable reasons is that the population did not see any perceived benefit from the said measure. On the contrary, even when the solar bonus program also diminishes or eliminates a subsidy, the users get, in exchange, a solar rooftop and a discount of 20% in their electricity bill. This approach makes the solar bonus program quite different to the gasoline case. However, even when the program is very benign, it is crucial to develop a communication strategy that avoids misleading manipulation of the facts and the expectations. Regarding the grid's resilience to extreme weather, solar rooftops could be a valuable adaptation instrument providing technical measures are taken to facilitate the continued operations of PV modules through the deployment of micro or mini grids. However, more work is needed in this area.

Institutional Framework

The institutional framework for the solar bonus program depends on the implementation model. There are several options that must be decided by the policy makers. As for today, the electricity supply for most of the residential sector is heavily supported by the State through the subsidy and the corresponding tariff system that make it operable. One can say that current situation is like a first stage in solving electricity affordability to the people. To a lesser degree, the solar bonus has also a strong intervention from the State as the funds come from the avoided subsidy. However, the users' participation in partially financing the solar rooftops dampens the State's interventionism to a substantive degree. So, the solar bonus program could be considered as a second stage in a marching trend to a free market for the residential sector. This second stage also has the particularity to introduce a paradigm and technological change that obeys an exponential and disruptive trend already happening in many parts of the world. Once the solar bonus be fully deployed, a third stage could lead to a free market which hopefully will be totally sustainable in the full sense of the sustainable development with substantive benefits to the environment, and the social and economic realms.

State intervention for the solar bonus deployment could even be justified by technical reasons. In fact, solar distributed generation poses important challenges to the electricity infrastructure as it is seen in different parts of the world. In a free market scheme, distributed generation development follows strictly economic reasons tending to leave grid capacity considerations aside. PV saturation in Hawaii's distribution networks has been an issue that threatened distributed generation development. Additionally, there has been clashes between utilities and solar PV users in Hawaii, Nevada, Arizona and other locations, because distributed generation uses the grid as an electricity storage mean without any compensation for the utilities. There are allegations that state residential users without solar rooftops subsidize users with solar rooftops regarding grid maintenance. As self-sufficient users, under a net-metering scheme, no longer pay for electricity, grid maintenance costs are unfairly absorbed by conventional users. These conflicts are prone to arise for distributed generation in free market areas. On the other hand, schemes with a strong regulation like Germany's feed-in-tariff program (FiT), where utilities are obliged by law to buy electricity from distributed generators at very generous rates and to honor long term contracts, shows no conflict and a very briskly PV development. However, FiT programs have their own challenges and are not applicable everywhere. The solar bonus program, with the strong state intervention, is more akin to FiT than the US distributed generation schemes as markets in this country have been de-regulated since at least two decades ago.

Any solar bonus implementation option cannot ignore defining the role of CFE, which is a key and prominent player. A new subsidiary called CFE Distribution is mandated by law to be the only responsible for the monopolistic distribution network, which happens to be the support system for distributed generation as long as the storage-in-house option is still ahead in time. Additionally, between the PV rooftops and the distribution grid there is an intermediary for commercialization purposes called the provider or "suministrador" in Spanish, which is open to competition by the EIL. CFE has set up another subsidiary named Basic Services Supplier (CFE SSB), which will be the intermediary between the residential sector and CFE Distribution. This position is open for competition.

The Solar Bonus proposal has two possible implementation routes:

- An open market approach where, once the solar bonus is granted to the user, he or she is free to choose a bank to get the soft loan, and a developer to install the rooftop, following the classic schemes of full ownership, leasing, or rent-to-own; CFE SSB sole role could be limited to the net metering exchange as a supplier and to market CELs.
- A regulated market where CFE SSB will be the managing entity in charge of leasing or rent-to-own PV solar modules to users with the solar bonus included. To dilute this monopolistic approach, CFE SSB will subcontract, by auction or other competitive and transparent mean, private developers to supply, install, and maintain the solar rooftops. In fact, being one of the energy reform's main objectives, to substitute the monopolistic nature of Mexico's electricity system allowing more private sector participation, it is almost mandatory to include private developers in the solar bonus program. CELs will be marketed by CFE SSB as well as any electricity surplus

Both approaches have pros and cons; however, is important to analyze the competitive edge that CFE SSB has for the solar bonus implementation.

- Even when the "supplier" position in the mandatory value chain for the electricity industry is open for competition, in the foreseeable future, it is hard to consider that for the subsidized residential sector the supplier could be someone other than CFE SSB, to serve this financial black hole.
- CFE SSB is, for now, the only supplier for 36 million residential subsidized users, having the biggest billing and collecting system in the country.
- In several occasions, the now CFE SSB subsidiary has managed also the sale of efficient refrigerators, compact fluorescent light bulbs, and rooftop insulation services. So, it has experience of mass selling other products aside from electricity alone.
- CFE SSB is capable of suspending power supply to defaulters so the soft loan repayments are virtually guaranteed.
- Implementation risk, described above, will be lowered significantly in all the identified components. For example, as CFE SSL will benefit from modules financial intermediation, CELs marketing, and surplus generation management, can easily agree on strategic alliances with CFE Distribution to upgrade circuits and allow more PV solar penetration.

Having such strengths, one can conclude que CFE SSB will be the best suited entity to manage the solar bonus implementation. Any other supplier will be in the need to invest huge resources and time to set up a commercialization system similar to CFE's.

It is then quite probable that CFE SSB could be the implementer since it has the institutional framework practically set up for this endeavor. However, since the program manages fiscal funds, and it is required to deal with key decisions, such as the selection of places to begin deployment, the pace of the process, the source of resources, policy and regulations adaptation to facilitate the program, and other key issues, it will be quite probably that an additional neutral supervisory body shall be put in place to make the right decisions, supervise the implementer, and properly represent the interest of all stakeholders.

Expected Outcomes

GHG Reductions[36]

GHG reductions vary with the level of penetration. As was mentioned, scenario DG1.2-70 contributes with 22.8 million ton of CO_2 equivalent[37] per year for the electricity sector mitigation goals. As was said before, this scenario will complement the 46 MtonCO_2eq/yr already accounted for in PRODESEN, to add around 66 MtonCO_2eq/yr, a little bit more than the 63 MtonCO_2eq/yr committed in the INDCs for the electricity sector. The program hence, is entirely in line with Mexico's unconditional pledges relative to the 3°C path. The 2°C path will impose tougher reductions and, hence, the need to seek for more ambitious DG deployment in the future.

Benefits to the Electricity System

Transmission needs are estimated to be reduced by 20%, which will allow a better performance of the transmission grid and delay investments in new lines. Overloads, particularly during summer peaks will be also greatly avoided. In the case of distribution costs, as the most part of the electricity generated by rooftops is consumed in the same location, there is less electricity handled by the distribution grid particularly at the summer peak hours. The subsequent de-congestion of the grid will result in lower losses, failures and energy outages. The benefits vary per location and according to the distribution of solar rooftops.

Benefits to Public Finances

Scenario DG1.2-70 assumes that total subsidy for 2017 alone is around 119,238 million MXP, equivalent to 6.2 billion USD. From this amount, the proposal considers that only the 68% is available to be capitalized, namely, 81,330 million MXP. Considering also that only 70% of the subsidized residential users will be granted with the solar bonus in a 15-year process, Mexico will save 68,764 million MXP per year as avoided subsidy beginning in year 16; this means that the remaining subsidy will be only 12,566 million MXP per year considering just the capitalizable portion.

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[36] Most of the calculations presented here were done by the Latin American Regional Climate Initiative. Several spreadsheets with data, references and calculations are available upon request

[37] INECC; Quinta Comunicación Nacional; Cuadro IV.15; pg 271; 2012

The Internal Rate of Return (IRR) for government and users vary for each tariff group as shown in Figure 5. IIR cost calculations for users includes financial charges, grid maintenance, modules maintenance, and insurance. For the government, resources flow includes solar bonus, start-up loan, CELs, and yearly avoided subsidy as an income. For the DG1.2-70, IIR for users shows very favorable figures. In the case of government, IIR depends on the implementation strategy as each tariff group has different subsidy arrangements. Figure 1.5 presents the expected IIRs under a scenario with uniform implementation across the tariff groups with growing penetration percentages. Weighted IIR average for government is 12.7%. The graph evidences that highly subsidized tariffs have better IIR for users and lesser IIR for government.

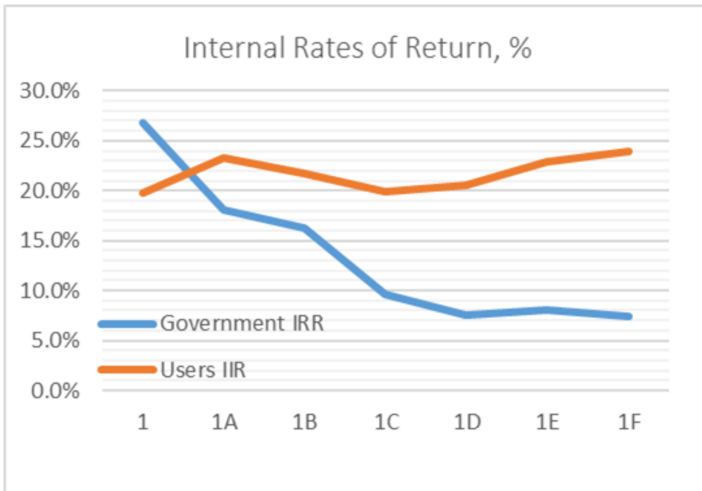

Figure 1.5– Internal Rate of Return for Government and Users per Tariff
Source: D. Chacon

Social, Environmental, and Health Benefits

Benefits to the public depends on the use the government makes of the freed funds. For example, the amount showed in the previous paragraph is comparable to the budget of *Prospera,* the flagship program to fight poverty, which has a budget of 75,000 million MXP/yr. Extra funds will mean that close to 12 million poor people can be helped instead of the present 6 million[38].

On the health side, this scenario avoids the emission of 760,000 tons per year of criteria pollutants such as CO, NO_x, SO_2 and PM with the subsequent health benefits[39].

Water conservation is also benefited. The water saved per year by substituting fossil fuel thermal plants represents the equivalent of the yearly water supply of a city with 1.1 million inhabitants[40].

[38] Available at: http://www.diputados.gob.mx/PEF2015/exposicion/decreto_presupuesto.pdf.

[39] INECC; Capítulo 2 Emisiones Derivadas de la Producción de Energía de Centrales Termoeléctricas; Available at: http://www2.inecc.gob.mx/publicaciones/libros/496/cap2.html

[40] NREL; Consumptive Water Use for U.S. Power Production NREL/TP-550-33905; 2003. Available at www.nrel.gov/docs/fy04osti/33905.pdf

Additionally, solar rooftops represent the opportunity for poor people to overcome present conditions of so called “energy poverty” evidenced by the low power consumption rates that the country has. Even under a heavily subsidized tariff system, lower income percentiles cannot afford an acceptable degree of wellbeing in hot regions because the electricity prices are still very high for them. Mexico’s average power consumption of 1,625 kWh/a per household is in the lowest global range, lower than the world’s average of 3,396 and lower than consumption in most of the economically comparable countries[41].

Houses’ expenditures on energy will be lower than present rates as the program renders to users the PV cost reduction trend. Under a conventional energy sources, the situation will be the contrary: energy expenditures will swing with oil and gas international prices but always following a growing trend as reserves decline.

The present subsidy is highly regressive, particularly within each tariff region. The solar bonus program deployment will address this regression by capping the solar bonus for the very high consumption subsector in each tariff region (just below HCR limit), and granting extra PV solar capacity to those in energy poverty.

Economic Benefits

Under scenario DG1.2-70, estimated solar bonus users are around 25.1 million. Assuming that PV rooftops deployment will be uniform along 15 years, the annual installation rate will be 1.6 million, equivalent to 6,600 rooftops per working day. If each rooftop requires 32 man hours for installing and considering one administration and logistic job per every 3 installing workers, the required working force will be around 37,000 persons constantly working for 15 years. Additionally, the value chain created by 1.6 million rooftops per year will also generate their proper working force which has still to be estimated. All these direct jobs will create indirect jobs at a rate not fully known. Some references estimate that jobs creation is in the order of 3 indirect jobs for each direct one. Total jobs created could probably reach a figure of 200,000.

Investments for this scenario are around 527,966 million MXP, equivalent to 27.7 billion USD. Assuming a linear deployment of the program, yearly investments could be equivalent to two tenths of the GDP. Total government contribution as solar bonus is 314,770 million MXP while users contribute with 213,196. Start-up loan sum up 67,495 million MXP equivalent to 3.5 billion USD broken down in 6 to 7 disbursements at the beginning of the program.

Additionally, a series of value chains will be developed. It is estimated that for DG1.2-70, investments in the order of 11,827 million MXP, equivalent to 695 million USD[42], will be required for installing PV modules assembly plants. This, in turn, will generate still not quantified additional jobs.

This scenario will avoid burning the equivalent of 200,000 barrels of oil per day, worth 7 million USD at 30 USD per barrel, providing the program will substitute bunker fuel generation plants.

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[41] *Ibid* 2

[42] Empresa Mexicana IUSASOL próxima a abrir un módulo de planta solar; published in http://www.cadenasecoeficientes.mx/noticias/item/156-nota-iusasol

Cost per ton of GHG

In a normal approach, fresh funds coming from a suitable financing source are invested in mitigation measures and then GHG reductions are rated accordingly to the funds spent and compared with other measures rendering comparable results. In the case of the solar bonus, cost per reduced ton of GHG must be viewed from a different perspective because funds are already being spent by the State to support the subsidy and the task is to rescue them from a very ineffective situation. Cost per ton, thus, has to be approached from the standpoint of the two key stakeholders: the users, and the Mexican state.

For users, the cost per ton is based on granting them the solar bonus whose main objective is to lower the cost of solar rooftops. The solar bonus accelerates the parity between the PV technology and today's highly subsidized tariffs. In general, scenario DG2.1-70 has an overnight cost in the order of 527,966 million MXP (27.1 billion USD) for installed PV modules. The total solar bonus is 314,770 million MXP (16.5 billion USD). Users' investment totals 213,196 million MXP (11.2 billion USD). As mitigated GHGs are in the order of 23.6 MtonCO2eq/yr, and the rooftops operating life is 25 years, the cost per ton for users is 19 USD/tonCO_2eq.

On the other hand, the required bridge loan for this scenario amounts to 67,495 million MXP (3.5 billion USD) representing just 12.7% of the total capital investment.

For the Mexican State, the only meaningful contribution is the start-up loan because the subsidy must be spent with or without the program. Also, aside from the users' contribution, is the only fresh money in the equation. As this loan catalyzes the whole program, and assuming that the funds were not reimbursed, the cost per ton would be 6.0 USD/tonCO_2eq. However, as the bridge loan will be reimbursed by virtue of the avoided subsidy, the real cost per ton resulting from this loan is irrelevant as the only issue accountable for this purpose is the cost of the money, but being less relevant than the fund itself, the cost per ton from the bridge loan will be the very small in practical terms.

Part 2: Solar Bonus Scaled Down Deployment

Proposal

Objective

This proposal aims to apply the Solar Bonus concept, explained in Part 1, to a scaled down number of residential users with the purpose of testing the Solar Bonus assumptions in different timeframes. The scaled number will be large enough to make these assumptions significant for evaluation purposes, and will be applied to different tariff groups in several locations. Due to the timescale involved in the Solar Bonus program, there are variables that can be evaluated in the short term while others can only be evaluated in longer terms.

It is proposed to fund a scaled down version of the program that will cover 1.4 million users within all subsidized tariff groups. This version will require $304 million USD as the start-up fund and the revolving reinvestment of the avoided subsidy to reach the said number of households. Timeframe will be 12 years to fully deliver the downsized scenario's benefits. However, from the very beginning, the version will render incremental results that will set a trend that can be continuously evaluated.

Variables

Variables to be evaluated and their timeframes are as follows:

Table 2.1 – Evaluation variables		
Installation rate	Rooftops per year, MW per year	Full term
PV costs evolution	Dollars and MXP per kW	Full term
Installation time	H-H per rooftop	Full term
Energy generation	kWh per year	Short term
Plant factor	%	Short term
Soft loan conditions	Term and rate	Full term
Users payments	monthly, bimonthly MXP	Full term
Effects on distribution circuits	TBD	Full term

Benefited Population

The pace of solar rooftop implementation is shown in Figure 2.1. At the beginning, the pace is slow to allow the buildup of capacities and establishing the value chains needed for the program. The pace of penetration also allows one to choose the distribution circuits with better characteristics to host a growing number of solar rooftops.

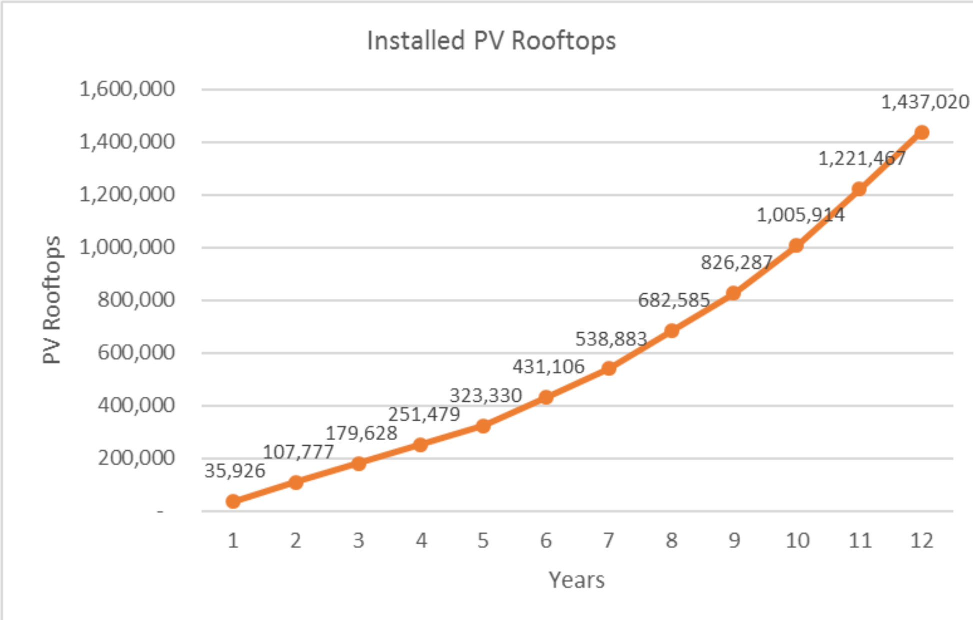

Figure 2.1 – Accumulated Rooftops
Source: D. Chacon

Total number of benefited households and their relative size with respect to total users per each tariff group is as follows:

Table 2.2 – Benefited Households			
Tariff Group	Households benefited	Total households in the country	Percentage benefited, %
Tariff 1	808,168	20,204,212	4.0
Tariff 1A	86,118	2,152,949	4.0
Tariff 1B	163,594	4,089,854	4.0
Tariff 1C	226,670	5,666,755	4.0
Tariff 1D	50,387	1,259,679	4.0
Tariff 1E	47,613	1,190,331	4.0
Tariff 1F	54,469	1,361,720	4.0
TOTAL	1,437,019	35,925,500	

It can be seen that tariff group 1 is the largest by far compared to the rest. This is because most of the population is concentrated in the central part of the country where climate conditions are very favorable. Demand is low and almost flat across the year. The rest of the tariff groups apply to regions with less favorable conditions and, therefore, higher consumption and seasonal variations.

Technical, Economic and Financial Variables

Technical characteristics of the PV solar deployment at a general level are shown in Table 2.3. Calculations are based on average consumption per tariff group, at least 10% surplus capacity rounded-up to the next 250-watts modules for each user, and a flat plant factor of 0.18 for all regions except for tariff group 1F where a factor of 0.19 is used. Resulting penetration in the residential electric sector is around 4.0%.

Each tariff group has a certain percentage of a package of energy-efficiency (EE) measures that has the effect, in this case, of lowering the demand and the need of PV capacity by around 10%. The cost of the EE measures is included in the solar bonus.

Table 2.3. – General Technical Characteristics			
Tariff Group	Capacity to Install MWp	Generation, GWh/yr	Demand seasonality
Tariff 1	606	956	Low
Tariff 1A	86	136	Low
Tariff 1B	204	322	Medium
Tariff 1C	397	625	Medium
Tariff 1D	101	159	High
Tariff 1E	119	188	High
Tariff 1F	177	295	Very high
TOTAL	1,690	2,618	

At a household level, the technical conditions are shown in Table 2.4.

Table 2.4. – Household's PV Rooftops Technical Characteristics for Scaled Down Project						
Tariff Group	Average Consumption kW/yr before EE	Average Consumption kW/yr after EE	Average PV Generation after EE+Surplus, kW/yr	Average capacity requirements, Wp	Avg. Number of 250-W modules	Rooftop area required m2
Tariff 1	1,111	1,066	1,183	750	3	<12
Tariff 1A	1,168	1,123	1,577	1,000	4	12
Tariff 1B	1,483	1,438	1,971	1,250	5	15
Tariff 1C	2,273	2,228	2,759	1,750	7	21
Tariff 1D	2,746	2,636	3,154	2,000	8	24
Tariff 1E	3,375	3,255	3,942	2,500	10	30
Tariff 1F	4,953	4,818	5,409	3,250	13	39

Economic considerations are shown in Table 2.5. Figures are presented in million US dollars (MUSD) at an exchange rate of 18 Mexican pesos (MXP) per US dollar. Figures in the first three columns include the *Annual Subsidy* for the number of houses within the program, the *Accumulated Subsidy* during the 12-year period, and the *Total Investment Required*. It can be seen that *Total Investment* is around 80% of the *Accumulated Avoided Subsidy*.

Table 2.5 – General Economic Conditions for Scaled Down Project									
Tariff Group	Annual Subsidy, MUSD/yr	Accumulated Subsidy in the Period, MUSD	Total Investment MUSD	Solar Bonus,		Investment by Users,		Start-up Loan,	
				MUSD	%	MUSD	%	MUSD	%
Tariff 1	85.7	1,028.3	664.7	378.1	66.9	286.6	43.1	92.3	13.9
Tariff 1A	10.0	120.4	91.6	62.7	68.4	28.9	31.6	15.7	17.1
Tariff 1B	20.1	240.7	213.5	141.8	66.4	71.8	33.6	40.5	19.0
Tariff 1C	33.6	403.3	405.3	240.0	59.2	165.3	40.8	79.2	19.5
Tariff 1D	9.1	109.1	104.9	61.8	58.9	43.1	41.1	20.1	19.2
Tariff 1E	11.6	139.6	122.8	77.5	63.1	45.4	36.9	24.3	19.7
Tariff 1F	19.0	228.4	180.9	107.3	59.3	73.6	40.7	32.3	17.9
TOTAL/*AVG*	189.1	2,269.8	1,783.7	1,069.2	*60.0*	714.7	*40.0*	304.4	*17.0*

Following columns include figures for *Solar Bonus*, *Investment by Users* and *Start-up Loan*. Each one contains the absolute amounts and the percentage with respect to the *Total Investment*. Weighted average for these items are 60% for *Solar Bonus,* 40% for *Investment by users* and 17% for *Start-up Loan*. These percentages mean that the solar bonus provided by the Treasury Secretariat covers around 60% of the solar rooftop cost while users cover 40% through a commercial loan or a leasing fee. Start-up loan is just a fraction of the total investment, 17.0%, which is a relatively modest amount.

Financial variables are shown in the following table. They are very favorable for government and users altogether because the former has a very efficient way to get rid of the subsidy, and the user or the leaser has a very profitable way to generate electricity. In fact, if one analyzes the user's or leaser's energy cost using the levelized cost of energy approach, the result is around 35 USD/MWh. As a comparison, this figure is in the lower range of the proposals during the last auctions held by CFE to buy renewable energy.

Table 2.6 – Financial Variables for Government and Users

Tariff Group	Government's Variables			Users' Variables		
	Net Present Value, MUSD	Internal Rate of Return, %	Payment period, yr	Net Present Value, USD	Internal Rate of Return, %	Payment period, yr
Tariff 1	461.2	14.0	12.0	650	20	4
Tariff 1A	56.9	11.9	12.8	726	22	4
Tariff 1B	88.1	9.1	13.8	907	22	4
Tariff 1C	107.2	7.3	14.6	1,328	20	4
Tariff 1D	28.6	7.5	14.5	1,632	20	4
Tariff 1E	37.6	7.7	14.4	2,101	23	4
Tariff 1F	73.2	9.4	13.6	3,143	23	3.2
TOTAL/AVG	852.7	10.5	13.1	9,941	20.8	3.8

Benefits

Being shown the financial advantages for the state and for the users of this downsized proposal, the following paragraphs will be focused on the economic benefits for the country, the social benefits especially for the poor in energy-usage terms, and for the environment in general, and the climate system, in particular.

As was mentioned before, the main premise of the Solar Bonus mechanism is to grant users around 20% rebate in their electricity bill. The rest of the mechanism is adjusted to this premise. As a result, users will have extra money to spend on other priorities. This money is considered as a societal benefit. Next table shows the money freed from each one of the tariff groups per year in the downsized project.

Table 2.7 – Savings to Users

Tariff Groups	Average savings per household, USD/yr	Average savings per tariff groups, MUSD/yr
Tariff 1	15.6	12.6
Tariff 1A	14.8	1.3
Tariff 1B	19.3	3.1

Tariff 1C	32.0	7.2
Tariff 1D	37.7	1.9
Tariff 1E	29.9	1.4
Tariff 1F	42.5	2.3
TOTAL/*AVG*		30.0

Another societal benefit is one related to the concept of energy poverty that has been recently addressed in Mexico. This poverty concept can be described as the inability of a significant portion of Mexican society to pay for the electricity consumption needed to achieve an acceptable level of wellbeing, even when domestic users enjoy a substantial electricity subsidy.

According to a recent study by the Latin American and the Caribbean Economic Commission (CEPAL), in Mexico there are 12.3 million households consuming less energy than the necessary to achieve an acceptable wellbeing level[43]. This figure is equivalent to 33% of Mexico's households. This proposal will include the development of a procedure to avoid any kind of regression in the solar bonus deployment. Without spending more money, the procedure will limit the solar bonus to households within the highest consumption rates in order to transfer the saved resources to households in the lowest consumption rates. Energy-poor users will have additional PV capacity to achieve a higher level of comfort, especially thermal comfort.

This project will also provide benefits to the Mexican state by avoiding the consumption of oil. In fact, if one considers this resource as part of the country's natural capital, and monetizes the saved oil[44] according to the international cost of this commodity, the savings are in the order of 211 million USD per year considering Mexican oil barrel at 45 USD/bbl[45].

Avoided CO_2eq emissions will be in the order of 1.26 million[46] tons per year by 2028. Due to the downsized version of this proposal, saved emissions will be only around 2% of the electricity sector's reduction commitments expressed in Mexico's NDCs. The Solar Bonus mechanism has a much higher potential, as was addressed in Part 1 of this document. Potential avoided CO_2eq emissions could be as much as 22 million tons per year with a 70% penetration level.

Avoided criteria pollutants combined emissions, including SO2, CO, NOx and PM10, are estimated in the order of 45,500 ton per year[47].

[43] García Ochoa, Rigoberto; Pobreza energética en América Latina; Comisión Económica para América Latina y el Caribe (CEPAL);2014

[44] US Energy Information Administration; How Much coal, natural gas, or petroleum is used to generate a kilowatthour of electricity?; October 2015. Available at: https://www.eia.gov/tools/faqs/faq.cfm?id=667&t=6

[45] According to US Energy Information Administration consulted in 04/24/2017. Available at: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=IMX2810004&f=M

[46] Applying an emission factor of 0.458 ton CO2eq/MWh according to INECC in: *Logros del PECC 2016*

[47] 17 ton per GWh per INECC; Capítulo 2 Emisiones Derivadas de la Producción de Energía de Centrales Termoeléctricas; Available at: http://www2.inecc.gob.mx/publicaciones/libros/496/cap2.html

Saved water in terms of inhabitants permanently served is equivalent to the supply for a small city of 66,000 persons[48].

Regarding job creation, the proposal will create the equivalent to 2,650 permanent direct jobs[49] during the duration of the program, plus the resulting indirect jobs.

[48] NREL; Consumptive Water Use for U.S. Power Production NREL/TP-550-33905; 2003. Available at: www.nrel.gov/docs/fy04osti/33905.pdf

[49] Considering 32 man-hours per rooftop, 240 working days per year and 1 administrative and logistic job every 3 installer jobs.