Market Analysis of Residential Solar in Chile

Current State, Opportunities, and Economic Impact Assessment

Nick Barrett, Andrew Dabrowski, Siddhartha Deo, Shoaib Rahman, Chris Selle

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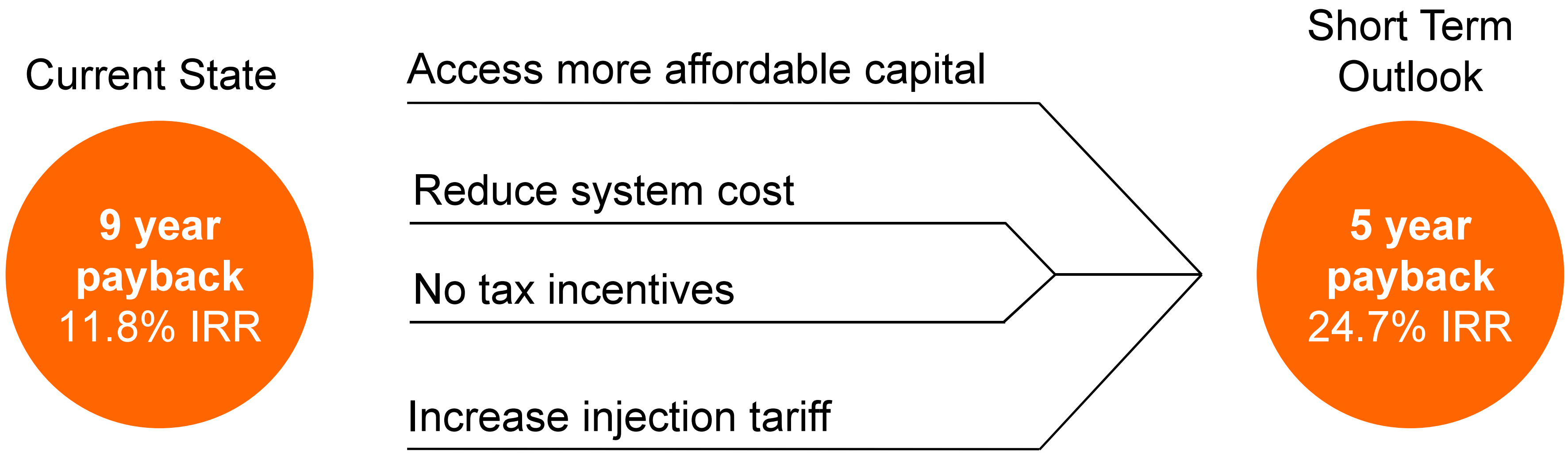
Agenda

- Executive Summary
- Approach
- Current State and Opportunities
- Cost/Benefit Analysis
- Final Recommendations

Executive Summary

Under current market conditions, residential solar is not economically viable in Chile. Through financial modeling, we analyzed potential paths toward viability through four different drivers that would reduce payback period and increase IRR.



Methods for valuing the benefits of distributed generation (DG) were evaluated to help assess a potential increase in the injection tariff

Our Approach

Preliminary Research	Stakeholder Interviews	Financial Analysis	Cost/Benefit Analysis	Findings & Next Steps
• Conduct research on the Chilean renewable energy industry • Conduct research on other countries with well-established renewable energy industries	• Conduct interviews with various Chilean solar energy stakeholders • Collect data documenting: the costs and benefits, the rate of adoption, and the challenges and opportunities of solar energy	• Develop a financial model representative of a typical residential solar project • Adjust model to evaluate the impact of various assumptions	• Identify and evaluate industry accepted methodologies for quantifying the costs and benefits associated with DG • Provide sample calculations for select benefit and cost categories	• Compile findings into a final presentation and research paper • Present to ACESOL stakeholders

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Stakeholder Engagement

SEC
SUPERINTENDENCIA DE ELECTRICIDAD Y COMBUSTIBLES

TRITEC

Ministerio de Energía
Gobierno de Chile

CIFES
Ministerio de Energía
Gobierno de Chile

ENERGIASDELFUTURO

SOLCOR

ecoenergías®

GESTIÓN SOLAR

chilectra
Grupo Enel

GRAMMER SOLAR

BEZANILLA-SOLAR.CL
INGENIERÍA Y SUMINISTROS

sunplicity

s-save
be smart, be sustainable

SUNBELT
SUMINISTRO · TECNOLOGÍA · CAPACITACIÓN

SMA

YINGLI SOLAR

LUMISOLAR®
ENVASAMOS LA ENERGIA DEL SOL

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Current State & Opportunities

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Current State of Residential Solar PV Market

Economics

Cash Flows

- Residential projects often do not demonstrate attractive returns
- Average ~9 year payback is not attractive to Chilean consumers

Financing

- Lack of access to affordable capital limits growth
- No solar-specific financing mechanisms have been created yet

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Current State of Residential Solar PV Market, continued

Public Policy

- Current public policy is oriented towards utility scale projects
- The "net billing" law was designed to enable grid connection for DG systems and to foster autoconsumption
- Most stakeholders disagree with subsidies, but believe that the current tariff does not reflect positive externalities of DG

Consumer Awareness

- Growing consumer awareness of solar PV and interest in sustainability
- Consumer expectations are misaligned with market realities

Technology & Grid

- Grid connection process is cumbersome, discourages growth
- No simplified process for smaller systems (e.g. under 10 kW)

Financial Model: Drivers and Base Case

Through financial modeling, we analyzed the impact of four financial drivers on the viability of a typical residential solar installation.

- System Installation Costs
- Injected Energy Tariff
- Interest Rates
- Government Subsidies

Base Case:

- 3kW system in Santiago
- 35% autoconsumption
- $2.26 cost per watt

Base Case		
Equity	IRR	Payback (years)*
100%	11.8%	9.0

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*Undiscounted

Sensitivity Analysis – Interest Rates and Installation Costs

Through financial modeling, we analyzed the impact of varying interest rates and installations costs on the viability of a typical solar installation.

Sensitivity of Interest Rates		
Interest Rate*	IRR	Payback**
20%	-6.8%	N/A
15%	4.6%	22.0
10%	16.0%	8.0
7%	23.7%	4.9

Sensitivity of Installation Costs		
$/Watt	IRR	Payback**
$2.26	11.8%	9.0
$2.00	13.4%	8.0
$1.80	14.9%	7.2
$1.60	16.8%	6.4
$1.25	21.3%	5.0

A 5-year payback can only be achieved by independently reducing the interest rate or installation costs to unrealistic levels.

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* Nominal interest rate

** Undiscounted payback

Sensitivity Analysis – Injection Tariff and Tax Credits

Neither increased injection tariff nor increased tax credits independently achieve a 5-year payback.

Sensitivity of Injection Tariff		
% of BT1	IRR	Payback*
58.5%	11.8%	9.0
65%	12.5%	8.5
70%	13.0%	8.2
80%	14.1%	7.6
90%	15.2%	7.1
100%	16.3%	6.6

Sensitivity of Tax Credits		
Tax Credit	IRR	Payback*
0%	11.8%	9.0
5%	12.4%	8.6
10%	13.0%	8.2
15%	13.8%	7.8
20%	14.6%	7.3
30%	16.5%	6.5

Chile should pursue a combination of all four drivers to make residential solar projects viable (5-year payback)

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*Undiscounted

International Market Government Incentives

United States

- Federal Tax Credits
- Full Net Metering in most US states
- Other incentives include federal grants and state/local tax credits

Germany

- FITs compensate distributed generators at a 20-year fixed rate for electricity injected into the grid
- Low cost per watt

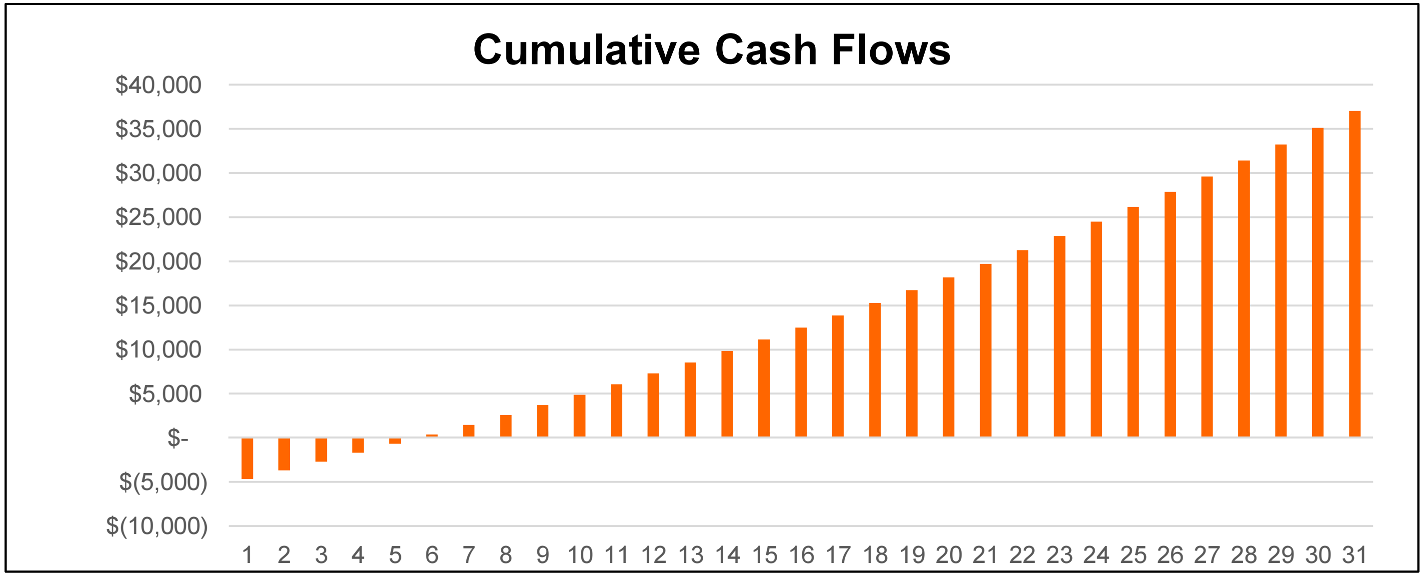
Colombia

- Starting February 2016, Colombia provides significant tax incentives for renewable energy projects (i.e. 50% of the investment can be deducted from an individual's tax burden over 5 years)

http://www.seia.org/policy/finance-tax/solar-investment-tax-credit
http://www.greentechmedia.com/squared/read/gtm-research-roundtable-the-itc-awakens
https://forms.greentechmedia.com/Extranet/95679/forms.aspx?msgid=98d3410f-c728-

Potential Impact of US Incentives in Chile

To model incentives similar to those in the US, we adjusted our baseline model to reflect a 30% tax deduction and full net metering.



Financial Viability with US Incentives	
IRR	Payback (years)*
22.6%	4.7

*Undiscounted

Potential Near- to Mid- Term Outlook

The following conditions are realistic possibilities in the next 2-3 years.

Reduce installation costs to $1.83 per watt

Financing option at 12% interest rate

Increase injection tariff to include VAT (69.7%)

No government tax incentives

<u>Base Case:</u>

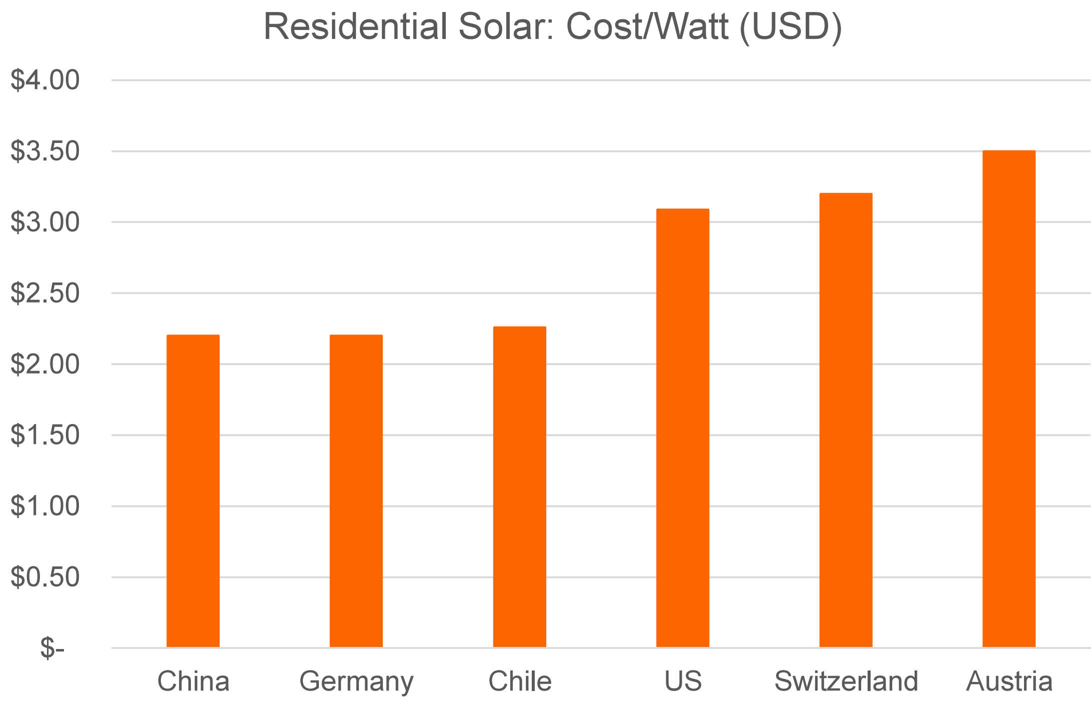
- 3kW system in Santiago
- 35% autoconsumption
- 80/20 Debt to Equity ratio

Ideal Case	
IRR	**Payback (years)***
24.7%	5.0

*Undiscounted

Reducing System Installation Costs

- Overall, stakeholders expressed that cost is a barrier to adoption
- At the same time, Chile's residential solar installation costs are lower than other mature markets like the US



*Chile and US costs are from 2015; Germany, Austria, and Switzerland are 2014.

Sources: http://www.nrel.gov/docs/fy15osti/64746.pdf
http://www.greentechmedia.com/articles/read/solar-pv-module-price-reach-57-cents-per-watt-in-2015-continue-to-fall-thro
http://www.sciencedirect.com/science/article/pii/S0960148115303384

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Reducing System Installation Costs, continued

- While soft costs in Chile are significantly less than in the US, opportunities still exist to reduce these costs through:
  - Economies of learning
  - Fast-track connection process to the grid
- Global markets for modules are also expected to continue to mature which will drive down hard costs

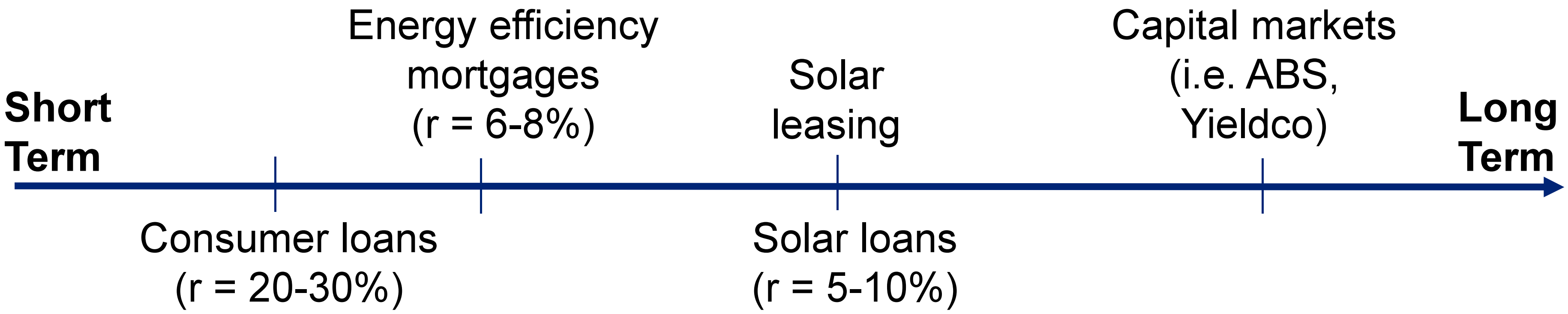
Total System Costs ($/Watt)		
	Chile	US
Hard Costs	1.58	1.40
Soft Costs	0.68	1.69
Total	**2.26**	**3.09**

Sources: http://www.nrel.gov/docs/fy15osti/64746.pdf
http://www.greentechmedia.com/articles/read/solar-pv-module-price-reach-57-cents-per-watt-in-2015-continue-to-fall-thro

Financing Mechanisms & Decreasing Borrowing Costs

Introducing new financing mechanisms will help reduce borrowing costs and incentivize growth.

<u>Potential Timeline of Financing Mechanisms:</u>



Developing Financing Mechanisms

Financial Sector

- Educate banks
- Develop partnerships with banks

Government Support

- Solar loan guarantees
- Soft credit loans
- PACE

Affordable Capital

Capital Markets

- Asset-Backed Securities
- Yieldcos

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Rationalizing the Injection Tariff

Increasing the injection tariff has a positive impact on the economic viability of residential solar projects

However, most stakeholders view increasing the injection tariff as a subsidy for the solar industry

In order to influence public opinion, other positive externalities of solar need to be valued

To justify an increased tariff, a detailed study is needed to determine the true value of distributed generation solar.

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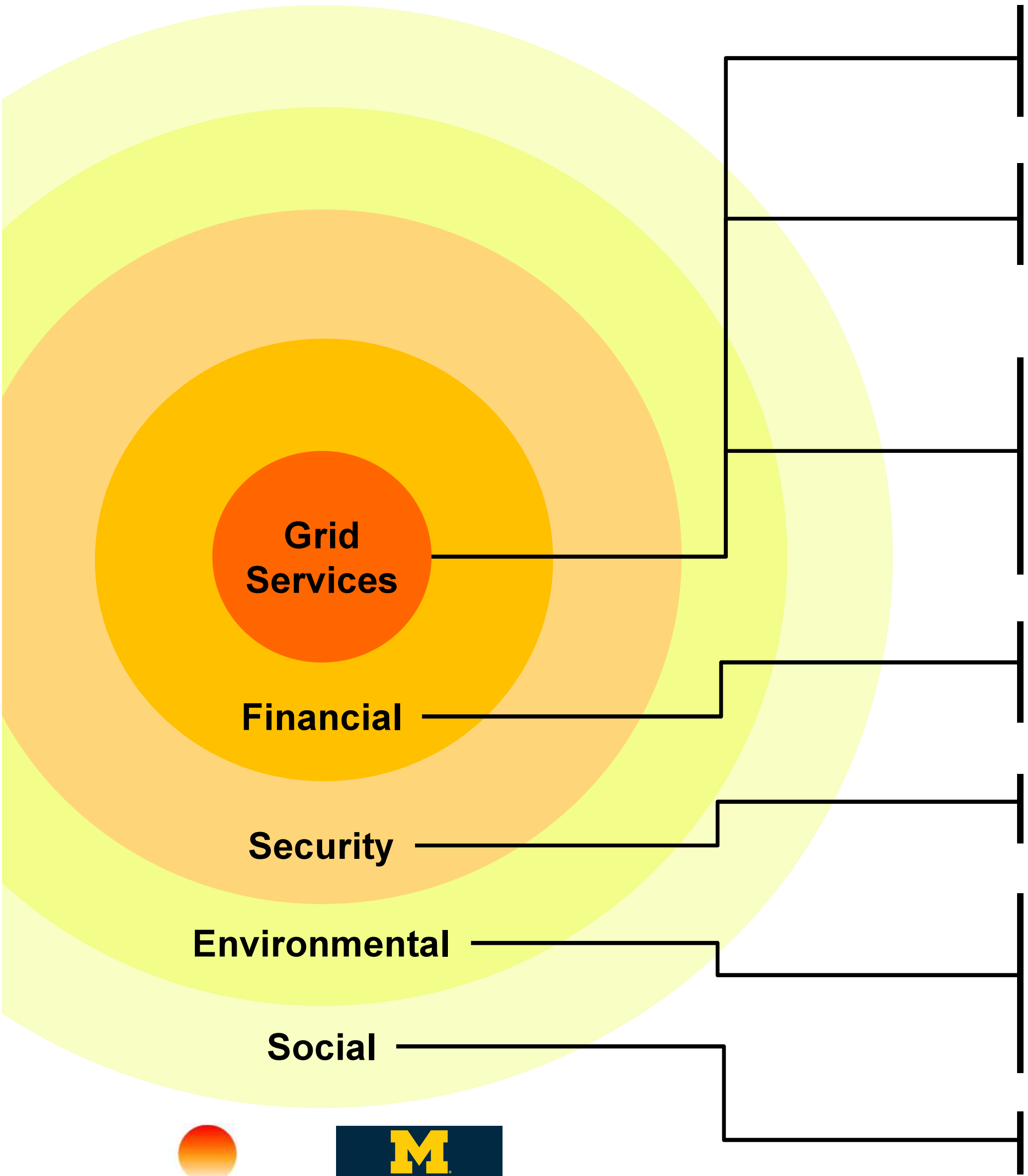
Costs and Benefits of Residential Solar

Assessing Costs & Benefits of Residential Solar

1. Identify methodologies for valuing distributed generation solar
2. Evaluate applicability of methodologies to the Chilean solar industry
3. Provide sample calculations for select benefit and cost categories

Benefits Categories



Energy
- Energy
- System Losses

Capacity
- Generation Capacity
- Transmission & Distribution Capacity

Grid Support Services
- Reactive Supply & Voltage Control
- Regulation & Frequency Response
- Energy & Generator Imbalance
- Synchronized & Supplemental Operating Reserves
- Scheduling, Forecasting, and System Control & Dispatch

Financial Risk
- Full Price Hedge
- Market Price Response

Security Risk
- Reliability & Resilience

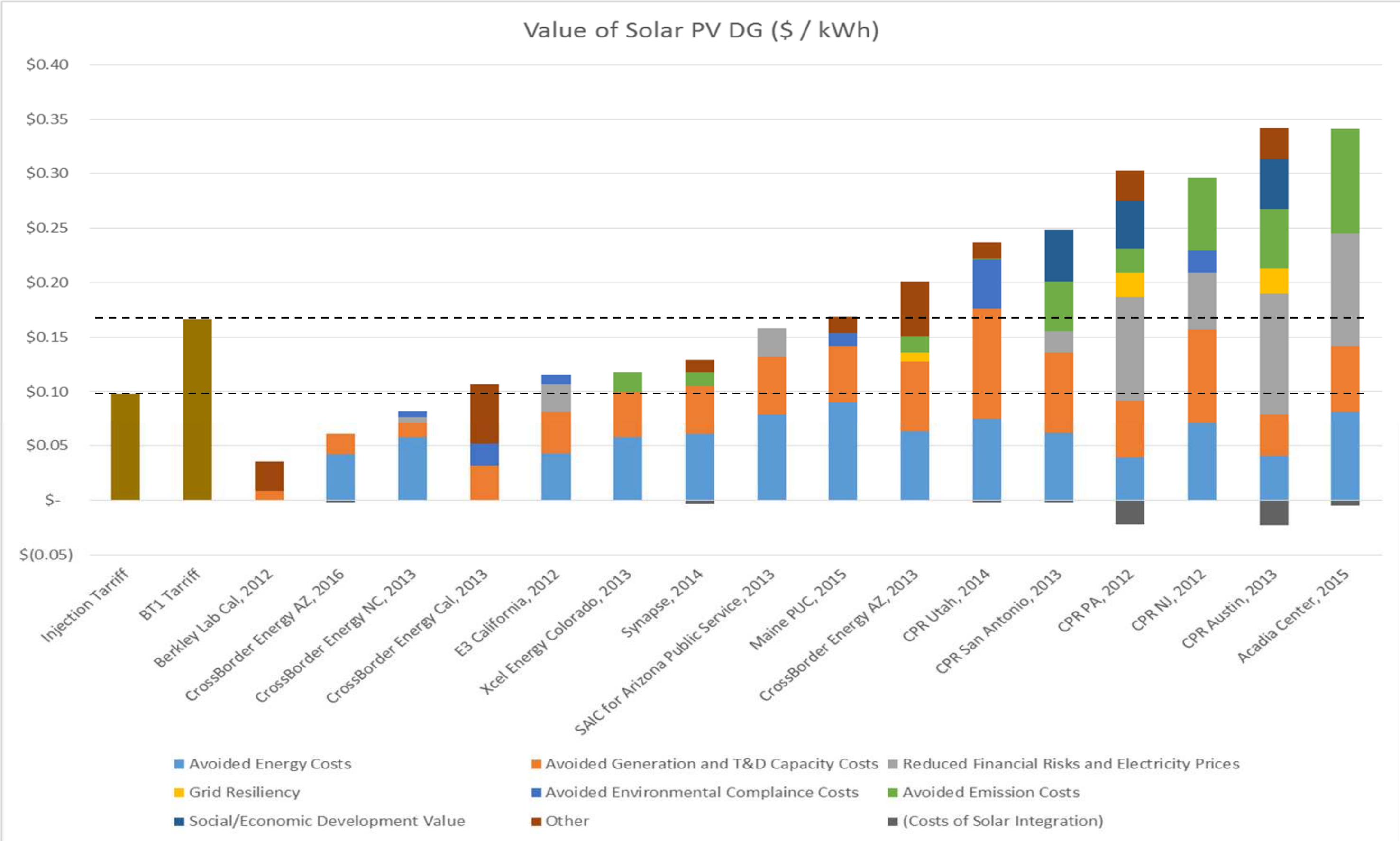
Environmental
- Carbon Emissions
- Criteria Air Pollutants (SO_2, NO_2, PM)
- Water
- Land

Social
- Economic Development (Jobs and Tax Revenues)

Source: http://www.rmi.org/elab_empower

International Studies of the Value of Distributed Generation

13 out of 16 international studies value solar at a higher amount per kWH than the current Chilean injection tariff and 8 out of 16 studies value solar at a higher amount per kWH than the current BT1 rate.



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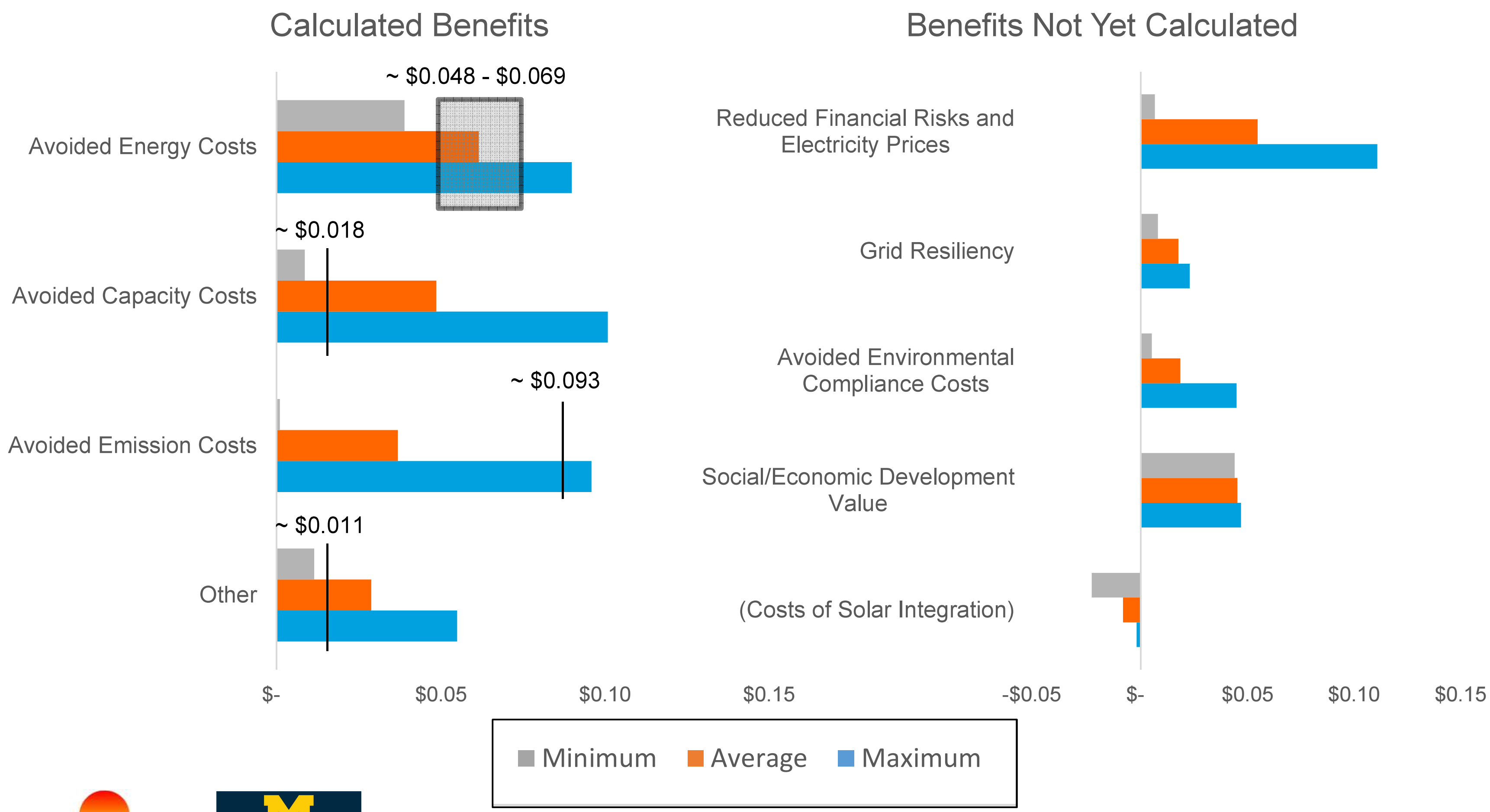
Source: http://www.rmi.org/elab_empower

Value of Distributed Generation by Component

Compared to calculated values from the US, Chilean benefits range from the low to the high end of the spectrum depending on market conditions.



Next Steps to Determine Value of Solar in Chile

Validate

- Review and evaluate recommended methodology

Calculate

- Validate current assumptions for monetized values
- Collect Chile-specific data to calculate non-monetized costs/benefits

Implement

- Use the results to inform policy debate regarding support of solar PV DG

Final Recommendations

Final Recommendations

Create New Financing Mechanisms

- Encourage the creation of new financing mechanisms
- Educate the financial services industry on solar

Drive Consumer Awareness

- Continue roadshows and develop educational tools to drive awareness
- Realign consumer expectations to the economic realities of solar

Evaluate the Value of Solar on the Grid

- Utilize the methodologies outlined in the report to determine the value of solar
- Gain input from distribution companies and the SEC to validate key inputs

Streamline Enrollment Process

- Simplify the process for small installations (i.e. <10 kW)
- Create an online process to reduce issues related to processing errors

Q&A

Appendix

Economics

NB [8]1
NB [2] [2]1
NB [3] [2]1
NB [4] [2]1

ncing – Current State

Financial Products

- No well-established financing products currently exist
- No mechanism for rolling solar projects into other loan products (i.e. mortgages)
- In some cases, solar companies are using their own capital and foreign investments to provide financing for residential consumers

Risk

- Banks are unfamiliar with the solar industry and view solar investments as risky
- Residential solar projects are often unable to demonstrate positive, guaranteed returns

High Cost of Capital

- Personal loans are one of the only available financing options for residential solar, but these come with 20+% interest rates
- Businesses with revolving credit lines have interest rates of ~14%, and investing in solar takes capital away from core firm operations

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Slide 31

NB [8]1 How does this compare to other countries/states?
Nick Barrett; 04/04/16

NB [2] [2]1 UF plus 4 or 5. That's the actual cost of capital for real estate projects.
Nick Barrett; 04/04/16

NB [3] [2]1 There are no specific tools for this industry, but the cost of capital for mortgages or real estate projects is much larger.
Nick Barrett; 04/04/16

NB [4] [2]1 But large PV installations plus 5.
Nick Barrett; 04/04/16

Financing – Opportunities

Financial Products

- The industry should explore options to roll solar projects into existing loan products (e.g. mortgages)
- Other financing mechanisms like solar leasing should also be explored to reduce the initial investment/risk by consumers

Risk

- Residential solar developers need to focus on demonstrating consistent cash flows and attractive returns
- Banks should be educated on solar projects to better enable them to develop financing products tailored to the solar industry

High Cost of Capital

- Solar developers should seek other sources of capital; external, international investors may be able to provide much more attractive costs of capital
- Chilean government could provide capital or guarantees that encourage the development of financial products

International Financing Mechanisms

Consumer Loans

- Unsecured loan
- Accessible through standard bank
- Interest rates range from 20-30%

Energy Efficiency Mortgages

- Homeowners can borrow up to 5% of home value for energy efficient improvements
- Loan is rolled into mortgage at purchase of new home or requires refinancing of existing mortgage
- Insured by the US government

Solar Leasing & PPA

- Fixed monthly payment for leasing or fixed rate for PPA
- 20 year terms
- Annual rate increase of 1-3%
- No upfront costs for consumer
- Expect 20-30% savings compared to utility electric costs
- **Examples:** sunrun, SolarCity

Solar Loan

- Loans provided by both private financial institutions and the government
- Secured and unsecured
- **Examples:**
- Home Equity Loan – borrow against equity built in home (r = 3.5-5.5%)
- Renovate America - partners with municipalities to collect payment through property taxes
- FHA PowerSaver Loans
  - Secured - $25,000 limit, r = 5-10%
  - Unsecured - $7,500 limit, r = 5-7.5%

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System Installation Costs – Current State

Installation Costs

- At an average of $2.22/watt, residential solar installations in Chile are on par with other competitive international solar markets (e.g. the US)
- There exists no in-country manufacturer of modules, requiring imports; purchasing through wholesalers also drives up costs

Achieving Scale

- Companies that can realize scale (e.g. purchase full containers of panels) are able to lower their costs

Soft Costs

- Soft costs (e.g. installation and labor) are 30% of total costs and are already significantly lower than other countries
- Sales/customer acquisition costs are high, but required for residential solar

System Installation Costs – Opportunities

Installation Costs

- Companies that can import supplies on their own and avoid using a wholesaler significantly lower costs

Achieving Scale

- Developers should look to realize scale through partnerships (both in-country and with international partners)

Soft Costs

- Even though soft costs are lower in Chile than other developed markets, opportunities still exist for lowering soft costs as economies of learning are realized

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Net Metering Tariff – Current State

Tariff for Residential Projects

- The current BT1 tariff for excess energy does not sufficiently incentivize residential consumer to invest in solar projects

Required Payback

- Payback period for average Chilean consumers is approximately 9 years.
- Most stakeholders agree that to make this investment palatable for Chilean consumer, this would need to be reduced to ~5 years.

Subsidies

- Most stakeholders disagree with subsidies, but believe that the current tariff does not reflect other positive externalities of DG

Net Metering Tariff – Opportunities

Tariff for Residential Projects

- Chile could adjust the tariff to match that of other countries (e.g. full net metering).

Subsidies

- Chile could adjust the tariff to incorporate other positive externalities associated with distributed generation

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International Market Government Incentives

United States

- Federal Tax Credits
  - 30% of the amount invested in the solar project can be deducted directly from the owner/developer's tax liability
  - Any unused credit can be rolled over into the following year(s)
  - This program was extended through 2019, then ramps down through 2022
- Full Net Metering in most US states
- Other incentives include federal grants and state/local tax credits

Germany

- FITs compensate distributed generators at a 20-year fixed rate for electricity injected into the grid
- The distribution company buys excess energy at the established rate and sells this to the wholesale market
- Any difference between the FIT and the wholesale market rate is paid for by consumers in the form of a levy
- Exemptions of this levy are given to some commercial/industrial consumers in targeted trade areas

Colombia

- Starting February 2016, Colombia provides significant tax incentives for renewable energy project:
  - 50% of the investment can be deducted from an individual's tax burden over 5 years
  - Renewable energy assets can take advantage of accelerated depreciation
  - Sales tax will not be levied on renewable energy project materials
  - Materials will also be exempt from import tariffs

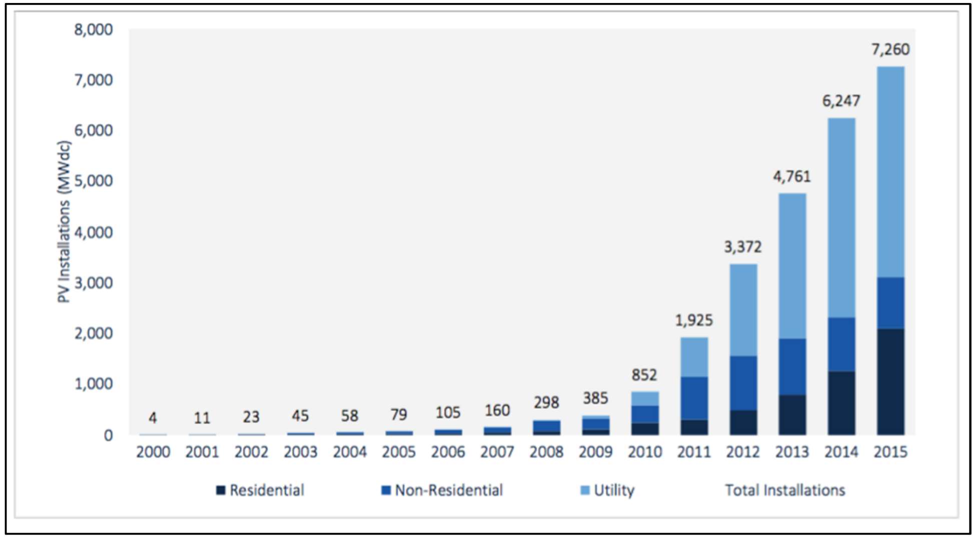
http://www.seia.org/policy/finance-tax/solar-investment-tax-credit
http://www.greentechmedia.com/squared/read/gtm-research-roundtable-the-itc-awakens
https://forms.greentechmedia.com/Extranet/95679/forms.aspx?msgid=98d3410f-c728-

Government Incentives – United States

The United States employs a variety of incentive programs focused on solar PV. The primary drivers are:

- Federal Tax Credits
  - 30% of the amount invested in the solar project can be deducted directly from the owner/developer's tax liability
  - Any unused credit can be rolled over into the following year(s)
  - This program was extended through 2019, then ramps down through 2022
- Full Net Metering in most US states
- Other incentives include federal grants and state/local tax credits

Annual US Solar PV Installations, 2000-2015

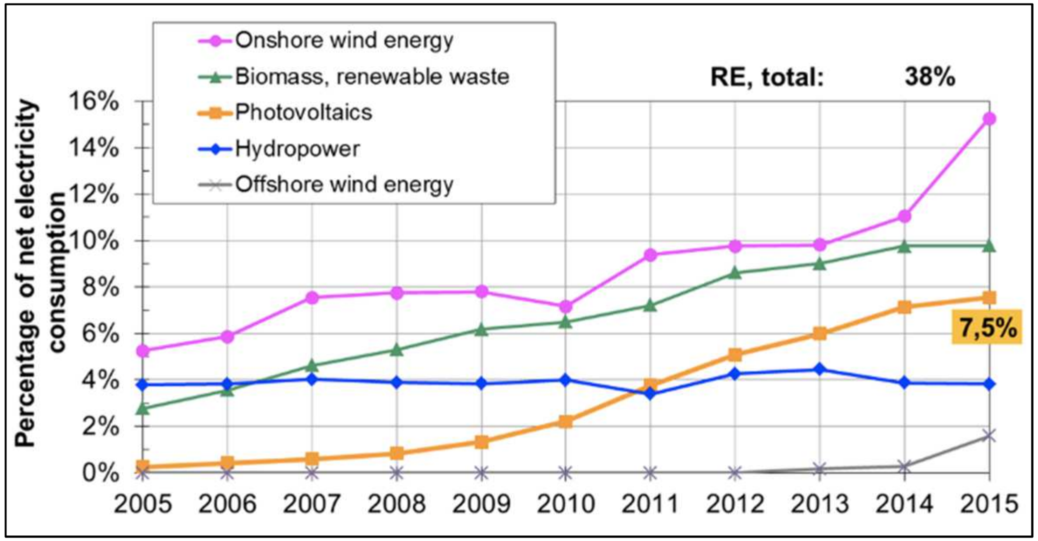


http://www.seia.org/policy/finance-tax/solar-investment-tax-credit
http://www.greentechmedia.com/squared/read/gtm-research-roundtable-the-itc-awakens
https://forms.greentechmedia.com/Extranet/95679/forms.aspx?msgid=98d3410f-c728-

Government Incentives – Germany

Germany's incentive program is primarily based on feed-in-tariffs (FITs).

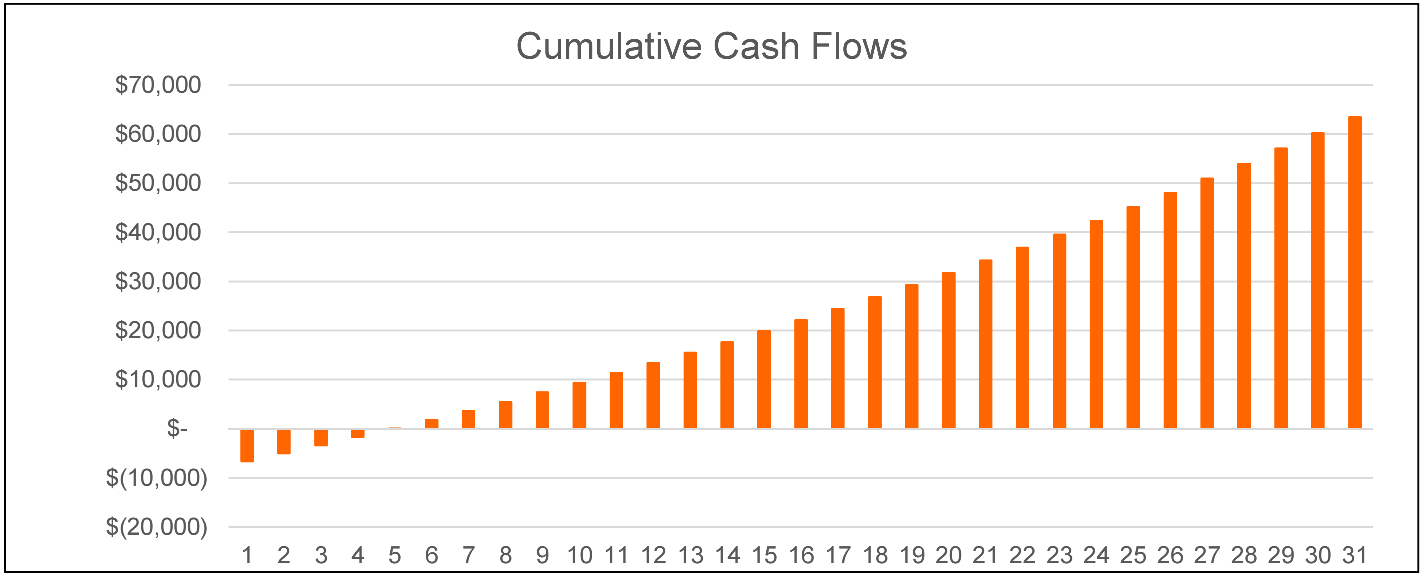
- FITs compensate distributed generators at a 20-year fixed rate for electricity injected into the grid
- The distribution company buys excess energy at the established rate and sells this to the wholesale market
- Any difference between the FIT and the wholesale market rate is paid for by consumers in the form of a levy
- Exemptions of this levy are given to some commercial/industrial consumers in targeted trade areas



http://www.seia.org/research-resources/solar-energy-support-germany-closer-look
https://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf

Potential Impact of German Incentives in Chile

To model incentives similar to those in the Germany, we adjusted our baseline model to incorporate a feed-in tariff* for injected energy.



Financial Viability with German FIT		
NPV	**IRR**	**Payback**
$12,652	**27%**	**3.9**

*As of October 2015, the German feed-in tariff was approximately 350% of the German energy spot prices, thus the feed-in tariff used in the model is 350% of the Chilean spot price.

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Government Incentives – Colombia

Starting February 2016, Colombia provides significant tax incentives for renewable energy project:

- 50% of the investment can be deducted from an individual's tax burden over 5 years
- Renewable energy assets can take advantage of accelerated depreciation
- Sales tax will not be levied on renewable energy project materials
- Materials will also be exempt from import tariffs

http://www.seia.org/research-resources/solar-energy-support-germany-closer-look
http://www.enerdata.net/enerdatauk/press-and-publication/energy-news-001/colombia-introduces-fiscal-incentives-renewables-2016_34900.html

Cost Breakdown for US Residential Solar

Figure 4. NREL modeled residential rooftop PV system prices (nationwide average, 5.2 kW)

http://www.nrel.gov/docs/fy15osti/64746.pdf

Consumer Awareness

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Consumer Awareness – Current State

Overall Awareness

- Due to construction of large solar plants in the north of Chile, the average consumer is generally aware of solar energy.

Support for Solar

- Chileans are sustainably-minded and supportive of renewable energy.

Consumer Education

- The Ministry of Energy has done some preliminary consumer educations, but developers often take on the majority of consumer education.

Misaligned Expectations

- Consumers that proactively express interest in solar often have unrealistic expectations of solar energy (e.g. solar will completely offset their energy consumption)

Consumer Awareness – Opportunities

Overall Awareness	• The Chilean government could conduct a marketing campaign focused on solar and sustainability in the home.
Consumer Education	• CIFES tools for consumers need to be more robust, including how to choose and installer, what are the expected benefits, etc. • ACESOL could also develop educational/marketing materials for developers • ACESOL could conduct a marketing analysis to identify attractive consumers • Education should focus on setting reasonable expectations for solar energy

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Public Policy

Government Assistance – Current State

The "Net Billing" Law

- The Chilean "net billing" law was designed to enable grid connection for DG systems
- The goal of the bill was to foster auto-consumption.
- The law was not designed to subsidize distributed generation systems.

Tariff for Injection

- Chileans are sustainably-minded and supportive of renewable energy.

Support for Subsidies

- Overall, Chilean policy is against outright subsidies.

Government Assistance – Opportunities

Incentive Programs

Other countries have adopted policy that fosters development in DG:

- The US uses federal tax credits and in some cases state/local tax credits and incentives to offset the cost of DG systems
- Germany uses a feed-in tariff (a long-term PPA) to stabilize the forecasted revenue of the DG system

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Net Billing Enrollment Process – Current State

"Net Billing" Enrollment Process

- The Chilean "net billing" law lays out a detailed process for approving DG systems to inject into the grid.
- Many stakeholder agree that the process is clear and straightforward.
- However, completing each step in the process is cumbersome, often requiring detailed and expensive engineering diagrams.
- The process is very time consuming, taking between 3 and 6 months to complete.
- Moreover, there exists no simplified process for smaller systems (e.g. under 3 kW)

Net Billing Enrollment Process – Opportunities

"Net Billing" Enrollment Process

- The enrollment/approval forms could be made available online.
- The process should be simplified for smaller projects, which do not heavily impact the grid and are generally low-risk.
- Distribution companies should be held to the timelines included in the law.

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Grid/Technology

Consumer Consumption Data – Current State

Consumer Consumption History

- Consumption history is not available at a detailed enough level ("node" or transformer level instead of the individual household/interval level)

Impact on Financial Forecasting

- Forecasts of consumer savings must be driven off of generic consumer profiles
- Profitability and competitiveness of PPA agreements with consumers cannot be determined due to inaccurate financial modeling

Consumer Consumption Data – Opportunities

Transparency in Consumption

- Developers and financing company will require a greater level of transparency to accurately forecast consumer savings

Smart Meters

- As smart meter technology is implemented in Chile, consumers should be provided access to their detailed consumption history.
- Developers and financing companies can use this history to more accurately forecast consumer savings.

Limits to Installed Capacity – Current State

Capacity Limitations

- Approximately 8 MW in additional theoretical capacity left before major grid investments are required
- Using current rate of requests, major grid investments will be required in the short to mid-term

Plan for Additional Investments

- No plan set in place to make additional investments

Limits to Installed Capacity – Opportunities

Capacity Limitations

- Evaluate the point at which capacity limitations will be met and grid investments will need to occur

Plan for Additional Investments

- Determine who will own future grid investments and how such investments will be financed

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Financial Impact of System Installation Costs

- According to interviewed stakeholders, the average Chilean consumer requires a payback period less than 5 years
- Total installation costs would have to drop below $1.25/Watt to meet this requirement

Impact of System Installation Costs on Project Financials				
Cost per Watt (100% Equity, r =10%)	NPV	IRR	Undiscounted Payback (years)	Discounted Payback (years)
$2.22	$1,550	12.3%	8.6	17.6
$2.00	$2,291	13.8%	7.8	14.3
$1.80	$2,965	15.3%	7.0	11.8
$1.60	$3,639	17.3%	6.2	9.8
$1.25	$4,818	21.9%	4.9	6.9

NB [7] [2] [2]1

Financial Impact of High Borrowing Costs

Interest rates offered by banks must be lowered from current rates in order to become economically viable for consumers

Impact of Interest Rate on Project Financials				
Discount Rate (100% Equity)	NPV	IRR	Undiscounted Payback (years)	Discounted Payback (years)
10%	$1,550	12.3%	8.6	17.6
Interest Rate (80/20 Debt to Equity)	NPV	IRR	Undiscounted Payback (years)	Discounted Payback (years)
8%	$2,417	23.4%	5.0	6.9
10%	$1,550	18.1%	6.9	10.5
15%	$3	10.0%	13.8	29.9
20%	$-3,210	-4.1%	N/A	N/A

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NB [7] [2] [2]1 Undercounted Payback and IRR
Nick Barrett; 04/04/16

Financial Impact of Net Metering Tariff

Simply raising the BT1 Tariff is not enough to reach a 5 year payback period with a cost of $2.22/Watt

Impact of Net Metering Tariff on Project Financials				
BT1 (100% Equity, r = 10%)	NPV	IRR	Undiscounted Payback (years)	Discounted Payback (years)
58.5%	$1,550	12.3%	8.6	17.6
65%	$2,015	13.0%	8.2	15.9
70%	$2,376	13.5%	7.9	14.7
80%	$3,097	14.6%	7.4	12.9
90%	$3,818	15.6%	6.9	11.5

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Financial Impact of Government Assistance: Tax Credits

With a 30% tax credit similar to the US, the undiscounted payback period drops by 2.4 years

Impact of Tax Credit on Project Financials				
Tax Credit (100% Equity, r =10%)	NPV	IRR	Undiscounted Payback (years)	Discounted Payback (years)
0%	$1,550	12.3%	8.6	17.6
5%	$1,883	13.0%	8.2	16.0
10%	$2,216	13.7%	7.8	14.5
15%	$2,549	14.4%	7.4	13.1
20%	$2,882	15.3%	7.0	11.9

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Cost/Benefit Analysis

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Value of Distributed Generation: Energy

- **Benefit from Solar PV DG**:
  - Solar PV DG is able to reduce the marginal cost of producing additional units of energy
  - This metric includes all variable costs (fuel, operating expenses, etc) for producing equivalent units of energy
- **Methodology:**
  - Calculated annual kWh production for the system and then multiplied this by the energy price derived from the tariff schedule for Santiago
  - The price of energy was assumed to grow at the rate of inflation over the period of analysis
  - These peso values were discounted back at the utility discount rate of 10.03%, summed, and then divided by total kW hours produced to arrive at the final figure

Value of Distributed Generation: Generation Capacity

- **Benefit from Solar PV DG**:
  - Solar PV DG contributes to deferral or avoiding the need for additional generation capacity investment by utilities to meet additional demand
  - The avoided cost of the marginal capacity resource (Combustion Turbines (CT)-least cost source of new utility-scale capacity) represents this value from Solar PV
  - Value will change with increasing level of Solar PV penetration
- **Methodology** (*Src: CrossBorderEnergy for Arizona Public Service*):
  - Looked at the Combustion Turbine Capital Cost ($/kW) and used utility discount rate to arrive at the levelized avoided generation capacity investment ($/kW/Year).
  - This levelized avoided generation capacity investment is then multiplied by ELCC of the plant and divided by the annualized solar production (kWH/kW) to arrive at the Avoided Generation Capacity Investment ($/kWH)

Value of Distributed Generation: T&D Capacity

- **Benefit from Solar PV DG:**
  - Solar PV is able to meet demand locally, thereby relieving grid of capacity constraints and in turn leads to deferral of need to invest in T&D infrastructure such as substations and lines
- **Costs from Solar PV DG:**
  - At significantly high levels of Solar PV Penetration additional T&D investment could be required if amount of solar production exceeds the demand in the local area and hence needs additional line capacity
- **Methodology** (*Src: CrossBorderEnergy for Arizona Public Service*):
  - Reviewed the T&D costs per kW increase in peak demand that can be avoided by using Solar PV DG and then used the utility discount rate to arrive at levelized Avoided T&D Capacity Investment ($ per kW-Year).
  - This levelized Avoided T&D Capacity Investment is then multiplied by the ELCC of the plant and divided by the annualized solar production (kWH/kW) to arrive at the Avoided T&D Capacity Investment ($/kWH).

Value of Distributed Generation: Grid Support Services

- **Benefit from Solar PV DG:**
  - Grid support services include: reactive supply and voltage control, regulation and frequency response, energy and generator imbalance, synchronized and supplemental operating reserves, scheduling, forecasting, and system control/dispatch (RMI, 2013).
  - Avoided supplemental and operating reserves represent the most notable and most easily quantified grid support benefit.
- **Methodology** (*Src: NREL, 2008*):
  - The required percent supplemental operating reserve was determined (based on government regulations). This value is 7% in the United States, and was assumed to be the same in Chile.
  - The avoided cost of energy (calculated elsewhere in our analysis) was multiplied by this percentage value to calculate the avoided supplemental and operating reserves cost.
  - All other grid support services are left uncalculated.

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Value of Distributed Generation: Financial Risk

- **Benefit from Solar PV DG:**
  - To offset risk from fluctuating energy prices, utilities hedge their exposure through energy derivatives. This is most commonly accomplished through natural gas futures. The cost of this hedge can be calculated as a benefit of solar energy because solar reduces the amount of hedging required.
- **Methodology** (*Src: Maine PUC, 2015)*:
  - The average cost to hedge 1 kWh of natural gas over the next 25 years (monthly) was computed by comparing the future energy payment discounted by the utility's cost of capital vs the risk free rate. The difference represents the sacrificed opportunity cost incurred by the utility because it made up-front payments for energy futures. This value was levelized using the risk free rate.

Value of Distributed Generation: Security Risk

- **Benefits from Solar PV DG:**
  - Distributed Generation can help improve the overall security and reliability of Chile's electricity grid through three primary factors:
    - The benefit to provide electricity to residential customers during power outages due to technical failures or rolling blackouts
    - Increased ability to provide electricity to customers during power outages caused by extreme weather events or natural disasters
    - Reduction in congestion on transmission lines that may contribute to technical failures
  - Although the Chilean electricity grid has proved resilient and adaptive, the country remains exposed to extreme weather events, ranking among the highest in the world based on the World Risk Index
- **Methodology**
  - Quantifying this value is difficult and highly sensitive to assumptions – more work is needed to accurately monetize this benefit category

Value of Distributed Generation: Environment and Health

- **Benefit from Solar PV DG:**
  - The Chilean grid relies heavily on fossil fuels. Burning such fuels releases CO_2, SO_2, NO_x, ammonia, methane, and products of incomplete combustion (PICs), which are harmful both to the environment and human health.
  - Solar energy releases no emissions, and hence avoids negative environmental and health problems. This can be valued monetarily.
- **Methodology** (*Src: Shindell, 2015*):
  - The "Social Cost of Atmospheric Release" (SCAR) model was consulted, which assigned dollar values to coal, natural gas, and diesel emissions.
  - The Chilean energy mix (percent composition) was obtained (IAEA, 2013).
  - Renewable energy was assumed to have zero emissions (in monetary terms).
  - A weighted average cost of emissions was computed for the Chilean electricity grid using the dollar values from SCAR as well as $0 for renewables.

Value of Distributed Generation: Social

- **Benefit from Solar PV DG:**
  - Social Value from Solar PV DG is associated with creation of additional jobs leading to reduced unemployment rate, higher tax revenue, and increased confidence for business development
  - Tax revenue enhancement as a metric can be used to quantify Social Value
- **Methodology** (*Src: CPR NJ and PA*):
  - Taking the capital costs of Solar PV and Combustion Turbines, calculate the net local-jobs traceable between PV and CCGT ($ per KWH in year 1)
  - Using a levelizing factor, calculate the net local jobs-traceable amount per generated PV KWH over the lifetime of PV panel ($/KWH)
  - Assuming an average salary to arrive at tax bracket, apply indirect job multiplier to calculate the tax collection increase ($ / KWH)
  - As per this study, the value ranged from 4.2-4.5 cents per KWH (2012$) accounting for ~15.0% of total benefit from Solar PV

Sample Calculation – Avoided Energy Costs

- Quantifies the benefit of the energy produced by distributed solar
- Standard methodology is to estimate lifetime production of a distributed solar installation, then multiply annual production by the Local Marginal Price of electricity
- These values are then discounted to present value, summed, and divided by total lifetime production to arrive at a kW/Hour figure

$$\frac{\sum_i \frac{(Annual\ Production\ \times Marginal\ Price\ of\ Energy)}{(1+r)^i}}{\sum_i (Annual\ Production)}$$

- Based on the method described above, our estimate for this value in Santiago is CLP $32.56 per kilowatt hour of installed capacity

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Discount rate of 10% based on average WACC of Chilean utility industry.