Scenarios for assessing the diffusion of solar generation in Colombia

Isaac Dyner, Maritza Jimenez, Monica Castañeda, Sebastián Zapata, Carlos Jaime Franco

Universidad de Bogotá Jorge Tadeo Lozano and Universidad Nacional de Colombia

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Agenda

1. Introduction
2. Problem definition
3. Literature review
4. Results
5. Conclusions

…Renewables are no longer limited to developed economies…

2005….

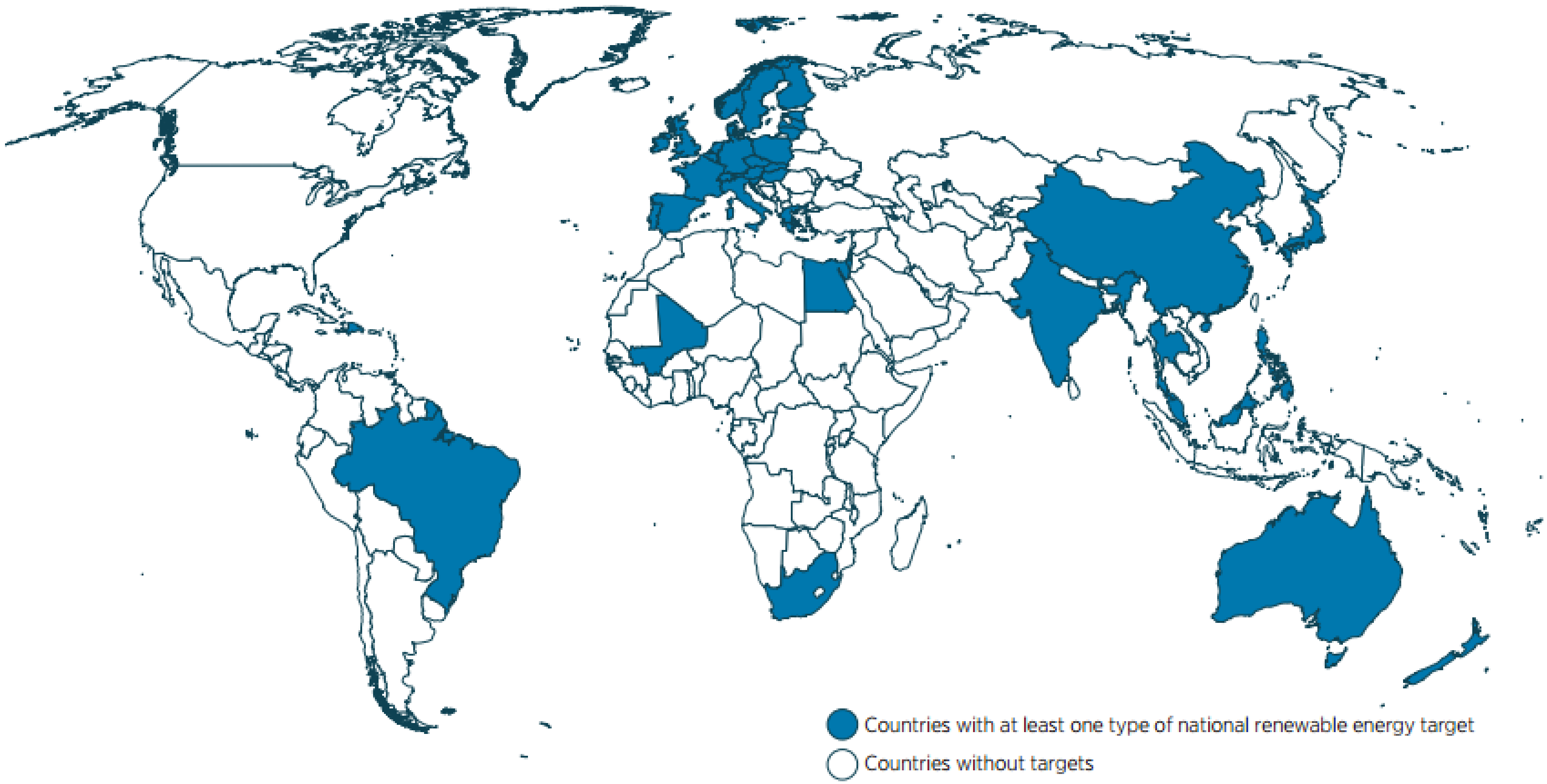


Figure 1. Global Map of National Renewable Energy Targets of All Types, 2005 (Irena, 2015)

2015….

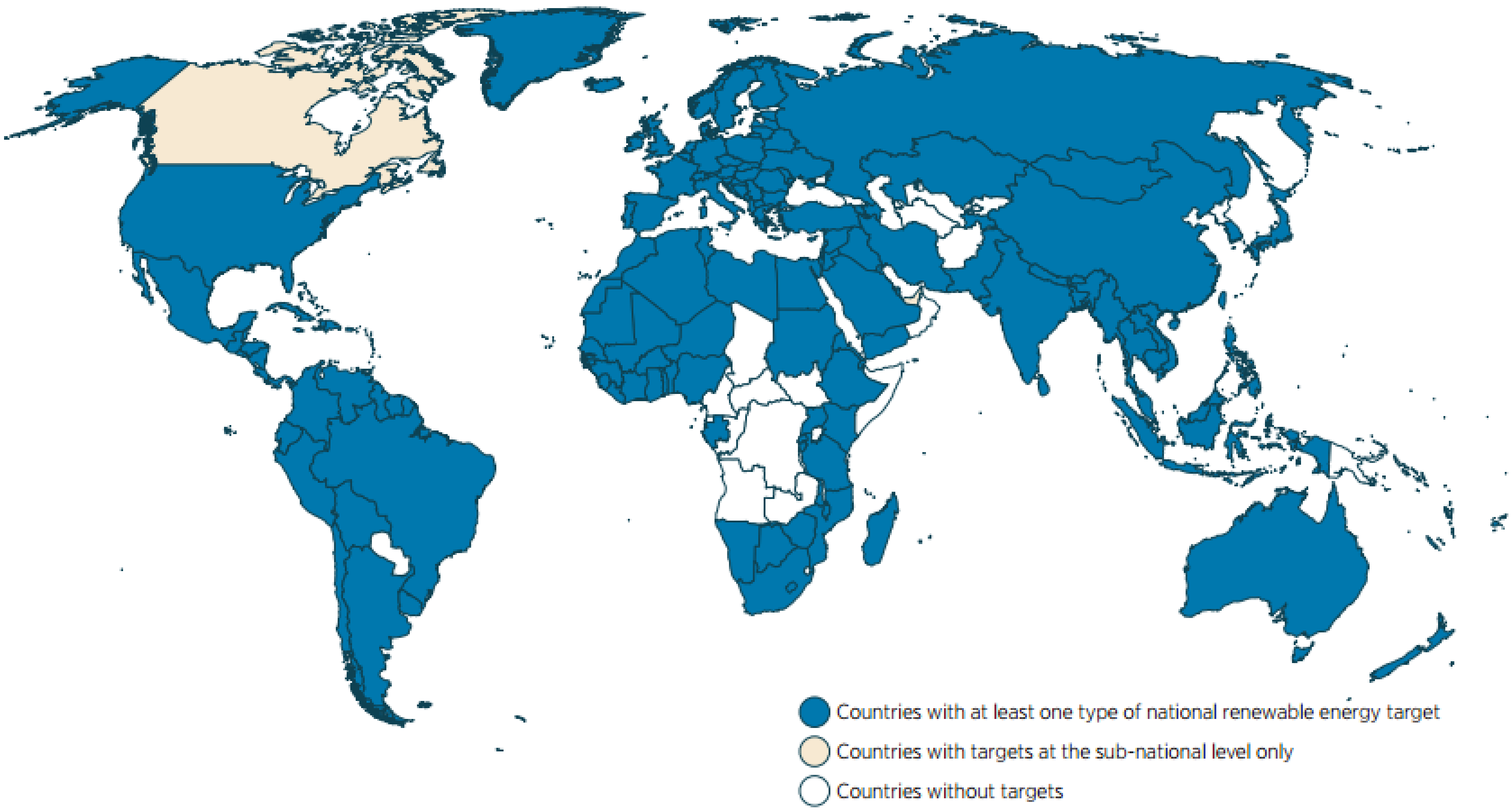
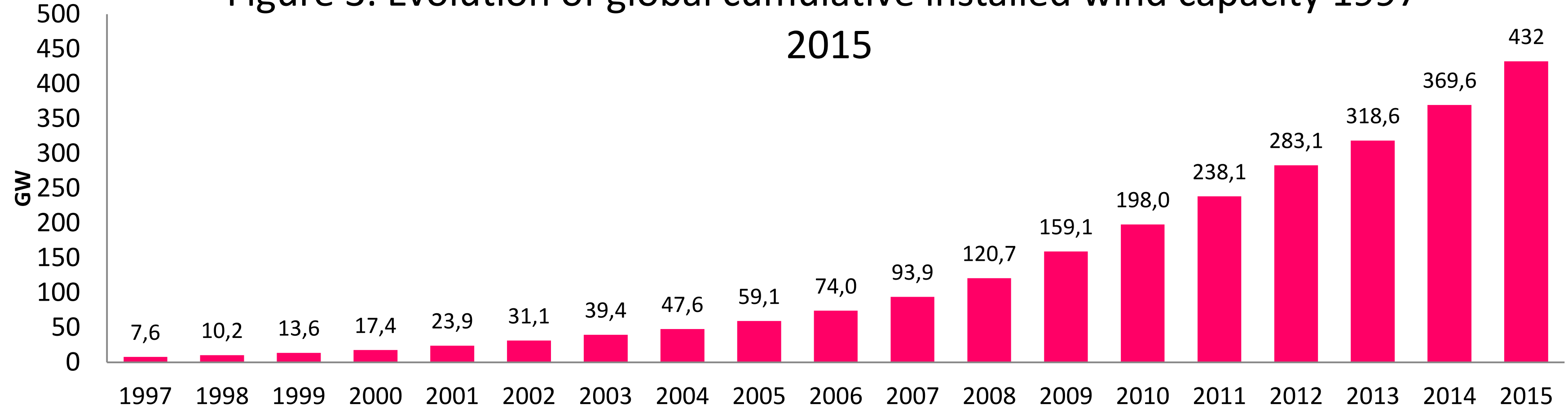


Figure 2. Global Map of National Renewable Energy Targets of All Types, 2005 (Irena, 2015)

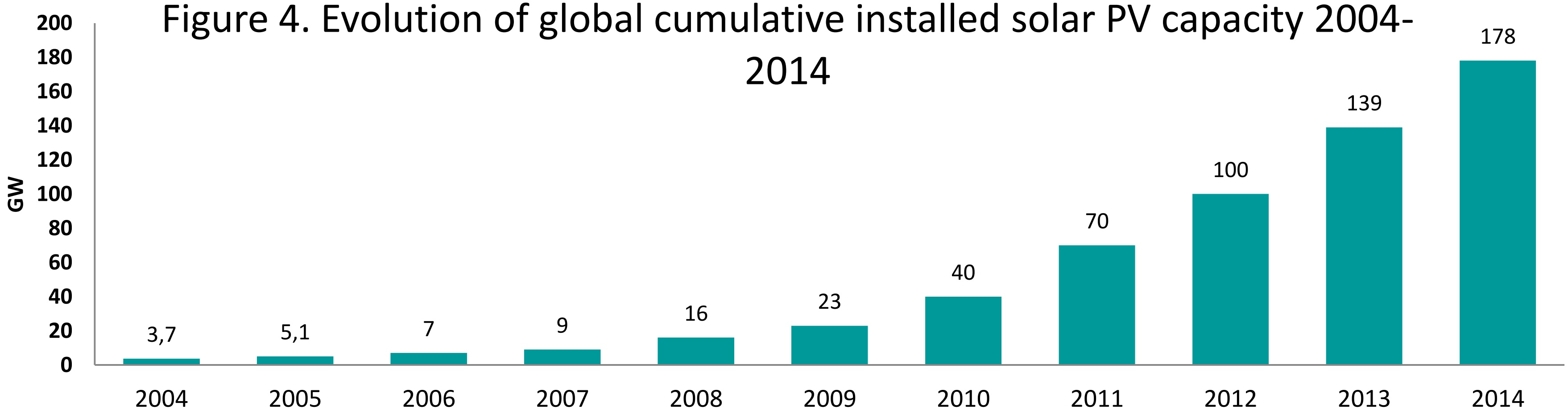
Growth of renewable power (1/3)

Figure 3. Evolution of global cumulative installed wind capacity 1997-2015



Source: Own elaboration from GWEC (2014)

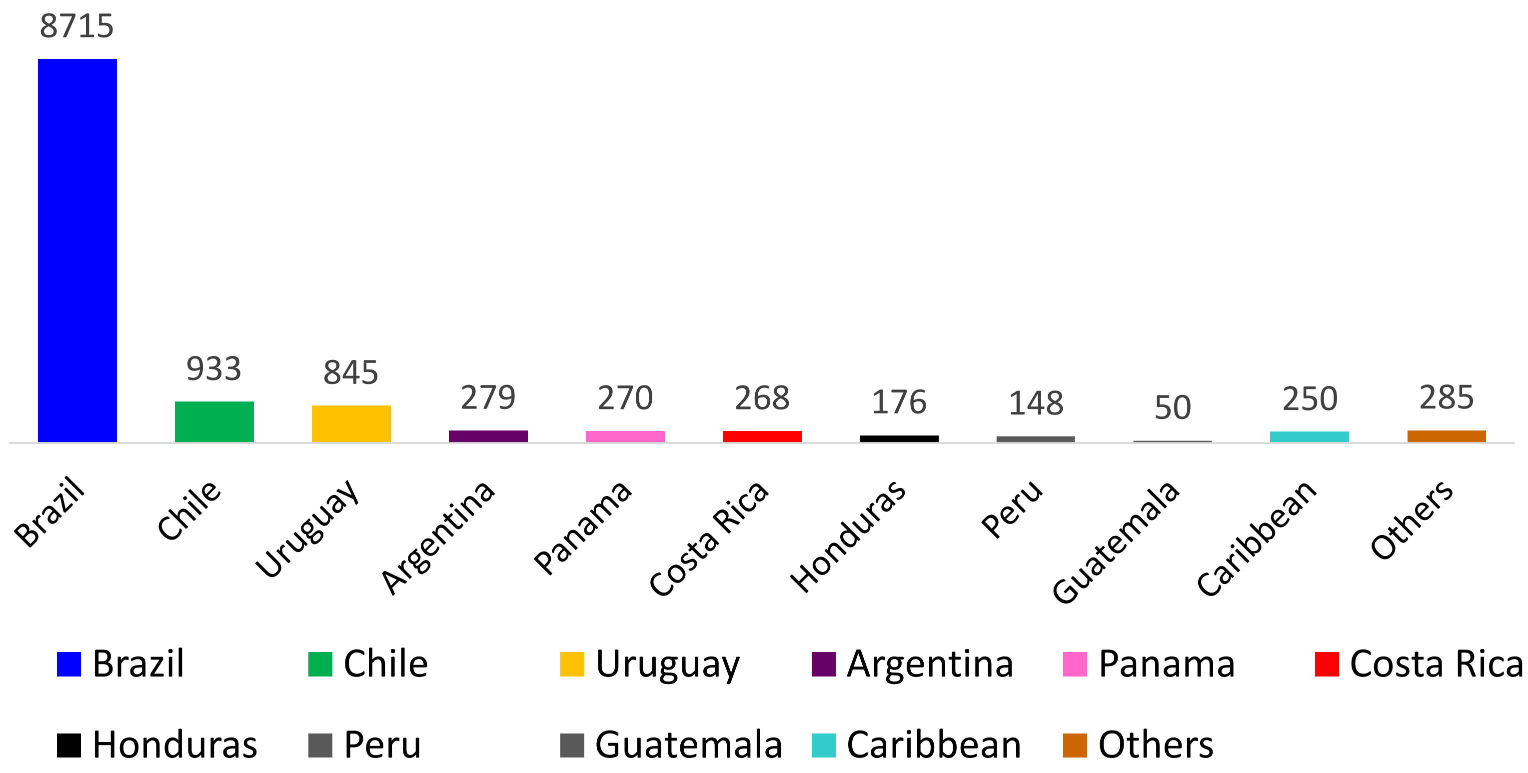
Figure 4. Evolution of global cumulative installed solar PV capacity 2004-2014



Source: Own elaboration from EPIA (2015)

Growth of renewable power (2/3)

Figure 5. Global installed wind power capacity (MW) 2015 – Latin America



Source: Own elaboration from GWEC (2015)

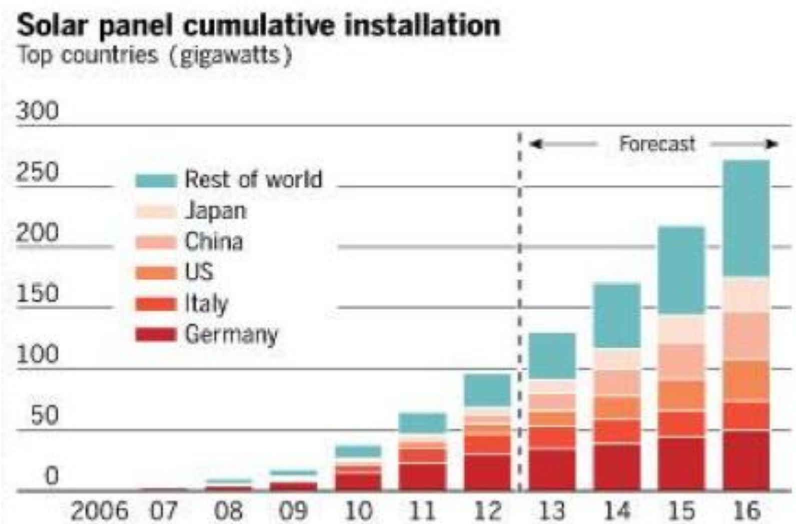
Growth of renewable power (3/3)

Table 1. Annual and cumulative installed PV power in 2014 (adapted from IEA (2014))

Country	MW	Country	MW	Country	MW
Germany	38200	*Greece*	2595	*Austria*	766
China	28199	*Korea*	2384	*Israel*	731
Japan	23300	*Czech Republic*	2134	*Denmark*	603
Italy	18460	*Canada*	1710	*Slovakia*	523
USA	18280	*Thailand*	1299	*Portugal*	391
France	5660	*Romania*	1219	*Chile*	368
Spain	5358	*Netherlands*	1123	*Mexico*	176
UK	5104	*Switzerland*	1076	*Malaysia*	160
Australia	4136	*Bulgaria*	1022	*Sweden*	79
Belgium	3074	*South Africa*	922	*Turkey*	58
India	2926	*Taiwan*	776	*Norway*	13

PV grid parity is here!

Breaking vicious circle…



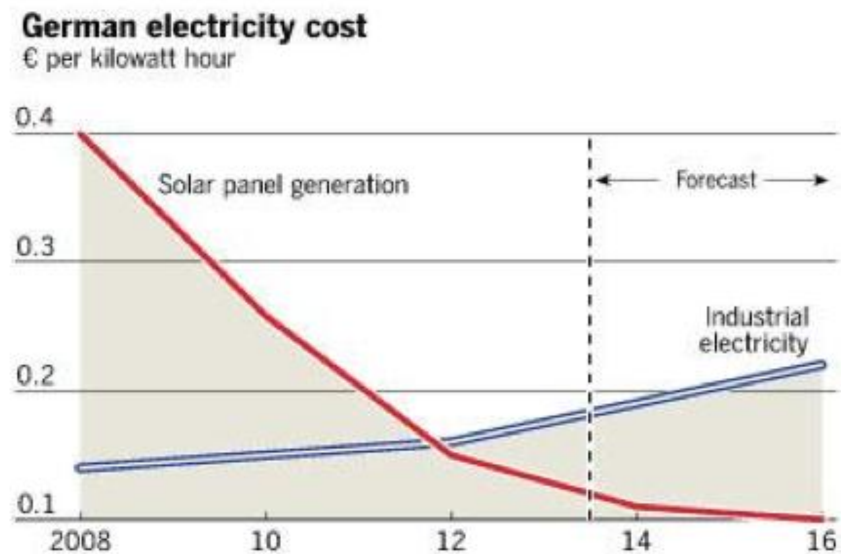


Figure 6. Learning effects.
Source: Renewables: A rising power, Financial Times, 8 Aug 2013 based on data from IHS Solar Demand Tracker.

From centralized to distributed energy…

Traditional supply chain

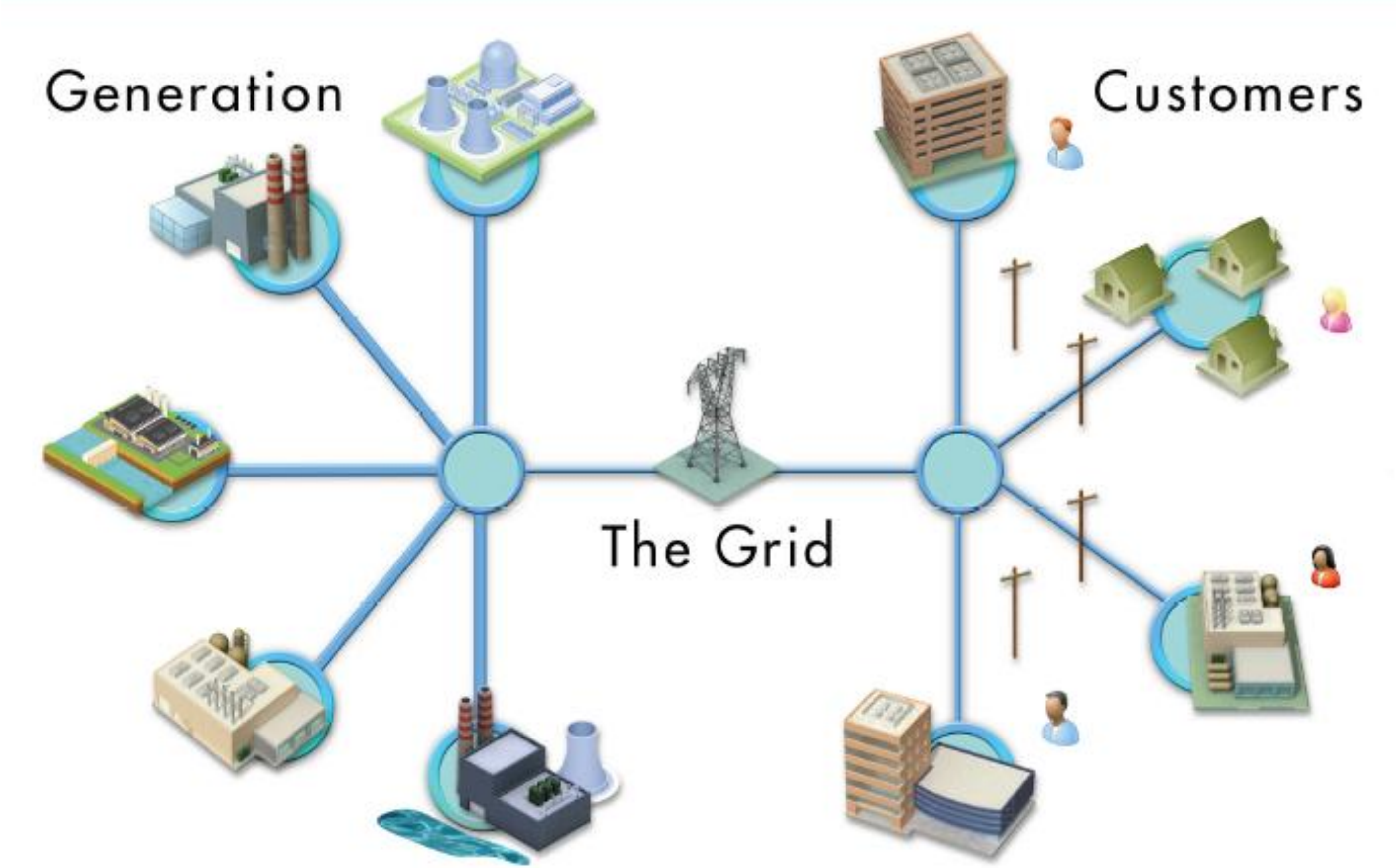


Figure 7. Today's Power System Characterized by Central Generation of Electricity, Transmission, and Distribution to End-Use Consumers (EPRI, 2014)

Wind of change…

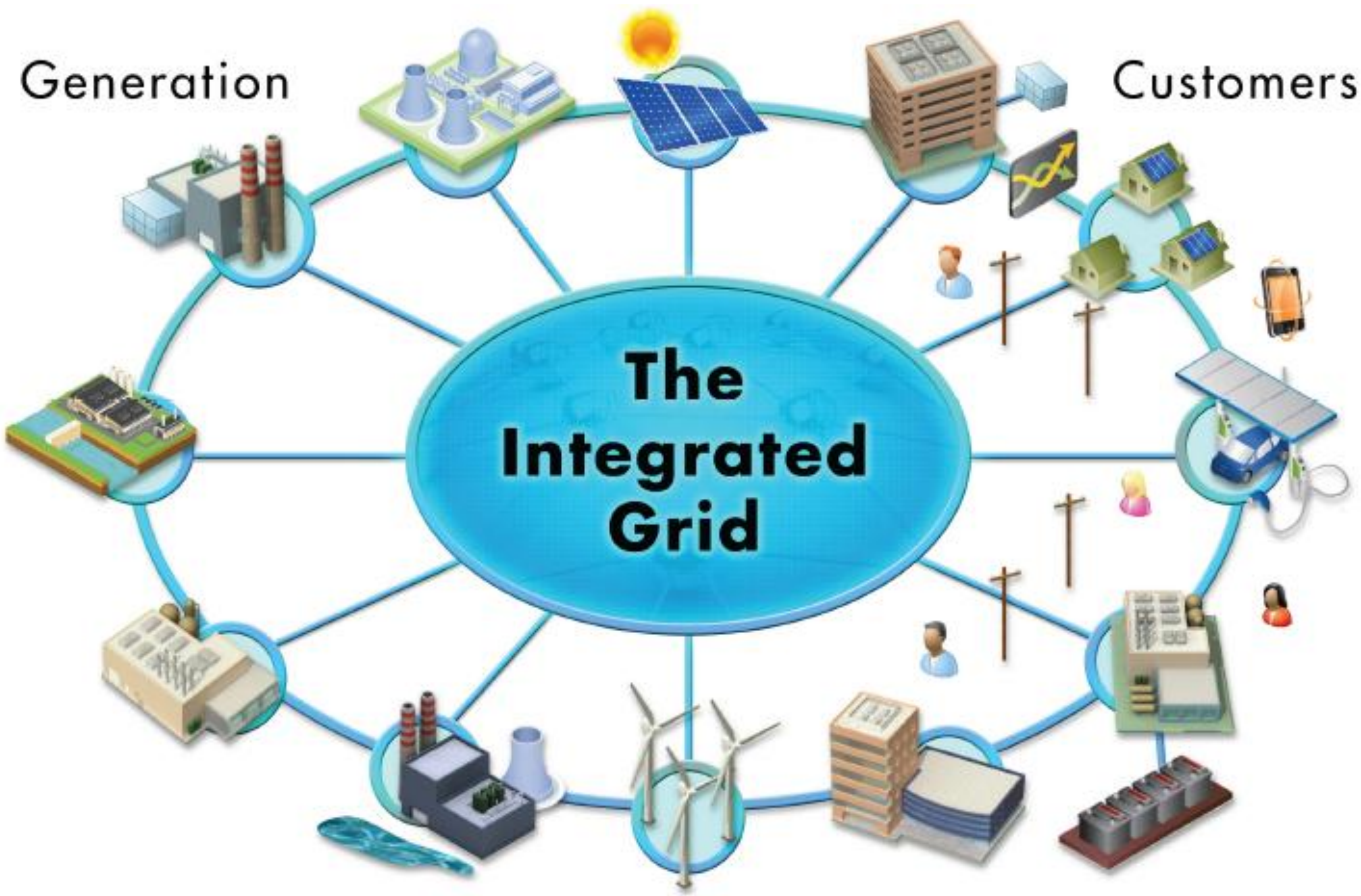


Figure 8. Creating an Architecture with Multi-Level Controller (EPRI, 2014)

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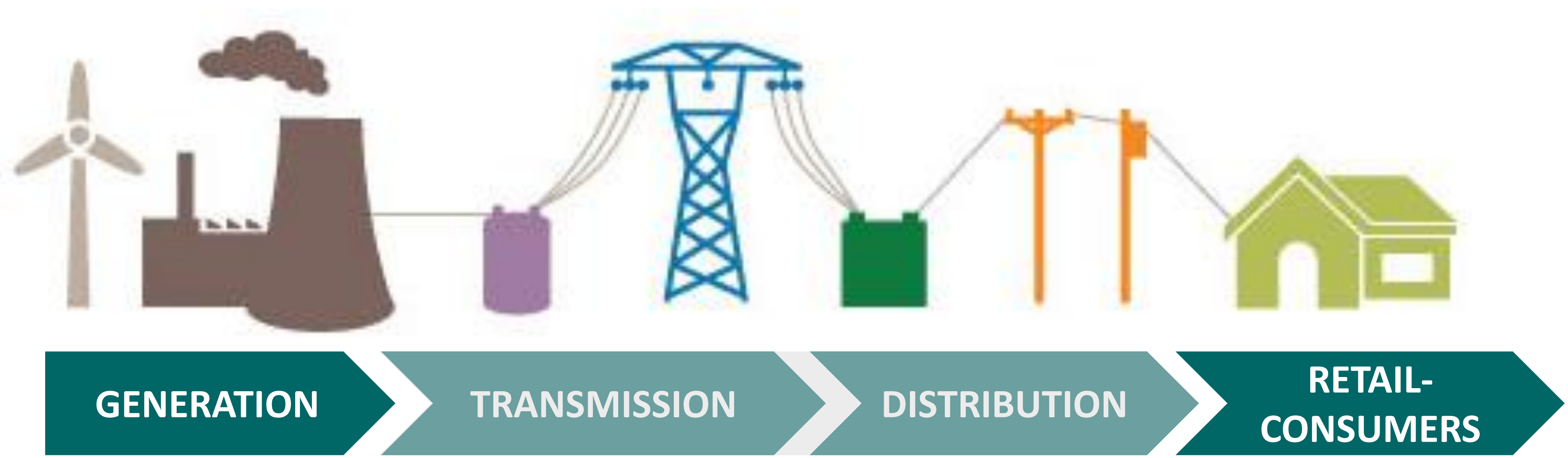
How does electricity get delivered to your home?



G + T + D + O = CU

Figure 9. Electricity supply chain

(Richter, 2012)

$$\uparrow D_t = \frac{Fixed\ network\ cost}{Electricity\ demand} \downarrow$$

Which are the threats for transmission and distribution activities?

TRANSMISOR/ DISTRIBUTOR

"FIT AND FORGET APPROACH"
(Ruester et al., 2014)

1. Energy efficiency
2. Conservation
3. **Distributed Generation DG deployment**

"The conflict between DG and energy conservation/efficiency is rooted in the fact that any use of distributed generation will cause a decline in the revenues being collected by local distribution companies".
(Brown 2013)

DG deployment–small scale, near point consumption, disruptive, bi-directional flows … integrated grid–(El-Khattam, 2004; EPRI, 2014)

…..Death spiral

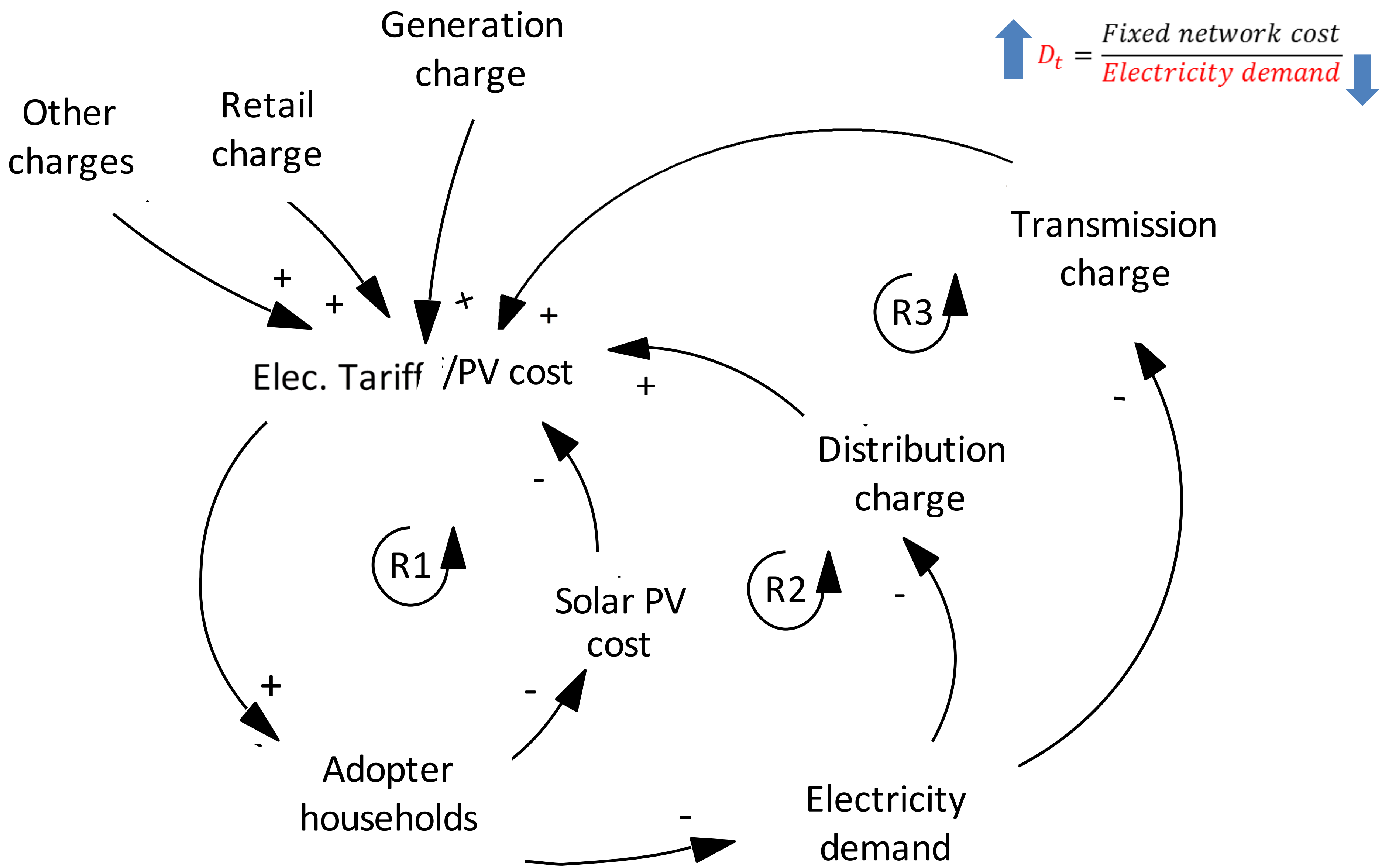


Figure 10. Dynamic Hypothesis

Research questions

- Which are the market conditions that will lead to a death spiral for utilities?
- Is it likely to occur?

Research in process:

- Can regulator and utilities avert a death spiral? Why?
- How to guarantee financial sustainability for utilities and fairness to all utility customers through **tariff design**?

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Literature review

Table 2. Literature review

Author	Topic
Nisar et al. (2013) Poisson-de Haro & Bitektine (2014) Richter (2012) Sioshansi (2014)	The effect of the disruption of electricity utilities by renewables
Felder & Athawale (2014) Khalilpour & Vassallo, (2015); Costello & Hemphill (2014); and, Severance, (2011) Eid et al. (2014) Grace (2015)	Death spiral
Cepeda & Finon, (2013); Jónsson, Pinson, & Madsen, (2010); Jensen & Skytte, (2003); O´Mahoney & Denny, (2011); Cludius & Hermann, (2013), and Sáenz de Miera et al., (2008).	Merit order effect

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The model

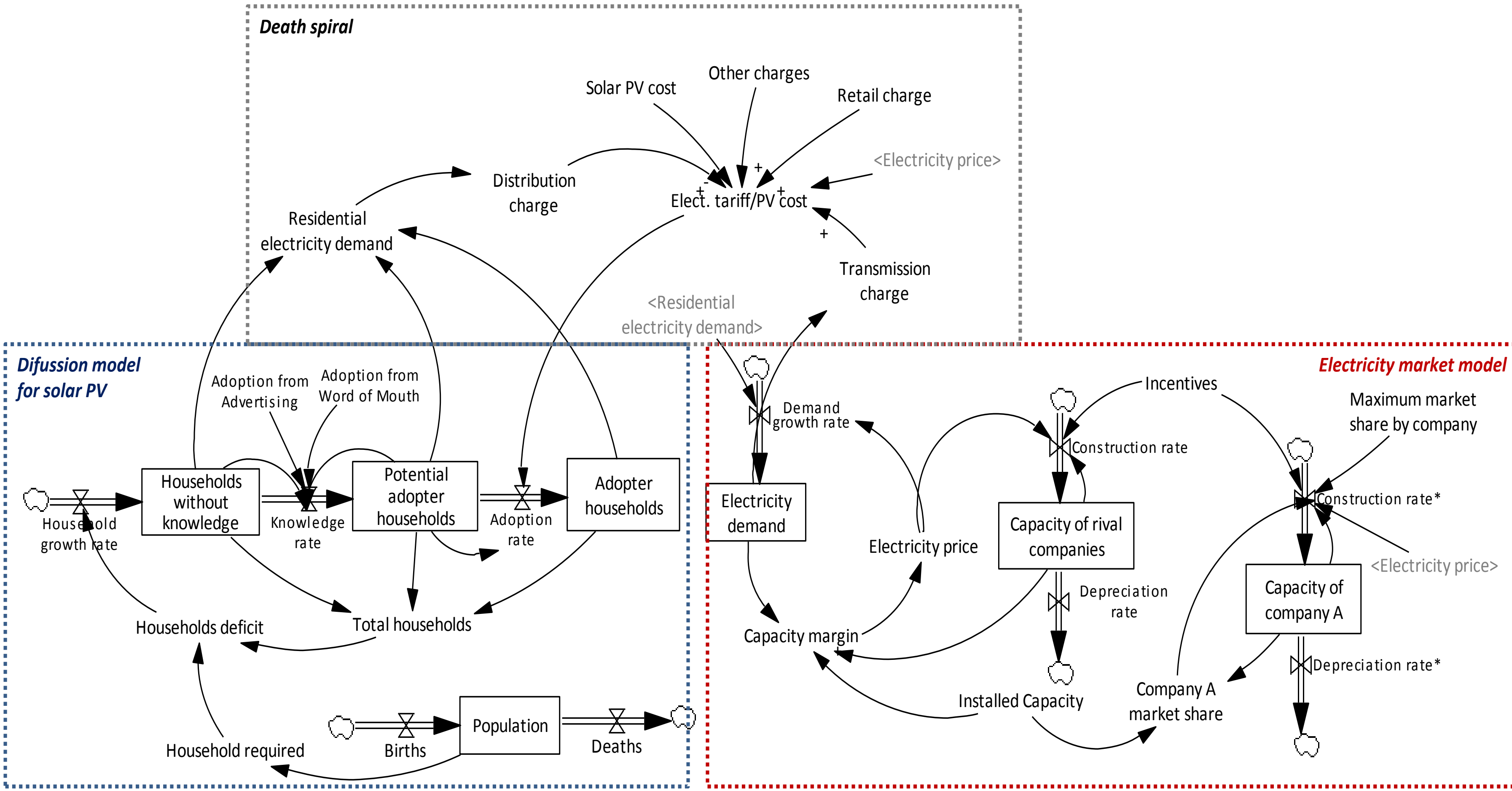

Figure 11. Flows and stocks diagram

Assumptions

Main assumptions concerning solar PV include:

i) The adoption of this technology may occur only residential sector

ii) Net-metering is in place

iii) Battery storage is not included

iv) No new investments are undertaken in distribution network assets

v) the size of the PV systems adopted by households remains invariable during the simulation period and it ranges between 1kW and 2kW

Scenarios for analysing renewable energy impact on a utility

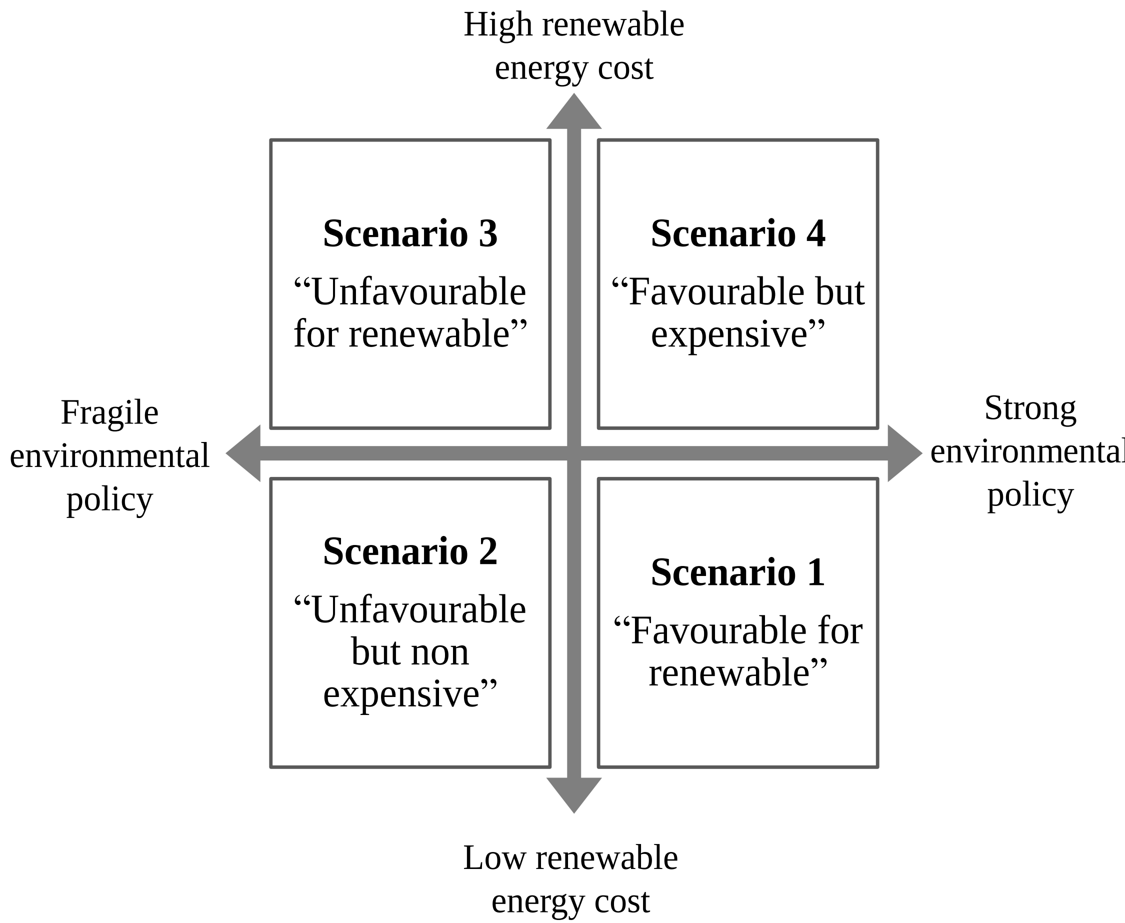

Figure 12. Scenarios

Impact on industry

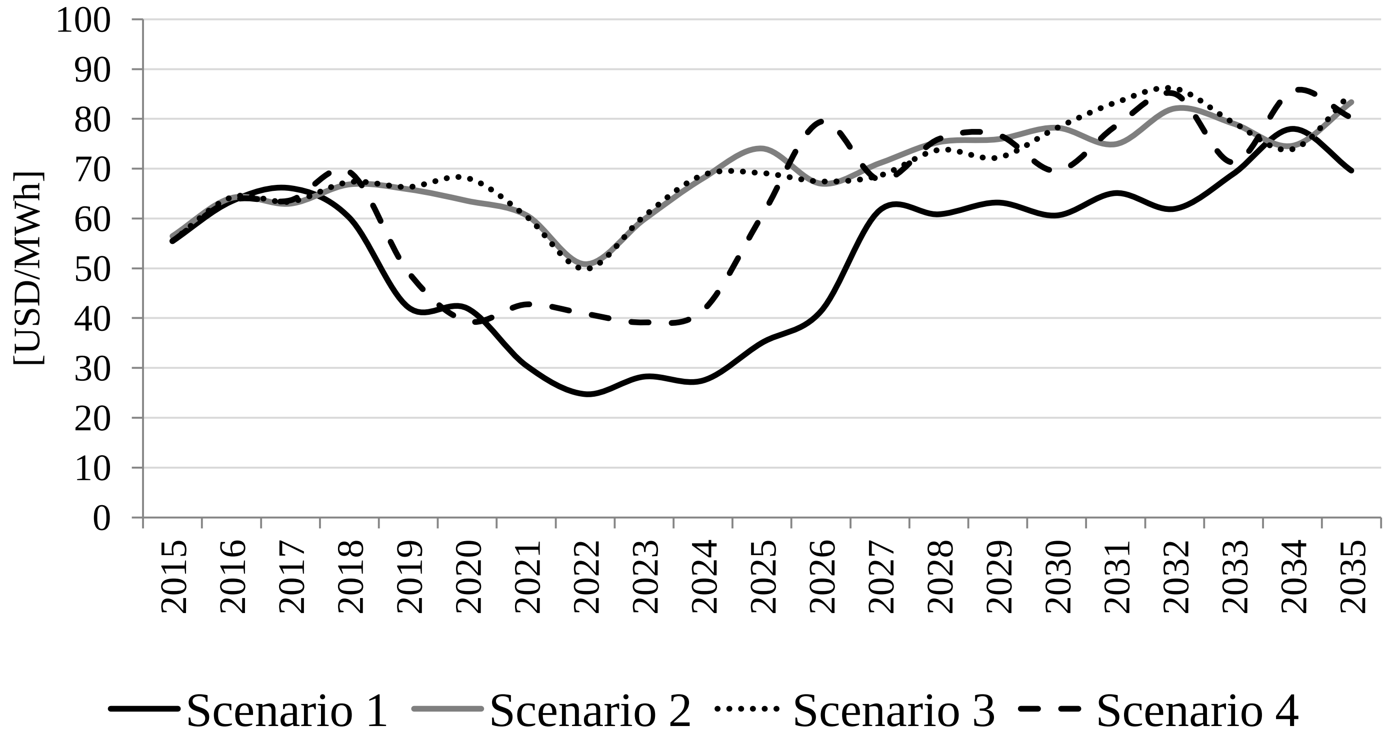

Figure 13. Wholesale electricity price.

Initially, prices drop due to the launch of 2,400 MW from the Ituango hydropower project in two stages between 2018 and 2022.

From 2022 onwards, market prices recover in all scenarios (a small share of fossil capacity is needed).

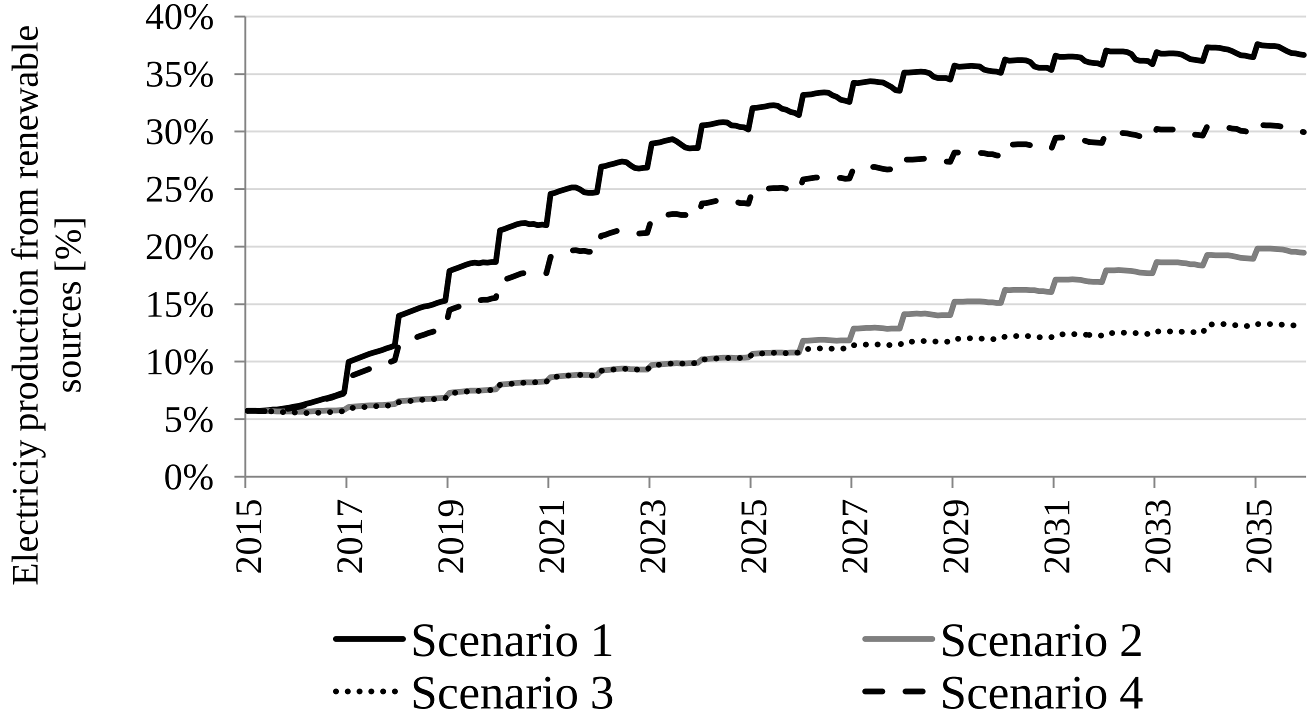

Figure 14. Share of renewable energy sources in electricity generation.

The environmental-friendly policy is more relevant than the cost of renewable energy, for the adoption of renewable technologies.

Solar PV electricity contributes about 13% (1,655 GWh/month) to Colombia's electricity supply from 2025 to 2035, under scenarios 1 and 4.

Impact on the utility

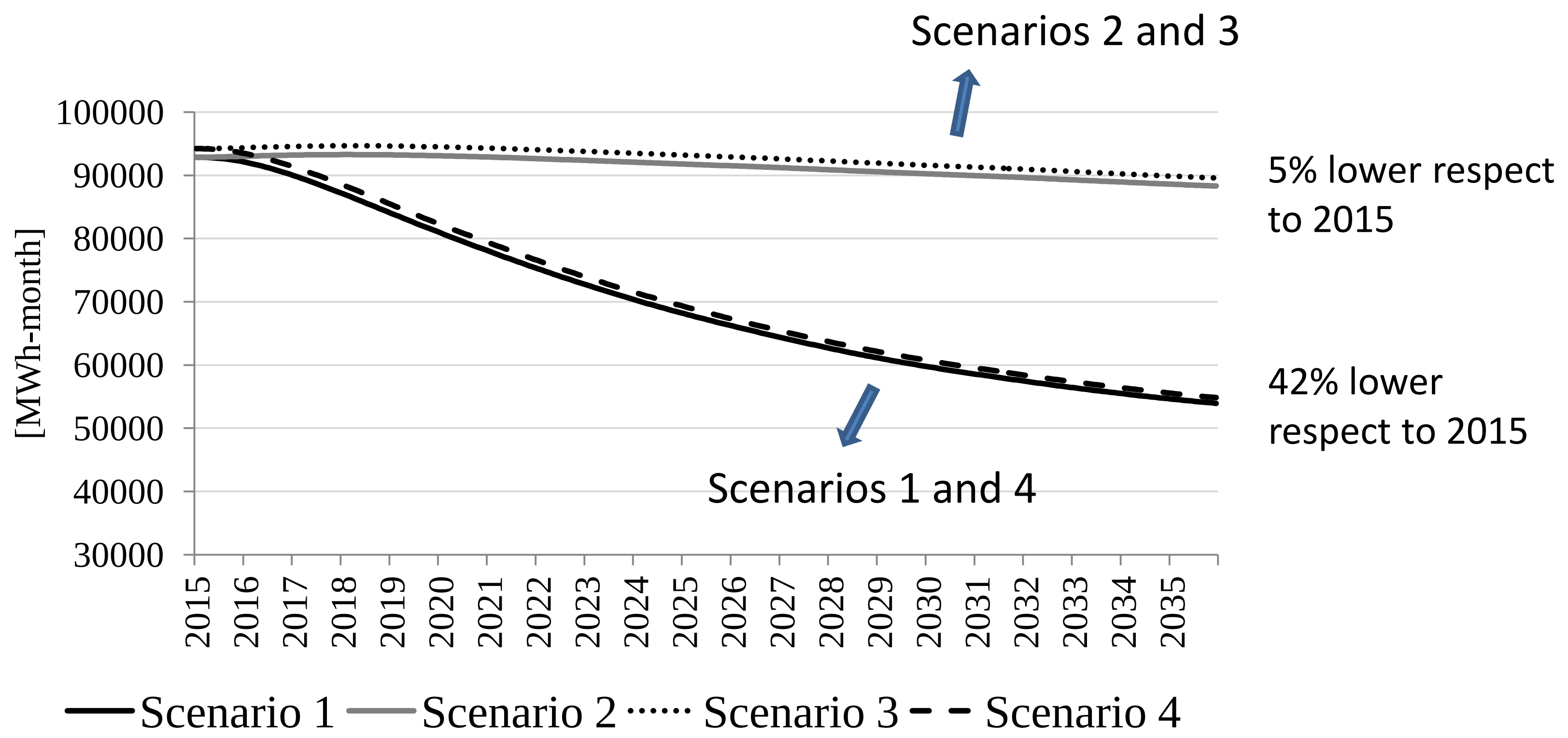

Figure 15. Electricity sales of Company A to the residential sector.

There are similarities in residential electricity sales by the utility, named here as Company A, under scenarios 1 and 4, and scenarios 2 and 3, as these scenarios have almost the same amount of solar PV.

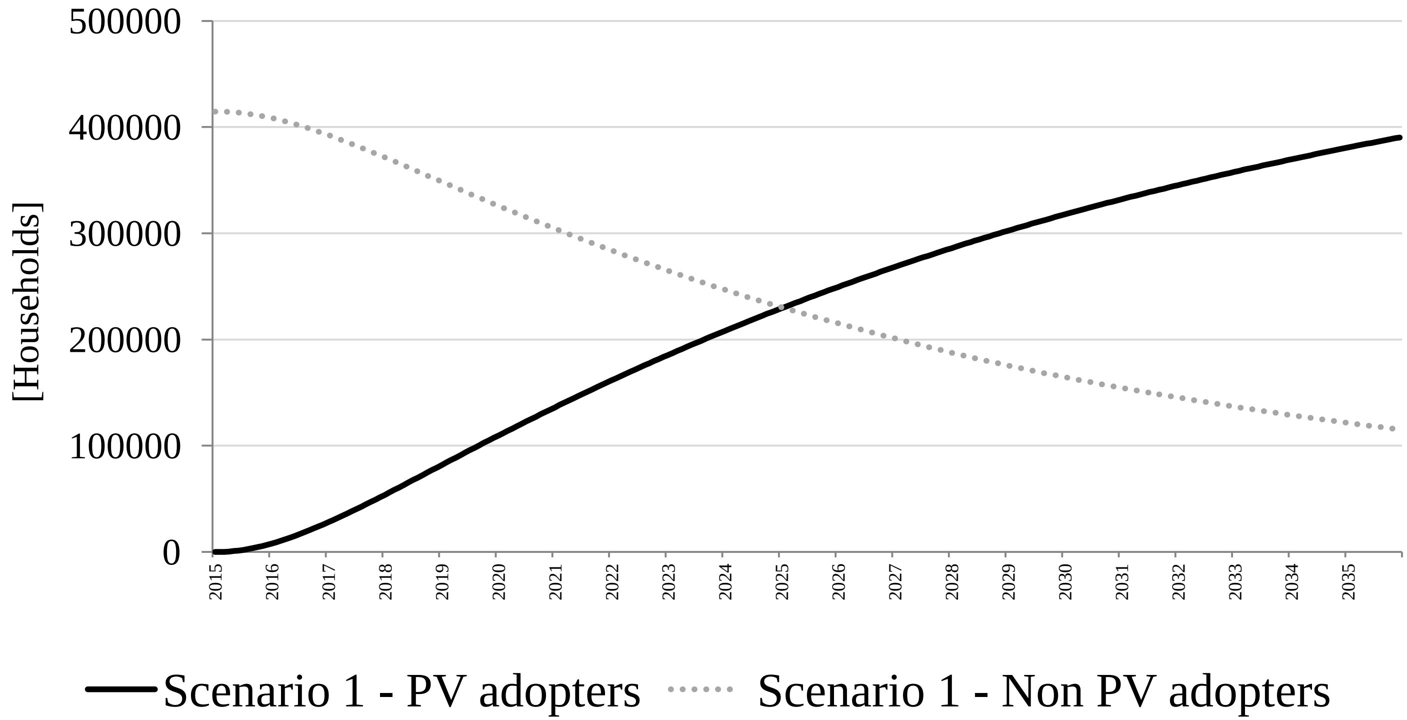

Figure 16. Non-PV adopter vs PV-adopters, for scenario 1.

Non-PV adopters decrease while PV-adopters increase, in scenario 1. Equilibrium is reached by 2025. From 2024 onwards, PV adopters exceed non-PV adopters.

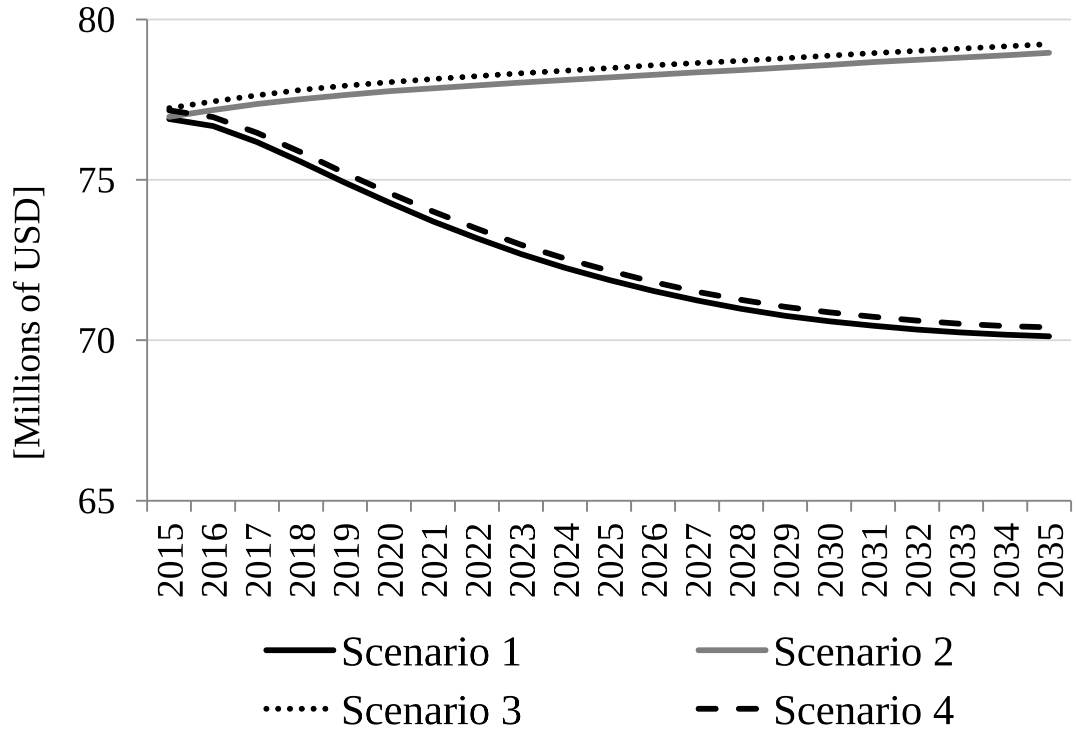

Figure 18. Revenues of Company A from distribution and retail business.

Solar PV erodes the electricity sales of utilities. Retailers will be more affected by solar PV growth, because self-generation means lost sales.

Effect of intense solar PV deployment policy

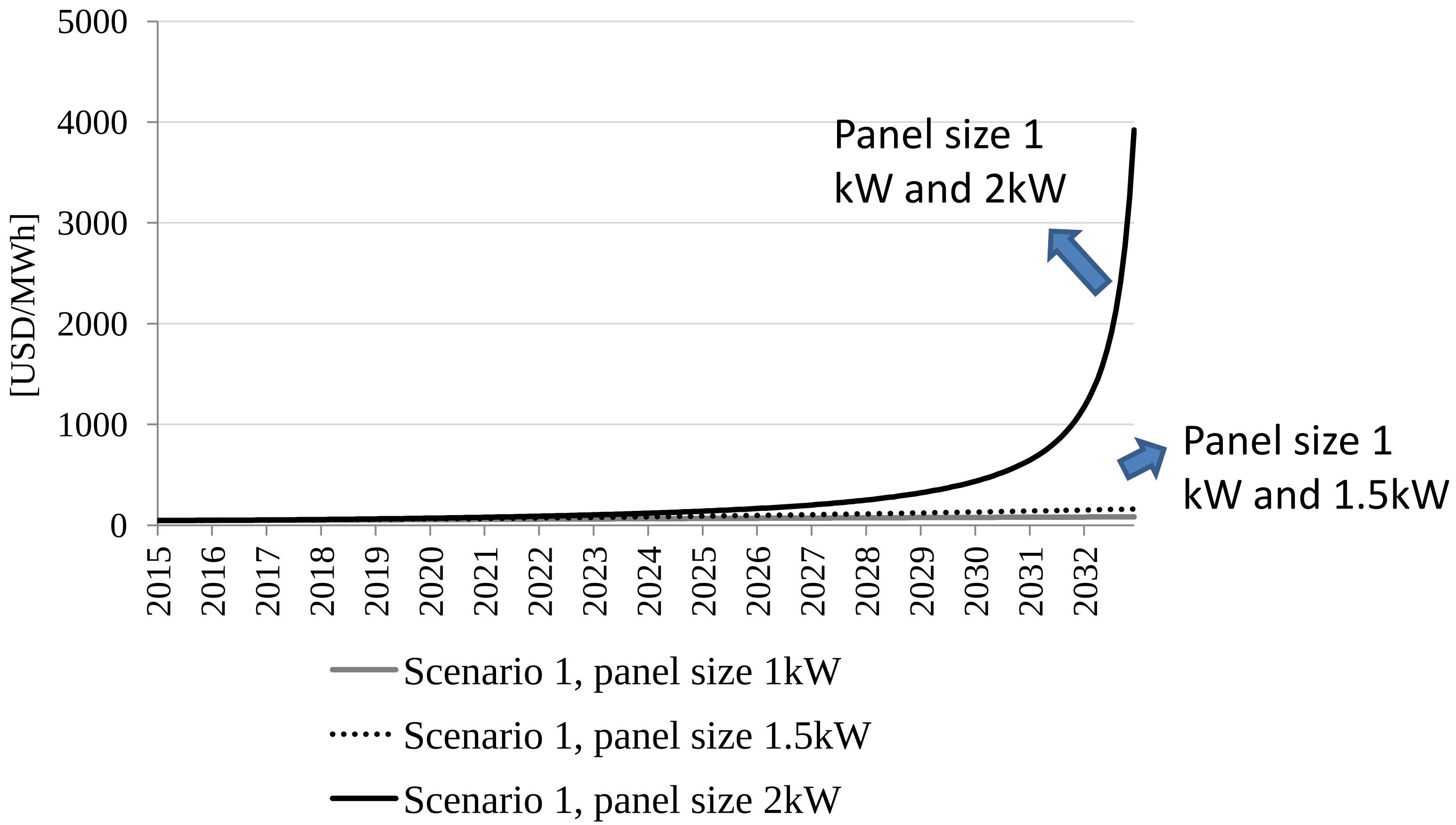

Figure 20. Distribution charge of Company A, for scenario 1 and different levels of PV expansion.

With a system size of 2KW, self-generation reduces the residential electricity demand to zero in the long run; this pushes grid costs to very high values, which become exponential

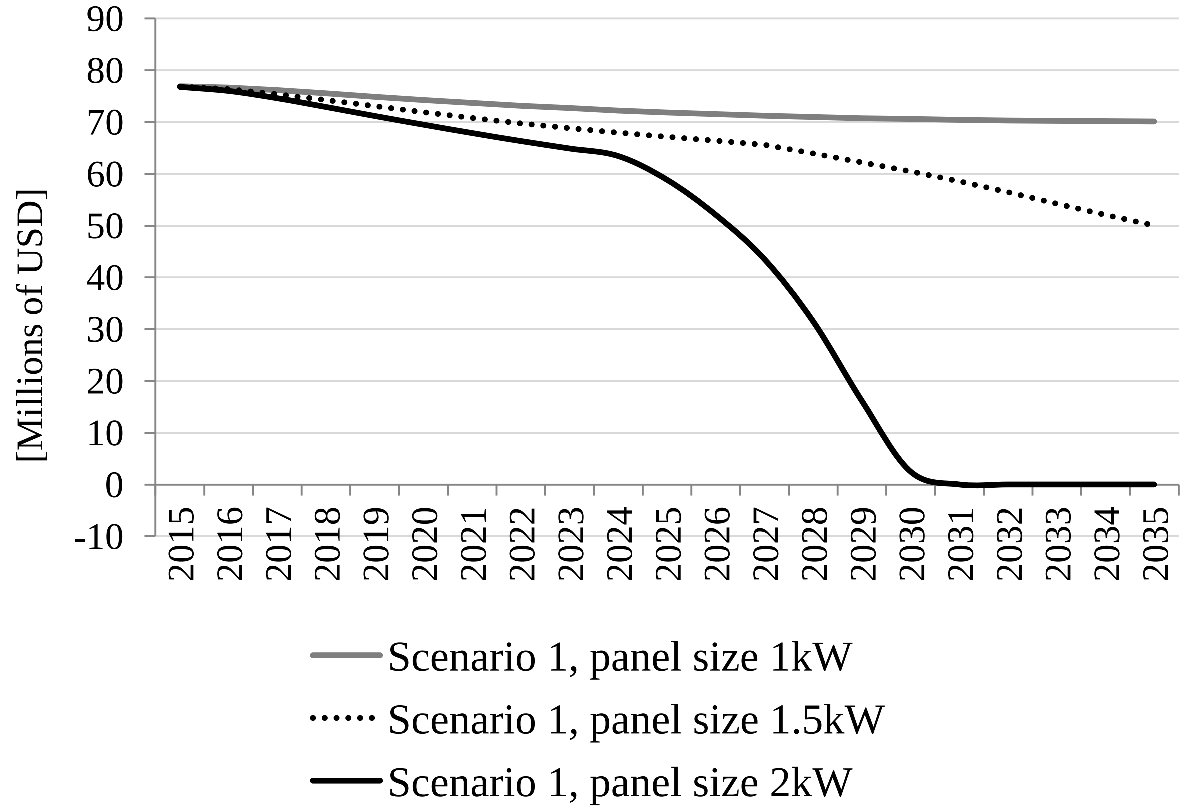

Figure 21. Company A's profitability from electricity distribution and retail business, for scenario 1 and different levels of PV expansion.

For scenario 1 with a panel size of 2 kW the distributor will experience financial difficulties in the long-term, as consumers will be unable to pay the extremely high electricity tariffs.

Financial impacts on non-PV adopters of different solar PV deployment

	Scenario 1 – 1kW (2035)	Scenario 1 – 1.5kW (2035)	Scenario 1 – 2kW (2033*)
Solar PV cumulative installed capacity	10,602 MW	15,947 MW	19,874 MW
Energy consumption by household	134 kWh	134 kWh	134 kWh
Grid Tariff (USD)	$0.20/kWh	$0.30/kWh	$6/kWh
Energy expense by household non PV-adopter	134kWh x $0.20/kWh=$27	134kWh x $0.30/kWh=$40	134kWh x $6/kWh=$804
Monthly salary lowest income household (USD)	$214**	$214	$214
Share of energy expense respect salary	13%	19%	376%

*These are the final values; beyond year 2033 the electricity system collapses.

**Minimum salary received by an employee.

Financial impacts on non-PV adopters of different solar PV deployment with different assumptions

Residential (30%), Scenario 1 - 2kW

Residential (30%), Scenario 1 - 2kW and Small companies (30%)

	Scenario 1 panel size of 2kW*, dates at 2035	Scenario 1 with special conditions**, dates at 2035
Solar PV cumulative installed capacity	9,030MW	19,843MW
Energy consumption by household	134 kWh	134 kWh
Grid Tariff (USD)	$0.19/kWh	$1.73/kWh
Expense on electricity by a non PV-adopter household	134kWh x $0.19/kWh =$25	134kWh x $1.73/kWh=$232
Monthly income of lowest income household (USD)***	$214	$214
Share of energy expense respect to income	12%	108%

*Under this scenario a 30% of households become PV adopters by 2035

** Under this scenario a 30% of households become PV adopters by 2035, also the deployment of solar PV on non-residential customers (such as small companies) was simulated.

***Minimum income received by an employee.

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Conclusions (1/2)

- **Death spiral means unfair bill for customers and network unsustainability, i.e., broken utilities.**

- **Death spiral is possible when:**

1. Declining energy consumption caused by increases in domestic PV generation
2. There are volumetric charge, net metering and grid parity

- **System collapses by death spiral when:**

1. Households are over-installed
2. Death spiral involves a myopic pricing strategy of utilities: where the utility attempts to maximize short-term profits but at the risk of suffering lower market share over time.

Conclusions (2/2)

- **Possible solutions to death spiral:**

  1. Change tariff design: energy charge and demand charge, energy charge and fixed charge, volumetric and real time pricing

  2. Reduce the electricity tariff and PV cost relation, for instance to stablish new rules for solar PV installations

  3. Limit net metering (limit on energy injected into the grid)

  4. Strategic game of the utility

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