NEARLY ZERO ENERGY CITIES: SCALABILITY OF ENERGY SELF-CONSUMPTION FROM BUILDINGS TO LARGE URBAN AREAS

Manuel Villa-Arrieta

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Low-Carbon Energy System Transformation:
Setting the Course for the Next Decade

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ABSTRACT AND HIGHLIGHTS

Study of the contribution of cities to the energy transition through the **scalability of the "Nearly Zero Energy concept" from buildings to large urban areas.**

The Nearly Zero Energy City model (**nZEC**) is an **indicator for the urban energy transition,** that include:

- Evaluation of the self-consumption "macro"
- Global Cost and Optimal Cost
- Analysis of the energy systems flexibility: Participation of Consumers, Producers and Producers in the energy distribution of cities

1. URBAN ENERGY TRANSITION

Problem

- >50% of the world's population is urban
- Consumption of fossil resources and increase of electric demand
- 70% of the global energy consumption and GHG emissions[1]

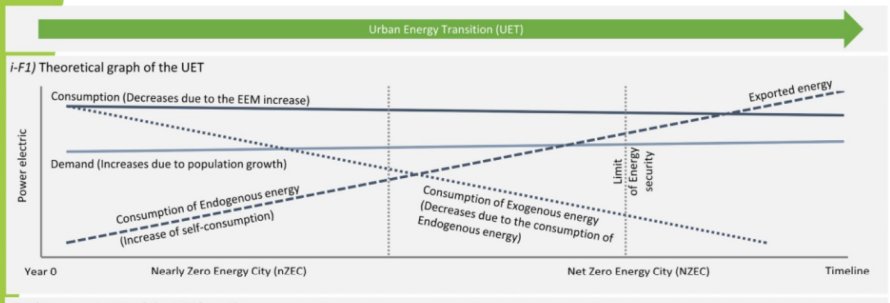
Technological context

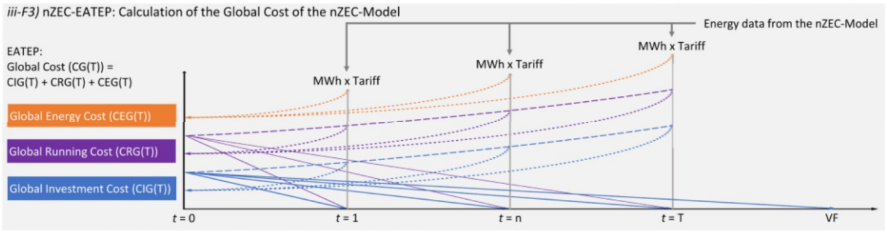
- Smart City model
- Smart Grids, Distributed Generation (DG) and Smart Meters
- Flexibility of the system: Consumers, Producers and Producers

Cities are at the center of the energy transition strategies

Source:
[1]UN Habitat. World Cities Report 2016 - Urbanization and Development: Emerging Futures

2. NEARLY ZERO ENERGY CITY CONCEPT

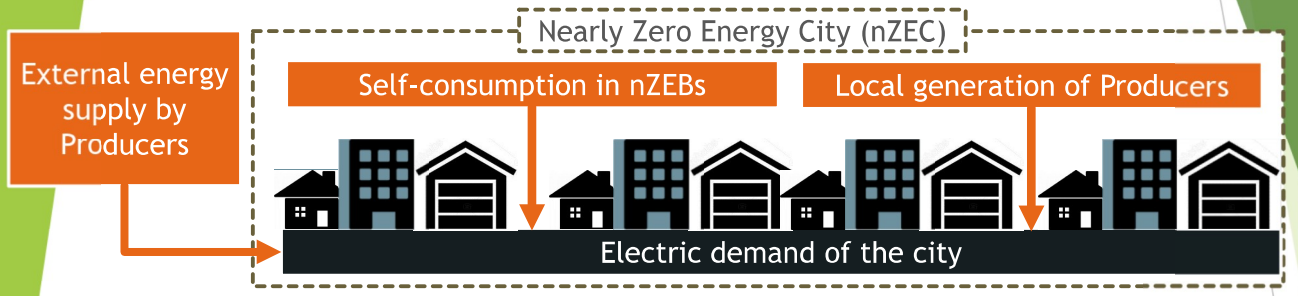




- Increase in the use of local energy resources.
- Increase of Nearly Zero Energy Buildings (nZEB)
- Energy Performance of Buildings Directive (EPBD)

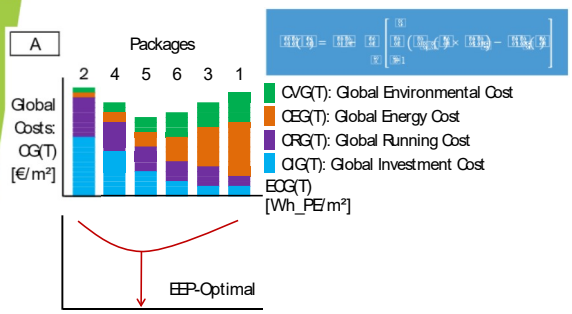
Source:
Villa-Arrieta M, Sumper A. Economic evaluation of Nearly Zero Energy Cities (2019), https://www.sciencedirect.com/science/article/pii/S0306261918319007

2.1 EVALUATION MODEL OF nZECs



$$EATEP:\ CG(T)\_Csr,Pdr,Psr = CIG\_(T)Csr,Pdr,Psr + CRG(T)\_Csr,Pdr,Psr + CEG(T)\_Csr,Pdr,Psr + CMG(T)\_Csr,Pdr,Psr$$

Global Cost (Present value of annual costs)

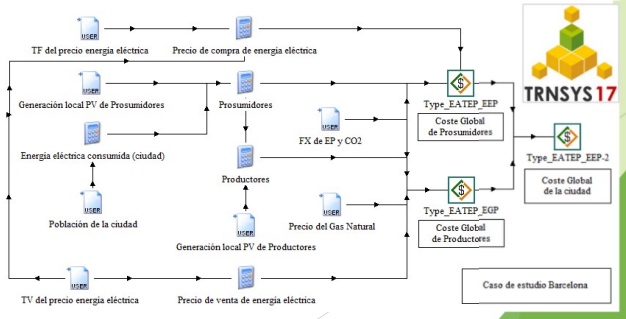


$$CG(T) = CIG(T) + \sum_{y=1}^{y} \left[CRG(T)_y \times (1+i)^{-y} + CEG(T)_y \times (1+i)^{-y} + CMG(T)_y \times (1+i)^{-y} \right]$$

- CVG(T): Global Environmental Cost
- CEG(T): Global Energy Cost
- CRG(T): Global Running Cost
- CIG(T): Global Investment Cost

EOG(T) [Wh_PE/m²]

Dynamic simulation in TRaNsient SYstem Simulation tool (TRNSYS)



Manuel Villa-Arrieta

Source:

- Villa-Arrieta M, Sumper A. A model for an economic evaluation of energy systems using TRNSYS (2018), https://www.sciencedirect.com/science/article/pii/S0306261918301703
- Villa-Arrieta M, Sumper A. Costes de Consumidores-Prosumidores y Productores de energía en el marco de la autosuficiencia energética de Barcelona como Ciudad Inteligente (2018), https://goo.gl/euBybM

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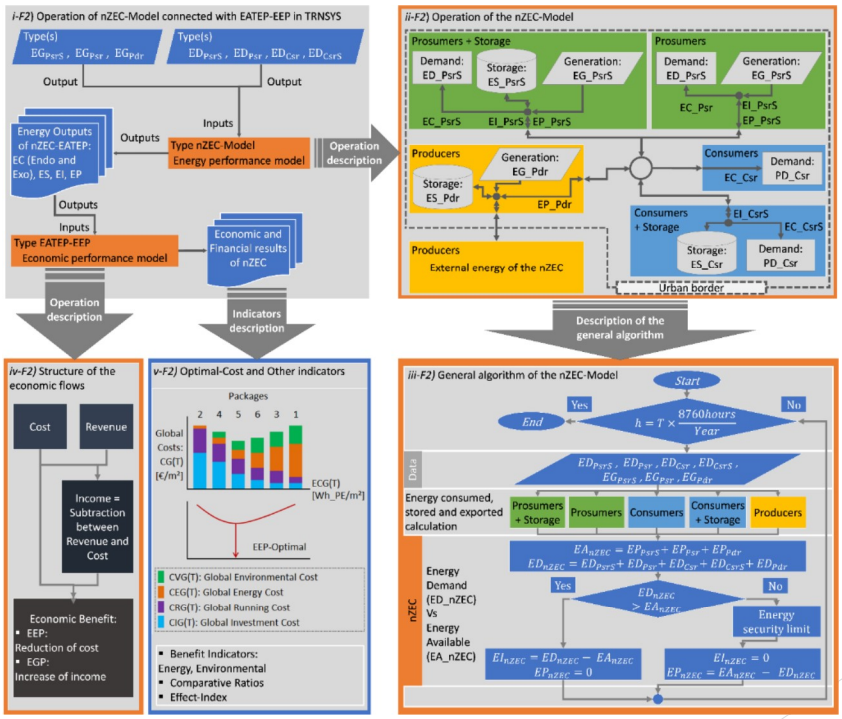

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Source:
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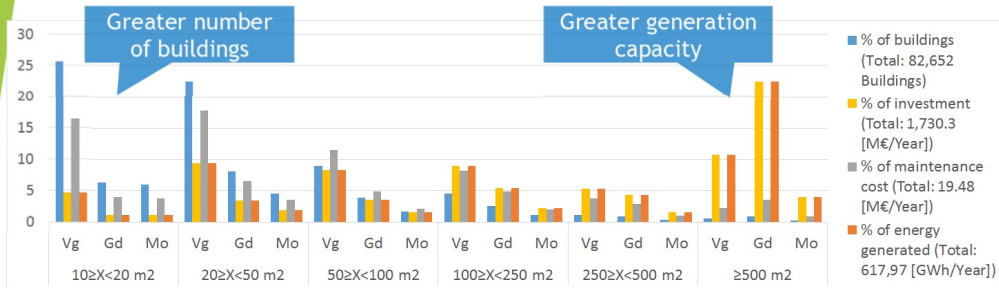
3. CASE OF STUDY: BARCELONA

Characteristics of the city

- Electric power consumption of 6,700-7,000 GWh/Year.
- Area 102,159 km^2
- 1% of total consumption comes from local renewable energy resources.
- 238,213 Buildings in the Map of renewable energy resources of Barcelona:

✓ 82,652 Buildings | 5.23 km^2 | 0.49 GW | 618 GWh

PV generation capacity (Map)



Source:
Barcelona Energia, A. de B. (2016a). ¿Cuánta energía puedes generar?. Barcelona Energia, A. de B. (2016b). Mapa de recursos d'energia renovable de Barcelona

3.1 CASES STUDIED

- Economic evaluation 2014-2050
- Self-consumption of the city: buildings and large rooftops
- Measures of Energy Efficiency in the façade of the buildings
- Distribution Peer-to-Peer (P2P) between Prosumers
- PV panels: 270 W | 2m^2 | 1,250 kWh/kWp·Year | 25 years of lifespan

1. Consumers and Producers invest in PV systems

- 52 Investment hypothesis:
  - ✓ By generation capacity groups (Scenarios B-C)
  - ✓ By groups of rooftop surfaces (Scenarios D-E-F)
  - ✓ By percentage of buildings (Scenarios G-H)
  - ✓ By selection of the generation capacity and surface of rooftops (Scenario I)
- Electricity prices and NG (Producers)

2. Prosumers and DG extra

- Hypothetical community P2P of Prosumers: 38,700 nZEBs (2-6 plants)
- Local extra generation in the city: 43,952 rooftops
- Six Packages of energy rehabilitation: Pg5 (general rehabilitation) and Pg6 (Low cost)
- Three electricity rates: Flat and two and three time periods of discrimination

Source:
- Villa-Arrieta M, Sumper A. Costes de Consumidores-Prosumidores y Productores de energía en el marco de la autosuficiencia energética de Barcelona como Ciudad Inteligente (2018), https://goo.gl/euBybM
- Villa-Arrieta M, Sumper A. Economic evaluation of Nearly Zero Energy Cities (2019), https://www.sciencedirect.com/science/article/pii/S0306261918319007
- ICAEN. Rehabilitació energètica d'edificis (2016)

3.1 CASE STUDIED

Case 2: Buildings typology

Distribution of buildings evaluated in Prosumers, Consumers and PV_Extra. Source: [64–67].

	Code | Subtotal	No. of floors	Type of building[a]	No. of buildings	Electric energy consumption [GWh/Year]
Prosumers	2F	2	A, B and C	12,463	61.787
	3F	3	D	6,238	41.853
	4F	4	I	4,842	245.457
	5F	5	E and H	7,082	339.516
	6F	6	F and G	8,075	274.779
	Subtotal	N/A	N/A	38,700	969.363
Consumers	Approach A	N/A	N/A	N/A	5,771.847
	Approach B	N/A	N/A	N/A	3,225.927
PV_Extra	N/A	No data	N/A	N/A	N/A
	N/A	1	N/A	2,135	N/A
	N/A	7	N/A	5,564	N/A
	N/A	8	N/A	3,606	N/A
	N/A	9	N/A	3,266	N/A
	N/A	≥10	N/A	3,636	N/A
	Subtotal	N/A	N/A	43,952	N/A
Total, Approach A		N/A	N/A	82,652	6,735.24
Total, Approach B		N/A	N/A	82,652	4,189.32

[a] Type of buildings: Single family detached house: A, built before 1951; B, built between 1951 and 1980; C, built between 1981 and 1990; D, built after 1990. Multi-family building: E, built before 1951; F, built between 1951 and 1980 with collective boiler; G, built between 1951 and 1980 without collective boiler; H, built between 1981 and 1990; I, built after 1990.

Source:
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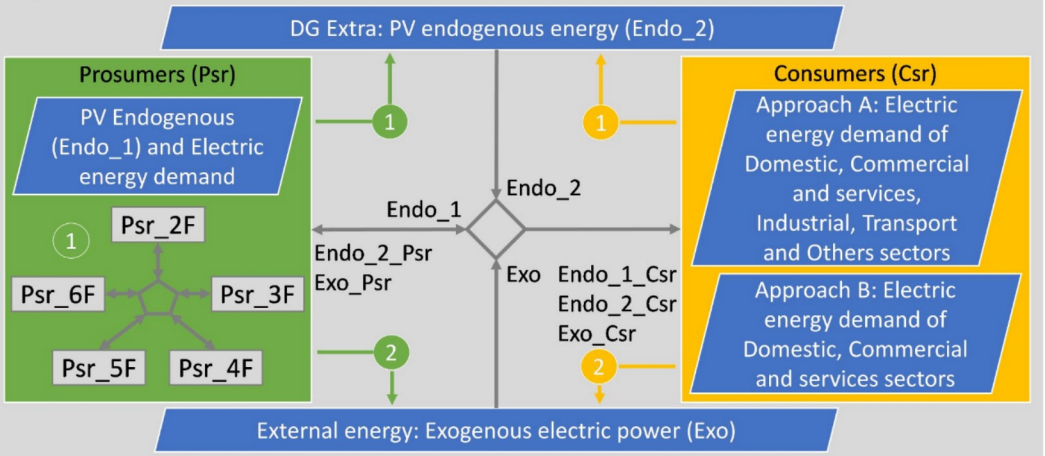
- ICAEN. Rehabilitació energètica d'edificis (2016)

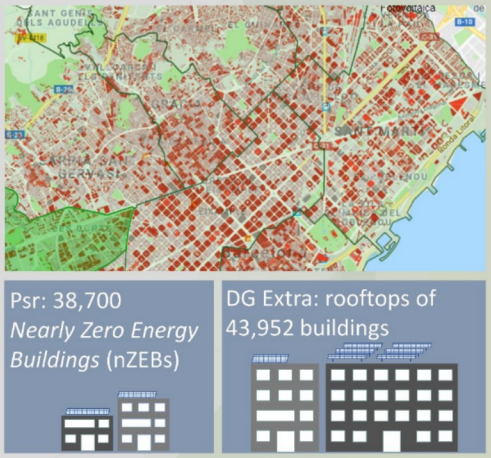
3.1 CASES STUDIED

2. Prosumers and DG extra

i-F3) nZEC-EATEP model - Barcelona

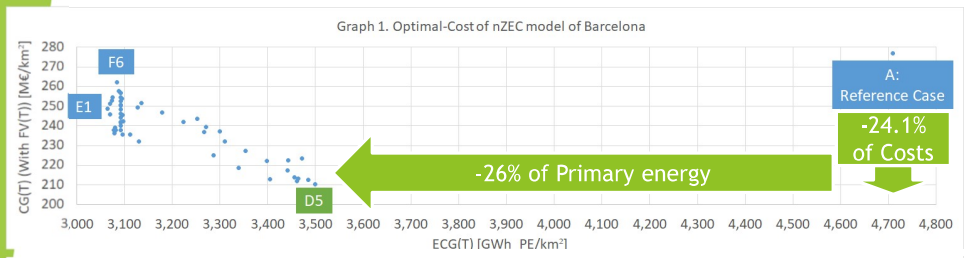


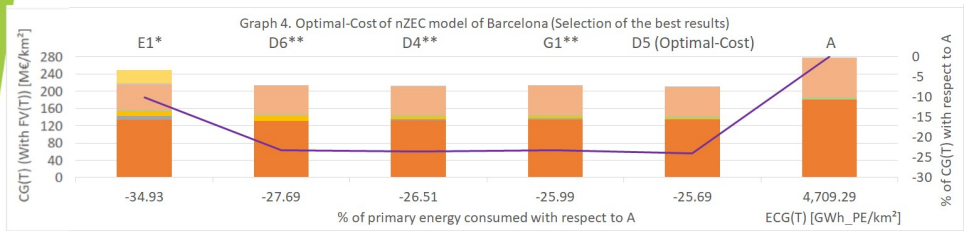
ii-F3) PV generation capacity data of Barcelona

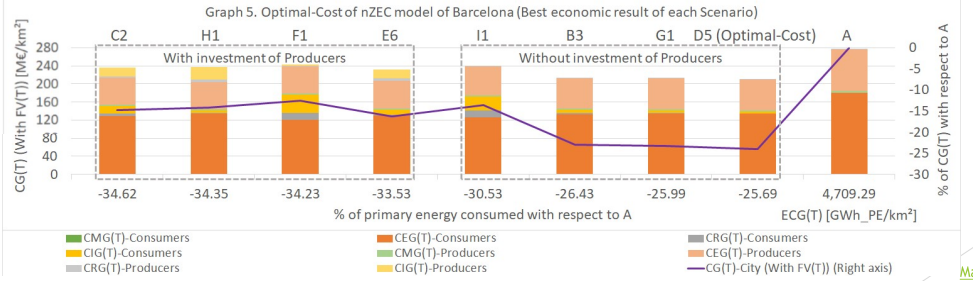


Source:
Villa-Arrieta M, Sumper A. Economic evaluation of Nearly Zero Energy Cities (2019), https://www.sciencedirect.com/science/article/pii/S0306261918319007

4. RESULTS OF THE CASE 1







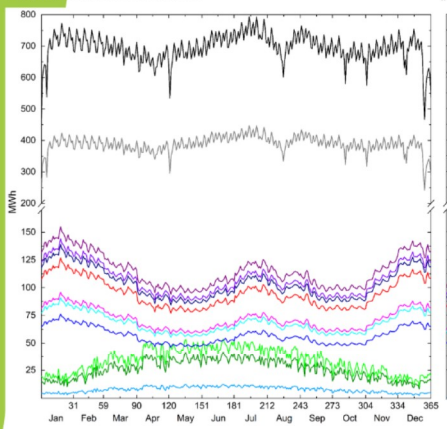
- Optimal Cost: D5, consumers investment in rooftops of 250-500m²

- Best results when Producers invest

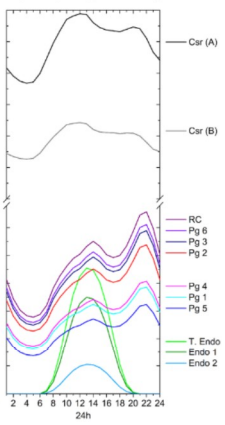
Source:
- Villa-Arrieta M, Sumper A. Costes de Consumidores-Prosumidores y Productores de energía en el marco de la autosuficiencia energética de Barcelona como Ciudad Inteligente (2018), https://goo.gl/euBybM

4. RESULTS OF THE CASE 2

i-F4) Daily average of the annual profile

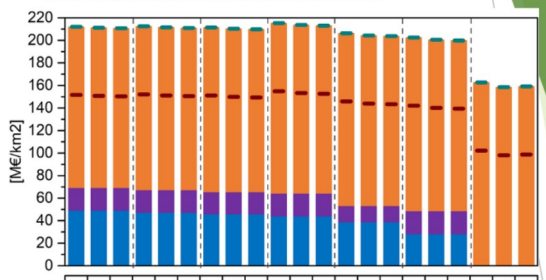


ii-F4) Hourly average of the daily profile



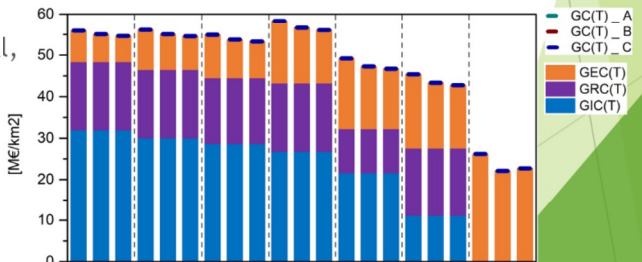
- Demand A: domestic, commercial and services, industrial, transport and other.
- Demand B: domestic, and comercial and services.
- Demanda C: community of Prosumers.
- Endo 1: Generation of Prosumers.
- Endo 2: Generation extra
- GC: Global Cost
- GEC: Global Energy Cost
- GRC: Global Running Cost
- GIC: Global Investment Cost

i-F5) A: Domestic, commercial and services, industrial, transport and other
B: Domestic and commercial sectors and services



	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
ECG(T)	5,583.28			5,667.86			5,696.15			5,872.72			5,941.71			5,971.09			6,181.80		
	Pg 5			Pg 1			Pg 4			Pg 2			Pg 3			Pg 6			RC		

ii-F5) C: Hypothetical community of Prosumers



	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
ECG(T)	180.97			216.17			227.94			301.42			330.13			342.36			367.97		
	Pg 5			Pg 1			Pg 4			Pg 2			Pg 3			Pg 6			RC		

Source:
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4. RESULTS OF THE CASE 2

- PV generation in the 34.7% of the rooftops of BCN and energy rehabilitation of 17% of its buildings:

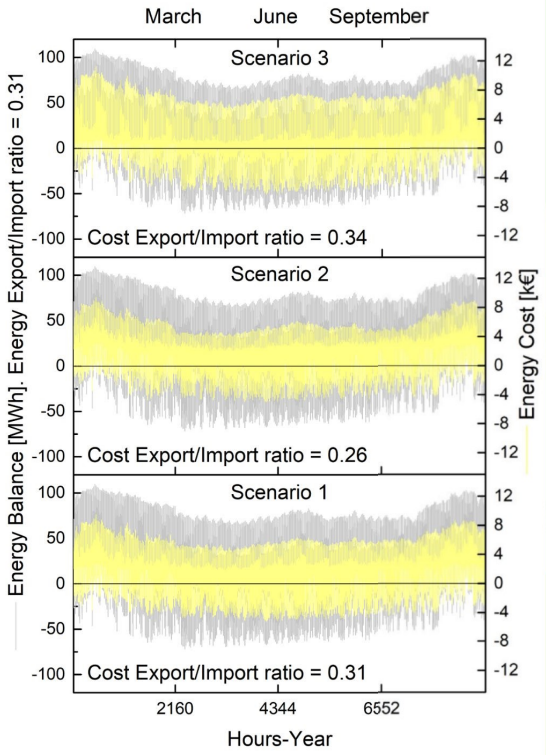
✓ Reduction of 3.41-9.68% of primary energy.

✓ Reduction of 4.16-12.25% in energy costs.

✓ Reduction of 5.16-11.43% of CO2 emissions.

✓ Better results with package of energy rehabilitation and the electricity tariff of three discrimination periods.

✓ The Prosumers community can reduce their primary energy consumption by up to 51%, up to 70% of CO2 emissions, and between 32-71.25% of their energy costs.



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5. CONCLUSIONS

- Any consumption of local renewable resources reduces the consumption of external energy (fossil) and the emission of GHG. But, at what cost?

- Evaluating these costs with the scalability of the "Nearly Zero Energy concept" we can also evaluate:

✓ Self-consumption “macro”.
✓ Energy flexibility of the distribution systems (Consumers, Prosumers and Producers).
✓ The tariff of three discrimination periods in Spain is favorable with the PV self-consumption.
✓ (Directive (UE) 2018/844 promotes the electromobility linked to the investment in systems of recharge in parkings).

Thank you

Manuel Villa-Arrieta

https://www.researchgate.net/profile/Manuel_Villa-Arrieta

mvilla@funseam.com