DE LA RECHERCHE À L'INDUSTRIE

A PROSPECTIVE ECONOMIC ASSESSMENT OF RESIDENTIAL PV SELF-CONSUMPTION WITH BATTERIES AND ITS SYSTEMIC EFFECTS: THE FRENCH CASE IN 2030

Hyun Jin Julie YU

Institute for Techno-Economics of Energy Systems **(I-tésé)**,
French Alternative Energies and Atomic Energy Commission
(CEA Saclay)
Paris-Saclay University

julie.yu@cea.fr

I-tésé

Institut de Technico-Economie des Systèmes Energétiques

www.cea.fr

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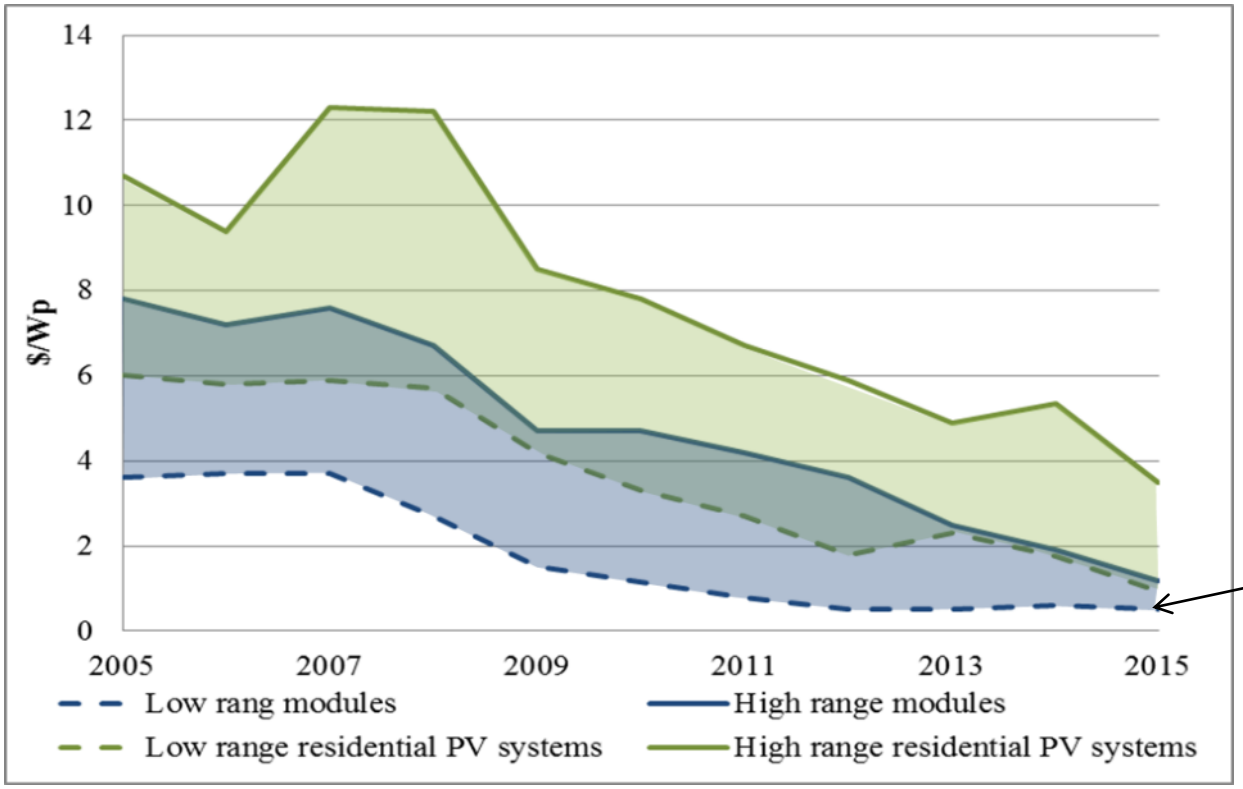
RAPID PV GROWTH & SHARP DECLINE IN PV PRICES

- Explosive growth of PV installations with political support (low-carbon energy transition): **> 305 GWp in 2016**

- PV prices are falling faster than expected (module price decline with global learning curve).



Germany
Residential PV System prices
1.5~1.9 $/Wp (2015)

PV Module ~0.5$/Wp

Very low contract prices : i.e. 24 $/MWh in Abu-Dhabi (UAE)

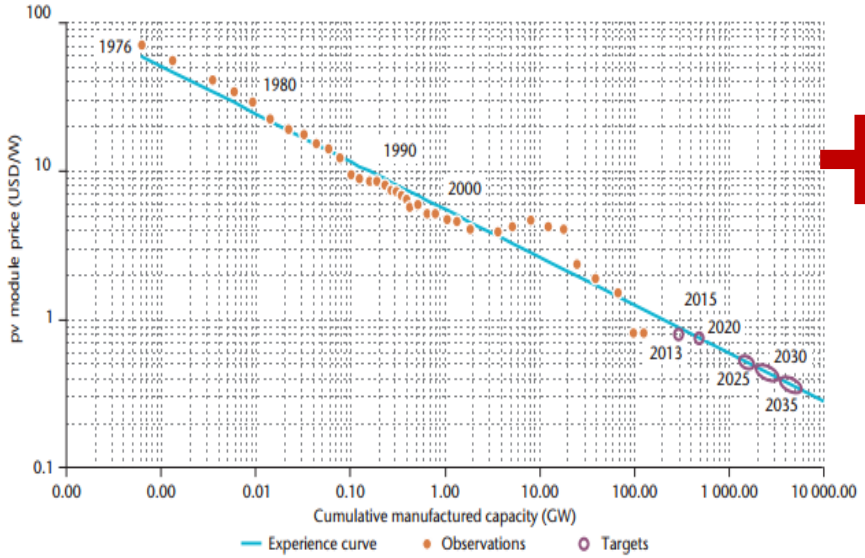
Source: Author's elaboration based on IEA PVPS Trends in photovoltaic applications [1]

RESIDENTIAL PV SELF-CONSUMPTION

PV self-consumption: PV electricity directly consumed at the same site where it is produced ➔ more suitable for the sectors with a good correlation between PV production & onsite consumption (e.g. ***Industrial / commercial)***

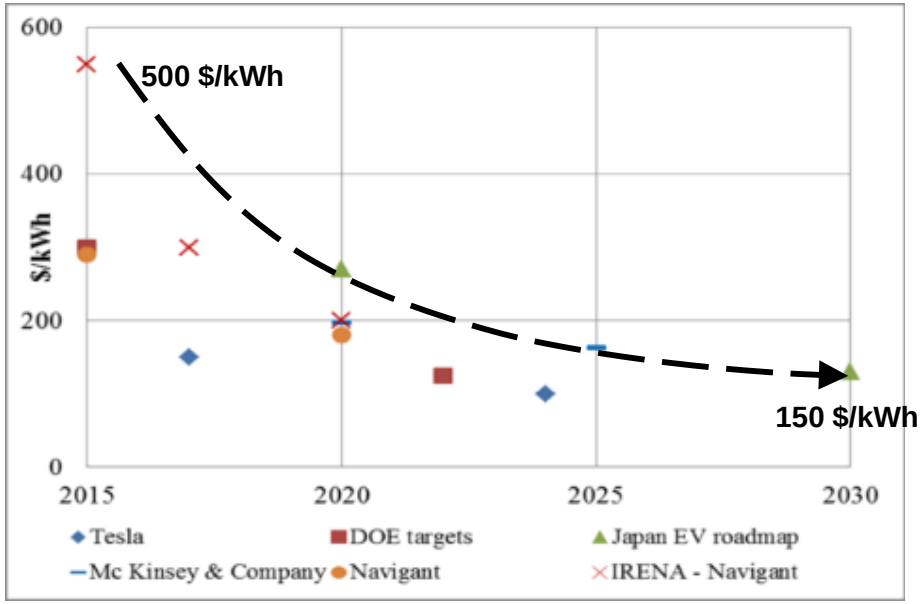
Residential sector **with a poor correlation**
➔improvement via demand response or storage solutions

Further reduction in PV system costs



Source: IEA's PV Technology roadmap 2014 [2]

Continuous decline in the battery costs (Li-ion)



Source: [3][4]

Natural PV demand in the residential sector ?

RESEARCH QUESTIONS

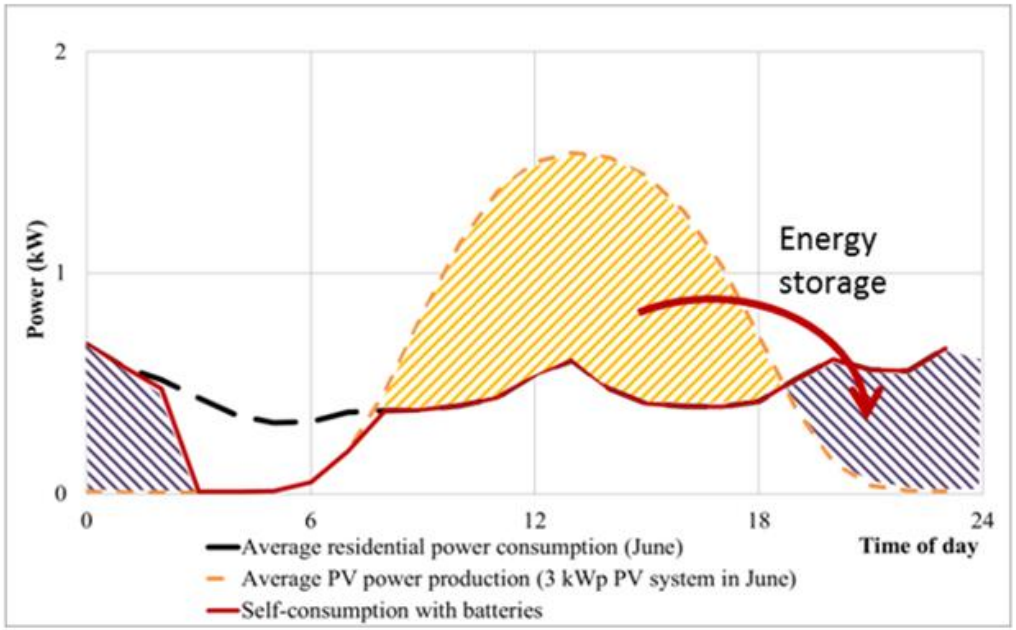


Figure 3: Principal of using the residential PV batteries

Advantages

- Limit grid injection at the high matching ratio
- Social demand for energy independency & green energies
- New biz opportunities (i.e. EVs, batteries, BIPV, grid services…)

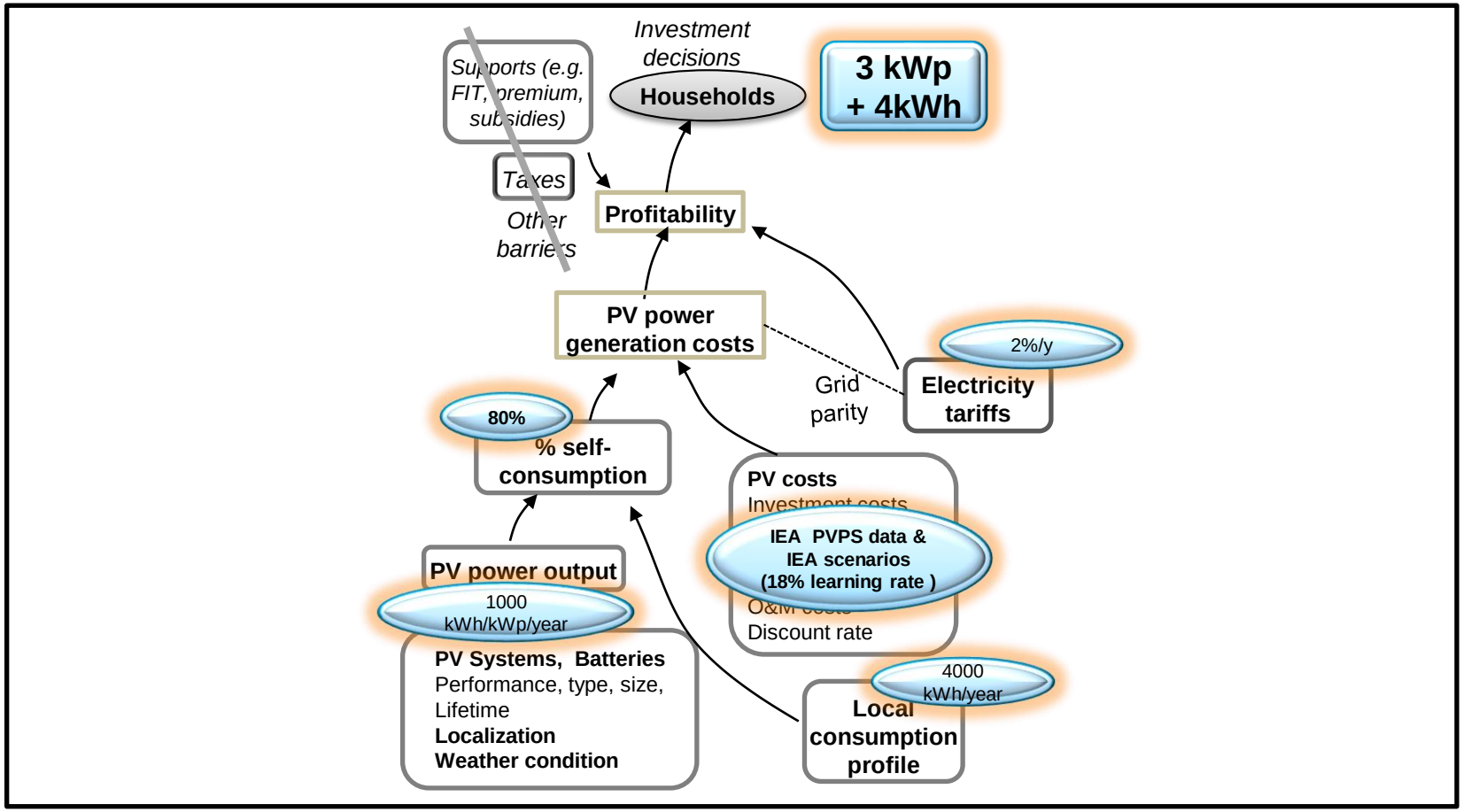
- **What costs** for French residential PV self-consumption systems coupled with lithium-ion batteries in 2030?
- **What systemic effects** under different scenarios?

ECONOMIC ANALYSIS OF RESIDENTIAL PV SYSTEMS WITH LI-ION BATTERIES IN FRANCE IN 2030

SCHEMATIC MODEL OF RESIDENTIAL PV SELF-CONSUMPTION WITH BATTERIES

- **Investment decision of household**

$$\Pi = \frac{\alpha \sum_{t=1}^{N} \frac{E_{PV}^{t}}{(1+r)^{t}} \times P_E}{\sum_{t=1}^{N} \frac{I_{PV}^{t} + O\&M^{t}}{(1+r)^{t}}} = \frac{P_E}{\frac{1}{\alpha} LCOE}$$

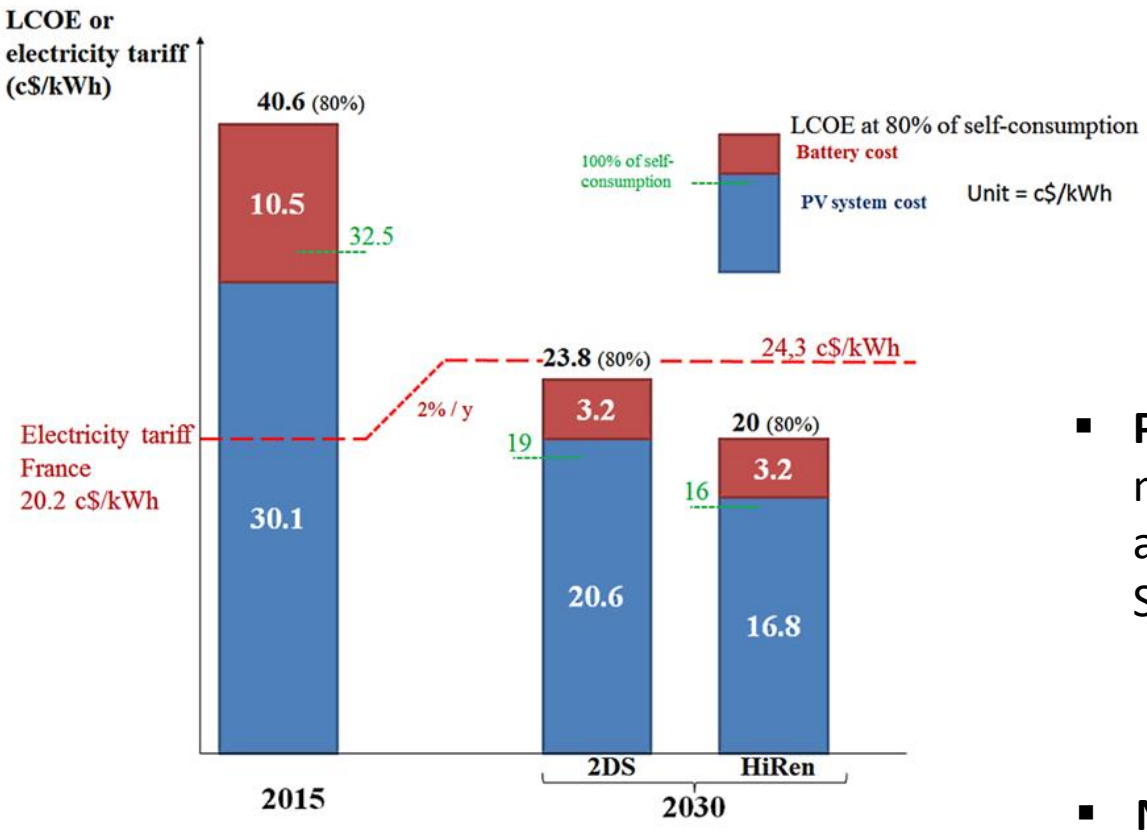


Legends: **Variables** **Stakeholders**

Source: [1][2][5][6]

PROFITABILITY OF INDIVIDUAL INVESTORS

- A self-consumption rate around 80% led by **the use of batteries**.



Source: Author's calculations, see [5][14]

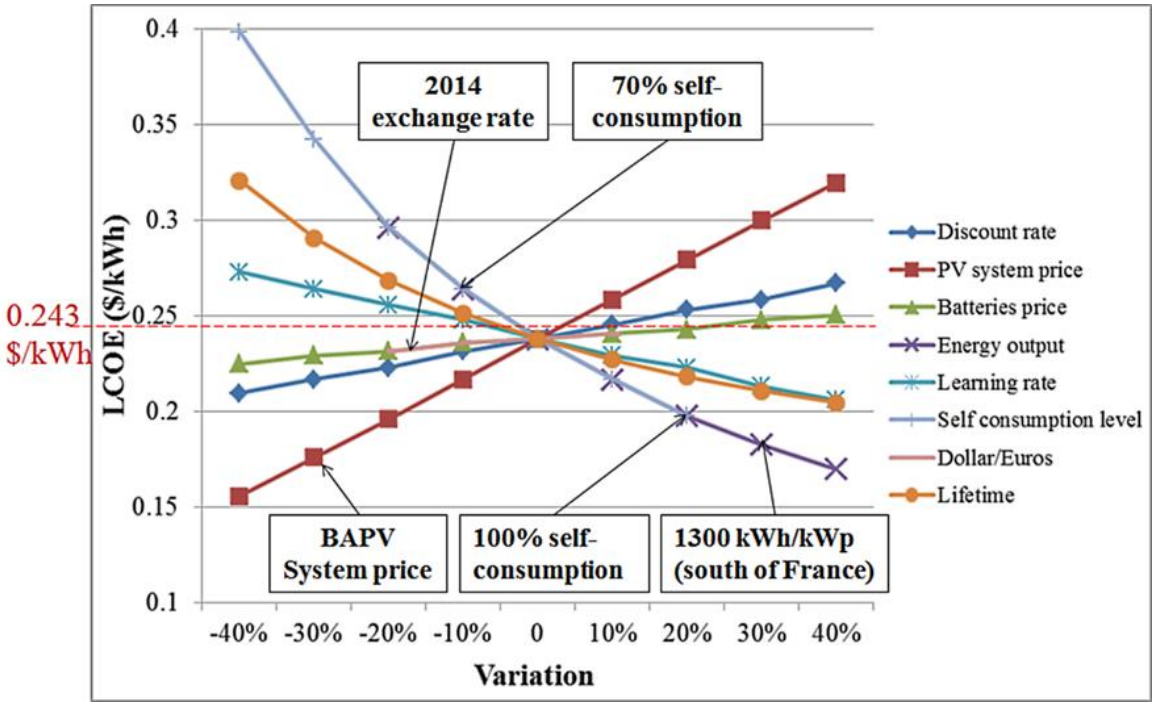
- Residential PV systems with batteries would become **profitable without political financial support** for individual investors in France by 2030 under the IEA scenarios in question

- **Possible to advance the time** if the model considers favourable assumptions (e.g. insolation in Southern regions, BAPV systems)

- **Natural demand** in the residential sector is expected.

SENSITIVITY ANALYSIS OF PV LCOE ESTIMATES

Criteria	Nominal values	Ranges	
		Minimal values (-40% by default)	Maximal values (+40% by default)
PV system price	$1.83/Wp	$1.1/Wp	$2.56/Wp
Batteries price	$150/kWh	$90/kWh	$210/kWh
Energy output	1000 kWh/kWp	800 kWh/kWp	1400 kWh/kWp
Lifetime	20 years	12 years	28 years
Discount rate	5%	3%	7%
Learning rate	18%	11%	25%
Self-consumption level	80%	48%	100% (+20%)
Dollar/Euro exchange rate	0.9	0.72 (-20%)	0.99 (+10%)



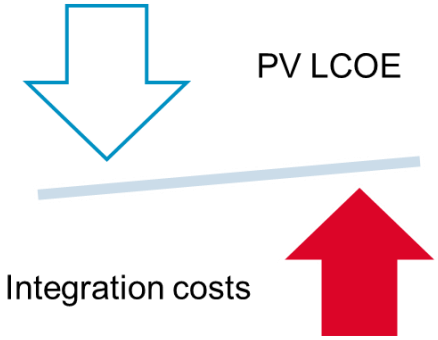
The PV system price, the energy output (insolation) and the self-consumption ratio have the greatest influence on the PV LCOE estimates

RISKS OF TRANSITIONING TO PV SELF-CONSUMPTION AND SYSTEMIC EFFECTS

- What if 18.8 million of individual houses in France swift to PV self-consumption? *[7]*

- Potential aggregate demand of 56 GWp, 10% of French demand

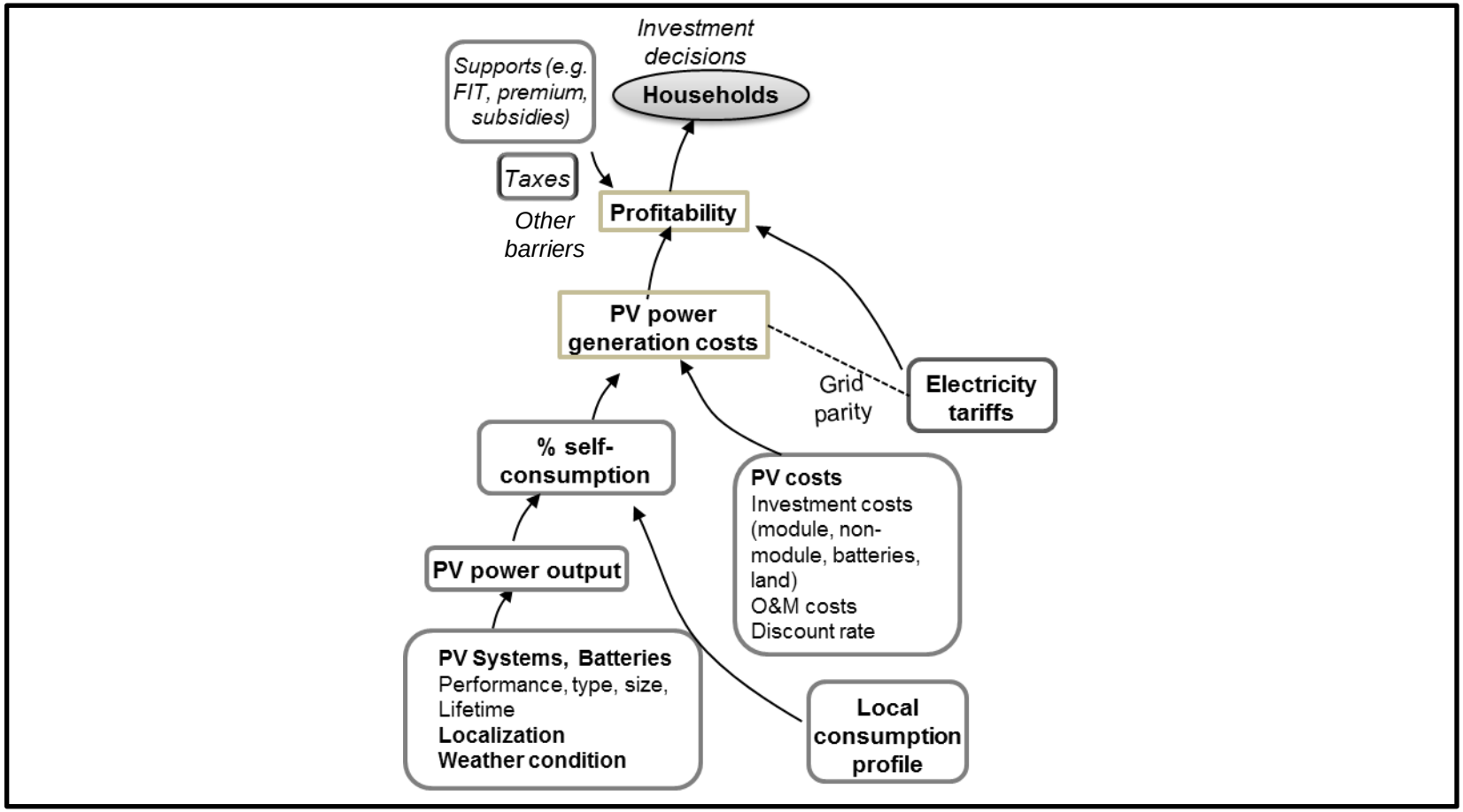
- Massive & rapid deployments : impacts on electricity systems & stakeholders



- What **systemic effects**?

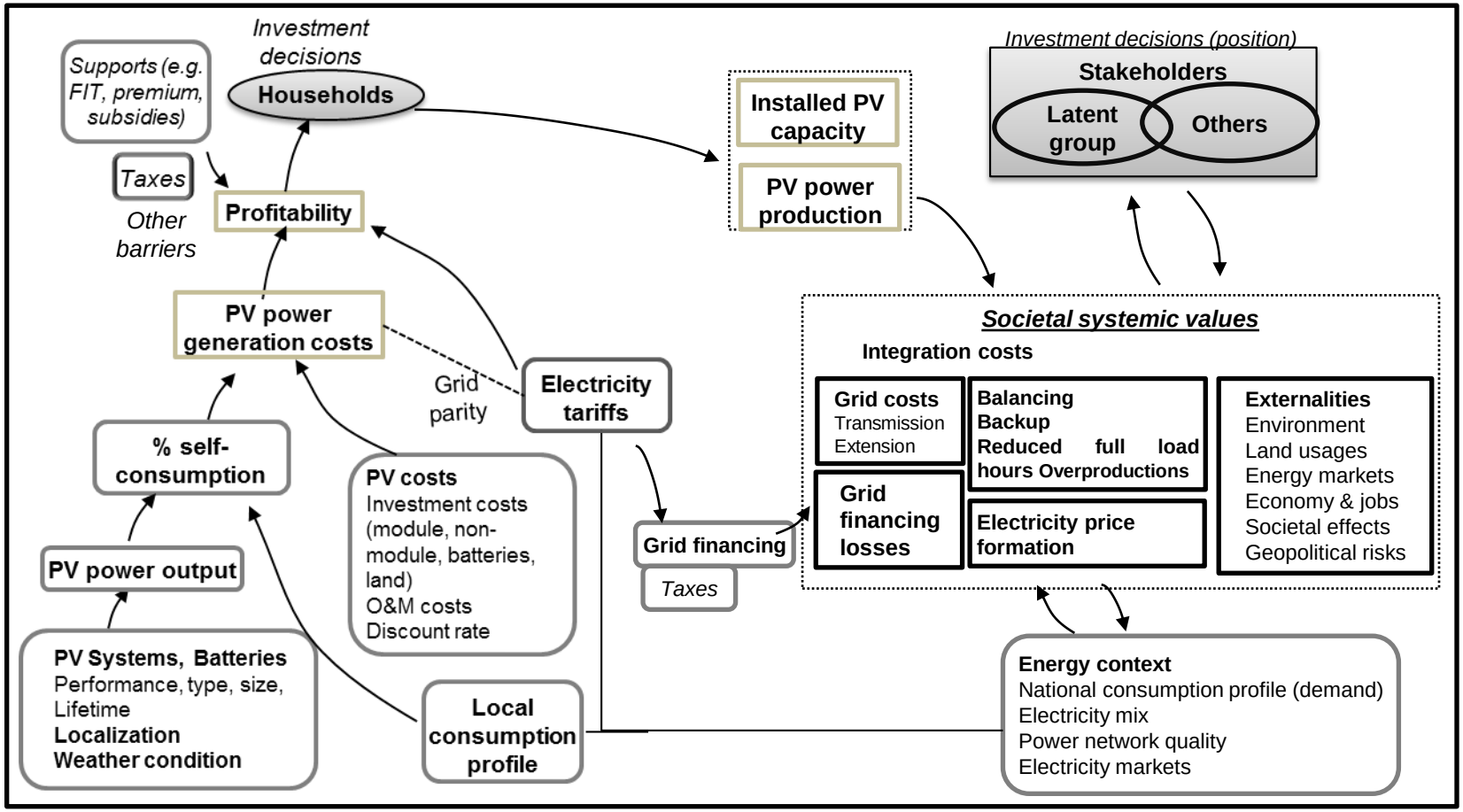
SCHEMATIC MODEL OF RESIDENTIAL PV CONSUMPTION WITH BATTERIES

- **Impacts on stakeholders (systemic effects)**



SCHEMATIC MODEL OF RESIDENTIAL PV CONSUMPTION WITH BATTERIES

- **Impacts on stakeholders (systemic effects)**

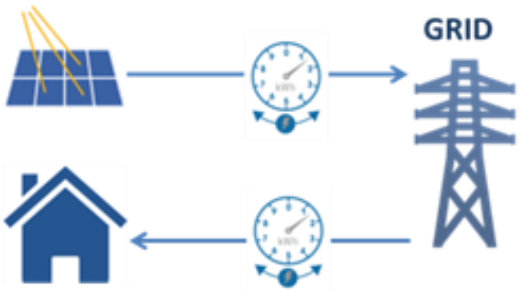


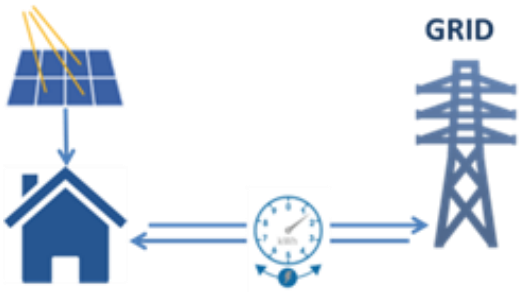
SYSTEMIC ANALYSIS OF PV INTEGRATION INTO THE NATIONAL ELECTRICITY SYSTEM

FOUR TYPES OF PV INTEGRATION SCENARIOS

- **Difference options** in regard with PV deployment in French electricity system

In front of the meter grid connection (FIT) *or* **Behind the meter grid connection (Self-consumption)**





Rapid integration (e.g. identical mix)

Grid injection (full)

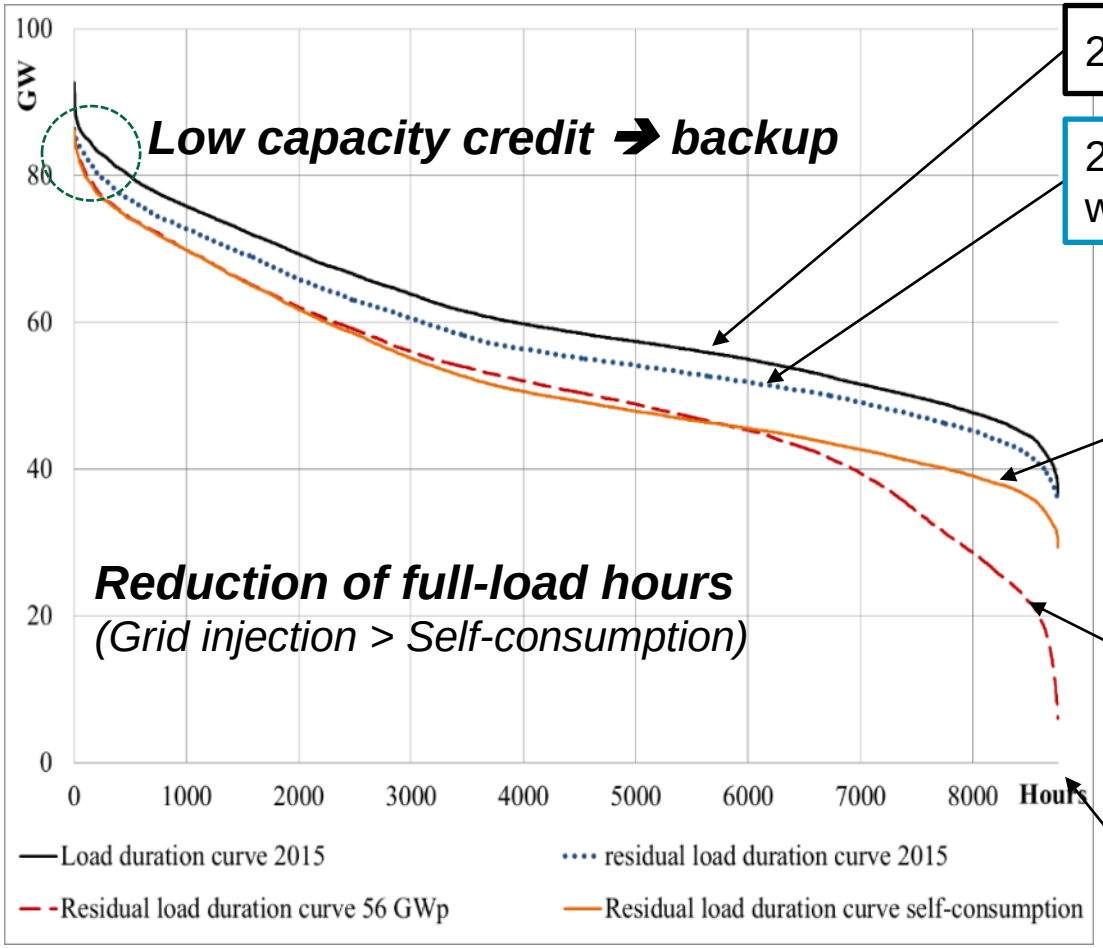
Saved grid injection (e.g. PV self-consumption with batteries)

Scenario G with Rapid integration	Scenario S with Rapid integration
Scenario G with Progressive integration	Scenarios S with Progressive integration

Progressive integration (adjusted optimal mix)

RESIDUAL LOAD DURATION CURVE REDUCTION

Current French power mix: PV of 56 GWp (1.6%) and wind power of 9 GWp (3.8%)



2015 load duration curve

2015 Residual load curve without PV +Wind (**baseline**)

56 GWp of new PV capa. added

Residual load curve (**PV self-consumption 80%**)

Residual load curve **(Full grid injection)**

Overproduction
(Grid injection > Self-consumption)

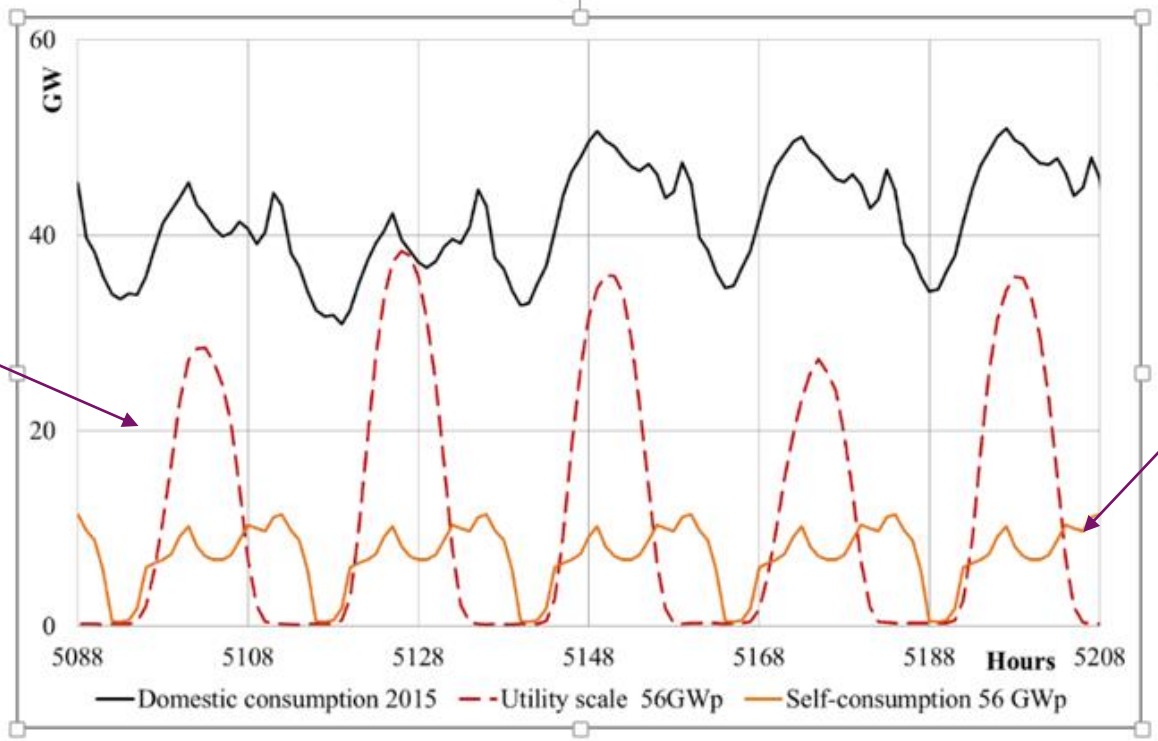
Source:[8][9]

Assumptions: wind power remains constant.

Author's calculation, see [8] for methodology

IMPACTS ON NEGATIVE PRICES

PV production without storage (full grid injection)



PV self-consumption 80%

Figure 11: PV production without batteries, PV production with batteries and demand for the week of 1 August (Author's elaboration based on data of RTE) *[9]*

- With a high penetration of variable PV power, negative prices can be observed because of **the excess power production**.
- The residential PV self-consumption model with batteries **significantly reduces the risks related to negative prices**.

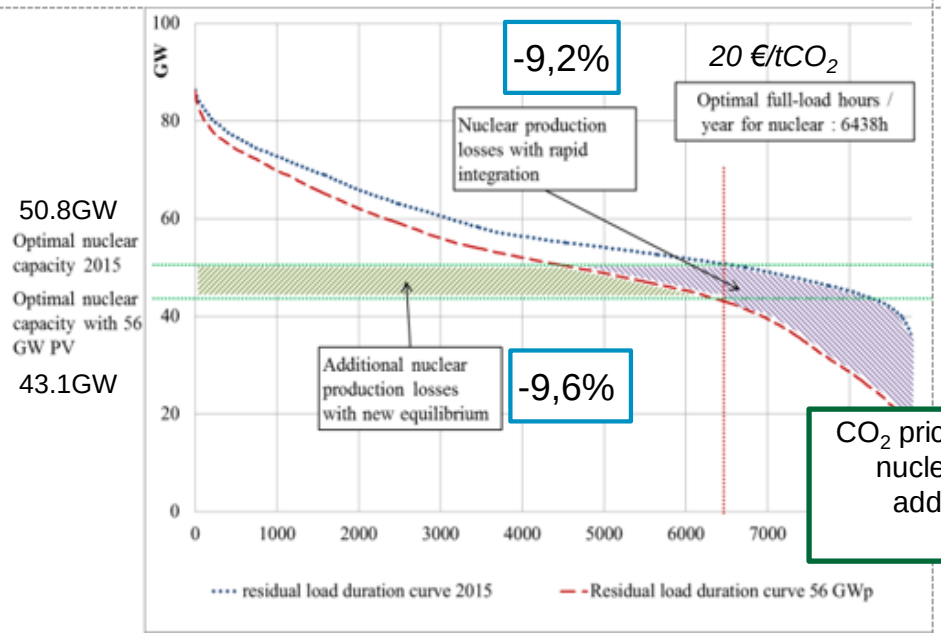
NUCLEAR POWER PRODUCTION LOSSES

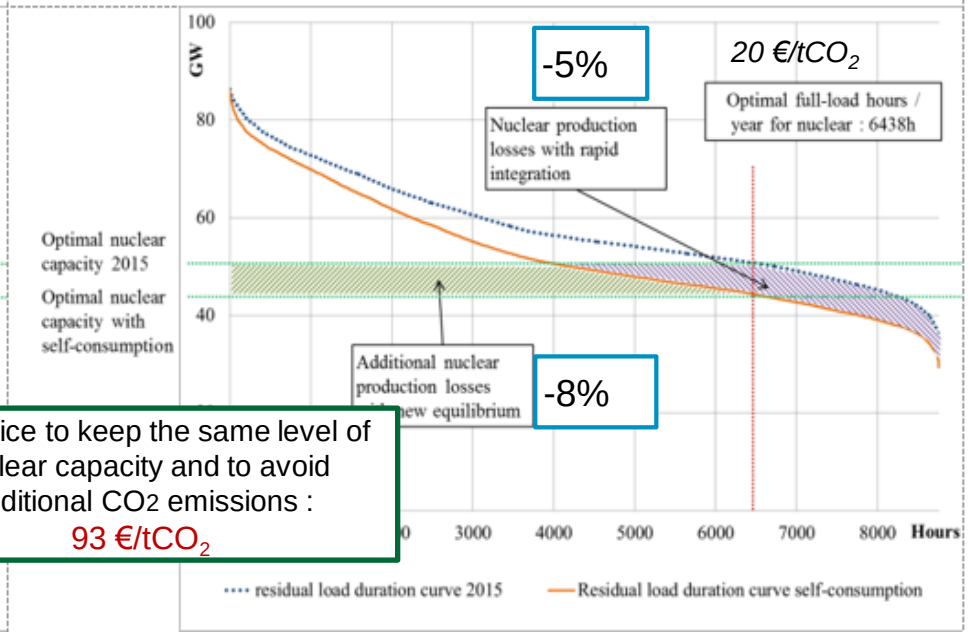
French nuclear power production in 2015 (434 TWh) as a baseline of comparison

Grid injection (full)

Bigger impacts on nuclear

Saved grid injection (e.g. PV self-consumption with batteries)





CO_2 price to keep the same level of nuclear capacity and to avoid additional CO2 emissions : 93 €/tCO_2

Nuclear power production (TWh/year)	Grid injection (Scenario G)	No Grid injection (Scenario S)
Speed Rapid (R)	394 (loss: -9.2%)	412 (loss: -5%)
Speed Progressive (P)	352 (loss: -18.8%)	379 (loss: -13%)

PV INTEGRATION COSTS

PV integration into the mix: additional efforts to address intermittency of variable PV power

Grid-level costs *Literature data [10][11]*

10% (France)	Grid injection (Scenario G)	No Grid injection (Scenario S)
Grid-related	~6 $/MWh	~0 $/MWh
Balancing costs	~2 $/MWh	~0 $/MWh
Back up	16-~ 19 $/MWh	16 ~ 19 $/MWh

Profile costs *Author's calculation based on [8]*

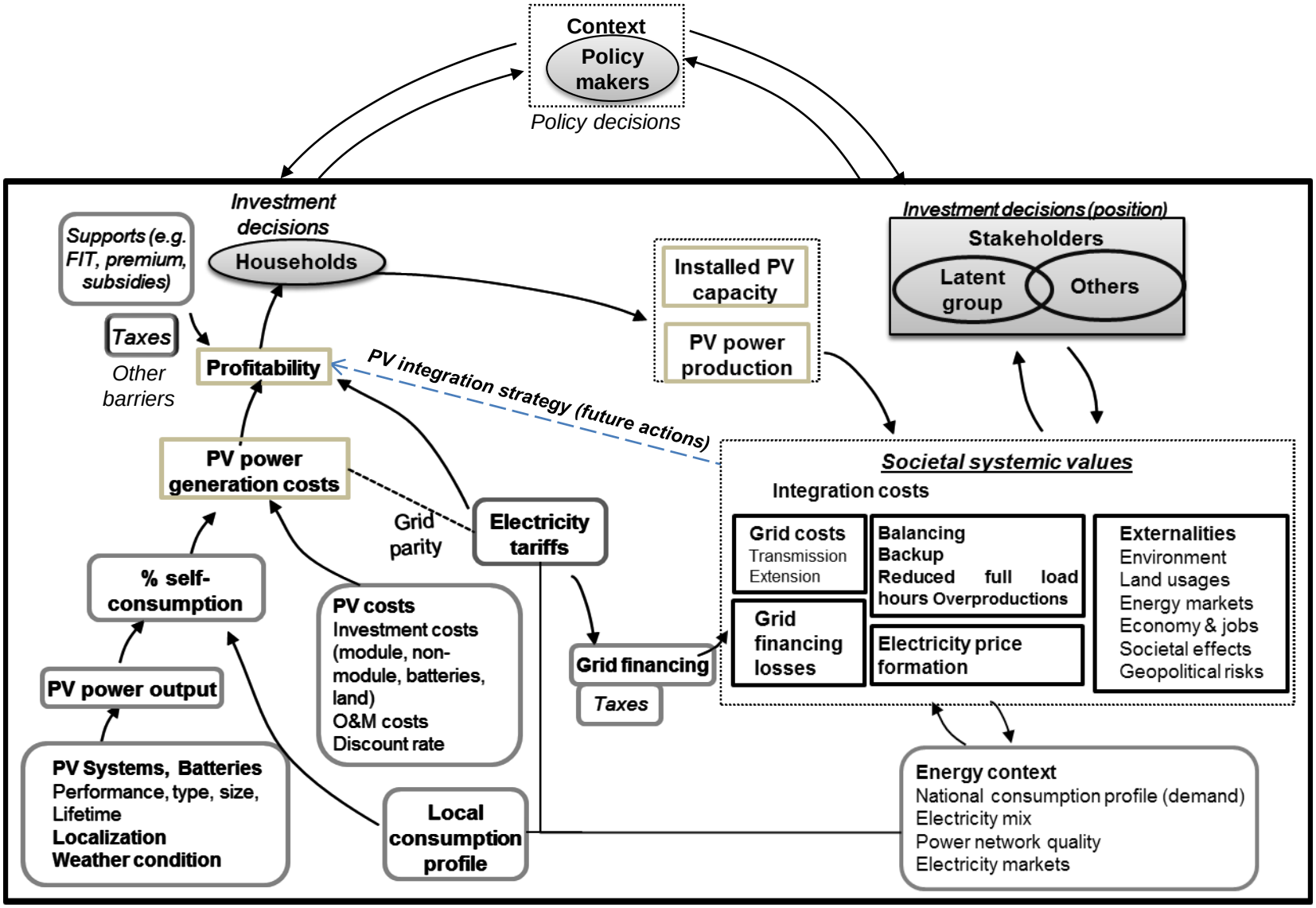
Profile costs (56 GWp added, 10%)	Grid injection (Scenario G)	No Grid injection (Scenario S)
Unit	**€/MWh PV**	**€/MWh PV**
Speed Rapid (R)	33	26
Speed Progressive (P)	29.3	19.3

PV integration costs need to be taken into account for PV policy decisions!

i.e. Long-term investment decision, system security.

Other source:[12][13]

FUTURE PV POLICIES



Legends: Variables | Stakeholders

CONCLUSIONS

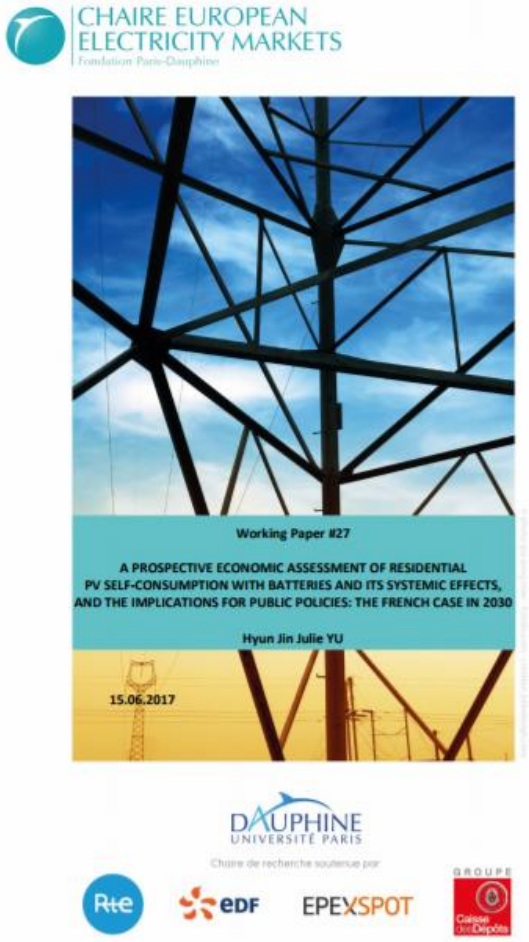
- PV self-consumption with batteries could **become profitable without political support for individual investors** in France before 2030.
- New issues related to **changes in interests of stakeholders** in the electricity systems:
  - negative impacts on long-term investment choices in the electricity sector
  - impacts on the power system and network management (to associate with grid financing reform).
- **A regular and progressive policy** when transitioning to PV self-consumption : allow enough time for concerned stakeholders to adapt to the change (**gradual changes in the mix led by the national plan**)
- **The early encouragement of PV self-consumption** can be intentionally planned **to secure the constant growth model of PV installations.**
- Policy needs to present **a clear and long-term vision of PV integration,** connected to the national plan (e.g. industry policy).

FOR MORE INFORMATION

Author's article is available:

H.J.J. Yu, A prospective economic assessment of residential PV self-consumption with batteries and its systemic effects, Chaire European Electricity Market, Working paper 27 (2017), University Paris-Dauphine

http://www.ceem-dauphine.org/working/fr/A-PROSPECTIVE-ECONOMIC-ASSESSMENT-OF-RESIDENTIAL-PV-SELF-CONSUMPTION-WITH-BATTERIES-AND-ITS-SYSTEMIC-EFFECTS



Thank you for your attention

Contact: julie.yu@cea.fr
Institut de technico-économie des systèmes énergétiques
Commissariat à l'énergie atomique et aux énergies alternatives
Centre de Saclay | 91191 Gif-sur-Yvette Cedex

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FRENCH ENERGY SUPPLY & PV TARGET

France energy policy targets

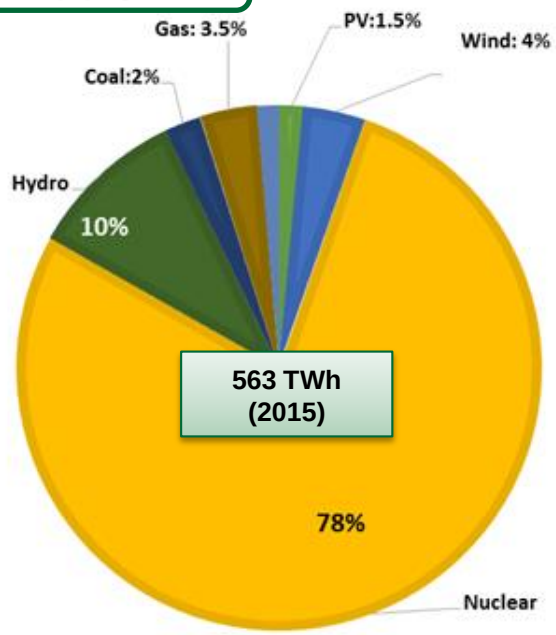
Renewables energies : 40% of power mix (2030)

PV target: > 20 GWp in 2023

Fossil fuels

Nuclear : 50% of power mix (2025)

Supply



Demand