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SYSTEM CONTRIBUTIONS OF RESIDENTIAL BATTERY SYSTEMS: NEW PERSPECTIVES ON PV SELF-CONSUMPTION

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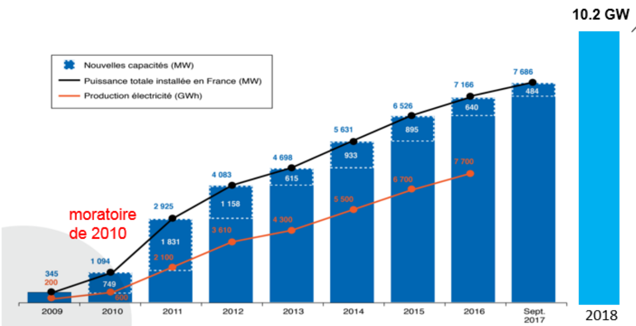
SOLAR TRAJECTORY IN FRANCE

Solar PV development in France



Parc total photovoltaïque et production d'électricité annuelle en France
Source : Observ'ER d'après les chiffres du SDES

20.6 GW

2023
targets

Multiannual Energy Programme (PPE)

35.6 - 44.5 GW

2028	2030	2035	2050
~8 billion €/ year to NRE	*Solar: x5*	*Reduction of nuclear to 50%*	

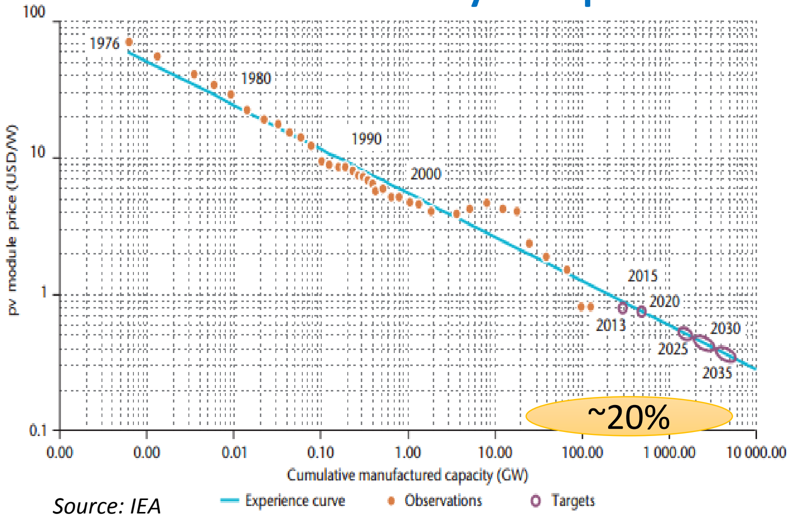
40% reduction of fossil fuel use → **Carbon neutrality**

https://www.gouvernement.fr/en/multiannual-energy-programme-what-are-its-aims

- What **systemic impact would be** led by a large-scale penetration of solar energy?
- What **integration strategies (or political decision)** can be considered to mitigate risks and to gain opportunities (**sector coupling, new business models**)?

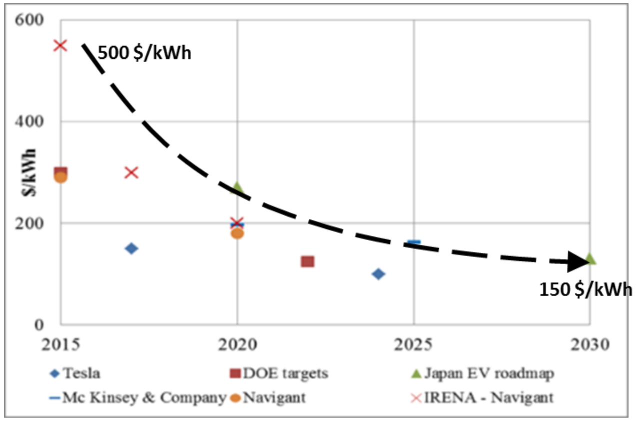
SUBSIDY-FREE PV DEMAND IN THE RESIDENTIAL SECTOR IN FRANCE

Further reduction in PV system prices



Source: IEA

Continuous decline in the battery prices (Li-ion)



Author's elaboration based on literature review

- Solar with storage is becoming competitive in power sector ➔ opportunities and risks of PV self-consumption (residential)

Prospective economic studies (Yu, energy policy, 2018)

Projected residential costs: French case in 2030?

PV self-consumption in 2035 (million houses)

Enedis (upper)	**11.6**
Enedis (lower)	5.8
RTE	3.8

	2017	CPS	NPS	SDS
System cost ($/Wp)	2.06	1.48	1.39	1.24
LCOE (c$/kWh)(1)	18	13	12	11
LCOE self-cons. (c$/kWh)(2)	32	19	18	17

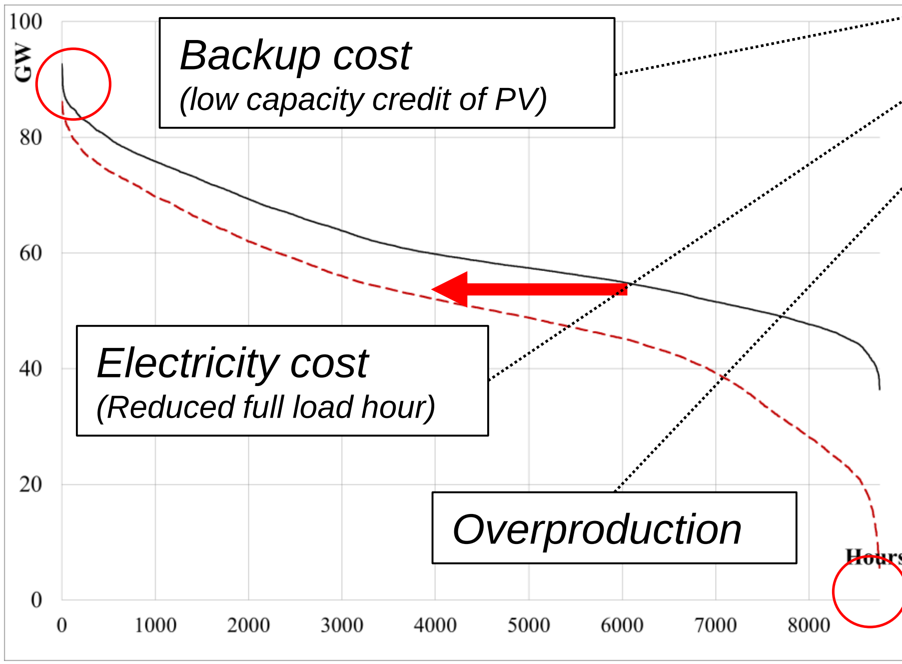
(1) LCOE in Paris, 1030 kWh/kWp on 20 years
(2) 3kWp PV with 4kWh battery inducing 80% of self-consumption and 20% losses

PV INTEGRATION COSTS

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

Grid related costs **+** ***Balancing costs*** **+** ***Profile cost***

(Ueckerdt et al. [12])



2015 load duration curve

Residual load curve with 10% penetration of PV and full grid injection

~ 28 - 40 €/MWh

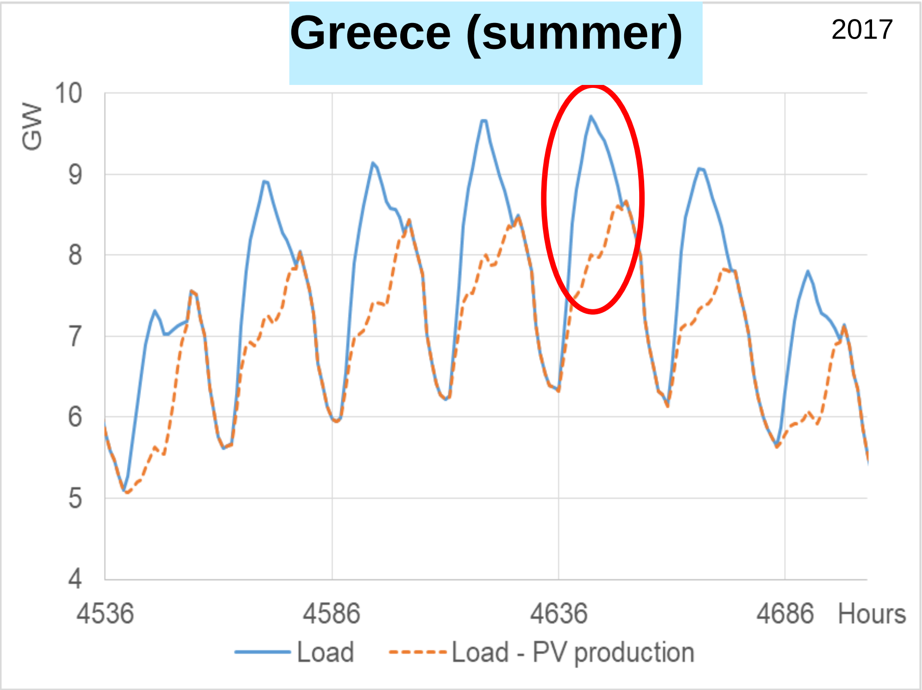
Yu 2018

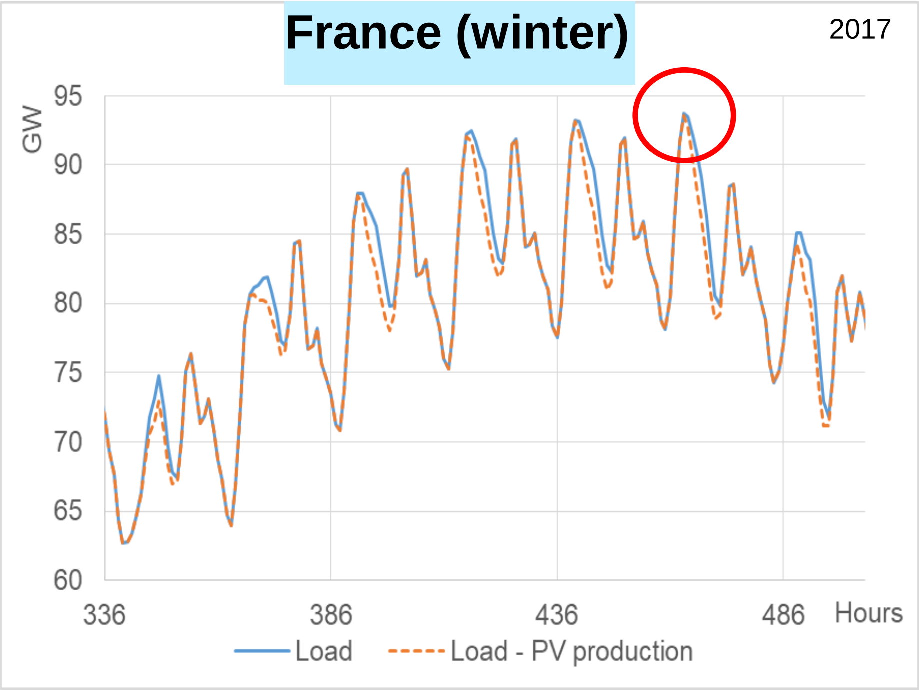
PV integration costs need to be taken into account for PV policy decisions !

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

What are **potential systemic contributions** from the secondary-use application of residential batteries of PV self-consumption in France (flexible load management) ?

PV output and annual demand peaks





Annual demand peaks in Greece occurred (midday in summer) when PV was producing.

Annual demand peaks in France occurred (morning or evening during winter) when PV was not producing.

PV capacities installed in France : almost no contribution to providing electricity during annual demand peaks (low capacity credit) ➔ We need backup solutions in France

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USE OF BATTERIES COUPLED WITH A PV SYSTEM IN THE RESIDENTIAL SECTOR

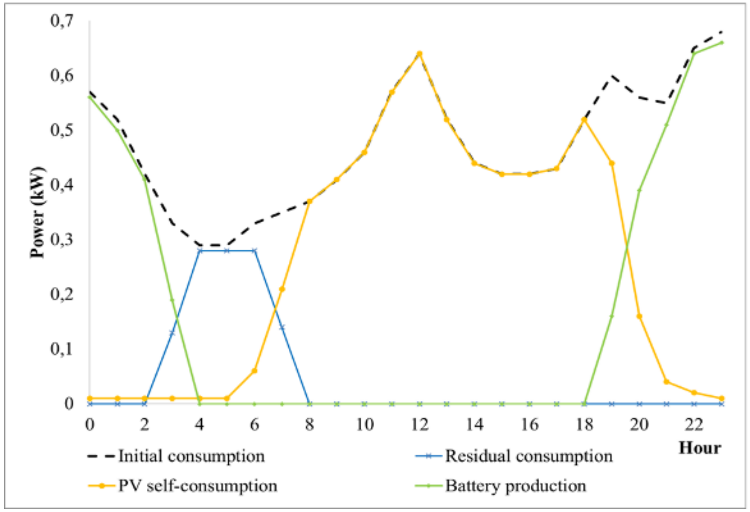
The use of batteries becomes almost null during the winter months.

3kWp PV + 4kWh batteries

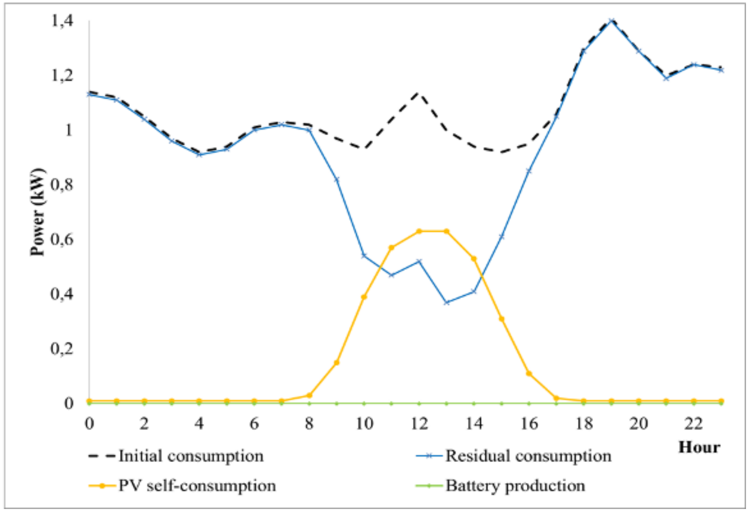
18.8 million houses

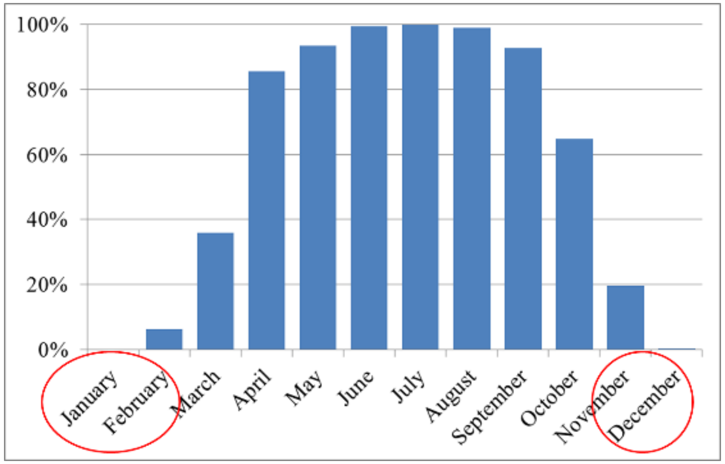
75 GWh (aggregate capacities of batteries)

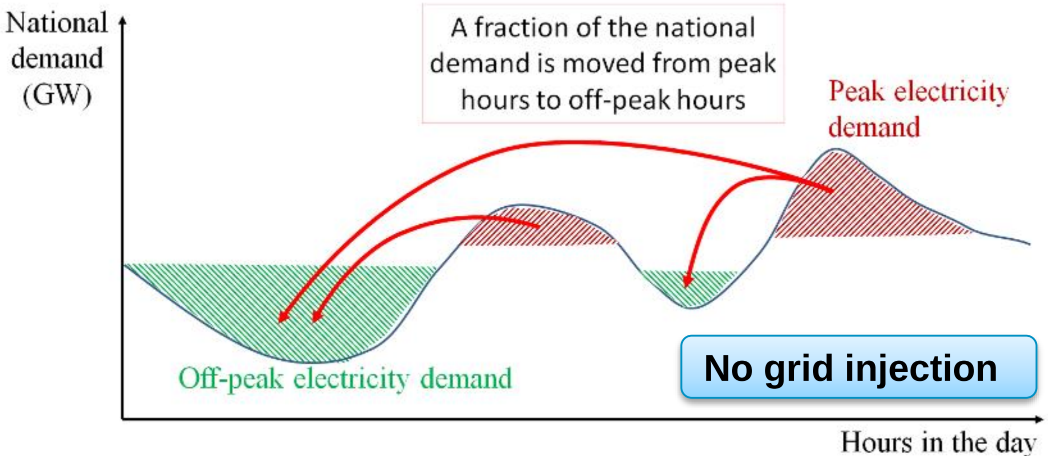
July



January





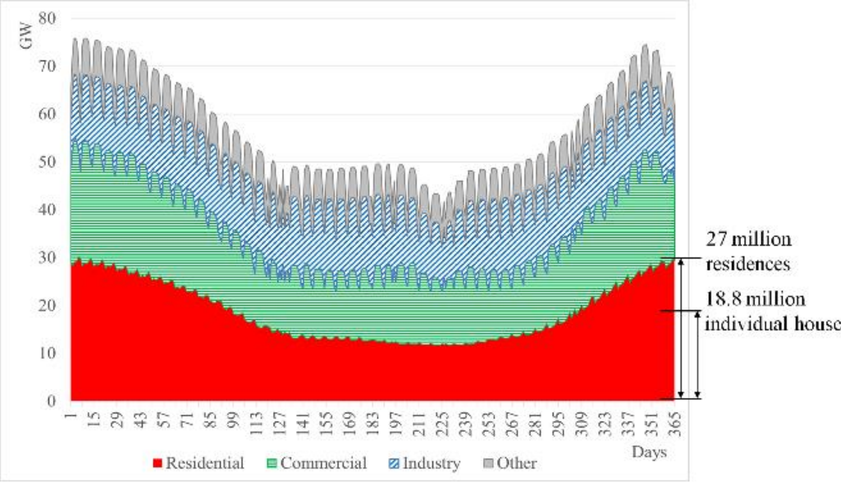


No grid injection

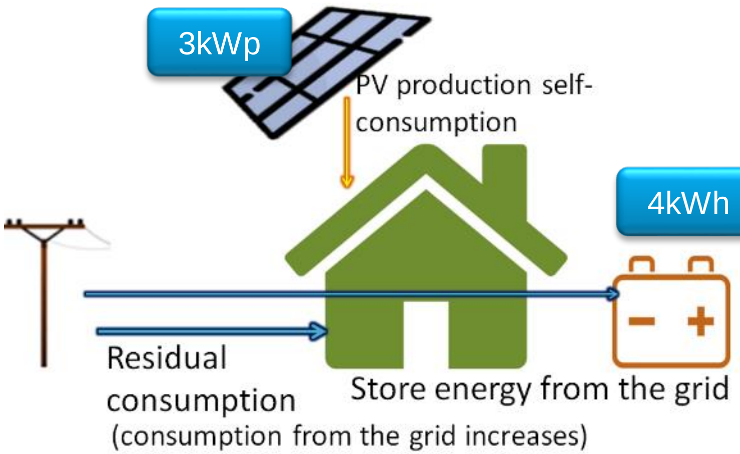
DATA AND ASSUMPTIONS

The total consumption in 2015 was used as the baseline for our simulation (456 TWh excl. PV+wind) (data: RTE)

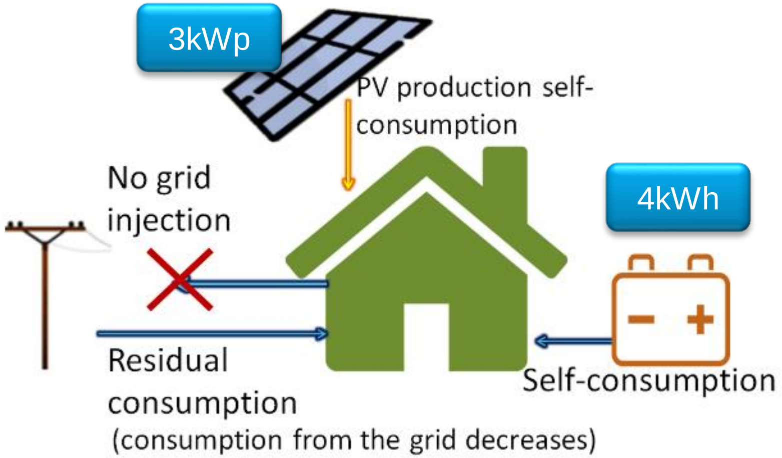
	Residential	Industrial	commercial	others	Total
TWh	164	115	148	56	483
%	34%	24%	31%	11%	100%



Winter battery service (no PV surplus) **:**
low demand period



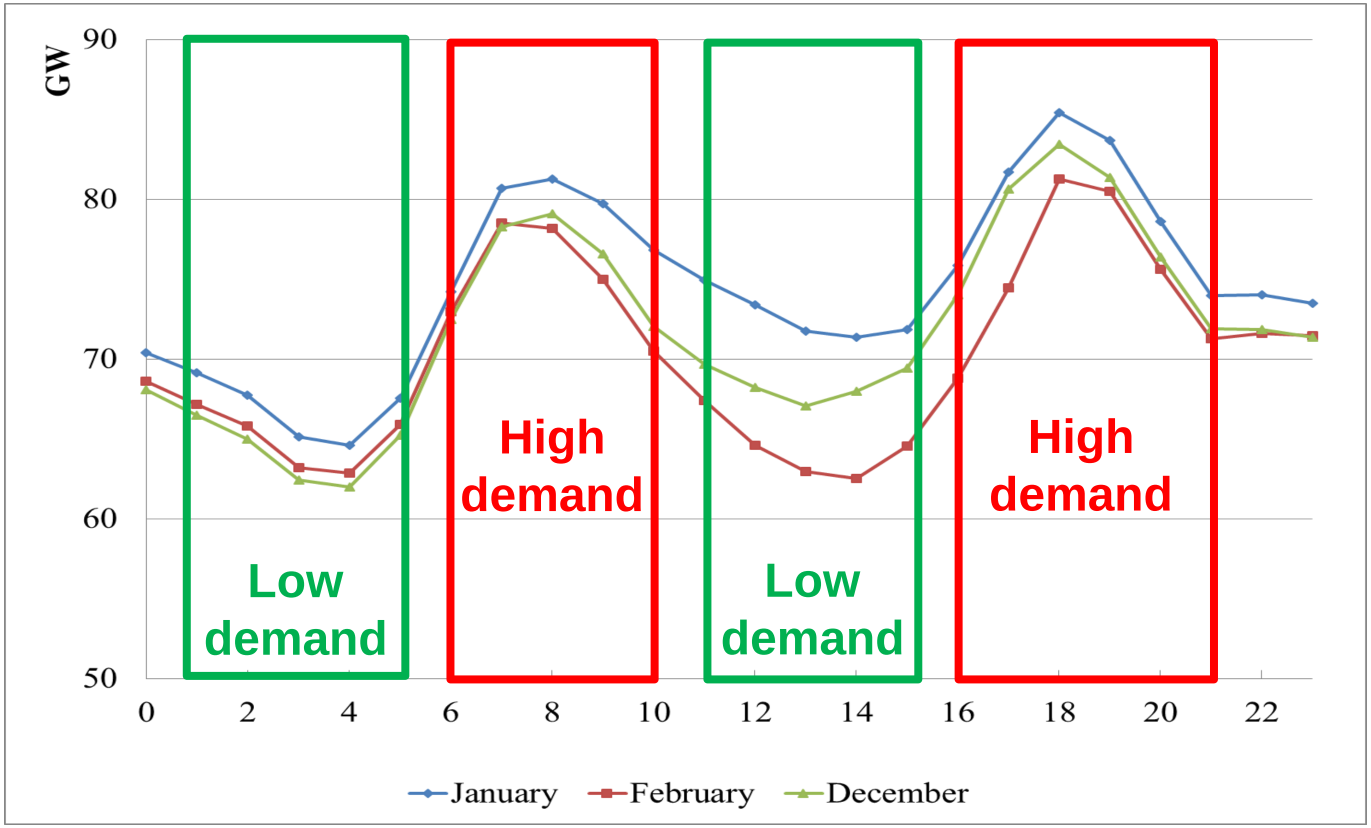
Winter battery service (no PV surplus) **:**
Stress demand period



- A total cumulated residential storage capacity of 75.2 GWh in the French power mix.

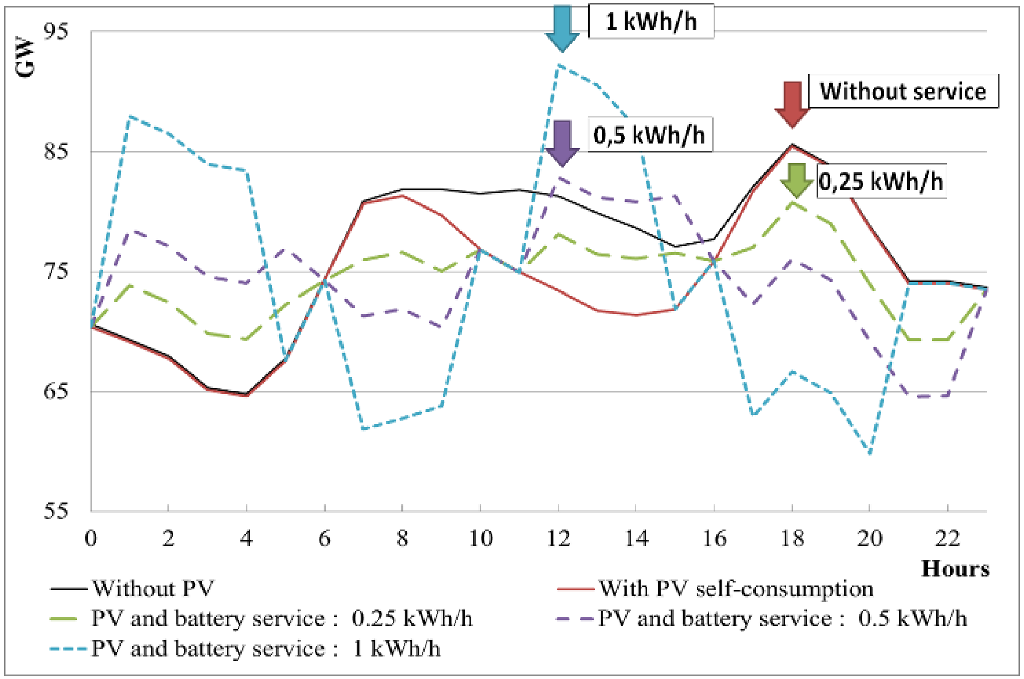
TIME-BASED CHARGING AND DISCHARGING

Maximum residual consumption from the grid for each hour of the day with PV self-consumption for December, January and February



RATES OF CHARGING AND DISCHARGING

Impact on the national demand profile in January



(variation from 0.25 KWh/h to 1/kWh/h)

- a shift in the peaks in demand to different timeslots
- a rapid change in the demand profile directly related to the battery charging and discharging decision (e.g. concurrent automatic charging)

Based on the results from an optimization loop of our numeric simulation, we decided to fix :

- A rate of **0.3 kWh/h for charging**
- A rate of **0.4 kWh/h for discharging**

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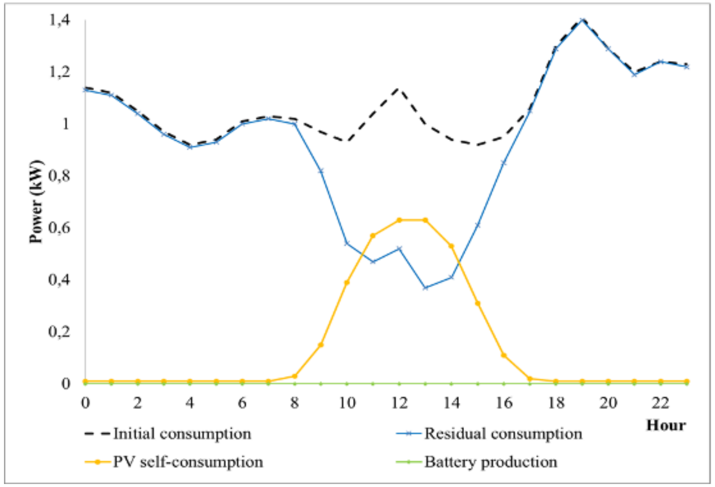
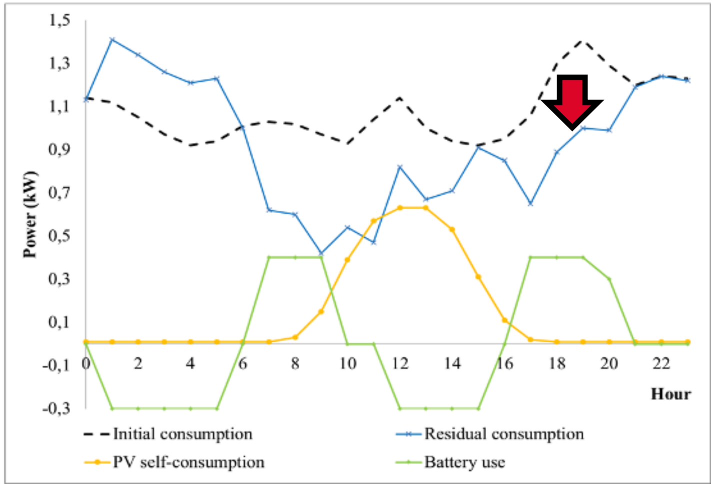
SYSTEMIC CONTRIBUTION: DAILY PEAK SHAVING

Residential profiles without (left) and with grid services (right): 4 January 2015 (annual peak)

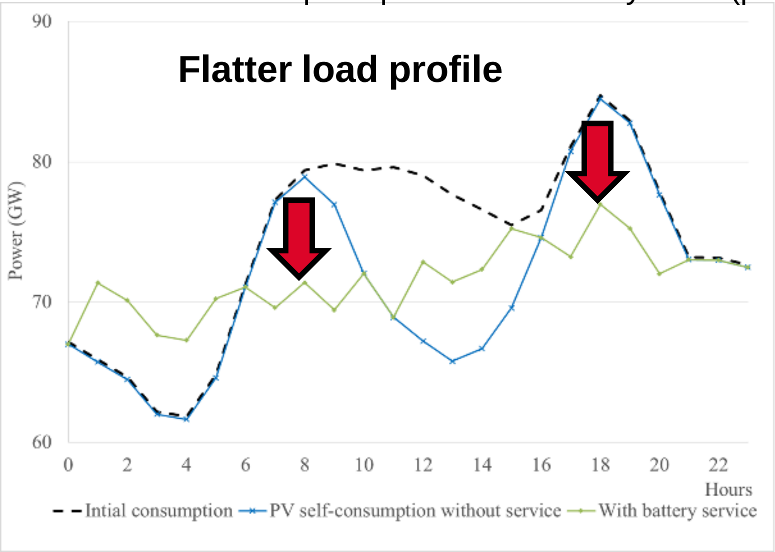
PV self-consumption without battery grid services



PV self-consumption with battery grid services



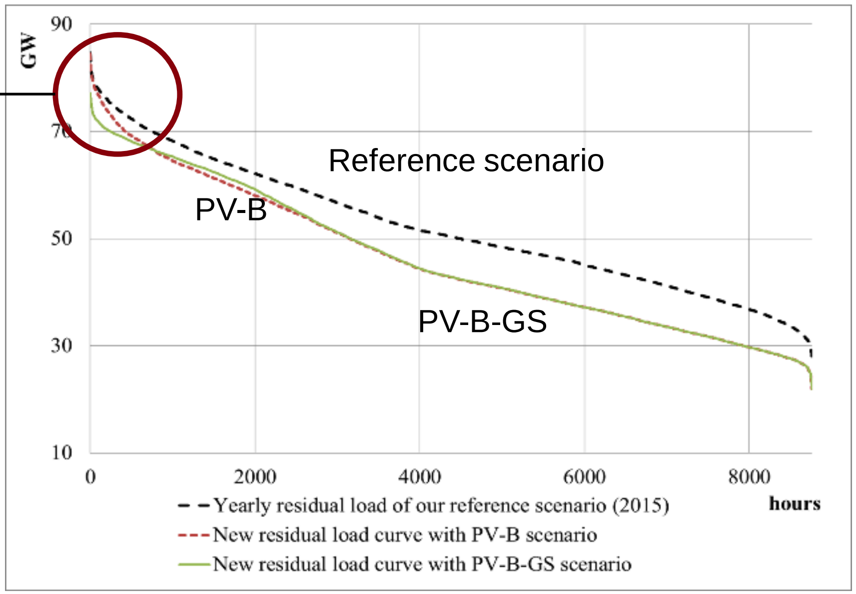
National consumption profiles: 4 January 2015 (peak day)



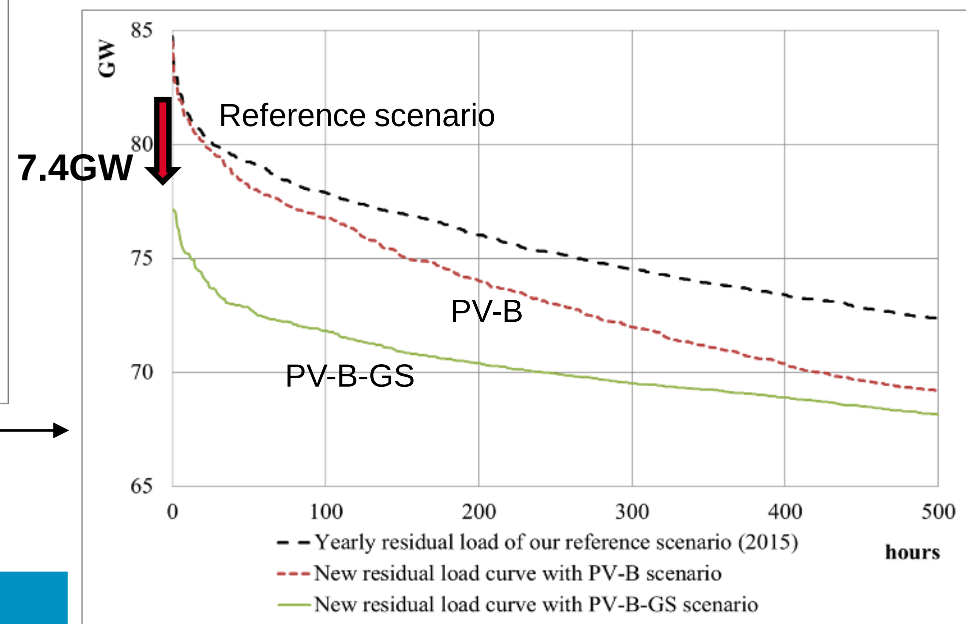
Average gains in daily balancing (Max.-Min.)

Average consumption variation	PV-B scenario	PV-B-GS scenario	Delta
December	20.3 GW	10.2 GW	-10.1 GW
January	18.5 GW	7.8 GW	-10.7 GW
February	21.7 GW	13.4 GW	-8.3 GW

Changes in the load duration curve (PV-B vs. PV-B-GS)



Focus on the annual peak period of the load duration curves



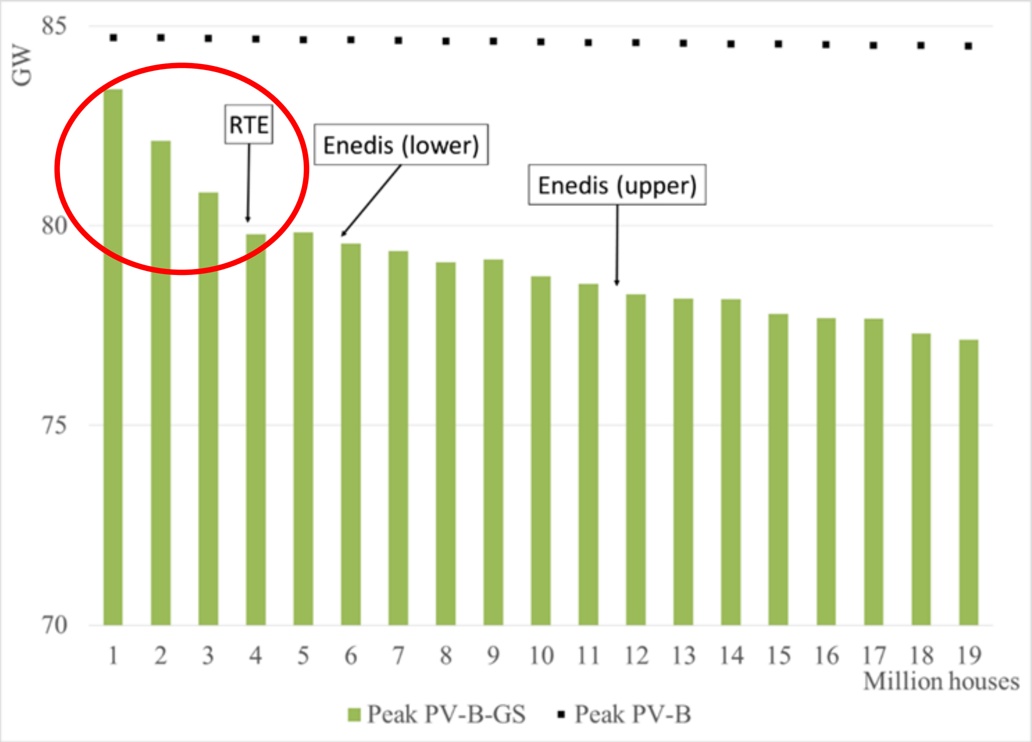
Profile costs	€/MWh PV (Unit costs per megawatt-hours)
PV-B (no grid service)	27.7
PV-B-GS (grid service)	17

System contribution : reduction of PV integration costs

SENSITIVITY ANALYSIS: ANNUAL PEAK SAVING

	PV self-consumption in 2035 (million houses)	Aggregate capacities of batteries (GWh)	Optimal rates of charging / discharging (kWh/h)
Base case (maximum uptake)	18.8	**75.2** 7.4 GW	0.3 / 0.4
Enedis (upper)	11.6	46.4	0.35 / 0.55
Enedis (lower)	5.8	23.2	0.55 / 0.85
RTE	3.8	**15.3** 4.7 GW	0.7 / 1.3

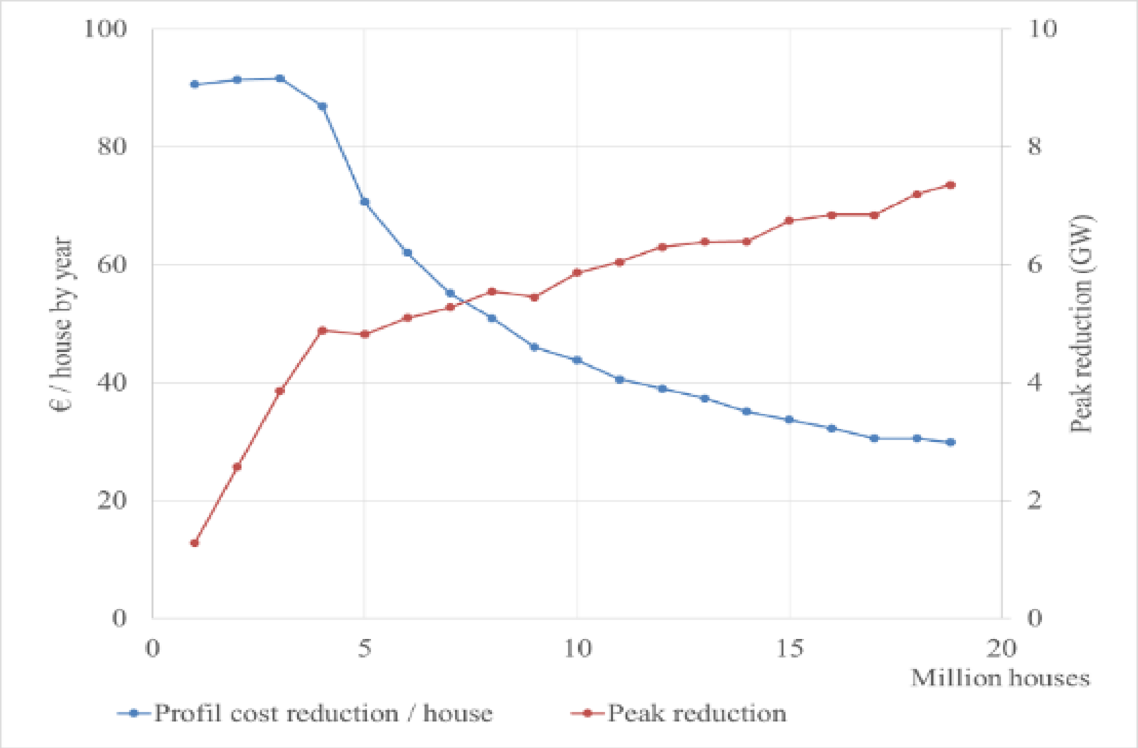
Parameters of sensitivity analysis



The annual peak shaving impact is significantly **greater in the beginning of the PV diffusion with fewer batteries**.

SENSITIVITY ANALYSIS: COUPLED IMPACT

Sensitivity of the peak shaving impact and annual profile cost reduction by each household according to PV diffusion



- Systemic contributions of batteries from early PV diffusion are greater than late entrants (a higher level of remuneration can be developed for early participation).
- System design based on an initial target of around 5 million houses can be a reasonable objective of remuneration scheme.

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CONCLUSIONS

- The optimized residential PV self-consumption model with grid services **significantly helps address balancing and back-up issues**. ➔ the model needs a relatively simple yet standardized control system: incl. automatic operation based on optimal conditions (rates, times).

- **Possible risks** due to the rapid change in demand related to battery charging ➔ more sophisticated solutions that smooth the start and end of battery charging/discharging : refined remote control systems, sub-level management (e.g. collaborative actions with aggregators, grid operators) to maximize the benefits of the grid service.

- **Policy can support the development of the model** (e.g. regulation, standardizations, pricing mechanism).

- **New business models and applications** can be further discussed based on our model (e.g. revenue creation for battery owners)

THANK YOU FOR YOUR ATTENTION

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