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SMART GRID, LOAD MANAGEMENT AND DYNAMIC PRICING FOR ELECTRICITY: FINDINGS FROM A FIELD PROJECT IN SWITZERLAND

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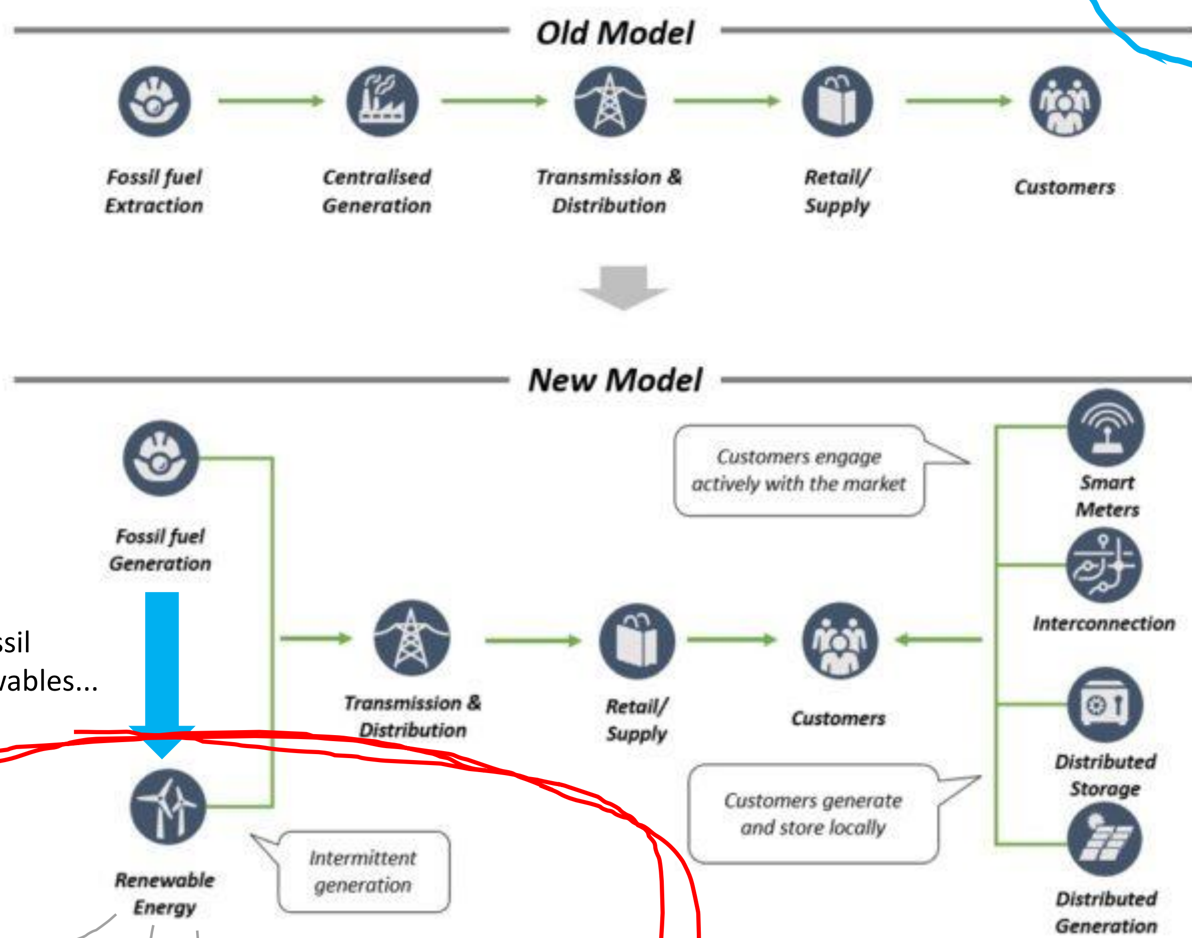
The background (1)

The role of operators and institutions is changing



From fossil
to renewables...

Volatility

Intermittency

Back-up

Disruptive technologies

The background (2)

Results:

- more frequent peak load,
- higher congestion's cost
- physical constraint in carrying out energy flows

Possible strategies:

- Investment in capacity and distribution;
- Increasing in consumers' demand sensitivity (also with AMIs, the prerequisite for ADR programs)
- Rise in decentralized storage capacity

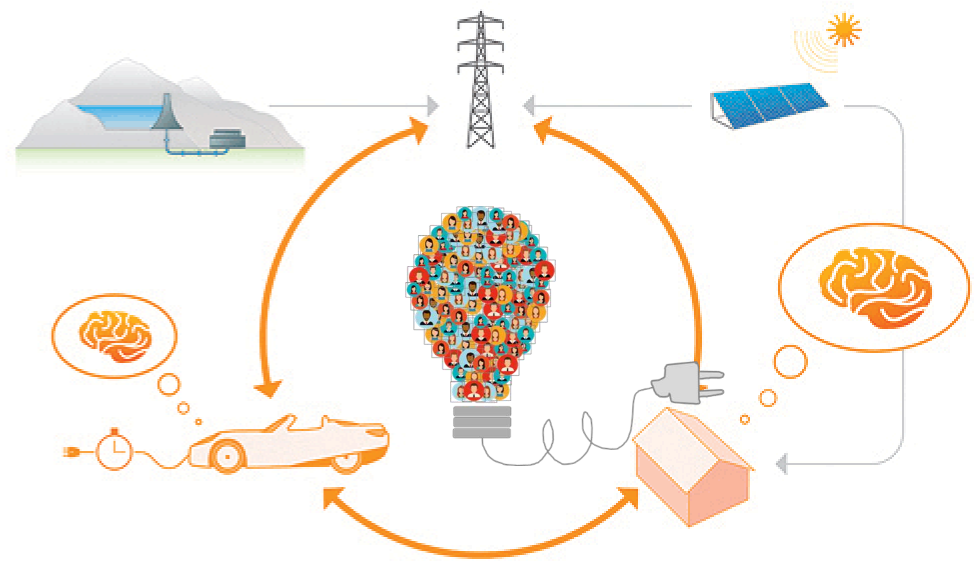
All those considerations have been taken into account in the development of the Swiss2Grid pilot project

The Swiss-to-Grid project (S2G)

The primary idea is to optimise grid management by means of a new concept of Smart-Grid which moves from the bottom (local distribution network) to top (global network).

Main goald:

- Demonstrate the photovoltaic system integration potential in the local area;
- Check how the electricity grid is affected by decentralised energy production combined with the storage of this energy in EV batteries;
- Understand the problems involved in managing a large number of independent homes connected to the smart grid;
- Investigate the extent to which the need to communicate with a centralised system can be reduced or even avoided
- Develop an innovative approach for grid load management based on an active algorithm on individual homes, governed by simple network rules and parameters in order to reduce the level of complexity of the system.
- Examine the financial advantages for the final users and for the electricity companies.



The economic task of the S2G project was aimed to provide an optimal set of tariff/pricing scenarios useful to empirically test many aspects of the optimization and simulation process, also reflecting players' expectations about the future development of the local electricity market.

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The price test design: technical assumptions

- Literature and field projects review (demand elasticity, dynamic prices, role of AMIs, etc..) + results on a qualitative analysis based on the expectations of the main distributors and production players involved;
- Selection of a set of prices to be integrated as an algorithm parameter

Boilers:

- Bolier_1: Average Boiler, 5kW, 500 L with 100L7 day hot water consumption (uniform usage). Thermal conductance 2W/K, heating efficiency 100%. Temperature range: 57 to 63 degC, ambient temperature 20 degC.
- Boiler_2: Average/Large Boiler, 7kW, 700L with ~200L/day hot water consumption (uniform usage). Thermal conductance 2W/K, heating efficiency 100%. Temperature range: 57 to 63 degC.

EVs:

- EV_1: Electric Vehicle used every day from 7 am to 17 pm, plugged in with a state of charge of 30%.
- EV_2: Electric Vehicle used only on working days; it is unplugged from 7 am to 9 am and plugged in from 4 pm and 6 pm with a state of charge between 50% and 70%.
- EV_3: is the Electric Vehicle currently in use at ISAAC, the Institute that develops the HAC; simulation will use data of its actual use.

Price scheme

1) Time of use (control group)
2) Time of use with dynamic rates (CED)
3) Flat rate with dynamic rates (CED)
4) Real time pricing

Figure 4. Details of S2G selected tariffs

Tariff	*Type*	*Peak*	*Off Peak*	*Dynamic Rates*	
				amount	*when*
1	Time-of-Use	14,40 ctsCHF	11,10 ctsCHF		
2	Time-of-Use with Peak Time Rebate	14,40 ctsCHF	11,10 ctsCHF	1 CHF/kWh	5 CED – from 7 pm to 8 pm
3	Flat Rate with Peak Time Rebate	12,90		1 CHF/kWh	5 CED – from 7 pm to 8 pm
4	Real Time Prices	Spot market prices (energy) and network prices			

RTP = spot market + mark up
Network tariff: peak and off peak
2013 and 2017

How the price test has been ran?

1. A simulation in which appliances are not controlled by algorithms has been ran. This simulation generates an energy usage curve: for every minute in the month, we compute how much energy the appliances used; note that, because in this simulation appliances are not considering the energy price, the energy usage curve is the same regardless on the price profile. From the energy usage curve, we compute the total energy cost based on the energy price profile.

2. We run a simulation in which appliances are controlled by algorithms has been completed. This simulation generates an energy usage curve that depends on the price profile, as algorithms attempt, where possible, to shift energy use to low-cost periods. Again, the total energy cost has computed.

3. For each price profile, this yields the energy cost without and with algorithms; the savings results as the difference between these two values.

The algorithm has been ran with two definite objectives, each with the same weight of importance:

- the consumers' monthly electricity bill minimization and
- the load optimization, intended as a load shifting from peak to off-peak consumption curve

Selected rates have been tested on one single house
The algorithm basically does not consider an energy consumption reduction.

Price test simulation results (1)

Figure 5. Monthly bill with and without the algorithm in 2013: Boilers (CHF)

2013		Price scheme			
		1	2	3	4
Boiler_1	Without HAC	25.46	25.46	26.79	24.77
	With HAC	23.13	20.89	25.56	17.61
Boiler_2	Without HAC	43.95	43.95	46.05	42.30
	With HAC	40.27	36.86	43.00	31.02

Figure 6. Monthly bill with and without the algorithm in 2013: EVs (CHF)

2013		Price scheme			
		1	2	3	4
EV_1	Without HAC	58.7	49.7	50.1	56.1
	With HAC	38.9	28.1	35.2	30.5
EV_2	Without HAC	20.8	20.8	19.7	22.9
	With HAC	17.0	9.1	13.3	12.1
EV_3	Without HAC	13.8	13.8	13.4	14.8
	With HAC	12.6	7.4	8.6	10.3

Figure 7. Monthly bill with and without the algorithm in 2017: Boilers (CHF)

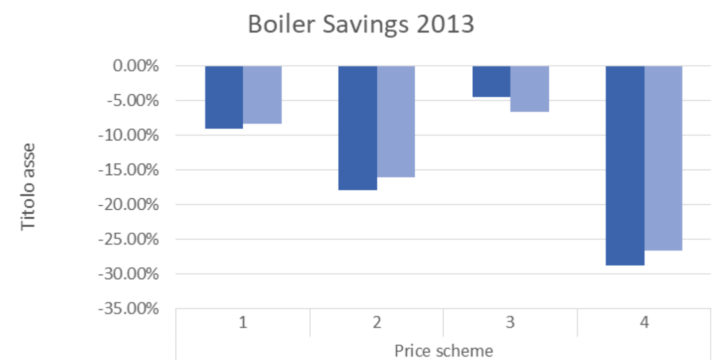
2017		Price scheme			
		1	2	3	4
Boiler_1	Without HAC	29.68	29.68	26.79	27.63
	With HAC	28.77	27.32	26.79	24.68
Boiler_2	Without HAC	51.19	51.19	46.05	47.43
	With HAC	50.27	48.05	46.37	42.91

Figure 8. Monthly bill with and without the algorithm in 2017: EVs (CHF)

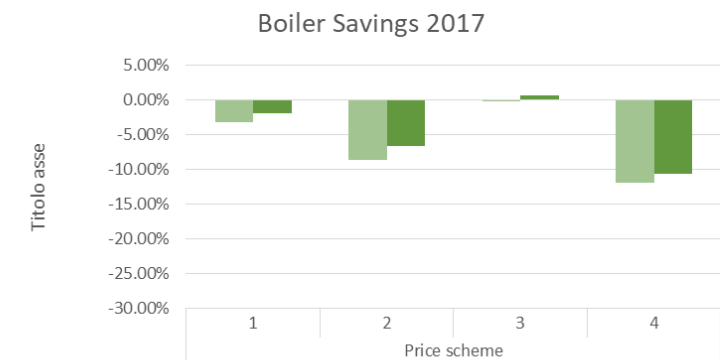
2017		Price scheme			
		1	2	3	4
EV_1	No HAC	57.5	57.5	50.1	56.7
	with HAC	51.0	39.0	38.2	45.1
EV_2	No HAC	23.9	23.9	19.7	22.7
	with HAC	20.1	15.5	15.2	17.1
EV_3	No HAC	16.0	15.9	13.4	14.7
	with HAC	14.6	13.3	12.0	12.5

Price test simulation results (2)

Figure 9. Monthly savings with and without the algorithm: boilers (2013 and 2017)

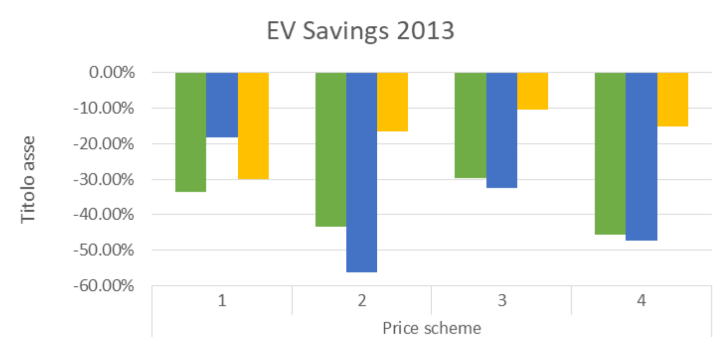


	1	2	3	4
Boiler_1 savings	-9.15%	-17.95%	-4.59%	-28.91%
Boiler_2 savings	-8.37%	-16.13%	-6.62%	-26.67%

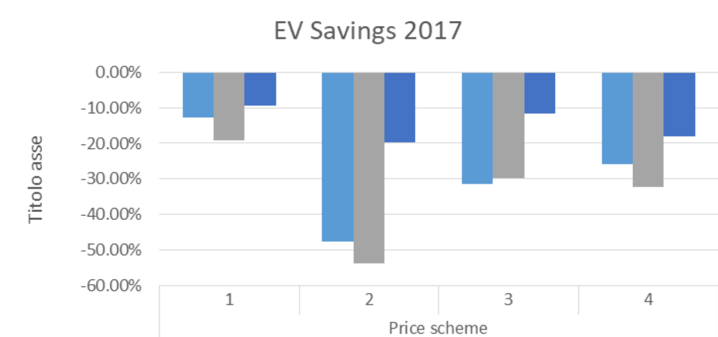


	1	2	3	4
Boiler_1 savings	-3.16%	-8.63%	0.00%	-11.95%
Boiler_2 savings	-1.83%	-6.55%	0.69%	-10.53%

Figure 10. Monthly savings with and without the algorithm: EVs (2013 and 2017)



	1	2	3	4
EV_1 savings	-33.73%	-43.46%	-29.74%	-45.63%
EV_2 savings	-18.27%	-56.25%	-32.49%	-47.16%
EV_3 savings	-30.01%	-16.56%	-10.48%	-15.29%



	1	2	3	4
EV_1 savings	-12.80%	-47.52%	-31.32%	-25.77%
EV_2 savings	-19.15%	-53.75%	-29.70%	-32.33%
EV_3 savings	-9.47%	-19.85%	-11.71%	-18.05%

Price test simulation results (3)

In general, we can notice that:

- higher savings in terms of monthly bills could be obtained with an appropriate management of EVs charging;
- in general, results could be a little underestimated due to the invariance in total consumption;
- most interesting price schemes seem to be ToU combined with dynamic rates (PTR) and Real Time Prices;
- in particular, RTPs seem to privilege boilers. Savings for EVs are remarkable; due to their strong flexibility in terms of use they could give back higher price advantages;
- again, for EVs the incidence of PTR rewards is very relevant, in certain cases higher than for boiler; this because at 7 p.m. EVs without algorithm are usually plugged in. The baseline is so very high as much potential savings with HAC;
- results seem to confirm the evidence from international pilot projects, with high savings with ToU combined with dynamic rates (in our case PTR) and RTP;
- the role of PTR reward and RTP utilities mark up is critical. In detail, keeping the same mark up, we need to halve the reward to change results and make the RTP price scheme more attractive;
- Monthly savings for boiler and actual usage of EVs seem in line with empirical evidence/pilot projects.

Some suggestions of public policy on the new roles for market players

We are moving towards a smart electricity market.

Challenges?

- ✓ design new arrangement for a RES-integrated electricity market describing roles and duties of old and new relevant market players, as well as potential regulatory framework improvements;
- ✓ define the most appropriate valorisation of each transaction between market actors. Efficient market design requires good pricing principles to manage transitions (Newberry, 2017);
- ✓ Risk allocation between players.

New, innovative business models are needed:

- DSOs will have a growing role in ensuring the smooth working of the system, also with the help of enabling technologies
- DSOs as pure network operators vs value added players
- Very significant role that final end users and communities can play in helping to meet energy and climate change challenges (Rogers et al. 2008; Li, Yu, 2014; Musall 2011, Li et al. 2012);
- ICT improvements (es: blockchain technology)

- Towards a P2P market for electricity?.........

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Thank you for your kind attention!
Any suggestions are welcomed!

Barbara