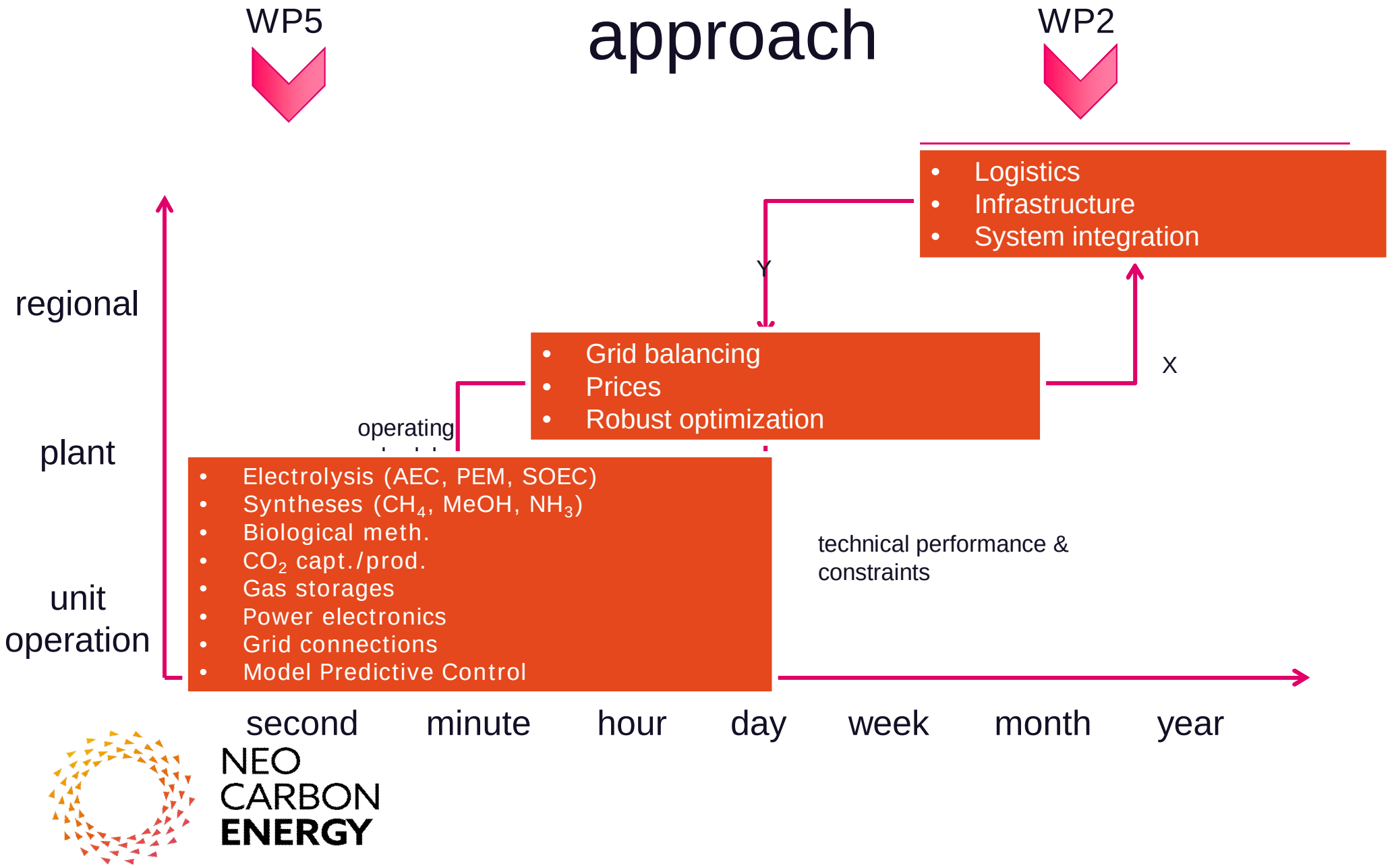
Robust optimization of PtX plant operation scheduling

29.8.2016 Work in progress

Robert Weiss, WP4

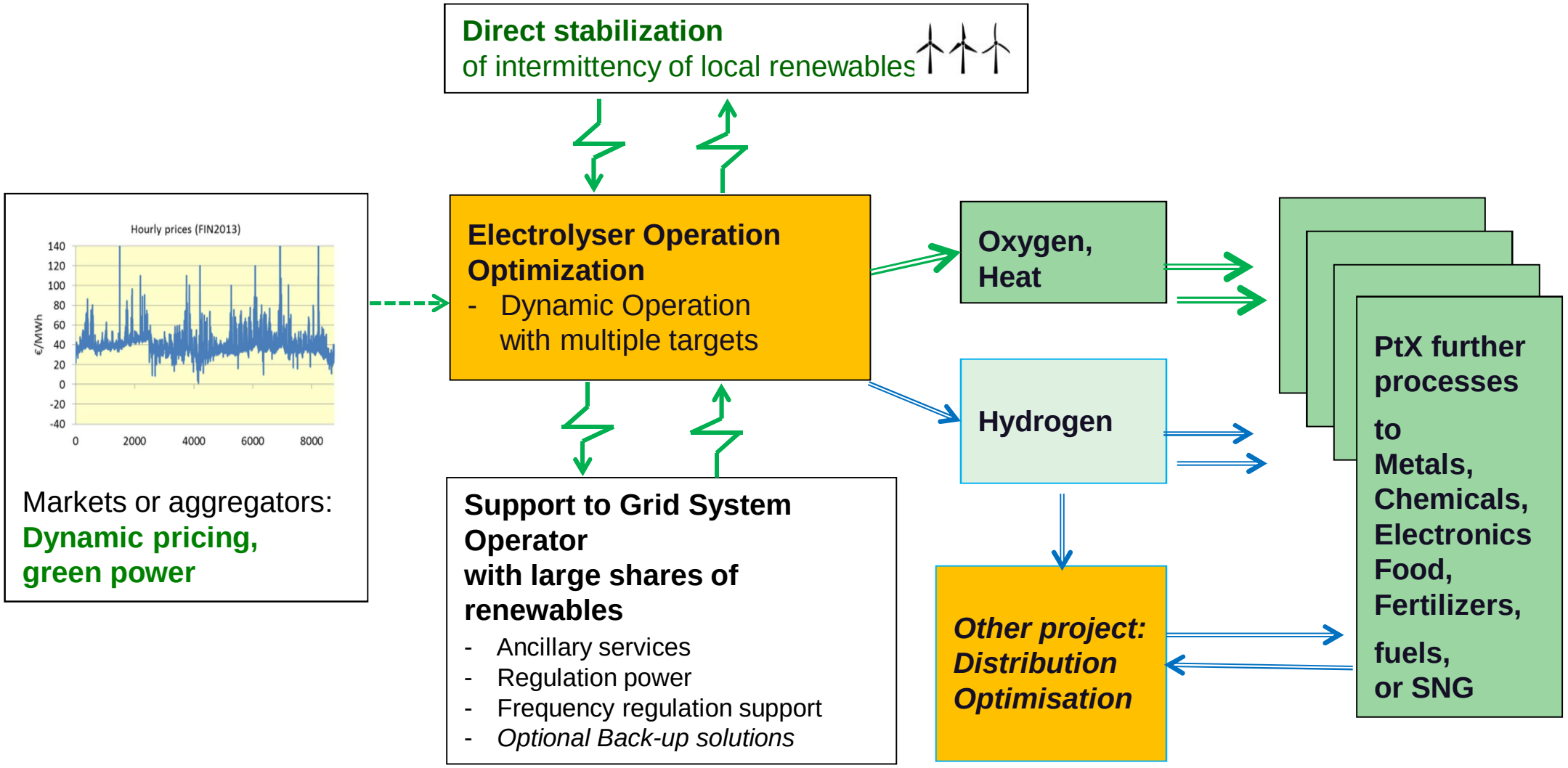
WP4 overall structure – a three level approach



NEO CARBON ENERGY

Example case:

PtX plant with stable H_2 demand, *inflexible* end of process



Example case:

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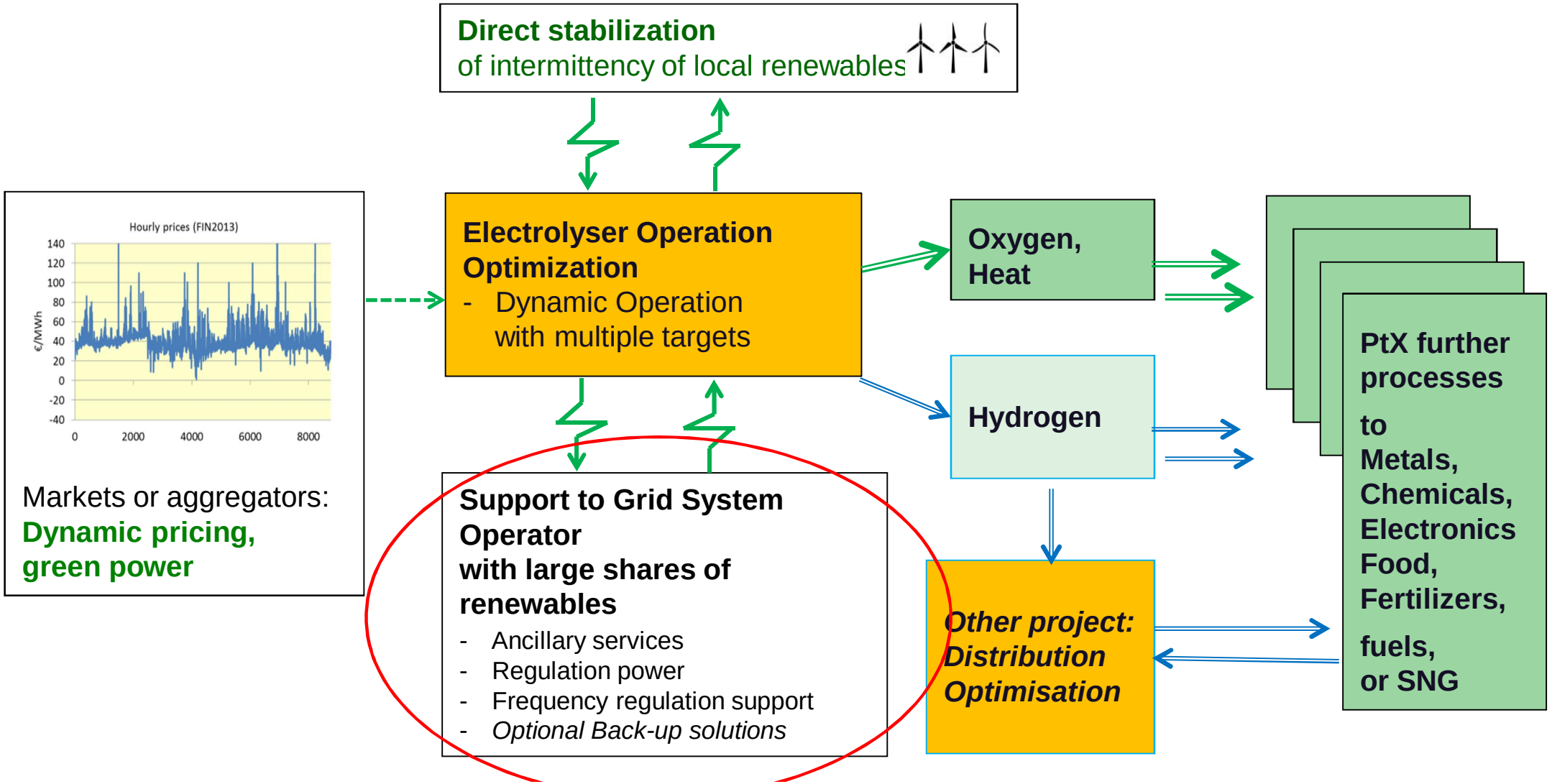
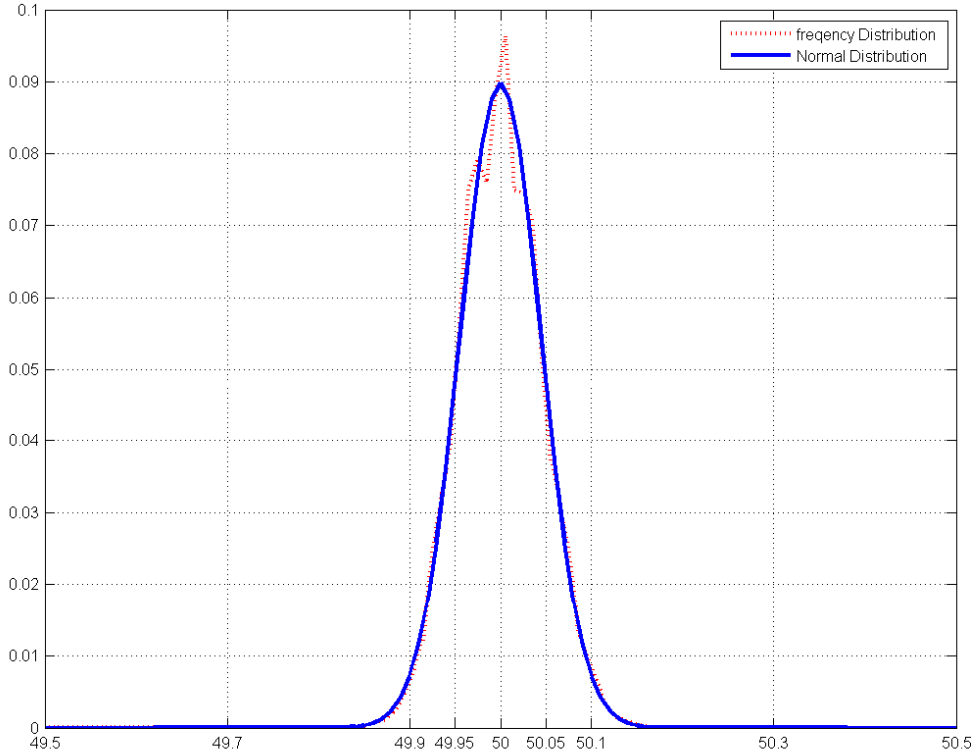


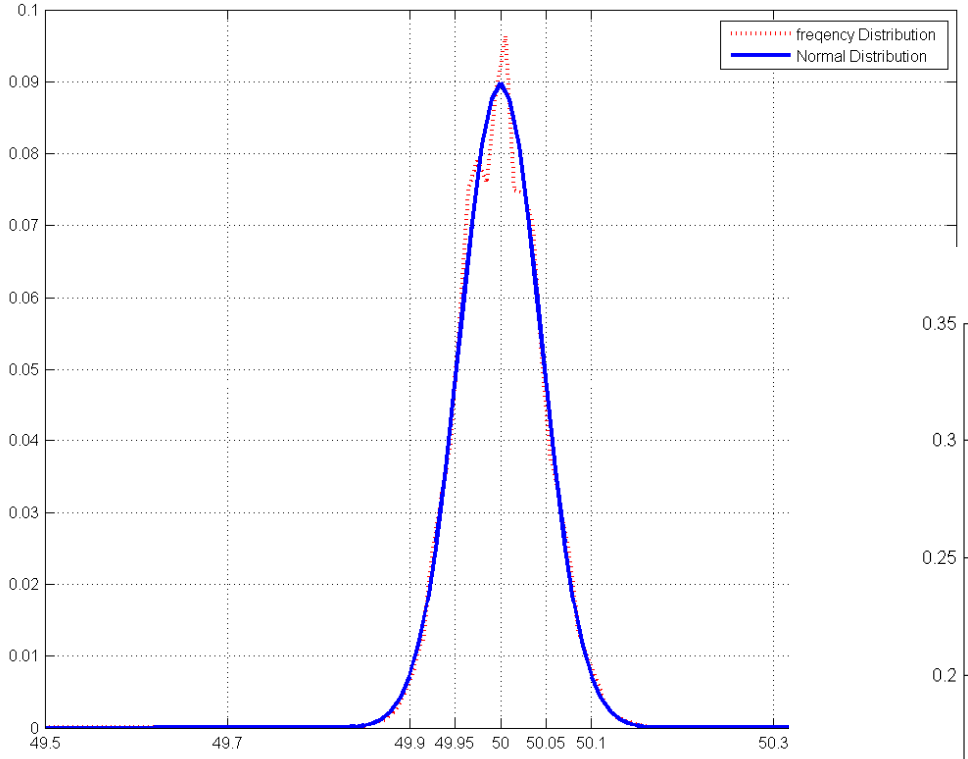
System Frequency - variation



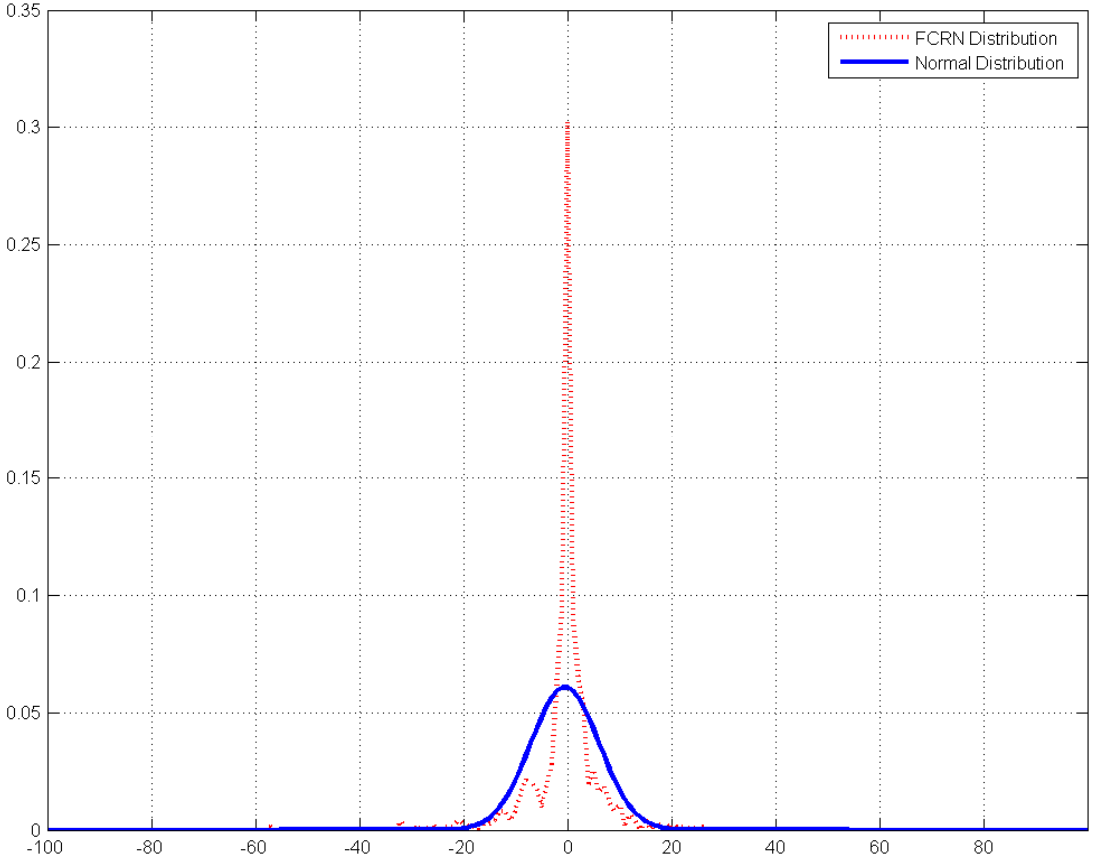
Distribution of Frequency,
0.1s samples
for one month

Utilizing Finnish TSO Fingrid data

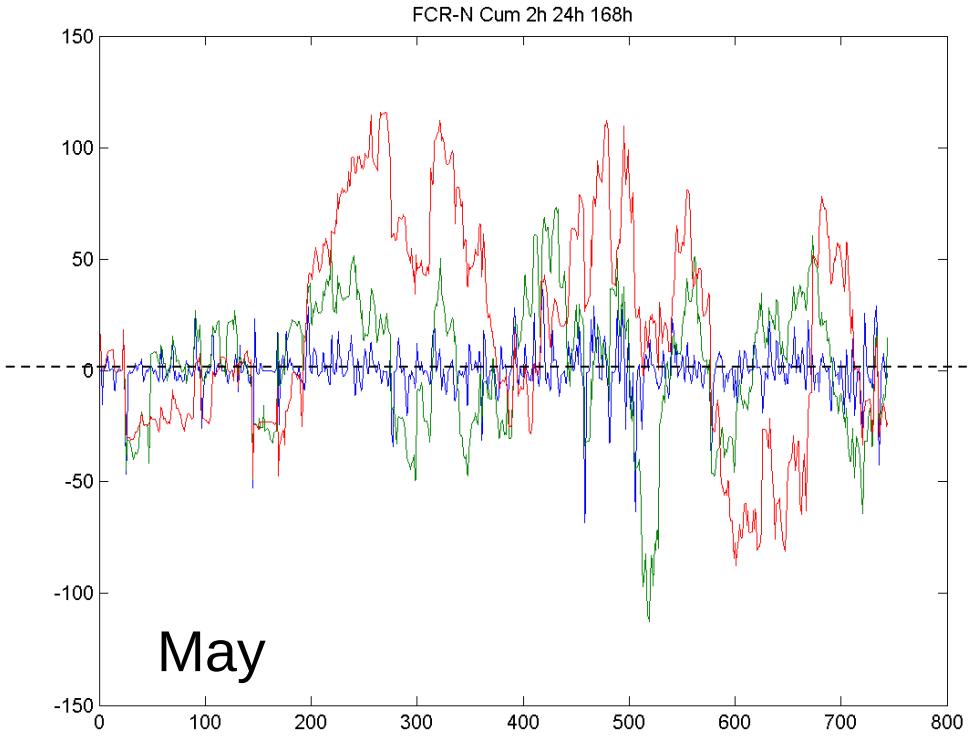
System Frequency -
FCR-N demand execution

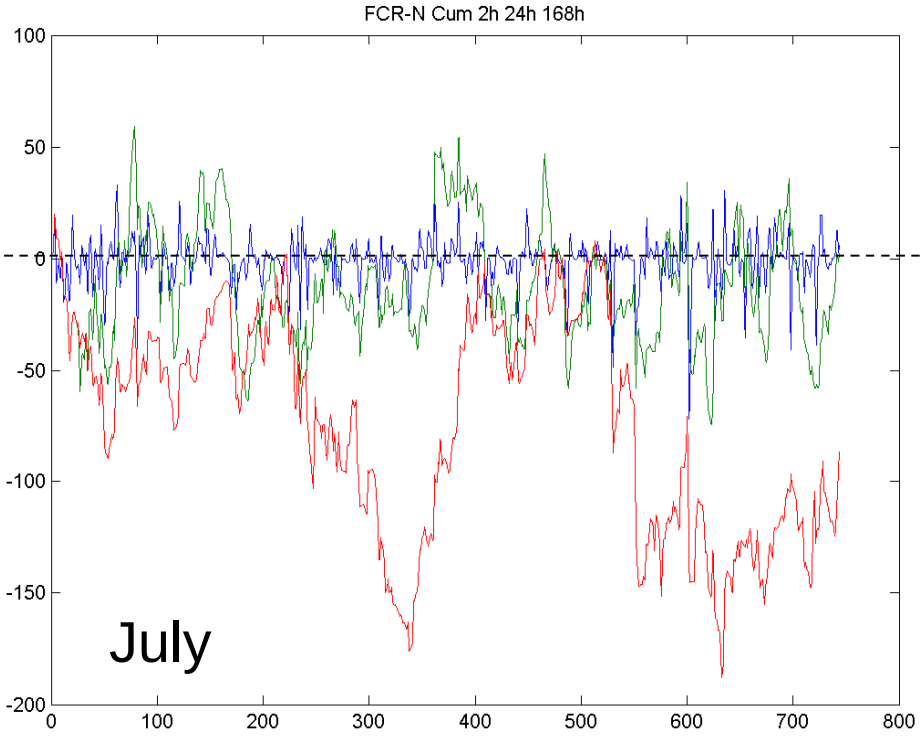


Utilizing Finnish TSO Fingrid data

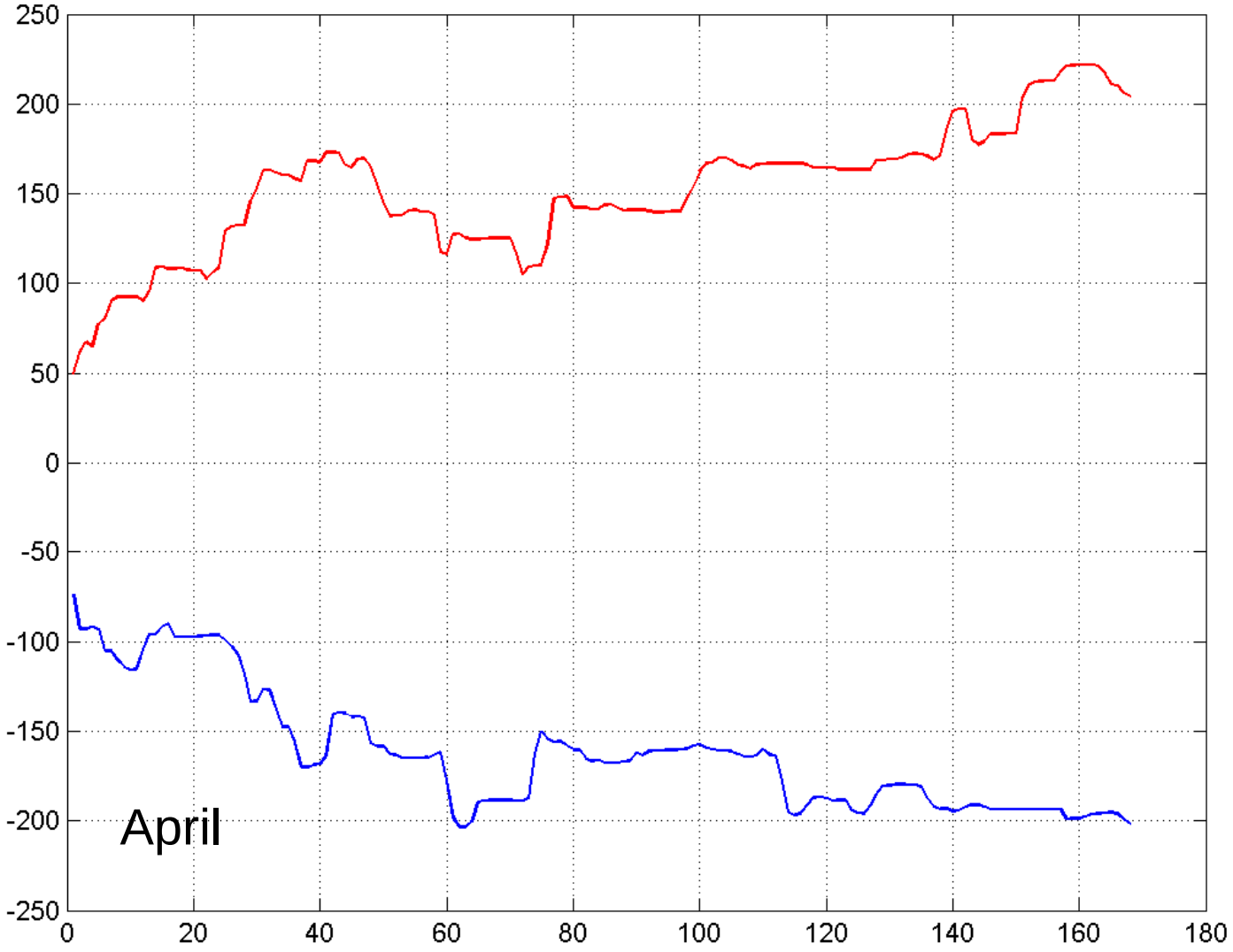


System Frequency -
FCR-N demand execution, longer cumulative trends

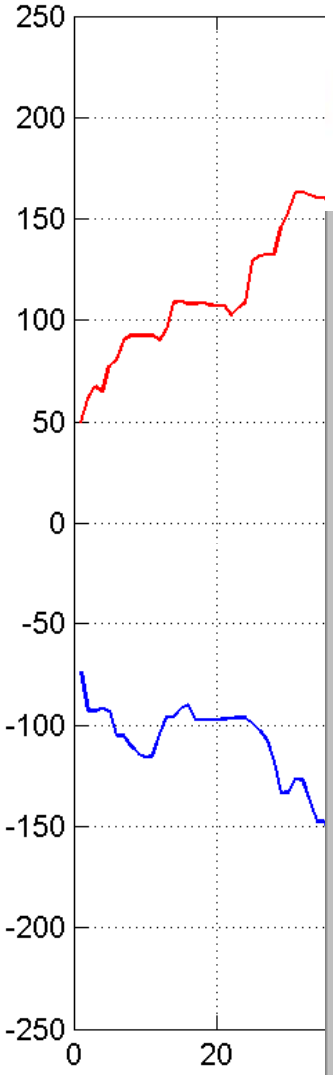




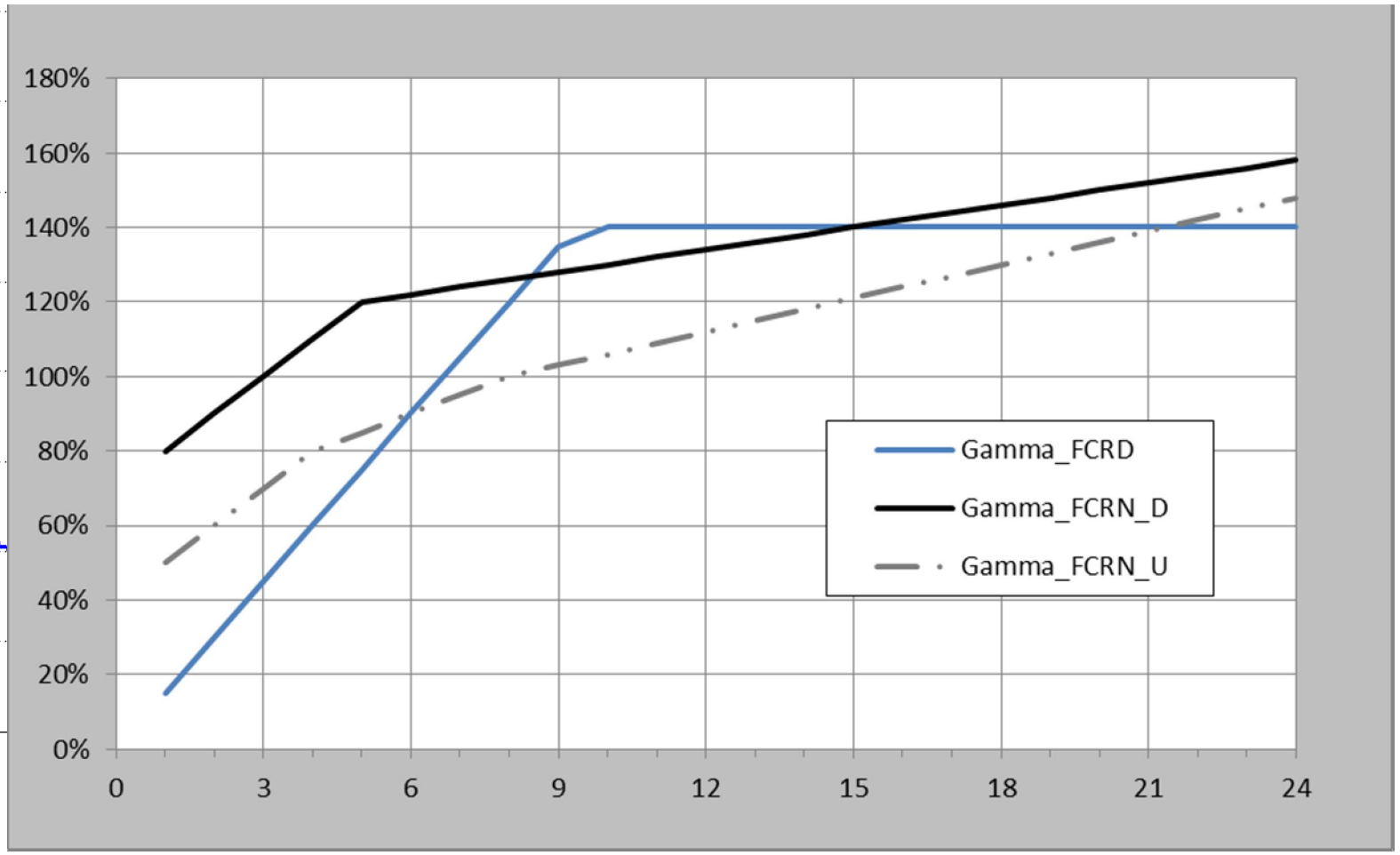
System Frequency -
FCR-N cumulative maximum ”risk” curves



System Frequency - FCR products,
Implementation of maximum ”risk” curves into *Robust Scheduling*



$$U(RC) = \left\{ w : ED_t^{re} = RC_t\, w_t,\ 0 \le w_k \le 1\ \forall\, k \ge 1,\ \sum_{k=1}^{t} w_k \le \Gamma_t\ \forall\, t \in \overline{T} \right\}$$

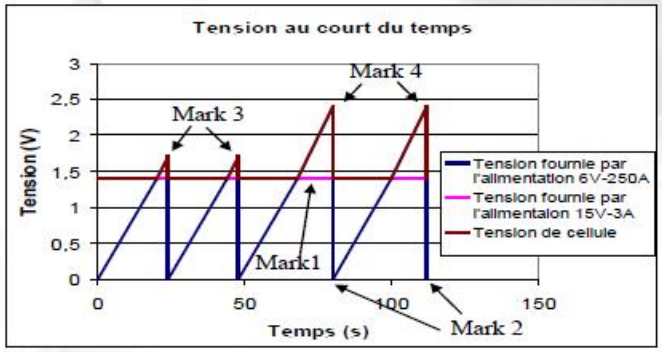


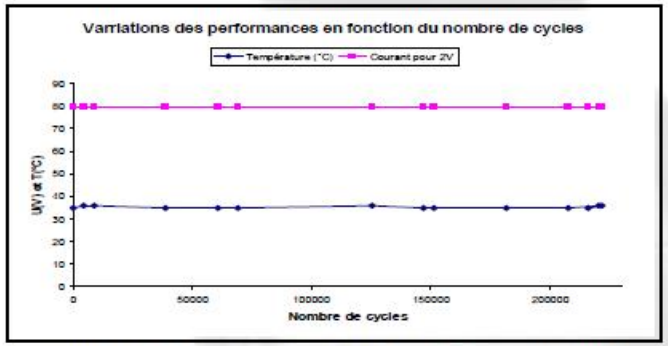
Electrolyzer Cycling vs aging

Lifetime

- Up to 10% efficiency loss : 35 000 h
- Cell Voltage increase : <5,4µV/h
- No effect due to cycling : 500 000 Cycles

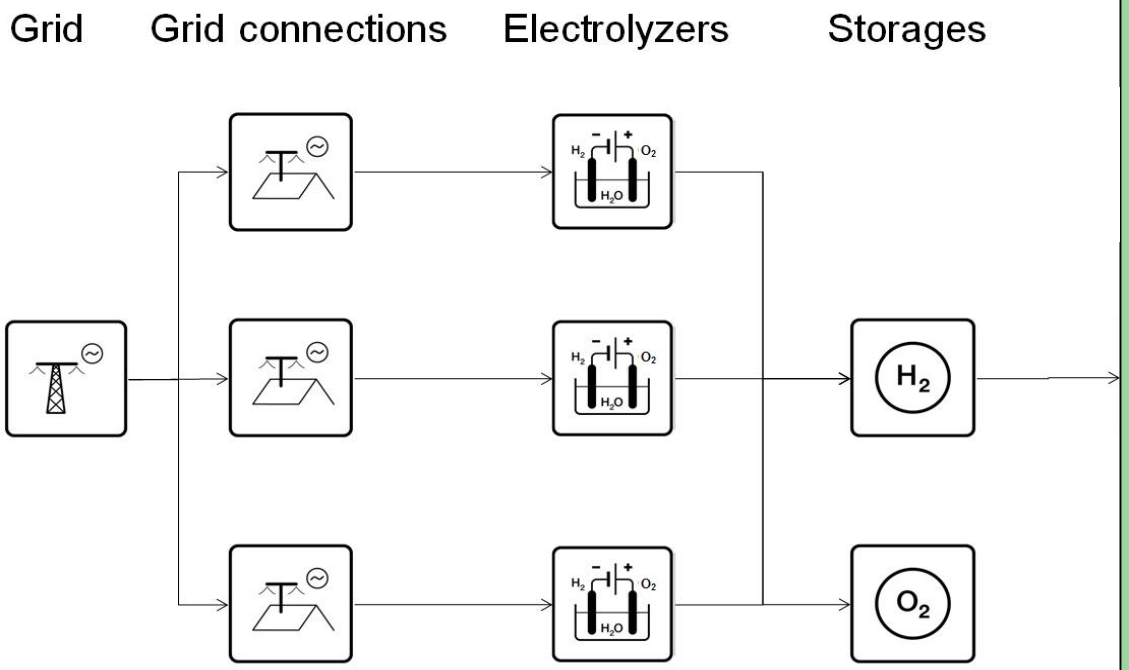
Generally difficult
to find good data sets
or real information
on aging





Fraunhofer ISE : Freiburg, March the 12th 2013

Industrial PtX case with stable but *inflexible* H2 demand



PtX further processes steps

to
Metals, Chemicals,
Electronics, Food, Fertilizers,
Fuels etc

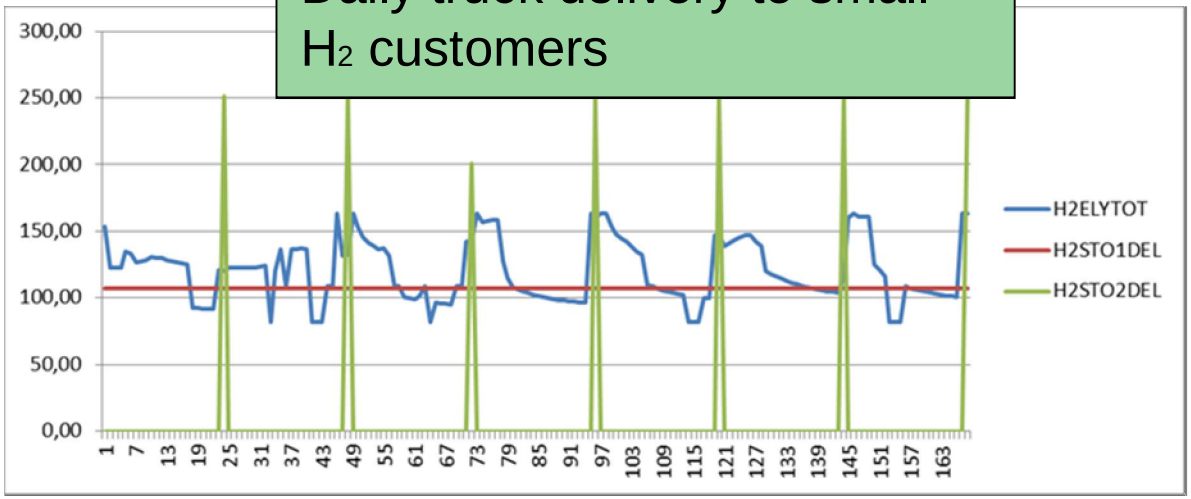
No Flexibility
in further process steps

Stable (24x7) process demand of H_2

Daily truck delivery to small H_2 customers

Case study:
3 * 3 MW electrolyser

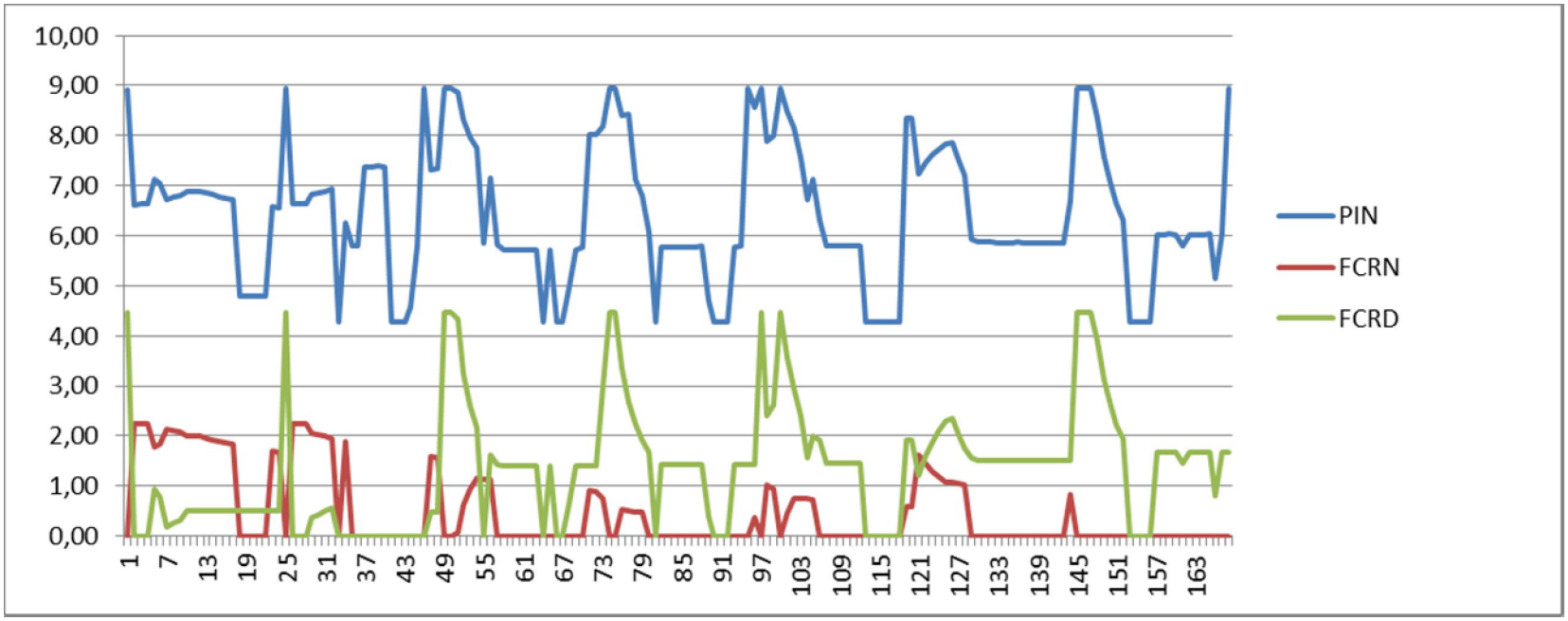
Work-in-progress



Industrial PtX, Case study results 3 * 3 MW electrolyser (1)

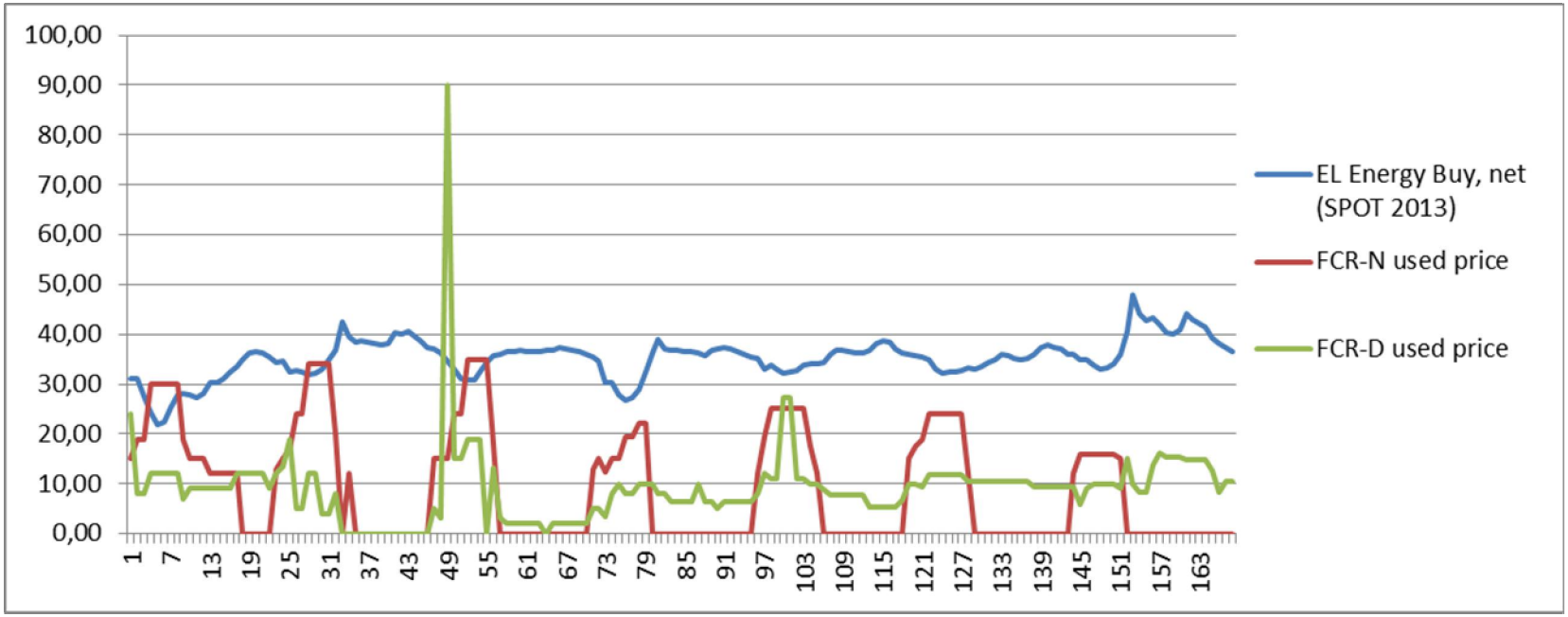
H2SALES	PCOSTS	FCRNSALE	FCRDSALE	NETCASHFLOW	
					Fix power contract
5 025 571 €	3 722 982 €	0,00 €	0,00 €	1 302 589 €	@ ave spot price 41.15 EUR/MWH
100,0 %	100,0 %	0,0 %	0,0 %	26 %	
5 014 991 €	3 634 002 €	0,00 €	0,00 €	1 380 989 €	Spot only, no FCR
100,0 %	100,0 %	0,0 %	0,0 %	28 %	
5 041 413 €	3 878 111 €	549 678 €	580 930 €	2 293 911 €	FCR-N & FCR-D hourly, Robust
81,7 %	100,0 %	8,9 %	9,4 %	37,2 %	
5 046 931 €	3 788 543 €	541 618 €	571 476 €	2 371 482 €	FCR-N & FCR-D hourly, NOT Robust
81,9 %	100,0 %	8,8 %	9,3 %	38,5 %	

Example on Production schedules



FCR-N&D hourly, Robust

Snapshot week In January 2013



Industrial PtX, Case study results 3 * 3 MW electrolyser (2)

H2SALES	PCOSTS	FCRNSALE	FCRDSALE	NETCASHFLOW	
5 050 069 €	3 891 409 €	269 942 €	0,00 €	1 428 601 €	FCR-N yearly, Robust
94,9 %	100,0 %	5,1 %	0,0 %	26,9 %	25% eq max at 168h risk level = 2.5)
5 041 413 €	3 878 111 €	549 678 €	580 930 €	2 293 911 €	FCR-N & FCR-D hourly, Robust
81,7 %	100,0 %	8,9 %	9,4 %	37,2 %	
5 027 451 €	3 783 165 €	689 579 €	0,00 €	1 933 866 €	FCR-N hourly, Robust
87,9 %	100,0 %	12,1 %	0,0 %	33,8 %	
5 031 350€	3 803 629€	0,00 €	740 866	1 968 587€	FCR-D hourly, Robust
87,2 %	100,0 %	0,0 %	12,8 %	34,1 %	67% of Ely capacity used

Reduce Electrolyzer capacity 2 MW

* from ave 67% used to ave 95% used
* Buffer storage similarily reduced

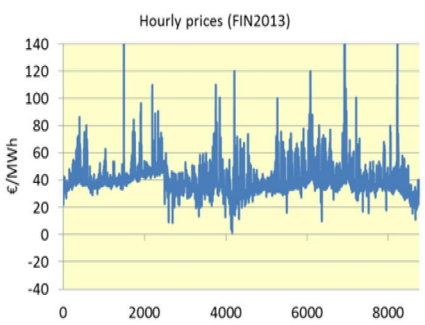
-> reduced cash flow 200 kEUR /MW,year

5 008 734 €	3 815 700 €	0,00 €	674 873 €	1 867 907 €	FCR-D hourly,
88,1 %	100,0 %	0,0 %	11,9 %	32,9 %	95% of Ely capacity used

Example case:

PtX plant with stable H_2 demand, *inflexible* end of process

Direct stabilization
of intermittency of local renewables



Markets or aggregators:
Dynamic pricing, green power

Electrolyser Operation Optimization
- Dynamic Operation with multiple targets

Oxygen, Heat

Hydrogen

PtX further processes to Metals, Chemicals, Electronics Food, Fertilizers, fuels, or SNG

Other project: Distribution Optimisation

Support to Grid System Operator with large shares of renewables
- Ancillary services
- Regulation power
- Frequency regulation support
- *Optional Back-up solutions*

Industrial PtX, Case study ”directly” connected to PV field

3 * 3 MW electrolyser + PV in south Finland

HELEN Suvilahti PV production measurements 26.8.2015-25.8.2016

PV measurements calibrated to max ELY output => 33.3 of such PV plants.

H2SALES	PCOSTS	FCRNSALE	FCRDSALE	NETCASHFLOW	
5 041 616 €	3 267 361 €	548 454 €	579 455 €	2 902 164 €	FCR-N&D hourly,
81,7 %	100,0 %	8,9 %	9,4 %	47,0 %	PV 0EUR/MWH

608253 EUR saved by PV

8073	MWh PV used	91 %	75EUR/MWh
8828	MWh PV produced (lost 10%)		69EUR/MWh
49101	MWh External power purchased	86 %	

H2SALES	PCOSTS	FCRNSALE	FCRDSALE	NETCASHFLOW	
5 031 583 €	3 190 389 €	0,00 €	738 197 €	2 579 390 €	FCR-D hourly,
87,2 %	100,0 %	0,0 %	12,8 %	44,7 %	PV 0EUR/MWH, Robust

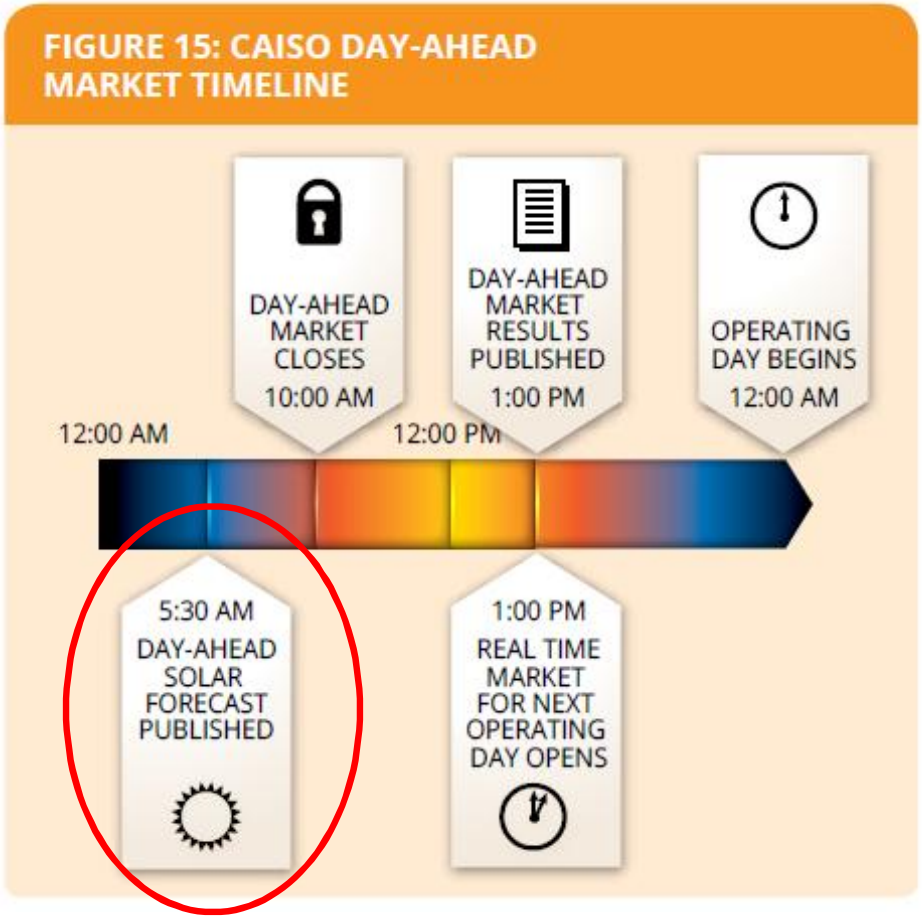
Next steps?

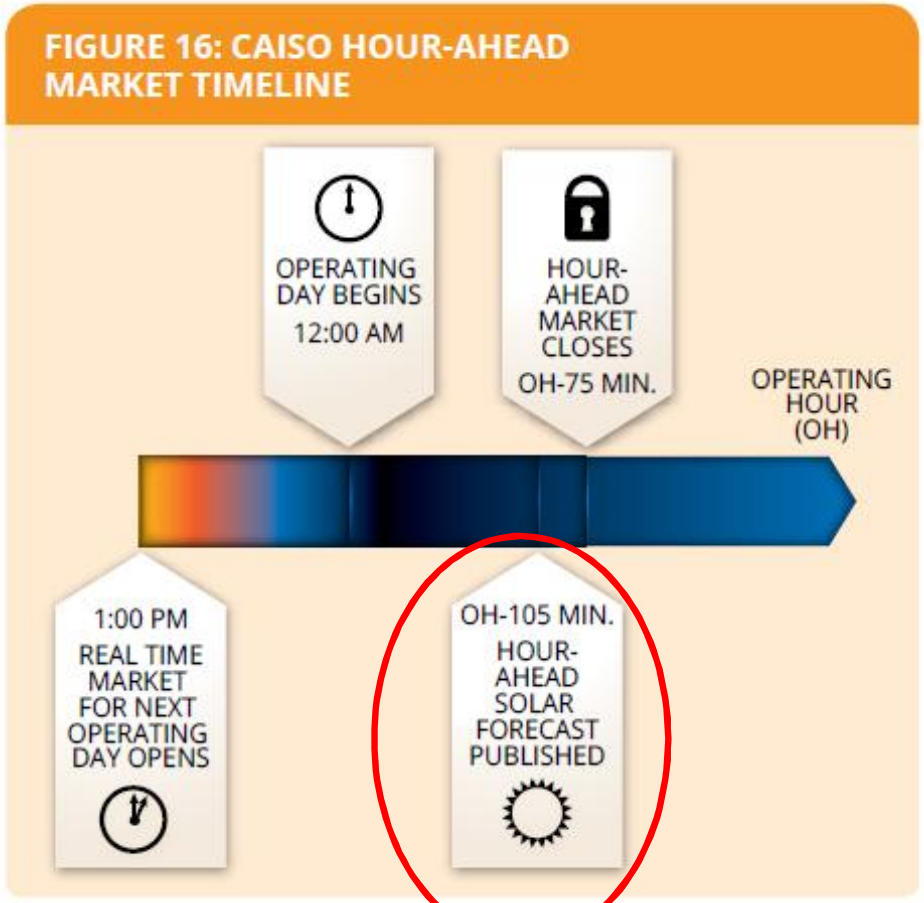
Flexible PtX processes, uncertainty in demand

Battery or Smart Grid supported PV/Wind

Uncertainty in Wind or PV forecasts

Intraday market





AIChE Annual meeting 2016, San Francisco, 13-16.11.16

Optimal co-production of market-based power grid support and renewable fuels or chemicals

Weiss Robert; Kannari Lotta; Pennanen Jari; Sihvonen Teemu; Savolainen, Jouni