EUROPEAN WORKSHOP ON DRIFTING APART: COSTS, PRICES AND TARIFFS IN EU ELECTRICITY MARKETS

PARIS, JULY 09, 2014

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- 2. THE POTENTIAL OF WIND AND SOLAR ENERGY TECHNOLOGIES AND THE ROLE OF THE MARKET
- 3. QUANTIFYING THE IMPACT OF RENEWABLES ON WHOLESALE POWER PRICES
- 4. NEGATIVE PRICES IMPORTANT PRICE SIGNALS





RENEWABLE ENERGY - THE ENERGY DU JOUR

• IN MID-MARCH 2011, GERMAN CHANCELLOR MERKEL SAID:

"WE WANT TO END THE USE OF NUCLEAR ENERGY AND REACH THE AGE OF RENEWABLE ENERGY AS FAST AS POSSIBLE"

- A SENSE OF DÉJÀ VU:
 - THREE CENTURIES AGO WE USED NOTHING BUT RENEWABLES WITH A FULLY SUSTAINABLE ENERGY SYSTEM (WINDMILLS, WATER MILLS, AND WOOD STOVES AND ANIMAL POWER.)
 - WE ARE RETURNING TO THE PAST, WITH THE ADDITION OF NEW SOURCES (SOLAR AND GEOTHERMAL.) BUT THE POPULATION HAS INCREASED TENFOLD AND THE ECONOMIC ACTIVITY BY SEVERAL ORDERS OF MAGNITUDE.





RENEWABLE ENERGY - THE ENERGY DU JOUR

• IN JANUARY 2014, GERMAN ECONOMY MINISTER GABRIEL SIGMAR UNVEILED PLANS TO CUT STATE SUBSIDIES FOR RENEWABLE ENEGY. HE CALLED ON HIS CRITICS TO HELP KEEP GERMAN'S SOARING ENERGY BILLS IN CHECK:

"WE NEED TO BREAK THE DYNAMICS OF EVER-RISING ELECTRICITY BILLS, WHILE ENSURING A STABLE SUPPLY OF ENERGY FOR ALL"

- TO MAKE INFORMED DECISIONS ABOUT THE FUTURE OF RENEWABLE ENERGY, POLICYMAKERS NEED TO HAVE ANSWERED TWO QUESTIONS:
 - IS RENEWABLE ENERGY MORE EXPENSIVE THAN FOSSIL ENERGY?
 - CAN IT BE MADE AVAILABLE ON A LARGE ENOUGH SCALE TO REPLACE MUCH OF OUR FOSSIL FUELS USE?





COMPARING THE COSTS OF RENEWABLES AND CONVENTIONAL POWER PLANTS

RENEWABLES

- LARGE FIXED COSTS SUBSTANTIAL UP-FRONT CAPITAL EXPENDITURES BEFORE ANY ENERGY IS GENERATED.
- LOW OR NO VARIABLE COSTS ALL EXCEPT WASTE-TO-ENERGY NEED NO FUEL, AND WASTE IS USUALLY FREE.
- AVERAGE COSTS VERY DEPENDENT ON OUTPUT LEVELS.

FOSSIL FUEL POWER STATIONS

- SIGNIFICANT FUEL COSTS A LARGE COAL-FIRED POWER STATION CAN USE 10,000 TONS OF COAL DAILY, COSTING BETWEEN \$50 AND \$100 PER TON. FUEL COSTS CAN BE BETWEEN HALF A MILLION AND A MILLION DOLLARS DAILY.
- BURNING ONE TON OF COAL PRODUCES BETWEEN 1.5 AND 3.5 TONS OF CO2 A BIG COAL POWER STATION PRODUCES 15,000 - 30,000 TONS OF CO2 DAILY. A PRICE OF \$30 PER TON CO2 COULD DOUBLE THE FUEL COSTS.

NUCLEAR

• CLOSE TO RENEWABLES – LARGE CAPITAL COSTS AND SMALL ONGOING FUEL COSTS.





IS INVESTING IN RENEWABLES ATTRACTIVE?

THIS DEPENDS ON FOUR PARAMETERS:

- THE COST OF OIL AND OTHER FOSSIL FUELS (THEY TEND TO MOVE TOGETHER.)
- THE COST OF CARBON EMISSIONS OR EQUIVALENTLY THE EXTENT TO WHICH EXTERNAL COSTS ARE INTERNALIZED.
- THE COST OF CAPITAL.
- THE INCENTIVES AVAILABLE TO GREEN POWER PRODUCERS (ANOTHER DIMENSION OF THE INTERNALIZATION OF EXTERNAL COSTS.)





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INTERMITTENCY UNFAVORABLE OUTPUT PATTERNS AND THE ROLE OF THE MARKET



- RENEWABLES UNFAVORABLE PRODUCTION PATTERNS (WHEN THE LOAD NET FROM RENEWABLES OVER THE PEAK PERIOD IS LESS THAN THE BASE LOAD POWER CAPACITY, FOR INSTANCE) POSE DIFFICULTIES FOR BASELINE POWER GENERATORS WHOSE OUTPUT CANNOT BE VARIED EASILY.
- MARKET COUPLING HELPS OVERCOME THIS ISSUE (OPTIMAL ALLOCATION OF AVAILABLE TRASMISSION CAPACITIES REDUCING UNFAVORABLE LOCAL LOADS VARIATIONS.)
- EFFICIENT DAY-AHEAD MARKETS SEND THE RIGHT PRICE SIGNALS FOR THE NEEDED INVESTMENTS AND INCITIVES (FLEXIBILITY, INTERCONNECTORS, DEMAND-RESPONSE.)





INTERMITTENCY DAY-AHEAD FORECAST ERRORS AND THE ROLE OF THE MARKET



- RENEWABLES GENERATION MIGHT TURN OUT TO BE MUCH LOWER OR HIGHER THAN ITS DAY-AHEAD FORECAST.
- LIQUID INTRADAY MARKETS HELP ADJUST THE REALIZED RENEWABLES OUTPUT TO THE DAY-AHEAD FORECAST WHILE REWARDING FLEXIBILITY.
- THE PRICES ON EFFICIENT INTRADAY MARKETS ADJUST TO THE MOST RECENT NEWS. THEY REWARD THE EXISTING FLEXIBILITY, AND REVEAL THE NEEDED FLEXIBILITY AND ITS VALUE (FLEXIBLE GENERATION, INTERCONNECTORS, DEMAND-RESPONSE.)





INTERMITTENCY INTRA-DAY INTERMITTENCY AND THE ROLE OF THE MARKET



- EPISODES OF NEGATIVE OR VERY LOW HOURLY PRICES (ON HIGH RENEWABLES OUTPUT AT TIMES OF LOW DEMAND, FOR INSTANCE) MIGHT BE QUICKLY FOLLOWED BY HIGH HOURLY PRICES (WHEN THE WIND STOPS BLOWING OR THE SUN STOPS SHINING, FOR INSTANCE.)
- MARKET COUPLING HELPS OVERCOME THIS ISSUE, AND THE INTERCONNECTORS PLAY A SIMILAR ROLE TO THAT OF FLEXIBLE POWER PLANTS IN THESE SITUATIONS.
- DAY-AHEAD HOURLY PRICES CONSTITUTE THE RIGHT SIGNALS FOR THE NEEDED INVESTMENTS AND INCITIVES (FLEXIBILITY, INTERCONNECTORS, DEMAND-RESPONSE.)





INTERMITTENCY INTRA-HOUR INTERMITTENCY AND THE ROLE OF THE MARKET



- VARIABLE RES ARE BRINGING A NEW TYPE OF RAMPS (RANDOM IN THEIR TIMING, DIRECTION, AND INTENSITY, AND SOMETIMES WITHIN EXTREMELY SHORT TIME HORIZONS.) GREATER CONTROLLABLE FLEXIBLE GENERATION IS NEEDED TO QUICKLY RAMP UP AND DOWN TO MAINTAIN ELECTRIC GRID RELIABILITY UNDER SUCH CONFIGURATIONS.
- THE ALREADY ESTABLISHED EPEX SPOT 15 MINUTES INTRADAY MARKET CONSTITUTE AN INTERESTING VENUE WHERE INTRA-HOUR FLEXIBILITY BUYERS AND SELLERS CAN TRANSACT.
- 15 MINUTES PRICE SIGNALS REVEAL THE REQUIRED MEGA-FLEXIBILITY (WHICH TECHNOLOGY AND HOW MUCH CAPACITY), AND CONTRIBUTE IN GIVING INCITIVES TO DEVELOP MORE FLEXIBILITY.
- EPEX SPOT WILL LAUNCH A SEPARATE AUCTION FOR 15 MINUTES CONTRACTS.







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ECONCOMETRIC MODEL

- LINEAR MODEL FOR EPEX GERMANY/AUSTRIA BASELOAD: $Y_t = \sum_i \alpha_i X_{i,t} + \varepsilon_t$
- THE DEPENDENT VARIABLE Y_t : (DAY AHEAD BASE MONTH FUTURE BASE)
- THE INDEPENDENT VARIABLES X_i : DAY OF WEEK, BANK HOLIDAY, TRANSFORMATIONS OF TEMPERATURES, RENEWABLES
- OFF-PEAK SUPPLY CURVES ARE GENERICALLY LESS RESILIENT THAN PEAK SUPPLY CURVES. RENEWABLES IMPACT IS ADDED AS TWO LINEAR TERMS:

(1) RENEWABLES OUTPUT FORECAST OVER THE PEAK PERIOD, AND(2) DELTA BASE TO PEAK

	Average Resiliency To 0.5 GW Price Inelastic Sell Order	Average Resiliency To 1 GW Price Inelastic Sell Order	Average Resiliency To 1.5 GW Price Inelastic Sell Order	
OFF-PEAK 1	-1.05	-2.27	-3.86	
PEAK	-0.83	-1.72	-2.59	
OFF-PEAK 2	-0.97	-1.93	-3.33	





COEFFICIENTS ESTIMATES

	Estimate	Std. Error	t value	Pr(> t)	Signif.
Intercept	(-) 07.20	0.66	(-) 10.93	< 2e-16	***
Bank Holiday Non Sunday	(-) 13.14	1.09	(-) 12.06	< 2e-16	***
Monday Before Bank Holiday	(-) 08.35	3.37	(-) 02.48	0.0133	*
1 Day Before BH Non Sun & Mon	(-) 04.81	1.38	(-) 03.48	0.0005	***
2 Days Before BH Sat / Sun / Mon	(-) 03.31	1.37	(-) 02.42	0.0156	*
Monday	14.24	0.76	18.85	< 2e-16	***
Tuesday	15.16	0.75	20.16	< 2e-16	***
Wednesday	16.01	0.75	21.27	< 2e-16	***
Thursday	16.02	0.75	21.35	< 2e-16	***
Friday	14.65	0.75	19.59	< 2e-16	***
Saturday	07.51	0.75	10.02	< 2e-16	***
Lag Extreme Low Temperature	03.78	0.38	09.96	< 2e-16	***
Renewables (RES) Peak Forecast	(-) 1.17 e-03	0.057 e-03	(-) 20.45	< 2e-16	***
Delta Base to Peak RES Forecast	(-) 1.93 e-03	0.148 e-03	(-) 13.08	< 2e-16	***

Multiple R-squared: 0.5738, Adjusted R-squared: 0.5687, F-statistic: 111.9 on 13 and 1080 DF, p-value: < 2e-16



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THE DYNAMICS OF RENEWABLES IMPACT ESTIMATES



- THE ESTIMATES FOR THE RENEWABLES IMPACT ON THE DEPENDENT VARIABLE RANGED:
 - FROM (-) 0.00122 TO (-) 0.00116 OVER PEAK HOURS. THAT IS **1GW MORE RENEWABLES OUTPUT OVER THE PEAK PERIOD DECREASED THE DEPENDENT VARIABLE BY €/MWh 1.16 TO €/MWh 1.22.**
 - FROM (-) 0.00216 TO (-) 0.00190 ON DELTA BASE TO PEAK. 1GW DELTA BASE TO PEAK (OR EQUIVALENTLY, 2GW MORE RENEWABLES OUTPUT OVER THE OFF-PEAK THAN OVER THE PEAK) DECREASED THE DEPENDENT VARIABLE BY €/MWh 1.90 TO €/MWh 2.16MORE.







QUANTIFYING THE IMPACT OF RENEWABLES



- FROM THE COEFFICIENTS ESTIMATES, ONE FINDS THAT WITHOUT THE RENEWABLES, THE AVERAGE GERMAN/AUSTRIAN BASELOAD OVER 2013 WOULD HAVE BEEN AT BEST €/MWh 7.83 HIGHER THAN THE REALIZED (€/MWh 45.61 VERSUS €/MWh 37.78.)
- THE BOOM IN RENEWABLES IS NOT THE ONLY DRIVER IN THE DROP IN AVERAGE POWER PRICES THE CRASH IN EUA CARBON ALLOWANCES, AND THE DECREASE IN COAL PRICES HAVE CONTRIBUTED TO THE DECLINE IN ELECTRICITY PRICES, AMID A GENERAL DEMAND DECLINE AND OVERSUPPLY OF GENERATION CAPACITY.





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NEGATIVE PRICES THEORY



• THE COMBINATION OF LOW DEMAND, HIGH RENEWABLES AND OPERATIONALLY INFLEXIBLE GENERATION, AND LIMITED AVAILABLE TRANSMISSION CAPACITIES TO EXPORT THE EXCESS OF LOCAL GENERATION TO THE OTHER REGIONS MIGHT PRODUCE NEGATIVE PRICES.

EUROPEAN POWER EXCHANGE



NEGATIVE PRICES EXPERIENCE



- THE NUMBER OF NEGATIVE HOURLY PRICES HAS NOT TREMENDOUSLY INCREASED POST 2010.
- NEGATIVE PRICES OCCURRED MOST IMPORTANTLY OVER LOW DEMAND OFF-PEAK 1 HOURS.
- ABOVE HISTORICAL NUMBER OF NEGATIVE HOURS OVER PEAK HOURS HAS BEEN RECORDED IN 2013 ON HIGHER INSTALLED PV CAPACITY AND ABOVE NORMAL TEMPERATURES.
- IN COMPARISON TO OTHER WELL ESTABLISHED POWER MARKETS (SUCH AS, PJM NORTHERN, MISO LOWA ZONE, ERCOT WEST), THE PERCENTAGE OF NEGATIVE HOURLY PRICES IS STILL VERY LOW (0.7% IN 2013 ON EPEX GERMANY/AUSTRIA DAY-AHEAD MARKET.)





NEGATIVE PRICES

IMPORTANT PRICE SIGNAL – NOT INHERENTLY BAD IN ITSELF



- NEGATIVE PRICES, IF DRIVEN BY PHYSICAL AND ECONOMIC CONSTRAINTS, ARE FUNDAMENTALLY COMPATIBLE WITH, AND DO NOT UNDERMINE THE PRINCIPLES OF COMPETITIVE ELECTRICITY WHOLESALE MARKETS.
- THEY SEND THE RIGHT SIGNALS, FOR THE REQUIRED FLEXIBILITY (TECHNOLOGY AND CAPACITY) AND INCITIVES THAT HAVE TO COME INTO PLAY TO PROMOTE THIS FLEXIBILITY.



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