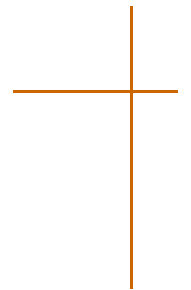


Spanish Electricity Market Case Study Estadística II

Eugenio Sánchez Úbeda
May 2020



Introduction



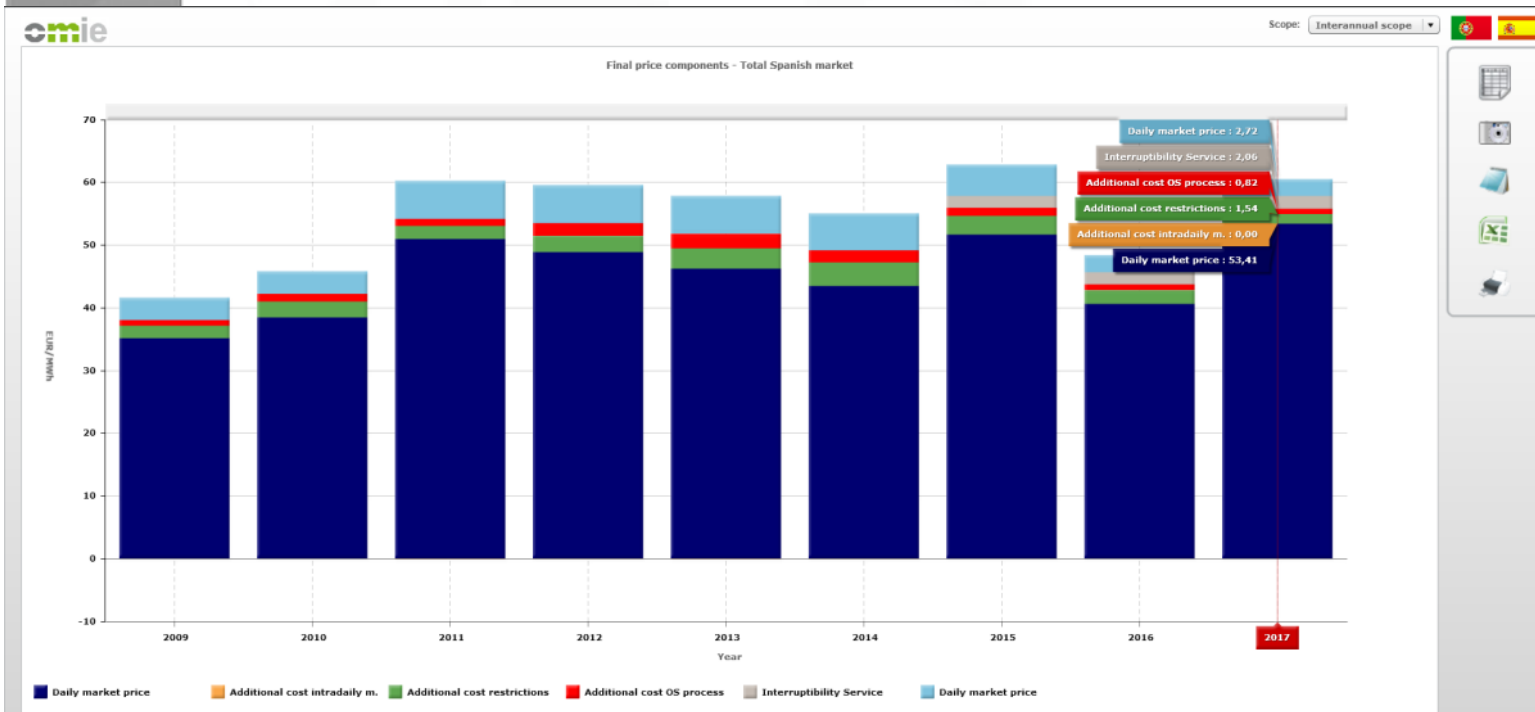
Spanish Electricity Market

- OMIE (www.omie.es/en/) manages the **wholesale electricity market** (referred to as cash or “spot”) on the Iberian Peninsula. Like any other, the electricity market caters for the trading of electricity between agents (producers, consumers, retailers, etc.) at a price that is known, transparent and accessible. At OMIE, we guarantee that the market is operated in a transparent and non-discriminatory manner. In **January 1998** we began our operations for the **Spanish market**, and in **July 2007** we extended them to cover the whole of the **Iberian Market**.
- According to www.esios.ree.es/en/, the role of REE as **System Operator** consists on maintaining the balance generation-consumption and, for this purpose, it produces the electricity demand forecasts, oversees the operation of the generation facilities and manages the transmission facilities in real-time, constantly ensuring that scheduled generation in power stations matches consumer demand.

Market Products

- Market Operator (MO)
 - Daily Market
 - Intraday Market
- System Operator (SO)
 - Interruptibility Service
 - Capacity Payment
 - Adjustment Services

<http://www.omie.es/files/flash/ResultadosMercado.swf>



- Technical constraints
- Secondary reserve
- Tertiary reserve
- Upward reserve power
- Imbalances

Daily market Intradaily market Average final prices

Interannual final price - Total Spanish demand

Interannual final price - Free market

Interannual final price - Reference retailers

Final price components - Total Spanish market

Final price components - Free market

Final price components - Reference retailers

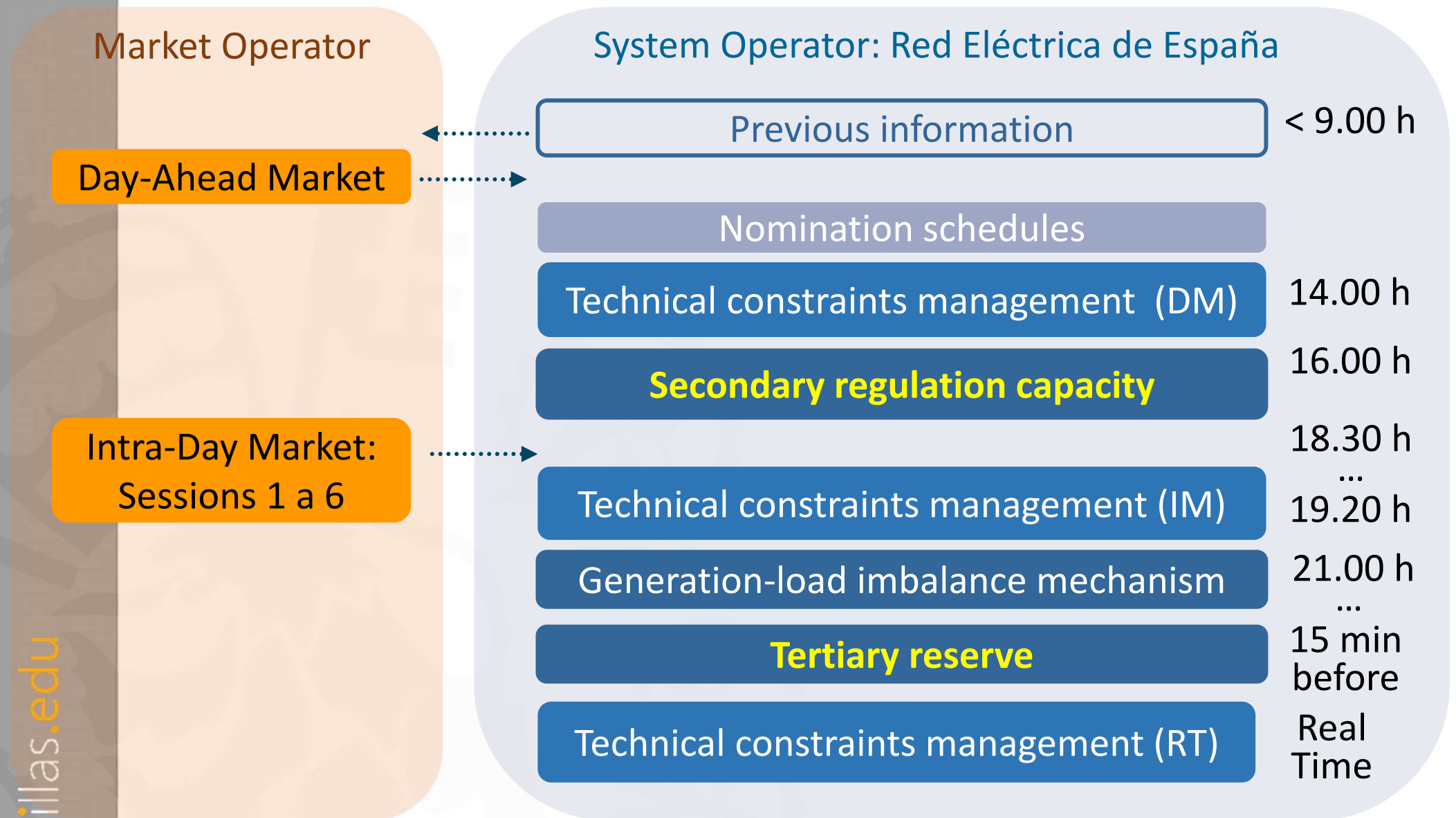
Hide menu

Files access

Historical access

Help

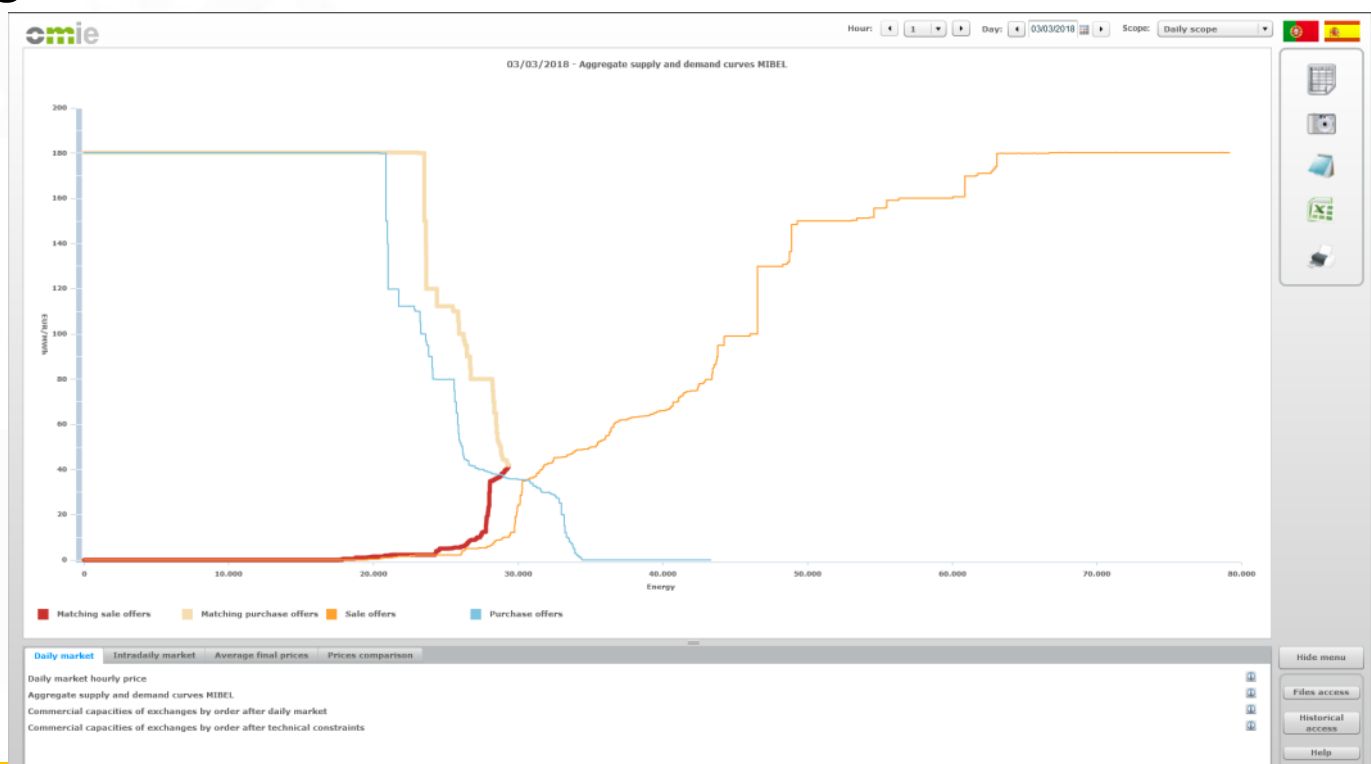
Short-term operation scheduling



Source: M. de la Torre, J. Paradinas *Integration of renewable generation. The case of Spain*

Spanish Daily Electricity Market

- In the day-ahead market, buying and selling agents submit their purchase and sale bids for the twenty-four hours of the following day. The price and volume of energy over a specific hour are determined by the point at which the supply and demand curves meet, according to the marginal pricing model adopted by the EU, based on the algorithm approved for all European markets (EUPHEMIA). The scheduled generation of each unit is also obtained as result of this algorithm.



Spanish Daily Electricity Market

- Market price as a function of the technologies

More about the **electricity market**

[+ info](#)

More about the **European market**

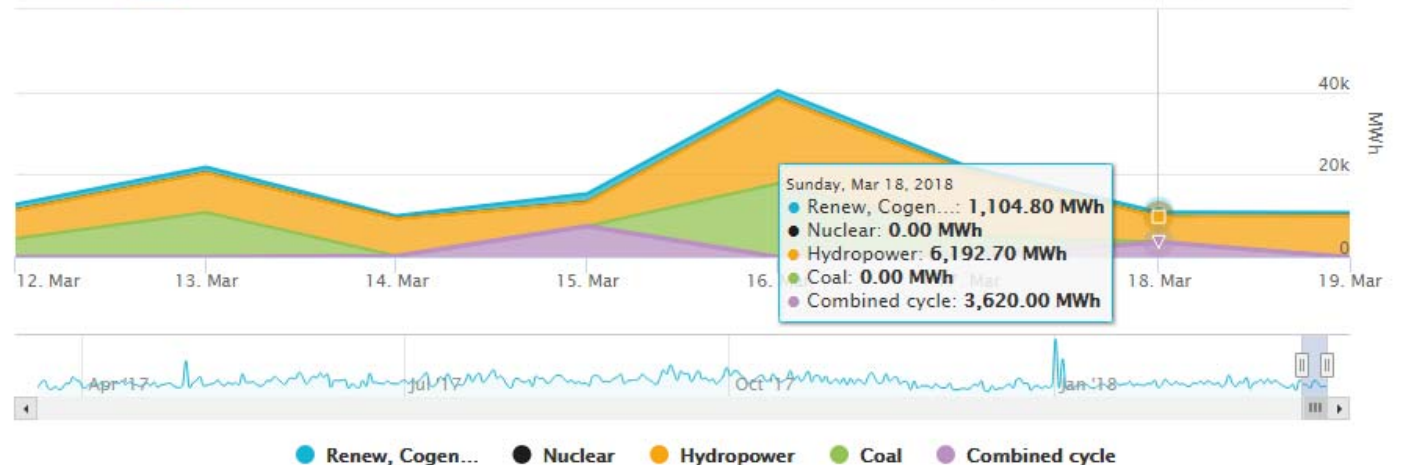
[+ info](#)

Spain Portugal

Technologies that mark the market price

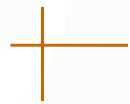
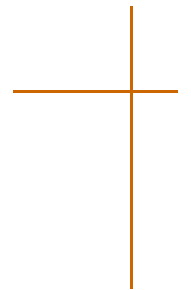
Zoom 1d **1w** 1m 6m 1Y

From 12/03/2018 To 19/03/2018





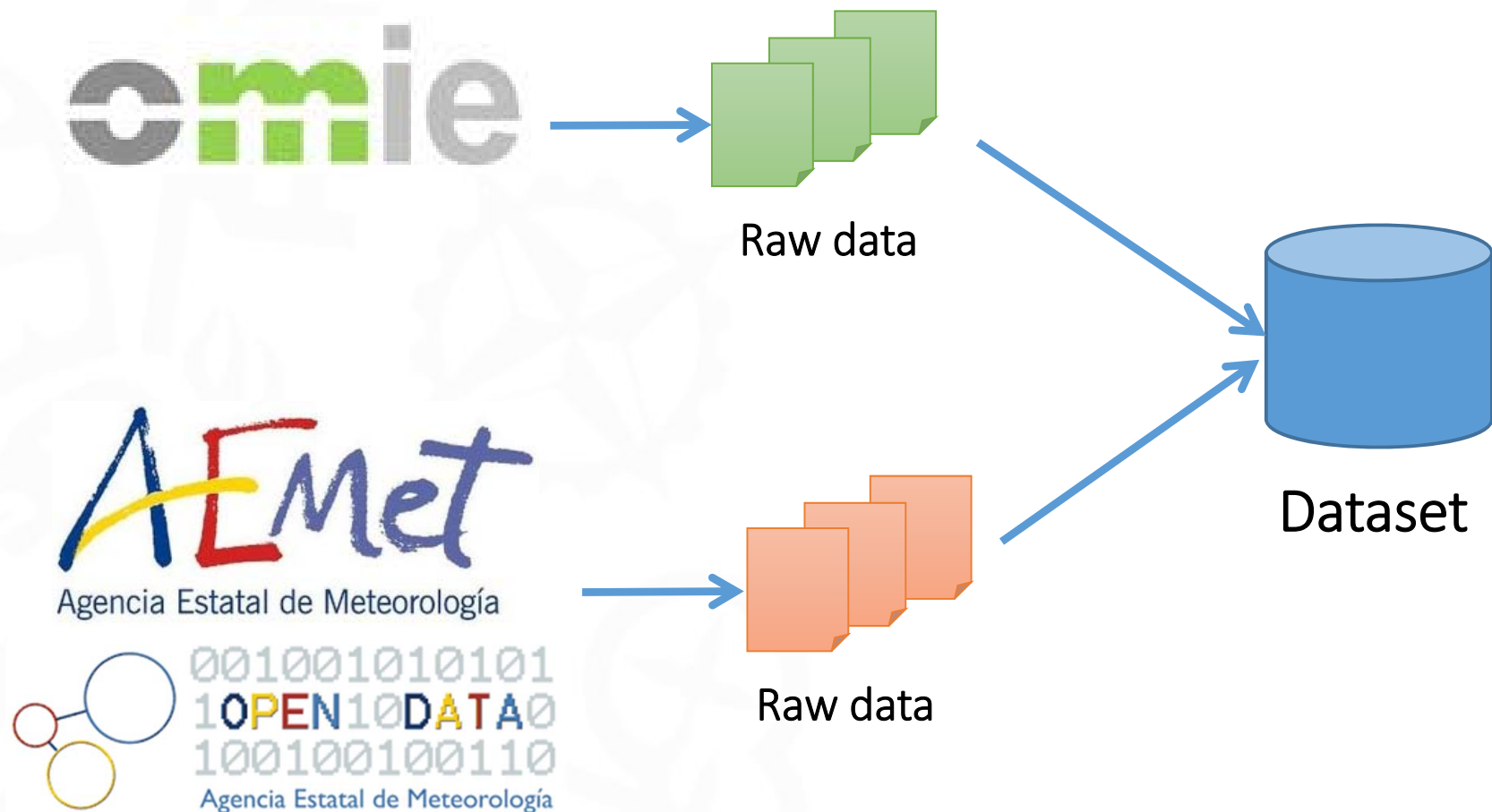
Dataset



Dataset

From raw data to structured data

- Prepare the data for the analysis



Dataset

Daily data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	FECHA	MES	DIA	ANNO	DIASEM	L	M	X	J	V	S	D	DEM	TMIN_OVIEDO	TMIN_SANTANDER	TMIN_BILBAO
2	01/01/2014	1	1	2014	3	0	0	1	0	0	0	0	598262	5,1	10,7	8,2
3	02/01/2014	1	2	2014	4	0	0	0	1	0	0	0	665506	8,8	12,7	9,4
4	03/01/2014	1	3	2014	5	0	0	0	0	1	0	0	668607	12,7	12,0	12,7
5	04/01/2014	1	4	2014	6	0	0	0	0	0	1	0	670662	8,1	13,1	11,5
6	05/01/2014	1	5	2014	7	0	0	0	0	0	0	1	641586	6,8	5,6	6,8
7	06/01/2014	1	6	2014	1	1	0	0	0	0	0	0	591327	16,9	16,6	14,0
8	07/01/2014	1	7	2014	2	0	1	0	0	0	0	0	677469	8,6	12,7	17,1
9	08/01/2014	1	8	2014	3	0	0	1	0	0	0	0	721111	10,2	13,6	8,2
10	09/01/2014	1	9	2014	4	0	0	0	1	0	0	0	708195	9,5	12,5	14,4
11	10/01/2014	1	10	2014	5	0	0	0	0	1	0	0	715452	8,3	10,1	6,6
12	11/01/2014	1	11	2014	6	0	0	0	0	0	1	0	642302	7,6	12,2	10,2
13	12/01/2014	1	12	2014	7	0	0	0	0	0	0	1	609819	5,4	7,6	8,6
14	13/01/2014	1	13	2014	1	1	0	0	0	0	0	0	732623	6,1	10,4	9,0
15	14/01/2014	1	14	2014	2	0	1	0	0	0	0	0	756649	8,0	6,8	10,5

Dataset

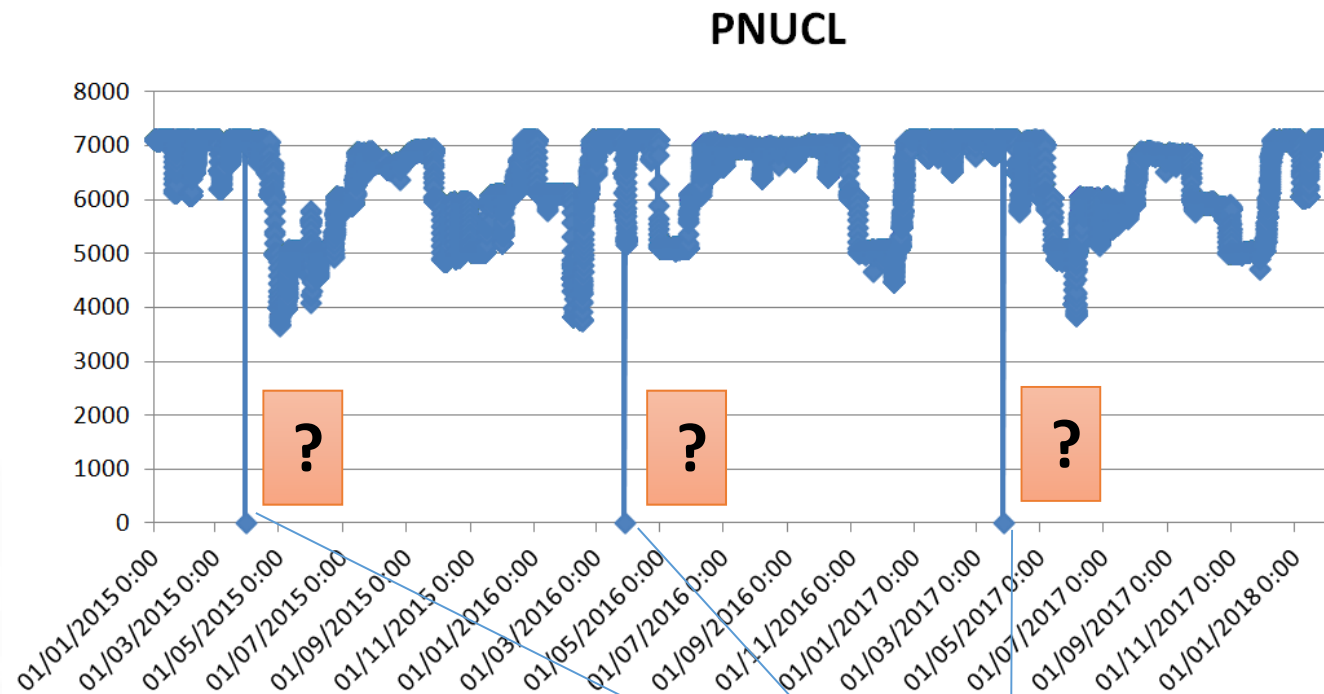
Hourly data

- Data from 1/1/2015 to 28/2/2018 (approx. 3 years)

DATE	MONTH	DAY	YEAR	HOUR	WEEKDAY	PBOMB_V	PCARBON	PCC	PCOGN	PEOL	PFG	PHIDCONV	PNUCL	PSOLFOT	PSOLTERM	PTERMNORV	PTERMRV	PTOT	PRECIO
01/01/2015 0:00	1	1	2015	0	5	0	5077,9	3458,1	1586,9	5517,4	421,6	2621,9	7105	0	16	0	486,4	26291,2	50,1
01/01/2015 1:00	1	1	2015	1	5	0	5086,3	3789,5	1591,2	5034,4	422,3	2532,3	7104	0	16	0	486,4	26062,4	48,1
01/01/2015 2:00	1	1	2015	2	5	0	4827,6	3458,9	1584,6	4674,8	422,5	2421,8	7104	0	7	0	486	24987,2	47,33
01/01/2015 3:00	1	1	2015	3	5	0	4382,7	3066	1585,3	4257,6	421,8	1742,5	7104	0	0	0	486,1	23046	42,27
01/01/2015 4:00	1	1	2015	4	5	0	3925,6	2722,4	1534,5	4130,3	421,2	1612,1	7104	0	7	0	469,8	21926,9	38,41
01/01/2015 5:00	1	1	2015	5	5	0	3734,3	2716,1	1537,7	3735	421,9	1613,4	7104	0	0	0	453,6	21316	35,72
01/01/2015 6:00	1	1	2015	6	5	0	3407,7	2693,6	1547	3412	422,7	1831	7104	0	0	0	455,2	20873,2	35,13
01/01/2015 7:00	1	1	2015	7	5	0	3204,6	2639,8	1589,8	3173,9	423,1	1976,6	7105	56,4	0	0	457,5	20626,7	36,22
01/01/2015 8:00	1	1	2015	8	5	0	3412	2639,8	1619,3	2893	422	2157,3	7105	216,6	0	0	458,7	20923,7	32,4
01/01/2015 9:00	1	1	2015	9	5	0	3223,1	2658,8	1619,2	2739	421,4	2379,7	7105	944,5	5	0	461,3	21557	36,6
01/01/2015 10:00	1	1	2015	10	5	0	3514	2465,4	1635,1	2640,9	419,9	2700,7	7105	1868,5	176,9	0	475,9	23002,3	43,1
01/01/2015 11:00	1	1	2015	11	5	0	4265,9	2358,6	1642,1	2549,5	415,7	2618,2	7105	2495,2	809,9	0	462,4	24722,5	45,14
01/01/2015 12:00	1	1	2015	12	5	0	4508,8	2337,8	1630,6	2574,9	414,4	2457,2	7105	2749	1112,1	0	463,8	25353,6	45,14
01/01/2015 13:00	1	1	2015	13	5	0	4537,6	2344,8	1625,9	2506,8	417,4	2381,1	7104	2776	1109,5	0	463,7	25266,8	47,35
01/01/2015 14:00	1	1	2015	14	5	0	4400,7	2438,5	1624,3	2328,7	417,8	2187,7	7104	2555,5	1178,9	0	461,8	24697,9	47,35
01/01/2015 15:00	1	1	2015	15	5	0	4050,1	2322,6	1623,4	2270,8	417,2	2071,9	7104	2080,6	1334,8	0	462,9	23738,3	43,61
01/01/2015 16:00	1	1	2015	16	5	0	4394,7	2364,5	1628,7	2321,6	412,8	2063	7104	1207,8	1436,6	0	462,5	23396,2	44,91
01/01/2015 17:00	1	1	2015	17	5	0	5016,5	2479,8	1641,1	2489,5	416,9	2548,2	7104	340,5	999,4	0	460,3	23496,2	48,1
01/01/2015 18:00	1	1	2015	18	5	476,8	4923,3	3351,7	1697,3	2688,1	423,6	4004,8	7105	27,1	273,6	0	462,4	25433,7	58,02
01/01/2015 19:00	1	1	2015	19	5	1228,1	5301,3	2878,4	1706,5	2796,1	426,6	5215,8	7105	23,3	70,1	0	462,5	27213,7	61,01
01/01/2015 20:00	1	1	2015	20	5	1456	5305,3	2734,5	1708,7	2822,1	426,9	5974,4	7105	23,2	52	0	462,6	28070,7	62,69
01/01/2015 21:00	1	1	2015	21	5	1446	5367,1	3178,7	1710,6	2723,6	428,6	6125,7	7105	0	20	0	456,6	28561,9	60,41
01/01/2015 22:00	1	1	2015	22	5	1095	5351,9	3206,4	1708,2	2779,7	428,8	5405,9	7105	0	10	0	456,8	27547,7	58,15
01/01/2015 23:00	1	1	2015	23	5	543	5181	3215,7	1704,3	2862,4	428,7	4072,6	7105	0	10	0	452,8	25575,5	53,6
02/01/2015 0:00	1	2	2015	0	6	0	4990,2	3299,1	1679,9	2982,9	422,2	3257,8	7103,6	0	10	0	453,6	24199,3	47,34
02/01/2015 1:00	1	2	2015	1	6	0	4833,7	3487,4	1662	2817,5	422,5	2018	7102,6	0	10	0	453,7	22807,4	40,4
02/01/2015 2:00	1	2	2015	2	6	0	4856,3	3114,9	1659,8	2755,7	422,6	1547,1	7102,6	0	10	0	449,7	21918,7	36

Dataset

Preprocessing the data



FECHA	PBOMB_V	PCARBON	PCC	PCOGN	PEOL	PFG	PHIDCONV	PNUCL	PSOLFOT	PSOLTERM	PTERMNORV	PTERMRV
29/03/2015 23:00	0	0	0	0	0	0	0	0	0	0	0	0
27/03/2016 23:00	0	0	0	0	0	0	0	0	0	0	0	0
26/03/2017 23:00	0	0	0	0	0	0	0	0	0	0	0	0

There is no 23:00 hour in the days when clocks are changed due to Daylight Savings Time



Remove or **complete (better)** these hours with the data of the previous ones

Dataset

Variables

Variables	Descripción (P48)
MES	Mes
HORA	Hora
DIASEM	Día de la semana
DIA	Día
ANNO	Año
PBOMB_V	Total Venta Turbinación Bombeo
PCARBON	Total Carbón
PCC	Total Ciclo Combinado
PCOGN	Total Cogeneración
PEOL	Total Eólica
PFG	Total Fuel-Gas
PHIDRO	Total Hidráulica
PNUCL	Total Nuclear
PSOLFOT	Total Solar Fotovoltaica
PSOLTERM	Total Solar Térmica
PTERMNORV	Total Residuos No renovables
PTERMRV	Total Otras Renovables
PRECIO	Precio Mdo. Diario España
PRECIOD	Precio Mdo. Diario España discretizado



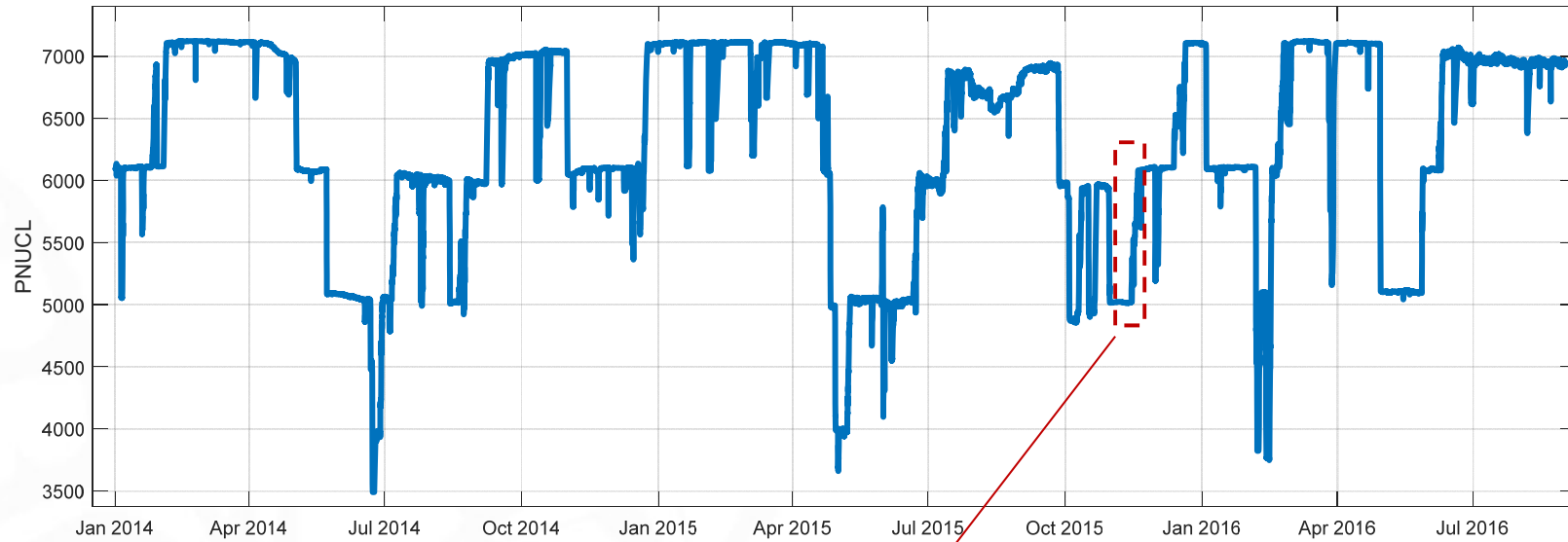
Question 1:

Does the generation of the different technologies vary with factors such as the month, the day of the week, or the hour?

Question 1

Exploratory analysis

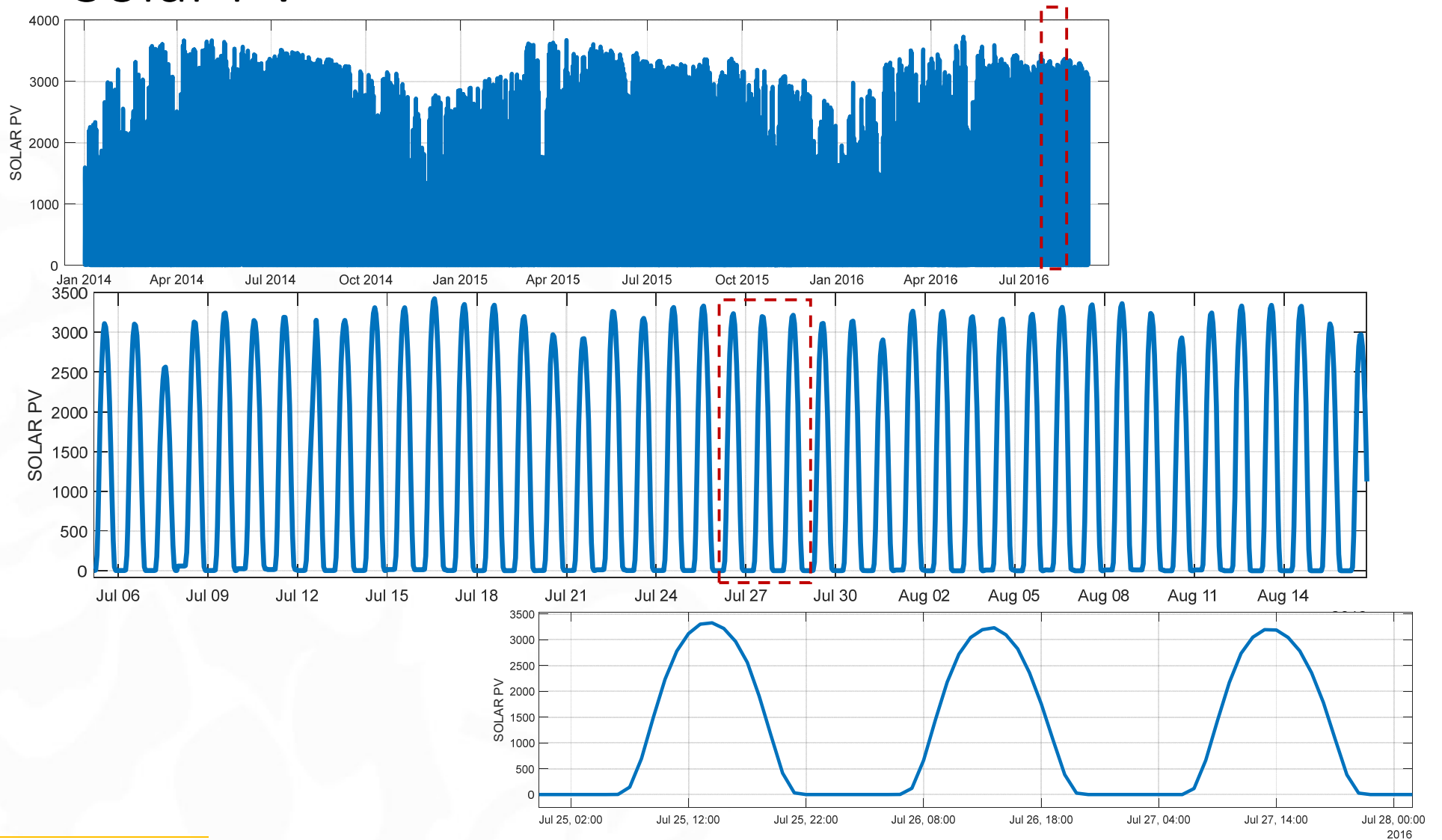
- Nuclear



Question 1

Exploratory analysis

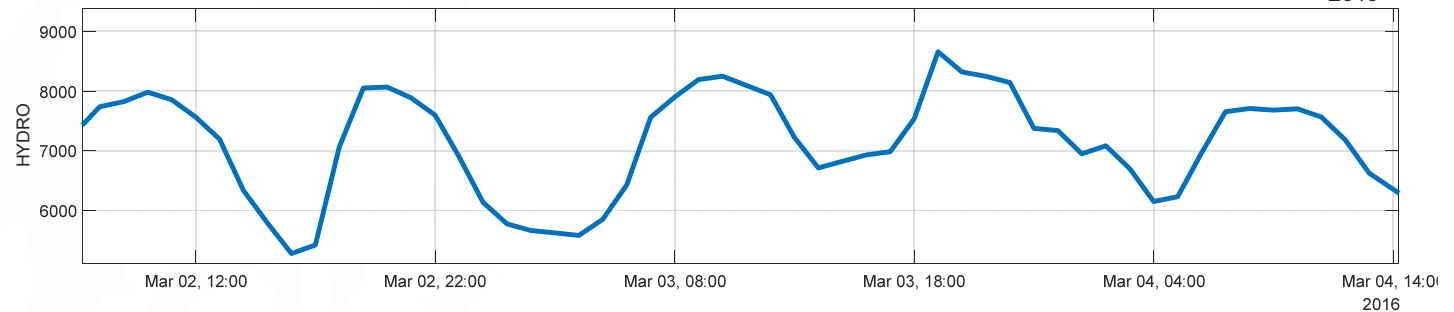
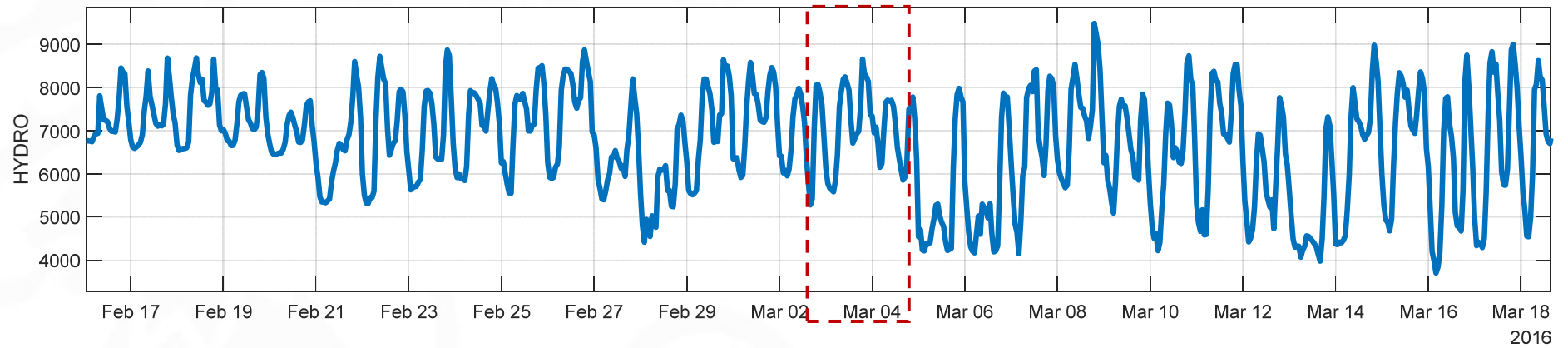
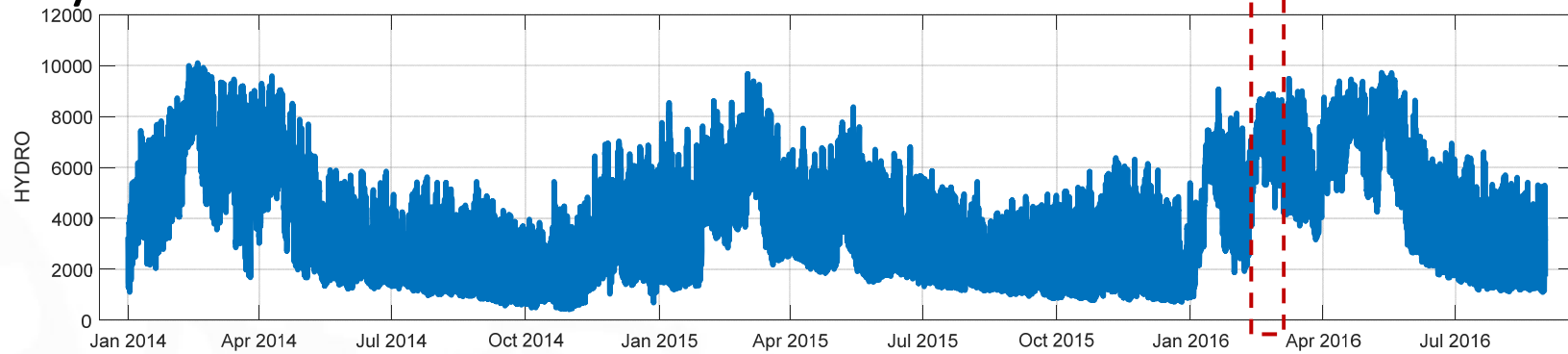
- Solar PV



Question 1

Exploratory analysis

- Hydro



Question 1

Robust answer

- Does the **generation of the different technologies vary with factors** such as the month, the day of the week, or the hour?



- **Data analytics with ANOVA**
 - Output: The produced energy with a given technology (MWh)
 - Inputs: factors such as month, weekday, hour, ...

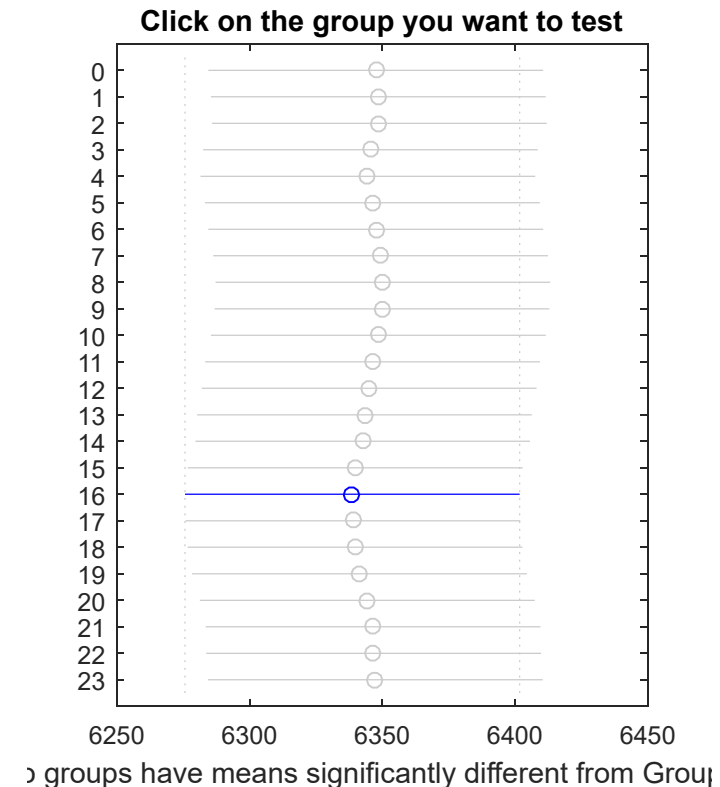
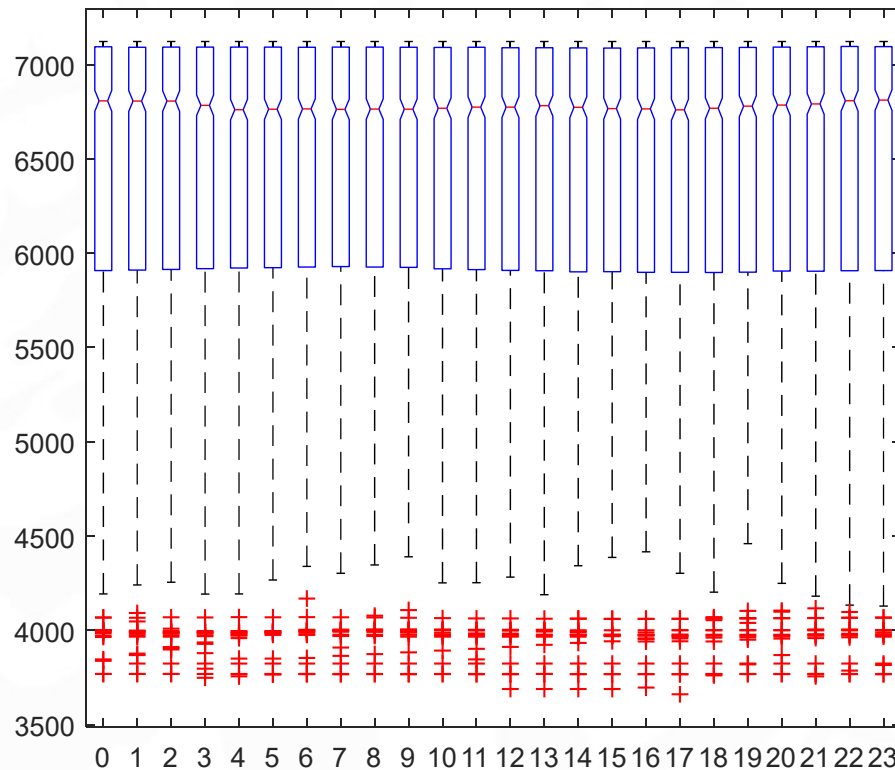
Question 1

ANOVA for Nuclear production (one-way)

- Nuclear versus HOUR

ANOVA Table					
Source	SS	df	MS	F	Prob>F
Groups	326577.9	23	14199	0.02	1
Error	18459961946.7	27144	680075.2		
Total	18460288524.6	27167			

It is clear that the Nuclear production doesn't depend on HOUR



Question 1

ANOVA for Nuclear production (two-way with interaction)

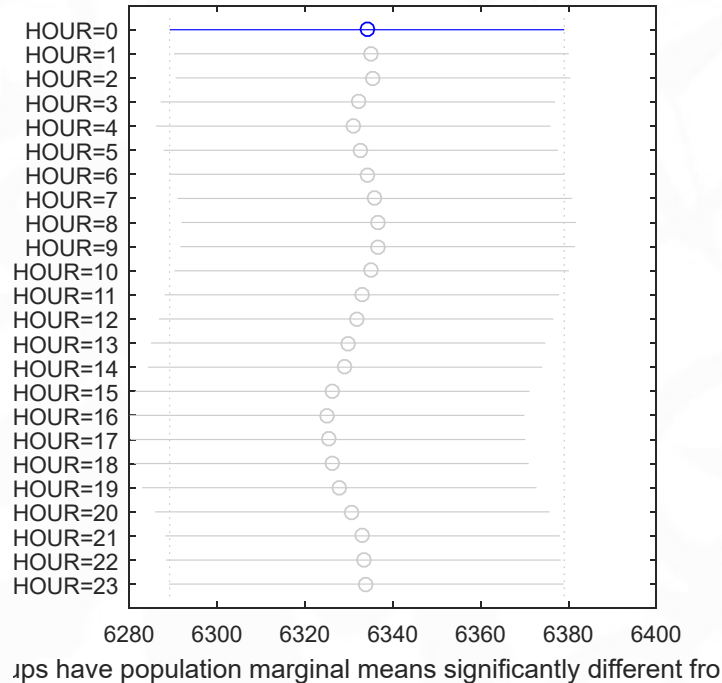
- Nuclear versus HOUR and MONTH

Analysis of Variance					
Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
HOUR	341002.2	23	14826.2	0.04	1
MONTH	9242424003.7	11	840220364	2451.05	0
HOUR*MONTH	3068404.5	253	12128.1	0.04	1
Error	9214469538.6	26880	342800.2		
Total	18460288524.6	27167			

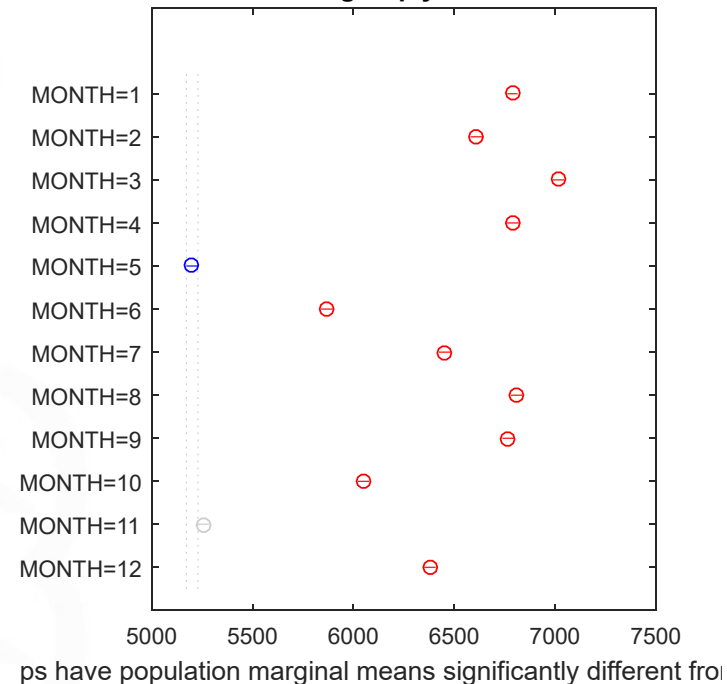
Constrained (Type III) sums of squares.

Nuclear production varies with the MONTH, not with the HOUR or its interaction with MONTH

Click on the group you want to test



Click on the group you want to test

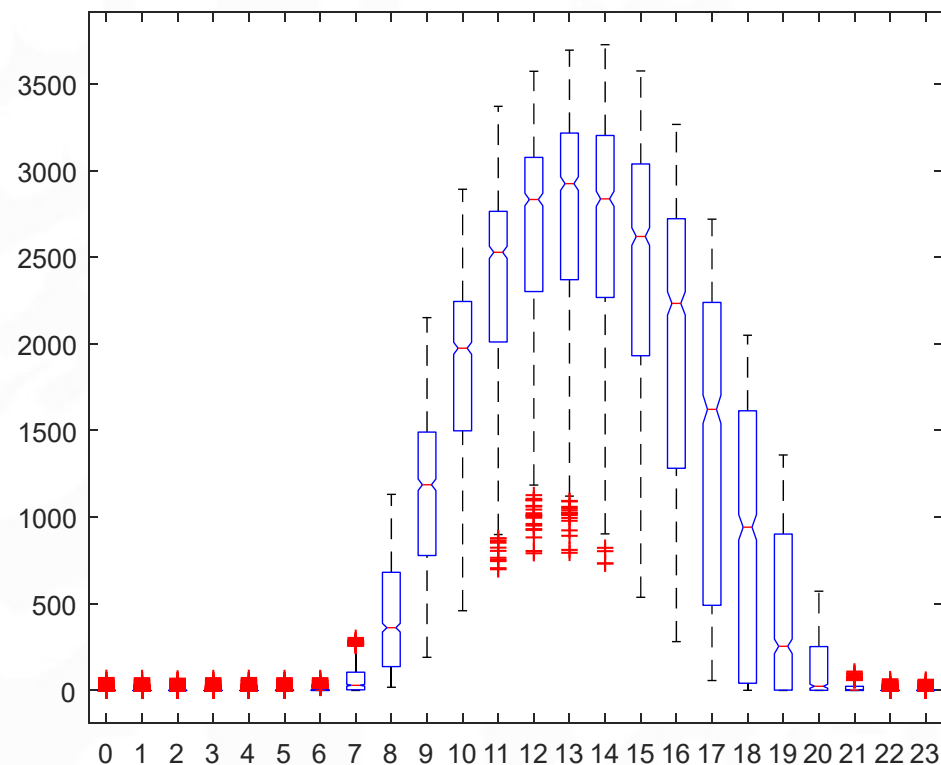


Question 1

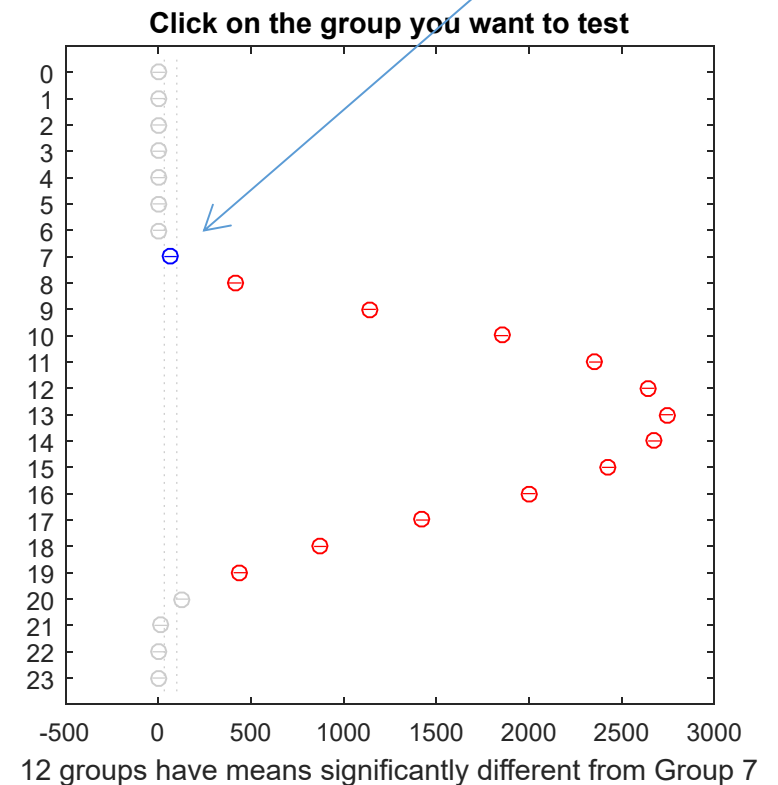
ANOVA for Solar PV (one-way)

- Solar PV versus HOUR

ANOVA Table					
Source	SS	df	MS	F	Prob>F
Groups	2.97379e+10	23	1292950114.7	6553.43	0
Error	5.35534e+09	27144	197293.7		
Total	3.50932e+10	27167			



Note that the solar-photovoltaic production in the range [0-7] and [20-23] hours can be considered null



Question 1

ANOVA for Solar PV (two-way without interaction)

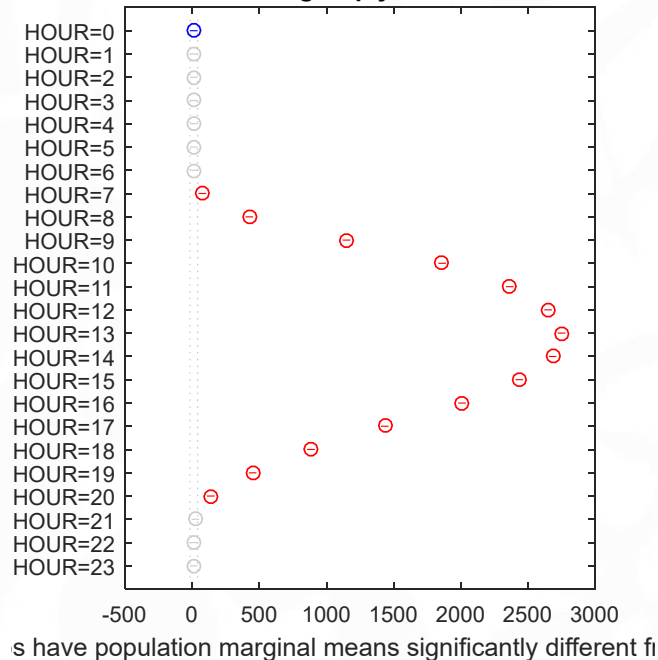
- Solar PV versus HOUR and MONTH

Analysis of Variance					
Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
HOUR	2.97379e+10	23	1292950114.7	9250.56	0
MONTH	1.56296e+09	11	142087610.8	1016.58	0
Error	3.79238e+09	27133	139769.9		
Total	3.50932e+10	27167			

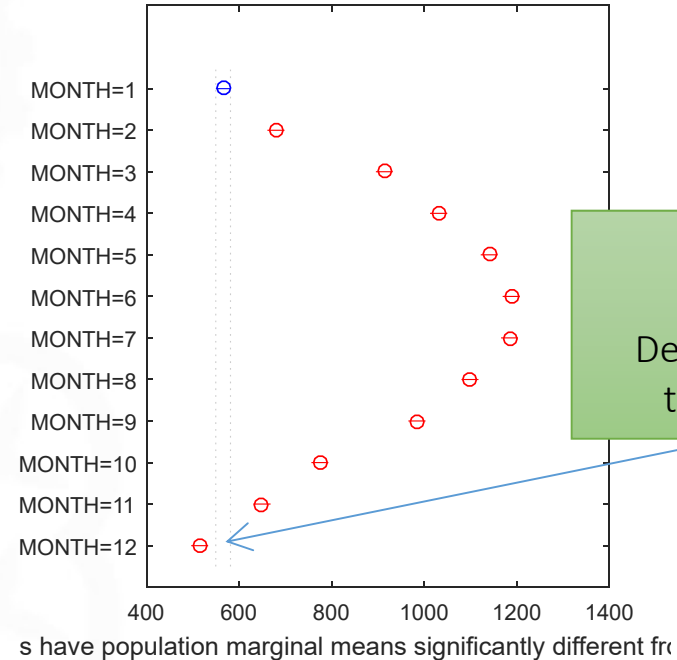
Constrained (Type III) sums of squares.

Solar-PV production depends on the HOUR and the MONTH

Click on the group you want to test



Click on the group you want to test



The solar-PV production in December is lower than in January

Question 1

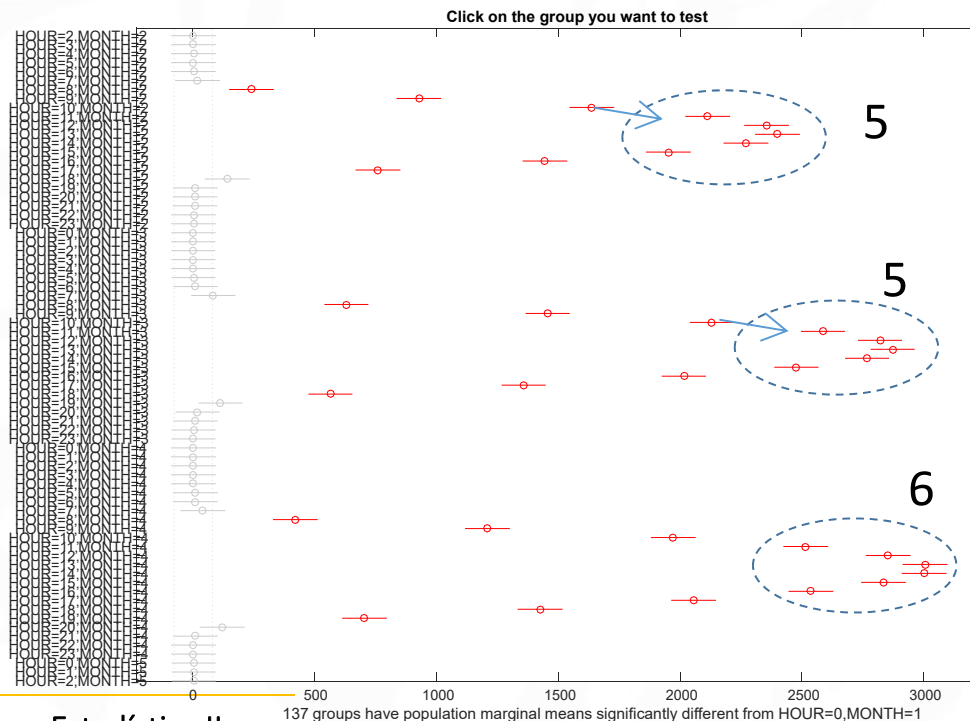
ANOVA for Solar PV (two-way with interaction)

- Solar PV versus HOUR and MONTH

Analysis of Variance					
Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
HOUR	2.99544e+10	23	1302364520.1	19237.48	0
MONTH	1.56296e+09	11	142087610.8	2098.8	0
HOUR*MONTH	1.97262e+09	253	7796913.6	115.17	0
Error	1.81976e+09	26880	67699.3		
Total	3.50932e+10	27167			

Constrained (Type III) sums of squares.

The interaction between HOUR and MONTH is also relevant



Analysis of Variance					
Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
HOUR	2.97379e+10	23	1292950114.7	9250.56	0
MONTH	1.56296e+09	11	142087610.8	1016.58	0
Error	3.79238e+09	27133	139769.9		
Total	3.50932e+10	27167			

Constrained (Type III) sums of squares.



With interaction the MSE decreases a lot!

Analysis of Variance					
Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
HOUR	2.99544e+10	23	1302364520.1	19237.48	0
MONTH	1.56296e+09	11	142087610.8	2098.8	0
HOUR*MONTH	1.97262e+09	253	7796913.6	115.17	0
Error	1.81976e+09	26880	67699.3		
Total	3.50932e+10	27167			

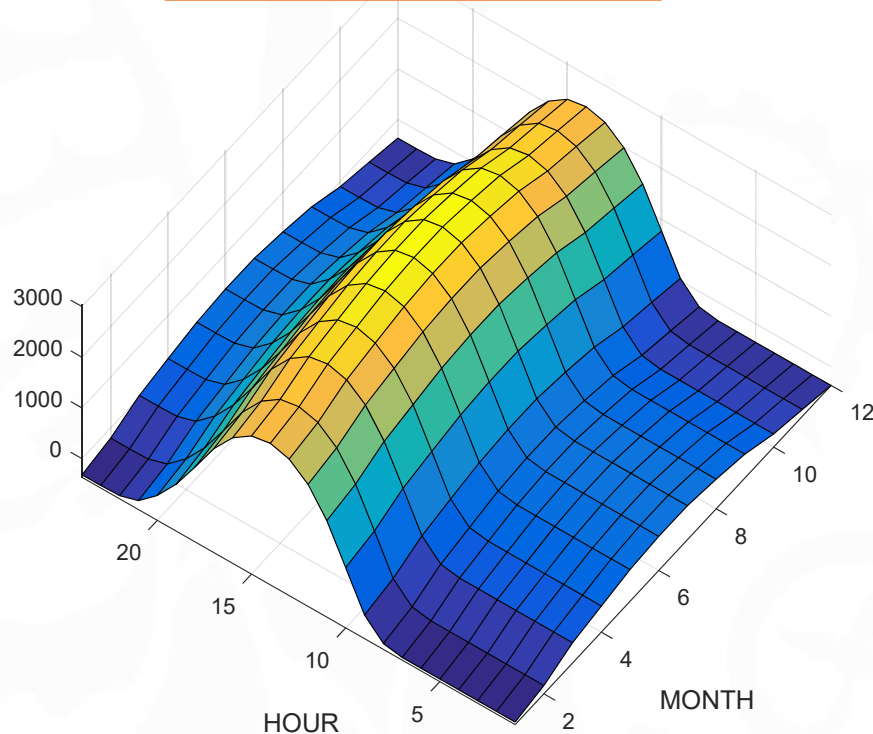
Constrained (Type III) sums of squares.

Question 1

ANOVA for Solar PV (two-way with interaction)

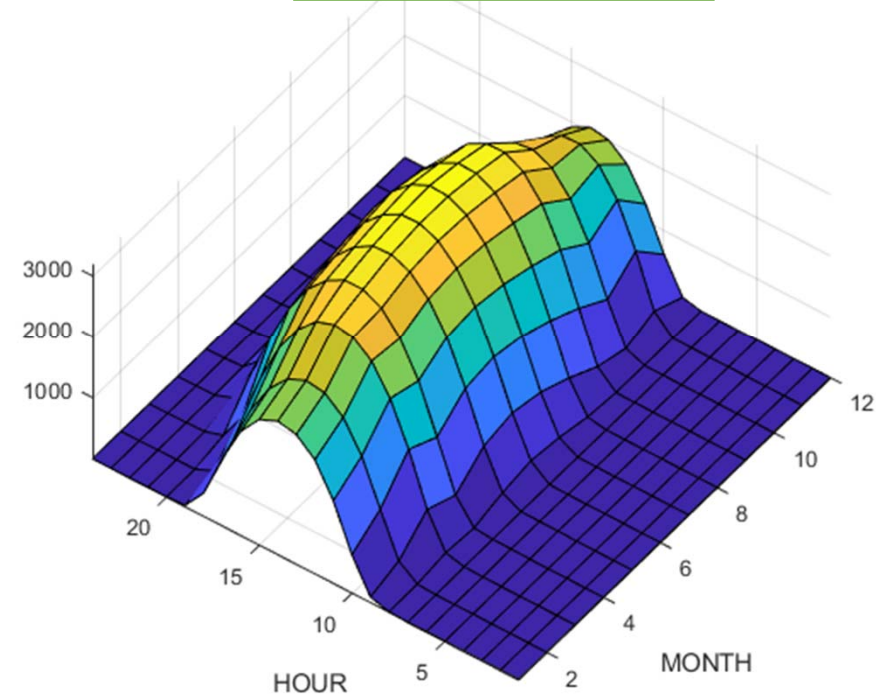
- Solar PV versus HOUR and MONTH (**full means models**)
 - Notice the difference

Without interaction



MSE: 139769.9 MWh²

With interaction



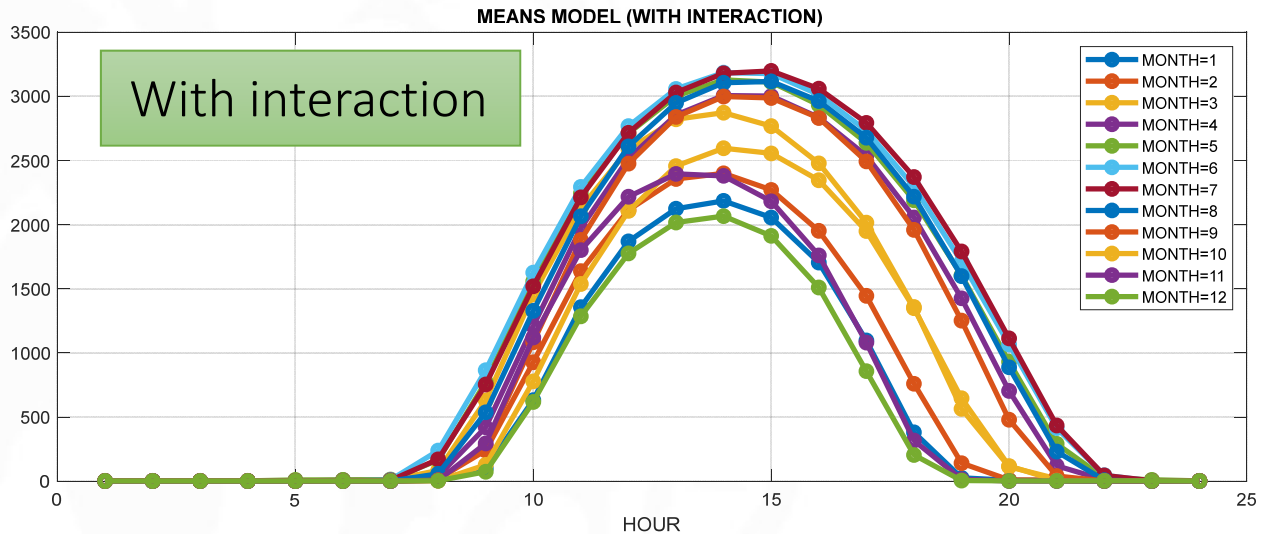
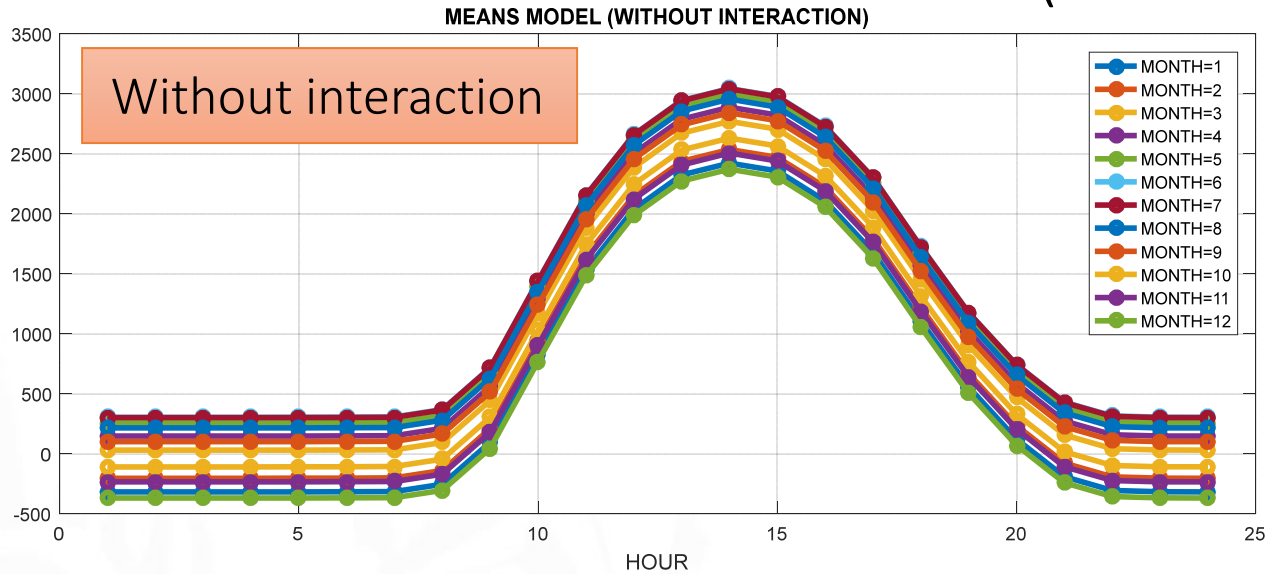
MSE: 67699.3 MWh²

Question 1

ANOVA for Solar PV (two-way with interaction)

- Solar PV versus HOUR and MONTH (full means models)

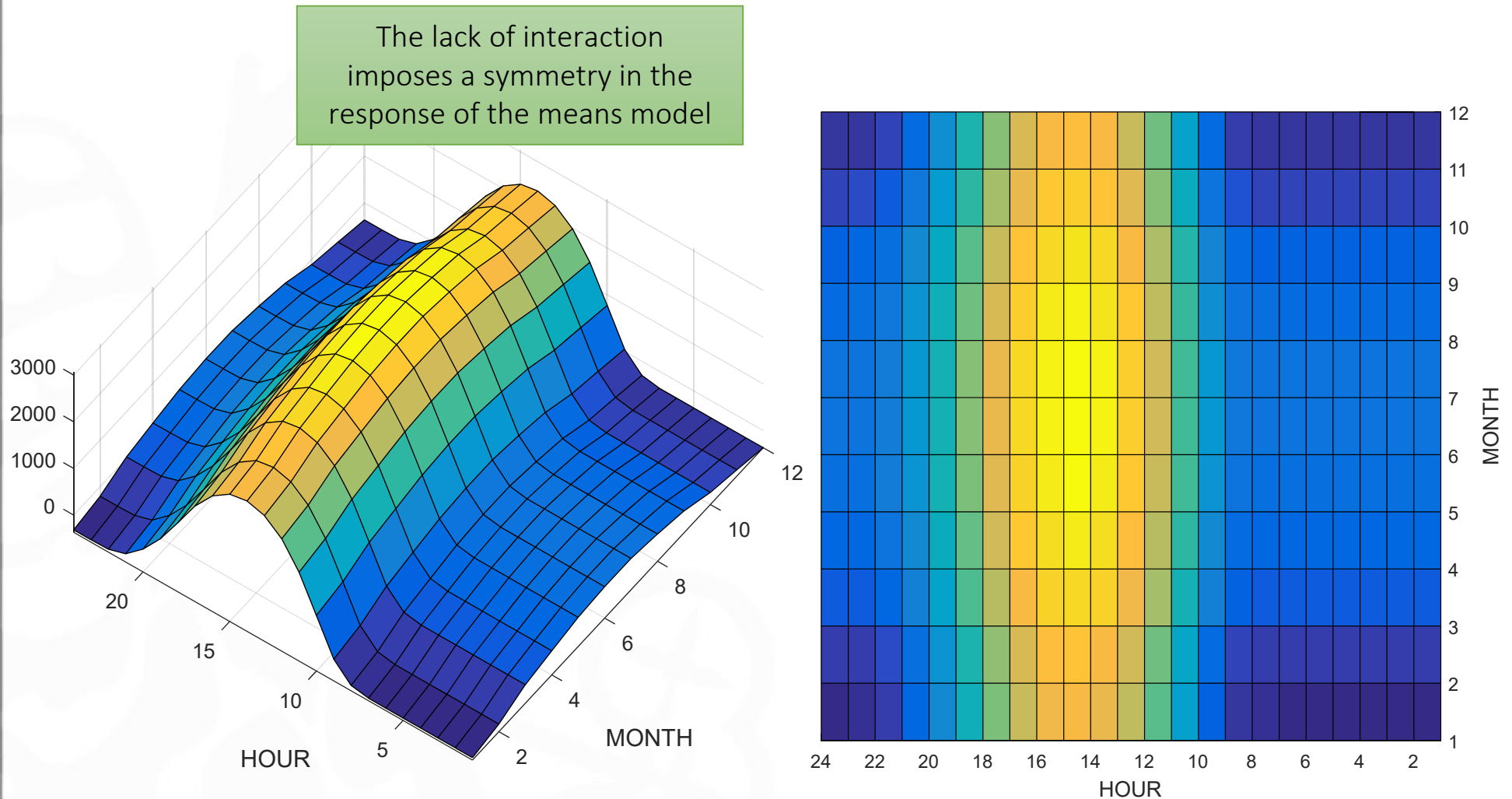
A different view of the means model



Question 1

ANOVA for Solar PV (two-way without interaction)

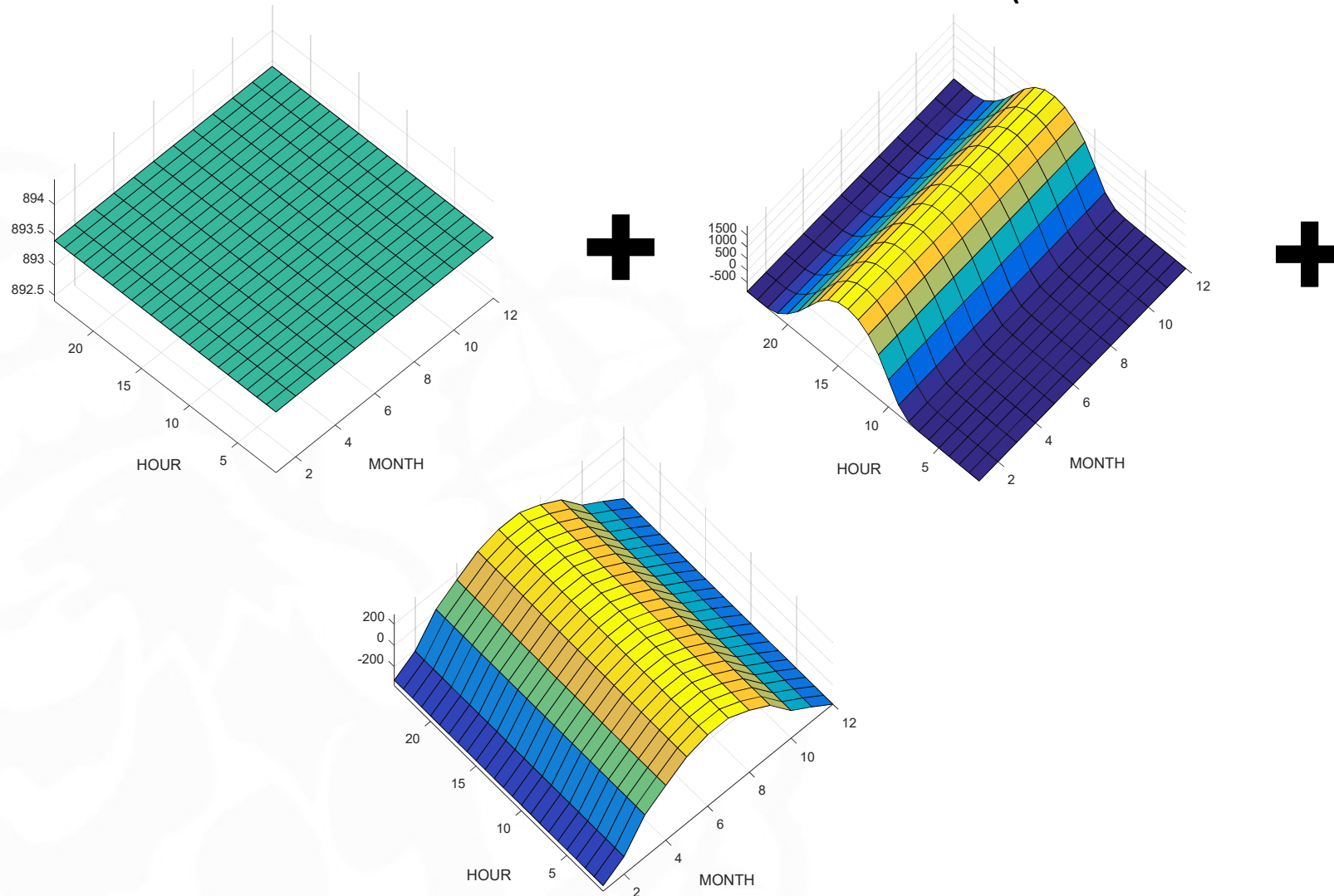
- Solar PV versus HOUR and MONTH (**full means model**)



Question 1

ANOVA for Solar PV (two-way without interaction)

- Solar PV versus HOUR and MONTH (**full means model**)

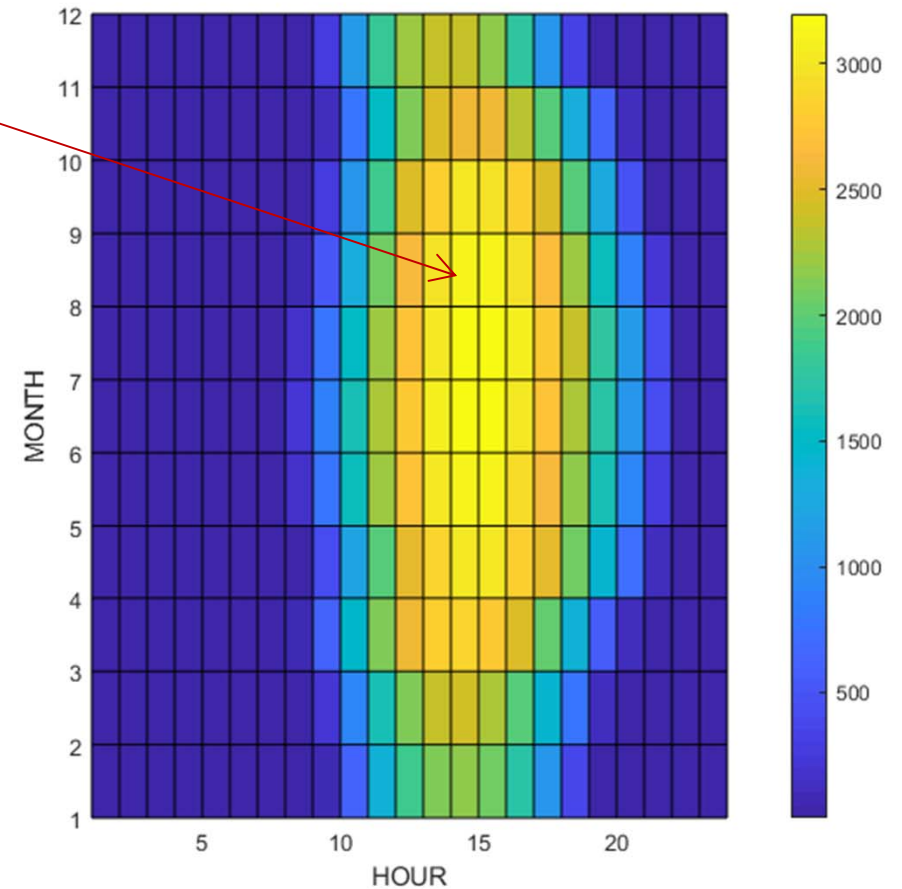
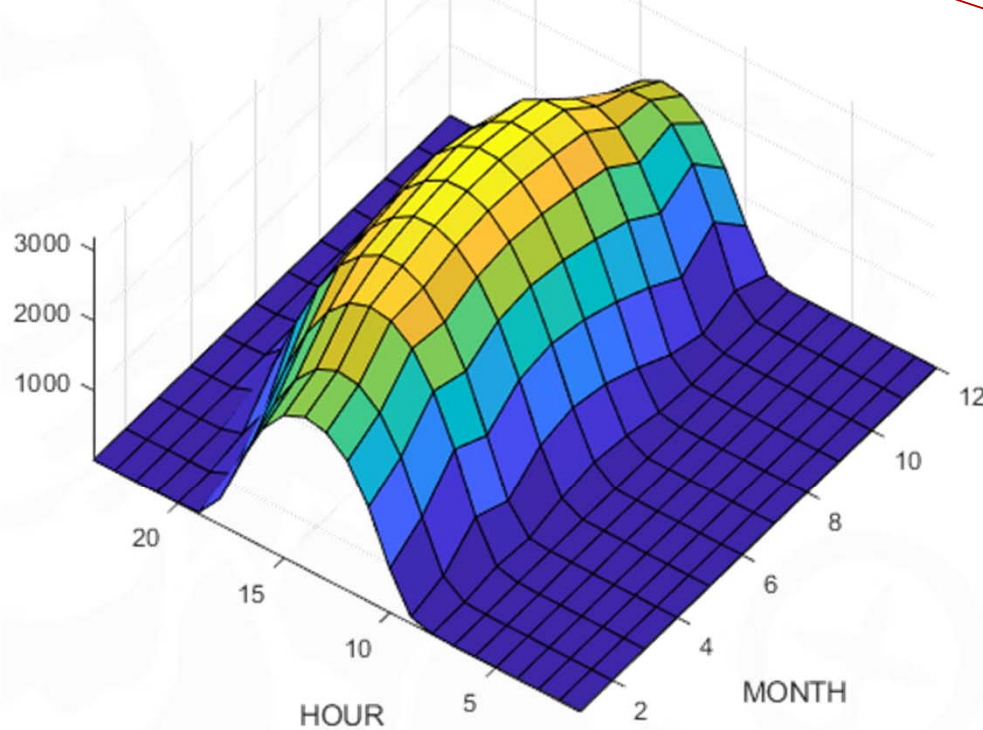


Question 1

ANOVA for Solar PV (two-way with interaction)

- Solar PV versus HOUR and MONTH (full means model)

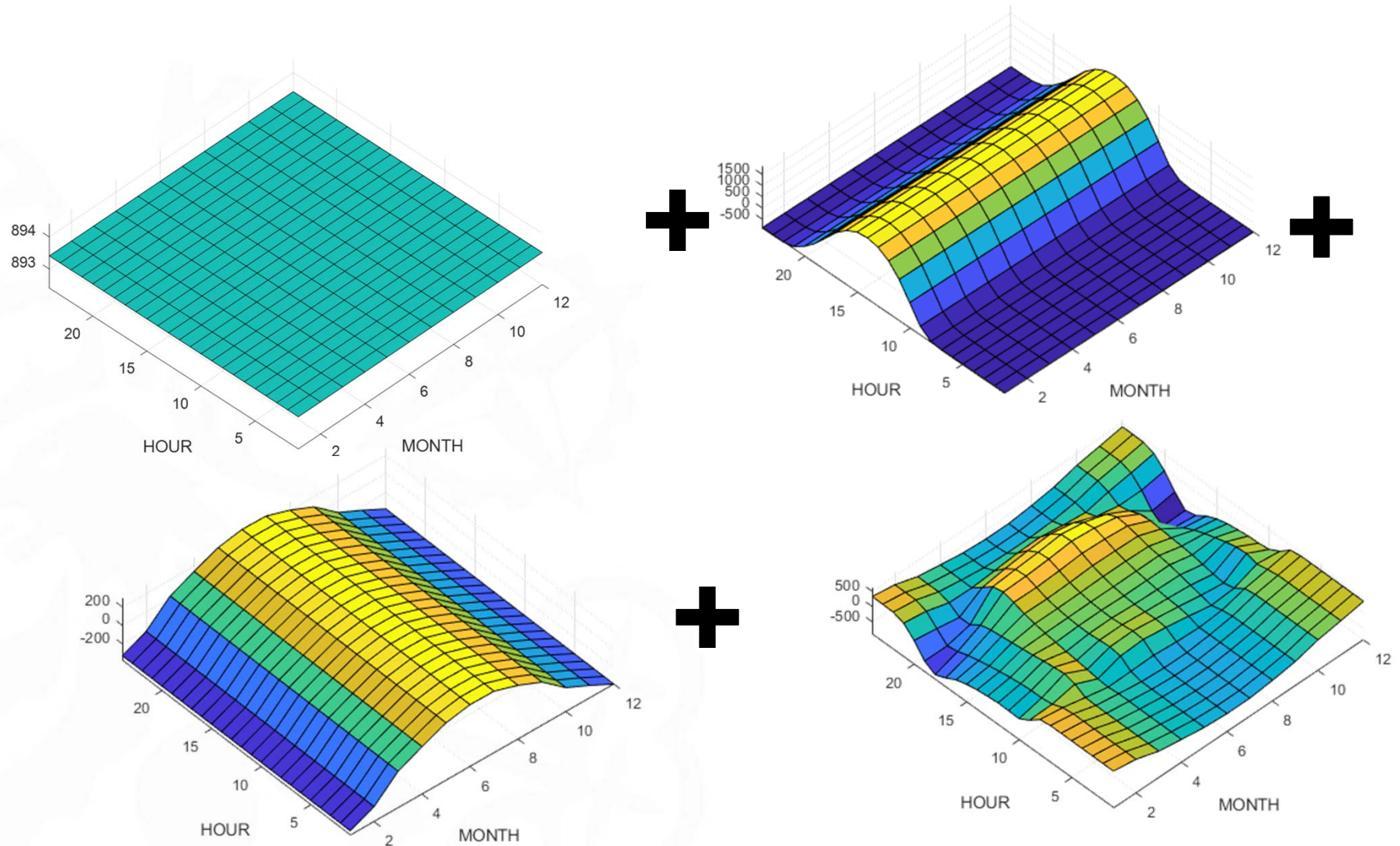
The interaction allows us to estimate a different hourly pattern for each month



Question 1

ANOVA for Solar PV (two-way with interaction)

- Solar PV versus HOUR and MONTH (**full means model**)



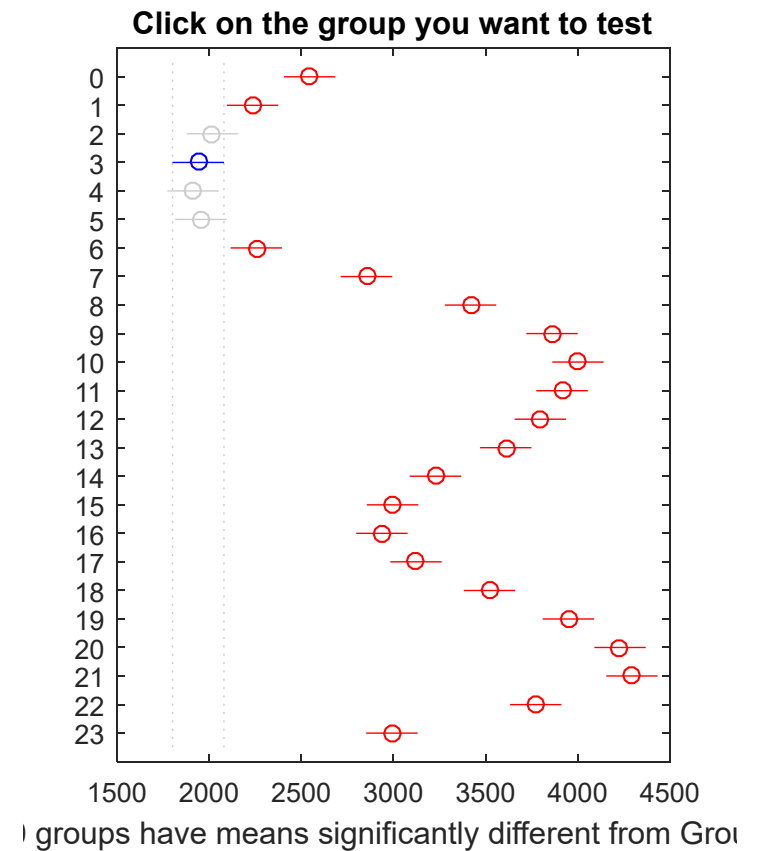
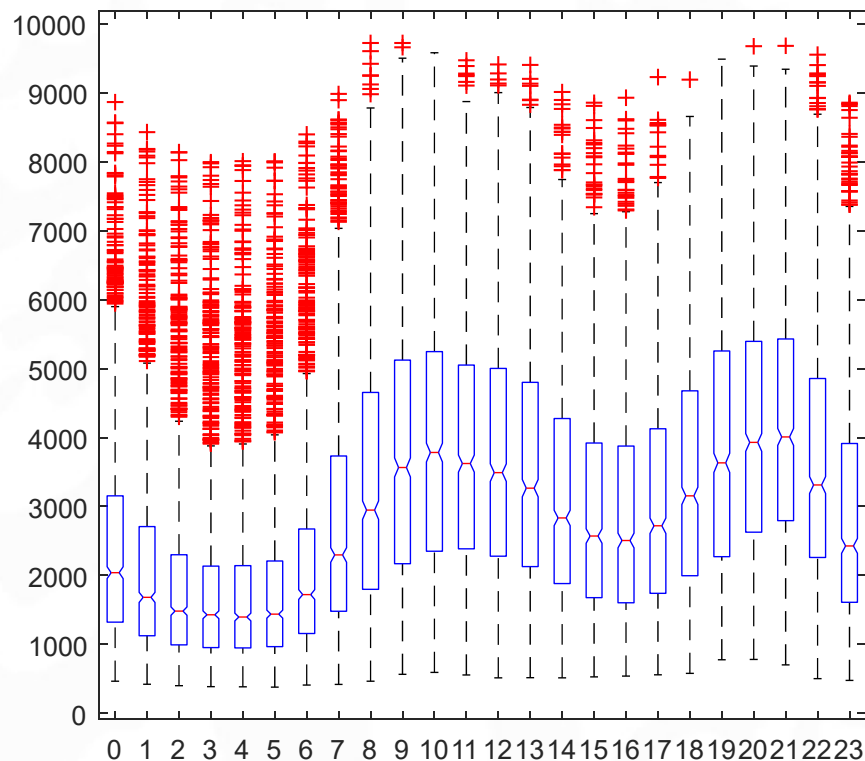
Question 1

ANOVA for Hydro production (one-way)

- Hydro versus HOUR

ANOVA Table					
Source	SS	df	MS	F	Prob>F
Groups	1.58866e+10	23	6.90722e+08	207.71	0
Error	9.02663e+10	27144	3.32546e+06		
Total	1.06153e+11	27167			

It is clear that the Hydro production depends on HOUR



Question 1

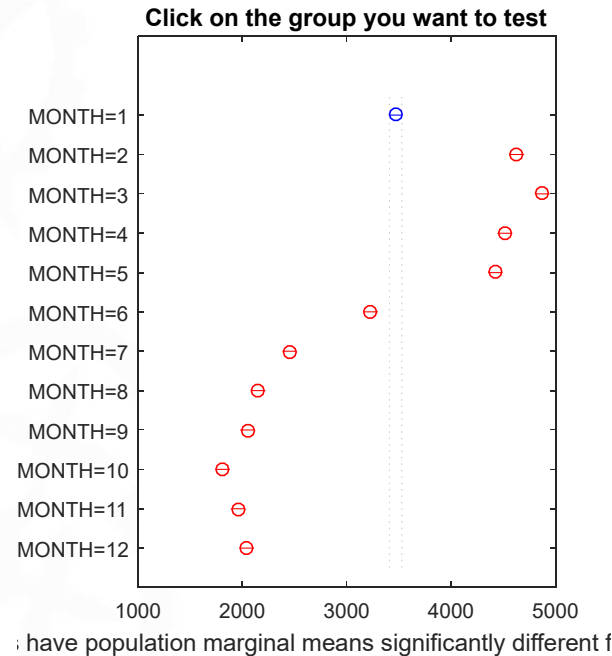
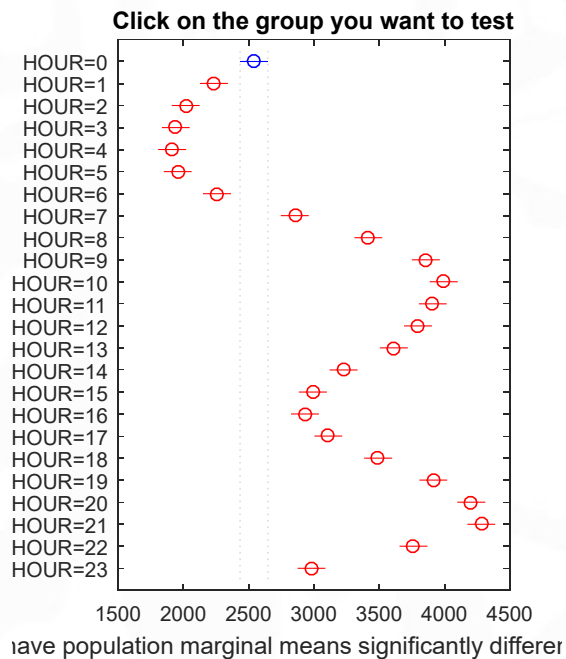
ANOVA for Hydro production (two-way with interaction)

- Hydro versus HOUR and MONTH

Analysis of Variance					
Source	Sum Sq.	d. f.	Mean Sq.	F	Prob>F
HOUR	1.55599e+10	23	6.76518e+08	348.37	0
MONTH	3.50693e+10	11	3.18812e+09	1641.71	0
HOUR*MONTH	2.99742e+09	253	1.18475e+07	6.1	0
Error	5.21996e+10	26880	1.94195e+06		
Total	1.06153e+11	27167			

Constrained (Type III) sums of squares.

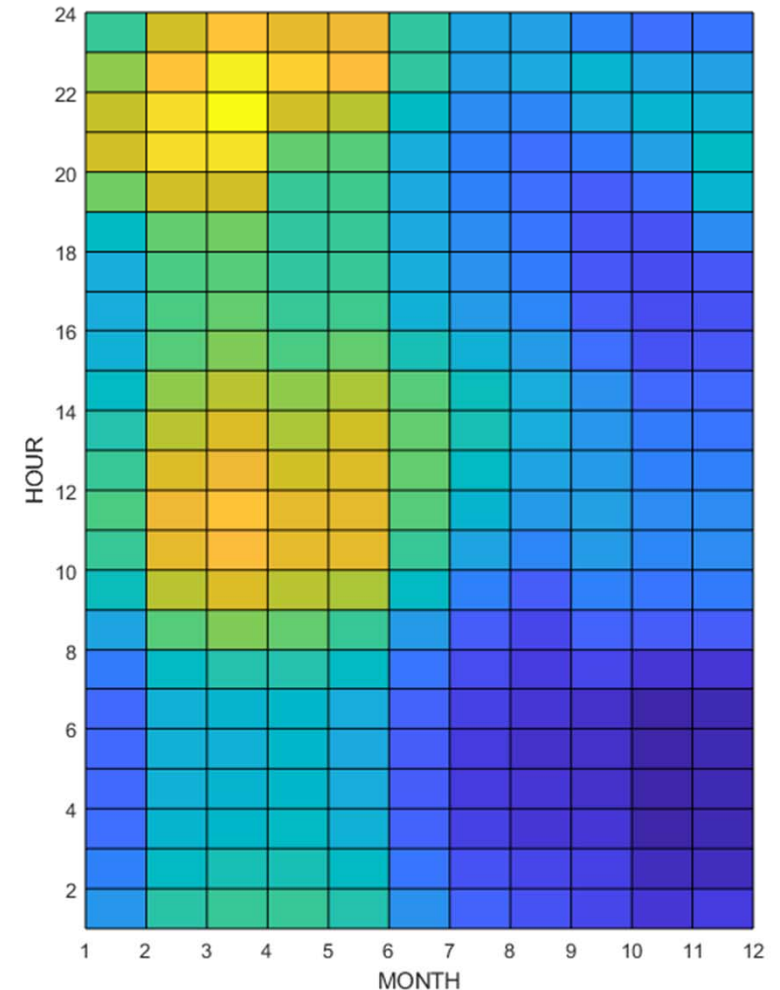
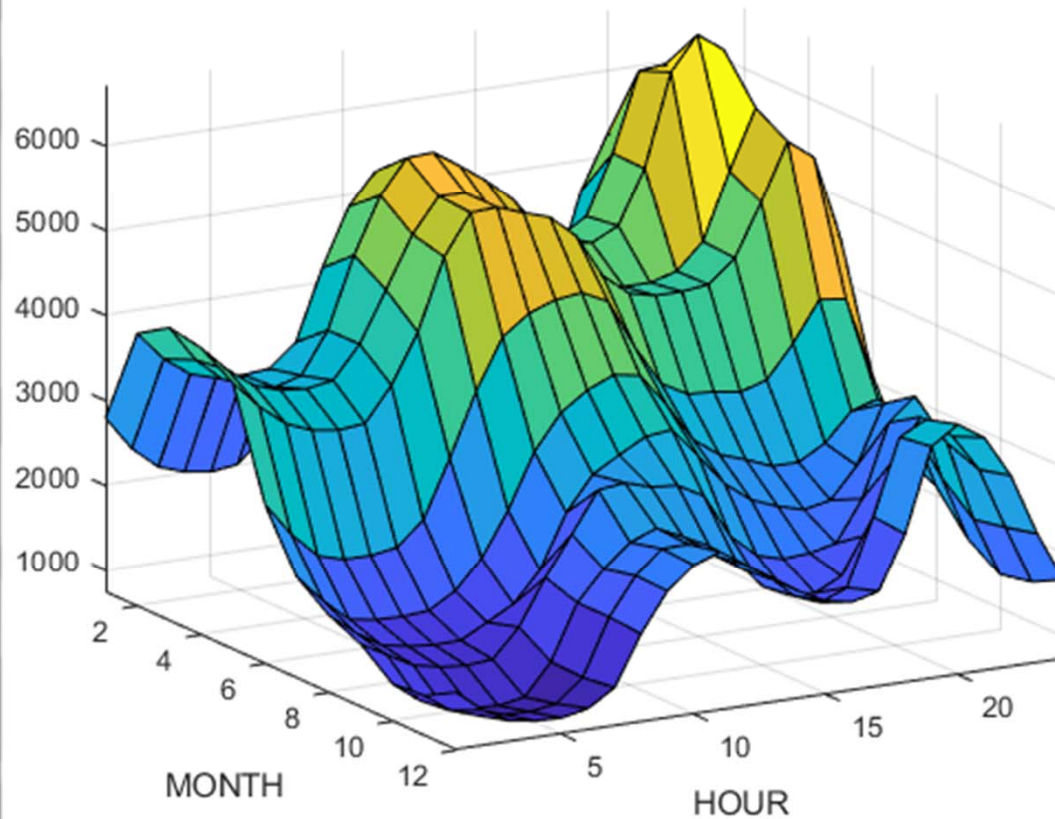
Hydro production depends on the HOUR and the MONTH, as well as the interaction between HOUR and MONTH



Question 1

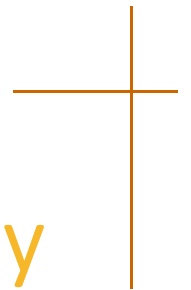
ANOVA for Solar PV (two-way with interaction)

- Hydro versus HOUR and MONTH (full means model)





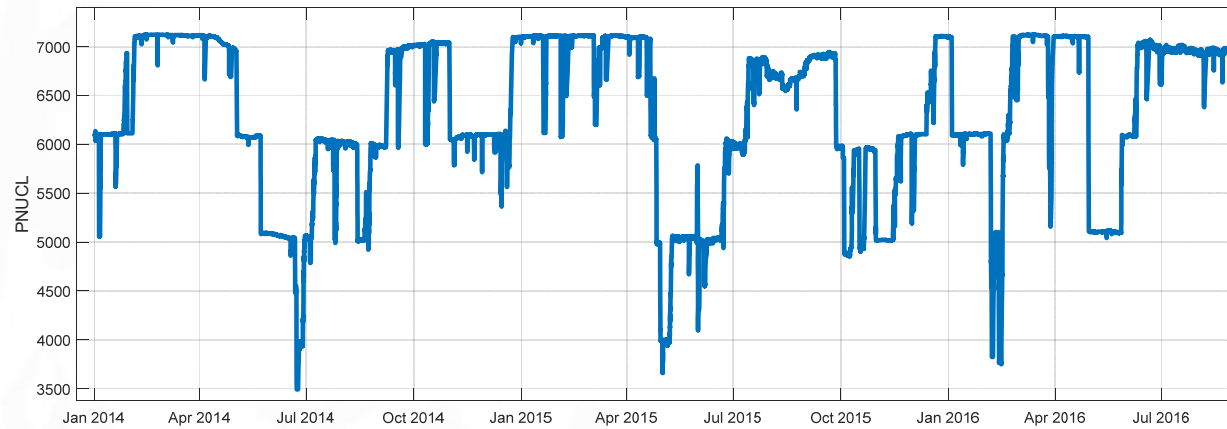
Question 2:
Is it really necessary to work with hourly data?



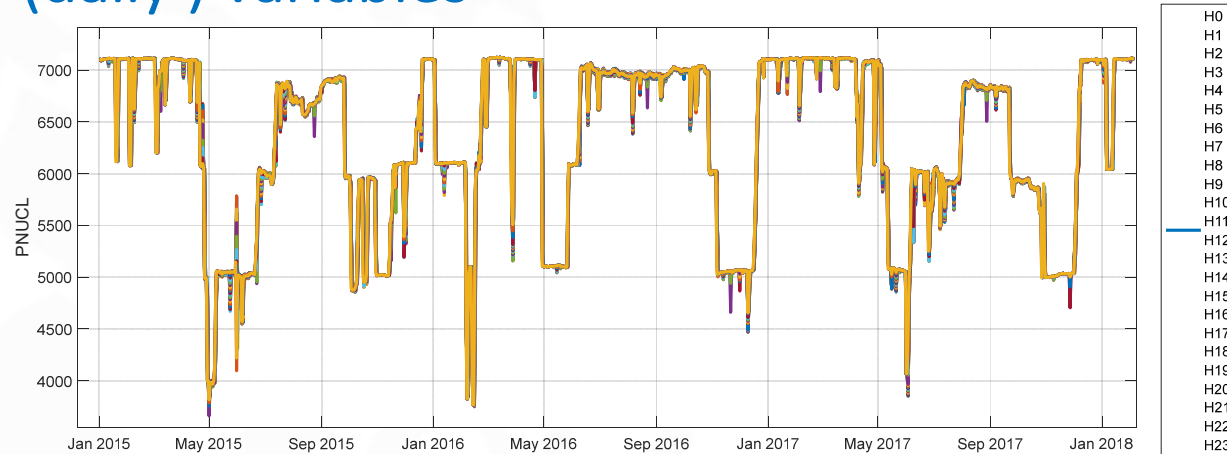
Question 2

Exploratory analysis

- Nuclear
 - One hourly variable



- 24 (daily) variables

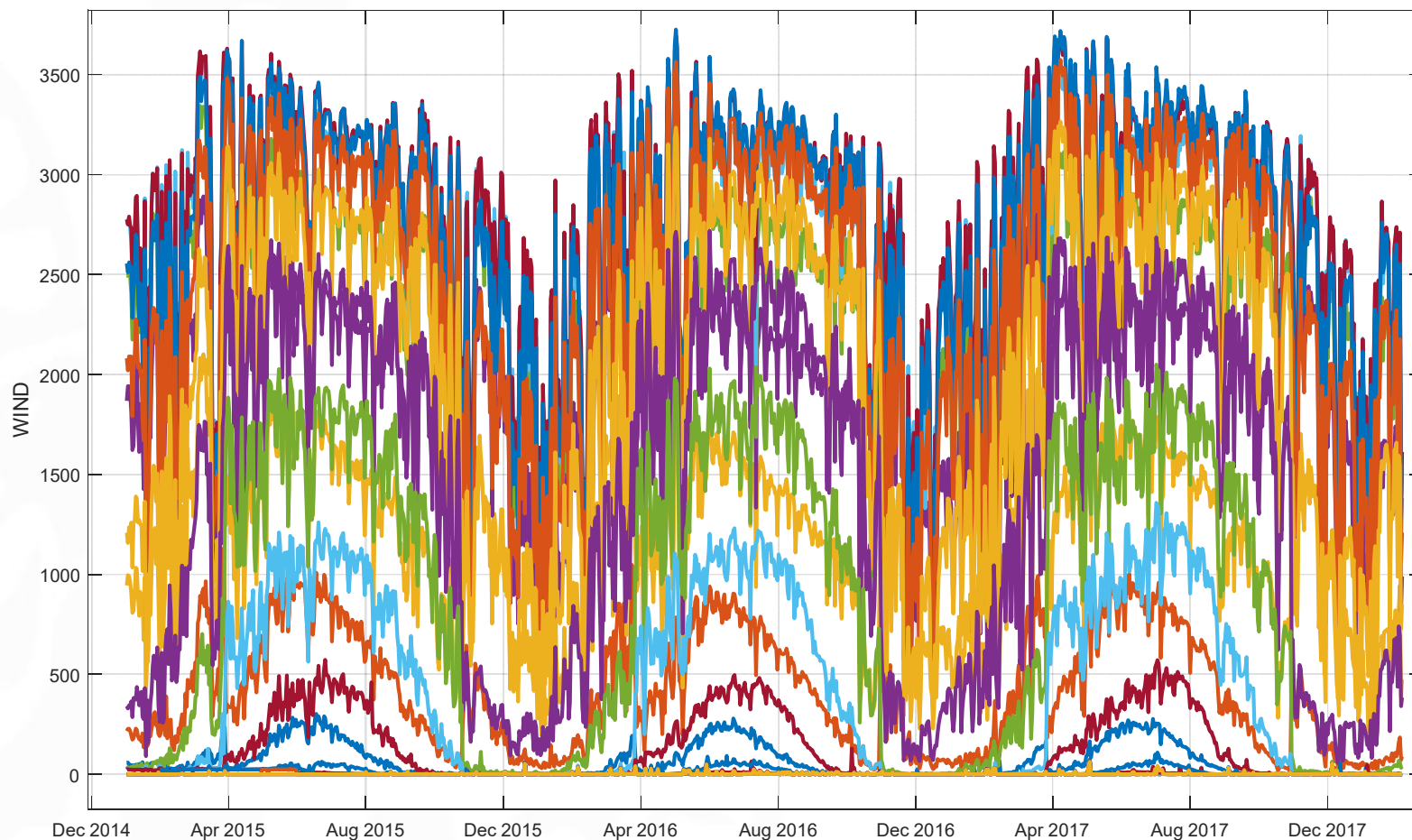
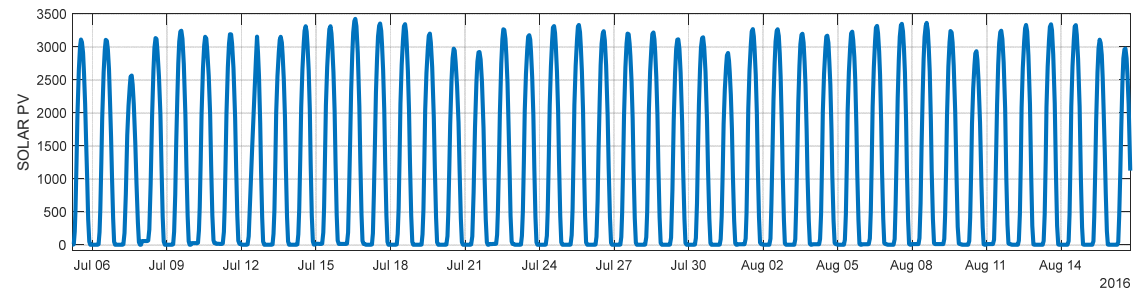


Very similar

Question 2

Exploratory analysis

- Solar PV
 - 24 variables



Question 2

Robust answer

- Is it really necessary to **work with hourly data**?

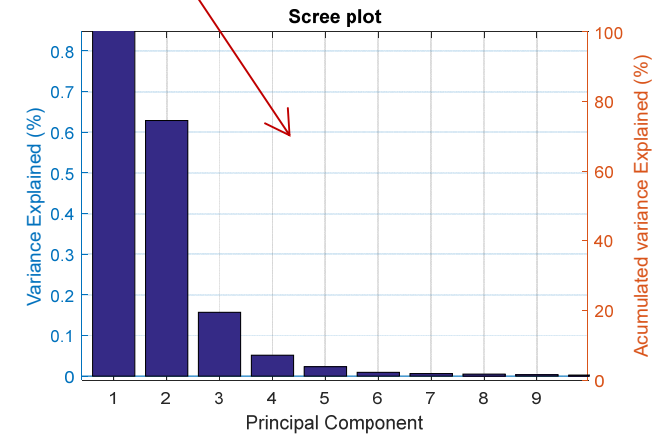
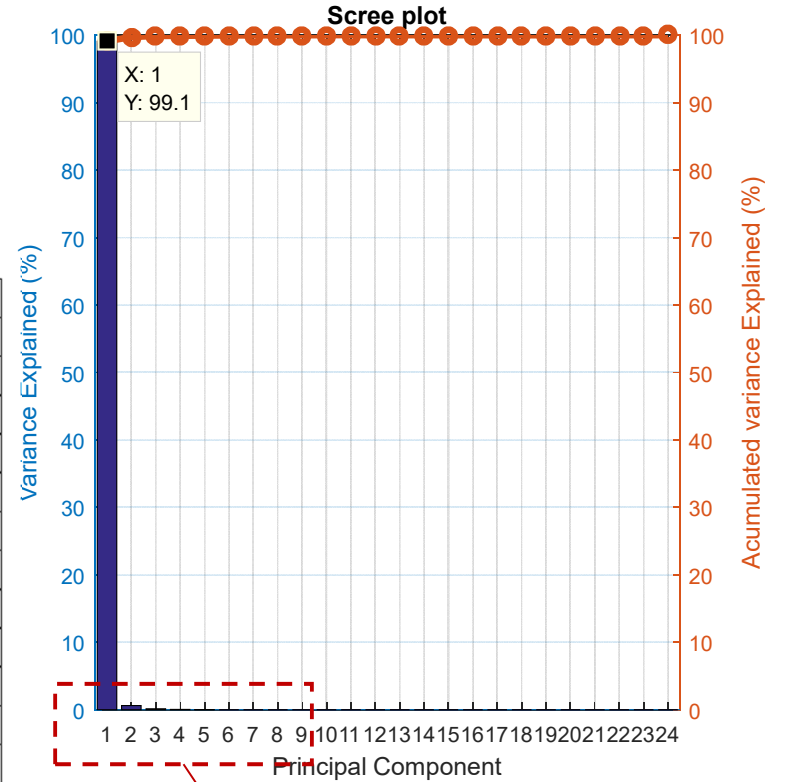
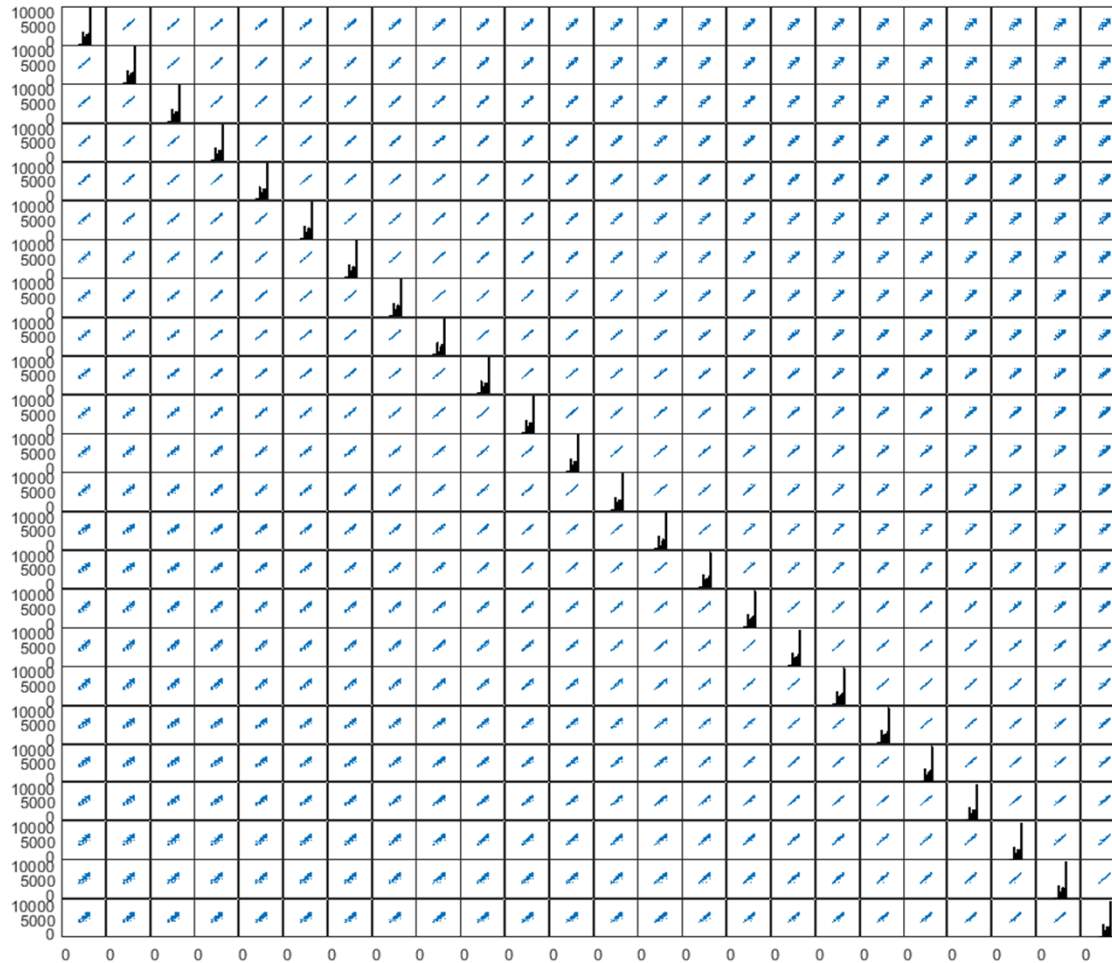


- **Data analytics with PCA**
 - Output: None
 - Inputs: 24 variables of the technology

Question 2

PCA for Nuclear production

- Very highly correlated variables

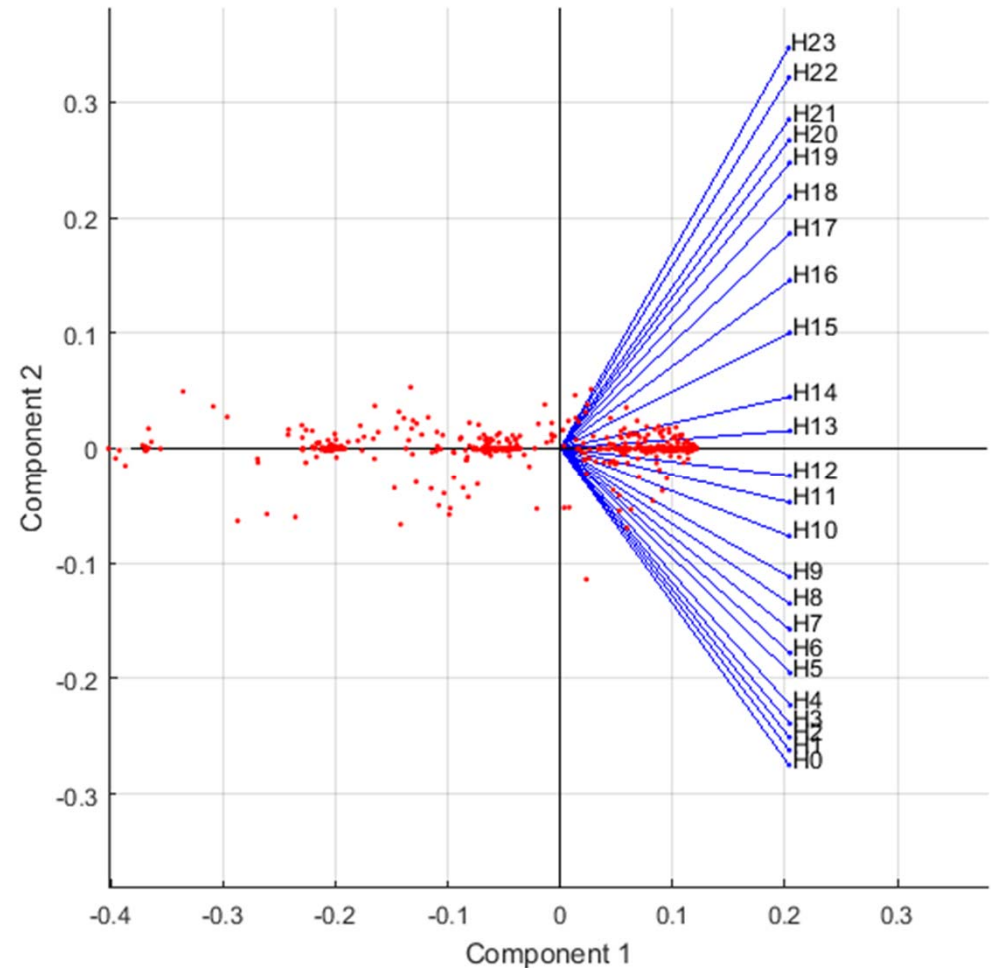
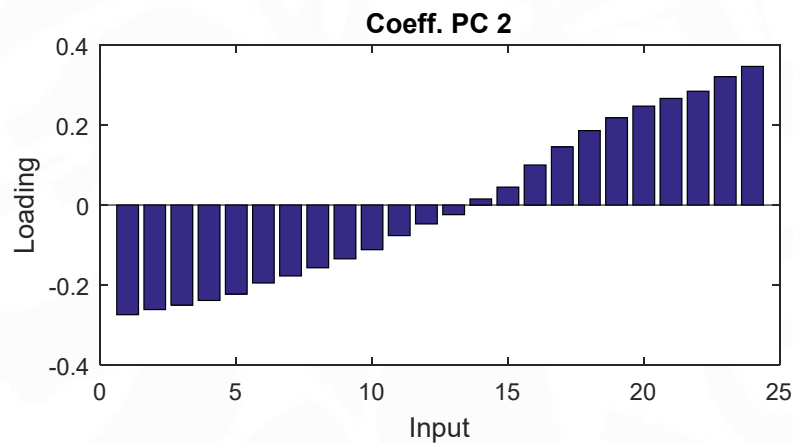
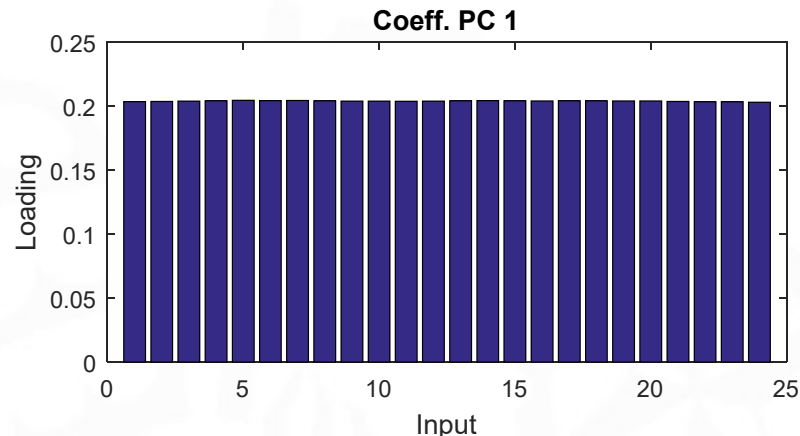


Question 2

PCA for Nuclear production

- First 2 PC's

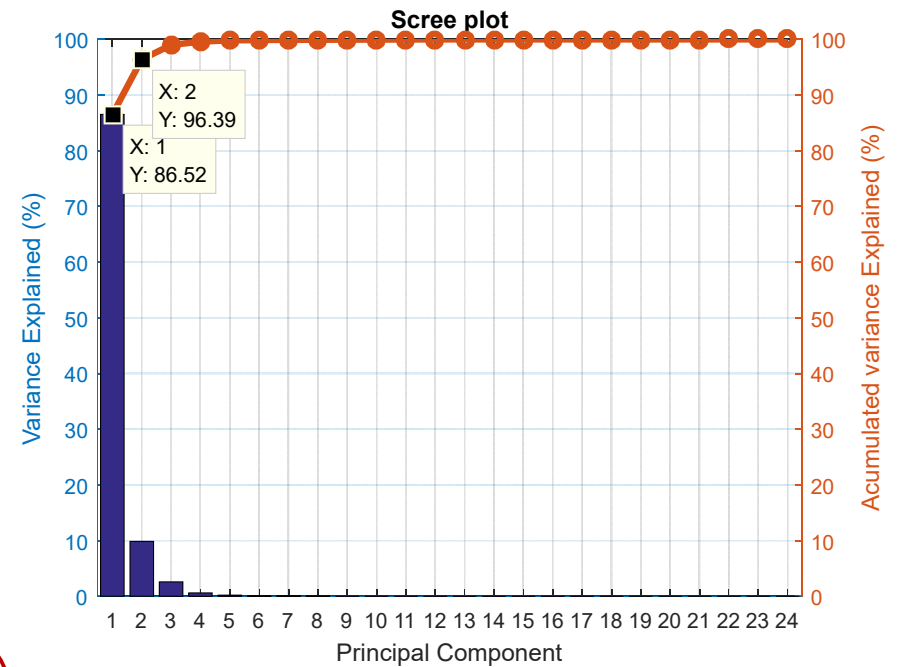
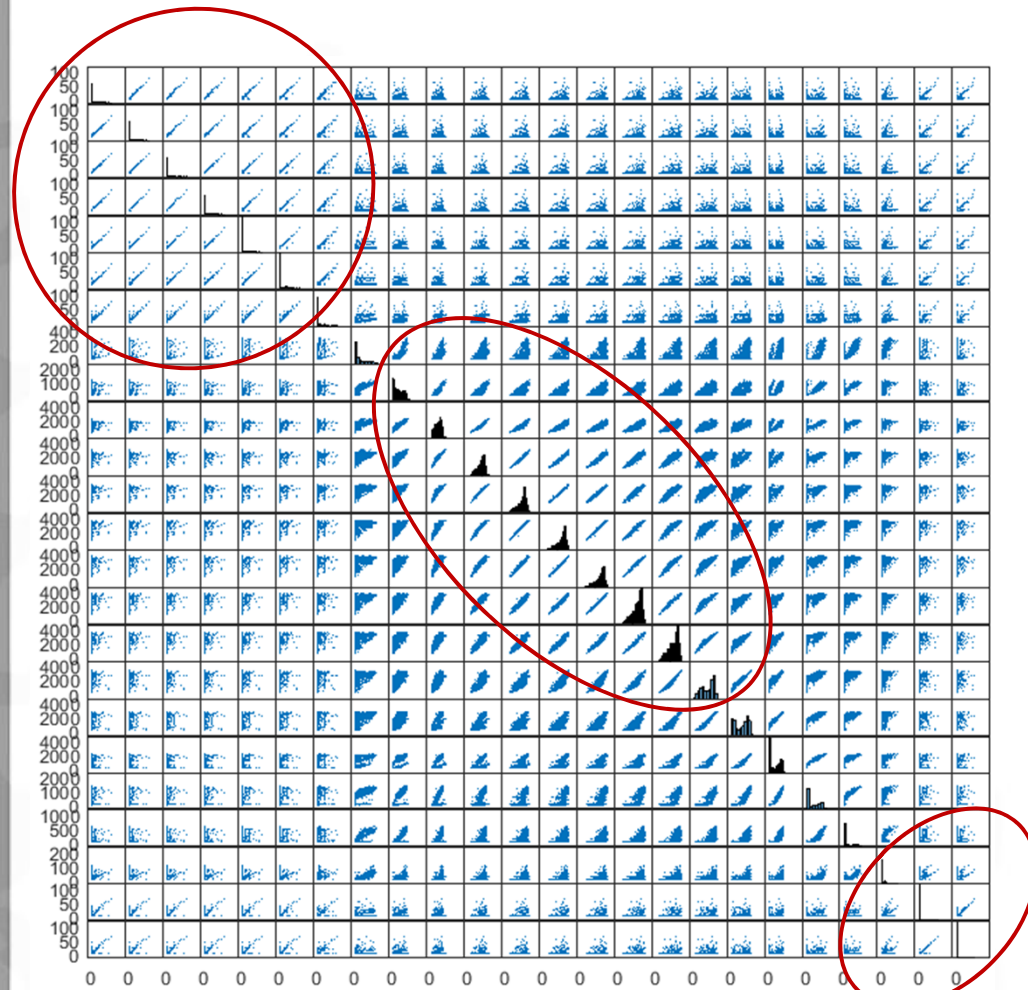
The first PC is the mean, explaining 99.1% of the total variance



Question 2

PCA for Solar PV production

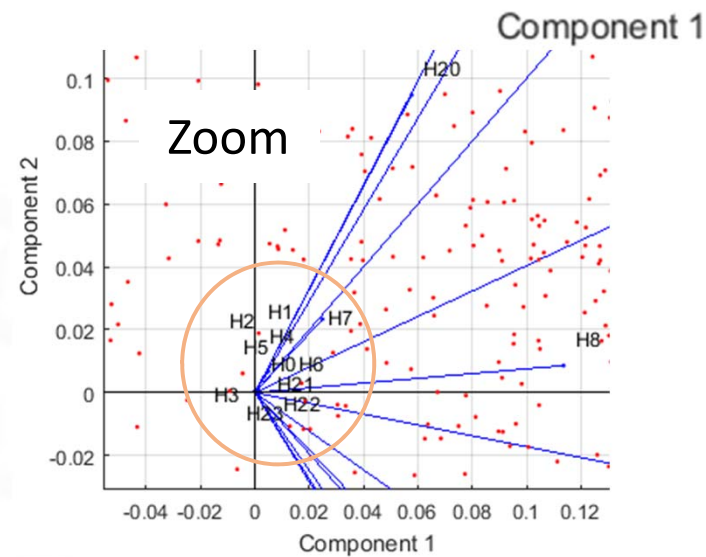
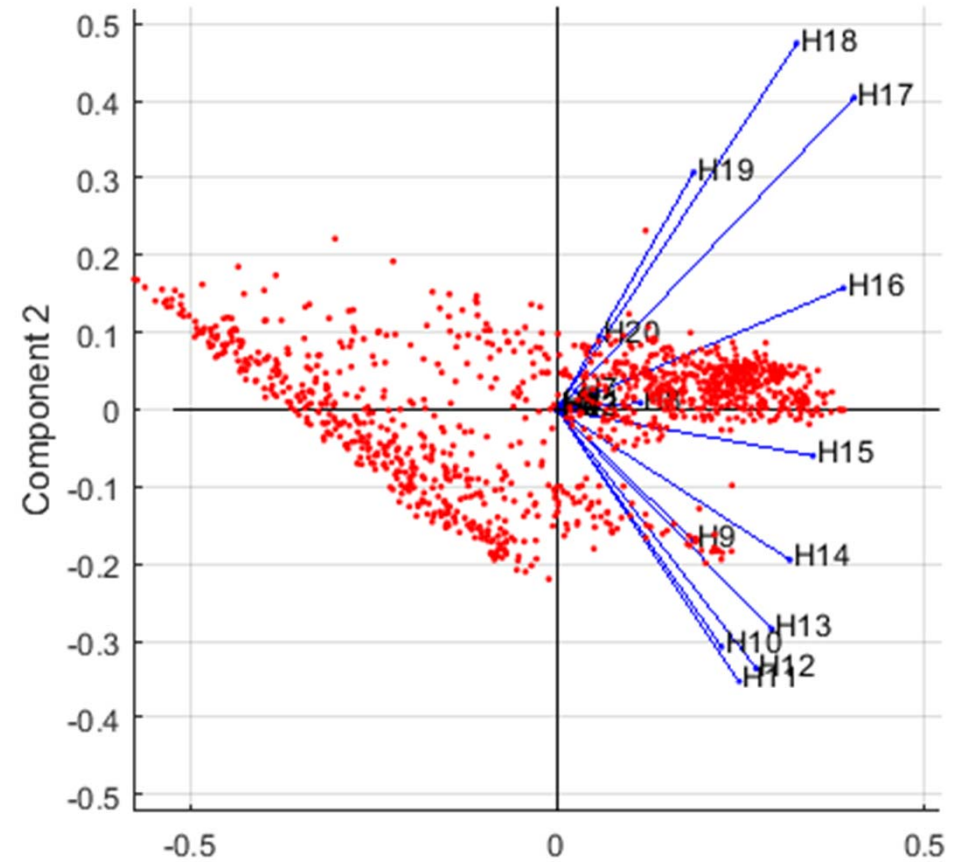
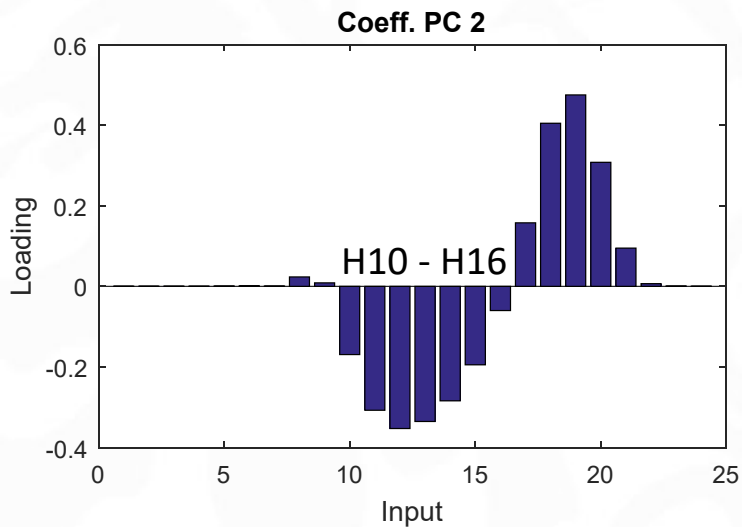
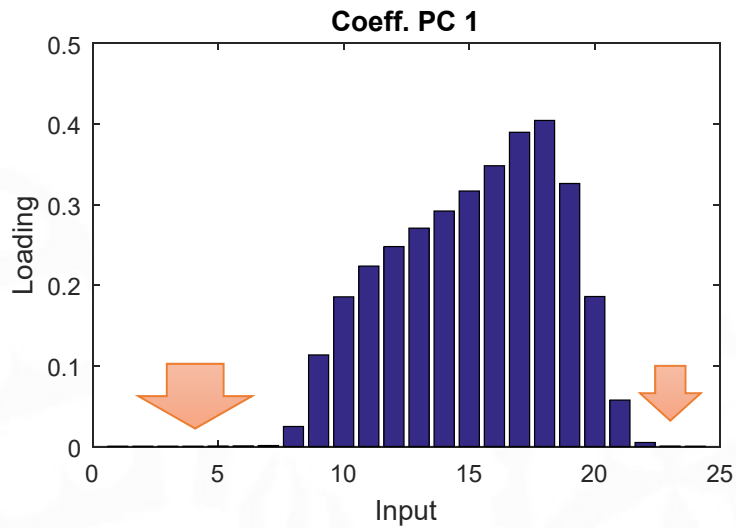
- There are highly correlated variables



Question 2

PCA for Solar PV production

- First 2 PC's



Question 2

PCA for Solar PV production

- Reconstruction from the first 2 PC's

