Assessment of renewable energy sources impact on Nuclear power: The case of France

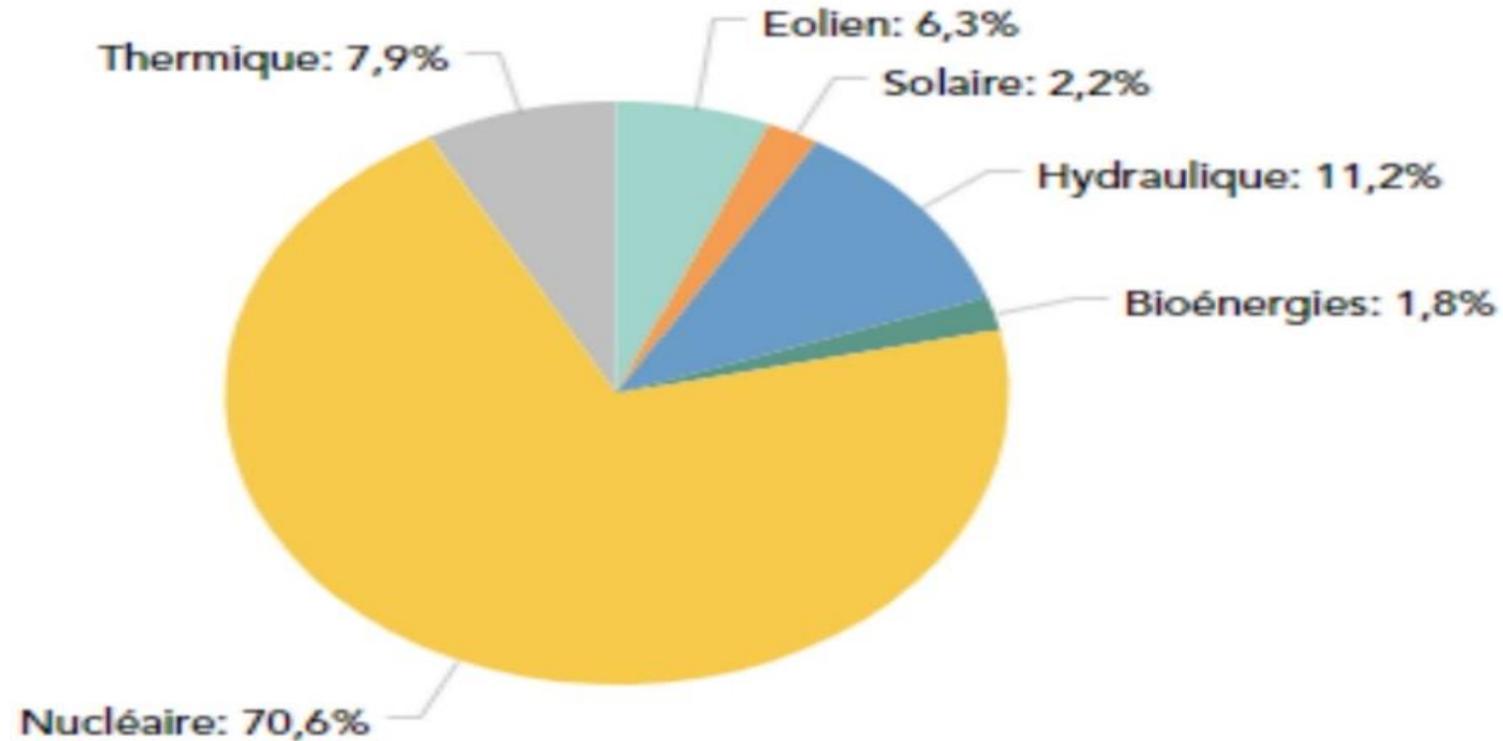**François Benhmad**   **Jacques Percebois**

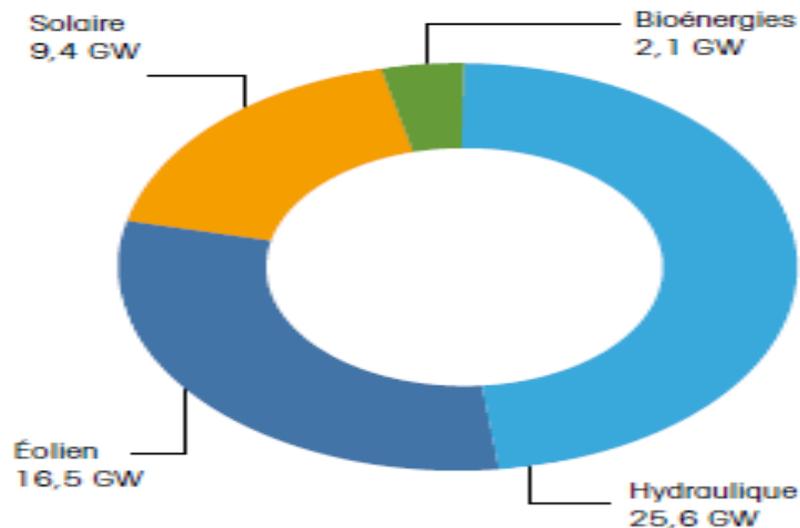**Montpellier University**

Motivation

➢European Commission adopted a package of proposals to make the EU's climate, energy, land use, transport and taxation **policies fit for reducing net greenhouse gas emissions by at least 55% by 2030**, compared to 1990 levels.

➢As energy production and use accounts for 75% of EU emissions, the **<u>Renewable Energy Directive</u>** will set an **increased target to produce 40% of our energy from renewable sources** by 2030.

Figure 1. Share of gross electricity generation 2019 (Source RTE)

- Eolien: 6,3%
- Solaire: 2,2%
- Hydraulique: 11,2%
- Bioénergies: 1,8%
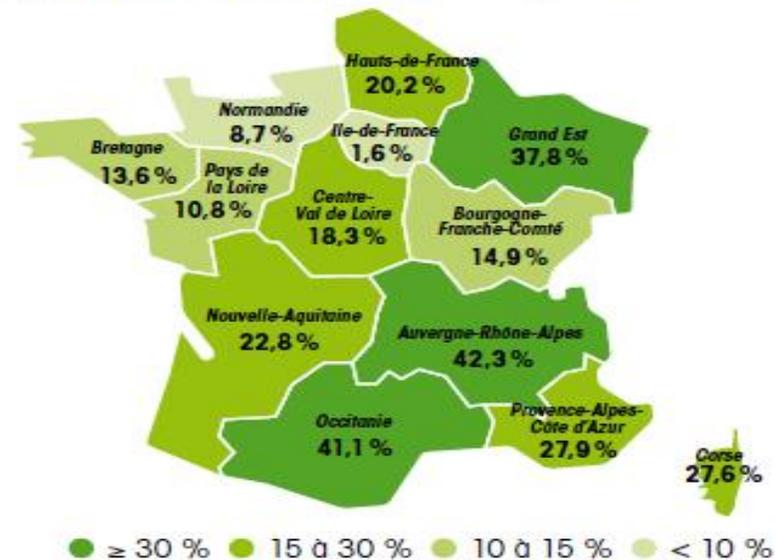- Thermique: 7,9%
- Nucléaire: 70,6%

- In **France,** as shown by figure 1, wind and solar share of gross electricity generation does not exceed **8.5%** whereas the nuclear energy share is more than **70%**.
- EDF (Electricité de France), operating the world's largest fleet of nuclear reactors, is **challenged** by the growing market share of renewable energy sources like wind and solar.
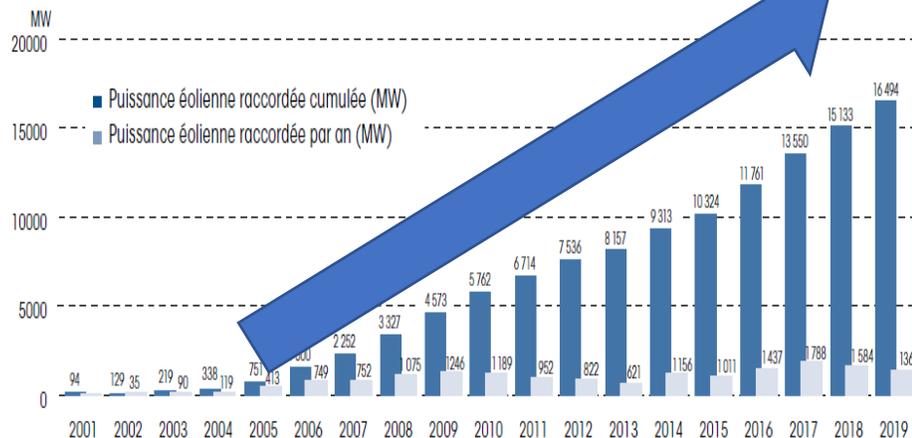
Parc renouvelable au 31 décembre 2019

Solaire 9,4 GW

Bioénergies 2,1 GW

Éolien 16,5 GW

Hydraulique 25,6 GW

Couverture de la consommation par la production renouvelable en 2019

Hauts-de-France 20,2 %

Normandie 8,7 %

Île-de-France 1,6 %

Grand Est 37,8 %

Bretagne 13,6 %

Pays de la Loire 10,8 %

Centre-Val de Loire 18,3 %

Bourgogne-Franche-Comté 14,9 %

Nouvelle-Aquitaine 22,8 %

Auvergne-Rhône-Alpes 42,3 %

Occitanie 41,1 %

Provence-Alpes-Côte d'Azur 27,9 %

Corse 27,6 %

● ≥ 30 %   ● 15 à 30 %   ● 10 à 15 %   ● < 10 %

Évolution de la puissance éolienne raccordée (MW)

- ■ Puissance éolienne raccordée cumulée (MW)
- ■ Puissance éolienne raccordée par an (MW)

Année	Cumulée	Par an
2001	94	35
2002	129	
2003	219	90
2004	338	119
2005	751	413
2006	1 500	749
2007	2 252	752
2008	3 327	1 075
2009	4 573	1 246
2010	5 762	1 189
2011	6 714	952
2012	7 536	822
2013	8 157	621
2014	9 313	1 156
2015	10 324	1 011
2016	11 761	1 437
2017	13 550	1 788
2018	15 133	1 584
2019	16 494	1 361

PARC ÉOLIEN 16 494 MW

Évolution de la puissance solaire raccordée (MW)

- ■ Puissance solaire raccordée cumulée (MW)
- ■ Puissance solaire raccordée par an

| Année	Cumulée	Par an
2008	61	54
2009	190	129
2010	878	688
2011	2 584	1706
2012	3 727	1143
2013	4 366	639
2014	5 297	931
2015	6 196	899
2016	6 773	577
2017	7 656	883
2018	8 546	890
2019	9 436	890
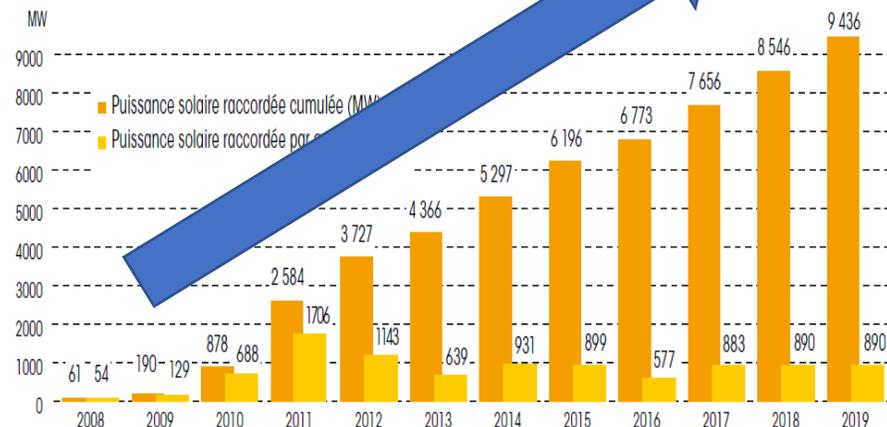
PARC SOLAIRE 9 436 MW

Research question

**What is the impact of renewable energy sources on Nuclear power ?**

•Renewable energy sources (RES) have priority for grid access, participating in the auction process at zero marginal cost **replaces** every other energy source with **higher** marginal cost. The so called merit order effet (Jensen and Skytte (2002), Wurzburg et al. (2013) , Ketterer (2014), Cludius et al. (2014), **Benhmad &Percebois (2016, 2017, 2018)).**

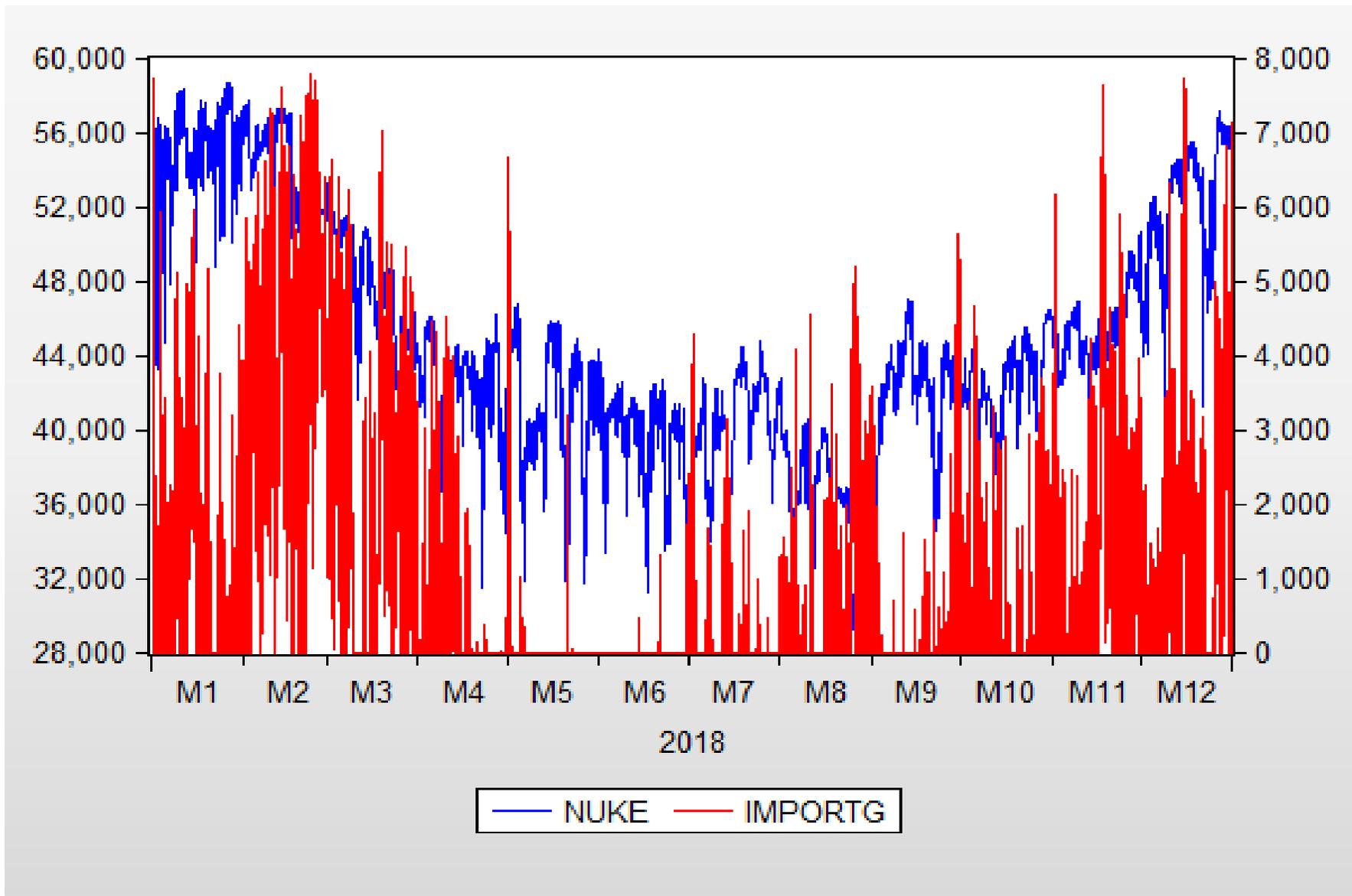• Nuclear plants could suffer from this crowding out effect.

Data

From 1 January 2018 to 31 December 2018

➢ **Hourly nuclear** power generation.
➢ **Hourly wind** and **photovoltaic** generation.
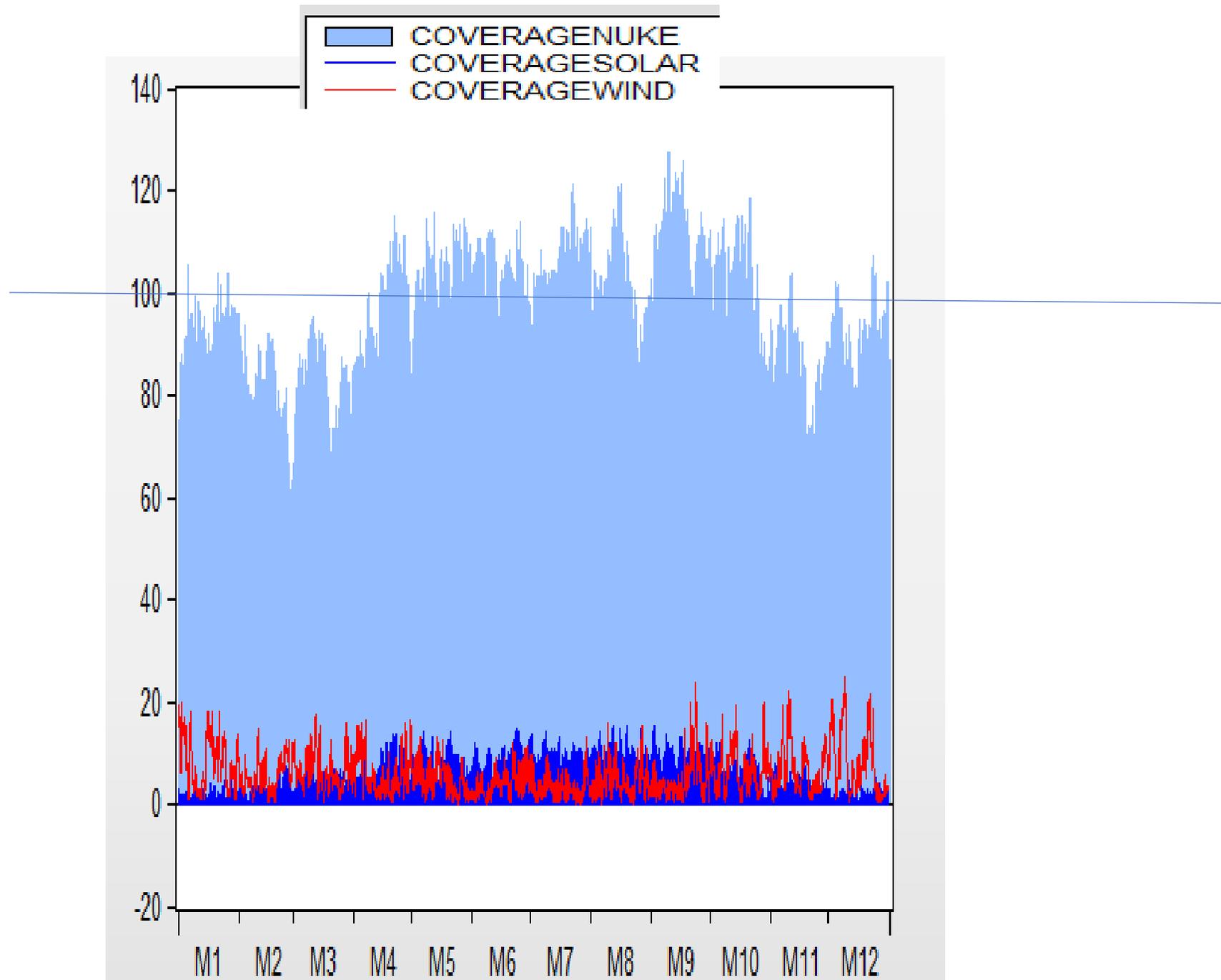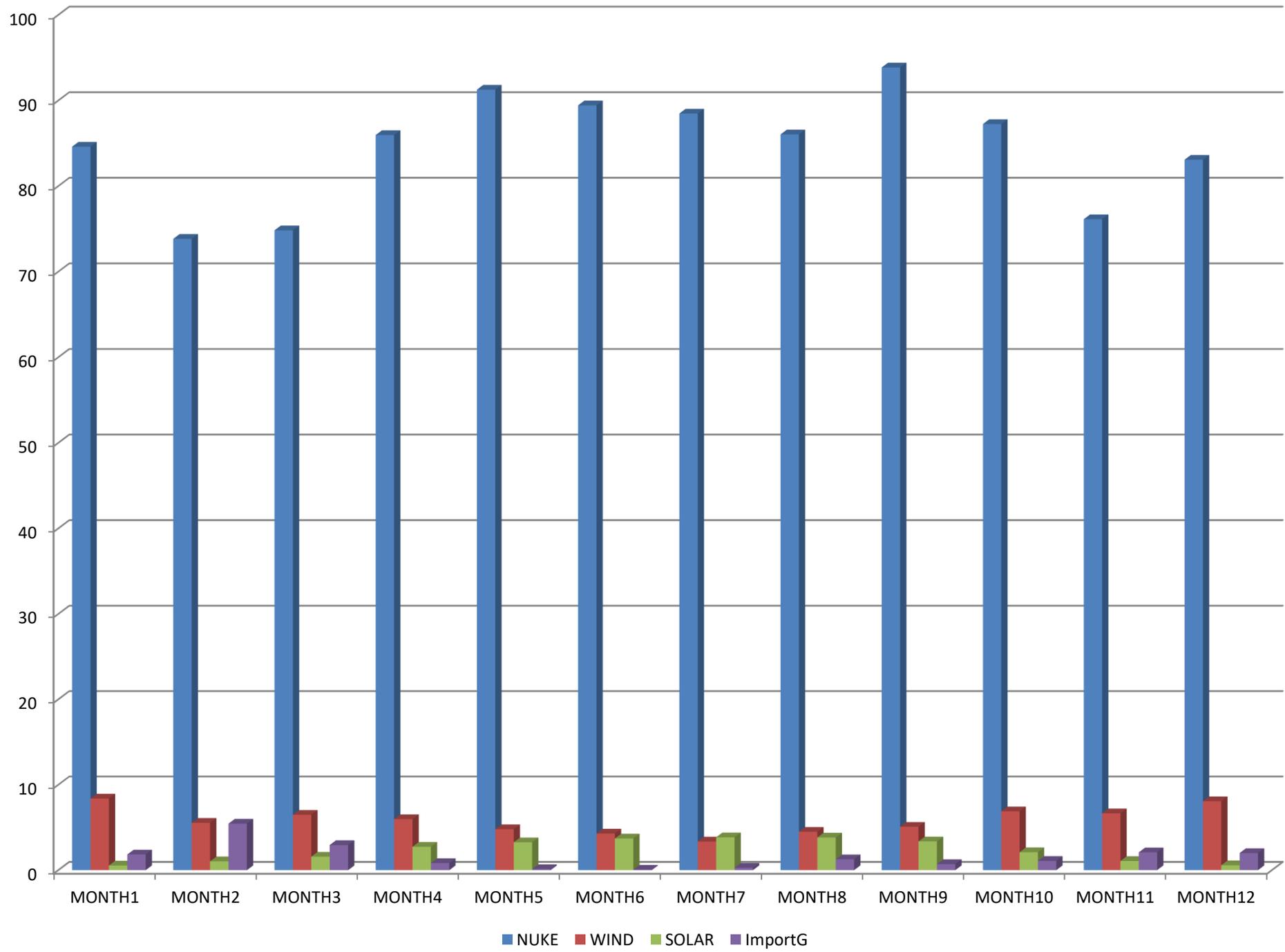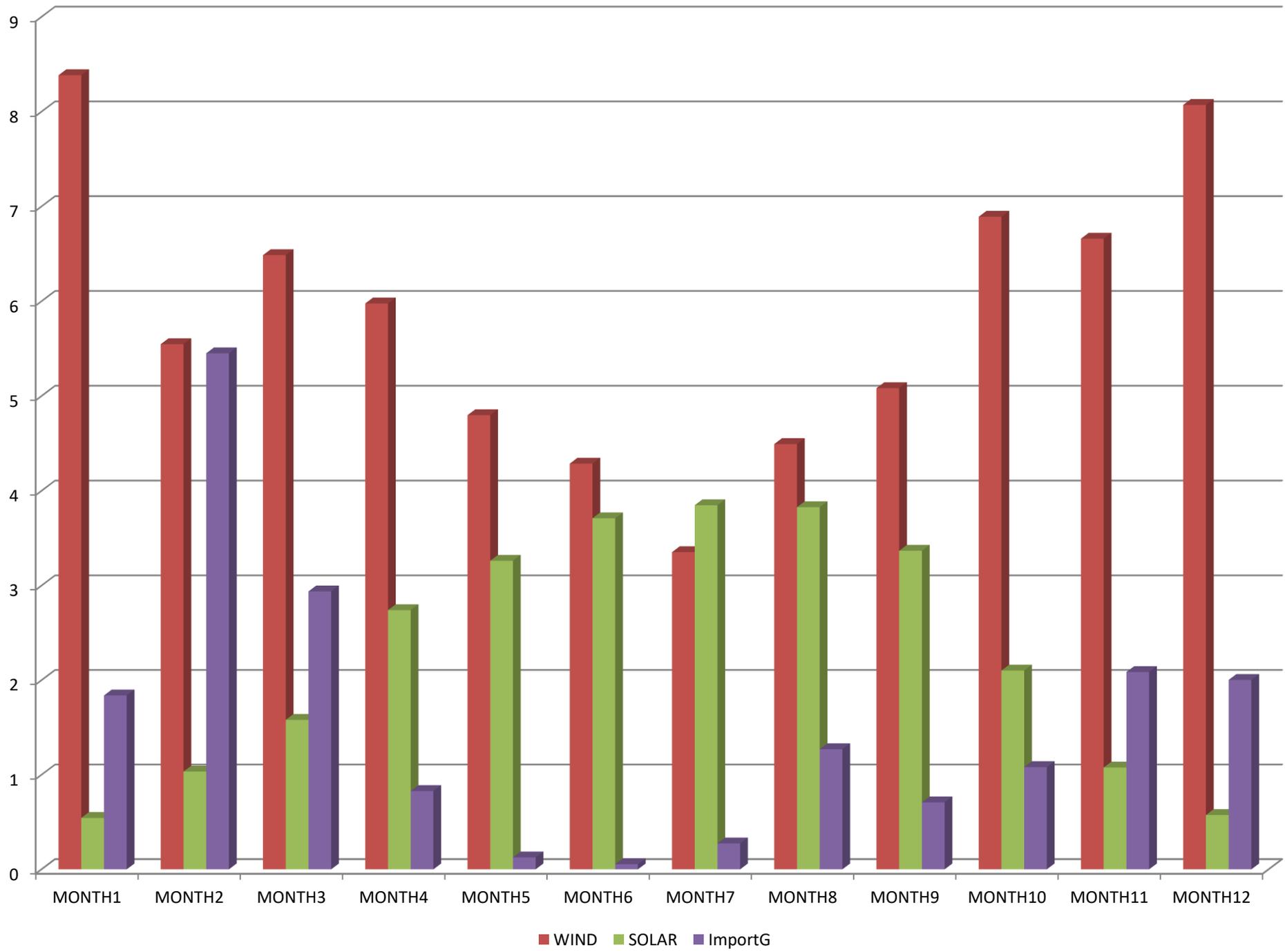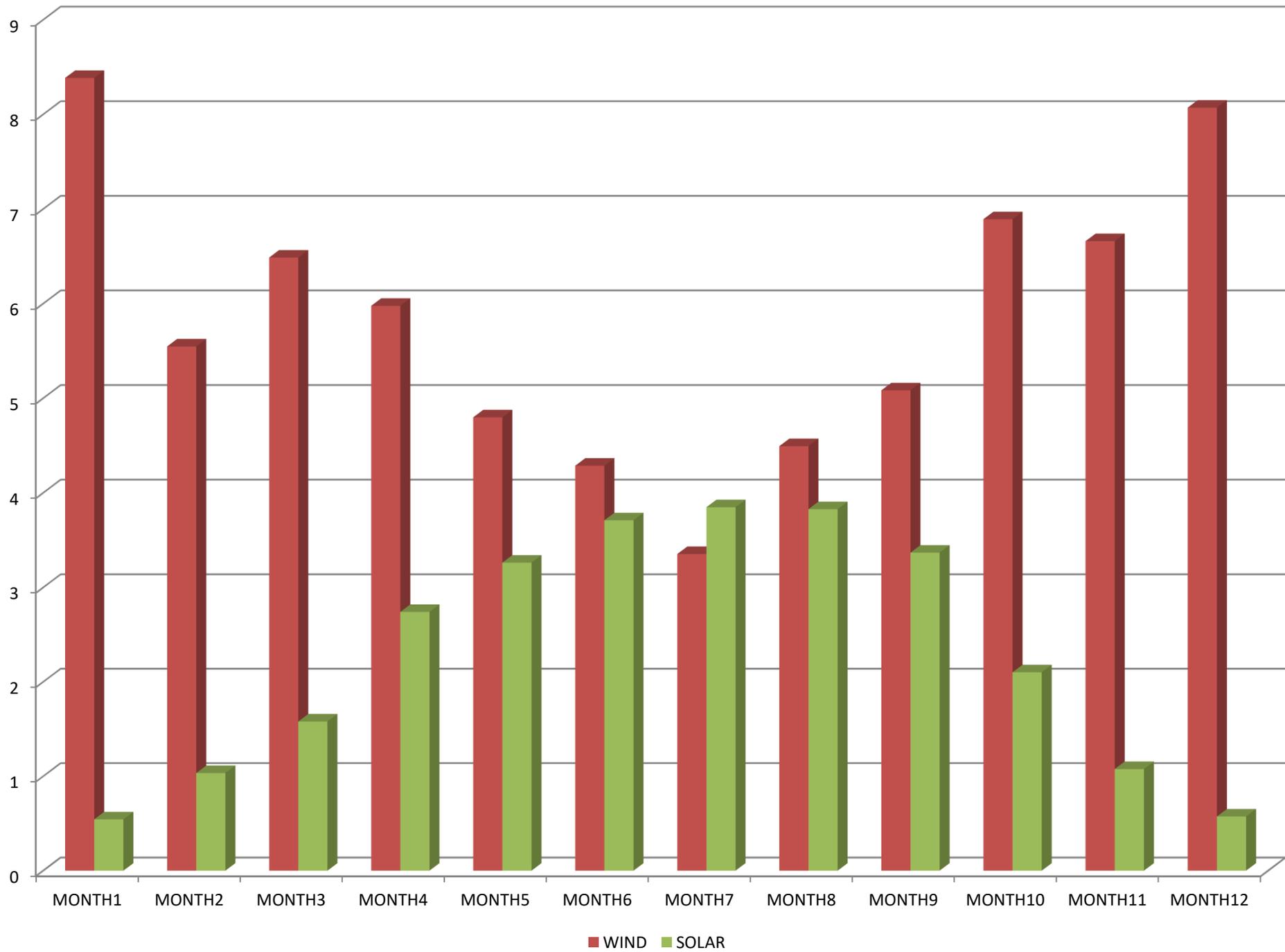➢ **Hourly load**
➢ **Hourly import from Germany**
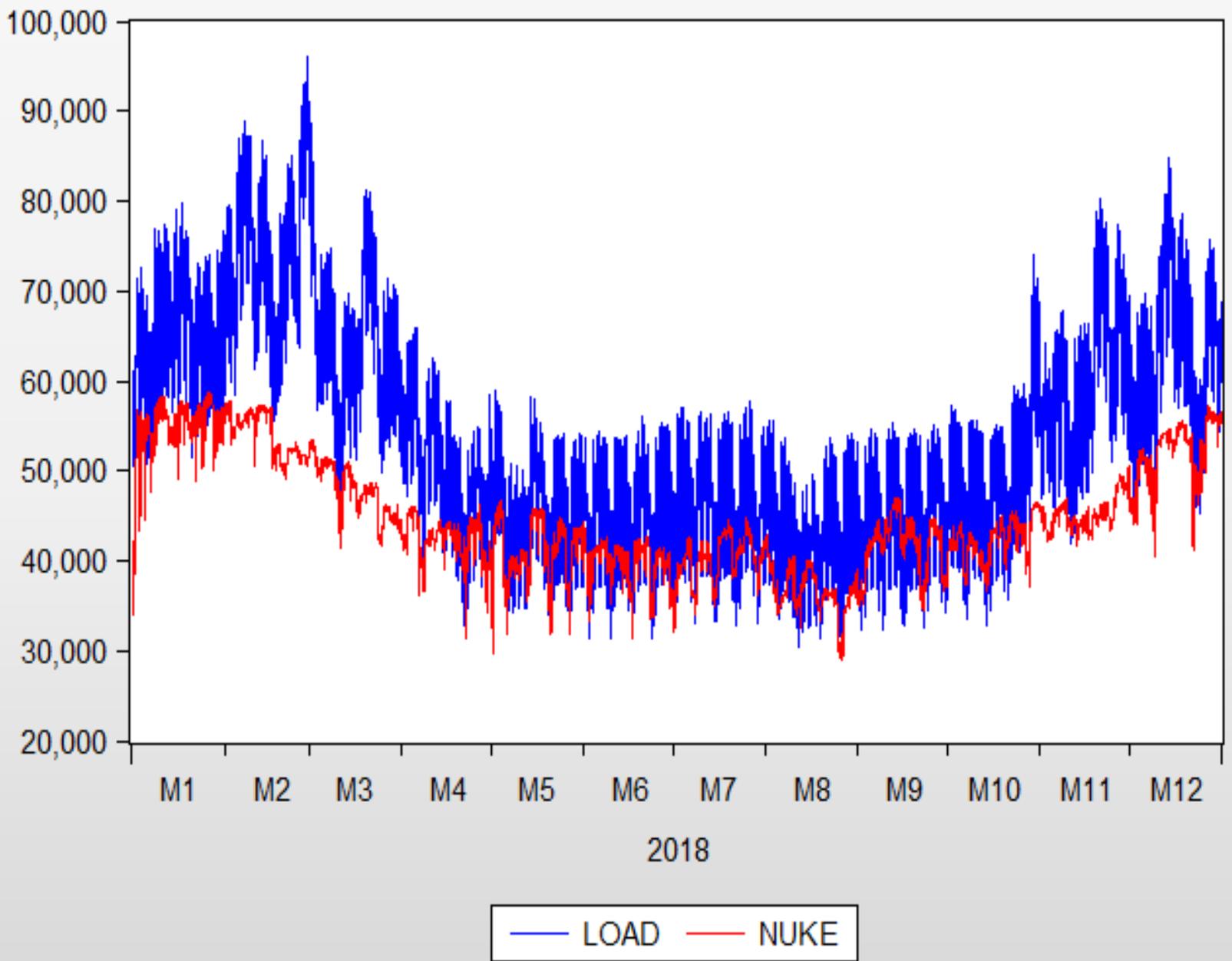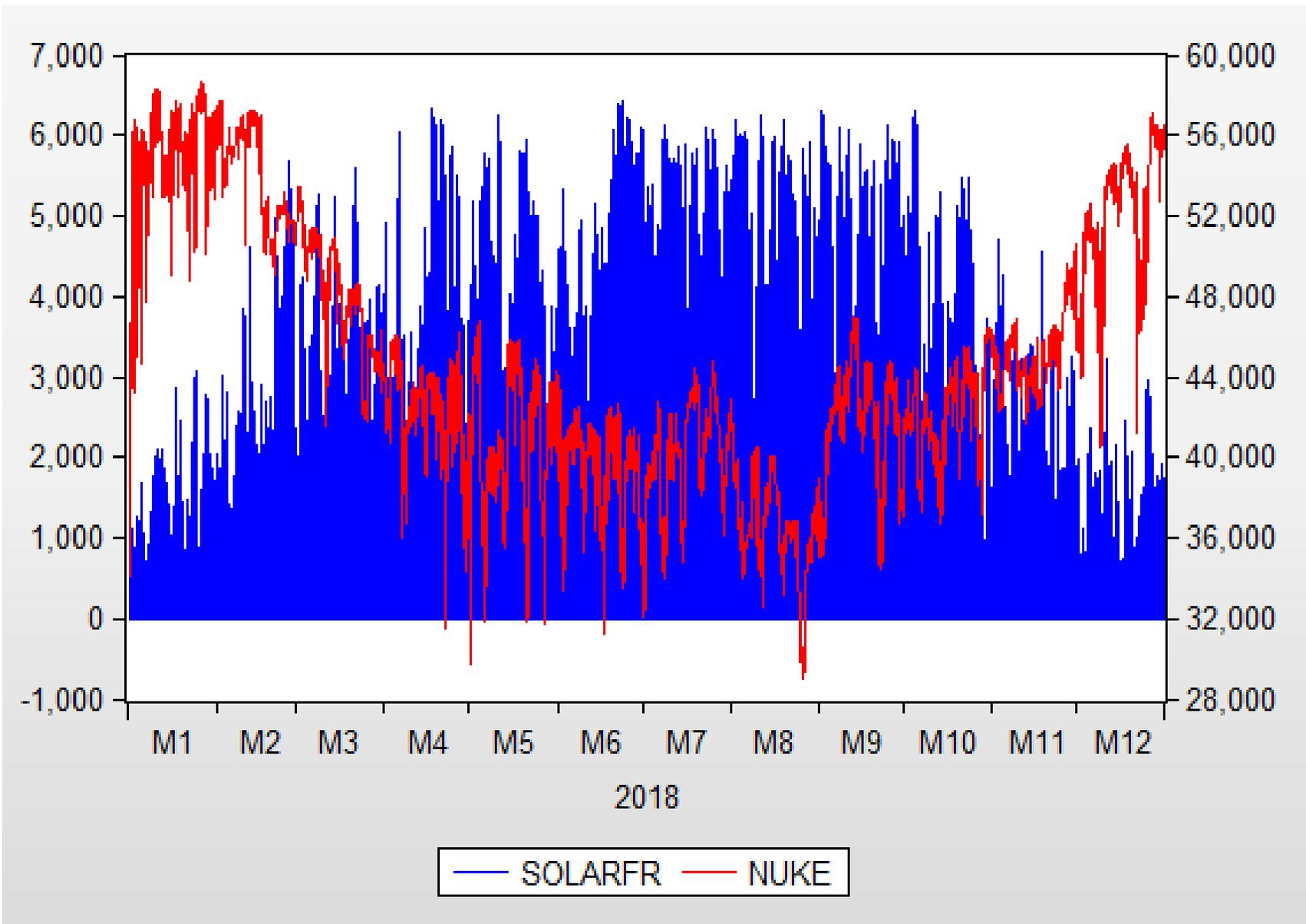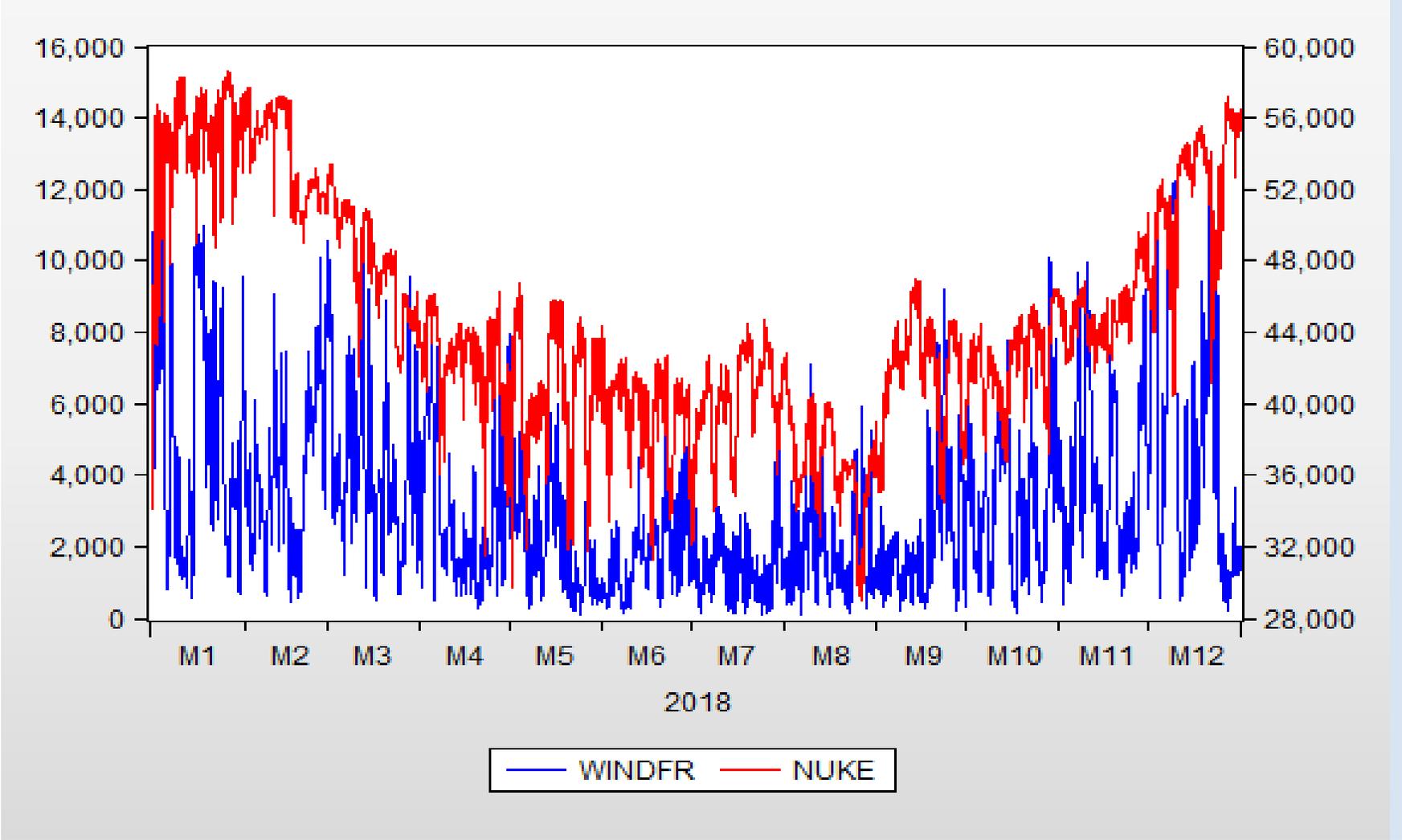
Descriptive Statistics (MWh)

	LOAD	NUKE	SOLAR	WIND	IMPORTG
Mean	54281.70	44845.50	1207.798	3211.355	957.8718
Maximum	95987.00	58635.00	6430.000	12203.00	7766.000
Minimum	30475.00	28984.00	0.000000	84.00000	0.000000
Std. Dev.	12243.49	6400.324	1738.474	2489.132	1631.643

WIND   SOLAR   ImportG

Empirical model

$$Nuke\_sa_t = c(1) + c(2) * Load_{sa_t} + c(3) * Solar_{sa_t} + c(4) * Wind_{sa_t} + c(5) * Nuke\_sa_{t-1}$$

Empirical Results

Dependent Variable: NUKESA				
Method: ARMA Conditional Least Squares				
Sample (adjusted): 1/01/2018 01:00 12/31/2018 23:00				
Included observations: 8759 after adjustments				

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	37495.37	436.0564	85.98742	0.0000
LOADSA	0.153572	0.008183	18.76741	0.0000
SOLARFRSA	-0.261116	0.018611	-14.02992	0.0000
WINDFRSA	-0.169471	0.020848	-8.128877	0.0000
IMPORTSA	-0.188975	0.035305	-5.352570	0.0000
AR(1)	0.968964	0.004059	238.7102	0.0000

R-squared	0.952693	Mean dependent var	44846.43
Adjusted R-squ	0.952666	S.D. dependent var	2359.567
S.E. of regressi	513.3574	Akaike info criterion	15.32051
Sum squared r	2.31E+09	Schwarz criterion	15.32535
Log likelihood	-67090.16	Hannan-Quinn criter.	15.32216
F-statistic	35254.35	Durbin-Watson stat	1.500402
Prob(F-statisti	0.000000		

➢ The empirical results show a negative impact of both solar and wind feed-in on nuclear generation in France.

➢ The downward effect is more pronounced for solar photovoltaic than for wind feed-in as the solar plants produce when the demand is low especially during summer season.

➢ Indeed, the average hourly impact of solar generation should induce a decrease of 0.26 MWh of nuclear feed-in for each additional MWh of solar output, whereas the average hourly impact of wind feed-in should induce a decrease of 0.17 MWh of nuclear feed-in for each additional MWh of wind generation.

➢ The imported electricity from Germany exacerbates the downward pressure on nuclear generation in France as both wind and solar power coming from Germany play the same role of the wind and solar generated in France.

➢ Indeed, the high level of electricity demand during winter induces a negative impact of the German imports (mainly wind) on nuclear generation. In contrast, during summer season, the German power imports (mainly solar PV) This negative impact is much more important on nuclear generation as the power demand is low

Conclusion:

- Large-scale penetration of renewables has the effect of **crowding out** fossil fuel plants and **even conventional nuclear plants.**
- Nuclear energy will progressively behave as a **back-up** of renewables.
- **Excess** nuclear electricity would be transformed into hydrogen (**power-to-gas**), whereas logically it is renewables that **should** be stored in this form.
- **Need of reform in electricity market design**.