



Feasibility study of a solar PV financial investment product in Spain

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Índex

1. Hybridation concept
2. The Project.
3. Existing wind farm. Technical data
4. Solar farm. Technical data and equipment
5. Costs, output and assumptions
6. Results
7. Conclusions
8. Questions

1.- Hybridation concept

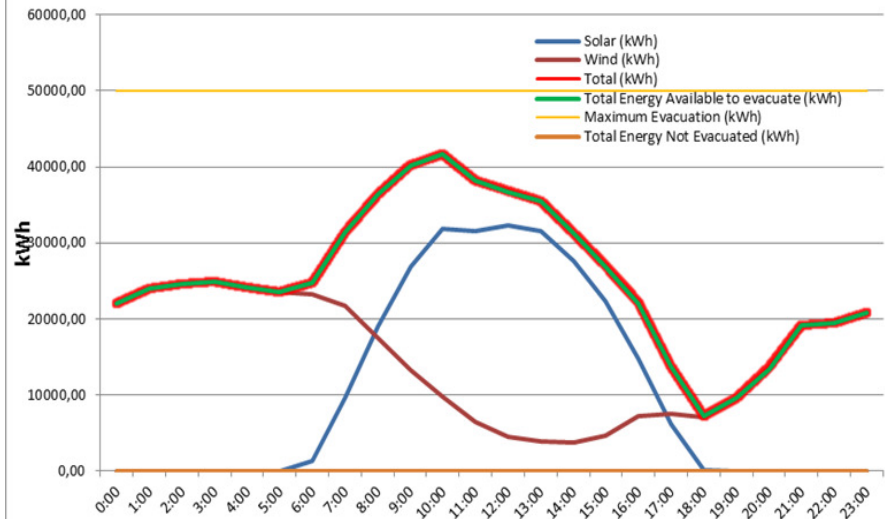


- Hybridation is when we use the same electrical evacuation infrastructure either for solar as for wind farm. That means wind resource and solar resource are complementaries.
- When you use the same electrical infraestructure you have to assume small production losses.
- Solar farm and wind farm will evacuate the generation through the same electrical line and the same transformer that it will be connected to the main transformer station, and thanks to this the cost of the line and the transformer for the solar farm will be reduced dramatically (90% less).
- It won't be necessary to apply for additional evacuation capacity in the existing substation. It won't be also necessary to change the line from single circuit to double circuit because the solar farm will evacuate the electrical generation when the wind farm is not performing or when the performance is below 100% (because wind resource is very low or because one wind turbine is under maintenance Jobs).
- For this case study the assumption is that the wind farm will have dispatch priority against the solar farm because the wind farm generation is receiving incentives.

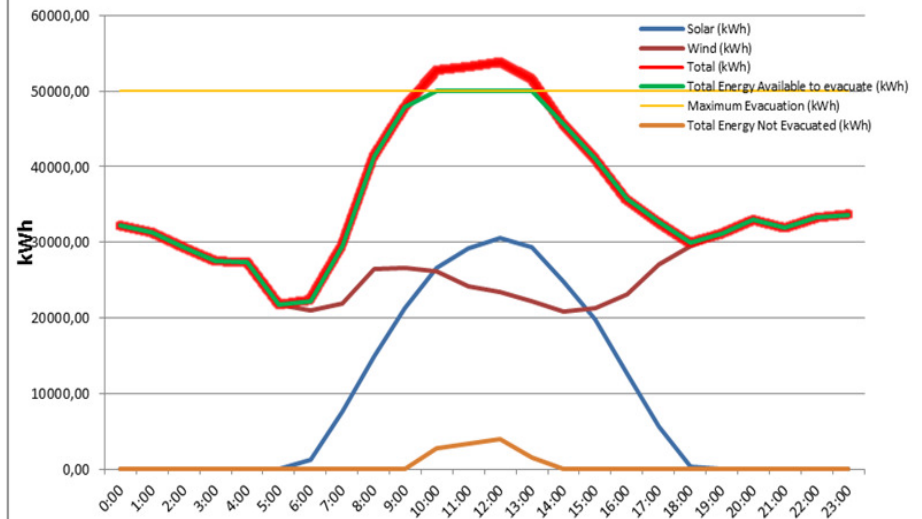
1.- Hybridation concept

- The graphs below shown real examples related to output performance curves for both technologies in a existing wind farm with 50 MW of evacuation capacity .

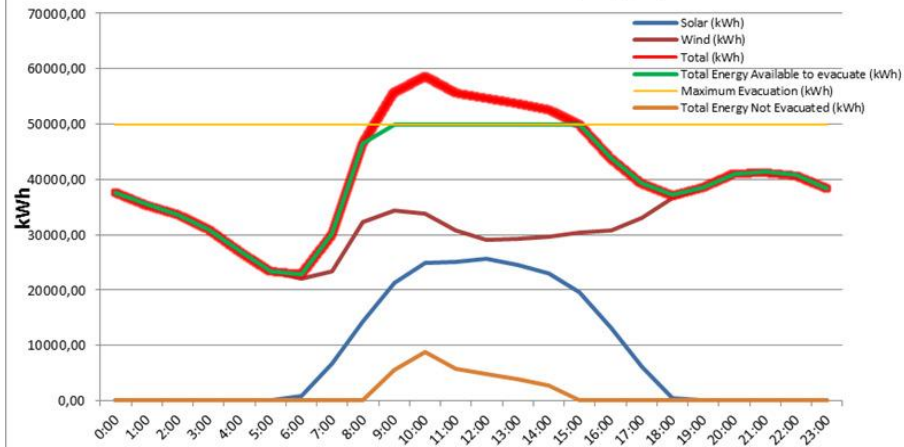
Solar & Wind Generation Graphs_May



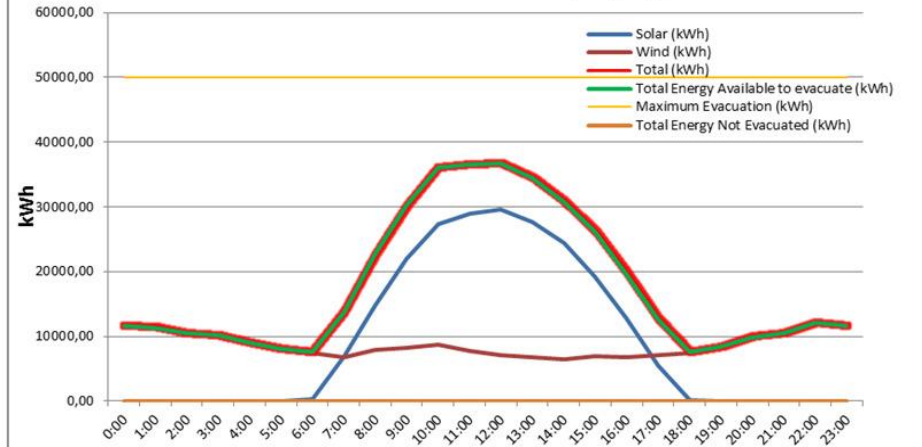
Solar & Wind Generation Graphs_June



Solar & Wind Generation Graphs_July



Solar & Wind Generation Graphs_August

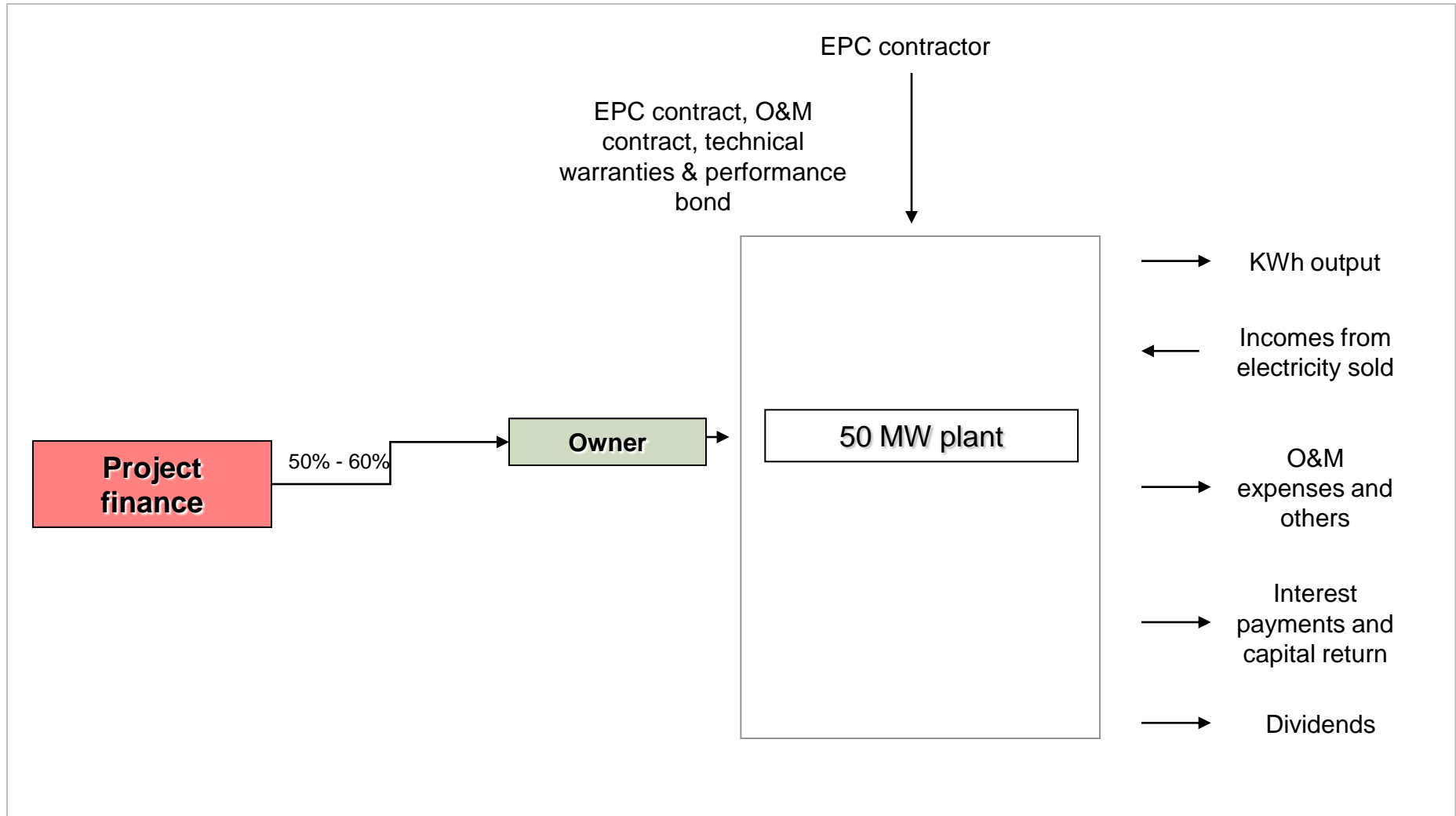


2.- The project. Overview









- The solar farm will be built close to 4 existing wind farms.
- The installed capacity will be 50 MW AC and 58 MWp.
- The solar farm will be built by an EPC contractor.
- The solar farm will have the following warranties:
 - ✓ Performance Ratio bond for 5 years.
 - ✓ Maintenance contract for 25 years.
 - ✓ Security.
 - ✓ Insurance.
- The wind farm will work under the existing regulatory framework (RD 413/2014).

2.- The project. Financial structure




2.- The project. Financial structure


Main assumptions – Project finance (I)

- Finance owner:  New SPV focused on installation and operations
- Duration:  15-18 years
- Debt percentage:  50-65%
- Interest rate:  Euribor + %margin
- Depreciation:  Constant for 15 years
- Warranties: 
 - cash-flow
 - Shares liability
 - Priority over the incomes
 - Debt service coverage 6 months
 - Assets mortgage

2.- The project. Financial structure

Main assumptions – Project finance (II)

- Warranties:  - O&M and EPC contract warranties
- Performance warranty

- Other requirements:  - Prelación of payments
- Licenses and permits
- Turnkey contracts
- O&M contract with a experienced company

3.- Existing wind farm. Technical data



- At the transformer station we have four wind farms already connected, wind farm A, wind farm B, wind farm C and wind farm D. Each one is connected to a 30/220 kV transformer. We also have an aerial electrical line with 14 km length and 220 kV voltage that connects to the main transformer station.
- Some technical details of the wind farm:
 - ✓ Wind farm A: 26 Ag V90 1.875 MW a 105 HH, total power 48,75 MW
 - ✓ Wind farm B: 21 Ag V90 1.875 MW a 105 HH, total power 39,375 MW.
 - ✓ Wind farm C: 15 Ag G90 1.875 MW a 100 HH, total power:28,125 MW.
 - ✓ Wind farm D: 18 Ag G90 1.875 MW a 100 HH, total power: 33,750 MW.

4.- Existing wind farm. Technical data



- Power installed: → 50 MW nominal - 58 MWp
- Aggregated anual output: → 108.576 MWh
(1872 kwh/Kwp/year)

Regarding to the yearly running hours considered for the solar farm, those are lower than the number considered by the Spanish government for the recent Renewable tenders held in Spain. The reason is because the solar system will works together (hibridated) with the wind farm system which it will have priority dispatch because it receives incentives under the existing regulatory framework. Due to that situation, we have considered potential generation losses. We have used PV SYST software.

- Investment period: → > 25 years
- Módules life cycle: → > 30 years

5.- Costs, output and assumptions.



- Total investment: (trafo excluded) → € 40,95 millions (0,706 eur/Wp)
- Policristaline modules → Jinko JKM 335PP -72V-2016
- Inverters → 20 inverters Ingeteam(2,5 MW)
- 1 horizontal axis tracker → Nextracker, Soltec, Hiasa
- Capex:
 - Módulos: → 0.34 EUR/Wp
 - BOS: → 0.36 EUR/Wp
 - Interconexión:
 - Buried línea (30 kV): → 120.000 EUR/km
 - Aerial line (30kV): → 80.000 EUR/km (5 km línea)

(capex values are real and are lower than the number considered by the Spanish government for the recent Renewable tenders held in Spain)

5.- Costs, output and assumptions.



- Performance ratio (PR) → 83,94%

Performance ratio is the relation between maximum output in a sunny day at 25°C and the real output.

It is reasonable to have a PR close to 80%.

We have considered that we will have hourly monitoring of all the production data and that any problem or major failure will be sorted in 24-48h

- O&M costs → 14 Eur/MWh

This ratio is very low because we have synergies with the operation of the existing wind farm. This value includes 7% of generation tax y 0,5 Eur/MWh of tolls.

- Selling price → 40 Eur/MWh

6.- Results (production).



PVSYST V6.52		19/07/17		Page 1/5					
Grid-Connected System: Simulation parameters									
Project :	Torrelobaton								
Geographical Site	Torrelobaton	Country	Spain						
Situation	Latitude	41.71° N	Longitude	5.04° W					
Time defined as	Legal Time	Time zone UT+1	Altitude	839 m					
	Albedo	0.20							
Meteo data:	Torrelobaton	SolarGIS Monthly aver. , period not spec. - Synthetic							
Simulation variant :	SAT DC/AC 1.25 GCR 0.4								
	Simulation date	19/07/17 10h14							
Simulation parameters									
Tracking plane, tilted Axis	Axis Tilt	0°	Axis Azimuth	0°					
Rotation Limitations	Minimum Phi	-60°	Maximum Phi	60°					
Backtracking strategy	Tracker Spacing	7.50 m	Collector width	3.01 m					
Inactive band	Left	0.05 m	Right	0.05 m					
Models used	Transposition	Perez	Diffuse	Perez, Meteonom					
Horizon	Free Horizon								
Near Shadings	According to strings		Electrical effect	100 %					
PV Array Characteristics									
PV module	Si-poly	Model	JKM 335PP-72-V 2016						
Custom parameters definition	Manufacturer	Jinkosolar							
Number of PV modules	In series	28 modules	In parallel	219 strings					
Total number of PV modules	Nb. modules	6132	Unit Nom. Power	335 Wp					
Array global power	Nominal (STC)	2054 kWp	At operating cond.	1851 kWp (50°C)					
Array operating characteristics (50°C)	U mpp	963 V	I mpp	1923 A					
Total area	Module area	11898 m²	Cell area	10746 m²					
Inverter									
Custom parameters definition	Model	INGECON SUN 1640TL B630 OUTDOOR+							
Characteristics	Manufacturer	Ingeteam							
	Operating Voltage	915-1300 V	Unit Nom. Power	1637 kWac					
Inverter pack	Nb. of inverters	1 units	Total Power	1637 kWac					
PV Array loss factors									
Array Soiling Losses			Loss Fraction	1.5 %					
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s					
Wiring Ohmic Loss	Global array res.	8.4 mOhm	Loss Fraction	1.5 % at STC					
LID - Light Induced Degradation			Loss Fraction	1.2 %					
Module Quality Loss			Loss Fraction	-0.8 %					
Module Mismatch Losses			Loss Fraction	0.8 % at MPP					
Incidence effect, user defined profile									
	0°	20°	30°	40°	50°	60°	70°	80°	90°
	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.77	0.00
System loss factors									
AC wire loss inverter to transfo	Inverter voltage	630 Vac tri							
	Wires: 3x2500.0 mm²	209 m	Loss Fraction	0.8 % at STC					
External transformer	Iron loss (24H connexion)	6072 W	Loss Fraction	0.3 % at STC					
	Resistive/Inductive losses	2.0 mOhm	Loss Fraction	1.0 % at STC					

6.- Results. (production)



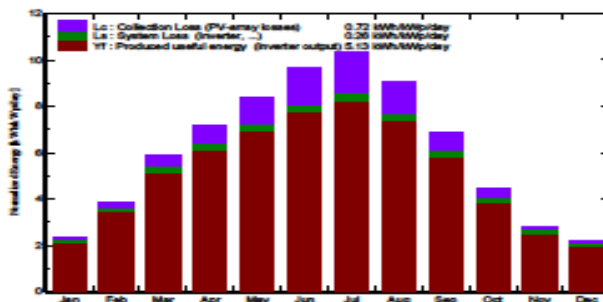
Grid-Connected System: Main results

Project : Torrelobaton
Simulation variant : SAT DC/AC 1.25 GCR 0.4

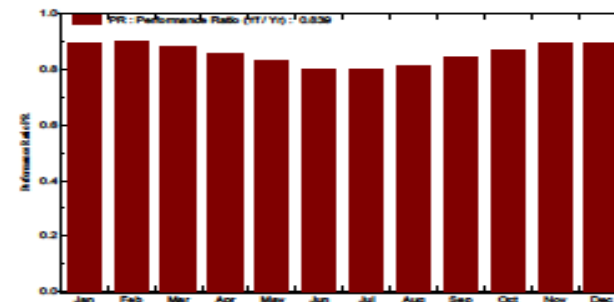
Main system parameters	System type	Grid-Connected	
Near Shadings	According to strings tracking, tilted axis, Axis Tilt	Electrical effect	100 %
PV Field Orientation	0°	Axis Azimuth	0°
PV modules	Model JKM 335PP-72-V 2018	Pnom	335 Wp
PV Array	Nb. of modules 6132	Pnom total	2054 kWp
Inverter	INGECON SUN 1640TL B630 OUTDOOR+	Pnom	1637 kW ac
User's needs	Unlimited load (grid)		

Main simulation results	Produced Energy	Specific prod.
System Production	3845 MWh/year	1872 kWh/kWp/year
Performance Ratio PR	83.94 %	

Normalized productions (per installed kWp): Nominal power 2054 kWp



Performance Ratio PR



SAT DC/AC 1.25 GCR 0.4
Balances and main results

	GlobHor kWh/m ²	T Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	55.0	3.50	73.7	69.4	144.9	135.6	16.54	15.47
February	81.0	4.90	108.2	102.7	210.5	199.3	16.35	15.48
March	135.0	7.70	181.8	173.2	345.0	328.4	15.95	15.19
April	163.0	9.20	216.0	205.6	396.8	378.3	15.44	14.72
May	199.0	13.60	260.0	247.9	463.2	442.2	14.97	14.29
June	221.0	19.00	290.9	278.0	499.9	477.8	14.44	13.80
July	236.0	22.40	319.5	306.3	550.2	526.3	14.47	13.84
August	207.0	22.00	281.2	269.4	491.1	469.5	14.68	14.03
September	151.0	17.00	206.6	197.0	375.9	358.7	15.29	14.59
October	103.0	12.10	138.1	131.2	259.8	246.5	15.80	15.00
November	63.0	7.10	85.1	80.6	166.0	156.1	16.39	15.41
December	50.0	4.50	68.8	64.9	135.5	126.4	16.56	15.45
Year	1664.0	11.96	2229.9	2126.2	4038.9	3845.1	15.22	14.49

Legends: GlobHor Horizontal global irradiation
 T Amb Ambient Temperature
 GlobInc Global incident in coll. plane
 GlobEff Effective Global, corr. for IAM and shadings
 EArray Effective energy at the output of the array
 E_Grid Energy injected into grid
 EffArrR Effic. Eout array / rough area
 EffSysR Effic. Eout system / rough area

6.- Results- Financial analysis

	2.018	2.019	2.020	2.021	2.022	2.023	2.024	2.025	2.026	2.027	2.028	2.029	2.030	2.031	2.032	2.033	2.034	2.035	2.036
'000 Euros																			
Ingresos por venta energía electrica	0	4.343	4.364	4.385	4.406	4.428	4.449	4.470	4.491	4.512	4.534	4.555	4.576	4.597	4.618	4.639	4.660	4.681	4.701
Gastos de explotación	0	1.520	1.512	1.505	1.497	1.489	1.482	1.474	1.466	1.459	1.451	1.443	1.435	1.428	1.420	1.412	1.405	1.397	1.389
Gastos amortización	0	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	0	0	0
Beneficio de explotación	0	116	145	174	203	232	261	290	318	347	376	405	434	462	491	520	3.255	3.283	3.312
Gastos financieros y asimilados	422	377	357	337	317	296	275	254	233	211	189	167	144	121	97	74	49	25	0
Beneficio de las actividades ordinarias	422	261	212	163	114	65	15	35	85	136	187	238	290	342	394	446	3.206	3.259	3.312
Subvenciones	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beneficio antes de impuestos	422	261	212	163	114	65	15	35	85	136	187	238	290	342	394	446	3.206	3.259	3.312
Impuestos	0	0	0	0	0	0	0	0	0	0	0	24	101	120	138	156	1.122	1.141	1.159
Beneficio despues de impuestos	422	261	212	163	114	65	15	35	85	136	187	214	188	222	256	290	2.084	2.118	2.153

Flujos de caja	-17.525	2.873	1.165	1.194	1.223	1.251	1.280	1.309	1.338	1.367	1.396	1.376	1.275	1.344	1.355	1.365	520	437	2.131
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IRR (%)	7,45%
VAN	2.652
Payback actualizado (años)	24
Payback sin actualizar (años)	14

7.- Conclusions.



- We have used conservative assumptions to calculate project IRR. IF we use real market values Project IRR could increase up to 300 pb if:
 - The yearly average pool Price increase 2 Eur more, that means project profitability will also increase 110 pb (PV plants Works when the pool Price is higher)
 - OPEX decrease 2 eur that means that Project profitability will increase 100 pb. This goal is easy to achieve due to the synergies with the O&M of the wind farm.
 - The Project works 100 h/year more than expected, that means Project profitability will also increase 90 pb. This is caveat to the O&M manager criteria.
- Discount rate = 6%
- We have also considered a 1% of yearly inflaction for OPEX and the pool Price increase 1% yearly.
- Solar farm is not going to receive any subsidy..
- Leverage = 65%
- Duration:18 years
- Interés rate =1.5 %.

8.- Questions



- Wind – solar PV systems are already in place in several countries like India, however they need more development in Europe. Some questions are still pending:
 - ❑ Dispatch priority of the new system ?
 - ❑ Is it necessary to install two different metering equipments?
 - ❑ Ancillary services. Together or separately?
 - ❑ The new installation, hybridated with an existing one, without subsidies is it included in the existing regulatory framework?
 - ❑ Permit to built of the existing generation plant is still valid?