



Closed Loop Wind Farm Control

DELIVERABLE REPORT

Feasibility analysis, business models, and business plan industrial partners and large Engineering firms and Value Proposition

Deliverable No.	D5.2	Work Package No.	WP5	Task/s No.	Tasks 5.2.1/5.2.2/5.2.3
Work Package Title		WP5. IPR, Exploitation, Dissemination and Communication of results			
Linked Task/s Title		Task 5.2.1 Feasibility Analysis and Business Model (LCoE, TCO). Task 5.2.2 Industrial Detailed Business Plan Task 5.2.3 Value Proposition			
Status		Draft Final	(Draft/Draft Final/Final)		
Dissemination level		PU	(PU-Public, PP, RE-Restricted, CO-Confidential) (https://www.iprhelpdesk.eu/kb/522-which-are-different-levels-confidentiality)		
Due date deliverable		2019-10-31	Submission date		2019-10-30
Deliverable version		CL-Windcon-D5.2-DraftFinal-Business Models			



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727477

DOCUMENT CONTRIBUTORS

Deliverable responsible		Qi Energy	
Contributors	Organization	Reviewers	Organization
Juan de Blas	Qi Energy	Alessandro Croce	POLIMI
Javier Medina	Qi Energy	Torben Knudsen	AAU
Oscar Pires	CENER		
Sergio Monreal	CENER		

DOCUMENT HISTORY

Version	Date	Comment
V1	2019-09-30	D5.2 Feasibility Analysis-Draft-V1
V2	2019-10-24	D5.2 Feasibility Analysis-Draft-V2
V3	2019-10-29	D5.2 Feasibility Analysis-Draft Final-V3
DraftFinal	2019-10-30	Draft Final

TABLE OF CONTENTS

EXECUTIVE SUMMARY	6
1 INTRODUCTION	8
2 METHODOLOGY	9
3 SENSIBILITY ANALYSIS	10
3.1 PREAMBLE	10
3.2 SENSIBILITY ANALYSIS METHODOLOGY	12
3.3 SENSIBILITY ANALYSIS SINGLE RESULTS	13
3.3.1 Modification of the OPEX costs	13
3.3.2 Modification of the Net Energy Production	15
3.3.3 Variation of the WACC.....	16
3.3.4 Variation of the inflation rate.....	17
4 PRELIMINAR BUSINESS STRUCTURING	20
4.1 TYPE OF ENTITIES	20
4.2 TYPE OF APPLICATIONS	20
4.3 TYPE OF SERVICES.....	22
5 BUSINESS MODELS	25
5.1 INTRODUCTION	25
5.2 CANVAS FOR GROUP OF “PURE RESEARCHERS”	26
5.3 CANVAS FOR GROUPS OF “MIX ORGANIZATIONS”	29
5.4 CANVAS FOR GROUPS OF “PURE BUSINESS”	33
6 BUSINESS PLANS.....	36
6.1 OVERVIEW OF THE WIND SECTOR.....	36
6.2 COMPETITIVE POSITION OF THE CL-WINDCON LARGE COMPANIES.....	40
6.2.1 ENEL GREEN POWER – Competitive Position	40
6.2.2 DNV GL – Competitive Position	41
6.2.3 GE – Competitive Position	42
6.2.4 RAMBOLL – Competitive Position	43
6.2.5 DEWI – Competitive Position	44
6.2.6 Global view Serviceable Addressable Market (SAM) large companies	45
6.3 MIX ORGANIZATIONS- COMPETITIVE POSITION	47
6.4 PURE RESEARCHER ORGANIZATION – COMPETITIVE POSITION	48
6.5 GLOBAL ECONOMIC IMPACT	48
7 CONCLUSIONS	49
8 REFERENCES	50

LIST OF FIGURES

Figure 1. Windfarm layout.....	10
Figure 2. Pessimistic and Optimistic scenario when varying OPEX (in Yaw scenario) over most probable	14
Figure 3. Pessimistic and Optimistic scenario when varying Net Load Factor	15
Figure 4. Pessimistic and Optimistic scenario when varying the WACC	17
Figure 5. Pessimistic and Optimistic scenario when varying the Inflation Rate.....	18
Figure 6. Baseline and yaw differences under a combination of positive and negative effects.....	19
Figure 7. CANVAS model	25
Figure 8. Global annual installed wind capacity 2001-2018.....	36
Figure 9. Global cumulative installed wind capacity 2001-2018.....	37
Figure 10. New installations and total capacity in onshore and offshore in 2018.....	38
Figure 11. Global Cumulative Wind Power Capacity. WEC Outlook 2016.	39
Figure 12. EGP Green energy distribution globally	40
Figure 13. Revenues distribution DNV by sector.....	42
Figure 14. Services provided by UL Renewables	45

LIST OF TABLES

Table 1. Sensibility analysis main results.....	6
Table 2. Economic impact of technology in large companies in CL-Windcon.....	7
Table 3. Results of the yaw and base control systems in the most probable scenario	12
Table 4. Sensibility analysis. Parameters modified	13
Table 5. Pessimistic and Optimistic scenarios when varying the OPEX costs in the yaw scenarios	14
Table 6. Pessimistic and Optimistic scenario when varying the Net Energy production over most probable	15
Table 7. Pessimistic and Optimistic scenario when varying the WACC over most probable	16
Table 8. Pessimistic and optimistic scenarios when varying the inflation rate.....	17
Table 9. Combination of all negative and positive variables with all effects simultaneously.....	18
Table 10. Applications for the software developed	21
Table 11. Market routes for the different software.....	22
Table 12. Market potential from the perspective of the Industrial /large Consulting partners.....	23
Table 13. CANVAS Pure Researcher organizations.....	28
Table 14. Mix Organizations CANVAS model	32
Table 15. Pure Businesses CANVAS model.....	35
Table 16. Installed and managed Wind Capacity World/ENEL 2017.....	41
Table 17. EPG Distribution of capacity managed by country and technology, (EGP web site – April 2018).....	41
Table 18. TAM and SAM markets.....	46
Table 19. SOM market for EGP.....	46
Table 20. SOM market for GE.....	47
Table 21. SOM market for the Consultancy and Engineering companies.....	47
Table 22. Global SOM market for large CL-Windcon firms (2026-2030)	47

LIST OF ABBREVIATIONS

Abbreviation	Description
AEP	Annual energy production
BOP	Balance of Plant
CAPEX	Capital Expenditure
EOL	End of life
ESC	Energy Service Company
KPI	Key performance indicator
LCA	Life cycle assessment
LCC	Life Cycle Costing
LCOE	Levelized Cost of Electricity
MO	Mixed Organizations (organizations market and research driven)
MW	Megawatt
O&M	Operation and maintenance
OPEX	Operational Expenditure
PB	Pure Businesses (organizations business oriented)
PR	Pure Researchers (organizations research driven)
RWF	Reference Wind Farm
SAAS	Software as a Service
SAM	Serviceable Available Market or market we can serve
SOM	Serviceable Obtainable Market or market quote
TAM	Total Addressable Market
TCO	Total Cost of Ownership
WACC	Weighted average cost of capital

EXECUTIVE SUMMARY

Deliverable D5.2 provides an overview of the economic impacts the technology will generate in the marketplace and is based on the results obtained in an exercise implemented in deliverable D4.6 entitled Cost benefit analysis and some other information collected in the project. The baseline scenario was compared with the yaw scenario where the wakes were reoriented to improve the Wind farm performance.

The economic results are not conclusive so far, as they only considered one of the technics the CL-Windcon project considered “the wake redirection”. Therefore, there is margin for improvement in case other technics were implemented at same time. Indeed, the methodology to calculate wake effects was slightly simplified, and some authors differs on results (please check deliverable D4.6 Cost-benefit analysis, for further results). For that reason, to extend the conclusions, the first chapter of deliverable D5.2 introduces a sensibility analysis to check the evolution of the model in case any of the main assumptions will vary. The parameters modified were WACC, Inflation Rate, level of O&M costs and energy generation.

We established a positive, most likely and negative scenarios and the results showed that LCC could vary out of EUR 30 million up or down making the LCC negative in the worst case but saving around EUR 46 million in the best case during the whole lifetime.

ALL EFFECTS SIMULTANEOUSLY		PESSIMISTIC		PROBABLE		OPTIMISTIC	
		BASE	YAW	BASE	YAW	BASE	YAW
Discounted Rate (WACC)	%	8.00		5.19		4.00	
Inflation rate	%	1.0		1.5		2.0	
OPEX Costs	€	1,286,897,125	1,355,557,262	1,286,897,125	1,291,006,916	1,286,897,125	1,286,897,125
Total Costs (PV)	€	2,156,198,509	2,189,326,877	2,448,294,807	2,451,886,907	2,678,384,462	2,679,306,542
Net Energy production	(MWh/MW/y)	4,542.24	4,577.92	5,678	5,722	5,961.69	6,008.52
LCOE	€/MWh	46.85	47.20	30.97	30.78	27.53	27.33
Total Energy Produced (PV)	MWh	46,021,401	46,382,907	79,049,256	79,670,200	119,233,800	120,170,400
Increase in LCC (Present Value)	€	-33,128,368		-3,592,100		-922,080	
Incr.Net Energy sales (PV,50€)	€	18,075,262		31,047,208		46,830,000	
Net differences (PV)	€	-15,053,106		27,455,109		45,907,920	

Table 1. Sensibility analysis main results

With the most probably scenario, with extra savings of EUR 27 million at present value in 25 years, we prepared three CANVAs models to assess the potential business opportunities for three different groups of partners; those focused on making research (mainly universities), those we called mix organizations (technological centres and some market driven universities), who look for private incomes through services but are also research oriented as the first group. Finally, the third group entitled “Pure Businesses” gathering the large companies involved in CL-Windcon. The Value Proposition was determined for the three groups and then a business case was prepared for each large company in the project and the rest of partners.

The value proposition for the Pure Business with the biggest market impact is described below:

Large companies involved in the promotion of a new Wind farm or the retrofitting of an existing one will offer extra incomes from 0,15% to 0,30% in electricity sales, a reduction between 1% to 2% in the LCC during the project lifetime and a reduction of the LCOE close to 0.70%. These advantages allow them to adjust prices in auctions and competitions gaining margins or reducing prices to end users.

The business case conclusion is that regardless less ambitious results than expected and the limits of the exercise done, there is still a great market opportunity which can be perceived in the joined Table 2 of results below:

Concept	EGP	Unit	DNV	Unit	GE	Unit	RAMBOLL	Unit	DEWI	Unit	TOTAL	Unit
SAM 2026-2030	16.0	GW	800.0	GW	80.0	GW	800.0	GW	800.0	GW		
Wind sector Revenues	25,000.0	million €	112.5	million €	12,200.0	million €	180.0	million €	100.0	million €	37,592.5	million €
Business linked to CL-Windcon	108.0	million €	11.3	million €	326.2	million €	18.0	million €	10.0	million €	473.5	million €
SOM 2026-2030 (50%)	54.0	million €	5.6	million €	163.1	million €	9.0	million €	5.0	million €	236.7	million €

Table 2. Economic impact of technology in large companies in CL-Windcon

A total of EUR 236.7 million could be generated solely by the large companies in the project plus the contribution of the remaining partners. That represent a generation of 2500 new employment in 5 years (from 2026, the entry point for the technology at large scale and 2030). Technological centres, Universities and SMEs may add around EUR 14 million from 2021 to 2030 (simulation and design will enter in advance as SaaS) totalizing **EUR 250 million generated by the CL-Windcon technology in 10 years.**

1 INTRODUCTION

This deliverable is addressed to respond to subtasks 5.2.1. “Feasibility Analysis and Business Model” (LCoE, TCO), subtask 5.2.2. “Industrial Detailed Business Plan” and subtask 5.2.3. “Value Proposition” in relation to the new Windfarm control software. The analysis is based on results of deliverable D4.6 entitled “Cost benefit analysis” that included a Life Cycle Costing (LCC, economic viewpoint) and a Life Cycle Analysis (LCA, environmental viewpoint). The analysis is also based in the evolution of the wind markets which is included in the last innovation management deliverable (D5.3) and the last version of the IPR updates (deliverable D5.4).

This report will be then organized in four main blocks of information according to the proposal:

- The **sensibility analysis** prepared to extend the conclusions of the economic analysis when some assumptions were modified.
- The **Feasibility Study** reviews main options to determine the best Business Model for the new control algorithms exploitation. The Business Model will be defined for each company in the Consortium, describing best ways to generate revenues/cost-effectiveness and make a profit from operations in terms of time and costs. The model includes the components and functions of the business, as well as the revenues it generates and the expenses it incurs.
- **Value Proposition.** A review and analysis of the benefits, costs and value that an organization can deliver to its customers, prospective customers, and other constituent groups and outside the organization will be the target. The entities will perceive the operational profitability that the new control algorithms would bring to them.
- A **detailed Business Plan** is developed for the main industrial partners (EGP, GE) and large engineering companies (DNV, RAMBOLL, DEWI), who will be responsible to land the final products into the marketplace. Product definition, channels for commercialization, main competitors, prices, marketing tools, economic insights, etc., This analysis is done gathering the companies by profile as the results were not so promising to deepen inside each of project partners.

As a final comment, we must insist again that the results from the LCC and LCA cannot be considered conclusive due to the complexity of simulating the expected failure rates of a turbine submitted to a different inflow wind compared with greedy conditions (base case). This simulation affects the Operation and Maintenance (O&M) that increases costs, but at same time improves the energy output with the result of a slightly better LCOE. The impossibility to prove the technology in a complete real environment (Sedini wind farm was used partially to simulate some results in a short period of time) and see what happen during 30 years in the real life, summed up to the variations of the wind and terrain conditions, the windfarm layout in every site and the capacity of the engineering team in charge of the windfarm to define the wake redirections in the appropriate way, provides a great range of uncertainty of results.

For that reasons, we include a sensibility analysis modifying some of the parameters (WACC, Inflation rate, O&M costs, energy output) to check what happen with the results in such a case. A very positive or a very negative result will modify the business model and the corresponding company business plans. However, we will analyse the results focusing on the Base case and leaving the positive and negative options just for information, without making a deep analysis.

2 METHODOLOGY

The methodology to drawing up this deliverable was based on the usage of scientific papers, annual reports from large sectorial consultancy companies and internal data and previous deliverables generated within the project. The main purpose of the report is to conduct a quantitative analysis to determine the impact of the new control algorithms in the marketplace.

Supported by a former intermediate deliverable that reviewed the market trends and opportunities (D5.9 Innovation management), the final version (D5.3), pointed out the most relevant updated information on market trends connected to the technology. Deliverable D4.6 Cost benefit analysis, provided as well a complete LCC and LCA. With this information, we have calculated here the economic impact in the main project partners as soon as the technology will enter into the market.

The market information developed in deliverables D5.3 was based on qualitative analysis carried out through the consultation of numerous and updated annual reports of international organizations such as the Global Wind Energy Council (GWEC), International Renewable Energy Agency (IRENA), International Energy Agency (IEA), WindEurope, etc. These reports described the current situation of the wind energy market and the possible future trends, giving a general overview of the potential growth of the market. Please check references in deliverable D4.6.

The economic-quantitative analysis presented in deliverable D4.6, concerns the calculation of the Life Cycle Costing (LCC) and the Levelized Cost of Energy (LCOE) and was also supported by scientific and public literature, such as a Guide to an offshore windfarm, BVGA and Catapult, 2019, Forecasting Wind Energy Costs and Cost drivers, the view of the world leading experts NREL, 2016, Cost of Wind Energy Review, NREL, 2015, Floating Offshore Wind: Market and Technology Review, Carbon Trust, 2015, Parametric CAPEX, OPEX, and LCOE expressions for offshore windfarms based on global deployment parameters, Cranfield University, 2018, among others. Please check the references also in deliverable D4.6.

Some internal data arising from the pilot experiences (Sedini and wind tunnel) and the company calculations were also used to elaborate the final conclusions.

These final conclusions can be viewed as the fruit of the analyses conducted by the deliverable authors according dedicated calculation along with o the findings encountered in the market search. However, they are not conclusive and should be rather used internally by project partners to initiate new activities or propose new strategic actions. Thus, the document is divided in three main chapters.

1. Sensibility analysis
2. Business models (Through CANVAS) including the Value Proposition
3. Business Plans (for three different groups of partners)

3 SENSIBILITY ANALYSIS

3.1 Preamble

Deliverable D4.6 showed the results of an economic and environmental study over an offshore reference windfarm (Norcowe) where the introduction of a new control system was simulated. The Project developed advanced control algorithms for induction control and wake redirection to optimize the operation of the windfarm, making a balance between annual energy production, lifetime and O&M cost, aimed at minimizing the LCoE. To that end, it has applied techniques as loads-optimized power curtailment; event triggered Individual Pitch Control (IPC) for loads reduction under partial wake conditions, fault-tolerant and fast wake recovery techniques.

The Norcowe Windfarm is virtual windfarm used the reference Windfarm or (RWF hereinafter). It is placed in the North Sea and is located around 80 km west of the German island Sylt and near the met mast FINO 3. The RWF comprises 80 turbines of the type DTU 10 MW RWT (800 MW) and the layout of the windfarm can be seen in Figure 1. Positions 26 and 61 in the layout are the positions of substations. The distance between the rows is 8 rotor diameters and the distance between the turbines is 7 rotor diameters.

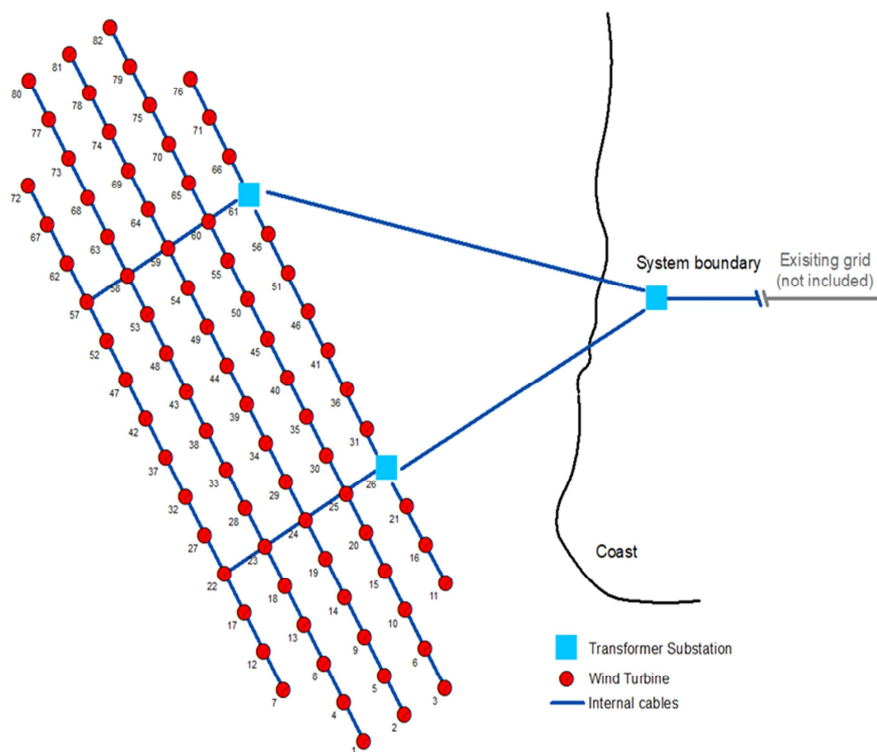


Figure 1. Windfarm layout

The main characteristics of the RWF are the following:

Description	Value
• Rated Power (MW)	10
• Rotor Diameter (m)	178.3
• Hub height (m)	119
• Cut-in speed (m/s)	4
• Rated Speed (m/s)	11.4
• Cut-out speed (m/s)	25
• Cut-in Rotor speed (RPM)	6
• Cut-out Rotor speed (RPM)	9.6

The wind turbine is mounted on a jacket structure of which the main parameters can be found in the next list:

Description	Value
• Number of legs (units)	4
• Base Width (m)	33
• Top Width (m)	16
• Interface elevation (mMSL)	26
• Transition Piece height (m)	8
• Jacket legs outer diameter (upper/lower leg mm)	1422/1828
• 1 st eigen frequency (1 st bending mode) (Hz)	0.2635

The impact of the wake steering control strategy on power and fatigue load distribution was the cornerstone of the study. Turbine level load data from wake steering control simulations was used to estimate damage equivalent loads (DEL) for a range of wind speeds and yaw misalignments. This data was checked with farm-level wind speed and direction distributions and thereby the distribution of fatigue loading all along the windfarm was estimated.

According to results of deliverable D4.6, the wake redirection induces an increase in the average loads of the windfarm. The reduction of the turbulences generated by the wakes in downstream turbines, improves the wind velocity received and the corresponding loads. So, there is an increase of failure rates due to this increase in loads. The main effect is therefore the growth of the O&M costs (more repairing, more transportation, more spare parts) but at same time the energy output of the windfarm is also increased, slightly improving the LCOE (€/MWh). Some other authors in CL-Windcon consider that using a more precise simulation tool, the loads are not increased but reduced. The reason is the consideration that partial wakes in a turbine increase loads much more than the free wind (with no wakes) and when you yaw the wakes, you reduce failure rates. This is the reason why we have foreseen a sensibility analysis to measure to what extend the LCOE may vary modifying some of the assumptions.

3.2 Sensibility analysis methodology

We present here the results of an exercise where we consider three scenarios; the optimistic one, the most likely and the pessimistic, characterized as follows:

Most likely: The most probable scenario was described in deliverable D4.6 and corresponds with the table below. The WACC was considered 5.12 (calculated by Ramboll in deliverable D4.5), the inflation rate was 1.5% considering the trends in the last years, the variation between the OPEX from base and yaw was limited to a 0,32% increase due to the raise of the failure rates an loads (please check deliverable D4.6 for additional explanations). The net energy production is increased in 0.79% also because of the average raise in loads. These two effects modify the LCOE with a 0.63% reduction.

The last three rows represent the economic results; increase or decrease of the Life Cycle Costing considering the modifications of the operations and maintenance activities, increase of the net energy production (as of the loads' increase) and the net differences summing up both concepts. The net difference represents the savings in economic terms comparing the yawed turbines belonging to the wind farm with the same in greedy conditions (non-controlled).

BASELINE CASE		PROBABLE		
		BASE	YAW	Variation
Lifetime Windfarm	Years	25+1		
Discounted Rate (WACC)	%	5.12		
Inflation rate	%	1.50		
OPEX Costs	€	1,286,897,125	1,291,006,916	0.32%
Total Costs (PV)	€	2,448,294,807	2,451,886,907	0.15%
Net Energy production	(MWh/MW/y)	5,677.80	5,722.40	0.79%
LCOE	€/MWh	30.97	30.78	-0.63%
Total Energy Produced (PV)	MWh	79,049,256	79,670,200	0.79%
Increase in LCC (Present Value)	€	-3,592,100		
Increase in Net Energy sales (PV,50€)	€	31,047,208		
Net differences (Present Value)	€	27,455,109		

Table 3. Results of the yaw and base control systems in the most probable scenario

The table indicates that in the most likely scenario, there will be a reduction of 0.63% in the LCOE when using the new control algorithms, with a EUR 27.4 million savings (at present value) during the whole project lifetime (around €1.08 million savings per year). The installation lifetime was considered 25 years plus one additional year for dismantling.

However, some of the assumptions could be modified. For that reason, the next exercise (a sensibility analysis) intends to modify some of the assumptions and see what happen with the LCOE. The next sensibility analysis table identifies the parameters modified in the pessimistic and optimistic scenarios.

SENSIBILITY ANALYSIS		PESSIMISTIC		PROBABLE		OPTIMISTIC	
		BASE	YAW	BASE	YAW	BASE	YAW
Discounted Rate (WACC)	%	WACC _{Probable} +4		WACC _{Probable}		WACC _{Probable} -1.19	
Inflation rate	%	IR _{Probable} -0.5		IR _{Probable}		IR _{Probable} + 0.5	
OPEX Costs	€	OPEX _{base}	OPEX _{yaw} + 5%	OPEX _{base}	OPEX _{yaw}	OPEX _{base}	OPEX _{base}
Net Energy production	MWh/MW/y	NEP _{base} -20%	NEP _{yaw} -20%	NEP _{base}	NEP _{yaw}	Net _{base} +5%	Net _{yaw} +5%
LCOE	€/MWh	X ₁	X ₁ '	LCOE _{base}	LCOE _{yaw}	X ₂	X ₂ '
Increase in LCC (Present Value)	€	Inc/Dec LCC _{poss}		Incr/ Dec LCC _{Probable}		Inc / Dec LCC _{opt}	
Increase in Net Energy sales (PV,50€)	€	Incr. NES _{poss}		Incr. NES _{Probable}		Incr. NES _{opt}	
Net differences (Present Value)	€	Net Diff _{poss}		Net Diff _{Probable}		Net Diff _{opt}	

Table 4. Sensibility analysis. Parameters modified

The methodology for the sensibility analysis modifies some of the initial assumptions. The effects of each of these modifications are depicted in successive tables one by one, to prevent distorting that effect by the accumulation of two or more effects at same time. At the end, all the negative assumptions are gathered and the positive as well, to reach the extremes in the range of effects by the combination of all them.

3.3 Sensibility analysis single results

3.3.1 Modification of the OPEX costs

We consider here than for the **pessimistic scenario**, the yaw calculations could be incorrect and the real expenditure, when applying the new control algorithm (yaw scenario), might be 5% over the most likely case. This higher figure could be reached in case we had to add extra gauges for different windfarm configurations plus the extra expenses to run the control software. A 5% increase in the OPEX could be possible due to this indetermination and other factors (cost of mobilization of boats, increase in spare parts, etc.).

For the **optimistic scenario**, we consider that base and yaw scenarios require the same level of investment for the Operation and Maintenance activities. This case relies in a more realistic calculation of turbine loads based on the assumptions of other authors different to those involved in deliverable D4.5 O&M Cost model (implemented by a team headed by Ramboll). These other authors consider that the increase in loads when yawing the inflow wind (eliminating turbulences and increasing the wind speed) could be offset with the reduction of the high partial loads a wake can infer over the next turbine). Please for further explanations, revise deliverable D4.6¹.

The results are showed in the next table:

VARIATION OF OPEX COSTS /REST THE SAME		PESSIMISTIC		PROBABLE		OPTIMISTIC	
		BASE	YAW	BASE	YAW	BASE	YAW
OPEX Costs	€	1,286,897,125	1,306,884,130	1,286,897,125	1,291,006,916	1,286,897,125	1,286,897,125
Total Costs (PV)	€	2,448,294,807	2,462,201,903	2,448,294,807	2,451,886,907	2,448,294,807	2,449,216,887
Net Energy production	(MWh/MW/y)	5,677.80	5,722.40	5,677.80	5,722.40	5,677.80	5,722.40
LCOE	€/MWh	30.97	30.90	30.97	30.78	30.97	30.74
Total Energy Produced (PV)	MWh	79,049,256	79,670,200	79,049,256	79,670,200	79,049,256	79,670,200
Incr. in LCC (Present Value)	€	-13,907,096		-3,592,100		-922,080	
Incr.Net Energys sales (PV,50€)	€	31,047,208		31,047,208		31,047,208	
Net differences (PV)	€	17,140,113		27,455,109		30,125,128	

Table 5. Pessimistic and Optimistic scenarios when varying the OPEX costs in the yaw scenarios

The results show that an underestimation of the OPEX costs in the yaw scenario in just 5% could significate reduce the Net differences almost in a 40% with savings of €17 million instead of €27 million in present value for the 25 years of operation.

In addition, in the optimistic scenario, if we consider that fatigue loads on the turbines in the base case and the yaw case are more or less equivalent, then, the O&M expenditure might be also equivalent, but the energy production will still be higher in the yaw scenario. This situation improves significantly the net differences reaching EUR 30.1 million instead of EUR 27.4 million.

We add here a summary graph with the main results in the three scenarios:

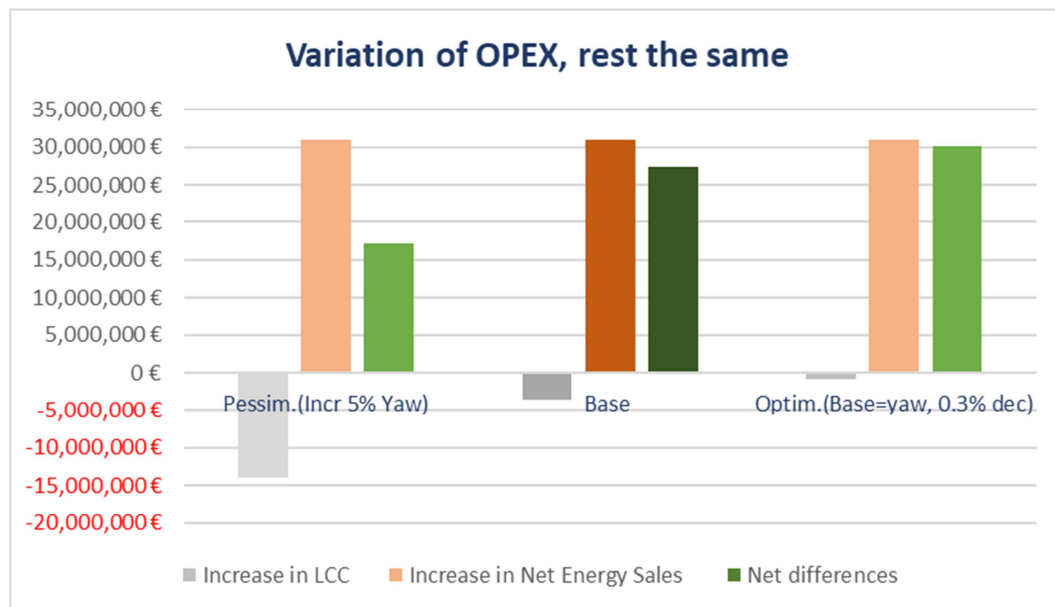


Figure 2. Pessimistic and Optimistic scenario when varying OPEX (in Yaw scenario) over most probable

3.3.2 Modification of the Net Energy Production

The most likely scenario has considered Net Load Factors close to 65% which is rather high although reachable as some offshore recent windfarms has demonstrated². This chapter modifies the Net Load Factor to a figure close to 50% (more realistic nowadays). The exercise intends to evaluate the net economic savings when reducing the wind output by 20% in the pessimistic scenario or increase the wind output by 5% in the optimistic scenario. Results are in the following table:

VARIATION OF NET ENERGY PRODUCTION /REST THE SAME		PESSIMISTIC		PROBABLE		OPTIMISTIC	
		BASE	YAW	BASE	YAW	BASE	YAW
OPEX Costs	€	1,286,897,125	1,291,006,916	1,286,897,125	1,291,006,916	1,286,897,125	1,291,006,916
Total Costs (PV)	€	2,448,294,807	2,451,886,907	2,448,294,807	2,451,886,907	2,448,294,807	2,451,886,907
Net Energy production	(MWh/MW/y)	4,542	4,578	5,677.80	5,722.40	5,962	6,009
LCOE	€/MWh	38.71	38.47	31.55	31.35	29.50	29.50
Total Energy Produced (PV)	MWh	63,239,405	63,736,160	77,603,141	78,212,726	83,001,719	83,653,710
Increase in LCC (Present Value)	€	-3,592,100		-3,592,100		-3,592,100	
Incr.Net Energy sales (PV,50€)	€	24,837,767		31,047,208		32,599,569	
Net differences (PV)	€	21,245,667		27,455,109		29,007,469	

Table 6. Pessimistic and Optimistic scenario when varying the Net Energy production over most probable

The results show that the effect is less relevant than in the case of the OPEX reduction. A 20% reduction in the net load factor reduces the savings in 23%. An increase in 5% increases the savings in a 5.6%. The LCOE is increased in the pessimistic scenario substantially becoming close to 40 €/MWh. Below the graph summarizing the results:

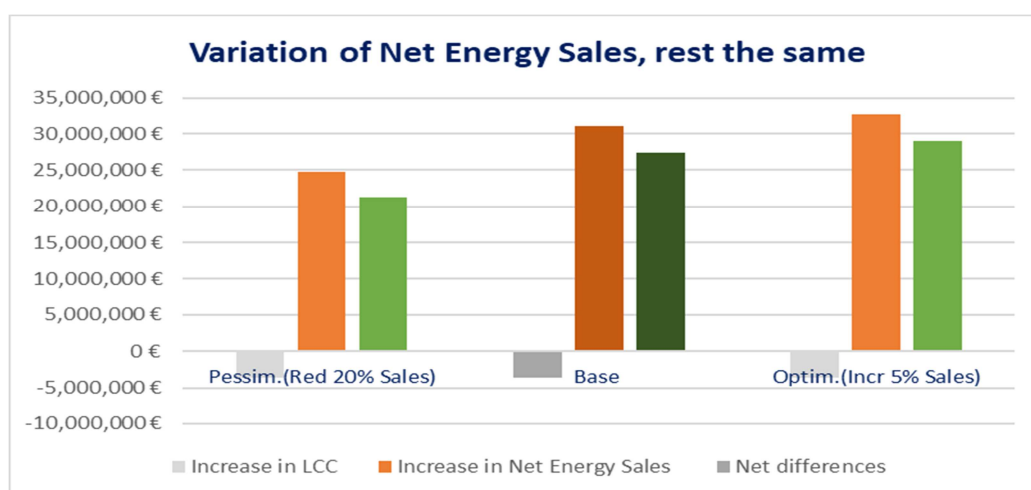


Figure 3. Pessimistic and Optimistic scenario when varying Net Load Factor

3.3.3 Variation of the WACC

The WACC has been fixed in 5.12 for the most likely scenario according to D4.5 team. However, some investors could ask for more or less return, depending on the windfarm circumstances and risk of the operation. According to the simplified formula below, the $WACC_{real}$ is linked to the inflation rate but also depends on the company market capitalization and the cost of the equity and the debt. So, this factor can easily vary a lot.

$$WACC_{real} = \frac{1+WACC_{nom}}{1+Rinf} - 1 \approx WACC_{nom} - Rinf$$

$$WACC_{nom} = \left(\frac{E}{V} * R \right) + \left(\left(\frac{D}{V} * Rd \right) * (1 - T) \right)$$

Equation 1. Formulation for the WACC

Being:

WACC real = Real Weighted Average Cost of Capital, when discounting inflation rate

WACC nominal = Nominal Weighted Average Cost of Capital

Rinf = Inflation rate

E = market value of the firm's equity (market cap)

D = market value of the firm's debt

V = total value of capital (equity plus debt)

E/V = percentage of capital that is equity (30%)

D/V = percentage of capital that is debt (70%)

Re = cost of equity (required rate of return)

Rd = cost of debt (yield to maturity on existing debt)

T = tax rate, considered 25%

The exercise has been proposed with WACC real of 4% (optimistic scenario, low risk) and 8% (pessimistic, high risk).

VARIATION OF WACC / REST THE SAME		PESSIMISTIC		PROBABLE		OPTIMISTIC	
		BASE	YAW	BASE	YAW	BASE	YAW
VARIATION (WACC)	%	8.00		5.12		4.00	
OPEX Costs	€	1,286,897,125	1,291,006,916	1,286,897,125	1,291,006,916	1,286,897,125	1,291,006,916
Total Costs (PV)	€	2,192,578,715	2,195,523,970	2,448,294,807	2,451,886,907	2,601,553,366	2,605,517,099
Net Energy production	(MWh/MW/y)	5,677.80	5,722.40	5,677.80	5,722.40	5,677.80	5,722.40
LCOE	€/MWh	36.32	36.08	30.97	30.78	29.76	29.58
Total Energy Produced (PV)	MWh	60,373,685	60,847,930	79,049,256	79,670,200	87,404,396	88,090,971
Increase in LCC (Present Value)	€	-2,945,256		-3,592,100		-3,963,733	
Incr.Net Energy sales (PV,50€)	€	23,712,233		31,047,208		34,328,755	
Net differences (PV)	€	20,766,977		27,455,109		30,365,022	

Table 7. Pessimistic and Optimistic scenario when varying the WACC over most probable

The graph with the main results is depicted below:

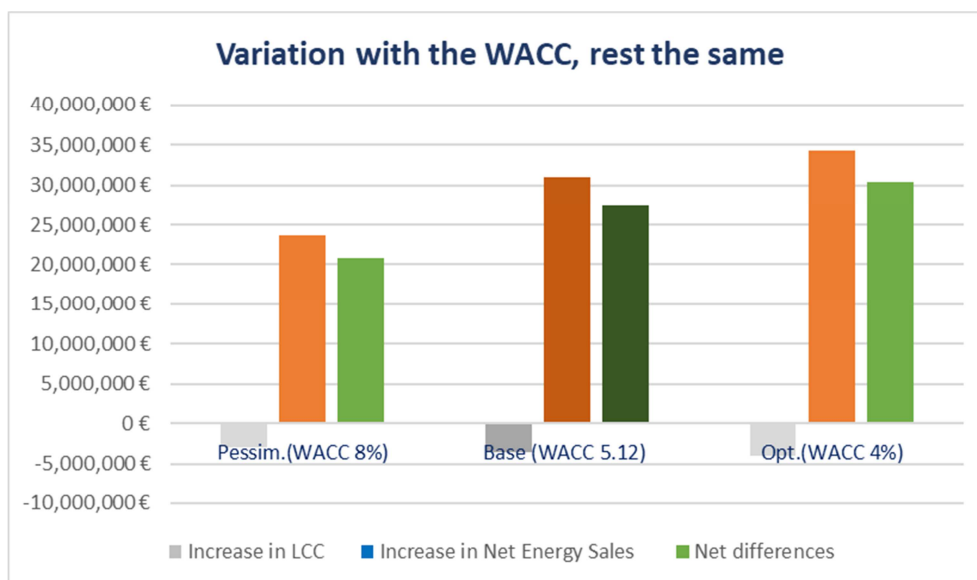


Figure 4. Pessimistic and Optimistic scenario when varying the WACC

The increase in the WACC real from 5.12% to 8% (56%) supposes a reduction of the net differences in €7 Million from €27 to €20 Million (32%). The reduction of the WACC in almost a point (22%, from 5.12% to 4%) supposes to increase the savings in € 3Million (10%, from €27 Million to €30 Million).

3.3.4 Variation of the inflation rate

The inflation rate will be very apparently low due to the global economy deceleration and especially the European economy. We have established 1.5% as the most likely scenario with variations up and down of 0.5%. The results of the LCOE comparing baseline and yaw scenarios for the optimistic and pessimistic scenarios according to the inflation rate are shown below:

VARIATION OF INFLATION RATE / REST THE SAME		PESSIMISTIC		PROBABLE		OPTIMISTIC	
		BASE	YAW	BASE	YAW	BASE	YAW
VARIATION INFLATION RATE	%	1.0		1.5		2.0	
OPEX Costs	€	1,286,897,125	1,291,006,916	1,286,897,125	1,291,006,916	1,286,897,125	1,286,897,125
Total Costs (PV)	€	2,391,003,623	2,394,453,999	2,448,294,807	2,451,886,907	2,510,597,924	2,514,342,349
Net Energy production	(MWh/MW/y)	5,677.80	5,722.40	5,677.80	5,722.40	5,677.80	5,722.40
LCOE	€/MWh	31.96	31.75	31.55	31.35	30.03	29.84
Total Energy Produced (PV)	MWh	74,820,070	75,407,794	79,049,256	79,670,200	83,596,406	84,253,069
Increase in LCC (Present Value)	€	-3,450,376		-3,592,100		-3,744,425	
Incr.Net Energy sales (PV,50€)	€	29,386,163		31,047,208		32,833,137	
Net differences (PV)	€	25,935,787		27,455,109		29,088,712	

Table 8. Pessimistic and optimistic scenarios when varying the inflation rate

The impact of the inflation rate is the lowest compared with other variables.

A diagram is also disclosed below:

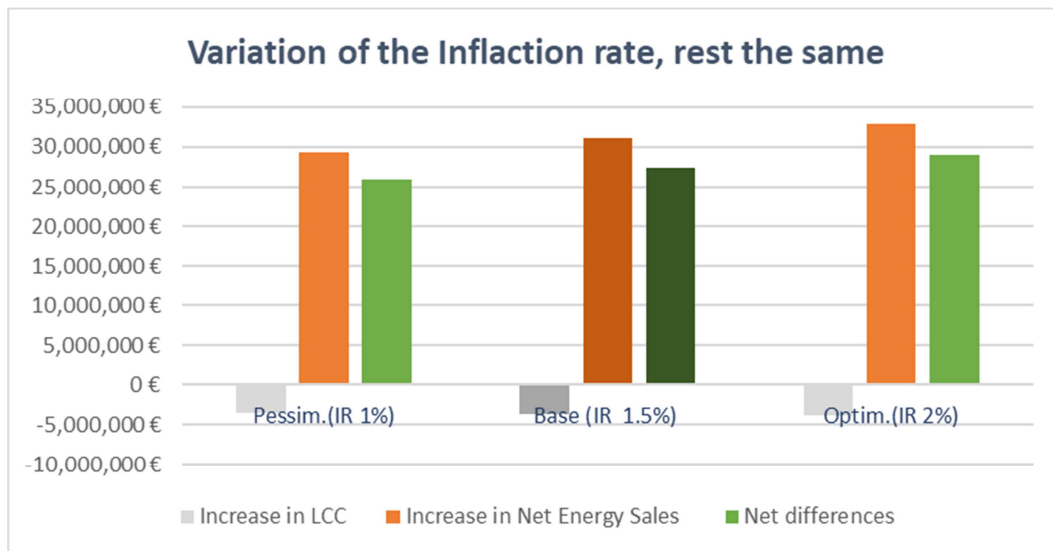


Figure 5. Pessimistic and Optimistic scenario when varying the Inflation Rate

Finally, we have joined all the variables together, to estimate the most pessimistic scenario and the most positive to check to potential economic impacts. The results are the following:

ALL EFFECTS SIMULTANEOUSLY		PESSIMISTIC		PROBABLE		OPTIMISTIC	
		BASE	YAW	BASE	YAW	BASE	YAW
Discounted Rate (WACC)	%	8.00		5.19		4.00	
Inflation rate	%	1.0		1.5		2.0	
OPEX Costs	€	1,286,897,125	1,355,557,262	1,286,897,125	1,291,006,916	1,286,897,125	1,286,897,125
Total Costs (PV)	€	2,156,198,509	2,189,326,877	2,448,294,807	2,451,886,907	2,678,384,462	2,679,306,542
Net Energy production	(MWh/MW/y)	4,542.24	4,577.92	5,678	5,722	5,961.69	6,008.52
LCOE	€/MWh	46.85	47.20	30.97	30.78	27.53	27.33
Total Energy Produced (PV)	MWh	46,021,401	46,382,907	79,049,256	79,670,200	119,233,800	120,170,400
Increase in LCC (Present Value)	€	-33,128,368		-3,592,100		-922,080	
Incr.Net Energy sales (PV,50€)	€	18,075,262		31,047,208		46,830,000	
Net differences (PV)	€	-15,053,106		27,455,109		45,907,920	

Table 9. Combination of all negative and positive variables with all effects simultaneously

The main conclusion of this table is that a combination of pessimistic situations (the OPEX in the yaw scenario is solely 5% over the calculated, the energy output is 20% less reduced than in the baseline, the WACC is the highest (8%) and the energy production is reduced 20%), the LCOE moves up far above 45 €/MWh. In this case, the Yaw control system introduces a deficit of € 15 million in the LCC during the whole lifetime. So, the yaw control is worst in this case than making no control.

For the optimistic scenario, if we consider a WACC of 4% (very low, representing a good economic situation and confidence), inflation rate of 2% (the optimum for the economy), the operational costs (OPEX) in the yaw scenario are equivalent to the baseline (this means that the calculation of fatigue loads is not modified with a very realistic simulation) and finally, the energy production is 5% higher than in the most likely scenario, then, the net difference raises to EUR 45 million positive. Below the diagram:

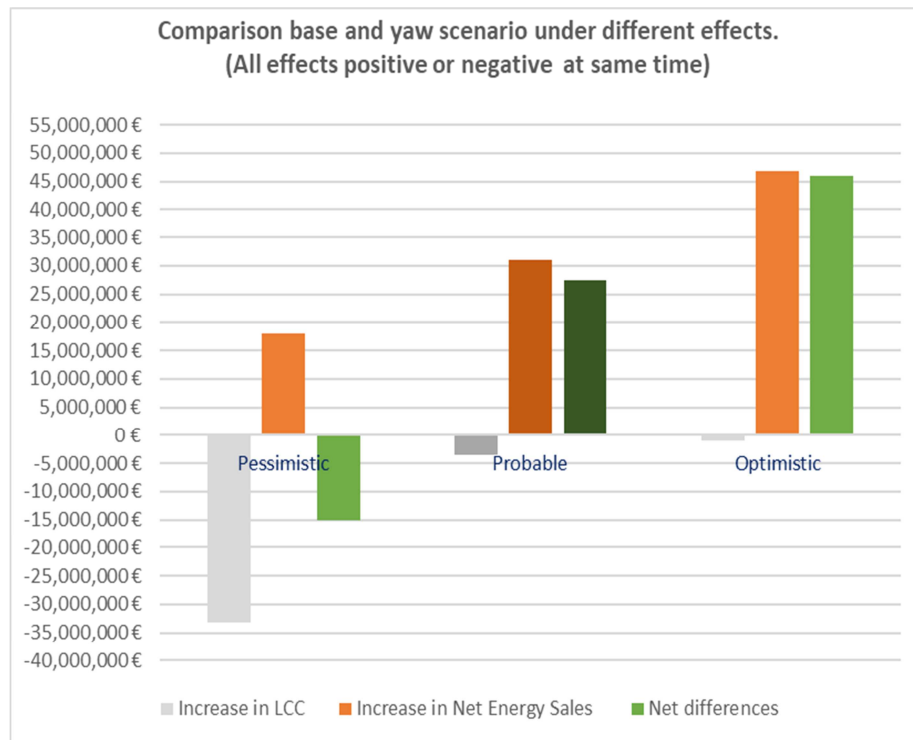


Figure 6. Baseline and yaw differences under a combination of positive and negative effects

The main conclusions of the analysis are:

- Cost variation of the OPEX is the most affecting factor when comparing the baseline (greedy control) and the yaw scenario (wake redirection and induction control...)
- Inflation rate, WACC and energy output does not modify the net differences to the same extend than the OPEX.
- **The new control system in the most likely conditions saves around EUR 27 million from a total investment of EUR 2.1 billion. However external factors like the IR, the WACC or the reduction or increase of the energy output, may bring net losses (in the pessimistic scenario) to EUR -15 million negative or net benefits to EUR 46 million positive. Thus, the range can move €60 million up or down depending on the circumstances and the windfarm management.**

4 PRELIMINAR BUSINESS STRUCTURING

In advance to enter in the business model analysis, it is important to classify and structure the business environment where the CL-Windcon partners are involved. There are different partners with different profiles, different business opportunities, different applications, services, etc. In the next chapter we will try to classify this diversity of business conditions.

4.1 Type of entities

- i. **Entities “research driven”.** We consider inside this group those universities which are not interested in exploiting commercially their products. They are research teams made of professors, doctorates, etc. and their main interest is the transference of knowledge, the training of students and the participation in granted projects to finance the research. Representatives for this group might be **AAU, TUM or USTUFF**. These entities usually work in open source. We will call them hereafter **“Pure Researchers or PR”**
- ii. **Mixed organizations “research but also market driven”.** We include here Technological Centres (public or private) plus some special type of universities which work close to the industry. They are interested in the same activities than group i, but also by means of public-private foundations or by any other business profiles. They establish long-term relationships with the Industry. To that end, they set up organizations with fix employed plus some rotational students that participate in the projects in a case by case basis. Examples in CL-Windcon of this profile could be **IKERLAN, CENER, TNO or TUDELFT and POLIMI**. These entities combine open source with tailored services. We will call them **“Mixed organizations or MO”**. The two universities provide strong market services like the POLIMI wind tunnel or the software developed by TUDelft offered as SaaS.
- iii. **Large Business companies.** We must distinguish among windfarm promoters, large consultancy or engineering companies and components’ manufacturers. Large companies invest in R&D to a certain extend. They usually prefer to buy the technology and protect it carefully developing an in-house know-how based on their own discoveries and that they eventually incorporate from third parties. Examples of these profiles in CL-Windcon are **DNV, RAMBOLL, DEWI, ENEL or GE**. We will call them herein **“Pure businesses or PB”**
- iv. **Small SMES.** They usually provide specialized services to large companies, technological Centres or universities. Their research capacity is limited due to the lack of resources. An example could be **Qi Energy or Zabala**. Hereinafter called as **“SMEs”**

4.2 Type of applications

Every entity profile usually provides similar services but of course some of them are not prepared to implement certain type of activities. Within the CL-Windcon project and considering the “group of products or services” developed, we can distinguish the following applications:

- i. **Installations’ design.** Design means all the activities implemented before the setting up of the windfarm to assess the business opportunity and plan the future works.

- ii. **Simulations.** Simulation is a technical development to advance the potential results a process will have in the real life through computing. Simulations are possible at the design phase, during project set up or after project start up. It can be used to visualise a new modification of the layout or the working conditions in advance to make the investment. Simulations can be also used to make forecasts of future installation behaviour.
- iii. **Maintenance.** Some software is used to control the maintenance services in the real life. It is very common nowadays to optimise these processes with feedback and feedforward information.
- iv. **Components design.** Specific software is also prepared to design, or redesign components of an equipment based on the experience of the designer.
- v. **Improve certain aspects.** Finally, some software is used to improve certain tasks or activities where there is more margin of improvement.

In the next table, we describe the software upgraded by the partners and the potential application.

SUPPLIER/?	SOFTWARE	Design and installation?	Simulate an Installation	Maintain an installation	Design components?	Improve certain aspects
IKERLAN	Opendiscon		Y		Y	
DNV	WindFarmer/Longsim	Y	Y	Y	Y	Y
CENER	FLORIS	P	Y			Y
	Fast.Farm		Y		P	Y
	SOWFA		Y			Y
AAU	SimWindFarm	Y	Y		P	Y
TUDELFF	SOWFA		Y			
	FLORIS	P	Y	P	Y	Y
	WFSim		Y	Y	Y	Y
USTUFF	Wake dissipation model					Y
RAMBOLL	O3M Software		Y	Y		Y
POLIMI	CP-lambda /CP Max		Y		Y	Y
TNO	FarmFlow	Y				Y
TUM	FLORIS	Y	Y	P	P	Y
	SOWFA		Y			

Table 10. Applications for the software developed

“Y “means yes and “P” means partially.

From the table, we can infer that the developed algorithms are mainly oriented to simulations and the improvement of certain aspects. In general terms, they are not applicable to manage real installations and only three of them can be used for maintenance purposes or components design but with some limitations.

4.3 Type of services

In deliverable D5.3 IPR activities, a questionnaire was distributed asking for the intention to exploit and/or protect the results. In the next table, brought from that deliverable, we include their opinions.

SUPPLIER/?	Will it be sold as a lump sum?	Will it be licensed?	Will it be for internal use only?	Will it be exploited for third parties SaaS	references in terms of pricing	Difficult to know at this stage.
IKERLAN	Modifications will be offered	Yes, open licensing for modifications	No	Yes	Case by case	Confidential
DNV	Possibly, not decided	Possibly, not decided	Yes	Possibly, not decided	Not yet	Yes
CENER	Floris No	No	No	Maybe	No	Yes
	FastFarm. No	No	No	Maybe	No	Yes
	Sowfa. No	No	Yes	No	No	No
AAU	Sindwindfarm. No	No	Maybe	Don't know	No	Yes
TUDELFF	No	No, but could be used in commercial applications	No	Maybe	Free	Yes
USTUFF	No	Open licence	No	?	Difficult	Yes
RAMBOLL	No	No	Yes	Engineering solutions	Free	No
POLIMI	No	Protected	No	Yes	No comments	No comments
TNO	Not for sale	Generally not	Yes	Yes	Confidential	No comments
TUM	No	No	Yes, extend the knowledge and get grants	No	No	No

Table 11. Market routes for the different software

Some partners will just use the project results internally. Their profile coincides with the PR group mentioned in chapter 5.1. A second group is very much enthusiastic with the Software as a Service (SaaS). They are very much linked to the so-called MO or mixed organizations. Large companies are not in this questionnaire prepared just for software suppliers, but it is interesting to understand their opinion about the project results. Except for some specific cases (Super controller from TUDELFF) and the general interest from DNV, most of the discoveries have no or relative interest in the level of development they are up to now. However, all the large companies insist in the need to continue improving research results.

ENTITY/ SOFTWARE	SOWFA	SimWindFarm	FLORIS	FarmFlow	WindFarmer/ Longsim	WFSim	Fast.Farm	Data reduction technologies	Wake dissipation model	O&M Software
GE	They believe their expertise is ahead CL-Windcon	Don't believe to use it	Some engineering models interesting	Do not see reasons to adopt it	Do not see reasons to adopt it	Well, but far from the real world	Do not see reasons to adopt it	No applicable to their technology	Very specific model. No applications for the moment	No data
DNV	High level of interest	High level of interest	High level of interest	High level of interest	High level of interest	High level of interest	High level of interest	High level of interest	High level of interest	No data
DEWI	Still in doubt	Still in doubt	Still in doubt	Still in	Still in doubt	Still in doubt	Still in	Still in doubt	Still in doubt	No data
EGP	TUDELf Super-controller is the most interesting	No opinion	No opinion	No opinion	No opinion	No opinion	No opinion	No opinion	No opinion	No data
RAMBOLL	No data	No data	No data	No data	No data	No data	No data	No data	No data	Internal Use

Table 12. Market potential from the perspective of the Industrial /large Consulting partners

The main conclusion is that the group of PB (Large companies) are supervising the evolution of the different solutions and they will pick the best of them in case they appreciate a competitive advantage. In some cases, they mention that their internal software outpaces the software developed in CL-Windcon.

According to this vision, we have determined five types of market routes:

- i. **Software as a Consulting or Engineering Service.** The entities will not sell the software (indeed, this is not possible in most cases, because the original owners offered them in open sources) but they will provide complex services using the software as technical support. The MO entities has refined and upgraded the different algorithms and based on them will offer high-quality services to simulate or design installations. In this case, the supplier receives a progressive payment against the development of the service solution in selected milestones. The total amount can be variable, depending on the degree of accomplishment.
- ii. **ESC.** One interesting option is to act as an **Energy Service Company** that is being paid based on the savings. This option can be applied to any existing windfarm that introduces the new control system. The software supplier obtains a fix amount in the signature and a percentage of the savings when yawing the turbines considering the historical windfarm behaviour. 1.1% of LCC savings represents around € 27 million € in the total lifetime of an 800 MW windfarm (approximately € 1.1 million per year at present value). If the solution is implemented with a total cost around €1 million of CAPEX and €0.2 million per year (OPEX), the payback will be possible in just 2 years. Please revise for further details the Business plan chapter (Nº7)
- iii. **Lump Sum.** The client pays a lump sum. This is the traditional contract. The customer defines and asks for a concrete solution. Once developed, the supplier receives the full payment.
- iv. **Software integrated.** This is the option for the large companies (windfarm promoters, OEMs, large consultancy or engineering companies). These companies usually cover a great part of the value chain. They participate in the projects from the cradle to the grave and implement research, consultancy, engineering and/or installations. The upgrade piece of software (usually an improved algorithm) is integrated with the rest of the software and used for the project purposes. Large companies use tens of programs in their daily activity

and it is very difficult to extract an independent price for the software used. The customers pay for a global solution that incorporates the upgraded software.

- v. **Licencing.** Only those organizations with in-house software are open to licencing. This is for instance the case of DNV or RAMBOLL, although they are still thinking on the best options for exploitation.

5 BUSINESS MODELS

5.1 Introduction

Hereinafter, we describe all the components of a conventional business model applied to the three identified profiles (PR, MO and PB).

The CANVAS model developed by the Swiss economic theorist Alexander Osterwalder and the computer scientist Yves Pigneur in 2005 will be used. With the GANVAS model you get an overview of what the business model really is. The CANVAS needs to describe the following aspects:

- Customer Segments: Who are the customers? What do they think? See? Feel? Do?
- Value Propositions: What's compelling about the proposition? Why do customers buy, use?
- Channels: How are these propositions promoted, sold and delivered? Why? Is it working?
- Customer Relationships: How do you interact with the customer through their 'journey'?
- Revenue Streams: How does the business earn revenue from the value propositions?
- Key Activities: What uniquely strategic things does the business do to deliver its proposition?
- Key Resources: What unique strategic assets must the business have to compete?
- Key Partnerships: What can the company not do so it can focus on its Key Activities?
- Cost Structure: What are the business' major cost drivers? How are they linked to revenue?

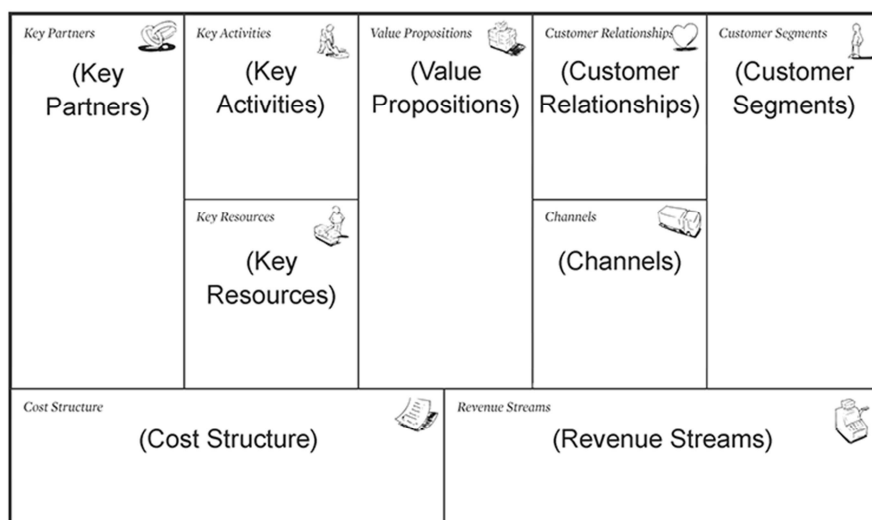


Figure 7. CANVAS model

5.2 CANVAS for group of “Pure Researchers”

As mentioned, this group is represented by the Universities which main goal is the transference of knowledge and not or very reduced interest in the market.

- **Key Partners.**

The main interest of universities is the acquisition of knowledge. The way to do that is through public funding and the EU grants which represent the best way to connect with cutting-edge technologies. Thus, key partners for the universities are EU organizations (all types) working in the same strategic research areas.

- **Key activities.**

PE group needs to attend research conferences, write research papers, specializes in working areas where the research community identify them and overall, participates in high-level research projects with low and intermediate TRL (technology readiness level). They also need to collaborate if possible, with the industry and adapt themselves to the industry requirements (mainly quality, speed and accomplishment of milestones and expected deliverables).

- **Key Resources**

Resources for this group come from public sources or in some cases private. H2020 or the future program Horizon Europe is an important way to be a get financing. Universities manage their own research funds, but they are most times limited and must be complemented with additional sources. The EU programs finance 100 % in Research activities, being perfect in the follow up of their interests. The universities need also to set up to-date labs, keeps a stable research team and certain autonomy and free time to implement research.

- **Customer relationships**

Customers for a University are those entities who pay them for their research services. The main customers are, therefore, the administrations who provide grants and some private clients if Universities demonstrate enough level of compromise and quality management. Northern EU countries are more familiar with the liaison between university and industry. The search of pre and post PHD students is a very good entry point to set up the initial relationships with the industry.

- **Business channels.**

Attending research conferences, interchange of professors and Pre and post PHD students through the Erasmus program. Collaboration with industries in their search processes. Attending info days in Brussels, participation in national opportunities, establishing lobbying groups around local industries (trusted groups)

- **Customers segments**

Local industries establishing trusted liaisons, national and European funding administrations, research peers' group in Europe to launch common RTD projects, International research conferences to meet European research opportunities.

- **Cost structure.**

Research in the University is complex as the professor must combine the teaching with the research activities. Publication of research papers is however necessary to flourish. Intermediate organizations

Private-Public partnerships like foundations are a good way to mix both activities. Professors are partially paid by the research projects and also by their teaching activity. A group of researchers is kept in the organization with a full salary whilst some students are hired for a period associated to the projects. Cost and revenues must be adapted according to the level of success in national and EU financing.

- **Revenues streams**

There will be a base contribution from the University funds summed up to the incomes received from public or private financing from RTD projects. The structure of the working team will rely on the level of success, the quality of the works implemented and the approach to the Industry (that provides long-term business relationships). Contribution from € 100000 to € 400000 could be a good order of magnitude for a 3 to 4 years project lifetime.

- **Value proposition**

Universities or Pure Research groups involved in windfarm optimization through wake redirection, induction control, etc., working in high-level RTD projects may provide added value in research activities linked to simulation, windfarm design, etc. or any research activity at low TRL for new unknown solutions. Universities treasury basic knowledge and are prepared to explore new disruptive fields at relatively low costs.

In the next CANVAS model, we synthetize the business model for Universities or pure research groups according to the descriptions already done:

Business Model Canvas		SCENARIO	PURE RESEARCHERS		
		Design by	QI EUROPE	Date	OCTOBER 2019
KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	RELATIONS WITH CUSTOMERS	CLIENTS	
<p>*EU organizations working in the same strategic research areas.</p> <p>*Long-term agreements with industrial companies.</p>	<p>Attend research conferences, write research papers, specialize in working areas where the research community identify them and overall, participates in high-level research projects with low and intermediate TRL, collaborate with the industry and adapt themselves to the industry requirements.</p> <p>KEY RESOURCES</p> <p>*Public sources or in some cases private.</p> <p>*H2020 or the future program Horizon Europe must be an important way to be a get financing.</p>	<p>Universities or Pure Research groups involved in Wind farm optimization through wake redirection, induction control, etc., working in high-level RTD projects may provide added value in research activities linked to simulation, wind farm design, etc. or any research activity at low TRL for new unknown solutions.</p> <p>Universities treasury basic knowledge and are prepared to explore new disruptive fields at relatively low costs.</p>	<p>*The main customers are: the administrations who provide grants and some private clients.</p> <p>*The search of pre and post PHD students is a very good entry point to set up the initial relationships with the industry.</p> <p>CHANELS FOR DISTRIBUTION</p> <p>*Attending research conferences</p> <p>*Interchange of professors and Pre and post PHD students through the Erasmus program.</p> <p>*Collaboration with industries in their search processes.</p> <p>*Attending info days in Brussels</p> <p>*Participation in national opportunities</p> <p>*Establishing lobbying groups around local industries (trusted groups)</p>	<p>*Local industries establishing trusted liaisons</p> <p>*National and European funding administrations</p> <p>*Research peers' group in Europe to launch common RTD projects</p> <p>*International research conferences to meet European research opportunities</p>	
COST STRUCTURE			REVENUES STREAMS		
<p>*Publication of research papers in however necessary to flourish.</p> <p>*Intermediate organizations Private-Public partnership like foundations are a good way to mix research projects and their teaching</p> <p>*Cost and revenues must be adapted according to the level of success in national or EU grants.</p>			<p>*Base contribution from the University funds summed up to the incomes received from public or private financing from RTD projects.</p> <p>*Contribution from € 100000 to € 400000 could be a good order of magnitude for a 3 to 4 years project lifetime.</p>		

Table 13. CANVAS Pure Researcher organizations

5.3 CANVAS for groups of “Mix Organizations”

These organizations combine the activities of the “Pure Research” groups but also offer services to the market usually under the model “Software as a Service”. The weight of the public and private funding rounds 50%.

- **Key partners.**

The Mix Organizations combine as main goals the acquisition of knowledge but also the generation of revenues streams. They are closer to the market in a position between conventional universities and enterprises. They provide high-added services filling the research gap than conventional companies cannot reach.

Key partners for them are the same than “Pure Research groups” i.e., EU organizations working in the same strategic research areas but also industrial companies. The technological centres must be a reference in their sector and be completely specialized in those activities demanded by the market. Research will not be in low TRLs but closer to the market with higher TRLs (beyond TRL4).

Technological centres in the wind sector must work with large companies in real projects in cutting-edge technologies. They must be part of trusted groups and take care of long-term relationships. Patent offices, certification bureaus or consultancy companies are key partners to find market opportunities.

- **Key activities.**

The mix organizations may find an equilibrium between the activities implemented by the PE group like attending research conferences, writing RTD papers, look for specialization in working areas to be identified and participate in high-level research projects with low, intermediate and close to market TRLs (technology readiness level), but they also need to collaborate with the industry and adapt themselves to the industry requirements much more than the PE groups. The private area must be as strong as the public one looking for long term alliances with well-known industries. In the CL-Windcon field of activities, they must provide Software as a Service, lump sum services and even Energy Services if they are financially solvent. If not, strategic agreements can be signed with financing organizations like risk capital, banks, family offices, etc., to provide a global solution to the client.

There is an opportunity with the new control software to provide continuous optimization services with strong entry barriers for third companies as the technology is quite complex to manage, thus keeping the competitive advantage overtime.

- **Key Resources**

Key resources are; financial backing in case the Energy Service model will be implemented, a strong research team with capacity to work in pure research but also in applied research, a recognized research infrastructure (labs, pilot plants, etc.), a good communication policy attending research events, publishing RTD papers, implementing marketing campaigns, etc. In the field of the CL-Windcon project, it is important to convince a large industry to use the developed software and highlight that relationship as a reference. In this complex sector, prestige is transmitted by the word of mouth. Count with demos in the real life is also important to success.

The wind sector is very regulated, and any new discovery must be solidly tested in advance to its use as investments compromised are very high.

- **Customer relationships**

Customers for the Mix Organizations are the same described for the PO group, plus industries and other type of large companies (Engineering companies, consultancy companies, etc.).

In one side, administrations providing grants are important to cover at least 50% of expenditure (base) but also industrial partners are needed. Technological Centres must gain the confidence of large industries when exploring new fields of activity. Usually, the industrial relationships are long-term based on confidential agreements that also serve as entry barrier for competitors.

- **Business channels.**

In one side, same as the Pure Research Groups like attending research conferences, interchange of professors and Pre and post PHD students through the Erasmus program, info days in Brussels, participation in national opportunities, but also establishing lobbying groups around industries (preferable big size multinationals). International wind conferences are places to look for clients and EU projects and long-term relations. The CL-Windcon new control software is quite a narrow niche with few active actors. The word of mouth is the best way to contact potential clients.

- **Customers segments**

Same actors than PR groups like local industries establishing trusted liaisons, national and European funding administrations, research peers' group in Europe to launch common RTD projects, International research conferences to meet European research opportunities. The segment is connected to the wind sector where the software is used for design, simulation, maintenance or improvement of special aspects.

- **Cost structure.**

A combination of public and private resources (ideally 50% each). Public resources must be used as a sustainability base whilst private resources must be used to pay the variable costs and finance the entity growth. In the specific case of the CL-Windcon algorithms, if results are confirmed, there is a great margin of manoeuvre. With an investment of 1 to 2 million €, the payback can be reached in just one or two years. The software can be sold under the ESC model with a small fix income at the signature to cover the basic expenses and a large variable fee retained against savings on a yearly basis. Another possibility is receiving a lump sum for a specific development (pay per product). Finally, the SaaS model is similar to the ESC but without associating it to the windfarm savings. You receive a periodic income when providing a service (like maintenance supervision or daily wake redirection forecast, etc.). ROI must be at least close to 60 to 100.

- **Revenues streams**

Revenues stream are linked to the services provided but it is expected large EBITDAs around 50 to 60 % of revenues. The reason is that the technology will generate important savings but at same time the technology is difficult to adjust and manage. Only a set of companies will be able to program the Wind turbines in the appropriate way and that will generate a high demand with a small offer. Therefore, the negotiation power will be in the hands of the offer with high benefits. In the other hand, the technology is quite new, unknown by the market and must be refined and proven to be fully admitted by the market actors.

- **Value proposition**

Value Proposition for Mix Organizations is the most promising. We can describe the technology advantages as follows;

Wake redirection and induction control is a novel technology that substantially increase energy output in new or existing windfarms with no or very reduced OPEX extra expenditure, generating between 1% to 2% savings in terms of Life Cycle Costing during the whole project lifetime. The company can offer payments per measured savings compared to historical data. LCOE is reduced around 0.60%-0.80%. The technology is easy to implement without the need to installing additional measurement equipment. Applicable to onshore and offshore wind farms.

In the next CANVAS model, we synthesize the business model for Mix Organizations:

Business Model Canvas		SCENARIO	MIX ORGANIZATIONS	
		Design by	QI EUROPE	Date OCTOBER 2019
KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	RELATIONS WITH CUSTOMERS	CLIENTS
<ul style="list-style-type: none"> *EU organizations working in the same strategic research areas. *Large industrial companies in real projects in cutting-edge technologies. *Patent offices, certification bureaus or consultancy companies. 	<ul style="list-style-type: none"> *Attending research conferences, writing RTD papers, look for specialization in working areas, participate in research projects, collaborate with the industry. *In the CL-Windcon field of activities, they must provide SaaS, lump sum services and Energy Services, provide continuous optimization services for third companies. 	<ul style="list-style-type: none"> *Wake redirection and induction control is a novel technology that substantially increase energy output in new or exiting wind farms with not or very reduced *The company can offer payments per measured savings compared to historical data. *LCOE is reduced around 0.60%. *Easy to implement without the need to installing additional measurement equipment. *Applicable for onshore and offshore wind farms. 	<ul style="list-style-type: none"> *Administrations providing grants are important to cover at least 50% of expenditure (base) *Large industrial relationships are long-term based on confidential agreements that also serve as entry barrier for competitors. 	<ul style="list-style-type: none"> *Local industries establishing trusted liaisons. *National and European funding administrations *Research peers' group in Europe to launch common *International research conferences to meet European research opportunities.
	KEY RESOURCES <ul style="list-style-type: none"> *Financial backing, a strong research team, a recognized research infrastructure (labs, pilot plants, etc.), a good communication policy attending research events, publishing RTD papers, implementing marketing campaigns, etc. *It is important to convince a large industry to use the developed software and highlight that relationship as a reference. Count with demos in the real life is important to success. *The wind sector is very regulated, and any new discovery must be solidly tested. 		CHANELS FOR DISTRIBUTION <ul style="list-style-type: none"> *Attending research conferences *Interchange of professors and Pre and post PHD students through the Erasmus program *Infodays in Brussels *Participation in national opportunities *Establishing lobbying groups around industries *International wind conferences. *The word of mouth is the best way to contact potential clients. 	
COST STRUCTURE		REVENUES STREAMS		
<ul style="list-style-type: none"> *A combination of public and private resources (ideally 50% each). Public resources must be used as a sustainability base whilst private resources must be used to pay the variable costs and finance the entity growth. *There is a great margin of maneuver. With an investment of 1 to 2 million €, they payback can be obtained in just one or to years. *The software can be sold under the ESC model with a small fix income at the signature to cover the basic expenses and a large variable *Another possibility is receiving a lump sum for a specific development (pay per product). *SaaS model is similar to the ESC but without associating it to the wind farm savings. You receive a periodic income when providing a service (like maintenance supervision or daily wake redirection forecast, etc.). *ROI must be at least close to 60 to 100. 		<ul style="list-style-type: none"> *Large EBITDAs are expected: around 50 to 60 % of revenues. The technology will generate important savings but is difficult to adjust and manage. We will work with high demand with a small offer. Therefore, the negotiation power will be in the hands of the offer with high benefits. 		

Table 14. Mix Organizations CANVAS model

5.4 CANVAS for groups of “Pure Business”

The next CANVAS is linked to the activity of large organizations of different types; windfarm promoters, OEMs, large consultancy or engineering companies, etc. In the same way than previous analysis, we describe hereinafter the content of the different CANVAS chapters.

- **Key Partners.**

Large corporations usually work with a group of trusted entities. In case they incorporate the new CL-Windcon algorithms with the intention to apply in a real installation, all the partners around must be familiarized with the technology. For instance, a promoter willing to modify the control system of an existing windfarm, will likely inform the designing company, the company involved in maintenance, the OEM providing the turbines, etc. All of them need to understand the new challenge and receive training of the new technology. Thus, key partners are all participants in the deployment of a windfarm.

- **Key activities.**

Training to all stakeholders (participants) is a key activity. Another one will be to arrange an agreement with the technology provider. The technology will come from a supplier (research group) and the conditions for collaboration must be set out. In case the promoter of the technology will be a consultancy or engineering company, an agreement might be signed also with the windfarm owner. In all cases, the technology must be transferred horizontally to all the stakeholders.

- **Key Resources**

Large companies can easily support the new technology with their own resources. However, there will be some limitations with the regulation. Nowadays there is a strict regulation with the turbines and windfarm behaviour and this technology substantially changes the way the windfarms are controlled. Internally, the technical operators in charge of the installation, regardless an external provider will help in the operation, need to receive training. In case, the business model assumes the ESC option, a business contract of this type must be prepared.

- **Customer relationships**

The customers of a large utility who owns a windfarm are the citizens consuming the energy and the local, regional or national authorities launching the offer. Citizens will be benefitted from the LCOE reduction leaving additional margins for the utility or reducing prices to end users to gain competitiveness.

The customers of an OEM involved in a project with the new control algorithms are the promoter or windfarm owner who buys the turbines. The OEM will have to be aligned with the promoter desires when asking for adapted software to allow independent yawing of turbines.

The customers of a large consultancy or engineering company supplying the technology will be the windfarm owner. The Consultancy or Engineering companies will have to search an alliance with the OEMs and convince the windfarm owner of the benefits of the technology.

- **Business channels.**

Large companies are automatically informed on any new contract opportunity. They can use the new technology to reduce prices in auctions and win the competitions. Any new advance in the LCOE index is very welcome by the marketplace.

- **Customers segments**

All the clients are in the Wind sector. Customers can be local, regional or national energy authorities but also outsources companies, OEMS, private wind promoters, all of them working in the renewable sector.

- **Cost structure.**

From the point of view of the large utilities, they will be able to reduce the overall costs to certain extent of new windfarm installations or for those recently renewed. They will have to consider energy savings minus the margin of the technologist providing the technology. Their LCC will be reduced from 1% to 2% minus the margin of the outsourced supplier.

Large Consultancy or Engineering companies will add the new control algorithms service to the set of services they provide to the windfarm owner, gaining some margin in the operation.

- **Revenues streams**

Extra revenues are expected from the sales of the extra electricity produced due to the wake redirection, the induction control and the rest of technologies applied. This extra electricity will be in the range of 0.15 to 0.30% compared to a greedy control installation.

- **Value proposition**

Large companies involved in the promotion of a new windfarm or the retrofitting of an existing one will offer extra incomes from 0,15% to 0,30% in electricity sales, a reduction between 1% to 2% in the LCC during the project lifetime and a reduction of the LCOE close to 0,70%. These advantages allow them to adjust prices in auctions and competitions gaining margins or reducing prices to end users.

In the next CANVAS model, we synthetize the business model for Large companies (Pure businesses):

Business Model Canvas		SCENARIO	PURE BUSINESSES				
		Design by	QI EUROPE		Date	OCTOBER 2019	
KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	RELATIONS WITH CUSTOMERS	CLIENTS			
<p>*Large corporations, designing company, the company involved in maintenance, the OEM providing the turbines, all participants in the deployment of a Wind Farm.</p> <p>*All of them need to understand the new challenge and receive training of the new technology.</p>	<p>Training to all stakeholders, arrange an agreement with the technology provider, agreement with the promoter of technology and wind farm owner, technology transferr horizontally to all the stakeholders.</p>	<p>Large companies involved in the promotion of a new Wind farm or the retrofitting of an existing one will offer:</p> <p>*Extra incomes from 0,15% to 0,30% in electricity sales</p> <p>*A reduction between 1% to 2% in the LCC during the project lifetime</p> <p>*Reduction of the LCOE close to 0.70%.</p> <p>This advantages allow them to adjust prices in auctions and competitions gaining margins or reducing prices to end users.</p>	<p>Customers: citizens consuming the energy and authorities launching the offer.</p> <p>The customers of a large consultancy or engineering company supplying the technology will be the Wind farm owner. They will have to search an alliance with the OEMs and convince the Wind Farm owner of the benefits of the technology.</p>	<p>*All the clients are in the Wind sector.</p> <p>*Local, regional or national energy authorities, suppliers, outsources companies, OEMS.</p>			
	KEY RESOURCES						
	<p>*Large companies can easily support the new technology with their own resources.</p> <p>*Strict regulation with the turbines and wind farm</p> <p>*The operators in charge of the installation need to receive training.</p> <p>*The business model assumes the ESC option, a business contract of this type must be prepared.</p>		<th>CHANELS FOR DISTRIBUTION</th>	CHANELS FOR DISTRIBUTION			
			<p>*Large companies are automatically informed on any new contract opportunity. They can use the new technology to reduce prices in auctions and win the competitions.</p> <p>*Any new advance in the LCOE index in very welcome by the marketplace.</p>				
COST STRUCTURE		REVENUES STREAMS					
<p>*Large utility: reduce the overall costs, energy savings minus the margin of the technologist providing the technology, LCC wil be reduced from 1% to 2% minus the margin of the outsourced supplier.</p> <p>*Consultancy or Engineering companies will add the costs and revenues of the new control algorithms to the set of services they provide to the Wind Farm owner, gaining some margin.</p>		<p>Extra revenues are expected from the sales of the extra electricity produced due to the wake redirection, the induction control and the rest of technologies applied. This extra electricity will be in the range of 0.15 to 0.30%</p>					

Table 15. Pure Businesses CANVAS model

6 BUSINESS PLANS

In this chapter, we have included an approach to understand to what extend the new control algorithms will impact in the partners involved in the proposal. Of course, major impact will be assigned to the large companies. We must pinpoint that technology is not in a state that can be transferred to the market in the short term. The project has contributed to move TRL from level 3 to level 5, although at least five years and the demo of the software in a real installation for a long period are still needed to approach to the marketplace. In deliverable D5.3 Innovation management³, we have included the worldwide competitive position of the partners involved in the proposal. We first review these positions to understand the market opportunities. Then, we will introduce a draft forecast for each partner or group of partners.

6.1 Overview of the wind sector

An extended review of the Wind sector (on and offshore) was included in deliverable D5.3 Report, Innovation manager activities (final). We bring here a short summary to prepare the analysis.

According to the Global Wind Energy Council (GWEC⁴), it's clear that the 2018 market and the following years, kept staying above 50 GW, reaching record years on the offshore sector.

In fact, the total installations in 2018 were **51,3 GW**, bringing the global total to 591 GW.

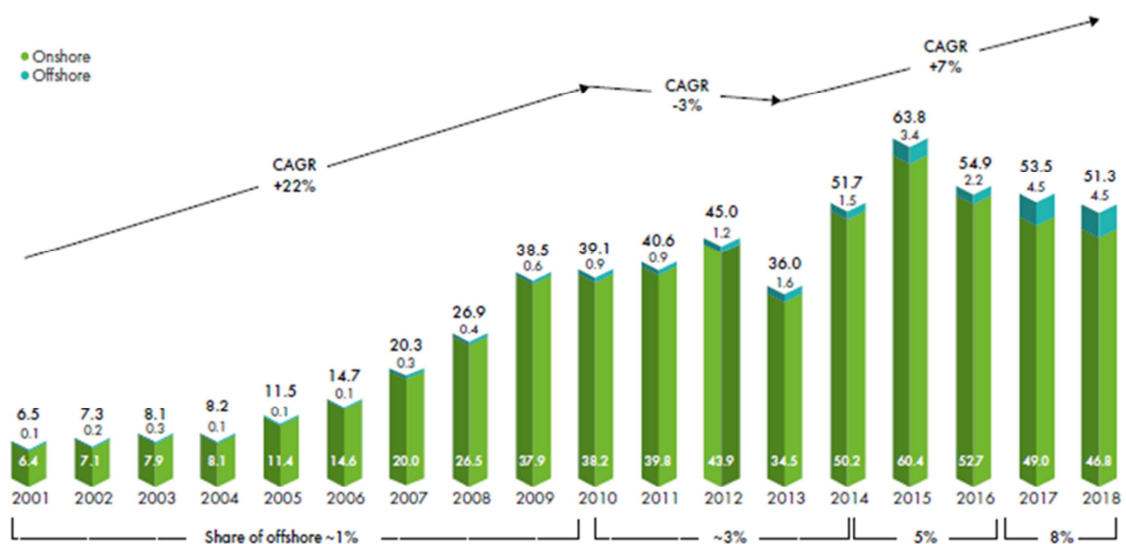


Figure 8. Global annual installed wind capacity 2001-2018

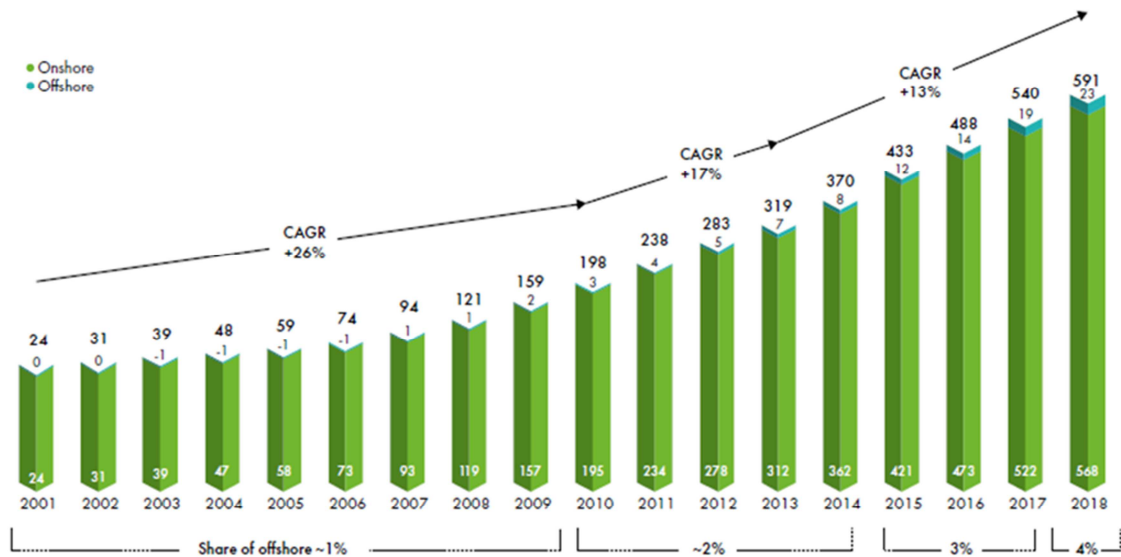


Figure 9. Global cumulative installed wind capacity 2001-2018

In the next diagram (Figure 10) we add a diagram from GWEC where we can see the distribution of the wind capacity and new installations worldwide. 76 % of the total new capacity belongs to China, US and Germany in onshore and 91% of total new capacity in offshore is assigned to China, UK and Germany. Clearly China is the word leader in both markets, increasing the distance with the following providers every year.



Figure 10. New installations and total capacity in onshore and offshore in 2018

The most important conclusions from these charts is that Europe is losing competitive position against Asian suppliers (China, India, etc.) except in offshore where Europe is still a reference with the leadership of UK, Germany and Denmark although China is approaching very fast. However, the large companies involved in CL-Windcon operate globally and their markets can be global as well.

To measure the Total Addressable Market (TAM) for onshore and offshore, we have made a simplification considering the trends in the market for the next ten years. According to the symphony scenario (moderate) showed by the World Energy Council (WEC⁵) in 2030, around 1600 GW of wind energy will be operative in the moderate scenario.

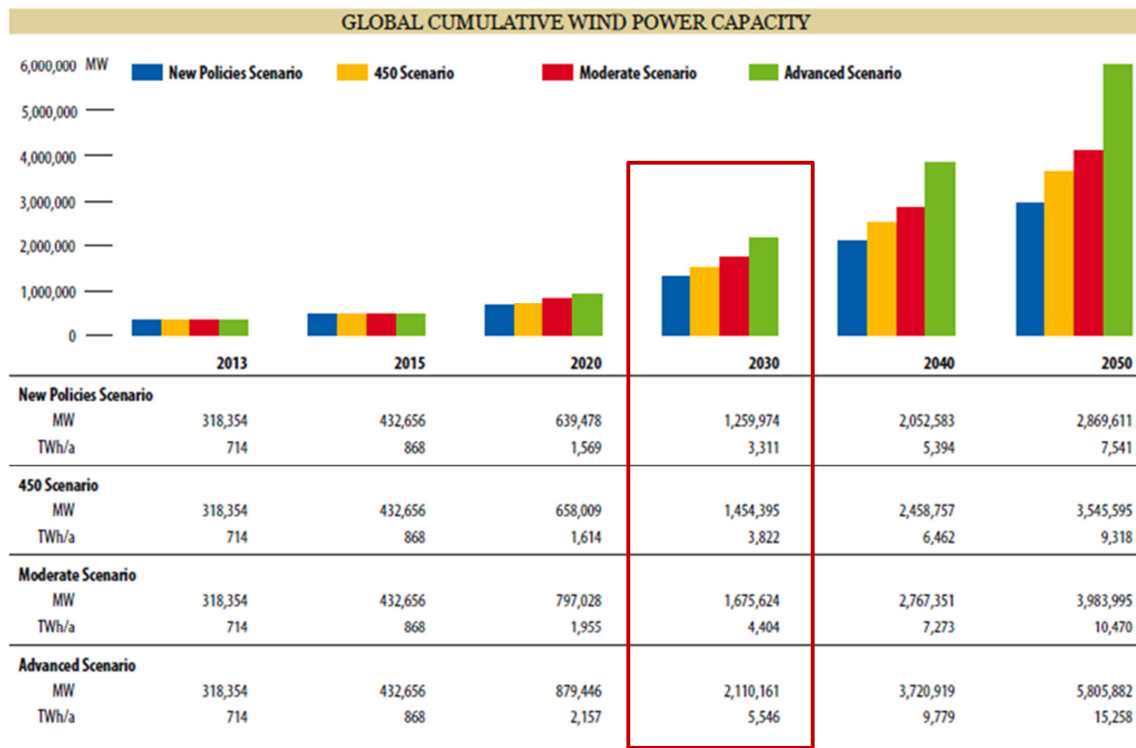


Figure 11. Global Cumulative Wind Power Capacity. WEC Outlook 2016.

In summary, with an average 55 to 65 GW additional GW per year, and starting from the current 600 GW, in ten years-time, there will be around 1600 GW operative. We will consider that time to market will set 2026 as the starting point for the new technology massive distribution. One of the advantages of the technology is that it can be applied to new windfarms but also to facilities in operation. **Thus, total addressable market (TAM) between 2026 and 2030 will be around the mentioned 1600 GW in onshore and offshore. In 2026, 1100 GW will be in operation and additional 500 GW will be installed from 2026 to 2030.**

In a rough calculation, the large companies involved in CL-Windcon will not get access to the Asian territory or the access will be limited. Following Figure 10, the onshore Asian markets represent the 35 % with an increasing tendency (please check D5.3). **So, roughly the Serviceable Available Markets (SAM) in a combination of onshore and offshore, from 2026 to 2030 will be around 50% of TAM, or 800 GW.**

6.2 Competitive position of the CL-Windcon large companies

6.2.1 ENEL GREEN POWER – Competitive Position

Following the discoveries of deliverable D5.3 Innovation management report, the status of EGP worldwide in 2018 is described through the following figure

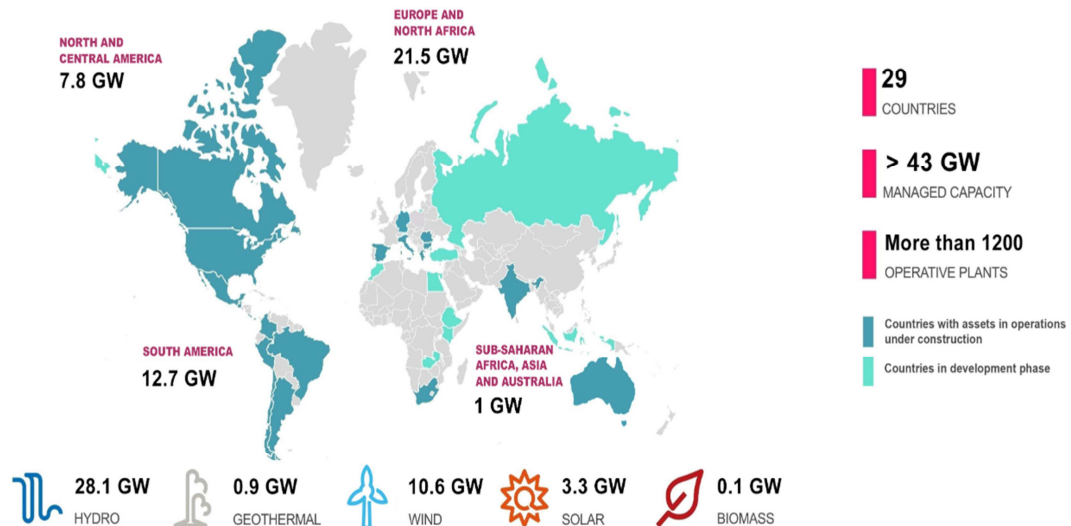


Figure 12. EGP Green energy distribution globally

According from the last consolidated report 2018, revenue for 2018 amounted to EUR 75,672 million, an increase of EUR 1,033 million (+1.4%) compared with 2017. **22% was addressed to wind the wind sector or EUR 16.6 billion.**

The managed capacity for wind reached 10,6 GW. EGP represents one of the strongest leaders in the energy production from renewable sources worldwide. In the next table it is depicted that EGP reached the **1,72% of the overall Wind Energy market in 2017, although it was not active in offshore wind.** The company is present in the five continents.

EGP - Data in MW - 2017			
Wind Power	Global	Enel GP	Market Share
Onshore	520.767	9250	1,76%
Offshore	18.814	0	0%
Total	539.581	9.250	1,76%

Table 16. Installed and managed Wind Capacity World/ENEL 2017⁶

The distribution of capacity by continent in April 2018 is as follows, considering the plants operated, managed and under construction:

Net Generation Capacity ACTUAL 2017 (GW)	Large Hydro ex-Gx	Hydro EGP	Wind	Geothermal	Solar	Biogas/biomass	TOTAL
South America	9.65	0.33	1.36	0.04	1.39	-	12.77
Argentina	1.33	-	-	-	-	-	1.33
Brazil	1.04	0.23	0.67	-	0.72	-	2.66
Chile	3.46	0.09	0.64	0.04	0.49	-	4.72
Colombia	3.06	-	-	-	-	-	3.06
Peru	0.78	-	-	-	0.18	-	0.96
Uruguay	-	-	0.05	-	-	-	0.05
Europa & North Africa	15.61	1.59	3.13	0.76	0.55	0.06	21.70
Italy	10.90	1.52	0.77	0.76	0.42	0.06	14.43
Spain	4.71	0.04	1.62	-	0.01	0.00	6.38
Romania	-	-	0.50	-	0.04	-	0.53
Grecia	-	0.02	0.20	-	0.09	-	0.31
Bulgaria	-	-	0.04	-	-	-	0.04
North/Central Americas	-	0.90	4.38	0.07	0.37	-	5.73
Mexico	-	0.05	0.68	-	0.12	-	0.84
Panama	-	0.30	-	-	0.05	-	0.35
USA	-	0.30	3.61	0.07	0.20	-	4.18
Canada	-	-	0.10	-	-	-	0.10
Guatemala	-	0.16	-	-	-	-	0.16
Costa Rica	-	0.08	-	-	-	-	0.08
Subsaharian Africa & Asia	-	-	0.37	-	0.32	-	0.69
South Africa	-	-	0.20	-	0.32	-	0.52
India	-	-	0.17	-	-	-	0.17
TOTAL EGP	25.26	2.81	9.25	0.87	2.64	0.06	40.89

Table 17. EPG Distribution of capacity managed by country and technology, (EGP web site – April 2018)

We can estimate that according to company desires to continue growing in this sector, the market position between 2026 and 2030 could reach 2% of the SAM market. That represents 16 GW of windfarms worldwide (SAM for EGP) with global revenues of EUR 25.000 million.

6.2.2 DNV GL – Competitive Position

Following deliverable D5.3 Innovation management DNV GL⁷ is a global quality assurance and risk management company. Its purpose of safeguarding life, property and the environment allow enabling customers to advance the safety and sustainability of their business. DNV GL provides classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. It also provides certification, supply chain and data management services to customers across a wide range of industries. With origins stretching back to 1864 and operations in more than 100 countries, DNV GL's experts are dedicated to helping customers make the world safer, smarter and greener.

DNV GL is structured into five business areas, a Global Shared Services organization and a Group Centre, with a Strategic Research unit:

- **MARITIME BUSINESS ASSURANCE SOFTWARE ENERGY** - DNV GL helps enhance the safety, efficiency and sustainability of customers in the global shipping industry, covering all vessel types and mobile offshore units.
- **OIL & GAS** - From the drawing board to decommissioning, DNV GL provides technical advice to enable oil and gas companies to enhance safety, increase reliability and manage costs in projects and operations.
- **ENERGY** - DNV GL supports its customers across the electric power value chain in ensuring reliable, efficient and sustainable energy supply.
- **BUSINESS ASSURANCE** - DNV GL helps customers in all industry sectors build sustainable business performance and create stakeholder trust.
- **SOFTWARE** - DNV GL's software solutions are based on broad domain competence and developed to improve customers' operational efficiency and business optimization

In 2016 DNV GL achieved revenues of EUR 2.165 million and earnings before interest and tax of EUR 16.028 million.

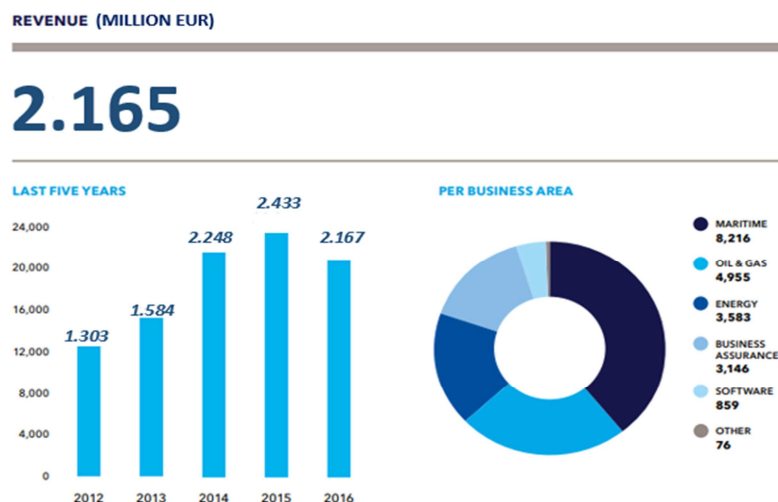


Figure 13. Revenues distribution DNV by sector

Around 18% of the activity is destined to energy and globally around 50% of that amount is focused in wind. If we consider an average of EUR 2500 million/year total revenues between 2026 and 2030, in the five years around EUR 1125 million will be addressed to wind services. **Software may represent 10% of such quantity or EUR 112.5 million (SAM in software services for DNV GL between 2026 and 2030).**

6.2.3 GE – Competitive Position

According to a recent report from GWEC⁸, there were 20,641 wind turbines installed in 2018 from 37 manufacturers with a combined capacity of 50,617 MW. (21,691 wind turbines were installed globally in 2017 with a combined capacity of 52,150 MW).

The Top 10 leading Wind Energy Companies accounts for around 270GW installed wind power which is almost three-quarters of the global total. The companies' turbines range from 20+ year-old

kilowatt machines to brand new megawatt designs.

- **Vestas** held the title as the world's largest turbine supplier in 2018, due to the Danish supplier's wide geographic diversification strategy and strong performance in the US.
- **Chinese supplier Goldwind** moves up one position to the second place in 2018, after its domestic market share increased by 5.1% in 2018.
- **Siemens-Gamesa** fell one position to third place, primarily due to the lower installation in the UK, Germany and India in 2018
- **GE Renewable Energy** retained fourth place by taking advantage of stronger performance in the US market, where it recaptured the title as the N° 1 supplier
- **Envision** (China) replaced Enercon in the fifth place, mainly due to its strong growth in China and the sharp drop of installations in Enercon's domestic German market in 2018.
- Chinese suppliers **Mingyang, United Power and Sewind** moved up to seventh, ninth and tenth respectively, which can be largely attributed to stable performance in their home markets.
- **Suzlon** dropped out of the top 10 turbine suppliers ranking in 2018, primarily a result of reduced installation, by up to one third, in its home market in India.

GE has a strong position on the wind turbine market where they are the fourth largest supplier on the onshore wind market with a market share **of 10%**. GE sold **2,825 turbines during 2017** which is a decrease from the previous year when they sold 3,289 turbines. A strong factor of GE's growth in the wind turbine sector has been due to the acquisitions of Alstom in 2015 and LM wind power in 2017. The acquisition of Alstom increased the turbine shipments with 420 that year and increased the shipped megawatts by 32%. The acquisition of LM brought value in form of external customers worldwide, new advanced rotor solutions, improved blade efficiency, increased rotor swept area and a greater reach to the major global markets for wind.

The revenues GE-GP generated from renewables were 10.3 billion dollars during 2017 where 89% from the revenue was from the wind segment. Please check deliverable D5.3. Innovation management report. So, revenues in 2017 applied to the wind sector in EUR were around EUR 8000 million with almost 52.1 GW (roughly EUR 153.50 million /GW manufactured).

If we consider that GE-GP keeps the 10% of the market, from the 800 GW, SAM market, GE will take **80 GW in five years (from 2026 to 2030) or EUR 12 280 million**. 80 GW represents **100 windfarms of 800 MW each**. This is the total SAM market for GE-GP

6.2.4 RAMBOLL – Competitive Position

Ramboll GmbH is a leading consultancy on the international market finding innovative and durable solutions to the challenges of the physical environment in which life unfolds. This includes natural resources, infrastructure, buildings and structures, urban spaces and the transition towards a more resource efficient future. These challenges are met by seven business units – Buildings, Environment & Health, Transport, Water, Management Consulting, Energy, and Oil and Gas. Since January 2018,

Oil & Gas is part of the Energy business unit. Ramboll is a Nordic company with Danish roots that is well represented on the international market especially in Germany, UK and North America

The Energy sector incorporates the Ramboll Wind market, which offers comprehensive expert services for the different project stages in the wind energy industry from early feasibility, business case and impact assessment studies to planning, engineering, implementation, commissioning and the subsequent operation & maintenance. Ramboll is a full-range service provider in wind energy projects. The service encompasses the entire project cycle from concept to commissioning and the subsequent operation & maintenance period in onshore wind power projects all over the world. In the offshore wind industry Ramboll is the world leader within design of offshore foundations, having a market share of about 65% of the world's offshore wind turbines on more than 40 offshore wind farms. Ramboll carries out all the necessary analyses to select the foundation type best suited for the offshore wind farm project, based on factors such as the choice of turbine and site conditions.

According to our recent investigation in deliverable D5.3 Innovation management, from a total of EUR 1400 million in 2017 around EUR 120 million corresponds to the energy activities and 75% can be applied to the wind sector (approximately EUR 90 million for the 65% of 600 GW (390 GW). During period 2026 to 2030 Ramboll will have direct access to the global SAM market (800 GW), so around **EUR 180 million will be received in wind services. This is the SAM market for Ramboll.**

6.2.5 DEWI – Competitive Position

UL Renewables with its entities **UL DEWI** and UL AWS True Power is part of the UL Company. Both are global service providers serving the wind energy industry in the areas of Certification, advisory, testing and inspection with the following service portfolio:

- Certification of Grid Code compliance
- Wind turbine testing
- Forecasting
- Wind measurements
- Energy yield assessment
- Wind mapping
- Due diligence services
- Power curve verification
- Grid integration
- Project certification
- Software
- Type certification
- Component certification
- Research and studies

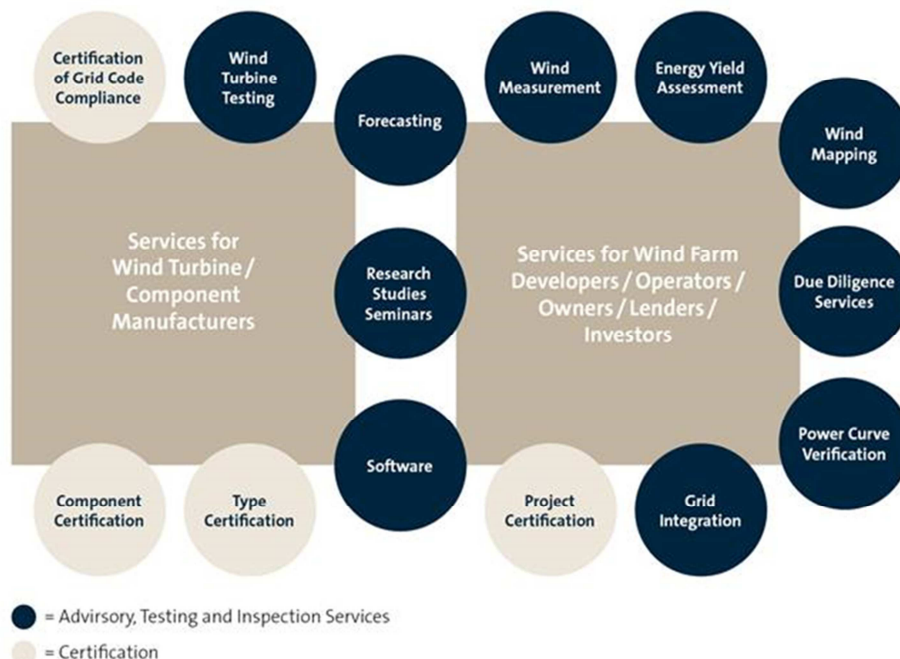


Figure 14. Services provided by UL Renewables

UL Renewables conducts these services with more than 500 people in over 134 countries and yields a global revenue about 56 million US Dollars (around EUR 50 million, 100% wind sector).

DEWI will have access to all the SAM market 800 GW between 2026 and 2030. If it keeps the revenues EUR 50 million per year, for a current 390 GW market (65% of total current market of 600 GW), the total expected revenues between 2026 and 2030 will be EUR around **100 million (SAM market)**.

6.2.6 Global view Serviceable Addressable Market (SAM) large companies

During the previous analysis we have considered that between 2021 and 2030, 1600 GW new capacity will be installed (Total Addressable Market). From them, CL-Windcon partner might get access to around half of them. Asian markets access will be limited. That provides a figure of 800 GW where the new technology could be installed (this is the most optimistic scenario). This is the Serviceable Available Market or SAM represented in the table below.

FORECAST WIND (2021-2030)	Global	Unit
TAM. Total Addressable Market (CL-Windcon)	1,600.0	GW
Installed 2020-2025	1,100.0	GW
Installed 2026-2030	500.0	GW
SAM Serviceable AvailableMarket (CL-Windcon)	800.0	GW

Table 18. TAM and SAM markets

However, how many of these theoretical markets will be accessible for the big companies at CL-Windcon?

To answer that question, we must consider the competitive position of these large companies globally and infers their position between 2026 and 2030. To that end, we consider the following assumptions:

- Taking in consideration the results of deliverable D4.6 cost benefit analysis for a 800 MW offshore windfarm, savings associated to the new algorithms yaw control reached EUR 27 million during the whole project lifetime. Thus, every year, the savings reaches EUR 1.1 million at present value for the windfarm owner/promoter. Then, in the case of EGP, a windfarm of 800 MW generates EUR 5.5 million in five years. If they manage 16,000 MW, the savings with the new control will reach EUR 108 million. However, we consider that only 50% of installations apply the new technology reducing the incomes to EUR 54 million (Serviceable Obtainable Market or SOM).

ASSUMPTIOS FOR EGP CALCULATION	Data	Unit
Results from D4.5	800.0	MW
Savings	27.0	Million €
Savings (5 years) PV	5.4	Million/5 year

Concept	EGP	Unit
SAM 2026 -2030	16.0	GW
Wind sector Revenues	25,000.0	million €
Business linked to CL-Windcon	108.0	million €
SOM 2026-2030 (50%)	54.0	million €

Table 19. SOM market for EGP

- For the OEMs (GE) we consider that introducing the modifications in the control software at turbine level and adding new more refined gauges to determine loads, could be sold at a price of 10,000 € per turbine. Below the calculations for GE associated to the new technology. With a ratio of 2.45 MW/turbine, 80 000 MW represents 32 623 turbines and EUR 326.2 million revenues. The SOM market will be half of it.

GE	Quantity	Units
Ratio	2.5	MW/turbine
Turbines	32,623.0	turbines

Concept	GE	Unit
SAM 2026 -2030	80.0	GW
Wind sector Revenues	12,200.0	million €
Business linked to CL-Windcon	326.2	million €
SOM 2026-2030 (50%)	163.1	million €

Table 20 SOM market for GE

In the case of the consultancy and engineering companies DNV, RAMBOL and DEWI), the services associated to the CL-Windcon new software could represent the 10% of the total services as SaaS.

Finally, we do consider that the CL-Windcon partners reaches 50% of the total SAM market (Serviceable Available Market) fixing the SOM market (Serviceable Obtainable Market). The economic results are depicted below:

Concept	DNV	Unit	RAMBOLL	Unit	DEWI	Unit
SAM 2026 -2030	800.0	GW	800.0	GW	800.0	GW
Wind sector Revenues	112.5	million €	180.0	million €	100.0	million €
Business linked to CL-Windcon	11.3	million €	18.0	million €	10.0	million €
SOM 2026-2030 (50%)	5.6	million €	9.0	million €	5.0	million €

Table 21. SOM market for the Consultancy and Engineering companies

Considering all the assumptions done for the large companies, the expected economic impact of the CL-Windcon algorithms from 2026 (market entry) to 2030 is reflected below in:

Concept	TOTAL	Unit
SAM 2026 -2030		
Wind sector Revenues	37,592.5	million €
Business linked to CL-Windcon	473.5	million €
SOM 2026-2030 (50%)	236.7	million €

Table 22. Global SOM market for large CL-Windcon firms (2026-2030)

6.3 MIX Organizations- Competitive Position

Within this group, a large number of partners is included; CENER, TNO, TUDELFF, POLIMI, and IKERLAN. It is difficult to estimate how much business these organizations will reach from project end to 2030. They don't need to wait until the product will be in the market to start making business as some preparatory works must be done in advance. We consider that roughly every year, they will

reach EUR 0.25 million/year in services associated to the new technology thorough public or private customers. That will add in 10 years additional **EUR 12.5 million to the global impact.**

6.4 Pure Researcher Organization – Competitive Position

TUM, USTUFF and AUU will improve the knowledge transference. As in the previous case, they will continue working but we less economic expectations in the order of EUR 0.05 million/year. The same figure can be applied to Zabala and Qi Energy (SMEs). In total revenues for SMEs and PR might reach **EUR 2.5 million.**

6.5 Global Economic Impact

In total, approximately **EUR 250 million** revenues will be generated by the CL-Windcon partners from 2021 to 2030. In 10 years (2021 to 2030) job creation might be around 2500 new direct employment and 2500 **indirect totalizing 5000 new employment.**

7 CONCLUSIONS

The deliverable provides an overview of the economic impacts that the new windfarm control technology will generate in the marketplace in a period of ten years (from 2021 to 2030) and is based on the results obtained in an exercise implemented in deliverable D4.6 entitled Cost benefit analysis and some other information collected in the project and deliverable author own calculations. A baseline scenario was compared with a yaw scenario where the turbine wakes are reoriented to improve the global windfarm performance. When considering this simplified methodology to calculate the loads and OPEX variations between both scenarios, the economic results are interesting as an average of EUR 27 million savings in the most likely scenario, generated due to the increase of energy output during the whole lifetime of the project. The sensibility analysis demonstrates that this figure could vary up or down around EUR 30 million in case some of the external conditions like WACC, inflation rate or internal performance (less or more O&M costs or additional energy output) were applied, making difficult to estimate at this stage if the yaw solution could positively modify the economic result. Besides, the theoretical exercise done in deliverable 4.6 just considered the effects of the wake redirection without adding other technics to optimize the windfarm behaviour, so there is a great margin of improvement.

Anyway, with the mentioned gaining between the yaw and the baseline scenarios, the partners in the project were classified in three different groups; pure researchers (PR), pure businesses (PB) and mixed organizations (MO), according to their interest for the research, the market or both. Then, a Canvas model was prepared for these groups and the Value Proposition identified. Later, each large company was analysed to determine their competitive position and the impact of the new technology in their accounts. Total results showed EUR 250 million impact for all the partners between 2021 and 2030, being 2026, the entry point of the technology in the market for the large companies, whilst SME, Technological Centres and Universities may start exploiting results from early 2021.

The final conclusion is that there has been a great advantage of knowledge during the project execution, in a very complex problem that will require additional research in the future, but the exercise in CL-Windcon has proven that the margin to reduce LCOE and generate additional savings is very high. Another great advantage of the control algorithms is that they can be applied to existing or new windfarms in onshore and offshore applications and can be used for windfarm design, simulation, redesign, operation, maintenance or research in specific windfarm elements. It is very likely, that in the future, most windfarms will use these technics to optimize their performance.

8 REFERENCES

¹ De Blas, J, Schwartz D, Medina, J, Langner, F, Ristow, H, Schwarzkopf, MA., Cosack, N, CL-Windcon Deliverable D4.6 Cost benefit analysis, October 2019

² <https://www.greentechmedia.com/articles/read/worlds-first-floating-offshore-wind-farm-65-capacity-factor#gs.3xaq46>

³ De Blas, J., Medina, J., Potenza, GC., Calabretta, D., Smolka, U., Schwarzkopf, MA and Elorza, I. CL-Windcon Deliverable D5.3 Report, Innovation manager activities (final), October 2019

⁴ GWEC, Global Wind Report 2018, April 2019

⁵ Accenture Strategy, Paul Scherrer Institute, WEC World Energy Scenarios 2019, Exploring Innovation Pathways to 2040, 2019

⁶ QiE Calculation

⁷ <https://www.dnvgl.com/about/index.html>

⁸ GWEC, Global Wind Market Development. Supply Side Data 2018