

# Economic Feasibility of Wind Energy Participation in Secondary Reserves Markets

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DU VÉHICULE DÉCARBONÉ ET  
COMMUNICANT ET DE SA MOBILITÉ

## Outline

- Objectives
- Assumptions
- Methodology
- Work Performed
- Conclusions

# Objectives

**Main Objective: To determine the economic feasibility of allowing wind producers into the ancillary services markets**

- **Secondary Reserves (Primary Focus)**
- **From Single Agent perspective (wind operator)**

**Secondary Objectives: Define the extent of profitability**

- **Investment Analysis**
- **Constraints associated with providing service:**
  - **All of wind forecast**
  - **Only percentage**
  - **Capacity Factor Requirements**

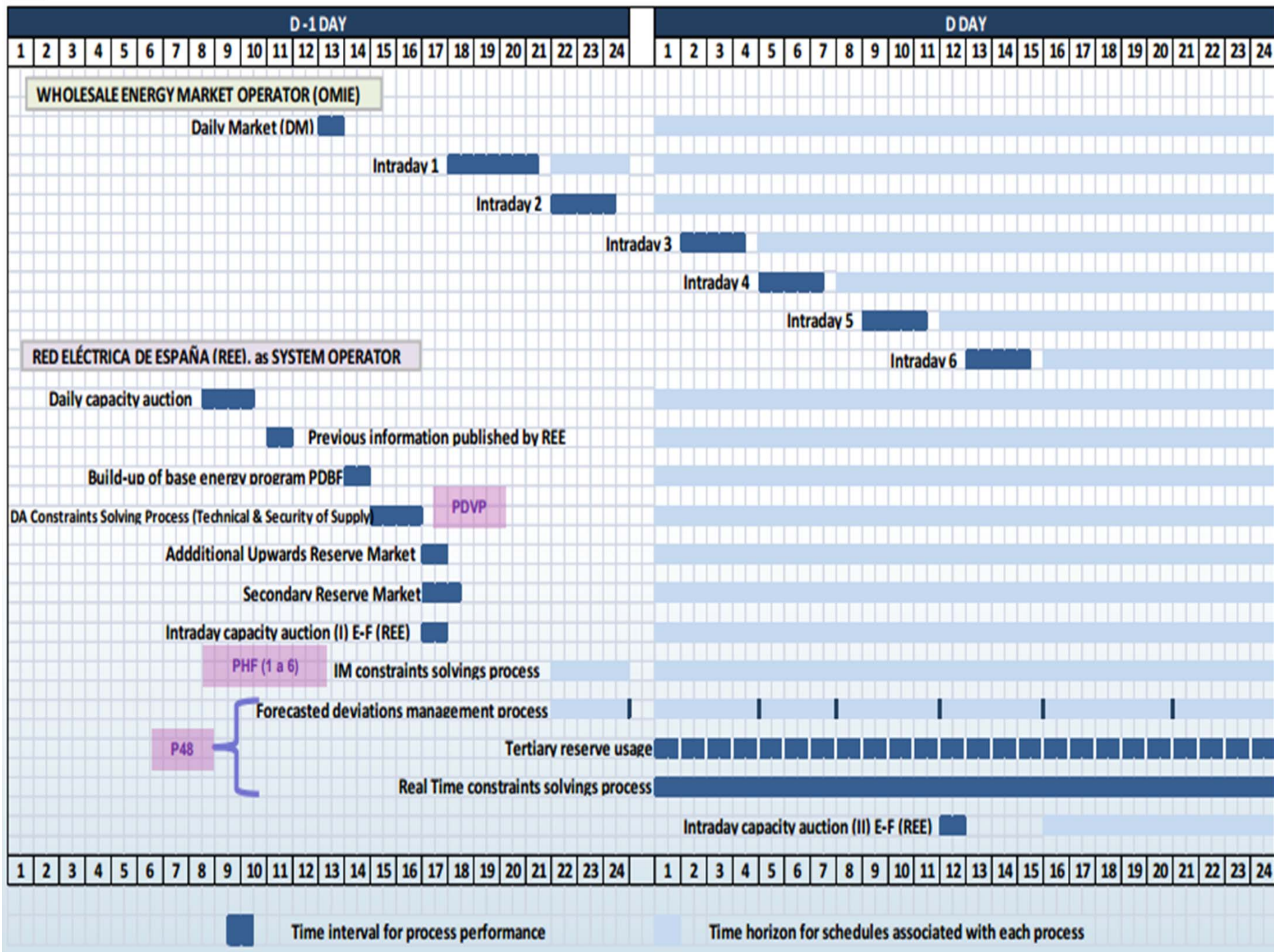
# Assumptions

## Technical Feasibility

- **Literature Review**
  - TWENTIES Project
  - IIT Comillas Research
  - FENIX Project
  - NREL Research

## Economic Feasibility

- **Economic profitability analysis using current market rules**
  - Comparison of necessary investment versus estimated capturable income
  - Based on Real-time market data
  - From agent perspective (RES-E generator)



# Assumptions

## 1.) Generators Offer Full Possible Band

- **Min Feasible Operation (25% of nominal power, TWENTIES)**
- **Max Reliable Operation (Minimum point of real time production over one hour)**
- **Only downward band offered (TWENTIES, IIT, others)**

## 2.) Investment Costs

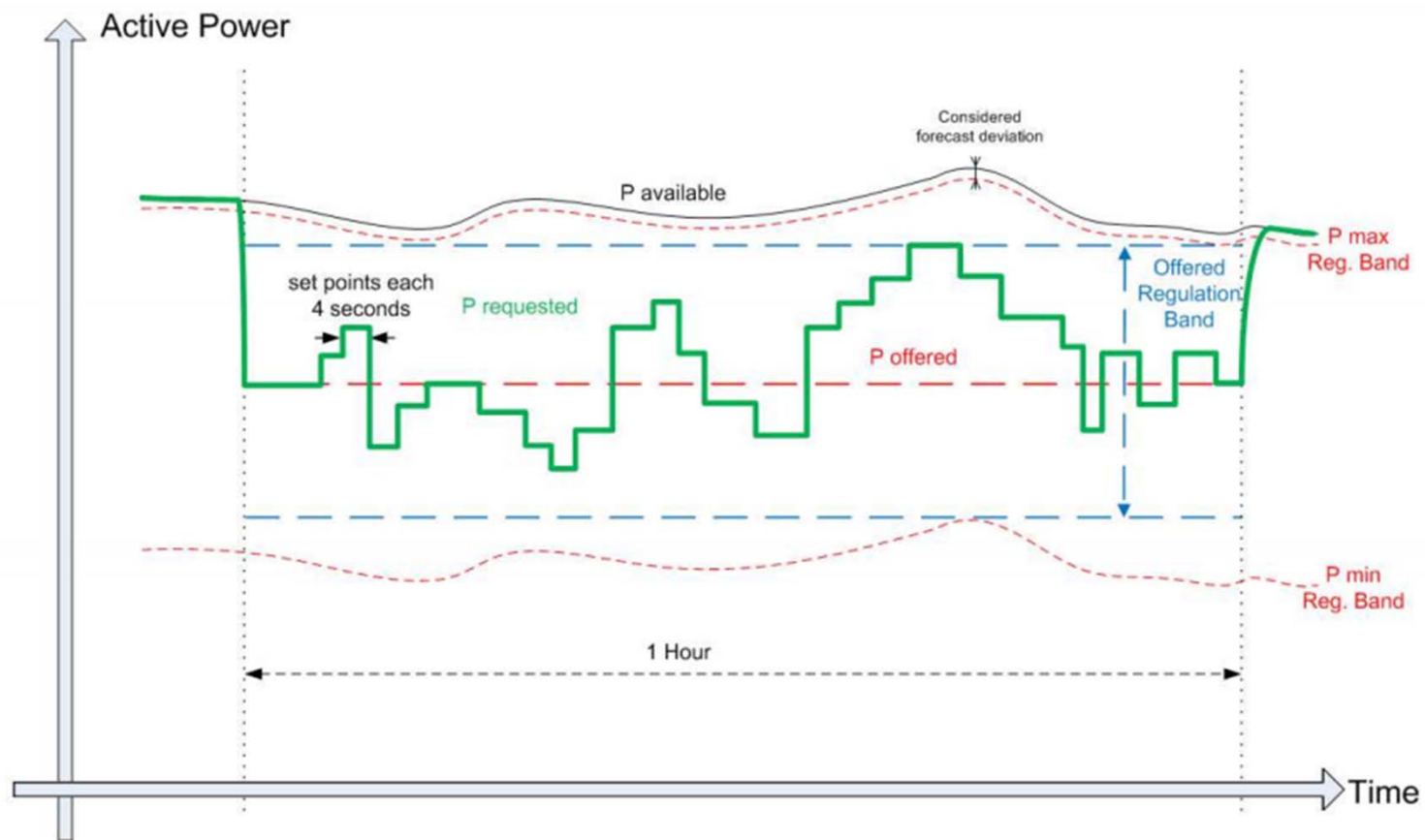
- **TWENTIES Project Research**

## 3.) Estimated Capturable Income

- **Difference between participating only in Daily Market vs participating in Secondary Reserves, taking into account:**
  - **Band Price**
  - **Power Availability (Capacity Factor)**
  - **Realistic Band Offer**
  - **Intraday Barter Costs**

# Methodology

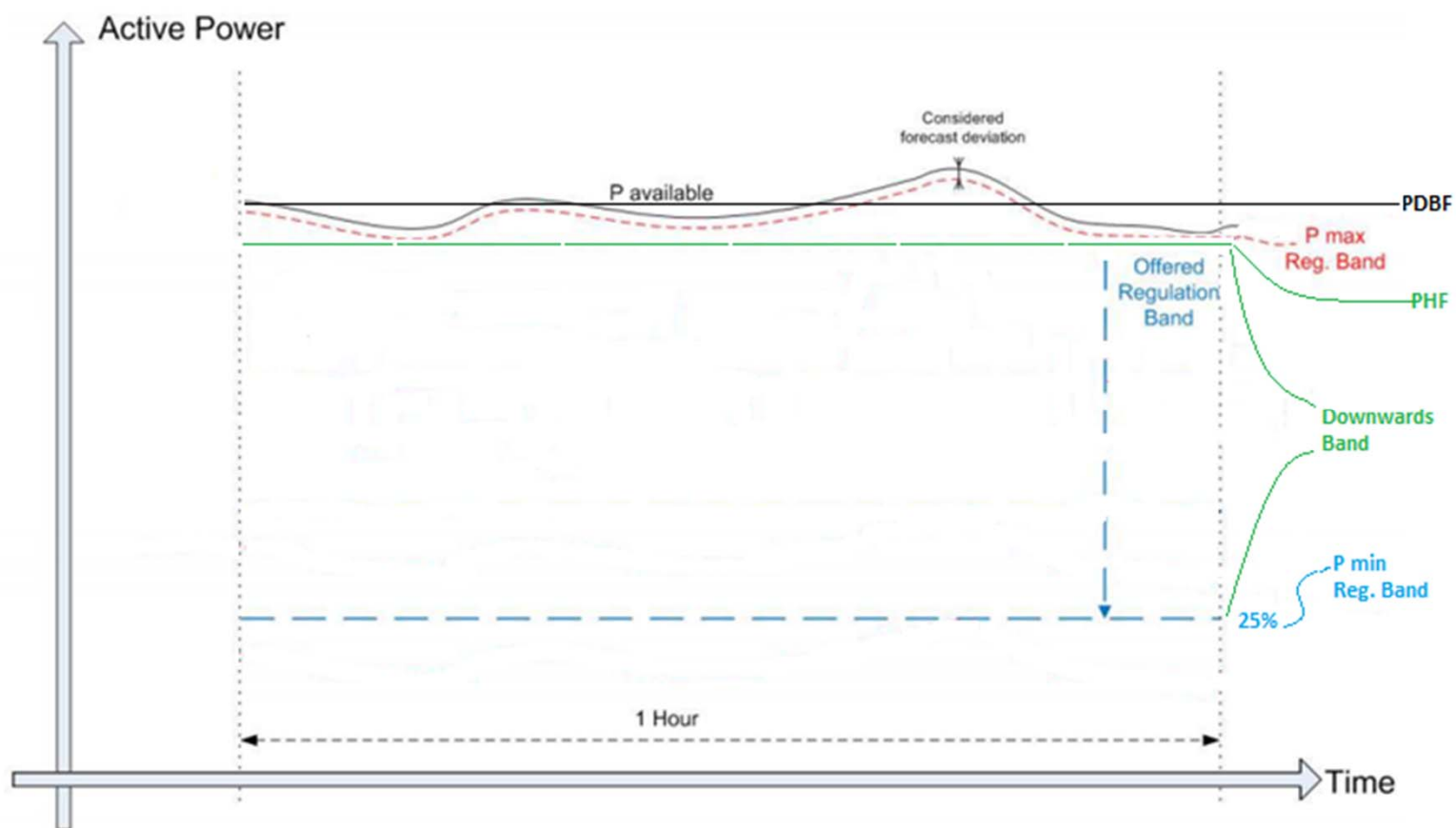
## Generators Offer Full Band



Source: TWENTIES Project Deliverable 9.1

# Methodology

## Generators Offer Full Band



Adapted from source: TWENTIES Project Deliverable 9.1



# Methodology

## Investment Costs Assumed

		CAPEX			OPEX (€)	Production loss(MWh) Installation/Validation	Annual production loss(MWh/WTG) Continuous Operation
		Development (€)	Equipment & Installation (€)	Total Capex(€)			
Scenario#1 independent services	Secondary Frequency Control	105900	1306890	1412790	0	149,96	1756
	WTG	24000	8100	32100	0		
	WF	11400	427090	438490	0		
	Cluster	70500	871700	942200	0		

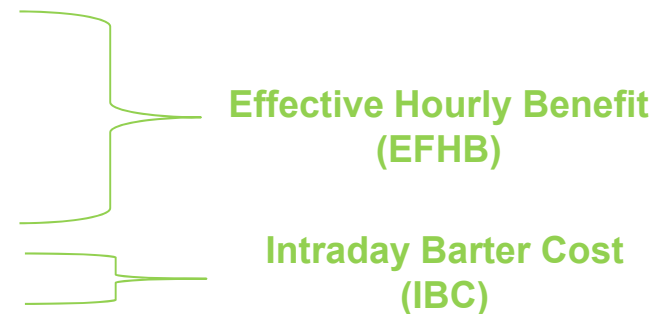
Source: TWENTIES Project Deliverable 9.2

- **Study conducted with three clusters of wind farms:**
  - **Huenaje: 254 MW**
  - **Tajo de la Encantada: 122 MW**
  - **Arcos de la Frontera: 112 MW**
  
- **Total: 488 MW**

## Methodology

### Estimated Capturable Income (ECI)

- **Difference between Daily Market and Secondary Reserves Market taking into account:**
  - Secondary Band Price (2BP)
  - Daily Market Price (DMP)
  - Capacity Factor (CF)
  - Realistic Band Offer (RBO)
  - Intraday Market Price (IMP)
  - Production Factor (B): Amount of production offered as band
  - Production Factor (C): Amount of production change managed in Intraday Market



$$(2BP_h - DMP_h) \times CF_h \times RBO_h \Rightarrow EFHB_h$$

$$(DMP_h - IMP_h) \Rightarrow IBC_h$$

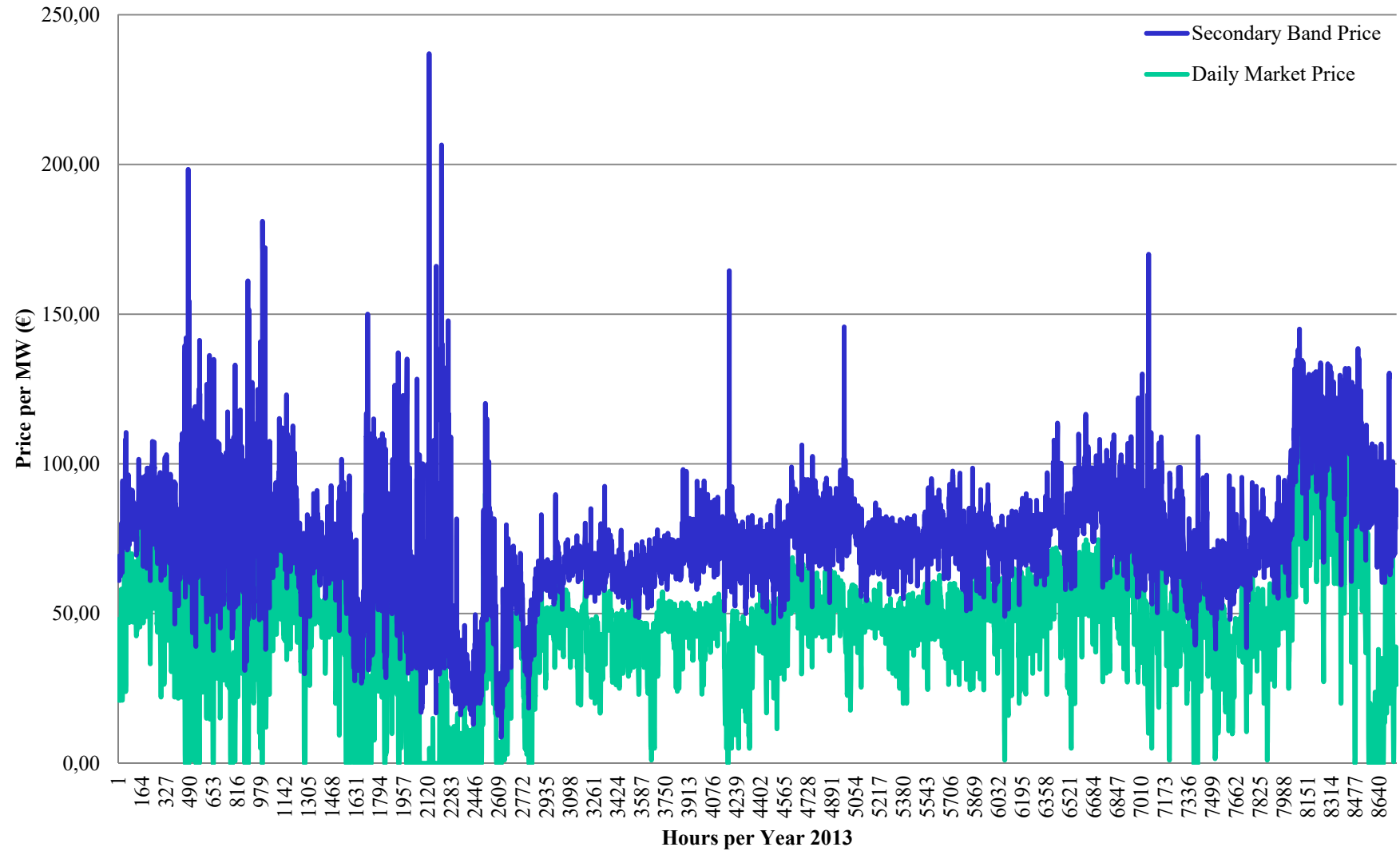
$$\text{Hourly Band Factor} \Rightarrow B_h$$

$$\text{Hourly Cost Factor} \Rightarrow C_h$$

$$ECI = \sum_h (B_h * EFHB_h + C_h * IBC_h)$$

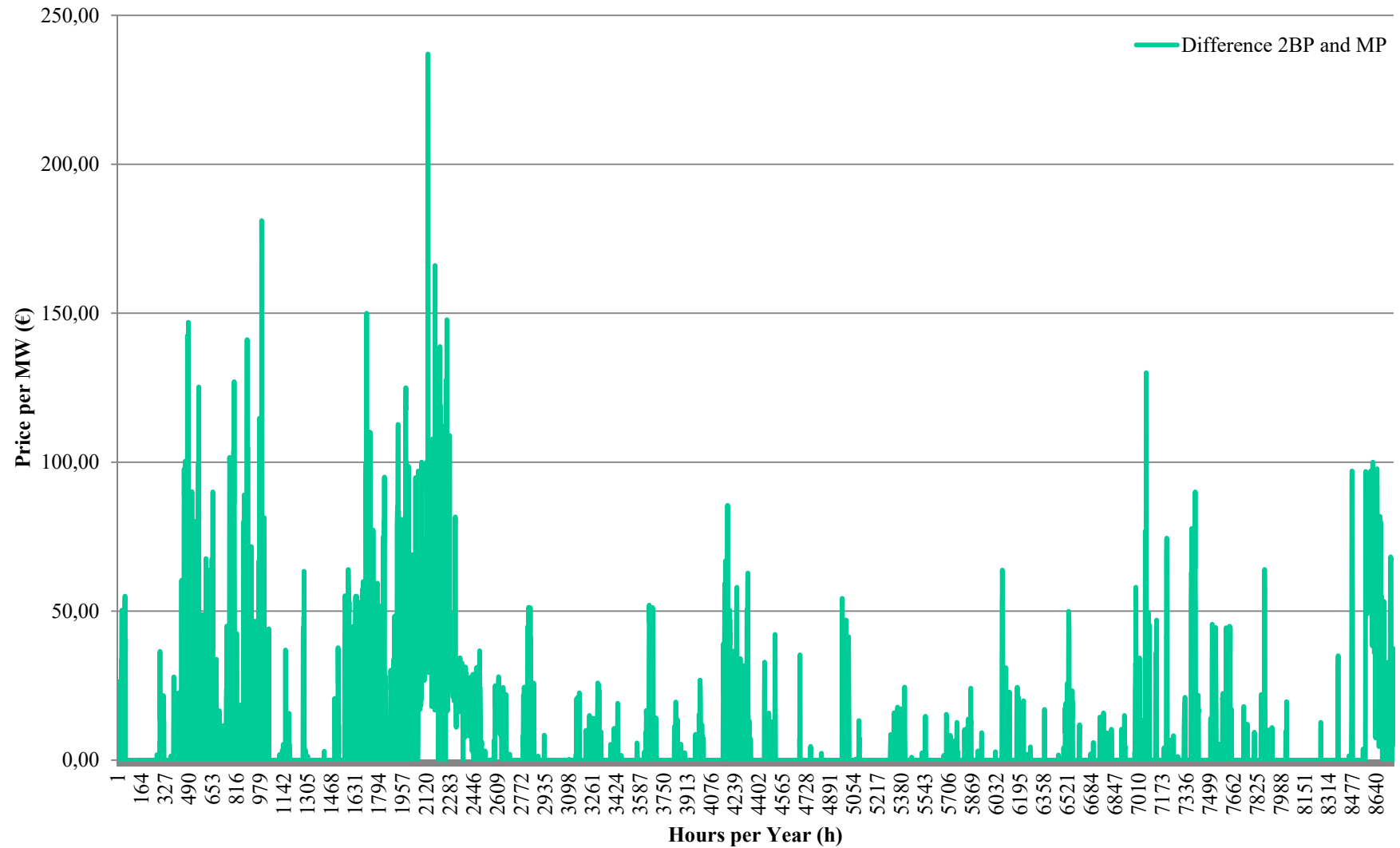
# Work Performed

## Secondary Band Price vs Daily Market Price



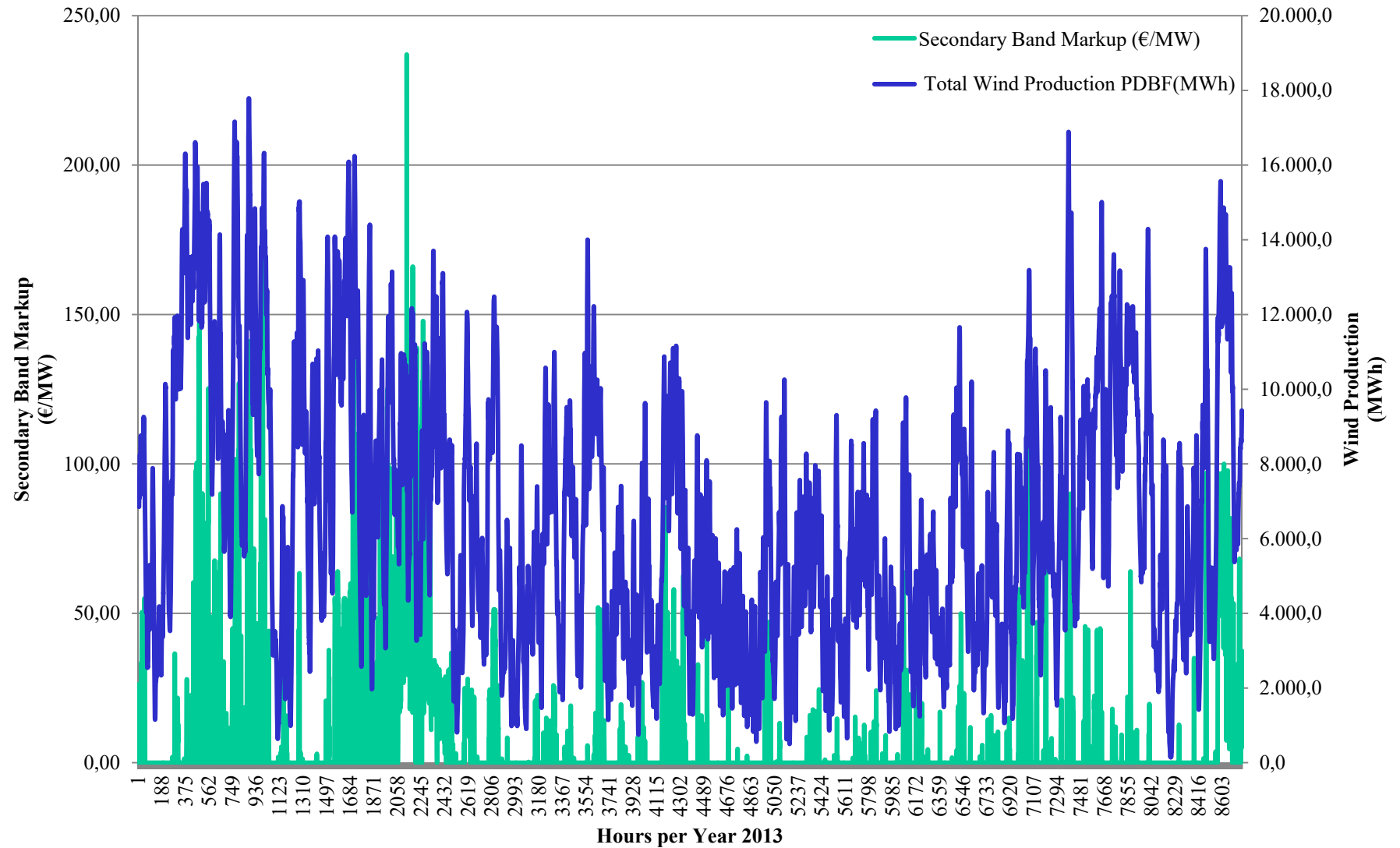
# Work Performed

## Secondary Band Markup



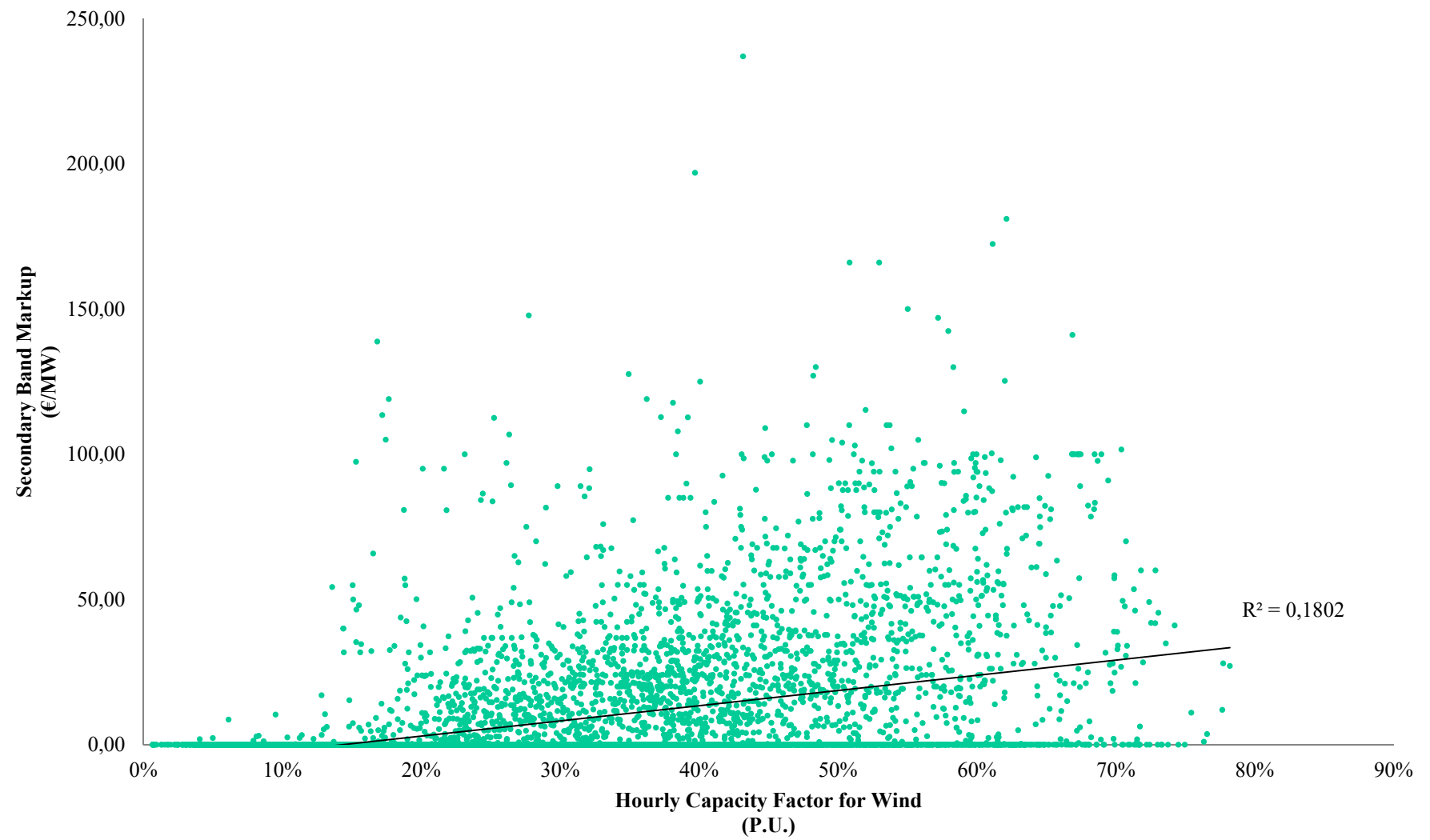
# Work Performed

## Secondary Band Markup vs Wind Production



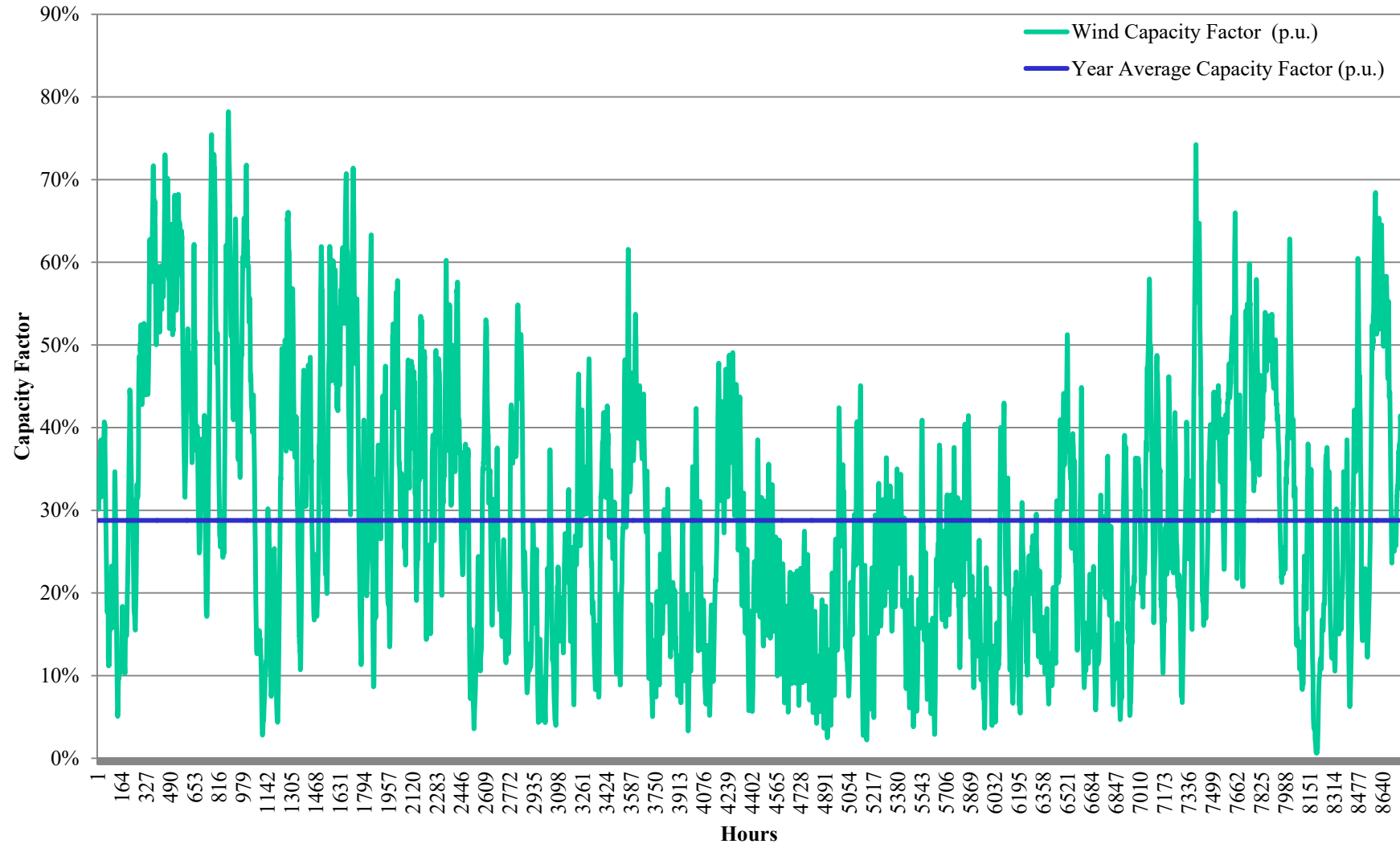
# Work Performed

## Secondary Band Markup vs Hourly Capacity Factor (Wind)



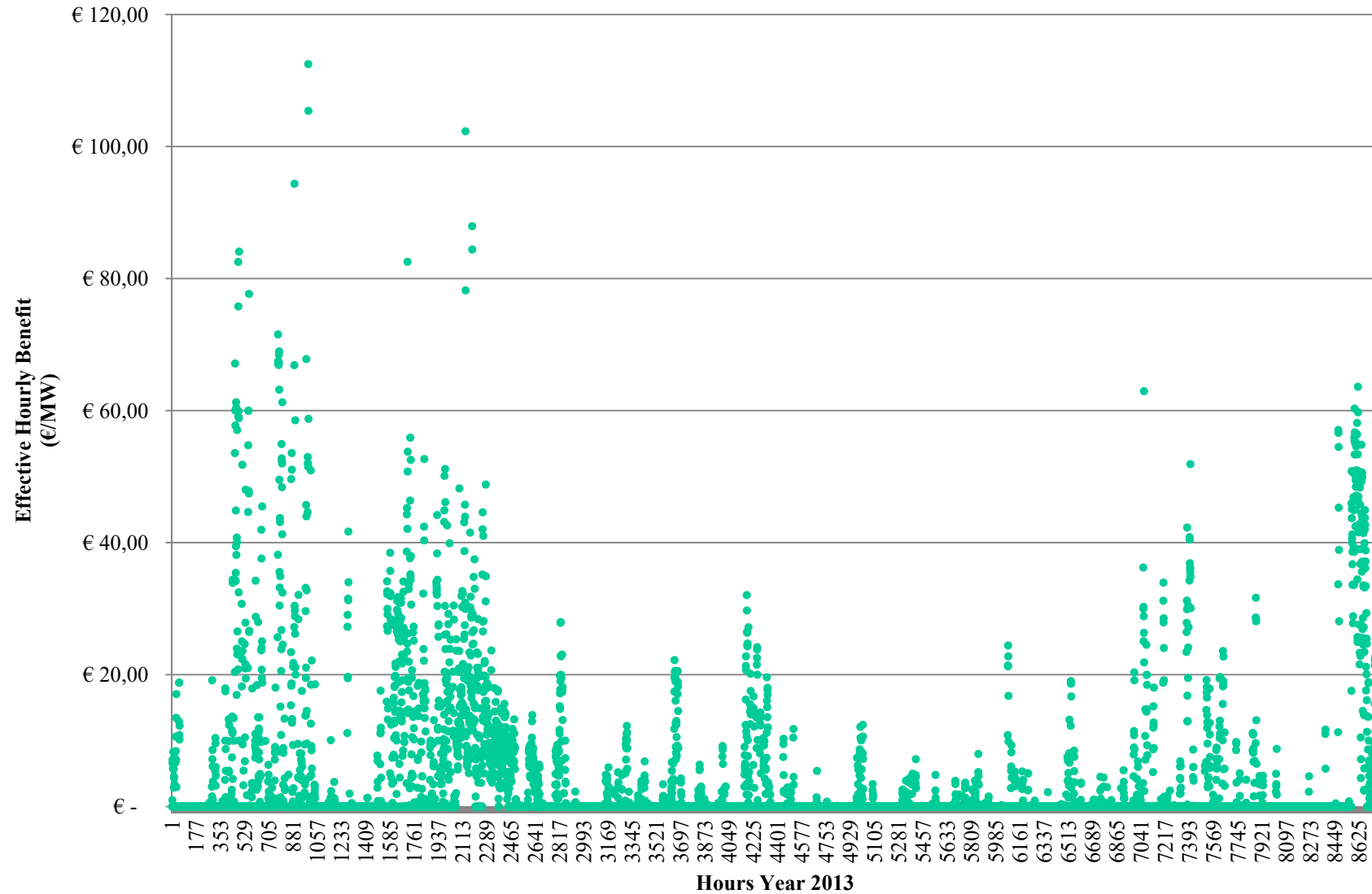
# Work Performed

## Hourly Wind Capacity Factor 2013



# Work Performed

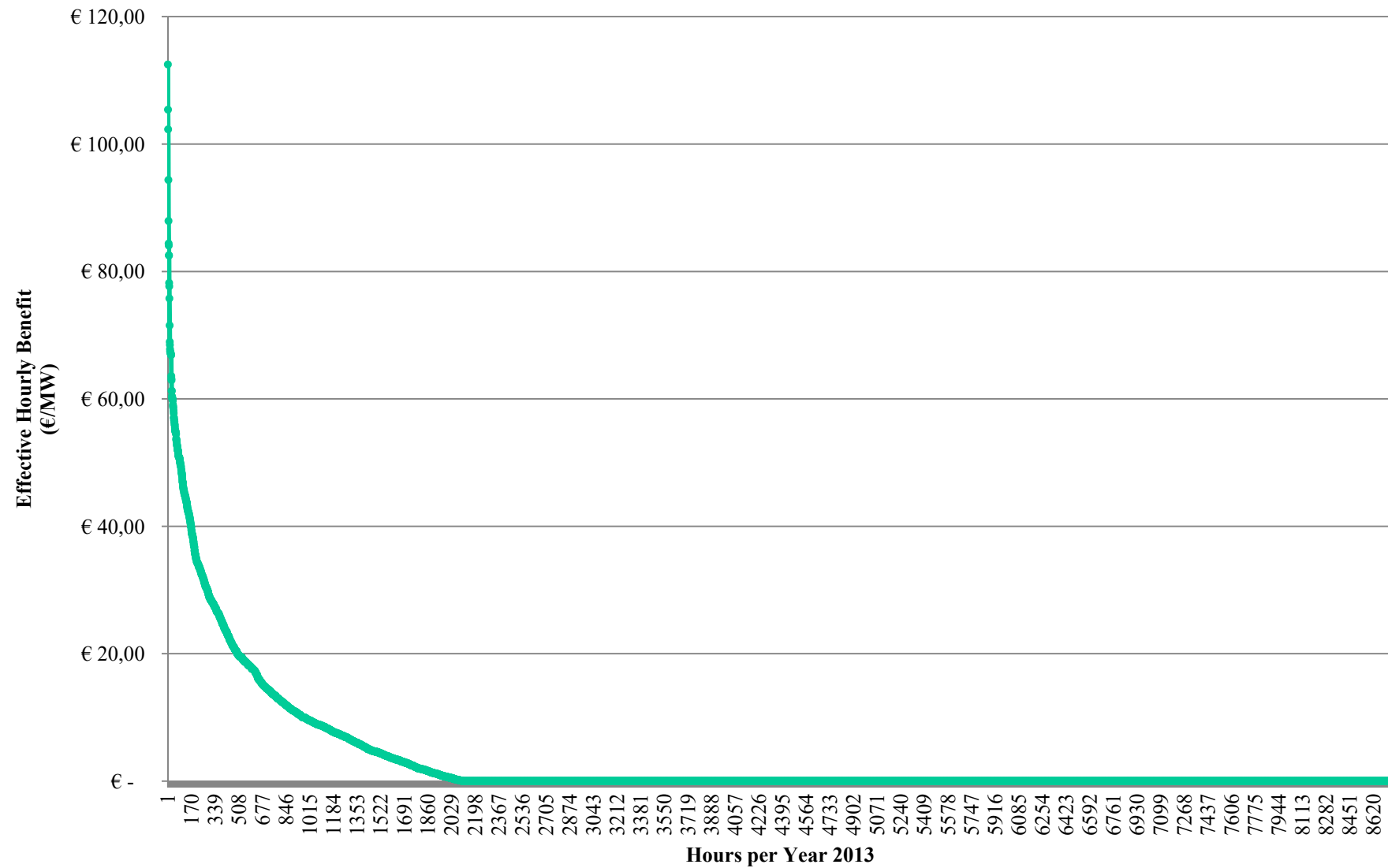
## Potential Hourly Benefit





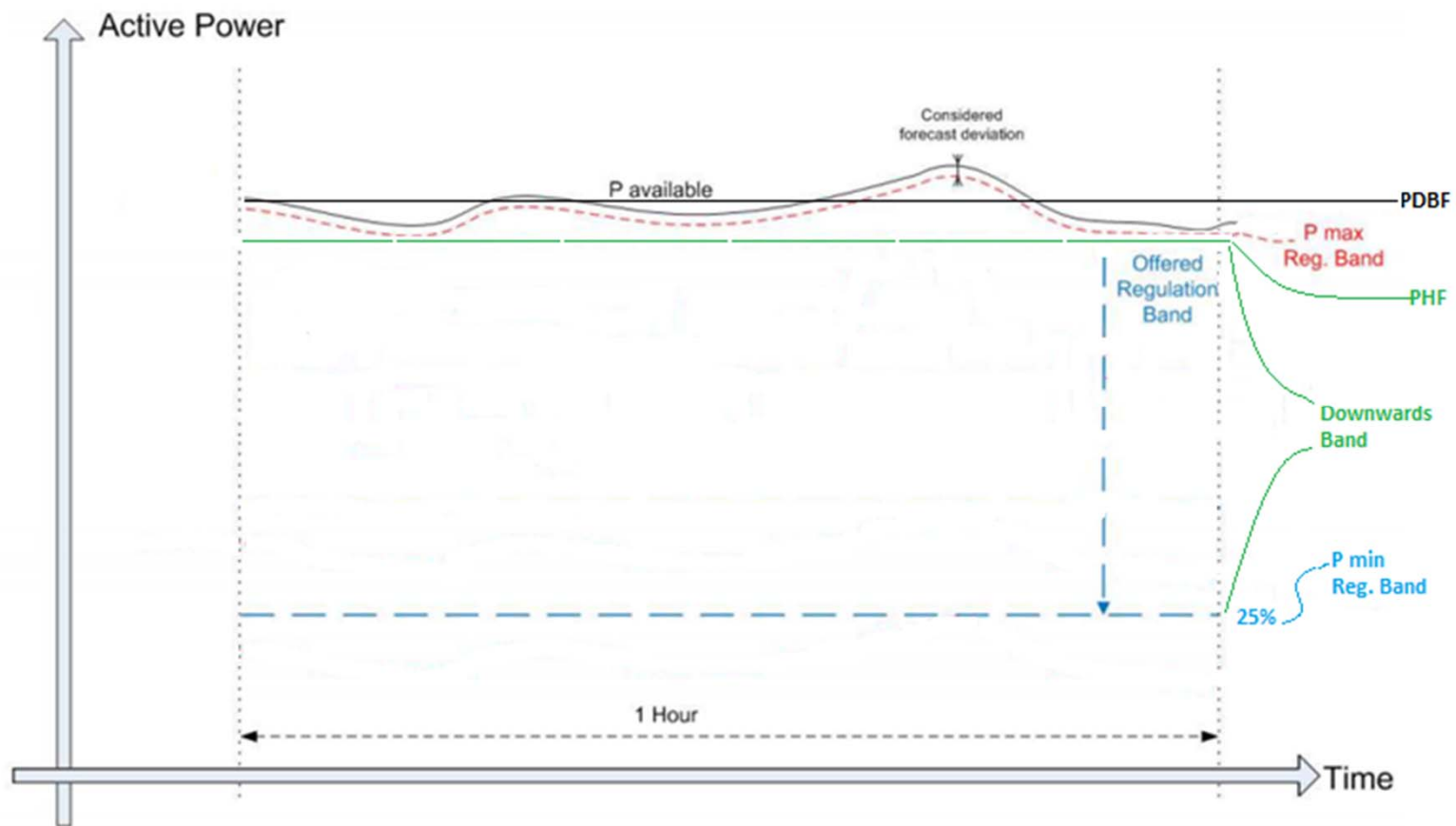
# Work Performed

## Duration Curve of Potential Hourly Benefit



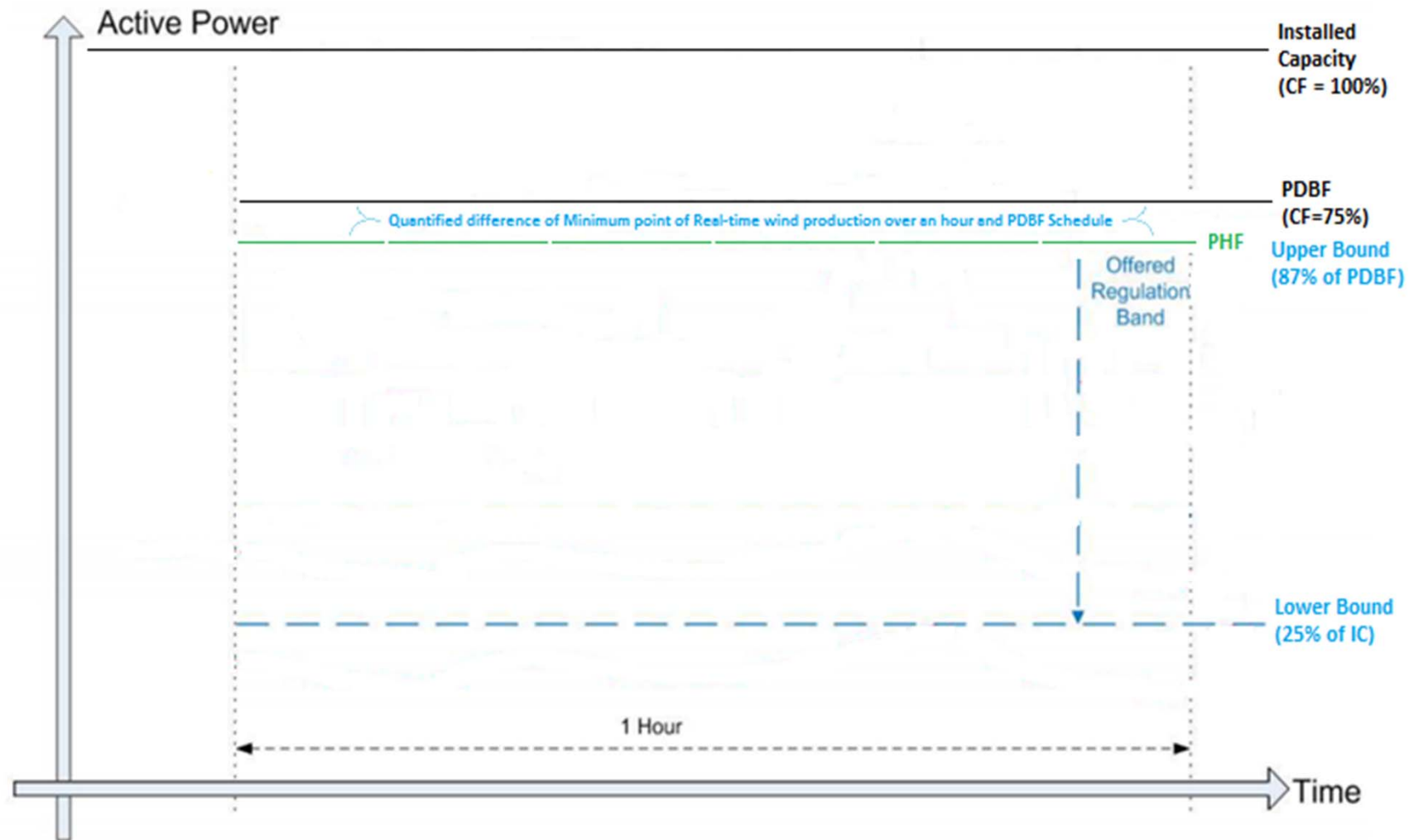
# Work Performed

## Generators Offer Full Band Continued



Adapted from source: TWENTIES Project Deliverable 9.1

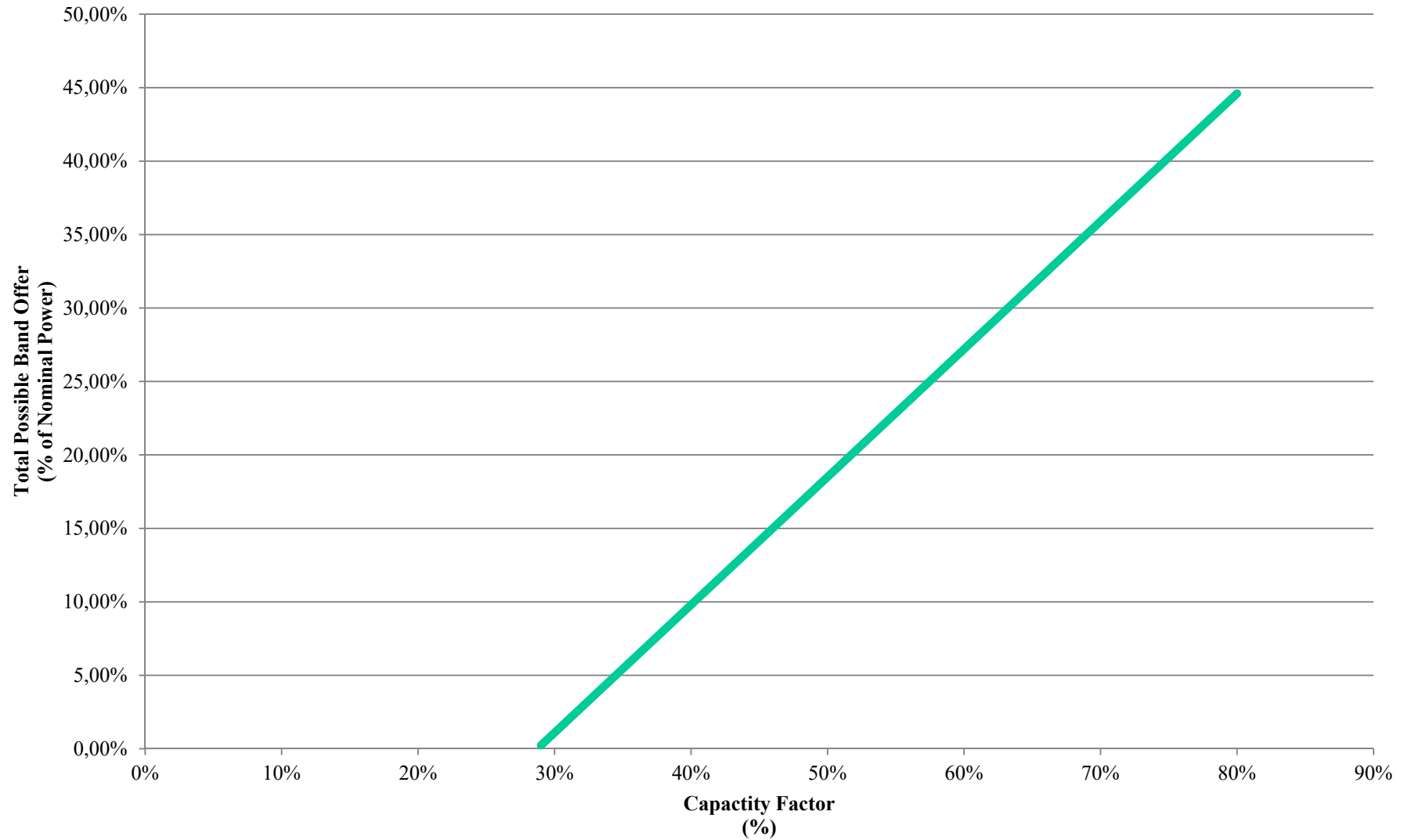
# Work Performed



$$CF75\% * 0.87 \Rightarrow 65.25\% - 25\% = 40.25\%$$

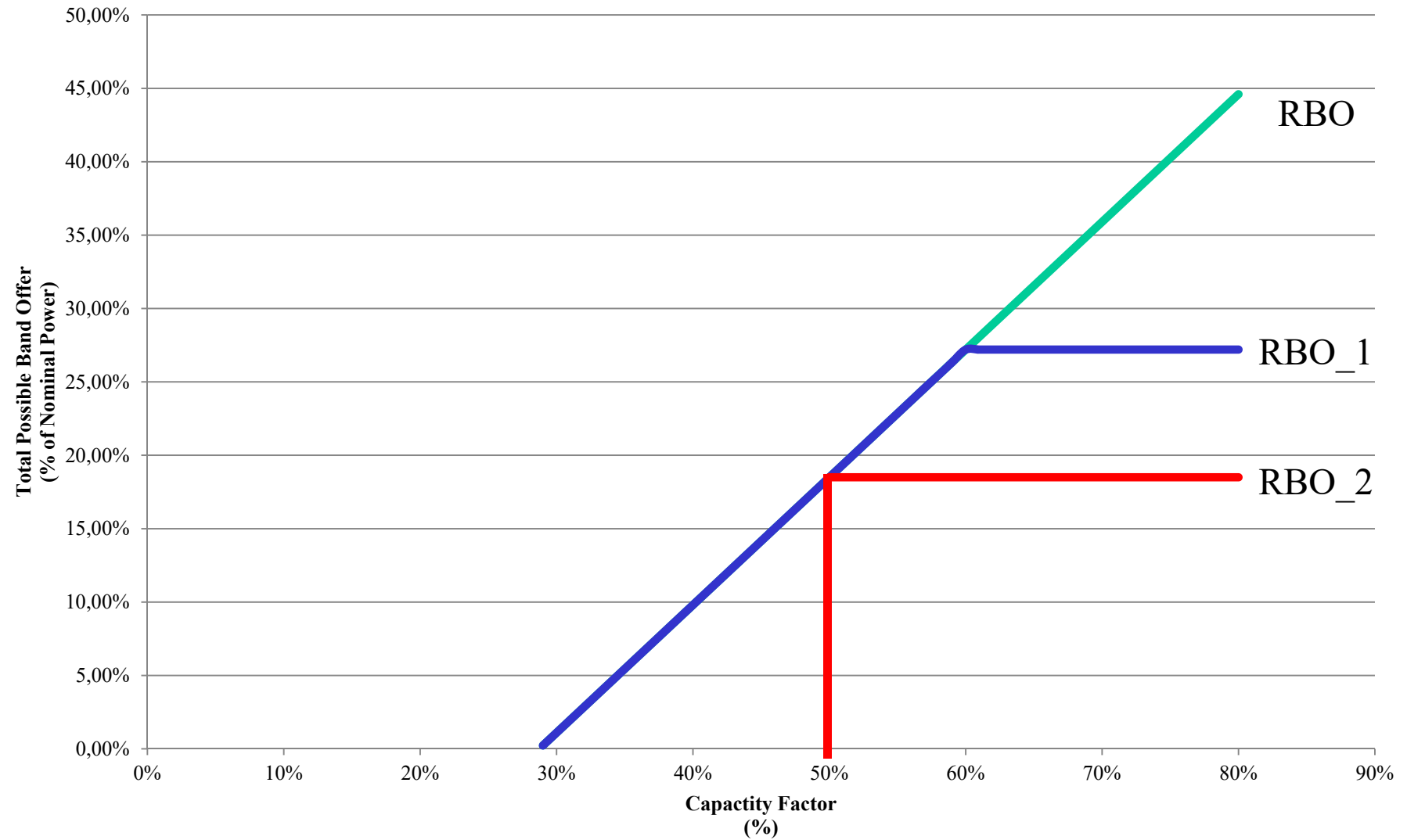
# Work Performed

## Realistic Band Offer (RBO)



# Work Performed

## Realistic Band Offer (RBO)



## Work Performed

### Estimated Capturable Income (ECI)

$$(2BP_h - DMP_h) \times CF_h \times RBO_h \Rightarrow EFHB_h$$
$$(DMP_h - IMP_h) \Rightarrow IBC_h$$

*Hourly Band Factor*  $\Rightarrow B_h$

*Hourly Cost Factor*  $\Rightarrow C_h$

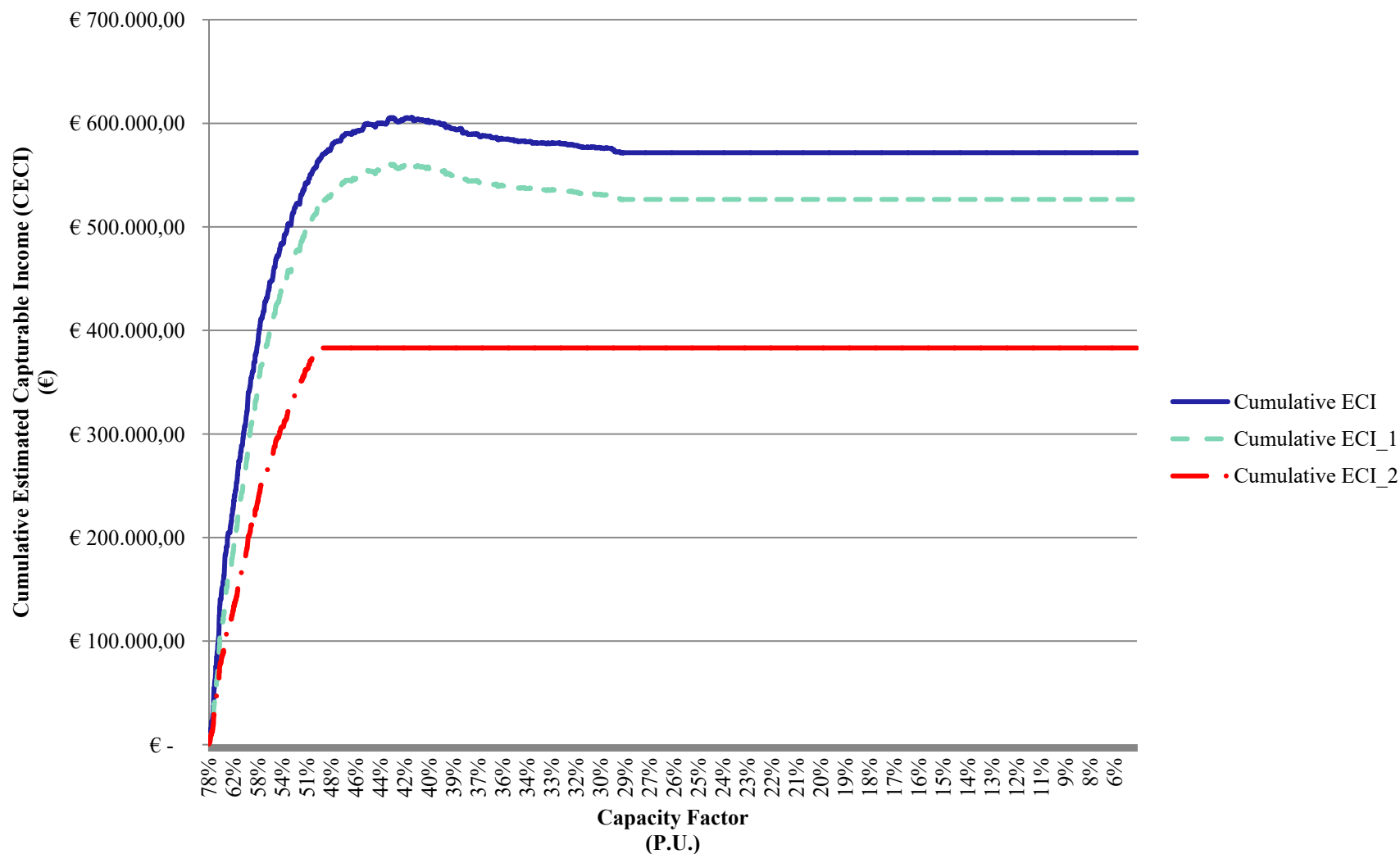
$$ECI = \sum_h (B_h * EFHB_h + C_h * IBC_h)$$

Primary Effects

Secondary Effects

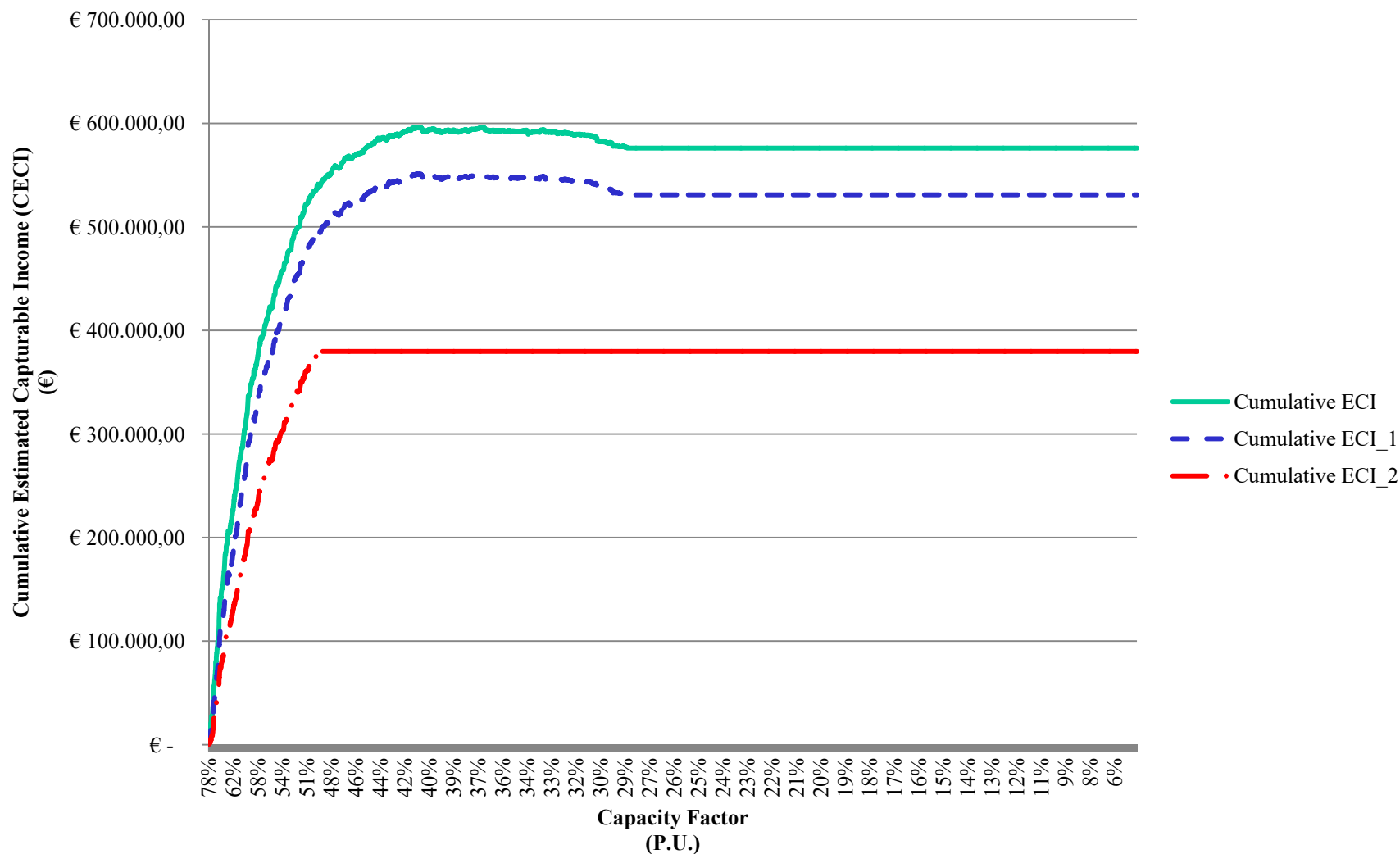
# Optimizing ECI

## Cumulative ECI (Strategy 1)



# Optimizing ECI

## Cumulative ECI (Strategy 2)





# Conclusions

Economic Feasibility S1	Cluster				
	Socialized	Per MW	Huéneja	Tajo de la Encantada	Arcos de la Frontera
Costs					
Turbine Impact	€ 32,100.00	€ 65.78	€ 12,840.00	€ 6,420.00	€ 12,840.00
Wind Farm Impact	€ 438,490.00	€ 898.55	€ 169,246.00	€ 98,544.00	€ 170,700.00
Cluster Impact	€ 1,012,700.00	€ 2,075.20	€ 337,566.67	€ 337,566.67	€ 337,566.67
Production Impact	€ 6,765.85	€ 13.86	€ 3,521.57	€ 1,691.46	€ 1,552.82
Total	€ 1,490,055.85	€ 3,053.39	€ 523,174.24	€ 444,222.13	€ 522,659.49
Revenues					
ECI	€ 604,644.77	€ 1,239.03	€ 314,712.65	€ 151,161.19	€ 138,770.93
ECI_1	€ 559,534.14	€ 1,146.59	€ 291,232.93	€ 139,883.53	€ 128,417.67
ECI_2	€ 372,250.38	€ 762.81	€ 193,753.27	€ 93,062.60	€ 85,434.51
Economic Profit					
ECI	€ (885,411.08)	€ (1,814.37)	€ (207,646.36)	€ (292,722.64)	€ (385,042.08)
ECI_1	€ (930,521.72)	€ (1,906.81)	€ (231,126.08)	€ (304,000.30)	€ (395,395.34)
ECI_2	€ (1,117,805.47)	€ (2,290.58)	€ (328,605.74)	€ (350,821.24)	€ (438,378.49)
Payback Period (years)					
ECI	2.5	2.5	1.7	2.9	3.8
ECI_1	2.7	2.7	1.8	3.2	4.1
ECI_2	4.0	4.0	2.7	4.8	6.1

# Conclusions

Strategy 1	Socialized	Huéneja	Tajo	Arcos
<b>NPV</b>				
ECI	€ 3,673,853.03	€ 2,158,038.40	€ 849,172.12	€ 666,642.51
ECI_1	€ 3,291,828.01	€ 1,959,197.51	€ 753,665.86	€ 578,964.64
ECI_2	€ 1,705,792.34	€ 1,133,678.94	€ 357,156.95	€ 214,956.45
<b>IRR</b>				
ECI	40%	61%	33%	24%
ECI_1	37%	56%	30%	22%
ECI_2	22%	36%	17%	11%

Strategy 2	Socialized	Huéneja	Tajo	Arcos
<b>NPV</b>				
ECI	€ 3,359,496.91	€ 1,994,418.61	€ 770,583.09	€ 594,495.21
ECI_1	€ 2,994,992.34	€ 1,804,696.97	€ 679,456.94	€ 510,838.42
ECI_2	€ 1,621,309.11	€ 1,089,706.11	€ 336,036.14	€ 195,566.86
<b>IRR</b>				
ECI	37%	56%	30%	22%
ECI_1	34%	52%	27%	19%
ECI_2	21%	35%	16%	10%

# Conclusions

## Results are promising:

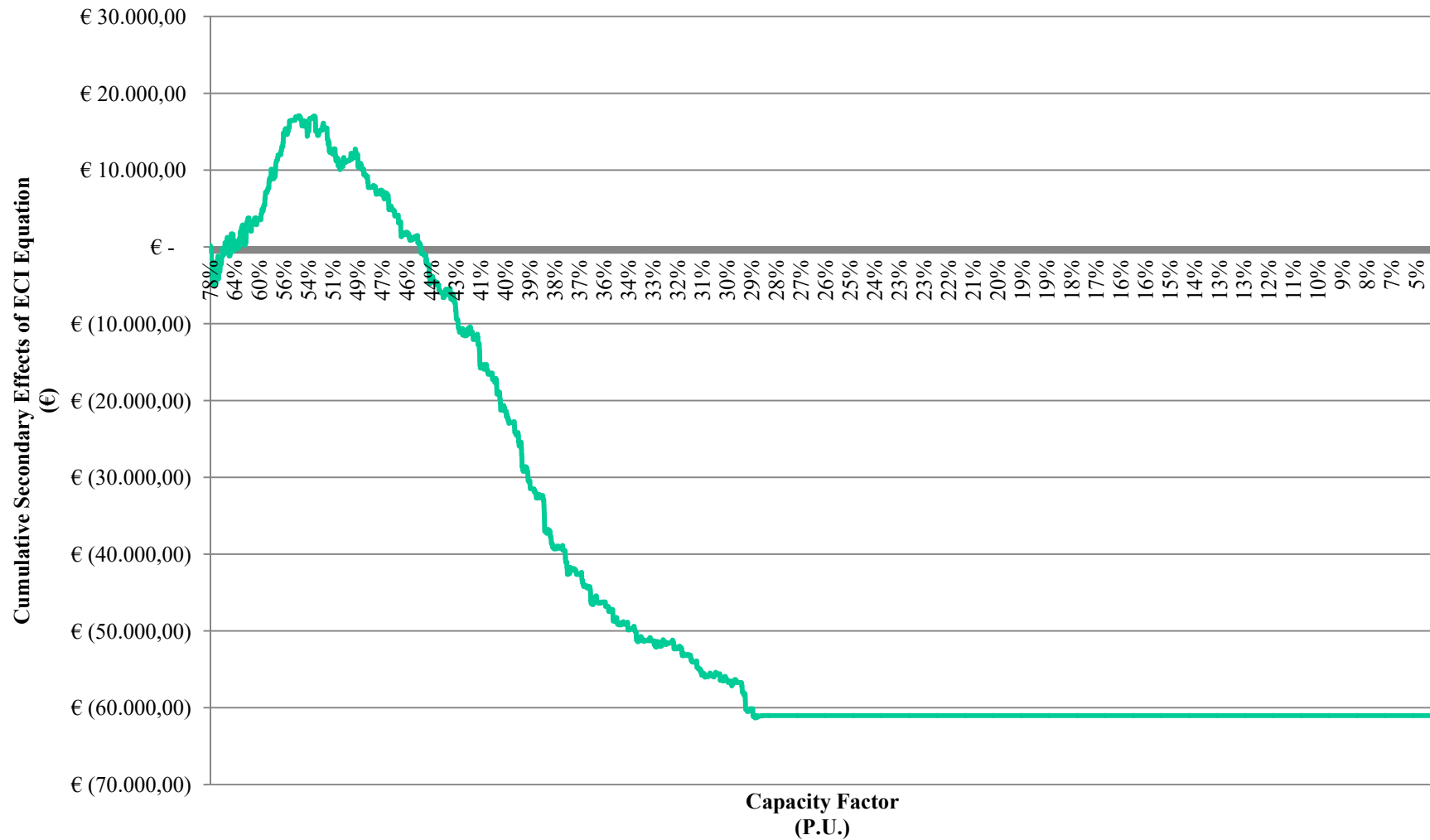
- Wind Producers could expect to earn between €762 - €1,238 per MW of Installed Capacity and should only participate if CF is at least 41%
  
- When applying this to an existing case: The Hueneja cluster of 254 MW, Wind operators could expect to earn between € 193,753 – €314,712 annually and could recoup investment within three years
  
- Investment analysis:
  - IRR 35% - 56%
  - NPV €1.1 – €2 Million for initial investment of €523,174
  
- Market conditions for Wind in Secondary Reserves would be attractive.

Thank you



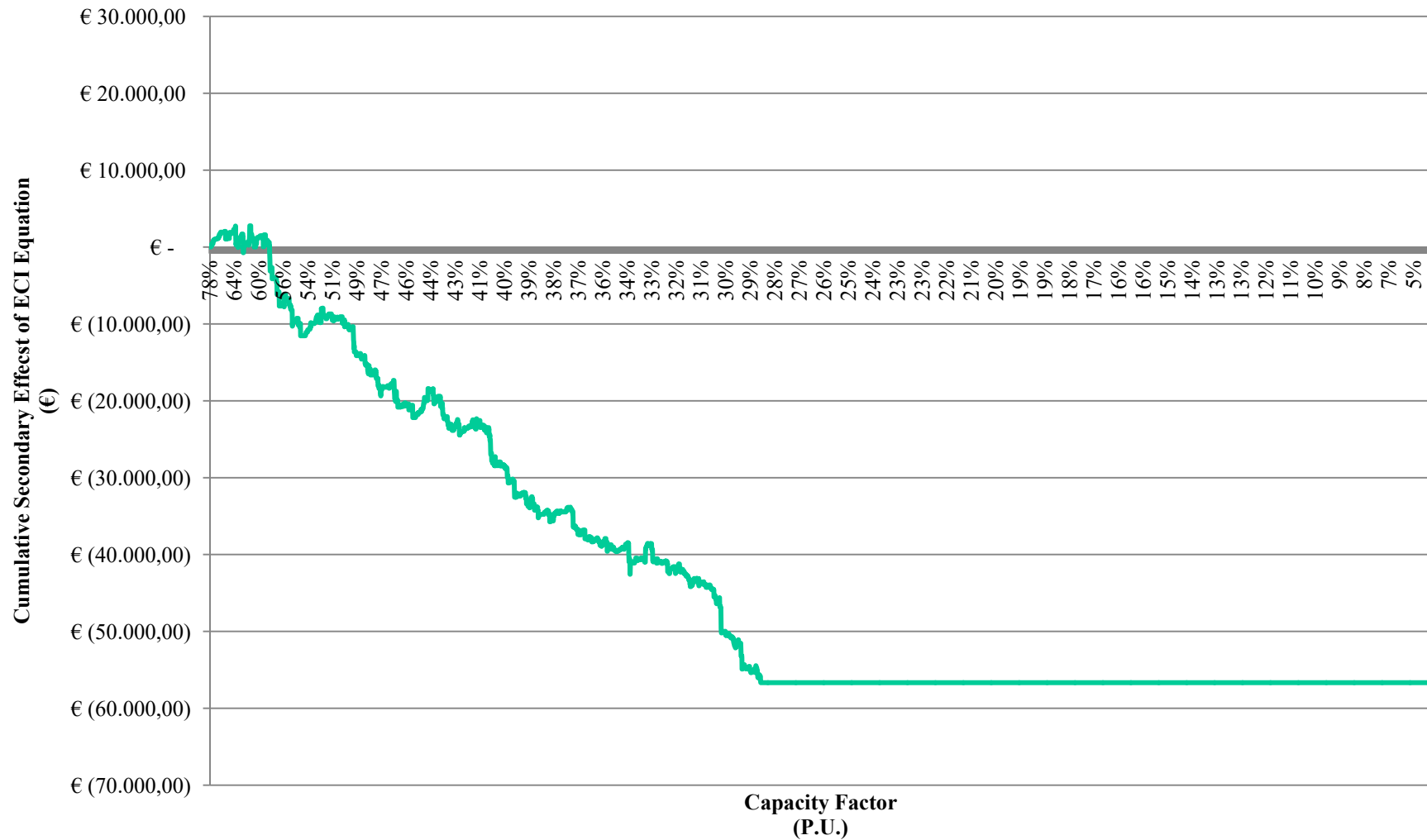
Extra

### Cumulative Secondary Effects (Strategy 1)



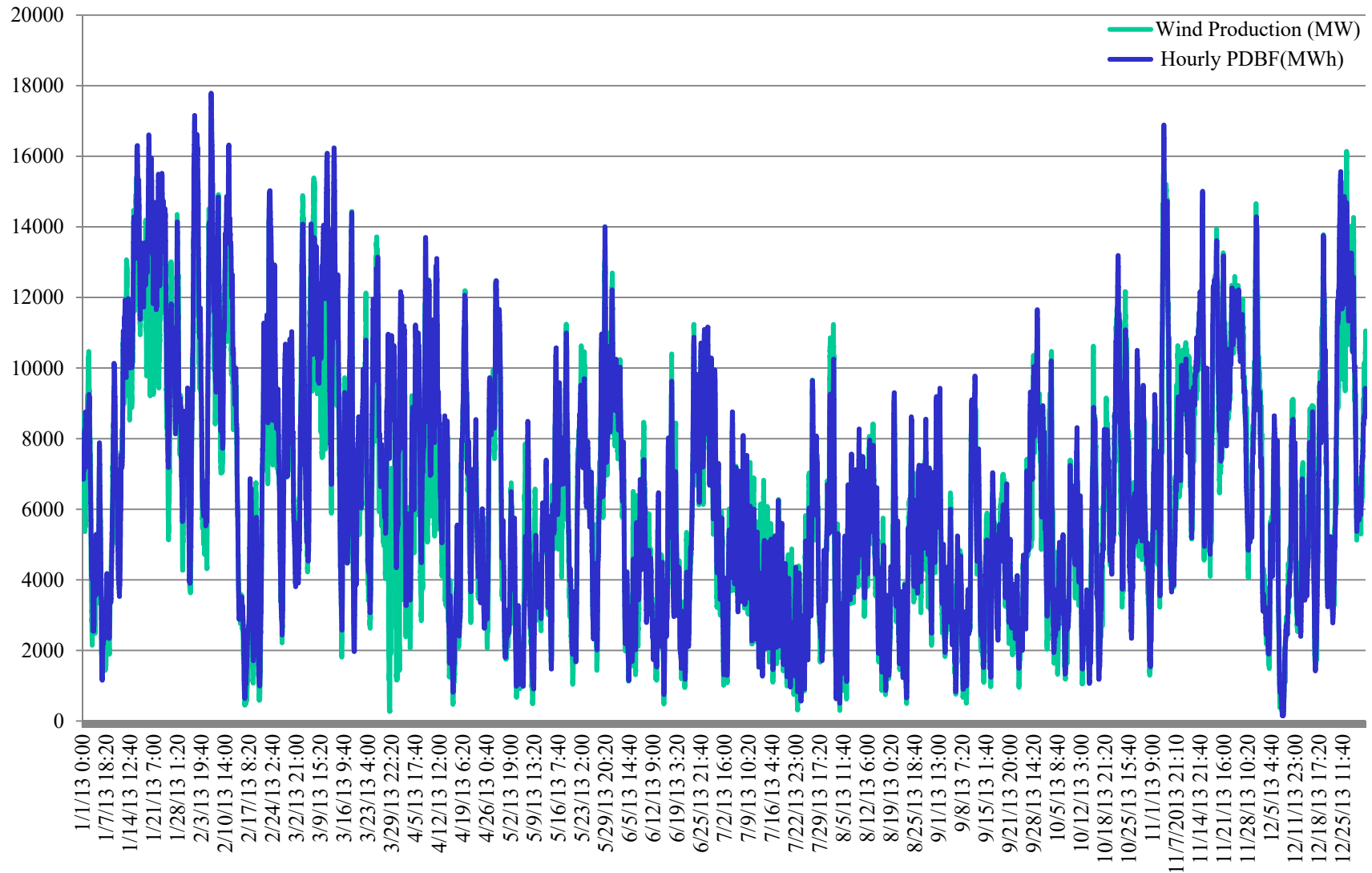
Extra

### Cumulative Secondary Effects (Strategy 2)



# Extra

## Real-time Wind Production vs PDBF Scheduled Production



# Extra

Descriptive Statistics for Difference between Forecast and PDBF	
Mean	3.65%
Standard Error	0.00
Median	3.90%
Mode	#N/A
Standard Deviation	16.97%
Sample Variance	0.03
Excess Kurtosis	5.90
Skew	-0.22
Range	246.50%
Minimum	-146.50%
Maximum	100.00%
Sum	31939%
Data Count	8760
Confidence Interval (95.0%)	0.36%
Upper Bound if normal (95%)	38%
Lower Bound if normal (95%)	-30%

## Percentage Difference of Forecasted vs PDBF Scheduled Wind Production

