Deepening cost analysis for Onshore Wind Technology

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Scope

To develop a more relevant method to investigate costs of energy technologies

• What is missing, and which needs improvements?

• To what extent can each costs component be analysed?

• The lesson learned can be applied for different energy technologies?
Costs drivers investigated in current methods

**HIGH LEVEL DRIVERS → MACRO-SYSTEM DYNAMICS**

- Learning due to deployment
- Knowledge spillovers between actors
- Policy support
- Economies of scale (size – plant, industry)
- Research achievements
- Local industry development
- Inputs costs

**LOW LEVEL DRIVERS → OBSERVABLE TECHNICAL PARAMETERS**

- Economies of scale (size – device)
- Technical quality (performance, material use)
- Site characteristics (distance)
- Installation efficiency (time)
# Methods to investigate cost reductions

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<tr>
<th>System boundaries level of analysis</th>
<th>COST-BREAKDOWN STRUCTURE</th>
<th>BOTTOM-UP COST MODEL</th>
<th>LEARNING CURVES</th>
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<tr>
<td>PROJECT LEVEL</td>
<td>INDUSTRY/NATIONAL LEVEL</td>
<td>INDUSTRY/NATIONAL/GLOBAL LEVEL</td>
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<tr>
<th>Data gathering and Drivers of costs reduction</th>
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<th>LEARNING CURVES</th>
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<tr>
<td>ENGINEERING ASSESSMENT (TECHNICAL AND SPECIFICS)</td>
<td>DATABASE ANALYSIS (TECHNICAL BUT GENERAL)</td>
<td>DATABASE ANALYSIS (TECHNICAL BUT GENERAL, MACRO-SECTOR TRENDS)</td>
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<tr>
<td>OBSERVABLE TECHNICAL PARAMETERS/LOW LEVEL DRIVERS</td>
<td>OBSERVABLE TECHNICAL PARAMETERS/LOW LEVEL DRIVERS</td>
<td>MACRO ECONOMICS DRIVERS/ HIGH LEVEL DRIVERS</td>
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<tr>
<th>Extent range (Scope)</th>
<th>COST-BREAKDOWN STRUCTURE</th>
<th>BOTTOM-UP COST MODEL</th>
<th>LEARNING CURVES</th>
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<td>CASE SPECIFIC (limited)</td>
<td>GENERAL CASE</td>
<td>GENERAL CASE</td>
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<tr>
<th>Reduction costs approach by drivers</th>
<th>COST-BREAKDOWN STRUCTURE</th>
<th>BOTTOM-UP COST MODEL</th>
<th>LEARNING CURVES</th>
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<tr>
<td>SENSITIVITY ANALYSIS (STATIC)</td>
<td>1. SENSITIVITY ANALYSIS (STATIC)</td>
<td>REGRESSION ANALYSIS IN TIME (ECONOMETRIC MODEL-DYNAMIC)</td>
<td></td>
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<tr>
<td>2. TIME VARIATION OF TECHNO-ECONOMIC DRIVERS (DYNAMIC)</td>
<td></td>
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</table>
ISSUES
1. LOW LEVEL FACTORS ARE NOT ALL DIRECTLY LINKED TO ALL MACRO SYSTEM LEARNING DRIVERS (later costs analysis)

ISSUES
1. LIMITS TO ADDRESS REALITY - DRIVER/FACTOR (before costs analysis)
**LCOE cost components**

- **Investment costs** - CAPEX plant
- **Balance of the system (BoS costs)**
- **Technology costs**
- **O&M Plant**
- **Fuel costs**
- **Cost of capital**
- **Performance drivers**

**Technology components** (e.g. blades, transformers, PV module)
- Main costs components of technology costs:
  - Capital costs
  - Input material
  - Labor costs
  - Energy costs
  - Overhead

**Hard/Soft deployment costs:**
- Planning and project design costs
- Transport costs
- Installation/assembly
- Grid connection costs

**Main costs components of technology costs**:
- Equipment costs
- Labor costs
- Financial costs
- Customers acquisition/administration
- Technical feasibility
- Overhead

**Energy generation costs (LCOE)**
- **OPEX plant**
- **FUEL costs**
- **FINANCIAL**
- **PERFORMANCE**

- Land site lease cost
- Legal-administrative costs (tax, rates, insurances)
- Operation
- Maintenance, replacement
- Primary energy resource
- Transportation costs
- Transformation costs
- Discount rate (financial risk)

**Performance drivers**
- Capacity Factor (Resource quality)
- Technology life
- Technology choice
- Degradation
Turbine technology price

- **MATERIALS**
  - $f$(usage, market price)
  - $f$(components length, weight, device scale)

- **ENERGY**

- **LABOUR**
  - $f$(industry scale-up, learning by-doing)

- **CAPITAL DEPRECIATION**

- **OVERHEAD**
  - $f$(industry scale-up, learning by-doing, industry formation & cluster, market)
Technology price – Input costs drivers (Vestas)

![Bar chart showing technology price trends with ASP Turbine costs comparing 2005 and 2017. The differences in costs are highlighted with a vertical arrow indicating a decrease of $568 per kW. The chart details various cost components such as capital depreciation, energy costs, materials, and labor.]

- **ASP Turbine (Vestas-DK)** [$2016/kW]
- **Capital Depreciation and amortization costs**
- **Energy costs (Price and quantity)**
- **Materials (price and quantity)**
- **Labour costs (manufacturing + installation)**

The chart shows a decrease of $568 per kW from 2005 to 2017, with notable changes in specific cost components.
Input drivers changes 2005-2017

Total cost reduction → 568 $/kW

<table>
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<th>[$2016/kW]</th>
<th>Reduction</th>
<th>%</th>
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<tr>
<td>Contributions of input costs drivers</td>
<td>129</td>
<td>23%</td>
</tr>
<tr>
<td>Other costs (overhead)</td>
<td>439</td>
<td>77%</td>
</tr>
</tbody>
</table>

Bar chart showing cost reductions:
- Materials: 79 $/kW
- Labour (production + installation): -18 $/kW
- Labour (transport + administration + O&M): 60 $/kW
- Capital Depreciation and amortization costs: 5 $/kW
- Energy costs: 3 $/kW

TOTAL: 129 $/kW
Material costs variation (Vestas)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>2005</th>
<th>2017</th>
<th>2005-2017 Differences</th>
<th>1st case</th>
<th>2nd case</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEEL</td>
<td>94</td>
<td>79</td>
<td>15</td>
<td>14.96</td>
<td>-8.47</td>
</tr>
<tr>
<td>CAST IRON</td>
<td>14</td>
<td>9</td>
<td>5</td>
<td></td>
<td></td>
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<tr>
<td>ALUMINUM</td>
<td>34</td>
<td>14</td>
<td>10</td>
<td>6.06</td>
<td></td>
</tr>
<tr>
<td>COPPER</td>
<td>16</td>
<td>9</td>
<td>7</td>
<td>-5.44</td>
<td></td>
</tr>
<tr>
<td>POLYMER TURBINE</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>-0.27</td>
<td></td>
</tr>
<tr>
<td>POLYMER (CABLES)</td>
<td>11</td>
<td>4</td>
<td>2</td>
<td>-0.94</td>
<td></td>
</tr>
<tr>
<td>CONCRETE</td>
<td>78</td>
<td>57</td>
<td>21</td>
<td>7.35</td>
<td></td>
</tr>
<tr>
<td>CERAMIC/GLASS + CARBON</td>
<td>29</td>
<td>33</td>
<td>10</td>
<td>1.40</td>
<td></td>
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<tr>
<td>TOTAL COSTS OF MATERIALS</td>
<td>280</td>
<td>208</td>
<td>223</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>CONTRIBUTION ON MATERIAL EFFICIENCY</td>
<td>72</td>
<td>57</td>
<td>59</td>
<td></td>
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</tr>
</tbody>
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1st case: NO CHANGE IN COMMODITY PRICES

2nd case: NO CHANGES IN TURBINE TECHNOLOGY

17-21% MARKET CHANGES
79-83% TECHNICAL IMPROVEMENTS
Overhead (still unexplained)

439 $2016/kW → ~77% Wind Turbine Technology price

How can we cover the gap for overhead costs?

- **COMPANY PROFIT**
  - Average of main manufactures in the world

- **TRANSPORTATION / INSTALLATION COSTS**
  - Local behavior – Country specific analysis

- **SUPPLIER - COMPETITORS COSTS**
  - Local behavior - Industry formation and market dynamics

- **FINANCIAL and OTHERS**
  - Market, policy, manufacture learning, industry scale-up
1FLC – market deployment

15% - US
58% - Denmark

Global market deployment: 21%

US - DK comparison

Capacity deployment [GW]
Prices [$2016/kW]

Overhead (DK)
Overhead (US)
ASP Turbine (Vestas-DK) [$2016/kW]
ASP Turbine US [$2016/kW]
US market deployment [GW]
DK - Market deployment [GW]
Conclusion and Follow-up

- Most of technology costs components are still not explained
- Focus on understanding cost reduction dynamics of overhead costs is needed

Are they dependent on local or global conditions? 
Project level data could provide more insights? 
More specific data needs: Low drivers or global drivers? Which is the best approach?

- FUTURE ANALYSES
  1) Balance of the system of wind farm at project level analysis
  2) Consideration stage where still deployment is not achieved