



# › IDL TOWER: LCOE CALCULATION AND LCA

N. Saraswati

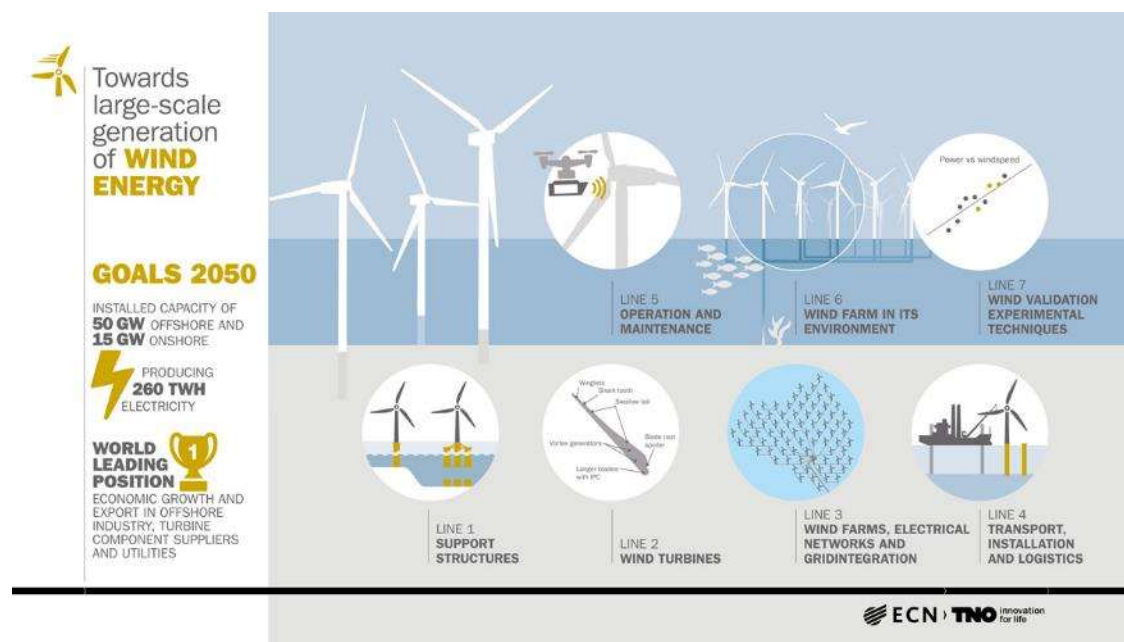
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# AGENDA

- › Introduction & Motivation
- › LCOE modelling and simulation
  - › IDL tower case study: Comparing LCOE steel vs composite tower case
- › Life cycle assessment
  - › IDL tower case study: Comparing environment impact between steel vs composite tower case
- › Conclusions and recommendations

# TOWARDS LARGE-SCALE GENERATION OF WIND ENERGY

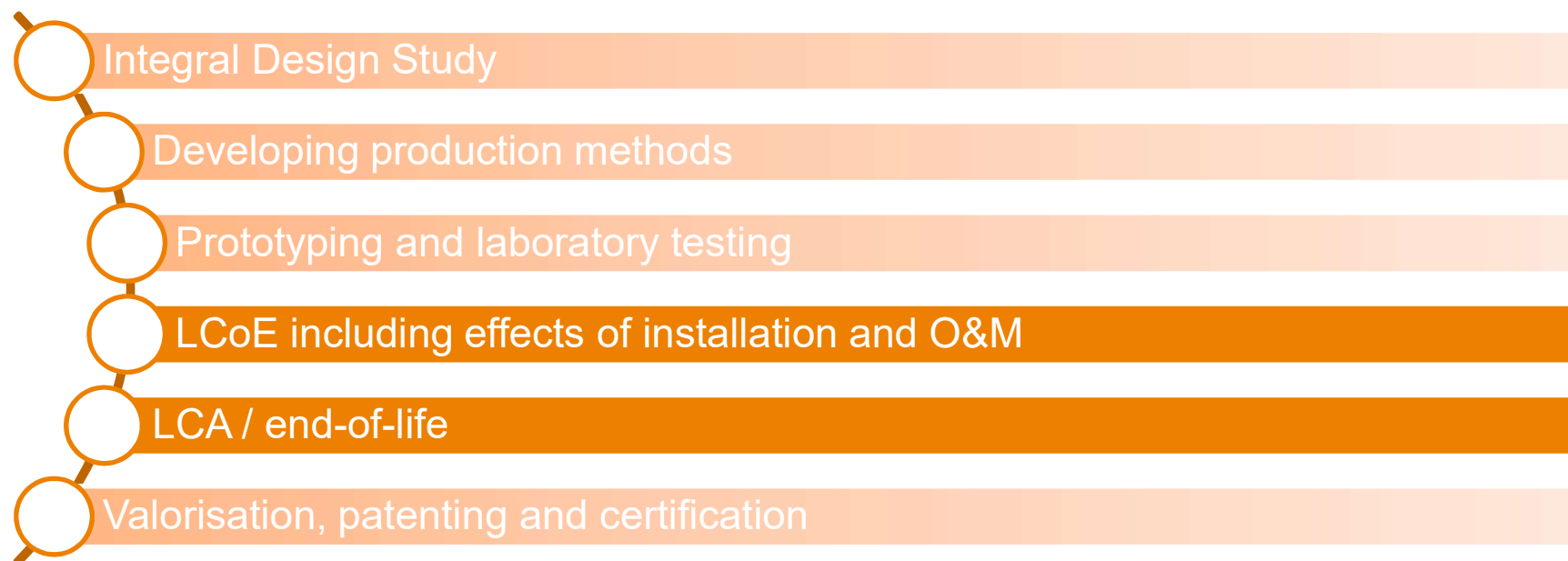


## IDL TOWER BACKGROUND

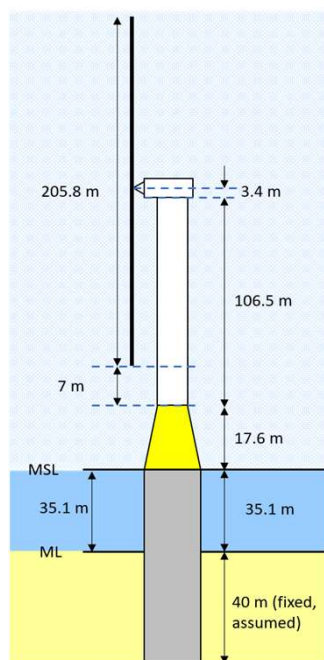
- › Continuation of C-Tower: >40% lighter tower concept based on GFRP
- › The aim is to evaluate the technical, economic and environmental effects of a lighter, more flexible composite tower, with substantial lower eigen frequencies than a conventional steel tower.
- › Alternative for steel tower
  - › Energy intensive steel fabrication
  - › Less weight in transportation
  - › Less maintenance against corrosion and other environmental effects



## IDL TOWER SCOPES & WORKS



## IDL TOWER DESIGN



- › Avatar 10 MW x 77 WT = 770 MW (Borssele area)
- › For the integrated tower design, an offshore load set according to IEC 61400-3:2009 was used.
- › The composite tower, steel transition piece and steel monopile were optimized using the FOCUS6 software and verified for ultimate, buckling and fatigue strength and eigenfrequency constraints
- › Layup composite tower (GFRP polyester)

|                       | Steel  | IDL   | Red           |
|-----------------------|--------|-------|---------------|
| Material price (€/kg) | 1.80   | 4.63  |               |
| Tower mass (mT)       | 790.3  | 320.5 | <b>-59.4%</b> |
| MP Mass (mT)          | 1186.0 | 788.6 | <b>-33.5%</b> |
| TP Mass (mT)          | 251.0  | 162.2 | <b>-35.4%</b> |

# LCOE CALCULATION



## ECN COST MODEL

- › The cost model is developed with the idea to provide an economic evaluation of an offshore wind farm:
- › Currently is tuned for “traditional” OWF, but flexible enough to be expanded with new technologies/knowledge

- › Wind turbine with a single (3 bladed) rotor

- › Monopile support structure

- › Rectangular or square shape farm

- › Installation and O&M with SOVs and/or CTVs that are used in today’s market

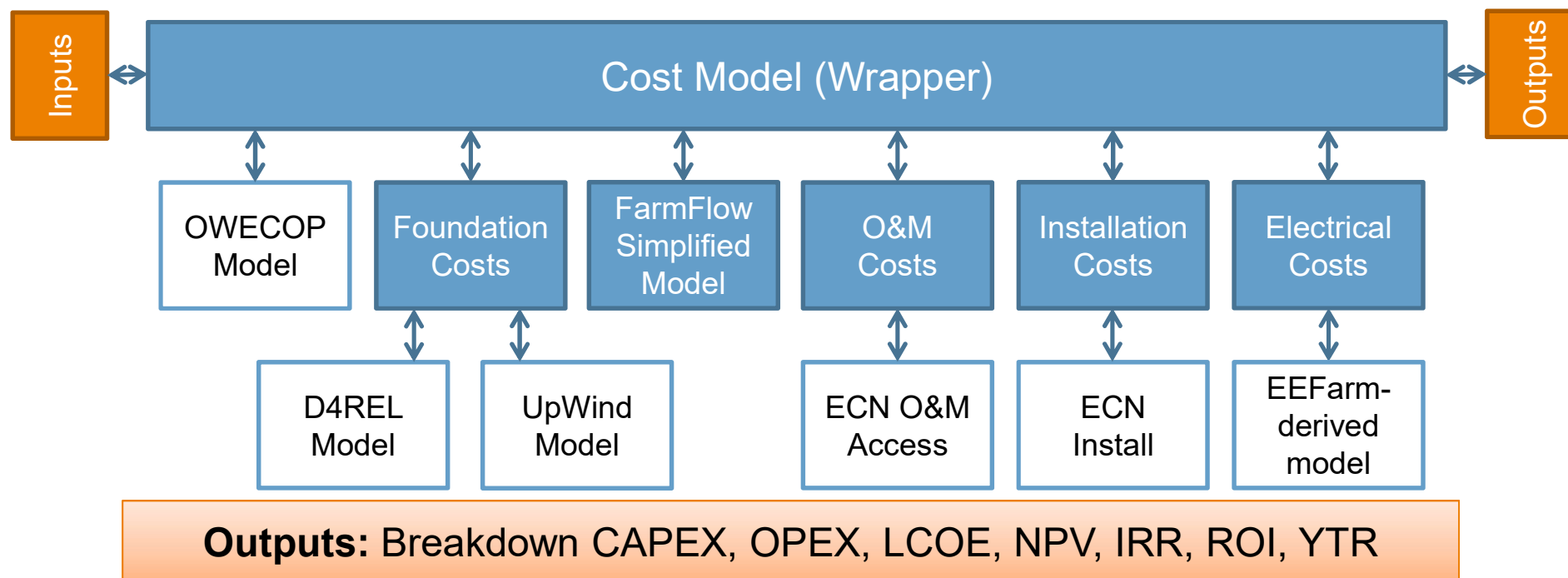
- › Typical electrical infrastructure

$$LCoE = \frac{\left(\frac{CapEx}{a} + OpEx\right)}{AEP}$$

- › Next development are: floating support structure, multi-rotor/airborne technology, etc.



## ECN COST MODEL



## STEEL VS. IDL TOWER CASES

### *Installation*

- Deck space: 3600m<sup>2</sup>
- Crane: 1000 mT
- Cargo 6000 mT
- Cases:
  - Steel: 3 WTs or 3 foundations per trips
  - IDL: 4 WTs or 4 foundations per trips

A: 100%



- Deck space: 4600m<sup>2</sup>
- Crane: 1500 mT
- Cargo 8000 mT
- Cases:
  - IDL: 6 WTs or 6 foundations per trips

B: 160%



- Deck space: 3200m<sup>2</sup>
- Crane: 600 mT
- Cargo 4000 mT
- Cases:
  - IDL: 12 towers/trip
  - Add vessel type A to carry 5 nacelles, hubs and blades

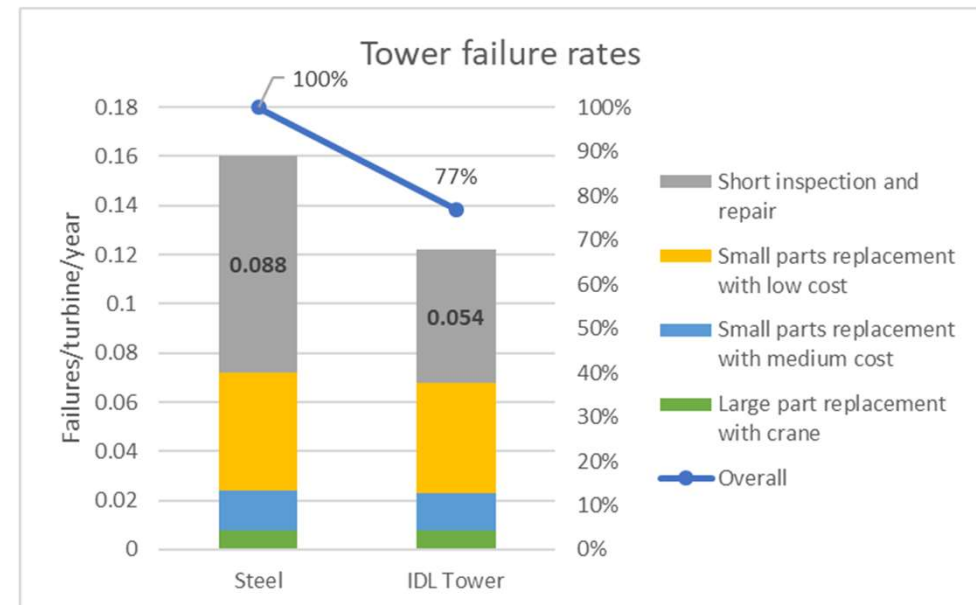
C: 50%



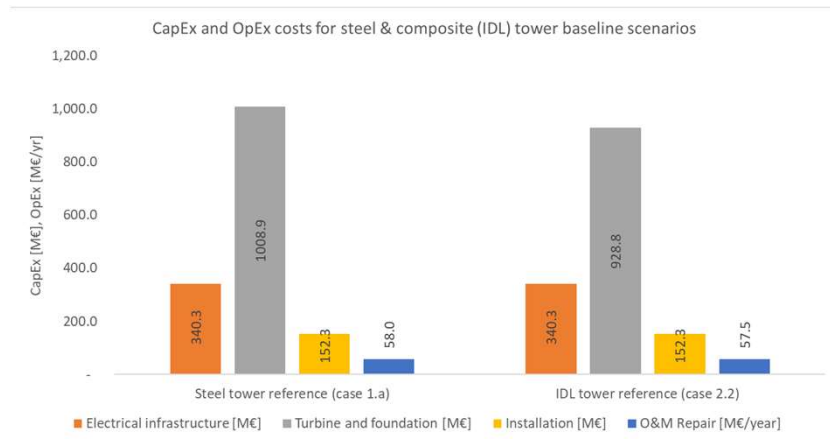
# STEEL VS. IDL TOWER CASES

## *O&M*

- › Changes only in UMD – Turbine Structure / Tower failure rates
  - › Reduction in short inspection and repair (bolts and welding)
- › Same maintenance response as default
  - › Short inspection and small repair
    - › 4 hours
    - › Using consumables
    - › 3 technicians

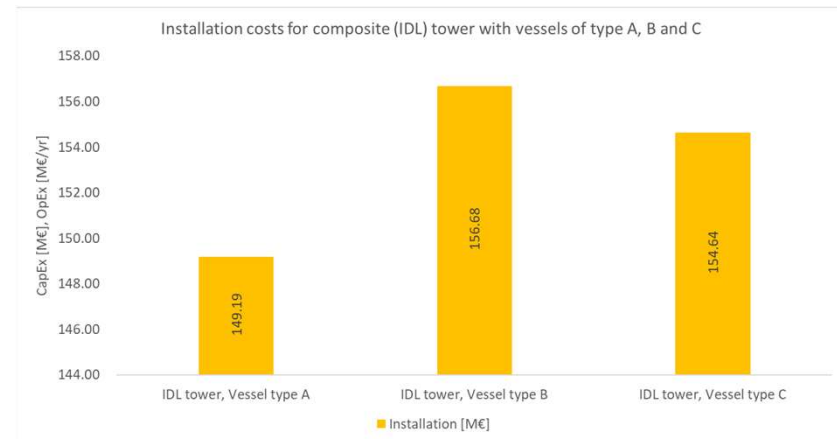


## RESULTS



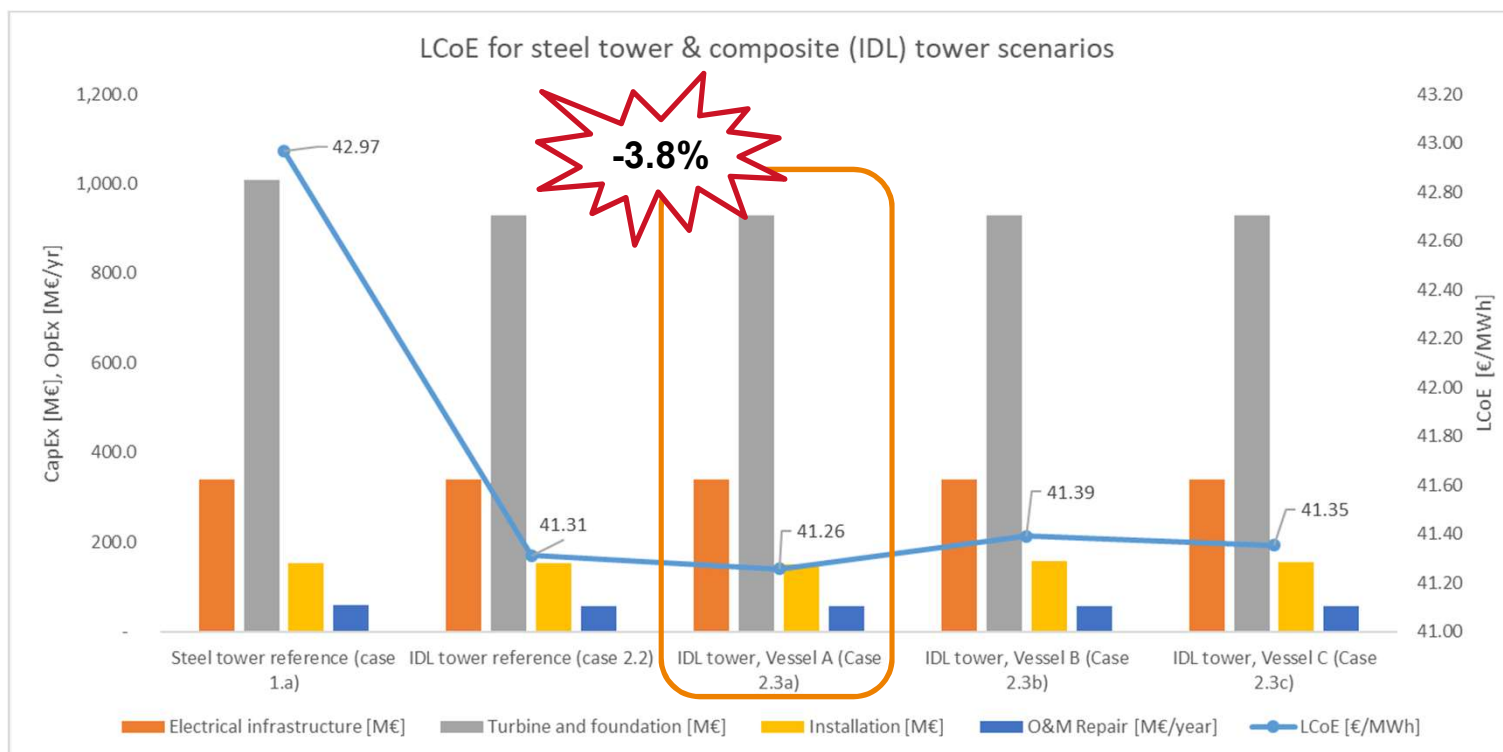
### › Reductions

- › Tower & foundation costs: 80M€
- › O&M costs: ~0.5 M€/year



- › Using vessel A (Carry 4 sets of WTs/trip and 4 sets of foundations/trip) is the cheapest
- › Reduction of 3.1M€ or 2% of installation costs

# SUMMARY



IDL Tower: LCOE Calculation and LCA

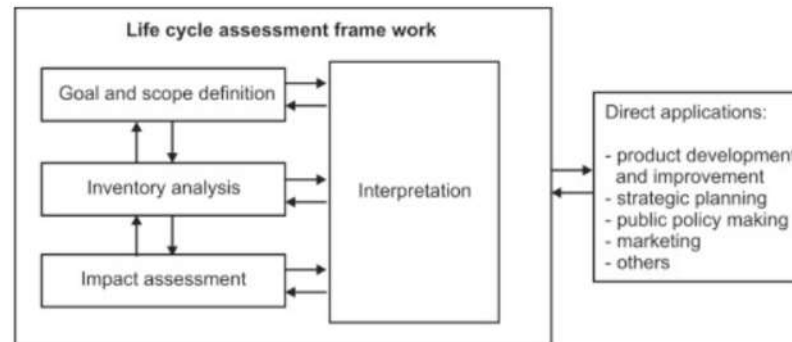
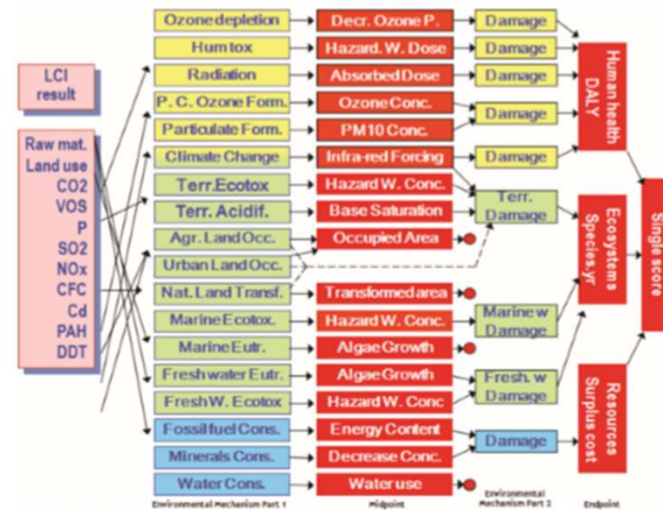


# LIFE CYCLE ASSESSMENT



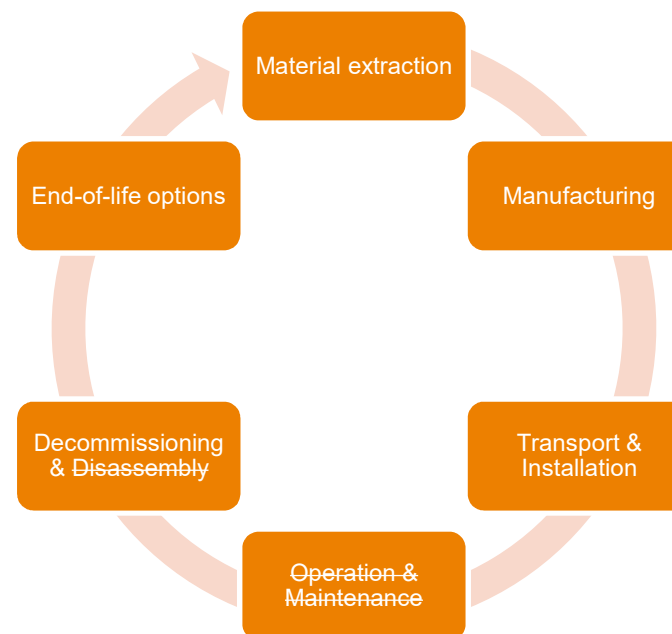
# LIFE CYCLE ASSESSMENT

- › LCA is a methodology used to evaluate the environmental impacts associated with a product or service throughout their life cycle, by
  - › Compiling the environmental inputs and outputs
  - › Evaluating their potential environment impacts
  - › Considering their life cycle



## IDL VS STEEL CASE LCA

- › Scope
  - › Components:
    - › Foundations: monopile + TP
    - › Tower: steel vs composite
  - › Process (see pictures)
- › Functional unit: 1 piece of each component
- › Methodology
  - › ReCiPe 2016 Mid point / End point (E)
  - › Energy cumulative demand
- › Tool: SimaPro





# MATERIAL & MANUFACTURING

## › Foundations (monopile + TP)



Figure: © COWI A/S.

### Steel case

- 99% steel (incl. rolling & welding)
- 1% aluminium, alkyl resin, powder coating, copper, lead

TP: 251 mT  
MP: 1186 mT

### IDL Case

TP: 162.2 mT  
MP: 788.6 mT

- › 33.8% reduction in weight (foundations)
- › Add: heat, tap water, electricity mix based in NL

## › Tower



### Steel case

- 98.2% steel (incl. rolling, welding)
- Rest: copper, steel coating, alkyl resin, etc.

790.3 mT

### IDL Case

- 62% glass fibres
- 37% polyester resin
- Organic chemical for curing agent and coating
- Emission: 0.25%-w styrene

320.5 mT

## OTHER PHASES

### Installation

- Perform by jack-up vessel "Transport, freight, sea, transoceanic ship" tonnes.km
- tonnes.km
  - Vessel usage
  - Fuel consumption
  - Maintenance
  - Port facilities
  - Emissions
  - Waste and waste treatments

### O&M

- No large replacement (foundations, towers)
- Almost no difference in vessel use
- Calculation is excluded

### Decommissioning

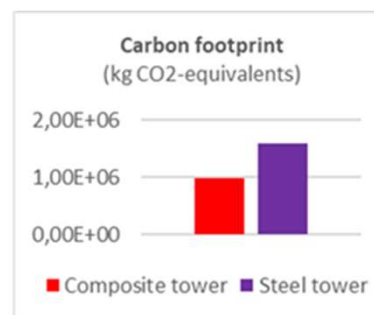
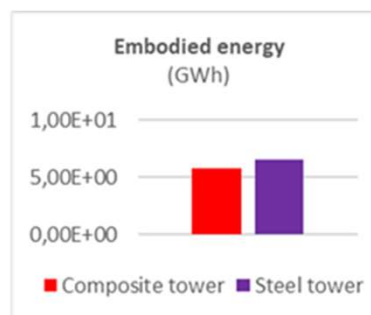
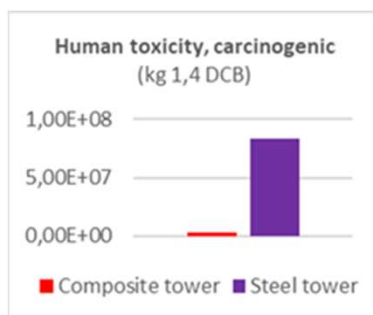
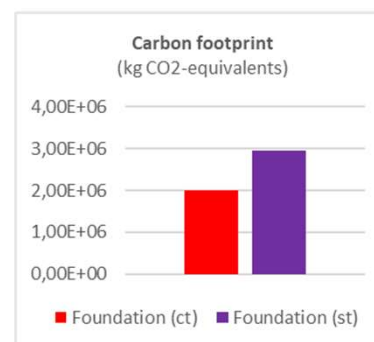
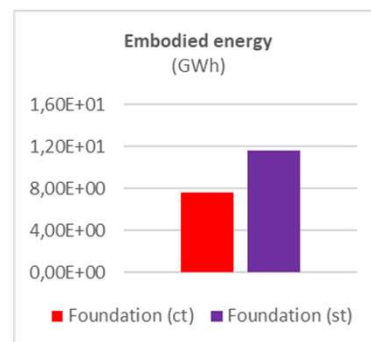
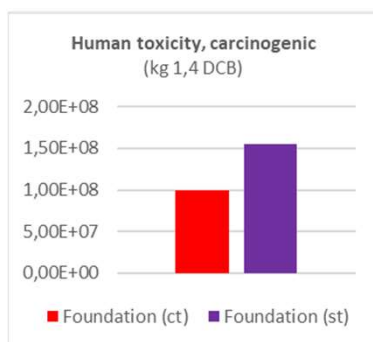
- Perform by same type of vessels as installation
- Decommissioning = installation port distance

### End of Life

- Steel, copper, and aluminium are recycled (80-90%) based on TNO's model
- GFRP is incinerated
- Other is sorted, incinerated, or landfill



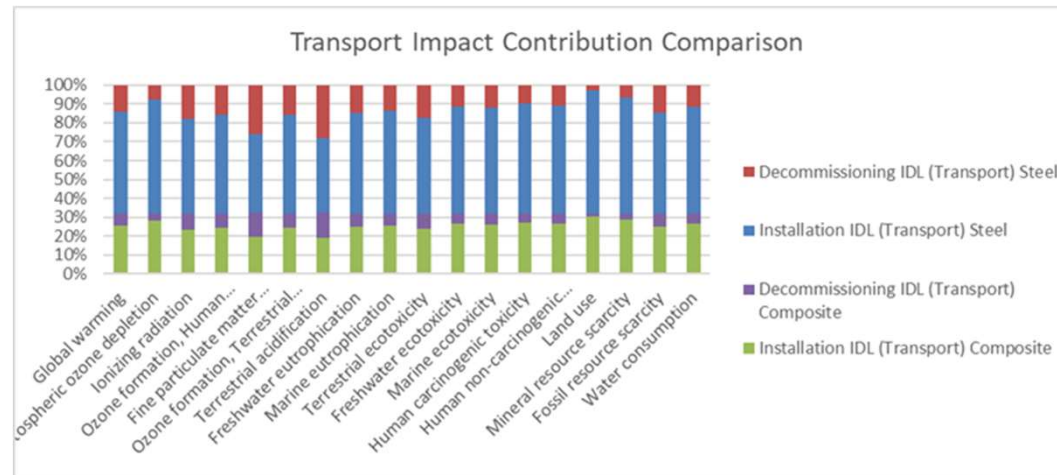
## LCA RESULTS: MATERIAL COMPARISON



- › Foundations: factors of the weight (reductions of 33.8%)
- › Embodied energy difference is marginal (tower)
- › Almost all impact categories, IDL tower < steel towers
  - › Except 2/18 (stratospheric ozone depletion and land use)

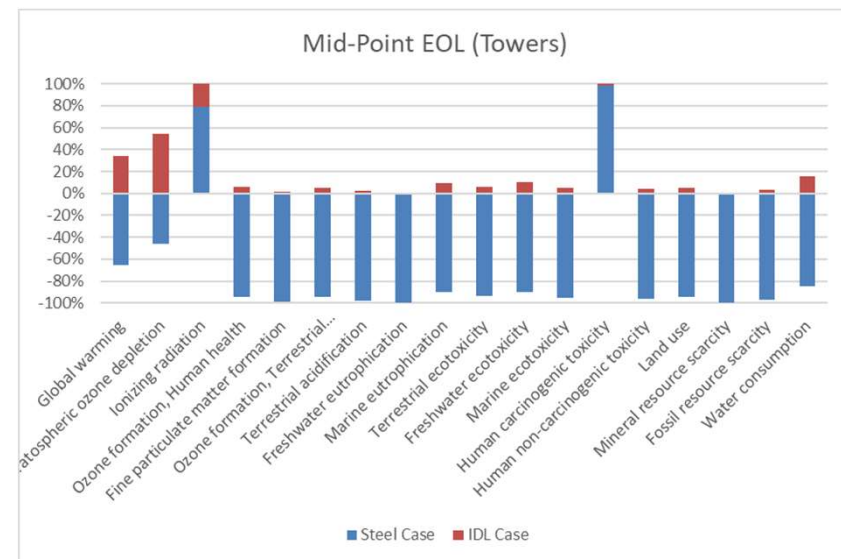
## LCA RESULTS: TRANSPORT RELATED

- › IDL tower case has less impact than the steel tower as it's less weight to carry (all proportional)
- › Installation & Decommissioning contribution is very small compared to overall life cycle (<5%)

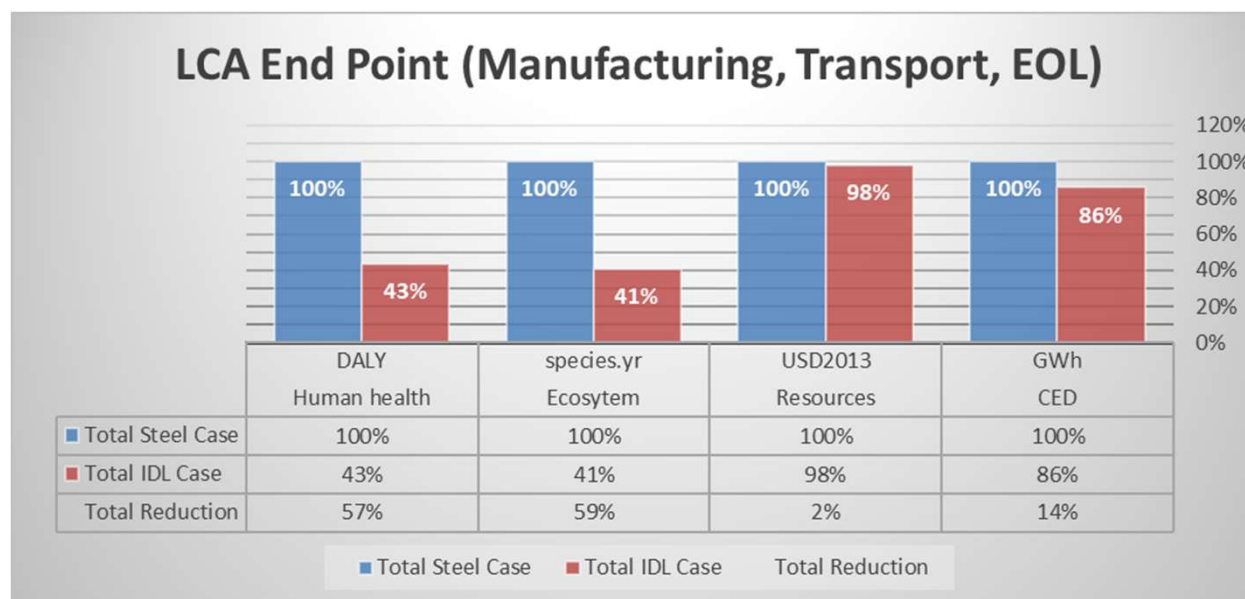


## LCA RESULTS: END OF LIFE

- › Steel is relatively easy to recycle → potential environment benefit or credit in the future
- › For foundations, steel case gives higher benefit
- › For towers
  - › Steel tower gives high benefits as MP + TP
  - › Composite tower is not recycled hence
    - › Additional impacts at the end-of-life



## OVERALL LCA COMPARISON





# CONCLUSION



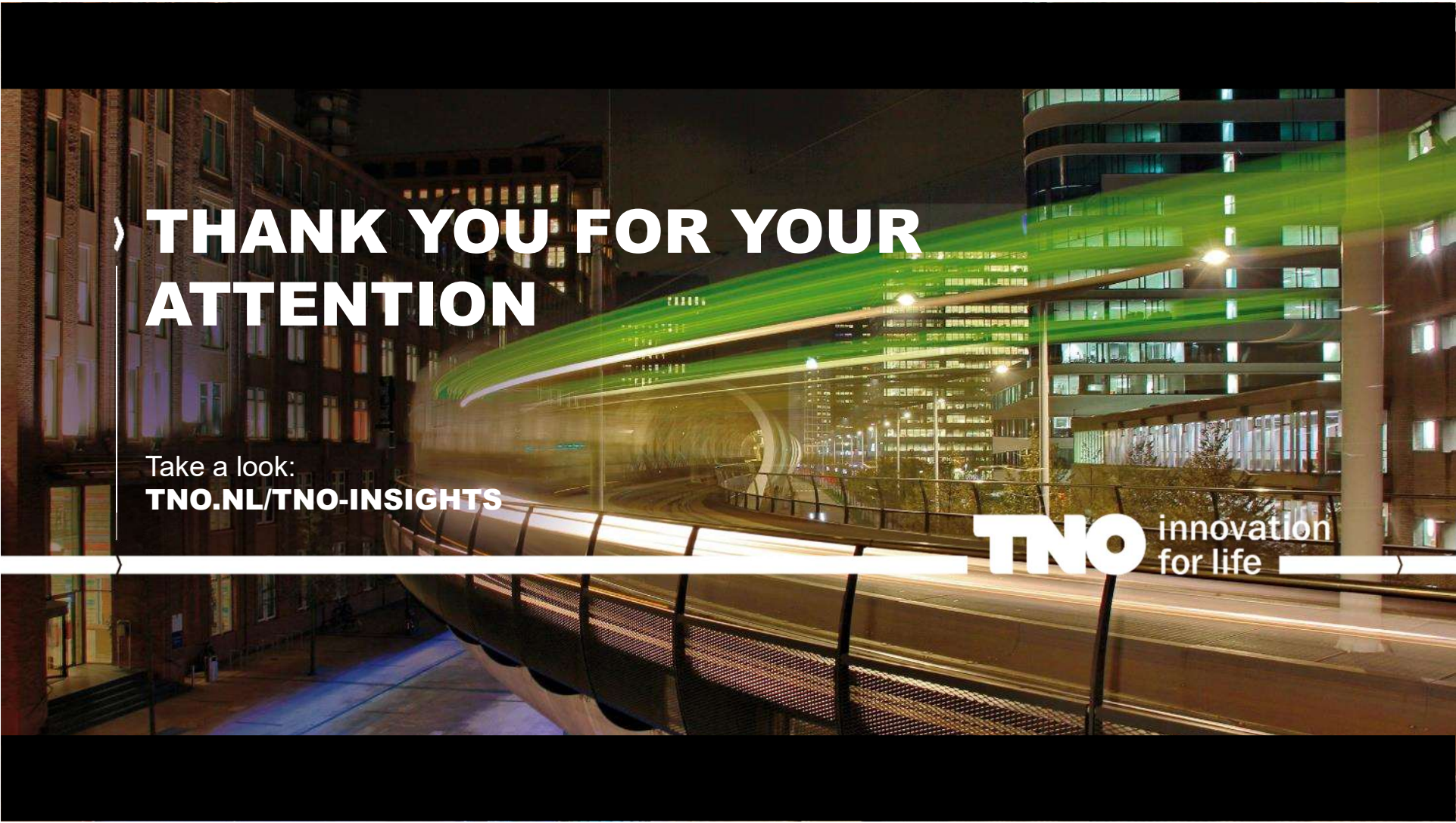
## CONCLUSIONS

- › IDL Tower: reductions of 59.4% and 33.8% mass reduction in tower and foundation
- › Costs and environment impacts/benefits can be evaluated,
  - › ECN Cost model is used to get insight in LCOE or costs breakdown
  - › LCA is used to evaluate technology beyond their economic values
- › IDL tower case led to ~3.9% LCOE reduction, mostly come from weight reduction but also installation
- › IDL tower case led to lower environment impacts in total, even though at EoL composite tower shows higher impacts,
  - › Steel is highly and easily recycled hence at the EoL there is potential environment credit
  - › Potential benefit (not included) if composite is recycled

## RECOMMENDATION & NEXT STEPS

- › Further validation in the manufacturing, usage related to the O&M, and certification.
- › Further roll out: real life demonstration to monitor the performance, degradation, load and vibration measurements
- › Sensitivity (LCOE and LCA) when using IDL tower with current and future turbine sizes
- › CAPEX of IDL tower will be influenced by economies of scale and production capacity
- › Development of composite recycling within the wind industry
- › When viable recycling processes are included, it is expected that the composite case will have potential environmental benefit as in steel tower case.



A nighttime photograph of a city street. On the left is a brick building with lit windows. On the right is a modern building with a curved facade and many lit windows. A curved pedestrian bridge or walkway runs across the middle of the frame. Long, horizontal light trails in green and yellow are visible, suggesting motion from a light source or vehicle. The overall scene is illuminated by city lights.

› **THANK YOU FOR YOUR  
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