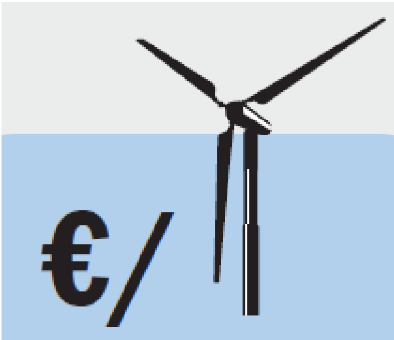
Incorporation of Life Cycle Models in determining Optimal Wind Energy Infrastructural Provision in Ireland

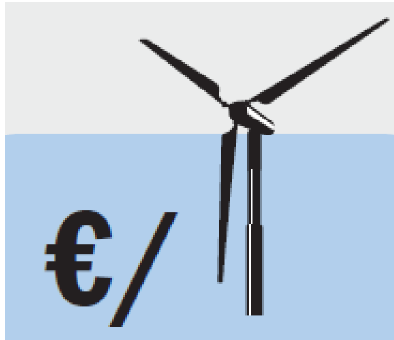


By

Brendan Cleary
BA BAI MSc CEng MIEI MIWEA

School of Civil & Building Services Engineering, DIT

Supervisors: Dr Aidan Duffy DIT & Dr Alan O'Connor TCD



Date: 10th of January 2012

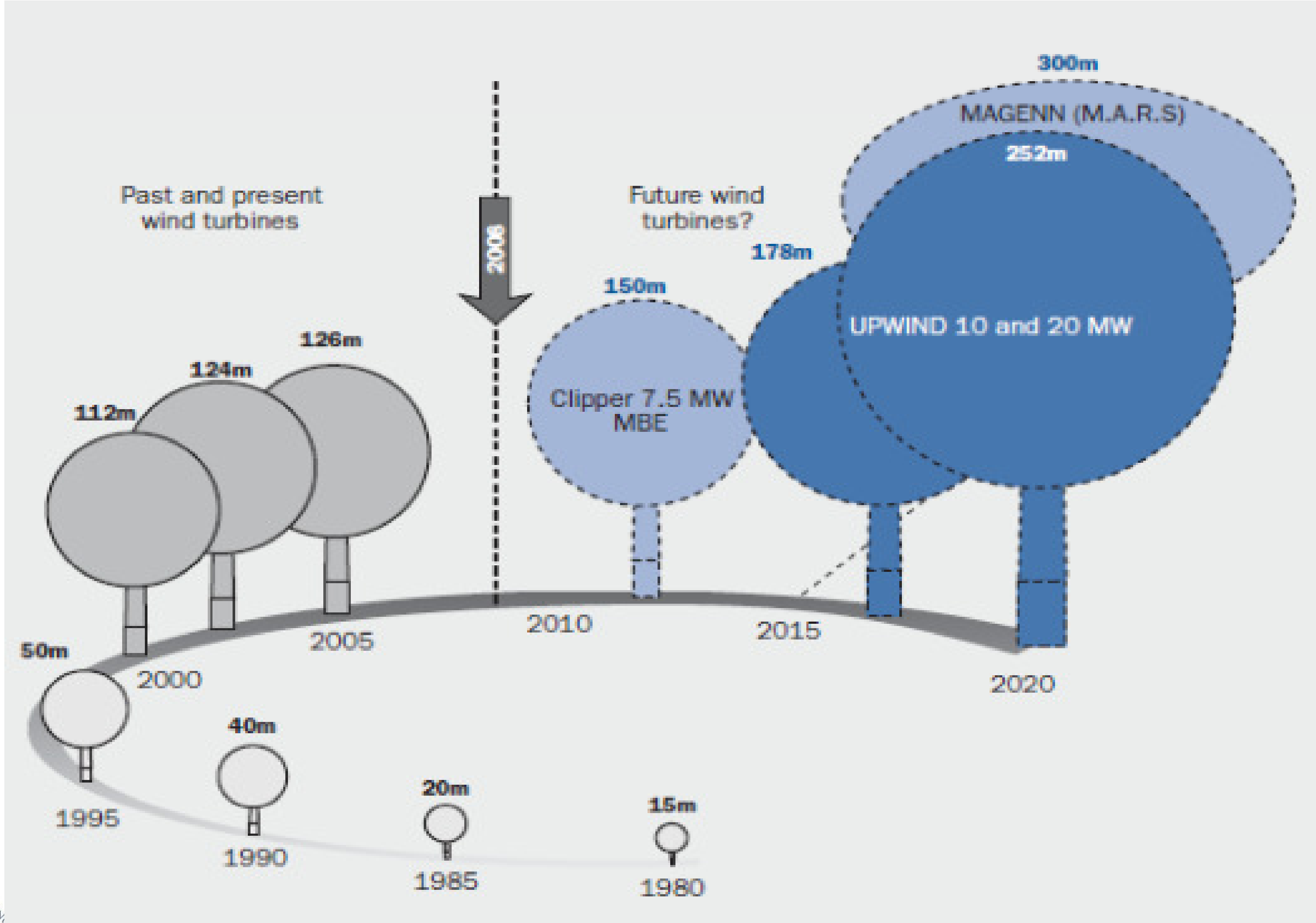
INTRODUCTION

- Background
- Aim & Objective
- Methodology
- Results to date
- Conclusions
- Work to be done

BACKGROUND

- 42.5% of energy from renewable sources by 2020
- Electricity in a more economical & environmentally friendly
- Larger wind turbines 7 – 10MW
- Wind Turbine Towers (WTTs) need to become:
  - Taller, Stronger & Stiffer
- Steel WTTs become unmanageable
- Issues with steel WTTs beyond 85m

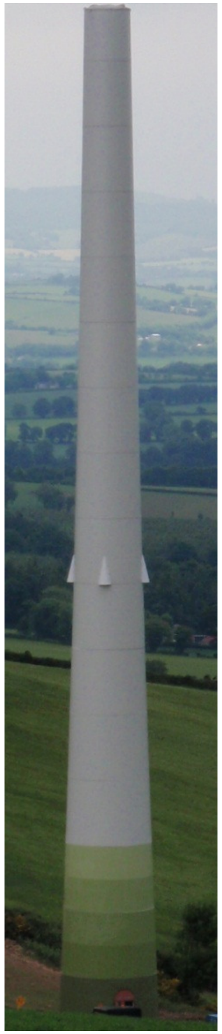
BACKGROUND



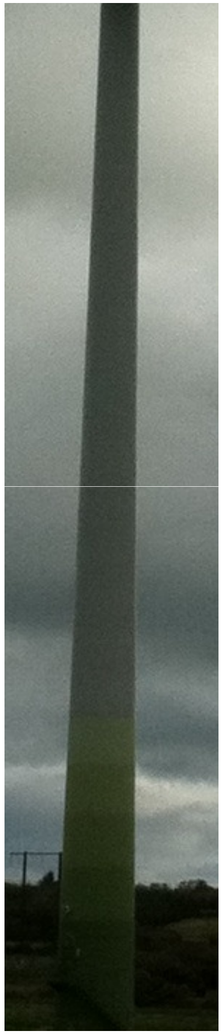
Past and present wind turbines
Future wind turbines?
2008
300m
MAGENN (M.A.R.S)
252m
178m
150m
UPWIND 10 and 20 MW
Clipper 7.5 MW MBE
126m
124m
112m
50m
40m
20m
15m
2020
2015
2010
2005
2000
1995
1990
1985
1980

AIM & OBJECTIVE

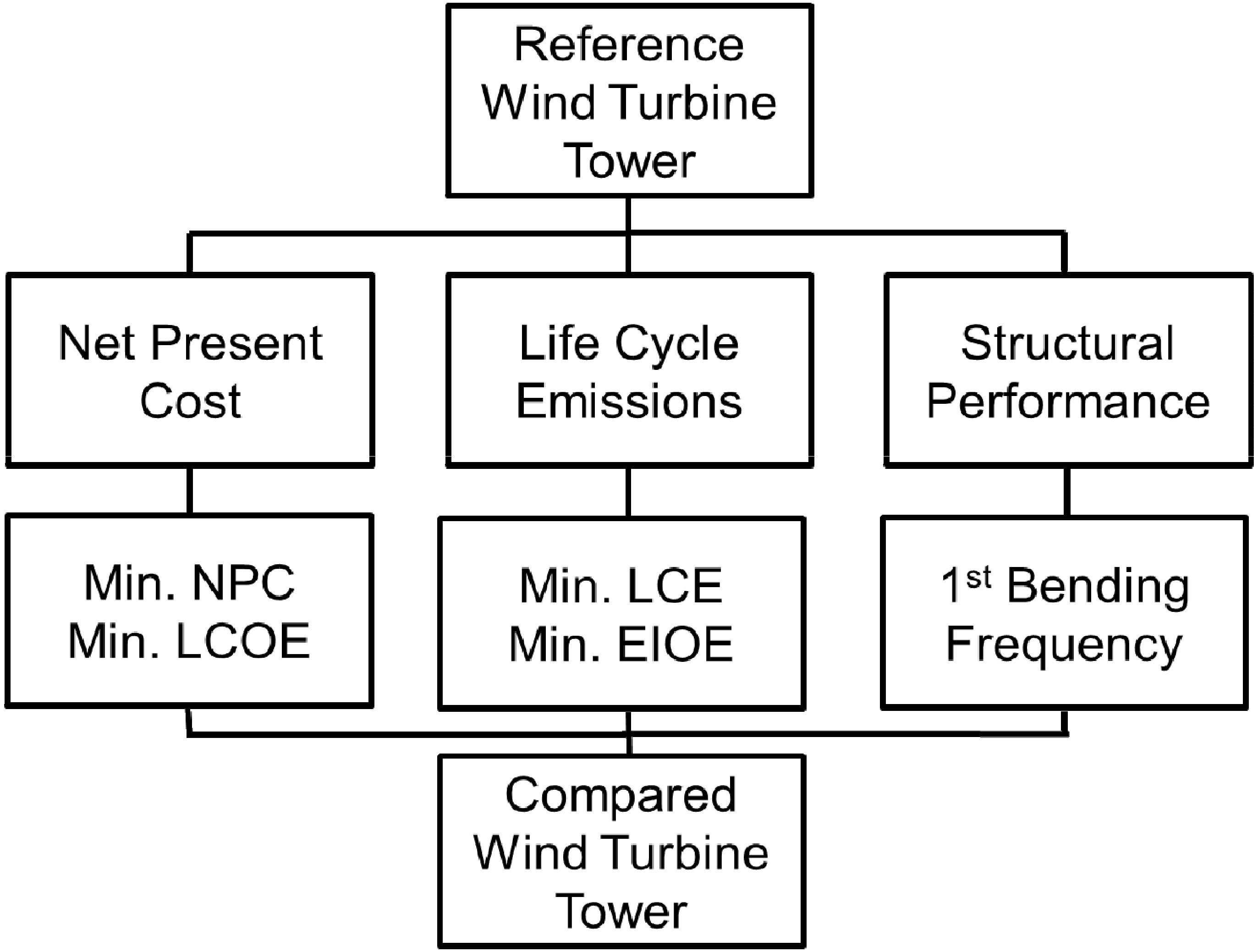
- Concrete WTTs vs. Steel WTTs
  - Economic
  - Environmental
  - Structural Performance
- Identify a WTT solution



vs.



METHODOLOGY



dublin energy lab.

METHODOLOGY

	Steel		Concrete	
Height (m)	126.5	96.55	126.5	96.55
Top Diameter (m)	3.4	3.5	3	3
Top Thickness (m)	0.02	0.01	0.4	0.4
Base Diameter (m)	5.1	4.5	8	8.2
Base Thickness (m)	0.06	0.02	0.6	0.6
Young's Modulus (GPa)	200	200	30	30
Density (Kg/m3)	7,850	7,850	2,400	2,400
Tower Mass (Kg)	625,000	142,000	2,146,000	1,856,000
Wind Turbine Type	Offshore	Onshore	Offshore	Onshore
Wind Turbine Rating (MW)	3.6	2	3.6	2
Average Energy Yield (MWh)	13,000	4,000	13,000	4,000
Wind Turbine Mass (Kg)	1,364,000	80,000	1,364,000	80,000
Location	Arklow Bank, Co.Wicklow, Ireland	Castledockrell, Co.Wexford, Ireland	Arklow Bank, Co.Wicklow, Ireland	Castledockrell, Co.Wexford, Ireland

METHODOLOGY

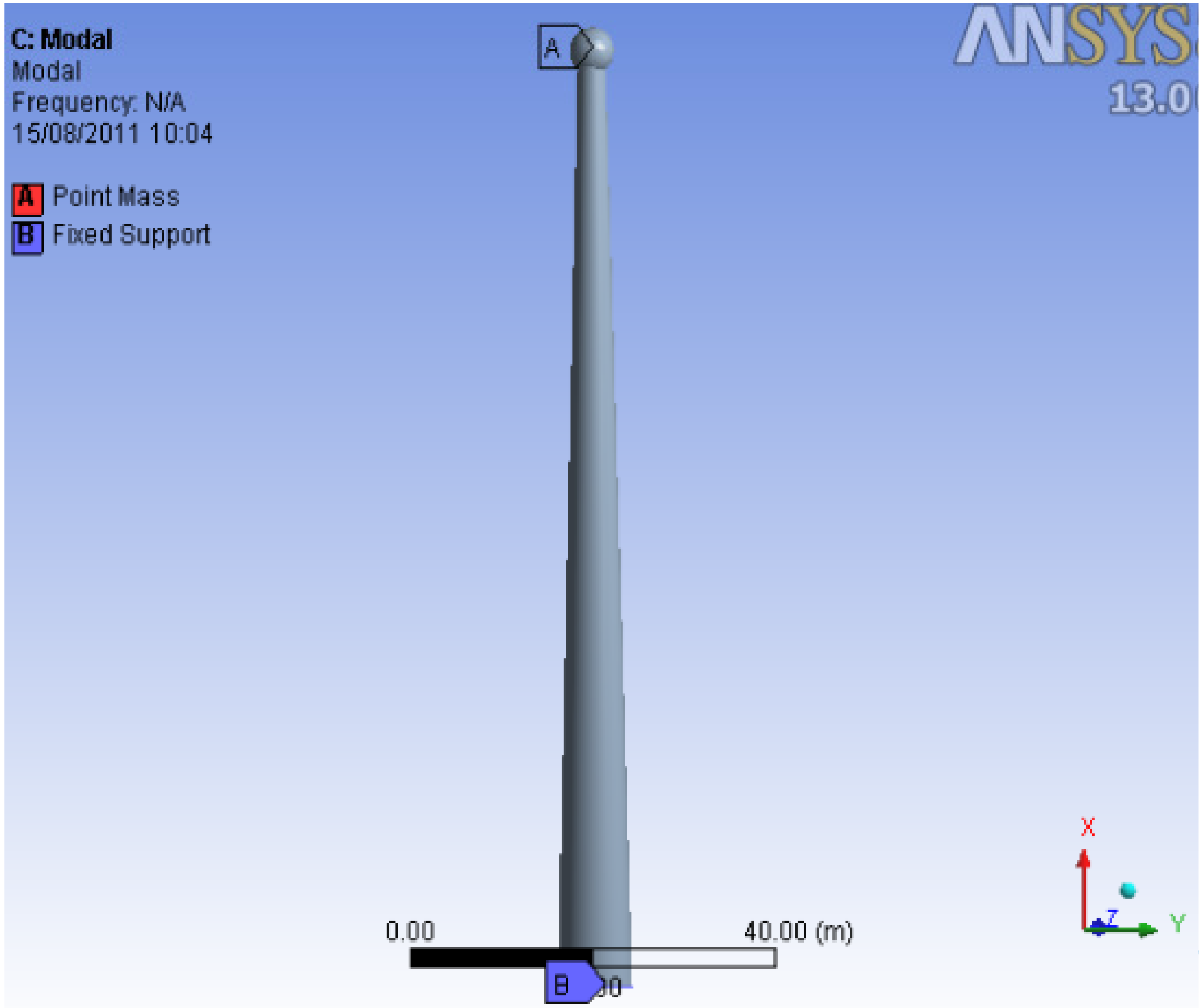
- Life Cycle Cost (LCC)
  - Capital Costs
  - Operation & Maintenance Costs
  - Decommissioning Costs
- Net Present Cost (NPC)
- Levellised Cost of Electricity Production (LCOE)
- Limitations

METHODOLOGY

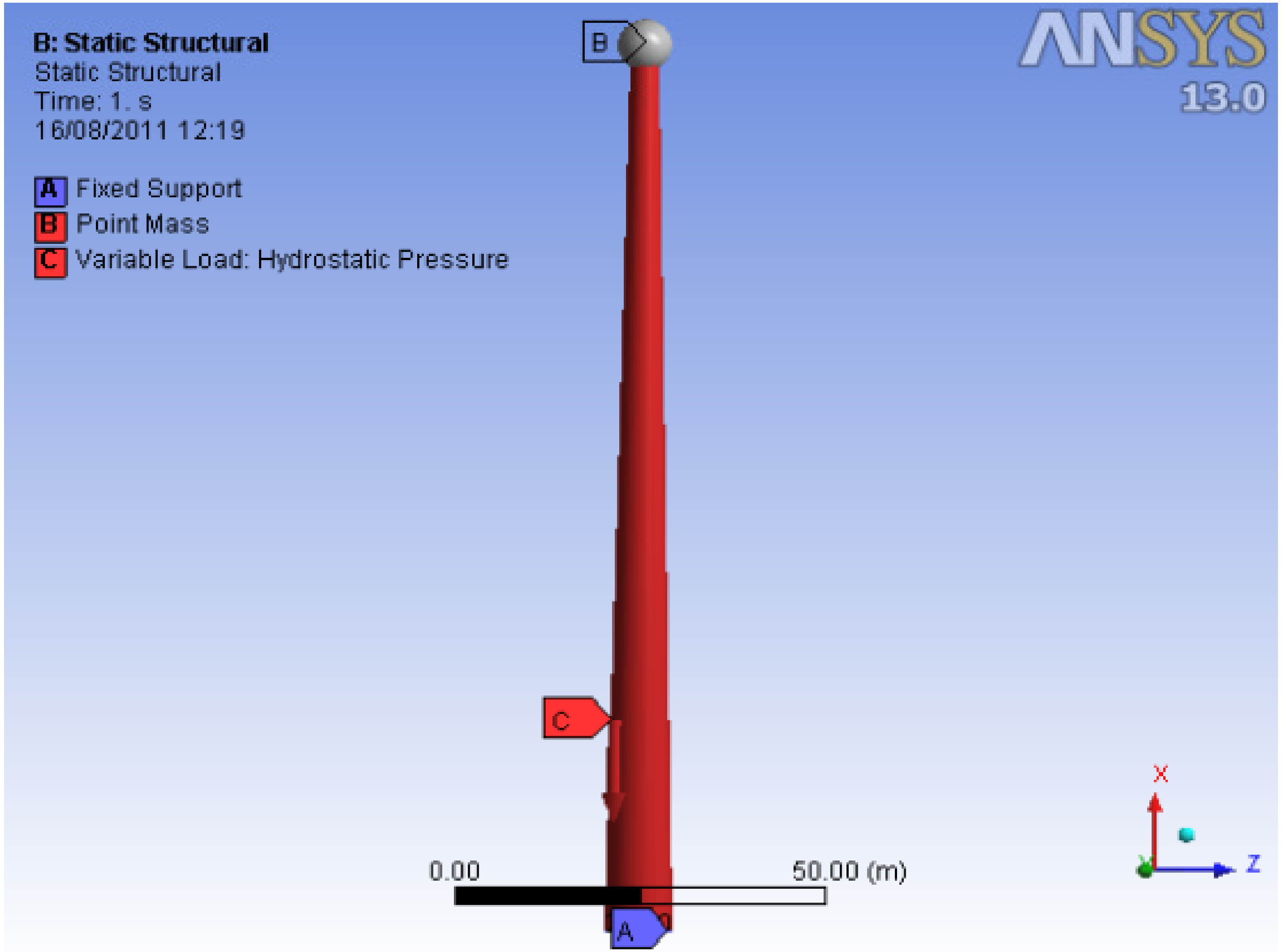
- Emissions Life Cycle Assessment (LCA)
- Hybrid analysis incorporating process & Input-Output (I-O)
- Life Cycle Inventory (LCI)
  - Life cycle stages
  - Breaking components into sub-components
  - Specifying material type and quantity
  - Embodied GHG ($kgCO_{2\text{-}eq}/kg$) intensity factor
  - Life Cycle Emissions (LCE) & Emissions Intensity of Electricity Production (EIOE)

METHODOLOGY

- Basic finite element models developed in ANSYS 13.0



METHODOLOGY

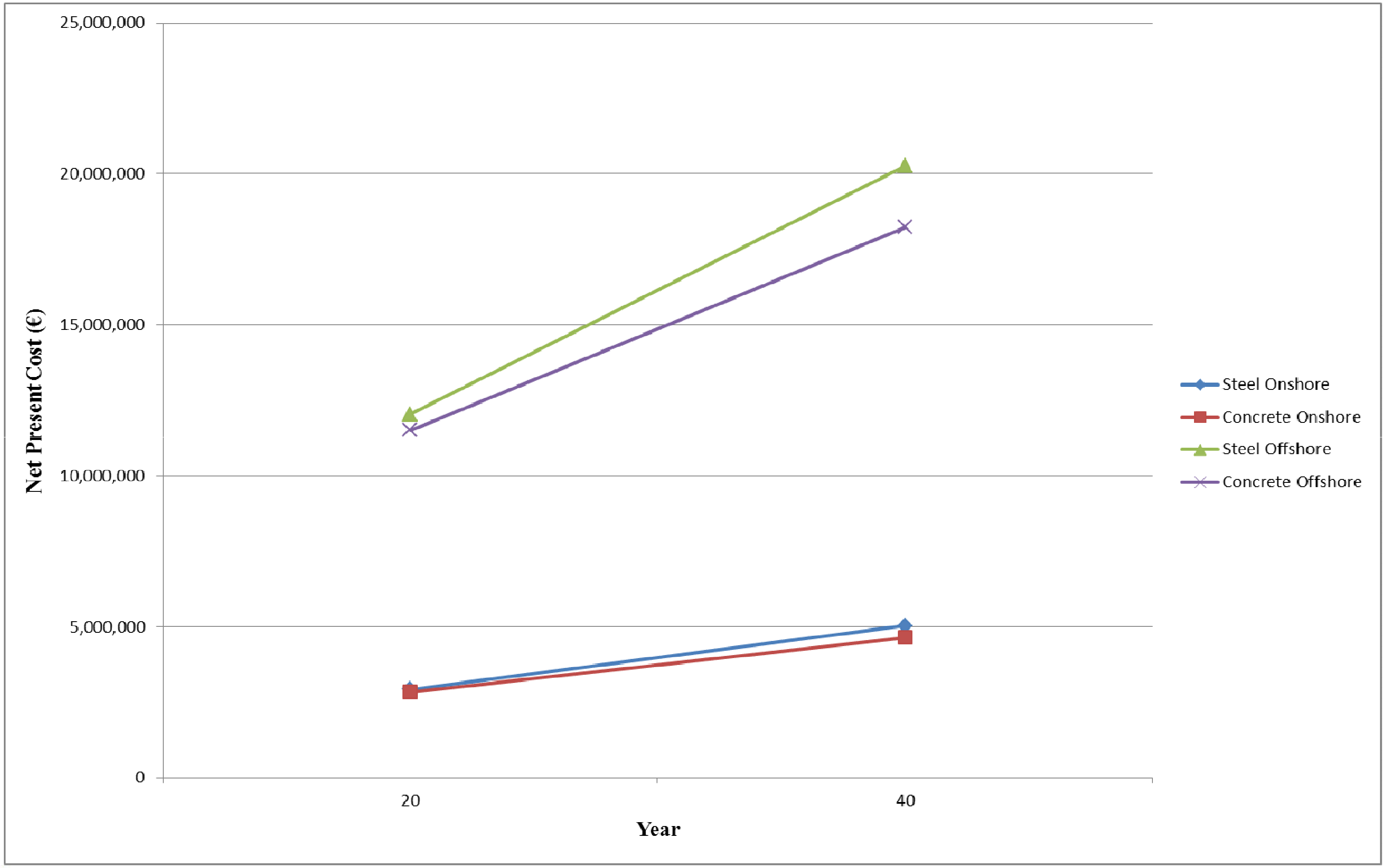


RESULTS TO DATE

- Net present cost (€)

WTT Type	WTT Height (m)	Year	Steel NPC (€)	Concrete NPC (€)	Concrete as a % of Steel
Onshore	96.55	20	2,933,194	2,840,939	97%
Onshore	96.55	40	5,027,148	4,641,886	92%
Offshore	126.5	20	12,044,767	11,504,833	96%
Offshore	126.5	40	20,265,100	18,233,918	90%

RESULTS TO DATE



RESULTS TO DATE

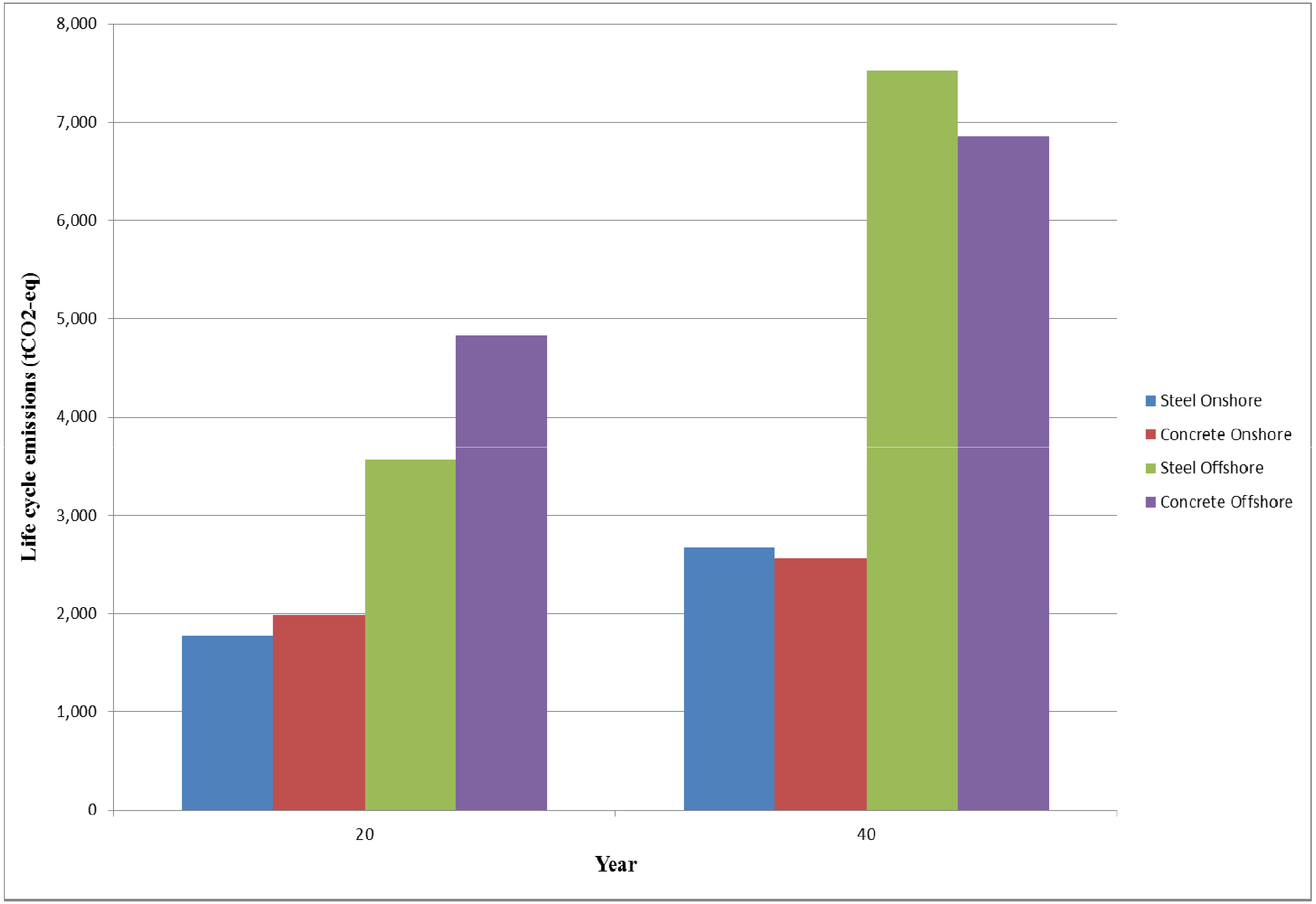
- Levellised cost of electrical production (€c/kWh)

WTT Type	WTT Height (m)	Year	Steel LCOE (€c/kWh)	Concrete LCOE (€c/kWh)	Concrete as a % of Steel
Onshore	96.55	20	7.2	7.0	97%
Onshore	96.55	40	6.2	5.7	92%
Offshore	126.5	20	9.1	8.7	96%
Offshore	126.5	40	7.6	6.9	90%

- Life cycle emissions ($tCO_{2\text{-}eq}$)

WTT Type	WTT Height (m)	Year	Steel Emissions (tCO2-eq)	Concrete Emissions (tCO2-eq)	Concrete as a % of Steel
Onshore	96.55	20	1,779	1,984	112%
Onshore	96.55	40	2,671	2,565	96%
Offshore	126.5	20	3,568	4,829	135%
Offshore	126.5	40	7,523	6,858	91%

RESULTS TO DATE



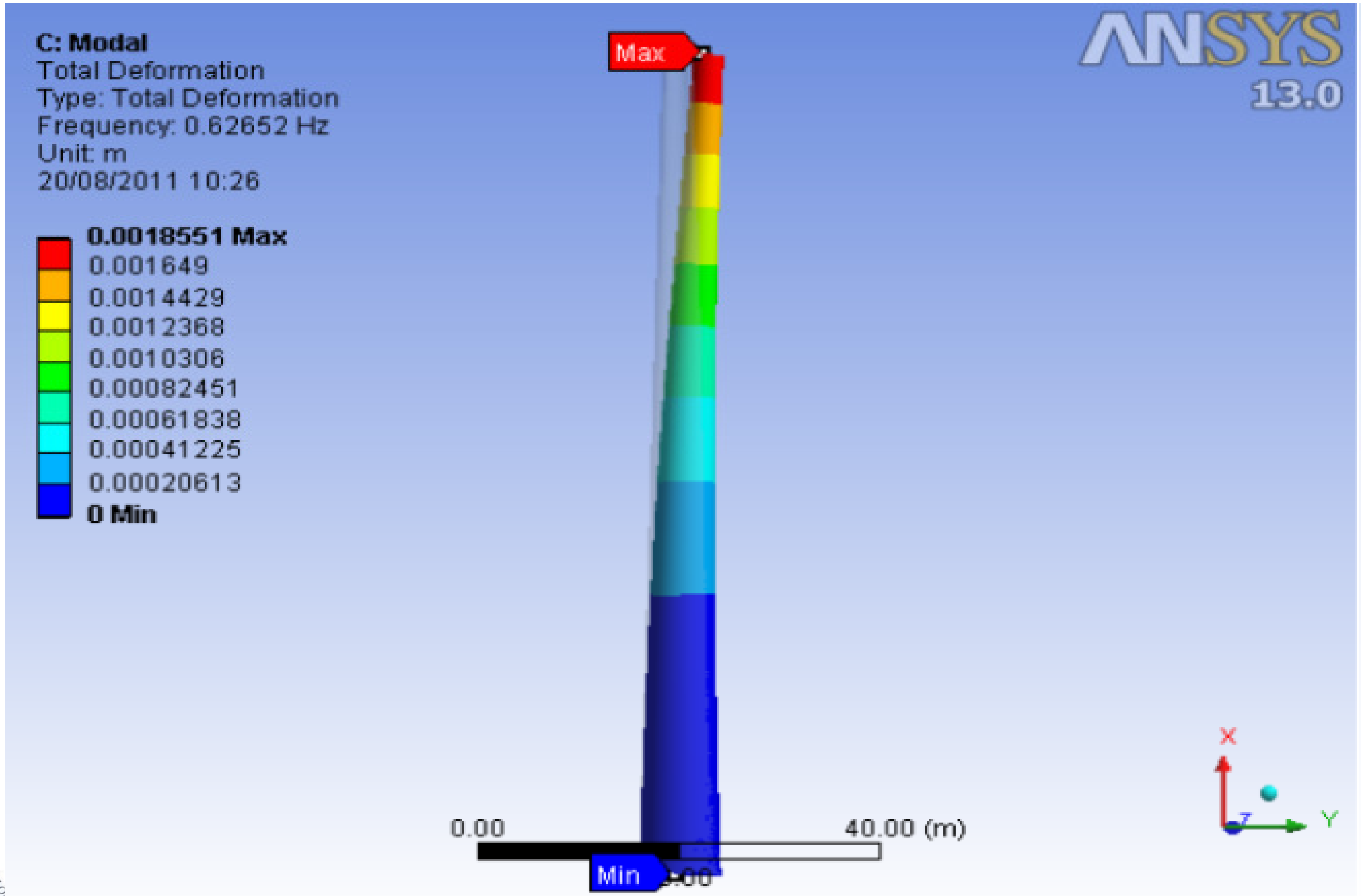
RESULTS TO DATE

- Effect of % of GGBS addition on the concrete WTT emissions

WTT Type	WTT Height (m)	GGBS (%)	Concrete Emissions ($tCO_{2\text{-}eq}$)	Emissions % decrease
Onshore	96.55	0 (using CEM 1)	1,984	0%
Onshore	96.55	50	1,805	9%
Onshore	96.55	70	1,706	14%
Offshore	126.5	0 (using CEM 1)	4,829	0%
Offshore	126.5	50	4,394	9%
Offshore	126.5	70	4,249	12%

RESULTS TO DATE

- Max & min total deformation for onshore concrete WTT



RESULTS TO DATE

WTT Type	WTT Height (m)	Max Total Deformation (m)		
		Steel	Concrete	Concrete as % of Steel
Onshore	96.55	0.00340	0.00186	55%
Offshore	126.5	0.00254	0.00143	56%

WTT Type	WTT Height (m)	1st Natural Bending Frequency Range (Hz)	
		Steel	Concrete
Onshore	96.55	0.121	0.632
Offshore	126.5	0.116	0.405

WTT Type	WTT Height (m)	Steel	Concrete
Onshore	96.55	Soft-Soft	Soft
Offshore	126.5	Soft-Soft	Soft

CONCLUSIONS

- At year 40, the LCOE results showed cost savings of 8-10% for concrete WTTs relative to steel WTTs for both facilities
- At year 40, LCE are 4% and 9% lower for concrete WTTs for both onshore and offshore facilities respectively
- Reduction in LCE and increase in durability with GGBS
- Total deformation for concrete WTT outperforms the steel WTT by 45% for both facilities
- Concrete WTTs provide an alternative to steel WTTs for larger wind turbines

WORK TO BE DONE

- Develop industry contacts in order to obtain information and data for incorporation into models
- Develop a life cycle multi criteria optimisation model in order to determine an optimal WTT design
- Currently writing a paper for a journal based on research to date
- Attend conferences in 2012
- Possible collaboration with the IEA on Task 26

QUESTIONS