O&M Forward… The Digital Turbine Lifecycle

Kent Dawson, Ph.D.
Director, Business Development
AKSELOS

Organized by FWE Quest Offshore

Technology required to reduce offshore wind LCOE

eia Independent Statistics & Analysis
U.S. Energy Information Administration

February 2021

Levelized Costs of New Generation Resources in the *Annual Energy Outlook 2021*

Table 1b. Estimated unweighted levelized cost of electricity (LCOE) and levelized cost of storage (LCOS) for new resources entering service in 2026 (2020 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[1]	Levelized variable cost	Levelized transmis-sion cost	Total system LCOE or LCOS	Levelized tax credit[2]	Total LCOE or LCOS including tax credit
Dispatchable technologies								
Ultra-supercritical coal	85%	$43.80	$5.48	$22.48	$1.03	$72.78	*NA*	$72.78
Combined cycle	87%	$7.78	$1.61	$26.68	$1.04	$37.11	*NA*	$37.11
Combustion turbine	10%	$45.41	$8.03	$44.13	$9.05	$106.62	*NA*	$106.62
Advanced nuclear	90%	$50.51	$15.51	$2.38	$0.99	$69.39	-$6.29	$63.10
Geothermal	90%	$19.03	$14.92	$1.17	$1.28	$36.40	-$1.90	$34.49
Biomass	83%	$34.96	$17.38	$35.78	$1.09	$89.21	*NA*	$89.21
Battery storage	10%	$57.98	$28.48	$23.85	$9.53	$119.84	*NA*	$119.84
Non-dispatchable technologies								
Wind, onshore	41%	$27.01	$7.47	$0.00	$2.44	$36.93	*NA*	$36.93
Wind, offshore	44%	$89.20	$28.96	$0.00	$2.35	$120.52	*NA*	$120.52
Solar, standalone[3]	29%	$23.52	$6.07	$0.00	$3.19	$32.78	-$2.35	$30.43
Solar, hybrid[3, 4]	28%	$31.13	$13.25	$0.00	$3.29	$47.67	-$3.11	$44.56
Hydroelectric[4]	55%	$38.62	$11.23	$3.58	$1.84	$55.26	*NA*	$55.26

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2021*

[1]O&M = operations and maintenance

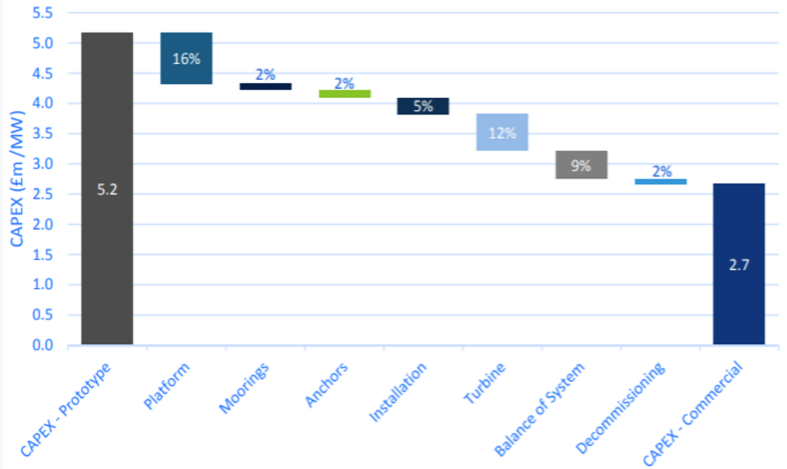
[2]The tax credit component is based on targeted federal tax credits such as the production tax credit (PTC) or investment tax credit (ITC) available for some technologies. It reflects tax credits available only for plants entering service in 2026 and the substantial phaseout of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as *NA*, or *not available*. The results are based on a regional model, and state or local incentives are not included in LCOE and LCOS calculations. See text box on page 2 for details on how the tax credits are represented in the model.

[3]Technology is assumed to be photovoltaic (PV) with single-axis tracking. The solar hybrid system is a single-axis PV system coupled with a four-hour battery storage system. Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

[4]As modeled, EIA assumes that hydroelectric and hybrid solar PV generating assets have seasonal and diurnal storage, respectively, so that they can be dispatched within a season or a day, but overall operation is limited by resource availablility by site and season for hydroelectric and by daytime for hybrid solar PV.

CARBON TRUST
FLOATING OFFSHORE WIND: MARKET AND TECHNOLOGY REVIEW

Figure 3.5.6. Cost reduction from prototype to commercial scale



> "The greatest potential for cost reduction is seen in reducing platform size [...] Reducing the size and weight of the floating platform represents an obvious area where CAPEX savings can be achieved by reducing the steel content and complexity of the structure"

25% REDUCTION IN PROJECT CAPEX DERIVED FROM THE FLOATING FOUNDATION OPTIMISATIONS ARE REALISTIC

THERE IS NO SILVER BULLET…

The world's infrastructure was, and will be designed using Finite Element Analysis

FEA is a way to use a computer representation of a physical phenomena and replaces the need for physical testing.

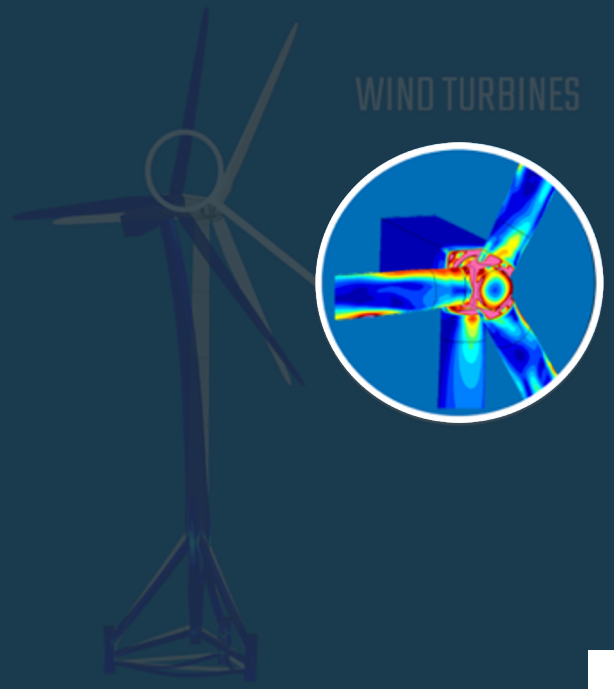
FEA IS THE BACKBONE OF THE MECHANICAL WORLD

INVESTING IN NEW INFRASTRUCTURE

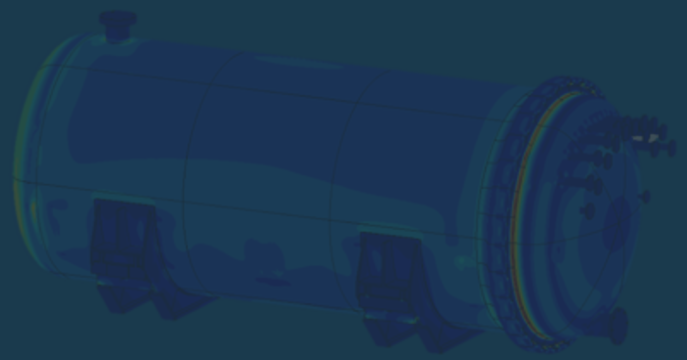
INVESTIGATING EXISTING INFRASTRUCTURE

FEA USED BY 99 OF FORTUNE 100 COMPANIES

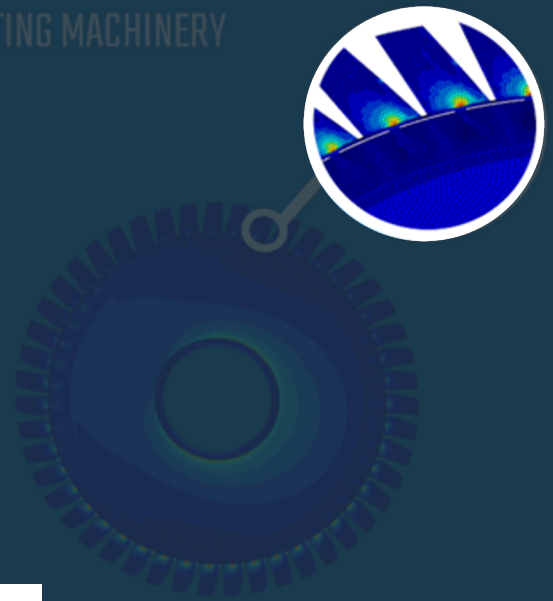
WIND TURBINES



PRESSURE VESSELS

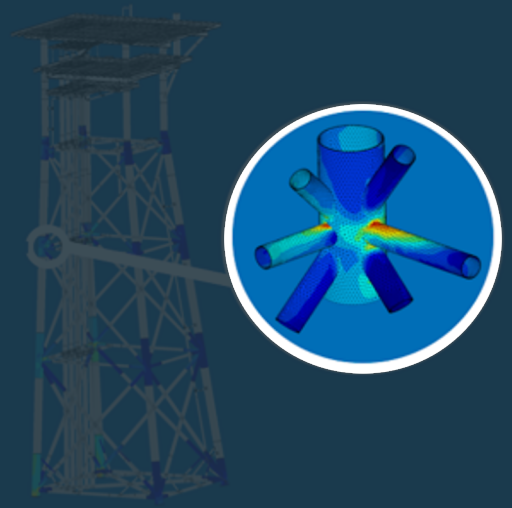


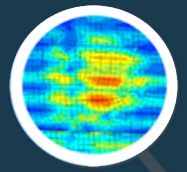
ROTATING MACHINERY



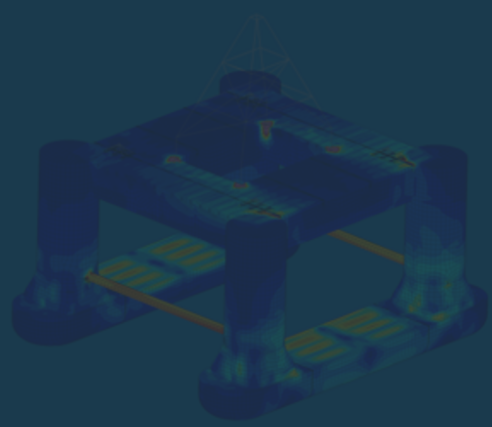
TODAY: LOCAL MODELS & SLOW COMPUTATION

FIXED STRUCTURES

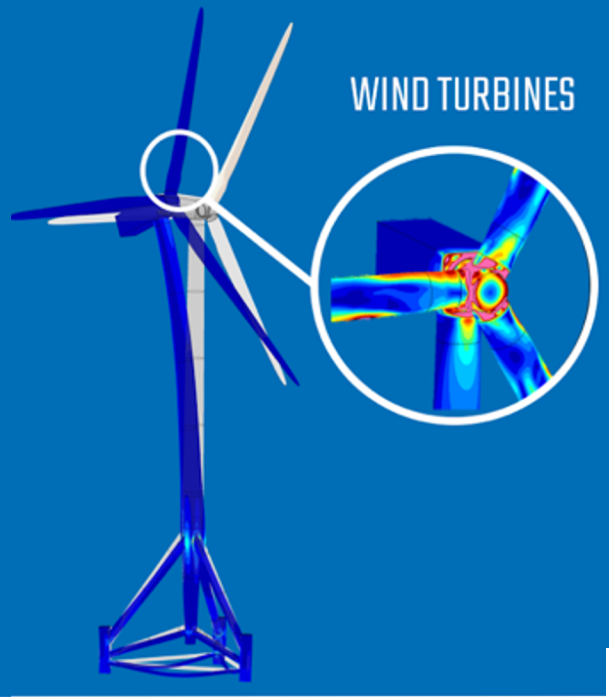




FLOATING STUCTURES



WIND TURBINES



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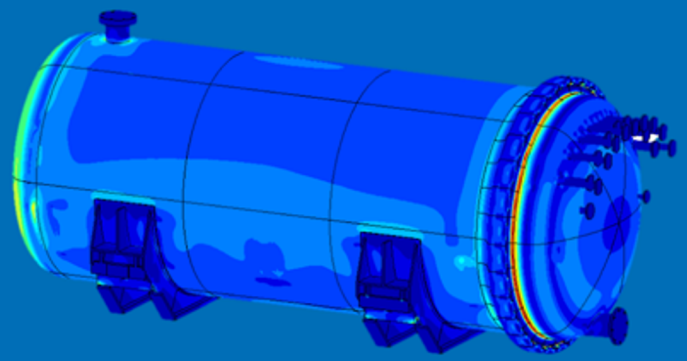

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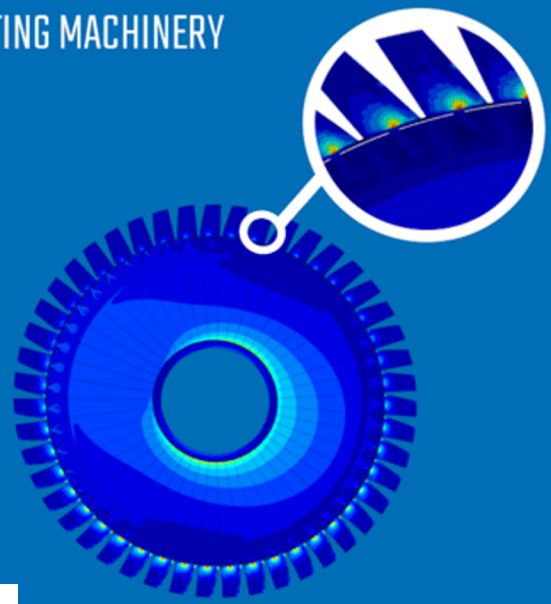
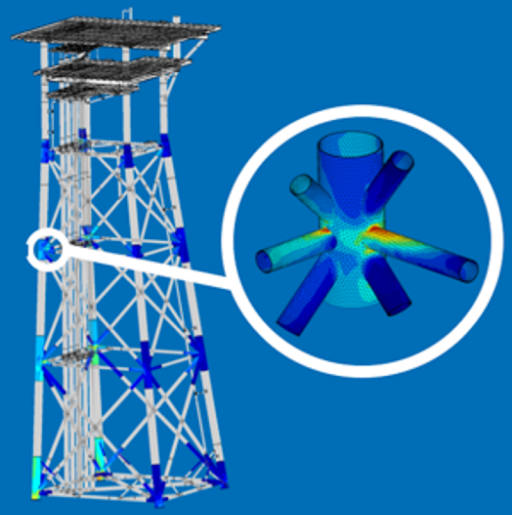
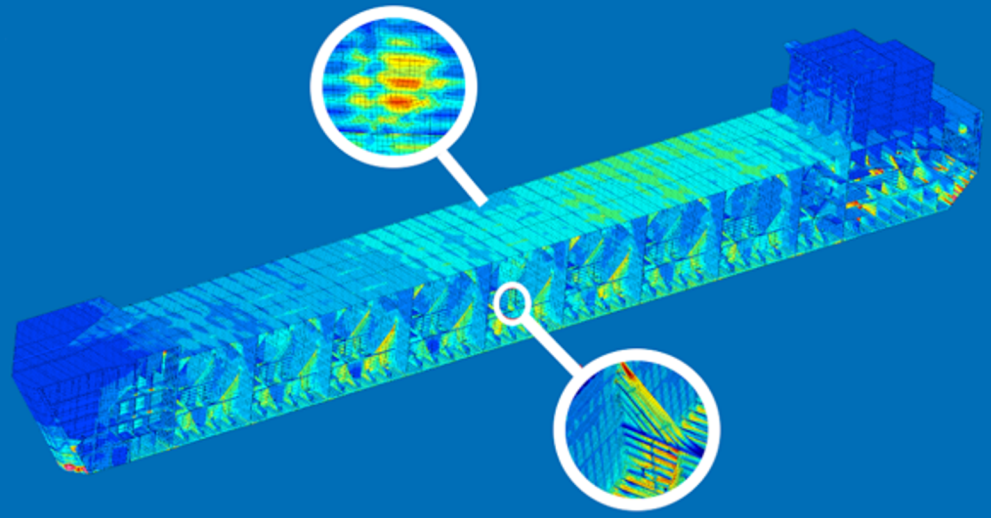


TO: LIVE HOLISTIC MODELS

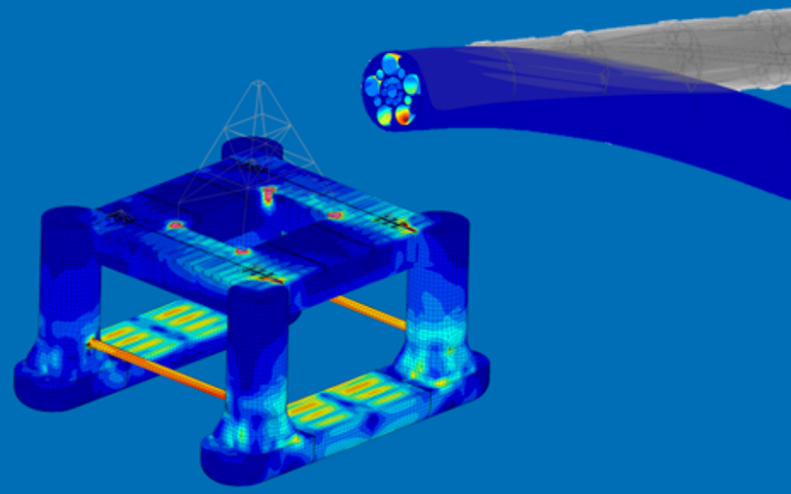
FIXED STRUCTURES

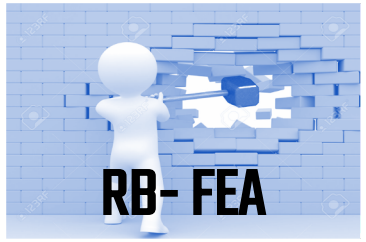


FLOATING STUCTURES



RISER/UMBILICALS





RB-FEA: Next Generation FEA with Revolutionary Results

AKSELOS RB-FEA

2 unique technology advantages

SPEED

RUN 1,000x FASTER

SCALE

Component based approach enables modelling huge complexities

CONDITION MONITORING

Lightning FAST "WHAT-IF"

IOT 4.0 CONNECTIVITY

SENSOR INTEGRATION

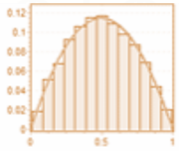
Floating Wind *Solutions*

THE DIGITAL TURBINE LIFECYCLE... BRING O&M TOOLS FORWARD TO DESIGN

DESIGN

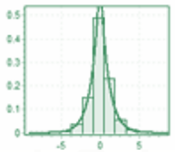
FROM: Long and **siloed** concept design limited by software, leading to **conservative designs**

WIDE RANGE



TO: Hundreds of designs assessed at system level. Finding optimal designs based on site specific conditions.

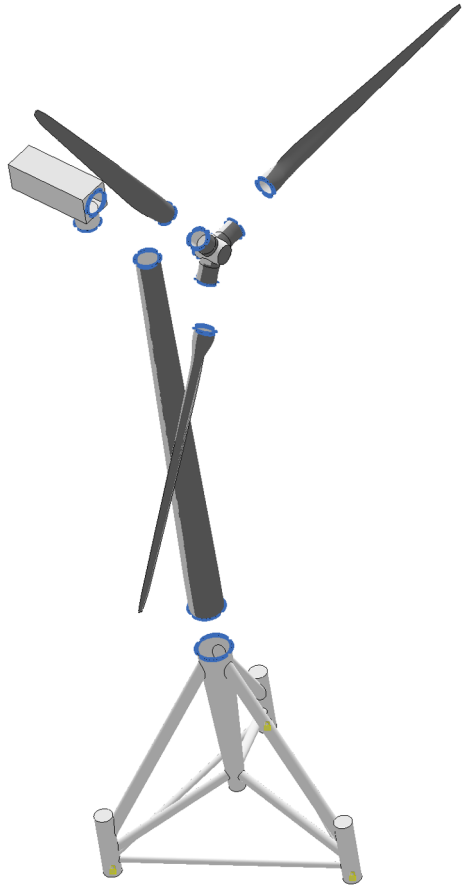
PRECISE RANGE

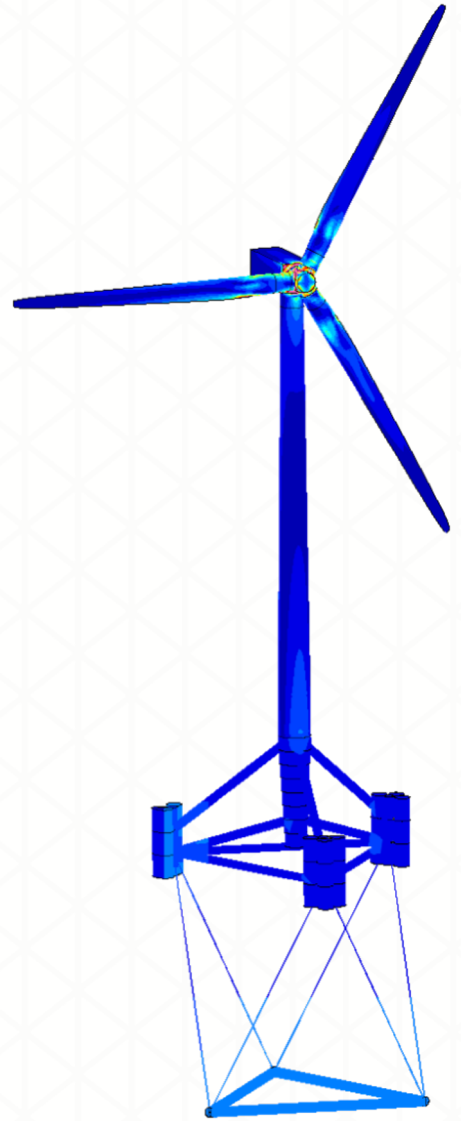


20-30% IN CAPEX

IMPACT: Targeting 30% CAPEX for Wind

ACHIEVED: 30% Steel reduction in jacket foundations





Floating Wind *Solutions*

THE DIGITAL TURBINE LIFECYCLE… BRING O&M TOOLS FORWARD TO DESIGN

DESIGN

FROM: Long and **siloed** concept design limited by software, leading to **conservative designs**

WIDE RANGE

TO: Hundreds of designs assessed at system level. Finding optimal designs based on site specific conditions.

PRECISE RANGE

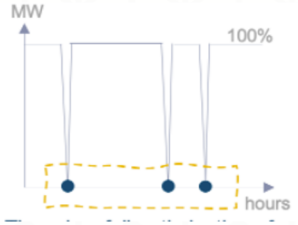
20-30% IN CAPEX

IMPACT: Targeting 30% CAPEX for Wind

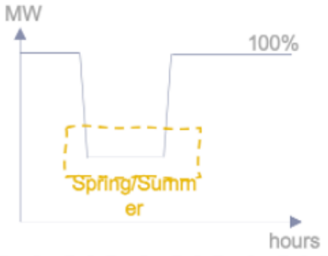
ACHIEVED: 30% Steel reduction in jacket foundations

OPERATIONS/LIFE EXTENSION

FROM: Siloed O&M based on design assumptions, component level failure rates, and **time-based maintenance**



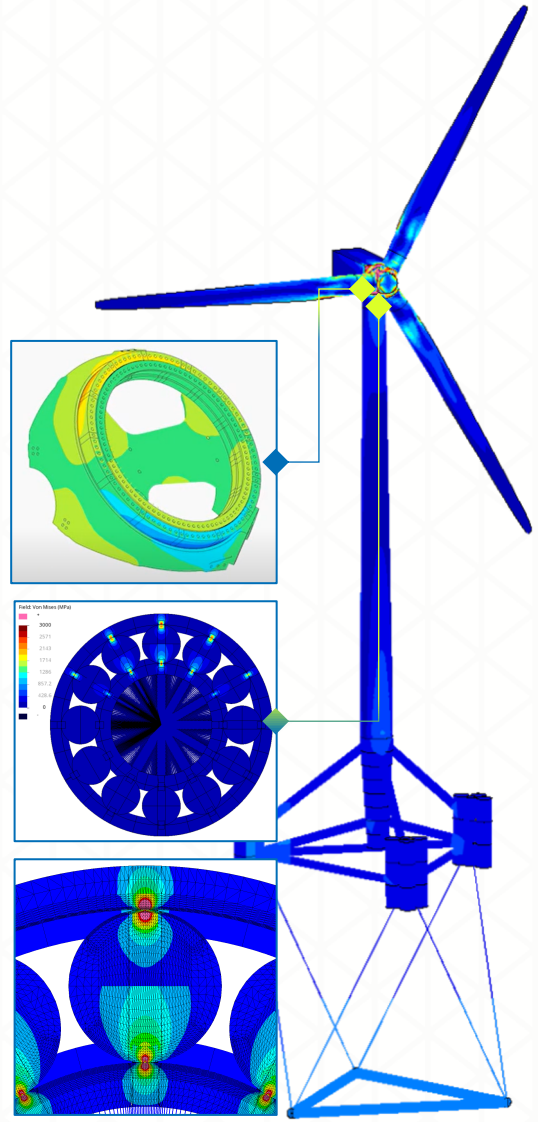
TO: Fully integrated, real-time system level structural **health monitoring based on as built, as is, and live sensor data.**



10-25% IN OPEX

IMPACT: Targeting 25% OPEX reduction

ACHIEVED: - 6 month O&M workflow reduced to 48 hrs
25 year life extension

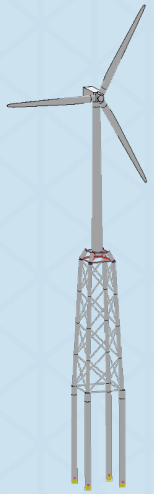


COMPLETE AND AUTOMATED O&M WORKFLOW

OPERATIONS

DESIGN MODEL

DIGITAL TWIN MODEL



AS BUILT DATA

SENSOR DATA

What is the **condition** of the WTG **right now**? What is the accumulated fatigue?

INSPECTION DATA

WIND AND WAVE DATA

INDIVIDUAL TURBINE CONDITION BASED DIGITAL TWIN

ELECTRICITY PRICE

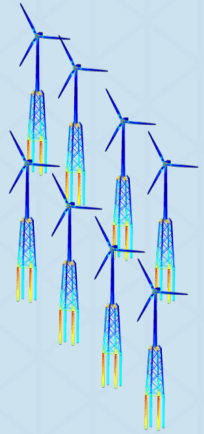
TURBINE GENERATION

How to run the turbine and perform maintenance to generate most revenue

WEATHER DATA

TURBINE ACCESS

FLEET LEVEL HOLISTIC REVENUE BASED O&M



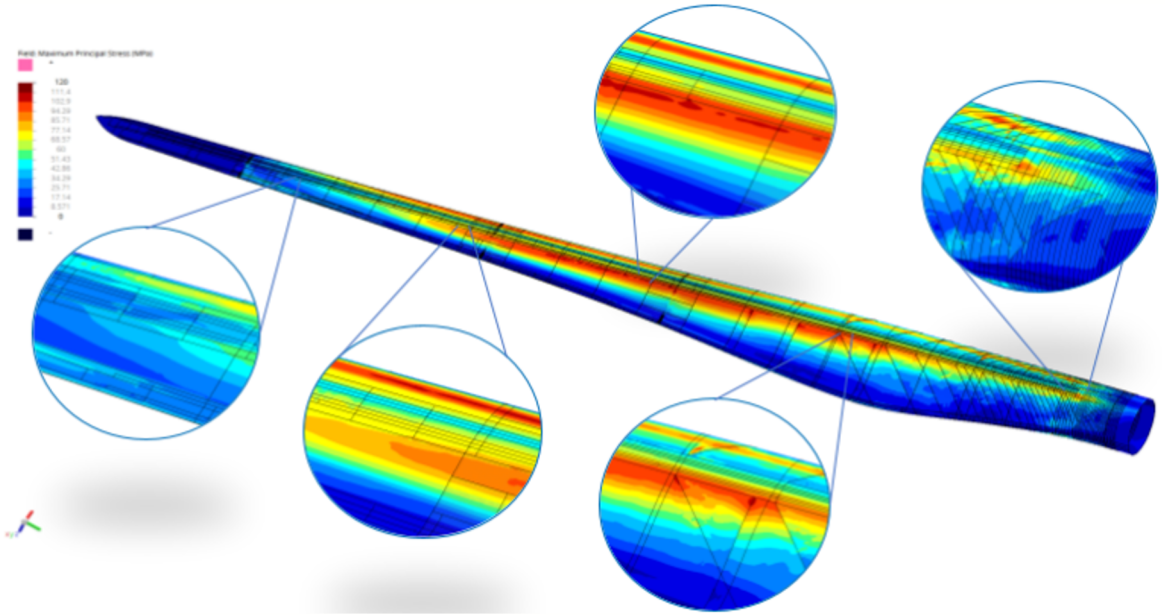
What are assets worth today? What is the remaining fatigue life of each turbine?

Ensuring assets are generating optimally

FATIGUE ANALYSIS

100 MM DOF

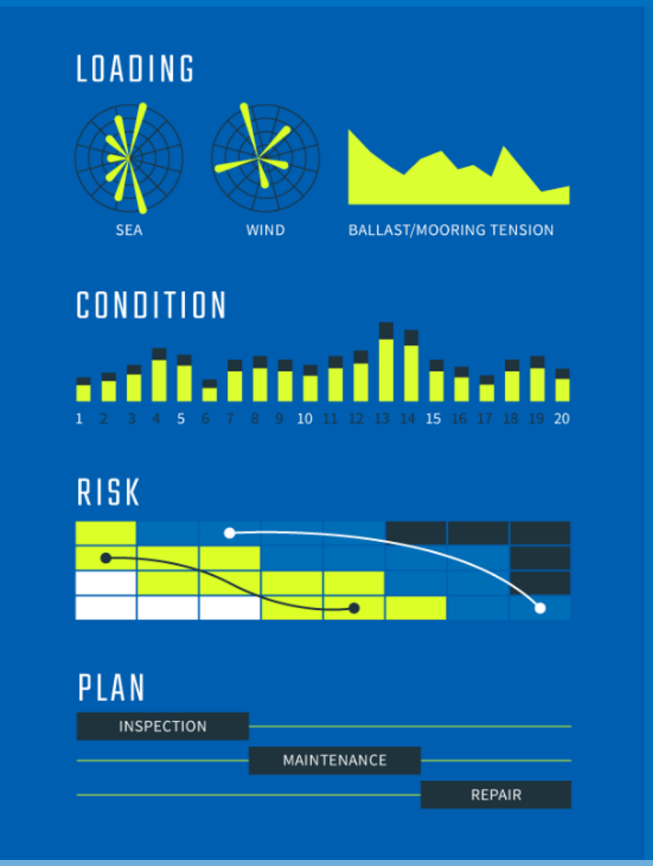
1000 SOLVES

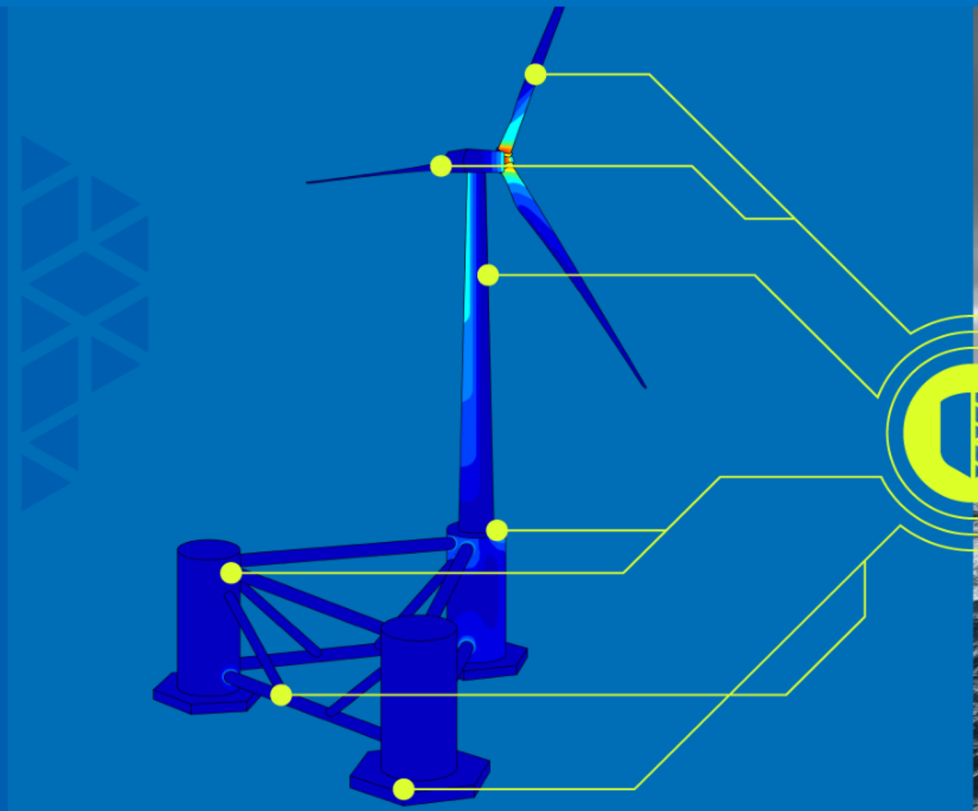


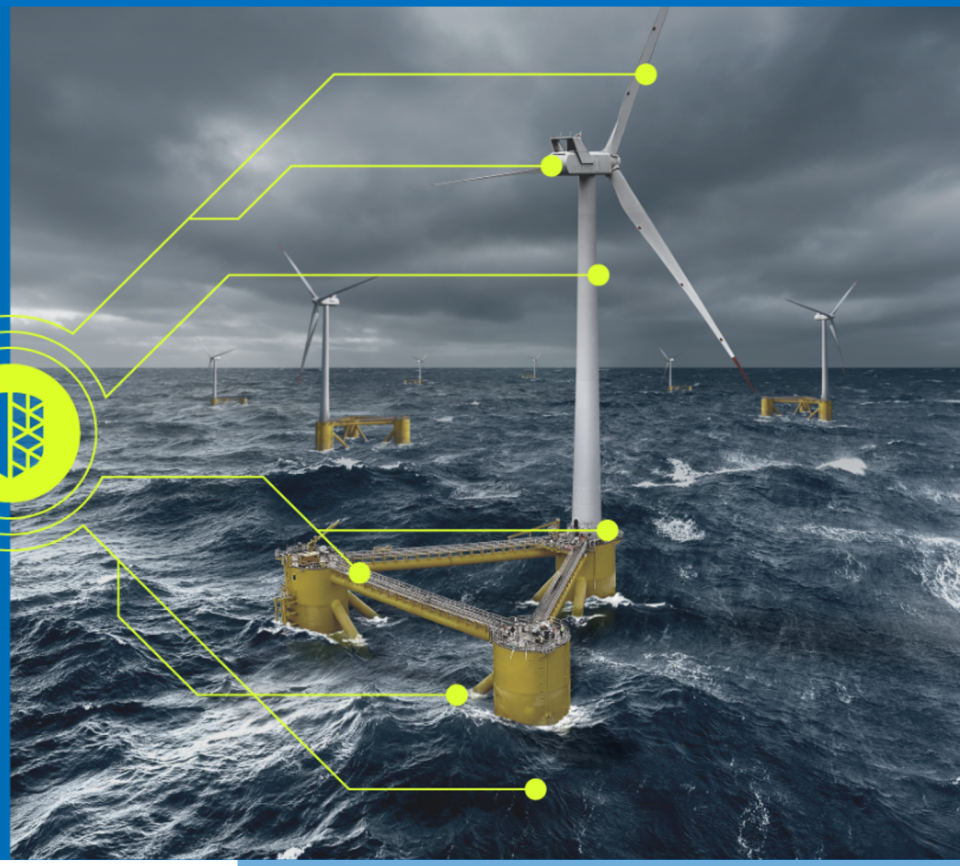
FEA SOLVE	> 4 DAYS
AKSELOS SOLVE	15 SECONDS

ATLANTIS DIGIFLOAT PROJECT

High-fidelity Digital Twins Of a Floating Offshore Wind Farm







PRINCIPLE POWER

ABS

arpa·e
CHANGING WHAT'S POSSIBLE

edp renewables

AKSELOS

Our Technology

Design Optimization

Conditional Monitoring

Life Extension

Questions:

kent.dawson@akselos.com