Global Mapping of Maintenance Strategies with Quantification of Key Performance Indicators

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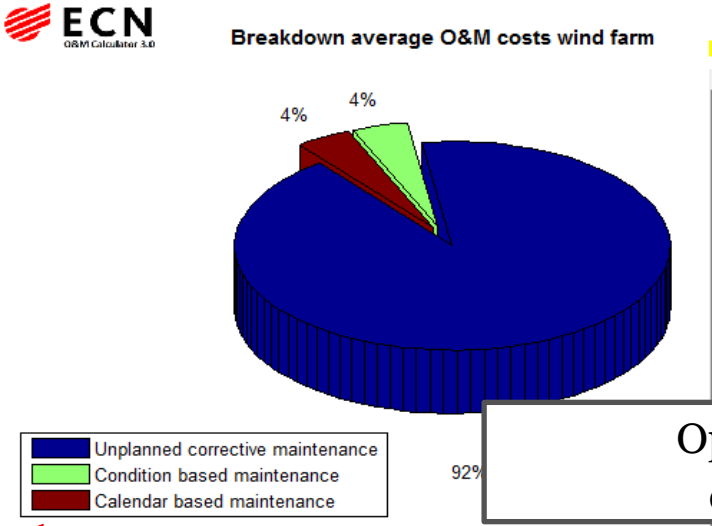
London, June 6 - 8th

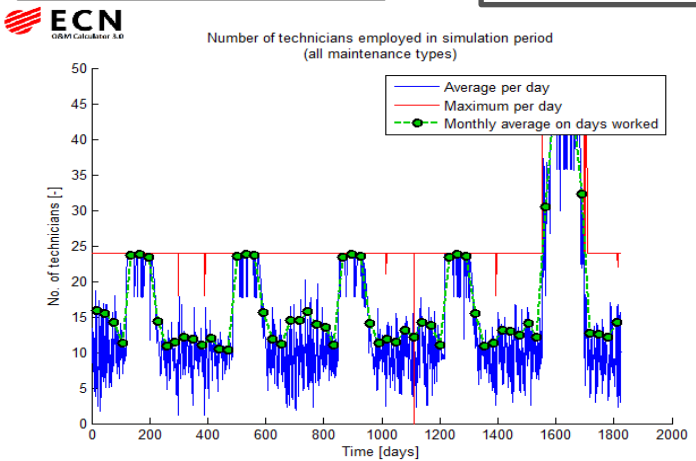
Offshore Wind Energy 2017

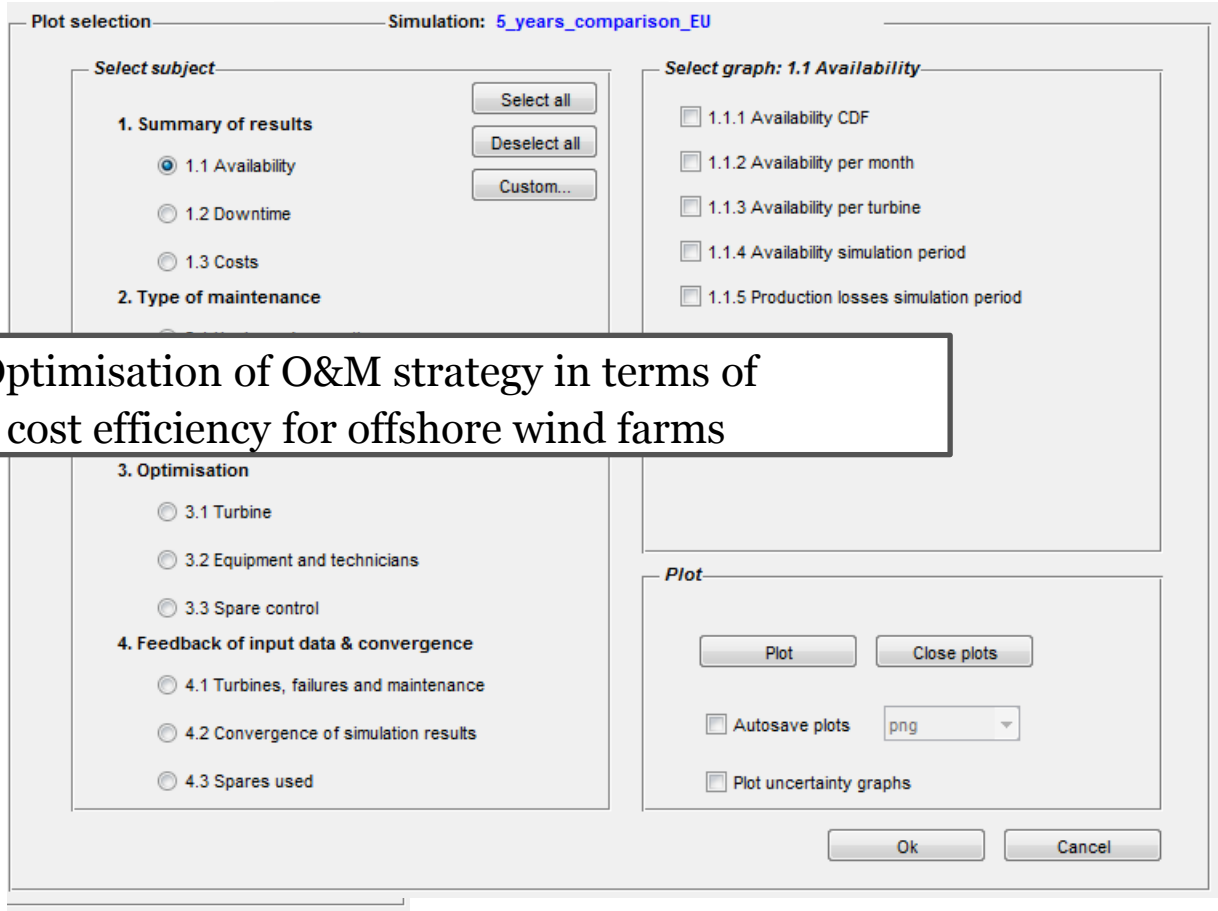
Leaders in O&M Modelling for offshore wind

ECN O&M Calculator



Optimisation of O&M strategy in terms of cost efficiency for offshore wind farms





5 Wind Farms in Europe

Hywind

400 MW (50x 8 MW)

20 km / 200 m depth

Horns Rev 3

400 MW (100 x 4 MW)

30 km / 20-25 m depth

Dogger Bank

800 MW (200 x 4 MW)

150 km / 30-35 m depth

Bard

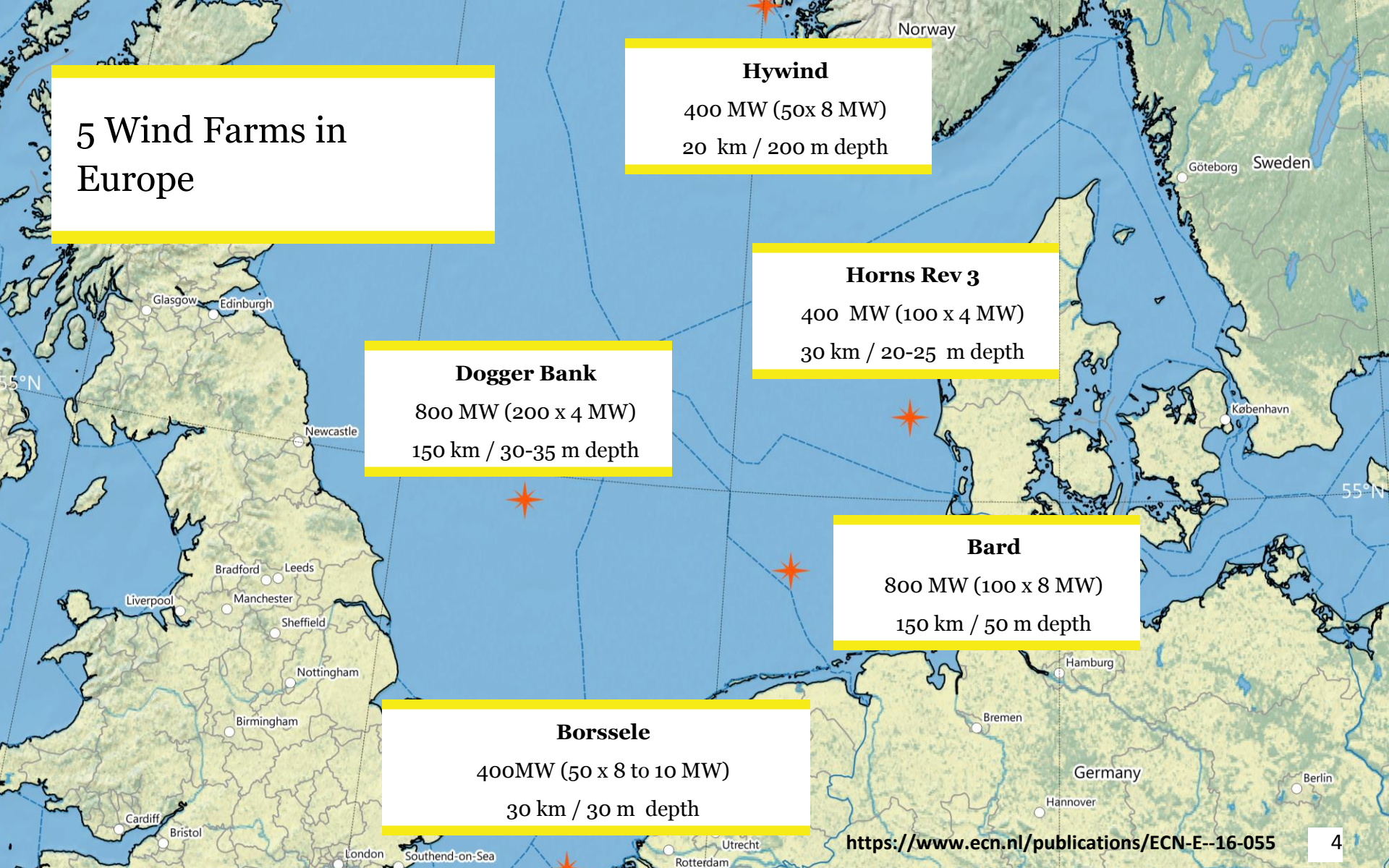
800 MW (100 x 8 MW)

150 km / 50 m depth

Borssele

400MW (50 x 8 to 10 MW)

30 km / 30 m depth



6 Wind Farms in United States

Lake Erie

345 MW (100 x 3.45 MW)

30 km / 30 m depth

New York

600 MW (100 x 6MW)

70km / 30 m depth

In collaboration with:

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Channel Island North

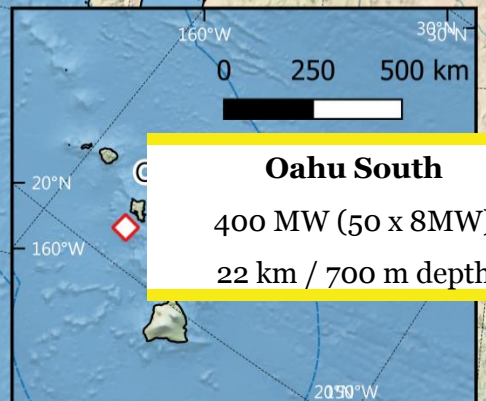
600 MW (75 x 8MW)

127 km / 575 m depth

Kitty Hawk

600 MW (100 x 6MW)

143 km / 30 m depth



Oahu South

400 MW (50 x 8MW)

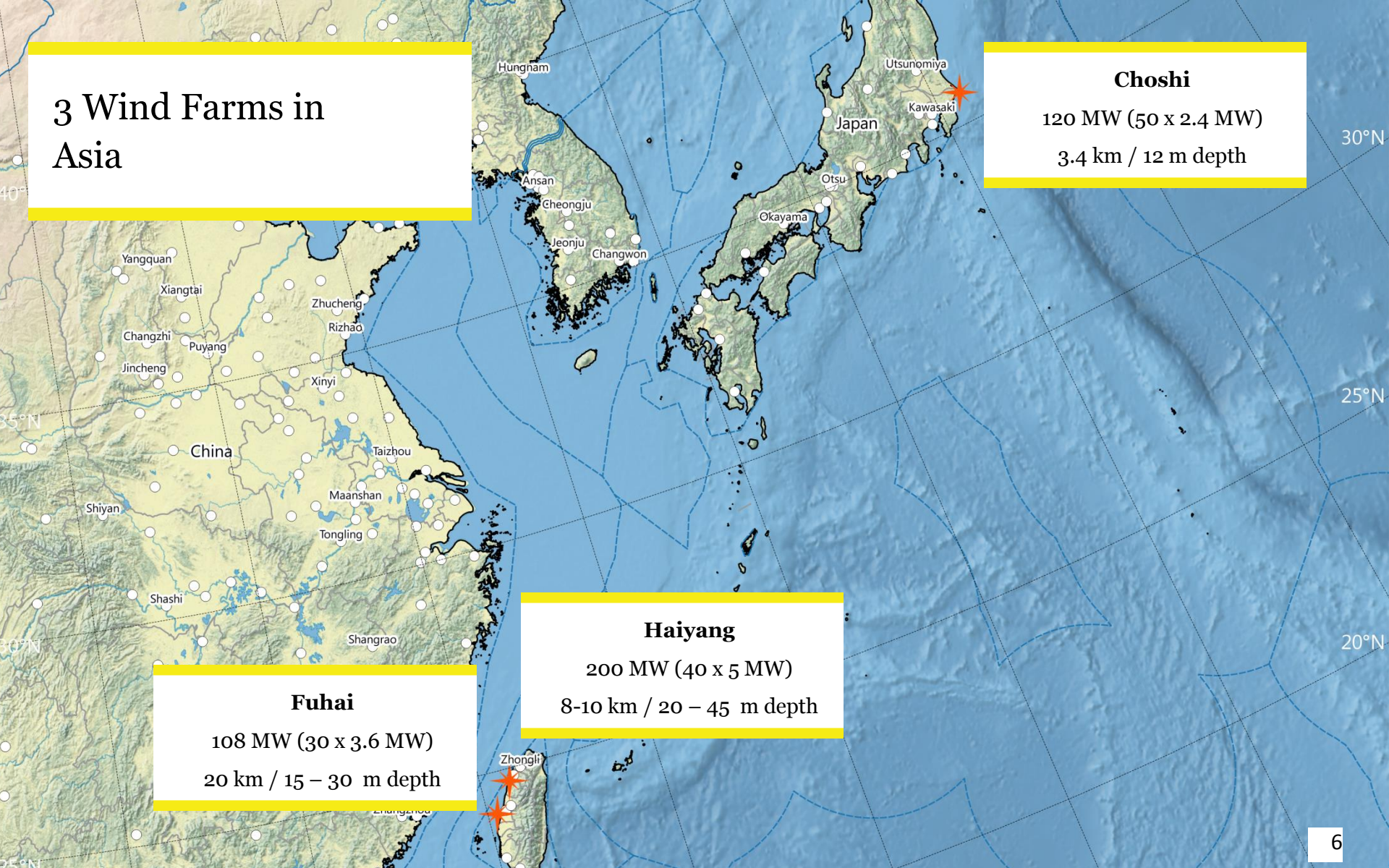
22 km / 700 m depth

Corpus Christi

600 MW (100 x 6MW)

102 km / 30 m depth

3 Wind Farms in Asia



Choshi

120 MW (50 x 2.4 MW)

3.4 km / 12 m depth

Haiyang

200 MW (40 x 5 MW)

8-10 km / 20 – 45 m depth

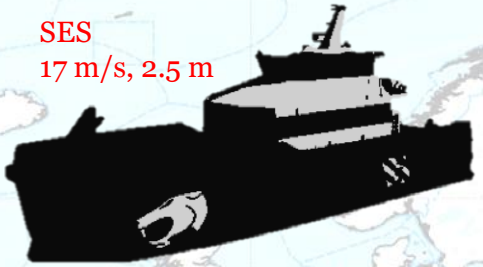
Fuhai

108 MW (30 x 3.6 MW)

20 km / 15 – 30 m depth

CTV
12 m/s, 1.5 m

CTV+
15 m/s, 2.0 m

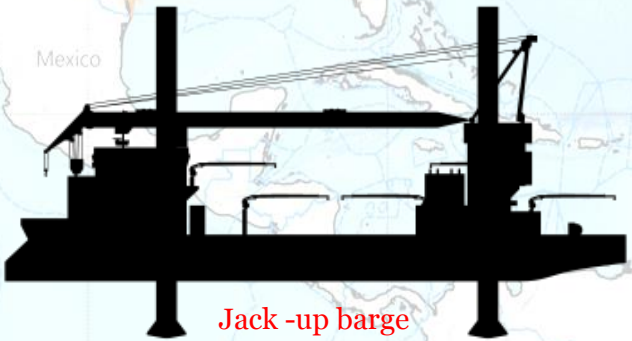


SES
17 m/s, 2.5 m

SOV
20 m/s, 3.0 m

Daughter craft
10 m/s, 1.0 m

Helicopter
20 m/s, 4.0 m



Jack -up barge
10 m/s, 2.0 m

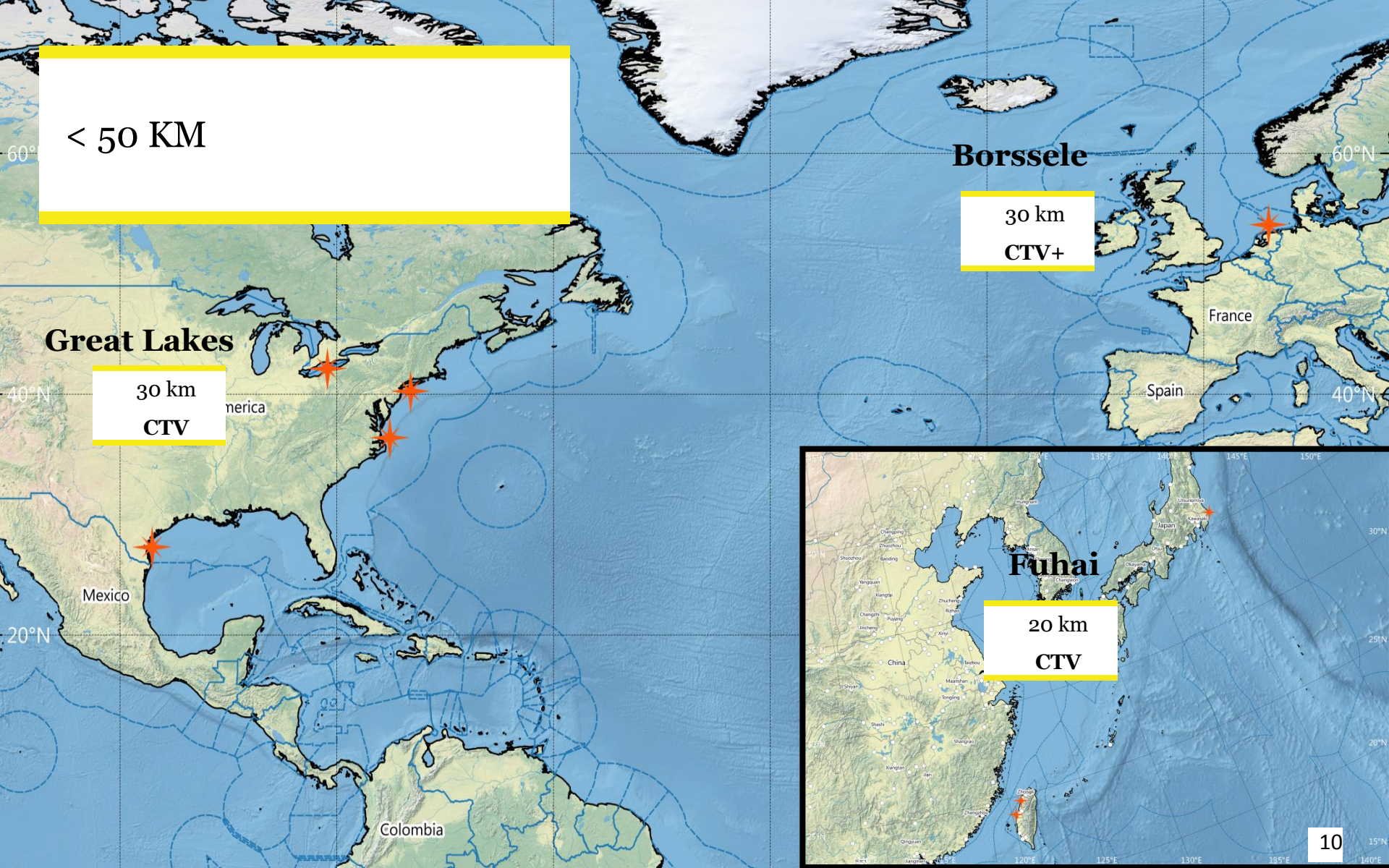
Vessels for replacement

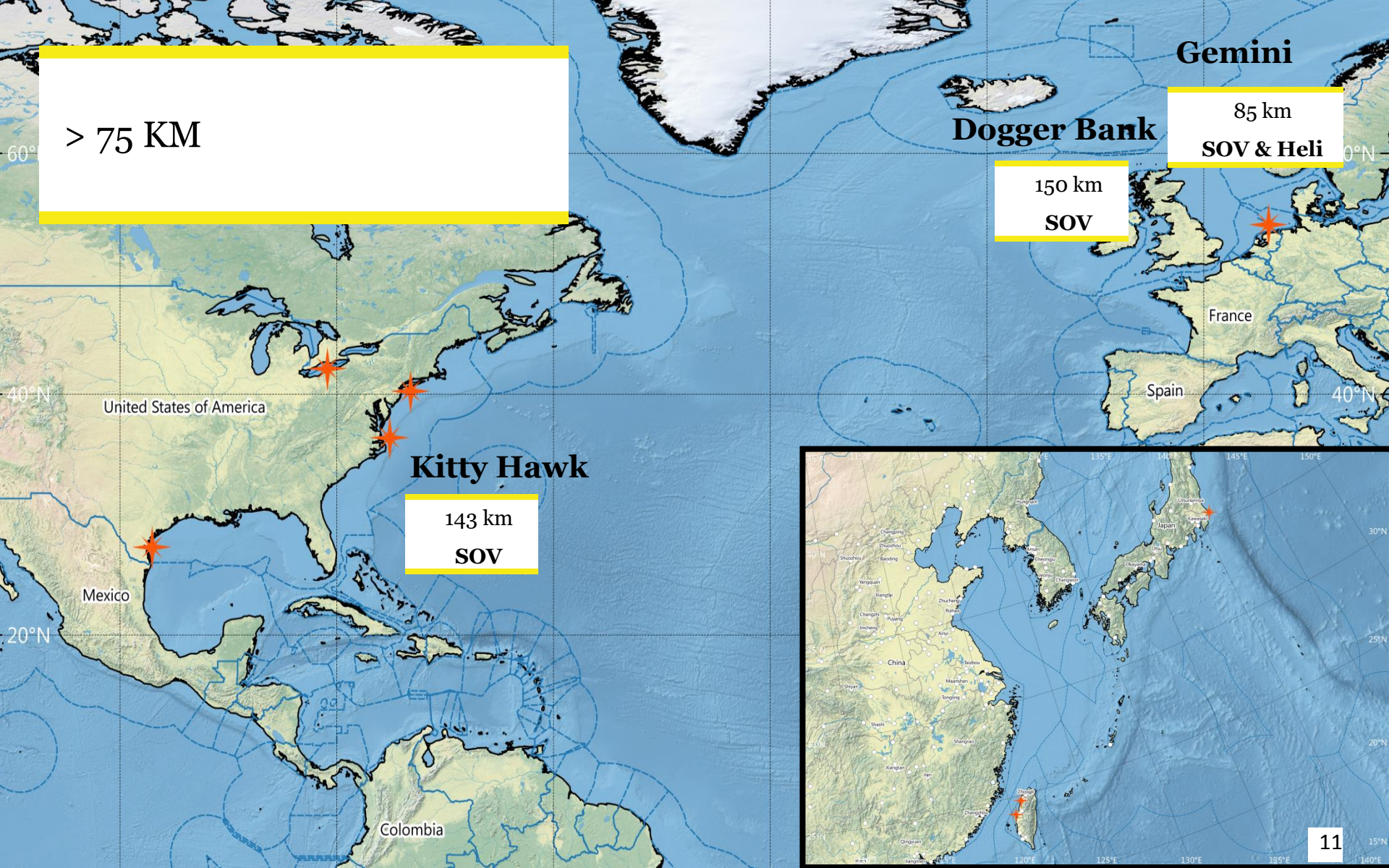
7

Optimisation and Selection of the “most suitable O&M Strategy” with ECN O&M Calculator

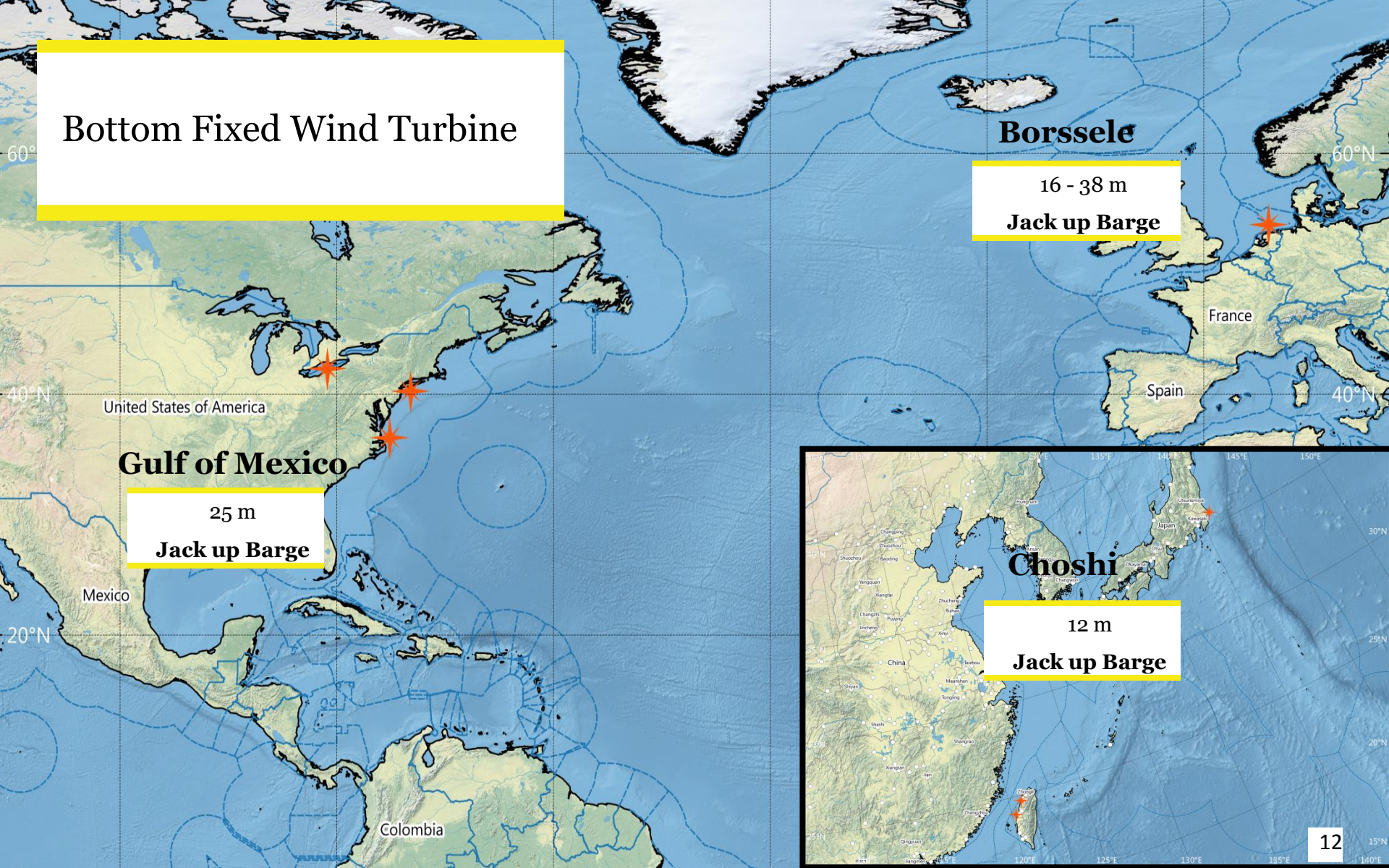
- Criterion of min 95% availability (Time and Yield)
- Cost-effective solution


Fuel_Consumption
Service_Operating_Vessel
Regulations
Condition_Based_Maintenance
Surface_Balance_of_Plant
Location_Challenges
Crew_Transfer_Vessel
Helicopter
Travel_Time
Calendar_Based_Maintenance
Surface_Effect_Ship
Workboat
Significant_Wave_Height
Weather_Conditions
Daughter_Craft
Fixed_yearly_price
Technicians
SOV
Revenue_Losses
Availability
Spare_parts
Downtime
O&M
Crane
Harbors
Vessels
Workability
Electricity_Prices
Mobilisation_Time
LCOE
Gangway
Inspection
SES
Schedules
Shifts
Power_Curve
Ports
Repair
Wind_Speed
Replacement
Wind_Turbine
CTV
Costs
Equipment
Failure_Rate
Logistic_Data
Mean_Time_To_Failure
Distance_To_Shore
Weather_Window
Jack_up_barge
Monitoring_Systems
Water_Depth
Accessibility
Daily_rates
Unplanned_Maintenance
Cable_Laying_Vessel


< 50 KM
Borssele
30 km
CTV+
Great Lakes
30 km
CTV
Fuhai
20 km
CTV
France
Spain
Mexico
Colombia
China
Japan
60°N
40°N
20°N


> 75 KM
Gemini
85 km
SOV & Heli
Dogger Bank
150 km
SOV
Kitty Hawk
143 km
SOV
France
Spain
United States of America
Mexico
Colombia
China
Japan
60°N
40°N
20°N
11

Bottom Fixed Wind Turbine



Floating Wind Turbine

Hywind

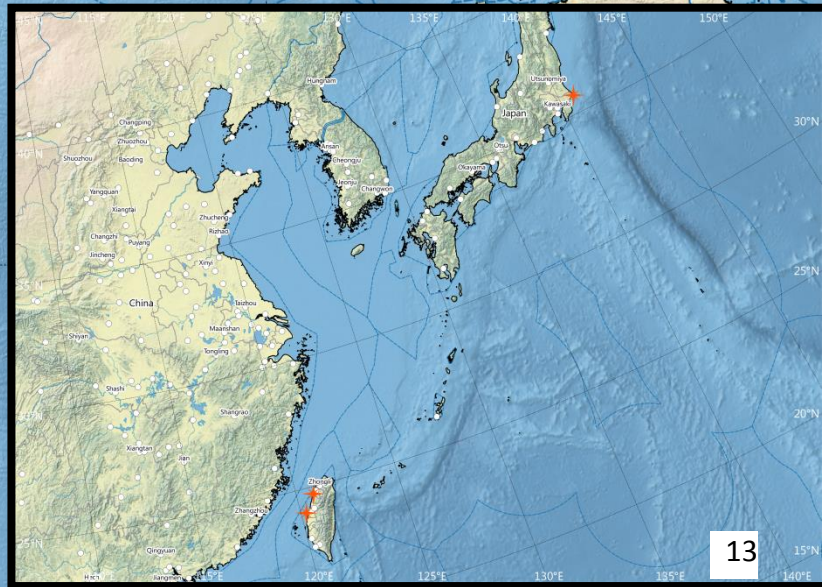
200 m

Towing Vessel + 2 Tug boats

Hawaii

700 m

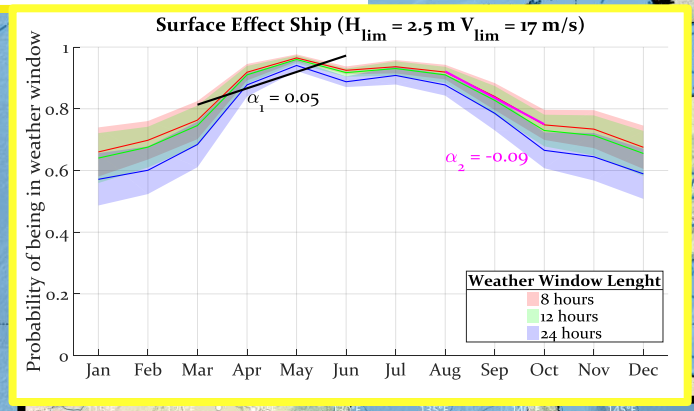
Towing Vessel + 2 Tug boats

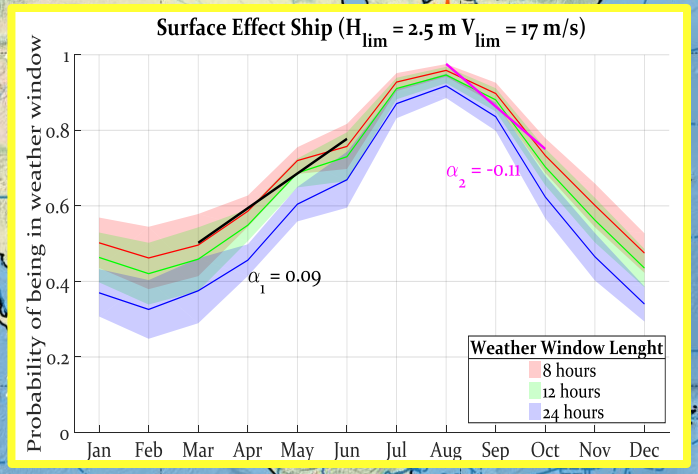


Weather conditions

Ws = 7.63 m/s , Hs = 1.55 m

Gemini



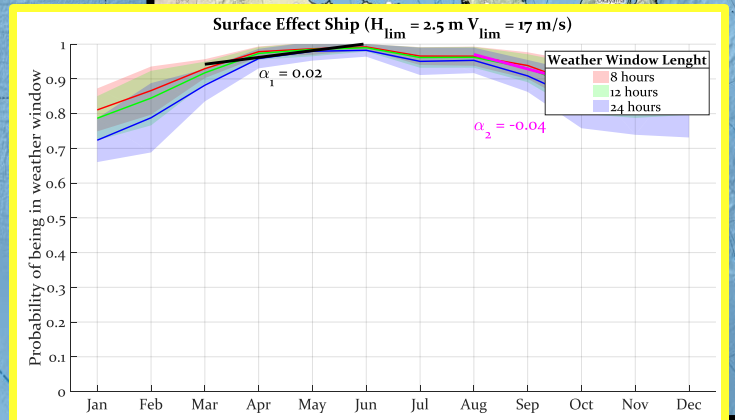


Pacific

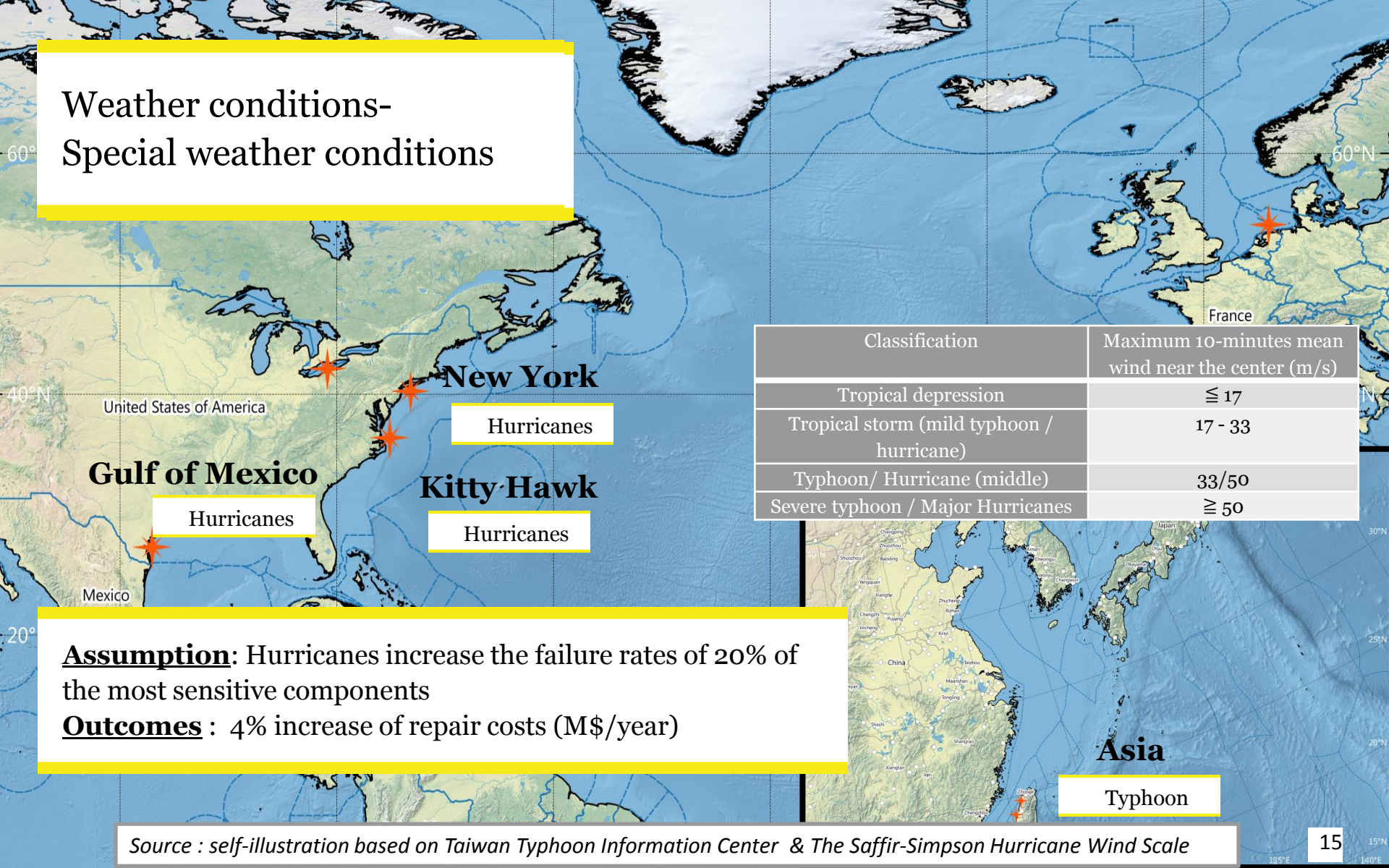
Ws = 8.24 m/s , Hs = 2.01 m

Fuhai

Ws = 6.39 m/s , Hs=1.55 m



Weather conditions-
Special weather conditions



Classification	Maximum 10-minutes mean wind near the center (m/s)
Tropical depression	≦ 17
Tropical storm (mild typhoon / hurricane)	17 - 33
Typhoon/ Hurricane (middle)	33/50
Severe typhoon / Major Hurricanes	≧ 50

<u>Assumption</u>: Hurricanes increase the failure rates of 20% of the most sensitive components

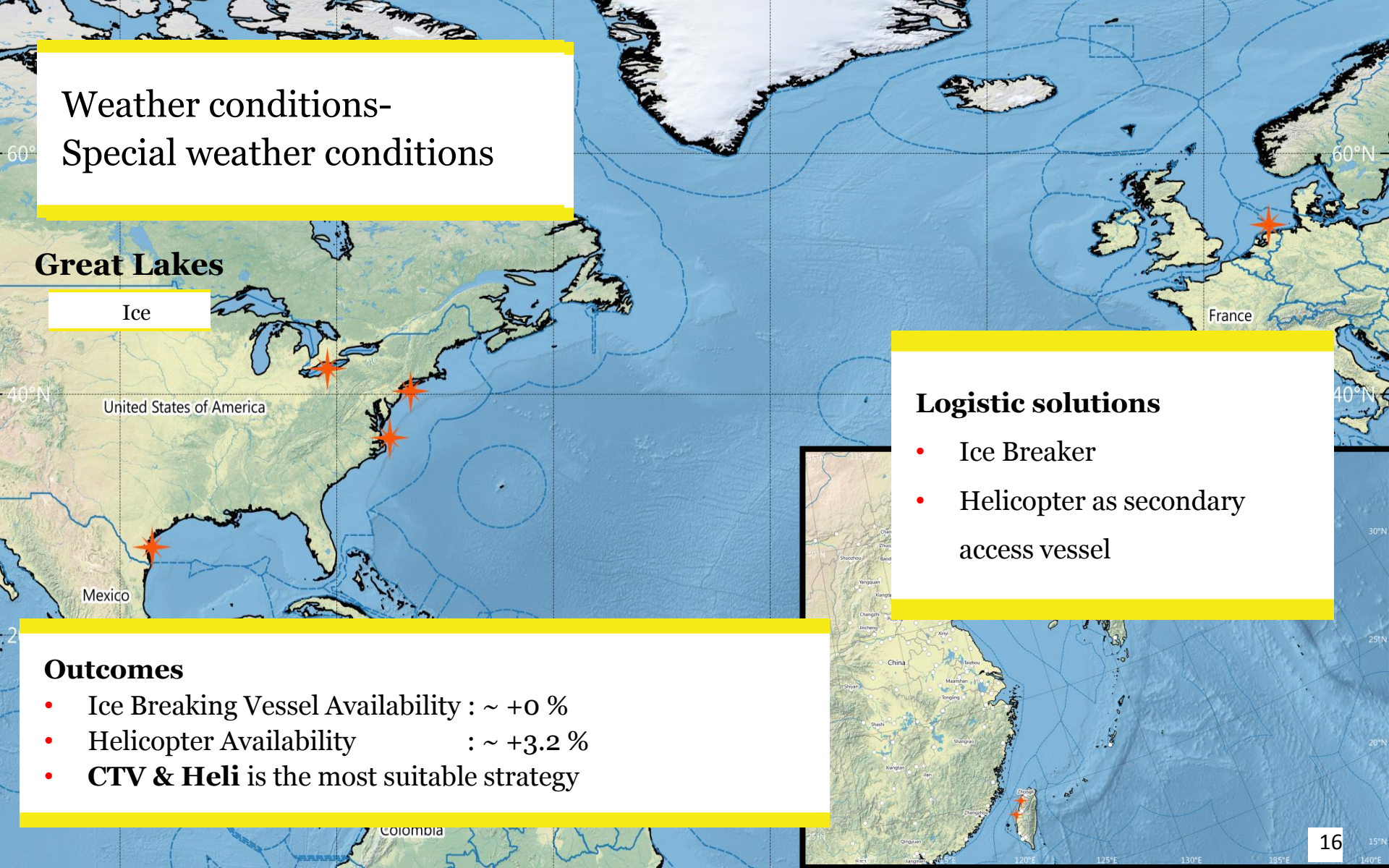
<u>Outcomes</u> : 4% increase of repair costs (M$/year)

Source : self-illustration based on Taiwan Typhoon Information Center & The Saffir-Simpson Hurricane Wind Scale

Weather conditions-
Special weather conditions

Great Lakes

Ice



Logistic solutions

- Ice Breaker
- Helicopter as secondary access vessel

Outcomes

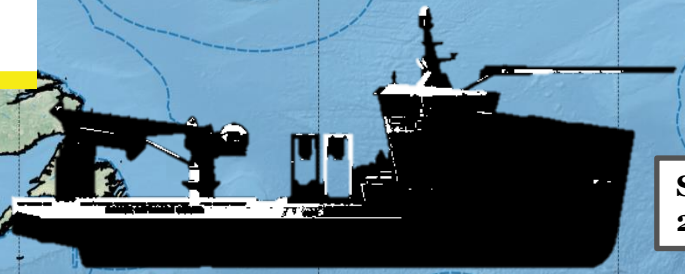
- Ice Breaking Vessel Availability : ~ +0 %
- Helicopter Availability : ~ +3.2 %
- **CTV & Heli** is the most suitable strategy

Vessels advancement
Market variety

Gemini

85 km

SOV & Heli



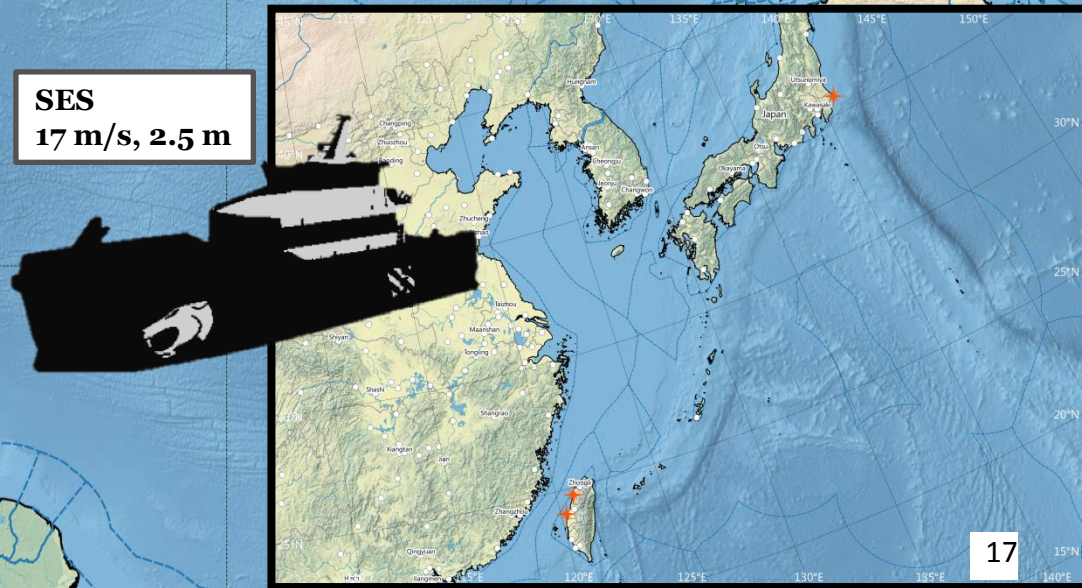
SOV
20 m/s, 3.0 m

New York

70 km

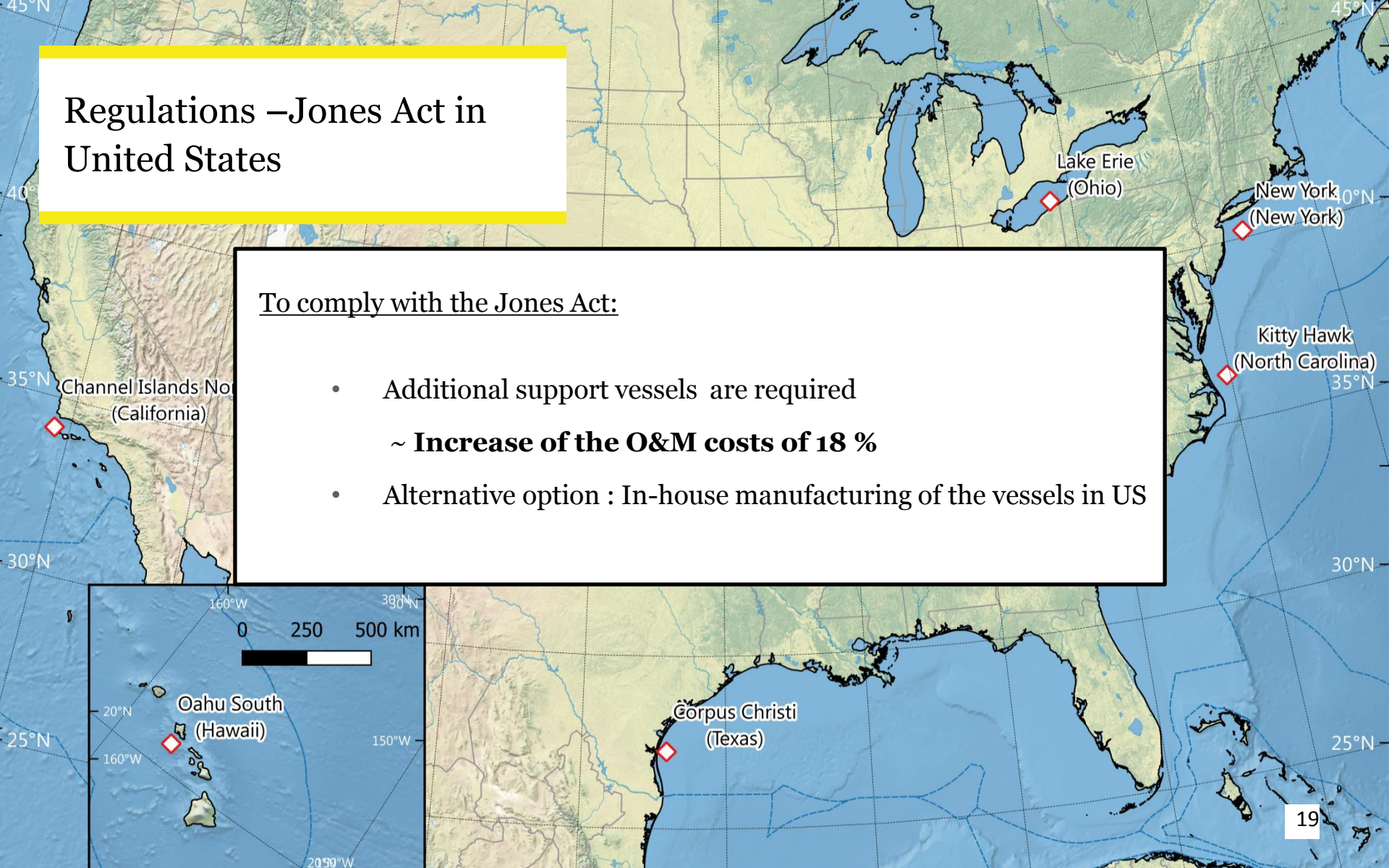
SES

SES
17 m/s, 2.5 m



What are the main drivers to optimize the O&M Strategy?

Regulations –Jones Act in United States



To comply with the Jones Act:

- Additional support vessels are required

  ~ Increase of the O&M costs of 18 %

- Alternative option : In-house manufacturing of the vessels in US

Optimization of O&M Strategy in the Future

Future of O&M:

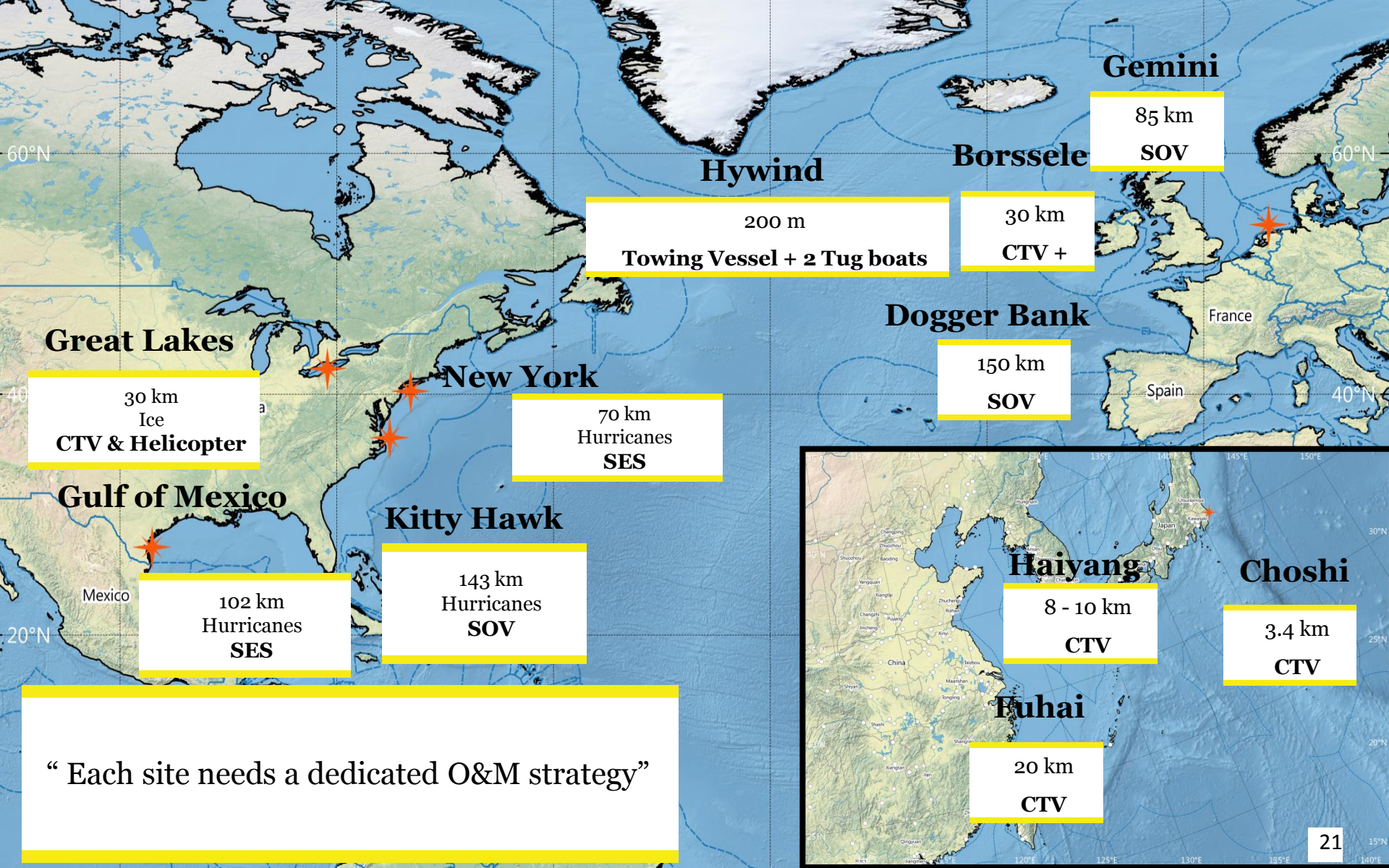
- Sharing of Resources
  - **~ Vessels**
  - **~ Harbours**

  ⇨ Between 2 wind farms : 14.5 M€/year* savings
- Condition based maintenance : monitoring systems

  ~ Decrease of failure rates by 25 %

  ⇨ Saving of 12.5 % in total O&M effort (M$/year) **

* Considering 2 wind farms of 400 MW
**Considering a monitoring system price of 2 M$/year



“ Each site needs a dedicated O&M strategy”

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