natural capital PROJECT

Offshore Wind Energy

Woods Institute for the Environment Stanford University

WWF

The Nature Conservancy

Institute on the Environment University of Minnesota Driven to Discover

Spatial wind energy model

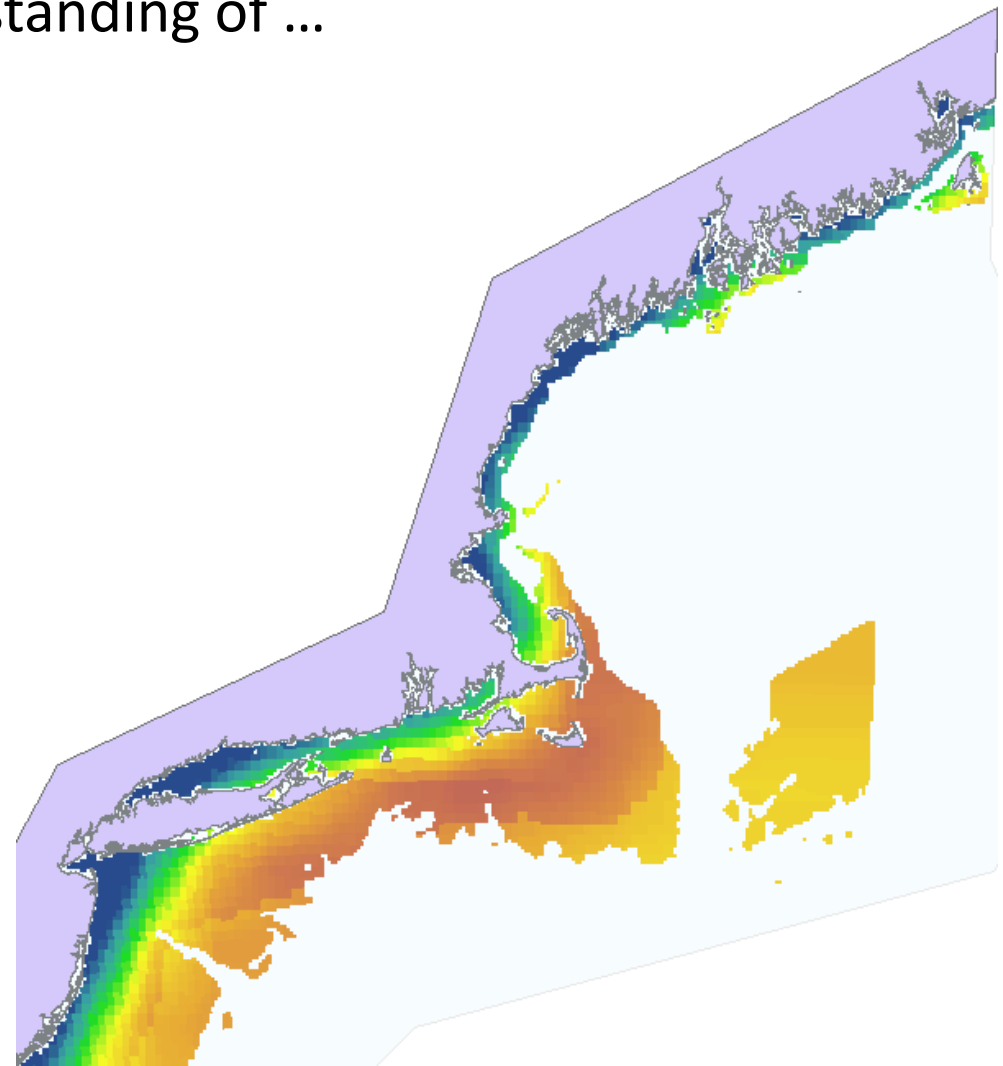
Why important? Spatial understanding of …

- Energy potential
- *Cost*
- *Value*
- Use conflicts

Builds on/extends

- CREST model (NREL)
- TCI/TDI (URI)
- $/MW models

Modeling/Data Collection



Nuts and bolts

Inputs

- Wind Speed
- Turbine Info
- Cables and Grid Info
- Financial Parameters

Constraints

Energy Model

Power density

$$P = \frac{1}{2}\rho \sum_{j=1}^{c} f(V_j){V_j}^3$$

Weibull

$$f(V_j) = \frac{k}{\lambda}\left(\frac{V_j}{\lambda}\right)^{k-1} e^{-\left(\frac{V_j}{\lambda}\right)^k}$$

Profile power law

$$\frac{V}{Z_r} = \left(\frac{Z}{Z_r}\right)^{\alpha}$$

Output power

$$P(V) = \begin{cases} 0 & V < V_{cin} \text{ or } V > V_{cout} \\ P_{rate} & V_{rate} < V < V_{cout} \\ (V^m - V_{in}^m)/(V_{rate}^m - V_{in}^m), & V_{cin} \le V \le V_{rate} \end{cases}$$

Valuation Model

Equipment costs

$$CAP = \left(.91 km/_{turbine}\right)\left(\$.26/_{km}\right)(\#\ of\ turbines) + \begin{cases} (\$2.0 + \$8.0)(\#\ of\ turbines), & if\ Siemens\ 3.6MW \\ (\$2.6 + \$14.0)(\#\ of\ turbines), & if\ AREVA\ 5.0MW \end{cases} + \begin{cases} .81 * MW + 1.36 * Cable, & if\ Cable \le 60km\ (AC) \\ 1.09 * MW + .89 * Cable, & if\ Cable > 60km\ (DC) \end{cases}$$

Capital expenditures

$$CAPEX = CAP/(1 - .2 - .05)$$

Net present value

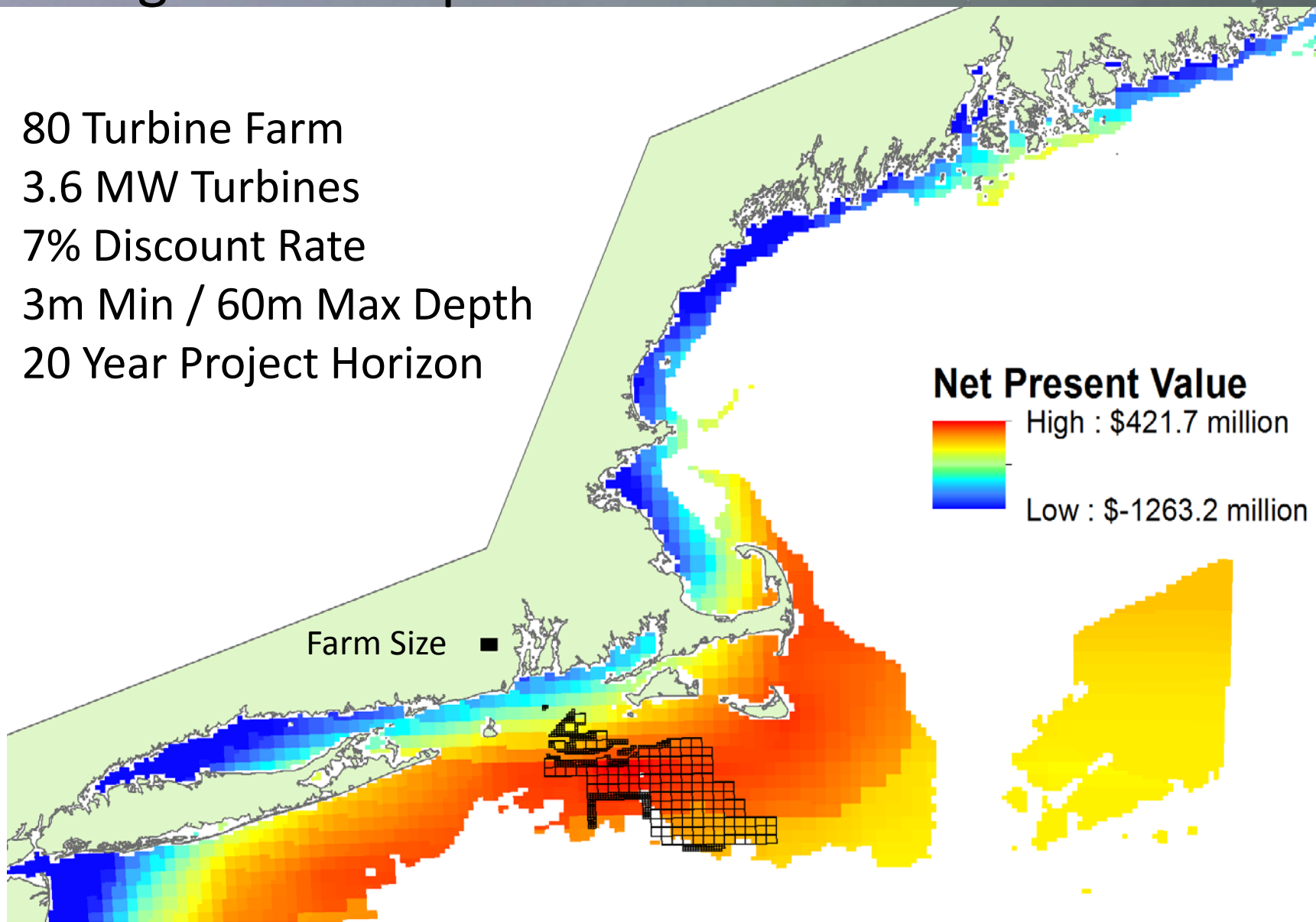
$$NPV = \sum_{t=1}^{T} \frac{(Rev_t - .035 * CAPEX)}{(1+i)^t} - \frac{.037 * CAPEX}{(1+i)^T} - CAPEX$$

Outputs

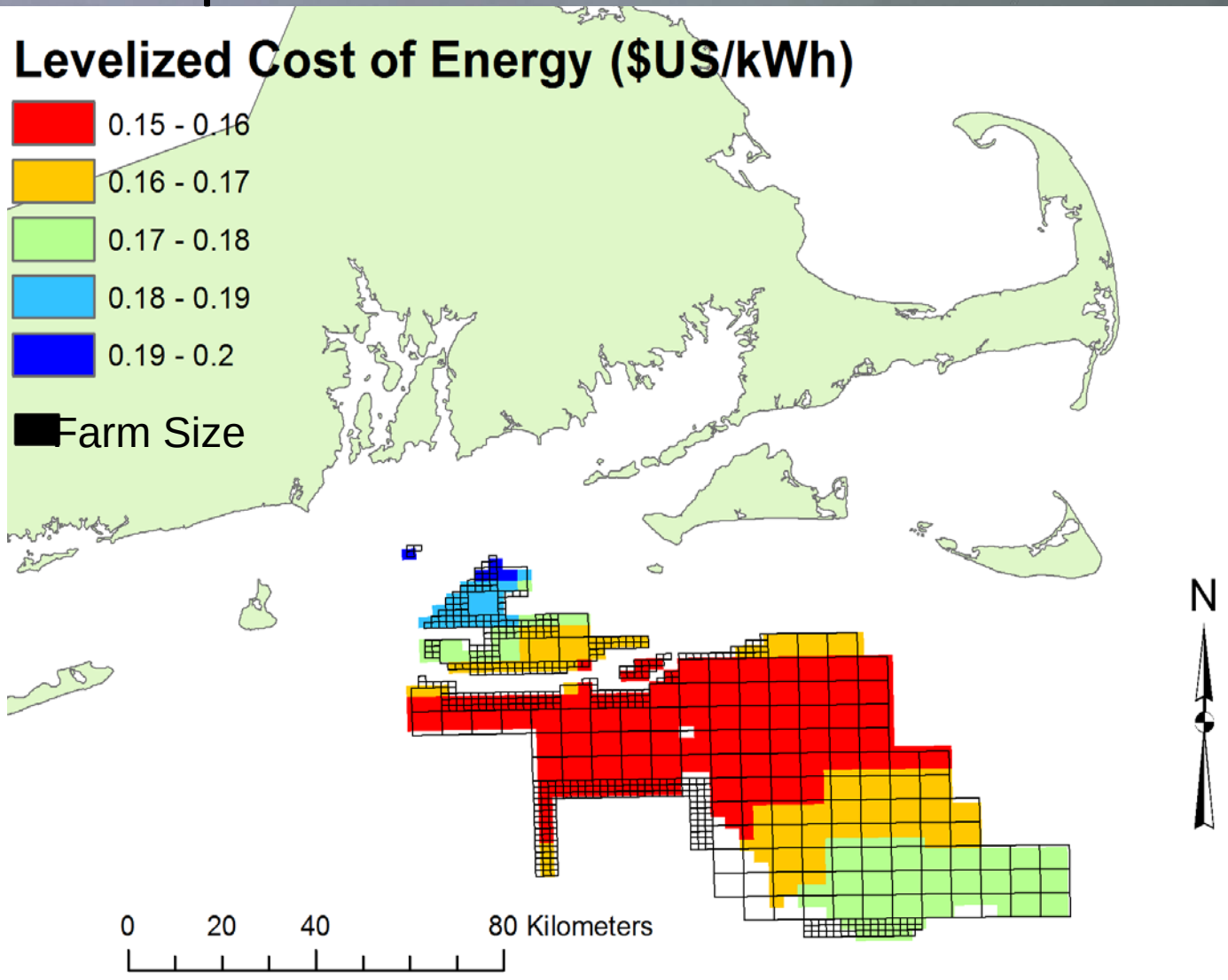
- Power Density
- Energy Generated
- Net Present Value
- Levelized Cost of Energy

New England example

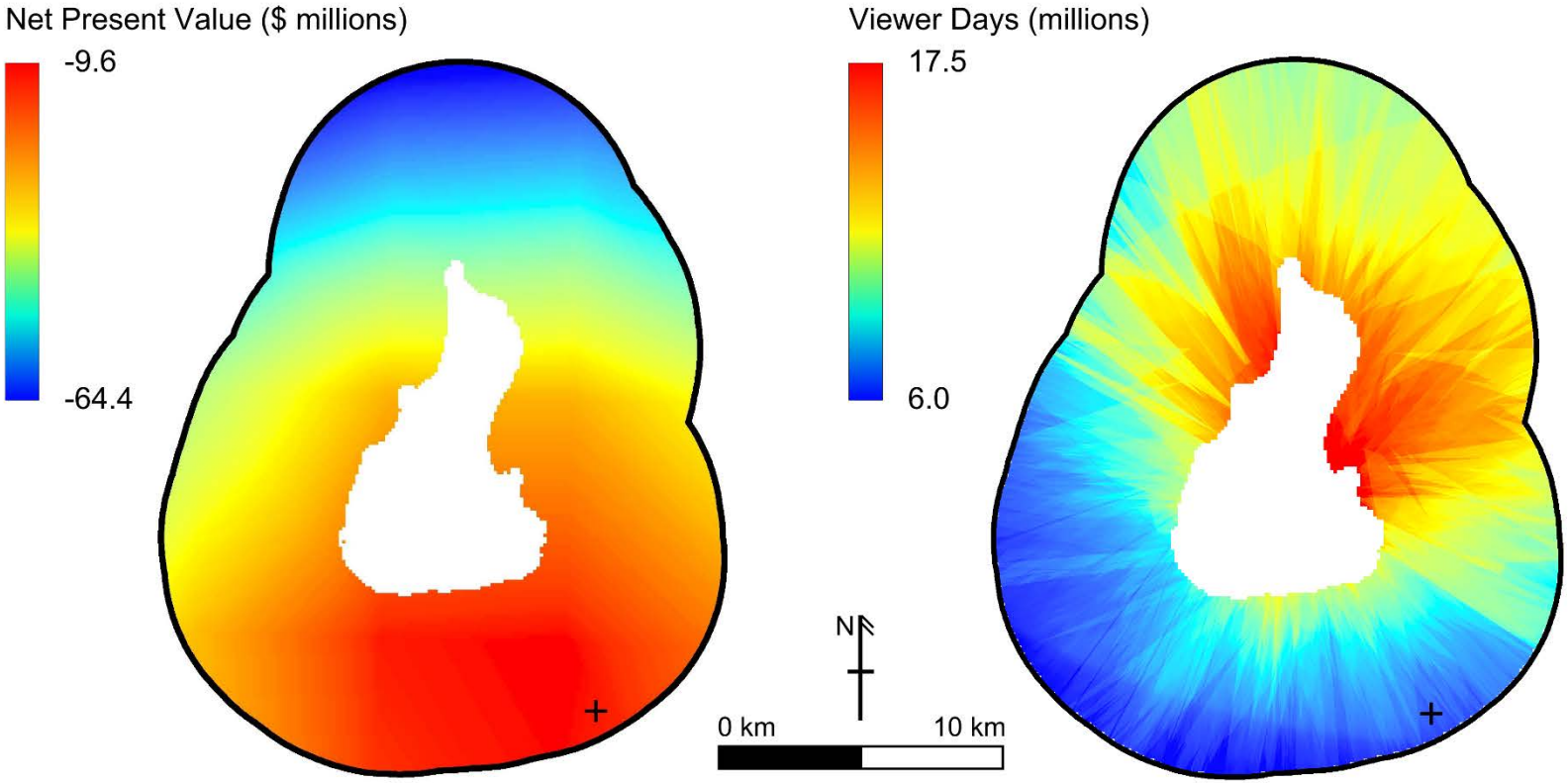
80 Turbine Farm
3.6 MW Turbines
7% Discount Rate
3m Min / 60m Max Depth
20 Year Project Horizon



RI/MA example



Marine Spatial Planning

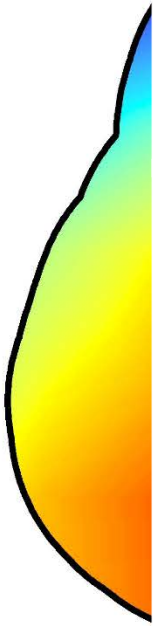


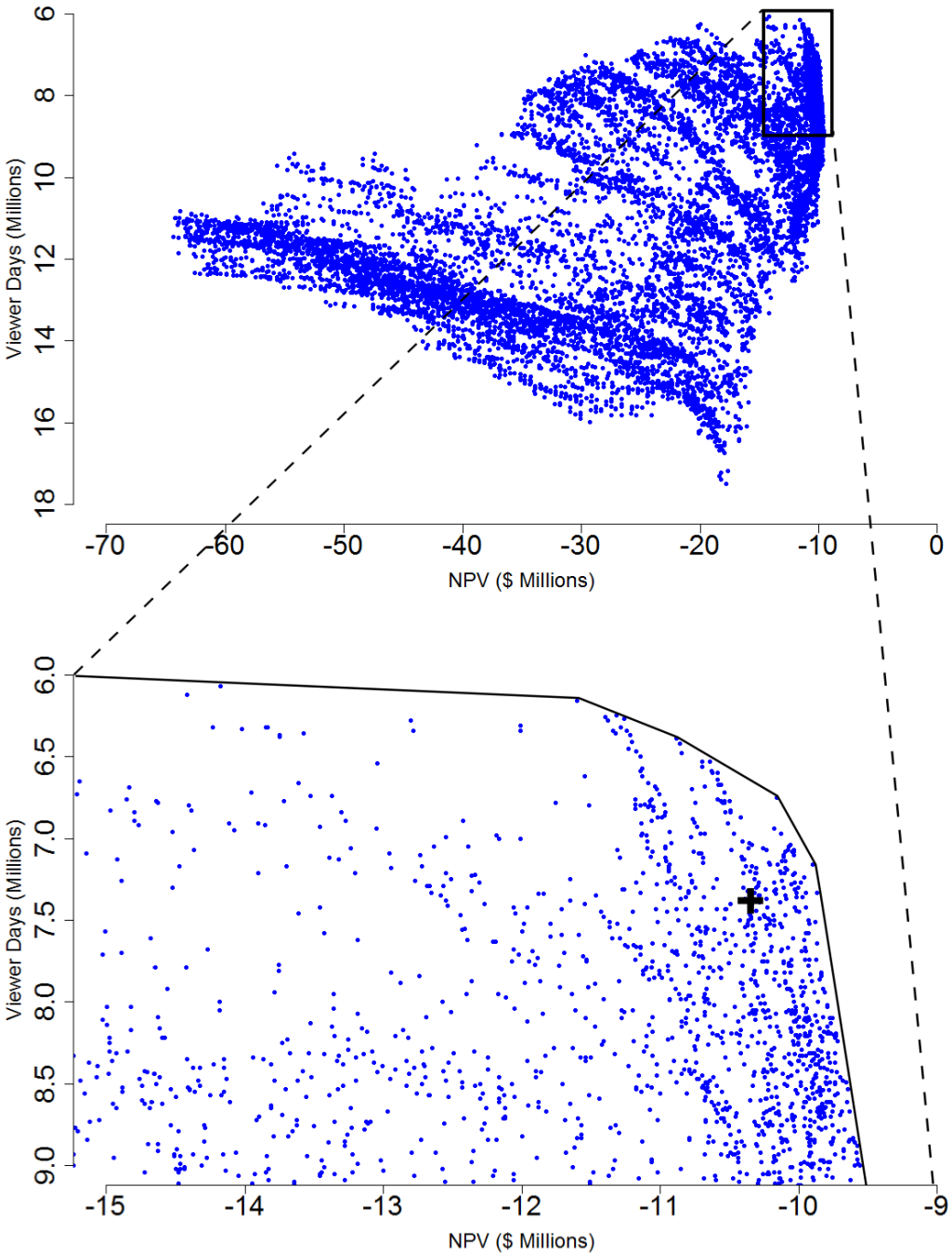
Marine Spa

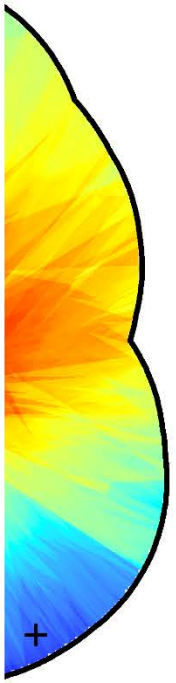
Net Present Value ($ r

-9.6

-64.4







Wind energy valuation

Discounted Cash Flow → $\mathrm{NPV} = \sum_{t=0}^{T} \frac{(\mathrm{Rev_t} - \mathrm{Cost_t})}{(1+\mathrm{i})^{\mathrm{t}}}$

<u>Capital expenditures (t=0)</u>
- Farm components
- Transmission
  TC = f(MW, cable length)

<u>Other costs</u>
- Installation and misc
- Operations and management
- Decommissioning

<u>Revenue</u>
- Energy generated
- User entered price/kWh
- Discount rate or WACC

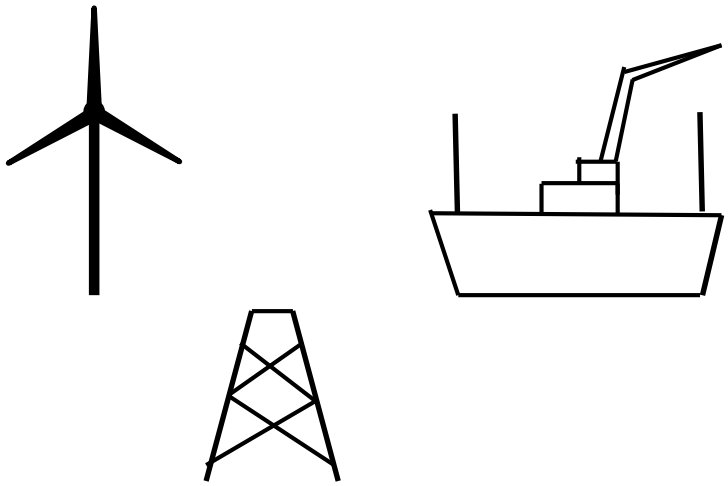
Valuation advances

Advances

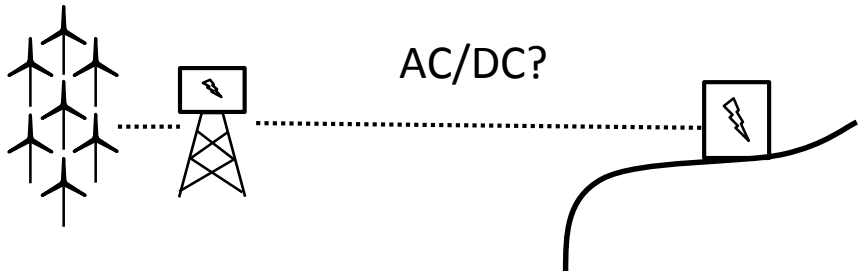
- Component-level model
  - Spatial valuation (revenue and costs)
  - Data collection

<u>Transmission model</u>

$/unit



system



Cost model validation