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Evaluating the Underwater Compressed Air Energy Storage Potential in the Gulf of Maine

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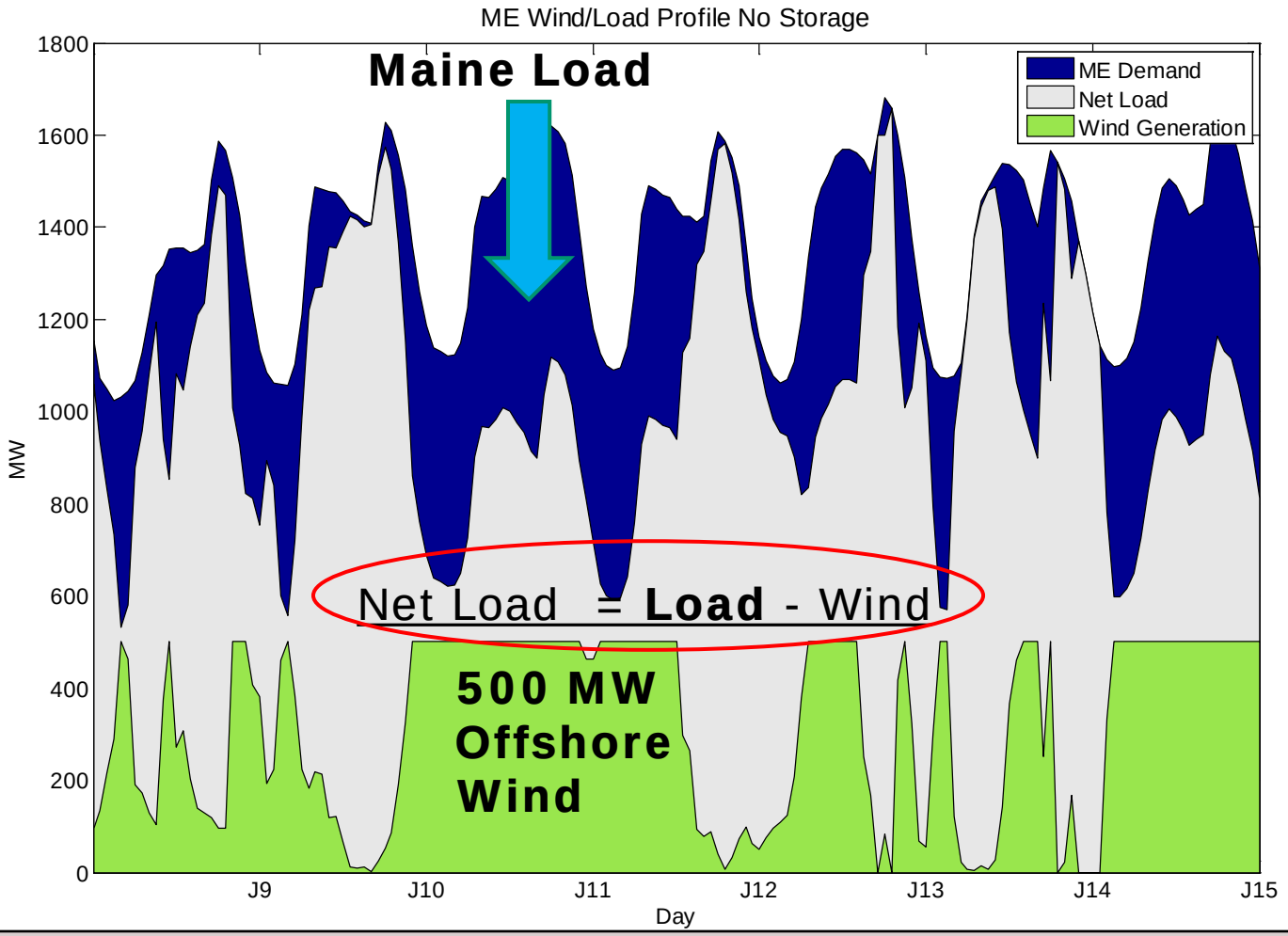
Introduction – Why Storage?



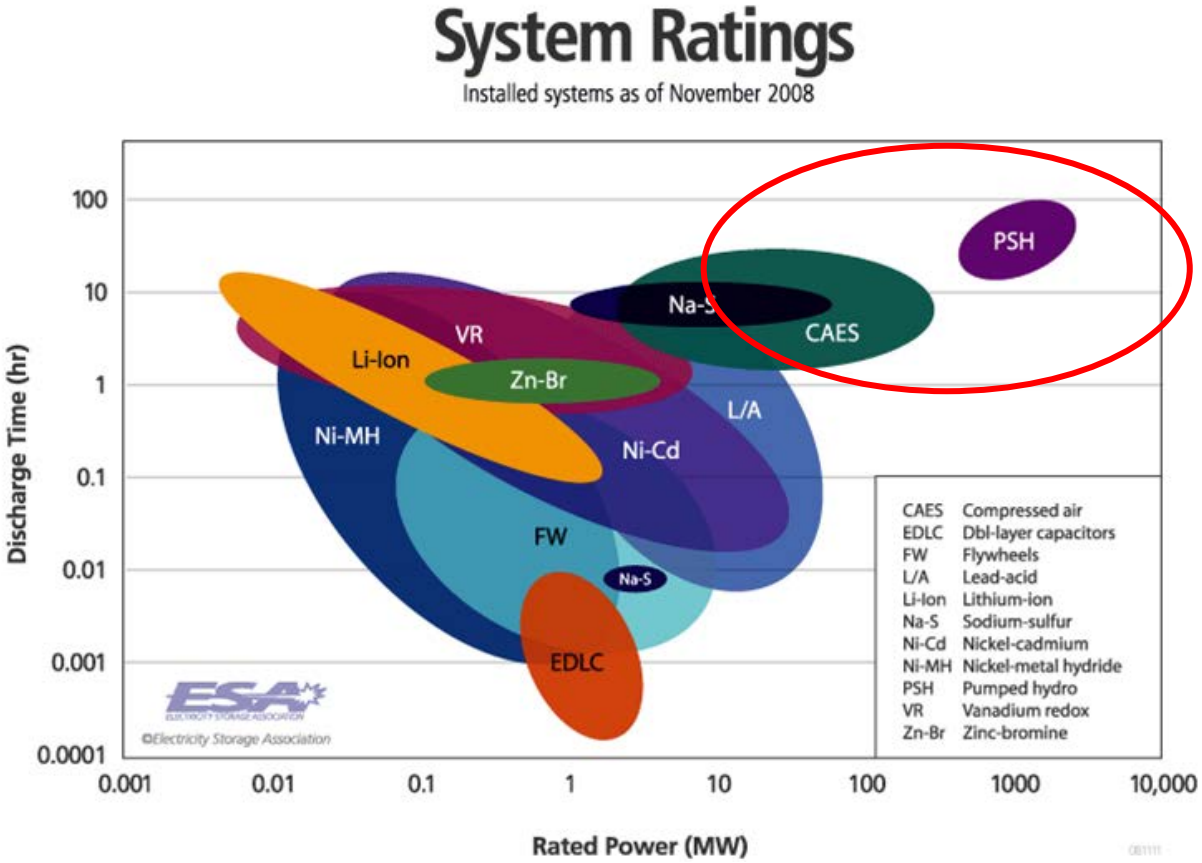
High Penetration Levels of Renewable Generation may be a problem

Utility-scale storage maybe a potential solution…

Project Goals:

1) Analyze and compare ideal CAES/PHS models
2) Integrate into ArcGIS to estimate potential resource

Introduction – Why CAES?



Source: Energy Storage Association

- Utility-Scale
- High efficiency 70-80%
- Shifting power
- Transmission utilization
- Firm wind capacity
- Reduce spinning reserve
- Aids in BOS
- TES and UWCAES

Analysis – Storage Density of Idealized Cases

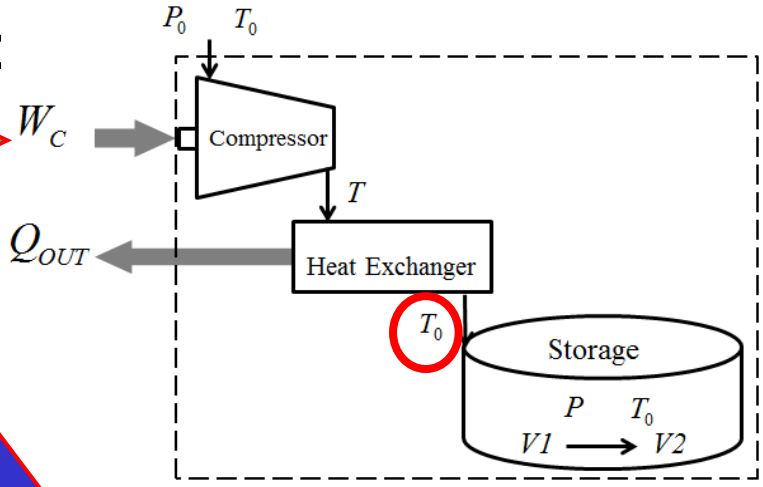
Three CAES Models & One PHS:

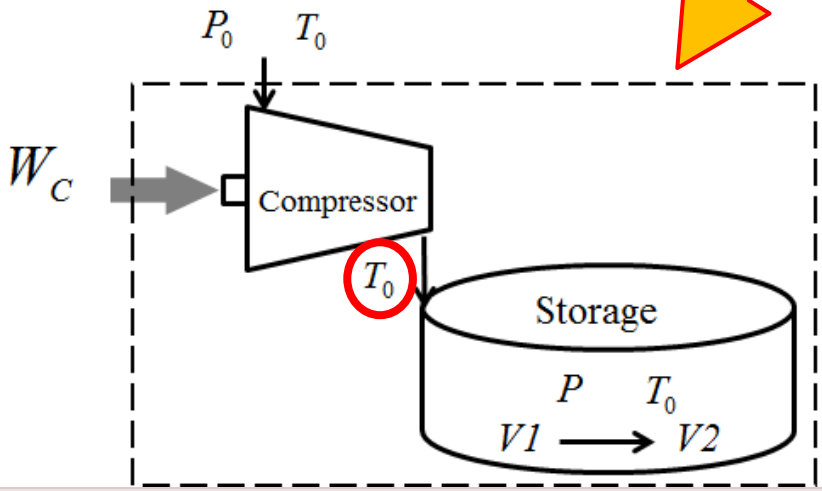
1) Adiabatic CAES

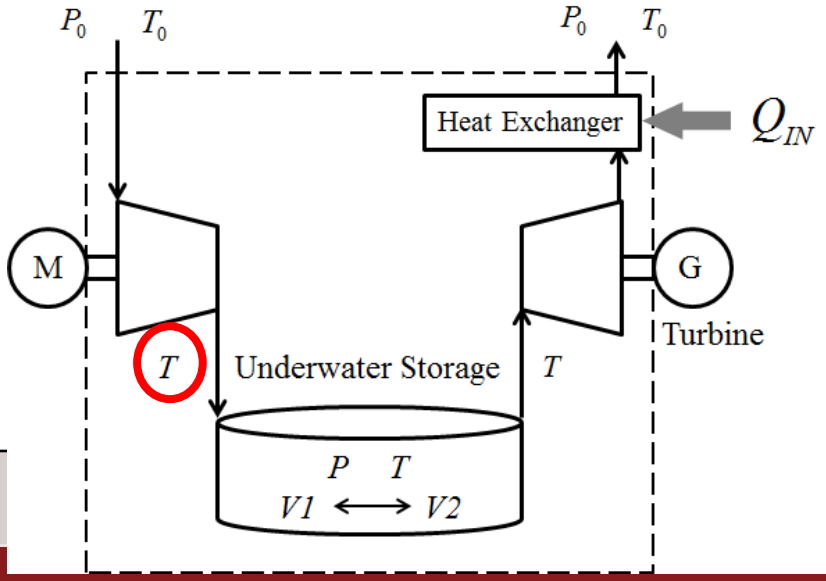
2) NO TES CAES

3) Isothermal CAES

4) Underwater PHS







Results – Thermodynamic Analysis

Energy density of stored air from CV analysis:

1) Adiabatic CAES

$$\frac{\Delta U}{\Delta V}_{Adiabatic} = \frac{\gamma P_0}{\gamma - 1}\left(\frac{P_{abs}}{P_0}\right)\left(\left(\frac{P_{abs}}{P_0}\right)^{\gamma - 1/\gamma} - 1\right) \quad with... P_{abs} = P_0 + \rho g d$$

2) NO TES CAES

$$\frac{\Delta U}{\Delta V}_{NO\_TES} = \frac{\gamma P_0}{\gamma - 1}\left(\left(\frac{P_{abs}}{P_0}\right)^{1/\gamma} - \left(\frac{P_{abs}}{P_0}\right)\right)$$

3) Isothermal CAES

$$\frac{\Delta U}{\Delta V}_{ISO} = P_0\left(\frac{P_{abs}}{P_0}\right)\ln\left(\frac{P_{abs}}{P_0}\right)$$

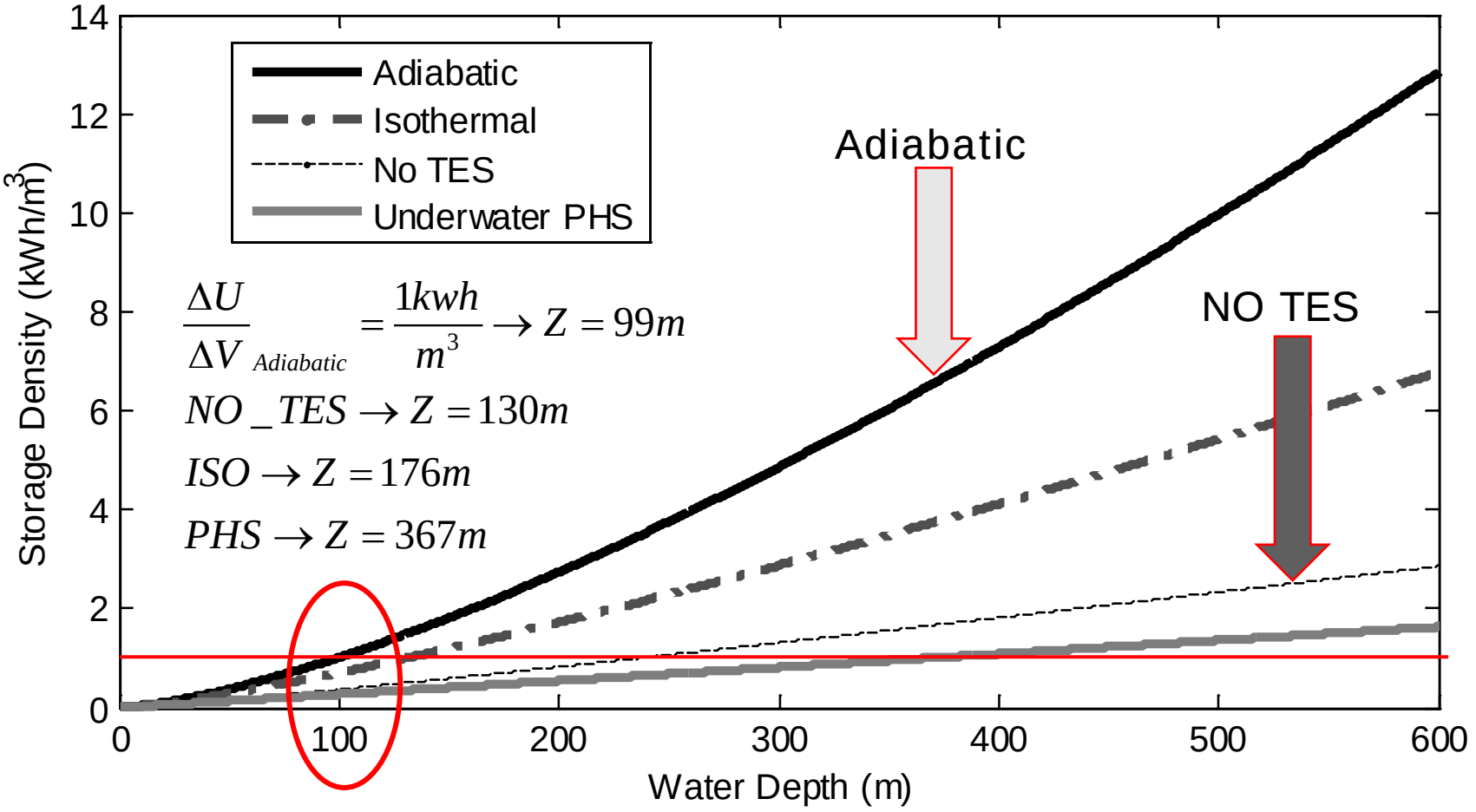
4) Underwater PHS

$$\frac{\Delta U}{\Delta V}_{PHS} = \rho g H \eta$$

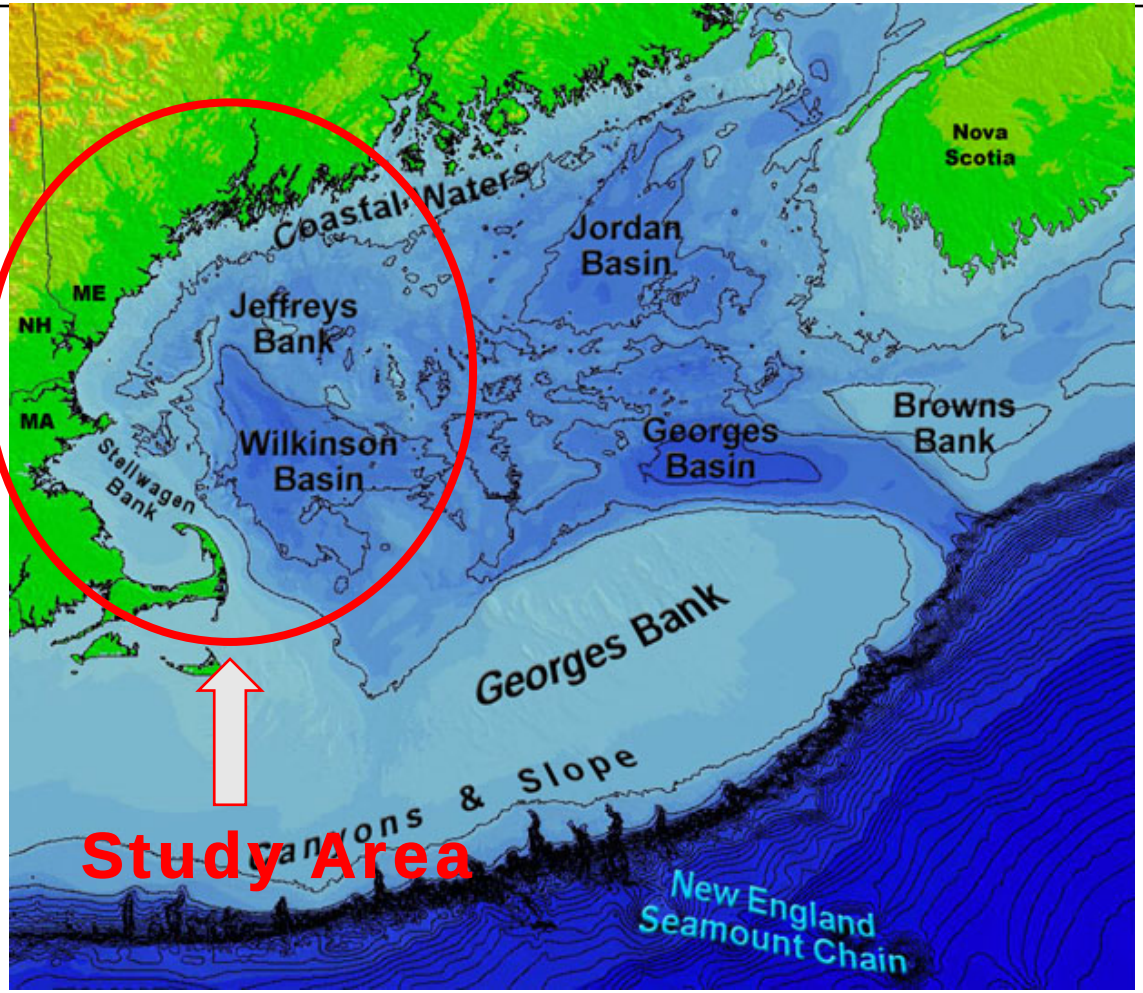
Assume:

- Ideal System (reversible)
- Ideal Gas Law
- Constant Cv & Cp
- 100% Efficiency
- Density of Water

Results – Storage Density Comparison

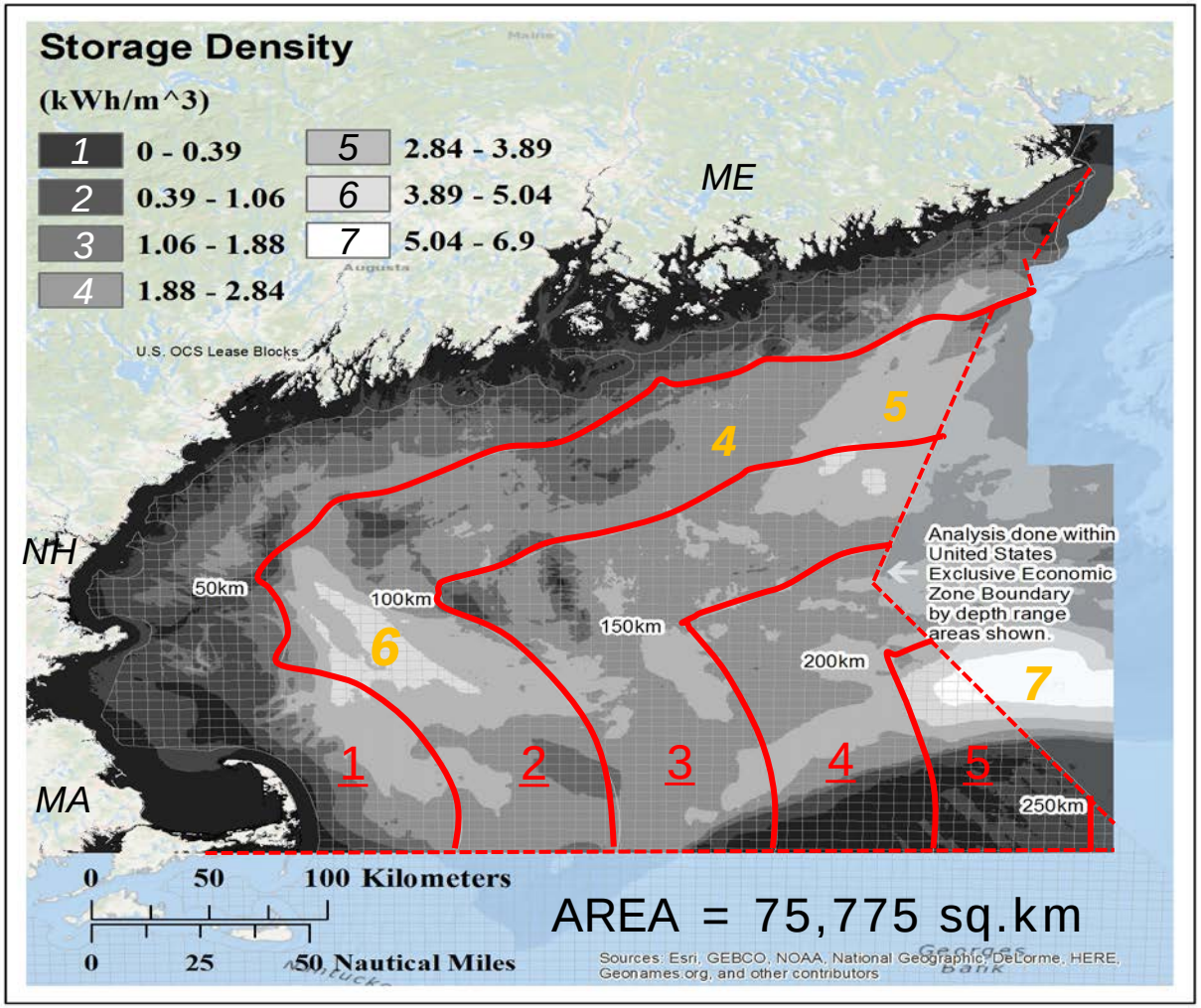


Case Study – Gulf of Maine



- GoM Area = 170,000 sq.km
- Excellent offshore wind Resource
- 156GW capacity within 90km, 80% in waters >60m
- ArcGIS used with NOAA Bathymetry data
- Integrated Storage density equation in ArcGIS

Results – GoM Storage Density Map



Class	Depth
1	0-50m
2	50-100m
3	100-150m
4	150-200m
5	200-250m
6	250-300m
7	>300m (max 375)

Region	Distance
1	0-50km
2	50-100km
3	100-150km
4	150-200km
5	200-250km

Results – Storage Resource Adiabatic Model

Region	(1) 0-50km		(2) 50-100km		(3) 100-150km		(4) 150-200km		(5) 200-250km		TOTAL	
Class	Area m^2	Capacity TWh	**Area m^2**	**Capacity TWh**	Area m^2	Capacity TWh	**Area m^2**	**Capacity TWh**	Area m^2	Capacity TWh	**Area m^2**	**Capacity TWh**
1	11190	2.1	**89**	**0.016**	238	0.044	**1445**	**0.26**	941	0.17	**13904**	**2.5**
2	9145	6.2	**378**	**0.27**	476	0.32	**426**	**0.29**	1495	1.0	**11919**	**8.1**
3	5793	8.6	**3006**	**4.5**	829	1.2	**130**	**0.19**	70	0.11	**9828**	**15**
4	3222	7.7	**9617**	**23**	8124	19	**3775**	**9.1**	214	0.51	**24952**	**60**
5	1595	5.2	**5517**	**18**	3665	12	**1966**	**6.4**	373	1.2	**13116**	**43**
6	83	0.35	**1037**	**4.4**	170	0.72	**14**	**0.061**	542	2.3	**1847**	**7.8**
7	0	0	**0**	**0**	0	0	**0**	**0**	211	1.1	**211**	**1.1**

Conclusions and Future Work

- 1st law analysis shows Adiabatic model has the highest storage density followed by the Isothermal case. The PHS had the lowest storage density.
- Case study analysis show great resource potential less than 100km from shore. Several “hotspots” near load centers like Boston.
- Future work will look at integrating CAES models with offshore wind and load data for New England. More work with GIS to assess potential environmental implications and site assessment issues.

Acknowledgements

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https://windenergyigert.umass.edu/