East-coast offshore wind – design, evaluation, and policy

James McCalley

Iowa State University

(jdm@iastate.edu)

PSERC Webinar
November 2, 2022

Acknowledgements

<u>Based on work done in the ongoing project</u>:
"Transmission Expansion Planning Models for Offshore Wind Energy,"

<u>Funded by</u>:
- New York State Energy Research & Development Agency (NYSERDA)
- US Department of Energy (DOE)

<u>Managed by</u>:
- National Offshore Wind Research & Development Consortium (NOWRDC), Christine Sloan

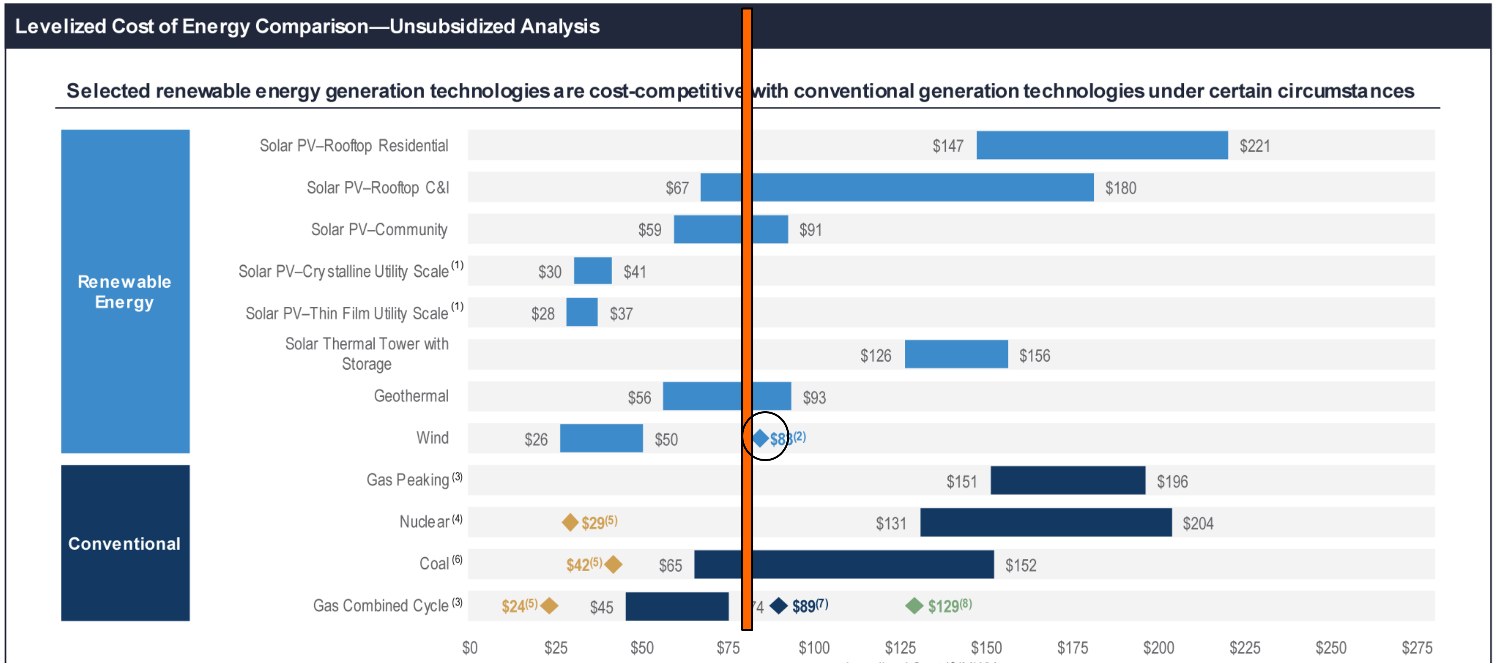
<u>Project investigators</u>:
- Eric Hines (lead), Per-Anders Lof, Barbara Kates-Garnick, Rebecca Wolf, Julia Harris, Tufts University
- Johan Enslin, Moaazam Nazir, Clemson University
- James McCalley, Ali Jahanbani, Abhinav Venkatraman, Iowa State University

Overview

1. Motivation for offshore wind
2. US offshore wind policy targets & progress
3. Offshore transmission designs
4. POI/Landfall identification
5. Two critical issues for offshore wind

Motivation for offshore wind

1. A zero-carbon resource; (though not least cost)



2. Provides economic development (jobs!)
3. Adds resource diversity
4. Lowers variability relative to onshore wind & solar
5. Offers transmission development less available onshore

US Offshore wind capacity targets

9 GW by 2035, NY State Goal, 2019

N. Skopljak, "New York Charts 9 GW by 2035 Offshore Wind Path," www.offshorewind.biz/2019/01/16/new-york-charts-9gw-2035-offshore-wind-path/

23.7 GW by 2035, 7 states, 2019

39.3 GW by 2040, 7 states, 2021

New York, Virginia, Mass., N. Carolina, NJ, Conn, Maryland

States Betting on Offshore Wind for Renewable Power, Jobs (governing.com), Feb. 8, 2022

US DOE "Offshore wind market report, 2021 edition," www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf.

25 GW (floating) by 2045, California, Aug, 2022

California adopts 25-GW floating offshore wind goal by 2045 (renewablesnow.com), Aug. 11, 2022

30 GW by 2030, Biden Admin, 2021

"Fact Sheet: Biden Administration Launches New Federal-State Offshore Wind Partnership to Grow American-Made Clean Energy," June 23, 2022, www.whitehouse.gov/briefing-room/statements-releases/2022/06/23/fact-sheet-biden-administration-launches-new-federal-state-offshore-wind-partnership-to-grow-american-made-clean-energy/.

110-150 GW by 2050, Biden Admin, DOE 2021

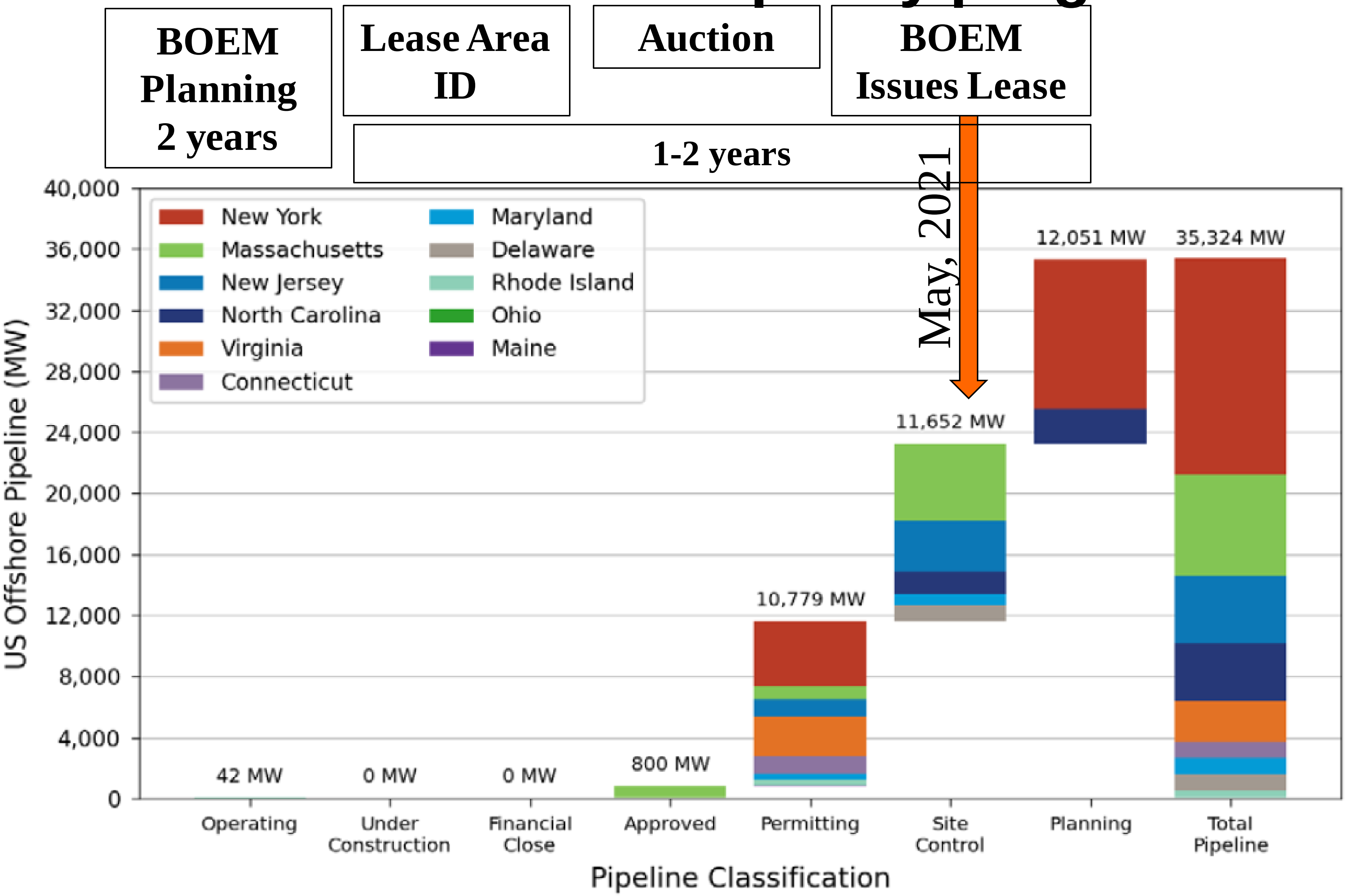
"Fact Sheet: Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs," March 29, 2021, www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/

US DOE, "Atlantic Offshore Wind Transmission Literature Review and Gaps Analysis," October 2021, www.energy.gov/sites/default/files/2021-10/atlantic-offshore-wind-transmission-literature-review-gaps-analysis.pdf.

Atlantic Offshore Wind Transmission Study, 2021

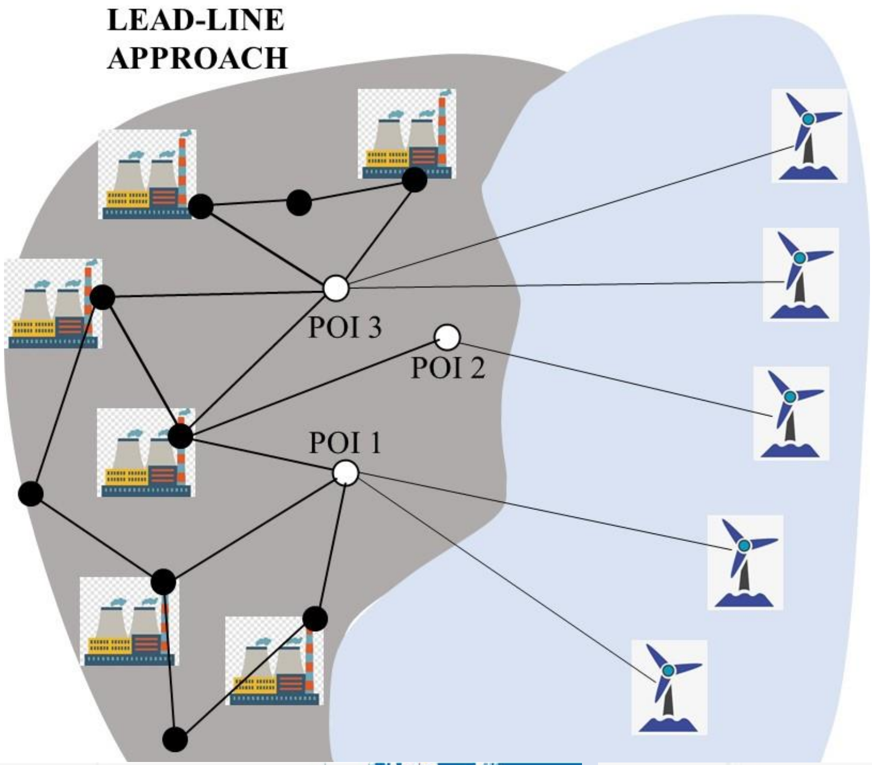
Atlantic Offshore Wind Transmission Study | Wind Research | NREL.

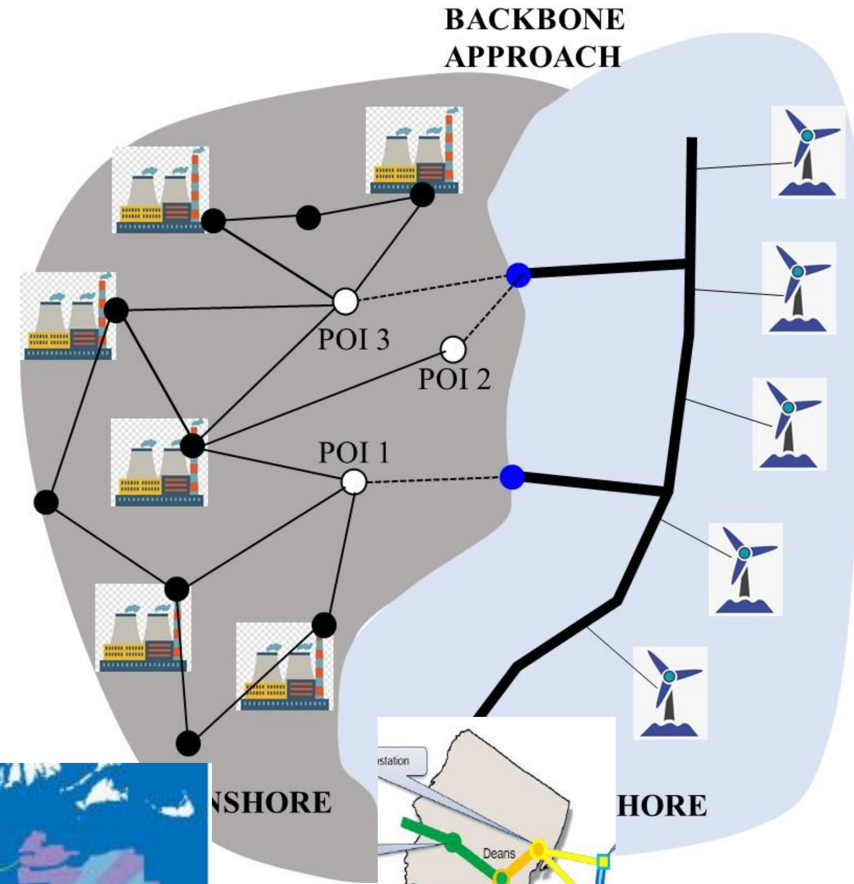
US Offshore wind capacity progress

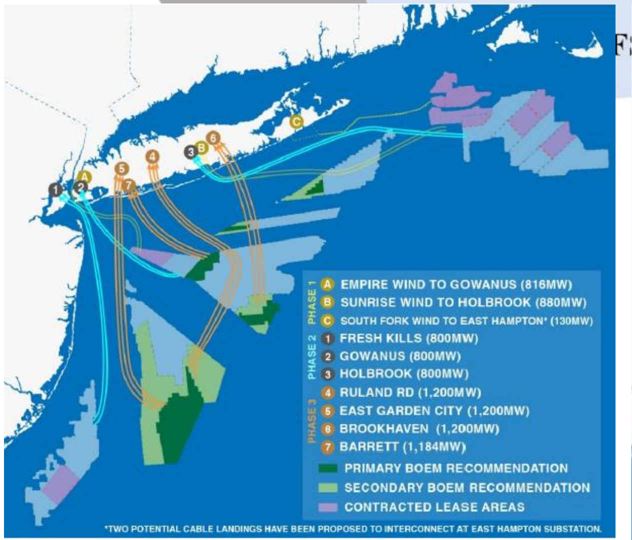


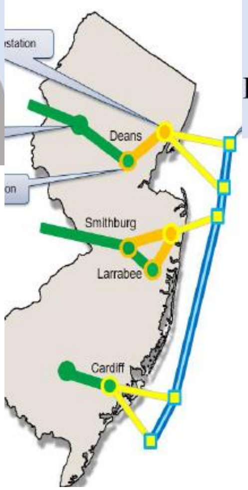
Reference: US DOE, "Atlantic Offshore Wind Transmission Literature Review and Gaps Analysis," October 2021, www.energy.gov/sites/default/files/2021-10/atlantic-offshore-wind-transmission-literature-review-gaps-analysis.pdf.

Two transmission designs



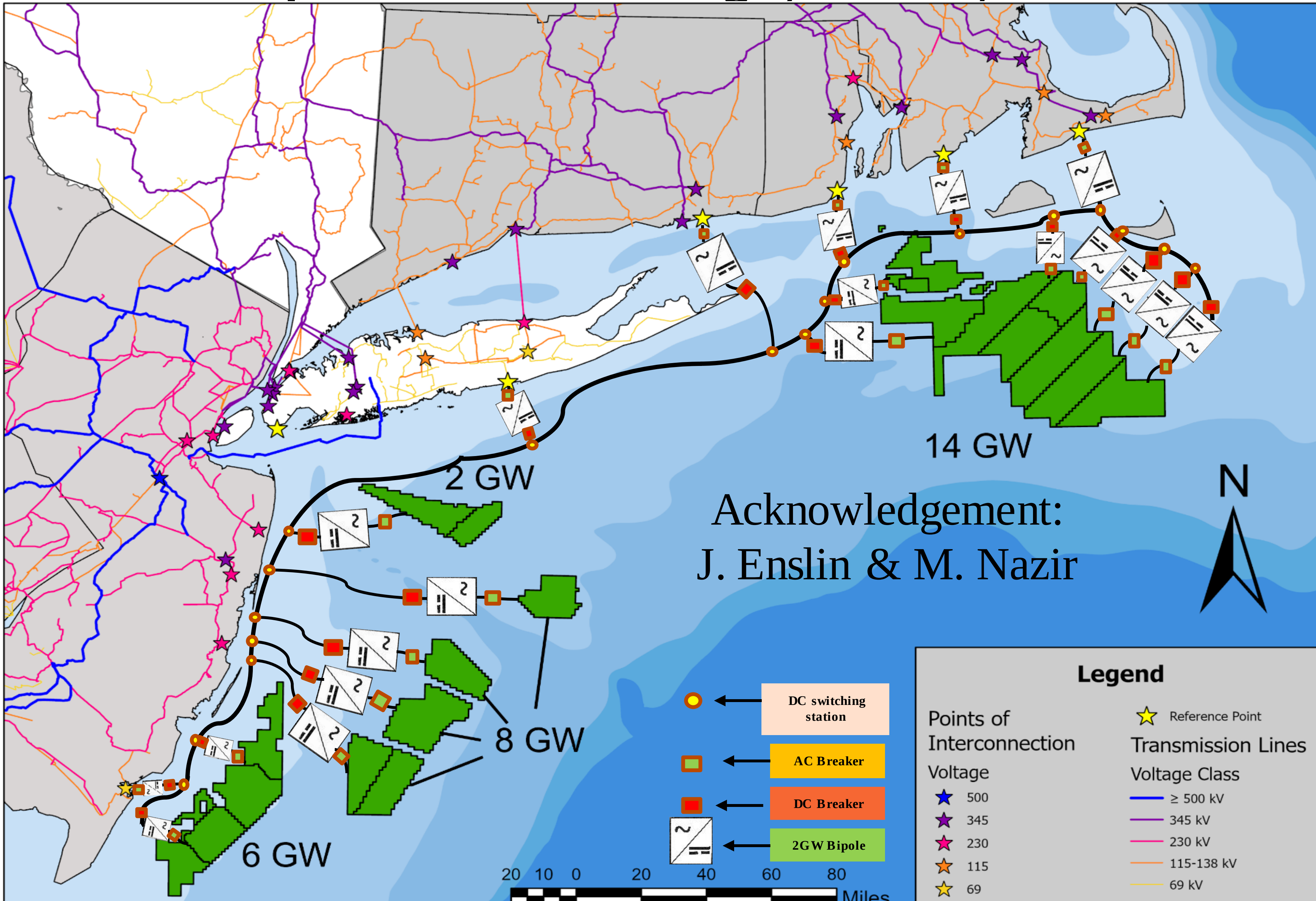




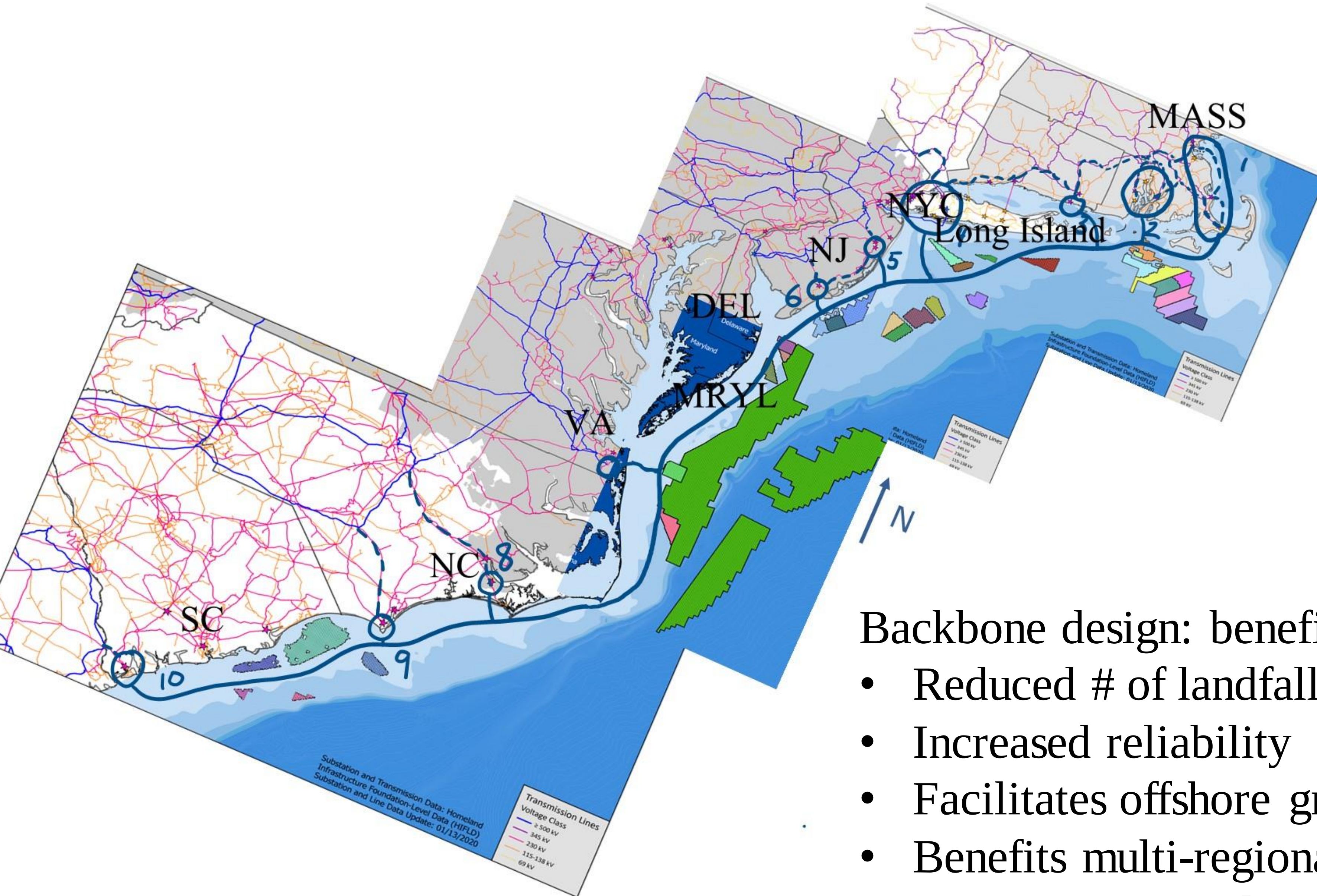


J. Pfeifenberger, "New Yor State+ Regional Transmission Planning, 3/30/22.

30 GW Proposed MTDC Design, ISONE, NYISO & PJM



100+ GW MTDC design, ISONE to S. Carolina

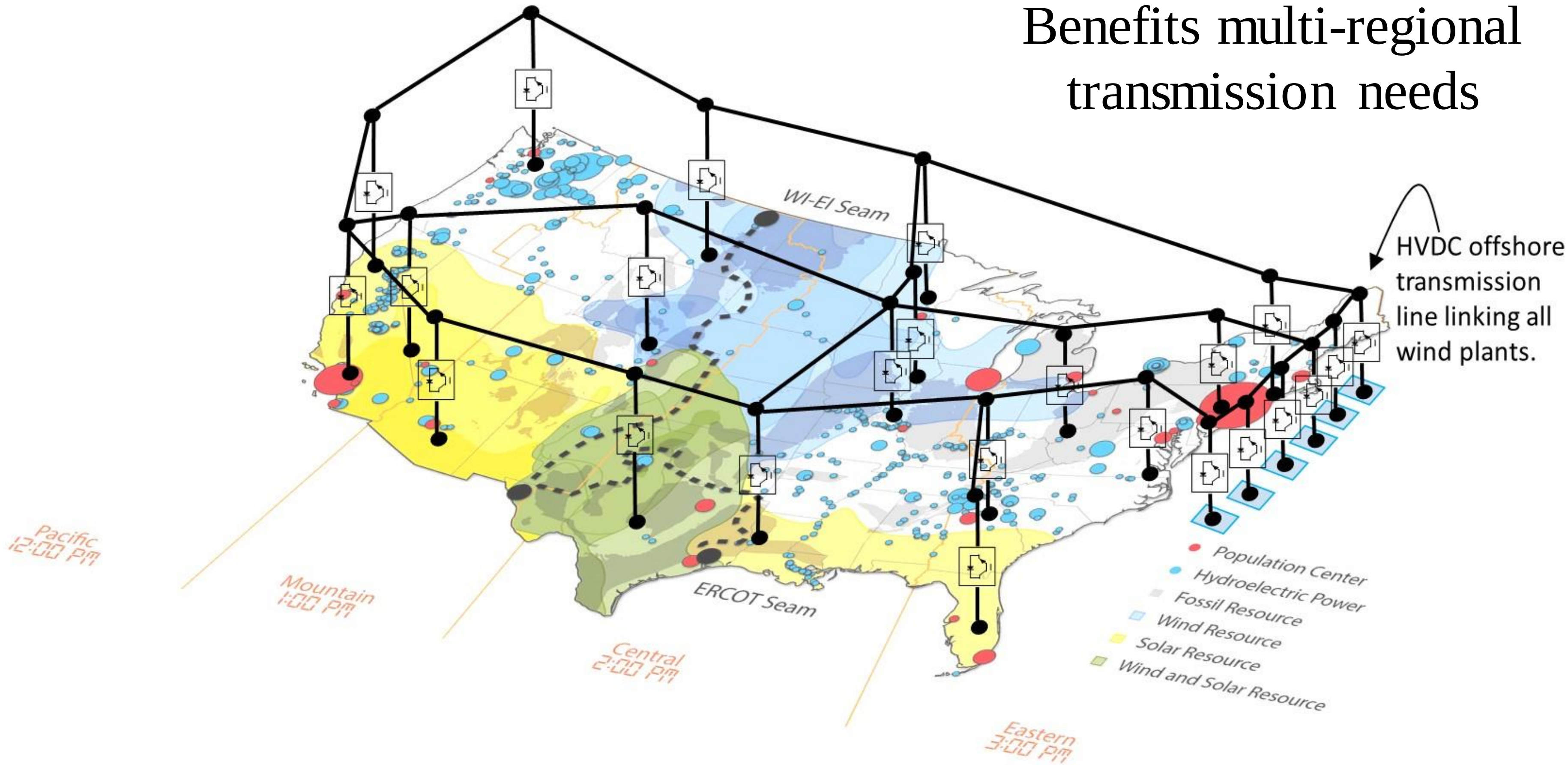


Backbone design: benefits:

- Reduced # of landfalls
- Increased reliability
- Facilitates offshore growth
- Benefits multi-regional transmission needs

A Macrogrid with offshore backbone transmission

Benefits multi-regional transmission needs



Two problems

<u>Problem 1</u>:

Design the offshore transmission system to enable loss of any segment without tripping more than the single-source contingency limit (SSCL).

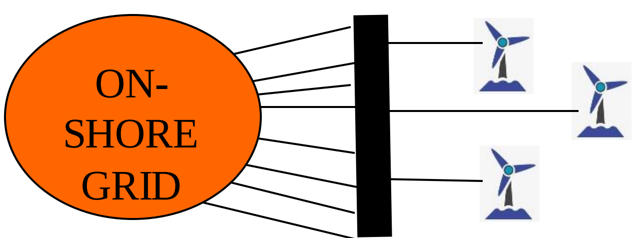
SSCL: limit placed on external and generation interfaces in which losing a single piece of equipment (N-1) could cause a loss > S_{max} MW

www.iso-ne.com/isoexpress/web/reports/operations/-/tree/single-src-cont

www.iso-ne.com/static-assets/documents/2015/07/crop_36004.pdf

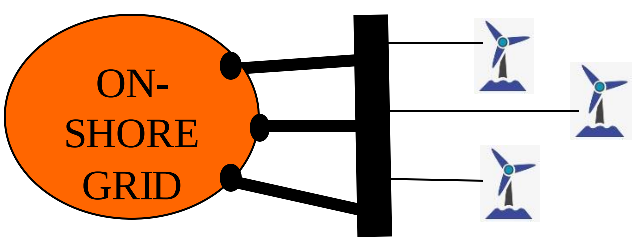
S_{max}=1200-1400 MW.

USE MANY LOW-CAPACITY POIs ➔SATISFIES SSCL



DESIGNING OFFSHORE BACKBONE TRANSMISSION

USE FEW HIGH-CAPACITY POIs ➔VIOLATES SSCL



Two problems

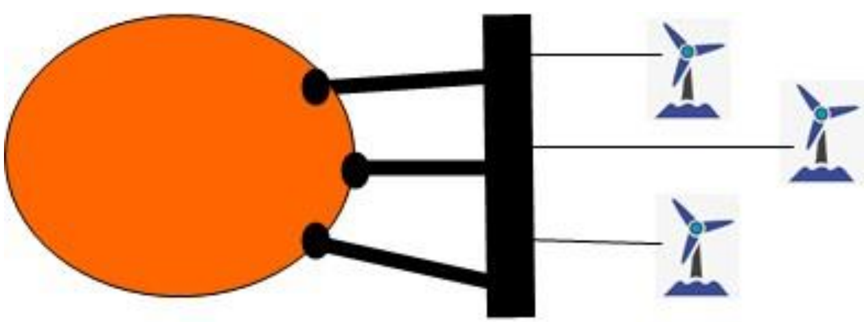
<u>Problem 1</u>:

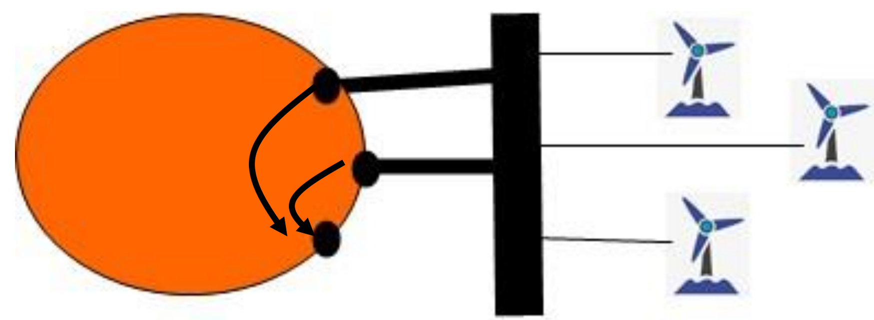
Design the offshore transmission system to enable loss of any segment without tripping more than the single-source contingency limit (SSCL).

DESIGN WITH "RULE OF THREE" GUIDELINE:

- With 2 circuits and 25% emergency overload, you need to derate to 62% capacity to safely sustain a bipole outage➔Lose 38% capacity.
- With 3 circuits, the derating goes to 83% ➔Lose 17% capacity.
- With 4 circuits, the derating goes to 94%➔Lose 6% capacity.

Assumes onshore xfer capability from remaining POIs to outaged POI.



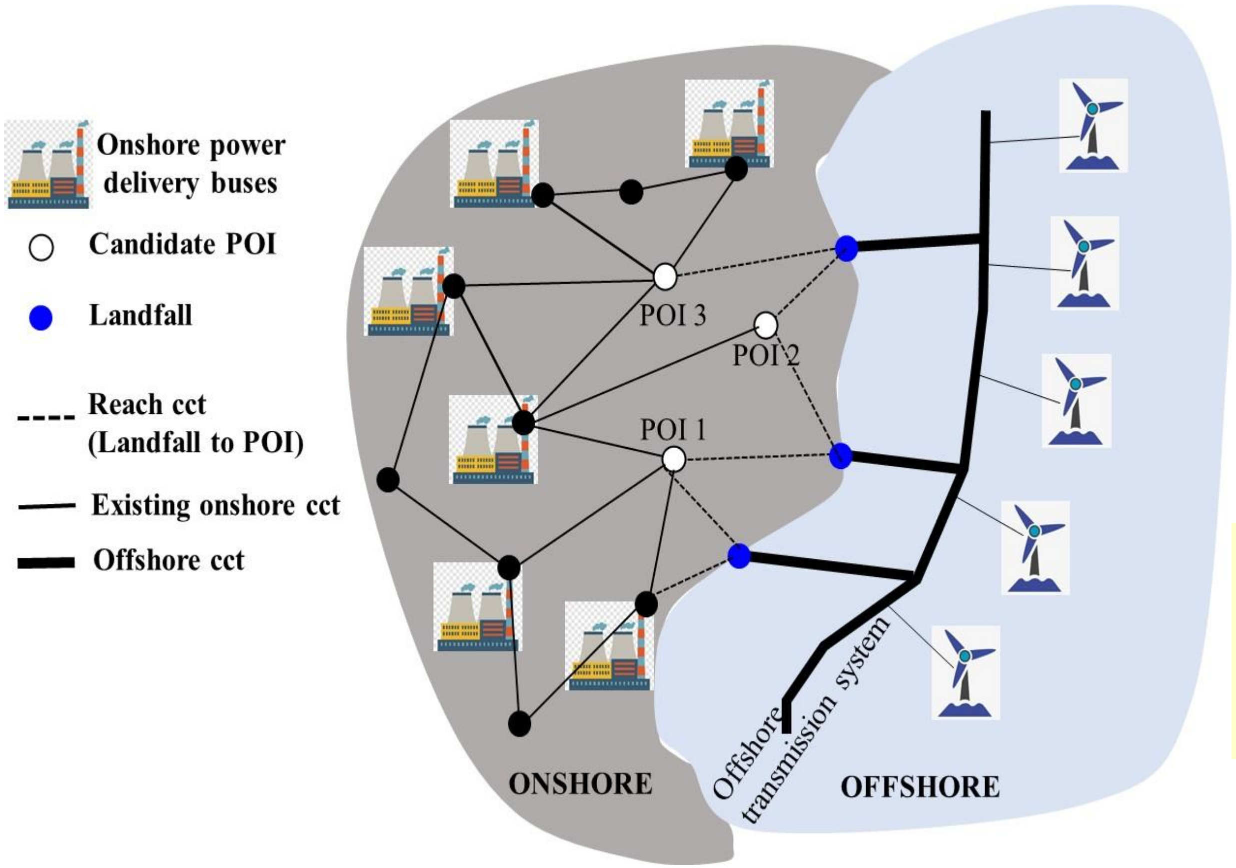


➔THEN YOU LOSE NO POWER FOR POI OUTAGE

Two problems

Problem 2:

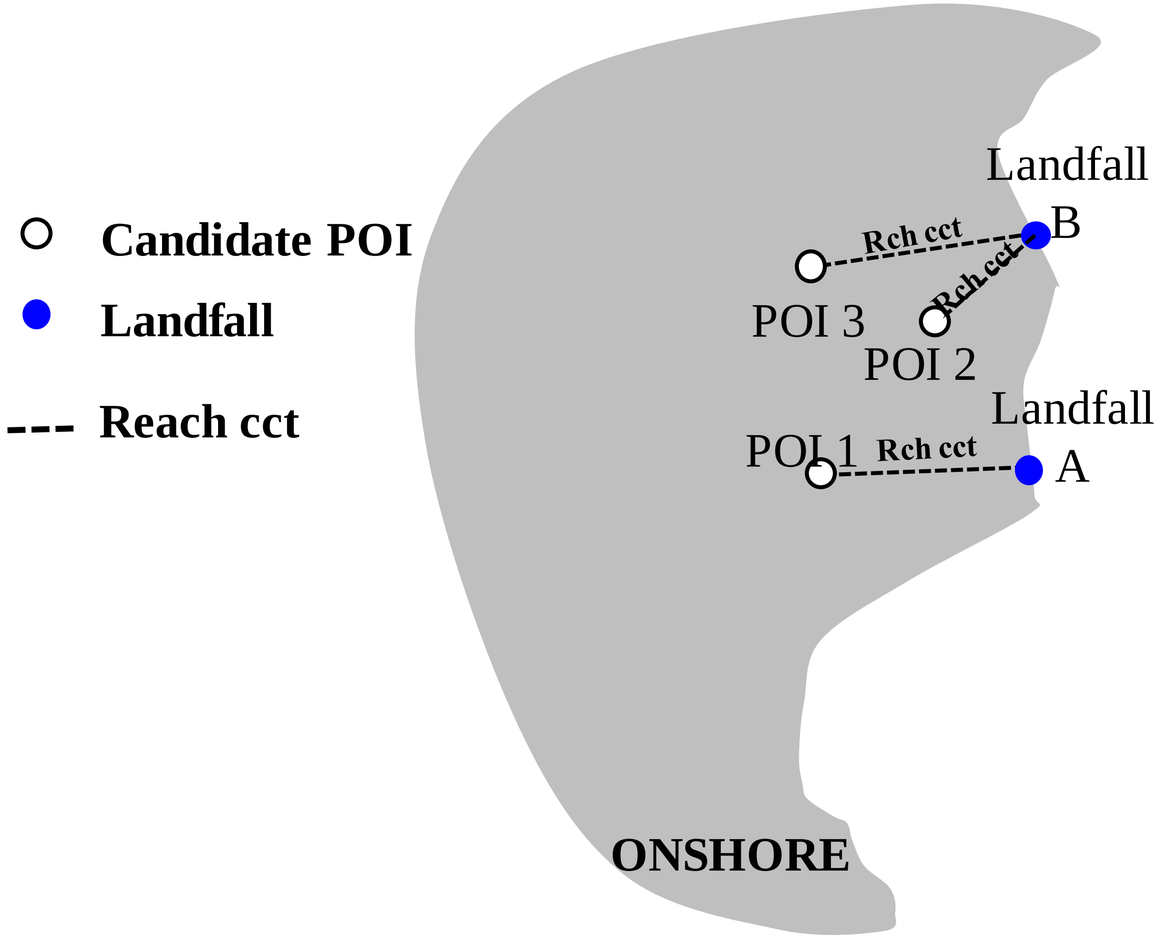
Identify the minimum cost landfalls & POIs to interconnect with a total offshore capacity of C GW.



COSTS:

1. Offshore wind plants
2. Offshore Tx system
3. Reach circuit
4. Onshore expansion
    - Circuits
    - Substations

Reach circuit cost



Each POI has a "closest ref pt" which establishes the reach cct.

Each reach cct cost may be evaluated with high accuracy.

We have approximated:
RchCctCost=(Cost/mile)×Length

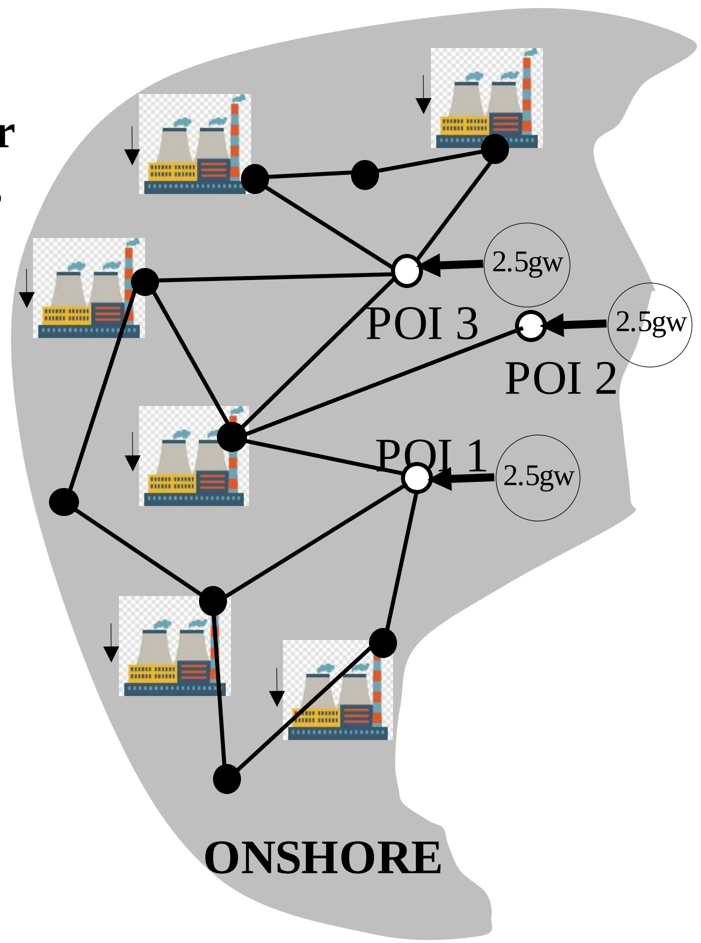
Cost/mile=$4.5M/mile
(high-end of overhead ±500kV bipole HVDC line w/o converter)

Onshore expansion cost

Onshore power delivery buses

Candidate POI

Existing onshore cct



Find least cost POI to inject 2.5 GW

Total cost=Reach cct cost

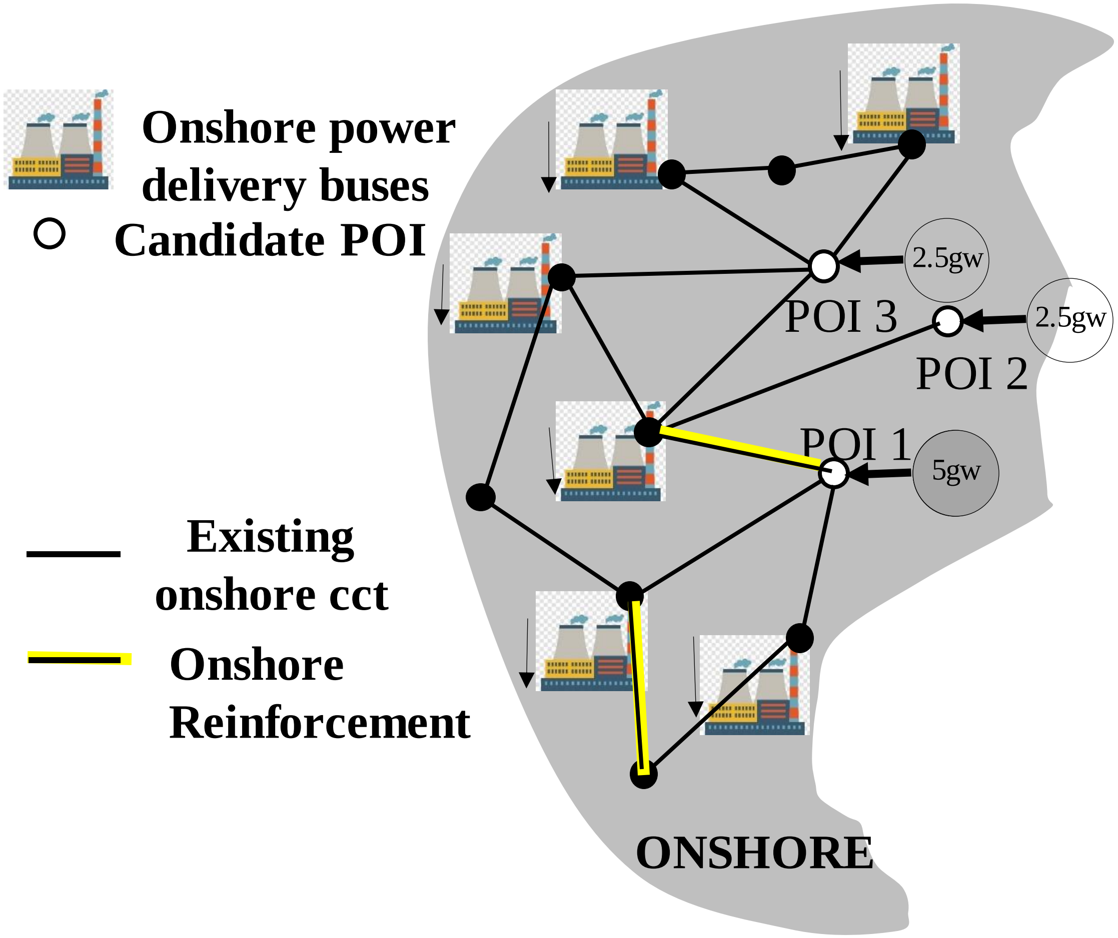
+expansion cost.

Repeat for all POIs.

POI 1:	\$40M
POI 2:	\$50M
POI 3:	\$45M

➔Choose POI 1

Onshore expansion cost



Now we want to find a 2nd POI to inject another 2.5 GW (and thus to have 5 GW total), and we want to do that at least cost.

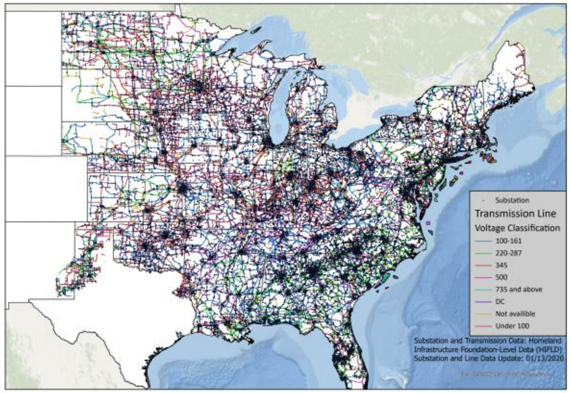
Fix the POI 1, 2.5GW injection and add corresponding reinforcements.

Then evaluate POIs 1, 2 and 3 for an additional 2.5 GW each.

POI 1: $40M
POI 2: $25M
POI 3: $35M

➔Choose POI 2

Reach Cct + Exp Cost Evaluation



- Used 90,000 bus 2031 EI peak power flow case
- Used commercial-grade package TARA to identify all overloads for normal and all N-1 conditions for each 2.5GW injection.

Sending System	Receiving System	Max Test MW	Monitored Facility	Fr Bus	Fr Name	To Bus	To Name	CKT	kVs	TrLim	Dfax	Rate Base	Rate Cont	Cont Name	Cont ID	Base Flow MW (No Transfer)	Cont Flow MW (No Transfer)
100002_ORR	SINK	5000	100002 ORRINGTON 345 103004 S388SCAP 345 2	100002	ORRINGTON	103004	S388SCAP	2	345	414.9	0.86616	1429.4	1429.4	100002 ORRINGTON 345 100004 S3023SCAP 345 2	2	645.5	1070
100002_ORR	SINK	5000	100002 ORRINGTON 345 103004 S388SCAP 345 2	100002	ORRINGTON	103004	S388SCAP	2	345	419	0.86616	1429.4	1429.4	100004 S3023SCAP 345 100092 ALBION ROAD 345 1	5	645.5	1066.4
100002_ORR	SINK	5000	103004 S388SCAP 345 100005 COOPERS MILL 345 1	103004	S388SCAP	100005	COOPERS MILL	1	345	424.9	0.86616	1429	1429	100002 ORRINGTON 345 100004 S3023SCAP 345 2	2	636.6	1061
100002_ORR	SINK	5000	103004 S388SCAP 345 100005 COOPERS MILL 345 1	103004	S388SCAP	100005	COOPERS MILL	1	345	429	0.86616	1429	1429	100004 S3023SCAP 345 100092 ALBION ROAD 345 1	5	636.6	1057.5
100002_ORR	SINK	5000	100004 S3023SCAP 345 100092 ALBION ROAD 345 1	100004	S3023SCAP	100092	ALBION ROAD	1	345	447.7	0.85187	1429	1429	100002 ORRINGTON 345 103004 S388SCAP 345 2	4	485.4	1047.6
100002_ORR	SINK	5000	100004 S3023SCAP 345 100092 ALBION ROAD 345 1	100004	S3023SCAP	100092	ALBION ROAD	1	345	456.8	0.85187	1429	1429	100005 COOPERS MILL 345 103004 S388SCAP 345 1	11	485.4	1039.8
100002_ORR	SINK	5000	126641 MOTT HAVEN 345 126643 RAINEY EAST 345 3	126641	MOTT HAVEN	126643	RAINEY EAST	3	345	468.1	0.09308	785	925	126641 MOTT HAVEN 345 126642 RAINEY WEST 345 4	371	475.3	881.4
100002_ORR	SINK	5000	126641 MOTT HAVEN 345 126642 RAINEY WEST 345 4	126641	MOTT HAVEN	126642	RAINEY WEST	4	345	511	0.09279	785	925	126641 MOTT HAVEN 345 126643 RAINEY EAST 345 3	372	421.4	877.6

- Wrote code, POIA, to process TARA output:

  For each candidate POI,

  For each cct,

  1. Evaluate minimum added capacity to eliminate overloads
  2. Estimate cost of minimum added capacity to eliminate overloads
  3. Compute cost of reach circuit.

➔ Sum cost of #2,#3 across all ccts to get total POI reinforcement cost

Reach Cct + Exp Cost Evaluation

Sending System	Receiving System	Max Test MW	Monitored Facility	Fr Bus	Fr Name	To Bus	To Name	CKT	kVs	TrLim	Dfax	Rate Base	Rate Cont	Cont Name	Cont ID	Base Flow MW (No Transfer)	Cont Flow MW (No Transfer)
100002_ORR	SINK	5000	100002 ORRINGTON 345 103004 S388SCAP 345 2	100002	ORRINGTON	103004	S388SCAP	2	345	414.9	0.86616	1429.4	1429.4	100002 ORRINGTON 345 100004 S3023SCAP 345 2	2	645.5	1070
100002_ORR	SINK	5000	100002 ORRINGTON 345 103004 S388SCAP 345 2	100002	ORRINGTON	103004	S388SCAP	2	345	419	0.86616	1429.4	1429.4	100004 S3023SCAP 345 100092 ALBION ROAD 345 1	5	645.5	1066.4
100002_ORR	SINK	5000	103004 S388SCAP 345 100005 COOPERS MILL 345 1	103004	S388SCAP	100005	COOPERS MILL	1	345	424.9	0.86616	1429	1429	100002 ORRINGTON 345 100004 S3023SCAP 345 2	2	636.6	1061
100002_ORR	SINK	5000	103004 S388SCAP 345 100005 COOPERS MILL 345 1	103004	S388SCAP	100005	COOPERS MILL	1	345	429	0.86616	1429	1429	100004 S3023SCAP 345 100092 ALBION ROAD 345 1	5	636.6	1057.5
100002_ORR	SINK	5000	100004 S3023SCAP 345 100092 ALBION ROAD 345 1	100004	S3023SCAP	100092	ALBION ROAD	1	345	447.7	0.85187	1429	1429	100002 ORRINGTON 345 103004 S388SCAP 345 2	4	485.4	1047.6
100002_ORR	SINK	5000	100004 S3023SCAP 345 100092 ALBION ROAD 345 1	100004	S3023SCAP	100092	ALBION ROAD	1	345	456.8	0.85187	1429	1429	100005 COOPERS MILL 345 103004 S388SCAP 345 1	11	485.4	1039.8
100002_ORR	SINK	5000	126641 MOTT HAVEN 345 126643 RAINEY EAST 345 3	126641	MOTT HAVEN	126643	RAINEY EAST	3	345	468.1	0.09308	785	925	126641 MOTT HAVEN 345 126642 RAINEY WEST 345 4	371	475.3	881.4
100002_ORR	SINK	5000	126641 MOTT HAVEN 345 126642 RAINEY WEST 345 4	126641	MOTT HAVEN	126642	RAINEY WEST	4	345	511	0.09279	785	925	126641 MOTT HAVEN 345 126643 RAINEY EAST 345 3	372	421.4	877.6

NORMAL CONDITIONS

$$\Delta F_{m0}(P_{\max}) = abs\left(\underbrace{TDF_{m0} \times P_{\max}}_{\substack{\text{Flow on line } m \text{ due to} \\ P_{max} \text{ transfer at POI}}} + \underbrace{F_{m0}}_{\text{Flow on line } m \text{ with no transfer}} \right) - \underbrace{RATEA_m}_{\text{Flow limit on line m}}$$

CONTINGENCY CONDITIONS

$$\Delta F_{mc}(P_{\max}) = \frac{1}{k_{rating}} \left[abs\left(\underbrace{TDF_{mc} \times P_{\max}}_{\substack{\text{Flow on line } m \text{ due to} \\ P_{max} \text{ transfer at POI}}} + \underbrace{F_{mc}}_{\substack{\text{Flow on line } m \text{ following} \\ \text{contingency } c \text{ but with no transfer}}} \right) - \underbrace{RATEB_m}_{\text{Flow limit on line m}} \right]$$

$$\Delta F_{m,\max} = \max_c \left\{ \Delta F_{mc}(P_{\max}) \right\}$$

Cost Data

Line cost per MW-mile* for each kV [1]

Nominal voltage (kV)	Cost ($M/MW-mile)
765	0.0013
735	0.0017
500	0.0026
345	0.0046
230	0.0092
161	0.0147
138	0.0210
115	0.0250
100	0.0300
60	0.0450

*** Line length estimated based on reactance**

Xfmr cost per MVA [1]

ID	ratio *nv1:nv2*	Cost ($/MVA)
1	69/115	4139
2	69/138	4581
3	69/161	4822
4	69/230	5348
5	69/345	6566
6	69/500	8468
7	69/765	11914
8	115/138	4581
9	115/161	4822
10	115/230	5348
11	115/345	6241
12	115/500	7659
13	115/765	9802
14	138/161	6241
15	138/230	5348
16	138/345	6241
17	138/500	7659
18	138/765	9802
19	161/230	5631
20	161/345	6566
21	161/500	8058
22	161/765	9802
23	230/345	6566
24	230/500	8058
25	230/765	9802
26	345/500	8466
27	345/765	10286
28	500/765	11347

[1] MidContinent Independent System Operator (MISO), "Transmission Cost Estimation Guide for MTEP 22," April, 2022. Available, 20220208 PSC Item 05c Transmission Cost Estimation Guide for MTEP22 Draft622733.pdf (misoenergy.org).

Candidate POIs

Bus name	Bus kV	Bus #	Area #	Area Name	Zone #	Zone Name	Distance to Ref Pt (miles)
ROCK_TAV	345	125001	7	HUDSON___	154	CENT HUD____	75
PLTVLLEY	345	126294	7	HUDSON___	176	CE AREA 7___	80
RAMAPO	345	126297	7	HUDSON___	176	CE AREA 7___	55
CRICKET_VLLY	345	128284	7	HUDSON___	154	CENT HUD____	50
E_FISHKILL	345	126281	8	MILLWOOD_	167	CE AREA 9___	60
MILLWOOD	345	126291	8	MILLWOOD_	167	CE AREA 9___	40
SPRAINBROOK	345	126298	9	DUNWOODIE	169	CE AREA 8___	45
DUNWOODIE	345	126266	9	DUNWOODIE	169	CE AREA 8___	40
GOETHLS	345	126283	10	NYC______	159	CE AREA 10__	10
GOWANUS	345	126287	10	NYC______	159	CE AREA 10__	10
W_49_ST	345	126304	10	NYC______	159	CE AREA 10__	25
MOTT_HAVEN	345	126641	10	NYC______	159	CE AREA 10__	20
RAINEY_WEST	345	126642	10	NYC______	159	CE AREA 10__	20
RAINEY_EAST	345	126643	10	NYC______	159	CE AREA 10__	20
FARRAGUT_WES	345	126644	10	NYC______	159	CE AREA 10__	10
FARRAGUT_EAS	345	126645	10	NYC______	159	CE AREA 10__	10
ASTORIA2	138	126353	10	NYC______	159	CE AREA 10__	10
ACADEMY	345	126847	10	NYC______	159	CE AREA 10__	17
SHORE_RD	345	128835	11	L ISLAND_	156	LIPA________	20
EHAMP	69	129868	11	L ISLAND_	156	LIPA________	1
HOLBROOK	138	129421	11	L ISLAND_	156	LIPA________	9
BARRETT	138	129202	11	L ISLAND_	156	LIPA________	1
RULAND RD	69	129692	11	L ISLAND_	156	LIPA________	10
NORTHPORT	138	129341	11	L ISLAND_	156	LIPA________	25
NEWBRIDGE	138	129310	11	L ISLAND_	156	LIPA________	10
PILGRIM	138	129355	11	L ISLAND_	156	LIPA________	20
E.G.C.-1	345	128822	11	L ISLAND_	156	LIPA________	10

Using 90,000 bus HS31 90/10 Case.

GOAL: Find least-cost POI's for delivering 8515 MW to NYISO.

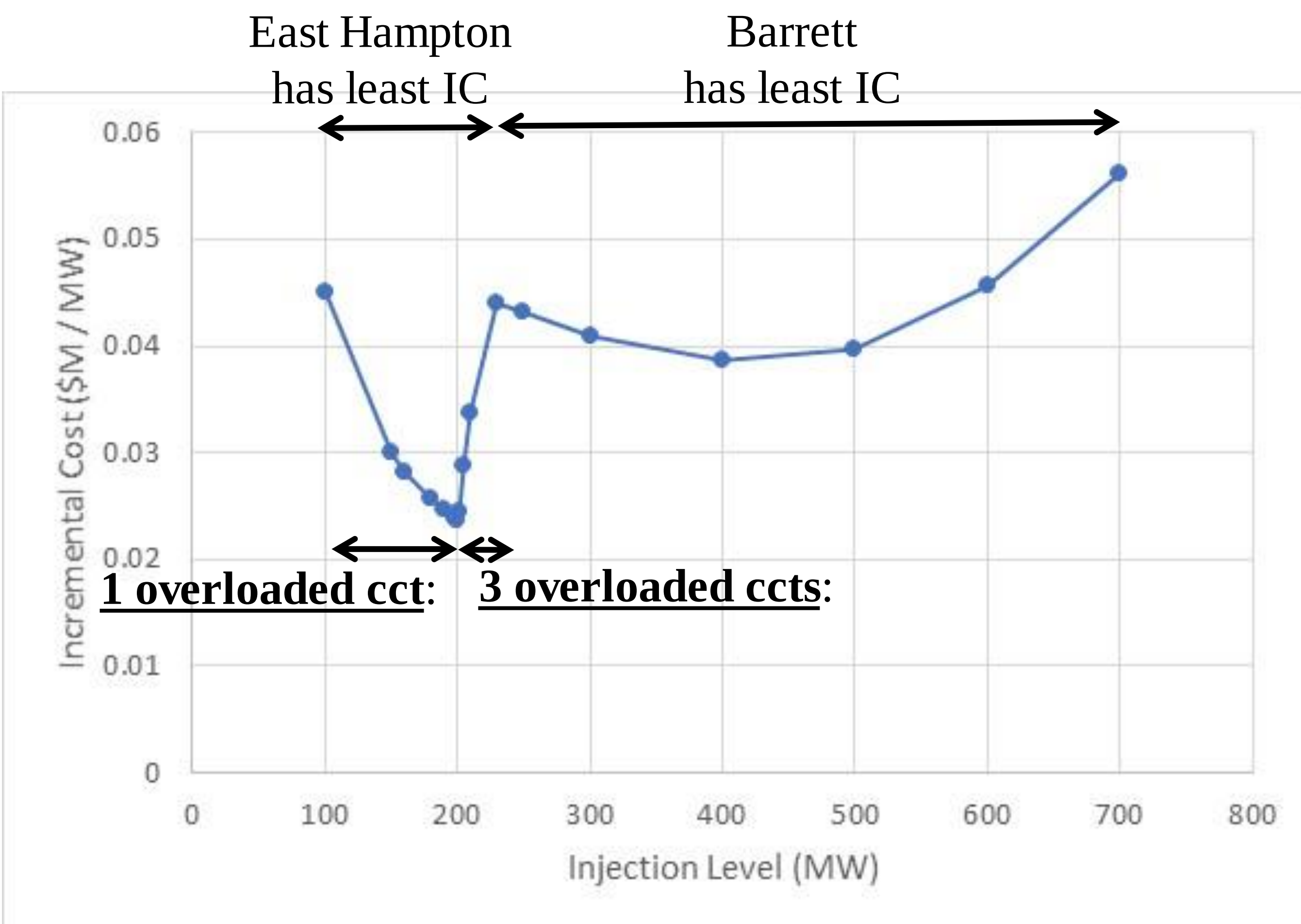
Iteration 1: 600 MW capacity

POI_NAME	POI_kV	Area#	AreaName	Zone#	ZoneName	# of Expanded Ccts	Line exp need (MWmiles)	Xfmr exp need (MW)	ReachCct Cost	Expan Cost ($M)	TotalCost ($M)	Incremental Cost ($M/MW)
129202_BARRETT1____	138	11	L ISLAND_	156	LIPA________	11	1146.8632	8.316	4.5	22.91578	27.41578	0.045693
129421_HOLBROOK____	138	11	L ISLAND_	156	LIPA________	4	163.7754	0	40.5	1.248007	41.74801	0.06958
126644_FARRAGUT_WES	345	10	NYC______	159	CE AREA 10__	0	0	0	45	0	45	0.075
126645_FARRAGUT_EAS	345	10	NYC______	159	CE AREA 10__	0	0	0	45	0	45	0.075
129310_NEWBRGE_____	138	11	L ISLAND_	156	LIPA________	6	181.70866	0	45	1.835898	46.8359	0.07806
128822_E.G.C.-1____	345	11	L ISLAND_	156	LIPA________	9	197.63455	509.0592	45	5.437625	50.43763	0.084063
129692_RULND_RD____	69	11	L ISLAND_	156	LIPA________	14	722.94811	0	45	26.41193	71.41193	0.11902
126847_ACADEMY_____	345	10	NYC______	159	CE AREA 10__	2	119.52748	0	76.5	0.549826	77.04983	0.128416
126642_RAINEY_WEST_	345	10	NYC______	159	CE AREA 10__	0	0	0	90	0	90	0.15
126643_RAINEY_EAST_	345	10	NYC______	159	CE AREA 10__	0	0	0	90	0	90	0.15
128835_SHORE_RD____	345	11	L ISLAND_	156	LIPA________	2	135.39942	0	90	0.622837	90.62284	0.151038
129355_PILGRIM_____	138	11	L ISLAND_	156	LIPA________	7	197.95921	0	90	2.675148	92.67515	0.154459
126641_MOTT_HAVEN__	345	10	NYC______	159	CE AREA 10__	2	1031.3299	0	90	4.744117	94.74412	0.157907
126304_W_49_ST_____	345	10	NYC______	159	CE AREA 10__	0	0	0	112.5	0	112.5	0.1875
129341_NRTHPRT1____	138	11	L ISLAND_	156	LIPA________	10	1204.1035	0	112.5	23.80418	136.3042	0.227174
126287_GOWANUS_____	345	10	NYC______	159	CE AREA 10__	4	20154.6	0	45	92.71116	137.7112	0.229519
126353_ASTORIA_W-N_	138	10	NYC______	159	CE AREA 10__	13	4937.8038	51.536	45	104.0155	149.0155	0.248359
126283_GOTHLS______	345	10	NYC______	159	CE AREA 10__	7	23748.632	0	45	109.2437	154.2437	0.257073
126291_MILLWOOD____	345	8	MILLWOOD_	167	CE AREA 9___	2	121.2759	0	180	0.557869	180.5579	0.30093
126266_DUNWOODIE___	345	9	DUNWOODIE	169	CE AREA 8___	2	135.39942	0	180	0.622837	180.6228	0.301038
126298_SPRAINBROOK_	345	9	DUNWOODIE	169	CE AREA 8___	2	119.52748	0	202.5	0.549826	203.0498	0.338416
129868_EHAMP_______	69	11	L ISLAND_	156	LIPA________	21	4790.5651	0	4.5	209.4564	213.9564	0.356594
128284_CRICKET_VLLY	345	7	HUDSON___	154	CENT HUD____	2	125.54839	0	225	0.577523	225.5775	0.375963
126297_RAMAPO______	345	7	HUDSON___	176	CE AREA 7___	2	122.38552	0	247.5	0.562973	248.063	0.413438
126281_E_FISHKILL__	345	8	MILLWOOD_	167	CE AREA 9___	2	126.84497	0	270	0.583487	270.5835	0.450972
125001_ROCK_TAV____	345	7	HUDSON___	154	CENT HUD____	2	124.075	0	337.5	0.570745	338.0707	0.563451
126294_PLTVLLEY____	345	7	HUDSON___	176	CE AREA 7___	2	125.54839	0	360	0.577523	360.5775	0.600963

Iteration 1: 200 MW capacity

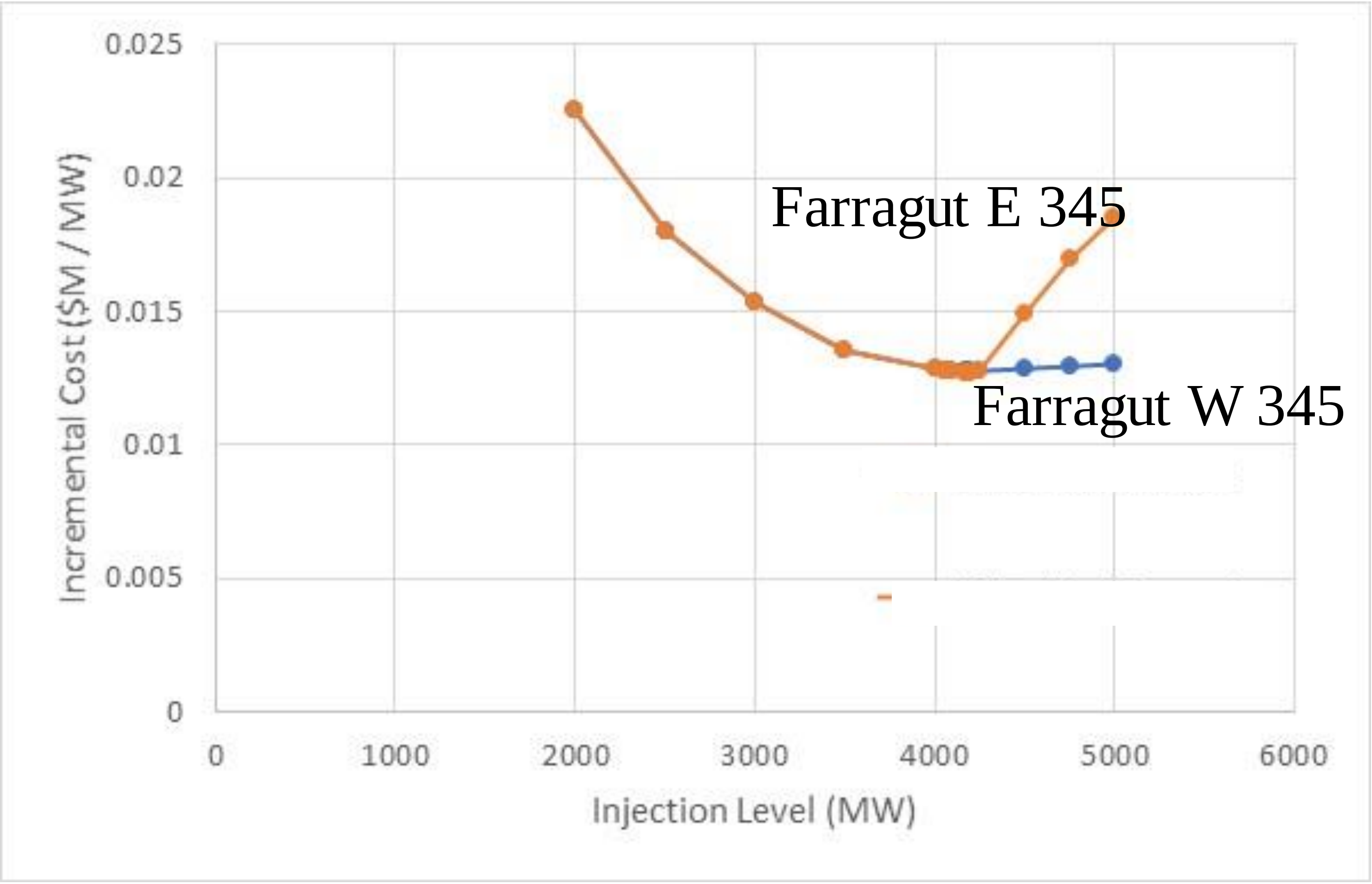
POI_NAME	POI_kV	Area#	AreaName	Zone#	ZoneName	# of Expanded Ccts	Line exp need (MWmiles)	Xfmr exp need (MW)	ReachCct Cost	Expan Cost ($M)	TotalCost ($M)	Incremental Cost ($M/MW)
129868_EHAMP________	69	11	L ISLAND_	156	LIPA________	1	5.474895	0	4.5	0.24637	4.74637	0.023732
129202_BARRETT1____	138	11	L ISLAND_	156	LIPA________	3	228.80154	0	4.5	4.827432	9.327432	0.046637
129421_HOLBROOK____	138	11	L ISLAND_	156	LIPA________	0	0	0	40.5	0	40.5	0.2025
126283_GOTHLS______	345	10	NYC______	159	CE AREA 10__	0	0	0	45	0	45	0.225
126287_GOWANUS_____	345	10	NYC______	159	CE AREA 10__	0	0	0	45	0	45	0.225
126644_FARRAGUT_WES	345	10	NYC______	159	CE AREA 10__	0	0	0	45	0	45	0.225
126645_FARRAGUT_EAS	345	10	NYC______	159	CE AREA 10__	0	0	0	45	0	45	0.225
129310_NEWBRGE_____	138	11	L ISLAND_	156	LIPA________	0	0	0	45	0	45	0.225
129692_RULND_RD____	69	11	L ISLAND_	156	LIPA________	0	0	0	45	0	45	0.225
126353_ASTORIA_W-N_	138	10	NYC______	159	CE AREA 10__	1	1.950094	0	45	0.040952	45.04095	0.225205
128822_E.G.C.-1____	345	11	L ISLAND_	156	LIPA________	2	0.158926	71.12	45	0.451012	45.45101	0.227255
126847_ACADEMY_____	345	10	NYC______	159	CE AREA 10__	0	0	0	76.5	0	76.5	0.3825
126642_RAINEY_WEST_	345	10	NYC______	159	CE AREA 10__	0	0	0	90	0	90	0.45
126643_RAINEY_EAST_	345	10	NYC______	159	CE AREA 10__	0	0	0	90	0	90	0.45
128835_SHORE_RD____	345	11	L ISLAND_	156	LIPA________	0	0	0	90	0	90	0.45
129355_PILGRIM_____	138	11	L ISLAND_	156	LIPA________	0	0	0	90	0	90	0.45
126641_MOTT_HAVEN__	345	10	NYC______	159	CE AREA 10__	2	266.24974	0	90	1.224749	91.22475	0.456124
126304_W_49_ST_____	345	10	NYC______	159	CE AREA 10__	0	0	0	112.5	0	112.5	0.5625
129341_NRTHPRT1____	138	11	L ISLAND_	156	LIPA________	3	237.59417	0	112.5	4.989478	117.4895	0.587447
126266_DUNWOODIE___	345	9	DUNWOODIE	169	CE AREA 8___	0	0	0	180	0	180	0.9
126291_MILLWOOD____	345	8	MILLWOOD_	167	CE AREA 9___	0	0	0	180	0	180	0.9
126298_SPRAINBROOK_	345	9	DUNWOODIE	169	CE AREA 8___	0	0	0	202.5	0	202.5	1.0125
128284_CRICKET_VLLY	345	7	HUDSON___	154	CENT HUD___	0	0	0	225	0	225	1.125
126297_RAMAPO______	345	7	HUDSON___	176	CE AREA 7___	0	0	0	247.5	0	247.5	1.2375
126281_E_FISHKILL__	345	8	MILLWOOD_	167	CE AREA 9___	0	0	0	270	0	270	1.35
125001_ROCK_TAV____	345	7	HUDSON___	154	CENT HUD___	0	0	0	337.5	0	337.5	1.6875
126294_PLTVLLEY____	345	7	HUDSON___	176	CE AREA 7___	0	0	0	360	0	360	1.8

Iteration 1: Incremental Cost Curve



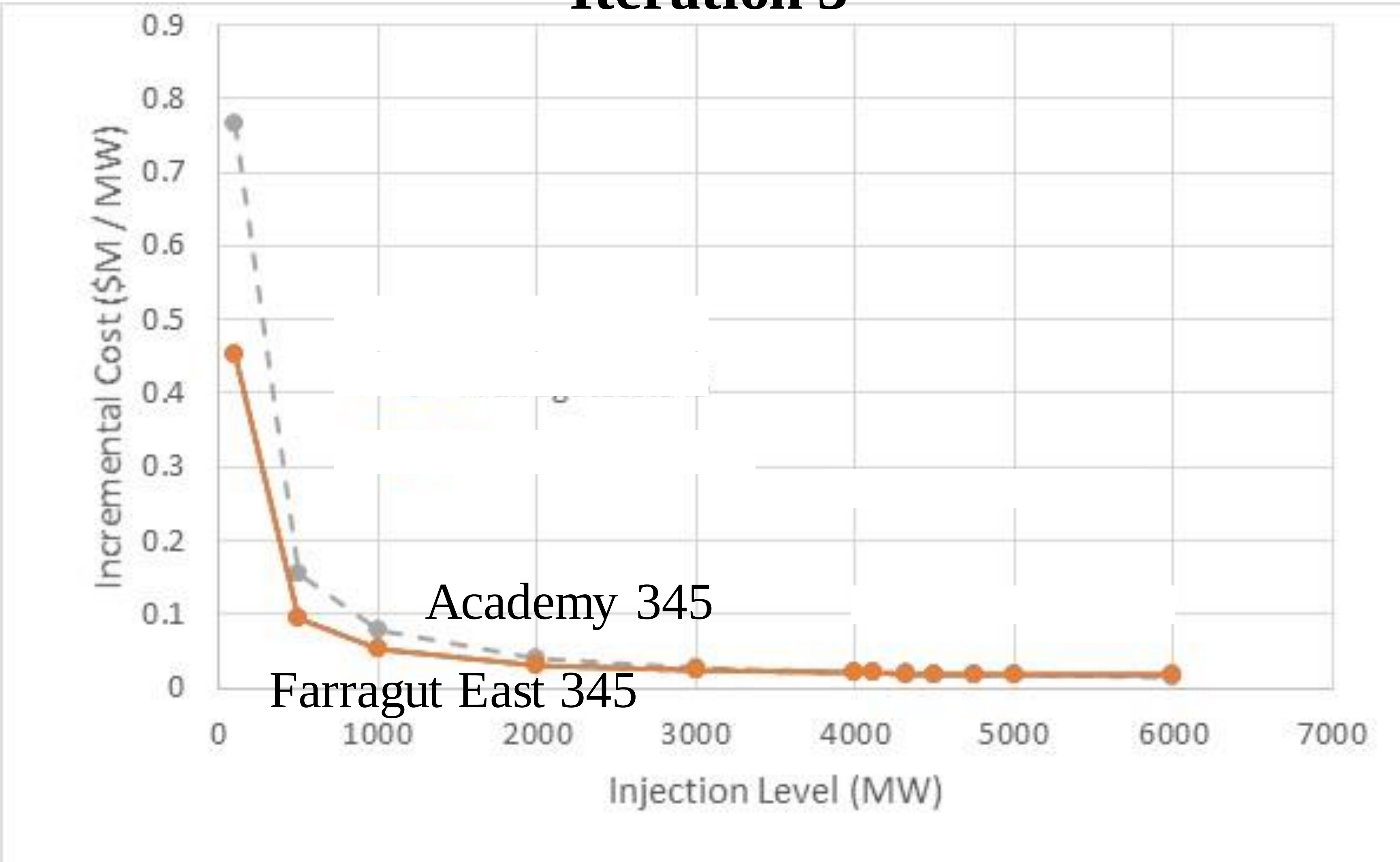
CONCLUSION: Model 200 MW at BUS A, together with necessary reinforcements

Iteration 2



CONCLUSION: Model 4200 MW at BUS C, together with necessary reinforcements

Iteration 3



CONCLUSION: Model 4115 MW at BUS E, together with necessary reinforcements

Final Result

Bus	Capacity (MW)	
	Industry info (via NREL)	This method
Gowanus 345	816	0
Astoria 138	1230	0
Farragut East 345	1310	2100
Farragut West 345	1310	2100
W. 49th 345	1310	0
East Hampton 69	139	200
Holbrook 138	1050	0
Barrett 138	1350	0
Academy 345 kV	0	4115
TOTAL NYISO	**8515**	**8515**

Optimality

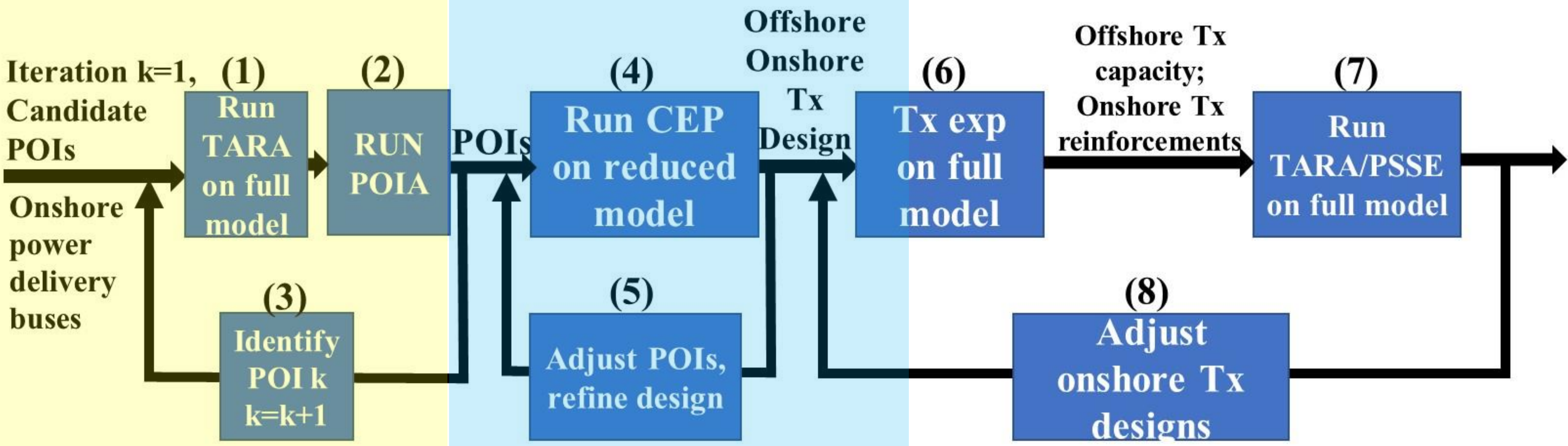
This approach gives us good but not best solutions.

The reason is that each POI injection changes flows seen by future POI selections, i.e., POI cost is path-dependent (it matters how you got there).

At each step, we are guaranteed to select next the best single POI, but this approach does not ensure the next pair of POIs will be best.

After selecting A and B, we are guaranteed that C will be the best choice. But after selecting A, it may be that D-E is better than B-C.

Overall Offshore/Onshore Design Approach

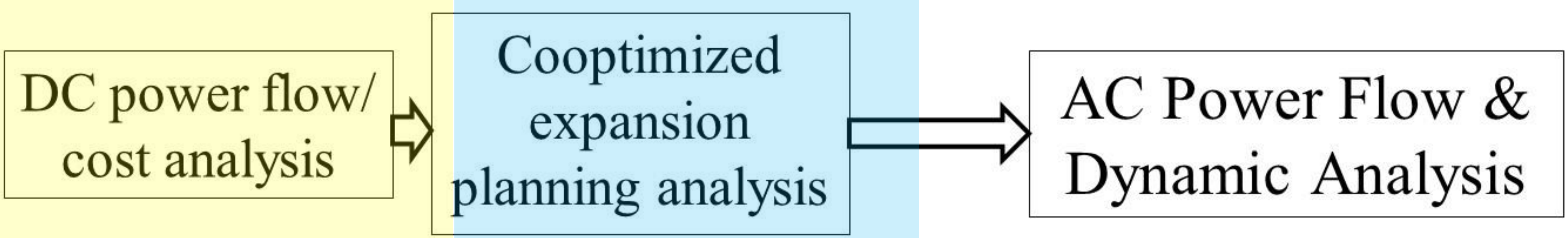


USE TARA/POIA ON FULL MODEL TO IDENTIFY POIs

USE TARA/PSSE ON FULLMODEL TO REFINE OFFSHORE & ONSHORE DESIGN

CEP offers ability to study interdependencies between

- offshore trans design
- POI selection+capacity
- Onshore expansion cost



Conclusion: Two critical issues for offshore wind

Cost allocation:

➔Who pays for offshore trans backbone? Developers; local, state, fed govt

➔Who pays for onshore trans reinforcements? Transcos; local & state govt.

Principle: Government should participate at the highest level for which no lower level can represent all beneficiaries.

NJ/PJM STATE AGREEMENT APPROACH asked developers to submit:

1. Onshore upgrades to the existing grid
2. Onshore new transmission connection facilities;
3. Offshore new transmission connection facilities (landfall & offshore substations);
4. Offshore network (backbone/networked offshore grid)

Received 80 proposals from 13 transmission developers.

➔See J. Pfeifenberger, et al., “New Jersey State Agreement Approach for Offshore Wind Transmission: Evaluation Report,” Oct. 26, 2022.

Multiregional transmission operation:

➔Who operates the backbone transmission system?

Principle: Seek collaborative development of requirements & guidelines from operational organizations affected by the backbone transmission.

Questions?

James McCalley

(jdm@iastate.edu)