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The ENGINE Model: Determining optimal development of the Irish electricity sector under different policy scenarios

esipp Energy Systems Integration Partnership Programme

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Presentation Outline

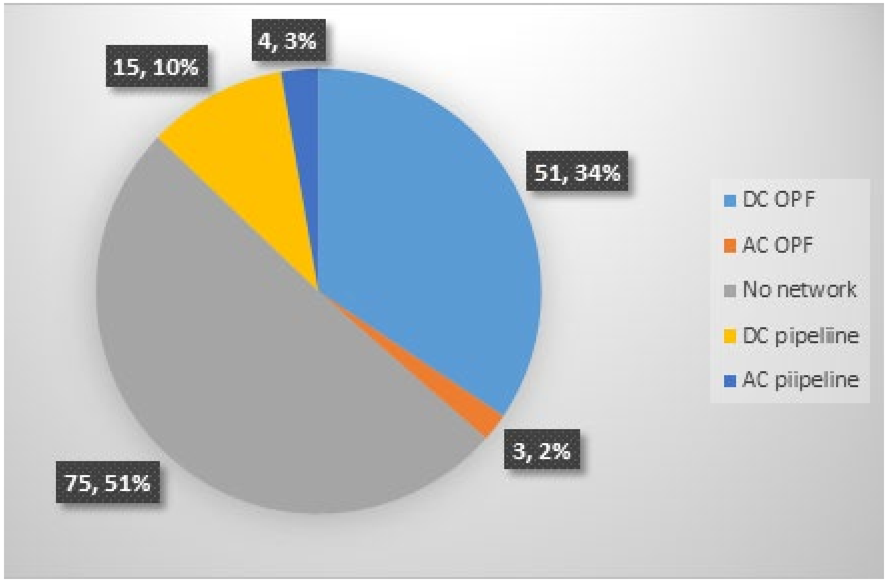
- Introduction
- The ENGINE Model
- Application Examples
  - Insights from Irish Case Study
- Summary

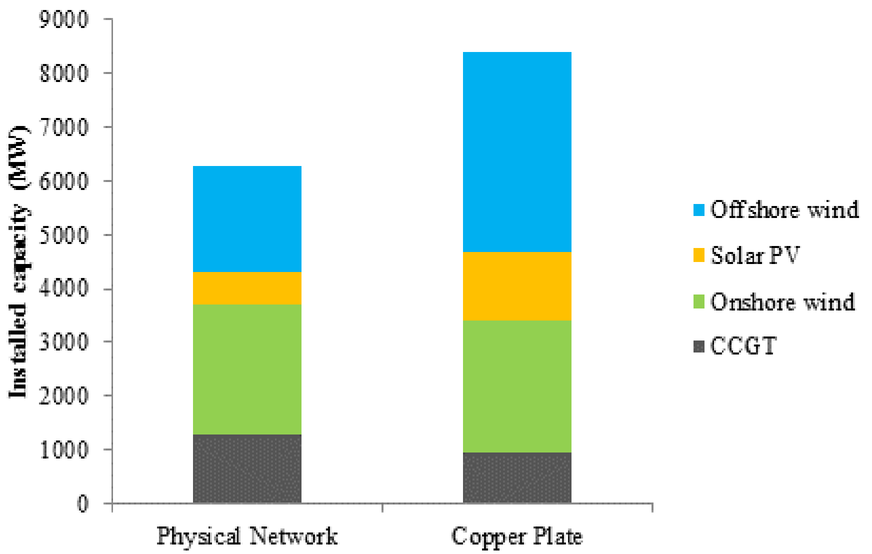
Introduction (1/2)

- EU-wide ambitious targets for emission reduction
  - 80% below the 1990 level [EC 2017, 2050 Low-carbon Economy]
  - All energy sectors are expected to contribute to this goal.
- In particular, a massive electrification of heating and transport sectors is anticipated in the coming years.
  - And, the energy has to be sourced from renewables and renewables only
- Increased renewable generation and electrification of energy sectors (other than electricity) is posing new challenges for power system planners.
  - Variability and uncertainty
- The location, as well as the level and operation, of each generation resource is increasingly important.
  - Implications on costs, emissions, grid reinforcements and technical issues
- Many commercial and public models exist:
  - **Integrated energy system models** such as TIMES, PRIMES, MESSAGE, POLES, OSeMOSYS, MARKAL, REDS, NEMS, ……………………….., **BACKBONE**
  - **Energy models** such as PLEXOS, BALMOREL, METIS, NePlan, LEAP, ...
  - **Power system models** such as FAST, WILMAR, Promod, ……, **ENGINE**

Introduction (2/2)

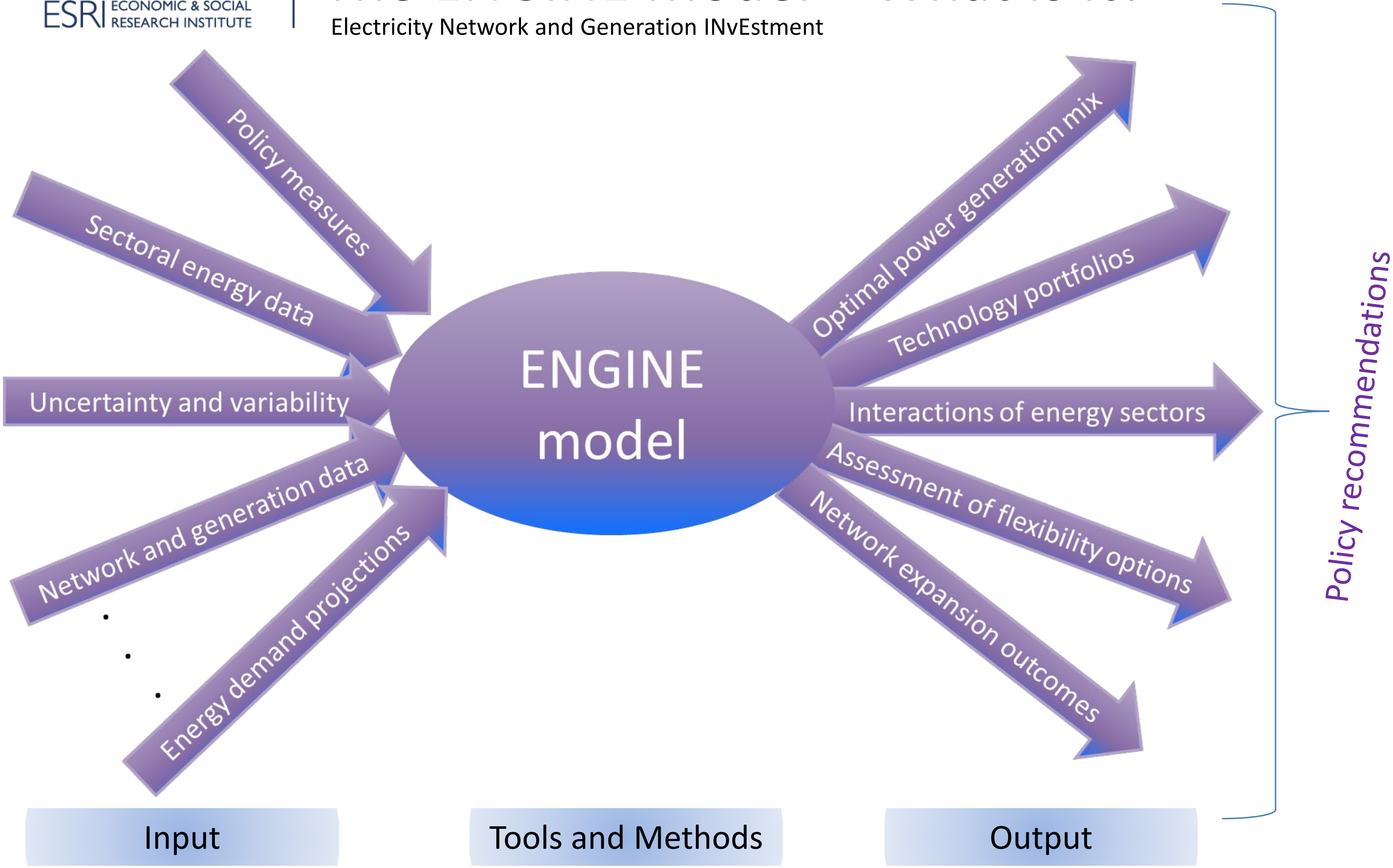
- Also, several models in the extant literature
- However, most fail to account for **spatial aspects** and electricity **network effects**.
- Hence, solutions obtained without considering these effects may prove infeasible or suboptimal.
- This is especially important in insular and weakly interconnected systems.
- E.g. for the Irish case, a Copper Plate assumption may lead to a totally different expansion solution that is 26% less expensive as compared to the model that uses a “Physical Network”.
- The ENGINE model has evolved because of all these issues.



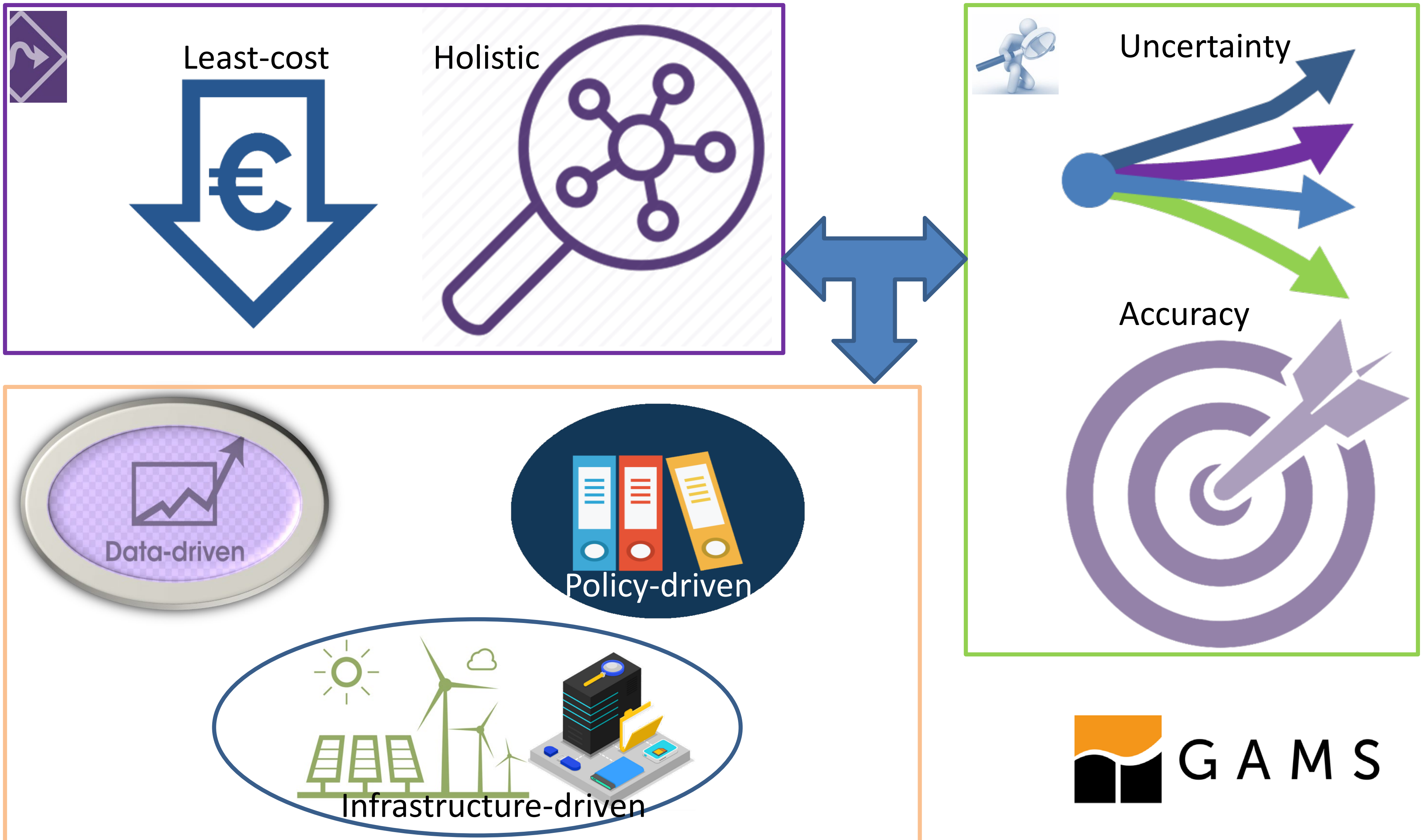


The ENGINE Model – What Is It?

Electricity Network and Generation INvEstment

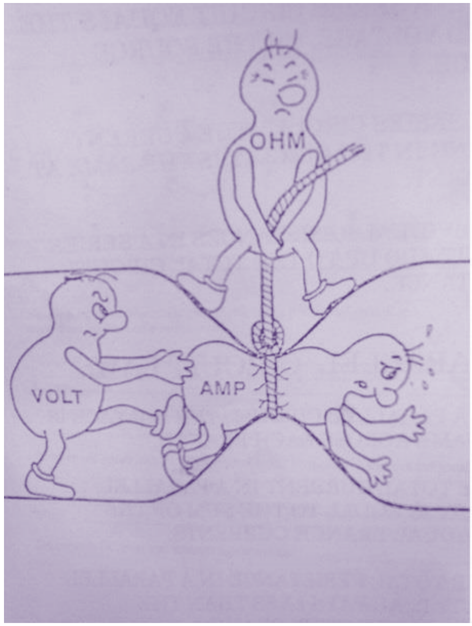


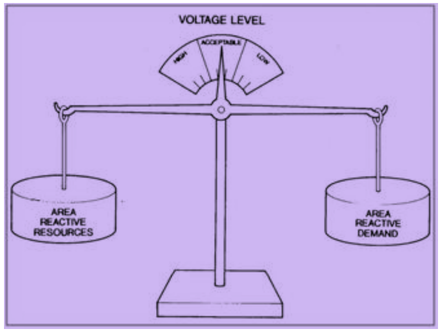
The ENGINE Model – Key Features (1/3)



The ENGINE Model – Key Features (2/3)

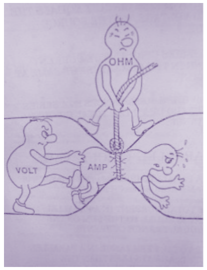
- Reasonably accurate representation of the physical characteristics of power systems via
  - Linearized AC optimal power flow based network model
  - Considers both active and reactive power flows in a linear manner.
  - Captures natural voltage magnitude deviations from nominal values across electric transmission systems.
- Generally, the model closely resembles the AC optimal power flow one, which governs flows in power systems.





The ENGINE Model – Key Features (1/3)

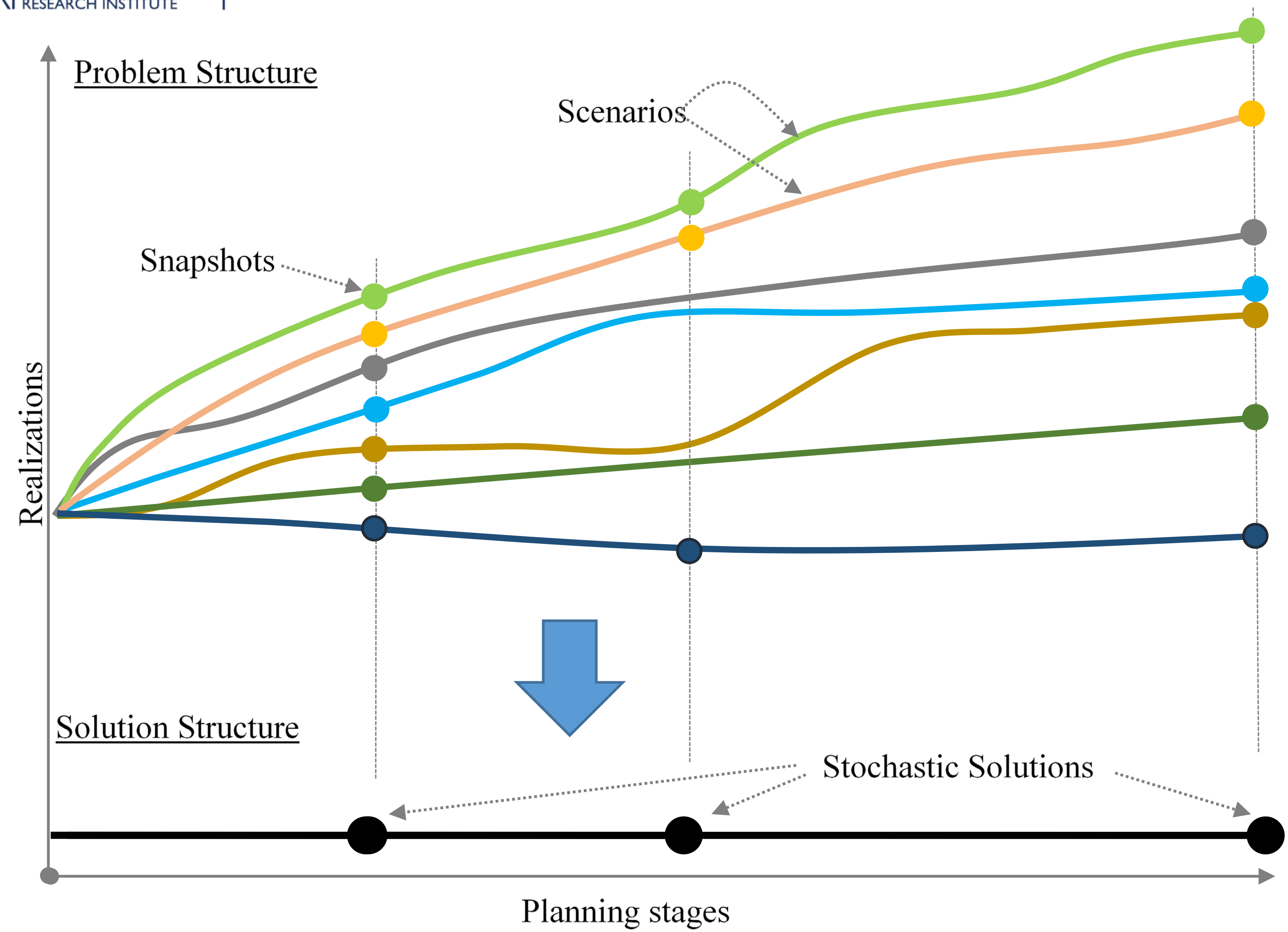
- Objective function
  - Minimize TC = Investment Cost + O&M Cost + Unserved Power Cost + Emission Cost
- Constraints:
  - Active and reactive power load balances at each transmission node (Kirchhoff's current law)
  - Flow limits
  - Constraints related to network losses
  - Active and reactive power flows (Kirchhoff's voltage law)
  - Power production limits
  - Logical and budget constraints
  - Reactive power source limits
  - Renewable portfolio standard (RPS) limit
  - Spatial renewable allocation constraints
  - System non-synchronous penetration (SNSP) limit



Reactive power

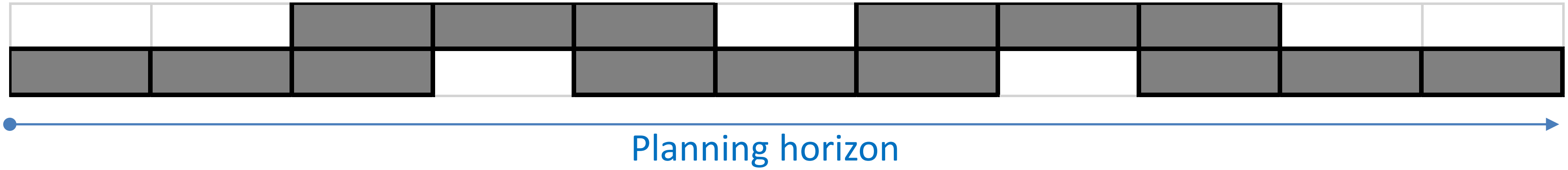
Active power

Problem and Solution Structures

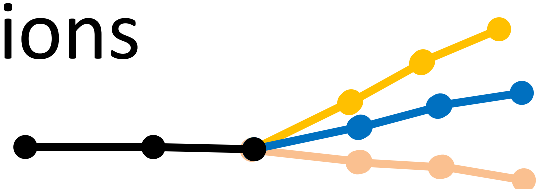


More Solution Structures

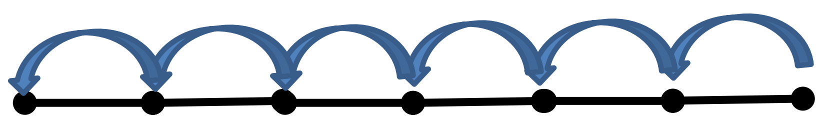
- Rolling horizon with overlaps
  - To avoid end-of-horizon effects



- Robust plus "What-if" Solutions



- Backward or forward propagation approach

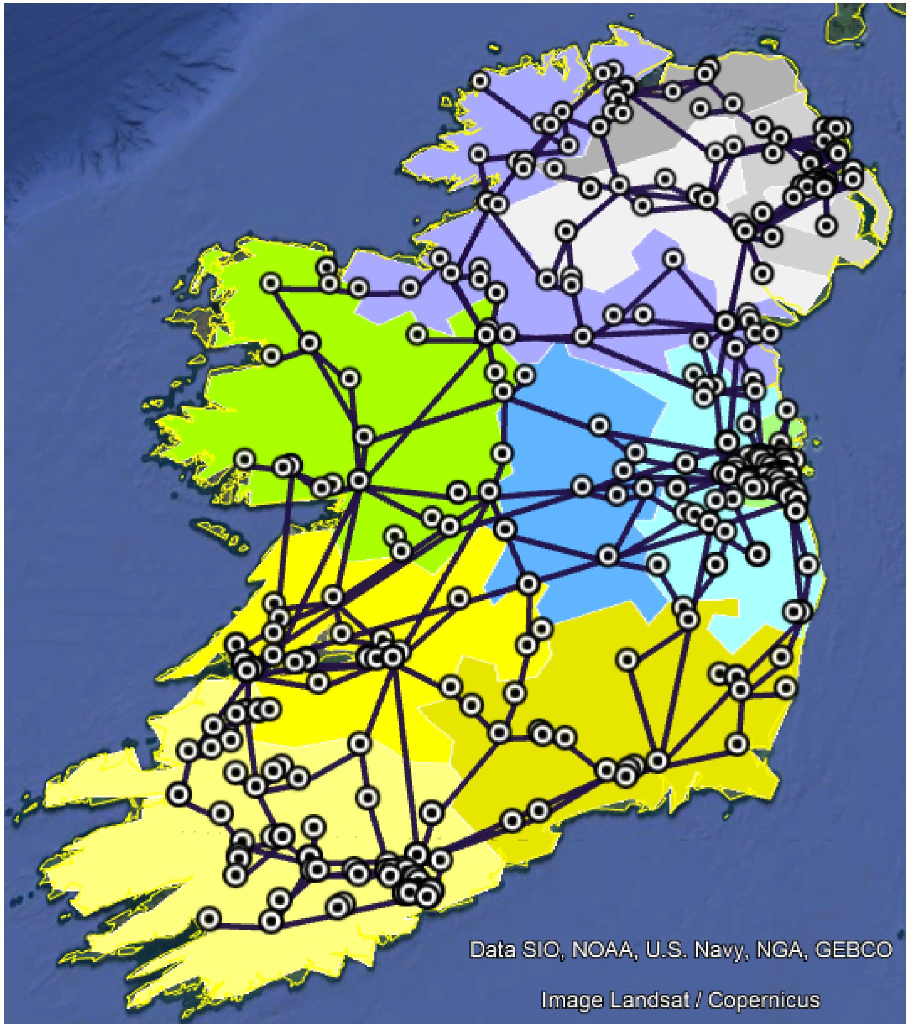


Model Application Examples

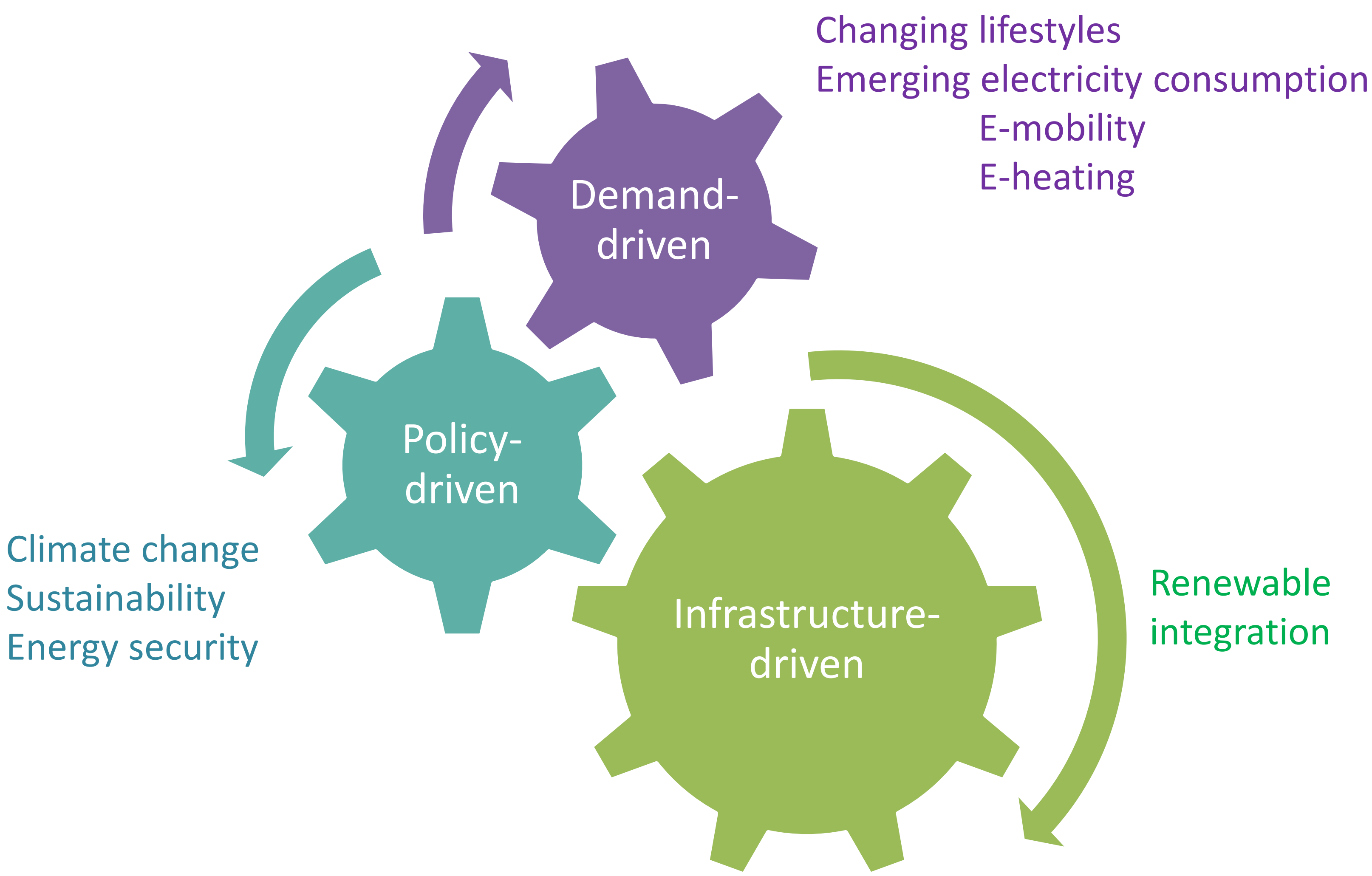
Irish Case Studies

About the Irish System

- Irish system data
  - Main source is EirGrid
- Represents the network aggregated at 110 kV or higher voltage level
  - plus generator nodes and
  - NI's transmission network.
- Overall the base case system has
  - 676 nodes
  - 900 lines and transformers
  - 174 generators
  - 292 MW pumped hydro
  - 10 MW battery storage



Four Scenarios



Further Considerations

- Regional weights for onshore wind allocation

NUTS3 region	IE022	IE012	IE013	IE023	IE024	IE025	IE011
ξ_{reg}	1.00	2.06	2.70	1.79	1.61	1.55	2.07

- Generation technologies
  - CCGT with and without CCS, Coal with and without CCS
  - Biomass, Solar PV, Wind onshore, Wind offshore
- Storage
  - Battery and Pumped hydro

Emission price (Euros/tons of CO_2)	
Year	Price
2018	17
2020	20
2025	25
2030	30

		Cost reduction (cumulative)		
Technology	Capex (M€/MW)	2020	2025	2030
Wind onshore	1.4	0.05	0.1	0.2
Wind offshore	3.65	0.05	0.1	0.2
PV	1.5	0.05	0.1	0.2
Biomass	2.25	0.02	0.05	0.1
Coal	0.8	0.05	0.08	0.1
Coal with CCS	2.4	0.05	0.08	0.1
CCGT	1.1	0.05	0.08	0.1
CCGT with CCS	4.4	0.05	0.08	0.1

Decommissioning

and

North-south Interconnector

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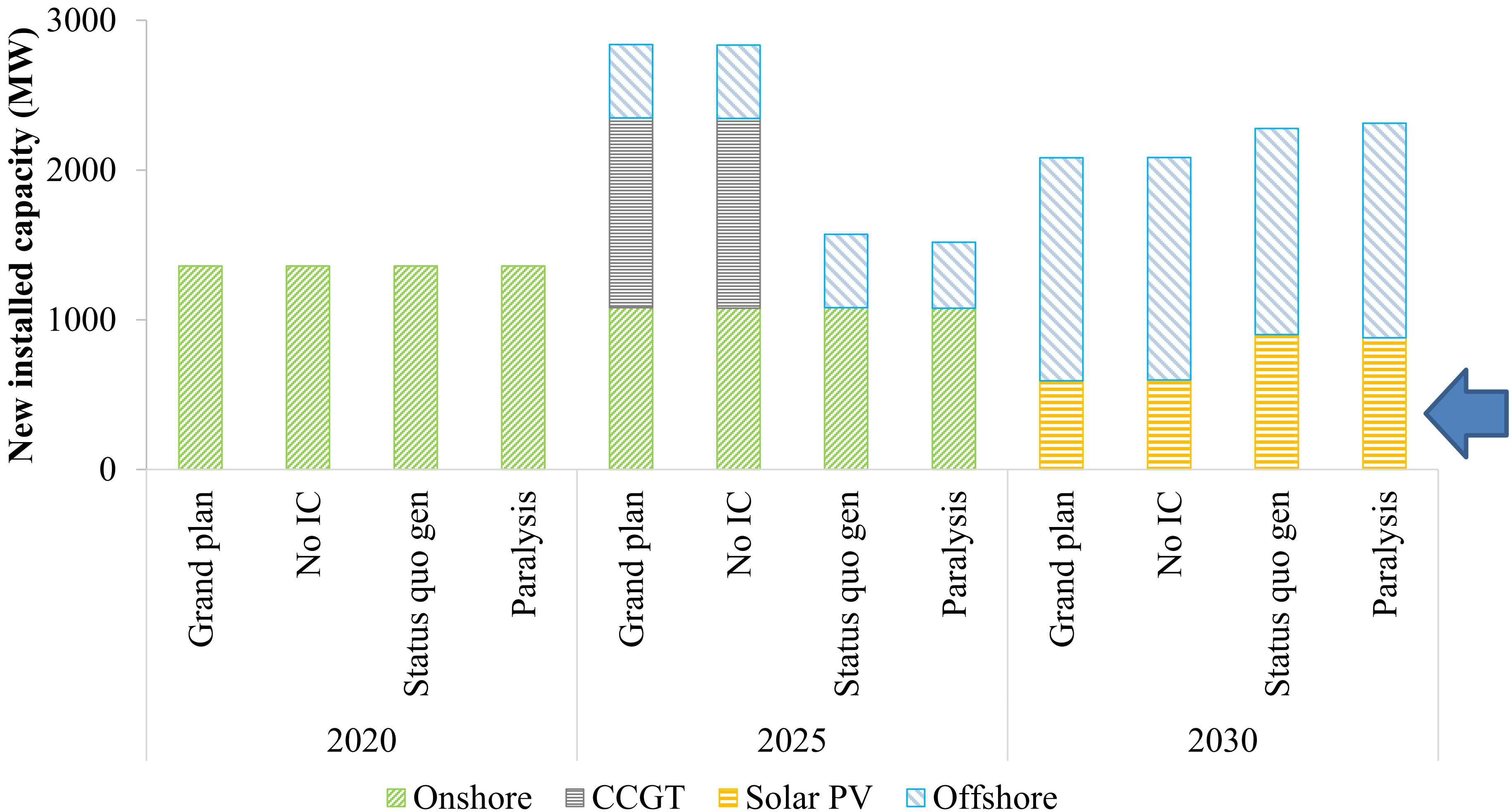
Considered Cases

Cases	Variations	
	Decommissioning	Interconnector
Grand plan	Yes	Yes
No IC	Yes	No
Status quo gen	No	Yes
Paralysis	No	No

- 50% RES-E target by 2030
- SNSP level set to 75%
- No storage and HVDC interconnections

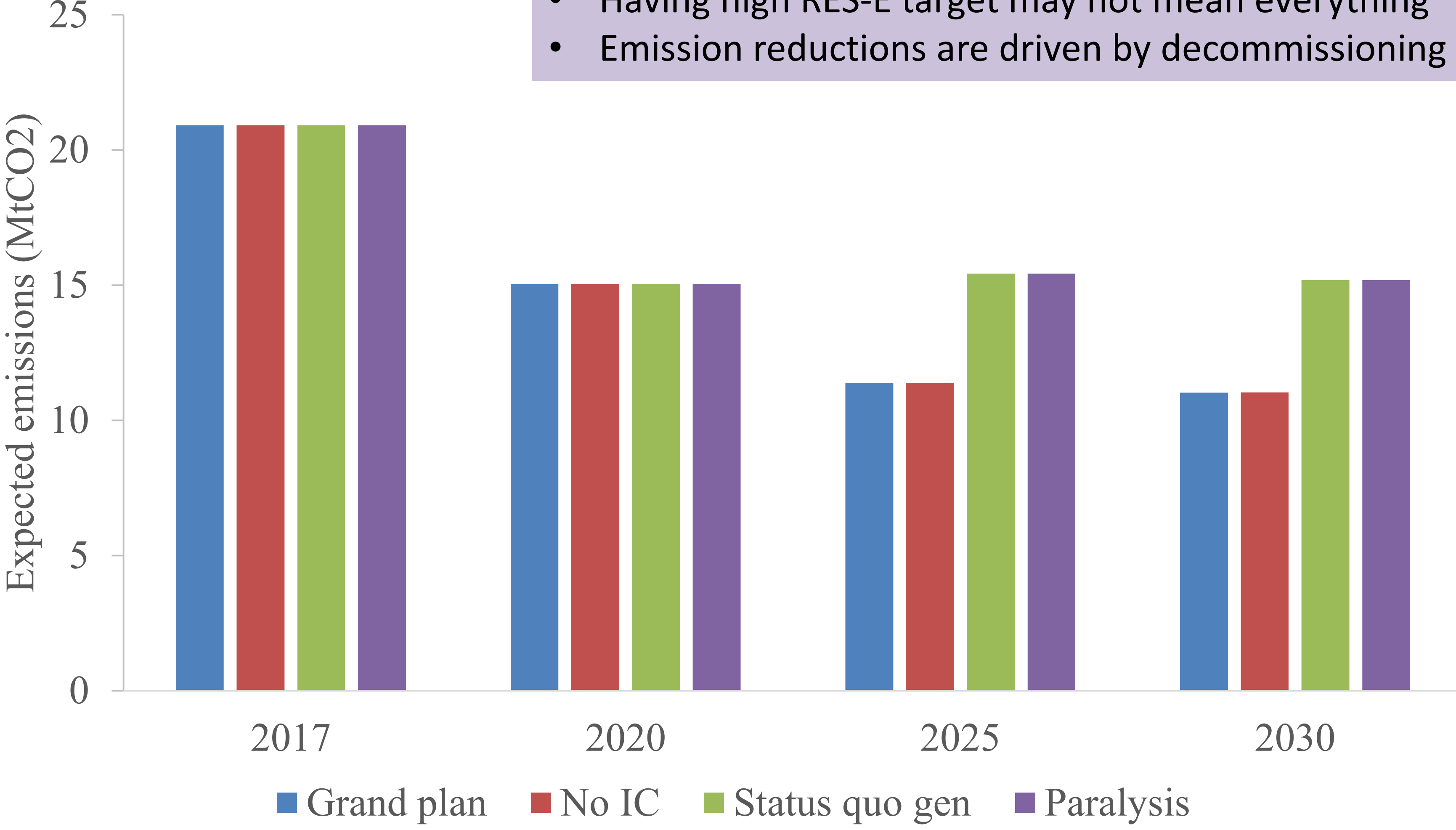
*Desta Z. Fitiwi, Muireann Lynch and Valentin Bertsch, "**Optimal development of electricity generation mix considering fossil fuel phase-out and strategic multi-area interconnection**", ESRI Working Paper No. 616, Feb. 2019 (published).*

Generation Expansion Results

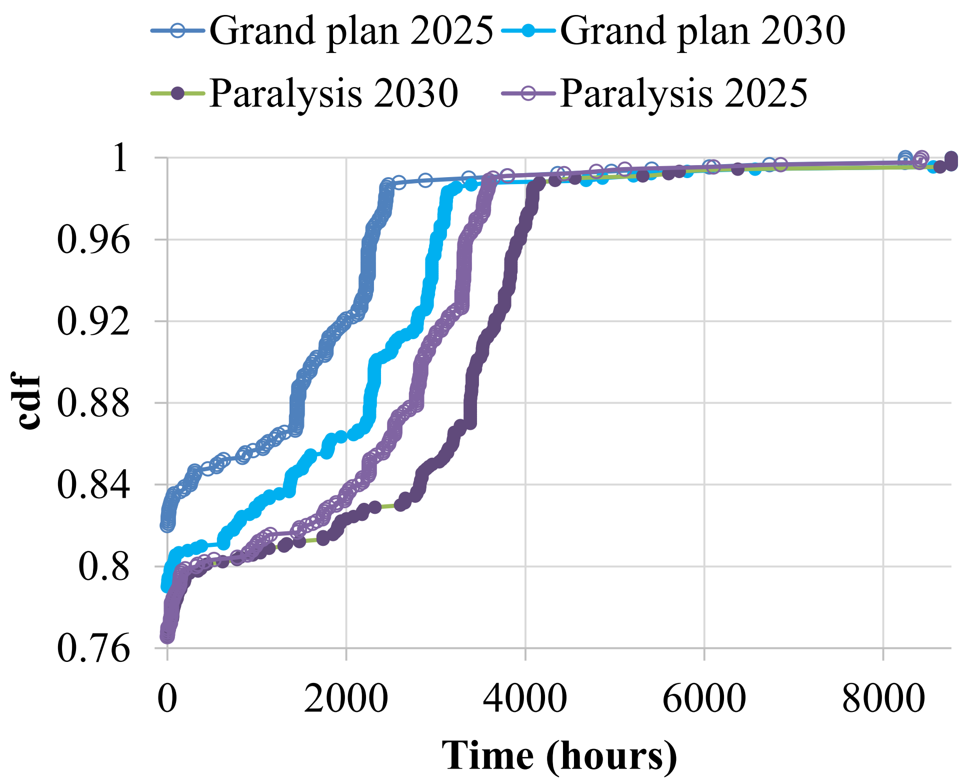


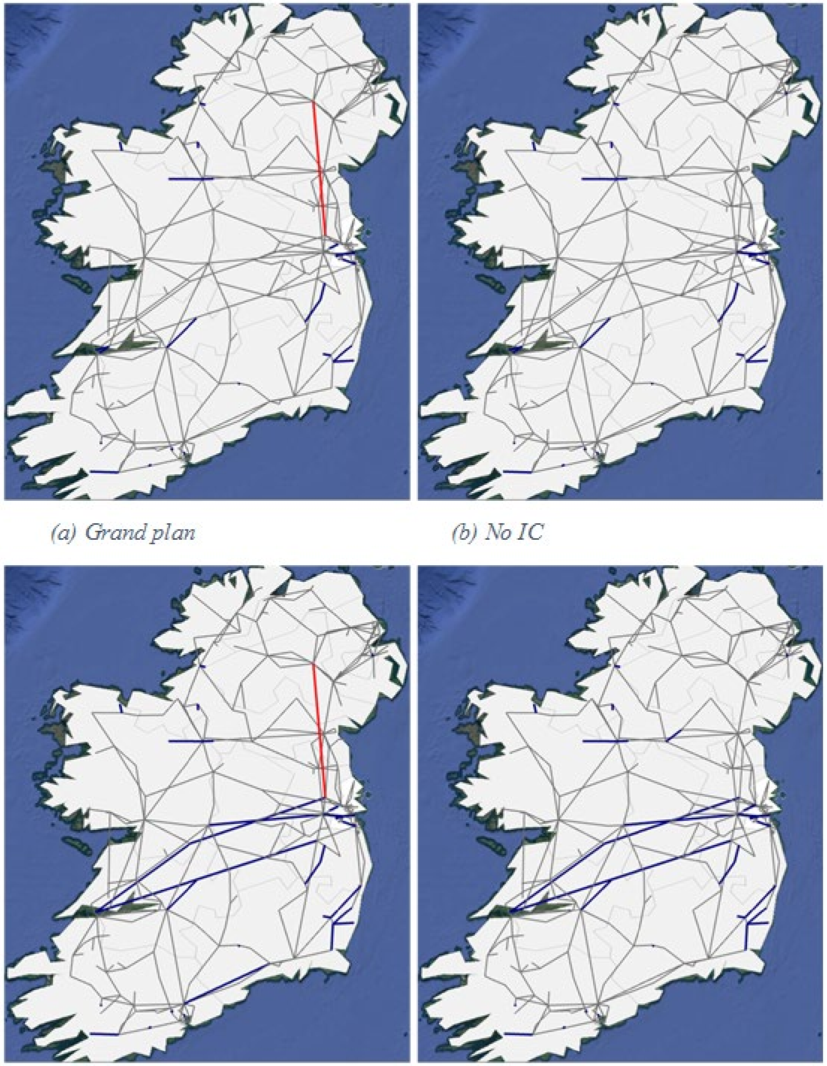
Impact on Emissions

- Having high RES-E target may not mean everything
- Emission reductions are driven by decommissioning



Grid Expansion Needs (1/2)





(a) Grand plan (b) No IC

(c) Status quo gen (d) Paralysis

The *Paralysis* scenario leads to more congestion and hence more grid investment needs

Grid Expansion Needs (2/2)

Comparison of congestion across the cases

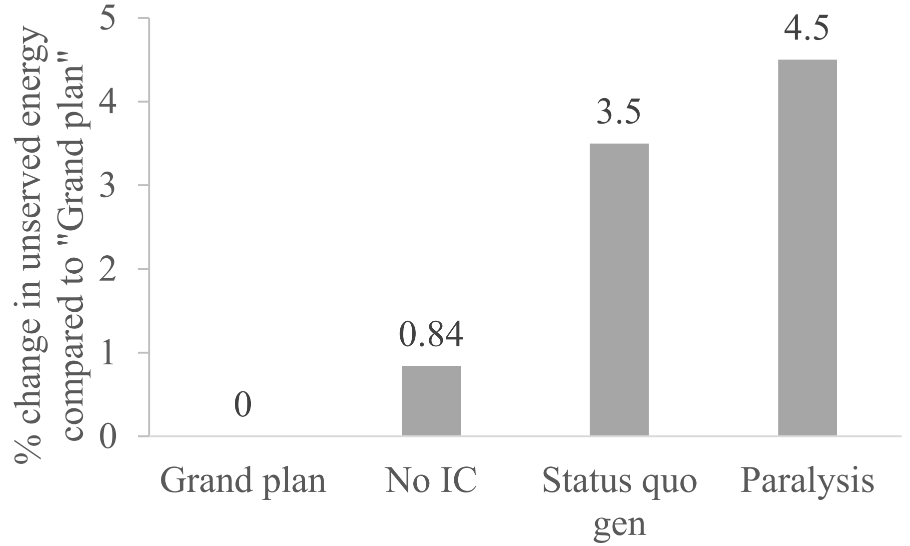
Cases	Grand plan	No IC	Status quo gen	Paralysis
Number of components congested	142	154	151	176
Total congested length (km)	3.509	3,659	4,020	4,435
Congested length-year (km*hour/year)	9,943	10,354	13,920	15,409

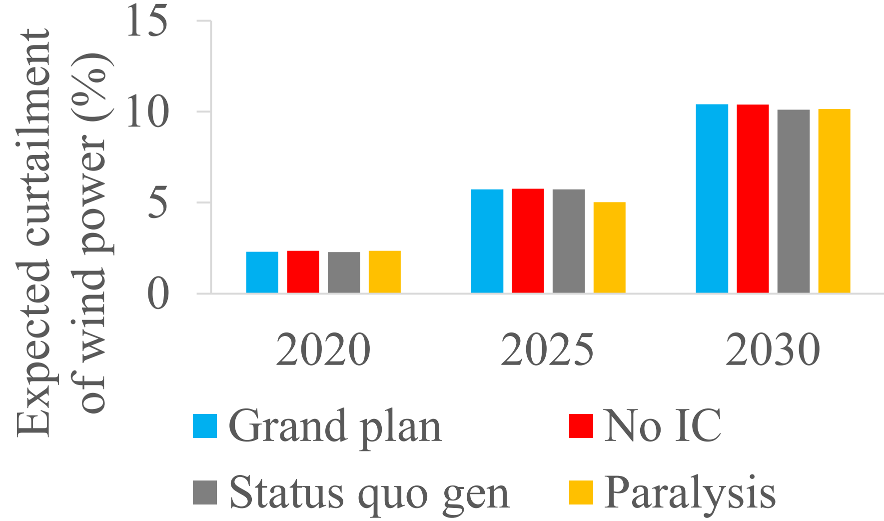
Paralysis scenario leads to the most grid reinforcement needs

- 35% more congested length compared to that of the *Grand plan* scenario

Reliability and RES Curtailment

- “Paralysis” leads to the highest EENS.
- N-S interconnector seems to have some contribution in terms of reliability.
- But, no visible differences in RES curtailments among the cases

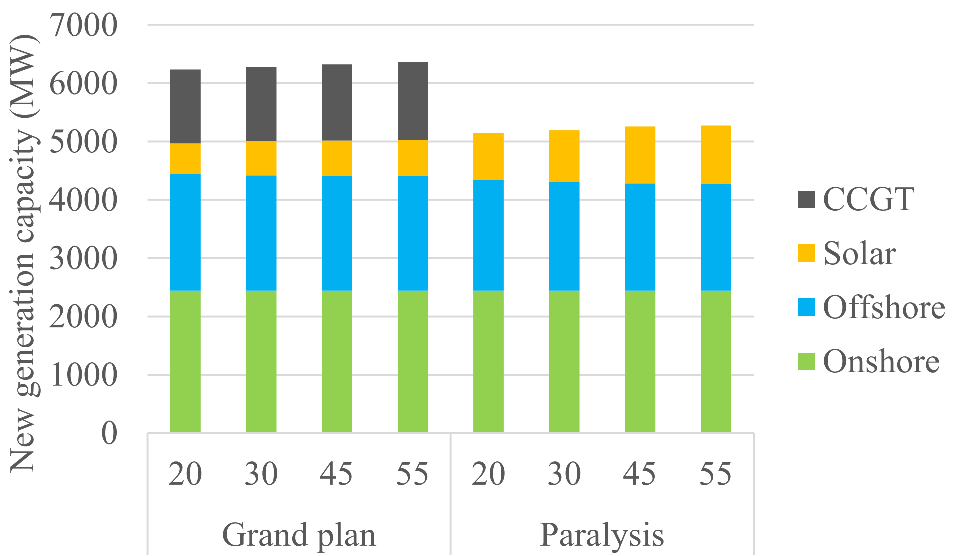




Effect of Changes in Carbon Price

	Grand plan				Paralysis			
Carbon price (€/tCO_2)	20	30	45	55	20	30	45	55
Change in system cost (%)	0.0	+2.6	+6.3	+8.5	0.0	+3.5	+8.3	+11.3
Change in expected wind energy curtailment (%)	0.0	-0.6	-0.7	-1.1	0.0	-0.6	-1.4	-2.0
Changes in expected emissions (%)	0.0	-0.1	-0.1	-0.2	0.0	-0.25	-0.30	-0.32

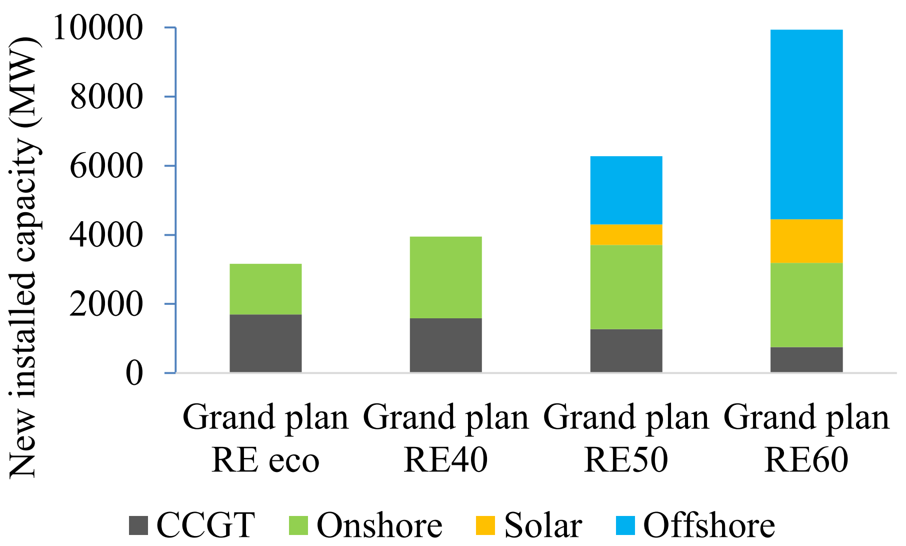
- Increased carbon price has little effect in reducing emissions
- High RES-E target may render carbon price signal ineffective
- Costs increase substantially with carbon price



Effect of Changes in RES-E Target

	Grand plan RE eco	Grand plan RE40	Grand plan RE50	Grand plan RE60
RES-E target	35	40	50	60
Change in system cost (%)	0	+1	+11	+25
Change in expected RES energy curtailment (%)	0	-71	+55	+81
Changes in expected emissions (%)	0	-4	-16	-30

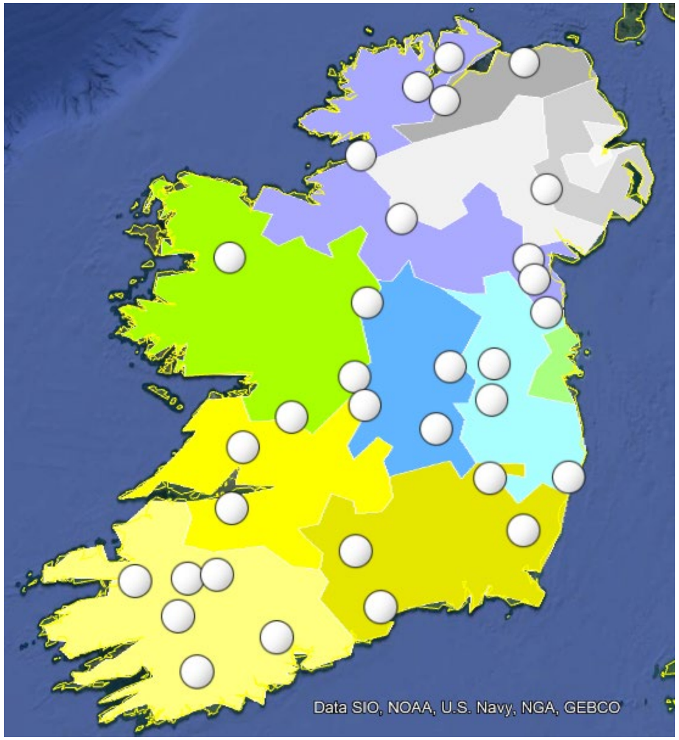
- Exponential increase in generation capacity needs with increased RES-E target
- So is curtailed RES energy
- This may be due to the lack of energy storage media.

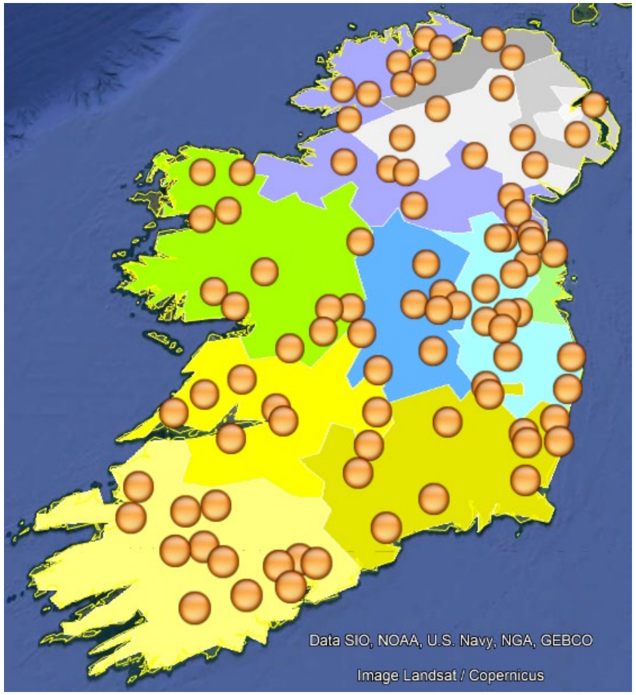


Centralized

vs

Decentralized



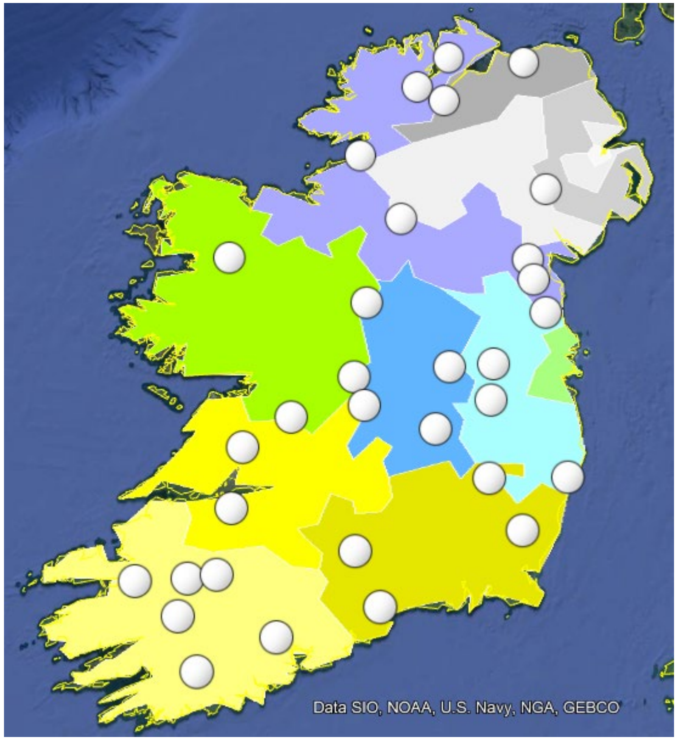


RES Development

*Desta Z. Fitiwi, Muireann Lynch and Valentin Bertsch, "**Optimal development of electricity generation mix under centralised and decentralized RES development portfolios: Insights from Irish case study**", ESRI Working Paper No. XXX, XXX. 2019 (forthcoming)*

Centralized vs Decentralized (1/4)

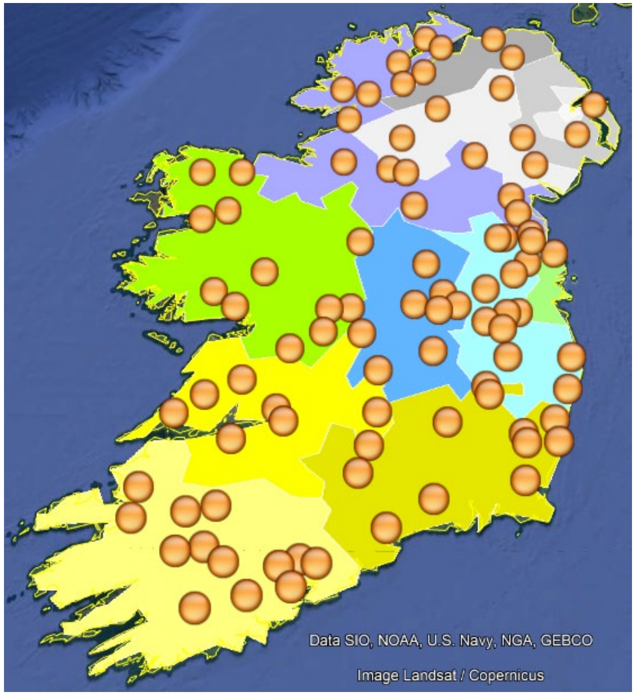
- Centralized RES development portfolio
  - Large-scale wind and solar PV investments determined by a high level central planner.
  - A few connection nodes
  - Selected based on electrical connectivity and proximity to resources
  - Storage system mainly composed of large-scale pumped hydro and battery
- Up to 55% RES-E integration target by 2030.
- System Non-Synchronous Penetration (SNSP) is set to 75%.



PHEP Locations
COOMATAGGART
TRALEE
CASTLEBAR
BALLYBEG
OLDSTREET (360 MW)

Centralized vs Decentralized (2/4)

- Decentralized RES development portfolio
  - Solar PV and onshore wind installations are mainly community-driven.
    - ✓ High-level incentives for self-sufficiency
    - ✓ Which means more embedded generations
  - Only solar PV can be installed in populated areas
  - Storage mainly composed of distributed battery energy storage systems
    - ✓ No investment in 2020, moderate by 2025 and high in 2030
- Up to 55% RES-E integration target by 2030.
- System Non-Synchronous Penetration (SNSP) is set to 75%.

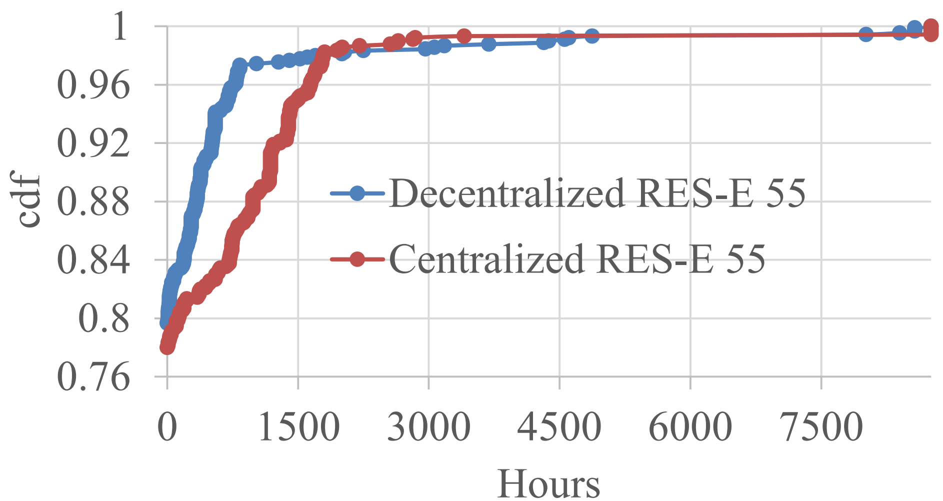


PHEP Locations
COOMATAGGART
TRALEE
CASTLEBAR
BALLYBEG
OLDSTREET (360 MW)

Centralized vs Decentralized (3/4)

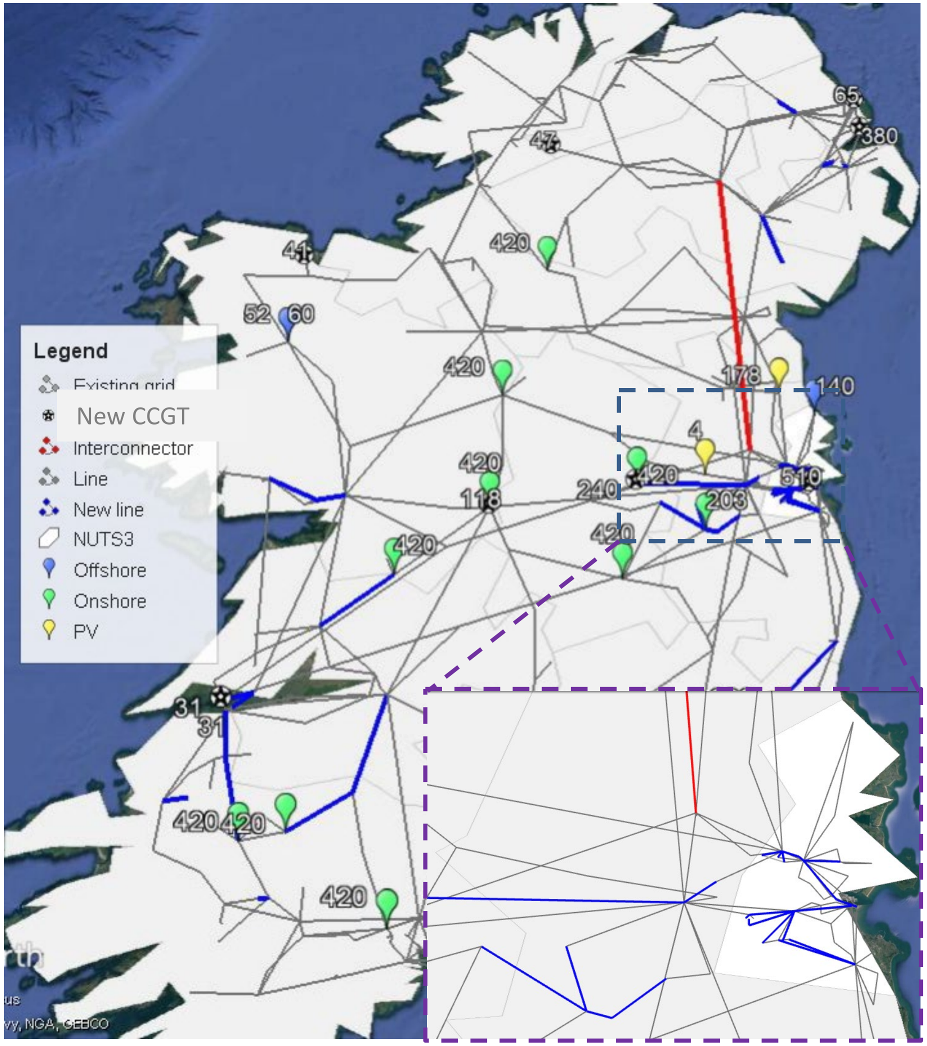
		Centralized	Decentralized	% Change
2020	Onshore wind	1464	1450	-1
2025	New CCGT	1108	1046	-6
	Onshore wind	2160	2180	+1
	BESS	39	168	+77
2030	Onshore wind	1518	115	-1225
	Solar PV	160	349	+54
	BESS	0	171	+100
	PHEP	737	1239	+41
	Aggregate (MW)	6827	6717	-1
	Cumulative cost (M€)	**4447**	**4334**	**-3**

- Centralized RES development leads to more congestion in the system
  - ➢ Implications on grid expansion needs

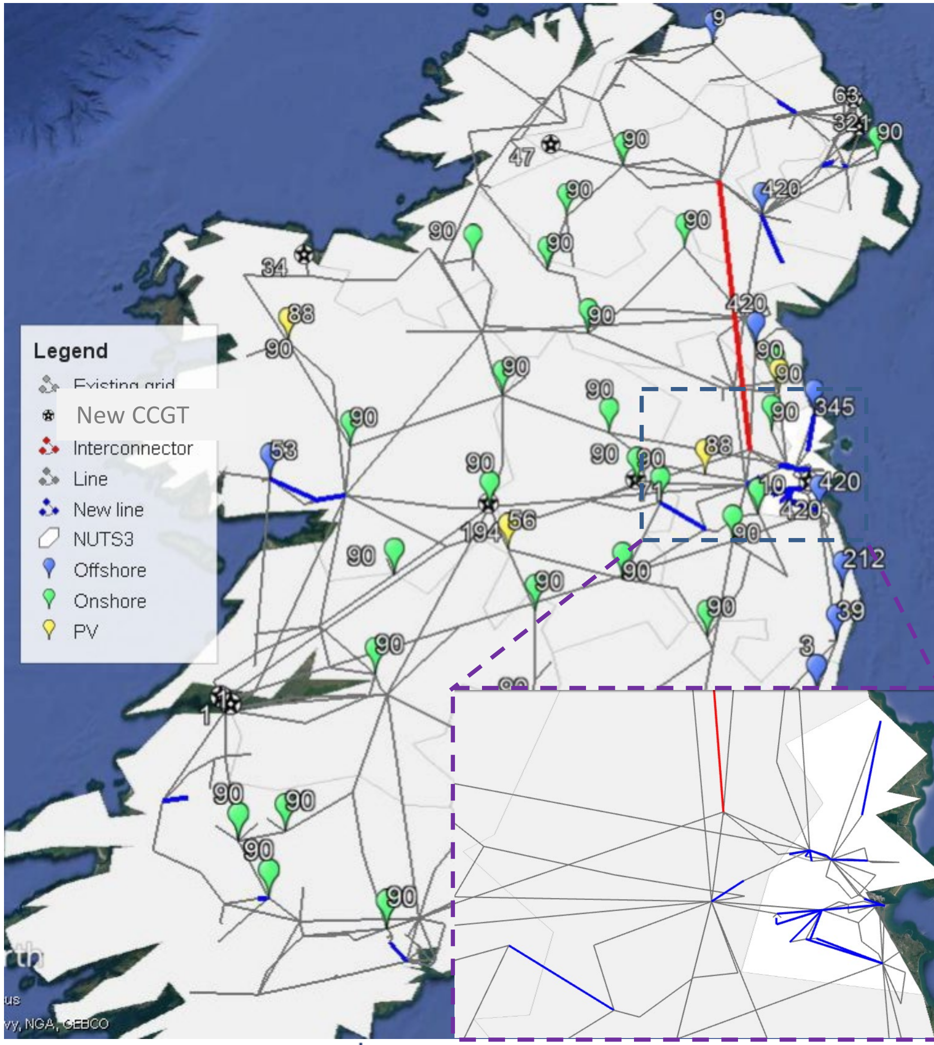


Centralized vs Decentralized (4/4)

Centralized

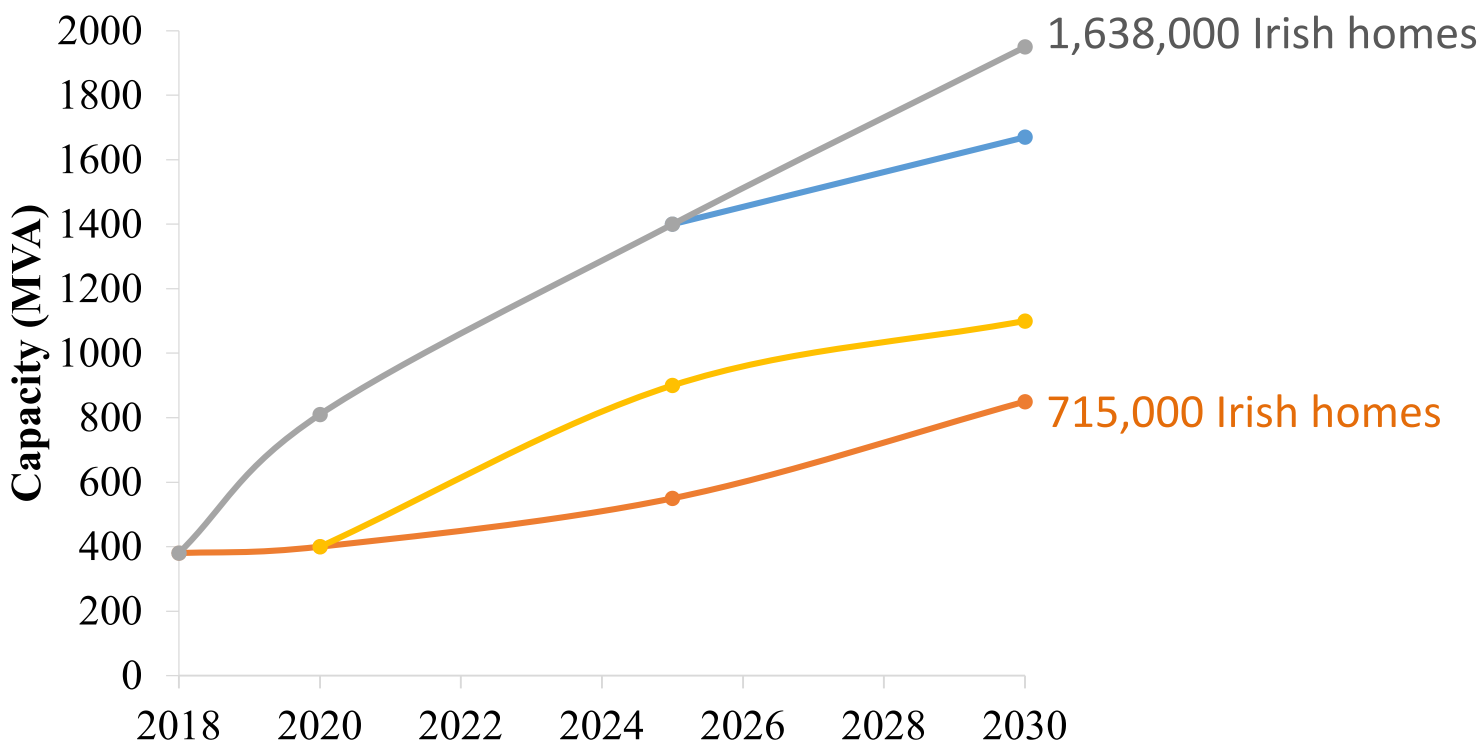


Decentralized



Growing Datacentres

Anticipated Datacentre Growth in IE

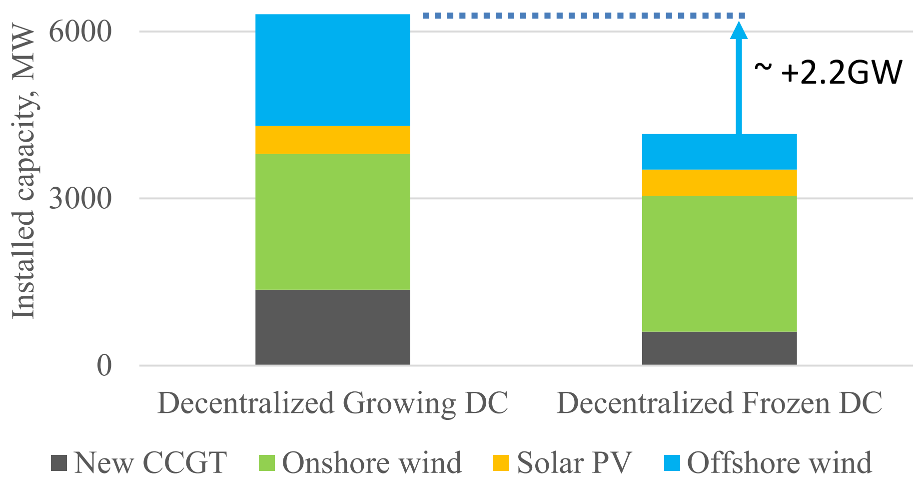


For comparison, Ireland's housing stock in 2016 had 2,003,645 houses and apartments (CSO, 2017)

Possible System-wide Effects

		Datacentre frozen at 2020 level				Growing datacentre				
		y2020	y2025	y2030	Cumulative	y2020	y2025	y2030	Cumulative	% Increase
Generation expansion (MW)	CCGT	0	686	0	**686**	0	1046	0	**1046**	**+34**
	Onshore wind	1450	1438	757	**3644**	1450	2180	115	**3744**	**+3**
	Solar PV	0	0	0	**0**	0	0	349	**349**	**+100**
	Offshore wind	0	0	0	**0**	0	0	0	**0**	**-**
Storage (MW)	BESS	0	181	0	**181**	0	168	171	**339**	**+47**
	PHEP	0	0	738	**738**	0	0	1239	**1239**	**+40**
Self-sufficiency (%)		10	19	23	**51**	10	21	22	**53**	**+2**
NPV cost (M€)		1884	1293	822	**3999**	1884	1433	1017	**4334**	**+8**
Expected emissions (MtCO2)		18	12	11	**41**	18	12	13	**44**	**+7**
Expected RES curtailment (%)		2	6	7	**15**	2	7	3	**12**	**-22**

Impact on Generation Expansion Needs

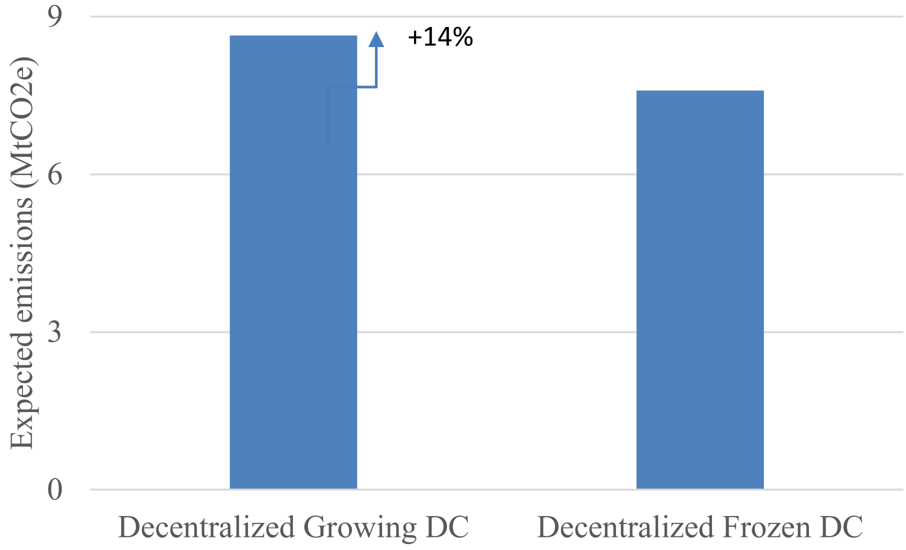


No storage

- As much as 50% increase in new generation expansion needs.
- System-wide costs may increase by 29%.

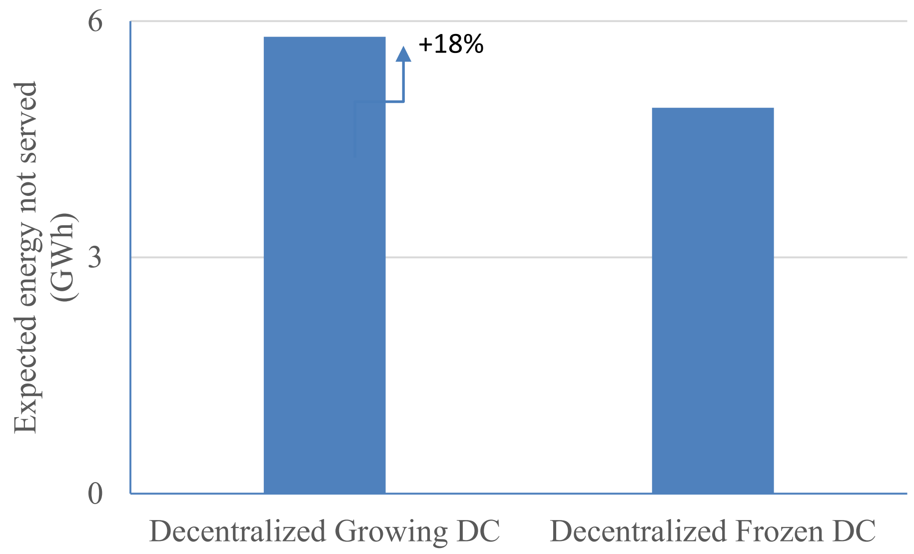
Impact on Expected Emissions

No storage



- On average, emissions in the power sector across the island may increase by more than 14%.
- A hurdle to meeting Ireland's stringent emission reduction targets.

Impact on Expected Energy Not Served



No storage

- Involuntary load shedding in the entire island may increase by more than 18%.
- A big concern for ordinary consumers.
- And, system operators may also feel the pressure.

Impact on Network Expansion Needs

No storage

RES Development Portfolios	Growing datacentres		Datacentre capacity frozen at 2018 level	
	Centralized	Decentralized	Centralized	Decentralized
Lines	39	23	28	19
Transformers	8	6	7	4
Length (km)	500	200	370	145

28%

- N.B. Expansion needs assessments are plain, and do not account for N-1 security criteria.

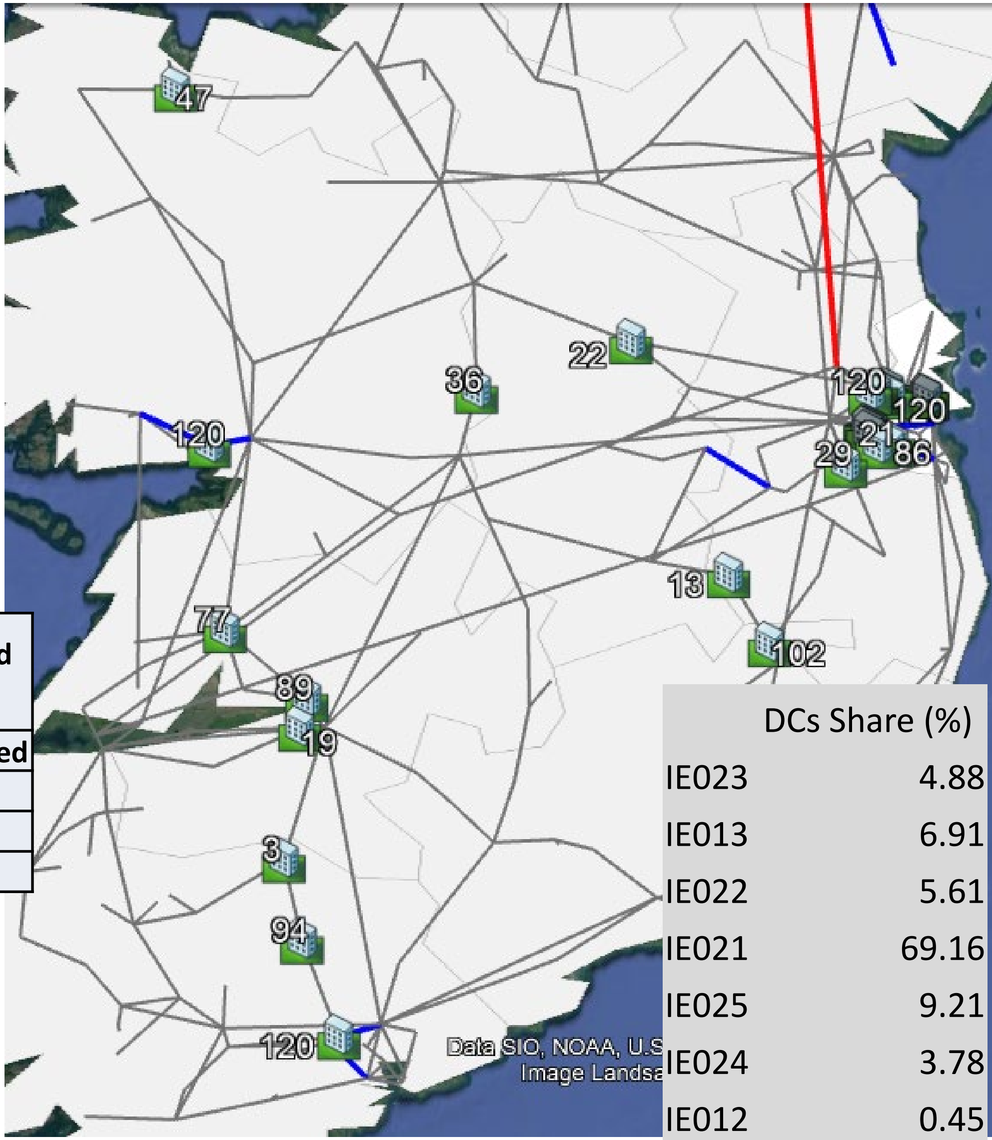
Alleviating the Impacts

Optimally allocating 30% of new DCs along the fibre optics corridor and adopting decentralized RES development can, for example, reduce network reinforcement needs by ~66%.

Case	Growing DC capacity		DC capacity frozen at 2018 level	Distributed DCs
	Centralized	Decentralized	Decentralized	Decentralized
Lines	39	23	19	23
Transformers	8	6	4	6
Length (km)	500	200	145	170

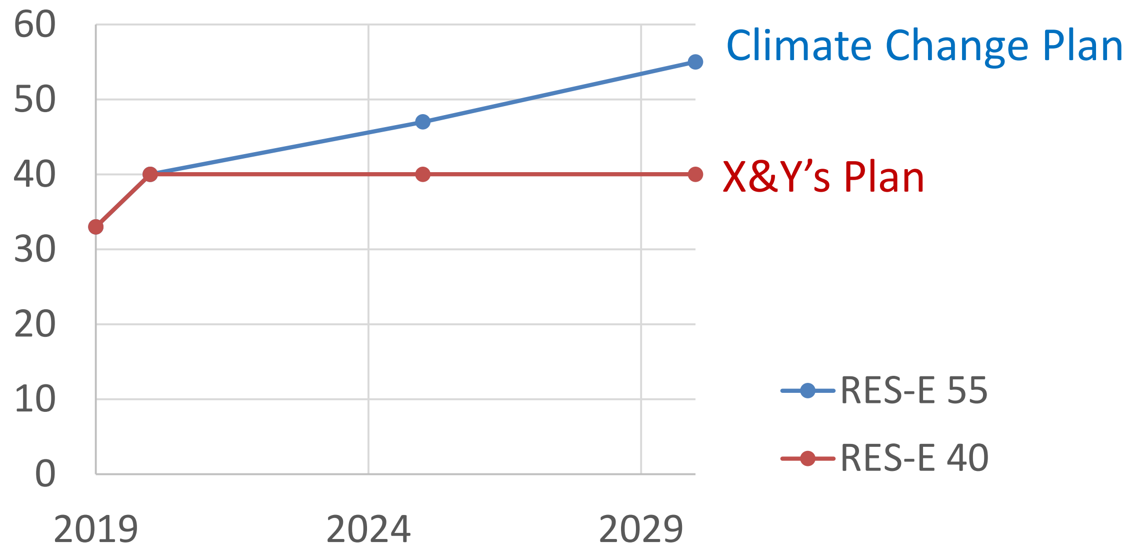
66%

No storage



DCs Share (%)	
IE023	4.88
IE013	6.91
IE022	5.61
IE021	69.16
IE025	9.21
IE024	3.78
IE012	0.45

Difference between 55 and 40?



Group calls for 70% target for renewable electricity by 2030

A report from energy and utilities analysts Baringa says target is technically possible and would be cost neutral to the consumer

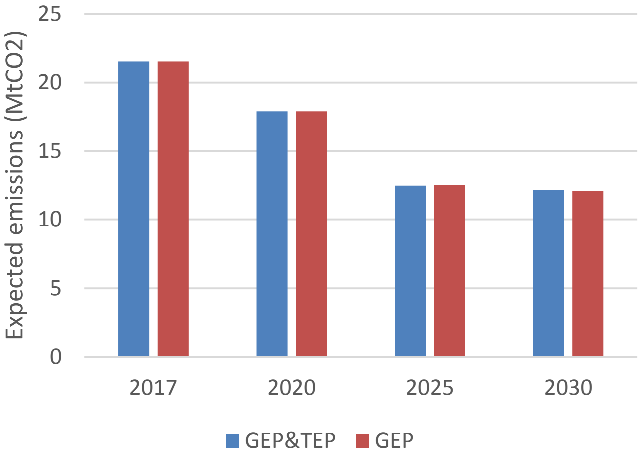
RES-E 40 to RES-E 55

		y2020	y2025	y2030	Cumulative	y2020	y2025	y2030	Cumulative	% Increase
Generation expansion (MW)	CCGT	0	1358	3	**1361**	0	1046	0	**1046**	**-30**
	Onshore wind	1450	797	32	**2279**	1450	2180	115	**3744**	**+39**
	Solar PV	0	0	349	**349**	0	0	349	**349**	**0**
	Offshore wind	0	0	0	**0**	0	0	0	**0**	**-**
Storage (MW)	BESS	0	0	240	**240**	0	168	171	**339**	**+29**
	PHEP	0	0	360	**360**	0	0	1239	**1239**	**+71**
Self-sufficiency (%)		10	13	14	**37**	10	21	22	**53**	**+30**
NPV cost (M€)		1884	1386	993	**4263**	1884	1433	1017	**4334**	**+2**
Expected emissions (MtCO2)		18	13	14	**45**	18	12	13	**44**	**-3**
Expected RES curtailment (%)		2	5	4	**11**	2	7	3	**12**	**+8**

Coordination of Generation and Transmission Expansion Planning

Benefits of GEP-TEP Coordination

		Centralized		
		GEP&TEP	GEP	
2020	Onshore wind	1464	1464	
2025	New CCGT	1094	1108	
	Onshore wind	1848	2160	
	BESS	28	39	
2030	Onshore wind	1804	1518	
	Solar PV	0	160	
	PHEP	770	737	
	Total (MW)	7008	6827	
	Cumulative cost (M€)	4267	4447	**4% reduction**



		Decentralized		
		GEP&TEP	GEP	
2020	Onshore wind	1450	1450	
2025	New CCGT	1050	1046	
	Onshore wind	2183	2180	
	BESS	170	168	
2030	Onshore wind	111	115	
	Solar PV	0	349	
	BESS	0	171	
	PHEP	1344	1239	
	Total (MW)	**6308**	**6717**	**6% reduction**
	Cumulative cost (M€)	**4286**	**4334**	**1% reduction**

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Energy Storage for Ireland (ESFI)?

Role of Storage (1/2)

		With storage	No storage	
	[Units in MW]	Centralized	Centralized	% Change
2020	Onshore wind	1464	1464	0
2025	New CCGT	1108	1132	+2
	Onshore wind	2160	2177	+1
	BESS	39	0	-
2030	Onshore wind	1518	3499	+57
	Biomass	0	0	-
	Solar PV	160	160	+0
	Offshore wind	0	1977	+100
	BESS	0	0	-
	PHEP	737	0	-
	Cumulative (MW)	7187	10408	+31
	Cumulative cost (M€)	4447	4477	+1

COOMATAGGART
TRALEE
CASTLEBAR
BALLYBEG
OLDSTREET (360 MW)

- Investment deferral
- Reducing stress on the network

Role of Storage (2/2)

	[Units in MW]	With storage Decentralized	No storage Decentralized	% Change
2020	Onshore wind	1450	1464	+1
2025	New CCGT	1046	1138	+8
	Onshore wind	2180	2260	+4
	BESS	168	0	-
2030	Onshore wind	115	115	0
	Biomass	0	0	-
	Solar PV	349	2404	+85
	Offshore wind	0	1791	+100
	BESS	171	0	-
	PHEP	1239	0	-
	Cumulative (MW)	6717	9171	+27
	Cumulative cost (M€)	4334	4612	+6

COOMATAGGART
TRALEE
CASTLEBAR
BALLYBEG
OLDSTREET (360 MW)

Investment deferral
Reducing stress on the network

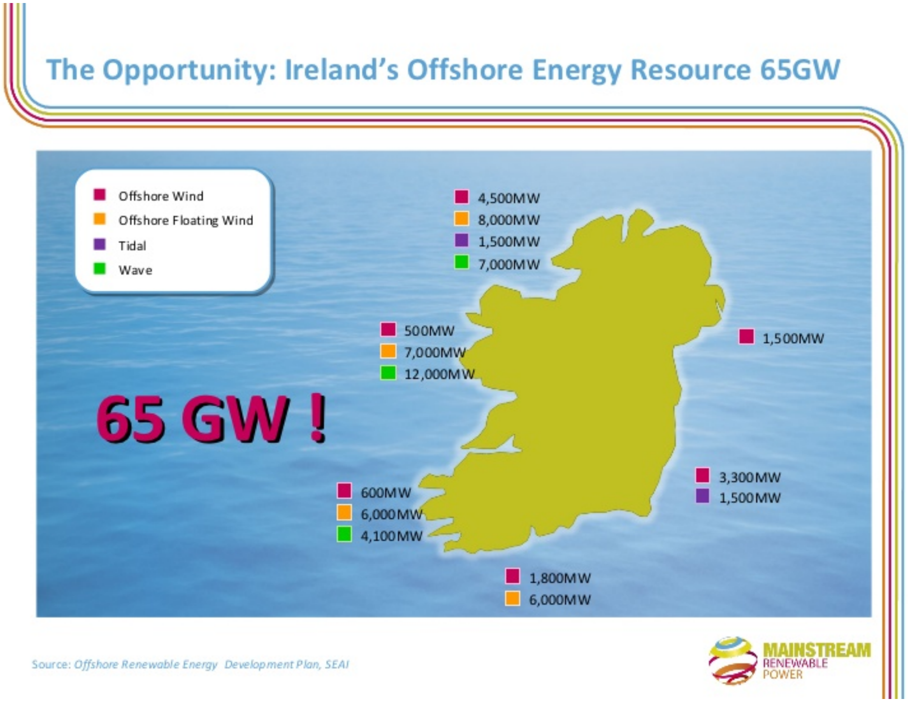
Hypothetical Experiments

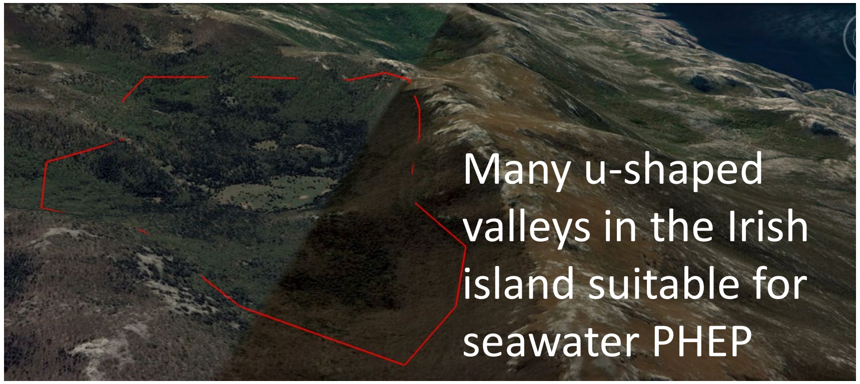
“Offshore Wind Only” Policy (1/2)

<u>HYPOTHETICAL EXPERIMENT 1</u>

Strong public opposition to onshore wind and solar PV power installations forces change in renewable development portfolio.

- By 2021, a favourable renewable support scheme is put in place.
  - ✓ Which encourages massive investments in offshore wind.
- Hence, offshore wind constitutes a lion’s share of the total generation capacity additions by 2025 and beyond.
- This will be accompanied by investments in new pumped hydro and large-scale battery.





“Offshore Wind Only” Policy (2/2)

		y2020	y2025	y2030	**Cumulative**	**Decentralized RES-E 55**
Generation expansion (MW)	CCGT	0	861	0	861	
	Onshore wind	1450	0	0	1450	
	Offshore wind	0	1724	637	2361	
Storage (MW)	BESS	0	458	153	**611**	**339**
	PHEP	0	0	900	**900**	**1239**
	NPV cost (M€)	1884	1624	1179	**4686**	**4334**
	Expected emissions (MtCO2)	18	12	13	**43**	**44**
	Expected RES curtailment (%)	2	5	4	**10**	**12**

The “Offshore wind only” policy

- Leads to only 7% increase in system cost.
- Achieves the same RES-E target with lower generation capacity.
- Requires lower investment in storage, thanks to the relatively stable offshore wind power output.
- Lower emissions and curtailments.

Next Irish General Election 2021 (1/2)

HYPOTHETICAL EXPERIMENT 2

By 2021, Ireland abandons its commitments for climate action.

- Hence, fossil fuels will continue to be the mainstream sources of power generation.
- New policy with limited or no support for renewable power generation.
- Not conducive for new investments in renewables.

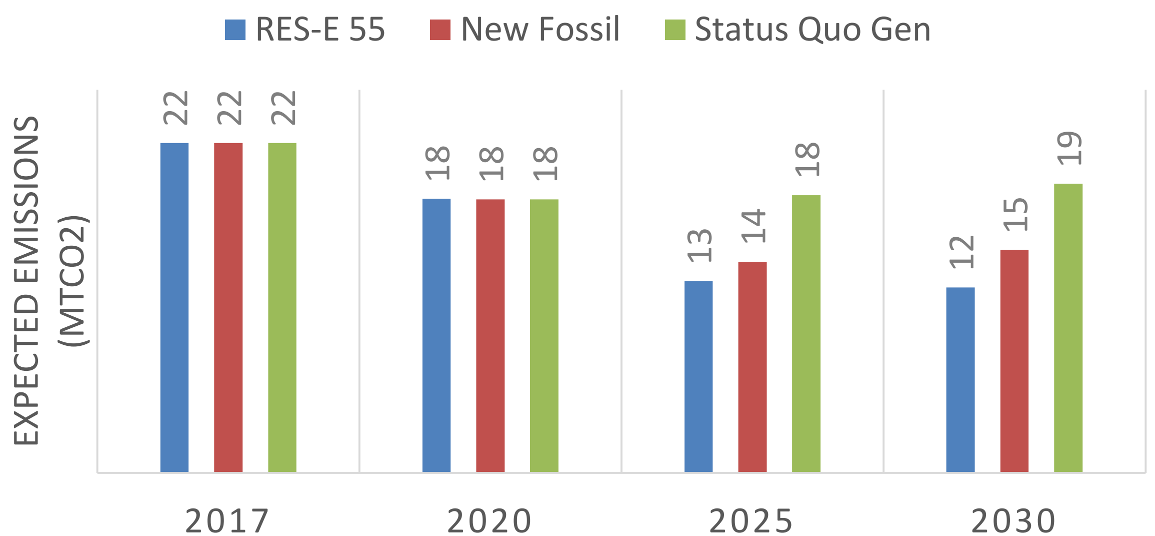
Next Irish General Election 2021 (2/2)

	2020	2025	2030
New generation capacity (MW)	1450	1516	213
Total cost (M€)	1884	1375	1306
Renewable curtailment (%)	2	4	3
Renewable share (%)	40	36	34

New fossil

2020	2025	2030
1450	0	0
1884	1373	1261
2	11	8
40	33	33

Status quo gen



Diversification Policy (1/2)

HYPOTHETICAL EXPERIMENT 3

The policy stipulates new investments in renewable power generation sources should be composed of:

- ✓ 55% Onshore wind
- ✓ 30% Offshore wind
- ✓ 5% Biomass
- ✓ 10% Solar PV
- ✓ ?% Tidal and Wave

Diversification Policy (2/2)

		Centralized	Diversify Centralized	% Change	Decentralized	Diversify Decentralized	% Change
2020	Onshore wind	1464	1464	0	1450	1450	0
2025	New CCGT	1108	1108	0	1046	1046	0
	Onshore wind	2160	2160	0	2180	2180	0
	BESS	39	39	0	168	168	0
2030	Onshore wind	1518	0	-	115	0	-
	Biomass	0	329	**+100**	0	330	**+100**
	Solar PV	160	659	**+76**	349	660	**+47**
	Offshore wind	0	1977	**+100**	0	1980	**+100**
	BESS	0	0	-	171	171	0
	PHEP	737	493	**-49**	1239	496	**-150**
Cumulative (MW)		7187	8229	**+13**	6717	8480	**+21**
Cumulative cost (M€)		4447	4584	**+3**	4334	4437	**+2**

- Such a policy leads to lower need for energy storage media.

Summary

- The utility of ENGINE model has been demonstrated by running various policy scenarios:
    - Decommissioning, North-south interconnection, RES development portfolios, Massive datacentre rollout, RES-E targets, Carbon price, SNSP level, GEP-TEP interaction, Storage, High RES diversification and Do-nothing
    - Future analysis will include the impact of increasing electrification of heating and transport sectors
- Costs and emissions are driven primarily by the decommissioning of old inefficient generation units
- High RES target may render carbon price relatively ineffective in reducing system emissions.
    - Increased carbon prices have little effect other than increasing costs.
- With no storage, renewable portfolio is initially onshore wind based, and investments in solar PV and offshore wind are delayed until 2030.
- But with storage, the optimal renewable portfolio is mainly onshore wind based.

Summary

- Numerical results demonstrate clear benefits of:
  - Deploying energy storage systems in the Irish system, mainly in terms of deferring expensive power generation and transmission infrastructures.
  - Coordinating generation and transmission expansion planning
- Moderate diversification may not be too costly.
- Offshore wind oriented policy requires lower storage capacity.
- The anticipated growth of datacentres by 2030 could have strong implications new generation capacity, grid expansion needs, average GHG emissions and involuntary load shedding.
- Investors should be encouraged to plan for power generation self-sufficiency.
  - By investing in onsite or offsite generation and energy storage systems.
  - Adopting energy efficiency measures.
- Right policy to optimally allocate new datacentres in regional places.
  - E.g. Reduction in grid reinforcement needs by two third if 30% of new DC capacity is allocated in regional places and decentralized RES development is adopted.

Thank you very much for your attention!

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Energy Systems Integration Partnership Programme

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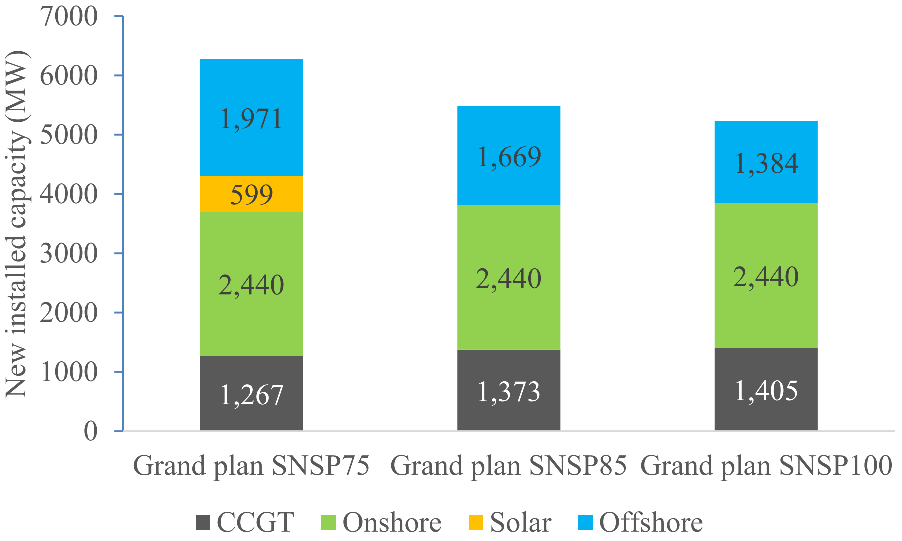
Cost Comparisons

NPV of system-wide cost (in M€)

		Case			
Year	Cost term	**Grand plan**	No IC	Status quo gen	Paralysis
2020	Investment	**130**	130	130	130
	Emission	**263**	263	263	263
	O&M	**1355**	1355	1355	1355
2025	Investment	**206**	206	153	152
	Emission	**177**	177	240	240
	O&M	**1004**	1004	1026	1026
2030	Investment	**173**	173	175	179
	Emission	**137**	137	189	189
	O&M	**1276**	1278	1294	1295
Cumulative		**4721**	4724	4825	4829

Effect of Changes in SNSP Limit

	Grand plan SNSP75	Grand plan SNSP85	Grand plan SNSP100
SNSP limit	75	85	100
Change in system cost (%)	0	-2	-4
Change in expected variable RES power curtailment (%)	0	-106	-596
Change in expected emissions (%)	0	+2	+4



Effects of Datacentre

DC Status Quo					
		2020	2025	2030	**Cumulative**
Generation expansion (MW)	CCGT	0	686	0	**686**
	Onshore wind	1450	1438	757	**3644**
	Solar PV	0	0	0	**0**
	Offshore wind	0	0	0	**0**
Storage (MW)	BESS	0	181	0	**181**
	PHEP	0	0	738	**738**
Self-sufficiency level (%)		10	19	23	**17***
NPV cost (M€)		1884	1293	822	**3999**
Expected emissions (MtCO2)		18	12	11	**41**
Expected RES curtailment (%)		2	6	7	**15**

Expanding DC						
		2020	2025	2030	**Cumulative**	**% Increase**
Generation expansion (MW)	CCGT	0	1046	0	**1046**	**34**
	Onshore wind	1450	2180	115	**3744**	**3**
	Solar PV	0	0	349	**349**	**100**
	Offshore wind	0	0	0	**0**	**-**
Storage (MW)	BESS	0	168	171	**339**	**47**
	PHEP	0	0	1239	**1239**	**40**
Self-sufficiency level		10	21	22	**18***	**2**
NPV cost (M€)		1884	1433	1017	**4334**	**8**
Expected emissions (MtCO2)		18	12	13	**44**	**7**
Expected RES curtailment (%)		2	7	3	**12**	**-22**

Parameter Assumptions

Table A.1. Parameter assumptions of generators (existing and candidate alike)

Generation technology	Operation cost (€/MWh)	Emission rate (tCO_2/MWh)	Investment cost (M€/MW)	Cost reductions (cumulative)		
				2020	2025	2030
Offshore wind	22.8	0.015	3.65	0.05	0.10	0.20
Onshore wind	13.0	0.015	1.40	0.05	0.10	0.20
Solar PV	11.4	0.046	1.50	0.05	0.10	0.20
Biomass	54.0	0.230	2.25	0.02	0.05	0.10
Coal	34.0	0.925	0.90	0.05	0.08	0.10
Coal with CCS	38.0	0.185	4.40	0.05	0.08	0.10
CCGT	40.0	0.367	0.90	0.05	0.08	0.10
CCGT with CCS	55.0	0.037	2.40	0.05	0.08	0.10
Hydro	10.5	0.010	-	-	-	-
Gas oil fired	80.0	1.041	-	-	-	-
Heavy fuel oil fired	100.0	0.769	-	-	-	-

Policy Implications

- Given the anticipated datacentre growth, policy makers should be aware that meeting national renewable and emission reduction targets in the coming decade or so would require unprecedented effort.
  - With massive investments in renewables, decommissioning of existing older generators, which need to also be accompanied by large-scale grid reinforcements.
- Thus, data companies should be encouraged/urged to:
  - Partly (or fully) cover their electricity consumption; Invest in key infrastructures such as energy storage systems;
  - Adopt swift energy efficiency measures.
- Other remedies also exist
  - adopting decentralized RES development, and optimally allocating new datacentres at regional places rather than in and around Dublin.