Departamento de Ingenierías Química y Biomolecular
Universidad de Cantabria

Renewable electricity integration at a regional level: Cantabria case study

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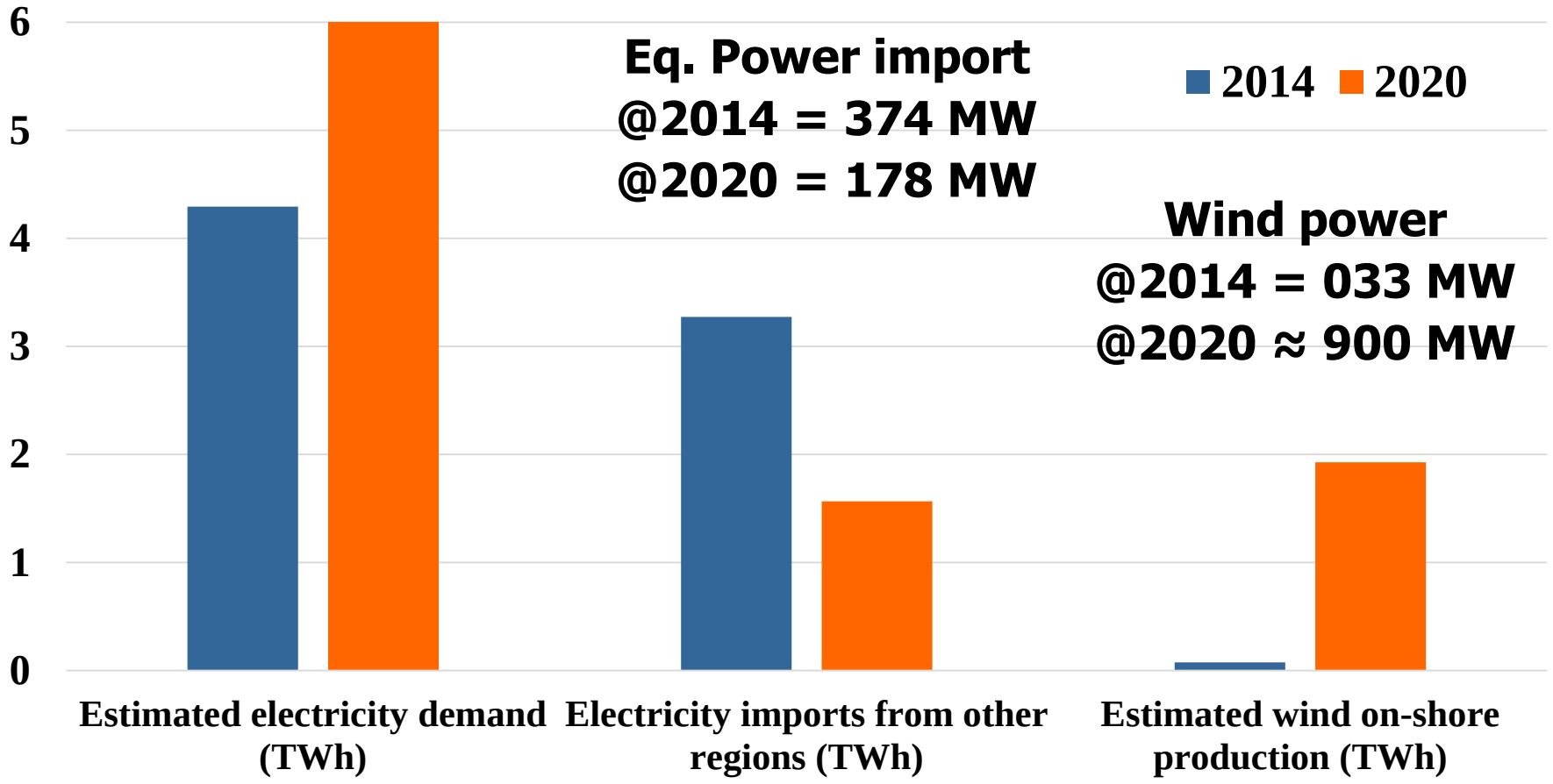
wholeSEM workshop
Workshop on integrated energy system models incorporating spatial and temporal detail
May 24th, 2016, London, UNITED KINGDOM

Sustainability Energy Programme for Cantabria

www.cantabria.es/web/direccion-general-industria/

Sustainability Energy Programme for Cantabria

Eq. Power demand (+6,1%·yr^{-1})
@2014 = 490 MW
@2020 = 699 MW



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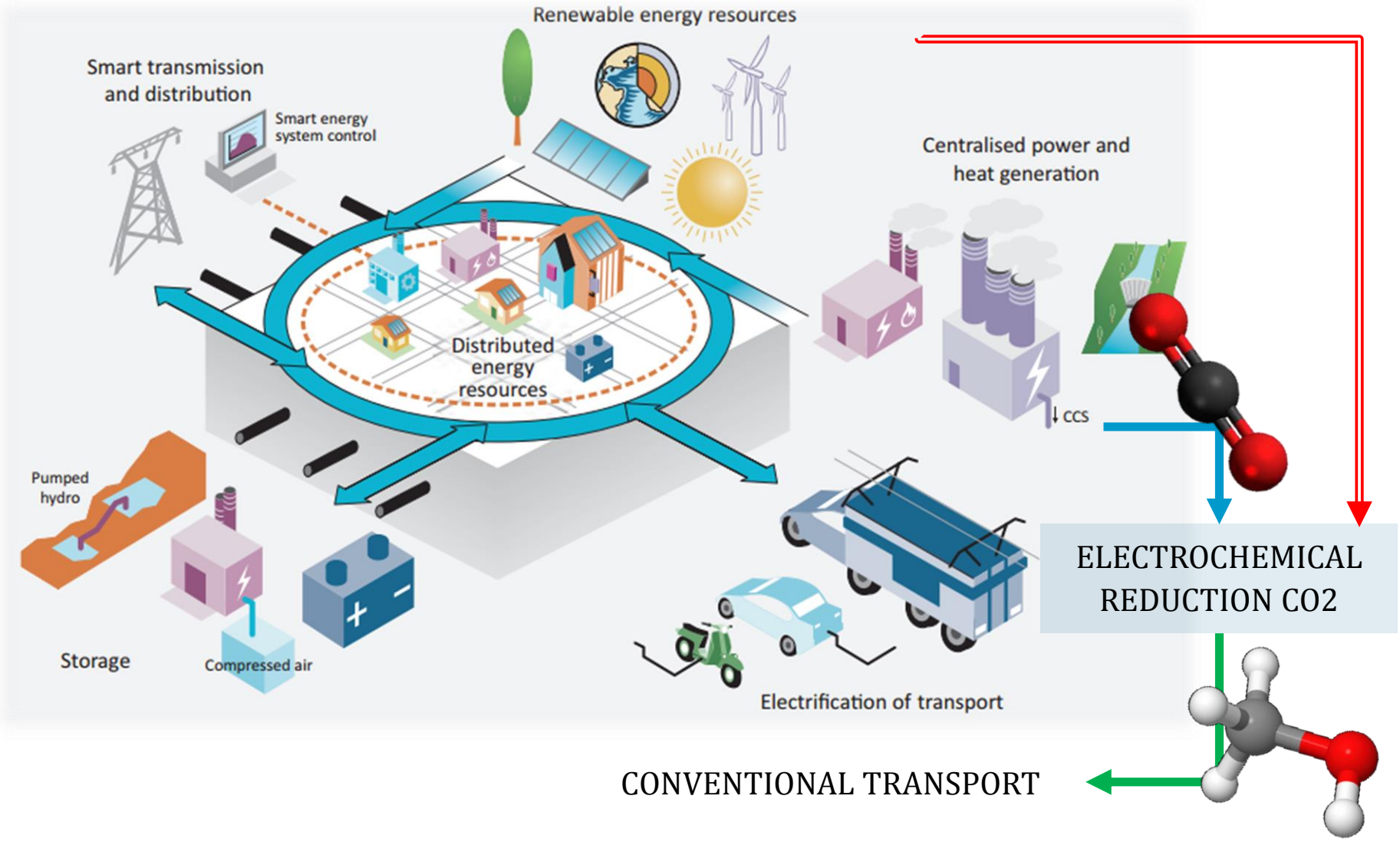
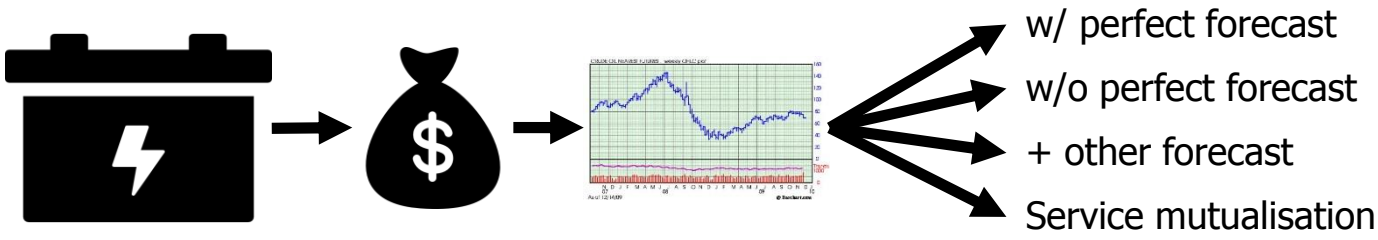
An integrated and intelligent electricity system



http://www.iea.org/publications/freepublications/publication/EnergyTechnologyPerspectives_ES.pdf

Engineering versus system electricity models

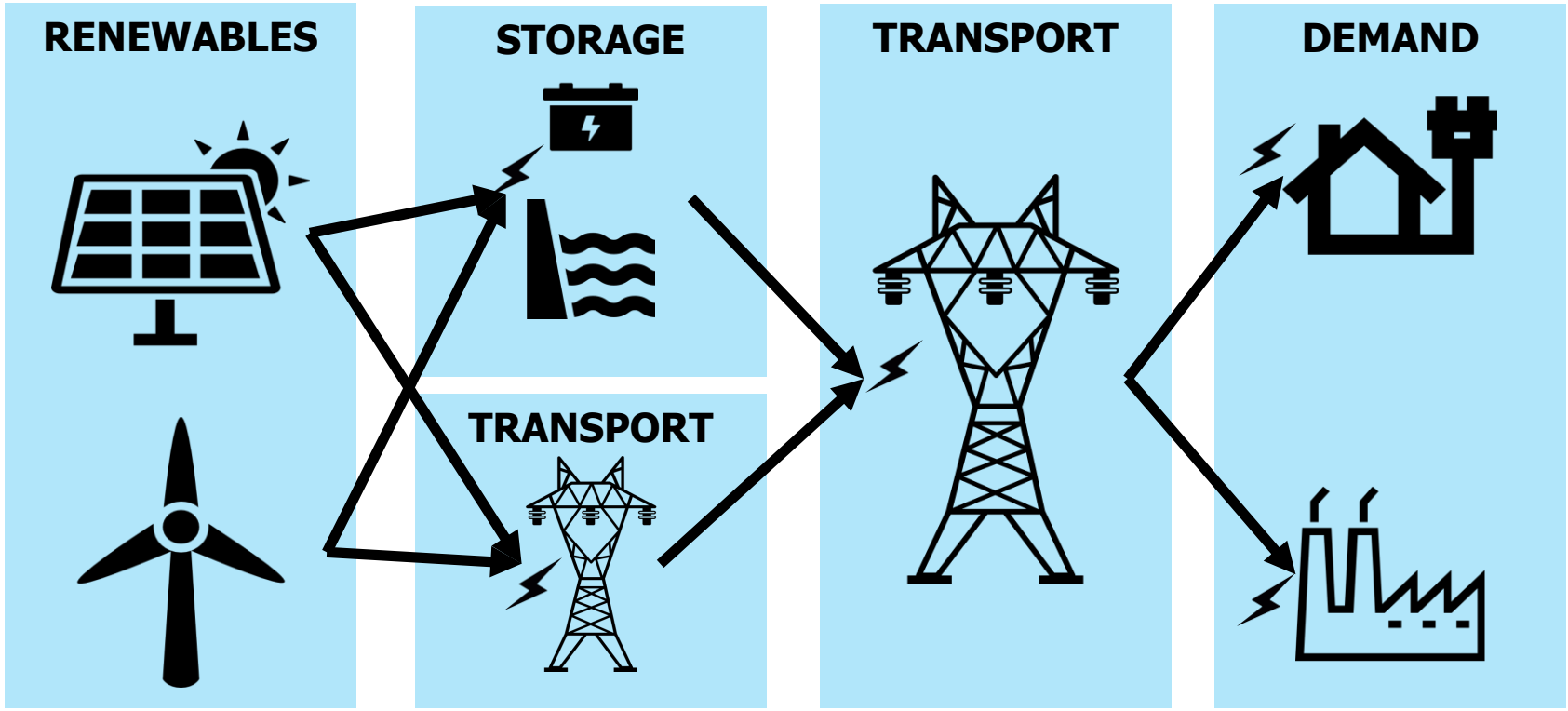
ENGINEERING → Techno-economic performance of storage

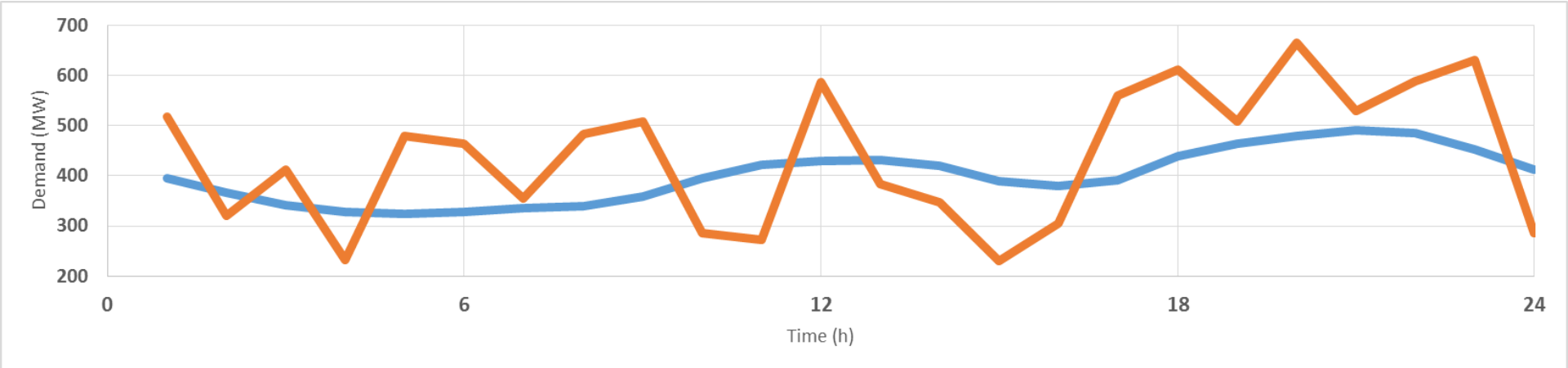


SYSTEM ⟶ Minimum cost solution for energy services

Energy system	**National to regional energy policies**
Market	Optimizing one part of the chain
Network	Flows in the grid
Other	Isolated systems

Time and geographical domains matters





Before the STeMES model…

Hourly resolution

Geographic domains

Storage considerations

Strategy based on the decomposition method

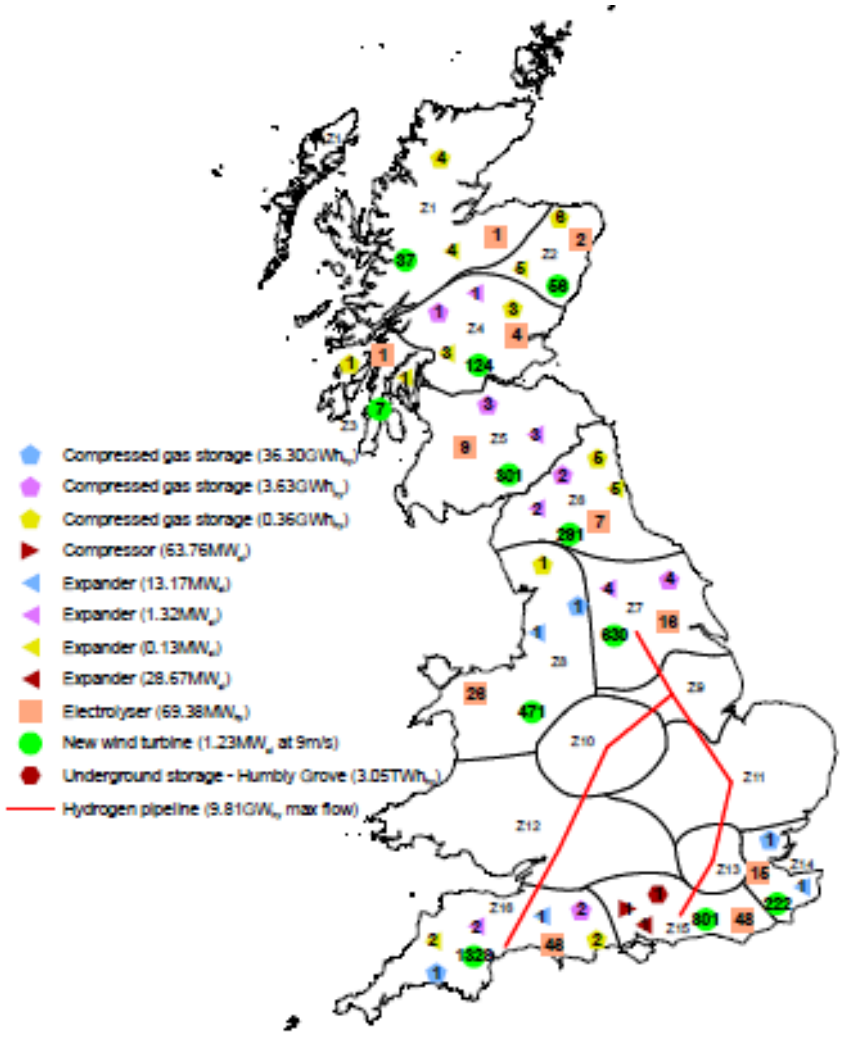
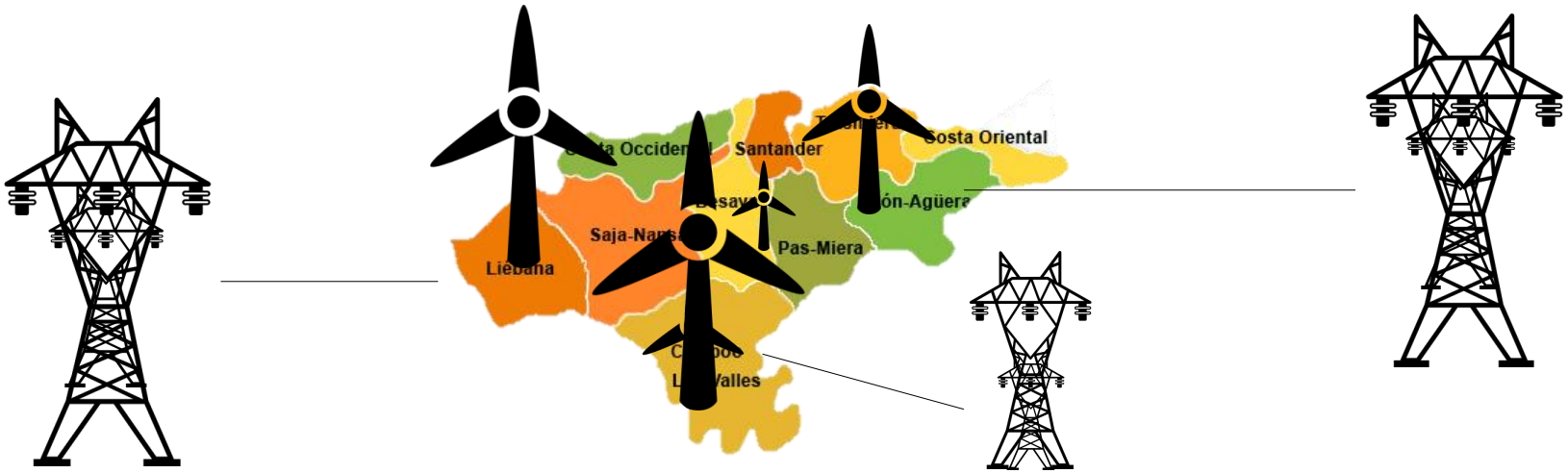


Figure 12: Optimal network structure for the base case

Samsatli et al, 2016

Main question

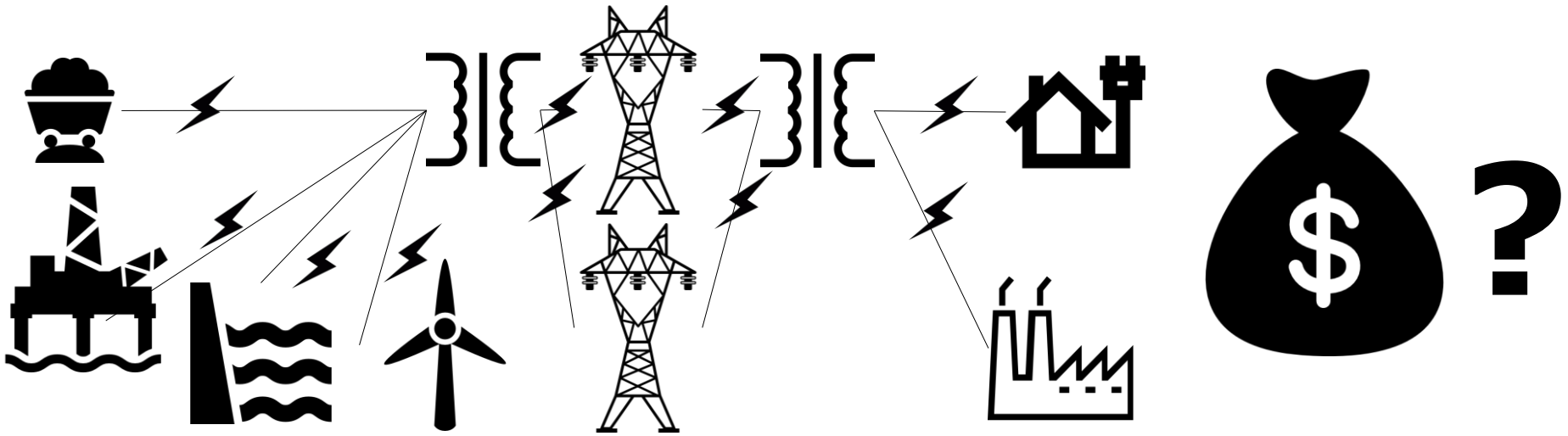
"Is the expected increase in electricity demand technically compatible with the wind on-shore expansion and reductions in imports considering space limitations?"



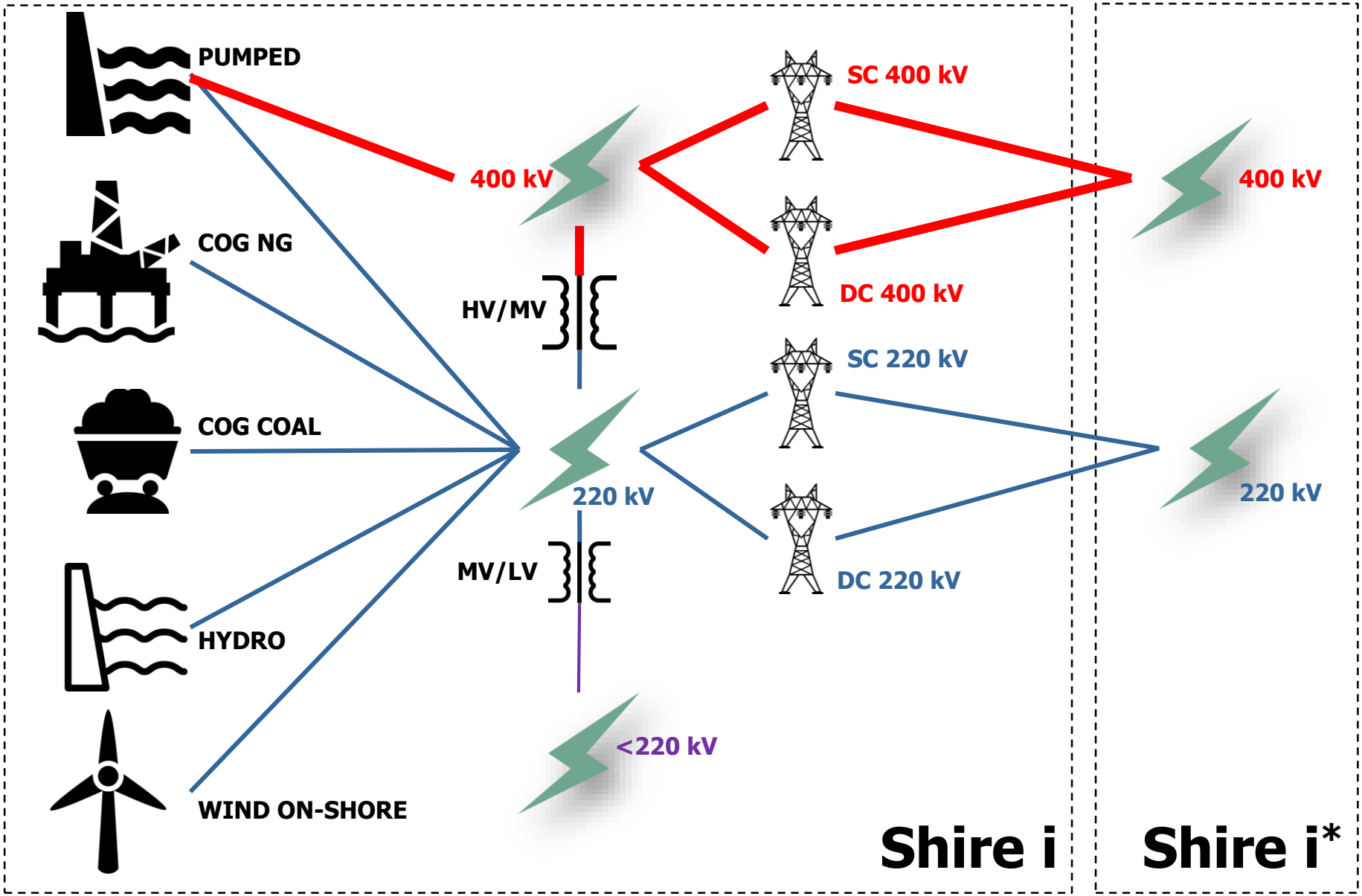
Aim and scope

SPEC proposes cutting imports, relying on wind expansion for supplying demand

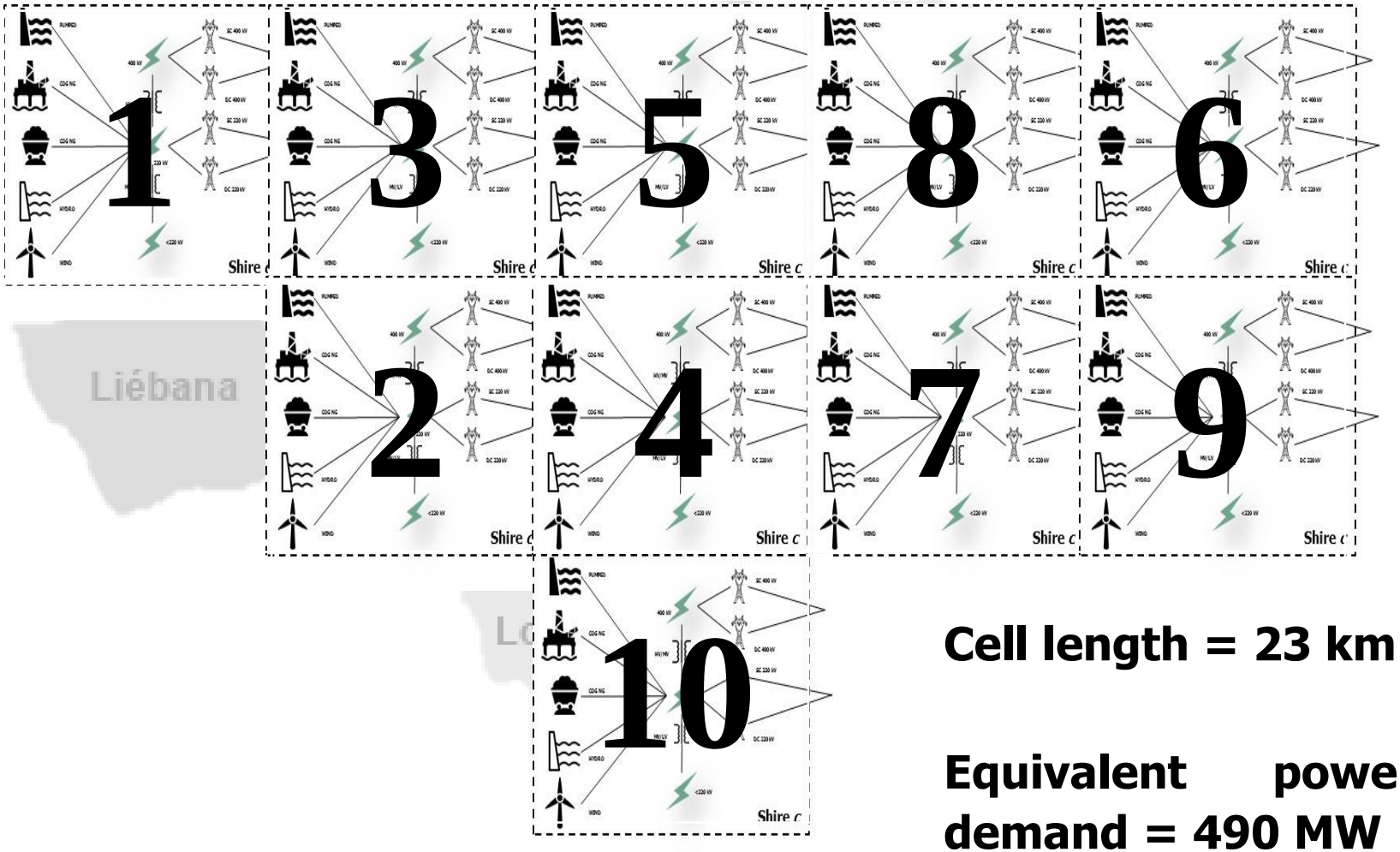
Minimum Total Cost due to infrastructure, operation and import for supplying demand from 2014-2020 under 5 scenarios



Resource Task Network



Resource Task Network



Cell length = 23 km

Equivalent power demand = 490 MW

Mathematical model

Indexes & Sets

r	Resources $\mathbb{R}$	400 kV, 220 kV , <220 kV
i, i^*	Shires $\mathbb{I}$	1, 2,…, 10
t_m	Year $\mathbb{T}$	2014,…, 2020
j	Technologies $\mathbb{J}$	cog_ng, cog_coal, hydro, pumped, wind, subMV, subHV
PL	Type of power line $\mathbb{PL}$	SC, DC

Mathematical model

Objective function

$$min\ \mathbf{TC} =$$

$$\sum_{t_m \in \mathbb{T}} \sum_{j \in \mathbb{J}} \sum_{i \in \mathbb{I}} CINV_{ji} INV_{jit_m}$$

INVESTMENTS

$$+ \sum_{t_m \in \mathbb{T}} \sum_{j \in \mathbb{J}} \sum_{i \in \mathbb{I}} COP_j P_{jit_m} \phi$$

TECHNOLOGY OPERATIONS

$$+0.5 \sum_{r \in \mathbb{R}} \sum_{PL \in \mathbb{PL}} \sum_{i \in \mathbb{I}} \sum_{i^* \in \mathbb{I}} CTR_j d_{ii^*} INV_{INF\,rPLii^*t_m}$$

TRANSPORT INFRASTRUCTURE

$$+ \sum_{t_m \in \mathbb{T}} \sum_{r \in \mathbb{R}} \sum_{PL \in \mathbb{PL}} \sum_{i \in \mathbb{I}} \sum_{i^* \in \mathbb{I}} CQ_{rPL} Q_{rPLii^*t_m} \phi$$

TRANSPORT OPERATIONS

$$+ \sum_{r \in \mathbb{R}} \sum_{PL \in \mathbb{PL}} \sum_{i \in \mathbb{I}} CIMP_r IMP_{rPLit_m} \phi$$

IMPORTS

Mathematical model

Resource balance

$$E_{rit_m} + D_{rit_m} - IM_{rit_m} =$$

EXCESS + DEMAND - EXT. IMPORTS

$$\sum_{j \in \mathbb{J}} MU_{jr} P_{ijt_m}$$

PRODUCTION

$$+ \sum_{r \in \mathbb{R}} \sum_{PL \in \mathbb{PL}} \sum_{i \in \mathbb{I}} \sum_{i^* \in \mathbb{I}} Q_{rPLi^* it_m}$$

IMPORTS

$$- \sum_{r \in \mathbb{R}} \sum_{PL \in \mathbb{PL}} \sum_{i \in \mathbb{I}} \sum_{i^* \in \mathbb{I}} Q_{rPLii^* t_m}$$

EXPORTS

$$\forall\, r \in \mathbb{R}, i \in \mathbb{I}, t_m \in \mathbb{T}$$

Mathematical model

Technology balance

$$N_{jit_m} =$$ **EXISTING TECHNOLOGY**

$$N_{jit_m-1}$$ **PREVIOUS TECHNOLOGY**

$$+INV_{jit_m}$$ **INVESTMENT TECHNOLOGY**

$$\forall\, j \in [transf, Wind\ on\ shore, pumped], i \in \mathbb{I}, t_m \in \mathbb{T}$$

Mathematical model

Infrastructure balance

$$Y_{rPLii^*t_m} =$$ **EXISTING INFRASTRUCTURE**

$$Y_{rPLii^*t_m-1}$$ **PREVIOUS INFRASTRUCTURE**

$$+INV_{INF\,rPLii^*t_m}$$ **INVESTMENT INFRASTRUCTURE**

$$\forall\, r \in \mathbb{R}, PL \in \mathbb{PL}, i \in \mathbb{I}, t_m \in \mathbb{T}$$

Mathematical model

Main constraints

$$MU_{jr} = 1 \qquad \forall\, j \in [GEN], r = 220\ kV$$

$$CF_{jt_m} = CF_{jt_m}\Big|_{t_m=2014} \qquad \forall\, j \in \mathbb{J}, t_m \in \mathbb{T}$$

$$IM_{rit_m} = 0 \qquad \forall\, i \notin [1,6,10],\ r \in \mathbb{R}, t_m \in \mathbb{T}$$

$$Q_{rPLii^*t_m} \leq Y_{rPLii^*t_m} Qmax_{rPL} \qquad \forall\, r \in \mathbb{R}, PL \in \mathbb{PL}, i \in \mathbb{I}, t_m \in \mathbb{T}$$

Scenarios description

	Scenarios				
	A1	**A2**	**B**	**C**	**D**
Imports cap	No	No	Yes	Yes	Yes
Land	No	No	No	Yes	Yes
Power	No	Yes	Yes	Yes	Yes
Cap. factors	cst	cst	cst	cst	Variable

Mathematical model and scenarios in GAMS 24.4.6

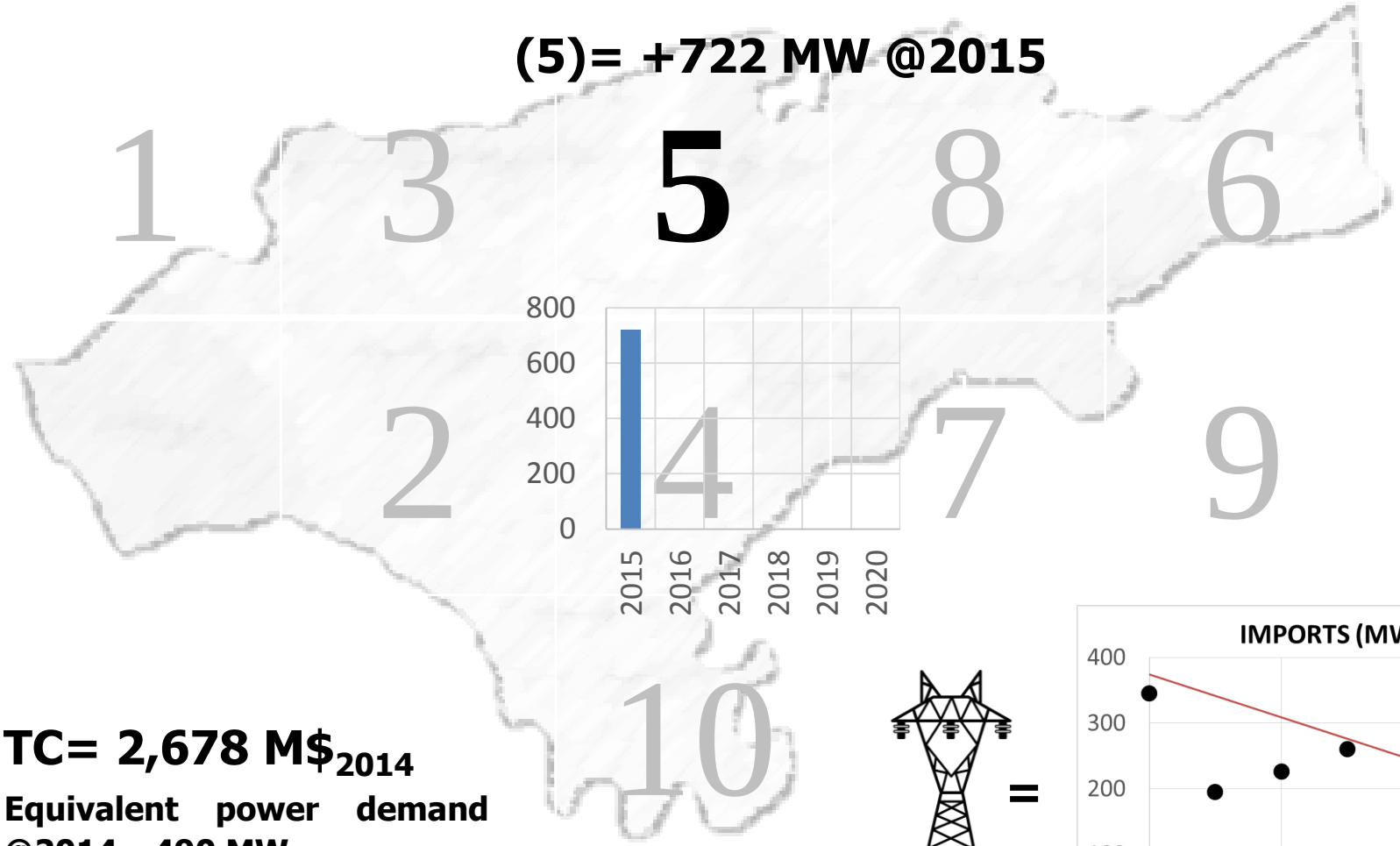
Mathematical model statistics

	Scenarios			
	A1-2	**B**	**C**	**D**
Problem type	MIP	MIP	MIP	NLP
Single equations	19k	19k	19k	19k
Single variables	23k	23k	23k	23k
Execution time (s)	<1	<1	<1	<60
Solver	CPLEX	CPLEX	CPLEX	BARON

SCENARIO A1: wind deployment

Scenario A1

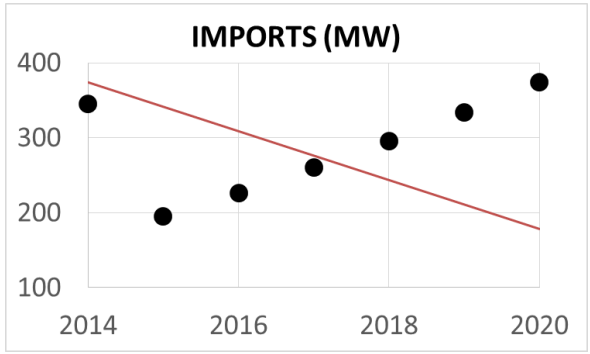
(5)= +722 MW @2015



TC= 2,678 M$$_{2014}$

Equivalent power demand
@2014= 490 MW
@2020= 699 MW

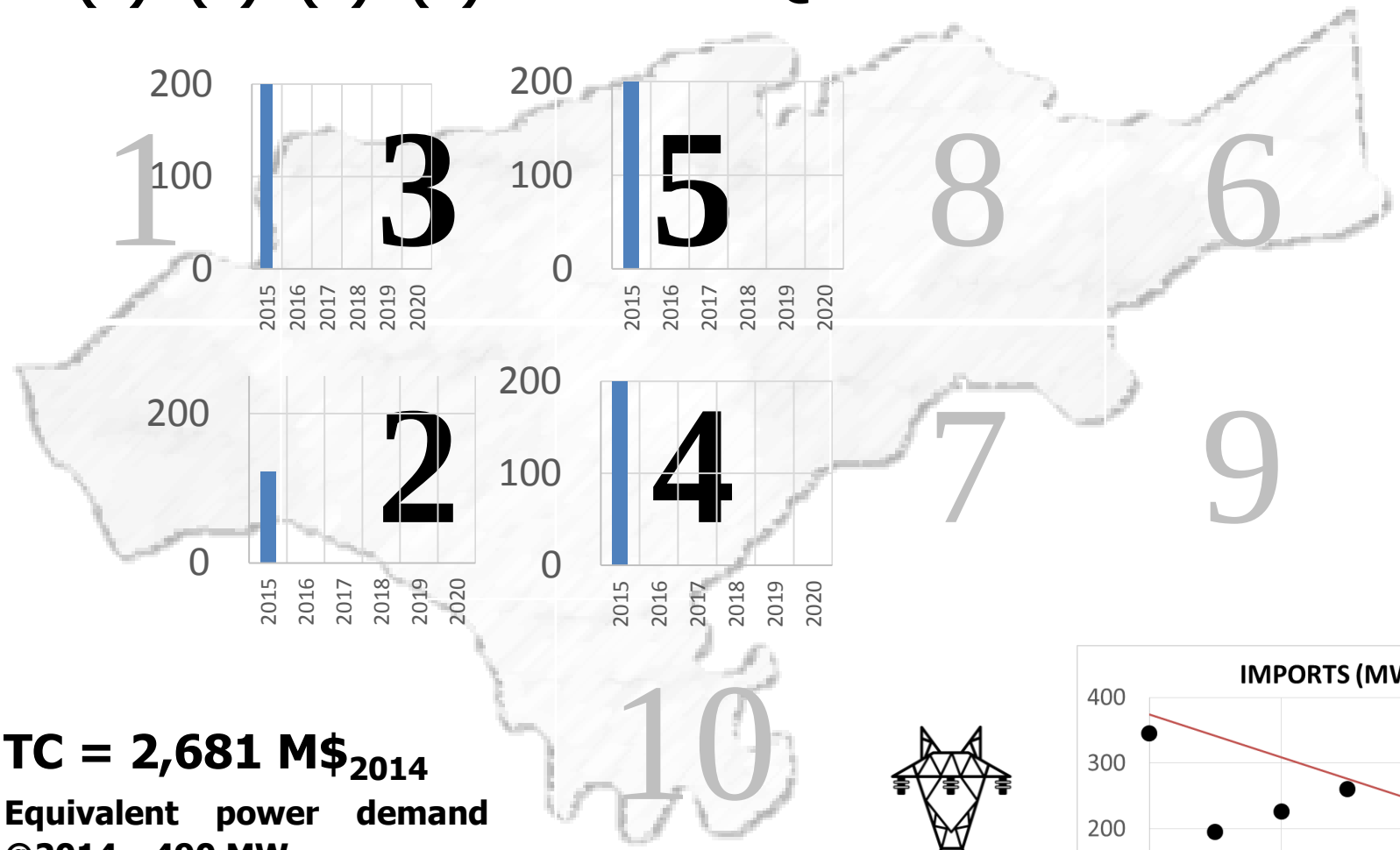
=



SCENARIO A2: wind deployment

Scenario A2

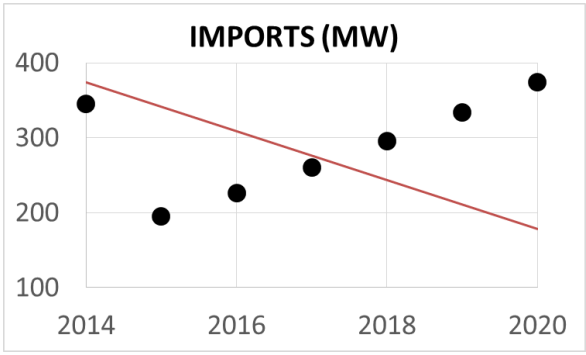
(2)+(3)+(4)+(5)= +722 MW @2015



TC = 2,681 M$$_{2014}$$

Equivalent power demand
@2014= 490 MW
@2020= 699 MW

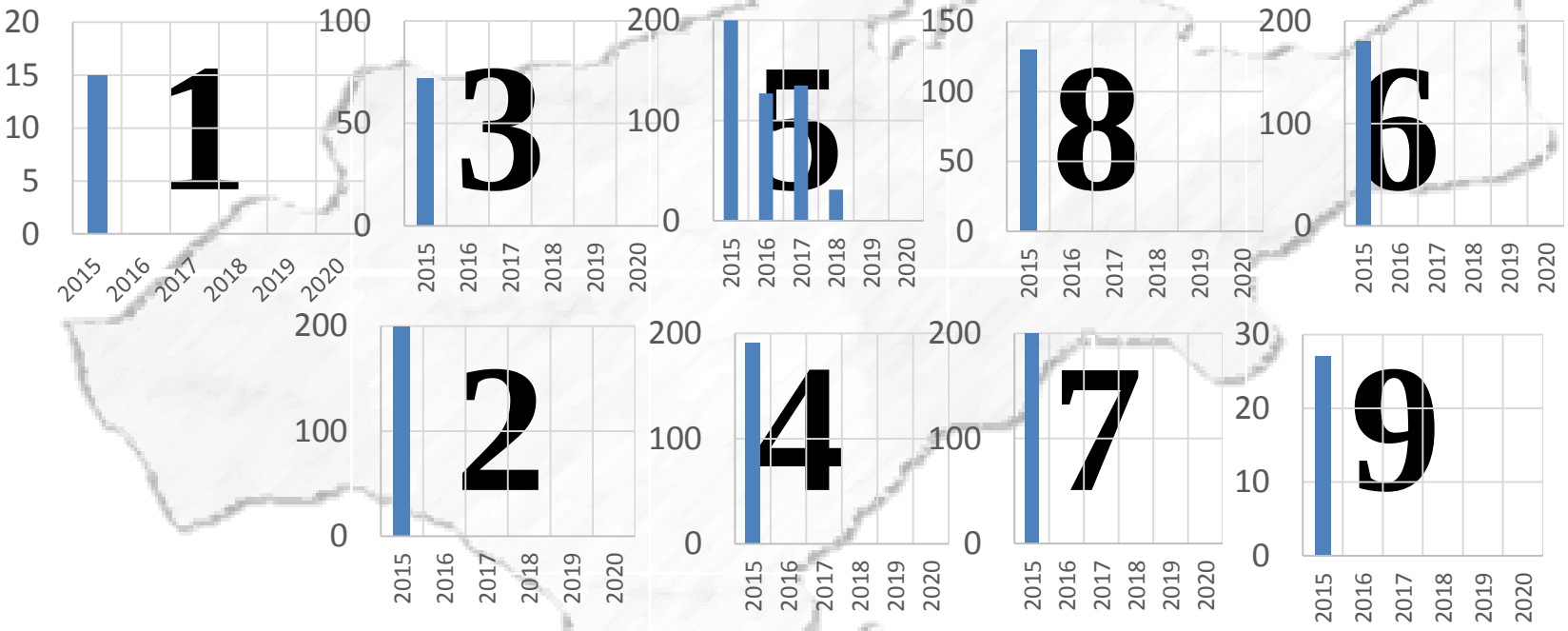
=



SCENARIO B: wind deployment

Scenario B

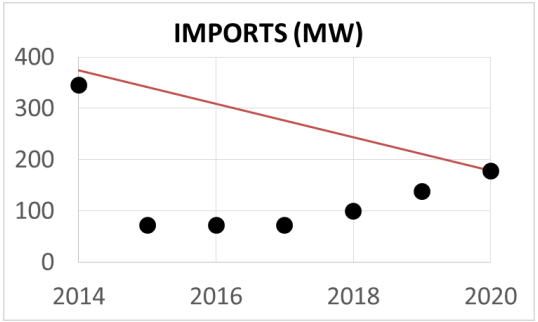
+1215 MW @2015
+293 MW @2015-2018



TC = 3,485 M$$_{2014}$$

Equivalent power demand
@2014= 490 MW
@2020= 699 MW

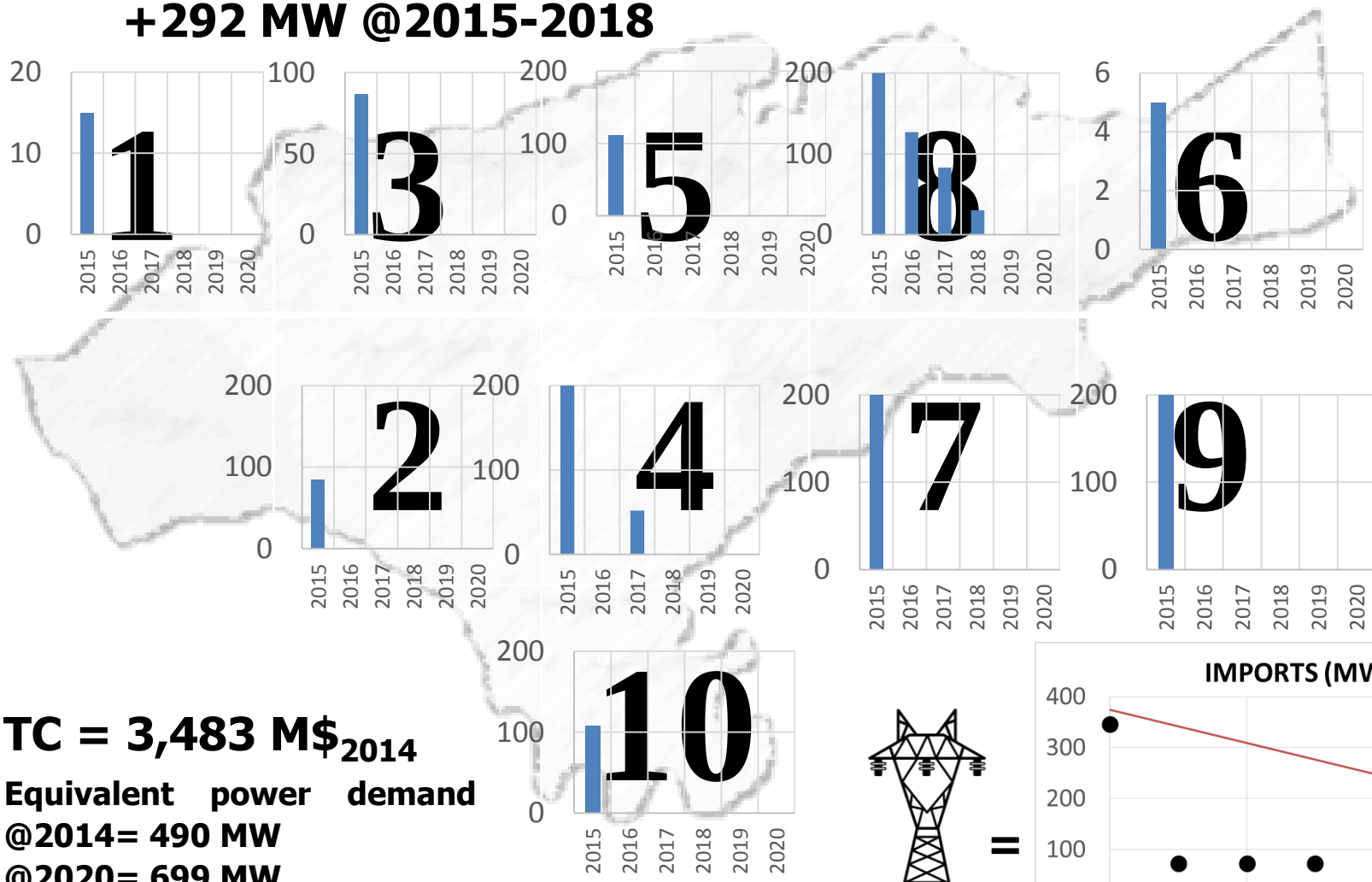
=



SCENARIO C: wind deployment

Scenario C

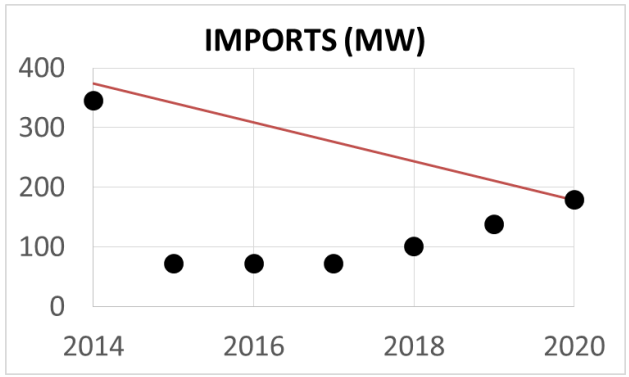
+1212 MW @2015
+292 MW @2015-2018



TC = 3,483 M$$_{2014}$$

Equivalent power demand
@2014= 490 MW
@2020= 699 MW

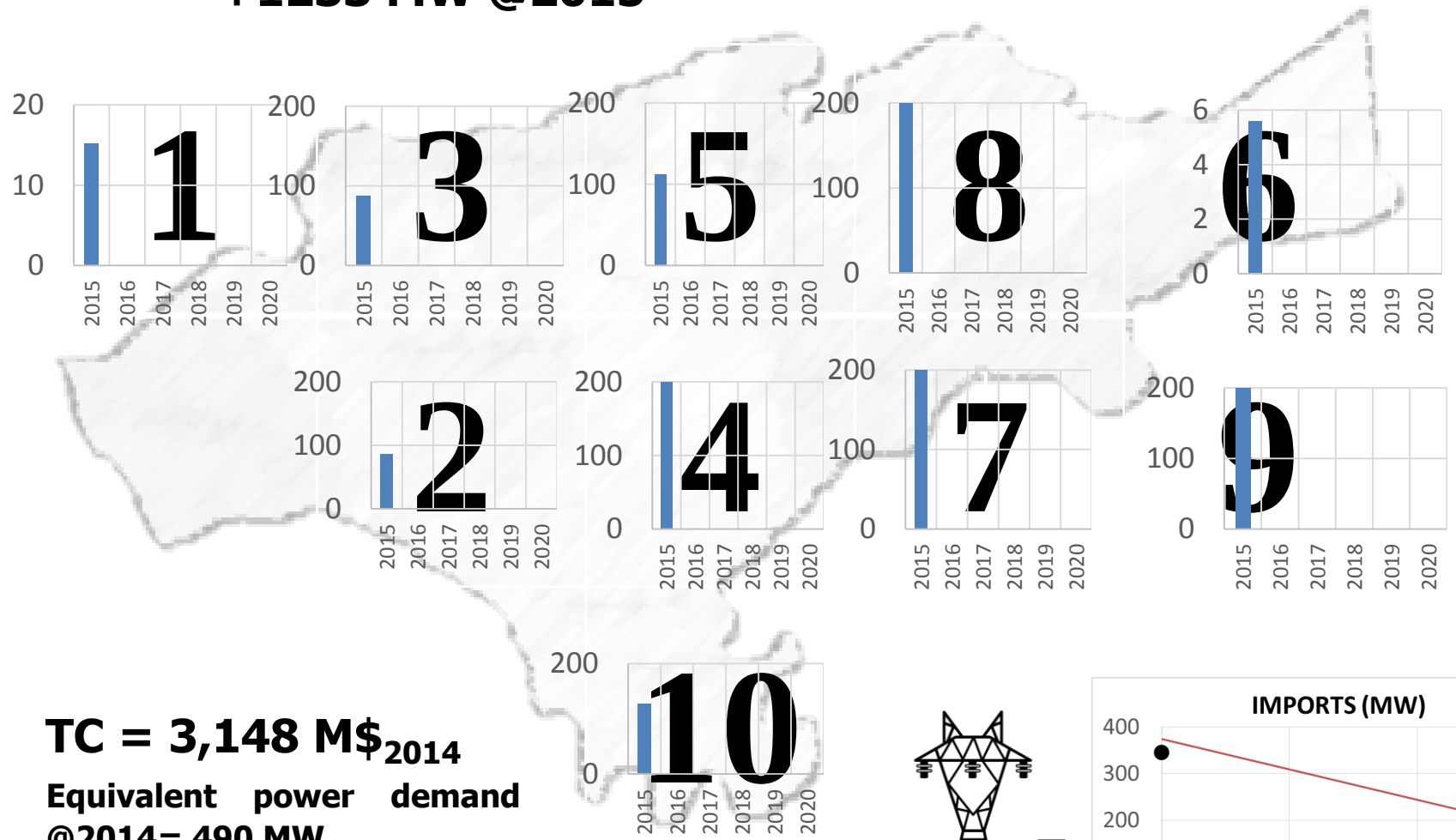
=



SCENARIO D: wind deployment

Scenario D

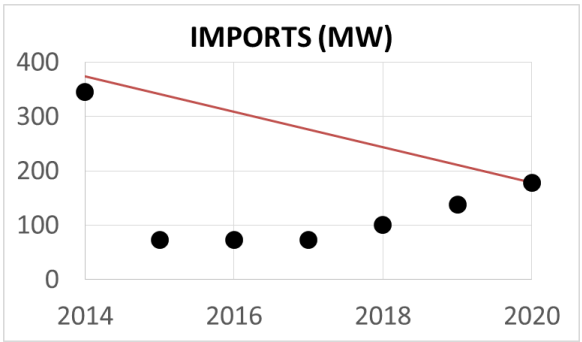
+1233 MW @2015



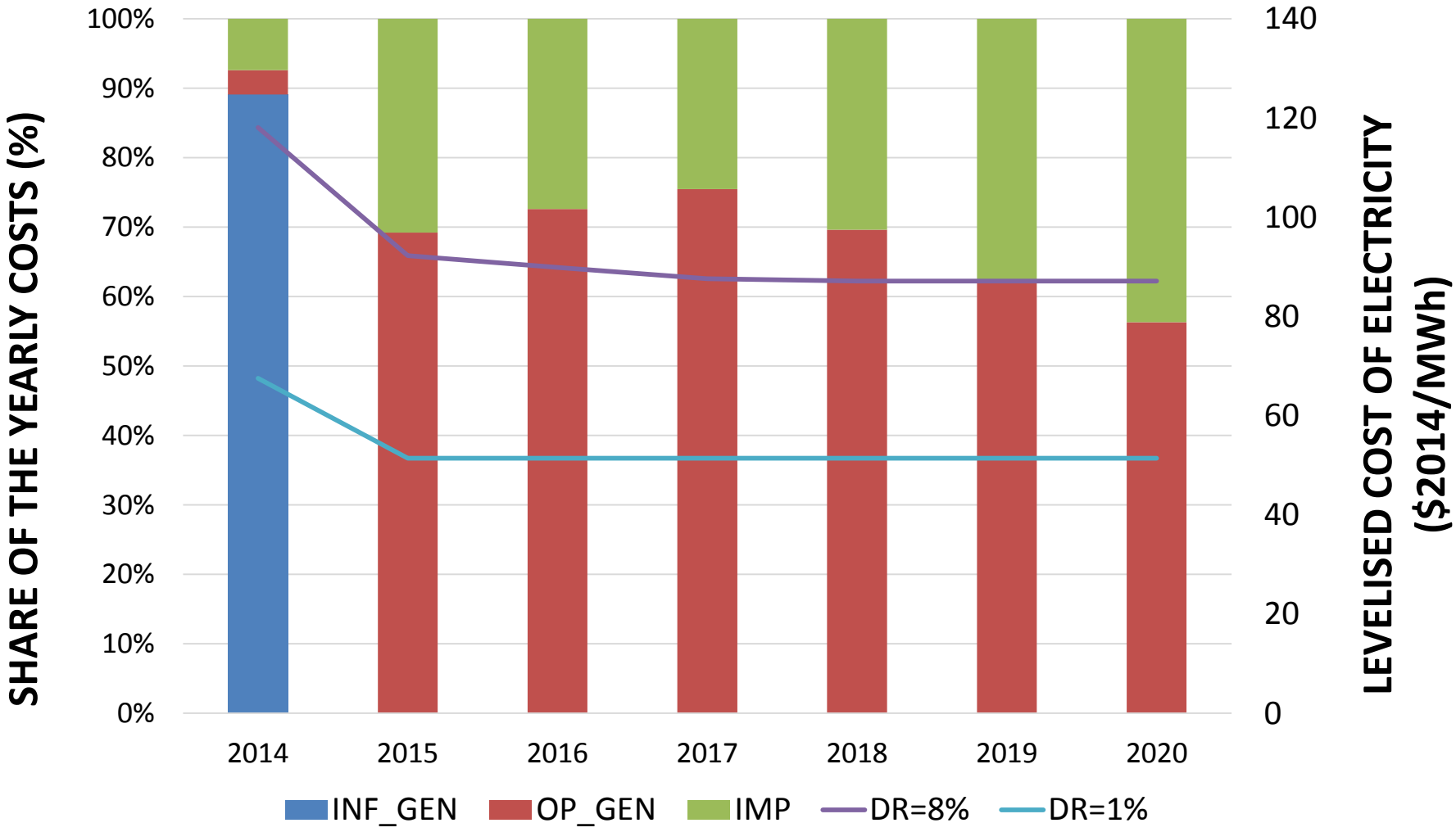
TC = 3,148 M$$_{2014}$$

Equivalent power demand
@2014= 490 MW
@2020= 699 MW

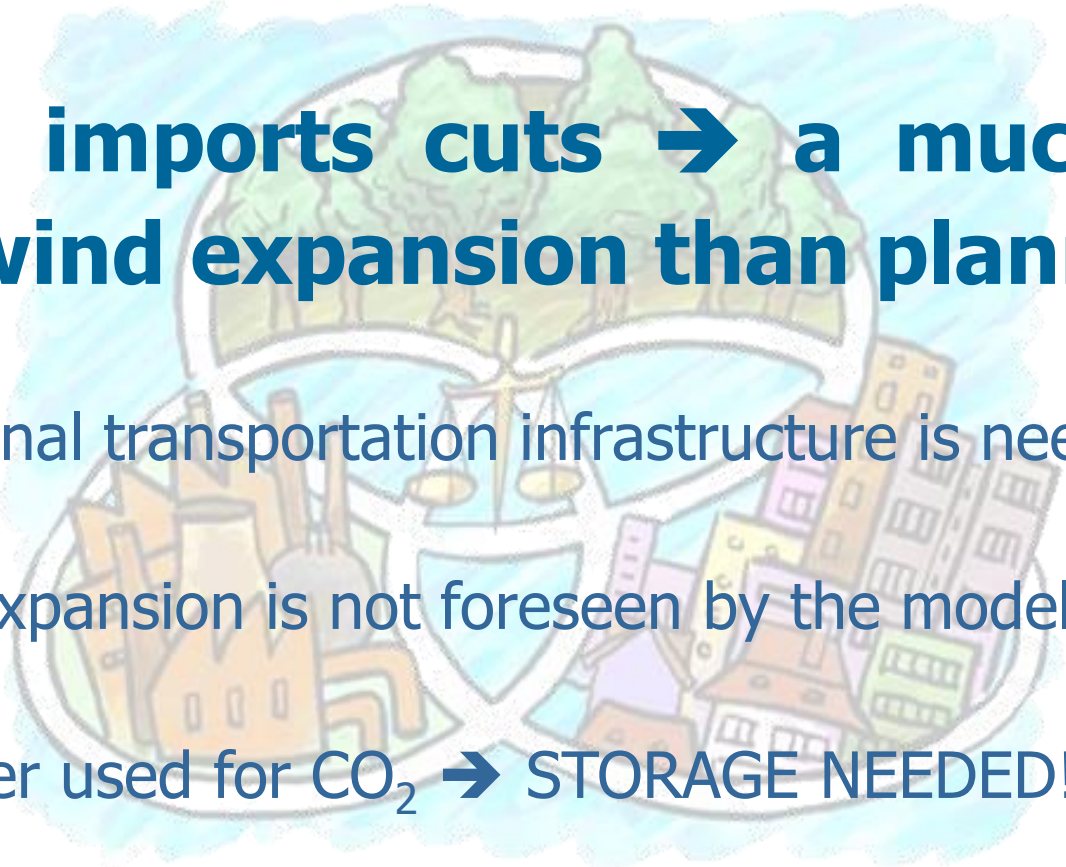
=



SCENARIO D: time cost profile and LCOE



RENEWABLE ELECTRICITY INTEGRATION AT A REGIONAL LEVEL: CANTABRIA CASE STUDY



- **Future imports cuts ➔ a much more large wind expansion than planned**
- No additional transportation infrastructure is needed
- Pumped expansion is not foreseen by the model
- Peak power used for CO_2 ➔ STORAGE NEEDED!

Acknowledgements

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