Italian Methodology for Assessing the Cost-effective Target Capacity

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Agenda

Introduction

Context and Roadmap of Target Capacity Assessment

Planning the grid **transmission expansion** is a key problem for TSOs and policymakers, especially in terms of **efficiency** and **sustainability**. The long-term energy scenarios uncertainty requires **new approaches** aimed at defining **cost-effective transmission infrastructure development strategies** in order to reach the electricity **interconnection targets** *(e.g. **15%** by 2030 set by the European Council in 2014 to meet the EU climate and energy objectives)*.

In 2017 the Italian Regulator (ARERA) requested Terna to identify the **target capacity:** *"the cost-efficient transmission capacity to realize across internal market sections and towards external borders of the Italian power system"*. The target capacity methodology has been introduced on Italian side as **it has the proper robustness for the Italian regulatory scope and output-based incentive scheme definition**, while system needs analysis carried out by ENTSOe is subject to compulsory simplification in relation to internal needs identification rather than for regulation scheme.

Since 2018 a **new methodology** for the assessment of target capacity has been developed and updated.
By 2024 **three editions of Target Capacity Report** have been published, each following a period of **public consultation** and **independent expert–based evaluation,** as requested by regulator. In general, the **Report is prepared and published every of two years** in line with the frequency of the European, and therefore Italian, scenarios update.

2017 | 2018 | 2019 | 2020 | 2021 | 2022/2023 | 2024/2025

- 2018: ***1st Edition of Target Capacity Report***
- 2020: ***2nd Edition of Target Capacity Report***
- 2022/2023: ***3rd Edition of Target Capacity Report*** — *Methodology Focus*
- 2024/2025: ***4th Edition of Target Capacity Report*** — WORK IN PROGRESS

Agenda

Introduction

Methodology

Italian Case Study

Regulatory Incentive and actual transmission developments

Methodology
Overview

The **purpose** of the method is to **identify the additional cost-effective transmission capacity** (internal “sections” bidding zones and at borders) of the Italian Transmission System in order to **support the output-based regulatory scheme** that rewards the increases of transmission capacities and facilitates the efficient transmission system development.

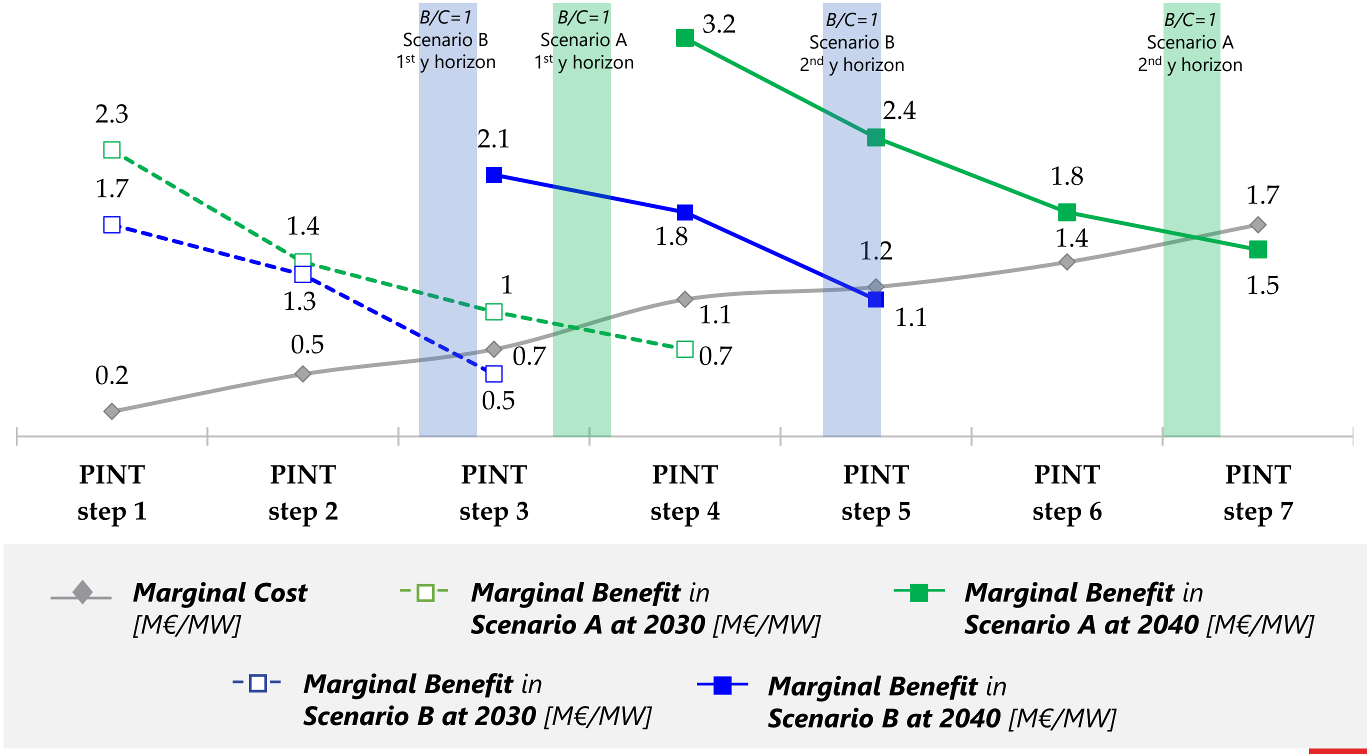
The **target capacity** is defined as the **transmission capacity** which is **economically efficient to realize**, as its **benefits are higher than its costs.**

$$\frac{\textit{Benefits}^{(1)}}{\textit{Costs}} > 1$$

The **cost-effective target capacity** for each section/border under study in each considered scenario is **defined around** the **cross point** of:

- An **increasing marginal cost curve** [M€/MW] related to the transmission capacity investment costs (input information according to reference values for each section/border)
- A **decreasing marginal benefit curve** [M€/MW] calculated as output per each iterations of «additional transmission capacity step» in each section/border, scenario and time horizon under consideration

Starting from the 2030 scenario results the iterative analysis for the 2040 scenario are carried out.



1. *aiming to be compared life cycle investment costs with yearly benefits, in the ratio B/C the yearly benefits are considered x15,6 which is the equivalent actual value of 1 p.u./y in 25 year cash flows*

Methodology

Iterative process work-flow

Iterative Process and Benefit Curve definition

TOOT analysis evaluates the **benefits** related to the planned **projects included in the base case**.

BASE CASE

Selection of **sections/borders** for testing a PINT of additional transmission capacity

- Check of Benefits / Costs > 1 per each tested additional capacity and each scenario;
- Additional transmission capacities are confirmed on the sections/borders if **marginal benefits are higher than costs.**

The **least regret approach** allows the identification of the unique value.

TOOT: "Take Out One a Time" method
PINT: "Put In One a Time" method

Description

In order to build the initial point of the interested sections/borders marginal benefit curve, the "Take Out One at the Time" (**TOOT**) method is applied, in compliance with the cost-benefit analysis performed in the European context.

The initial network (or "base case") is made up of the existing grid considering inside all projects already authorized and foreseen in service at the date of the short term scenarios (e.g. by 2025)

Sections/borders are selected for additional transfer capacity installation only if they have suitable conditions in each analysis scenarios. A multi-criteria method (**TOPSIS**) is used to identify the sections/borders on which the transmission capacity increases must be tested at the beginning of each iteration.
Four **criteria** are investigated:

- *Congestion hours*
- *Price spread*
- *Investment cost for transmission capacity increase*
- *Project progress*

- Marginal benefits are compared with marginal costs using the "Put IN one at the Time" (**PINT**) method: if the **ratio Benefits / Costs is > 1**, the additional capacity for that section or border is confirmed and the next iteration starts
- The iterative process stops when no section/border presents favourable conditions to new additional capacity: benefits are lower than costs for each and all sections/borders

The iterative flow allows to obtain as many development strategies as the number of analysis scenarios. The least **regret approach** applied for each border/section at contrasting scenarios allows the identification of the unique value to aim for.

Methodology

Marginal Cost and Benefits Curve Evaluation

Marginal Cost Curves Evaluation

input

General principles:

- with regard to **planned projects** included in the National Development Plan (NDP) and up to their expected capacity planned values, **the investment costs estimation refers to the most recent NDP***
- the single input in the marginal investment curve considers the NDP project investment cost with criteria of **capacity increase contribution**
- for transmission capacity increase over the planned projects in the NDP, updated investment information are considered (i.e. related to new project presented in the NDP and/or the ACER unit investment cost report)
- with regard to marginal investment cost for cross-border projects without detailed agreements, it is assumed each country bears 50% of total investment cost

Marginal Benefit Curves Evaluation

output

Zonal market and **nodal network** simulations are performed in order to evaluate, in each **iteration,** the benefits related to the transmission capacity increases selected with the multi-criteria analysis:

Code	Benefit categories included	
	Description	***Simulator***
B1	Socio Economic Welfare (SEW)	Day Ahead zonal market
B3	Energy Not Supplied (ENS) reduction	Grid Reliability and Adequacy nodal network
B5	RES integration	Grid Reliability and Adequacy nodal network
B7	Zonal dispatching costs variation	Ancillary service zonal market
B8	Nodal dispatching costs variation	Grid Reliability and Adequacy nodal network
B18	CO_2 variation	Day Ahead zonal market
B19	Non–CO_2 emissions variation	Day Ahead zonal market

** Infrastructural project costs refer to the increase of the exchange capacity (TTC), including eventually reinforcements, rationalizations or interfering works able to allow the project implementation*

Methodology

Least Regret Method

Since the iterative methodology results in the identification of *n* development strategies (or "options") (one for each scenario under study), the **least regret approach** is carried out to define the **unique set of cost-effective target capacities** to aim for.

1. Definition of the **Net Benefit indicator** for each development strategy
2. Identification of the **reference strategy** in each scenario, as the option which presents the highest net benefit (**NB$_{\text{Best St.}}$**) in that scenario
3. Evaluation of the «**regret**» related to each development strategy in each scenario, as the gap of each option to the reference strategy
4. Identification of development strategy with the **lowest maximum regret** among all scenarios under study, exposing the entire system to the **least amount risk**

Net Benefit (NB) =
Total Benefit (Btot) – Total investment cost (Ctot)*

* *Total Benefit has to be evaluated for the entire operational life-time of the additional transmission capacity foreseen by the development strategy*

$$Regret_i = Net\ B_{BestSt.} - Net\ B_i$$

$$min[max\ (regret_i)\ ]$$

Example

Net benefit (M€)

	Strategy 1	Strategy 2	Strategy 3
Scenario A	380	200	**400**
Scenario B	120	**165**	125
Scenario C	**350**	50	250
Scenario D	160	150	**185**

***Reference strategy** in the considered scenario*

Regret (M€)

	Strategy 1	Strategy 2	Strategy 3
Scenario A	20	200	0
Scenario B	**45**	0	40
Scenario C	0	**300**	**100**
Scenario D	25	35	0
Worst regret	**45**	**300**	100

***Highest regret** in the considered development strategy*

Best strategy

Methodology

European framework

- **ENTSO-E,** the European Network of Transmission System Operators for Electricity**, is the association for the cooperation of the European transmission system operators (TSOs).**
- **ENTSO-E's 10-year network development plan (TYNDP)** is the European electricity infrastructure development plan. It **links, supports and complements national grid development plans and assess Cost-Benefits Analysis of transmission and storage investment projects.**
- In this framework, the **TYNDP System Need Study (IoSN) is set** with the aim of investigating where the opportunities are to make Europe's power system more efficient. It shows where new solutions, beyond already planned investments, are needed to reach European decarbonization targets and keep security of electricity supply and costs under control.
- Besides the goals set for IoSN (*ENTSO-e*) and Target Capacity Methodology (*Terna*) are quite similar, **some differences can be highlighted between the two approaches:**

	IoSN 2022	***Target Capacity 2023***
METHODOLOGY AND SIMULATION TOOL	Additional **transmission and storage** capacity **needs** assessment through the resolution of an **optimization problem** with **Antares tools**	Additional **transmission** capacity **needs** assessment through an **iterative heuristic method** solved with **Promed, Modis and Grare internal tools**
TIME HORIZONS	**2030** and **2040**	**2030** and **2040**
BIDDING ZONES	**European cross-border** needs	**Italian cross-border and internal** needs
REFENCENCE GRID	2025 Reference Grid for 2030 and 2040 time horizon	• 2025 Reference Grid for 2030 time horizon • 2030 Target capacity for 2040 time horizon
CBA INDICATORS	**Market Benefits** (es. SEW)	**Multiple Market and Grid Benefits** (es. SEW, ENS, RES Penetration, CO2 variation, dispatching costs)
SCENARIOS	**Single** energy scenario investigated for each time horizon	**Multiple** energy scenarios investigated for each time horizon and **least regret approach** applied to identify one set of target values
SENSITIVITIES	-	Cap on Italian storage installed capacity to actual values and on Italian cross-border development to planned interconnection capacity

The **differences on simulation tools logic operation and CBA indications** are the main reasons that **explain the need for Terna to develop its own methodology.**

Agenda

Introduction

Methodology

Italian Case Study

Regulatory Incentive and actual transmission developments

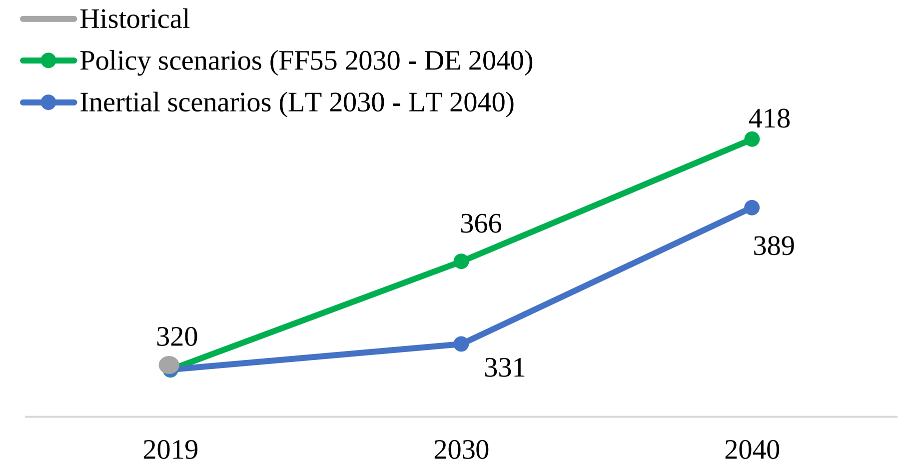
Italian Case Study

Energy Scenario

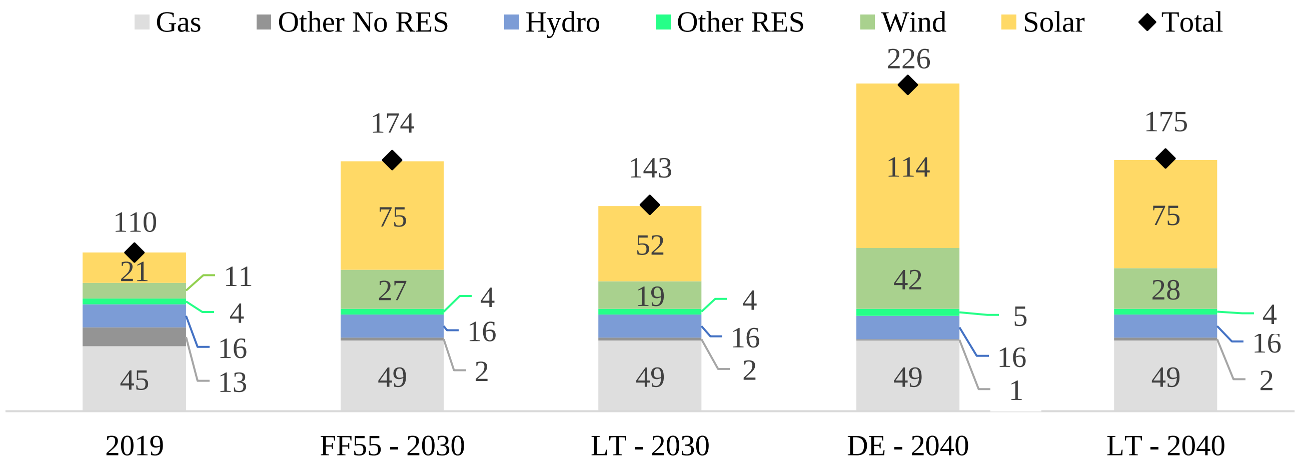
The target capacity assessment has been performed at both **long term 2030 and very long term 2040 year horizons** in the same relevant planning scenarios adopted in the 2023 NDP cost-benefit analyses, in particular:

- the policy scenarios **"Fit for 55" at 2030** ("FF55 2030") and **"Distributed Energy" at 2040 ("DE 2040")** in line with CO_2 emissions reduction and share of renewables on the total electricity demand in Italy, requiring approximately **+70 GW by 2030 and +120 GW by 2040 of new RES capacity;**
- the technology-driven **scenarios "Late Transition" at 2030 and 2040** ("LT 2030" and "LT 2040") mostly aligned with the less challenging objectives of the previous National Energy and Climate Plan (NECP).

Demand trend forecast [TWh]



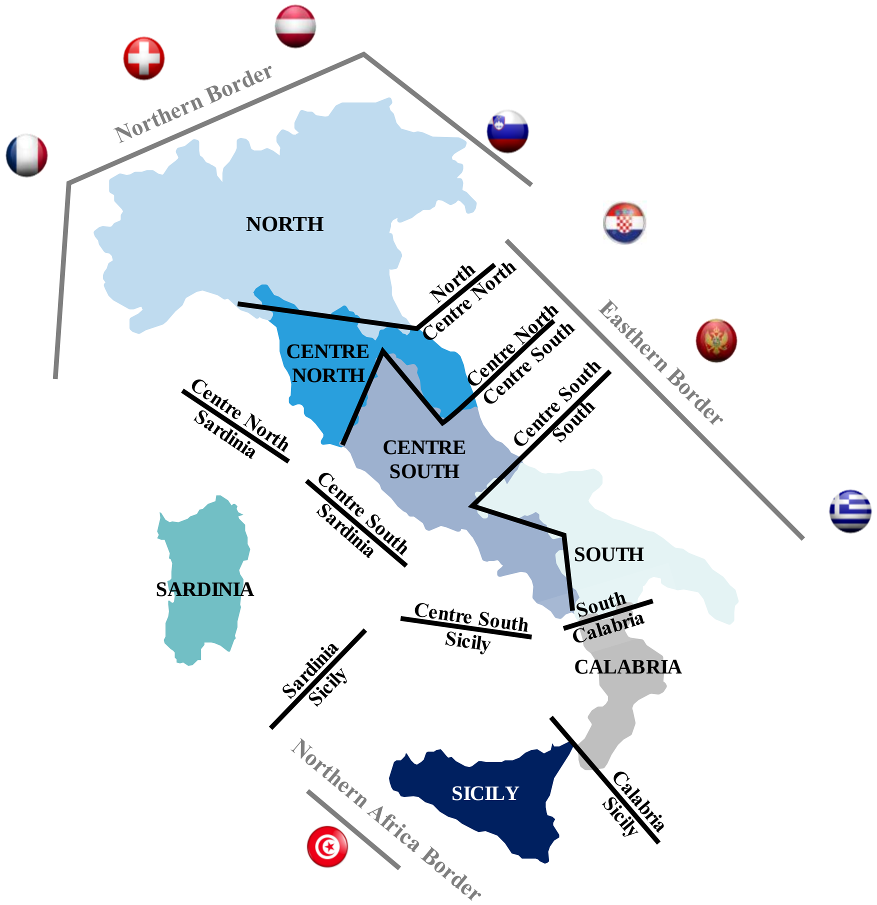
Generation Mix [GW]



Italian Case Study

Reference Grid

Bidding zones of the Italian power system: internal sections and external borders under study

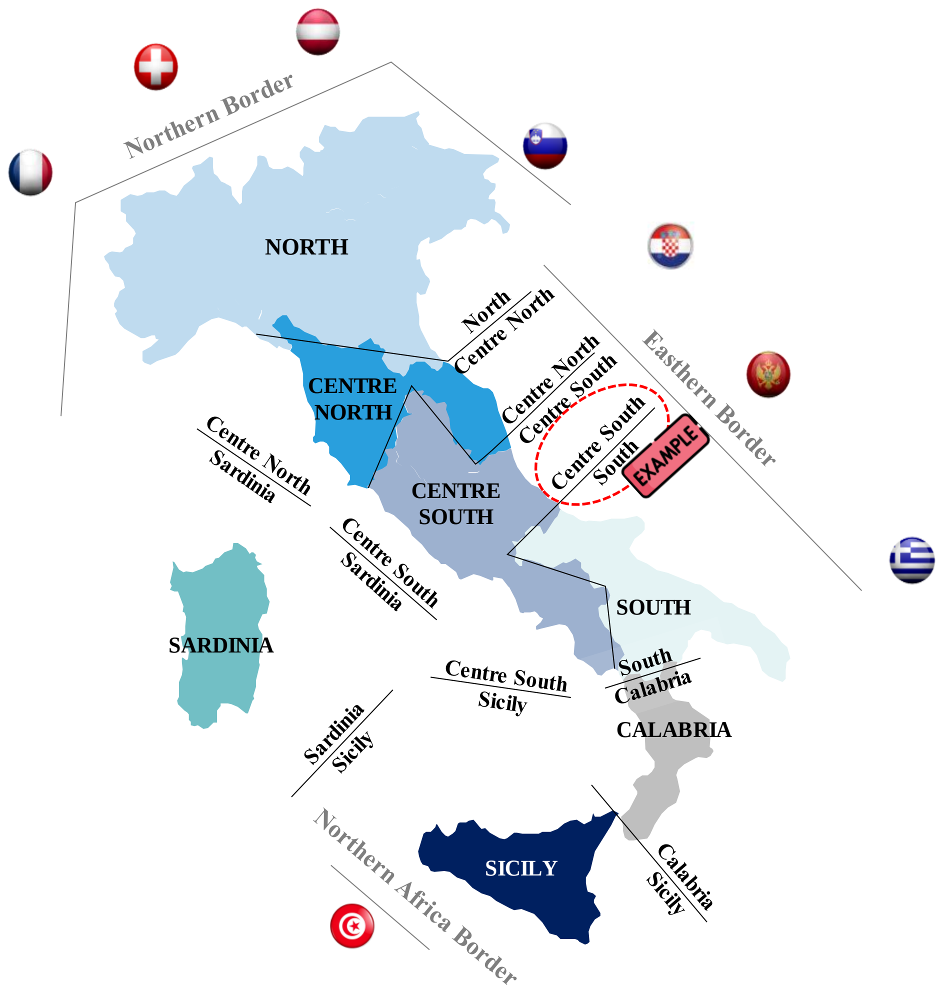


Planned development projects included in the base case: transmission capacity increase provided (MW) and section/border

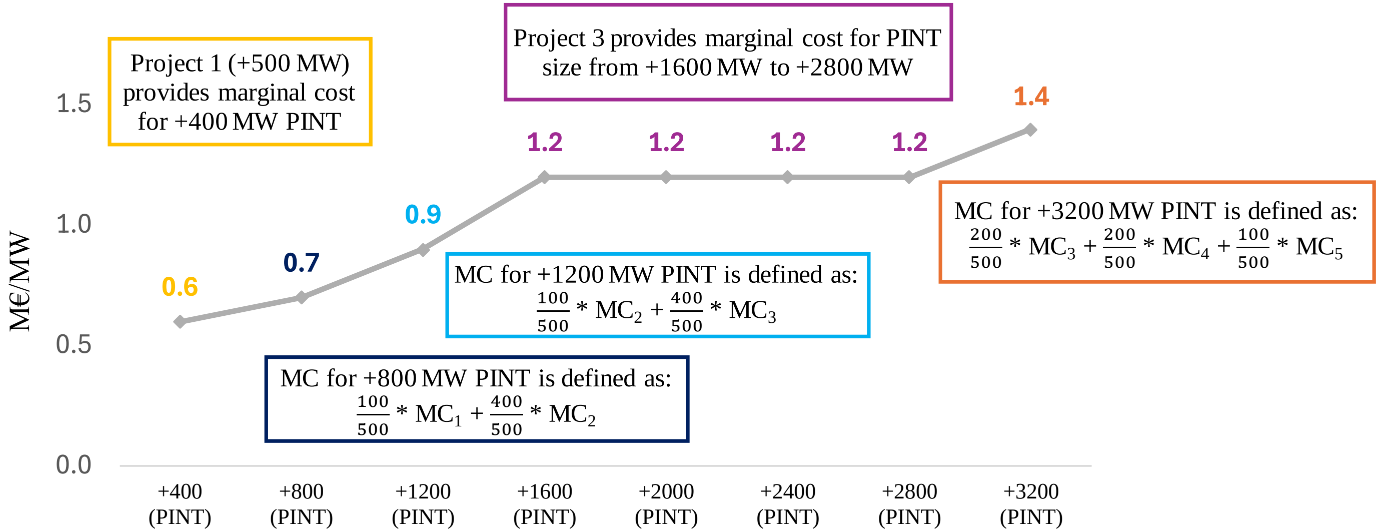
	Project	MW	Section/Border	
1	HVDC Italia - Francia	1200	ITn – FR	*Project completed in 2023*
2	El. 220 kV Nauders - Glorenza	300	ITn – AT	
3	El. 132 kV Brennero - Steinach	100	ITn – AT	*Advanced status of works*
4	El. 380 kV Calenzano - Colunga	200	ITn – ITcn	

Italian Case Study

Example of Cost Curve Definition : Centre South – South Section



Projects contributing to marginal cost curve building				
Planned/Standard Projects		**TTC (MW)**	**Marginal Cost (M€/MW)**	***Assesment***
1	*Project 1*	+500	0.6 (MC_1)	PINT
2	*Project 2*	+500	0.7 (MC_2)	PINT
3	*Project 3*	+2000	1.2 (MC_3)	PINT
4	*Project 4*	+200	1.4 (MC_4)	PINT
5	*Project 5*	+600	1.6 (MC_5)	PINT



Italian Case Study

Iteration Process on one exemplative scenario: *Policy 2030*

TOOT Assessment ***PINT Assessment***

POLICY 2030		ITERATION 0 - TOOT			ITERATION 1 - PINT				ITERATION 2 - PINT				ITERATION 3 - PINT			ITERATION 4 - PINT		
		Marg. Cost [M€/MW]	Capacity [MW]	B/C	Marg. Cost [M€/MW]	Topsis	Capacity [MW]	B/C	Marg. Cost [M€/MW]	Topsis	Capacity [MW]	B/C	Marg. Cost [M€/MW]	Capacity [MW]	B/C	Marg. Cost [M€/MW]	Capacity [MW]	B/C
Northern Border	AT - ITn	0,4	400	2,8	0,1	NO	500		0,1	NO	500		0,1	500	7,6	0,3	1000	2,8
	CH - ITn				0,4	NO	500		0,4	SI	500	1,4	0,5	1000	1,3	1,0	1500	0,5
	FR - ITn	0,6	1200	4,1	0,5	NO	500		0,5	SI	500	3,8	-	0		-	0	
	SI - ITn				0,3	SI	500	2,4	0,5	NO	1000		0,2	400		0,2	400	
Balkan Border	ITcn - HR				0,8	NO	500		0,8	NO	500		0,8	500		0,8	500	
	ME - ITcs				0,6	NO	500		0,6	SI	500	3,1	0,7	1000	2,5	0,6	600	
	ITbr - GR				0,8	SI	500	5,6	0,8	NO	1000		0,8	1000	4,0	0,8	500	
Northern Africa Border	ITsic - TUN				0,8	SI	500	7,3	0,9	SI	1000	3,4	0,8	600		0,8	600	
Internal Sections	ITcn - ITn	1,4	200	3,0	0,6	NO	400		0,6	NO	400		0,6	400	4,0	0,6	800	3,0
	ITcs - ITcn				0,4	SI	400	6,7	0,4	SI	800	3,6	0,5	1200	1,2	0,7	1600	0,2
	ITs - ITcs				0,6	SI	400	9,0	0,7	SI	800	4,3	0,9	1200	2,8	1,2	1600	1,5
	ITsar-Itcn				1,3	SI	100	7,2	2,2	SI	800	4,8	2,5	1200	3,7	2,8	1600	0,8
	ITsar-ITcs				2,0	NO	400		2,0	NO	400		2,0	400	2,9	2,0	800	0,9
	ITsar-ITsic				2,0	SI	400	5,7	2,0	NO	800		2,0	800	2,6	2,2	1200	0,1
	ITsic-ITcs				1,9	SI	400	7,9	1,9	SI	800	8,0	2,0	1200	3,9	2,2	1600	0,9
	ITsic-ITcal				0,4	NO	400		0,4	NO	400		0,4	400	19,0	0,7	800	3,3
	ITcal-ITs				0,1	NO	400		0,1	NO	400		0,1	400	18,3	0,1	800	11,2

TOPSIS Assessment

Legend: PINT Confirmed (B/C>1) PINT Not Confirmed (B/C<1) CAP on border achieved (*)

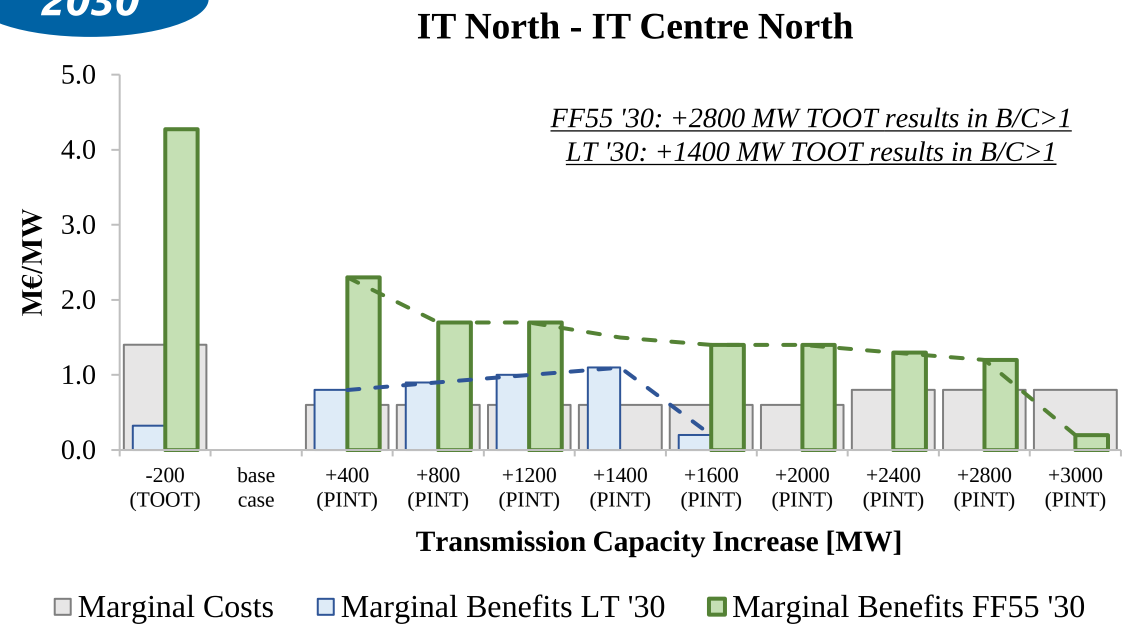
(*) The capacity increases (PINT) at the borders have been confirmed up to the values provided by the planned projects in the Development Plan

Italian Case Study

Main results on one exemplative section: *North – Centre North*

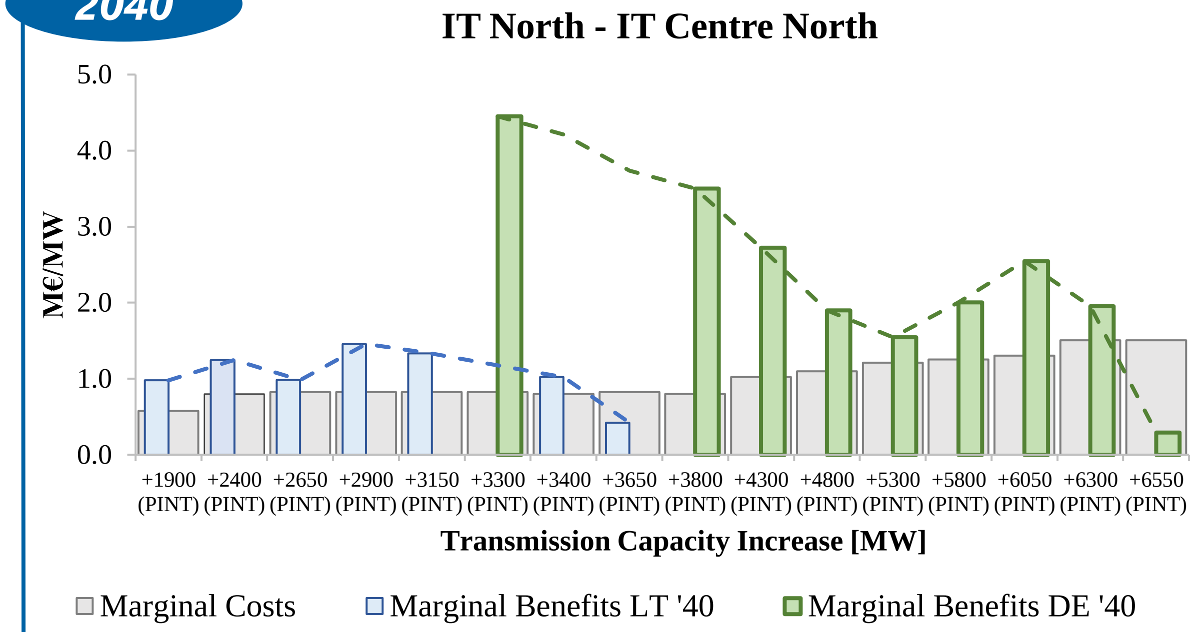
For each market section and year under study, target capacity is obtained as the **intersection between each respective decreasing marginal benefit curve and increasing marginal cost curve.**
In addition, pursuing selectivity and efficiency criteria, only for **2030 time horizon**, an additional **TOOT of 400 MW is executed** in order to refine the achieved results.

2030



Target Capacity FF55 2030: +3.000 MW
Target Capacity LT 2030: +1.600 MW

2040

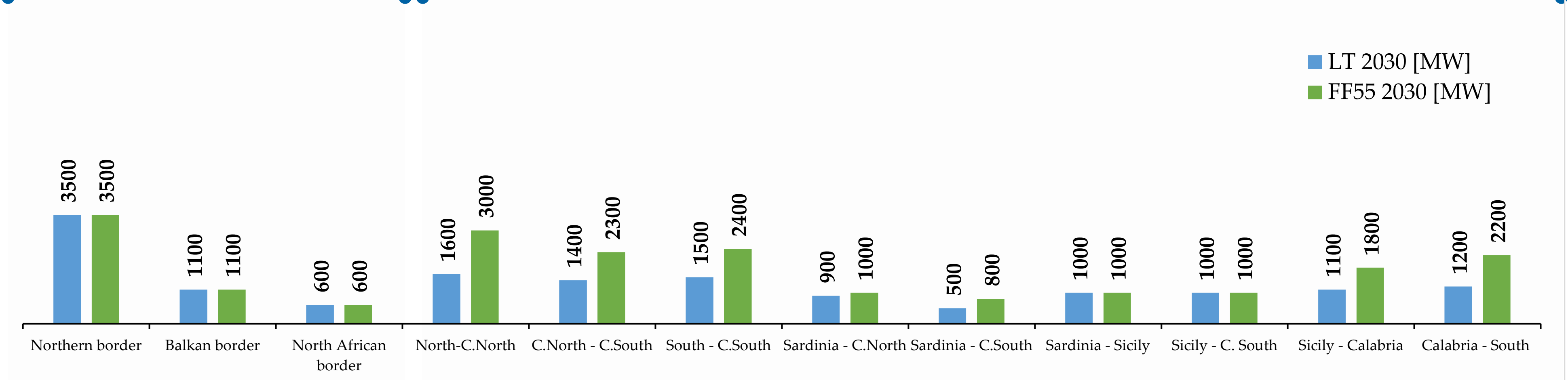


Target Capacity DE 2040: +6.500 MW
Target Capacity LT 2040: +3.700 MW

Italian Case Study

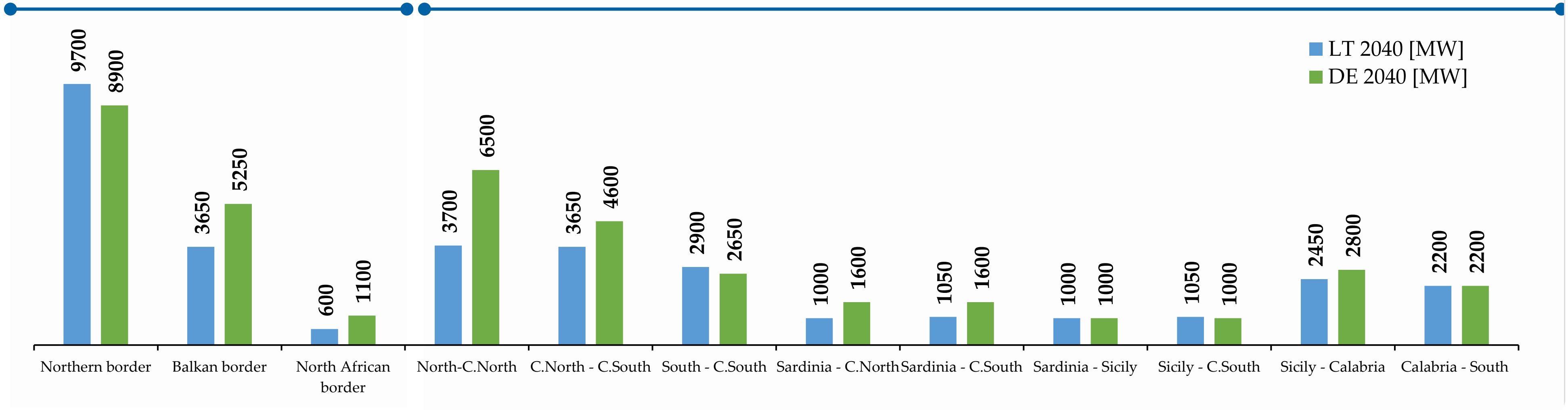
Results [1/2]

External Borders — **Internal Sections**



Cost-effective transmission capacity increases [MW] at 2030 time horizon *for each section/border and each energy scenario*

External Borders — **Internal Sections**



Cost-effective transmission capacity increases [MW] at 2040 time horizon *for each section/border and each energy scenario*

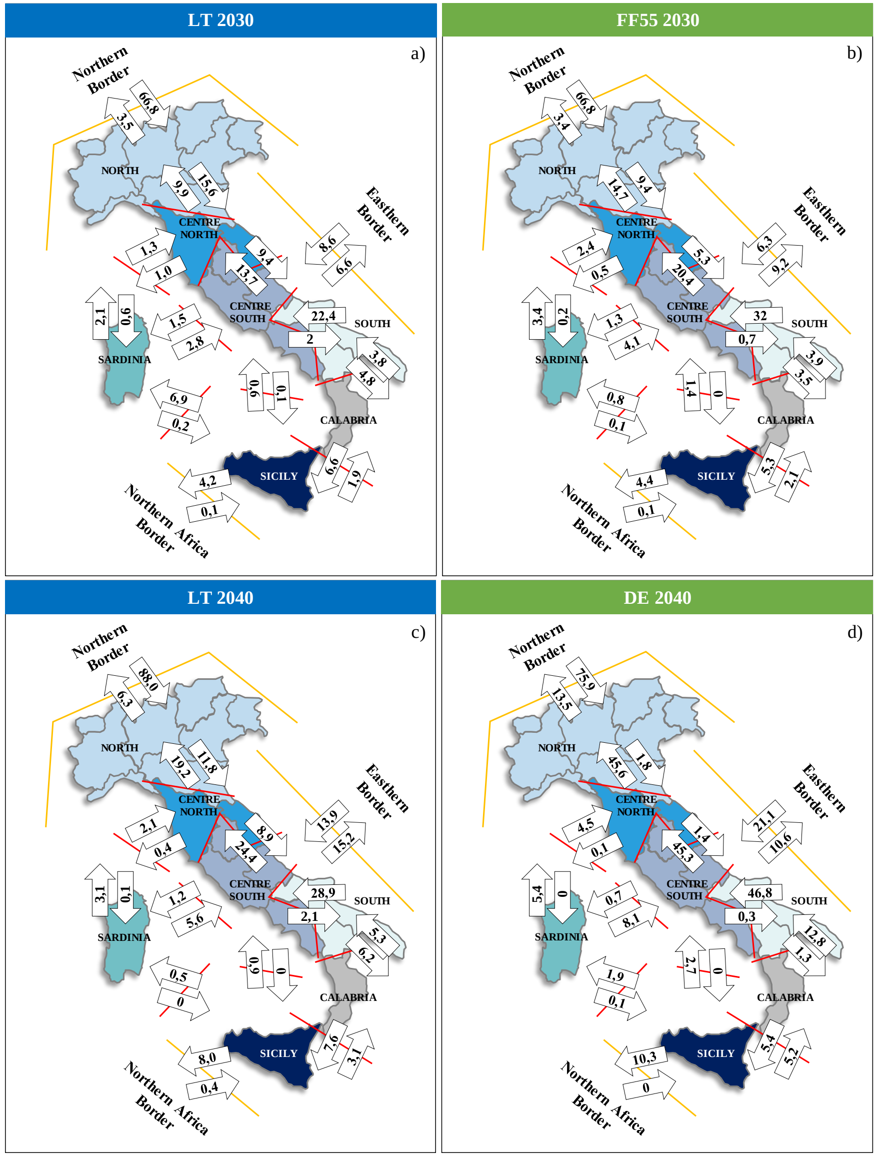
Italian Case Study

Results [2/2]

Values in MW

Section/Border	Main Direction	Actual Value	Additional Target Capacity 2030	Total Target Capacity 2030	Additional Target Capacity 2040	Total Target Capacity 2040
Northern border – IT	→	8935	3500	12435	9100	18035
Balkan border – IT	→	1100	1100	2200	4400	5500
	←	1100		2200		5500
Northern Africa border – IT	←	0	600	600	800	800
North – Centre North	→	3100	2300	5400	5100	8200
	←	4300		6600		9400
Centre North – Centre South	→	2800	1800	4600	4100	6900
	←	2900		4700		7000
South – Centre South	→	5000	1900	6900	2700	7700
Sardinia – Centre North	→	395	900	995	1300	1395
	←	315		915		-
Sardinia – Centre South	→	900	600	1500	1300	2200
	←	720		1320		-
Sardinia – Sicily	→	0	1000	1000	1000	-
	←	0		1000		1000
Sicily – Centre South	→	0	1000	1000	1000	1000
	←	0		1000		-
Sicily – Calabria	→	1300	1400	2700	2600	3900
	←	1500		2900		4100
Calabria – South	→	2350	1700	4050	2200	4550
	←	1100		2800		3300

Expected Power Flows (TWh) resulting from the implementation of the identified additional target capacity.



Italian Case Study

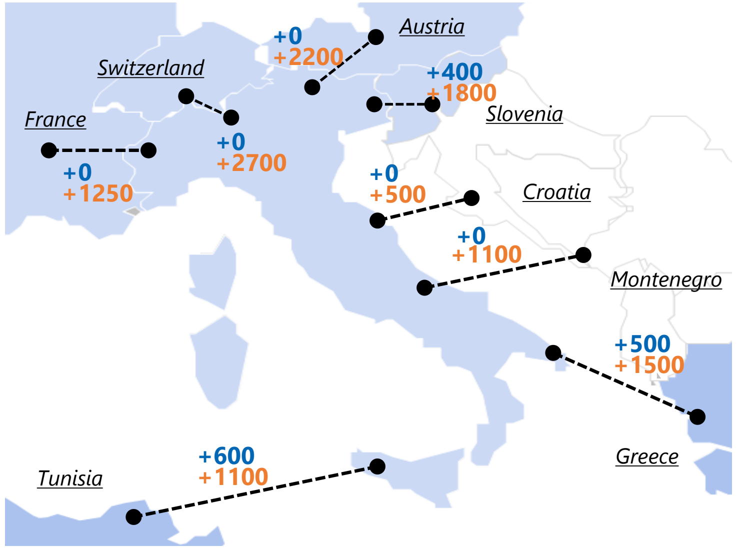
Sensitivity Analysis

Starting from the development strategies obtained on case study market sections, the following analysis have been performed:

CROSS-BORDER SENSITIVITY

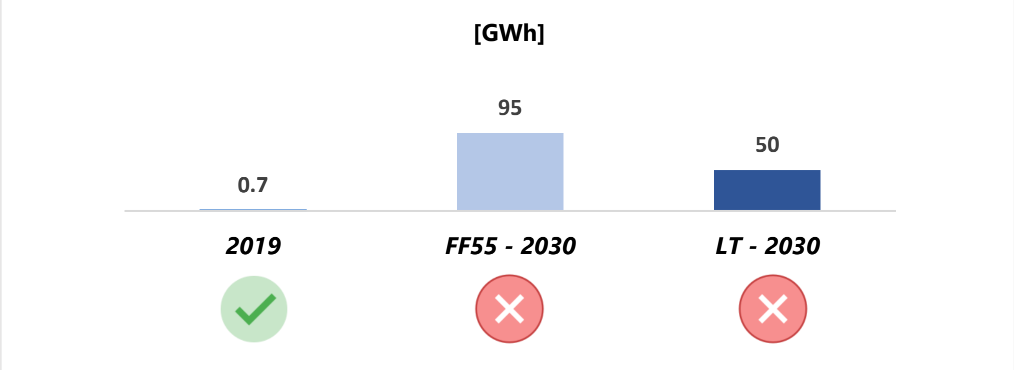
> the **sensitivity on cross border additional transmission capacity** considered as feasible **at 2030 and 2040 horizons**. A cap according to the planned interconnection projects expected into operation at the same year horizon of analysis has been enforced (*only already planned projects at 2030 and further private initiatives and concept projects at 2040*);

+ [MW] Cap imposition with respect to the base case reference grid in 2030 year horizon
+ [MW] Cap imposition with respect to the base case reference grid in 2040 year horizon



STORAGE SENSITIVITY

> the **sensitivity on installed storage capacity at 2030**: storage capacity has been imposed to actual installed values in order to identify additional target capacity on internal market sections need to cover missing storage project concretization.



Agenda

Introduction

Methodology

Italian Case Study

Regulatory Incentive and actual transmission developments

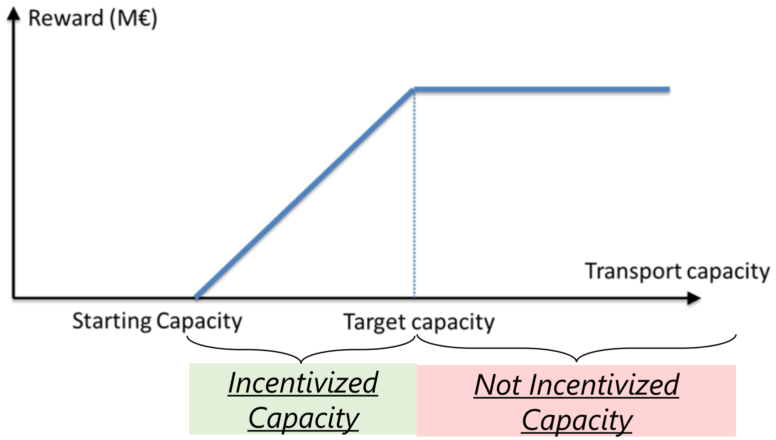
Introduction

Context and Roadmap of Target Capacity Assessment

Terna is **incentivized** by ARERA **for the implementation of additional transmission capacity** until the target capacity values approved.

Output-based Mechanism → **Efficiency Incentive** → **Monitoring**

- **Incentives (up to €150 million for the 2019-2023 regulatory period) in case of** the implementation of **additional transmission capacity up to target capacity values calculated by Terna and verified/approved by ARERA.**
- For each section/border, the reward is calculated based on historical congestion rents (2016 and 2017) and the social economic welfare benefit, as pro-rata between realized capacity vs. target capacity.



$$(40\%\ x\ Congestion\ Rents_{2016} + 40\%\ x\ Congestion\ Rents_{2017} + 20\%\ x\ Socio\ Economic\ Welfare)\ x\ \frac{Additional\ transmission\ capcity\ realized}{Target\ Capacity}$$

- **Output-based mechanism has been extended for 2024,** confirming the parameters and raising the **cap to €180 million.** Additionally **for the 2025-2027 period, a cap of €90 million** has been set and **the update of parameters** for calculating rewards has been requested.

Introduction

Context and Roadmap of Target Capacity Assessment

Output-based Mechanism → **Efficiency Incentive** → **Monitoring**

- **Additional incentive for investment costs lower than the reference costs,** defined by ARERA, **or for the realization of 'capital light' projects,** with a cost lower than €10 million (e.g., Dynamic Thermal Rating, Phase Shifting Transformer, …).
- The additional **rewards** are **related to cost efficiency (% of the difference between the standard reference cost** for the section **and the actual cost)**
- The **maximum reward per section is €10 million**, applicable only for the first capital light increase.

- **Moreover, efficiency incentive has been extended for the 2024-2025 period,** with a **reward of €5 million for the second** occurrence of **capital light interventions** and a **cap of €60 million.**

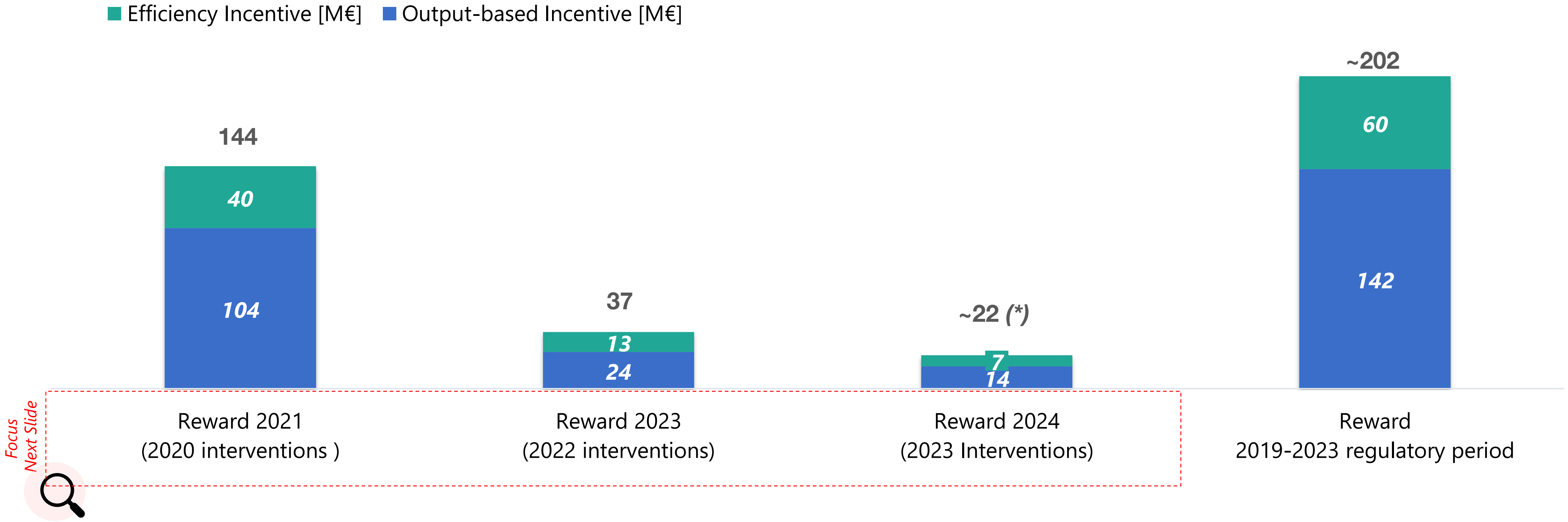
- The rewards are verified and confirmed by the Authority in the year following the realization of the interventions.
- A **three-year monitoring of the capacity increases is planned**, with a *clawback* of the reward in case the available transmission capacity in the Day-Ahead Market is significantly lower than the historical values (unless due to documented causes independent of Terna).

Introduction

Context and Roadmap of Target Capacity Assessment

The **incentive mechanism drove Terna to increase interzonal transport capacity** in the regulatory period 2020-2023, both with infrastructural and capital light projects, for a total **of around 2.3 GW** of additional capacity **of which around +1.7 GW on internal sections and +0.6 GW on the northern border** of the Italian power system. **The total reward gained in the 2019-2023 regulatory period is ~202 M€.**

** Reward estimation*



Introduction

Context and Roadmap of Target Capacity Assessment

Focus

Approximately the **75% of the transmission capacity increases are “*capital light*”,** characterized by efficiency improvements in terms of construction times and lower costs compared to “*copper and iron*” solutions.

Year 2020

Transmission capacity increases:

IT North ↔ IT Centre North: 400 MW
IT Centre North ↔ IT Centre South: 400 MW
IT South → IT Centre South: 250 MW
IT Calabria → IT Sicily: 400 MW

Year 2022

Transmission capacity increases:

Northern border → IT North: 277 MW
IT South → IT Centre South: 250 MW

Year 2023

Transmission capacity increases:

Northern border → IT North: 300 MW

THANK YOU
FOR YOUR ATTENTION!

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