The role of innovative grid-impacting technologies in the South East Europe Region: an integrated zonal analysis based on GridTech scenarios

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Outline

- Project overview
- Technology focus and tool
- Pan-European study: key drivers and scenarios build-up
- Pan-European study: main 2030 results with focus on SEE
- Sensitivity analyses with Italian zonal model detail
- Discussion
GridTech is a project co-funded by the European Commission under the Intelligent Energy Europe Programme.

Duration:
May 2012 - April 2015

Full title: Impact Assessment of New Technologies to Foster RES-Electricity Integration into the European Transmission System
About the project

GridTech’s main goal:

→ Conduct a fully integrated assessment of new grid-impacting technologies and their implementation into the European electricity system.

This will allow comparing different technological options, towards the exploitation of the full potential of future electricity production from renewable energy sources (RES-E), with the lowest possible total electricity system cost.
Project objectives

- Assess the **non-technical barriers** for transmission expansion and market compatible renewable electricity integration in Europe.
- Develop a robust **cost-benefit analysis methodology** on investments in most suitable **new technologies fostering large-scale renewable electricity integration** into the European transmission grid.
- Apply and verify the cost-benefit analysis methodology for **investments in the transmission grid, on national and European level**.
- Achieve a common understanding among key actors and target groups on **best practise** criteria for the implementation of new technologies fostering large-scale renewable electricity and storage integration.
- Deliver tailor-made **recommendations** and **action plans**, taking into account the legal, regulatory, and market framework.
Technology focus

The analysis focuses on the most promising and innovative technologies that directly or indirectly impact on the transmission system.
Grid-impacting technologies

1st category --> technologies directly impacting on the transmission system:
→ Transmission grid technologies (TGT)

2nd category --> technologies indirectly impacting on the transmission system:
→ Electricity generation technologies (EGT)
→ Energy storage technologies (EST)
→ Electricity demand technologies (EDT) (incl. electric mobility technologies)
Innovative grid-impacting technologies

**EGT**
- Onshore and offshore wind energy
- Large-scale solar technologies: Concentrated Solar Power (CSP) and Photovoltaics (PV)

**EST**
- Pumped Hydro Energy Storage
- Compressed Air Energy Storage

**TGT**
- HVDC - High Voltage Direct Current, both VSC (Voltage Source Converter)-based and CSC (Current Source Converter)-based
- FACTS - Flexible Alternating Current Transmission System
- PST - Phase Shifting Transformers
- WAMS - Wide Area Monitoring System
- DLR - Dynamic Line Rating-based OHLs
- HTLS - High Temperature Low Sag Conductor-based OHLs

**EDT**
- Demand Response Technologies/Measures and electric vehicles

**Bulk energy storage technologies**
Within the 2020, 2030 and 2050 time horizons, the aim is to assess, among innovative technologies, i) which, ii) where, iii) when, and iv) to which extent they could effectively contribute to the further development of the European transmission system

... fostering the integration of an ever-increasing penetration of RES-E generation

... and boosting the creation of a pan-European electricity market, while maintaining competitive and sustainable electricity supply.
Pan-European system

Source: JRC (2010)
In addition to top-down modelling on EU30+ and taking stock from it in a consistent data input-output flow, GridTech focuses on 7 countries, representative of the existing and future European electricity systems, studied at 2020, 2030 and 2050 by detailed grid/zonal analyses.
The Pan-European study in the project

Pan-European study (top-down approach)

Transmission expansion: non-technical barriers
Innovative technologies screening

RES integration: market issues
Cost-benefit methodology

Regional case studies (bottom-up approach)

Results and recommendations
The goals of the Pan-European study are threefold:

- Setting the boundary conditions for the regional case studies in a tightly correlated manner at 2020, 2030, 2050
- Analyzing the 2020, 2030, 2050 Pan-European scenarios including the effects of new technologies
- Applying a techno-economic assessment methodology to the 2020, 2030 and 2050 Pan-European scenarios including the effects of new technologies fostering large-scale RES-E integration.

The Pan-European study is based on a top-down approach by including the entire European system (EU30+) in the model: the tool for conducting this kind of scenarios analyses is MTSIM (Medium Term SIMulator), developed by RSE over the years.
MTSIM is a medium-term simulator of a generic day-ahead zonal market (DAM).

The model is devised to carry out system-wide energy evaluations (i.e. fuel consumption) and emission evaluations (CO₂ and other pollutants).

MTSIM calculates a hourly clearing price all over the year, by means of a DC Optimal Power Flow minimizing the energy price, considering variable fuels costs, environmental costs and hourly bid-up of each group (input of the model).

The transmission network among zones is modeled by an inter-zonal equivalent system including both HVAC corridors (whose physical constraints are represented through a PTDF matrix) and HVDC interconnectors, operated independently of HVAC.

A key feature of MTSIM relates to the so-called planning modality allowing to calculate the optimal dispatch whenever it is possible to install additional interconnection capacity between the market zones.

MTSIM provides also the possibility of including in the model innovative technologies, such as

- HVDC
- PST/FACTS
- Storage
- DSM/DR
Main features of MTSIM

MTSIM provides **main outputs for techno-economic assessments:**

- Hourly zonal generation dispatch
- Dispatch cost
- Inter-zonal flow transits
- Load shedding (EENS)
- RES curtailment (EIE)
- CO₂ emissions
- Hourly zonal marginal costs/prices
- Fuel consumption
- Revenues, margins and market quotas
## Key scenario drivers

<table>
<thead>
<tr>
<th>Main factors/Scenarios</th>
<th>S0 (baseline)</th>
<th>S1 (TGT-oriented)</th>
<th>S2 (EST-oriented)</th>
<th>S3 (EDT-oriented)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic and financial conditions</td>
<td>Favourable</td>
<td>Favourable</td>
<td>Favourable</td>
<td>Favourable</td>
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<td>Market and regulatory framework</td>
<td>European</td>
<td>European</td>
<td>European</td>
<td>European</td>
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<td>CO₂ penalty tax level</td>
<td>Moderately increasing</td>
<td>Moderately increasing</td>
<td>Moderately increasing</td>
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<td>Fossil fuel price level</td>
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<td>National/European</td>
<td>National/European</td>
<td>National/European</td>
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<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>CCS deployment</td>
<td>Low/limited</td>
<td>Low/limited</td>
<td>Low/limited</td>
<td>Low/limited</td>
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<td>Bulk storage expansion</td>
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<td>no</td>
<td>yes</td>
<td>no</td>
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<tr>
<td>Cross-border/inter-zonal transmission expansion</td>
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<td>yes</td>
<td>no</td>
<td>no</td>
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<tr>
<td>Total electricity demand</td>
<td>High/moderate</td>
<td>High/moderate</td>
<td>High/moderate</td>
<td>High/moderate</td>
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<td>Demand response penetration</td>
<td>Not present</td>
<td>Not present</td>
<td>Not present</td>
<td>Present</td>
</tr>
<tr>
<td>Electric vehicles penetration</td>
<td>Partially present</td>
<td>Partially present</td>
<td>Partially present</td>
<td>Partially present</td>
</tr>
<tr>
<td>Heat pumps penetration</td>
<td>Partially present</td>
<td>Partially present</td>
<td>Partially present</td>
<td>Partially present</td>
</tr>
<tr>
<td>Efficiency measures</td>
<td>Limited/present</td>
<td>Limited/present</td>
<td>Limited/present</td>
<td>Limited/present</td>
</tr>
</tbody>
</table>
Scenarios definition

- TGT progress: advanced
- EDT (DR) progress: advanced
- EST progress: advanced
- RES penetration: base
  - S1: high
  - S0
  - S2
  - S3: advanced

Diagram:
- RES penetration (vertical axis)
- EDT (DR) progress (horizontal axis)
- EST progress (negative horizontal axis)
- Points:S0, S1, S2, S3
Scenario definition

2 + 4 (+1) + 4 (+1) + 4 = 14 (+2) cases in total at least

<table>
<thead>
<tr>
<th>Scenario/year</th>
<th>2020</th>
<th>2030</th>
<th>2050-1 (with PTDF)</th>
<th>2050-2 (without PTDF)</th>
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<tr>
<td><strong>S0</strong> (baseline)</td>
<td>base TGT-2020</td>
<td>base TGT-2030</td>
<td>base TGT-2050</td>
<td>base TGT-2050</td>
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<tr>
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<td>base EST-2020</td>
<td>base EST-2030</td>
<td>base EST-2050</td>
<td>base EST-2050</td>
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<td>base EDT-2030</td>
<td>base EDT-2050</td>
<td>base EDT-2050</td>
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<td><strong>S1</strong> (TGT-oriented)</td>
<td>base TGT-2020</td>
<td>advanced TGT-2030*</td>
<td>advanced TGT-2050*</td>
<td>advanced TGT-2050*</td>
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<tr>
<td></td>
<td>base EST-2020</td>
<td>base EST-2030</td>
<td>base EST-2050</td>
<td>base EST-2050</td>
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<tr>
<td></td>
<td>base EDT-2020</td>
<td>base EDT-2030</td>
<td>base EDT-2050</td>
<td>base EDT-2050</td>
</tr>
<tr>
<td><strong>S2</strong> (EST-oriented)</td>
<td>base TGT-2020</td>
<td>base TGT-2030</td>
<td>base TGT-2050</td>
<td>base TGT-2050</td>
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<tr>
<td></td>
<td>base EST-2020</td>
<td>advanced EST-2030</td>
<td>advanced EST-2050</td>
<td>advanced EST-2050</td>
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<tr>
<td></td>
<td>base EDT-2020</td>
<td>base EDT-2030</td>
<td>base EDT-2050</td>
<td>base EDT-2050</td>
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<tr>
<td><strong>S3</strong> (EDT-oriented)</td>
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<td>base TGT-2030</td>
<td>base TGT-2050</td>
<td>base TGT-2050</td>
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<td></td>
<td>base EST-2020</td>
<td>base EST-2030</td>
<td>base EST-2050</td>
<td>base EST-2050</td>
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<tr>
<td></td>
<td>advanced EDT-2020</td>
<td>advanced EDT-2030</td>
<td>advanced EDT-2050</td>
<td>advanced EDT-2050</td>
</tr>
</tbody>
</table>

*: by application of MTSIM planning modality
The Pan-European study, based on **EU30+ zonal model**, endogenously includes:

- EU28 countries -> 30 systems (including 2 German zones + Northern Ireland)
- EEA countries -> 3 systems
- Western Balkans -> 5 systems
- Turkey
- additional 5-7 potential offshore islands (after 2030)

Pan-European study exogenously includes:

- Bordering systems of North Africa
- Bordering systems of Middle East
- Bordering systems of eastern edge (Russia, Belarus, Ukraine, Moldova)
Pan-European study

Geographic perimeter of the Pan-European study
Pan-European study

European transmission system (2020, planned)

Source: JRC-IET (based on ENTSO-E and PLATTES data)
Pan-European study

European transmission system (2030, preliminary)

Source: JRC-IET (based on ENTSO-E and PLATTS data)
Pan-European study

Pan-European zonal model (2030, potential)
Data requirements and main sources for the Pan-European study:

**Generation**
- Installed capacities for each technology type/category (ENTSO-E, TSOs, NRAs, WP5 partners, RSE, EEG)
- Thermal plants availability, efficiency, maintenance (SUSPLAN, TSOs, WP5 partners)
- Hydro plants characteristics, reservoir and pumping volumes, inflows, operation hours (TradeWind, Eurelectric, ENTSO-E, PCI, WP5 partners, NREAPs, RSE)
- Solar timeseries (JRC)
- Wind timeseries (SUSPLAN/TradeWind, TSOs, RSE)
- CSP timeseries (UPComillas)
- Wave, tidal and DWW timeseries (EirGrid)
- CHP timeseries (WP5 partners, TSOs)
- Biomass and geothermal operation hours (NREAPs, TSOs, WP5 partners, EEG)
- Fuel costs (ENTSO-E)
- Emission factors (TradeWind)
- CO2 penalty tax (EC Trends to 2050, EU, IEA WEO)
Pan-European model: inputs

**Data requirements and main sources for the Pan-European study:**

**Demand**
- Total consumption level (ENTSO-E, TSOs, WP5 partners, EEG, RSE)
- Load timeseries (RSE, ENTSO-E, TSOs, WP5 partners)

**Transmission**
- NTC values (ENTSO-E TYNDPs, RSE, TSOs, WP5 partners) -> diversified (winter/summer) NTC values (assuming 85% of winter NTC in the period 1 May-30 Sep.)
- PTDF matrix (RSE, ENTSO-E STUM2020)
- Exogenous regions injections (RSE, ENTSO-E, WP5 partners, TSOs)
Pan-European study: baseline scenarios (S0)
Pan-European model: 2030 S0 inputs

Total generation capacity at 2030 (derived from an extended ENTSO-E 2030 V3 scenario):

- Nuclear 108.6 GW
- Lignite 56.6 GW
- Hard Coal (incl. CCS) 76.5 GW
- Gas (CCGT, OCGT, ST) (incl. CCS) 311.2 GW
- Oil/oil shale 16.6 GW
- Other non RES (CHP, waste) 53 GW
- Hydro (ROR, reservoir, PHES) 297 GW
- Wind (onshore, offshore) 373.7 GW
- Solar (PV, CSP) 243.2 GW
- Other RES (biomass, geothermal, tidal, wave) 78.1 GW

Total load demand at 2030: 4772 TWh

Total inter-zonal HVAC capacity: 131.0 GW
Total inter-zonal HVDC capacity: 32.7 GW
Total bulk storage (PHES, SPHES): 71.5 GW
## Pan-European model: 2030 inputs

<table>
<thead>
<tr>
<th>Country/Zone</th>
<th>Load demand (TWh)</th>
<th>2030 Load shifting</th>
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<tr>
<td>AL</td>
<td>15.431</td>
<td>5.0%</td>
</tr>
<tr>
<td>AT</td>
<td>91.81</td>
<td>6.4%</td>
</tr>
<tr>
<td>BA</td>
<td>17.95</td>
<td>3.0%</td>
</tr>
<tr>
<td>BE</td>
<td>104.80</td>
<td>5.8%</td>
</tr>
<tr>
<td>BG</td>
<td>40.50</td>
<td>2.3%</td>
</tr>
<tr>
<td>CH</td>
<td>78.60</td>
<td>3.0%</td>
</tr>
<tr>
<td>CY</td>
<td>8.958</td>
<td>2.9%</td>
</tr>
<tr>
<td>CZ</td>
<td>82.09</td>
<td>2.6%</td>
</tr>
<tr>
<td>DE1</td>
<td>546.10</td>
<td>5.2%</td>
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<tr>
<td>DE2</td>
<td>88.90</td>
<td>5.2%</td>
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<tr>
<td>DK</td>
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<tr>
<td>EE</td>
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<tr>
<td>ES</td>
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<tr>
<td>FI</td>
<td>104.40</td>
<td>10.1%</td>
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<tr>
<td>FR</td>
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<td>GB</td>
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<tr>
<td>GR</td>
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<tr>
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<tr>
<td>HU</td>
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<tr>
<td>IE</td>
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<tr>
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<td>NL</td>
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<tr>
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<td>PT</td>
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<td>RO</td>
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<td>RS</td>
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<tr>
<td>SE</td>
<td>157.95</td>
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<tr>
<td>SI</td>
<td>19.99</td>
<td>5.8%</td>
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<tr>
<td>SK</td>
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<tr>
<td>TR</td>
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<td>10.0%</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>4771.76</strong></td>
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</table>
Pan-European model: 2030 inputs

Fuel costs at 2030:

- Nuclear: 0.377 €/GJ
- Lignite: 0.44 €/GJ
- Hard Coal: 2.21 €/GJ
- Gas: 7.91 €/GJ
- Mixed oil/gas: 9.88 €/GJ
- Light oil: 16.73 €/GJ

CO₂ penalty tax at 2030:

- 35 €/tCO₂ (base case)
- 55 €/tCO₂ (sensitivity 1)
- 93 €/tCO₂ (sensitivity 2)
Pan-European study results (2030 S0, base)

Main (updated) outcomes:

- Load shedding is null
- RES curtailment (9.4 TWh) is rather higher than in 2020 S0: it mostly concerns CY, DE1, DK, ES, GB, IE, IS (while it is very limited in MT, NI, NL, PT)
- Zonal marginal costs are higher than in 2020
- HVDC corridors are rather fully utilised
- The system needs first reinforcements across British islands, in Balkan, Iberian and Baltic regions, on north-south Central Europe axis and around isolated zones
2030 SO (base) results: zonal costs

Average zonal marginal costs (€/MWh)

Average hourly zonal marginal cost (weighted over zonal load) in Europe (2030 base case)
2030 S0 (base) results: inter-zonal flows

- The following countries/zones result to be net exporter at 2030 S0: BG, CZ, DE1, DK, ES, FI, FR, GB, IE, LT, LV, ME, NO, RO, SE, SI, SK

- The following countries/zones result to be net importer at 2030 S0: AL, AT, BA, BE, CH, DE2, EE, GR, HR, HU, IT, LU, MK, MT, NI, NL, PL, PT, RS, TR
2030 base case results: inter-zonal flows
2030 S0 (planning) results: expansion needs

HVDC expansions (up to 5000 MW):
- ES-FR (5000 MW, VSC USC)
- GB-FR (5000 MW, VSC USC)
- GB-IE (1338 MW, VSC USC)
- CY-TR (409 MW, VSC USC)
- SE-DE1 (1341 MW, CSC USC)
- IE-IS (915 MW, CSC USC)
- GB-NO (1014 MW, CSC USC)

HVDC unit costs (2030):
- VSC USC CAPEX: 1430 €/(km MW)
- 2 VSC converters CAPEX: 219 k€/MW
- CSC USC CAPEX: 1373 €/(km MW)
- 2 CSC converters CAPEX: 146 k€/MW
Pan-European study

Pan-European zonal model (2030, updated)
Pan-European study results (2030 S1, TGT)

Main outcomes:

- Load shedding is null
- High benefits are brought by TGT (HVDC) in terms of RES curtailment reduction (7.5 TWh) and dispatch cost decrease (4.6 b€) with respect to 2030 S0
- Zonal costs are changing depending on countries, RES penetration, energy mix
- Impact of TGT (HVDC) on CO₂ emission leads to ca. 0.28 MtCO₂ emission reduction
- HVDC corridors are rather fully utilised
2030 TGT case results: inter-zonal flows

SOUTH EAST
Base Case (year 2030) _06_TGT
value in TWh

AC
DC

FR
CH

IT

NA
MT

AT
SI

BA
ME

AL

MK

GR

HU


RO

BD

SK

UA

MD

GE

AM

AZ

IR

IQ

SY

AR

RF

EA

UN

\( \text{value in TWh} \)

\( \text{year 2030} \)
2030 S1 (TGT) results: inter-zonal flows

- The following countries/zones result to be net exporter at 2030 S1:
  - BG, CZ, DE1, DK, ES, FI, FR, GB, IE, IS, LT, LV, ME, NO, RO, SE, SI, SK
- The following countries/zones result to be net importer at 2030 S1:
  - AL, AT, BA, BE, CH, CY, DE2, EE, GR, HR, HU, IT, LU, MK, MT, NI, NL, PL, PT, RS, TR

Upgraded HVDC corridors with respect to 2030 S0:
- ES-FR (5500 MW, +900 MW)
- GB-FR (6400 MW, +2400 MW)
- GB-IE (2300 MW, +1300 MW)
- CY-TR (400 MW, +400 MW)
- SE-DE1 (1200 MW, +600 MW)
- IE-IS (900 MW, +900 MW)
- GB-NO (2400 MW, +1000 MW)
Pan-European study results (2030 S2, EST)

EST capacity expansions over 2030 S0:
- New PHES capacity: 3890 MW (in CY, EE, TR)
- Expanded PHES capacity: 4760 MW (in FR, LT, NO, PL)
- New SPHES capacity: 3143 MW (in IE, IT)
- New CAES capacity: 2225 MW (in DE1, ES, NI)

Main outcomes:
- Load shedding is null
- RES curtailment is reduced (by 1.44 TWh) due to EST effect
- Dispatch cost reduction amounts to 800 M€ with respect to 2020 S0
- CO₂ emissions reduction by EST: 0.41 MtCO₂
Main outcomes:

- Load shedding is null
- EDT (DR) brings higher benefits than in 2020 in terms of RES curtailment reduction (1391 GWh) and dispatch cost decrease (1.34 b€) over S0
- Zonal costs are changing depending on countries, RES penetration, energy mix
- Impact of EDT (DR) on CO₂ emissions variation is negative (CO₂ emissions increase: 7.4 MtCO₂)
Starting from 2030 S0, several variant cases and sensitivity analyses focused on Italy and SEE Region have been conducted.

The first step has consisted in including the Italian zonal repartition (6 zones) in the Pan-European model at 2030 S0, leading to A0 case.

Total IT load (S0/A0): 460.45 TWh
- IT_NO load (A0): 244.8 TWh
- IT_CN load (A0): 48.5 TWh
- IT_CS load (A0): 70.05 TWh
- IT_SU load (A0): 53.8 TWh
- IT_SI load (A0): 28.6 TWh
- IT_SA load (A0): 14.7 TWh

Source: Terna
Pan-European model: 2030
S0 IT variants

➢ The presence of the Italian inter-zonal constraints leads as expected to an increase of the total dispatch cost and of the total RES curtailment, which mostly concerns the 6 Italian zones and also Malta, while in the rest of SEE Region, as in the original S0 scenario, only Cyprus is affected by RES curtailment. On the other hand, a reduction of total CO2 emissions in the EU30+, due to a decrease of thermal (coal-fired) production, is recorded in A0 with respect to S0.

➢ The presence of the Italian inter-zonal constraints does not alter the net electricity import/export balance trend at the borders of the Italian system, confirming the status of Italy as net importer, also from the other zones of the SEE Region, such as Slovenia, Greece, Montenegro.

<table>
<thead>
<tr>
<th>2030 outcomes</th>
<th>original baseline scenario (S0)</th>
<th>augmented baseline scenario (A0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dispatch cost</td>
<td>105.7 b€</td>
<td>106.1 b€</td>
</tr>
<tr>
<td>Total RES curtailment</td>
<td>9369 GWh</td>
<td>9970 GWh</td>
</tr>
<tr>
<td>Total CO2 emissions</td>
<td>1145 MtCO2</td>
<td>1144 MtCO2</td>
</tr>
</tbody>
</table>
A conservatively updated situation concerning the interconnections between Italy and the SEE Region has been taken into account: the HVAC OHL project Udine (IT) - Okroglo (SI), originally part of the 2030 pan-European model (S0, A0), has not been included in the updated augmented baseline scenario (B0) of EU30+ at 2030, in accordance with the most recent list of projects of ENTSO-E TYNDP 2016.
Further sensitivity analyses have been conducted at 2030 on the Italian load demand (460.45 TWh vs. 355.0 TWh) and on the effects of HVDC Italy-Montenegro interconnection.

4 sensitivity cases have been analysed:

- **B0**: Updated augmented baseline scenario with higher IT electricity demand
- **B1**: Sensitivity case with lower IT electricity demand
- **B2**: Sensitivity case with higher IT electricity demand and without HVDC IT-ME
- **B3**: Sensitivity case with lower IT electricity demand and without HVDC IT-ME.

Total IT load (B1/B3): 355.0 TWh
- IT_NO load (B1/B3): 188.8 TWh
- IT_CN load (B1/B3): 37.4 TWh
- IT_CS load (B1/B3): 54.0 TWh
- IT_SU load (B1/B3): 41.5 TWh
- IT_SI load (B1/B3): 22.0 TWh
- IT_SA load (B1/B3): 11.3 TWh
Comparing the outcomes of B1 with the ones of B0, the effects of a rather lower IT demand level at 2030 are evident in terms of total reduction of the dispatch cost and of CO2 emissions and by a significant increase of total RES curtailment.

By considering the results of B2 with respect to the ones of B0, the effects of the HVDC IT-ME interconnection can be highlighted at 2030, consisting in a total dispatch cost saving of ca. 135 M€ and in a total RES curtailment reduction of ca. 156 GWh, while the CO2 emissions totally increase of ca. 1512 ktCO2.

The effects of the HVDC IT-ME interconnection are even more visible and remarkable comparing the respective cases, B1 and B3, presenting a lower IT demand level at 2030: in fact, a dispatch cost saving of ca. 562 M€ and a RES curtailment reduction of ca. 944 GWh have been totally recorded, while the CO2 emissions globally increase of ca. 289 ktCO2.

<table>
<thead>
<tr>
<th>2030 outcomes</th>
<th>B0 scenario</th>
<th>B1 scenario</th>
<th>B2 scenario</th>
<th>B3 scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dispatch cost</td>
<td>106.2 b€</td>
<td>100.9 b€</td>
<td>106.3 b€</td>
<td>101.5 b€</td>
</tr>
<tr>
<td>Total RES curtailment</td>
<td>9971 GWh</td>
<td>12299 GWh</td>
<td>10127 GWh</td>
<td>13243 GWh</td>
</tr>
<tr>
<td>Total CO₂ emissions</td>
<td>1140 MtCO₂</td>
<td>1097 MtCO₂</td>
<td>1139 MtCO₂</td>
<td>1096 MtCO₂</td>
</tr>
</tbody>
</table>
Main conclusions

- The applications of HVDC, storage and DR across the EU30+ system prove the important benefits provided by these technologies, especially towards social welfare increase and RES integration support.
- HVDC technologies have performed very effectively.
- From a society perspective, the use of DR might be very effective -> price signals to industry and customers are needed.
- Storage may be less effective to improve system behaviour -> the pan-European case reflects a quite ideal situation while the regional case studies with grid constraints may see a wider storage application.
- The analyses including the detailed Italian zonal system in the EU30+ model have given the possibility to more specifically evaluate the impact and the benefits of key links interconnecting Italy with the other zones of SEE: the 2030 beneficial effects of the HVDC IT-ME link are proved. Further analyses, also on HVDC IT-SI link, are ongoing.
- Sensitivity analyses provide the importance of load levels estimation.
- Flexibility, controllability, resilience and socio-environmental impact will be more and more crucial aspects to be further investigated.
Discussion

- The full electric power system integration of the SEE with the rest of Europe represents a key objective of the European Energy Union, as set by the EC.

- The trend of power flows across Italy and the western SEE Region, at 2030 and beyond, will much depend on the scenario developments for the SEE Region, in particular for Turkey, especially in terms of RES and load demand evolutions.

- Q1: How do you evaluate potential of Hydro Power Plants in Baltic Countries?

- Q2: How do the authors evaluate possibility of power flows increase between EU and Moldova/Ukraine?
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IEE GridTech project
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Thanks!

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