European Commission
Directorate-General for Transport and Energy

# Under the Multiple Framework Services Contract for Impact Assessments and Evaluations TREN/A2/143-2007 Lot 1

# The revision of the trans-European energy network policy (TEN-E)TREN/A2/143-2007/SI2.544824

## Appendices

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# Revision and Authorisation History

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|---|---|---|---|
| 5.0 | 21/10/10 | Sudhir Junankar | Appendices to final report – revised with final date of submission. |
| 4.0 | 25/08/10 | Rachel Beaven | Appendices to final report – revised to address comments made by Commission. |
| 3.0 | 12/08/10 | Sudhir Junankar | Appendices to revised Draft Final Report |
| 2.0 | 31/03/10 | Sudhir Junankar | Appendices to Revised interim report submitted in response to changes requested by the client (letter of 2/03/10 sent to COWI) |
| 1.0 | 12/02/10 | SJ | Version submitted |

# Contents

# 1 Appendix I: New Power Transmission Projects

| Code | Countries | Project | Description | Status | Expected Date | Comments |
|---|---|---|---|---|---|---|
| **50** | France - Luxembourg | Moulaine (FR) – Beval (LX) line | Creation of a 225 kV | Permitting | 2010 | Region: Central West<br>TSO in charge: RTE & SOTEL<br>Project driver: consumer connection<br>Source: UCTE |
| **3** | France - Belgium | Moulaine (FR) – Aubange (BE) | Upgrade of the existing 225 kV line Moulaine (FR) – Aubange (BE) | Permitting | 2010 | Region: Central West<br>Project driver: congestion remediation<br>Scope: Installation of a 2nd circuit and replacement of conductors<br>Studies are being carried out<br>Project driver: Congestion on the 225 kV line between the Lorraine area (FR) and Belgium<br>TSOs in charge: RTE & ELIA<br>Source: UCTE |
| **52** | Netherlands – United Kingdom | BritNed HVDC link | New HVDC link between (Isle of Grain, Kent) and the Netherlands (Maasvlakte), Transmission capacity 1320 MW, length 260 km. | Under construction | 2012 | Region: Central West<br>Project driver: Security of Supply<br>Scope: enhancing diversity and security of supply for both markets: open access for all market parties by explicit auction and market coupling; increase of interconnection capacity |

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| | | | | | | TSOs in charge: TenneT TSO and National Grid<br>Source: UCTE |
| **53** | Luxembourg - Belgium | New interconnector in the southern section of the LU grid | New 220 kV underground cable between substations of Bascharage (LU) and Aubange (BE) | Design & permitting | 2012 | Region: Central West<br>Project driver: security of supply for the public grid<br>Scope: -<br>TSOs in charge: Cegedel Net & Elia<br>Source: UCTE |
| **17** | Netherlands - German | Line Doetinchem (NL) – Niederrhein (DE) | 60 km new double circuit 400 kV OHL | Planned | Earliest 2013 | Region: Central West<br>Project driver: Congestion in the area around German – Dutch border during peak hours and wind in-feed<br>Scope: -<br>TSOs in charge: TenneT & RWE TSO |
| **3** | France - Belgium | Interconnection France - Belgium | Strengthening of present interconnection or new interconnection project | Under consideration (study in progress) | 2012-2015 | Region: Central West<br>Project driver: constraints appear on the France – Belgium border due to development in generation in Northern France<br>TSOs in charge: RTE & ELIA<br>Source: UCTE |
| **35** | Germany - Norway | NORD.LINK | HVDC transmission system 700 – 1400 MW | Under consideration (feasibility study performed by Statnett and EON.Netz) | >2015 | Region: Central West<br>Project Driver: coupling the hydro-dominated Norwegian electricity system and the wind and thermal dominated electricity system in the northern |

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| | | | | | | Germany<br>Scope: first Norway-Germany interconnector<br>Source: UCTE |
| **54** | Belgium – United Kingdom | Belgium – United Kingdom Interconnector | HVDC link | Under study with National Grid | To be determined | Region: Central West<br>Project driver: creating trading capacities by coupling the Belgian grid (ELIA) and the British grid (NG)<br>Scope : establishing a direct power exchange capacity<br>TSOs in charge: ELIA & National grid<br>Source: UCTE |
| **55** | Germany - Belgium | Investigation of grid extension options | New interconnection between the 400 kV ELIA nd RWE TSO grids on the central Western European market | Under consideration | To be determined | Region: Central West<br>Project Driver: establish a direct exchange capacity<br>TSOs in charge: ELIA & RWE TSO<br>Source: UCTE |
| **7** | Germany - France | Esdorf (DE) – St. Avold (FR) line | Identification of possibilities to improve the Ensdorf (DE) – St. Avold (FR) interconnection | Under consideration | To be determined | Region: Central West<br>Project driver: increase the power exchange capacity on the DE-FR border<br>TSOs in charge: RWTE & RWE TSO<br>Source: UCTE |
| **56** | Netherlands - Danemark | Cobra project | HVDC link<br>Capacity 600-700 MW in both directions<br>Total length | Under consideration | 2016 | Region: Central West<br>Project driver: Market coupling Denmark – Netherlands |

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| | | | of about 350 km | | | Scope: To allow exchange and integration of wind energy and increase value of renewable energy into the Dutch and Danish Power systems and to increase security of supply<br>TSOs in charge: TenneT TSO and Energinet.dk<br>Source: UCTE |
| **6** | Germany - Denmark | Strengthening AC interconnections | Under study | Under consideration | To be determined | Region: Central West<br>Project driver: Strengthening AV interconnections<br>Scope: identification of possibilities to increase capacity on AC interconnections<br>TSOs in charge: E.ON Netz & Energinet.dk<br>Source: UCTE |
| **5** | CzechRepublic - Germany | Hradec (CZ) – Vernerov (CZ) – Vitkov (CZ) – Mechlenreuth (DE) | New 400 kV double circuit overhead interconnection line through two 400 kV substations | Under consideration | First planning is due on 2016 | Region: Central East<br>Project driver: increasing the current power exchange capacity between the CzechRepublic and Germany<br>Scope: interconnector between Germany and the CzechRepublic<br>TSOs in charge (to be confirmed): CEPS, E.ON Netz & VE-T.<br>Source: UCTE |

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| 5 | CzechRepublic-Germany | Increase of interconnection capacity on the Czech – German border | Possible new overhead line (new route) or reinforcement of expositing OHL Hradec (CZ) – Röhsdorf (DE) | Under consideration | After 2016 | Region: Central East<br>Project driver: Increasing the (n-1) security and interconnection capacity on the border<br>Scope: maintain the security of supply and support the Central Eastern Europe Market development<br>TSOs in charge: VE Transmission and CEPS<br>Source: UCTE |
| 4 | Austria - Germany | Increasing the current power exchange capacity between Austria and Germany | New 380 kV double circuit line St. Peter (AT) – Isar/Pleinting (DE) | Under consideration | 2017 | Region: Central East<br>Project driver: increasing the current power exchange capacity<br>Scope: Interconnector Austria-Germany<br>TSOs in charge: E.ON Netz & APG<br>Source: UCTE |
| 24 | Hungary - Slovakia | Increasing power exchange capacity on Hungary – Slovakia border | OVH 400 kV double lines (3 options) | Joint negotiations are in progress | After 2014 | Region: Central East<br>Project drivers:<br>• Improve the security and reliability of the network of both partners<br>• Increase transmission capacity in the North-South direction<br>Scope: one of the following options:<br>1. Sajoivanka (HU) - Rimavska Sobota (SK) 400 kV double line or<br>2. Vleke Kapusany (SK)-Hungary 400 kV double line (this |

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| | | | | | | project replaces interconnection Moldava (SK) ) - Sajoivanka (HU) or 3. Sajoivanka (SK) - Gabcikovo (HU) 400 kV double line<br>TSOs in charge: MAVIR & SEPS<br>Source: UCTE |
| **19** | Poland - Germany | Increasing the power exchange capacity through the upgrading of existing cross border interconnection lines | Upgrading of transmissions lines Krajnik (PL) – Vierranden (DE) (including PST installation in Krajnik (PL) and Mikulowa (PL) | Planned Financing scheme not yet decided | Before 2013 | Region: Central East<br>Project driver: increase of the security and interconnection capacity on PL-DE border<br>Scope: Conversion of the existing 220kV double circuit line into a 400 kV line together with phase Shifting transformers installation on 400 kV lines: Krajnik (PL) –Vierranden (DE- and Mikulowa (PL) – Hagenwerder (DE).The project will decrease the loop flow from DE to PL and to CZ/SK, stimulate the market development and prepare for the RES integration<br>TSOs in charge: VE T (DE) and PSE Operator (PL)<br>Source: UCTE |
| **19** | Poland - Germany | Increasing power exchange capacity across the Poland – | Construction of the third 400 kV interconnection | Under consideration<br>Financing | After 2015 | Region: Central East<br>Project driver: Possible effect of |

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| | | Germany border | n line between Baczyna/Plewiska (PL) and Eisenhuttenstadt (DE) with reinforcement of the Polish grid | scheme not yet decided | | the project will be evaluated in joint studies<br>Scope: It is expected that the project will support the CEE market development, RES integration and maintain security of supply.<br>TSOs in charge: VE T (DE) and PSE Operator (PL)<br>Source: UCTE |
| 25 | Poland - Slovakia | Increasing power exchange capacity across the Poland – Slovak | New interconnection between Byczyna (PL) and Varin (SK) with reinforcement of the Polish internal grid | Under consideration<br>Joint negotiations are in progress.<br>Financing scheme in preparation | After 2018 | Region: Central East<br>Project driver: Possible effect of the project will be evaluated in joint studies<br>Scope: -<br>TSOs in charge : SEPS (SK) & PSE-Operator (PL)<br>Source: UCTE |
| 57 | Poland - Lituania | Interconnection between Poland and Lithuania | Construction of a new 400 kV double circuit interconnection between Elk (PL) and Alytus (LT) together with back-to-back 1000 MW power station in Alytus (LT) and reinforcement of internal Polish and Lithuanian grids | Planned<br>Financing scheme in preparation | 1st step: 2015<br>2nd step: 2020 | Region: Central East<br>Project driver: Incorporation of Baltic states into Internal electricity Market (IEM) of EU<br>Possible effect of the project will be evaluated in joint studies<br>Scope: Implementation in 2 steps:<br>• Reinforcement of internal PL and LT transmission grids to make possible power import capacity of 600 MW from Lithuania to |

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| | | | | | | Poland;<br>• Additional reinforcement of PL ant LT transmissions grids to reach 1000 MW of transfer capacity.<br>TSOs in charge:<br>PSE Operator (PL) & Lietuvos Energia (LT)<br>Source: UCTE |
| **58** | Pologne - Ukraine | Resumption of existing and not used interconnection | resumption and renovation of the existing 750 kV interconnection between Rzeszow (PL) and Khmelnitskaya (UA) | Planned Financing scheme not yet decided | After 2010 | Region: Central East<br>Project driver: installation of back-to-back 2*600 MW – convertors in Rzeszow (PL) substation<br>Scope: -<br>TSOs in charge:<br>PSE Operator (PL) and Ukrainian TSO<br>Source: UCTE |
| **45** | Slovakia - Ukraine | Increasing power exchange capacity through the Slovakia and Ukraine border | 2*400 kV line V. Kapusany (SK) – Muchchevo (UA) (Conditionality: the interconnection between Velké Kapusany (SK) and Hungary is not realized) | Under consideration<br>Financing scheme not yet decided | After 2014 | Region: Central East<br>Project driver: increasing power exchange capacity<br>Scope: reinforcing the existing 400 kV interconnection between Ukraine and Slovakia with circuit doubling. If the interconnection between Velké Kapusany (SK) and Hungary is realized, the reinforcement of existing interconnection between Slovakia and Ukraine will not be taken into account<br>TSOs in charge: |

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| | | | | | | subject to discussion<br>Source: UCTE |
| **59** | Slovakia - Austria | New interconnection line between Austria and Slovakia | 2*400 kV tie-line Stupava (SK) – Bisamberg / Wien (AT) | Under consideration<br>Further common negotiations needed | After 2020 | Region: Central East<br>Project driver: developing power exchange capacities<br>Scope: possible effects will be evaluated in joint studies. Another possible option would be a new interconnection between SK and AT via Gabcikovo substation (SK) – Vienna (AT) in combination with the project Gabcikovo (SK) - Gyor (HU) in the time horizon after 2014.<br>HU using one circuit of the existing line Gyor (HU)<br>TSO in charge: SEPS (SK), APG (AT), MAVIR (HU)<br>Source: UCTE |
| **9** | Austria - Hungary | Increasing the transmission capacity of the existing tie-line Wien SO (AT) – Györ/Sombathely (HU) | Tie-line Wien SO (AT) – Gyor/Szombathely (HU) 2nd system | Design & permitting | 2010 | Region: Central East<br>Project driver: Increase the security and transmission capacity on the Austria – Hungary border<br>Scope: installation of a 2nd circuit on the existing tie line from Wien SO (AT) to border |

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| | | | | | | (both systems have been already installed on the HU side, one connected to Györ, the other to Szombathely)<br>TSO in charge: APG<br>Source: UCTE |
| **11** | France - Italie | Upgrading of the 220 kV line from Trinite Victor (FR) to Camporosso (IT) | Installation of a PST in Italy | Design & permitting | 2011 | Region: Central South<br>Project driver: alleviating the congestion, allowing for closed operation of this 220 kV line<br>Scope: Optimizing the utilization capacity of the line<br>TSOs in charge: TERNA & RTE<br>Source: UCTE |
| **11** | France - Italie | Increasing transfer capacity through the France – Italy border (Albertville (FR) – Rondissone/Piossasco (IT) | Replacement of existing circuits by high temperature conductors of the existing 400 kV line. | French side: Design & permitting<br>Italian side: Under construction | 2012 | Region: Central South<br>Project driver: Taking the best advantage of the existing network and increasing the capacity on this axis which limits the transmission capacity towards Italy.<br>Scope: includes in particular the rehabilitation of a 400 kV line currently out of use (Albertville (FR) – Grande Ile n°3 (FR) with high temperature conductors and connection existing Albertville substation to bus |

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| | | | | | | bar in the existing Albertville (FR) substation<br>TSOs in charge: RTE & TERNA<br>Source: UCTE |
| **27** | Italy - Slovenia | Increasing transmission capacity on the Italian – Slovenian border | New 380 kV double circuit line between Udine Ovest (IT) and Okrogolo (SI) | Planned | Long term | Region: Central South<br>Project driver: congestion on Italian – Slovenian border has a low security level and a low transfer capacity; the 380 kV Redipugnlia (IT) – Divaca (SI) line is particularly congested, limiting power exchanges with Slovenia.<br>TEN –E Project Scope: Increasing the capacity of the current interconnection of the North-Eastern Italian border<br>TSOs in charge: TERNA & ELES<br>Source: UCTE |
| **10** | Italy - Austria | Increasing transmission capacity on Italy-Austria border | New 220 kV PST in Lintz (AT) | Design & permitting | 2011 | Region: Central South<br>Project diver: congestion on the Italian – Austrian border<br>Scope: increase n-1 security and capacity on Italian – Austrian border<br>TSOs in charge: APG & TERNA<br>Source: UCTE |
| **10** | Italy - Austria | Increasing transmission capacity on Italy-Austria border | New 380 kV interconnection between Italy and Austria | Under consideration | Long term | Region: Central South<br>Project driver: constraints on the Italian – Austrian |

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| | | | | | | border<br>Scope: An optimized route of existing 220 kV Soverzene (IT) – Lienz (AT) interconnection line would be used to minimize environmental impact<br>TSOs in charge: APG & TERNA<br>Source: UCTE |
| **10** | Italy - Austria | Increasing transmission capacity on Italy-Austria border | New 380 kV GIL Insbruck (AT) – Bressanone (IT) through the planned Brenner Basel Tunnel | Under consideration | Long term | Region: Central South<br>Project driver: limitation of transmission capacities<br>Scope: In the 2003 TEN-E Study, the possibility of increasing the transfer capacity between Austria and Italy was investigated. The GIL solution seems the most feasible, using the planned pilot Tunnel of the Brenner Base Tunnel.<br>TSOs in charge: TERNA & TIWAG – Netz AG<br>Source: UCTE |
| **10** | Italy - Austria | Increasing transmission capacity on Italy-Austria border | New 220 kV tie-line Reschenpass | Under consideration | Long term | Region: Central South<br>Project driver: Constraints on Italian – Austrian border<br>Scope: 380 kV/220 kV substation directly located at the border and |

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| | | | | | | erection of 220 kV connection till Graun and upgrade of the existing line Graun-Glorenza. Additional connection of 110 kV distribution grid in Austria at new substation.<br>TSOs in charge: TERNA & APG & TIWAH-Netz AG<br>Source: UCTE |
| **10** | Italy - Austria | Increasing transmission capacity on Italy-Austria border | 110 kV/132 kV line Prati di Vizze (IT) – Steinach (AT) | Design & permitting | Long term | Region: Central South<br>Project driver: Constraints on Italian – Austrian border<br>Scope: In order to increase transfer capacity between Italy and Austria, a new link across the Valico de Brennero (Brennerpass) could be renewed. The project on both sides (IT & AT) comprises the upgrading of the existing line Prati di Vizze (IT) – Steinach (ATcurrently operated at medium voltage and the installation of a 110 kV/132 kV PST in Steinach (AT)<br>TSOs in charge: TERNA & APG & TIWAH-Netz AG<br>Source: UCTE |
| **24** | Italy Switzerland | Increasing transmission capacity on | 380 kV line between Lavorgo (CH) | Under consideration | Long term | Region: Central South<br>Project driver: |

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| | | Italy-Switzerland border | and Morbegno (IT) | | | Increase the current power exchange and evacuation of future generation capacities in Switzerland<br>Scope: various options are envisaged<br>TSOS in charge: RTE, Swissgrid (& TERNA)<br>Source: UCTE |
| **60** | France - Switzerland | Increasing transmission capacity on Italy-Switzerland border | Different options are currently studied | Under consideration | Long term | Region: Central South<br>Project drivers:<br>• elimination of current bottlenecks on the French – Swiss border<br>• evacuation of future generation capacities in Switzerland<br>• Increase of power exchange capacity between france and switzerland<br>Scope: to be dtermined<br>TSOs in charge: RTE, Swissgrid & TERNA<br>Source: UCTE |
| **11** | France-Italy | Increasing transmission capacity on French-Italy-border | New HVDC cable Piossasco (IT) – Grande Ile (FR) | Planned | Long term | Region: Central South<br>Project driver:<br>Scope: underground cable of 1000 MW capacity. In the 2005 TEN-E Study, the possibility to increase the transfer capacity from France to Italy was investigated. The |

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| | | | | | | HVDC seems the most feasible, using the existing infrastructure corridors<br>TSOs in charge: TERNA & RTE<br>Source: UCTE |
| **4** | Germany - Austria | Increasing power exchange capacity between Germany and Austria | Upgrading the 220 kV grid from Oberbachern (DE) and Silz (AT) | Under consideration | Long term | Region: Central South<br>Project driver: to be clarified<br>Scope: to be determined<br>TSOs in charge: project suggested by TIWAG Netz, E.ON Netz (not yet confirmed)<br>Source: UCTE |
| **4** | Germany - Austria | Increasing power exchange capacity between Germany and Austria | Interconnection between Germany and the Alpine region | Under consideration | Long term | Region: Central South<br>Project driver: transmission and evacuation of the future generation capacity in the Alps<br>Scope: to be determined<br>TSOs in charge ENBW TNG, RWE TSO, Swissgrid & VKW Netz<br>Source: UCTE |
| **61** | Germany - Switzerland | Increasing power exchange capacity between Germany and Austria | Interconnection between Germany and the Alpine region | Under consideration | Long term | Region: Central South<br>Project driver: transmission and evacuation of the future generation capacity in the Alps<br>Scope: to be determined<br>TSOs in charge ENBW TNG, |

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| | | | | | | RWE TSO, Swissgrid & VKW Netz<br>Source: UCTE |
| **62** | Italy - Malta | Interconnection line between Italy and Malta | New submarine cable between Italy and Malta | Under consideration | Mid-term | Region: Central South<br>Project driver: In June 2008, Terna and Enelmalta signed a cooperation agreement on a feasibility study for a new link between the two countries<br>Scope: to be specified<br>TSOs in charge: TERNA and ENELMALTA<br>Source: UCTE |
| **63** | Italy - Tunisia | Interconnection between Italy and Tunisia | New HVDC submarine cable between Cape Bon (TU) and Sicily (IT)<br>Double submarine cable with 170 km length, 1000 MW transmission capacity | Design & permitting | 2016 | Region: Central South<br>Project driver: reinforcing supply security of Italy<br>Scope: building up interconnection capacities in line with the construction of a new power plant in El Houaria (TU). The plant will generate 1200 MW, 800 MW of which being directed towards Italy and 400 MW towards Tunisia<br>TSOs in charge: TERNA & STEG<br>Source: UCTE |
| **64** | Italy - Montenegro | Establishing East-West Corridor in South Eastern Europe | 400 kV interconnection from Tivat (ME) and Villanova (IT) OHL & DC | Planned | Mid-term | Region: South East<br>Project driver: Increase Italy's import from the Balkans (BG, RO)<br>Scope: sub-sea |

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| | | | cable | | | cable total length 375 km. To be realized together with ongoing interconnection projects between MK and BG and future project between MK and AL.<br>TSOs in charge: TERNA (IT) & EPCG (ME)<br>Source: UCTE |
| **65** | Hungary – Croatia (HR) | Building up transmission capacities across Hungarian and Bosnian border | 400 kV double line Pecs (HU) – Ernestinovo (HR) | Under construction | 2010 | Region: South East<br>Project driver: strengthening East-West and North-South corridors and increase the transmission capacity<br>Scope: project carried out complementary to another 400 kV line between HU and RO already completed (2008)<br>TSOs in charge: HEP-OPS & MAVIR<br>Source: UCTE |
| **8** | Greece - Bulgaria | Northern Borders | New 400 kV line N. Santa (GR) – Maritsa (BG) Length 130 km | Design and Permitting | 2012-2015 | Region: South East<br>Project driver: alleviation of imports limitations from northern interconnections mainly due to the sparse structure of the Blakan networks<br>Scope: complement the already completed project dedicated to the interconnection from Turkey to |

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| | | | | | | Greece<br>TSOs in charge: HTSO and NEK<br>Source: UCTE |
| **24** | Slovenia - Hungary | East Border | New 400 kV double line Cirkovce (SI) – Pince (HU border) for connections Cirkovce (SI) – Heviz (HU) and Circovce (SI) – Zerjavinec (HR) | Design & permitting | 2013 | Region: South East<br>Project driver: connection to new power systems and increase of power exchange capacity<br>Scope: first interconnection line between SI and HU; the line already exist on HU and creation sides<br>TSOs in charge: ELES<br>Source: UCTE |
| **12** | Italy - Greece | Increase interconnection capacity | Second HVDC link between Greece & Italy | Under consideration | To be determined | Region: South East<br>Project driver: N/A<br>Scope: N/A<br>TSOs in charge: TERNA & HTSO<br>Source: UCTE |
| **66** | Croatia - Italy | Interconnection between Croatia and Italy | New direct 400 kV HVDC sub-sea cable between HR and IT | Under consideration | Mid-term | Region: South East<br>Project driver: The interconnection would be of regional importance of the Internal Electricity Market<br>Scope: N/A<br>TSOs in charge: TERNA & HEP-OPS<br>Source: UCTE |
| **67** | Romania - Turkey | South East border | 400 kV HVDC submarine cable from Constanza (RO) to Pasakoy (TR)<br>Length: 400 km | Planned | 2018 | Region: South East<br>Project driver: Enable the power export to Turkey<br>Scope: N/A<br>TSOs in charge: Transelectrica & TEIAS |

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| | | | | | | Source: UCTE |
| **42** | Romania – Serb Republic | Eastern corridor | 400 kV line Sacalaz (RO) - Novi Sad (RS)<br>Length: 128 km | Under consideration | 2018 | Region: South East<br>Project driver: increase security of entire interconnection operation<br>Scope: pre-feasibility study carried out on the RO side. EMS got donation to carry out the project design, prefeasibility and environmental studies<br>TSOs in charge: Transelectrica & EMS<br>Source: UCTE |
| **25** | Portugal - Spain | Portugal – Spain Douro interconnection reinforcement | New 400 kV single circuit interconnection Aldeadavila (ES) -Lagoaça (PT) and associated changes in the topology and cables of some 220 kV lines of the area<br>Length 400 kV: 1 km in ES, 60+40+5 km in PT<br>Length 220 kV: 1 km ES, 5 + 12 km PT | Construction (PT) or permitting (almost under construction (ES)) | 2010 | Region: South West<br>Project driver: alleviate the congestion of the 220 kV network in the Douro area making possible the reception of a new amount of power under construction (500 MW) or under permitting process (300 MW) in the Douro River System<br>Scope: includes new substations in Lagoaça (PT) and Armamar (PT) and a new double line on river crossing. The other corridors on this area will be used to build the 400 kV single circuit line. At |

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| | | | | | | Lagoaça (PT) substation, several existing 220 kV lines will be opened.<br>TSOs in charge: REN & REE<br>Source: UCTE |
| **25** | Portugal - Spain | Portugal - Spain Southern interconnection | New OHL 400 kV line South interconnection Guillena (ES) – Puebla de Guzman (ES) – Tavira (PT)<br>Transmission capacity : 1700 MVA (winter)<br>Length : 153 km in ES (Guillena-border), 110 km in PT (Portimao-border) | Under construction : Guillena (ES) - P.Guzman (ES)<br>Permitting: (P.Guzman (ES) - Tavira (PT) | 2011 | Region: South West<br>Project driver: Alleviate the congestion on existing 400 kV line Alqueva (ES) – Brovales (PT) at low levels of exportation from Spain to Portugal. Besides, the project enables the total integration of ES inside MIBEL<br>Scope: The project involves a combination of single and double circuit lines as well as two new 400 kV substations in P. Guzman (ES) and Tavira (PT)<br>TSOs in charge: REN & REE<br>Source: UCTE |
| **28** | Spain - France | Cross-border interconnection | New HVDC interconnection line in the eastern part of the border<br>Transmission capacity: being defined<br>Length: 28 km in Spain, 40 km in France | Design & permitting<br>Political agreement on a new underground HVDC line between Baixas (FR) and Santa Llogaia (ES) | 2014 | Region: South West<br>Project driver: The total interconnection faces a high congestion level limiting the transmission capacity. Limitations in particular on the production of wind-power energy |

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| | | | | | | in the Iberian system<br>Scope: included in the priority Interconnection Plan (TEN-E Guidelines). A European coordinator has been appointed for this project.<br>TSOs in charge: RTE & REE<br>Source: UCTE |
| **25** | Portugal - Spain | Portugal – Spain Northern interconnection | New 400 kV Northern interconnection<br>Transmission capacity: 1700 MVA (Winter)<br>Length: 110 km in ES (Cartelle-border), 112 km in PT (Recarei-border) | Design & Permitting | 2013/2014 | Region: South West<br>Project driver: alleviate the congestion on the existing 400 kV line Cartelle (ES) – Lindoso (PT) at low exportation levels from ES to PT. Besides, the project enables the total integration of ES and PT in MIBEL<br>Scope: included in the priority Interconnection Plan (TEN-E Guidelines).<br>TSOs in charge: REN & REE<br>Source: UCTE |
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| **36** | Sweden - Norway | South West link | New 1200 MW HVDC connection reinforcing the grids between the southern and central parts of Sweden and Norway | Included in in the Nordic Grid Master Plan 2008<br>Under development | 2013 (SE)/-15/-16 (NO) (Earliest commissioning) | Region: Nordel<br>Project driver: Increasing the effectiveness of the Nordic electricity market and increase the system reliability<br>Scope: Additional capacity between NO and SE will be |

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| | | | | | | 1200 MW at the highest. Project complemented with an additional AC line in SE<br>TSO in charge: N/A<br>Source: Nordel. |
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| **36** | Sweden - Norway | North – South axis | New 420 kV line Orskok-Fardal | Included in in the Nordic Grid Master Plan 2008 | 2013 (Earliest Commissioning) | Region: Nordel<br>Project driver: Increasing the effectiveness of the Nordic electricity market and increase the system reliability<br>Scope: Will strengthen the the SE/NO north-South capacity and at the same time decrease potential capacity problems related to cross-section 2 in Sweden<br>TSO in charge: N/A<br>Source: Nordel |
| **30** | Sweden - Finland | Interconnection Sweden-Finland | New AC line between Northern Finland and Northern Sweden | Studies started | To be determined | Region: Nordel<br>Project driver: Increasing the effectiveness of the Nordic electricity market and increase the system reliability<br>Scope: N/A<br>TSO in charge: Fingrid & Svenska Kraftnät<br>Source: Nordel |
| **68** | Norway - Netherlands | NorNed | New HVDC link between Norway and the Netherlands | N/A | Commissioned in 2008 | Region: Nordel<br>Project driver: N/A<br>Scope: N/ANord.Link<br>TSO in charge: |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Transmission capacity: 700 MW | | | N/A<br>Source: Nordel |
| **69** | Norway - Germany | Nord.link | New HVDC line between Southern Norway and Northern Germany | Feasibility study in preparation (a consortium of investors has started the licensing process) | To be determined | Region: Nordel<br>Project driver: N/A<br>Scope: The result of the study is expected to form the basis for a decision entering into a re-licensing phase. Link expected capacity into the range of 700 MW – 1400 MW.<br>TSOs in charge: Statnett (NO) & E.ON Netz (GE)<br>Source: Nordel |
| **6, 29** | Denmark – Germany - Sweden | | AC lines: phase shifting transformers on the two 220 kV lines Jutland-Germany | Svenska Krafnät, Vattenfall Europe Transmission & Energinet.dk are conducting a pre-feasibility study | 2012 | Region: Nordel<br>Project driver: Increasing market capacity<br>Scope: This will increase the market capacity from 950/1500 MW to approximately 1500/2000 MW (import/export) which includes the off-shore farms potential development<br>TSOs in charge:<br>Source: Nordel |
| **56** | Denmark - Netherlands | Cobra | 600 MW HVDC link between the Netherlands and Jutland | Business case under process | To be determined | Region: Nordel<br>Project driver: N/A<br>Scope: N/A<br>TSOs in charge: TenneT & Energinet.dk<br>Source: Nordel |
| | | | | | | |
| **2** | Estonia-Finland | Estlink 2 | From Anttila to Püssi<br>The project | Planned Standard authorizatio | 2014 | Region: Baltic<br>Project driver: integration of the |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | includes a 400-500 kV DC OHL 14km (FI), sea cable around 130-135 km and underground cable in terrestrial section of Estonia 13,5 km<br>Transmission capacity: 650 MW | n processes in both FI & EE<br>Environmental assessment approved in 2009 (EE); still to be carried out in FI | | future power market of the Baltic Member States with Nord Pool;<br>- enhancement of the security of supply, particularly in the BALTSO area, thanks to possible power import from Nordic countries in emergency conditions;<br>- increased reliability of the Estonian power system,<br>- decrease of the dependency of Estonian and other Baltic republics from Russia power supply.<br>Scope: The AC reinforcements to be built upward and downward the interconnector to exploit its full capacity are:<br>1. Extension of Antiltila substation needed (FI side) and reinforcement of Püssi substation is needed (ES side)<br>2. No new lines needed upward and downward from Püssi or Anttila substations<br>TSOs in charge: Põhivõrk (EE) & Finngrid (FI)<br>Source: CESI, BALSO |
| **70** | Sweden - Latvia | Ambergate | HVDC line from | Planned Implementat | 2018 (starting | Region: Baltic<br>Project driver: |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Norrköping (SE) to Ventspils (LV)<br>Transit capacity: 700 MW<br>The following possible routes of Interconnection Latvia – Sweden were considered in the Assessment report prepared by AS Latvenergo and AS Augstsprieguma t•kls (Fig. 6-5):<br>1. Ventspils – Norrköping (390 km);<br>2. Ventspils – Stockholm (310 km);<br>3. Ventspils – Ygne – Oskarshamn (325 km);<br>4. Grobina (Liepaja) – Oskarshamn (300 km);<br>5. Grobina (Liepaja) – Nybro (325 km). | ion time impacted by:<br>EIA implementation;<br>definition of routing and land expropriation on SE side;<br>construction of new AC lines and substations in LT | commissioning) | - Improvement of the security of supply of Latvian consumers and improvement of the system operation service provision. As a matter of fact, Latvian power supply system has the most negative balance situation in whole EU.<br>with overall lower average electricity prices and higher competitiveness (this justification is in fact common to the other interconnection alternatives EstLink 2 and SwedLit);<br>- Fostering the development of wind power generation;<br>- Better exploitation of the generation endowment in Latvia by transferring through the new Latvia-Sweden interconnection the excess energy from the planned Kurzeme TPP (coal+biomass) to the Nordic power systems if the market prices will allow for that;<br>- Improvement of the local security of power supply in Kurzeme (western |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Latvia), especially in the big transiting sea-ports of Liepaja and Ventspils;<br>- Lower risk of dependency of electricity import from Russia, who might exert the role of the dominating power supplier and dictate the electricity prices.<br>Scope: Need to build the 330 kV lines Ventspils-Globina and Ventspils-Imanta and related substations; No information available from the SE side<br>TSOs in charge: Augstsprieguma T•kls. (LV) & Svenska Kraftnät (SE)<br><br>Source: CESI, BALSO |
| **71** | Sweden - Lituania | SwedLit | HVDC submarine line from Nybro to Hemsjï-Klaipeda<br>Transit capacity: cable 700-1000 MW 330 kV<br>340 km | - SPV InterLinks, UAB created;<br>- Cable route and connection point on Lithuanian side located;<br>- Seabed survey initiated;<br>- Technical requirements for | 2017 | Region: Baltic<br>Project drivers:<br>- Development of Baltic electricity market and increased competition (justification in common with the other interconnection alternatives EstLink 2 and AMBERGATE);<br>- Increased security of supply;<br>- Better utilization |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | converter station issued by TSO Lietuvos Energija<br>- Environmental impact assessment procedure started;<br>- Land acquisition issues are being solved | | possibilities of Kruonis HPSPP (900 MW installed capacity) for balancing load. Scope: 82 km of 330 kV line in Lithuania (Telsiai-Klaipeda). In addition a second AC line Musos PP-Panevezys shall be built<br>TSOs in charge: Lietuvos Energija AB (LT) & Svenska Kraftnät (SE)<br><br>Source: CESI, BALSO |
| **57** | Lituania - Poland | LitPol | AC OHL line From Elk to Alytus<br>Capacity: 500/1000 MW | Possible development in stages | 2020 | Region: Baltic<br>Project drivers:<br>Scope: AC reinforcement on the LT grid: 330 kV line Alytus-Kruonis and Ignalina-Kruonis; the exploitation of the full capacity of the interconnector is constrained by heavy AC reinforcement within Poland<br>TSOs in charge: Lietuvos Energija AB (LT)<br>& PSE operator SA (PL)<br>Source: CESI |
| **13** | Latvia - Estonia | Latvia - Estonia Interconnection | Line Harku-Sindi-Riga<br>For the HVAC solutions the rated capacity is 1000-1200 | Economic, technical study and line route selection in progress. Final | 2020 of after | Region: Baltic<br>Project driver: fostering the penetration of wind generation in the western regions of Latvia and Estonia |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | MVA<br>For the HVDC solutions the rated capacity is 600 MW | investment decision for this connection not made. | | (Saaremaa island).<br>Scope: The new Latvia-Estonia interconnection shall warrant an increase of NTC equal to 500-600 MW. The interconnector embed itself the upwards/downwards reinforcements<br>TSOs in charge: Lietuvos Energija AB (LT)<br>Source: CESI, BALTSO |
| **19** | Germany - Poland | DE-PL first project | 2*1630 MVA Vierranden(DE) – Krajnik (PL) | | 2013 | Region: Baltic<br>Project driver:<br>• need for increased transfer capacities because high volatile and unpredictable flows caused by wind generation in Germany and in the Baltic area<br>• Increasing the security of supplies<br>Scope:<br>TSOs in charge:<br>Source: CESI, BALTSO |
| **19** | Germany - Poland | DE-PL Second project | 400 kV double circuit Eisenhüttenstadt (DE) – Bazcyna/Plewiska (PL)<br>Capacity: To be defined | Routing activities started | N/A | Region: Baltic<br>Project driver: need for increased transfer capacities for smoothing the congestion level in Northern and Southern PL-DE interconnection<br>Scope:<br>TSOs in charge: PSE operator SA (PL)<br>Source: CESI, BALTSO |

# 2 Appendix II: Size of Power Transmissions Equipment

| From | To | Upstream connectio | Downstream connection | AC OHL | DC undergroun | DC Subse | Status | Expected dat | Type | Length (km | Region |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | Germany | St. Peter (AT) | Isar/Pleinting (DE) | 380 kV | | | Under consideration | 2017 | New | 110 | Central East |
| Austria | Germany | Silz (AT) | Oberbachern (DE) | 220 kV | | | Under consideration | Long term | Upgrade | 223 | Central South |
| Austria | Italy | Lints (AT) | | 220 kV | | | Design & permitting | 2011 | New | 70 | Central South |
| Austria | Italy | | | 380 kV | | | Under consideration | Long term | New | 80 | Central South |
| Austria | Italy | Insbruck (AT) | Bressanone (IT) | | 380 kV | | Under consideration | Long term | Reinforcement | 83 | Central South |
| Austria | Italy | | | 220 kV | | | Under consideration | Long term | Reinforcement | 250 | Central South |
| Austria | Italy | Steinach (AT) | Prati di Vizze (IT) | 110 kV/132 kV | | | Design & permitting | Long term | New | 50 | Central South |
| Austria | Slovakia | Bisamberg / Wien (AT) | Stupava (SK) | 2*400 kV | | | Under consideration | 2020 | New | 11 | Central East |
| Austria | Slovakia | Wien SO (AT) | Györ/Sombathely (HU) | N/A | | | Design & permitting | 2010 | Reinforcement | 255 | Central East |
| Belgium | France | | | | | | Under consideration | 2015 | N/A | 9 | Central West |
| Belgium | Germany | | | 400 kV | | | Under consideration | To be determined | New | 153,8 | Central West |
| Belgium | Luxembourg | Aubange (BE) | Bascharage (LU) | | 220 kV | | Design & permitting | 2012 | N/A | 10 | Central West |
| Belgium | United Kingdom | | | | | N/A | Under study | To be determined | New | 250 | Central West |
| Bulgaria | Greece | Maritsa (BG) | Santa (GR) | 400 kV | | | Design & permitting | 2015 | New | 130 | South East |
| Croatia | Hungary | Ernestinovo (HR) | Pecs (HU) | | | | Under construction | 2010 | New | 104 | South East |
| Croatia | Italy | | | | | N/A | Under consideration | Mid term | New | 300 | South East |
| Czech Republic | Germany | Hradec (CZ) – Vernerov (C | Mechlenreuth (DE) | 400 KV | | | Under consideration | 2016 | New | 173 | Central East |
| Denmark | Germany | | | N/A | | | Under consideration | To be determined | N/A | 165,8 | Central West |
| Denmark | Germany - Sweden | | | 220 kV | | | Under study | 2012 | Reinforcement | 250 | Nordel |
| Denmark | Netherlands | | | | | 400 kV | Under consideration | 2016 | New | 350 | Central West |
| Denmark | Netherlands | | | | | 600 MW | Under study | 2014 | New | 165,8 | Nordel |
| Estonia | Finland | Püssi | Antilla | | | 400-500 kV | Planned | 2014 | New | 260 | Baltic |
| Estonia | Latvia | Harku-Sindi | Riga | 1000-1200 MVA | | 600 MW | Under study | 2020 | New | 293 | Baltic |
| Finland | Sweden | | | N/A | | | Under study | To be determined | New | 131,8 | Nordel |
| France | Belgium | Aubange (BE) | Moulaine (FR) | 225 kV | | | Permitting | 2010 | N/A | 18 | Central West |
| France | Italie | Trinite Victor (FR) | Camporosso (IT) | 220 kV | | | Design & permitting | 2011 | Upgrade | 57 | Central South |
| France | Italie | Albertville (FR) | Rondissone/Piossasco (IT) | 400 kV | | | Under construction | 2012 | N/A | 180 | Central South |
| France | Italy | Grande Ile (FR) | Piossasco (IT) | | N/A | | Planned | To be determined | New | 50 | Central South |
| France | Luxembourg | Moulaine (FR) | Beval (LU) | 225 kV | | | Permitting | 2010 | N/A | 20 | Central West |
| France | Spain | Baixas (FR) | Llogaia (ES) | | N/A | | Design & permitting | 2014 | New | 68 | South West |
| France | Switzerland | | | N/A | | | Under consideration | Long term | New or reinforcement | 139,4 | Central South |
| Germany | France | Esdorf (DE) | St.Avold (FR) | N/A | | | Under consideration | To be determined | N/A | 460 | Central West |
| Germany | Netherlands | Niederrhein (DE) | Doetinchem (NL) | 400 kV | | | Planned | 2013 | N/A | 50 | Central West |
| Germany | Norway | | | | | 700-1400 MW | Under consideration | 2015 | New | 800 | Central West |
| Germany | Poland | Vierranden (DE) | Krajnik/Mikulowa (PL) | 2*1630 MVA | | | Planned | 2013 | Upgrade | 330 | Central East |
| Germany | Poland | Eisenhüttenstadt (DE) | Bazcyna/Plewiska (PL) | N/A | | | Under study | To be determined | New | 357 | Baltic |
| Germany | Swizerland | | | N/A | | | Under consideration | Long term | New or reinforcement | 200 | Central South |
| Greece | Italy | | | | | N/A | Under consideration | To be determined | New | 300 | South East |
| Hungary | Slovenia | Cirkovce (SI) | Pince (HU ), Heviz (HU) ,Zerjavinec (HR) | 400 kV | | | Design & permitting | 2013 | New | 187 | South East |
| Italy | Malta | | | | | N/A | Under consideration | Mid term | New | 125 | Central South |
| Italy | Slovenia | Ovest (IT) | Okrogolo (SI) | 380 kV | | | Planned | Long term | New | 50 | Central South |
| Italy | Switzerland | Morbegno (IT) | Lavorgo (CH) | 380 kV | | | Under consideration | Long term | New or reinforcement | 138 | Central South |
| Italy | Tunisia | Sicily (IT) | Cape Bon (TU) | | | 1000 MW | Design & permitting | 2016 | New | 170 | Central South |
| Italy | Montenegro | Villanova (IT) | Tivat (ME) | | | 400 kV | Planned | Mid term | New | 375 | South East |
| Latvia | Sweden | Ventspils (LV) | Norrköping (SE) | | | 700 MW | Planned | 2018 | New | 200 | Baltic |
| Lituania | Poland | Alytus (LT) | Elk (PL) | 500/1000 MW | | | Planned | 2020 | New | 158 | Central East |
| Lituania | Sweden | Hemsjï-Klaipeda | Nybro | | | 700-1000 MW | Design & permitting | 2017 | New | 200 | Baltic |
| Netherlands | Norway | | | | | 700 MW | Commissioned | To be determined | New | 500 | Nordel |
| Netherlands | United Kingdom | Maasvlakte | Isle of Grain (UK) | | | 1320 MW | Under construction | 2012 | N/A | 250 | Central West |
| Norway | Sweden | Fardal | Orskok | 420 kV | | | Planned | 2013 | New | 251 | Nordel |
| Poland | Slovakia | Byczyna (PL) | Varin (SK) | N/A | | | Under cosideration | 2018 | New | 285 | Central East |
| Poland | Ukraine | Rzeszow (PL) | Khmelnitskaya (UA) | 750 kV | | | Planned | 2010 | Resumption | 200 | Central East |
| Portugal | Spain | Lagoaça (PT) | Aldeadavila (ES) | 400 kV | | | Under construction | 2010 | New | 143 | South West |
| Portugal | Spain | Tavira (PT) | Guillena (ES) – Puebla de Guzman (ES) | 400 kV | | | Under construction | 2011 | New | 263 | South West |
| Portugal | Spain | Recarei | Cartelle | 400 kV | | | Design & permitting | 2014 | New | 222 | South West |
| Romania | Serb Republic | Sacalaz (RO) | Novi Sad (RS) | 400 kV | | | Under consideration | 2018 | New | 128 | South West |
| Romania | Turkey | Constanza (RO) | Pasakoy (TR) | | | 400 kV | Planned | 2018 | New | 400 | South East |
| Slovakia | Ukraine | Kapusany (SK) | Muchchevo (UA) | 2*400 kV | | | Under consideration | 2014 | Reinforcement | 151 | Central East |

# 3 Appendix III[1]: TradeWind Study Results

### Wind power scenarios per country (MW)

| | | Actual 2005 | Low 2008 | Medium 2008 | High 2008 | Low 2010 | Medium 2010 | High 2010 |
|---|---|---|---|---|---|---|---|---|
| AT | Austria | 819 | 990 | 1,015 | 1,045 | 1,100 | 1,160 | 1,250 |
| BE | Belgium | 167 | 357 | 571 | 834 | 469 | 750 | 1,119 |
| BU | Bulgaria | 10 | 30 | 40 | 55 | 90 | 183 | 245 |
| HR | Croatia | 6 | 150 | 230 | 380 | 250 | 400 | 600 |
| CZ | Czech Republic | 29 | 120 | 220 | 350 | 180 | 580 | 1,100 |
| DK | Denmark | 3,130 | 3,129 | 3,129 | 3,286 | 3,329 | 3,629 | 4,229 |
| FI | Finland | 82 | 150 | 200 | 250 | 250 | 350 | 500 |
| FR | France | 702 | 2,100 | 2,700 | 5,100 | 3,098 | 4,840 | 9,680 |
| DE | Germany | 18,428 | 21,622 | 22,900 | 24,063 | 22,665 | 25,291 | 28,466 |
| GB | Great Britain | 1,460 | 2,822 | 4,086 | 6400 | 5,550 | 7,512 | 8,900 |
| GR | Greece | 573 | 845 | 1,098 | 1,350 | 958 | 1,479 | 2,000 |
| HU | Hungary | 17 | 106 | 250 | 325 | 250 | 325 | 330 |
| IE | Ireland | 583 | 1,246 | 1,326 | 1,525 | 1,478 | 1,955 | 2,858 |
| IT | Italy | 1,381 | 2,075 | 4,233 | 5,810 | 2,490 | 5,893 | 8,300 |
| LU | Luxembourg | 35 | 45 | 54 | 53 | 54 | 66 | 66 |
| NL | Netherlands | 1,224 | 2,058 | 2,228 | 2,328 | 2,528 | 2,950 | 3,400 |
| NO | Norway | 274 | 454 | 544 | 595 | 508 | 1,057 | 1,458 |
| PL | Poland | 83 | 450 | 550 | 650 | 1,000 | 1,200 | 1,500 |
| PT | Portugal | 1,014 | 2,699 | 2,841 | 2,983 | 3,894 | 4,099 | 4,304 |
| RO | Romania | 1 | 50 | 80 | 120 | 160 | 345 | 460 |
| SC | Serbia | 0 | 0 | 2 | 5 | 5 | 10 | 30 |
| SK | Slovakia | 5 | 20 | 55 | 90 | 100 | 175 | 410 |
| SI | Slovenia | 0 | 0 | 20 | 40 | 0 | 85 | 130 |
| ES | Spain | 11,482 | 13,929 | 15,477 | 17,025 | 17,528 | 19,475 | 21,423 |
| SE | Sweden | 493 | 750 | 1,050 | 1350 | 1,100 | 1,600 | 2,150 |
| CH | Switzerland | 12 | 15 | 18 | 20 | 15 | 40 | 100 |
| | Total | 42,011 | 56,212 | 64,917 | 76,012 | 69,047 | 85,449 | 105,007 |

| | | Low 2015 | Medium 2015 | High 2015 | Low 2020 | Medium 2020 | High 2020 | Low 2030 | Medium 2030 | High 2030 |
|---|---|---|---|---|---|---|---|---|---|---|
| AT | Austria | 1,400 | 3,000 | 3,400 | 1,700 | 3,500 | 4,900 | 2,300 | 4,300 | 7,900 |
| BE | Belgium | 986 | 1,286 | 1,952 | 1,218 | 2,289 | 3,034 | 2,262 | 4,983 | 6,086 |
| BU | Bulgaria | 300 | 540 | 650 | 680 | 875 | 1,150 | 1,495 | 2,160 | 3,450 |
| HR | Croatia | 370 | 580 | 1,150 | 700 | 1,400 | 2,800 | 1,200 | 3,000 | 5,600 |
| CZ | Czech Republic | 220 | 900 | 1,800 | 230 | 1,200 | 2,500 | 250 | 1,500 | 4,000 |
| DK | Denmark | 3886 | 4,318 | 4,750 | 4,778 | 5,309 | 5,840 | 6,562 | 7,291 | 8,020 |
| FI | Finland | 500 | 900 | 1,600 | 1,000 | 1,700 | 3,000 | 2,000 | 3,200 | 6,000 |
| FR | France | 12,313 | 16,745 | 23,000 | 23,000 | 30,000 | 37,000 | 38,000 | 45,000 | 49,950 |
| DE | Germany | 27,383 | 36,004 | 42,612 | 34,170 | 48,202 | 56,640 | 44,857 | 54,244 | 63,587 |
| GB | Great Britain | 6,864 | 10,813 | 16,979 | 9,995 | 16,278 | 26,087 | 11,059 | 18,136 | 29,183 |
| GR | Greece | 1,988 | 2,744 | 3,500 | 2,280 | 3,640 | 5,000 | 3,126 | 5,628 | 8,130 |
| HU | Hungary | 330 | 450 | 500 | 330 | 850 | 900 | 330 | 900 | 1,600 |
| IE | Ireland | 1,747 | 3,257 | 4,444 | 2,993 | 4,537 | 5,344 | 3,295 | 4,998 | 5,891 |
| IT | Italy | 3,403 | 9,130 | 12,865 | 4,150 | 11,620 | 15,770 | 6,640 | 15,355 | 19,090 |
| LU | Luxembourg | 78 | 96 | 98 | 102 | 126 | 132 | 117 | 184 | 206 |
| NL | Netherlands | 4,100 | 5,250 | 6,700 | 5,100 | 6,950 | 10,100 | 5,150 | 7,050 | 10,200 |
| NO | Norway | 940 | 2,350 | 4,070 | 1,380 | 3,660 | 6,660 | 1,990 | 5,980 | 11,970 |
| PL | Poland | 3,000 | 3,500 | 4,000 | 5,000 | 6,000 | 7,000 | 10,000 | 12,000 | 14,000 |
| PT | Portugal | 5,365 | 5,647 | 5,930 | 6,850 | 7,211 | 7,572 | 8,516 | 8,964 | 9,412 |
| RO | Romania | 600 | 1,100 | 1,350 | 1,600 | 2,500 | 3,100 | 2,300 | 3,300 | 4,000 |
| SC | Serbia | 20 | 40 | 80 | 40 | 80 | 150 | 100 | 200 | 500 |
| SK | Slovakia | 160 | 245 | 545 | 177 | 280 | 545 | 205 | 303 | 545 |
| SI | Slovenia | 102 | 220 | 340 | 205 | 430 | 560 | 310 | 540 | 860 |
| ES | Spain | 23,028 | 26,476 | 30,924 | 29,029 | 34,477 | 39,425 | 40,031 | 48,479 | 53,427 |
| SE | Sweden | 2,150 | 3,600 | 5,600 | 4,000 | 6,500 | 10,000 | 6,500 | 10,000 | 17,000 |
| CH | Switzerland | 50 | 150 | 300 | 100 | 300 | 600 | 300 | 600 | 1,100 |
| | Total | 101,282 | 139,342 | 179,139 | 140,807 | 199,915 | 255,808 | 198,895 | 268,295 | 341,707 |

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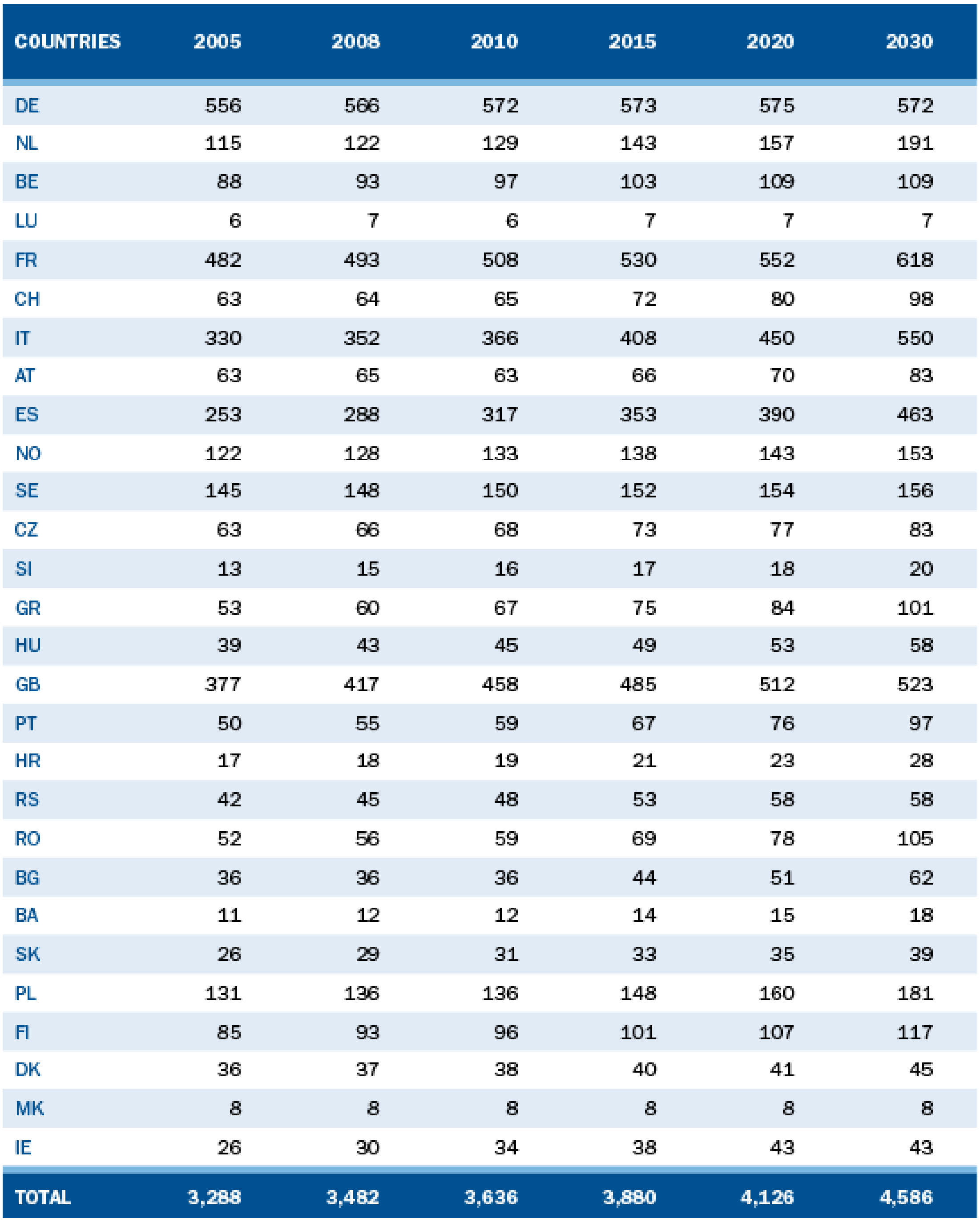
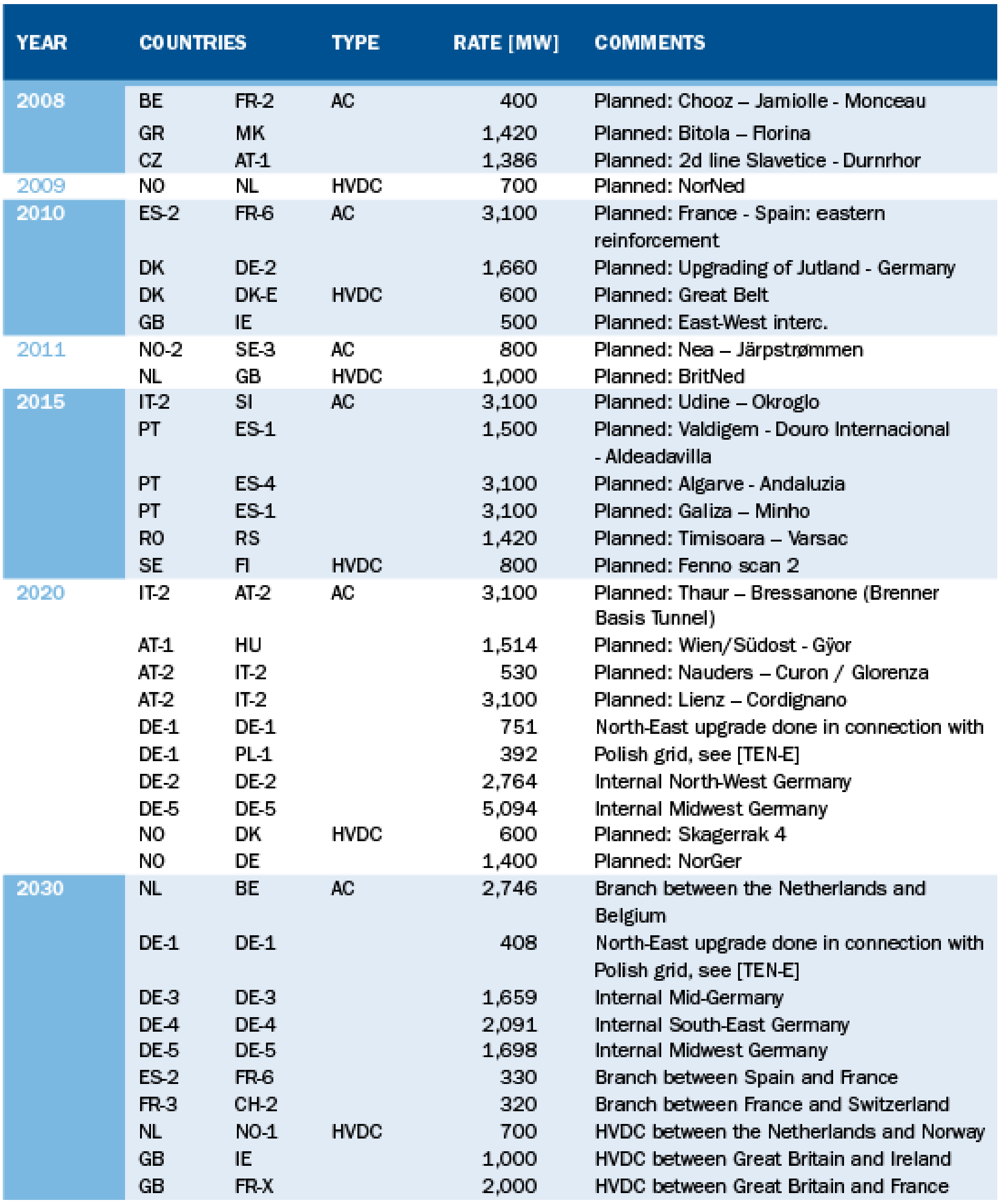
[1] Source: TradeWind; Integrating Wind, Developing Europe's power market for the large scale integration of wind power, February 2009.

**Annual electricity consumption for power flow and market modelling in TWh;scenario based on Eurprog 2006**



| COUNTRIES | 2005 | 2008 | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|---|
| DE | 556 | 566 | 572 | 573 | 575 | 572 |
| NL | 115 | 122 | 129 | 143 | 157 | 191 |
| BE | 88 | 93 | 97 | 103 | 109 | 109 |
| LU | 6 | 7 | 6 | 7 | 7 | 7 |
| FR | 482 | 493 | 508 | 530 | 552 | 618 |
| CH | 63 | 64 | 65 | 72 | 80 | 98 |
| IT | 330 | 352 | 366 | 408 | 450 | 550 |
| AT | 63 | 65 | 63 | 66 | 70 | 83 |
| ES | 253 | 288 | 317 | 353 | 390 | 463 |
| NO | 122 | 128 | 133 | 138 | 143 | 153 |
| SE | 145 | 148 | 150 | 152 | 154 | 156 |
| CZ | 63 | 66 | 68 | 73 | 77 | 83 |
| SI | 13 | 15 | 16 | 17 | 18 | 20 |
| GR | 53 | 60 | 67 | 75 | 84 | 101 |
| HU | 39 | 43 | 45 | 49 | 53 | 58 |
| GB | 377 | 417 | 458 | 485 | 512 | 523 |
| PT | 50 | 55 | 59 | 67 | 76 | 97 |
| HR | 17 | 18 | 19 | 21 | 23 | 28 |
| RS | 42 | 45 | 48 | 53 | 58 | 58 |
| RO | 52 | 56 | 59 | 69 | 78 | 105 |
| BG | 36 | 36 | 36 | 44 | 51 | 62 |
| BA | 11 | 12 | 12 | 14 | 15 | 18 |
| SK | 26 | 29 | 31 | 33 | 35 | 39 |
| PL | 131 | 136 | 136 | 148 | 160 | 181 |
| FI | 85 | 93 | 96 | 101 | 107 | 117 |
| DK | 36 | 37 | 38 | 40 | 41 | 45 |
| MK | 8 | 8 | 8 | 8 | 8 | 8 |
| IE | 26 | 30 | 34 | 38 | 43 | 43 |
| **TOTAL** | **3,288** | **3,482** | **3,636** | **3,880** | **4,126** | **4,586** |

**Stage 1 branch reinforcements including planned new connections; Internal zones reinforcements are marked with grey colour[2]**



| YEAR | COUNTRIES | | TYPE | RATE [MW] | COMMENTS |
|---|---|---|---|---|---|
| 2008 | BE | FR-2 | AC | 400 | Planned: Chooz – Jamiolle - Monceau |
| | GR | MK | | 1,420 | Planned: Bitola – Florina |
| | CZ | AT-1 | | 1,386 | Planned: 2d line Slavetice - Durnrhor |
| 2009 | NO | NL | HVDC | 700 | Planned: NorNed |
| 2010 | ES-2 | FR-6 | AC | 3,100 | Planned: France - Spain: eastern reinforcement |
| | DK | DE-2 | | 1,660 | Planned: Upgrading of Jutland - Germany |
| | DK | DK-E | HVDC | 600 | Planned: Great Belt |
| | GB | IE | | 500 | Planned: East-West interc. |
| 2011 | NO-2 | SE-3 | AC | 800 | Planned: Nea – Järpstrømmen |
| | NL | GB | HVDC | 1,000 | Planned: BritNed |
| 2015 | IT-2 | SI | AC | 3,100 | Planned: Udine – Okroglo |
| | PT | ES-1 | | 1,500 | Planned: Valdigem - Douro Internacional - Aldeadavilla |
| | PT | ES-4 | | 3,100 | Planned: Algarve - Andaluzia |
| | PT | ES-1 | | 3,100 | Planned: Galiza – Minho |
| | RO | RS | | 1,420 | Planned: Timisoara – Varsac |
| | SE | FI | HVDC | 800 | Planned: Fenno scan 2 |
| 2020 | IT-2 | AT-2 | AC | 3,100 | Planned: Thaur – Bressanone (Brenner Basis Tunnel) |
| | AT-1 | HU | | 1,514 | Planned: Wien/Südost - Gÿor |
| | AT-2 | IT-2 | | 530 | Planned: Nauders – Curon / Glorenza |
| | AT-2 | IT-2 | | 3,100 | Planned: Lienz – Cordignano |
| | DE-1 | DE-1 | | 751 | North-East upgrade done in connection with |
| | DE-1 | PL-1 | | 392 | Polish grid, see [TEN-E] |
| | DE-2 | DE-2 | | 2,764 | Internal North-West Germany |
| | DE-5 | DE-5 | | 5,094 | Internal Midwest Germany |
| | NO | DK | HVDC | 600 | Planned: Skagerrak 4 |
| | NO | DE | | 1,400 | Planned: NorGer |
| 2030 | NL | BE | AC | 2,746 | Branch between the Netherlands and Belgium |
| | DE-1 | DE-1 | | 408 | North-East upgrade done in connection with Polish grid, see [TEN-E] |
| | DE-3 | DE-3 | | 1,659 | Internal Mid-Germany |
| | DE-4 | DE-4 | | 2,091 | Internal South-East Germany |
| | DE-5 | DE-5 | | 1,698 | Internal Midwest Germany |
| | ES-2 | FR-6 | | 330 | Branch between Spain and France |
| | FR-3 | CH-2 | | 320 | Branch between France and Switzerland |
| | NL | NO-1 | HVDC | 700 | HVDC between the Netherlands and Norway |
| | GB | IE | | 1,000 | HVDC between Great Britain and Ireland |
| | GB | FR-X | | 2,000 | HVDC between Great Britain and France |

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[2] The number after the country code (for example AT-2) indicates the grid zone within the country. Details can be found in the TradeWind WP6 report.

# 4 AppendixIV: TEN-E Projects Eligible for Grants

TRANS-EUROPEAN ENERGY NETWORKS[3]

Axes for priority projects, including sites of projects of European interest, as defined in Articles 7 and 8

The priority projects, including projects of European interest, to be carried out on each axis for priority projects are listed below.

ELECTRICITY NETWORKS

*EL.1. France — Belgium — Netherlands — Germany:*

electricity network reinforcement in order to resolve congestion in electricity flow through the Benelux States.

Including the following projects of European interest:

- Avelin (FR) — Avelgem (BE) line
- Moulaine (FR) — Aubange (BE) line.

EL.2. Borders of Italy with France, Austria, Slovenia and Switzerland:

increasing electricity interconnection capacities.

Including the following projects of European interest:

- Lienz (AT) — Cordignano (IT) line
- New interconnection between Italy and Slovenia
- Udine Ovest (IT) — Okroglo (SI) line
- S. Fiorano (IT) — Nave (IT) — Gorlago (IT) line
- Venezia Nord (IT) — Cordignano (IT) line
- St. Peter (AT) — Tauern (AT) line
- Südburgenland (AT) — Kainachtal (AT) line
- Austria — Italy (Thaur-Brixen) interconnection through the Brenner rail tunnel.

EL.3. France — Spain — Portugal:

increasing electricity interconnection capacities between these countries and for the Iberian peninsula and grid development in island regions.

Including the following projects of European interest:

- Sentmenat (ES) — Bescan• (ES) — Baixas (FR) line
- Valdigem (PT) — Douro Internacional (PT) — Aldeadávila (ES) line and ‘Douro Internacional’ facilities.

*EL.4. Greece — Balkan countries — UCTE System:*

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[3] DECISION No 1364/2006/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 September 2006laying down guidelines for trans-European energy networks and repealing Decision 96/391/EC andDecision No 1229/2003/EC.

development of electricity infrastructure to connect Greece to the UCTE System and to enable the development of the south-east European electricity market.

Including the following project of European interest:

- Philippi (EL) — Hamidabad (TR) line.

*EL.5. United Kingdom — continental Europe and northern Europe:*

establishing/increasing electricity interconnection capacities and possible integration of offshore wind energy.

Including the following project of European interest:

- Undersea cable to link England (UK) and the Netherlands.

*EL.6. Ireland — United Kingdom:*

increasing electricity interconnection capacities and possible integration of offshore wind energy.

Including the following project of European interest:

- Undersea cable to link Ireland and Wales (UK).

*EL.7. Denmark — Germany — Baltic Ring (including Norway — Sweden — Finland — Denmark — Germany — Poland — Baltic States — Russia):*

increasing electricity interconnection capacities and possible integration of offshore wind energy.

Including the following projects of European interest:

- Kassø (DK) — Hamburg/Dollern (DE) line
- Hamburg/Krümmel (DE) — Schwerin (DE) line
- Kassø (DK) — Revsing (DK) — Tjele (DK) line
- Vester Hassing (DK) — Trige (DK) line
- Submarine cable Skagerrak 4: between Denmark and Norway
- Poland — Lithuania link, including necessary reinforcement of the Polish electricity network and the Poland-
- Germany profile in order to enable participation in the internal energy market
- Submarine cable Finland — Estonia (Estlink)
- Fennoscan submarine cable between Finland and Sweden
- Halle/Saale (DE) — Schweinfurt (DE).

*EL.8. Germany — Poland — Czech Republic — Slovakia — Austria — Hungary — Slovenia:*

increasing electricity interconnection capacities.

Including the following projects of European interest:

- Neuenhagen (DE) — Vierraden (DE) — Krajnik (PL) line
- Dürnrohr (AT) — Slav•tice (CZ) line
- New interconnection between Germany and Poland
- Ve•ký Kapušany (SK) — Lemešany (SK) — Moldava (SK) — Sajóivánka (HU) line
- Gab•íkovo (SK) — Vel'ký •ur (SK) line
- Stupava (SK) — south-east Vienna (AT) line.

*EL.9. Mediterranean Member States — Mediterranean Electricity Ring*

increasing electricity interconnection capacities between Mediterranean Member States and Morocco — Algeria

— Tunisia — Libya — Egypt — near eastern countries — Turkey.

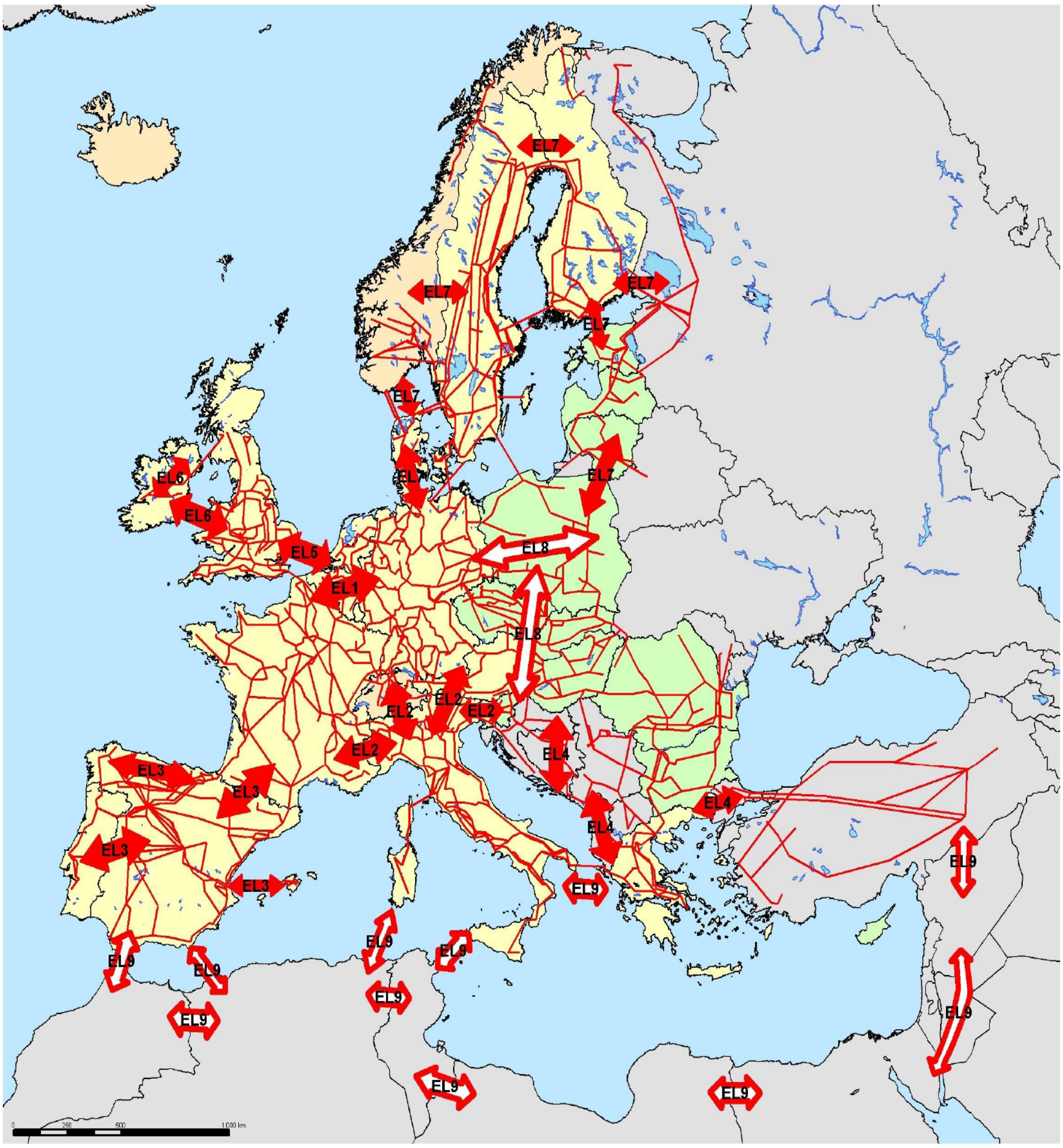
Including the following project of European interest:

- Electricity connection to link Tunisia and Italy.

**TRANS-EUROPEAN NETWORKS
PRIORITY PROJECTS
FOR ELECTRICITY**

**Electricity Priority Projects
in the European Union and
in neighbouring Countries**

03/2004



**Priority Projects decided (June 2003):**

- 🟥 EL1: France - Belgium - The Netherlands - Germany
- 🟥 EL2: Connections on the borders of Italy
- 🟥 EL3: France - Spain - Portugal
- 🟥 EL4: Greece - Balkan countries - UCTE System
- 🟥 EL5: United Kingdom - Continental and Northern Europe
- 🟥 EL6: Ireland - United Kingdom
- 🟥 EL7: Denmark - Germany - Baltic Electricity Ring

**Priority Projects proposed (Dec 2003):**

- □ EL8: Connections in Central Europe
- □ EL9: Mediterranean Electricity Ring

**Other information**

- — Existing electricity network

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Cartography: Eurostat - GISCO, 04/2003

# 5 Appendix V: Literature Review of Electricity Infrastructure Requirements

## 5.1 Introduction

**Overview**

This appendix presents a review of the literature of future infrastructure requirements in the electricity sector.

It should be noted that this analysis was carried out before the publication of the ENTSO-E Ten Year Network Development Plan (TYNDP) and the data are gathered from alternative sources.

The development of power transmission infrastructures is largely covered by recent studies carried out on behalf of TSO and institutional organizations. The emphasis is usually put on the following issues:

- analysis of current net transfer capacities (NTC) throughout the EU countries, whether they belong to specific organizations
- forecasts of power market evolution in the medium and long term (up to 2030)
- identification of key interconnection projects with specific emphasis on the cross-border capacities
- identification of related investment (in limited cases only)

The compilation and the analysis of available datahighlight several difficulties. Among the most constraining difficulties, we underline the following:

- diverging objectives: technological developments, impact of RES, political issues[4]
- divergence in methodological aspects, especially with regard to calculation processes; some forecasting studies are based on extrapolations, while others are based on the utilization of load flow calculation tools for instance
- divergence in the scope of the analysis: levels of detail, regional aspects, etc

**Structure of this chapter**

So as to address the questions raised by DG Energy, this report covers the following:

1 The most recent developments in infrastructure plans that are included in the available documentation and, in particular, the most recent reports

2 The possibility to reconcile current infrastructure plans with the recent simulations carried out on behalf of the EC with the PRIMES macroeconomic model with a time horizon including 2020 and 2030 respectively

3 An estimate of the projected investments related to the expected infrastructure improvements before 2020 and between 2020 and 2030, respectively (see Section 5.8 onwards)

In some cases, missing data have been estimated on the basis of the information that is available (for example the length of additional interconnection lines is estimated as 20% of the distance between the capitals of both countries[5]).

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[4] For example, the re-connection of Greece to the UCTE grid.

[5] Gross figure mostly used for some long term interconnections which includes the side investments required for reinforcing the cross border interconnection on both sides.

AC, underground DC and sub-sea DC cables have been identified separately, due to their large economic impact in terms of investments.

**Assumptions and limitations of the analysis**

Three possible shortcomings in the analysis must be highlighted:

1. The possibility of double counting, which cannot be avoided as various sources have been exploited and, in some cases, projects are not fully specified[6].
2. The lack of links between the proposed extended transmission capacities and the economic development of the EU27 member states[7].
3. The lack of information regarding the impact of the future developments in the field of renewable energy sources utilization.

## 5.2 Analysis based on available studies

The identification of the new projects is detailed in Table I of Appendix I. It summarizes the available data gathered after the consultation of various sources, includingour main sources UCTE, NORDEL,and BALTSO. The table reports the following items:

- countries between which the reinforcement of NTC is envisaged
- project scope
- project description
- project status:
  - under consideration
  - planned
  - design & permitting
  - etc.
- expected completion date
- comments:
  - region covered
  - project driver
  - project scope (if available)
  - sources (see above)

For analysis purposes, the table in Appendix I was summarized in the form of a database, in Appendix II (Table II). The emerging results are developed below.

**Assessment of new infrastructure**

This section and the following section provide a summary of the planned developments that are provided by our list of sources. The dimensions we consider are:

- type of infrastructure (ACOHL, DC underground and subsea)
- geographical location
- completion date
- project type (new or upgrade)
- project driver

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[6] This was initially the case for the two projects between Austria and Germany as mentioned in Appendix I (reason for which the length of the second projects is assimilated to nil). Another example was the line Vierranden-Krajnik (DE-PL). Identified overlaps, including the above mentioned, have been written off from the table.

[7] Most often, references reported by TSOs and various related studies do not refer explicitly to well-defined and comprehensive economic scenarios.

*Disaggregation by region*

Based on the database we have constructed, Table 5.1 indicates that the projects in the field of AC OHL are concentrated mainly in UCTE central East & South regions while DC subsea lines are more likely to be built in other regions.

A majority of projects envisaged during the next 20 years relate to AC lines (5,979 km) but they are almost matched by DC offshore projects (5,353 km).

**TABLE 5.1: BREAKDOWN OF LENGTHS BY REGION**

| | ACOHL length (km) | DC underground length (km) | DC subsea length (km) |
|---|---|---|---|
| Baltic | 305 | - | 807 |
| Central East | 1,663 | - | - |
| Central South | 1,437 | 133 | 295 |
| Central West | 868 | 10 | 1,650 |
| North | 633 | - | 1,226 |
| South East | 445 | - | 1,375 |
| South West | 628 | 68 | - |
| Total | 5,979 | 211 | 5,353 |

Source(s): UCTE, NORDEL, BALTSO, various others and author's calculations.

*Disaggregation by completion date*

Table 5.2 shows that 2,960 km of AC projects will be built before 2020 (including mid-term), against 1,934 km in the longer run and 1,085 km for which the implementation is still to be determined. It is estimated that 75% of the planned or expected projects with specified end dates should be implemented during the first half of decade[8].

The forecasts are more balanced in the field of DC offshore infrastructures where at least 52% of the backlog should be realized before 2020, mainly from 2015 onwards. The ratio of projects for which the implementation planning is not yet defined is important in both cases: 18% in the case of AC lines and 33% for DC offshore line projects. This is consistent with the length of the planning period.

If we count mid-term projects as ones that will be implemented before 2020, the situation is as follows (see Table 5.3):

- 6,615km (76%) of the total projected length should be realized before 2020 against 2,067km (24%) between 2020 and 2030
- 2,960km (50%)of AC lines should be built by 2020
- 3,577km (67%) of DC offshore lines should be built by 2020

**TABLE 5.2: BREAKDOWN OF LENGTHS BY EXPECTED COMPLETION DATE**

| | ACOHL length (km) | DC underground length (km) | DC subsea length (km) |
|---|---|---|---|
| 2010 | 181 | | |
| 2011 | 390 | | |
| 2012 | 430 | 10 | 250 |
| 2013 | 818 | | |

---

[8] Excluding medium-term projects.

| | | | |
|---|---|---|---|
| 2014 | 222 | 68 | 260 |
| 2015 | 176 | | 800 |
| 2016 | | | 520 |
| 2017 | 110 | | 200 |
| 2018 | 128 | | 600 |
| 2020 | 305 | | 147 |
| Long term | 1,934 | 133 | |
| Mid term | 200 | | 800 |
| To be determined | 1,085 | | 1,776 |
| Total | 5,979 | 211 | 5,353 |

Source(s): UCTE, NORDEL, BALTSO, various others and author’s calculations.

**TABLE 5.3: BREAKDOWN OF LENGTHS BY TIME HORIZON**

| | ACOHL length (km) | DC underground length (km) | DC subsea length (km) |
|---|---|---|---|
| 2010 | 181 | | |
| 2020 | 2,779 | 78 | 3,577 |
| 2030 | 1,934 | 133 | |
| To be determined | 1,085 | | 1,776 |
| Total | 5,979 | 211 | 5,353 |

Source(s): UCTE, NORDEL, BALTSO, various others and author’s calculations.

*Disaggregation by project type*

However, the indicated lengths do not correspond systematically to the construction of new infrastructure, except perhaps for DC lines. Various projects address in turn:

- the rehabilitation of existing infrastructures
- the upgrading of transfer capacities
- the installation of phase shift transformers, etc.

Table 5.4 summarises the various European cross-border projects by type. Of the total projected length of new infrastructure projects (11,542 km), 83% is described as new or reinforcement projects. Only four upgrade projects are anticipated and the combined length of these is relatively small. For around 10% of all the cross-border projects it is not known whether they are new, reinforcement or upgrade projects.

**TABLE 5.4: BREAKDOWN OF LENGTHS BY PROJECT TYPES**

| Project Type | Total length (km) |
|---|---|
| New or reinforcement | 9,578 |
| Upgrade projects | 810 |
| Type of project unknown | 1,154 |
| Total | 11,542 |

Source(s): UCTE, NORDEL, BALTSO, various others and author’s calculations.

*Transmission equipment*

Another aspect to consider is the size of transmission equipment. The table in Appendix II indicates, whenever possible, references in this respect. Usually, projects address 400kV lines or above. High voltage is usually justified by the goals of the projects under review, especially when long-distance transportation is envisaged and in the case of offshore connectors, for which important developments are foreseen in the coming decades (see below). However, data are not available for all of them, especially in the case of investments to be realized after 2020, due to uncertainties impacting on long-term planning. Therefore, special attention was required when the investment projects planned in the long runwere converted to investment values.

*Disaggregation by country*

Table 5.5 summarizes the breakdown of length of planned projects expected to be completed by 2030 between each country[9].

If confirmed, these figures indicate that those countries concentrating the cross-borders projects are, in terms of interconnection length:

- Austria
- Germany
- Italy

In the table, European countries are listed as row titles. If the project is between two European countries, the first country listed in the original source is used in the row, and the second one is indicated by the column.

### Limitations in the analysis

As mentioned at the start of this chapter, these preliminary estimates are taken from several different sources. Besides the risk of double counting, the general coherence is not guaranteed because the results reflect more the sum of investments identified at national level, rather than a global, internally consistent project. Some of the mentioned projects also seem rather questionable, such as the interconnection between Germany and Norway, although in this case it is not the objective of the project itself but the recommended option (DC offshore cable) that could tentatively bypass the logic of the NORDEL market.

The power dependency of other countries, such as Italy, could also be reassessed in the long run with regard to the implementation of an alternative energy policy at national level. This could tentatively reduce the input of envisaged investments such as the new DC offshore interconnection between Greece and the SouthernItalian peninsula[10].

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[9] Important neighbor countries are also mentioned to specify the country of origin/destination e.g. Ukraine, Turkey or Norway.

[10] A recent ex-post evaluation carried out on behalf of the EIB indicated that the existing cable was barely reaching half of its NTC and was mainly used for balancing the two markets.

## TABLE 5.5: BREAKDOWN OF LENGTHS OF PLANNED PROJECTS, KM (HORIZON 2030)

| | Belgium | Finland | France | Germany | Germany-Sweden | Greece | Italy | Latvia | Luxembourg | Malta | Montenegro | Netherlands | Norway | Poland | Serbia | Slovakia | Slovenia | Spain | Sweden | Switzerland | Tunisia | Turkey | Ukraine | United Kingdom | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | | | | 333 | | | 533 | | | | | | | | | 11 | | | | | | | | | 877 |
| Belgium | | | | | | | | | 10 | | | | | | | | | | | | | | | 250 | 260 |
| Bulgaria | | | | | | 130 | | | | | | | | | | | | | | | | | | | 130 |
| Croatia | | | | | | | 300 | | | | | | | | | | | | | | | | | | 300 |
| Czech Rep. | | | | 173 | | | | | | | | | | | | | | | | | | | | | 173 |
| Denmark | | | | 166 | 250 | | | | | | | 516 | | | | | | | | | | | | | 932 |
| Estonia | | 260 | | | | | | 293 | | | | | | | | | | | | | | | | | 553 |
| Finland | | | | | | | | | | | | | | | | | | | 132 | | | | | | 132 |
| France | 18 | | | | | | 287 | | 20 | | | | | | | | | 68 | | 139 | | | | | 532 |
| Germany | 154 | | 460 | | | | | | | | | | 800 | | | | | | | 200 | | | | | 1,614 |
| Hungary | | | | | | | | | | | | | | | | | 187 | | | | | | | | 187 |
| Italy | | | | | | 300 | | | | 125 | 375 | | | | | | 50 | | | 138 | 170 | | | | 1,158 |
| Latvia | | | | | | | | | | | | | | | | | | | 200 | | | | | | 200 |
| Lithuania | | | | | | | | | | | | | | 204 | | | | | 200 | | | | | | 404 |
| Netherlands | | | | 50 | | | | | | | | | | | | | | | | | | | | 250 | 300 |
| Norway | | | | 560 | | | | | | | | 500 | | | | | | | 251 | | | | | | 1,311 |
| Poland | | | | 687 | | | | | | | | | | | | 285 | | | | | | | 200 | | 1,172 |
| Portugal | | | | | | | | | | | | | | | | | | 628 | | | | | | | 628 |
| Romania | | | | | | | | | | | | | | | 128 | | | | | | | 400 | | | 528 |
| Slovakia | | | | | | | | | | | | | | | | | | | | | | | 151 | | 151 |
| **Total** | 172 | 260 | 460 | 1,969 | 250 | 430 | 1,120 | 293 | 30 | 125 | 375 | 1,016 | 800 | 204 | 128 | 296 | 237 | 696 | 783 | 477 | 170 | 400 | 351 | 500 | 11,542 |

EU countries that are not included have no planned interconnection projects.This table is built on the basis of the information available on related interconnection projects. The link Germany Sweden-Denmark (Kriegers Flak) is currently developed as a bilateral project between Denmark and Germany, after the withdrawal of Sweden from the initial project.

Source(s): UCTE, NORDEL, BALTSO, various others and author’s calculations.

## 5.3 Project drivers and the impact of RES

**Project drivers**

In various cases, projects identified by TSOs fail to elaborate on the reasons for which new interconnectors are needed. However, where possible we have attempted to identify the main drivers of each project. Many of the future electricity interconnection projects address several targets including namely, but not exclusively, the following factors:

- the mitigation of existing congestion on cross-border lines
- the security of national networks in case of possible collapse of one or several generators
- the interoperability of networks in line with the foreseeable development of the electricity market
- the need for additional transport capacity generated by the construction of new generating facilities, such as wind farms or back-to-back thermal stations

Furthermore, some of the projects reported by TSOs do not address direct increase of transmission capacity but the optimization of flows at international grid level, such as the installation of phase-shift transformers.

Table 5.6 summarises the anticipated projects by the driver(s) behind them. It should be noted that there is a significant degree of double counting in this table as many of the projects have more than one driver.

The most commonly cited drivers of the infrastructure projects are to increase general transfer capacities, resolve congestion or constraint problems or to develop the effectiveness of existing energy networks and/or markets. In comparison, as discussed below, the total length of projects explicitly driven by the aim of integrating renewable energy supplies is relatively small.

**TABLE 5.6: BREAKDOWN OF LENGTHS BY PROJECT DRIVER**

| **Project Driver** | **Total length (km)** |
|---|---|
| Security of supply | 1,748 |
| Market coupling | 2,131 |
| Increased transfer capacities | 2,760 |
| Resolving congestion or constraint problems | 1,469 |
| Developing the effectiveness of existing energy networks/ markets | 2,783 |
| Developing renewable energy networks | 1,611 |
| Project driver unknown | 2,441 |
| *Total (including double counting)* | *14,943* |

Source(s): UCTE, NORDEL, BALTSO, various others and author's calculations.
Note(s): Due to some projects having more than one driver, some project lengths will be double counted in the total.

*Links between drivers and project scale*

In the cases of easing congestion and ensuring security of supply, projects do not always require the construction of long new lines. Distances can be short and, in certain circumstances, the project can be limited to the updating of existing infrastructure.However, when linking different markets or incorporating new RES, the scope of the project can be much larger in terms of distance. In various cases it involves offshore cables.

The average length of projects proposed by TSOs and related studies is 165 km for onshore interconnectors (mostly OHL) while it amounts to 310 km for offshore cables.

## Integration of RES

According to Appendix I and Table 5.6, only five projects, with a total length of 1,611km, cite integration of renewables as a project driver. However, it should be noted that integration of RES may implicitly be the driver behind many of the other connections, for example a reported increase in transfer capacities could be due to an increase in generation capacity in a country developing large amounts of renewable sources.

### *The Trade Wind study*

A recent study carried out under the umbrella of Trade Wind[11] provides additional suggestions of future interconnectors in Europe, driven by the requirements of large-scale development and deployment of wind generation technologies. This study is based on forecasts of demand that are comparable to the baseline projections produced by the PRIMES model. It suggests that more than 20 projects will include expansion of international transmission capacities to incorporate more wind power. It is not always possible to consolidate the projects mentioned in the study with those listed in Appendix I but, working on the basis of the report in addition to our mains sources, the number of projects driven by integration of RES increases to 17 and the total length of the projects to 3,038 km.

A summary of outputs from the Trade Wind study is provided in Appendix III.

### *Other renewable sources*

We have not found any documents that explicitly discuss the international infrastructure requirements for integrating non-wind renewable sources. However, the *Ten year network development plan 2010-2020* published by ENTSO-E[12] provides details of other projects involving the integration of renewables other than wind energy.

For example, a project between Norway and Finland aims to connect both wind and small scale hydro power systems to the energy grid to enhance security of supply. Other projects between Norway and the UK, Norway and the Netherlands, and Denmark and Norway are all expected to create connections between hydro and thermal power stations.

In the longer term, up to 2050, the possibility of connections to north Africa should also be considered, although these projects are at too early a stage to be included in our list of possibilities.

### *Conclusions*

Our results show quite a large range for the share of capacity increase that is driven by the development of renewables. Our initial estimate from the main sources used is likely to understate the true extent due to projects having more than one driver, or not explicitly acknowledging the role of RES. On the other hand, the Trade Wind study may provide an overestimate, and it is also not always easy to consolidate the findings from this study with our main sources.

Apart from wind generation, the infrastructure requirements, at least in terms of international connections, is expected to be limited in the short term, with only some connections related to hydro-electric generation quoted in our main sources. In the

---

[11] Source: TradeWind; Integrating Wind, Developing Europe's power market for the large scale integration of wind power, February 2009.

[12] ENTSO-E; Ten-Year Network Development Plan, 2010-20, March 2010.

longer term, however, there is a possibility that imports of electricity generated from solar plants will require large-scale infrastructure developments.

In Table 5.7 we combine the outputs from the Trade Wind study with those from the ENTSO-E report to give a maximum number and length of projects. However, this mainly serves to enforce the view that there is a wide range of estimates available.

**TABLE 5.7: CONTRIBUTION OF RENEWABLE INTEGRATORS**

| Sources | Number of projects | Total length (km) |
|---|---|---|
| Main sources | 5 | 1,611 |
| All sources | 36 | 7,571 |

Source(s): The main sources are UCTE, NORDEL and BALTSO. Other sources are Trade Wind and ENTSO-E.
Note(s): In some cases lengths of projects were estimated.

## Creation of a super grid?

Given the analysis above,it is difficult to envisage that the listed projectsabove and in Appendix I can be considered to be part of the super-grid concept: this is for two main reasons:

- Distances are usually too short to allow one of the targeted effects of super grids, related to the possibility to transfer the variable output of new RES, namely wind energy in the northern countries, over long distances.
- The technology used is still the synchronous HV lines in the range of 220-400 kV which remains more dissipative than higher-voltage (say 700 KV) asynchronous lines[13].

The conclusion is that further measures are required at the European level in order to advance the possibility of the development of a European super grid[14].

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[13] Offshore DC lines are not considered here, as they are very expensive technologies, more dissipative, and restricted to targeted purposes.

[14] In current usage, "super grid" has two definitions: the first of being a superstructure layer overlaid or super-imposed upon the existing regional transmission grid or grids, and the second of having some set of superior abilities exceeding those of even the most advanced existing grids. The concept of a super grid dates back to the 1960's and was used to describe the emerging unification of the Great Britain grid. While such grids cover great distances, due to congestion and control issues, the capacity to transmit large volumes of electricity remains limited. The SuperSmart Grid (Europe) and the Unified Smart Grid (US) specify major technological upgrades that proponents claim are necessary to assure the practical operation and promised benefits of such transcontinental mega grids (*source: Wikipedia*).
In practice, supergrids in fact deal with very high voltage transmission lines (> 400 kV). The very high voltage aims at limiting transmission losses over long distances, it is also considered with the use of alternative technologies: asynchronous – DC – instead of synchronous – AC – connections. The rationality of these investments is mainly supported by the ongoing development of RES. Using asynchronous lines facilitates the interconnection with HV offshore cables.
However, the approach is still rather speculative as it would imply very high investments to be compared to the potential benefits. It is worth mentioning that the transportation of power over long distance is very expensive and is accompanied by substantial energy losses. These extra costs must be added to the additional costs of the RES.
The concept of supergrids also exists in the gas sector where it targets the possible development of hydrogen pipes.

## 5.4 Link with TEN-E projects

The list of TEN-E projects eligible for EC grants is presented in Appendix IV.

From this input, it turns out that:

- There is a *global convergence* between the interconnection projects to be developed by the Transmission Operators. This convergence addresses both onshore and offshore interconnectors under consideration. This is the case, for instance, for the following projects:
  - Moulaine (FR) — Aubange (BE) line; Udine Ovest (IT) — Okroglo (SI) line; Neuenhagen (DE) — Vierraden (DE) — Krajnik (PL) line
  - new interconnection between Germany and Poland; undersea cable to link England (UK) and the Netherlands
  - undersea cable to link Ireland and Wales (UK)
- The scope of *new projects* usually goes beyond the investments identified under the TEN-E umbrella e.g. Halle/Saale (DE) — Schweinfurt (DE); Hamburg/Krümmel (DE) — Schwerin (DE) line; Kassø (DK) — Revsing (DK) — Tjele (DK) line; Vester Hassing (DK) — Trige (DK) line
- Eventually, possible mismatches are likely to occur as priority concerns of EU TSOs address internal links as well as links with close neighbours, while TEN-E encompasses broader projects such as those increasing electricity interconnection capacities between Mediterranean Member States and Morocco — Algeria — Tunisia — Libya — Egypt — and near eastern countries — Turkey.

## 5.5 Integration of PRIMES projections

**Methodology**

In this section we use the outputs from the PRIMES macroeconomic model and compare these against current supply capacities. The figures used are from the 2010 reference case. One of the outputs from the model addresses the energy balances of each member state which provides our measure of demand. Cross-border flows, where supply meets demand, are then integrated in an input-output matrix.

The time horizon corresponds to the terms of reference of the present study: 2020 and 2030, respectively. In order to consider the NTC requirements in 2020 and 2030, the available data have been processed including the following:

1 Interconnections cover both intra-EU flows and exchanges with foreign countries such as Norway, Switzerland and other non-EU Central European countries. However, for the purpose of the final presentation, external exchanges have been condensed in one item: Total Other.

2 The basis of the calculation is 2010: data available for 2008 are inflated[15].

3 NTC are driven from UCTE and related statistical sources (NORDEL, BALTSO), annual reports 2008.

4 Cross-border flows are based on the ENTSOE statistical yearbook 2008.

5 Flow values in 2020 and 2030 are first estimated on the basis of average flows, and then readjusted for taking account in a second sub-step of the variance originated by peak flows.

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[15] Average rate 1.1% pa.

6 Flow data are then extrapolated on the basis of net power import and adjusted for peak flows, driven from PRIMES outputs (2020 and 2030).

7 In both 2020 and 2030, the overall grid architecture is provided by the existing infrastructure (2010).

The proposed approach is subject to several limitations among which the most important include, in turn:

- the fact that no reference is done vis-à-vis the load flow which would characterize the utilization of the grid during the peak time
- the utilization of transmission infrastructure is also directly impacted by dispatching centres operating at national level with peak-shaving objectives

Intermediate results corresponding to the various stages of the calculation process are presented in Appendix VI.

Based on the methodology outlined above, the outcome of the computation process is summarized in Tables 9.8 and 9.9. Excess capacity is defined as that which is above current existing capabilities and so requires new infrastructure to be built.

### Cross-border excess flows in 2020

Based on the inputs used, the EU27 grid would be characterized by a total increase of 4,812 MW corresponding to the peak load in 2020.

Computing the needs for new exchanges on the basis of the projections of energy balances in each country in 2020, the breakdown of excess capacities vis-à-vis the present situation would be as shown in Table 5.8.

Italy appears to be the most constrained country with NTC increases on all of its main borders.

**TABLE 5.8: EXCESS OF TRANSMISSION CAPACITIES TO BE COVERED BY 2020 (MW)**

| Country | Bulgaria | Greece | Italy | Lux'brg | Portugal | Slovakia | Slovenia | UK | Total |
|---|---|---|---|---|---|---|---|---|---|
| Austria | | | 45 | | | | | | 45 |
| Belgium | | | | 231 | | | | | 231 |
| Bulgaria | | 565 | | | | | | | 565 |
| Czech Rep | | | | | | 390 | | | 390 |
| France | | | 230 | | | | | 265 | 496 |
| Germany | | | | 807 | | | | | 807 |
| Poland | | | | | | 31 | | | 31 |
| Romania | 996 | | | | | | | | 996 |
| Slovenia | | | 22 | | | | | | 22 |
| Spain | | | | | 155 | | | | 155 |
| Other | | | | | | | 779 | | 1,074 |
| Total | 996 | 565 | 592 | 1,038 | 155 | 421 | 779 | 265 | 4,812 |

Source(s): European Commission, author's calculations.

### Cross-border excess flows in 2030

Table 5.9 represents the same output, additional transfer capacity required compared to the current situation, in 2030 in the form of an input-output matrix.

The basis of the comparisons in Tables 9.8 and 9.9 is not incremental but compared to the current situation (2010). Taking into account the expected growth of energy balances driven from the PRIMES model, there would need to be an increase of 8,245 MW for the transfer flows by 2030.

Based on the calculation process, the most loaded interconnections broadly follow the same pattern, with a couple of exceptions. An interconnection is required between Denmark and Sweden by 2030, whereas no extra interconnection, in addition to the requirement by 2020, is required between the UK and France.

These forecasts result directly from the energy balances and assume that the power exchanges are directed on the basis of the present exchange pattern[16].

**TABLE 5.9: EXCESS OF TRANSMISSIONS CAPACITIES TO BE COVERED BY 2030 (MW)**

| Country | Bulgaria | Denmark | Greece | Italy | Lux'brg | Portugal | Slovakia | Slovenia | Total |
|---|---|---|---|---|---|---|---|---|---|
| Austria | | | | 10 | | | | 3 | 13 |
| Belgium | | | | | 219 | | | | 219 |
| Bulgaria | | | 524 | | | | | | 524 |
| Czech Rep | | | | | | | 1,742 | | 1,742 |
| Germany | | | | | 764 | | | | 764 |
| Poland | | | | | | | 547 | | 547 |
| Romania | 1,415 | | | | | | | | 1,415 |
| Spain | | | | | | 308 | | | 308 |
| Sweden | | 94 | | | | | | | 94 |
| Other | | | | | | | | 2,618 | 2,618 |
| Total | 1,415 | 94 | 524 | 10 | 983 | 308 | 2,289 | 2,621 | 8,245 |

Source(s): European Commission, author's calculations.

In practice, various factors will impact, directly or indirectly, and to a variable extent, on the load flow throughout the EU27 grid. Among those factors, we suggest the following as priorities:

- the grid structure in terms of impedance and impact on the load flows
- the development of new interconnections (especially between 2020 and 2030)
- the impact of national dispatching in the field of peak shaving capacities
- the impact of the RES development, especially on the countries located near seashores
- the impact of energy-saving programmes on power demand, especially in the field of DSM

Following our methodology (see Box 5.1), the reported lengths provide an indication on the investments required on the existing grid "all things the same" to transport excess capacities. But the breakdown between countries is purely indicative as it is not supported by a load flow but only calculated on the basis of energy balances.

These are the figures that are used as the basis for the estimates of the investment requirements that are discussed in Section 5.8.

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[16] Situation in 2008, which isthe latest available year of data.

### Box 5.1: How the excess transmission needs are calculated

The excess transmission needs are cross-border flows that are additional to those that that existed in the most recent year of data (2008). We provide estimates for 2020 and for 2030.

The methodology to calculate the excess transmission needs is based on data available from ENTSO-E and the projections from the PRIMES model. We illustrate the calculations with an example.

According to the PRIMES projections, Bulgaria is expected to import 208 ktoe of electricity in 2010 and 653 ktoe in 2020. This is equivalent to 2,419 and 7,594 GWh respectively.

From the ENTSO-E report we know that net transfer capacities into Bulgaria were from Greece (150MW) and from Romania (600MW), but figures are only provided for cross-border flows from Romania (3,095 GWh in 2008).

A figure for 2010 is estimated using an assumed growth rate of 1.1% pa. We get 3,163 GWh of flows from Romania to Bulgaria.

This is converted into an available capacity, using the standard conversion factor of 8.76, so the capacity required for average flows is 368MW. This is revised to get a required capacity for peak flows using the load variance from the ENTSO-E Statistical Yearbook. In the case of Bulgaria, it is relatively high, at 0.76, so the required capacity increases to 646 MW.

The same calculations are carried out for 2020, assuming that between, 2010 and 2020, cross-border flows increase at the same rate as net imports from the PRIMES projections. This gives an estimate of required net transfer capacity of 2,028 MW (to meet peak flows).

The excess transmission needs beyond 2008 capabilities are thus (2,028 – 600) MW, giving 1,428 MW. It should be noted that a small part of this requirement could conceivably be met by the connection to Greece but the assumption is that it remains unused.

It should be noted that the input-output matrix used for this calculation is built on the basis of projected energy balances and patterns in existing flows at the end of 2008. For this reason, proposed results are considered as indicative and may diverge from the results computed from a load-flow model at the EU 27 level.

## 5.6 Emerging corridors

**Background**

The concept of 'Corridors' is widely used in the oil & gas sector where it has been used for years, based around pipelines. In the electricity sector, however, its reference is rather new. The reason is that until the end of the 1980s at least, electricity markets were national.

The NTC of cross-border interconnectors has been rather limited to cover a small part of the generating capacity. The purpose of these links was mostly focused on the security of the system in case of loss of one or more power stations.

However, the logic of long distance transmission is not obvious either. Various studies have been devoted to the comparison of transportation costs with gas pipelines and electric wire lines[17]. They tend to indicate that the electric option is more expensive than the transportation of primary energy over long distances. It could be tentatively the case for gas transportation combined with a gasification process[18].

The recent development of RES, especially wind farms and solar power stations[19], together with the emergence of more competitive technologies in the field of power transmission[20] has stimulated a new enthusiasm for long-distance projects, especially when projects involve partially or globally offshore links.

So far, long transmission projects remain expensive. One of the issues is that the additional transportation fees are not usually charged to the generating cost.

**Grid interoperability**

A recent study[21] analyses the existing situation at EU level as regards the NTC compared to the generation capacities available in the member states. Part of this study is based on the Trade Wind results that were discussed previously. The current situation is depicted in Figure 5.1.

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[17] E.g. Comparing Pipes & Wires: A capital cost analysis of energy transmission via natural gas pipelines and overhead electric wire lines; A Joint Study by the Bonneville Power Administration and the Northwest Gas Association, date not available.

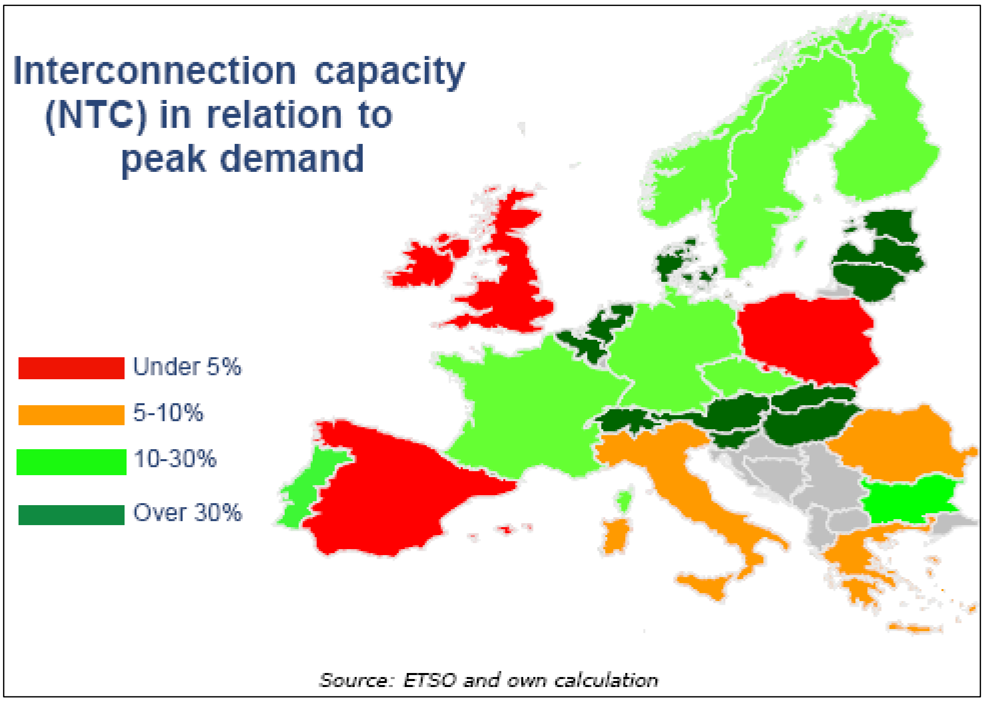
[18] Transport or transmit? Should we transport primary energy resources or transmit them as electricity?; Alexandre Oudalov, Muhamad Reza ; ABB Review 1/2008.

[19] Ex. DESERTEC in the Sahara region.

[20] HV DC, onshore or offshore.

[21] T E N - ENERGY Priority: Corridors for Energy Transmission; Ramboll Oil & Gas & MERCADOS - ENERGY MARKETS INTERNATIONAL S.A.; November 2008.

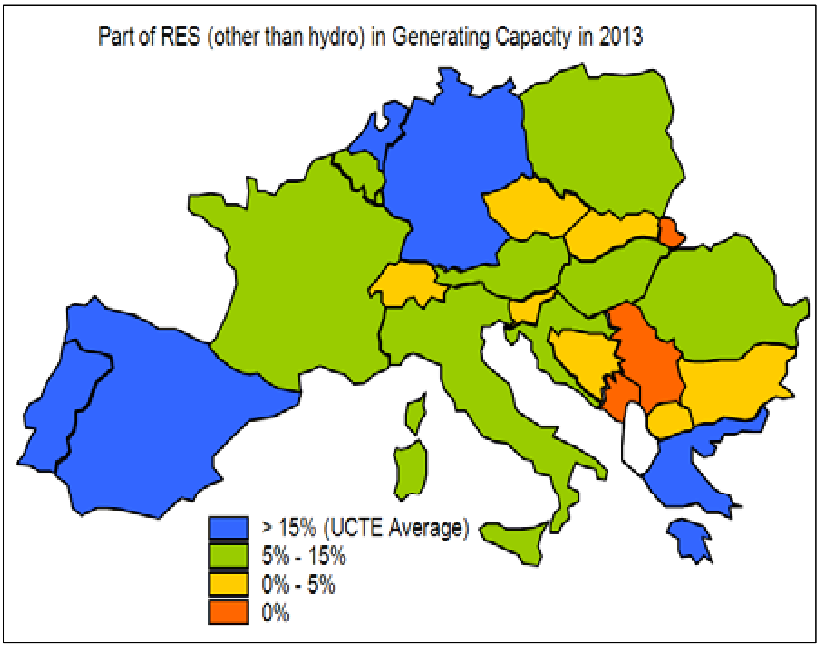
Figure 5.1: Interconnection capacities vs. peak demand



Source: ETSO and own calculation

If a minimum of 10% of NTC vis-à-vis the generation capacity is required to secure the functioning of the power system at national level, the majority of the EU countries are in a rather comfortable situation as their NTC exceeds this threshold or is even above 30%.

Figure 5.2: Impact of RES in generation capacities by 2013



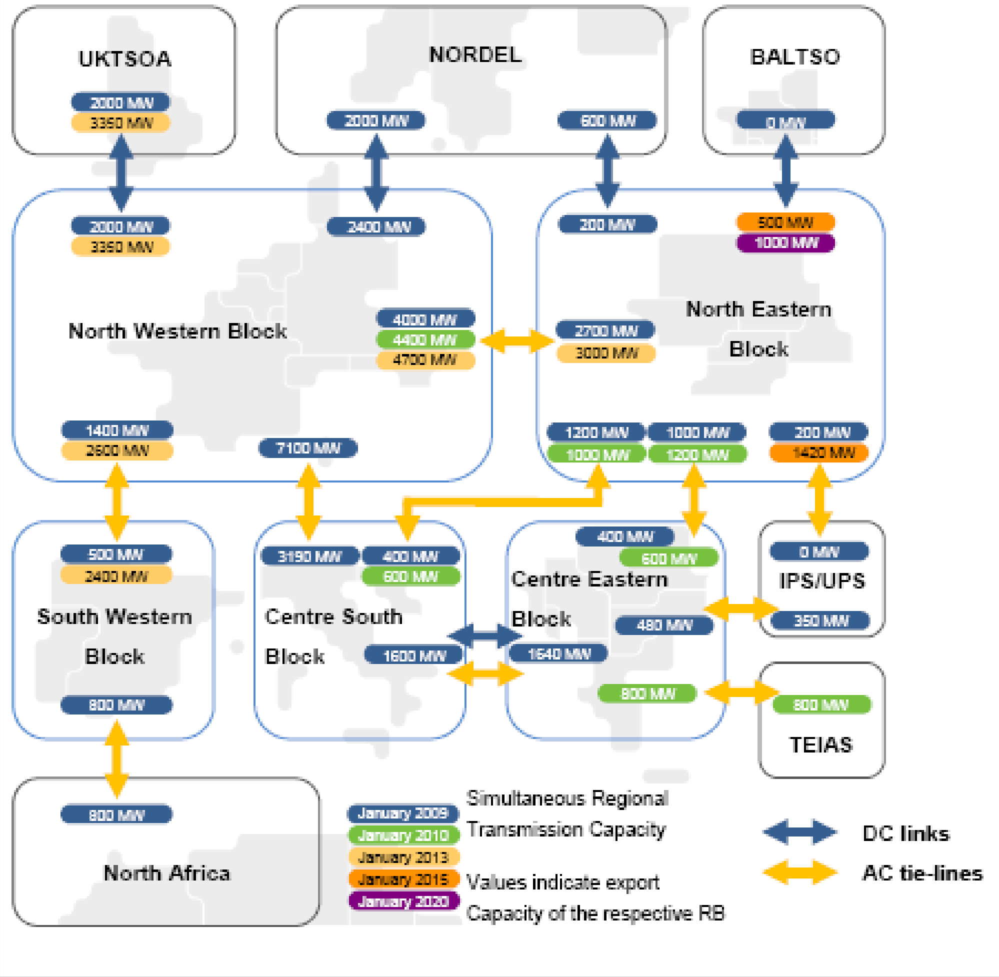
The most delicate situations are faced by Italy, Greece and Romania. Spain, the UK, Ireland, and Poland are in an even worse case as the ratio drops below 5%. However, even for the countries benefiting from strong exchange capacities, this does not mean that no congestion can be observed on one or several borders.

Another approach is to assess the share of RES (other than hydro) in national generating capacities. A recent study carried out by UCTE[22] indicates the following results in the medium term (January 2013).

Still from the same source[23], Figure 5.2 sums up the evolution of Simultaneous Regional Transmission Capacity in 2009 and its forecasted evolution in the next five years based on identified projects.

Beyond this five-year period, too much uncertainty prevents us from assessing any relevant SITC evolution. Uncertainties characterize both generating cross-border capacity development and consumption patterns.

Figure 5.3: Transmission capacities between blocks



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[22] UCTE System Adequacy Forecast 2009-2020; Union for the co-ordination of transmission of electricity, UCTE, January 5th 2009 (scenario B).

[23] UCTE, see above.

In terms of power exchange capacity, emerging corridors would be, in turn:

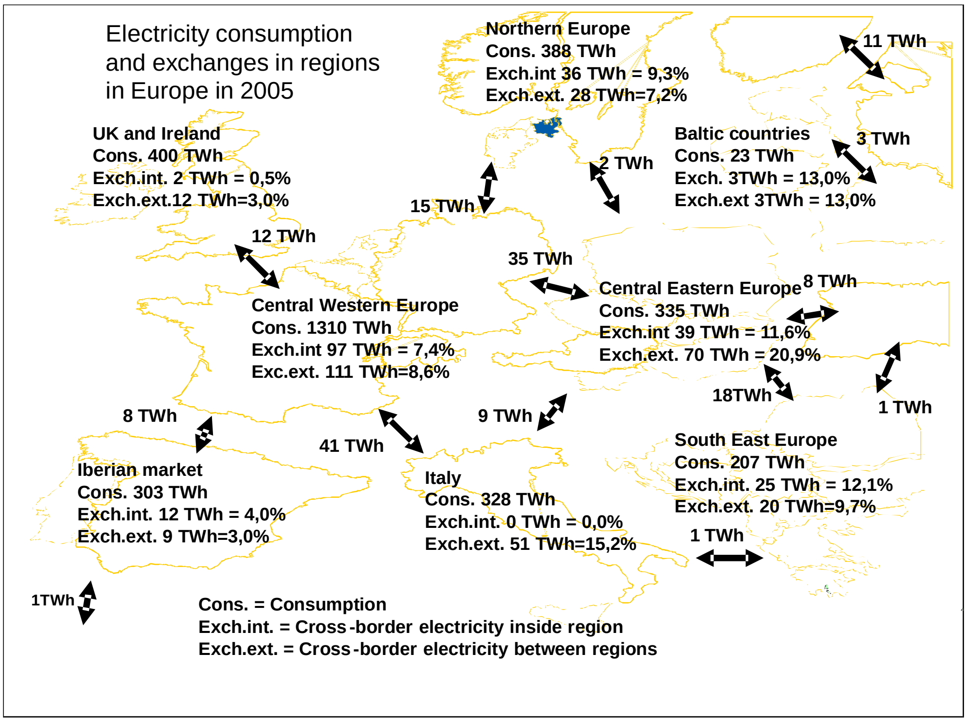
- Centre South Block- North Western Block (7100/3190 MW)
- North Western Block – North Eastern Block (4700/3000 MW)
- North Western Block – South Western Block (2600/2400 MW)
- North Western Block – NORDEL (2000/2400 MW).

This is shown in Figure 5.3. France, Germany, Denmark, Austria and Italy play a major role in this architecture.

**Market organization**

An alternative approach starts form the architecture of energy markets and related energy exchanges. Figures issues by the EC outline the situation in 2005[24]; this is shown in Figure 5.4.

Figure 5.4: Power consumption and exchanges between EU regions (2005)



In the described situation, the existing corridors are[25]:

- France-Italy (41 TWh)
- Czech Republic–Germany (35 TWh)
- Romania-Hungary (18 TWh)
- Spain-Morocco (17 TWh)
- Germany-Denmark (15 TWh)
- France-United Kingdom (12 TWh)

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[24] EU Energy Networks Policy, Trans-European Networks Energy; Casablanca, 21st March 2008.

[25] Divergence can be observed between existing studies in this respect. Part of this divergence is explained by the methodology and, especially, by the study objectives. The situation is different in this respect if we consider exercises in projecting energy flows on the one hand (see input-output projections based on the outputs from the PRIMES model developed in this report), and commercial objectives focused on the creation of an integrated market on the other hand. Other specific sources of divergence could be found in the project scope (such as the EWEA Wind Energy targets 2020/2030).

Important interconnections address also the following links:

- Baltic countries-Northen Europe (11 TWh)
- Italy-Central Eastern Europe (9 TWh)
- Iberian market-Central Western Europe (8 TWh).

## 5.7 Comments

Several remarks can be formulated about the identification of transmission corridors and, more broadly speaking, new interconnectors.

1 The electric grid is a system. As long as incremental increasesare introduced in the field of either generating or transmission capacities, load flows will be reallocated throughout the entire grid. This can be accompanied with a subsequent reallocation of peak flows on congested borders which implies the need for further investment should be reassessed on a regular basis.

2 Some of the identified new transmission routes can tentatively result from the bad functioning of a specific market. For instance, this is the case for the interconnector Algeria – Spain. In present circumstances, there is no need to export power from Algeria to Spain but to Morocco. The latter country is covering more than 15 % of its power needs from Spain through the AC line under the Strait of Gibraltar. The answer to the present shortage in Morocco is found in the recent achievement of the 400 kV[26] line crossing Maghreb countries.

3 With regard to the projected new asynchronous interconnection Greece – Italy, the project was evaluated after its completion by the EIB. Based on these findings, it appeared that the initial project was designed to export to the Italian market the energy produced by a CCGT plant to be built in Greece. After the period required for building the interconnector and the preliminary years of the utilization time, it appeared that Greece did not yet have the excess capacity required for corresponding exports[27]. The cable was basically used for balancing the two markets in a reverse-flow mode. The construction of a new cable could be re-assessed on the basis of this situation, if not changed in the meantime.

4 Among the observed emerging trends, we can point out the foreseeable development of offshore interconnections. They materialize the philosophy of back-to-back power stations, especially in the case of the introduction of RES on the grid. Attention should be paid in this respect as, if the technology is now largely available, the option remains expensive in the case of long-range power lines, especially when their development is justified by the construction of large wind farms, for which capital expenses already exceed the investment costs related to traditional energy sources.

Items 2 to 3 are only examples and must be considered at EU 27 level. They do not imply that specific questions of this type are only concentrated in specific regions such as the Mediterranean Basin.

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[26] Since the Winter 2009-2010.

[27] Even if this technology is a priori not appropriate for the reverse flow utilization mode.

## 5.8 Investment assessment in the electricity sector

**Estimate of unit costs**

A survey issued in 2002 provides a comprehensive overview of the unit costs incurred for the construction of HV lines[28].

According to this source, using a double circuit 380kV line as an example, compared to the base case cost of 401,000 €/km, the results suggest that the countries can be classified into five cost groupings, as shown in Table 5.10.

TABLE 5.10: COST ESTIMATIONS OF HV OHL BY COUNTRIES

| Group | Country | '000 €/km | Specific cost factors |
|---|---|---|---|
| 1 | Finland<br>Sweden | 200-300 | Flat land (fewer towers)<br>Less populated |
| 1 | Greece<br>Portugal | 200-300 | Low costs (land, labour) |
| 2 | Denmark<br>Norway<br>Spain | 300-400 | Close to base case |
| 3 | Belgium<br>Netherlands<br>Italy | 400-500 | Close to base case<br>Heavily populated |
| 4 | France<br>Germany | 500-600 | Heavily populated<br>High labour costs |
| 5 | UK (England & Wales) | 600-800 | 'n-2' standard applied & more towers/km<br>High right-of-way costs<br>Heavily populated |
| 5 | Austria<br>Switzerland | 600-800 | High environmental issues<br>Topography, high wind pressure limits<br>High labour costs |

Source(s): ICF Consulting Ltd.

These costs exclude the cost of transformers and of other substation equipment. The most significant items are transformers and busbar bays.

Based on the information provided by TSOs, 400kV transformers cost between €2-4m and 400kV bays between €1.5-2.5m.[29]

For 220kV, our base assumes that the construction cost is 67% of the cost of a corresponding 380kV line. Costs of 220kV relative to 380kV vary from 40% in Italy to 83% in Switzerland, depending on the number and size of conductors. 400kV DC cables cost between five and eight times the cost of a single 380 kV line[30].

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[28] Unit Costs of constructing new transmission assets at 380 kV within the European Union, Norway and Switzerland; Prepared for the DG TREN/European Commission; Study Contract NoTREN/CC/03-2002; ICF Consulting Ltd, Final Report - October 2002.

[29] Excluding compensation payments to local authorities and landowners.

[30] The cost excludes converter stations.

In a more recent study[31], the analysis is carried out on the basis of unit costs reported in the latter survey[32] to compute the required investments in new interconnections. Investment costs are in the following range:

- for new AC OH lines: between 220 and 746 €/km/MVA, averaging 465 €/km/MVA
- for DC submarine interconnectors: between 965 and 6,770 €/km/MVA), averaging 2,880 €/km/MVA

These figures remain subject to two opposing factors:

- inflation, on the one hand, which tends to increase the unit costs at least if the prices of raw materials follows recent trends (copperand aluminium)[33]
- learning effects reflecting the impact of both experience and economies of scale

The last studyprovides the following investment costs of DC technology:

- sea/land cable (supply + laying down + protection): €0.77m/km
- MV sea metallic return cable: €0.15m/km[34]
- DC overhead line: €0.35m/km
- converter stations (both ends): €0.16m/MW
- bay cost: €1.5m/bay

However, these figures seem to underestimate the real cost, especially for DC offshore lines. The same technology and interconnection scheme is assumed for DC interconnectors: LCC[35] with MV[36]sea cable return for submarine links. AC OHL is given different values for each country, depending on voltage level, line rating and territory morphology. These unit costs were used in particular for the assessment of the following projects: EstLink2, SwedLit and Ambergate.

*Our assumptions on unit costs*

Clearly there is a wide range of uncertainty over the actual costs of building the new transmission capabilities, but we are required to make a best estimate in order to calculate total costs. Based on the set of inputs listed above, we will assume the following unit costs for the purpose of the investment appraisal:

- HV AC OHL (reference 380 kV): €0.6m/km
- HV DC onshore (reference 400 kV): €2.0m/km

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[31] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighboring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an inventory of the Technical Status of the European Energy-Network for the Year 2003, Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI, Issue Date: October 2005, Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy, IIT (Instituto de Investigación Tecnológica), – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark.

[32] References: “Unit costs of constructing new transmission assets at 380kV within the European Union, Norway and Switzerland”, prepared for the E.C.-DG TREN - Contract NoTREN/CC/03-2002. IFC Consulting Ltd.

[33] Copper prices inflated by 160% in $ terms from Dec 30th 2008 and Jan 12th 2010. During the same period aluminium prices increased by 30% (Source: The Economist, 16/01/10).

[34] In the Multiregional study, when estimating the investment costs different values for the MV return cable have been adopted, in the range between €0.1m/km and €0.2m/km. The value adopted for the estimations presented is the average between the two extremes.

[35] LCC: Line Commutated Converters, technology based on thyristors.

[36] MV: Medium Voltage.

- HV DC offshore (reference 400 kV)[37]: €4.8m/km

### Cost estimates for the proposed developments

In Table 5.3 we outlined the total lengths of the planned projects in km. These lengths are multiplied by the assumed unit costs to give a preliminary estimate of total costs (see Table 5.11).

It should be noted that these figures do not include substations and converters, and do not include indirect costs related to the construction of interconnectors for which no visibility is provided in the available documentation.

**TABLE 5.11: PRELIMINARY ESTIMATION OF INVESTMENT COSTS**

| | ACOHL (€m) | DC onshore (€m) | DC offshore (€m) | Total (€m) |
|---|---|---|---|---|
| 2010 | 109 | | | 109 |
| 2020 | 1,667 | 156 | 17,167 | 18,990 |
| 2030 | 1,160 | 266 | | 1,426 |
| To be determined | 651 | | 8,525 | 9,176 |
| Total | 3,587 | 422 | 25,692 | 29,701 |

Source(s): See Table 3.3, ICF Consulting Ltd, EstLink2, SwedLit, Ambergate, author's calculations.

Attention must be paid to the fact that:

1 Unit costs on which the evaluation process is based remain highly speculative; this is especially the case for offshore interconnectors which represent the largest part of the investment.

2 In the case of AC OHL, the situation is also complicated by the fact that only part of the envisaged project covers the construction of new lines; even if this is mostly the case, possible savings can be generated in the case of upgrading of existing lines.

Taking all these issues into consideration, we suggest that a target of €30-40 bn could be tentatively envisaged taking into consideration contingencies and spin-off investments. A total of 85% of the budget is absorbed by new DC lines, especially offshore projects.

#### *Cost estimates to cover integration of renewables*

In earlier sections of this appendix, we identified a range of proposed developments that are, or may be, driven by the requirement to integrate renewable sources of generation into electricity grids. Using the same assumptions as above we can estimate the costs associated with these projects. We get a range of:

Minimum: €5,877m (5 projects, 1,611 km)

Maximum: €19,096m (36 projects, 7,571 km)

As is discussed in earlier sections, the range of outcomes is due to the fact that the different sources used often in conflict as to which projects are explicitly driven by integration of renewables.

### Cost estimates to cover excess capacity

We now consider the investments required to meet the 'excess' (greater than current) capacity required by 2030. Our starting point is the European connections outlined in Table 5.9 and we use the same assumptions that are used in that table.

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[37] Offshore interconnectors represent the bulk of considered projects. This can be regarded as a minimum.

The first step is to convert the capacities in Table 5.9 to lengths. We do this in Table 5.12, making the following three assumptions:

1. The basis for our analysis is the excess flows which are estimated from the projections from the PRIMES model and existing interconnections.
2. The average distance for each line is 20% of the distance between the capitals of the countries.
3. The maximum power capacity per line is 500 MW[38].

Given these inputs, we suggest that around2,158 km of new lines will need to be built by 2030. This is lower than the planned length of ACOHL suggested earlier.

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[38] This is a conservative assumption.

**TABLE 5.12: LENGTHS OF INTERCONNECTIONS REQUIRED BY 2030, km**

| Country | Bulgaria | Denmark | Greece | Italy | Lux'brg | Portugal | Slovakia | Slovenia | Total |
|---|---|---|---|---|---|---|---|---|---|
| Austria | | | | 277 | | | | 69 | 346 |
| Belgium | | | | | 46 | | | | 46 |
| Bulgaria | | | 317 | | | | | | 317 |
| Czech Rep | | | | | | | 331 | | 331 |
| Germany | | | | | 311 | | | | 311 |
| Poland | | | | | | | 254 | | 254 |
| Romania | 296 | | | | | | | | 296 |
| Spain | | | | | | 126 | | | 126 |
| Sweden | | 131 | | | | | | | 131 |
| Other | | | | | | | | - | - |
| Total | 296 | 131 | 317 | 277 | 357 | 126 | 585 | 69 | 2,158 |

Source(s): See Table 3.9, author's calculations.

Based on these lengths, projected investments would be limited to €1.3 bn, including both the price of OHL and externalities. This figure is far below the total investment costs estimated for planned developments but this is due to the fact that it does not include offshore interconnectors which absorb the greatest part of the budget.

In any case, these results remain subject to the various limitations detailed above, especially as regards the breakdown of interconnections. We stress that the total investment for cross-border lines is much lower than the replacement and the upgrading of national grids that will be implemented during the next two decades.[39]

### Investments by member state

Table 5.13 presents our suggestions of the regional disaggregation for the investments. We provide results based on planned projects, and the requirements to meet excess demands in 2030.

Our mid-central values make the assumption that half of the investment for each interconnector is made in each country. We are aware that there are cases where this is not realistic (for example it is likely that most of the connection between Germany and Luxembourg will lie in Germany), so we also provide maximum values based on the entire cost of the development being borne by a single country (so is double the central value). Our final estimate takes the central value and adds on a fixed factor to take into account the additional costs for substations and converters and related investments.

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[39] In 20 years between one third and half of the existing HV lines will be replaced.

**TABLE 5.13: INVESTMENT COSTS BY COUNTRY, €m**

| | Planned Projects | | | To meet excess demands | | |
|---|---|---|---|---|---|---|
| | **Mid** | **Max** | **Final** | **Mid** | **Max** | **Final** |
| Austria | 321 | 642 | 395 | 68 | 136 | 84 |
| Belgium | 662 | 1,323 | 814 | 14 | 28 | 17 |
| Bulgaria | 39 | 78 | 48 | 159 | 318 | 196 |
| Cyprus | 0 | 0 | 0 | 0 | 0 | 0 |
| Czech Rep. | 52 | 104 | 64 | 683 | 1,366 | 840 |
| Denmark | 1,338 | 2,726 | 1,646 | 131 | 262 | 161 |
| Estonia | 1,020 | 2,039 | 1,254 | 0 | 0 | 0 |
| Finland | 664 | 1,327 | 816 | 0 | 0 | 0 |
| France | 380 | 760 | 468 | 363 | 726 | 446 |
| Germany | 3,981 | 8,012 | 4,897 | 587 | 1,174 | 722 |
| Greece | 759 | 1,518 | 934 | 48 | 96 | 59 |
| Hungary | 56 | 112 | 69 | 0 | 0 | 0 |
| Ireland | 0 | 0 | 0 | 0 | 0 | 0 |
| Italy | 3,444 | 6,887 | 4,236 | 287 | 574 | 353 |
| Latvia | 876 | 1,751 | 1,077 | 0 | 0 | 0 |
| Lithuania | 541 | 1,082 | 666 | 0 | 0 | 0 |
| Luxembourg | 16 | 32 | 20 | 154 | 308 | 189 |
| Malta | 300 | 600 | 369 | 0 | 0 | 0 |
| Netherlands | 3,053 | 6,107 | 3,756 | 0 | 0 | 0 |
| Poland | 413 | 826 | 508 | 420 | 840 | 517 |
| Portugal | 188 | 377 | 232 | 0 | 0 | 0 |
| Romania | 998 | 1,997 | 1,228 | 111 | 222 | 137 |
| Slovakia | 134 | 268 | 165 | 976 | 1,952 | 1,200 |
| Slovenia | 71 | 142 | 87 | 46 | 92 | 57 |
| Spain | 256 | 513 | 315 | 0 | 0 | 0 |
| Sweden | 1,125 | 2,300 | 1,384 | 0 | 0 | 0 |
| UK | 1,200 | 2,400 | 1,476 | 0 | 0 | 0 |
| Non-EU | 7,814 | - | 9,611 | - | - | - |
| Total | 29,701 | - | 36,532 | 4,047 | - | 4,978 |

Source(s): Author’s calculations.

## 5.9 Impact on transmission fees

**Assumptions used**

The achievement of a fully open market means that two activities are subject to competition: production and commercial activities. In the case of transmission, especially at HV level, the activities are still regulated.

The economic logic is to charge a transmission fee for the transport capacity of the grid which must be designed, built and maintained to absorb the maximum power flow at peak load[40]. In the case of additional transmission capacities, the impact on tariffs

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[40] “Maximum coinciding power”.

will depend on the increase of depreciation costs, financial costs and O&M costs. All these items are fixed costs.

Losses amount to an average of 5% on HV grid. This amount should be added to the fixed costs. However, in normal circumstances, it is much lower than other fixed costs and remains limited as long as interconnectors, even sub-sea links, cover a very small proportion of the total grid length which is not normally used at full load.

The basic assumptions are described below:

- depreciation scheme: 40 years[41]
- cost of capital: 7% (pa; nominal)
- O&M: 4,- % (pa)
- power generation capacity in 2020: 900 GW (EU27)
- power generation capacity in 2030: 950 GW (EU27)
- power generation (2030): 4.400 TWh

**Impacts on fees** Using these assumptions and the two sets of investment costs derived earlier in this chapter, our estimates of the impacts on transmission fees are outlined in Table 5.14. We have used rough estimates for the investment costs (€35 bn and €5 bn) to reflect the accuracy of the assumptions.

**TABLE 5.14: PRELIMINARY ESTIMATIONS OF COST IMPACTS (UP TO 2030)**

| Costs breakdown | Unit | Proposed Developments (on & offshore | To meet excess demands in 2030 |
|---|---|---|---|
| Incremental investment | €m | 35,000 | 5,000 |
| Power generation 2030 | MW | 950,000 | 950,000 |
| Power production | MWh | 4,400 | 4,400 |
| Depreciation | €m/y | 875 | 125 |
| Cost of capital | €m/y | 2,450 | 350 |
| O&M costs | €m/y | 1,400 | 200 |
| Total | €m/y | 4,725 | 675 |
| Impact on fixed tariffs | €/MW/y | 4,974 | 710 |
|  | €/kWh | 1.07 | 0.15 |

Source(s): Author's calculations.

The impact on price inflation will vary depending on the global evolution of prices but also on the pace of the investment process. This would require a detailed analysis based on the investment cash flows (Table 5.14 considers the period up to 2030).

Beyond the scope of the utilization of national grids, cross-border flows can be subject to an auctioning process in case of limited transfer capacity. The marginal costs incurred by the market operators for the utilization of these transfer capacities depend on the supply and demand. These extra costs can be high in the case of severe NTC limitations.Additional interconnections would reduce these costs, and possibly counterbalance the negative cost impact calculated above.

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[41] This value exceeds the fiscal amortization but remains well below the reference reported by some sources: 50 years.

The underlying hypothesis is that the implementation of the anticipated investments will gradually decrease the possible impact of these extra costs which can be considered as realistic in 2030.

Another aspect is the relative size of the projects planned up to 2030. We must keep in mind in this respect that the total UCTE grid amounts to 110,000 km of HV lines. Limited to the sole UCTE, the total investment would average 10% of the network length. It will be lower in practice for the EU27.

This figure is likely to be increased on monetary terms as the extensions under review comprise a rather high amount of offshore lines, which are much more expensive. In addition, offshore investments are likely to impact more significantly on maritime countries than the inter-land countries. Compensation mechanisms could therefore be required.

## 5.10 Conclusions

**Results from the literature review**

Various aspects related to the identification of new development projects of cross-border HV lines have been covered by recent studies. However, the approach is fragmented. The studies usually cover part of the EU27 and its Member States while their scope varies in terms of time horizon or modeling emphasis.

Furthermore, these studies are not as recent as the most recent PRIMES projections, which are able to take into account the most recent developments, for example regarding thefinancial and economic crisis.

The review combines two complementary approaches:

- on the one hand, the review of the main output of the most recent developments in the field of grid expansion in the medium and long terms
- on the other hand, an alternative approach based on the assessment of the length of new interconnection facilities that could tentatively be envisaged by 2030

The latter is based on the existing grid architecture and the output of therecent projections based on the PRIMES model[42].

Although the approach was limited by various data inconsistencies, the analysis highlights the following findings:

- There is a certain convergence between the interconnection projects to be developed by the Transmission Operators.
- The scope of new projects usually goes beyond the investments identified under the TEN-E umbrella.
- Eventually, possible mismatches are likely to occur as priority concerns of EU TSOs address internal links as well as links with close neighbors, while TEN-E encompasses broader projects.

The baseline projections from the PRIMES model suggest a total increase of 8,245 MW of transfer flow capacity in the EU27 by 2030.

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[42] *Energy and Transport; Trends to 2030*, European Commission, Directorate General for Energy and Transport.

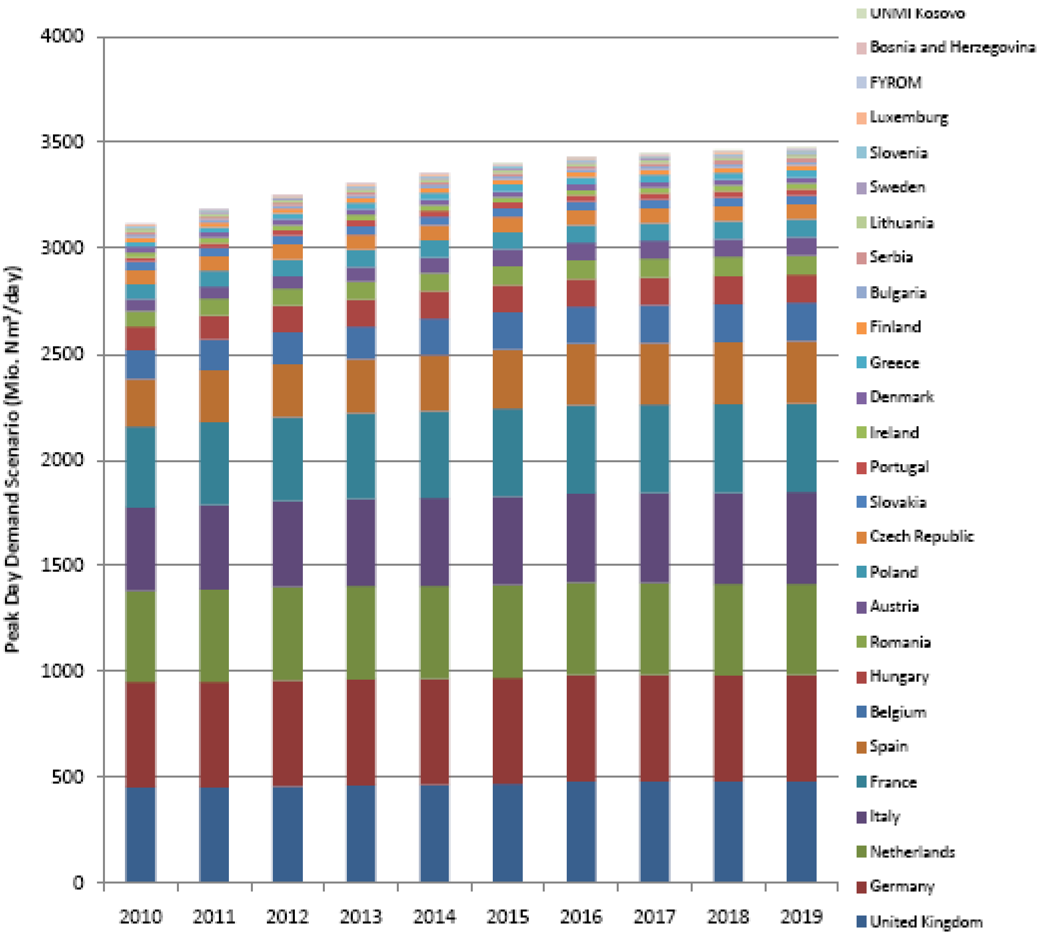
# 6 Appendix VI: Data & Calculations for Appendix V

This is included as a separate spreadsheet file.

# 7 Appendix VII: Background Data to Chapter 4

## 7.1 Long Term DemandForecasts

Figure 7.1.1: ENTSOG Peak Day Demand Scenario[43]



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[43] European Ten Year Network Development Plan; 2010 – 2019,December 2009 (Ref. 09ENTSOG).

Figure 7.1.2: EU-27 Gas Demand Forecasts[44]

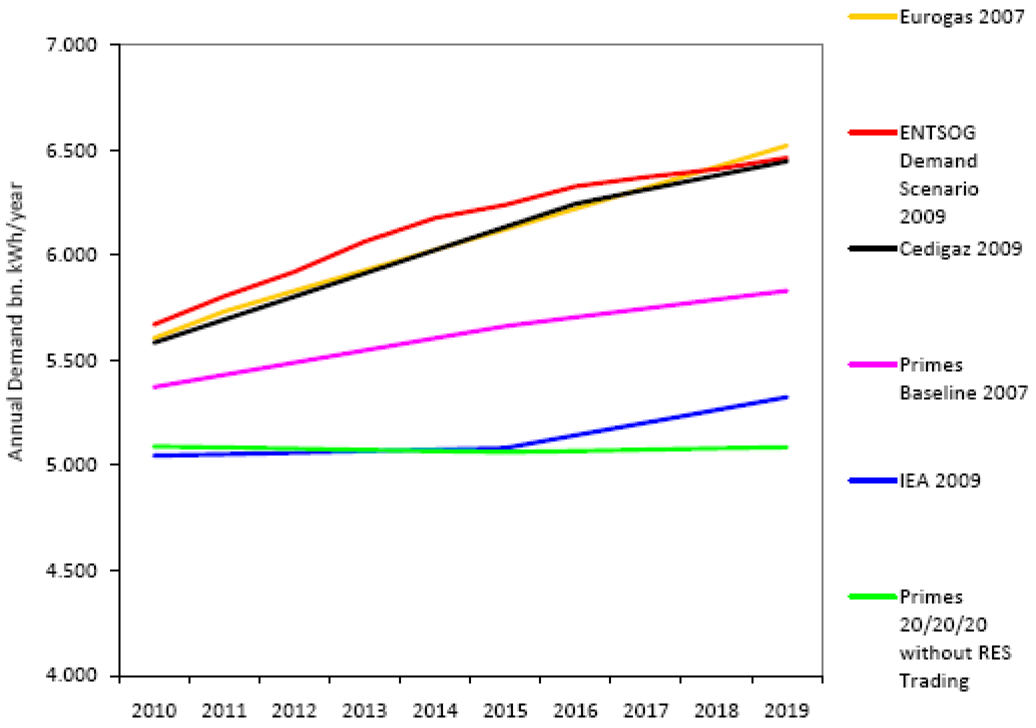
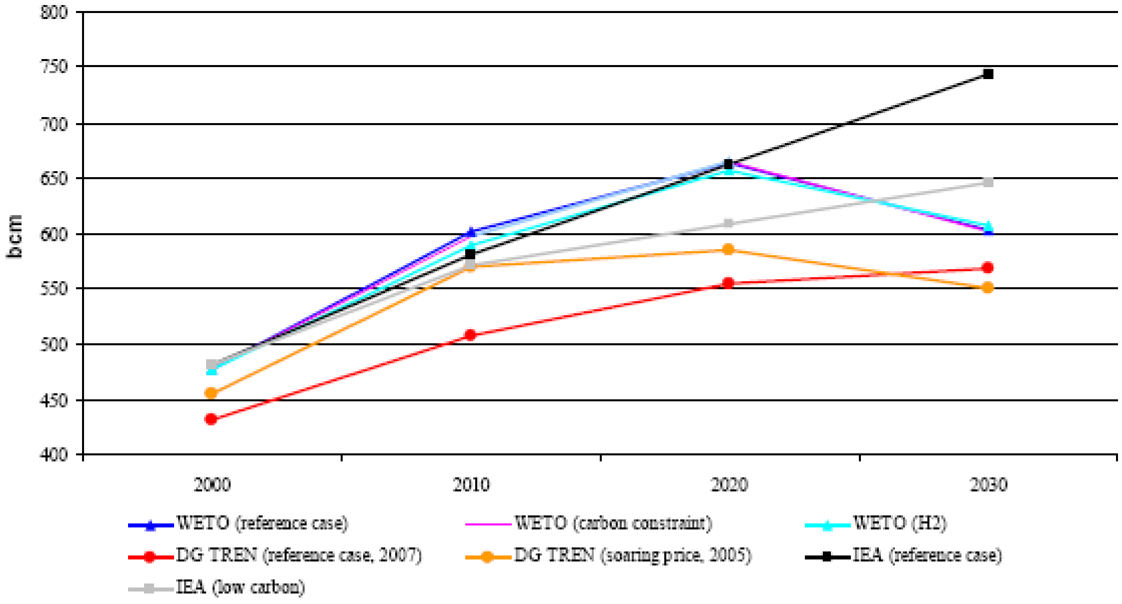


Figure 7.1.3: Long term natural gas demand projection for the EU[45,46]



[46] EU-27 natural gas demand in 2006 accounted for 545 bcm. There is a high uncertainty about future demand development. Figure 1 compares different forecasts based on varying scenarios, including the updated "European Energy and Transport Trends to 2030" baseline scenario published by the European Commission in 2007. In the mid-term, until 2020, these forecasts remain relatively similar expecting a demand level between 550 and 670 bcm. However, things change in the longer-term. For the period up to 2030, the highest scenario (IEA reference case) and the lowest scenario (WETO carbon constraint case) differ by 200 bcm.

Figure 7.1.4: Final Energy Consumption by Fuel 2006 (in Mtoe)[47]

**TABLE 7.1.4: FINAL ENERGY CONSUMPTION BY FUEL 2007 (MToe)**

| Country | All fuels | Solid fuels | Oil | Gas | Electricity | Heat | Renewables & wastes | Bio fuels |
|---|---|---|---|---|---|---|---|---|
| EU27 | 1157.7 | 53.8 | 484.6 | 268.8 | 244.5 | 41.6 | 63.1 | 7. |
| EU25 | 1123.9 | 51.4 | 474.0 | 260.6 | 238.6 | 39.0 | 59.2 | 7. |
| Belgium | 34.9 | 1.9 | 14.5 | 10.1 | 7.1 | 0.4 | 0.8 | 0. |
| Bulgaria | 9.8 | 1.0 | 3.7 | 1.2 | 2.3 | 0.8 | 0.7 | 0. |
| Czech republic | 25.8 | 3.4 | 7.2 | 6.4 | 4.9 | 2.1 | 1.6 | 0. |
| Denmark | 15.7 | 0.3 | 7.4 | 1.7 | 2.9 | 2.3 | 1.2 | 0. |
| Germany | 210.3 | 9.6 | 78.4 | 59.4 | 45.6 | 6.3 | 10.9 | 4. |
| Estonia | 3.0 | 0.1 | 1.0 | 0.2 | 0.6 | 0.5 | 0.5 | 0. |
| Ireland | 13.2 | 0.6 | 8.6 | 1.6 | 2.2 |  | 0.2 | 0. |
| Greece | 22.0 | 0.5 | 14.7 | 0.7 | 4.7 | 0.0 | 1.3 | 0. |
| Spain | 98.7 | 1.8 | 54.1 | 16.2 | 22.4 | 0.0 | 4.2 | 0. |
| France | 154.0 | 5.0 | 70.0 | 31.1 | 36.6 |  | 11.3 | 1. |
| Italy | 132.1 | 3.7 | 57.1 | 39.4 | 26.6 | 3.1 | 2.2 | 0. |
| Cyprus | 1.9 | 0.0 | 1.4 | 0.0 | 0.4 |  | 0.1 | 0. |
| Latvia | 4.4 | 0.1 | 1.6 | 0.5 | 0.6 | 0.6 | 1.0 | 0. |
| Lithuania | 5.0 | 0.2 | 1.9 | 0.6 | 0.8 | 0.9 | 0.6 | 0. |
| Luxembourg | 4.4 | 0.1 | 2.9 | 0.7 | 0.6 | 0.1 | 0.1 | 0. |
| Hungary | 16.9 | 0.6 | 5.2 | 6.3 | 2.9 | 1.2 | 0.8 | 0. |
| Malta | 0.4 | 0.0 | 0.3 | 0.0 | 0.2 |  | 0.0 | 0. |
| Netherlands | 51.3 | 1.5 | 18.6 | 19.0 | 9.2 | 2.4 | 0.8 | 0. |
| Austria | 26.5 | 1.4 | 10.9 | 4.4 | 4.9 | 1.4 | 3.1 | 0. |
| Poland | 61.2 | 11.9 | 19.3 | 8.8 | 9.8 | 6.9 | 4.1 | 0. |
| Portugal | 18.8 | 0.2 | 9.9 | 1.4 | 4.2 | 0.3 | 2.7 | 0. |
| Romania | 24.0 | 1.5 | 6.9 | 7.0 | 3.5 | 1.8 | 3.3 | 0. |
| Slovenia | 4.9 | 0.1 | 2.4 | 0.6 | 1.1 | 0.2 | 0.4 | 0. |
| Slovakia | 10.5 | 1.5 | 2.2 | 3.5 | 2.1 | 0.7 | 0.5 | 0. |
| Finland | 26.6 | 0.9 | 8.1 | 1.3 | 7.4 | 4.3 | 4.5 | 0. |
| Sweden | 33.5 | 1.3 | 10.5 | 0.8 | 11.4 | 4.1 | 5.3 | 0. |
| UK | 147.9 | 4.6 | 65.7 | 46.0 | 29.4 | 1.1 | 1.0 | 0. |
| Croatia | 6.5 | 0.2 | 3.2 | 1.2 | 1.3 | 0.2 | 0.3 | 0. |
| Turkey | 72.8 | 14.5 | 23.5 | 14.4 | 13.1 | 1.0 | 6.3 | 0. |
| Norway | 18.8 | 0.7 | 7.0 | 0.3 | 9.5 | 0.2 | 1.1 | 0. |
| Switzerland | 21.1 | 0.2 | 11.5 | 2.5 | 4.9 | 0.4 | 1.4 | 0. |

Source(s): Eurostat
Note(s): Renewables and wastes includes solar heat, biomass, geothermal, wastes.

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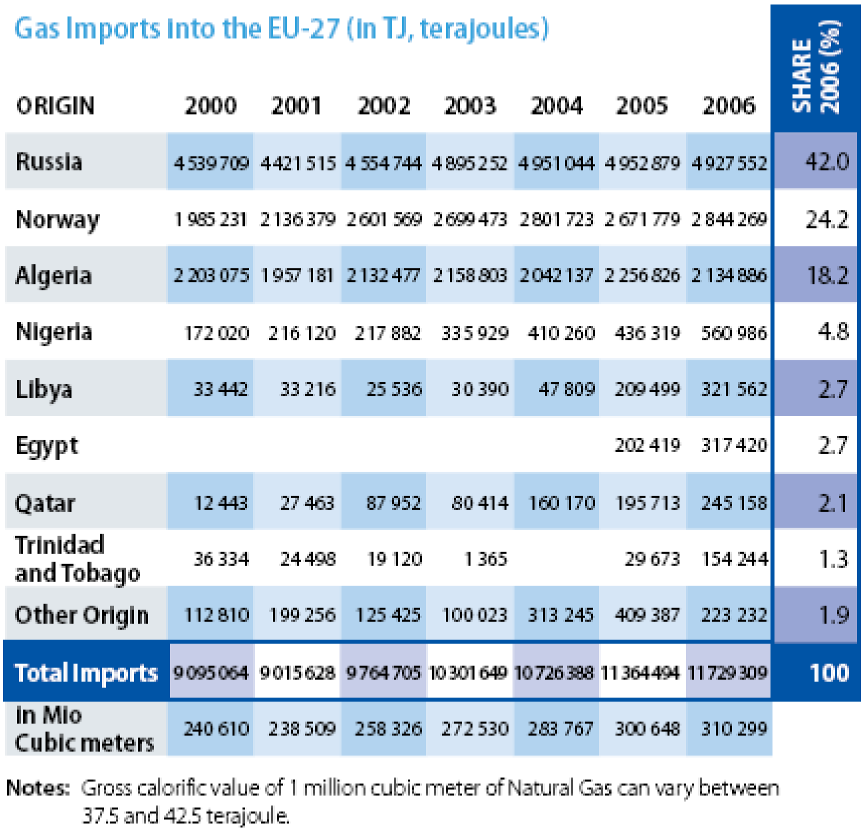
[47] Eurostat, December 2008

## 7.2 Long Term Supply Forecasts

Table 7.2.1: Gas imports into the EU-27 countries (in TJ, terajoules)[48]



Gas Imports into the EU-27 (in TJ, terajoules)

| ORIGIN | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | SHARE 2006 (%) |
|---|---|---|---|---|---|---|---|---|
| **Russia** | 4 539 709 | 4 421 515 | 4 554 744 | 4 895 252 | 4 951 044 | 4 952 879 | 4 927 552 | 42.0 |
| **Norway** | 1 985 231 | 2 136 379 | 2 601 569 | 2 699 473 | 2 801 723 | 2 671 779 | 2 844 269 | 24.2 |
| **Algeria** | 2 203 075 | 1 957 181 | 2 132 477 | 2 158 803 | 2 042 137 | 2 256 826 | 2 134 886 | 18.2 |
| **Nigeria** | 172 020 | 216 120 | 217 882 | 335 929 | 410 260 | 436 319 | 560 986 | 4.8 |
| **Libya** | 33 442 | 33 216 | 25 536 | 30 390 | 47 809 | 209 499 | 321 562 | 2.7 |
| **Egypt** |  |  |  |  |  | 202 419 | 317 420 | 2.7 |
| **Qatar** | 12 443 | 27 463 | 87 952 | 80 414 | 160 170 | 195 713 | 245 158 | 2.1 |
| **Trinidad and Tobago** | 36 334 | 24 498 | 19 120 | 1 365 |  | 29 673 | 154 244 | 1.3 |
| **Other Origin** | 112 810 | 199 256 | 125 425 | 100 023 | 313 245 | 409 387 | 223 232 | 1.9 |
| **Total Imports** | 9 095 064 | 9 015 628 | 9 764 705 | 10 301 649 | 10 726 388 | 11 364 494 | 11 729 309 | **100** |
| **in Mio Cubic meters** | 240 610 | 238 509 | 258 326 | 272 530 | 283 767 | 300 648 | 310 299 |  |

**Notes:** Gross calorific value of 1 million cubic meter of Natural Gas can vary between 37.5 and 42.5 terajoule.

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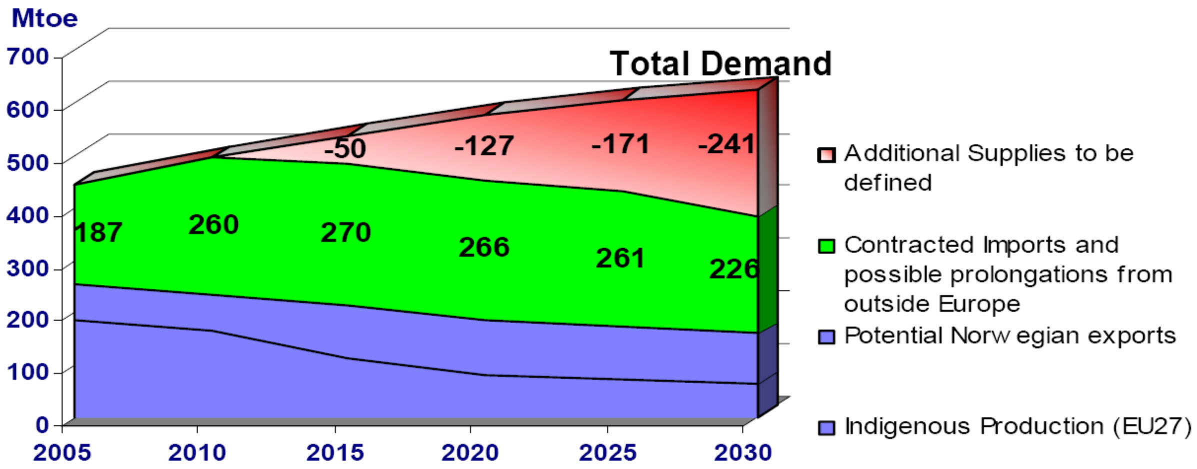
[48] Eurostat, December 2008

Figure 7.2.2: Long term supplies projection for EU-27[49]



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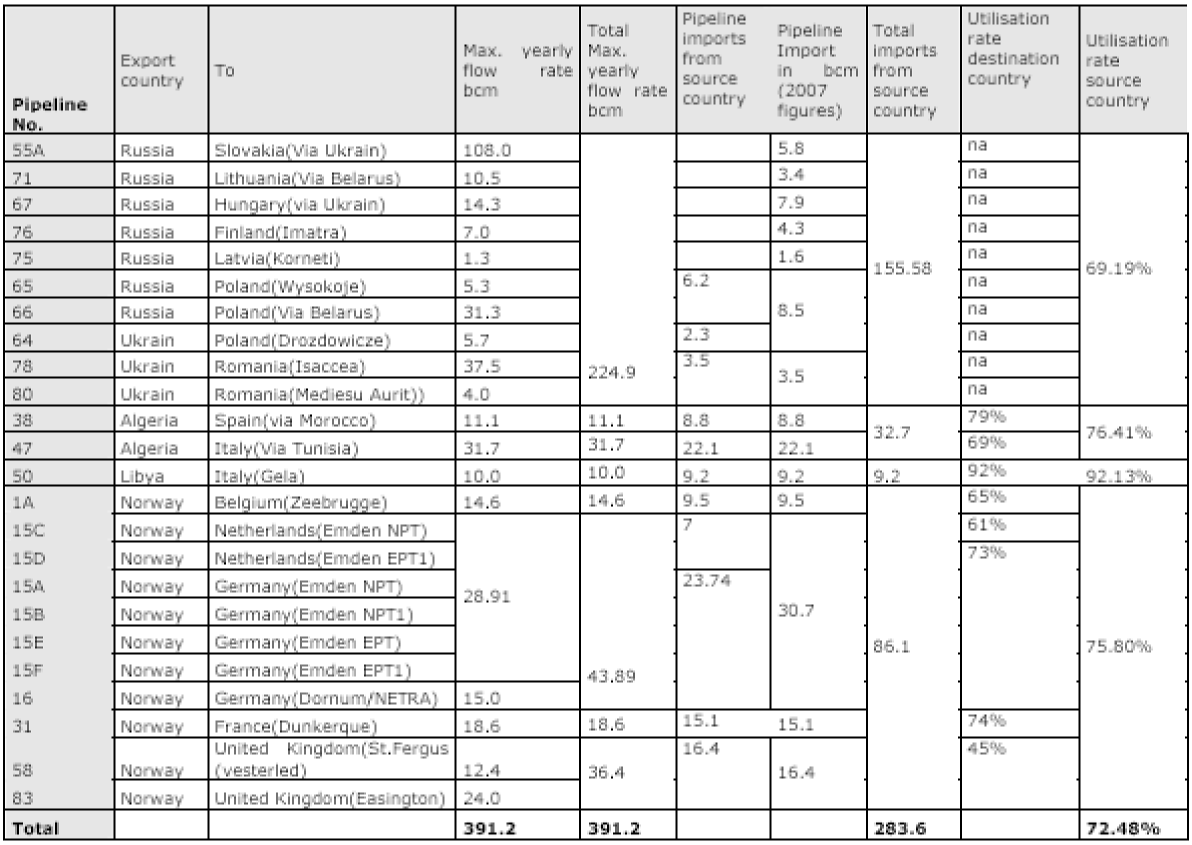
[49] Natural gas Demand & Supply; Long term Outlook to 2030, Eurogas.

## 7.3 Pipeline utilization rates

Table 7.3: Pipeline Utilization rates[50]



| Pipeline No. | Export country | To | Max. yearly flow rate bcm | Total Max. yearly flow rate bcm | Pipeline imports from source country | Pipeline Import in bcm (2007 figures) | Total imports from source country | Utilisation rate destination country | Utilisation rate source country |
|---|---|---|---|---|---|---|---|---|---|
| 55A | Russia | Slovakia(Via Ukrain) | 108.0 | 224.9 | | 5.8 | 155.58 | na | 69.19% |
| 71 | Russia | Lithuania(Via Belarus) | 10.5 | | | 3.4 | | na | |
| 67 | Russia | Hungary(via Ukrain) | 14.3 | | | 7.9 | | na | |
| 76 | Russia | Finland(Imatra) | 7.0 | | | 4.3 | | na | |
| 75 | Russia | Latvia(Korneti) | 1.3 | | | 1.6 | | na | |
| 65 | Russia | Poland(Wysokoje) | 5.3 | | 6.2 | 8.5 | | na | |
| 66 | Russia | Poland(Via Belarus) | 31.3 | | | | | na | |
| 64 | Ukrain | Poland(Drozdowicze) | 5.7 | | 2.3 | | | na | |
| 78 | Ukrain | Romania(Isaccea) | 37.5 | | 3.5 | 3.5 | | na | |
| 80 | Ukrain | Romania(Mediesu Aurit)) | 4.0 | | | | | na | |
| 38 | Algeria | Spain(via Morocco) | 11.1 | 11.1 | 8.8 | 8.8 | 32.7 | 79% | 76.41% |
| 47 | Algeria | Italy(Via Tunisia) | 31.7 | 31.7 | 22.1 | 22.1 | | 69% | |
| 50 | Libya | Italy(Gela) | 10.0 | 10.0 | 9.2 | 9.2 | 9.2 | 92% | 92.13% |
| 1A | Norway | Belgium(Zeebrugge) | 14.6 | 14.6 | 9.5 | 9.5 | 86.1 | 65% | 75.80% |
| 15C | Norway | Netherlands(Emden NPT) | 28.91 | 43.89 | 7 | 30.7 | | 61% | |
| 15D | Norway | Netherlands(Emden EPT1) | | | | | | 73% | |
| 15A | Norway | Germany(Emden NPT) | | | 23.74 | | | | |
| 15B | Norway | Germany(Emden NPT1) | | | | | | | |
| 15E | Norway | Germany(Emden EPT) | | | | | | | |
| 15F | Norway | Germany(Emden EPT1) | | | | | | | |
| 16 | Norway | Germany(Dornum/NETRA) | 15.0 | | | | | | |
| 31 | Norway | France(Dunkerque) | 18.6 | 18.6 | 15.1 | 15.1 | | 74% | |
| 58 | Norway | United Kingdom(St.Fergus (vesterled) | 12.4 | 36.4 | 16.4 | 16.4 | | 45% | |
| 83 | Norway | United Kingdom(Easington) | 24.0 | | | | | | |
| **Total** | | | **391.2** | **391.2** | | | **283.6** | | **72.48%** |

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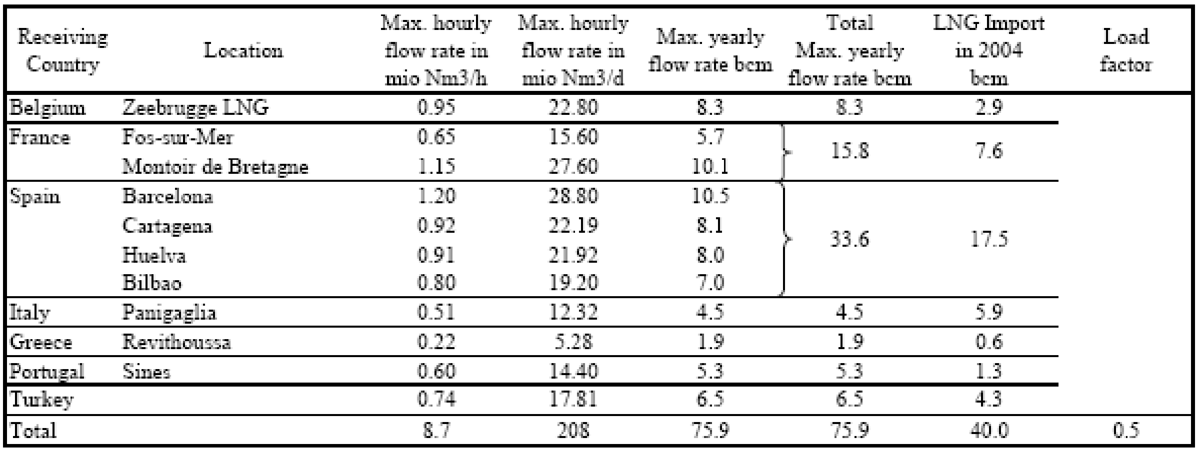
[50] T E N - ENERGY Priority Corridors for Energy Transmission; Part One: Legislation, Natural Gas and Monitoring; prepared by Ramboll A/S and Mercados SA; November 2008

## 7.4 LNG regazification capacities

Table 7.4.1: LNG regasification capacities and gas imports in 2004[51]



| Receiving Country | Location | Max. hourly flow rate in mio Nm3/h | Max. hourly flow rate in mio Nm3/d | Max. yearly flow rate bcm | Total Max. yearly flow rate bcm | LNG Import in 2004 bcm | Load factor |
|---|---|---|---|---|---|---|---|
| Belgium | Zeebrugge LNG | 0.95 | 22.80 | 8.3 | 8.3 | 2.9 | |
| France | Fos-sur-Mer | 0.65 | 15.60 | 5.7 | 15.8 | 7.6 | |
| | Montoir de Bretagne | 1.15 | 27.60 | 10.1 | | | |
| Spain | Barcelona | 1.20 | 28.80 | 10.5 | 33.6 | 17.5 | |
| | Cartagena | 0.92 | 22.19 | 8.1 | | | |
| | Huelva | 0.91 | 21.92 | 8.0 | | | |
| | Bilbao | 0.80 | 19.20 | 7.0 | | | |
| Italy | Panigaglia | 0.51 | 12.32 | 4.5 | 4.5 | 5.9 | |
| Greece | Revithoussa | 0.22 | 5.28 | 1.9 | 1.9 | 0.6 | |
| Portugal | Sines | 0.60 | 14.40 | 5.3 | 5.3 | 1.3 | |
| Turkey | | 0.74 | 17.81 | 6.5 | 6.5 | 4.3 | |
| Total | | 8.7 | 208 | 75.9 | 75.9 | 40.0 | 0.5 |

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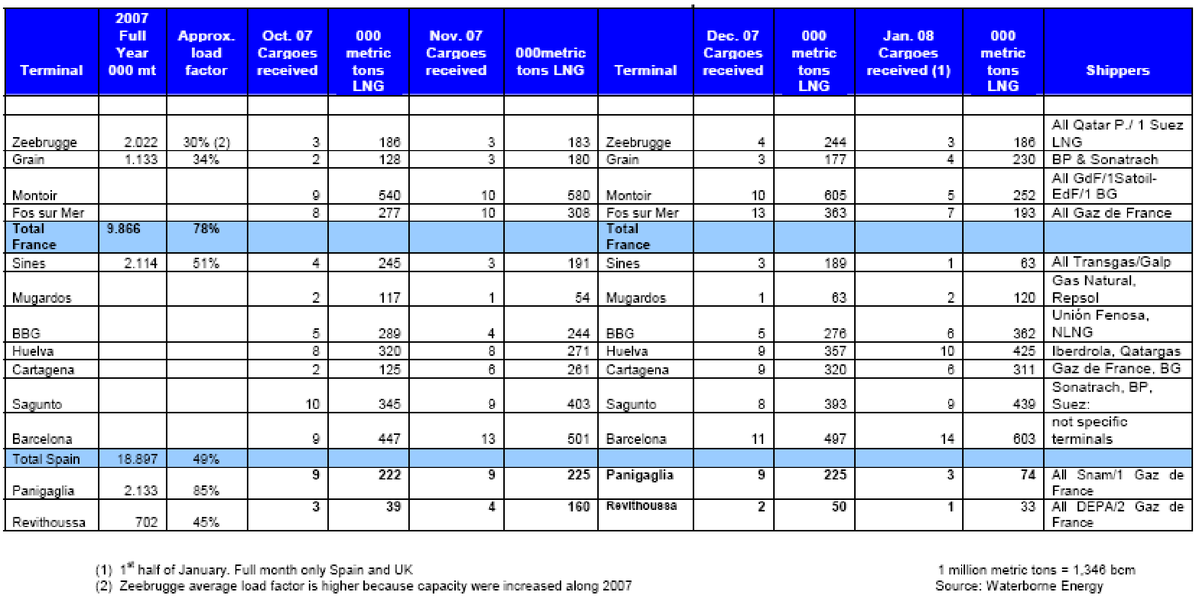
[51] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighboring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy ,IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.



| Terminal | 2007 Full Year 000 mt | Approx. load factor | Oct. 07 Cargoes received | 000 metric tons LNG | Nov. 07 Cargoes received | 000metric tons LNG | Terminal | Dec. 07 Cargoes received | 000 metric tons LNG | Jan. 08 Cargoes received (1) | 000 metric tons LNG | Shippers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| Zeebrugge | 2.022 | 30% (2) | 3 | 186 | 3 | 183 | Zeebrugge | 4 | 244 | 3 | 186 | All Qatar P./ 1 Suez LNG |
| Grain | 1.133 | 34% | 2 | 128 | 3 | 180 | Grain | 3 | 177 | 4 | 230 | BP & Sonatrach |
| Montoir | | | 9 | 540 | 10 | 580 | Montoir | 10 | 605 | 5 | 252 | All GdF/1Satoil-EdF/1 BG |
| Fos sur Mer | | | 8 | 277 | 10 | 308 | Fos sur Mer | 13 | 363 | 7 | 193 | All Gaz de France |
| **Total France** | **9.866** | **78%** | | | | | **Total France** | | | | | |
| Sines | 2.114 | 51% | 4 | 245 | 3 | 191 | Sines | 3 | 189 | 1 | 63 | All Transgas/Galp |
| Mugardos | | | 2 | 117 | 1 | 54 | Mugardos | 1 | 63 | 2 | 120 | Gas Natural, Repsol |
| BBG | | | 5 | 289 | 4 | 244 | BBG | 5 | 276 | 6 | 362 | Unión Fenosa, NLNG |
| Huelva | | | 8 | 320 | 8 | 271 | Huelva | 9 | 357 | 10 | 425 | Iberdrola, Qatargas |
| Cartagena | | | 2 | 125 | 6 | 261 | Cartagena | 9 | 320 | 6 | 311 | Gaz de France, BG |
| Sagunto | | | 10 | 345 | 9 | 403 | Sagunto | 8 | 393 | 9 | 439 | Sonatrach, BP, Suez: |
| Barcelona | | | 9 | 447 | 13 | 501 | Barcelona | 11 | 497 | 14 | 603 | not specific terminals |
| Total Spain | 18.897 | 49% | | | | | | | | | | |
| Panigaglia | 2.133 | 85% | 9 | 222 | 9 | 225 | Panigaglia | 9 | 225 | 3 | 74 | All Snam/1 Gaz de France |
| Revithoussa | 702 | 45% | 3 | 39 | 4 | 160 | Revithoussa | 2 | 50 | 1 | 33 | All DEPA/2 Gaz de France |

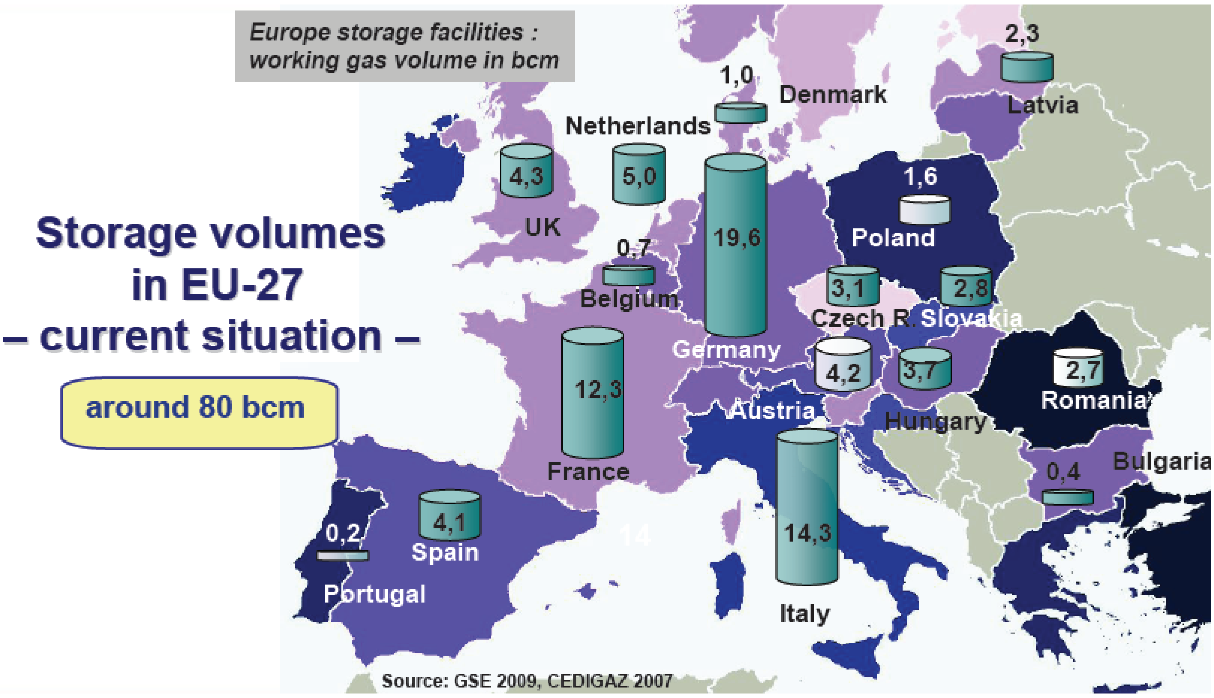
(1) 1st half of January. Full month only Spain and UK
(2) Zeebrugge average load factor is higher because capacity were increased along 2007

1 million metric tons = 1,346 bcm
Source: Waterborne Energy

Table 7.4.2: Utilization of LNG terminals in EU[52]

## 7.5 Storage capacities

Figure 7.5.1: Storage volumes in EU-27[53]



Source: GSE 2009, CEDIGAZ 2007

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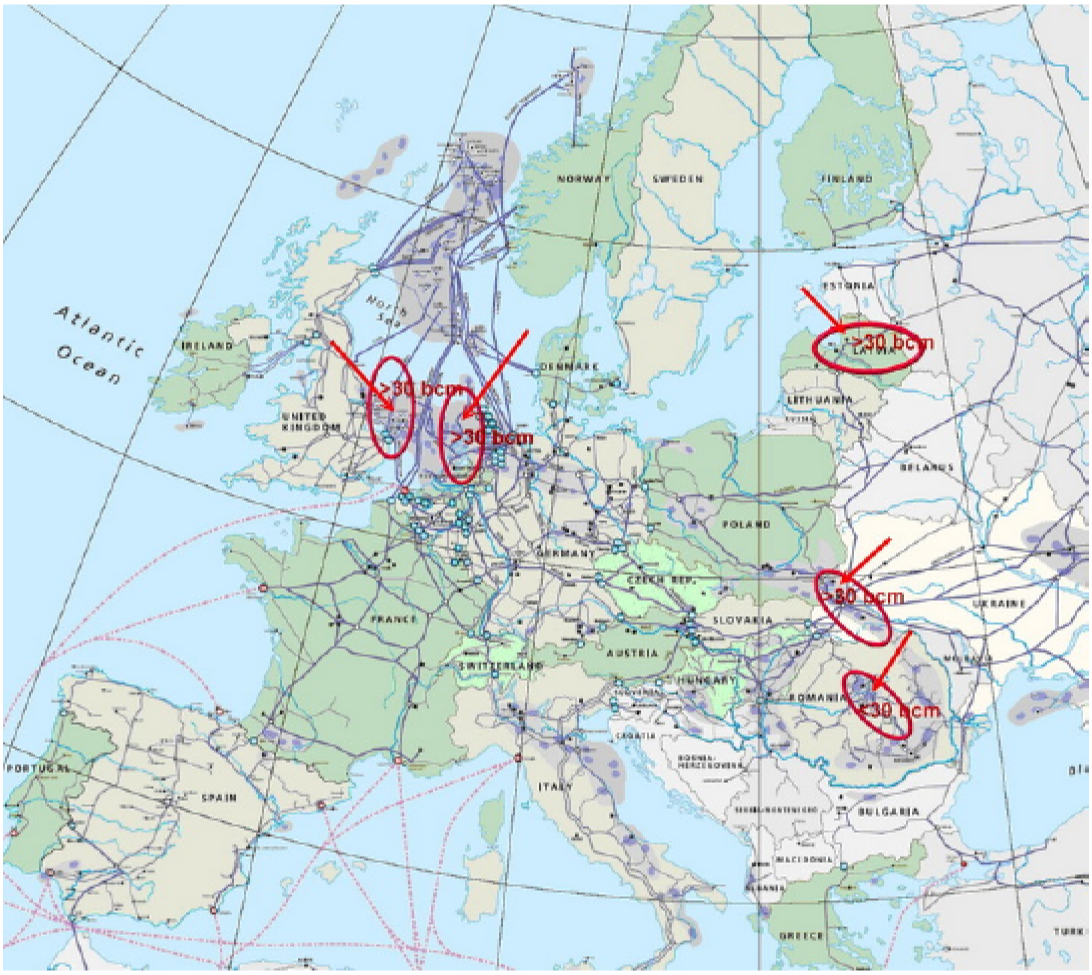
[52] Study on Interoperability of LNG Facilities and Interchangeability of Gas and Advice on the Opportunity to Set-up an Action Plan for the Promotion of LNG Chain Investments, FINAL REPORT, May 2008, DG TREN Framework Contract: TREN/CC/05-2005, lot 3, Technical Assistance in the Fields of Energy and Transport, Contract Awarded to MVV Consulting under the Contract number S07.78755; Contract duration from 02/01/2008 to 30/04/2008.

Figure 7.5.2: Map of depleted field distribution in Europe: future potential[54]



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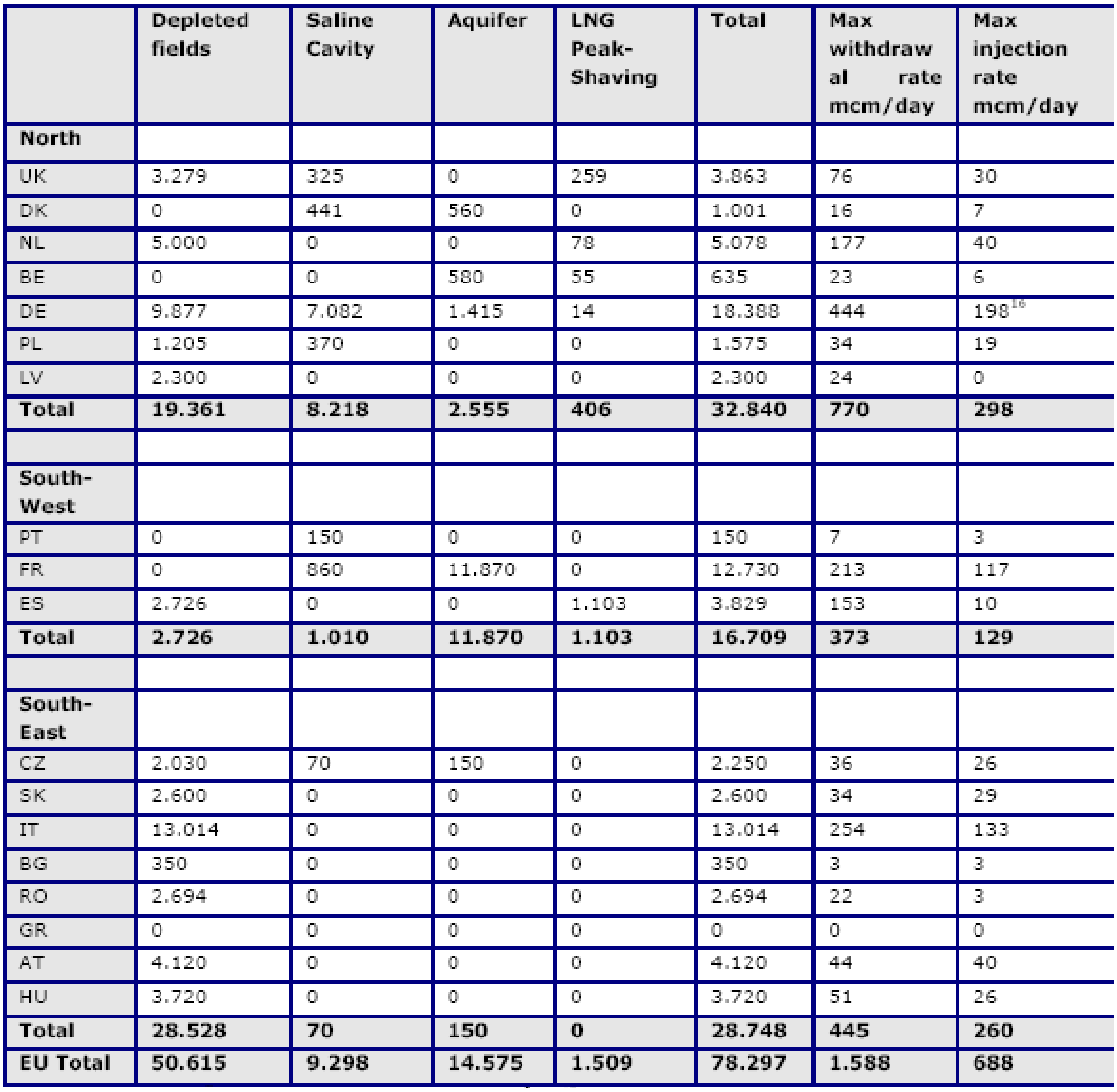
[53] The role of natural gas storage in the changing gas market landscape in the changing gas market landscape; Jean-Marc Leroy, GSE President, CEO of Storengy, 24th World Gas Conference, Argentina, 5-9 October 2009.

[54] GSE Storage maps. In DG TREN C1; Study on natural gas storage in the EU, Draft Final Report, October 2008.

Table 7.5.3: Storage capacities by country, in mcm[55]



| | Depleted fields | Saline Cavity | Aquifer | LNG Peak-Shaving | Total | Max withdrawal rate mcm/day | Max injection rate mcm/day |
|---|---|---|---|---|---|---|---|
| **North** | | | | | | | |
| UK | 3.279 | 325 | 0 | 259 | 3.863 | 76 | 30 |
| DK | 0 | 441 | 560 | 0 | 1.001 | 16 | 7 |
| NL | 5.000 | 0 | 0 | 78 | 5.078 | 177 | 40 |
| BE | 0 | 0 | 580 | 55 | 635 | 23 | 6 |
| DE | 9.877 | 7.082 | 1.415 | 14 | 18.388 | 444 | 198[16] |
| PL | 1.205 | 370 | 0 | 0 | 1.575 | 34 | 19 |
| LV | 2.300 | 0 | 0 | 0 | 2.300 | 24 | 0 |
| **Total** | **19.361** | **8.218** | **2.555** | **406** | **32.840** | **770** | **298** |
| | | | | | | | |
| **South-West** | | | | | | | |
| PT | 0 | 150 | 0 | 0 | 150 | 7 | 3 |
| FR | 0 | 860 | 11.870 | 0 | 12.730 | 213 | 117 |
| ES | 2.726 | 0 | 0 | 1.103 | 3.829 | 153 | 10 |
| **Total** | **2.726** | **1.010** | **11.870** | **1.103** | **16.709** | **373** | **129** |
| | | | | | | | |
| **South-East** | | | | | | | |
| CZ | 2.030 | 70 | 150 | 0 | 2.250 | 36 | 26 |
| SK | 2.600 | 0 | 0 | 0 | 2.600 | 34 | 29 |
| IT | 13.014 | 0 | 0 | 0 | 13.014 | 254 | 133 |
| BG | 350 | 0 | 0 | 0 | 350 | 3 | 3 |
| RO | 2.694 | 0 | 0 | 0 | 2.694 | 22 | 3 |
| GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AT | 4.120 | 0 | 0 | 0 | 4.120 | 44 | 40 |
| HU | 3.720 | 0 | 0 | 0 | 3.720 | 51 | 26 |
| **Total** | **28.528** | **70** | **150** | **0** | **28.748** | **445** | **260** |
| **EU Total** | **50.615** | **9.298** | **14.575** | **1.509** | **78.297** | **1.588** | **688** |

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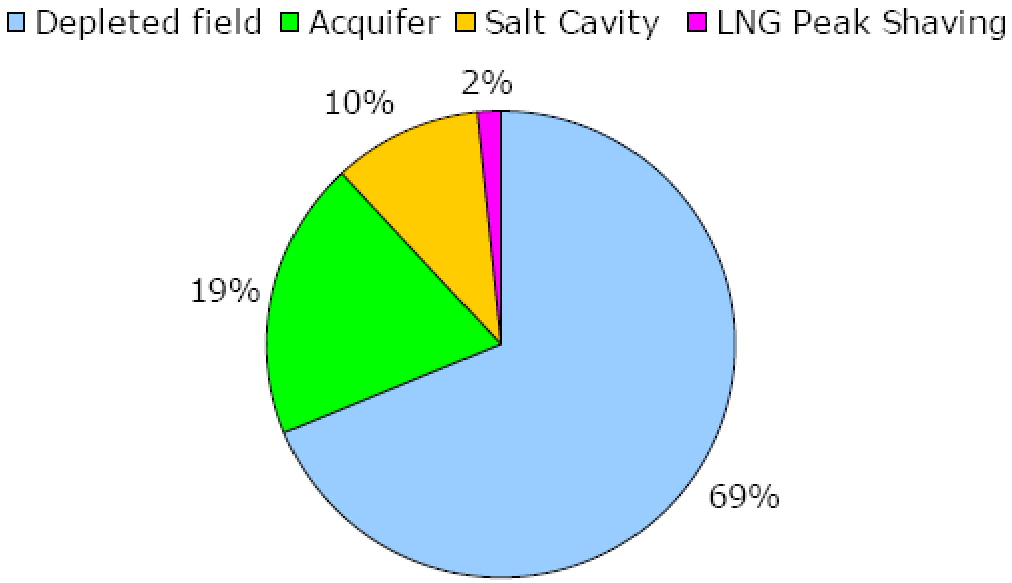
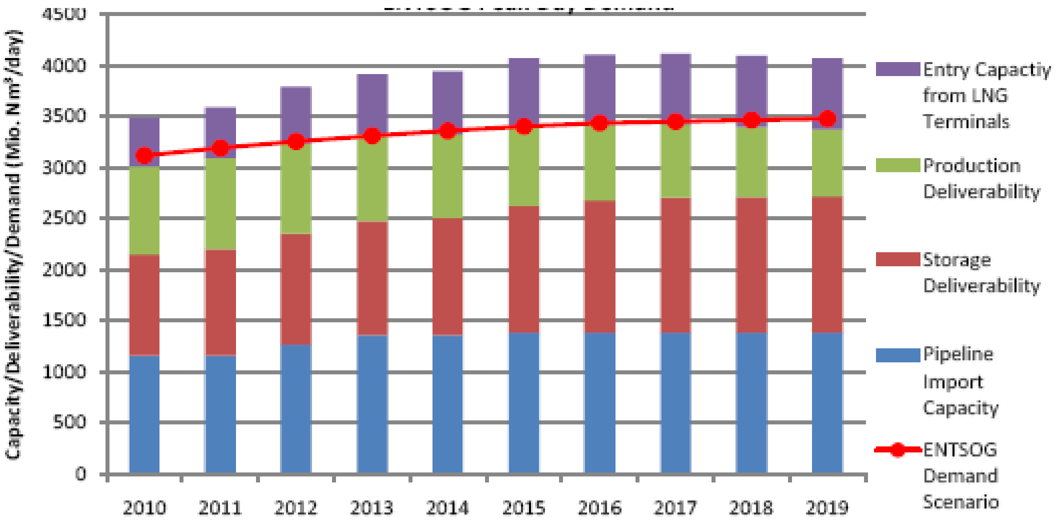
[55] GSE, ERDGAS KOHLE 122, Jg. 2006, Heft 11.

Figure 7.5.4: Shares of existing types of storages based on volume capacity[56]



## 7.6 Network extension forecasts

Figure 7.6.1: ENTSOG Peak day Potential Supply vs ENTSOG Peak day Demand[57]



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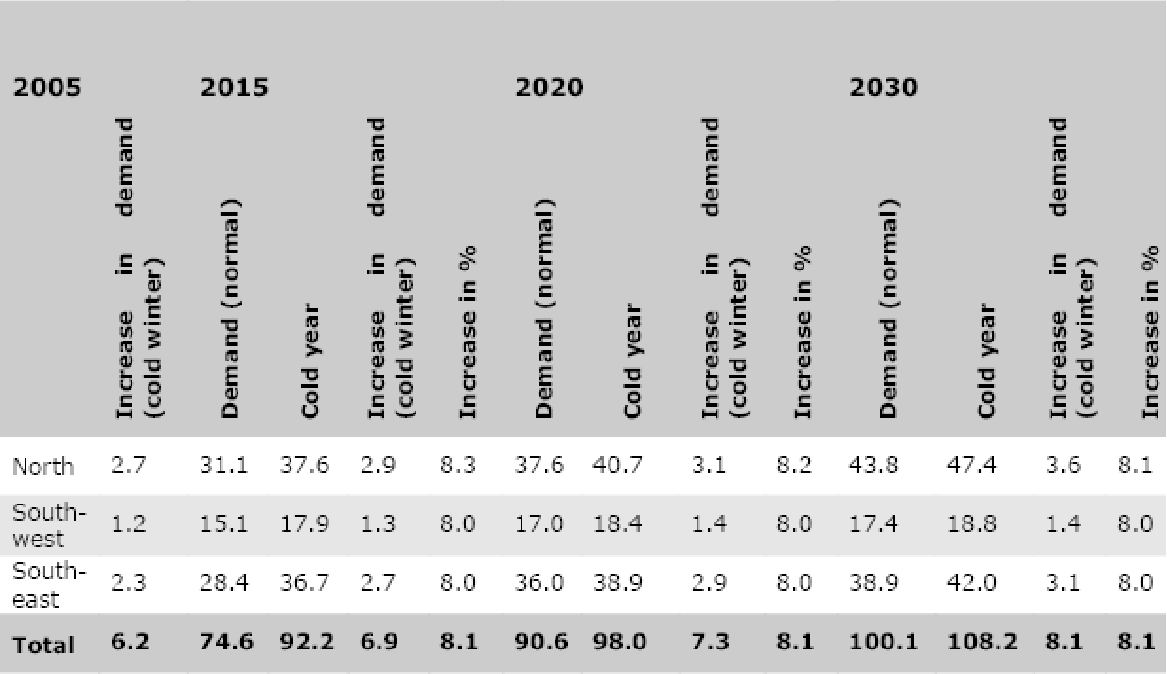
[56] Source ; GSE.

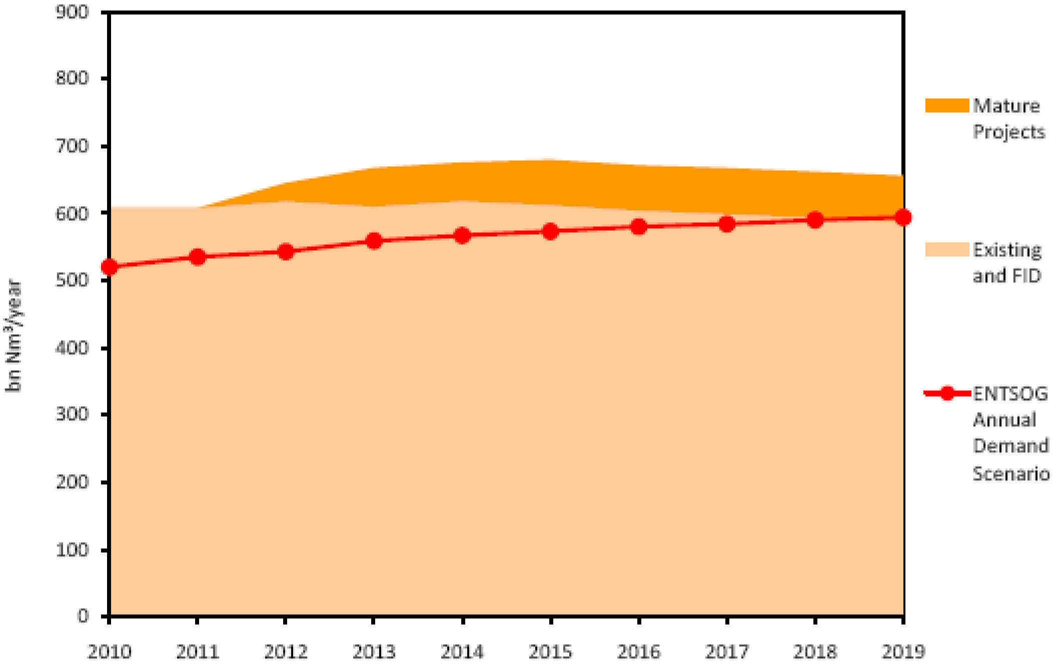
[57] European Ten Year Network Development Plan; 2010 – 2019,December 2009 (Ref. 09ENTSOG).

Table 7.6.3: Cold Winter storage Demand, baseline 2007, bcm[58]



| 2005 | | 2015 | | | | 2020 | | | | 2030 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Increase in demand (cold winter) | Demand (normal) | Cold year | Increase in demand (cold winter) | Increase in % | Demand (normal) | Cold year | Increase in demand (cold winter) | Increase in % | Demand (normal) | Cold year | Increase in demand (cold winter) | Increase in % |
| North | 2.7 | 31.1 | 37.6 | 2.9 | 8.3 | 37.6 | 40.7 | 3.1 | 8.2 | 43.8 | 47.4 | 3.6 | 8.1 |
| South-west | 1.2 | 15.1 | 17.9 | 1.3 | 8.0 | 17.0 | 18.4 | 1.4 | 8.0 | 17.4 | 18.8 | 1.4 | 8.0 |
| South-east | 2.3 | 28.4 | 36.7 | 2.7 | 8.0 | 36.0 | 38.9 | 2.9 | 8.0 | 38.9 | 42.0 | 3.1 | 8.0 |
| **Total** | **6.2** | **74.6** | **92.2** | **6.9** | **8.1** | **90.6** | **98.0** | **7.3** | **8.1** | **100.1** | **108.2** | **8.1** | **8.1** |

Figure 7.6.4: ENTSOG Annual Potential Supply Scenario split by Potential Supplies fromExisting and FID Infrastructure and Potential Supplies from Mature Projects[59]



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[58] In DG TREN C1; Study on natural gas storage in the EU, Draft Final Report, October 2008.

[59] European Ten Year Network Development Plan; 2010 – 2019,December 2009 (Ref. 09ENTSOG).

Figure 7.6.5: ENTSOG Annual Potential Supply Scenario including Import Pipeline Projects[60]vs ENTSOG Annual Demand Scenario[61]

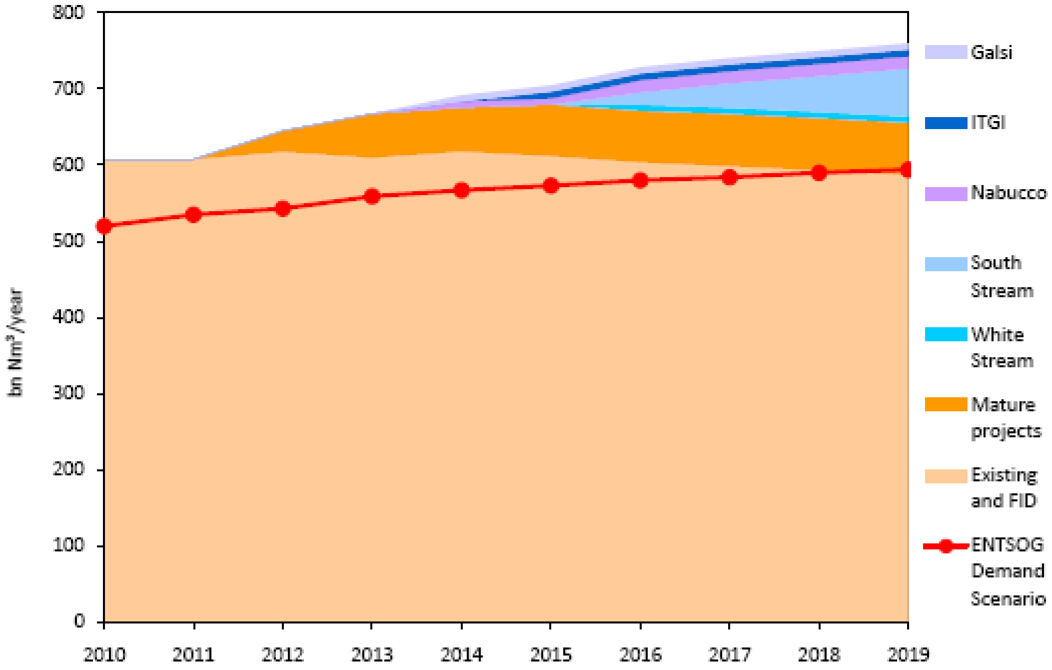
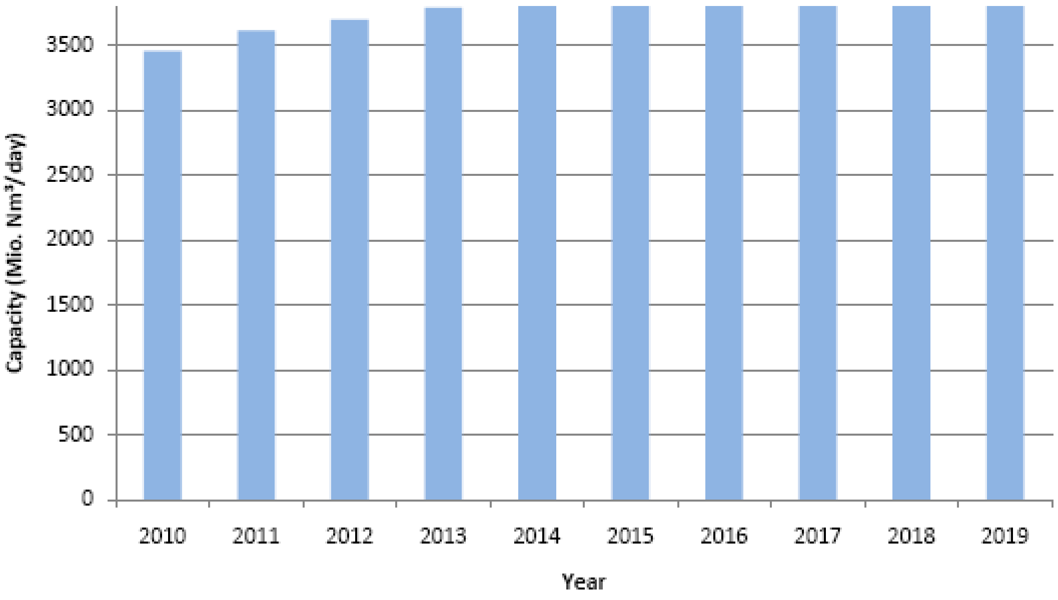


Figure 7.6.5: Indicative measure for the Development of Interconnection capacities[62]



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[60] European Ten Year Network Development Plan; 2010 – 2019, December 2009 (Ref. 09ENTSOG).

[61] European Ten Year Network Development Plan; 2010 – 2019, December 2009 (Ref. 09ENTSOG).

[62] European Ten Year Network Development Plan; 2010 – 2019,December 2009 (Ref. 09ENTSOG).

Figure 7.6.6: Increase in import demand and current transmission capacity[63]

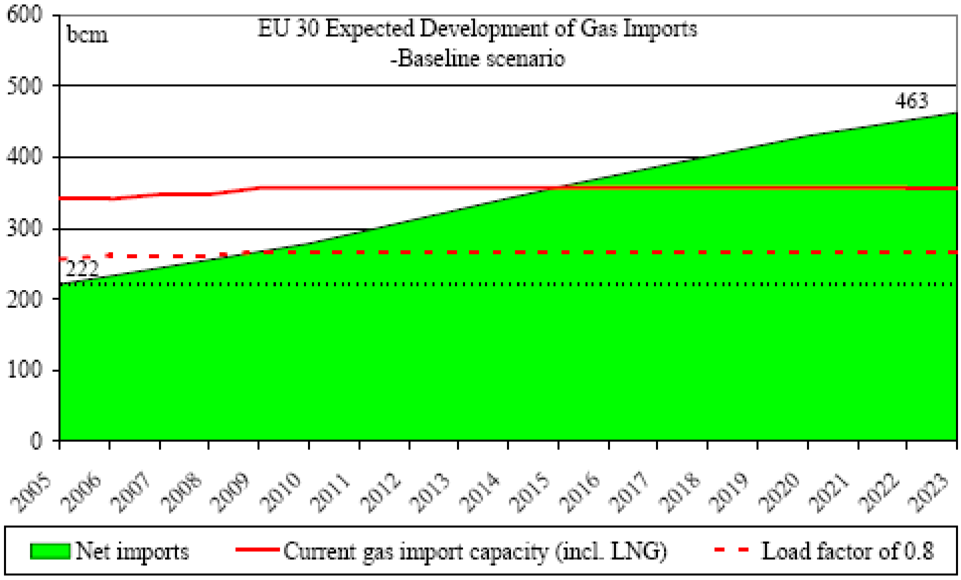

Figure 7.6.7.a: Gasification terminals in EU: existing plans & projects[64]

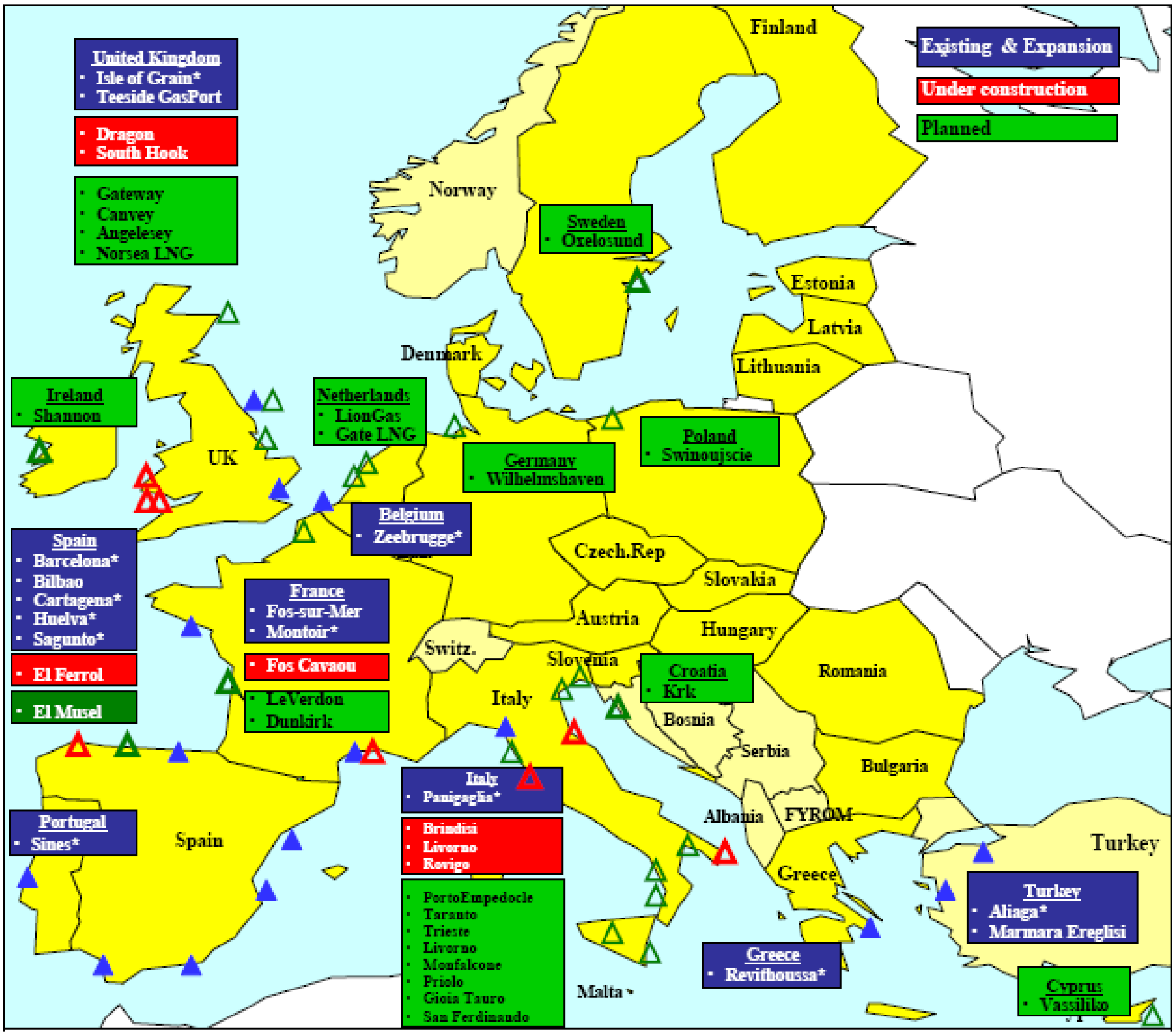

Figure 7.6.7.b: Gasification terminals in EU: existing plans & projects[65]

| Country | Status | Location | Operators | Start-up | Send-out | Storage | # Tanks |
|---|---|---|---|---|---|---|---|
| BE | Existing | Zeebrugge | Fluxys LNG | 1987 | 9,0 | 380000 | 4 |
| DE | Proposed | Wilhelmshafen | dftg (e.on) | N/A | 10,8 | N/A | N/A |
| DE | Proposed | Wilhelmshafen 2 | Excelerate, RWE | 2010 | N/A | N/A | N/A |
| DE | Proposed | Rostock | Vopak, Gasunie, VNG | N/A | N/A | N/A | N/A |
| ES | Existing | Barcelona | Enagas | 1968 | 14,5 | 540000 | 5 |
| ES | Existing after extension | Barcelona (ext.) | Enagas | 2009 | 17,0 | 680000 | 6 |
| ES | Existing | Huelva | Enagas | 1988 | 11,8 | 460000 | 4 |
| ES | Existing after extension | Huelva (ext.) | Enagas | 2015 | 11,8 | 760000 | 6 |
| ES | Existing | Cartagena | Enagas | 1989 | 10,5 | 437000 | 4 |
| ES | Existing after extension | Cartagena (ext.) | Enagas | 2014 | 14,5 | 590000 | 5 |
| ES | Existing | Bilbao | Bahia de Bizkaia (BBG) | 2003 | 7,0 | 300000 | 2 |
| ES | Existing after extension | Bilbao (ext.) | Bahia de Bizkaia (BBG) | 2011 | 12,3 | 600000 | 4 |
| ES | Existing | Sagunto | Saggas | 2006 | 7,0 | 300000 | 2 |
| ES | Existing after extension | Sagunto (ext.) | Saggas | 2014 | 14,0 | 750000 | 5 |
| ES | Existing | El Ferrol | Reganosa | 2007 | 3,6 | 300000 | 2 |
| ES | After extension | El Ferrol (ext.) | Reganosa | 2013 | 7,3 | 300000 | 2 |
| ES | Under construction | Gijón (Musel) | Enagas | 2011 | 10,5 | 600000 | 4 |
| ES | Under construction | Gran Canaria (Arinaga) | Gascan | 2012 | 2,0 | 3000000 | 2 |
| ES | Under construction | Tenerife (Arico-Granadilla) | Gascan | 2011 | 2,0 | 3000000 | 2 |
| FR | Existing | Montoir de Bretagne | Elengy | 1980 | 10,0 | 360000 | 3 |
| FR | Existing after extension | Montoir de Bretagne (ext.) | Elengy | N/A | 16,5 | 360000 | 3 |
| FR | Existing | Fos Tonkin | Elengy | 1972 | 7,0 | 150000 | 3 |
| FR | Under construction | Fos Cavaou | STFMC | 2009 | 8,3 | 330000 | 3 |
| FR | Proposed | Dunkerque | Dunkerque LNG | 2014 | 10-13 bcm/y | N/A | N/A |
| FR | Proposed | Fos Faster | Shell | 2015 | 8,0 | N/A | N/A |
| FR | Proposed | Le Havre - Antifer | Gaz de Normandie | 2014 | 9,0 | N/A | N/A |

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[65] GLE, LNG Map, www.gie.eu.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FR** | Proposed | Le Verdon (Pegaz) | 4GAS | 2013 | 9,0 | N/A | N/A |
| **FR** | Proposed | Le Verdon | La Snet | N/A | N/A | N/A | N/A |
| **GR** | Existing | Revithoussa | DESFA | 2000 | 5,3 | 130000 | 2 |
| **GR** | Proposed | Korakia | DESFA, PPC (Public Power Corporation) | 2012 | N/A | N/A | N/A |
| **IT** | Existing | Panigaglia | (ENI) GNL Italia | 1971 | 3,4 | 100000 | 2 |
| **IT** | Existing after extension | Panigaglia (ext.) | (ENI) GNL Italia | 2014 | 8,0 | 240000 | 2 |
| **IT** | Under construction | Adriatic LNG | Adriatic LNG | 2009 | 7,6 | 250000 | 2 |
| **IT** | Under construction | Brindisi | Brindisi LNG | 2010 | 16,0 | 640000 | 4 |
| **IT** | Under construction | Toscana Offshore | OLT / Endesa / E.ON. / Iride | 2011 | 3,8 | 137000 | N/A |
| **IT** | Under construction | Rotterdam; GATE Terminal (Maasvlakte) | Gasunie / Vopak | 2011 | 16,0 | 720000 | 4 |
| **IT** | Proposed | Alpi Adriático / Montefalcone / Trieste Offshore | Endesa / E.ON | 2012 | 8,0 | N/A | N/A |
| **IT** | Proposed | Taranto | gasNatural | 2010 | 9,0 | 300000 | 2 |
| **IT** | Proposed | Porto Empedocie | Nuove Energie | 2010 | N/A | N/A | N/A |
| **IT** | Proposed | Priolo | ERG / Shell | 2010 | N/A | N/A | N/A |
| **IT** | Proposed | Senigaglia / Ancona | GDFSuez / Hoegh LNG | 2012 | 5,0 | N/A | N/A |
| **IT** | Proposed | Civitavecchia | Gavio | N/A | N/A | N/A | N/A |
| **IT** | Proposed | Atlas LNG (Ravenna / offshore) | Bellelli | N/A | N/A | N/A | N/A |
| **LT** | Proposed | N/A | N/A | 2013 | N/A | N/A | N/A |
| **NL** | Under construction | Rotterdam; GATE Terminal (Maasvlakte) | Gasunie / Vopak | 2011 | 12,0 | 540000 | 3 |
| **NL** | Proposed | Eemshaven | Gasunie / Essent / Vopak | 2014 | 13,0 | 376000 | 2 |
| **NL** | Proposed | Rotterdam | 4GAS | 2011 | 10,0 | N/A | N/A |
| **NL** | Proposed | Rotterdam | TAQA | 2011 | 9,0 | N/A | N/A |
| **PL** | Proposed | Swinoujscie | Gaz-system / PLNG | 2014 | N/A | N/A | N/A |
| **PL** | Proposed | Croatia, Adria LNG; Omisalj (Dina) - Krk island | Total / Geoplin / RWE / EON / OMV | 2012 | 1,2 | N/A | N/A |
| **PT** | Existing | Sines | REN Atlantico | 2004 | 5,5 | 240000 | 2 |
| **PT** | Existing after extension | Sines (ext.) | REN Atlantico | 2011 | 5,5 | 390000 | 3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **RO** | Proposed | Constanta | Romgaz | N/A | N/A | N/A | N/A |
| **SE** | Proposed | Oxelösund | E.on | N/A | N/A | N/A | N/A |
| **SE** | Proposed | Brunnsviksholmen (Nynäshamn) | AGA | 2011 | N/A | N/A | N/A |
| **UK** | Existing | Isle of Grain (Grain LNG) | GrainLNG | 2005 | 13,4 | 8000000 | 7 |
| **UK** | Existing after extension | Isle of Grain (Grain LNG) (ext.) | GrainLNG | 2010 | 20,8 | 1000000 | 8 |
| **UK** | Existing | Teesside | Elengy | 1980 | 10,0 | 360000 | 3 |
| **UK** | Under construction | Milford Haven | BG / Petronas / 4Gas | 2009 | 9,0 | 5400000 | 3 |
| **UK** | Under construction | Milford Haven | South Hook | 2009 | 7,8 | 775000 | 5 |
| **UK** | Proposed | Canvey LNG | Calor Gas | 2014 | 5,4 | N/A | N/A |
| **UK** | Proposed | Anglesey (Amlwch) | Canatxx | N/A | N/A | N/A | N/A |
| **UK** | Proposed | PortMeridian (Barrow-in-Furness) | Hoegh LNG | 2011 | N/A | N/A | N/A |
| **UK** | Proposed | Teesside | Norsea Pipeline Ltd | N/A | N/A | N/A | N/A |
| **UK** | Proposed | Shannon | Shannon LNG (subsidiary of HESS) | 2011 | N/A | N/A | N/A |

Table 7.6.8: Storage projects under consideration or development[66]

| Country | Company | Name of facility | Type of facility | Investment | Status | Capacity Delivered | Expected Capacity (Mcm WG) | Expected Date / Date of project completion | Last Update Date | Source of Info |
|---|---|---|---|---|---|---|---|---|---|---|
| **AUSTRIA** | OMV Gas | Schonkirchen Tief | Reservoir | New facility | Planned | | 750 | by 2013 (PhaseI) | February 2009 | GSE Member |
| **AUSTRIA** | OMV Gas | Schonkirchen Tief | Reservoir | New facility | Planned | | 1250 | by 2018 (Phase II) | February 2009 | GSE Member |
| **AUSTRIA** | RAG/Wingas/Gazprom Export | Haidach | Reservoir | New facility | **Live** | 1200 | | June 2007 | | GSE Member |
| **AUSTRIA** | RAG/Wingas/Gazprom Export | Haidach | Reservoir | New facility | Under construction | | 1200 | by 2011 | February 2009 | GSE Member |
| **BELGIUM** | Fluxys | Loenhout | Aquifer | Expansion | Under construction | | 100 | by 2010 | 5 July 2007 | GSE Member |
| **BULGARIA** | Bulgartransgaz | Chiren | Reservoir | Expansion | Planned | | 450 | by 2010 | November 2007 | GSE Member |
| **CZECH REPUBLIC** | RWE Gas Storage | Not specified | | Expansion (various projects) | Planned/Committed | | 795 | by 2013 | February 2009 | GSE Member |
| **DENMARK** | DONG Storage | Stenlille | Aquifer | Expansion | **Live** | 90 | | October 2007 | | GSE Member |
| **DENMARK** | DONG Storage | Stenlille | Aquifer | Expansion | Committed | | 30 | by May 2009 | June 2008 | GSE Member |
| **FRANCE** | Storengy | Céré La Ronde/Soings | Aquifer | Expansion | Under construction | | 60 | by 2012 | February 2009 | GSE Member |
| **FRANCE** | Storengy | Céré La Ronde/Soings | Aquifer | Expansion | **Live** | 40 | | April 2008 | June 2008 | GSE Member |
| **FRANCE** | Storengy | Etrez/Manosque | Salt cavity | Expansion | Under Construction | | 200 | by 2015 | February 2009 | GSE Member |

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[66] GSE STORAGE INVESTMENT DATABASE; February2009.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **FRANCE** | Storengy | Etrez/Manosque | Salt cavity | Expansion | **Live** | 100 | | April 2008 | June 2008 | GSE Member |
| **FRANCE** | Storengy | Hauterives | Salt cavity | New facility | Committed | | 100 | by 2013 | February 2009 | GSE Member |
| **FRANCE** | Storengy | Ile-de-France Nord/ Gournay | Aquifer | Expansion | Under construction | | 200 | by 2013 | February 2009 | GSE Member |
| **FRANCE** | Storengy | Ile-de-France Nord/ Gournay | Aquifer | Expansion | **Live** | 40 | | April 2008 | June 2008 | GSE Member |
| **FRANCE** | Storengy | Alsace Sud | Salt Cavity | New facility | Planned | | 160 | by 2017 | February 2009 | GSE Member |
| **FRANCE** | Storengy | Trois Fontaines | Reservoir | New facility | Under Construction | | 80 | by 2013 | February 2009 | GSE Member |
| **FRANCE** | TIGF | Izaute/Lussagnet | Aquifer | Expansion | Planned | | 240 | by 2015 | February 2009 | GSE Member |
| **FRANCE** | TIGF | Pécorade | Reservoir | New facility | Planned | | 750 | by 2015 | February 2009 | GSE Member |
| **GERMANY** | E.ON Gas Storage | Etzel EGS | Salt cavity | New facility | Planned/Committed | | 2500 | by 2016 | February 2009 | GSE Member |
| **GERMANY** | E.ON Gas Storage | Etzel EGL (share EGS) | Salt cavity | Expansion | under construction | | 250 | by 2011 | February 2009 | GSE Member |
| **GERMANY** | E.ON Gas Storage | Epe EGS H-Gas | Salt cavity | Expansion | under construction | | 273 | by 2011 | February 2009 | GSE Member |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GERMANY** | E.ON Gas Storage | Krummhörn | Salt cavity | Reparation | under construction | | 229 | by 2011 | February 2009 | GSE Member |
| **GERMANY** | E.ON Gas Storage | Bierwang | depleted field | Expansion | under construction | | 359 | by 2015 | February 2009 | GSE Member |
| **GERMANY** | EDF Trading/ EnBW | Etzel | Salt cavity | New facility | Planned | | 360 | by 2011 | June 2008 | GSE member |
| **GERMANY** | Storengy Deutschland GmbH | Behringen | Reservoir | New facility | Planned | | 1000 | by 2013 | June 2008 | other |
| **GERMANY** | Storengy Deutschland GmbH | Peckensen Phase 2 | Salt cavity | New facility | Committed/under construction | | 160 | by 2010 | June 2008 | other |
| **GERMANY** | Storengy Deutschland GmbH | Peckensen Phase 3 | Salt cavity | New facility | Committed | | 180 | by 2014 | June 2008 | other |
| **GERMANY** | E-ON Hanse | Kiel-Rönne | Salt cavity | New facility | Planned | | 50 | by 2015 | 5 July 2007 | GSE Member |
| **GERMANY** | Essent Energie Gasspeicher GmbH | Epe | Salt cavity | New facility | Under development | | 200 | by 2011 | June 2008 | GSE Member |
| **GERMANY** | Essent Energie Gasspeicher GmbH | Epe 2A | Salt cavity | Expansion | Under construction | | 110 | by November 2008 | June 2008 | GSE Member |
| **GERMANY** | Essent Energie Gasspeicher GmbH | Epe 2A (part) | Salt cavity | Expansion | **Live** | 57,9 | | January 2008 | | GSE Member |
| **GERMANY** | EWE | Huntorf | Salt cavity | New facility | Planned | | 150 | by 2015 | 5 July 2007 | other |
| **GERMANY** | EWE | Nuentermoor | Salt cavity | New facility | Planned | | 180 | by 2015 | 5 July 2007 | other |
| **GERMANY** | EWE | Ruedersdorf | Salt cavity | New facility | Planned | | 300 | by 2015 | 5 July 2007 | other |
| **GERMANY** | Gas Union | Reckrod | Salt cavity | New facility | Planned | | 30 | by 2015 | 5 July 2007 | other |
| **GERMANY** | GHG | Empelde | Salt cavity | New facility | Planned | | 110 | by 2015 | 5 July 2007 | other |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **GERMANY** | RWE Energy | Epe | Salt cavity | Expansion | **Live** | 63 | October 2007 | | GSE Member |
| **GERMANY** | RWE Energy | Xanten | Salt cavity | Expansion | Planned | 125 | by 2015 | June 2008 | GSE Member |
| **GERMANY** | RWE Dea | Wolfersberg | Reservoir | Expansion | Planned | 45 | by 2010 | June 2008 | GSE Member |
| **GERMANY** | Saar Ferngas | Frankenhal | Aquifer | Expansion | Planned | 130 | by 2015 | 5 July 2007 | other |
| **GERMANY** | SPC Rheinische Epe Gasspeicher GmbH&Co KG / Essent Energy Productie B.V. | Epe | Salt cavity | New facility | Planned | 365 | by 2010 | 30 June 2008 | GSE Member |
| **GERMANY** | VNG | Bernburg | Salt cavity | New facility | Planned | 300 | by 2015 | 5 July 2007 | GSE Member |
| **GERMANY** | Wingas | Jemgum | Salt cavity | New facility | Planned | 1200 | by 2011/2012 | February 2009 | GSE Member |
| **GERMANY** | Wintershall | Reckrod-Walf | Salt cavity | New facility | Planned | 120 | by 2015 | 5 July 2007 | other |
| **HUNGARY** | MMBF Zrt. | Szoereg-1 | Reservoir | New facility | Under construction | 1900 | by 2010 | Janaury 2009 | GSE Member |
| **HUNGARY** | E.ON. Foedlgaz Storage | Zsana | Reservoir | Expansion | Under construction | 400 | | February 2009 | GSE Member |
| **ITALY** | Edison Stoccaggio | Cellino & Collato | Reservoir | Expansion | Under construction | 552 | by 2010 | November 2007 | GSE Member |
| **ITALY** | Edison Stoccaggio | Cotignola & San Potito | Reservoir | New facility | Committed | 915 | by 2013 | November 2007 | GSE Member |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **ITALY** | Edison Stoccaggio | Not specified | Reservoir | New facility / expansion | Planned | | 1400 | by 2015 | November 2007 | GSE Member |
| **ITALY** | ERG Rivara Storage srl | Rivara | Aquifer | New facility | Planned | | 3000 | by 2013 | November 2008 | other |
| **ITALY** | Geogas | Cugno Le Macine | Reservoir | New facility | Planned | | 740 | by 2015 | 5 July 2007 | other |
| **ITALY** | Ital Gas Storage | Cornegliano | Reservoir | New facility | Planned | | 600 | by 2015 | 5 July 2007 | other |
| **ITALY** | Stogit | Bordolano | Reservoir | New facility | Under construction | | 1500 | by 2013 | February 2009 | GSE Member |
| **ITALY** | Stogit | Caleppio-Merlino | Reservoir | New facility | Under construction | | 450 | by 2013 | February 2009 | GSE Member |
| **ITALY** | Stogit | Cignone | Reservoir | New facility | Committed | | 200 | by 2013 | February 2009 | GSE Member |
| **ITALY** | Stogit | Cortemaggiore Pool C | Reservoir | Expansion | **Live** | 180 | | June 2008 | | GSE Member |
| **ITALY** | Stogit | Fiume Treste BCC1 | Reservoir | New facility | Under construction | | 350 | by 2010 | February 2009 | GSE Member |
| **ITALY** | Stogit | Fiume Treste C2 | Reservoir | Expansion | Under construction | | 200 | by 2010 | February 2009 | GSE Member |
| **ITALY** | Stogit | Fiume Treste DEE0 | Reservoir | New facility | Under construction | | 600 | by 2010 | February 2009 | GSE Member |
| **ITALY** | Stogit | Ripalta | Reservoir | Expansion | Under construction | | 300 | by 2010 | February 2009 | GSE Member |
| **ITALY** | Stogit | Sergnano | Reservoir | Expansion | Under construction | | 200 | by 2010 | February 2009 | GSE Member |
| **ITALY** | Stogit | Sergnano (part) | Reservoir | Expansion | **Live** | 150 | | Sepetmber 2008 | | GSE Member |
| **LATVIA** | Latvijas Gaze | Incukalns | Reservoir | Expansion | Planned | | 1000 | by 2015 | 5 July 2007 | other |
| **LITHUANIA** | Dujotekana | Not specified | Reservoir | New facility | Planned | | 500 | by 2015 | 5 July 2007 | other |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **NETHERLANDS** | Taqa | Bergermeer | Reservoir | New facility | Planned | 4100 | by 2013 | February 2009 | GSE Member |
| **NETHERLANDS** | Zuidwending VOF | Zuidwending | Salt cavity | New facility | Under construction | 180 | by 2011 | June 2008 | GSE Member |
| **NETHERLANDS** | Zuidwending VOF | Zuidwending | Salt cavity | Expansion | Planned | 180 | by 2014 | June 2008 | GSE Member |
| **POLAND** | PGNIG | Bonikowo | Reservoir | New facility | Committed | 200 | by 2010 | June 2008 | GSE Member |
| **POLAND** | PGNIG | Daszewo | Reservoir | New facility | Under construction | 30 | by 2010 | June 2008 | GSE Member |
| **POLAND** | PGNIG | Kosakowo | Salt cavity | New facility | Committed | 250 | by 2020 | June 2008 | GSE Member |
| **POLAND** | PGNIG | Mogilno | Salt cavity | Expansion | Under construction | 420 | by 2018 | June 2008 | GSE Member |
| **POLAND** | PGNIG | Strachocina | Reservoir | Expansion | Committed | 180 | by 2012 | June 2008 | GSE Member |
| **POLAND** | PGNIG | Wierzchowice | Reservoir | Expansion | Committed | 625 | by 2011 | June 2008 | GSE Member |
| **PORTUGAL** | REN Armazenagem | Carrico | Salt cavity | Expansion | | 30 | | November 2007 | GSE Member |
| **ROMANIA** | AMGAZ | Nades-Prod-Seleus | Reservoir | Expansion | Planned | 250 | by 2011 | June 2008 | GSE Member |
| **ROMANIA** | Romgaz | Roman-Margineni | Reservoir | New facility | Planned | 1600 | by 2015 | 5 July 2007 | other |
| **ROMANIA** | Depomures | Tirgu-Mures | Reservoir | Expansion | Planned | 300 | by 2013 | November 2007 | GSE Member |
| **SERBIA** | Srbijagas | Banatski Dvor | Reservoir | New facility | | 800 | | November 2007 | GSE Member |
| **SPAIN** | Engas | Barcelona | LNG Peak Shaving | Expansion | Committed | 84 | by 2011 | June 2008 | GSE Member |
| **SPAIN** | Engas | Huelva | LNG Peak Shaving | Expansion | Committed | 175 | by 2011 or 2015 | June 2008 | GSE Member |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **SPAIN** | Engas | Cartagena | LNG Peak Shaving | Expansion | Committed | | 175 | by 2010 | June 2008 | GSE Member |
| **SPAIN** | BBG | Bilbao | LNG Peak Shaving | Expansion | Committed | | 88 | by 2012 | June 2008 | GSE Member |
| **SPAIN** | Saggas | Sagunto | LNG Peak Shaving | Expansion | Committed | | 260 | 2012 | June 2008 | GSE Member |
| **SPAIN** | Enagas | Musel (Gijon) | LNG Peak Shaving | New facility | Committed | | 350 | by 2015 | June 2008 | GSE Member |
| **SPAIN** | Reganosa | Ferrol | LNG Peak Shaving | New facility | **Live** | 175 | | May 2007 | | GSE Member |
| **SPAIN** | Gascan | Gran Canaria | LNG Peak Shaving | New facility | Committed | | 88 | by 2012 | June 2008 | GSE Member |
| **SPAIN** | Gascan | Tenerife | LNG Peak Shaving | New facility | Committed | | 88 | by 2011 | June 2008 | GSE Member |
| **SPAIN** | Escal UGS (ACS, Enagas, CLP) | Castor | Reservoir | New facility | Committed | | 1500 | by 2010 | June 2008 | GSE Member |
| **SPAIN** | Enagas/Repsol YPF | Gaviota | Reservoir | Expansion | Committed | | 580 | by 2010 | June 2008 | GSE Member |
| **SPAIN** | | Marismas | Reservoir | New facility | Committed | | 660 | by 2010 | June 2008 | GSE Member |
| **SPAIN** | | Poseidon | Reservoir | New facility | Committed | | 300 | | June 2008 | GSE Member |
| **SPAIN** | Enagas | Yela | Aquifer | New facility | Committed | | 1350 | by 2010 | June 2008 | GSE Member |
| **SPAIN** | | Las Barreras | Reservoir | New facility | Committed | | 88 | by 2011 | June 2008 | GSE Member |
| **SPAIN** | | El Ruedo | Reser | New facility | Committed | | 120 | by 2011 | June 2008 | GSE Member |

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|---|---|---|---|---|---|---|---|---|---|
| **UK** | Centrica/Perenco | Baird | Offshore Reservoir | New facility | Planned | 1670 | by 2013 | February 2009 | GSE Member |
| **UK** | Canatxx | Fleetwood | Salt cavity | New facility | Planned | 1200 | by 2012 | June 2008 | other |
| **UK** | Centrica/GdF/First Oil | Bains | Offshore Reservoir | New facility | Planned | 570 | by 2011 | June 2008 | GSE Member |
| **UK** | British Salt | British Salt | Salt Cavity | New facility | Planned | 1000 | after 2010 | June 2008 | other |
| **UK** | ENI/Perenco | Hewett | Offshore Reservoir | New facility | Planned | 5000 | by 2015 | June 2008 | other |
| **UK** | EDF Trading | Hole House phase 2 | Salt cavity | Expansion | Under construction | 55 | by 2010 | June 2008 | other |
| **UK** | Portland Gas | Isle of Portland | Salt Cavity | New facility | Planned | 1000 | by 2015 | June 2008 | other |
| **UK** | E.ON. Gas Storage UK | Holform (formerly Byley) | Salt cavity | New facility | Under construction | 165 | by 2010 | June 2008 | other |
| **UK** | E.ON. Gas Storage UK | Whitehill Farm | Salt cavity | New facility | Planned | 420 | by 2012/2013 | June 2008 | GSE Member |
| **UK** | Storengy UK Ltd | Stublach | Salt cavity | New facility | Under construction | 400 | from 2013 to 2018 | December 2008 | other |
| **UK** | Petronas | Albury Phase 1 | Reservoir | New facility | Planned | 170 | by 2012 | June 2008 | GSE Member |
| **UK** | Petronas | Albury Phase 2 | Reservoir | Expansion | Planned | 730 | by 2012 | June 2008 | GSE Member |
| **UK** | Petronas | Welton / Scampton North | Reservoir | New facility | Planned | 450 | by 2012 | June 2008 | GSE Member |
| **UK** | Petronas | Bletchingley | Salt cavity | New facility | Planned | 850 | by 2010 | June 2008 | other |
| **UK** | Petronas / EnCore | Esmond / Gordon | Offshore reservoir | New facility | Planned | 4100 | by 2015 | June 2008 | GSE Member |
| **UK** | SSE/Statoil | Aldbrough phase | Salt | New facility | Under construction | 420 | by 2009 | June 2008 | other |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | cavity | | | | | | | |
| **UK** | SSE/Statoil | Aldbrough phase 2 | Salt cavity | Expansion | Planned | | 420 | by 2012 | June 2008 | other |
| **UK** | Stag Energy | Gateway | Salt cavity | New facility | Planned | | 1140 | by 2012 | June 2008 | other |
| **UK** | Centrica plc | Caythorpe | Reservoir | New facility | Planned | | 210 | by 2010 | June 2008 | other |
| **UK** | Wingas | Saltfleetby | Reservoir | New facility | Planned | | 715 | by 2011 | February 2009 | GSE Member |

Table 7.6.9 : Reverse flow projects under consideration or implementation[67]

| | Project | Goal | Capacity created in reverse flow | Capital expenditures | Countries involved | Project maturity | Funds breakdown | Commencement of operations |
|---|---|---|---|---|---|---|---|---|
| **Czech Republic** | 2. Interconnector Czech Republic –Poland | Create interconnection between Poland and Czech Republic on high pressure leve; Increased safety of supply in Poland, region North Silesia; Development of North-South connection. | 500 mcm/a CZ <-> PL | 7 M€ | Czech, Poland | Construction in 2010 | Pipeline: 6 mio€; Engineering: 1 mio€ | 2010 |
| **Austria** | OMV Gas : 1 – Upgrading the Baumgarten metering and compressor station for bi-directional use | Availability of gas transport from Austrian storages to the CEE countries | 1,0 mcm/hat 50 bar | 4,0 M€ | Slovakia, CEE countries | Basic design | 2009-2011 | first half of 2011 Upgrading |
| **Austria** | OMV Gas : 2 – Upgrading the WAG metering and compressor station in Baumgarten for bi-directional use on behalf of BOG GmbH | Availability of gas transport from Austrian storages and from Western European sources to the CEE countries | 1 800 000Nm³/hat 71 bara | 3,767 M€ | CEE countries | Basic design | 16 months | déc-10 |

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[67] GTE; Reverse Flow Study, Technical solutions, 21 July 2009.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Austria** | OMV Gas : 3 – Increasing the interconnection capacity from OMV Gas system into the TAG system for gas not coming from Slovakia | Availability of more intake from Austrian storages and from Western European sources into the Baumgarten gas turntable, toward eustream, TAG and SOL system and toward CEE countries | 1,0 mcm/h at 50 bar | 1,6 M€ | Austria, CEEcountries | Basic designed | 15 months | 2010 |
| **Poland** | 2 –Poland-Czech Republic Connection – Phase II | Integration of gas systems in order to diversify and ensure stable gas supplies to end customers; Increasing safety of systems markets | 2-3 bcm/a | 106 M€ | Poland, Czech Republic | Study phase | Pipeline: 71 M€Compressor St: 33 M€Transfer station: 2 M€ | Dependent on market demand |
| **Poland** | 3 –Poland-Germany Connection | Integration of gas systems in order to ensure stable gas supplies to end customers; Increasing safety of systems operations | ca 0,5 + 0,5 bcm/a | 60 + 16 M€ | Poland, Germany | Engineering ongoing | N/A | Phase I: 2011Phase II: 2015 |
| **Austria** | TAG : Option1 | Reverse flow to the Slovakian border without internal off-takes | From 9 Mio Sm³/d to Mio Sm³/d | From 9,7 M€ to 20,6M€ | Austria –Italy-Slovakia | Pre-feasibility study currently ongoing | FID (final investment decision) + 19 months | FID (final investment decision) + 20 months |
| **Austria** | TAG : Option2 | Reverse flow to the Slovakian border with internal off-takes | From 32 Mio Sm³/d in Arnoldstein to 18 Mio Sm³/d in Baumgarten | 20,6 M€ | Austria –Italy –Slovakia – Slovenia | Pre-feasibility study currently ongoing | FID (final investment decision) + 19 months | FID (final investment decision) + 20 months |

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|---|---|---|---|---|---|---|---|---|
| **Austria** | TAG : Option3 | Reverse flow to the Slovakian border with internal off-takes | From 40 Mio Sm³/d in Arnoldstein to 25.5 Mio Sm³/d in Baumgarten | 29,5 M€ | Austria –Italy –Slovakia – Slovenia | Pre-feasibility study currently ongoing | FID (final investment decision) + 19 months | FID (final investment decision) + 20 months |
| **France** | 2 –Taisnières H -Gas treatment | Treatment of natural gas in order to remove THT (odorant used in France) | 300 000 (n) m3/h (60 bar) | 167 €/m3/hof capacity | France, Belgium | Pre-feasibility studies | 12/11/2010 | Not decided(Q4 2012 atthebest) |
| **Poland** | 1 –Poland-DenmarkConnection | Integration of gas systems in order to diversify and ensure stable gas supplies to end customers; Increasing safety of systems and markets | DK • PL : 9 mcm/d; PL • DK : 3-7,5 mcm/d | 450 M€ | Poland, Denmark | EIA ongoing | N/A | Dependent on market demand –not earlier than 2013 |
| **Romania** | 1 –Interconnection between the Romanian and Bulgarian Gas Transmission Systems | Construction of a new interconnection pipeline between the Bulgarian and Romanian Gas Transmission Systems | 1,5 bcm/a | Depending on results of study | Romania, Bulgaria | Feasability study | 2010-2011 | Depending on results of study |
| **Belgium** | 1 –Zelzatemetering | Reverse metering station at Zelzate to allow flows from NL to BE | 1.2 mcm/h (59 bar) | 3,9 M€ | BE, NL | Phase 1 under construction | Phase 1 : 2009-2010 Phase 2 : 2011 | Phase 1 : end 2010 Phase 2 : 2011Bi- |
| **Czech Republic** | 3 b) Flexibility increase of gas storage to transit system | (UGS Dolni Dunajovice –CS Breclav) | 16 mcm/d | 36 M€ | CzechRepublic, Germany, Slovakia | Running | 2009-2011 | Q4/2011 |

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|---|---|---|---|---|---|---|---|---|
| **Germany** | E.ON Gastransport: North-South de-bottlenecking | Numerous capacity expansion projects, including major north-south de-bottlenecking. This improves transport capacity via Austria to South-East Europe. | Austria : 4.742 MW (Exit: approx. 18.000 MW; Entry: approx. 11000 MW) | approx. 400 M€ | Germany, Austria | Investment decision taken | 2009-2012 | part 2011, part 2012 |
| **Romania** | 2 –Interconnection pipeline between the Romanian | Construction of a new interconnection pipeline between the Hungarian and Romanian gas transmission systems | max. 4,4 bcm/a | 12 M€ | Romania, Hungary | Under development | 2009 | 2010 |
| **Slovakia** | 3–Capacity increase of Labstorage connection | Increase of the daily capacity in a connection between underground storage Laband eustream transmission system | 4 mcm/day | 0,4 M€ | Slovak republic | In implementation | 2009 | 2010 |
| **United Kingdom** | 1 – KingsLynntoWisbech | GoalIncrease West-East transport capacity from sources such as the new LNG terminals in Wales towards Bacton Interconnectors | 81 GWh/d | 79,2 M€ (assuming £1 = €1.1) | UK, Netherlands, Belgium | Feasibility study and conceptual design stages completed | 09/10 – €27,72m; 10/11 - €43,56m; 11/12 -€7,92m | 2011 |
| **United Kingdom** | 2 – WisbechtoPeterborough | Increase West-East transport capacity from sources such as the new LNG terminals in Wales towards Bacton Interconnectors | 76 GWh/d | 108,2 M€ (assuming £1 = €1.1) | UK, Netherlands, Belgium | Feasibility study completed | 09/10 – €5,41m; 10/11 -€32,46m; 11/12 - €59.51m; 12/13 - €10,82m | 2012 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **France** | 1 –TaisnièresH - Existingfacilities | Existing reverse flows capacities | Up to 1.106 (n) m3/h of odorised gas(about 55 bar) | N/A | France,Belgium | Implemented | N/A | In operation |
| **France** | 3 –Obergailbach- Existing facilities | Existing reverse flows capacities | 300 000 (n) m3/h of odorised gas (65 bar) | N/A | France, Germany | implemented | N/A | In operation |
| **Slovakia** | 1 –Bi-directional flow in transmission system | Enabling reverse flow in Slovak gas transmission system | 60,0 mcm/day at 56 barg | 3,5M€ | Slovak republic | In preparation | 2009 | 2010 |
| **Slovakia** | 2–Connection Slovakia –Hungary (Slovak part) | Construction of a pipeline connecting Slovak gas transmission system with Hungarian gas transmission system | 30 mcm/day | Slovakia 20M€ | Slovak republic, Hungary | Planning | 2009 | 2012 |
| **Slovakia** | 4 –New connection to storage Gajary-Baden | Construction of a connection between the new underground storage Gajary-Baden and eustreamtransmission system | 22 mcm/day | 9M€ | Slovakrepublic | In preparation | 2009 | 2011 |
| **Spain** | 1 –Larrau reverse flow | Increase of main flows and development of reverse flow between France and Spain through the Larrau interconnection point | ES • FR : 110 GWh/day (summer), 100 (winter); FR • ES : 100 GWh/day | N/A | France, Spain | Coordinated Open Suscription Period done (Enagás • TIGF) | 2009 | Increase of main flow capacity: 1st April 2009; Reverse flow capacity (ES • FR): 1st November 2010; Increase of reverse flow |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | capacity (4Q 2012) |
| **Bulgaria** | 1 – ReverseflowfromTurkeyat Malkochlar | Allow reverse flow from Turkey to Bulgaria at Malkochlar interconnection point | N/A | 0,25 M€ | Turkey, Bulgaria | N/A | N/A | N/A |
| **Bulgaria** | 2 – IncreasereverseflowfromTurkeytoBulgaria | Increase capacity of transit system and enhance reverse flow from Turkey to Bulgaria | 2.4 mcm/day | 25 M€ | Bulgaria | N/A | N/A | N/A |
| **Bulgaria** | 3 – ReverseflowfromGreeceat Kula/ Sidirokastron | Improving SoS of Bulgaria by allowing reverse flow from Greece | 2.4 mcm/day | N/A | Bulgaria | N/A | N/A | N/A |
| **Austria** | OMV Gas : 4 – Upgrading the Überackernexport facility | Availability of reverse flow of Penta West system | 0,3 mcm/h at 65 bar | 1,7 M€ | Austria, CEE countries | Planned | 2009 | 2011 |
| **Czech Republic** | 1 a) Adaptations at BTS HoraSv. Kateriny | Cross-border SoS, increase of reverse flow capacity from existing 16 mcm/dup to 24 mcm/dfrom Germany (Sayda) to Czech Rep. | 8 mcm/d | 0.6 M€ | CzechRepublic, Germany, Slovakia | Planned | 2010-2011 | Q4/2011 |

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|---|---|---|---|---|---|---|---|---|
| **Germany** | WingasTransport : Upgrading the import grid point “Überackern”forbi-directional use | 0.3 mcm/h at 70 bar | N/A | N/A | Germany, Austria | Planned | N/A | Q1/2011 |
| **Italy** | 1 –Additionalcapacityat Tarvisioexit point | Increase existing export capacity from Italy to Austria at Tarvisioexit point | 40 mil Sm³/d | 15 M€ | Italy | Planned | 18 months | Q1/2011 |
| **Romania** | 3 –Technical solution for supplying Bulgaria from the Romanian transmission system | Create a technical possibility to supply Bulgaria with natural gas from the Romanian transmission system in crisis situations | 2,6 mcm/d | approx. 2 M€ | Romania, Bulgaria | Planned | 2010-2011 | Yet unknown |
| **Czech Republic** | 1 b) Adaptation of piping at JPHospozin | The project will increase reverse flow capacity and higher flexibility of the transmission system | up to 15 mcm/d | 0,7 M€ | CzechRepublic, Germany, Slovakia | Ready for implementation | 2009-2010 | Q4/2010 |
| **Czech Republic** | 1 c) Adaptation of piping at CS Kralice nad Oslavou | Cross-border SoS, increase of existing reverse flow gas compression at CS B•eclavfrom 25 mcm/dup to 39,5 mcm/din the direction from H. Sv. Kate•iny(north) to Czech (Moravian UGSs) and further to Waidhaus(Germany) or Lanžhot(Slovakia) | up to 14,5 mcm/d*) | 2,9 M€ | CzechRepublic, Germany, Slovakia | Ready for implementation | 2009-2010 | Q4/2010 |
| **Czech Republic** | 1 d) Adaptation of piping at JP Malesovice | Cross-border SoS, increase of existing reverse flow capacityfrom25 mcm/d upto 35 mcm/d in the direction fromH. Sv. Kate•iny(north) via Malešovice to Waidhaus (Germany)or Lanžhot (Slovakia). | 10 mcm/d *) | 1,3 M€ | CzechRepublic, Germany, Slovakia | Ready for implementation | 2009-2010 | Q4/2010 |

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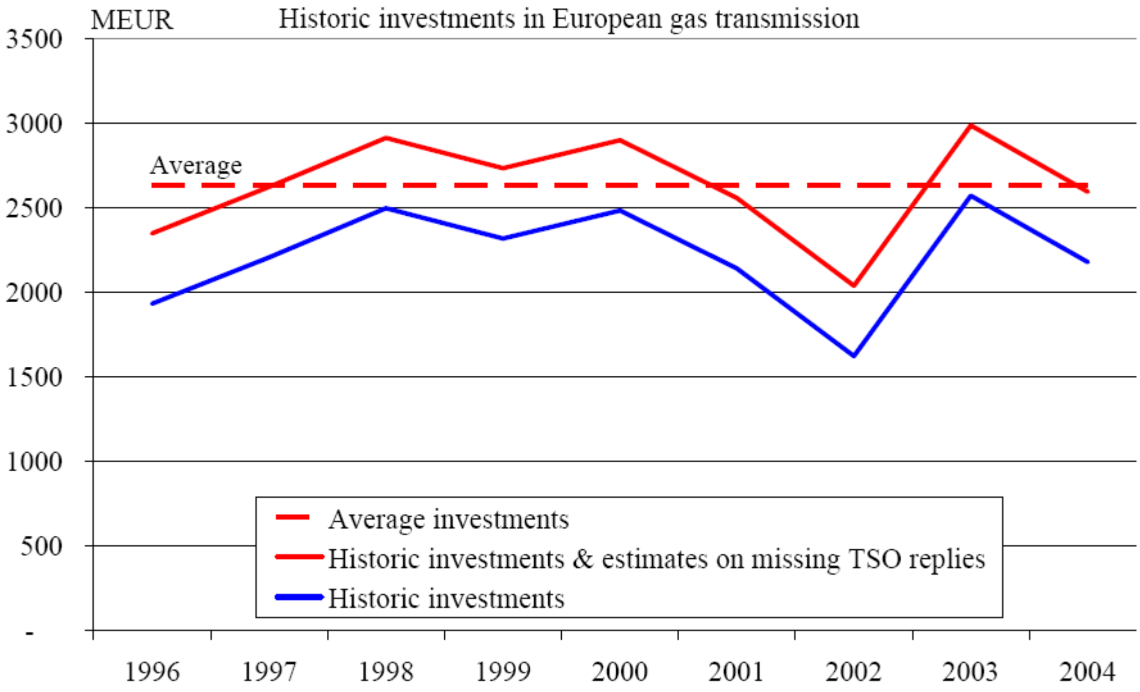
|---|---|---|---|---|---|---|---|---|
| **Czech Republic** | 1 e) Adaptationof thepipingsystém of hallI. of CS BreclavenablinggastransmissionfromtheCzech Republicto theSlovakRepublic | Cross-border SoS, reverse flow gas compression at CS B•eclav (from Czechto Slovakia). | 15mcm/d | 0,5 M€ | CzechRepublic, Germany, Slovakia | Ready for implementation | 2009-2010 | Q4/2010 |
| **Czech Republic** | 1 f)Adaptationof BTS Lanzhotforwest-to-easttransmission | CrossborderSoS, reverse flow gas compression at BTS Lanžhot (fromCzechto Slovakia). | 28 mcm/d | 1,35 M€ | CzechRepublic, Germany, Slovakia | Ready for implementation | 2009-2010 | Q4/2010 |
| **Czech Republic** | 3 a) Flexibility increase of gas storage to transit system (UGS Tvrdonice –CS Breclav) | CrossborderSoS, UGS connection to transit system. | 10 mcm/d | 4.6 M€ | Czech Republic, Germany, Slovakia | Ready for implementation | 2009-2010 | Q4/2010 |
| **Poland** | 2 –Poland-Czech Rep. Connection –Phase I | Integration of gas systems in order to diversify and ensure stable gas supplies to end customers; Increasing safety of systems operations | PL • CZ : up to 1,6 mcm/d | 21 M€ | Poland, Czech Republic | Construction in 2010 | Pipeline: 18 M€<br>Transfer station: 3M€ | 2010 |
| **Hungary** | 1–Városföld node modification | Help to cover the demand for capacity in the domestic transmission and transport of gas towards Serbia, Bosnia Herzegovina, Romania and later towards Croatia | 1.0 mcm/h at 63 bar | 5,5 M€ | Hungary | Under decision | 2010 | 2011 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hungary** | 2–Pilisvörösvár node modification | New flow control system at Pilisvörösvár node | 8-9 mcm/d at 50 bar | 3,5 M€ | Hungary | Under decision | 2010 | 2011 |
| **Hungary** | 3–Adony nodemodification | Reverse flow connections and flow control systems at Adonynode | 14 mcm/dat 50 barg | 2,5 M€ | Hungary | Under decision | Underdecision | 2011 |
| **Hungary** | 4–Algy•nodeflow control system | New flow control system at Algy•node | 3 mcm/d at 50 bar | 2,1 M€ | Hungary | Under decision | 2010 | 2011 |
| **Hungary** | 5–Vecsésnode flow control system | New flow control system at Vecsésnode | 3,6 mcm/d at 50 bar | 1.5 M€ | Hungary | Under decision | 2010 | 2010 |
| **Hungary** | Slovak-Hungary Interconnection pipeline | New interconnection pipeline between Hungary and Slovakia allowing a diversification of gas supplies for Hungary and neighbouring countries and more stable gas supplies to end-customers | 14,4 mcm/d at 40 bar | 120-130.0 M€ (preliminary) | Slovakia, Hungary | Under decision | N/A | 2012-2013 |
| **Spain** | 2 –Biriatou, Larrau: 2013 Capacities* | Increase of reverse and main flows between Spain and TIGF and vice versa | Larrau : 55 GWh/day (total : 165);<br>Biriatou : 55 GWh/day (total : 60) | N/A | France, Spain | OS under development | 2009-2010 | 2013 |
| **Spain** | 3 –MidCat: 2015 Capacities* | New interconnection point between Spain and France and vice versa | ES • FR : 230 GWh/day;<br>FR • ES : 180 GWh/day | N/A | France, Spain | OS under development | 2010 | 2015 |

## 7.7 Investments

Fig. 7.7.1: EU 30 historic investments in EU gas transmission[68]



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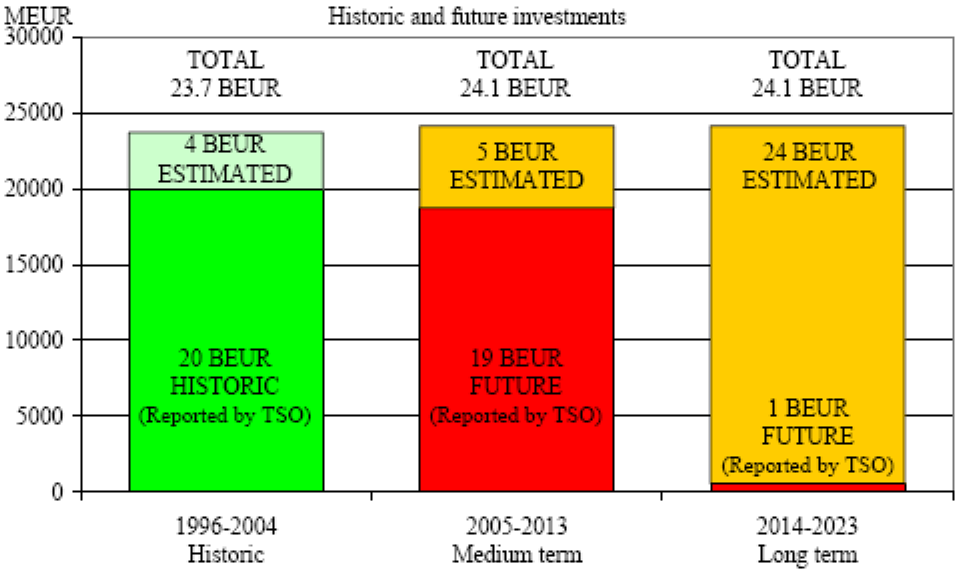
[68] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighbouring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy ,IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005; (data were missing, and therefore estimated according to the length of the transmission system, for Luxemburg, Czech Republic, Austria, Bulgaria, Slovakia, three TSOs from Germany and partly for Spain). The data has been adjusted.

Figure 7.7.2: EU 30: TSO reported historic and future investments (result of survey) – investments in TSO national grid[69]



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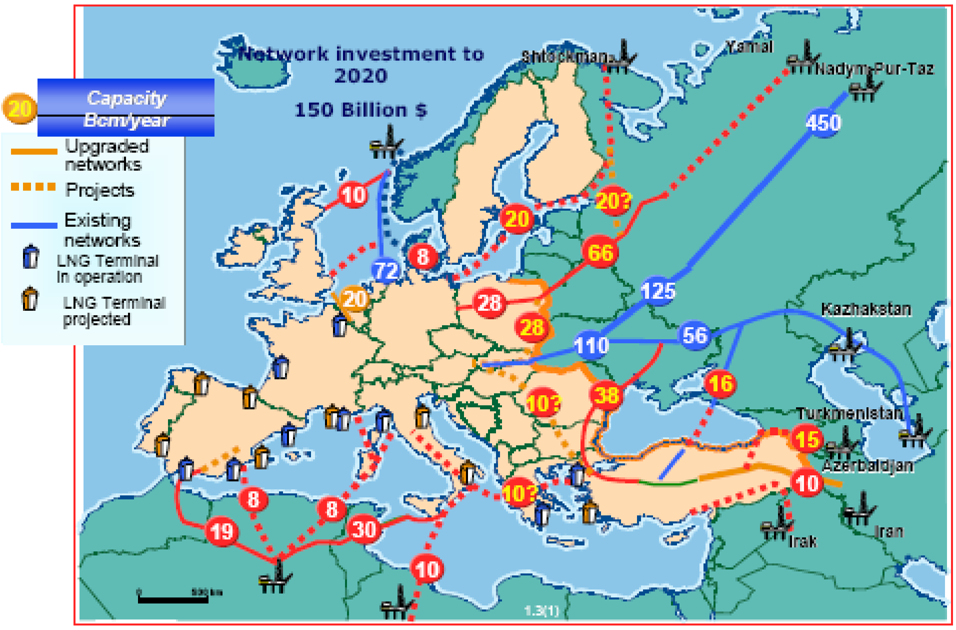
[69] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighbouring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy, IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.

Figure 7.7.3 : Network investments to 2020[70]



Tab. 7.7.4 : Gas pipeline supply routes[71]

| Pipeline Route | EU list | Type of Work | Capacity bcm/year | Estimated cost M EUR |
|---|---|---|---|---|
| Russia-Germany | NG1 | New pipeline offshore in Baltic Sea | 35 | 4700 |
| Yamal Europe II | NG1 | Second line across Poland | 32 | 1520 |
| Yamal Europe, doubling capacity | NG1 | Third line across Poland | 32 | 1520 |
| Across the strait of Gibraltar | NG2 | New pipeline | 9 | 150 |
| Algeria-Spain (Medgaz) | NG2 | New deep water offshore pipeline | 18 | 1437 |
| Algeria-France/Italy | NG2 | New pipeline | 20 | 5000 |
| Turkey-Grece-Italy | NG3 | New pipeline | 8 | 1612 |
| Turkey-Austria | NG3 | Nabucco pipeline | 30 | 4400 |
| Total | | | 184 | 20340 |

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[70] Energy center of the Netherlands, www.ecn.nl: http://www.ecn.nl/fileadmin/ecn/units/bs/INDES/indes-pc2_paper.pdf (21/02/10).

[71] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighbouring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy ,IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.

Table7.7.5 : Gas pipeline supply routes: Analysis[72]

| Location/Entry point in EU | Exit point (EU) | Capacity (bcm/yr) | Total length (km) | Estimated budget (M€) | Starting project date | Starting operation (estimated) |
|---|---|---|---|---|---|---|
| **Lithuania** | Poland | 5 | 300 | 300 | | 2014 |
| **Denmark** | Germany | 3 | 200 | 225 | | 2006 |
| **Norway** | Poland | 3 | 260 | 350 | 2001 | 2011 |
| **Finland** | Estonia | 2 | 80 | 100 | | 2011 |
| **Algeria** | Italy | 8 | 900 | 1.200 | | 2010 |
| **Turkey** | Greece | 8 | 600 | 450 | | 2012 |
| **Norway** | United Kingdom | 22 | 1.200 | 1.200 | | 2007 |
| **Algeria** | Spain | 8 | 210 | 1.437 | 2001 | 2009 |
| **Romania** | Austria | 31 | 3.300 | 7.900 | 2002 | 2014 |
| **Russia** | Germany | 55 | 1.220 | 6.000 | | 2010 |
| **Greece** | Italy | 8 | 210 | 500 | 2004 | 2012 |
| **Georgia** | Romania | 32 | 1.238 | 2.500 | | 2016 |

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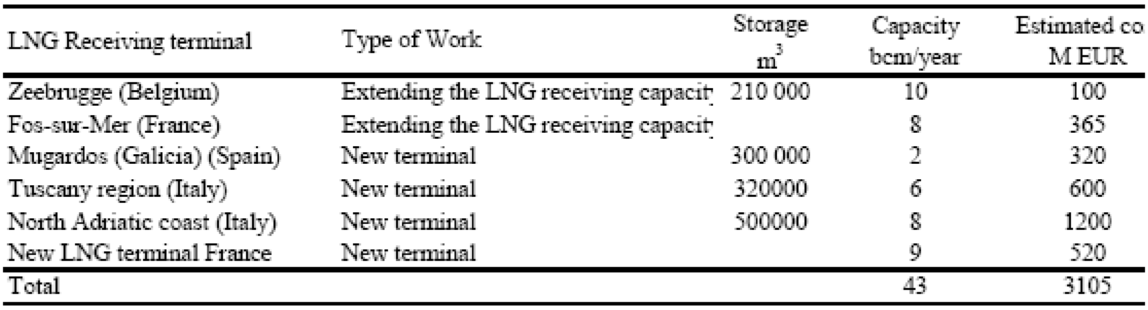
[72] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighbouring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy, IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.; Various sources including projects presentations and web sites www.nabucco-pipeline.com, www.nord-stream.com, www.igi-poseidon.com; own calculation.

Table7.7.6: Investments in new import capacity[73]



| LNG Receiving terminal | Type of Work | Storage $m^3$ | Capacity bcm/year | Estimated co M EUR |
|---|---|---|---|---|
| Zeebrugge (Belgium) | Extending the LNG receiving capacit | 210 000 | 10 | 100 |
| Fos-sur-Mer (France) | Extending the LNG receiving capacit | | 8 | 365 |
| Mugardos (Galicia) (Spain) | New terminal | 300 000 | 2 | 320 |
| Tuscany region (Italy) | New terminal | 320000 | 6 | 600 |
| North Adriatic coast (Italy) | New terminal | 500000 | 8 | 1200 |
| New LNG terminal France | New terminal | | 9 | 520 |
| Total | | | 43 | 3105 |

Energy Infrastructure Costs and Investments between 1996 and 2013(medium-term) and further to 2023 (long-term) on the Trans-EuropeanEnergy Network and its Connection to Neighboring Regions withemphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including anInventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy
,IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.

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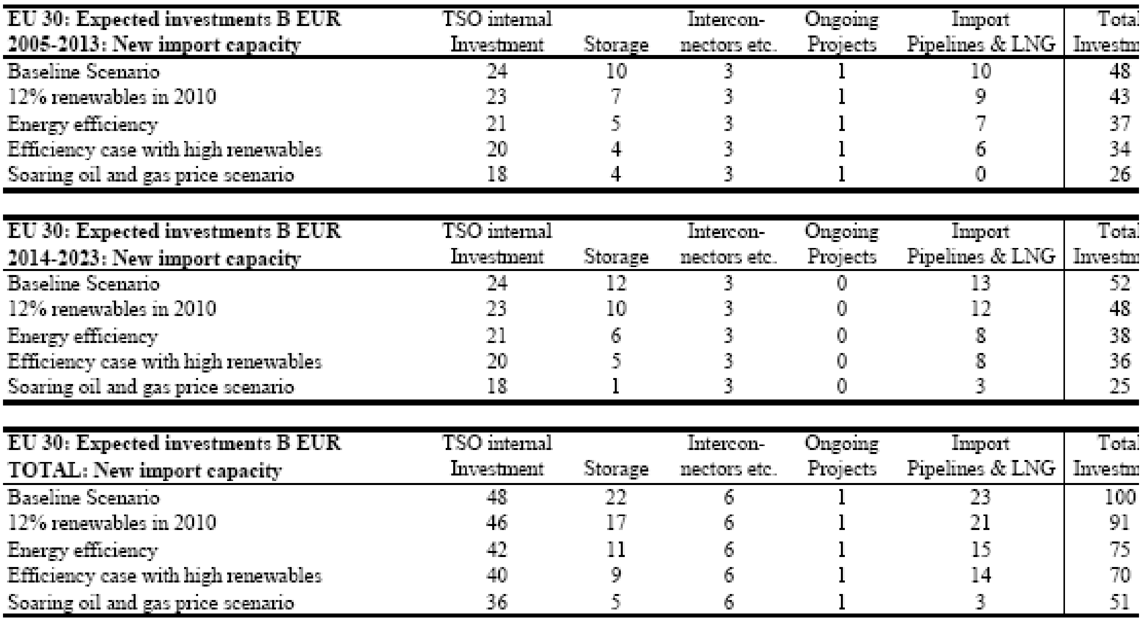
[73] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighbouring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy ,IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.

Table 7.7.7: Total investments till 2013 and till 2023[74]



| **EU 30: Expected investments B EUR 2005-2013: New import capacity** | TSO internal Investment | Storage | Intercon-nectors etc. | Ongoing Projects | Import Pipelines & LNG | Total Investm |
|---|---|---|---|---|---|---|
| Baseline Scenario | 24 | 10 | 3 | 1 | 10 | 48 |
| 12% renewables in 2010 | 23 | 7 | 3 | 1 | 9 | 43 |
| Energy efficiency | 21 | 5 | 3 | 1 | 7 | 37 |
| Efficiency case with high renewables | 20 | 4 | 3 | 1 | 6 | 34 |
| Soaring oil and gas price scenario | 18 | 4 | 3 | 1 | 0 | 26 |

| **EU 30: Expected investments B EUR 2014-2023: New import capacity** | TSO internal Investment | Storage | Intercon-nectors etc. | Ongoing Projects | Import Pipelines & LNG | Total Investm |
|---|---|---|---|---|---|---|
| Baseline Scenario | 24 | 12 | 3 | 0 | 13 | 52 |
| 12% renewables in 2010 | 23 | 10 | 3 | 0 | 12 | 48 |
| Energy efficiency | 21 | 6 | 3 | 0 | 8 | 38 |
| Efficiency case with high renewables | 20 | 5 | 3 | 0 | 8 | 36 |
| Soaring oil and gas price scenario | 18 | 1 | 3 | 0 | 3 | 25 |

| **EU 30: Expected investments B EUR TOTAL: New import capacity** | TSO internal Investment | Storage | Intercon-nectors etc. | Ongoing Projects | Import Pipelines & LNG | Total Investm |
|---|---|---|---|---|---|---|
| Baseline Scenario | 48 | 22 | 6 | 1 | 23 | 100 |
| 12% renewables in 2010 | 46 | 17 | 6 | 1 | 21 | 91 |
| Energy efficiency | 42 | 11 | 6 | 1 | 15 | 75 |
| Efficiency case with high renewables | 40 | 9 | 6 | 1 | 14 | 70 |
| Soaring oil and gas price scenario | 36 | 5 | 6 | 1 | 3 | 51 |

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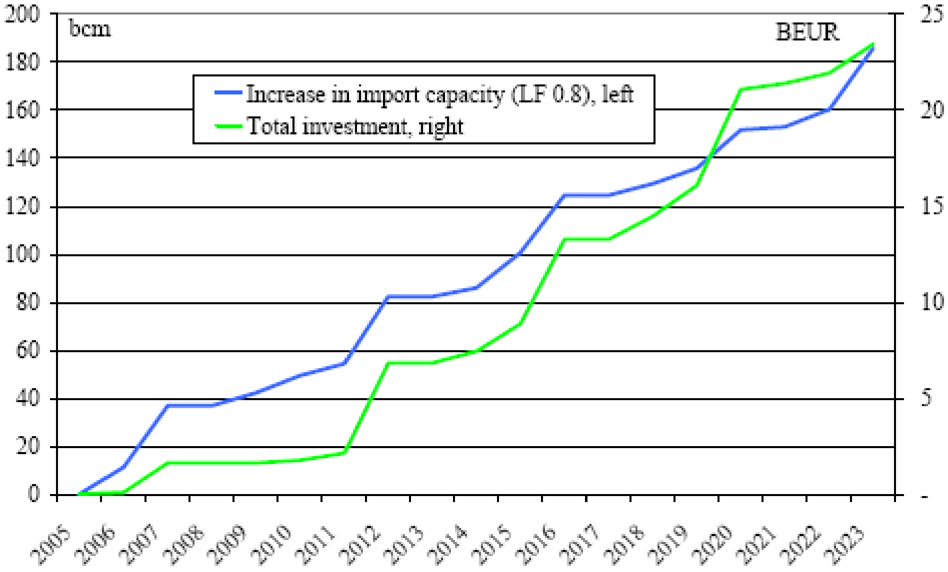
[74] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighbouring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy ,IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.

Fig. 7.7.8: The development of investment needs in new import routes only[75]



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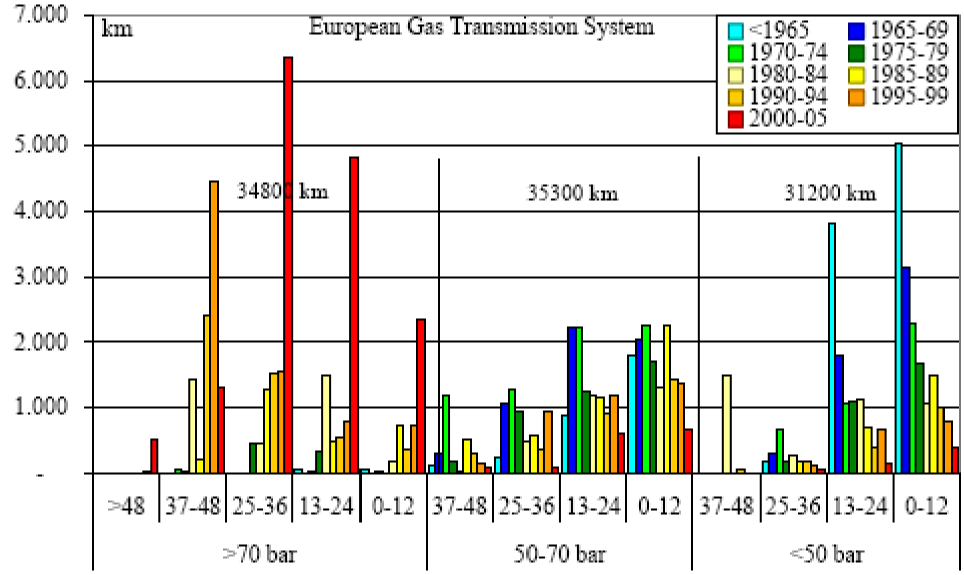
[75] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighboring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy ,IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.

Fig. 7.7.9: EU 30 current gas transmission system showing age, pipelinemissing for several TSOs)[76]



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[76] Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighbouring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy,IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.

Figure 7.7.10: Cost of underground gas storage as function of working gas capacity[77]

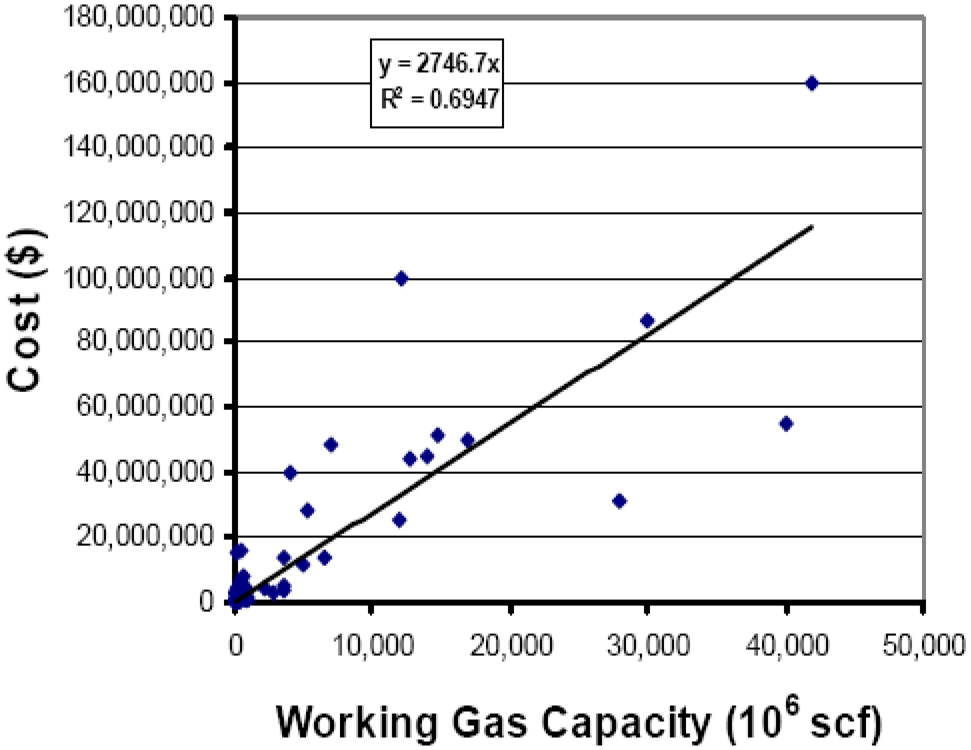
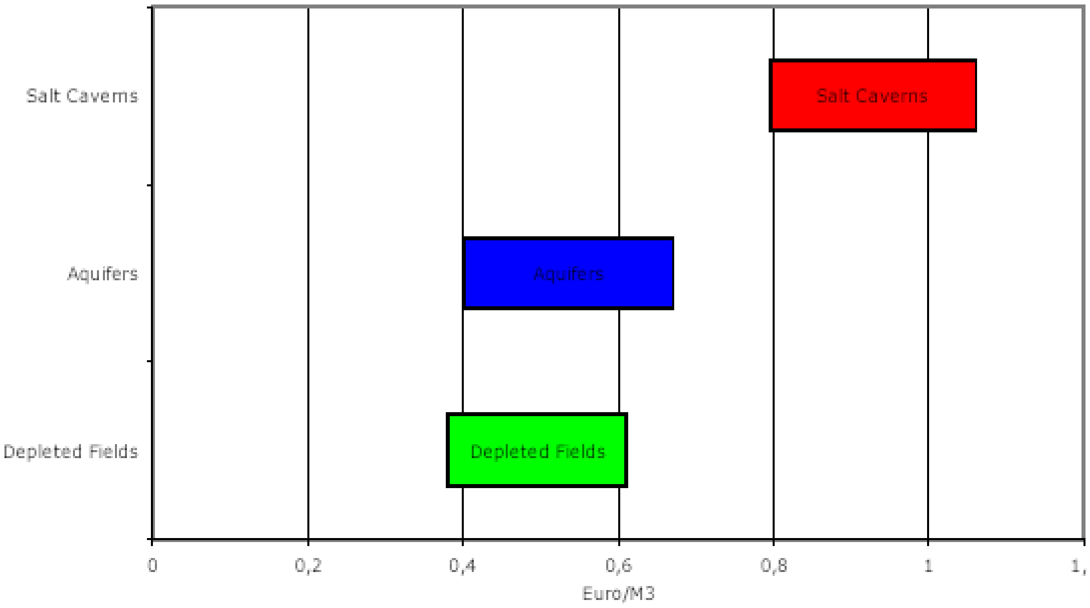


Figure 7.7.11: Investment cost EUR/m³ for different volume storages[78]



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[77] In DG TREN C1; Study on natural gas storage in the EU, Draft Final Report, October 2008.

[78] DG TREN C1; Study on natural gas storage in the EU, Draft Final Report, October 2008.

Table 7.7.12: Projects in Authorization phase (situation in 2006)[79]

| New Ten Code Annex III | Axis | Country A | Country B | Priority project (guidelines) | Estimated cost (M€) |
|---|---|---|---|---|---|
| **6.3** | NG4 | ES | ES | LNG terminal in Las Palmas de Gran Canaria (ES) | 152 |
| **6.8** | | GR | GR | Extension of the gas network to Corinth | 32 |
| **7.12** | NG3 | GR | IT | Interconnector Greece Italy | 966 |
| **7.13** | | GR | GR | Compression station on the main pipeline in Greece | 34 |
| **7.16** | NG3 | AT | TR | Corridor Austria-Turkey renamed Nabucco pipeline | 4.600 |
| **7.21** | NG1 | DE | SE | Baltic gas interconnector between Denmark, Germany and Sweden | 300 |
| **8.11** | NG4 | IT | IT | LNG terminal near Trieste | 580 |
| **8.14** | NG4 | IT | IT | LNG Terminal near Tarento | 496 |
| **8.15** | NG4 | IT | IT | LNG terminal near Genoa Turo | 365 |
| **8.16** | NG4 | IT | IT | LNG terminal at Livorno (offshore) | 250 |
| **8.16** | NG4 | IT | IT | LNG terminal at Rosignano | 270 |
| **8.27** | NG5 | ES | ES | Underground gas storage Rous (COSA) | 180 |
| **8.34** | | AT | AT | Underground storage Haidach (new site), including pipeline to EU grid | 250 |
| **9.1** | NG1 | DK | SE, NO | Scandinavian gas ring | 500 |
| **9.14** | NG1 | DK | LT | UE Amber - 2nd version Niechorse-Gdansk-Suwallei-Jaumunsi | |
| **9.14** | | SK | SK | Transport pipeline upgrading: increase of the transport capacity and link to underground storage | 40 |
| **9.21** | NG3 | BG | SB | Dupnica (BG) - Nis (Serbia) gas pipeline | 100 |
| **9.27** | BalticPipe EIA | | | | |
| **9.31** | NG2 | DZ | IT | TRANSMED from Sicilia to Italy - NTN's neuw compression units | 539 |

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[79] COMMISSION STAFF WORKING DOCUMENT; Annex to the REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS ON THE IMPLEMENTATION OF THE GUIDELINES FOR TRANS-EUROPEAN ENERGY NETWORKS IN THE PERIOD 2002 –2004; Pursuant to Article 11 of Decision 1229/2003/EC; {COM(2006) 443 final}; 7.8.2006.

## 7.8 Link with Primes

Table: 7.8.1: PRIMES forecasts till 20020 and 2030 (in ktoe)[80]

| Country | Item | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| **Austria** | Net Imports | 7.070 | 9.573 | 9.232 |
| **Austria** | Gross Inland Consumption | 8.517 | 9.973 | 9.232 |
| **Belgium** | Net Imports | 14.491 | 16.833 | 17.861 |
| **Belgium** | Gross Inland Consumption | 14.491 | 16.833 | 17.861 |
| **Bulgaria** | Net Imports | 2.549 | 2.710 | 3.692 |
| **Bulgaria** | Gross Inland Consumption | 2.785 | 2.879 | 3.814 |
| **Cyprius** | Net Imports | 195 | 602 | 805 |
| **Cyprius** | Gross Inland Consumption | 195 | 602 | 805 |
| **Czech Republic** | Net Imports | 7.788 | 8.269 | 8.786 |
| **Czech Republic** | Gross Inland Consumption | 7.947 | 8.438 | 8.965 |
| **Denmark** | Net Imports | -4.298 | -2.568 | -2.171 |
| **Denmark** | Gross Inland Consumption | 4.702 | 2.809 | 2.829 |
| **Estonia** | Net Imports | 973 | 798 | 867 |
| **Estonia** | Gross Inland Consumption | 973 | 798 | 867 |
| **Finland** | Net Imports | 4.163 | 4.675 | 4.188 |
| **Finland** | Gross Inland Consumption | 4.163 | 4.675 | 4.188 |
| **France** | Net Imports | 42.901 | 43.488 | 44.465 |
| **France** | Gross Inland Consumption | 42.901 | 43.488 | 44.465 |
| **Germany** | Net Imports | 68.153 | 75.578 | 81.499 |
| **Germany** | Gross Inland Consumption | 81.653 | 86.578 | 89.999 |
| **Greece** | Net Imports | 4.320 | 5.750 | 6.485 |

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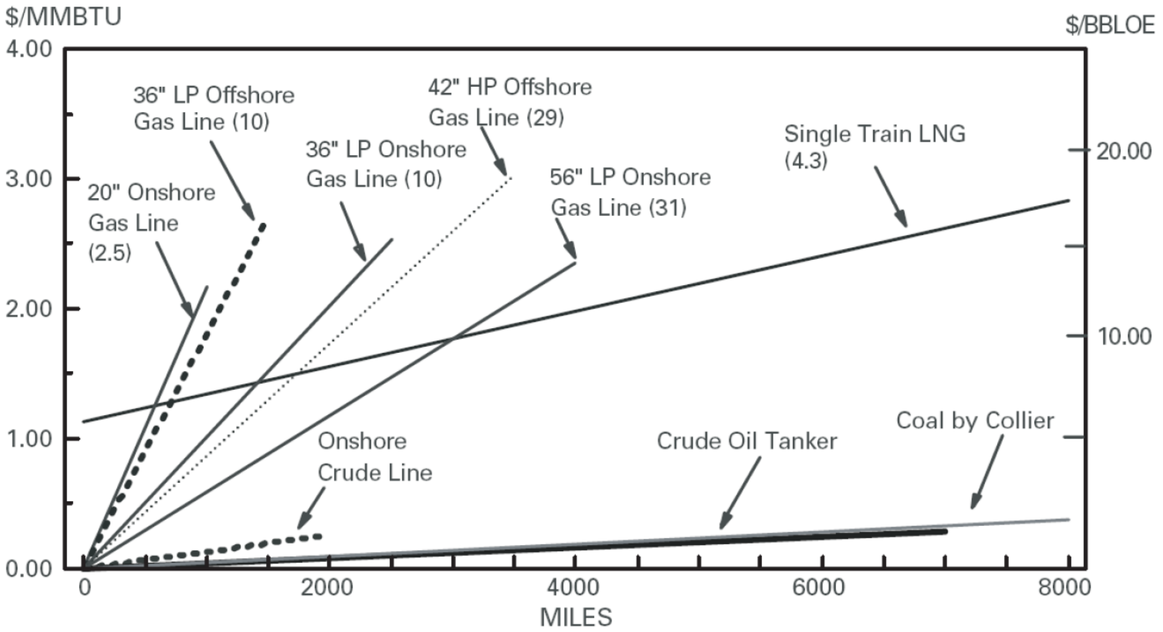
[80] EUROPEAN ENERGY AND TRANSPORT TRENDS TO 2030 — UPDATE 2007; EU-27 ENERGY BASELINE SCENARIO TO 2030; European Commission: Directorate-General for Energy and Transport; April 2008.

| | | | | |
|---|---|---|---|---|
| **Greece** | Gross Inland Consumption | 4.354 | 5.750 | 6.485 |
| **Hungary** | Net Imports | 10.389 | 12.651 | 13.541 |
| **Hungary** | Gross Inland Consumption | 12.589 | 14.551 | 15.241 |
| **Ireland** | Net Imports | 3.250 | 3.756 | 4.106 |
| **Ireland** | Gross Inland Consumption | 3.748 | 4.331 | 4.606 |
| **Italy** | Net Imports | 67.755 | 80.874 | 88.024 |
| **Italy** | Gross Inland Consumption | 78.779 | 88.874 | 96.024 |
| **Latvia** | Net Imports | 1.594 | 2.109 | 2.387 |
| **Latvia** | Gross Inland Consumption | 1.594 | 2.109 | 2.387 |
| **Lithuania** | Net Imports | 3.663 | 3.628 | 4.231 |
| **Lithuania** | Gross Inland Consumption | 3.663 | 3.628 | 4.231 |
| **Luxembourg** | Net Imports | 1.161 | 1.405 | 1.428 |
| **Luxembourg** | Gross Inland Consumption | 1.161 | 1.405 | 1.428 |
| **Malta** | Net Imports | 59 | 106 | 220 |
| **Malta** | Gross Inland Consumption | 59 | 106 | 220 |
| **Netherlands** | Net Imports | -16.148 | -10.552 | 5.019 |
| **Netherlands** | Gross Inland Consumption | 37.152 | 38.628 | 37.689 |
| **Poland** | Net Imports | 10.911 | 16.093 | 20.606 |
| **Poland** | Gross Inland Consumption | 14.111 | 19.093 | 23.306 |
| **Portugal** | Net Imports | 4.423 | 4.750 | 5.750 |
| **Portugal** | Gross Inland Consumption | 4.423 | 4.750 | 5.750 |
| **Romania** | Net Imports | 4.524 | 5.845 | 9.530 |
| **Romania** | Gross Inland Consumption | 14.874 | 16.853 | 19.352 |
| **Slovak Republic** | Net Imports | 6.010 | 7.199 | 8.350 |
| **Slovak Republic** | Gross Inland Consumption | 6.141 | 7.355 | 8.532 |

| | | | | |
|---|---|---|---|---|
| **Slovenia** | Net Imports | 1.156 | 1.367 | 1.588 |
| **Slovenia** | Gross Inland Consumption | 1.161 | 1.367 | 1.588 |
| **Spain** | Net Imports | 35.008 | 38.360 | 33.285 |
| **Spain** | Gross Inland Consumption | 35.138 | 38.360 | 33.285 |
| **Sweden** | Net Imports | 1.382 | 2.767 | 2.853 |
| **Sweden** | Gross Inland Consumption | 1.382 | 2.767 | 2.853 |
| **United Kingdom** | Net Imports | 10.783 | 53.897 | 54.820 |
| **United Kingdom** | Gross Inland Consumption | 73.783 | 77.897 | 69.820 |

Figure 7.8.2: Break-even of LNG and pipeline transportation[81]



Note: Numbers in brackets show gas delivery capability in BCM

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[81] Jensen (2004); in: Advice on the Opportunity to Set up an Action Plan for the Promotion of LNG Chain Investments-Economic, Market, and Financial Point of View -FINAL REPORT, Chair of Energy Economics and Public Sector Management, Dresden University of Technology; Prof. Dr. Christian von Hirschhausen, Dr. Anne Neumann, Dipl.-Wi.-Ing. Sophia Ruester, Danny Auerswald, Study for the European Commission, DG-TREN, Contracting party: MVV Consulting; Dresden, May 2008.

# 8 Appendix VIII: Chapter 4 Tables Expressed in Mtoe

**TABLE 8.1 (4.1): ESTIMATIONS OF FUTURE GAS IMPORT POTENTIAL**

| **Origin (in Mtoe/yr)** | **2010** | **2020** | **2030** |
|---|---|---|---|
| Russia/ Central Asia | 143 | 169 | 178 |
| Norway | 81 | 82 | 86 |
| Algeria | 70 | 95 | 99 |
| Libya | 10 | 22 | 33 |
| Egypt | 24 | 24 | 24 |
| Trinidad & Tobago/ Venezuela | 5 | 5 | 5 |
| West Africa | 18 | 33 | 39 |
| Iraq | 17 | | |
| Qatar/UAE/Oman/Yemen | 3 | 59 | 76 |
| Iran | | 30 | 30 |
| Azerbaijan/Turkmenistan | | 11 | 11 |

Source(s): OME.

### TABLE 8.2 (4.2): CAPACITIES OF MAIN EU SUPPLY ROUTES

| Max flow in Mtoe/ yr | Type | BE | DE/NL | ES | FI | FR | GR | HU | IT | LT | LV | PL | PT | RO | SK | UK | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Russia | Pipelines | | | | 6.0 | | | 12.3 | | 9.1 | 1.1 | 31.6 | | | 93.1 | | 153.2 | 36.2% |
| Ukraine | Pipelines | | | | | | | | | | | 4.9 | | 35.8 | | | 40.7 | 9.6% |
| Algeria | Pipelines | | | 9.6 | | | | | 27.3 | | | | | | | | 36.9 | 8.7% |
| Norway | Pipelines | 12.6 | 37.8 | | | 16.0 | | | | | | | | | | | 66.5 | 15.7% |
| Libya | Pipelines | | | | | | | | 8.6 | | | | | | | 31.4 | 40.0 | 9.5% |
| Subtotal | Pipelines | 12.6 | 37.8 | 9.6 | 6.0 | 16.0 | | 12.3 | 35.9 | 9.1 | 1.1 | 36.5 | | 35.8 | 93.1 | 31.4 | 337.2 | 79.7% |
| Other imports | LNG terminal | 7.3 | | 46.9 | | 15.8 | 1.8 | | 4.1 | | | | 5.2 | | | 4.7 | 85.7 | 20.3% |
| Grand total | | 19.8 | 37.8 | 56.5 | 6.0 | 31.8 | 1.8 | 12.3 | 40.0 | 9.1 | 1.1 | 36.5 | 5.2 | 35.8 | 93.1 | 36.1 | 422.9 | 100.0% |
| % | | 4.7% | 8.9% | 13.4% | 1.4% | 7.5% | 0.4% | 2.9% | 9.5% | 2.1% | 0.3% | 8.6% | 1.2% | 8.5% | 22.0% | 8.5% | 100.0% | |

Source(s): T E N - ENERGY Priority Corridors for Energy Transmission; Part One: Legislation, Natural Gas and Monitoring; prepared by Ramboll A/S and Mercados SA; November 2008.

## TABLE 8.3 (4.5): CAPACITY FORECASTS OF SUPPLY ROUTES UNDER DEVELOPMENT

| Capacity (Mtoe/yr) | 2010 | 2011 | 2012 | 2014 | 2016 | Total |
|---|---|---|---|---|---|---|
| Pipeline mix | 7 | | | | | 7 |
| Pipeline offshore | 47 | 4 | 7 | | 28 | 86 |
| Pipeline onshore | | | 7 | 31 | | 38 |
| Total | 54 | 4 | 14 | 31 | 28 | 131 |

Source(s): Energy Infrastructure Costs and Investments between 1996 and 2013 (medium-term) and further to 2023 (long-term) on the Trans-European Energy Network and its Connection to Neighbouring Regions with emphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including an Inventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy, IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005.; Various sources including projects presentations and web sites www.nabucco-pipeline.com, www.nord-stream.com, www.igi-poseidon.com; own calculation.

## TABLE 8.4 (4.6): BREAKDOWN OF NEW LNG PROJECTS STATUS

| Send out capacity (Mtoe/yr) | After extension | Existing after extension | Proposed | Under construction | Total |
|---|---|---|---|---|---|
| 2010 | | 17.9 | 7.8 | 13.8 | 39.5 |
| 2011 | | 15.3 | 16.4 | 38.2 | 69.9 |
| 2012 | | | 12.2 | 1.7 | 14.0 |
| 2013 | 6.3 | | 7.8 | | 14.1 |
| 2014 | | 31.5 | 23.6 | | 55.1 |
| 2015 | | 10.2 | 6.9 | | 17.1 |
| N/A | | 14.2 | 9.3 | | 23.5 |
| Total | 6.3 | 89.1 | 84.0 | 53.7 | 233.0 |

Source(s): GLE map& data base, own calculation.

### TABLE 8.5 (4.7): BREAKDOWN OF SEND-OUT CAPACITIES FOR NEW LNG PROJECTS

| Send out capacity (Mtoe/yr) | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | N/A | Total |
|---|---|---|---|---|---|---|---|---|
| DE | | | | | | | 9.3 | 9.3 |
| ES | | 21.4 | 1.7 | 6.3 | 24.6 | 10.2 | | 64.1 |
| FR | | | | 7.8 | 7.8 | 6.9 | 14.2 | 36.6 |
| GR | | | | | | | | |
| IT | 21.6 | 17.1 | 11.2 | | 6.9 | | | 56.7 |
| LT | | | | | | | | |
| NL | | 26.7 | | | 11.2 | | | 37.9 |
| PL | | | 1.0 | | | | | 1.0 |
| PT | | 4.7 | | | | | | 4.7 |
| RO | | | | | | | | |
| SE | | | | | | | | |
| UK | 17.9 | | | | 4.7 | | | 22.6 |
| Total | 39.5 | 69.9 | 14.0 | 14.1 | 55.1 | 17.1 | 23.5 | 233.0 |

Source(s): GLE map & data base, own calculation.

### TABLE 8.6 (5.15): GAS PIPELINE PROJECTS PLANNED BEFORE 2020

| Project name | Gas origin | Location/ entry point in EU | Entry point in EU | Capacity (Mtoe/yr) | Load factor | Work capacity (Mtoe/yr) | Cumulated work capacity (Mtoe/yr) | Starting operation (estimated) | Estimated budget (€m) |
|---|---|---|---|---|---|---|---|---|---|
| Galsi | Algeria | Italy | Italy | 7 | 0.8 | 5 | 5 | 2010 | 1,200 |
| Nord Stream | Russia | Germany | Germany | 47 | 0.8 | 38 | 43 | 2010 | 6,000 |
| Baltic Pipe | Norway | Poland | Poland | 3 | 0.8 | 2 | 46 | 2011 | 350 |
| Baltic Connector | Russia | Finland | Estonia | 2 | 0.8 | 2 | 47 | 2011 | 100 |
| ITGI | Caspian | Greece | Italy | 7 | 0.8 | 5 | 53 | 2012 | 950 |
| Nabucco | Caspian | Bulgaria | Austria | 27 | 0.8 | 22 | 74 | 2014 | 7,900 |
| White stream | Caspian | Romania | Romania | 28 | 0.8 | 22 | 96 | 2016 | 2,500 |

Source(s): Energy Infrastructure Costs and Investments between 1996 and 2013(medium-term) and further to 2023 (long-term) on the Trans-EuropeanEnergy Network and its Connection to Neighbouring Regions withemphasis on investments on renewable energy sources and their integration into the Trans-European energy networks, including anInventory of the Technical Status of the European Energy-Network for the; Year 2003; Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI; Issue Date: October 2005; Prepared by: CESI spa (Centro Elettrotecnico Sperimentale Italiano) – Italy, IIT (Instituto de Investigación Tecnológica) – Spain, ME (Mercados Energeticos) – Spain, RAMBØLL A/S – Denmark; October 2005; Various sources including projects presentations and web sites www.nabucco-pipeline.com, www.nord-stream.com, www.igi-poseidon.com; own calculation.

# 9 Appendix IX: E3ME and KEMA Model Descriptions

## 9.1 Introduction to E3ME

E3ME is a computer-based model of Europe's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe for policy assessment, for forecasting and for research purposes.

**E3ME's structure**

The structure of E3ME is based on the system of national accounts, as defined by ESA95 (European Commission, 1996), with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, with estimated sets of equations for labour demand, supply, wages and working hours. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2008 and the model projects forward annually to 2050[82]. The main data sources are Eurostat, DG Ecfin's AMECO database and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. Gaps in the data are estimated using customised software algorithms.

**The main dimensions of the model**

The other main dimensions of the model are:

- 29 countries (the EU27 member states plus Norway and Switzerland)
- 42 economic sectors, including disaggregation of the energy sectors and 16 service sectors
- 43 categories of household expenditure
- 19 different users of 12 different fuel types
- 14 types of air-borne emission (where data are available) including the six greenhouse gases monitored under the Kyoto protocol.
- 13 types of household, including income quintiles and socio-economic groups such as the unemployed, inactive and retired, plus an urban/rural split

Typical outputs from the model include GDP and sectoral output, household expenditure, investment, international trade, inflation, employment and unemployment, energy demand and CO2 emissions. Each of these is available at national and EU level, and most are also defined by economic sector.

The econometric specification of E3ME gives the model a strong empirical grounding and means it is not reliant on the assumptions common to Computable General Equilibrium (CGE) models, such as perfect competition or rational expectations. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (eg up to 2020) and rebound effects[83], which are included as standard in the model's results.

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[82] See Chewpreecha and Pollitt (2009).

[83] Where an initial increase in efficiency reduces demand, but this is negated in the long run as greater efficiency lowers the relative cost and increases consumption. See Barker et al (2009).

**E3ME's key strengths**

In summary the key strengths of E3ME lie in three different areas:

- the close integration of the economy, energy systems and the environment, with two-way linkages between each component
- the detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios
- the econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends

A longer description of E3ME is provided in the next chapter. For further details, the reader is referred to the model manual available online from www.e3me.com.

## 9.2 A brief history of E3ME

**Quantifying the short and long-term effects of E3 policies**

E3ME was originally intended to meet an expressed need of researchers and policy makers for a framework for analysing the long-term implications of Energy-Environment-Economy (E3) policies, especially those concerning R&D and environmental taxation and regulation. The model is also capable of addressing the short-term and medium-term economic effects as well as, more broadly, the long-term effects of such policies, such as those from the supply side of the labour market.

**The European contribution**

The first version of the E3ME model wasbuilt by an international European team under a succession of contracts in the JOULE/THERMIE and EC research programmes. The projects 'Completion and Extension of E3ME'[84] and 'Applications of E3ME'[85], were completed in 1999. The 2001 contract, 'Sectoral Economic Analysis and Forecasts'[86] generated an update of the E3ME industry output, product and investment classifications to bring the model into compliance with the European System of Accounts, ESA 95. This led to a significant disaggregation of the service sector. The 2003 contract, Tipmac[87], led to a full development of the E3ME transport module to include detailed country models for several modes of passenger and freight transport and Seamate (2003/2004)[88]resulted in the improvement of the E3ME technology indices. The COMETR[89] (2005-07), Matisse[90] (2005-08) and CEDEFOP[91] (2007-2010) projects allowed the expansion of E3ME to cover 29 European countries, including the twelve accession countries. More recently the model has been used to contribute to European Impact Assessments, including reviews of the EU ETS, Energy Taxation Directive and TEN-E infrastructure policy. E3ME is now applied at the national, as well as European, level.

A full list of recent projects involving E3ME, and references from related publications, is available from the model website.

E3ME is the latest in a succession of models developed for energy-economy and, later, E3 (energy-environment-economy) interactions in Europe, starting with

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[84] European Commission contract no. JOS3-CT95-0011

[85] European Commission contract no. JOS3-CT97-0019

[86] European Commission contract no. B2000/A7050/001

[87] European Commission contractno. GRD1/2000/25347-SI2.316061

[88] European Commission contractno. IST-2000-31104

[89] European Commission contract no. 501993 (SCS8)

[90] European Commission contract no. 004059 (GOCE)

[91] European Commission project no. 2007-0089/AO/AZU/Skillsnet-Supply/010/07 and European Commission project no. 2006/S 125-132790

EXPLOR, built in the 1970s, then HERMES in the 1980s. Each model has required substantial resources from international teams and has learned from earlier problems and developed new techniques. E3ME is now firmly established as a tool for policy analysis in Europe. The current version is closely linked to the global E3MG[92] model, which is similar in structure and dimensions.

## 9.3 The theoretical background to E3ME

Economic activity undertaken by persons, households, firms and other groups in society has effects on other groups after a time lag, and the effects persist into future generations, although many of the effects soon become so small as to be negligible. But there are many actors, and the effects, both beneficial and damaging, accumulate in economic and physical stocks. The effects are transmitted through the environment (with externalities such as greenhouse gas emissions contributing to global warming), through the economy and the price and money system (via the markets for labour and commodities), and through the global transport and information networks. The markets transmit effects in three main ways: through the level of activity creating demand for inputs of materials, fuels and labour; through wages and prices affecting incomes; and through incomes leading in turn to further demands for goods and services. These interdependencies suggest that an E3 model should be comprehensive, and include many linkages between different parts of the economic and energy systems.

These economic and energy systems have the following characteristics: economies and diseconomies of scale in both production and consumption; markets with different degrees of competition; the prevalence of institutional behaviour whose aim may be maximisation, but may also be the satisfaction of more restricted objectives; and rapid and uneven changes in technology and consumer preferences, certainly within the time scale of greenhouse gas mitigation policy. Labour markets in particular may be characterised by long-term unemployment. An E3 model capable of representing these features must therefore be flexible, capable of embodying a variety of behaviours and of simulating a dynamic system. This approach can be contrasted with that adopted by general equilibrium models: they typically assume constant returns to scale; perfect competition in all markets; maximisation of social welfare measured by total discounted private consumption; no involuntary unemployment; and exogenous technical progress following a constant time trend (see Barker, 1998, for a more detailed discussion).

## 9.4 E3ME as an E3 model

The E3ME model comprises:

- the accounting balances for commodities from input-output tables, for energy carriers from energy balances and for institutional incomes and expenditures from the national accounts
- environmental emission flows
- 33 sets of time-series econometric equations (aggregate energy demands, fuel substitution equations for coal, heavy oil, gas and electricity; intra-EU and extra-EU commodity exports and imports; total consumers' expenditure; disaggregated

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[92] See www.e3mgmodel.com

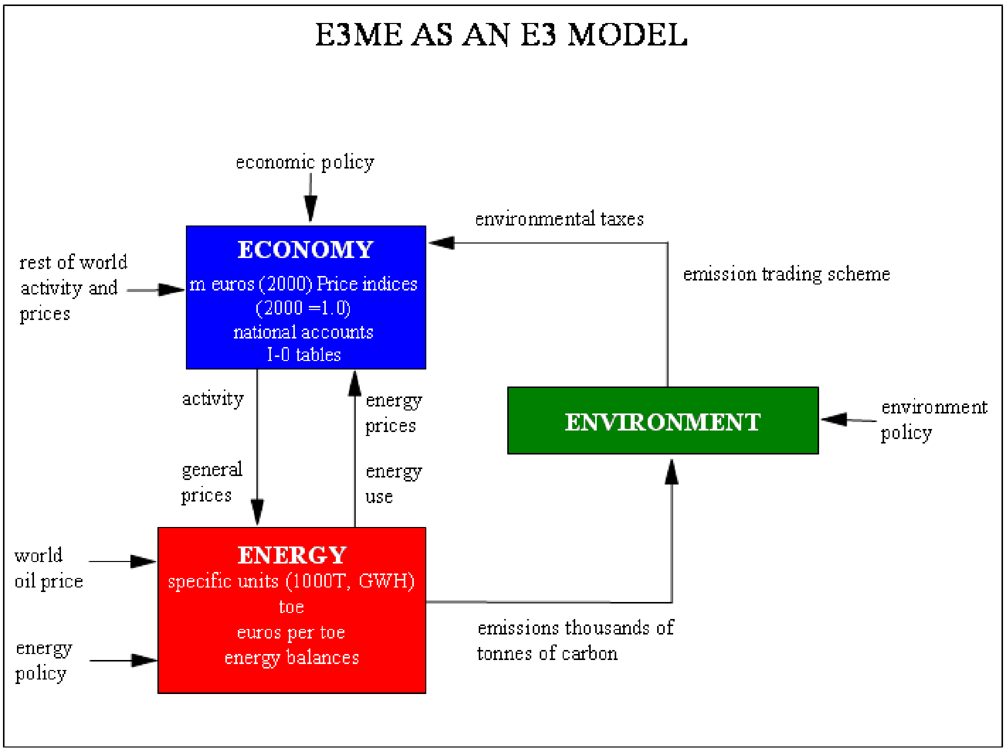
consumers' expenditure; industrial fixed investment; industrial employment; industrial hours worked; labour participation; industrial prices; export and import prices; industrial wage rates; residual incomes; investment in dwellings; normal output equations and physical demand for seven types of materials)

Energy supplies and population stocks and flows are treated as exogenous.

**The E3 interactions**

Figure 9.1 shows how the three components (modules) of the model - energy, environment and economy - fit together. Each component is shown in its own box with its own units of account and sources of data. Each data set has been constructed by statistical offices to conform with accounting conventions. Exogenous factors coming from outside the modelling framework are shown on the outside edge of the chart as inputs into each component. For the EU economy, these factors are economic activity and prices in non-EU world areas and economic policy (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the outside factors are the world oil prices and energy policy (including regulation of energy industries). For the environment component, exogenous factors include policies such as reduction in SO2 emissions by means of end-of-pipe filters from large combustion plants. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

Figure 9.1



The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides measures of emissions of the main air pollutants to the environment module, which in turn gives measures of damage to health and buildings (estimated using the most recent ExternE[93] coefficients). The

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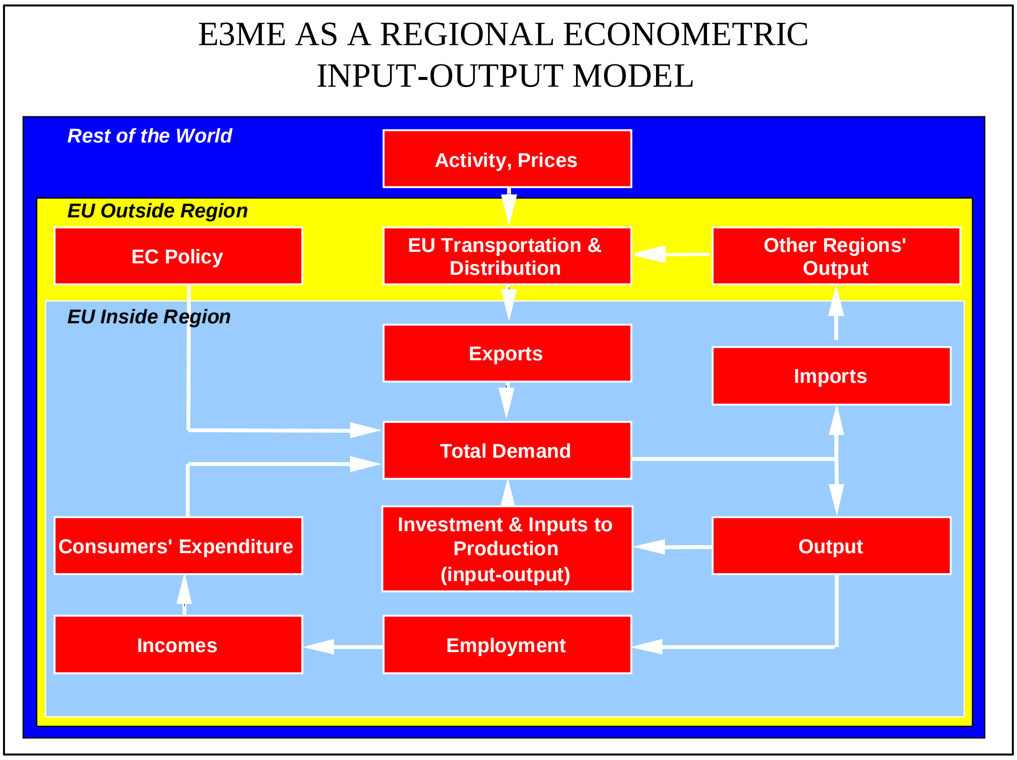
[93] http://www.externe.info/tools.html

energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

## 9.5 The E3ME regional econometric input-output model

Figure 9.2 shows how the economic module is solved as an integrated EU regional model. Most of the economic variables shown in the chart are at a 42-industry level. The whole system is solved simultaneously for all industries and all 29 countries, although single-country solutions are also possible. The chart shows interactions at three spatial levels: the outermost area is the rest of the world; the next level is the European Union outside the country in question; and finally, the inside level contains the relationships within the country.

Figure 9.2



The chart shows three loops or circuits of economic interdependence, which are described in some detail below. These are the export loop, the output-investment loop and the income loop.

**The export loop**

The export loop runs from the EU transport and distribution network to the region's exports, then to total demand. The region's imports feed into other EU regions' exports and output and finally to these other regions' demand from the EU pool and back to the exports of the region in question.

*Treatment of international trade*

An important part of the modelling concerns international trade. The basic assumption is that, for most commodities, there is a European 'pool' into which each region supplies part of its production and from which each region satisfies part of its demand. *This might be compared to national electricity supplies and demands: each power plant supplies to the national grid and each user draws power from the grid and it is not possible or necessary to link a particular supply to a particular demand.*

The demand for a region's exports of a commodity is related to three factors:

- domestic demand for the commodity in all the other EU regions, weighted by their economic distance from the region in question
- activity in the main external EU export markets, as measured by GDP or industrial production
- relative prices, including the effects of exchange rate changes.

*Economic distance*

Economic distance is measured by a special distance variable. For a given region, this variable is normalised tobe 1 for the home region and values less than one for external regions. The economic distance to other regions is inversely proportional to trade between the regions. In E3ME regional imports are determined for the demand and relative prices by commodity and region. In addition, measures of innovation (including spending on R&D) have been introduced into the trade equations to pick up an important long-term dynamic effect on economic development.

### The output-investment loop

The output-investment loop includes industrial demand for goods and services and runs from total demand to output and then to investment and back to total demand. For each region, total demand for the gross output of goods and services is formed from industrial demand, consumers' expenditure, government consumption, investment (fixed domestic capital formation and stockbuilding) and exports. These totals are divided between imports and output depending on relative prices, levels of activity and utilisation of capacity. Industrial demand represents the inputs of goods and services from other industries required for current production, and is calculated using input-output coefficients. The coefficients are calculated as inputs of commodities from whatever source, including imports, per unit of gross industrial output.

*Determination of investment demand*

Forecast changes in output are important determinants of investment in the model. Investment in new equipment and new buildings is one of the ways in which companies adjust to the new challenges introduced by energy and environmental policies. Consequently, the quality of the data and the way data are modelled are of great importance to the performance of the whole model. Regional investment by the investing industry is determined in the model as intertemporal choices depending on capacity output and investment prices. When investment by user industry is determined, it is converted, using coefficients derived from input-output tables, into demands on the industries producing the investment goods and services, mainly engineering and construction. These demands then constitute one of the components of total demand.

In this project the investments are in specific equipment (mainly transmission lines and pipelines) so a larger share of investment costs are absorbed by the construction industry than would be the case, for example, in building new plant where more design is required.

*Accumulation of knowledge and technology*

Gross fixed investment, enhanced by R&D expenditure in constant prices, is accumulated to provide a measure of the technological capital stock. This avoids problems with the usual definition of the capital stock and lack of data on economic scrapping. The accumulation measure is designed to get round the worst of these problems. Investment is central to the determination of long-term growth and the model embodies endogenous technical change and a theory of endogenous growth which underlies the long-term behaviour of the trade and employment equations.

### The income loop

In the income loop, industrial output generates employment and incomes, which leads to further consumers' expenditure, adding to total demand. Changes in output are used to determine changes in employment, along with changes in real wage costs, interest rates and energy costs. With wage rates explained by price levels and conditions in the labour market, the wage and salary payments by industry can be calculated from the industrial employment levels. These are some of the largest payments to the personal sector, but not the only ones. There are also payments of interest and dividends, transfers from government in the form of state pensions, unemployment benefits and other social security benefits. Payments made by the personal sector include mortgage interest payments and personal income taxes. Personal disposable income is calculated from these accounts, and deflated by the consumer price index to give real personal disposable income.

*Determination of consumers' demand*

Totals of consumer spending by region are derived from consumption functions estimated from time-series data (this is a similar treatment to that adopted in the HERMES model). These equations relate consumption to regional personal disposable income, a measure of wealth for the personal sector, inflation and interest rates. Sets of equations have been estimated from time-series data for each of the 43 consumption categories reported by Eurostat in each country.

## 9.6 Energy-Environment links

**Top-down and bottom-up methodologies**

E3ME is intended to be an integrated top-down, bottom-up model of E3 interaction. In particular, the model includes a detailed engineering-based treatment of the electricity supply industry (ESI). Demand for energy by the other fuel-user groups is top-down, but it is important to be aware of the comparative strengths and weaknesses of the two approaches. Top-down economic analyses and bottom-up engineering analyses of changes in the pattern of energy consumption possess distinct intellectual origins and distinct strengths and weaknesses (see Barker, Ekins and Johnstone, 1995).

**A top-down submodel of energy use**

The energy submodel in E3ME is constructed, estimated and solved for 19 fuel users, 12 energy carriers (termed fuels for convenience below) and 29 countries. Figure 9.3 shows the inputs from the economy and the environment into the components of the submodel and Figure 9.4 shows the feedback from the submodel to the rest of the economy.

*Determination of fuel demand*

Aggregate energy demand, shown at the top of Figure 9.3, is determined by a set of co-integrating equations[94], whose the main explanatory variables are:

- economic activity in each of the 19 fuel users
- average energy prices by the fuel users relative to the overall price levels
- technological variables, represented by investment and R&D expenditure, and spillovers in key industries producing energy-using equipment and vehicles

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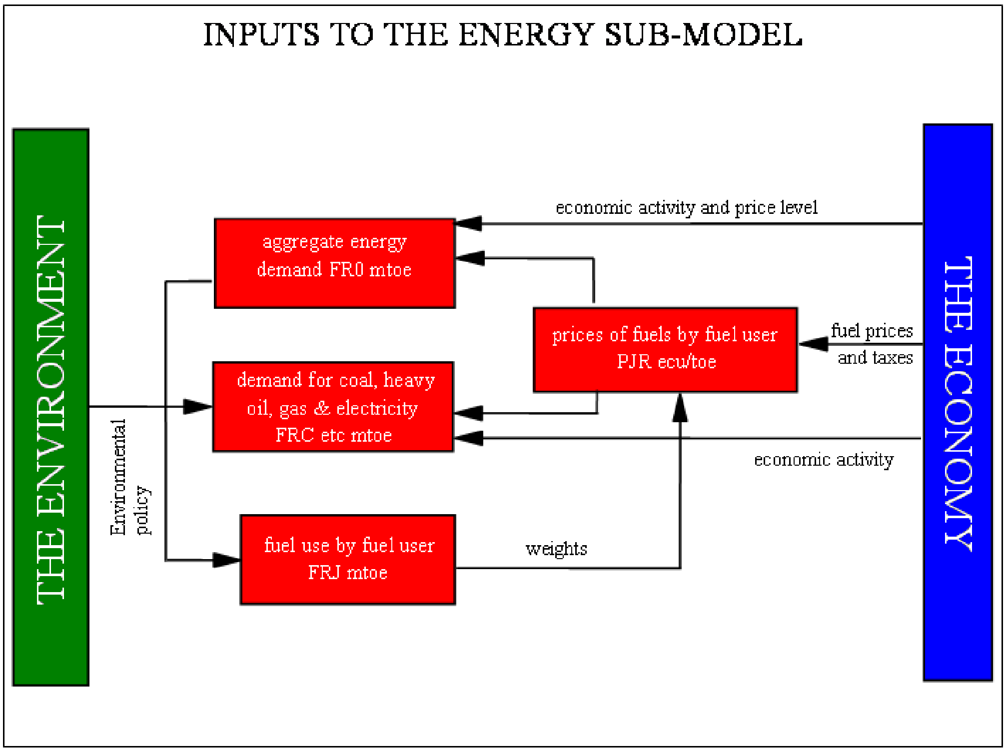
[94] Cointegration is an econometric technique that defines a long-run relationship between two variables resulting in a form of 'equilibrium'. For instance, if income and consumption are cointegrated, then any shock (expected or unexpected) affecting temporary these two variables is gradually absorbed since in the long-run they return to their 'equilibrium' levels. Note that a cointegration relationship is much stronger relationship than a simple correlation: two variables can show similar patterns simply because they are driven by some common factors but without necessarily being involved in a long-run relationship.

Figure 9.3



*Fuel substitution* Fuel use equations are estimated for four fuels - coal, heavy oils, gas and electricity – and the four sets of equations are estimated for the fuel users in each region. These equations are intended to allow substitution between these energy carriers by users on the basis of relative prices, although overall fuel use and the technological variables are allowed to affect the choice. Since the substitution equations cover only four of the twelve fuels, the remaining fuels are determined as fixed ratios to similar fuels or to aggregate energy use. The final set of fuels used must then be scaled to ensure that it adds up to the aggregate energy demand (for each fuel user and each region).

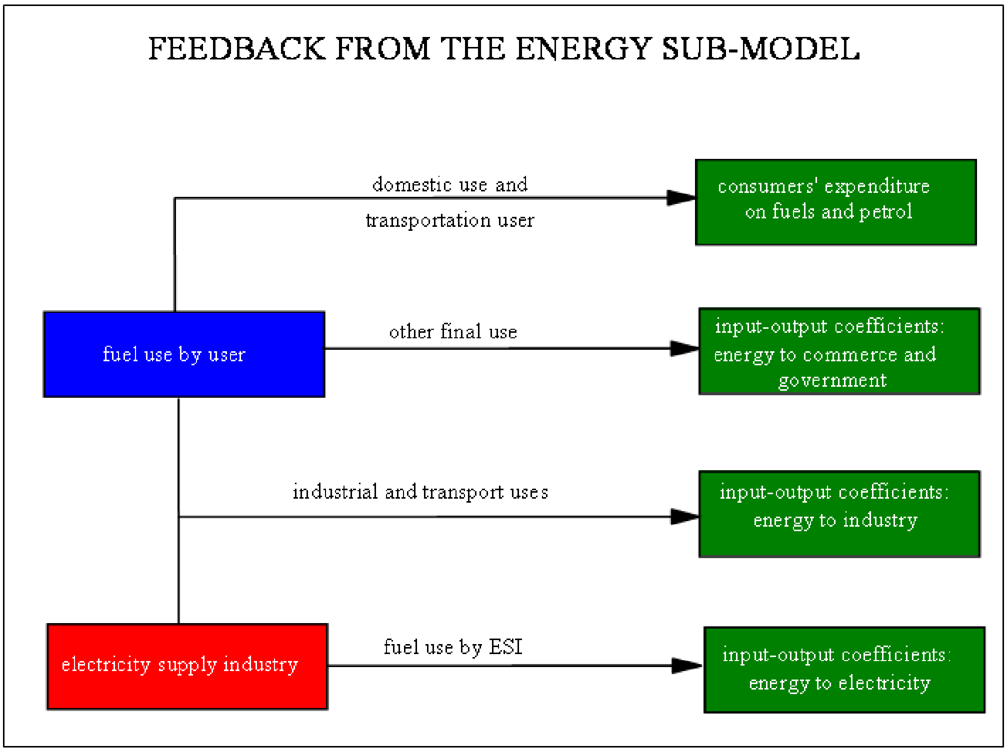
**Emissions submodel** The emissions submodel calculates air pollution generated from end-use of different fuels and from primary use of fuels in the energy industries themselves, particularly electricity generation. Provision is made for emissions to the atmosphere of carbon dioxide (CO2), sulphur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), methane (CH4), black smoke (PM10), volatile organic compounds (VOC), nuclear emissions to air, lead emissions to air, chlorofluorocarbons (CFCs) and the other four greenhouse gases: nitrous oxide (N2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF6). These four gases together with CO2 and CH4 constitute the six greenhouse gases (GHGs) monitored under the Kyoto protocol. Using estimated (ExternE) damage coefficients, E3ME may also estimate ancillary benefits relating to reduction in associated emissions eg PM10, SO2, NOx.

*CO2 emissions* Emissions data for CO2 are available for fuel users of solid fuels, oil products and gas separately. The energy submodel estimates of fuel by fuel user are aggregated into these groups (solid, oil and gas) and emission coefficients (tonnes of carbon in CO2 emitted per toe) are calculated and stored. The coefficients are calculated for each year when data are available, then used at their last historical values to project future emissions. Other emissions data are available at various levels of disaggregation from a number of sources and have been constructed carefully to ensure consistency.

**Feedback to the rest of the economy**

Figure 9.4 shows the main feedbacks from the energy submodel to the rest of the economy. Changes in consumers' expenditures on fuels and petrol are formed from changes in fuel use estimated in the energy submodel, although the levels are calibrated on historical time-series data. The model software provides an option for choosing either the consumers' expenditure equation solution, or the energy equation solution. Whichever option is chosen, total consumer demand in constant values matches the results of the aggregate consumption function, with any residual held in the unallocated category of consumers' expenditure. The other feedbacks all affect industrial, including electricity, demand via changes in the input-output coefficients.

Figure 9.4



## 9.7 Parameter estimation

The econometric modelhas a complete specification of the long-term solution in the form of an estimated equation that has long-term restrictions imposed on its parameters. Economic theory, for example the recent theories of endogenous growth, informs the specification of the long-term equations and hence properties of the model; dynamic equations that embody these long-term properties are estimated by econometric methods to allow the model to provide forecasts. The method utilises developments in time-series econometrics, in which dynamic relationships are specified in terms of error correction models (ECM) that allow dynamic convergence to a long-term outcome. The specific functional form of the equations is based on the econometric techniques of cointegration and error-correction, particularly as promoted by Engle and Granger (1987) and Hendry et al (1984).

## 9.8 Introduction to the KEMA/ICL model

The KEMA/ICL modelling framework contains a number of modules that together provide a coherent methodology for estimating the additional generation and network investment requirements and the power system operation costs of alternative generation mix scenarios. It is a computer-based multi-node model of regional electricity system. The modelling framework consists of two main elements:

- an applied power systems analysis framework[95] (APS model) to evaluate cost-optimal regional interconnection and generation capacity requirements for system security purposes, and the annual operating costs of the system
- a cost estimation tool for the calculation of the cost of integration of offshore wind

It was originally developed for the European Climate Foundation Roadmap 2050 project and the version being used here is a development of that model providing greater granularity. It also has an enhanced ability to implement pre-defined generation capacity factors (e.g. those obtained from PRIMES model's output for PRIMES specific scenarios) of various generation plants in the system.

**Overview of the APS model**

The APS model minimizes the total system costs composed of additional generating capacity cost and additional inter-regional transmission network capacity cost, together with annual electricity production cost from a real-time simulation of hourly dispatch while maintaining the required level of system reliability and respecting multiple operating constraints. This cost minimization process considers the tradeoffs between the cost of additional generating capacity (additional generation backup), additional transmission infrastructure, and renewable energy curtailment and the transmission constraint cost associated with network congestion management. The model is not a market model, and assumes that the electricity system would be optimised as a whole, within the limits of the available and economic new build resources.

The APS model follows two main steps:

- First, the required additional generation and interconnection transmission capacity is determined by minimizing the infrastructure investment costs and hourly system operation costs across the time horizon of a year, while delivering specified(historical) levels of security of supply. The model takes into account the trade-off between the generation capacity and interconnection investments and the potential benefits of storage in reducing the need for additional generating capacity and inter-regional transmission. The impact of extreme conditions of low output of renewable generation and extreme peak demands on both generation and network capacity requirements are also examined.
- Second, the operation of the system is optimized throughout the year. Using a stochastic framework that captures multiple possible realizations of renewable generation outputs, the daily production costs are minimized while allocating adequate resources needed for the management of uncertainties in demand, conventional generation and intermittent renewablesoutput. The model incorporates a range of dynamic technical constraints and cost characteristics of various generating technologies in the system (such as stable generation levels, ramp rates, minimum up/down times, start up and no load costs, etc) together with

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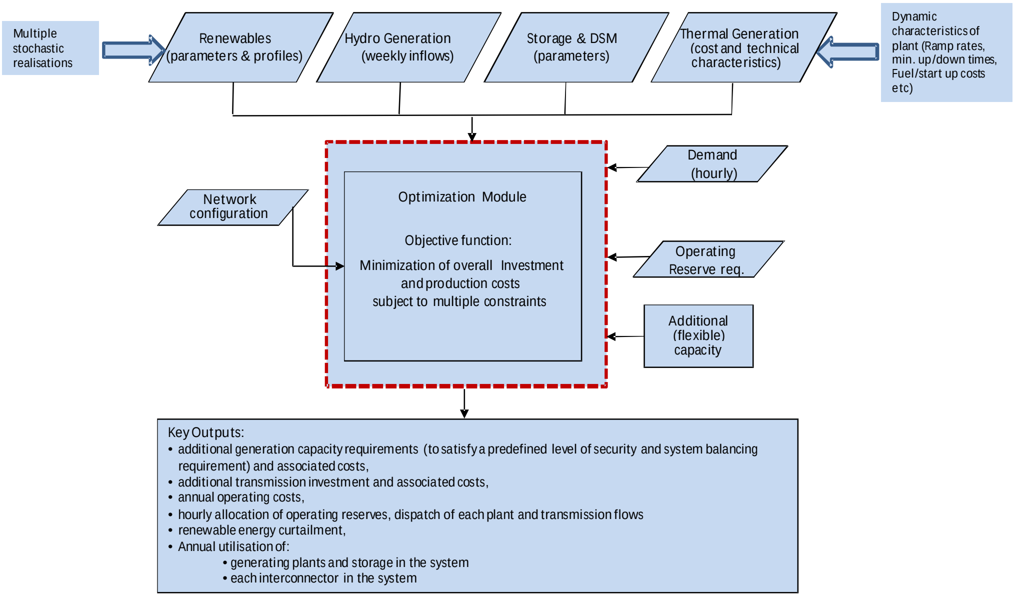
[95] Developed by Imperial College London

characteristics of energy storage (reservoir capacities and efficiency losses). While maintaining the required levels of short and long term reserves, based on the existing ENTSO-E's rules, the model takes into account the benefits of diversity in renewable generation production, diversity in demand and resource sharing across different regions enabled by the regional transmission network.

A simplified representation of the APS model is depicted in Figure 9.5 below.

Figure 9.5



**Adjustment in the APS model for PRIMES studies**

In order to evaluate the interconnector and additional generating capacity infrastructure requirements for PRIMES model based studies, the energy production from generation technologies in respective countries were harmonized with those obtained from the PRIMES model. This was accomplished by an alteration in the model formulation that would match the generation capacity factor of various plants inline with PRIMES outputs as the first priority, before minimizing the overall system costs.

**The main dimensions of the APS model**

The main dimensions of the model are:

- 29 countries (the EU27 member states plus Norway and Switzerland)
- 203 thermal generator groups across 6 fuel types (nuclear, coal, gas, oil, biomass, and geothermal)
- 4 types of hydro generation (hydro reservoir, run of river, a combination of hydro reservoir and pumped storage, pure pumped storage) for each country
- 2 types of wind generation (offshore and onshore) for individual countries where available
- 2 types of solar generation (Photovoltaic (PV) and Concentrated Solar Power (CSP)) for individual countries where available
- 54 interconnection possibilities among 29 modelled countries
- simulation of hourly system operation across one year period

**Key modelling inputs**

Key inputs to the APS model include a time series of hourly electricity demand profiles and regional hourly profiles for the available renewable energy sources (wind and solar), seasonal availability of hydro energy for both 'run of river' and hydro with reservoir. Initial levels of installed capacity (generation and transmission), dynamic characteristics and operating costs of various generation technologies, investment cost of additional generating capacity in each region, network topology and network reinforcement cost.

Furthermore, the required system reliability constraint is also defined in the form of Loss of Load Expectation (LOLE)[96].

### Typical outputs of the model

Typical outputs from the APS model include:

- additional generation capacity requirements (to satisfy a predefined level of security and system balancing requirement) and associated costs
- additional transmission investment and associated costs
- annual operating costs
- hourly allocation of operating reserves
- renewable energy curtailment
- transmission flows
- Annual utilisation of
    - generating plants and storage in the system
    - each interconnector in the system

### KEMA/ICL key strengths

The modelling framework provides an *integrated assessment of the electricity generation and transmission capacity investment requirements* that is both; cost (investment and operating) optimal and secure under defined system security standards.

The *system operation simulation is modelled in a stochastic framework* . In order to take into account of the uncertainties associated with the availability (and output variation) of the intermittent renewables a number of renewable output realizations are considered for each hour looking forward upto 36 hours. The supply resources as well as responsive demand in each region are simultaneously scheduled in order to cover multiple renewable generation outputs while maintaining the network constraints.

Both the system investments and operating requirements, and associated costs are based on *concurrent operation of the electricity system in each country*taking into account the optimal transmission flows through the interconnections.

### Offshore and solar CSP integration

The second element of the modeling framework estimates the investment requirements for energy transport and integration of offshore wind parks and solar CSP parks. These generation sources are assumed to connect at the fringes of the transmission networks and therefore investments are required to integrate them into the main network, creating new within Member State transmission investment. The approach assumes that the full installed capacity of the wind or solar park has to be carried to the notional centre of gravity of the country. This approach results in significant transmission investments and serve as a proxy for a range of reinforcements within the Member State transmission system to relieve local congestion. Exhibit X illustrates these various elements.

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[96] LOLE represents the expected number of hours per year when demand may exceed available generation.

## 9.9 Modelling approach

A conservative approach has been followed throughout the grid integration modeling. This is manifested through a range of prudent modeling assumptions adopted, such as higher levels of short term forecasting errors of renewable generation (based on persistence forecasting techniques); the fact that load curtailments are not considered as an option for the provision of backup; exclusion of frequency responsive loads (e.g. refrigeration) in the provision of frequency regulation services and incorporatingextremely low outside temperatures in winter peak demands.

Additionally the effects of low availability of intermittent (wind) generation during peak demand periods that is coincident with a dry hydro year is also considered.

**Assessment and allocation of operating reserve**

In order to deal with the uncertainties associated with conventional generation availability, demand fluctuations and variability of output of (variable) renewable generation two types of operating reserve are modelled:

- short-term reserve (for seconds to few minutes time periods) for automatic frequency regulation requirements
- long-term reserve (from few minutes to few hours time periods) to mitigate unforeseen imbalances between demand and supply over longer time horizons in each region

The determination of the amount of reserve requirements is based on ENTSO-E’s rules. As mentioned above, the contribution of any frequency sensitive loads towards frequency regulation (for example smart refrigerators) is not modelled. A key modelling assumption is that short term reserves will be managed within each Member State while long-term reserve can be shared across regions taking into account the limitations of the transmission network.

The stochastic modelling of intermittent renewable generation results in an optimal allocation of long-term operating reserve between standing reserve and synchronised spinning reserve plant to maintain supply/demand balance. Longer term reserve allocation between these two categories is optimised dynamically, taking into account the system situation in each instance, in order to enhance the ability of the system to absorb renewable output. Any inadequacy in terms of the ability of the system to meet the demand given the need for reserve is managed by appropriate augmentation of generation capacity.

**Generation and reserve scheduling**

The scheduling of reserves imposes further constraints on system operation for the following reasons. Reserve scheduling causes generation output deviations from the optimal generation schedule in order to provide sufficient flexibility for generation output to either be increased or decreased in response to variations in demand and/or supply. The operating characteristics of reserve generation introduce additional constraints including reducing the generation capacity available to supply demand and imposing limits on the lowest output to be delivered from flexible generation. The first effect can lead to requirements for greater generation capacity within the system either within each region or via interconnecting transmission. The second effect can lead to increased curtailment of variable renewable generation as the system must maintain adequate reserves, which will require flexible plant to be readily dispatchable. Where reserve generation is constrained by minimum stable operating limits, this can displace renewable generation unless sufficient transmission capacity is available to facilitate exports outside the region or sufficient storage is available within the region.

The detailed production and reserve optimisation model, is set up within a stochastic optimisation framework. The dynamic scheduling process is modelled looking ahead over a 36 hour period at the demand profile to be met and associated reserve requirements. The model then schedules generation, storage and demand response for each 24 hour time horizon to meet these requirements. The actual day-ahead is varied by the stochastic modelling of the energy output from the renewable generation sources. The stochastic framework allows a number of renewable output realizations to be evaluated for each hour looking forward 36 hours. The generation and responsive demand resources in each region are simultaneously scheduled in order to consider multiple renewable generation output conditions for a prescribed set of network constraints. The model takes account of losses and costs incurred through the use of demand response and storage resources. The system operation model for scheduling generation and operating reserves in each region exploits the diversity of demand and renewable outputs across Europe to minimize operating costs while significantly enhancing the ability of the system to accommodate the output of variable renewable generation sources.

**Impact of low availability of renewables and dry hydro conditions**

Following the earlier mentioned conservative approach, the results are evaluated considering the low availability of wind generation during peak demand periods in Northern Europe that my coincide with a dry hydro year across Europe. The modelled input assumptions in this regard include:

- extreme weather conditions, 5 days with 50% lower wind for Northern Europe compared to forecast
- dry hydrological year, with 20% less than average available energy from European hydro resources
- higher peak demand driven by an assumed fuel switch to meet higher electrical heating load (5% in 2020 and 10% in 2030)

**Inter-regional transmission**

The transmission investment model divides the EU-27 countries plus Norway and Switzerland into twenty nine regions. Today's congestion within the member state regions associated with the existing networks is not considered and is assumed to be addressed in the ENTSO-E TYNDP.

Each member state region has a “centre of gravity”, which functions as the point from and to which transmission capacity will be required. The scope of the transmission system analysis is focused on incremental capacity requirements between the regions for each of the scenario pathway relative to the current 2010 baseline, but respecting the 2020 capacity expectations within the ENTSO-E TYNDP, i.e. all investments in the ENTSO-E TYNDP are assumed to happen in all scenarios.

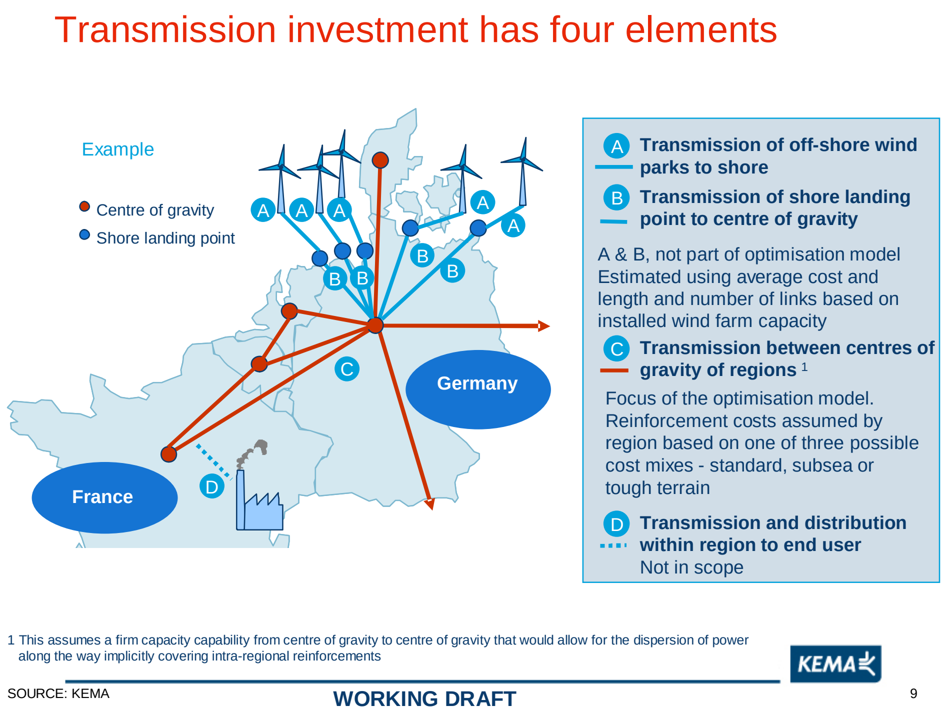
The model does not assess the investment requirements for growing demand connections or investment in the distribution network.

**Off-shore transmission**

The overlap of offshore wind farm and solar CSP transmission integration costs and the way in which expansion factors and unit costs for interconnection transmission expansion have been set drive an investment cost that seeks to on average provide sufficient investment to provide secure capacity and include within-member state region internal reinforcement requirements. Further explanation of the assumptions regarding transmission expansion factors can be found in section 9.10 below.

More detailed transmission studies will be needed in the future to support more granular decision-making. These studies would ideally be undertaken with ENTSO-E coordination as part of the SET Plan's European Electricity Grid Initiative.

Figure 9.6



## Transmission investment has four elements

**A** **Transmission of off-shore wind parks to shore**

**B** **Transmission of shore landing point to centre of gravity**

A & B, not part of optimisation model Estimated using average cost and length and number of links based on installed wind farm capacity

**C** **Transmission between centres of gravity of regions** [1]

Focus of the optimisation model. Reinforcement costs assumed by region based on one of three possible cost mixes - standard, subsea or tough terrain

**D** **Transmission and distribution within region to end user**

Not in scope

[1] This assumes a firm capacity capability from centre of gravity to centre of gravity that would allow for the dispersion of power along the way implicitly covering intra-regional reinforcements

SOURCE: KEMA

WORKING DRAFT

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## 9.10 Transmission cost assumptions

The modelling approach adopted relies on a cost estimation methodology. It seeks to provide a reasonable indication of the capital costs associated with expanding the transmission capacity between regions to maintain a power system with security characteristics similar to those experienced today. The costs are estimated based on an assumption that they will be able to deliver a secure network (N-1), i.e. providing sufficient network redundancy such that a single circuit fault would not cause the transfer capacity to be reduced.

The transmission costs estimations include several elements. The costs of sub sea cables for the offshore wind farms (A in Figure 9.6) are estimated based on a typical distance from the shore and a single unit cost of €4 million per GWkm.

The connection of increased demand (Part D) is excluded from the transmission modelling. This is because the increased demand to be met in all of the scenarios is the same and therefore it is assumed that the costs to meet these demand increases will appear in each case.

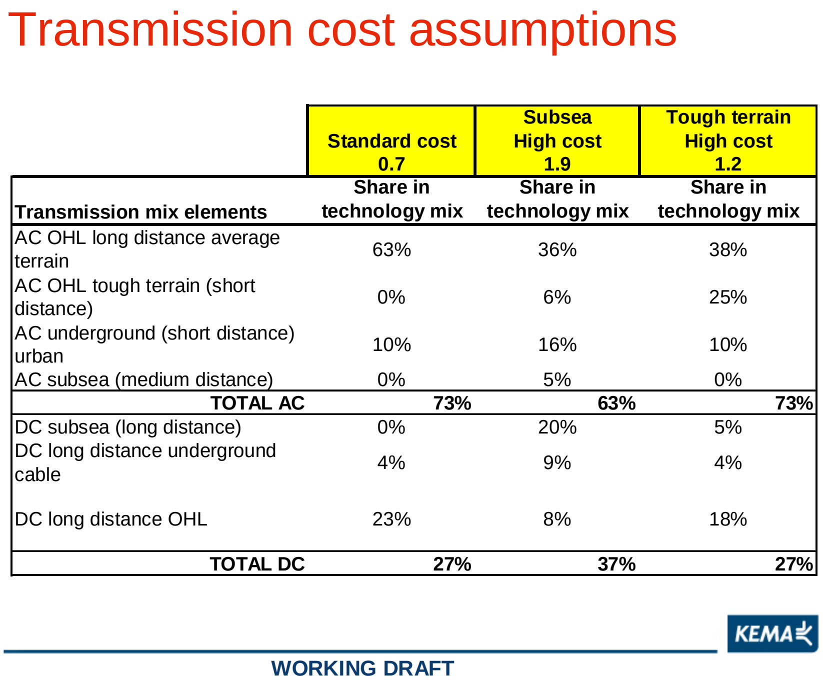
The transmission network investment cost modelling undertaken addresses elements B and C in Figure 9.6, however, the methodology adopted to estimate the capacity and costs is different for each element.

Part B transmission capacity is calculated by evenly distributing the total assumed offshore wind farm capacity along the available coastline of the region. This requires the total offshore wind capacity to be divided into wind parks. These are limited to a maximum of 1.5GW capacity, which reflects a conservative assumption for a typical circuit capacity. From each of the landing points distributed evenly along the regional shoreline, it is assumed that transmission capacity is required to move the power to the centre of gravity, before it can be transmitted more widely. Transmission capacity costs have been estimated based on the Standard cost assumption. This methodology has also been adopted to reflect the likely concentration of solar CSP in southern Spain. It has been assumed that 75% of the solar CSP parks are connected to the south of the centre of gravity.

The detailed modelling work focuses on the Part C investments, in Figure 9.6. The costs of the Part C investments are integrated within the wider APS framework which is described in details in sections 9.8 and 9.9 above. The modelling frameworkuses the composite cost assumptions shown in Figure 9.6 to undertake a cost optimisation.

The model trades off the various investment elements and optimises based upon input cost assumptions. For the transmission investment three composite costs were created to represent the costs of expansion between Member States. These costs were biased to recognise that different interconnections that are likely to have varying compositions of technologies. It is not intended to provide specific costs for a particular routing of a line to form the indicated transmission capacity.

Figure 9.7



## Transmission cost assumptions

| | Standard cost<br>0.7 | Subsea<br>High cost<br>1.9 | Tough terrain<br>High cost<br>1.2 |
|---|---|---|---|
| **Transmission mix elements** | **Share in technology mix** | **Share in technology mix** | **Share in technology mix** |
| AC OHL long distance average terrain | 63% | 36% | 38% |
| AC OHL tough terrain (short distance) | 0% | 6% | 25% |
| AC underground (short distance) urban | 10% | 16% | 10% |
| AC subsea (medium distance) | 0% | 5% | 0% |
| **TOTAL AC** | **73%** | **63%** | **73%** |
| DC subsea (long distance) | 0% | 20% | 5% |
| DC long distance underground cable | 4% | 9% | 4% |
| DC long distance OHL | 23% | 8% | 18% |
| **TOTAL DC** | **27%** | **37%** | **27%** |

WORKING DRAFT

The composite cost assumed a balanced approach to technology selection based on experience of network developments. Each international interconnector is allocated one of the three composite costs, (standard, subsea or tough terrain) based on a general analysis of the terrain the would be encountered between the centres of gravity.