Global Experience of Unbundling National Power Utilities

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Overview

Globally we have seen a wave of power sector reforms which have included unbundling of vertically-integrated electricity utilities. The main drivers of these reform have been the need for improved sector performance and increased investment. More than 90 countries have established independent transmission and system operation companies, the vast majority of which are state-owned.

Introduction to power sector reform and objectives

Reliable and cost-effective electricity is fundamental for driving economic growth and socio-economic development in modern economies. The structure of the electricity supply industry is an important determinant of its ability to meet such goals. Vertically-integrated utilities (VIUs), played a crucial early role in providing electricity for economic and social development for much of the 20th century, however, the limitations and inefficiencies of this institutional model for electricity supply have become increasingly evident the world around, and the inability of VIUs to adapt to the fast changing dynamics of technology, market and financial innovations in the power sector in the 21st century, has initiated a move away from VIUs (Chawla & Pollitt, 2013; Eberhard & Godinho, 2017; Sen, Nepal, & Jamasb, 2016).

OECD countries were the earliest adopters of power sector reform, with countries such as Chile and England and Wales initiating power sector reforms in the 1980s, followed by many others in the 1990s. In the case of OECD countries, drivers for reform were predominantly to introduce competition, increase efficiencies and reduce end-user costs, generally within the context of excess generation capacity and stable institutions (Sen et al., 2016).

In contrast, the drivers for power sector reform in non-OECD countries were a response to poorly performing utilities and the need to attract investment in generation capacity, networks and electrification. Reforms were often championed by multi-lateral donors and were sometimes part of structural adjustment packages to access donor funding. Unlike in OECD countries, power sectors in non-OECD countries were mostly characterised by severe electricity supply shortages, poor performance levels, high levels of public debt, weak institutional capacity and unstable political contexts (Eberhard & Godinho, 2017; Sen et al., 2016).

Albeit with vastly different starting points, countries across income classifications in all regions of the world adopted at least part of what became known as the 'standard model' of power sector reform, consisting of the following elements.

- the corporatisation and commercialisation of national utilities
- restructuring and unbundling of generation, transmission and distribution
- Introducing competition in generation and, sometimes, in the retail/sale of electricity
- facilitating private sector participation
- establishing independent regulatory authorities
- creating power markets for trading electricity.

This note provides an overview of one element of these reforms: viz. the global experiences of restructuring through the unbundling of vertically integrated utilities, with a focus on independent transmission and system operators (TSOs) (Chawla & Pollitt, 2013; Eberhard & Godinho, 2017).

Unbundling power utilities and types of TSO arrangements

Unbundling refers to the functional, structural and/or legal separation of different components of electricity production and supply, viz. generation, transmission, distribution and retail supply or sale of electricity (Chawla & Pollitt, 2013; Sen et al., 2016). A modest form unbundling might simply be functional and/or accounting unbundling: i.e. having a separate Transmission Division (which is already the case in South Africa's vertically-integrated power utility Eskom), or creating a separate Transmission business unit, with its own accounts (which was the case in Eskom a few years ago, before its accounting units were centralised). These forms of unbundling do not fundamentally change the power sector and are not considered in any detail here.

Meaningful unbundling of a vertically-integrated utility (VIU), to separate transmission/system operation from generation and distribution, involves establishment of a legally unbundled transmission and system operator (LTSO), or an independent transmission and system operator (ITSO), or an independent system operator (ISO) on its own.

VIUs refer to cases where one entity is responsible for generation, transmission, distribution and retail. A LTSO is a company that operates the transmission grid and system operator but is a subsidiary of a parent company that owns other parts of electricity supply such as generation, distribution and retail. In the case of an ITSO, an independent company is responsible for ownership and operation of the transmission grid and is independent from any other players in the electricity market. The state may still own an ITSO. An ISO, on the other hand, is responsible only for system operation (i.e. balancing demand and supply in real time) while a separate transmission company (ITO) owns, operates and maintains the transmission grid (Chawla & Pollitt, 2013).

Table 1: Different categories of unbundling

VIU	VIU/F	VIU/A	LTSO	ITSO	ISO	ITO
Vertically Integrated Utility	Functional unbundling	Accounting unbundling	Legal unbundling	Ownership unbundling	System operator	Transmission op
Generation, transmission and distribution Integrated in a single company	Generation, transmission and distribution in separate divisions within VIU	Generation, transmission and distribution have separate accounts within VIU	Transmission and system operator in separate subsidiary company of VIU	Transmission and system operator in separately owned company	System operator in separate company	Transmission in separate company

One of the primary reasons for separating transmission from other components of the electricity supply industry is to remove conflicts of interest that may occur in state-owned VIUs, where it is generating its own power while also being a single-buyer from independent power producers. In many cases this has caused a departure from least-cost power planning and procurement. Establishing an

independent transmission grid and system operator can facilitate competition by allowing also the entry of privately funded generators. This makes sense where the incumbent VIU struggles to raise capital for new investments and where alternative power generators might be cost competitive. The following section documents the extent and nature of Transmission and System Operation unbundling globally. Some countries have established combined Transmission and System Operator Companies (ITSOs). Others have independent System Operators (ISOs), also with independent Transmission Companies (ITOs).

TSO arrangements according to country classification by income

The experience of power sector reform has differed markedly in different regions of the world and particularly in OECD compared to non-OECD countries. Tables 2 to 5 provide a summary of countries that have initiated unbundling in the order of when the unbundling was initiated, the type of TSO arrangements, the year unbundling was initiated and whether the ownership of the TSO is public, private or public-private. The tables group countries according to the World Bank's income classification of high income, upper-middle income, lower-middle income and low income.

Table 2: Examples of unbundling in high-income countries

Country	TSO	Type	Ownership	Year	Sources
Chile	National Electric Coordinator (Coordinador Eléctrico Nacional, CEN)	ISO	Private	1985	Chalwa, 2013; World Bank, 2019; CEN, 2019; IAEA, 2018;
Spain	See 2010	ISO	Public-Private	1985	Chalwa, 2013; World Bank, 2019
England and Wales	National Grid plc	ITSO	Private	1990	Chalwa, 2013; World Bank, ENTSO-E, 2019; 2019; National Grid plc, 2019;
Norway	Statnett SF (Statsforetak)	ITSO	Public	1992	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Statneet, 2019
Argentina	Compañía Administradora del Mercado Mayorista Eléctrico (CAMMESA)	ISO	Private	1992	Chalwa, 2013; World Bank, 2019; ECN, 2015;
New Zealand	Transpower	ITSO	Public	1994	Chalwa, 2013; World Bank, 2019; Electricity Authority, 2019; TransPower, 2019
Portugal	REN - Redes Energéticas Nacionais, SGPS, S.A	LTSO	Private	1996	Chalwa, 2013; World Bank, 2019; REN, 2019;
Sweden	Svenska kraftnät	ISO	Public	1996	Chalwa, 2013; World Bank, 2019; Svenska kraftnät, 2019
US	New England (ISO-NE); Midcontinent Independent System Operator; PJM Interconnection; Southwest Power Pool (SPP); California Independent System Operator (California ISO); New York Independent System Operator (NYISO);	ISO	Private	1996	Chalwa, 2013; World Bank, 2019; EIA, 2019;

	Electric Reliability Council of Texas (ERCOT).				
Finland	Fingrid Oyj	ITSO	Public-Private (53.1-46.9%)	1997	Chalwa, 2013; World Bank, 2019, Fingrid, 2019, ENTSO-E, 2019
Czech Republic	See 2004	LTSO		1998	Chalwa, 2013; World Bank, 2019
Netherlands	TenneT TSO B.V.	ITSO	Public	1998	Chalwa, 2013; World Bank, 2019; Tennet, 2019; ENTSO-E, 2019;
Australia	Australian Energy Market Operator	ISO	Private	1998	Chalwa, 2013; World Bank, 2019; AEMO, 2019;
Canada	Alaska Interconnection, Alberta Electric System Operator, BC Transmission Corporation, Hydro One, Hydro-Québec, Independent Electricity System Operator, Midcontinent Independent System Operator, Midwest Reliability Organization, New Brunswick System Operator, Newfoundland and Labrador Hydro, Newfoundland Power Inc., Northeast Power Coordinating Council, Western Electricity Coordinating Council	ISO	Public-Private	1998	Chalwa, 2013; World Bank, 2019
Panama	ETESA	ISO	Public	1998	Chalwa, 2013; World Bank, 2019; Panama Today, 2018; export.gov, 2016;
Denmark	See 2005	LTSO		1999	Chalwa, 2013; World Bank, 2019
Greece	Independent Power Transmission Operator S.A. (ADMIE)	LTSO	Private	1999	Chalwa, 2013; World Bank, 2019; ADMIE, 2019
UAE	bu Dhabi Transmission and Despatch Company (TRANSCO), DEWA, FEWA	LTSO	Public	1999	Chalwa, 2013; World Bank, 2019; Practical Law, 2016
Austria	Verbund AG; Austrian Power Grid	ITSO	Public-Private (51%-49%)	1999	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Verbund, 2015; Verbund, 2019
Belgium	Elia System Operator SA	ITSO	Public-Private	1999	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Elia Group, 2019;
Slovenia	ELES, Ltd., Electricity Transmission System Operator	ITSO	Public	1999	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; ELES, 2019;
Germany	TransnetBW GmbH TenneT TSO GmbH Amprion GmbH	ITSO	Private	1999	Chalwa, 2013; World Bank, 2019; Danwitz, 2006

	50Hertz Transmission GmbH				
Italy	See 2005	ISO		1999	Chalwa, 2013; World Bank, 2019
Northern Ireland	See 2009	LTSO		2000	Chalwa, 2013; World Bank, 2019
Portugal	REN - Redes Energéticas Nacionais, SGPS, S.A.	ITSO	Private	2000	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; REN, 2019;
Croatia	Croatian Transmission System Operator	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019; HOPS, 2019;
Ireland	EirGrid	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019; EirGrid, 2019;
Slovak Republic	Slovak Electricity Transmission System (SEPS)	ISO	Public	2002	Chalwa, 2013; World Bank, 2019; SEPS, 2019
Cyprus	Cyprus Transmission System Operator	LTSO	Public	2003	Chalwa, 2013; World Bank, 2019; Cyprus TSO, 2019
Singapore	Singapore Power PowerAssets & PowerGrid	ISO	Public	2003	Chalwa, 2013; World Bank, 2019; OIES, 2016
Poland	Polskie Sieci Elektroenergetyczne S.A (PGE)	LTSO	Public	2004	Chalwa, 2013; World Bank, 2019; PGE, 2019;
Estonia	See 2010	LTSO		2004	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Elering, 2019
Czech Republic	ČEPS a.s.	ITSO	Public	2004	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; CEPS, 2019
Cyprus	Cyprus Transmission System Operator	ISO		2004	Chalwa, 2013; World Bank, 2019; Cyprus TSO, 2019
France	Réseau de Transport d'Électricité (RTE)	LTSO	Public-Private	2005	Chalwa, 2013; World Bank, 2019; RTE, 2019;
Hungary	Hungarian Transmission System Operator (MAVIR)	LTSO	Public	2005	Chalwa, 2013; World Bank, 2019; MAVIR, 2019;
Latvia	Augstsprieguma Tīkls AS (AST)	LTSO	Public	2005	Chalwa, 2013; World Bank, 2019; AST, 2019;
Oman	Oman Electricity Transmission Company (OETC)	LTSO	Public	2005	Chalwa, 2013; World Bank, 2019; Global Transmission, 2018;
Iceland	Landsnet	ITSO	Public	2005	Chalwa, 2013; World Bank, 2019; Askjaenergy, 2019
Italy	Terna - Rete Elettrica Nazionale SpA	ITSO	Private	2005	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Terna, 2019;
Denmark	Energinet	ITSO	Public	2005	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Energinet, 2019;
Scotland	Scottish Power Transmission Limited,	ISO	Private	2005	Chalwa, 2013; World Bank, 2019; Ofgem, 2019

	Scottish Hydro Electric Transmission plc				
Luxembourg	Creos Luxembourg SA	LTSO	Public-Private	2009	Chalwa, 2013; World Bank, 2019; Reegle, 2013;
Switzerland	Swissgrid ag	ITSO	Private	2009	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Swissgrid, 2019;
Northern Ireland	System Operator of Northern Ireland (SONI)	ISO	Private	2009	Chalwa, 2013; World Bank, 2019; SONI, 2019;
Spain	Red Eléctrica de España S.A.	ITSO	Public-Private	2010	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; REE, 2019;
Estonia	Elering AS	ITSO	Private	2010	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Elering, 2019
Saudi Arabia	Saudi Electricity Company	LTSO		2012	Chalwa, 2013; World Bank, 2019; SE, 2019
Lithuania	Litgrid	ITSO	Public	2012	Chalwa, 2013; World Bank, 2019; Litgrid, 2019
Latvia	Augstsprieguma Tīkls AS (AST)	ISO	Public	2012	Chalwa, 2013; World Bank, 2019
Singapore	Singapore Power PowerAssets & PowerGrid	ISO	Public	2003	OIES, 2016

Table 3: Examples of unbundling in upper-middle income countries

Country	**TSO**	**Type**	**Ownership**	**Year**	**Sources**
Peru	Red de Energía del Perú S.A. (REPSA), and Consorcio Energético Huancavelica (CONENHUA), Consorcio Transmantaro S.A. (S.A. Transmantaro), Eteselva S.R.L, Interconexión Eléctrica ISA Perú (ISAPERU) and Red Eléctrica del Sur.S.A. (REDESUR),	ISO	Private	1992	Chalwa, 2013; World Bank, 2019; ESMAP, 2012;
Colombia	Interconexión Eléctrica S.A. (ISA)	ITSO	Public-Private	1994	Chalwa, 2013; World Bank, 2019; World Bank, 1995;
Kazakhstan	Kazakhstan Electricity Operating Company (KEGOC)	ITSO	Public	1996	Chalwa, 2013; World Bank, 2019; US Commercial Service, 2013;
Guatemala	Electricity Transport and Control Company (ETCEE)	ISO	Public-Private	1996	Chalwa, 2013; World Bank, 2019; Practical Law, 2018;

Ecuador	CELEC EP TRANSELECTRIC	ISO	Public	1996	Chalwa, 2013; World Bank, 2019; CELEC EP, 2019;
Brazil	National Electric System Operator (ONS)		Public	1998	ONS, 2019; BN Americas, 2019
Jordan	National Electric Power Company (NEPCO)	ITSO	Public	1999	Chalwa, 2013; World Bank, 2019; IAEA, 2018;
Romania	Transelectrica	ISO	Public-Private	2000	Chalwa, 2013; World Bank, 2019; Transelectrica, 2019;
Jordan	National Electric Power Company (NEPCO)	LTSO		2001	Chalwa, 2013; World Bank, 2019
Turkey	TEİAŞ	ITSO	Public	2001	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; TEIAS, 2019
Dominican Republic	Empresa de Transmisión Eléctrica Dominicana (ETED). National grid Coordinating entity (Organismo Coordinador del Sistema Eléctrico Nacional Interconectado)	ISO	Public	2001	Chalwa, 2013; World Bank, 2019; IRENA, 2016;
Algeria	SONELGAZ	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019
China	State Power Corporation of China (SPCC)	ITSO	Public	2002	OIES, 2016
Bosnia and Herzegovina	BiH Independent System Operator	ISO		2004	Chalwa, 2013; World Bank, 2019; BiH ISO, 2019;
Serbia	Elektromreža Srbije	ITSO	Public	2005	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; EMS, 2019
Armenia	The High Voltage Energy Network (HVEN) of Armenia	ISO	Public	2005	Chalwa, 2013; World Bank, 2019; Export.gov, 2019;
Albania	OST sh.a – Albanian Transmission System Operator	ITSO	Public	2006	Chalwa, 2013; World Bank, 2019, OST, 2019; ENTSO-E, 2019
Bulgaria	Electricity System Operator EAD	LTSO	Public	2007	Chalwa, 2013; World Bank, 2019; ESO, 2019
Russia	Federal Grid Company of Unified Energy System	ISO	Public	2008	Chalwa, 2013; World Bank, 2019; FSK, 2019
Mexico	Federal Electricity Commission (Comisión		Public	2013	Ibarra-Yunez, 2015

	Federal de Electricidad or CFE)				
Malaysia	Tenaga Nasional Berhad (Public); Sabah Electricity Sdn Bhd (SESB); and Sarawak Energy Berhad (SEB)		Public-Private		OIES, 2016
Thailand	Electricity Generating Authority of Thailand	ITSO	Public		OIES, 2016

Table 4:Examples of unbundling in lower-middle income countries

Country	**TSO**	**Type**	**Ownership**	**Year**	**Sources**
Bolivia	ENDE Corporation, ISA Bolivia, and San Cristobal TESA	ISO	Public	1994	Chalwa, 2013; World Bank, 2019
Ukraine	UKRENEGRO	ITSO	Public	1996	Chalwa, 2013; World Bank, 2019; UKRENEGRO, 2019
Bangladesh	Power Grid Company of Bangladesh Ltd		Public	1996	OIES, 2016
Kenya	KPLC & KETRACO	ITSO	Public	1997	KETRACO, 2019; Eberhard & Godinho, 2017; Nworie, 2017;
Georgia	Georgian State Electrosystem (GSE)	ITSO	Public	1997	Chalwa, 2013; World Bank, 2019; GSE, 2019;
Pakistan	Pakistan Electric Power Company (PEPCO)	LTSO	Public	1998	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017;
Nicaragua	National Electricity Transmission Company (ENATREL)	ITSO	Public	1999	Chalwa, 2013; World Bank, 2019; ENATREL, 2019; Reinstein et al, 2011;
El Salvador	The Transmitting Company of El Salvador, SA DE CV (ETESAL) - Public. Transactions Unit - system operator	ISO	Private	1999	Chalwa, 2013; World Bank, 2019; PROESA, 2015; ETESAL, 2019
Egypt	Egyptian Electricity Transmission Company	LTSO	Public	2001	Chalwa, 2013; World Bank, 2019; EEHC, 2019;
Kyrgyzstan	National Electrical Grid of Kyrgyzstan JSC	ITSO	Public	2001	Chalwa, 2013; World Bank, 2019; State Department, 2010;
Philippines	See 2009	ITSO	Public	2001	Chalwa, 2013; World Bank, 2019;

Mongolia	NPTG	ISO	Public	2001	Chalwa, 2013; World Bank, 2019; World Bank 2017; IEEJ, 2014;
Mongolia	Central Regional Electricity Transmission Company		Public	2001	Reegle, 2014
Bangladesh	Power Grid Company of Bangladesh Ltd. (PGCB)	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; PGCB, 2019;
India	Power Grid Corporation of India Limited (POWERGRID)	ITSO	Public	2003	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; POWERGRID, 2019;
Nigeria	Transmission Company of Nigeria	LTSO	Public	2005	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; TCN, 2019; Nworie, 2017;
Vietnam	Electricity of Vietnam (EVN)	LTSO	Public	2005	World Bank, 2013
Ghana	Ghana Grid Company of Ghana Ltd	ITSO	Public	2006	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; APUA, 2019; Gridco, 2019; Nworie, 2017;
Philippines	TransCo	ISO		2009	Chalwa, 2013; World Bank, 2019; TransCo, 2019
Angola	Rede Nacional de Transporte de Electricidade (RNT)		Public	2014	Eberhard & Godinho, 2017
Sudan	Sudanese Transmission Co Ltd		Public		Eberhard & Godinho, 2017; Global Transmission, 2018;
Bhutan	Bhutan Power Corporation Limited		Public		Eberhard & Godinho, 2017; BPC, 2019; OIES, 2016;
Indonesia	PLN (Perusahaan Listrik Negara/State Electricity Company)		Public		DifferGroup, 2012

Table 5: Examples of unbundling in low-income countries

Country	Independent grid operator	Type	Ownership	Year	Sources
Uganda	Uganda Electricity Transmission Company Limited (UETCL)	ITSO	Public	2001	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; Nworie, 2017;
Ethiopia	Ethiopian Electric Power		Public	2013	Eberhard & Godinho, 2017; Norton Rose Fulbright, 2016

From the above it is apparent that more than 90 countries globally have unbundled their electricity utilities and have established either combined independent transmission / system operators (ITSOs) or separate System Operators (ISOs) and Independent Transmission Companies (ITOs). The main driver for unbundling has been the recognition that competition is possible in power generation, while the grid remains mostly a regulated natural monopoly. Having an independent Transmission and System Operator allows least-cost power to be contracted competitively.

Tables 2 to 5 clearly show unbundling is most prevalent in richer countries, but 21 upper-middle income countries and 24 lower-middle income countries have also undertaken unbundling and restructuring reforms. Regional trends more or less mirror those of income classification with nearly all utilities in Europe having been vertically unbundled to some extent. In comparison 12 out of 23 countries in Latin America have vertically unbundled utilities (these include all the larger emerging economies such as Brazil, Argentina, Chile, Peru, Columbia, etc). In Sub-Sharan Africa this figure is lower with 10 out of 48 countries having vertically unbundled utilities (Eberhard & Godinho, 2017).

Another trend highlighted by tables 2 to 5 is the split between privately and publicly-owned ITSOs. Establishing and differentiating the roles of the state and private sector is a major concern in power sector reform, particularly in developing countries. Out of the countries listed in tables 2 to 5, the vast majority are state owned; only 16 TSOs were privatised, and 11 are partially government-owned with some private participation. Outside high-income countries, only 2 TSOs are owned by the private sector. Part of the reason for this is that transmission is typically regarded as a natural monopoly and well-suited to state ownership and regulation. On the other hand, power generation and retail supply are considered to be competitive with the potential for improving efficiencies, performance and reducing end-user costs. Vertical unbundling, and specifically the creation of an independent transmission grid and system operator, can allow the grid to remain state-owned, and system operation to be independent from other components of the ESI. Country experiences around the world, have shown this to be an effective way of improving reliability and transparency (Eberhard & Godinho, 2017; Sen et al., 2016).

Based on their study of 161 utilities (Chawla & Pollitt, 2013) illustrate in Table 6 the global distribution of TSO arrangements according to world region, which corroborates the above Tables.

Table 1: Global distribution of TSO arrangements by region (Chawla & Pollitt, 2013)

Current global distribution of TSO arrangements according to region				
Regions	ISO	ITSO	LTSO	VIU
Africa	0	2	3	48
Australasia & Asia	6	7	2	40
Europe	12	20	7	1
Middle East	0	1	6	9
North America	14	1	0	56
South America	6	1	0	7
Global	38	32	18	161

References

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Sen, A., Nepal, R., & Jamasb, T. (2016). *Reforming Electricity Reforms? Empirical Evidence from Asian Economies*.

Appendix 1:

Chronology of country experiences of unbundling

Country	TSO	Type	Ownership	Year	Sources
Chile	National Electric Coordinator (Coordinador Eléctrico Nacional, CEN)	ISO	Private	1985	Chalwa, 2013; World Bank, 2019; CEN, 2019; IAEA, 2018;
Spain	See 2010	ISO	Public-Private	1985	Chalwa, 2013; World Bank, 2019
England and Wales	National Grid plc	ITSO	Private	1990	Chalwa, 2013; World Bank, ENTSO-E, 2019; 2019; National Grid plc, 2019;
Norway	Statnett SF (Statsforetak)	ITSO	Public	1992	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Statneet, 2019
Argentina	Compañía Administradora del Mercado Mayorista Eléctrico (CAMMESA)	ISO	Private	1992	Chalwa, 2013; World Bank, 2019; ECN, 2015;
Peru	Red de Energía del Perú S.A. (REPSA), and Consorcio Energético Huancavelica (CONENHUA), Consorcio Transmantaro S.A. (S.A. Transmantaro), Eteselva S.R.L, Interconexión Eléctrica ISA Perú (ISAPERU) and Red Eléctrica del Sur.S.A. (REDESUR),	ISO	Private	1992	Chalwa, 2013; World Bank, 2019; ESMAP, 2012;
Bolivia	ENDE Corporation, ISA Bolivia, and San Cristobal TESA	ISO	Public	1994	Chalwa, 2013; World Bank, 2019
Colombia	Interconexión Eléctrica S.A. (ISA)	ITSO	Public-Private	1994	Chalwa, 2013; World Bank, 2019; World Bank, 1995;
New Zealand	Transpower	ITSO	Public	1994	Chalwa, 2013; World Bank, 2019; Electricity Authority, 2019; TransPower, 2019
Portugal	REN - Redes Energéticas Nacionais, SGPS, S.A	LTSO	Private	1996	Chalwa, 2013; World Bank, 2019; REN, 2019;

Ukraine	UKRENEGRO	ITSO	Public	1996	Chalwa, 2013; World Bank, 2019; UKRENEGRO, 2019
Kazakhstan	Kazakhstan Electricity Operating Company (KEGOC)	ITSO	Public	1996	Chalwa, 2013; World Bank, 2019; US Commercial Service, 2013;
Sweden	Svenska kraftnät	ISO	Public	1996	Chalwa, 2013; World Bank, 2019; Svenska kraftnät, 2019
Guatemala	Electricity Transport and Control Company (ETCEE)	ISO	Public-Private	1996	Chalwa, 2013; World Bank, 2019; Practical Law, 2018;
US	New England (ISO-NE); Midcontinent Independent System Operator; PJM Interconnection; Southwest Power Pool (SPP); California Independent System Operator (California ISO); New York Independent System Operator (NYISO); Electric Reliability Council of Texas (ERCOT).	ISO	Private	1996	Chalwa, 2013; World Bank, 2019; EIA, 2019;
Ecuador	CELEC EP TRANSELECTRIC	ISO	Public	1996	Chalwa, 2013; World Bank, 2019; CELEC EP, 2019;
Bangladesh	Power Grid Company of Bangladesh Ltd		Public	1996	OIES, 2016
Kenya	KPLC & KETRACO		Public	1997	KETRACO, 2019; Eberhard & Godinho, 2017; Nworie, 2017;
Finland	Fingrid Oyj	ITSO	Public-Private (53.1-46.9%)	1997	Chalwa, 2013; World Bank, 2019, Fingrid, 2019, ENTSO-E, 2019
Georgia	Georgian State Electrosystem (GSE)	ITSO	Public	1997	Chalwa, 2013; World Bank, 2019; GSE, 2019;
Czech Republic	See 2004	LTSO		1998	Chalwa, 2013; World Bank, 2019
Pakistan	Pakistan Electric Power Company (PEPCO)	LTSO	Public	1998	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017;
Netherlands	TenneT TSO B.V.	ITSO	Public	1998	Chalwa, 2013; World Bank, 2019; Tennet, 2019; ENTSO-E, 2019;
Australia	Australian Energy Market Operator	ISO	Private	1998	Chalwa, 2013; World Bank, 2019; AEMO, 2019;

Canada	Alaska Interconnection, Alberta Electric System Operator, BC Transmission Corporation, Hydro One, Hydro-Québec, Independent Electricity System Operator, Midcontinent Independent System Operator, Midwest Reliability Organization, New Brunswick System Operator, Newfoundland and Labrador Hydro, Newfoundland Power Inc., Northeast Power Coordinating Council, Western Electricity Coordinating Council	ISO	Public-Private	1998	Chalwa, 2013; World Bank, 2019
Panama	ETESA	ISO	Public	1998	Chalwa, 2013; World Bank, 2019; Panama Today, 2018; export.gov, 2016;
Brazil	National Electric System Operator (ONS)		Public	1998	ONS, 2019; BN Americas, 2019
Denmark	See 2005	LTSO		1999	Chalwa, 2013; World Bank, 2019
Greece	Independent Power Transmission Operator S.A. (ADMIE)	LTSO	Private	1999	Chalwa, 2013; World Bank, 2019; ADMIE, 2019
UAE	bu Dhabi Transmission and Despatch Company (TRANSCO), DEWA, FEWA	LTSO	Public	1999	Chalwa, 2013; World Bank, 2019; Practical Law, 2016
Austria	Verbund AG; Austrian Power Grid	ITSO	Public-Private (51%-49%)	1999	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Verbund, 2015; Verbund, 2019
Belgium	Elia System Operator SA	ITSO	Public-Private	1999	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Elia Group, 2019;
Slovenia	ELES, Ltd., Electricity Transmission System Operator	ITSO	Public	1999	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; ELES, 2019;
Jordan	National Electric Power Company (NEPCO)	ITSO	Public	1999	Chalwa, 2013; World Bank, 2019; IAEA, 2018;
Nicaragua	National Electricity Transmission Company (ENATREL)	ITSO	Public	1999	Chalwa, 2013; World Bank, 2019; ENATREL, 2019; Reinstein et al, 2011;

Germany	TransnetBW GmbH TenneT TSO GmbH Amprion GmbH 50Hertz Transmission GmbH	ITSO	Private	1999	Chalwa, 2013; World Bank, 2019; Danwitz, 2006
El Salvador	The Transmitting Company of El Salvador, SA DE CV (ETESAL) - Public. Transactions Unit - system operator	ISO	Private	1999	Chalwa, 2013; World Bank, 2019; PROESA, 2015; ETESAL, 2019
Italy	See 2005	ISO		1999	Chalwa, 2013; World Bank, 2019
Northern Ireland	See 2009	LTSO		2000	Chalwa, 2013; World Bank, 2019
Portugal	REN - Redes Energéticas Nacionais, SGPS, S.A.	ITSO	Private	2000	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; REN, 2019;
Romania	Transelectrica	ISO	Public-Private	2000	Chalwa, 2013; World Bank, 2019; Transelectrica, 2019;
Egypt	Egyptian Electricity Transmission Company	LTSO	Public	2001	Chalwa, 2013; World Bank, 2019; EEHC, 2019;
Jordan	National Electric Power Company (NEPCO)	LTSO		2001	Chalwa, 2013; World Bank, 2019
Kyrgyzstan	National Electrical Grid of Kyrgyzstan JSC	ITSO	Public	2001	Chalwa, 2013; World Bank, 2019; State Department, 2010;
Philippines	See 2009	ITSO	Public	2001	Chalwa, 2013; World Bank, 2019;
Uganda	Uganda Electricity Transmission Company Limited (UETCL)	ITSO	Public	2001	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; Nworie, 2017;
Turkey	TEİAŞ	ITSO	Public	2001	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; TEIAS, 2019
Mongolia	NPTG	ISO	Public	2001	Chalwa, 2013; World Bank, 2019; World Bank 2017; IEEJ, 2014;
Dominican Republic	Empresa de Transmisión Eléctrica Dominicana (ETED). National grid Coordinating entity (Organismo Coordinador del Sistema Eléctrico Nacional Interconectado)	ISO	Public	2001	Chalwa, 2013; World Bank, 2019; IRENA, 2016;
Mongolia	Central Regional Electricity Transmission Company		Public	2001	Reegle, 2014

Croatia	Croatian Transmission System Operator	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019; HOPS, 2019;
Bangladesh	Power Grid Company of Bangladesh Ltd. (PGCB)	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; PGCB, 2019;
Algeria	SONELGAZ	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019
Zimbabwe	Zimbabwe Transmission and Distribution Company	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; ZETDC, 2019;
Ireland	EirGrid	LTSO	Public	2002	Chalwa, 2013; World Bank, 2019; EirGrid, 2019;
Slovak Republic	Slovak Electricity Transmission System (SEPS)	ISO	Public	2002	Chalwa, 2013; World Bank, 2019; SEPS, 2019
China	State Power Corporation of China (SPCC)	ITSO (transmission & distribution not separated)	Public	2002	OIES, 2016
Cyprus	Cyprus Transmission System Operator	LTSO	Public	2003	Chalwa, 2013; World Bank, 2019; Cyprus TSO, 2019
India	Power Grid Corporation of India Limited (POWERGRID)	ITSO	Public	2003	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; POWERGRID, 2019;
Singapore	Singapore Power PowerAssets & PowerGrid	ISO	Public	2003	Chalwa, 2013; World Bank, 2019; OIES, 2016
Poland	Polskie Sieci Elektroenergetyczne S.A (PGE)	LTSO	Public	2004	Chalwa, 2013; World Bank, 2019; PGE, 2019;
Estonia	See 2010	LTSO		2004	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Elering, 2019
Czech Republic	ČEPS a.s.	ITSO	Public	2004	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; CEPS, 2019
Bosnia and Herzegovina	BiH Independent System Operator	ISO		2004	Chalwa, 2013; World Bank, 2019; BiH ISO, 2019;
Cyprus	Cyprus Transmission System Operator	ISO		2004	Chalwa, 2013; World Bank, 2019; Cyprus TSO, 2019
France	Réseau de Transport d'Électricité (RTE)	LTSO	Public-Private	2005	Chalwa, 2013; World Bank, 2019; RTE, 2019;

Hungary	Hungarian Transmission System Operator (MAVIR)	LTSO	Public	2005	Chalwa, 2013; World Bank, 2019; MAVIR, 2019;
Latvia	Augstsprieguma Tīkls AS (AST)	LTSO	Public	2005	Chalwa, 2013; World Bank, 2019; AST, 2019;
Nigeria	Transmission Company of Nigeria	LTSO	Public	2005	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; TCN, 2019; Nworie, 2017;
Oman	Oman Electricity Transmission Company (OETC)	LTSO	Public	2005	Chalwa, 2013; World Bank, 2019; Global Transmission, 2018;
Iceland	Landsnet	ITSO	Public	2005	Chalwa, 2013; World Bank, 2019; Askjaenergy, 2019
Serbia	Elektromreža Srbije	ITSO	Public	2005	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; EMS, 2019
Italy	Terna - Rete Elettrica Nazionale SpA	ITSO	Private	2005	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Terna, 2019;
Denmark	Energinet	ITSO	Public	2005	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Energinet, 2019;
Armenia	The High Voltage Energy Network (HVEN) of Armenia	ISO	Public	2005	Chalwa, 2013; World Bank, 2019; Export.gov, 2019;
Scotland	Scottish Power Transmission Limited, Scottish Hydro Electric Transmission plc	ISO	Private	2005	Chalwa, 2013; World Bank, 2019; Ofgem, 2019
Vietnam	Electricity of Vietnam (EVN)	LTSO	Public	2005	World Bank, 2013
Albania	OST sh.a – Albanian Transmission System Operator	ITSO	Public	2006	Chalwa, 2013; World Bank, 2019, OST, 2019; ENTSO-E, 2019
Ghana	Ghana Grid Company of Ghana Ltd	ITSO	Public	2006	Chalwa, 2013; World Bank, 2019; Eberhard & Godinho, 2017; APUA, 2019; Gridco, 2019; Nworie, 2017;
Ireland	EirGrid	ISO	Public	2006	Chalwa, 2013; World Bank, 2019; EirGrid, 2019;
Bulgaria	Electricity System Operator EAD	LTSO	Public	2007	Chalwa, 2013; World Bank, 2019; ESO, 2019

Russia	Federal Grid Company of Unified Energy System	ISO	Public	2008	Chalwa, 2013; World Bank, 2019; FSK, 2019
Luxembourg	Creos Luxembourg SA	LTSO	Public-Private	2009	Chalwa, 2013; World Bank, 2019; Reegle, 2013;
Switzerland	Swissgrid ag	ITSO	Private	2009	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Swissgrid, 2019;
Philippines	TransCo	ISO		2009	Chalwa, 2013; World Bank, 2019; TransCo, 2019
Northern Ireland	System Operator of Northern Ireland (SONI)	ISO	Private	2009	Chalwa, 2013; World Bank, 2019; SONI, 2019;
Spain	Red Eléctrica de España S.A.	ITSO	Public-Private	2010	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; REE, 2019;
Estonia	Elering AS	ITSO	Private	2010	Chalwa, 2013; World Bank, 2019; ENTSO-E, 2019; Elering, 2019
Saudi Arabia	Saudi Electricity Company	LTSO		2012	Chalwa, 2013; World Bank, 2019; SE, 2019
Lithuania	Litgrid	ITSO	Public	2012	Chalwa, 2013; World Bank, 2019; Litgrid, 2019
Latvia	Augstsprieguma Tīkls AS (AST)	ISO		2012	Chalwa, 2013; World Bank, 2019
Ethiopia	Ethiopian Electric Power		Public	2013	Eberhard & Godinho, 2017; Norton Rose Fulbright, 2016
Mexico	Federal Electricity Commission (Comisión Federal de Electricidad or CFE)		Public	2013	Ibarra-Yunez, 2015
Angola	Rede Nacional de Transporte de Electricidade (RNT)		Public	2014	Eberhard & Godinho, 2017
Sudan	Sudanese Transmission Co Ltd		Public		Eberhard & Godinho, 2017; Global Transmission, 2018;
Malaysia	Tenaga Nasional Berhad (Public); Sabah Electricity Sdn Bhd (SESB); and Sarawak Energy Berhad (SEB)		Public-Private		OIES, 2016
Thailand	Electricity Generating Authority of Thailand	ITSO	Public		OIES, 2016

Bhutan	Bhutan Power Corporation Limited		Public		Eberhard & Godinho, 2017; BPC, 2019; OIES, 2016;
Indonesia	PLN (Perusahaan Listrik Negara/State Electricity Company)		Public		DifferGroup, 2012