

Global Trends in Electricity Transmission System Operation: Where does the future lie?

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Abstract: Unbundling of the Electricity Supply Industry (ESI) has resulted in establishment of different arrangements of electricity transmission system operation. While there is a significant move away from the traditional vertically integrated utility arrangement, it remains to be seen which one arrangement will evolve as a global winner.

I. Introduction: There is a growing recognition of the importance of developing insights into designing and operating different components of the low-carbon smart³ power networks of the future. We exclusively examine the current global state of the business of electricity transmission system operation and identify the trends that are compatible with this future of power networks. Currently, there are several types of electricity transmission system operation arrangements worldwide that have evolved at different rates over the last three decades. In general, most of these arrangements can be categorised into one of the four groups (Table 1) based on the extent of ownership unbundling of transmission assets as well as coupling of Transmission Operation⁴ (TO) function with System Operation⁵ (SO) function.

In this research, we review the transmission system operation segment of the electricity supply industry (ESI) in 178 countries covering 249 Transmission System Operators (TSOs). With a view to understand the trends in the transmission system operation holistically, we also look at certain characteristics such as the total installed generation capacity connected to the grid (MW) and the type of existing electricity generation market associated with all the TSOs examined for this research. Looking forward, the aim is to offer general insights into the long-term prospects for each type of the transmission system operation arrangement.

[Insert Table 1]

II. Trends Over Time: Over the last three decades, there has been a significant global trend towards liberalization and restructuring of the ESI for various reasons such as lowering end-user prices, improving efficiency in the functioning of utilities, and increasing reliability in the delivery of electricity (Song et al., 2003). In the transmission sector, this process has involved a move away from the traditional vertically integrated utility arrangement to an independent organization in charge of System Operation and/or Transmission Operation has been observed across different regions of the

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³ According to Global Smart Grid Federation, 'A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.' Last accessed on March 14, 2013 from <http://www.globalsmartgridfederation.org/smartgriddef.html>.

⁴ Includes maintenance and long-term development of physical transmission assets (NordReg, 2006).

⁵ Includes reliable operation of the physical transmission assets to ensure a constant balance between electricity supplied and electricity demanded (Oren et al., 2006).

world. Figure 1 presents the timeline over which TSOs from different countries have unbundled their transmission business from other segments of the ESI. Between 1999 and 2001, more than 20 countries adopted such liberalisation reforms, representing the largest volume of this shift over time.

[Insert Figure 1]

The first wave of transmission unbundling took place in countries such as Chile (1985), Britain (1990), Norway (1992), Argentina (1992) and Peru (1992). Soon after many European, North American as well as South American countries followed suit. Lately, countries that have adopted (different degrees of) liberalisation reforms include Saudi Arabia (LTSO) in the Middle East, and Lithuania (ITSO) and Latvia (ISO) in the Baltic region. More interesting to note are the stages in which unbundling of transmission system operation has taken place in some of these countries (Table 2). For instance, in Czech Republic and Denmark, liberalisation was initiated with the legal unbundling of the incumbent utilities during 1998-99. This led to complete ownership unbundling during 2004-05 that resulted in the formation of ITSOs: CEPS, a.s. and Energinet.dk respectively. A similar transition from LSO/LTSO arrangement to ISO/ITSO arrangement took place in countries such as Ireland (LSO → ISO), Northern Ireland (LSO → ISO), Cyprus (LTSO → ISO), and Estonia (LTSO → ITSO) between 2000 and 2008.

In the case of Philippines, the Electric Power Industry Reform Act (EPIRA) of 2001 resulted in the formation of National Transmission Corporation (TransCo) as an ITSO. At the beginning of 2009, National Grid Corporation of the Philippines was established which took over the operation of the grid as an ISO while the TO function was retained within TransCo (ITSO → ISO + ITO).

[Insert Table 2]

Spain and Italy, on the other hand, are unique examples where liberalisation first resulted in the formation of separate independent organisations responsible for SO and TO functions respectively. This was followed by a unification of both operation and ownership of transmission assets within the same organisation (ISO + ITO → ITSO).

III. Current Scenario: The current global distribution of different types of TSO arrangements suggests that while many developed countries have successfully undergone liberalisation and unbundled their transmission segment from the rest of the ESI, countries in Africa, Asia and the Middle-East still lack the political will to implement such reforms (Nagayama, 2011). In the Middle-

[Insert Table 3]

East, liberalisation has been set into a motion with the legal separation of the transmission segment within the incumbent utilities, especially, among the GCC countries (Al-Asaad, 2008). In general, the pace of implementing reforms in the Middle-East seems faster than in Africa and Asia. On comparing numbers, Table 3 also suggests that while the European countries have favoured the ITSO arrangement (except Belarus that stands as the last European country with a VIU structure); North and South American countries seem to be inclined towards the ISO arrangement. Overall, it remains to be seen what arrangement will emerge as the global winner when liberalisation reforms eventually take place in many of the Asian and African countries.

[Insert Figure 2]

IV. A More Holistic View: Some interesting facts are revealed upon a careful examination of characteristics such as the installed generation capacity (connected to the grid), and the type of

generation market associated with each of the TSOs examined in this research. From the graph in Figure 3, we observe that even though the number of ISOs is only one-third the number of VIUs globally, the magnitude of the installed generation capacity dealt by ISOs is more than half of that dealt by VIUs. This implies that the arrangements that are significant by number may not be significant by the capacity of generation installed on the networks that they operate.

Moving forward, we categorize all the electricity generation markets into one of the three groups, namely, no-wholesale⁶ market, single-buyer⁷ wholesale market, and competitive wholesale⁸ market. At the global level, we find that the total installed generation capacity (on the grid) associated with competitive wholesale generation markets is dramatically more than those associated with no-wholesale markets or single-buyer wholesale generation markets. Looking at this more carefully, the graphs (Figure 4) also suggest that a major proportion of installed generation capacity under no-wholesale or single-buyer wholesale markets is associated with the traditional VIU arrangement. Exceptions being Australia, Brazil, Canada, Japan and the USA that allow for competitive wholesale generation markets to co-exist with the VIU arrangement.

[Insert Figure 3]

[Insert Figure 4]

Other interesting observations include absence of competitive wholesale markets in the Middle-East as well as in Kyrgyzstan where unbundling has already resulted in the formation of an ITSO arrangement but not the establishment of a wholesale electricity market.

V. Conclusion: What this review of the global evidence on electricity system operation arrangements strongly suggests is that, in spite of a discernible move away from the traditional VIU arrangement, there is no evidence for a clear winning TSO arrangement yet. However, certain arrangements seem to have gained regional popularity, i.e., ITSO arrangement in the Europe and ISO arrangement in North America. While the number of LTSOs globally seems to have stabilised in the last couple of years, the numbers for ISOs and ITSOs are consistently increasing. Some of the interesting questions that remain unanswered include: what is the distribution of outages under different types of TSO arrangements; how is the connection of intermittent renewable sources of energy affected by different types of TSO arrangements; why do different regions favour different types of arrangements; and most importantly, will there ever be a convergence in the global choice of a particular TSO arrangement?

⁶ A no wholesale market is where the incumbent utility is solely in charge of electricity supply. All the Independent Power Producers (IPPs) , if they may exist, provide directly to the VIU in order to mitigate capacity shortages (Nagayama, 2011).

⁷ Single-buyer wholesale market is where all the generating companies sell their electricity output to a single energy provider (which may be the incumbent VIU/ TSO/ Separate entity) on a competitive basis through Power Purchase Agreements (Lovei, 2000).

⁸ A competitive wholesale market is where all the generating companies compete with each other to provide electricity to distributors and/or retailers. Last accessed on March 15, 2013 from http://en.wikipedia.org/wiki/Electricity_market.

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Tables and Figures

Table 1: A Brief Description on Different Types of TSO Arrangements

Name	Description
<p style="text-align: center;">Vertically Integrated Utilities (VIU)</p>	<p>Characteristic: The traditional energy-market model of no competition, where one electricity provider is in charge of generation, transmission, distribution and retailing (Pollitt, 2012)</p>
	<p>Advantage: Scope for reduction in general costs of labour, management, O&M, and planning (Chao et al., 2007)</p>
	<p>Disadvantage: Lack of transparency in costs allocation; discrimination against other generating companies (gencos) for access to the transmission grid (Thomas, 2007)</p>
	<p>Variants: For appropriate allocation of costs due to different segments of ESI, accounting unbundling can take place that ensures separate records are maintained (Thomas, 2007). E.g., Uzbekenergo, the joint stock company in Uzbekistan</p>
<p style="text-align: center;">Legally-unbundled Transmission System Operator (LTSO)</p>	<p>Characteristic: When there is a separate company responsible for both ownership and operation of the transmission grid, however, this company is a subsidiary of a parent company that also holds subsidiaries involved in generation, distribution and/or retail segments of the ESI (Thomas, 2007)</p>
	<p>Advantage: Appropriate allocation of transmission costs (SO + TO) from the other segments of the ESI</p>
	<p>Disadvantage: Lack of complete independence as the LTSO may still favour the generating subsidiaries of the parent company for access to the transmission grid (Thomas, 2007)</p>
	<p>Variants: Apart from carrying out the minimum functions of maintaining and operating the transmission grid (TO+SO), LTSO could also take on the responsibility of carrying out Market operation (MO) functions of monitoring and compliance (in day-ahead, transmission rights, capacity, and ancillary markets). E.g., MAVIR (Hungary). Another variation of this arrangement is when the parent company has two distinct legally-separate subsidiaries responsible for TO and SO respectively, i.e., LSO and LTO. E.g., Algeria, Armenia, and Latvia until 2005</p>
<p style="text-align: center;">Independent Transmission System Operator (ITSO)</p>	<p>Characteristic: When there is a separate company solely responsible for both ownership and operation of the transmission grid, and this company is also independent of any form of influence from other electricity-market players (Leveque et al., 2009)</p>
	<p>Advantage: This arrangement allows for fair competition among gencos for access to the transmission grid, and coordination in long term planning and investment decisions between the TO and SO segments of the business (Pollitt, 2012)</p>
	<p>Disadvantage: There may be political resistance against allowing complete ownership unbundling of transmission assets, and difficulty in conducting inter-regional coordination (Pollitt, 2008 and Leveque et al., 2009)</p>

	<p>Variants: Apart from carrying out the minimum functions of maintaining and operating the transmission grid (TO+SO), an ITSO could also take on the responsibility of carrying out market operation functions of monitoring and compliance (in day-ahead, transmission rights, capacity and ancillary markets), and inter-regional coordination. E.g., National Grid Plc (England and Wales)</p>
<p style="text-align: center;">Independent System Operator (ISO)</p>	<p>Characteristic: When there is a clear distinction between organisations that are responsible for operating the transmission grid in real-time and those that own and maintain it (Thomas, 2007)</p>
	<p>Advantages: This arrangement allows for fair competition amongst genscos for access to the transmission grid without dealing with the economic and political challenges of ownership unbundling of the transmission assets (Pollitt, 2008)</p>
	<p>Disadvantage: Coordination problems in terms of information exchange (reliability), and allocation of investments costs (for building new transmission assets) between the ISO and the ITO (Nagayama, 2011)</p>
	<p>Variants: Apart from carrying out the minimum functions of scheduling and load dispatching, an ISO could take on the additional responsibility of carrying out Transmission/Generation interconnection studies, market monitoring and compliance (in day-ahead, transmission rights, capacity and ancillary markets), and inter-regional coordination (with greater geographical control). E.g., PJM Interconnection LLC (USA)</p>

Figure 1: Evolution of Different Types of TSO Arrangements Overtime

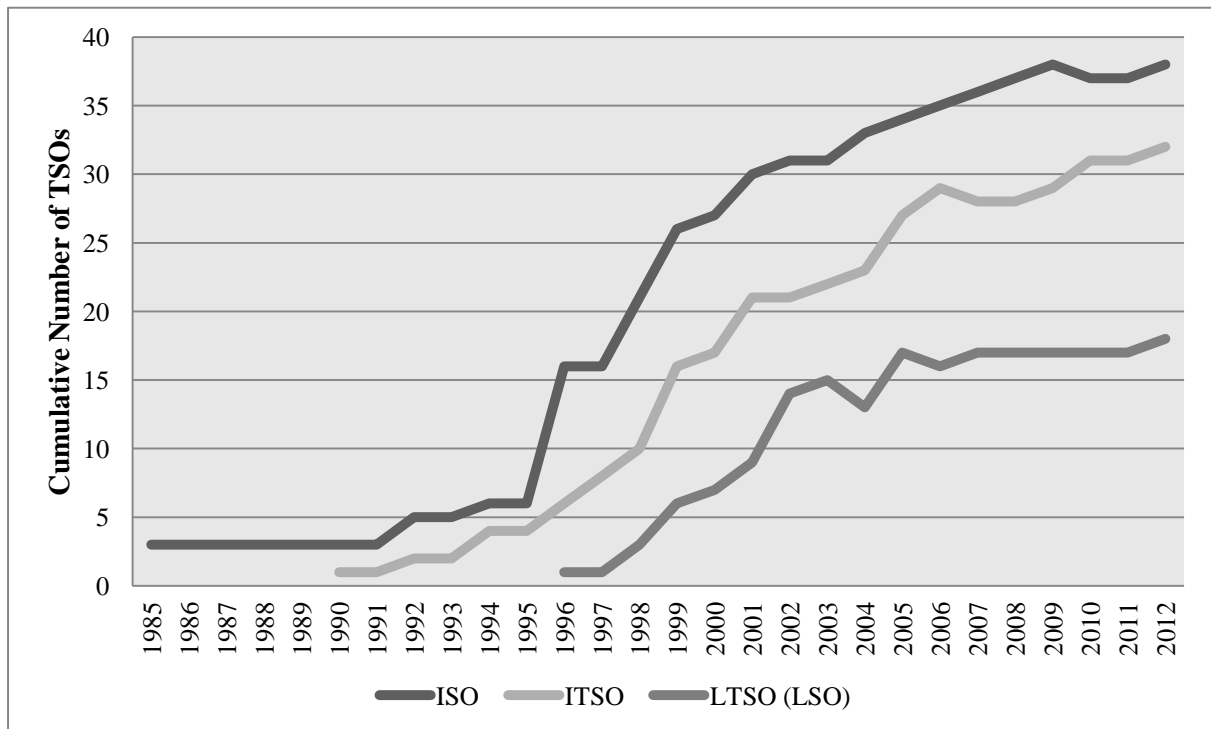


Table 2: Detailed Timeline of TSO Unbundling in Different Countries

Year	Countries moving away from the VIU arrangement and adopting the following types of TSO arrangements*		
	LTSO	ITSO	ISO
1985			Chile , Spain
1986			
1987			
1988			
1989			
1990		England and Wales (NGC)	
1991			
1992		Norway	Argentina, Peru
1993			
1994		New Zealand, Colombia	Bolivia
1995			
1996	Portugal	Ukraine, Kazakhstan	Sweden, Guatemala, USA, Ecuador
1997		Finland, Georgia	
1998	Czech Republic, Pakistan (PEPCO)	Netherlands	Australia (AEMO), Canada, Panama
1999	Denmark, Greece, UAE	Austria, Belgium, Slovenia, Jordan, Nicaragua, Germany	El Salvador, Germany, Italy
2000	Northern Ireland (SONI)	Portugal	Romania
2001	Egypt, Jordan	Kyrgyzstan, Philippines, Uganda, Turkey	Mongolia, Singapore, Dominican Republic
2002	Croatia, Bangladesh, Algeria, Zimbabwe, Ireland		Slovakia
2003	Cyprus	India	Bosnia and Herzegovina, Cyprus
2004	Poland, Estonia	Czech Republic	
2005	France, Hungary, Latvia (LSO), Nigeria, Oman	Iceland, Serbia, Italy, Denmark	Armenia, Scotland (NGC)
2006		Albania, Ghana	Ireland
2007	Bulgaria		
2008			Russia
2009	Luxembourg	Switzerland	Philippines, Northern Ireland (SONI)
2010		Spain, Estonia	
2011			
2012	Saudi Arabia	Lithuania	Latvia

Please Note: Of the 249 TSOs studied for this research, by the end of 2012, 88 in total had switched away from the VIU arrangement (as shown above) leaving 161 incumbent utilities as VIU

Table 3: Current Distribution of TSO Arrangements across Different Regions

Regions	ISO	ITSO	LTSO	VIU	Total no. of TSOs studied	Total no. of Countries studied
Africa	0	2	3	48	53	52
Australasia & Asia	6	7	2	40	55	37
Europe	12	20	7	1	40	38
Middle East	0	1	6	9	16	16
North America	14	1	0	56	71	23
South America	6	1	0	7	14	12
Global	38	32	18	161	249	178

Figure 2: Summary of Current Distribution of TSO Arrangements (by Number of Firms studied)

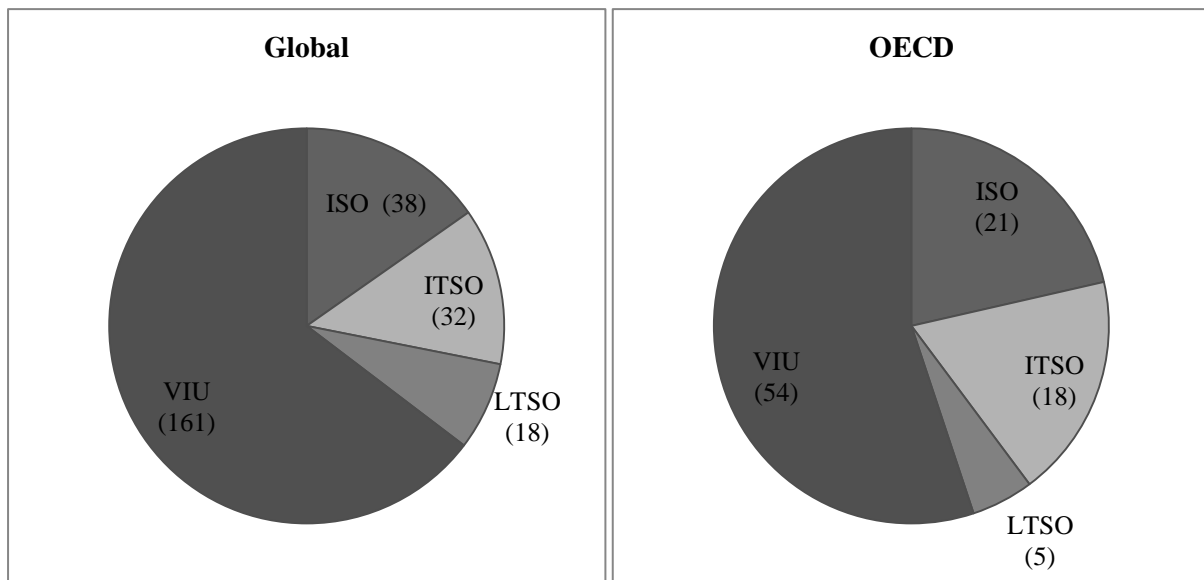


Figure 3: Distribution of Total Installed Generation Capacity (on the grid) by Type of TSO Arrangement across Different Regions

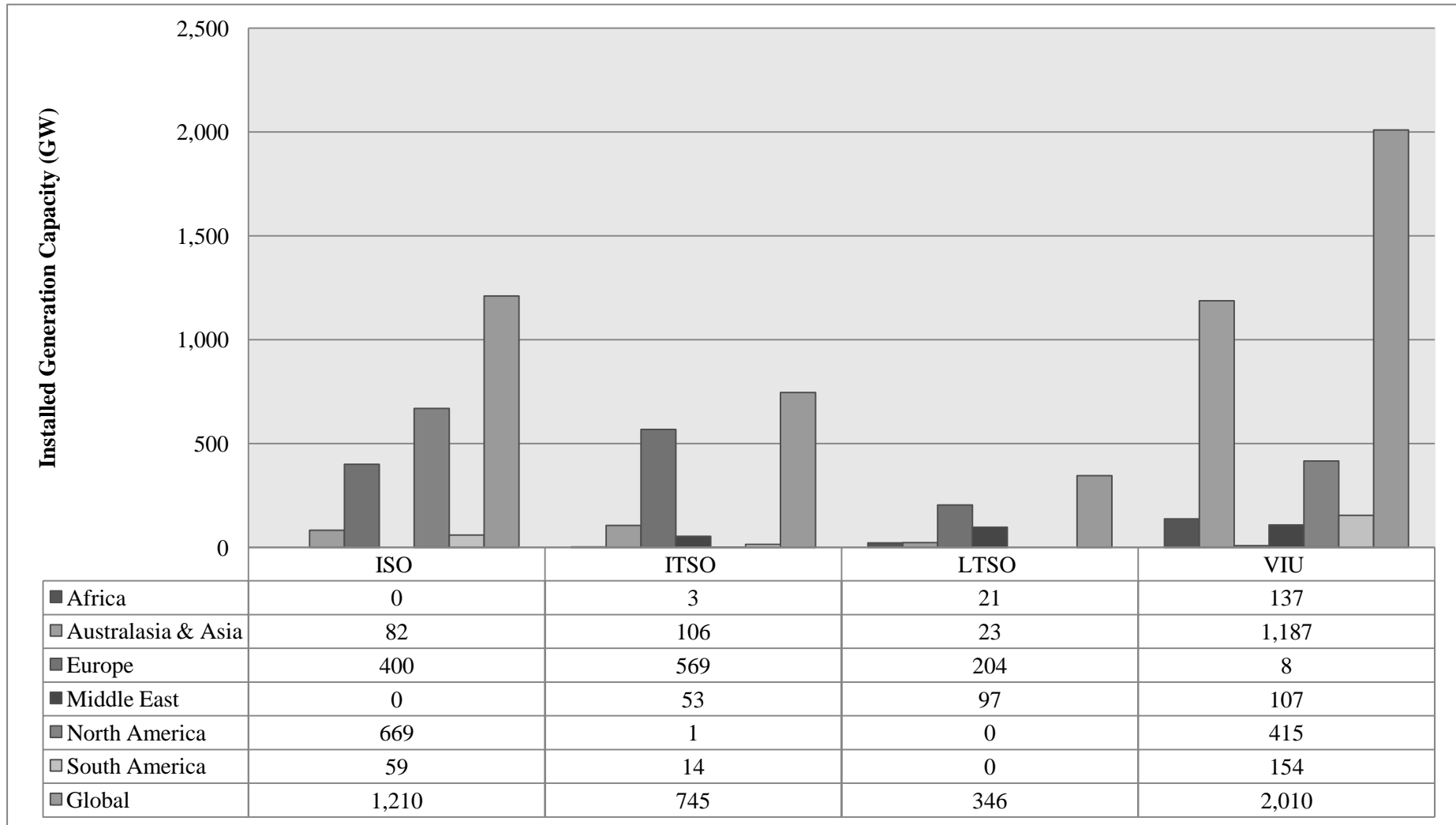
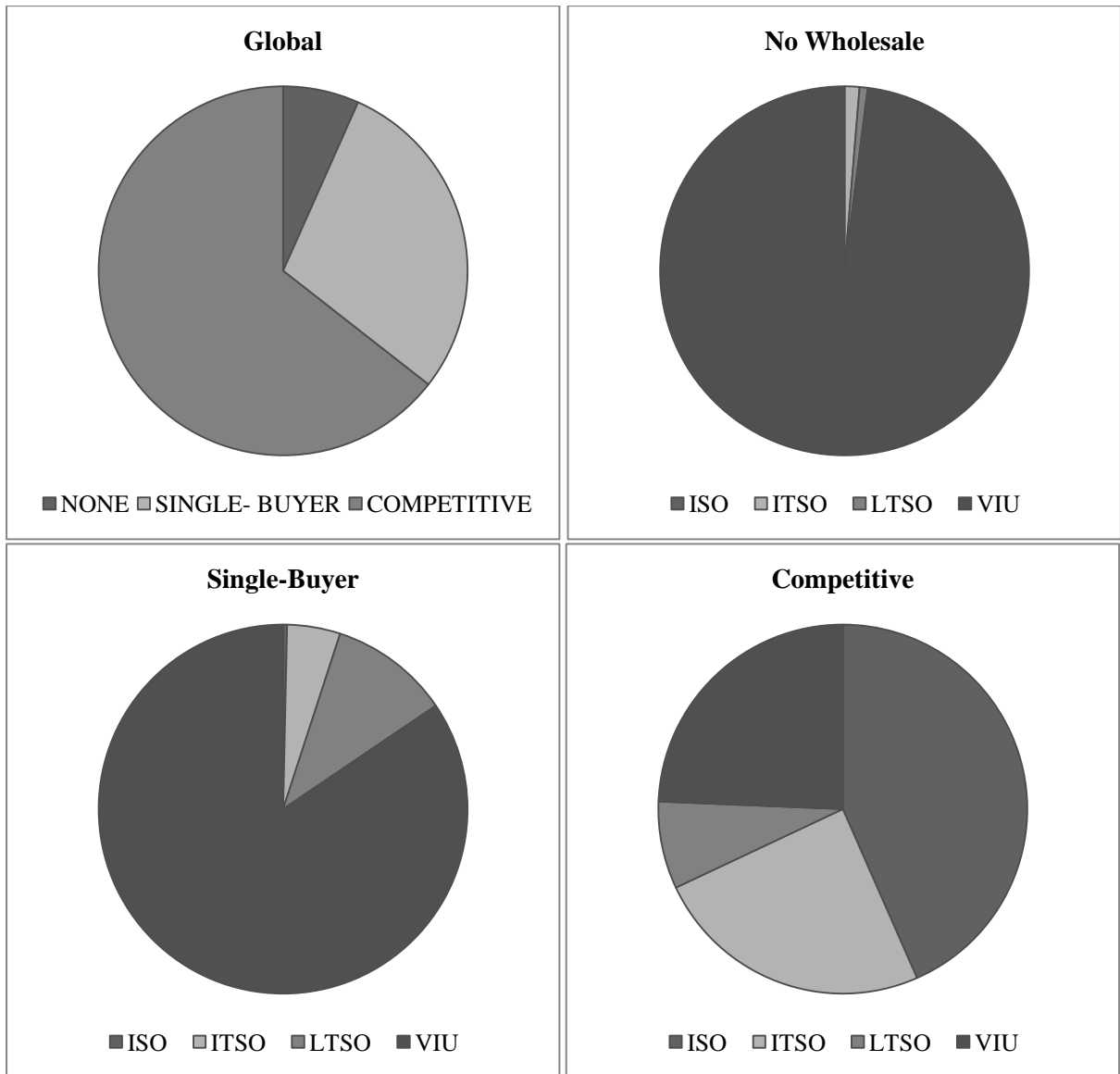


Figure 4: Distribution of Installed Generation Capacity (on the grid) by Type of TSO Arrangement across Different Market Structures



Appendix: Details on All the TSOs

	Country	Type	Name	Number of TSOs	Installed Generation Capacity (MW)	Year corresponding to data on IGC (MW)	Market Structure
AFRICA							
1	Algeria	LSO	Opérateur Système Electrique - (OS)	1	10926	2011	Single-Buyer
2	Angola	VIU	Empresa Nacional de Electricidades	1	1187	2008/09	NO
3	Benin	VIU	Communauté Electrique du Bénin (CEB)	1	93	2000	Single-buyer
4	Botswana	VIU	Botswana Power Corporation (BPC)	1	132	2009	NO
5	Burkina Faso	VIU	Société Nationale Burkinabè d'Electricité (SONABEL)	1	259*	2009	NO
6	Burundi	VIU	Régie de Production et Distribution d'Eau et d'Electricité (REGIDESO)	1	52	2008	NO
7	Cameroon	VIU	AES Sonel	1	935	2009	NO
8	Cape Verde	VIU	Empresa de Electricidad e Agua (ELECTRA)	1	116	2010	NO
9	Central African Republic	VIU	Énergie Centrafricaine (ENERCA)	1	37	2009	NO
10	Chad	VIU	Société Tchadienne d'Eau et d'Electricite (STEE)	1	72	2009	NO
11	Comoros	VIU	MAMWE	1	6*	2009	NO
12	Congo, Democratic Republic of the	VIU	Société Nationale d'Electricité (SNEL)	1	2437	2009	NO
13	Congo, Republic of the	VIU	Société National d'Electricité (SNE)	1	237	2009	NO
14	Cote d'Ivoire	VIU	Compagnie Ivoirienne d'Electricite ("CIE")	1	1391	2010	Single-buyer
15	Djibouti	VIU	Electricité de Djibouti (EDD)	1	123	2011	NO
16	Equatorial Guinea	VIU	Sociedad de Electricidad de Guinea Ecuatorial (SEGESA)	1	86	2011	NO
17	Eritrea	VIU	Eritrea Electric Corporation (EEC)	1	140*	2009	NO
18	Ethiopia	VIU	Ethiopia Electric Power Corporation (EEPCo)	1	60000	2010/11	NO
19	Gabon	VIU	Société d'Electricité et d'Eaux du Gabon (SEEG)	1	374	2011	NO
20	Gambia, The	VIU	National Water and Electric Company (NAWEC)	1	62*	2009	Single-buyer

21	Ghana	ITSO	Ghana Grid Company (GRIDCO)	1	2186	2010	Competitive
22	Guinea	VIU	Guinea State Electricity Company, EDG (Societe d'Etat d'Electricite de Guinee)	1	181	2010	NO
23	Guinea-Bissau	VIU	Electricity and Water Company of Guinea-Bissau (Electricidade e Aguas de Guinea-Bissau, EAGB)	1	5.6	2010	NO
24	Kenya	VIU	Kenya Power and Lighting Company (KPLC)	1	1354	2011	Single-buyer
25	Lesotho	VIU	Lesotho Electricity Company (LEC)	1	134	2009/10	NO
26	Liberia	VIU	Liberia Electricity Corporation (LEC)	1	197*	2009	NO
27	Libya	VIU	General Electricity Company of Libya (GECOL)	1	6300	2010	NO
28	Madagascar	VIU	Jiro sy Rano Malagasy (JIRAMA)	1	315.96	2009	NO
29	Malawi	VIU	Electricity Supply Corporation of Malawi (ESCOM)	1	287	2010	NO
30	Mali	VIU	Malian utility "Énergie du Mali" (EDM-SA)	1	295	2010	NO
31	Mauritania	VIU	Société Mauritanienne de l'électricité (SOMELEC)	1	150	2010	NO
32	Mauritius	VIU	Central Electricity Board (CEB)	1	739*	2009	NO
33	Morocco	VIU	Office National de l'Electricité (ONE)	1	6135	2009	Single-buyer
34	Mozambique	VIU	Electricidade de Mocambique (EDM)	1	233	2010	NO
35	Namibia	VIU	NamPower	1	393	2010	Single-Buyer
36	Niger	VIU	Société nigérienne d'électricité (NIGELEC)	1	91	2010	Single-Buyer
37	Nigeria	LTSO	Transmission Company of Nigeria	1	8425	2010	Competitive
38	Rwanda	VIU	Energy, Water and Sanitation Authority (EWSA)	1	84.4	2010	
39	Sao Tome and Principe	VIU	Empresa de Agua e Electricidade (EMAE)	1	20.4	2011	
40	Senegal	VIU	Société Nationale d'Électricité du Sénégal (SENELEC)	1	629	2010	Single-Buyer
41	Seychelles	VIU	Public Utilities Corporation (PUC)	1	95	2008	NO
42	Sierra Leone	VIU	National Power Authority	1	106	2011	NO
43	Somalia	VIU	Nugal Electrical Company (NEC)	1	80	2006	
44	South Africa	VIU	ESKOM	1	44170	2010	Single-Buyer
45	Sudan	VIU	National Electricity Corporation of Sudan "(NEC)"	1	1083	2011	NO
46	Swaziland	VIU	Swaziland Electricity Company (SEC)	1	70	2010	NO
47	Tanzania	VIU	TANESCO	1	1150	2011	Single-buyer
48	Togo	VIU	Communauté Electrique du Bénin (CEB)	2	85*	2009	Single-buyer

48	Togo	VIU	Electricity Energy Company of Togo (CEET)	2		2009	
49	Tunisia	VIU	Société Tunisienne d'Electricité et du Gaz (STEG)	1	3480	2009	Single-Buyer
50	Uganda	ITSO	Uganda Electricity Transmission Company Ltd (UETCL)	1	342	2011	Single-Buyer
51	Zambia	VIU	Zambia Electricity Supply Corporation (ZESCO)	1	1812	2010	Single-Buyer
52	Zimbabwe	LTSO	Zimbabwe Electricity Transmission and Distribution Company (ZETDC)	1	2045	2010	NO
AUSTRALASIA & ASIA							
1	Afghanistan	VIU	Da Afghanistan Breshna Moassesa	1	489*	2009	NO
2	Armenia	ISO	CJSC Operator Systemy Electroenergetiky	1	3238	2008	Single Buyer
		ISO	NEMMCo/ AEMO		49110	2011	Competitive
3	Australia	VIU	System Management (SM) under Western power	4	5541	2012	Competitive
		VIU	Horizon Power (HP)		160	2013	Competitive
		VIU	Power and Water Corporation		615	2012	NO
4	Azerbaijan	VIU	Azerenergy	1	6200	2008	NO
5	Bangladesh	LTSO	Power Grid Company of Bangladesh	1	5823	2010	Single Buyer
6	Bhutan	VIU	Bhutan Power Corporation	1	1504	2012	NO
7	Brunei	VIU	Department of Electrical Services (DES)	1	759*	2009	NO
8	Burma	VIU	Ministry of Electric Power	1	1684*	2009	NO
9	Cambodia	VIU	Electricité du Cambodge	1	403.61	2008	Single Buyer
10	China	VIU	State Grid Corporation of China	2	535460**	2011	Single Buyer
		VIU	China Southern Power Grid		188000	2011	Single Buyer
11	Cyprus	ISO	Cyprus Transmission System Operator	1	1438	2010	Competitive (weak)
12	Georgia	ITSO	Georgian State Electric System	2	4538*	2009	Competitive
		ITSO	Sakrusenergo				
13	Hong Kong	VIU	China Light & Power Company (CLP)		6908	2012	NO
		VIU	Hongkong Electric Company Limited (HEC).	2	3756	2010	NO

14	India	ITSO	Power Grid Corporation of India Limited with SO handed by POSCO	1		65973	2012	Competitive
15	Indonesia	VIU	Perusahaan Umum Lishtrik Negara (PLN)	1		27000	2010	Single Buyer
		VIU	Tokyo Electric Power Company (TEPCO)	Largest one		66472	2011	Competitive (weak)
16	Japan	VIU	Electricity market is monopolized by 9 (and TEPCO) major electric utilities that are vertical integrated and are strictly regulated by METI.	9		140940	2011	Competitive (weak)
17	Jordan	ITSO	National Electric Power Company (NEPCO)	1		3186	2012	Single Buyer
18	Kazakhstan	ITSO	Kazakhstan Electricity Grid Operating Company (KEGOC)	1		19000	2011	Competitive
19	Korea, South	VIU	Korea Electric Power Corporation	1		76649	2012	Single Buyer
20	Kyrgyzstan	ITSO	NEGC OJSC	1		3740	2011	NO
21	Laos PDR	VIU	Electricité du Laos	1		1800	2010	Single Buyer
22	Macau	VIU	Companhia de Electricidade de Macau – CEM, S.A.	1		472	2012	NO
		VIU	Tenaga National Berhad			15826	2012	Single Buyer
23	Malaysia	VIU	Syarikat SESCO Berhad	3		803.6	2008	Single Buyer
		VIU	Sabah Electricity Limited			1324	2012	Single Buyer
24	Maldives	VIU	tate Electric Company (STELCO)	1		79.2	2012	NO
25	Mongolia	ISO	National Dispatching Centre Company			1062	2012	Single Buyer
26	Nepal	VIU	Nepalese Electricity Authority (NEA)	1	630*		2009	Single Buyer
27	New Zealand	ITSO	Transpower New Zealand Limited (TPNZ)	1	9100*		2009	Competitive
28	Pakistan	LTSO	National Transmission & Power Dispatch Company (NTDC) under Pakistan Electric Power Company (PEPCO)	2		17366	2007	Single Buyer
		VIU	Karachi Electric Supply Corporation (KESC)			3362	2012	Single Buyer
29	Philippines	ISO	National Grid Corporation of the Philippines	1		15896	2010	Competitive
30	Singapore	ISo	Power System Operator			11077.5	2012	Competitive
31	Sri Lanka	VIU	Ceylon Electricity Board	1		3141	2011	Single Buyer
32	Taiwan	VIU	Taipower	1		40247	2009	Single Buyer

33	Tajikistan	VIU	Barqi Tojik	1	4700	2010	NO
34	Thailand	VIU	Electricity Generating Authority of Thailand (EGAT)	1	14998	2011	Single Buyer
35	Turkmenistan	VIU	Turkmenenergo State Corporation	1	4000	2010	NO
36	Uzbekistan	VIU	Uzbekenergo	1	12400	2009	NO
37	Vietnam	VIU	Electricit du Vietnam	1	21000	2011	Single Buyer
EUROPE							
1	Albania	ITSO	OST	1	1550	2011	Single-buyer
2	Austria	ITSO	Austrian Power Grid AG (APG)	1	18157	2011	Competitive
3	Belarus	VIU	Belarus has no specially appointed Transmission System Operator (TSO) but the functions are shared by Belenergo, ODU and the Oblenergos.	1	7 974.4	2010	No
4	Belgium	ITSO	ELIA System Operator SA (Elia Transmission)	1	15402	2011	Competitive
5	Bosnia and Herzegovina	ISO	Independent System Operator in BH (ISO BH)	1	3903.6	2010	YES (almost)
6	Bulgaria	LTSO (in transition)	Electricity System Operator EAD (ESO)	1	12668	2012	Competitive
7	Croatia	LTSO	HEP- Operator prijenosnog sustava d.o.o. (HEP-OPS)	1	3745	2011	Competitive
8	Czech Republic	ITSO	CEPS a.s.	1	20250	2011	Competitive
9	Denmark	ITSO	Energinet.dk Independent Public Enterprise	1	13707	2010	Competitive
10	Estonia	ITSO	Elering OU	1	2652	2012	Competitive
11	Finland	ITSO	Fingrid Oyj' (Finnish Power Grid Plc)	1	16817	2011	Competitive
12	France	LTSO	Réseau de Transport d'Electricité	1	123500	2010	Competitive
13	Germany	ISO	TransnetBW GmbH (88% of the company owned by Enw which involved in generation, transmission and distribution and procuremnt.. Not sure who owns the grid)	4	13500	2012	Competitive
		ISO	TenneT TSO GmbH (System operator with partial grid ownership)		67000	2011	

		ITSO	Amprion GmbH (subsidiary of RWE AG)		45000	2012	
		ISO	50Hertz Transmission GmbH (System operator with partial grid ownership)		14210	2011	
14	Greece	LTSO	The Independent Power Transmission Operator (IPTO or ADMIE)	1	16260	2013	Competitive
15	Hungary	LTSO	MAVIR Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zártkörűen Működő Részvénytársaság	1	9200	2009	Competitive
16	Iceland	ITSO	Landsnet hf	1	2579	2010	Competitive (weak)
17	Ireland	Iso	EirGrid plc	1	8504	2011	Competitive
18	Italy	ITSO	Terna - Rete Elettrica Nazionale SpA	1	110290	2010	Competitive
19	Latvia	ISO	JSC Augstsprieguma tīkls	1	2530	2010	Competitive
20	Lithuania	ITSO	Litgrid	1	3872	2010	Competitive
21	Luxembourg	LTSO	Creos Luxembourg S.A.	1	1740*	2011	YES (almost)
22	Malta	NONE					
23	Netherlands	ITSO	TenneT TSO B.V.	1	24130*	2011	Competitive
24	Norway	ITSO (almost)	Statnett	1	31714	2011	Competitive
25	Poland	LTSO	PSE Operator S.A.	1	37010	2011	Competitive
26	Portugal	ITSO	Rede Eléctrica Nacional, S.A	1	18901	2011	Competitive
27	Romania	ISO	CN Transelectrica SA	1	16160	2011	Competitive
28	Russia	ISO	Federal Grid Company	1	211846	2011	Competitive
29	Serbia	ITSO	Elektromreža Srbije (EMS)	1	8373	2009	Competitive
30	Slovakia	ISO	Slovenská elektrizačná prenosová sústava (SEPS)	1	8152	2011	Competitive
31	Slovenia	ITSO	Elektro Slovenija d.o.o.	1	3086	2011	Competitive
32	Spain	ITSO	Red Eléctrica de España: S.A.	1	108296	2012	Competitive
33	Sweden	ISO	Affärsverket Svenska Kraftnät	1	36447*	2011	Competitive

34	Switzerland	ITSO	swissgrid ag	1	17440	2006	Competitive (weak)
35	Ukraine	ITSO	Ukrenergo	1	52000	2011	Competitive
36	Northern Ireland	ISO	SONI Limited (EirGrid Plc)	1	6808	2010/11	Competitive
37	Scotland	ISO	NGC in Scotland	1	11200	2008/09	Competitive
38	England and Wales	ITSO	National Grid Electricity Transmission plc (a subsidiary of National Grid plc), the GB system operator	1	54300	2009	Competitive
MIDDLE EAST							
1	Bahrain	VIU	Electricity and Water Authority	1	3168*	2009	Single-Buyer
2	Cyprus	LTSO	Cyprus Transmission System Operator of Electrical Energy (Cyprus TSO)	1	1365.2	2012	Single-Buyer
3	Egypt	LTSO	Egyptian Electricity Transmission Company	1	27049	2010/11	Single-Buyer
4	Iran	VIU	<i>Tavanir</i>	1	52944	2008	Single-Buyer
5	Iraq	VIU	Ministry of Electricity	1	12000	2010	NO
6	Israel	VIU	Israel Electricity Corporation	1	12748	2012	NO
7	Jordan	LTSO	National Electric Power Company (NEPCo)	1	3366	2011	Single-Buyer
8	Kuwait	VIU	Kuwait's electric power system (KEPS)	1	11300	2010	NO
9	Lebanon	VIU	Electricité du Liban (EDL)	1	2038	2009	NO
10	Oman	LTSO	Oman Electricity Transmission Company	1	3392	2008	Single-Buyer
11	Qatar	VIU	KAHRAMAA (Qatar General Electricity and Water Corporation)	1	4314	2008	Single-Buyer
12	Saudi Arabia	LTSO	National Grid Company S.A. Public Establishment for Electricity Generation and Transmission (PEEGT)	1	41924	2011	Single-Buyer
13	Syria	VIU	Turkish Electricity Transmission Joint Stock Company (TEIAS)	1	7800	2010	NO
14	Turkey	ITSO	TRANSCO	1	53000	2012	Single-Buyer
15	United Arab Emirates	LTSO	Public Electricity Company	1	19814*	2009	Single-Buyer
16	Yemen	VIU		1	1069	2009	NO

NORTH AMERICA									
1	Antigua and Barbuda	VIU	Antigua Public Utility Authority (APUA)	1	50.9	2012	NO		
		VIU	Grand Bahama Power Company	2	105	2012	NO		
2	Bahamas	VIU	Bahamas Electricity Corporation		438	2013	NO		
3	Barbados	VIU	Barbados Light and Power (BL&P)	1	240	2009	NO		
4	Belize	VIU	Belize Electricity Limited (BEL)	1	28.3	2011	NO		
		ISO	Alberta Electric System Operator		14066	2012			
		ISO	Ontario Independent Electricity System Operator (IESO)		34079	2011			
		ISO	New Brunswick System Operator (NBSO)		4515	2010/11			
		VIU	BC Hydro for the Province of BC		12000	2012			
		VIU	SaskPower for the Province of Saskatchewan		3513	2011			
		VIU	Manitoba Hydro for the Province of Manitoba		5485	2012			
		VIU	Hydro Quebec for the Province of Quebec		35829	2011			
		5	Canada	VIU	Nova Scotia Power for the Province of Nova Scotia	13	2293	2011	Competitive
				VIU	Maritime Electric for the Province of Prince Edward Island		150	2013	
				VIU	Newfoundland and Labrador Hydro for Newfoundland and Labrador		7309	2010	
				VIU	Northwest Territories Power Corporation for the Northwest Territories		151.5	2010	
				VIU	Yukon Energy for the Yukon		132	2013	
VIU	Qulliq Energy Corporation for Nunavut		55	2007					
6	Costa Rica	VIU	ICE (Instituto Costarricense de Electricidad)	1	2605	2010	NO		
7	Cuba	VIU	Union Eléctrica (UE)	1	3267	2008	NO		
8	Dominica	VIU	Dominica Electricity Services Limited (DOMLEC)	1	26.7	2011	NO		
9	Dominican Republic	ISO	Coordination Agency (Organismo Coordinador del Sistema Eléctrico Interconectado , OC - SENI)	1	2960	2010	Competitive		

10	El Salvador	ISO	Unit of Transactions or Unidad de Transacciones (UT) SA of C.V	1	1480.3	2010	Competitive
11	Grenada	VIU	Grenada Electricity Services Ltd (GRENLEC)	1	39	2011	NO
12	Guatemala	ISO	Wholesale Market Administrator –Administradora del Mercado Mayorista (AMM)	1	2194.08	2011	Competitive
13	Haiti	VIU	Electricity of Haiti (EdH)	1	155	2008	NO
14	Honduras	VIU	Empresa Nacional de Energía Eléctrica (ENEE)	1	1610	2010	NO
15	Jamaica	VIU	The Jamaica Public Service Company (JPSCo)	1	1161	2010	NO
16	Mexico	VIU	Federal Electricity Commission (Comisión Federal de Electricidad or CFE)	1	58000	2008	NO
17	Nicaragua	ITSO	Empresa Nacional de Transmisión Eléctrica (ENATREL)	1	1068	2010	Competitive
18	Panama	ISO	ETESA	1	1974	2010	Competitive
19	Saint Kitts and Nevis	VIU	Saint Kitts Electricity Department (SKED)	2	37.5	2010	NO
		VIU	Nevis Electricity Company Ltd. (NEVLEC)		13.2	2010	NO
20	Saint Lucia	VIU	LUCELEC	1	76	2012	NO
21	Saint Vincent and the Grenadines	VIU	St. Vincent Electricity Services Limited (VINLEC)	1	49	2009	NO
22	Trinidad and Tobago	VIU	Trinidad and Tobago Electricity Commission (T&TEC)	1	1669	2010	NO
		RTO	ISO New England		33700	2010	
		RTO	The Midwest Independent Transmission System Operator, Inc. (MISO)		144697	2012	
		RTO	PJM Interconnection LLC (PJM)		185600	2011	
23	USA	RTO	Southwest Power Pool (SPP)	35	72700	2011	Competitive
		ISO	California Independent System Operator (California ISO)		58698	2012	
		ISO	New York Independent System Operator (NYISO)		38190	2011	
		ISO	Electric Reliability Council of Texas (ERCOT)		74000	2011	
		VIU	Progress Energy Florida - Duke Energy		10019	2012	

VIU	Florida Power & Light Company		24460	2011
VIU	Tampa Electric		4700	2012
VIU	Jacksonville Electric Authority		3757	2013
VIU	Southern Company Services, Inc.		46000	2013
VIU	Entergy Corporation		30000	2013
VIU	Bonneville Power Administration		16573	2011
VIU	PacifiCorp		10579	2011
VIU	Portland General Electric Company		2781	2012
VIU	Avista Corporation		3060	2012
VIU	Duke Energy Carolinas		22173	2012
VIU	South Carolina Electric & Gas		5900	2005
VIU	Tucson Electric Power		2473	2011
VIU	Public Service Company of Colorado	5163***		2011
VIU	Salt River Project		8284	2012
VIU	Puget Sound Energy, Inc.		2484	2007
VIU	Arizona Public Service		4000	2006
VIU	NV Energy (Nevada Power Company and Sierra Pacific Power)		6050	2012
VIU	NorthWestern Montana (NWMT)		3190	2006
VIU	Los Angeles Department of Water and Power (LADWP)		7197	2010
VIU	South Carolina Public Service Authority (Santee Cooper)		6098	2008
VIU	Seattle City Light		1872	2010
VIU	Sacramento Municipal Utility District		3299	2007
VIU	Associated Electric Cooperative Inc.		5895	2011
VIU	WAPA - Desert Southwest Region		2503	2010
VIU	WAPA - Rocky Mountain		681	2010
VIU	WAPA - Upper Great Plains		2420	2010

		VIU	Tennessee Valley Authority		37300	2012	
SOUTH AMERICA							
1	Argentina	ISO	Companhia Administradora del Mercado Mayorista Electrico, SA (CMMESA)	1	29440	2011	Competitive
2	Bolivia	ISO	Comité nacional de despacho de carga (CNDC)	1	1317.2	2011	Competitive
3	Brazil	VIU	ONS		117134	2011	Competitive
4	Chile	ISO	CDEC-SIC (Sistema Interconectado Central)	2	12200	2012	Competitive
		ISO	CDEC- SING (Sistema Interconectado de Norte Central)		4580	2011	
5	Columbia	ITSO	Interconexión Eléctrica S.A. E.S.P. (ISA) Ecuadorian National Power Control Centre	1	14420	2011	Competitive
6	Ecuador	ISO	(CENACE)	1	5050	2009	Competitive
7	Guyana	VIU	Guyana Power & Light (GPL)	1	175.1	2012	NO
8	Paraguay	VIU	Administracion Nacional de Electricidad (ANDE)	1	10289	2012	NO
9	Peru	ISO	Comité de operación económica del sistema interconectado nacional (COES SINAC)	1	6416	2011	Competitive
10	Suriname	VIU	NV Energiebedrijven Suriname (NV EBS)	2	287	2012	NO
		VIU	Suralco or Alcoa Power Generating Inc. ("APGI")		78	2010	NO
11	Uruguay	VIU	Administración Nacional de Usinas y Transmisiones Eléctricas - UTE (National Electricity Plants and Transmission Authority)	1	1484	2011	NO
12	Venezuela	VIU	Oficina de Operacion de Sistema Interconectados (OPSIS)	1	24800.8	2011	NO

The TSOs for which there was no information available on the Total Installed Generation Capacity, Net Installed Generation Capacity (NIGC) was used instead

* Net Installed Generating Capacity (MW).

** Peak Annual Demand (MW).

*** Net Installed Dependable Generating Capacity (MW).