Grid Integration Issues of Renewable Energy in Japan and Transparency of Grid Data

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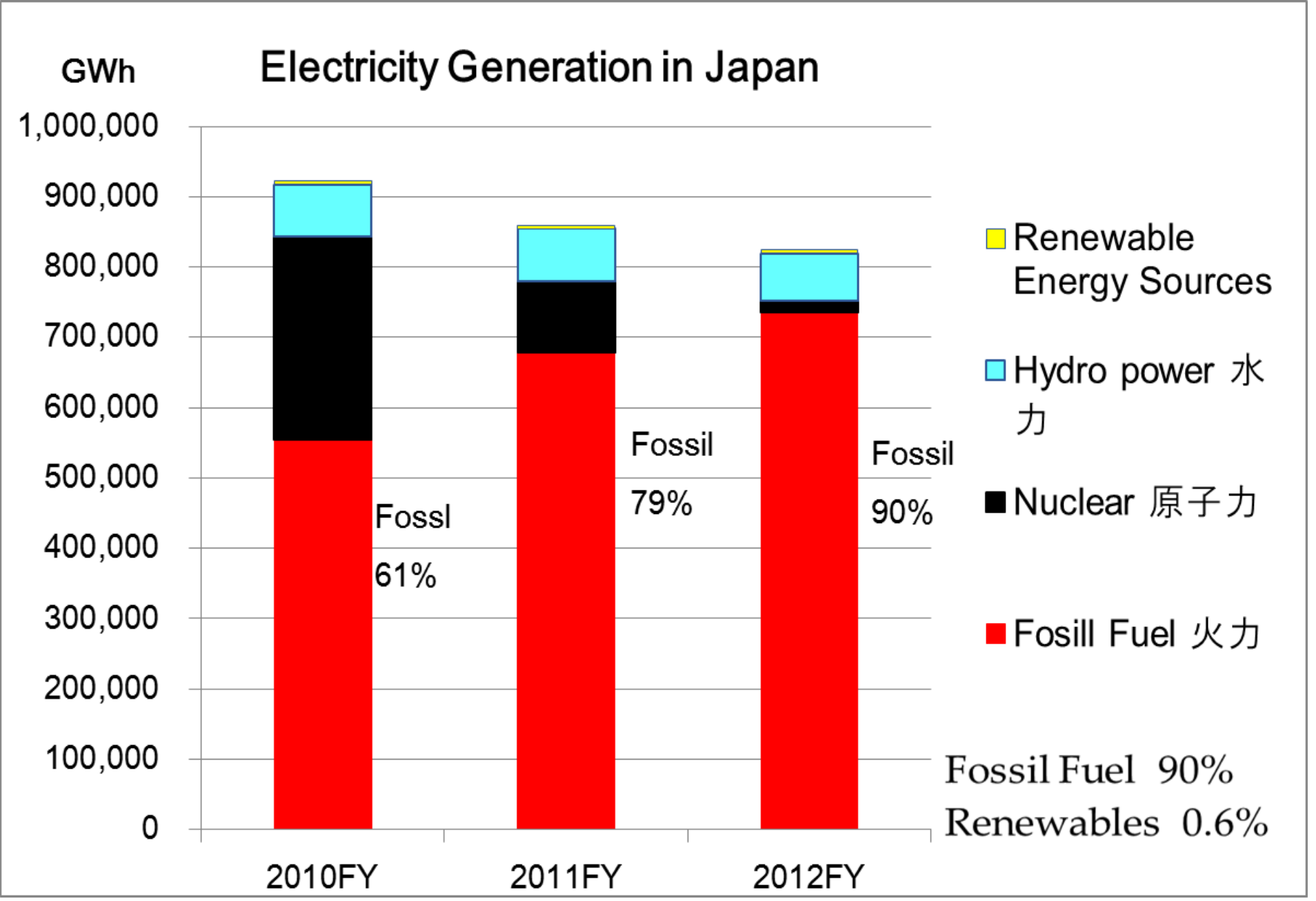
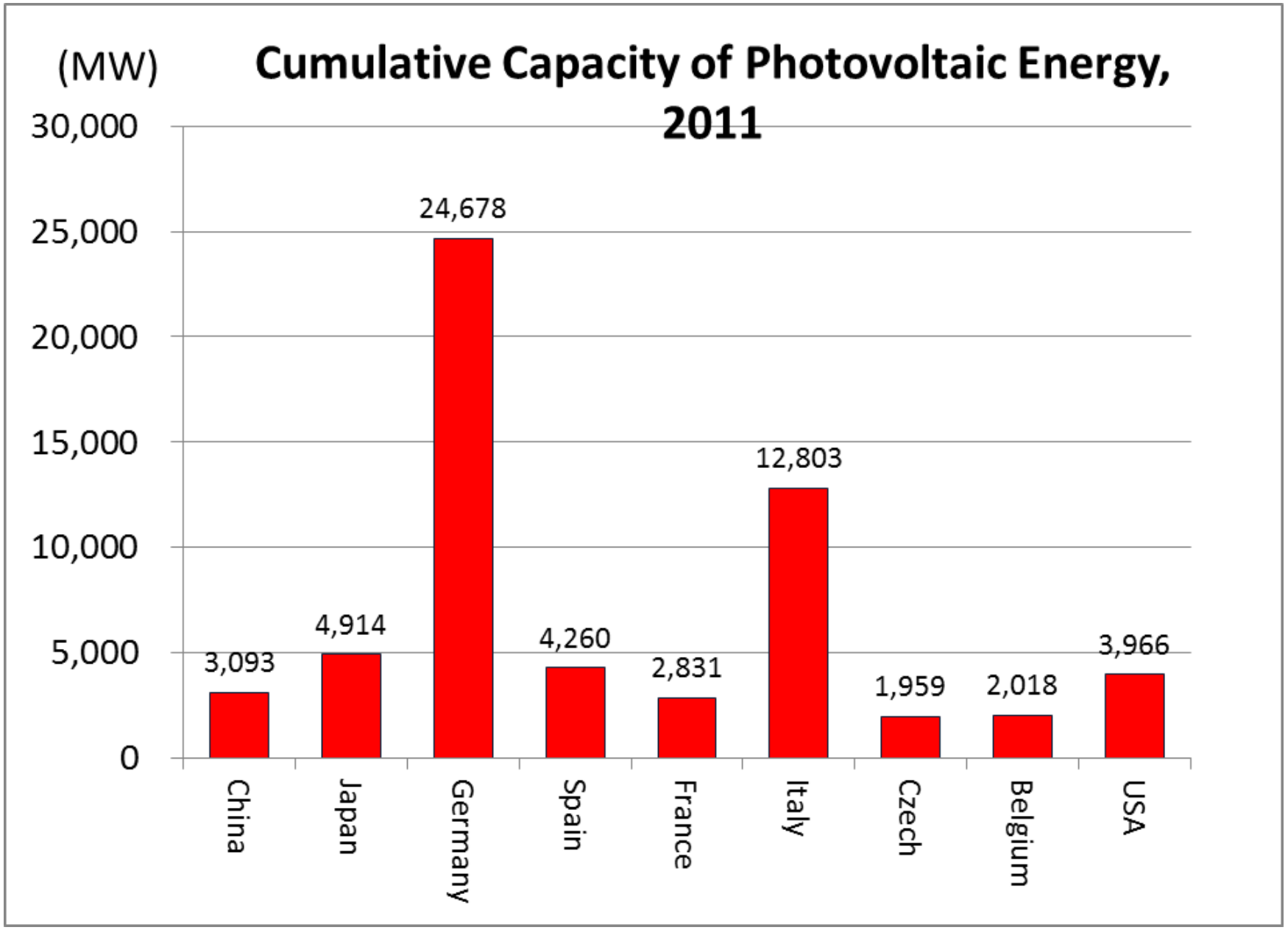
■Outline

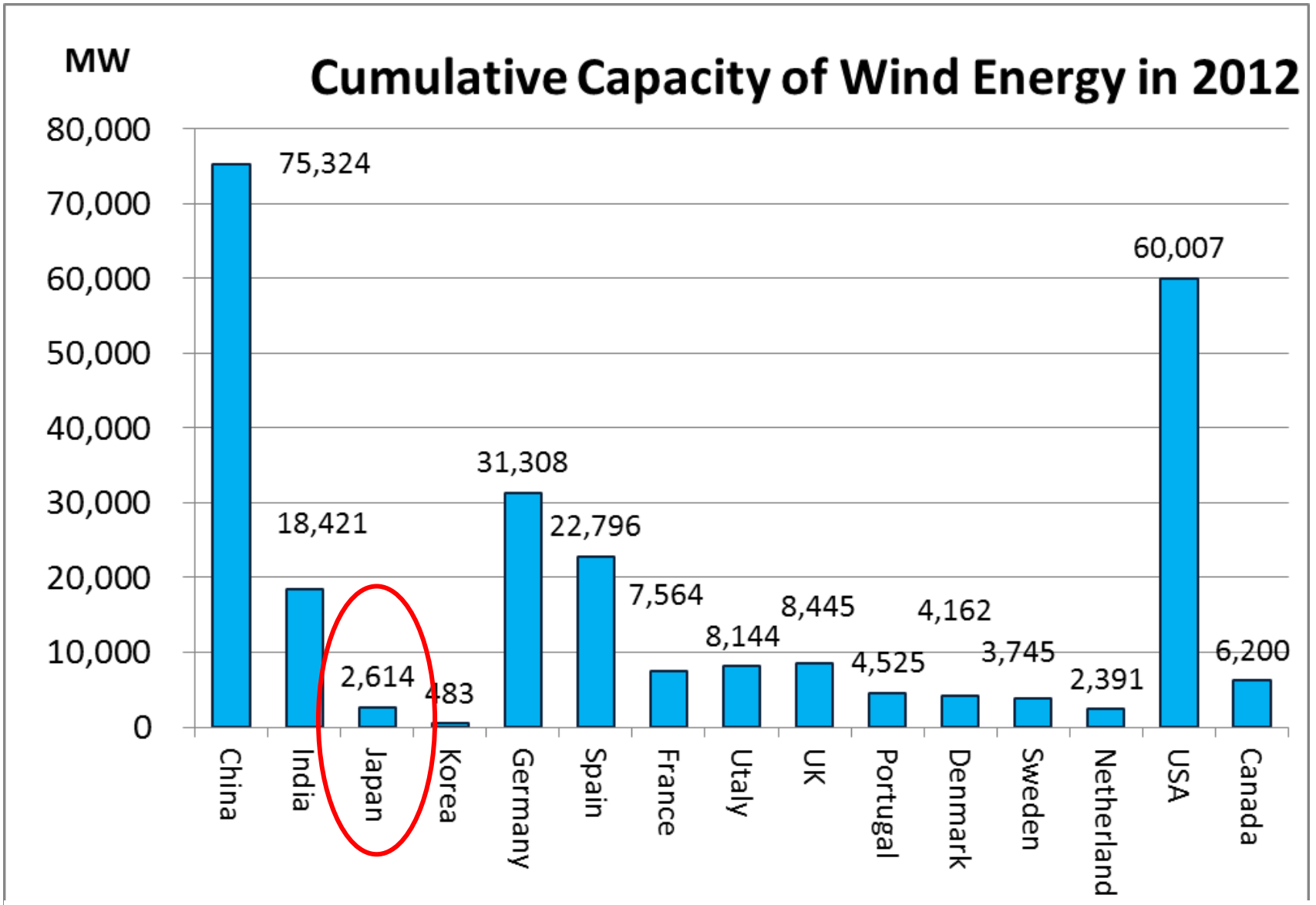
- Current situation of grid integration of wind and solar energy in Japan
- Capacity limit of grid connection for wind and large solar in Japan
- Necessity of transparency of wind feed-in and solar feed-in data
- We must learn from data disclosure by German TSOs
- Case study: Transparency of feed-in data in 50hertz zone
- Grid data concerning following points are analyzed
- How much wind feed-in was exported from 50hertz zone?
- How much wind feed-in was absorbed into German domestic demand?
- How much wind feed-in was transmitted from DSO to TSO? (Distribution Grid Operators to Transmission grid Operators)
- How much wind forecast is reliable ?



Source: Takehama, based on the data by Electricity Statistical Report, Ministry of Economy, Trade and Industry (2012)



* Note: PV Capacity in Germany, End of 2012, 32.6GW



Japan's wind capacity : 2.6 GW

Wind capacity in Germany : 31.3 GW

Japan's Transmission Grid System, Vertically integrated entities

- 9 Major power companies = Vertical Integrated Monopolies. **Not yet unbundled**
- 9 Monopolies own **90%** **of power plants, almost all** of **grid system**.
- Each control zone is **relatively independent**.
- Limited amount of electricity is exchanged through inter-zone transmission cables.
- Small-Independent, Not-Well Integrated Grid Use :
- They are reluctant to increase inter-zone exchange.

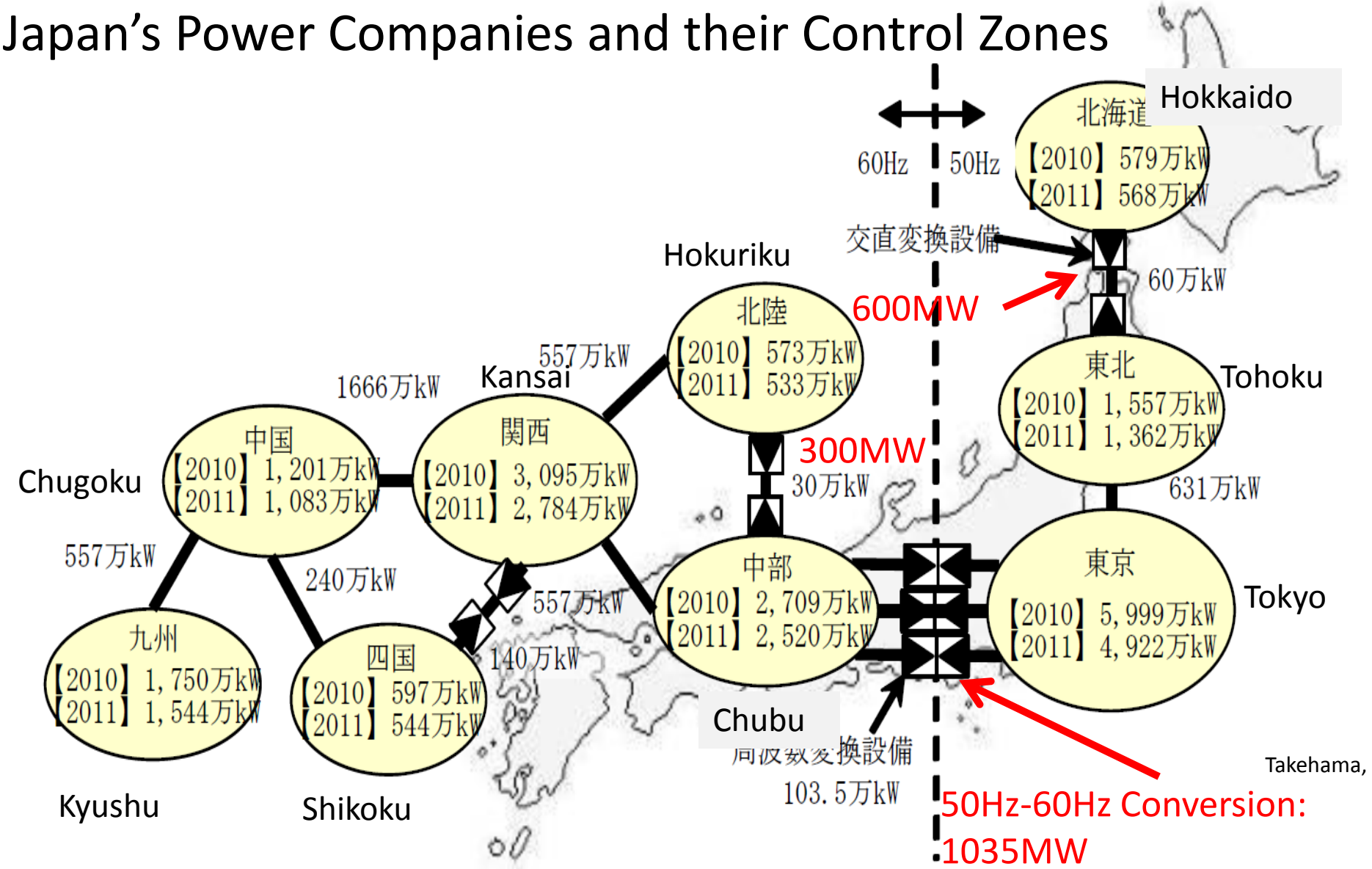
Japan's Transmission Grid System, Vertically integrated entities

- Limitation of **Negative Vertical Load (backward feed-in of RES-E)**
- Japan's technical requirements for grid integration **restricted Backward feed-in from 66kV Distribution Grid to Higher Voltage Transmission Grid.**
- **This had negative impacts on solar grid integration.**
- **At the end of May 2013**, the requirements were revised and backward feed-in is permitted.

Japan's Transmission Grid System, Limited capacity in several lines

- **Inter-zone transmission cables** have **small capacity**.
- **Hokkaido** (North Island) —**Tohoku: 600 MW**
- **Hokuriku –Chubu :** 300 MW
- 60Hz-50Hz Conversion (Tokyo-Chubu): 1035 MW
- Hokkaido : High wind potential, limited transmission capacity.

Japan's Power Companies and their Control Zones



万kW = 10MW. Nine circles show each major power company's control zone. Figures in each circle show maximum electricity demand in each control zone. Figures between circles : Capacity of main transmission lines between control zones.

Source: Power System Reform Committee, Ministry of Economy Trade and Industry .「地域間連系線等の強化に関するマスタープラン研究会中間報告書」、電力システム改革専門委員会, p.5.

Generation Capacity in the end of 2012

		Total Capacity [MW]	% of [A/B]	of which, Nuclear [MW]	%	of which, Renewable Energy [MW]		
						Wind	Solar PV	Geothermal
General Power Companies 一般電気事業者	Hokkaido 北海道	7,548	3%	2,070	4%	0	1	25
	Tohoku 東北	17,766	8%	3,274	7%	0	4	224
	Tokyo 東京	65,269	28%	14,496	31%	1	30	3
	Chubu 中部	33,437	14%	3,617	8%	22	9	0
	Hokuriku 北陸	8,061	3%	1,746	4%	5	4	0
	Kansai 関西	34,950	15%	9,768	21%	0	10	0
	Chugoku 中国	11,989	5%	1,280	3%	0	3	0
	Shikoku 四国	6,963	3%	2,022	4%	α	2	0
	Kyushu 九州	20,637	9%	5,258	11%	3	3	210
	Okinawa 沖縄	2,183	1%	0	0%	α	0	0
	Total of General Power Companies [A]	**208,804**	90%	**43,531**	**94%**	**32**	**65**	**462**
Wholesale Power Companies 卸電気事業者	**J-Power 電源開発**	16,983	7%	0		0	0	15
	Japan Atomic Power Company 日本原子力発電	2,617	1%	2,617	6%	0	0	0
	Total of Wholesale Power Companies	19,600	8%	2,617	6%	0	0	15
Tokutei Power Companies 特定電気事業者		280	0%	0		0	0	0
Tokutei-Kibo Power Companies 特定規模電気事業者		2,120	1%	0		53	0	0
Total Generation Capacity in Japan [B]		**230,804**	100%	**46,148**	**100%**	**85**	**65**	**477**
(of which, the share of nuclear power in the total nuclear power in Japan)		**100%**		**20%**				

Notes: Japan Atomic Power Company and some of independent power suppliers (Wholesale, Tokutei, Tokutei-Kibo) are subsidiary companies of General Power Companies. Source: Ministry of Ecomony,Trade and Industry. Power Generation statistics

Capacity limit of grid connection for wind and large PV

- **Capacity Limit of Grid Connection** for Wind and Large Solar Energy (more than 500kW of PV)
- set by Japan's power companies
- **Only 5% - 12%** of **Generation Capacity** in March 2013
- Only 5,460 MW + α
- (Tokyo, Kansai, Chubu power companies do not set the capacity limit.)
- What kind of calculation is used ?
- The major power companies show their calculation, but it is very conservative.

Capacity Limit for Wind Energy Grid Connection by Major Power Companies in March 2012

Power Company (Control Zone Region)	Total Capacity for Generation (MW) [A]	Cumulative Capacity of Grid Conecctd Wind Energy 2013 (MW) [B] *1)	Capacity Limit For Wind Energy Grid Connection 2013 (MW) [C] *1)	Share of the Capacity Limit in Generation Capacity (%) [C/A]	Wind Energy Potential (MW) [D] *2)
Hokkaido (North Islan d)	7,420	289	560	7.5%	132,170
Tohoku (North Eastern)	16,550	542	2,000	12%	71,880
Tokyo	64,490	371	No limit is set	Non	4,040
Hokuriku	7,960	146	450	6%	4,810
Chubu (Nagoya region)	32,630	224	No limit is set	Non	7,930
Kansai (Osaka, Kyoto, Kobe region)	34,320	78	No limit is set	Non	12,840
Chugoku	11,990	299	1,000	8%	9,200
Shikoku (Shikoku Island)	6,670	166	450	7%	4,840
Kyusyu (Kyushyu Island)	20,030	361	1,000	5%	20,580
Total in Japan	202,060	2,476	5,460		268,290

Source: *1) This limit of grid connection is set by respective power company. Data is based on Federation of Electric Power Companies of Japan in March 2013: http://www.fepc.or.jp/environment/new_energy/renkei/index.html *2) Ministry of Environment (2011), Renewable energy potential report (環境省(2011), 再生生可能エネルギー導入ポテンシャル調査報告書)

March 2013

The Logic of Vertically Integrated Power Companies, Japan (1)

- They have weak grid systems.
- Especially, the inter-zone transmission grids are weak.
- They cannot transmit excess power from high-wind-low-demand areas to high-load areas.
- **Japan is island country. Japan cannot use cross border exchange.**
- **The Japanese grid system cannot accept fluctuation of wind and solar energy in a large scale.**
- If they accept large scale wind / solar power, the grid system would be destabilized.

The Logic of Vertically Integrated Power Companies, Japan (2)

- **Germany can export power through cross-border exchange.**
- **Therefore they can accept wind and solar energy in a large scale.**
- The output from wind and solar power has large fluctuation.
- Wind forecast and solar forecast is not sufficiently reliable.

Weakness of Japan's FIT Scheme

- Act on Feed-in Tariff for Electricity from Renewable Energy Sources
- **No Priority Access**: Major power companies are not obliged to give priority access for RES-E.
- Power companies CAN refuse grid connection with RES-E, when RES-E may **unreasonably harm the profit** of the power companies.
- **No Grid Expansion Obligation**: Power companies have **no obligation of grid expansion for connecting RES-E.**

Comparison of FIT scheme

	Germany	Japan
The Law	Erneuerbare-Energien-Gesetz– EEG	Act on Feed-in Tariff for Electricity from Renewable Energy Sources
Priority Access	Priority Access: Grid operators shall give a priority connect for RES-E.	Major power companies are not obliged to give priority access for RES-E. Power companies CAN refuse grid connection with RES-E, when RES-E may unreasonably HARM the profit of the power companies. (Section 4, 5)

Unbundling of Generation business from Transmission business

Germany	Japan
Generation businesses are fully unbundled from transmission businesses (Directive2009/72/EC)	Not yet unbundled: Major power companies = Vertically integrated monopolies. The 9 power companies own almost of all power plants and major transmission grid system.

Obligation of Grid Expansion

Germany	Japan
Obligatory Grid Expansion: Grid operators shall immediately strengthen / expand their grid systems in order to guarantee the purchase of RES-E. (by EEG)	Grid operators (power companies) have NO obligation of grid expansion

Output reduction at the time of high feed-in from RES-E

Germany	Japan
Feed-in Management (Output Reduction): When there are risks of grid bottleneck in the event of grid overload, grid operators are entitled to set output reduction of RES-E.	When output exceeds the demand in each contol zone, major power companies are entitled to set output reductions of RES-E up to 30 days a year without compensation.

Compensation for output reduction on RES-E (Feed-in Management)

Germany	Japan
When grid operators set ourput reduction on RES-E in order to avoid Grid Bottlenecks, grid operators must compensate RES-E operators for 95% ~100% of lost income. (EEG Section 12).	Up to 30 days a year, major power companies can set output reduction of renewable energy electricity WITHOUT compensation for RES-E.

Order of Output Reduction and Must Run Capacity at the time of high wind / solar feed-in

Germany	Japan
RES-E has a priority for feed-in. Conventional power plants must be reduced firstly to the minimum, except for Must Run Capacity.	Major power companies must reduce the output of Fossil Fuel and Pump-Up Hydropower before ourput reduction of RES-E.
Must Run Capacity= Power output to keep the stability of the grid system. Must Run Capacity can stay in the grid, at the time of excess feed-in from RES-E	They DO NOT need to reduce the output from Nuclear Power.

Verification, Data Disclosure of Output Reduction

Germany	Japan
Grid operators must disclose the grid data that they fed-in RES-E as much as they could. Numerical data is required for Feed-in Management. Verification for the necessity of Feed-in Management is required.	Evidence for the necessity of feed-in reduction must be shown by 'Documents'. What Kind of Document ? What kind of Data must be disclosed? Not specified by the law

Required Data Disclosure of Grid Feed-in

Germany	Japan
Real Wind Feed-in, Wind Forecast, Real Solar Feed-in, Solar Forecas, Load, Vertical Load, Export and Import, Redispatch, Feed-in Management (Output Reduction on RES-E) in 15 minutes by TSOs, Intraday Trade, Use of Balancing Energy, by 15minutes by TSOs.	The law does not specifies data disclosure on output reducion (of fossil fuel plants and RES-E).

Case study of transparency of feed-in data, in 50hertz zone

■50hertz has **some similarit**ies with **Hokkaido** and **Tohoku**

- High wind potential / High wind feed-in
- Low load
- Weak grid
- Weak inter-zone lines with Tennet

■**Differences** from Hokkaido and Tohoku:

- German TSO Grid is large scale grid use, well-integrated grid use including cross-border exchange
- RES-E has a priority feeding.

Comparison of Grid Stuations in 50hertz, Hokkaido, Tohoku Zones

	Load-Peak (MW)	Load Min (MW)	Inter-Zone Connection (Domestic, MW)	Installed Wind Capacity (MW)
50hertz	13,963 (2012) *1)	5,164 (2012)*1)	5000 (around) (with Tennet) *2)	12,420 *1)
Hokkaido	5,345 (Mar, 2004) *3)	2,384 (Mar, 2004) *3)	600 (2009) *3)	289 *4)
Tohoku	13,910 (Mar, 2004) *3)	5,863 (Mar, 2004) *3)	6,310 (2012) *5)	542 *4)

*1) 50hertz, Kennzahlen

*2) Hearing from 50hertz GmBH, in a stable condition

*3) Data by Junji Kondoh, National Institute of Advanced Industrial Science and Technology (AISO)

*4) Federation of Electric Power Companies of Japan, June 2013

*5) Committee for power system reform by Ministry of Economy, Trade and Industry, 2012

Summary of Grid Situation in 50hertz Zone, 2012

	Total Capacity	connection to 380kV/ 220kV	connection to 110kV and less
Wind Power Cumulative Capacity [MW] 1)	12,420	1110	11260
Photovoltaic Power Cumulative Capacity [MW] 1)	7,220	4	7216

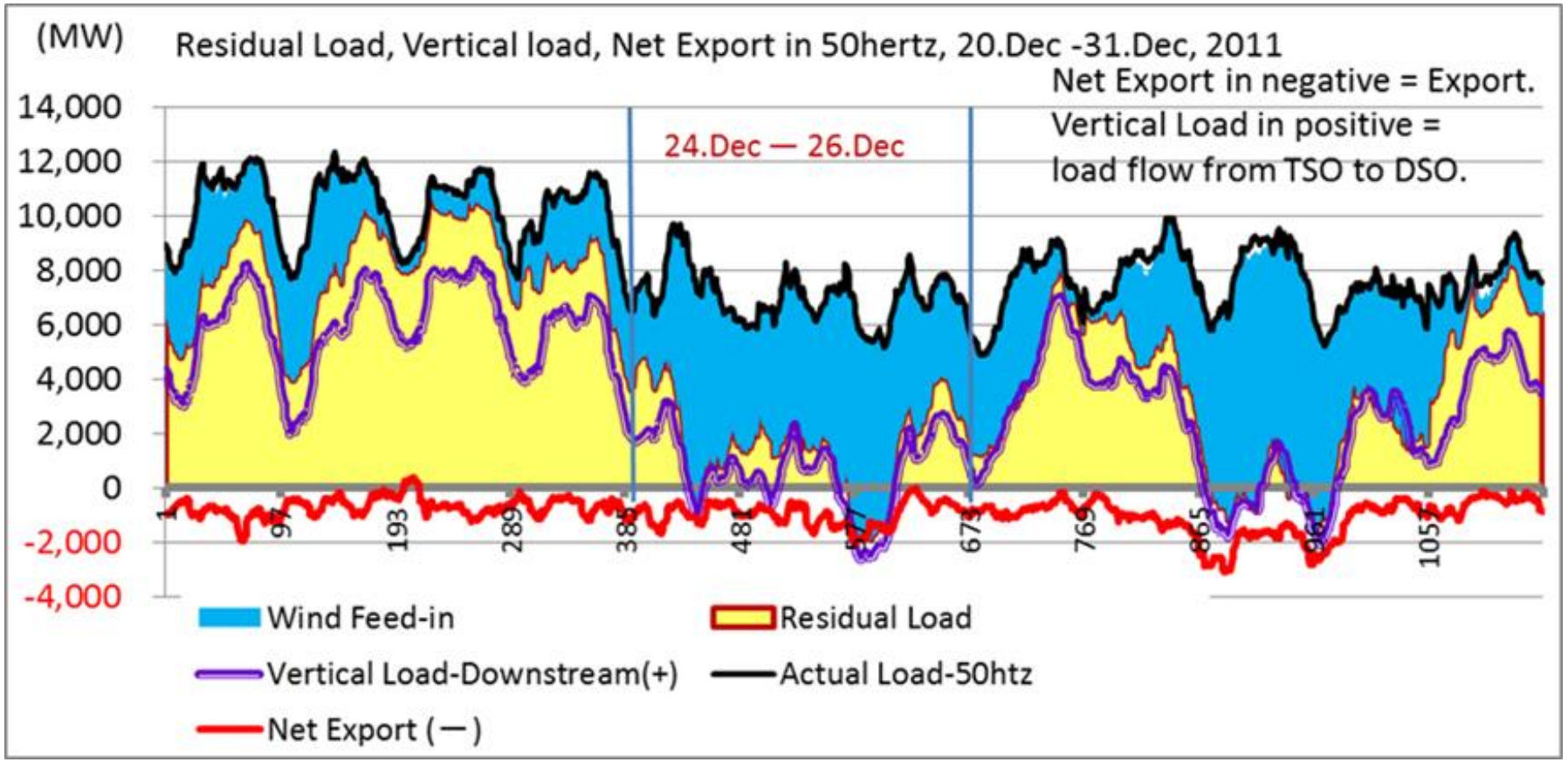
	Max [MW]	Mini [MW]
Load 2)	13,963	5,164
Wind feed-in 2)	10,208	0
Solar feed-in 2)	4,631	0
Residual load 3)	13,369	-2,070
Net export 2)	3887	-1891

1) 50hertz (2013), "50hertz Almanach"

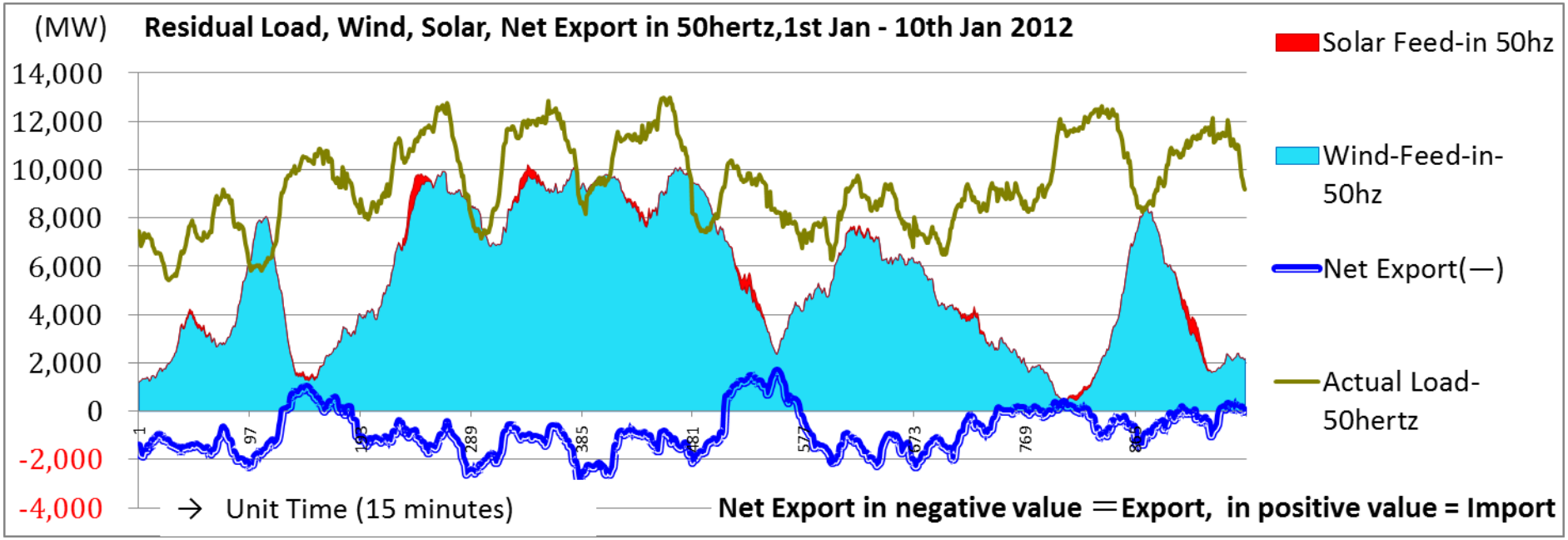
2) 50hertz, "Kennzahlen" in 2012.

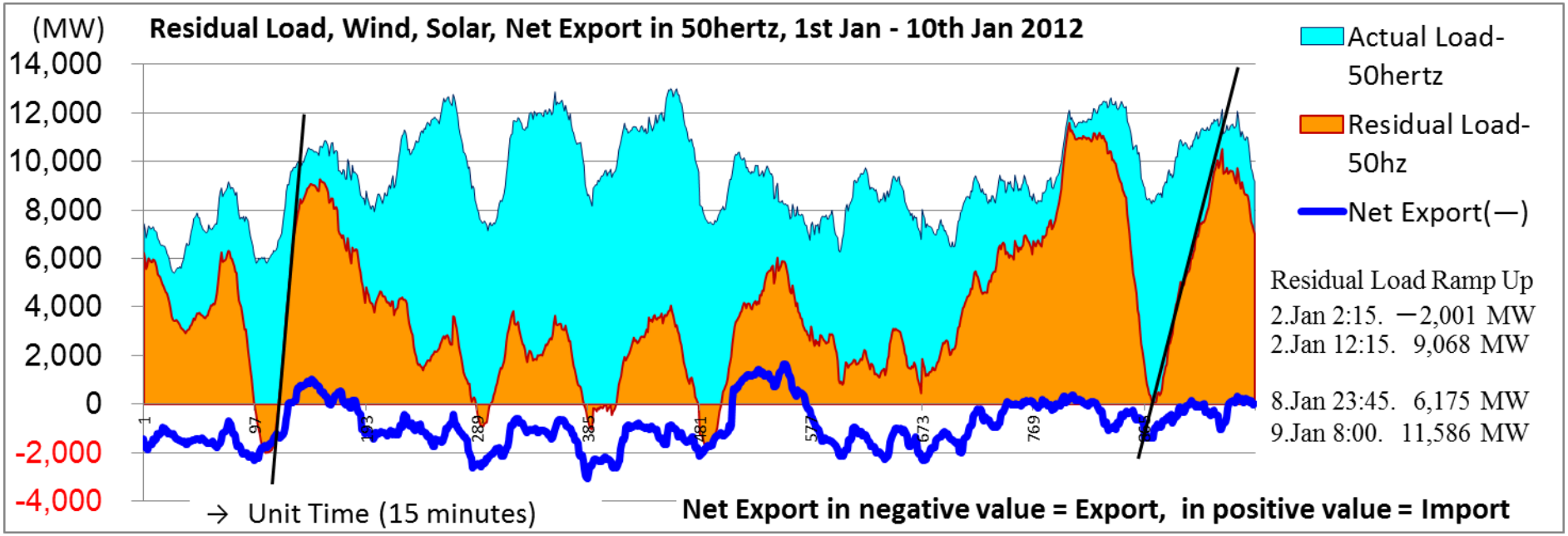
3) Residual load = Load-(Wind + Solar). Based on 50hertz's "Kennzahlen".

- How wind feed-in and solar feed-in data is disclosed in 50hertz?



Source: Calculated by 50hertz's grid data Kennzahlen





Source: Calculated by 50hertz's grid data Kennzahlen

Residual Load Ramp in 50hertz 2012

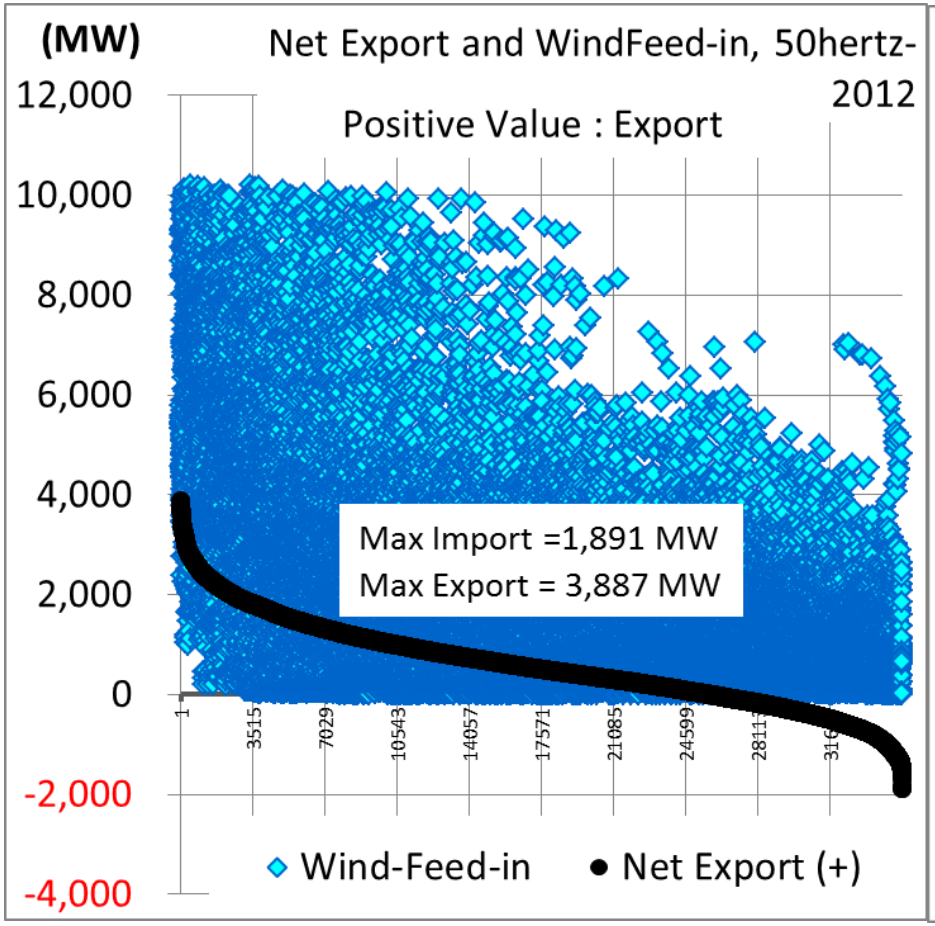
[MW]	in 15 min	per unit	in 1 hour	per unit	in 4 hours	per unit
Wind max up-ramp	1006	8.7%	2229	19.3%	5644	48.8%
Wind max down-ramp	-975	-8.4%	-2147	-18.6%	-5208	-45.1%
Residual load, max up-ramp	2,026		2,751		8,112	
Residual load, max down-ramp	-2,111		-2,807		-6,968	

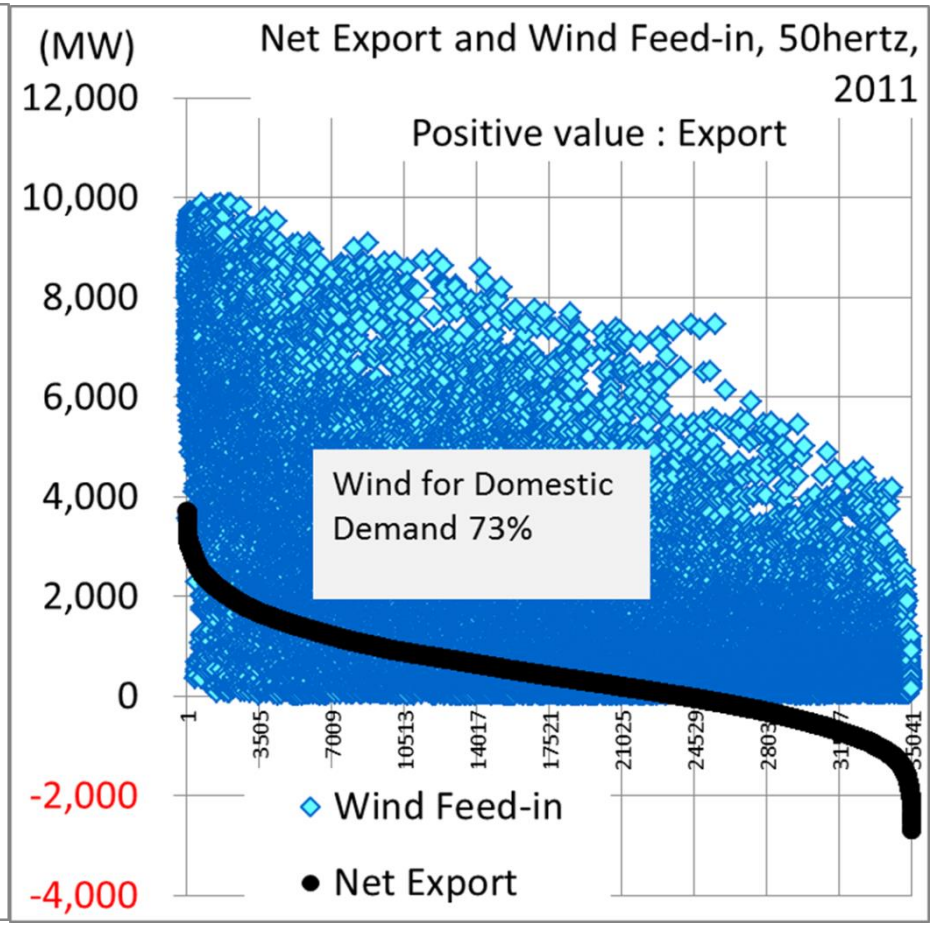
1) Wind power capacity in 50hertz, end of 2011 : 11,557 MW.

Source: Calculated by 50hertz's grid data Kennzahlen

[MW]	in 8 hours	per unit	in 12 hours	per unit	in 24 hours	per unit
Wind max up-ramp	7247	62.7%	8031	69.5%	9007	77.9%
Wind max down-ramp	-7145	-61.8%	-8034	-69.5%	-8572	-74.2%
Residual load, max up-ramp	10,828		11,199		11,260	
Residual load, max down-ramp	-9,822		-11,170		-9,528	

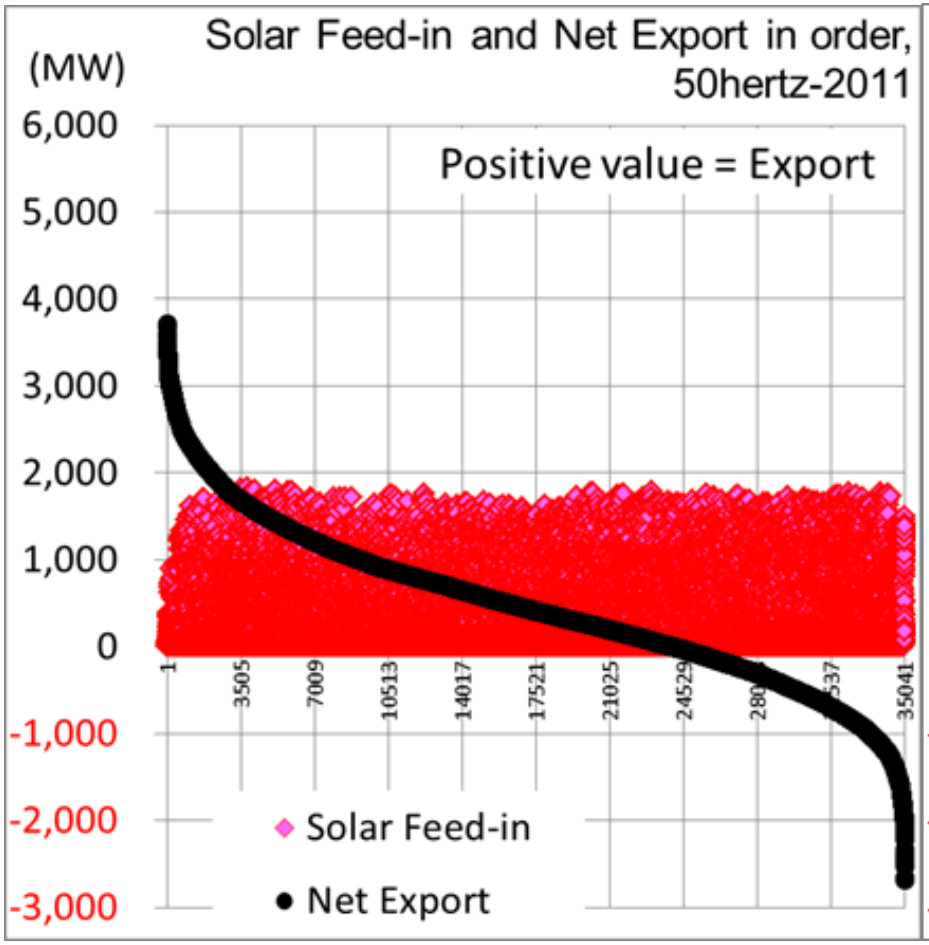
Source: Calculated by 50hertz's grid data Kennzahlen

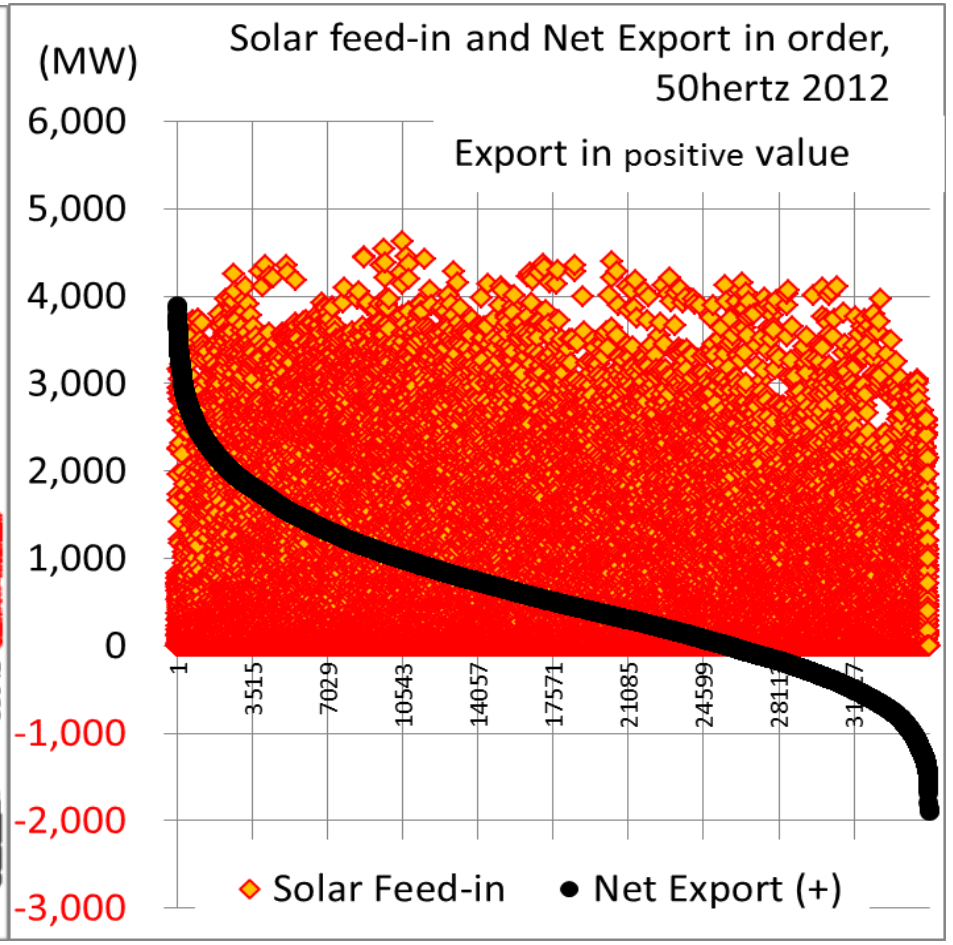




Around 70 % of wind feed-in was absorbed by the domestic demand. Around 30% of wind feed-in was exported.

Source: Calculated by 50hertz's grid data Kennzahlen in 2011 and 2012





Solar feed-in does not correlate with export in 50hert region in 2012.

Source: Calculated by 50hertz's grid data Kennzahlen in 2011 and 2012

Domestic Feed-in of Wind and Solar, Export Dependency, 2012-50hertz [MWh]

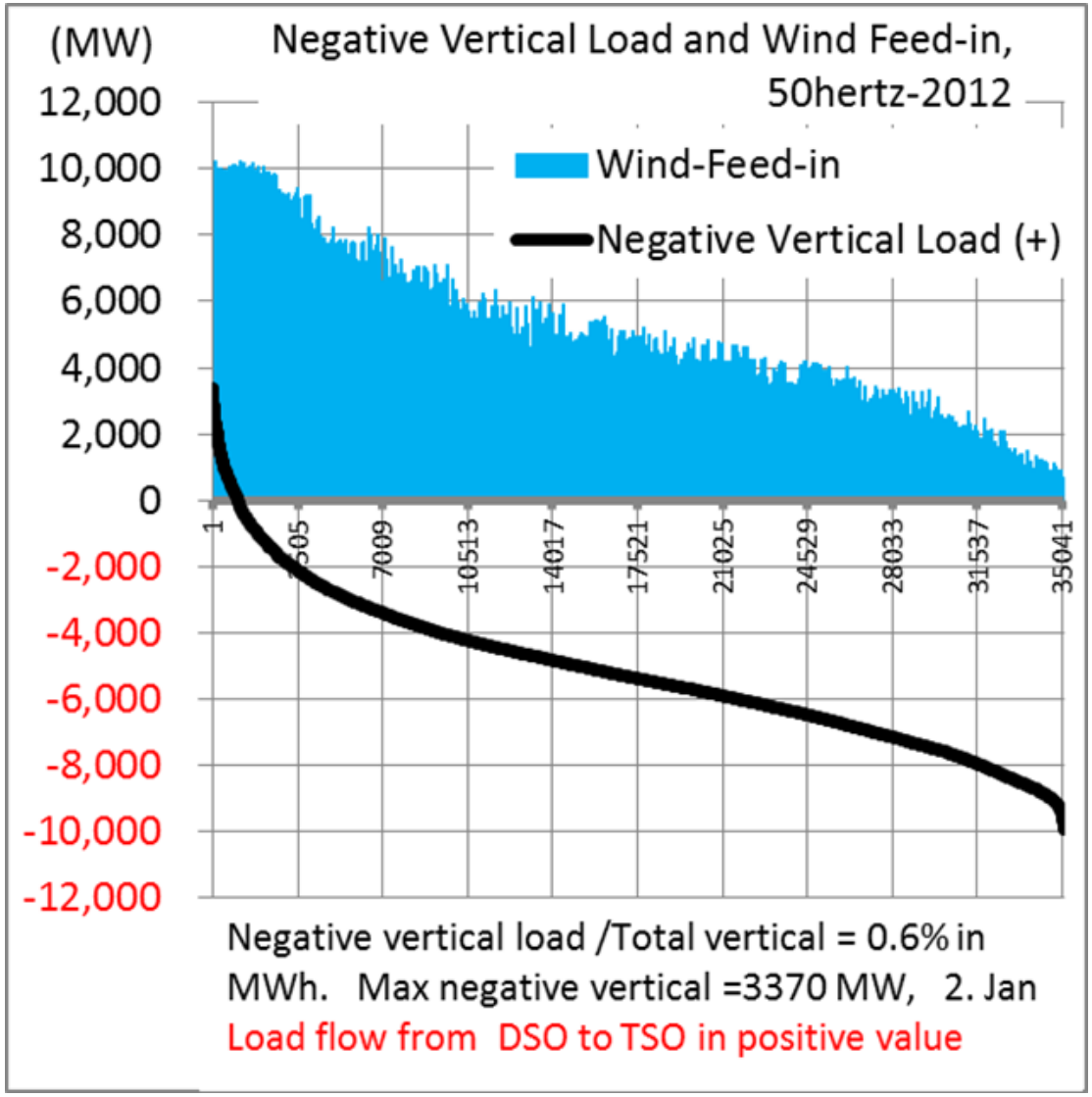
国内需要に向けられた風力発電と太陽光発電の給電量　50hertz区域, 2012年

Wind Feed-in [MWh]	**18,511,758**	Solar Feed in [MWh]	**5,128,782**	Wind+Solar Feed-in [MWh]	**17,735,923**
Domesic Wind Feed-in [MWh]	**13,026,279**	Domestic Solar Feed-in [MWh]	**4,527,183**	Domestic Feed-in Wind+Solar [MWh]	**23,640,540**
Domesic Wind Feed-in [%]	**70.4%**	Domesic Solar Feed-in [%]	**88.3%**	Domesic Feed-in Wind + Solar [%]	**75.0%**

Note: Domestic Wind Feed-in =（Wind－Net Export）. Domestic Solar Feed-in =（Solar－Net Export).

Domestic wind feed-in and domestic solar feed-in are calculated by wind feed-in, solar feed-in and export at each unit time (15minutes) in MW.

Source: Calculated by 50hertz's grid data Kennzahlen in 2011 and 2012

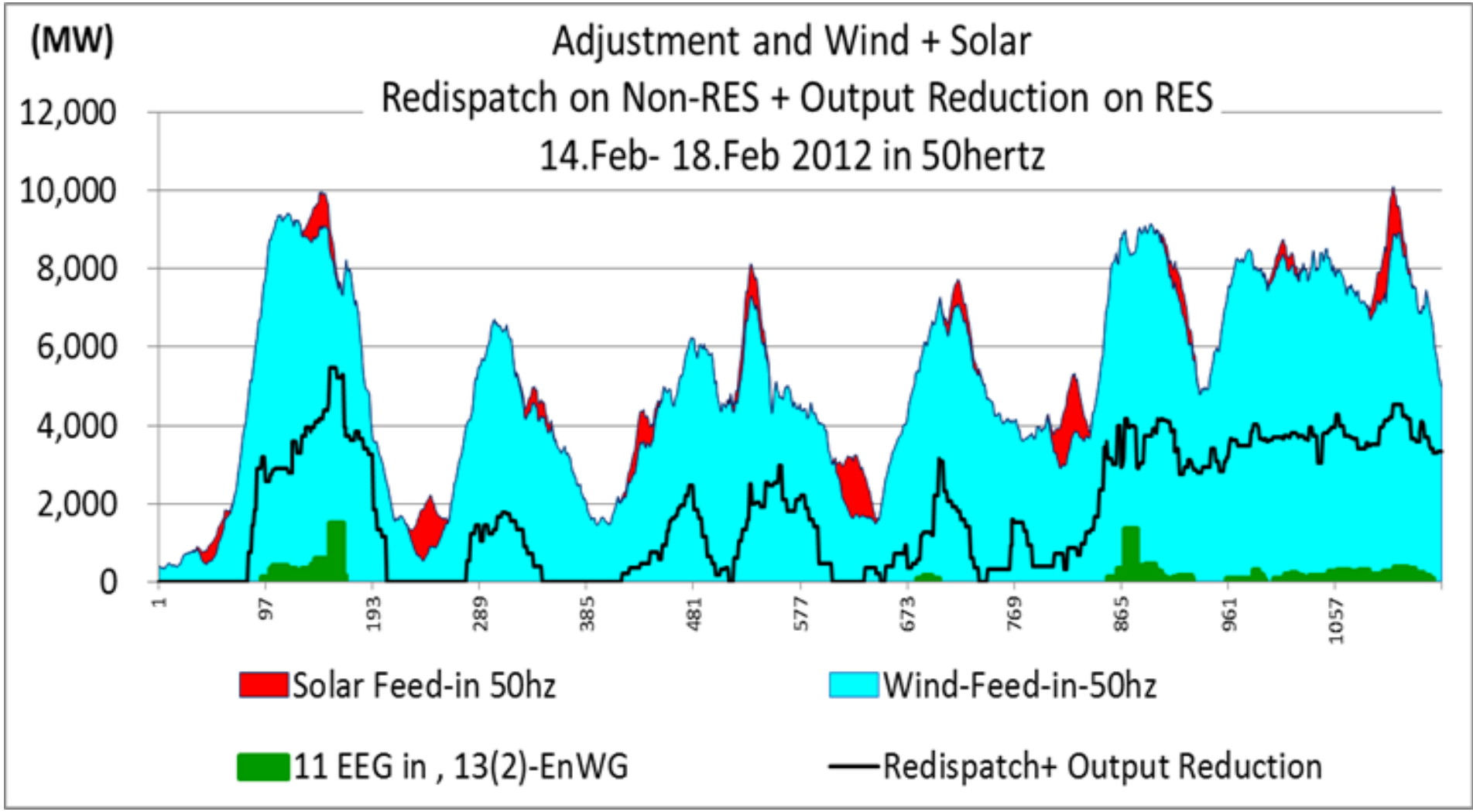


When wind feed-in was very high, negative vertical load happened. Excess wind feed-in was transferred from DSO grid to TSO grid. Source: Calculated by 50hertz's grid data Kennzahlen in 2011 and 2012

Negative Vertical Load in 50 hertz

	2011	2012	Increase
Vertical Load : from TSO to DSO [MWh] 垂直ロード電力量（送電網→配電網）	48,241,250	45,560,017	-5.6%
Negative Vertical Load from DST to TSO [MWh] 逆垂直ロード電力量（配電網→送電網）	-159,375	-288,941	81.3%
Total Electricity Exchange in (TSO - DSO) [MWh] 送電網・配電網の取引量 (a)	48,400,625	45,848,959	-5.3%
% of Negative Vertical Load in Total Exchange (TSO and DSO) [%] 送電網・配電網の取引量 (a) に対する逆垂直ロード電力量の割合	**0.3%**	**0.6%**	
Hours of Negative Vertical Load [hour] 逆垂直ロード発生時間	174	260	
Max Negative Vertical Load [MW] 逆垂直ロード最大値	2,631	3,370	
Wind Feed-in at the Time of Max Negative Vertical Load [MW] 逆垂直ロードが最大の時の風力給電	7,474	7,875	

Source: Calculated by 50hertz's grid data Kennzahlen in 2011 and 2012



Source: Calculated by 50hertz's grid data Kennzahlen in 2012

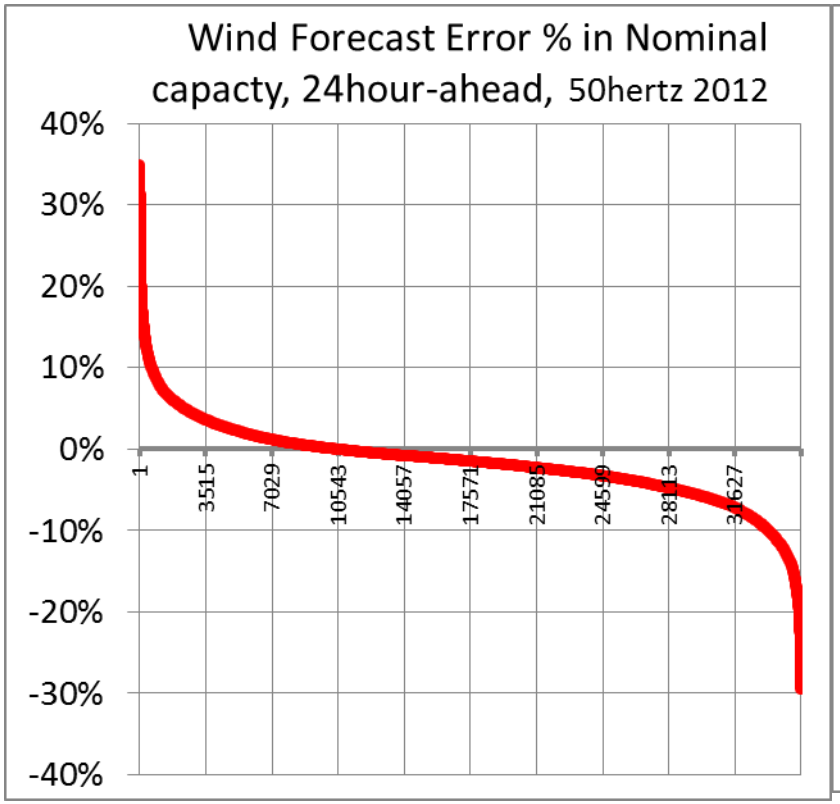
Wind Feed-in and Adjustment for Grid Systems Security in 2012, 50hertz

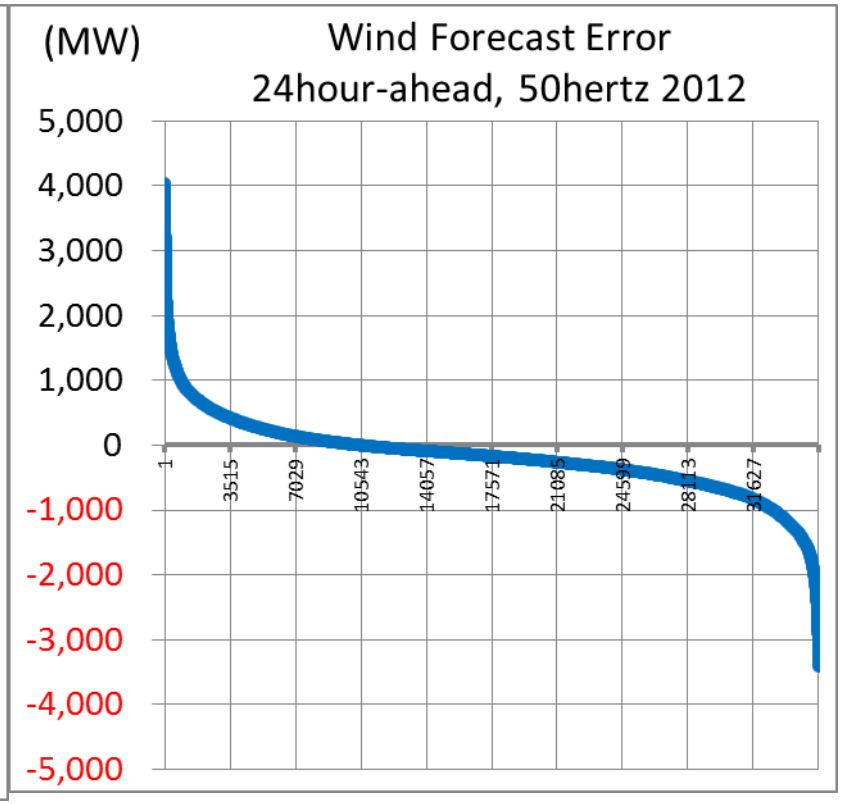
	[MWh]	[%]	
Wind Feed-in Total	18,511,758	100%	
13(1) EnWG Adjustment (Mainly Redispatch of Conventionl Plants)	2,824,454	15.3%	主に、火力に 送電先変更 措置
13(2)EnWG and 11EEG Adjustment Total (Output Reduction of Conventional and RES-E)	119,846	0.6%	全ての電源に 出力抑制、主 への抑制
Redispatch and Output Reduction Total	2,944,300	15.9%	

13(1) EnWG adjustments were 262 days.

13(2) EnWG and 11 EEG adjustments were 77 days.

Source: 50hertz Almanach 2012. Calculated by Massnahmen nach 13(1) EnWG and 13(2)EnWG.





Source: Calculated by 50hertz's grid data Kennzahlen in 2012

Wind Forecast Error of 24 Hours-ahead Error, in 50hertz, 2012

	Root Mean Square Error [MWh]	Max Error (+) [MW]	Min Error (–) [MW]	Error more than 10% of Nominal Capacity in 2012 [hour]
Forecast Error	429	4,031	-3,404	603
Share in Nominal Capacity [%]	3.7%	34.9%	-29.5%	Share in Annual Total Hours: 6.9%

Cumulative Wind Capacity in end of 201, 50hertz : 11,557 [MW]

Source: Calculated by 50hertz's grid data Kennzahlen in 2012

Conclusions

- Detail feed-in data must be disclosed to renewable energy operators by 15 minutes time unit.
- Transparency of feed-in from renewable power must be defined by the Japan's FIT law.
- **Around 70 % of wind feed-in in 50hertz zone** was absorbed in **German domestic market.**
- Around 30 % of wind feed-in was exported to neighboring countries, although.
- → Japanese power companies must pay proper efforts and **make proper investments** for wind and solar power integration.
- In order to get out of nuclear energy, we must have high data disclosures of wind feed-in and solar feed-in data, like German scheme.

風力発電および太陽光発電に関連する主要な給電データ開示制度

情報開示項目	開示を規定する根拠法規	開示方法、備考
風力給電予測（24時間前）、風力給電リアルタイム推定。太陽光給電予測（24時間前）、太陽光給電リアルタイム推定。送電区域ごと、15分単位、[MW] 法律の開示義務は「1時間単位」出力。現状は、15分単位で開示。リアルタイム推定は発電実績ではなく、モニター機器からの推定	§ 2, AusglMechAV（Ausgleichsmechanismus-Ausführungsverordnung: バランシング・メカニズム実施規則）。再エネ電力買取費用負担を全国平準化する実施規則。§45-49, EEG。	http://www.eeg-kwk.net グラフ、エクセル・データ、CSVデータ
EEX（欧州電力取引市場）Spot市場の当日取引における再エネ電力取引量。1時間単位。送電区域ごと。全ての種類の再エネ電力の合算値 [MW]	§ 2, AusglMechAV	グラフ、エクセル・データ、CSVデータ. http://www.eeg-kwk.net/de/Strommengen.htm。
全ての再エネ電力の24時間前の給電予測値と、EEX-Spot市場での取引実績値（前日取引量＋当日取引量）の乖離量。EEG流動性準備金の利用の有無。1時間単位、送電区域ごと。全ての再エネ電力の合算表示 [MW]。	§ 2, AusglMechAV	http://www.eeg-kwk.net/de/Einspeiseprognose.htm. グラフ、エクセル・データ、CSVデータ
EEG（再生可能エネルギー法）による再エネ電力の認定設備の登録データ （EEG-Anlagenstammdaten）。 再生可能エネルギー電源が連系する配電業者または送電業者の名前。風力、太陽光など電源種類、設備容量 [kW]。連系する電圧水準。コンバインド・サイクル併設の有無。系統運用者から出力抑制の指示を実施するためのリモート・コントロール設備の有無。発電開始日。発電設備の所在地。	§45-49, EEG（Erneuerbare-Energien-Gesetz: 再生可能エネルギー法）. 固定価格買取制の法律）	CSVデータ、インターネット開示 http://www.eeg-kwk.net/de/Anlagenstammdaten.htm
送電網から配電網への垂直ロード（Vertical load）[MW／hour]、年間最大需要 [MW/15分]、ロードカーブ[MW/15分]、域内送電線に連系する発電所と配電網からの給電電力[MW/15分]、風力給電[MW/hour]、停電回数と停電継続時間。	§ 17 Stromnetzzugangsverordnung (StromNZV, 電力ネットワーク接続規則）	数値表形式、およびCSVデータでインターネット開示が義務。送電会社各社のウエブサイトで開示義務
国際送電線の負荷と送電容量[MW]、連結点等の概要。送電区域ごと。	§ 17 Absatz 1, Stromnetzzugangs-verordnung (StromNZV)	
電力系統の安定性を維持するたの市場介入データ。非再エネ電源に対する送電変更（redispatch）と出力抑制の量。再エネを含むすべての電源に対する出力抑制の量。介入した場所（送電設備）、介入の種類（送電変更または出力抑制など）、影響を受けた配電業者、介入により需給調整を受けた出力[MW], 介入の時刻と継続時間（15分単位）、リスクのタイプ（隘路回避等）、介入された配電網設備の開示。	§ 13(1),§13(2), EnWG（Energiewirtschaftsgesetz、エネルギー事業法）.	送電業者には、系統安定性を維持するため、必要な需給調整のための市場介入の権限が認められている。1）電力網の一部で隘路の発生を回避するために、非再エネ電源に対する送電変更（redispatch)や出力抑制（§13（1）EnWG)。これらの方法によっても電力系統の安定性に危険がある場合、2）再エネ電源を含むすべての電源に対する出力抑制措置（§13（2）EnWG)。
Redistach(送電先変更）のデータ。実施日、実施時刻と継続時間、対象送電区域、実施理由(電流制御など）、方針（有効電力削減または有効電力増加など）、電圧別（中圧、高圧）に制御した出力[MW]、制御した総電力量[MWh]、Redispatch を実施した送電業者とこれを要請した送電業者、Redispatchの影響を受けた発電所名。	Bundesnetzagentur （連邦ネットワーク規制庁）による指示	EEG/KWK-G (送電業者4社の共通情報開示ポータル）に開示。CSVデータ。 http://www.eeg-kwk.net/de/Redispatch.htm.
バランシング市場(Balancing Energy、またはRegelleistung)の入札結果。リアルタイムの需給の過不足に対応するための予備力の入札結果のうち、2次予備力、3次予備力の入札結果と投入量。	§ 9 Stromnetzzugangsverordnung (StromNZV)	送電業者の共通情報開示ポータルで開示を義務をづけ。（www.regelleistung.net）

注）主に、電力の同時同量の需給バランスに関連する情報項目に絞って、筆者がまとめた。法的開示義務の項目は、これ以外にも、電力市場の取引データ（価格と量）、EEG会計（電力量[MWh]、集計費用、価格）、電気料金の表示方法等の開示義務があるが、ここでは省略した。