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ANALYSIS OF UK WIND POWER GENERATION

NOVEMBER 2008 TO DECEMBER 2010

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JOHN MUIR TRUST

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Issue 2

ANALYSIS OF UK WIND POWER GENERATION
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A Report by Stuart Young

Supported by

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Foreword by the John Muir Trust

The John Muir Trust is the leading wild land conservation charity in the UK. We seek to ensure that wild land is protected and that wild places are valued by and for everyone. Wild land helps to sustain human life as well as plant, bird and animal life. Our wild landscapes provide the foundation for our tourist industry. In the UK, we are defending our last wild land.

Scottish National Heritage (SNH) reported recently that the extent of Scotland unaffected by any form of visual influence (that is, the impact of development activities visible from any single vantage point) declined from 41% in 2002 to 31% by 2008 (see *SNH Heritage Indicators, 2009*). It then declined to 28% by the end of 2009.

SNH stated to the Scottish Parliament Public Petitions Committee that: 'Our initial analysis suggests that the most significant contributor to this decline is the development of wind farms, a consequence of their prominence and extensive visibility and siting in rural locations with little or no previous development.'

In the absence of adequate statutory protection for wild land, the Trust has grown increasingly concerned at the rate and scale of loss and our subsequent inability to defend landscapes within the planning and development process. In order to take the best decisions for wild land, we need to look at the evidence to better understand the real costs and benefits.

When the Trust heard about Stuart Young's painstaking research analysing publicly available data on the generation from National Grid-monitored wind developments in the UK, we were interested to see his results. His report shows that some key assumptions for wind developments are falling short of expectations.

We hope the evidence in the report will lead to a more open, honest and informed debate about large-scale, industrialised wind power, and remind people what is at risk when these developments are located in wild land areas.

Find out more about the John Muir Trust at www.jmt.org

About Stuart Young

Stuart Young is a semi-retired construction consultant living in Caithness. He provides a service in windfarm visualisations (see www.syvisuals.co.uk) and he is currently Chair of Caithness Windfarm Information Forum (for more information, see www.caithnesswindfarms.co.uk).

Over a fifteen month period, Young examined wind generation data daily as it was published, alongside the historical record, for the period between November 2008 and December 2010. He then collated that information into the following report.

The data used in the report is published by the Balancing Mechanism Reporting System (BMRS) at www.bmreports.com. The BMRS reports on the generation of all forms of electricity in the UK using data published by National Grid every five minutes.

For more information about the source data and methodology, please see the relevant page on the John Muir Trust website at www.jmt.org/wind-analysis-report.

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EXECUTIVE SUMMARY

PRINCIPAL FINDINGS
in respect of analysis of electricity generation from all the U.K. windfarms which are metered by National Grid, November 2008 to December 2010

The following five statements are common assertions made by both the wind industry and Government representatives and agencies. This Report examines those assertions.

1. "Wind turbines will generate on average 30% of their rated capacity over a year."
2. "The wind is always blowing somewhere."
3. "Periods of widespread low wind are infrequent."
4. "The probability of very low wind output coinciding with peak electricity demand is slight."
5. "Pumped storage hydro can fill the generation gap during prolonged low wind periods."

This analysis uses publicly available data for a 26 month period between November 2008 and December 2010 and the facts in respect of the above assertions are:

1. Average output from wind was 27.18% of metered capacity in 2009, 21.14% in 2010, and 24.08% between November 2008 and December 2010 inclusive.
2. There were 124 separate occasions from November 2008 till December 2010 when total generation from the windfarms metered by National Grid was less than 20MW. (Average capacity over the period was in excess of 1600MW).
3. The average frequency and duration of a low wind event of 20MW or less between November 2008 and December 2010 was once every 6.38 days for a period of 4.93 hours.
4. At each of the four highest peak demands of 2010 wind output was low being respectively 4.72%, 5.51%, 2.59% and 2.51% of capacity at peak demand.
5. The entire pumped storage hydro capacity in the UK can provide up to 2788MW for only 5 hours then it drops to 1060MW, and finally runs out of water after 22 hours.

OTHER FINDINGS

have emerged in the course of this analysis in addition to the Principal Findings which related to the testing of five common assertions. These Other Findings are listed below.

1. During the study period, wind generation was:
   - **below 20% of capacity more than half the time.**
   - **below 10% of capacity over one third of the time.**
   - **below 2.5% capacity for the equivalent of one day in twelve.**
   - **below 1.25% capacity for the equivalent of just under one day a month.**

   The discovery that for one third of the time wind output was less than 10% of capacity, and often significantly less than 10%, was an unexpected result of the analysis.

2. Among the 124 days on which generation fell below 20MW were 51 days when generation was 10MW or less. In some ways this is an unimportant statistic because with 20MW or less output the contribution from wind is effectively zero, and a few MW less is neither here nor there. But the very existence of these events and their frequency - on average almost once every 15 days for a period of 4.35 hours - indicates that a major reassessment of the capacity credit of wind power is required.

3. Very low wind events are not confined to periods of high pressure in winter. They can occur at any time of the year.

4. The incidence of high wind and low demand can occur at any time of year. As connected wind capacity increases there will come a point when no more thermal plant can be constrained off to accommodate wind power. In the illustrated 30GW connected wind capacity model with "must-run" thermal generation assumed to be 10GW, this scenario occurs 78 times, or 3 times a month on average. This indicates the requirement for a major reassessment of how much wind capacity can be tolerated by the Grid.

5. The frequency of changes in output of 100MW or more over a five minute period was surprising. There is more work to be done to determine a pattern, but during March 2011, immediately prior to publication of this report, there were six instances of a five minute rise in output in excess of 100MW, the highest being 166MW, and five instances of a five minute drop in output in excess of 100MW, the highest being 148MW. This indicates the requirement for a re-assessment of the potential for increased wind capacity to simulate the instantaneous loss (or gain) of a large thermal plant.

6. The volatility of wind was underlined in the closing days of March 2011 as this Report was being finalised.

    - At 3.00am on Monday 28th March, the entire output from 3226MW capacity was 9MW.
    - At 11.40am on Thursday 31st March, wind output was 2618MW, the highest recorded to date.
    - The average output from wind in March 2011 was 22.04%.
    - Output from wind in March 2011 was 10% of capacity or less for 30.78% of the time.

The nature of wind output has been obscured by reliance on "average output" figures. Analysis of hard data from National Grid shows that wind behaves in a quite different manner from that suggested by study of average output derived from the Renewable Obligation Certificates (ROCs) record, or from wind speed records which in themselves are averaged.

It is clear from this analysis that wind cannot be relied upon to provide any significant level of generation at any defined time in the future. There is an urgent need to re-evaluate the implications of reliance on wind for any significant proportion of our energy requirement.

ANALYSIS OF UK WIND POWER GENERATION

NOVEMBER 2008 TO DECEMBER 2010

INTRODUCTION

There is a growing concern that wind generation may not be able to deliver the contribution which has been predicted and used in government projection assumptions. Several studies have indicated that output is often less than anticipated or was claimed, at the planning stage of development. Every wind farm proposal is accompanied by a claim with regard to "meeting the average needs of x thousand homes" or similar, for example:

> "The current proposal has 30 turbines with an installed capacity of up to 75 megawatts (MW) of renewable electricity. With a capacity of this size in such a windy part of Scotland, the project will meet the average needs of some 42,000 households and offset the annual release of over 100,000 tonnes of carbon dioxide, the main greenhouse gas contributing to climate change, which would otherwise come from power stations burning fossil fuels."
> http://www.spittalwindfarm.co.uk/proposal.html

The following five assertions are commonly put forward as if they are indisputable facts:

1. **"Wind turbines will generate on average 30% of their rated capacity over a year".**
2. **"The wind is always blowing somewhere."**
3. **"Periods of widespread low wind are infrequent."**
4. **"The probability of very low wind output coinciding with maximum electricity demand is slight."**
5. **"Pumped storage hydro can fill the generation gap during prolonged low wind periods."**

There is little evidence available to support these assertions, and knowing the average output of a wind generator over a period tells us nothing about how that average output was delivered. This Report examines wind generation performance and draws on information published by the Balancing Mechanism Reporting Service (BMRS).

The data originates from National Grid (NG) and has been published every five minutes of every day since 1st November 2008 (excluding instrumentation failures and the like). This Report covers the period from that date until 31st December 2010.

The **current** data is found on the BMRS website at www.bmreports.com , and **historical** data can be found on the ELEXON Portal website at
https://elexonexchange.bsccentralservices.com/ref=HISTORICGENERATIONBYFUELTYPE
Registration is required to create an account.

The data on which this Report is founded is accessible to, and verifiable by, anyone with an internet connection.

ELEXON Ltd is the Balancing and Settlement Code Company (BSCCo) defined and created by the Balancing and Settlement Code (BSC and also known as the Code). ELEXON Ltd procures, manages and operates services and systems, which enables balancing and settlement of the wholesale electricity market and retail competition in electricity supply.

A wealth of information is to be found on the **Balancing Mechanism Reporting Service (BMRS)** website at www.bmreports.com from where links to related sites are found.

I am grateful to ELEXON Ltd for permission to use its generation data, and for the not inconsiderable help I have had from the BSC Service Desk. BSCServiceDesk@logica.com.

EXPLANATORY NOTES

These notes explain the objective of this report, briefly describe the BMRS website, explain about wind generation which is "visible" to National Grid, and outlines the methodology employed in producing the Analysis which is at the heart of this report.

Objective

This analysis seeks to test the "assertions" by examining and presenting historical generation data. There is nothing technical or difficult in this work. It is simply the accessing and recording of generation data from the 227,808 five-minute files in chronological order from 1st November 2008 until 31st December 2010, and presentation of the information by time, and by level of wind generation output relative to time.

It is the objective of this Report to set out hard indisputable facts about how wind power delivers its "average" output, and to place these facts before engineers, politicians, economists, and others who are hopefully in a position to influence energy policy.

The BMRS Website

National Grid (NG) has been publishing electricity generation by fuel type data every five minutes on its NETA website www.bmreports.com since 1st November 2008. This covers generation from all conventional industrial generators by fuel type, and from a **large proportion** of the industrial wind generation installations in UK.

Wind Generation which is "visible" to National Grid

There is no central instantly-accessible record of all industrial wind generated electricity. NG can only "see" the generation which is metered at the point of connection to the transmission system under NG's control and where it has operational metering.

If a wind farm connects to a substation owned or operated by NG, NG can "see" it. If it simply hooks into the wider distribution system, NG cannot "see" it. It is an invisible source of power satisfying an invisible demand. However, it remains NG's responsibility to balance the Grid to ensure that the invisible demand which wind satisfies when it is generating continues to be met when it is not generating.

NG can "see" around 50% of all industrial UK wind generation. There is no reason to believe that wind generation not "seen" by NG performs any more efficiently. Indeed, it is possible that, since all the onshore wind generation in the metered total is presently in Scotland, which is generally windier than the rest of the UK, the "unseen" wind generation may perform less well.

Until July 2010, all wind generation "visible" to NG, and in the data analysed in this Report, was from onshore wind in Scotland. It represented about 80% of all industrial wind generation in

Scotland and had a good geographical spread. It is reasonable to assume, due to the good geographical spread, that the "visible" generation was a fair representation of all generation in Scotland at that time.

After July 2010, with output from offshore wind farms off North East England, in the Solway Firth and at Thanet off the Kent coast having been added to those "visible", the geographical spread became dispersed, and the data is no longer representative of any particular area.

However, one simple fact remains true. **If there is little or no wind generated power available at any one time from the whole of the "visible" wind fleet, then there is little or no wind generated power available from any part or geographical sub-section of the wind fleet at that time.**

Methodology

Where this analysis refers to a percentage output from wind, it is the actual output in MW expressed as a percentage of the installed capacity.

Every five minutes of every day, the BMRS website publishes generation data from NG which includes wind generated power data. This information is also available historically from the ELEXON Portal website. This analysis has used the historical record.

This Report set out to test a few assumptions. One hypothesis which seemed likely is that if wind farms generate at 30% of their rated capacity on average, then it might be reasonable to expect that they will generate over 30% for about half the time and under 30% for about half the time. However, it is now clear that wind behaviour is not so simple.

The wind generation data was, therefore, sorted in an EXCEL spreadsheet in output bands, and the number of five minute periods which wind generation spent in each of those bands is the basis of the analysis.

The output bands are:

- Over 30% rated capacity
- 20% to30%
- 10 to 20%
- 5 to 10%
- 2.5 to 5%
- 1.25 to 2.5%
- Less than 1.25% of rated capacity.

Where there was a gap in data, for example due to instrumentation failure, then the last credible data before the event and the first credible data after the event have been averaged, and the appropriate number of five minute periods inserted at these average values. This maintains 288 five minute periods in each day.

The numbers of five minute periods in each output band was initially expressed as a percentage of the total numbers of five minute periods in the month in question.

Having established the length of time of generation in each output band, this was further sorted into periods of time above and below the 30% "average " output as follows:

Over 30% rated capacity
Under 30% rated capacity
Under 20%
Under 10%
Under 5%
Under 2.5%
Under 1.25%

The data were then sorted to establish average wind generation outputs for the following periods:

1st November 2008 to 31st December 2010
November and December 2008
2009
2010
2009 and 2010

The record was examined for individual low wind events. Five-minute periods which were recorded as 10MW or less and 20MW or less output were identified.

The record was also examined to determine wind generation at the major peak demands in 2010.

The generation record has been presented graphically on twenty-six sheets. Each sheet shows one graph of recorded generation (top graph) with a line identifying the expected 30% average and another line for actual average outputs, and another graph (bottom graph) showing;

a) actual recorded demand along with

b) actual recorded generation factored up to represent generation from 30GW wind capacity (red data line).

In round terms, 30GW connected wind capacity is expected by the year 2020. There is currently around 5GW connected wind capacity. The factored output shows what contribution to the total demand might be achieved from the expected wind fleet in 2020.

ANALYSIS

Average Outputs

The basis for calculation of average output is the actual output expressed as a percentage of metered capacity over the specified period.

Average outputs from metered wind farms were:

2008 (November and December only)	31.72%
2009	27.18%
2010	21.14%
2009/2010	23.63%
2008/2009/2010	24.08%

The belief that onshore wind farms generate on average 30% of rated capacity is not supported by the record of generation from November 2008 to December 2010 inclusive.

Time at Banded Generation Output Levels

The numbers of five minute periods with generation in each band were abstracted and expressed as a percentage of total time in each band:

OUTPUT LEVELS	2008-2010	2008	2009	2010	2009/2010
% Time over 30% capacity	33.44	47.22	38.55	26.02	32.29
% Time 20-30%	12.70	9.14	13.90	12.09	13.00
% Time 10-20%	20.45	15.06	18.56	23.25	20.91
% Time 5-10%	15.47	10.09	14.04	17.80	15.92
% Time 2.5-5%	9.79	9.88	8.68	10.88	9.78
% Time 1.25-2.5%	5.06	5.08	4.33	5.80	5.06
% Time <1.25%	3.09	3.53	1.94	4.16	3.05

The aggregated period percentages of total time above and below the threshold bands were calculated:

OUTPUT LEVELS	2008-2010	2008	2009	2010	2009/2010
% Time over 30% capacity	33.44	47.22	38.55	26.02	32.29
% Time under 30% capacity	66.56	52.78	61.45	73.98	67.71
% Time under 20% capacity	53.86	43.64	47.55	61.88	54.72
% Time under 10% capacity	33.41	28.59	28.99	38.64	33.81
% Time under 5% capacity	17.94	18.50	14.95	20.84	17.89
% Time under 2.5% capacity	8.15	8.62	6.27	9.96	8.11
% Time under 1.25% capacity	3.09	3.53	1.94	4.16	3.05

The hypothesis that generation would be over and under 30% of capacity for roughly equal amounts of time has not been supported.

The significant information to come from this analysis is the aggregated lengths of time at unexpectedly low levels of output:

- **More than half the time below 20% of capacity.**
- **Over one third of the time below 10% of capacity.**
- **The equivalent of one day in twelve below 2.5% capacity.**
- **The equivalent of just under one day a month below 1.25% capacity.**

Incidence of Very Low Wind Events

The record was scrutinised for “Very Low Wind Events”. Periods in which generation from the total metered capacity was 10MW or less and 20MW or less were identified and recorded, regardless of the level of metered capacity at the time. (The average metered capacity over the study period was in excess of 1600MW so these represented very small percentages of capacity whenever they occurred).

10MW Events

Between 1st November 2008 and 31st December 2010, a period of 791 days, there were 51 days on which generation fell below 10MW for at least one five minute period. The shortest time was five minutes and the longest was seventeen hours and fifteen minutes. The total number of five minute periods below 10MW was 2662.

The average frequency and duration of low wind events below 10MW over the period in question can be calculated thus;

Frequency: 791 days divided by 51 = 15.51 days
Duration: 2662 five minute periods divided by 51 = 52.2 periods = 4.35 hours

20MW Events

Between 1st November 2008 and 31st December 2010, a period of 791 days, there were 124 days on which generation fell below 20MW for at least one five minute period. The shortest time was five minutes and the longest was thirty-three hours. The total number of five minute periods below 20MW was 7330.

The average frequency and duration of low wind events below 20MW over the period in question can be calculated thus.

Frequency: 791 days divided by 124 = 6.38 days
Duration: 7330 five minute periods divided by 124 = 59.11 periods = 4.93 hours

- **Between November 2008 and December 2010 inclusive, a less than 20MW event occurred on average once every six and a half days and lasted for almost five hours. This included 10MW events occurring on average once every fifteen and a half days and lasting for just under four and a half hours**.

- **Very low wind events are frequent and not confined to isolated high pressure events in winter.**

Coincidence of Peak Demand with Low Wind Output

PEAK DEMANDS AND WIND OUTPUT IN 2010.					
DATE	TIME	DEMAND MW	WIND MW	METERED WIND CAPACITY MW	% of METERED WIND CAPACITY
7th JANUARY 2010	17.05 HRS	59541	75	1588	4.72
7th DECEMBER 2010	17.20 HRS	60191	134	2430	5.51
20th DECEMBER 2010	17.20 HRS	60017	62	2430	2.55
21st DECEMBER 2010	17.30 HRS	59405	61	2430	2.51

- **The four highest daily peak demands of 2010 occurred at periods of very low wind output.**

DEMAND is taken for this purpose as the total electricity generation recorded at any time on the "24 Hour Instantaneous Data" spreadsheet accessed from the "Generation by Fuel Type (Table)" in the "Electricity Data Summary" on the BMRS website at www.bmreports.com
or from Historical Data on the ELEXON Portal website
(https://elexonexchange.bsccentralservices.com/ref=HISTORICGENERATIONBYFUELTYPE)
Registration is required to create an account.

GRAPHICAL REPRESENTATIONS

The analysis of wind output by real time rather than "on average" presents a very different and much more informative picture of how wind power is actually delivered, but a spreadsheet analysis does not convey the nature of the delivery of wind power.

Twenty-six pages of graphical representations of wind output, one for each month in the study period, are appended. Each page has two different graphs on it.

The top graph records wind output. The red data line comprises each five minute record of wind output in sequence. Along with grid lines indicating generation levels, a horizontal blue line has been incorporated which shows the level of 30% of the metered capacity at the time of generation, and a horizontal green line indicates the actual average generation over the given period.

The lower graph records Demand, obtained as for wind data, and the actual metered wind output factored up to 30GW capacity (red data line) to represent the 2020 scenario to the same scale.

Study of the graphs highlight the following conditions:

Rapid rise and fall

Due to the necessarily small scale of the wind output graph, a high degree of "smoothing" masks the true volatility of wind output.

Below is a snapshot from the beginning of June 2010 showing the short-term volatility of wind output. The period shown was not particularly volatile, but the nature of change in output can be seen.

Changes in output in excess of 100MW over a five minute period are not uncommon.

Incidence of low wind

In each of the 26 months of the study period, the output data line "bumps along the bottom" at some time, often for a prolonged period – even in months where average output is more than 30%. There were fifty-one days in the period on which generation was 10MW or less at some point, including two days during the period when the metered capacity was 2590MW. This included approximately 80% of Scotland's onshore wind fleet, and Robin Rigg, Burbo Bank, Barrow Offshore, and Thanet offshore windfarms.

Low wind periods are very common – see all twenty-six graph pages.

Incidence of high wind and low demand.

It might have been expected that the coincidence of high wind and low demand would have been confined to summer time but, over the study period, as can be seen in the 30GW connected capacity scenario, such events would have been spread across the period if the projected 2020 wind generation capacity had been installed.

There will come a point during a high wind output event which is coincident with low demand when, for operational reasons, no more thermal plant can be constrained off. Wind generation will have to be constrained off instead.

This Report cannot determine at what level that point occurs, but it seems likely that the "must-run" level of thermal generation will be above 10GW. A simple visual inspection of the graphical record using a set of dividers indicated 78 separate instances where the gap between notional wind generation from 30GW capacity and actual demand was 10GW or less.

Nature of high wind events

High wind events are typically of short duration, and are frequently accompanied by sharp rises and falls in output. In the following snapshot of generation during the period from 7.35am to 10.05am on 16th December 2010, the spreadsheet was filtered to find instances of greater than ±50MW magnitude of movement in wind output between consecutive five minute periods.

	A	B	C	D	E	F	L	M	Q	S	T	U	V
1	FUEL HH	PUBLISH TIME	PERIOD	CCGT	COAL	INTFR if+	NPSHD	NUCLEAR	PS if +	WIND	DEMAND	RISE	FALL
4413	FUELINST	16/12/2010 07:35	4412	17335	20875	0	189	8367	919	1115	48800		
4414	FUELINST	16/12/2010 07:40	4413	17539	20934	0	191	8360	1041	1160	49225		
4415	FUELINST	16/12/2010 07:45	4414	17713	21083	0	190	8363	1086	1372	49807	212	
4416	FUELINST	16/12/2010 07:50	4415	17939	21216	0	190	8362	1081	1401	50189		
4417	FUELINST	16/12/2010 07:55	4416	18126	21417	0	188	8365	1030	1400	50526		
4418	FUELINST	16/12/2010 08:00	4417	18244	21526	0	189	8368	1001	1408	50736		
4419	FUELINST	16/12/2010 08:05	4418	18348	21569	0	191	8368	907	1408	50791		
4420	FUELINST	16/12/2010 08:10	4419	18495	21684	0	192	8370	862	1391	50994		
4421	FUELINST	16/12/2010 08:15	4420	18595	21698	0	191	8372	874	1394	51124		
4422	FUELINST	16/12/2010 08:20	4421	18632	21796	0	191	8364	868	1425	51276		
4423	FUELINST	16/12/2010 08:25	4422	18646	21817	0	190	8364	847	1417	51281		
4424	FUELINST	16/12/2010 08:30	4423	18626	21870	0	203	8365	841	1424	51329		
4425	FUELINST	16/12/2010 08:35	4424	18564	21814	0	209	8363	795	1492	51237	68	
4426	FUELINST	16/12/2010 08:40	4425	18573	21762	0	212	8364	724	1562	51197	70	
4427	FUELINST	16/12/2010 08:45	4426	18506	21860	0	213	8366	729	1583	51257		
4428	FUELINST	16/12/2010 08:50	4427	18463	21824	0	218	8372	723	1582	51182		
4429	FUELINST	16/12/2010 08:55	4428	18466	21832	0	214	8371	758	1557	51198		
4430	FUELINST	16/12/2010 09:00	4429	18554	21739	0	234	8367	780	1620	51294	63	
4431	FUELINST	16/12/2010 09:05	4430	18580	21843	0	257	8364	747	1769	51560	149	
4432	FUELINST	16/12/2010 09:10	4431	18632	21949	0	255	8363	785	1802	51786		
4433	FUELINST	16/12/2010 09:15	4432	18687	22057	0	254	8368	835	1735	51936		-67
4434	FUELINST	16/12/2010 09:20	4433	18723	22079	0	252	8358	1016	1616	52044		-119
4435	FUELINST	16/12/2010 09:25	4434	18806	22060	0	253	8358	1029	1629	52135		
4436	FUELINST	16/12/2010 09:30	4435	18792	22022	0	254	8363	1122	1740	52293	111	
4437	FUELINST	16/12/2010 09:35	4436	18858	22002	0	254	8366	1050	1761	52291		
4438	FUELINST	16/12/2010 09:40	4437	18875	22010	0	241	8362	1263	1695	52446		-66
4439	FUELINST	16/12/2010 09:45	4438	18904	22038	0	235	8362	1155	1689	52383		
4440	FUELINST	16/12/2010 09:50	4439	18979	22061	0	234	8373	1063	1667	52377		
4441	FUELINST	16/12/2010 09:55	4440	19117	22104	0	235	8372	947	1616	52391		-51
4442	FUELINST	16/12/2010 10:00	4441	19180	22138	0	243	8369	949	1541	52420		-75
4443	FUELINST	16/12/2010 10:05	4442	19233	22153	0	245	8371	982	1506	52490		

It may be that there are other explanations for some of the results shown, but errors in recording are normally easy to spot as they are often accompanied by not credible results from other fuel type generation. In the instances above there are no contra-indications from other fuel types and the trend in demand appears logical.

Movements in excess of 100MW over a five minute period are relatively common even at the low levels of metered capacity during the study period. As more wind power is connected the magnitude of rapid changes will increase.

The argument is often put that thermal plant is intermittent as it can fail instantaneously but wind does not, thereby allowing time for alternative generation to be put in place. Study of the record indicates that with higher wind capacity, rapid generation movements might well be of a magnitude to simulate the instantaneous loss (or gain) of a large thermal plant. At the very least, this scenario deserves immediate expert assessment.

Duration of low wind events

The graphs show the frequency and duration of low wind events. If "low wind output" is taken arbitrarily to be below 10% of capacity, then over the study period, low wind events occurred for over one third of the time, or almost nine months in aggregate. Even if a low wind event was taken as below 5% of capacity, then low wind events occurred for almost 18% of the time, or for the equivalent of five full months out of twenty-eight.

PUMPED STORAGE HYDRO

Pumped storage hydro is frequently cited as the solution to long periods of low wind output. However, if all four UK pumped storage plants were to be run simultaneously at full capacity, the stored water would be exhausted in around 24 hours. Once exhausted, the reservoirs can only be replenished when there is a surplus of generation over demand, and it takes longer to replenish the reservoirs than it does to empty them.

UK PUMPED STORAGE CAPACITY				
Plant	**Dinorwig**	**Ffestiniog**	**Cruachan**	**Foyers**
Capacity	1728MW	360MW	400MW	300MW
Duration at peak output	5 hours	20 hours	22 hours	Not found

No details of the period at which Foyers can run at full capacity were found, but at a massive flow of 100m³ per second, it is not likely to be of long duration.

The existing 2788MW of installed UK pumped storage hydro plays a key role in balancing the grid. If it is to be used as a replacement for wind in windless times, then it cannot do its current job as well.

Scottish and Southern Energy have announced plans to construct two pumped storage schemes near Loch Ness with capacity of 600-1200MW between them, and have Planning Consent for 60MW at Loch Sloy, near Loch Lomond.

All three new schemes are designed to help meet peak demand. If they were to be used as back-up for wind in protracted low output periods, they would have the same limitations on duration of supply and would be unable to fulfil the purpose for which they are to be built.

It would require the approximate equivalent output of three Cruachan Power Stations (400MW) to replace 1000MW of wind-generated energy for one day. [(1000MW x 24 hours) ÷ (400MW x 22 hours) = 2.72.] The logistics of backing up wind energy with pumped storage hydro are such that even if there were enough suitable locations, the scale and cost of the Civil Engineering exercise to construct it would be prohibitive.

STUART YOUNG
STUART YOUNG CONSULTING
MARCH 2011

APPENDIX A

EXAMPLES OF ASSERTIONS

APPENDIX A

Examples where the five assertions have been used

The five assertions have become commonly held beliefs due to their constant repetition in a wealth of material, ranging from UK and devolved Government publications to wind industry claims, independent reports, and media coverage. Here are a few readily accessible examples of such material.

1. Wind turbines will generate on average 30% of their rated capacity over a year

From RenewableUK's website http://www.bwea.com/edu/calcs.html - "Calculations for wind energy statistics"

> "0.3 is a constant, the capacity factor, which takes into account the intermittent nature of the wind, the availability of the wind turbines and array losses"
>
> "This is only an average estimation given that in many places, particularly Scotland and offshore, the wind speeds are higher leading to a greater electricity production per turbine, as power output is a cube of the wind speed."
>
> "N.B. 0.3 capacity factor is also stated as 30% load factor"

2. The wind is always blowing somewhere.

Extract from the Executive Summary of a Report by the Environmental Change Institute for the Department of Trade and Industry "wind power and the UK wind resource".
(Found at http://www.eci.ox.ac.uk/publications/downloads/sinden05-dtiwindreport.pdf
and linked to from Scottish Government's "Onshore Wind Frequently asked questions" at
http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/WindFAQ):

> *"Extreme lows or highs in wind speed are a natural feature of the UK wind climate; however a diversified wind power system would be less affected as it is rare that these extreme events affect large areas of the country at the same time. This report found that:*
>
> - *Low wind speed conditions affecting 90% or more of the UK would occur in around one hour every five years during winter;"*

3. Periods of widespread low wind are infrequent.

See 2 above.

Also, taken from **yes2wind** website at http://www.yes2wind.com/explore/debunking-the-myths :

Myth 5 - Wind power isn't reliable

> "A great advantage of wind power is that the available wind resource is much greater during the colder months of the year, when energy demand is at its highest. And the wind will never stop blowing everywhere in the UK at once!"

4. The probability of very low wind output coinciding with peak electricity demand is slight.

The following is from National Grid's Consultation "Operating the Electricity Networks in 2020, Initial Consultation, June 2009" followed by E.ON's response: http://www.nationalgrid.com/NR/rdonlyres/32879A26-D6F2-4D82-9441-40FB2B0E2E0C/39517/Operatingin2020Consulation1.pdf

> "para 6.44
> National Grid's view at this stage is that for 2020, a wind generation output assumption of up to 15% of capacity at times of peak demand is reasonable. However, taking the issues explored above and our recent operational experience together, we believe that it is essential to look carefully at the implications of infrequent 'low wind' events within Great Britain. "

From EON response to that consultation http://www.nationalgrid.com/NR/rdonlyres/4F15AC9D-C47E-4447-9D07-5DDCAD2BC987/38401/EonUK.pdf

> *"Question 17: Is National Grid's current view that 'low wind' events across Great Britain need to be considered when evaluating electricity operating margins reasonable?*
>
> Yes. National Grid should consider all relevant factors when setting margins, and we agree that periods of low wind speeds across Britain at times of high electricity demand are sufficiently frequent to require consideration in their own right. Failure to do so would risk seriously reducing the security of electricity supply. If decarbonising heat supply leads to greater use of electricity either for direct heating or heat pumps then the effect could be magnified.
>
> "The 95% confidence level for wind output (5% probability of being worse) is a reasonable reference point for assessing capacity credit as it puts wind on a similar footing to thermal plant, which achieves reliability at around that level over winter peak periods. However, this value must be considered across the entire portfolio, because unlike

thermal plant there is a strong correlation of wind output from different sites. Also, the estimate of the level of wind output that can be relied upon with that degree of confidence is much lower than the 15% quoted from the SKM report. National Grid should also consider the 10% and 5% cases as these are likely in the winter, when it is possible to see peak demand coincide with minimal wind generation (very cold, still days). "

5. **Pump storage hydro can fill the generation gap during prolonged low wind periods.**

From "Power of Scotland Secured, Summary for policy makers"

(Friends of the earth Scotland, RSPB, WWF)
http://www.rspb.org.uk/Images/POSS_FinalReport_tcm9-272152.pdf

"4. System Security

This section considers alternative scenarios for achieving reliability of electricity supply in the context of a 100% renewable energy production.

There are four main ways to provide or contribute to 'security of supply':

3) Energy storage

In Scotland, the main opportunities to store energy in forms that can then be turned back into electricity are pumped storage, and electric vehicles. *Scottish andSouthern Energy* are already developing schemes for new pumped storage plant[25].

25 And for conversion of an existing hydro station to provide additional pumped storage capability"

APPENDIX B

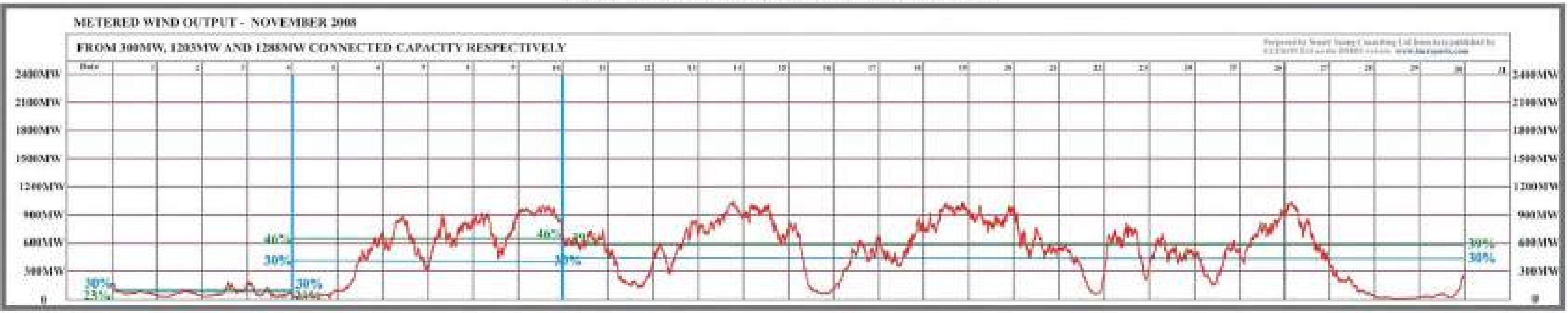
GRAPHS

Note. Graphs printable at A3 can be downloaded from the "supporting documents" on the John Muir Trust website

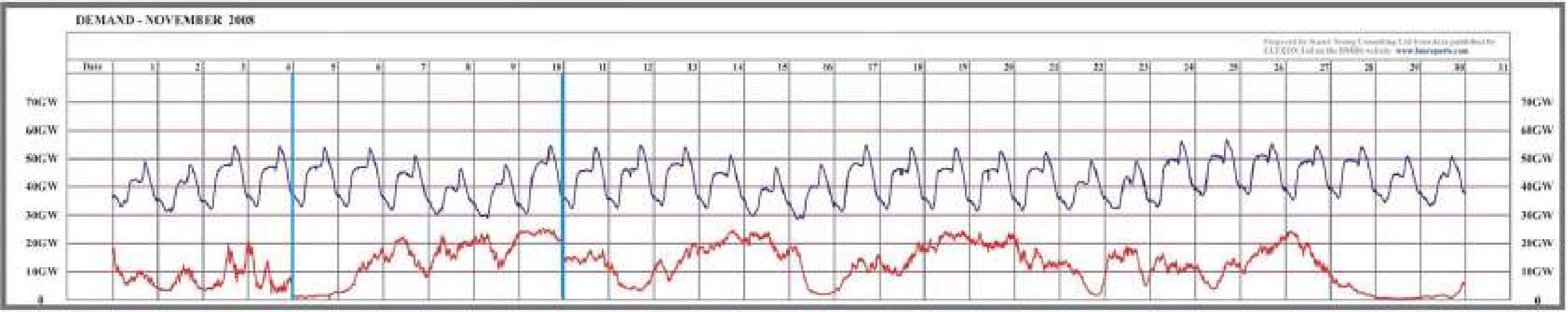
www.jmt.org

ANALYSIS OF WIND POWER GENERATION NOVEMBER 2008 TO DECEMBER 2010

ILLUSTRATION OF ACTUAL METERED WIND OUTPUT, ACTUAL DEMAND, AND ACTUAL METERED WIND OUTPUT FACTORED UP TO A NOTIONAL 30GW METERED CAPACITY



NOVEMBER 2008



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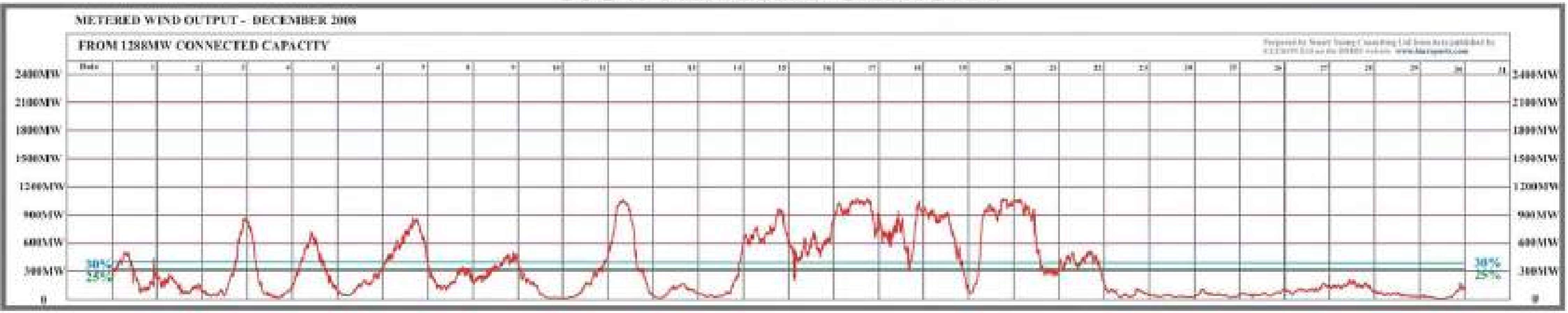
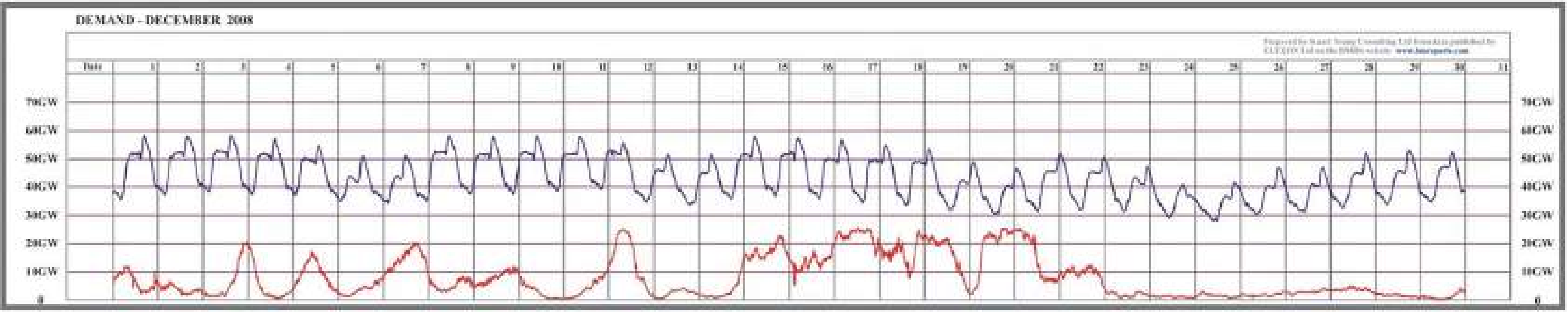


DECEMBER 2008



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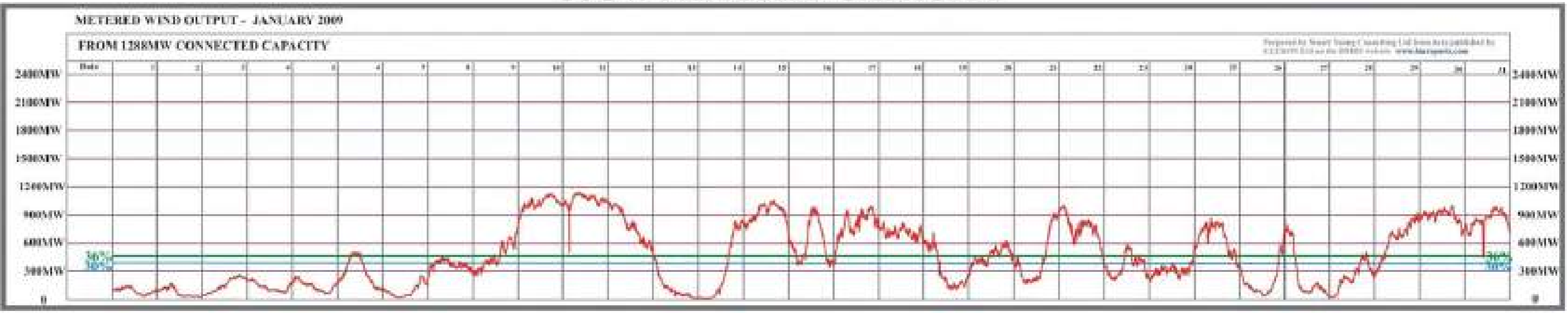

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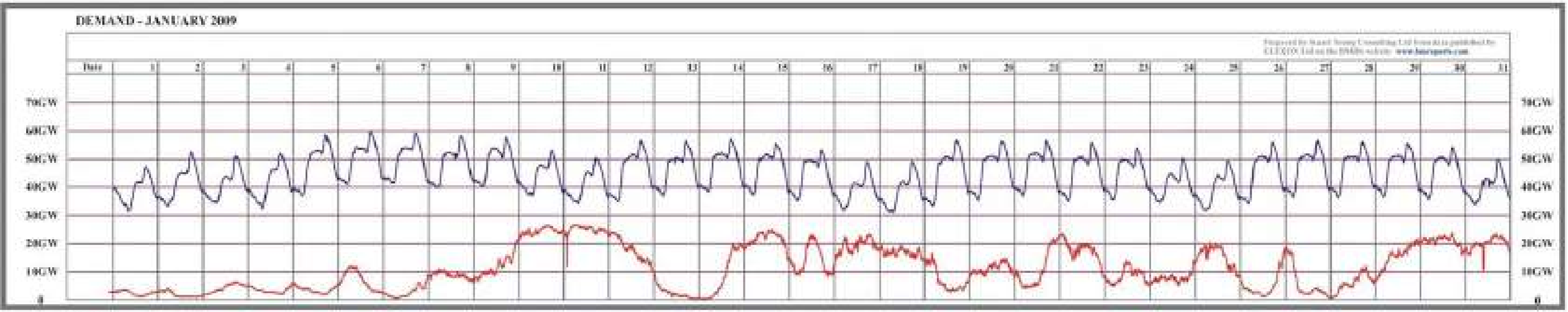

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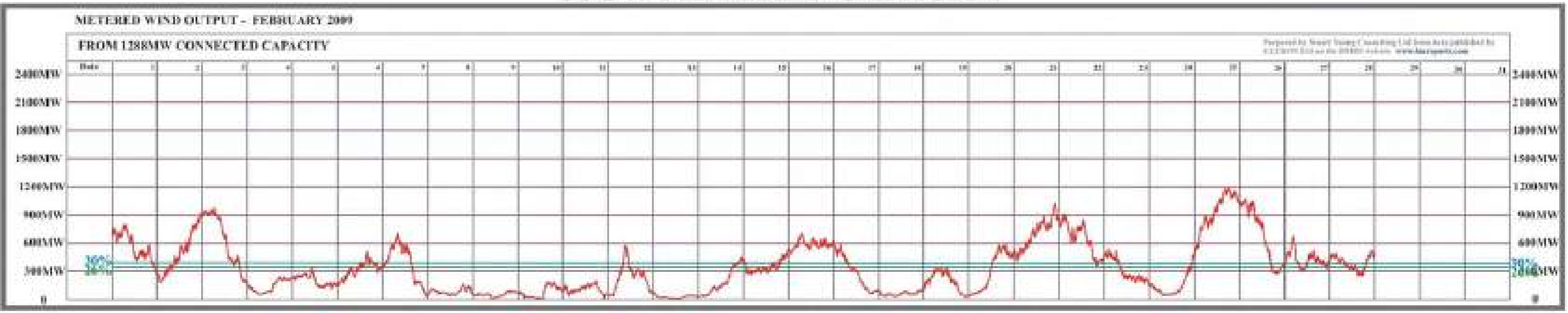

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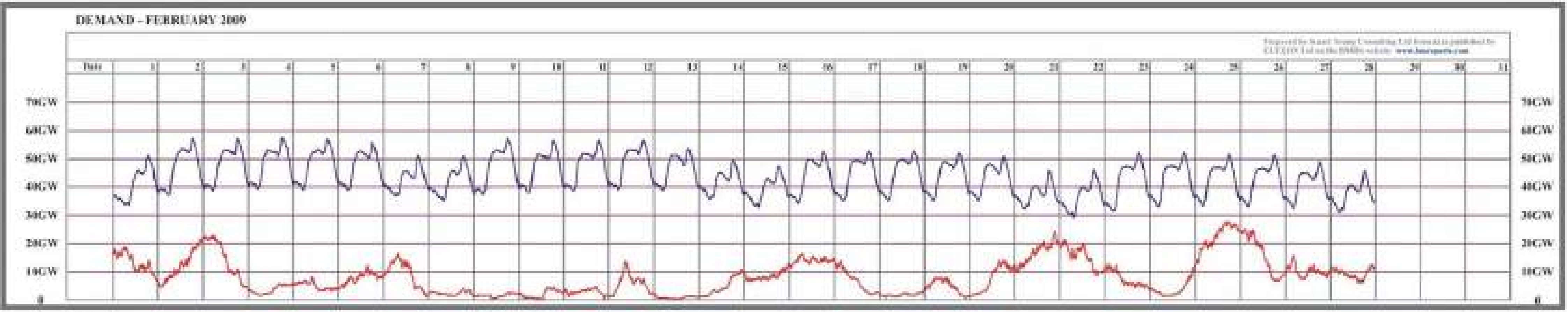

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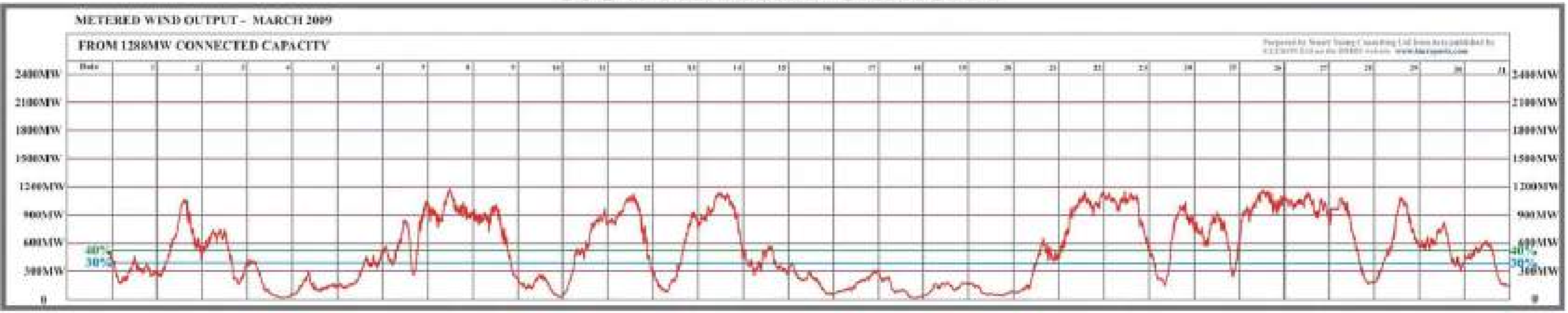

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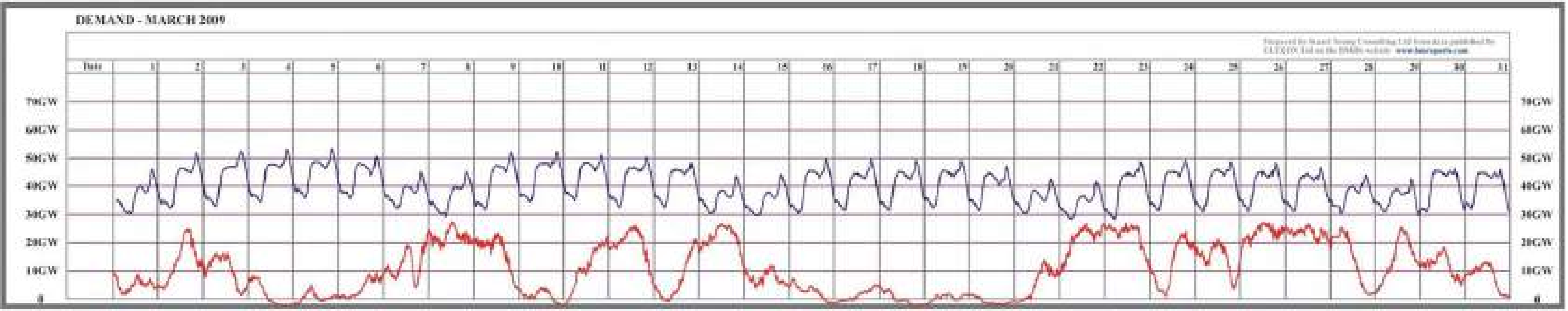

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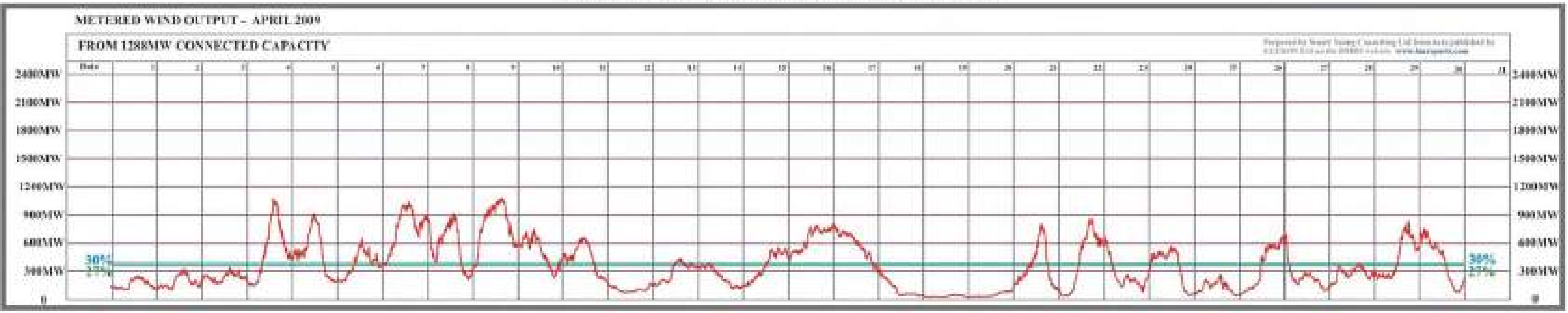

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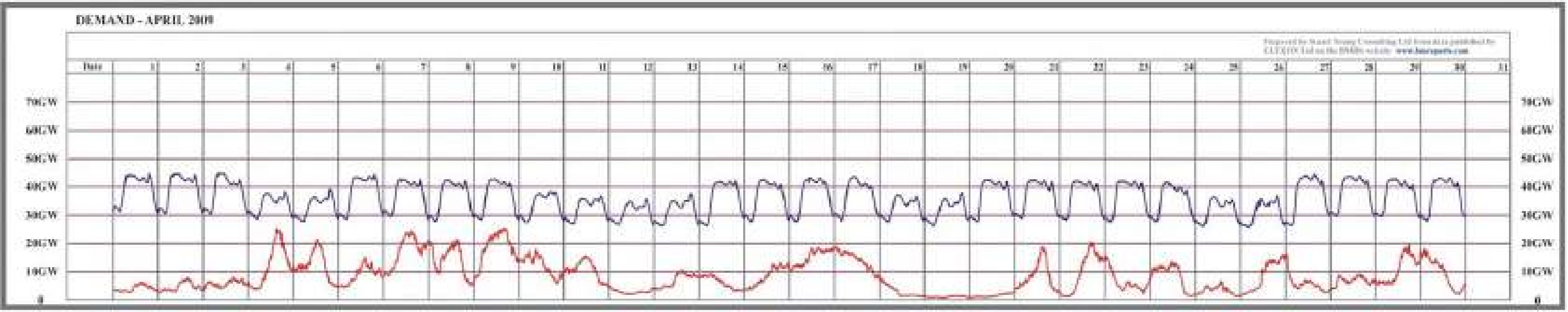

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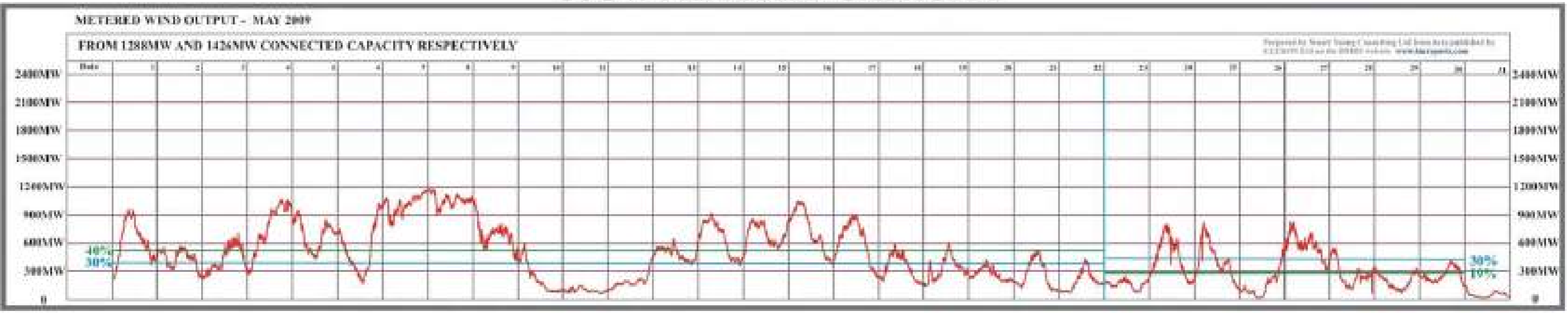

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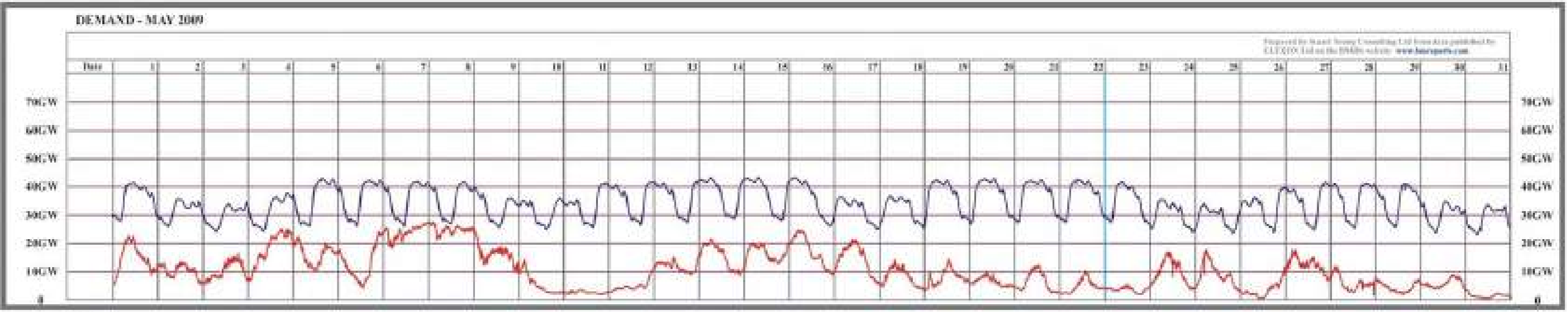

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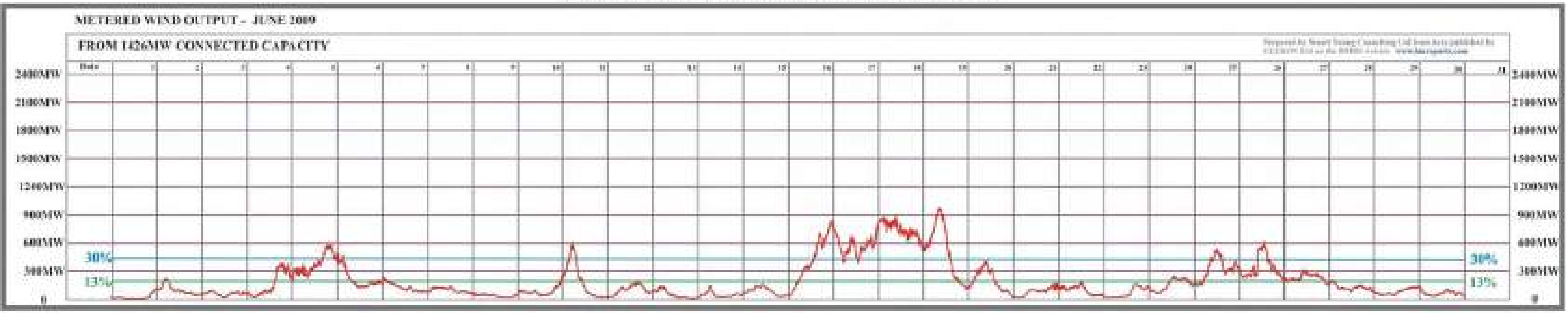

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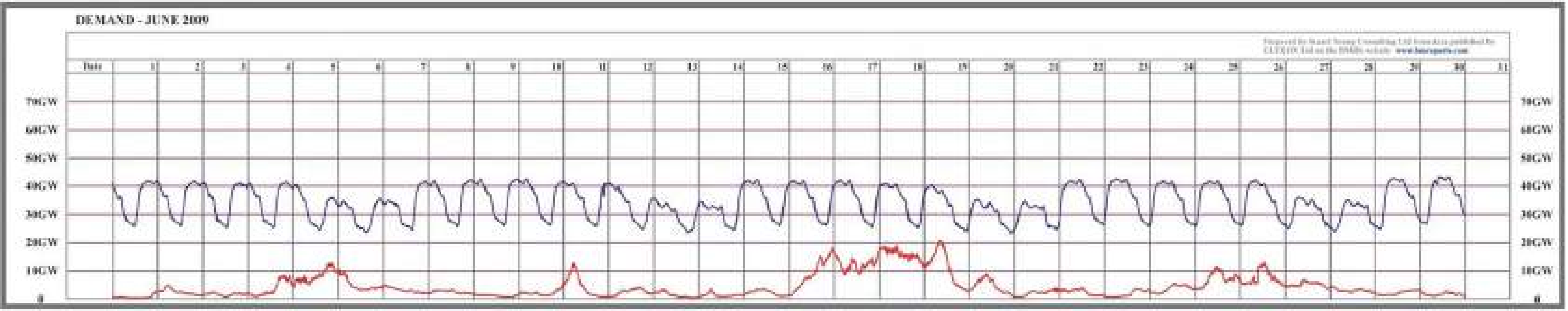

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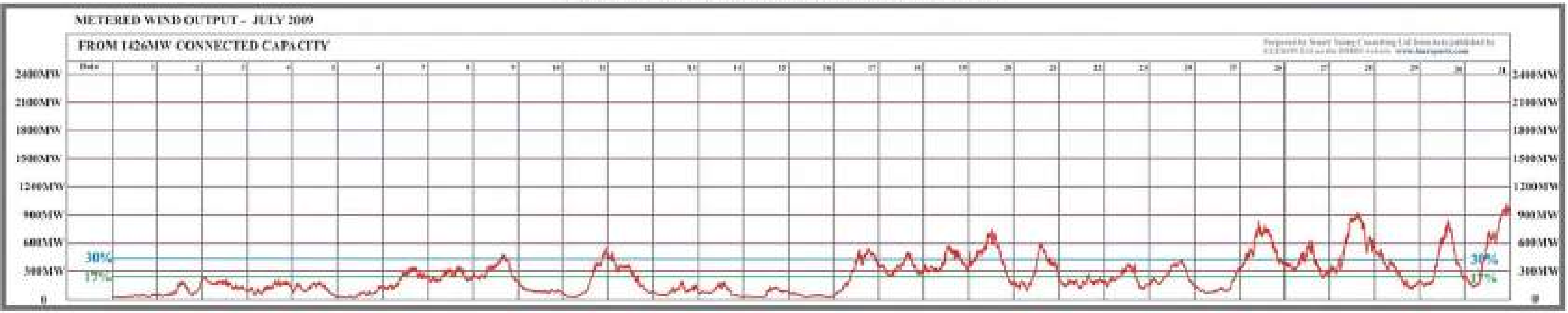

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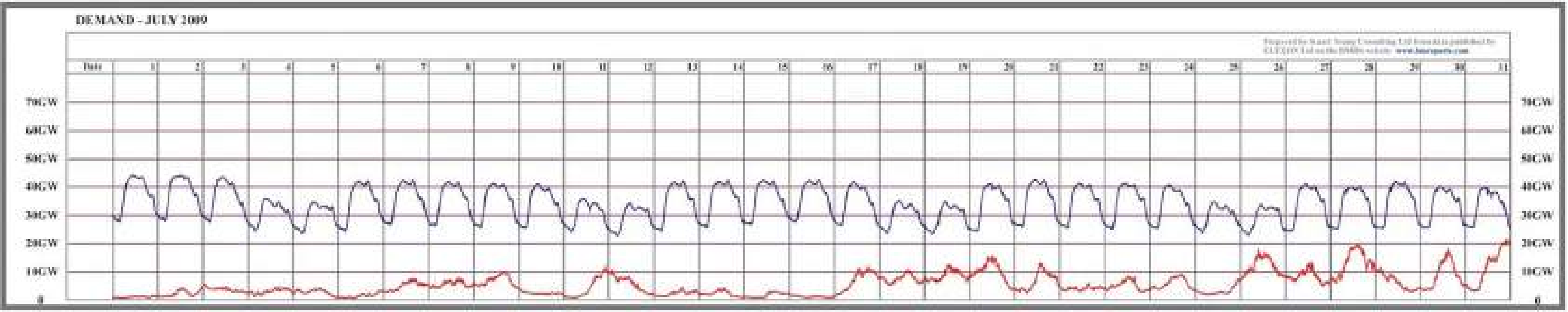

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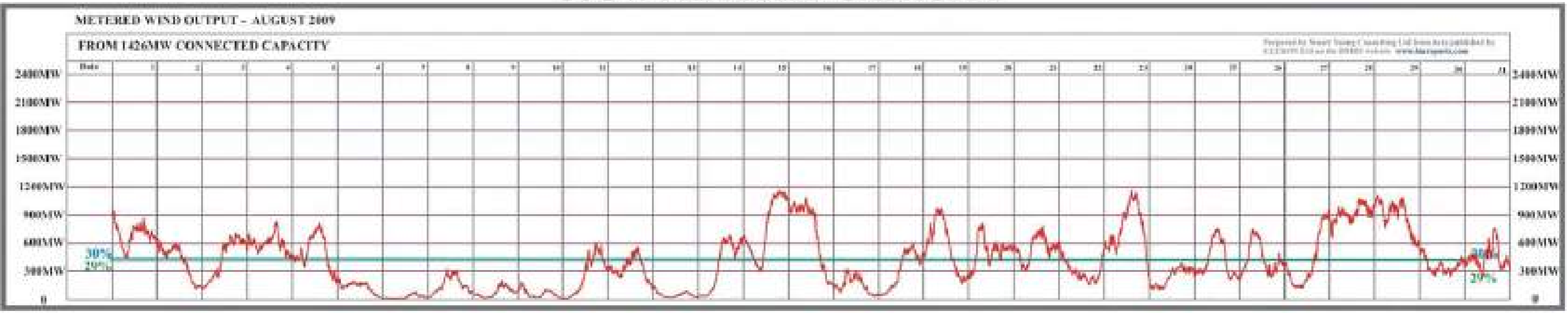

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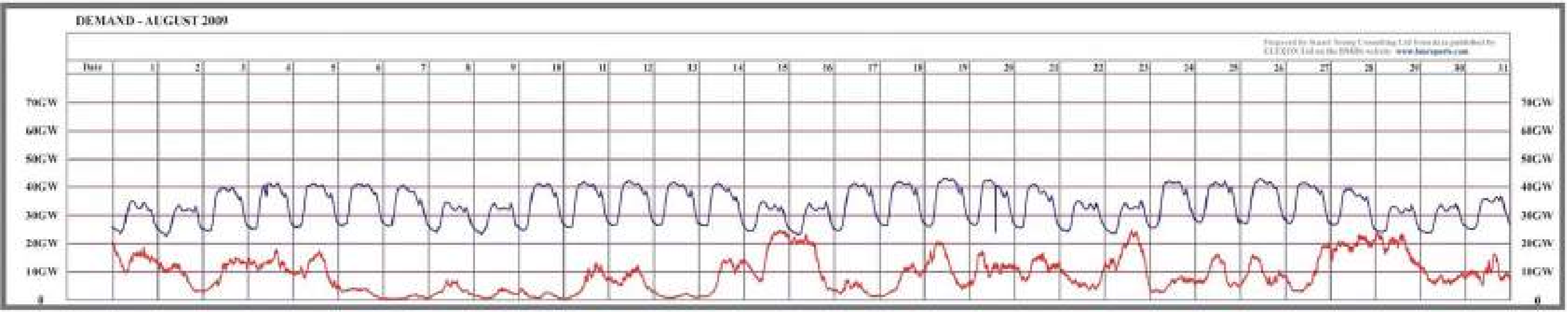

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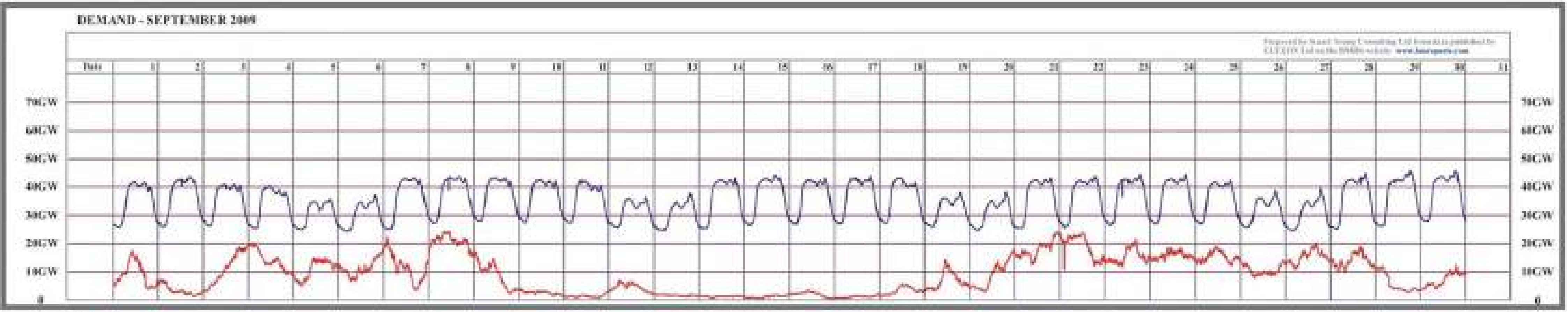

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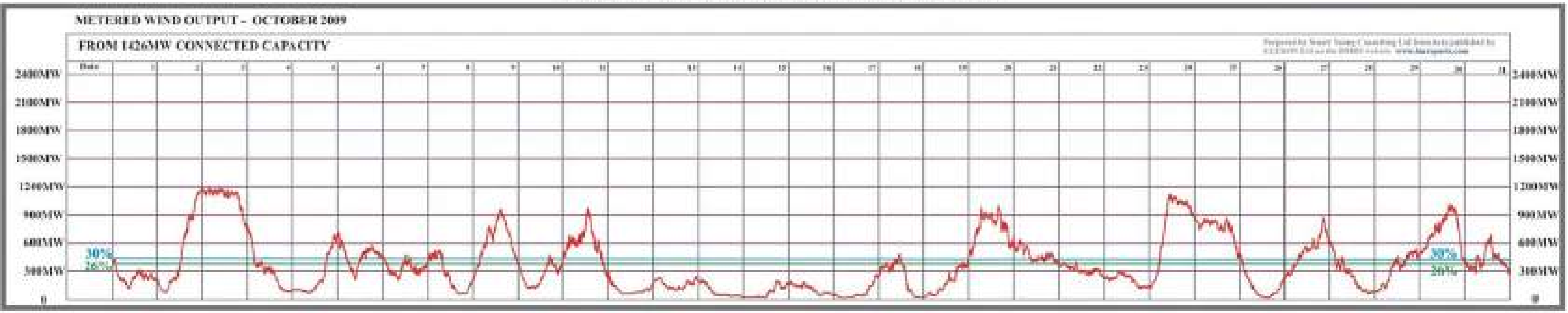

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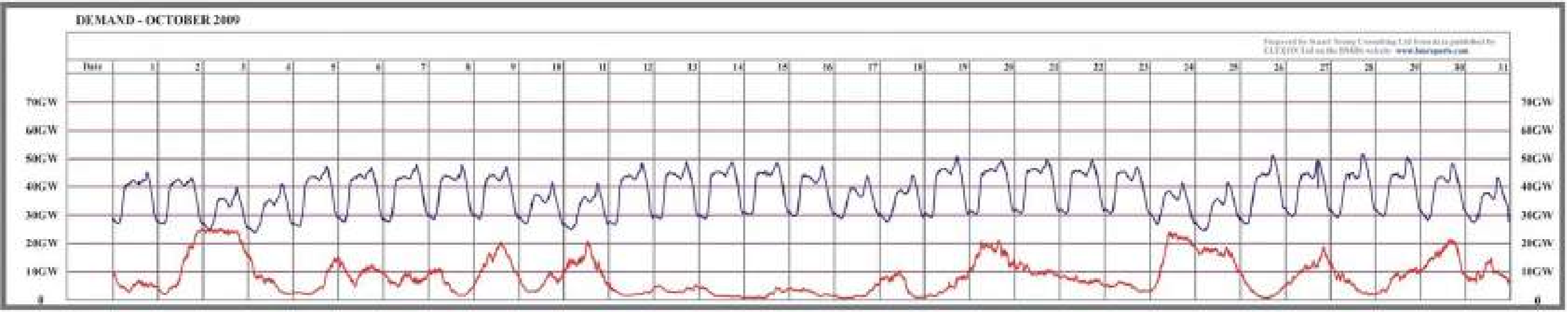

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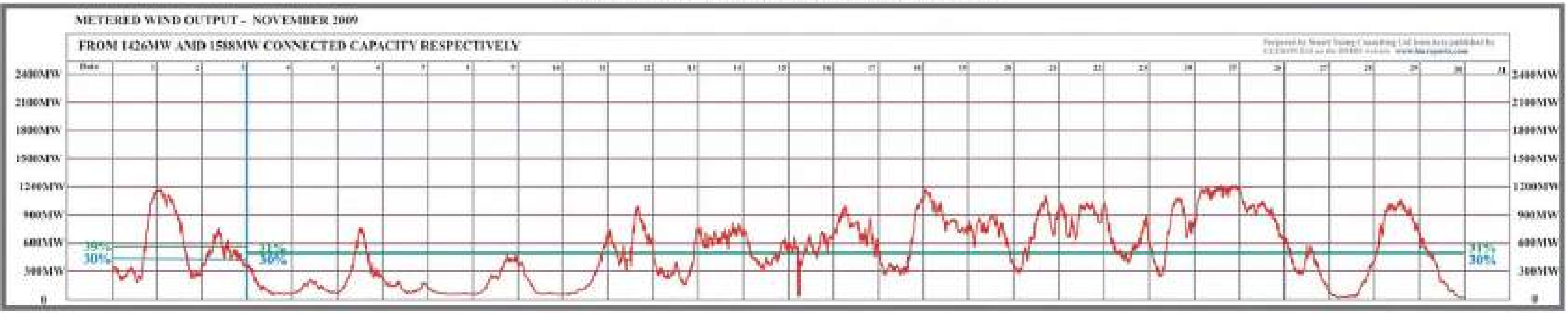

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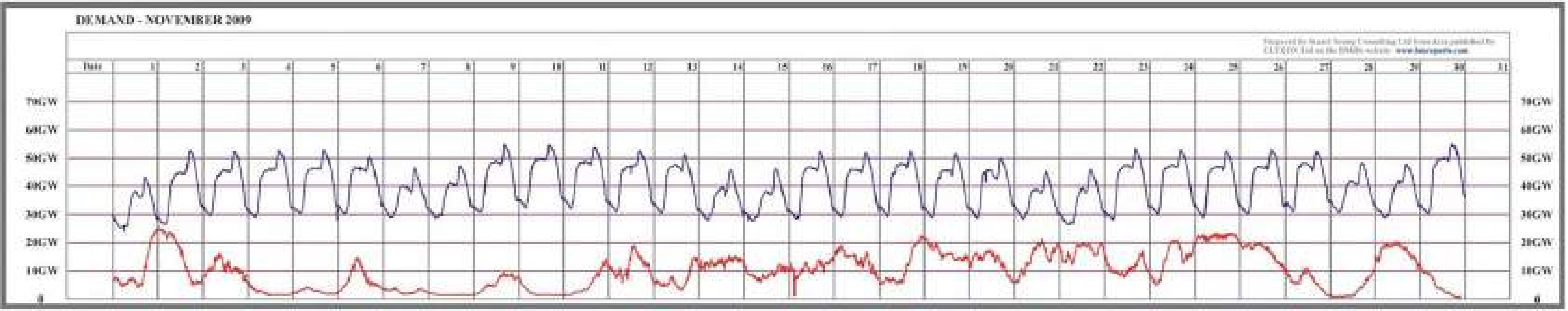

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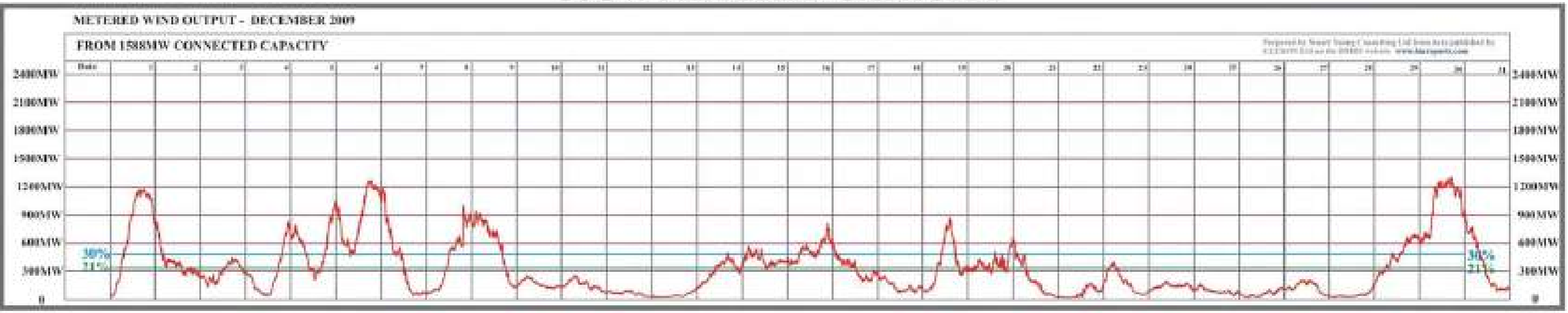

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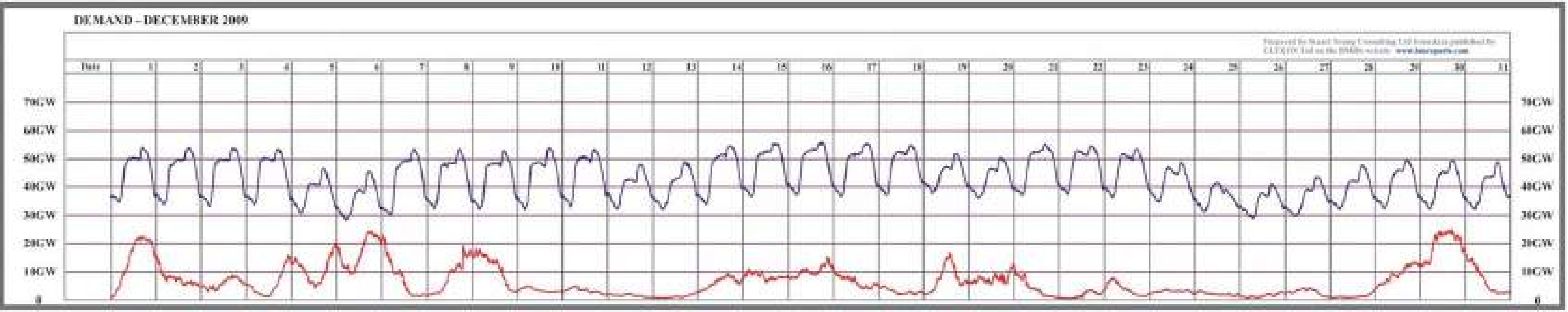

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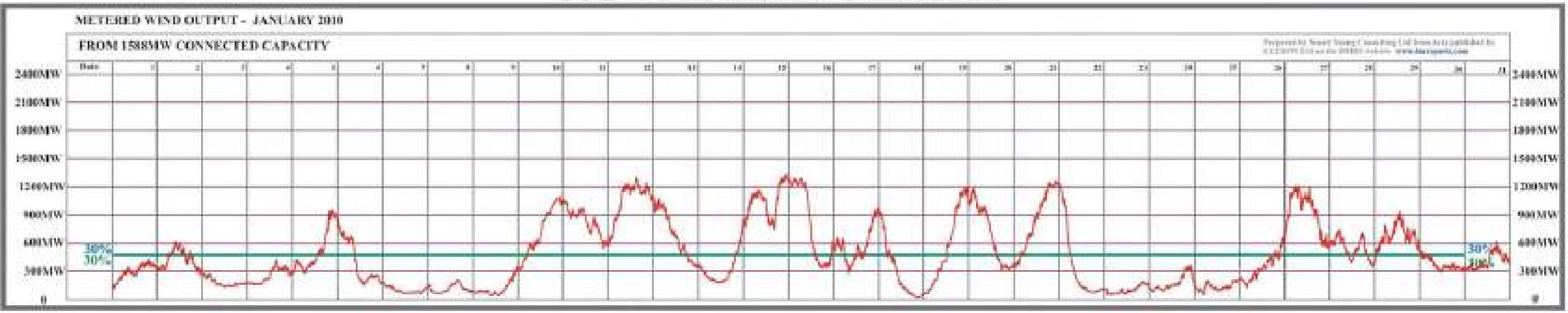
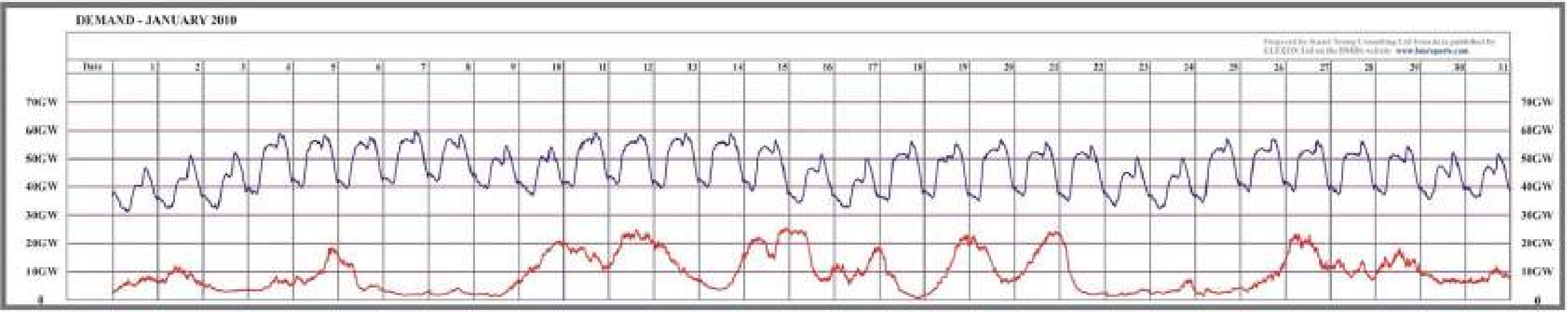


JANUARY 2010



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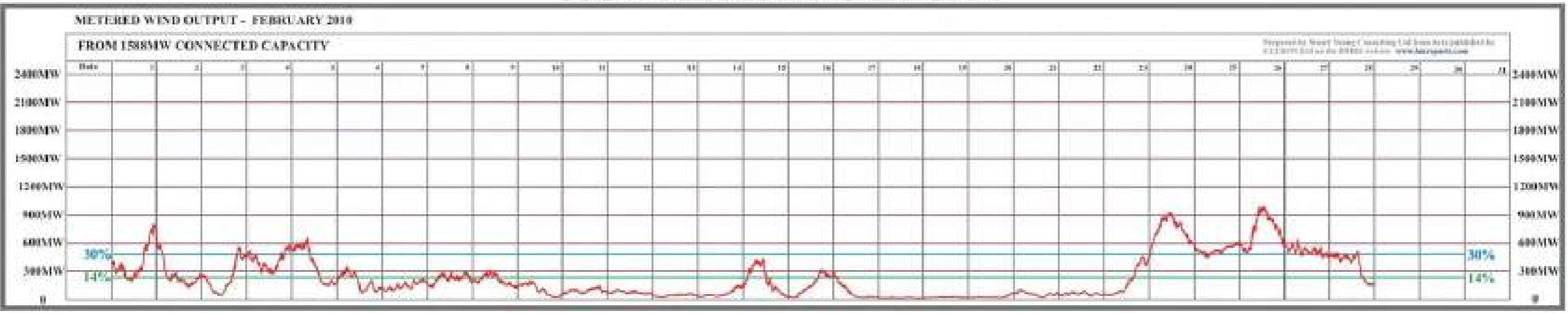

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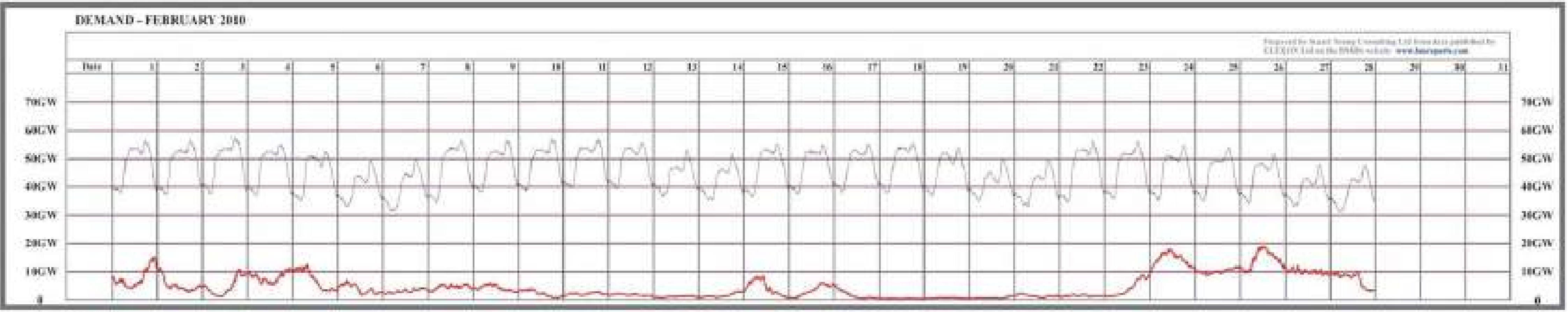

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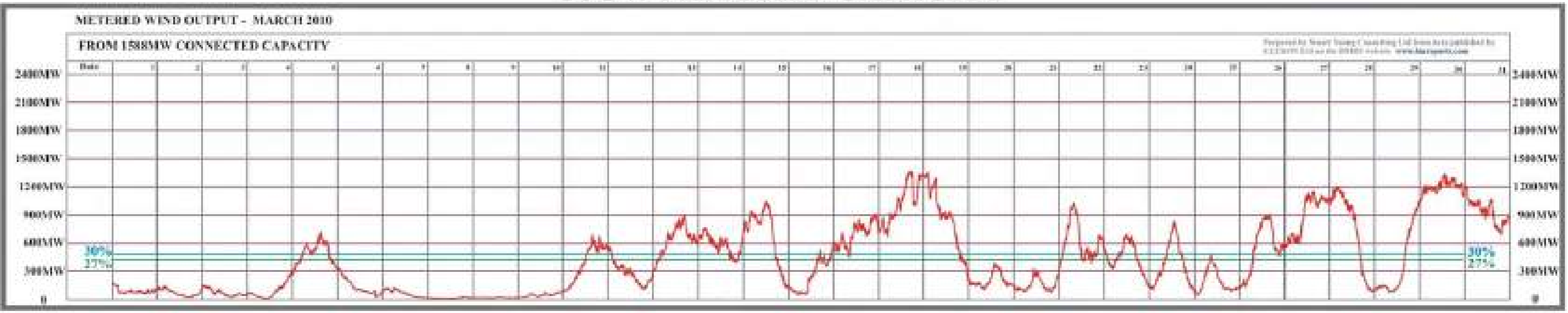
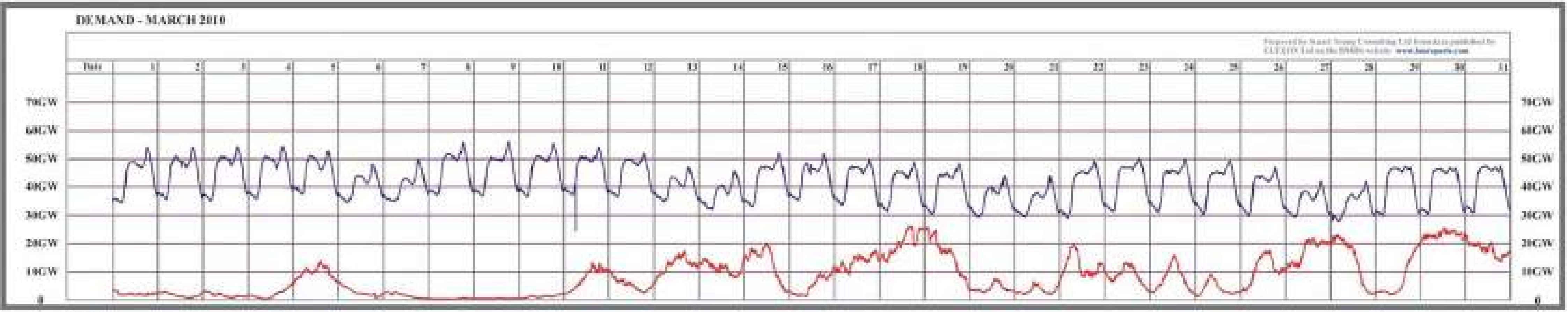


MARCH 2010



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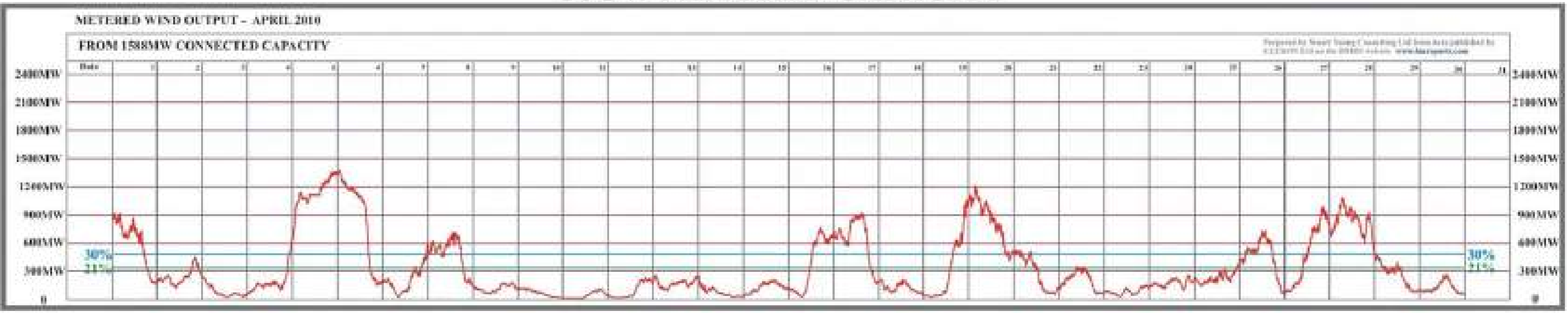

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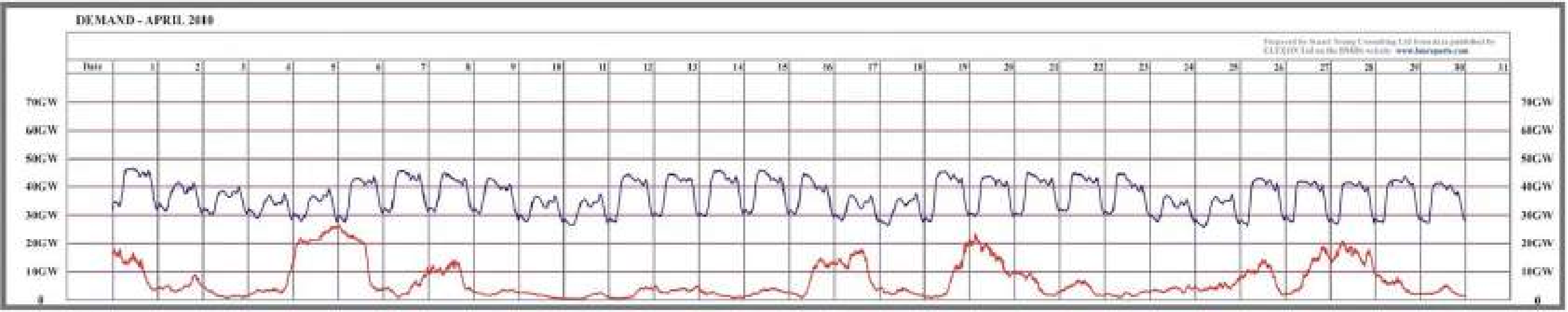

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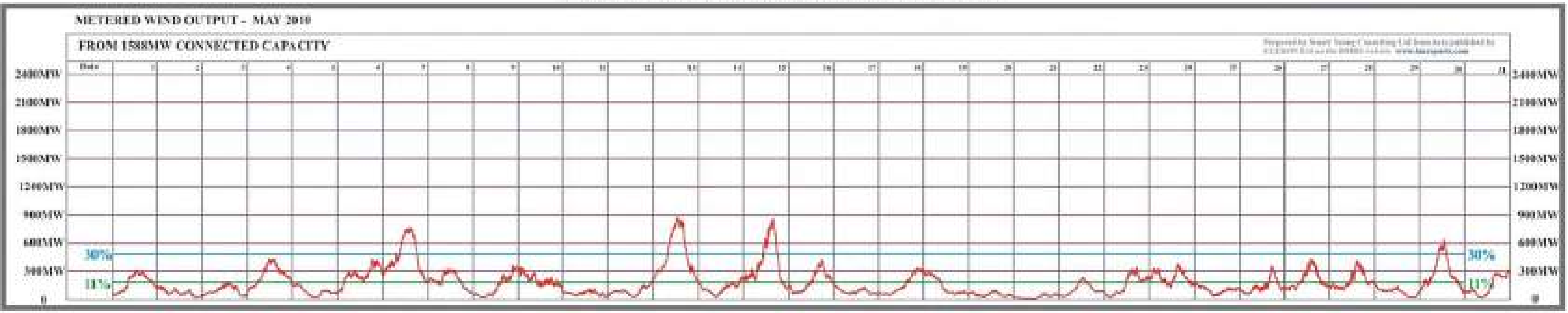

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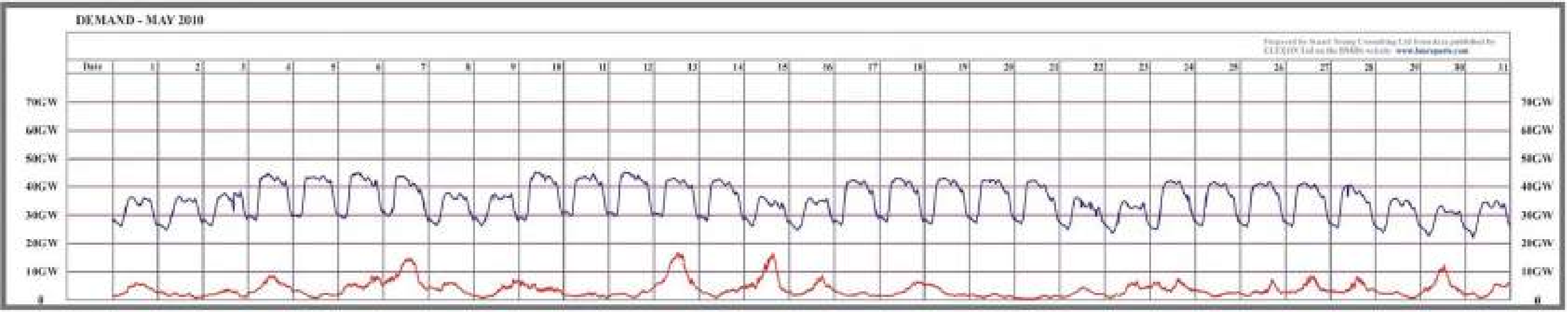

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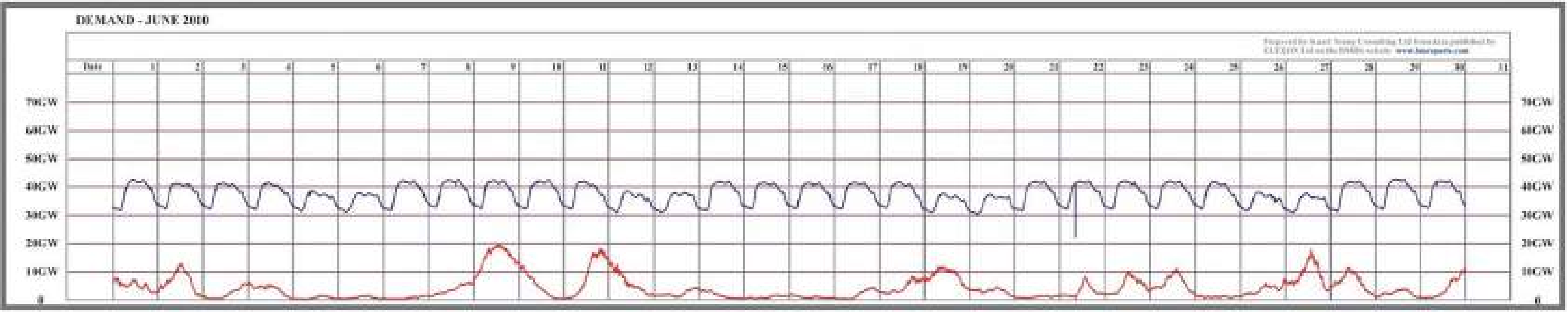

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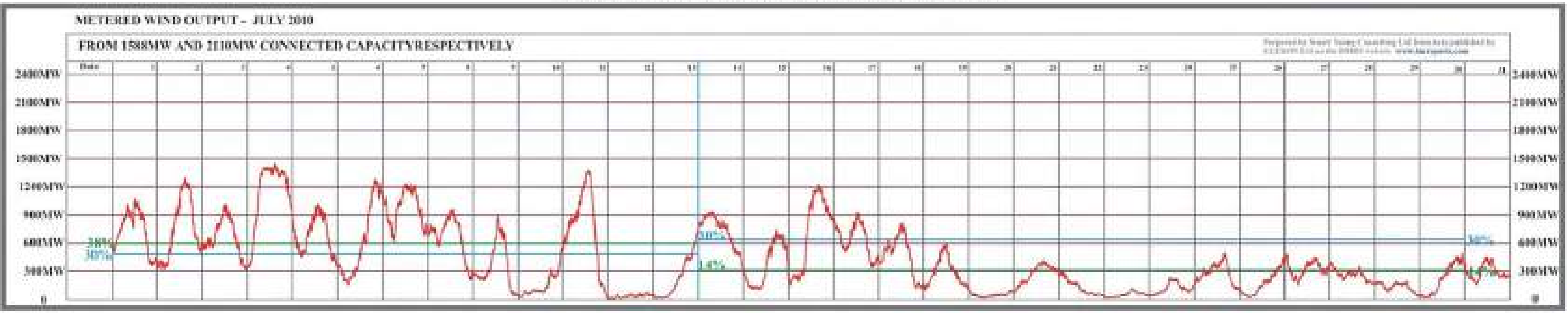

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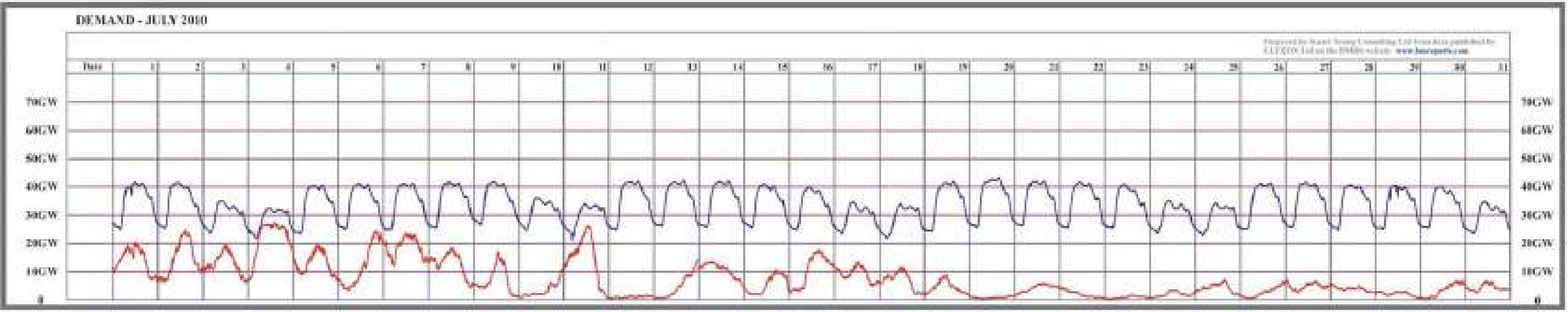

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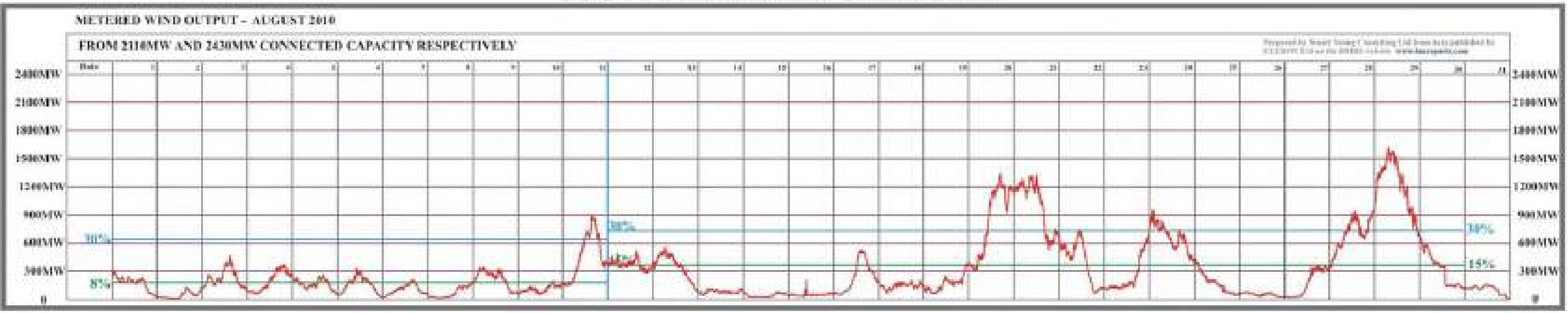

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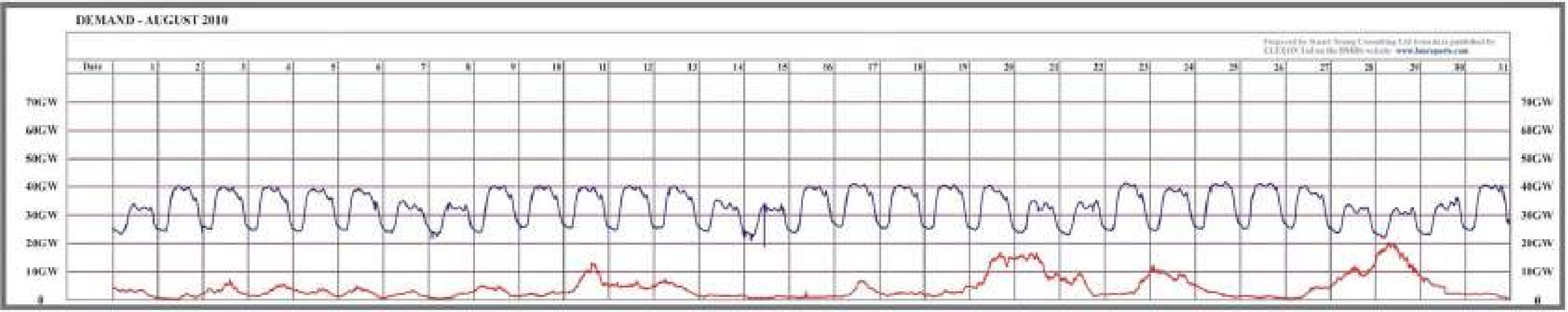

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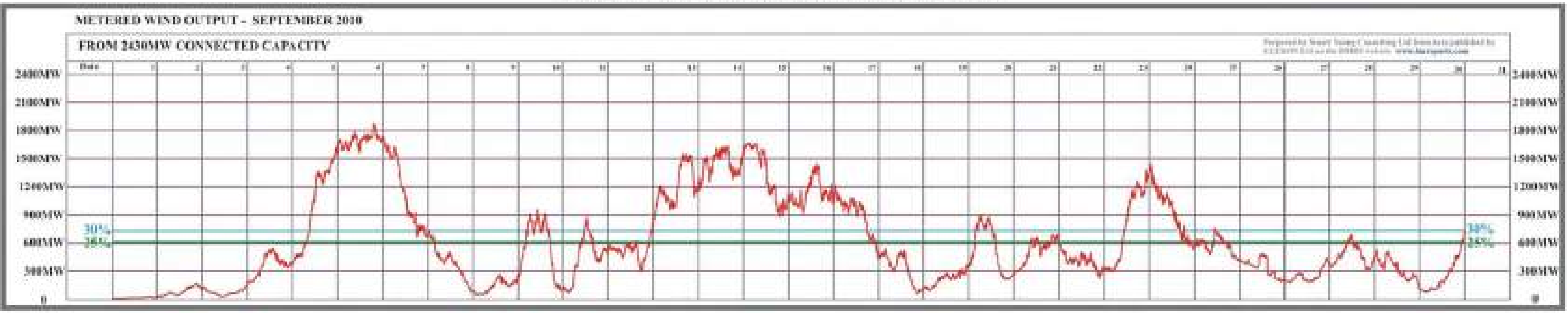

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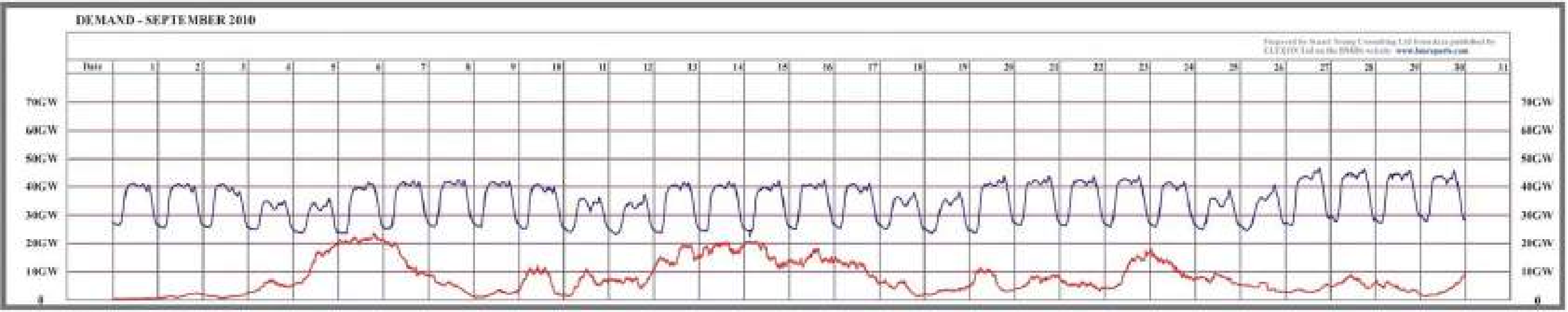

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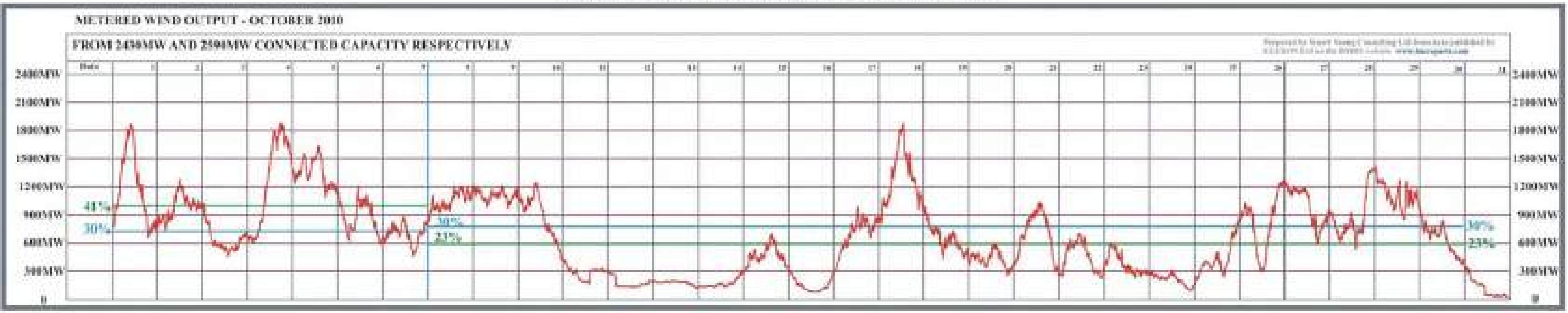
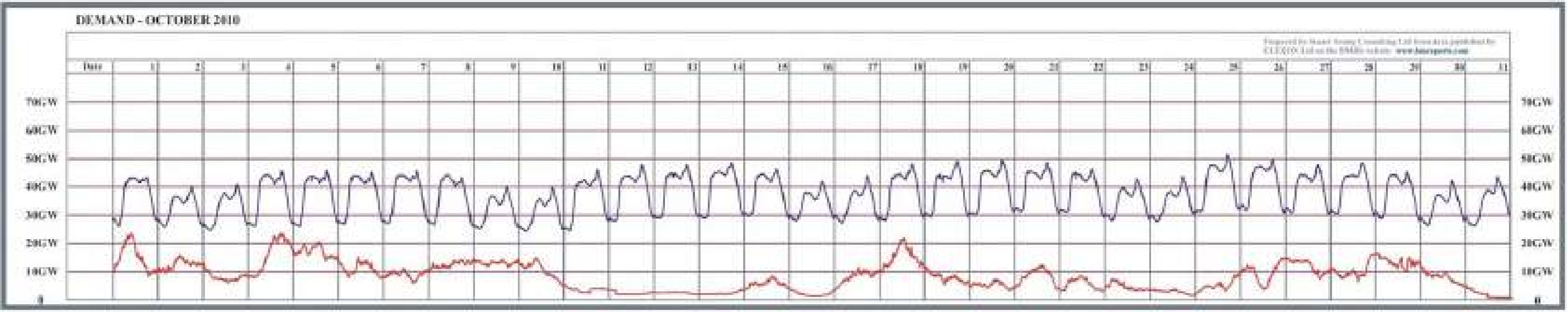


OCTOBER 2010



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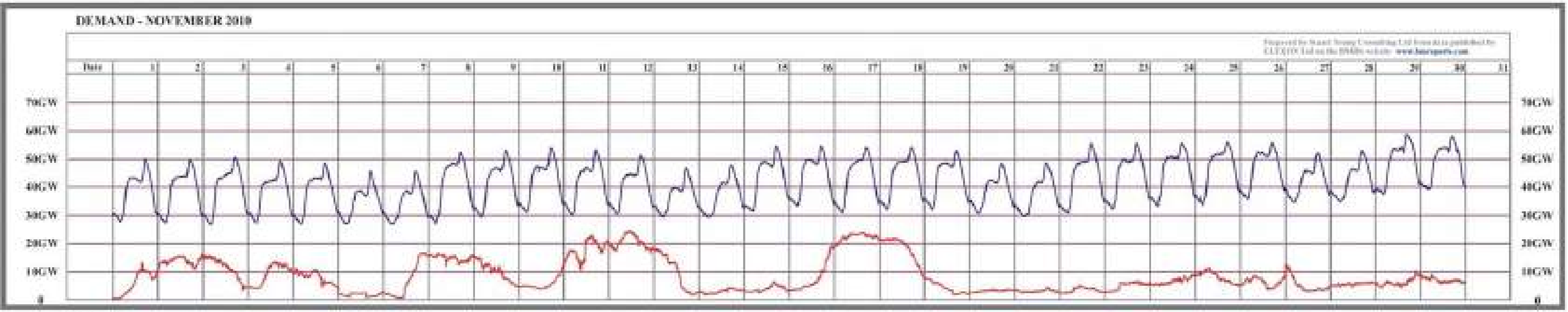

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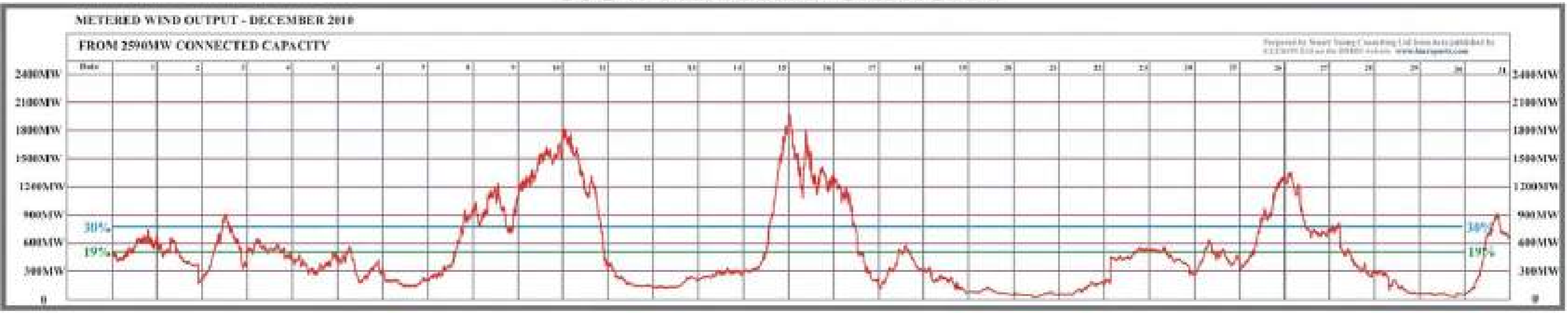
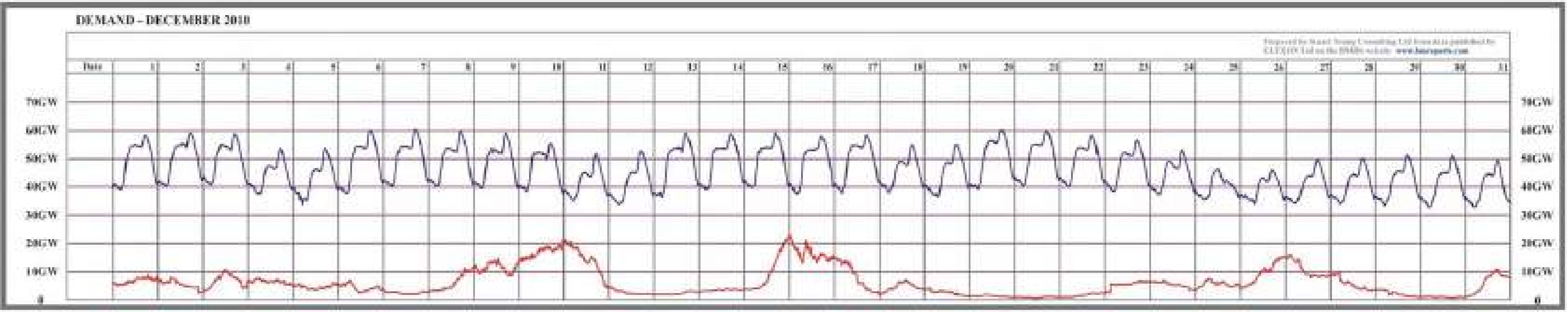


DECEMBER 2010



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APPENDIX C

WIND STATISTICS
NOVEMBER 2008 TO DECEMBER 2010

WIND STATISTICS NOVEMBER 2008 TO DECEMBER 2010

STUART YOUNG CONSULTING

JOHN MUIR TRUST FOR wild LAND & wild PLACES

1st APRIL 2011

AVERAGE WIND GENERATION AS A PERCENTAGE OF PLATED CAPACITY, NOVEMBER 2008 TO DECEMBER 2010

1ST NOVEMBER 2008 TO 31ST DECEMBER 2010	24.08%
2008 (NOVEMBER AND DECEMBER ONLY)	31.72%
2009	27.18%
2010	21.14%
2009 AND 2010	23.63%

INCIDENCE OF TOTAL METERED GENERATION BELOW 10MW

In the 791 days between 1st November 2008 and 31st December 2010, regardless of capacity being metered by National Grid at that time, generation fell below 10MW on 51 separate days for a total of 2662 five-minute periods. That works out on average once every 15.51 days for a period of 4.35 hours.

INCIDENCE OF TOTAL METERED GENERATION BELOW 20MW

In the 791 days between 1st November 2008 and 31st December 2010, regardless of capacity being metered by National Grid at that time, generation fell below 20MW on 124 separate days for a total of 7330 five-minute periods. That works out on average once every 6.38 days for a period of 4.93 hours.

SUMMARYOF WIND GENERATION BY TIME, NOVEMBER 2008 TO DECEMBER 2010

BETWEEN NOVEMBER 2008 AND DECEMBER 2010 INCLUSIVE, FOR THE FOLLOWING VARIOUS COMBINATIONS OF METERED CAPACITY WHICH NATIONAL GRID CAN SEE,

	NOV 2008 TO DEC 2010 INCL	2008 (NOV AND DEC ONLY)	2009	2010	2009 AND 2010	
OUTPUT WAS 30% OF CAPACITY OR MORE FOR	33.44	47.22	38.55	26.02	32.29	% of the time
OUTPUT WAS BETWEEN 20% AND 30% OF CAPACITY FOR	12.70	9.14	13.90	12.09	13.00	% of the time
OUTPUT WAS BETWEEN 10% AND 20% OF CAPACITY FOR	20.45	15.06	18.56	23.25	20.91	% of the time
OUTPUT WAS BETWEEN 5% AND 10% OF CAPACITY FOR	15.47	10.09	14.04	17.80	15.92	% of the time
OUTPUT WAS BETWEEN 2.5% AND 5% OF CAPACITY FOR	9.79	9.88	8.68	10.88	9.78	% of the time
OUTPUT WAS BETWEEN 1.25% AND 2.5% OF CAPACITY FOR	5.06	5.08	4.33	5.80	5.06	% of the time
OUTPUT WAS LESS THAN 1.25% OF CAPACITY FOR	3.09	3.53	1.94	4.16	3.05	% of the time
THEREFORE,						
OUTPUT WAS 30% OF CAPACITY OR MORE FOR	33.44	47.22	38.55	26.02	32.29	% of the time
OUTPUT WAS LESS THAN 30% OF CAPACITY FOR	66.56	52.78	61.45	73.98	67.71	% of the time
OUTPUT WAS LESS THAN 20% OF CAPACITY FOR	53.86	43.64	47.55	61.88	54.72	% of the time
OUTPUT WAS LESS THAN 10% OF CAPACITY FOR	33.41	28.59	28.99	38.64	33.81	% of the time
OUTPUT WAS LESS THAN 5% OF CAPACITY FOR	17.94	18.50	14.95	20.84	17.89	% of the time
OUTPUT WAS LESS THAN 2.5% OF CAPACITY FOR	8.15	8.62	6.27	9.96	8.11	% of the time
OUTPUT WAS LESS THAN 1.25% OF CAPACITY FOR	3.09	3.53	1.94	4.16	3.05	% of the time

COINCIDENCE OF HIGH DEMAND AND LOW WIND

DATE	TIME	TOTAL OUTPUT	WIND OUTPUT	METERED CAPACITY	% OF CAPACITY
05/01/2009	17:20	58274MW	61MW	1288MW	4.74
21/12/2009	17:15	54989MW	55MW	1588MW	3.46
07/01/2010	17:05	59541MW	75MW	1588MW	4.72
07/12/2010	17:20	60191MW	134MW	2430MW	5.51
20/12/2010	17:20	60017MW	62MW	2430MW	2.59
21/12/2010	17:30	59405MW	61MW	2430MW	2.51

NOTES

1. The periods of generation levels metered are:

300MW	1/11/08 to 5/11/08	All fromScottish onshore windfarms
1203MW	6/11/08 to 10/11/08	All fromScottish onshore windfarms
1288MW	11/11/08 to 21/5/09	All fromScottish onshore windfarms
1426MW	22/5/09 to 3/11/09	All fromScottish onshore windfarms
1588MW	4/11/09 to 13/7/10	All fromScottish onshore windfarms
2110MW	14/7/10 to 11/8/10	1930MW Scottish onshore, 180MW NE England offshore
2430MW	12/8/10 to 7/10/10	1930MW Scottish onshore, 180MW Scottish offshore (Robin Rigg), 180MW NE England offshore, 140MW Thames Estuary (Thanet)
2590MW	8/10/10 to 31/1/10	As above plus 160MW at Thanet

2. By the end of 2010, National Grid had metering equipment on 2590MW of connected windfarm capacity. In round terms, this represents approximately 50% of UK connected capacity and includes around 80% of Scottish onshore connected capacity. National Grid can only meter windfarms connected directly to the Grid, not those embedded in the wider distribution network. According to RenewablesUK at http://www.bwea.com/ukwed/index.asp there is currently 5200MW connected wind capacity nationwide. According to Scottish Renewables at http://www.scottishrenewables.com/static/uploads/energy_database/110309_renewablessummary.pdf there is currently (March 2011) 2384MW connected onshore windfarm capacity in Scotland.

3. The summaries on this page are extracted from a report being prepared for the John Muir Trust by Stuart Young Consulting Ltd. The source of the information on which this analysis is based is to be found at the Balancing Mechanism Reporting Service website which is the responsibility of ELEXON Ltd, the Balancing and Settlement Code Company. More information is to be found on the website at www.bmreports.com from where links to related sites are found. I am grateful to ELEXON Ltd for permission to use the generation data.

APPENDIX D

INCIDENCE OF LOW WIND OUTPUT

INCIDENCE OF METERED WIND GENERATION BELOW 10MW AND 20MW
1ST NOVEMBER 2008 TO 31ST DECEMBER 2010

SUMMARY

DURING THE STUDY PERIOD, WIND GENERATION OUTPUT WAS BELOW 10MW

NUMBER OF DAYS IN STUDY PERIOD		791	DAYS
NUMBER OF DAYS GENERATION FELL BELOW 10MW		51	DAYS
NUMBER OF FIVE MINUTE PERIODS BELOW 10MW		2662	PERIODS
	ON AVERAGE,		
FREQUENCY OF DAYS GENERATION FELL BELOW 10MW	**ONCE EVERY**	**15.51**	**DAYS**
AVERAGE TIME BELOW 10MW ON DAYS GENERATION FELL BELOW 10MW	**FOR**	**4.35**	**HOURS**

DURING THE STUDY PERIOD, WIND GENERATION OUTPUT WAS BELOW 20MW

NUMBER OF DAYS IN STUDY PERIOD		791	DAYS
NUMBER OF DAYS GENERATION FELL BELOW 20MW		124	DAYS
NUMBER OF FIVE MINUTE PERIODS BELOW 20MW		7330	PERIODS
	ON AVERAGE,		
FREQUENCY OF DAYS GENERATION FELL BELOW 20MW	**ONCE EVERY**	**6.38**	**DAYS**
AVERAGE TIME BELOW 20MW ON DAYS GENERATION FELL BELOW 20MW	**FOR**	**4.93**	**HOURS**