Feasibility Studies with the Aim of Developing a Bilateral Offset Credit Mechanism FY2011

Studies for Project Development and Organization

Organization Research Of Global Warming Countermeasure Applying Smart Grid Technology in the Republic of Poland

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Chapter 1 Outline of Survey Program

Chapter 2 Basic Information of Poland

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Chapter 7 Introducing Japanese Smart Grid Technologies and Smart grid related needs/potential project in Poland

Chapter 8 Conclusion
## NEDO’s Intent of public offering

Appropriately evaluate the amount of greenhouse gas which could be reduced if Japan’s world class low carbon technologies and products are actively disseminated and transferred, and establish a bilateral or multilateral agreement as a new framework where such reduction is converted as Japan’s own emission reduction.

### Term

July 2011 through February 29, 2012

### Entrustee

Chugoku EPCO and Mizuho Corporate Bank

### Outline

1. **Chugoku EPCO**
   - Identification of problems caused by the expansion of introduction volume of renewable energy
   - Examination of measures for expanding the introduction volume of renewable energy

2. **Mizuho CB**
   - Examination of business plan for obtaining a bilateral credit and confirmation of cooperation policy
   - Introduction of Japanese manufacturers’ smart grid technologies and identification of needs and projects.

### Survey system

- **Mizuho CB**
- **Chugoku EPCO**
- **Project Operator**
- **Cooperation Agreement**
  - PSE
  - ENERGA
- **Outsource**
- **Re-entrust**
- **IEN**
- **IAE**
- **CRIEPI**
- **Hitachi**
1. **Identification of problems and examination of measures against them to be caused by the expansion of the introduction volume of renewable energy**

As the reinforcement of power system such as transmission line and distribution line is expected to cause problems including cost to respond to the expansion of introduction volume of wind power generation, **examine measures for the introduction of renewable energy in order to minimize the cost of secure operation.**

2. **Examination of commercialization of measures and bilateral credit**

Investigate a possible CO2 credit framework through a bilateral agreement and like after considering the commercialization of the measures.

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**Measures for Stable Operation of Power Systems**

- **Special Protection Scheme (SPS):** Appropriately control the connection between the power source and the transmission and distribution system in the event of fault in order to maintain the secure operation of the power system.

- **Variable Speed Pumped Storage Hydroelectric Power Plant:** Change the rotating speed of pump mill wheels to finely adjust input power during pumping in accordance with the supply-demand situation in the power system.

- **Storage Battery:** Absorb output fluctuations of natural energy and generate smooth resultant output, supplying stable power in response to power demand.
1. Overview of Electricity Transmission and Distribution in Poland

- The state-owned company Polskie Sieci Elektroenergetyczne (PSE) is responsible for the transmission of electricity.
- The distribution companies are dominated by 4 company groups, ENEA group (in western Poland), Tauron Group (in southern Poland), Energa group (in central and northern Poland) and PGE group (in eastern Poland).

2. Progress of Wind Power

- Wind power stations are actively installed in the north area of Poland, coastal area of Baltic Sea, and its trend intensify year by year.
- Reinforcement of transmission and distribution lines are highly required for further installment of Wind Power.
- Increased demand for power reserves or loss of supply-demand balance caused by wind power output fluctuation is a concern.
Chapter 3 Identification of Problems on Power System

Expected increase of wind power generation will cause various challenges – e.g., overload of power lines, difficulties in supply-and-demand balance, voltage regulation, -- in a power system.

<table>
<thead>
<tr>
<th>Overload of power lines</th>
<th>Penetration of Wind Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small Near Future</td>
</tr>
<tr>
<td></td>
<td>Large Farther Future</td>
</tr>
<tr>
<td>EHV</td>
<td>HV, EHV</td>
</tr>
<tr>
<td>Dynamic Rating</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>System Reinforcement</td>
<td>Special Protection Scheme</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supply-&amp;-demand balance</th>
<th>Balancing</th>
<th>Spinning Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forecasting</td>
<td>Energy storage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Voltage problems</th>
<th>MV</th>
<th>HV, EHV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No LVRT for old/MV wind turbine</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SC, ShR + WT control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SVC, STATCOM</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Related Smart Grid Technologies</th>
<th>Smart Meter</th>
<th>DSM</th>
<th>Battery</th>
<th>Other Smart grid technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distribution Automation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SC (Shunt Capacitor), ShR (Shunt Reactor), WT (Wind Turbine), DSM (Demand Side Management)

(Note) Technologies in red letters are the proposed ones.
Propose several measures which utilize Japan’s original or advantageous technologies for each problem.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Proposed Measure</th>
</tr>
</thead>
</table>
| 1. Overload mitigation in power lines       | **1.1 Automatic control through Special Protection Scheme (SPS) in the event of fault**  
Automatically control wind power output in the event of power line tripping (e.g. in the case of fault).  
**1.2 Decision support system for optimal power system control (guidance)**  
Support operators to select the optimal power system control method (e.g. such as power system switching and/or generation shedding) in the event of power line tripping.  
**1.3 Overload control through storage batteries**  
Suppress overload in the power line by charging/discharging storage batteries installed in substations. |
| 2. Insufficient adjusting reserve           | **2.1 Utilization of storage batteries for power system**  
Introduce storage batteries for the power system to shift a peak and suppress fluctuations.  
**2.2 Introduction of variable speed pumped storage hydroelectric power plant**  
Introduce a variable speed pumped storage hydroelectric power plant as an adjusting reserve measure |
| 3. Measure for voltage                      | **3.1 Voltage control system for distribution power system**  
Introduction of smarter voltage control system as a measure against voltage problem in the power system. |
| 4. Smart grid construction                  | **4.1 Automatic distribution system**  
Introduce an automatic distribution system which satisfies needs for automating the distribution system.  
**4.2【Reference】** EMS AMI system and regional EMS |
1.1 Automatic Control through SPS in the Event of Fault

Introduction of SPS to curtail the power generation to mitigate overload of power lines in case of tripping

**Basic Function Flow**

1. Master station calculates n-1 contingencies of overload every 30 seconds, and selects the most suitable provision such as curtailment of power generation.

2. Send the control signal to the appropriate agent to invoke the provisions.

3. Agent detects the overload in power lines with the information of protective relays and circuit breakers, then invokes the provisions.

**Agent at Substation or Power Station (Wind farm)**
1.2 Decision Support System for Appropriate Operation Control

Decision support system can show the appropriate provisions to human operator with the forecasting wind power and contingency information.

**Example**
1. Power generation re-dispatching
2. Re-configuration on network topologies
3. Curtailment thermal/wind power after fault, etc.

**Diagram Description**

- **EMS System**
  - Decision Support System
  - Contingency Data
  - Wind power forecasting

- **Decision Support System**
  - Evaluate Contingencies with wind power forecasting
  - Calculate most appropriate provisions
  - Display provisions to human operator

- **Load flow data before fault**

- **CIM**
  - Master Station
  - Operator support
1.3 Energy Storage for Mitigating Congestion

Introduction of Storage Batteries to Mitigate Congestion or Prevent Overload

Energy Storage system can mitigate the congestion of power lines

Energy Storage at Substation

EMS System

Battery

Charge

Suppress Overload

Discharge

Power System
2.1 Utilization of Storage Batteries for Power System

Utilization of Storage Batteries to Northern Polish Grid for Peak Load Shaving and Compensation of Forecasting Error.

<table>
<thead>
<tr>
<th>Location</th>
<th>Purpose</th>
<th>Necessary Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Farm</td>
<td>Compensation of forecasting error</td>
<td>(1) Role of Batteries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) Selection of suitable battery type for each roles</td>
</tr>
<tr>
<td>Substation</td>
<td>(1) Providing power reserve</td>
<td>(3) Control schemes for SOC (state of charge) management etc.</td>
</tr>
<tr>
<td></td>
<td>(2) Peak Load Shaving</td>
<td></td>
</tr>
<tr>
<td>Customers</td>
<td>(1) Curtailment of PV (Photovoltaic Cell) Output into the grid</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Peak Load Shaving</td>
<td></td>
</tr>
</tbody>
</table>
2.2 Adjustable (variable) speed pumped storage system

Introduction of adjustable (variable) speed pumped storage to provide the secondary / tertiary reserve power at light load time

Adjustable speed pumped storage can control input power in pumping operation, and provide the secondary and tertiary reserve power to grid. This feature contributes the expansion of introductions of renewable energy.

<table>
<thead>
<tr>
<th>System</th>
<th>Conventional system (Fixed speed)</th>
<th>Adjustable speed system (Active power control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor</td>
<td>Salient pole type</td>
<td>Cylindrical type</td>
</tr>
<tr>
<td>Exciter</td>
<td>DC rectifier (DC current)</td>
<td>Frequency converter (3 phase AC current)</td>
</tr>
<tr>
<td>LFC (Load Frequency Control)</td>
<td>Only generation</td>
<td>Generation and pumping</td>
</tr>
</tbody>
</table>
3.1 Voltage Control System in Distribution Network

Introduction of “Smart” Voltage Control Function into Distribution Management System (DMS), and STATCOM for Wind Turbines at MV Network

SVR : Step Voltage Regulator, CB : Circuit Breaker

① Tap Control
② Shunt Capacitor Control
③ Tap Control
④ Reactive Power Control
⑤ WT Output Control

DMS
Operator’s Console
Server
Communication Network
WT
STATCOM
Low voltage network
feeder
r+jx
R+jx
Q
4.1 Distribution Management System

Introduction of DMS (Distribution Management System) to improve reliability of electric supply in distribution network

RTU: Remote Terminal Unit
FTU: Field Terminal Unit
FDIR: Fault Detection Isolation and Restoration
DSS: Decision Support System
4.2 AMI and C-EMS (for reference)

In this page, experimental research projects of AMI and Community-EMS(C-EMS) in Japan, will be described for your reference.

PHV (Plug-in Hybrid Vehicle), PCS (Power Conditioning System)
NAS (Sodium-sulfur battery), JWD (Japan Wind Development Co., Ltd.)
C-EMS (Community Energy Management System)
## Chapter 4 Discussion on Provisions (Verification of Proposed Measures)

<table>
<thead>
<tr>
<th>Problems in power system</th>
<th>Proposed measure</th>
<th>Evaluation for necessity</th>
<th>Items subject to next survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overload mitigation in power line</td>
<td>1.1 Automatic control through SPS in the event of tripping</td>
<td>◎</td>
<td>• Effects verification through simulation and quantitative evaluation for the expanded introduction volume of wind power generation</td>
</tr>
<tr>
<td></td>
<td>1.2 Support for the optimal power system control</td>
<td>◎</td>
<td>• Effect verification through simulation and quantitative evaluation for the expanded introduction volume of wind power generation</td>
</tr>
<tr>
<td></td>
<td>1.3 Overload control through storage batteries</td>
<td>○</td>
<td>• Effect verification through simulation</td>
</tr>
<tr>
<td>2. Supply-demand balance</td>
<td>2.1 Utilization of storage batteries for power system</td>
<td>◎</td>
<td>• Effect verification through simulation</td>
</tr>
<tr>
<td></td>
<td>2.2 Introduction of variable speed pumped storage hydropower plant</td>
<td>◎</td>
<td>• Effect verification through simulation • Detailed proposal satisfying PSE’s needs</td>
</tr>
<tr>
<td>3. Voltage problem</td>
<td>3.1 Voltage control system in distribution system</td>
<td>○</td>
<td>• Detailed proposal satisfying Energa’s needs</td>
</tr>
<tr>
<td>4. Smart grid construction</td>
<td>4.1 Automatic distribution system</td>
<td>○</td>
<td>• Detailed proposal satisfying Energa’s needs</td>
</tr>
<tr>
<td></td>
<td>4.2 AMI system and regional EMS (reference)</td>
<td>○</td>
<td>• Detailed proposal satisfying PSE’s and Energa’s needs</td>
</tr>
</tbody>
</table>

© Very important  ○ Important  △ Not so important
We simulated measures for (1) mitigating overload in the power line and (2) balancing the supply-demand for the model power system in northern Poland and evaluated effects considering evaluation results of the measures.

**Measure for preventing overload in the transmission line**

1. Overload control through SPS (Special Protection Scheme)
   - Power system control such as power generation shedding eliminates overload.
   - Increasing the potential of installed capacity of wind power generation from 950MW to 1,900MW

2. Overload control through storage batteries
   - The installation of storage batteries eliminate overload by charging/discharging.
   - Required output of storage batteries could become enormous.

**Supply-demand balance**

1. Measure for balancing supply-demand through storage batteries
   - Introduction of storage batteries of 50MW or higher suppresses fluctuations.
   - Storage batteries of approx. 200MW/600MWH bring about a certain peak shifting effect.

2. Measure for balancing supply-demand through variable speed pumped storage hydroelectric power plant
   - Variable speed pumped storage power plant shifts a peak and suppresses fluctuations during pumping.
### Proposed Measure

**Commercialization model**

- Automatically control points which require instantaneous operation by SPS based on decision support system of DSS.

### Evaluation

**Practical problems**

- The operation exceeding N-1 standard required
- Consultations and agreements with multiple companies (e.g. PSE, ENERGA and ENEA) required
- Contract with power plants on generation curtailment required
- Necessary to conduct analysis for all the power systems, and to consider transient stability measures for HVDC and pumped storage hydroelectric power plant.
- Necessary to quickly eliminate overload exceeding 120%.

### Costs

- Facility cost  
  12-16 million PLN  
  (Master station: 1, agent: 5 to 6)
- Annual operation cost  
  0.08 million PLN  
  (maintenance cost)

### Counter proposal of commercialization model

- Reinforcement of 8 transmission lines of 110kV
- Cost of counter proposal  
  ~40 million PLN
Chapter 5 Examination of Commercialization (Cash flaw analysis)

Cash flow analysis of SPS

-Cash flow analysis in the condition of SPS investment by 2024

-Set up 3 cases
  - case 1: without government grant or cash inflow from CO2 credit as the base case
  - case 2: government grant available
  - case 3: cash inflow from CO2 credit sales is available

Cash flow analysis of 110kV lines investment

-As the counter proposal, compare between the case invested in the SPS and 110kV lines reinforcement

Comparison of NPV

<table>
<thead>
<tr>
<th></th>
<th>Investment in SPS</th>
<th>110kV lines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
<td>Case 2</td>
</tr>
<tr>
<td>NPV</td>
<td>-13,545</td>
<td>-9,652</td>
</tr>
</tbody>
</table>

By comparison of NPVs, the cost saving will be realized by the installation of the SPS and DSS in any cases.
Study of Baseline Setting for bilateral offset Credit

The concept of potential installable capacity of wind, baseline setting and CO2 emission reduction by the countermeasure of grid stabilization in the target area is shown as below.

- Possible installation capacity of wind power plant to be expanded by SPS
- Wind power generation capacity baseline set through simulation (Marginal Capacity)
- The wind power generation capacity corresponding to the baseline
- The wind power generation capacity which exists before the application of SPS

Wind power generation capacity after the grid stabilization measurement
Possible installation capacity of wind power plant to be expanded by SPS
Wind power generation capacity baseline set through simulation (Marginal Capacity)
The capacity of wind power plant corresponding to the baseline
Wind power generation capacity targeted for emission reduction
Chapter 6  Bilateral offset Credit (Emission Reduction1)

◆ Estimation of the wind power plant capacity grow in the target region

<Conditions>
- Installed wind power in the target region in 2014 is assumed as 950MW which is the same value of the baseline wind power plant capacity.
- Installed wind power in the target region in 2020 is assumed as 2,000MW
- Installed wind power between 2015 and 2019 in the target region were linearly interpolated with a growth rate of 18.4%

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind power plant capacity in Target Region in Energia (MW)</td>
<td>950</td>
<td>1,125</td>
<td>1,300</td>
<td>1,475</td>
<td>1,650</td>
<td>1,825</td>
<td>2,000</td>
</tr>
</tbody>
</table>

◆ Emission Reduction

<Conditions>
- Rate of operation: 25% <Assumption>
- Emission factor: 0.702t-CO2/MWh <Calculated in 6.2.2>
- Snapshot in the simulation: 2015
- Electricity consumption in the grid stabilization equipment: 0MWh <This is a simplification to estimate the emission reduction>
- Credit period: 5 years from the snapshot(= 2015-2019)

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind power plant capacity beyond baseline capacity (MW)</td>
<td>175</td>
<td>350</td>
<td>525</td>
<td>700</td>
<td>875</td>
</tr>
<tr>
<td>Generating amount (MW h)</td>
<td>383,250</td>
<td>766,500</td>
<td>1,149,750</td>
<td>1,533,000</td>
<td>1,916,250</td>
</tr>
<tr>
<td>Emission reduction (t-CO2)</td>
<td>269,096</td>
<td>538,191</td>
<td>807,287</td>
<td>1,076,382</td>
<td>1,345,478</td>
</tr>
</tbody>
</table>
The comparison of the investment cost and accumulated CO2 credit value

<Condition>
• CO2 credit unit price is put as 5 EUR.
• Exchange rate: 4 PLN / EUR
We had meetings with transmission company (PSE-Operator) and Major Distribution companies in Poland to present Japanese Smart Grid technologies and demonstration projects.

In the meetings we discussed their interest and needs on the smart grid.

< Key points of the interest and needs>
- The battery for the Grid system is supposed to be promise in the future but at this moment it is expensive and immature technically.
- Peak cut (Peak shaving) with Battery system is difficult economically in Poland, because the price difference between peak and off-peak is very small.
- Smart metering has already started implementing and will be spread throughout Poland by around 2020.
- Energy management system such as HEMS and BEMS is supposed to be promising as a demand side management tool.
- V2H is supposed to be promising as a demand side management tool.
- Interested in Automated Distribution System
Polish power companies showed a high interest in the measure for suppressing the output of power generation through the function of Special Protection Scheme (SPS).

As for the measure of utilization of storage batteries, at present, there are problems on the commercial introduction in terms of economic efficiency. The technology development is expected to reduce the cost.
Thank you for your attention.
Appendix
Chapter 6. Calculation Methodology

Baseline Emission is calculated as follows

Baseline emission =
[1] Total sold electricity to the Grid from Wind Power Generation Capacity
X [3] Combined Margin Emission Factor

Project Emission is calculated as follows

Project emission =
[2] Consumed electricity in the Grid stabilization equipments
X [4] Average Operating Margin emission factor <Average of the latest three years>

Emission Reduction is calculated as follows

Emission Reduction = Baseline emission - Project emission
Grid emission factor is calculated according to the CDM methodological tool as follows. Tool to calculate the emission factor for an electricity system (version 02.2.1) <http://cdm.unfccc.int/methodologies/PAmethodologies/approved>

### Operating margin

<table>
<thead>
<tr>
<th>Source</th>
<th>2006(1-12)</th>
<th>2007(1-12)</th>
<th>2008(1-12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electricity Production (GWh)</td>
<td>Fuel Consumption (TJ)</td>
<td>Emission Coefficient (tCO2/TJ)</td>
</tr>
<tr>
<td>Total gross generation</td>
<td>161,742</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Fossil fuel thermal generation</td>
<td>154,161</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard coal</td>
<td>90,910</td>
<td>1,028,906</td>
<td>96.301</td>
</tr>
<tr>
<td>Lignite</td>
<td>57,699</td>
<td>526,323</td>
<td>99.176</td>
</tr>
<tr>
<td>Petroleum products</td>
<td>2,441</td>
<td>7,034</td>
<td>73.696</td>
</tr>
<tr>
<td>Natural gas</td>
<td>3,111</td>
<td>40,361</td>
<td>55.820</td>
</tr>
<tr>
<td>ΣFi,j,2006-2008*COEFi,j (tCO2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Σ total gross GENj,2006-2008 (GWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EFOM(2006-2008) (tCO2/GWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 6  Grid Emission Factor  (2)

◆ Build margin

<table>
<thead>
<tr>
<th>Fuel Consumption rate by source (kJ/kWh)</th>
<th>Total consumption in 2010 (TJ)</th>
<th>Power generation in 2010 (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Coal</td>
<td>8,646</td>
<td>780,548</td>
</tr>
<tr>
<td>Lignite</td>
<td>9,469</td>
<td>470,356</td>
</tr>
<tr>
<td>Gas</td>
<td>5,870</td>
<td>28,922</td>
</tr>
</tbody>
</table>

\[ \text{Build margin} = \frac{(941.7 \text{ tCO}_2/\text{GWh} + 462.6 \text{ tCO}_2/\text{GWh})}{2} = 702 \text{ tCO}_2/\text{GWh} \]

◆ Combined margin

\[ \text{EF}_{\text{CMCP}} = \frac{(941.7 \text{ tCO}_2/\text{GWh} + 462.6 \text{ tCO}_2/\text{GWh})}{2} = 702 \text{ tCO}_2/\text{GWh} \]
## Monitoring Methodology

<table>
<thead>
<tr>
<th>Items</th>
<th>Monitoring Procedure</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1] Sold electricity from the targeted wind power plants</td>
<td>Direct monitoring by a recorder</td>
<td>DSO or TSO monitors the sold electricity from the wind power plant</td>
</tr>
<tr>
<td>[2] Electricity amount supplied from the Grid to operate the grid stabilization equipment</td>
<td>Direct monitoring by a recorder</td>
<td>DSO or TSO monitors the supplied electricity from the grid</td>
</tr>
<tr>
<td>[3] Grid emission factor to be replaced by the targeted wind power plants</td>
<td>Combined margin emission factor calculated by the latest available 3 years’ data at the time of completing the monitoring report</td>
<td>Data source: 1&lt;sup&gt;st&lt;/sup&gt; choice: Euro stat 2&lt;sup&gt;nd&lt;/sup&gt; choice: Energy Market Agency</td>
</tr>
<tr>
<td>[4] Grid emission factor to be consumed in the grid stabilization equipment</td>
<td>Simple operating margin emission factor calculated by the latest available 3 year’s data at the time of completing the monitoring report</td>
<td>Data source: 1&lt;sup&gt;st&lt;/sup&gt; choice: Euro stat 2&lt;sup&gt;nd&lt;/sup&gt; choice: Energy Market Agency</td>
</tr>
</tbody>
</table>