STRATEGY FOR NORTHEAST ASIA POWER SYSTEM INTERCONNECTION
EDF TECHNICAL ASSISTANCE TO MONGOLIA
ADB PROJECT

MID-TERM INFORMATION ON THE PROJECT
PHILIPPE LIENHART EDF

Prepared by EDF for the Government of Mongolia and the Asian Development Bank to be presented in the UNESCAP Forum
Ulaanbaatar – Mongolia
October 31st, 2018
Summary

• EDF Group presentation with contributions and adaptations to EU PSI

• Strategy for NAPSI / Technical Assistance for Mongolia: objectives and organization

• Generation Studies

• Market studies

• Grid Studies

• Conclusion
EDF Group: a Responsible Industrial Firm with corporate social responsibility goals

1. Low carbon policy
Go beyond the requirements of the 2 °C trajectory set by COP21 by drastically reducing our CO₂ emissions.

2. Respect for people
Integrate best practice in the way we develop our people: health and safety, gender diversity and internal development.

3. Responsibility
Offer all vulnerable people information about and support with energy use and energy benefits.

4. Innovation
Innovate through digital energy efficiency solutions to enable all customers to use energy better.

5. Concertation
Systematically organise a process of transparent and open dialogue and consultation for every new project around the world.

6. Environment
Launch a positive approach to biodiversity, not limited to understanding and reducing the impacts of our activities in the long run but having a positive effect on biodiversity.

- 36.7 million customers worldwide
- 160,000 employees
- €71 billion sales
- 584 TWh electricity generation

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PHASE 1: 1956-2000 Common System Operation

Integration Goals:
- Exchanges of electricity
- Grid Safety improvement
- Cost Optimization

Harmonized Rules:
- UCTE
- NORDEL
- ETSOE

EDF adaptation:
- Many Cross border OHL
- Submarine HVDC interconnector with UK: IFA

PHASE 2: Since 2000, EU Electricity Market

TPA introduced deep changes:
- Unbundling: 42 TSOs
- Private interconnections allowed
- Interconnections vs price zones

EU GRID CODES:
- ACER
- ENTSOEU
- CORESO

EDF adaptation:
- Development of RES: EDF EN
- Reduction of coal-fired fleet
- Few new OCGTs & CCGTs

PHASE 3: EU Energy Policy, 20% of RES in 2020

Interconnections are Key Assets
- Intermittency Management
- More Flexibility
- No RES Curtailment

EDF adaptation:
- Interconnections more difficult to built in OHL: underground HVDC interconnector with Spain INELFE

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EDF R&D

• A European leader in R&D
With 3 Strategic Priorities:

1- Consolidate and develop competitive and zero-carbon production mixes (nuclear & renewables)

2- Develop and test new energy services for clients

3- Pave the way for the electrical systems of the future

3 French EDF Lab & 7 International R&D Centres (UK, Germany, Italy, China, USA, Singapore, Poland)
ADB Contract TA-9001 MON: Strategy for Northeast Asia Power System Interconnection

The contract consists of a support to Mongolia State (EA) for entering the NAPSI discussions with a consensual project based on the huge Renewable Energy Potential.

EDF’s recognized experience in Power System Integration in a region representing 25% of the world GDP

EDF with:
Nova Terra in Mongolia
China EPRI

Cooperation with PJSC ROSSETI

3 MASTER PLANS over 20 years

Renewable generation
Market & Power Trade
Interconnection Grid

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EDF and Subcontractors
WS1: Methodology and Work Organization

Module 1: Inception
- Data collection & methodology

Module 2: Market & power trade assessment
- Demand scenarios
- Economic analysis

Module 3: Planning & evaluation criteria
- Development of technical, financial, political and environmental criteria

Module 4: Energy sector profile & projections
- Analysis of current sector and assessment of renewable potential
- Identification of suitable areas for solar and wind development

Module 5: Power system interconnection expansion plan
- Review of current planning and review of technologies for expansion plan
- Analysis of benefits of interconnection

Module 6: Power Trade and Regulation
- Create and enabling environment for power trade
- Promote coordinated regional planning and investment

WS1 in Ulaanbataar
MONGOLIA
6/2017

Interim WS2
in Gwangju
KOREA
6/2017

WS3 in
Tokyo
JAPAN
3/2018

WS4 in
Beijing
CHINA
10/2018

WS1 in
Ulaanbataar
MONGOLIA
6/2017

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## Context

<table>
<thead>
<tr>
<th></th>
<th>GDP (in billion dollars)</th>
<th>Population (in million people)</th>
<th>Electricity generated (in TWh)</th>
<th>CO₂ emissions (in million tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>8,909 (6.5)</td>
<td>1,376</td>
<td>5,811</td>
<td>9,154</td>
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<tr>
<td>Japan</td>
<td>5,986 (47.2)</td>
<td>127</td>
<td>1,036</td>
<td>1,208</td>
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<tr>
<td>South Korea</td>
<td>1,267 (25.0)</td>
<td>50</td>
<td>522</td>
<td>649</td>
</tr>
<tr>
<td>Mongolia</td>
<td>12 (3.9)</td>
<td>3</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Russia</td>
<td>1,616 (11.0)</td>
<td>143</td>
<td>1,063</td>
<td>1,483</td>
</tr>
<tr>
<td>Northeast Asia</td>
<td>17,790 (~10.5)</td>
<td>1,699</td>
<td>8,437</td>
<td>12,512</td>
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<tr>
<td>World</td>
<td>74,889 (10.2)</td>
<td>7,349</td>
<td>24,098</td>
<td>33,508</td>
</tr>
<tr>
<td>Share of Northeast Asia</td>
<td>20-25%</td>
<td>20-25%</td>
<td>30-35%</td>
<td>~37%</td>
</tr>
</tbody>
</table>

Source: Created by Renewable Energy Institute based on data released by national governments and international organizations.

**NAPSI**
- 25% of Global GDP
- 22% of Global population
- 40% of Global CO₂ Emission

**Mongolia**
- Central Key Position
- Huge Potential in Wind and Solar RES
- Main Stake: Private investor attractiveness
Review of 4 key drivers for Mongolia, Russia, Japan, South Korea and PRC

**Generation**
- Cost of technologies
- Criteria for Generation planning
- Existing and Expansion Plan

**Transmission**
- Comparison HVAC vs HVDC
- Cost of Technologies
- Safety Systems Rules
- Existing and Expansion Plan

**Technical criteria**

**Socio Environmental Criteria**

**Planning and Evaluation Criteria**

**Political and Regulatory Criteria**

**Economic and Financial Criteria**

**Demographics**
- Geopolitical environment
- Foreign investment
- Regulation of Power Sector

**Economies of Different Markets**
- Electricity Consumptions

**CO2 emissions**
- Energy Mix
- Focus on Coal
- Export Driven RES capacity
- Interviews of 7 Mongolian Representatives
Recommendation: NAPSI Grid code for rules harmonization

Principles:

- Different synchronous electricity systems in the Northeast Asian region have different characteristics, which need to be taken into account when setting the requirements for HVDC systems.

- System security depends partly on the technical capabilities of HVDC systems.

Harmonized rules for grid connection for HVDC systems should be set out:

- To provide a clear legal framework for grid connections, facilitating Northeast Asian Region wide trade in electricity,

- To ensure system security,

- To facilitate the integration of renewable electricity sources,

- To develop competition, and

- To allow more efficient use of the network and resources, for the benefit of consumers.
Recommendation: NAPSI Grid Authority

Co-operation between Countries, Mutual assistance between Authorities, and Fair competition between Players

Main Functions:

- To enable NAPSI implementation including financing the interconnection assets through capital injection from the relevant Authorities/Entities;
- To manage the NAPSI-Supervision Center including supervision of real-time power transfers, performing adequate technical studies and coordinating bilateral energy transactions;
- To provide a transparent and efficient decision process;
- To be the owner of the NAPSI assets;
- To organize the operation and maintenance of the equipment;
- To ensure fair transaction between players scattered all over the five interconnected Northeast Asian Countries.

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A specific Regulation framework will be necessary to favour private RES Investments

- Stable Revenues
- Priority dispatch / no curtailment
- Legal maturity
- Financing facilities
- Visibility on the renewable targets
- Pre-permitted sites,
- Grid connection
Confirmation of Mongolian Wind and Solar potential

Specific GIS model with last updated data and most recent technologies
Including grid and ranking methodology

Best common wind & solar areas
Wind & Solar Potential for exportation

Best score areas are close to exportation representing 200 GW Wind – 1200GW Solar PV
In the short term (2020), limited to grid capacity around 350MW-550MW

Wind areas > 10 km² (i.e. capacity > 50 MW). Wind speed > 8 m/s (Score 4)
Solar PV areas > 0.25 km² (i.e. capacity > 10 MW). GHI > 1700 kWh/m² (Score 4)

A new strong national and exportation grid will be necessary
The potential of Wind and Solar PV development in Mongolia is huge thanks to an outstanding wind resource (wind speed > 8 m/s), a good solar resource (Global Horizontal Irradiance GHI > 1700 kWh/m2) and to numerous suitable areas.

The results are much higher than previous potential assessment studies due to new wind and solar technologies.

The Wind and Solar PV potential capacity far exceeds the envisaged development scenarios for exportation within the next 20 years: +5GW, +10GW, +100GW.

The best potential sites for wind and solar have the same location close to the direction of export toward PRC.

The Solar and Wind energies produced in Mongolia are the most competitive of the NEA region.
Market Assessment: Scenarios

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Results on profitability

- **Gross gain**: collective benefits, including the savings in terms of investment expenses and operation expenses, but excluding the investments linked to interconnection infrastructures and renewables in Mongolia.
- **Net gain**: final collective profits including all expenses and revenues.
- Consideration of a **range** around net gain to take into account uncertainties (particularly on interconnection infrastructure costs).

**Results of the Cost-Benefits Analysis, scenarios 2036**

- Deviations from the isolated situation.
- Bn$/y: billion dollars per year.
Impact of interconnection and RES in Mongolia on the CO2 emissions within the NAPSI region in the 2036 scenarios

Combined effect of interconnection and RES in Mongolia: significant CO2 emissions savings thanks to the substitution of coal and gas by renewables

Market Assessment: Reduction of CO2 Emissions

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• The interconnection will be cost-effective due to important differences in marginal costs between the 5 involved countries.

• The interconnection would already be cost-effective if it were existing today

• Solar and Wind power from Mongolia will find a market in the 4 other countries

• The NEA region is today 25% of Global GDP and 40% of Global CO2 emissions. Exporting the abundant Renewable Resources of Mongolia in Solar and Wind through the future NEA Power System Interconnection (NAPSI) will help for cutting the CO2 emissions of the region and meeting the Paris agreement
Mongolian Grid

Structure of Mongolian energy sector

- **Western Energy System**
  - Hydro PP-1, electricity transmission and distribution

- **Central Energy System**

- **Eastern Energy System**
  - Altai-Uliastain Energy System
    - Hydro PP-1, electricity transmission and distribution
Framework for Network Configuration for RE Development

• Methodology
  – Quarantined
  – Integrated DC
  – Integrated AC
• Technologies
• HVDC
• HVAC
Transmission Technologies

• Main LCC, VSC
  – LCC-HVDC technologies are more suited for point-to-point transmission of large amount of power from remote generation to load centres.
  – VSC-HVDC technologies are generally more flexible and do not suffer from commutation failures. Therefore, they are also used in multi-terminal configuration and HVDC networks. They are mainly used with cables

• HVDC cables
  – Several projects in operation with 500+ kV cables in Europe
  – Discussion with manufacturers, R&D towards 800kV cables and ultra-deep submarine cable on going

<table>
<thead>
<tr>
<th>Project</th>
<th>Length</th>
<th>Power</th>
<th>Voltage</th>
<th>Go Live</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skagerrak 4 (Sweden)</td>
<td>240 km</td>
<td>715 MW</td>
<td>500 kV</td>
<td>2014</td>
<td>VSC</td>
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<td>Western Link (Wales- England)</td>
<td>450 km</td>
<td>2200 MW</td>
<td>600 kV</td>
<td>2016</td>
<td>LCC</td>
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<tr>
<td>Italy – Montenegro</td>
<td>515 km</td>
<td>1000 MW</td>
<td>500 kV</td>
<td>2017</td>
<td>LCC</td>
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<tr>
<td>NordLink (Norway-Germany)</td>
<td>620 km</td>
<td>1400 MW</td>
<td>525 kV</td>
<td>2020</td>
<td>VSC</td>
</tr>
<tr>
<td>NSN Link (Norway-UK)</td>
<td>760 km</td>
<td>1400 MW</td>
<td>525 kV</td>
<td>2021</td>
<td>VSC</td>
</tr>
</tbody>
</table>
Potential Route for Russia FE - Japan
Network Development

Mongolia

- Internal System Integration with HVAC 500kV Grid.
- North: Interconnection with Russia
  - with HVAC 500kV Scenario 1 & 2
  - with HVAC 500kV + HVDC 800kV Scenario 3
- South West: Interconnection with China for exportation of large scale Wind and Solar power around the Gobi Desert
  - with HVAC 500kV Scenario 1: 5GW
  - with HVAC 500kV + HVDC +/- 500kV Scenario 2: 10GW
  - with HVAC 500kV + HVDC +/- 800kV scenario 3: 100GW

NEA

- Scenario 1&2:
  - Internal transit should be feasible with no major reinforcement
  - China-ROK / ROK-Japan / Japan-Russia: undersea cables HVDC +/- 500kV
  - Japan-Russia: Ultra-Deep Cable should allow important Grid Savings
  - Option: Russia–ROK through DPRK with OHL HVDC +/- 500kV
- Scenario 3:
  - HVDC +/- 800kV reinforcements will be required
Phase 0

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Phase I: 2026 Gobi RE Base to Reach 5GW
Phase II: 2036 Gobi RE Base to Reach 10GW
Phase III: 2036+ Gobi RE base to reach 100GW
Conclusions

Generation in Mongolia

- Mongolia Wind and Solar Potential is confirmed:
  - Short term limited by 2020 grid to 350 - 550MW
  - Provided a new strong national and exportation grid, 5GW in 2026, 10 GW in 2036 and even 100GW are feasible

NAPSI Market

- Interconnection is beneficial for exchange of electricity
- Wind and Solar RES Development in Mongolia is the most competitive
- NAPSI will reduce CO2 emissions

Power System Interconnection

- HVDC Interconnection: SGCC expansion Plan modifications and Undersea Cables

Recommendations

- Mongolia: a specific Regulation framework will be necessary to favour private RES Investments
- NAPSI Grid code for rules harmonization
- NAPSI Authority for supervision, feedback analysis and decision making
Thank you for your attention!