Reforming the Mexican Electricity Market: Design and Regulatory Issues

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DIW Berlin and CIDE
Outline

1. New industry and institutional structure
2. Challenges:
   – Market design under the assumptions of the energy reform
   – Introduction a nodal-price system and FTR auctions
   – Transmission network expansion and large-scale renewable integration
3. Implications for policy making in Mexico
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New industry structure

**Generation**
- CFE Subsidiary “A”
- CFE Subsidiary “B”
- CFE Subsidiary “C”
- Private Parties

**System Control and Electric Market**
- Spot Market
- Cenace
- CFE

**Retailing**
- CFE
- Long Term Contracts
- Auctions
- Unregulated Supply
- Regulated Supply

**Consumption**
- Qualified Users
- Basic Service Users

**Transmission and Distribution**
- CFE and Contracts

ANEXO MEM.PPTX
New institutional framework

Pre-Reform

Generation
- Expansion Plan
- Generation "Modality"
- Approve Expansion Plan
- Permits

Control/Dispatch
- CFE
  - Dispatch Rules
  - Reliability Standards

Transmission
- CFE
  - Expansion Plan
  - Generator Interconnection
  - Approve Expansion Plan

Distribution
- SENER
  - Final Rates
  - Participate in Final Rates

Marketing
- CRE
  - SHCP
  - Final Rates
  - Participate in Final Rates

Reform

Generation
- Cenace
  - Operation of Short and Long Term Markets

Control/Dispatch
- Cenace
  - System Operation
- SENER
  - Initial Market Rules

Transmission
- SENER
  - Planning and Interconnection Studies
  - Approve expansion plan
  - Regulated Tariffs
  - Supervision of Interconnection

Distribution
- CRE
  - Minimum consumption to be Qualified User
- CRE
  - Svc. Quality Requirements

Marketing
- CRE
  - Final Rates (Basic Service)
Clean energy potential in Mexico

• Mexico has sufficient resources to exceed its goals of 35% non-fossil generation in 2024, 40% in 2035 and 50% in 2050.
• Portfolio standard will assure that they can be developed.

<table>
<thead>
<tr>
<th></th>
<th>Installed Capacity 2° semester 2014 (MW)</th>
<th>Actual Generation Year 2013 (% of total GWh)</th>
<th>Actual Generation + Proven Resources</th>
<th>Actual Generation + Proven Resources +Probable Resources</th>
<th>Actual Generation + Proven Resources +Possible Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>1900</td>
<td>1.38%</td>
<td>5.30%</td>
<td>5.30%</td>
<td>34.80%</td>
</tr>
<tr>
<td>Geothermal</td>
<td>823</td>
<td>2.04%</td>
<td>2.22%</td>
<td>22.52%</td>
<td>40.03%</td>
</tr>
<tr>
<td>Solar</td>
<td>64</td>
<td>0.01%</td>
<td>0.65%</td>
<td>0.65%</td>
<td>22.52%</td>
</tr>
<tr>
<td>Mini Hydro</td>
<td>419</td>
<td>0.54%</td>
<td>1.72%</td>
<td>9.48%</td>
<td>40.03%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3206</strong></td>
<td><strong>3.97%</strong></td>
<td><strong>9.89%</strong></td>
<td><strong>37.95%</strong></td>
<td><strong>2,288.59%</strong></td>
</tr>
</tbody>
</table>
**Opportunities for transmission investment**

**Existing Program:** In the 15 year plan, CFE has included 19.3 billion USD of transmission projects including 19,555 circuit-km of lines.

**Planning:** Expansion plan will be proposed by an independent entity with a mandate to promote open access (CENACE).

- Transmission in US and Canada expands faster than demand growth.
- Expansion in Mexico should become more aggressive.
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Challenges

• Key *issues* related to the implementation of the Mexican electricity reform.

• Optimal design of an electricity market driven by the assumptions of the energy reform, e.g., network expansion, horizontal and vertical integration, ISO’s corporate governance.

• Implementation of a nodal pricing system and introduction of financial transmission rights (FTRs).

• Optimal regulation of the transmission network to promote large-scale integration of renewables.
First issue: Electricity market design under the assumptions of the energy reform

• First problem: horizontal competition in the generation subsector under a dominant incumbent (CFE):
  – And under the existence of IPPs with long-term contracts of energy sales to CFE
  – How to accomplish a level-playing-field to allow fair competition?

• Second problem: regulation of the transmission network:
  – Application of an incentive mechanism to promote the efficient regulation of the operation and expansion of the Mexican networks.

• Third problem: corporate governance and regulation of the independent system operator (CENACE):
  – What would be the structure of incentives for the ISO? Would be a profit-maximizing dispatch entity? Or welfare-maximizing?
Organización industrial nueva: Separación horizontal

Generación
- Generadores CFE
- CFE Generación 1
- CFE Generación 2
- CFE Generación 3
- CFE Generación n

Distribución
- CFE distribución 1
- CFE distribución 2
- CFE distribución 3
- CFE distribución n
- Contrato privado 1
- Contrato privado n
A combined merchant-regulatory mechanism


Upper level problem: Profit maximizing Transco:

\[
\max_{k,F} \pi = \sum_{t}^{T} \left[ \sum_{i} (p_{i}^{t} d_{i}^{t} - p_{i}^{t} g_{i}^{w}) + F^{t} N^{t} - \sum_{i,j} c(k_{ij}^{t}) \right]
\]

s.t.

\[
\frac{\sum_{i} (p_{i}^{t} d_{i}^{w} - p_{i}^{t} g_{i}^{w}) + F^{t} N^{t}}{\sum_{i} (p_{i}^{t-1} d_{i}^{w} - p_{i}^{t-1} g_{i}^{w}) + F^{t-1} N^{t}} \leq 1 + RPI + X
\]

Regulatory constraint

Lower level problem:

ISO welfare maximization:

\[
\max_{d,g} W = \sum_{i,t} \left( \int_{0}^{d_{i}^{t}} p_{i}(d_{i}^{t}) dd_{i}^{t} \right) - \sum_{i,t} mc_{i} g_{i}^{t}
\]

s.t.

Line capacity restriction

Energy balance

Plant capacity restriction
MAPA 2. Zonas congestionadas en México

GRÁFICA 1. Desarrollo de los precios en México

Fuente: Elaboración propia.
Second issue: Introduction to the Mexican electricity market of a nodal-price system and FTR auctions

- Transition to nodal prices starting from subsidized prices
- Model to study initial free allocations of FTRs to smooth out revenue or cost shocks (distributive efficiency)
- Grandfathered FTRs
Market clearing

\[
\begin{align*}
\min_G & \sum_p m_c G_{p,t} \\
\sum_n d_{n,t} - \sum_p G_{p,t} - \sum_n g_{n,t}^{\text{RES}} &= 0 \\
0 &\leq G_{p,t} \leq g^\text{max}_p
\end{align*}
\]

Congestion management

\[
\begin{align*}
\min_{G_{UP}, G_{DOWN}} & \sum_p m_c (G^\text{UP}_{p,t} - G^\text{DOWN}_{p,t}) \\
d_{n,t} &- \sum_{p \in A(n)} (g_{p,t} + G^\text{UP}_{p,t} - G^\text{DOWN}_{p,t}) - g_{n,t}^{\text{RES}} - \sum_{nn} b_{n,nn} \Delta_{n,t} = 0 \\
0 &\leq G_{p,t} \leq g^\text{max}_p - g_{p,t} \\
0 &\leq G^\text{DOWN}_{p,t} \leq g_{p,t} \\
\left| \sum_l h_{l,n} \Delta_{n,t} \right| &\leq p^\text{max}_l \\
\Delta_{n',t} &= 0
\end{align*}
\]

FTR allocation

\[
\min G \sum_p m c_p G_{p,t} \\
\sum_{p \in A(n)} G_{p,t} - g_{n,t}^{RES} - \sum_{nn} b_{n,nn} \Delta_{n,t} = 0 \\
0 \leq G_{p,t} \leq g_{p}^{max} \\
\left| \sum_l h_{l,n} \Delta_{n,t} \right| \leq p_{l}^{max}
\]

\[
\min \Delta \varepsilon \\
\sum_n FTR^n_D - \sum_n FTR^n_{RES} - \sum_p FTR^G_p = 0 \\
FTR^n_D - FTR^n_{RES} - \sum_{p \in A(n)} FTR^G_p - \sum_{nn} b_{n,nn} \Delta_{n,t} = 0 \\
\sum_n \left( \text{price}_{\text{slack},t} - \text{price}_{A(n),t} \right) FTR^G_p - \sum_n \left( \text{price}_{\text{slack},t} - \text{price}_{n,t} \right) FTR^n_{RES} - \sum_n \left( \text{price}_{n,t} - \text{price}_{\text{slack},t} \right) FTR^n_D = 0 \\
\left| \sum_l h_{l,n} \Delta_{n,t} \right| \leq p_{l}^{max} \\
\Delta_{n',t} = 0
\]
Average change in surplus of demand in the high wind winter week under production-based allocation approach.
Precios nodales: esquema CTCP mejorado y ampliado
Third issue: Optimal incentive regulation of the transmission network and large-scale renewable integration


**Issue 3.1: Transmission expansion under renewable integration of with time resolution and supply and demand fluctuations**

- Understanding how to regulate and expand transmission networks under large-scale renewable integration in Mexico.
- Include fluctuating renewable energy with hourly time resolution so as to substantially increase the applicability of regulatory mechanisms.
Lower level as in Hogan et al. (2010), but with more time resolution:

\[
\max \sum_{q, g, \lambda_1, \lambda_2, \lambda_4, \lambda_5, \lambda_3} \sum_{n, t} \left( \sum_{\tau \in T} \sum_{n \in N} \left( \int_{0}^{t} p_{n, t, \tau} (q_{n, t, \tau}) dq_{n, t, \tau} - \sum_{s \in S} c_s g_{s, n, t, \tau} \right) \right) \frac{1}{(1 + \delta_s)^{t-1}}
\]

s.t. \( \sum_{n} \frac{I_{l, t}}{X_{l, t}} \Delta_{n, t, \tau} - P_{l, t} \leq 0 \quad (\lambda_{1, l, t, \tau}) \quad \forall l, t, \tau \)

\( -\sum_{n} \frac{I_{l, t}}{X_{l, t}} \Delta_{n, t, \tau} - P_{l, t} \leq 0 \quad (\lambda_{2, l, t, \tau}) \quad \forall l, t, \tau \)

\( \sum_{s} g_{n, s, t, \tau} - \sum_{m} B_{n,m} \Delta_{m, n, t, \tau} - q_{n, t, \tau} = 0 \quad (p_{n, t, \tau}) \quad \forall n, t, \tau \)

\( g_{n, s, t, \tau} - \bar{g}_{n, s} \leq 0 \quad (\lambda_{4, n, s, t, \tau}) \quad \forall n, s, t, \tau \)

\( slack_n \Delta_{n, t, \tau} = 0 \quad (\lambda_{5, n, t, \tau}) \quad \forall n, t, \tau \)

Upper level as in Rosellón and Weigt (2011):

\[
\max \Pi = \sum_{t \in T} \left( \left( \sum_{n} \sum_{t} \sum_{\tau} \left( p_{n, t, \tau} q_{n, t, \tau} - \sum_{s \in S} p_{n, t, \tau} g_{s, n, t, \tau} \right) \right) + fixpart_t - \sum_{l \in L} \sum_{n \in N} ec_{l, ext_{l, n}} \right) \frac{1}{(1 + \delta^p)^{t-1}}
\]

s.a.

\[
\sum_{n \in N} \sum_{t \in T} \left( p_{n, t+1, \tau} q_{n, t, \tau} - \sum_{s \in S} p_{n, t+1, \tau} g_{s, n, t, \tau} \right) + fixpart^HRV_{t+1} \leq 1 + RPI - X
\]

\[
\sum_{n \in N} \sum_{t \in T} \left( p_{n, t, \tau} q_{n, t, \tau} - \sum_{s \in S} p_{n, t, \tau} g_{s, n, t, \tau} \right) + fixpart^HRV_t \leq 1 + RPI - X
\]

\[
fixpart^CostReg_{t+1} = \sum_{l \in L} \sum_{n < t+1} ec_{l, ext_{l, n}} (1 + r) + fixpart^CostReg_t
\]
Comparison of welfare and extension results

- Fluctuating demand and wind power both increase the gap between \textit{wf-max} and the regulatory cases.
- HRV much closer to \textit{wf-optimum} in all cases → robust!
**Third issue: Optimal incentive regulation of the transmission network and large-scale renewable integration**


**Issue 3.2: Transmission expansion under the dynamic transformation of the generation park towards renewables**

- Rationality of transmission investment under a dynamic process of renewable integration.
- Transmission investment under gradual substitution of conventional energy (e.g., coal or fuel oil) with renewables (wind, solar or geothermal energy).
- Diverse developments of the technological mix in the generation park that implies different network congestion scenarios.
Development of the congestion rent
Table 1: Welfare changes relative to the case without extension

<table>
<thead>
<tr>
<th>Weights</th>
<th>Static</th>
<th>Temporarily increased congestion</th>
<th>Permanently increased congestion</th>
<th>Permanently decreased congestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>WFMax</td>
<td>0.29%</td>
<td>1.28%</td>
<td>11.62%</td>
<td>0.00%</td>
</tr>
<tr>
<td>NoReg</td>
<td>0.00%</td>
<td>0.00%</td>
<td>9.25%</td>
<td>0.00%</td>
</tr>
<tr>
<td>CostReg</td>
<td>0.00%</td>
<td>1.27%</td>
<td>9.22%</td>
<td>0.00%</td>
</tr>
<tr>
<td>HRV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laspeyres</td>
<td>0.25%</td>
<td>1.01%</td>
<td>9.02%</td>
<td>-0.17%</td>
</tr>
<tr>
<td>Paasche</td>
<td>-0.11%</td>
<td>0.38%</td>
<td>9.39%</td>
<td>-0.32%</td>
</tr>
<tr>
<td>Average Lasp.-Paasche</td>
<td>0.29%</td>
<td>0.89%</td>
<td>9.21%</td>
<td>-0.32%</td>
</tr>
<tr>
<td>Ideal</td>
<td>0.29%</td>
<td>1.28%</td>
<td>11.62%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
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Implications for policy making in Mexico

• Analysis of allocative, productive and distributive efficiencies in the electricity sector.
• Increase in economic welfare.
• Efficient integration of renewable energies into transmission networks (with consequent reduction of greenhouse emissions).
• Efficient expansion of transmission networks.
• Nodal-price systems and financial hedging mechanisms that grant adequate property rights which incent efficient investments.
• Research results with potential to be applied in actual public-policy making: CIDE-CRE academic agreement (Rosellón, 2008):