Institutional and business aspects in the diffusion of distributed (co)generation (DG)

Neil D. Strachan  
nnds2@andrew.cmu.edu

CEIC Seminar Series  
CMU, Pittsburgh. November 8, 2001

Outline of Talk

- An emerging family of new gas fired DG technologies:  
  » micro-turbines, fuel cells, IC engines, stirling engines
- DG/CHP offers an alternative paradigm of energy generation and delivery  
  » Focus on experiences in Netherlands and UK

1. Overview of DG/CHP - determinants of economic return
2. The critical role of institutional support, especially utilities
3. The role of early technology suppliers
Distributed generation (DG)
(DG = small CHP)

- Cogeneration technology
  » 50kWe to 2MWe, Heat to Power Ratio (HPR) ~ 2:1
  » Efficiency gains and avoidance of electricity transmission offsets economy of scale of centralized generation.
  » Electricity can be consumed on-site or sold to grid
  » Heat can be used directly, can drive absorption chillers, or can be dumped to the atmosphere
  » Modern control systems to ensure safe, reliable operation

- HPR matching:
  » Technology output to both application and system energy demands
    › e.g. HPR; NY average: 2.3:1, coldest: 7:1; FL average =1.1:1, hottest = 0.5:1.
  » BUT diurnal variation, who provides back-up?

Engineering-economic model of DG investment

- Probabilistic investment model
  » Uncertainty and parametric analysis

- Model parameters
  » Site level data collected on all UK engine cogen installations (1984-97)
  » Extended for Netherlands investments
  » Case studies and actual operating data
  » Expert interviews

- Net Present Values of investments in IC engine DG/CHP
  » Savings versus grid gas and electricity purchases
  » Electricity sales, heat dumping
  » Capital, operation & maintenance and gas purchase costs
Economies of scale (Maintenance costs)

IC engine investment: probability of positive NPV

Size thresholds: UK = 140 kWe, Netherlands = 100 kWe

Economies of geographic concentration (Maintenance costs)
Better buy-back tariffs make electricity export worthwhile

Typical Electricity Export Prices

Netherlands
UK

Median NPV by % of electricity sales: Netherlands

Netherlands:
DG investment return with electricity buy-back

Electricity export %
-0%
-25%
-50%
-75%
-100%

Size (kWe)

Page 4
Median NPV by % of electricity sales: UK

So far...

- Bigger unit sizing is better
- Higher density of DG units is better
- Low connection costs are better
- Electricity buy-back to the grid is better
  » Heat can be stored or dumped, electricity can not / shouldn’t be
  » Increases the number of feasible sites
  » Allows larger units

- Thus, success of DG is in the co-operation of market players
  » Particularly distribution utilities (discos)
Market participants

Government
  » Prices
  » Regulation
  » Information

DG/CHP trade body

Energy service companies

Distribution utilities

Technology suppliers

Consumers

Impressive diffusion in the Netherlands
Struggle to diffuse in the UK

Note: The UK energy market is approximately 4 times larger than the Netherlands.
Non-explanatory diffusion factors

- Technical uncertainty
- Different overall potential
- Fuel supply constraints
- Adoption barriers (including financing)
- Energy prices and energy price volatility
- Adopter networks
- Public subsidies
  » Improved returns on all units

Netherlands and UK were similar markets

Netherlands DG units have a better ROI, which is further improved by subsidies but DG units in the Netherlands are so much larger...
..and the full economic size range is not exploited in the Netherlands

![Size ranges of DG units](chart.png)

How are the units sized and operated?

- **The Netherlands**
  - Size the unit to meet all but extreme heat loads.
  - Sell excess electricity to the grid.
  - Often do not need a peaking boiler.
  - Rarely need to buy power
  - Common sites are often not heat limited (with electricity export are not size limited)

- **UK**
  - Size the unit to meet base heat requirements.
  - No excess electricity is for off-site sale.
  - Always need to invest in peaking boiler.
  - Always need to purchase some power
  - Most common sites are heat limited (with no electricity export are size limited)
## Win-win investments
Utilities and adopters

- **Utilities**
  - Cheap electricity
  - Potential to improve distribution network management
    - 23% of DG electricity was exported to grid
  - Met CO₂ reduction targets
  - Access to liberalized generation market
  - Publicity (for staid utilities!)

- **Adopters**
  - Cheap heat/electricity
  - Reduced risk and investment decision requirements
  - Access to (provision of) capital
  - Access to technical expertise
  - Name recognition

- Standard contract process facilitated financing, ownership and operation of DG units
  - Contracts ranged from knowledge of electricity use, to control over exports

---

## Virtuous cycle

- Innovative ownership of distributed cogeneration
- Benefits to utilities and adopters
- Being able to sell power allows a different sizing & operation strategy
- More installations lowers maintenance costs
- Lower maintenance costs improves economics
Market participants (2)

- Government
  - Prices
  - Regulation
  - Information
- DG/CHP trade body
- Energy service companies
- Distribution utilities
- Technology suppliers
- Consumers

Implications of small DG units in the UK?
Why installed?, why financed?

Graph showing comparisons between the Netherlands and UK from 1984 to 1999, with thresholds indicated for both countries.
UK technology suppliers
(under utility hostility)

• Supplier innovation
  » Technical: remote control, unit packaging
  » Managerial: supplier financing, energy services

• Industry shakeout
  » From ~15 to 4 suppliers in 5 years
  » (second shakeout with entrants from the Netherlands)

• But supply under institutional constraints
  » Little electricity buyback, size constraints, small market (~110MWe)
  » Difficult market: low energy prices, withdrawn utility investment

• Revenue from
  » Unit sales, electricity production (Size dependent)
  » Maintenance contracts (Size independent)

Two marketing strategies
Firms A, C, D (UK) ; Firm B (Netherlands)
Try to develop industrial sector for DG/CHP  
(looking for best on-site applications)

<table>
<thead>
<tr>
<th></th>
<th>Firm A</th>
<th></th>
<th>Firm B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of sites</td>
<td>Median Size (kWe)</td>
<td>% of sites</td>
<td>Median Size (kWe)</td>
</tr>
<tr>
<td>Hotel</td>
<td>36%</td>
<td>95</td>
<td>39%</td>
<td>110</td>
</tr>
<tr>
<td>Leisure Center</td>
<td>29%</td>
<td>95</td>
<td>12%</td>
<td>154</td>
</tr>
<tr>
<td>Hospital</td>
<td>23%</td>
<td>75</td>
<td>11%</td>
<td>383</td>
</tr>
<tr>
<td>Other Buildings</td>
<td>4%</td>
<td>148</td>
<td>8%</td>
<td>293</td>
</tr>
<tr>
<td>Multi residential</td>
<td>3%</td>
<td>95</td>
<td>6%</td>
<td>100</td>
</tr>
<tr>
<td>Sewage</td>
<td>2%</td>
<td>38</td>
<td>4%</td>
<td>128</td>
</tr>
<tr>
<td>Industry</td>
<td>1%</td>
<td>54</td>
<td>18%</td>
<td>800</td>
</tr>
<tr>
<td>Education</td>
<td>1%</td>
<td>165</td>
<td>2%</td>
<td>167</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100%</td>
<td>95</td>
<td>100%</td>
<td>167</td>
</tr>
</tbody>
</table>

Evolution of UK market  
(Firm B is the Dutch entrant)

![Cumulative Installed DG Capacity](image-url)
Netherlands technology suppliers and win-win partnerships

- In Netherlands
  - 5,000 DG units, 1,500MWe (40 times UK level, per capita)
  - 6% of national electric capacity, saved 3% of national CO₂ emissions

- Utilities the major direct investor (1990-1995)
- Utilities move from support to neutral (1995-)
- BUT…
  - Large unit sizing and electricity buyback continue
  - Disciplined/expert DG suppliers
  - Positive adopter network
  - Reduced maintenance costs and virtuous cycle of improved economics

Over the hump

Netherland DG investment by primary customer

All sites had access to utility/adopter co-operative agreements

Last year of capital and fuel subsidies
Netherlands technology suppliers: Continued innovation

• Complementary markets
  » UK, Germany, Spain
  » Standby, other DG technologies, energy services, marine engines

• Continuing partnerships with utilities/engineering firms
  » Financing, risk management
  » Access to R&D
  » Name recognition in liberalized markets

• Aim for ‘clusters’ of DG/CHP units
  » Overall size of investment (e.g. 20MWe) utilities are familiar with
  » Network management (especially in supply constrained regions)
  » Become a generation player
  » Benefits from geographical economies of scale
  » DG reliability benefits (who backs up who?)

Summary
(Lessons for the US)

• DG means CHP
• DG allows innovative approaches to energy supply
• Successful diffusion requires co-operation between market participants, particularly distribution utilities
• What time-frame is correct, for how much DG/CHP capacity?

• For the US
  » DG means CHP, DG means a new approach to energy supply
  » Resolve interconnection debate
  » Can market co-operation be achieved?
  » What will affect DG deployment:
    › DG costs, system costs, reliability or emissions concerns
## Capital costs

![Capital costs Chart](chart.png)

### Market similarities - overcame adoption barriers

<table>
<thead>
<tr>
<th>Known barrier to adoption</th>
<th>Market and institutional situation in the UK and Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply constraint on input fuel for DG</td>
<td>Extensive natural gas networks</td>
</tr>
<tr>
<td>Decision-makers are not aware of the technology</td>
<td>Government information programs, supported by cogon/DG trade groups</td>
</tr>
<tr>
<td>Idealized engineering-economic projected savings never being achieved</td>
<td>Case studies and operation data on successful installations</td>
</tr>
<tr>
<td>Investors are wary to invest their own capital, or capital for energy related investments is not available</td>
<td>Availability of supplier financing</td>
</tr>
<tr>
<td>Additional costs that organizations face to change their method of operation deterred them from making the investment</td>
<td>Proven packaged technology, and technical standards for interconnection with the electricity network</td>
</tr>
<tr>
<td>Regulatory restrictions on DG investments and electricity sales</td>
<td>Separation of electricity generation and distribution, with open third party access to the distribution network and power purchasing based on avoided costs</td>
</tr>
<tr>
<td>Government imposed moratoriums on new power generation facilities</td>
<td>DG exempt from moratoriums on new power generation facilities (1994 in the Netherlands, 1998 in UK)</td>
</tr>
<tr>
<td>Concern over the spatial and temporal impacts of DG on local air pollution</td>
<td>DG support was given for reduction in CO₂ emissions. IC engine cogen was exempted from regulations controlling NOₓ, CO, or hydrocarbons (HC) emissions</td>
</tr>
</tbody>
</table>
### Promotion of DG in Netherlands and UK

<table>
<thead>
<tr>
<th>Part of government policy on climate change</th>
<th>Netherlands</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support measures directly linked to climate policy goals</td>
<td></td>
<td>no</td>
</tr>
<tr>
<td>Capital subsidy</td>
<td></td>
<td>limited</td>
</tr>
<tr>
<td>Fuel subsidy</td>
<td></td>
<td>no</td>
</tr>
<tr>
<td>Information office</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordination of suppliers, utilities and users</td>
<td></td>
<td>no</td>
</tr>
<tr>
<td>Restructured gas and electricity industries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance in meeting DG/cogen target</td>
<td>Exceeded</td>
<td>Failed</td>
</tr>
</tbody>
</table>

### DG subsidies and installed capacity

<table>
<thead>
<tr>
<th>Capital subsidy</th>
<th>Netherlands</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information gathering and dissemination</td>
<td>$167</td>
<td>$15</td>
</tr>
<tr>
<td>Fuel subsidy</td>
<td>$17.7</td>
<td>$9.5</td>
</tr>
<tr>
<td>Energy tax exemption</td>
<td>$137</td>
<td>0</td>
</tr>
<tr>
<td>Utility incentives for CO₂ controls</td>
<td>~0.15¢/kWhr</td>
<td>0</td>
</tr>
<tr>
<td>Installed distributed generation capacity</td>
<td>1,500MWe</td>
<td>160MWe</td>
</tr>
<tr>
<td>Subsidy per unit capacity installed</td>
<td>$215/kWe</td>
<td>$155/kWe</td>
</tr>
</tbody>
</table>
Fuel prices in the Netherlands and UK

The Netherlands

UK

Low adoption rate in UK
Most popular sectors are generally heat limited
High adoption rate in Netherlands
Popular sectors are not heat limited

![Diagram showing Netherlands installations by user](image-url)

- Sewage & water
- Residential and DH
- Industry
- Health
- Leisure, hotels, offices, education
- Agriculture & other