Carnegie Mellon Electricity Industry Center (CEIC)
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Institutional and business aspects in the diffusion of distributed (co)generation (DG)

QuickTime™ and a Photo - JPEG decompressor are needed to see this picture.

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CEIC Seminar Series
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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

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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?

3

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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

4

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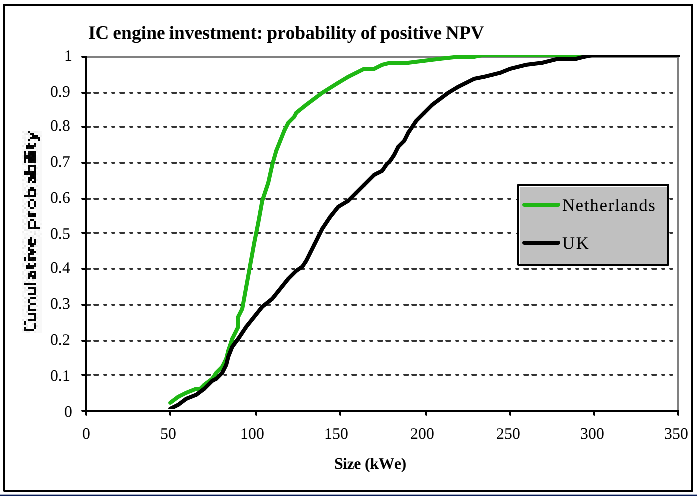
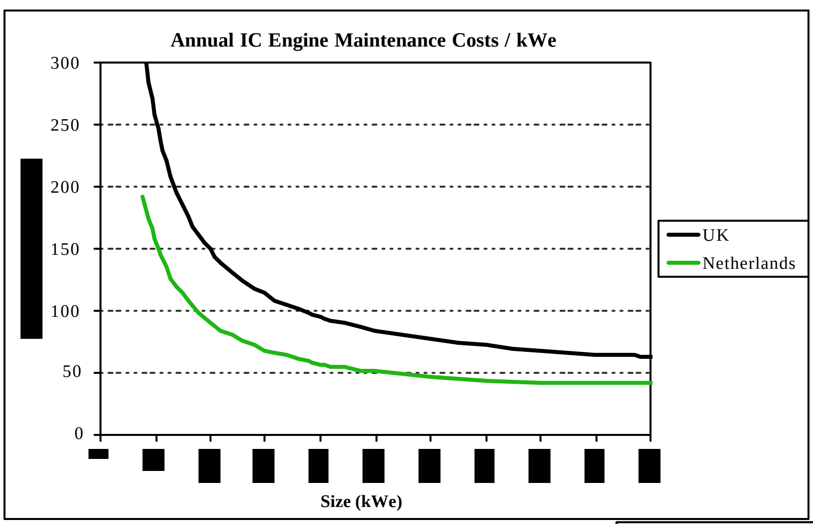
Economies of scale
(Maintenance costs)



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

Economies of geographic concentration
(Maintenance costs)



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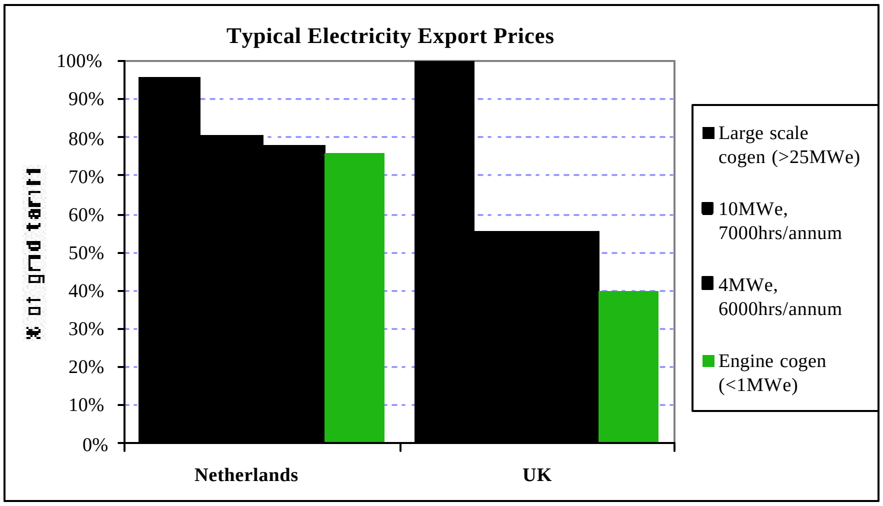
Better buy-back tariffs make electricity export worthwhile



7

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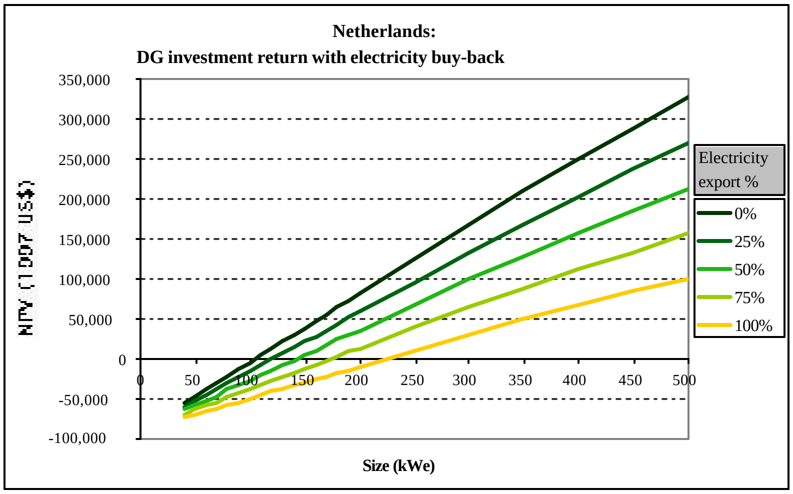
Median NPV by % of electricity sales: Netherlands



8

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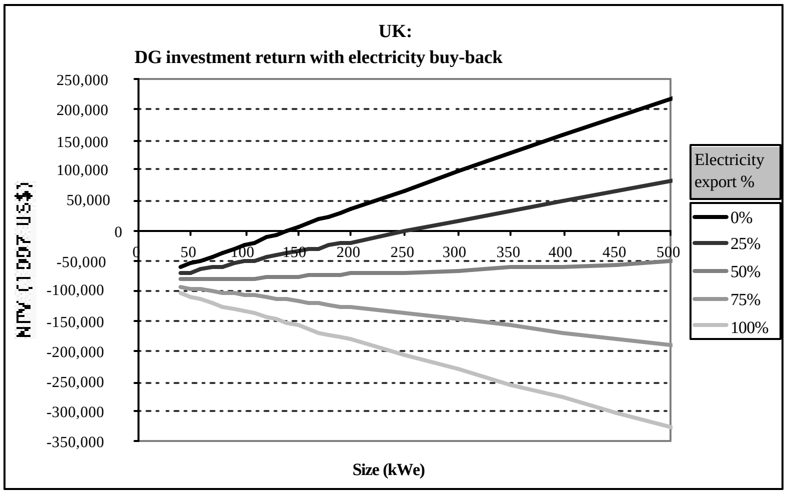
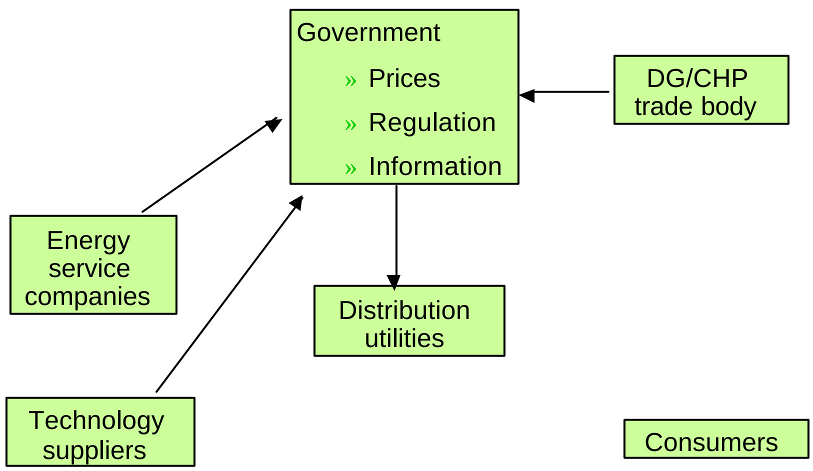
Median NPV by % of electricity sales: UK



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



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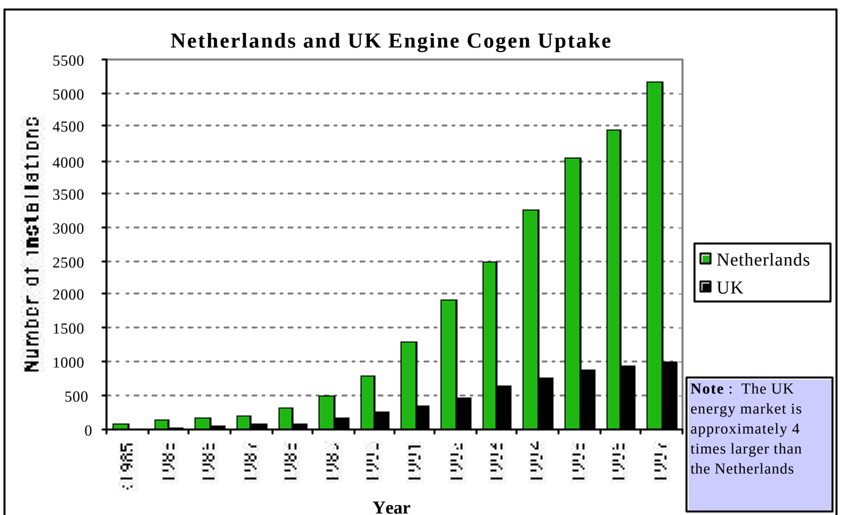
Impressive diffusion in the Netherlands Struggle to diffuse in the UK



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Non-explanatory diffusion factors

Netherlands and UK were similar markets

- 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

13

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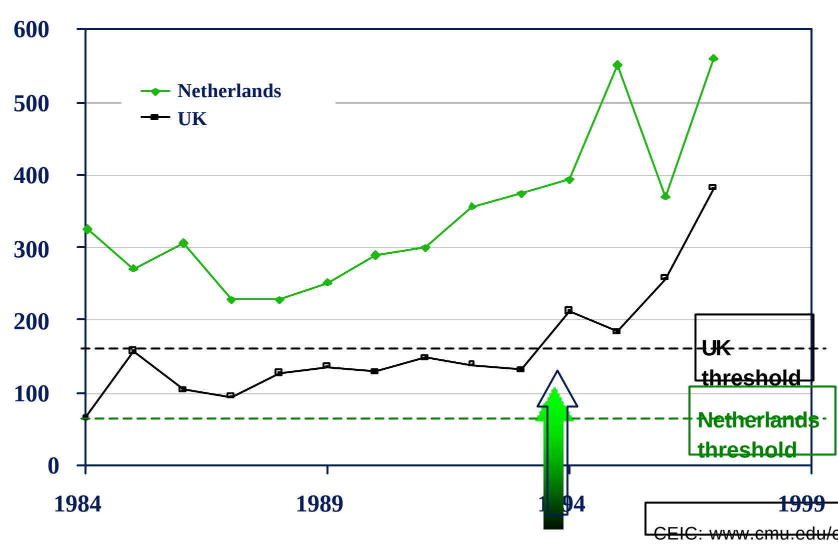
Netherlands DG units have a better ROI, which is further improved by subsidies but DG units in the Netherlands are so much larger...



14

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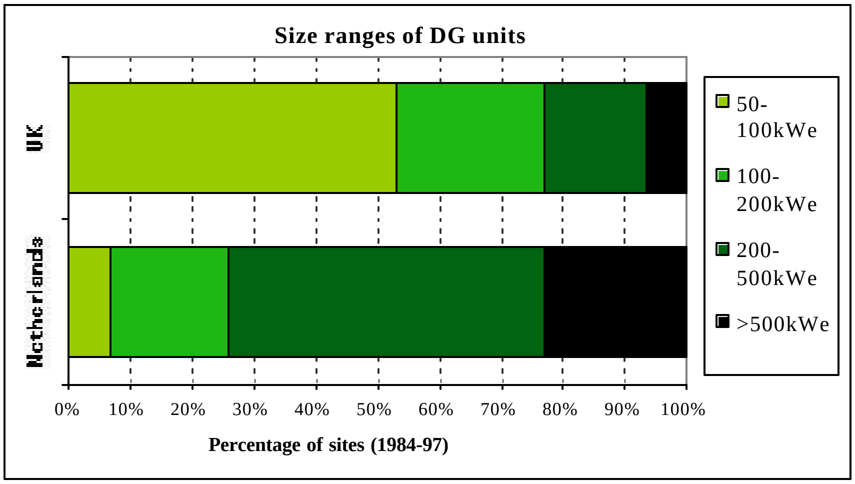
..and the full economic size range is not exploited in the Netherlands



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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)

16

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Win-win investments
Utilities and adopters

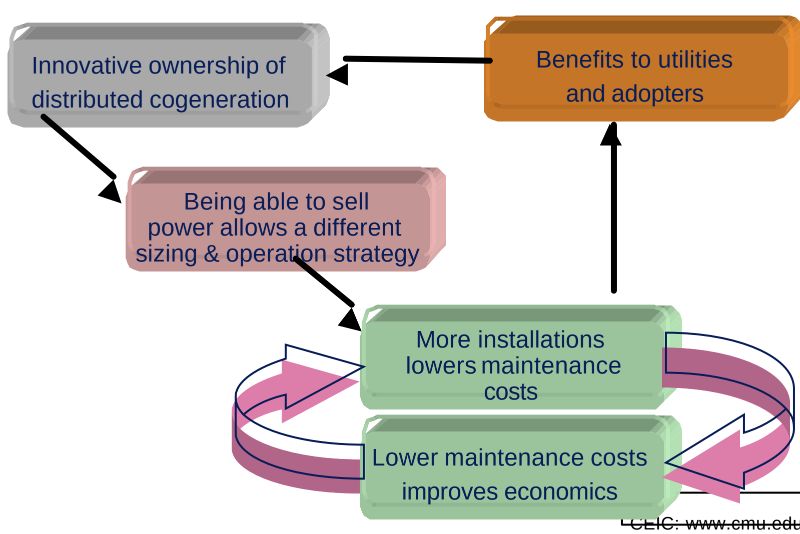
»Standard contract process facilitated financing, ownership and operation of DG units

- » Contracts ranged from knowledge of electricity use, to control over exports

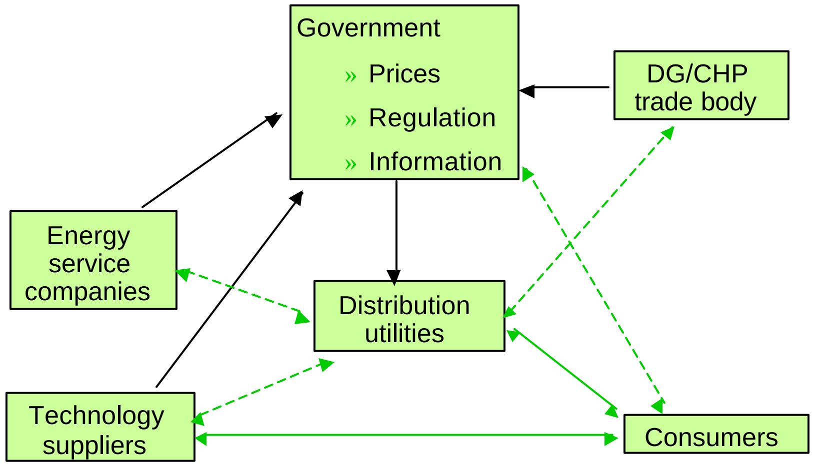
- Utilities
  - » Cheap electricity
  - » Potential to improve distribution network management
    - › 23% of DG electricity was exported to grid
  - » Met CO_2 reduction targets
  - » Access to liberalized generation market
  - » Publicity (for staid utilities!)

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

Virtuous cycle

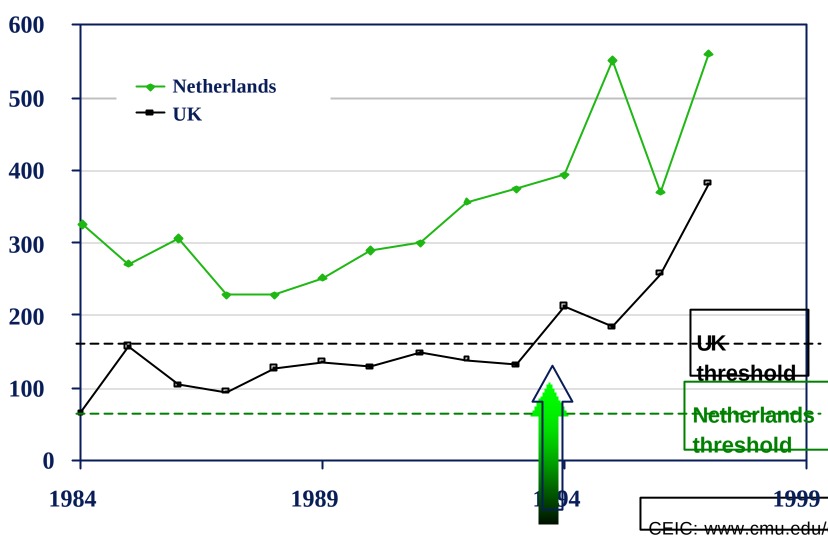


Market participants (2)



Implications of small DG units in the UK?

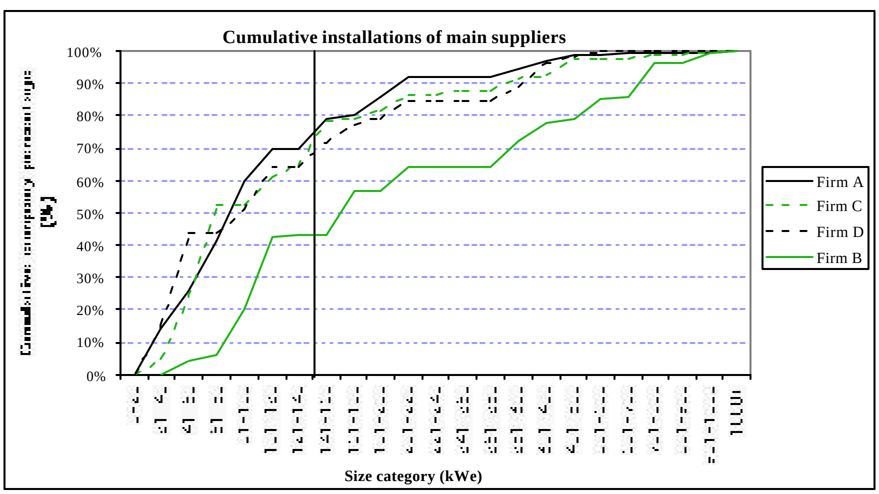
Why installed?, why financed?



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)

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

23

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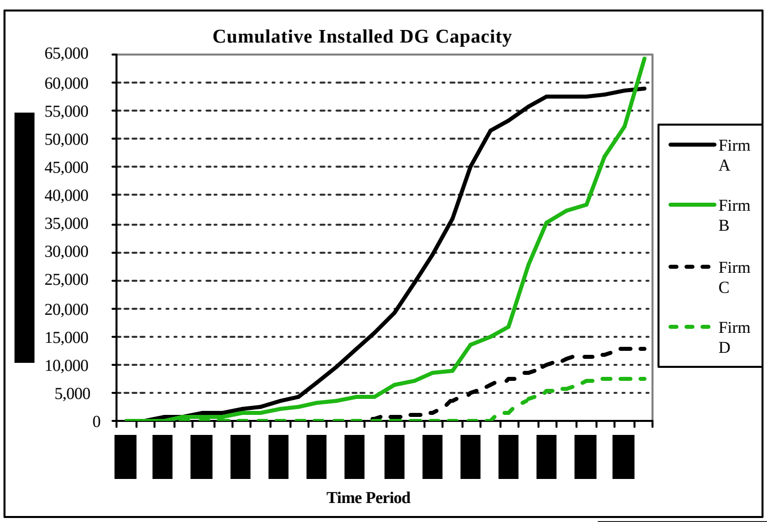
Evolution of UK market

(Firm B is the Dutch entrant)



24

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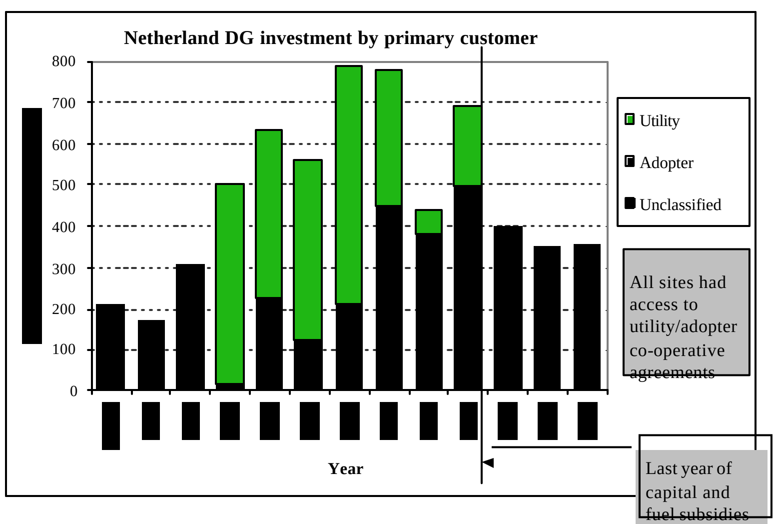
Netherlands technology suppliers and win-win partnerships

- In Netherlands
  - 5,000 DG units, 1,500MWe (40 times UK level, per capita)
  - 6% of national electric capacity, saved 3% of national CO_2 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



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?)

27

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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

28

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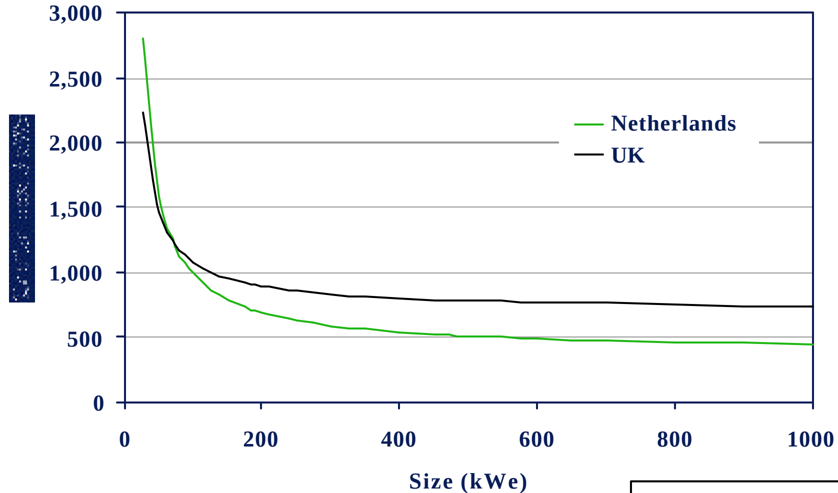
Capital costs



29

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Market similarities - overcame adoption barriers

Known barrier to adoption	Market and institutional situation in the UK and Netherlands
Supply constraint on input fuel for DG	Extensive natural gas networks
Decision-makers are not aware of the technology	Government information programs, supported by cogen/DG trade groups
Idealized engineering-economic projected savings never being achieved	Case studies and operation data on actual installations
Investors are wary to invest their own capital, or capital for energy related investments is not available	Availability of supplier financing
Additional costs that organizations face to change their method of operation deterred them from making the investment	Proven packaged technology, and technical standards for interconnection with the electricity network
Regulatory restrictions on DG investments and electricity sales	Separation of electricity generation and distribution, with open 3rd party access to the distribution network and power purchasing based on avoided costs
Government imposed moratoriums on new power generation facilities	DG exempt from moratoriums on new power generation facilities (1994 in the Netherlands, 1998 in UK)
Concern over the spatial and temporal impacts of DG on local air pollution	DG support was given for reduction in CO_2 emissions. IC engine cogen was exempted from regulations controlling NO_X, CO or hydrocarbons (HC) emissions

30

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Promotion of DG in Netherlands and UK

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

31

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DG subsidies and installed capacity

	Netherlands	UK
Capital subsidy	\$M 167	\$M 15
Information gathering and dissemination	\$M 17.7	\$M 9.5
Fuel subsidy	\$M 137	0
Energy tax exemption	\$M 3.9	0
Utility incentives for CO_2 controls	~0.15¢/kWhr	0
Installed distributed generation capacity	1,500MWe	160MWe
Subsidy per unit capacity installed	\$215/kWe	\$155/kWe

32

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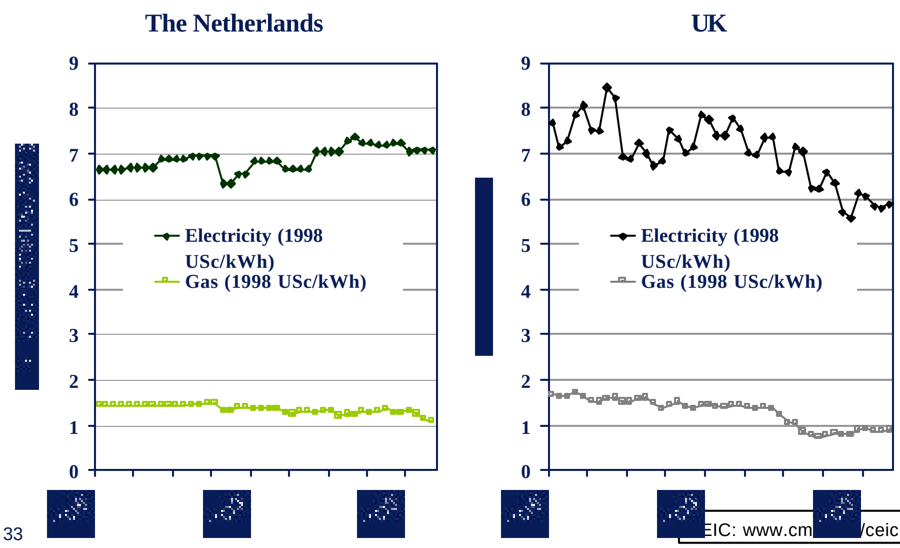
Fuel prices in the Netherlands and UK



33

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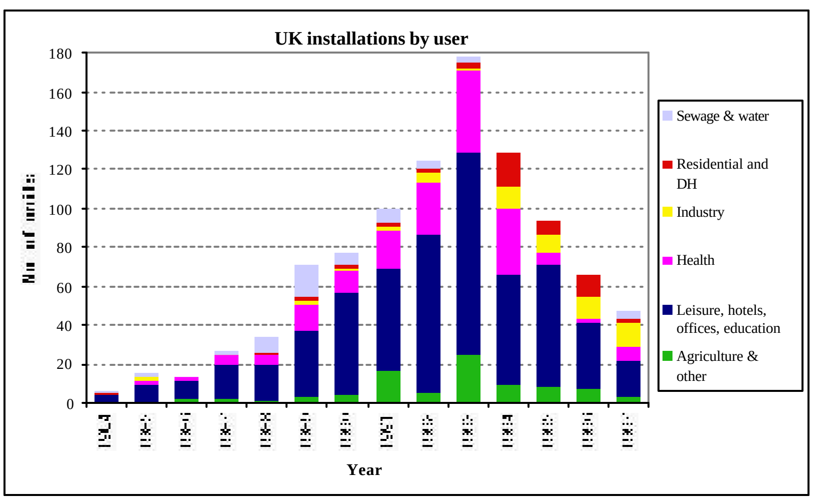
Low adoption rate in UK
Most popular sectors are generally heat limited



34

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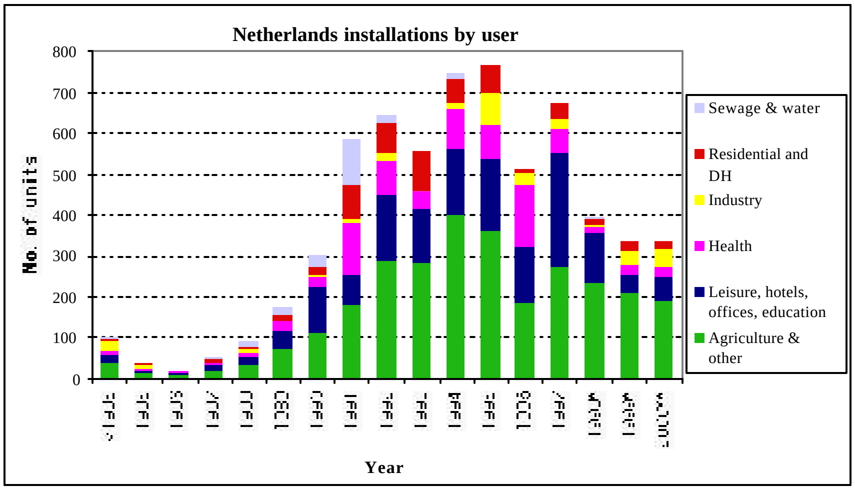
High adoption rate in Netherlands
Popular sectors are not heat limited



35

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