ECN

Energy research Centre of the Netherlands

EES-UETP

Electric Energy Systems - University Enterprise Training Partnership

Massive penetration of distributed generation: EU practical experiences

Jeroen de Joode

ECN: Sustainable energy innovation

- Largest Dutch R&D institute on energy
- Independent and committed
- “Missing link” between fundamental academic research and market application
- International co-operation

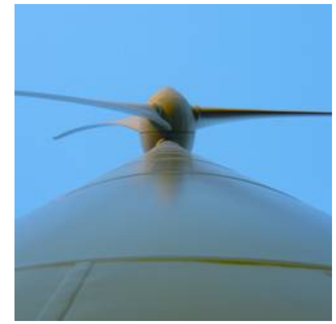
Mission statement

ECN develops and brings to market high-level knowledge and technology for a sustainable energy society

ECN's organisation structure: 5 units

Solar energy

Biomass

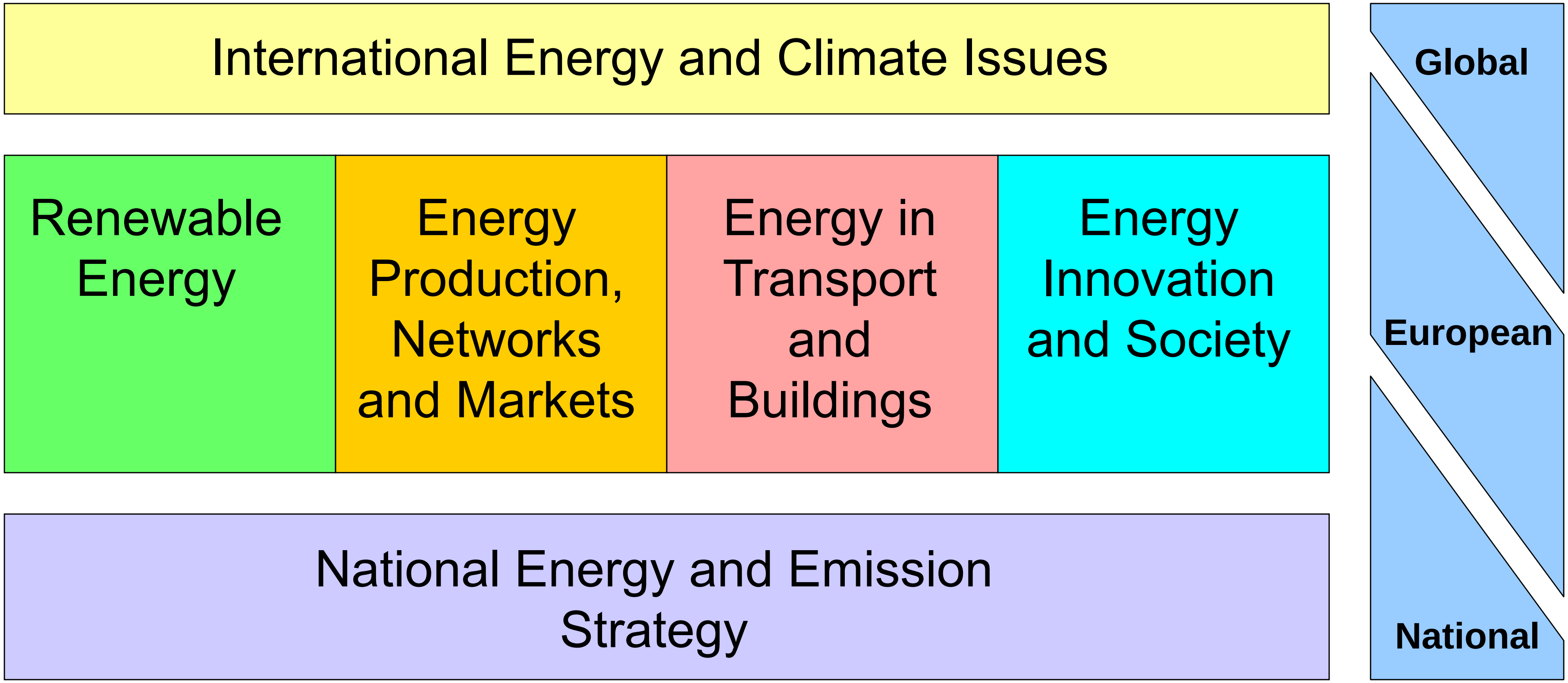


Wind energy

Efficiency & Infrastructure

Policy Studies

Policy Studies unit consists of six groups



Main storyline of this lecture

- Increase in distributed generation across EU
- Impact on various parts of the electricity system
- Increased understanding of underlying drivers of impacts (cost / benefit) may improve further integration
- How to decrease negative and increase positive impacts?
- Adaptation of regulation and market design required

Outline

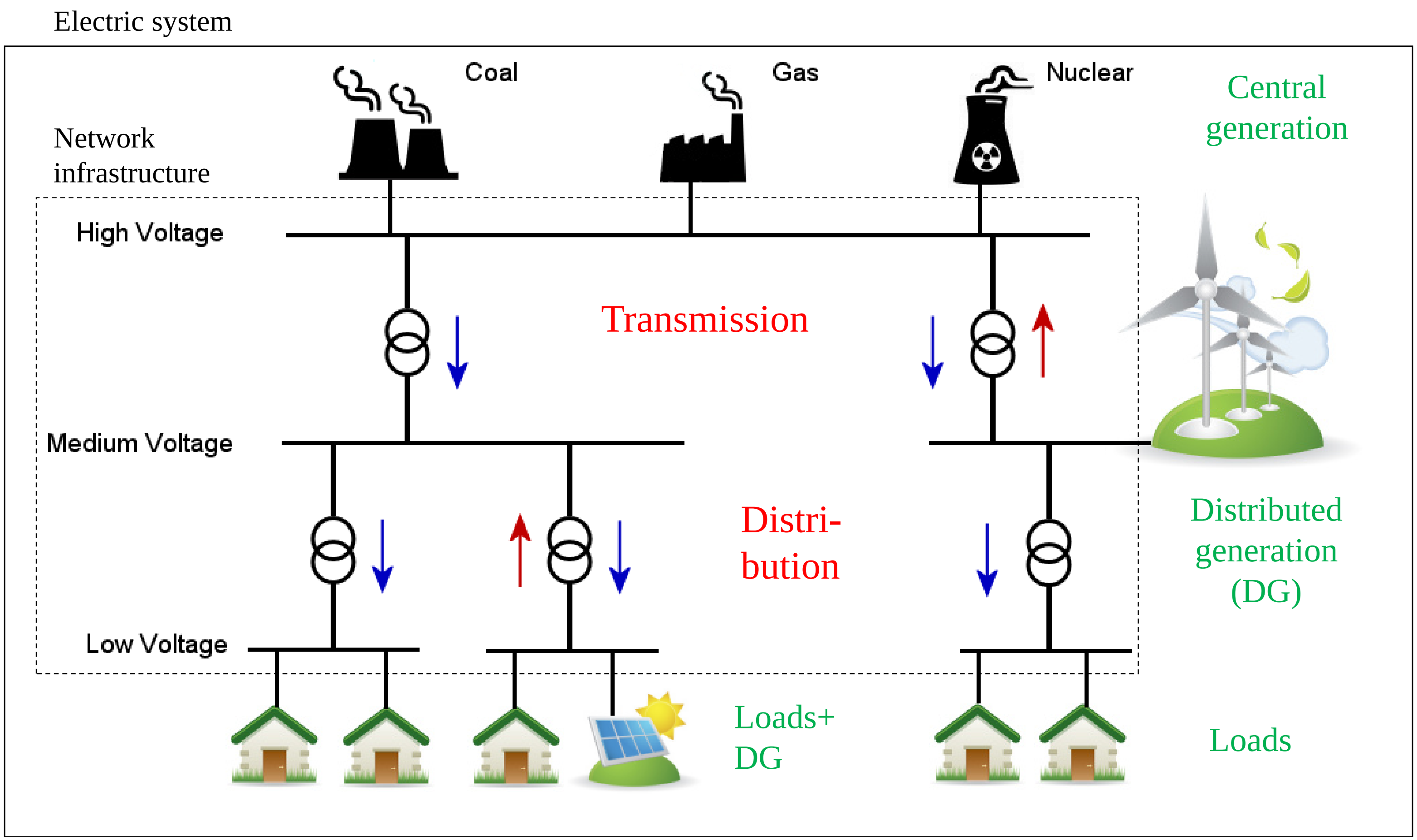
1. Terminology
2. Background
3. Impact on electricity system
4. Practical case studies
5. Conclusions & implications

1. Terminology

1. Terminology: Distributed Generation (DG)

- DG
  - Ackermann (2001): "… an electric power source connected directly to the distribution network or on the customer site of the meter"
- DG/RES-E
  - Distributed generation / electricity from renewable energy sources

1. Terminology: distributed generation (DG)



1. Terminology: DG/RES-E

	Combined Heat and Power (CHP)	Renewable Energy Sources (RES)
Large scale generation	• Large district heating [a] • Large industrial CHP [a]	• Large hydro [b] • Offshore wind • Onshore wind (partly) • Co-firing biomass in coal power plants • Geothermal energy
Distributed Generation (DG)	• Medium district heating • Medium industrial CHP • Commercial CHP • Micro CHP	• Medium and small hydro • On-shore wind (partly) • Tidal energy • Biomass and waste incineration/gasification • Solar energy (PV)

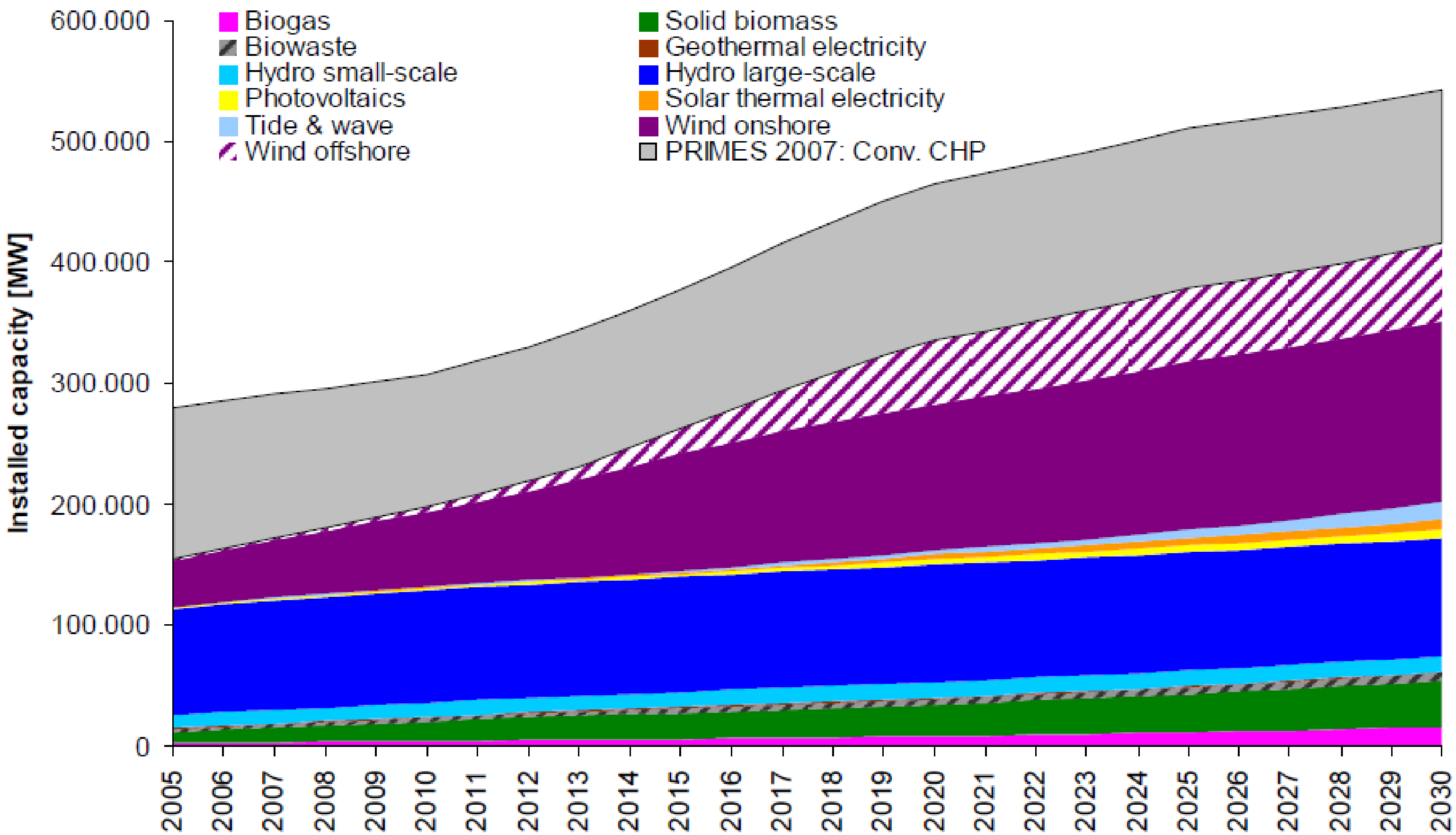
Source: Scheepers (2004)

1. Terminology: network management

- Network management: business philosophy regarding how to develop and operate a network
- Passive network management (PNM)
  - BAU, passive approach towards load and DG, also known as ´connect and forget´ approach
- Active network management (ANM)
  - DG integrated into network control, with greater coordination of power system operation, rather than connection only. ‘DG’ includes demand response

2. Background

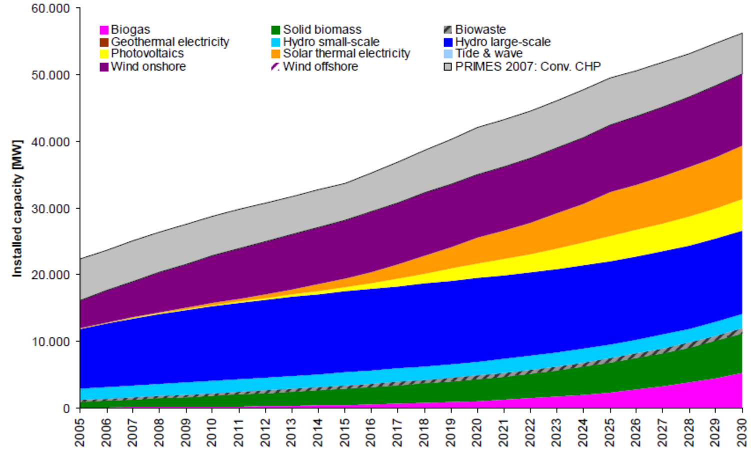
2. Background: Increase in DG/RES-E in EU-27



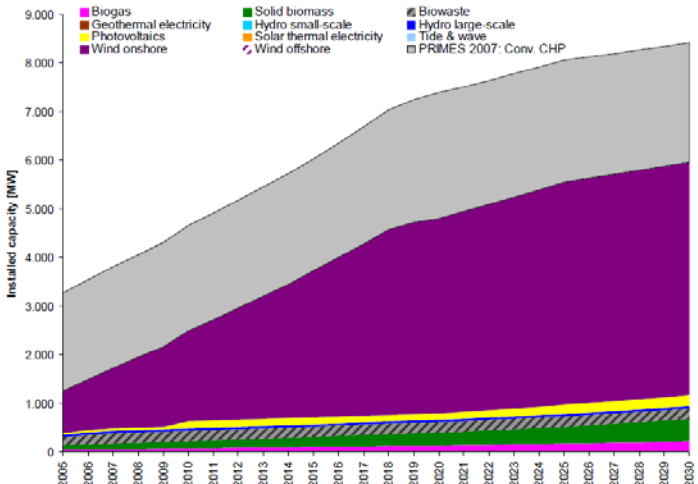
Source: Prüggler (2009)

… but different patterns across EU

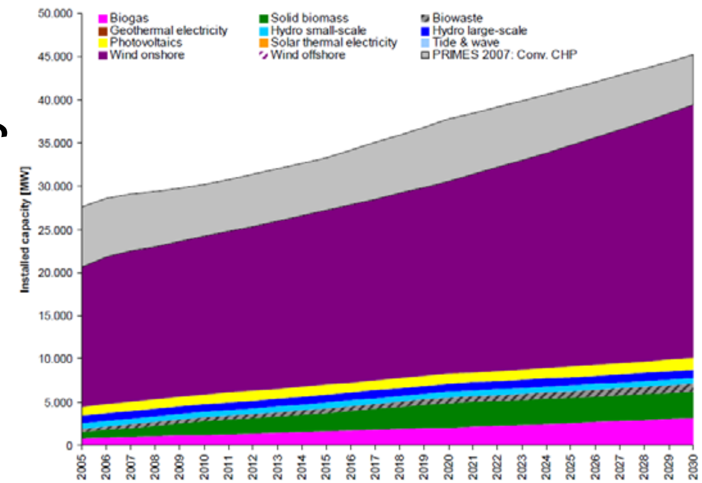
Spain



Netherlands



Germany



Source: Prüggler (2009)

3. Impact on electricity system

3. Impact on electricity system

- What happens if the amount of DG/RES-E in the European electricity system increases?

- Integral system perspective
- Positive and negative consequences
- Electricity system actors may gain or lose

- Which impacts may be identified?

3. Impact on electricity system

1. Distribution and transmission network
2. Electricity generation market
3. Externalities of electricity generation (CO_2 emissions)
4. Balancing market
5. Social welfare:
   - Consumer welfare
   - Energy sector profits

3. Impact on electricity system: Network cost impact

- Distribution network cost impact
  - New investment required
  - … or investment delayed (avoided)
  - Decrease in energy losses
  - … or increase in energy losses

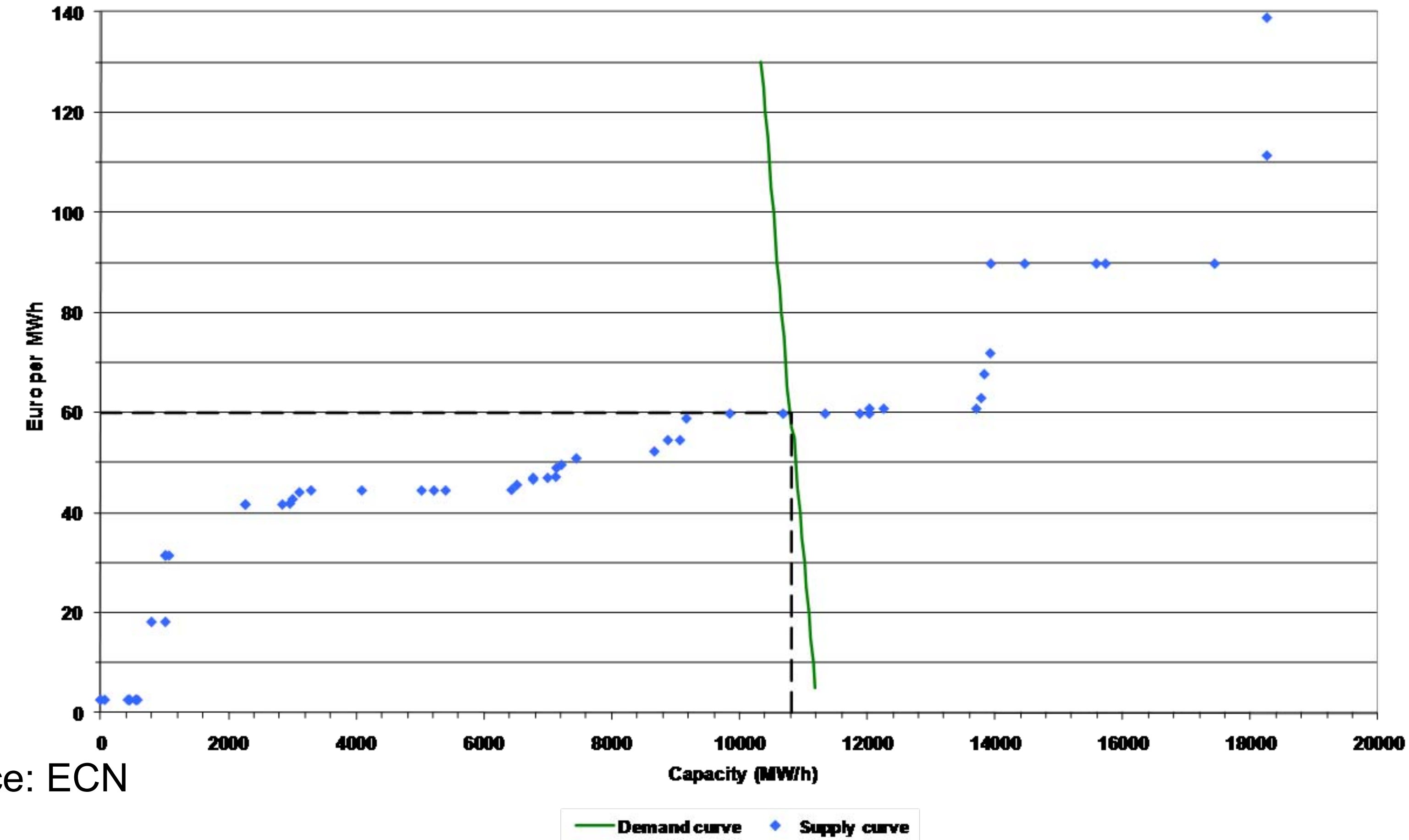
- Transmission network cost impact
  - Idem.

3. Impact on electricity system:
Generation cost impact

- Total cost of electricity generation in the electricity system is affected
  - Variable cost of generation
    - I.e. fuel cost, O&M cost
  - Fixed (capital) cost of generation
    - I.e. investment cost

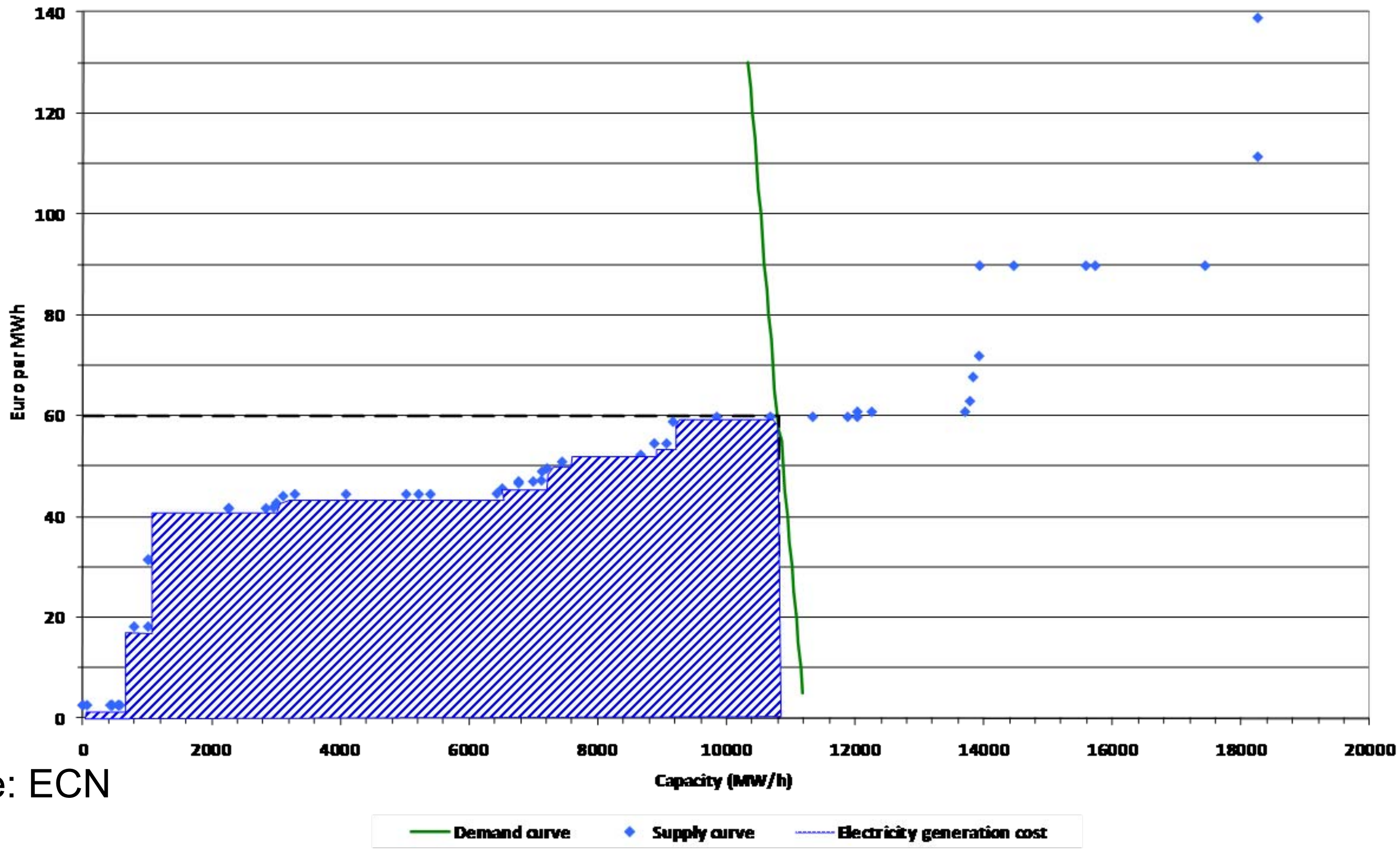
- Total variable generation cost might *decrease*
- Total fixed (capital) generation cost might *increase*

3. Impact on electricity system:
Illustration of generation cost impact



Source: ECN

3. Impact on electricity system:
Illustration of generation cost impact



Source: ECN

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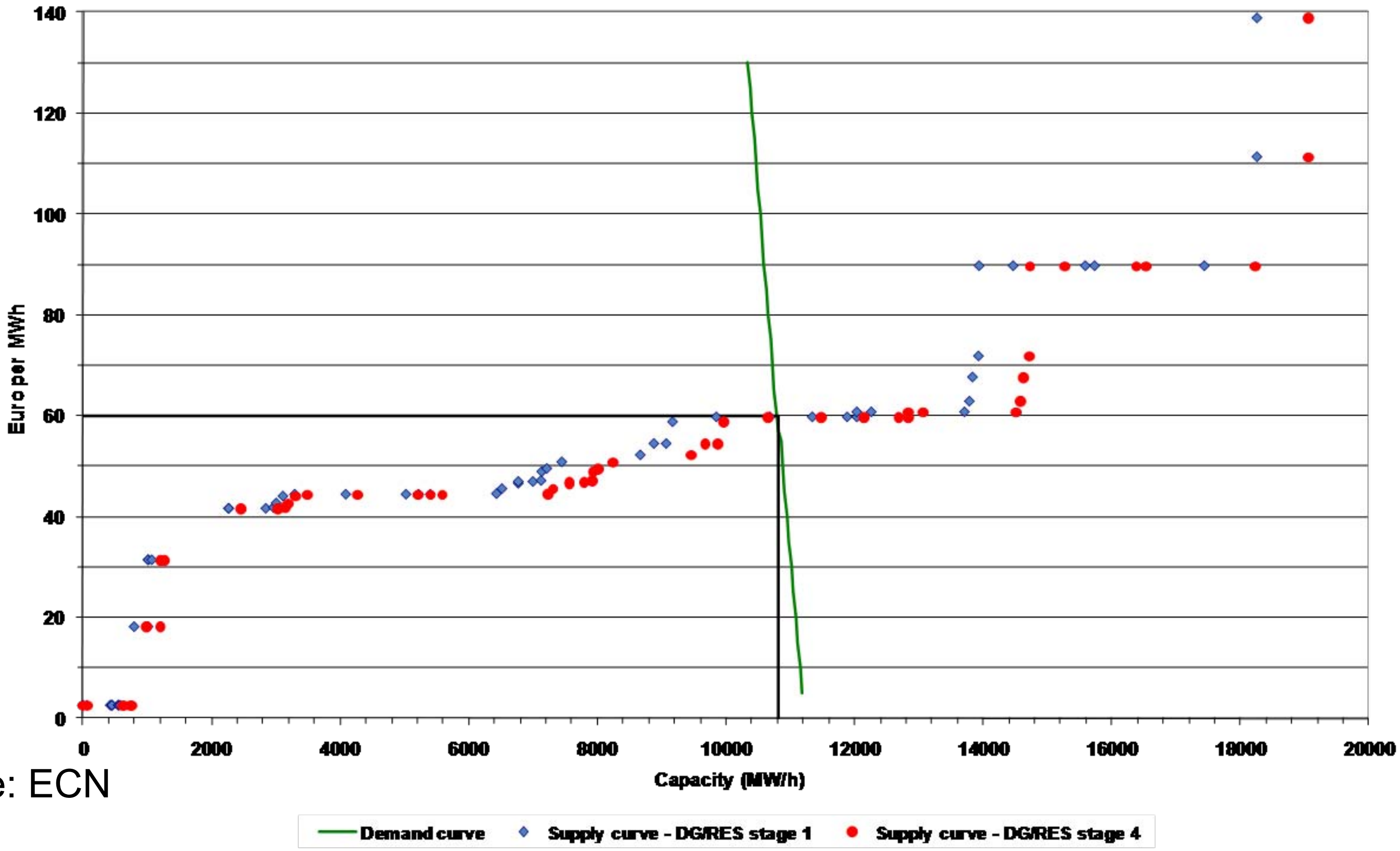
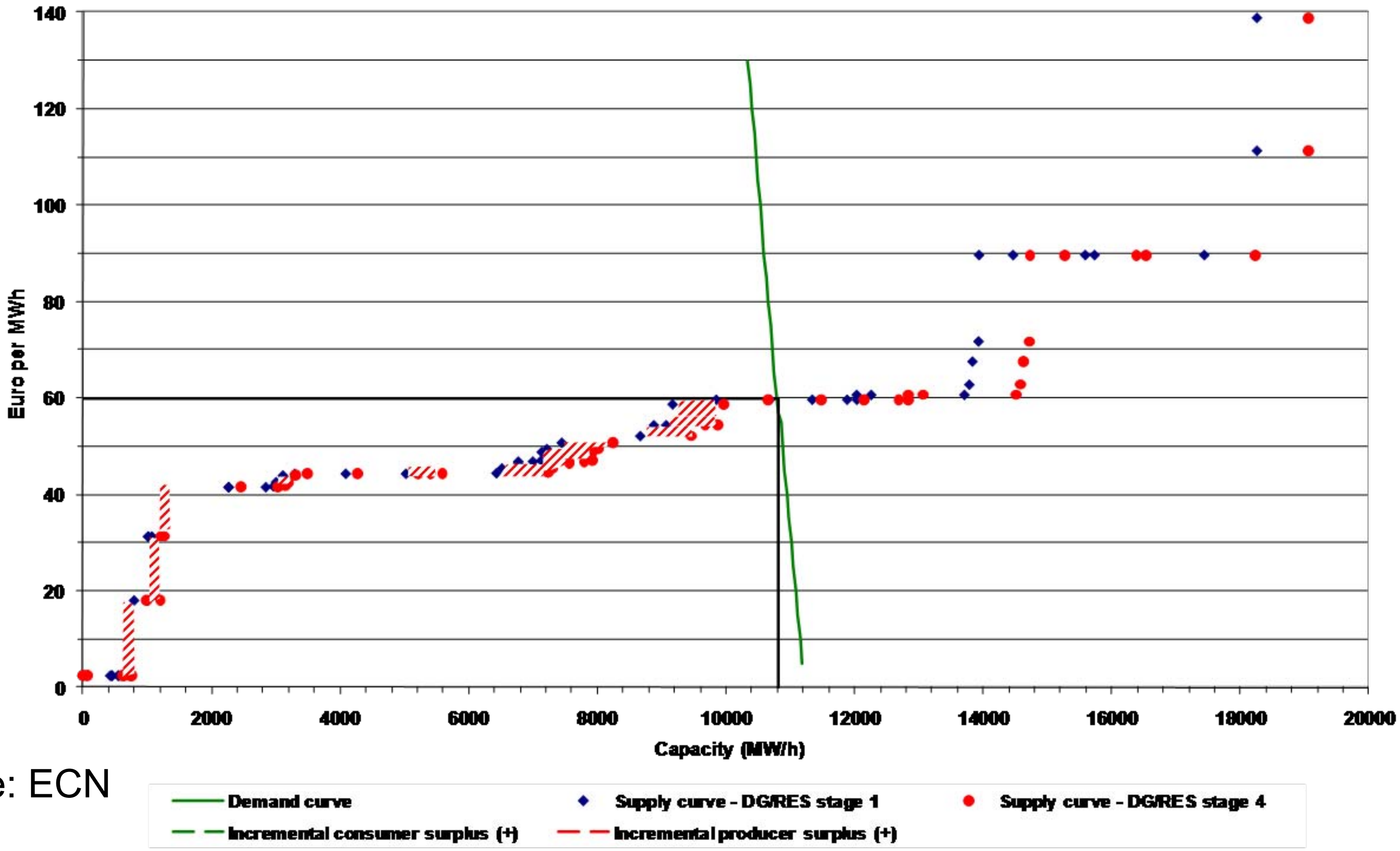
Illustration of generation cost impact



Source: ECN

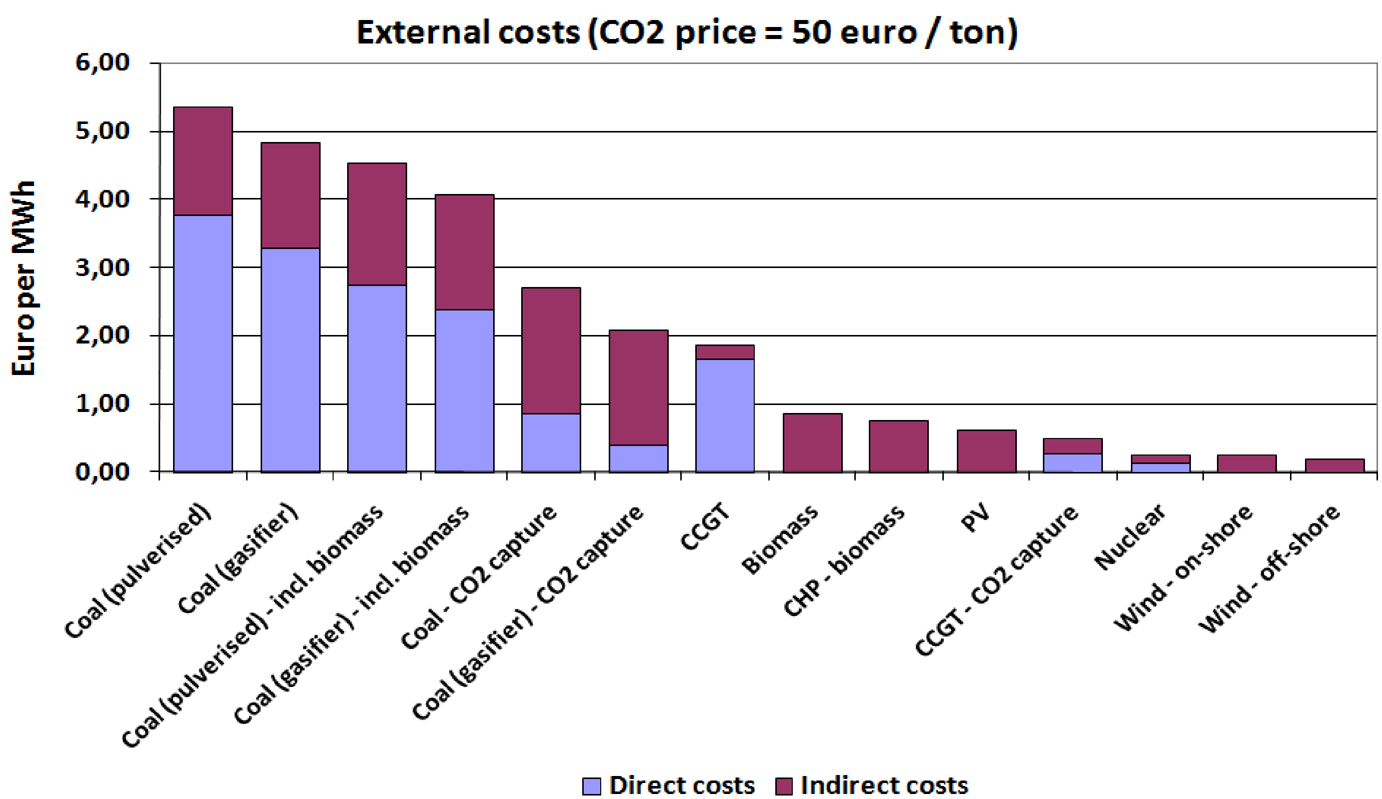
3. Impact on electricity system:
Illustration of generation cost impact



Source: ECN

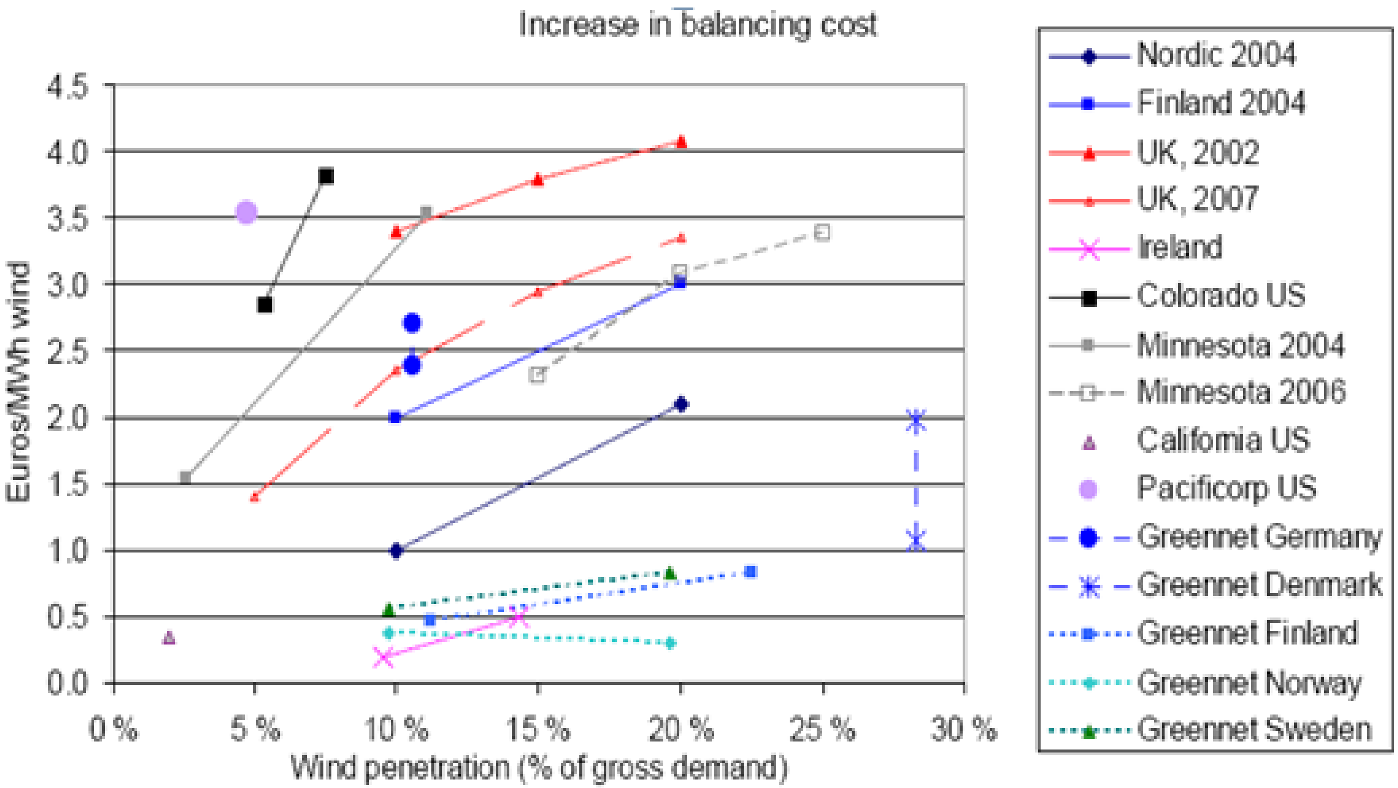
3. Impact on electricity system:
External cost impact

- External costs: monetised costs of emitting polutants
- CO_2 cost is in reality internalised via ETS and is reflected in operational generation cost



Source: ECN, based on Kuik (2007)

3. Impact on electricity system:
Balancing cost impact

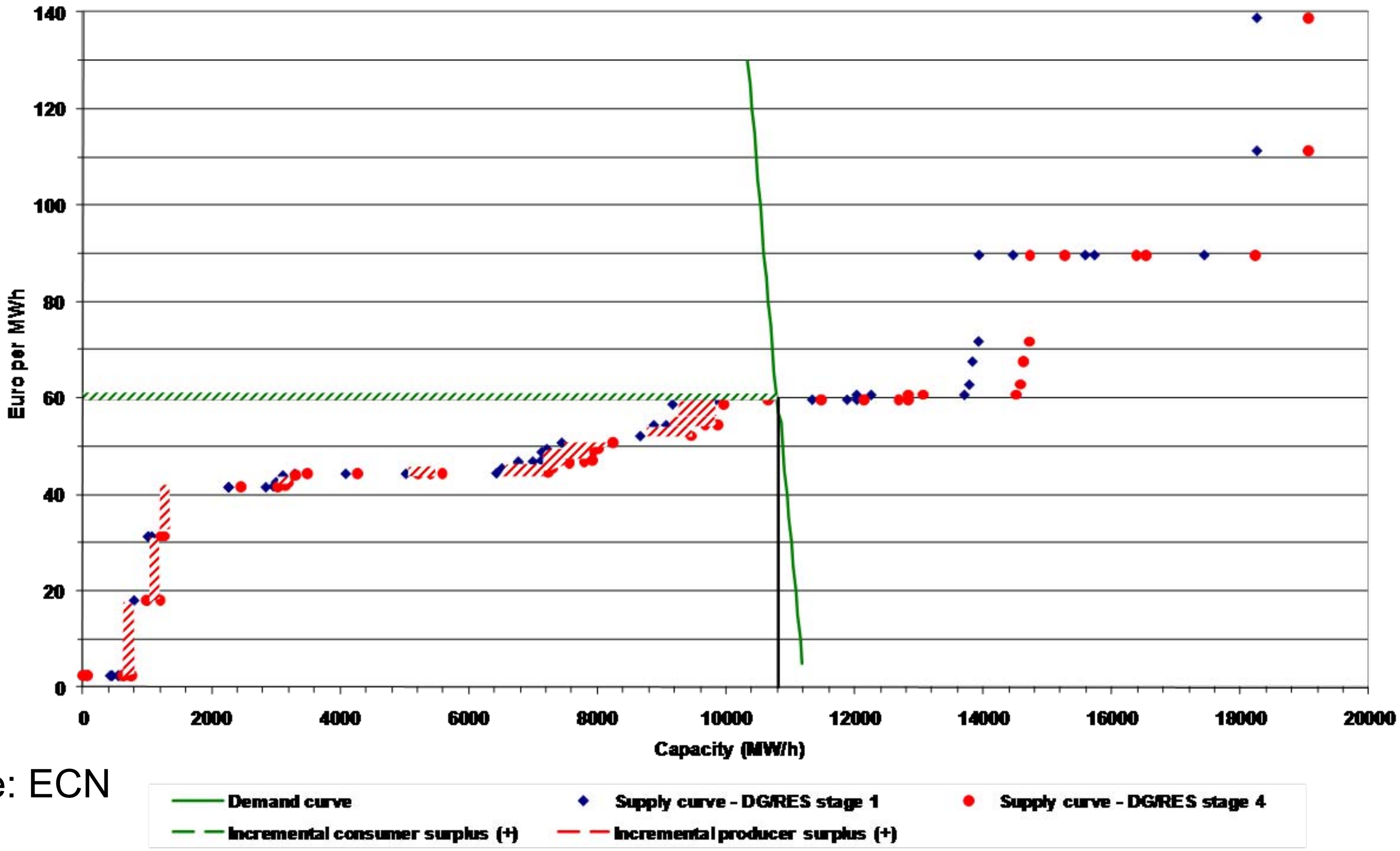


Source: Holttinen, based on (IEA, 2009)

3. Impact on electricity system: Social welfare impact

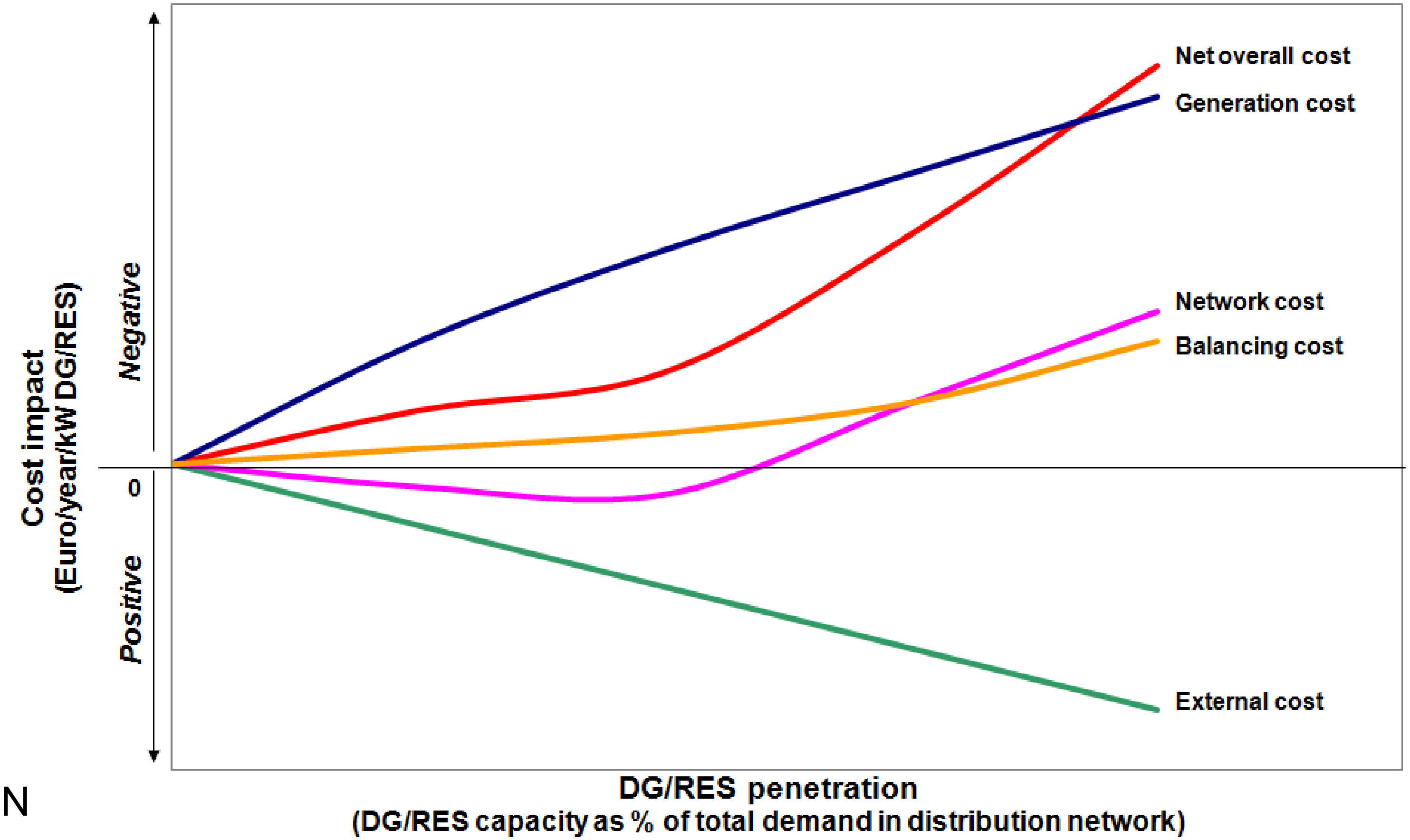
- Electricity generator profits increase of decrease depending on DG/RES impact on supply curve / marginal price
- When DG/RES lowers marginal price, consumer welfare might increase

3. Impact on electricity system:
Illustration of social welfare impact



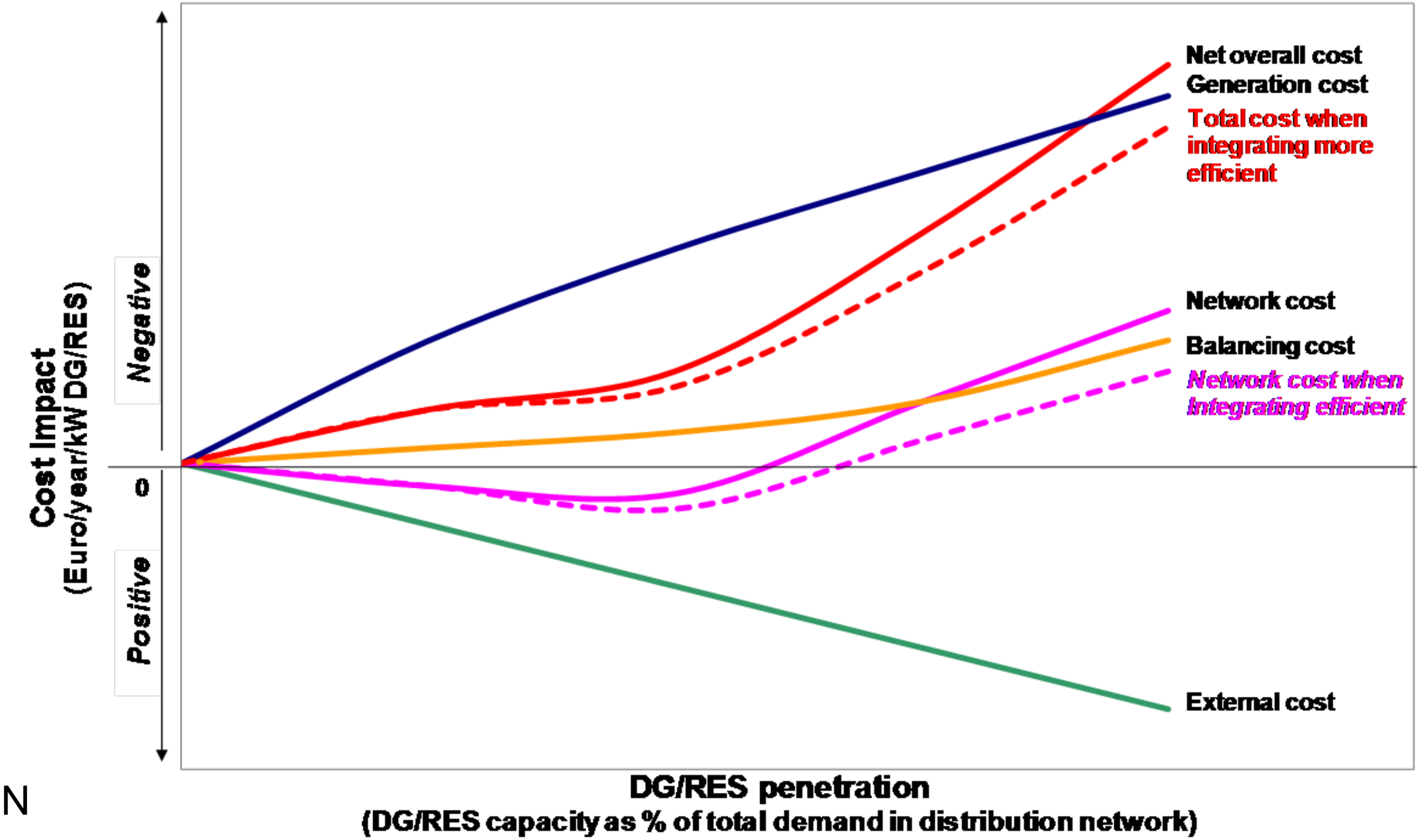
Source: ECN

3. Impact on electricity system:
Illustration of total cost impact



Source: ECN

3. Impact on electricity system:
Illustration of total cost impact



Source: ECN

4. Practical case studies

4. Practical case studies
Overview

- Main questions:
  - What is the impact on electricity system in practice?
    - Identify separate impacts
  - Regarding network impact: How can alternative network management influence this impact?

4. Practical case studies Methodology

- Modeling approach using real distribution network Three regions / distribution network regions in:
  - Netherlands, Germany, Spain
    → Focus on Kop van Noord-Holland (Netherlands)

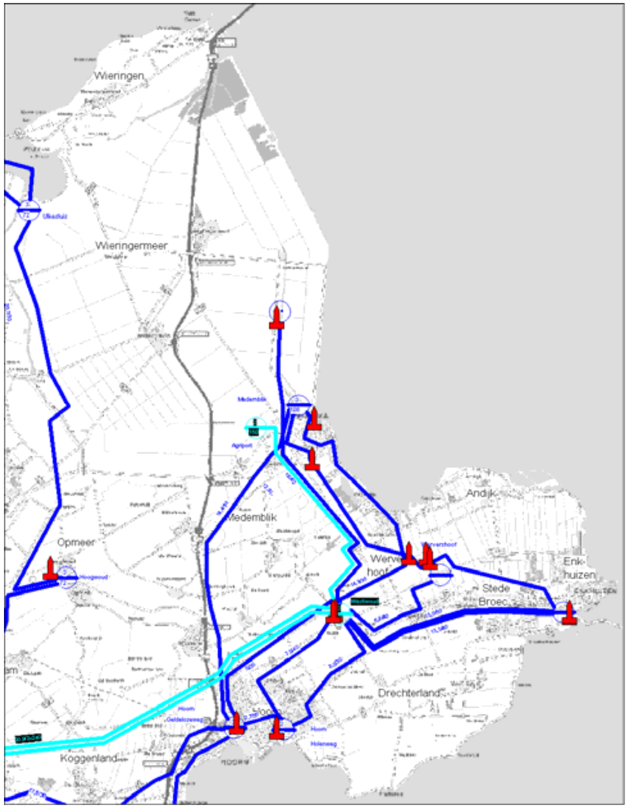
- Selection takes into account:
  - Amount and spread of DG/RES-E
  - Amount of spread of load
  - (Distribution) network topology

4. Practical case studies Methodology

1. Network cost impact
   - What network is needed when you increase DG/RES?
   - Tools: Network models of Comillas
2. Generation cost impact
   - How are fixed and variable generation costs affected with increased DG/RES?
   - Tool: Electricity market model COMPETES
3. External cost impact
   - How are external costs affected due to DG/RES?
   - Tool: Electricity market model COMPETES
4. Balancing cost impact

4. Practical case studies
Case of Kop van Noord-Holland (the Netherlands)

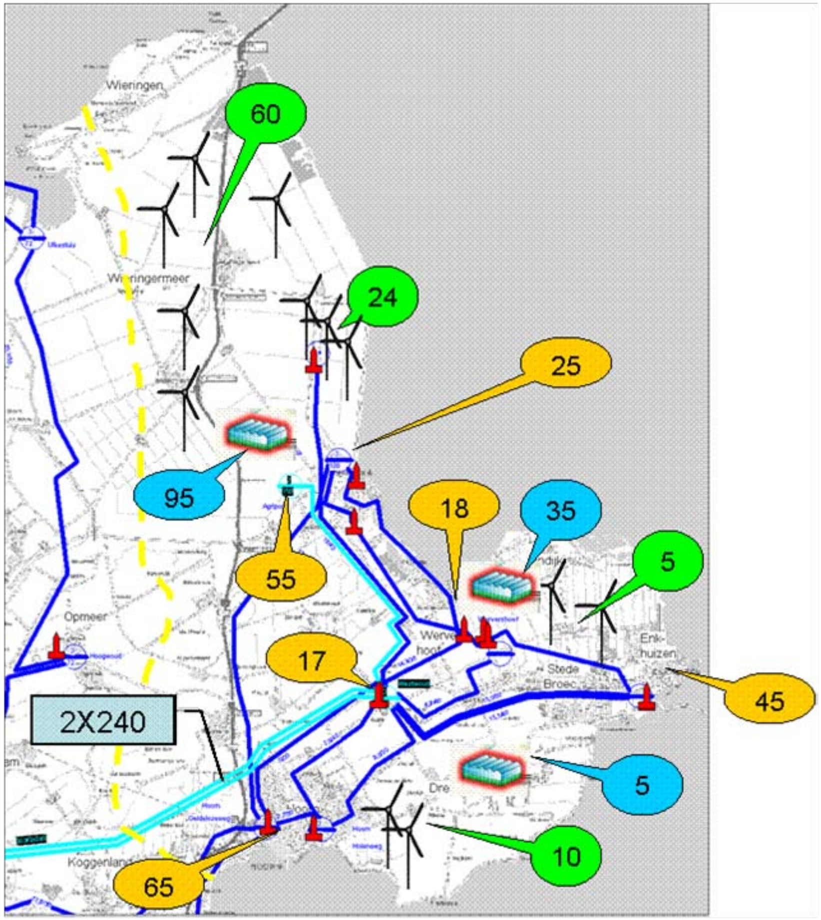
- Sub-urban, rural area
- 80,000 customers, 675km^2
- Large penetration levels of wind and CHP
- DG production may exceed peak demand.
- Operated by Liander



4. Practical case studies
Case of Kop van Noord-Holland (the Netherlands)

Situation in 2008

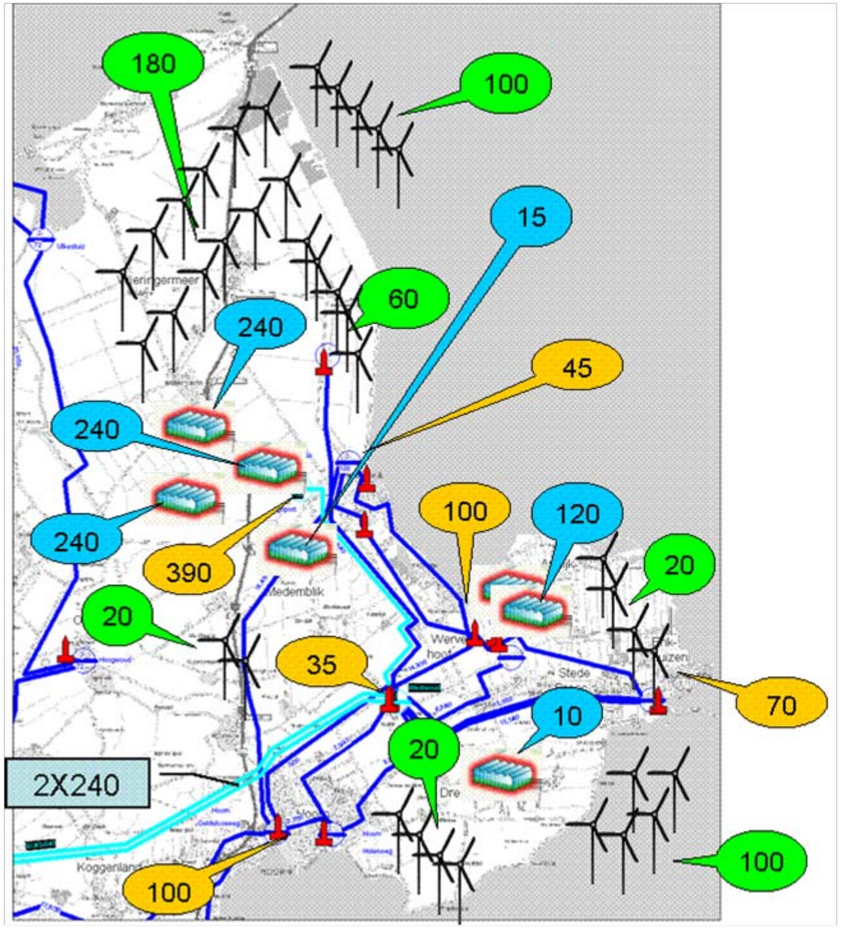
- Brown: load centres
  - 225 MW
- Green: Wind
  - 100 MW
- Blue: CHP
  - 135 MW



4. Practical case studies
Case of Kop van Noord-Holland (the Netherlands)

Situation in 2020 in high DG/RES-E scenario

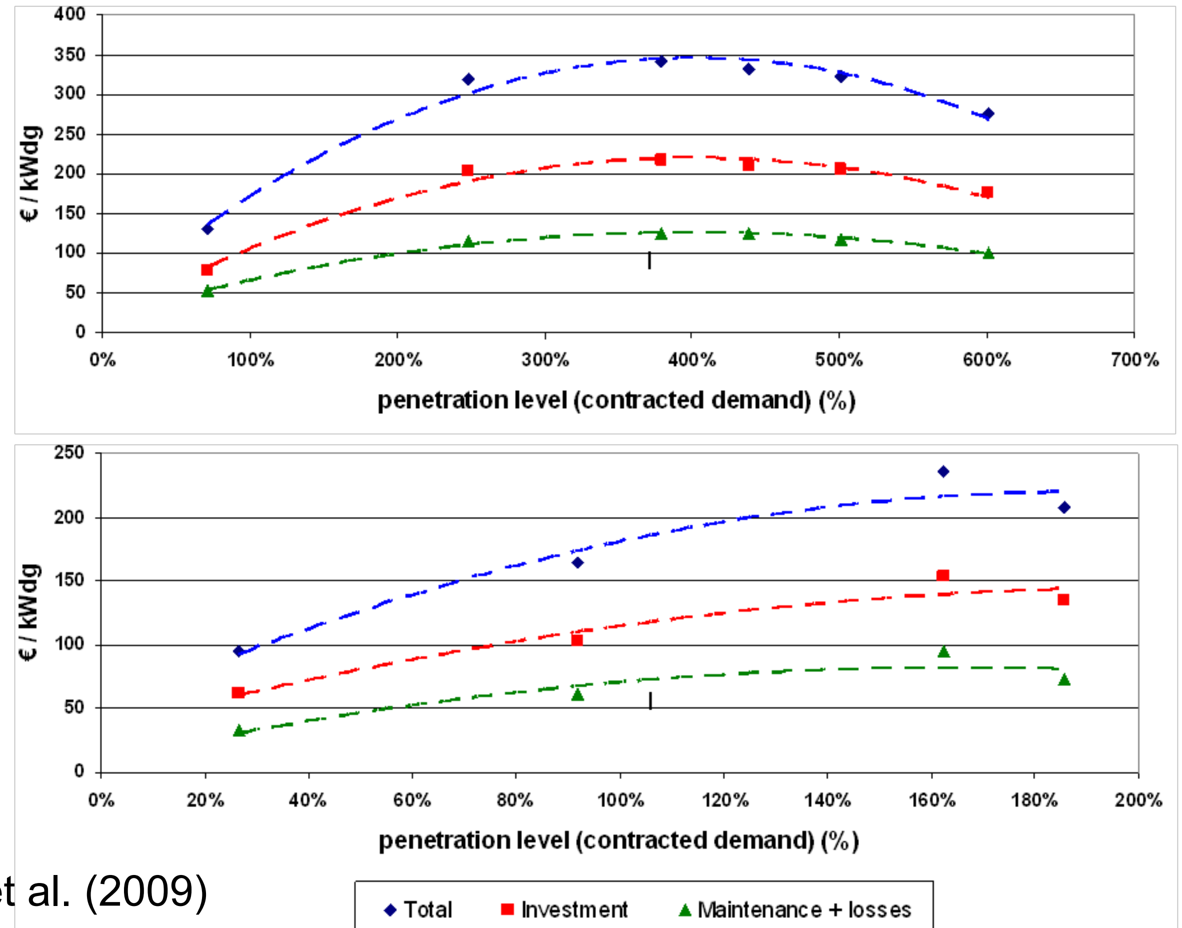
- Brown: load centres
  - 225 MW → 740 MW
- Green: Wind
  - 100 MW → 500 MW
- Blue: CHP
  - 135 MW → 865 MW



4. Practical case studies
Distribution cost impact in Kop van Noord-Holland

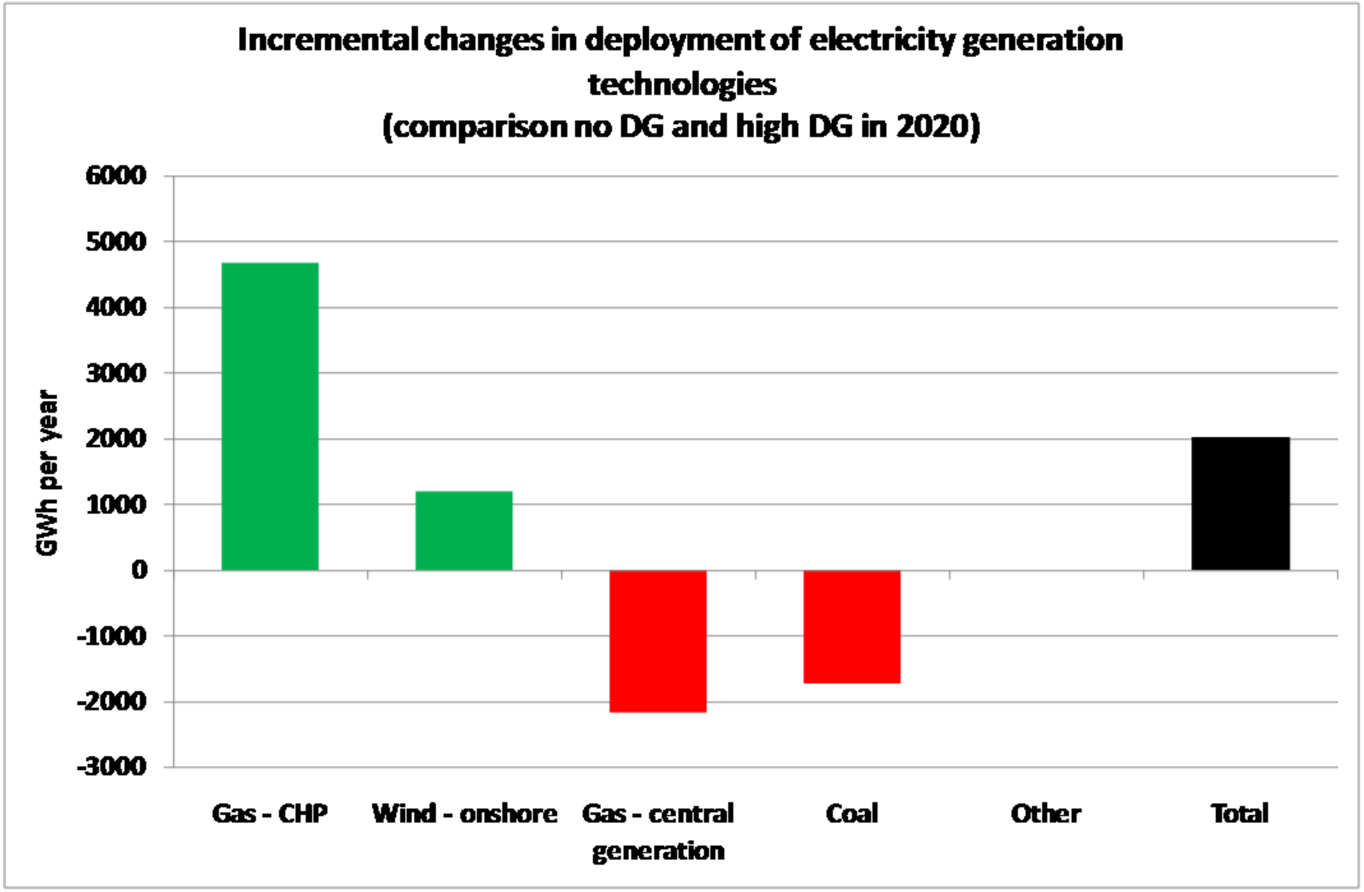
Demand 2008

Demand 2020



Source: Olmos et al. (2009)

4. Practical case studies
Generation cost impact in Kop van Noord-Holland



Source: ECN

4. Practical case studies
Results from Kop van Noord-Holland

- Calculations on impact of DG/RES against fixed background of demand situation (i.e. yearly load)

Scenarios	No DG	Current DG	2008 DEMAND Future DG (medium)	Future DG (High)
DG penetration level [%]	0%	71%	248%	438%
Cost concepts				
Variable Generation Costs [€/kW installed DG/year]	0.0	-70.8	-34.8	-22.9
Fixed Generation Costs [€/kW installed DG/year]	0.0	67.5	60.7	62.1
Distribution Costs [€/kW installed DG/year]	0.0	8.3	20.3	21.2
Balancing costs [€/kW installed DG/year]	0.0	0.8	0.4	0.5
External Costs [€/kW installed DG/year]	0.0	-4.5	-3.4	-4.3
Transmission Costs [€/kW installed DG/year]	0.0	0.0	3.3	11.4
Total cost [€/kW installed DG/year]	0.0	1.2	46.4	68.1

Source: Olmos et al. (2009)

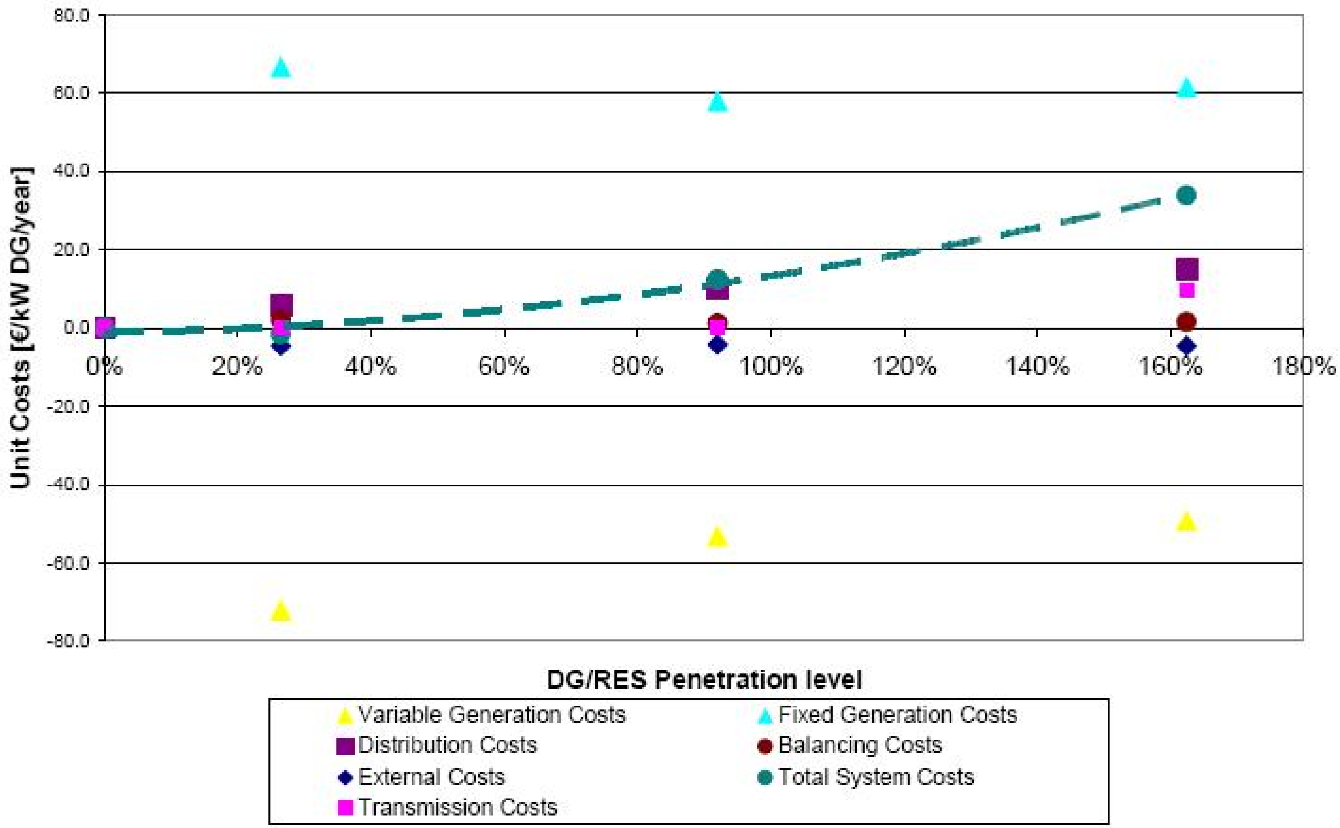
4. Practical case studies
Results from Kop van Noord-Holland

- When demand background changes, number change, but sign and order of magnitude remain the same

Scenarios	No DG	Current DG	2020 DEMAND Future DG (medium)	Future DG (High)
DG penetration level [%]	0%	26%	92%	162%
Cost concepts				
Variable Generation Costs [€/kW installed DG/year]	0.0	-72.0	-53.1	-49.3
Fixed Generation Costs [€/kW installed DG/year]	0.0	66.7	58.0	61.5
Distribution Costs [€/kW installed DG/year]	0.0	6.1	10.4	15.0
Balancing costs [€/kW installed DG/year]	0.0	2.2	1.2	1.6
External Costs [€/kW installed DG/year]	0.0	-4.5	-4.1	-4.5
Transmission Costs [€/kW installed DG/year]	0.0	0.0	0.0	9.5
Total cost [€/kW installed DG/year]	0.0	-1.5	12.4	33.9

Source: Olmos et al. (2009)

4. Practical case studies
Results from Kop van Noord-Holland



Source: Olmos et al. (2009)

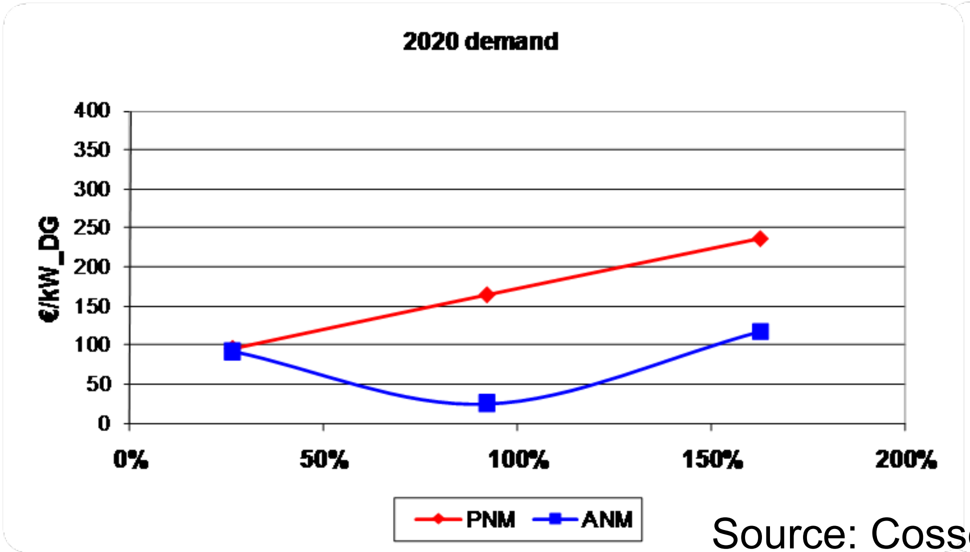
4. Practical case studies
Alternative network management options in Kop van Noord-Holland

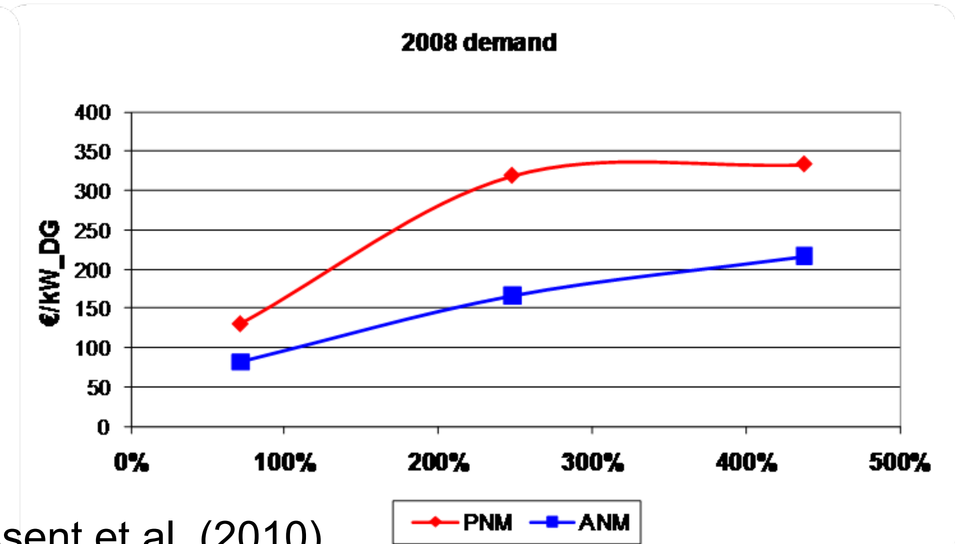
1. Wind curtailment
   - Temporarily reduce output of wind turbines
2. Shifting combined heat and power (CHP) generation
   - Reduce during peak generation; increase during peak load
3. Demand response
   - Shifting greenhouse lighting load to different hours

4. Practical case studies

Effect of ANM on distribution network impact in Kop van Noord-Holland

- Distribution network costs still increase of DG
- Substantial potential for savings
- Main savings correspond to transformer capacity due to a reduction in maximum DG production

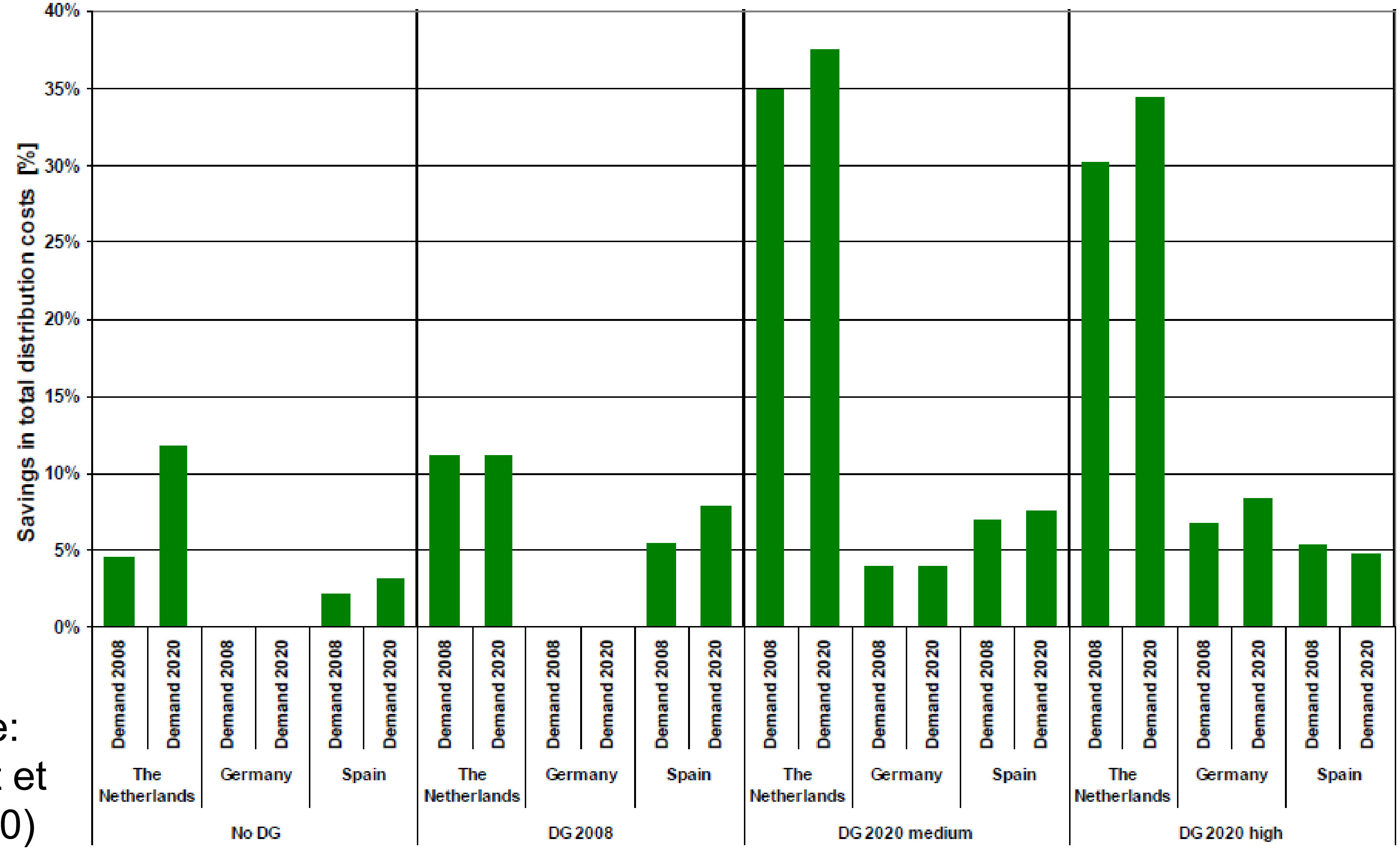




Source: Cossent et al. (2010)

4. Practical case studies

Benefits of ANM (as % of distribution costs) across case studies



Source: Cossent et al. (2010)

4. Practical case studies
Benefits of ANM (annualised costs / benefits)

	Network cost savings €/kW$_{DG}$/year	Technology cost (ICT) €/kW$_{DG}$/year	Net benefits €/kW$_{DG}$/year
Spain	3.3	7.9	-4.6
Germany	10.5	2.5	8.0
Netherlands	8.6	0.1	8.5

Source: Cossent et al. (2010)

- NB: 'Germany' = case with household scale PV + μ-CHP; 'Netherlands' = only large-scale: CHP, wind, DSM; 'Spain' = mix of large CHP, PV and household-scale DSM
- ICT costs differ, depending on household-scale applications (ES, DE) or only large-scale (NL)
- High uncertainty on costs and net benefits → more pilot projects needed such as e.g. the German E-Energy programme

4. Practical case studies
Rough estimation of impact for EU-25 in 2020

- DG will increase from 201 GW to 317 GW in 2020 (investments of more than €200 bn)
- Requiring additional network cost of about €25 bn
- ANM will reduce network costs by €1-3 bn
  - About 5-10% savings in additional network costs
- Putting ANM in perspective:
  - Network benefits of flexible integration of DG are only about 1% of the investment cost in DG

5. Conclusions & implications

- Large difference in DG/RES developments
  - Across countries
  - Across distribution networks within countries
- Results on impacts are very much context dependent
  - Balancing costs depending on e.g. network interconnections
  - Distribution network costs depending on
    - load level and concentration
    - DG/RES level and concentration
  - Generation cost savings
  - Investment cost impact partly temporary phenomenon
- Distribution network investment cost most relevant cost

5. Conclusions & implications

- Demand response and active generation control of DG can contribute to market integration of DG/RES, with as a consequence less need for conventional back-up capacity
- Electricity system benefits > network benefits
- Electricity retailers / ESCOs may become important players in implementation ANM
- Regulatory challenge: smart grid cost are in the regulated domain, while benefits accrue to market parties

5. Conclusions & implications
Progress on different aspects

- Regulation of distribution networks
  - More and more regulatory authorities acknowledge impact of DG/RES-E on networks and/or re-focus on investment and innovation instead of efficiency
- Balancing markets
  - Impact of intermittent energy sources can be relieved by a range of respond options: not all readily available, and relatively cheap options are currently used
- Electricity generation
  - Adequacy of generation investment: can electricity prices cover investment costs? Capacity mechanisms may be needed to guarantee investment in (peak) generation units

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Questions & discussion

More information:

www.improgres.org / dejoode@ecn.nl

Statements for discussion

- Should we focus more on large-scale RES instread of DG/RES (e.g. via support schemes)
- Optimal integration of DG/RES is mainly a national member state issue, not an EU issue
- Technology is not the barrier in achieving a cost-efficient sustainable energy system, but public acceptance and a credible long-term CO_2 price are the key issues to be resolved