MORE MICROGRIDS Workshop

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Microgrid impact on the development of electricity infrastructure

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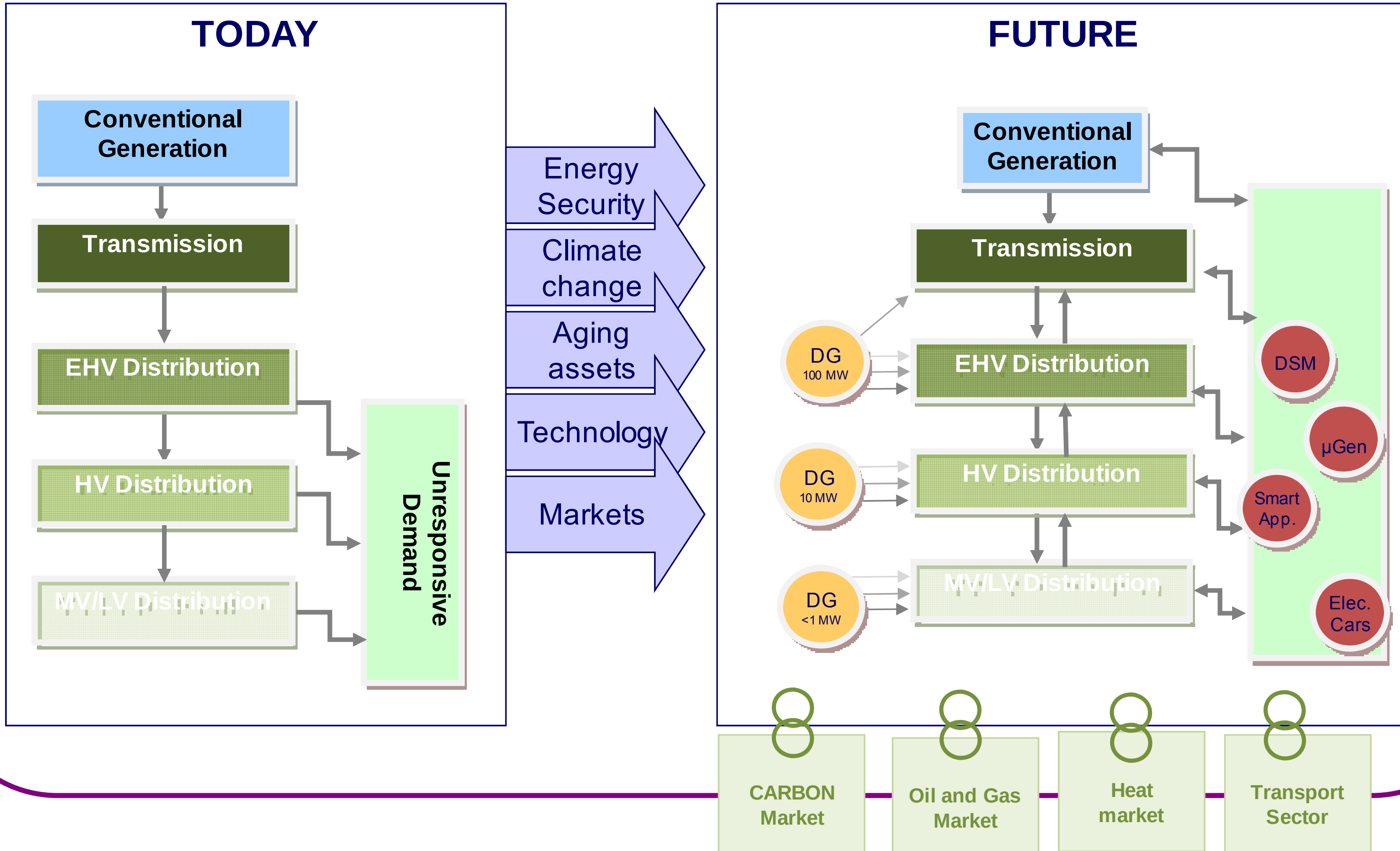
Outline

- Background
- Microgrid impact on distribution networks
- Microgrids impact on transmission networks
- Microgrids impact on central generation
- Concluding remarks

Background

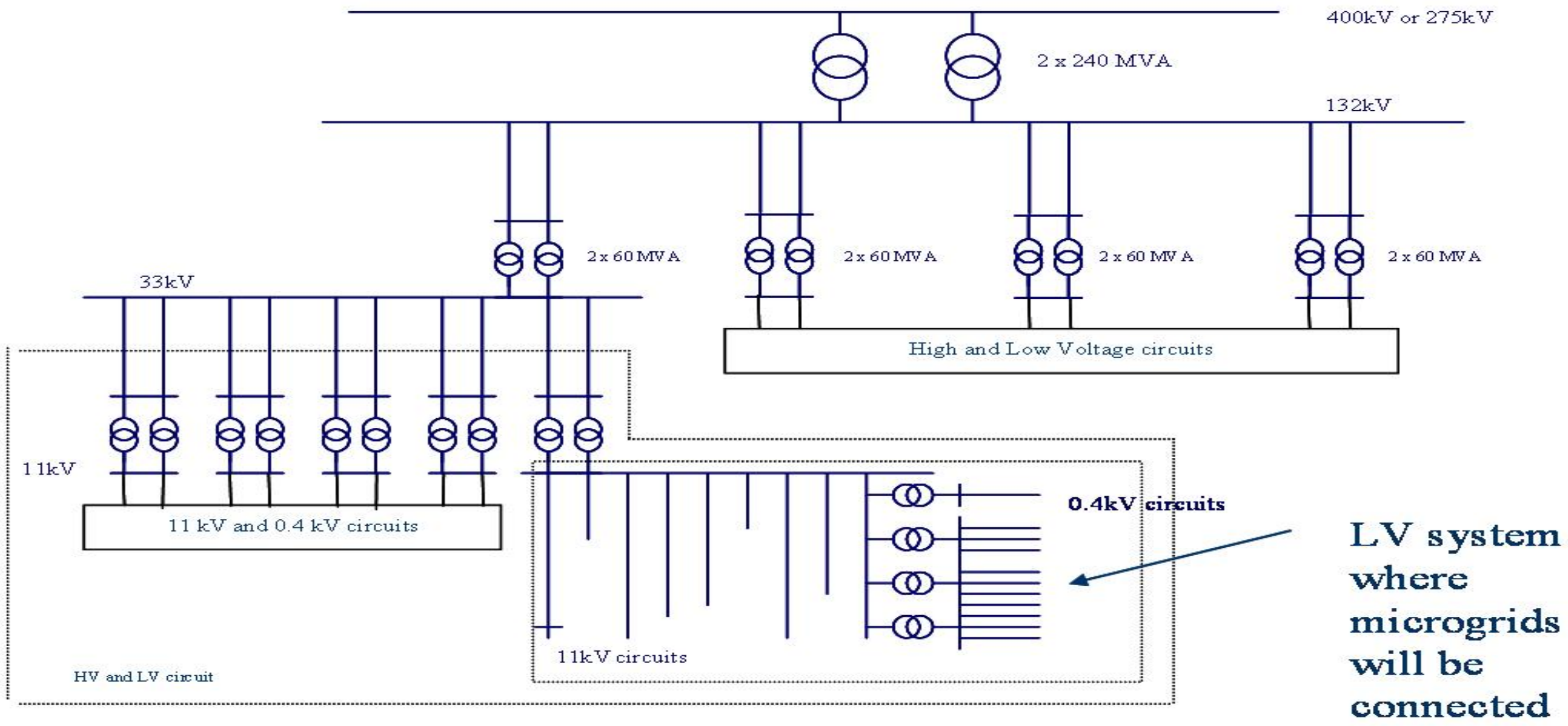
Electricity system in transition



Impact on Distribution Networks

GDS model

Representation of typical multi-voltage level distribution networks from **Germany, Netherlands, Poland, FYROM, UK**



Scope of the analysis

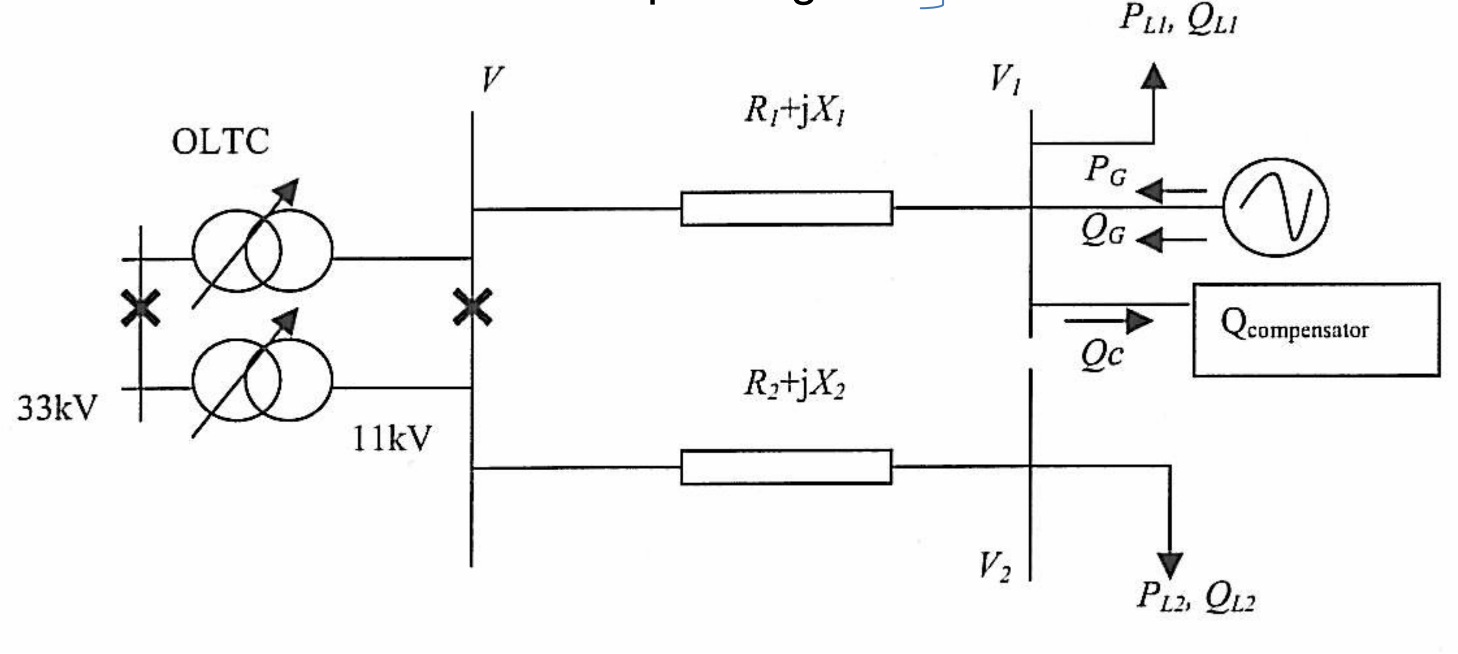
- Assessing the impacts of Microgrids on **reinforcement cost** (related to voltage, thermal or fault level issues) and losses
- Identifying **Active Management** (AM) strategies to be undertaken in Microgrids, and evaluating their additional benefits, by taking into account their implementation costs (**Cost-Benefit Analysis**)
- Comparing the impacts of DG characteristics and AM on **networks of different characteristics**

Active Management Modelling

Instead of reinforcing existing feeders (**passive management** approach), alternative actions can be taken in order to resolve voltage problems:

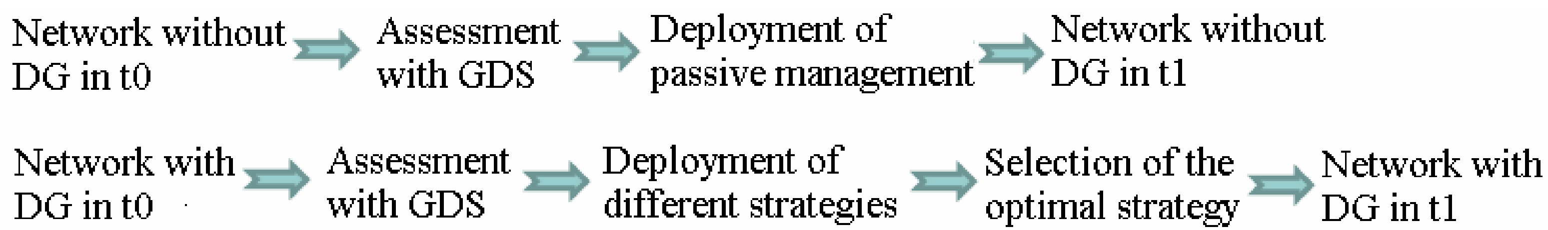
1) Generation curtailment
2) Reactive compensation
3) Co-ordinated control of on-load tap changers

Identification of optimal AM solution



Groups of studies:
1. Dynamic network assessment

- Based on the data provided by the project partners regarding demand and DG in a number of future snapshots
- Taking **optimal decisions** on network investment, including selection of AM strategies to be implemented within a Microgrid framework **at different milestone times**



- Evaluation of the dynamic impacts of adopting Microgrids (e.g. cases of reinforcement deferral)

-> roadmap for network evolution

Groups of studies:
2. Parametric assessment of Microgrids

- Analysis of the impacts of micro DG (micro CHP and micro PV) on current networks
- Quantification of the sensitivity of Microgrid impact with respect to the level of:

1. micro DG penetration (low, medium, high)
2. demand (low, high)

Key outcomes from partners' scenarios

Impacts on **reinforcement cost reduction**

- Substantial value in the Polish, FYROM, UK networks (reduction of demand-driven upgrade)
- Zero value in the very strong Dutch network
- Small negative value in the (quite strong) German network at very high DG penetration (fault level problems arising)

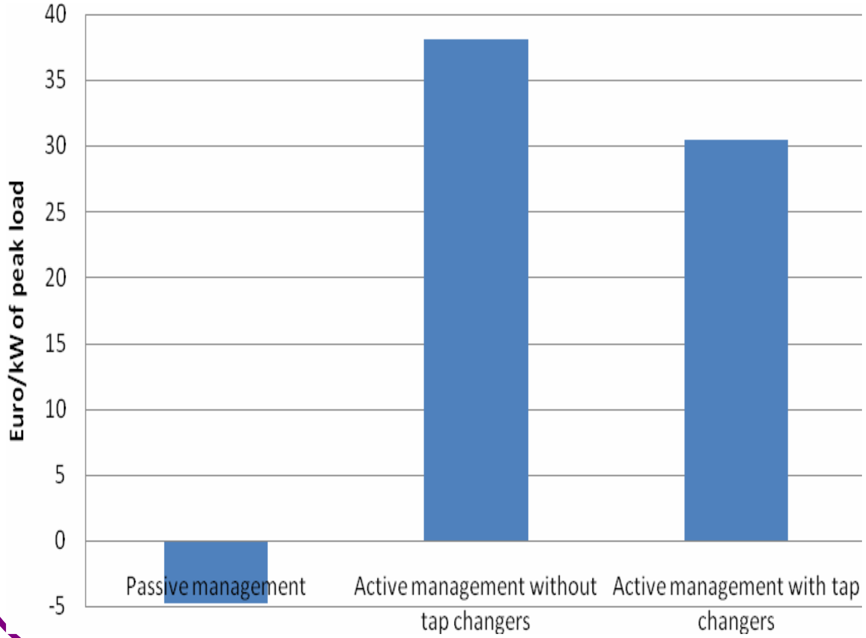
Impacts on **losses reduction**

- Positive, apart from some cases in the Dutch network (significant reverse power flows emerging)

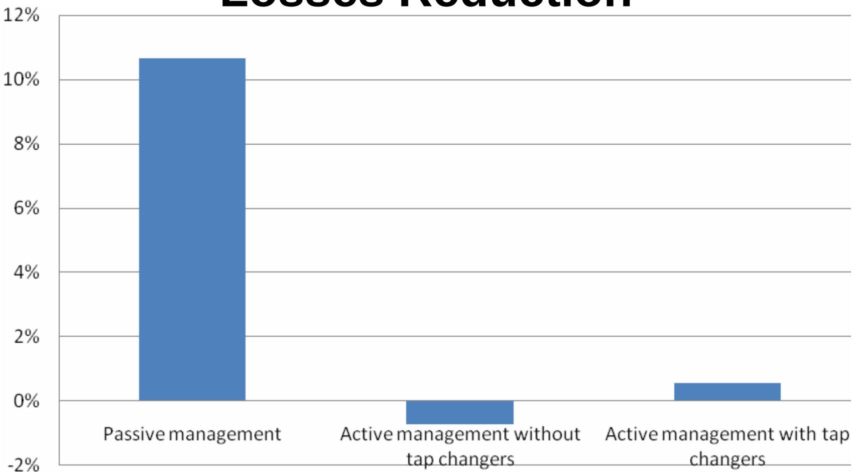
Key outcomes: AM benefits

In cases where voltage problems emerge (e.g. Poland), AM reduces significantly the reinforcement cost, at the expense of higher losses. However, in every case AM is deployed, its overall effect on the total network cost is positive

Reinforcement Cost Reduction

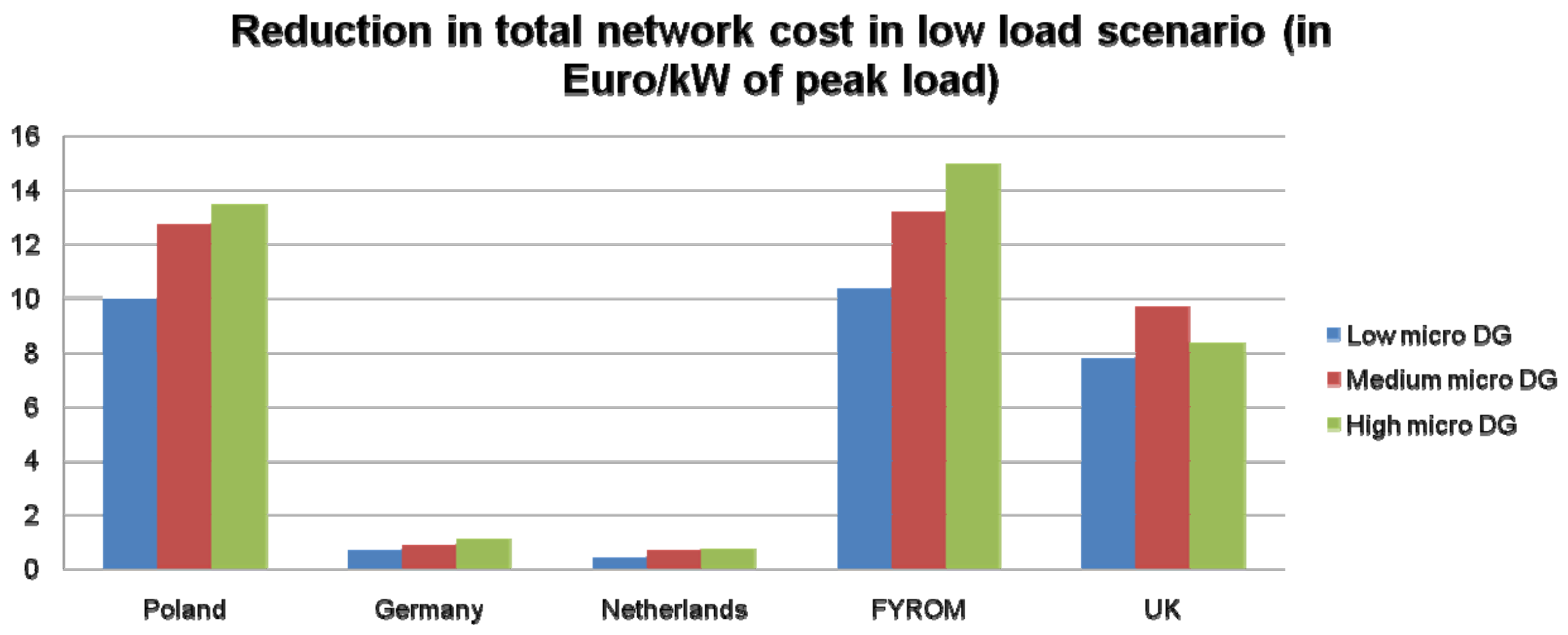


Losses Reduction

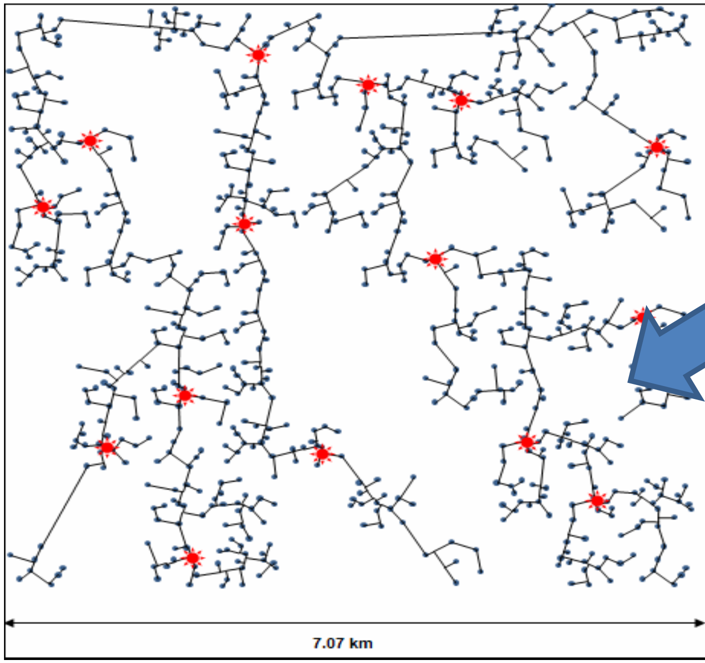


Key outcomes: Parametric analysis

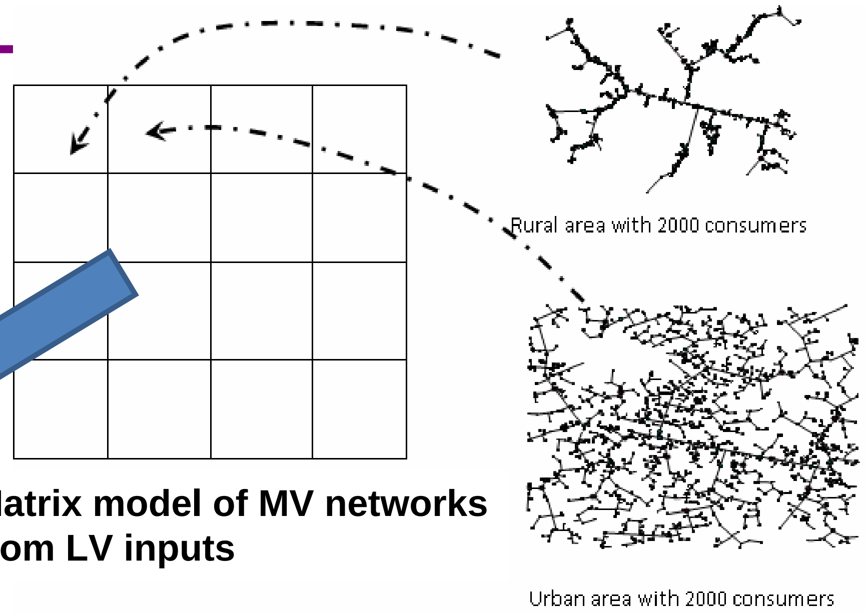
- Significant room for Microgrids to reduce the total network cost in the weaker networks of Poland, FYROM, UK
- The impact is marginal in the stronger Dutch and German networks



Modelling of infrastructure replacement scenarios



MV network with fifteen 33/11 kV substation (UK case) generated from sixty-five LV network inputs

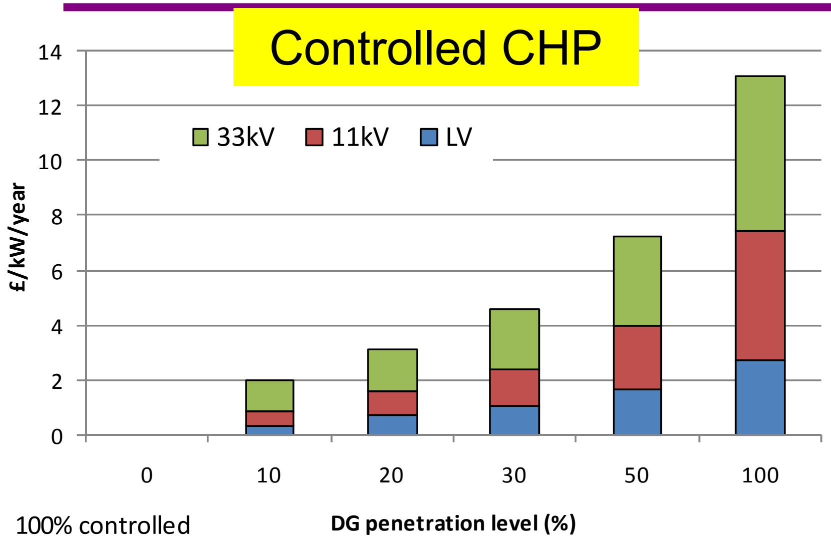


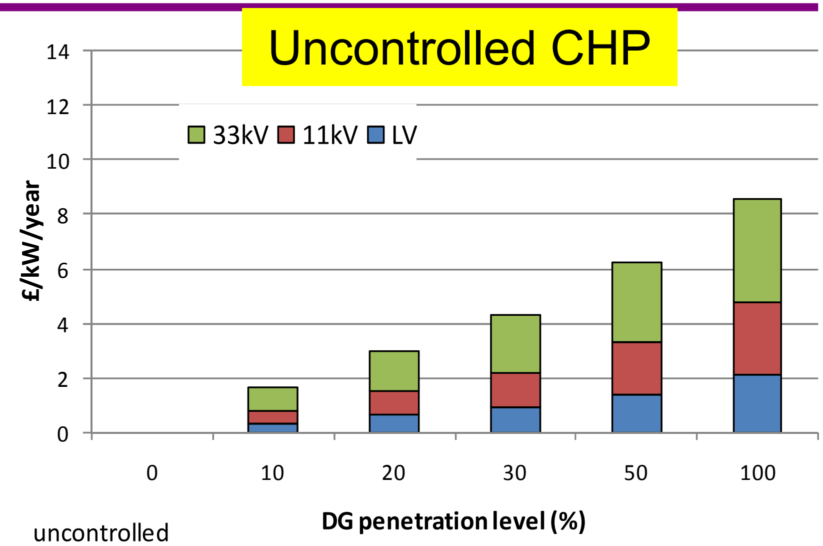
Matrix model of MV networks from LV inputs

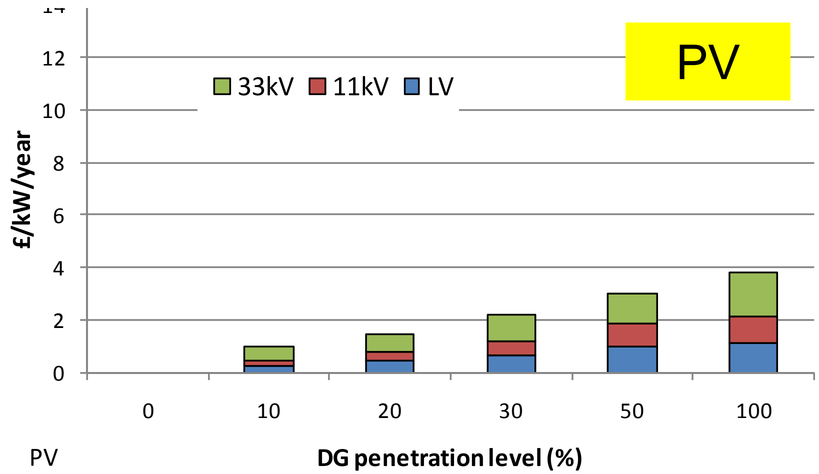
Urban network characteristic	LV	MV
Peak demand [MVA]	5	370
Load density [MVA/km2]	5	3.7
Number of 11/0.4kV subst.	25	1,800
Number of 33/11kV subst.	-	12
Network area [km2]	1	100
Network length [km]	27	322
Number of LV consumers	2,000	150,000

Optimal economic design strategy is used here

Value of DG in urban areas (per voltage levels)







- **Uncontrolled CHP** (heat following) is relatively well correlated
- **Controlled CHP** that modulates its output to follow electricity provides the highest value for avoided network cost
- **PV** is highly uncorrelated generation/demand profile

Percentage of value of DG w.r.t to total network cost (LV, MV, HV)

Total network cost (% of base cost without DG): losses and investment cost of circuits and transformers

Note: Excludes cable installation cost

urban

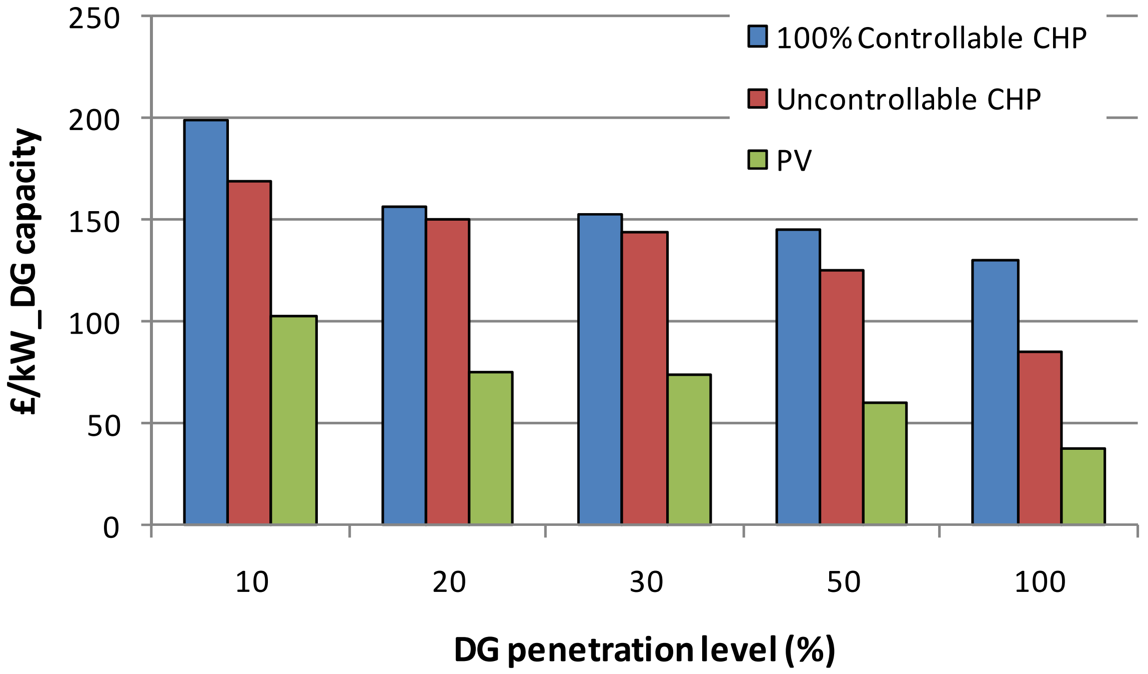
	DG penetration levels (%)					
Scenarios	0	10	20	30	50	100
PV	0.0	2.8	4.2	6.1	8.4	10.6
Uncontrolled CHP	0.0	4.7	8.3	12.0	17.3	23.7
Controlled CHP	0.0	5.5	8.7	12.7	20.1	**36.3**

rural

	DG penetration levels (%)					
Scenarios	0	10	20	30	50	100
PV	0.0	1.2	2.0	2.6	3.3	3.7
Uncontrolled CHP	0.0	3.0	5.4	8.9	14.0	23.2
100% Controlled CHP	0.0	3.3	7.0	11.3	17.4	30.1

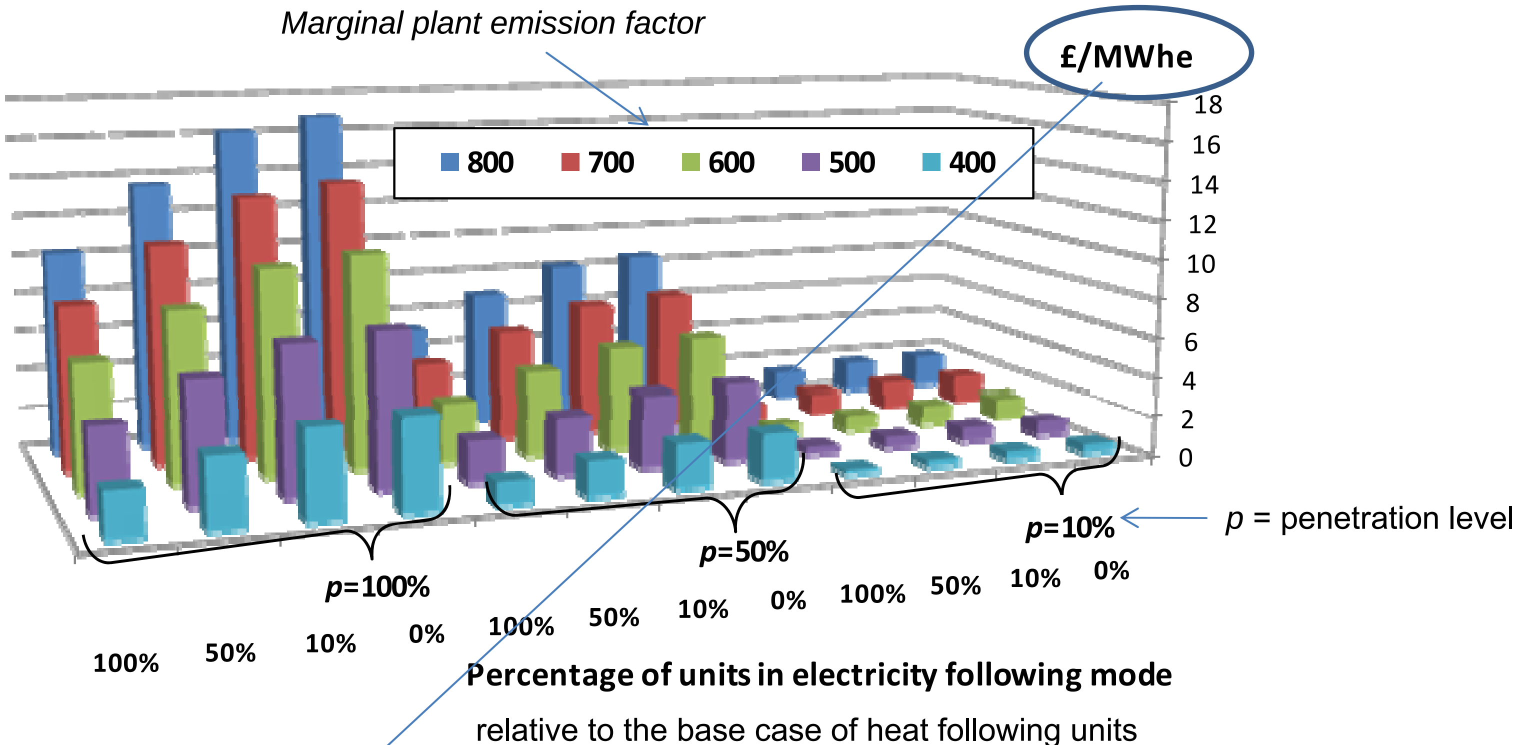
With 100% controlled CHP (fully autonomous Microgrids), about 1/3 of total network cost can be saved

Total specific value of DG (in £/kW of installed DG capacity)



DG provides the highest value (per total installed DG capacity) at lower DG penetration levels and starts to saturate at higher penetrations levels

Environmental benefits (external costs)



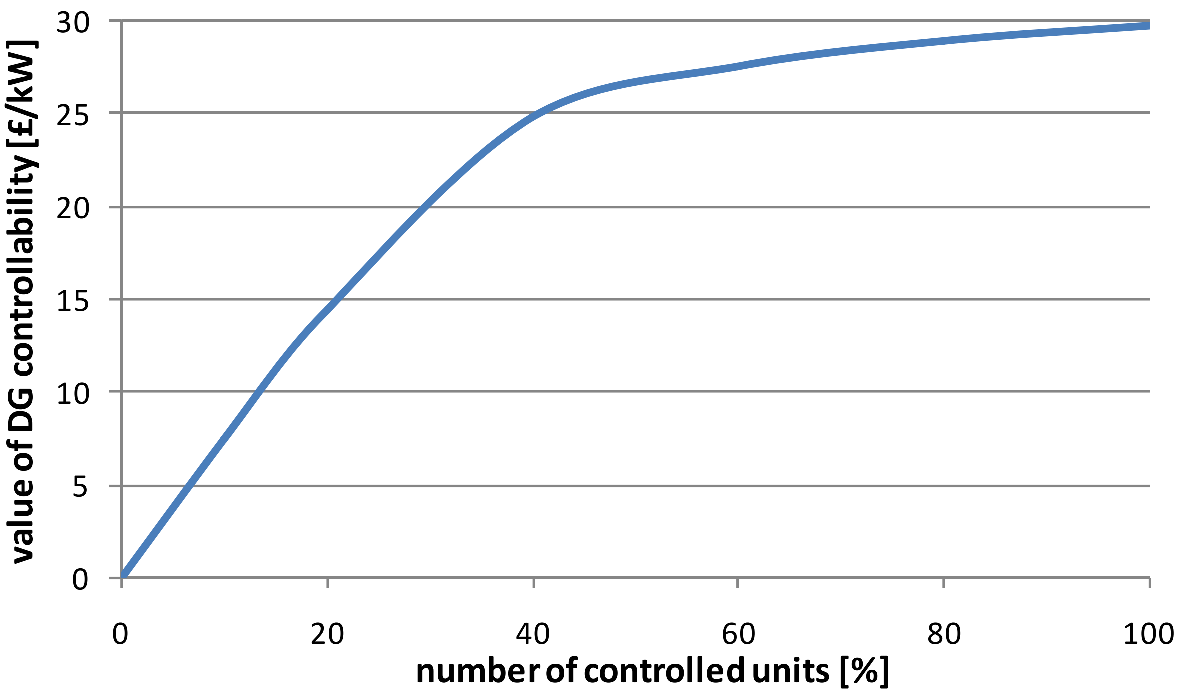
Environmental benefits estimated for a carbon price of 20 £/ton

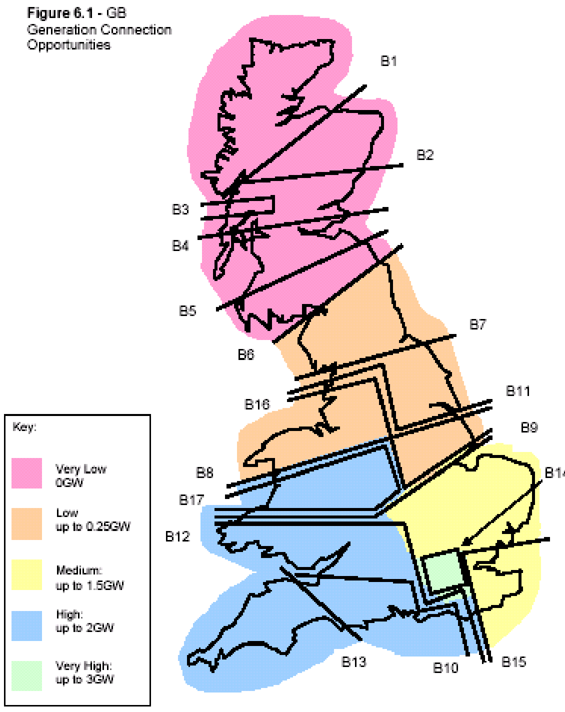
Value of reliability improvement: Allowable expenditure to enable islanding

Customer Sector:		Residential	Commercial
Annual benefit	=	1.4 €/kW_{pk}	15 €/kW_{pk}
Net present value	=	15 €/kW_{pk}	160 €/kW_{pk}
Peak demand	=	2 kW	1000 kW
Perm. expenditure	=	€30	€160,000
MicroGrid (2,000kW)		€30,000	€320,000

Impact on Transmission Networks

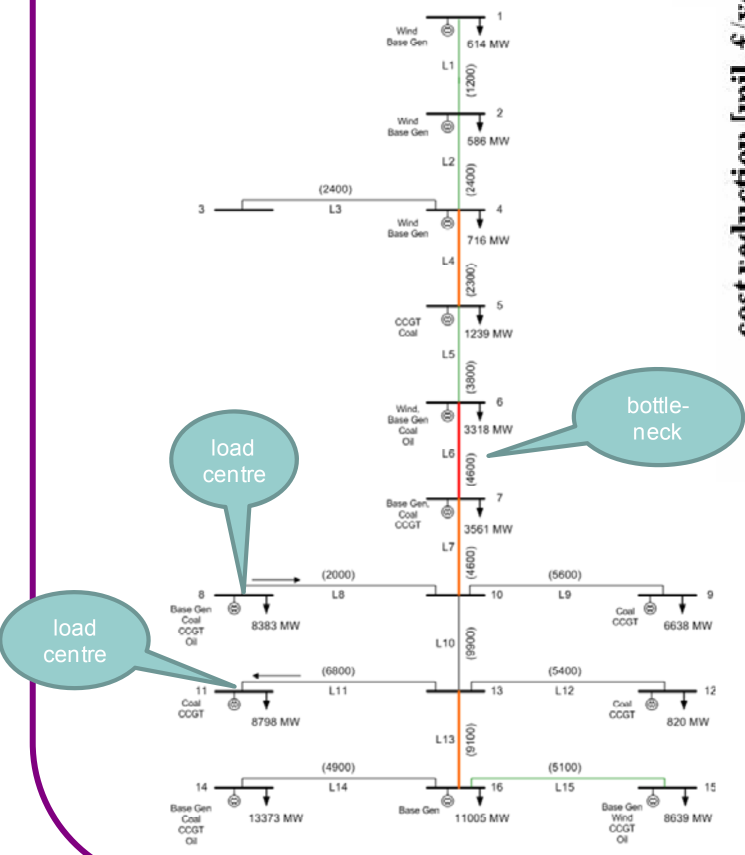
Transmission studies: impact of DG and controllability for network development

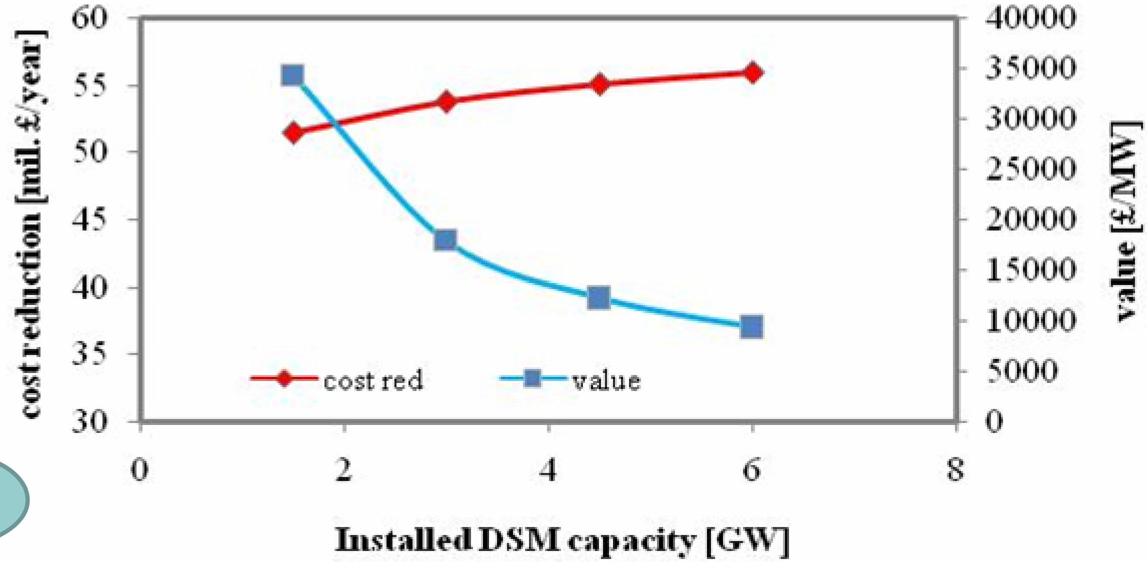




The analysis is based on cost-benefit analysis for optimal transmission development taking into account the trade-off between cost of congestion and cost of losses

Transmission studies: impact of controllable loads for capacity release





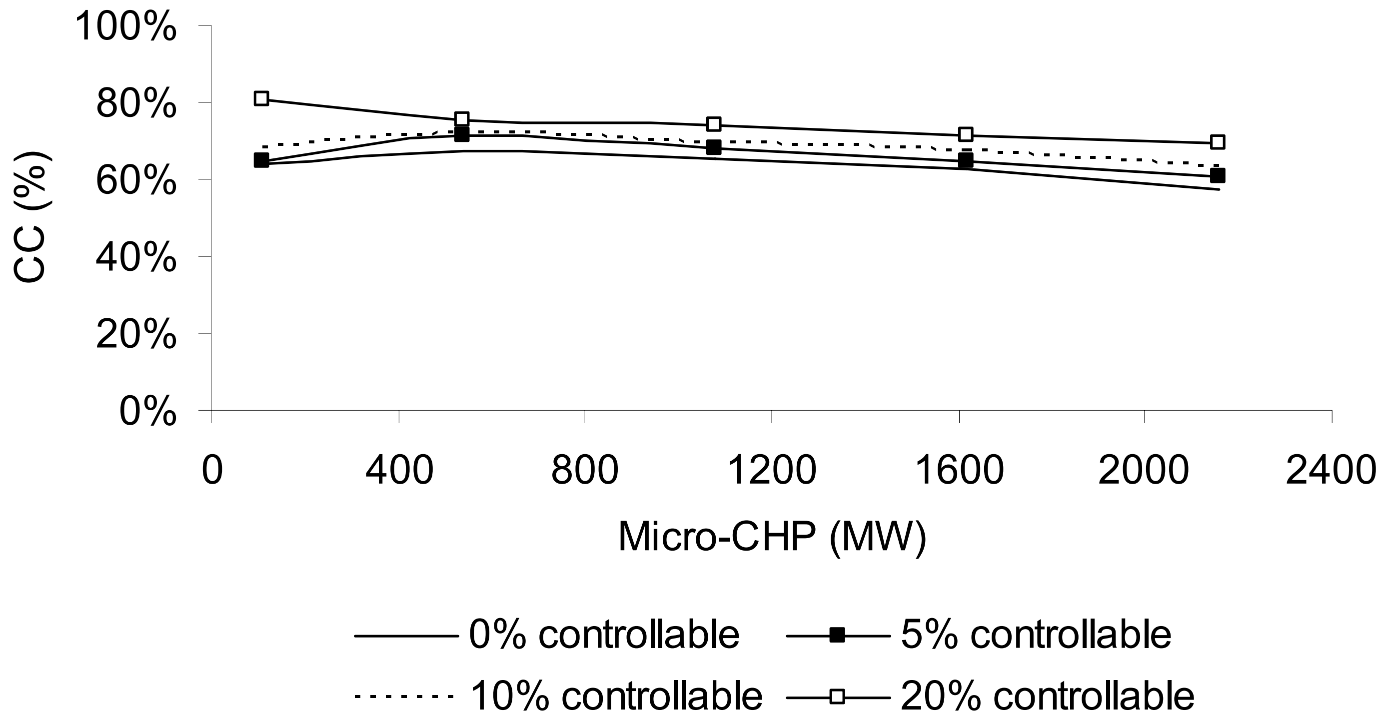
General system data:

- 80 generators, ~95 GW
- Generator capacity range: 8-7874 MW
- Wind generators in buses 1, 2, 4, 6, 15
- Wind generation: 15 GW, 40 TWh
- Peak demand ~68 GW

Impact on Central Generation

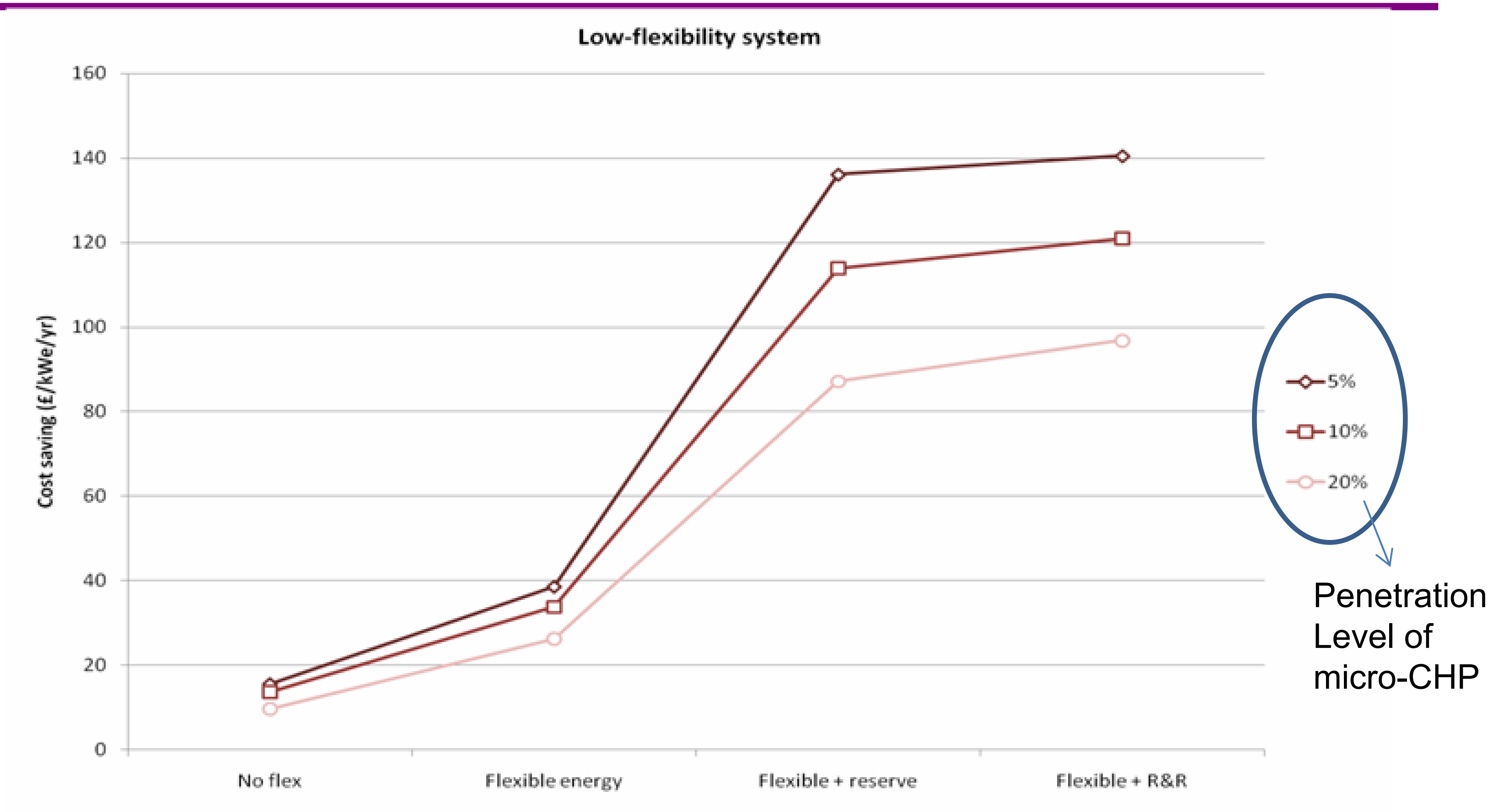
Generation studies: capacity credit

Portuguese study



Effect of controllability of micro-CHP for capacity adequacy purposes

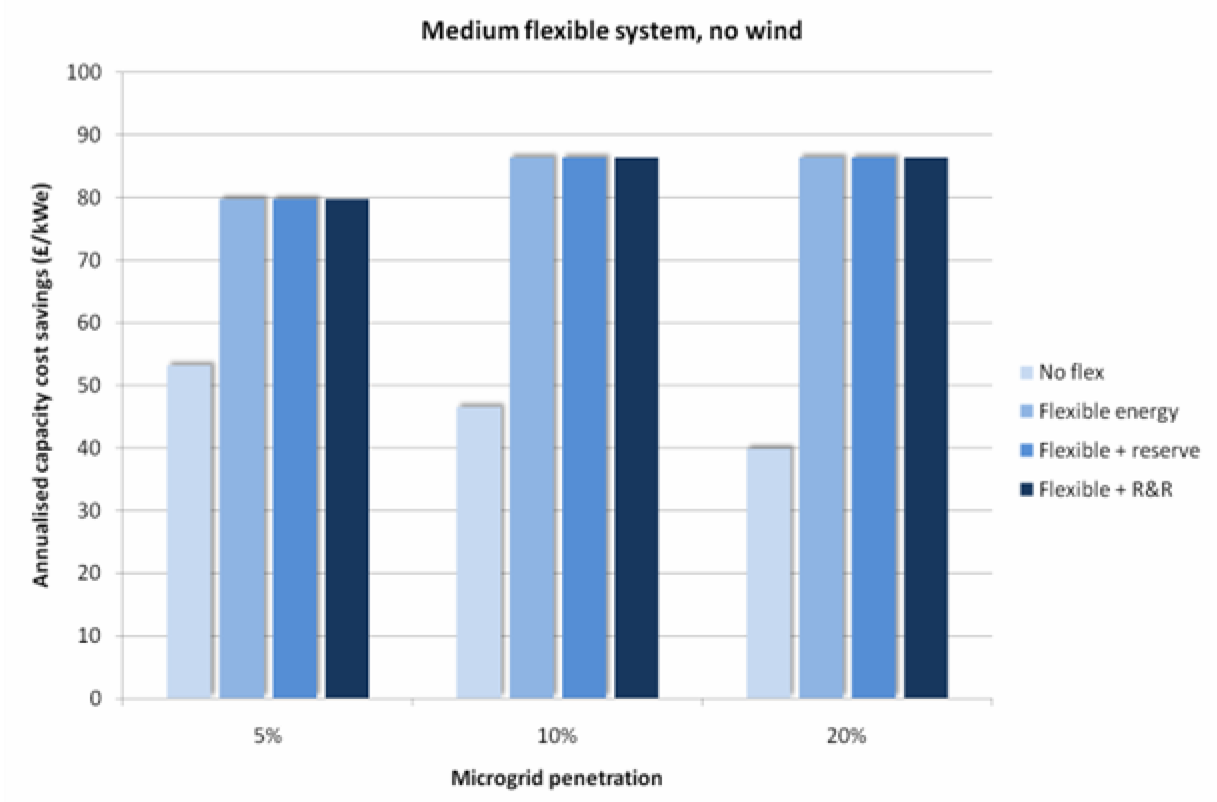
Generation studies: value of the contribution to balancing and reserve



Low-flexible system (CCS-nuclear-wind)

Generation studies: cost savings from displaced conventional capacity

Economic magnitude of the capital cost benefits to be traded off against the installation cost of micro-CHP



Concluding remarks

Network value (Externalities): order of magnitude

Positive externality	Value*
Losses reduction in distribution networks	20-40 €/kW
Investment deferral in distribution networks	80-150 €/kW
Congestion relief/capacity release in transmission networks	100-180 €/kW
Combined Heat and Power (emission benefits)	10-60 €/kW
Energy and environmental efficiency: marginal plants displaced by RES/CHP for energy/balancing services	~ 100 €/kW

* Figures are given per kW of DG installed capacity

Regulation framework: investment and operational incentives

- MicroGrids have the potential to increase utilisation of existing infrastructure and substitute for reinforcements
- The existing regulation incentivises investment over operational alternatives
- This may prevent implementation of technically effective and economically efficient ‘non-network’ solutions, such as Microgrid, as an alternative to the conventional network asset reinforcement based solutions
- Integration of Microgrids will lead to increase in network loading
- Being “smart” may reduce revenue to network operators while potentially increasing risks
- Efficient solutions are commercially unattractive

Summary

- New class of tools for comprehensive assessment of economic and environmental performance of Microgrids
- A number of system-level benefits of Microgrids identified and quantified throughout Europe
  - Network benefits are higher for weaker and more congested networks, and controllable systems broaden the overall range of benefits
  - Benefits to central generation operation are extremely significant for inflexible systems
- New regulatory and commercial framework for facilitating competition between conventional and distributed energy is needed

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