Incentivising the connection of DG: Promoting efficient connection and appropriate benefit sharing

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Contents

1. Introduction

About the UKPN Flexible Plug and Play (FPP) Project and Cambridge Energy Policy Research Group (EPRG):

- EPRG has completed five papers, results of two of these are presented today
- The two papers relate to the benefits that different parties may be entitled for connecting more DG in a specific constrained area (March Grid, operated by UK Power Networks)
  - *"Finding the optimal approach for allocating and realising distribution system capacity: Deciding between interruptible connections and firm DG connections"*

  quantifies the **benefits that DG owners may have for connecting to the distribution grid** under two types of connection: firm connections and non-firm connections

  - *"Opportunities for Distribution Network Operators and Society"*

  measures the **benefits for DNOs and wider societal benefits (from gases emission reduction due to losses reduction,)**

- Total benefits (**societal benefits**) are represented by adding all benefits: (1) DG owners including a share of embedded benefits for generators, (2) DNOs and (3) wider societal benefits including a share of embedded benefits for suppliers .

2.Background – Curtailment

Definition of Curtailment: Any limitation that prevents the generator to export its maximum capacity to the distribution or transmission network

Different possible rules for Allocation of Curtailment (known as a 'Principle of Access' or POA):

- **LIFO (last in first out):** Generators are given a specific order for being curtailed (based on a selected parameter such as the connection date);
- **Pro Rata:** Curtailment is equally allocated between all generators that contribute to the constraint ;
- **Market-Based:** Generators curtailed by offering a market price at which they will accept curtailment .

Each of these incorporates non-firm access.

2. Background-Connections (non-firm, firm)

- **Firm connection**, the traditional connection, allows the export of full generation capacity, but at the same time it is also subject to higher connection costs (especially in case of reinforcement) in comparison with the non-firm connection option.

- **Non-firm or interruptible connection** allows a quicker and cheaper integration of DG by sacrificing the export of full generation capacity.

- The selection of either connection option will depend on the DG business model, and the market and regulatory context.

3. Cost Benefit Analysis Method

NPV=$\sum benefits \; - \; \sum costs$

$$\textbf{\textit{Benefits}} = electricity\ \ revenues + incentives\ (FIT, RO, LEC) + embedded\ benefits + energy\ savings\ (only\ solar\ PV)$$

$$\textbf{\textit{Costs}} = generation\ costs\ (capex + opex) + FPPconnection\ costs + reinforcement\ costs$$

Where:

All benefits and costs are discounted

3. Cost Benefit Analysis Method

Variables

1. Cost variables: CAPEX, OPEX, FPP connection costs, reinforcement costs, business as usual (BAU) connection costs*
2. Revenues: sale of electricity in the wholesale market, subsidies/incentives, energy savings (only for solar PV)
3. Embedded Benefits (EB): (1) generator avoidance balancing system charges, (2) generator transmission loss reduction, (3) distribution use of system charges, (4) supplier avoidance balancing system charges, (5) supplier transmission loss reduction, (6) distribution line loss
4. Technical variables: capacity factor (wind: 30%, solar PV: 9.7%, AD CHP: 84%), PV module degradation (0.55% pa), export rate for PV (85%), losses average transmission (2%), ratio (losses): 45% generator, 55% supplier;
5. Rent and tax: discount rate (10%), corporate tax (21%);
6. Power Purchase Agreement: set for sale of electricity and incentives/subsidies.

* BAU connection refer to the S16 quotation. In this case there is no use of smart solutions and share of reinforcement costs. Based on the minimum scheme which provides the capacity required for new connection at the lowest overall capital cost.

4. Connection Scenarios

- Four scenarios are proposed:
  - Scenario 1: with partial interruptible connected capacity – 100% wind;
  - Scenario 2: with full interruptible connected capacity –100% wind;
  - Scenario 3: with full interruptible connected capacity- a mix of DG generation;
  - Scenario 4: with full interruptible connected capacity and option of network reinforcement – 100% wind.
- Diversity of scenarios:
  - illustrates and assesses different connection options in case of restricted capacity (constrained area);
  - provides insights about the possible solutions (deciding between smart interruptible connections or full connection subject to reinforcement) and the costs of selecting one or other (net present value of each solution);
  - contributes to a better explanation of the different connection situations that generators face in the real world.

4. Connection Scenarios

Table 1: Summary of Scenarios

Scenarios	Non- firm capacity (smart option) (MW)	Firm capacity (reinforcement option) (MW)	# Generators [2/]	Generation Mix wind	solar PV	AD CHP	Curtailment level (%) [3/]
Scenario 1	18 MW	18 MW	5	100%			0.33
Scenario 2	33.5 MW	33.5 MW	7	100%			5.33
Scenario 3	33.5 MW	33.5 MW	11	82.84%	13.43%	3.73%	5.33 (wind), 2.57 (solar PV), 1.73 (AD CHP)
Scenario 4	33.5 MW	90 MW [1/]	7 (20)	100%			5.33

[1/] Due to the addition of 56.5 MW (33.5+56.5=90 MW) by 2019/2020. [2/] In Scenario 4 the number of generators is 20 after the period 2019/20

[3/] Only applicable to non-firm (smart) connections. In Scenario 4 this % is only valid up to the period 2019/20. After this, a firm connection if offered.

4. Connection Scenarios (detail)

- Assumptions:
  - All scenarios refer to a specific constrained area (March Grid) operated by UK Power Networks, the largest DNO in the UK (with 8.1m customers) ;
  - Total interruptible capacity quota: 33.5 MW (maximum interruptible capacity offered to generators under Pro Rata). After fulfilling this capacity a LIFO approach would be applicable;
  - Fixed demand across the four scenarios;
  - Only one level of curtailment across scenarios (maximum curtailment level that depends on technology). Different generators have different generation patterns;
  - Curtailment level with full interruptible capacity quota: 5.33% (wind), 2.57% (solar PV), 1.73% (AD CHP);
  - The number of generators and their capacity based on the list of generators provided by UK Power Networks;
  - Export capacity (85%) only in case of solar PV.

4. Connection Scenarios

Table 2: Generators' Figures (capacity, curtailment, costs)

Generators			Scenario 1	Scenario2	Scenario 3	Scenario 4		Costs (2012 prices)	
No	Type of generator	Capacity (MW)	Estimated curtailment - annual MWh	Estimated curtailment - annual MWh	Estimated curtailment - annual MWh	Estimated curtailment (2014-2019/20) - annual MWh	Estimated curtailment (2019/20 onwards) - annual MWh	connection costs (BAU offer) £	FPP smarter connection costs £
1	wind	0.5	4	70	70	70	0	1,900,000	234,779
2	wind	1	9	140	140	140	0	2,000,000	384,711
3	wind	1.5	13	210	210	210	0	1,900,000	157,137
4	wind	5	43	700	700	700	0	1,200,000	649,788
5	wind	10	86	1,400	1,400	1,400	0	4,800,000	590,817
6	wind	7.2		1,008	1,008	1,008	0	3,456,000	425,388
7	wind	8.3		1,162		1,162	0	3,984,000	490,378
8	wind	2.55			357			3,230,000	267,133
9	solar PV	4.5			113			1,080,000	233,916
10	AD CHP	0.5			64			1,900,000	350,000
11	AD CHP	0.5			64			2,500,000	100,000
12	AD CHP	0.25			32			2,205,750	117,450
13	wind	0.5					0	1,900,000	234,779
14	wind	1					0	2,000,000	384,711
15	wind	1.5					0	1,900,000	157,137
16	wind	5					0	1,200,000	649,788
17	wind	10					0	4,800,000	590,817
18	wind	7.2					0	3,456,000	425,388
19	wind	8.3					0	3,984,000	490,378
20	wind	0.5					0	1,900,000	234,779
21	wind	1					0	2,000,000	384,711
22	wind	1.5					0	1,900,000	157,137
23	wind	5					0	1,200,000	649,788
24	wind	10					0	4,800,000	590,817
25	wind	5					0	1,200,000	649,788

5. Distribution of Benefits

- **Benefits of connecting DG are distributed as follows:**
  - **DG owners**
    - For all scenarios, profits from connecting DG units (revenues – costs; inc. generator share of embedded benefits, less suggested smart connection fee)
  - **DNO**
    - DG incentives
    - We also suggest smart connection fee (only for non-firm connections)
  - **Wider society (suppliers and consumers)**
    - Supplier (and hence customer) share of embedded benefits (less DNO DG incentives paid by consumers)
    - Emissions decrease due to losses reduction

5. DG owners' Benefits

- **Summary of Results (Scenario 1, 2, 3 and 4) – NPV**

Table 3: Summary of Results*

Scenarios	With Embedded Benefits			Without Embedded Benefits		
	Smart connection option	Reinforcement connection option	Business as Usual	Smart connection option	Reinforcement connection option	Business as Usual
Scenario 1						
NPV(£m)	4.84	1.55 (3/5)	-3.15 (2/5)	4.48	1.19 (3/5)	-3.50 (2/5)
NPV(£m/MW)	0.27	0.09	-0.17	0.25	0.07	-0.19
Scenario 2						
NPV(£m)	3.04 (4/7)	2.49 (4/7)	-7.6 (2/7)	2.41 (4/7)	1.83 (4/7)	-8.26 (2/5)
NPV(£m/MW)	0.09	0.07	-0.23	0.07	0.05	-0.25
Scenario 3						
NPV(£m)	5.61 (9/11)	4.91 (9/11)	-10.43 (2/11)	5.00 (9/11)	4.27 (9/11)	-11.07 (2/11)
NPV(£m/MW)	0.17	0.15	-0.31	0.15	0.13	-0.33
Scenario 4						
years		2019 2020			2019 2020	
NPV(£m)		16.49 15.91			15.14 14.62	
NPV(£m/MW)		0.35 0.34			0.32 0.31	

*Embedded benefits refer only to generator share of these benefits.
Numbers in parentheses are number of individual projects with positive NPV.

5. DNO Benefits

Total DNO Benefits: DG Incentives and a proposed Smart Connection Fee

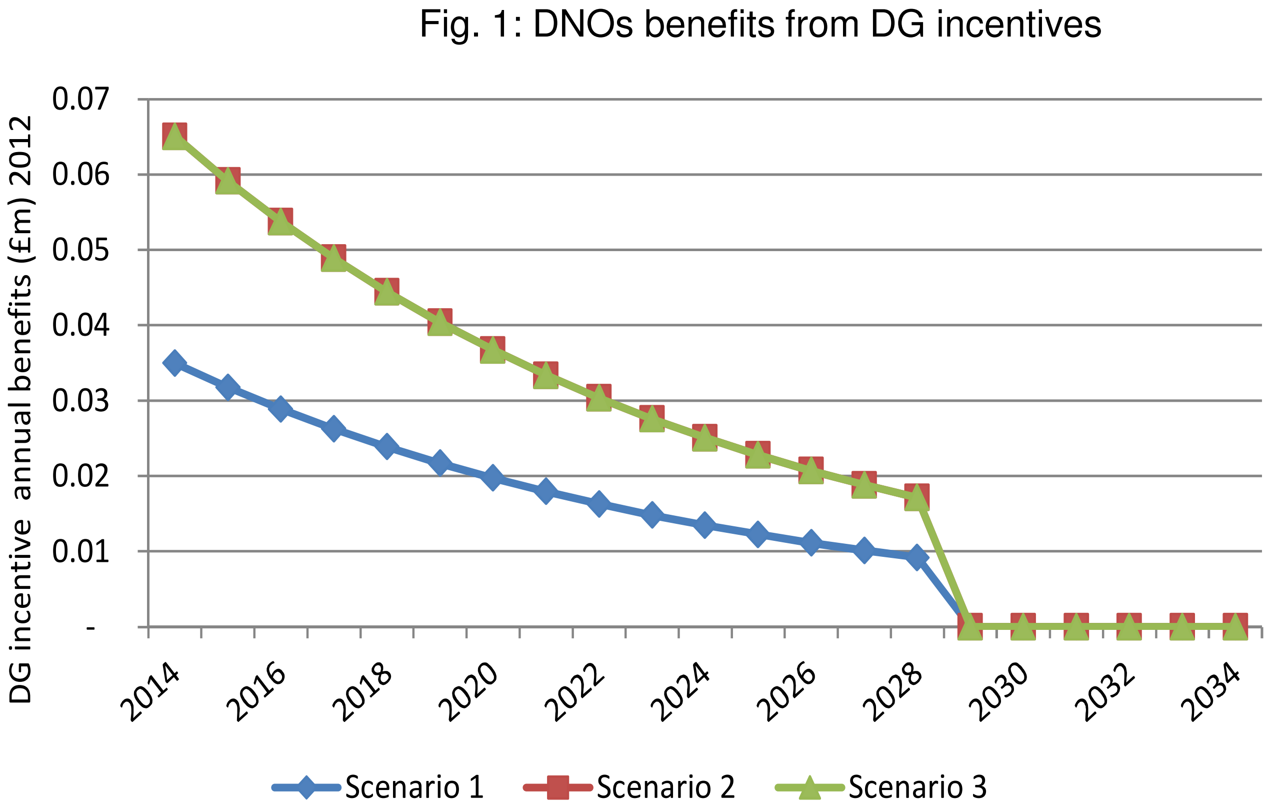
a. DG Incentives (cost-recovery mechanism)

- Designed to encourage efficient and economic investment: reduce the risk to DNOs and customers of bad forecasts
- To be removed in April 1st , 2015 (RIIO- ED1)
- Two types of incentives have been considered (for DG units connected before April 2015):
  - Capacity incentive (£1.00/kW/yr)
  - O&M allowance (£1.00/kW/yr)

Both incentives regardless of the use of system capex (e.g. reinforcement)

5. DNO Benefits

a. DG Incentives (results) – annual benefits



NPV:
£0.3m
(Scenario 1)

£0.53m
(Scenarios 2, 3)

5. DNO Benefits

b. We propose a *one off* smart connection fee.

- The propose of this is to recreate the benefits from the losses incentive (now removed), which was £48.42 / MWh saved (2012/13 prices)

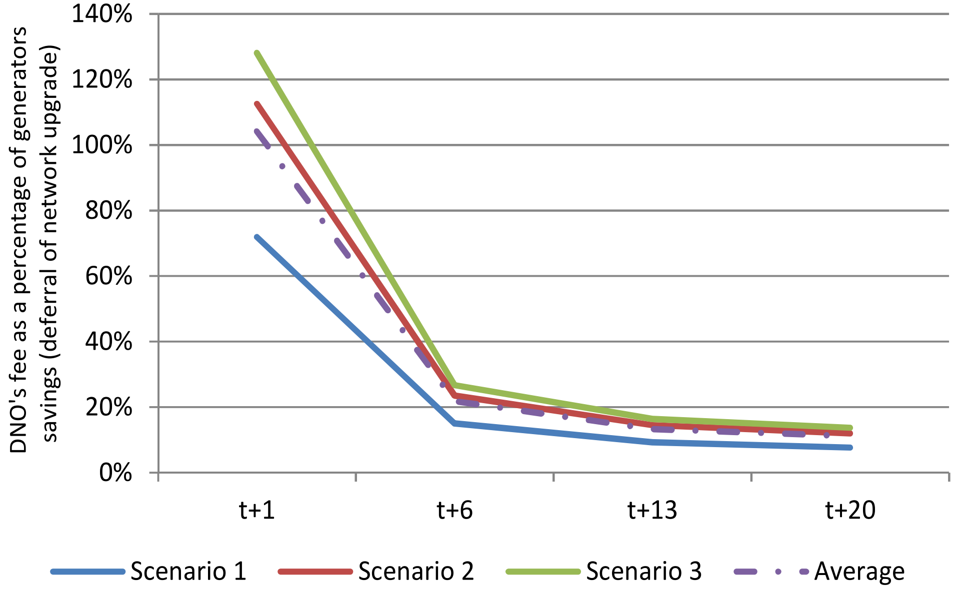
- We compare this fee with the value of deferring a network upgrade of £4.1m from time t to time t+i, where i=1 up to 20 years (using a 10% discount rate).

5. DNO Benefits

b. Example smart connection fee:

- Smart connection fee: £12,300/MW (Scenario 1), £10,349/MW (Scenario 2) and £11,776/MW. **Average: £11,475/MW** (based on Ofgem (2003)).
- Looking at how reasonable this is:
  - DNO's fee as % of savings due to deferral of investment varies based on the year when the network upgrade is made (t+1,…., t+20)
  - Smart connection fee (as % of total reinforcement costs) varies from 7.7% (Scenario 1, t+20) to 128% (Scenario 3, t+1)

Fig. 2 Smart connection fee as percentage of total savings for network investment deferral

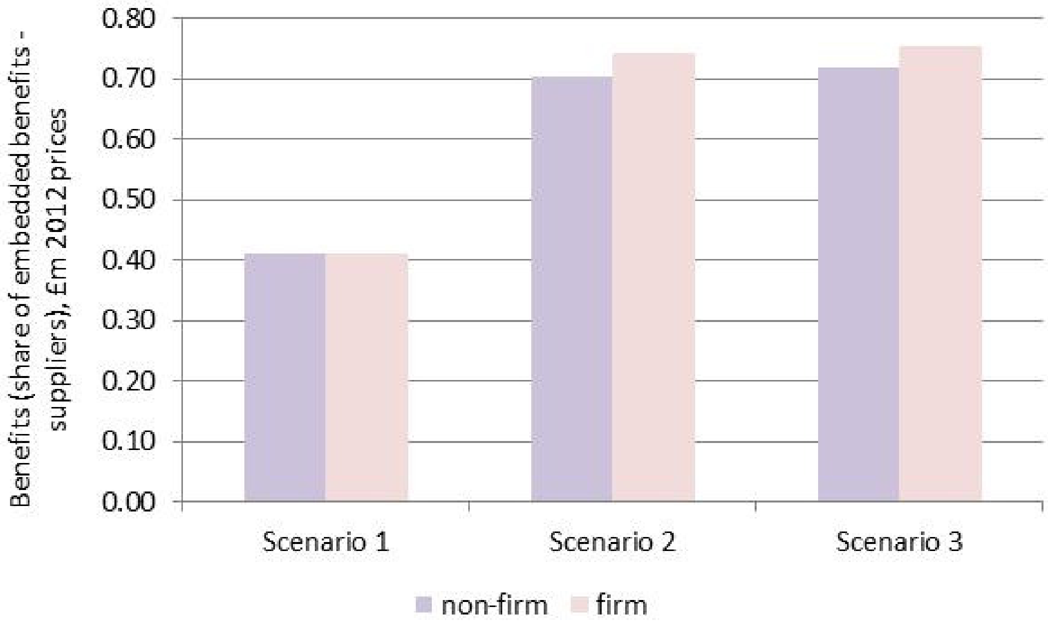


5. Wider society benefits (suppliers and customers)

a. Benefits from share of embedded benefits (suppliers)

- There are two associated losses benefits (transmission and distribution losses)
- Distribution line losses benefits estimated based on OFGEM (2003)

Fig. 3: Benefits from share of embedded benefits – suppliers (from CBA)

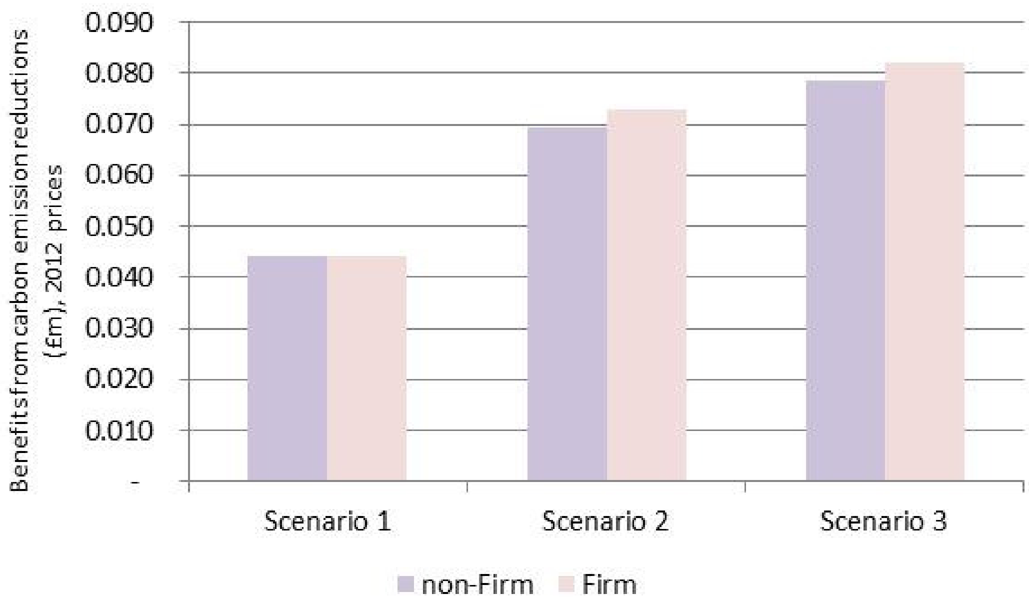


5. Wider society benefits (suppliers and customers)

b. Benefits from carbon emission reductions due to losses reduction

- GHG conversion factor (kg CO2 emission/MWh): 0.532 (2014) to 0.242 kg CO2/MWh (2034)
- Traded carbon price (DECC): 6.74 (2014) to £110.2/t CO2 (2034)
- In agreement with OFGEM (2003) distribution losses and OFGEM Cost Benefit Analysis (CBA) modelling for RIIO ED1

Fig. 4: Benefits from carbon emission reductions



6.Total benefits (societal benefits)

Table 4: Societal benefits

Parties	Type of benefit	Unit	Scenario 1	Scenario 2	Scenario 3
DG owners	Non-firm connections (going smarter)	£m	4.48	2.41	5.00
	Embedded benefits (generators)	£m	0.35	0.63	0.62
	(-) Smart connection fee	£m	-0.22	-0.35	-0.39
DNO	DG incentives	£m	0.33	0.62	0.62
	Smart connection fee	£m	0.22	0.35	0.39
Wider society	Embedded benefits (suppliers)	£m	0.41	0.70	0.72
	Carbon emission reductions	£m	0.04	0.07	0.08
	(-) DG incentives	£m	-0.33	-0.62	-0.62
Total societal benefits		£m	**5.29**	**3.81**	**6.41**
		£/MW	**0.29**	**0.11**	**0.19**

7. Final Remarks

About the distribution of benefits:

- DG owners benefit the most from smarter connections.
- N.B. from 2015 there will be no benefit to DNOs from smart connection.
- DNOs should be allowed to charge DG owners. A smart connection fee should be an option, especially when DG incentives are removed.
- Incentives/subsidies paid by wider society are more than their direct benefits (from losses and carbon savings), but reflect learning benefits of strategic deployment and cost of achieving the EU renewables target.

About our CBA:

- This is not a full social cost benefit analysis. Social discount rates and full economic costs need to be used/included.
- Results are subject to a range of uncertainty due to some static assumptions related to generation mix (and the associated curtailment levels), timescale of network upgrades and demand growth.
- Results represent a conservative estimate of individual project value based on the simultaneous connection of all other projects.

7. Final Remarks

- Substantial benefits from smart connection arrangements over conventional alternative for all generators below maximum available network capacity.
- Towards maximum available network capacity, smaller generators might prefer to share reinforcement costs over smart connection.
- Pro-Rata curtailment may encourage too much connection behind a constraint boundary.
- However there is substantial value from smarter connection if it accelerates connection and early reinforcement.
- This implies Pro-Rata may be better than LIFO in medium run.

- ***Smart commercial arrangements need further investigation*, as the savings in costs and the benefit to DG acceleration appear to be substantial.**

- ***However the benefits of faster, smarter connection need to be shared out better, in a way that all parties (particularly DNOs and wider society) clearly benefit.***

References

- Anaya, K. and Pollitt, M. (2012), *Experience of the use of smarter connection arrangements for distributed wind generation facilities.* [Online]. Available: http://www.ukpowernetworks.co.uk/internet/en/innovation/documents/FPP_International_Experience_Report_v1.0_final_281212.pdf
- Anaya, K. and Pollitt, M. (2013), *Understanding best practice regarding interruptible connections for wind generation: lessons from national and international experience.* EPRG WP 1309, University of Cambridge. [Online]. Available: http://www.eprg.group.cam.ac.uk/wp-content/uploads/2013/05/1309-Final.pdf
- Baringa – UK Power Networks (2012), *Flexible Plug and Play: Principle of Access*, December 2012.
- Baringa – UK Power Networks (2013), *Flexible Plug and Play: Reinforcement quota calculation for March Grid*, February 2013.
- Currie et al. (2011), *Commercial arrangements to facilitate active network management. Presented at 21st Int. Conf. on electricity distribution (CIRED).* [Online]. Available: http://www.cired.net/publications/cired2011/part1/papers/CIRED2011_1186_final.pdf
- DECC (2011a) "UK Renewable Energy Roadmap 2011", in Department of Energy and Climate Change, London.
- DECC (2011b), "Consultation on proposal for the levels of banded support under the Renewable Obligation for the period 2013-17 and the Renewable Obligation Order 2012", Department of Energy and Climate Change, London.
- DECC (2012a), "Solar PV cost update". Prepared by Parsons Brinckerhoff, Department of Energy and Climate Change, London.
- DECC (2012b), "Government response to the consultation on proposals for the levels of banded support under the Renewables Obligation for the period 2013-17 and the Renewables Obligation Order 2012", Department of Energy and Climate Change, London.
- Elexon (2012), Information Sheet. Overview of Transmission Losses.
- ENA (2011), "Distributed generation connection guide. A guide for connecting generation that falls under G59/2 to the distribution network", Version 3.3, Energy Networks Association, London.
- Energy and Climate Change Committee (2012), "The economics of wind power: Written evidence", UK Parliament, London.
- OFGEM (2003), "Electricity distribution losses: A consultation document", Office of Gas and Electricity Market, London.
- OFGEM (2009), "Electricity distribution price control review. Final proposal – Incentives and Obligations", Office of Gas and Electricity Market, London.
- OFGEM (2013a), "The Renewables Obligation buyout price and mutualisation ceiling 2013/14. Information Note", Office of Gas and Electricity Market, London.
- OFGEM (2013b), "Strategy decision for the RIIO-ED1 electricity distribution price control. Outputs, incentives and innovation. Supplementary annex to RIIO-ED1 overview paper", Office of Gas and Electricity Market, London.
- Pöyry (2013), "Potential impact of revised Renewable Obligation technology bands: updated modelling", Pöyry Management Consultancy, Oxford.
- UK Power Networks (2013), "Innovation update," Issue 2, Spring 2013, UK Power Networks, London.

Appendix: Smart Connection Fee

Assumptions for estimation of our example level of Smart Connection Fee:

- Estimated based on benefits from losses incentive to DNOs;
- Accordingly to OFGEM (2003), the share of distribution losses is 19% (132kV), 14% (33kV), 34% (11 kV) and 34% (LV);
- If a generator is connected at 33kV, electric losses are 19% of the average distribution losses;
- If a generator is connected at 11kV, electric losses are 33% (19%+14%);
- Average distribution losses: 4.89% (Easter Power Networks, period 2005/06-2009/10);
- Example: wind farm (0.5MW, connected at11kV) generates 1,310 MWh pa, annual losses would be 64.05 MWh (1,310*4.89%), thus losses reduction are 21.13 MWh pa (64.05*33%)
- Same procedure is applied for the rest of generators (across Scenarios: 1, 2, 3)
- Losses reduction value at £48.42 MWh (OFGEM)