Derivation of Economic Incentives for Grid Operators in the Grid Regulation Process to Favour DG/RES-E Grid Integration

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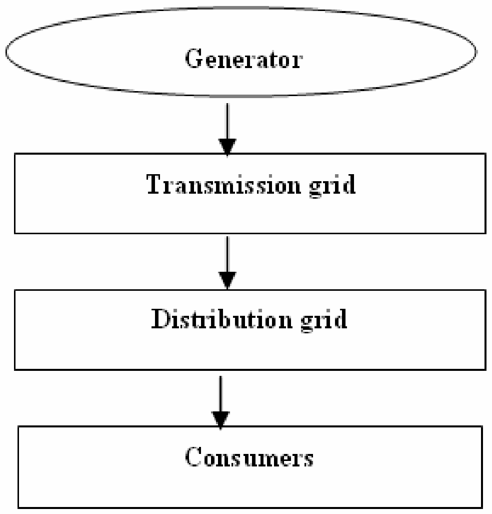
Agenda

1. Increasing Relevance of Distributed (DG/RES-E) Generation
2. The Grid Connection/Access Boundary Question
3. The Problem of Asset Stranding for Distribution Grid Operators
4. Forward-looking Regulatory Framework Supporting Large-Scale DG/RES-E Integration
5. Outlook: The Future Vision of Smart Grids

1. Increasing Relevance of Distributed (DG/RES-E) Generation

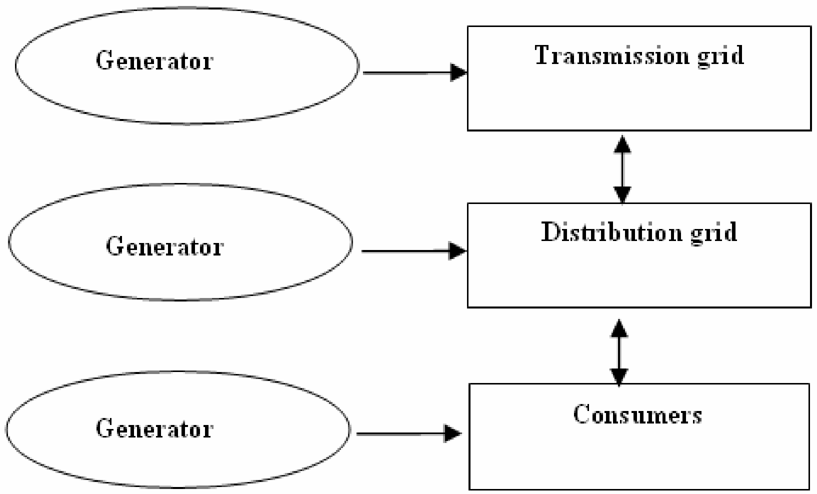
1.1 The Changing Role of Electricity Grids

Change of paradigm towards significant distributed (DG/RES-E) generation also in the medium (MV) and low (LV) voltage distribution grids (i.e. generation closer at the consumers).



Status Quo

Centralised Electricity System



Future

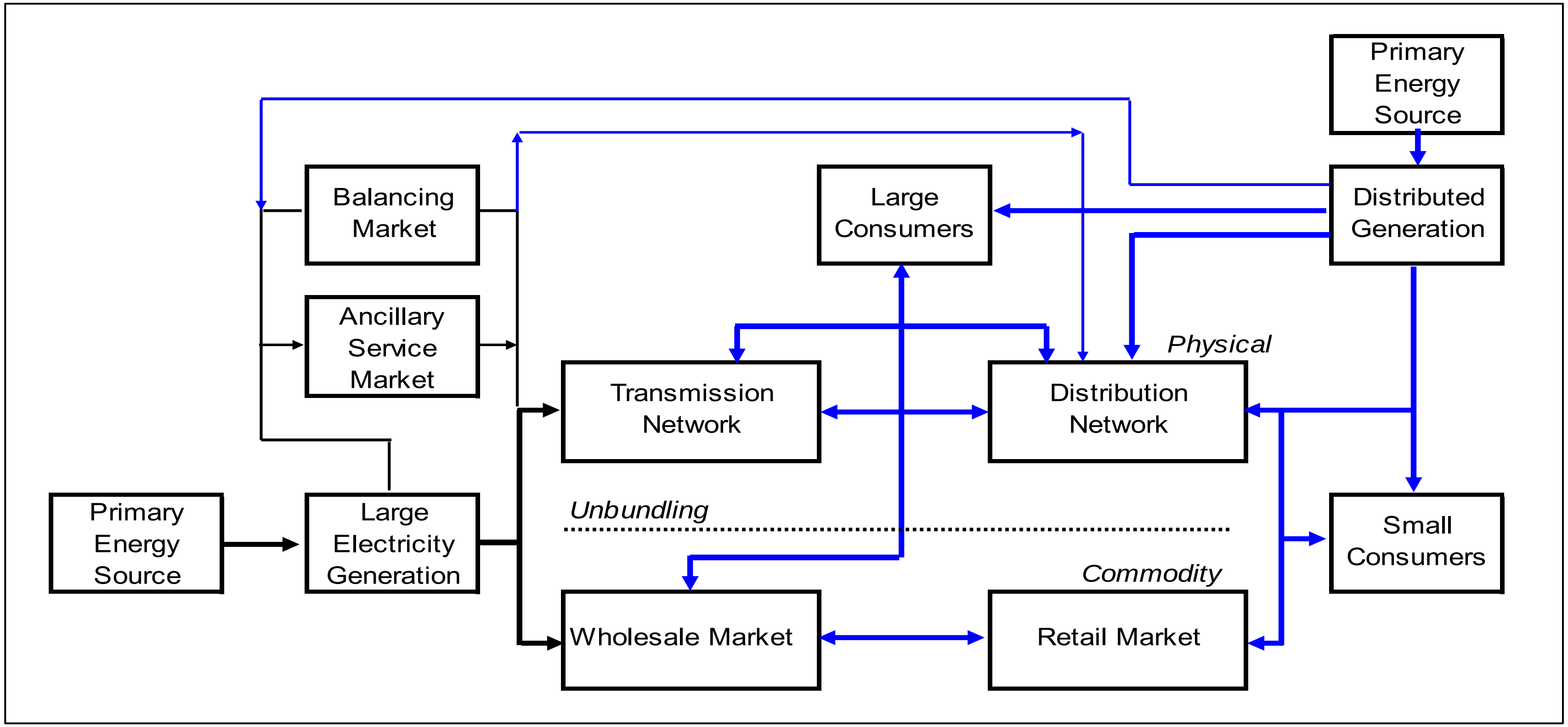
Decentralised Electricity System

1.2 Benefits of Distributed (DG/RES-E) Generation

Distributed generation significantly…

- **reduces losses and postpones necessary network investments;**
- **enhances security of energy supply (because dispersed generation is located closer to demand centres);**
- **contributes in meeting demand growth;**
- **assists in meeting climate change objectives (RES generation; increased primary fuel efficiency due to CHP generation; reduction of network losses due to more dispersed generation);**
- **contributes to market entry and competition (in general, as more players enter the generation market, competition increases, with a consequential benefit in downward pressure on consumer prices);**

1.3 Impact of Distributed (DG/RES-E) Generation on the Liberalised Electricity Market



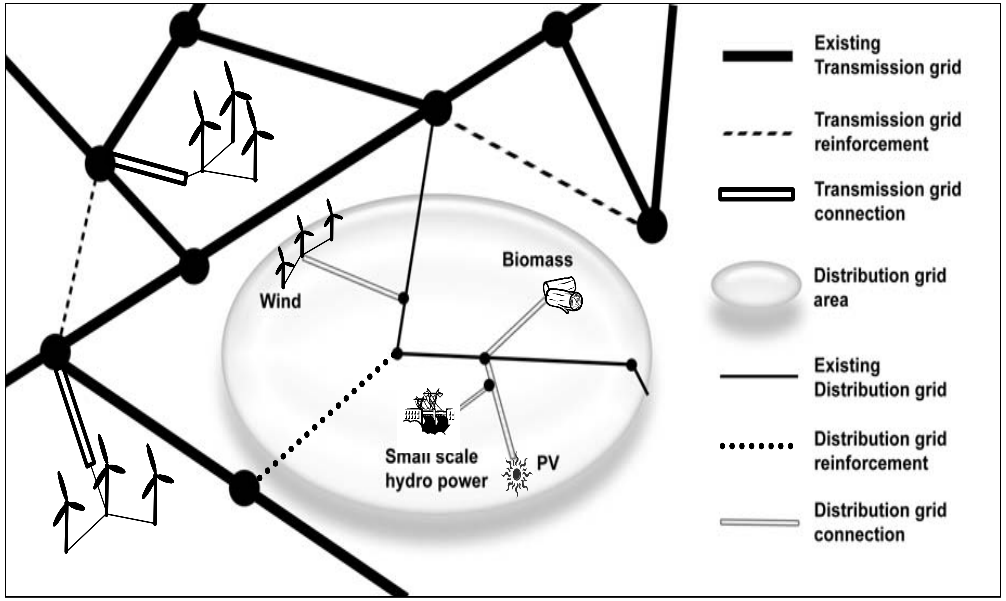
<u>Decentralised system:</u> Most important segments in the physical and commodity market

Source: van Werven/Scheepers (2005)

2. The Grid Connection/Access Boundary Question

2.1 The Role of Unbundling

- Grid connection may be a significant economic barrier for DG/RES-E developers in dispersed locations.
- If the new DG/RES-E developer has to pay all the cost of grid connection up-front, then a compromise between best generation sites and acceptable grid connection conditions has to be made.
- If grid connection / grid reinforcement cost are covered by the grid operator and the cost are socialized in the grid tariffs, then the initial burden does not fall on the DG/RES developer.

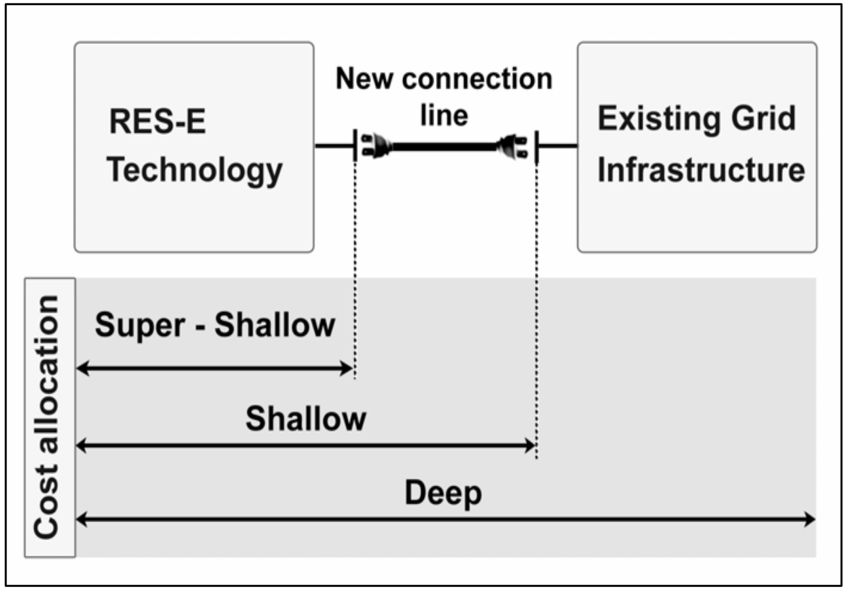


Large-Scale DG/RES-E Integration expects new Grid Connection and Grid Reinforcement/Extension Infrastructure Elements

2.2 Different Grid Connection Boundaries for DG/RES-E Generators

Possible grid connection boundaries between the DG/RES-E generation facilities and the grid infrastructure:

- **<u>“Deep” Integration:</u> DG/RES-E developer bears several extra grid-infrastructure related DG/RES-E integration cost (i.e. grid connection as well as grid reinforcement/extension cost) and includes them into the total DG/RES-E project cost.**
- **<u>“Shallow” Integration:</u> DG/RES-E developer bears the grid connection cost, but not the grid reinforcement/ extension cost (they are socialised in the grid tariffs).**
- **<u>“Super-Shallow” Integration:</u> This is supposed to be the most convenient approach for the DG/RES-E developers since neither the grid connection cost nor the grid reinforcement/ extension cost are borne by them.**



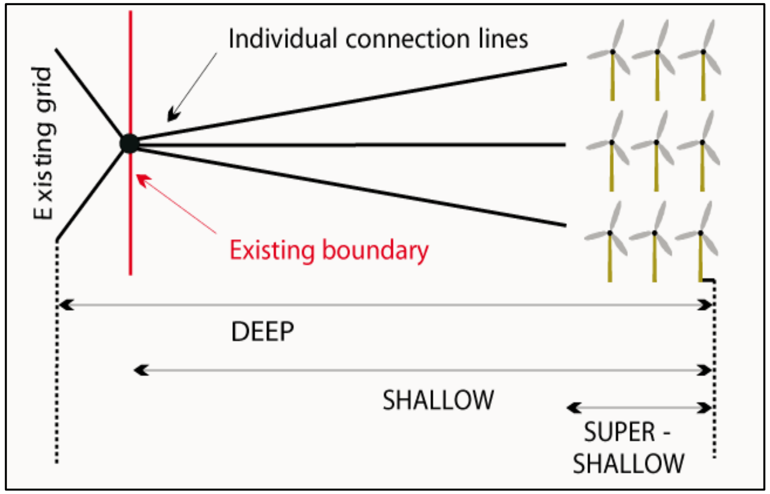
DG/RES-E grid integration and cost allocation policy in the 'old' EU15 Member States in 2007

	RES-E grid integration cost allocation scheme	Max. grid connection cost	Cost transparency
Austria	Deep	10% of investment	Low
Belgium	Hybrid	5-10% of investment	High
Denmark	Shallow	5-10% of investment	High
Finland	No standardised approach	-	Medium
France	Hybrid	10-20% of investment	Medium
Germany	Hybrid	-	Low
Greece	Hybrid	-	Low
Ireland	Deep	3-8% of investment	High
Italy	Deep	-	Low
Luxembourg	Deep	-	Low
Netherlands	Hybrid	-	High
Portugal	Deep	15% of investment	Medium
Spain	Deep	-	Low
Sweden	Deep	10% of investment	Low
UK	Hybrid	8-12% of investment	High

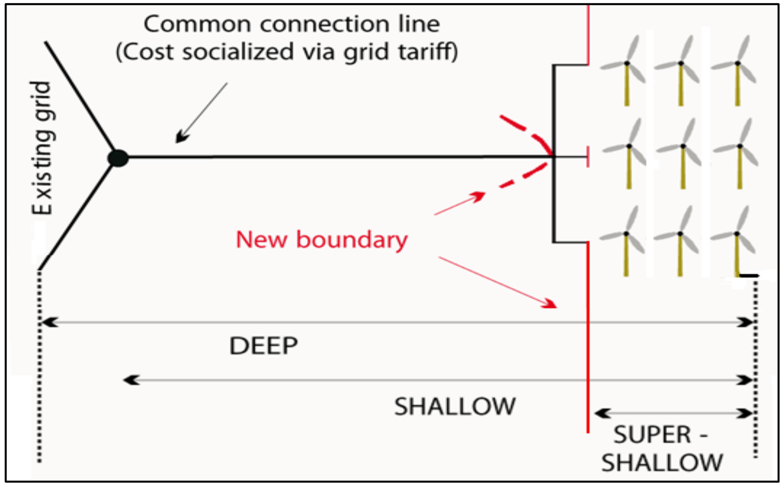
Offshore Wind Integration: "Super-shallow" Approach with Common Connection Line

If $C_{Transmission,i}$ are the offshore transmission grid connection cost of an individual wind farm i in case of separate grid connection (left Figure below) and $C_{Transmission,common}$ the common offshore transmission grid connection cost of all wind farms (c_i is the individual short distribution grid component of wind farm i; right Figure below) the following relationship exists

$$C_{Transmission,common} + \sum_{i=1}^{n} c_i < \sum_{i=1}^{n} C_{Transmission,i}$$



Separate offshore grid connection of each individual offshore wind farm (not recommended)



Common offshore grid connection of several offshore wind farms (recommended)

2.3 The Locational Signal Aspect in the Context of DG/RES-E Integration

“Deep” Integration: Ideal versus Real World

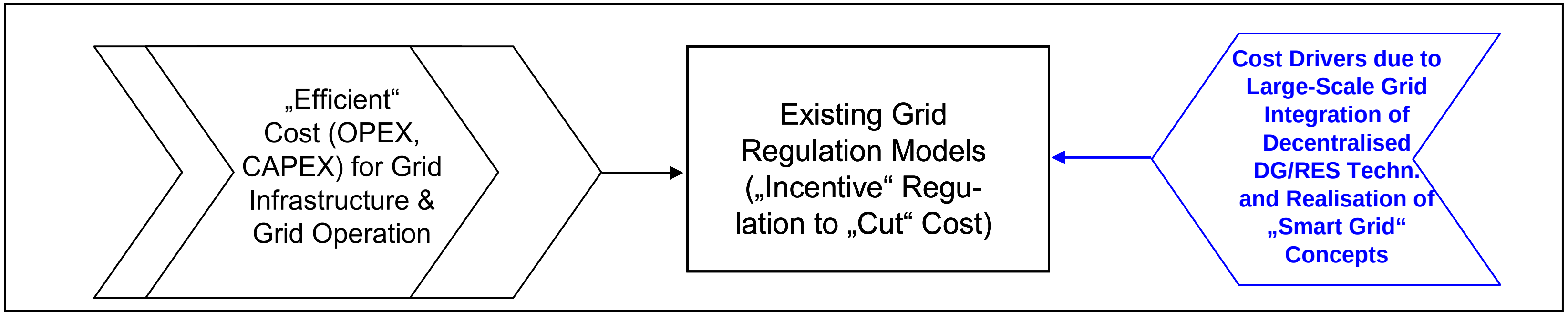
- **Although deep DG/RES-E integration is characterised by favourable locational signals to new entrants, the computation of proper deep connection cost (and, subsequently, connection charges to DG/RES-E generators) is very difficult.**
- **It is impossible to correctly foresee the future set of entrants on the distribution grid, their needs (e.g. connection capacity) and the values they place on each location.**
- **A best guess has to be made when calculating location-specific deep connection charges, trading-off the benefits of larger increments against the risk of over-sizing connection capacity and hence prescribing overcharges for connection of DG/RES-E generators.**
- **Assuming the case that the connection assets of a specific location are shared by more than one DG/RES-E generator, the cost would also be shared, but as the assets would be quasi-public goods, efficient charges would not necessarily be the same for several new entrants at the same location if their willingness to pay is different.**
- **DG/RES-E connection inquires are rather sequential in time than simultaneous. For sequential connection inquiries the first mover problem at a specific location is inherent, i.e. the critical question arises whether or not the first entrant shall be charged the full cost and encourage subsequent entrants to rebate some fraction (either by granting the right to the first entrant to charge successors, or calculating a charge for successors by the distribution grid operator and rebating it to the first entrant).**
- **There exists a strong concern about the deterrent effects on large-scale DG/RES-E deployment in case of deep integration charging policies. This approach completely violates the basic unbundling principle and, therefore, also undermines the legal framework of the EC-Directives of the European Commission trying to implement a common internal European electricity market.**

“Shallow” Integration: Ideal versus Real World

Compared to the deep integration approach, shallow integration charging has at least the following further advantages:

- **Shallow DG/RES-E integration cost and corresponding charges are presumably easier to define than those for the deep integration approach.**
- **The first mover problem disappears since the first entrant is expected to be charged only for the cost of the connection in proportion to the use made of it.**
- **From the distribution grid operator’s point-of-view the risk of cost remuneration in case of over-sizing connection capacity (e.g. for providing the basis for synergies for later DG/RES-E connections at the same location) disappears since grid reinforcement and upgrading cost are socialised in the grid tariffs and, therefore, are directly borne by the network users.**
- **Barriers for entry are low in case of shallow integration policies, providing favourable framework conditions for large-scale DG/RES-E deployment on distribution grid level. Moreover, shallow DG/RES-E integration is supposed to be more transparent and acceptable for several parties involved.**
- **Total DG/RES-E integration cost are lower in case of shallow integration policies. This is due to the fact that financing cost are likely to be higher for DG/RES-E developers than for regulated distribution grid operators.**
- **The shallow DG/RES-E integration approach goes even more in line with the basic unbundling principles of the EC-Directives than the deep approach.**
- **Due to clear separation of the assets of DG/RES-E generation facilities, on the one hand, and the grid infrastructure, on the other hand, extra grid infrastructure cost (grid reinforcements, upgrades and extensions) caused by large-scale DG/RES-E integration can even better be incorporated directly into “forward-looking” grid regulation models where an extra term can be foreseen to socialise these kind of extra cost.**

3. Problem of Asset Stranding for Distribution Grid Operators



„Efficient“ Cost (OPEX, CAPEX) for Grid Infrastructure & Grid Operation

Existing Grid Regulation Models („Incentive“ Regulation to „Cut“ Cost)

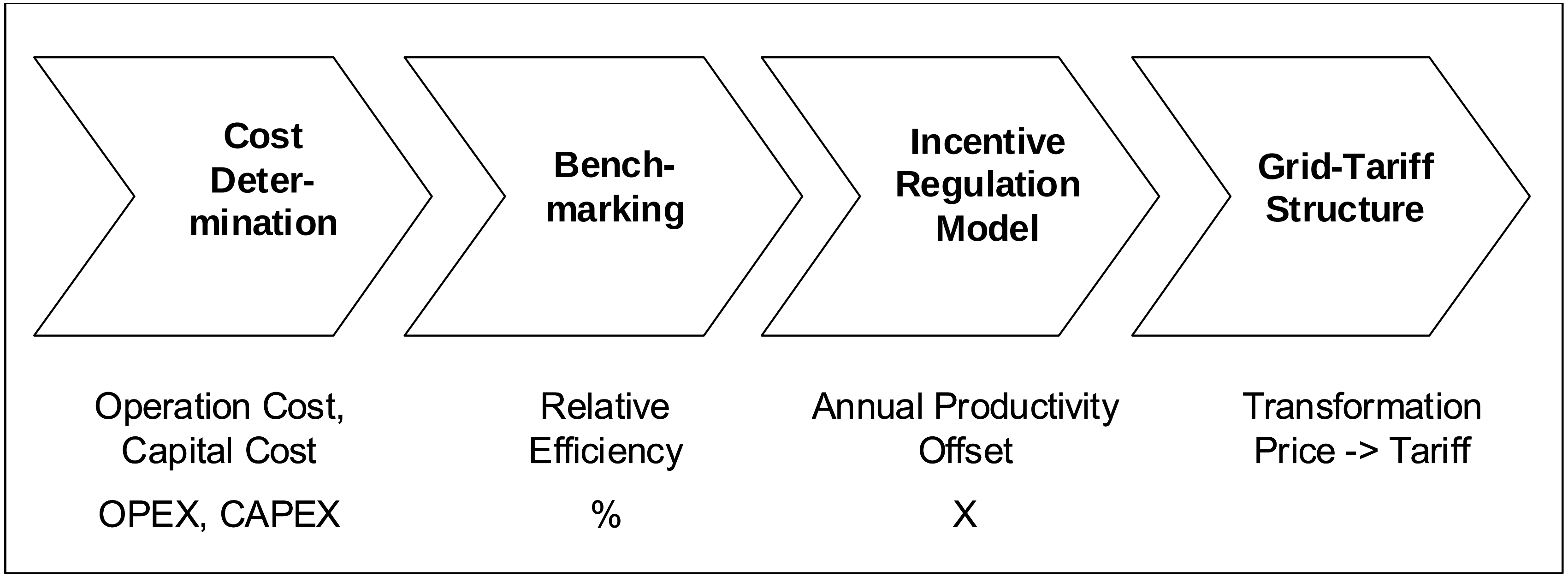
Cost Drivers due to Large-Scale Grid Integration of Decentralised DG/RES Techn. and Realisation of „Smart Grid“ Concepts

Problem of asset stranding in existing grid regulation models due to unconsidered cost drivers caused by large-scale DG/RES-E integration

At present, distribution grid operator are confronted with two different cost pressure forces:

- **On the one hand, currently implemented incentive regulation models (based on cost-benchmarking) apply a strong downward pressure on the distribution grid operator’s cost and, subsequently, also distribution grid tariffs. At present, this regulatory environment adversely affects any investment initiatives into the electricity grid infrastructure, not only those foreseen to provide a level playing field for large-scale DG/RES-E integration and other innovations like so-called “smart grid” concepts.**
- **On the other hand, electricity grids are capital-intensive infrastructure elements being characterized by grid assets’ life-times over many decades. Therefore, long-term investments into the grid infrastructure expect stable regulatory conditions. Moreover, once investments are made they are effectively sunk and, therefore, grid assets are vulnerable to changes in regulatory conditions which could prevent or hinder cost recovery. Therefore, distribution grid operators are extremely reluctant to enable large-scale integration of DG/RES-E generation facilities into their distribution grids, unless the corresponding extra cost drivers in this context are not understood, quantified and – most importantly – cost recovery is guaranteed based on innovative, forward-looking grid regulation models.**

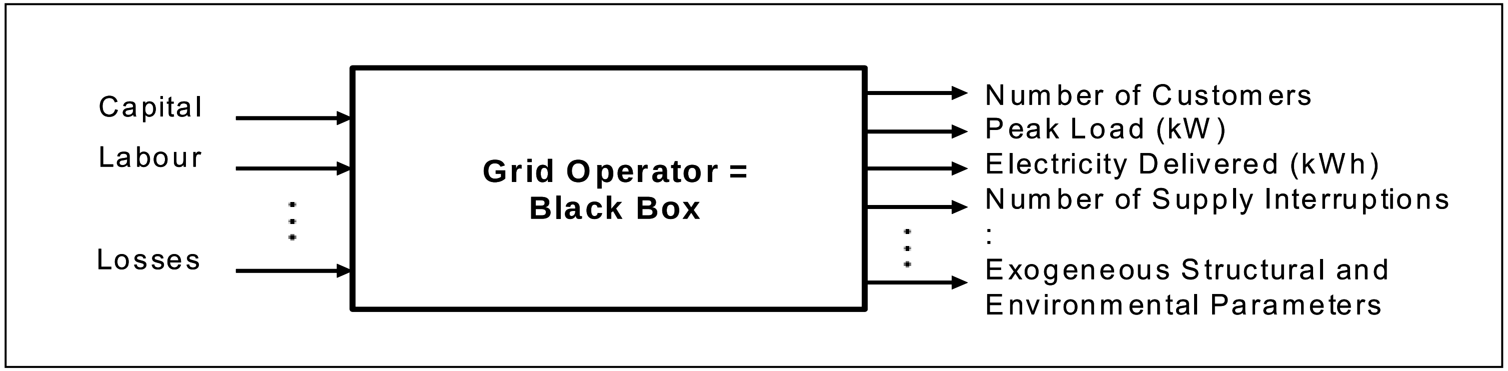
3.1 Cost Drivers for Grid Operators due to Incentive Regulation



Cost Determination	Benchmarking	Incentive Regulation Model	Grid-Tariff Structure
Operation Cost, Capital Cost	Relative Efficiency	Annual Productivity Offset	Transformation Price -> Tariff
OPEX, CAPEX	%	X	

Overview of the different steps of a grid regulation process

Cost-Benchmarking of Grid Operators



Capital
Labour
:
Losses

Grid Operator =
Black Box

Number of Customers
Peak Load (kW)
Electricity Delivered (kWh)
Number of Supply Interruptions
:
Exogeneous Structural and Environmental Parameters

The grid operator as a simple Input-Output model

Inputs of a Grid Operator:

-> Capital Cost (CAPEX), Operation Cost (OPEX), Network Losses, …

Outputs of a Grid Operator:

-> Grid Connection Point in a Certain Geographic Region, Energy Supply [kWh], Guaranteed Load [kW], Guaranteed Security of Supply Standards, …

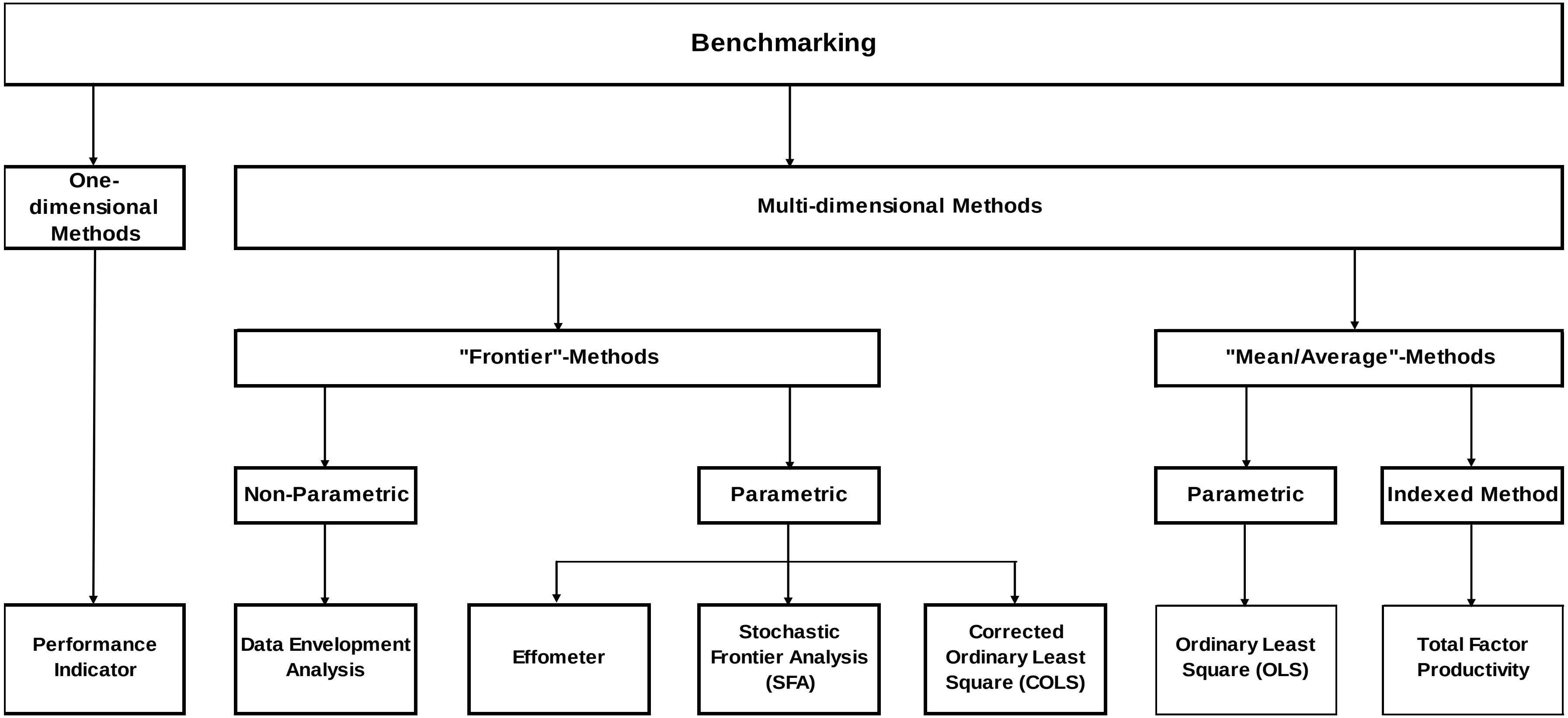
Exogeneous Structural and Environmental Parameters:

-> Depending on geography, topology, environmental constraints, structure/distribution of customers, ….

Important:

-> Cost Benchmarking expects careful consideration of: (i) methology used, (ii) parameters used, (iii) empirical data used, and (iv) interpretation of benchmarking results ….

Overview of Different Benchmarking Techniques used for Cost Benchmarking of Grid Operators



Benchmarking

One-dimensional Methods

Multi-dimensional Methods

"Frontier"-Methods

"Mean/Average"-Methods

Non-Parametric

Parametric

Parametric

Indexed Method

Performance Indicator

Data Envelopment Analysis

Effometer

Stochastic Frontier Analysis (SFA)

Corrected Ordinary Least Square (COLS)

Ordinary Least Square (OLS)

Total Factor Productivity

Integration of Cost-Benchmarking Results into the „1+RPI-X“ Incentive Regulation Formula

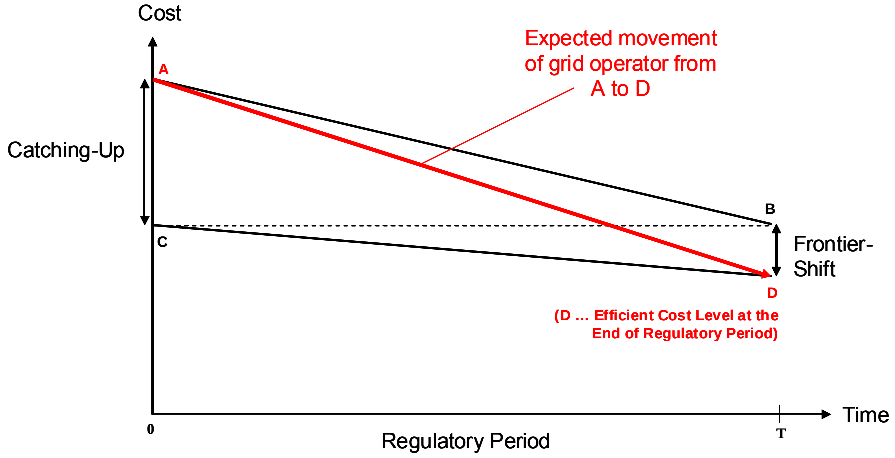
3 Principles Applied in Practise:

- **Creation of efficiency clusters followed by ‚moderate‘ implementation of efficiency improvement expectations (e.g. Norway, Austria)**
- **1:1 translation of cost-benchmarking results into efficiency improvement expectations (e.g. UK, Netherlands)**
- **Individuelle interpretation of benchmarking results without standardized methodolog in case of small number of grid operators (e.g Victoria/Australia)**

Efficiency Improvement Expectations within a Regulatory Period

- **Annually constant efficiency improvement expectations (X-factor)**
- **High efficiency improvement expectations (X-factor) in the first year(s), moderate afterwards**

Besides individual X-factors (‚Catching-Up‘) also general X-factors (‚Frontier-Shift‘) are usually implemented



Total efficiency expectations split up into the individual X-factor (catching-up) & general X-factor (frontier-shift).

Key Characteristics of Incentive Regulation Models

1. Rate-of-Return (ROR) and/or Cost-Plus Regulation

Revenue = Capital Cost (Rate of Return, Depreciation) + Operation Cost + Taxes

Advantage: simple and cheap grid regulation models
Disadvantage: less cost efficient; excess capitalization of grid operators; high grid tariffs

2. Price-Cap Regulation

$$P_{i,t} = P_{i,t-1} * (1 + RPI - X_i) \pm Z_i$$

Advantage: cost efficient; grid users are protected against high grid tariffs
Disadvantage: due to strong cost cutting incentives no/less investments into the grid infrastructure (decreasing security of supply); grid operators maximise the amount of electricity delivered (general disincentives for energy efficiency implementation and distributed generation)

3. Revenue-Cap (Sliding Scale) Regulation

$$r_t = r_{t-1} - \lambda (r_{t-1} - r^*)$$

Similar to price-cap model (revenues instead of prices are capped (compensates almost all disadvantages of price-cap regulation models)); additional earning sharing mechanism between grid operator and network users adjusts grid tariffs automatically

3.2 Cost Drivers for Grid Operators due to Large-Scale DG/RES-E Grid Integration

Grid operators are dealing with the following unsolved problems, if they shall provide the infrastructure platform for large-scale DG/RES-E integration:

1. National regulators implement new grid regulation models (price-cap or revenue-cap regulation), benchmark existing grid infrastructure and grid operation cost and expect “cost efficiency” (i.e. reduction of existing cost basis and, subsequently, grid tariffs for end-users)

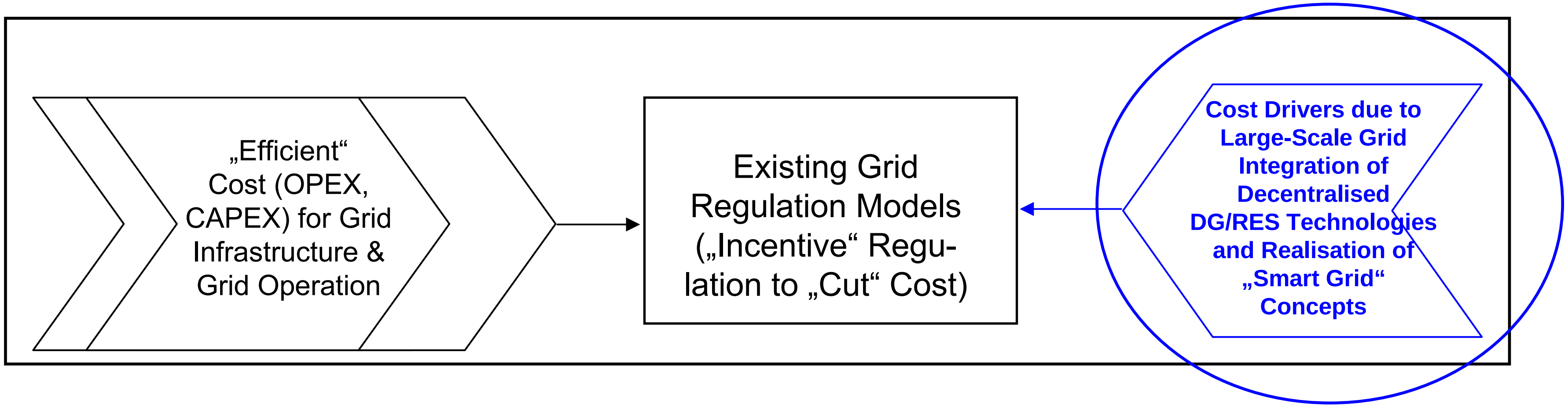
   -> These expectations neither trigger investments into existing grids nor into innovations in general

   -> But increasing shares of DG/RES-E integration expect investments into the grid infrastructure and investments into intelligent new technologies for grid operation as well as implementation of completely new concepts of interactions between several (new) market players (“Smart Grids”)

2. Cost recovery is essential for grid operators since investments into the capital intensive infrastructures and innovative solutions are effectively sunk and, therefore, vulnerable to regulatory changes.

If there exist regulatory uncertainties and/or exclusively “ex-post” oriented grid regulation models (e.g. price-caps or revenue-caps), large-scale DG/RES-E and SmartGrid solutions <u>hardly can / will be</u> implemented in the future.

Unconsidered Cost Drivers in the Grid Regulation Process due to Large-Scale DG/RES-E Grid Integration



„Efficient“ Cost (OPEX, CAPEX) for Grid Infrastructure & Grid Operation

Existing Grid Regulation Models („Incentive“ Regulation to „Cut“ Cost)

Cost Drivers due to Large-Scale Grid Integration of Decentralised DG/RES Technologies and Realisation of „Smart Grid“ Concepts

Not considered in the grid regulation models at the moment

Examples of Cost Drivers:

- **Completely new design criteria and operational concepts necessary due to bidirectional load flows in case of dispersed DG/RES-E generation on distribution grid level;**
- **Reinforcements and extensions for existing lines, cables, transformers, and switching devices;**
- **Higher technical standards for V/f-Regulation, accounting and billing devices and procedures;**
- **Installation of new IT & communication technology necessary to manage „active“/“intelligent“ grids;**
- **Higher transaction cost to operate „active“/“intelligent“ grids due to new market actors;**
- **etc.**

‚Ex-post oriented‘ Price-Cap and Revenue-Cap Regulation Models: Disincentives for Grid Operators to Integrate DG/RES-E Generation

Basic Incentive Regulation Formula: $P_t = P_{t-1} * (1 + RPI - X)$

Economic Decision Criteria from the Grid Operator‘s Point-of-View:

Price-Cap: $\text{Profit}\ \pi = \max\limits_{x,c} px - c \qquad \text{p} = \text{fixed} \quad \text{x, c} = \text{variable}$

Revenue-Cap: $\text{Profit}\ \pi = \max\limits_{p,x,c} px - c \qquad \text{p, x, c} = \text{variable}$

If DG/RES-E integration cost of grid operators are ‚not eligible‘ in the grid regulation model (i.e. no remuneration of the cost in the grid tariffs possible), there exist no incentives for grid operators to connect and integrate DG/RES-E generation:

$$\frac{\partial \pi}{\partial c} < 0 \qquad \text{Increasing Integration Cost reduce Profit !}$$

4. Forward-looking Regulatory Framework Supporting Large-Scale DG/RES-E Integration

4.1 Best-Practise Case: New UK Grid Regulation Model (since 2005)

- Boundaries on both ends of the grid (towards DG/RES generators and customers) are the same: switch from “deep“ to „shallow“ / „super-shallow“ approach.
- Distribution grid operators are allowed to recover their DG/RES generation connection cost directly in the grid tariffs by a combination of pass through (80% of cost) and an incentive per kW connected (2.16 €/kW (singular) and 1.44€/kW/yr (annually)).
- *Innovation Funding Incentive (IFI):* IFI projects can embrace any aspect of distribution system asset management including connection of DG/RES generation. A distribution grid operator is allowed to spend up to 0.5% of its revenue on eligible IFI projects and can recover a significant proportion of associated costs from its customers (90% in 2005/2006).
- *Registered Power Zones (RPZ):* In contrast to the IFI, RPZs are focused specifically on the connection of generation to distribution systems. RPZs are intended to encourage distribution grid operators to develop and demonstrate new, more cost effective ways of connecting and operating generation that will deliver specific benefits to new distributed generators and broader benefits to consumers generally.

4.2 Amendment of the Existing Incentive Regulation Models

Way Forward: Implementation of an additional ex-ante element into the ´incentive regulation´ formulas enabling cost remuneration of cost caused by DG/RES-E integration and Smart Grid solutions:

$$\boxed{P_t = P_{t-1} * (1 + RPI - X) + \Delta C_{DG/RES\,i,\,j} * \Delta kW_{DG/RES\,i,\,j} * (1 + RPI - LR_{\Delta C_{DG/RES\,i,\,j}})}$$

Well-known ex-post element

Ex-ante element enabling large-scale DG/RES-E Integration

P_t..........authorized price-cap in year t
P_{t-1}.......authorized price-cap in year (t-1)
RPI.......annual inflation index (Retail Price Index)
X...........productivity offset
$\Delta C_{DG/RESi,j}$……specific cost for a distribution grid operator caused by the integration of a DG/RES-E generation technology i into an existing grid topology and/or smart grid concept j
$\Delta kW_{DG/RESi,j}$….installed capacity of DG/RES-E generation technology i integrated into an existing grid topology and/or smart grid concept j
$LR_{\Delta CDG/RESi,j}$….expected dynamic learning rate and/or economies of scale of specific grid integration cost caused by the integration of a DG/RES-E generation technology i into an existing grid topology and/or smart grid concept j

Expected Features of Forward-looking Incentive Regulation Models

Besides the well-known ‘1+RPI-X’ factor an additional forward-looking term has to be implemented into the existing incentive regulation model fulfilling at least the following features:

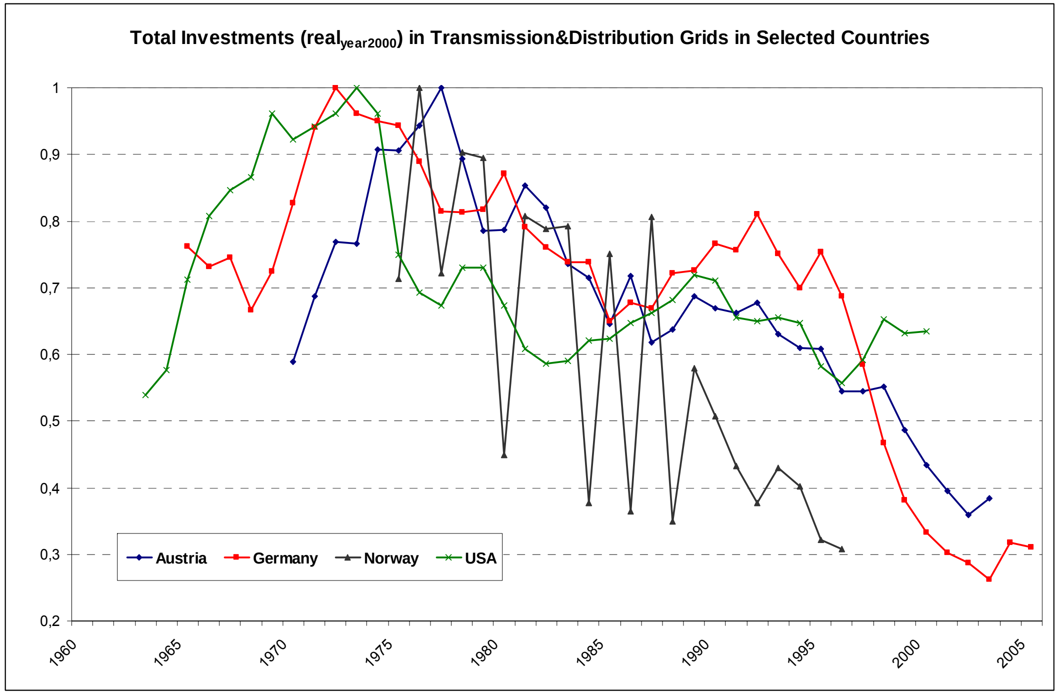
- Consideration of a mechanism to directly socialise – at least parts of – grid connection, grid reinforcement and grid extension cost in the distribution grid tariffs (e.g. direct cost pass through as well as other fixed connection (e.g. €/kW$_{DG/RES}$, €/kW$_{DG/RES/yr}$) and volume based (€/kWh$_{DG/RES}$) use of system charges having to be paid by DG/RES-E generators directly to distribution grid operators) similar to UK’s recently modified incentive regulation model.

- Provision of some kind of cost-reflective locational signals for DG/RES-E generators, e.g. on the basis of forward-looking long run incremental cost (LRIC) rather than solely in relation to the direct cost incurred of a specific connection of a single DG/RES-E generation facility. This approach is supposed to minimise the problems associated with first movers and free-riding in case of more than one DG/RES-E generator on the same connection point on distribution grid level.

- Consideration of a mechanism to directly cover and/or remuneration operational cost allocated to innovative DG/RES-E grid integration projects (i.e. personnel cost for research, feasibility studies and preparatory operations of DG/RES-E grid integration projects) in the incentive regulation model.

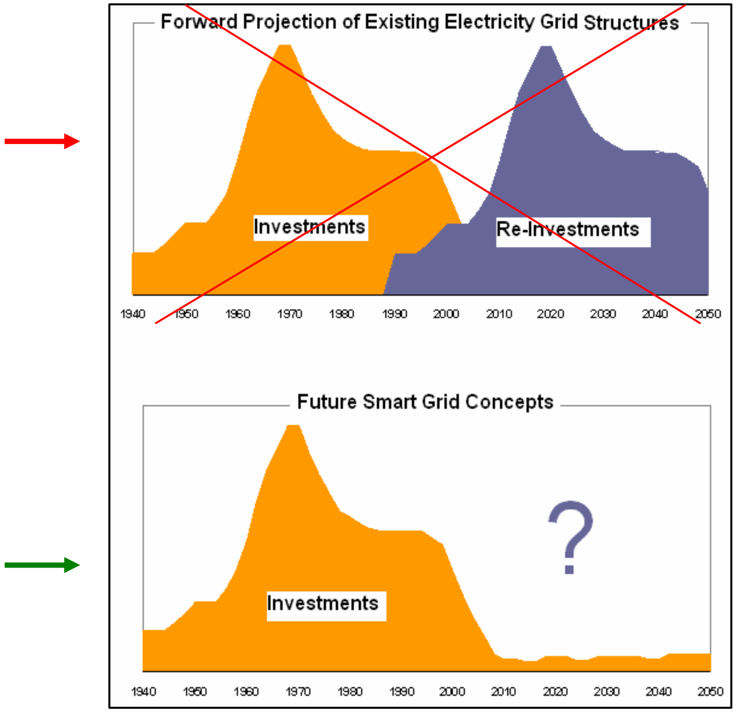
- Avoidance of unmanageable complexity of additional forward-looking terms in an extended incentive regulation formula.

5. Outlook: The Future Vision of Smart Grids



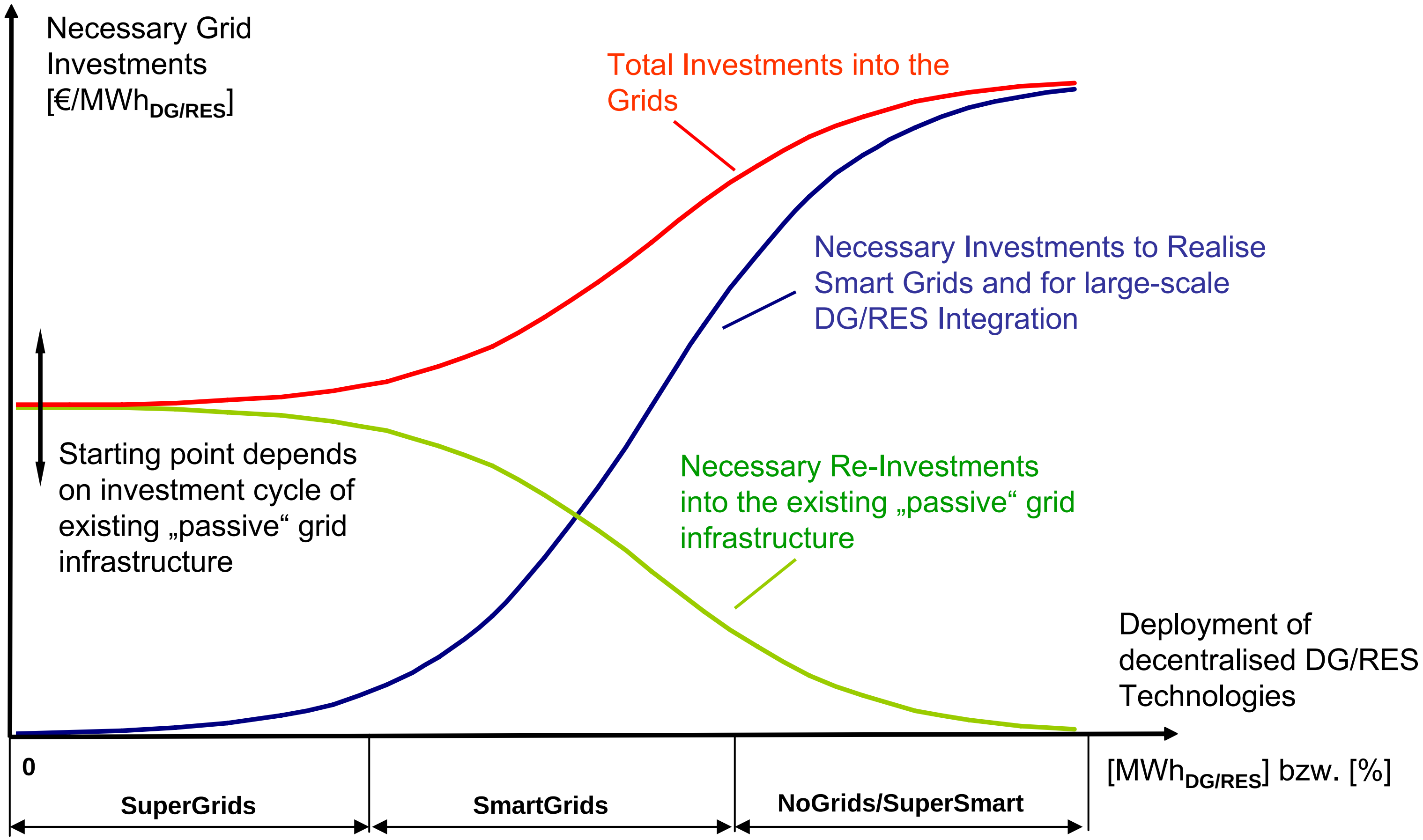
Historical investment cycle of T&D grids in selected countries since 1960

NO Smart Grids



Smart Grids…
...but innovation is not for free !

Necessary Investments into the Grids Depending on the Future Deployment of Dispersed DG/RES-E Generation



Further Information on Smart Grid Concepts: EU Technology Platform: www.smartgrids.eu