Cost Entropy:
The End of Cost-Reflective Prices and Tariffs in Electricity Markets

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Drifting Apart: Costs, Prices And Tariffs In EU Electricity Markets,
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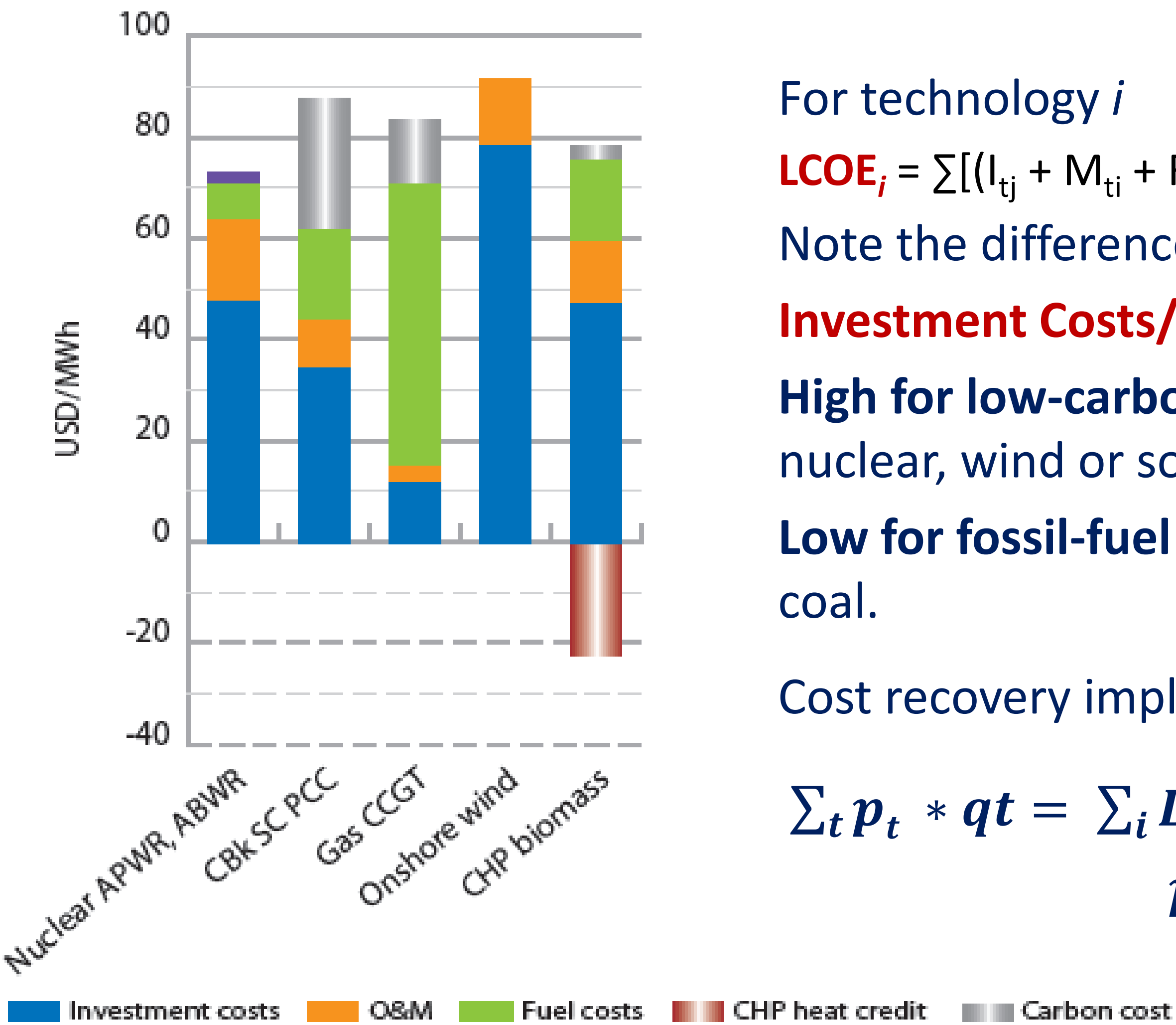
Costs I – Plant Level Production Costs



EPRI from IEA/OECD NEA (2010)

For technology *i*

LCOE$_i$ $= \sum[(I_{tj} + M_{ti} + F_{ti} + CO2_{ti})*(1+r)^{-t}]/\sum[E_{ti}*(1+r)^{-t}]$

Note the differences in the ratio of

Investment Costs/Variable Costs.

High for low-carbon technologies such as nuclear, wind or solar PV,

Low for fossil-fuel technologies such as gas or coal.

Cost recovery implies

$$\sum_t p_t * qt = \sum_i LCOE_i * qi$$ where

$$p_t = CVit$$

Costs II – System Costs (SC) and Public Goods (PG)

System Costs at the Grid Level (average of 6 countries - USD/MWh)

	System Costs at the Grid Level [USD/MWh]											
Technology	***Nuclear***		***Coal***		***Gas***		***On-shore wind***		***Off-shore wind***		***Solar***	
Penetration level	*10%*	*30%*	*10%*	*30%*	*10%*	*30%*	*10%*	*30%*	*10%*	*30%*	*10%*	*30%*
Back-up Costs (Adequacy)	0.00	0.00	0.05	0.05	0.00	0.00	6.03	7.38	5.71	7.67	15.88	18.04
Balancing Costs	0.53	0.35	0.00	0.00	0.00	0.00	4.19	8.34	4.19	8.34	4.19	8.34
Grid Connection	1.71	1.71	0.94	0.94	0.51	0.51	6.24	6.24	18.68	18.68	13.71	13.71
Grid Reinforcement and Extension	0.00	0.00	0.00	0.00	0.00	0.00	2.23	6.28	1.51	3.82	4.46	13.55
Total Grid-Level System Costs	***2.24***	***2.05***	***0.99***	***0.99***	***0.51***	***0.51***	***18.69***	***28.24***	***30.11***	***38.51***	***38.25***	***53.64***

OECD NEA (2012)

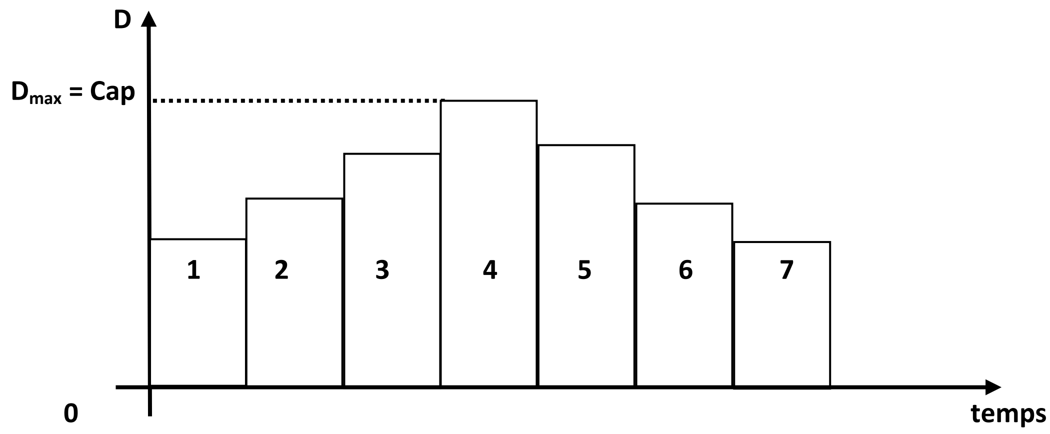
Added to plant-level LCOE are **grid-level system costs** (transport, distribution, system services and balancing) and the costs of public goods (public service).

A cost-reflective tariff system with different tariffs T_j for the consumption *qj* for consumer group *j* must satisfy $\sum_j \boldsymbol{T_j} * \boldsymbol{qi} = \sum_i \boldsymbol{LCOE_i} * \boldsymbol{qi} + \sum_i \boldsymbol{SC_i} * \boldsymbol{qi} + \boldsymbol{PG}$.

Four factors impede easy attainment of this equality:

1. Wholesale prices in liberalised markets not reflective of LCOE, especially for low carbon technologies, without numerous periods of VOLL;
2. Long lags between investment, operation and cost recovery allows periods where consumers can live off historical rents with **p << replacement cost**;
3. Social and political resistance to both VOLL pricing and tariff increases;
4. Insufficient acknowledgement of system costs.

From Costs to Prices and Tariffs – The Basic Idea



Optimally regulated system for single non-storable good sets prices such that

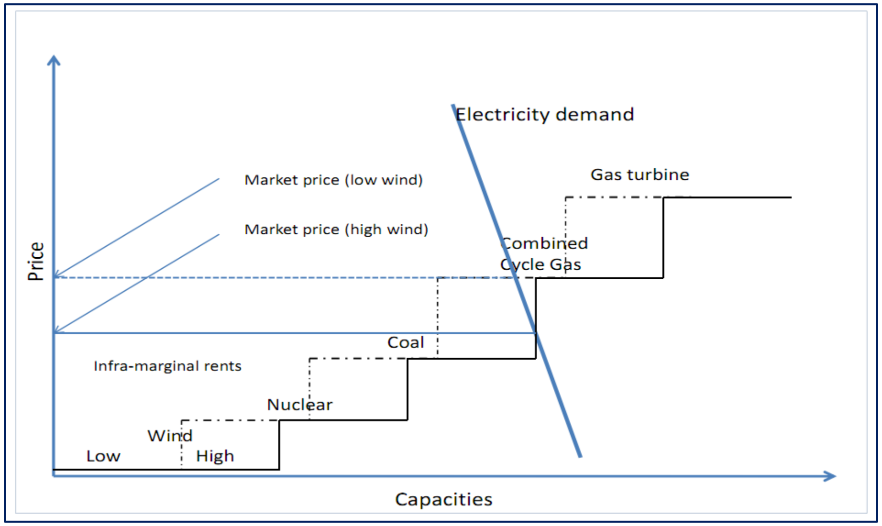
$$\sum_i q_i * CV + CAP*r = \sum_{i\neq 4} q_i * CV + q_4 * (r + CV) = \sum_{i\neq 4} q_i * p_i + q_4 * p_4$$

With $p_1 = p_2 = p_3 = p_5 = p_6 = p_7 = CV$

$p_4 = r + CV$ and $q_4 = CAP$.

In principle, a liberalised market can replicate such non-linear prices even with multiple technologies by eliciting demand response at VOLL

From Costs to Prices and Tariffs – What's the Problem?



In the past system worked with few VOLL hours due to combination of:

- High variable costs for marginal (carbon-intensive) technology and hence high prices;
- Ample load factors for DT,
- Capacity financed at historic costs.

Influx of VaREN has lead to:

- Lower prices (exacerbated by collapse of EU ETS) and reduced load factors,
- Capacity retirements as free cash flow < fixed O&M costs,
- Will lead to higher costs of residual production in the future

Financing of fixed costs for un-subsidised dispatchable technologies requires:

- High number of VOLL hours (politically and socially unsustainable)
- Free provision of back-up services by utilities (economically unsustainable)
- Alternative capacity financing mechanisms (CRMs)

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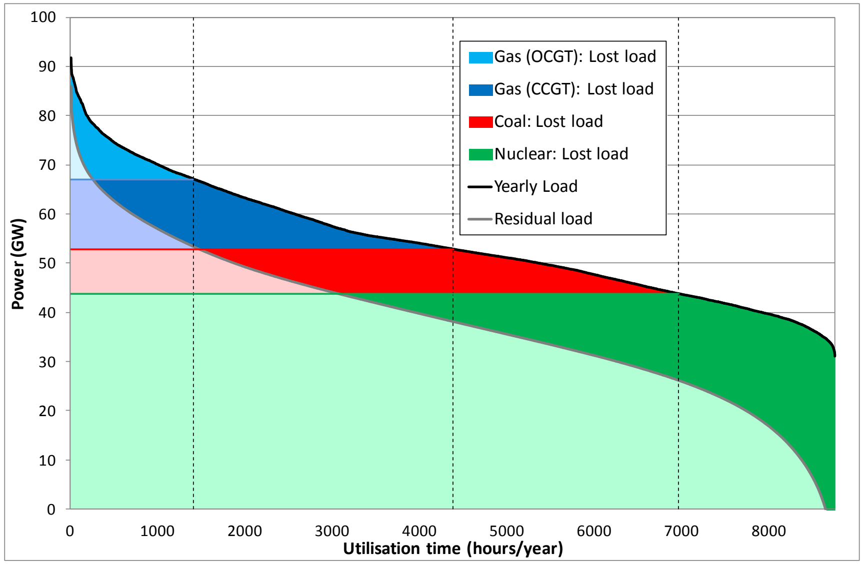
Prices Declines and Load Losses

Modelling Results

VaREN with zero marginal costs replace conventional technologies with higher marginal costs (gas, coal and nuclear):

- Lower load factors of dispatchable plants (*compression effect*);
- In the absence of **plant closures**, reductions in the average electricity price (*merit order effect*).



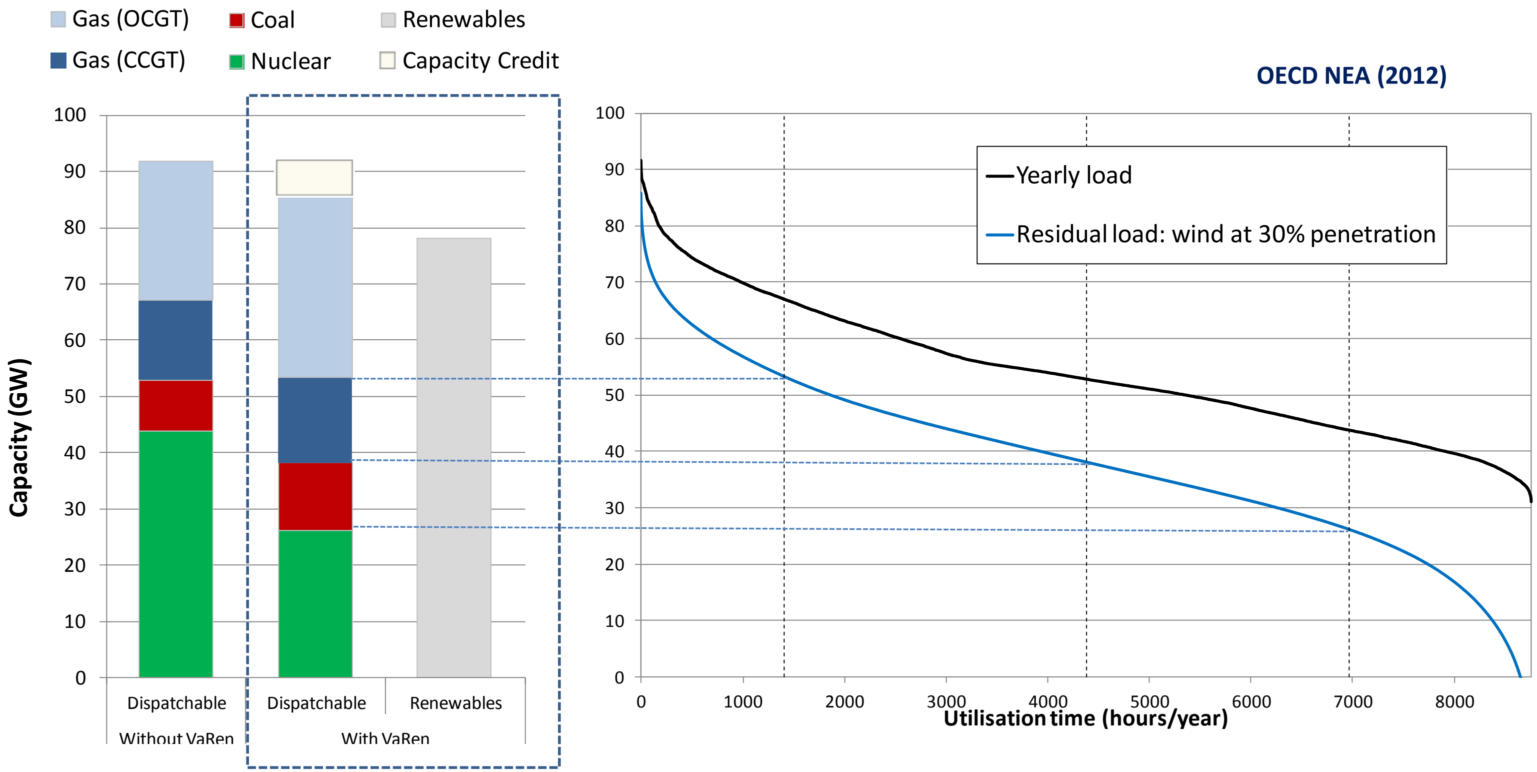
		10% Penetration level		30% Penetration level	
		Wind	*Solar*	*Wind*	*Solar*
Load losses	*Gas Turbine (OCGT)*	-54%	-40%	-87%	-51%
	Gas Turbine (CCGT)	-34%	-26%	-71%	-43%
	Coal	-27%	-28%	-62%	-44%
	Nuclear	-4%	-5%	-20%	-23%
Profitability losses	*Gas Turbine (OCGT)*	-54%	-40%	-87%	-51%
	Gas Turbine (CCGT)	-42%	-31%	-79%	-46%
	Coal	-35%	-30%	-69%	-46%
	Nuclear	-24%	-23%	-55%	-39%
Electricity price variation		-14%	-13%	-33%	-23%

- Declining profitability especially for OCGTs and CCGTs;
- Logical consequences:
  - Insufficient incentives for new investment;
  - Gas plants close, 30 GW during last two years.

OECD NEA (2012)

Rte Réseau de transport d'électricité · EDF · EPEXSPOT European Power Exchange · UFE Union Française de l'Électricité

Plant Closures not an Option



- Plant retirements are logical response to price, load factor and profit declines.
- Limits as VaREN have low capacity credits (10% wind energy → -14% price → -40% profit (CCGT) but only 2% of dispatchable capacity can be safely retired).

Disconnect between socially and privately optimal levels of capacity!

Distributional Issues

Then: Dispatchable Technologies Only

***Plant-level costs*:**

Borne by operator; variable costs integrated in electricity price; due to **high** variable costs of marginal technology marginal cost pricing works.

Grid-level costs:

- Grid connection, extension and reinforcement -- socialized through network tariffs (except in rare locational pricing, PJM)

Result: Due to mix of modest monopoly power and carbon pricing (GF) prices ≥ costs and system works with very few VOLL hours. **Wholesale prices and tariffs move together.**

Now: Dispatchable Technologies + VaREN

***Plant-level costs*:**

Borne by operator (DT), socialized for VaREN; variable costs integrated in price but due to **low** variable costs of marginal technology marginal cost pricing no longer works.

Grid-level costs:

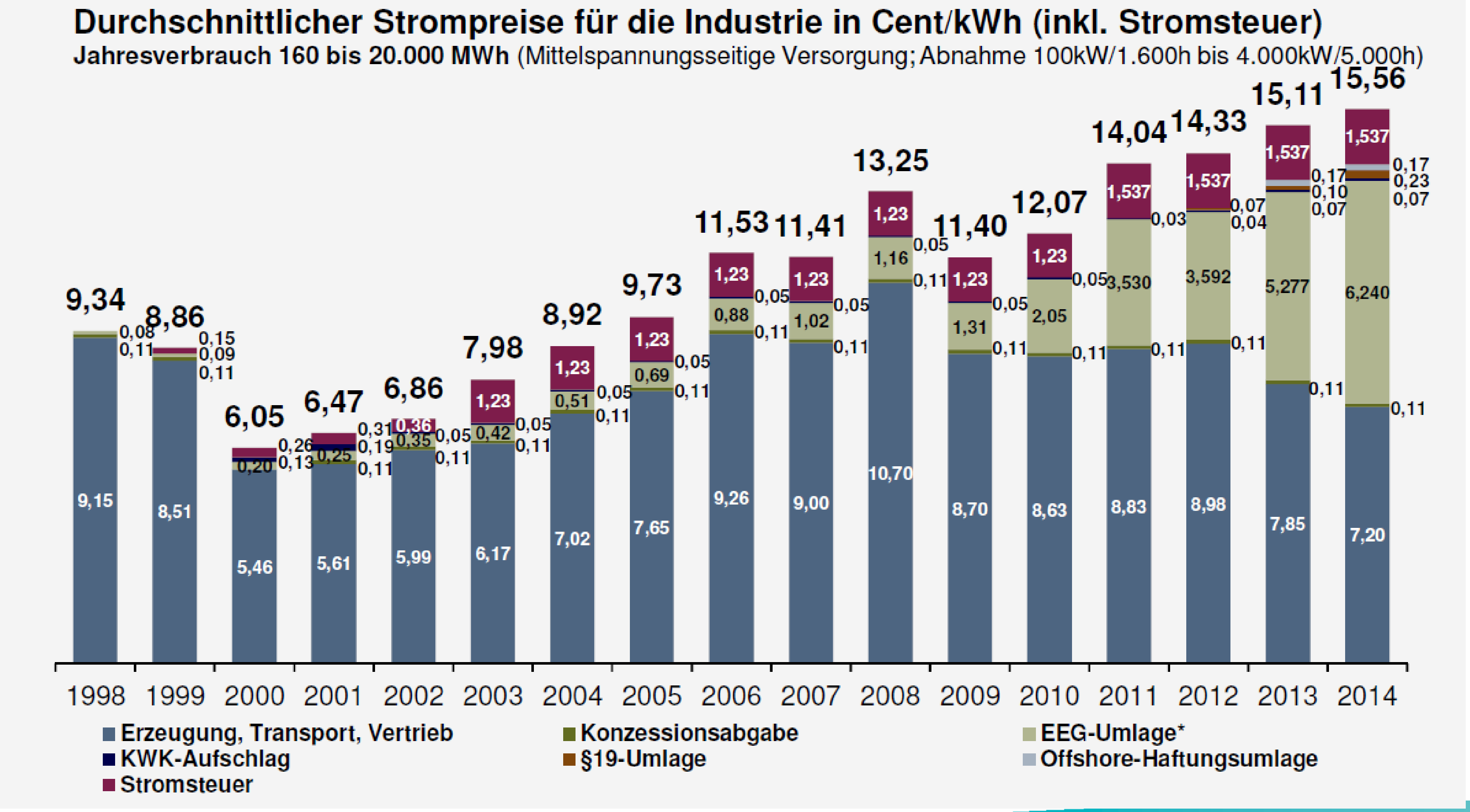
- Grid connection, extension and reinforcement – increased and socialized
- Short-term balancing costs – new & socialized
- **Costs for maintaining adequate back-up capacity – provided as free service by operators of dispatchable technologies**

Result: Due to prices << LCOE and carbon pricing (AUC) investment stops and plant closures. Historical oversupply just about maintains SoS for now. **Wholesale prices and tariffs move in opposite directions!**

The Wedge

Strompreis für die Industrie (inkl. Stromsteuer)

bdew
Energie. Wasser. Leben.



The Impacts of "Cost Entropy"

1. **Costs are incompressible:** This holds for plant-level costs (LCOE), grid-level costs (connection, balancing, back-up) and social costs (CO2, security of supply), whether in the short-term or the long-term (investment). Once created, they will inevitably be borne sooner or later by someone, individually or collectively.
2. **Cost entropy (the allocation of a cost to agents other than the one who decides whether to incur it)** shields decision-makers from cost pressures leading to (1) misguided incentives and (2) lack of transparency. As implicit subsidisation (grid costs, back-up services, increased CO2 and decreased SoS) is added to explicit subsidisation, economic inefficiencies increase strongly (MSC > MPB > MPC > MSB).
3. **In addition to moving away from Pareto-optimality, cost entropy has multiple direct and indirect distributional effects not always obviously justifiable.**
4. **The more widespread and the more entrenched cost entropy becomes, the more unwieldy and difficult system management becomes as levers of action have been immunised against economic incentives.**

Conclusions for Electricity System

1. **Strategic conflict between decarbonisation (high fixed cost technologies), full cost recovery with variable cost pricing in liberalised energy-only markets) and security of supply.** Theory could only be satisfied with historical operators assuming large transitional losses and high number of VOLL hours.
2. At current technologies, **capacity remuneration mechanisms (CRMs) inevitable to bridge gap between privately and socially optimal levels of capacity.**
3. **Increasing cost entropy will come back to haunt energy sector** as inefficiencies, notably through misguided investment decisions, become entrenched, and rents are considered "acquis sociaux".
4. **Tariffs reflecting replacement costs almost impossible to impose (UK, France, Germany, Spain).** In France alone it would roughly require doubling. Much pedagogy required. Remember: costs cannot be negotiated away!
5. **Voluntary and remunerated demand response (rather than enforced VOLL) is the rare bright spot.** Integration with capacity mechanisms important step forward. **With significant VaREN in the system the scarce resource is *capacity* not *energy*. Future pricing arrangements must reflect this.**