9. Internationale Energiewirtschaftstagung, 11.-13. Februar 2015, TU Wien

An efficient mechanism for cross-border support of renewable electricity in the European Union

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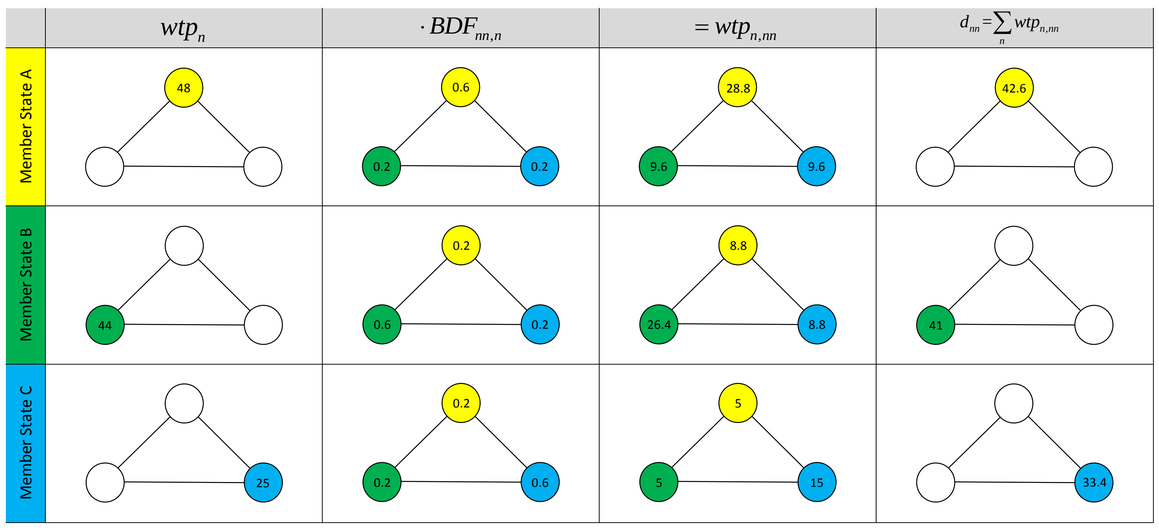
Introduction

We propose a new mechanism for cross-border support of renewable electricity (RES-E) in the European Union. The guiding idea is that the cross-border mechanism allocates new RES-E generation to where it is most valuable. This can, but need not coincide with the most cost efficient allocation. The mechanism would be designed as an EU wide auction in that Member States and generators of renewable electricity bid prices indicating their willingness-to-pay for, respectively their costs of additional RES-E generation. In addition to prices the auctioneer uses a matrix that indicates the spill-over of benefits between Member States induced from RES-E generation as input parameter. The auctioneer then selects the set of bids that maximizes EU-wide surplus, which provides for economic efficiency.

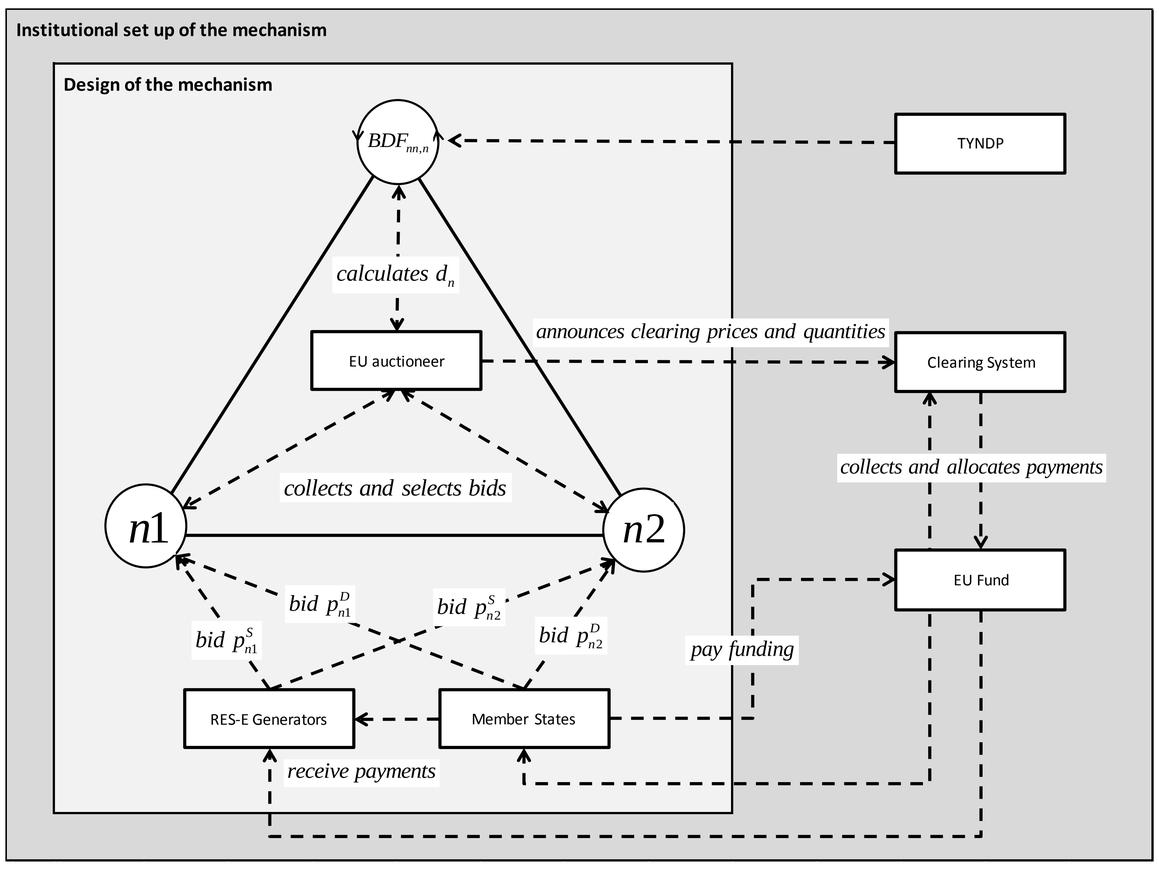
Distribution of benefits in the internal electricity market and willingness-to-pay for renewable electricity generation expansion



Description of the mechanism

Let each Member State (n) submit a sealed bid naming the price ($p^D_{n,b}$) that he would be willing to pay for an additional MWh (or a multiple thereof) of renewable electricity generated **on its own territory**, whereby "D" denotes that the price refers to a demand bid for additional electricity generation. The price may or may not be equal to his true willingness-to-pay. Let also each generator of renewable electricity bid a price ($p^S_{nn,b}$) that he asks for an additional MWh of renewable electricity production, whereby RES-E producers and thus their bids are assigned the index "n" of the Member State (or node respectively) where they feed the renewable electricity into the grid and "S" denotes that the price refers to a supply bid for additional electricity generation. Thus in the following "n" refers to a "demand node" of RES-E generation and´"nn" refers to a "supply" node of RES-E generation, whereby a node can simultaneously (which will usually be the case) be a supply and demand node.

The decision variables of the auctioneer are given by ($x^D_{nn,b}$) and ($x^S_{nn,b}$). $x^D_{nn,b}$ determines for each bid the quantity of demand that is accepted at each supply node . $x^S_{nn,b}$ determines for each bid the quantity of supply that is accepted from a RES-E generator that is assigned to supply node "n" Equations (2) and (3) ensure that these quantities cannot become larger than the maximum quantity offered at a certain price level. Equation (4) ensures that the accepted demand bids at each node have to be matched with supply. Respecting these constraints, the auctioneer then choses the set of bids that maximizes the aggregate surplus and announces $x^D_{nn,b}$ and $x^S_{nn,b}$.



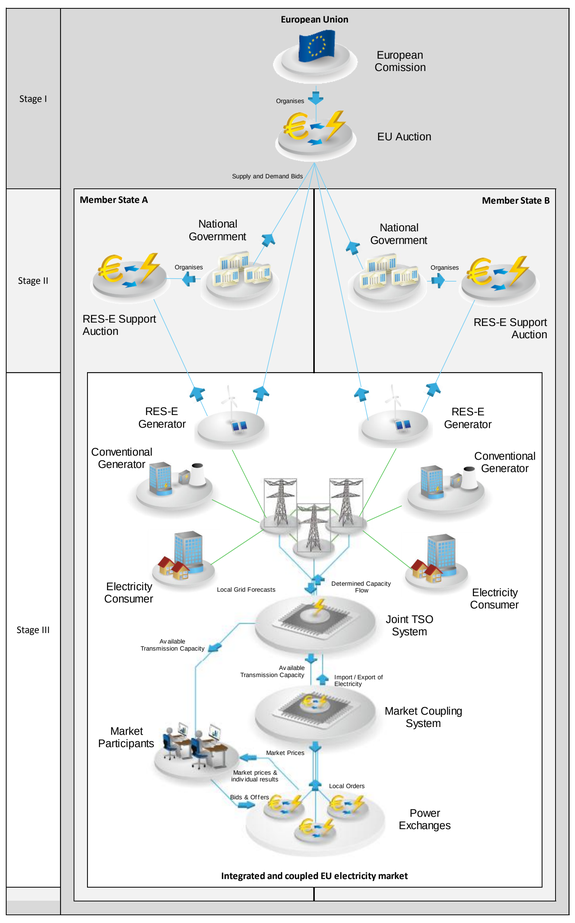
Surplus maximization problem of the auctioneer

$$\max_{x^D_{n,nn,b},\, x^S_{nn,b}} \; surplus = \sum_{nn}\sum_{b}\left(\sum_{n}\left(p^D_{n,b}\cdot BDF_{nn,n}\right)\cdot x^D_{nn,b} - p^S_{nn,b}\cdot x^S_{nn,b}\right) \quad (1)$$

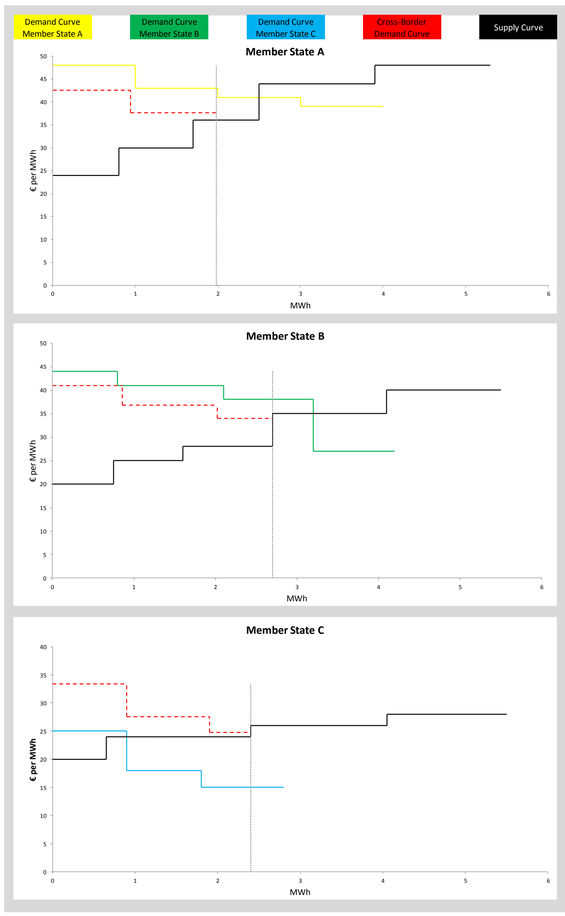
$$s.t.$$

$$\sum_{nn}\left(x^D_{nn,b}\cdot BDF_{nn,n}\right) \le x\max^D_{n,b} \quad \forall n,b. \quad (2) \qquad x^S_{nn,b} \le x\max^S_{nn,b} \quad \forall nn,b. \quad (3) \qquad \sum_b x^D_{nn,b} = \sum_b x^S_{nn,b} \quad \forall nn. \quad (4)$$

A three-stage framework



An illustrative example



Payment streams

The clearing of the cross-border auction induces some payments streams as shown in the table on the right. For the institutional set-up of the administration of the payments two options can be thought of: bilateral payments and an EU fund. After clearing of the auction the auctioneer calculates the gross payments between all combinations of Member State as shown in equation (5) and a remaining surplus can be redistributed according to equation (6).

$$p^{clear}_{n,nn} = \sum_b p^D_{n,b}\cdot BDF_{nn,n}\cdot x^D_{nn,b} \quad (5)$$

$$s^{redistributed}_{nn,n} = \frac{p^{clear}_{n,nn}}{\sum_n p^{clear}_{n,nn}}\cdot\left(\sum_n p^{clear}_{n,nn} - \sum_b p^S_{nn,b}\cdot x^S_{nn,b}\right) \quad (6)$$

	from / to	MS A	MS B	MS C	SUM
Bilateral Payments	Gross Payments				
	MS1	53,90	23,81	21,34	99,05
	MS2	16,80	66,74	19,92	103,46
	MS3	8,44	10,52	28,80	47,76
	Payments corrected for surplus				
	MS1	38,33	15,79	16,75	70,88
	MS2	11,95	44,28	15,64	71,86
	MS3	6,00	6,98	22,61	35,59
	Net Payments				
	MS1	0,00	3,85	10,75	14,60
	MS2	0,00	0,00	8,66	8,66
	MS3	0,00	0,00	0,00	0,00
EU Fund	Gross Payments				
	MS to EU Fund	99,05	103,46	47,76	250,28
	Surplus redistributed				
	EU Fund to MS	28,17	31,60	12,17	71,95
	Net Payments				
	MS to EU Fund	70,88	71,86	35,59	178,33

Nomenclature

Sets	
$b \in B$	Bids
$n, nn \in N$	Nodes
Parameters	
$BDF_{nn,n}$	Benefit Distribution Factor
$p^D_{n,b}$	Willingness-to-pay [€ per MWh] offered by MS n for generation in node n
$p^S_{nn,b}$	Price [€ per MWh] asked for by generator situated in supply node nn
$x\max^D_{n,b}$	Maximum size for demand bid [MWh]
$x\max^S_{nn,b}$	Maximum size for supply bid [MWh]
Decision variables of the auctioneer	
$x^D_{nn,b}$	Quantity of demand of bid b accepted at supply node nn [MWh]
$x^S_{nn,b}$	Quantity of supply of bid b accepted at supply node nn [MWh]