

Designing Auctions for Renewable Energy Support – Experimental Analysis of Multi- Technology Auctions

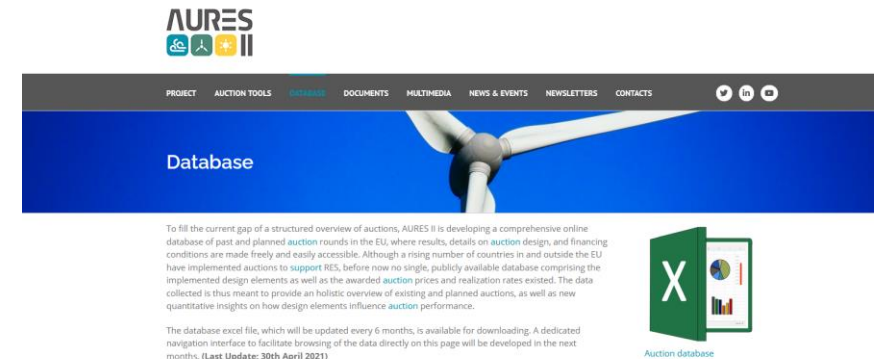
Ann-Katrin Hanke (Takon GmbH, Karlsruhe Institute of Technology)

Online IAEE 2021, June 9th

Auctions for renewable energy support in the EU



- AURES II Database
 - 413 auctions from 20 countries
 - Technology-specific
 - Multi-technology
 - Includes different design elements
 - Prequalification criteria
 - Securities and penalties
 - Remuneration scheme
 - Pricing rule and auction format
 - Quotas
 - Etc.
 - Outcomes (prices, competition,...)



<http://aures2project.eu/auction-database/>

		Country	Source	Year	Submitted capacity [MW]	Submitted budget [€]	Submitted electricity [kWh]	Number of submitted bids	Highest submitted bid price [ct/kWh]	Lowest submitted bid price [ct/kWh]	Average awarded price [ct/kWh]	Highest awarded price [ct/kWh]	Lowest awarded price [ct/kWh]	Adjusted average awarded price [ct/kWh]	Awarded capacity [MW]	Awarded budget [€]	Awarded electricity [kWh]	Compet (Estimated volume) [MW]
626	SL_6_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	13962			n/a	n/a	6.08	6.08	6.08	6.28	200			2.21	
627	SL_6_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	9789			n/a	n/a	6.43	6.43	6.43	6.66	300			19.74	
628	SL_6_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	153612			n/a	n/a	13.42	13.42	7.21	9.13	7750			19.74	
629	SL_7_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	139650			n/a	n/a	13.42	13.42	13.42	13.62	400			19.74	
630	SL_7_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	13962			n/a	n/a	9.35	13.19	7.21	9.63	7300			19.74	
631	SL_7_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	130961			n/a	n/a	7.48	6.5	6.42	7.70	6600			19.74	
632	SL_8_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	139650			n/a	n/a	6.5	6.5	6.5	6.73	3000			19.74	
633	SL_8_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	14302			n/a	n/a	6.85	6.85	6.85	7.05	2600			19.74	
634	SL_8_MF	Slovenia	https://www.aures.eu/aures2/2017	2017	9789			n/a	n/a	7.03	6.45	6.42	7.24	2900			19.74	
635	SL_8_MF	Slovenia	https://www.aures.eu/aures2/2018	2018	205987			n/a	n/a	6.34	6.75	5.789	6.42	105100			3.10	
636	SL_8_MF	Slovenia	https://www.aures.eu/aures2/2018	2018	26038			n/a	n/a	6.63	6.14	6.62	6.71	11400			3.10	
637	SL_8_MF	Slovenia	https://www.aures.eu/aures2/2018	2018	297308			n/a	n/a	6.31	6.75	5.79	6.29	93700			3.10	
638	SL_10_MF	Slovenia	https://www.aures.eu/aures2/2018	2018	25494			n/a	n/a	6.75	13.9	7.16	8.85	5213			4.89	
639	SL_10_MF	Slovenia	https://www.aures.eu/aures2/2018	2018	25494			n/a	n/a	6.75	13.9	7.16	8.85	5213			4.89	
640	SL_10_MF	Slovenia	https://www.aures.eu/aures2/2018	2018	309447			n/a	n/a	6.71	6.75	6.82	6.79	19000			16.11	
641	SL_11_MF	Slovenia	https://www.aures.eu/aures2/2018	2018	297308			n/a	n/a	6.75	6.75	6.75	6.83	15000			16.11	
642	SL_12_MF	Slovenia	https://www.aures.eu/aures2/2018	2018	11339			n/a	n/a	6.53	6.56	6.82	6.61	400			16.11	
643	SL_12_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	11339			n/a	n/a	n/a	n/a	n/a	n/a	n/a			16.11	
644	SL_12_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	41312.4			n/a	n/a	11.99	15.19	9.87	11.99	3130			13.22	
645	SL_12_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	7680			n/a	n/a	16.16	15.19	15.19	15.16	950			13.22	
646	SL_12_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	33732.4			n/a	n/a	10.58	14.70	9.67	10.58	2170			13.22	
647	SL_12_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	64451.4			n/a	n/a	7.38	17.007	6.489	7.38	7320			7.71	
648	SL_14_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	12423			n/a	n/a	6.99	8.19	6.49	6.99	4900			7.71	
649	SL_14_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	6			n/a	n/a	6.71	6.71	6.71	6.71	6			7.71	
650	SL_14_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	7680			n/a	n/a	17.01	17.01	17.01	17.01	56			7.71	
651	SL_14_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	33732.4			n/a	n/a	16.68	16.68	16.68	16.68	16			7.71	
652	SL_14_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	2712			n/a	n/a	7.98	10.01	6.79	7.98	2350			7.71	
653	SL_14_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a			n/a	
654	SL_16_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	27951			n/a	n/a	7.30	9.08	7.19	7.30	12940			2.16	
655	SL_16_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	27951			n/a	n/a	7.30	9.08	7.19	7.30	12940			2.16	
656	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	32096			n/a	n/a	8.04	14.89	7.25	8.04	13760			2.37	
657	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	2074			n/a	n/a	7.98	8.11	7.85	7.98	149			2.37	
658	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a			2.37	
659	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	2217			n/a	n/a	14.89	14.89	14.89	14.89	400			2.37	
660	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	27951			n/a	n/a	7.62	14.70	7.25	7.62	13001			2.37	
661	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2019	354			n/a	n/a	8.54	9.90	7.84	8.54	210			2.37	
662	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a			n/a	
663	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	9775			n/a	n/a	10.80	15.56	9.40	10.80	1046			9.35	
664	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	1419			n/a	n/a	8.67	14.25	8.40	8.67	800			9.35	
665	SL_17_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	8356			n/a	n/a	16.60	15.56	15.56	15.52	150			9.35	
666	SL_20_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	17039			n/a	n/a	0.01	15.58	6.64	7.99	12039			1.48	
667	SL_20_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	6149			n/a	n/a	8.97	6.14	6.64	6.64	3341			1.48	
668	SL_20_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a			1.48	
669	SL_20_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	1419			n/a	n/a	15.23	15.23	15.19	15.19	1209			1.48	
670	SL_20_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	8356			n/a	n/a	7.16	15.56	6.91	7.14	7076			1.48	
671	SL_20_MF	Slovenia	https://www.aures.eu/aures2/2018	2020	1624			n/a	n/a	9.98	10.11	7.29	9.94	903			1.48	

Multi-technology and technology-specific auctions

- Alone in the EU, there are 296 technology-specific auctions and 106 multi-technology auctions.
- In different countries, different approaches are used.
- Theory is in favour of multi-technology auctions in terms of prices and allocation-efficiency.
- What can be said from an experimental point of view?

Experiment design

- Two groups (= technologies) with costs in different intervals
A [300;400] and B [350;450]
- „*Technology A is cheaper in expectation than B*“
- Each bidder only has one good (single-unit supply)
- Comparison between separate auctions for A and B and joint auction for both

Separate A	Separate B
Bidder X_A	Bidder X_B
Bidder Y_A	Bidder Y_B
Bidder Z_A	Bidder Z_B



Joint A&B
Bidder X_A
Bidder Y_A
Bidder Z_A
Bidder X_B
Bidder Y_B
Bidder Z_B

Conduction

- 144 students at KD2lab in Karlsruhe <https://www.kd2lab.kit.edu/>
- Internet-based auctions (otree) <https://doi.org/10.1016/j.jbef.2015.12.001>
- 40 rounds of auctions
 - 1-10: Separate, Group A
 - 11-20: Separate, Group B
 - 21-30: Joint, Group A
 - 31-40: Joint, Group B
- Half-stranger setting
- Two pricing rules:
 - Pay-as-Bid (PaB)
 - Uniform Pricing (UP)



Hypotheses

Hypothesis 1

Average prices are lower in joint auctions than in separate auctions.

Hypothesis 2

The degree of efficiency is higher in joint auctions than in separate auctions.

Hypothesis 3

The outcome in joint and separate auctions does not depend on the pricing rule .

Did bidders behave irrational?

Almost 50% of bidders in UP bid lower than their costs.

Uniform Pricing	Joint Auctions	Separate Auctions
Bid > Cost	388	508
Bid = Cost	283	265
Bid < Cost	769	667

Only 3% of bidders in PaB bid their costs or below their costs.

Pay-as-Bid	Joint Auctions	Separate Auctions
Bid > Cost	1392	1410
Bid = Cost	24	13
Bid < Cost	24	17

Differences in prices are significant

- Significant differences between PaB and UP auctions, as well as between joint and separate ones ($p < 0.001$).

Prices	Joint Auctions	Separate Auctions
Pay-as-Bid	355.95	362.66
Uniform Pricing	361.58	371.76

- In the joint auctions, around 84% of awarded bidders (804) were in group A.
- There seems to be no change of behaviour over time, while it does make a difference if bidders first play separate or joint.

Efficiency is higher in joint auctions

- An auction is efficient, if the bidders with the lowest costs are awarded.
- Here, the degree of efficiency is defined as the percentage of bidders which are correctly awarded.

D_{eff}	Joint Auctions	Separate Auctions
Pay-as-Bid	84.38%	56.88%
Uniform Pricing	86.46%	55.63%

- Even with a stricter or a more loose definition, results are in general the same.

What can we say in conclusion?

Hypothesis 1



Average prices are lower in joint auctions than in separate auctions.

Hypothesis 2



The degree of efficiency is higher in joint auctions than in separate auctions.

Hypothesis 3



The outcome in joint and separate auctions does not depend on the pricing rule. *Pay-as-Bid leads to lower prices.*

There is still more to be done...



- At the moment, we suggest to conduct joint auctions with the pay-as-bid pricing rule as long as technologies are somehow comparable.
- We plan on conducting further experiments to include
 - Multi-item supply:
Each bidder has more than one project to offer.
 - Common value component:
The costs are not independently distributed, but there is a common value component, which is the same for all bidders.



Ann-Katrin Hanke
Takon GmbH, KIT
hanke@takon.com,
ann-katrin.hanke@kit.edu



AURES II

Website: <http://aures2project.eu/>
LinkedIn: AURES II
Twitter: @auctions4res
Newsletter: <http://eepurl.com/gd42zz>



AURES has received funds for the years 2018-2021
from the European Union's Horizon 2020 research and innovation programme
under grant agreement no. 817629