

# Benchmarking energy use in wastewater treatment plants

Longo S., Mauricio-Iglesias M., Lema J.M., Hospido A.

IWA Pi Conference, May 15th 2017, Vienna

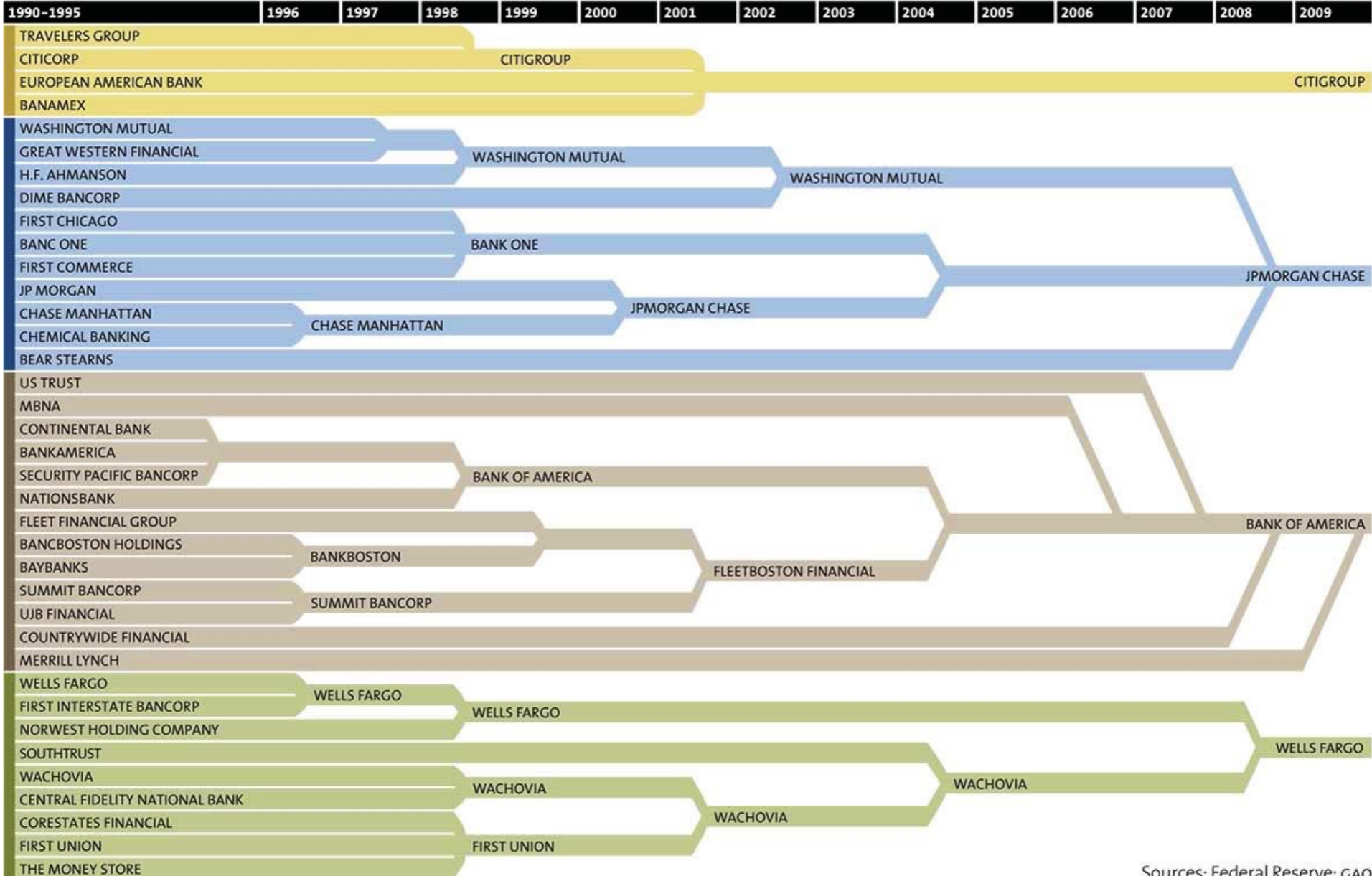
Energy efficiency = better water quality



# What is energy efficiency?

$$\frac{\text{Input}}{\text{Output}} = \frac{\text{kWh}}{\text{m}^3} = \frac{\text{kWh}}{\text{PE}} = \frac{\text{kWh}}{\text{kgCODrem}}$$

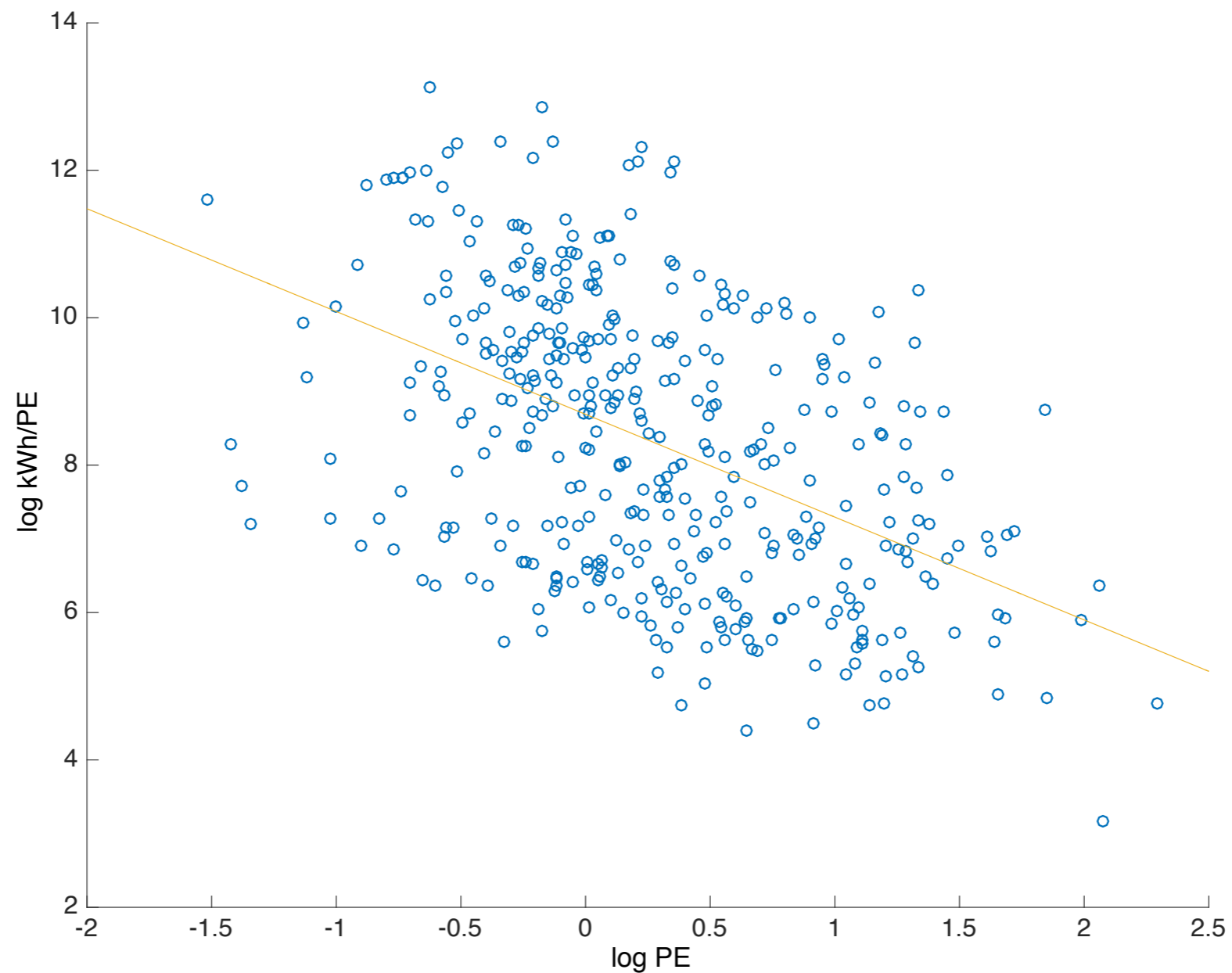
# Can we use the experience developed in the financial sector?



Sources: Federal Reserve; GAO

37 banks .....▶ 4 banks

# Plant size is not able to explicate all the variation



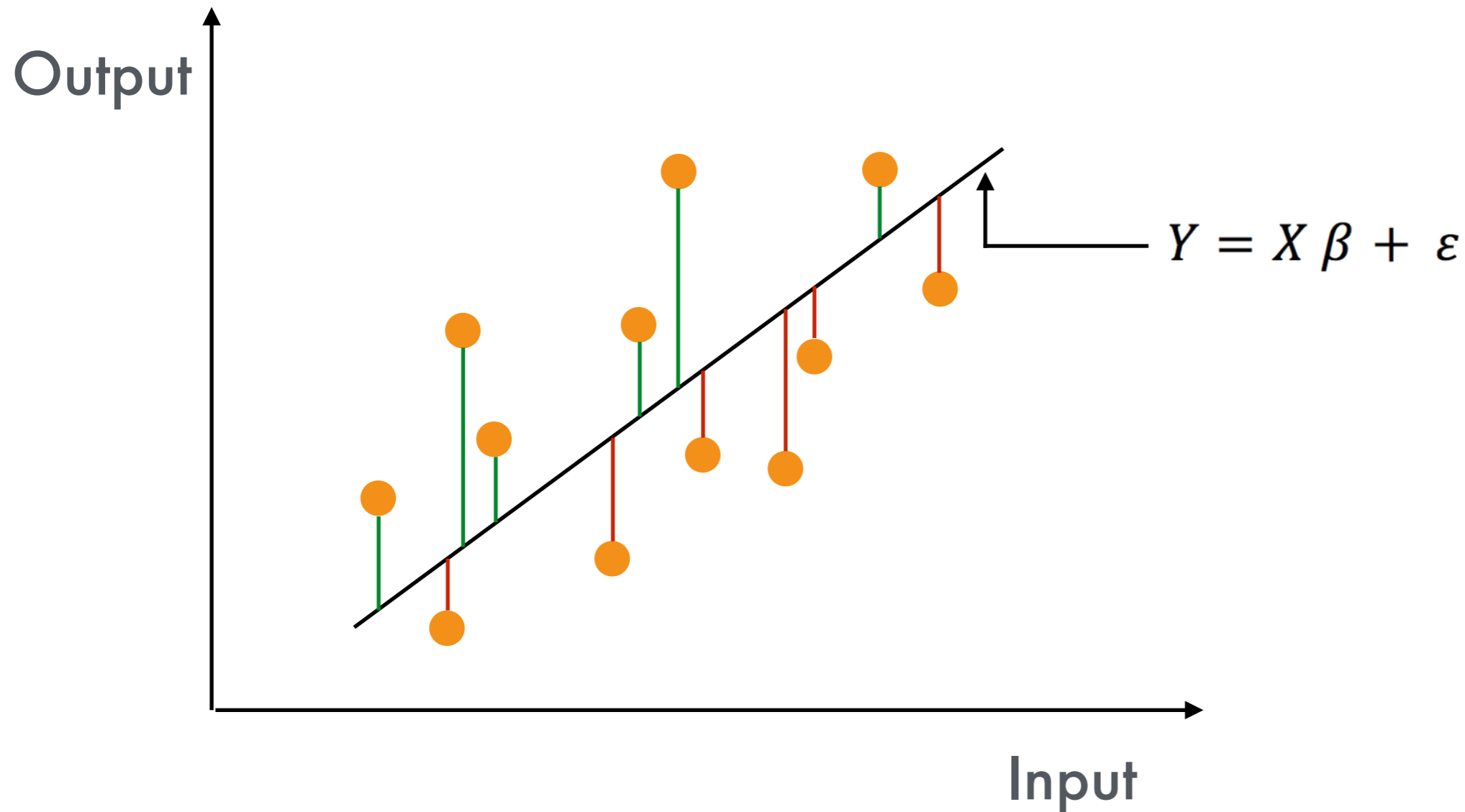
# Can we use the experience developed in the **financial sector**?

	Banks	WWTPs
Different scale	✓	✓
Different environmental conditions	✓	✓
Different services/functions	✓	✓
Different technologies	X	✓

# Objectives

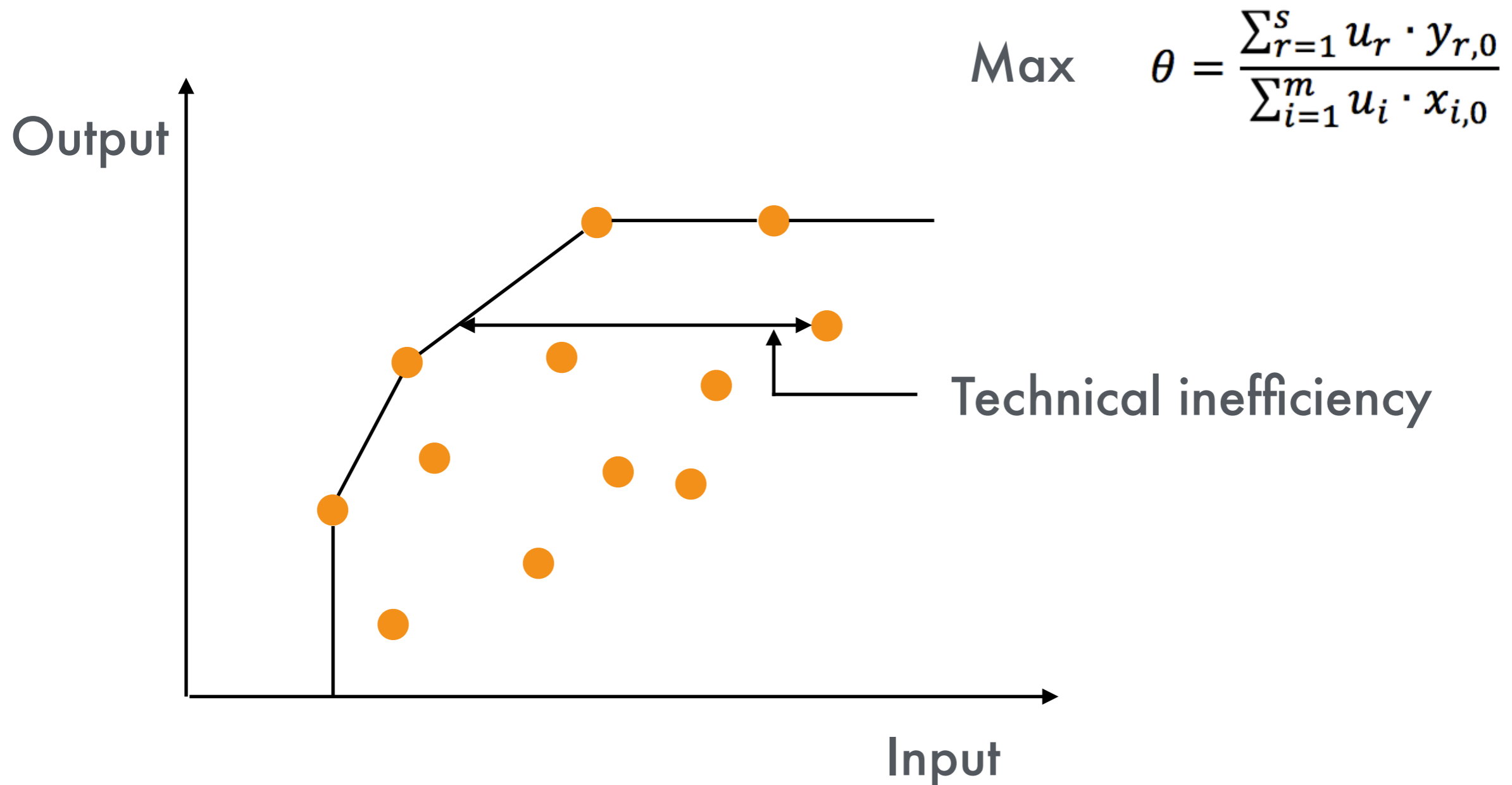
- To develop energy benchmarking system based on (i) linear regression and (ii) data envelopment analysis
- To compare their efficiency estimates on the same dataset
- To test their robustness for the assessment of the energy efficiency of WWTPs

# Ordinary least squares (OLS) predicts the expected energy consumption

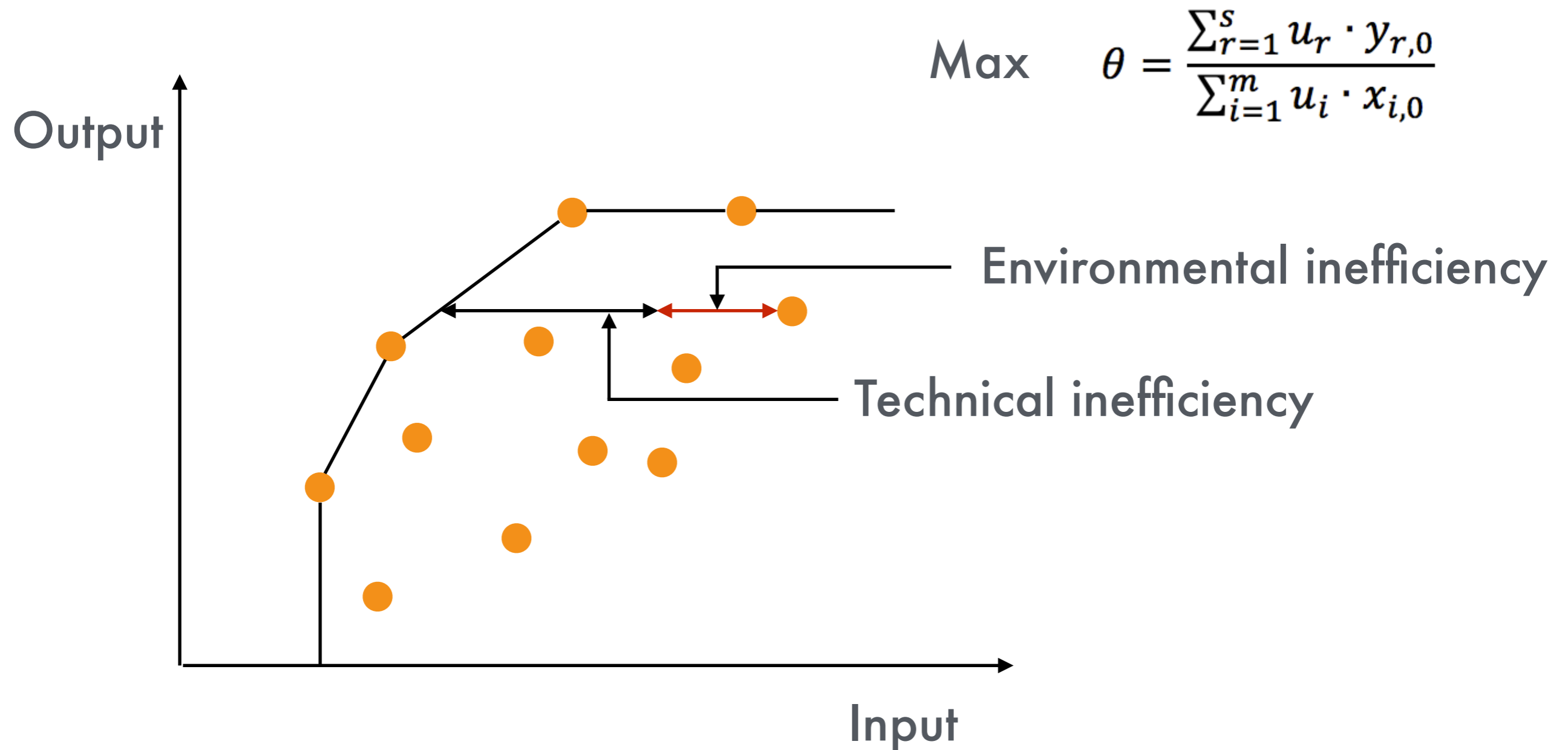




# Data Envelopment Analysis (DEA) builds a best performance frontier in a dataset



# Two-stage DEA corrects the impact of environmental variables



**Do various benchmarking approaches  
generate consistent energy efficiency  
assessment for WWTPs?**

# Data and variables

Variable name	Abbreviation	Average (st dev)	Units
Total energy consumption (input)	<i>E</i>	2261(4653)	kWh/d
kg of COD removed (output)	<i>CODrem</i>	2368(5580)	kgCOD/d
kg of N removed (output)	<i>Nrem</i>	144(363)	kgN/d
Tertiary treatment	<i>TerTreat</i>	YES' , 'NO'	-
Plant size	<i>SIZE</i>	20977(49467)	PE
Plant load factor	<i>PLF</i>	71(59)	%
Dilution factor	<i>DIL</i>	429(794)	L/(PE·d)
Outdoor Temperature	<i>TEMP</i>	12.1(3.2)	°C
Number plants	413		

# Consistency conditions 1: ranking correlation Spearman

Rank method 1	Rank method 2
1	12
2	11
3	10
4	9
5	8
6	7
7	6
8	5
9	4
10	3
11	2
12	1
Correlation = 1	Correlation = 0

# Consistency conditions 2: "best-" and "worst-practices" identification

Rank OLS	Rank DEA	Rank DEA
1	12	2
2	11	3
3	10	1
4	9	4
5	8	7
6	7	6
7	6	5
8	5	8
9	4	9
10	3	12
11	2	11
12	1	10
Correlation = 1	Correlation = 0	Correlation = 1

# Do they rank in the same order?

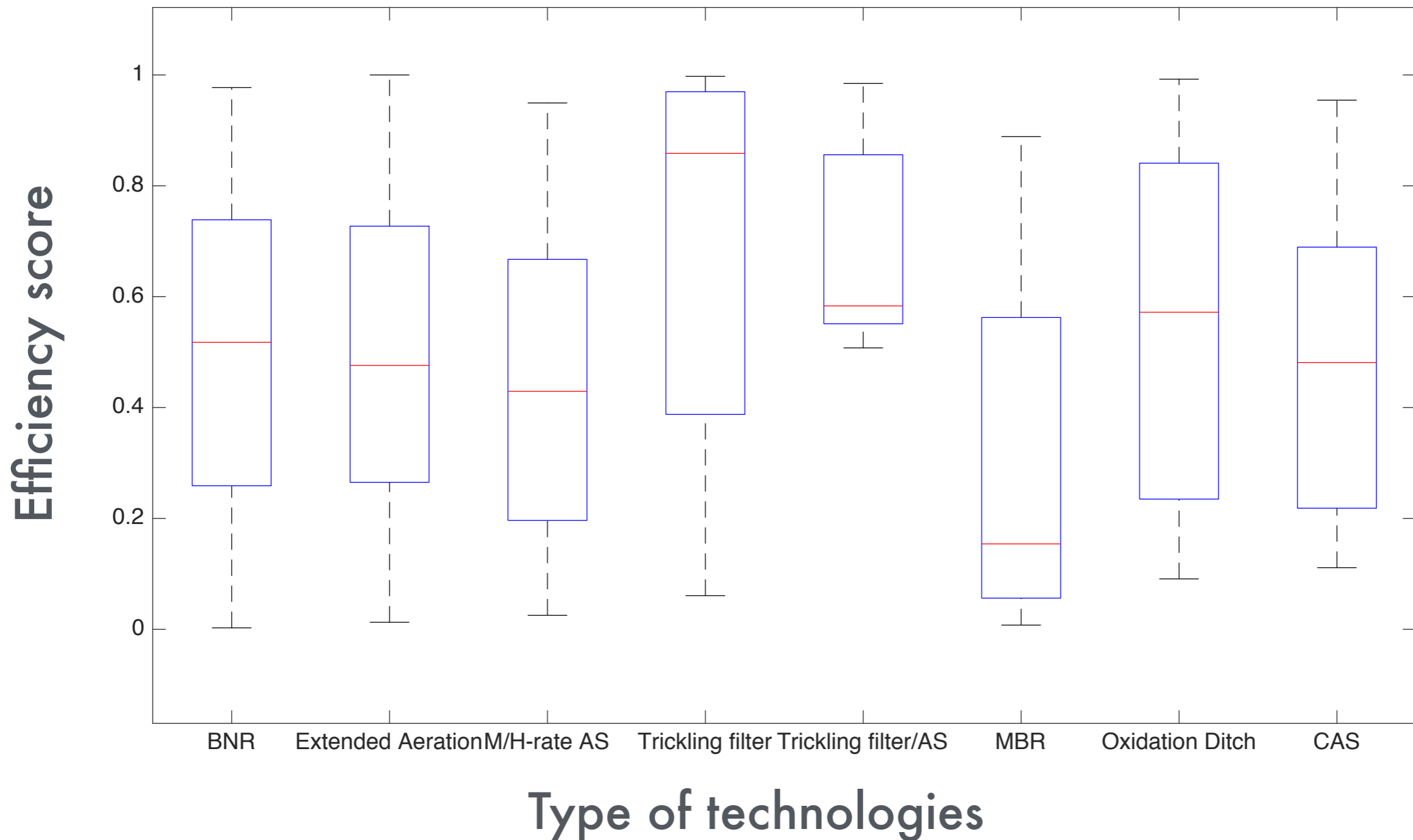
	OLS	DEA	two-stage DEA
OLS	1	0.489	0.689
DEA		1	0.634
two-stage DEA			1

# Do they identify the same “best-” and “worst-practices”?

	OLS	DEA-VRS	two-stage DEA
OLS	1	0.535	0.687
DEA-VRS	0.545	1	0.535
two-stage DEA	0.646	0.687	1



# Are there differences across technologies?



# Concluding...

- Energy efficiency is function of various factors, including exogenous factors
- Simply DEA-VRS may not reflect the real efficiency of a WWTP
- After controlling for environmental factors in DEA, a good consistency between OLS and two-stage DEA was found

An aerial photograph showing a coastal area. In the foreground, there is a large, vibrant green field, possibly a wetland or a large-scale agricultural field. To the left, a sandy beach is visible, crowded with people and umbrellas. In the background, a city skyline is visible, featuring several tall buildings, including a prominent white skyscraper. The sky is clear and blue.

**we can have less of this**

**Shandong, China, 2013**

and more of this



Carnota, Galicia, 2015

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