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Can nitrogen removal be a win-win situation?

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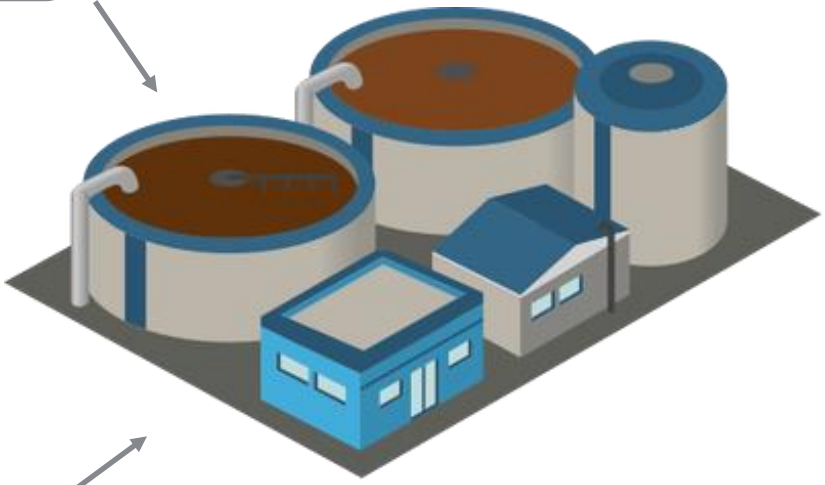
A wastewater treatment plant transforms wastewater

Wastewater
C/N/P

Energy

Chemicals



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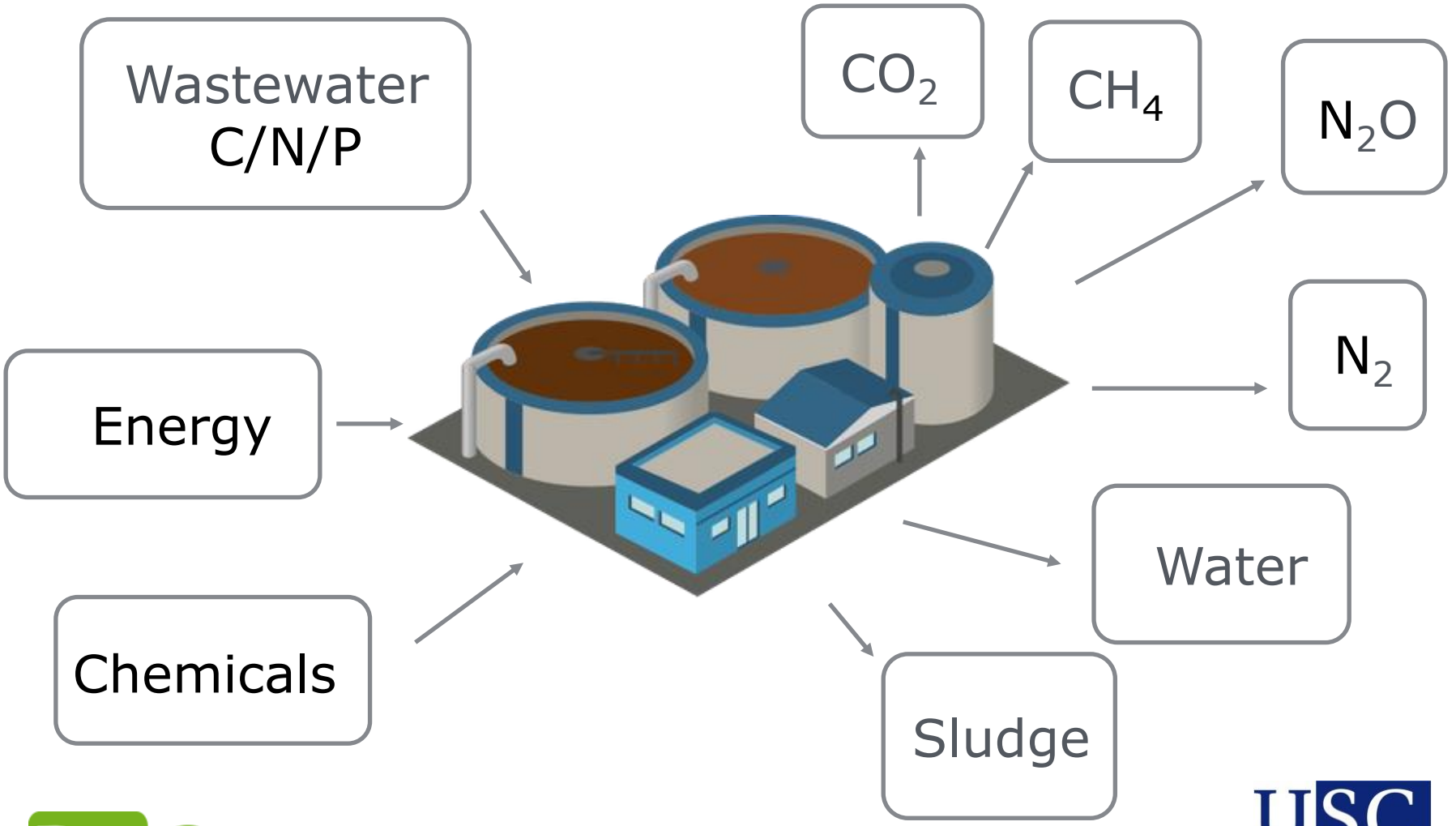
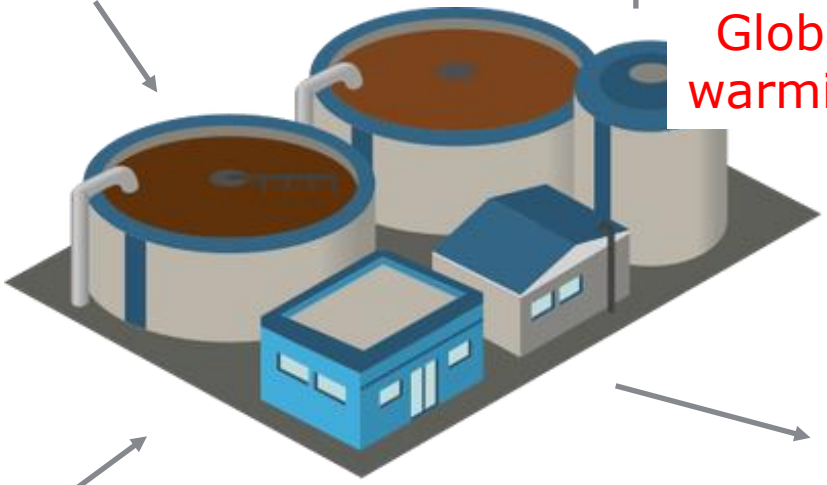


A wastewater treatment plant transforms environmental impacts



Eutrophication

Wastewater C/N/P

CO_2

CH_4

N_2O

Global warming

Global warming

Energy

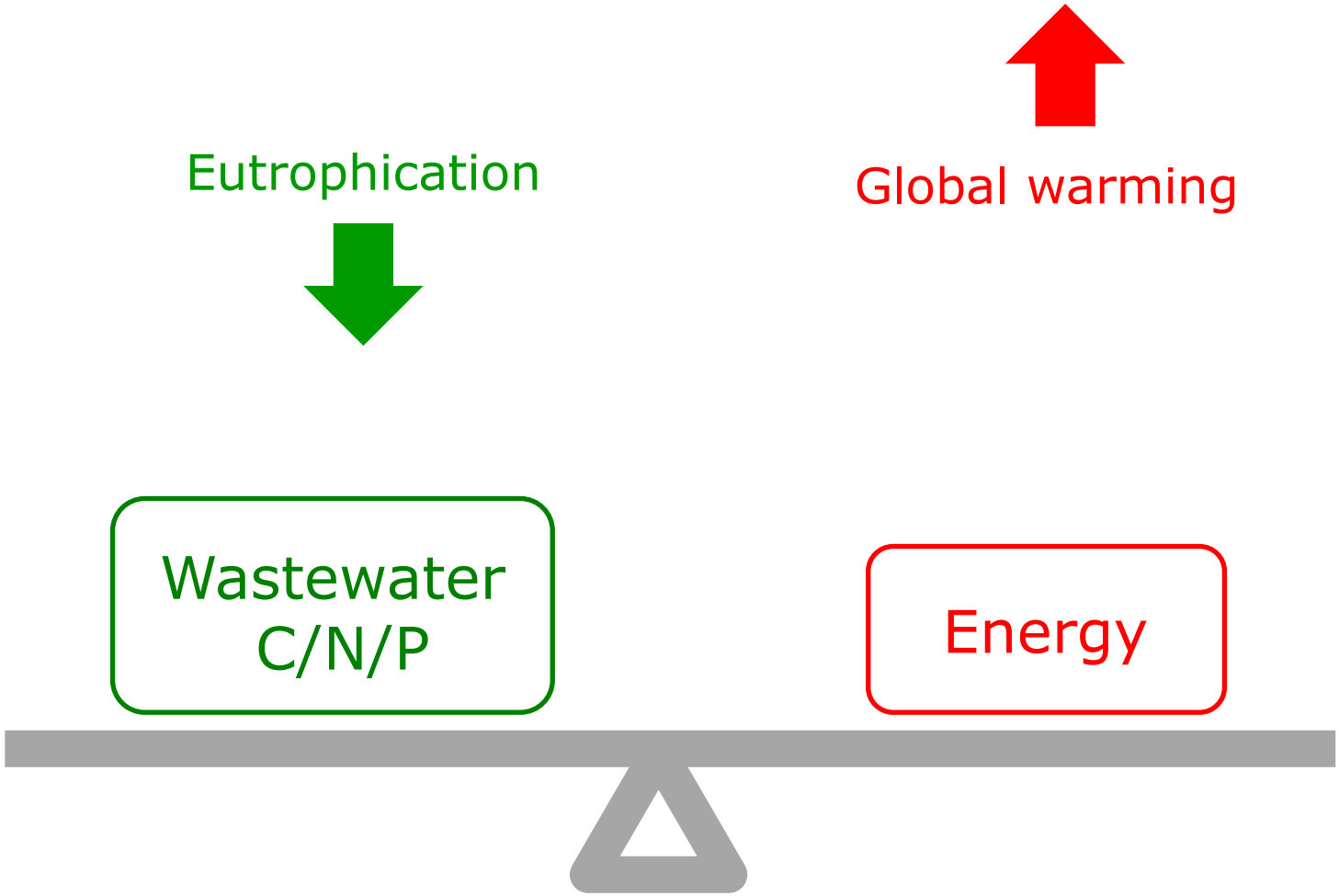
N_2

Water

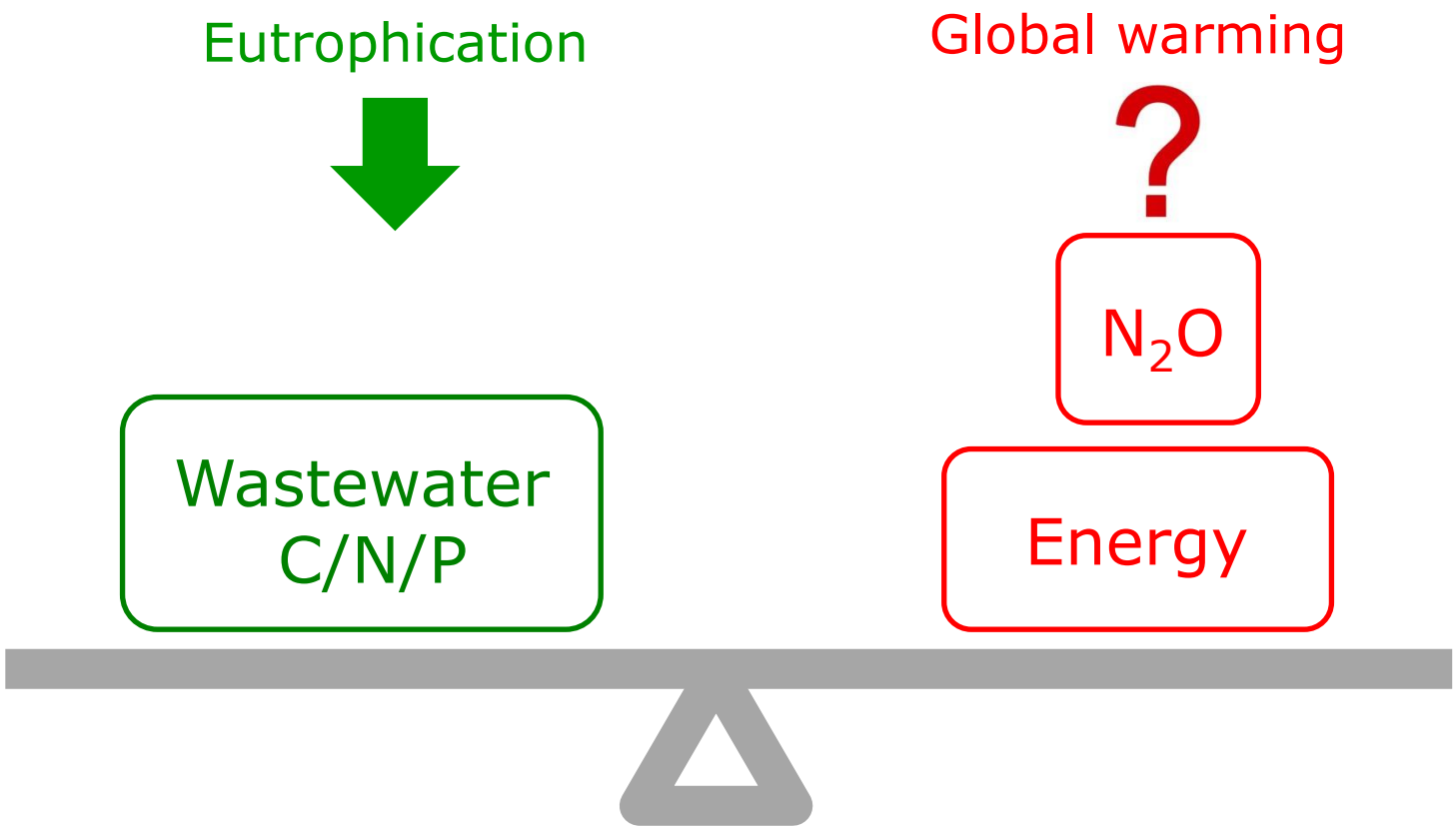
Chemicals

Sludge

Energy is required to remove nitrogen



But, is it really a trade off ?



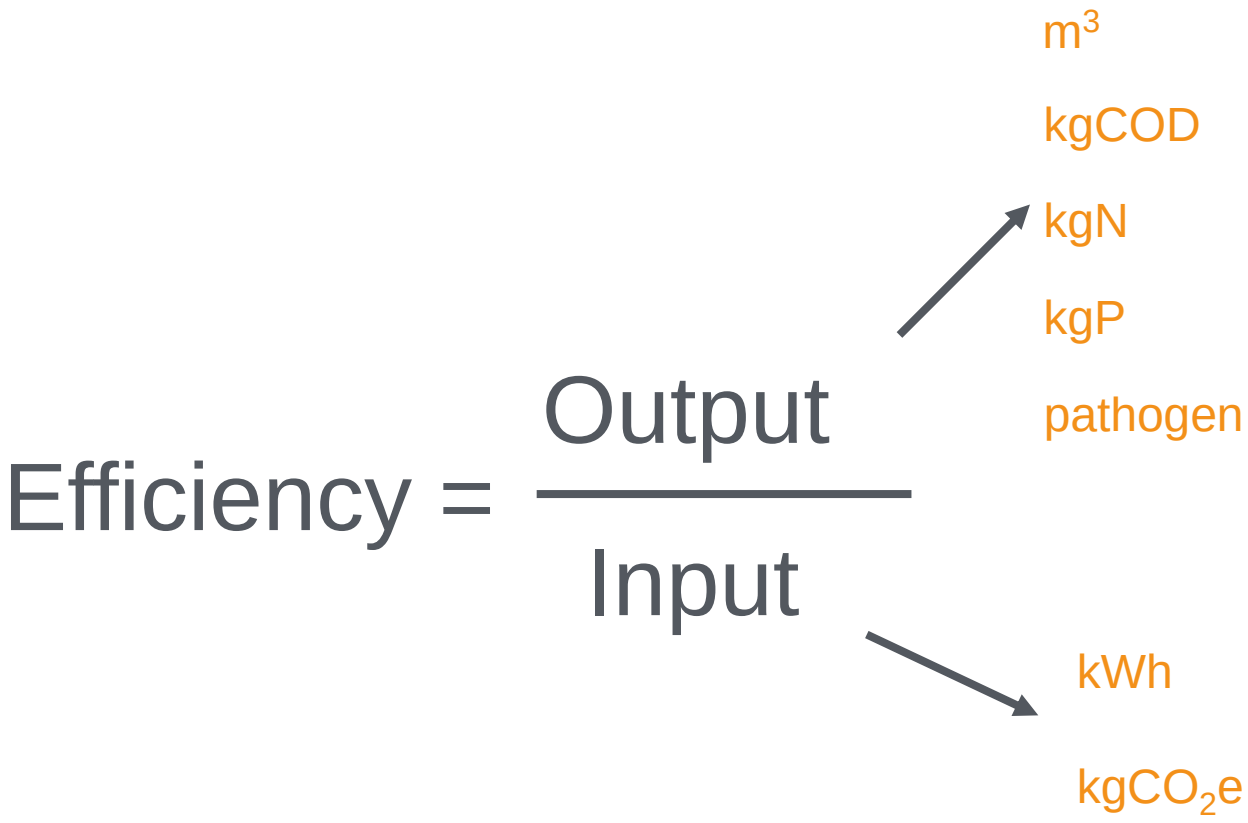
This is the question we study

- Can an increase in nitrogen removal lead to overall lower global warming impact ?

This is the method we follow

- We quantify by data envelopment analysis (DEA) the efficiency of a large set of WWTP, including an estimation of N2O emissions and check which one is the main contributor

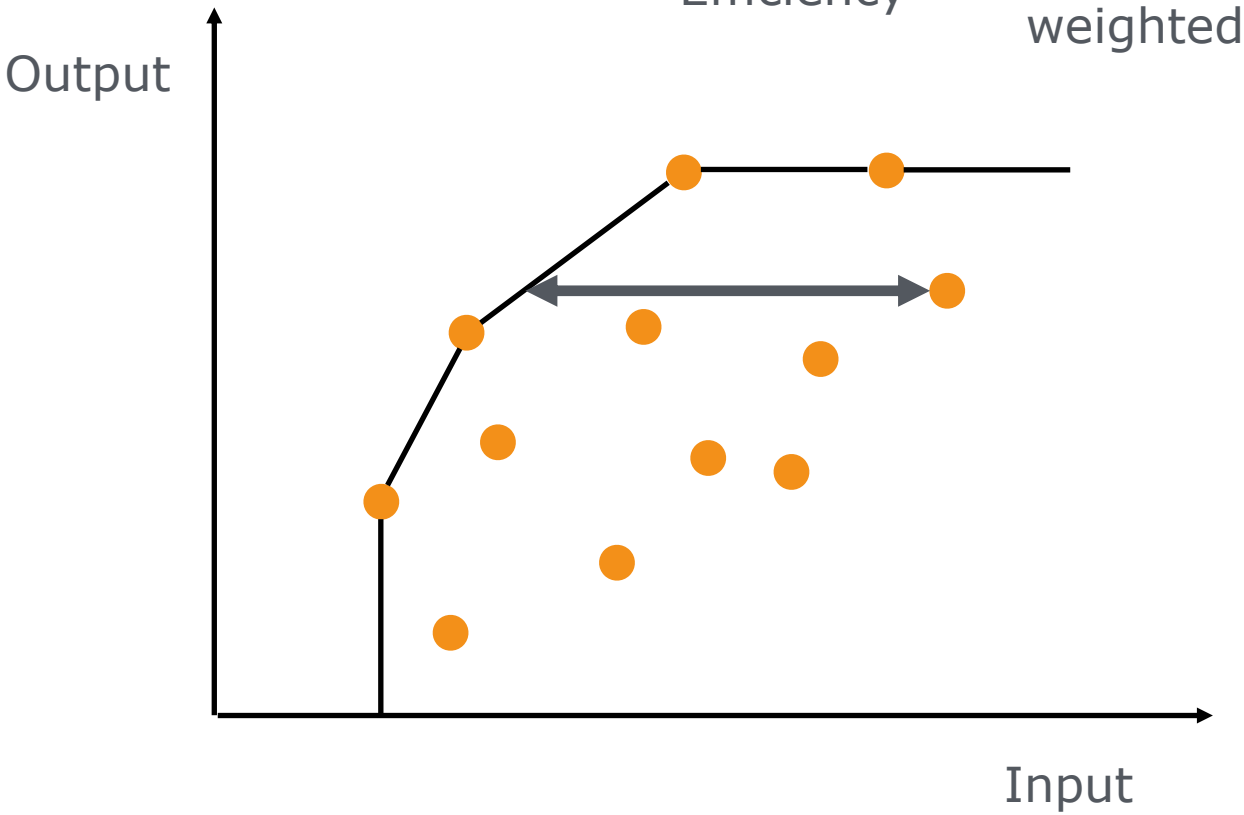
We define efficiency as a ratio between an input and an output



Longo et al (2016). Applied Energy

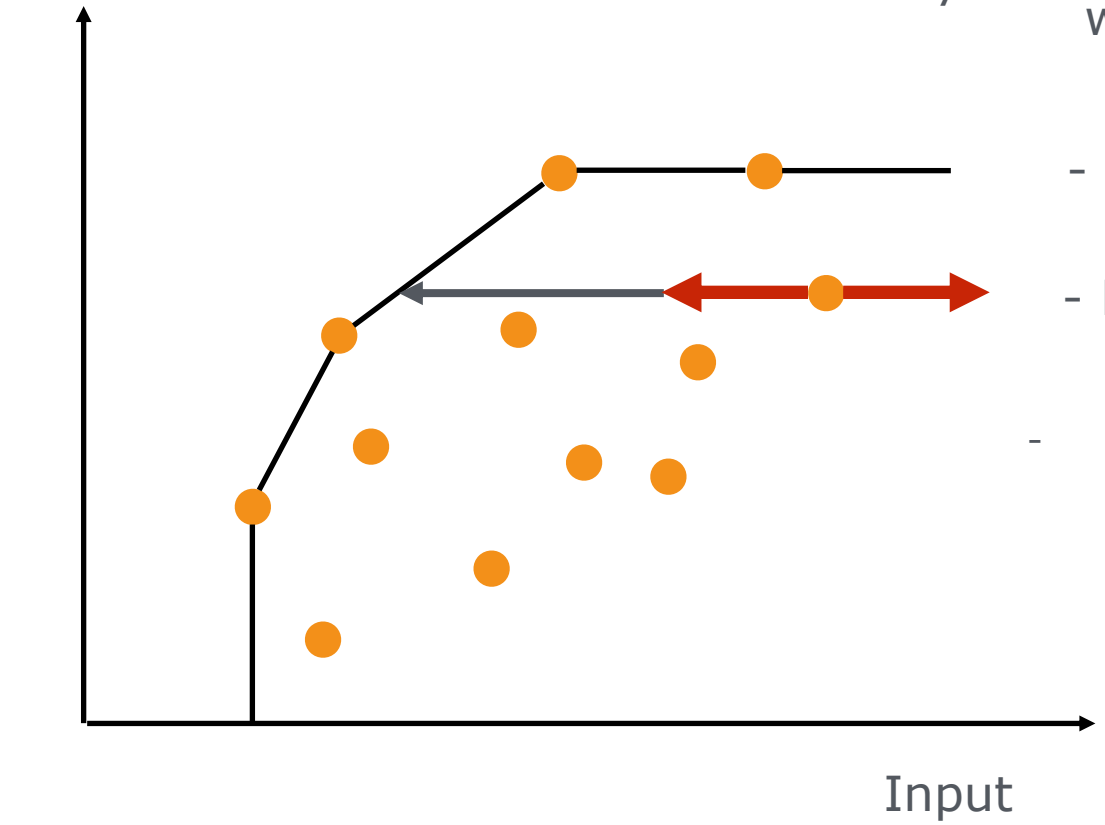
Data Envelopment Analysis (DEA) builds a best performance frontier in a dataset

$$\text{Efficiency} = \frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}$$



Longo et al (2017). submitted to Applied Energy

Two-stage DEA corrects the impact of environmental variables



$$\text{Efficiency} = \frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}$$

- DEA in stage 1
- Regression in stage 2
- Efficiency is adjusted on a number of exogenous factor

Longo et al (2017). submitted to Applied Energy

A case study based on data of 138 WWTPs

Data screening

Only activated sludge processes
60% < N removal < 95%

Variable	Definition	Obs.	Mean	SD	Min	Max
Input						
GHGs	Electricity consumption (kWh)	138	77,733.00	328,300.00	170.10	3,712,000.00
Outputs						
COD	COD removed (kg)	138	2,414.00	5,659.00	2.69	58,318.00
N	N removed (kg)	138	145.90	365.90	0.09	4,098.00
Exogenous categorical variables						
SECONDARY (Ref = Conventional activated sludge)						
EA	Extended aeration	15	/	/	/	/
MHLOAD	Medium/high rate activated sludge	8	/	/	/	/
MBR	Membrane bioreactor	7	/	/	/	/
OD	Oxidation ditch	15	/	/	/	/
TERTIARY (Ref = No tertiary treatment)						
YES	Filtration or UV disinfection	32				
Exogenous continuous variables						
SIZE	Actual plant size (PE)	138	23,601.76	60,029.23	23.91	507,511.16
LF	Load factor (%)	138	69.28	45.68	3.50	352.85
DF	Dilution factor (L/PE/d)	138	414.11	560.16	64.83	4,830.00
TEMP	Temperature (°C)	138	12.06	3.23	9.50	18.10

An input that represents the global warming cost and two outputs for the WWTP function

$$\frac{\text{Input: } CO2_{tot} = CO2_{N2O} + CO2_{kWh}}{\text{Outputs: } COD_{removed} = kgCOD_{in} - kgCOD_{out};\ N_{removed} = kgN_{in} - kgN_{out}} = \frac{\text{global warming impact}}{\text{service provided}} = \text{Efficiency}$$

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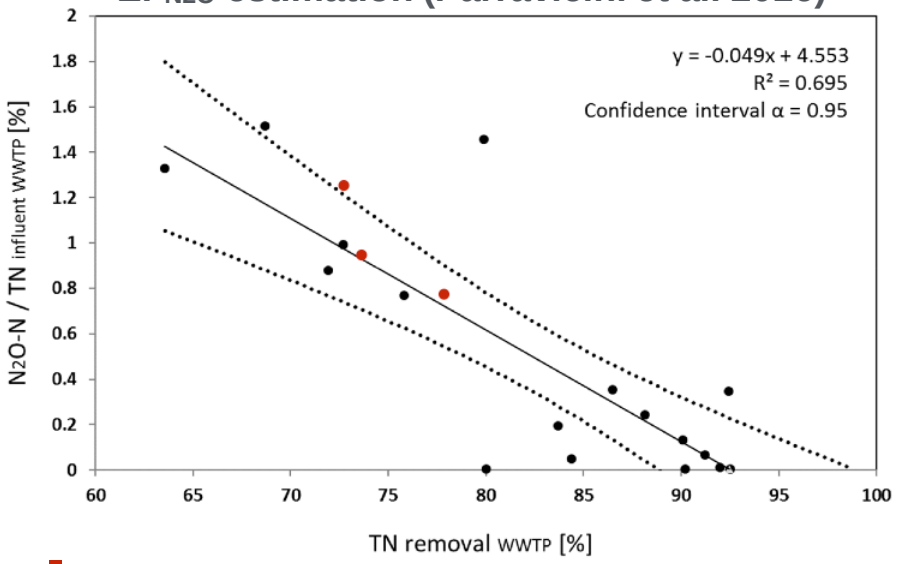
$N_2O_{emission} = N_{influent} * EF_{N2O}$

$CO2_{N2O} = N_2O_{emission} * GWP_{N2O}$

$CO2_{kWh} = GWP_{kWh}$

EF_{N2O} estimation (Parravicini et al. 2016)



- checked in a real WWTP by Longo et al. (2017)

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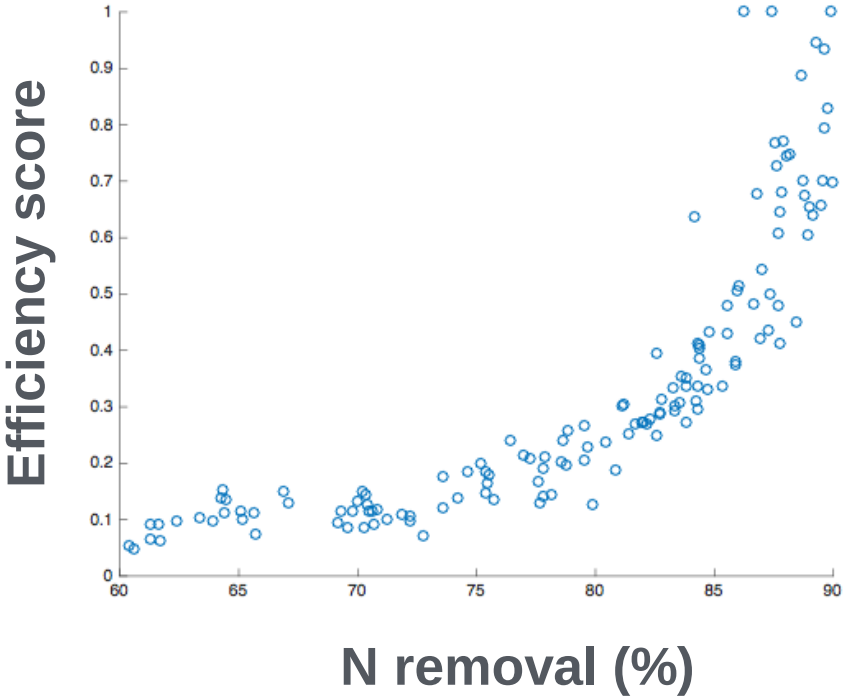
Removing more nitrogen does not imply a decrease in efficiency



- Increasing N removal leads to higher energy consumption
- Increasing N removal decrease the N_2O emissions

Reducing the N_2O emissions would outweight the higher energy consumption

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Increasing nitrogen removal can be a win-win strategy

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Standard method and online tool for assessing and improving the energy efficiency of wastewater treatment plants

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