Environmental and Economic Sustainability Assessment for Onsite Sewage Treatment and Disposal System (OSTDS)

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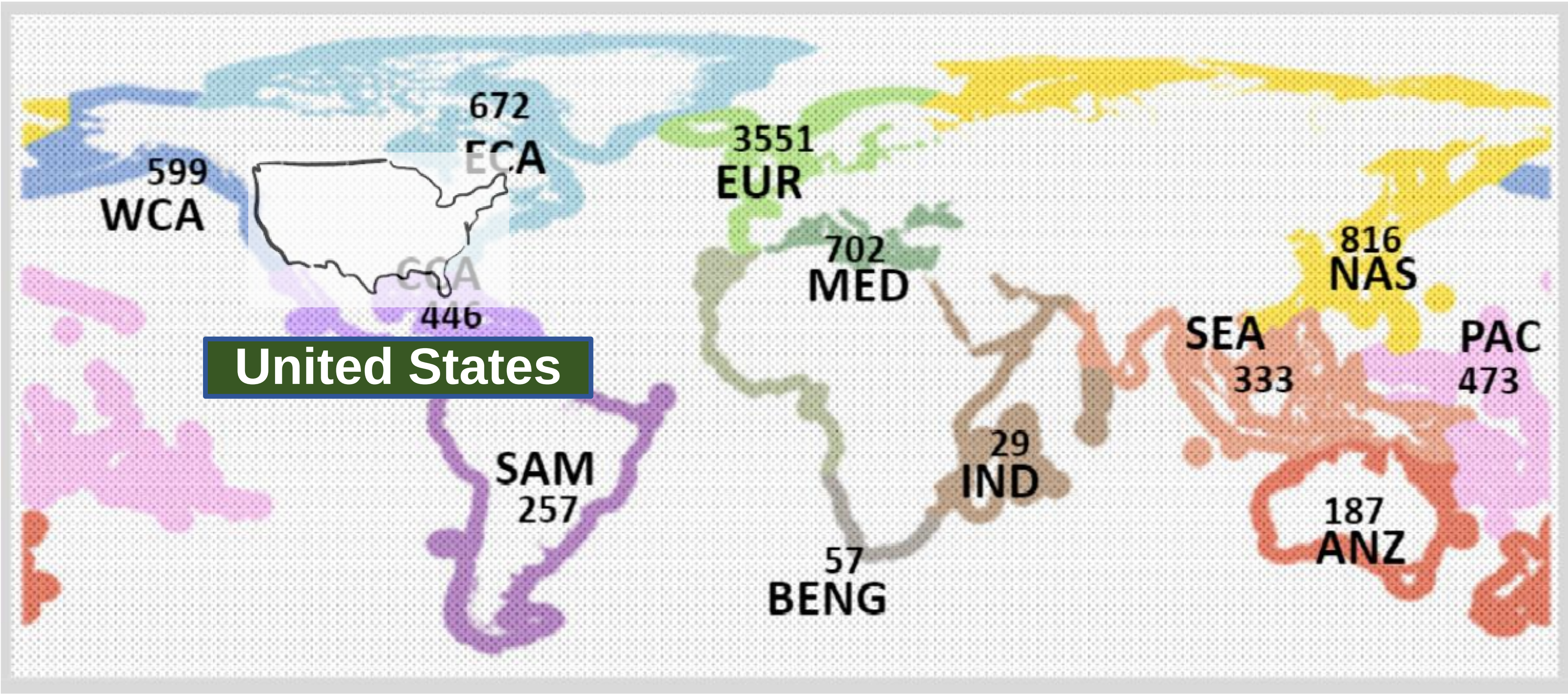
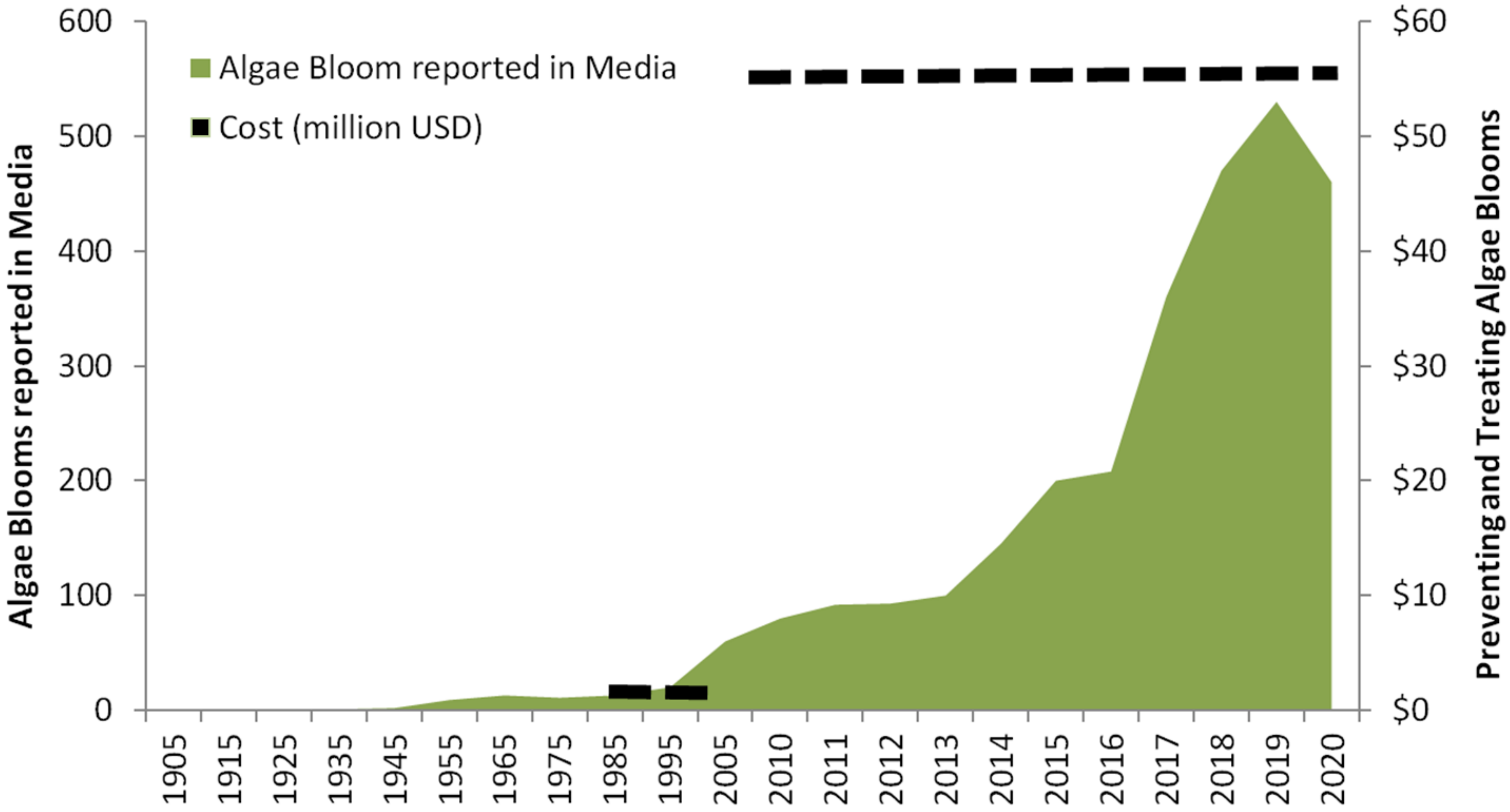
Harmful algal blooms (HABs) have occurred globally throughout the history.



ECA = East Coast America
EUR = Europe
SEA = Southeast Asia
CCA = Central America Caribbean
MED = Mediterranean
NAS = North Asia
SAM = South America
BENG = Benguela Current
ANZ = Australia New Zealand
WCA = West Coast America
IND = Indian Ocean
PAC = Pacific

(UNESCO, Global harmful algal bloom status report 1985-2021)

HABs have continued to increase in the United States despite significant investment in prevention and treatment efforts.

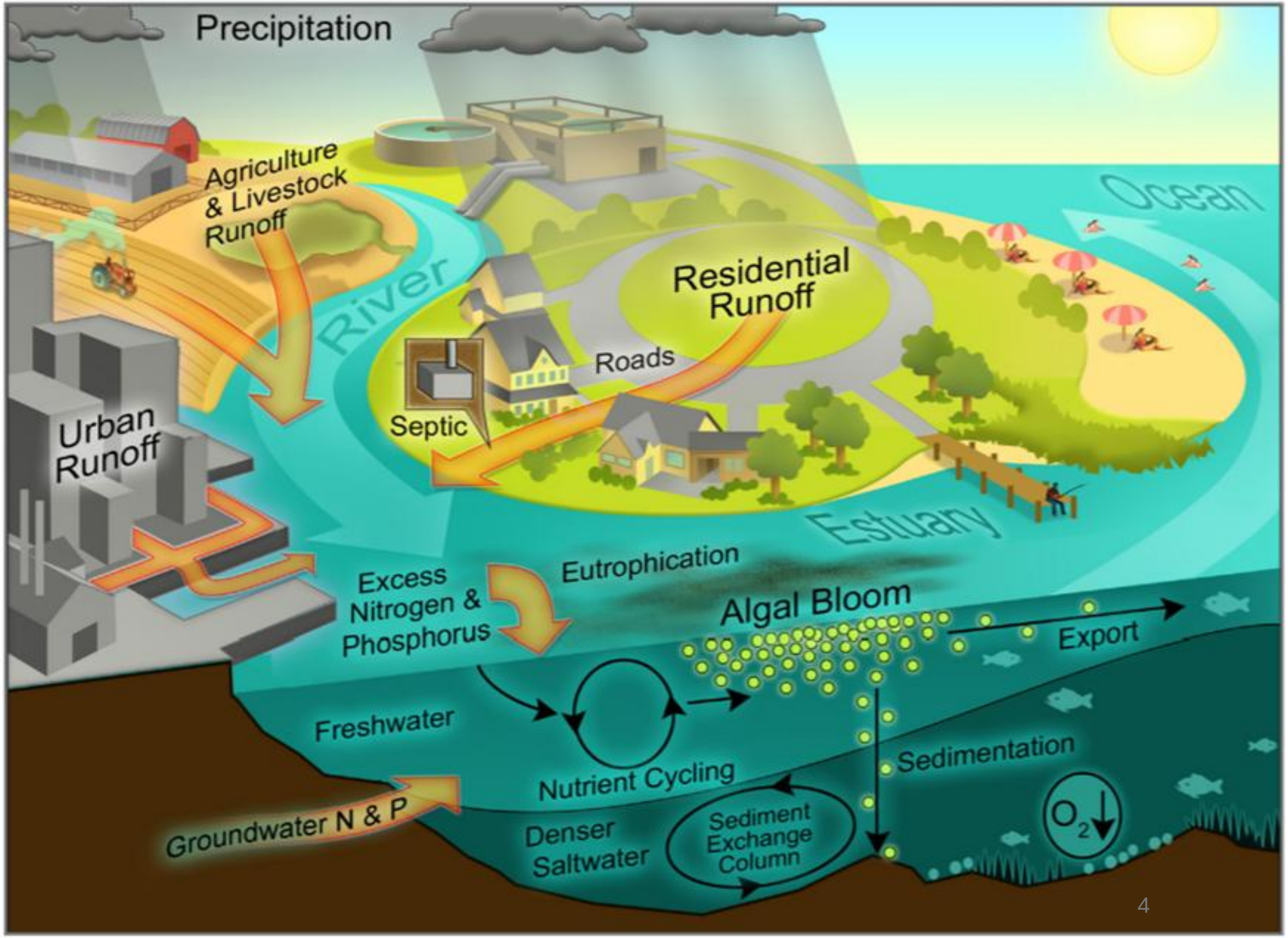


(EWG, 2020)

What causes harmful algal blooms?

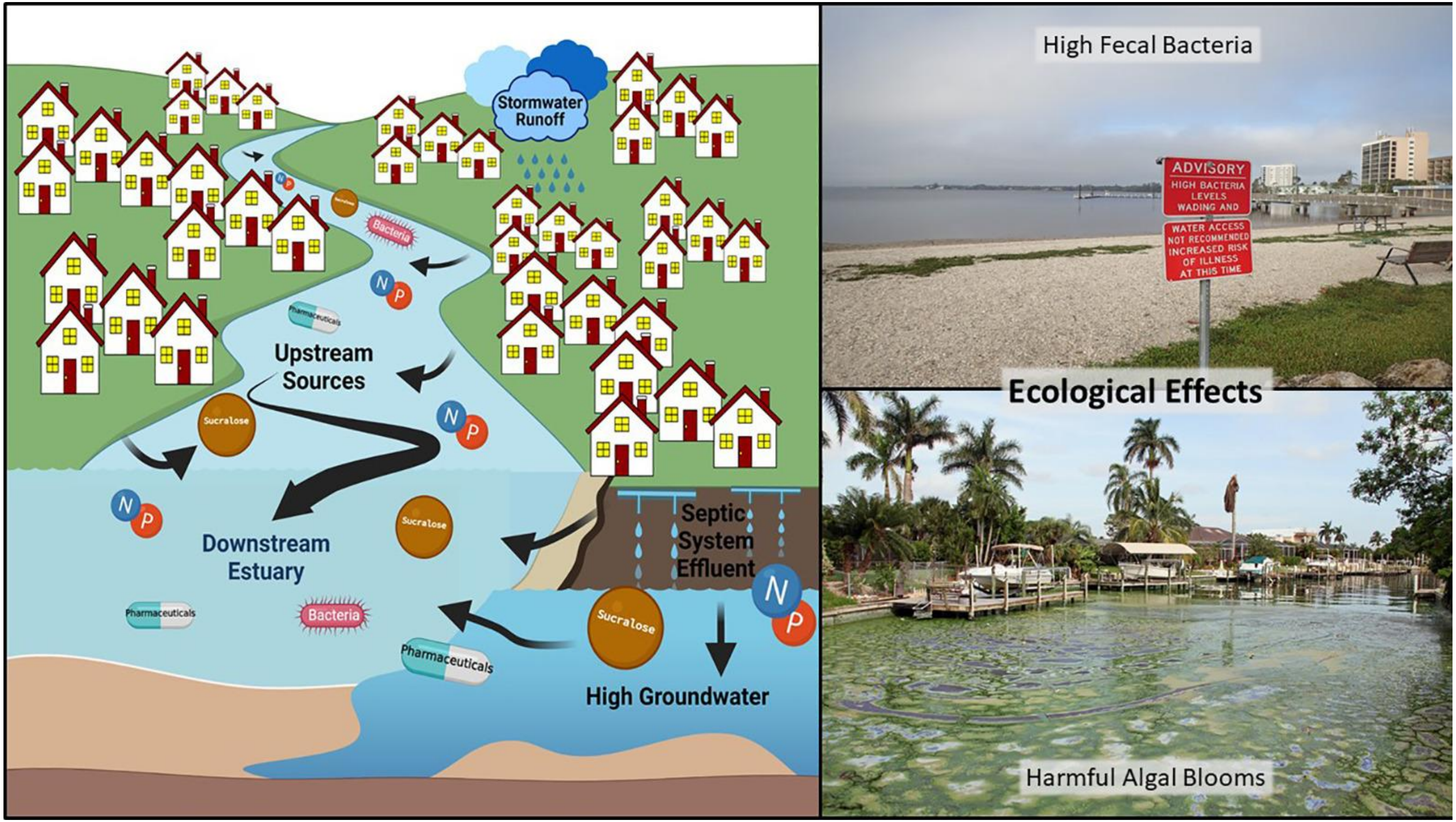
Natural factors
- Warmer temperature
- Slow-moving water
- Sufficient light

Anthropogenic factor
- Excessive nutrient loading



(Paerl, n.d.)

Septic systems contribute to harmful algal blooms in Florida.



(Brewton et al., 2022)

How to mitigate the environmental and economic impact? Four factors are considered in the design of scenarios.

Factor 1- Scale

Factor 2 – Preliminary treatment step

Factor 3 – Treated water disposal

Factor 4 – Maintenance frequency

Four factors are considered in the design of scenarios.

1, 10, or 100 households

Conventional septic tank & aerobic treatment unit

Traditional drainfield, drip irrigation & enhanced nitrogen removal

Proactive and reactive maintenance activities

Environmental and economic impact of 16 designed scenarios are assessed based on the functional unit.

Functional unit

Treating sewage from 100 households in 20 years, assuming 3 bedrooms (6 people) in 1 house.

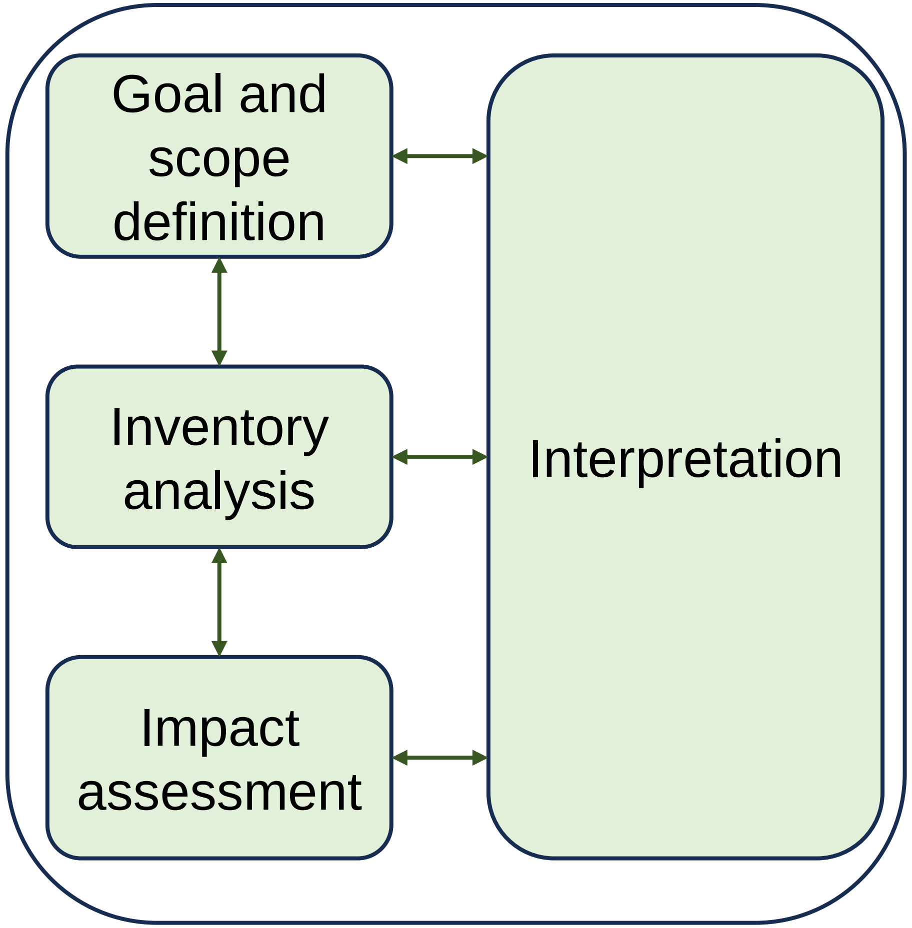
Abbreviation – Full name

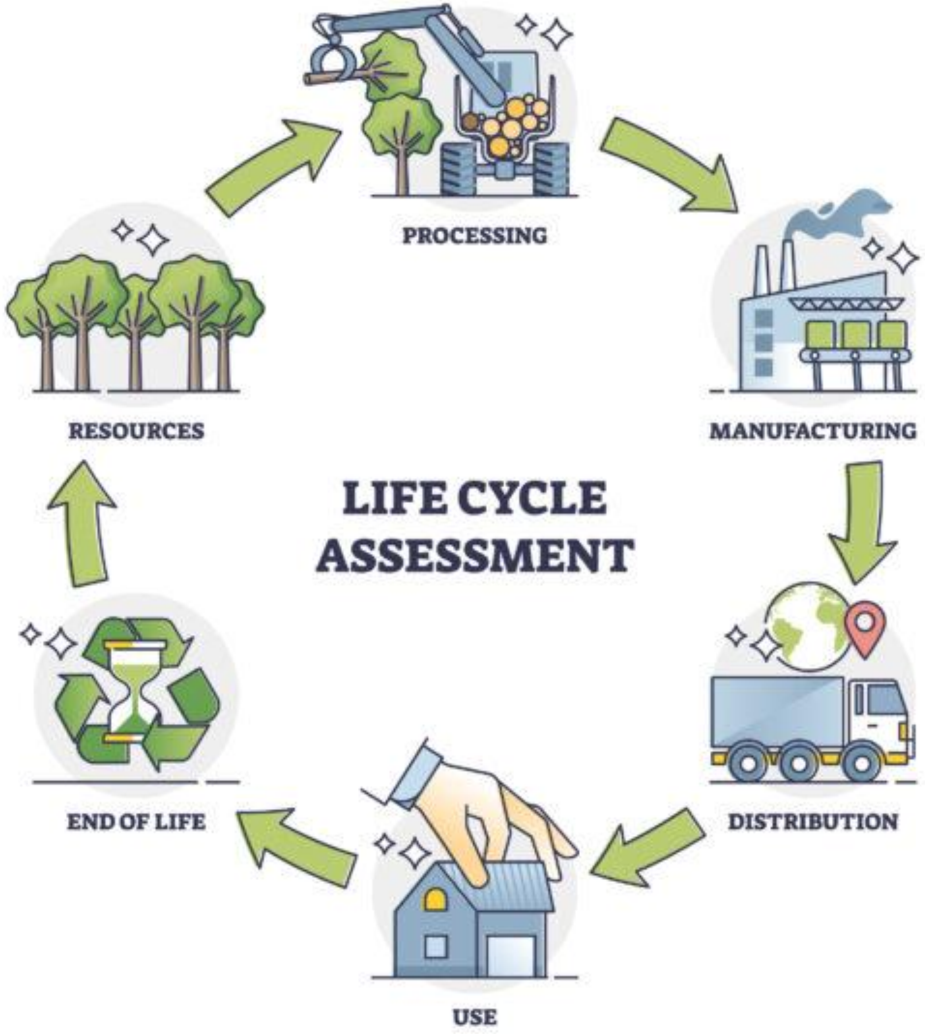
S – Single scale (1 household)
C – Cluster scale (10 households)
CST – Concrete septic tank
ATU – Aerobic treatment unit
TDF – Traditional drainfield
INRB – Inground nitrogen reducing biofilter
DI – Drip irrigation
P – Proactive maintenance
R – Reactive maintenance

Designed scenarios

S_CST_TDF_P/R
S_CST_INRB_P/R
S_ATU_TDF_P/R
S_ATU_DI_P/R
C_CST_TDF_P/R
C_CST_INRB_P/R
C_ATU_TDF_P/R
C_ATU_DI_P/R

Life cycle assessment (LCA) and life cycle cost analysis (LCCA) help measure environmental impact and costs associated with all processes in a system.





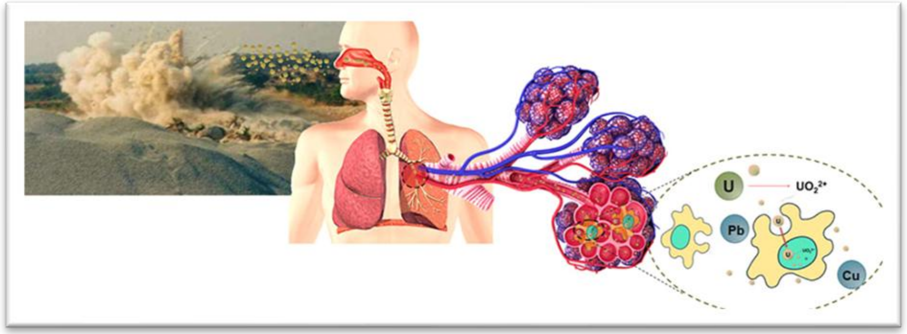
(ISO, 2006)

Seven impact categories are selected to analyze the designed scenarios.

ReCiPe Midpoint (H) V1.09 / World Recipe I

- Characterization (category indicator results)

Climate change



Human toxicity

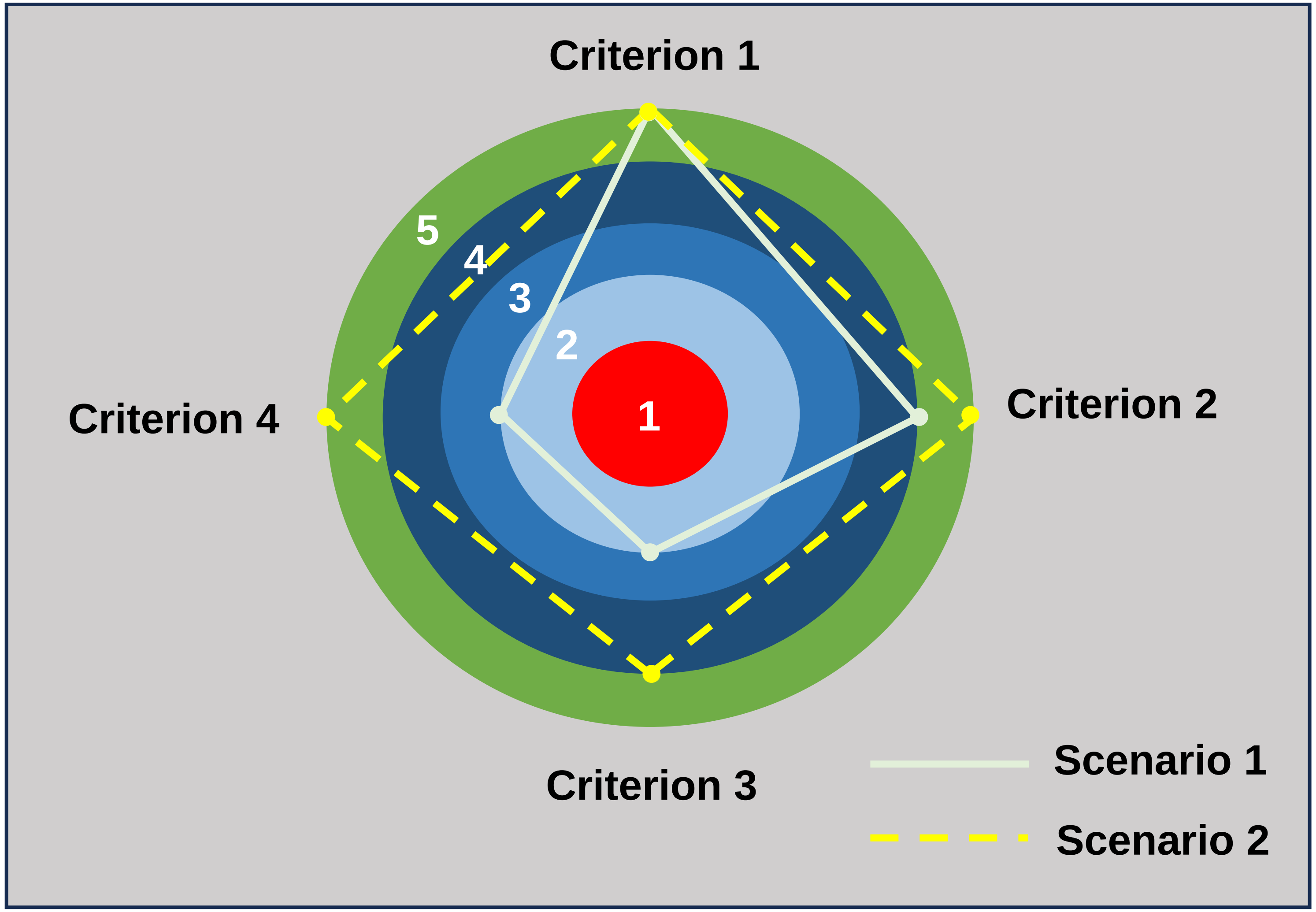
Fossil depletion

Freshwater eutrophication
Marine eutrophication

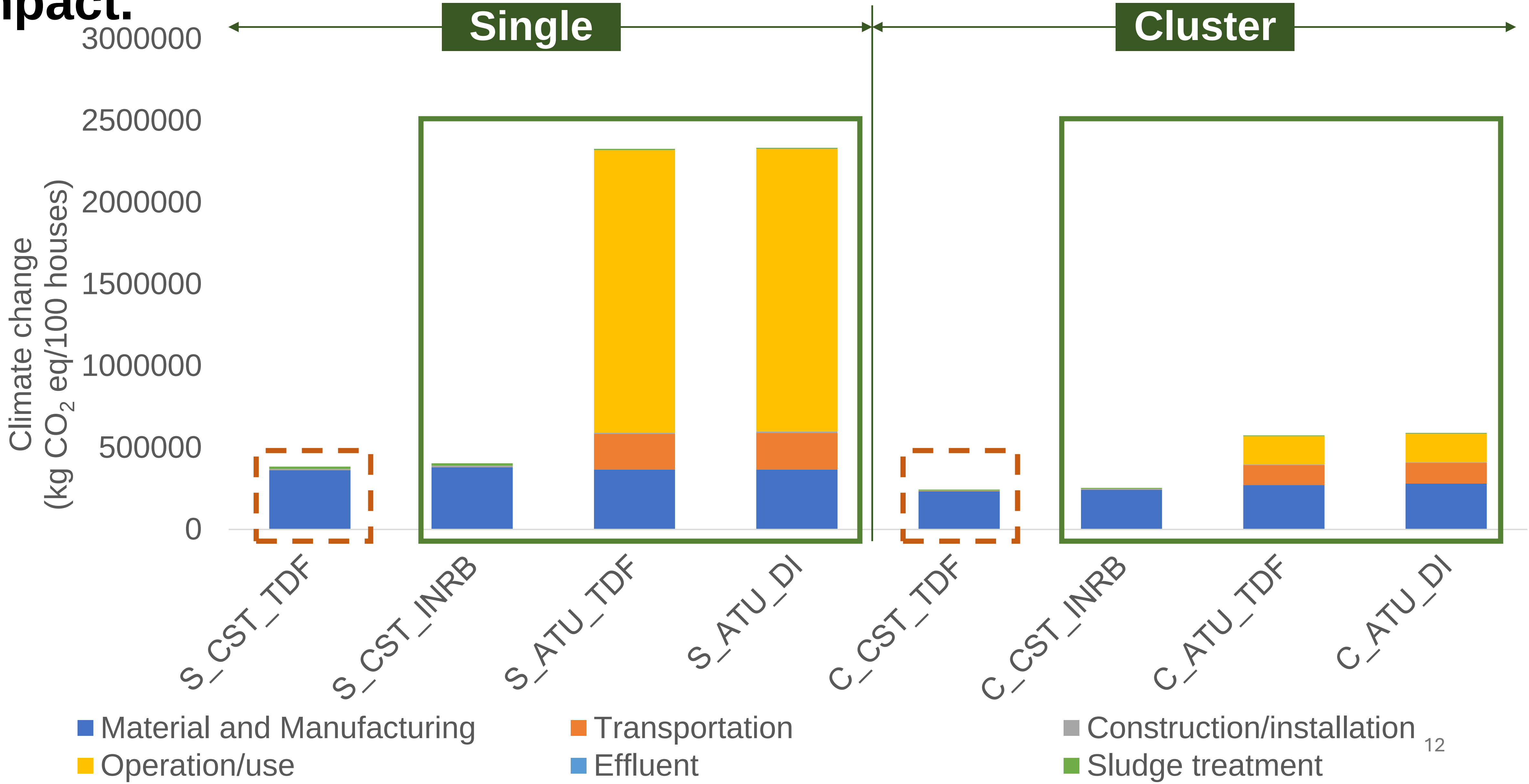
Freshwater ecotoxicity
Marine ecotoxicity

(Blogger, 2014; Ghimire, 2015; Rubasinghege, 2018; Norwegian University of Science and Technology, 2019; NASA, 2024)

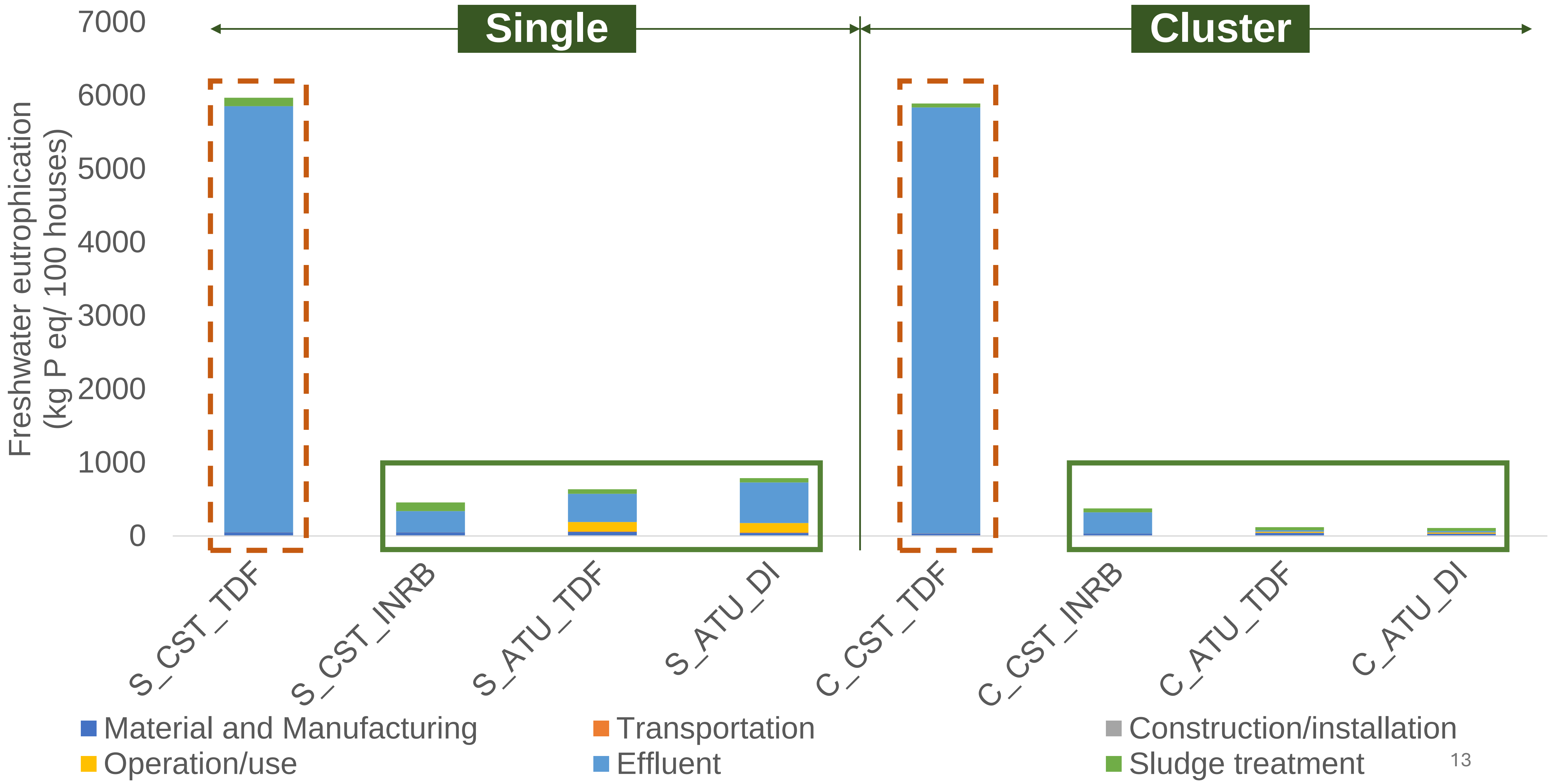
Target plot helps to investigate overall performance.



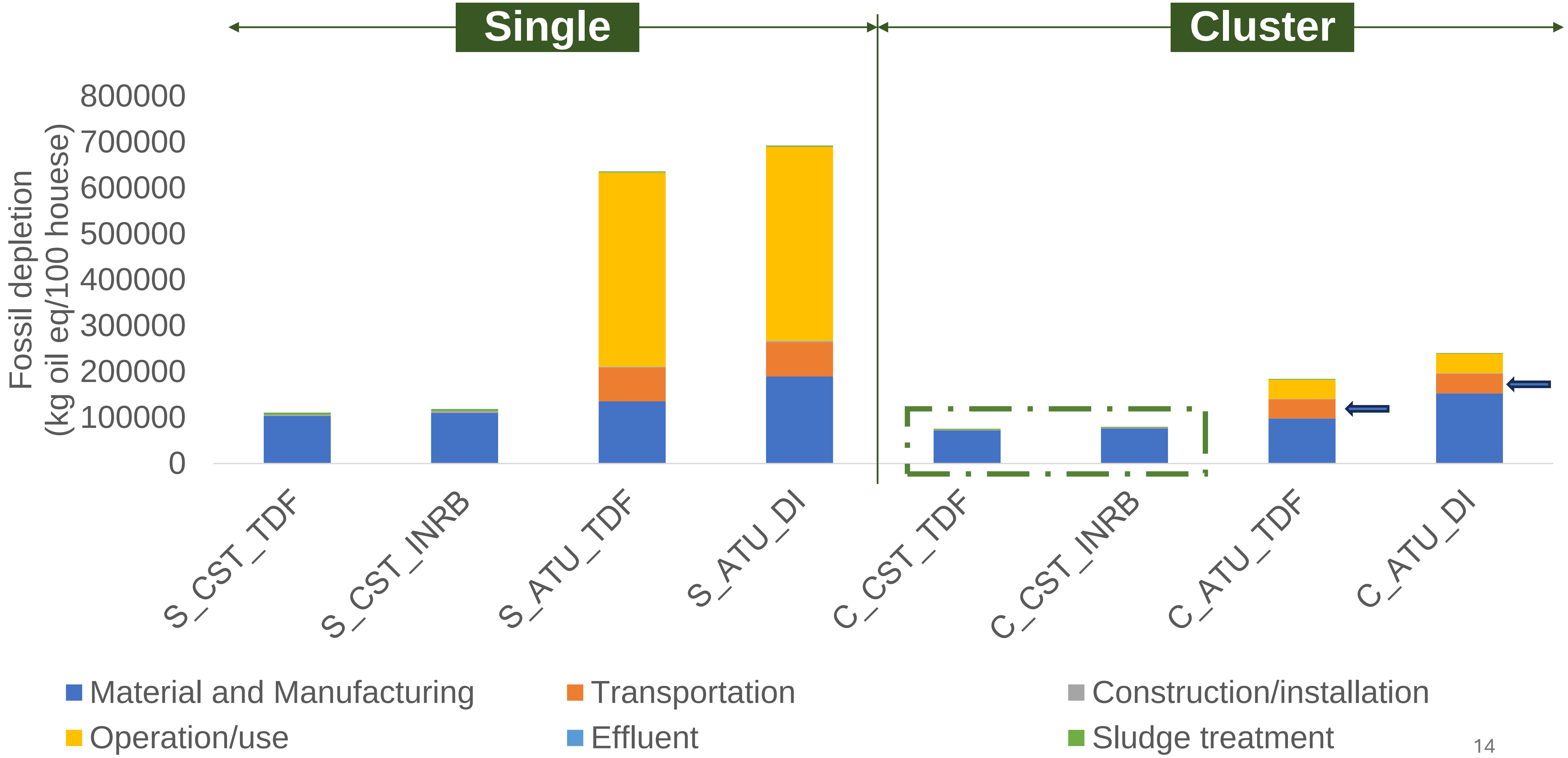
At the cluster scale, both the traditional design and enhanced nitrogen removal design resulted in the lowest climate change impact.



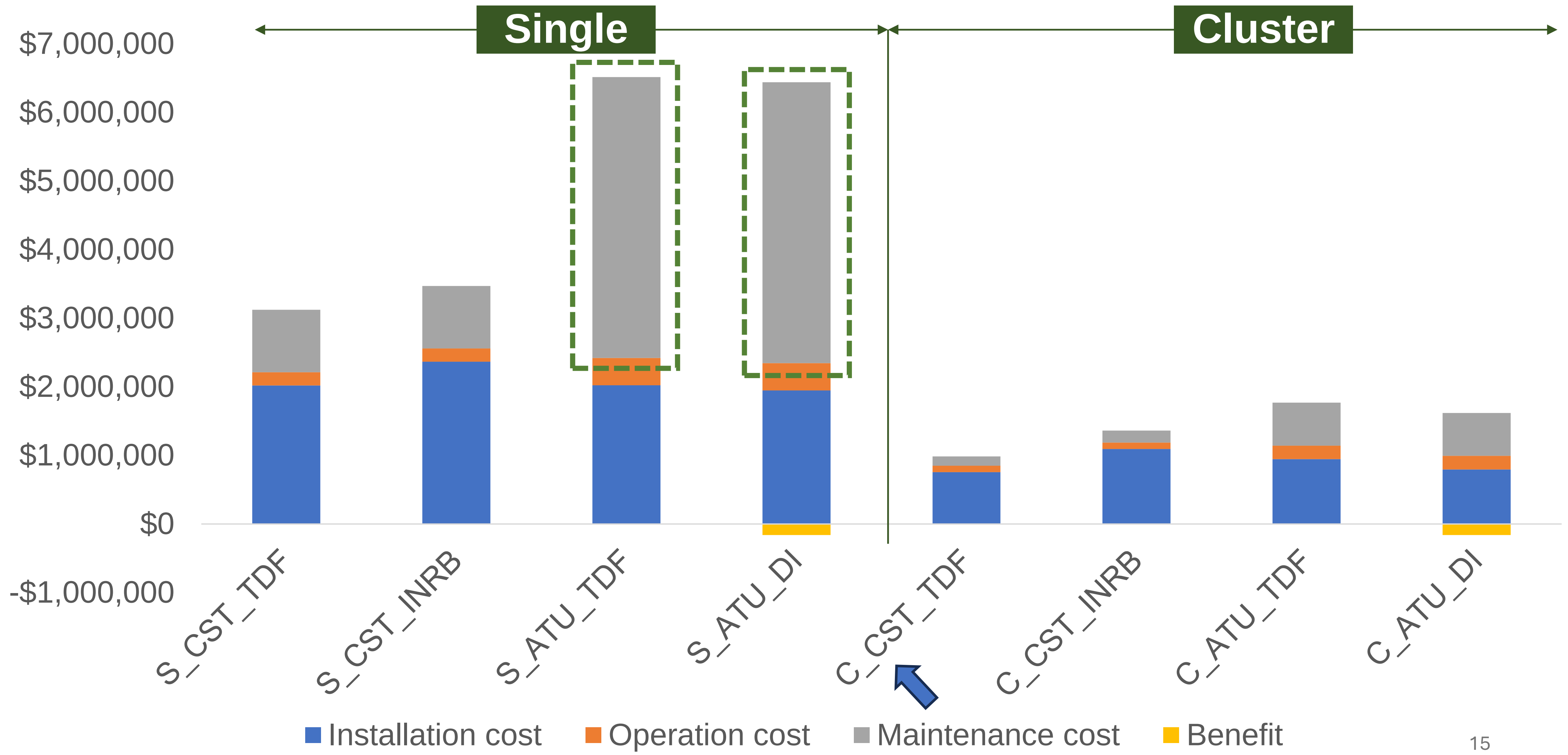
Advanced systems generated less freshwater eutrophication at both scales compared to traditional systems.



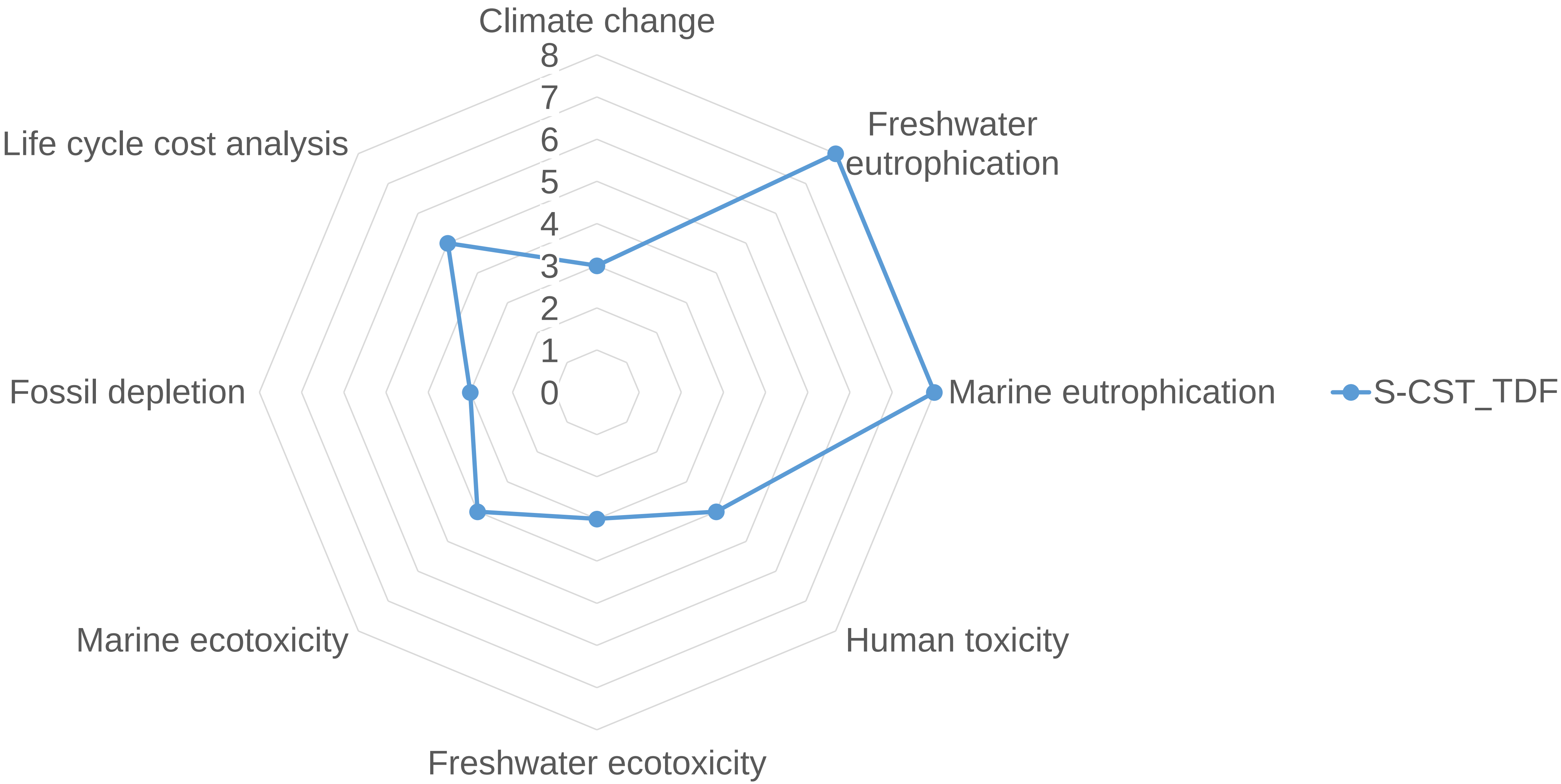
Fossil depletion results suggested installing system at a cluster scale using locally available resources.



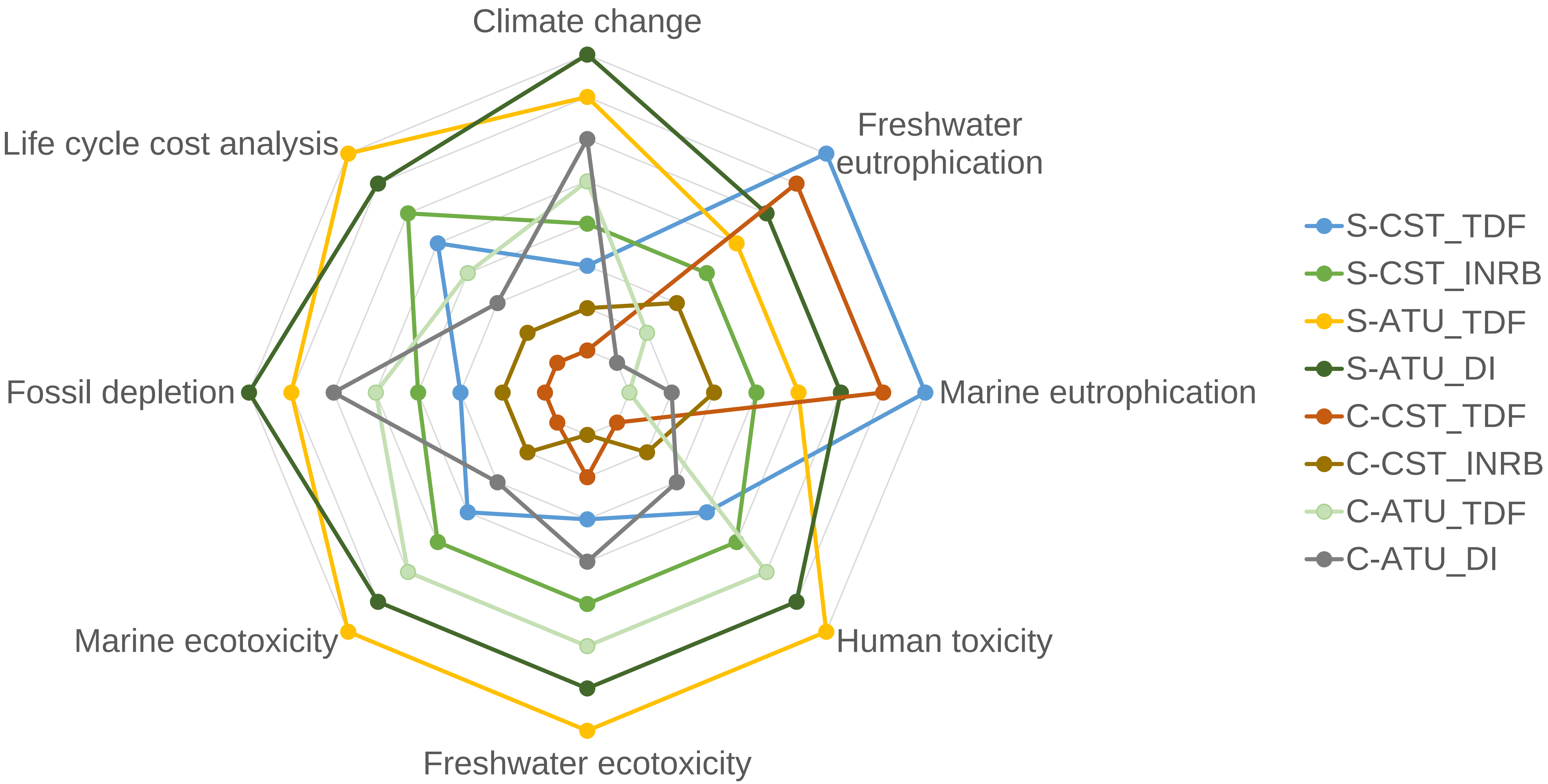
Cluster-scale systems cost less than single-scale systems.



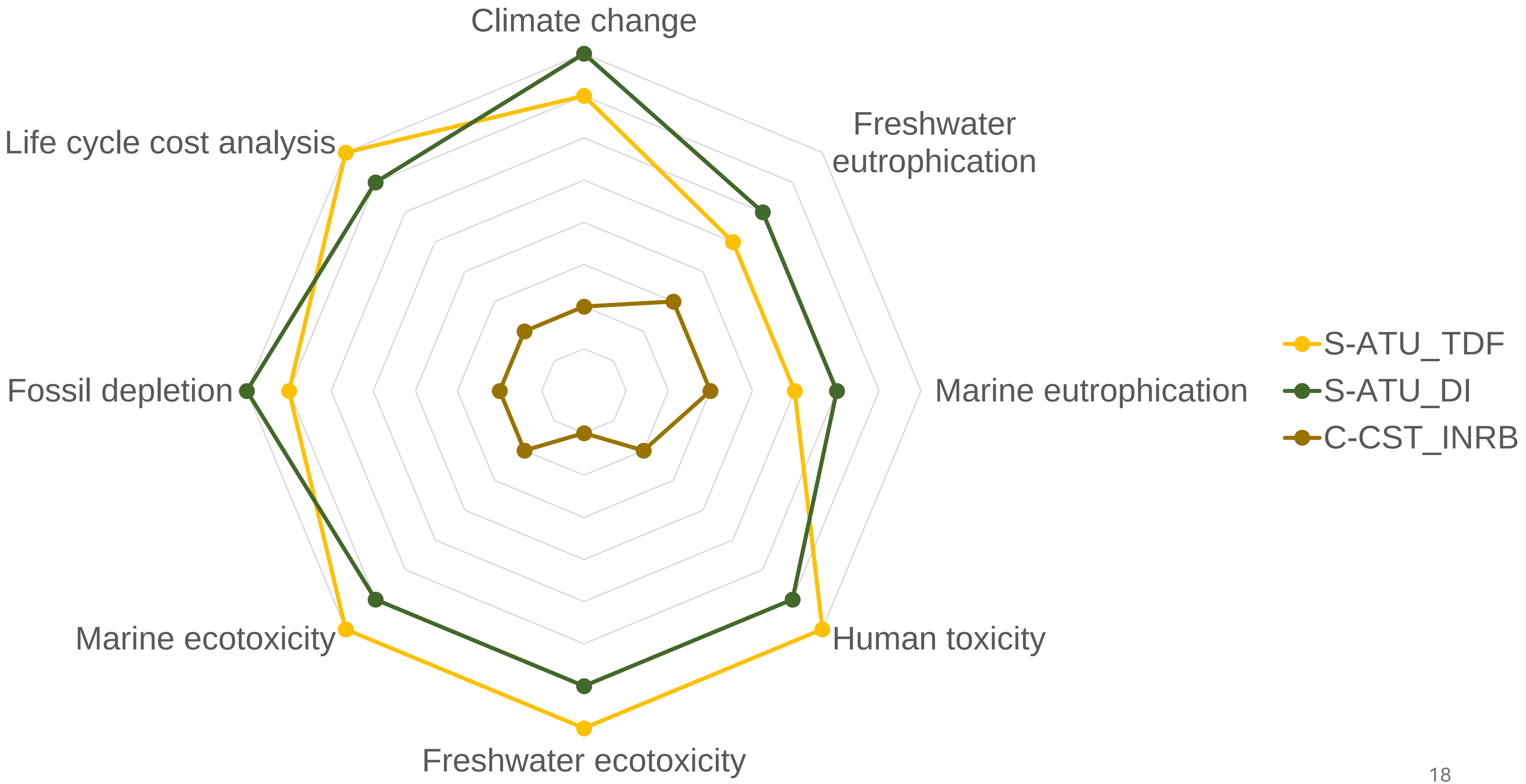
Points closer to the center indicate a better performance.



Performance of the designed scenarios varied depending on the criteria used for evaluation.

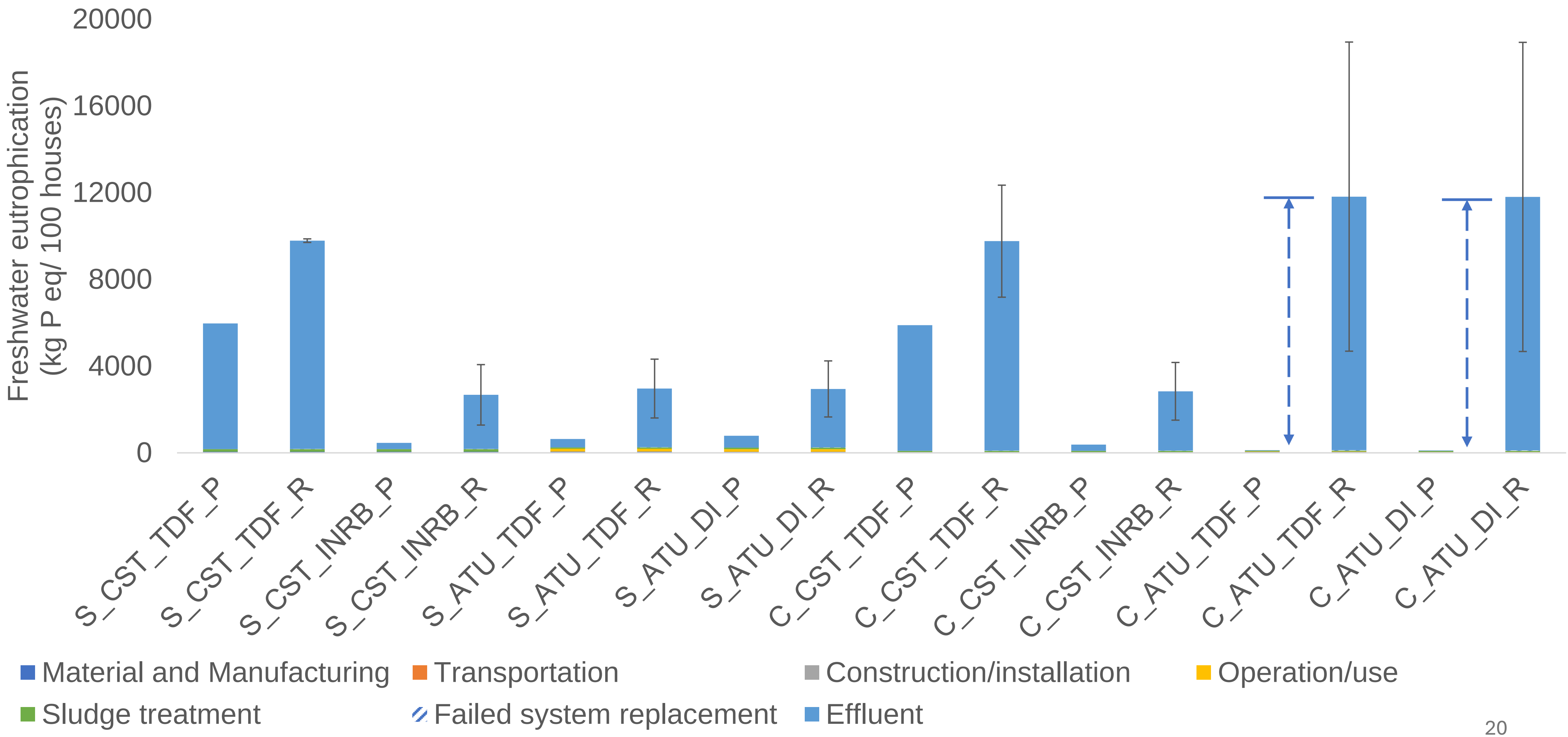


Enhanced nitrogen removal system at the cluster scale performed best across all criteria.

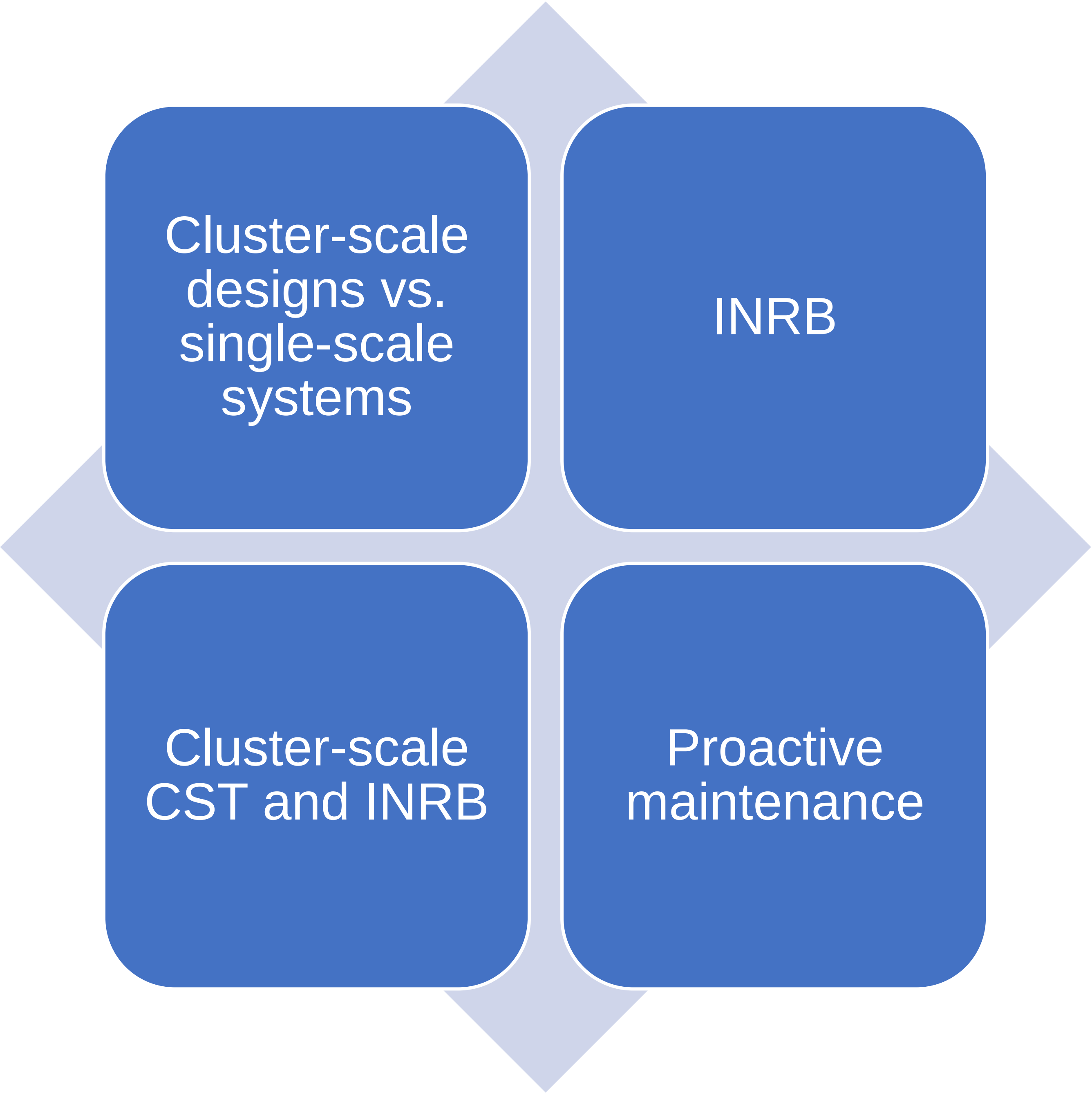


At the cluster scale, the process of failed system replacement with ATU significantly contributed to the total impact.

At both scales, system effluent without effective treatment led to significant increase in freshwater eutrophication.



Key messages



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Thanks!

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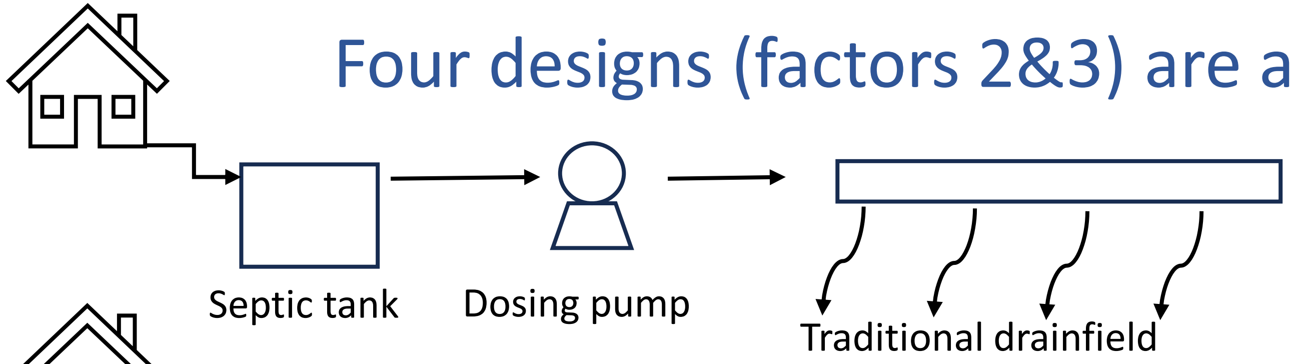
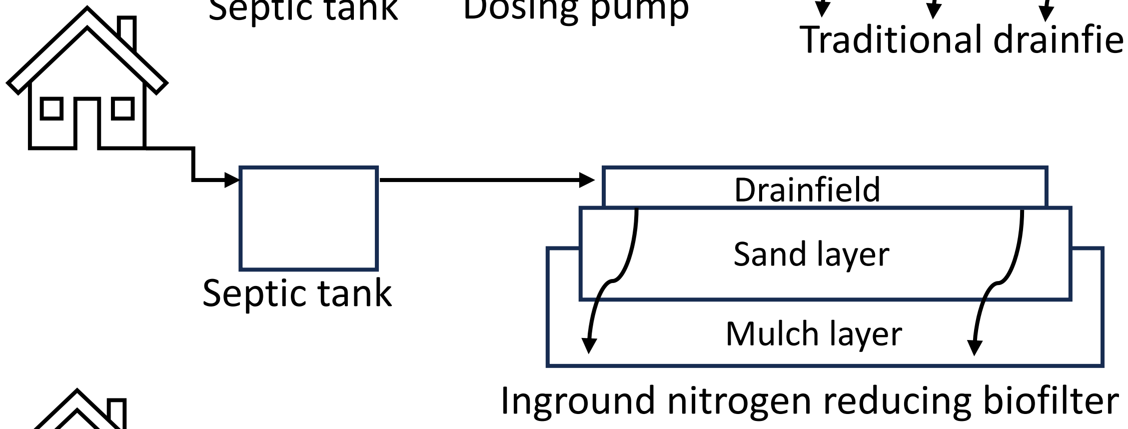
Four designs (factors 2&3) are applied according to FL Code 62-6.



Design 1

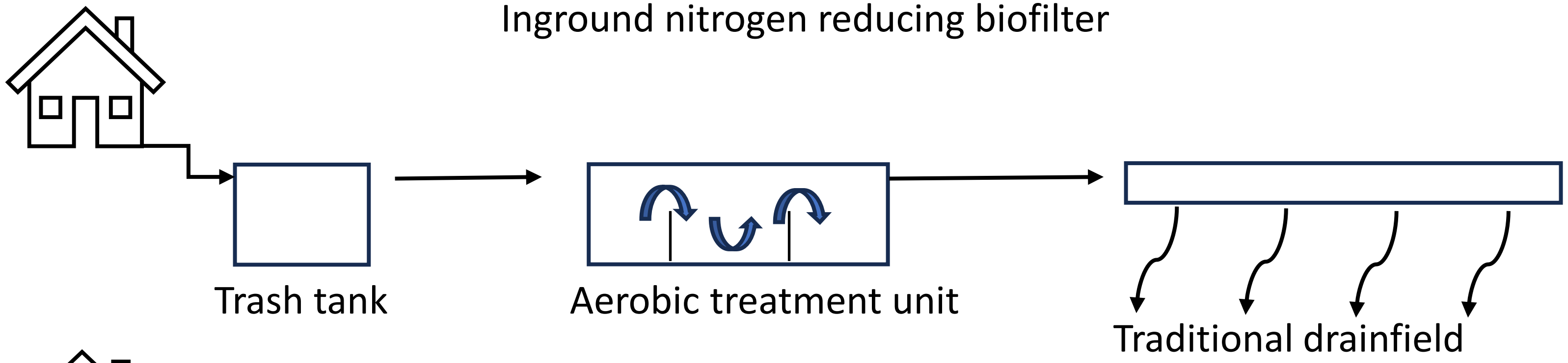
Concrete septic tank (CST) + traditional drainfield (TDF)



Design 2

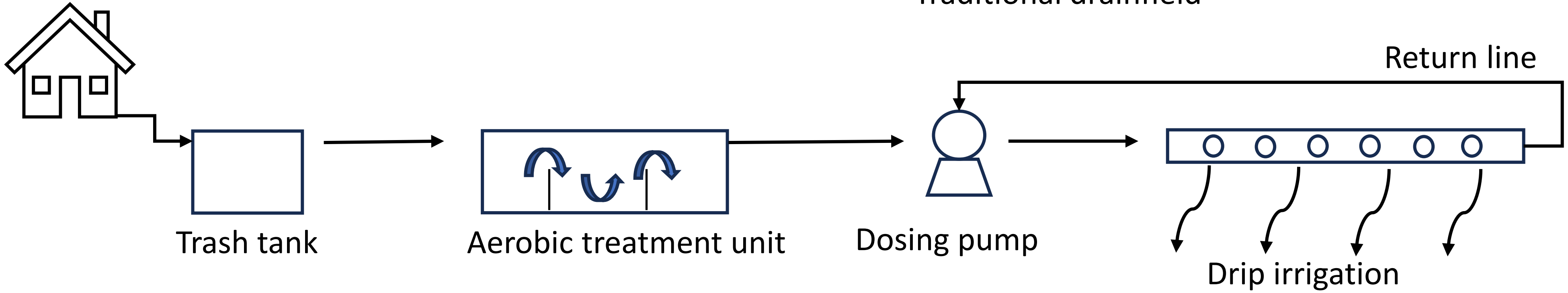
Concrete septic tank (CST) +

inground nitrogen reducing biofilter (INRB)



Design 3

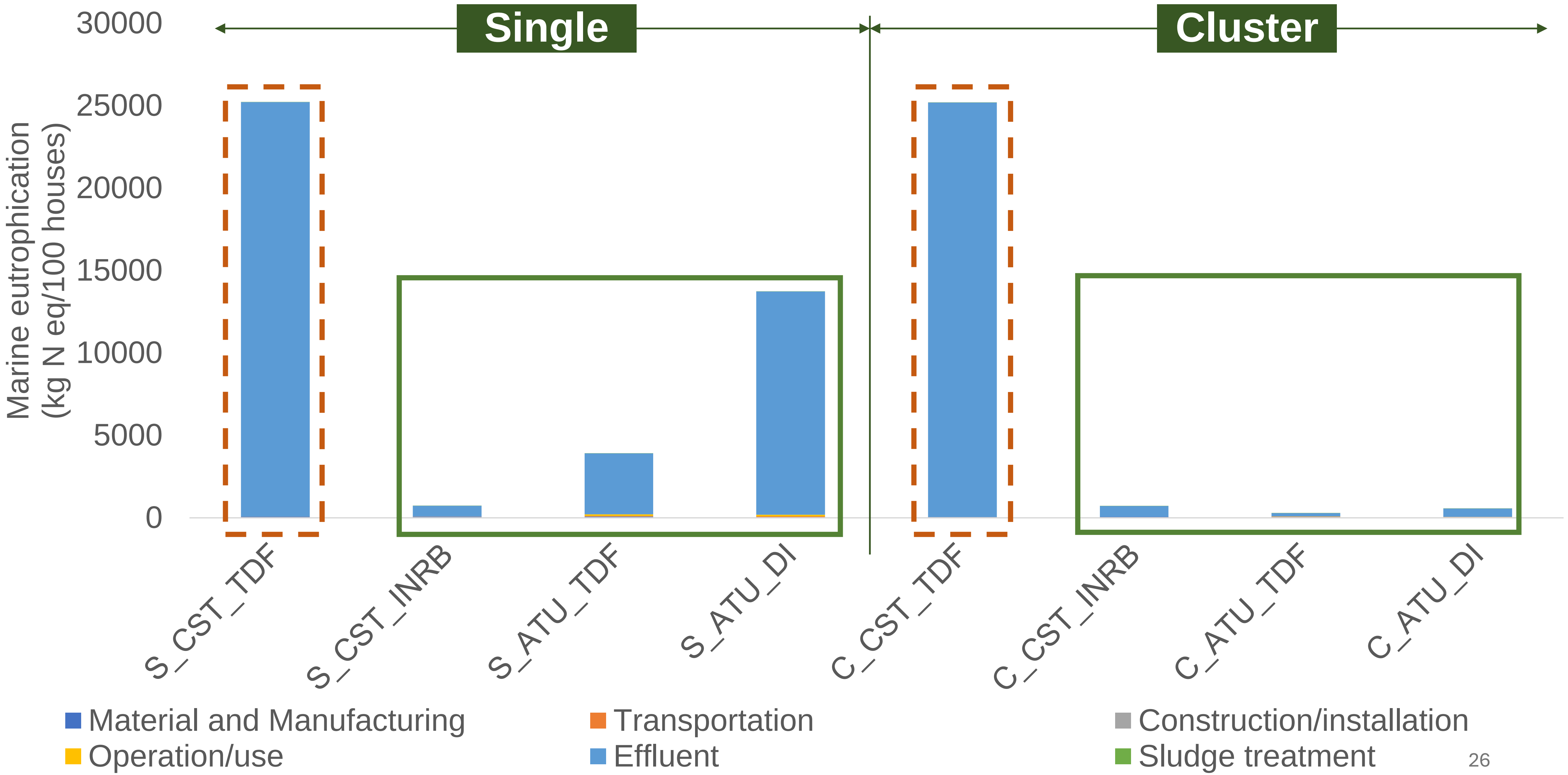
Aerobic treatment unit (ATU) + TDF

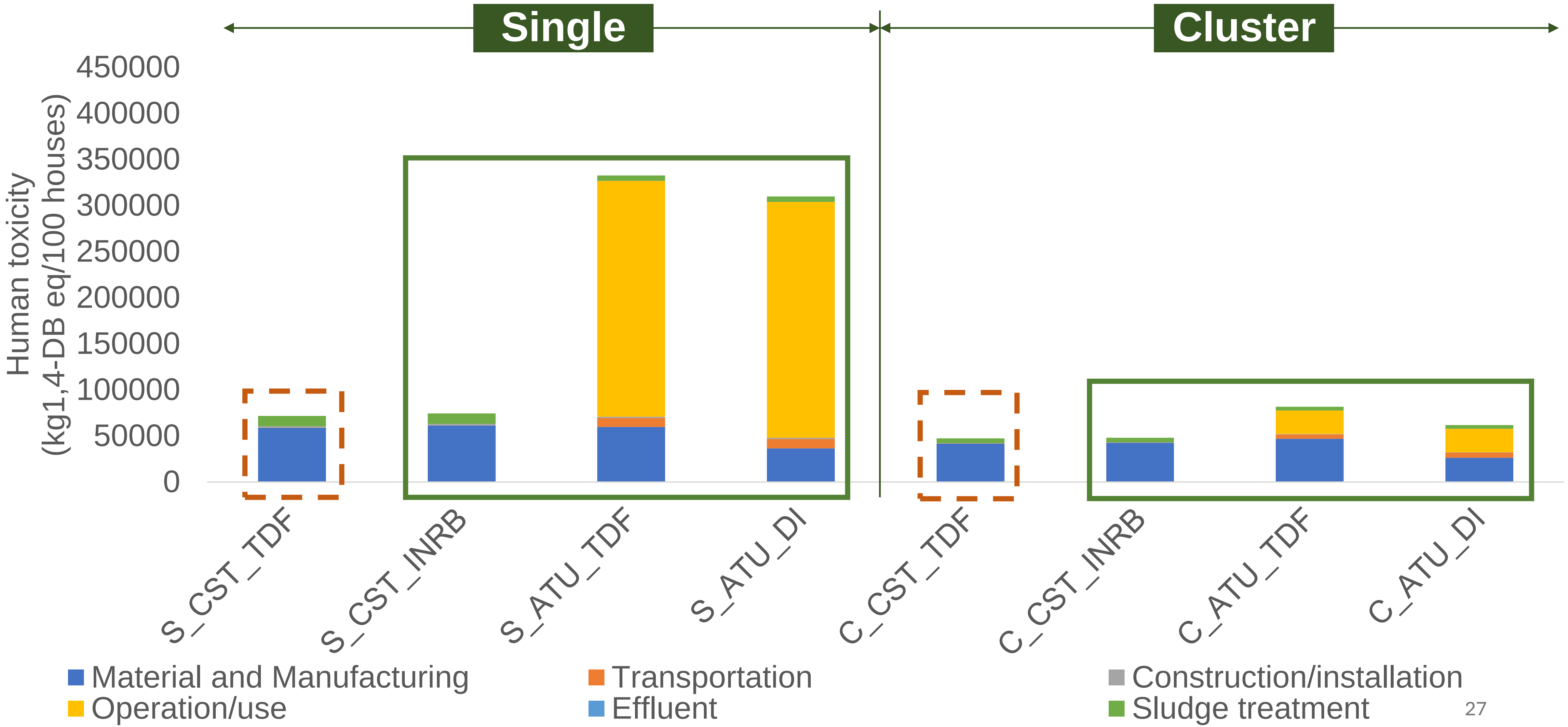


Design 4

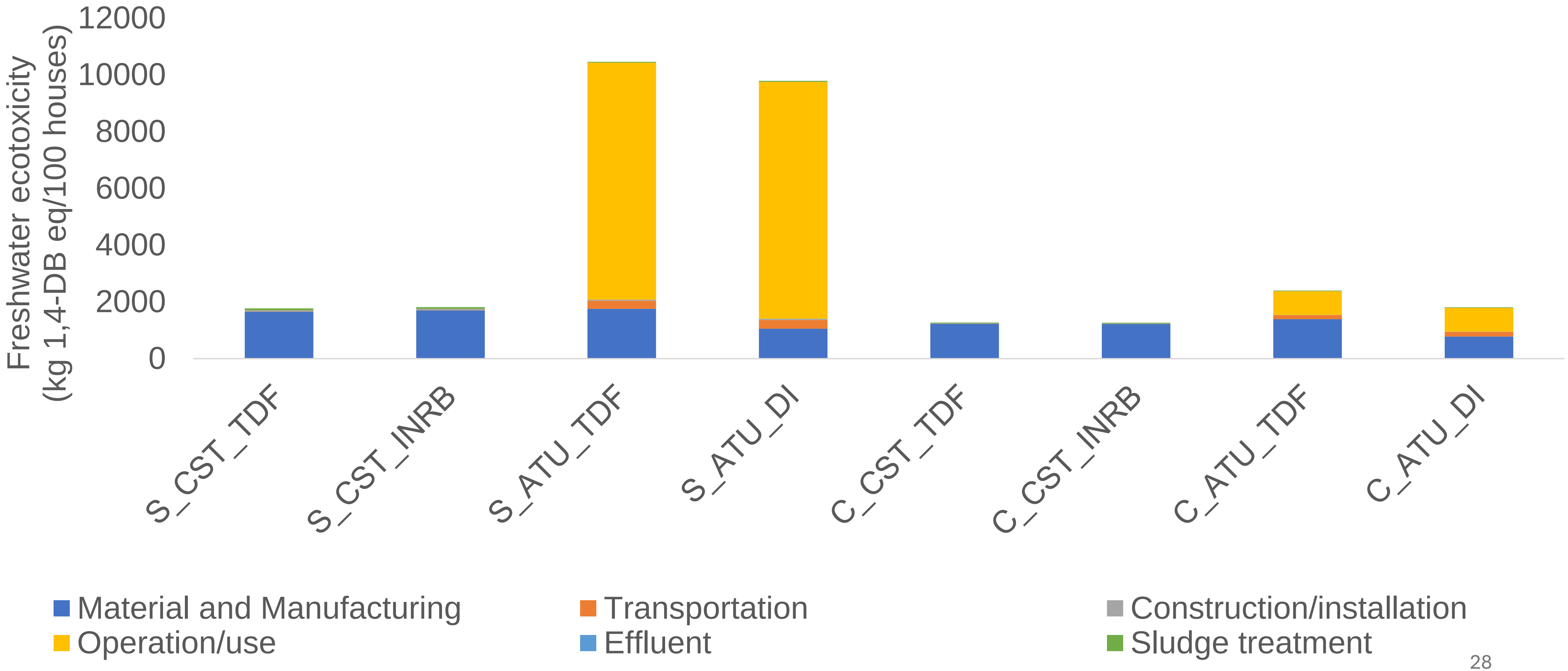
ATU + drip irrigation (DI)

Advanced systems generated less marine eutrophication at the cluster scale.

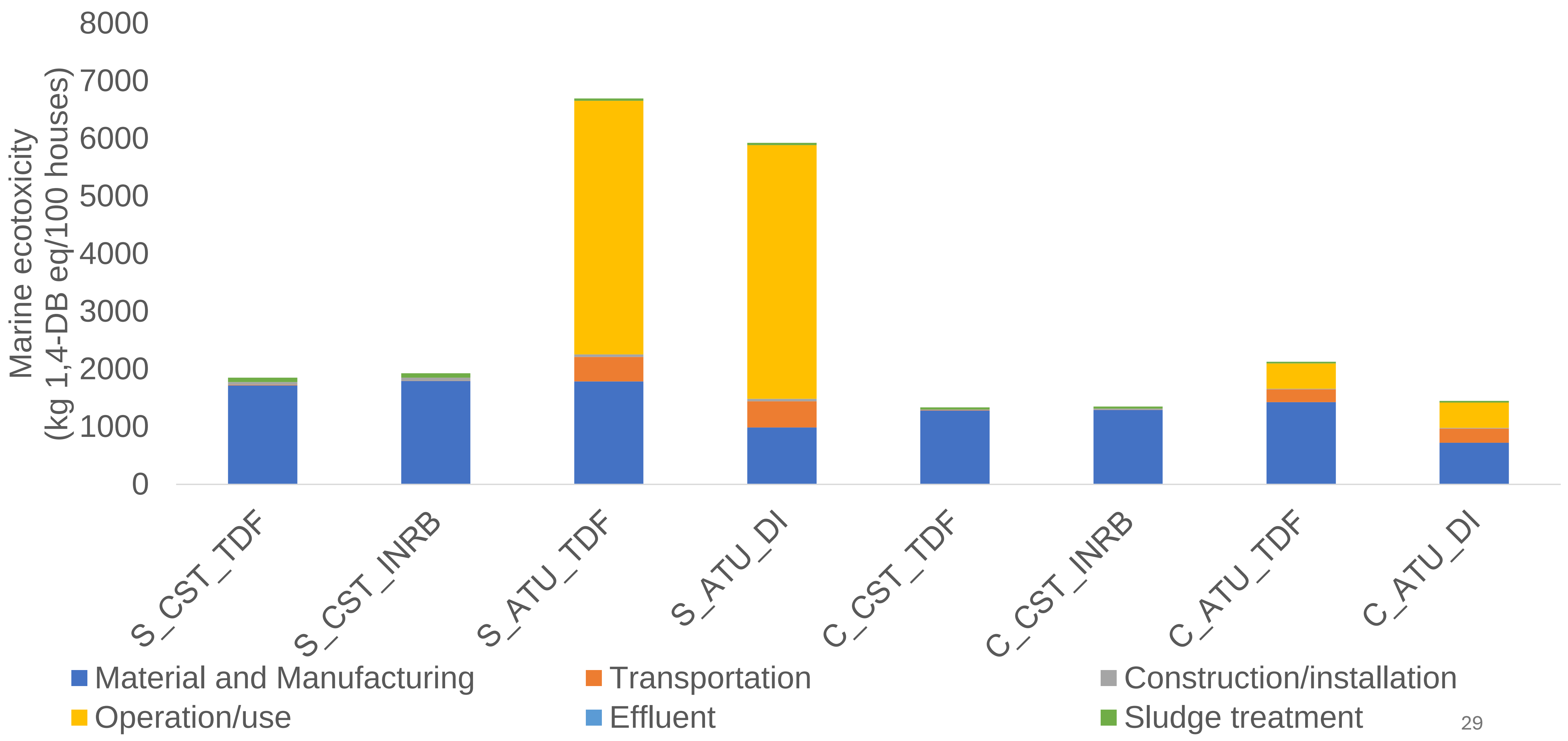


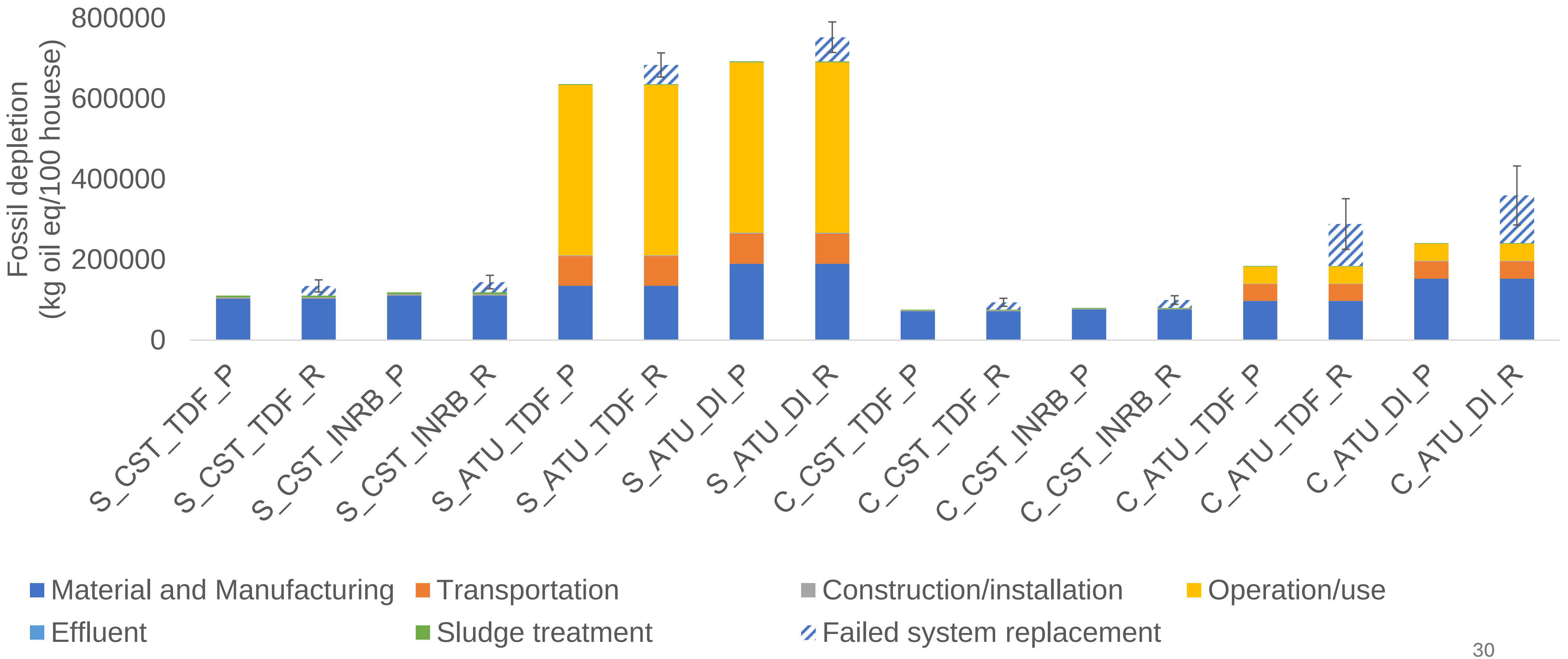


Single
Cluster
Human toxicity
(kg1,4-DB eq/100 houses)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
S_CST_TDF
S_CST_INRB
S_ATU_TDF
S_ATU_DI
C_CST_TDF
C_CST_INRB
C_ATU_TDF
C_ATU_DI
Material and Manufacturing
Transportation
Construction/installation
Operation/use
Effluent
Sludge treatment



Freshwater ecotoxicity
(kg 1,4-DB eq/100 houses)
12000
10000
8000
6000
4000
2000
0
S_CST_TDF
S_CST_INRB
S_ATU_TDF
S_ATU_DI
C_CST_TDF
C_CST_INRB
C_ATU_TDF
C_ATU_DI
Material and Manufacturing
Transportation
Construction/installation
Operation/use
Effluent
Sludge treatment


Marine ecotoxicity
(kg 1,4-DB eq/100 houses)
8000
7000
6000
5000
4000
3000
2000
1000
0
S_CST_TDF
S_CST_INRB
S_ATU_TDF
S_ATU_DI
C_CST_TDF
C_CST_INRB
C_ATU_TDF
C_ATU_DI
Material and Manufacturing
Transportation
Construction/installation
Operation/use
Effluent
Sludge treatment



Fossil depletion
(kg oil eq/100 houese)
800000
600000
400000
200000
0
S_CST_TDF_P
S_CST_TDF_R
S_CST_INRB_P
S_CST_INRB_R
S_ATU_TDF_P
S_ATU_TDF_R
S_ATU_DI_P
S_ATU_DI_R
C_CST_TDF_P
C_CST_TDF_R
C_CST_INRB_P
C_CST_INRB_R
C_ATU_TDF_P
C_ATU_TDF_R
C_ATU_DI_P
C_ATU_DI_R
Material and Manufacturing
Transportation
Construction/installation
Operation/use
Effluent
Sludge treatment
Failed system replacement