

Nye - Assessing the environmental and economic sustainability

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Nye - Assessing the environmental and economic sustainability

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Master thesis project:



Eco-efficiency evaluation of a new urban water system with rainwater collection in Aarhus



Vision

2

Flood protection

New urban water system with rainwater collection

Rainwater use for toilet flushing and laundry



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(source: Nye Lokal plan, 2016)

Motivation



(source: DANVA, 2013)

• Aarhus average annual rainfall intensity:



688 mm/year



- Nye 1^{st} phase: ca. 18 ha --> reduced area: ca. 9 ha
- Population: 2,000 inhabitants



- Estimated runoff: ca. 50,000 m³/y
- Water demand (toilet flushing & laundry): 31,000 m³/y

Planning area: Nye, first phase



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- Four main basins: Volume of 8600 m³
- Trenches/Channels: ca. 1 Km length

Planning area: Nye, first phase



Two water supply networks:

1.DW network → potable water demand

2. SW network → non-potable water demand

3. **SW Treatment Plant** \rightarrow capacity ca 6 m³/h

Source	Runoff [m ³ /year]	Contribution to the total runoff [%]
Roofs	38,000	76 %
Streets	3,710	8 %
Main roads	5,838	12 %
Other	1,820	4 %
Total	50,000	

Aim of the master thesis project



Sustainability Assessment

✓ Assess the sustainability of options for collecting and re-using the rainwater for non-potable use as an alternative to conventional groundwater-based drinking water in Nye, Aarhus

 \checkmark Two dimensions of sustainability: Environmental and Economic



Eco-efficiency

Methodology: Eco-efficiency

Phases:



Fig. 1. Phases in eco-efficiency assessment according to ISO 14045 (ISO 14045, 2012).



Methodology: LCA

ISO 14040: 2006

<u>**Cradle to grave**</u> approach \rightarrow Inventory of materials' consumption and emissions along the life cycle





Methodology: LCA

Example of a life cycle **inventory analysis**

Secondary Water pipes					
Process: SW pipes	Amount	Unit	Assumptions/Calculations	Source	
Material: HD-PE	1841	Kg	Estimated from total length, volume,	Aarhus Vand/ AV-Wavin	
			and density		
Transportation of pipes to construction site	46211	Kg.km	Distance 25.1 Km	See Appendix F-I	
Construction: Excavation volume	1699	m ³	Estimated	See Appendix F-I	
Construction : Filling with soil from another	448521	Kg	22 % of total excavated volume is	See Appendix F-I	
construction site			filled with soil from another		
			construction site.		
Transportation of soil from another construction site	2242604	Kg.km	Distance: 5 Km	See Appendix F-I	
Operation : Distribution energy of the secondary water	127357	Kwh	Specific energy: app. 0.2 Kwh/m ³ ,	See Appendix P	
			estimated through Haaland and Darcy-		
			Weisbach equation.		
Decommissioning: Excavation volume	1699	m ³	Assumption	See Appendix F-I	
Disposal: HD-PE	1565	Kg	85 % recyclable	See Appendix F-I	
Life time SW pipes	100	years	It is assumed that the system is		
			dismantled after 25 years, and thus		
			the recycling occur at the end of the 25		
			years even though the life time of the		
			pipes can be up to 100 years		

Methodology: LCA

Inventory of inputs and outputs



ILCD methodology

Impacts





Lower costs – Higher System value

Alternatives' definition



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Functional Unit and System boundaries

Functional Unit:

"An urban water system aimed at *providing 31000* m³/year of water for <u>non-potable applications</u>, to 2000 inhabitants in Nye, while protecting from flooding"

Assessment time: 25 years



Results



- ✓ Total normalised impacts
- ✓ Life stages contribution
- ✓ Overall comparison
- ✓ Effect of runoff pollutants
- ✓ Total costs
- ✓ System value
- ✓ EEA quantification
- ✓ Overall interpretation

1. LCA: Total Normalised Impacts

 \checkmark The performance of A0-GW is the worst \rightarrow due to the relative increase in energy and detergents consumption at the end-user level

✓ Large percentage difference between A0 and the other alternatives in the Freshwater Withdrawal Impacts

✓ Only in the Eco-toxicity, A0 performs slightly better compared to CT1, CT2, and CT3 (2 % lower impacts)



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1. LCA: Life stage's contribution/performance



1. LCA: Overall comparison of the alternatives with rainwater use





1 CT1 and CT2 seem the most sustainable according to *Climate Change* and *Fossil* Resource Depletion Lenergy consumption

DT seem the most sustainable according to *Eco-toxicity* and *Reserve base* Resource Depletion ㅣ Chemicals consumption

and s. steel amount

1. LCA: Inclusion of the effect of runoff pollutants



- ✓ Increased Impacts in Ecotoxicity, freshwater, and marine eutrophication
- \checkmark DT shows the best performance \rightarrow filter rejection sent to WWTP discharging in Aarhus Bay



■ A0-GW ■ CT1 UF-UV ■ CT2 UF-H2O2 ■ CT3 RO-UV ■ DT-RWH

2. LCC: Total annual costs and system value

- \checkmark A0 is more costly than the alternatives with rainwater use (around 30 %)
- ✓ Investment costs are the highest if we exclude water taxes
 ✓ Compared to A0, the alternatives with rainwater use show higher system value (lower costs)
- \checkmark DT-RWH shows the lowest costs and the highest system value (3 14 % higher system value)



3. Eco-efficiency assessment





- ✓ DT-RWH the most eco-innovative according to all the impact categories
- ✓ CT1 and CT2 also eco-innovative according to climate change and fossil resource depletion



Limitations and future perspectives

Limitations in the LCA assessment:

- 1. Effect of the temperature of the rainwater during winter \rightarrow not included
- 2. Water balance based on estimates provided by Aarhus Vand
- 3. Rainwater quality estimates missing: derived from literature

Limitations in the <u>Economic assessment:</u>

- 1. Secondary water price not yet estimated by Aarhus Vand
- 2. Missing costs were found through online search and literature
- 3. Costs of avoiding flooding and non-monetized costs not included
- 4. Total value added of each actor involved instead of system value calculated through LCC

Conclusion

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With respect to the LCA assessment:

- 1. The alternatives with rainwater use are more sustainable than the BAU scenario \rightarrow Lower Freshwater withdrawal impacts and lower energy and laundry detergents consumption at the households' level
- The most influential life stages: Operation and Maintenance (electricity and chemicals) and materials' generation (basins, trenches, tank materials)
- 3. The treatment of rainwater with ultrafiltration (CT1 and CT2) was found to be the most sustainable according to climate change and fossil resource depletion.
- 4. The private rainwater harvesting systems (DT-RWH) the most sustainable according to Eco-toxicity and Resource depletion reserve base
- 5. The inclusion of the runoff pollutants increased the relevance primarily of the Eco-toxicity and secondarily of freshwater and marine eutrophication

Conclusion

With respect to the Economic assessment:

- 1. The alternatives with rainwater use are less costly (around 30 %) than A0
- 2. The performance of the alternative with rainwater use are almost the same and the system value does not differ significantly between the alternatives
- The decentralised private rainwater harvesting (DT-RWH) has slightly higher system value (2-14 %) compared to the centralised alternatives

Conclusion

With respect to the <u>Eco-efficiency assessment</u>:

- 1. LCA impacts were found to be the deciding factor in the selection of the most eco-efficient alternative
- 2. The DT-RWH is found to be the most eco-innovative according to all the impact categories
- 3. The alternatives CT1 and CT2 are "eco-innovative" according to Climate change and Fossil resource depletion
- 4. The urban water system in Nye can be considered a role model for sustainable and self-sufficient cities.

Thank you for your attention!

Questions?