D4.4 Performance assessment (LCA)

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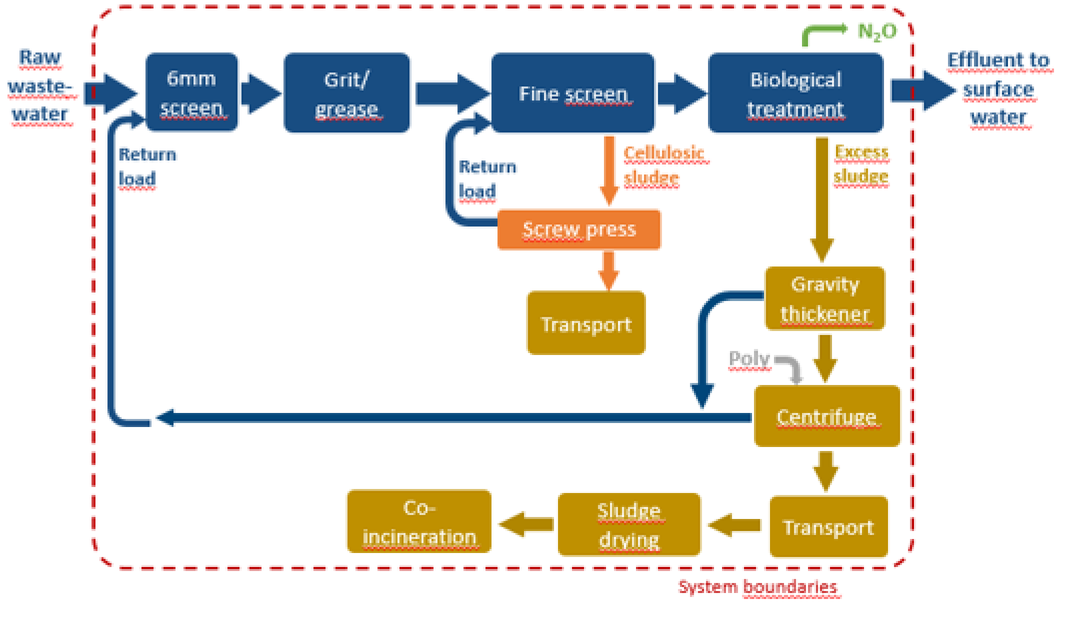
Executive summary

In Work Package 4 the performance of the fine screen technology and the impact on the wastewater treatment process is assessed. As part of Work Package 4, this Performance Assessment assesses the environmental and economic performance of the project. The basis of this assessment are twofold. First of all, the data collected during the project and the Monitoring report. Secondly, two Life Cycle Analysis (LCA) studies that have been published in the Netherlands on the effect of fine screen technology, cellulose recovery and valorisation.

The system boundaries for this assessment are defined as follows:



Life Cycle Analysis published by A.F. van Nieuwenhuijzen (2016) and by STOWA (2016), show the environmental benefit of fine screens compared to a standard WWTP is 34 to 46 kPt/year. One kPt represents the environmental impact or load (i.e. entire production/consumption activities in the economy) of 1 average person living in the western world. Valorisation routes like separate digestion of cellulosic screenings and the use of cellulosic screenings as substitute for residual wood both have a positive environmental impact.

At the start of the project, performance indicators were defined. Based on these indicators, the yearly greenhouse gas emission reduction is 77.5 million kg per year. Sludge reduction is 500 tons/year and the reduction in the usages of chemicals is 9.5 tons/year. The additional biomethane production is 2.3 million m^3 per year. In financial terms, these indicators combined represent yearly savings of approximately €1.1 million.

1 Summary of existing LCA studies for WWTP in the Netherlands

In Work Package 4 the performance of the fine screen technology and the impact on the wastewater treatment process is assessed. As part of Work Package 4, this Performance Assessment evaluates the environmental and economic performance of the project. This assessment builds on two recent LCA studies which have been published in the Netherlands on the effect of fine screen technology, cellulose recovery and valorisation. These studies are summarised in this chapter.

Waste water contains valuable resources. One of the raw materials that can be recovered from waste water is cellulose. The cellulose can be separated at the WWTP as sieve material ("screenings"). These screenings can be turned into energy through fermentation or can be upgraded into cellulose fibres. The cellulose can for example be used in asphalt or in insulation (replacing paper).

In 2016 a Life Cycle Analysis was published by A.F. van Nieuwenhuijzen a.o.[1] on recovering different waste materials from waste water. This study was funded by STOWA, RvO and coordinated by Energy Factory and Resource Factory of the Dutch Water Authorities. One of the valorisation routes for organic matter from wastewater that was investigated, was the recovery of cellulose from influent with fine screen technology. None of the routes described form a perfect match with the "old" or "new" situation at Aarle-Rixtel, but they do provide valuable insights.

1.1 LCA Van Nieuwenhuijzen a.o.

The LCA performed by Van Nieuwenhuijzen a.o. was based on a WWTP processing 100,000 p.e. of inflow of a medium consistency type of waste water. It compared a "standard" WWTP with a WWTP with fine screens in operation and analysed the differences in energy, utilities, chemicals, transport and final disposal. The LCA was performed using the proven and internationally accepted analytical method ReCiPe. In the study the "single score" method was used, in which all the environmental impacts were weighed and expressed in points (Pt) or kilopoints (kPt). One kPt represents the environmental impact or load (i.e. entire production/consumption activities in the economy) of 1 average person living in the western world.

The main conclusion from the analysis was that the environmental benefit compared to a standard WWTP is 34 to 46 kPt/year. The recommendation was to focus on the utilisation of cellulosic screenings for material re-use rather than using the screenings to produce energy. This matches with the waste hierarchy, which indicates the order of preference for actions to reduce waste. Reuse of materials normally provides more benefits than energy recovery. Utilisation of screenings for material reuse would lead to an even higher positive environmental impact than the presented 34 to 46 kPt/year.

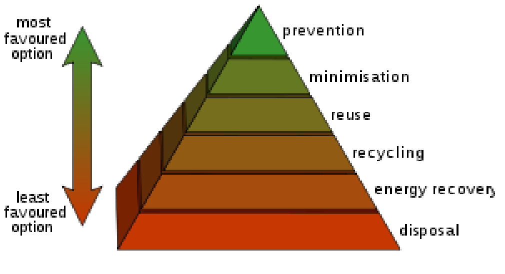


Figure 1.1 Waste hierarchy

[1] A.F. van Nieuwenhuijzen, C. Visser, I. Y. R. Odegard, G. C. Bergsma, C. A. Uijterlinde and C.S. Erp-Taalman-Kip; Life Cycle Analysis of Recovered Resource Products from Used Water; Singapore International Water Week, 2016.

1.2 LCA STOWA

The STOWA is the Dutch Foundation for Applied Water Research. It is the knowledge centre of the regional water managers (mostly the Dutch Water Authorities) in the Netherlands. In 2016, the STOWA published a report "Life cycle analysis of resources from wastewater"[2].

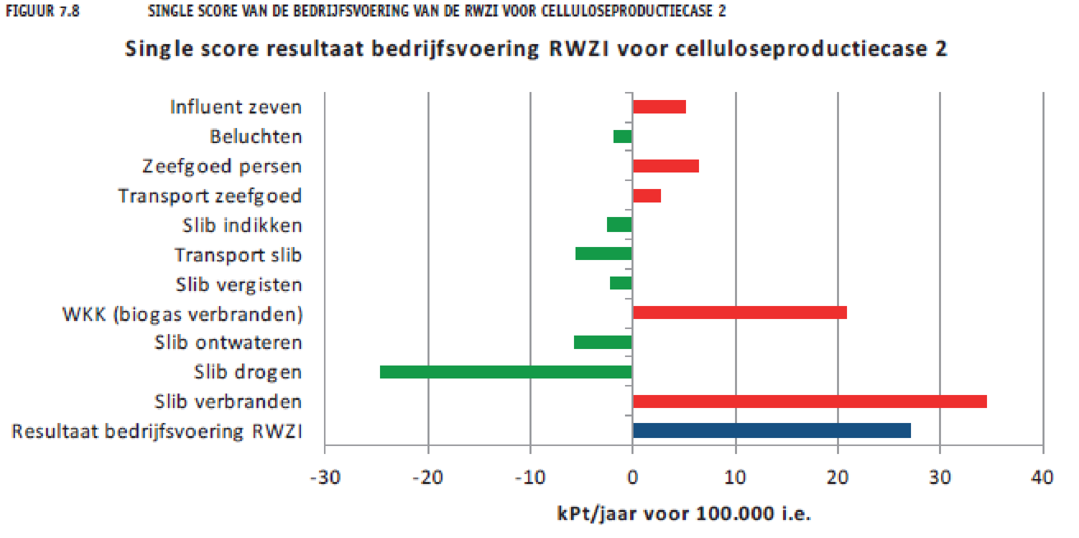


Figure 1.2 Single score for operation WWTP with finecreen technology (excluding impact recovered cellulose)

Figure 1.2 shows that if one just looks at the operations of the WWTP (including sludge processing) the removal of cellulosic screenings reduce the impact of sludge processing. However, it also reduces the biomethane production and the heat and electricity produced by sludge incineration. This results in an negative environmental impact of 27 kPt per year for the fine screen case compared to the reference case.[3] If the impact of the cellulosic screening is taken in consideration, the environmental impact becomes positive:

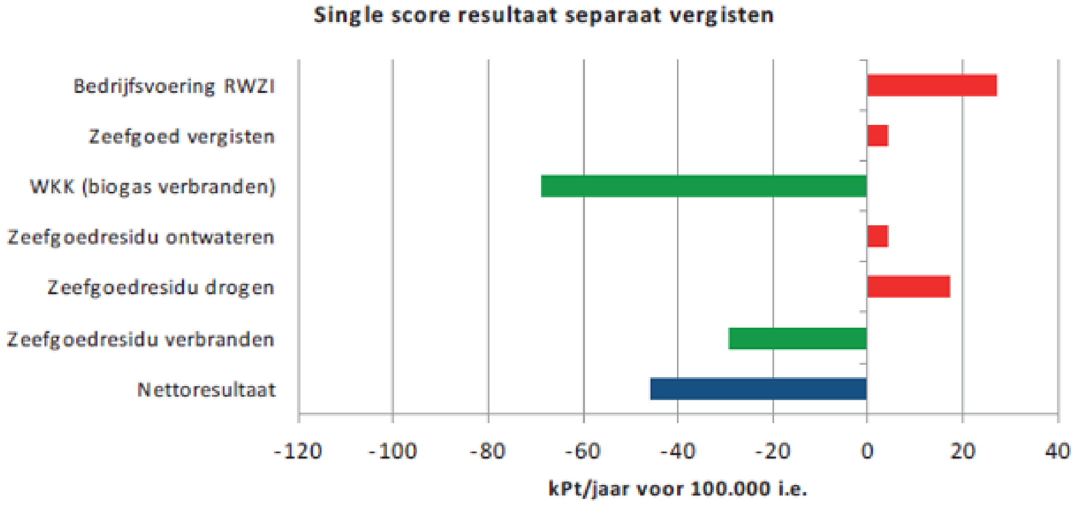


Figure 1.3 Single score for separate digestion of cellulosic screenings

[2] STOWA, Levenscyclusanalyse van grondstoffen uit rioolwater, 2016.
[3] STOWA, Levenscyclusanalyse van grondstoffen uit rioolwater, 2016, page 75.

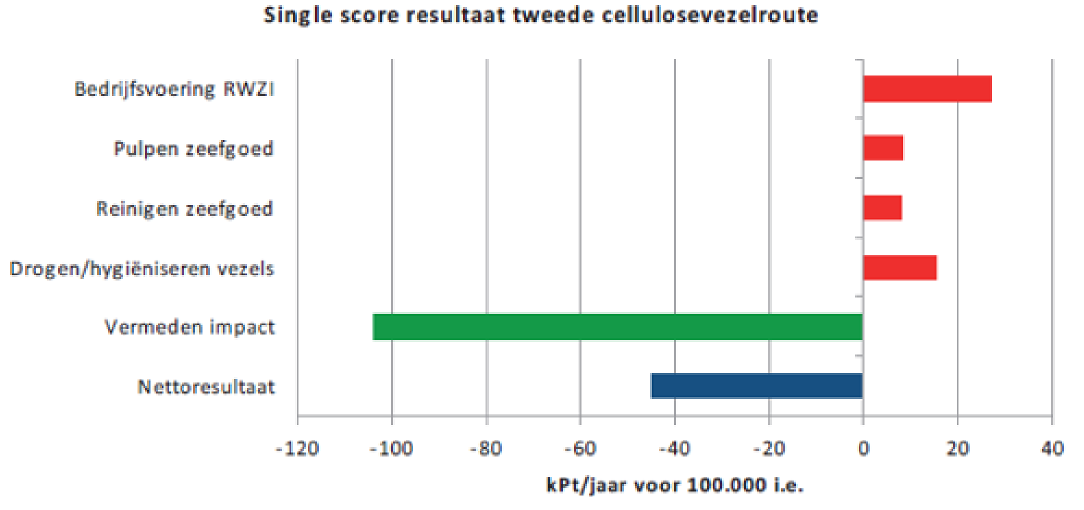


Figure 1.4
Single score for use of cellulosic screenings as substitute for residual wood

Figures 1.3 and 1.4 show two different valorisation routes. Figure 1.3 shows the separate digestion of cellulosic screenings and figure 1.4 the use of cellulosic screenings as substitute for residual wood. Both cellulose routes have a positive environmental impact. The first line item summarises the WWTP operation of figure 1. The separate digestion of cellulose (figure 1.3) has a positive environmental impact of 46 kPt per year. Use of the cellulose fibres, replacing residual wood, including hygienising, pulping, cleaning and drying, has an impact of 45 kPt per year. It should be noted that the hygienising, pulping, cleaning and drying of the material, which are energy intensive processes, were performed at a pilot scale during the research, partly with energy inefficient, oversized equipment. More recent experience with these processes at demonstration scale, show a significantly better result.[4]

[4] CirTec research at SMART-Plant in Geestmerambacht. Part of Horizon 2020 research programme, results to be published.

2 Starting points for design

The starting points that were the basis for the design of the Screencap installation are included in the table below. The original expected load in 2015 is set as a horizon for design.

Table 2.1. Process starting points based on annual report 2011 (Waterboard Aa and Maas) and the 2015 forecast

Parameter	2011	2015	Unit
Average capacity	68,925	72,685	m^3/d
Feed hours	24	24	
Average feed flow	2,872	3,029	m^3/h
DWF	3,500	3,500	m^3/h
FFT	14,000	14,000	m^3/h
	162,000	162,000	m^3/d
Maximum flow measured	258,058		m^3/d
COD	496	507	mg/l
	34,187	36,874	kg/d
BOD	186	190	mg/l
	12,820	13,828	kg/d
TKN	38	42	mg/l
	2,619	3,047	kg/d
P_{tot}	6.1	6.1	mg/l
	420	445	kg/d
TSS	179	176	mg/l
	12,338	12,823	kg/d
TOC (calculated)	670	699	mg/l
	46,156	50,800	kg/d
COD:BOD (calculated)	2.7	2.7	
BOD:N (calculated)	4.9	4.5	
COD:TSS (calculated)	2.8	2.9	
Load	312,477	343,177	p.e. (150 g TOC)
Design	272,000	272,000	p.e. (150 g TOC)
Increase design capacity	15%	26%	

Table 2.1 shows that the WWTP was already overloaded at the start of the project by 15%, and that, without measures, in four years' time the WWTP would be overloaded by 26% (2015). The increase in the WWTP's load was mainly caused by industrial wastewater from a slaughterhouse and a textile company. The following estimate has been made:

- The load in 2011 was 312,477 PE (based on 1 p.e. of 150 grams TOC). This increases by 11% to 343,177 PE in 2015.
- Increase in COD load from a slaughterhouse and a textile company expected with 86 and 1,256 kg COD/ d respectively in 2015.
- The increase in the load from inhabitants, greenhouse horticulture and industrial areas was expected to rise by 3.9% in 2017 and by 6.1% in 2022.
- The feed flow was expected to rise with 20% by 2022. This represents a yearly increase of 1.4%.

The refurbished WWTP Aarle-Rixtel was commissioned in 2008 and treats sewage according to the mUCT process. The WWTP was overloaded (Table 2.1), but the consent effluent levels were met. Optimizations have been performed to maintain good effluent quality. These measures include increasing the aeration capacity (boost pressure) and maintaining the circulation speed at peak feeding.

Figure 2.1: Aerial overview of the WWTP Aarle-Rixtel (before installation of fine screens)

Figure 2.1 shows an aerial view of the WWTP at the start of the project. Table 2.2 shows the sizing of the main process components.

Table 2.2 Dimensions WWTP Aarle-Rixtel (commissioned in 2008)

Technical detail	Value	Unit	remarks
Design capacity	272,000	PE. à 150 g TOC	
Pump capacity	1* 1,000 4* 3,500	min. cap. m^3/h max. cap. m^3/h	Frequency controlled
Coarse screening	4 pcs	6 mm	
Grit removal	1 * 400 1 * 625	m^2 m^2	Type Dorr
Anaerobic selector	2 * 3,500	m^3	
Pre-denitrification tank	2 * 3,200	m^3	
Activated sludge circuit	2 * 12,800	m^3	Fine bubble aeration; circular tanks
Sludge load	0.2	kg COD/kg ds.d	
Sludge concentration	4.8	kg/m^3	
Clarification	10 * 1,800 8 * 3,600 2 * 4,200	m^2 m^2 m^2	Central bottom scraper
Pre-thickening	3 * 240 3 * 960	m^2 m^2	Gravitation
Sludge holding tank	2 * 960	m^3	External sludge
Sludge dewatering	2 * 40 2 * 800	m^3/h kg ds/h	Centrifuge

3 Performance indicators Screencap at Aarle-Rixtel

To assess the performance of the fine screen technology and the impact on the wastewater treatment process, this chapter defines the performance indicators of the Screencap project. These indicators are the basis of the analysis of the environmental and economic performance of the project.

Figure 3.1 shows a general framework for the performance assessment of a Waste Water Treatment Plant (WWTP). Inputs are raw wastewater, electricity, fuels, chemicals and infrastructure. Outputs are effluent, products and emissions.

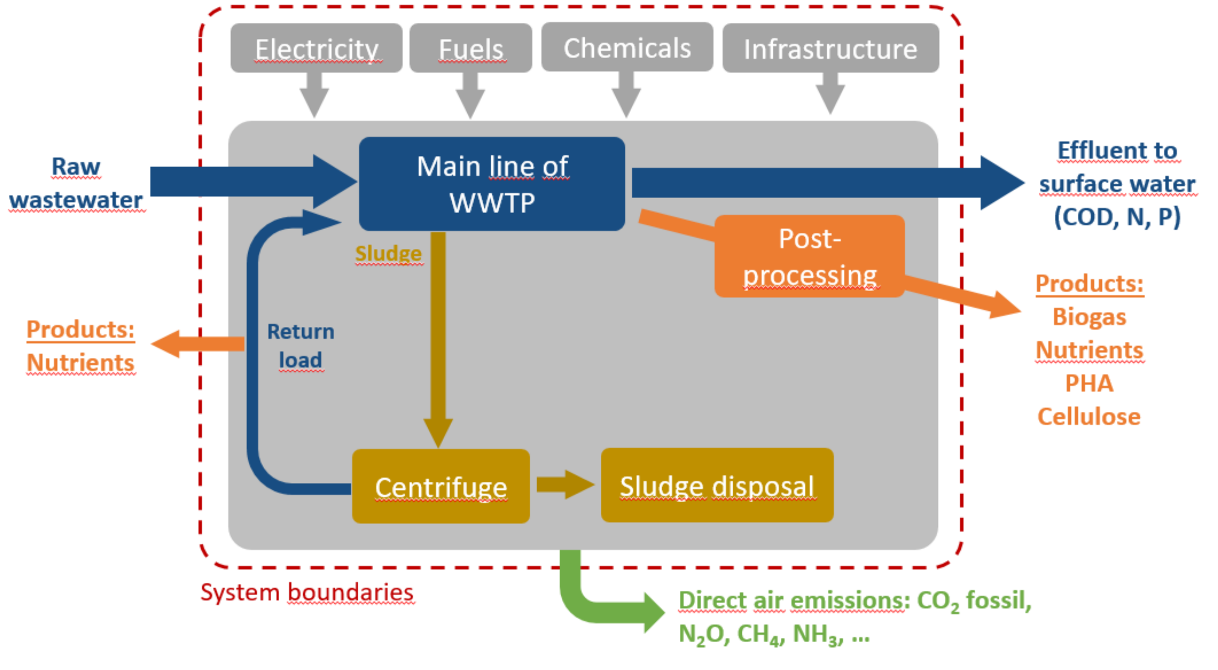


Figure 3.1: General framework for Performance Assessment WWTP

The WWTP of Aarle-Rixtel consists of a main inlet with bar screens, after which the waste water flows to a grit/fat removal. Afterwards, the waste water is split into two identical trains. In train one the rotating belt filters (fine screens) are placed, train two receives the water straight from the grit/fat removal. The treatment plant processes are treated as a black box for the process assessment.

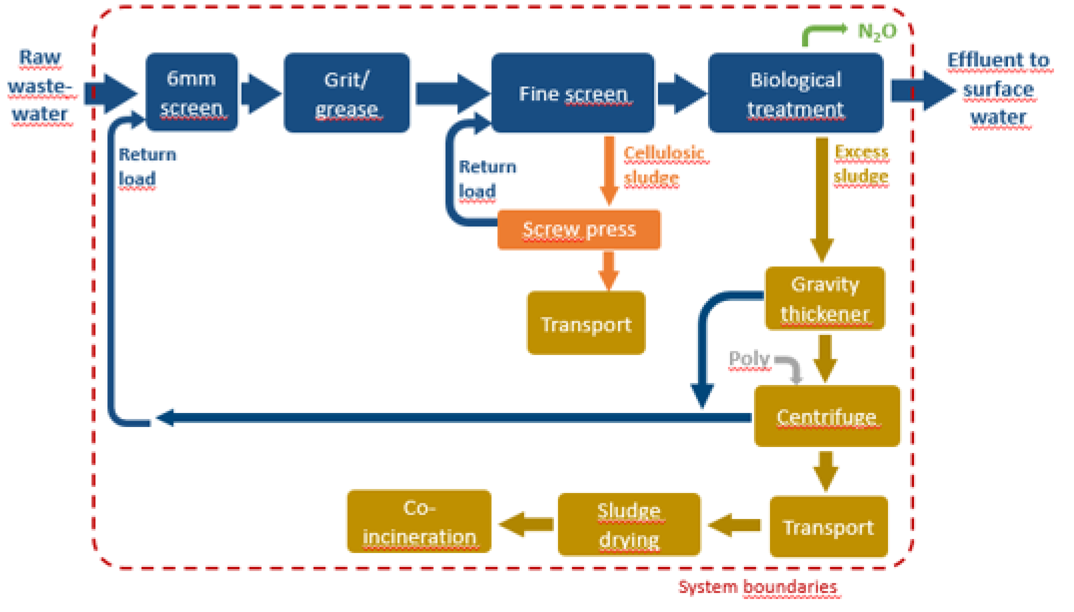


Figure 3.2: System boundaries for Performance Assessment Aarle-Rixtel (cellulose recovery)

In order to assess the performance of the fine sieves, this document focusses on the changes in effluent quality, sludge disposal, chemicals, energy, sludge and transportation both in financial terms as well as the total reduction of greenhouse gas emissions.

4 Environmental and economic impact

4.1 Indicators and measurement process

At the start of the project, the indicators listed in table 4.1 were defined in relation to the performance of the process at the end of the project. The assumption was that at the end of the project four similar installations would be operational.

Table 4.1 Performance assessment indicators as defined at the start of Screencap

Objective	Indicators		Absolute Impact	Relative Impact
Improved Environmental Performance	Greenhouse gas emissions	CO_2	253,521 tons / year	24% change to baseline
		Methane	n.r.	
	Air quality	Particulate matters	n.r.	
	Reduction / substitutions of dangerous substances	Irritant / Corrosive	n.r.	
		Mutagenic / Carcinogenic	n.r.	
		Toxic	n.r.	
		Persistent / Bioaccumulative	n.r.	
	Waste management	Prevention	n.r.	
		Waste minimization	6,720 tons / year	47% change to baseline
		Reuse of waste / Substance recovery	n.r.	
		Material recycling	56,000 tons / year	25% change to baseline

		Waste diverted from landfills	n.r.	
		Hazardous waste	n.r.	
Better use of natural resources	Reduced resource consumption (excluding energy)		n.r.	
	Water	Reduced water consumption	n.r.	
	Energy	Energy from RES	1,182,000 m^3 / year	36% change to baseline
		Reduced energy consumption	2,711,808 kwh/year	12% change to baseline
Economic Performance / Market Replication	Business development / market replication		4 installations	n.a.
	Market potential	Market size in mullion Euros	2,880,000 Euros	n.a.
		Market size in number of customers	6 full-scale applications in backlog	n.a.
	Entry in new transnational markets		2 installations in new transnational markets in Europe	n.a.
	Entry into different sectors		n.r.	
	Reduction of cost per unit or process		300,000 Euros / unit	n.a.
	Payback Time	Capital invested / net income	4-8 years	n.a.

	Patents	1	n.a.
Others	Polyelectrolyte	35,000 kg/year	30% change to baseline

n.a. Not Applicable; n.r. Not Relevant

During the research multiple parameters were measured in the influent, filtrate of the rotating belt filters (fine screens), the aeration tanks, the effluent of the WWTP, the sludge flows and the screenings. Next to these parameters in the wastewater, parameters like electrical consumption and disposal of sludge were also monitored.

The removal efficiency of the fine screens has been monitored closely, at least once a week. For the TSS measurements a glass fibre filter with a pore size of 1.2 µm was used. For the COD, Nitrogen and Phosphorus the WWTP lab used cuvette tests. All measurements have also been done at a lab (Aquon) for confirmation of the results measured by the WWTP lab.

4.2 Effluent quality

The removal rate of the fine screens is determined by the WWTP lab and by Aquon, an accredited lab. The removal rates measured by both laboratories give similar results: TSS removal ±30%, COD removal ± 10%, BOD removal ± 15%. Nitrogen and Phosphorus are hardly removed by the fine screens (± 2%) since these components are mostly soluble. About 1275 kg/day ds. of screenings are produced. There is no significant change in effluent quality because of the fine screen installation.

4.3 Energy

There is an approximate decrease of 15% in m^3 aeration (=energy), which is equal to 400 kWh/day of energy savings. The fine screen installation, on the other hand, consumes energy while treating wastewater. The energy consumption of the fine screen installation is approximately 560 kWh/day.[5]

With some tweaks to the blowers the installation may be energy neutral, meaning the energy consumed by the fine screen installation is equal to the energy saved in the aeration tank. This means that the net energy saving equals 0%.

4.4 Sludge

As a result of the removal of suspended solids in the pre-treatment there is a 10% decrease in sludge production in the lane that has the fine screens compared to the lane without fine screens. This is a third lower than the expected decrease of 30%. The dry weight of the sludge in kg/ton dm stays the same.

[5] Excluding pumps. Due to the configuration in Aarle-Rixtel there is a high energy demand for pumping. Typically, the fine screens would be integrated in the waterline, which means pumping is not required. The total energy demand in Aarle-Rixtel is 75 W per m^3 of wastewater, of which 45 W/m^3 is consumed by the pumps and 30 W/m^3 is consumed by the fine screen installation. This accumulates to a total energy consumption of the total installation of approximately 1,400 kWh/day.

4.5 Chemicals

The reduction in sludge production results in a 8% decrease in PE consumption, in kg/day. This was determined by comparing actual PE usage during the Screencap research period from October 2017 to August 2017 to the PE usage in the period prior to the commissioning of the fine screens (January to October 2016).

4.6 Transportation

The trucking of sludge waste to the sludge incineration plant has been reduced by 10%, equal to the decrease in sludge production.

4.7 Summary

The table below summarises the expected as well as the realised performances assessment indicators as explained above, including the reduction in greenhouse gas emissions.

Table 4.2 Performance assessment indicators as defined at the start of the project, including realisation at the end of Screencap

Objective	Indicators		Absolute Impact	Relative Impact	Realised Absolute Impact	Realised Relative Impact
Improved Environmental Performance	Greenhouse gas emissions	CO_2	253,521 tons / year	24% change to baseline	77,490 tons / year	7% change to baseline
		Methane	n.r.			
	Air quality	Particulate matters	n.r.			
	Reduction / substitutions of dangerous substances	Irritant / Corrosive	n.r.			
		Mutagenic / Carcinogenic	n.r.			
		Toxic	n.r.			
		Persistent / Bioaccumulative	n.r.			
	Waste	Prevention	n.r.			

	management	Waste minimization	6,720 tons / year	47% change to baseline	2,000 tons / year	14% change to baseline
		Reuse of waste / Substance recovery	n.r.			
		Material recycling	56,000 tons / year	25% change to baseline	13,949 tons / year	6% change to baseline
		Waste diverted from landfills	n.r.			
		Hazardous waste	n.r.			
Better use of natural resources	Reduced resource consumption (excluding energy)		n.r.			
	Water	Reduced water consumption	n.r.			
	Energy	Energy from RES	1,182,000 m^3 / year	36% change to baseline	2.3 million m^3 / year	71% change to baseline
		Reduced energy consumption	2,711,808 kwh/year	12% change to baseline	0 kwh / year	0% change to baseline
Economic Performance / Market Replication	Business development / market replication		4 installations	n.a.	4 installations	n.a.
	Market potential	Market size in mullion Euros	2,880,000 Euros	n.a.	2,680,000 Euros	n.a.

		Market size in number of customers	6 full-scale applications in backlog	n.a.	7	n.a.
	Entry in new transnational markets		2 installations in new transnational markets in Europe	n.a.	3	n.a.
	Entry into different sectors		n.r.		n.r.	
	Reduction of cost per unit or process		300,000 Euros / unit	n.a.	300,000 Euros / unit	n.a.
	Payback Time	Capital invested / net income	4-8 years	n.a.	9 year	n.a.
	Patents		1	n.a.	0	n.a.
Others	Polyelectrolyte		35,000 kg/year	30% change to baseline	9,500 kg/year	8% change to baseline

n.a. Not Applicable; n.r. Not Relevant

The Material recycling as defined in the performance indicators is in the form of biomethane. With 13,949 tons per year of cellulosic screenings the yearly biomethane production is 2.3 million m^3.

5 Economic Impact

The WWTP Aarle-Rixtel was overloaded at the start of the project. The conventional response would have been to place an additional primary settling tank. The fine screens formed an economical alternative. Fine screens require less surface area, enable material recovery and this solution turned out to be the most economic way to extend the capacity of the WWTP: it was almost 30% cheaper than the conventional solution.[6]

The yearly financials savings related to indicators listed in chapter 4 are shown in the table below.

Table 5.1 Economic impact performance assessment indicators, based on the results of Screencap

Component	Parameter	Impact	€/unit	Total (€)
Greenhouse gas emissions	CO_2	77,490 tons/year	7.38[7]	€ 571,875
Sludge	Waste minimization	2,000 tons/year	35[8]	€ 70,000
Material recycling	Biomethane production	2.3 million m^3/year	0.15	€ 347,326
Energy	Reduced energy consumption	0 kwh/year	0.10	€ 0
Chemicals	PE	9,500 kg/year	9	€ 85.500
Total				**€ 1,074,702**

[6] Presentation "Fine screen project WWTP Aarle-Rixtel", Johannes Boersma, Water Authority Aa en Maas, June 1, 2017.

[7] European Emission Allowances, CO_2 price as of October 31, 2017, https://www.eex.com/en/market-data/environmental-markets/spot-market/european-emission-allowances#!/2017/10/31

[8] The sludge removal costs of Water Authority Aa en Maas are relatively low as they are co-owner of the sludge incinerator SNB in Moerdijk.

6 Conclusions

This Performance Assessment contains the environmental and economic performance of the project.

Life Cycle Analysis published by A.F. van Nieuwenhuijzen (2016) and by STOWA (2016), show that the environmental benefit of fine screens compared to a standard WWTP is 34 to 46 kPt/year. One kPt represents the environmental impact or load (i.e. entire production/consumption activities in the economy) of 1 average person living in the western world. Valorisation routes like separate digestion of cellulosic screenings and the use of cellulosic screenings as substitute for residual wood both have a positive environmental impact.

This project focused on the performance indicators at the wastewater treatment plant of Aarle-Rixtel. From the obtained results it can be concluded that there is 10% less sludge production, a reduced use of chemicals and an increased biomethane production. The total greenhouse gas emission reduction is 77,490 ton per year and the yearly savings are approximately €1.1 million.