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PERFORM

WP 4.2 - ECONOMIC EVALUATION | DINKELMAN, D. (DORIEN), SHOEBI OMRANI, P.S. (PEJMAN), DE ZWART, H. (HIDDE)

GOAL

- The goal of this task is to evaluate the economy of optimization measures investigated in PERFORM.
  - Will it produce more energy
  - Will it produce against lower cost
- For the economic assessment a tool is used which calculates the economy of a doublet using a discounted cashflow model.
- Site specific economic evaluation to compare the impact of conventional and new techniques
  - Dutch site
  - Danish site with modified Danish subsidy regulations

ECONOMIC TOOL

CASH FLOW METHODOLOGY

- Cash flow methodology is largely based on Dutch economic models and spreadsheets developed by ECN / TNO
- A: Options Power or Heat (inc. ATES)
- B: Includes simplified geothermal system input
- C: Subsurface costs
- D: Surface costs (power or heat)
- E: Fiscal rules
- F: LCOE output (also calculated: complete cashflow over doublet lifetime)

Calculation of LCOE of renewable heat and electricity

Geothermal Energy

Operational choice	A	heat

INPUTVARIABLES	used	Value	Unit	Comment
Flowrate	1	65.0	L/s	flow rate which is achieved from the subsurface (measured at surface conditions)
depth of the storage well	1	400	m	along hole depth (total length) of a single borehole in the subsurface
Surface temperature	1	10	C	average yearly surface temperature
waste heat temperature	1	22	C	production temperature (reservoir temperature, corrected for temperature losses)
Economic lifetime	1	15	Years	lifetime for cash flow calculations
subsurface costs				
well costs	1	1000	eur/m depth	costs of drilling, negative number means use thermoGIS wellcostscaling costs
well costs	1	0.40	mln euro/Well	calculated costs for drillling the wells
Stimulation and other Cost	1	0	mln euro/Well	additional well costs for stimulation (and other costs) of the reservoir
Pump investment	1	0.1	Mln euro/pump	investements. Workover is assumed every 5 years at installment costs
Number of wells	1	2	-	number of wells in the reservoir
subsurface capex	1	**0.9**	mln euro	calculated subsurface capex for wells, stimulation and pumps
subsurface parasitic				
COP (gross)	1	210	-	comparable coefficient of performance (MWth/MWe) to drive the pumps for heat instead of ATES
COP (net)	1	210	-	coefficient of performance (MWth/MWe) to drive the pumps. Ratio of thermal and electric power.
electricity price for driving the pumps	1	50	euro /MWhe	electricity price for the power consumed by the subsurface pumps
Variable O&M	1	**0.238**	euro/MWhth	calculated variable O&M per unit of heat produced (1MWhth=3.6GJ)
power temperature range used				
(co) heat relative starting temperature	1	0%	%	relative value (100%= Tx,0%=Tbase) for upper limit of temperature range for heat
outlet temperature power plant (Toutlet)	0	180	C	upper limit of Temperature for (co)heat use
power surface facilities				
thermal power for electricity	0	**-42.820**	MWth	net power produced, taking into account the relative efficiency recorded by operating binary and flash
electric power		-0.551	MWe	net power produced, taking into account the relative efficiency recorded by operating binary and flash
power Loadtime	0	8000	hours/year	effective load hours in a year for electricity production
power Plant investment costs	0	2.000	mln Euro/MWe	costs for power conversion system
power Distance to grid	0	5000	m	distance for the connection to the power grid
power Grid investment	0	80	Euro/kWe	grid connection cost per unit of power installed
power Grid Connection Variable	0	100	Euro/m	grid connection cost per unit of distance
power plant capex	0	**0.000**	mln Euro	calculated capex for power plant and grid connection
power Fixed O&M rate	0	1%	%	O&M costs as percentage of caclulated capex for (sub)surface facilities
power Fixed O&M	0	-16	kEuro/MWe	calculated O&M costs per unit of power installed
power Variable O&M	0	18.51958525	Euro/MWhe	calculated variable O&M costs (dependent on COP, and efficiency of conversion)
(co)heat surface facilities				
cascaded exit temperature	1	120	C	injection temperature (effective temperature range is Toutlet..Treinject)
direct heat production	1	16.302	MWth	heat production
direct heat load hours	1	2000	hours/year	effective load hours in a year for heat production
direct heat plant investment costs	1	110	kEuro/MWth	heat surface installation costs per unit of heat production
direct heat capex	1	**1.793**	mln Euro	calculate capex for heat production surface facilities
direct heat Fixed O&M rate	1	1.0%	%	O&M costs as percentage of caclulated capex for (sub) surface facilities
direct heat Fixed O&M	1	2	kEuro/MWth	calculated O&M costs per unit of heat production installed
direct heat Variable O&M	1	0.238095238	Eur/MWHth	calculated variable O&M costs (dependent on COP)
complementary sales				
complementary electricity sales	1	0.00	Euro/MWh	complementary revenues from electricity sales
complementary heat sales	1	0	euro/GJ	complementary revennues from heat sales
fiscal stimulus				
fiscal stimulus on lowering EBT	1	**no**	yes/no	apply fiscal stimulus on lowering earnings before tax (EBT) of the project developer
percentage of CAPEX for fiscal stimulus	1	42%	%	percentage of CAPEX which can be deducted from EBT
legal max in allowed tax deduction	1	63	mln Euro	legal maximum in tax benefit
NPV of benefit to project	1	0.0	mln Euro	effective benefit to project
Inflation	1	0%	%	inflation for costs and benefits in project cash flow
loan rate	1	6.0%	%	interest rate on debt
Required return on equity	1	15%	%	required return on equity
Equity share in investment	1	50%	%	share of equity in the effective investment
Debt share in investment	1	50%	%	share of debt(the loan) in effective investment
Tax	1	25.5%	%	tax rate for company
Term Loan	1	15	Year	number of years for the loan
Depreciation period	1	15	Year	number of years for depreciation (linear per unit of production)

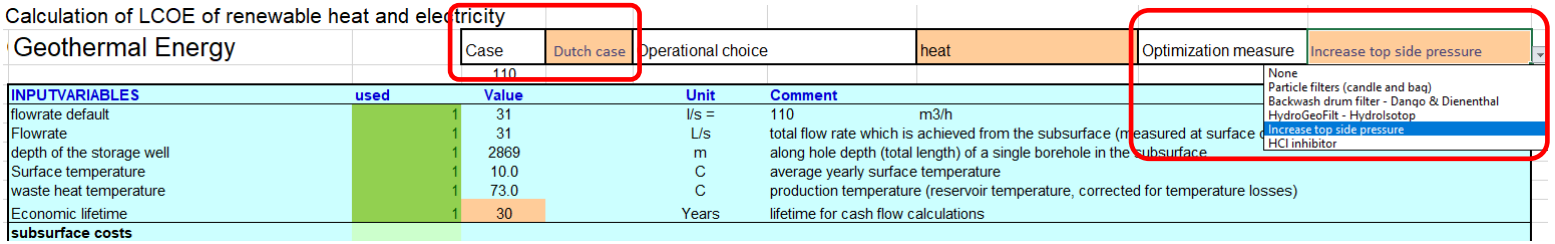
POWER (power,co-heat)	used	Value	Unit
levelized cost of energy (LCOE)	0	0.00	Euro/Mwhe

HEAT SHEET (heat)		Value	Unit
levelized cost of energy (LCOE)	1	4.02	Euro/GJ
			MWhth=3.6GJ

heat	value	unit
direct heat efficiency	1	-
ATES heat efficiency	0.75	-

OPTIMIZATION MEASURES

- Scaling
  - Increase top side pressure (WP 2)
  - To be added: calcite inhibitor HCl (WP 4)
- Filters
  - Candle and bag particle filters, backwash drumfilter



Calculation of LCOE of renewable heat and electricity

Geothermal Energy

Case	Dutch case	Operational choice	heat	Optimization measure	Increase top side pressure

110

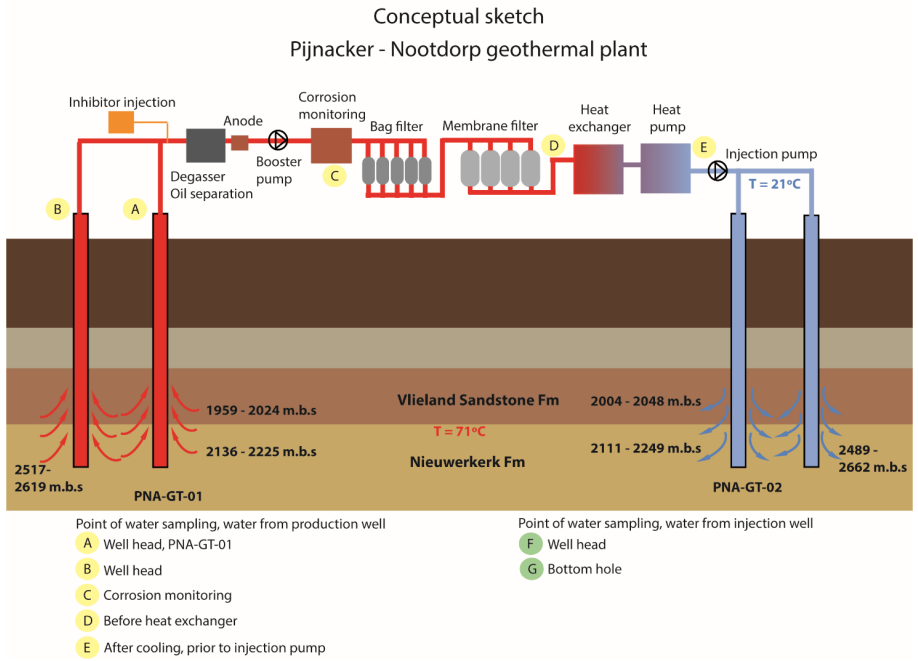
None
Particle filters (candle and bag)
Backwash drum filter - Danqo & Dienenthal
HydroGeoFilt - HydroIsotop
Increase top side pressure
HCl inhibitor

INPUTVARIABLES	used	Value	Unit	Comment
flowrate default	1	31	l/s =	110 m3/h
Flowrate	1	31	L/s	total flow rate which is achieved from the subsurface (measured at surface
depth of the storage well	1	2869	m	along hole depth (total length) of a single borehole in the subsurface
Surface temperature	1	10.0	C	average yearly surface temperature
waste heat temperature	1	73.0	C	production temperature (reservoir temperature, corrected for temperature losses)
Economic lifetime	1	30	Years	lifetime for cash flow calculations
subsurface costs				

CASE STUDY
PIJNACKER NOOTDORP

- Calculated geothermal power 7 MW_{th}
- Temperature 71 °C production, 21 °C injection
- Flow rate 110 m^3/h
- Economic lifetime 30 years

- Example type of calculation of tool
  - ESP replacement every 5 years → 11,94 EUR/GJ
  - ESP replacement every 2 years → 13,01 EUR/GJ
  - From 110 m^3/h to 180 m^3/h → 8.14 EUR/GJ



Costs estimation Ammerlaan doublet (ThermoGIS/general)	
Drilling costs	2000 EUR/m depth
CAPEX pump	580 kEURO
OPEX pump replacement	640 kEURO
CAPEX subsurface	12,3 MEURO
Direct heat plant investment costs	300 kEUR/MWth
CAPEX surface installation	2 MEURO
OPEX variable	4,25 EUR/MWhth
OPEX fixed (1% of total CAPEX)	22 kEUR/MWth

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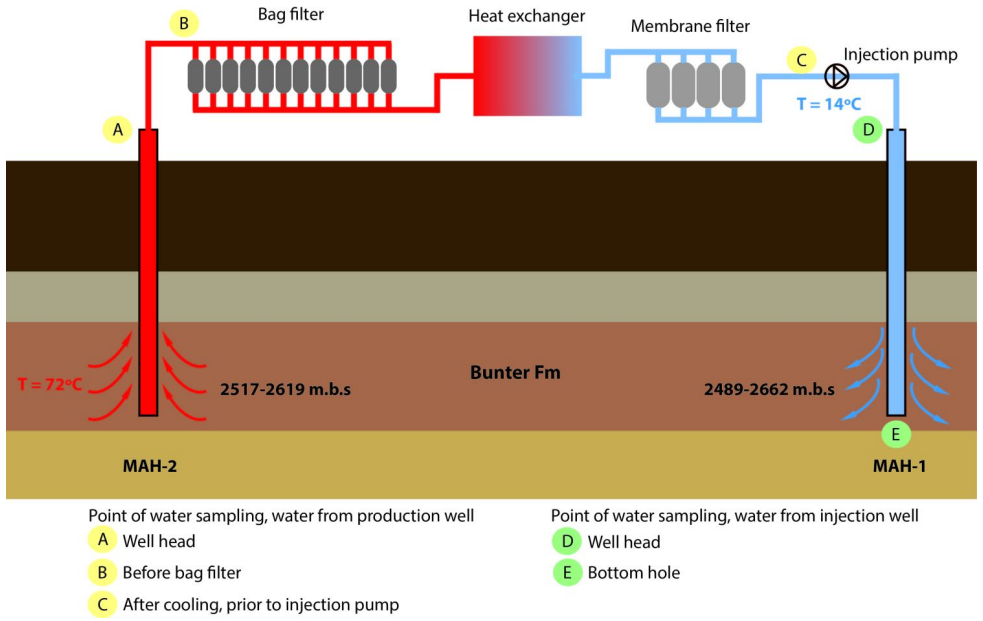
CASE STUDY
MARGRETHEHOLM

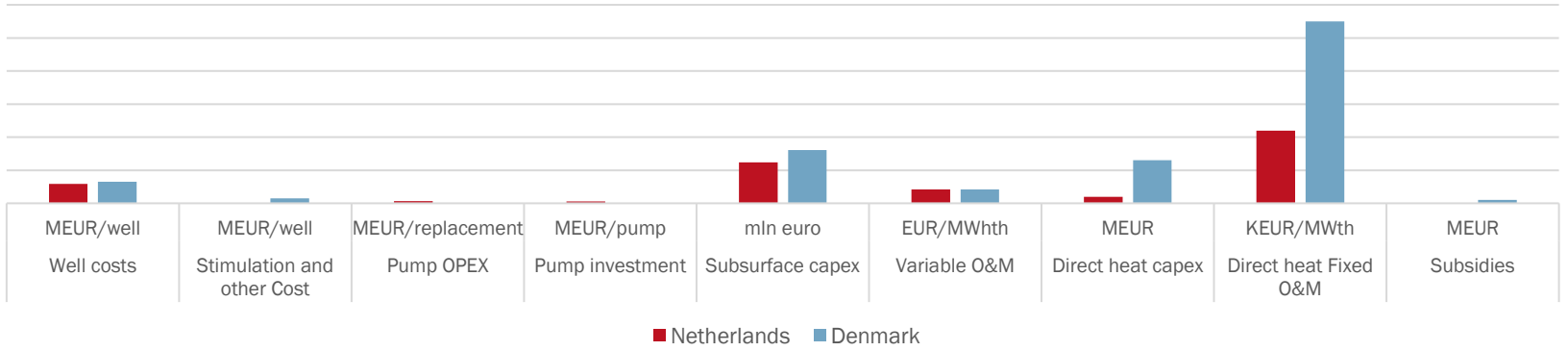
- Calculated geothermal power 13-14 MW_{th}
- Temperature 73 °C production, 17 °C injection
- Flow rate 200 m^3/h
- Economic lifetime 30 years
- Subsidy scheme included

- Example calculation:
  - 14 MW, 4000 h/yr → 19,67 EUR/GJ
  - 14 MW, 7000 h/yr → 11,74 EUR/GJ

Conceptual sketch
Margretheholm geothermal plant



Cost estimations



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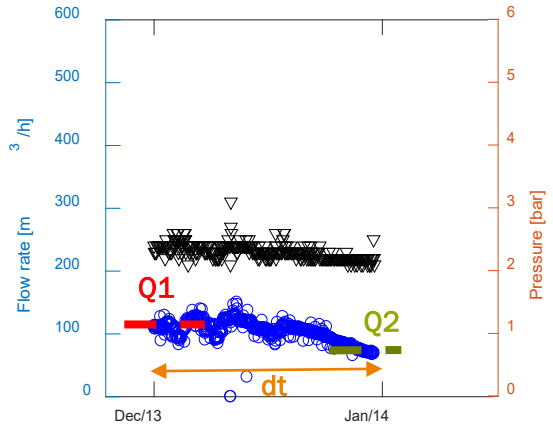
OPTIMIZATION MEASURE
INCREASE TOP SIDE PRESSURE

- Increase top side pressure → reduce degassing → reduce scaling
- Data from Dutch case on flowrate and tank pressure (WP 2 and 4)
- New flowrate and ESP power dependent on top side pressure



ECONOMIC EVALUATION
SCALING INHIBITOR HCL

- Modelling results WP4
- Cost indication from Brenntag

OPTMIZATION MEASURE

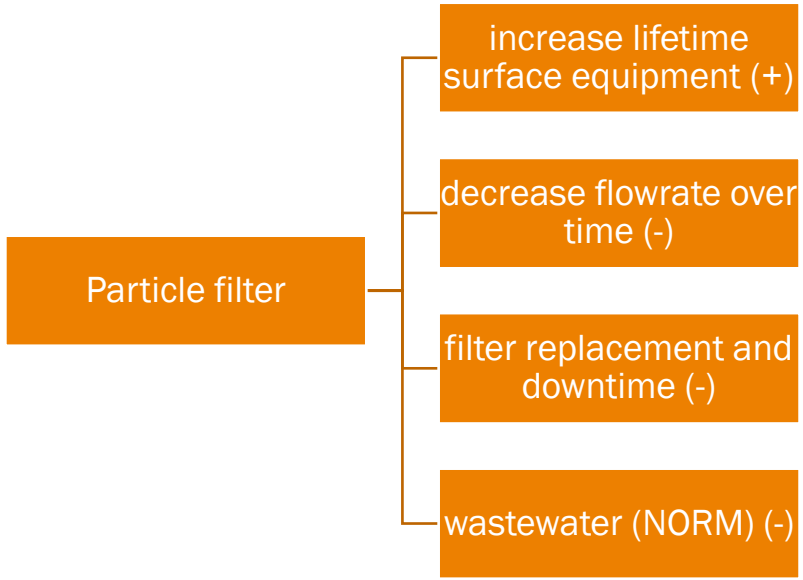
PARTICLE CANDLE AND BAG FILTER

- As an alternative to adding inhibitors, improved particle and cation filters have been developed in PERFORM
- Not modelled in WP 2, experiments in WP 3 still pending
- Approach: compare commerically available bag and candle filters with backwash drum filter

- Candle filters
  - Replacement every month
  - 20 filters needed
  - €120,- per filter
- Bag filters
  - Replacement every month
  - 6 filters needed
  - €25,- per filter
- Downtime costs (assumption: in fixed O&M)
- Additional costs associated to NORM: ~€15.000-30.000 per year

Bollfilter

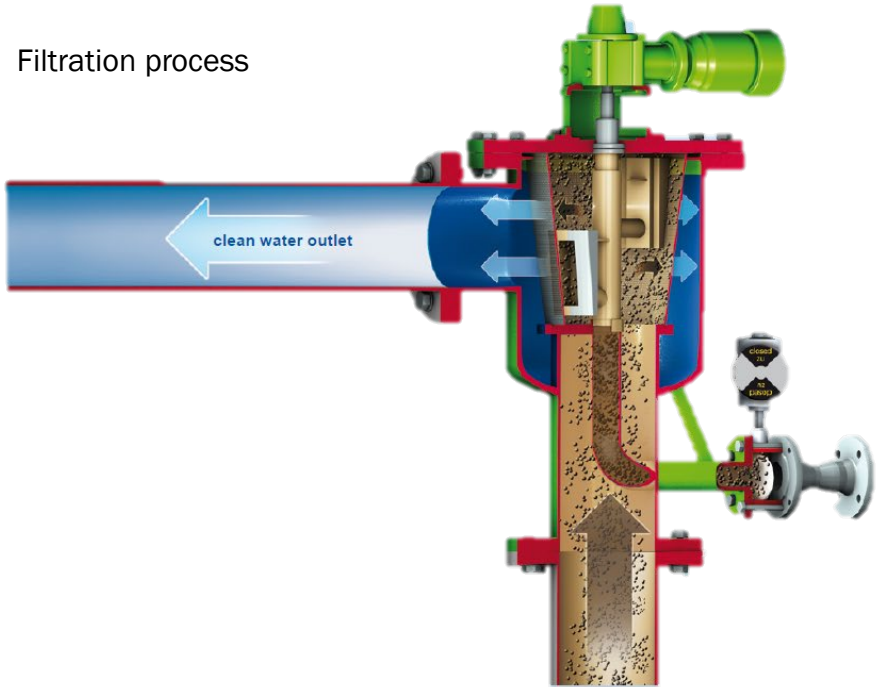
Dango & Dienenthal



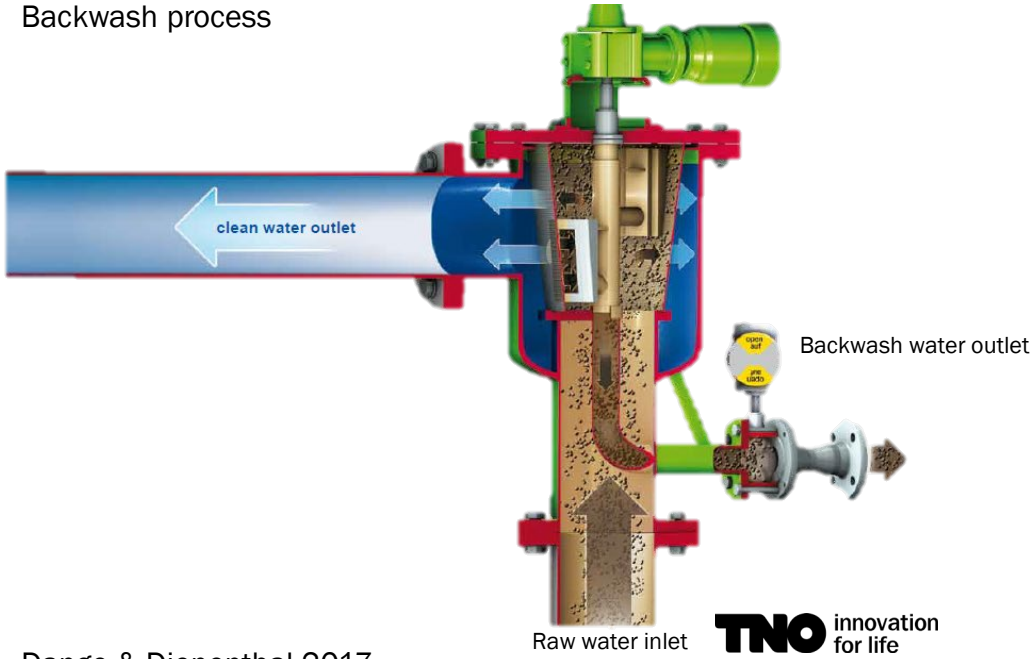
OPTIMIZATION MEASURE
BACKWASH DRUMFILTER

- Commercially available backwash filter, example:
  - Backwash process activated at defined differential pressure between raw water inlet and clean water outlet (degree of pollution)
  - 15-20 seconds process finished
  - During backwashing the filtration process is not interrupted
  - Longest lifetime: 10 years
  - Maintainance is negligable, only checking.
  - ~€38.000,- per filter, two filters needed. One in operation, one filter in standby.

Filtration process



Backwash process



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OPTIMIZATION MEASURE
HYDROGEOFILT FILTER

- PERFORM: The HydroGeoFilt system has been tested successfully in the laboratory. Long-time onsite tests are, however, still missing.
- Innovative particle filter with self-cleaning function with ultrasonic device.
- Now in candle, bag or drum filters: carbonate and iron sulphide precipitations lead to a blocking of the candles.
- These effects make the normal back wash process impossible and the cartridges have to be manually removed and acidified frequently.
- The newly developed system shell requires low-maintenance, is efficient and economic in operation.
- The system will be tested in pilot plant scale.

- Update: no cost indication available for economic evaluation.

HydroGeoFilt

ECONOMIC EVALUATION
CANDLE AND BAG FILTER VS BACKWASH DRUM FILTER

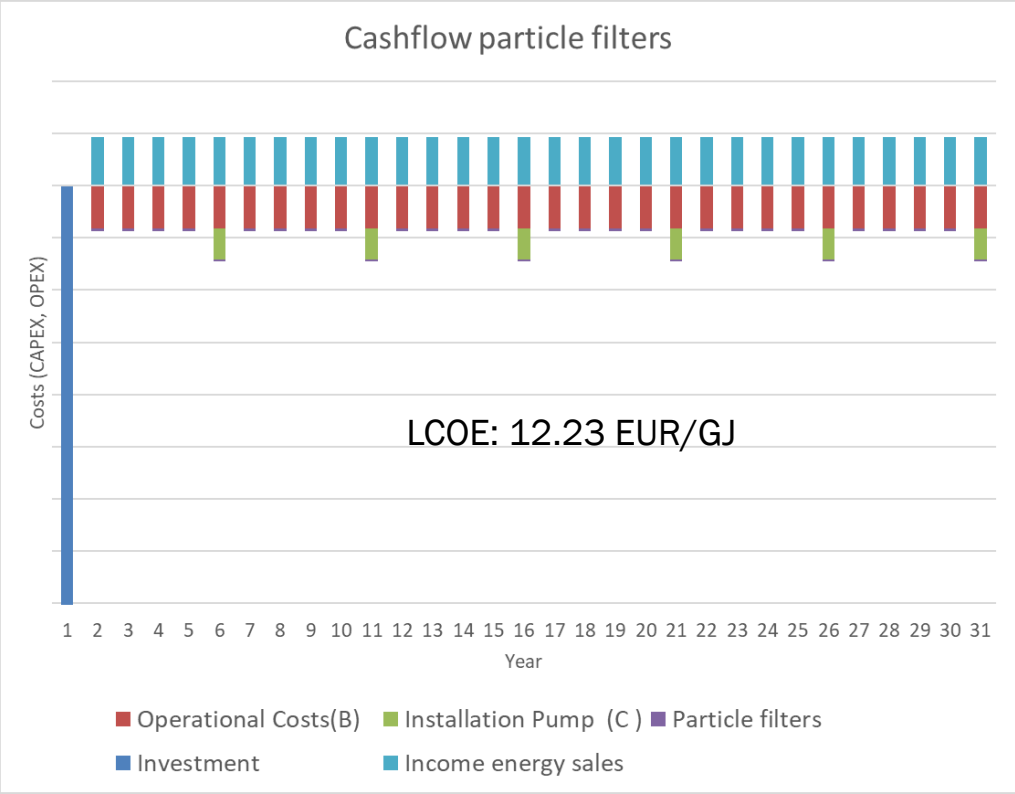
Particle filters	
Candle filters	
Replacement every month	
20 filters needed	€28.800/yr
€120,- per filter	
Bag filters	
Replacement every month	
6 filters needed	€1800/yr
€25,- per filter	
NORM costs	€17.000/yr
	_____ +
Total	€47.700/yr

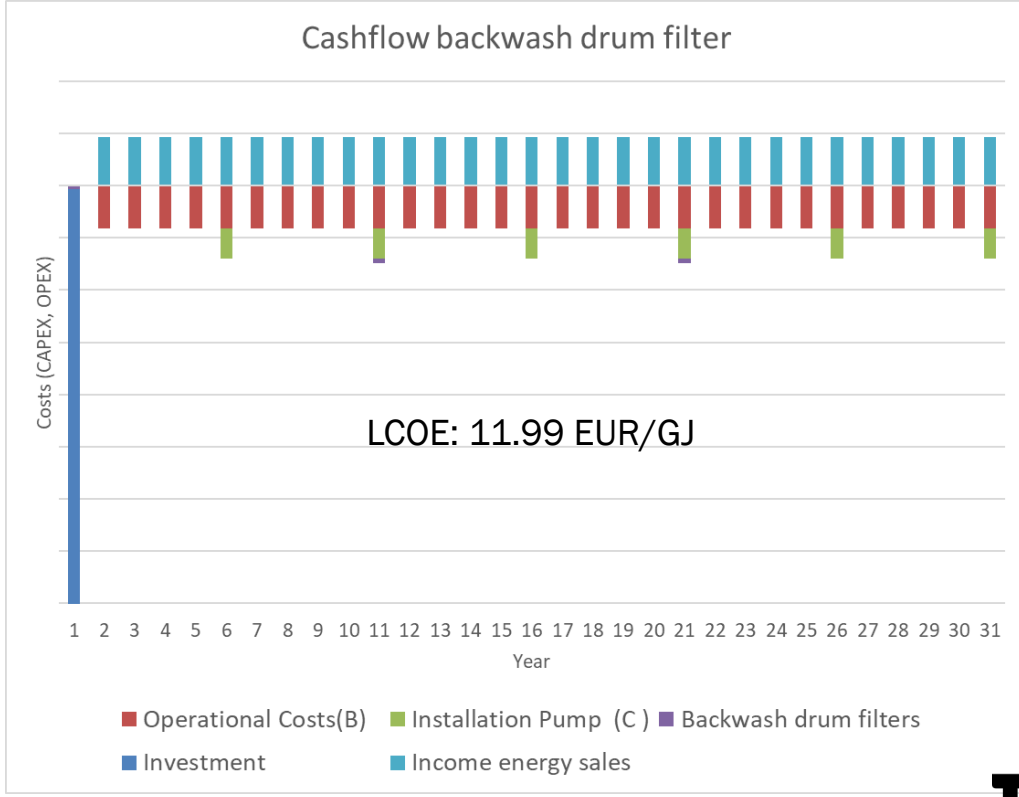
Backwash drumfilter	
~38.000 per filter	
2 filters needed	€76000/10 yr
Lifetime max. 10 yr	
Total	€7600/yr

ECONOMIC EVALUATION

CANDLE AND BAG FILTER VS BACKWASH DRUM FILTER

- Dutch case
- Savings by using backwash drumfilter: €39.400/yr
- Effect on LCOE is minor due to relatively small costs compared to operational costs and pump installation





ECONOMIC EVALUATION

CANDLE AND BAG FILTER VS BACKWASH DRUM FILTER

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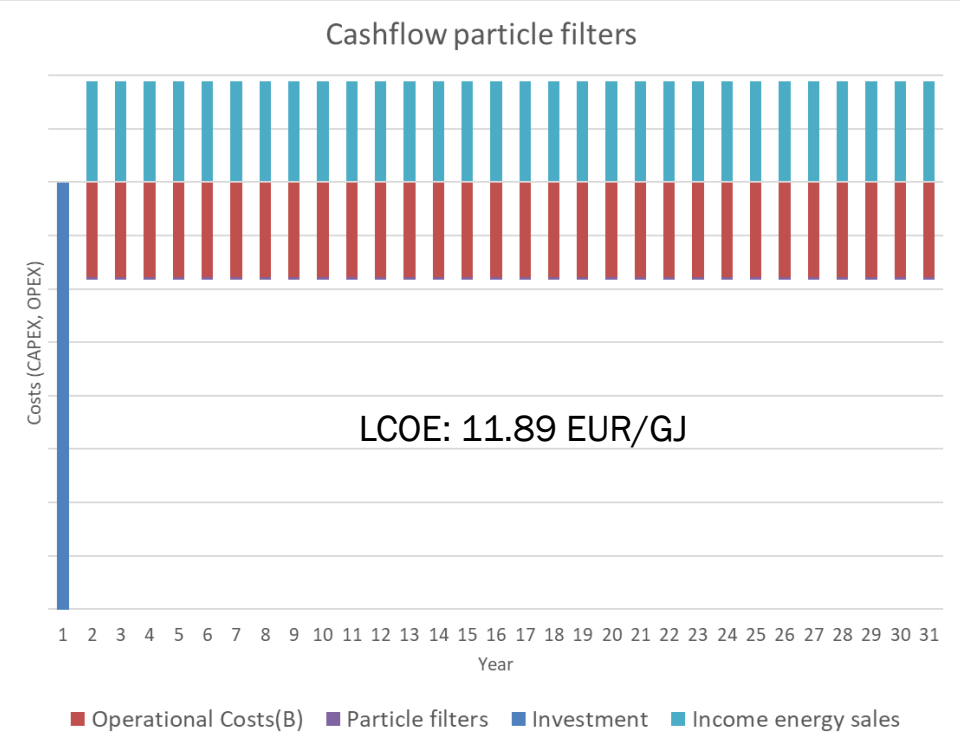

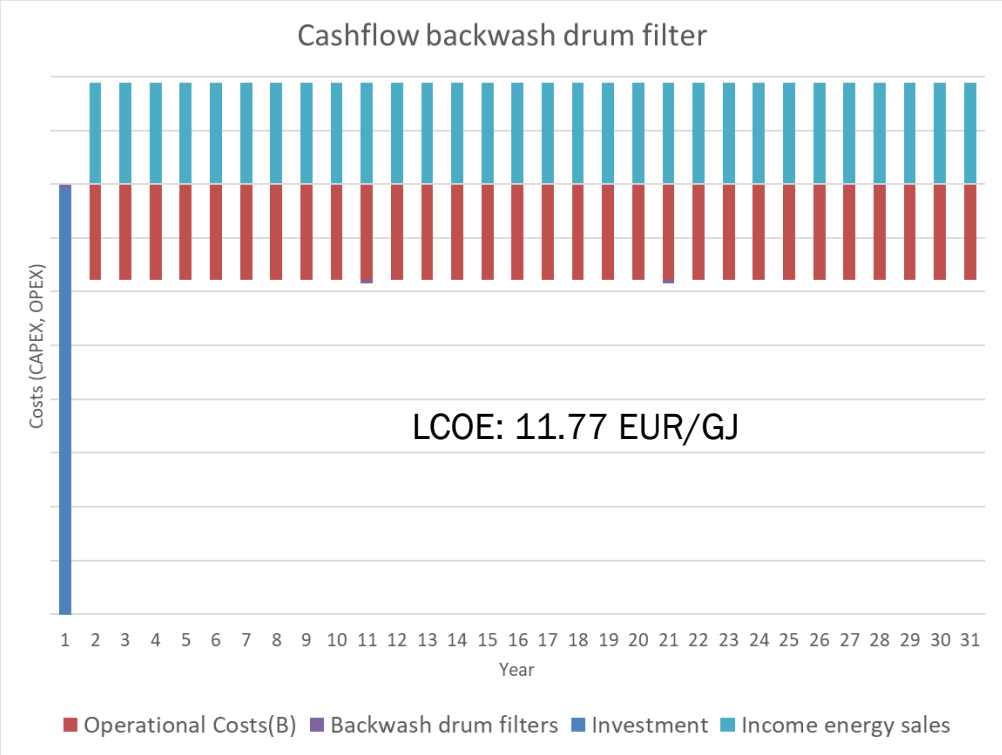

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CONCLUSION

- Modified version of the tool will become publicly available on the PERFORM website
- Report on economy of optimization measures, data and assumptions

- Short demo

BEDANKT VOOR
UW AANDACHT

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