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Appendix A

A.1 Fuel cycle cost

The mass of fuel was calculated per refuelling cycle. Equation A.1 shows the formula used.

$$Mass\ of\ fuel\left(\frac{tHM}{year}\right) = \frac{Thermal\ power(MW) * Availability * 365\ (days)}{Burnup\left(\frac{MWd}{tHM}\right) * (year)} \quad (A.1)$$

Table A.1 illustrates the values taken from Koeberg used in the calculations. It is assumed that the availability is increased by 2,5% when the refuelling cycles are extended from 18 months to 24 months.

The burnup used in equation A.1 is calculated from equation A.2.

$$Burnup = 236{,}25 * P\left(\frac{kW}{kg}\right) * L * n * T_c(years) \quad (A.2)$$

$$P = spesific\ power\left(\frac{kW}{kg}\right) \sim 38{,}3\ for\ Koeberg \quad (A.3)$$

$$L = Overall\ cycle - average\ availability\ factor \quad (A.4)$$

$$1/n = Fraction\ of\ the\ core\ replaced\ each\ refuelling \quad (A.5)$$

$$Tc = Cycle\ length\ in\ years \quad (A.6)$$

The values used in equation A.1 and A.2 are taken from Koeberg and are given in Table A.1.

Table A.1 Koeberg values

Property	Value	Unit
Thermal power	2 785	MWth
Availability (18 months)	80	%
Availability (24 months)	82,5	%
Fraction of the core replaced each refuelling	1/3	-

The composition of the fuel was calculated according to Table A.2.

Table A.2 Composition of fuels

	U	Th	Pu
UO_2	100%	-	-
$(Th/U)O_2$	25%	75%	
$(Th/Pu)O_2$	-	87%	13%

The amount of raw materials was calculated by taking into account the losses of every process step. The losses for each process step are given in Table A.3.

Table A.3 Process step losses for front end of fuel cycle

Process step	Losses
Conversion	0,5%
Fabrication	1%

The separative work units (SWU) were calculated according to equation A.7

$$SWU\ (\frac{ton}{cycle}) = Mp * V(xp) + Mt * V(xt) - Mf * V(xf) \quad \text{(A.7)}$$

$$Mp = Mass\ of\ product\ stream\ (\frac{tU}{cycle}) \quad \text{(A.8)}$$

$$Mt = Mass\ of\ tails\ stream\ (\frac{ton}{cycle}) \quad \text{(A.9)}$$

$$Mf = Mass\ of\ feed\ stream\ (\frac{ton}{cycle}) \quad \text{(A.10)}$$

$$V(uranium\ fraction\ of\ spesific\ stream) = Value\ function \quad \text{(A.11)}$$

$$Value\ function{:}\ V(x) = (1-2x) * ln\ (\frac{1-x}{x}) \quad \text{(A.12)}$$

A.2 Cost of refuelling downtime

The cost of refuelling downtime was calculated by using equation A.13

$$Outage\ cost = power(kW) * \ [(I_e * \frac{hours}{outage}) + (C_{re} * t_{re} * t_r)] \quad \text{(A.13)}$$

$$I_e = income\ of\ electricity \left(\frac{R}{kWh}\right) \quad \text{(A.14)}$$

$$C_{re} = \ cost\ of\ replacement\ electricity \left(\frac{R}{kWh}\right) \quad \text{(A.15)}$$

$$t_{re} = \ replacement\ electricity\ duration \left(\frac{hours}{day}\right)) \quad \text{(A.16)}$$

$$t_r = duration\ of\ refuelling(days) \quad \text{(A.17)}$$

The values used to calculate the refuelling outage cost are given in Table A.4.

Table A.4 Values used to calculate the refuelling outage cost

Property	Value	Unit
Running cost of electricity	0,206	R/kWh
Selling price of electricity	0,52	R/kWh
Income of electricity	0,314	R/kWh
Replacement electricity cost	0,374	R/kWh
Replacement duration (for peak times)	5	hours/day
Duration of refueling	30	days

The excel model developed for the uranium fuel cycle calculation is shown in Figure A.1

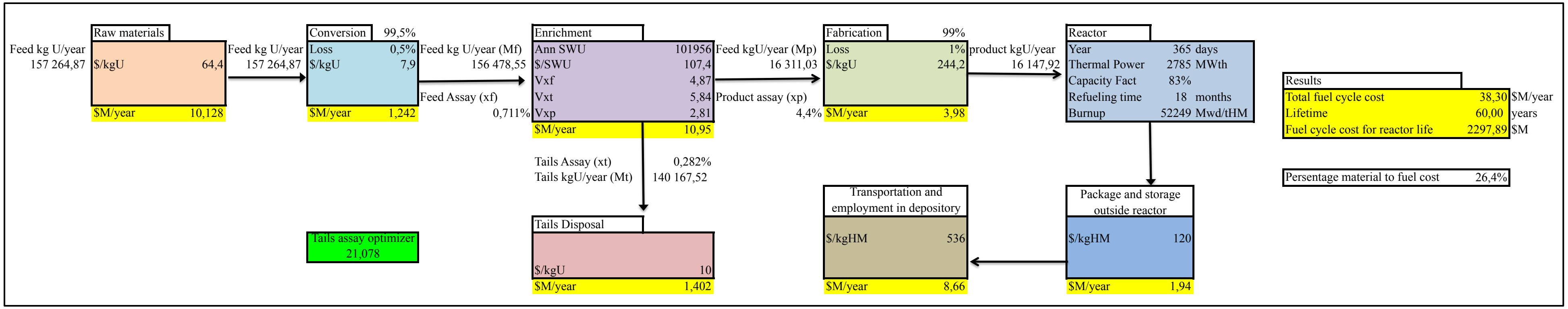

Figure A.1 Model for the uranium fuel cycle calculation

The excel model developed for the Th/U fuel cycle calculation is shown in Figure A.2

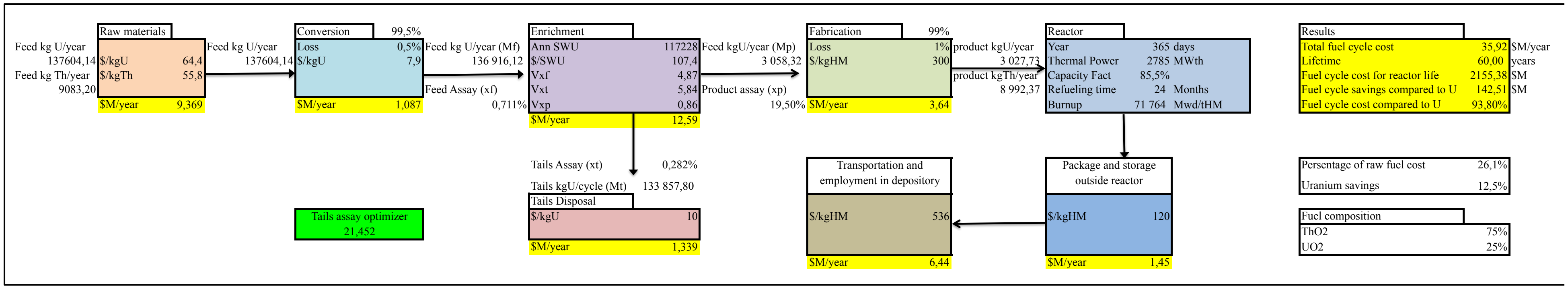

Figure A.2 Model for the Th/U fuel cycle calculation

The excel model developed for the Th/Pu fuel cycle calculation is shown in Figure A.3

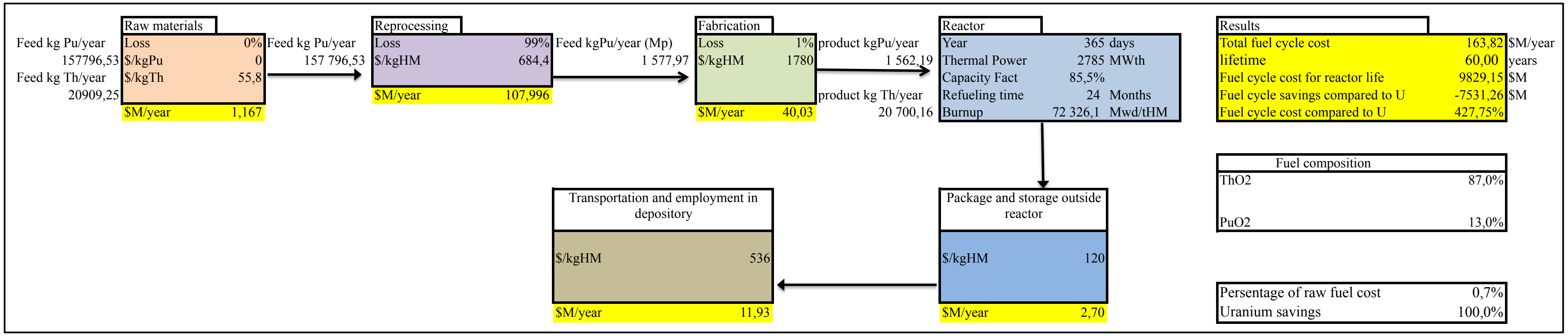

Figure A.1 Model for the Th/Pu fuel cycle calculation