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THE INTEGRATED PLASTIC WASTE MANAGEMENT: A TECHNICAL-ECONOMICAL ASSESSMENT OF AN INTEGRATED SORTING – FEEDSTOCK RECYCLING SYSTEM

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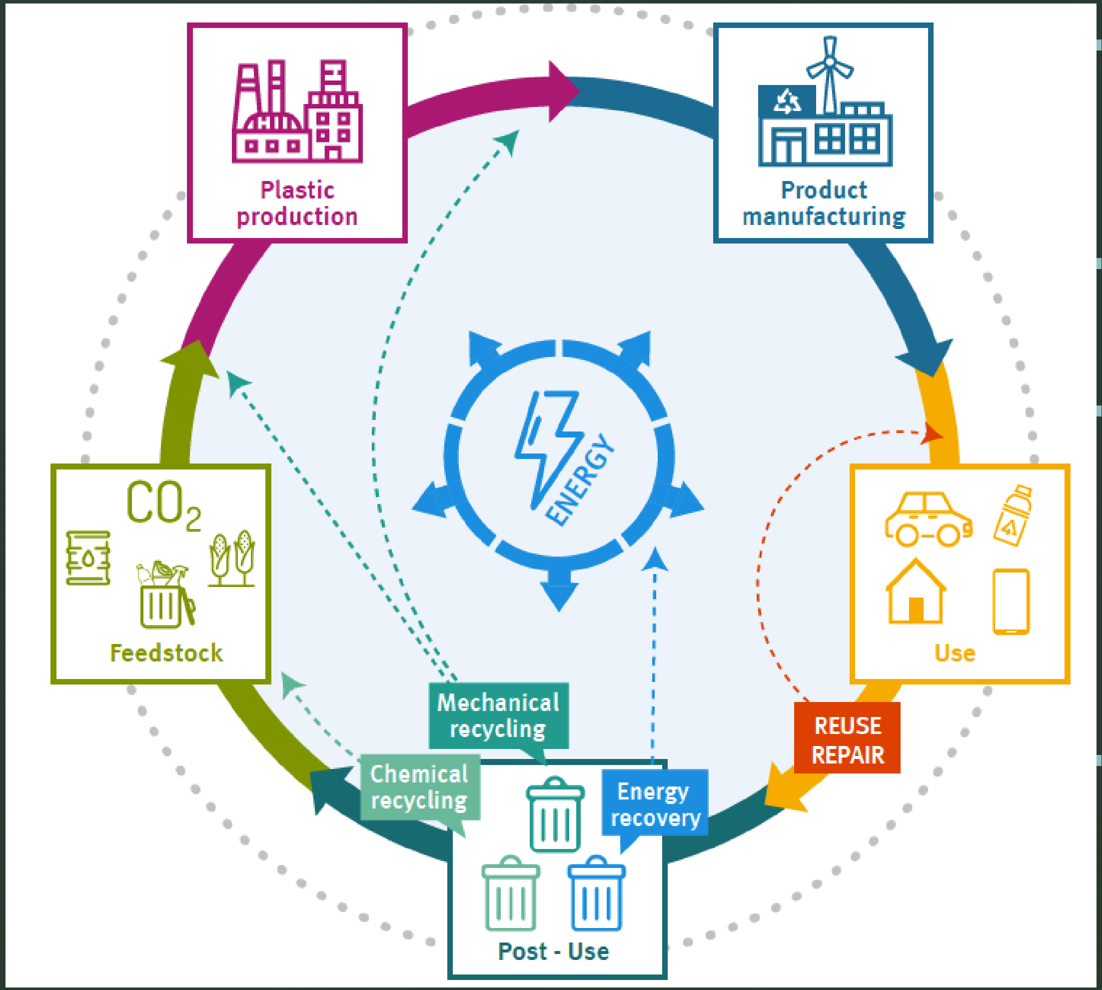
Background and scope$_{-1}$

Source: Plastics Europe



- Last data from Plastics Europe show that 335 millions of tons of plastic materials were produced worldwide in 2016.
- Standard plastic waste management includes collection, mechanical reprocessing, energy recovery and landfilling.
- The mechanical recycling of plastics should be preferred when a mono-material collection of plastics must be treated, since the cost of the separation processes is very high: more than 70kWh/t is required by sorting the plastic waste into monomaterial streams suitable to be recycled into materials or feedstock.
- Otherwise, if a mixture of different polymers has to be treated, it could be convenient to take into account the feedstock recycling and, as last option, the energy recovery processes.

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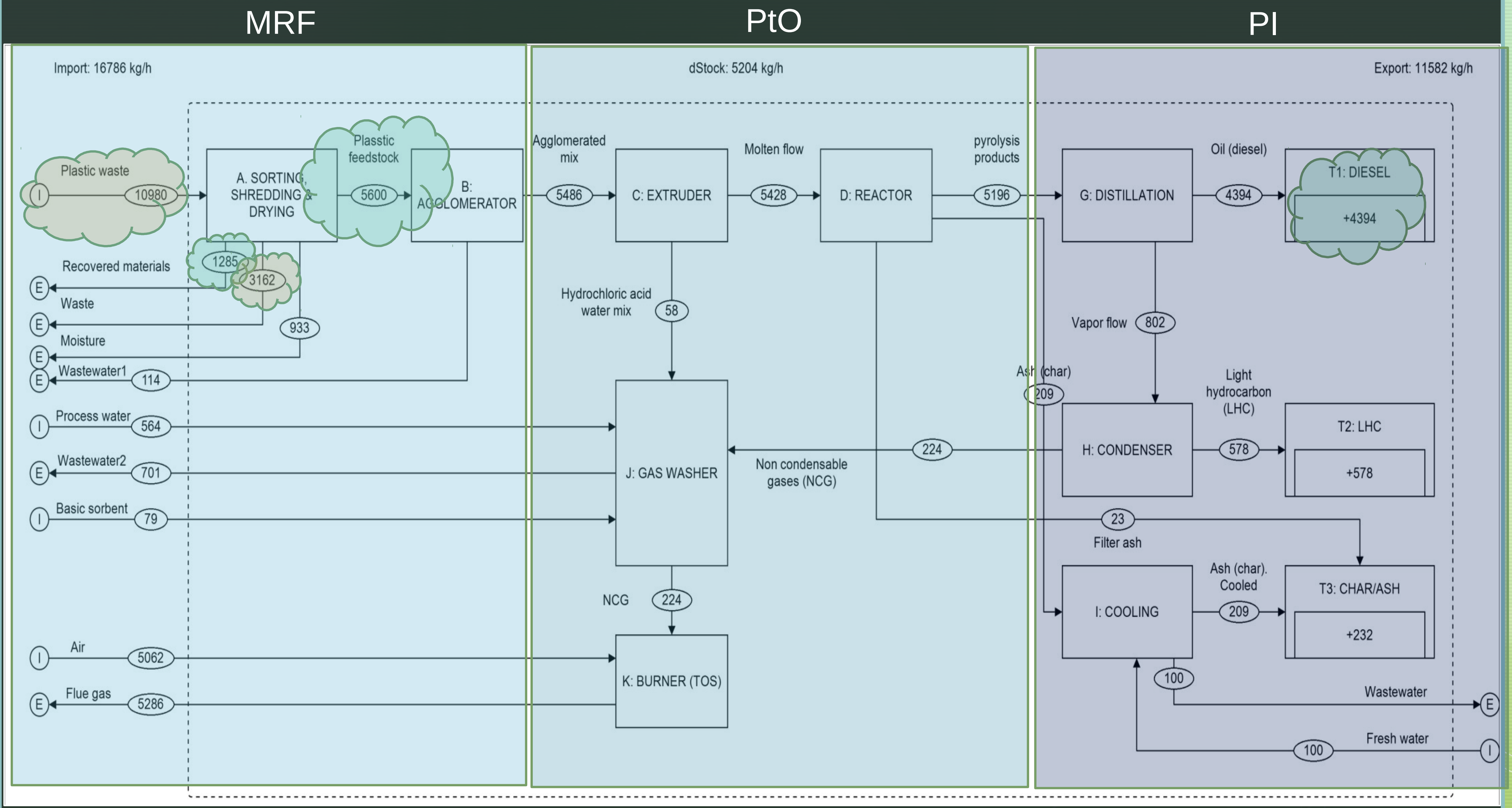
Background and scope-2

- The plastic conversion into oil (or to feedstock, more in general) is not yet applied as a suitable option to exploit the plastic waste due to the absence of refineries-recycling links but it can become an interesting integration, not a competitor, of the standard management system by developing agreements to this end.
- The common point of all technologies available on the market for PtO is the limited scale; a typical capacity of 20.000t/year is proposed. This limitation suggests considering these technologies as integration at local/regional level of MRF.
- The scope of this work is to assess which are the expected advantages of this integration.

MRF - PtO –PI: integrated mass balance



Materials

- The plastic waste collected by separate collection is related to a door-by-door collection system.

Plastic packaging (27% PET, 11% PE)	52%
Aluminium packaging	1%
Ferrous packaging	8%
Paper & cardboard	3%
Glass	4%
Other recyclables	2%
Foreign matter	9%

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Methods

- The assessment method used to evaluate the advantages and the drawbacks of the integrated industrial network between MRF – PtO - PI has been by using:
  - The scenarios comparison (base case and alternatives)
  - The Material Flow Assessment
  - The Indexing

Methods-2

- The comparison between the scenarios has been made by defining some performance's indexes. The first set of indexes are related to the mass flows of: material recycled as new goods ($Y_{M,MR}$), materials used as fuel in processes for energy production ($Y_{M,ER}$) and the materials landfilled ($Y_{M,L}$).
- The exact definition is the following:

$$Y_{M,MR} = \frac{mass\ flow\ of\ recycled\ goods\ (\sum_i F_i)}{mass\ flow\ of\ F1}$$

$$Y_{M,ER} = \frac{mass\ flow\ of\ materials\ utilised\ as\ fuels\ (\sum_j F_j)}{mass\ flow\ of\ F1}$$

$$Y_{M,L} = \frac{mass\ flow\ of\ materials\ addressed\ to\ landfill\ (\sum_k F_k)}{mass\ flow\ of\ F1}$$

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Methods_3

- The same indexes measuring the scenario performance reported with reference to the mass flows have been defined and evaluated regarding the energy flows.
- These “energy yields” are defined as:

$$Y_{E,MR} = \frac{energy\ flow\ of\ recycled\ goods\ (\sum_i F_i)}{energy\ flow\ of\ F1}$$

$$Y_{E,ER} = \frac{energy\ flow\ of\ materials\ utilised\ as\ fuels\ (\sum_j F_j)}{energy\ flow\ of\ F1}$$

$$Y_{E,L} = \frac{energy\ flow\ of\ materials\ addressed\ to\ landfill\ (\sum_k F_k)}{energy\ flow\ of\ F1}$$

Results and Discussion: base case and alternative scenarios

- The base case scenario is labelled "scenario A" and refers to the actual plastic waste management network.
- Alternative scenarios B and C are set up in order to measure the improving of the overall sustainability of the network in term of recovered materials and energy.
- Scenario B is normally applied for which Countries having a sufficient residual capacity of incineration plants or other energy recovery options such as foundries and cement kilns licensed to use the plastic derived fuels.

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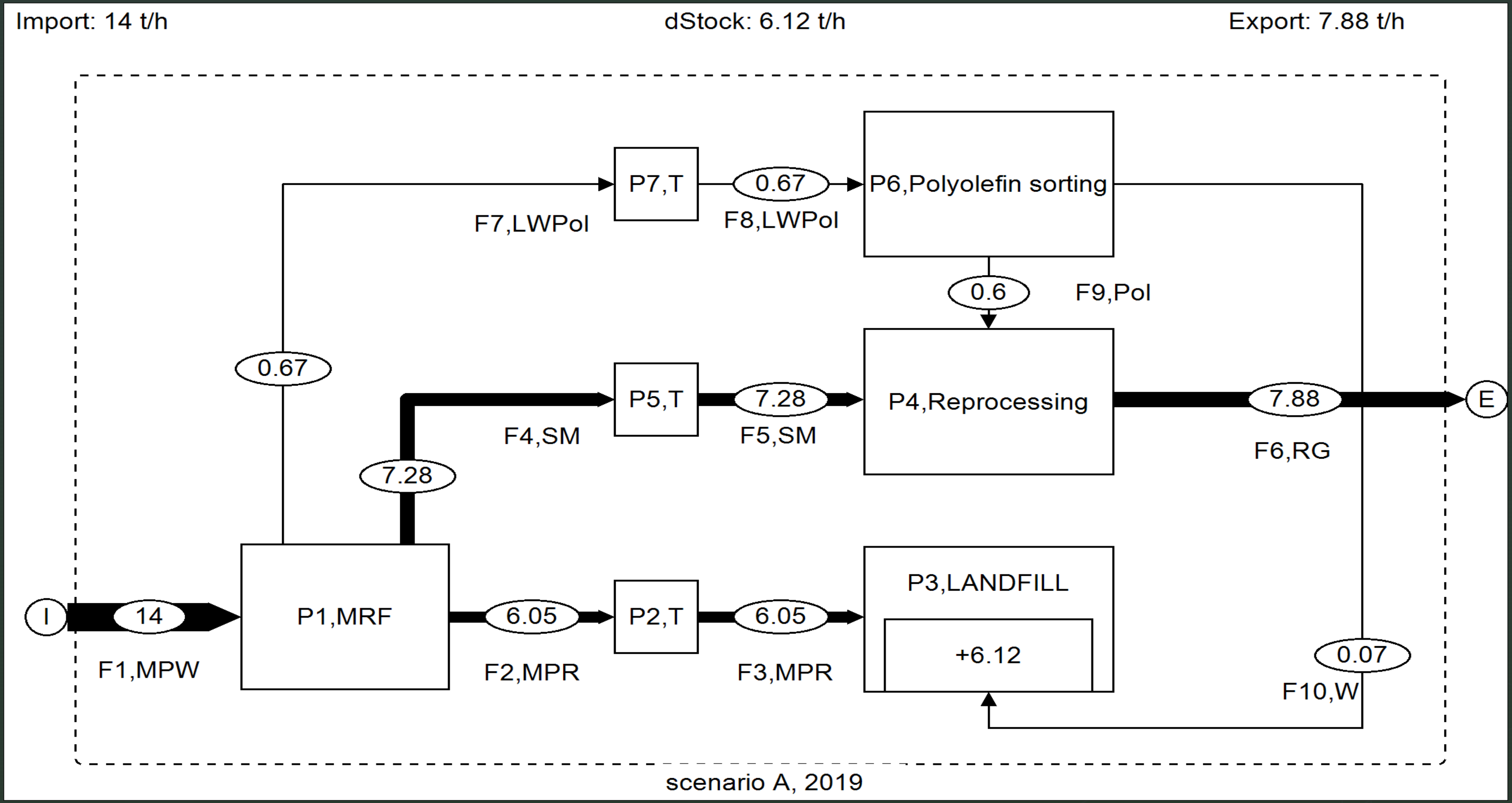
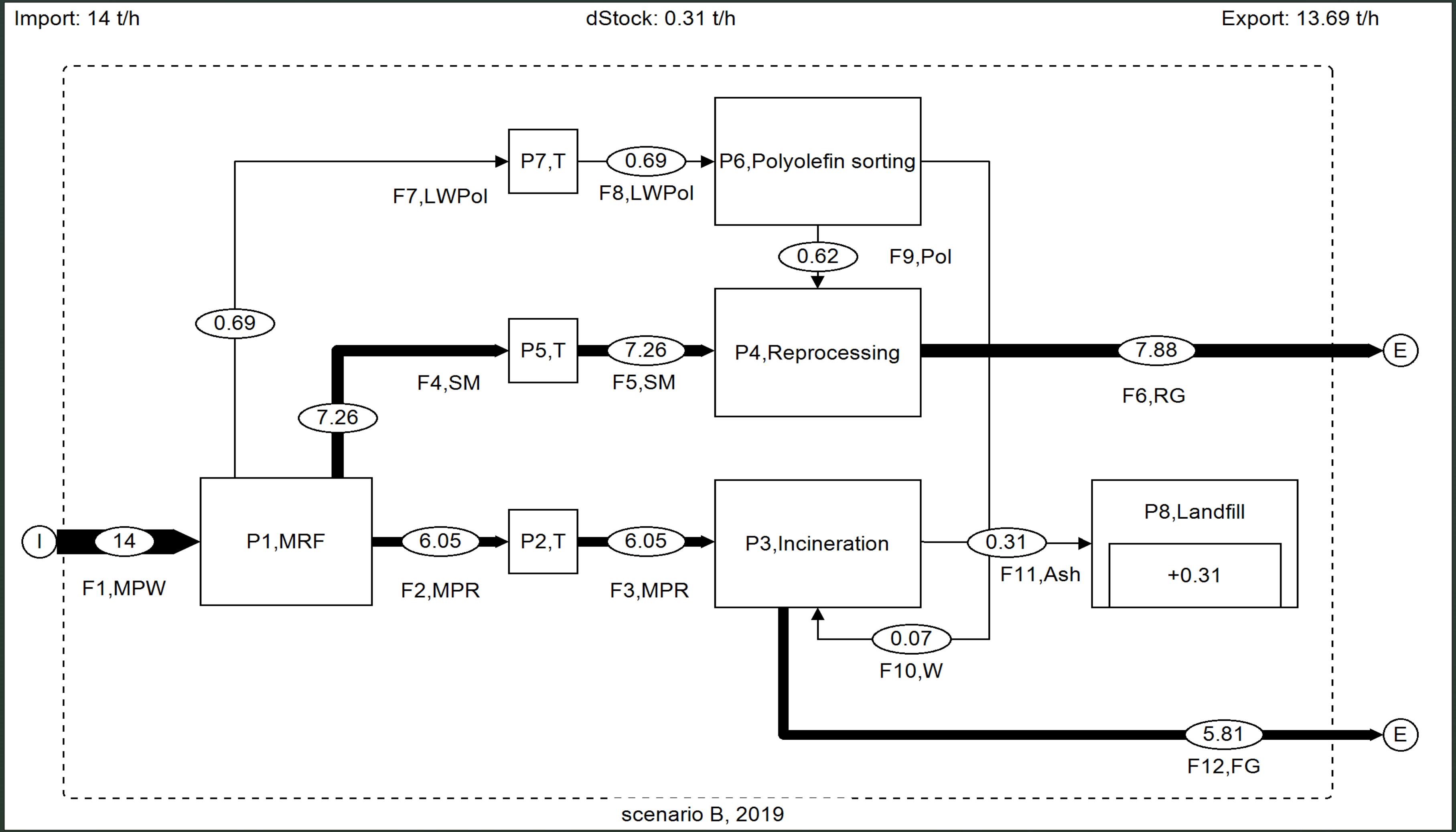
Base Case A: MFA



Base Case B: MFA



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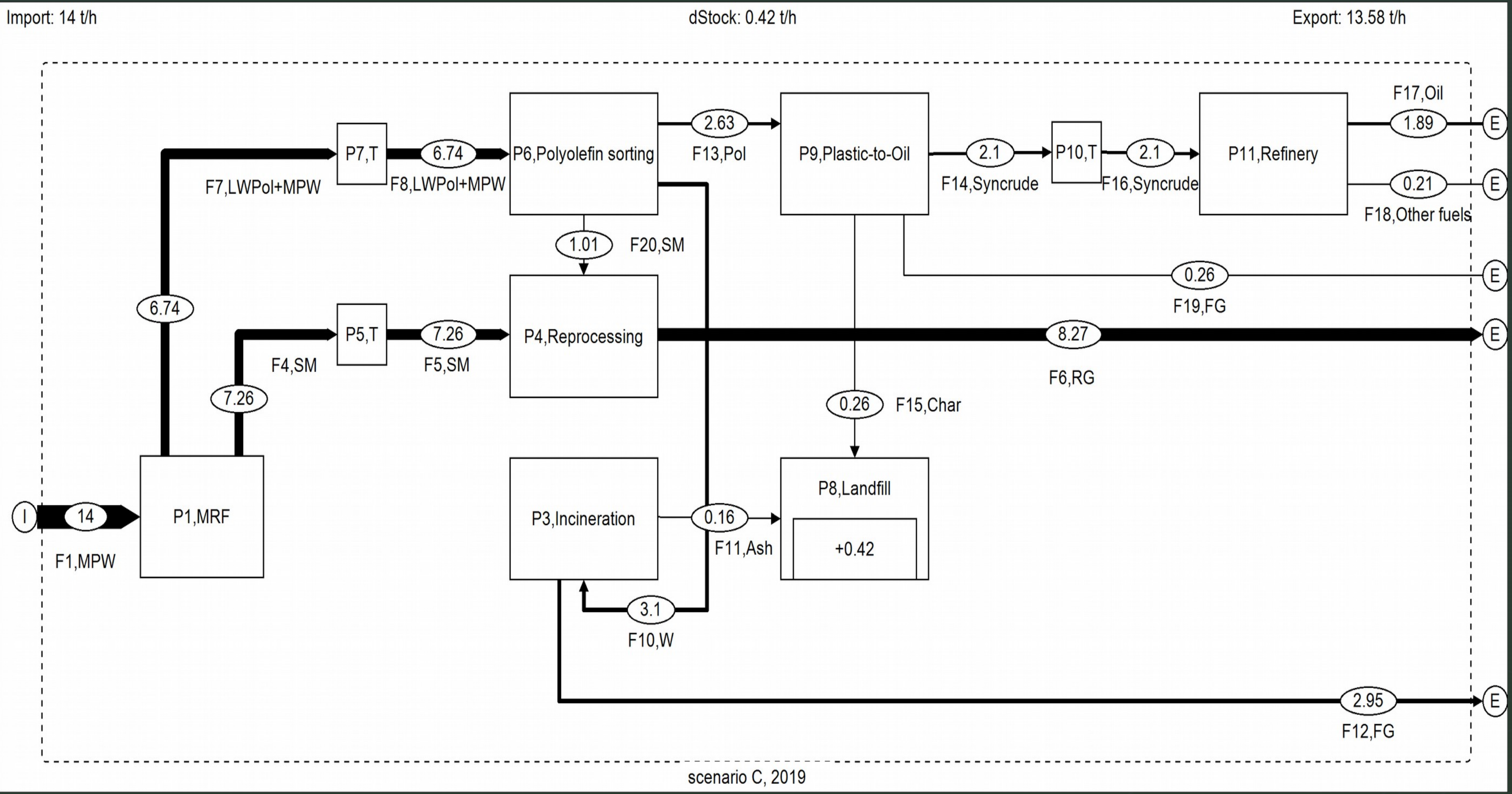
Base Case C: MFA



Results and discussion

- The mentioned indexes have been then evaluated for the three scenarios and reported in the table.
- Their values demonstrate that the highest material recycling yield is obtained for scenario C while the minimum landfill demand is obtained for scenario B.

Scenario	Material recycling yield ($Y_{M,MR}$, t/t)	Energy recovery yield ($_{M,ER}$, t/t)	Landfill yield ($Y_{M,L}$, t/t)
A	0.563	0	0.437
B	0.563	0.415	0.022
C	0.741	0.229	0.030

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Results and discussion: mass and feedstock energy balance

SCENARIO A	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10				
From	Ext	P1	P2	P1	P5	P4	P1	P7	P6	P6	P2 + P6			
To	P1	P2	P8	P5	P4	Ext	P7	P6	P4	P8	P8			
Mass flow rate, t/h	14	6,05	6,05	7,26	7,28	7,88	0,67	0,67	0,6	0,07	6,12			
High Heating Value, MJ/t	28,76	37,20	37,20	20,71	20,71	22,19	40,05	40,05	40,05	40,05	37,24			
Feedstock energy, MJ/h	402,6	225,1	225,1	150,4	150,8	174,8	26,8	26,8	24,0	2,8	227,9			
SCENARIO B	F1	F2	F3	F4	F7	F8	F9	F10	F5	F6	F11	F12		
From	Ext	P1	P2	P1	P1	P7	P6	P6	P5	P4	P3	P3		
To	P1	P2	P3	P5	P6	P6	P4	P3	P4	Ext	P8	Ext		
Mass flow rate, t/h	14	6,05	6,05	7,26	0,67	0,67	0,62	0,07	7,28	7,88	0,31	5,81		
High Heating Value, MJ/t	28,76	37,20	37,20	20,71	40,05	40,05	40,05	40,05	20,71	22,19	0	0		
Feedstock energy, MJ/h	402,6	225,1	225,1	150,4	26,8	26,8	24,8	2,8	150,8	174,9	0,0	0,0		
SCENARIO C	F1	F4	F7	F8	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19
From	Ext	P1	P1	P7	P6	P3	P3	P6	P9	P9	P10	P11	P11	FG
To	P1	P5	P7	P6	P8	P8	Ext	P9	P10	P8	P11	Ext	Ext	Flue gas
Mass flow rate, t/h	14	7,26	6,74	6,74	3,1	0,16	2,95	2,63	2,1	0,26	2,1	1,89	0,21	P9
High Heating Value, MJ/t	28,76	22,97	35,00	35,00	34,64	0	0	35	42,06	20	45,4	45,4	12,03	Ext
Feedstock energy, MJ/h	402,6	166,8	235,9	235,9	107,4	0,0	0,0	92,1	88,3	5,2	95,3	85,8	2,5	0,26

Conclusions

- The values of the feedstock energy indexes confirm that the Scenario C strongly improves the performance of the waste management system by **maximizing the recovery of high-value materials**, both secondary materials and secondary feedstocks, **minimizing the energy recovery** and **allowing to send to landfill only mineralised waste**.

Scenario	Material recycling yield ($Y_{E,MR}$, t/t)	Energy recovery yield ($Y_{E,ER}$, t/t)	Landfill yield ($Y_{E,L}$, t/t)
A	0.434	0.000	0.566
B	0.434	0.566	0.000
C	0.691	0.296	0.013