Supplementary Table 1. Chemical analyses performed during the fermentation process at BM

Traditional system			Automated system		
Sugars (g/L)	Ethanol %	Days of fermentation	Sugars (g/L)	Ethanol %	Days of fermentation
		1			1
		2			2
155.10	0.20	3	154.28	0.28	3
148.26	0.35	4	150.65	0.51	4
145.81	0.40	5	138.15	0.87	5
138.72	0.83	6	115.08	2.28	6
120.58	1.96	7	78.01	4.55	7
72.94	5.55	8	19.42	9.01	8
53.95	6.69	9	3.41	9.87	9
36.88	7.77	10	1.88	10.03	10
19.81	8.85	11	0.34	10.18	11
11.07	9.41	12			
2.32	9.96	13			
1.51	10.01	14			
0.70	10.05	15			

Supplementary Table 2. Input and output data: oenological products and water at BM

INPUT	**Units**	**Traditional system**	**Automated system**
Glera must	10^2 L	540	540
SO2	kg	1.08	1.08
Yeast ICV Okay	kg	5.4	5.4
Goferm	kg	5.2	5.2
Dhizote f	kg	11	5
Springarom	kg	15	5
Alea cell	kg	6	6
O2	kg	0.324	0.478
Water	L	14960	14825
Viniliquid	kg	0	25.27
DAP liquid	kg	0	12.78
OUTPUT	**Units**	**Traditional system**	**Automated system**
Cloudy base wine	10^2 L	520	520
Lees	10^2 L	16.2	16.2
CO2	kg	4092	4092

Supplementary Table 3. Input and output data: oenological products and water at FP

INPUT	Units	**Traditional system**
Sangiovese must	10^2 L	1350
SO2	kg	3.375
Yeast red fruit	kg	10
Yeast BE fruit	kg	10
Energy glu 3.0	kg	5.1
Superstart	kg	0
Nutristart	kg	10.1
Enoact DAP	kg	12.7
Stab micro M	kg	3.4
Grape seed tannin	kg	30.1
Tanferm color	kg	7.6
Vitamon CE	kg	15.2
DESO2	kg	0
B special	kg	10.1
Fermaid E	kg	25.3
Viniliquid	kg	0
DAP liquid	kg	0
O2	kg	Reassembly
Water	L	18200
Removil liquid	L	40
OUTPUT	Units	**Traditional system**
Red wine	10^2 L	1310
Lees	10^2 L	40.5
CO2	kg	8910
INPUT	Units	**Automated system**
Sangiovese must	10^2 L	1350
SO2	kg	6.8
Yeast red fruit	kg	20
Yeast BE fruit	kg	0
Energy glu 3.0	kg	5.05
Superstart	kg	5.05
Nutristart	kg	0
Enoact DAP	kg	12.7
Stab micro M	kg	0
Grape seed tannin	kg	0
Tanferm color	kg	0
Vitamon CE	kg	0
DESO2	kg	20.1
B special	kg	0
Fermaid E	kg	0

Viniliquid	kg	74.176
DAP liquid	kg	30.801
O2	kg	4.68
Water	L	17450
Removil liquid	L	40
OUTPUT	Units	**Automated system**
Red wine	10^2 L	1310
Lees	10^2 L	40.5
CO2	kg	8910

INPUT	Units	**Traditional system**	**Automated system**
Sangiovese must	10^2 L	1350	1350
SO2	kg	3.375	6.8
Yeast red fruit	kg	10	20
Yeast BE fruit	kg	10	0
Energy glu 3.0	kg	5.1	5.05
Superstart	kg	0	5.05
Nutristart	kg	10.1	0
Enoact DAP	kg	12.7	12.7
Stab micro M	kg	3.4	0
Grape seed tannin	kg	30.1	0
Tanferm color	kg	7.6	0
Vitamon CE	kg	15.2	0
DESO2	kg	0	20.1
B special	kg	10.1	0
Fermaid E	kg	25.3	0
Viniliquid	kg	0	74.176
DAP liquid	kg	0	30.801
O2	kg	Reassembly	4.68
Water	L	18200	17450
Removil liquid	L	40	40
OUTPUT	Units	**Traditional system**	**Automated system**
Red wine	10^2 L	1310	1310
Lees	10^2 L	40.5	40.5
CO2	kg	8910	8910

Supplementary Table 4. Percentage compositions of oenological products

Oenological products	**Ingredients**	**Quantity (%)**
Yeast LALVIN ICV Okay	*Saccharomyces Cerevisiae*	100
Yeast red fruit	*Saccharomyces Cerevisiae*	100
Yeast BE fruit	*Saccharomyces Cerevisiae*	100
Goferm	*Saccharomyces Cerevisiae* autolysate	100
Dhizote f	Diammonium phosphate	99.5
	Thiamine hydrochloride	0.5
Springarom	*Saccharomyces Cerevisiae* inactivated	100
Alea cell	Cellulose	100
Energy glu 3.0	*Saccharomyces Cerevisiae* autolysate	99.5
	Thiamine hydrochloride	0.5
Superstart	*Saccharomyces Cerevisiae* autoliysate and inactivated	100
Nutristart	*Saccharomyces Cerevisiae* autoliysate and inactivated	59.9
	Diammonium phosphate	40
	Thiamine	0.1
Enoact DAP	Diammonium phosphate	85
	Adsorbing and anti-caking substances	14.9
	Thiamine	0.1
Stab micro M	Chitosan	n.d
	Purified yeast peel	n.d
	Ascorbic acid	n.d
	Lactic acid	n.d
Grape seed tannin	Tannin	100
Tanferm color	Tannin	100
Vitamon CE	*Saccharomyces Cerevisiae* autoliysate and inactivated	59.9
	Diammonium phosphate	40
	Thiamine	0.1
DESO2	*Saccharomyces Cerevisiae* autoliysate and inactivated	59.9
	Diammonium phosphate	40
	Thiamine	0.1
B special	*Saccharomyces Cerevisiae* autolysate	100
Fermaid E	*Saccharomyces Cerevisiae* autoliysate and inactivated	59.9
	Diammonium phosphate	40
	Thiamine	0.1
Viniliquid	*Saccharomyces Cerevisiae* partial autolysate	60
	Water	40
DAP liquid	Potassium metabisulfite and malic acid	traces

	Diammonium phosphate	50
	Water	50
Removil liquid	Sodium hydroxide	50
	Water	50

Supplementary Table 5. Oenological products costs at BM

Traditional system			
Raw material/Oenological product	Price (€/kg)	Quantity (kg)	**Cost (€)**
Glera must	1.1	67500	**74250**
SO2	0.5	1.08	**0.54**
Lievito ICV Okay	10	5.4	**54**
LALLEMAND Goferm	2.8	5.2	**14.56**
HTS ENOLOGIA Dhizote f	3.5	11	**38.50**
HTS ENOLOGIA Springarom	33	15	**495.00**
ALEA EVOLUTION Alea cell	3.2	6	**19.2**
O2	1.72	0.324	**0.56**
Water	0.00137	14960	**20.50**
Automated system			
Raw material/Oenological product	price (€/kg)	Quantity (kg)	**Cost (€)**
Glera must	1.1	67500	**74250**
SO2	0.5	1.08	**0.54**
Lievito ICV Okay	10	5.4	**54**
LALLEMAND Goferm	2.8	5.2	**14.56**
HTS ENOLOGIA Dhizote f	3.5	5	**17.50**

HTS ENOLOGIA Springarom	33	5	**165.00**
ALEA EVOLUTION Alea cell	3.2	6	**19.2**
O2	1.72	0.48	**0.82**
Water	0.00137	14825	**20.31**
HTS ENOLOGIA Viniliquid	20	25.28	**505.54**
HTS ENOLOGIA DAP liquid	1.7	12.78	**21.72**

Supplementary Table 6. Manpower and energy costs at BM

Manpower cost	Man unit cost (€/h)		Manpower time (h)		**Cost (€)**	
Traditional system	10		4.467		**44.67**	
C17	10		3.667		**36.67**	
C3	10		3.667		**36.67**	
Automated system	10		3.667		**36.67**	
ENERGY COST	CF (€/kWh)	CV (€/kWh)	Energy tot (kWh)	CF (€)	CV (€)	**CT (€)**
Traditional system	0.0141	0.13	338.84	5.03	44.05	**49.08**
C17	0.0141	0.13	356.34	5.03	46.32	**51.35**
C3	0.0141	0.13	356.59	5.03	46.36	**51.38**
Automated system	0.0141	0.13	356.46	5.03	46.34	**51.37**

Supplementary Table 7. Oenological products cost at FP

Traditional system			
Raw material/Oenological product	Price (€/kg)	Quantity (kg)	**Cost (€)**
Sangiovese must	1.17	192857.1	**225642.86**

SO2	0.5	3.4	**1.69**
Yeast BE fruit	20	10	**200**
Yeast red fruit	20	10	**200**
FERMOPLUS Energy glu 3.0	10	5.1	**51**
LAFFORT Nutristart	10	10.1	**101**
ENARTIS Stab micro M	100	3.35	**335**
Grape seed tannin CAVIRO	7.5	30.05	**225.38**
ENARTIS Tanferm color	15	7.55	**113.25**
Vitamon CE	10	15.15	**151.50**
OENOFRANCE Enoact DAP	3.2	12.65	**40.48**
B special	20	10.1	**202**
LALLEMAND Fermaid E	10	25.25	**252.50**
O2	0	Reassembly	**0**
Water	0.00137	18200	**24.93**
Removil liquid (l)	1.6	40	**64**
Automated system			
Raw material/Oenological product	Price (€/kg)	Quantity (kg)	**Cost (€)**
Sangiovese must	1.17	192857.1	**225642.857**
SO2	0.5	6.8	**3.38**
Yeast red fruit	20	20.0	**400**
FERMOPLUS Energy glu 3.0	10	5.05	**50.5**
LAFFORT Superstart	20	5.05	**101**
OENOFRANCE Enoact DAP	3.2	12.65	**40.48**
NUTROZIM DESO2	10	20.10	**201**

HTS ENOLOGIA Viniliquid	20	74.18	**1483.52**
HTS ENOLOGIA DAP liquid	1.7	30.80	**52.36**
O2	1.72	4.67	**8.03**
Water	0.00137	17450	**23.91**
Removil liquid	1.6	40	**64**

Supplementary Table 8. Manpower and energy cost at FP

MANPOWER COST	Man unit cost (€/h)		Manpower time (h)		**Cost (€)**	
151	10		7.983		**79.83**	
158	10		8.017		**80.17**	
161b	10		5.033		**50.33**	
161a	10		6.917		**69.17**	
Traditional system	10		8.017		**80.17**	
Automated system	10		5.992		**59.92**	
ENERGY COST	CF (€/kWh)	CV (€/kWh)	Energy Tot (kWh)	CF (€)	CV (€)	**CT (€)**
151	0.0141	0.13	27798.65	392.10	3613.82	**4005.92**
158	0.0141	0.13	27808.41	392.10	3615.09	**4007.19**
161b	0.0141	0.13	25259.58	392.10	3283.75	**3675.84**
161a	0.0141	0.13	25275.37	392.10	3285.80	**3677.90**
Traditional system	0.0141	0.13	27803.53	392.10	3614.46	**4006.56**
Automated system	0.0141	0.13	25267.47	392.10	3284.77	**3676.87**

Supplementary Table 9. Numerical comparison of the environmental impact: traditional vs automated system at BM

Traditional vs automated system					
Impact category	Units	Traditional system	Automated system	R (%)	**Advantage (%)**
Acidification (fate not incl.)	kg SO2 eq	2.636	2.601	98.65	**1.35**
Eutrophication	kg PO4--- eq	0.591	0.581	98.40	**1.60**

Global warming (GWP100a)	kg CO2 eq	4392.89	4384.53	99.81	**0.19**
Photochemical oxidation	kg NMVOC	0.926	0.907	97.95	**2.05**
Abiotic depletion, elements	kg Sb eq	0.00127	0.00126	98.74	**1.26**
Abiotic depletion, fossil fuels	MJ	3261.12	3153.98	96.71	**3.29**
Water scarcity	m3 eq	442.03	437.12	98.89	**1.11**
Ozone layer depletion (ODP)	kg CFC-11 eq	3.4686E-05	3.360E-05	96.86	**3.14**

Supplementary Table 10. Numerical comparison of the environmental impact regarding nutrients addition at BM

Traditional vs automated system (nutrients addition)					
Impact category	Units	Traditional system	Automated	R(%)	**Advantage (%)**
Acidification (fate not incl.)	kg SO_2 eq	0.114	0.077	67.56	**32.44**
Eutrophication	kg PO_4 eq	0.034	0.023	67.02	**32.98**
Photochemical oxidation	kg NMVOC	0.031	0.022	71.10	**28.90**
Abiotic depletion, elements	kg Sb eq	8.0343E-05	5.25E-05	65.33	**34.67**
Abiotic depletion, fossil fuels	MJ	250.998	172.998	68.92	**31.08**
Water scarcity	m^3 eq	27.382	16.389	59.86	**40.14**
Ozone layer depletion (ODP)	kg CFC-11 eq	1.82658E-06	1.3E-06	70.92	**29.08**

Supplementary Table 11. Numerical comparison of the environmental impact: Traditional vs automated system at FP

Impact category	Units	Traditional	Automated	R (%)	**Advantage (%)**
Acidification (fate not incl.)	kg SO_2 eq	52.251	48.573	92.96	7.04
Eutrophication	kg PO_4 eq	13.885	12.643	91.06	8.94
Global warming (GWP100a)	kg CO_2 eq	21089.49	19987.32	94.77	5.23
Photochemical oxidation	kg NMVOC	27.739	25.326	91.30	8.70
Abiotic depletion, elements	kg Sb eq	0.0250	0.0234	93.58	6.42
Abiotic depletion, fossil fuels	MJ	156292.45	142270.280	91.03	8.97
Water scarcity	m^3 eq	7598.78	6925.000	91.13	8.87
Ozone layer depletion (ODP)	kg CFC-11 eq	1.583E-03	1.439E-03	90.93	9.07

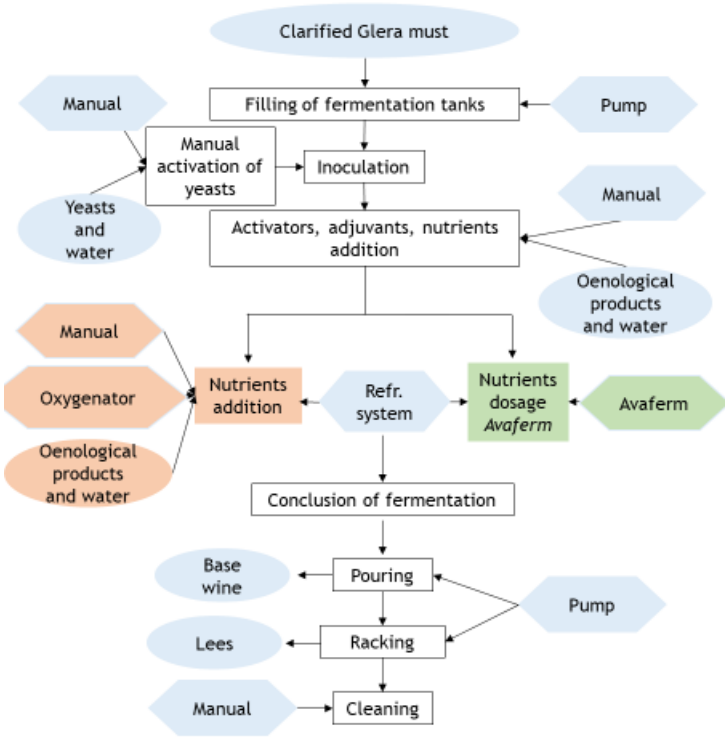
Supplementary Table 12. Variable cost analysis at BM

Traditional system	**Cost (€)**	**Automated system**	**Cost (€)**
Manpower	44.67	Manpower	36.67
Oenological products and preliminary nutrients	270.26	Oenological products and preliminary nutrients	270.26
Nutrients in differentiation	351.00	Nutrients in differentiation	527.26
Oxygen	0.56	Oxygen	0.82
Water	20.50	Water	20.31
Energy	49.08	Energy	51.37
Total	736.06	Total	906.69

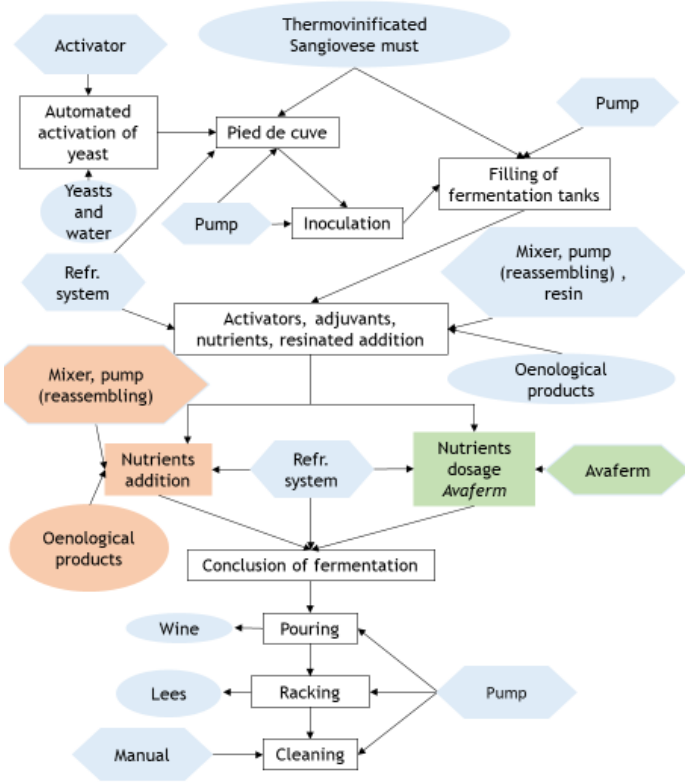
Supplementary Table 13. Variable cost analysis at FP

Traditional system	**Cost (€)**	**Automated system**	**Cost (€)**
Manpower	80.17	Manpower	59.92
Oenological products and preliminary nutrients	1619.61	Oenological products and preliminary nutrients	792.98
Nutrients in differentiation	252.50	Nutrients in differentiation	1535.88
Oxygen	0	Oxygen	8.03
Water	24.934	Water	23.91
Energy	4006.56	Energy	3676.87
Total	5983.76	Total	6097.58

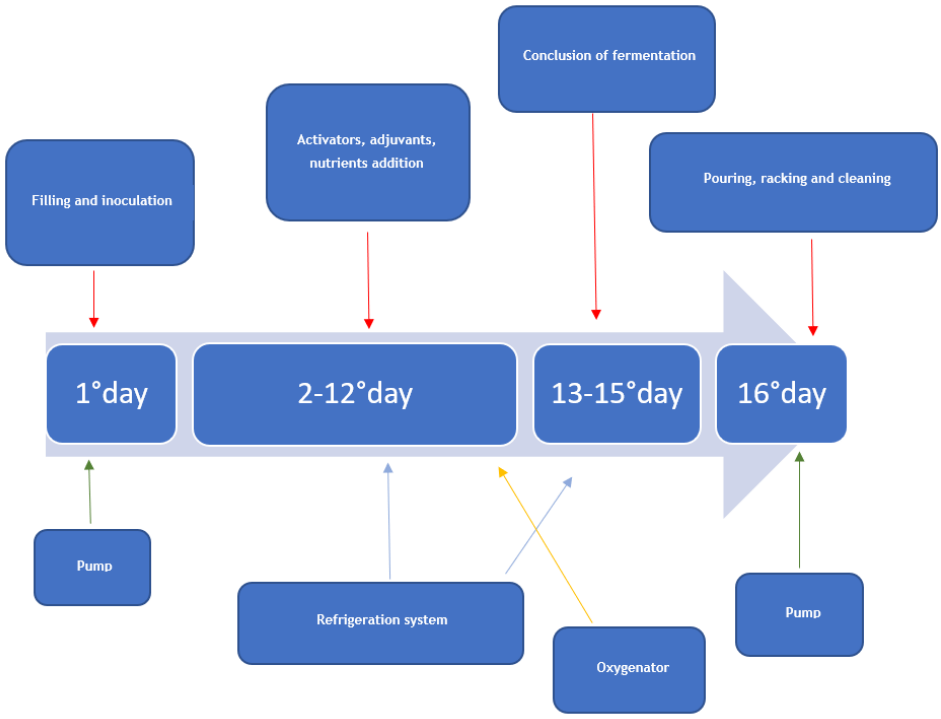
Supplementary Figures



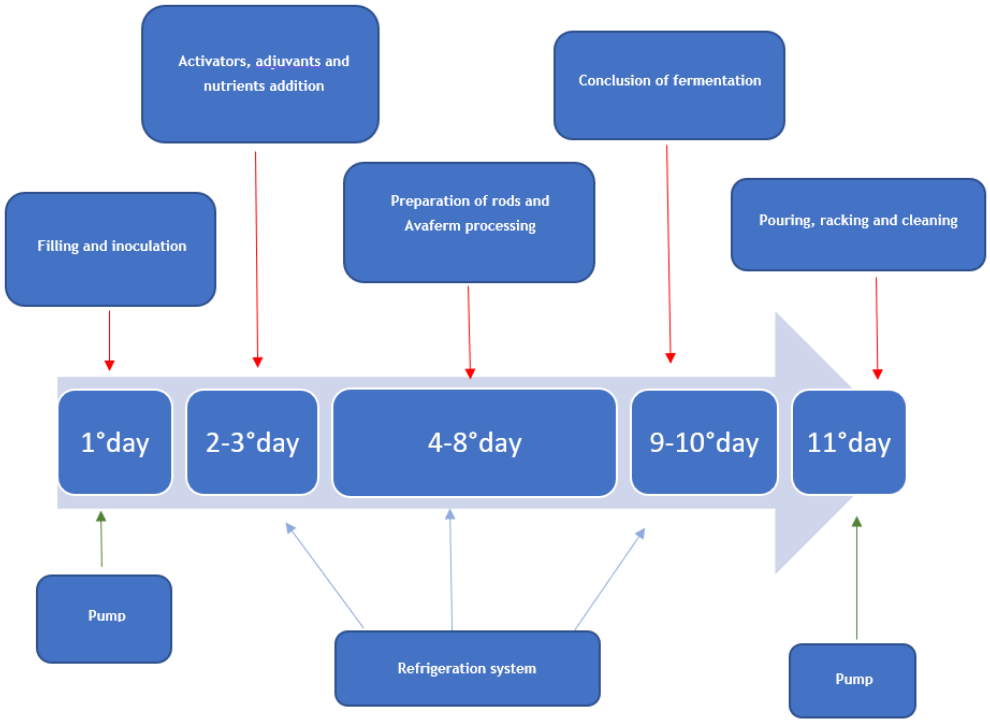
Supplementary Figure 1. Production process flowsheet at BM



Supplementary Figure 2. Production process flowsheet at FP

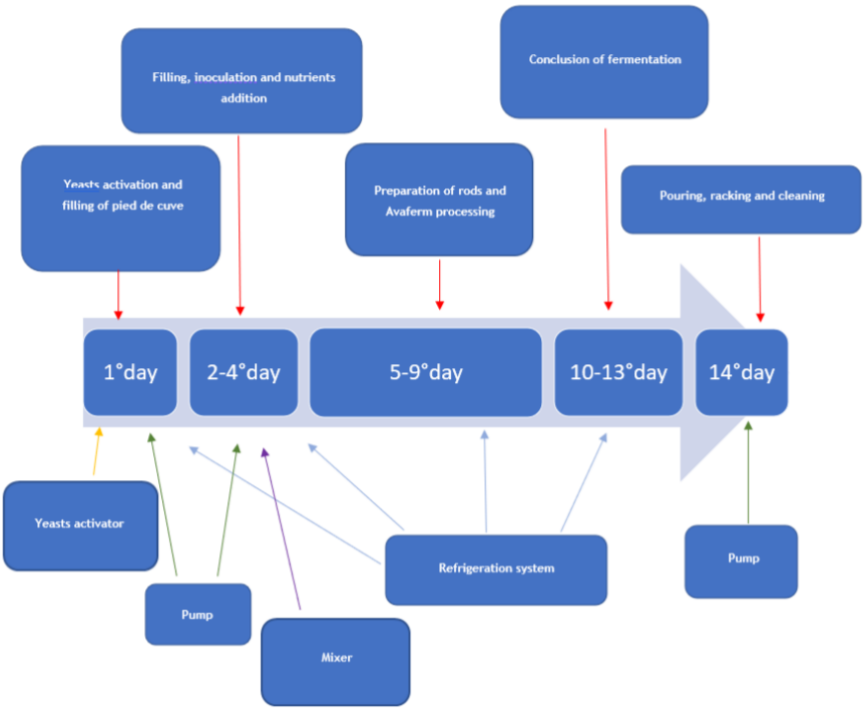


Supplementary Figure 3. Timeline for traditional system at BM

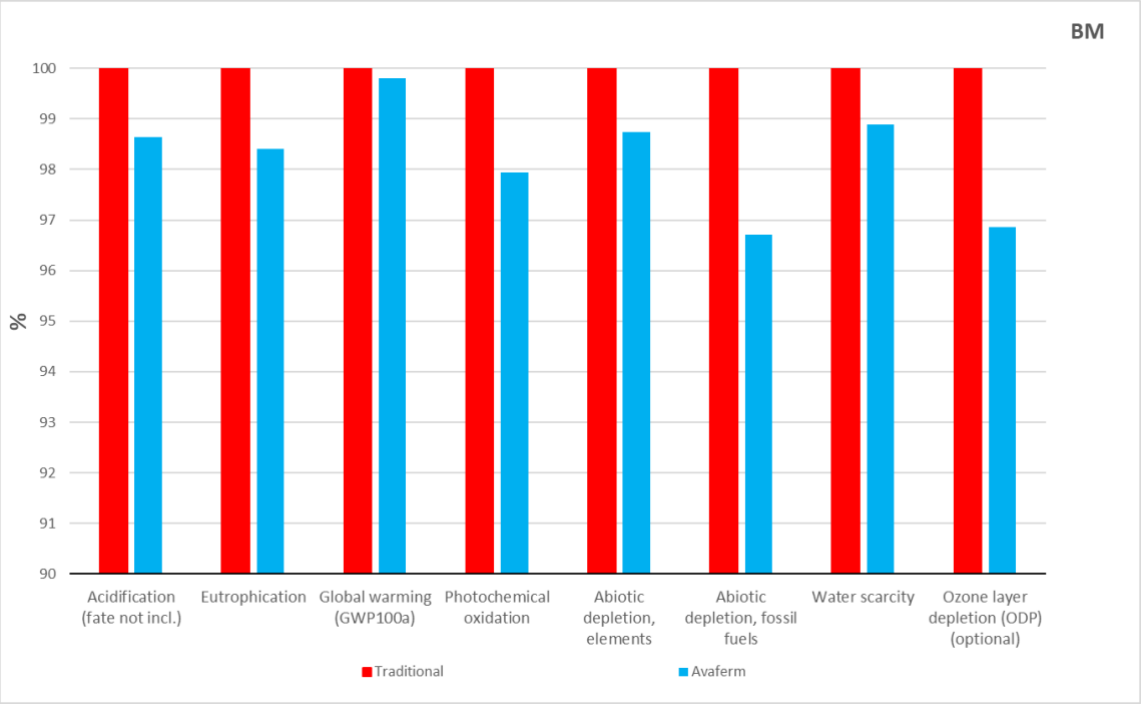


Supplementary Figure 4. Average timeline for automated system at BM

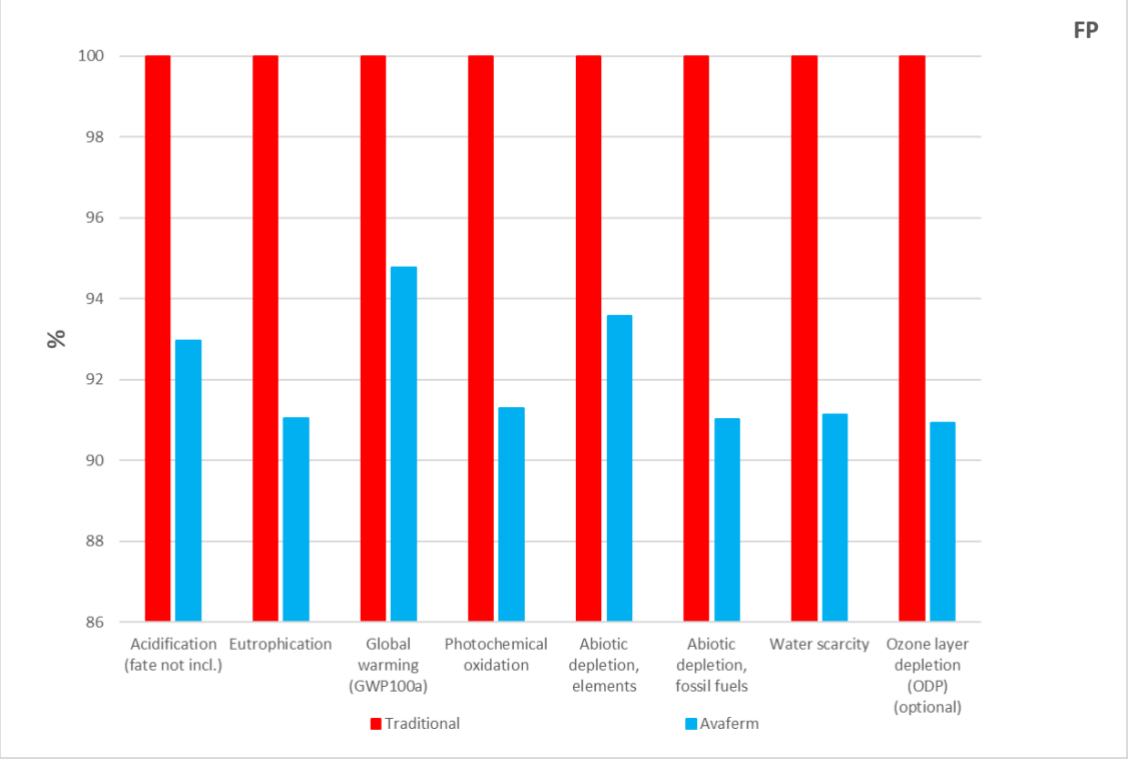
Supplementary Figure 5. Average timeline for traditional system at FP



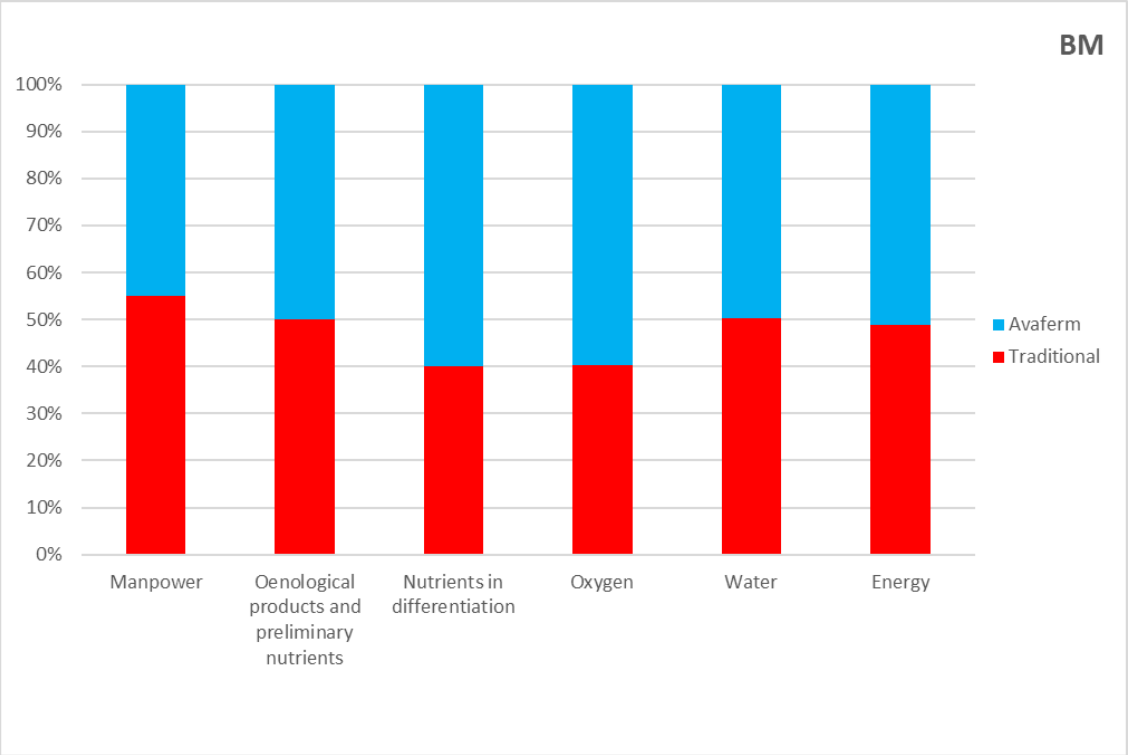
Supplementary Figure 6. Average timeline for automated system at FP



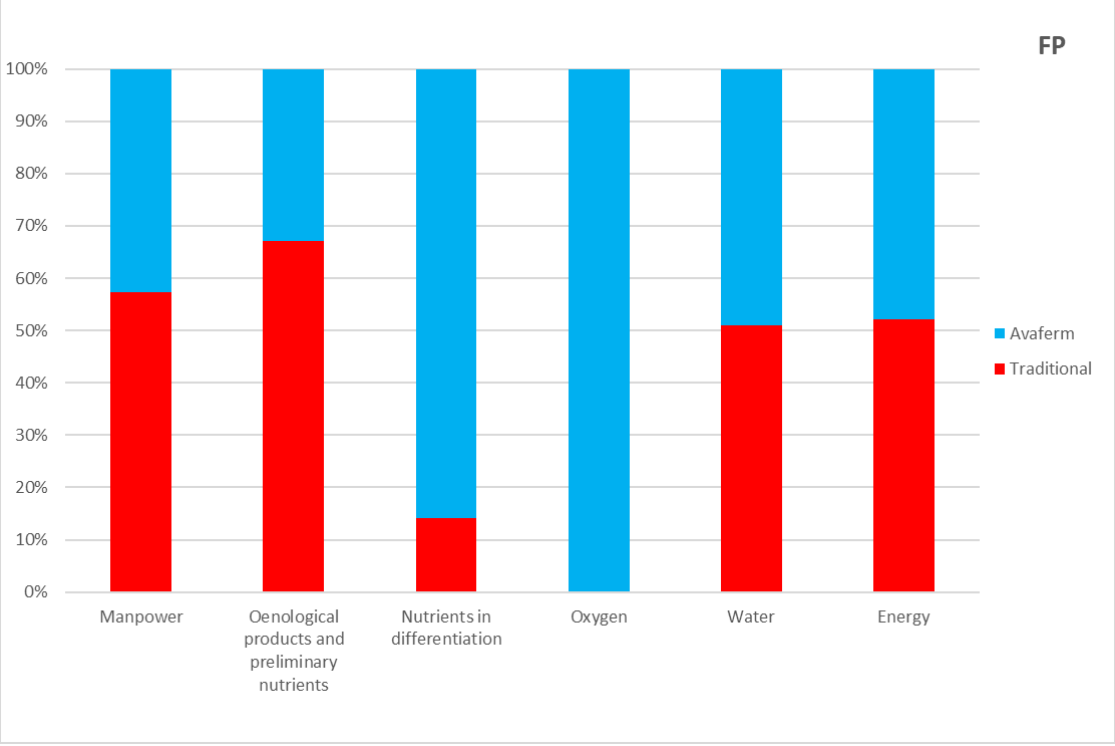
Supplementary Figure 7. Comparison of the environmental impact: traditional (red) vs automated (blue) systems at BM



Supplementary Figure 8. Comparison of the environmental impact: traditional (red) vs automated (blue) systems at FP



Supplementary Figure 9. Comparison in percentage for the single variable cost items at BM



Supplementary Figure 10. Comparison in percentage for the single variable cost items at FP