

**TECHNOLOGY & COSTS****Technoeconomics - Energy & Chemicals (TECH)****TECH 2021S11 Material Recovery Facilities**

## Table of Contents

A Report by **NexantECA, the Energy and Chemical Advisory company**

Published Date: September 2021

[www.nexanteca.com/subscriptions-and-reports](http://www.nexanteca.com/subscriptions-and-reports)**Contents**

1	Executive Summary .....	1
1.1	Introduction.....	1
1.2	MSW Feedstock .....	2
1.2.1	United States .....	3
1.2.2	Western Europe .....	3
1.2.3	Asia Pacific.....	4
1.3	Commercial Technology.....	4
1.4	Economics .....	7
2	Introduction.....	12
2.1	The Issue with Plastic Waste .....	12
2.2	Plastic Waste Disposal Methods .....	14
2.3	Obstacles to Plastic Recycling .....	15
2.3.1	Plastic Waste Overview.....	15
2.3.2	Obstacles to Waste Plastic Recycling .....	18
2.4	Material Recovery Facilities (MRFs) .....	20
3	MSW Feedstock .....	23
3.1	United States .....	26
3.2	Western Europe .....	32
3.3	Asia Pacific.....	38
4	Commercial Technology.....	41
4.1	Introduction.....	41
4.2	Infeed Equipment .....	42
4.2.1	Feeders .....	42
4.2.2	Bag Splitters .....	44
4.3	Pre-Sorting .....	44
4.4	Sorting .....	45
4.4.1	Manual Sorting .....	45
4.4.2	Screens .....	46
4.4.3	Ballistic Separators.....	49
4.4.4	Air Separation.....	50
4.4.5	Electromagnetic Separation .....	52

4.4.6	Eddy Currents .....	54
4.4.7	Optical Sorting .....	55
4.4.8	Post Sorting Technologies .....	73
4.5	Developing Recycling and Sorting Technologies .....	76
4.5.1	Multilayer Packaging Recycling .....	76
4.5.2	Watermark Tagging() .....	81
4.5.3	Single-Use Paper Cups Recycling .....	82
4.6	Comparison of Technologies .....	83
4.7	Key Equipment Providers .....	85
4.7.1	Bulk Handling Systems .....	85
4.7.2	CP Group .....	89
4.7.3	Machinex .....	91
4.7.4	Van Dyk Recycling Solutions .....	93
4.7.5	Bollegraaf Group .....	94
4.7.6	TOMRA .....	95
4.7.7	Walair .....	97
4.7.8	STADLER® Anlagenbau GmbH .....	98
4.7.9	OKAY Engineering .....	99
4.7.10	Witham Mills Engineering .....	101
4.7.11	AMP Robotics .....	101
5	Commercial Overview .....	102
5.1	United States .....	102
5.1.1	Material Recovery Facilities (MRFs) .....	102
5.2	Western Europe .....	107
5.2.1	Material Recovery Facilities (MRFs) .....	107
5.3	Asia Pacific .....	115
5.3.1	Material Recovery Facilities (MRFs) .....	115
6	Economics .....	118
6.1	Costing Basis .....	119
6.1.1	Investment Basis .....	119
6.1.2	Pricing Basis .....	119
6.1.3	Cost of Production Basis .....	122
6.2	Cost of Production Estimates .....	123
6.2.1	Large Scale MRF: Cost of Processing Commingled Recyclables .....	126
6.2.2	Small Scale MRF: Cost of Processing Commingled Waste .....	137
6.3	Evaluation .....	148
6.4	Impacts on Economic Analysis .....	152

## Appendices

A	Definitions of Capital Cost Terms Used in Process Economics .....	156
B	Definitions of Operating Cost Terms Used in Process Economics .....	161
C	TECH Program Title Index (2011-2021) .....	164
D	References .....	167

## Figures

Figure 1	MRF USGC Cost of Production .....	8
Figure 2	MRF Western Europe Cost of Production .....	9
Figure 3	USGC Cost of Production and Product Pricing Comparison .....	10
Figure 4	Western Europe Cost of Production and Product Pricing Comparison .....	11
Figure 5	Major Rivers Contributing to Ocean Plastic Pollution .....	12
Figure 6	Typical Time Required for Waste to Decompose .....	13
Figure 7	Resin Identification Codes .....	17
Figure 8	Block Diagram of a Typical MRF .....	22
Figure 9	Global MSW Generation in Million Tons Per Year .....	23
Figure 10	Global MSW Composition 2016 .....	24
Figure 11	Global MSW Treatment and Disposal 2016 .....	25
Figure 12	U.S. Municipal Solid Waste Generated by Material Type, 2018 .....	26
Figure 13	MSW Generation Over Time .....	27
Figure 14	MSW Stream 2020, by Type .....	27
Figure 15	EU MSW Generation .....	32
Figure 16	Western Europe MSW Composition .....	33
Figure 17	MRF Plastic Input, by Plastic Type .....	34
Figure 18	UK Collected Household Waste Sent for Recycling .....	35
Figure 19	Asia Pacific MSW Generation by Country and Material, 2016 .....	38
Figure 20	Typical MRF Configuration .....	41
Figure 21	Drum Feeders .....	43
Figure 22	Bag Splitter .....	44
Figure 23	Trommel Screens .....	46
Figure 24	Screen Types .....	47
Figure 25	Disc Screen Example .....	48
Figure 26	Ballistic Separator .....	49
Figure 27	Air Classifier .....	50
Figure 28	Air Knives .....	51
Figure 29	Windshifters .....	52
Figure 30	Overhead Electromagnetic Separation .....	53
Figure 31	Electromagnetic Belt Separators .....	53
Figure 32	Eddy Current Separation Technique .....	54
Figure 33	Optical Sorting Technologies Wavelengths .....	56
Figure 34	Optoelectronic Sorting System .....	58
Figure 35	Structure of a Sorting System .....	59
Figure 36	NIR Spectroscopy Splitter Plate Position .....	60
Figure 37	Complete NIR Sorting Module .....	61
Figure 38	X-Ray Fluorescent Tracer Detection System .....	62
Figure 39	X-Ray Sorter .....	63
Figure 40	Laser Aided Material Identification .....	64
Figure 41	Laser Sorter .....	65

Figure 42	Color Sorting Machine, Satake .....	66
Figure 43	Components of a Typical Color Sorting Machine .....	67
Figure 44	Black Plastics Sorting Machine .....	67
Figure 45	AMP Neuron Technology Identification Example .....	69
Figure 46	AMP Cortex Sorting Process .....	70
Figure 47	Bollegraaf RoBB-AQC System .....	71
Figure 48	PRISM Technology Flourescent Markers .....	72
Figure 49	Balers .....	74
Figure 50	Open-End Extruder Single Ram Baler .....	75
Figure 51	Two-Ram Baler .....	75
Figure 52	Newcycling® ProcessBlock Flow Diagram .....	78
Figure 53	Process Flow Diagram Saperatec Process .....	80
Figure 54	U.S. MRF Ownership, 2020 .....	102
Figure 55	Paprec Group MRFs .....	113
Figure 56	Feedstock Composition, USGC .....	123
Figure 57	Feedstock Composition, Western Europe .....	124
Figure 58	Large-Scale MRF Process Flow Diagram .....	127
Figure 59	Small Scale MRF Equipment Flow Diagram .....	137
Figure 60	MRF USGC Cost of Production .....	149
Figure 61	MRF Western Europe Cost of Production .....	150
Figure 62	USGC Cost of Production and Product Pricing Comparison .....	151
Figure 63	Western Europe Cost of Production and Product Pricing Comparison .....	151
Figure 64	U.S. MRF Capacity and Utilisation .....	153

## Tables

Table 1	MRF Technology Summary .....	5
Table 2	Key MRF Equipment Providers .....	7
Table 3	Example Single-Stream Waste Composition .....	28
Table 4	Single-Stream Recycling Items .....	30
Table 5	Single-Stream Contamination Levels 2019 .....	31
Table 6	MRF Feedstocks.....	34
Table 7	Typical Recycling Materials .....	36
Table 8	MRF Typical Contamination Levels.....	37
Table 9	Composition of MSW in China, 2016.....	39
Table 10	Baler Types Summary .....	76
Table 11	MRF Technology Summary .....	83
Table 12	Key MRF Equipment Providers .....	85
Table 13	BHS Equipment .....	86
Table 14	Nihot Equipment .....	87
Table 15	NRT Machines .....	88
Table 16	CP Group Equipment .....	90
Table 17	Machinex Equipment .....	92
Table 18	Van Dyk Equipment.....	94
Table 19	Bollegraaf Recycling Solutions Equipment.....	95
Table 20	TOMRA Optical Sorting Equipment.....	97
Table 21	Walair Air Separation Equipment .....	98
Table 22	STADLER Equipment.....	99
Table 23	OKAY Engineering Equipment .....	100
Table 24	Prices of Raw Materials, Products, Utilities, and Labor.....	121
Table 25	Comingled Recyclables Composition .....	125
Table 26	Cost for Production Estimate for: 150 000 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to ERF; USGC Basis .....	129
Table 27	Cost for Production Estimate for: 300 000 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to ERF; USGC Basis .....	130
Table 28	Cost for Production Estimate for: 150 000 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to Landfill; USGC Basis .....	131
Table 29	Cost for Production Estimate for: 300 000 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to Landfill; USGC Basis .....	132
Table 30	Cost for Production Estimate for: 150 000 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to ERF; Western Europe Basis .....	133
Table 31	Cost for Production Estimate for: 300 000 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to ERF; Western Europe Basis .....	134

Table 32	Cost for Production Estimate for: 150 000 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to Landfill; Western Europe Basis .....	135
Table 33	Cost for Production Estimate for: 300 000 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to Landfill; Western Europe Basis .....	136
Table 34	Cost for Production Estimate for: 31 680 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to ERF; USGC Basis .....	140
Table 35	Cost for Production Estimate for: 63 360 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to ERF; USGC Basis .....	141
Table 36	Cost for Production Estimate for: 31 680 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to Landfill; USGC Basis .....	142
Table 37	Cost for Production Estimate for: 63 360 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to Landfill; USGC Basis .....	143
Table 38	Cost for Production Estimate for: 31 680 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to ERF; Western Europe Basis .....	144
Table 39	Cost for Production Estimate for: 63 360 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to ERF; Western Europe Basis .....	145
Table 40	Cost for Production Estimate for: 31 680 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to Landfill; Western Europe Basis .....	146
Table 41	Cost for Production Estimate for: 63 360 Tons per Year Processing Capacity MRF Process: Comingled Single-Stream PET and HDPE (Colored and Natural) Recovery; Residue to Landfill; Western Europe Basis .....	147



## TECHNOLOGY & COSTS

# Technoeconomics - Energy & Chemicals (TECH)

The NexantECA Subscriptions' Technoeconomics - Energy & Chemicals (TECH) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. Technoeconomics - Energy & Chemicals (TECH) reports are available as a subscription program or on a single report basis.

### Contact Details:

#### Americas:

Marcos Nogueira Cesar, Vice President, Global Subscriptions and Reports  
Phone: + 1-914-609-0324, e-mail: [mcesar@NexantECA.com](mailto:mcesar@NexantECA.com)

Erica Hill, Client Services Coordinator, Subscriptions and Reports  
Phone: + 1-914-609-0386, e-mail: [ehill@NexantECA.com](mailto:ehill@NexantECA.com)

#### EMEA:

Anna Ibbotson, Vice President, Sales and Marketing  
Phone: +44-207-950-1528, [aibbotson@NexantECA.com](mailto:aibbotson@NexantECA.com)

#### Asia:

Chommanad Thammanayakatip, Managing Consultant  
Phone: +66-2793-4606, email: [chommanadt@NexantECA.com](mailto:chommanadt@NexantECA.com)

NexantECA Subscriptions and Reports provide clients with comprehensive analytics, forecasts and insights for the chemicals, polymers, energy and cleantech industries. Using a combination of business and technical expertise, with deep and broad understanding of markets, technologies and economics, NexantECA provides solutions that our clients have relied upon for over 50 years.

Copyright © 2000-2021 NexantECA (BVI) Limited. All rights reserved