

Supplementary Data

**Bio-oil Production via Catalytic Microwave Pyrolysis of Model Municipal
Solid Waste Component Mixtures**

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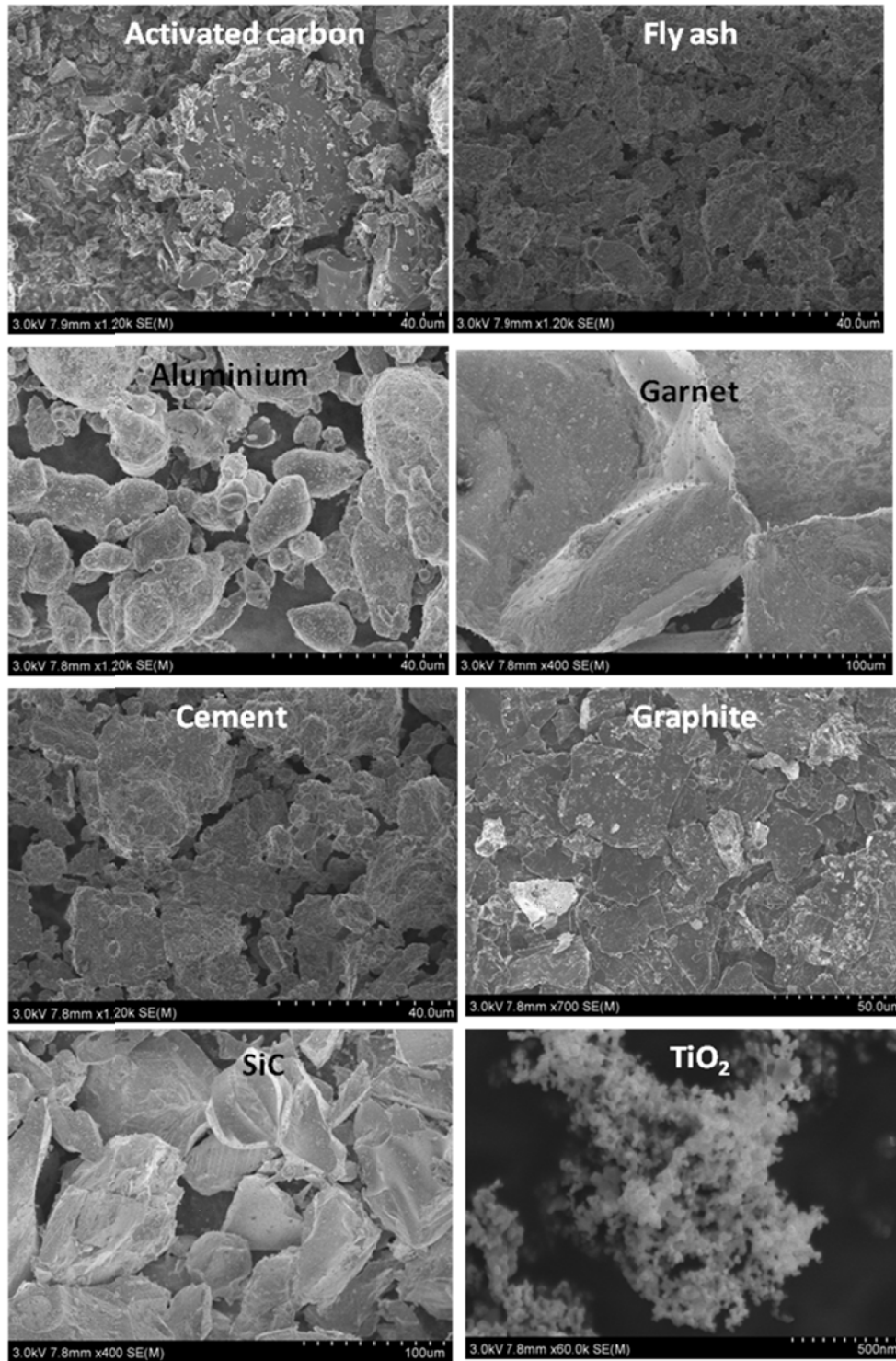


Figure S1. SEM micrographs of various susceptors.

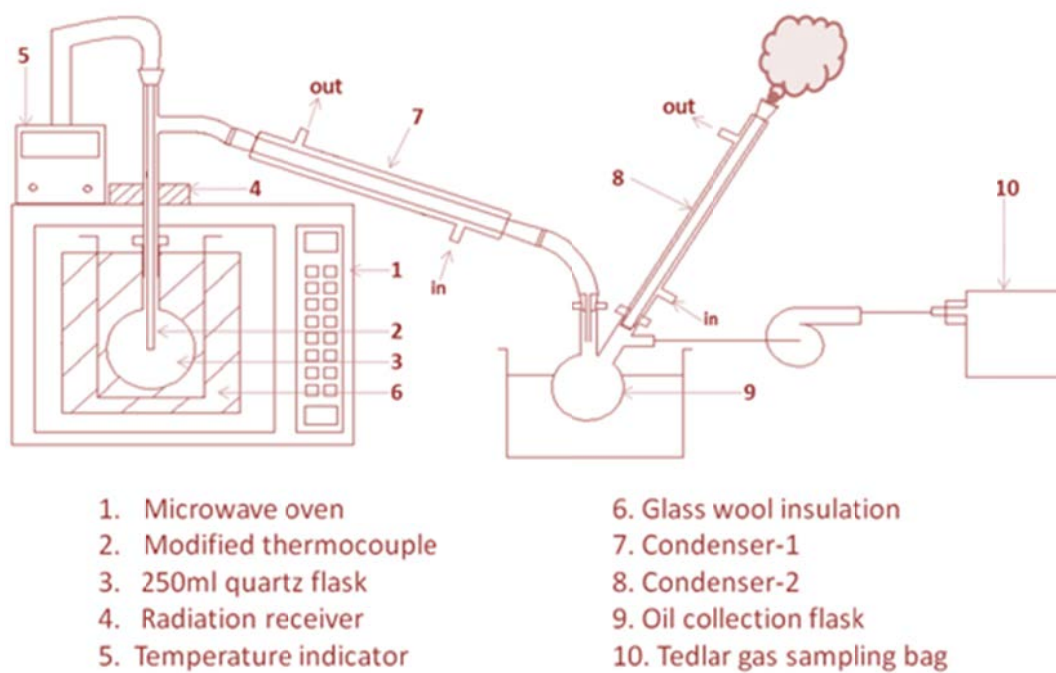


Figure S2. Schematic of the microwave pyrolysis experimental set-up.^{21,24}

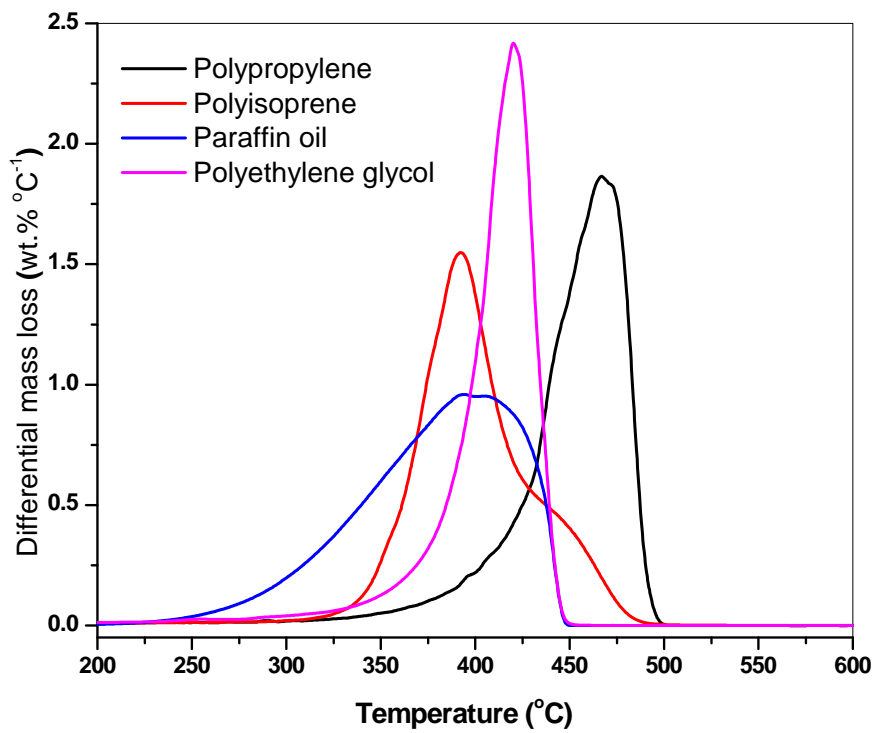


Figure S3. Differential mass loss profiles of various polymers and paraffin oil.

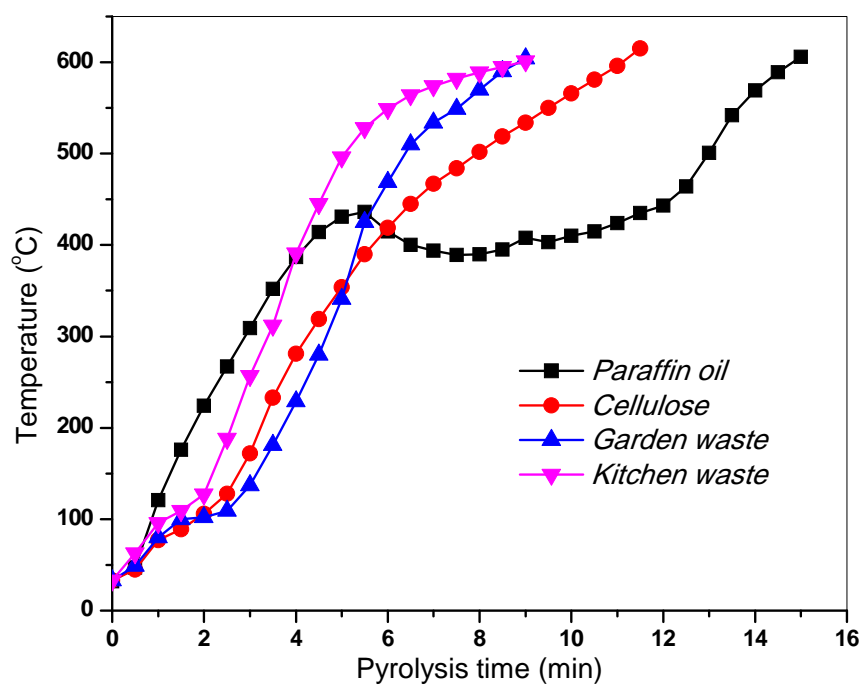


Figure S4. Temperature profiles achieved during the pyrolysis of individual MSW components at 450 W microwave power and 1:1 wt./wt. of feed:graphite.

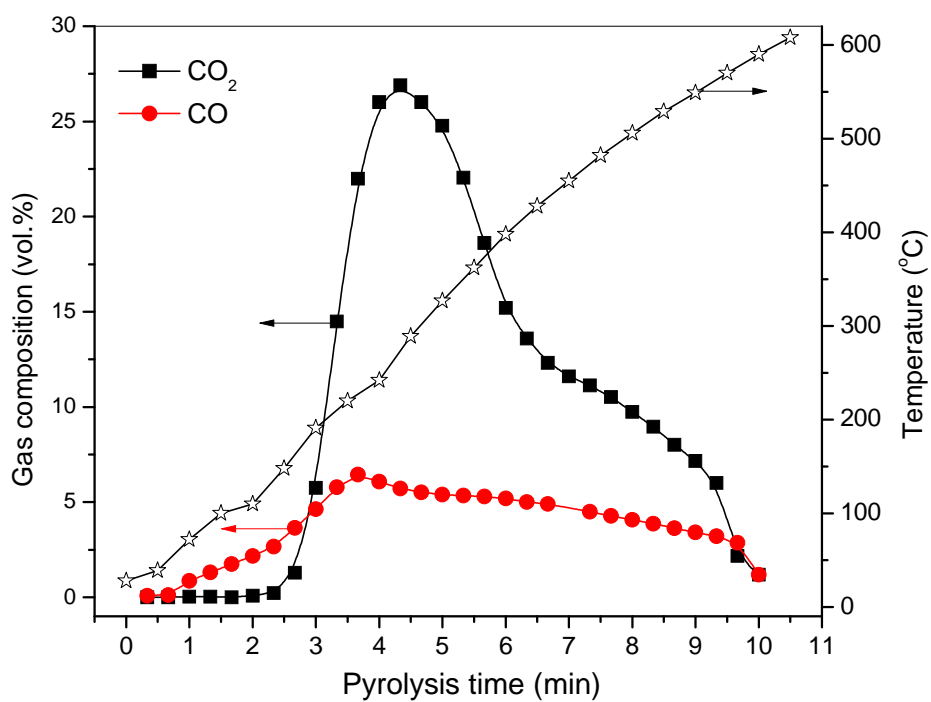


Figure S5. Online analysis of CO and CO₂ during microwave pyrolysis of 1:1 MSW-A:graphite. Compared to CO₂, CO evolution was very low owing to the composition of the model MSW mixture.

Table S1. Composition of garnet, cement, fly ash, silica beads and TiO₂.

Garnet	Composition (wt.%)
SiO ₂	43.16
Fe ₂ O ₃	32.17
MgO	9.13
Al ₂ O ₃	6.49
CaO	3.87
FeO	5.18
Cement	Composition (wt.%)
Ca ₃ Al ₂ O ₆	9.87
Ca ₄ Al ₂ Fe ₂ O ₁₀	8.34
Ca ₂ SiO ₅	19.59
Ca ₃ SiO ₄	55.38
Na ₂ O & K ₂ O	1.94
CaSO ₄ .2H ₂ O	4.88
Fly ash	Composition (wt.%)
SiO ₂	26.97
Fe ₂ O ₃	4.77
CaO	17.85
MgO	2.00
Al ₂ O ₃	10.34
Na ₂ O	1.05
K ₂ O	8.40
TiO ₂	0.70
LOI*	14.71%
Silica beads	Composition (wt.%)
SiO ₂	69-71
CaO	8-9
Na ₂ O	13
K ₂ O	5

Al ₂ O ₃	1
Aeroxide® TiO₂ P25**	Composition (wt.%)
TiO ₂	≥ 99.50
Al ₂ O ₃	≤ 0.30
SiO ₂	≤ 0.20
Fe ₂ O ₃	≤ 0.01
HCl	≤ 0.30
LOI*	≤ 2.0%

*LOI - loss on ignition

**Aeroxide® TiO₂ P 25, Evonik Industries, 2007, www.aerosil.com (accessed 20 Nov. 2014).

Table S2. Composition of bio-oil obtained by pyrolyzing paraffin oil with graphite at 1:1 (wt./wt.) on moisture free basis.

Product	Composition (area%)
Alkanes	25.32
Heptane	2.70
Pentane, 3-ethyl-2-methyl-	1.63
Octane	4.04
Octane, 3-methyl-	1.18
Nonane	3.96
Decane	4.74
1,8-Dimethyl decane	1.36
Heptane, 3,4-dimethyl-	1.99
2,9-Dimethylundecane	1.20
Decane, 2,4,6-trimethyl-	1.06
Dodecane, 2,6,10-trimethyl-	0.90
Undecane, 3,4-dimethyl-	0.54
Cycloalkanes	5.46
Cyclohexane, methyl-	0.70
Cyclopentane, pentyl-	0.73
Cyclooctane, 1,2-dimethyl-	0.95
Cyclopropane, octyl-	1.40
Cyclopentane, 1,1,3-trimethyl-	1.01
Cyclopentane, decyl-	0.68
Alkenes	35.68
1,3,5-Hexatriene	1.16
1-Heptene	5.19
1-Heptene, 2-methyl-	2.22
1-Octene	2.93
1-Octene, 7-methyl-	0.63
1-Nonene	4.71
11-Tricosene	1.03
1-Decene	4.52
2-Dodecene	4.49
5-Dodecene	0.65
3-Dodecene	0.84
1-Octene, 3,7-dimethyl-	0.89
4-Tetradecene	2.15
1-Nonadecene	0.81
3-Eicosene	1.57

9-Octadecene	1.17
1-Nonadecene	0.74
Cycloalkenes	5.23
Cyclopentene, 4,4-dimethyl-	0.80
1,3-Cyclopentadiene, 1,2-dimethyl-	0.90
Cyclohexane, 2-propenyl-	1.30
Cyclohexane, 1,1-dimethyl-2-propyl	0.81
Cyclohexene, 1,6-dimethyl-	0.57
Cyclohexane, 1,2-dimethyl-3,5-bis(1-methylethenyl)-	0.85
Alkynes	7.33
5-Dodecyne	1.87
7-Tetradecyne	2.29
8-Hexadecyne	0.69
7-Hexadecyne	0.95
1-Hexadecyne	0.92
1-Pentadecyne	0.61
Single ring aromatic hydrocarbons	9.37
Benzene	3.12
Toluene	2.64
P-Xylene	2.97
Benzene, 1-ethyl-4-methyl-	0.63
Polycyclic aromatic hydrocarbons	3.10
Indene	2.35
Naphthalene, 1-methyl-	0.75
Total	91.49

Table S3. Composition of bio-oil obtained by pyrolyzing cellulose with graphite at 1:1 (wt./wt.) on moisture free basis.

Product	Composition (area%)
Furan derivatives	9.60
Furfural	5.24
Ethanone, 1-(2-furanyl)-	1.31
Furanone, 5-methyl-	0.12
2-Furancarboxaldehyde, 5-methyl- (5-methyl furfural)	2.93
Phenolics	0.17
P-Cresol	0.10
Phenol, 2,4-dimethyl-	0.07
Alkanes	0.94

Tritetracontane	0.15
Hexadecane	0.79
Cycloalkanes	6.26
Cyclohexane, 1,1'-(1,2-dimethyl-1,2-ethanediyl)-	1.42
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl	0.93
Cyclohexane, 2,4-diisopropyl-1,1-dimethyl-	0.82
Cyclotetracosane	0.50
Cyclohexane, 1,2,4,5-tetraethyl-	0.61
Cyclotetracosane	0.55
Cyclodocosane, ethyl-	1.43
Alkenes	10.57
1-Docosene	1.42
1-Nonadecene	2.84
5-Methyl-Z-5-docosene	0.43
1-Hexacosene	1.42
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	4.46
Cycloalkenes	0.21
Cyclohexene, 4-(4-ethylcyclohexyl)-1-pentyl	0.21
Alkynes	0.70
8-Hexadecyne	0.70
Ketone derivatives	2.53
2-Propanone, 1-hydroxy- (Acetol)	0.36
Ethanone, 1-cyclopropyl-	0.09
3-Hexanone	0.51
3-Penten-2-one	0.20
Cyclopentanone	0.11
5,9-Dodecadien-2-one, 6,10-dimethyl	0.18
4-Cyclopentene-1,3-dione	0.22
1,2-Cyclopentanedione	0.09
2-Butanone, 1-(acetyloxy)-	0.10
2-Cyclopenten-1-one, 3-methyl-	0.28
Levoglucosenone	0.39
Alcohols derivates	11.65
1,2-Ethanediol, diacetate	0.43
2,6,10-Undecatrien-8-ol, 2,6-dimethyl	0.09
Octacosanol	0.47
Behenic alcohol	0.11
1-Heneicosanol	2.21
Tetracosanol	1.49
11,13-Dimethyl-12-tetradecen-1-ol acetate	0.61
14-Methyl-8-hexadecyn-1-ol	0.42

1-Heptacosanol	5.82
Aliphatic aldehydes/acids	0.92
2-Butenal	0.39
Nonahexacontanoic acid	0.53
Total	43.55

Table S4. Composition of bio-oil obtained by pyrolyzing garden waste with graphite at 1:1 (wt./wt.) on moisture free basis.

Product	Composition (area%)
Furan derivatives	3.92
Furfural	3.10
3-Furanmethanol	0.15
Butyrolactone	0.09
2-Furancarboxaldehyde, 5-methyl-	0.10
Benzofuran, 2,3-dihydro-	0.48
Aromatics	1.03
Toluene	0.53
P-Xylene	0.34
Benzene, 1-ethenyl-2-methyl-	0.16
Condensed ring aromatics	0.71
Naphthalene	0.46
Naphthalene, 1,2,3,4-tetrahydro-5,6-dimethyl	0.08
Naphthalene, 2-methyl-	0.17
Phenolics	4.25
Phenol	0.89
P-Cresol	1.20
Phenol, 2-methoxy-	0.56
Phenol, 2,5-dimethyl-	0.18
Phenol, 4-ethyl-	0.14
Phenol, 2,4-dimethyl-	0.06
2-Methoxy-4-vinylphenol	0.75
3-Hydroxy-4-methoxybenzoic acid	0.23
P-tert-Butyl catechol	0.08
Phenol, 2,6-dimethoxy-4-(2-propenyl)-	0.16
Alkanes	0.00
Cycloalkanes	4.09
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	4.09
Cycloalkenes	1.05

Cyclohexane, 1,1'-(1,2-dimethyl-1,2-ethanediyl)-	1.05
Alkenes	12.24
1-Hexacosene	2.77
12-Pentacosene	0.18
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	9.29
Ketone derivatives	2.16
2-Propanone, 1-hydroxy-	1.03
3-Buten-2-one, 3-methyl-	0.09
3-Penten-2-one	0.10
Cyclopentanone	0.08
2-Propanone, 1-(acetyloxy)-	0.63
1,2-Cyclopentanedione	0.07
Bicycloheptane-2,5-dione, 1,7,7-trimethyl-	0.16
Alcohol derivatives	0.81
6-Octen-1-ol, 3,7-dimethyl-, acetate	0.16
Cycloheptanol, 2-methylene	0.65
Other oxygenates	1.57
Acetic acid	0.24
Propanoic acid, 2-oxo-, methyl ester	0.10
Maltol	0.06
2-Propenal, 2-methyl-3-phenyl-	0.17
4-Ethylbenzoic acid, but-3-yn-2-yl ester	0.08
4-Methoxy-2-methyl-1-(methylthio)benzene	0.06
4-Methyl-2,5-dimethoxybenzaldehyde	0.06
Tridecanedial	0.74
2-Naphthalenone, octahydro-4,7,7-trimethyl-	0.06
Total	31.83

Table S5. Composition of bio-oil obtained by pyrolyzing kitchen waste with graphite at 1:1 (wt./wt.) on moisture free basis.

Product	Composition (area%)
Furan derivatives	7.61
Furfural	4.28
2-Furanmethanol	0.67
Butyrolactone	0.40
2-Furancarboxaldehyde, 5-methyl-	2.09
2-Acetyl-5-methylfuran	0.09
Benzofuran, 2-methyl-	0.08

Aromatics	0.25
Toluene	0.25
Condensed ring aromatics	0.35
Indene, 1-methyl-	0.10
Naphthalene	0.12
Naphthalene, 2,6-bis(1,1-dimethylethyl)-	0.08
Indene, 4,7-dimethyl-	0.05
Phenolics	3.41
Phenol	0.38
Phenol, 2,4-dimethyl-	0.60
Phenol, 3-ethyl-	0.14
P-Cresol	2.07
Phenol, 2-methoxy-	0.07
2-Methoxy-4-vinylphenol	0.06
Trans-Isoeugenol	0.09
Alkanes	1.37
Tetracosane	0.90
Octadecane	0.47
Cycloalkanes	2.5
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	2.50
Alkenes	9.8
Limonene	0.06
1-Hexacosene	2.41
2,4-Hexadiene, 3,4-dimethyl-	0.04
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	7.29
Ketone derivatives	2.86
2-Propanone, 1-hydroxy-	1.20
3-Penten-2-one	0.08
2-Cyclopenten-1-one, 2-methyl-	0.94
2-Cyclopenten-1-one, 3-methyl-	0.07
2-Cyclopenten-1-one, 3,4-dimethyl-	0.18
1,2-Cyclopentanedione, 3-methyl-	0.22
7-Methylindan-1-one	0.04
Cyclohexanone, 3-ethenyl-	0.08
Ethanone, 1-(methylenecyclopropyl)	0.05
Alcohol derivatives	2.80
2-Methyl-1,5-hexadiene-3-ol	0.05
3-Methylbenzyl alcohol	0.10
Cycloheptanol, 2-methylene	1.44
11,13-Dimethyl-12-tetradecen-1-ol acetate	1.21
Other oxygenates	3.20

1,6-Dianhydro-.alpha.-d-glucopyranose	0.18
4-Acetylphenyl ether	0.21
Fumaric acid, 4-cyanophenyl dodecyl ester	1.40
Tridecanedial	1.20
Benzene, 1-ethyl-4-methoxy-	0.10
Cyclopropane, 1-(1'-propenyl)-2-hydroxymethyl-	0.11
Total	34.15

Table S6. Composition of bio-oil obtained from experiment E1 on moisture free basis.

Product	Composition (area%)
Furan derivatives	5.66
Furan, 2,5-dimethyl-	0.51
Furfural	3.56
Ethanone, 1-(2-furanyl)-	0.26
5-Isopropyl-3,3-dimethyl-2-methylene-2,3-dihydrofuran	0.25
2-Furancarboxaldehyde, 5-methyl-	1.08
Single ring aromatic hydrocarbons	11.47
Benzene	1.17
Toluene	4.22
Ethylbenzene	0.81
P-Xylene	1.69
Styrene	2.09
Benzene, propyl-	0.16
Benzene, 1,2,4-trimethyl-	0.21
Benzene, 1-ethenyl-3-methyl-	0.38
Benzene, [1-(2,4-cyclopentadien-1-ylidene)ethyl]-	0.19
Benzene, pentyl-	0.26
Benzene, (1,2-dimethyl-1-propenyl)	0.29
Polycyclic aromatic hydrocarbons	5.18
Indene	0.47
1H-Indene, 1,3-dimethyl-	0.21
Naphthalene	2.43
1H-Indene, 2,3-dimethyl-	0.17
Naphthalene, 1-methyl-	1.23
Naphthalene, 2,7-dimethyl-	0.29
Naphthalene, 1,6,7-trimethyl-	0.17
1H-Phenylene	0.21
Phenol derivatives	0.26
Phenol, 3-methyl-	0.26

Saturated aliphatic hydrocarbons	4.16
Cyclohexane, 1,2,3-trimethyl-	0.20
Cyclopentane, 2-ethyl-1,1-dimethyl	0.35
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	2.49
Octadecane	0.21
Cyclopentadecane	0.18
Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	0.73
Unsaturated aliphatic hydrocarbons	11.17
1-Heptene	0.41
1-Undecene	1.51
2-Pentene, 3-methyl-	0.20
1,3,5-Hexatriene, 2-methyl-	0.22
1-Decene	0.66
2-Octene	0.17
1-Tridecene	1.21
8-Hexadecyne	0.50
Guaia-1,11-diene	0.16
1-Nonadecene	1.23
Cyclohexane, 1,1-dimethyl-2,4-bis(1-methylethenyl)-	0.25
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	4.65
Cycloxygenated organics	2.25
Cyclopentanone, 2,2-dimethyl-	0.56
2-Cyclopenten-1-one, 2-methyl-	0.63
2-Cyclopenten-1-one, 2-hydroxy-3-methyl-	0.45
2-Cyclohexen-1-ol	0.27
2-Cyclopenten-1-one, 2,3-dimethyl-	0.34
Others	2.19
1-Nonanol	0.88
2(1H)-Naphthalenone, octahydro-4,7,7-trimethyl-	0.31
Nonahexacontanoic acid	0.57
1-Undecanol	0.43
Total	42.34

Table S7. Composition of bio-oil obtained from experiment E2 on moisture free basis.

Product	Composition (area%)
Furan derivatives	0.65
Furan, 2,5-dimethyl-	0.32
3-Furaldehyde	0.33
Single ring aromatic hydrocarbons	17.77
Benzene	1.76
Toluene	4.90
Ethylbenzene	1.36
P-Xylene	4.63
Benzene, propyl-	0.09
Benzene, 1-ethyl-3-methyl-	3.52
Benzene, 1,2,3-trimethyl-	0.18
Benzene, 1-ethyl-2,3-dimethyl-	0.42
Benzene, (2-methyl-1-propenyl)-	0.13
Benzene, pentyl-	0.43
P-Cymene	0.35
Polycyclic aromatic hydrocarbons	6.55
Indane	0.72
1H-Indene, 2,3-dihydro-1,3-dimethyl-	0.09
Naphthalene	2.87
1H-Indene, 1-ethenyl-2,3-dihydro-	0.14
1H-Indene, 1,3-dimethyl-	0.20
Naphthalene, 2-methyl-	2.07
Naphthalene, 2,7-dimethyl-	0.14
Naphthalene, 1-propyl-	0.13
1-Isopropenylnaphthalene	0.11
9H-Fluorene, 2,3-dimethyl-	0.08
Phenol derivatives	0.00
Saturated aliphatic hydrocarbons	3.22
Cycloheptane	0.12
Heptane	0.35
Heptane, 2-methyl-	0.28
Heptane, 2,4-dimethyl-	0.59
Octane, 2,6-dimethyl-	0.10
Decane	0.11
Undecane	0.18
Cycloundecane, 1,1,2-trimethyl-	0.10
4-Tetradecene	0.16

Cyclopentadecane	0.12
Cyclopentane, 1-butyl-2-pentyl-	0.11
Cyclohexane, (2,2-dimethylcyclopentyl)-	0.11
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	0.40
Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	0.26
Hexadecane, 7,9-dimethyl-	0.12
Octadecane	0.11
Unsaturated aliphatic hydrocarbons	4.11
3-Vinyl-1-cyclobutene	0.24
1,3-Cyclopentadiene, 5-methyl-	0.10
Cyclopentene, 1-methyl-	0.13
1,3-Cyclohexadiene	0.31
1-Heptene	0.34
2,4-Heptadiene	0.17
1-Butene, 3,3-dimethyl-	0.13
1,3,5-Hexatriene, 3-methyl	0.21
2,4-Hexadiene, 3-methyl-	0.13
1-Heptene, 2-methyl-	0.58
1-Octene	0.35
3-Octene	0.09
1-Nonene	0.38
3-Undecene	0.10
5-Undecene	0.10
Tricycloundec-9-ene,2,6,6,9-tetramethyl-	0.09
8-Hexadecyne	0.16
Cyclobutane, (1-methylethylidene)-	0.26
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	0.24
Cyclo oxygenated organics	0.00
Others	0.08
1-Heptanol, 3-methyl-	0.08
Total	32.38

Table S8. Composition of bio-oil obtained from experiment E3 on moisture free basis.

Product	Composition (area%)
Furan derivatives	5.95
Furan, 2,5-dimethyl-	0.65
Furan, 2,3-dihydro-3-methyl-	0.11
Furfural	3.48
2-Furanmethanol	0.13

Ethanone, 1-(2-furanyl)-	0.25
2-Furancarboxaldehyde, 5-methyl-	1.21
Benzofuran, 2-methyl-	0.12
Single ring aromatic hydrocarbons	7.09
Benzene	1.78
Toluene	3.68
Ethylbenzene	0.19
Benzene, 1,3-dimethyl-	1.11
Benzene, 1-ethyl-2-methyl-	0.23
Benzene, 1,2,4-trimethyl-	0.10
Polycyclic aromatic hydrocarbons	1.77
Indene	0.53
1H-Indene, 1-methylene-	0.15
Naphthalene	0.38
2-Methylindene	0.15
1H-Indene, 1,3-dimethyl-	0.25
Naphthalene, 1-methyl-	0.19
Naphthalene, decahydro-2,3-dimethyl-	0.12
Phenol derivatives	1.59
Phenol, 2-methyl-	0.18
Phenol	0.10
P-Cresol	1.04
Phenol, 2,4-dimethyl-	0.18
Phenol, 3-ethyl-	0.09
Saturated aliphatic hydrocarbons	1.46
Bicyclooctane, 2-methyl-	0.10
Cyclodecane	0.26
Cyclopentane, propyl-	0.19
Cyclopropane, 1-ethyl-1-methyl-	0.12
Cyclopentane, 3-hexyl-1,1-dimethyl	0.12
Dodecane, 2,6,10-trimethyl-	0.10
Bicyclooctane	0.13
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	0.34
Cyclohexane, (2,2-dimethylcyclopentyl)-	0.10
Unsaturated aliphatic hydrocarbons	11.24
1-Cyclobutyl cyclobutene	0.19
1,4-Hexadiene	0.14
2-Hexen-4-ene	0.27
1,3-Cyclopentadiene, 5,5-dimethyl-	0.34
5-Methyl-2-hexene	0.24
1-Heptene	0.70

2-Butene, 2,3-dimethyl-	0.20
1,3-Cyclopentadiene, 1,2-dimethyl-	0.12
1-Octene	0.64
Cyclohexene, 1,2-dimethyl-	0.20
1-Nonene	0.13
2-Heptene	0.71
1-Decene	0.60
1-Isopropylcyclohex-1-ene	0.12
D-Limonene	0.19
2-Decene, 8-methyl-	0.14
1-Dodecene	0.70
17-Pentatriacontene	0.13
1-Tridecene	0.79
7-Tetradecyne	0.21
6-Dodecene	0.19
2-Tetradecene	0.36
1-Undecene	1.22
5-Octadecene	0.33
1,3,5,7-Cyclooctatetraene	0.56
3-Undecene, 9-methyl-	0.44
8-Heptadecene	0.18
5-Octadecene	0.23
9-Octadecene	0.10
1-Docosene	0.11
7-Hexadecyne	0.24
1-Hexadecyne	0.10
17-Pentatriacontene	0.10
Bicyclononane, 3-methylene-	0.10
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	0.22
Cycloxygenated organics	0.76
Cyclopentanone	0.15
2-Cyclopenten-1-one, 3-methyl-	0.52
1,2-Cyclopentanedione, 3-methyl-	0.09
Others	0.92
2-Butanone, 3-methyl-	0.20
1,2-Ethandiol, diacetate	0.39
14-Methyl-8-hexadecyn-1-ol	0.10
1H-Inden-1-one, 2,3-dihydro-3,4,7-trimethyl-	0.23
Total	30.78

Table S9. Composition of bio-oil obtained from experiment E4 on moisture free basis.

Product	Composition (area%)
Furan derivatives	0.69
Furan, 2,5-dimethyl-	0.11
Furfural	0.58
Single ring aromatic hydrocarbons	12.38
Benzene	2.15
Toluene	4.46
Ethylbenzene	0.69
P-Xylene	1.11
Styrene	2.33
Benzene, propyl-	0.19
Benzene, 1-ethyl-3-methyl-	0.68
Benzene, 1,2,4-trimethyl-	0.22
1-Propyne, 3-phenyl-	0.34
Benzene, 1,2-diethyl-	0.21
Polycyclic aromatic hydrocarbons	7.65
Indene	1.06
1H-Indene, 1,3-dimethyl-	0.15
Naphthalene	3.82
Naphthalene, 2-methyl-	1.17
Naphthalene, 2-ethenyl-	0.18
Naphthalene, 1,4-dimethyl-	0.08
Biphenylene	0.63
Naphthalene, 1,4,5-trimethyl-	0.07
3,3'-Dimethylbiphenyl	0.06
9H-Fluorene, 2-methyl-	0.06
Stilbene	0.08
Pyrene	0.22
Phenanthrene	0.07
Phenol derivatives	0.15
Phenol	0.15
Saturated aliphatic hydrocarbons	2.09
Cyclopropane, pentyl-	0.11
Cyclopropane, 1-methyl-2-pentyl-	0.41
7-Formylbicycloheptane	0.11
Bicyclooctane, 2-methyl-	0.09
Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	0.31
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	0.77

Bicycloheptane, 2,6,6-trimethyl-	0.08
1-Methylbicyclooctane	0.10
Cyclohexane, (2,2-dimethylcyclopentyl)-	0.11
Unsaturated aliphatic hydrocarbons	2.32
4-Methylenecyclopentene	0.07
1,3-Cyclopentadiene, 5-methyl-	0.09
1-Heptene	0.17
1,3,5-Hexatriene, 3-methyl-	0.10
1-Heptene, 2-methyl-	0.29
1-Octene	0.27
Cyclohexene, 1,4-dimethyl-	0.07
1-Decene	0.28
1-Tridecyne	0.06
1-Dodecene	0.08
3-Eicosene	0.07
1-Nonadecene	0.07
7-Tetradecyne	0.09
5-Nonadecene	0.11
Cyclopentane, 1,3-bis(methylene)-	0.09
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	0.41
Cycloxygenated organics	0.07
2-Cyclopenten-1-one, 2,3-dimethyl-	0.07
Others	0.79
1-Undecanol	0.05
N-Tridecan-1-ol	0.37
1-Tetradecanol	0.17
Heptacosyl acetate	0.07
N-Tetracosanol-1	0.13
Total	26.14

Table S10. Composition of bio-oil obtained from experiment E5 on moisture free basis.

Product	Composition (area%)
Furan derivatives	2.21
Furan, 2,5-dimethyl-	0.78
Furfural	1.26
Ethanone, 1-(2-furanyl)-	0.17
Single ring aromatic hydrocarbons	19.05
Benzene	3.77
Toluene	7.32

Ethylbenzene	1.31
P-Xylene	1.65
Styrene	2.64
Benzene, propyl-	0.17
Benzene, 1-ethyl-4-methyl-	1.68
Mesitylene	0.17
Benzene, pentyl-	0.17
Benzene, (1,2-dimethyl-1-propenyl)	0.17
Polycyclic aromatic hydrocarbons	7.16
Indene	1.13
1H-Indene, 1-methylene-	0.65
2-Methylindene	0.84
Naphthalene	2.79
1H-Indene, 4,7-dimethyl-	0.25
1,2,3-Trimethylindene	0.14
Naphthalene, 2-methyl-	0.63
Naphthalene, 2,3-dimethyl-	0.34
9H-Fluorene, 2-methyl-	0.15
Anthracene	0.24
Phenol derivatives	0.00
Saturated aliphatic hydrocarbons	2.38
Cis-1-Butyl-2-methylcyclopropane	0.71
9-Methylbicyclononane	0.13
Tetramethyl-cyclohexane	0.20
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	0.95
Hexadecane	0.29
Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	0.10
Unsaturated aliphatic hydrocarbons	9.55
1,3-Cyclopentadiene, 1-methyl-	0.79
Cyclopentene, 1-methyl-	0.29
4-Methylenecyclopentene	0.12
1-Heptene	0.92
2,4-Heptadiene	0.18
1,3,5-Hexatriene, 3-methyl-	0.11
2,4-Hexadiene, 2-methyl-	0.14
1-Heptene, 2-methyl-	0.88
1-Heptene, 2,6-dimethyl-	0.56
1-Nonene	0.94
1-Decene	0.72
1-Heptene, 3-methyl-	0.13
1-Undecene	1.05

1-Tridecene	0.91
6-Dodecyne	0.14
7-Tetradecene	0.20
1-Pentadecyne	0.13
7-Tetradecyne	0.15
Bicyclotridec-1-ene	0.21
8-Hexadecyne	0.14
1-Octadecene	0.11
1-Docosene	0.11
1-Nonadecene	0.14
Ethylidenecyclobutane	0.31
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	0.17
Cycloxygenated organics	0.00
Others	0.74
3,6-Octadien-1-ol, 3,7-dimethyl-	0.16
Octacosanol	0.28
1-Heneicosanol	0.30
Total	41.09

Table S11. Composition of bio-oil obtained from experiment E6 on moisture free basis.

Product	Composition (area%)
Furan derivatives	0.21
Furan, 2,5-dimethyl-	0.11
Furfural	0.10
Single ring aromatic hydrocarbons	9.84
Benzene	0.66
Toluene	6.85
P-Xylene	0.28
Benzene, propyl-	0.32
Benzene, (1-methylethyl)-	0.08
Benzene, 1,2,3-trimethyl-	0.21
Benzene, 1-ethyl-2-methyl-	0.44
Benzene, 1-ethenyl-3-methyl-	0.12
Benzene, 4-ethyl-1,2-dimethyl-	0.08
Benzene, 1-propynyl-	0.24
Benzene, 2-ethenyl-1,4-dimethyl-	0.08
Benzene, 1,3-diethenyl-	0.11
Benzene, 1,3-diethyl-5-methyl-	0.11
Benzene, 1-methyl-4-butyl	0.13

(1-Methylpenta-2,4-dienyl)benzene	0.13
Polycyclic aromatic hydrocarbons	3.47
Naphthalene	1.98
1H-Indene, 1,3-dimethyl-	0.12
Naphthalene, 2-methyl-	0.28
Naphthalene, 2,3-dimethyl-	0.20
Aromandendrene	0.20
Naphthalene, decahydro-1,2-dimethyl	0.25
Naphthalene, decahydro-2-methyl-	0.11
1,1,4,5,6-pentamethyl-2,3-dihydro-1H-indene	0.22
1-Isopropenylnaphthalene	0.11
Phenol derivatives	0.44
P-Cresol	0.08
Phenol, 2,5-dimethyl-	0.36
Saturated aliphatic hydrocarbons	2.96
Cyclopentane, 1,2-dimethyl-	0.30
1-Nonene	1.21
2,6-Dimethyl-1,3,6-heptatriene	0.08
1-Decene	0.20
Cyclobutane, 1,2-diethyl-, trans-	0.11
Cyclohexane, 1,2,3-trimethyl-	0.28
1-Methylbicyclooctane	0.13
6-Tridecane	0.11
1-Methyl-2-methylenecyclohexane	0.21
Tricycloundecane	0.07
Bicycloheptane, 3-methyl-7-pentyl-	0.10
1-Methylbicyclooctane	0.16
Unsaturated aliphatic hydrocarbons	6.3
1,3,5-Hexatriene, 2-methyl-	0.54
1,4-Hexadiene, 4-methyl-	0.33
1,3-Cycloheptadiene	0.34
Cyclohexene, 1,4-dimethyl-	0.22
4,5-Nonadiene, 2-methyl-	0.18
1-Hexene, 3-methyl-	0.11
1-Decene	1.05
9-Octadecyne	0.09
3-Vinyl-1-cyclobutene	0.17
1-Pentene, 3-methyl-	0.11
1,3-Cycloheptadiene	0.25
2,4-Dimethyl-1-hexene	0.36
Cyclohexene, 1,6-dimethyl-	0.08

5-Hexadecyne	0.21
5-Undecyne	0.14
6-Tetradecyne	0.20
6-Dodecyne	0.22
4-Decyne	0.19
1,5-Cycloundecadiene, 9-(1-methylethylidene)-	0.14
Cyclohexene, 1,2-dimethyl-	0.12
5-Eicosene	0.10
Bicyclotridec-1-ene	0.11
3-Eicosene	0.28
Cyclopentane, 1,2-dimethyl-3-methylene-	0.08
Cyclopropane, 1,1-dimethyl-2-(2-methyl-2-propenyl)-	0.09
1-Isopropenyl-3-propenylcyclopentane	0.11
Cyclohexane, (2-ethyl-1-methyl-1-butenyl)-	0.22
Cyclohexane, 1,5-diethenyl-2,3-dimethyl-	0.13
Cyclohexane, 1,5-dimethyl-2,3-divinyl-	0.13
Cycloxygenated organics	0.36
2-Cyclohexen-1-ol, 1-methyl-	0.08
2-Cyclopenten-1-one, 2,3-dimethyl-	0.28
Others	0.88
Cis-4-Decenal	0.06
3,6-Nonadienal	0.15
1-Hydroxymethyl-2-methyl-1-cyclohexene	0.09
1-Undecanol	0.33
2-Ethyl-1-dodecanol	0.08
N-Nonadecanol-1	0.10
Oxalic acid, allyl pentadecyl ester	0.07
Total	24.46

Table S12. Composition of bio-oil obtained from experiment E7 on moisture free basis.

Product	Composition (area%)
Furan derivatives	0.30
2-Furancarboxaldehyde, 5-methyl-	0.30
Single ring aromatic hydrocarbons	5.82
Benzene	0.75
Toluene	2.07
Ethylbenzene	0.20
P-Xylene	0.95
Styrene	1.33

Benzene, 1-ethenyl-4-methyl-	0.11
Benzene, 1,2,3-trimethyl-	0.12
Benzene, 1-methyl-4-propyl-	0.03
Benzene, (2-methyl-1-propenyl)-	0.07
Benzene, 1,2,4,5-tetramethyl-	0.03
Benzene, 2-butenyl-	0.03
Benzene, 1-methyl-1,2-propadienyl-	0.13
Polycyclic aromatic hydrocarbons	4.95
Indene	0.70
Naphthalene, 1,2-dihydro-	0.05
1H-Indene, 2,3-dihydro-1,2-dimethyl-	0.05
Naphthalene	2.43
1H-Indene, 2,3-dimethyl-	0.04
Naphthalene, 1-methyl-	1.34
Naphthalene, 2,6-dimethyl-	0.04
Naphthalene, decahydro-1,2-dimethyl-	0.03
Biphenylene	0.07
Aromandendrene	0.04
Naphthalene, 1,6,7-trimethyl-	0.03
1H-Phenalene	0.03
Anthracene	0.04
Fluorene	0.06
Phenol derivatives	0.73
Phenol	0.19
Phenol, 2-methyl-	0.23
P-Cresol	0.14
Phenol, 2-ethyl-	0.03
Phenol, 3-ethyl-	0.14
Saturated aliphatic hydrocarbons	0.18
Bicyclooctane, 2-methyl-	0.03
Trans-1-Butyl-2-methylcyclopropane	0.05
1-Methylbicyclooctane	0.05
Cyclopropane, 1-butyl-2-pentyl-	0.05
Unsaturated aliphatic hydrocarbons	0.77
1-Heptene	0.04
3-Methylenecyclohexene	0.03
Trans-3,5-Dimethylcyclohexene	0.05
4-Undecene	0.06
1-Tridecene	0.10
5-Octadecene	0.10
3-Eicosene	0.06

1-Tetradecyne	0.06
2-Hexene	0.05
5-Decene	0.03
1,3-Cyclopentadiene, 5,5-dimethyl-2-ethyl-	0.07
1-Pentadecyne	0.05
1-Nonadecene	0.04
Cyclohexane, 1,3-dimethyl-2-methylene-	0.03
Cycloxygenated organics	5.27
2-Cyclopenten-1-one	4.62
2-Cyclopenten-1-one, 2-methyl-	0.62
2-Cyclopenten-1-one, 2,3-dimethyl-	0.03
Others	1.27
3-Penten-2-one	0.08
2-Propenoic acid, 6-methylheptyl ester	0.05
Butanoic acid, 4-hydroxy-	0.04
2,6-Nonadienal	0.05
Benzenemethanol, 4-methyl-	0.07
Cyclohexanone, 3-phenyl-	0.04
Pyridine	0.31
Pyridine, 2-methyl-	0.45
Pyridine, 3-methyl-	0.14
Pyridine, 2,3-dimethyl-	0.04
Total	19.29

Table S13. Composition of bio-oil obtained from experiment E8 on moisture free basis.

Product	Composition (area%)
Furan derivatives	3.11
Ethanone, 1-(2-furanyl)-	0.20
Furfural	2.06
2-Furancarboxaldehyde, 5-methyl-	0.85
Single ring aromatic hydrocarbons	13.09
Benzene	1.81
Toluene	4.95
Ethylbenzene	0.76
P-Xylene	1.52
Styrene	2.86
Benzene, propyl-	0.17
Mesitylene	0.14
Benzene, 1-ethyl-3-methyl-	0.15

Benzene, 1-ethenyl-3-methyl-	0.14
1-Propyne, 3-phenyl-	0.43
Benzene, 1,3-diethyl-5-methyl-	0.16
Polycyclic aromatic hydrocarbons	10.95
Indene	1.58
1H-Indene, 1,3-dimethyl-	0.24
Naphthalene	4.85
1H-Indene, 4,7-dimethyl-	0.14
Naphthalene, 2-methyl-	1.98
Naphthalene, 2-ethenyl-	0.34
Naphthalene, 2,3-dimethyl-	0.32
Alloaromadendrene	0.21
1-Isopropenylnaphthalene	0.12
9H-Fluorene, 2-methyl-	0.11
Phenanthrene, 1,2-dihydro-	0.11
Phenanthrene, 9,10-dihydro-1-methyl-	0.12
3H-Benz[e]indene, 2-methyl-	0.23
Pyrene	0.48
4,6,8-Trimethylazulene	0.12
Phenol derivatives	0.18
Phenol, 3-methyl-	0.18
Saturated aliphatic hydrocarbons	3.61
Cyclobutane, 1,2-diethyl-	0.17
2-Methylbicyclooctane	0.11
Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	0.74
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	1.10
Cyclohexane, (2,2-dimethylcyclopentyl)-	0.71
Hexadecane	0.21
Cyclohexane, 1,2,3,5-tetraisopropyl-	0.20
Decane, 3,8-dimethyl-	0.37
Unsaturated aliphatic hydrocarbons	4.6
1,3-Cyclohexadiene	0.21
1-Heptene	0.24
1,3,5-Hexatriene, 2-methyl-	0.18
1,3,5-Heptatriene	0.11
1-Heptene, 2-methyl-	0.20
1-Nonene	0.53
9-Octadecyne	0.13
5-Undecyne	0.14
Cyclohexene, 4-(4-ethylcyclohexyl)-1-pentyl-	0.17
2-Methyl-Z-4-tetradecene	0.16

8-Hexadecyne	0.16
17-Pentatriacontene	0.44
Cyclohexane, 3,4-bis(1-methylethenyl)-1,1-dimethyl-	0.12
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	1.81
Cycloxygenated organics	0.61
3-Cyclohexene-1-carboxaldehyde, 1-methyl-	0.16
2-Cyclopenten-1-one, 2,3-dimethyl-	0.14
Cyclododecanone, 2-methylene-	0.13
2-Cyclopenten-1-one, 2,3-dimethyl-	0.18
Others	1.29
1-Undecanol	0.13
1-Decanol	0.26
1-Dodecanol	0.62
Tridecanedial	0.14
Oxalic acid, cyclobutyl pentadecylester	0.14
Total	37.44

Table S14. Composition of bio-oil obtained from experiment E9 on moisture free basis.

Product	Composition (area%)
Furan derivatives	0.63
Furfural	0.33
2-Furanmethanol	0.07
2-Furancarboxaldehyde, 5-methyl-	0.07
Benzofuran, 2-methyl-	0.16
Single ring aromatic hydrocarbons	2.92
Benzene	0.44
Toluene	0.49
Ethylbenzene	0.18
P-Xylene	0.12
Styrene	0.59
Benzene, propyl-	0.06
Benzene, 1-ethyl-3-methyl-	0.62
Benzene, (2-methyl-2-propenyl)-	0.07
Benzene, 1-methyl-1,2-propadienyl-	0.32
Benzene, 1-cyclopenten-1-yl-	0.03
Polycyclic aromatic hydrocarbons	10.03
1H-Indene, 1-methyl-	0.24
Azulene	0.12
1,4-Dihydronaphthalene	0.29

1H-Indene, 1,3-dimethyl-	0.04
Naphthalene	3.41
Naphthalene, decahydro-1,2-dimethyl-	0.09
Naphthalene, 1-methyl-	1.77
Naphthalene, 2-ethenyl-	0.40
Naphthalene, 1,6-dimethyl-	0.38
Biphenylene	0.66
Naphthalene, 1,6,7-trimethyl-	0.18
1H-Phenylene	0.21
Fluorene	0.15
9H-Fluorene, 1-methyl-	0.18
Anthracene	0.69
Phenanthrene, 9,10-dihydro-1-methyl-	0.03
Phenanthrene, 2-methyl-	0.05
Pyrene	0.30
Indene	0.84
Phenol derivatives	0.62
Phenol	0.20
P-Cresol	0.24
Phenol, 2,4-dimethyl-	0.07
Phenol, 4-ethyl-	0.05
1,4-Benzenediol, 2,6-dimethyl-	0.06
Saturated aliphatic hydrocarbons	0.16
Cyclotetradecane	0.16
Unsaturated aliphatic hydrocarbons	0.73
1,3,5-Hexatriene, 3-methyl-	0.05
1-Nonene	0.12
1-Decene	0.07
1-Undecene	0.11
1-Undecene, 10-methyl-	0.04
5-Tetradecene	0.10
5-Dodecene	0.06
Bicycloundeca-1,3,5,7,9-pentaene	0.04
6-Tetradecyne	0.14
Cycloxygenated organics	0.06
2-Cyclopenten-1-one, 2-methyl-	0.03
1,2-Cyclopentanedione, 3-methyl-	0.03
Others	0.46
2,3-Butanedione	0.08
Benzeneethanol, .beta.-ethenyl-	0.06
1,4-Benzenediol, 2,6-dimethyl-	0.05

N-Tridecan-1-ol	0.05
Isolongifolol, methyl ether	0.08
Pyridine	0.08
Pyridine, 2-methyl-	0.06
Total	15.61

Table S15. Composition of bio-oil obtained from experiment E10 on moisture free basis.

Product	Composition (area%)
Furan derivatives	10.73
Furan, 2,5-dimethyl-	1.64
Furan, 2-ethyl-5-methyl-	0.33
3-Furaldehyde	0.14
Ethanone, 1-(2-furanyl)-	0.80
2-Furancarboxaldehyde, 5-methyl-	1.68
Benzofuran, 4,7-dimethyl-	0.19
Furfural	5.95
Single ring aromatic hydrocarbons	13.75
Benzene	1.68
Toluene	5.13
P-Xylene	1.91
Styrene	2.65
Benzene, propyl-	0.19
Mesitylene	0.64
Benzene, 1,2,3-trimethyl-	0.13
Benzene, 1-ethenyl-3-methyl-	0.32
Benzene, 1-ethynyl-4-methyl-	0.64
Benzene, 1-ethyl-2,4,5-trimethyl-	0.15
Benzene, (1-ethylpropyl)-	0.18
(1-Methylpenta-2,4-dienyl)benzene	0.13
Polycyclic aromatic hydrocarbons	5.79
Indene	0.83
1H-Indene, 1-methyl-	0.13
1H-Indene, 1,3-dimethyl-	0.53
Naphthalene	2.70
1H-Indene, 4,7-dimethyl-	0.24
Naphthalene, decahydro-2-methyl-	0.16
Naphthalene, 2-methyl-	0.74
Naphthalene, 2-ethenyl-	0.22
Naphthalene, 1,6,7-trimethyl-	0.24

Phenol derivatives	0.32
P-Cresol	0.20
Phenol, 4-ethyl-2-methoxy-	0.12
Saturated aliphatic hydrocarbons	1.81
Cyclopentane, 1,3-dimethyl-	0.29
1-Methylbicyclooctane	0.14
Bicyclooctane, 2-methyl-	0.31
6-Tridecane	0.33
Cyclodecane, methyl-	0.12
Heptane, 3,4-dimethyl-	0.12
Trans-Pinane	0.24
Tricyclodecane, 4-methyl-	0.13
Tricyclononane, 2,2,5,5,8,8-hexamethyl-	0.13
Unsaturated aliphatic hydrocarbons	8.37
1,3-Cyclohexadiene	0.16
1-Pentene, 2-methyl-	0.41
1-Heptene	0.50
1,3,5-Hexatriene, 2-methyl-	0.17
2,4-Hexadiene, 2-methyl-	0.17
1-Heptene, 2-methyl-	0.96
1-Octene	0.75
1-Heptene, 2,6-dimethyl-	0.51
1-Nonene	0.81
1-Decene	0.62
1-Decene, 9-methyl-	0.21
Cyclohexene, 1-butyl-	0.26
6-Dodecyne	0.15
1-Undecene	0.94
9-Octadecyne	0.17
2,7-Octadiene, 4-methyl-	0.15
Bicyclotridec-1-ene	0.30
3,4-Octadiene, 7-methyl-	0.17
3-Eicosene	0.38
Tetradecyne	0.14
1-Octadecyne	0.14
Cyclohexane, 1,5-diethenyl-2,3-dimethyl-	0.18
Cyclohexane, 1,5-dimethyl-2,3-divinyl-	0.12
Cycloxygenated organics	0.96
3-Cyclohexene-1-carboxaldehyde, 1,3,4-trimethyl-	0.14
2-Cyclopenten-1-one, 2-methyl-	0.82
Others	2.79

3-Buten-2-one, 3-methyl-	0.71
2-Propanone, 1-(acetyloxy)-	0.25
Benzenemethanol, 4-methyl-	0.33
1-Undecanol	0.15
N-Heptadecanol-1	0.19
Decan-2-one	0.14
1-Dodecanol	0.38
3-Buten-2-one, 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-	0.20
1-Hexacosanol	0.14
N-Tetracosanol-1	0.18
Octacosanol	0.12
Total	44.52

Table S16. Selectivity of light gases obtained from microwave pyrolysis of 20 g of MSW-A at microwave power of 450 W and different MSW:graphite ratios (wt./wt).

Compound	20:1	5:1	1:1	1:2
Methane	14.89	12.75	13.64	1.41
Ethylene	8.49	12.86	7.45	0
Ethane	7.19	5.62	7.06	21.48
Propylene	8.1	10.16	7.20	0.9
Propane	2.21	1.02	2.42	0
Propadiene	0	0	0.00	3.64
Σ C1-C3	40.88	42.41	37.77	27.43
Isobutane	0.13	0.06	0.14	0
Isobutene	2.91	3.19	0.00	2.22
1,3-Butadiene	0	0	2.76	1.21
n-Butane	0.45	0.08	1.08	2.15
cis-2-Butene	0.46	0.44	0.48	0
n-Pentane	0.19	0.25	0.24	0
2-Methyl-2-butene	0.88	0.78	0.77	1.78
Σ C4-C5	5.02	4.80	5.47	7.36
H ₂	41.70	40.83	24.88	46.90
O ₂	4.06	7.145	6.39	1.27
CO ₂	3.87	1.41	1.18	1.71

The selectivity of CO was less than 1% in all the experiments.

Table S17. Composition of bio-oil obtained from experiment E11 on moisture free basis.

Product	Composition (area%)
Furan derivatives	3.40
Furfural	2.37
3-Furanmethanol	0.10
2-Furancarboxaldehyde, 5-methyl-	0.67
Benzofuran, 2-methyl-	0.09
Benzofuran, 2,3-dihydro-	0.17
Single ring aromatic hydrocarbons	12.37
Benzene	3.75
Toluene	4.54
Ethylbenzene	0.34
P-Xylene	1.24
Styrene	1.61
Benzene, propyl-	0.80
O-Cymene	0.09
Polycyclic aromatic hydrocarbons	4.90
Indene	0.75
2-Methyl indene	0.27
Naphthalene	1.63
1H-Indene, 1,3-dimethyl-	0.15
Naphthalene, 2-methyl-	2.10
Phenol derivatives	1.27
Phenol	0.78
Phenol, 3-methyl-	0.11
Phenol, 3,5-dimethyl-	0.14
Trans-Isoeugenol	0.12
Creosol	0.12
Saturated aliphatic hydrocarbons	3.63
Cyclopropane, 1-butyl-2-pentyl-	0.13
Cyclopentane, 3-hexyl-1,1-dimethyl	0.09
Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	0.20
Cyclopentane, 1-butyl-2-pentyl-	0.31
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	2.90
Unsaturated aliphatic hydrocarbons	9.10
1-Heptene	0.23
1-Octene	0.30
3-Octyne	0.10
1-Decene	0.55

D-Limonene	0.30
1-Undecene	0.89
Cyclooctene, 3-(1-methylethenyl)-	0.09
1-Decene	0.55
Cycloundecene, 1-methyl-	0.10
Cyclohexene, 1,2-dimethyl-	0.09
4-Nonene, 2-methyl-	0.10
5-Dodecyne	0.11
1-Nonadecene	0.79
5-Octadecene	0.27
1-Nonene	0.09
1-Hexacosene	0.35
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	4.19
Cyclooxxygenated organics	0.30
2-Cyclopenten-1-one, 2-methyl-	0.18
1,2-Cyclopentanedione, 3-methyl-	0.12
Others	0.48
Pyridine	0.09
1,2-Ethanediol, diacetate	0.39
Total	35.45

Table S18. Composition of bio-oil obtained from experiment E12 on moisture free basis.

Product	Composition (area%)
Furan derivatives	7.66
Furan, 2,3-dihydro-3-methyl-	0.29
Furfural	5.52
Ethanone, 1-(2-furanyl)-	0.46
2-Furancarboxaldehyde, 5-methyl-	1.14
Benzofuran, 2-methyl-	0.25
Single ring aromatic hydrocarbons	9.76
Benzene	2.31
Toluene	4.45
Ethylbenzene	0.17
Benzene, 1,3-dimethyl-	1.48
Benzene, 1-ethenyl-4-methyl-	1.04
Benzene, (1-methyl-2-cyclopropen-1-yl)-	0.17
Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	0.14
Polycyclic aromatic hydrocarbons	4.00
Naphthalene	1.54

1H-Indene, 1,3-dimethyl-	0.30
Naphthalene, 2-methyl-	1.04
Naphthalene, 1,2,3,4-tetrahydro-1,1,6-trimethyl-	0.27
Naphthalene, 1,6,7-trimethyl-	0.31
Naphthalene, 1-methyl-7-(1-methylethyl)-	0.31
1,4,5,8-Tetramethylnaphthalene	0.23
Phenol derivatives	4.21
Phenol, 2-methyl-	0.14
Phenol	1.51
P-Cresol	2.14
Phenol, 2-methoxy-5-(1-propenyl)-	0.21
Trans-Isoeugenol	0.21
Saturated aliphatic hydrocarbons	7.96
Cyclodecane	0.19
Hexadecane	1.54
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	4.58
Cyclopentane, (2-hexyloctyl)-	0.29
Heptadecane, 3-methyl-	0.45
Heptadecane	0.46
Eicosane	0.45
Unsaturated aliphatic hydrocarbons	15.28
1-Heptene	0.74
1-Octene	0.33
Cyclohexene, 1,2-dimethyl-	0.15
1,3,5,7-Cyclooctatetraene	0.68
Cyclohexene, 1-methyl-4-(1-methylethenyl)-	0.21
1-Decene	0.43
9-Octadecene	0.30
5-Tetradecene	0.19
1-Nonadecene	3.67
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	8.58
Cycloxygenated organics	2.30
Cyclopentanone	0.16
2-Cyclopenten-1-one, 2-methyl-	1.60
1,2-Cyclopentanedione, 3-methyl-	0.18
2-Cyclopenten-1-one, 2,3-dimethyl-	0.36
Others	1.84
3-Hexanone	0.13
2-Propanone, 1-(acetyloxy)-	0.73
2(1H)-Naphthalenone, octahydro-4,7,7-trimethyl-	0.13
1-Decanol, 2-hexyl-	0.38

Behenic alcohol	0.47
Total	53.01

Table S19. Composition of bio-oil obtained from experiment E13 on moisture free basis.

Product	Composition (area%)
Furan derivatives	6.05
Furan, 2,5-dimethyl-	1.38
2-Furancarboxaldehyde, 5-methyl-	4.37
Benzofuran	0.30
Single ring aromatic hydrocarbons	22.37
Benzene	6.39
Toluene	10.06
Ethylbenzene	1.25
p-Xylene	1.16
Benzene, 1,2,4-trimethyl-	0.49
Benzene, 1,2,4,5-tetramethyl-	0.24
Benzene, 1-methyl-1,2-propadienyl-	0.91
(1-Methylbuta-1,3-dienyl)benzene	0.24
m-Cymene, 5-tert-butyl-	0.20
Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	1.43
Polycyclic aromatic hydrocarbons	3.01
Indene	0.35
Indane, 1-methyl-	0.24
Naphthalene	0.64
1H-Indene, 4,7-dimethyl-	0.23
Alloaroma dendrene	0.40
Naphthalene, 2,6-dimethyl-	0.20
Biphenylene	0.52
Fluorene	0.43
Phenol derivatives	3.17
Phenol	0.57
Phenol, 2-methyl-	0.34
Phenol, 3-methyl-	0.48
Phenol, 2-ethyl-	0.24
Phenol, 2,6-dimethoxy-	0.95
Phenol, 2-methoxy-4-(1-propenyl)-	0.28

Phenol, 2,4-dimethyl-	0.31
Saturated aliphatic hydrocarbons	3.55
Propane, 2-cyclopropyl-	0.33
Cyclopropane, 1-methyl-2-octyl-	0.26
Cyclobutane, 1-butyl-2-ethyl-	0.19
Nonadecane	0.26
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	1.17
Tridecane, 7-propyl-	0.59
Heneicosane	0.40
Pentadecane	0.35
Unsaturated aliphatic hydrocarbons	8.30
1-Heptene	0.39
Cyclohexene, 1,2-dimethyl-	0.30
Cyclooctene, 3-methyl-	0.24
Bicycloocta-1,3,5-triene	3.17
5-Undecyne	0.21
5-Tetradecyne	0.26
Caparratriene	0.24
3-Eicosene	0.54
2-Hexene, 3,5-dimethyl-	0.22
2-Hexene, 2-methyl-	0.24
7-Tetradecyne	0.76
1-Pentadecyne	0.22
8-Hexadecyne	0.25
Cyclohexene, 4-(4-ethylcyclohexyl)-1-pentyl-	0.21
1-Hexadecyne	0.20
1-Nonadecene	0.50
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	0.35
Cyclooxxygenated organics	2.18
3-(2-Cyclopenten-1-yl)propanal	0.32
Cyclopentanone	0.28
2-Cyclopenten-1-one, 2-methyl-	1.09
1,2-Cyclopentanedione, 3-methyl-	0.49
Others	3.98
Acetic acid	1.01
1,3-Dianhydro-4-O-acetyl- β -mannopyranose	0.25
Butanoic acid, 4-hydroxy-	0.34
N-Pentadecanol	0.30
β -D-Glucopyranose, 1,6-anhydro-	0.31

1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-	0.25
1H-Pyrazole, 1,3,5-trimethyl-	0.24
Imidazole, 1,4,5-trimethyl-	0.20
Benzenamine, 3-(1,2,3-thiadiazol-4-yl)-	0.27
1-Heptacosanol	0.32
1-Decanol, 2-hexyl-	0.20
1-Dodecanol, 2-octyl-	0.29
Total	52.61

Table S20. Composition of bio-oil obtained from experiment E14 on moisture free basis.

Product	Composition (area%)
Furan derivatives	5.82
Furan, 2,5-dimethyl-	0.86
Furfural	3.73
Ethanone, 1-(2-furanyl)-	0.46
2-Furancarboxaldehyde, 5-methyl-	0.30
Benzofuran, 2,3-dihydro-	0.47
Single ring aromatic hydrocarbons	18.88
Benzene	2.96
Toluene	8.69
Ethylbenzene	0.95
P-Xylene	2.81
Styrene	2.19
Methylstyrene	0.18
Benzene, 1-ethenyl-3-methyl-	0.37
Benzene, 1,2-diethyl-	0.45
O-Cymene	0.28
Polycyclic aromatic hydrocarbons	4.14
1H-Indene, octahydro-	0.22
Indene	1.20
2-Methylindene	0.40
Naphthalene	0.27
1H-Indene, 2,3-dimethyl-	0.21
Naphthalene, 2-methyl-	1.61
Phenanthrene, 2-methyl-	0.23
Phenol derivatives	2.60
Phenol	1.16
Phenol, 3-methyl-	0.96

Phenol, 2,5-dimethyl-	0.25
Phenol, 2,6-dimethyl-	0.23
Saturated aliphatic hydrocarbons	3.56
1-Heptene	1.62
Cyclopentane, 1,2-dimethyl-	0.34
Bicycloheptane, 3-methyl-	0.17
1-Methylbicyclooctane	0.43
6-Tridecane	0.40
1-Methylbicyclooctane	0.21
Cyclohexane, (2,2-dimethylcyclopentyl)-	0.19
Cyclopentane, 1,1'-[3-(2-cyclopentylethyl)-1,5-pentanediy]-	0.20
Unsaturated aliphatic hydrocarbons	17.12
1,3-Cyclopentadiene, 1-methyl-	0.20
Cyclopentene, 1-methyl-	0.22
3-Methylenecyclopentene	0.68
Cyclopentene, 4,4-dimethyl-	0.20
Cyclopentene, 3-undecyl-	0.20
1,3,5-Hexatriene, 3-methyl-	0.17
1-Heptene, 2-methyl-	0.81
1-Octene	1.40
2-Octene	0.19
Cyclohexene, 1,2-dimethyl-	0.34
3-Heptene	0.30
1-Heptene, 2,6-dimethyl-	0.27
1-Nonene	0.87
Cyclopropene, 1-butyl-2-ethyl-	0.17
3-Octyne, 5-methyl-	0.17
1-Decene	1.77
D-Limonene	0.32
1-Undecene	2.19
1-Dodecene	1.36
6-Dodecene	0.28
Cycloundecene, 1-methyl-	0.31
1-Octene, 3,7-dimethyl-	0.19
1-Heptene, 2,6-dimethyl-	0.23
5-Tetradecene	0.94
3-Dodecyne	0.53
Cyclohexene, 1-butyl-	0.24
5-Dodecyne	0.18
Cyclohexene, 1,6-dimethyl-	0.17
5-Octadecene	0.43

3-Eicosene	0.64
1-Octadecene	0.24
5-Octadecene	0.24
8-Hexadecyne	0.23
1-Octadecene	0.23
Ethylidenecyclobutane	0.21
Cycloxygenated organics	0.52
2-Cyclopenten-1-one, 2-methyl-	0.52
Others	2.16
2-Propanone, 1-(acetyloxy)-	0.42
1-Octanol, 2-butyl-	0.18
Longifolenaldehyde	0.30
1-Dodecanol, 3,7,11-trimethyl-	0.36
Docosanol	0.18
1-Heptacosanol	0.18
1-Decanol, 2-hexyl-	0.19
P-Menth-8(10)-en-9-ol, cis-	0.18
Methyl-8-hexadecyn-1-ol	0.17
Total	54.80

Table S21. Composition of bio-oil obtained from experiment E15 on moisture free basis.

Product	Composition (area%)
Furan derivatives	3.40
Furan, 2,5-dimethyl-	0.22
Furfural	2.37
2-Furanmethanol	0.16
Ethanone, 1-(2-furanyl)-	0.24
2-Furancarboxaldehyde, 5-methyl-	0.41
Single ring aromatic hydrocarbons	9.55
Toluene	3.68
P-Xylene	2.96
Benzene, 1,2,3-trimethyl-	0.15
Benzene, 1-ethyl-2-methyl-	2.59
1,1'-Biphenyl, 2-methyl-	0.17
Polycyclic aromatic hydrocarbons	5.32
Azulene	0.22
Naphthalene	2.02
Naphthalene, 2-methyl-	2.55
Phenanthrene, 9,10-dihydro-1-methyl-	0.32

9H-Fluorene, 9-methylene-	0.21
Phenol derivatives	3.39
Phenol	0.18
P-Cresol	0.26
Phenol, 2-methoxy-	1.59
Phenol, 2,3-dimethyl-	0.63
Phenol, 4-ethyl-	0.30
2-Methoxy-4-vinylphenol	0.43
Saturated aliphatic hydrocarbons	6.12
Tridecane	0.22
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	3.00
2-methyltetracosane	0.16
Cyclohexane, 1,1'-(1,2-dimethyl-1,2-ethanediyl)-	0.86
Heneicosane	0.43
Octadecane	0.48
Hexadecane	0.49
Octadecane, 2,6,10,14-tetramethyl-	0.48
Unsaturated aliphatic hydrocarbons	7.04
1-Nonene	0.28
1,3-Hexadiene, 3-ethyl-2-methyl-	0.16
1-Undecene	0.36
4-Octyne, 2-methyl-	0.29
1-Dodecene	0.28
8-Hexadecyne	0.28
1-Nonadecene	0.36
8-Hexadecyne	0.38
9-Hexacosene	0.42
1-Hexacosene	0.42
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	3.81
Cyclooxxygenated organics	3.66
Cyclopentanone	0.31
2-Cyclopenten-1-one, 2-methyl-	0.97
Cyclopentanone	0.16
1,2-Cyclopentanedione	0.15
2-Cyclopenten-1-one, 3-methyl-	1.00
1,2-Cyclopentanedione, 3-methyl-	0.84
4-Ethyl-2-hydroxycyclopent-2-en-1-one	0.23
Others	9.00
Acetic acid	0.60
2-Propanone, 1-hydroxy-	3.59
3-Buten-2-one, 3-methyl-	0.28

Propanoic acid	0.31
3-Penten-2-one	0.45
1,2-Ethanediol, diacetate	1.21
4-Ethylbenzoic acid, benzyl ester	0.14
Benzene, 1,3,5-trimethoxy-	0.18
Benzaldehyde, 4,6-dihydroxy-2,3-dimethyl	0.20
3,3-Dimethyl-hepta-4,5-dien-2-ol	0.28
8-Hexadecenal, 14-methyl-	0.40
Nonahexacontanoic acid	0.42
1-Hexacosanol	0.41
Maltol	0.32
1H-Benzimidazole, 2-ethyl-	0.21
Total	47.48

Table S22. Composition of bio-oil obtained from experiment E16 on moisture free basis.

Product	Composition (area%)
Furan derivatives	6.46
Furfural	3.78
Furan, 2,5-dihydro-2,2-dimethyl-5-(1-methylethenyl)-3-methylethyl-	0.30
Butyrolactone	0.16
Furan, 2,5-dimethyl-	0.17
Ethanone, 1-(2-furanyl)-	0.32
2-Furancarboxaldehyde, 5-methyl-	1.73
Single ring aromatic hydrocarbons	5.45
Benzene, 1-propynyl-	0.33
Benzene, 1-butynyl-	1.06
P-Xylene	1.20
Benzene, 1-ethyl-3-methyl-	1.14
(1-Methylbuta-1,3-dienyl)benzene	0.13
Toluene	1.21
Ethylbenzene	0.38
Polycyclic aromatic hydrocarbons	2.19
Naphthalene	1.23
Naphthalene, 1-methyl-	0.96
Phenol derivatives	2.29
Phenol, 2-methoxy-	0.25
Phenol	0.63
P-Cresol	1.20

Phenol, 4-ethyl-	0.21
Saturated aliphatic hydrocarbons	5.24
Octadecane	0.49
Hexadecane, 2,6,10,14-tetramethyl-	0.43
Cyclobutane, 1,2-diethyl-, trans-	0.17
Eicosane	0.25
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	3.50
Cyclopentane, 1-pentyl-2-propyl-	0.27
Cyclooctane, 1,4-dimethyl-, cis-	0.13
Unsaturated aliphatic hydrocarbons	11.44
1,3,5,7-Cyclooctatetraene	1.24
12-Pentacosene	0.93
7-Tetradecyne	0.12
6-Dodecyne	0.15
4-Undecene	0.15
1-Octene	0.18
1-Nonene	0.49
1-Nonadecene	0.47
1-Eicosene	0.13
1-Dodecene	0.58
1-Docosene	0.47
1-Decene	0.57
1,3-Hexadien-5-yne	1.09
7-Tetradecene	0.17
1-Hexacosene	0.36
1-Heptene	0.29
1,4-Cyclohexadiene, 3-ethenyl-1,2-dimethyl	0.22
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	3.83
Cycloxygenated organics	1.55
2-Cyclopenten-1-one, 3-methyl-	0.37
2-Cyclopenten-1-one, 2-methyl-	0.78
2-Cyclopenten-1-one, 2,3-dimethyl-	0.40
Others	3.06
3,3-Dimethyl-hepta-4,5-dien-2-ol	0.46
2-Propenal, 2-methyl-3-phenyl-	0.24
1-Undecanol	1.30
3-Penten-2-one	0.25
1,2-Ethanediol, diacetate	0.32
4-Ethylbenzoic acid, benzyl ester	0.21
3-Penten-2-one	0.28

Total	37.68
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Table S23. Composition of bio-oil obtained from experiment E17 on moisture free basis.

Product	Composition (area%)
Furan derivatives	6.84
Furan, 2,3-dihydro-3-methyl-	0.71
Furan, 2,5-dimethyl-	0.37
Furfural	4.57
Ethanone, 1-(2-furanyl)-	0.42
Butyrolactone	0.34
Benzofuran, 2,3-dihydro-	0.13
2-Furancarboxaldehyde, 5-methyl-	0.30
Single ring aromatic hydrocarbons	6.41
Toluene	3.24
Ethylbenzene	0.32
P-Xylene	1.65
Benzene, 1,2,3-trimethyl-	0.66
Benzene, 1-ethenyl-3-methyl-	0.16
Benzene, 1-propynyl-	0.25
Hexa-2,4-dienylbenzene	0.13
Polycyclic aromatic hydrocarbons	3.77
Naphthalene	1.03
Naphthalene, 2,6-bis(1,1-dimethylethyl)-	0.35
2-Ethyl-1-H-indene	0.15
Naphthalene, 2-methyl-	1.17
Naphthalene, 1,7-dimethyl-	0.21
7-Methanoazulene, octahydro-1,4,9,9-tetramethyl	0.33
Anthracene	0.53
Phenol derivatives	5.26
Phenol	0.81
P-Cresol	2.41
Phenol, 2-methoxy-	0.49
Phenol, 2,4-dimethyl-	0.68
Phenol, 4-ethyl-	0.39
2-Methoxy-4-vinylphenol	0.48
Saturated aliphatic hydrocarbons	6.02
Cyclopropane, pentyl-	0.18
Cyclopropane, octyl-	0.41
Decane, 2,3,5-trimethyl-	0.24

Heptadecane	0.19
Pentadecane, 2-methyl-	0.33
Cyclopentane, (2-hexyloctyl)-	0.36
Nonadecane	0.39
Cyclohexane, 1,2-dimethyl-3-pentyl-4-propyl-	3.92
Unsaturated aliphatic hydrocarbons	12.12
1-Heptene	0.18
1-Nonene	0.27
1-Decene	0.32
4-Octyne, 2-methyl-	0.16
1-Dodecene	0.39
5-Tetradecene	0.14
1-Tridecene	0.44
Cyclohexene, 1,2-dimethyl-	0.13
Camphene	0.14
7-Hexadecyne	0.12
1-Nonadecene	0.89
1-Hexacosene	0.89
Cyclopropane, trimethylmethylene-	0.13
2,6,10,14-Tetramethyl-7-(3-methylpent-4-enylidene) pentadecane	7.92
Cycloxygenated organics	1.07
2-Cyclopenten-1-one, 2-methyl-	0.94
Cyclohexaneethanol, 4-methyl-.beta-methylene	0.13
Others	5.81
2-Propanone, 1-hydroxy-	2.48
3-Penten-2-one	0.23
2-Penten-1-ol	0.15
1,2-Ethandiol, diacetate	0.85
Cis-1-Ethoxy-1-butene	0.17
2-Butanone, 1-(acetyloxy)-	0.53
1-Dodecanol	0.19
Maltol	0.36
1H-Indazole, 3,6-dimethyl-	0.35
1-(4-Tert-Butylphenyl)propan-2-one	0.15
3,3-Dimethyl-hepta-4,5-dien-2-ol	0.35
Total	47.30

Table S24. C, H and O content in MSW feed and bio-oil. Reaction conditions correspond to 1:1 wt./wt. of MSW:graphite

Feedstock	Feed composition (%)			Bio-oil composition (%)		
	C	H	O	C	H	O
MSW-A	53.26	8.01	37.96	82.9	11.38	5.71
MSW-B	59.65	9.37	30.37	84.64	12	3.36
MSW-C	51.19	7.67	40.52	80.63	11.2	8.17
MSW-D	51.73	7.56	39.95	83.05	11.51	5.45
MSW-E	50.47	7.45	41.01	82.2	11.1	6.7

C, H and O content in bio-oil was evaluated by calculating C, H and O yields of the bio-oil components from GC/MS data.