

TABLE OF CONTENTS

1 RESEARCH METHODOLOGY.....	71
1.1 Technology Readiness Level (TRL)	71
2 INTRODUCTION	74
2.1 Aims and objectives of the study	74
2.2 Market definition.....	74
2.2.1 Properties of nanomaterials	74
2.3 Categorization of engineered nanomaterials	75
3 THE GLOBAL MARKET FOR ENGINEERED NANOMATERIALS..	77
3.1 Production, manufacturing and consumption of engineered nanomaterials.....	77
3.2 Environmental emissions of nanomaterials	81
3.2.1 Emissions and exposures of nanomaterials	82
3.2.2 Life cycle assessment.....	87
3.2.3 Nanomaterials for Carbon Capture and Utilization.....	97
3.3 ALUMINIUM OXIDE NANOPARTICLES/POWDERS.....	101
3.3.1 Market overview.....	101
3.3.2 Properties	102
3.3.3 Markets and applications.....	103
3.3.4 Technology Readiness Level (TRL)	104
3.3.5 Global consumption in metric tonnes, 2010-2033.....	105
3.3.5.1 Consumption by market	107
3.3.5.1.1 Market segmentation 2021 (%).....	107
3.3.5.1.2 Market segmentation 2021 (MT).....	108
3.3.5.1.3 Market segmentation 2033 (%).....	108
3.3.5.1.4 Market share 2033 (MT)	109
3.3.5.2 Consumption by region	109

3.3.5.2.1	Consumption by region 2021 (%).....	109
3.3.5.2.2	Consumption by region 2021 (MT).....	110
3.3.5.2.3	Consumption by region 2033 (%).....	110
3.3.5.2.4	Consumption by region 2033 (MT).....	111
3.3.6	Prices.....	111
3.3.7	Producers.....	111
3.4	ANTIMONY TIN OXIDE NANOPARTICLES/POWDERS.....	114
3.4.1	Market overview.....	114
3.4.2	Properties.....	115
3.4.3	Markets and applications.....	115
3.4.4	Technology Readiness Level (TRL).....	116
3.4.5	Global consumption in metric tonnes, 2010-2033.....	116
3.4.5.1	Consumption by market.....	118
3.4.5.1.1	Market segmentation 2021 (%).....	118
3.4.5.1.2	Market Segmentation 2021 (MT).....	119
3.4.5.1.3	Market share 2033 (%).....	119
3.4.5.1.4	Market share 2033 (MT).....	119
3.4.5.2	Consumption by region.....	120
3.4.5.2.1	Consumption by region 2021 (%).....	120
3.4.5.2.2	Consumption by region 2021 (MT).....	120
3.4.5.2.3	Consumption by region 2033 (%).....	121
3.4.5.2.4	Consumption by region 2033 (MT).....	121
3.4.6	Prices.....	122
3.4.7	Producers.....	122
3.5	BISMUTH OXIDE NANOPARTICLES/POWDERS.....	125
3.5.1	Market overview.....	125
3.5.2	Properties.....	125
3.5.3	Markets and applications.....	126

3.5.4	Technology Readiness Level (TRL)	127
3.5.5	Global consumption in metric tonnes, 2010-2033.....	128
3.5.5.1	Consumption by market	130
3.5.5.1.1	Market segmentation 2021 (%).....	130
3.5.5.1.2	Market Segmentation 2021 (MT)	130
3.5.5.1.3	Market share 2033 (%)	131
3.5.5.1.4	Market share 2033(MT)	131
3.5.5.2	Consumption by region	132
3.5.5.2.1	Consumption by region 2021 (%).....	132
3.5.5.2.2	Consumption by region 2021 (MT).....	132
3.5.5.2.3	Consumption by region 2033 (%).....	133
3.5.5.2.4	Consumption by region 2033 (MT).....	133
3.5.6	Prices.....	134
3.5.7	Producers	134
3.6	CELLULOSE NANOFIBERS.....	136
3.6.1	Market overview.....	136
3.6.2	Properties	137
3.6.3	Markets and applications.....	139
3.6.4	Products.....	140
3.6.5	Technology Readiness Level (TRL)	147
3.6.6	Global consumption in metric tonnes, 2010-2033.....	148
3.6.6.1	Consumption by market	151
3.6.6.1.1	Market segmentation 2021 (%).....	151
3.6.6.1.2	Market Segmentation 2021 (MT)	151
3.6.6.1.3	Market share 2033 (%)	152
3.6.6.1.4	Market share 2033 (MT)	153
3.6.6.2	Consumption by region	154
3.6.6.2.1	Consumption by region 2021 (%).....	154

3.6.6.2.2	Consumption by region 2021 (MT).....	154
3.6.6.2.3	Consumption by region 2033 (%).....	155
3.6.6.2.4	Consumption by region 2033 (MT).....	155
3.6.7	Prices.....	155
3.6.8	Producers	157
3.7	CERIUM OXIDE NANOPARTICLES/POWDERS.....	163
3.7.1	Market overview.....	163
3.7.2	Properties	164
3.7.3	Markets and applications.....	164
3.7.4	Technology Readiness Level (TRL)	166
3.7.5	Global consumption in metric tonnes, 2010-2033.....	166
3.7.5.1	Consumption by market	168
3.7.5.1.1	Market segmentation 2021 (%).....	168
3.7.5.1.2	Market Segmentation 2021 (MT)	168
3.7.5.1.3	Market share 2033 (%)	169
3.7.5.1.4	Market share 2033(MT)	169
3.7.5.2	Consumption by region	170
3.7.5.2.1	Consumption by region 2021 (%).....	170
3.7.5.2.2	Consumption by region 2021 (MT).....	170
3.7.5.2.3	Consumption by region 2033 (%).....	171
3.7.5.2.4	Consumption by region 2033 (MT).....	171
3.7.6	Prices.....	172
3.7.7	Producers	172
3.8	COBALT OXIDE NANOPARTICLES/POWDERS	174
3.8.1	Market overview.....	174
3.8.2	Properties	175
3.8.3	Markets and applications.....	175
3.8.4	Technology Readiness Level (TRL)	176

3.8.5	Global consumption in metric tonnes, 2010-2033.....	176
3.8.5.1	Consumption by market	178
3.8.5.1.1	Market segmentation 2021 (%).....	178
3.8.5.1.2	Market Segmentation 2021 (MT)	178
3.8.5.1.3	Market share 2033(%)	179
3.8.5.1.4	Market share 2033 (MT)	179
3.8.5.2	Consumption by region	180
3.8.5.2.1	Consumption by region 2021 (%).....	180
3.8.5.2.2	Consumption by region 2021 (MT).....	180
3.8.5.2.3	Consumption by region 2033 (%).....	181
3.8.5.2.4	Consumption by region 2033 (MT).....	181
3.8.6	Prices.....	182
3.8.7	Producers	182
3.9	COPPER OXIDE NANOPARTICLES/POWDERS.....	183
3.9.1	Market overview.....	183
3.9.2	Properties	184
3.9.3	Markets and applications.....	184
3.9.4	Technology Readiness Level (TRL)	186
3.9.5	Global consumption in metric tonnes, 2010-2033.....	186
3.9.5.1	Consumption by market	188
3.9.5.1.1	Market segmentation 2021 (%).....	188
3.9.5.1.2	Market Segmentation 2021 (MT)	188
3.9.5.1.3	Market share 2033(%)	189
3.9.5.1.4	Market share 2033 (MT)	189
3.9.5.2	Consumption by region	190
3.9.5.2.1	Consumption by region 2021 (%).....	190
3.9.5.2.2	Consumption by region 2021 (MT).....	191
3.9.5.2.3	Consumption by region 2033 (%).....	191

3.9.5.2.4	Consumption by region 2033 (MT).....	192
3.9.6	Prices.....	192
3.9.7	Producers	193
3.10	DENDRIMERS	195
3.10.1	Market overview.....	195
3.10.2	Properties	196
3.10.2.1	Types.....	196
3.10.3	Markets and applications.....	198
3.10.4	Technology Readiness Level (TRL)	199
3.10.5	Global consumption in metric tonnes, 2010-2033.....	199
3.10.5.1	Consumption by market	201
3.10.5.1.1	Market segmentation 2021 (%).....	201
3.10.5.1.2	Market Segmentation 2021 (MT)	201
3.10.5.1.3	Market share 2033 (%).....	202
3.10.5.1.4	Market share 2033 (MT)	202
3.10.5.2	Consumption by region	203
3.10.5.2.1	Consumption by region 2021 (%)	203
3.10.5.2.2	Consumption by region 2021 (MT)	203
3.10.5.2.3	Consumption by region 2033 (%)	204
3.10.5.2.4	Consumption by region 2033(MT)	204
3.10.6	Prices.....	205
3.10.7	Producers	205
3.11	FULLERENES.....	207
3.11.1	Market overview.....	207
3.11.2	Properties	208
3.11.3	Products.....	208
3.11.4	Markets and applications.....	209
3.11.5	Technology Readiness Level (TRL)	210

3.11.6	Global consumption in metric tonnes, 2010-2033.....	210
3.11.6.1	Consumption by market	212
3.11.6.1.1	Market segmentation 2021 (%).....	212
3.11.6.1.2	Market Segmentation 2021 (MT)	212
3.11.6.1.3	Market share 2033 (%)	213
3.11.6.1.4	Market share 2033 (MT)	213
3.11.6.2	Demand by region.....	214
3.11.6.2.1	Consumption by region 2021 (%)	214
3.11.6.2.2	Consumption by region 2021 (MT)	214
3.11.6.2.3	Consumption by region 2033 (%)	215
3.11.6.2.4	Consumption by region 2033(MT)	215
3.11.7	Prices.....	216
3.11.8	Producers	216
3.12	GOLD NANOPARTICLES/POWDERS (Au-NPs).....	219
3.12.1	Market overview.....	219
3.12.2	Properties	220
3.12.3	Markets and applications.....	220
3.12.4	Technology Readiness Level (TRL)	221
3.12.5	Global consumption in metric tonnes, 2010-2033.....	222
3.12.5.1	Consumption by market	223
3.12.5.1.1	Market segmentation 2021 (%).....	224
3.12.5.1.2	Market Segmentation 2021 (MT)	224
3.12.5.1.3	Market share 2033 (%)	225
3.12.5.1.4	Market share 2033 (MT)	225
3.12.5.2	Consumption by region	225
3.12.5.2.1	Consumption by region 2021 (%)	226
3.12.5.2.2	Consumption by region 2021 (MT)	226
3.12.5.2.3	Consumption by region 2033 (%)	227

3.12.5.2.4	Consumption by region 2033 (MT)	227
3.12.6	Prices	228
3.12.7	Producers	228
3.13	GRAPHENE	231
3.13.1	Market overview	231
3.13.2	Properties	232
3.13.3	Markets and applications.....	233
3.13.4	Technology Readiness Level (TRL)	242
3.13.5	Products.....	243
3.13.6	Global consumption in metric tonnes, 2010-2033.....	246
3.13.6.1	Consumption by market	250
3.13.6.1.1	Market segmentation 2021 (%).....	250
3.13.6.1.2	Market share 2033 (%)	251
3.13.6.2	Consumption by region	252
3.13.6.2.1	Consumption by region 2021 (%)	253
3.13.6.2.2	Consumption by region 2021 (MT)	253
3.13.6.2.3	Consumption by region 2033 (%)	254
3.13.6.2.4	Consumption by region 2033 (MT)	254
3.13.7	Prices.....	255
3.13.8	Producers	255
3.14	IRON OXIDE NANOPARTICLES/POWDERS	266
3.14.1	Market overview	266
3.14.2	Properties	267
3.14.3	Markets and applications.....	267
3.14.4	Technology Readiness Level (TRL)	268
3.14.5	Global consumption in metric tonnes, 2010-2033.....	269
3.14.5.1	Consumption by market	271
3.14.5.1.1	Market segmentation 2021 (%).....	271

3.14.5.1.2	Market Segmentation 2021 (MT)	271
3.14.5.1.3	Market share 2033 (%)	272
3.14.5.1.4	Market share 2033 (MT)	272
3.14.5.2	Consumption by region	273
3.14.5.2.1	Consumption by region 2021 (%)	273
3.14.5.2.2	Consumption by region 2021 (MT)	273
3.14.5.2.3	Consumption by region 2033 (%)	274
3.14.5.2.4	Consumption by region 2033 (MT)	274
3.14.6	Prices	275
3.14.7	Producers	275
3.15	MAGNESIUM OXIDE NANOPARTICLES/POWDERS	279
3.15.1	Market overview	279
3.15.2	Properties	279
3.15.3	Markets and applications	280
3.15.4	Technology Readiness Level (TRL)	281
3.15.5	Global consumption in metric tonnes, 2010-2033	281
3.15.5.1	Consumption by market	283
3.15.5.1.1	Market segmentation 2021 (%)	283
3.15.5.1.2	Market Segmentation 2021 (MT)	283
3.15.5.1.3	Market share 2033 (%)	284
3.15.5.1.4	Market share 2033 (MT)	284
3.15.5.2	Consumption by region	285
3.15.5.2.1	Consumption by region 2021 (%)	285
3.15.5.2.2	Consumption by region 2021 (MT)	285
3.15.5.2.3	Consumption by region 2033 (%)	286
3.15.5.2.4	Consumption by region 2033 (MT)	286
3.15.6	Prices	287
3.15.7	Producers	287

3.16	MANGANESE OXIDE NANOPARTICLES/POWDERS.....	290
3.16.1	Market overview.....	290
3.16.2	Properties	290
3.16.3	Markets and applications.....	291
3.16.4	Technology Readiness Level (TRL)	291
3.16.5	Global consumption in metric tonnes, 2010-2033.....	292
3.16.5.1	Consumption by market	294
3.16.5.1.1	Market segmentation 2021 (%).....	294
3.16.5.1.2	Market Segmentation 2021 (MT).....	294
3.16.5.1.3	Market share 2033 (%).....	295
3.16.5.1.4	Market share 2033 (MT).....	295
3.16.5.2	Consumption by region	296
3.16.5.2.1	Consumption by region 2021 (%)	296
3.16.5.2.2	Consumption by region 2021 (MT)	296
3.16.5.2.3	Consumption by region 2033 (%)	297
3.16.5.2.4	Consumption by region 2033 (MT)	297
3.16.6	Prices.....	298
3.16.7	Producers	298
3.17	MULTI-WALLED CARBON NANOTUBES (MWCNT).....	299
3.17.1	Market overview.....	299
3.17.2	Properties	300
3.17.3	Markets and applications.....	301
3.17.4	Technology Readiness Level (TRL)	306
3.17.5	Global consumption in metric tonnes, 2010-2033.....	307
3.17.5.1	Consumption by market	309
3.17.5.1.1	Market segmentation 2021 (%).....	309
3.17.5.1.2	Market Segmentation 2021 (MT).....	311
3.17.5.1.3	Market share 2033 (%).....	312

3.17.5.1.4	Market share 2033 (MT)	313
3.17.5.2	Consumption by region	313
3.17.5.2.1	Consumption by region 2021 (%)	314
3.17.5.2.2	Consumption by region 2033 (MT)	314
3.17.5.2.3	Consumption by region 2033 (%)	315
3.17.5.2.4	Consumption by region 2033(MT)	315
3.17.6	Prices.....	316
3.17.7	Producers	317
3.18	NANOCLAYS	323
3.18.1	Market overview.....	323
3.18.2	Properties	323
3.18.3	Markets and applications.....	324
3.18.4	Technology Readiness Level (TRL)	326
3.18.5	Global consumption in metric tonnes, 2010-2033.....	326
3.18.5.1	Consumption by market	327
3.18.5.1.1	Market segmentation 2021 (%).....	328
3.18.5.1.2	Market Segmentation 2021 (MT)	328
3.18.5.1.3	Market share 2033 (%)	329
3.18.5.1.4	Market share 2033 (MT)	329
3.18.5.2	Consumption by region	330
3.18.5.2.1	Consumption by region 2021 (%)	330
3.18.5.2.2	Consumption by region 2021 (MT)	330
3.18.5.2.3	Consumption by region 2033 (%)	331
3.18.5.2.4	Consumption by region 2033 (MT)	331
3.18.6	Prices.....	332
3.18.7	Producers	332
3.19	NANODIAMONDS.....	335
3.19.1	Market overview.....	335

3.19.2	Properties	335
3.19.2.1	Types	336
3.19.2.2	Fluorescent nanodiamonds (FNDs).....	338
3.19.3	Markets and applications.....	339
3.19.4	Technology Readiness Level (TRL)	342
3.19.5	Global consumption in metric tonnes, 2010-2033.....	343
3.19.5.1	Consumption by market	344
3.19.5.1.1	Market segmentation 2021 (%).....	344
3.19.5.1.2	Market Segmentation 2021 (MT)	344
3.19.5.1.3	Market share 2033 (%)	345
3.19.5.1.4	Market share 2033 (MT)	345
3.19.5.2	Consumption by region	346
3.19.5.2.1	Consumption by region 2021 (%)	346
3.19.5.2.2	Consumption by region 2021 (MT)	346
3.19.5.2.3	Consumption by region 2033 (%)	347
3.19.5.2.4	Consumption by region 2033 (MT)	347
3.19.6	Prices.....	348
3.19.7	Producers	349
3.20	NANOFIBERS	353
3.20.1	Market overview	353
3.20.2	Properties	353
3.20.2.1	Types	354
3.20.2.1.1	Synthetic polymer nanofibers	355
3.20.2.1.2	Alumina nanofibers.....	360
3.20.2.1.3	Carbon nanofibers.....	360
3.20.2.1.4	Natural polymers	361
3.20.2.1.5	Silicon nanofibers	362
3.20.3	Markets and applications.....	362

3.20.4	Technology Readiness Level (TRL)	363
3.20.5	Global consumption in metric tonnes, 2010-2033.....	364
3.20.5.1	Consumption by market	366
3.20.5.1.1	Market segmentation 2021 (%).....	366
3.20.5.1.2	Market Segmentation 2021 (MT)	366
3.20.5.1.3	Market share 2033 (%).....	367
3.20.5.1.4	Market share 2033 (MT)	367
3.20.5.2	Consumption by region	368
3.20.5.2.1	Consumption by region 2021 (%)	368
3.20.5.2.2	Consumption by region 2021 (MT)	368
3.20.5.2.3	Consumption by region 2033 (%)	369
3.20.5.2.4	Consumption by region 2033 (MT)	369
3.20.6	Producers	370
3.21	NANOSILVER	376
3.21.1	Market overview.....	376
3.21.2	Properties	376
3.21.3	Markets and applications.....	377
3.21.4	Technology Readiness Level (TRL)	378
3.21.5	Global consumption in metric tonnes, 2010-2033.....	379
3.21.5.1	Consumption by market	381
3.21.5.1.1	Market segmentation 2021 (%).....	381
3.21.5.1.2	Market Segmentation 2021 (MT)	381
3.21.5.1.3	Market share 2033 (%).....	382
3.21.5.1.4	Market share 2033 (MT)	382
3.21.5.2	Consumption by region	383
3.21.5.2.1	Consumption by region 2021 (%)	383
3.21.5.2.2	Consumption by region 2021 (MT)	383
3.21.5.2.3	Consumption by region 2033 (%)	384

3.21.5.2.4	Consumption by region 2033 (MT)	384
3.21.6	Prices	385
3.21.7	Producers	385
3.22	NICKEL NANOPARTICLES/POWDERS	388
3.22.1	Market overview	388
3.22.2	Properties	389
3.22.3	Markets and applications.....	389
3.22.4	Technology Readiness Level (TRL)	389
3.22.5	Global consumption in metric tonnes, 2010-2033.....	390
3.22.5.1	Consumption by market	392
3.22.5.1.1	Market segmentation 2021 (%).....	392
3.22.5.1.2	Market Segmentation 2021 (MT)	392
3.22.5.1.3	Market share 2033 (%)	393
3.22.5.1.4	Market share 2033 (MT)	393
3.22.5.2	Consumption by region	394
3.22.5.2.1	Consumption by region 2021 (%)	394
3.22.5.2.2	Consumption by region 2021 (MT)	394
3.22.5.2.3	Consumption by region 2033 (%)	395
3.22.5.2.4	Consumption by region 2033 (MT)	395
3.22.6	Prices.....	396
3.22.7	Producers	396
3.23	QUANTUM DOTS	398
3.23.1	Market overview.....	398
3.23.2	Properties	399
3.23.2.1	Cadmium QDs	400
3.23.2.2	Cadmium-free QDs	400
3.23.3	Markets and applications.....	400
3.23.4	Products.....	402

3.23.5	Technology Readiness Level (TRL)	403
3.23.6	Global consumption in metric tonnes, 2010-2033.....	404
3.23.6.1	Consumption by market	406
3.23.6.1.1	Market segmentation 2021 (%).....	406
3.23.6.1.2	Market Segmentation 2021 (MT)	406
3.23.6.1.3	Market share 2033 (%).....	407
3.23.6.1.4	Market share 2033 (MT)	407
3.23.6.2	Consumption by region	408
3.23.6.2.1	Consumption by region 2021 (%)	408
3.23.6.2.2	Consumption by region 2021 (MT)	408
3.23.6.2.3	Consumption by region 2033 (%)	409
3.23.6.2.4	Consumption by region 2033 (MT)	409
3.23.7	Prices.....	409
3.23.8	Producers	410
3.24	SILICON OXIDE NANOPARTICLES/POWDERS.....	414
3.24.1	Market overview.....	414
3.24.2	Properties	415
3.24.3	Markets and applications.....	415
3.24.4	Technology Readiness Level (TRL)	416
3.24.5	Global consumption in metric tonnes, 2010-2033.....	417
3.24.5.1	Consumption by market	419
3.24.5.1.1	Market segmentation 2021 (%).....	419
3.24.5.1.2	Market Segmentation 2021 (MT)	419
3.24.5.1.3	Market share 2033 (%).....	420
3.24.5.1.4	Market Segmentation 2021 (MT)	420
3.24.5.2	Consumption by region	421
3.24.5.2.1	Consumption by region 2021 (%)	421
3.24.5.2.2	Consumption by region 2021 (MT)	421

3.24.5.2.3	Consumption by region 2033 (%)	422
3.24.5.2.4	Consumption by region 2033 (MT)	422
3.24.6	Prices	422
3.24.7	Producers	423
3.25	SINGLE-WALLED CARBON NANOTUBES (SWCNT)	427
3.25.1	Market overview	427
3.25.2	Properties	428
3.25.3	Markets and applications	431
3.25.4	Technology Readiness Level (TRL)	433
3.25.5	Prices	434
3.25.6	Global consumption in metric tonnes, 2010-2033	435
3.25.7	Producers	436
3.26	TITANIUM DIOXIDE NANOPARTICLES/POWDERS	438
3.26.1	Market overview	438
3.26.2	Properties	439
3.26.2.1	Photocatalytic	439
3.26.2.2	UV-filter	439
3.26.3	Markets and applications	440
3.26.4	Technology Readiness Level (TRL)	441
3.26.5	Global consumption in metric tonnes, 2010-2033	441
3.26.5.1	Consumption by market	443
3.26.5.1.1	Market segmentation 2021 (%)	444
3.26.5.1.2	Market Segmentation 2021 (MT)	444
3.26.5.1.3	Market share 2033 (%)	445
3.26.5.1.4	Market share 2033 (MT)	445
3.26.5.2	Consumption by region	446
3.26.5.2.1	Consumption by region 2021 (%)	446
3.26.5.2.2	Consumption by region 2021 (MT)	446

3.26.5.2.3	Consumption by region 2033 (%)	447
3.26.5.2.4	Consumption by region 2033(MT)	447
3.26.6	Producers	448
3.27	ZINC OXIDE NANOPARTICLES/POWDERS	450
3.27.1	Market overview	450
3.27.2	Properties	451
3.27.3	Markets and applications.....	452
3.27.4	Technology Readiness Level (TRL)	454
3.27.5	Global consumption in metric tonnes, 2010-2033.....	455
3.27.5.1	Consumption by market	457
3.27.5.1.1	Market segmentation 2021 (%).....	458
3.27.5.1.2	Market Segmentation 2021 (MT)	458
3.27.5.1.3	Market share 2033 (%)	459
3.27.5.1.4	Market share 2033 (MT)	459
3.27.5.2	Consumption by region	460
3.27.5.2.1	Consumption by region 2021 (%)	460
3.27.5.2.2	Consumption by region 2021 (MT)	460
3.27.5.2.3	Consumption by region 2033 (%)	461
3.27.5.2.4	Consumption by region 2033 (MT)	462
3.27.6	Producers	462
3.28	ZIRCONIUM OXIDE NANOPARTICLES/POWDERS	465
3.28.1	Market overview	465
3.28.2	Properties	466
3.28.3	Markets and applications.....	466
3.28.4	Technology Readiness Level (TRL)	468
3.28.5	Global consumption in metric tons, 2010-2033.....	468
3.28.5.1	Consumption by market	470
3.28.5.1.1	Market segmentation 2021 (%).....	471

3.28.5.1.2	Market Segmentation 2021 (MT)	471
3.28.5.1.3	Market share 2033 (%)	472
3.28.5.1.4	Market share 2033 (MT)	472
3.28.5.2	Consumption by region	473
3.28.5.2.1	Consumption by region 2021 (%)	473
3.28.5.2.2	Consumption by region 2021 (MT)	473
3.28.5.2.3	Consumption by region 2033 (%)	474
3.28.5.2.4	Consumption by region 2033(MT)	474
3.28.6	Prices	475
3.28.7	Producers	475
3.29	OTHER NANOMATERIALS	480
3.29.1	Carbon Nanohorns (CNHs)	480
3.29.1.1	Properties	480
3.29.1.2	Markets and applications	480
3.29.2	Cellulose nanocrystals	481
3.29.2.1	Synthesis	481
3.29.2.2	Properties	484
3.29.2.3	Markets and applications	485
3.29.2.4	Prices	487
3.29.2.5	Production	487
3.29.2.6	Producers	488
3.29.3	Bacterial nanocellulose (BNC)	490
3.29.3.1	Production	490
3.29.3.2	Applications	492
3.29.3.3	Producers	493
3.29.4	Boron Nitride nanotubes (BNNTs)	494
3.29.4.1	Properties	494
3.29.4.2	Markets and applications	495

3.29.4.3	Prices.....	495
3.29.5	Erbium oxide nanoparticles/nanopowders.....	496
3.29.5.1	Properties, applications, prices and producers.....	496
3.29.6	Indium oxide nanoparticles/powders.....	497
3.29.6.1	Properties.....	497
3.29.7	Molybdenum nanoparticles/powders.....	497
3.29.7.1	Properties.....	497
3.29.8	Perovskite quantum dots.....	498
3.29.8.1	Properties.....	498
3.29.8.1.1	Comparison to conventional quantum dots.....	499
3.29.8.2	Synthesis methods.....	500
3.29.8.3	Applications.....	500
3.29.8.3.1	Displays.....	501
3.29.9	Carbon quantum dots (CDs).....	503
3.29.9.1	Properties.....	503
3.29.9.2	Markets and applications.....	504
3.29.10	Graphene quantum dots.....	505
3.29.10.1	Composition.....	506
3.29.10.2	Comparison to quantum dots.....	506
3.29.10.3	Properties.....	507
3.29.10.4	Synthesis.....	507
3.29.10.4.1	Top-down method.....	508
3.29.10.4.2	Bottom-up method.....	508
3.29.10.4.3	Comparison of synthesis methods.....	509
3.29.10.5	Markets and applications.....	510
3.29.10.6	Producers.....	513
3.30	OTHER 2D MATERIALS.....	515
3.30.1	Comparative analysis of graphene and other 2D materials.....	518

3.30.2	Production methods	519
3.30.2.1	Top-down exfoliation	520
3.30.2.2	Mechanical exfoliation method	521
3.30.2.3	Liquid exfoliation method.....	521
3.30.3	Bottom-up synthesis.....	521
3.30.3.1	Chemical synthesis in solution	521
3.30.3.2	Chemical vapor deposition	521
3.30.4	Types of 2D materials	522
3.30.4.1	Hexagonal boron-nitride (h-BN)/boron nitride nanosheets (BNNSs).....	522
3.30.4.1.1	Properties.....	522
3.30.4.1.2	Applications and markets	524
3.30.4.2	MXenes.....	525
3.30.4.2.1	Properties.....	525
3.30.4.2.2	Applications.....	526
3.30.4.3	Transition metal dichalcogenides (TMD)	528
3.30.4.3.1	Properties.....	528
3.30.4.3.2	Molybdenum disulphide (MoS ₂)	528
3.30.4.3.3	Tungsten ditelluride (WTe ₂)	529
3.30.4.4	Borophene	532
3.30.4.4.1	Properties.....	532
3.30.4.4.2	Applications.....	532
3.30.4.5	Phosphorene/ Black phosphorus.....	533
3.30.4.5.1	Properties.....	533
3.30.4.5.2	Applications.....	534
3.30.4.6	Graphitic carbon nitride (g-C ₃ N ₄).....	537
3.30.4.6.1	Properties.....	537
3.30.4.6.2	C ₂ N	537
3.30.4.6.3	Applications.....	537

3.30.4.7	Germanene.....	538
3.30.4.7.1	Properties.....	539
3.30.4.7.2	Applications.....	540
3.30.4.8	Graphdiyne	541
3.30.4.8.1	Properties.....	541
3.30.4.8.2	Applications.....	542
3.30.4.9	Graphane.....	544
3.30.4.9.1	Properties.....	544
3.30.4.9.2	Applications.....	544
3.30.4.10	Rhenium disulfide (ReS ₂) and diselenide (ReSe ₂)	545
3.30.4.10.1	Properties.....	545
3.30.4.10.2	Applications.....	545
3.30.4.11	Silicene.....	545
3.30.4.11.1	Properties.....	546
3.30.4.11.2	Applications.....	546
3.30.4.12	Stanene/tinene	548
3.30.4.12.1	Properties.....	548
3.30.4.12.2	Applications.....	548
3.30.4.13	Antimonene	549
3.30.4.13.1	Properties.....	549
3.30.4.13.2	Applications.....	549
3.30.4.14	Indium selenide	550
3.30.4.14.1	Properties.....	550
3.30.4.14.2	Applications.....	550
3.30.4.15	Layered double hydroxides (LDH)	551
3.30.4.15.1	Properties.....	551
3.30.4.15.2	Applications.....	551
3.30.5	2D Materials producers and suppliers	553

4 MARKETS FOR NANOTECHNOLOGY AND ENGINEERED NANOMATERIALS..... 555

4.1	ADHESIVES	555
4.1.1	Market drivers	555
4.1.2	Markets and applications.....	556
4.1.2.1	Properties	557
4.1.2.2	End user markets.....	558
4.1.2.3	Nanomaterials in adhesives	558
4.1.3	Technology Readiness Level (TRL)	560
4.1.4	Global revenues to 2033	562
4.1.5	Product developers	563
4.2	AEROSPACE AND AVIATION.....	566
4.2.1	Market drivers	567
4.2.2	Markets and applications.....	569
4.2.2.1	Composites.....	570
4.2.2.2	Coatings.....	572
4.2.3	Technology Readiness Level (TRL)	575
4.2.4	Global revenues to 2033	576
4.2.5	Product developers	578
4.3	AUTOMOTIVE	584
4.3.1	Market drivers	584
4.3.2	Markets and applications.....	586
4.3.2.1	Composites.....	587
4.3.2.2	Paints and coatings.....	590
4.3.2.3	Tires.....	593
4.3.3	Technology Readiness Level (TRL)	594
4.3.4	Global revenues to 2033	595
4.3.5	Product developers	599

4.4	BATTERIES	610
4.4.1	Market drivers	610
4.4.2	Markets and applications.....	611
4.4.2.1	Lithium-ion batteries (LIB)	612
4.4.2.2	Nanomaterials in Lithium–sulfur (Li–S) batteries	617
4.4.2.3	Sodium-ion batteries	618
4.4.2.4	Lithium-air batteries.....	619
4.4.2.5	Magnesium batteries.....	620
4.4.3	Technology Readiness Level (TRL)	620
4.4.4	Global revenues to 2033	621
4.4.5	Product developers	625
4.5	BIOMEDICINE AND HEALTHCARE	636
4.5.1	Medical biosensors	637
4.5.1.1	Market drivers and trends.....	637
4.5.1.2	Applications.....	638
4.5.1.3	Technology Readiness Level (TRL)	640
4.5.1.4	Global revenues to 2033	640
4.5.1.5	Product developers	642
4.5.2	Drug formulation and delivery	644
4.5.2.1	Market drivers	644
4.5.2.2	Applications.....	645
4.5.2.2.1	Products	651
4.5.2.3	Technology Readiness Level (TRL)	656
4.5.2.4	Global revenues to 2033	657
4.5.2.5	Product developers	659
4.5.3	Medical imaging and diagnostics.....	666
4.5.3.1	Market drivers	666
4.5.3.2	Applications.....	668

4.5.3.3	Technology Readiness Level (TRL)	671
4.5.3.4	Global revenues to 2033	671
4.5.3.5	Product developers	673
4.5.4	Medical coatings and films	678
4.5.4.1	Market drivers	678
4.5.4.2	Applications.....	680
4.5.4.3	Technology Readiness Level (TRL)	684
4.5.4.4	Global revenues to 2033	685
4.5.4.5	Product developers	686
4.5.5	Medical implants	692
4.5.5.1	Market drivers	692
4.5.5.2	Applications.....	693
4.5.5.3	Technology Readiness Level (TRL)	695
4.5.5.4	Global revenues to 2033	695
4.5.5.5	Product developers	697
4.5.6	Wound care.....	699
4.5.6.1	Market drivers	699
4.5.6.2	Applications.....	700
4.5.6.3	Products.....	701
4.5.6.4	Technology Readiness Level (TRL)	702
4.5.6.5	Global revenues to 2033	702
4.5.6.6	Product developers	704
4.5.7	Dental	706
4.5.7.1	Market drivers	706
4.5.7.2	Applications.....	706
4.5.7.3	Technology Readiness Level (TRL)	707
4.5.7.4	Global revenues to 2033	708
4.5.7.5	Product developers	709

4.6	COATINGS AND PAINTS	711
4.6.1	Market drivers	711
4.6.2	Markets and applications.....	713
4.6.3	Technology Readiness Level (TRL)	720
4.6.4	Global revenues to 2033	721
4.6.5	Product developers	722
4.6.5.1	Anti-fingerprint nanocoatings.....	722
4.6.5.2	Anti-bacterial nanocoatings	725
4.6.5.3	Anti-corrosion nanocoatings.....	728
4.6.5.4	Abrasion and wear resistant nanocoatings.....	730
4.6.5.5	Barrier nanocoatings	732
4.6.5.6	Anti-fogging nanocoatings.....	734
4.6.5.7	Anti-fouling and easy-to-clean nanocoatings.....	735
4.6.5.8	Self-cleaning (bionic) nanocoatings.....	737
4.6.5.9	Self-cleaning (photocatalytic) nanocoatings	738
4.6.5.10	UV-resistant nanocoatings	740
4.6.5.11	Thermal barrier and flame retardant nanocoatings.....	741
4.6.5.12	Anti-icing and de-icing nanocoatings.....	742
4.6.5.13	Anti-reflective nanocoatings	744
4.6.5.14	Self-healing nanocoatings	746
4.7	COMPOSITES	748
4.7.1	Market drivers	748
4.7.2	Markets and applications.....	751
4.7.2.1	Thermal management	755
4.7.2.2	Electrostatic discharge (ESD) and electromagnetic interference (EMI) shielding.....	756
4.7.2.3	Flame retardants.....	756
4.7.3	Technology Readiness Level (TRL)	757
4.7.4	Market opportunity	757

4.7.5	Global revenues to 2033	763
4.7.6	Product developers	764
4.8	CONDUCTIVE INKS	774
4.8.1	Market drivers	775
4.8.2	Markets and applications.....	776
4.8.3	Global revenues to 2033	780
4.8.4	Companies.....	782
4.9	CONSTRUCTION AND BUILDINGS.....	785
4.9.1	Market drivers	785
4.9.2	Markets and applications.....	786
4.9.2.1	Insulation and thermal management	787
4.9.2.1.1	Product developers.....	788
4.9.2.2	Exterior coatings (protective, wood and glass)	789
4.9.2.2.1	Product developers.....	790
4.9.2.3	Smart windows and glass products	794
4.9.2.3.1	Product developers.....	795
4.9.2.4	VOC mitigation and air filtration.....	796
4.9.2.4.1	Product developers.....	797
4.9.2.5	Concrete and cement.....	797
4.9.2.6	Self-healing construction materials.....	799
4.9.2.6.1	Product developers.....	801
4.9.2.7	Asphalt and bitumen	802
4.9.3	Technology Readiness Level (TRL)	803
4.9.4	Global revenues to 2033	803
4.9.5	Product developers	806
4.10	COSMETICS AND SUNSCREENS	814
4.10.1	Market drivers	814
4.10.2	Markets and applications.....	816

4.10.2.1	Products.....	820
4.10.3	Technology Readiness Level (TRL)	824
4.10.4	Global revenues to 2033	825
4.10.5	Product developers	827
4.11	ELECTRONICS AND PHOTONICS.....	832
4.11.1	Flexible electronics, conductive films and displays	832
4.11.1.1	Market drivers	832
4.11.1.2	Applications.....	835
4.11.1.3	Technology Readiness Level (TRL)	837
4.11.1.4	Global revenues to 2033	837
4.11.1.4.1	Touch panel and ITO replacement	837
4.11.1.4.2	Displays.....	838
4.11.1.5	Product developers	841
4.11.2	Transistors, integrated circuits and other components Market drivers	845
4.11.2.1	Applications.....	847
4.11.2.2	Technology Readiness Level (TRL)	848
4.11.2.3	Global revenues to 2033	848
4.11.2.4	Product developers	851
4.11.3	Memory devices.....	853
4.11.3.1	Market drivers	853
4.11.3.2	Applications.....	854
4.11.3.3	Technology Readiness Level (TRL)	855
4.11.3.4	Global revenues to 2033	855
4.11.3.5	Product developers	857
4.11.4	Electronics coatings	858
4.11.4.1	Market drivers	858
4.11.4.2	Applications.....	860
4.11.4.3	Technology Readiness Level (TRL)	861

4.11.4.4	Global revenues to 2033	862
4.11.4.5	Product developers	863
4.11.5	Photonics	866
4.11.5.1	Market drivers	866
4.11.5.2	Applications.....	867
4.11.5.2.1	Si photonics versus graphene	868
4.11.5.2.2	Optical modulators	869
4.11.5.2.3	Photodetectors	870
4.11.5.2.4	Plasmonics.....	870
4.11.5.2.5	Fiber lasers	871
4.11.5.3	Technology Readiness Level (TRL)	871
4.11.5.4	Global revenues to 2033	872
4.11.5.5	Product developers	873
4.12	FILTRATION	875
4.12.1	Market drivers	875
4.12.2	Applications.....	877
4.12.2.1	Desalination and water filtration	878
4.12.2.2	Airborne filters.....	880
4.12.2.3	Gas separation.....	882
4.12.3	Technology Readiness Level (TRL)	883
4.12.4	Global revenues to 2033	883
4.12.5	Product developers	885
4.13	FOOD AND AGRICULTURE	890
4.13.1	Market drivers	890
4.13.2	Markets and applications.....	891
4.13.2.1	Food packaging	892
4.13.2.2	Coatings.....	895
4.13.2.3	Sensors.....	897

4.13.2.4	Additives in food additives and supplements	898
4.13.2.5	Agricultural production	898
4.13.3	Technology Readiness Level (TRL)	899
4.13.4	Global revenues to 2033	900
4.13.5	Product developers	901
4.14	FUEL CELLS.....	906
4.14.1	Market drivers	906
4.14.2	Markets and applications.....	907
4.14.2.1	Fuel cells.....	908
4.14.2.2	Hydrogen storage.....	909
4.14.3	Technology Readiness Level (TRL)	910
4.14.4	Global revenues to 2033	910
4.14.5	Product developers	912
4.15	HOUSEHOLD CARE AND SANITARY	914
4.15.1	Market drivers	914
4.15.2	Markets and applications.....	916
4.15.2.1	Anti-microbial coatings	916
4.15.2.2	Self-cleaning & easy clean coatings.....	916
4.15.2.3	Photocatalytic coatings	917
4.15.2.4	Anti-fingerprint nanocoatings.....	917
4.15.3	Technology Readiness Level (TRL)	919
4.15.4	Global revenues to 2033	919
4.15.5	Product developers	921
4.16	LIGHTING	925
4.16.1	Market drivers	925
4.16.2	Markets and applications.....	926
4.16.3	Technology Readiness Level (TRL)	927
4.16.4	Global revenues to 2033	928

4.16.5	Product developers	929
4.17	LUBRICANTS.....	931
4.17.1	Market drivers	931
4.17.2	Markets and applications.....	932
4.17.3	Technology Readiness Level (TRL)	934
4.17.4	Global revenues to 2033	934
4.17.5	Product developers	936
4.18	MARINE	937
4.18.1	Market drivers	937
4.18.2	Markets and applications.....	938
4.18.3	Technology Readiness Level (TRL)	940
4.18.4	Global revenues to 2033	940
4.18.5	Product developers	942
4.19	OIL, GAS AND MINING.....	945
4.19.1	Market drivers	945
4.19.2	Markets and applications.....	947
4.19.2.1	Sensing and reservoir management.....	947
4.19.2.2	Coatings.....	948
4.19.2.3	Drilling fluids.....	948
4.19.2.4	Sorbent materials.....	950
4.19.2.5	Separation.....	950
4.19.3	Technology Readiness Level (TRL)	951
4.19.4	Global revenues to 2033	952
4.19.5	Product developers	954
4.20	PACKAGING	957
4.20.1	Market drivers	957
4.20.2	Markets and applications.....	959
4.20.3	Technology Readiness Level (TRL)	963

4.20.4	Global revenues to 2033	963
4.20.5	Product developers	966
4.21	RUBBER	970
4.21.1	Market drivers	970
4.21.2	Markets and applications.....	970
4.21.3	Technology Readiness Level (TRL)	972
4.21.4	Global revenues to 2033	974
4.21.5	Product developers	975
4.22	SECURITY AND DEFENCE	978
4.22.1	Market drivers	978
4.22.2	Markets and applications.....	980
4.22.2.1	Military textiles	980
4.22.2.2	Military equipment	980
4.22.2.3	Anti-counterfeiting	981
4.22.2.4	Sensors and detection	982
4.22.2.5	Ballistic protection	984
4.22.3	Technology Readiness Level (TRL)	984
4.22.4	Global revenues to 2033	985
4.22.5	Product developers	986
4.23	SENSORS.....	991
4.23.1	Market drivers	991
4.23.2	Markets and applications.....	992
4.23.2.1	Gas sensors.....	994
4.23.2.2	Strain sensors	995
4.23.2.3	Biosensors	996
4.23.2.4	Food sensors	997
4.23.2.5	Image sensors	998
4.23.2.6	Infrared (IR) sensors	998

4.23.2.7	Optical sensors	999
4.23.2.8	Pressure sensors	999
4.23.2.9	Humidity sensors.....	1000
4.23.2.10	Acoustic sensors	1000
4.23.2.11	Wireless sensors	1000
4.23.3	Technology Readiness Level (TRL)	1001
4.23.4	Global revenues to 2033	1001
4.23.5	Product developers	1003
4.24	PHOTOVOLTAICS	1007
4.24.1	Market drivers	1007
4.24.2	Markets and applications.....	1008
4.24.2.1	Solar cells	1009
4.24.2.2	Solar water splitting.....	1012
4.24.2.3	Solar coatings	1013
4.24.3	Technology Readiness Level (TRL)	1014
4.24.4	Global revenues to 2033	1014
4.24.5	Product developers	1016
4.25	SUPERCAPACITORS	1021
4.25.1	Market drivers	1021
4.25.2	Markets and applications.....	1022
4.25.3	Technology Readiness Level (TRL)	1024
4.25.4	Global revenues to 2033	1024
4.25.5	Product developers	1026
4.26	TEXTILES & APPAREL.....	1028
4.26.1	Market drivers	1028
4.26.2	Markets and applications.....	1032
4.26.2.1	Protective textiles	1033
4.26.2.2	Electronic textiles	1034

4.26.3	Technology Readiness Level (TRL)	1039
4.26.4	Global revenues to 2033	1039
4.26.5	Product developers	1042
4.27	TOOLS & MANUFACTURING	1046
4.27.1	Market drivers	1046
4.27.2	Markets and applications	1047
4.27.3	Technology Readiness Level (TRL)	1048
4.27.4	Global revenues to 2033	1049
4.27.5	Product developers	1050
4.28	3D PRINTING	1055
4.28.1	Markets and applications	1055
4.28.2	Technology Readiness Level (TRL)	1056
4.28.3	Global revenues to 2033	1057
4.28.4	Product developers	1059
4.29	OTHER MARKETS	1061
4.29.1	CATALYSTS	1061
4.29.1.1	Markets and applications	1061
4.29.1.2	Product developers	1062
4.29.2	WIRE AND CABLE	1063
4.29.2.1	Markets and applications	1063
4.29.2.1.1	Composites	1063
4.29.2.1.2	Coatings	1063
4.29.2.2	Product developers	1063
4.29.3	SPORTING GOODS	1065
4.29.3.1	Markets and applications	1065
4.29.3.1.1	Composites	1065
4.29.3.1.2	Coatings	1065
4.29.3.2	Product developers	1065

4.29.4	WIND ENERGY	1067
4.29.4.1	Market drivers	1067
4.29.4.2	Markets and applications.....	1067
4.29.4.2.2	Product developers	1069
4.29.5	THERMOELECTRICS	1070
4.29.5.1	Market drivers	1070
4.29.5.2	Markets and applications.....	1070
4.29.5.3	Application and product developers	1071

5 REFERENCES 1072

LIST OF TABLES

Table 1.	Technology Readiness Level (TRL) Examples.....	72
Table 2.	Categorization of engineered nanomaterials.....	75
Table 3.	The Global market for engineered nanomaterials in 2021-consumption, market characteristics and growth prospects.....	77
Table 4.	Global consumption of engineered nanomaterials in metric tonnes (MT), 2010-2033.	79
Table 5.	Occupational exposure limits associated with nanomaterials.....	86
Table 6.	Life cycle assessment studies on nanomaterials.....	87
Table 7.	Nanomaterials utilized in carbon capture and utilization-advanatages & disadvantages.	97
Table 8.	CO ₂ capture performance of nanomaterials sorbents.....	99
Table 9.	Market overview for aluminium oxide nanoparticles/powders -Selling grade particle diameter, usage, advantages, high volume applications, low volume applications and novel applications.	101
Table 10.	Markets, benefits and applications of aluminium oxide nanoparticles/powders.	103
Table 11.	Global consumption of aluminium oxide nanoparticles/powders (MT), 2010-2033.	105
Table 12.	Aluminium oxide nanoparticles/powders Market Segmentation 2021 (MT)	108
Table 13.	Aluminium oxide nanoparticles/powders market consumption 2031 (MT).	109
Table 14.	Consumption of aluminium oxide nanoparticles/powders by region 2021 (MT).	110
Table 15.	Consumption of aluminium oxide nanoparticles/powders by region 2033 (MT).	111

Table 16. Prices of aluminium oxide nanoparticles/powders from producers & distributors.....	111
Table 17. Aluminium oxide nanoparticles/powders producer profiles.....	111
Table 18. Market summary for antimony tin oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.....	114
Table 19. Markets, benefits and applications of antimony tin oxide nanoparticles/powders	115
Table 20. Global consumption of antimony tin oxide nanoparticles/nanopowders, in metric tonnes, 2010-2033.....	116
Table 21. Antimony tin oxide nanoparticles/powders Market Segmentation 2021 (MT).	119
Table 22. Antimony tin oxide nanoparticles/powders market consumption 2031 (MT).	119
Table 23. Consumption of antimony tin oxide nanoparticles/powders by region 2021 (MT).	120
Table 24. Consumption of antimony tin oxide nanoparticles/powders by region 2033 (MT).	121
Table 25. Prices of antimony tin oxide nanoparticles/powders.....	122
Table 26. Antimony tin oxide nanoparticles/powders/nanopowders producers and suppliers.	122
Table 27. Market overview bismuth oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.....	125
Table 28. Markets, benefits and applications of aluminium oxide nanoparticles/powders	126
Table 29. Global consumption of bismuth oxide nanoparticles/powders in metric tonnes, 2010-2033.....	128
Table 30. Bismuth oxide nanoparticles/powders Market Segmentation 2021 (MT).	130
Table 31. Bismuth oxide nanoparticles/powders Market share 2033 (MT).	131
Table 32. Consumption of bismuth oxide nanoparticles/powders by region 2021 (MT).....	132
Table 33. Consumption of bismuth oxide nanoparticles/powders by region 2033(MT).....	133
Table 34. Prices of bismuth oxide nanoparticles/powders.....	134
Table 35. Bismuth oxide nanoparticles/powders/nanopowders producers and suppliers.	134
Table 36. Market overview for nanocellulose-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	136
Table 37. Properties of nanocellulose, by type.	138
Table 38. Markets and applications of nanocellulose.....	139
Table 39. Cellulose nanofibers-based commercial products.....	140

Table 40. CNF production capacities and production process, by producer.....	148
Table 41. Global demand for cellulose nanofibers/MFC by market in metric tonnes, 2018-2033.	149
Table 42. Cellulose nanofibers (CNF) Market Segmentation 2021 (MT).	151
Table 43. Cellulose nanofibers (CNF) Market share 2033 (MT).	153
Table 44. Consumption of Cellulose nanofibers (CNF) by region 2021 (MT).	154
Table 45. Consumption of Cellulose nanofibers (CNF) by region 2033 (MT).	155
Table 46. Product/price/application matrix of cellulose nanofiber producers.	156
Table 47. Nanocellulose producers.....	157
Table 48. Market overview for cerium oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	163
Table 49. Markets, benefits and applications of cerium oxide nanoparticles/powders.	164
Table 50. Global consumption of cerium oxide nanoparticles/powders (MT), 2010-2033.....	166
Table 51. Cerium oxide nanoparticles/powders Market Segmentation 2021 (MT).....	168
Table 52. Cerium oxide nanoparticles/powders Market share 2033 (MT).....	169
Table 53. Consumption of Cerium Oxide Nanoparticles/powders by region 2021 (MT).....	170
Table 54. Consumption of Cerium Oxide Nanoparticles/powders by region 2033 (MT).....	171
Table 55. Prices of cerium oxide nanoparticles/powders.	172
Table 56. Cerium oxide nanoparticles/powders and nanopowders producers and suppliers.....	172
Table 57. Market overview for cobalt oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	174
Table 58. Markets, benefits and applications of cobalt oxide nanoparticles/powders.	175
Table 59. Global consumption of cobalt oxide nanoparticles/powders (MT), 2010-2033.....	176
Table 60. Cobalt oxide nanoparticles/powders Market Segmentation 2021 (MT).....	178
Table 61. Cobalt oxide nanoparticles/powders Market share 2033 (MT).....	179
Table 62. Consumption of Cobalt Oxide Nanoparticles/powders by region 2021 (MT).....	180
Table 63. Consumption of Cobalt Oxide Nanoparticles/powders by region 2033 (MT).....	181
Table 64. Prices of cobalt oxide nanoparticles/powders.....	182

Table 65. Market overview for copper oxide nanoparticles/powders -Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	183
Table 66. Markets, benefits and applications of copper oxide nanoparticles/powders.....	184
Table 67. Global consumption of copper oxide nanoparticles/powders (MT), 2010-2033.....	186
Table 68. Copper oxide nanoparticles/powders Market Segmentation 2021 (MT).	188
Table 69. Copper oxide nanoparticles/powders Market share 2033 (MT).	189
Table 70. Consumption of copper oxide nanoparticles/powders by region 2021 (MT).....	191
Table 71. Consumption of copper oxide nanoparticles/powders by region 2033 (MT).....	192
Table 72. Example prices of copper oxide nanoparticles/powders.....	192
Table 73. Copper and copper oxide nanoparticles/powders and nanopowders producers and suppliers..	193
Table 74. Market overview for dendrimers -Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	195
Table 75. Types of dendrimer.	196
Table 76. Markets, benefits and applications of dendrimers.	198
Table 77. Global consumption of dendrimers in metric tonnes, 2010-2033.	199
Table 78. Dendrimers Market Segmentation 2021 (MT).	201
Table 79. Dendrimers Market share 2033 (MT).	202
Table 80. Consumption of dendrimers by region 2021 (MT).	203
Table 81. Consumption of dendrimers by region 2033 (MT).	204
Table 82. Example prices of dendrimers.....	205
Table 83. Dendrimers producers.	205
Table 84. Market overview for fullerenes-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	207
Table 85. Types of fullerenes and applications.	208
Table 86. Products incorporating fullerenes.....	209
Table 87. Markets, benefits and applications of fullerenes.....	209
Table 88. Global consumption of fullerenes in metric tonnes, 2010-2033.	210
Table 89. Fullerenes Market Segmentation 2021 (MT).	212

Table 90. Fullerenes Market share 2033 (MT).	213
Table 91. Consumption of fullerenes by region 2021 (MT).....	214
Table 92. Consumption of fullerenes by region 2033 (MT).....	215
Table 93. Example prices of fullerenes.	216
Table 94. Fullerene producers and suppliers.	216
Table 95. Market overview for gold nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	219
Table 96. Markets, benefits and applications of gold nanoparticles/powders.	220
Table 97. Global consumption of gold nanoparticles in metric tonnes, 2010-2033.	222
Table 98. Gold nanoparticles/powders Market Segmentation 2021 (MT).....	224
Table 99. Gold nanoparticles/powders Market share 2033 (MT).....	225
Table 100. Consumption of gold nanoparticles by region 2021 (MT).	226
Table 101. Consumption of gold nanoparticles by region 2033 (MT).	227
Table 102. Price of gold nanoparticles/powders.	228
Table 103. Gold nanoparticle producers and suppliers.	228
Table 104. Market overview for graphene-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	231
Table 105. Properties of graphene.	232
Table 106. Markets, benefits and applications of graphene.	233
Table 107. Products incorporating graphene.	243
Table 108. Main graphene producers by country, annual production capacities, types and main markets they sell into 2020.	246
Table 109. Consumption of graphene (tons), 2018-2033.	249
Table 110. Consumption of graphene by region 2021 (MT).	253
Table 111. Consumption of graphene by region 2033 (MT).	254
Table 112. Graphene types and cost per kg.	255
Table 113. Graphene producers and suppliers.	255

Table 114. Market overview for iron oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	266
Table 115. Markets, benefits and applications of iron oxide nanoparticles/powders.....	268
Table 116. Global consumption of iron oxide nanoparticles/powders in metric tonnes, 2010-2033.	269
Table 117. Iron oxide nanoparticles/powders Market Segmentation 2021 (MT).....	271
Table 118. Iron oxide nanoparticles/powders Market share 2033 (MT).....	272
Table 119. Consumption of iron oxide nanoparticles/powders by region 2021 (MT).	273
Table 120. Consumption of iron oxide nanoparticles/powders by region 2033 (MT).	274
Table 121. Example prices of iron oxide nanoparticles/powders.....	275
Table 122. Iron oxide nanoparticle/nanopowder producers and suppliers.....	275
Table 123. Market overview for magnesium oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, market estimates, high volume applications, low volume applications and novel applications.	279
Table 124. Markets, benefits and applications of magnesium oxide nanoparticles/powders.	280
Table 125. Global consumption of magnesium oxide nanoparticles/powders in metric tonnes, 2010-2033.	281
Table 126. Magnesium oxide nanoparticles/powders Market Segmentation 2021 (MT).....	283
Table 127. Magnesium oxide nanoparticles/powders Market share 2033 (MT).....	284
Table 128. Consumption of magnesium oxide nanoparticles/powders by region 2021 (MT).....	285
Table 129. Consumption of magnesium oxide nanoparticles/powders by region 2033 (MT).....	286
Table 130. Example prices of magnesium oxide nanoparticles/powders/nanopowders.	287
Table 131. Magnesium oxid nanoparticle/nanopowder producers and suppliers.	287
Table 132. Market overview for manganese oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	290
Table 133. Markets, benefits and applications of manganese oxide nanoparticles/powders.....	291
Table 134. Global consumption of manganese oxide nanoparticles/powders in metric tonnes, 2010-2033, 2010-2033.....	292
Table 135. Manganese oxide nanoparticles/powders Market Segmentation 2021 (MT).....	294
Table 136. Manganese oxide nanoparticles/powders Market share 2033 (MT).	295

Table 137. Consumption of manganese oxide nanoparticles/powders by region 2021 (MT).....	296
Table 138. Consumption of manganese oxide nanoparticles/powders by region 2033 (MT).....	297
Table 139. Example prices of manganese oxide nanoparticles/powders.	298
Table 140. Manganese oxide nanoparticle/nanopowder producers and suppliers.	298
Table 141. Market overview for multi-walled carbon nanotubes-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	299
Table 142. Properties of multi-walled carbon nanotubes and comparable materials.	300
Table 143. Markets, benefits and applications of multi-walled Carbon Nanotubes (MWCNT).	301
Table 144. Key MWCNT producers production capacities 2021.	307
Table 145. MWCNT Market Segmentation 2021 (MT).	311
Table 146. MWCNT Market share 2033 (MT).	313
Table 147. Consumption of MWCNT by region 2033 (MT).	314
Table 148. Consumption of MWCNT by region 2033 (MT).	315
Table 149. Carbon nanotubes pricing (MWCNTS, SWCNT etc.) by producer.....	316
Table 150. Multi-walled carbon nanotube (MWCNT) producers and suppliers.....	317
Table 151. Market overview for nanoclays -Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	323
Table 152. Markets, benefits and applications of nanoclays.	325
Table 153. Global consumption of nanoclays in metric tonnes, 2010-2033.....	326
Table 154. Nanoclays Market Segmentation 2021 (MT).	328
Table 155. Nanoclays Market share 2033 (MT).	329
Table 156. Consumption of nanoclays by region 2021 (MT).	330
Table 157. Consumption of nanoclays by region 2033 (MT).	331
Table 158. Example prices of nanoclays.	332
Table 159. Main nanoclays producers and products.....	332
Table 160. Market summary for nanodiamonds-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.....	335
Table 161. Properties of nanodiamonds.	338

Table 162. Markets, benefits and applications of nanodiamonds.....	339
Table 163. Nanodiamonds Market Segmentation 2021 (MT).....	344
Table 164. Nanodiamonds Market share 2033 (MT).....	345
Table 165. Consumption of nanodiamonds by region 2021 (MT).....	346
Table 166. Consumption of nanodiamonds by region 2033 (MT).....	347
Table 167. Pricing of nanodiamonds, by producer/distributor.....	348
Table 168. Production methods, by main ND producers.....	349
Table 169. Nanodiamond producers and suppliers.....	350
Table 170. Market summary for nanofibers- Selling grade particle diameter, advantages, average price/ton, high volume applications, low volume applications and novel applications.....	353
Table 171. Nanofibers types, properties and applications.....	354
Table 172. Electrospinning instrument manufacturers.....	357
Table 173. Applications of polymer, alumina, carbon and other nanofibers.....	362
Table 174. Global revenues for nanofibers, by market 2018-2033, millions USD.....	364
Table 175. Nanofibers Market Segmentation 2021 (MT).....	366
Table 176. Nanofibers Market share 2033 (MT).....	367
Table 177. Consumption of Nanofibers by region 2021 (MT).....	368
Table 178. Consumption of Nanofibers by region 2033 (MT).....	369
Table 179. Nanofibers producers.....	370
Table 180. Market overview for nanosilver-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.....	376
Table 181. Markets, benefits and applications of nanosilver.....	377
Table 182. Global consumption of nanosilver in metric tonnes, 2010-2033.....	379
Table 183. Nanosilver Market Segmentation 2021 (MT).....	381
Table 184. Nanosilver Market share 2033 (MT).....	382
Table 185. Consumption of nanosilver by region 2021 (MT).....	383
Table 186. Consumption of nanosilver by region 2033 (MT).....	384
Table 187. Prices of nanosilver.....	385
Table 188. Nanosilver producers.....	385

Table 189. Market overview for nickel nanoparticles/powders -Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	388
Table 190. Markets, benefits and applications of nickel nanoparticles/powders.	389
Table 191. Global consumption of nickel nanoparticles/powders in metric tonnes, 2010-2033.	390
Table 192. Nickel nanoparticles/powders Market Segmentation 2021 (MT).	392
Table 193. Nickel nanoparticles/powders Market share 2033 (MT).	393
Table 194. Consumption of nickel nanoparticles/powders by region 2021 (MT).	394
Table 195. Consumption of nickel nanoparticles/powders by region 2033 (MT).	395
Table 196. Example prices of nickel nanoparticles/powders.	396
Table 197. Nickel nanoparticle/nanopowders producers and suppliers.	396
Table 198. Market overview for quantum dots -Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	398
Table 199. Markets, benefits and applications of quantum dots.	400
Table 200. Quantum dot display products.	402
Table 201. Global consumption of quantum dots in metric tonnes, 2018-2033.	404
Table 202. Quantum dots Market Segmentation 2021 (MT).	406
Table 203. Quantum dots Market share 2033 (MT).	407
Table 204. Consumption of quantum dots by region 2021 (MT).	408
Table 205. Consumption of quantum dots by region 2033 (MT).	409
Table 206. Example prices of quantum dots.	410
Table 207. Quantum dot producers and suppliers.	410
Table 208. Market overview for silicon oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	414
Table 209. Markets, benefits and applications of silicon oxide nanoparticles/powders.	415
Table 210. Global consumption of silicon oxide nanoparticles/powders in metric tonnes, 2010-2033.	417
Table 211. Silicon oxide nanoparticles/powders Market Segmentation 2021 (MT).	419
Table 212. Silicon oxide nanoparticles/powders Market share 2033 (MT).	420
Table 213. Consumption of silicon oxide nanoparticles/powders by region 2021 (MT).	421

Table 214. Consumption of silicon oxide nanoparticles/powders by region 2033 (MT).....	422
Table 215. Example prices of silicon oxide nanoparticles/powders.....	422
Table 216. Silicon oxide nanoparticles/powders/nanopowders producers and suppliers.....	423
Table 217. Market overview for single-walled carbon nanotubes-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.....	427
Table 218. Properties of single-walled carbon nanotubes.....	429
Table 219. Typical properties of SWCNT and MWCNT.....	430
Table 220. Markets, benefits and applications of single-walled Carbon Nanotubes.....	431
Table 221. SWCNT prices.....	434
Table 222. Annual production capacity of the key SWCNT producers,	435
Table 223. Global consumption of SWCNTs in metric tonnes, 2018-2033.....	435
Table 224. SWCNT producers.....	436
Table 225. Market overview for titanium dioxide nanoparticles/powders -Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.....	438
Table 226. Markets, benefits and applications of titanium dioxide nanoparticles/powders.....	440
Table 227. Global consumption of titanium dioxide nanoparticles/powders in metric tonnes, 2010-2033.....	441
Table 228. Titanium dioxide nanoparticles/powders Market Segmentation 2021 (MT).....	444
Table 229. Titanium dioxide nanoparticles/powders Market share 2033 (MT).....	445
Table 230. Consumption of titanium dioxide nanoparticles/powders by region 2021 (MT).....	446
Table 231. Consumption of titanium dioxide nanoparticles/powders by region 2033 (MT).....	447
Table 232. Titanium dioxide nanoparticles/powders/nanopowders producers and suppliers.....	448
Table 233. Market overview for zinc oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.....	450
Table 234. Markets and applications for zinc oxide nanoparticles/powders.....	452
Table 235. Main Zinc oxide nanoparticles/powders-Suppliers, products, primary particle size.....	454
Table 236. Global consumption of zinc oxide nanoparticles/powders in metric tonnes, 2010-2033.....	456
Table 237. Zinc oxide nanoparticles/powders Market Segmentation 2021 (MT).....	458

Table 238. Zinc oxide nanoparticles/powders Market share 2033 (MT).....	459
Table 239. Consumption of zinc oxide nanoparticles/powders by region 2021 (MT).....	460
Table 240. Consumption of zinc oxide nanoparticles/powders by region 2033 (MT).....	462
Table 241. Zinc oxide nanoparticle/nanopowder producers and suppliers,	462
Table 242. Market overview for zirconium oxide nanoparticles/powders-Selling grade particle diameter, usage, advantages, average price/ton, high volume applications, low volume applications and novel applications.	465
Table 243. Markets, benefits and applications of zirconium oxide nanoparticles/powders.	466
Table 244. Global consumption of zirconium oxide nanoparticles/powders in metric tons, 2010-2033.....	468
Table 245. Zirconium oxide nanoparticles/powders Market Segmentation 2021 (MT).	471
Table 246. Zirconium oxide nanoparticles/powders Market share 2033 (MT).	472
Table 247. Consumption of zirconium oxide nanoparticles/powders by region 2021 (MT).	473
Table 248. Consumption of zirconium oxide nanoparticles/powders by region 2033 (MT).	474
Table 249. Prices of zirconium oxide nanoparticles/powders.....	475
Table 250. Zirconium oxide nanoparticles/powders/nanopowders producers and suppliers.	476
Table 251. Synthesis methods for cellulose nanocrystals (CNC).....	482
Table 252. CNC sources, size and yield.	483
Table 253. CNC properties.....	484
Table 254. Mechanical properties of CNC and other reinforcement materials.....	484
Table 255. Applications of cellulose nanocrystals (CNC).....	485
Table 256. Product/price/application matrix of cellulose nanocrystal producers.....	487
Table 257: Cellulose nanocrystal production capacities and production process, by producer.....	487
Table 258. Cellulose nanocrystal producers.	488
Table 259. Applications of bacterial nanocellulose (BNC).....	492
Table 260. Bacterial nanocellulose producers.	493
Table 261. Comparative properties of BNNTs and CNTs.....	494
Table 262. Applications of BNNTs.	495
Table 263. BNNT pricing by producer.....	496
Table 264. Erbium oxide nanoparticles/nanopowders-Properties, applications, prices and producers.	496

Table 265. Indium oxide nanoparticles/powders-Properties, applications, prices and producers.	497
Table 266. Molybdenum nanoparticles/powders-Properties, applications, prices and producers.	497
Table 267. Comparative properties of conventional QDs and Perovskite QDs.....	499
Table 268. Applications of perovskite QDs.	500
Table 269. Development roadmap for perovskite QDs.....	501
Table 270. Properties of perovskite QLEDs comparative to OLED and QLED.	502
Table 271. Applications of carbon quantum dots.	504
Table 272. Comparison of graphene QDs and semiconductor QDs.....	507
Table 273. Advantages and disadvantages of methods for preparing GQDs.	510
Table 274. Applications of graphene quantum dots.	511
Table 275. Graphene quantum dots companies.	513
Table 276. 2D materials types.	517
Table 277. Comparative analysis of graphene and other 2-D nanomaterials.	518
Table 278. Comparison of top-down exfoliation methods to produce 2D materials.	520
Table 279. Comparison of the bottom-up synthesis methods to produce 2D materials.	522
Table 280. Properties of hexagonal boron nitride (h-BN).	523
Table 281. Electronic and mechanical properties of monolayer phosphorene, graphene and MoS ₂	534
Table 282. Properties and applications of functionalized germanene.....	539
Table 283. GDY-based anode materials in LIBs and SIBs.....	542
Table 284. Physical and electronic properties of Stanene.....	548
Table 285. 2D materials producers and suppliers.	553
Table 286. Market drivers for nanotechnology and nanomaterials in adhesives.	556
Table 287. Market overview for nanotechnology and nanomaterials in adhesives.	556
Table 288. Nanomaterials properties relevant to application in adhesives.	557
Table 289. Applications of nanomaterials in adhesives, by market.	558
Table 290: Applications in adhesives, by nanomaterials type.	558
Table 291. Market assessment for nanotechnology and nanomaterials in adhesives.	561
Table 292. Global revenues for nanotechnology and nanomaterials in adhesives, 2018-2033, conservative and optimistic estimates (millions USD)	562

Table 293: Nanotechnology and nanomaterials product developers in adhesives.	563
Table 294. Market assessment for nanotechnology and nanomaterials in aerospace and aviation.....	566
Table 295. Market drivers for nanotechnology and nanomaterials in aerospace and aviation.....	567
Table 296. Market overview for nanotechnology and nanomaterials in aerospace and aviation.....	569
Table 297. Applications in aerospace composites, by nanomaterials type and benefits thereof.....	570
Table 298. Types of nanocoatings utilized in aerospace and application.	572
Table 299. Applications in aerospace coatings, by nanomaterials type and benefits thereof.	574
Table 300. Global revenues for nanotechnology and nanomaterials in aerospace and aviation, 2018-2033, millions USD.	576
Table 301. Nanotechnology and nanomaterials application and product developers in the aerospace and aviation industry.	578
Table 302. Market drivers for nanotechnology and nanomaterials in automotive.	584
Table 303. Market overview for nanotechnology and nanomaterials in automotive.....	586
Table 304. Applications in automotive composites, by nanomaterials type and benefits thereof.....	587
Table 305. Nanocoatings applied in the automotive industry.	590
Table 306: Applications in automotive tires, by nanomaterials type and benefits thereof.	593
Table 307. Market assessment for nanotechnology and nanomaterials in automotive.....	595
Table 308. Global revenues for nanotechnology and nanomaterials in automotive, 2018-2033, millions USD.	597
Table 309. Nanotechnology and nanomaterials product developers in the automotive industry.....	599
Table 310. Market drivers for nanotechnology and nanomaterials in batteries.....	610
Table 311. Market overview for nanotechnology and nanomaterials in batteries.....	612
Table 312. Applications in LIB, by nanomaterials type and benefits thereof.....	613
Table 313. Applications in Li-S batteries, by nanomaterials type and benefits thereof.	618
Table 314. Applications in sodium-ion batteries, by nanomaterials type and benefits thereof.	618
Table 315. Applications in lithium-air batteries, by nanomaterials type and benefits thereof.	619
Table 316. Applications in magnesium batteries, by nanomaterials type and benefits thereof.	620
Table 317. Market assessment for nanotechnology and nanomaterials in batteries.....	621

Table 318. Global revenues for nanotechnology and nanomaterials in batteries, 2018-2033, millions USD.	624
Table 319. Nanotechnology and nanomaterials product developers in batteries.....	625
Table 320. Market drivers for nanomaterials-based products in medical biosensors.....	637
Table 321. Applications in medical biosensors, by nanomaterials type and benefits thereof.....	638
Table 322. Global revenues for nanotechnology and nanomaterials in medical biosensors, 2018-2033, millions USD.	640
Table 323. Nanotechnology and nanomaterials product developers in medical biosensors.	642
Table 324. Market drivers for nanomaterials-based products in drug formulation and delivery.	644
Table 325. Types of Nanocarriers.....	645
Table 326. Applications in drug formulation and delivery, by nanomaterials type and benefits thereof.....	647
Table 327. Types of nanoparticles and products thereof.....	649
Table 328. Nanotechnology drug products.	652
Table 329. List of antigens delivered by using different nanocarriers.....	655
Table 330. Global revenues for nanotechnology and nanomaterials in drug delivery, 2018-2033, millions USD.	657
Table 331. Nanotechnology and nanomaterials products developers in drug formulation and delivery.	659
Table 332. Market drivers for Nanotechnology and nanomaterials-based products in imaging and diagnostics.	667
Table 333: Applications in medical imaging and diagnostics, by nanomaterials type and benefits thereof.	668
Table 334. Global revenues for nanotechnology and nanomaterials in imaging and diagnostics, 2018-2033, millions USD.	671
Table 335. Nanotechnology and nanomaterials product developers in medical imaging and diagnostics .673	
Table 336. Market drivers for nanomaterials-based products in medical coatings and films.	678
Table 337. Nanocoatings applied in the medical industry-type of coating, nanomaterials utilized, benefits and applications.	681
Table 338. Nanomaterials utilized in medical coatings and films coatings-benefits and applications.	682
Table 339. Global revenues for nanomaterials in medical coatings, 2018-2033, millions USD.....	685
Table 340: Nanomaterials-based products developers in medical coatings and films.	686

Table 341: Market drivers for nanomaterials-based products in medical implants.....	692
Table 342. Applications in medical implants and devices, by nanomaterials type and benefits thereof.	694
Table 343. Global revenues for nanomaterials in medical implants 2018-2033, millions USD.....	696
Table 344: Nanotechnology and nanomaterials product developers in medical implants and devices.	697
Table 345. Market drivers for nanotechnology and nanomaterials in wound care.	699
Table 346. Applications in wound care, by nanomaterials type and benefits thereof.....	700
Table 347: Medical wound care products.....	701
Table 348. Global revenues for nanotechnology and nanomaterials in wound care, 2018-2033, millions USD.	702
Table 349: Nanomaterials-based products and application developers in wound care.	704
Table 350. Market drivers for nanotechnology and nanomaterials-based products in dental.	706
Table 351: Applications in dental, by nanomaterials type and benefits thereof.	706
Table 352. Global revenues for nanotechnology and nanomaterials in dental, 2018-2033, millions USD.	708
Table 353. Nanomaterials-based product developers in dental.....	709
Table 354. Market drivers in nanocoatings.	711
Table 355. Market overview for nanotechnology and nanomaterials in coatings and paints.....	713
Table 356. Properties of nanocoatings.	715
Table 357. End user markets for nanocoatings.....	716
Table 358. Anti-fingerprint nanocoatings companies.	722
Table 359. Anti-bacterial nanocoatings companies.....	725
Table 360. Anti-corrosion nanocoatings coatings.....	728
Table 361. Abrasion and wear resistant nanocoatings companies.....	730
Table 362. Barrier nanocoatings companies.....	732
Table 363. Anti-fogging nanocoatings companies.....	734
Table 364. Anti-fouling and easy-to-clean nanocoatings companies.....	735
Table 365. Self-cleaning (bionic) nanocoatings companies.	737
Table 366. Self-cleaning (photocatalytic) nanocoatings companies.	738
Table 367. UV-resistant nanocoatings companies.	740
Table 368. Thermal barrier and flame retardant nanocoatings companies.....	741

Table 369. Anti-icing and de-icing nanocoatings companies.....	742
Table 370. Anti-reflective nanocoatings companies.....	744
Table 371. Market drivers for nanotechnology and nanomaterials in composites.	748
Table 372. Market overview for nanotechnology and nanomaterials in composites.	750
Table 373. Applications in polymer composites, by nanomaterials type and benefits thereof.....	751
Table 374. Applications in thermal management composites, by nanomaterials type and benefits thereof.	755
Table 375. Applications in ESD and EMI shielding composites, by nanomaterials type and benefits thereof.	756
Table 376. Applications in flame retardants, by nanomaterials type and benefits thereof.....	756
Table 377. Market assessment for nanotechnology and nanomaterials in composites.	757
Table 378. Global revenues for nanotechnology and nanomaterials in composites, 2018-2033, millions USD.....	763
Table 379. Nanotechnology and nanomaterials-based application and product developers in composites.	764
Table 380. Comparative properties of conductive inks.....	774
Table 381. Market drivers for nanotechnology and nanomaterials in conductive inks.	775
Table 382. Market overview for nanotechnology and nanomaterials in conductive inks.....	776
Table 383. Applications in conductive inks by nanomaterials type and benefits thereof.....	777
Table 384. Market assessment for nanotechnology and nanomaterials in conductive inks.....	778
Table 385. Global revenues for nanotechnology and nanomaterials in conductive inks, 2017-2033, millions USD.....	780
Table 386. Nanotechnology and Nanomaterials-based application and product developers in conductive inks.	782
Table 387. Market drivers for nanotechnology and nanomaterials in construction.	785
Table 388. Market overview for nanotechnology and nanomaterials in construction, building protection and architectural coatings.	786
Table 389. Applications in insulation and heating, by nanomaterials type and benefits thereof.....	787
Table 390. Nanomaterials-based product developers in insulation.	788
Table 391. Applications in exterior coatings by nanomaterials type and benefits thereof.....	789

Table 392: Nanomaterials-based product developers in exterior coatings.	790
Table 393. Applications in smart windows by nanomaterials type and benefits thereof.....	794
Table 394. Nanomaterials-based product developers in smart windows and glass products.	795
Table 395. Applications in VOC mitigation and filtration by nanomaterials type and benefits thereof.	796
Table 396: Nanomaterials-based product developers in VOC mitigation and filtration.	797
Table 397. Applications in concrete and cement by nanomaterials type and benefits thereof.	798
Table 398. Applications in self-healing construction materials by nanomaterials type and benefits thereof.	800
Table 399. Nanomaterials-based product developers self-healing construction materials.....	801
Table 400. Nanomaterials for asphalt and bitumen.....	802
Table 401. Global revenues for nanotechnology and nanomaterials in construction, 2018-2033, millions USD.	804
Table 402. Nanotechnology and nanomaterials-based application and product developers in construction, building protection and architectural coatings.....	806
Table 403: Market drivers for nanotechnology and nanomaterials in cosmetics and sunscreens.....	814
Table 404: Applications in cosmetics and sunscreens, by nanomaterials type and benefits thereof.	816
Table 405. Cosmetics products incorporating nanomaterials/nanocarriers.	820
Table 406. Global revenues for nanotechnology and nanomaterials in cosmetics and sunscreens, 2018- 2033, millions USD.....	825
Table 407. Nanotechnology and nanomaterials-based product developers in cosmetics and sunscreens market.....	827
Table 408. Market drivers for nanotechnology and nanomaterials in flexible electronics, conductive films and displays.	832
Table 409. Applications in flexible electronics, flexible conductive films and displays, by nanomaterials type and benefits thereof.	835
Table 410. Global revenues for nanomaterials in flexible electronics, 2018-2033.	839
Table 411. Global revenues for nanotechnology and nanomaterials in displays, 2018-2033.	840
Table 412: Nanotechnology and nanomaterials-based product developers in flexible electronics, flexible conductive films and displays.....	841
Table 413. Market drivers for nanotechnology and nanomaterials in transistors, integrated circuits and other components.	845

Table 414. Applications in transistors, integrated circuits and other components, by nanomaterials type and benefits thereof.	847
Table 415. Global revenues for nanotechnology and nanomaterials in transistors, integrated circuits and other components, 2018-2033.....	849
Table 416. Nanotechnology and Nanomaterials-based product developers in transistors, integrated circuits and other components.	851
Table 417. Market drivers for nanotechnology and nanomaterials in memory devices.....	853
Table 418. Applications in memory devices, by nanomaterials type and benefits thereof.	854
Table 419. Global revenues for nanotechnology and nanomaterials in memory devices, 2018-2033.....	856
Table 420: Nanotechnology and Nanomaterials-based product developers in memory devices.	857
Table 421. Market drivers for nanotechnology and nanomaterials in electronics coatings.	858
Table 422. Nanocoatings applied in the consumer electronics industry.	860
Table 423. Global revenues for nanotechnology and nanomaterials in electronics coatings, 2018-2033. .	862
Table 424. Nanotechnology and Nanomaterials-based product developers in electronics coatings.	863
Table 425. Market drivers for nanotechnology and nanomaterials in photonics.	866
Table 426. Applications in photonics, by nanomaterials type and benefits thereof.	867
Table 427: Graphene properties relevant to application in optical modulators.	869
Table 428. Global revenues for nanotechnology and nanomaterials in photonics, 2018-2033.	872
Table 429. Nanotechnology and Nanomaterials-based product developers in photonics.....	873
Table 430. Market drivers for nanotechnology and nanomaterials in filtration and environmental remediation.	875
Table 431. Types of filtration.....	878
Table 432. Applications in desalination and water filtration, by nanomaterials type and benefits thereof. .	879
Table 433. Applications in airborne filters, by nanomaterials type and benefits thereof.....	881
Table 434. Applications in gas separation, by nanomaterials type and benefits thereof.	882
Table 435. Global revenues for nanotechnology and nanomaterials in filtration, 2018-2033, millions USD.	883
Table 436. Nanotechnology and Nanomaterials-based product developers in filtration and environmental remediation.	885
Table 437. Market drivers for nanotechnology and nanomaterials in food and agriculture.	890

Table 438. Applications in food packaging, by nanomaterials type and benefits thereof.	893
Table 439. Food packaging products incorporating nanomaterials.	894
Table 440. Applications in food coatings, by nanomaterials type and benefits thereof.	896
Table 441. Applications in food additives and supplements, by nanomaterials type and benefits thereof.	898
Table 442. Applications in agricultural production, by nanomaterials type and benefits thereof.	898
Table 443. Global revenues for nanomaterials in food and agriculture, 2018-2033, millions USD.....	900
Table 444: Nanotechnology and Nanomaterials-based product developers in food and agriculture.....	901
Table 445. Market drivers for nanotechnology and nanomaterials in fuel cells and hydrogen storage.	906
Table 446. Applications in fuel cells, by nanomaterials type and benefits thereof.	908
Table 447. Applications hydrogen storage, by nanomaterials type and benefits thereof.	909
Table 448. Global revenues for nanotechnology and nanomaterials in fuel cells, 2018-2033, millions USD.	911
Table 449. Nanotechnology and Nanomaterials-based product developers in fuel cells and hydrogen storage.....	912
Table 450. Market drivers for nanotechnology and nanomaterials in household care and sanitary.	914
Table 451. Applications in anti-microbial coatings, by nanomaterials type and benefits thereof.	916
Table 452. Applications in anti-fingerprint nanocoatings, by nanomaterials type and benefits thereof.....	918
Table 453. Global revenues for nanotechnology and nanomaterials in household care and sanitary, 2018- 2033, millions USD.....	919
Table 454. Nanomaterials-based application and product developers in household care and sanitary.	921
Table 455. Market drivers for nanotechnology and nanomaterials in lighting.	925
Table 456. Applications in lighting, by nanomaterials type and benefits thereof.....	927
Table 457. Global revenues for nanotechnology and nanomaterials in lighting, 2018-2033, millions USD.	928
Table 458: Nanotechnology and Nanomaterials-based product developers in lighting.....	929
Table 459: Market drivers for nanotechnology and nanomaterials in lubricants.	931
Table 460. Nanomaterial lubricant products.....	932
Table 461. Applications in lubricants, by nanomaterials type and benefits thereof.	933
Table 462. Global revenues for nanotechnology and nanomaterials in lubricants, 2018-2033, millions USD.	934

Table 463. Nanotechnology and Nanomaterials-based product developers in lubricants.....	936
Table 464. Market drivers for nanotechnology and nanomaterials in the marine market.....	937
Table 465. Nanocoatings applied in the marine industry-type of coating, nanomaterials utilized and benefits.	939
Table 466. Global revenues for nanotechnology and nanomaterials in the marine sector, 2018-2033, millions USD.	940
Table 467. Nanotechnology and Nanomaterials-based product developers in the marine industry.....	942
Table 468. Market drivers for nanotechnology and nanomaterials in oil, gas and mining.....	945
Table 469. Applications in sensing and reservoir management, by nanomaterials type and benefits thereof.	947
Table 470. Applications in oil, gas and mining coatings, by nanomaterials type and benefits thereof.....	948
Table 471. Applications in oil & gas exploration drilling fluids, by nanomaterials type and benefits thereof.	949
Table 472. Applications in oil & gas exploration sorbent materials, by nanomaterials type and benefits thereof.....	950
Table 473. Applications in separation, by nanomaterials type and benefits thereof.....	950
Table 474. Global revenues for nanotechnology and nanomaterials in oil, gas and mining, 2018-2033, millions USD.	952
Table 475. Nanotechnology and Nanomaterials-based product developers in oil & gas exploration.	954
Table 476. Market drivers for nanotechnology and nanomaterials in packaging.	957
Table 477. Application markets, competing materials, nanomaterials advantages and current market size in packaging.....	960
Table 478. Applications in packaging, by nanomaterials type and benefits thereof.....	962
Table 479. Global revenues for nanotechnology and nanomaterials in packaging, 2018-2033, millions USD.	964
Table 480. Nanotechnology and Nanomaterials-based product developers in packaging.....	966
Table 481: Market drivers for nanotechnology and nanomaterials in rubber.	970
Table 482. Market overview for nanotechnology and nanomaterials in rubber.....	970
Table 483. Applications in rubber and elastomers, by nanomaterials type and benefits thereof.....	971
Table 484. Market assessment for nanotechnology and nanomaterials in rubber.....	972
Table 485. Global revenues for nanotechnology and nanomaterials in rubber, 2018-2033, millions USD.	974

Table 486. Nanotechnology and Nanomaterials-based product developers in rubber.....	975
Table 487. Market drivers for nanotechnology and nanomaterials in security and defence.....	978
Table 488. Applications in military textiles, by nanomaterials type and benefits thereof.	980
Table 489. Applications in military equipment, by nanomaterials type and benefits thereof.	980
Table 490. Applications in anti-counterfeiting, by nanomaterials type and benefits thereof.	982
Table 491. Applications in security and defence sensors and detection, by nanomaterials type and benefits thereof.....	983
Table 492. Applications in ballistic protection, by nanomaterials type and benefits thereof.	984
Table 493. Global revenues for nanotechnology and nanomaterials in security and defence, 2018-2033, millions USD.	985
Table 494: Nanotechnology and Nanomaterials-based product developers in security and defence.	986
Table 495. Market drivers for nanotechnology and nanomaterials in sensors.	991
Table 496. Graphene properties relevant to application in sensors.....	993
Table 497. Applications in strain sensors, by nanomaterials type and benefits thereof.	994
Table 498.Applications in strain sensors, by nanomaterials type and benefits thereof.	996
Table 499. Applications in biosensors, by nanomaterials type and benefits thereof.	996
Table 500. Applications in food sensors, by nanomaterials type and benefits thereof.....	997
Table 501. Applications in image sensors, by nanomaterials type and benefits thereof.	998
Table 502. Applications in infrared (IR) sensors, by nanomaterials type and benefits thereof.....	998
Table 503. Applications in optical sensors, by nanomaterials type and benefits thereof.....	999
Table 504. Applications in pressure sensors, by nanomaterials type and benefits thereof.	999
Table 505. Applications in humidity sensors, by nanomaterials type and benefits thereof.....	1000
Table 506. Applications in acoustic sensors, by nanomaterials type and benefits thereof.....	1000
Table 507. Applications in wireless sensors, by nanomaterials type and benefits thereof.....	1000
Table 508. Global revenues for nanotechnology and nanomaterials in sensors, 2018-2033, millions USD.	1001
Table 509. Nanotechnology and Nanomaterials-based product developers in sensors.....	1003
Table 510. Market drivers for nanotechnology and nanomaterials in photovoltaics.....	1007
Table 511. Applications in photovoltaics, by nanomaterials type and benefits thereof.	1010

Table 512: Applications in solar water splitting, by nanomaterials type and benefits thereof.....	1012
Table 513: Applications in solar coatings, by nanomaterials type and benefits thereof.	1013
Table 514. Global revenues for nanotechnology and nanomaterials in photovoltaics, 2018-2033, millions USD.	1015
Table 515. Nanotechnology and nanomaterials-based products and application developers in photovoltaics.	1016
Table 516. Market drivers for nanotechnology and nanomaterials in supercapacitors.	1021
Table 517. Applications in supercapacitors, by nanomaterials type and benefits thereof.	1023
Table 518. Global revenues for nanotechnology and nanomaterials in supercapacitors, 2018-2033, millions USD.	1025
Table 519. Nanotechnology and Nanomaterials-based product developers in supercapacitors.	1026
Table 520. Market drivers for nanotechnology and nanomaterials in textiles and apparel.....	1028
Table 521. Desirable functional properties for the textiles industry afforded by the use of nanomaterials.	1032
Table 522. Applications in textiles, by nanomaterials type and benefits thereof.	1034
Table 523. Nanocoatings applied in the textiles industry-type of coating, nanomaterials utilized, benefits and applications.	1036
Table 524. Global revenues for nanotechnology and nanomaterials in textiles and apparel, 2018-2033, millions USD.	1040
Table 525. Nanotechnology and Nanomaterials-based product developers in textiles.....	1042
Table 526. Market drivers for nanotechnology and nanomaterials in tools & manufacturing.	1046
Table 527. Applications in tools & manufacturing, by nanomaterials type and benefits thereof.....	1047
Table 528. Global revenues for nanotechnology and nanomaterials in tools and manufacturing, 2018-2033, millions USD.	1049
Table 529. Nanotechnology and nanomaterials-based product developers in tools & manufacturing.	1050
Table 530. Applications in 3D printing, by nanomaterials type and benefits thereof.	1055
Table 531. Market assessment for nanotechnology and nanomaterials in 3D printing.	1057
Table 532. Global revenues for nanotechnology and nanomaterials in 3D printing, 2018-2033, millions USD.	1058
Table 533. Nanotechnology and Nanomaterials-based product developers in 3D printing.....	1059
Table 534. Applications in catalysts, by nanomaterials type and benefits thereof.	1061

Table 535. Nanotechnology and Nanomaterials-based product developers in catalysts.	1062
Table 536. Nanotechnology and Nanomaterials-based product developers in cabling.....	1063
Table 537. Nanotechnology and Nanomaterials-based product developers in sporting goods.....	1065
Table 538. Applications in wind energy nanocomposites, by nanomaterials type and benefits thereof. ...	1068
Table 539: Applications in wind energy nanosensors, by nanomaterials type and benefits thereof.....	1068
Table 540: Applications in wind energy nanocoatings, by nanomaterials type and benefits thereof.	1068
Table 541: Nanotechnology and Nanomaterials-based product developers in wind energy.....	1069
Table 542. Applications in thermoelectrics, by nanomaterials type and benefits thereof.	1070
Table 543. Nanotechnology and nanomaterials product developers in thermoelectrics.	1071

LIST OF FIGURES

Figure 1. Global production volume of engineered nanomaterials in metric tonnes (MT), 2010-2033.	80
Figure 2. Transportation pathways of natural and artificial (incidental and engineered).	82
Figure 3. Engineered nanomaterials life cycle.	87
Figure 4. Technology Readiness Level for aluminium oxide nanoparticles/nanopowders.	105
Figure 5. Global consumption of aluminium oxide nanopowders/particles (MT), 2010-2033.....	106
Figure 6. Aluminium oxide nanoparticles/powders Market Segmentation 2021 (%).	107
Figure 7. Aluminium oxide nanoparticles/powders Market segmentation 2033 (%).	108
Figure 8. Consumption of aluminium oxide nanoparticles/powders by region 2021 (%).	109
Figure 9. Consumption of aluminium oxide nanoparticles/powders by region 2033 (%).	110
Figure 10. Stage of commercial development for Antimony Tin Oxide Nanoparticles/powders.	116
Figure 11. Global consumption of antimony tin oxide nanoparticles/nanopowders, in metric tonnes, 2010-2033.....	118
Figure 12. Antimony tin oxide nanoparticles/powders Market Segmentation 2021 (%).	118
Figure 13. Antimony tin oxide nanoparticles/powders Market share 2033 (%).	119
Figure 14. Consumption of antimony tin oxide nanoparticles/powders by region 2021 (%).	120
Figure 15. Consumption of antimony tin oxide nanoparticles/powders by region 2033 (%).	121

Figure 16. Technology Readiness Level (TRL) for Bismuth Oxide Nanoparticles/powders.....	127
Figure 17. Global consumption of bismuth oxide nanoparticles/powders in metric tonnes, 2010-2033.	129
Figure 18. Bismuth oxide nanoparticles/powders Market Segmentation 2021 (%).	130
Figure 19. Bismuth oxide nanoparticles/powders Market share 2033 (%).	131
Figure 20. Consumption of bismuth oxide nanoparticles/powders by region 2021 (%).	132
Figure 21. Consumption of bismuth oxide nanoparticles/powders by region 2033 (%).	133
Figure 22. Dorayaki.	141
Figure 23. ENASAVE NEXT.	141
Figure 24. GEL-KAYANO™.	142
Figure 25. Kirekira! toilet wipes.	143
Figure 26. "Poise" series Super strong deodorant sheet.	144
Figure 27. SC-3 (B) speakers.	145
Figure 28. SE-MONITOR5 headphones.	145
Figure 29. "Skin Care Acty" series Adult diapers.	146
Figure 30. "SURISURI" Lotion.	146
Figure 31. Technology Readiness Level (TRL) for nanocellulose.	147
Figure 32. Global demand for cellulose nanofibers/MFC in metric tonnes by market, 2018-2033.	150
Figure 33. Cellulose nanofibers (CNF) Market Segmentation 2021 (%).	151
Figure 34. Cellulose nanofibers (CNF) Market share 2033 (%).	152
Figure 35. Consumption of Cellulose nanofibers (CNF) by region 2021 (%)	154
Figure 36. Consumption of Cellulose nanofibers (CNF) by region 2033 (%)	155
Figure 37. Technology Readiness Level (TRL) for cerium oxide nanoparticles/powders.	166
Figure 38. Global consumption of cerium oxide nanoparticles/powders (MT), 2010-2033.	167
Figure 39. Cerium oxide nanoparticles/powders Market Segmentation 2021 (%)	168
Figure 40. Cerium oxide nanoparticles/powders Market share 2033 (%)	169
Figure 41. Consumption of Cerium Oxide Nanoparticles/powders by region 2021 (%).	170
Figure 42. Consumption of Cerium Oxide Nanoparticles/powders by region 2033 (%).	171
Figure 43. Technology Readiness Level (TRL) for Cobalt Oxide Nanoparticles/powders.	176

Figure 44. Global consumption of cobalt oxide nanoparticles/powders (MT), 2010-2033.....	177
Figure 45. Cobalt oxide nanoparticles/powders Market Segmentation 2021 (%).....	178
Figure 46. Cobalt oxide nanoparticles/powders Market share 2033 (%).....	179
Figure 47. Consumption of Cobalt Oxide Nanoparticles/powders by region 2021 (%).....	180
Figure 48. Consumption of Cobalt Oxide Nanoparticles/powders by region 2033 (%).....	181
Figure 49. Cobalt oxide nanoparticles/powders and nanopowders producers and suppliers.....	182
Figure 50. Technology Readiness Level (TRL) for copper oxide nanoparticles/powders.....	186
Figure 51. Global consumption of copper oxide nanoparticles/powders (MT), 2010-2033.....	187
Figure 52. Copper oxide nanoparticles/powders Market Segmentation 2021 (%).....	188
Figure 53. Copper oxide nanoparticles/powders Market share 2033 (%).....	189
Figure 54. Consumption of copper oxide nanoparticles/powders by region 2021 (%).....	190
Figure 55. Consumption of copper oxide nanoparticles/powders by region 2021 (%).....	191
Figure 56. Dendrimer structure.....	196
Figure 57. Dendrimer schematic for application in biomedicine.....	197
Figure 58. Technology Readiness Level (TRL) for dendrimers.....	199
Figure 59. Global consumption of dendrimers in metric tonnes, 2010-2033.....	201
Figure 60. Dendrimers Market Segmentation 2021 (%).....	201
Figure 61. Dendrimers Market share 2033 (%).....	202
Figure 62. Consumption of dendrimers by region 2021 (%).....	203
Figure 63. Consumption of dendrimers by region 2033 (%).....	204
Figure 64. Technology Readiness Level (TRL) for fullerenes.....	210
Figure 65. Global consumption of fullerenes in metric tonnes, 2010-2033.....	211
Figure 66. Fullerenes Market Segmentation 2021 (%).....	212
Figure 67. Fullerenes Market share 2033 (%).....	213
Figure 68. Consumption of fullerenes by region 2021 (%).....	214
Figure 69. Consumption of fullerenes by region 2033 (%).....	215
Figure 70. Technology Readiness Level (TRL) for gold nanoparticles/powders.....	221
Figure 71. Global consumption of gold nanoparticles in metric tonnes, 2010-2033.....	223

Figure 72. Gold nanoparticles/powders Market Segmentation 2021 (%).....	224
Figure 73. Gold nanoparticles/powders Market share 2033 (%).....	225
Figure 74. Consumption of gold nanoparticles by region 2021 (%).....	226
Figure 75. Consumption of gold nanoparticles by region 2033 (%).....	227
Figure 76. Technology Readiness Level (TRL) for graphene.....	243
Figure 77. Consumption of graphene, 2018-2033, tons.....	249
Figure 78. Graphene Market Segmentation 2021 (%).....	250
Figure 79. Graphene Market share 2033 (%).....	251
Figure 80. Consumption of graphene by region 2021 (%).....	253
Figure 81. Consumption of graphene by region 2033 (%).....	254
Figure 82. Technology Readiness Level (TRL) for iron oxide nanoparticles/powders.....	269
Figure 83. Global consumption of iron oxide nanoparticles/powders in metric tonnes, 2010-2033.....	270
Figure 84. Iron oxide nanoparticles/powders Market Segmentation 2021 (%).....	271
Figure 85. Iron oxide nanoparticles/powders Market share 2033 (%).....	272
Figure 86. Consumption of iron oxide nanoparticles/powders by region 2021 (%).....	273
Figure 87. Consumption of iron oxide nanoparticles/powders by region 2033 (%).....	274
Figure 88. Technology Readiness Level (TRL) for magnesium oxide nanoparticles/powders.....	281
Figure 89. Global consumption of magnesium oxide nanoparticles/powders in metric tonnes, 2010-2033.	282
Figure 90. Magnesium oxide nanoparticles/powders Market Segmentation 2021 (%).....	283
Figure 91. Magnesium oxide nanoparticles/powders Market share 2033 (%).....	284
Figure 92. Consumption of magnesium oxide nanoparticles/powders by region 2021 (%).....	285
Figure 93. Consumption of magnesium oxide nanoparticles/powders by region 2033 (%).....	286
Figure 94. Technology Readiness Level (TRL) for manganese oxide nanoparticles/powders.....	291
Figure 95. Global consumption of manganese oxide nanoparticles/powders in metric tonnes, 2010-2033.	293
Figure 96. Manganese oxide nanoparticles/powders Market Segmentation 2021 (%).....	294
Figure 97. Manganese oxide nanoparticles/powders Market share 2033(%).....	295
Figure 98. Consumption of manganese oxide nanoparticles/powders by region 2021 (%).....	296

Figure 99. Consumption of manganese oxide nanoparticles/powders by region 2033 (%).....	297
Figure 100. Technology Readiness Level (TRL) for multi-walled Carbon Nanotubes by application.	307
Figure 101. Global consumption of multi-walled carbon nanotubes in metric tonnes, 2010-2033.....	308
Figure 102. MWCNT Market Segmentation 2021 (%).....	310
Figure 103. MWCNT Market share 2033 (%).....	312
Figure 104. Consumption of MWCNT by region 2021 (%).....	314
Figure 105. Consumption of MWCNT by region 2033 (%).....	315
Figure 106. Technology Readiness Level (TRL) for nanoclays.....	326
Figure 107. Global consumption of nanoclays in metric tonnes, 2010-2033.....	327
Figure 108. Nanoclays Market Segmentation 2021 (%).....	328
Figure 109. Nanoclays Market share 2033(%).....	329
Figure 110. Consumption of nanoclays by region 2021 (%).....	330
Figure 111. Consumption of nanoclays by region 2033 (%).....	331
Figure 112. Detonation Nanodiamond.....	336
Figure 113. DND primary particles and properties.....	337
Figure 114. Functional groups of Nanodiamonds.....	338
Figure 115. Technology Readiness Level (TRL) for nanodiamonds.....	342
Figure 116. Global consumption of nanodiamonds in metric tonnes, 2010-2033	343
Figure 117. Nanodiamonds Market Segmentation 2021 (%).....	344
Figure 118. Nanodiamonds Market share 2033 (%).....	345
Figure 119. Consumption of nanodiamonds by region 2021 (%).....	346
Figure 120. Consumption of nanodiamonds by region 2033 (%).....	347
Figure 121. Technology Readiness Level (TRL) for nanofibers.....	364
Figure 122. Global revenues for nanofibers, by market 2018-2033, millions USD.....	365
Figure 123. Nanofibers Market Segmentation 2021 (%)	366
Figure 124. Nanofibers Market share 2033 (%)	367
Figure 125. Consumption of Nanofibers by region 2021 (%).....	368
Figure 126. Consumption of Nanofibers by region 2033 (%).....	369

Figure 127. Supply chain for nanosilver products.	377
Figure 128. Technology Readiness Level (TRL) for nanosilver.....	379
Figure 129. Global consumption of nanosilver in metric tonnes, 2010-2033.	380
Figure 130. Nanosilver Market Segmentation 2021 (%).	381
Figure 131. Nanosilver Market share 2033(%).	382
Figure 132. Consumption of nanosilver by region 2021 (%).	383
Figure 133. Consumption of nanosilver by region 2033 (%).	384
Figure 134. Technology Readiness Level (TRL) for nickel nanoparticles/powders.....	389
Figure 135. Global consumption of nickel nanoparticles/powders in metric tonnes, 2010-2033.	391
Figure 136. Nickel nanoparticles/powders Market Segmentation 2021 (%).	392
Figure 137. Nickel nanoparticles/powders Market share 2033 (%).	393
Figure 138. Consumption of nickel nanoparticles/powders by region 2021 (%).	394
Figure 139. Consumption of nickel nanoparticles/powders by region 2033 (%)	395
Figure 140. Technology Readiness Level (TRL) for quantum dots.	404
Figure 141. Global consumption of quantum dots in metric tonnes, 2018-2033.	405
Figure 142. Quantum dots Market Segmentation 2021 (%).	406
Figure 143. Quantum dots Market share 2033 (%)	407
Figure 144. Consumption of quantum dots by region 2021 (%)	408
Figure 145. Consumption of quantum dots by region 2033 (%)	409
Figure 146. Technology Readiness Level (TRL) for silicon oxide nanoparticles/powders.	417
Figure 147. Global consumption of silicon oxide nanoparticles/powders in metric tonnes, 2010-2033.....	418
Figure 148. Silicon oxide nanoparticles/powders Market Segmentation 2021 (%).	419
Figure 149. Silicon oxide nanoparticles/powders Market share 2033 (%).	420
Figure 150. Consumption of silicon oxide nanoparticles/powders by region 2021 (%).	421
Figure 151. Consumption of silicon oxide nanoparticles/powders by region 2033 (%).	422
Figure 152. Technology Readiness Level (TRL) for Single-walled Carbon Nanotubes.	433
Figure 153. SWCNT market demand forecast (metric tons), 2018-2033.	436
Figure 154. Technology Readiness Level (TRL) for Titanium Oxide Nanoparticles/powders.	441

Figure 155. Global consumption of titanium dioxide nanoparticles/powders in metric tonnes, 2010-2033.	443
Figure 156. Titanium dioxide nanoparticles/powders Market Segmentation 2021 (%).	444
Figure 157. Titanium dioxide nanoparticles/powders Market share 2033 (%).	445
Figure 158. Consumption of titanium dioxide nanoparticles/powders by region 2021 (%).	446
Figure 159. Consumption of titanium dioxide nanoparticles/powders by region 2033 (%).	447
Figure 160. Technology Readiness Level (TRL) for zinc oxide nanoparticles/powders.	455
Figure 161. Global consumption of zinc oxide nanoparticles/powders in metric tonnes, 2010-2033.	457
Figure 162. Zinc oxide nanoparticles/powders Market Segmentation 2021 (%).	458
Figure 163. Zinc oxide nanoparticles/powders Market share 2033 (%).	459
Figure 164. Consumption of zinc oxide nanoparticles/powders by region 2021 (%).	460
Figure 165. Consumption of zinc oxide nanoparticles/powders by region 2033 (%).	461
Figure 166. Technology Readiness Level (TRL) for zirconium oxide nanoparticles/powders.	468
Figure 167. Global consumption of zirconium oxide nanoparticles/powders in metric tons, 2010-2033.	470
Figure 168. Zirconium oxide nanoparticles/powders Market Segmentation 2021 (%).	471
Figure 169. Zirconium oxide nanoparticles/powders Market share 2033 (%).	472
Figure 170. Consumption of zirconium oxide nanoparticles/powders by region 2021 (%).	473
Figure 171. Consumption of zirconium oxide nanoparticles/powders by region 2033 (%).	474
Figure 172. Schematic representation of carbon nanohorns.	480
Figure 173. Schematic illustration of three-chamber system for SWCNH production.	481
Figure 174. TEM image of cellulose nanocrystals.	481
Figure 175. CNC preparation.	482
Figure 176. Extracting CNC from trees.	483
Figure 177. CNC slurry.	486
Figure 178: Schematic of Boron Nitride nanotubes (BNNTs). Alternating B and N atoms are shown in blue and red.	494
Figure 179. A pQLED device structure.	499
Figure 180. Perovskite quantum dots under UV light.	502
Figure 181. Carbon dots development.	503
Figure 182: Green-fluorescing graphene quantum dots.	505

Figure 183. Schematic of (a) CQDs and (c) GQDs. HRTEM images of (b) C-dots and (d) GQDs showing combination of zigzag and armchair edges (positions marked as 1–4).....	506
Figure 184. Graphene quantum dots.	508
Figure 185. Top-down and bottom-up methods.	509
Figure 186. Structures of nanomaterials based on dimensions.....	515
Figure 187. Schematic of 2-D materials.....	517
Figure 188. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in adhesives.	561
Figure 189. Global revenues for nanotechnology and nanomaterials in adhesives, 2018-2033, conservative and optimistic estimates (millions USD).	563
Figure 190. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in aerospace and aviation.	575
Figure 191. Global revenues for nanotechnology and nanomaterials in aerospace and aviation, 2018-2033, millions USD.	577
Figure 192. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in automotive. ...	595
Figure 193. Global revenues for nanotechnology and nanomaterials in automotive, 2018-2033, millions USD.	599
Figure 194. Electrochemical performance of nanomaterials in LIBs.....	615
Figure 195. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in batteries.....	621
Figure 196. Global revenues for nanotechnology and nanomaterials in batteries, 2018-2033, millions USD.	625
Figure 197. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in medical biosensors.....	640
Figure 198. Global revenues for nanotechnology and nanomaterials in medical biosensors, 2018-2033, Millions USD.	641
Figure 199. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in drug delivery.	657
Figure 200. Global revenues for nanotechnology and nanomaterials in drug delivery, 2018-2033, millions USD.	658
Figure 201. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in medical imaging and diagnostics	671
Figure 202. Global revenues for nanotechnology and nanomaterials in imaging and diagnostics, 2018-2033.....	672

Figure 203. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in medical coatings and films.	684
Figure 204. Global revenues for nanomaterials in medical coatings 2018-2033, millions USD.	686
Figure 205. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in medical implants.	695
Figure 206. Global revenues for nanomaterials in medical implants, 2018-2033, millions USD.	697
Figure 207. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in medical wound care.....	702
Figure 208. Global revenues for nanotechnology and nanomaterials in wound care, 2018-2033, millions USD.	704
Figure 209. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in dental.....	707
Figure 210. Global revenues for nanotechnology and nanomaterials in dental, 2018-2033, millions USD.....	709
Figure 211. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in coatings and paints.	720
Figure 212. Global revenues for nanotechnology and nanomaterials in coatings and paints, 2018-2033, millions USD.	722
Figure 213. Self-healing nanocoatings.....	746
Figure 214. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in composites. ...	757
Figure 215. Global revenues for nanotechnology and nanomaterials in composites, 2018-2033, millions USD.	764
Figure 216. Global revenues for nanotechnology and nanomaterials in conductive inks, 2017-2033, millions USD.	782
Figure 217. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in construction and buildings.....	803
Figure 218. Global revenues for nanotechnology and nanomaterials in construction, 2018-2033, millions USD.	806
Figure 219. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in cosmetics and sunscreens.....	825
Figure 220. Global revenues for nanotechnology and nanomaterials in cosmetics and sunscreens, 2018-2033, millions USD.....	826
Figure 221. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in flexible electronics, conductive films and displays.	837

Figure 222: QD-LCD supply chain.	838
Figure 223. Global revenues for nanotechnology and nanomaterials in flexible electronics, 2018-2033. ..	840
Figure 224. Global revenues for nanomaterials in displays, 2018-2033.	841
Figure 225. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in transistors, integrated circuits and other components.	848
Figure 226. Global revenues for nanotechnology and nanomaterials in transistors, integrated circuits and other components, 2018-2033.	850
Figure 227. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in memory devices.	855
Figure 228. Global revenues for nanotechnology and nanomaterials in memory devices, 2018-2033.	857
Figure 229. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in electronics coatings.	862
Figure 230. Global revenues for nanotechnology and nanomaterials in electronics coatings, 2018-2033.	863
Figure 231. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in photonics.	871
Figure 232. Global revenues for nanotechnology and nanomaterials in photonics, 2018-2033.	873
Figure 233. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in filtration.	883
Figure 234. Global revenues for nanotechnology and nanomaterials in filtration, 2018-2033, millions USD.	884
Figure 235. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in food and agriculture.	899
Figure 236. Global revenues for nanomaterials in food and agriculture, 2018-2033, millions USD.	900
Figure 237. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in fuel cells.	910
Figure 238. Global revenues for nanotechnology and nanomaterials in fuel cells, 2018-2033, millions USD.	912
Figure 239. Technology Readiness Level (TRL) for nanotechnology and nanomaterials household care and sanitary.	919
Figure 240. Global revenues for nanotechnology and nanomaterials in household care and sanitary, 2018-2033, millions USD.	920
Figure 241. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in lighting.	927
Figure 242. Global revenues for nanotechnology and nanomaterials in lighting, 2018-2033, millions USD.	929

Figure 243. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in lubricants.	934
Figure 244. Global revenues for nanotechnology and nanomaterials in lubricants, 2018-2033, millions USD.	935
Figure 245. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in marine.	940
Figure 246. Global revenues for nanotechnology and nanomaterials in the marine sector, 2018-2033, millions USD.	941
Figure 247. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in oil, gas and mining.	951
Figure 248. Global revenues for nanotechnology and nanomaterials in oil, gas and mining, 2018-2033, millions USD.	953
Figure 249. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in packaging.	963
Figure 250. Global revenues for nanotechnology and nanomaterials in packaging, 2018-2033, millions USD.	965
Figure 251. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in rubber.	972
Figure 252. Global revenues for nanotechnology and nanomaterials in rubber, 2018-2033, millions USD.	975
Figure 253. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in security and defence.	984
Figure 254. Global revenues for nanotechnology and nanomaterials in security and defence, 2018-2033, millions USD.	986
Figure 255. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in sensors.	1001
Figure 256. Global revenues for nanotechnology and nanomaterials in sensors, 2018-2033, millions USD.	1002
Figure 257. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in photovoltaics.	1014
Figure 258. Global revenues for nanotechnology and nanomaterials in photovoltaics, 2018-2033, millions USD.	1016
Figure 259. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in supercapacitors.	1024
Figure 260. Global revenues for nanotechnology and nanomaterials in supercapacitors, 2018-2033, millions USD.	1026

Figure 261. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in textiles and apparel.....	1039
Figure 262. Global revenues for nanotechnology and nanomaterials in textiles and apparel, 2018-2033, millions USD.	1041
Figure 263. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in tools & manufacturing.	1048
Figure 264. Global revenues for nanotechnology and nanomaterials in tools and manufacturing 2018-2033, millions USD.	1050
Figure 265. Technology Readiness Level (TRL) for nanotechnology and nanomaterials in 3D printing. .	1056
Figure 266. Global revenues for nanotechnology and nanomaterials in 3D printing, 2018-2033, millions USD.	1059