List of Figures

Fig. No.	Figure caption	Pg. No.
1.1	Energy resources of the world	5
1.2	Renewable energy share of global electricity production based on renewable generating capacity at the end of year 2015	7
1.3	World energy use and renewable energy share in heat sector in %	8
1.4	Comparison of conventional solar thermal energy absorbers with nanofluid based absorbers	24
2.1	Types of solar absorber coatings	43
3.1	Experimental setup for preparation of copper and aluminium nanofluid under high intensity ultrasound irradiation	96
3.2	Experimental setup for measurement of heat transfer coefficient (h)	97
3.3	Experimental setup for solar energy absorption using Cu and Al nanofluid	98
3.4	Experimental setup for copper nanoparticles enabled solar distillation of azeotropic mixture	100
3.5	X-ray diffraction patterns of Cu nanoparticles showing effect of amount of reducing agent (A) 10 g glucose, (B) 15 g glucose and (C) 20 g glucose	101
3.6	SEM images of Cu nanoparticles showing effect of amount of reducing agent (A) 10 g glucose, (B) 15 g glucose and (C) 20 g glucose	102
3.7	DLS results of Cu nanoparticles showing effect of amount of reducing agent (A) 10 g glucose, (B) 15 g glucose and (C) 20 g glucose	103
3.8	X-ray diffraction patterns of Cu nanoparticles showing effect of type of surfactant (A) SLS, (B) PVP (C) CTAB and (D) Myristic acid	104
3.9	SEM images of Cu nanoparticles showing effect of type of surfactant (A) SLS, (B) PVP (C) CTAB and (D) Myristic acid	105

3.10	X-ray diffraction patterns of Cu nanoparticles showing effect of concentration of SLS surfactant (A) 0.01 M SLS, (B) 0.05 M SLS and (C) 0.1 M SLS	106
3.11	X-ray diffraction patterns of Cu nanoparticles showing effect of concentration of PVP surfactant (A) 0.001 M PVP, (B) 0.002 M PVP and (C) 0.003 M PVP	106
3.12	X-ray diffraction patterns of Cu nanoparticles showing effect of concentration of CTAB surfactant (A) 0.005 M CTAB and (B) 0.01 M CTAB	107
3.13	SEM images of Cu nanoparticles showing effect of concentration of SLS surfactant (A) 0.01 M SLS, (B) 0.05 M SLS and (C) 0.1 M SLS	108
3.14	SEM images of Cu nanoparticles showing effect of concentration of PVP surfactant (A) 0.001 M PVP, (B) 0.002 M PVP and (C) 0.003 M PVP	108
3.15	DLS results of Cu nanoparticles showing effect of concentration of SLS surfactant (A) 0.01 M SLS, (B) 0.05 M SLS and (C) 0.1 M SLS	109
3.16	DLS results of Cu nanoparticles showing effect of concentration of PVP surfactant (A) 0.001 M PVP, (B) 0.002 M PVP and (C) 0.003 M PVP	110
3.17	DLS results of Cu nanoparticles showing effect of concentration of CTAB surfactant (A) 0.005 M CTAB and (B) 0.01 M CTAB	110
3.18	X-ray diffraction patterns of aluminium nanoparticles	111
3.19	FESEM images of aluminium nanoparticles	112
3.20	Variation of density of nanofluid with concentration (volume %) of copper in water	113
3.21	Variation of viscosity of nanofluid with concentration of copper (volume %) in water	114
3.22	Variation of density of nanofluid with concentration of aluminium (volume %) in water	115
3.23	Temperature versus time plot for solar energy absorption by using copper (100 nm) nanofluid in water	116
3.24	Effect of particle concentration on efficiency of solar energy absorption for copper (100 nm) nanofluid in water	117

3.25	Temperature versus time plot for solar energy absorption by using copper (100 nm) nanofluid in ethylene glycol (MEG)	119
3.26	Temperature versus time plot for solar energy absorption by using copper (100 nm) nanofluid in silicone oil	120
3.27	Temperature versus time plot for solar energy absorption by using aluminium (150 to 250 nm) nanofluid in water	121
3.28	Effect of particle concentration on efficiency of solar energy absorption for aluminium (150-250 nm) nanofluid in water	122
3.29	Temperature versus time plot for solar energy absorption by using aluminium (150 to 250 nm) nanofluid in ethylene glycol (MEG)	123
3.30	Temperature versus time plot for solar energy absorption by using aluminium (150 to 250 nm) nanofluid in silicone oil	124
3.31	Temperature versus time plot for solar desalination by using copper nanoparticles (100 nm) in hard water	125
3.32	Effect of particle concentration on efficiency of solar water desalination for copper nanoparticle (100 nm)	126
3.33	Temperature versus time plot for solar desalination by using copper nanoparticles (100 nm) in sea water	127
3.34	Temperature versus time plot for solar desalination by using aluminium nanoparticles (150 to 250 nm) in hard water	128
3.35	Effect of particle concentration on efficiency of solar water desalination for aluminium nanoparticle (150 to 250 nm)	128
3.36	Temperature versus time plot for solar desalination by using aluminium nanoparticles (150 to 250 nm) in sea water	130
4.1	XRD patterns of CuO nanomaterial showing effect of NaOH concentration (A) 0.25M NaOH, (B) 0.5M NaOH and (C) 1M NaOH	144
4.2	SEM images of CuO nanomaterial showing effect of NaOH concentration (A) 0.25M NaOH, (B) 0.5M NaOH and (C) 1M NaOH	145
4.3	DLS results of CuO nanomaterial showing effect of NaOH concentration (A) 0.25M NaOH, (B) 0.5M NaOH and (C) 1M NaOH	146

4.4	XRD patterns of CuO nanomaterial showing effect of initial concentration of reactants (A) 0.076 M $CuCl_2$ and 1 M NaOH, (B) 0.038 M $CuCl_2$ and 0.5 M NaOH and (C) 0.0076 M $CuCl_2$ and 0.1 M NaOH	147
4.5	SEM images of CuO nanomaterial showing effect of initial concentration of reactants (A) 0.076 M $CuCl_2$ and 1 M NaOH, (B) 0.038 M $CuCl_2$ and 0.5 M NaOH and (C) 0.0076 M $CuCl_2$ and 0.1 M NaOH	148
4.6	DLS results of CuO nanomaterial showing effect of initial concentration of reactants (A) 0.076 M $CuCl_2$ and 1 M NaOH, (B) 0.038 M $CuCl_2$ and 0.5 M NaOH and (C) 0.0076 M $CuCl_2$ and 0.1 M NaOH	148
4.7	XRD patterns of CuO nanomaterial showing effect of amount of surfactant (PVP, K-30) (A) 0.5 g PVP, (B) 1 g PVP and (C) 1.5 g PVP	149
4.8	SEM images of CuO nanomaterial showing effect of amount of surfactant (PVP, K-30) (A) 0.5 g PVP, (B) 1 g PVP and (C) 1.5 g PVP	150
4.9	DLS results of CuO nanomaterial showing effect of amount of surfactant (PVP, K-30) (A) 0.5 g PVP, (B) 1 g PVP and (C) 1.5 g PVP	151
4.10	X-ray diffraction patterns of Fe_2O_3 nanoparticles	152
4.11	SEM images of Fe_2O_3 nanoparticles	152
4.12	Variation of density of nanofluid with concentration (volume %) of CuO in water	154
4.13	Variation of viscosity of nanofluid with concentration of CuO (volume %) in water	155
4.14	Variation of density of nanofluid with concentration (volume %) of Fe_2O_3 in water	156
4.15	Temperature versus time plot for solar energy absorption by using CuO (133 nm) nanofluid in water	157
4.16	Effect of particle concentration on efficiency of solar energy absorption for CuO (133 nm) nanofluid in water	158

4.17	Temperature versus time plot for solar energy absorption by using CuO (133 nm) nanofluid in ethylene glycol (MEG)	159
4.18	Temperature versus time plot for solar energy absorption by using CuO (133 nm) nanofluid in silicone oil	160
4.19	Temperature versus time plot for solar energy absorption by using Fe_2O_3 (300 nm) nanofluid in water	162
4.20	Effect of particle concentration on efficiency of solar energy absorption for Fe_2O_3 (300 nm) nanofluid in water	163
4.21	Temperature versus time plot for solar energy absorption by using Fe_2O_3 (300 nm) nanofluid in ethylene glycol (MEG)	164
4.22	Temperature versus time plot for solar energy absorption by using Fe_2O_3 (300 nm) nanofluid in silicone oil	165
4.23	Temperature versus time plot for solar desalination by using CuO nanomaterial (133 nm) in hard water	166
4.24	Effect of particle concentration on efficiency of solar water desalination for CuO nanomaterial (133 nm)	166
4.25	Temperature versus time plot for solar desalination by using CuO nanomaterial (133 nm) in sea water	168
4.26	Temperature versus time plot for solar desalination by using Fe_2O_3 nanoparticles (300 nm) in hard water	168
4.27	Effect of particle concentration on efficiency of solar water desalination for Fe_2O_3 nanoparticles (300 nm)	169
4.28	Temperature versus time plot for solar desalination by using Fe_2O_3 nanoparticles (300 nm) in sea water	170
5.1	XRD pattern of SiO_2 nanoparticles synthesized by Stober's method (325 nm)	187
5.2	EDS analysis of SiO_2 nanoparticles synthesized by Stober's method (325 nm)	188
5.3	FESEM images of SiO_2 nanoparticles synthesized by Stober's method (325 nm)	189
5.4	EDS analysis of SiO_2 nanoparticles synthesized by microwave method (65 nm)	190

5.5	FESEM images of SiO_2 nanoparticles synthesized by microwave method (65 nm)	190
5.6	EDS analysis of SiO_2 nanoparticles synthesized by microwave method (23 nm)	191
5.7	FESEM images of SiO_2 nanoparticles synthesized by microwave method (23 nm)	191
5.8	XRD pattern of Ag-doped SiO_2 nanoparticles (23 nm)	192
5.9	FESEM images of Ag-doped SiO_2 nanoparticles (23 nm)	192
5.10	XRD pattern of ZnO quantum dots synthesized by colloidal route	193
5.11	FESEM images of ZnO quantum dots synthesized by colloidal route	194
5.12	EDS analysis of ZnO nanowires synthesized by hydrothermal method	194
5.13	SEM images of ZnO nanowires synthesized by hydrothermal method	195
5.14	XRD pattern of TiO_2 nanotubes synthesized by hydrothermal method	195
5.15	FESEM images of TiO_2 nanotubes synthesized by hydrothermal method	196
5.16	XRD pattern of TiO_2 nanowires synthesized by hydrothermal method	196
5.17	FESEM images of TiO_2 nanowires synthesized by hydrothermal method	197
5.18	XRD pattern of carbon-doped TiO_2 nanoparticles synthesized by hydrothermal method	197
5.19	FESEM images of carbon-doped TiO_2 nanoparticles synthesized by hydrothermal method	198
5.20	Variation of density of nanofluid with concentration (volume %) of SiO_2 (65 nm) in water	199
5.21	Variation of density of nanofluid with concentration (volume %) of ZnO QDs (10 nm) in water	200
5.22	Variation of density of nanofluid with concentration (volume %) of TiO_2 in water	202

5.23	Temperature versus time plot for solar energy absorption by using SiO_2 (23 nm) nanofluid in water	203
5.24	Effect of particle concentration on efficiency of solar energy absorption for SiO_2 (23 nm) nanofluid in water	204
5.25	Effect of particle size and doping on efficiency of solar energy absorption for SiO_2 nanofluid in water	205
5.26	Temperature versus time plot for solar energy absorption by using SiO_2 (different sizes) nanofluid in ethylene glycol (MEG)	206
5.27	Temperature versus time plot for solar energy absorption by using SiO_2 (different sizes) nanofluid in silicone oil	207
5.28	Temperature versus time plot for solar energy absorption by using ZnO QDs (10 nm) nanofluid in water	208
5.29	Effect of particle concentration on efficiency of solar energy absorption for ZnO QDs (10 nm) nanofluid in water	209
5.30	Temperature versus time plot for solar energy absorption by using ZnO QDs (10 nm) nanofluid in ethylene glycol (MEG)	210
5.31	Temperature versus time plot for solar energy absorption by using ZnO QDs (10 nm) nanofluid in silicone oil	211
5.32	Temperature versus time plot for solar energy absorption by using ZnO NWs (200 to 300 nm) nanofluid in water	212
5.33	Effect of particle concentration on efficiency of solar energy absorption for ZnO NWs (200 to 300 nm) nanofluid in water	213
5.34	Temperature versus time plot for solar energy absorption by using ZnO NWs (200 to 300 nm) nanofluid in ethylene glycol (MEG)	214
5.35	Temperature versus time plot for solar energy absorption by using ZnO NWs (200 to 300 nm) nanofluid in silicone oil	215
5.36	Temperature versus time plot for solar energy absorption by using TiO_2 Aeroxide® P25 (21 nm) nanofluid in water	216
5.37	Effect of particle concentration on efficiency of solar energy absorption for TiO_2 Aeroxide® P25 (21 nm) nanofluid in water	217
5.38	Temperature versus time plot for solar energy absorption by using TiO_2 Aeroxide® P25 (21 nm) nanofluid in ethylene glycol (MEG)	218

5.39	Temperature versus time plot for solar energy absorption by using TiO_2 Aeroxide® P25 (21 nm) nanofluid in silicone oil	219
5.40	Temperature versus time plot for solar energy absorption by using TiO_2 Aeroxide® P90 (14 nm) nanofluid in water	220
5.41	Effect of particle concentration on efficiency of solar energy absorption for TiO_2 Aeroxide® P90 (14 nm) nanofluid in water	221
5.42	Temperature versus time plot for solar energy absorption by using TiO_2 Aeroxide® P90 (14 nm) nanofluid in ethylene glycol (MEG)	222
5.43	Temperature versus time plot for solar energy absorption by using TiO_2 Aeroxide® P90 (14 nm) nanofluid in silicone oil	223
5.44	Temperature versus time plot for solar energy absorption by using TiO_2 NTs (12 to 29 nm diameter) nanofluid in water	224
5.45	Effect of particle concentration on efficiency of solar energy absorption for TiO_2 NTs (12 to 29 nm diameter) nanofluid in water	225
5.46	Temperature versus time plot for solar energy absorption by using TiO_2 NTs (12 to 29 nm diameter) nanofluid in ethylene glycol (MEG)	226
5.47	Temperature versus time plot for solar energy absorption by using TiO_2 NTs (12 to 29 nm diameter) nanofluid in silicone oil	227
5.48	Temperature versus time plot for solar energy absorption by using TiO_2 NWs (15 to 29 nm diameter) nanofluid in water	228
5.49	Effect of particle concentration on efficiency of solar energy absorption for TiO_2 NWs (15 to 29 nm diameter) nanofluid in water	229
5.50	Temperature versus time plot for solar energy absorption by using TiO_2 NWs (15 to 29 nm diameter) nanofluid in ethylene glycol (MEG)	230
5.51	Temperature versus time plot for solar energy absorption by using TiO_2 NWs (15 to 29 nm diameter) nanofluid in silicone oil	231
5.52	Temperature versus time plot for solar desalination by using SiO_2 nanoparticles (65 nm) in hard water	232
5.53	Effect of particle concentration on efficiency of solar water desalination for SiO_2 nanoparticles (65 nm)	233

5.54	Temperature versus time plot for solar desalination by using SiO_2 nanoparticles (23 nm) in hard water	234
5.55	Effect of particle concentration on efficiency of solar water desalination for SiO_2 nanoparticles (23 nm)	235
5.56	Temperature versus time plot for solar desalination by using ZnO QDs (10 nm) in hard water	236
5.57	Effect of particle concentration on efficiency of solar water desalination for ZnO QDs (10 nm)	237
5.58	Temperature versus time plot for solar desalination by using ZnO NWs (200 to 300 nm) in hard water	238
5.59	Effect of particle concentration on efficiency of solar water desalination for ZnO NWs (200 to 300 nm)	238
5.60	Temperature versus time plot for solar desalination by using TiO_2 Aeroxide® P25 (21 nm) in hard water	240
5.61	Effect of particle concentration on efficiency of solar water desalination for TiO_2 Aeroxide® P25 (21 nm)	241
5.62	Temperature versus time plot for solar desalination by using TiO_2 Aeroxide® P25 (21 nm) in sea water	242
5.63	Temperature versus time plot for solar desalination by using TiO_2 Aeroxide® P90 (14 nm) in hard water	243
5.64	Effect of particle concentration on efficiency of solar water desalination for TiO_2 Aeroxide® P90 (14 nm)	243
5.65	Temperature versus time plot for solar desalination by using TiO_2 NTs (12 to 29 nm diameter) in hard water	244
5.66	Effect of particle concentration on efficiency of solar water desalination for TiO_2 NTs (12 to 29 nm diameter)	245
5.67	Temperature versus time plot for solar desalination by using TiO_2 NTs (12 to 29 nm diameter) in sea water	246
5.68	Temperature versus time plot for solar desalination by using TiO_2 NWs (15 to 29 nm diameter) in hard water	247
5.69	Effect of particle concentration on efficiency of solar water desalination for TiO_2 NWs (15 to 29 nm diameter)	247

5.70	Temperature versus time plot for solar desalination by using TiO_2 NWs (15 to 29 nm diameter) in sea water	248
6.1	EDS analysis of carbon nanoparticles synthesized by hydrothermal method (325 nm)	264
6.2	FESEM images of carbon nanoparticles synthesized by hydrothermal method (325 nm)	264
6.3	EDS analysis of carbon nanoparticles synthesized by hydrothermal method (65 nm)	265
6.4	FESEM images of carbon nanoparticles synthesized by hydrothermal method (65 nm)	265
6.5	EDS analysis of carbon nanoparticles obtained commercially (30 nm)	266
6.6	FESEM images of carbon nanoparticles obtained commercially (30 nm)	267
6.7	Variation of density of nanofluid with concentration (volume %) of carbon (30 nm) in water	268
6.8	Temperature versus time plot for solar energy absorption by using carbon (30 nm) nanofluid in water	269
6.9	Effect of particle concentration on efficiency of solar energy absorption for carbon (30 nm) nanofluid in water	270
6.10	Temperature versus time plot for solar energy absorption by nanofluids containing different size carbon nanoparticles in water	271
6.11	Effect of size of nanoparticles on efficiency of solar energy absorption for carbon nanofluid in water	272
6.12	Temperature versus time plot for solar energy absorption by using carbon (30 nm) nanofluid in ethylene glycol (MEG)	273
6.13	Temperature versus time plot for solar energy absorption by nanofluids containing different size carbon nanoparticles in MEG	274
6.14	Effect of size of nanoparticles on efficiency of solar energy absorption for carbon nanofluid in MEG	274
6.15	Temperature versus time plot for solar energy absorption by using carbon (30 nm) nanofluid in silicone oil	275

6.16 Temperature versus time plot for solar energy absorption by nanofluids containing different size carbon nanoparticles in silicone oil 276

6.17 Effect of size of nanoparticles on efficiency of solar energy absorption for carbon nanofluid in silicone oil 277

6.18 Temperature versus time plot for solar desalination by using carbon nanoparticles (30 nm) in hard water 278

6.19 Effect of particle concentration on efficiency of solar water desalination for carbon nanoparticles (30 nm) 278

6.20 Temperature versus time plot for solar desalination by using carbon nanoparticles (30 nm) in sea water 280