Contents

		page
Abstract		I
Acknowledgements		iii
Contents		v
List of Figures		vii
List of Tables		x
List of Symbols		xi
List of Abbreviations		xiv
Chapter 1: INTRODUCTION		1
1.1	*Solar thermal in drying, process heating, food, and agriculture*	3
1.2	*Solar thermal in thermochemical, metal processing and metallurgy*	3
1.3	*Objective of thesis*	6
Chapter 2: Open Volumetric Air Receiver		7
2.1	*Introduction*	7
2.2	*OVAR Scale-up*	12
	2.2.1 Heating strategy	13
2.3	*Mathematical modelling*	14
	2.3.1 Governing equation	15
	2.3.1.1 Receiver casing	16
	2.3.1.2 Absorber	17
	2.3.1.3 Peripheral absorber	17
	2.3.1.4 Intermediate absorber	19
	2.3.1.5 Central absorber	20
	2.3.1.6 Primary air	22
	2.3.1.7 Return air	23
	2.3.1.8 Return air flow through the peripheral region	24
	2.3.1.9 Return air flow through the intermediate region	25
	2.3.1.10 Return air flow through the central region	25
	2.3.2 Grid independence test and validation	26
2.4	*Results and discussion*	28
	2.4.1 Volumetric heating	29
	2.4.2 Non-volumetric heating	33
	2.4.3 Parametric investigation of an OVAR design	37
	2.4.3.1 Effect of air return ratio	37
	2.4.3.2 Effect of $\dot{q}/\dot{m}_a$	38
	2.4.3.3 Effect of absorber diameter to length ratio	38
	2.4.3.4 Effect of absorber gap to length ratio	39
	2.4.3.5 Effect of absorber porosity	40
	2.4.3.6 Effect of return air inlet temperature	41
	2.4.3.7 Effect of absorber emissivity	41
	2.4.3.8 Effect of time-dependent solar irradiance	42
	2.4.4 Comparative assessment for the scale-up OVAR designs	43
	2.4.5. Summary & conclusions	44
Chapter 3: Experimental Assessment of Thermal Energy Storage		45
3.1	*Introduction*	45
3.2	*Thermal storage*	49
3.3	*Experiment methodology*	50
	3.3.1 Primary thermal energy storage: Charging	50
	3.3.2 Primary thermal energy storage: Discharging	51
3.4	*Results and Discussions*	52
	3.4.1 Charging of primary thermal energy storage	52
	3.4.2 Discharging of primary thermal energy storage	59

3.5 *Uncertainty analysis* 64
3.6 *Summary & conclusions* 64

Chapter 4: Solar convective furnace 67
4.1 *Introduction* 67
4.2 *Solar convective furnace* 68
4.3 *Full-scale industrial furnace* 69
4.4 *Retrofitted scale-down solar convective furnace* 70
4.5 *Part-scale down model* 71
4.6 *Methodology* 74
4.6.1 SCF with heater 74
4.6.2 SCF with TES 75
4.7 *Experimental results* 75
4.7.1 SCF with heater 75
4.7.2 SCF with TES 77
4.8 *Summary & conclusions* 78

Chapter 5: Solar convective furnace system 79
5.1 *Introduction* 79
5.2 *System dynamics* 80
5.2.1 Charging 81
5.2.1.1 Energy balance: charging 81
5.2.2 Discharging 82
5.2.1.2 Energy balance: discharging 83
5.3 *Operation strategy of SCF system* 84
5.4 *Solar convective furnace system efficiency* 88
5.5 *Numerical modelling* 89
5.5.1 Numerical modelling of TES 89
5.5.2 Grid independent 93
5.5.3 Validation 94
5.5.4 Parametric study 95
5.5.4.1 Effect of inlet temperature 95
5.5.4.2 Effect of mass flow rate 95
5.5.4.3 Effect of porosity 96
5.5.4.4 Effect of specific heat of material 97
5.5.4.5 Effect of thermal conductivity of material 97
5.5.5 Numerical modelling of solar convective furnace 98
5.5.6 Numerical modelling of insulated pipe 101
5.5.7 Integrated model for SCFS 103
5.5.7.1. Charging process 103
5.5.7.2. Discharging process 105
5.6 *Summary & Conclusions* 107

Chapter 6: Summary, Conclusions, and future scope 109
6.1 Summary 109
6.2 Conclusions 110
6.3 Future work 111
References 113
Publications 122