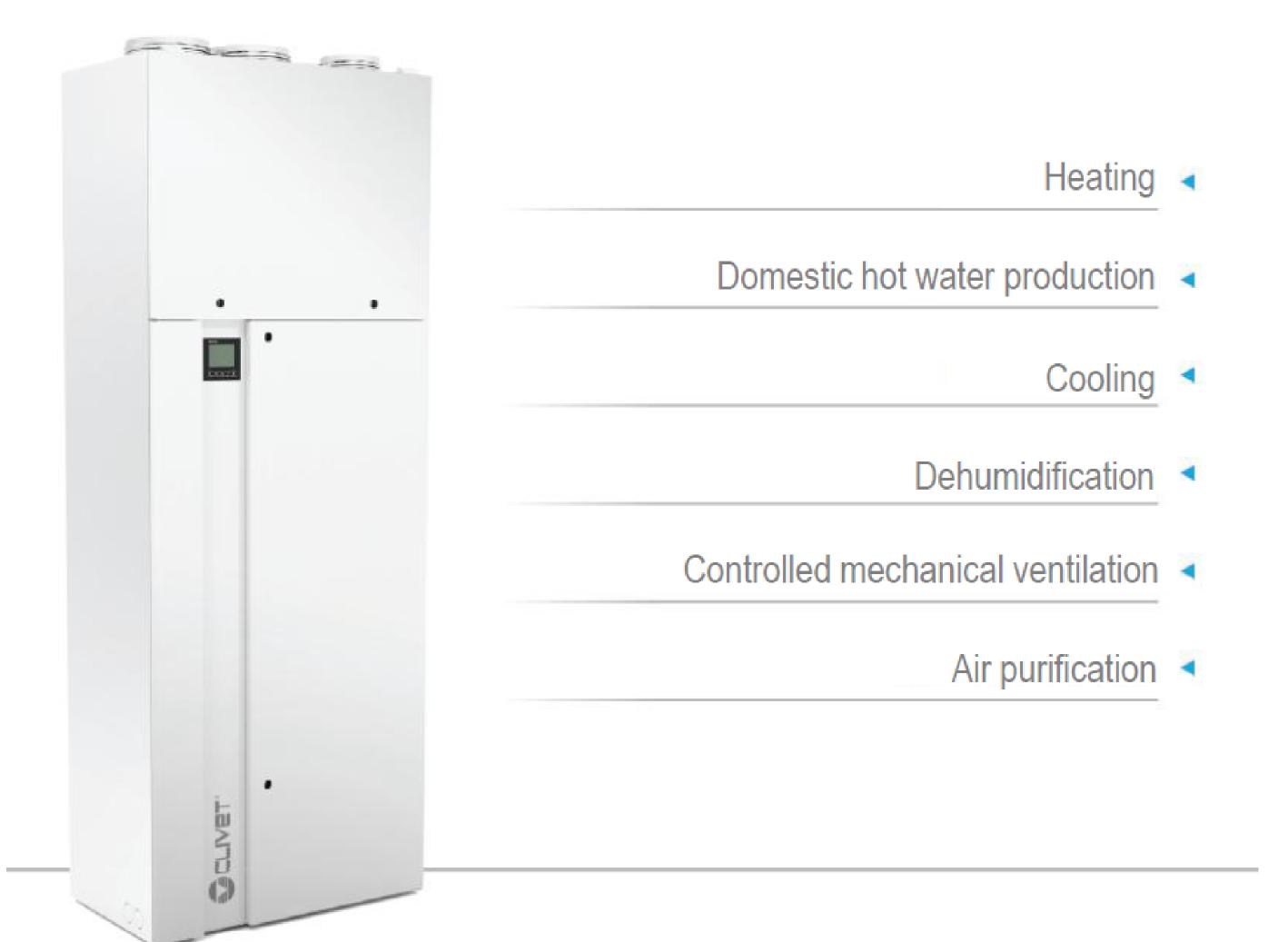
# Test and modification of ELFOPack system

### Introduction

With multifunction aeraulic heat pump system working, the ELFOPack unit can provide for all the comfort functions of the house, including heating, cooling, DHW production, dehumidification, controlled mechanical ventilation and air purification. ELFOPack unit was tested under a variety of operating conditions to characterize the heating and cooling capacities. The purpose was to test the capabilities of the existing ELFOPack System and identify specific areas that need modification for it to satisfy the performance requirements of NYSERDA.

### Functions

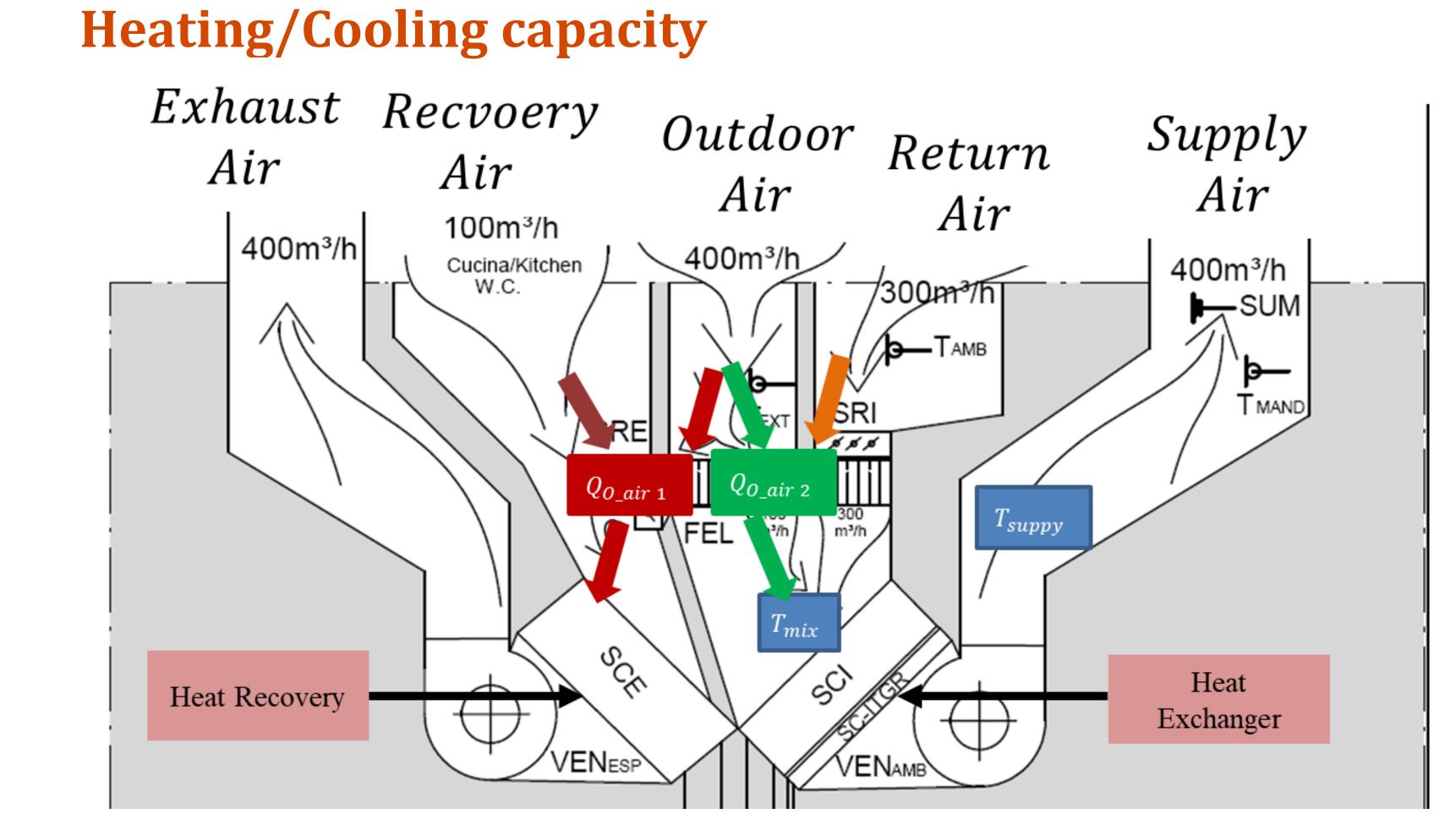


### **Requirements of NYSERDA**

Table 4: Heating and Cooling Loads by Climate Zone

Loads		Coolin	g	Heating					
Zone	HDD	Btu/hr per 1000 ft2	tons/1000 ft2	Btu/hr per 1000 ft2	tons/1000 ft2				
4	5200	2470	0.21	5930	0.5				
5	5400	2250	0.19	5640	0.5				
	7200	2190	0.18	6800	0.6				
6	7200	1820	0.15	5980	0.5				
	9000	690	0.06	6780	0.6				

## Syracuse University College of Engineering & Computer Science



### **Comparison of performance**

Exte	rnal te	empe	rature		C	°C	0		5		10		15		20	)
Heat	ting ca	pacit	ÿ		١	W	316	5.0	250	)9.6	205	5.8	15	10.1	69	1.4
DHV	V heat	ing ca	apacity		١	W	90.7	7	42.	1	332	.3	53	7.5	18	5.8
Vent	tilatio	n capa	acity		١	W	V 615		105	5.3	73.4		29.1		31.9	
Transmission capacity				١	W 245		8.3	236	52.2	2.2 1506.		9 943.5		47	473.6	
	Absorbed power				١	W	612	)	523	523.2		.2	31	2	84	
СОР						5.17	7	4.8	0	4.5	)	4.8	4	8.	23	
<b>Room supply temperature</b>			C	°C	36.4			4	35.9	•	33		31	8		
3	4	5	6	7		8		9	10	11		12	13		14	15
2254	2130	2006	1882	179	0	1698	10	607	1446	128	5 1	362	120	1 1	041	290
290	290	290	290	290	)	290	2	90	290	290	)	290	290		290	290
515	472	429	386	343	3	300	2	57	214	172	2	129	86		43	0
1450	1368	1287	1206	115	7	1108	1(	059	942	824	1	943	826		708	0
649	605	561	517	471		425		79	330	280	)	371	322		272	80
3,47	3,52	3,58	3,64	3,80	0	4,00	4	,24	4,39	4,5	8	67,	3,73	3	3,82	3,63
33	32	31	30	28		27	27 26		25	24		23	22		21	20
External temperature		°C	2	7	28	5	29	3	0	33	L	32	•			
Coolir	ng cap	acity			W	7	9.4	20	0.7	557.	1 8	08.7	<b>9</b> !	58.2	11	.57.0
Ventil	ation	capad	city		W 2.2		.2	49.9		75.8	1	32.0	) 1!	57.8	16	8.8
DHW	heatir	ng cap	pacity		W	W 290		290		290 2		90	290		290	
Trans	missio	n cap	acity		W	W 77.		150.8		481.3		76.7	8	00.4	98	8.2
Absor	bed p	ower			W			15	2	255.	43	29.6	5 40	)9.4	51	1.8
СОР						3	.7	3.2	2	3.3	3	.3	3.	0	2.	8
Room	suppl	ly ten	nperatu	ire	°C	2	4.6	24	.8	22.3	2	2.3	2:	L.3	19	.5
28	29		30			31		3	2		33		34			35
268	53	6	804			1073		13	341	1	609		187	7		2145
290	29	0	290			290		2	90		290		290	)		290
30	59	)	89			118		1	48		177		207	1		236
239	47	7	716			955		1	193	1	432		167	1		1909
66	25	7	352			444		5	42		652		779	)		964
,36	3,2	2	3,11			3,07		3	,01		2,91		2,7	8		2,53
26	24	1	22			21		2	20		19		18			17

						Exte	ernal to	empe	rature		°C	0		5	1	0	15	2	20
						Hea	ting ca	apacit	у		W	31	55.0	250	9.6 2	055.8	1510	.1 6	591.4
						DH\	DHW heating capacity				W	90.	7	42.1	. 3	32.3	537.5	; 1	L85.8
					•	Ven	Ventilation capacity					61	5.9	105	5.3 73.4		29.1	3	<b>31.9</b>
1	Meas	su	rem	ent	$\rightarrow$		Transmission capacity					24	58.3	236	2.2 1	506.9	943.5	<b>;</b> 2	173.6
	Requ	iir	em	ent			Absorbed power					612	2	523	.2 4	81.2	312	ξ	34
					COF		•				5.1		4.80	) 4	.50	4.84		3.23	
↓ Performance							plv te	mpera	ture	°C	36.		37.4		5.9	33		31.8	
External Air Temperature °C 0 1 2					3	4	ς Γ	6	7	8		9	10	11	12	13	14	15	
Heating capacity		w	2713	2560	2407	2254	2130	2006	1882	1790	_		607	1446	1285	1362	1201	1041	
DHW heating capacity		w	290	290	290	290	290	290	290	290	29		290	290	290	290	290	290	
Ventilation heating capacity		w	643	600	557	515	472	429	386	343	30		257	214	172	129	86	43	0
Transmission heating capacity		w	1780	1670	1560	1450	1368	1287	1206	1157	11		059	942	824	943	826	708	
Absorbed power		W	869	796	722	649	605	561	517	471	42		379	330	280	371	322	272	
Thermodynamic COP			3,12	3,22	3,33	3,47	3,52	3,58	3,64	3,80	4,0	0	1,24	4,39	4,58	3,67	3,73	3,82	3,63
Room supply temperature	c	°C	36	35	34	33	32	31	30	28	2	7	26	25	24	23	22	21	20
						Extor	naltar	mor	turo	(	°C	27	28		29	30	31		32
											27 79.4			557.1	30 808.7			L157.0	
							Cooling capacityVVentilation capacityV												
								•	-		N	2.2	49.		75.8	132.0			L68.8
	Meas	<b>su</b>	rem	ient	$\rightarrow$		heatin	• .	-		N	290	290		290	290	290		290
	Requ	uir	em	ent			missio	-	acity		N	77.1			481.3	676.7			988.2
	•						rbed p	ower			N	77	152		255.4	329.6			511.8
		<b>1</b>				COP						3.7	3.2		3.3	3.3	3.0		2.8
Performance						Roon	n supp	ly ten	nperati	ire '	°C	24.6	24.	8	22.3	22.3	21.3	1	L9.5
External Air Temperature		°(		27		28	29	)	30		31		32	2	33		34		35
Cooling capacity		W	I	0		268	53	6	804		1073	}	134	41	1609	9	1877		2145
DHW heating capacity		W		290		290	29		290		290		29	0	290		290		290
Ventilation cooling capacity		W		0		30	59		89		118		14		177		207		236
Transmission cooling capacity		W		0		239	47		716		955		119		1432		1671		1909
Absorbed power		W		80		166	25		352		444		542		652		779		964
Total thermodynamic efficiency			_	3,63		3,36				3,07 3,01			2,91		2,78		2,53		
Room supply temperature		°(		27		26	24	4	22		21		20	0	19		18		17

Measurement	$\rightarrow$
Requirement	

Exte	rnal te	empe	rature		0	°C	0		5		10		15		20	)
	ting ca	•			V	N	31	65.0	250	9.6	205	5.8	1510	.1	69	1.4
DHV	V heat	ing ca	apacity		V	N	90	.7	42.	1	332	3	537.	5	18	5.8
Vent	tilatio	n cap	acity		V	W 615		5.9	105	5.3	.3 73.4		29.1		31.9	
Tran	smissi	ion ca	pacity		V	W 245		58.3	236	52.2	2.2 1506.		9 943.5		473.6	
	orbed				V	N	61	2	523	523.2		2	312		84	
СОР					5.1	L7	4.8	0	4.50	)	4.84		8.2	23		
Room supply temperature			0	°C	36	.4			35.9	)	33		31	.8		
3	4	5	6	7	Т	8		9	10	11		12	13	1	4	15
2254	2130	2006	1882	179	0	1698	3	1607	1446	128		362	1201	10	41	290
290	290	290	290	290	0	290		290	290	290	) 2	90	290	29	<del>9</del> 0	290
515	472	429	386	343	3	300		257	214	172	2 1	29	86	4	3	0
1450	1368	1287	1206	115	7	1108	}	1059	942	824	1 9	43	826	70	)8	0
649	605	561	517	47	1	425		379	330	280	) 3	71	322	27	72	80
3,47	3,52	3,58	3,64	3,8	0	4,00		4,24	4,39	4,5	8 3	,67	3,73	3,8	82	3,63
33	32	31	30	28		27		26	25	24		23	22	2	1	20
External temperature		°C	2	27	28	8	29	3	)	31		32				
Coolir	ng cap	acity			W	7	79.4	20	0.7	557.	1 8	)8.7	958	.2	11	57.0
Ventil	ation	capad	city		W 2.2		2.2	2 49.9		75.8	13	32.0	157	.8	16	8.8
DHW	heatir	ng cap	pacity		W 29		290	0 290		290		90	290		29	0
Transı	missio	n cap	acity		W	w 77.:		. 15	150.8		3 6	76.7	800	.4	98	8.2
Absor	bed p	ower			W	7	77	15	52	255.	4 32	29.6	409	.4	51	1.8
СОР						3	3.7	3.	2	3.3	3.	3	3.0		2.8	3
Room	suppl	y ten	nperatu	ire	°C	2	24.6	5 24	.8	22.3	22	2.3	21.3	3	19	.5
28	29		30			31		3	32		33		34			35
268	53	6	804		1	1073		13	341	1	609		1877			2145
290	29	0	290			290		2	90		290		290			290
30	59	)	89			118		1	48		177		207			236
239	47	7	716			<mark>955</mark>		1	193	1	432	_	1671			1909
66	25	7	352			444		5	42		652		779			964
,36	3,2	2	3,11			3,07		3	,01		2,91		2,78			2,53
26	24	1	22			21			20		19		18			17

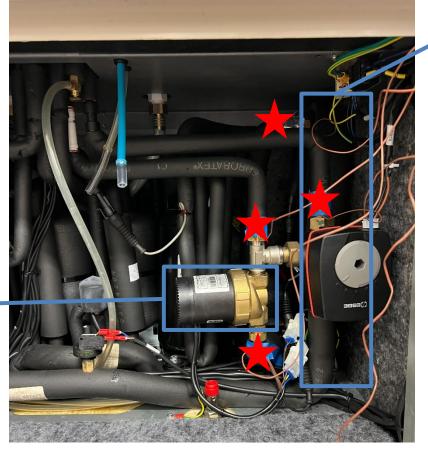
					External temperature										1	.5	2(	)	
						ting ca	•			°C W	316	5 5.0 25	09.6	2055.		.510.2		91.4	
								pacity		W	90.7	7 42	.1	332.3	5	37.5	18	35.8	
						tilatio	-	• •		W	615	.9 10	5.3	73.4	2	29.1	32	L <b>.9</b>	
Me	asu	rem	ient	$\rightarrow$			-	-		W	245			1506.		43.5		73.6	
Red	auir	rem	ent			Transmission capacity Absorbed power								481.2				84	
	<u>а</u> ,				COP	•								4.50		.84		23	
$\checkmark$							nlv te	mperat	ture	°C	5.17 36.4			35.9	-	3		L.8	
	°C	0	1	2	3	4	5	6	7	8		9 10		12		13	14	15	
	W	2713	2560	2407	2254	2130	2006	1882	1790	169		507 144				201	1041	290	
	w	290	290	290	290	290	290	290	290	290		90 290				290	290	290	
	W	643	600	557	515							57 214				86	43	0	
	W	1780	1670	1560	1450	1368	1287	1206 1157		110	8 10	942	824	943	3 8	826	708	0	
	W	869	796	722	649	605	561	517	471	425	3	79 330	280	371		322	272	80	
		3,12	3,22	3,33	3,47	3,52	3,58	3,64	3,80	4,00	) 4,	24 4,3	4,58	3,67	7 3	3,73	3,82	3,63	
	°C	36	35	34	33	33 32 31 30 28					2	6 25	24	23		22	21	20	
External temperature °								°C 2	27	28	29	30		31	32	2			
					Coolii	ng cap	acity		١	<b>N</b>	79.4	200.7	557.2	L 808	3.7	958.2	2 11	57.0	
					Venti	ation	capac	ity	١	N 2	2.2	49.9	75.8	132	2.0	157.8	3 16	58.8	
Me	asu	iren	nent	$\rightarrow$	DHW	heatir	ng cap	acity	١	$\mathbf{v}$ :	290	290	290	290	)	290	29	90	
D					Trans	missio	n cap	acity	١	N I	77.1	150.8	481.3	8 676	5.7	800.4	1 98	88.2	
Ke	qui	rem	ent		Absor	bed p	ower	-	١	<b>N</b>	77	152	255.4	1 329	9.6	409.4	<b>5</b> 1	1.8	
	$\downarrow$	•			СОР						3.7	3.2	3.3	3.3		3.0	2.	8	
	Ţ	•				suppl	ly tem	peratu	re °			3.2	3.3 22.3	3.3 22.		3.0 21.3		8 9.5	
		°C	27			suppl	-	peratu 30	ire °		3.7	3.2	22.3		3				
			27 0		Room			-	ire °	°C	3.7 24.6	3.2 24.8	22.3	22.	3	21.3	19	9.5	
		°C			<b>Room</b> 28	29	6	30	ire °	° <b>C</b> 2 31	3.7 24.6	3.2 24.8 32	<b>22.3</b>	<b>22.</b>	<b>3</b>	<b>21.3</b> 34	19	<b>9.5</b> 35	
		°C W	0		<b>Room</b> 28 268	29	6 0	30 804	ire <sup>c</sup>	° <b>C</b> 2 31 1073	3.7 24.6	3.2 24.8 32 1341	22.3 : 1 ;	<b>22.</b>	3	<b>21.3</b> 34 877	19	<b>9.5</b> 35 2145	
		°C W W	0 290		Room 28 268 290	29 53 29	6 0 9	30 804 290	ire <sup>c</sup>	° <b>C</b> 2 31 1073 290	3.7 24.6	3.2 24.8 32 1341 290	22.3	<b>22.</b> 33 509 90	3	<b>21.3</b> 34 877 290	19	<b>9.5</b> 35 2145 290	
		°C W W W	0 290 0		Room         28         268         290         30	29 53 29 59	6 0 9 7	30 804 290 89		2°C 2 31 1073 290 118	3.7 24.6	3.224.8321341290148	22.3	<b>22.</b> 33 509 90 77	<b>3</b>	<b>21.3</b> 34 877 290 207	19	<b>9.5</b> 35 2145 290 236	
		°C W W W W	0 290 0 0		Room         28         268         290         30         239	29 53 29 59 59 47	6 0 0 7 7 7	30 804 290 89 716		290 118 955	3.7 24.6	3.224.83213412901481193	22.3 : 1 2 1 2 1 1 6	<b>22.</b> 33 509 90 77 432	<b>3</b>	<b>21.3</b> 34 877 290 207 671	19	<b>9.5</b> 35 2145 290 236 1909	

### **Modification with preheater**

### Measurement

Masurentent							
External temperature	°C	- 12	- 10	- 8	- 6	- 4	- 2
Heating capacity	W	3321	3239	3142	3250	3251	3262
Recovery capacity	W	24.1	96.7	41.0	17.3	5.9	19.9
Ventilation capacity	W	704.3	675.4	670.8	663.2	668.7	672.7
Transmission capacity	W	2592.9	2466.8	2430.2	2569.7	2578.4	2569.3
ELFOPack power	W	517.6	511.0	505.6	516.6	534.3	536.2
Preheater power	W	468.0	446.6	421.8	336.3	201.3	87.1
СОР		3.37	3.38	3.39	3.81	4.42	5.23
Room supply temperature	°C	37.64	37.61	36.82	37.83	37.77	37.78

### **Domestic hot water test**



Circulator <

### Measurement

Outdoor temperature	°C	0	- 5	-
Stage 1 heating capacity	W	2642	2870	2
<b>Recovery capacity</b>	W	187	322	2
DHW heat input	W	1147	619	8
Absorbed power *	W	584	873	1
СОР		4.52	3.29	2
Stage 2 heating capacity	W	2862	3042	3
Recovery capacity	W	144	134	1
DHW heat input	W	1210	758	1
Absorbed power *	W	603	1002	1
СОР		4.75	3.04	2



### Project Team:

Syracuse University, USA: Professor Bing Dong (PI), Professor Jianshun Zhang (Co-PI), Yuewei Li, Zhipeng Deng Clivet, Italy: Mario Smaniotto, Fabio Turra , Franco Ceccato, Francesca De Pra, Leo Liu



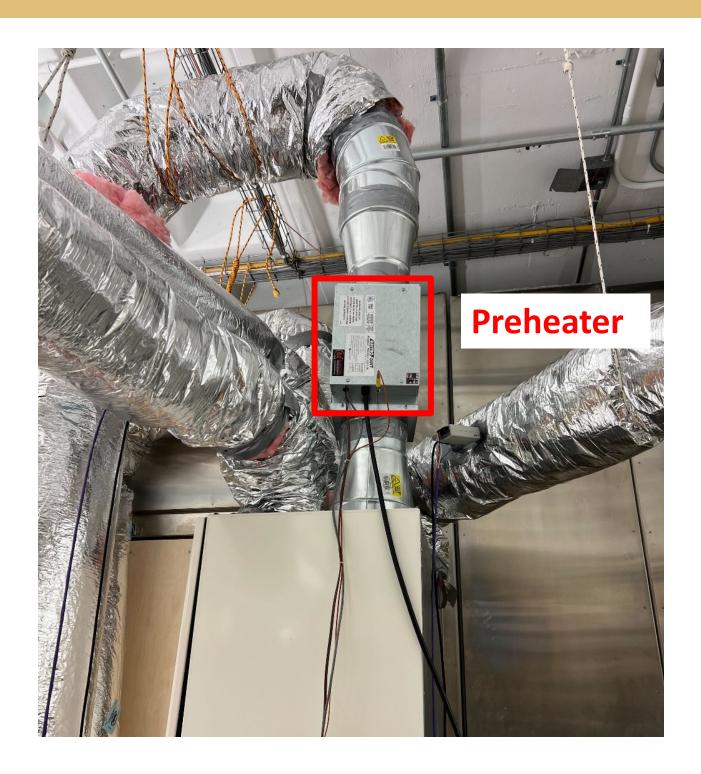
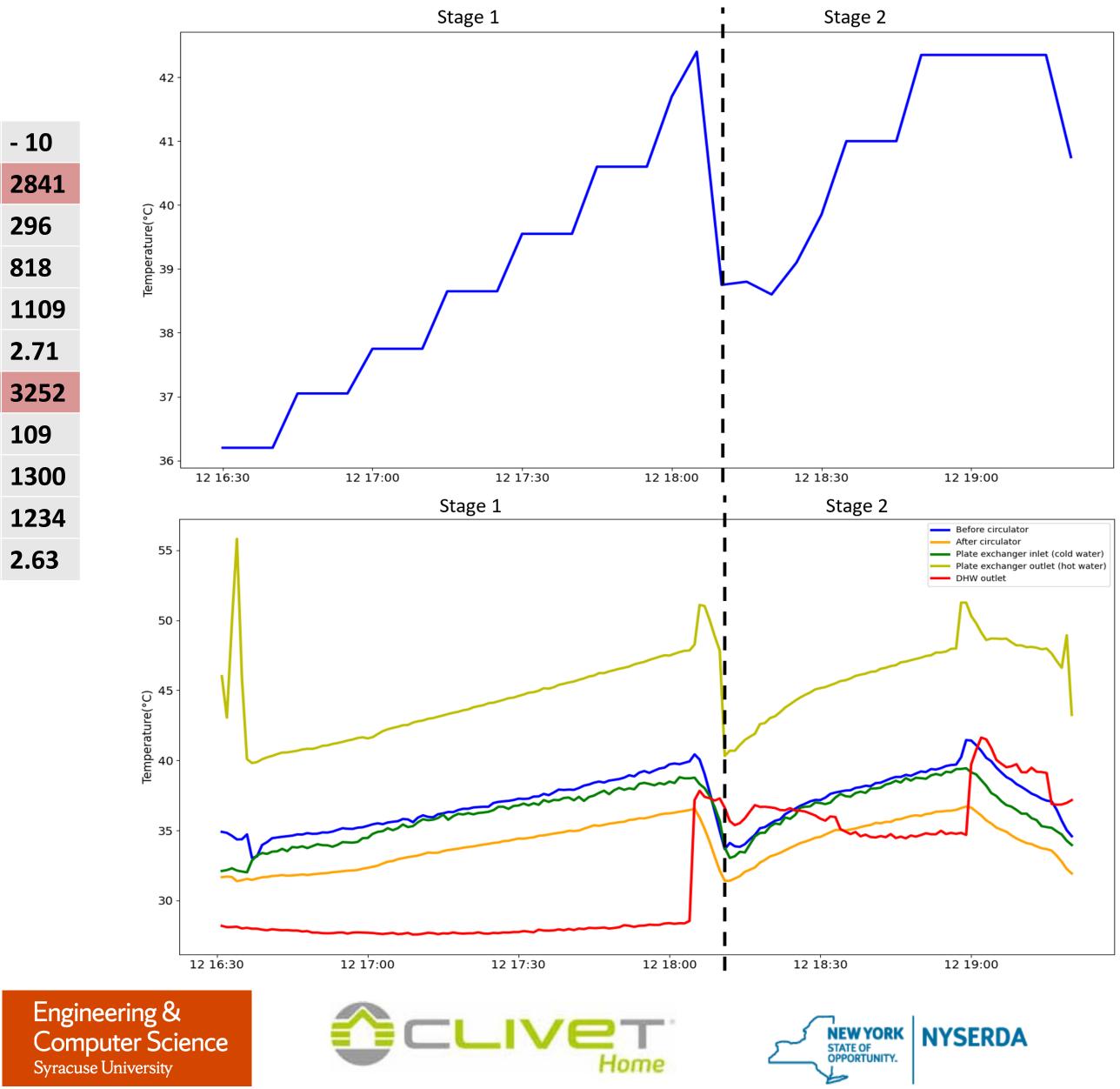


Plate exchanger



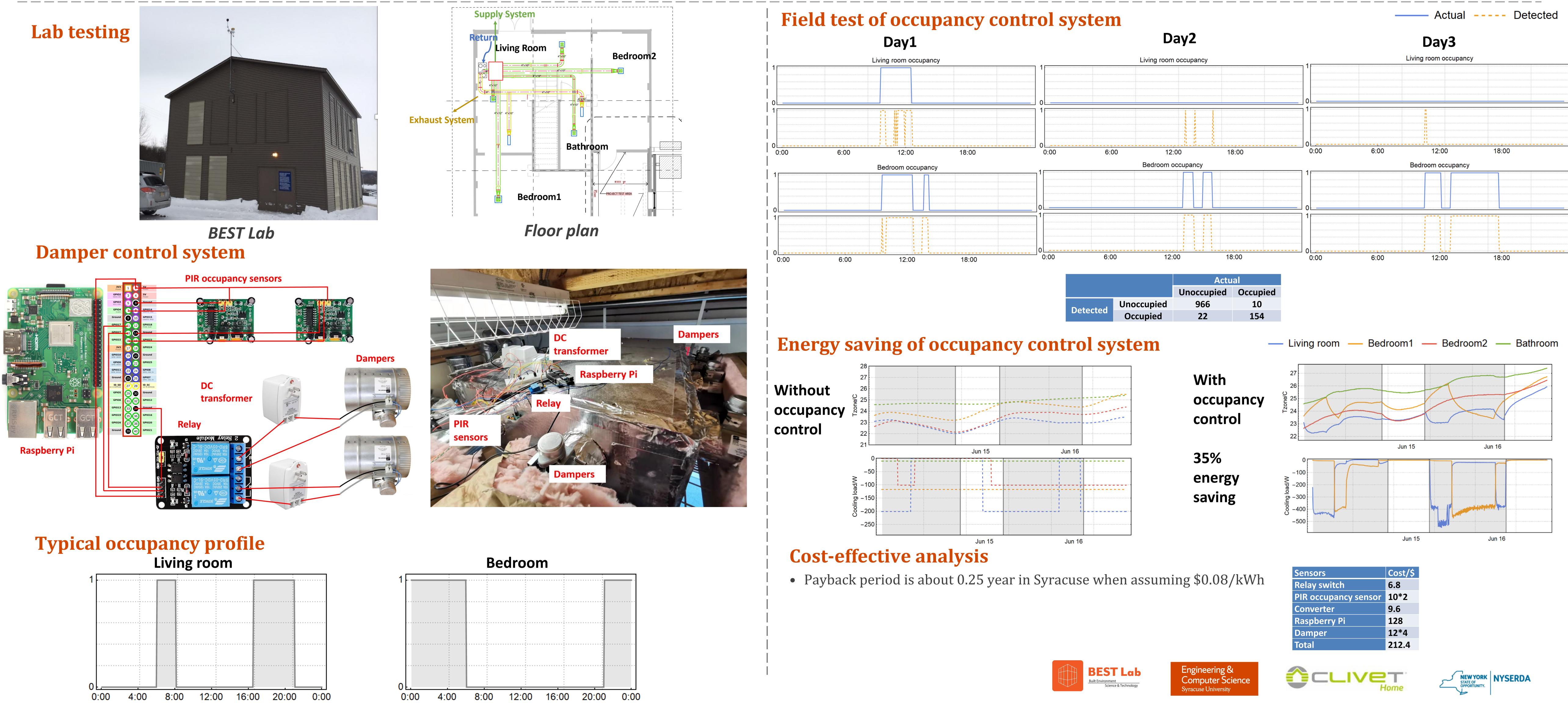


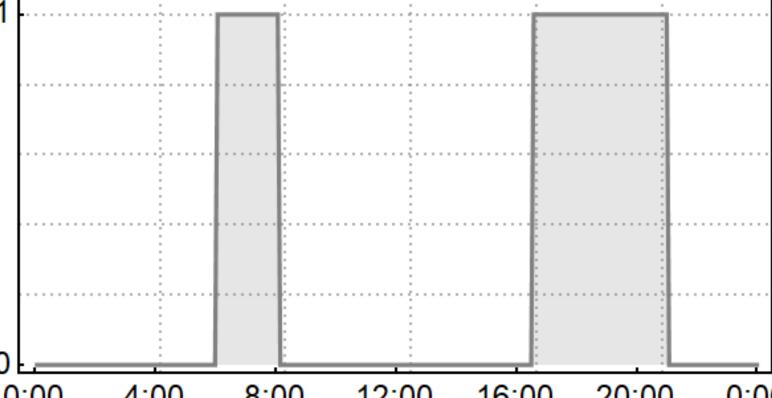
# Design and implement occupancy-based control for ELFOPack system

### Introduction

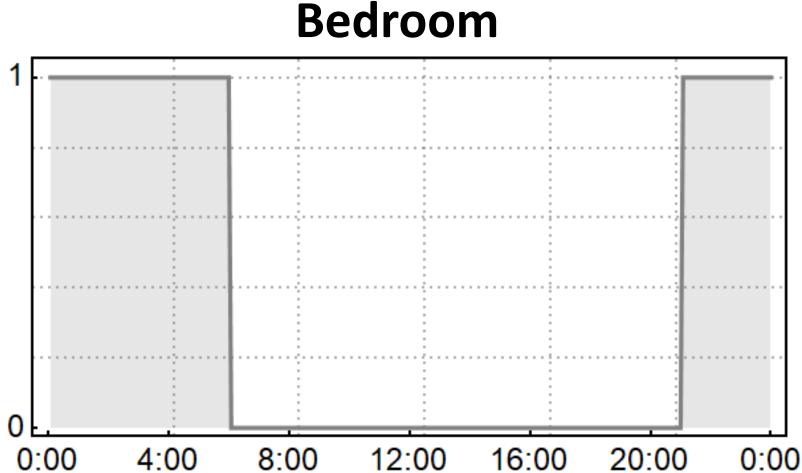
Space heating accounted for 38% of energy delivered in buildings, much more than any other end-use. Meanwhile, electricity used for space cooling by residential sectors was about 10% of total US electricity consumption. With energy-saving and sustainability demands, we need optimal control for the HVAC systems in residential buildings. The potential for energy saving through occupancy control of ventilation and hot water system varies from 5% to 20% based on previous studies. The purpose was to test the potential energy efficiency in residential buildings equipped ELFOPack with an occupancy sensor in NYS.







## Syracuse University College of Engineering & Computer Science





Project Team:

Syracuse University, USA: Professor Bing Dong (PI), Professor Jianshun Zhang (Co-PI), Yuewei Li, Zhipeng Deng Clivet, Italy: Mario Smaniotto, Fabio Turra , Franco Ceccato, Francesca De Pra, Leo Liu



