Heat Pump Pilot Study in Ulaanbaatar

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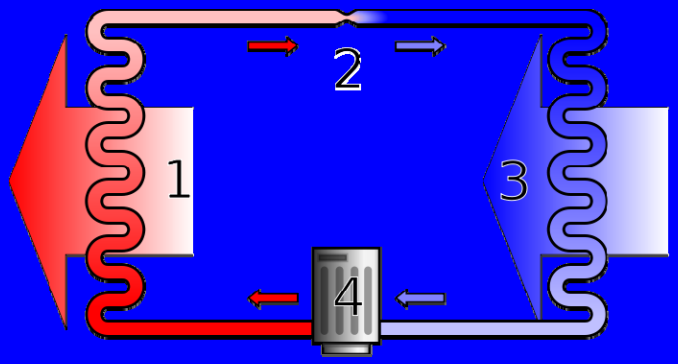
Heat pumps

- A **heat pump** is a device that **transfers** heat energy from a source of heat to a destination called a "heat sink".
- Heat pumps are designed to move thermal energy in the opposite direction of spontaneous heat transfer by absorbing heat from a cold space and releasing it to a warmer one.

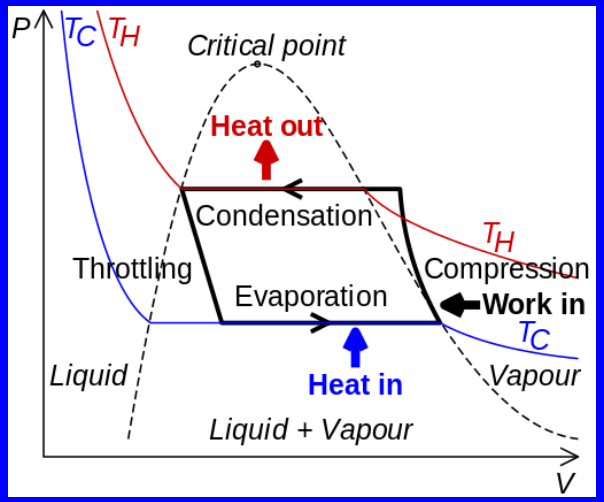


A simple stylized diagram of a heat pump's vapor-compression refrigeration cycle: 1) condenser, 2) expansion valve,
3) evaporator, 4) compressor.

$$COP = \frac{Q}{W} \leq \frac{T_H}{T_H - T_C}$$

Q is the amount of heat delivered to a hot reservoir at temperature T_H.
W is the energy consumption of heat pump (work input).
T_H and T_C are the temperature of hot and cold reservoir, respectively.

Hypothetical pressure-volume diagram for a typical refrigeration cycle



Heat Pumps, cont.

- Heat pumps draw heat from the cooler external air **(air source heat pump**) or from the ground (ground source heat pump).
- Although air conditioners and freezers are familiar examples of heat pumps, the term "heat pump" is more general and applies to many HVAC (heating, ventilating, and air conditioning) devices used for **space heating**.

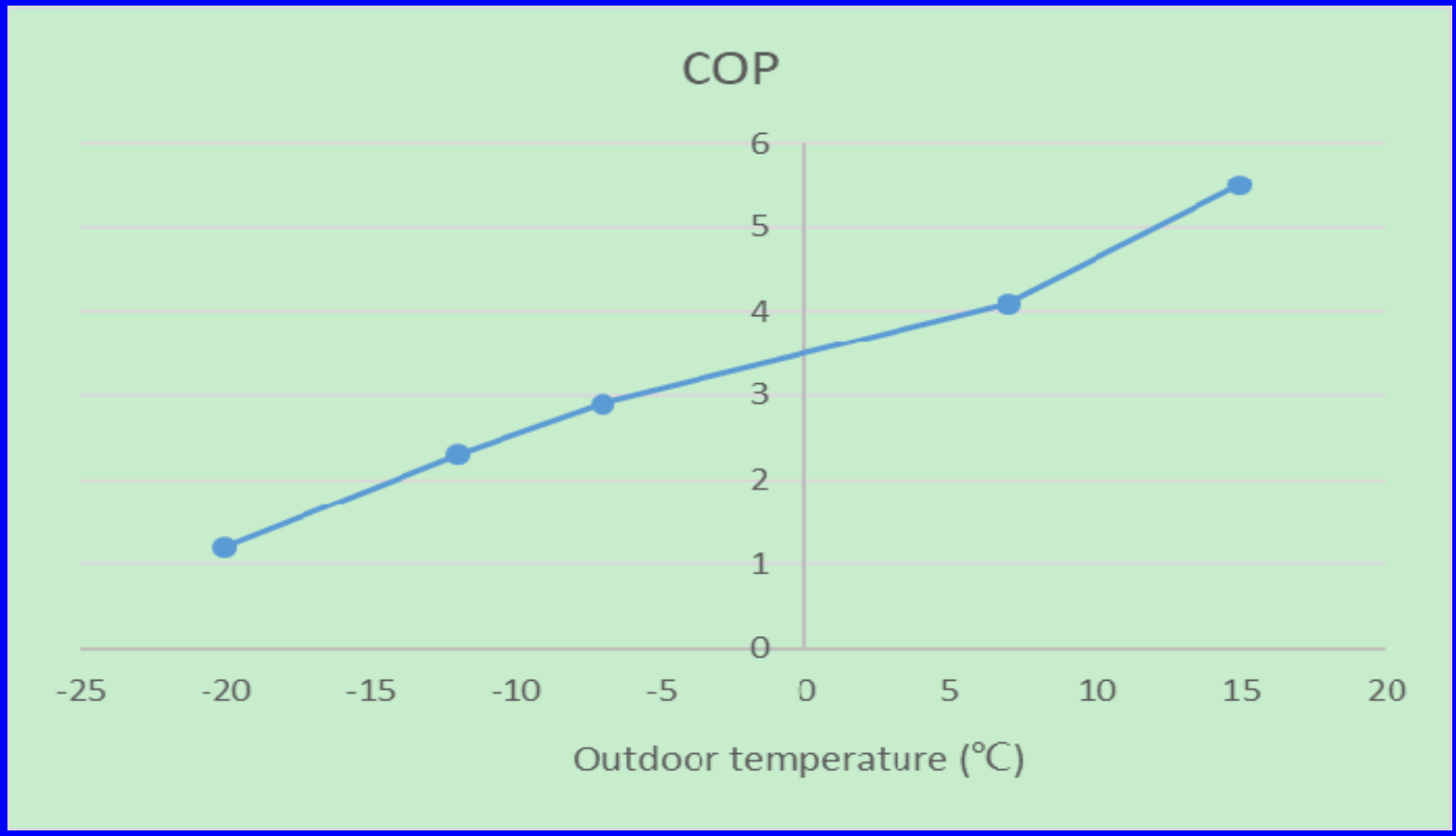
Coefficient of Performance (COP)

- A heat pump uses a small amount of external power to accomplish the work of transferring energy from the heat source to the heat sink.
- The term **coefficient of performance (COP)** is used to describe the ratio of useful heat movement per work input.

COP, cont.

- **The COP for heat pumps range from 3 to 5** for air source heat pumps, that means heat pumps are three to five times more effective at heating than simple electrical resistance heaters using the same amount of electricity.
- Due to refrigeration cycle efficiency limits, the **COP will decrease as the outdoor-to-indoor temperature difference increases** (outside temperature gets colder).

COP: Normal Heat Pump



Problems of conventional heat pumps in cold areas

Heating capacity is insufficient in cold ambient conditions

As the outside air temperature drops, the buildings heating load increases but the heat pumps efficiency decreases.

Low reliability in cold ambient conditions

As the ambient temperature decreases, the suction pressure decreases, which is likely to increase the compression ratio and rapidly increase the discharge temperature. The high discharge temperature may lead to the decomposition of refrigerants and the carbonization of lubricant oils.

Low thermal comfort in heating season

A traditional wall-mounted air source heat pump blows warm air from upper sideways, which causes the warm air to accumulate in and be constrained to the top of the room. Temperature stratification occurs in the vertical direction, which reduces comfort (for instance, owing to cold feet).

Improvement by changing compressor

Traditional single stage compressor (one cylinder)

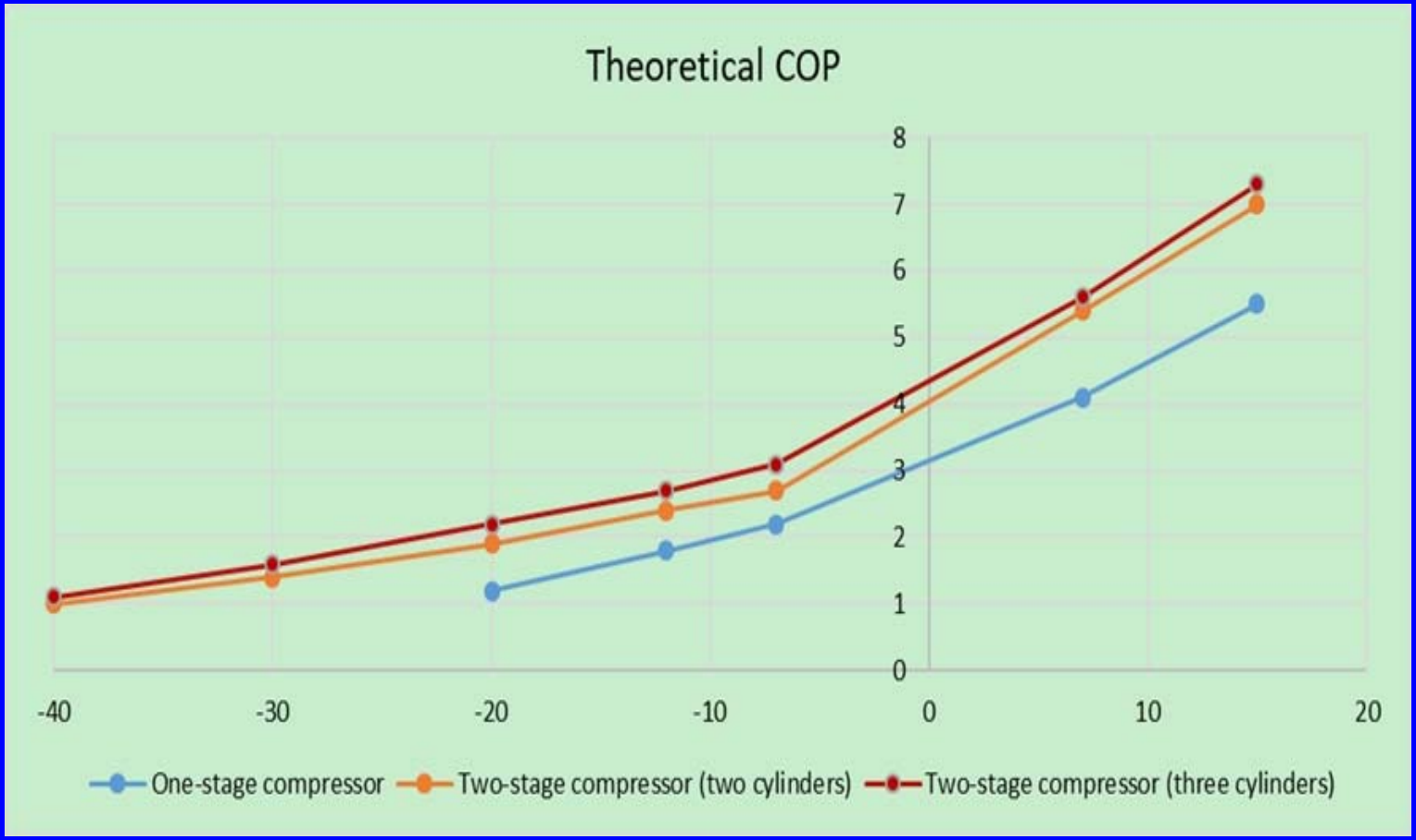
Improved double stage enthalpy-added compressor

(Two cylinders)

(Three cylinders)

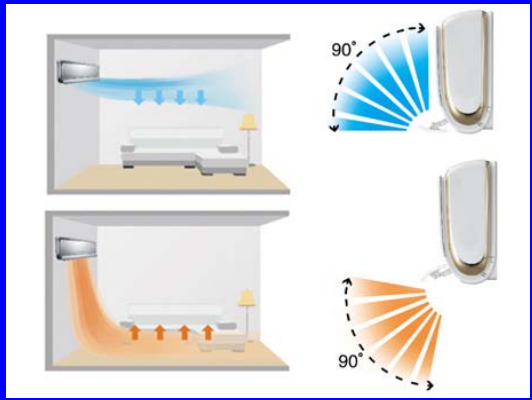
- Enhanced capacity in cold ambient Improved conditions
- COP is up to 2.0+ at the outdoor temperature of -20℃
- Can running normally at the outdoor temperature of -35℃
- Includes automatic defrost
- Working fluid is R-32 , Difluoromethane, also called HFC-32.

Benefits of Double Compression



Improvements of thermal comfort

Generation 1



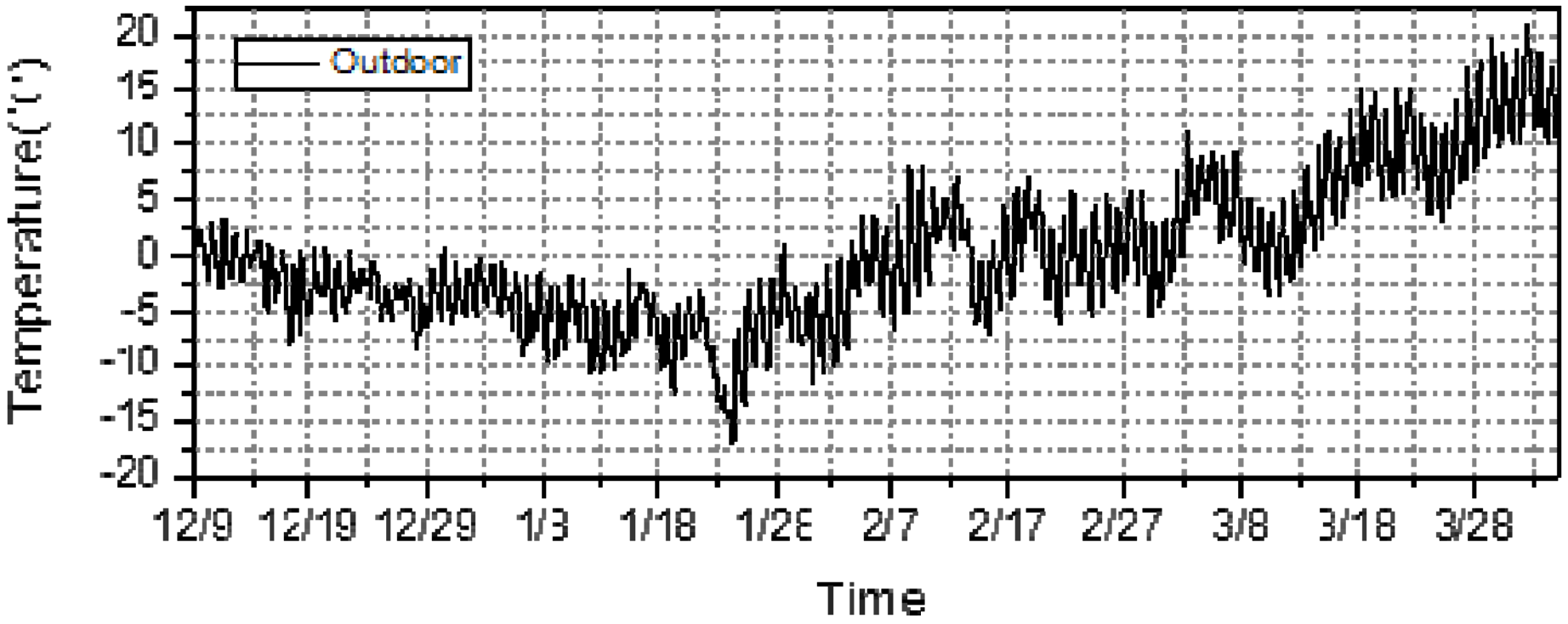
Motional air distribution technology
Big air guide louver allows 180°up&down swing and 130°left&right swing. Air distribution is much wider, with cooling from top to bottom and **heating from bottom to top**.

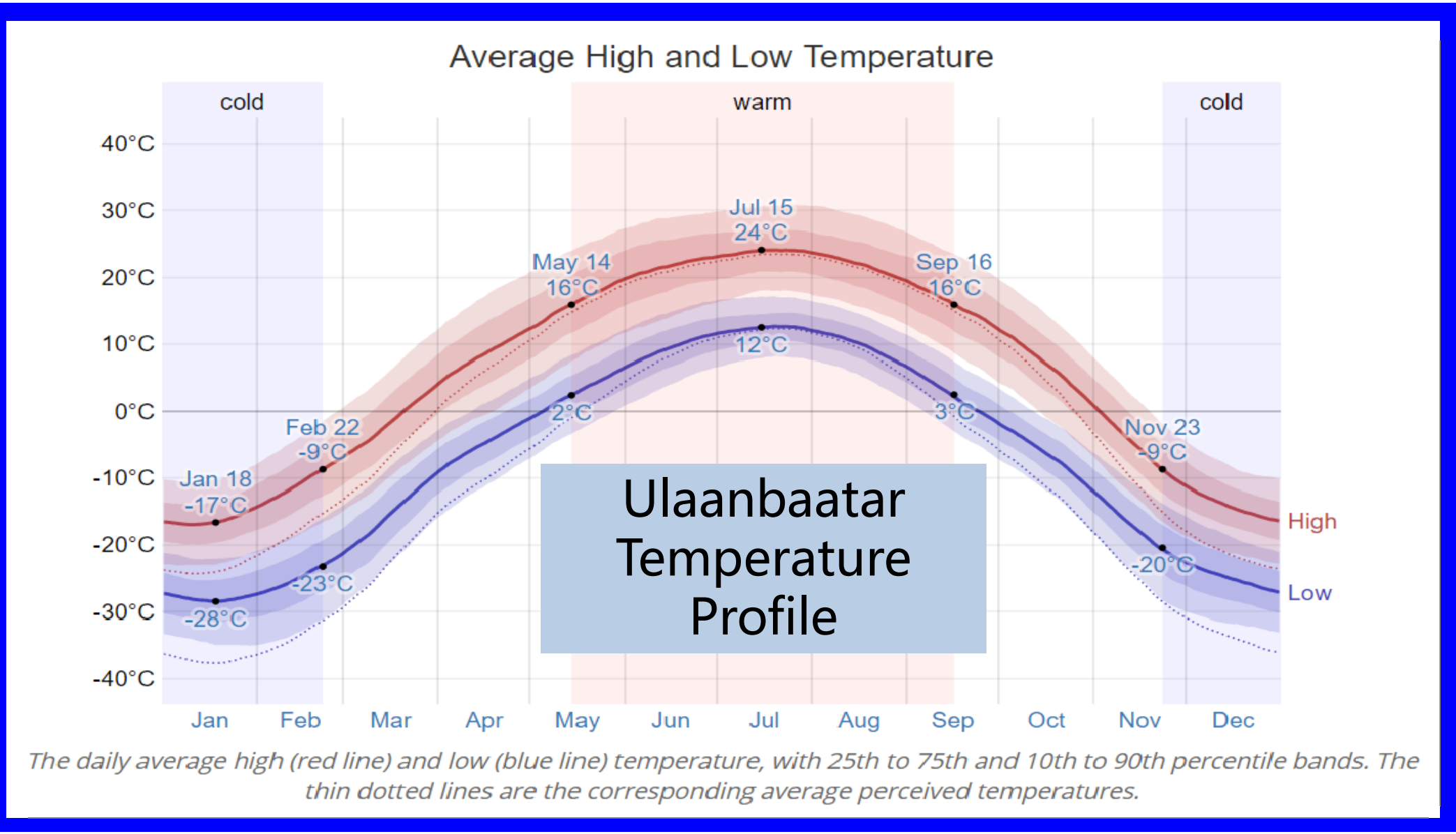
Generation 2

2 air supply outlets Warm air can be transported to human body (upper) and **feet** at the same time.

Case studies in the Beijing Area

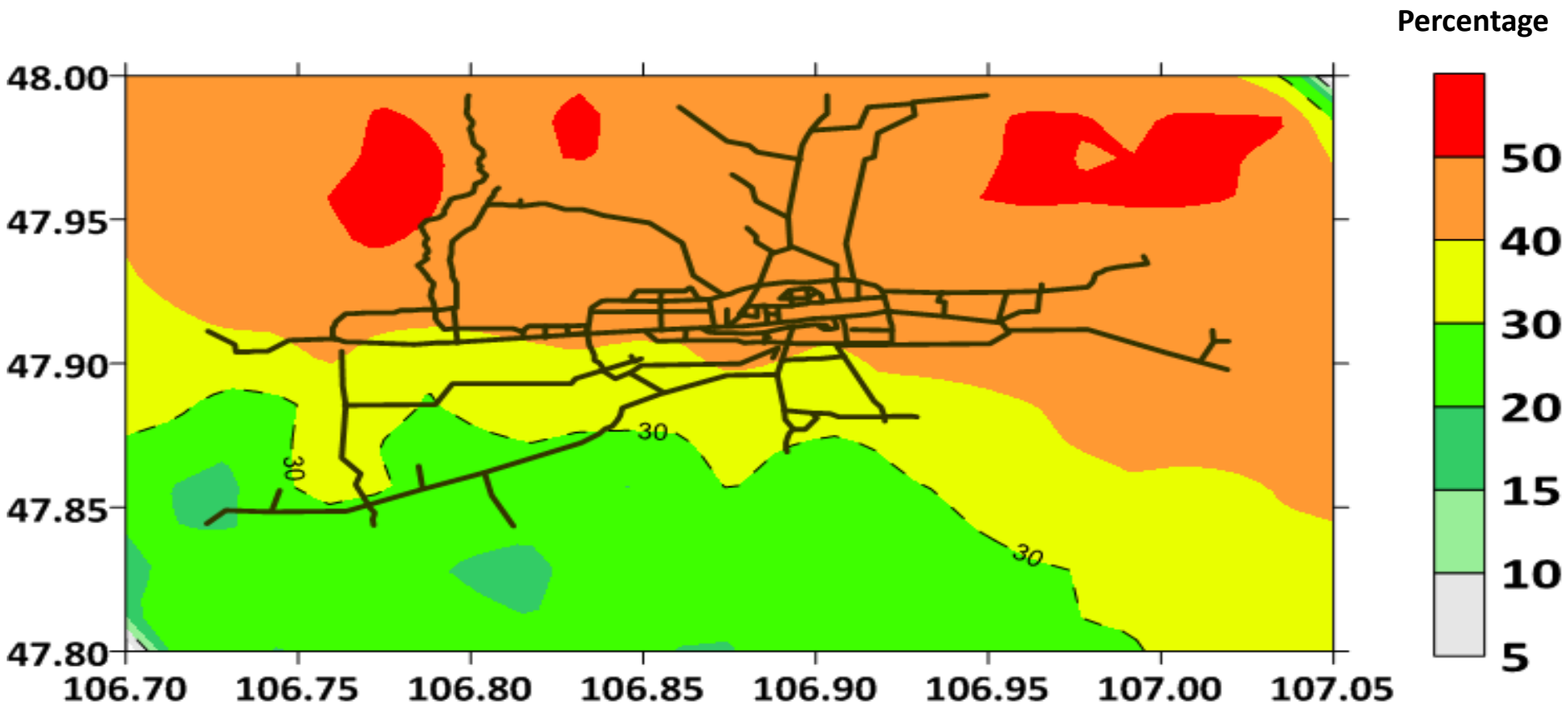
Temperature Profile in China





The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

Modelled Stove Contributions
Winter Months: Ulaanbaatar



Guttikunda, 2014

The Current Deployment

- Change in Government in mid-2017 led to greater interest in solving the coal heating problem
- Seven advanced heat pumps were imported from China: two were smaller, less expensive, models.
- Based on surveys and informed consent of householders, they were installed in 2 gers and 5 houses
- The electric company rewired to achieve 4 or 6 kW and installed second meters
- They are being monitoring continuously using both real time data transmitted through cell/web technology
- And dataloggers installed and maintained by the Mongolian team
- Plus regular surveys


GREE

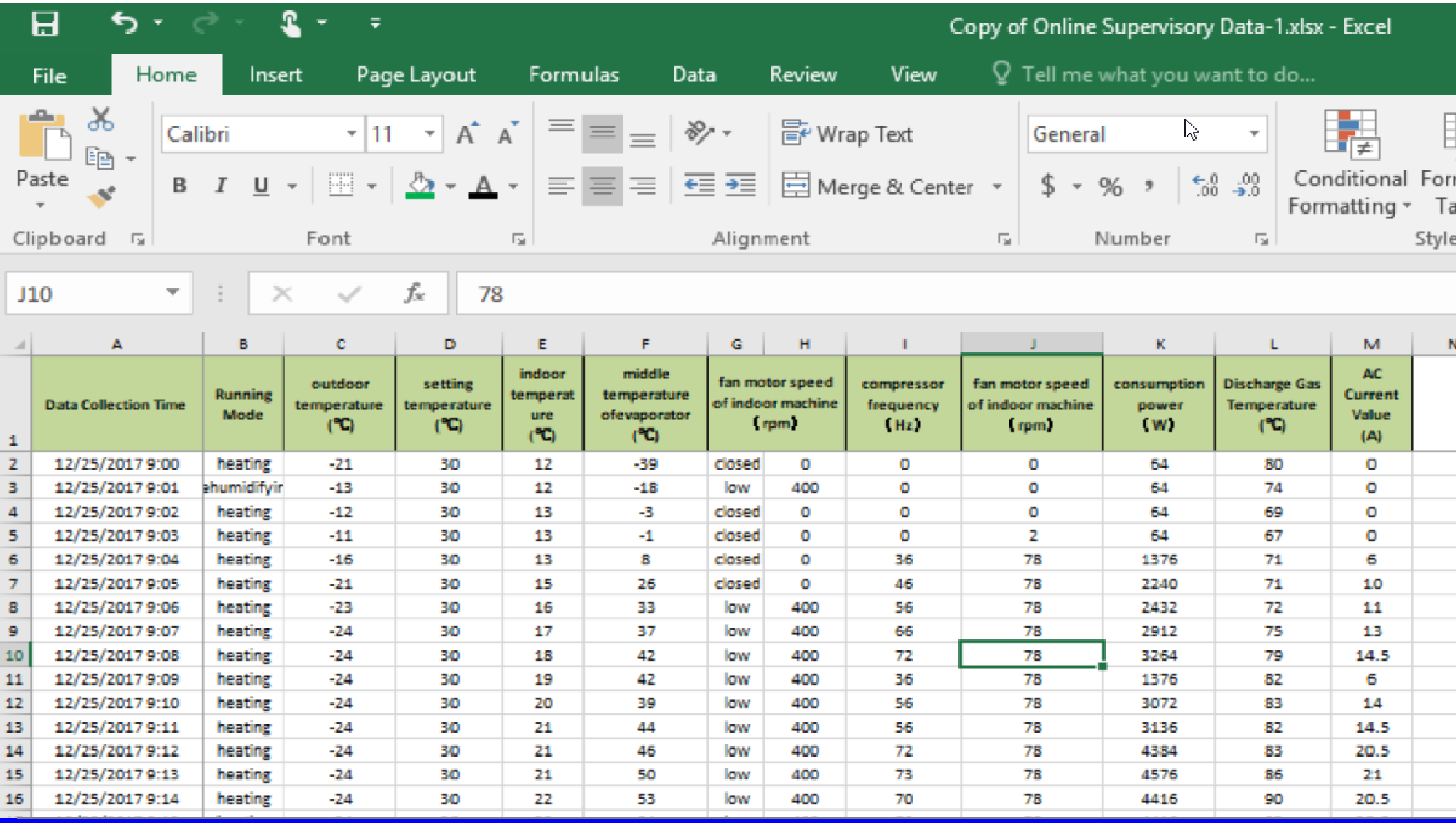

GREE

1. Detail information about the installation of experimental prototypes

Seven sets of experimental prototypes, including 2 sets of warm air blower which heating capacity is 4000W and 5 sets of packaged unit which heating capacity is 8500W, are installed in different zone, the detail information are as below.

Sequence NO.	Type	Model	Prototype No.	Installation Location	Building Type	Indoor Area (㎡)	Photos about Installation Location
1	warm air blower	GN-40DZW/(40549)FNhAa-1	1#	See the Attachment No .1	ger	28.26	
2		GN-40DZW/(40549)FNhAa-1	2#			28.26	
3	Packaged unit	KFR-72LW/(72518)FNhAb-A1	3#		household	19.78	
4		KFR-72LW/(72518)FNhAb-A1	4#			39	
5		KFR-72LW/(72518)FNhAb-A1	5#			28	
6		KFR-72LW/(72518)FNhAb-A1	6#			27	
7		KFR-72LW/(72518)FNhAb-A1	7#			42	

Attachment No .1, detail information about installation lacation:



Copy of Online Supervisory Data-1.xlsx - Excel

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J10 78

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Data Collection Time	Running Mode	outdoor temperature (℃)	setting temperature (℃)	indoor temperature (℃)	middle temperature ofevaporator (℃)	fan motor speed of indoor machine (rpm)		compressor frequency (Hz)	fan motor speed of indoor machine (rpm)	consumption power (W)	Discharge Gas Temperature (℃)	AC Current Value (A)
2	12/25/2017 9:00	heating	-21	30	12	-39	closed	0	0	0	64	80	0
3	12/25/2017 9:01	ehumidifyir	-13	30	12	-18	low	400	0	0	64	74	0
4	12/25/2017 9:02	heating	-12	30	13	-3	closed	0	0	0	64	69	0
5	12/25/2017 9:03	heating	-11	30	13	-1	closed	0	0	2	64	67	0
6	12/25/2017 9:04	heating	-16	30	13	8	closed	0	36	78	1376	71	6
7	12/25/2017 9:05	heating	-21	30	15	26	closed	0	46	78	2240	71	10
8	12/25/2017 9:06	heating	-23	30	16	33	low	400	56	78	2432	72	11
9	12/25/2017 9:07	heating	-24	30	17	37	low	400	66	78	2912	75	13
10	12/25/2017 9:08	heating	-24	30	18	42	low	400	72	78	3264	79	14.5
11	12/25/2017 9:09	heating	-24	30	19	42	low	400	36	78	1376	82	6
12	12/25/2017 9:10	heating	-24	30	20	39	low	400	56	78	3072	83	14
13	12/25/2017 9:11	heating	-24	30	21	44	low	400	56	78	3136	82	14.5
14	12/25/2017 9:12	heating	-24	30	21	46	low	400	72	78	4384	83	20.5
15	12/25/2017 9:13	heating	-24	30	21	50	low	400	73	78	4576	86	21
16	12/25/2017 9:14	heating	-24	30	22	53	low	400	70	78	4416	90	20.5

Data Collection Time	Running Mode	outdoor temperature (℃)	fan motor speed of indoor machine （rpm）		setting temperature (℃)	indoor temperature (℃)	consumption power （W）	COP
1/22/2018 0:00	Heating	-34	medium	500	26	25	1008	1.89
1/22/2018 0:01	Heating	-34	medium	500	26	25	1040	1.88
1/22/2018 0:02	Heating	-34	medium	500	26	25	1008	1.89
1/22/2018 0:03	Heating	-34	medium	500	26	25	1040	1.88
1/22/2018 0:04	Heating	-34	medium	500	26	25	1008	1.89
1/22/2018 0:05	Heating	-34	medium	500	26	25	1040	1.88
1/22/2018 0:06	Heating	-34	medium	500	26	25	1040	1.88
1/22/2018 0:07	Heating	-34	medium	500	26	25	1040	1.88
1/22/2018 0:08	Heating	-34	medium	500	26	25	1040	1.88
1/22/2018 0:09	Heating	-34	medium	500	26	25	1040	1.88

What we need to show

- Cost of heating will be a function of electricity cost and capital cost of the pumps with installation (including lifetime, maintenance, etc)
- Electricity demand will be a function of outside temperature, inside temperature, and household characteristics such as insulation and ventilation
- The pumps will work at all temperatures, but will have a COP close to 1 at the lowest levels in UB, i.e. -40 deg C
- Question is the total electricity demand over the heating season given the distribution of usage with the distribution of outside temperature, i.e. COP
- And how fast the householders can learn how to use the devices optimally

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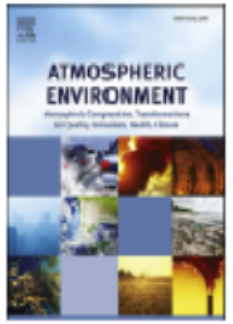

The impact of household cooking and heating with solid fuels on ambient $PM_{2.5}$ in peri-urban Beijing

Jiawen Liao [a, *, 1], Anna Zimmerman Jin [a], Zoë A. Chafe [a, b], Ajay Pillarisetti [a], Tao Yu [c], Ming Shan [c], Xudong Yang [c], Haixi Li [d], Guangqing Liu [d], Kirk R. Smith [a]

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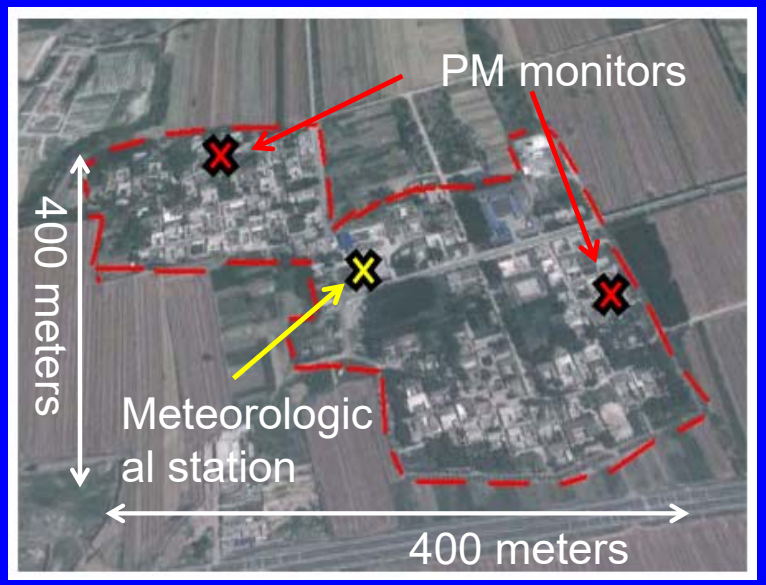
[d] Department of Environmental Engineering, Beijing University of Chemical Technology, Beijing, China

Ambient Air Pollution in a Peri-urban Village in Beijing

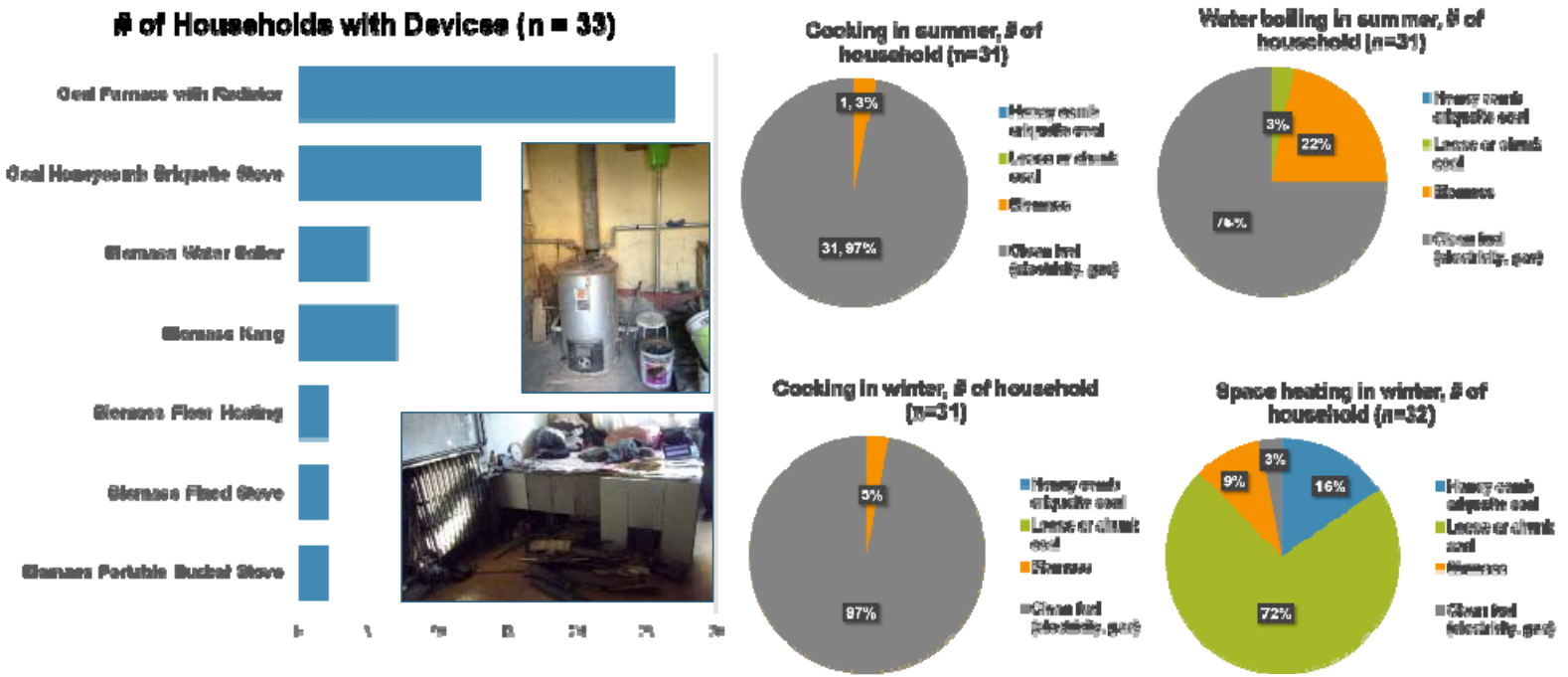


- We conducted surveys on fuel use and monitored solid fuel heating and cooking devices using SUMS in recruited households from January 9th to March 10th, 2013.
- Ambient $PM_{2.5}$ concentrations were measured, and a meteorological station was installed at the village center from January 9th to March 10th 2013.

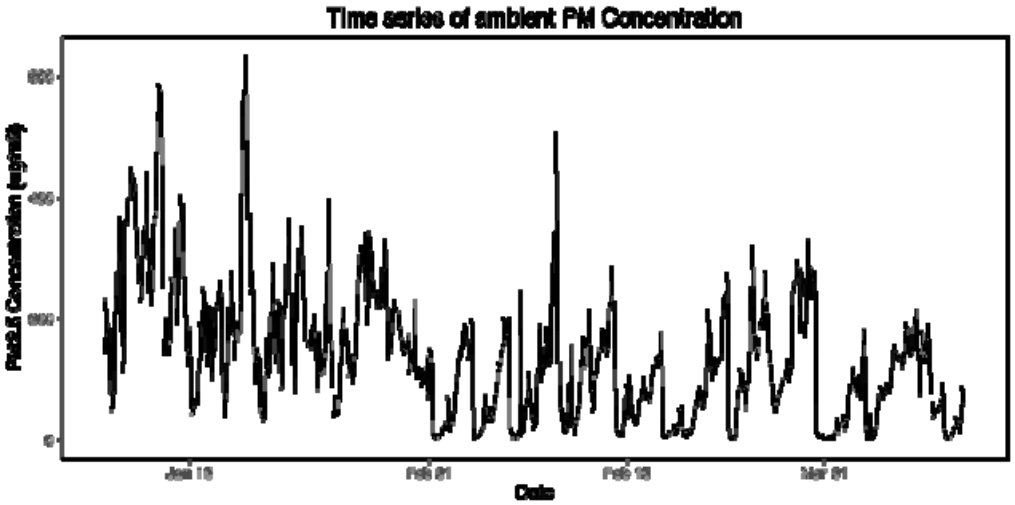
Energy Use Patterns in EHZ village

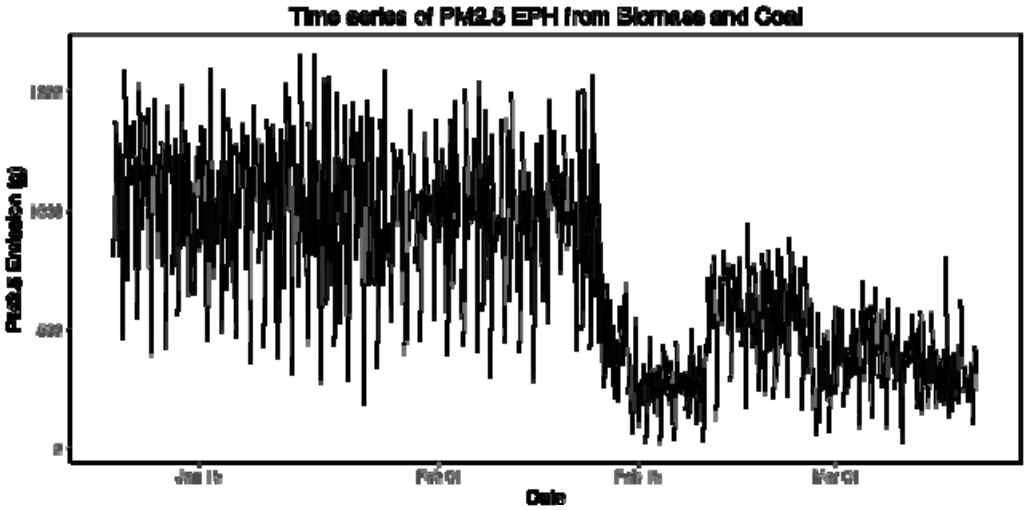
- Most of household adopted clean fuel to cook, but still using large amount of solid fuel for space heating in winter.
- The average biomass for cooking, biomass for space heating and coal for space heating per household is 87 kg/year, 102 kg/year and 3,000kg/year, respectively.
- In winter heating season, 92% of the primary $PM_{2.5}$ emission from household solid fuel use are from coal combustion for space heating.

Primary Fuel for household tasks in summer and winter



Contribution of Space Heating to Ambient Air Pollution





Time Series Modeling:
During Jan. 9th to Mar. 10th, 2013, the average ambient $PM_{2.5}$ concentration is 139±107 μg/m³ (mean ± standard deviation), and average primary $PM_{2.5}$ EPH from household biomass and coal is 735.5±381 g/hour at study site.

During the heating season, 39% of hourly averaged ambient $PM_{2.5}$ was associated with household space heating emissions.

EHZ Village Today

- With government incentives, essentially all households have shifted to heat pumps for heating (Tsinghua is monitoring)
- Very little biomass and coal now used for cooking or other needs
- We are monitoring the PM2.5 in the village again this winter
- Compare results to five years ago when all households used coal/biomass heating

Seeking funds

Berkeley Research Team
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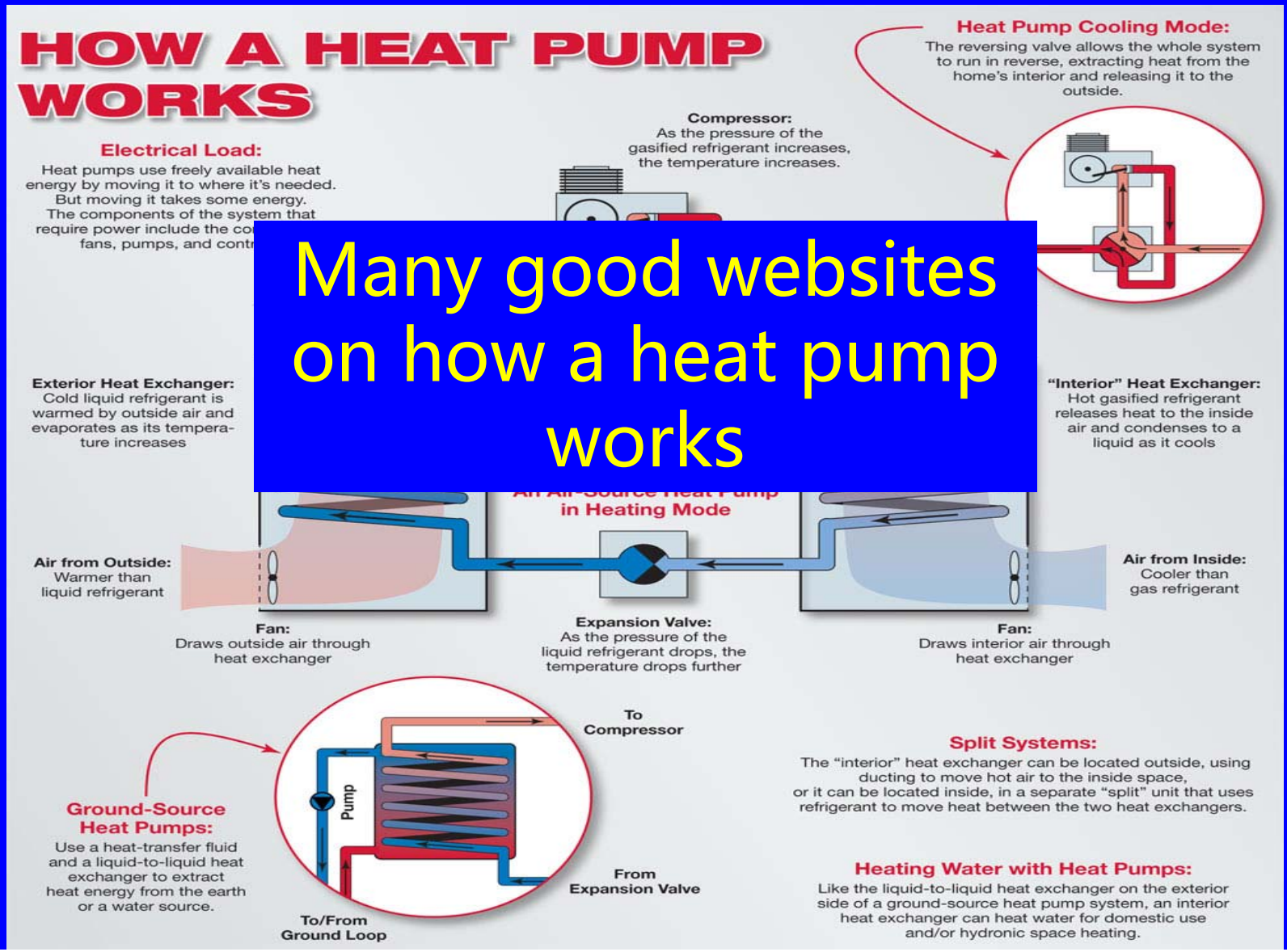
Thank you

Presentations and publications on website: Just Google "Kirk R. Smith"


HOW A HEAT PUMP WORKS
Heat Pump Cooling Mode:
The reversing valve allows the whole system to run in reverse, extracting heat from the home's interior and releasing it to the outside.
Compressor:
As the pressure of the gasified refrigerant increases, the temperature increases.
Electrical Load:
Heat pumps use freely available heat energy by moving it to where it's needed. But moving it takes some energy. The components of the system that require power include the co
fans, pumps, and contr
Many good websites on how a heat pump works
Exterior Heat Exchanger:
Cold liquid refrigerant is warmed by outside air and evaporates as its tempera-ture increases
"Interior" Heat Exchanger:
Hot gasified refrigerant releases heat to the inside air and condenses to a liquid as it cools
in Heating Mode
Air from Outside:
Warmer than liquid refrigerant
Air from Inside:
Cooler than gas refrigerant
Fan:
Draws outside air through heat exchanger
Expansion Valve:
As the pressure of the liquid refrigerant drops, the temperature drops further
Fan:
Draws interior air through heat exchanger
To Compressor
Pump
From Expansion Valve
To/From Ground Loop
Ground-Source Heat Pumps:
Use a heat-transfer fluid and a liquid-to-liquid heat exchanger to extract heat energy from the earth or a water source.
Split Systems:
The "interior" heat exchanger can be located outside, using ducting to move hot air to the inside space, or it can be located inside, in a separate "split" unit that uses refrigerant to move heat between the two heat exchangers.
Heating Water with Heat Pumps:
Like the liquid-to-liquid heat exchanger on the exterior side of a ground-source heat pump system, an interior heat exchanger can heat water for domestic use and/or hydronic space heating.

Good videos also

https://www.youtube.com/watch?v=14MmsNPtn6U

https://www.youtube.com/watch?v=g39nM7GbSJA