

Integrated Heat Pump System Technology Development for Net Zero Energy Home (ZEH) Applications



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**IEA Annex 32 Workshop
Zurich, Switzerland
May 19, 2008**

DOE/BT Strategic Goal – Net ZEH Technology Market Ready by 2020

Net Zero Energy Home (ZEH) Definition:

A home with greatly reduced energy use (60% to 70% less) through efficiency gains, with the balance of energy needs supplied by renewable technologies.

HVAC & Water Heating Program Supporting Goal:

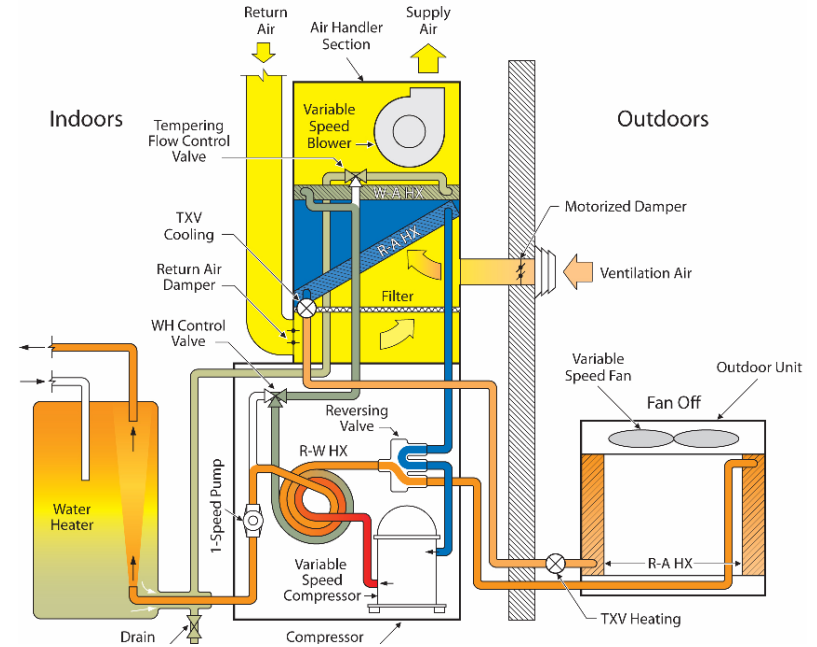
Develop equipment that has potential to reduce HVAC/WH energy use by 50% (from Building America benchmark) in net ZEHs while providing indoor humidity control with no increase in net monthly costs for mortgage and utilities.

Assessment of Advanced HVAC/WH Technology Options for NZEH Applications

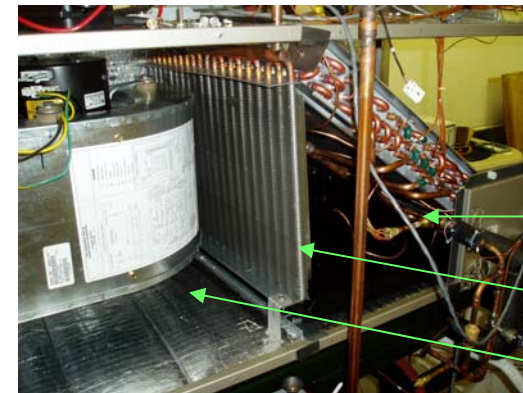
- Objective – identify portfolio of system options with potential to be developed into 50% savers in long term
- Completed initial scoping studies of HVAC and integrated appliance/water heating options in 2005
 - IHP system concept identified as highest ranked option

AS-IHP Concept

- Full integration to heat, cool, ventilate, dehumidify, and heat water as needed
- AS-IHP concept, in dehumidification/ventilation/WH mode, shown at right - many modes possible
 - H or C/ventilation/WH
 - Dedicated water heating
 - Dedicated dehumidification and/or humidification
 - Ventilation air pre-treatment; H in winter, C & dehumidify in spring/summer/fall
- Lab prototype constructed and tested



Possible AS-IHP packaging approach



Lab prototype air handler

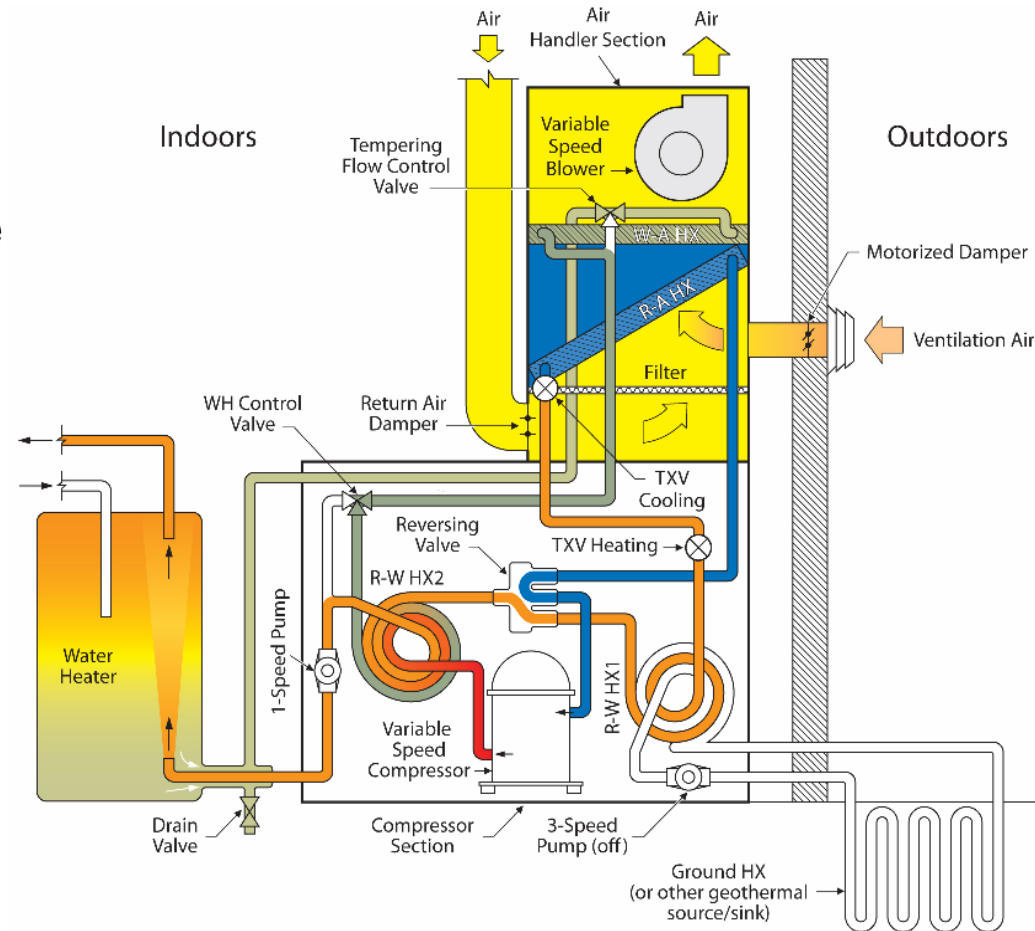
ref/air HX

water/air HX

blower

GS-IHP Concept

- Performance expected to exceed that of AS-IHP in most locations
 - Geothermal source sink (ground HX, etc) generally provides more favorable operating conditions for compressor than OD air
- Cost could approach that of AS-IHP with enhanced GHX designs under development
 - e.g., solid-water-sorbent (SWS) to enhance GHX effectiveness as described in US contribution to Annex 29
 - GHX installed in house foundation excavation (FHX)



**GS-IHP system concept –
dehumidification/ventilation/WH mode shown**

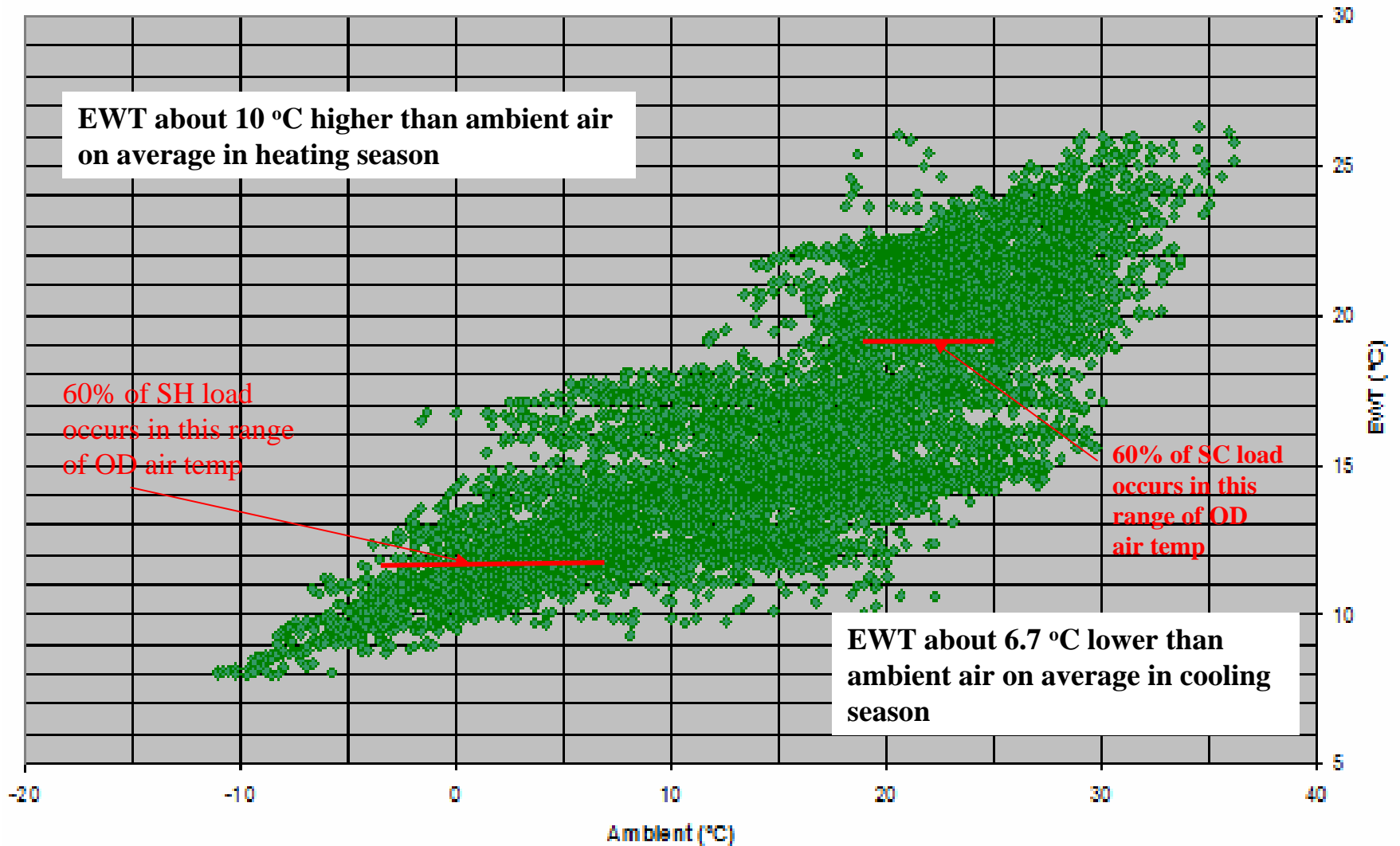
IHP – System Simulation and Performance Analysis Approach

- Lab test data used to calibrate detailed heat pump system model
 - DOE/ORNL Heat Pump Design Model (HPDM)
- Calibrated HPDM used for design optimization and control assessments
 - Establish target compressor and blower speed ranges for major operation modes
 - initially for lab prototype system components (R-22 based)
 - added R-410A compressor map to HPDM and re-optimized design and speed/control relationships for R-410A based systems (both air source and ground source IHPs)

IHP – Performance Analyses

- Detailed annual performance assessments and initial estimate of installed cost & payback vs. baseline system
 - Baseline system – individual systems to deliver same energy services
 - air-source heat pump + electric storage water heater + stand alone dehumidifier + whole-house ventilation system
 - current or proposed minimum efficiency levels
- Calibrated HPDM linked to TRNSYS simulation engine
 - Enables sub-hourly analysis of IHP annual performance
 - using optimized R-410A based design
 - Confirmed ~50% or greater energy savings potential in most locations for both AS-IHP and GS-IHP
 - Exceptions: AS-IHP in Chicago (~45% savings) and Phoenix (~49% savings)
 - poor heat pump SH and WH efficiency and high reliance on back up electric resistance during extreme cold weather periods in Chicago
 - SC efficiency not quite high enough during extreme hot weather periods in Phoenix to achieve 50% savings
- Estimated performance on following slides

IHP – Performance Analyses; GS Entering Water Temp (EWT) vs. OD Air Temp, Atlanta, GA

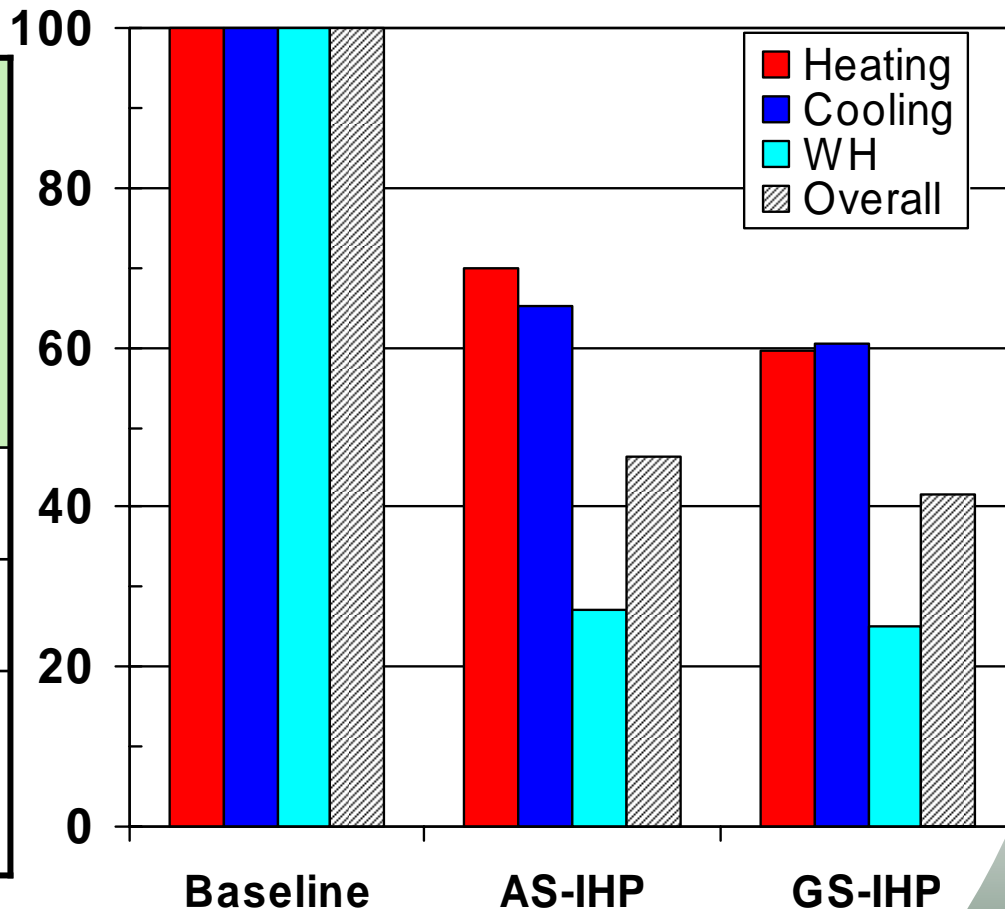


IHP – Performance Comparison in 167m² NZEH in Atlanta, GA

Efficiency Equivalent

	Baseline (air/air heat pump + electric resistanc e water heater)	AS-IHP	GS- IHP
HSPF (W/W)	2.67	3.82	4.48
CSPF (W/W)	3.49	5.34	5.76
WH Energy Factor (W/W)	0.89	3.30	3.57

% Energy Use



Loads and Energy Consumption by Operational Mode for IHPs in Atlanta, GA, from TRNSYS/HPDM Simulation – Example Detailed Results

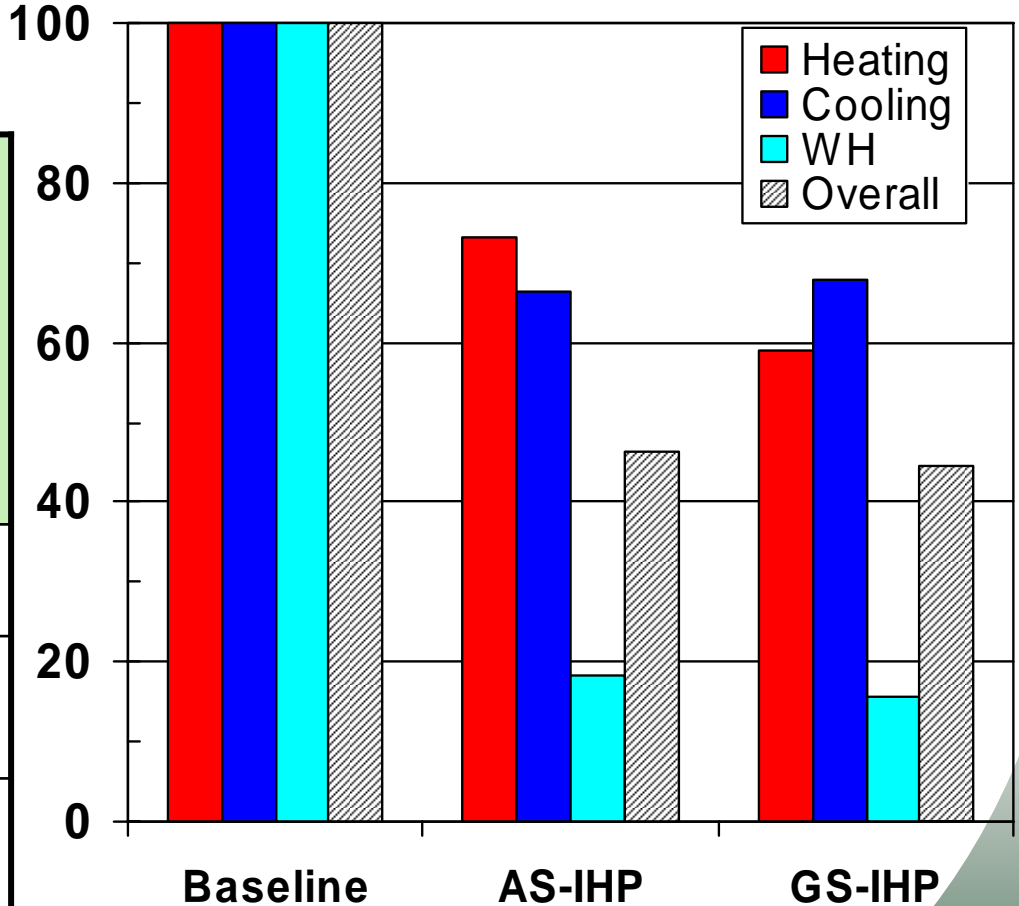
Loads (167 m ² NZEH)		Equipment				
		Baseline	AS-IHP		GS-IHP	
Source	kWh	Energy use, kWh (I ² r)	Energy use, kWh (I ² r)	Energy reduction compared to baseline	Energy use, kWh (I ² r)	Energy reduction compared to baseline
Atlanta						
Space Heating	4775	1789 (51)	1251	30.1%	1066	40.4%
Space Cooling	5735	1643	1073	34.7%	996	39.4%
Water Heating	3032	3402	924 (142)	72.8%	855 (144)	74.9%
Dedicated DH	158	208	82	60.4%	73	64.9%
Ventilation fan	-	189	20	89.6%	17	90.9%
Totals	13701	7230	3349	53.7%	3007	58.4%
Humidifier water use	499 kg		618 kg		647 kg	

IHP – Performance Comparison in 167m² NZEH in Houston, TX

Efficiency Equivalent

	Baseline (air/air heat pump + electric resistanc e water heater)	AS-IHP	GS- IHP
HSPF (W/W)	2.73	3.73	4.64
CSPF (W/W)	3.48	5.24	5.13
WH Energy Factor (W/W)	0.89	4.84	5.75

% Energy Use

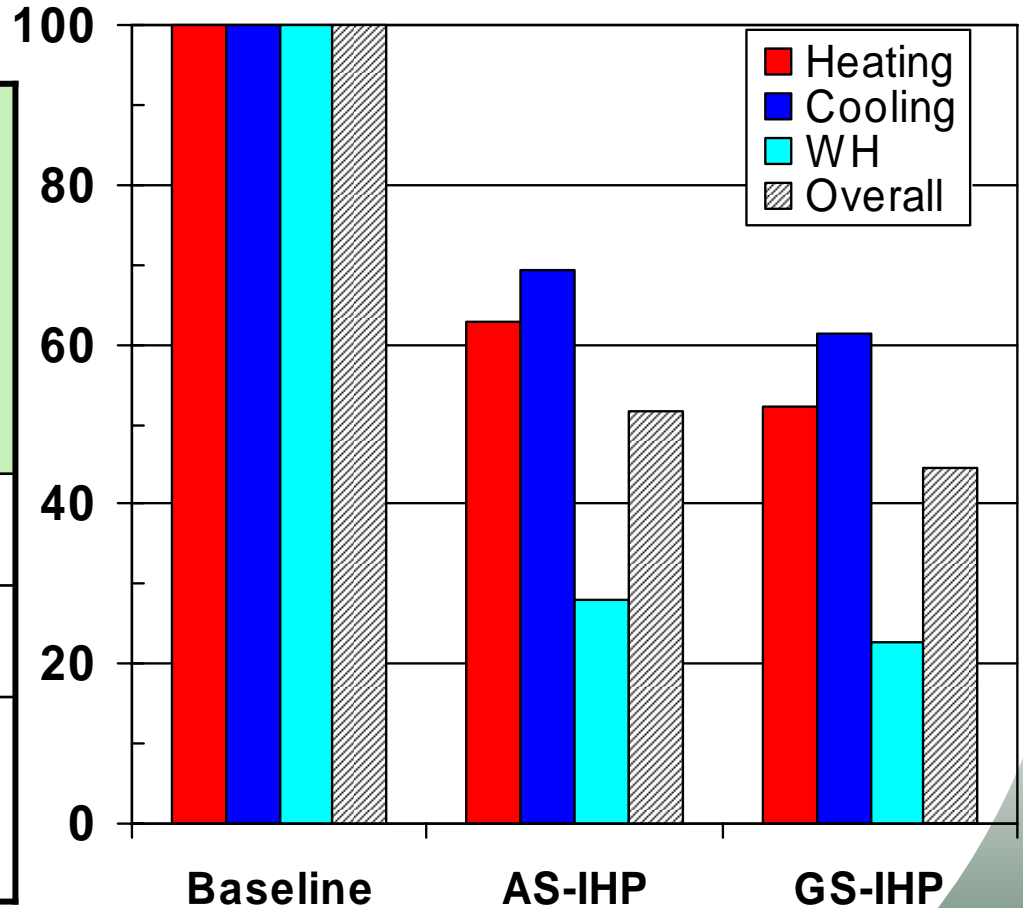


IHP – Performance Comparison in 167m² NZEH in Phoenix, AZ

Efficiency Equivalent

	Baseline (air/air heat pump + electric resistanc e water heater)	AS-IHP	GS- IHP
HSPF (W/W)	2.95	4.70	5.66
CSPF (W/W)	2.94	4.25	4.79
WH Energy Factor (W/W)	0.89	3.56	4.42

% Energy Use

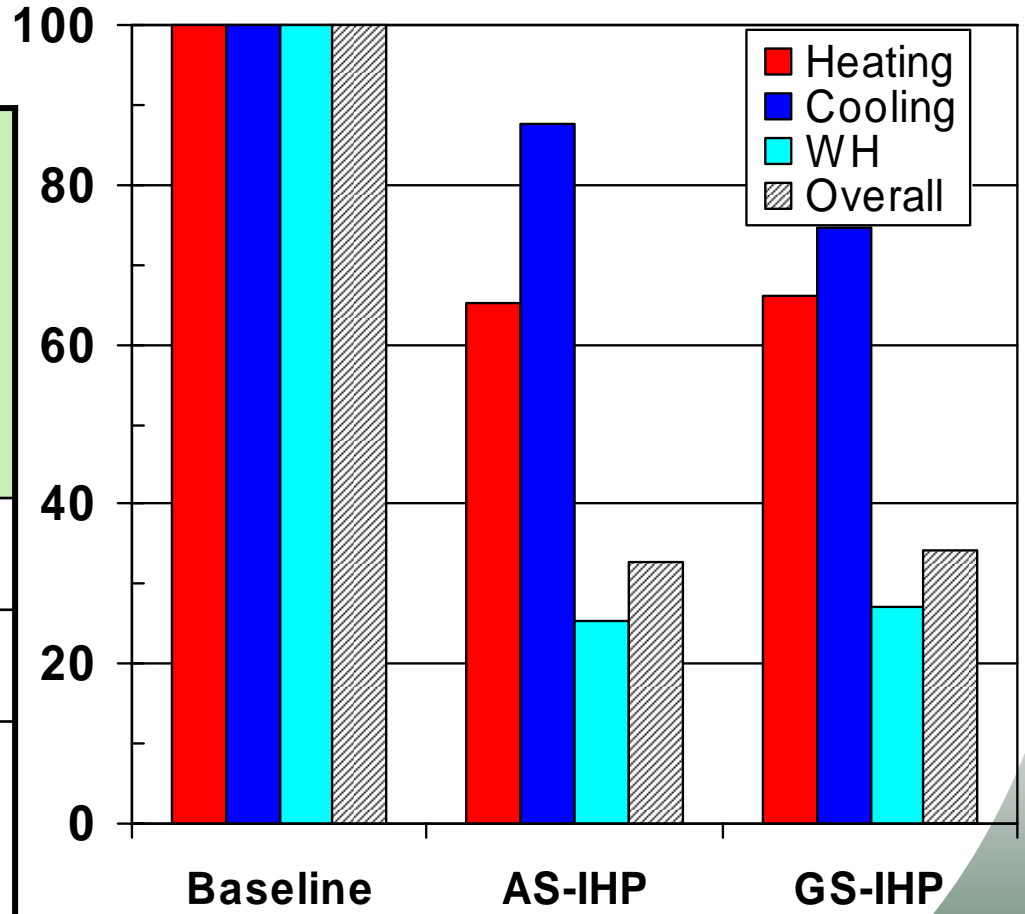


IHP – Performance Comparison in 167m² NZEH in San Francisco, CA

Efficiency Equivalent

	Baseline (air/air heat pump + electric resistance water heater)	AS-IHP	GS-IHP
HSPF (W/W)	3.09	4.75	4.68
CSPF (W/W)	3.38	3.83	4.63
WH Energy Factor (W/W)	0.90	3.55	3.31

% Energy Use

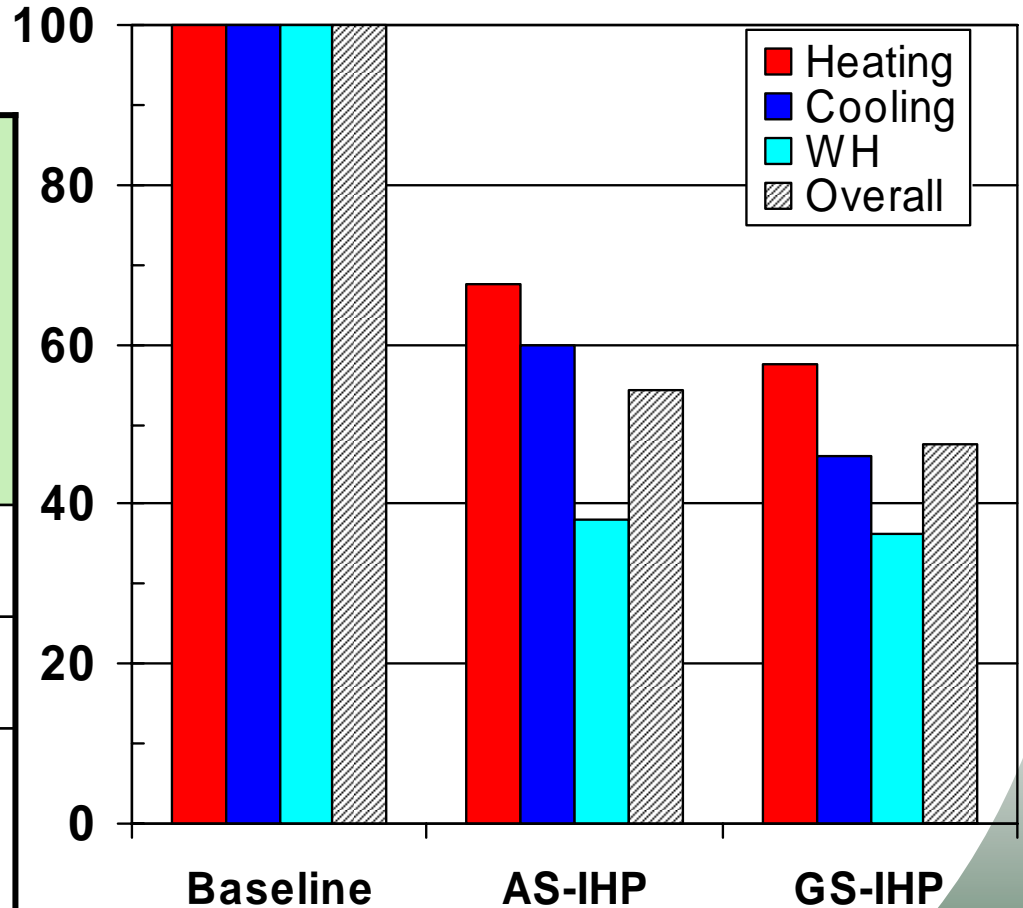


IHP – Performance Comparison in 167m² NZEH in Chicago, IL

Efficiency Equivalent

	Baseline (air/air heat pump + electric resistance water heater)	AS-IHP	GS-IHP
HSPF (W/W)	2.10	3.10	3.65
CSPF (W/W)	3.50	5.85	7.61
WH Energy Factor (W/W)	0.89	2.32	2.44

% Energy Use



IHP – Conclusions To-Date and Future Directions

- IHP system simulations show significant performance enhancement compared to current baseline equipment system for net zero energy houses (ZEH) in range of US climate types
 - AS-IHP; 46% (Chicago) to 67% (San Francisco) improvement
 - GS-IHP; 52% (Chicago) to 66% (San Francisco) improvement
 - very mild ambient temperatures favor air source systems in San Francisco
- Significant summer peak electric demand reduction also
 - AS-IHP; 20% (Phoenix) to 60% (Chicago) at utility peak time
 - GS-IHP; 45% (Phoenix) to 70% (Chicago) at utility peak time
- Initial estimates of simple payback vs.. baseline *in net ZEH*
 - AS-IHP; 5 (Houston) – 10 (Phoenix) years
 - GS-IHP; 6.5 (Chicago) – 14 (Phoenix) years (*with vertical bore GHX*)
 - with successful cost reduction efforts (SWS enhanced GHX, FHX concept, etc.) costs could be about equal to those of AS-IHP

IHP – Conclusion To-Date and Future Directions, Contd.

- All R&D so far focused on net ZEH application
 - that market is vanishingly small at present
- During next 1-2 years, we will be working with two manufacturer to develop initial products based on IHP concept
 - One for AS-IHP and one for GS-IHP; GS-IHP development at more advanced stage
 - AS-IHP: evaluating potential product configurations and potential markets; if outcome positive will begin prototype lab development/testing by late 2008 with initial field tests beginning mid-late 2010; 2nd round field test/demonstration of ~10 pre-production units planned to begin mid-late 2011
 - GS-IHP: prototype development/testing underway; initial field testing planned to begin by December 2009; 2nd round pre-production test/demonstration planned to begin late 2010
 - Both approaches will be modifications of ZEH IHP design described in this presentation – to meet needs of current housing market and specific manufacturer capabilities
 - Probably eliminate some functions – demand dehumidification to be option
 - Possibly use less expensive components
 - Final compromises to be determined