

Legal Text for Annex 41

Cold Climate Heat Pumps

(Improving low ambient temperature performance of Air-Source Heat Pumps)

1. Background

During the 1970s, following the first oil embargoes, heat pumps became of great interest to northern electric power companies. This was particularly true of those experiencing large peak demands during the heating season, as shortages of natural gas and oil led to increased usage of direct electric heating. Air-source heat pumps (ASHP), given their greater availability and almost universal applicability, were of primary interest at the time. It is generally recognized, however that ASHPs based on the simple vapour compression cycle suffer both heating capacity (output) and efficiency (coefficient of performance or COP) degradation as the outdoor ambient temperature drops. At the same time building heat demand is increasing so ASHPs require a supplemental heating source – usually direct electric resistance heat elements - to bridge the gap between the building heat demand and the ASHP heating output. This characteristic causes lower seasonal performance (heating SPF) and limits peak electric demand reduction potential leading to limited acceptance of ASHPs in areas that experience large numbers of hours at very cold temperatures (e.g., at or below -7°C). A primary criteria for ASHPs to achieve good seasonal performance in cold areas is achieving high heating output at low ambient temperatures so as to minimize reliance on supplemental heat sources.

Considerable research and development activity was undertaken to improve the performance of ASHPs in the late 1970's and 1980's, resulting in higher efficiency and more reliable products (see references 1-3). During the decade from 1975 to 1985 a great deal was learned about the technology needs to enable heat pumps to become more competitive for northern climate applications. In intervening years heat pump designs have been pursued (and some have been brought to the market) that incorporate design concepts or features for improved cold climate performance (references 4 and 5 describe two US product examples). Most of these have not been successful due to the continuing relatively low cost of fossil fuels and the higher cost of these products and systems.

With increasing concern for technology options that can result in reduced CO₂ emissions, it is appropriate to revisit research and development work undertaken in different countries on heat pump systems for cold climates and to examine technology improvements that could lead to more successful heat pumps for future building applications in cold regions. ASHPs have the biggest challenges given their inherent low ambient temperature performance problems alluded to above. Availability of ASHP systems with improved low ambient performance would help bring about a much stronger heat pump market presence in cold areas which today rely predominantly on fossil fuel furnace heating systems.

References:

1. Groff, G.C., and Reedy, W.R., Investigation of Heat Pump Performance in the Northern Climate Through Field Monitoring and Computer Simulation, ASHRAE Transactions, Vol. 84, Part I, pp.767-785, 1978.
2. Sizing of Air-to-Air Heat Pumps for Northern Climate Residential Heating

Applications, Bullock, C.E., Groff, G.C. and Reedy, W.R., Proceedings of International HVAC Congress, Berlin, 1980.

3. Heat Pump Performance Improvements for Northern Climate Applications, Groff, G.C., Bullock, C.E., and Reedy, W.R., Proceedings of the 13th Intersociety Energy Conversion Engineering Conference, San Diego, 1978.

4. Acadia™ Heat Pump, 2010. “Product & Technology Review#19”, <http://tinyurl.com/prodtech>, accessed December 30, 2010.

5. Hadley, A., Callahan, J. Strok, R. 2006. “Without strip heat: In-situ monitoring of a multi-stage air source heat pump in the Pacific Northwest,” ACEEE Summer Study on Energy Efficiency in Buildings, 2006.

2. Description of Technical Sector

The primary technical sector is high efficiency (low energy) residential buildings, though commercial buildings can also benefit from the technology. Availability of viable ASHP system solutions for efficient buildings in cold climate locations would significantly extend the market reach of heat pump technologies.

3. Objectives and scope

This project is primarily focused on air-source heat pumps with air or hydronic heating systems (e.g., air-to-air or air-to-water heat pumps) since these products have the greatest challenge in providing sufficient heat output and maintaining high efficiency levels at lower outdoor temperatures. While electrically driven air-source heat pumps will be the main focus, thermally activated air-source heat pumps (engine-driven, absorption, etc.) may also be considered within the scope of the project. Ground-source heat pumps may also be included at the discretion of individual participants. The main technical objective is to identify technical solutions that can lead to improved ASHPs with a heating SPF ≥ 2.63 W/W, the minimum level necessary in order to gain recognition as a renewable technology in the EU.

These objectives have parallel interest under the IEA Framework of Implementing Agreements as the intent is to identify, quantify, and deliver information to key industry stakeholders and policy makers and to provide pertinent resources to building owners and operators. The objectives will be achieved by independent studies and investigations performed by the country-specific participants. The main output of this Annex is information sharing on viable means to improve ASHP heating performance under cold (≤ -7 °C) ambient temperature conditions so that better cross-country understanding is achieved to reduce energy consumption (and the related CO₂-emissions) while satisfying the needs of building owners and operators.

4. Means

Each participating Annex partner will focus on those ASHP types and applications of primary interest to their residential and commercial building sectors. As noted in the scope, participants may include GSHPs in the scope of their contributions as well, but ASHPs are the primary overall focus of this Annex. It is anticipated that each country’s recognized standards, industry practices, and measurement instrumentation approaches will serve as the basis for the individual Annex partner efforts.

The Annex work is subdivided into the following tasks:

Task 1: Critical literature survey

Undertake literature review and critical analysis of the results from prior related research work with reference to projects and studies in various IEA HPP member countries and particularly in the countries participating in this Annex. The objective for this project stage will be to identify a

number of potentially strong ASHP system design possibilities for further evaluation and study. Concepts that feature new technologies or insights, as well as advancements to conventional vapor compression systems will be welcome. It is expected that frosting of outdoor heat exchangers, sizing of the equipment for cold climates, controls (including improved defrost controls) and system design and integration will represent major focus areas.

During this phase of the project it will also be important to formulate current specifications for heat pump systems, as appropriate to individual high efficiency building needs in the various countries, and to agree on overall performance objectives for improved ASHP systems for building space conditioning, water heating, etc., in cold climate locations.

Task 2: System design and application studies - modeling and/or laboratory-controlled measurements

Building on the literature search, and working with pertinent country experts, develop consensus performance targets for the advanced ASHP technology development to be included in the participant's investigations. As an example, the specific aim of the current U. S. Department of Energy's R&D is to demonstrate laboratory prototypes with heating capacity of up to 18 kW (~60,000 Btu/h) and a COP of 4.5 at the nominal U. S. Air-Conditioning, Heating, and Refrigeration Institute (AHRI) 8.3°C rating condition. The specific cold ambient performance goals are to limit COP and capacity degradation from the nominal rated levels to $\leq 25\%$ at -25°C (-13°F). These objectives are subject to review and modification based on input from the research institutions and potential industry partners involved and are focused on the prevailing central air-to-air heat pump type with central air distribution approach used in US systems. Other participants would establish their own performance targets based upon the heat pump and distribution systems of most interest to their industry and end users.

This task may comprise a number of subtasks depending upon individual participants' needs and interests:

1. Model advanced system concepts – e.g. system & component sizing for cold climates, concepts to reduce frosting/defrosting inefficiencies, modifications to vapor compression cycle to enhance heating capacity (multi-stage and/or cascaded vapor compression cycle concepts, etc.), advanced compressor concepts (variable capacity and/or single capacity), improved controls, system design & integration for cold climates, etc.
2. Based on critical review of subtask 1 results develop a design for a laboratory prototype advanced ASHP system based on the best cycle configuration. In this task, detailed design tools will be used to properly size the system components.
3. Fabricate the lab prototype system and conduct laboratory tests.
4. Prepare country report covering Tasks 1 and 2 and submit to Operating Agent (OA).
5. OA collates country reports and prepares Annex Interim report

Task 3: Simulations of energy savings impacts of prototype advanced ASHP design

This task will involve simulated performance projections to an agreed upon format for the preferred ASHP concept (or concepts) to determine energy savings potential over a range of climatic regions and other parameters (e.g. sizing, electric rates, control options, etc.).

Task 4: Report and information dissemination

Each participant's final report will address the results of the tasks above. The common format simulations from Task 3 is intended to enable characterization of each concept on a common basis. These final country reports will be assembled into a final Annex report by the OA. This report will also suggest further areas for study and equipment development.

5. Target audience and Benefits

The sectors targeted for this Annex include:

- HVAC practitioners responsible for designing, selecting, and sizing heat pump systems in varied applications with a focus on cold ambient locations.
- Building owner/operators in cold regions interested in achieving improved comfort conditioning and efficiency performance from their HVACR equipment.
- Entities charged with minimizing energy utilization (i.e., utilities, utility commissions, energy agencies, legislative bodies, etc.) in varied heat pump applications and geographic conditions.

6. Time schedule

The Annex shall tentatively commence 1 July 2012, and remain in force until 30 September 2015. Within the limits of the terms of the Agreement, this Annex may be extended by two or more of the participating countries (Participants), acting in the Executive Committee and taking into account any recommendation of the IEA's Committee on Energy Research and Technology concerning the terms of this Annex 41. Extensions shall thereafter apply only to those Participants.

The following is a tentative work schedule for the different tasks – exact timing will depend upon the actual start date of the Annex.

Start Date	End Date	Activity
July 2012	March 2013	Task 1 – Critical literature survey
	June 2012	Initial organizing meeting, San Antonio, US
	October 2012	Second organizing meeting, Nuremberg, Germany
December 2012	May 2014	Task 2 – System design and application studies
	July 1-2, 2013	First working meeting, Purdue University, West Lafayette, IN, USA
	March 2014	Draft Country reports on Tasks 1 and 2 due to OA
	May 2014	OA forwards interim report to ExCo and Heat Pump Centre
	May 2014	Open workshop at 11 th IEA Heat Pump Conference, Montreal Canada – discuss interim results
	May 2014	Second working meeting, Montreal, Canada
June 2014	February 2015	Task 3 – Simulations of energy savings impacts
	February 2015	Interim web meeting – discuss Task 3 results and plans for final report
March 2015	September 2015	Task 4 – Report and information dissemination
	August 2015	Open workshop – final results Final working meeting – final issues for Annex report Location – 2015 IIR Congress in Japan
	September 2015	OA forwards Annex report to ExCo and Heat Pump Centre

7. Deliverables

The deliverables of the Annex are:

- a) An Internet website (linked to the HPC-site), that will serve as the participants' portal for sharing their country efforts and viewing the work done by other countries.
- b) Progress reports to the HPC four times annually for publication in the Newsletter, and semi-annually to the HPP Executive Committee (May and November).
- c) An annual summary report for inclusion in the HPP Annual report describing the work carried out under the Annex.

- d) Final report consolidating the salient findings of the individual country inputs. This report will re-state the objectives of the Annex, its key findings, a description of the results of the Tasks undertaken by the Annex Participants, and recommendations for further study.

8. Funding

- a) Participant's Financial Obligations: Each Participant (country) will bear the costs of its own participation in the Annex, including any necessary reporting, travel costs to undertake their portion of the effort, and costs to organize and hold working meetings hosted by the country. Approximately one face-to-face working meeting per year is anticipated during the course of the Annex (schedule to be determined by the Participants). It is envisioned that many of the Annex activities can be undertaken via web-conferencing and e-mail communications.
- b) Publications: The cost/effort to prepare the draft Final Report and summary assessments described in paragraph 7 above ('Deliverables') shall be equally shared by all the Participants.
- c) Each Participant shall make a direct financial contribution to the Operating Agent to cover coordination, report submission/review/consolidation, and other Annex-related costs.

The table below shows the fees per Participant, based upon varying numbers of Participants. Each Participant's fee shall be paid in 3 annual installments.

No of participants	Participants' fees		
	2012/13	2013/14	2014/15
3	\$ 5000	\$ 5000	\$ 5000
4	\$ 4250	\$ 4250	\$ 4250
>4	\$ 3750	\$ 3750	\$ 3750

Each Participating country's fee shall be paid in US\$ as shown in the above Table.

9. Specific obligations and responsibilities of the participants

- a) Each Participant shall nominate a lead representative to participate in the work under this Annex and act as the point of contact (POC) with the Operating Agent. At his/her discretion the POC may appoint other individuals to lead the Participant's work in each of the Annex Tasks as defined in Section 4.
- b) Each Participant shall carry out the equivalent of at least 6-12 person months of task-sharing work during the Annex period unless otherwise agreed by the Participants.
- c) Each Participant shall contribute to the working meetings and workshop(s) on the results achieved through the activities conducted under this Annex, including the identification of speakers and participants.
- d) Each Participant shall make a direct financial contribution to the Operating Agent to cover co-ordination and report preparation expenses and other Annex related costs.
- e) Each Participant shall provide a Country Report as identified in Section 4 (Task 4) and shall contribute to the deliverables identified in Section 7.

10. Specific obligations and responsibilities of the Operating Agent

The Operating Agent shall:

- a) Develop, in co-operation with the Participants, a detailed work schedule, a framework for the Country Reports, and a budget for all the activities carried out under this Annex, including methodology and time schedule
- b) Provide the Executive Committee with periodic reports describing the progress of the work being accomplished under the Annex
- c) Deliver the results as described in Section 7 ('Deliverables')
- d) Provide to the Executive Committee, within six months after completion of all the Annex work, a draft of the Final Report for its approval and transmittal to IEA headquarters.

- e) In co-ordination with the Participants, use its best efforts to avoid duplication with activities of other related programs and projects implemented by or under the auspices of the Agency or by other competent bodies
- f) Provide the Participants with necessary guidelines for the work they carry out, assuring minimum duplication of effort
- g) Co-ordinate the efforts of all Participants and ensure the flow of information within the Annex
- h) Provide general administration

The IEA Heat Pump Centre will assist in the establishment of the Annex, in the organisation of any workshop(s) and the publication of the proceedings, and publication of the Final Report.

11. Information and Intellectual property

- a) *Executive Committee's Powers.* The publication, distribution, handling, protection and ownership of information and intellectual property arising from this Annex shall be determined by the Executive Committee, acting by unanimity, in conformity with this Annex.
- b) *Right to Publish.* The Participants shall have the right to publish information provided to or arising from their contribution to the Annex under Section 9b, except for proprietary information, as defined in paragraph (c) below.
- c) *Proprietary Information.* For the purposes of this Annex, proprietary information shall mean information of a confidential nature such as trade secrets and know-how (for example, computer programmes, design procedures and techniques, chemical compositions of materials, or manufacturing methods, processes or treatments) which is appropriately marked provided that such information:
 - 1) Is not generally known or publicly available from other sources
 - 2) Has not previously been made available by its owner(s) to others without obligation concerning its confidentiality; and
 - 3) Is not already in the possession of the recipient Participant(s) without obligation concerning its confidentiality.

It shall be the responsibility of each Participant supplying proprietary information, and of the Operating Agent, to identify such information as proprietary and to ensure that it is appropriately marked. The Participants and the Operating Agent shall take all necessary measures in accordance with this paragraph, the laws of their respective countries and international law to protect the proprietary information provided to or arising from this Annex.

- d) *Production of Relevant Information by Governments.* The Operating Agent should encourage the governments of all Agency Participating Countries to make available or identify to the Operating Agent all published or otherwise freely available information known to them that is relevant to the Annex.
- e) *Production of Relevant Information by Participants.* Each participant agrees to provide to the Operating Agent all previously existing information, and information developed independently of the Annex, which can assist or is needed by the Operating Agent to carry out its functions in this Annex, which is freely at the disposal of the Participants, and the transmission of which is not subject to any contractual and/or legal limitations, under the following conditions:
 - 1) The Participant will make such information available, at its own costs, provided that such costs are not substantial
 - 2) If substantial costs are necessary for the Participant to make such information available, the Operating Agent and all Participants will determine the charge of the costs for each participant, upon approval of the Executive Committee.
- f) *Use of Confidential Information.* If a Participant has access to confidential information which would be useful to the Operating Agent in carrying out the studies, assessments, analysis or evaluations described in this Annex, such information may be communicated to the Operating

- Agent but shall not become part of any report or other form of documentation issued as part of this Annex, nor shall it be communicated to the other Participants, except as may be agreed between the Operating Agent and the Participant who supplies such information. This information has to be marked clearly as “confidential”.
- g) *Acquisition of Information for the Annex.* Each Participant shall inform the Operating Agent of the existence of information that can be of value to the Annex, but which is not freely available, and each Participant shall endeavour to make such information available to the Annex under reasonable conditions, in which event the Executive Committee may, acting unanimity, decide to acquire each information.
 - h) *Reports on Work Performed under the Annex.* The Operating Agent shall, in collaboration with the other Participants, prepare reports on all work performed under the Annex and the result thereof, including studies, assessments, analysis, evaluations and other documentation, but excluding proprietary information, in accordance with paragraph 11(c) above.
 - i) *Copyright.* The Operating Agent, or each Participant for its own results, may take appropriate measures necessary to protect copyrightable material generated under this Annex. Copyright obtained shall be the property of the Operating Agent, for the benefit of the Participants provided, however, that Participants may reproduce and distribute such material, but shall not publish it with a view to profit, except as otherwise provided by the Executive Committee. The Contracting Parties understand and agree that the name, acronym and emblem of the IEA has been notified to the World Intellectual Property Organisation (WIPO) Secretariat according to Article 6 of the Paris Convention for the Protection of Industrial Property, as amended on 28 September 1979. The Contracting Parties further understand and agree that the OECD/IEA shall retain the copyright to all IEA deliverables, materials or publications published or to be published by the IEA or jointly by the IEA and a third party to this Annex. Should the Contracting Parties use any such deliverables, materials or publications they shall give full acknowledgement to the OECD/IEA as being the source of the material with a copyright notice in the following form: © OECD/IEA, (year of publication).
 - j) *Authors.* Each Participant shall, without prejudice to any rights of authors under its national laws, take necessary steps to provide the co-operation from its authors required to carry out the provisions in this paragraph. Each Participant shall assume the responsibility to pay awards or compensation required to be paid to its employees according to the laws of its country.

13. Operating Agent

The Oak Ridge National Laboratory (ORNL) and Purdue University, U.S.A. are designated as Co-Operating Agents.

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