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Paper

Equivalent full load hours for heating of reversible air-air heat pumps

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Summary

Modern air conditioning machines are often reversible air to air heat pumps and can be used for renewable heating. However, as the extent to which these systems are actually used for heating in the Netherlands is very uncertain, so is the calculated contribution of these systems to gross final renewable energy consumption. A few questions were added to a telephone market survey for companies that install these reversible cooling systems in the Netherlands to reduce this uncertainty. The survey showed that many of the reversible air to air systems newly installed in 2014 are actually used for heating. VRF systems are used much more for heating than split systems. The average equivalent full load hours for heating was about 500 which is substantially less than the current default value for the average climate zone for reversible air to air systems (710 hours) from the European Commission.

It is important to note that this default value refers to the stock of all installed systems and not to the newly installed systems. We assume that in the past the reversible systems were used less for heating. This makes the difference between the EU default and the results of this study even larger.

For the purpose of using the survey results to calculate the contribution of reversible air to air systems to gross final renewable energy consumption in the Netherlands, a table is proposed that reflects a gradual increase of the equivalent full load hours for heating for the year of installation from 2009 to 2015. Using this table in combination with the database of installed heat pumps per year, the calculated renewable energy production for the reversible air to air systems in 2013 goes from 0.8 PJ (existing calculation based on the most recent update of the national Protocol Monitoring Renewable Energy) to 0.5 PJ.

This new result is better supported empirically than before, but still contains substantial estimated elements. To reduce uncertainty in the future we recommend that the survey described should be repeated in a few years.

Inhoud

1. Introduction

Heat pumps are used to extract aerothermal and geothermal energy and thus contribute to the use of renewable energy. In 2013 heat pumps were responsible for 6 percent of the final consumption of renewable energy in the Netherlands (Statistics Netherlands, 2015) and this share has been growing in recent years.

To quantify the renewable heat pump heat production efficiently, Statistics Netherlands collects information on the sales of heat pumps in terms of numbers and capacity from the heat pump supplying companies and their trade associations DHPA and VERAC. Subsequently, the installed base of heat pumps is calculated assuming a heat pump life time of 15 years. Renewable heat pump heat production is then calculated by multiplying the total capacity with a fixed estimate for the equivalent full load hours and subtracting the driving energy (electricity or natural gas) of the heat pumps. These calculations are made separately for various types of heat pumps. This method is in line with the national Protocol Monitoring Renewable Energy (RVO and Statistics Netherlands in preparation) and the guidelines for establishing the contribution of heat pumps to renewable energy (European Commission, 2013).

There are many different types of heat pumps, which can be classified according the heat source and heat sink. Air to air heat pumps extract heat from the air and supply the heat to an air-based heating system. Similarly there are water to water systems that extract heat from the (surface or ground) water and supply the heat to a water-based heating system. This article focuses on the air to air heat pumps.

The estimate of the equivalent full load hours for heating forms a crucial part of the calculation. This parameter is hard to estimate for air to air heat pumps, because most are in fact conventional cooling machines (air-conditioning) which can technically heat as well. However, natural gas boilers are a very well established technology for heating in the Netherlands, and it is likely that a substantial, but unknown, part of the reversible air-air systems is not or only partly used for heating. In these cases an air-air system is used for cooling and a natural gas boiler for (most) heating. Heat pump supplying companies in general do not know to what extent their reversible systems are used for heating, because they sell their systems to installers and only the way in which an air to air system is installed determines whether it is used for heating.

The European default for the equivalent full load hours for heating for reversible air to air heat pumps in average climates is 710 hours (European Commission, 2013). The value for heating only air-air systems is larger, but less relevant as the market of reversible systems is much larger. In the Netherlands the parameter for the equivalent full load hours of all air to air heat pumps for heating, according to the recently updated Protocol Monitoring Renewable Energy, (RVO and Statistics Netherlands, 2015) is 550 for heat pumps > 12 kW and zero for smaller heat pumps. Hence, this parameter was set lower than the European default. This updated Protocol has not yet been applied by Statistics Netherlands for published data on heat pumps.

These values for the equivalent full load hours for heating from the European Commission and the national Protocol are only very rough estimates and therefore uncertain. In terms

of capacity, air to air systems represented 40 percent of all installed heat pumps in 2013. Consequently, the uncertainty in equivalent full load hours of the reversible air to air systems contributes substantially to the overall uncertainty of renewable energy from heat pumps.

To reduce this uncertainty, a few questions were added to an existing survey on the market for companies that install cooling equipment about the estimated use for heating of reversible heating/cooling machines for the most recent projects carried out by the companies surveyed.

This article describes these additional questions, reports the results and formulates recommendations for the parameter for equivalent full load hours of air to air heat pumps in the Dutch renewable energy statistics. Unfortunately, the study described in this article came too late to be integrated in the recent update of the national Protocol Monitoring Renewable Energy (RVO and Statistics Netherlands, 2015). However, this article is on time for the coming revision of the Dutch renewable energy statistics and was already announced in a footnote in the updated Protocol.

2. Description of the survey

The questions on the use of reversible air to air heat pumps were integrated in a survey commissioned by the NVKL (Dutch Association of refrigeration, air conditioning and heat pump (RACHP) contractors and suppliers) and supported by the Netherlands Enterprise Agency (RVO.nl). It was carried out by USP Marketing Consultancy in November and December of 2014. The main purpose of the survey was to quantify the market for companies active in installing and maintaining climate and cooling installations. CBS has collaborated with USP to include a couple of questions on the effective use of air-to-air heat pumps.

For the survey about 1200 companies were approached for an interview by telephone. The response rate was about 20 percent. For a limited number of large companies a more intensive calling procedure was applied and response rate was about 40 percent.

In the survey, two main markets are distinguished:
- Air conditioning (Climate technology)
- Refrigeration (Cooling technology)

Air conditioning technology refers to technology to achieve optimal air temperature and air quality mainly in buildings. Refrigeration refers to technology to purely cool dedicated storages or processes (e.g. storage of food). For the issue of air to air pumps, only the climate technology market is relevant.

Air conditioning was divided into three submarkets:-
- Small air conditioning
- Large air conditioning
- Heating only systems

For the air to air systems the first two groups are important.

Each participant in the survey was asked to provide more detailed information on the last two projects for each submarket in which they were active. This information included, amongst others, the type of heating/cooling product involved, the type of project (new building, renovation or maintenance) and the number of products.

Three main types of products were distinguished for air to air systems:
- Single-split systems: a typically small system with one outdoor and one indoor unit
- Multi-split systems: a system of typically intermediate size with one outdoor unit and multiple indoor units.
- VRF systems (Variable Refrigerant Flow): a flexible system of larger size.

Especially for the purpose of establishing the use of reversible air-air systems for heating questions were added on
- Whether or not the product is used for cooling only or both cooling and heating
- The type of heating (auxiliary heating, main heating with other technology as back-up, full heating)
- Thermal capacity of the product
- Estimated equivalent full load hours for heating

The questions on the use for heating were asked in a sequence of increasing accuracy and difficulty to answer. In this way we aimed to obtain for all respondents at least a very rough indication on the use for heating and to obtain the most accurate answer (equivalent full load hours) for the respondents that were able to answer this questions. This strategy worked out as planned, because nearly all respondents could answer the first two questions, whereas only about 40 percent could answer the question about the equivalent full load hours.

3. Results

In terms of number of products single and multi-split units are the most dominant product groups (table 1).

1: Share of type of product in total number of sold or maintained air-air products in 2014

	Percentage
Single-split	49
Multi-split	40
VRF	11
Total	100

Source: Statistics Netherlands and USP

About 90 percent of all systems is used for heating (table 2).

2: Application for heating of air to air systems in total number of sold or maintained air-air products in 2014

	Cooling only	heating and cooling	Total
	%		
Single-split	13	87	100
Multi-split	8	92	100
VRF	13	87	100

Source: Statistics Netherlands and USP

As expected VRF systems have the largest thermal capacity. Also, VRF systems are used more intensively for heating than the single-split and multi-split systems (table 3). This table also shows that for VRF systems the systems that are used for auxiliary heating are smaller than the systems that are used more intensively for heating. For the split systems, such a trend is not visible.

3: Average thermal capacity per product in the last two projects in 2014

	All types of heating[1)]	Auxiliary heating	Main heating with back up	Full heating
Average thermal capacity	kW			
Single-split	9	8	13	7
Multi-split	18	18	16	22
VRF	63	46	74	100
Number of observations				
Single-split	135	91	25	19
Multi-split	82	58	17	7
VRF	64	34	20	10

[1)] For the avergae thermal capacity this is calculated as the weighted average for all three types of heating
Source: Statistics Netherlands and USP

For the calculation of the average equivalent full load hours (to be applied to the installed capacity) it is most relevant to know the shares of the different heating types in terms of thermal capacity (table 4). For this table the number of observations (not shown) is comparable to table 3.

4: Share of heating type in terms of thermal capacity

	All types of heating	Auxiliary heating	Main heating with back up	Full heating
	%			
Single-split	100	79	13	7
Multi-split	100	69	13	18
VRF	100	40	36	24

Source: Statistics Netherlands and USP

For the equivalent full load hours the number of observations was substantially lower (table 5), because apparently this is hard to estimate for the respondents. For most situations the average number of equivalent full load hours for heating is about 300. An exception are the VRF systems that are used as main or full heating. Estimated use for heating of these systems is about 1100 equivalent full load hours. The total (average) for all systems is calculated using the shares for the three different heating types from table 4.

5: Average equivalent full load hours for air to air systems that are used for cooling and heating

	Auxiliary heating	Main heating with back up	Full heating	All types of heating [1)]
Average equivalent full load hours for heating				
Single-split	294	320	251	295
Multi-split	288	474	70	273
VRF	293	1 144	1 126	795
Number of observations				
Single-split	34	12	4	50
Multi-split	22	7	2	31
VRF	15	7	7	29

[1)] For the avergae equivalent full load hours this is calculated as the weighted average for all three types of heating
Source: Statistics Netherlands and USP

The equivalent full load hours in table 5 apply to the systems that are used for heating and cooling. There are also systems that are not at all used for heating (table 2). The average equivalent full load hours for all systems is calculated by combining table 2 and 5, leading to table 6:

6: Equivalent average full load hours for heating for air to air systems

Single-split	256
Multi-split	251
VRF	691
Total	473

Source: Statistics Netherlands and USP

In this table the total was calculated as the average with number of systems (table 1) and average system size (table 3) as weights.

Only 5 percent of all surveyed projects were maintenance projects. Hence, the calculated equivalent full load hours refer to newly installed heat pumps, either in new buildings or in renovated buildings.

The survey also covered air to air heating only systems. These systems covered only about 3 percent of the market in terms of thermal capacity and were therefore not included in the analysis.

4. Consequences of results for calculating the production of renewable energy from air to air heat pumps

For the first time, data are available on the actual use of heating of reversible air to air heat pumps in the Netherlands. The data are not based on actual measurements but on estimates of installers and the number of observations is limited. So improvement is still possible (but costly) in terms of data quality. However, the available data are much better than the rough estimates we had to use until now.

The data obtained cannot be directly used to calculate renewable energy production for the national renewable energy statistics, firstly because in the national statistics there is no breakdown of air- air systems in single split, multi-split and VRF systems and secondly, because for the renewable energy statistics parameters are needed for all working systems and not for the newly installed systems. In this chapter we 'convert' the results of the empirical study to definitions of the national renewable energy statistics. Inevitably, unfortunately, assumptions are needed for this conversion.

A difference between this study and the data available on installed capacities in the renewable energy statistics is the breakdown in the types of air-air heat pumps. In this study we have single split, multi-split and VRF systems, whereas in the national renewable energy statistics we have systems < 12 kW and systems > 12 kW. A simple approach to bridge this gap is assuming that, in terms of capacity, the <12 KW systems are single-split systems, whereas the > 12 kW systems are multi-split and VRF systems. This is not entirely true, but given the other uncertainties this is a reasonable simplification. The weighted average of the equivalent full load hours for multi-split and VRF systems is 467 hours.

We assume that in the past there was the use of reversible air to air heat pumps for heating was less than now. Also, it is likely that in the past a smaller fraction of the reversible heat pumps passed the threshold level for the energy performance (Seasonal Performance Factor, SPF> 2.5) of the renewable energy directive (European Commission (2013). In the Protocol Monitoring Renewable Energy (RVO and Statistics Netherlands, 2015) the assumption is made that air to air heat pumps installed before 2009 do not pass the SPF criterion. Merging the results of this study and this assumption in the Protocol we propose table 7 for the equivalent full load hours for air to air heat pumps.

This table implements the assumption that the use for heating (with a sufficient SPF) gradually increases from zero for the systems installed before 2009 to the observed levels in 2014. It is possible that the average full load hours for heating will increase in the future, but the opposite may also happen as result of decreasing heating demand and increasing cooling demand due to better isolation and climate change.

7: Proposed equivalent full load hours for heating of air-air heat pumps

Year of installation	<= 12 kW	> 12 kW
<2009	0	0
2009	0	200
2010	50	250
2011	100	300
2012	150	350
2013	200	400
2014	250	450
>=2015	250	500

Source: Statistics Netherlands and USP

In the current Dutch figures on renewable energy at the CBS and Eurostat website electric air to air heat pumps contribute 2.5 PJ to the gross final energy consumption of renewable energy for 2013. This number is based on the old Protocol Monitoring Renewable Energy of 2010 (Agentschap NL, 2010) with an average equivalent full load hours of 550 for all air-air heat pumps (that satisfy a COP criterion) except small heat pumps (< 10 kW) installed before 2010. According to the new Protocol (RVO and Statistics Netherlands, 2015), *without* taking into account the results described in this article, this would be 0.8 PJ. This 0.8 PJ has not been published. This is substantially less for three reasons:

1. All air-air heat pumps installed before 2009 are excluded, because it is assumed that they do not pass the SPF criterion of European Commission (2013).
2. All air to air heat pumps < 12 kW would be excluded, because it is assumed that are used for cooling only
3. The seasonal performance factor is now 2.6 (from European Commission, 2013) instead of 3.0 of the old Protocol

With the new table 7 small air – air systems (< 12 kW) are included as systems that contribute to renewable heating. However, the gross final energy consumption is further reduced to 0,5 PJ, because the resulting average equivalent full load hours for heating (after applying table 7 to the database of heat pump systems) is lower.

With the proposed parameters in table 7 the average equivalent full load hours of heating will gradually increase in the future, as the relative contribution of new systems with higher full load hours for heating with sufficient SPF will increase. However, one should remember that for deducing table 7 several assumptions were needed. To test the real development of the equivalent full load hours, we recommend that the study described in chapter 3 should be repeated in a few years.

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Verklaring van tekens

.	Gegevens ontbreken
*	Voorlopig cijfer
**	Nader voorlopig cijfer
x	Geheim
–	Nihil
–	(Indien voorkomend tussen twee getallen) tot en met
0 (0,0)	Het getal is kleiner dan de helft van de gekozen eenheid
Niets (blank)	Een cijfer kan op logische gronden niet voorkomen
2014–2015	2014 tot en met 2015
2014/2015	Het gemiddelde over de jaren 2014 tot en met 2015
2014/’15	Oogstjaar, boekjaar, schooljaar enz., beginnend in 2014 en eindigend in 2015
2012/’13–2014/’15	Oogstjaar, boekjaar, enz., 2012/’13 tot en met 2014/’15

In geval van afronding kan het voorkomen dat het weergegeven totaal niet overeenstemt met de som van de getallen.

Colofon

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