DRAINBACK SYSTEMS: MARKET OVERVIEW

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1 Introduction

One way to avoid overheating problems and the threat of freezing of the heat carrier fluid is to install drainback systems (DBS). DBS ensure a number of advantages in comparison to conventional pressurized solar thermal systems due to special hydraulic design and operation. A unique feature of DBS is a recurring three stages operation, comprised of the filling, operation, and draining of the circulating fluid. The DBS can sometimes use water as the heat carrier, which is cheap, available almost everywhere, and environmentally friendly. The hydraulic design of DBS requires fewer components, ensuring lower investment and maintenance. Despite several advantages, DBS are widespread only in few countries.

The present paper summarizes DBS available on the market. About 50 available drainback systems were identified, analyzed, and presented. The aim is not to advertise some systems or producers of the drainback technology, but to show the variety of different concepts, operation principles, and applied components. Information about the drainback market share is summarized initially. An estimation of the market share is presented for some European countries, the USA, and Russia. The following part includes the classification of DBS which highlights attributes of these systems, where operational advantages of every hydraulic concept are discussed. DBS are categorized in accordance to the location of the volume for draining the heat carrier fluid during non-operating times. Usually the drainback tank, heat storage, or oversized heat exchanger are applied for this purpose. Besides this classification, DBS are generally analyzed based on their component selection, including collectors, drainback tanks, heat storages, pumps, piping, and heat carriers, all of which are separately analyzed.

2 Market share of drainback systems

In 2012 the magazine “Sonne Wind & Wärme” published a market overview on drainback systems [Berner 2012]. According to this compilation, there are at least 35 drainback systems available on the world market. Further market investigation showed that at least 14 additional drainback configurations are offered to consumers. Some manufactures promote several concepts/configurations of DBS simultaneously, therefore 44 companies were counted in total (cf. attachment 1). There is a lack of publications and statistics on the share of drainback systems on the market. Companies often avoid publishing and disseminating such kind of commercial information for obvious reasons. Thus available sources, personal contacts, and indirect relevant statistics (solar thermal market, installed collector capacity, etc.) were applied for the analyses. The market situation is presented in table 1 for drainback systems in some countries for the last decade. Numbers show that drainback technologies are prevalent in some European countries such as Netherland, Belgium, and Norway. The USA is a country, where drainback systems have a good market penetration, forming twenty percent of solar thermal technologies. DBS cover furthermore 15% of the local market in France and Spain, whereas in Portugal and Italy about 10%.

Table 1: Statements on the market shares of drainback systems

№	Market share of DBS	Source
1	The share of DBS for domestic hot water applications and combisystems in **Norway** is about 70%	Estimation of Catch Solar Energy, Norway 2014
2	Less than 10% is the share of DBS in **Switzerland**	own estimation, 2014
3	About 2% of the total capacity of installed collectors in **Russia** are applied for drainback systems	Butuzov V. "Ujgeoteplo", Russia, 2014
4	The installed DBS in **France** represent almost 15% of the solar thermal market	Mugnier D. (TECSOL) - personal estimation
5	Drainback system is the usual domestic hot water system in **Belgium** and **Netherlands**	Mauthner F., Weiss W. "Solar Heat Worldwide", 2013
6	The share of drainback systems in **Italy** is 8%	Thermital 2011
7	Drainback types are almost negligible or hold a small share in most markets with the exception of the **U.S**: where they account for 20% of the market	BSRIA ltd., United Kingdom, (www.bsria.co.uk), 2009
8	The share of drainback systems in some European countries: **Spain** (15%), **Italy** (10%), **Portugal** (10%), **Greece** (<1%)	Wilhelms C., Schabbach T., "NEGST Project, drainback solar water heating system", 2006
9	"Over 80% of the **Dutch** solar energy systems and virtually all **Norwegian** solar combisystems include the drainback concept"	H.Visser, M.Peter "Report of IEA Task 26 " 2003

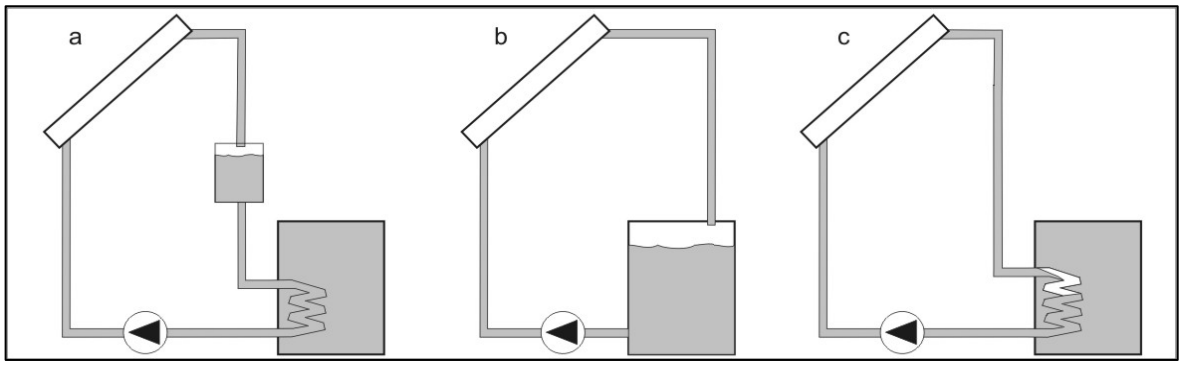
Germany and Austria are not in the table due to difficulties acquiring the data. On the other hand, there are plenty of companies in Germany which are fostering all existing concepts of DBS. However, own expertise confirms that DBS are rarely installed and are not popular in contrast to conventional pressurized solar thermal systems. The main problem has been and continues to be a lack of well educated, qualified installers who are playing a crucial role in the market. Drainback technologies need a coordinated operation between manufactures and installers. Otherwise it is easier for installers to advertise conventional pressurized solar thermal system avoiding possible responsibilities due to improper installation. DBS are slowly developing in Germany, but its share remains insignificant. Some indications, which are confirming a perspective of drainback technologies, are modernization and presentation of new drainback systems. For instance PAW GmbH introduced recently a modernized product called DrainBloc and Vaillant launched a new concept line titled auroFLOW.

3 Classification of drainback systems

Drainback systems can be distinguished between open and closed solar loops. Closed DBS are widely spread, whereas open DBS, which vent to the atmophere, are rarely used and should be protected from corrosion. Depending on the heat carrier, DBS are further categorized between water or anti-freeze mixture (propylen glycol) systems. Four concept variations of drainback systems on the Dutch market are mentioned in a report from IEA-Task 26 [Visser et al., 2003].
Another appropriate classification of DBS might be the location of the volume for the draining of the heat carrier during non-operating times. Once the pump is switched off, the DBS can gather the drained working fluid in a special hydraulic component such as a drainback reservoir, a heat storage, or an oversized heat exchanger. Thus, it can be distinguished between three types of drainback systems in terms of different volume, which in operation mode is filled with air (Picture 1):

- DBS with additional drainback reservoir, for instance Catch Solar Energy (NO), Fafco (US), Orkli (SP), PAW GmbH (DE), Solarhot (US), STI GmbH (DE), Viridian Solar Ltd. (GB), Vaillant (DE), Zen Renewables (NL) etc.

- Drainback systems with heat storage as drainback reservoir, for instance Agritec S.r.l. (IT), Bosswerk GmbH (DE), FSAVE (DE), ROTEX GmbH (DE)
- Drainback system with oversized heat exchanger, for instance ESE (BE), Termicol Energia (SP), Saunier Duval (FR), Wagner & CO Solartechnik (DE) etc.



Picture 1 - Drainback systems in accordance to the location of the volume of the drained heat carrier: a) drainback vessel, b) heat storage as drainback vessel, c) oversized heat exchanger

In picture 1 one can see schematic hydraulics of drainback systems. DBS with additional drainback reservoir (Picture 1a) can be referred to as standard DBS as the most widespred configuration. The drainback tank is always installed in the supply pipe line between collector outlet and heat storage inlet. There are some DBS which contain a heat exchanger inside the drainback tank (not in the picture). For these systems two pumps are necessary, one for the solar loop and another for the storage water (for instance Energy Lab). The drainback vessel without additional heat exchanger inside the tank is widely used. The considerable advantage of this DBS approach is a low lift head, which has to be delivered by the pump during the filling. The lift head is the difference in height between the water level in the drainback vessel (if the pump is off) and the highest point of the hydraulics. The lift head is directly correlated to the pump capacity. It means for a high lift head, the centrifugal pump has to be oversized, otherwise it will be not able to fill the solar loop. The Drainmaster (STI) for instance has the minimal possible height for DBS, as the drainback tank is located directly below the collectors. At the same time, the location of the drainback vessel outdoors obligates it to operate with antifreeze, to prevent freezing of the heat carrier. Besides Drainmaster, all other similar systems place the drainback tank indoor. DBS from ZEN Renewables (NL) use a drainback tank, which is integrated into the heat storage. This vessel locates at the bottom of the heat storage and is separated with a single wall.

Another hydraulic concept consists of using the heat storage itself as a volume for the draining fluid. For instance Agritec s.R.L. (IT), Bosswerk GmbH (DE), FSAVE (DE), and Rotex Heating GmbH (DE) use non-pressurized heat storages as the drainback reservoir (Picture 1b). The storage is made of non-pressure resistant plastic, and therefore should be permanently operated and vented at atmospheric pressure. The solar loop is connected to the heat storage via stratification device, which distributes the solar heat in the tank based on its temperature level. It is important not to disturb the primary function of the storage to collect and store the heat, where stratification plays an important role. There is no heat exchanger in the solar loop (open system), which enhances a heat transfer in DBS. Two identical pumps connected in series increase the lift head. Both pumps are in operation only during the filling process, afterwards one is swiched off. The main advantage of this system is a reduction of one hydraulic component. The heat carrier drains directly into the heat storage, always when the pump is switched off. In general, this hydraulics concept (Picture 1b) is presented by a couple of companies on the market.

The usage of oversized heat exchanger coil as a drainback volume is another concept of drainback technology. For instance Secusol, which was invented, patented and is currently

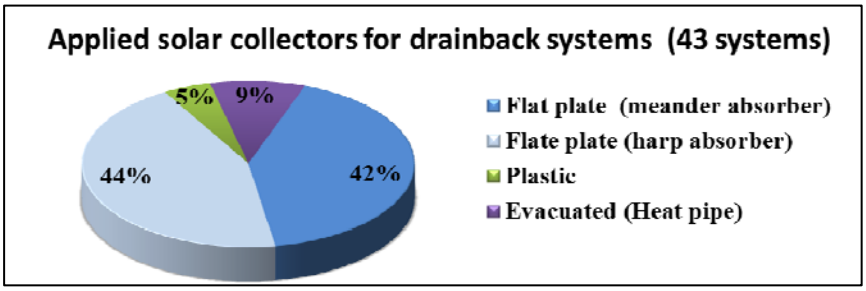
distributed on the market by Wagner & Co Solartechnik (DE). Thermicol Energia Solar (SP) and Vaillant (DE) are promoting this type of drainback hydraulics as well. Once the pump is deactivated, the fluid drains back to the heat exchanger in the storage. Such kind of system is a perfect solution for small scale e.g. DHW applications. Fewer components, easier installation, and esthetical advantages are all benefits to this approach. Similarly to the previous concept, the heat in circulating fluid will always be collected in the heat storage when the pump is deactivated.
It is to emhasize that 28 of summarized DBS are promoting concept with drainback tank, 15 DBS use oversized heat exchanger and 4 DBS drain the circulation fluid direct into the heat storage. Two companies construct various DBS depending on customer orders, therefore not considered in this classification.

4 Hydraulic components of drainback systems

Every company in the market tries to make their drainback product essential for an outstanding system. For instance Magen Eco-Energy Ltd (IL) uses all plastic glazed flat plate collector for the drainback system. Fafco promotes its plastic technologies as well, assembling their DBS with unglazed plastic collector, plastic drainback tank, and PEX (cross-linked polyethylene) piping. Some manufacturers propose using conventional centrifugal pumps (Rheem) and other positive displacement pumps (ESE) for optimal configuration in DBS. The shape, materials and size of drainback tanks vary greatly within market offerings. In order to show the variety of applied components, the hydraulic parts of DBS are presented in the following sections separately. Almost all important components such as collectors, drainback tanks, heat storages, pumps, piping, and heat carriers are taken into account.

4.1 Collectors

Collectors in drainback systems have the same function as for conventional pressurized system – to convert the solar radiation into useable heat. However, not all “solar radiation converters” are applicable for DBS due to the main requirement of having the ability to empty the collector field when the pump is stopped. Therefore the assortment of collectors suitable for drainback systems is restricted. Absorber shape and connection possibilities are considerable features for their selection. For flat plate, at least one connection must be located at the bottom of the collector. Possible trapping of the heat carrier must also be avoided during the installation for trouble-free and safe operation. The applied collectors of all identified drainback configurations on the market were evaluated. The pre-assembled kits that include just a drainback tank and the companies, which are promoting customer specific configurations (e.g. Orkli, Morley manufacturing, Tecsol SA, Vögelin Energie- und Solartechnik etc.) were not considered. Therefore a total of 43 drainback systems were taken into account. Collector types which are used for drainback systems are shown in picture 2.



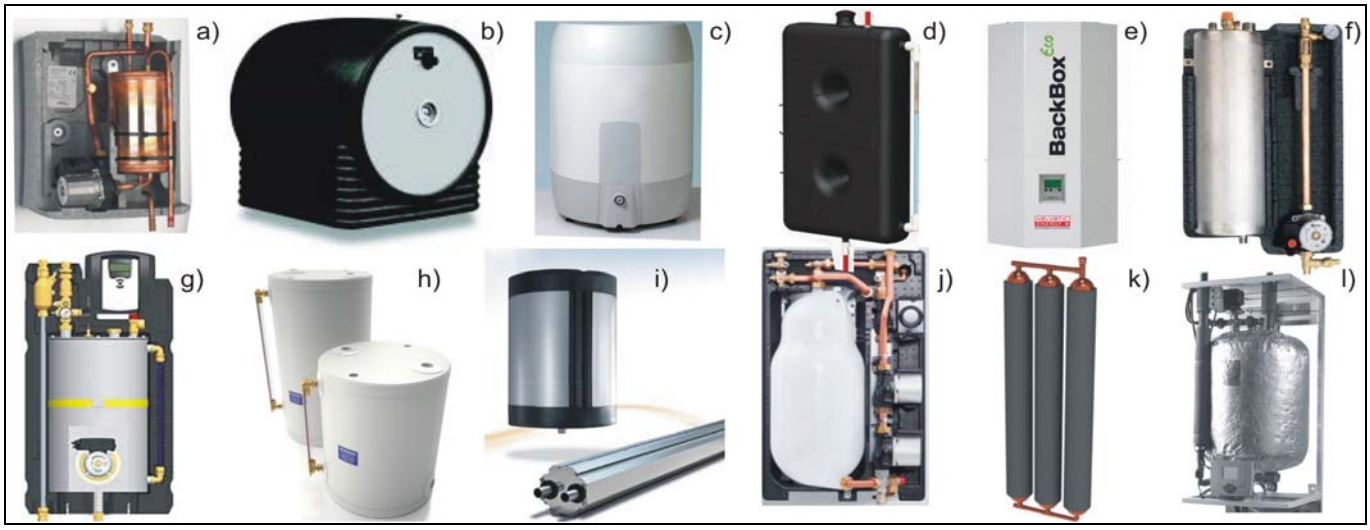
Picture 2 – Applied collectors types for drainback systems from different manufacturers

This pie chart shows that 86% of drainback packages available on the market are assembled with flat plate collectors. It is clearly shown that flat plate collectors with a harp absorber are almost as equally favored as with the meander absorber. Other companies as Agritec (IT),

Atmos (UK), FSAVE (DE), Bosswerk GmbH (DE) promote the drainback systems with heat pipe evacuated tubes. The advantage of using a heat pipe is not to reach higher temperatures, but to benefit from the more simplistic hydraulic shape of the header manifold. Some manifold can be considered as a pipe with distributed connections for evacuated tubes, which has better emptying properties as compared to a flat plate collector. Another drainback configuration on the market includes a plastic collector. At least two companies, Fafco (USA) and Magen Eco-Energy Ltd (IL) are fostering plastic technologies. Contrary to Fafco, which uses an unglazed absorber, Magen Eco-Energy offers a full plastic flat plate absorber. It can be concluded that almost all known collector types are applicable for the DBS. The conventional flat plate collector, however, remains the standard collector for DBS.

4.2 Drainback tanks

Drainback systems with a separate hydraulic component were mentioned in the above classification (Picture 1a). The drainback vessel enables the “drainback features” and is always installed in supply line between collector outlet and heat storage inlet. It is typically constructed of durable stainless steel or polymer materials in cylindrical form. For safe operations, the drainback tank must be large enough to displace the entire volume of air in the collector and upper piping with circulating fluid. The typical volume of the vessels ranges from of couple of liters (STI) to 100 l (Atmos). For instance, three volumes mainly exist in the USA: 37 l, 57 l, 76 l. The availability of variously sized drainback vessels below 37 Liters is widespread within the European market. Some drainback tanks are assembled with a heat exchanger coil inside, and other without. Almost all reservoirs are equiped with a sight glass, because the water level in the tank must be observed and maintain at certain level. Drainback vessels can be mounted separately as a hydraulic component. Other producers integrate it into a pump-station or place them directly under the collector. Completely premounted pump-stations, for example with a drainback tank, fittings and controller, offer a simple installation and maintenance process in comparison with a single drainback vessel. In picture 3, a number of drainback tanks are presented from different companies in alphabetical order.



Picture 3 – Different drainback vessels, available on the market: a) Alpha Inovation (UK), b) Atmos heating system (UK), c) Catch solar energy AS (NO), d) Fafco inc. (US), e) Helvetic Energy GmBH (CH), f) Orkli (SP), g) PAW GmbH (DE), h) Solar Hot (US), i) STI GmbH (DE), j) Vaillant (DE), k) SunEarth (US), l) Walter Meyer (CH).

Some interesting features of the tanks are summerized below:

- a) e) f) g) j) l) Pre-assebled pump station with a hidden drainback tank inside
- b) Plastic drainback tank with a volume of 100 liters weighting approximately 16 kg

- d) Rectangular drainback tank comletely made of plastic
- i) Drainback tank locates directly under the collectors
- k) fabricated from spun-end seamless copper tubing, cheap.

4.3 Heat storages

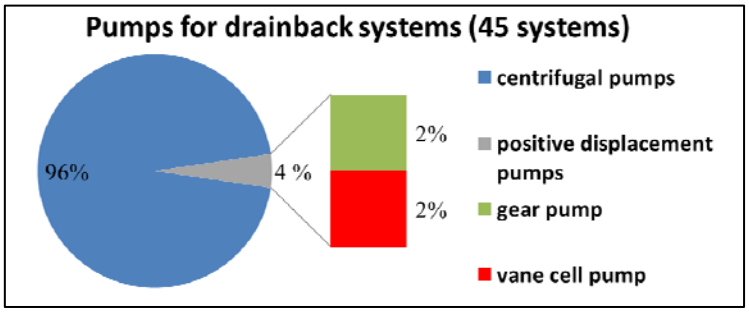
There are almost no restrictions to heat storages for drainback systems, and thus conventional storages (from Stainless Steel, PP-plastic) are used. It is emphasized that PP storages are well suited for open loop DBS, as these systems are operating under non-pressurized conditions.

4.4 Pumps

Pumps enable the filling and ensure circulation in drainback systems. For the DBS which vent to the atmosphere, the pumps should be corrosion resistant. Some systems therefore are equipped with bronze and not cast iron pumps. Other material, for instance, include plastic housed pumps, can be used for drainback systems. Transient operating processes such as filling, operating, and draining create additional requirements to the pumps, which include not only the frictional losses in the pipes and other hydraulic components but also the elevation head. Simultaneously a certain minimal flow rate of the circulating heat carrier fluid should be guaranteed, otherwise it will be not able to completely entrain the air in the downcomer. A gurgling sound in the supply side is often a typical symptom of insufficient speed (flow rate) during operation. For draining, the pumps should allow a backflow, or have a bypass. In order to fulfil these requirements and to reduce electricity consumption, different approaches are applied:

- usage of a single variable speed pump (AET, etc.)
- usage of two pumps connected in series (Rotex, etc.)
- usage of different types of pumps, centrifugal (Bulex, etc.) or positive displacement (ESE, etc.)

A variable speed pump is one of the most efficient ways to adjust pump performance to the desirable operation conditions of the solar thermal system. During the filling regime, the pump operates at the highest speed providing a sufficient fill. In operation the fluctuating solar radiation is also compensated by varying the pump speed, and thus supplying heat at the desired temperature. The usage of two pumps connected in series is another approach towards the reduction of electricity consumption. Both booster and circulating pumps are in operation only during filling. Once the filling process is succesfully completed, the booster pump is shut off. One pump is sufficient for circulation because the elevation head is already negated. Different pump types can be applied for DBS, optimizing their operation conditions. Besides the standard centrifugal pumps (non- self priming), there is a system from Catch Solar Energy with a self-priming pump. This pump uses a water-air mixture to create a low pressure situation, which initiates suction of the circulating fluid. In contrast to normal, non-self priming centrifugal pumps, this pump is installed in supply line. Walter Meyer uses a peripheral pump, which the QH-curve (head flow curve) differs from standard centrifugal pumps. It has a near linear downward slope and in a low flow regime, head is greatly increased. Positive displacement pumps have almost the same characteristics of QH-curve as a peripheral pump. Applications of a positive displacement pump is offered on the market by a few companies, i.e. ESE with gear pump or PAW GmbH with vane cell pump. Positive displacement pumps provide a nearly constant flow rate at fixed speed, regardless of the system pressure or head. There are significant advantages to positive displacement pumps for drainback systems which have a significant lift head and low-flow operation. The major drawback is a necessity to undertake an insulation campaign due to the higher noise level in comparison to cetrifugal pumps. In Picture 4 is shown a graphic illustration of pump application for drainback systems (45 systems were evaluated).



Picture 4 – Pump types used for drainback systems

As expected the centrifugal pumps is the typical standard pump for drainback systems. Wilo, Grundfos and Taco pumps represent the majority of installed pumps for DBS.

4.5 Piping

The collector loop plumbing for drainback systems requires a careful design and installation. Improper mounting of piping threatens a safe operation of the DBS. Fatal damages can occur when water remains in collector or upper piping after the pump has been deactivated. Therefore the most important hydraulics feature concerning piping is a slope towards the drainback tank and heat storage. In Table 2, summarized recommendations are exhibited regarding minimal piping slope and/or tilt angle for all evaluated drainback systems. It is emphasized that all US drainback systems have the same requirements: a piping must be sloped downwards from the collectors to the drainback tank/heat storage with at least 21 mm/m of length. Other sources have revealed the minimal suggested slope to be up to 5°. All vertical and horizontal piping must be accurately supported at certain intervals depending on piping materials, preventing the sagging of the tubes. Water pockets are not desirable for drainback systems and must be avoided. A sufficient insulation of the piping is also mandatory.

Table 2: Recommendations towards minimal required piping slope

Reference	recommended/minimal slope	tilt angle
Bokhoven T. 2000	1 cm per 1 m	0°34´
ASHRAE, all drainback systems in USA	1/4” inch per foot (21 mm/m)	1°11´
Hausner etc. 2000	1.5 to 3 cm/m	0°52´ to 1°43´
Rotex Heating Systems GmbH	2%	1°48´
Alpha Therm Ltd.	4 cm/m	2°17´
Orkli, S. coop	5 cm/m	3°
Rheem	9 cm/m	5°

Concerning material of the pipe, a copper tube is acceptable everywhere for DBS. This type of pipe is extremely durable, corrosion–resistant, and easy to install. The companies in Australia for instance limit comsumers to exclusively use copper pipes for drainback systems. Another configuration possibility is to connect hydraulic components of the DBS with stainless steel corrugated pipes. Transportable, flexible and relative light-weight piping can simplify the installation process and reduce the working time for a complex hydraulic configuration. However, corrugated shapes cause higher pressure losses than standart copper pipes. Application of plastic tubes is rare on the market. For instance ESE uses a special polyamide piping and FAFCO a conventional PEX tubes. SRCC (Solar Rating and Certification Corporation) has approved the use of PEX piping in non-pressurized drainback systems, under specific circumstances. One of the conditions is the requirement for the inlet and outlet of the collector to have uninsulated copper pipe with minimal length of 0.9 m. Other materials such as CPVC,PVC (polyvinyl chloride), galvanized steel are prohibited for drainback systems.

4.6 Heat carriers

The heat carrier is a fluid which transports the heat from the solar collector to the heat storage. The desirable properties of the heat carrier are the same as for pressurized solar thermal systems. Either water or antifreeze mixtures (propylene glycol-water) can be used in collector loops for the DBS, similar to pressurized systems. Evaluation of the existing drainback products show that about 50% of the systems are recommended to be filled with antifreeze. Specifically, all drainback systems with oversized heat exchanger for draining purposes use antifreeze as heat carrier. The other half operate with water as the circulating fluid within the collector loop. It is emphasized that some companies suggest filling their drainback systems with distilled water (Energy Lab, etc.), while others recommend normal tap water (Itho Daalderop BV, etc.). Generally, the “drainback” feature allows the usage of water for all drainback hydraulics, however some companies use antifreeze in order to eliminate the freezing risk completely.

5 Summary

Drainback systems currently offered on the market were presented in this paper. The aim was to showcase a variety of different concepts, operation principles, and applied components unique to this technology. Approximately 50 drainback systems, offered by 44 companies, were identified and evaluated. An estimation of the market share for DBS within selected countries was summarized. Drainback systems in the Netherlands, Belgium, and Norway represent the majority of installations there. The market share in the USA is about twenty percent, whereas in Portugal, Spain, and France, is around fifteen percent, and in Italy and Switzerland, up to ten percent. The penetration of DBS in other countries, in particular in Germany, is not significant yet. All drainback technologies were classified into three categories, depending on the location of the volume for draining, which could be a drainback tank, heat storage or an oversized heat exchanger. Hydraulic components such as collectors, heat storages, drainback tanks, pumps, piping, and heat carriers were taken into consideration separately. Eighty six percent of all evaluated DBS are assembled with flat plate collectors, whereas almost half of them are with meander and another half with harp absorber. The rest of DBS are offered with heat pipe evacuated tubes and plastic collectors. Various drainback tanks were illustrated and briefly described regarding their attributes. Cylindrical and rectangular, with heat exchanger and without, polymer, stainless steel and copper drainback tanks were presented. Several operation ways of the pumps for ensuring sufficient filling and efficient operation of DBS were summarized. Application of variable speed pumps, usage of different types of the pumps and their connection in series are typical approaches for DBS. It was discovered that different minimal slope recommendations for the piping ranged up to 5 degrees. Copper tubes are always applicable for all configurations of drainback technology, corrugated stainless steel pipes are not recommended by some producers and the plastic tubes are allowed by few manufactures. While water can safely be used as the heat carrier in DBS, only half of the available systems are encouraged to be filled with it. The remainders prefer antifreeze, to ensure against potential inaccuracies during system installation. It can be concluded that flat plate collectors, centrifugal pumps, and copper pipes are standard for DBS, but other types are also applicable. A number of new companies and new product concepts reflect a positive trend towards the development of DBS. This technology has already been approved in some countries and is currently penetrating and slowly extending into others.

Acknowledgments

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Attachment 1. List of companies, which are offering drainback systems on the market

№	Company	Country		№	Company	Country
1	Agritec s.R.L.	IT		23	Morley Manufacturing	US
2	Alpha Therm Ltd	UK		24	Orkli, S. Coop.	ES
3	Alternate Energy Technologie	US		25	PAW GmbH & Co. KG	DE
4	Astersa SA,	SP		26	Protherm s.r.o.	SK
5	Atmos Heating Systems	UK		27	Rheem	AU
6	Baymak A.S.	TR		28	Rotex Heating Systems GmbH	DE
7	Boilernova	IT		29	Saunier Duval	FR
8	Bosswerk GmbH& Co KG	DE		30	Solahart Industries Pty Ltd	AU
9	Bulex	BE		31	Solar Hot	US
10	Catch Solar Energy AS	NO		32	Solarskies	US
11	Eklor	FR		33	Soltop Schuppisser AG	CH
12	Energy Lab	US		34	STI GmbH	DE
13	European Solar Engineering SA	BE		35	SunEarth	US
14	Ezinç Metal San. Tic. A.S.	TR		36	Tecsol SA	FR
15	Fafco, Inc.	US		37	Teknoenergy	IT
16	Free Hot Water	US		38	Termicol Energía Solar S.L.	ES
17	FSAVE	DE		39	Vaillant GmbH	DE
18	Helvetic Energy GmbH	CH		40	Viridian Solar Ltd	GB
19	Hermann Saunier Duval	IT		41	Vögelin Energie- und Solartechnik	CH
20	Integrated Solar LLC	US		42	Wagner & Co Solartechnik GmbH	DE
21	Itho Daalderop BV	NL		43	Walter Meier (Klima Schweiz) AG	CH
22	Magen eco-Energy Ltd	IL		44	ZEN International	NL

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