Chapter 2. Providing water

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2.1. Introduction on providing water

2.1.1. These techniques concern the issue
Preparation of irrigation water.

2.1.2. Regions
All EU regions.

2.1.3. Crops in which the issue is relevant
This is not crop specific since it considers overall irrigation water storage.

2.1.4. Cropping type
All cropping types.

2.1.5. General description of the issue
In horticultural production, considerable volumes of water are commonly required for irrigation to ensure optimal growing conditions for the crops. The very large amounts of water required and the high price of tap water force growers to use other sources of water. Where the climatic conditions are suitable, a good option is to use rainwater. In more humid regions, sufficient rainwater can be collected to meet the entire irrigation requirement of crops. In drier regions, rainwater collection can partially meet irrigation requirements, thereby reducing the demand on other water sources (e.g. groundwater). To enable the use of rainwater, there are practical issues that must be considered such as the collection of water, storage systems and the variability of rainwater in terms of quantity, timing and quality. Additionally, current legislation must be considered.

2.1.5.1. Sub-issue A: Tools for dimensioning water storages have to be expanded to new crops and regions
Some tools for dimensioning water storages for rainwater already exist. However, they are generally based on fixed tables, referring to a specific crop in a specific region (e.g. tomato crop with recirculation in the North-West region of Europe). Therefore, the existing models should be improved with data to adapt these models to other crops and regions (Central East, North of Spain, France, etc.). However, the availability of relevant data is an issue here.

2.1.5.2. Sub-issue B: Financial evaluation of water storage
Rainwater is seen as “free” or “very cheap water” of very good quality. However, rainwater storage is expensive when considering the installation costs of specially lined water storage facilities and the associated loss of production area. Therefore, a combined model that calculates the required dimensions of the storage area and simultaneously conducts a financial analysis is required to guide growers in designing a water storage facility.

To meet the last percentages of the water requirements with rainwater, a very large water storage volume is required. Therefore, dimensioning the water storage should be linked to a
Transfer of INNOvative techniques for sustainable WAter use in FERtigated crops

financial model that considers strategies such as meeting specified percentages of total crop water requirements and expected rainfall.

For any calculation of water storage, the collection area for rainwater (e.g. greenhouse roofs) must be considered first to calculate the water collection potential. So, this technique is used specifically for covered cropping systems. Dimensioning tools provide information on the relationship between the storages water volume and the % of the crops freshwater demand that can be fulfilled by the water stored in this volume. The tools are mainly based on long-term precipitation data and the weekly or daily freshwater demand of the crop. In for example the WADITO model, the additional water for rinsing filters and facilities or moistening the substrate is not included in the model. But this could quite easily be done by changing the programming.

2.1.5.3. Sub-issue C: Risk assessment of large-scale lined reservoirs

Recently, the size of greenhouses in North-West Europe has increased significantly. The construction of large greenhouses requires storage of very large volumes of rainwater and buffering at times of intensive rainfall, in order to prevent flooding of the surrounding area or creeks. Specific mathematical models are required for these calculations.

2.1.5.4. Sub-issue D: Clarification of national and regional legislation regarding new water storage approaches

Innovative practices for storing water include underground storage, which is being developed in the SubSol project. It is not clear if new innovative ways of storing water, like SubSol, are meeting the regional/national legislation of the European Member States.

2.1.5.5. Sub-issue E: Poor water quality of the first rainwater flush

The first flush of rainwater from a roof can contain pollutants (plant protection products (PPP) that have drifted, chalk, sediments from the roofs, chemicals used for cleaning the roofs, etc.) that can harm both the crop and the irrigation systems. In addition, nutrient-rich water enhances algal growth. An important issue is to prevent these pollutants from entering the storage system.

2.1.6. Brief description of the socio-economic impact of the issue

2.1.6.1. Financial evaluation of water storages

It is a misconception to consider rainwater as “free” or “very cheap” water. In many regions, the use of rainwater requires large-scale water storages, for example, a net volume of 5000 m³/ha of soilless greenhouse tomato crops is required in North-West Europe to fulfil the yearly freshwater demand of the crop. The construction of this storage capacity is costly (4-45 €/m³ storage capacity, land costs excluded) depending on the type of water storage considered. If you want to cover the crops freshwater demand throughout very wet and very dry years, a large volume of water has to be buffered. In the wet years or months, extra water can then be stored for use in the dry years or months. So to fulfil the last percentages of the crops water demand by use of rainwater, a serious enlargement of the water storage, leading to higher installation costs, is required.

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2.1.6.2. Risk assessment of large-scale lined reservoirs
In densely populated regions, growers experience resistance from local residents who are afraid of potential flooding due to the loss of infiltration capacity caused by the construction of large-scale greenhouses and water storage.

2.1.7. Brief description of the regulations concerning the problem
In France, growers are forced by local laws to manage the rainwater diverted from infiltration into the soil because of the construction of greenhouses. In the UK, water that is captured on roofs and stored legally belongs to the grower who owns the structure. In case the water touches the ground before being stored, the laws that apply are different.

It is unclear if new ways of storing water, meet the legislation of the EU Member States.

2.1.8. Existing technologies to solve the issue/sub-issues
2.1.8.1. Sub-issue A (see 2.1.5): Expansion of tools for dimensioning water storages to new crops and regions
- WADITO
- Waterstromen (Wageningen University)

2.1.8.2. Sub-issue D (see 2.1.5): Clarification of national and regional legislation regarding new water storage principles like SubSol
Under groundwater storage is permitted in most Member States as this concerns water storage at a smaller scale (3000 m³). It is not clear if principles like SubSol (10000 m³) water storage are permitted in all Member States. Current legislation mentions the small scale, lined, underground reservoirs. SubSol inflicts possible risks since huge amounts of water are stored in underground water layers, which are unlined and in contact with the deeper groundwater. Legislation applying to this type of storage should be clarified.

2.1.8.3. Sub-issue E (see 2.1.5): Poor water quality of the first rainwater flush
Filters might remove sediments and chalk from the first flush, while residues of PPP that adhere to the roof after being transported there by drift, might be reduced by treating the greenhouse roof with a coating of titanium oxide (photocatalytic oxidation occurs). It is unclear if the coatings on greenhouse windows are allowed in food production areas. In addition, if this technique is somewhat expensive, growers will refuse to use it.

2.1.9. Issues that cannot be solved currently
Sub-issue B (see 2.1.5): Financial evaluation of water storage: It is not known if these evaluations are available for the moment; surveys are required.

Sub-issue C (see 2.1.5): Risk assessment of large-scale lined reservoirs: In France, this is conducted by engineering consultants, but every study is site-specific. In Flanders as well, site-specific studies are carried out. For other countries and regions, surveys are needed.

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2.1.10. References for more information


## 2.2. Summary of technologies subsequently presented in this chapter in individual technology descriptions (TDs)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Water storage type</th>
<th>Type A: &lt; 750 m³ or &lt; 100 m²</th>
<th>Type B: 750 – 5000 m³ or 100 – 250 m²</th>
<th>Type C: &gt; 5000 m³ or &gt; 250 m²</th>
<th>*excluding parcel costs</th>
<th><strong>Required</strong></th>
<th><strong>Weaknesses</strong></th>
<th><strong>Strengths</strong></th>
<th><strong>Limitations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lined water basin</td>
<td>aboveground basin</td>
<td>Type A: too small Type B: 5-9 €/m³ capacity* Type C: 4 €/m³ capacity*</td>
<td>Annually: algae control + 5% of the installation cost</td>
<td>Algae and evaporation (in warmer climates) prevention</td>
<td>Commercial space loss due to storage Algae issues and evapotranspiration</td>
<td>Long lifespan</td>
<td>-</td>
<td>-</td>
<td>For water storages &gt; 1000 m³ Depth depends on underground Top 0,5 m buffer area Lower 0,5 m unavailable: sediments and too hot (low water levels)</td>
</tr>
<tr>
<td>Lined water silo</td>
<td>aboveground silo</td>
<td>Type A: ‘23 €/m³ capacity* Type B: ‘26 €/m³ capacity* Type C: too big</td>
<td>Annually: algae control + 5% of the installation cost</td>
<td>Algae prevention</td>
<td>Limited loss of commercial space Max. lifespan: 15 years Algae issues and evapotranspiration</td>
<td>Not avail.</td>
<td>-</td>
<td>-</td>
<td>&gt; 500 m³ is not common in practice Depth is limited Top 0,5 m buffer area Lower 0,5 m unavailable: sediments and too hot (low water levels)</td>
</tr>
<tr>
<td>Ferro concrete reservoir</td>
<td>underground</td>
<td>1,5 - 2 m³: 500 €/pc.: incl. delivery, digging and installation Pipes: 5 €/m²</td>
<td>Not avail.</td>
<td>None</td>
<td>Not avail.</td>
<td>Nearly constant water temperature Long lifespan Prevents algae and evaporation</td>
<td>Available for water storages smaller than 20 m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferro concrete reservoir</td>
<td>underground</td>
<td>No data</td>
<td>Not avail.</td>
<td>None</td>
<td>Not avail.</td>
<td>Not avail.</td>
<td>Size limit not defined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Klimrek buffer</td>
<td>underground</td>
<td>30-45 €/m³ storage capacity (excl. installation cost)</td>
<td>Not avail.</td>
<td>None</td>
<td>Not avail.</td>
<td>Not avail.</td>
<td>Must fit between the support poles of the greenhouse Depth limit not defined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infiltration crates</td>
<td>underground</td>
<td>45 €/m³ storage capacity (excl. installation cost)</td>
<td>Not avail.</td>
<td>None</td>
<td>Not avail.</td>
<td>Not avail.</td>
<td>Must fit between the support poles of the greenhouse Depth limit not defined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SubSol water storage</td>
<td>underground</td>
<td>Type A and B: N.A. Type C: 25000 - 50000 € per installation</td>
<td>Not avail.</td>
<td>None</td>
<td>Not avail.</td>
<td>Not avail.</td>
<td>Water availability depending on water layers in the underground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td>Water storage type</td>
<td>Cost</td>
<td>Installation</td>
<td>Maintenance</td>
<td>Required</td>
<td>Weaknesses</td>
<td>Strengths</td>
<td>Limitations</td>
<td></td>
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<td>----------</td>
<td>------------</td>
<td>-----------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Standard tables for dimensioning water storage</td>
<td>aboveground: basin or silo</td>
<td>Published in books and articles</td>
<td>None</td>
<td>None</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>For water storage of 500-6000 m³ Only for recirculated soilless tomato crops in NW Europe Depth is not defined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WADITO</td>
<td>aboveground: basin</td>
<td>Commercial advice depends on the requested calculations</td>
<td>None</td>
<td>Computer skills</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Combination of max. 5 storages The weekly freshwater demand should be covered Long-term climate data set (at least 10 years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waterstromen</td>
<td>aboveground: basin or silo</td>
<td>Freely available on the web</td>
<td>None</td>
<td>Computer skills</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>1 water storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foil</td>
<td>aboveground: basin or silo</td>
<td>Type A: 20 €/m² Type B and C: 9 €/m²</td>
<td>Not avail.</td>
<td>None</td>
<td>Not avail.</td>
<td>- Prevents algae and evaporation - Prevents sediment suction</td>
<td>Not avail.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel cover</td>
<td>aboveground: basin or silo</td>
<td>Type A: 100 €/m² Type B and C: N.A.</td>
<td>Not avail.</td>
<td>None</td>
<td>Not avail.</td>
<td>Not avail.</td>
<td>Maximum size 100 m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balls</td>
<td>aboveground: basin or silo</td>
<td>Type A: 14 €/m² Type B and C: 13,75 €/m²</td>
<td>Not avail.</td>
<td>None</td>
<td>Not avail.</td>
<td>Not avail.</td>
<td>Not avail.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collecting condensed water</td>
<td>aboveground</td>
<td>Costs of the land 6000 €/ha: accessories and installation of gutters in multi-span arched-roof greenhouses</td>
<td>Not avail.</td>
<td>None</td>
<td>Parral greenhouse: contact with steel network forms drops Multispan: low slope near ridges makes drop sliding difficult</td>
<td>Avoids dripping of condensed water on the crop Reduces the crop disease risk Good quality and sustainable water source</td>
<td>Low quantities of water captured: theoretically 750 L/m² year (tomato &amp; eggplant in Almería, Spain) Availability of adequate plastic cladding materials Required angle 14-40° High T, condensations rate: max. 2 months anti-drip effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td>Floating pumps</td>
<td>aboveground: basin or silo</td>
<td>Company-specific</td>
<td>Not avail.</td>
<td>None</td>
<td>Clogging by algae Development of biofilm on surface</td>
<td>Prevents sediment suction</td>
<td>Not avail.</td>
<td></td>
</tr>
</tbody>
</table>
2.3. Lined (rain) water storage

(Authors: Els Berckmoes⁴, Esther Lechevallier⁴)

2.3.1. Used for
Preparation of irrigation water.

2.3.2. Region
All EU regions.

2.3.3. Crops in which it is used
All crops. Rainwater is a preferred water source in case of crops that are sensitive to sodium like strawberries, sweet peppers, lettuce, dandelion lettuce, leek, endive and roses.

2.3.4. Cropping type
All cropping types.

2.3.5. Description of the technology

2.3.5.1. Purpose/aim of the technology
In many European regions with intensive horticultural activity, rainwater quality is perfect for irrigation purposes. In most regions, the water contains no or very low concentrations of sodium and other elements. The aim of rainwater harvesting and storage is to assure:

- Rainwater availability during the cropping season. In many cases the precipitation pattern differs from the crop water demand, requiring water storage to cover the crop water demand. Figure 2-1 gives an example of the monthly water requirement of a specific eggplant crop with recirculation and the average monthly rainfall in Flanders
- Availability of water with very low sodium content in order to prevent sodium accumulation. This is essential in order to maintain recirculation of the nutrient solution of soilless grown crops

Figure 2-1. Evolution of the water demand in soilless eggplants undercover and the annual average precipitation (L/m²) in Flanders
2.3.5.2. Working Principle of operation

Lined water storage systems

“Lined” refers to the presence of a boundary between the underground and the stored water. In case of unlined water storage, there is no artificial boundary between the stored rainwater and the shallow groundwater that is present.

In order to construct a water storage, several steps have to be carried out.

A soil survey is required before dimensioning and drawing the rainwater storage. Knowledge of, for example, deeper ground layers, the groundwater table and groundwater table fluctuations are essential in order to choose the water storage depth.

Correct dimensioning of the water storage: water needs depend on several parameters like the annual precipitation pattern, the crop specific water demand pattern, parameters related to the constructions (greenhouses, tunnels, container fields, etc.). More details can be found in 2.6 Tools for dimensioning water storages.

Excavation work: Large water reservoirs mainly consist of soil walls or dikes. In general, these dikes are partially embedded to withstand the water pressure of the stored water. The quality and strength of the dikes must be looked at before and during construction.

Construction of the dikes: The excavated soil is useful for the dike construction. However, humus-rich soils should be avoided since decomposing humus influences the strength of the dikes. Loamy soil is preferred. Although the dimension of water storages varies significantly, the dimensions of the dikes are more fixed. Dikes are constructed at an angle of 45° and the upper width ranges between 0.8 and 1.2 m. In case of bigger water basins, thicker dikes are provided at the opposite side of the main wind direction to deal with waves.

Drainage system: in case the bottom of the water storage lies beneath or close to the groundwater table, a drainage system is required (Figure 2-2). This system will keep the groundwater level underneath the water storage level. In addition, the drainage system will discharge a possible excess of air (due to decomposition of organic matter). Both groundwater and air accumulation underneath the foil (Figure 2-3) can cause serious damage to the dikes and the foil itself.
Installation of the foil: Putting the foil in place requires much manpower (Figure 2-5). The foil is placed in the middle of the reservoir and then unfolded. At the upper part of the dikes, small ditches are provided (Figure 2-4). The foil is then placed in these ditches. Finally, these ditches are filled again and the foil is fixed. In case (small) rocks are present in the soil, it is desirable to install a protective cloth at first.

Finishing the dikes: In case foils with higher UV-sensitivity are applied, the dikes should be covered to protect the foils. This can be done by installing protection sheets. The opposite part of the dike can be covered with foil or grass can be sown.

Installing the supply and drain pipes: The installation of both the supply and drain pipes can occur in 2 ways: waterproof pipelines through (Figure 2-6) or over the dikes.

Installation of safety ropes is essential to climb the dikes in case someone is drowning.
Water silos

Water silos are made of a steel wall with a plastic foil in it (Figure 2-7).

In case the silo is installed at ground level, the subsurface should be levelled. In a later phase, the water silo will be anchored in the soil.

In case the silo is placed in an excavation, the soil is removed until 80 cm underneath the ground level. Again the subsurface should be levelled. The bottom level of the silo should be at least 20 cm above the highest groundwater level. In case of higher groundwater levels, a drainage system should be installed. A sand layer of 10 cm is applied in order to prevent sharp rocks and roots to penetrate the silo. Concrete tiles are placed in a circle at the base of the walls. In case the water silo is placed in an excavation pit, the lower row of silo plates should be covered with a special coating until 30 cm above ground level.

During the installation of the silo plates, it is important that:

- Thicker plates are positioned in the lower circles, thinner plates in the upper circles
- Plates should move up half a plate compared to the lower circle of plates
- Plates should be installed roof-like, preventing rainwater to seep between the plates and the foil

Finally, a protection cloth is installed, after which the foil is installed. In case of water silos, PolyVinyl Chloride (PVC) or Astryn foils are used. The higher elasticity of EPDM-foils makes this type of foils less suited for silos.
2.3.5.3. Operational conditions

Lined reservoirs

The dimension of the dikes: In most cases, lined reservoirs are partially built above the ground level. This implies that certain guidelines have to be maintained when constructing the rainwater basin. The dikes have to be designed in relation to the water pressure of the stored water.

In case of large water reservoirs, it may be appropriate to split the water storage (Figure 2-8) into several basins in order to avoid billow.

![Figure 2-8. Intermediate dike separating 2 water reservoirs to avoid billow](image)

Water silos

- Dimension: Water silos are made of iron panes that are nailed together. This limits the storage capacity as higher volumes of stored water lead to increased water pressure which may cause ruptures. The maximum content of a water silo is around 2000 m³, although volumes of 500 m³ are more common
- Lifetime: Corrosion of the plates causes weaker spots, which can cause cracking of the silo (Figure 2-9). Therefore, silos have to be checked frequently

![Figure 2-9. A silo has cracked due to corrosion of the lower plates](image)

Percentage of available water

At the top of the water storage a “maximum storage level” should be respected. This means that you cannot use the water storage for 100% (Figure 2-10). Generally, the upper 50-75 cm of water storage is not exploited. This area is a buffer for rainwater when excessive precipitation occurs and/or to prevent waves to run over the dikes. In case the water runs over the dikes, this can cause serious damage to the strength of the dike and even cause...
breaching of the dikes. The lower 50 cm of the water storage is also unused as this water may contain higher concentrations of sediments and the water temperature is too high.

![Schematic overview of the different zones in the water storage. Only the middle water volume, referred to as “useful water” is available to fulfil the crop water demand](image)

**Climate**

Precipitation amounts may limit the possibilities to construct a cost-effective water storage. In areas with small amounts of rainfall (Southern part of Europe) or very high precipitation amounts spread over very few precipitation days, it may not be cost-effective to construct big rainwater storages.

![Annual average precipitation in Europe](image)

**2.3.5.4. Cost data**

**Installation cost**

The costs for the water storages depend on several factors:

- Construction costs (excavation works, installation of drainage pipes, etc.)
- Material (PVC, Astryn, EPDM) and thickness of the foil (generally 0.5 or 1 mm)
- Protective covers (obliged for water silos, recommended for lined water basins in case roots or small rocks are present in the underground)

• Metal plates in case of a water silo

The cost of a water storage is highly related to the company-specific circumstances. In Table 2-1 some examples are given for lined water reservoirs and in Table 2-2 for water silos.

Table 2-1. Some examples of investment costs for lined water reservoirs/water basins

<table>
<thead>
<tr>
<th>Investments</th>
<th>1000 m³</th>
<th>2000 m³</th>
<th>3000 m³</th>
<th>50000 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation, Foil*, Pipes</td>
<td>7941 €</td>
<td>Not avail.</td>
<td>13613 €</td>
<td>Not avail.</td>
</tr>
<tr>
<td>Diverse (installation, etc.)</td>
<td>1134 €</td>
<td>Not avail.</td>
<td>2269 €</td>
<td>Not avail.</td>
</tr>
<tr>
<td>Total cost (without parcel costs)</td>
<td>9075 €</td>
<td>16650 €</td>
<td>15882 €</td>
<td>200000 €</td>
</tr>
<tr>
<td>Costs for parcel of water basin (18,15 €/m²)</td>
<td>15428 €</td>
<td>24502 €</td>
<td>36300 €</td>
<td>Not avail.</td>
</tr>
<tr>
<td>Total cost (parcel costs included)</td>
<td>24503 €</td>
<td>41152 €</td>
<td>52182 €</td>
<td>Not avail.</td>
</tr>
</tbody>
</table>

*foil types are not specified.

Table 2-2. Some examples of investment costs for water silos

<table>
<thead>
<tr>
<th>Investments</th>
<th>250 m³ - 1190 cm x 231 cm</th>
<th>1000 m³ - 1830 cm x 385 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Astryn</td>
<td>EPDM</td>
</tr>
<tr>
<td>Water silo</td>
<td>2106 €</td>
<td>2106 €</td>
</tr>
<tr>
<td>Water silo foil Astryn 0,5 mm</td>
<td>2567 €</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Water silo foil EPDM 1,0 mm</td>
<td>Not applicable</td>
<td>4715 €</td>
</tr>
<tr>
<td>Water silo cover (floating)</td>
<td>1138 €</td>
<td>1138 €</td>
</tr>
<tr>
<td>Total cost (without parcel costs, installation by grower)</td>
<td>5811 €</td>
<td>7959 €</td>
</tr>
<tr>
<td>Costs for parcel of water basin (18,15 €/m²)</td>
<td>2178 €</td>
<td>2178 €</td>
</tr>
<tr>
<td>Total cost (incl. parcel costs)</td>
<td>7989 €</td>
<td>10137 €</td>
</tr>
</tbody>
</table>

Maintenance

The costs for maintenance of the lined water storages (Table 2-3) include reparations for the foil, maintenance of pumps etc.

Table 2-3. Estimation of the maintenance costs for water silos and water reservoirs

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>1000 m³</th>
<th>3000 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lined reservoirs (5% of investment cost, cost for parcel excluded)</td>
<td>454 €</td>
<td>794 €</td>
</tr>
<tr>
<td>Water silos (1,5% of investment cost, cost for parcel excluded)</td>
<td>431 €</td>
<td>794 €</td>
</tr>
</tbody>
</table>

Remark: Water silos should be checked by professional companies. A check costs around 200-300 € and should be carried out every 2 years once the silo has reached the age of 7 years.

2.3.5.5. Technological bottlenecks

The first flush of harvested rainwater can contain pollutants like residues of plant protection products (drift on greenhouse roofs), chalk, sediments, etc.

Zinc (Zn) recovering can be a bottleneck in old greenhouses. A sealant can be required to protect the gutter of the greenhouses to prevent Zn leaching in the rainwater storage.

Varying precipitation patterns or insufficient rainfall in some regions (South-Europe).

Algae development (see Chapter 5. Optimising water quality – control of algae) and sedimentation problems (see 2.9 Floating pumps) can occur.

Evapotranspiration can lead to serious water losses in for example Southern-Europe.

Rainwater is not buffered and can be acidic. Therefore, the pH should be controlled and countered if necessary (see Chapter 3. Optimising water quality – Chemical composition).

2.3.5.6. Benefit for the grower

**Advantages**

- Good quality water
- Allows recirculation for most of the crops (even some for which it is indispensable)
- Independence to regulations related to groundwater

**Disadvantages**

- Use of “commercial space”
- Low buffering capacity of the rainwater
- Risk of contamination of the water storage with pesticides/Zn/chalk

2.3.5.7. Supporting systems needed

- Drainage system
- Foils: different types of foils are possible (Astryn, PVC, EPDM)
- Geotextile, placed underneath the foil when small rocks, roots, etc. are present
- A (floating) pumping system (see 2.9 Floating pumps)
- Water level sensors to alert the grower in case a maximum/minimum level is reached
- Treatment for pH adjustment if needed (see Chapter 3. Optimising water quality – Chemical composition)
- (Emergency) valves to prevent flooding of the water reservoir during excessive rainfall or to deviate the rainwater in case of a problem with the rooftop (cleaning the rooftop, bleaching)
- Equipment to prevent algae (see Chapter 5. Optimising water quality – Control of algae)
- Emergency ropes
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2.3.5.8. Development phase
This technology is commercialised.

2.3.5.9. Who provides the technology
- Several types of water storages are built by engineering consultancy companies
- Foils: Albers Alligator, etc.
- Silos: Benfried, Brinkman, etc.

2.3.5.10. Patented or not
This technology is not patented.

2.3.6. Which technologies are in competition with this one
- SubSol water storage: Systems to store water in the deeper groundwater layers and to retrieve it again afterwards (The Netherlands, Portugal, etc.) (see 2.5)
- Under groundwater storage systems like infiltrations crates, concrete cisterns, etc. (see 2.4)

2.3.7. Is the technology transferable to other crops/climates/cropping systems?
The availability of rainwater in some regions (e.g. Mediterranean region) is a bottleneck to use rainwater.

2.3.8. Description of the regulatory bottlenecks
If a grower wants to build a big rainwater storage, a study of impact is required by the national/regional authorities in order to evaluate the risk for flooding, contribution to drought stress, etc. (Flanders, France).

In some countries/regions, growers have to complete long procedures before finally receiving the building permit for a water reservoir (Slovenia, Flanders, the UK, etc.).

2.3.9. Brief description of the socio-economic bottlenecks
Fulfilling the last percentages of a crop’s water demand requires very big water storages. To make it possible to increase the percentage of water demand fulfilled by rainwater from 86-95% you should increase the water storage capacity from 3000-4000 m³, which is an increase of 33% in water storage dimension in order to fulfil an extra 9% of the crops water demand by rainwater. The installation of a water storage for rainwater is space consuming. In case this area could have been used to build a greenhouse or to grow a crop, this cost should be implemented in the calculations to determine the cost of a cubic meter of rainwater.

On the other hand, water and nutrient savings due to efficient recirculation should also be taken into account. Currently, financial models are not linked to dimensioning models.
2.3.10. Techniques resulting from this technology

There are no techniques that result from this technology.

2.3.11. References for more information


2.4. Underground water storage  
(Authors: Ronald Hand24, Els Berckmoes21, Georgina Key1)

2.4.1. Used for
- Preparation of irrigation water
- More efficient use of water

2.4.2. Region
All EU regions.

2.4.3. Crop(s) in which it is used
All crops.

2.4.4. Cropping type
- Protected
- Soil-bound
- Soilless

2.4.5. Description of the technology

2.4.5.1. Purpose/aim of the technology
Store bigger volumes of water in an outlined reservoir without the loss of productive area, which occurs when water is stored in water silos or water basins.

2.4.5.2. Working Principle of operation
Different methods are applied for outlined underground water storage.

**Concrete water reservoirs**
For the outlined underground water storage, mainly ferro concrete cisterns are used. These cisterns are installed at the time of the construction of new greenhouses or the nearby buildings. Plastic cisterns can be used when smaller water volumes have to be stored.

**Dynamic water buffers: Klimrek Water Buffer**
The irrigation water reservoir features a double liner that creates two compartments (Figure 2-12). Rainwater is stored in the upper compartment, referred to as the “floating compartment”. Other water, for example, from a nearby creek, is stored in the lower compartment. The design implements that the reservoir is 100% full at all times, which is necessary since the greenhouse floor is floating on this water storage. When rainwater is excessively available, the system is able to store 100% rainwater. In periods of rainwater scarcity, the lower compartment is filled from other sources to maintain the water level.
At the front of the reservoir, there is an overflow ridge where the side is slightly lower so that any excess water can drain from the lower compartment. When rainwater flows into the upper compartment, the excessive water in the lower part drains automatically.

If water is taken out of the rainwater compartment, the floor will lower slightly. A simple switch will be triggered and activates the pumps that fill the lower compartment with water.

![Figure 2-12. Schematic view of the Klimrek Water Buffer. The scheme at the left shows the situation when both the upper and lower compartments are filled with water. The right picture shows the increased volume of the upper water layer when rainfall occurs](http://www.klimrek.com/klimrek-reservoir-irrigation-water)

**Infiltration crates**

![Figure 2-13. Example of an infiltration crate](http://www.bpo.nl/en/portfolio/infiltration-crates/)

### 2.4.5.3. Operational conditions

Only for greenhouses under construction because the inner grounds of the building are dug up and replaced by the water storage. Other operational conditions are shown in Table 2-4.

**Table 2-4. Overview of operational conditions of the different systems**

<table>
<thead>
<tr>
<th>System</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic tanks</td>
<td>Limited scale to 5 m³</td>
</tr>
<tr>
<td>Ferro concrete tank:</td>
<td>Limited scale: 1,5-20 m³</td>
</tr>
<tr>
<td>- Preformed</td>
<td>Starting from 20 m³</td>
</tr>
<tr>
<td>- Constructed on site</td>
<td></td>
</tr>
<tr>
<td>Klimrek Water Buffer</td>
<td>Limited to each greenhouse compartment*</td>
</tr>
<tr>
<td>Infiltration crates</td>
<td>Limited to each greenhouse compartment*</td>
</tr>
<tr>
<td></td>
<td>Groundwater levels may be an issue</td>
</tr>
</tbody>
</table>

* No storage under a load-bearing pole (placed at regular intervals in the greenhouse).

2.4.5.4. Cost data

Only for greenhouses under construction because the inner grounds of the building are dug up and replaced by the water storage. Table 2-5 gives an overview of the related costs.

Table 2-5. Overview of the costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic tanks</td>
<td>0.33-1.56 €/m³ storage capacity*</td>
</tr>
<tr>
<td>Ferro concrete tank:</td>
<td>200-350 €/m³ storage capacity**</td>
</tr>
<tr>
<td>- Preformed</td>
<td>200-240 €/m³ storage capacity*</td>
</tr>
<tr>
<td>- Constructed on site</td>
<td></td>
</tr>
<tr>
<td>Klimrek Water Buffer</td>
<td>30-45 €/m³ storage capacity*</td>
</tr>
<tr>
<td>Infiltration crates</td>
<td>45 €/m³ storage capacity *</td>
</tr>
</tbody>
</table>

*installation cost excluded.  
**installation cost included.

2.4.5.5. Technological bottlenecks

For the Klimrek Water Buffer and the infiltration crates, the storages are mainly placed under the greenhouse floor. Poles, bearing the greenhouse roof, may not be placed upon both systems, so the dimension of the systems is limited to the span width of the greenhouse. The adjustments of the Klimrek Buffer Water system are based on pumps.

Oxygen levels should be maintained in the subsurface water storages in order to avoid anaerobic degradation processes and a biofilm in the underground storages should be prevented.

2.4.5.6. Benefit for the grower

**Advantages**

- No loss of productive area
- Minimal problems regarding algae
- Minimal problems regarding evapotranspiration losses
- Cooler water
- Less biological contaminations (bird droppings, etc.)
- Storage capacity to catch all precipitation

**Disadvantages**

- Higher costs
- Leakages are hard to fix

2.4.5.7. Supporting systems needed

- Pumps
- Switches and steering program (Klimrek Buffer)

2.4.5.8. Development phase

This technology is commercialised.
2.4.5.9. Who provides the technology
Klimrek Buffer: Klimrek productions (http://www.klimrek.com).
Infiltration crates: Gaasbox: JES product Development, HTW Infiltratie Uden, BPO, etc.

2.4.5.10. Patented or not
No patents for this technology have been found.

2.4.6. Which technologies are in competition with this one
- Water storage in lined reservoirs (see 2.3)
- Water storage in water silos (see 2.3)

2.4.7. Is the technology transferable to other crops/climates/cropping systems?
Lined subsurface water storage cisterns can be used both in covered crops and crops in the open air, as long as the surface area for water collection is sufficient.
In case of infiltration crates and Klimrek Buffer, the system is probably limited to the soilless covered crops, as soil cannot be used as a growing medium in this system and the surface for water capture must be sufficient.

2.4.8. Description of the regulatory bottlenecks
There are no regulatory bottlenecks known for this technology.

2.4.9. Brief description of the socio-economic bottlenecks
The cost per m³ storage capacity for subsurface water storage is significantly higher when compared to lined water reservoirs and water silo’s, especially when costs for the required surface area are excluded. In case the costs for the lost producing area are included, this financial gap becomes much smaller.

2.4.10. Techniques resulting from this technology
Klimrek Water Buffer (Klimrek producten): a closed plate and plastic that fills with caught rainwater. The bottom is pushed upwards by groundwater. If the box is filled with rainwater, there is no groundwater present, if there is no rainwater, the groundwater pushes the box towards to surface.
Gaasboxx (Figure 2-14): Underground honeycomb mesh that supports structures and growing systems in which water can be stored.
2.4.11. References for more information


2.5. Subsurface Water Solutions

(Authors: Ronald Hand\textsuperscript{24}, Els Berckmoes\textsuperscript{21}, Georgina Key\textsuperscript{1})

2.5.1. Used for

- Preparation of irrigation water
- More efficient use of water

2.5.2. Region

All EU regions.

2.5.3. Crop(s) in which it is used

All crops.

2.5.4. Cropping type

All cropping types.

2.5.5. Description of the technology

2.5.5.1. Purpose/aim of the technology

The aim of subsurface water solutions is to protect, enlarge and utilise fresh groundwater resources through advanced groundwater management and freshwater supply.

2.5.5.2. Working Principle of operation

Sophisticated new well design, configuration and management allow for maximum control over the water resources, which goes far beyond the levels of control provided by standard water management techniques. This makes these solutions applicable in coastal areas (Figure 2-15, Figure 2-16), where groundwater management is a severe challenge because of the presence of saline and brackish groundwater.

![Freshwater supply under pressure](http://www.subsol.org/about-subsol/reference-sites)

*Figure 2-15. Current freshwater supply in coastal areas under pressure due to salinisation of groundwater abstraction wells and unsuccessful aquifer storage and recovery (ASR) of freshwater surpluses in brackish aquifers* (http://www.subsol.org/about-subsol/reference-sites)
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Implementing subsurface water solutions

Figure 2-16. Subsurface water solutions to counteract salinisation by dedicated well systems to inject and recover freshwater while intercepting brackish-saline groundwater (http://www.subsol.org/about-subsol/reference-sites)

2.5.5.3. Operational conditions

- Typically a supply of 5000-1000000 m³/year
- For individual agriculturists or agricultural clusters
- Requires suitable aquifers (permeable sand layers or carbonates) in order to use wells for infiltration and recovery
- Coastal areas. Infiltration can be beneficial in areas with fresh groundwater to counter declining water levels and lower the iron levels in abstracted groundwater.

2.5.5.4. Cost data

- For installation: 25000-500000 € (scale-dependent)
- Yearly maintenance or inputs needed: 2000 €/year
- Approximately 0,05 €/m³

2.5.5.5. Technological bottlenecks

Automation of the installation: Solid operation of Aquifer Storage and Recovery systems (ASR, Figure 2-17) and interception wells requires automation to guarantee optimal pretreatment, infiltration and recovery of the freshwater and minimal maintenance/downtime. This can be achieved by making sensor-based decisions and regular backflushing of pretreatment filters and infiltration wells.

Maximal recovery of the freshwater stored in brackish-saline aquifers: Freshwater can easily become “irrecoverable” due to lateral drift and buoyancy effects, where the infiltrated high-quality water is mixed with brackish groundwater, making the recovered water mostly unsuitable for irrigation (Figure 2-18).

A priori prediction of the effectiveness: A very heterogeneous natural (subsurface) system is used, so information on the subsurface and crucial parameters on groundwater flow are essential. Secondly, these parameters need to be transferred into calculation tools to predict the effectiveness of subsurface water solutions.
2.5.5.6. Benefit for the grower

Advantages

- Limited claim on aboveground land
- Increased freshwater available
- Better water quality (preservation)

Disadvantages

Success is uncertain due to the lack of data of the subsurface.

In general, growers at reference sites were positive (The Netherlands). At the replication site Dinteloord (200 ha of greenhouses), it was even decided to expand the system in the future.
2.5.5.7. Supporting systems needed

- Groundwater injection/abstraction wells
- Pre-treatment
- Pumps
- Programmable logic controller
- Monitoring

2.5.5.8. Development phase

Field tests are being conducted in Nootdorp (2 ha orchids), ’s Gravenzande (Westland, 27 ha tomatoes) and Freshmaker Ovezande (fruit orchard): [www.kwrwater.nl/en/projecten](http://www.kwrwater.nl/en/projecten).

The technique has also been commercialised: AFC Nieuw-Prinsenland, Dinteloord and abound 100 systems in the Bleiswijk area, Aalsmeer, Agriport A7.

2.5.5.9. Who provides the technology

Several engineering companies in the agricultural sector provide this technology:

- Codema B-E de Lier: [http://codema.nl](http://codema.nl) (SubSol Member)
- Meeuwse Handelsonderneming: [www.meeuwse-goes.com](http://www.meeuwse-goes.com)

2.5.5.10. Patented or not

This technology is not patented.

2.5.6. Which technologies are in competition with this one

- Brackish water reverse osmosis (see Chapter 3. Optimising water quality - Chemical composition)
- Above ground rainwater storage (see 2.3)
- External water supply (surface water, piped water)

2.5.7. Is the technology transferable to other crops/climates/cropping systems?

Yes, even to high-end horticulture, industries and the drinking water sector.

2.5.8. Description of the regulatory bottlenecks

Water Framework Directive regarding groundwater quality: It should be guaranteed that infiltration does not negatively impact the groundwater quality. National regulations to verify the infiltration water quality can be strict (high-frequency of sampling and analyses), negatively impacting the business cases.

In the Netherlands, the Water Act and Soil Protection Act apply on a national scale and a Regulation by the Dutch Water Authorities (small-scale systems) and the Province (large-scale systems) applies regionally.
2.5.9. Brief description of the socio-economic bottlenecks

Acceptance by the public: willingness to store water with a different quality and potential contaminants in a (normally) “clean” subsurface. Especially if this is in the vicinity of drinking water well fields.

2.5.10. Techniques resulting from this technology

**Technique A: Freshkeeper (KWR, Vitens Water Supply)**

Dual-zone abstraction against water well salinisation. Fresh and brackish groundwater are pumped simultaneously from different depths, providing control over the position of the fresh-brackish interface. The pumped brackish water may serve as an additional water source for high added value freshwater applications after desalination (see Figure 2-19).

![Figure 2-19. Freshkeeper Vitens Water Supply (Zuurbier et al. 2017, www.SubSol.org)](image1)

**Technique B: Freshmaker (KWR, Meeuwse Goes BV)**

Enlarging, protecting and utilising freshwater lenses (convex layers of fresh groundwater that float on top of denser saltwater) with horizontal wells. This technique was initiated by the recent development of horizontal directional drilled wells (HDDWs). HDDWs enable abstraction of deeper saltwater below the freshwater lens over a long transect, while a second, shallow HDDW allows for infiltration and abstraction of large freshwater volumes (Figure 2-20, Figure 2-21).

![Figure 2-20. Illustration Freshmaker Meeuwse Goes (www.kwrwater.nl/projecten/zoet-zout-ovezande)](image2)
Technique C: ASR-coastal (KWR, Codema B-E de Lier)

Temporal storage of freshwater in brackish groundwater. Standard aquifer storage and recovery (ASR) approaches are unsuitable in brackish groundwater environments. ASR-coastal uses multiple partially penetrating wells to enable deep injection and shallow recovery of freshwater, which demonstrated a boost in freshwater recovery from less than 20% to more than 60% of the injected freshwater. See Figure 2-22 till Figure 2-24.

These first subsurface water solutions applications have all been developed within public-private partnerships of innovators in the water market and they are starting to gain the interest from the market's early adopters.
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Figure 2-23. Aquifer Storage and Recovery for horticulture (www.SubSol.org)

Figure 2-24. Aquifer Storage and Recovery for horticulture (Westland horticulture)

2.5.11 References for more information


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2.6. Tools for dimensioning water storages for greenhouse crops

(Authors: Els Berckmoes21, Esther Lechevallier4)

2.6.1. Used for
Preparation of irrigation water.

2.6.2. Region
All EU regions.

2.6.3. Crop(s) in which it is used
All crops.

2.6.4. Cropping type
All cropping types.

2.6.5. Description of the technology

2.6.5.1. Purpose/aim of the technology
The aim of these tools is to provide specific advice regarding the dimensions of water storages for rainwater harvesting for greenhouse crops.

Rainwater harvesting is being promoted to solve water problems for agricultural and horticultural uses in many European regions as rainwater contains very low concentrations of sodium and chlorine. This makes rainwater a high-quality water source, especially in soilless cropping systems where recirculation is applied.

Although rainwater is considered as a low-cost water source, rainwater storage can be quite expensive. The described tools aim to dimension the water storage in relation to water consumption of the greenhouse crops.

2.6.5.2. Working Principle of operation

Standard tables

For many years the advice for dimensioning rainwater storage for greenhouse crops was based on standard tables like the ones of Van Woerden (2001) and CTIFL (2002). These tables (Table 2-6 and Table 2-7) give an overview of the necessary volume of rainwater storage in function of the desired implementation of the water needs for 1 ha greenhouse.
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Table 2-6. Necessary water storage capacity and required ground surface in function of the desired percentage of rainwater in the total water demand of 1 hectare of greenhouse crops

<table>
<thead>
<tr>
<th>Water storage (m³)</th>
<th>% of rainwater in total water demand of the crop</th>
<th>Ground surface (m²)</th>
<th>Water silo</th>
<th>Water basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>60</td>
<td>225</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>70</td>
<td>450</td>
<td>850</td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td>75</td>
<td>675</td>
<td>1100</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>80</td>
<td>900</td>
<td>1350</td>
<td></td>
</tr>
<tr>
<td>2500</td>
<td>83</td>
<td>Not avail.</td>
<td>1850</td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>86</td>
<td>Not avail.</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td>95</td>
<td>Not avail.</td>
<td>2500</td>
<td></td>
</tr>
</tbody>
</table>

Table 2-7. Necessary water storage capacity and required volume of alternative water sources for 1 hectare of greenhouse tomato crops (CTIFL, 2002)

<table>
<thead>
<tr>
<th>Water storage (m³/ha)</th>
<th>% of rainwater in total water demand of the crop</th>
<th>Rainwater used (m³/ha)</th>
<th>Water volume required of additional sources (m³/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>65</td>
<td>4800</td>
<td>2700</td>
</tr>
<tr>
<td>1000</td>
<td>70</td>
<td>5200</td>
<td>2300</td>
</tr>
<tr>
<td>2000</td>
<td>80</td>
<td>6000</td>
<td>1500</td>
</tr>
<tr>
<td>3000</td>
<td>86</td>
<td>6400</td>
<td>1100</td>
</tr>
<tr>
<td>4000</td>
<td>92</td>
<td>6900</td>
<td>600</td>
</tr>
<tr>
<td>5000</td>
<td>96</td>
<td>7200</td>
<td>300</td>
</tr>
<tr>
<td>6000</td>
<td>100</td>
<td>7500</td>
<td>0</td>
</tr>
</tbody>
</table>

Models based on crop water consumption and precipitation characteristics

These models are mainly based on long-term data sets of climatological parameters (precipitation, solar radiation, evapotranspiration, etc. - Figure 2-25) and datasets or models for the crops’ specific water uptake. Both the Flemish model of Verdonck & Berckmoes (WADITO) and the Dutch model of Glastuinbouw Waterproof are based on this principle.

For example, WADITO is based on a daily simulation of the water level in the water storage. The daily rainwater supply is based on the climatic data (1965-2013). Transmission losses, losses due to evapotranspiration and overflow are integrated into the model. Water consumption through the greenhouse crop is based on daily average water consumption (based on long-term water consumption data). In the case of the model of Glastuinbouw Waterproof, the daily water consumption of the crop is based on the solar radiation.

The model provides the possibility to upload company-specific parameters in order to improve the accuracy of the model. As a result, the model will give the current percentage of the crop water demand that can be fulfilled with the stored rainwater. In addition, the model shows the frequency and average and maximum volume of water shortage for the dataset of 1965-2013.

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2.6.5.3. Operational conditions

Requirements for applying the different tools are presented in Table 2-8.

Table 2-8. Overview of the limitations of the different dimensioning tools

<table>
<thead>
<tr>
<th>Tool/Table</th>
<th>Dimension (m³)</th>
<th>Crop</th>
<th>Type of water storage</th>
<th>Cropping system</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table Van Woerden</td>
<td>500-4000</td>
<td>Tomato</td>
<td>Water basin</td>
<td>Greenhouse</td>
<td>The Netherlands</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water Storage</td>
<td>Soiless</td>
<td></td>
</tr>
<tr>
<td>Table CTIFL</td>
<td>500-6000</td>
<td>Tomato</td>
<td>Not defined</td>
<td>Greenhouse</td>
<td>Bretagne</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soiless</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WADITO</td>
<td>≥ 500</td>
<td>Standard crops (tomato, sweet pepper, strawberry, lettuce, azalea, roses) All crops: in case weekly freshwater demand is known</td>
<td>Water basin</td>
<td>Greenhouse Soiless Soilbound</td>
<td>Belgium (Mechelen)</td>
</tr>
<tr>
<td>Waterstromen</td>
<td>≥ 500</td>
<td>Tomato, sweet pepper, cucumber, roses, ficus, gerbera</td>
<td>Water basin</td>
<td>Greenhouse Soiless</td>
<td>The Netherlands</td>
</tr>
</tbody>
</table>

2.6.5.4. Cost data

Table 2-9. Cost data

<table>
<thead>
<tr>
<th>Calculation system</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table Van Woerden</td>
<td>Not avail.</td>
</tr>
<tr>
<td>Table CTIFL</td>
<td>Not avail.</td>
</tr>
<tr>
<td>WADITO</td>
<td>This model is specialised in the company-specific simulation and is therefore not freely available. The costs for the advice depend on the company-specific conditions and complexity</td>
</tr>
<tr>
<td>Waterstromen</td>
<td>The model is publicly available on the website of Waterproof</td>
</tr>
</tbody>
</table>
### 2.6.5.5. Technological bottlenecks

Rainfall characteristics differ from region to region: e.g. coastal region versus mountains. In order to provide company-specific advice, the models require long-term rainfall data.

### 2.6.5.6. Benefit for the grower

**Advantages**

Company-specific advice regarding dimension water storage.

**Disadvantages**

General tables: lack of specificity. Sweet pepper crops require significantly less water storage capacity when compared to tomato crops.

### 2.6.5.7. Supporting systems needed

- Long-term climatological data (rainfall, irradiation, evapotranspiration water, etc.)
- Data on crop water demands (on a daily basis)

### 2.6.5.8. Development phase

- Research: Spin-offs have developed to dimension the required buffer capacity for greenhouse crops, to dimension rainwater storage for other applications besides irrigation (like the washing of vegetables, etc.) and to dimension water storage facilities for container fields. Provided by: Proefstation voor de Groenteteelt (PSKW)
- Field tests: WADITO and WADITO for container fields are being validated continuously on several test locations
- Commercialised: Advice based on WADITO has been carried out for the construction of 3 new greenhouses (25 ha) and an extension of 2 greenhouses (15 ha) in Belgium

### 2.6.5.9. Who provides the technology

- Table of van Woerden, provided by Wageningen University Department Praktijkonderzoek Plant en Omgeving
- Table of CTIFL, provided by CTIFL
- Online calculation program, provided by Glastuinbouw Waterproof
- Calculating the company-specific optimal dimension for rainwater storage for (so far only Dutch growers') greenhouse crops: Waterstromen by Wageningen University

### 2.6.5.10. Patented or not

This technique is not patented.

### 2.6.6. Which technologies are in competition with this one

There are no technologies that are in competition with the water dimensioning tools.
2.6.7. Is the technology transferable to other crops/climates/cropping systems?  
The dimensioning tools can easily be transferred to other crops, climates and cropping systems if the water consumption of the crop/application and daily weather data are available.

The WADITO model is currently being transferred to different other applications:

- Dimensioning of the storage of rainwater and nutrient-rich runoff for container fields (experimental stage)
- Dimensioning of the rainwater storage for rainwater used to, for example, wash leek on small farms (commercial stage)
- Dimensioning of buffer capacities of rainwater storages and risk assessment for flooding due to heavy rainfall for medium- to large-scale greenhouses (field test)

2.6.8. Description of the regulatory bottlenecks  
In many European regions, rainwater is considered the most sustainable and qualitative water source for irrigation purposes. However, in several countries growers have to follow procedures in order to receive a permit to build a water storage facility.

In regions like Flanders, stringent security regulations oblige growers to provide a buffer capacity in case of heavy rainfall.

2.6.9. Brief description of the socio-economic bottlenecks  
Most of the models take into account the desired percentage of water consumption of the crop to be fulfilled with rainwater. Models do not sufficiently take into account the cost-benefit of the rainwater storage. Although rainwater is mostly referred to as a low-cost water source, the costs for water storage can be high (construction of a water storage, control of algae, loss of productive area, etc.). These costs and costs of alternative water sources should be taken into account to calculate the optimal water storage dimension.

2.6.10. Techniques resulting from this technology  
- Online tool Glastuinbouw Waterproof, provided by Glastuinbouw Waterproof
- WADITO (Proefstation voor de Groentetteelt)

2.6.11. References for more information  
2.7. Water storage covers

(Authors: Ronald Hand\textsuperscript{24}, Els Berckmoes\textsuperscript{21})

2.7.1. Used for
- Preparation of irrigation water
- More efficient use of water
- Minimising the impact to the environment by nutrient discharge

2.7.2. Region
All EU regions.

2.7.3. Crop(s) in which it is used
All crops.

2.7.4. Cropping type
All cropping types.

2.7.5. Description of the technology

2.7.5.1. Purpose/aim of the technology
Water storage covers are used to overcome the following storage-related problems:
- Algal bloom: water covers prevent sunlight from entering the stored water volume
- Evapotranspiration losses: by covering the water storage, water temperature is lowered some degrees and evaporated water is (partially) kept in the water storage
- Contamination: in case the covers are tied down to the walls, contaminations are not mixed with the stored water

2.7.5.2. Working Principle of operation
Water storage covers can be installed as a fixed or a floating construction.

\textit{Fixed covers}

The cover is mainly made of a plastic foil that is stretched over the water storage. The covers are tied down to the walls (Figure 2-26). In this way both precipitation, but also contaminants, like bird droppings, dust, leaves, etc. are prevented from entering the water.

In some cases, steel covers are made. The price of these covers is much higher compared to the plastic covers.

\textit{Floating covers}

Floating covers are being applied to both water silos and water basins. The stored water is covered with floating materials (foils, balls, etc.) in order to shield the water volume from sunlight. As algae need sunlight to survive, algal development is prohibited this way.
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2.7.5.3. Operational conditions

Fixed covers

- Impermeable foils are limited to a diameter of 5.5 m. In case a support is installed, the diameter can be increased to 15.5 m
- Steel covers are limited to a diameter of 12 m
- Permeable foils have no limitations, but the water storage tank is limited

Floating covers

Have a diameter of 8.3 m and more and can be fabricated in all shapes.

2.7.5.4. Cost data

Costs for water silo and water basin covers are respectively shown in Table 2-10 and Table 2-11.

Table 2-10. Overview of installation costs for fixed and floating covers for water silos

<table>
<thead>
<tr>
<th>Type of cover</th>
<th>Small: 25 m²</th>
<th>Medium: 250 m²</th>
<th>Large: 500 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed steel cover</td>
<td>100 €/m²</td>
<td>Not avail.</td>
<td>Not avail.</td>
</tr>
<tr>
<td>Fixed permeable plastic cover</td>
<td>10 €/m²</td>
<td>6 €/m²</td>
<td>5,5 €/m²</td>
</tr>
<tr>
<td>Floating permeable cover</td>
<td>20 €/m²</td>
<td>9 €/m²</td>
<td>9 €/m²</td>
</tr>
<tr>
<td>Floating balls</td>
<td>16 €/m²</td>
<td>15 €/m²</td>
<td>14 €/m²</td>
</tr>
</tbody>
</table>

Table 2-11. Overview of installation costs for covers for water basins

<table>
<thead>
<tr>
<th>Type of cover</th>
<th>Small: 1000 m²</th>
<th>Medium: 5000 m²</th>
<th>Large: 10000 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kristaldek®</td>
<td>40 €/m²</td>
<td>40 €/m²</td>
<td>40 €/m²</td>
</tr>
<tr>
<td>Floating balls</td>
<td>14 €/m²</td>
<td>13,75 €/m²</td>
<td>13,75 €/m²</td>
</tr>
</tbody>
</table>

Figure 2-26. Fixed cover stretched over a water silo

2.7.5.5. Technological bottlenecks

- Larger floating foils have to be correctly installed by specialised personnel
- Covers must be resistant to heavy weather conditions (hail, winds, frost, etc.)
- Floating covers are attractive biotopes for water birds, which can lead to contamination of the upper water layer

2.7.5.6. Benefit for the grower

**Advantages**

- Very effective to prevent algal bloom
- Quickly achieving results (after 2 weeks)
- Evaporation reduction up to 90-95%
- Fixed covers prevent precipitation and contaminants from entering the water
- Floating balls are easy
- Floating balls prevent waterfowl from entering the reservoir and nesting in the water

**Disadvantages**

- Higher installation costs
- Floating covers are attractive biotopes for water birds, leading to dirty covers
- Leaves and other particles can still enter the water storage
- Qualified staff is required to install the floating covers
- Sediments are accumulated on the foil and can facilitate plant growth
- Floating balls prevent ducks from entering the reservoir and nesting in the water
- Some cover types are less resistant to wind

An overview of the advantages and disadvantages of the different cover types is given in Table 2-12.

**Table 2-12. Overview of advantages and disadvantages of the different types of floating covers**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Floating cover</th>
<th>Floating balls</th>
<th>Fixed cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention of inflow of contaminants</td>
<td>good</td>
<td>sufficient</td>
<td>good</td>
</tr>
<tr>
<td>Prevention of algal bloom</td>
<td>very good</td>
<td>very good</td>
<td>very good</td>
</tr>
<tr>
<td>Evaporation reduction</td>
<td>very good</td>
<td>very good</td>
<td>very good</td>
</tr>
<tr>
<td>Ease of installation</td>
<td>mediocre</td>
<td>very easy</td>
<td>easy</td>
</tr>
<tr>
<td>Maintenance requirements</td>
<td>low</td>
<td>very low</td>
<td>low</td>
</tr>
<tr>
<td>Sediment deposition on the cover</td>
<td>low</td>
<td>very low</td>
<td>mediocre</td>
</tr>
<tr>
<td>Wind resistance</td>
<td>very high</td>
<td>mediocre</td>
<td>mediocre</td>
</tr>
</tbody>
</table>
2.7.5.7. Supporting systems needed

- Some floating foils require a floating structure
- In case of the LP-dek, a flexible hose is required to discharge precipitation falling on the cover
- Atlas cords (Figure 2-28) can be a tool to prevent birds landing on the floating covers of big water storages
- In case of floating balls, a sieve or a net has to be installed to avoid balls entering pipelines

2.7.5.8. Development phase

This technology is commercialised.

2.7.5.9. Who provides the technology

Covers: Royal Brinkman, Albers Alligator (Netherlands).
Floating balls: Beekenkamp verpakkingen (Netherlands).

2.7.5.10. Patented or not

Some of the covers are patented, such as for example:
- LP-dek® from Albers Alligator
- Kristaldek® from Albers Alligator
- Shadow Balls™
2.7.6. Which technologies are in competition with this one?

- Regarding algae control: all technologies to control/prevent algal bloom
- Regarding reduction of evaporation: under groundwater storage

2.7.7. Is the technology transferable to other crops/climates/cropping systems?

The technology can be applied to crops where water is stored and algal bloom and/or evapotranspiration losses must be prevented.

2.7.8. Description of the regulatory bottlenecks

There are no regulatory bottlenecks known for this technology.

2.7.9. Brief description of the socio-economic bottlenecks

Costs related to water storage coverage are experienced as high by growers. This price should be compared to the benefit resulting from the technology, being the absence of algae, prevention of evaporation losses, cleaner water, reduction of organic material in the water, etc. An economical estimation of these benefits is currently missing.

2.7.10. Techniques resulting from this technology

*Fixed water silo cover (LP-Dek®, Albers Alligator)*

This patented, fixed water cover is applied to water silos. The cover is unique as the cover itself moves along with the water level. The cover is constructed in a way this foil covers the water storage surface and the inner sides of the storage as the water volume decreases or increases. In the centre of the foil, a vent is installed to exchange gasses. Water falling on the fixed cover is discharged through a hose (see Figure 2-29).

*Floating water cover (Kristaldek®, Albers Alligator; MultiF®, Albers Alligator; Air Float, Brinkman; PAS Drijfdek)*

Kristaldek® (Figure 2-30) is a floating cover, made of a coated fabric impervious to light. The cover itself exists of a central foil with dimensions similar to the bottom surface. Floating
bodies are attached to this fabric foil. At the sides of the floating foil vertical slabs are attached, preventing light to enter the water body underneath the cover. The cover itself is attached to the shores by use of flexible cables.

Air float and PAS Drijfdek are floating covers designed for water silos.

Figure 2-30. Schematic view of the Kristeldek®. The central foil covers the area of storage floor. Vertical slabs at the sides of this foil, preventing light to enter the water body. Elastic cords, keep everything in place

In Figure 2-31 to Figure 2-33 the installation of this type of cover is illustrated.

Figure 2-31. Installing the floats (Source: PSKW)

Figure 2-32. Ballast is attached to the vertical slabs, attached all around the floating horizontal foil (Source: PSKW)

Figure 2-33. Manpower is needed to put the foil in its final position, so installation takes some hours (Source: PSKW)

**Floating balls (Armor BallTM, HexprotectTM, Shade Ball TM solutions, Beekenkamp)**

Hollow balls with a spherical or hexagonal form are placed in the water storage. Depending on the shape of the balls, a coverage of 91-99% can be reached in case sufficient balls are inserted into the storage.

Figure 2-34. Depending on the shape of the floating balls, a coverage up to 91-99% can be reached (Beekenkamp)

2.7.11. References for more information

2.8. Collecting condensed water

(Authors: Juan José Magán, Elisa Suárez-Rey)

2.8.1. Used for
More efficient use of water.

2.8.2. Region
All EU regions.

2.8.3. Crop(s) in which it is used
Crops in greenhouses.

2.8.4. Cropping type
- Protected
- Soil-bound
- Soilless

2.8.5. Description of the technology

2.8.5.1. Purpose/aim of the technology
This technology aims to collect the water condensing on the cover surfaces of the greenhouse in order to avoid its dripping on the crop (reducing the risk of crop diseases) and to use it in crop irrigation as a good quality and sustainable water source.

2.8.5.2. Working Principle of operation
Air in the atmosphere is a combination of dry air and water vapour. The capacity of the air to contain water vapour decreases with temperature. If the temperature of a surface immersed in the air is equal or lower than the dew temperature (temperature for full air saturation), then dew is formed on that surface (Figure 2-35). The cover and metal structure are frequently the coldest spots in greenhouses due to contact with the outside air and the emission of longwave radiation. These are the first surfaces of the greenhouse where dew appears.

Figure 2-35. Condensation on a greenhouse glass wall
Condensation in greenhouses tends to occur more frequently early in the morning, when solar radiation reaches the crop, thereby increasing transpiration and air humidity in the greenhouse, but plant (fruits) and cover temperature increases more slowly than air temperature. However, it is also possible during the night and the afternoon, when the temperature drops sharply and the greenhouse is humid due to crop transpiration.

Condensation on a surface may take place following two structural types:

- Condensation wets the entire surface and forms a continuous film, then constituting a new condensation surface of size equal to the initial surface
- Condensation occurs on a triple contact surface: solid, gas and the surface of the drops previously condensed. Here, drops are organised individually, initially having a microscopic size and increasing in size by merging with steam molecules. This phenomenon is known as coalescence (Figure 2-36). When the drop is big enough to reach a gravity force higher than capillarity (cohesion forces), its breaking point is reached and the drop slides over the condensing surface, allowing being collected

In a complete condensation cycle, four different phases can be distinguished: 1) a dry phase; 2) a condensation phase without run-off; 3) a condensation phase with run-off and 4) an evaporation phase.

Climatic variables involved in the phenomenon of condensation on a surface are basically air humidity and temperature, condensing surface temperature and wind speed. Condensation is also affected by the properties of the condensing surface.

2.8.5.3. Operational conditions

As a consequence of the different surface tension of cladding materials, condensation on glass surfaces usually appears as a film of water (Figure 2-38) which facilitates its run-off, while on many plastic films, condensation appears as drops which makes run-off more difficult. This also has a consequence on light transmission because of the higher reflection in the second case (Figure 2-37).
There are a number of methods to produce a continuous layer of condensed water, such as treatment of the film surface or oxidation of the polymer surface, but the most efficient method for agricultural films is the incorporation of additives during the manufacturing process (anti-drip plastic). In Figure 2-38 it is possible to see the different behaviour with respect to condensation of a conventional plastic compared to an anti-drip plastic. In a study carried out in Almería (Spain), the average condensation recovery in the conventional and the anti-drip plastics in a closed greenhouse without crop, but with gutters filled with water covering almost 10% of soil surface was 0,08 and 0,228 L/m²/day, respectively. The small quantity of water collected in case of the normal plastic indicates that most of the water evaporated in the greenhouse, falls down to the floor after condensation or is retained in the plastic until evaporating during the day. In case of the anti-drip plastic, water collection is very efficient. These values of water collection cannot be extrapolated to commercial greenhouses but even then, they show the effectiveness of anti-drip plastics, which are able to collect almost 300% more than normal plastics.

![Figure 2-38. Behaviour respect to condensation of different plastic types: left, anti-drip plastic with film condensation; right, conventional plastic with dropwise condensation](image)

The same closed greenhouse was tested as a passive solar desalination system (Figure 2-39), now using the whole surface as a reservoir (of saline water). The experimental data indicate that it is possible to collect around 750 L/m² of condensed water per year (in addition to rainwater). A limiting factor for the commercial use of this system is the price of the land, apart from the availability of adequate plastic cladding materials with high duration of the anti-drip effect under high temperature and condensation rate conditions. The duration of the anti-drip effect under such extreme conditions is presently only a few months. However, it may extend to more than one year in conventional growing conditions.

![Figure 2-39. Picture of closed greenhouse used as passive solar desalination system](image)
Measurements were carried out in commercial Venlo-type greenhouses growing tomato, cucumber and eggplant in Almería. The glasshouse where the cucumber was grown was located in an area with warmer nights in winter, which affected the results (Table 2-13).

A study in southern France gave average daily rates of 0.23 L/m²/day. The observed differences observed can be related to the thermal jump between the indoor and outdoor environment that was maintained in each case.

Table 2-13. Overview of condensation water recovered in different studies

<table>
<thead>
<tr>
<th>Crop</th>
<th>Period</th>
<th>Roof material</th>
<th>Accumulated condensation volume</th>
<th>Max. daily rate</th>
<th>Average daily rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Oct-June</td>
<td>Glass</td>
<td>27,7 L/m²</td>
<td>0,4 L/m²/day</td>
<td>0,11 L/m²/day</td>
</tr>
<tr>
<td>Tomato</td>
<td>Oct-June</td>
<td>Plastic</td>
<td>27,0 L/m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cucumber</td>
<td>Feb-March</td>
<td>Glass</td>
<td>Not avail.</td>
<td>0,15 L/m²/day</td>
<td>0,04 L/m²/day</td>
</tr>
<tr>
<td>Eggplant</td>
<td>Oct-May</td>
<td>Glass</td>
<td>11,6 L/m²</td>
<td></td>
<td>0,05 L/m²/day</td>
</tr>
</tbody>
</table>

2.8.5.4. Cost data

Installation of gutters for collecting condensed water in multi-span arched-roof greenhouses costs about 6000 €/ha, including the gutters, accessories and labour.

2.8.5.5. Technological bottlenecks

In parral-type greenhouses, the plastic film covering the roof is held between two galvanised steel networks and attached to an array of tension wires that connect the vertical posts supporting the roof. Condensed water from the internal roof cover frequently comes into contact with the steel network, forming drops that fall onto the crop. Condensed water collection is inefficient in these greenhouses (common in southeast Spanish Mediterranean).

In multi-span arched-roof greenhouses covered with plastic film, the roof slope near the ridges is very low, which makes drop sliding difficult on this part of the cover. Zabeltitz (2011) published some requirements, depending on the material of the roof:

- Conventional plastics without anti-drip additives: slope > 14° = formation of runoff lines. Most of the water moving in these runoff lines falls before reaching the collecting gutter.
- Normal plastic: slope > 15% = occurrence of a lot of dripping: both in the centre of the greenhouse (because of the low slope) and the rest of the greenhouse (because the angle is high and produces a quick drop sliding with dripping from the runoff lines).
- Plastic with anti-drip additives: angle between 14° and 40° = less dripping: dripping will come almost exclusively from the central area of the greenhouse (where the angle is usually low), while in the case of normal plastic.

Anti-drip additives added to the plastic tend to migrate towards the surface and are washed away by condensation. Anti-drip properties are usually lost before the end of the lifespan of...
the plastic. Multi-layer plastics use one of their central layers as a reservoir of anti-drip additives so that they continuously supply replacement to the additives lost by washing. However, this reservoir can be lost quite quickly in extreme conditions.

Another cause of dripping in multi-span arched-roof greenhouses is the contact of drops with the anti-insect net usually placed in the vents, which also hinders drop sliding. Finally, in this greenhouse type, the cladding material is tied to the structure by a special long piece joined to the rainwater gutter, where the plastic is usually bent towards the inside of the greenhouse for a higher resistance. The plastic surplus also makes drop sliding difficult and promotes dripping, if not cut properly.

Venlo type greenhouses (extensively used in cold areas) are equipped for collecting condensation. Multispan arched-roof greenhouses covered with plastic film (which are more typical of mild winter areas) are not always equipped for an efficient recovery.

2.8.5.6. Benefit for the grower

**Advantages**

- High-quality water for irrigation
- Reduced disease risk

**Disadvantages**

- Low quantities of water captured
- Low efficiency

2.8.5.7. Supporting systems needed

The gutters collecting the condensation have to be connected to pipes transporting the water to the reservoir.

2.8.5.8. Development phase

This technology is commercialised.

2.8.5.9. Who provides the technology

Companies building industrial greenhouses also install systems for condensation recovery.

2.8.5.10. Patented or not

This technique is not patented.

2.8.6. Which technologies are in competition with this one

- Active dehumidification systems
- Heat exchangers in closed greenhouses

2.8.7. Is the technology transferable to other crops/climates/cropping systems?

Yes, this technology is applicable to most greenhouses.
2.8.8. Description of the regulatory bottlenecks
There are no regulatory bottlenecks.

2.8.9. Brief description of the socio-economic bottlenecks
There are no socio-economic bottlenecks.

2.8.10. Techniques resulting from this technology
In some Venlo-type greenhouses, there are two gutters for condensed water collection (Figure 2-40). The upper gutter collects the condensation coming from the roof, as well as the rainwater in the outside part and the lower gutter collects the condensation produced on the upper gutter.

![Upper gutter and lower gutter](image)

Figure 2-40. Picture of Venlo-type greenhouse with a double gutter for condensed water collection (Source: Santiago Bonachela)

In multi-span arched-roof greenhouses and some Venlo-type greenhouses, a gutter under the gutter for rainwater collection can be installed for condensation recovery (Figure 2-40), condensation slides from the cladding material to the lower gutter through the upper gutter.

![Gutter for rainwater collection](image)

![Gutter for condensed water collection](image)

Figure 2-41. A multi-span arched-roof greenhouse with a gutter for condensed water collection. Left: separate gutter. Right: gutter made from the plastic surplus

Some growers in Almería using multi-span arched-roof greenhouses covered with plastic film make a gutter from the plastic surplus in order to ensure condensation recovery (Figure 2-41, Right).
2.8.11. References for more information


2.9. Floating pumps

(Authors: Esther Lechevallier\(^4\), Els Berckmoes\(^2\), Justyna Fila\(^6\))

2.9.1. Used for
Preparation of irrigation water.

2.9.2. Region
All EU regions.

2.9.3. Crop(s) in which it is used
All crop types.

2.9.4. Cropping type
All cropping types.

2.9.5. Description of the technology

2.9.5.1. Purpose/aim of the technology
Floating pumps enable to pump water from a certain level above the bottom of the water storage in order to:

- avoid the uptake of floating particles (sediment, aquatic plants, algae, etc.)
- pump cooler water (from the lower water levels)
- pump water at the centre of the water storage where the depth is maximal

2.9.5.2. Working Principle of operation

Like the term “floating” pumps indicates, the pumps are floating in the water body. The pump is not lying on the bottom of the reservoir like in a normal storage (Figure 2-42), but it is raised by a float (e.g. a floating raft made of empty water cans) or attached to a support (e.g. a pole).

*Pumps attached to a float*

When the pump is attached to a float, the pump will follow the water level variations. A flexible pipe can be attached to the float and anchored so that pump moves in a range of approximately 0,5 m below the water surface and the bottom of the water storage (Figure 2-43).

*Floating pump attached to a fixed structure*

In case the pump is attached to a fixed structure, the pump will be positioned just above the bottom of the water basin to avoid sediment uptake (Figure 2-44). The pump depths can then be adjusted manually.
Transfer of INNOvative techniques for sustainable WAtter use in FERtigated crops

Figure 2-42. System with a fixed position of the pump at the bottom of the water storage (Source: Esther Lechevallier)

Figure 2-43. Floating pump attached to a raft. Changes of the water level will change the depth of the pump (Source: Esther Lechevallier)

Figure 2-44. Floating pump attached to a support system. The position of the pump in relation to the bottom of the water body, will not change due to the changes in the water level (Source: Esther Lechevallier)

Figure 2-45. Examples of different constructions of floating pumps. Left and middle: pumps attached to floats; Right: floating pump attached to a fixed structure, in this case, a pole (Source: CATE)

2.9.5.3. Operational conditions

Pumps attached to a float

There are no limitations regarding scale, capacity, etc. but there are for the depth of water extraction. As the water level decreases, the floats will also move towards the bottom of the water storage. In case of very low water levels, the pumps must be switched off in order to avoid suctions of both sediments and water with too high water temperature.

Floating pump attached to a fixed structure

The width of the water storage can limit fixing the support and in case of very low water levels, the pump must be lowered manually. The uptake of sediments and water with too high water temperature should also be avoided here.

2.9.5.4. Cost data

Generally, floating systems are manufactured by the growers themselves. Costs depend on the type of pump and material used for the implementation (wooden pole with suspension, floating raft, etc.). Maintenance costs are limited to an installations check from time to time.

2.9.5.5. Technological bottlenecks

In case of very low water levels in the water storage, the floating pump must be switched off automatically or manually because of a risk for uptake of sediments or warmer water. In general, a minimum level of 0,5 m above the bottom of the reservoir is maintained.

2.9.5.6. Benefit for the grower

Advantages

- Avoids suction of sediments at the bottom of the water storage
- Avoids suction of algae at the water surface
- Easy implementation
- Water can be pumped from the middle of the storage where the depth is maximal
- Extraction of slightly warmer water from 20-30 cm below the water surface in winter

Disadvantages

- Pumps must be switched off in case of low water levels
- Pumps attached to a fixed structure have to be lowered manually to have the maximal benefit (higher water temperatures in winter, cooler in summer)

2.9.5.7. Supporting systems needed

- A simple screen filter at the insert opening of the pump to avoid suction of floating particles
- A flexible pipe so the floating pumps can follow the water level
- A fixed structure, including a system to lift or lower the pump
- A system to switch off the pump automatically in case of low water levels (sensors)
2.9.5.8. Development phase
This technology is commercialised: many growers install the floating pumps themselves.

2.9.5.9. Who provides the technology
Most of the local equipment companies provide these pumps.

2.9.5.10. Patented or not
This technology is not patented.

2.9.6. Which technologies are in competition with this one
- Fixed pumps
- Technologies avoiding sediments to enter water storages, e.g. water storage covers
- Technologies to prevent sediment build up, e.g. a vacuum cleaner for water storages

2.9.7. Is the technology transferable to other crops/climates/cropping systems?
This technology is not linked to regions, crops or cropping systems. It is directly linked to the methods of water storage (water basins or water silos).

2.9.8. Description of the regulatory bottlenecks
There are no regulatory bottlenecks known for this technology.

2.9.9. Brief description of the socio-economic bottlenecks
There are no economic bottlenecks because of the low cost of this technology.

2.9.10. Techniques resulting from this technology
There are no techniques resulting from this technology.

2.9.11. References for more information