Update on DC voltage

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Greenhouse horticulture

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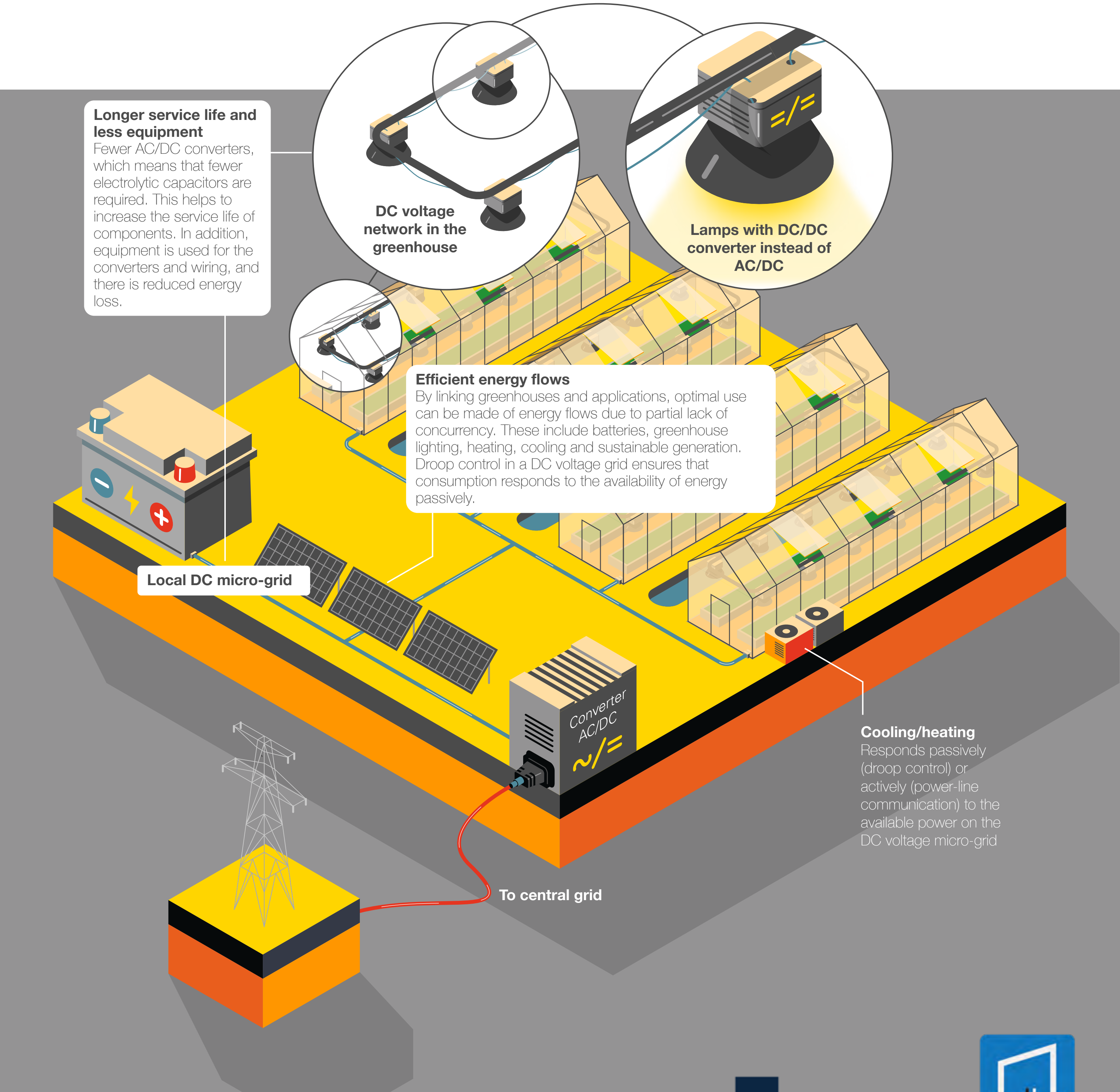

Berenschot

TKI URBAN ENERGY
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DC voltage in greenhouse horticulture

DC voltage applications in greenhouse horticulture can ensure that equipment lasts for longer and that apparatus can respond to changing voltages, so that the available capacity can be better controlled and there are fewer energy losses. The adoption of DC voltage in greenhouse horticulture does pose a number of difficulties, namely (1) high financial risks, (2) lagging adoption of LEDs, (3) a lack of a proof of concept and (4) the high investment costs and complexity of a local grid. It is recommended that a business case study be established for each type of crop, that a pilot be set up involving grid operators and that beneficial financing structures be established. We look at these aspects in more detail below.

Background

This white paper is part of a report on the current state of affairs of DC voltage in the Netherlands. The report is an update to the DC Voltage Roadmap, which was compiled in 2018. General information and details about the benefits, drawbacks and challenges of DC voltage are explained in the appendix update on DC voltage. In addition to the update on DC voltage, we also look more closely at five specific market segments by means of five white papers. In this white paper, the market segment that we will focus on is DC voltage applications in greenhouse horticulture. We will start with the concept, then look at the state of affairs, market adoption, difficulties and recommendations.

Introduction

In greenhouse horticulture, efficiency gains can be achieved at two levels: with a DC voltage grid in the greenhouse on the one hand, and with a DC voltage grid between and around greenhouses and around energy consumers and generators on the other. DC voltage within the greenhouse involves the implementation of Light Emitting Diode (LED) lighting in combination with an internal DC voltage grid. The switch to LED lighting means a reduction in energy. In addition, the use of an internal DC voltage grid within the greenhouse also results in lower electricity consumption due to significantly reduced conversion losses, equipment savings and increased reliability/a longer service life. Additionally, advantages can also be gained by creating a decentralised DC voltage grid to which not only the lighting is connected, but also the solar PV, cooling and/or heating system, and batteries, if applicable. Greenhouse horticulture is an energy-intensive industry and a significant proportion of the costs involved are due to energy consumption. Accordingly, the ability to control energy flows with limit values and to reduce losses, or to attain higher yields at the same cost, are extremely important to the industry. The lighting needs of crops can vary throughout the day. The use of LED lighting offers benefits in terms of energy savings and better performance when dimmed (reduced heat), which means that LED lighting can meet the lighting needs of crops. The current SON-T lighting consumes more energy, is more difficult to dim, has a different light colour/composition and becomes less efficient over time. On the other hand, SON-T lighting is cheaper to acquire. We elaborate on the concepts for DC voltage in greenhouse horticulture below:

■ **Concept 1. DC voltage lighting network**
The number of LED light fixtures in greenhouse horticulture is on the rise, replacing the current high-pressure sodium lamps. Conversion is now carried out in each lamp separately, necessitating a large number of small converters. It is possible to use a single, large converter for a group of lamps and to supply the fixtures from a DC voltage grid, as shown in Figure 1. This reduces losses as the large converter operates with greater efficiency than the smaller converter[1] (1). In addition, the fixtures last longer, as they

1) In the interviews conducted, views differ as to the extent to which these differences in conversion losses can be considered significant.

no longer contain electrolytic capacitors[2] (2). There is a trade-off here based on scale (3).

A traditional SON-T lamp emits light in a very broad spectrum. LED lighting does not— to supply the same amount of light to illuminate a crop, relatively more LED lighting needs be installed when compared to the general living environment (public lighting, built environment).

Connecting part of a greenhouse to DC voltage is relatively straightforward and requires a lower investment than transitioning the entire greenhouse to DC voltage all at once. The benefits are multiplied, however, when an entire greenhouse or even several greenhouses are connected to DC voltage, although this requires a higher investment, is more complex and involves greater operational risk. An important benefit of the use of DC voltage in greenhouses is that lighting is connected to DC voltage using DC/DC converters rather than AC/DC converters. DC/DC converters last longer: while fixtures fitted with AC/DC converters need to be replaced every four to six years, fixtures with DC/DC converters have a much longer service life. This means a longer replacement cycle and a much simpler financing structure for the grower.

■ Concept 2. Own infrastructure

Conversion losses can be avoided and equipment can be saved when a local DC voltage grid is used in greenhouse horticulture, as shown in Figure 2. The DC voltage grid supplies the fixtures in the greenhouses, but other applications can be connected to the grid as well, including solar PV, battery systems, heating and cooling systems. This enables savings on energy and equipment, as all applications are connected downstream of a single, large converter. In addition, less equipment is required for wiring (1).

Solar PV is a DC voltage technology that is increasingly being adopted by growers, particularly internationally[3]. This makes a DC voltage grid for lighting and solar PV a good match, particularly in conjunction with batteries. A larger grid with more DC voltage applications leads to higher gains in terms of both energy and equipment, as fewer AC/DC converters are required. In addition, there is also greater scope for economies of scale through the connection of multiple growers to the same grid. Growers with different crops have different energy requirements, dictated by divergent heat, lighting and cooling needs. A common DC voltage grid allows for smart exchange of energy flows and more efficient use of energy on the common grid (2).

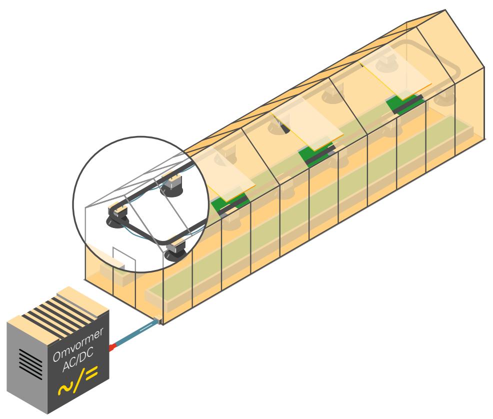

Figure 1 Lighting grid in a greenhouse or part thereof on DC voltage

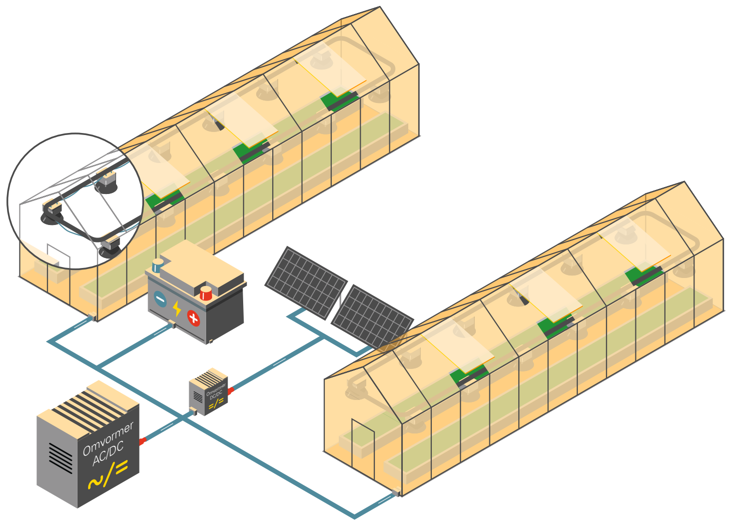

Figure 2 Own infrastructure

2) Electrolytic capacitors: these are required in AC/DC converters due to the frequency, but tend to wear relatively quickly and generate heat. For further information, see also the Update on DC voltage.
3) Greenhouse horticulture technology is an important export product for the Netherlands, and greenhouse horticulture in sunnier regions of the world can also benefit from the combination with PV panels and DC voltage.

Areas of overlap with other market segments

The concepts outlined above have areas of overlap with other market segments. Concept 1, where the lighting is supplied by a DC voltage grid, overlaps with the ‘public lighting’ market segment. A DC voltage grid is implemented in both market segments, whereby lighting is the primary application. Additionally, there is a trade-off in both market segments between the benefits of DC voltage grids and the benefits of LED lighting. One big difference between the two segments is the type of lamp. LED lighting in greenhouse horticulture is highly advanced and needs to deliver a range of different wavelengths to help plants to grow. In public lighting, a narrower spectrum is required, which means that LED lighting can save more energy—sometimes as much as 90%—when compared to the current state of affairs, than in greenhouse horticulture (40 – 50% savings). The costs of financing on account of high upfront investment means that the potential energy efficiency gains in the implementation of LED lighting in greenhouse horticulture are partially lost.

This makes the business case for greenhouse horticulture less profitable, which explains why only a small number of growers have thus far transitioned to LED lighting. This, coupled with uncertainty about the yields/effects on the crops, is causing some reluctance to adopt.

The second concept shares much in common with the ‘local DC voltage grids’ market segment, where multiple applications are connected to a local grid. As with the ‘local DC voltage grids’ market segment, it is notable that the impact of sustainable energy provides for a benefit for transitioning to a local DC voltage grid. This means fewer conversions, and an energy saving as a result. A more significant benefit is perhaps the saving on AC/DC converters and equipment for wiring. This is even greater when more DC voltage applications are connected to the DC voltage grid. The need for an additional AC/DC converter is reduced each time a DC application is added, although a DC/DC converter is still required. However, the latter is much smaller, wears less quickly and requires less equipment.

Current state of affairs

Table 1 shows projects involving DC voltage applications within greenhouse horticulture. There are only two, as the table shows. Both projects were undertaken with the aid of subsidies and are demonstration projects. Both projects are in the same area, with DOE DC being a continuation of the DC=DeCent project. These projects involved implementation of a DC voltage grid, whereby different applications are connected to one another in order to make optimal use of the lower number of converters. This is consistent with concept 2, as outlined above. The first project looked at the benefits of the application in this area, the second project focused on the development of this application. It was not possible to complete the business case in this project. The local setup delivered fewer cost savings than anticipated.

Project name	Project	Link to other technologies	Organisation	Subsidy	Type	Year (start)
DC=DeCent	The PrimAviera greenhouse region where the benefits of a DC voltage grid that is connected to the greenhouse region and that could function as a balance for the grid are being examined in conjunction with wind and solar PV.	Wind, solar PV, CHP	Direct Current/ InnoSys/Joulz/ Siemens/ Stallingsbedrijf Glastuinbouw Nederland/SGNL	IPIN subsidy finance 2011	Living lab and demonstration	2011 – 2015
DOE DC	The development and commissioning of a large-scale demonstration system in which a horticulture business was connected to a solar PV field.	Solar PV field	Direct Current/ Gavita/SGN/ Siemens/Solar Green Point/ SGNL/Vreeken Sierteelt	DEI	Demonstration	2015

Table 1 Greenhouse horticulture projects involving DC voltage applications

Market adoption

The 2018 DC Voltage Roadmap outlines timelines for the market adoption of DC voltage in different market segments. For greenhouse horticulture, the timeline outlined in the Roadmap is no longer realistic. The amended timeline is shown in Figure 3.

The Roadmap assumed that the application of DC voltage in greenhouse horticulture would be market ready by 2020, but the two projects shown in the table above have demonstrated that this is not the case. The year in which this phase is expected to be reached has, therefore, been postoned by five years, as indicated by the arrow in Figure 3.

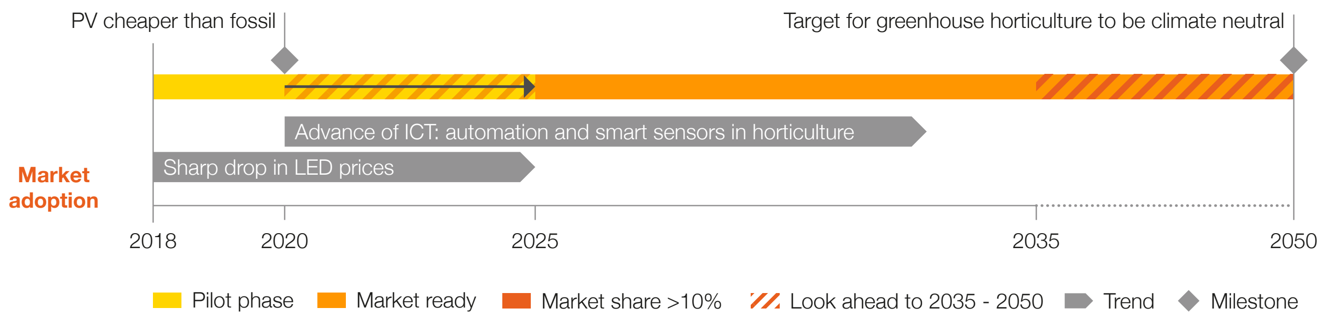

Figure 3 Amended timeline for greenhouse horticulture from DC Voltage Roadmap

Difficulties

High financial risk, lagging adoption of LED lighting and a lack of a proof of concept are difficulties that the development of DC voltage within greenhouse horticulture must overcome. In addition, the investment needed for a local DC voltage grid (concept 2) is often too high and too complex for a single business. These difficulties not only mean that a DC voltage grid has not yet been implemented, but that there is very little experimentation in the industry.

- **High financial risk (1)**
  Transition to DC voltage and LED lighting still involves high costs. These costs have a long payback time, so there are considerable financial risks involved with implementation by growers. Greenhouse horticulture operates from a commercial perspective, i.e. an innovation must be cheaper or offer major benefits for production before it is implemented. Neither is the case here, which explains why growers are not yet enthusiastic about using DC voltage. This is a major difference when compared to public lighting, where an innovation can be financed using public money.

- **Lagging adoption of LED lighting (2)**
  The quality of the light is of significant importance to growers. A traditional SON lamp emits light in a very broad spectrum, while LED lighting does not. To supply the same amount of light to illuminate a crop, relatively more LED lighting needs to be installed. Consequently, LED lamps are more expensive for greenhouse horticulture when compared to other market segments on account of the different quality/quantity of light required. Accordingly, the business case for LED lighting is different in greenhouse horticulture. The use of DC voltage makes sense only if it is paired with a transition to LED lamps, which makes the development of DC voltage grids dependent on the implementation of LED lighting.

- **Lack of proof of concept (3)**
  Proof of concept here is on two levels—inside the greenhouse and outside the greenhouse. The influence of LEDs differs from crop to crop. It is believed that crops respond differently to light of a certain wavelength, and growers are not yet clear on which crops respond well to which wavelengths (i.e. colours). Consequently, there are no business cases for growers, which means that they are not yet able to see the potential benefits of DC voltage and LEDs. The industry will only act once the technology has been proven to work with others, and experience from current pilot projects has not yet demonstrated that the technology has been proven.

- **Complexity of the local grid (4)**
  Major difficulties growers face in implementing a local DC voltage grid are the investment costs and the complexity of a local DC voltage grid. Most significantly, a professional infrastructure design will be required if several growers are to be connected to a single grid. This makes opting for a DC voltage grid a complex decision for individual growers. In addition, there is also the notion that the responsibility for a DC voltage grid rests with the grid operator.

Recommendations

There remains considerable ambiguity about the business case for DC voltage and LEDs in greenhouse horticulture. To remove these ambiguities, it is recommended that the business case and payback time for each crop type be made more transparent. When it comes to local DC voltage grids, grid operators must play a more active role in helping to shape the design of local DC voltage grids and the connection of wind or solar PV. If the business case appears to be positive, the government can lend support by eliminating the risks of implementing DC voltage.

- **Determine the business case for each crop type (A)**
  There remains considerable ambiguity about the **combined** effect of DC voltage and LED lamps, plus, no clear benefit has yet been quantified. For DC voltage to be a success, the effect of LEDs and DC voltage on different types of crop must be established. This will help to understand which products can benefit from LED lighting and DC voltage, and which products are less likely to be affected. Within this, the efficiency yield of a DC voltage grid must also be clearly defined, which will involve looking at the colour spectrum, the controllability and dimmability of the lamps.

- **Involve the grid operator in the process (B)**
  If it appears that DC voltage and LED lighting can offer major benefits for greenhouse horticulture, it will be important to involve grid operators in the implementation of local DC voltage grids. The grid operator could provide DC voltage to the infrastructure around the greenhouse area so that the farmer or grower can tap into it. It is also important that there is a smart setup behind the meter, especially in combination with PV panels. Here, the benefit for grid operators is that locally generated energy is fed into the local grid and not into the public low-voltage grid. Accordingly, a properly designed DC voltage system could help to reduce peak loads in the local grid. As such, it is recommended that a pilot be developed in which both growers and the grid operator play a role.

- **Eliminate risks (C)**
  For growers, there remain considerable risks associated with LED technology and DC voltage technology, independently of one another. Growers are heavily dependent on reliable lighting and will not readily transition to a new or unfamiliar technology. In addition, the long payback time and high investment costs mean that DC voltage is not financially attractive. If it appears that a major efficiency gain can be attained in greenhouse horticulture (see recommendation A), it may help to establish beneficial financing structures in order to remove the barrier of high investment.