**NOTE**

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| Distribution: | TC 312 and workgroups: 1, 2, 3 and 4. SKNG and SCF |
| Subject: |  |  |
| Comments and proposals for public enquiry of CEN prEN 15316-5 |

# Introduction

Commissioned by the Solar Certification Fund (5C8\_1 EPBD) an Excel implementation has been made that combines the hourly methods from prEN 15316-4-3 and prEN 15316-5 for evaluation purposes. Moreover, an Excel implementation of then prEN15316-4-3, method 2 (monthly) has been made for evaluation purposes.

During the development of the Excel implementation of the hourly method several major shortcomings have been identified that made it impossible to create a working evaluation tool. For that reason a list of comments and proposals for improvement have been drafted and is included in this document. Members of technical committees can use that for to complement their own comments and proposals.

The Excel implementation has been based on the prEN standards and the proposals in this document. As such is demonstrates of what the combination of both standards is capable of.

This document consist of the following:

* Revised text to be included in the prEN 15316-5 (this document)
* An Excel application as an attachement
* An annex with the comments in the format of CEN (as an attachement)

Contents:

1. Direct withdrawal of a heat quantity (volume to withdraw)
2. Temperature of the storage after volume withdrawal
3. Indirect heat input and output
4. Rearrange temperatures in the storage to a natural state
5. Thermal losses
6. Heat exchanger

# Annex I Text proposal to replace paragraph 6.4.3.4 of prEN 15316-5

Original title: Step 2 - Volume to be withdrawn from the storage (domestic hot water service)

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| **6.4.3.4 Step 2 - Direct withdrawal of a heat quantity (volume to withdraw)**The volume to be withdrawn is calculated according to the requirements for the direct heat output defined by the requested heat quantity, the minimum temperature and the maximum temperature. Note 1: the method is limited to direct heat output.Note 2: the method does not take into account simultaneous heating of the storage tank during the direct heat output.The maximum volume to withdraw is calculated by formula (4)

|  |  |
| --- | --- |
| $$V\_{sto;out;max}= \frac{Q\_{sto;out;req}}{ρ\_{w} ∙C\_{p;w} ∙ (ϑ\_{sto;out;req}- ϑ\_{sto;in})}$$ | (4) |

where

|  |  |  |
| --- | --- | --- |
| *Q*sto;out;req | kWh | is the requested heat output |
| *ϑ*sto;out;req | oC | is the requested output temperature |
| *ϑ*sto;in | oC | is the inlet temperature |

The maximum value of *V*sto;out;max is *V*sto;tot.The minimum value of *V*sto;out;max is 0. The heat stored for the service is calculated for each volume from *I*sto;in to *I*sto;out by formula (5a).

|  |  |
| --- | --- |
| $$Q\_{sto,i}= ρ\_{w} ∙C\_{p;w} ∙V\_{sto;vol,i} ∙ (ϑ\_{sto;vol,i}- ϑ\_{sto;in})$$ | (5a) |

where

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| --- | --- | --- |
| *i* | - | is the number of a volume in the storage tank, that ranges from *I*in to *I*out. |
| *I*sto;in | - | is the volume number of the cold water inlet (1 = bottom volume) |
| *I*sto;out | - | is the volume number of the hot water outlet  |
| *V*sto;vol,i | L | is the volume of a volume in the storage tank |
| *ϑ*sto;vol,i | oC | is the temperature of a volume in the storage tank |

The minimum value for *Q*sto,i is 0.The heat output for the service, without thresholds, is calculated, from outlet to inlet, with formula (5b) and the volume withdrawn, without thresholds, from the tank is calculated by formula (5c).

|  |  |
| --- | --- |
| $$Q\_{sto;out}= \sum\_{i=I\_{sto;out}}^{n}Q\_{sto,i}$$ | (5b) |

|  |  |
| --- | --- |
| $$V\_{sto;out}= \sum\_{i=I\_{sto;out}}^{n}V\_{sto;vol,i}$$ | (5c) |

where

|  |  |  |
| --- | --- | --- |
| *n* | - | is the number of a volume in the storage tank.The lowest value for *n* is *I*sto;in.*n* is limited to the volume number for which the condition (a) or (b) is met.Condition (a): $Q\_{sto;out}+Q\_{sto,i}>Q\_{sto;out;req}$Condition (b): $V\_{sto;out}+V\_{sto;vol,i}>V\_{sto;out;max}$ |

If condition (a) is met during the summation:The last volume (i) contains enough or more heat to comply with the requested heat. The part of this volume to be added to the total volume to withdraw is calculated by formula (5d).

|  |  |
| --- | --- |
| $$∆V\_{sto;out}= \frac{\left(Q\_{sto;our;req}-Q\_{sto;out}\right)}{ρ\_{w} ∙C\_{p;w} ∙\left(ϑ\_{sto;vol,i}- ϑ\_{sto;in}\right)}$$ | (5d) |

The maximum value for ∆*V*sto;out is *V*sto;out;max - *V*sto;outThe total withdrawn volume is calculated by formula (5e) and the total heat withdrawn is calculated by formula (5f).

|  |  |
| --- | --- |
| $$V\_{sto;out}=V\_{sto;out}+ ∆V\_{sto;out}$$ | (5e) |

|  |  |
| --- | --- |
| $$Q\_{sto;out}=Q\_{sto;out}+ ρ\_{w} ∙C\_{p;w} ∙ \left(ϑ\_{sto;vol,n}- ϑ\_{sto;in}\right)∙∆V\_{sto;out}$$ | (5f) |

 If condition (b) is met during the summation:The storage contains less heat than requested at the minimum output temperature, while the maximum volume withdrawn is reached. The remainder output heat is calculated with formula (5g) and the volume withdrawn from the tank is calculated by formula (5h).

|  |  |
| --- | --- |
| $$Q\_{sto;out}=Q\_{sto;out}+ ρ\_{w} ∙C\_{p;w} ∙ \left(ϑ\_{sto;vol,n}- ϑ\_{sto;in}\right)∙\left(V\_{sto;out;max }-V\_{sto;out}\right)$$ | (5g) |

|  |  |
| --- | --- |
| $$V\_{sto;out}=V\_{sto;out;max}$$ | (5h) |

In both cases the shortfall of output heat, if any, is calculated by formula (6).

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| $$Q\_{sto;del}=Q\_{sto;out;req}-Q\_{sto;out}$$ | (6) |

The hourly average output temperature is calculated by formula (7a).

|  |  |
| --- | --- |
| $$ϑ\_{sto;out}=ϑ\_{sto;in}+ \frac{Q\_{sto;out}}{ρ\_{w} ∙C\_{p;w} ∙V\_{sto;out}}$$ | (7a) |

If a bypass around the storage is assumed, and *V*sto;out < *V*sto;out;max, the outlet temperature after the bypass can be calculated by formula (7b).

|  |  |
| --- | --- |
| $$ϑ\_{sto;out;bypass}=ϑ\_{sto;in}+ \frac{Q\_{sto;out}}{ρ\_{w} ∙C\_{p;w} ∙V\_{sto;out;max}}$$ | (7b) |

The calculated volume to withdrawn is input for the subsequent calculation of the new storage temperatures in step 3 (6.4.3.4).Results of step 2: *V*sto;out, *Q*sto;out, *Q*sto;del, *ϑ*sto;out and *ϑ*sto;out;req. |

Further information for the editor:

Symbols used in the method (none local):

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| --- | --- | --- | --- |
| **Symbol** | **Dimension** | **Description** | **Input or output** |
| *Q*sto;out;req | kWh | Requested heat output | Input |
| *ϑ*sto;in | oC | Inlet temperature  | Input |
| *ϑ*sto;out;req | oC | Requested minimum outlet temperature (e.g. hot water temperature) | Input |
| *V*sto;vol,i | litres | Volume of volume I of the storage tank | Input |
| *ϑ*sto;vol,i | oC | Temperature of volume I of the storage tank | Input |
| *P*sto;in | - | Inlet volume number | Input |
| *P*sto;out | - | Outlet volume number | Input |
| *C*p;w | kWh/(kg.K) | Water specific heat (! **k**Wh!, to avoid repeated use of “1 000”) | Input |
| *ρ*w | Kg/l | Specific mass of water (! Litres ! t o avoid repeated use of “1 000”) | Input |
| *Q*sto;out | kWh | Realized heat output from the storage tank (≤ *Q*sto;out;req) | Output |
| *Q*sto;del | kWh | *Q*sto;out;req - *Q*sto;out | Output |
| *ϑ*sto;out | oC | Average outlet temperature | Output |
| *ϑ*sto;out;bypass | oC | Outlet temperature when an bypass control is applied | Output |

Additional info for Technical Report:

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| **6.4.3.4 Step 2 - Direct withdrawal of a heat quantity (volume to withdraw)**The following scenarios are valid for the use of the method for direct heat withdrawal.1. Direct heat withdrawal for domestic hot water
* *Q*sto;out;req is the heat demand for domestic hot water
* *ϑ*sto;in is the cold water temperature
* *ϑ*sto;out;req is the hot water temperature (minimum useful)
1. Direct heat withdrawal for space heating
* *Q*sto;out;req is the heat demand for space heating
* *ϑ*sto;in is the space heating distribution return temperature (low)
* *ϑ*sto;out;req is the required outlet temperature, calculated from the flow and *Q*sto;out;req (high)
 |

# Annex II Text proposal to replace paragraph 6.4.3.5 of prEN 15316-5

Original title: 6.4.3.5 Step 3 - Temperature of the storage after volume withdrawn for domestic hot water service

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| **6.4.3.5 Step 3 - Temperature of the storage after volume withdrawal** The volume withdrawn from the storage is assumed to be of plug-type. The assembly of the plug, in terms of volumes and temperatures, is determined as follows.Plug(*I*sto;in - 1): *V*sto;out and *ϑ*sto;inPlug(i): *V*sto;vol,i and *ϑ*sto;vol,iwherei = *I*sto;in to nn = is determined by the condition sVol > *V*sto;tot, where sVol is calculated by formula (3.1).

|  |  |
| --- | --- |
| $$sVol=\sum\_{i=P\_{sto;in-1}}^{n}V\_{plug,i}$$ | (3.1) |

The volume of the last plug volume *n* is adjusted according to formula (3.2).

|  |  |
| --- | --- |
| $$V\_{plug,n}=V\_{sto;vol,n}-(sVol-V\_{sto;tot})$$ | (3.2) |

The total volume of the plug replaces the corresponding volume of the storage tank, starting at the inlet volume (= *I*sto;in).The new temperature of each storage volume is calculated by blending (*V*plug,i < *V*sto;vol,j) or replacing (*V*plug,i > *V*sto;vol,j) an equal volume from the plug. Consequently this part of the plug is removed. The blending is calculated by formula (3.3)

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| $$ϑ\_{sto;vol,j}= \frac{V\_{plug,i} ∙ ϑ\_{plug,i}+V\_{plug,i+1} ∙ϑ\_{plug,i+1}+….}{V\_{sto;vol,j}}$$ | (3.3) |

The temperature stratification in the storage tank needs to be rearranged to its natural state by subsequent calculation according to the method in step 7 (6.4.3.8). |

Further information for the editor:

Symbols used in the method (none local):

|  |  |  |  |
| --- | --- | --- | --- |
| **Symbol** | **Dimension** | **Description** | **Input or output** |
| *V*sto;out | litres | Volume withdrawn from the storage tank | Input |
| *ϑ*sto;in | oC | Inlet temperature  | Input |
| *V*sto;vol,i | litres | Volume of volume i of the storage tank | Input |
| *ϑ*sto;vol,i | oC | Temperature of volume i of the storage tank | Input and output |
| *I*sto;in | - | Inlet volume number | Input |
| *I*sto;out | - | Outlet volume number | Input |
| *C*p;w | kWh/(kg.K) | Water specific heat (! **k**Wh!, to avoid repeated use of “1 000”) | Input |
| *ρ*w | Kg/l | Specific mass of water (! Litres ! t o avoid repeated use of “1 000”) | Input |

Scenarios for domestic hot water service and space heating service are equal

Graph to illustrate the plug.



Figure - Illustration of the behaviour of the 'plug' moving through the storage tank. V1 to V4 are the volume in the storage tank. P1 to P3 are the volumes of the plug. t1: the assembly of the plug. t2: V2 is replaced by P1 and part of P1 is removed from the plug. t3: V3 is replaced with a merge of part of P1 and P2 and removed from the plug. t4: V4 is replaced with a merge of P2 and P3.

# Annex III Text proposal to replace paragraph 6.4.3.8 of prEN 15316-5

Original title: 6.4.3.8 Step 6 – Energy input into the storage unit

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| **6.4.3.8 Step 6 - indirect heat input and output**The method describes indirect heat exchange in the storage tan. That is without replacing a volume of water. Note: the procedure is limited to the heat input and output in one volume of the storage. Note: in case of heat output from more than one volume, the highest volume shall be used. Note: in case of heat input in more than one volume, the lowest volume shall be used.Note: in case of more than one heat source, the procedure is called for each heat source from bottom to top.Note: in case of an external heat exchanger, the method can be applied as an acceptable alternative for direct heat input.Note: in case of a heat exchanger applied for indirect heat output, the inlet temperature for the storage is calculated with the procedure described in step 9 heat exchanger.The storage capacity for heat output, with a temperature above the inlet temperature, is calculated for each affected storage volumes by formula (9a).

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| $$Q\_{sto;out,i}= \left(ϑ\_{sto;vol,i}-ϑ\_{sto;out;inlet}\right)∙ ρ ∙C\_{p;w} ∙V\_{sto;vol,i}$$ | (9a) |

The minimum value of *Q*sto;out,i is 0.where  i = *I*sto to 1. *I*sto [-] is the highest volume affected by the heat output *ϑ*sto;vol,i [oC] is the temperature of storage volume *i* *V*sto;vol,i [l] is the volume of storage volume *i**ϑ*sto;out;inlet [oC] is the inlet temperatureThe heat output from the storage tank is calculated by formula (9b).

|  |  |
| --- | --- |
| $$Q\_{sto;out}= \sum\_{i=I\_{sto}}^{1}Q\_{sto;out,i}$$ | (9b) |

The maximum value for *Q*sto;out = *Q*sto;out;req. where *Q*sto;out;req [kWh] is the requested heat outputThe maximum storage capacity for heat input is calculated by formula (9c).

|  |  |
| --- | --- |
| $$Q\_{sto;in,i}= \left(ϑ\_{sto;max}- ϑ\_{sto;vol,i}\right)∙ ρ ∙C\_{p;w} ∙V\_{sto;vol,i}$$ | (9c) |

The minimum value of *Q*sto;in,i is 0.where  i = *I*sto to *N*vol. *I*sto [-] is the lowest volume affected by the heat input *N*vol [-] is the number of volumes of the storage tank *ϑ*sto;vol,i [oC] is the temperature of storage volume *i* *V*sto;vol,i [l] is the volume of storage volume *i**ϑ*sto;max [oC] is the thermostat setting of the heat sourceThe heat input in the storage tank is calculated by formula (9d).

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| --- | --- |
| $$Q\_{sto;in}= \sum\_{i=I\_{sto}}^{N\_{vol}}Q\_{sto;in,i}$$ | (9d) |

The maximum value for *Q*sto;in = *Q*sto;in;req. where *Q*sto;in;req [kWh] is the requested heat inputThe new temperature of volume *I*sto is calculated with formula (10).

|  |  |
| --- | --- |
| $$ϑ\_{sto;vol,I\_{sto}}= ϑ\_{sto;vol,I\_{sto}}+ \frac{Q\_{sto;in}-Q\_{sto;out}}{ρ ∙C\_{p;w} ∙V\_{sto;vol,I\_{sto}}} $$ | (10) |

Note: in case of a heat exchanger applied for indirect heat input, the inlet temperature for the heat source is calculated with the procedure described in step 9 heat exchanger.The procedure described in step 7 is subsequently executed to repair the natural temperature stratification in the storage tank. |

Further information for the editor:

Symbols used in the method (none local):

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| --- | --- | --- | --- |
| **Symbol** | **Dimension** | **Description** | **Input or output** |
| *I*sto | - | Target volume number | Input |
| *ϑ*sto;out;inlet | oC | Inlet temperature for heat output | Input |
| *ϑ*sto;vol,i | oC | Storage temperatures | In/Out |
| *V*sto;vol,i | litres | Storage volumes | Input |
| *Q*sto;in;req | kWh | Requested heat input | Input |
| *Q*sto;out;req | kWh | Requested heat output | Input |
| *ϑ*sto;max | oC | Thermostat setting for heat input | Input |
| *Q*sto;in | kWh | Heat input | Output |
| *Q*sto;out | kWh | Heat output | Output |
| *C*p;w | kWh/(kg.K) | Water specific heat (! **k**Wh!, to avoid repeated use of “1 000”) | Input |
| *ρ*w | Kg/l | Specific mass of water (! Litres ! t o avoid repeated use of “1 000”) | Input |

Scenario: Solar input

First call:

|  |  |
| --- | --- |
| *I*sto | Bottom volume of the storage  |
| *Q*sto;in;req | Result from solar thermal model |
| *ϑ*sto;max | 90 |
| *Q*sto;out;req | 0 |
| *ϑ*sto;out;inlet | 0 |

 Second call:

|  |  |
| --- | --- |
| *P*vol | third volume of four |
| *Q*sto;in;req | Maximum heat input from backup heater |
| *ϑ*sto;in;max | 70 |
| *Q*sto;out;req | Heat requested for space heating |
| *ϑ*sto;out;inlet | Space heating return temperature |

# Annex IV Text proposal to replace paragraph 6.4.3.9 of prEN 15316-5

Original title: 6.4.3.9 Step 7 – Temperatures in the storage after energy input

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| **6.4.3.9 Rearrange temperatures in the storage to a natural state** For each volume of the storage tank, starting with the lowest volume, the temperature difference between two adjacent volumes is evaluated.If *ϑ*sto;vol,i *> ϑ*sto;vol,i+1*,* both volumes are melted according to formula (11).

|  |  |
| --- | --- |
| $$ϑ\_{sto;vol,i}= ϑ\_{sto;vol,i+1}= \frac{ϑ\_{sto;vol,i} ∙V\_{sto;vol,i}+ ϑ\_{sto;vol,i+1} ∙V\_{sto;vol,i+1}}{V\_{sto;vol,i}+V\_{sto;vol,i+1}}$$ | (11) |

This procedure is repeated until the above condition is not met for any adjacent volumes. Note: for practical purposes a temperature difference of 0,01 K is assumed as being equal. |

# Annex V Text proposal to replace paragraph 6.4.3.10 of prEN 15316-5

Original title: 6.4.3.10 Step 8 – Step 8 Thermal losses and final temperature

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| **6.4.3.10 Step 8 - thermal losses** The thermal losses of the heat storage tank are calculated for each volume (i) by formula (12).

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| --- | --- |
| $$Q\_{sto;vol;ls,i}= \frac{H\_{sto;ls}}{1000} ∙ \frac{V\_{sto;vol,i}}{V\_{sto;tot}} ∙ \left(ϑ\_{sto;vol,i}- ϑ\_{sto;amb}\right)$$ | (12) |

where

|  |  |  |
| --- | --- | --- |
| *H*sto;ls | [W/K] | is the standby losses coefficient |
| *V*sto;vol,i | [l] | is the volume of volume segment I of the storage tank |
| *V*sto;tot | [l] | is the total volume of the storage tank |
| *ϑ*sto;vol,i | oC | is the temperature of volume i |
| *ϑ*sto;amb | oC | is the ambient temperature |

The new storage temperatures are calculated by formula (13).

|  |  |
| --- | --- |
| $$ϑ\_{sto;vol,i}=ϑ\_{sto;vol,i}- \frac{Q\_{sto;vol;ls,i}}{ρ ∙C\_{p;w} ∙V\_{sto;vol,i}}$$ | (13) |

where

|  |  |  |
| --- | --- | --- |
| *C*p;w | kWh/(kg.K) | is the water specific heat (! **k**Wh!, to avoid repeated use of “1 000”) |
| *ρ*w | Kg/l | is the specific mass of water (! Litres ! t o avoid repeated use of “1 000”) |

Note: formula (12) uses a volumetric coefficient for characterisation of the thermal lossesNote: the heat losses are assumed to be evenly distributed over the storage tank.  |

Further information for the editor:

Symbols used in the method (none local):

|  |  |  |  |
| --- | --- | --- | --- |
| *V*sto;vol,i | litres | Volume of volume i of the storage tank | Input |
| *ϑ*sto;vol,i | oC | Temperature of volume i of the storage tank | Input and output |
| *H*sto;ls | W/K | is the standby losses coefficient | Input |
| *ϑ*sto;amb | oC | is the ambient temperature | Input |
| *C*p;w | kWh/(kg.K) | Water specific heat (! **k**Wh!, to avoid repeated use of “1 000”) | Input |
| *ρ*w | Kg/l | Specific mass of water (! Litres ! t o avoid repeated use of “1 000”) | Input |

Scenarios:

Typically, the method is called after to finalize all calculations within an hour step.

# Annex VI Text proposal for heat exchanger

Original title: Not included in prEN15316-5

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| **6.4.3.11 Step 9 - heat exchanger** The heat exchanger forces a temperature difference, between the two attached water circuits, that is calculated by formula (VI.1)

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| $$∆ϑ\_{exch}=\frac{Q\_{exch} ∙1 000}{H\_{exch} ∙t\_{ci}}$$ | (VI.1) |

where

|  |  |  |
| --- | --- | --- |
| *Qexch* | kWh | is the heat transferred by the heat exchanger |
| *t*ci | h | is the time step of the calculation |
| *H*exch | W/K | is the heat transfer rate of the heat exchanger |

Note: a heat transfer rate of the heat exchanger of zero is not allowed. A heat transfer rate of a (relatively) high value effectively describes a situation without a heat exchanger.Note: the method can be used for an integrated heat exchanger and an external heat exchanger. |

Further information for the editor:

Symbols used in the method (none local):

|  |  |  |  |
| --- | --- | --- | --- |
| *Qexch* | kWh | is the heat transferred by the heat exchanger | Input |
| *t*ci | h | is the time step of the calculation | Input  |
| *H*exch | W/K | is the heat transfer rate of the heat exchanger | Input |

Additional info for Technical Report:

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| **6.4.3.11 Heat exchanger** The following scenarios are valid for the use of the method for the heat exchanger.1. Indirect heat input in the storage, using a solar collector loop.

The collector loop temperature is ‘free floating’ governed by the temperature of the storage. The collector loop inlet temperature, from the heat exchanger connected to the storage tank, is calculated by:

|  |  |
| --- | --- |
| $$ϑ\_{sol;loop;in}=ϑ\_{sto;out}+∆ϑ\_{exch}$$ |  |

where

|  |  |  |
| --- | --- | --- |
| *Q*exch | kWh | Is equal to the collector loop output (=*Q*sol;loop;out). |
| *ϑ*sto;out | oC | is the outlet temperature of the storage to the heat source loop |

The *ϑ*sto;out is related to the *Q*sol;loop;out. Iteration is required until the temperature difference between two successive *ϑ*sol;loop;in is smaller than 0,1 K.1. Indirect heat output from the storage to the space heating service.

The temperature level of this process is governed by the space heating (distribution) return temperature. The storage inlet temperature is calculated by:

|  |  |
| --- | --- |
| $$ϑ\_{sto;in}=ϑ\_{S;dis;rtn}+∆ϑ\_{exch}$$ |  |

where

|  |  |  |
| --- | --- | --- |
| *Q*exch | kWh | Is equal to the store output heat (=*Q*sto;out). |
| *ϑ*S;dis;rtn | oC | is the return temperature of the space heating distribution system |

The *ϑ*sto;in is related to the *Q*sto;out. Iteration is required until the temperature difference between two successive *ϑ*sto;in is smaller than 0,1 K. |