USER COMFORT

For Flexines it is important to define the comfort ranges of the different devices that we use. The larger the range, the more money can be saved. Because every person has a different comfort range we need to come up with a comfort range algorithm that can adjust itself according to user votes. In this chapter we describe a method to develop such an algorithm, and what factors influence the perception of comfort like price and comfort.

Wat is Comfort?

According to historian John Crowley, interpretations of comfort as “self-conscious satisfaction with the relationship between one’s body and its immediate physical environment” date from the seventeenth century (Crowley, 2001, p. 142). This relation of satisfaction has since been embodied to the extent that when applied to food, furniture, clothing, or the indoor climate, the labels of “comfort” or “comfortable” now describe an attribute of the item or experience in question.

So the comfort range is the range of temperatures in which the user feels comfortable, but we also need to take in account convenience. The term convenience, originally referring to fitness for purpose was adopted in the 1960s to describe arrangements, devices, or services that helped save or shift time; convenience food being classic example.
For example the washing machine has a small comfort range(it needs to be clean). For Flexines we can’t change the comfort expectations of users, but we can change convenience ranges. For a certain price people are willing to delay their washing. Maybe some delays can be beneficial or convenient .

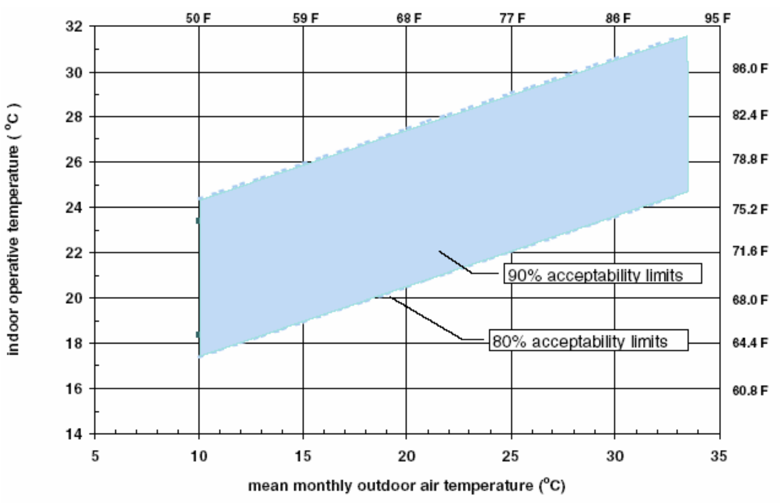
Thermal Comfort

During our search for information we found the paper written by Pfeffer, conducted by the university of California (Pfeffer, 2009). Their goal was to develop an adaptive algorithm for calculating the *thermal comfort range* in residential homes and to define a comfort range.
The results of this research can be used to answer some of our own research questions. The scope of this research is primarily focused on heating and cooling but the concept for an algorithm and the calculated comfort range and steps are interesting and useful for the Flexines project.
For developing the thermal comfort range algorithm they have used the current standard developed by the AHSRAE (The American Society of Heating, Refrigerating and Air-Conditioning). This standard is a model that calculates the desired temperature inside a building. The temperature ±2 .5 o°C is the comfort range in which 90% of all people feel comfortable or ±2 .5 o°C for 80% acceptability.
Because the model is developed for larger buildings like offices and not for residential homes the algorithm needs to be modified so that its suited for homes.
The difference between residential homes and offices is that home owners have a wide latitude in choice of clothing, activity and location in order to make the adjustments necessary to be comfortable. And people pay their own energy bill so they will accept more discomfort than at the office.
In the research conducted by Pfeffer they’ve added the influence from humidity, daily temperature that are not included in the ASHRAE standard.(Pfeffer, 2009)

"These weighting coefficients can be used to calculate the appropriate mean outdoor temperature (*T*mot) for subsequent input to an adaptive indoor temperature algorithm: *T*mot = 0.34*T*Dayx-1 + 0.23*T*Dayx-2 + 0.16*T*Dayx-3 +

0.11*T*Dayx-4 + 0.08*T*Dayx-5 + 0.05*T*Dayx-6 + 0.03*T*Dayx-7 and then the adaptive algorithm for indoor comfort temperatures in a naturally ventilated or free running building (de Dear & Brager 2002) can be written as comfort temperature (°C) = 0.31*T*mot + 17.8 (4) and the *acceptable range* of temperatures is defined as the optimal comfort temperature (Eq. 4) ± 2.5°C for 90% acceptability, or ±3.5°C for 80% acceptability (ASHRAE 2002)" (Morgan & de Dear, 2003).

The result of this algorithm is a range of temperatures as shown below



Other comfort devices

We can use the concept of this algorithm for other devices. We need to learn the comfort ranges of the user for several devices. Most interactions with these devices are[routinematig]. As discussed by James Pierce, Diane J. Schiano and Eric Paulos in their paper *Home, Habits, and Energy: Examining Domestic Interactions and Energy Consumption* is that everyday energy consumption behaviors appear to be strongly shaped and enforced by the micro-level systems (e.g., thermostat interface) and macro-level systems (e.g., HVAC standards and infrastructures) that compose our everyday material environments.(Pierce, Schiano, & Paulos)

For increasing the comfort range we could focus on micro and macro level systems design as described by Pierce, Schiano and Paulos but we could also educate the user.

For example, most people don't know their current refrigerator settings and people also don't know the different temperature zones in their refrigerator (Evans, Stanton, Russel, & James, 1991). So the comfort range of these devices aren't only determined by user votes but also by technical and hygienic limits.

Comfort scale

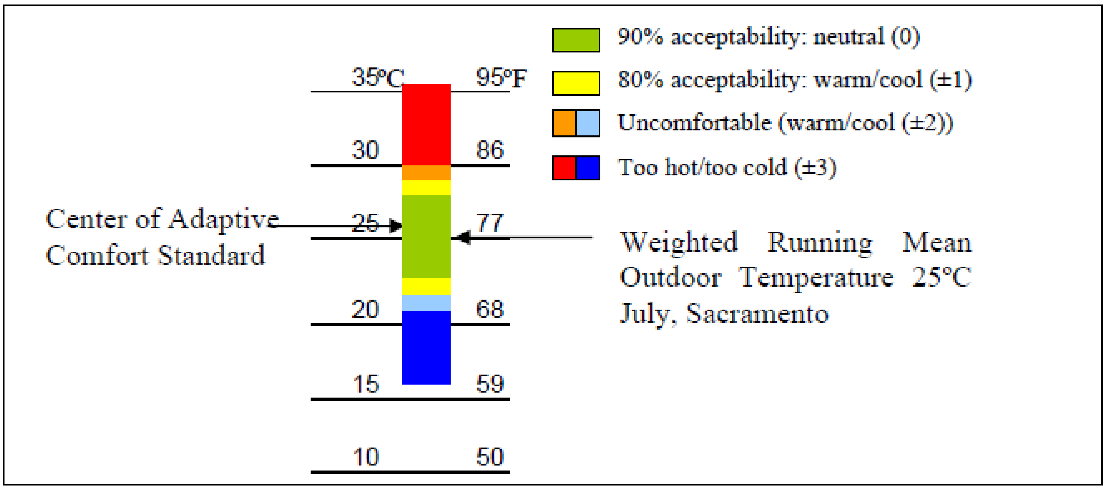
To give the user the control and determine its balance between comfort and saving money we can use a comfort scale. This scale is based on the Bedford psychophysical voting scale:

-1 to 1 is comfortable

-2 to -1 & 1 to 2 is comfortably cool/warm

-3 to -2 & 2 to 3 is uncomfortably cool or warm

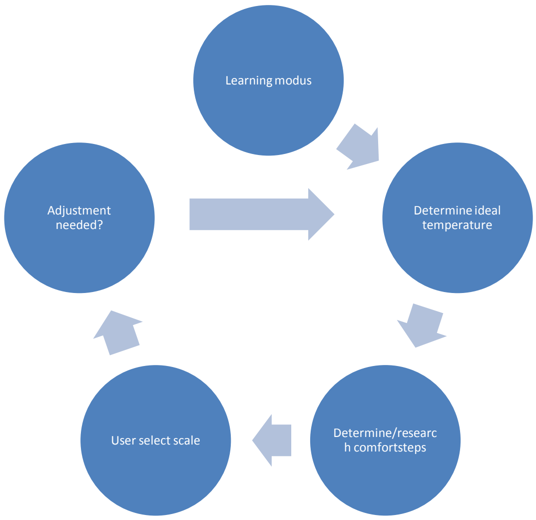
less than -3 & greater than 3 is very uncomfortably cool or warm



The most center step is most comfortable. This step is for example in thermal comfort the ideal temperature ±2 .5 o°C . If the user selects this zone the Flexines EMS doesn't exceed the set points for this comfort step resulting in a (near) perfect temperature. A result of selecting this step is that the EMS doesn't have a lot of room to save money. By selecting a different step the balance between comfort and saving money changes.
It is important that the user receives feedback over the chosen step. A user needs to know their possible savings. Why should the user otherwise select a wider step?
the user needs to know what he or she can save en how it's going to affect their comfort e.g. "*the top shelf in the refrigerator will be too hot for storing meat, but when meat is placed in the cooler bottom shelf you can save 10%*".

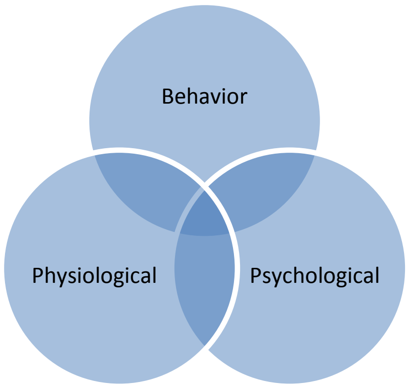
Price influence
We think that price has an influence on the comfort range. People want to be in control and want the feeling that they can control the range. Users should always receive feedback how much money they can save when they adjust the comfort-economy slider. Feedback on savings also gives the user the feeling that he is in control.

Learning mode
To learn the comfort range of the user the system needs to have a learning mode. During a period of a few weeks the device should try to discover the center of the comfort scale. Then the steps on the scale have to be discovered. After this period the system has setpoints for all steps in the comfort scale.

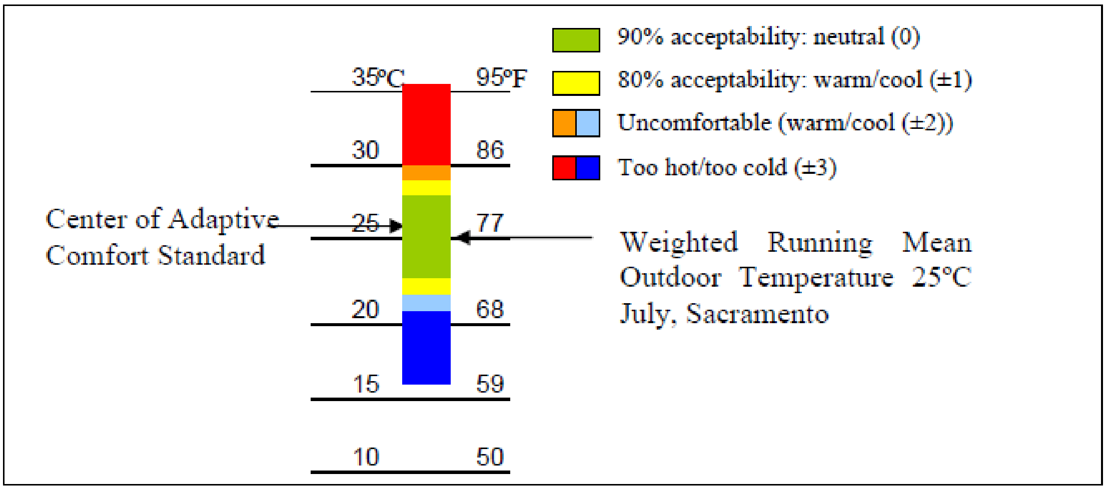


Conclusion

According to several researches it is possible to create an adaptive algorithm, but to create one that's good for everybody is a challenge. If a user doesn't get sufficient feedback the user won't accept certain limitations on their comfort.



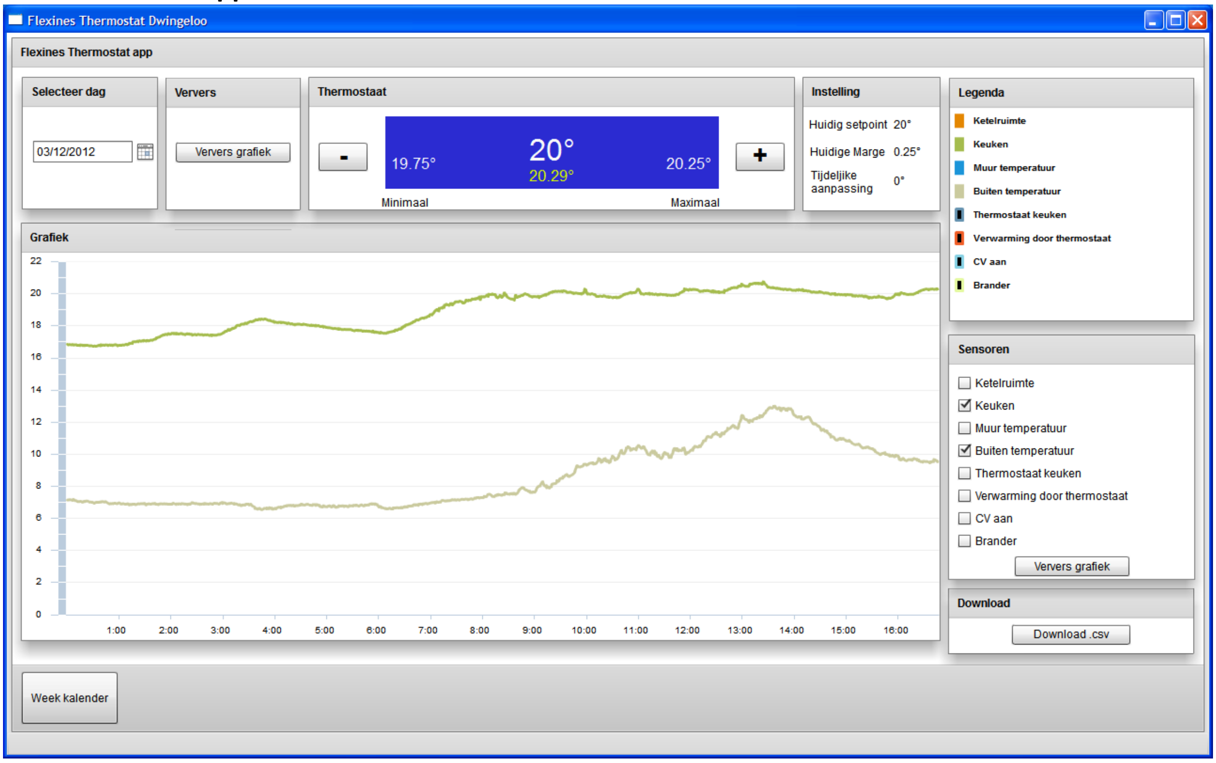
We can divide the variables into three groups: Behavior, Physiological and Psychological. The behavioral and psychological factors are possibly the hardest to determine.
We need to conduct field-test to determine the behavioral and psychological variables and how they affect the physiological variables. A example of the psychological aspect is the perception of control. Does the user need to be in control to accept certain temperatures? And is the user willing to lower their comfort standards if he can save money?
In order to give the user the option to lower his comfort standards in order to save money we need to develop a scale where a comfort step is related to money e.g. The EMS can adjust the thermostat +/- 2.5 degrees celcius to save money, and this setting can save you 10%, but another setpoint can be that de EMS can adjust the thermostat +/- 3.5 degrees celcius and can save you 20%.



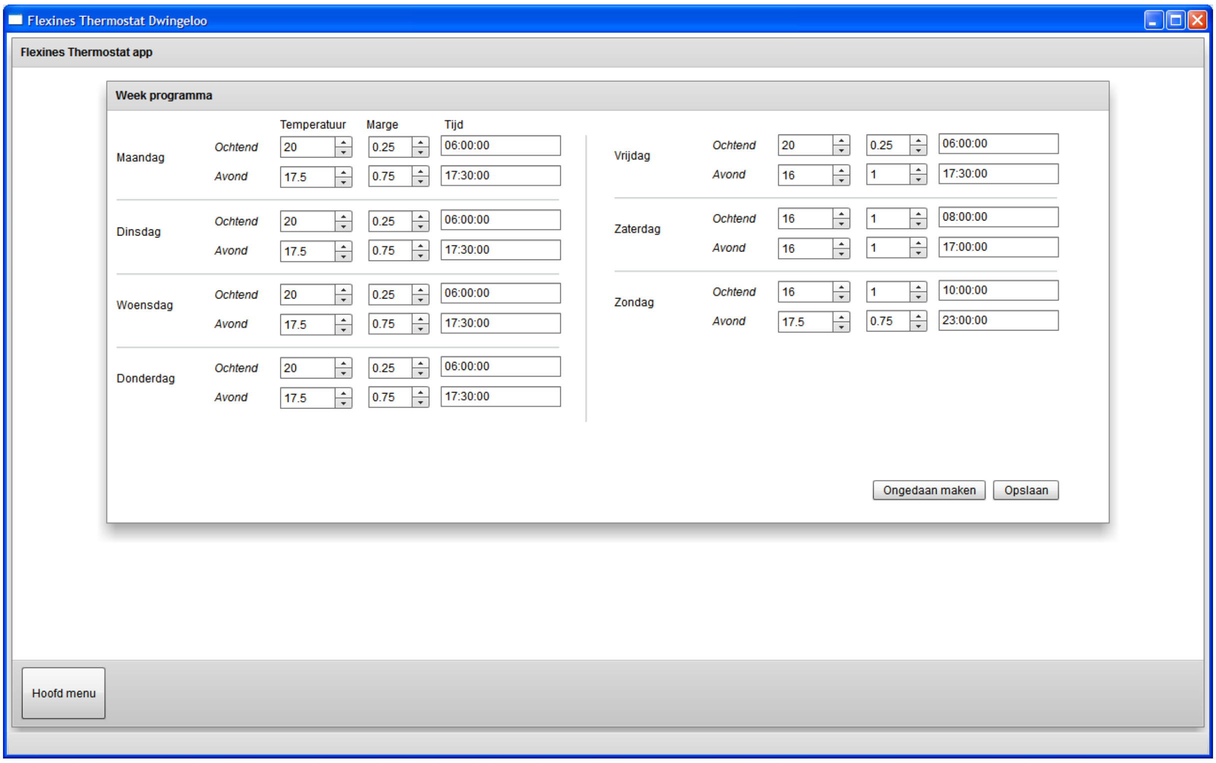
Application results / practical results

To test the reaction of users on the Flexines EMS we established a "production setup". The production setup consisted of an app and a Flexines control system, which controls the temperature in the house. The app provides allows users to define their comfortlevel by providing a temperature and a range. The temperature is the target temperature, and the range defines how many degrees warmer or colder the temperature in the house may actually be. The Flexines control system then finds - given the cost of energy - the optimal temperature whilst staying within the provided temperature range.

De thermostaat app



The main screen provides the user the relevant measurement data. The user has the capability to temporarily lower or increase (minus and plus buttons) the temperature.



The second screen allows the user to change the settings in a calendar. In this way, the user can program the future temperature in the house.

Results

The user did not affect any significant change to the comfortlevel settings in the Flexines app.

During the experiment, we did not test how energy prices influence user behaviour.