Personal Energy Administration Kiosk application:
an ICT-ecosystem for Energy Savings
through Behavioural Change, Flexible Tariffs and Fun
Contract No 695945

Deliverable 1.3
List of KPIs for the evaluation of the ICT's impact

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Content

1 Introduction and Motivation

The PEAKapp project develops a software tool that collects load profiles of households' electricity consumption, transforms this rather technical data into user friendly aggregates, and returns the information to the households in a way that is engaging and motivating to increase energy efficiency.

Deliverable 1.3 deals with the question of how the app actually stimulates energy efficient behaviour and related decisions of the households. To answer this question, PEAKapp carries out field tests in four European countries and, thereby, provides important information for decision makers from utility companies, policy, consumer associations, and regional or federal energy planners, as well as other stakeholders. In this deliverable we will define a set of indicators to analyse the collected information. Considering the differing technical preconditions and national legal/regulatory frameworks of the test sites, not all indicators can be provided for all sites.

In contrast to **Deliverable 1.5,** which developed key performance indicators that will support decision makers in assessing whether the tool developed in PEAKapp meets their requirements with respect to technical readiness, consumer comprehensibility, and the expected effort for the provision of the services to households, Deliverable 1.3 will focus on the indicators that measure the environmental impact of PEAKapp and how households' energy consumption patterns are changing.

The subsequent chapters describe these indicators in detail, as well as, the required data for their quantification and how to interpret them.

2 Information requirements inventory

PEAKapp targets the development of an app to trigger lasting energy savings through behavioural change and continuous engagement, to enable increased consumption of clean and low priced electricity from the spot market for household customers. The environmental key performance indicators (*eKPI*), presented in this deliverable, serve as internal and external evaluation tools of the impact of the app on consumers energy consumption behaviour.

This deliverable therefore lists the information that is required by decision makers for the judgment whether an ICT tool - like the one developed in PEAKapp - meets the aforementioned criteria or not.

2.1 Glossar

Term	Description
User	The PEAKapp **user** references one account to the PEAKapp system where one account is representing one household. Users will be randomly divided into three different of groups: Group A, Group B and Group C
Active User	A user is called active when he has logged in into the app at least once in a month.
Account	One household in the PEAKapp system, which can consist of one person or more.
Cohort	The term **cohort** refers to a Group of people who can be restricted geographically and/or demographically. An example for a cohort is: All Austrian citizens, younger than 50 years, living in a flat. If possible Groups will be defined for people living in a flat/house. The cohorts will be defined after the field test.
Group A	App users who benefit from the complete ICT-system, **including** the dynamic electricity prices.
Group B	App users who benefit from the complete ICT-system, **excluding** the dynamic electricity prices.
Group C	Control Group which is not enjoying the system at all, but only their consumption data is recorded.
Treatment Group A	Number of all users who have downloaded the app. Consists out of Group A.
Treatment Group B	Number of all users who have downloaded the app. Consists out of Group B.
Treatment Group	Number of all users who have downloaded the app. Consists out of Group A + Group B and refers to the variable “number of users in month *m*”**.**
Active Treatment Group	Number of all users who have downloaded the app and have logged in into the app at least once in a month. Consists out of Group A + B refers to the variable “number of active users in month *m*”**.**
Control Group	Number of people who are not using the app. Consists out of Group C

2.2 Indices

Index	Symbol	Units	Description
User identifier	*i*	a user	The index of a user, i.e. *i*=1 refers to the user number 1
Months after release	*m*	# of months	Counts the months since the release of the app, with *m* = 1 as the starting point.
Total months	*M*	# of months	*M* is the last month of the field test, e.g. *M* = 12 in the last month of the field tests if it is carried out for one year.
Group	*g*	a Group {A,B or C}	*g* is the affiliation to the respective treatment/control group of the user. Example: If a user is part of treatment group A, then *g* = A
Time slot for price incentive	*s*	a time interval {1,2 or 3}	*s* = 1 for before hours when the price incentive was granted, *s* = 2 for during hours when the price incentive was granted, *s* = 3 for after hours when the price incentive was granted Time intervals will be specified later in the project.

3 Environmental key performance indicators (*eKPI*)

In this section we will define the indicators which are measuring the impact of the ICT on consumer energy consumption behaviour. We will analyse whether the app has a significant impact on energy consumption by comparing average household energy consumption of the treatment group with the average energy consumption of the control group. Furthermore, a set of indicators will depict the average energy savings in monetary terms and in *GHG* emissions. We decided to calculate the *eKPIs* for the following different types of groups:

- Treatment Group (A + B)
- Active Treatment Group (A+B)

Furthermore the *eKPIs* will be calculated for different types of cohorts, like people living in a flat or living in a house.

By comparing the average energy consumption of the different treatment groups with the control group, we can assess whether the app has a significant impact on the user. Furthermore, we can analyse which of the groups had the largest shift in energy consumption or if there is no difference in average energy consumption between the different groups, i.e. no impact of the app on user behaviour.

The quantified change in energy consumption in kWh will be transformed into monetary terms and into *GHG* emissions. This transformation shows how much money could be saved on average and whether the app contributes to a significant decrease in households' *GHG* emissions.

3.1 Energy Saving *eKPIs*

Energy saving related *eKPIs* depict the change in the energy consumption of the app users over time. They compare the average energy consumption per month and the average energy consumption during the field test of the treatment groups with the average energy consumption of the control group. To calculate the *eKPIs*, the energy savings will be set into relation with the average energy consumption of the control group.

The reason for the comparison of the average value of energy consumption and not the total value of energy consumption is because treatment group and control group do not consist of the same number of people and therefore the comparison of the total energy consumptions of the respective groups would give misleading results.

The **average energy consumption** for the control group is calculated by **dividing the total energy consumption for each month, *m,* through the number of people** who belong to the control group in month *m*. The average energy consumption for the treatment groups is calculated in the same manner, but with the energy consumption and number of people of the respective group. To receive the **average energy savings in month *m,*** the average energy consumption of the control group has to be subtracted from the average energy consumption of the respective treatment group (see Eq 1 to Eq 4),

as we would expect the respective difference to be zero had there be no treatment in the treatment group.

The **average monthly energy savings** for the total field test duration are calculated by dividing the total energy saving of the respective group for m=1,…,M through the sum of month that respondents have participated in their respective group. In the final step of calculating the *eKPI,* the average energy savings of the respective group are divided by the average energy consumption of the Control Group. (see Eq 5 to Eq 8)

The **total average energy savings** for the whole field test duration is the sum of average monthly energy savings each weighed by the number of participants in the treatment Group in the respective month.

3.1.1 Energy Saving for the Treatment Group ($eKPI_{ES1,m}$, $eKPI_{ES1,a}$ and $eKPI_{ES1,M}$)

The indicators of the average energy savings for the treatment group show the difference between average energy consumption of the control group and treatment group. Three indicators have been defined:

The $\boldsymbol{eKPI_{ES1,m}}$ returns the average energy savings of the treatment group compared to the control group for one specific month *m*.

It is helpful to calculate the $eKPI_{ES1,m}$ for a certain time period, in order to compare the evolution of the average energy savings over time. This allows us to analyse the impact of updates and peak periods that can be identified.

The $\boldsymbol{eKPI_{ES1,a}}$ returns the average monthly energy savings of the treatment group compared to the control group during the whole field test period.

The second indicator averages the monthly energy savings over the whole field test and it depicts if the app users could overall reduce their energy consumption from the beginning until the end of the field test compared to the control group. This is important, as an initially high motivation for energy conservating behaviour might level off over time.

The $\boldsymbol{eKPI_{ES1,M}}$ gives the total average energy savings per user over the whole field test period.

The third indicator gives the average energy savings of a participant over the whole field test period.

Eq 1 to Eq 4 describe the calculation process for $eKPI_{ES1,m}$. In the first steps the average energy consumption per month of the treatment and control group ($AECG_m$ and $AETG_m$) are calculated by Eq 1 and Eq 2. The average energy consumption is calculated by dividing the energy consumption in month *m* of the respective group (ECG_m or ETG_m) through the number of users in the respective group (CG_m or TG_m).

In the second step the energy savings per month (ES_m) are calculated by subtracting the average energy consumption of the control group from the average consumption of the treatment group (Eq 3). Finally the energy savings per month are set into relation with the average energy consumption of the control group (Eq 4).

Necessary variables to calculate the indicators are listed in Table 1.

Table 1: Variables for the calculation of $eKPI_{ES1,m}$, $eKPI_{ES1,a}$ and $eKPI_{ES1,M}$

Variable	Symbol	Units	Description
Energy consumption of the control group in month *m*	ECG_m	in kWh	Total energy consumption of the control group in month *m*.
Energy consumption of the treatment group in month *m*	ETG_m	in kWh	Total energy consumption of the treatment group in month *m*.
Treatment group in month *m*	TG_m	# of users	Treatment group consists out of all users which have downloaded the app until month *m*.
Control group in month *m*	CG_m	# of non-users	Control group consists out of all selected non-users in month *m*.

Monthly energy consumption of the Control Group ($AECG_m$)

$$AECG_m = \frac{ECG_m}{CG_m} \quad \text{Eq 1}$$

Monthly energy consumption of the Treatment Group ($AETG_m$)

$$AETG_m = \frac{ETG_m}{TG_m} \quad \text{Eq 2}$$

Energy saving (ES_m)

$$ES_m = AETG_m - AECG_m \quad \text{Eq 3}$$

$$KPI_{ES1,m} = \frac{ES_m}{AECG_m} \quad \text{Eq 4}$$

The calculation of $eKPI_{ES1,a}$ follows the same process as mentioned above, but the calculations are based on the total energy consumption during the field test of the treatment and control group and the number of months that respondents have participated in their respective group. The calculation process for $eKIP_{ES1,a}$ is described by Eq 5 to Eq 8.

Average monthly energy consumption of the Control Group ($AECG_a$)

$$AECG_a = \frac{\sum_{m=1}^{M} ECG_m}{\sum_{m=1}^{M} CG_m} \quad \text{Eq 5}$$

Average monthly energy consumption of the Treatment Group ($AETG_a$)

$$AETG_a = \frac{\sum_{m=1}^{M} ETG_m}{\sum_{m=1}^{M} TG_m} \quad \text{Eq 6}$$

Average monthly energy saving (ES_a)

$$ES_a = AETG_a - AECG_a \quad \text{Eq 7}$$

$$eKPI_{ES1,a} = \frac{ES_a}{AECG_a} \quad \text{Eq 8}$$

The calculation of the $eKPI_{ES1,M}$ is described by Eq 9 to Eq 10. In the first step, to calculate ES_M the energy saving in month *m* is weighted by the number of participants in the treatment group in month *m* and then summed up over the whole field test period. In the second step the weighed sum of the energy saving over the whole field test is divided by the total average energy consumption over the whole field test period of the control group.

Total energy saving (ES_M)

$$ES_M = \sum_{m=1}^{M} ES_m \frac{TG_m}{max(TG_1, \dots, TG_M)} \quad \text{Eq 9}$$

$$eKPI_{ES1,M} = \frac{ES_M}{M \sum_{m=1}^{M} ECG_m / \sum_{m=1}^{M} CG_m} \quad \text{Eq 10}$$

Table 2 gives an example for the calculation of the two $eKPI_{ES1,m}$ and $eKPI_{ES1,a}$. The columns "Treatment Group" are indicating if the user is part of the treatment group or not with 1 = Treatment Group and 0 = Control Group. The $eKPI_{ES1,m}$ for m = 3 is -5.08 % compared to the average energy consumption of the control group. In m = 3 the average energy consumption of the treatment group is 15 kWh lower than the average energy consumption of the control group.

The $eKPI_{ES1,a}$ is calculated in the last column of Table 2. In an average month the treatment group could save 9.27 % of their energy consumption compared to the control group. In absolute terms, the monthly average energy savings of the treatment group compared to the control group during the whole field test are 27.92 kWh.

In the example the total average energy savings per user over the whole field test period are 4.7 %. The treatment group could save 56.6 kWh in total on average over the whole field test period compared to the control group which can be seen in the following calculations. The third indicator $eKPI_{ES1,M}$ is calculated from columns m=1,…,m=4 from Table 2:

$$\boldsymbol{ES_M = \sum_{m=1}^{M} ES_m \frac{TG_m}{max(TG_1,\ldots,TG_M)} = \left(5\ \frac{1}{3}\right) + \left(-5\frac{2}{3}\right) + \left(-15\frac{3}{3}\right) + \left(-40\frac{3}{3}\right) = -56.6\ \mathbf{kWh}.}$$

Based on ES_M the $eKPI_{ES1,M}$ is calculated as follows:

$$\boldsymbol{eKPI_{ES1,M} = \frac{ES_M}{M\sum_{m=1}^{M} ECG_m / \sum_{m=1}^{M} CG_m} = \frac{-56.6}{4\ (670+630+590+520)/(2+2+2+2)} = -4.7\%.}$$

The mentioned *eKPIs* can be calculated for different types of groups. It is planned to calculate these *eKPIs* for the treatment group A, which consists out of all app users who are benefiting from the complete ICT-system, including the dynamic electricity prices and for treatment group B, which is excluded of the dynamic electricity prices. Furthermore, these two *eKPIs* will be calculated for different cohorts, like people living in a flat or house.

Table 2: Example for the calculation of the average energy saving of the treatment group ($eKPI_{ES1,m}$ and $eKPI_{ES1,a}$)

Assumption: App release 1st January, field test duration 4 months		m=1		m=2		m=3		m=4		Total months		
		January		February		March		April		January-April		
ID	Date of download	Energy consumption (kWh)	Treatment Group	Energy consumption (kWh)	Treatment Group	Energy consumption (kWh)	Treatment Group	Energy consumption (kWh)	Treatment Group	Sum of Energy consumption (kWh)	Sum of Months TG	Sum of Months CG
1	20th January	340	1	300	1	280	1	220	1	1140	4	
2		330	0	300	0	290	0	240	0	1160		4
3	25th February			320	1	270	1	210	1	800	3	
4	2nd March					290	1	230	1	520	2	
5		340	0	330	0	300	0	280	0	1250		4
Control Group (CG_m, $\sum_{m=1}^{M} CG_m$)		2		2		2		2		8		
Treatment Group (TG_m, $\sum_{m=1}^{M} TG_m$)		1		2		3		3		9		
Energy Consumption *CG* (ECG_m, $\sum_{m=1}^{M} ECG_m$)		670 kWh		630 kWh		590 kWh		520 kWh		2,410 kWh		
Energy Consumption *TG* (ETG_m, $\sum_{m=1}^{M} ETG_m$)		340 kWh		620 kWh		840 kWh		660 kWh		2,460 kWh		
Average Energy Consumption *CG* ($AECG_m$, $AECG_a$)		335 kWh		315 kWh		295 kWh		260 kWh		301.25 kWh		
Average Energy Consumption *TG* ($AETG_m$, $AETG_a$)		340 kWh		310 kWh		280 kWh		220 kWh		273.33 kWh		
Energy Saving (ES_m, ES_a)		**5 kWh**		**-5 kWh**		**-15 kWh**		**-40 kWh**		**-27.92 kWh**		
$eKPI_{ES1,m}$ and $eKPI_{ES1,a}$		**1.49 %**		**-1.59 %**		**-5.08 %**		**-15.38 %**		**-9.27 %**		

Table 3 and Table 4 are giving an overview of success indicators for $eKPI_{ES1,m}$ and $eKPI_{ES1,tot}$ to check whether the project was a success, promising, missing the target.

Table 3: Success indication for the $eKPI_{ES1,m}$

Time specification in month *m*	Success	Promising	Missed the Target
1	< - 2 %	-2 % to 0 %	> 0 %
2	< - 2 %	-2 % to 0 %	> 0 %
3	< - 2 %	-2 % to 0 %	> 0 %
12	< - 2 %	-2 % to 0 %	> 0 %

Table 4: Success indication for the $eKPI_{ES1,a}$

Success	Promising	Missed the Target
< - 2 %	-2 % to 0 %	> 0 %

Table 5: Success indication for the $eKPI_{ES1,M}$

Success	Promising	Missed the Target
< - 2 %	-2 % to 0 %	> 0 %

3.1.2 Energy Saving for the Active Treatment Group ($eKPI_{ES2,m}$, $eKPI_{ES2,a}$ and $eKPI_{ES2,M}$)

The *eKPIs* explained in this section are highlighting the average energy saving of the active treatment group compared to the control group. The active treatment group consists out of the number of app users which are logged in into the app at least once in a month. The distinction between active and non-active treatment group allows us to make more precise conclusions about the impact of the app on consumer behaviour.

***eKPI*$_{ES2,m}$** gives the average energy saving of the active treatment group compared to the control group for one specific month *m*.

Like with the *eKPIs* in the last section it is helpful to calculate the $eKPI_{ES2,m}$ for a certain time period to compare the evolution of the average energy saving over time. This allows us to analyse the impact of updates and to identify peak periods.

***eKPI*$_{ES2,a}$** gives the average monthly energy saving of the active treatment group compared to the control group during whole field test period.

The second indicator summarizes the monthly average energy saving over the whole field test and it depicts if the app users could reduce their energy consumption from the beginning until the end of the field test compared to the control group.

The ***eKPI*$_{ES2,M}$** gives the total average energy savings per active user over the whole field test period.

The third indicator gives the average energy savings of an active participant over the whole field test period.

The calculation for $eKPI_{ES2,m}$ follows the same process as mentioned in Eq 1 to Eq 4. The difference is that for $eKPI_{ES2,m}$ the energy consumption of the active treatment group is considered and not the consumption of the whole treatment group. The situation is similar for $eKPI_{ES2,a}$ which follows the same process described by Eq 5 to Eq 8.

The calculation of the $eKPI_{ES2,M}$ is described by Eq 9 to Eq 10 like for the previous *eKPIs* also for the $eKPI_{ES2,M}$ the energy consumption of the active treatment group has to be considered.

Necessary variables to calculate both of the mentioned indicators are listed in Table 6.

Table 6: Variables for the calculation of $eKPI_{ES2,m}$, $eKPI_{ES2,a}$ and $eKPI_{ES2,M}$

Variable	Symbol	Units	Description
Energy consumption of the control group in month *m*	ECG_m	in kWh	Total energy consumption of the control group in month *m*.
Energy consumption of the active treatment group in month *m*	EAG_m	in kWh	Total energy consumption of the active treatment group in month *m*.
Active treatment group in month *m*	AG_m	# of users	Active treatment group consists out of all users which have downloaded the app until month *m* and have been logged in into the app at least once in month *m*.
Control group in month *m*	CG_m	# of non-users	Control group consists out of all selected non-users in month *m*.

Table 7 provides an example for the calculation of the two $eKPI_{ES2,m}$ and $eKPI_{ES2,a}$. The columns "Treatment Group" are indicating if the user is part of the treatment group or not with 1 = Treatment Group and 0 = Control Group. The columns "Active" are indicating if the user has been logged in into the app at least once in month *m*, with 1 = active and 0 = not active.

The $eKPI_{ES2,m}$ for *m* = 3 is -8.47 % compared to the average energy consumption of the control group. In *m* = 3 the average energy consumption of the active treatment group is 25 kWh lower than the average energy consumption of the control group.

The $eKPI_{ES2,a}$ is calculated in the last column of Table 7. Over all months the active treatment group could save 4.76 % of their energy consumption compared to the average energy consumption of the control group. In absolute terms the monthly average energy saving of the treatment group compared to the control group during the whole field test is 15 kWh.

In the example the total average energy savings per user over the whole field test period are 1.9 %. The active treatment group could save 18.33 kWh in total on average over the whole field test period compared to the control group, which can be seen in the following calculations. The third indicator $eKPI_{ES2,M}$ is calculated from columns *m*=1,…,*m*=3 from Table 7.

$$\boldsymbol{ES_M = \sum_{m=1}^{M} ES_m \frac{AG_m}{max(AG_1,\ldots,AG_M)} = \left(5\ \frac{1}{3}\right) + \left(-5\frac{2}{3}\right) + \left(-25\frac{2}{3}\right) = -18.33\ \text{kWh}.}$$

Based on ES_M the $eKPI_{ES,M}$ is calculated as follows:

$$\boldsymbol{eKPI_{ES1,M} = \frac{ES_M}{M\sum_{m=1}^{M} ECG_m/\sum_{m=1}^{M} CG_m} = \frac{-18.33}{3\ (670+630+590)/(2+2+2)} = -1.9\%.}$$

The mentioned *eKPIs* can easily be calculated for different types of groups. It is planned to calculate these *eKPIs* for the active treatment group A, which consists out of all app users who are benefiting from the complete ICT-system, including the dynamic electricity prices and for the active treatment group B, which is excluded of the dynamic electricity prices. Furthermore these two *eKPIs* will be calculated for different cohorts, like people living in a flat or house.

Table 7: Example for the calculation of the average energy saving of the Active Treatment Group ($eKPI_{ES2,m}$ and $eKPI_{ES2,a}$)

Assumption: App release 1st January, field test duration 3 months		m=1			m=2			m=3			Total Months			
		January			February			March			January-March			
ID	Date of download	Energy consumption (kWh)	TG	Active	Energy consumption (kWh)	TG	Active	Energy consumption (kWh)	TG	Active	Sum of Energy Consumption of TG in Active Months	Sum of Energy Consumption for CG	Active Months TG	Months CG
1	20th January	340	1	1	300	1	1	280	1	0	640		2	
2		330	0		300	0		290	0			920		3
3	25th February				320	1	1	250	1	1	570		2	
4	2nd March							290	1	1	290		1	
5		340	0		330	0		300	0			970		3
Control Group (CG_m, $\sum_{m=1}^{M} CG_m$)		2			2			2			6			
Active Treatment Group (AG_m, $\sum_{m=1}^{M} AG_m$)		1			2			2			5			
Energy Consumption CG (ECG_m, $\sum_{m=1}^{M} ECG_m$)		670 kWh			630 kWh			590 kWh			1,890 kWh			
Energy Consumption AG (EAG_m, EAG_{tot})		340 kWh			620 kWh			540 kWh			1,500 kWh			
Average Energy Consumption CG ($AECG_m$, $AECG_a$)		335 kWh			315 kWh			295 kWh			315 kWh			
Average Energy Consumption AG ($AEAG_m$, $AEAG_a$)		340 kWh			310 kWh			270 kWh			300 kWh			
Energy Saving (ES_m, ES_a)		**5 kWh**			**-5 kWh**			**-25 kWh**			**-15 kWh**			
$eKPI_{ES2,m}$ and $eKPI_{ES2,a}$		**1.49%**			**-1.59%**			**-8.47%**			**-4.76%**			

Table 8 to Table 10 are giving an overview of success indicators for $eKPI_{ES2,m}$, $eKPI_{ES2,a}$ and $eKPI_{ES2,M}$ to check whether the project was a success, promising or if it missed the target.

Table 8: Success indication for the $eKPI_{ES2,m}$

Time specification in month *m*	Success	Promising	Missed the Target
1	< - 2 %	-2 % to 0 %	> 0 %
2	< - 2 %	-2 % to 0 %	> 0 %
3	< - 2 %	-2 % to 0 %	> 0 %
12	< - 2 %	-2 % to 0 %	> 0 %

Table 9: Success indication for the $eKPI_{ES2,a}$

Success	Promising	Missed the Target
< - 2 %	-2 % to 0 %	> 0 %

Table 10: Success indication for the $eKPI_{ES2,M}$

Success	Promising	Missed the Target
< - 2 %	-2 % to 0 %	> 0 %

3.2 Monetary Saving $eKPI_{MS}$ ($eKPI_{MS,m}$, $eKPI_{MS,a}$ and $eKPI_{MS,M}$)

This section defines the average monetary saving *eKPIs* ($eKPI_{MS,m}$, $eKPI_{MS,a}$ and $eKPI_{MS,M}$). The average monetary saving *eKPIs* are highlighting the potential average monetary saving in € for the households through energy conservation. Therefore the average energy savings in kWh, which were already defined in the previous section, will be transformed into monetary terms.

The ***$eKPI_{MS,m}$*** gives the average monetary saving in € in month *m*.

Like in the previous section the second indicator summarizes the monthly average monetary saving over the whole field test period.

The ***$eKPI_{MS,a}$*** gives the monthly average monetary saving in € during the field test period.

The third indicator calculates the total average monetary savings over the whole field test period.

The ***$eKPI_{MS,M}$*** gives the total average monetary savings in € per active user over the whole field test period.

For many consumers the possibility of monetary savings is a motivation for energy conservation, therefore it is important to highlight the potential of energy savings, by using the app, in monetary terms. Because the households have different types of energy tariffs the monetary savings potential is different for the households. Those households who have to pay higher prices for the energy consumption will have higher monetary savings for equal energy savings than others who pay less per kWh. Therefore, the motivation for energy savings should be higher for households with higher energy prices. In this case the $eKPI_{MS}$ is calculated with the average energy price, but the $eKPI_{MS}$ can be calculated for different cohorts with different prices if tariff information is available.

The $eKPI_{MS}$ are calculated by multiplying the average energy savings of the treatment group compared to the control group with the energy price in € per kWh. The average energy savings for month *m* (ES_m) are calculated by Eq 3, the average monthly energy savings (ES_a) are calculated by Eq 7 and the average total energy savings (ES_M) are calculated by Eq 9.

The calculation of the $eKPI_{MS,m}$, $eKPI_{MS,a}$ and $eKPI_{MS,M}$ is given by Eq 11 to Eq 13.

$$eKPI_{MS,m} = ES_m x\ EP \qquad \text{Eq 11}$$

$$eKPI_{MS,a} = ES_a x\ EP \qquad \text{Eq 12}$$

$$eKPI_{MS,M} = ES_M x\ EP \qquad \text{Eq 13}$$

Table 11 shows the needed variable for the calculation of the $eKPI_{MS}$

Table 11: Variables for the calculation of $eKPI_{MS,m}$, $eKPI_{MS,a}$ and $eKPI_{MS,M}$

Variable	Symbol	Units	Description
Average Energy Price	EP	€ per kWh	EP gives the average energy price of the different types of energy tariffs in € per kWh.

Table 12 shows an example for the calculation of the monetary saving *eKPIs*. The information about energy saving for the calculation is given by the example which is shown in Table 2.

Assumption average energy price EP = 0,20 € per kWh

Table 12: Example for the calculation of the monetary saving *eKPIs*

Variable	ES_m for $m = 3$	ES_a	ES_M
Energy saving (ES_m, ES_a and ES_M)	- 15 kWh	- 27.92 kWh	- 56.6 kWh
Monetary saving ($eKPI_{MS,m}$, $eKPI_{MS,a}$ and $eKPI_{MS,M}$)	- 3.00 €	- 5.60 €	- 11.32 €

According to the example in Table 12 the average monetary savings due to energy consumption reduction in m=3 for the treatment group compared to the control group is 3.00 €. The monthly average monetary savings of the treatment group are 5.60 €, and finally, the total average monetary saving over the whole field test period are 11.32 €.

Table 13 to Table 15 are giving an overview of success indicators for the three different $eKPI_{MS}$ to check whether the project was a success, promising or if it missed the target.

Table 13: Success indication for the $eKPI_{MS,m}$

Time specification in month *m*	Success	Promising	Missed the Target
1	< - 3 €	- 3 € to 0 €	> 0 €
2	< - 3 €	- 3 € to 0 €	> 0 €
3	< - 3 €	- 3 € to 0 €	> 0 €
12	< - 3 €	- 3 € to 0 €	> 0 €

Table 14: Success indication for the $eKPI_{MS,a}$

Success	Promising	Missed the Target
< - 3 €	- 3 € to 0 €	> 0 €

Table 15: Success indication for the $eKPI_{MS,M}$

Success	Promising	Missed the Target
< - 3 € x *M*	- 3 € to 0 € x *M*	> 0 € x *M*

3.3 *GHG* Reduction $eKPI_{GHG}$ ($eKPI_{GHG,m}$, $eKPI_{GHG,a}$ and $eKPI_{GHG,M}$)

This section defines the average Green House Gas (*GHG*) emission reduction *eKPIs* ($eKPI_{GHG,m}$, $eKPI_{GHG,a}$ and $eKPI_{GHG,M}$). The average *GHG* emission reduction *eKPIs* are highlighting the potential average *GHG* emission reduction in kg $CO_{2\text{-eq}}$[1] for the households through energy consumption reduction. Therefore the average energy savings in kWh, which were already defined in the previous section, will be transformed into $CO_{2\text{-eq}}$ emissions.

The ***eKPI*$_{GHG,m}$** gives the average *GHG* emission reduction in kg $CO_{2\text{-eq}}$ in month *m*.

Like in the previous section the second indicator summarizes the monthly average *GHG* reduction.

The ***eKPI*$_{GHG,a}$** gives the monthly average *GHG* emission reduction in kg $CO_{2\text{-eq}}$ over the field test period.

The third indicator calculates the total average *GHG* emission reduction over the whole field test period.

The **eKPI$_{GHG,M}$** gives the total average *GHG* emission reduction in kg $CO_{2\text{-eq}}$ per active user over the whole field test period.

The reduction of *GHG* emissions mitigates the climate change effects. For a certain group of people the possibility of a *GHG* emission reduction is a motivation for energy savings. To highlight the potential of a *GHG* reduction through energy savings is, therefore, an important promotion point. Because households have different types of energy tariffs, the *GHG* reduction potential is different for the households. Some household will already have tariffs with very low *GHG* emissions, and some others not. The $eKPI_{GHG}$ are calculated with the average $CO_{2\text{-eq}}$ emission per kWh.

The $eKPI_{GHG}$ are calculated by multiplying the average energy savings of the treatment group compared to the control group with the $CO_{2\text{-eq}}$ emissions in kg per kWh. The average energy savings for month *m* (ES_m) are calculated by Eq 3, the average monthly energy savings (ES_a) are calculated by Eq 7, and the average total energy savings (ES_M) are calculated by Eq 9. The calculation of the $eKPI_{GHG,m}$, $eKPI_{GHG,a}$ and $eKPI_{GHG,M}$ is given by Eq 14 to Eq 16.

$$eKPI_{GHG,m} = ES_m x\ GHG \qquad \textbf{Eq 14}$$

$$eKPI_{GHG,a} = ES_a x\ GHG \qquad \textbf{Eq 15}$$

$$eKPI_{GHG,M} = ES_M x\ GHG \qquad \textbf{Eq 16}$$

Table 16 shows the needed variable for the calculation of the $eKPI_{GHG}$

Table 16: Variables for the calculation of $eKPI_{GHG,m}$, $eKPI_{GHG,a}$ and $eKPI_{GHG,,M}$

Variable	Symbol	Units	Description
***GHG* emission**	*GHG*	kg $CO_{2\text{-eq}}$ per kWh	Gives the average *GHG* emission of the different types of energy tariffs in kg $CO_{2\text{-eq}}$ per kWh.

Table 17 shows an example for the calculation of the *GHG* emission reduction *eKPIs*. The information about energy savings for the calculation is given by the example shown in Table 2.

[1] $CO_{2\text{-eq}}$ gives the emissions from different types of greenhouse gases with different global-warming potentials (GWP) converted into the equivalent amount of carbon dioxide with the same global warming potential. (see Eurostat (2014): Glossary: Carbon dioxide equivalent. http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Carbon_dioxide_equivalent. Download Date January 2017)

Assumption average *GHG* emission = 0.5 kg $CO_{2\text{-eq}}$ per kWh[2]

Table 17: Example for the calculation of the GHG emission reduction $eKPI_{GHG}$

Variable	ES_m for m = 3	ES_a	ES_M
Energy saving (ES_m, ES_a and ES_M)	- 15 kWh	- 27.92 kWh	-56.6 kWh
GHG reduction ($eKPI_{GHG,m}$, $eKPI_{GHG,a}$ and $eKPI_{GHG,M}$)	- 7.5 kg $CO_{2\text{-eq}}$	- 14 kg $CO_{2\text{-eq}}$	- 28.3 kg $CO_{2\text{-eq}}$

According to the example in Table 12 the average *GHG* emission reduction due to an energy consumption reduction in m=3 for the treatment group compared to the control group is 7.5 kg $CO_{2\text{-eq}}$. The treatment group could reduce *GHG* emission by a monthly average of 14 kg $CO_{2\text{-eq}}$ compared to the control group. Furthermore, 28.3 kg $CO_{2\text{-eq}}$ emission could be avoided in average over the whole field test period by the treatment group compared to the control group.

Because the $CO_{2\text{-eq}}$ emissions per kWh of energy consumption in the different European countries are site-specific the success indicators for the $eKPI_{GHG,m}$, $eKPI_{GHG,a}$ and $eKPI_{GHG,M}$ will be defined later in the project. The success indicators will base on the success indications of Table 3, Table 4 and Table 5, which are showing the success indications for the $eKPI_{ES1,}$ multiplied with the site-specific $CO_{2\text{-eq}}$ emission factors.

[2] See European Environment Agency (2016): Overview of electricity production and use in Europe. http://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-1/assessment Download Date January 2017

3.4 Load Shifting $eKPI_{LS,g,s,m}$

In this section the $eKPI_{LS,g,s,m}$ will be defined which is describing the load shift of energy consumption during peak times of renewable energy production. The aim of this project is to shift energy consumption from times with low renewable energy production to times of high production levels. This will be achieved by setting a price incentive for the customers during these peak times as motivation to increase energy consumption.

The $\boldsymbol{eKPI_{LS,g,s,m}}$ gives the energy consumption difference in % of treatment group A compared to treatment group B or the control group, before, during and after treatment group A receives the price incentive.

To measure the load shift treatment group A receives discounts on electricity prices in times of extraordinary high production from renewable sources. The monetary incentive should encourage treatment group A to consume during peak times with high production from renewable energy sources. Furthermore, energy consumption should be lower in times with less energy production from renewables, because energy demand is shifted to peak times.

The comparison between the energy consumption before, during, and after treatment group A receives the price discount with the control group, will show if the consumption behaviour of treatment group A has changed. It is assumed that in a business as usual case treatment group A on average would follow a similar consumption pattern as the control group.

The calculation process for $eKPI_{LS,g,s,m}$ is defined mathematically through Eq 17 to Eq 19. In the first step, the average energy consumption ($AEC_{g,m,s}$) of the respective groups will be calculated before, during, and after the price incentive was granted for treatment group A. $AEC_{g,m,s}$ is based on the sum of energy consumption in month m before, during, and after the price incentive was granted for the different groups ($EC_{g,m,s}$) divided through the number of users/non-users of the respective group in month m ($G_{g,m}$).

Next step is to calculate the difference between the average energy consumption of treatment group A compared to the other groups before, during, and after the price incentive was granted. This difference in energy consumption can be interpreted as the load shift ($LS_{g,m,s}$). Finally the load shift will be set into relation to the average energy consumption of the respective groups.

The $eKPI_{LS,g,s,m}$ gives the difference of the average energy consumption of group A compared to group B and group C in %, before (s=1), during (s=2), and after (s=3) the price incentive was granted. The calculation of the $eKPI_{LS,g,s,m}$ before, during, and after the price incentive was granted, allows to make comparisons of the magnitude of the energy consumption change over these time periods. Through these comparisons it can be analysed if treatment group A is changing its energy consumption behaviour during peak times of renewable energy production compared to the other groups. Necessary variables to calculate both mentioned indicators are listed in Table 18.

Table 18: Variables for the calculation of $eKPI_{LS,g,s,m}$

Variable	Symbol	Units	Description
Number of user/non-users in month *m*	$G_{g,m}$	# of users	Number of user in treatment group A, B or C in month *m*.
Energy consumption in month *m*	$EC_{g,m,s}$	in kWh	Sum of energy consumption of the respective group (A, B or C) in month *m*, before, during, and after the price incentive was granted to treatment group A. E.g. If person 1 receives a price discount for energy consumption on May 5th and May 17th then $EC_{g,m,s}$, for $m = 5$ and $s = 1$, is the sum of energy consumption before the price incentive was granted on only these two days.

Average energy consumption per group

$$AEC_{g,m,s} = \frac{EC_{g,m,s}}{G_{g,m}} \qquad \text{Eq 17}$$

Load shift – Difference in Energy consumption to Group A

$$LS_{g,m,s} = AEC_{A,m,s} - AEC_{g,m,s} \qquad \text{Eq 18}$$

$$eKPI_{LS,g,s,m} = \frac{LS_{g,m,s}}{AEC_{g,m,s}} \qquad \text{Eq 19}$$

Table 19 provides an example for the calculation of the $eKPI_{LS,g,s,m}$. The table shows energy consumption data in kWh for the different groups in month $m = 1$, before, during, and after the price incentive was granted to treatment group A. The average energy consumption per group ($AEC_{g,m,s}$) is calculated for the time before, during, and after treatment group A has received the price incentive.

Figure 1 illustrates an ideal example of the average energy consumption per group before, during, and after the price was granted to group A. The average energy consumption of treatment group A before the price incentive was granted is significantly smaller compared to the other groups. During the hours where the price incentive was granted, the energy consumption of treatment group A surpasses the energy consumption of the other groups. Afterwards the average energy consumption of treatment group A equalized with the other groups.

The load shift ($LS_{g,m,s}$) is calculated by subtracting the average energy consumption of treatment group A from the average energy consumption the other groups before, during, and after the price incentive was granted. Finally to calculate the $eKPI_{LS,g,s,m}$., the load shift is set into relation to the average energy consumption of the respective groups. The interpretation of the $eKPI_{LS,g,s,m}$ in m=1 and s=1 is, that treatment group A consumes 65 % less energy than treatment group B and 39 % less energy than the control group, before the price incentive was granted to treatment group A.

Table 19: Example for the calculation of the Average Energy consumption $AEC_{g,m,s}$

Energy consumption in m=1 in kWh					
ID	**Group (G)**	**Before (s=1)**	**During (s=2)**	**After (s=3)**	**Sum**
1	**A**	15	50	5	**70**
2	**B**	45	15	8	**68**
3	**C**	55	20	9	**84**
4	**A**	13	45	7	**65**
5	**B**	35	25	5	**65**
6	**C**	65	20	9	**94**
User per Group $G_{g,m}$	**A**	**2**	**2**	**2**	**2**
	B	**2**	**2**	**2**	**2**
	C	**2**	**2**	**2**	**2**
Average Energy consumption $AEC_{g,m,s}$	**A**	**14**	**47.5**	**6**	**67.5**
	B	**40**	**20**	**6.5**	**66.5**
	C	**60**	**20**	**9**	**89**
$LS_{B,m,s}$	***A/B***	**-26**	**27.5**	**-0.5**	**1**
$LS_{C,m,s}$	***A/C***	**-46**	**27.5**	**-3**	**-21.5**
$eKPI_{LSB,s,m}$	***A/B***	**-65%**	**138%**	**-8%**	**2%**
$eKPI_{LSC,s,m}$	***A/C***	**-77%**	**138%**	**-33%**	**-23%**

Figure 1: Example Average Energy consumption before, during and after the price incentive was granted in *m* = 1

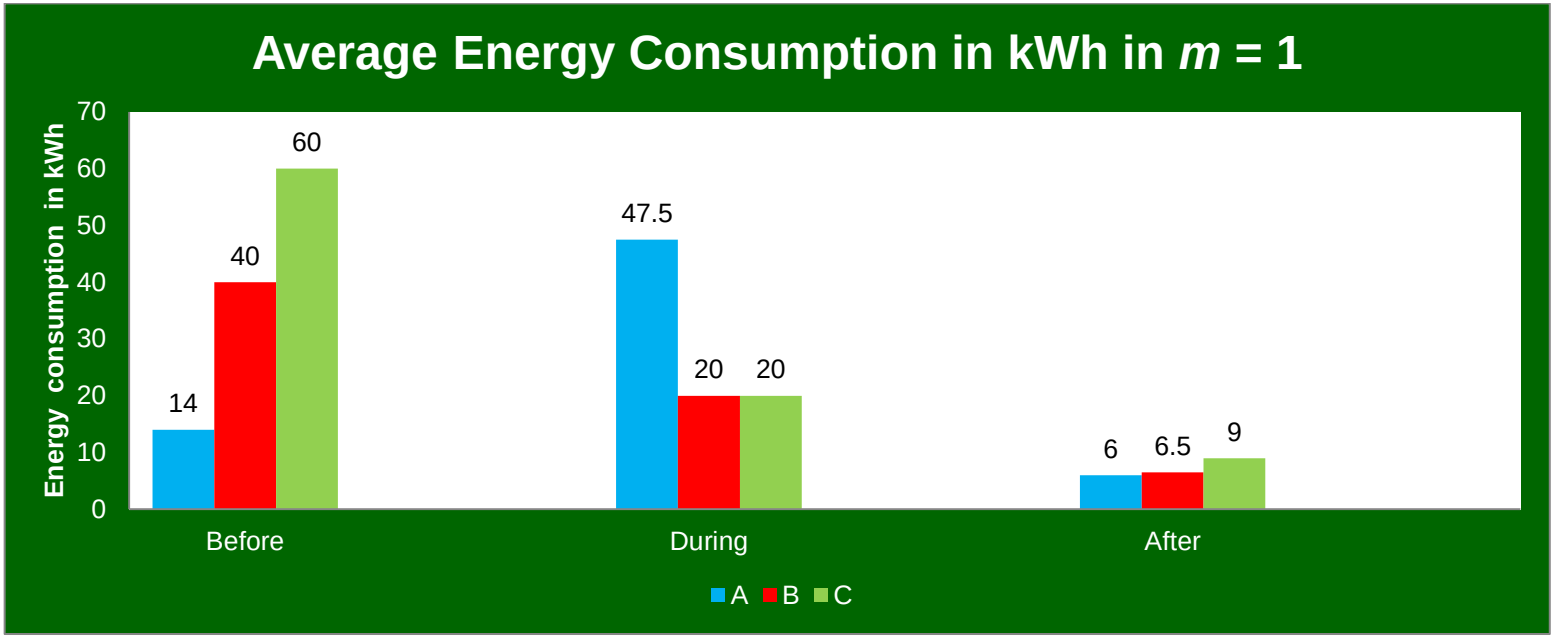

Table 20 gives an overview of success indicators for $eKPI_{LS,g,s,m}$ to check whether the project was a success, promising or if it missed the target.

Table 20: Success indication for the $eKPI_{LS,g,s,m}$ before, during and after the price incentive was granted to Group A

Time indication	Success	Promising	Missed the Target
Before (s=1)	< -3 %	-3 % to 0 %	> 0 %
During (s=2)	> 3 %	3 % to 0 %	< 0 %
After (s=3)	< - 1 %	- 1 % to 0 %	> 0 %

4 Annex

4.1 Variable List

The following table contains the variables which will be generated in the PEAKapp project. The term user is defined as follows:

The PEAKapp **user** references one account to the PEAKapp system where one account is presenting one household.

Variable Name	Var ID	Unit of measurement	Unit of observation	Description
Installation				
Number of downloads at month m	D_m	# in M1, # in M2, …	# of users	This variable contains the number of downloads per month.
Number of users in month t after the month of the download	$D_{t,m}$	# in M1, #in M2, …	# of users	This variable contains the number of downloads in month t after the month of the download
Dates of the downloads per user	DD_i	Date	per download per user	This variable contains the date of download.
Number of electronic appliances connected	NA_i	# of appliances	# of appliances per user	This variable contains the number of appliances per user i.
OS Type	OS_i	Type, e.g., Android	per download per user	This variable contains the Type of Software per user i with the download date
App Version	AV_i	Version, e.g. PEAKapp v1.05	per update per user	This variable contains the new versions/updates per user i.
App usage in general				
Active users in month m (m=months since app release, m=1: month off app release)	A_m	# in M1, #in M2, …	# of users	This variable contains the number of active users in month m
Number of log-ins per user per /month	NL_i	# in M1, #in M2, …	per user	This variable contains the number of log-ins per user i in month m.

Active users in month t after the month of the download	A_t	# in M1, #in M2, …	# of users	This variable contains the number of active users in the app in month t after the month of the download of the app.
	SD_m	Minutes	# of users	This variable contains the session duration of the app users in month m.
	SD_t	Minutes	# of users	This variable contains the session duration of the app users in month t after the month of the download.
Date, Daytime of each app use	DU_i DTU_i	Date, daytime	per access of the app	This variable contains the Date/Daytime of the log-in into the app per user i.
Consumption information				
Number of accessing the normal consumption information per month (i.e. all pages related to Cluster 1 as in the GA)	$NNC_{i,m}$	# in M1, # in M2, …	per user	This variable contains the number of accesses into the normal consumption information per user i in month m.
Date, Daytime of accessing Cluster 1 pages	DNC_i $DTNC_i$	Date, daytime	per access of Cluster 1 pages	This variable contains the Date, Daytime of accessing Cluster 1 pages per user i.
Duration of accessing Cluster 1 pages	$SDNC_i$	Minutes	per access of Cluster 1 pages	This variable contains the session duration of accessing Cluster 1 pages per user i in month m in minutes.
Number of accessing a benchmark per month (i.e. all pages related to Cluster 2 as in the GA)	$NBM_{i,m}$	# in M1, # in M2, …	per user	This variable contains the number of accesses in the benchmark per user I month m.

Date, Daytime and Type of requesting a benchmark.	DBM_i $DTBM_i$ TBM_i	Date, day time, type	Date, daytime, type	This variable contains the date, day time and type of requesting a benchmark per user i. The type of a benchmark is its respective timeframe, i.e., whether a monthly benchmark was requested, or a weekly benchmark, or….
Duration of requesting a benchmark	$SDBM_i$	Minutes	per request of a Benchmark	This variable contains the session duration of requesting a benchmark per user i in month m in minutes.
Price-related information				
Widget for retrieving price information	PI_i	1 / 0	per user	This variable contains the number of users who use a widget for retrieving price information with 1 = user uses widget and 0 = user don´t uses widget.
The finally applied prices/discounts	FP_i	user price per hour during the field test (around 8600 values)	one file for the Austrian field test	This variable contains the end-user price/discount per hour during the field test.
Serious Gaming				
Number of accessing the serious game per month (i.e. all pages related to Cluster 4 as in the GA)	$NSG_{i,m}$	# in M1, # in M2, …	per user	This variable contains the number of accesses into the serious game per user i in month m.
Number of total points scored per user, per month	$NTP_{i,m}$	# in M1, # in M2, …	per user	This variable contains the number of total points scored per user i in month m.
Number of total points scored by tweaking per user, per month	$TTP_{i,m}$	# in M1, #in M2, …	per user	This variable contains the number of total points scored by tweaking per user i in month m.
Number of accessing the hints	$NH_{i,m}$	# in M1, #in M2, …	per user	This variable contains the number of accesses of the hints per user i in month m.
Date, Daytime of using the serious game	DSG_i	Date, daytime	Date, daytime	This variable contains the Date/Daytime of using the serious game.
Duration of using the serious game	$SDSG_i$	Minutes	per user	This variable contains the duration session of using the serious game per user i in month m.

All stats earned/achieved/… ? in the serious game	ST_i	? tbd	per user	This variable contains all stats earned/achieved/... in the serious game per user i in month m.
Date of setting a bet	DB_i	Date, daytime	per user	This variable contains the date when a bet was placed per user i.
Bets in month m	B_m	# in M1, # in m2, …	# of users	This variable contains the number of bets in month m.
Bets in month t after the month of the download	B_t	# in M1, # in M2, …	# of users	This variable contains the number of bets in t month after the month of the download.
Social Networking				
Monthly number of facebook posts done from PEAKapp	$FP_{i,m}$ $FP_{i,t}$	# in M1, # in M2, …	per user	This variable contains the monthly number of Facebook posts done from PEAKapp
Date and Type of facebook post	DFP_i TFP_i	Date and type	per facebook post	This variable contains the date and type per Facebook posts. Type can be a consumption information, a benchmark, money saved through dynamic prices over a certain time period, a game score, etc
Push messages				
The sent push messages	PM_i	text	per message per user	This variable contains the sent push messages per message/user i
The date and time of the sent push messages	DPM_i $DTPM_i$	Date and time	per message per user	This variable contains the date and time of the sent push messages per message/user i
Others				
Total Target Group	N	Number of People	Customer of Energy supplier with Smart Meters within a certain cohort	This variable contains the total number of the target group of the energy supplier.
Call Center calls	CC	Quantitative: Amount of calls Qualitative: Type of calls (complains, questions, improvement suggestions,…)	# of call center call	This variable contains the total number of call center calls which are related to the PEAKapp project.
Meter Data	SMD_i	Load profile	per user	This variable contains the smart meter data per user i.