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

Deliverable 4.2
Quantification of the success indicators and the KPIs

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This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 695945.

Document control information		
Title	D4.2: Quantification of the success indicators and the KPIs	
Editor	Manuela Prieler (EI-JKU)	
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Dissemination Level	☐ **CO** Confidential, only for members of the consortium (including the Commission Services) ☐ **RE** Restricted to a group specified by the consortium (including the Commission Services) ☐ **PP** Restricted to other programme participants (including the Commission Services) ☒ **PU** Public	
Reviewers	☐ Baskent-Elek ☐ DTU ☐ EI-JKU ☐ ELDER ☐ ENAMO	☒ GreenPocket ☐ IJsfontein ☐ RTDS ☒ Tecnalia ☐ 220 Energia
Status	☐ Draft ☐ WP Manager accepted ☒ Co-ordinator accepted	
Action requested	☐ to be revised by Partners involved in the preparation of the deliverable ☐ to be reviewed by applicable PEAKapp Partners ☐ for approval of the WP Manager ☐ for approval of the Project Coordinator	
Requested deadline for Action		

Versions			
Version	**Date**	**Change**	**Comment/Editor**
V0.1	10/12/2018	First release	Initial analysis performed.
V1.0	08/05/2019	Second release	Completion of the analysis. Integration of comments from reviewers
VFinal	31/10/2019	Final version	Integration of comments from PO and monitors

Content

1 Introduction and Motivation

The PEAKapp project developed and testes a software tool that collected load profiles of households' electricity consumption, transformed this rather technical data into user friendly aggregates, and returned the information to the households in a way to engage and motivate increased household energy efficiency.

This deliverable represents the results PEAKapp eKPIs and KPIs defined in Del 1.3. and Del 1.5. The defined eKPIs covered and quantified the extent to which the app actually stimulated energy efficient behaviour and had an impact on the related to electricity consumption decisions of the households. To answer this question, PEAKapp carried out field tests to provide 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 a set pre-defined indicators is analysed. PEAKapp was tested in four European countries: Austria, Estonia, Sweden and Latvia. The data for the calculation of these KPIs includes only the Austrian subset of data. The field tests in Austria ran from June 2017 to October 2018. Austrian field test was the longest in terms of duration and also with the highest per country number of participating households. PEAKapp offered to Austrian consumers was paired with Google Analytics data which allowed to collect information on each session in the app, this information is required for calculation of the eKPIs and KPIs defined in Del 1.3 and 1.5. PEAKapp version in Estonia, Latvia and Sweden differed from Austrian in the price treatment, users of PEAKapp in these countries had access to spot-market prices, there was also no pairing with Google analytics service due a different setting of the app. It is important to take into account in this respect that PEAKapp users in Austria represent roughly 60% of all PEAKapp users the results of this deliverable should be interpreted respectively. An important advantage of PEAKapp in Austria is the availability of the Google analytics data which allows estimation of actual treatment effect of the app, us the detailed information on when the app was used and in which way is available for each of the treated households. Previous studies in the field of household energy efficiency including the widely famous OPOWER home energy reports or numerous studies with in-home displays were solely presenting a so called intend-to-treat effect. The intend-to-treat effect does not take into account whether households actually read the reports, looked at the-in-home displays or in PEAKapp case used the app. In PEAKapp in the contrary, we define treated household as the ones that used the app in the respective month at least once.

In this Deliverable, a set of pre-developed indicators addressing the second of the aforementioned questions is discussed. These indicators were defined in Deliverable 1.5. Considering the differing technical preconditions and national legal/regulatory frameworks of the test sites, not all indicators can be provided for all sites. For example, in Austria figures about households' electricity consumption are available in 15 minutes intervals, while Estonian regulation foresees metering of hourly values. In this Deliverable we focus on the data of the Austrian field test as for the calculations of the majority of the KPIs data about app usage from Google Analytics is required.

In contrast to the in Deliverable 1.5 pre-developed KPIs, 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, the predefined eKPIs of Deliverable 1.3 focus to measure the environmental impact of PEAKapp and as well as on the behavioural change in households' energy consumption patterns, which was driven by PEAKapp.

The subsequent chapters describe these indicators and their interpretation in detail and provide an overview on data required for their quantification.

2 Information requirements inventory

PEAKapp created 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.

Furthermore, the key performance indicators (*KPI*) presented in this deliverable shall support decision makers to assess 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. This chapter 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.
Months, after the download of the app	t	number of months	t gives the time in months after the download of the app. Example: User has downloaded the app in January (month of download = January), than for this user, January t = 0, February is t = 1, ...

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

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.

The eKPI are analysed using two different scenarios. The **1st scenario** includes the data from the **treatment group, which had downloaded the app**, while the **2nd scenario** includes data from members of the treatment group, **who used the app including the desktop version**. During the field tests in Austria roughly 1,000 households had access to PEAKapp, 811 of these household used the app. 378 out of the 811 downloaded the app while the rest representing more than 50% of the test users used PEAKapp desktop version. While such distribution was not predictable before the start of field test, we assume presenting results for both groups is interesting both for utilities which consider implementing similar tools for their clients as well as for policy makerts and reserachers.The second scenario is relevant in order to understand the actual impact of PEAKapp as if it is offered to a larger population not all the households that will be offered access to PEAKapp will actually download it, but many will prefer to use the app through a desktop version for several reasons. The results of scenario 1 are shown in violet colour and those of scenario 2 in green.

Looking at the KPIs in the two scenarios, we often observe differences in the outcome which also reflect that the group of users who used PEAKapp on the desktop differs from the group that uses the smart phone or app version. Also using PEAKapp at on a desktop version most likely happened at home so the gap between getting information about ways to increase household energy efficiency and the possible to make required actions to reach it was potentially smaller compared to people who used PEAKapp on their smart phones and tablets.

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

Table 2: Success indication for the e$KPI_{ES1,m}$

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 3: Success indication for the e$KPI_{ES1,a}$

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

Table 4: Success indication for the e$KPI_{ES1,M}$

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

Table 5 shows the results $eKPI_{ES1,a}$ and $eKPI_{ES1,M}$. The $eKPI_{ES1,a}$ for scenario 1 is 1,11 % and for the second scenario is -1,52%. These results should be interpreted as follows, in the second scenario households from the treatment group have 1.52% lower electricity consumption compared to the control group. However, in the first scenario, which does not take into account the households that used a desktop version of PEAkapp, the positive KPI means that the treatment group has 1.11 % higher electricity consumption on average compared to control group. Hence, the target is missed in scenario 1, while the results of scenario 2 are promising based on the predefined values of this KPI.

The treatment group could save 12.49 kWh (scenario 1) resp. 61.61 kWh (scenario 2) in total on average over the whole field test period compared to the control group. Looking at the $eKPI_{ES1,M}$ it can be seen that the results of both scenarios are promising, in scenario 1 the $eKPI_{ES1,M}$ is -0,23 % and in scenario 2 it is -1,12 %.

Table 5: $eKPI_{ES1,a}$ and $eKPI_{ES1,M}$ (Scenario 1 = violet and Scenario 2 =green)

$AECG_a$ [kWh]	$AETG_a$ [kWh]	ES_a [kWh]	$eKPI_{ES1,a}$ [%]	Success Indication	ES_M [kWh]	$eKPI_{ES1,M}$, [%]	Success Indication
322.77	326.36	3.59	1.11%	Missed the Target	-12.49	-0.23%	Promissing
322.77	317.85	-4.92	-1.52%	Promissing	-61.61	-1.12%	Promissing

In Table 6 for scenario 1 the central variables regarding the energy consumption of the treatment and the control group are visualized as well as the $eKPI_{ES1,m}$. The $eKPI_{ES1,m}$ varies depending on the month t in the range of -10,70 % to 6,70 %. In eight months the set targets (see success indication) were fulfilled (Success) in one month the result was promising and in eight months the target was missed.

For scenario 2 the resulting indicators can be seen in Table 7. In this case the $eKPI_{ES1,m}$ varies between -7,40 % and 5,45% depending on the month. In nine out of the 17 months the $eKPI_{ES1,m}$ indicates a success, two times it was promising and six times the target was missed. In both scenarios the months when the targets were missed are the winter months, thus, in this period less flexibility in terms of energy efficiency is directly related to lower air temperatures and heating season. Interestingly the months with the highest savings in scenario 1 occur toward the end of the field tests and reach in September and October approximately 10%. These results can be interpreted as an evidence of learning effect of the app. Although not as evident but still similar trend is observed in scenario 2, showing again evidence that using app more and more frequently over longer periods of time increased households awareness and knowledge in energy efficiency and helped to increase energy savings.

Table 6: Energy saving and average energy saving of the treatment and control group with $eKPI_{ES1,m}$ (Scenario 1)

Month		Control Group (CG_m, $\sum_{m=1}^{M} CG_m$) [kWh]	Treatment Group (TG_m, $\sum_{m=1}^{M} TG_m$) [kWh]	Energy Consumption CG (ECG_m, $\sum_{m=1}^{M} ECG_m$) [kWh]	Energy Consumption TG (ETG_m, $\sum_{m=1}^{M} ETG_m$) [kWh]	Average Energy Consumption CG ($AECG_m$) [kWh]	Average Energy Consumption TG ($AETG_m$) [kWh]	Energy Saving (ES_m) [kWh]	$eKPI_{ES1,m}$ [%]	Success Indication
m=0	May 17	307		84,179		274				
m=1	June 17	319	232	96,190	66,410	302	286	-15	-5,07%	Success
m=2	July 17	344	166	101,853	51,136	296	308	12	4,04%	Missed the Target
m=3	August 17	391	112	111,183	33,857	284	302	18	6,31%	Missed the Target
m=4	September 17	437	225	130,725	67,895	299	302	3	0,87%	Missed the Target
m=5	October 17	436	210	150,201	76,871	344	366	22	6,26%	Missed the Target
m=6	November 17	476	230	173,691	81,889	365	356	-9	-2,43%	Success
m=7	December 17	472	260	196,032	115,216	415	443	28	6,70%	Missed the Target
m=8	January 18	465	207	188,956	83,688	406	404	-2	-0,51%	Promissing
m=9	February 18	462	193	171,941	73,497	372	381	9	2,32%	Missed the Target
m=10	March 18	460	177	173,616	69,051	377	390	13	3,36%	Missed the Target
m=11	April 18	457	198	135,479	59,395	296	300	4	1,19%	Missed the Target
m=12	May 18	450	208	147,558	62,570	328	301	-27	-8,26%	Success
m=13	June 18	447	167	138,224	49,616	309	297	-12	-3,92%	Success
m=14	July 18	444	132	139,869	40,041	315	303	-12	-3,71%	Success
m=15	August 18	436	145	139,730	45,075	320	311	-10	-3,00%	Success
m=16	September 18	434	160	136,963	45,353	316	283	-32	-10,18%	Success
m=17	October 18	427	171	57,307	20,494	134	120	-14	-10,70%	Success
Total months	June 17 - Oct 18	7,357	3,193	2,389,517	1,042,054	323	326	4	1,11%	

Table 7: Energy saving and average energy saving of the treatment and control group with $eKPI_{ES1,m}$ (Scenario 2)

Month		Control Group (CG_m, $\sum_{m=1}^{M} CG_m$) [kWh]	Treatment Group (TG_m, $\sum_{m=1}^{M} TG_m$) [kWh]	Energy Consumption CG (ECG_m, $\sum_{m=1}^{M} ECG_m$) [kWh]	Energy Consumption TG (ETG_m, $\sum_{m=1}^{M} ETG_m$) [kWh]	Average Energy Consumption CG ($AECG_m$) [kWh]	Average Energy Consumption TG ($AETG_m$) [kWh]	Energy Saving (ES_m) [kWh]	$eKPI_{ES1,m}$ [%]	Success Indication
m=0	May 17	307	674	84,179	182,742	274	271	-3	-1,12%	
m=1	June 17	319	695	96,190	204,495	302	294	-7	-2,42%	Success
m=2	July 17	344	749	101,853	216,740	296	289	-7	-2,27%	Success
m=3	August 17	391	814	111,183	231,897	284	285	1	0,19%	Missed the Target
m=4	September 17	437	888	130,725	258,043	299	291	-9	-2,86%	Success
m=5	October 17	436	890	150,201	304,335	344	342	-3	-0,74%	Promissing
m=6	November 17	476	956	173,691	349,290	365	365	0	0,13%	Missed the Target
m=7	December 17	472	946	196,032	395,075	415	418	2	0,55%	Missed the Target
m=8	January 18	465	942	188,956	388,685	406	413	6	1,54%	Missed the Target
m=9	February 18	462	937	171,941	362,469	372	387	15	3,94%	Missed the Target
m=10	March 18	460	929	173,616	369,731	377	398	21	5,45%	Missed the Target
m=11	April 18	457	926	135,479	265,725	296	287	-9	-3,20%	Success
m=12	May 18	450	912	147,558	276,929	328	304	-24	-7,40%	Success
m=13	June 18	447	911	138,224	266,645	309	293	-17	-5,35%	Success
m=14	July 18	444	904	139,869	271,928	315	301	-14	-4,51%	Success
m=15	August 18	436	896	139,730	277,441	320	310	-11	-3,38%	Success
m=16	September 18	434	897	136,963	269,381	316	300	-15	-4,84%	Success
m=17	October 18	427	894	57,307	117,803	134	132	-2	-1,82%	Promissing
Total months	June 17 - Oct 18	7,357	15,760	2,389,517	5,009,353	323	318	-5	-1,52%	

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 8.

Table 8: 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 9 to Table 11 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 9: 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 10: Success indication for the $eKPI_{ES2,a}$

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

Table 11: Success indication for the $eKPI_{ES2,M}$

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

Table 12 provides the results of the $eKPI_{ES2,a}$ and $eKPI_{ES2,M}$. Like before, two scenarios are analyzed. The first scenario includes only data from the treatment group, which has downloaded the app while the results for the second scenario also include households that used a desktop version of the app.

The $eKPI_{ES2,a}$ for scenario 1 is -0.04 %, which is according to pre-defined values is promising result. In contrast the $eKPI_{ES2,a}$ for scenario 2 is 0.46% meaning that the target is missed. The $eKPI_{ES2,M}$ is -1.28% (scenario 1) and -1.02% (scenario 2), so in both constellations for calculating this indicator the results are promising. Meaning the total average energy savings per active user over the whole field test period KPI is achieved in both scenarios. When calculating this KPI taking into account not only whether a household had access to PEAKapp or not, but also including active usage we find higher total average saving per user over the field test in scenario 1 (group with downloaded app) and similar results in scenario 2 (group with downloaded app and desktop version)

Table 12: $eKPI_{ES2,a}$ and $eKPI_{ES2,M}$ (Scenario 1 = violet and Scenario 2 =green)

$AECG_a$, $\frac{\sum_{m=1}^{M} ECG_m}{\sum_{m=1}^{M} CG_m}$	$AETG_a$, $\frac{\sum_{m=1}^{M} ETG_m}{\sum_{m=1}^{M} TG_m}$	ES_a, $AETG_a - AECG_a$	$eKPI_{ES2,a}$, $\frac{ES_a}{AECG_a}$	ES_M, $\sum_{m=1}^{M} ES_m \frac{AG_m}{max(AG_1,\dots,AG_M)}$	$eKPI_{ES1,M}$, $\frac{ES_M}{M \sum_{m=1}^{M} ECG_m / \sum_{m=1}^{M} CG_m}$
322.77	326.36	-0.13	-0.04%	-70.31	-1.28%
322.77	317.85	1.47	0.46%	-56.30	-1.02%

The $eKPI_{ES2,m}$ is shown at Table 13 for scenario 1 and at Table 14 for scenario 2. The $eKPI_{ES2,m}$ varies in the range of -11.11% and 7.68 % depending on the month in scenario 1. The average energy consumption of the active treatment group varies between -33 kWh in m=5 to 29 kWh in month m =9 compared to the average energy consumption of the control group. In nine of 17 months the resulting $eKPI_{ES2,m}$ indicates an success, in three months the results are promising and in five months the target is missed. In October 2018 which was the last month of the field test, the monthly average energy saving of the active treatment group compared to the control group reached 11.11% which is the highest value during the whole PEAKapp project time in this scenario.

Similar pattern with the highest monthly savings towards the end of the field test is observed also in scenario 2.In comparison the range of the $eKPI_{ES2,m}$ over the different months is higher at scenario 2 with -10.60% (energy savings) to 10.22% (additional energy consumption) the related $E_{S,m}$ is in the range of -33 kWh to 38 kWh. The resulting $eKPI_{ES2,m}$ indicates an success in 10 months, while in 6 months the target is missed. Looking at the distribution of saving in different months we assume that during the first month when PEAKapp was just launched there was an effect of new device /new application and higher interest from the users. In the following summer months the monthly average savings scaled back possibly due during these months while the novelty component and increase interest was gone more knowledge on the effect of PEAKapp was gather by households. This knowledge and experience later transformed into higher saving towards the second half of the field test.

Table 13: Average energy saving of the Active Treatment Group ($eKPI_{ES2,m}$ and $eKPI_{ES2,a}$) (scenario 1)

Month		Control Group (CG_m, $\sum_{m=1}^{M} CG_m$) [-]	Active Treatment Group (AG_m, $\sum_{m=1}^{M} AG_m$) [-]	Energy Consumption CG (ECG_m, $\sum_{m=1}^{M} ECG_m$) [kWh]	Energy Consumption AG (EAG_m, EAG_{tot}) [kWh]	Average Energy Consumption CG ($AECG_m$, $AECG_a$) [kWh]	Average Energy Consumption AG ($AEAG_m$, $AEAG_a$) [kWh]	Energy Saving (ES_m) [kWh]	$eKPI_{ES2,m}$ [%]	Success Indication
m=0	May 17	307		84,179		274				
m=1	June 17	319	231	96,190	66,319	302	287	-14	-4.79%	Success
m=2	July 17	344	108	101,853	34,029	296	315	19	6.42%	Missed the Target
m=3	August 17	391	68	111,183	20,185	284	297	12	4.39%	Missed the Target
m=4	September 17	437	204	130,725	62,051	299	304	5	1.68%	Missed the Target
m=5	October 17	436	119	150,201	37,093	344	312	-33	-9.52%	Success
m=6	November 17	476	184	173,691	67,042	365	364	-1	-0.15%	Promissing
m=7	December 17	472	181	196,032	74,314	415	411	-5	-1.14%	Promissing
m=8	January 18	465	143	188,956	55,087	406	385	-21	-5.20%	Success
m=9	February 18	462	141	171,941	56,506	372	401	29	7.68%	Missed the Target
m=10	March 18	460	133	173,616	51,088	377	384	7	1.77%	Missed the Target
m=11	April 18	457	147	135,479	42,003	296	286	-11	-3.62%	Success
m=12	May 18	450	160	147,558	47,513	328	297	-31	-9.44%	Success
m=13	June 18	447	120	138,224	36,282	309	302	-7	-2.22%	Success
m=14	July 18	444	103	139,869	31,051	315	301	-14	-4.30%	Success
m=15	August 18	436	115	139,730	36,676	320	319	-2	-0.49%	Promissing
m=16	September 18	434	131	136,963	37,621	316	287	-28	-9.00%	Success
m=17	October 18	427	82	57,307	9,782	134	119	-15	-11.11%	Success
Total months		7,357	2,370	2,389,517	764,642	323	323	0	-0.04%	

Table 14: Average energy saving of the Active Treatment Group ($eKPI_{ES2,m}$ and $eKPI_{ES2,a}$) (scenario 2)

Month		Control Group (CG_m, $\sum_{m=1}^{M} CG_m$) [-]	Active Treatment Group (AG_m, $\sum_{m=1}^{M} AG_m$) [-]	Energy Consumption CG (ECG_m, $\sum_{m=1}^{M} ECG_m$) [kWh]	Energy Consumption AG (EAG_m, EAG_{tot}) [kWh]	Average Energy Consumption CG ($AECG_m$, $AECG_a$) [kWh]	Average Energy Consumption AG ($AEAG_m$, $AEAG_a$) [kWh]	Energy Saving (ES_m) [kWh]	$eKPI_{ES2,m}$ [%]	Success Indication
m=0	May 17	307		84,179		274				
m=1	June 17	319	265	96,190	74,606	302	282	-20	-6.63%	Success
m=2	July 17	344	130	101,853	40,045	296	308	12	4.04%	Missed the Target
m=3	August 17	391	84	111,183	24,764	284	295	10	3.67%	Missed the Target
m=4	September 17	437	241	130,725	72,278	299	300	1	0.26%	Missed the Target
m=5	October 17	436	143	150,201	45,373	344	317	-27	-7.90%	Success
m=6	November 17	476	216	173,691	81,838	365	379	14	3.83%	Missed the Target
m=7	December 17	472	208	196,032	87,120	415	419	4	0.85%	Missed the Target
m=8	January 18	465	167	188,956	66,459	406	398	-8	-2.07%	Success
m=9	February 18	462	163	171,941	66,860	372	410	38	10.22%	Missed the Target
m=10	March 18	460	154	173,616	60,048	377	390	12	3.31%	Missed the Target
m=11	April 18	457	170	135,479	48,171	296	283	-13	-4.42%	Success
m=12	May 18	450	185	147,558	54,920	328	297	-31	-9.47%	Success
m=13	June 18	447	136	138,224	40,382	309	297	-12	-3.98%	Success
m=14	July 18	444	114	139,869	33,581	315	295	-20	-6.49%	Success
m=15	August 18	436	128	139,730	39,980	320	312	-8	-2.54%	Success
m=16	September 18	434	143	136,963	40,345	316	282	-33	-10.60%	Success
m=17	October 18	427	92	57,307	11,328	134	123	-11	-8.26%	Success
Total months		7,357	2,739	2,389,517	888,098	323	324	1	0.46%	

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 $\boldsymbol{eKPI_{MS,m}}$ 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 $\boldsymbol{eKPI_{MS,a}}$ 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 $\boldsymbol{eKPI_{MS,M}}$ 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.

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

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

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

Table 15 shows the needed variable for the calculation of the $eKPI_{MS}$

Table 15: 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.

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

Table 16 to Table 19 give 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 the target was missed.

Table 16: 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 17: Success indication for the $eKPI_{MS,a}$

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

Table 18: Success indication for the $eKPI_{MS,M}$

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

The monetary savings based on energy consumption reduction for the treatment compared to the control $eKPI_{MS,m}$ depending on month vary from -6.42 € to 4.32 € in scenario 1. The values in scenario show a somewhat smaller variation from -4.85 € to 4.11 €. Again a similar knowledge accumulation pattern can be observed based on the value of the KPIs in each months, which we the highest towards the second half of the field test. The top 3 saving months were May, June and September 2018 in both scenarios. In May 2018 we initiated a lottery with a goal to increase interaction with the app and remind about its functionalities. Such activities as the organized lottery are one of the key advantages of PEAKapp and should be used in the market uptake to support the communication with the users and increase their interest in energy saving topics and the app.

Table 19: Monetary savings monetary e*KPI*$_{MS,m}$ (Scenario 1 = violet and Scenario 2 =green)

	Month	Energy saving ES_m [kWh]	Monetary saving $eKPI_{MS,m}$ [€]	Energy saving ES_m [kWh]	Monetary saving $eKPI_{MS,m}$ [€]
m=0	May 17			-3.07	-0.61
m=1	June 17	-15.29	-3.06	-7.30	-1.46
m=2	July 17	11.96	2.39	-6.71	-1.34
m=3	August 17	17.94	3.59	0.53	0.11
m=4	September 17	2.61	0.52	-8.55	-1.71
m=5	October 17	21.56	4.31	-2.55	-0.51
m=6	November 17	-8.86	-1.77	0.47	0.09
m=7	December 17	27.82	5.56	2.30	0.46
m=8	January 18	-2.07	-0.41	6.26	1.25
m=9	February 18	8.65	1.73	14.67	2.93
m=10	March 18	12.69	2.54	20.56	4.11
m=11	April 18	3.52	0.70	-9.49	-1.90
m=12	May 18	-27.09	-5.42	-24.26	-4.85
m=13	June 18	-12.12	-2.42	-16.53	-3.31
m=14	July 18	-11.68	-2.34	-14.21	-2.84
m=15	August 18	-9.62	-1.92	-10.84	-2.17
m=16	September 18	-32.12	-6.42	-15.27	-3.05
m=17	October 18	-14.36	-2.87	-2.44	-0.49
Total months		3.59	0.72	-4.92	-0.98

The average monthly monetary saving for the treatment group compared to the control group are -2.50 € in scenario 1 which is promising. In the case of scenario 2 the $eKPI_{MS,M}$ is -12.32 € which indicates a success. Concerning the total average monetary savings over the whole field test period ($eKPI_{MS,a}$) there are no savings in scenario 1, instead an increase of 0.72 € (which indicates that the target was missed). In scenario 2 over the whole field test period the total average monetary savings are 0.98 €, which indicates a promising result. The mentioned results are presented in Table 20.

Table 20: Monetary saving e*KPI*$_{MS,a}$ *and* e*KPI*$_{MS,M}$ (Scenario 1 = violet and Scenario 2 =green)

	ES_a		ES_M	
Energy saving (ES_a and ES_M)	3.59 kWh		-12.49 kWh	
Monetary saving ($eKPI_{MS,a}$ and $eKPI_{MS,M}$)	0.72 €	Missed the Target	-2.50 €	Promising
Energy saving (ES_a and ES_M)	-4.92 kWh		-61.61 kWh	
Monetary saving ($eKPI_{MS,a}$ and $eKPI_{MS,M}$)	-0.98 €	Promising	-12.32 €	Success

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 $\boldsymbol{eKPI_{GHG,m}}$ 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 $\boldsymbol{eKPI_{GHG,a}}$ 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 $\mathbf{eKPI_{GHG,M}}$ 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.

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

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

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

Table 21 shows the needed variable for the calculation of the $eKPI_{GHG}$

Table 21: 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.

[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]

The average GHG emissions per month m of the treatment group compared to the control group are in the range of -16.06 kg $CO_{2\text{-eq}}$ per kWh to 10.78 kg $CO_{2\text{-eq}}$ per kWh at scenario 1 and in the range of -12.13 kg $CO_{2\text{-eq}}$ per kWh to 10.28 kg $CO_{2\text{-eq}}$ per kWh in scenario 2 (see Table 22).

Table 22: Energy saving and GHG emission reduction (Scenario 1 = violet and Scenario 2 =green)

	Month	Energy saving ES_m [kWh]	GHG reduction $eKPI_{GHG,m}$ [kg $CO_{2\text{-eq}}$ / kWh]	Energy saving ES_m [kWh]	GHG reduction $eKPI_{GHG,m}$ [kg $CO_{2\text{-eq}}$ / kWh]
m=0	May 17			-3.07	-1.53
m=1	June 17	-15.29	-7.64	-7.30	-3.65
m=2	July 17	11.96	5.98	-6.71	-3.36
m=3	August 17	17.94	8.97	0.53	0.26
m=4	September 17	2.61	1.31	-8.55	-4.28
m=5	October 17	21.56	10.78	-2.55	-1.27
m=6	November 17	-8.86	-4.43	0.47	0.23
m=7	December 17	27.82	13.91	2.30	1.15
m=8	January 18	-2.07	-1.03	6.26	3.13
m=9	February 18	8.65	4.32	14.67	7.34
m=10	March 18	12.69	6.35	20.56	10.28
m=11	April 18	3.52	1.76	-9.49	-4.75
m=12	May 18	-27.09	-13.54	-24.26	-12.13
m=13	June 18	-12.12	-6.06	-16.53	-8.27
m=14	July 18	-11.68	-5.84	-14.21	-7.11
m=15	August 18	-9.62	-4.81	-10.84	-5.42
m=16	September 18	-32.12	-16.06	-15.27	-7.63
m=17	October 18	-14.36	-7.18	-2.44	-1.53
Total months		3.59	1.79	-4.92	-1.22

The average monthly *GHG* emission reduction due to an energy consumption reduction for the treatment group compared to the control group ($eKPI_{MS,M}$) is 6.25 kg $CO_{2\text{-eq}}$ in scenario 1 resp. 30.81 kg $CO_{2\text{-eq}}$ in scenario 2. Over the whole field test period the difference between the control group and the treatment group ($eKPI_{MS,a}$) is in average 1.79 kg $CO_{2\text{-eq}}$ in scenario 1 and -2.46 kg $CO_{2\text{-eq}}$ at scenario 2 (see Table 22).

Table 23: GHG emission reduction $eKPI_{GHG}$ (Scenario 1 = violet and Scenario 2 =green)

	ES_a	ES_M
Energy saving (ES_a and ES_M)	3.59 kWh	-12.49 kWh
GHG saving ($eKPI_{MS,a}$ and $eKPI_{MS,M}$)	1.79 kg $CO_{2\text{-eq}}$	-6.25 kg $CO_{2\text{-eq}}$
Energy saving (ES_a and ES_M)	-4.92 kWh	-61.61 kWh
GHG saving ($eKPI_{MS,a}$ and $eKPI_{MS,M}$)	-2.46 kg $CO_{2\text{-eq}}$	-30.81 kg $CO_{2\text{-eq}}$

[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 24.

Table 24: 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

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

Load shift – Difference in Energy consumption to Group A

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

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

Table 25 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 25: 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 %

The energy consumption per group, the amount of group members and the average energy consumption before, during and after a price incentive is shown in Table 27. The energy consumption per group for the different months during the field test period is shown in Table 28 and Table 27 and the average energy consumption over the whole test period as well as the load shift is visualized for each group in Table 26 and Figure 1. The underlying colours at Table 26 indicates the success for $eKPI_{LS,g,s,m}$, where green = success, yellow = promising and red = missed the target. The number of users in the treatment groups A, B and C varies between groups and months ($G_{g,m}$). The average energy consumption per group $AEC_{g,m}$,varies depending on the month, in general the energy consumption

is higher in the winter time than it is in summer time. The highest average energy consumption is observed for group A in each month over the whole field test period. Furthermore, the energy consumption per month in total and in average during the price incentive was the highest for group A compared to the other groups.

Looking at the load shift and energy consumption can be seen that there are differences between the groups A, B and C. Over the whole field test period the highest average energy consumption is observed for group A in each month and during the price incentive.

Table 26: Average Energy consumption $AEC_{g,m,s}$ and Load Shift

	Group	Before (s=1) [kWh]	During (s=2) [kWh]	After (s=3) [kWh]	Sum [kWh]
Average Energy consumption $AEC_{g,m,s}$	A	47.88	10.84	56.12	114.84
	B	41.47	9.35	49.18	100.01
	C	43.28	9.63	51.21	104.12
$LS_{B,m,s}$	A/B	6.40	1.49	6.94	14.84
$LS_{C,m,s}$	A/C	4.59	1.21	4.91	10.72
$eKPI_{LSB,s,m}$	A/B	15.4%	15.9%	14.1%	14.8%
$eKPI_{LSC,s,m}$	A/C	10.6%	12.6%	9.6%	10.3%

Figure 1: $AEC_{g,m,s}$ before, during and after the price incentive

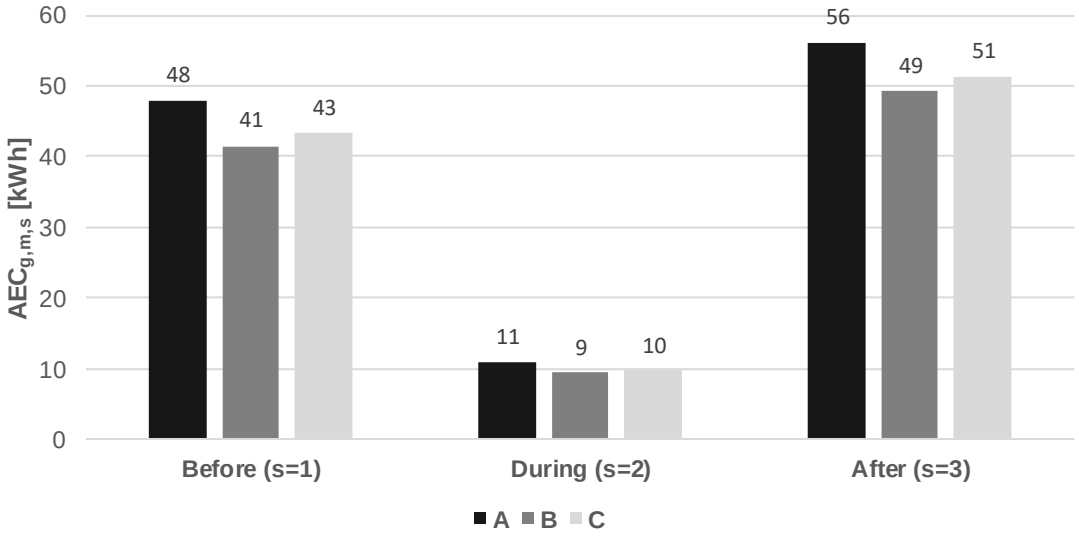

Table 27: Energy consumption before, during and after a price incentive

		Group	Total energy consumption				$G_{g,m}$ [-]	$AEC_{g,m,s}$ [kWh]
			Before (s=1) [kWh]	During (s=2) [kWh]	After (s=3) [kWh]	Sum [kWh]		
m=1	June 17	A	8,296	1,601	10,337	20,234	326	62.07
		B	6,898	1,287	8,776	16,961	369	45.96
		C	6,734	1,238	8,285	16,257	319	50.96
m=2	July 17	A	13,692	2,894	16,786	33,372	358	93.22
		B	12,188	2,540	15,407	30,135	391	77.07
		C	11,572	2,433	14,684	28,689	344	83.40
m=3	Aug.17	A	7,226	2,643	18,589	28,458	388	73.35
		B	6,100	2,386	16,660	25,146	426	59.03
		C	6,136	2,306	16,177	24,619	391	62.96
m=4	Sep.17	A	13,333	3,186	20,713	37,232	436	85.39
		B	11,984	2,893	19,040	33,917	452	75.04
		C	12,098	2,884	19,225	34,207	437	78.28
m=5	October 17	A	26,490	5,781	24,517	56,788	434	130.85
		B	23,925	5,207	22,675	51,806	456	113.61
		C	24,514	5,164	23,035	52,712	436	120.90
m=6	Nov.17	A	24,402	6,957	37,015	68,375	470	145.48
		B	22,713	6,331	34,500	63,544	486	130.75
		C	23,189	6,394	34,542	64,124	476	134.71
m=7	December 17	A	19,574	7,436	40,043	67,054	469	142.97
		B	17,157	6,638	36,145	59,940	477	125.66
		C	17,884	6,705	37,238	61,827	472	130.99
m=8	January 18	A	36,672	5,334	26,805	68,811	465	147.98
		B	33,324	4,770	24,174	62,269	477	130.54
		C	33,674	4,689	24,664	63,026	465	135.54
m=9	February 18	A	43,805	7,228	37,195	88,228	461	191.38
		B	40,113	6,352	34,080	80,545	476	169.21
		C	39,616	6,234	33,113	78,963	462	170.92
m=10	March 18	A	24,070	5,464	35,725	65,259	457	142.80
		B	21,874	4,804	31,691	58,369	472	123.66
		C	21,244	4,756	30,903	56,903	460	123.70
m=11	Apr.18	A	13,696	4,161	18,704	36,561	455	80.35
		B	12,430	3,781	17,481	33,691	471	71.53
		C	12,394	3,843	17,222	33,459	457	73.21
m=12	May 18	A	17,601	3,464	11,501	32,567	446	73.02
		B	16,085	3,357	10,957	30,399	466	65.23
		C	16,226	3,292	11,118	30,636	450	68.08
m=13	June 18	A	18,131	4,922	23,664	46,717	447	104.51
		B	16,661	4,641	22,537	43,838	464	94.48
		C	16,060	4,489	22,048	42,596	447	95.29
m=14	July 18	A	14,739	4,618	21,852	41,209	443	93.02
		B	13,411	4,262	20,701	38,373	461	83.24
		C	13,152	4,003	20,595	37,751	444	85.02
m=15	Aug.18	A	24,231	5,795	24,268	54,295	440	123.40
		B	22,022	5,261	22,425	49,708	456	109.01
		C	21,591	5,121	22,109	48,820	436	111.97
m=16	Sep.18	A	26,019	3,686	21,453	51,158	439	116.53
		B	24,129	3,356	19,713	47,198	458	103.05
		C	23,865	3,170	19,924	46,959	434	108.20
Total months		A	331,978	75,172	389,167	796,317	6,934	114.84
		B	301,013	67,865	356,962	725,840	7,258	100.01
		C	299,947	66,720	354,882	721,548	6,930	104.12

Table 28: Average energy consumption before, during and after a price incentive

		Group	Average energy consumption			
			Before (s=1) [kWh]	During (s=2) [kWh]	After (s=3) [kWh]	Sum (= $AEC_{g,m,s}$) [kWh]
m=1	June 17	A	25.45	4.91	31.71	62.07
		B	18.69	3.49	23.78	45.96
		C	21.11	3.88	25.97	50.96
m=2	July 17	A	38.24	8.09	46.89	93.22
		B	31.17	6.50	39.40	77.07
		C	33.64	7.07	42.69	83.40
m=3	Aug.17	A	18.62	6.81	47.91	73.35
		B	14.32	5.60	39.11	59.03
		C	15.69	5.90	41.37	62.96
m=4	Sep.17	A	30.58	7.31	47.51	85.39
		B	26.51	6.40	42.12	75.04
		C	27.68	6.60	43.99	78.28
m=5	October 17	A	61.04	13.32	56.49	130.85
		B	52.47	11.42	49.73	113.61
		C	56.22	11.84	52.83	120.90
m=6	Nov.17	A	51.92	14.80	78.76	145.48
		B	46.74	13.03	70.99	130.75
		C	48.72	13.43	72.57	134.71
m=7	December 17	A	41.74	15.86	85.38	142.97
		B	35.97	13.92	75.78	125.66
		C	37.89	14.21	78.89	130.99
m=8	January 18	A	78.87	11.47	57.64	147.98
		B	69.86	10.00	50.68	130.54
		C	72.42	10.08	53.04	135.54
m=9	February 18	A	95.02	15.68	80.68	191.38
		B	84.27	13.34	71.60	169.21
		C	85.75	13.49	71.67	170.92
m=10	March 18	A	52.67	11.96	78.17	142.80
		B	46.34	10.18	67.14	123.66
		C	46.18	10.34	67.18	123.70
m=11	Apr.18	A	30.10	9.15	41.11	80.35
		B	26.39	8.03	37.11	71.53
		C	27.12	8.41	37.69	73.21
m=12	May 18	A	39.47	7.77	25.79	73.02
		B	34.52	7.20	23.51	65.23
		C	36.06	7.31	24.71	68.08
m=13	June 18	A	40.56	11.01	52.94	104.51
		B	35.91	10.00	48.57	94.48
		C	35.93	10.04	49.32	95.29
m=14	July 18	A	33.27	10.42	49.33	93.02
		B	29.09	9.24	44.90	83.24
		C	29.62	9.02	46.39	85.02
m=15	Aug.18	A	55.07	13.17	55.16	123.40
		B	48.29	11.54	49.18	109.01
		C	49.52	11.74	50.71	111.97
m=16	Sep.18	A	59.27	8.40	48.87	116.53
		B	52.68	7.33	43.04	103.05
		C	54.99	7.30	45.91	108.20
Total months		A	47.88	10.84	56.12	114.84
		B	41.47	9.35	49.18	100.01
		C	43.28	9.63	51.21	104.12

4 Key performance indicators (KPI)

4.1 Customer satisfaction related key performance indicators

In the following chapter, key performance indicators which are related to the customer satisfaction with the app are analysed. The number and the activity level of users was measured to get a clear picture about the attractiveness of the app to the customers over time.

For a consistent understanding of the KPIs following definitions for the term user and cohort are necessary:

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

The term **cohort** refers to a group of people which can be restricted geographically and/or demographically. An example for a cohort is: All Austrian citizens, younger than 50 years living in a flat.

4.1.1 Active Users ($KPI_{AU1,m}$ and $KPI_{AU2,t,m}$)

The key performance indicator $\boldsymbol{KPI_{AU1,m}}$ gives the number of users who have opened the app at least once in month *m* compared to the total number of users.

$KPI_{AU1,m}$ depicts how the app is performing over a certain time period since the app release. This indicator gives an overview of the usage trends of the app over the time horizon of the app. An increase in $KPI_{AU1,m}$ over time indicates increased customer satisfaction with the app. Moreover $KPI_{AU1,m}$ is more informative about growing demand for the app than the accumulation of new users because it gives information about the activity of the customers.

$\boldsymbol{KPI_{AU2,t,m}}$ compares active users in relation to non-active users since the download of the app.

This indicator shows how many users are using the app in month t after the download of the app. This key figure is important to highlight the development of customer behaviour and satisfaction with the app. A very low $KPI_{AU2,t,m}$ can serve as a warning signal, that measures have to be made to increase customer satisfaction.

For calculating $KPI_{AU1,m}$ and $KPI_{AU2,t,m}$ the cohort (geographically, demographically) and all further input variables need to be defined. The definition of the input variables is found in Table 29.

$$\boldsymbol{KPI_{AU1,m}} = \frac{\boldsymbol{A_m}}{\boldsymbol{D_m}} \qquad \text{Eq. 1}$$

$$\boldsymbol{KPI_{AU2,t,m}} = \frac{\boldsymbol{A_t}}{\boldsymbol{D_{t,m}}} \qquad \text{Eq. 2}$$

Table 29: Variables for the calculation of Active User key performance indicators

Variable	Symbol	Units	Description
Active users in month t	A_t	# of users	Number of users who have logged in into the app at least once in month t.
Number of users in month t after the month of the download	$D_{t,m}$	# of users	Number of users that have had the app at least for t months within m months since the app release.
Number of users in month m	D_m	# of users	Number of all users which downloaded the app until month m.
Active users in month m	A_m	# of users	Number of users which have logged in into the app at least once in month m.

To give the $KPI_{AU1,m}$ the right interpretation, it is important to understand the composition of A_m. The number of active users within a month depends on new users which have opened the app in month m, users which have been inactive before but have been active in month m and retained users. $KPI_{AU1,m}$ therefore increases if the number of new users, re-activated users and retained users is larger than the number of lost/inactive users. $KPI_{AU1,m}$ has to be calculated over several months to be able to make comparisons and interpretations.

Because the key performance indicators are very volatile over time and difficult to forecast it was decided to give a range for the indicators to check if the project is a success, promising or if it missed the target. Table 30 provides the indication for the $KPI_{AU1,m}$.

Table 30: Success indication for the $KPI_{AU1,m}$

Month m after release	Success	Promising	Missed the Target
1	> 0.30	0.30 to 0.15	< 0.15
2	> 0.30	0.30 to 0.15	< 0.15
3	> 0.15	0.30 to 0.07	< 0.07
12	> 0.07	0.07 to 0.04	< 0.04

When working on the values of the indicators in Deliverable 1.5 we assumed that most users would start using the app as soon as it was released and therefore special emphasis in the indication of success was put on the usage within the first months. After the first months, the activity level was predicted to decrease which is shown by the $KPI_{AU2,t,m}$. Table 31 gives an overview of the range of $KPI_{AU2,t,m}$ to check if the project is successful, promising or if it missed the target.

Table 31: Success indication for the $KPI_{AU2,t,m}$

Month t after the download of the app	Success	Promising	Missed the Target
0	> 0.30	0.30 to 0.15	< 0.15
1	> 0.15	0.15 to 0.07	< 0.07
2	> 0.07	0.07 to 0.04	< 0.04
11	> 0.07	0.07 to 0.04	< 0.04

The $KPI_{AU1,m}$ showing active users in relation to non-active users since the download of the app. The results for the different months of the field test period are shown at Table 32. It can be seen that the $KPI_{AU1,m}$ varies in the range from 46% to 100% depending on the month. The average value of this KPI over the whole field test period the $KPI_{AU1,m}$ is 74%. The only month with promising results was September 2017, in all the other months the $KPI_{AU1,m}$ indicates a success. Furthermore, looking at the distribution of the KPI across the months of the field tests we find that there was a higher relation of active to non-active users towards the end of the field tests. Table 33 visualizes the $KPI_{AU2,t,m}$ for the whole field test period. The persistent interest in the functionalities of the app exceeded all the expectations, as users were active throughout all the 17 months of the field test. PEAKapp is of the first projects to demonstrate such long and persistent user engagement in the energy management ICT.

The success indication for the $KPI_{AU2,t,m}$ is visualized by different colours at Table 33.Green indicates a success, yellow a promising result and red that the set target is missed. The visualized success indication is based on the month t after the download of the app (see Table 31). Table 31: Success indication for the $KPI_{AU2,t,m}$

Table 32: Active User ($KPI_{AU1,m}$)

	Month	D_m	A_m	$KPI_{AU1,m}$	Success Indication
m=1	June 17	232	231	100%	Success
m=2	July 17	166	108	52%	Success
m=3	August 17	112	68	72%	Success
m=4	September 17	225	204	76%	Promissing
m=5	October 17	210	119	69%	Success
m=6	November 17	230	184	70%	Success
m=7	December 17	260	181	74%	Success
m=8	January 18	207	143	67%	Success
m=9	February 18	193	141	73%	Success
m=10	March 18	177	133	72%	Success
m=11	April 18	198	147	74%	Success
m=12	May 18	208	160	67%	Success
m=13	June 18	167	120	70%	Success
m=14	July 18	132	103	57%	Success
m=15	August 18	145	115	69%	Success
m=16	September 18	160	131	85%	Success
m=17	October 18	171	82	46%	Success
Total months		3,193	2,370	74%	

Table 33: Active User ($KPI_{AU2,t,m}$)

		m																	Over all months
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
t	0		100%	100%	100%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	1			60%	42%	60%	39%	53%	43%	29%	83%	59%	63%	38%	83%	71%	100%	80%	13%	52%
	2				59%	88%	33%	75%	69%	74%	88%	88%	73%	100%	100%	93%	67%	100%	75%	72%
	3					75%	89%	67%	71%	100%	68%	71%	87%	92%	33%	57%	75%	100%	50%	76%
	4						68%	56%	50%	63%	67%	75%	69%	88%	70%	100%	80%	80%	17%	69%
	5							69%	71%	50%	69%	89%	65%	77%	80%	80%	100%	71%	50%	70%
	6								75%	83%	50%	72%	70%	76%	67%	83%	80%	100%	33%	74%
	7									66%	71%	0%	63%	78%	60%	75%	80%	100%	0%	67%
	8										61%	67%	100%	74%	89%	81%	89%	73%	73%	73%
	9											76%	83%	100%	62%	88%	76%	70%	55%	72%
	10												80%	83%	100%	60%	88%	83%	45%	74%
	11													67%	33%		75%	75%	56%	67%
	12														71%	100%		72%	50%	70%
	13															77%	100%	100%	36%	57%
	14																72%	67%	0%	69%
	15																	86%	75%	85%
	16																		46%	46%
Over all months			100%	65%	61%	91%	57%	80%	70%	69%	73%	75%	74%	77%	72%	78%	79%	82%	48%	74%

Explanation for reading the table by an example: In month m =3 and t =1 there were 42% of the users active users. This means that 42% of those who have downloaded the app just a month before (t=1) are active users in August 2017 (m=3). For m=3 independent of t, the month when the app download accrued, there are 61 % of active users. For the t=1, there are 52% of active users over all the months m. The underlying colours visualizes the success indication based on t, green = success, yellow = promising and red = missed the target

4.1.2 Average Session Duration ($KPI_{ASD1,m}$ and $KPI_{ASD2,t,m}$)

Another important metric to measure the activity level of the users is the average time spent with the app. To calculate the KPI_{ASD} information about the total time which users spend in the app is needed.

In the next step the total time spend in the app will be set into relation to the total number of app users. The session duration is defined as the time between session start and session end. The session starts when the user logs in into the app and ends when the user logs out of the app. The KPI_{ASD} is divided into two indicators.

$\boldsymbol{KPI_{ASD1,m}}$ gives the average session duration of the users in month m.

The first indicator shows how the average session duration has changed since the app release.

$\boldsymbol{KPI_{ASD2,t,m}}$ gives the average session duration of the users in month t after the download of the app.

It therewith shows the development of the average session duration of the users since their download.

Table 34: Variables for the calculation of Average Session Duration key performance indicators

Variable	Symbol	Units	Description
Number of users in month m	D_m	# of users	Number of all users which downloaded the app until month m.
Session duration of users in month m	SD_m	time in minutes	Total time spend in the app of all users in month m
Number of users in month t after the month of the download	$D_{t,m}$	# of users	Number of users that have had the app at least for t months.
Session duration of users in month *t* after the month of the download	SD_t	time in Minutes	Total time spend in the app of all users who have used the app at least once in month t.

$$\boldsymbol{KPI_{ASD1,m} = \frac{SD_m}{D_m}} \quad \text{Eq. 3}$$

$$\boldsymbol{KPI_{ASD2,t,m} = \frac{SD_t}{D_{t,m}}} \quad \text{Eq. 4}$$

The interpretation for both *KPIs* is the following. The KPI_{ASD} is increasing if the session duration is increasing or the number of downloads are decreasing. An increase of the KPI_{ASD} is a sign for more activity in the app. The $KPI_{ASD1,m}$ shows the activity level of the users since the release of the app and the $KPI_{ASD2,t,m}$ gives the activity level of the users since their download of the app. The combination of both indicators depicts a clear picture of the activity development in minutes per user over time.

Because this project is based on a field experiment and therefore the suggestions for a success indication are very similar for $KPI_{ASD1,m}$ and $KPI_{ASD2,t,m}$. Table 35 gives an overview of $KPI_{ASD1,m}$ measured in minutes, to check whether the project was a success, promising or missed the target:

Table 35: Success indication for the $KPI_{ASD1,m}$

Month m after release	Success	Promising	Missed the Target
m=1	> 30 minutes per user	30 to 10 minutes per user	< 10 minutes per user
m=2	> 30 minutes per user	30 to 10 minutes per user	< 10 minutes per user
m=3	> 15 minutes per user	15 to 5 minutes per user	< 5 minutes per user
m=12	> 15 minutes per user	15 to 3 minutes per user	< 3 minutes per user

Table 36 gives an overview of $KPI_{ASD2,t,m}$ measured in minutes, to check whether the project was a success, promising or missed the target:

Table 36: Success indication for the $KPI_{ASD2,t,m}$

Month t after the download of the app	Success	Promising	Missed the Target
t=0	> 30 minutes per user	30 to 10 minutes per user	< 10 minutes per user
t=1	> 30 minutes per user	30 to 10 minutes per user	< 10 minutes per user
t=2	> 15 minutes per user	15 to 5 minutes per user	< 5 minutes per user
t=11	> 15 minutes per user	15 to 3 minutes per user	< 3 minutes per user

The average session duration can be seen in Table 37. The $KPI_{ASD1,m}$ varies between 7 min to 31 minutes per user, depending on the month. Looking at the different months can be seen that the session duration is typically higher in the first months after the app release and lower in the last months of the field test period. This effect is in line with the predicted usage pattern of the app. Namely due to novelty and no knowledge about the app and its functionalities households spent more time in the beginning for each session to get to know what it actually does. In the last months they average interaction time with the app decreased as the novelty interest has already been gone, but also as the household already gather a solid knowledge about which functionalities of the app to use and how to. In six months the results, regarding the average session is promising and in eleven months, the session duration indicates a success. The $KPI_{ASD2,t,m}$ is shown at Table 38.

Table 37: Average session duration ($KPI_{ASD1,m}$)

Month		D_m	SD_m	$KPI_{ASD1,m}$	Success Indication
m=1	June 17	232	7,112	31	Success
m=2	July 17	166	3,671	22	Promissing
m=3	August 17	112	2,713	24	Success
m=4	September 17	225	5,543	25	Success
m=5	October 17	210	4,650	22	Success
m=6	November 17	230	5,407	24	Success
m=7	December 17	260	4,538	17	Success
m=8	January 18	207	4,304	21	Success
m=9	February 18	193	4,079	21	Success
m=10	March 18	177	4,024	23	Success
m=11	April 18	198	3,547	18	Success
m=12	May 18	208	3,157	15	Success
m=13	June 18	167	2,129	13	Promissing
m=14	July 18	132	1,802	14	Promissing
m=15	August 18	145	1,783	12	Promissing
m=16	September 18	160	1,850	12	Promissing
m=17	October 18	171	1,135	7	Promissing
Total months		3,193	61,444	19	

Table 38: Average session duration ($KPI_{ASD2,t,m}$)

		m																	Over all months
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
t	0	31	58	13	24	33	20	13	47	26	17	21	21	28	12	31	12	10	27
	1		17	52	32	20	22	17	8	43	17	14	15	17	23	15	19	5	19
	2			22	77	11	27	13	21	9	52	18	36	16	16	15	5	4	24
	3				18	61	15	17	12	19	8	31	13	6	10	9	13	5	18
	4					18	57	4	17	11	18	7	16	13	5	21	13	7	17
	5						21	65	20	21	13	23	4	15	15	16	7	4	19
	6							18	63	8	21	9	16	4	22	11	5	3	18
	7								15	50	1	20	12	8	5	19	14	5	16
	8									14	70	9	14	9	9	6	15	9	15
	9										20	26	17	14	9	10	5	11	15
	10											13	6	15	14	6	9	3	11
	11												16	20		13	13	9	14
	12													11	42		12	8	12
	13														12	4	5	4	7
	14															12	15	8	12
	15																11	13	12
	16																	8	8
Over all months		31	22	24	25	22	24	17	21	21	23	18	15	13	14	12	12	7	19

Explanation for reading the table by an example: In month m =3 and t =1 there was the average session duration 52 minutes. This means that those who have downloaded the app just a month before (t=1) are used the app in August 2017(m=3) in average 52 minutes. For m=3 independent of t, the month when the app download accrued, the average session duration is 24 minutes. For the t=1, the average session duration is 19 minutes. The underlying colours visualizes the success indication based on t, green = success, yellow = promising and red = missed the target

4.1.3 Average Numbers of Bets ($KPI_{NB1,m}$ and $KPI_{NB2,t,m}$)

In the game the players have to make everyday a bet about their energy consumption. The KPI_{NB} measures the average number of bets of the users within a certain time period. The KPI_{NB} is divided into two indicators:

The $\boldsymbol{KPI_{NB1,m}}$ is an indicator which measures the average numbers of bets of the users in month m.

The first indicator shows the development of the average number of bets of the users in month m since the app release.

The $\boldsymbol{KPI_{NB1,t,m}}$ is an indicator which measures the average numbers of bets of the users in month t after the app download.

It therewith shows the development of the average number of bets of the users since their app download.

Like the indicators before, the number of bets is also an indicator for the activity level of the customers. To calculate this indicator the number of bets per user, within a cohort, within a certain month is needed. The difference to the number of active users, is that the users have to participate in the game with giving a bet on their consumption. It is not sufficient just to be logged in into the app. Furthermore the numbers of bets per user are restricted by one bet a day.

Table 39: Variables for the calculation of Average Numbers of Bets key performance indicator

Variable	Symbol	Units	Description
Bets in month m	B_m	# of bets	Total number of bets in month m
Number of users in month m	D_m	# of users	Number of all users which downloaded the app until month m
Number of users in month t after the month of the download	$D_{t,m}$	# of users	Number of users that have the app at least since t month.
Bets in t months after the month of the download	B_t	# of bets	Total number of bets of all users who set a bet at least once in month t.

$$\boldsymbol{KPI_{NB1,m} = \frac{B_m}{D_m}} \qquad \text{Eq. 5}$$

$$\boldsymbol{KPI_{NB2,t,m} = \frac{B_t}{D_{t,m}}} \qquad \text{Eq. 6}$$

The KPI_{NB} increases if the numbers of bets over a month are increasing or if total users over a month are decreasing. The $KPI_{NB1,m}$ shows the average number of bets per user since the release of the app and the $KPI_{NB2,t,m}$ gives the average number of bets per users since their download of the app. The combination of both indicators depicts a clear picture of the placement of bet development in bets per user over time.

As already mentioned this project is based on a field experiment and therefore the suggestions for a success indication are very similar for $KPI_{NB1,m}$ and $KPI_{NB2,t,m}$. Table 40 gives an overview of $KPI_{NB1,m}$ measured in placed bets, to check whether the project was a success, promising or missed the target:

Table 40: Success indication for the $KPI_{NB1,m}$

Month m after release	Success	Promising	Missed the Target
m=1	> 15 bets per user	15 to 5 bets per user	< 5 bets per user
m=2	> 15 bets per user	15 to 5 bets per user	< 5 bets per user
m=3	> 10 bets per user	10 to 5 bets per user	< 5 bets per user
m=12	> 5 bets per user	5 to 3 bets per user	< 3 bets per user

Table 41 gives an overview of $KPI_{NB2,t,m}$ measured in placed bets, to check whether the project was a success, promising or missed the target:

Table 41: Success indication for the $KPI_{NB2,t,m}$

Month t after the download of the app	Success	Promising	Missed the Target
t=0	> 15 bets per user	15 to 5 bets per user	< 5 bets per user
t=1	> 15 bets per user	15 to 5 bets per user	< 5 bets per user
t=2	> 10 bets per user	10 to 5 bets per user	< 5 bets per user
t=11	> 5 bets per user	5 to 3 bets per user	< 3 bets per user

The average bets per month and user are shown in Table 42. Looking at the KPI_{NB1} can be seen that in average 0.59 to 3.66 bets per user are made depending on the month. Over all the months of the field test the target was missed. The $KPI_{NB2,t,m}$ is shown at Table 43. Although the PEAK poker was the …. Visited page of the app with……views in the field tests, looking at the result of this KPI we find that the game was not played as often as predicted. There are several possible explanations for this effect, during the survey after the end of field tests we found out that a major share of PEAKapp users fall into category from 45 to 65 years old, so one possible explanation is that simply this age group is not attracted by game and its learning effects. Another possible explanation is the limited number of possibities to tweak you consumption which is the key learning tool of the game. Having played the game several times further playing could simple become uninteresting to the households. This results should be taken into consideration in the context of PEAKapp market uptake as each functionality costs money and the game although regular played was not the preferred option by the majority.

Table 42: Average Bets ($KPI_{NB1)}$

Month		D_m	B_m	$KPI_{NB1,m}$	Success Indication
m=1	June 17	232	489	2.11	Missed the Target
m=2	July 17	166	346	2.08	Missed the Target
m=3	August 17	112	410	3.66	Missed the Target
m=4	September 17	225	494	2.20	Missed the Target
m=5	October 17	210	495	2.36	Missed the Target
m=6	November 17	230	424	1.84	Missed the Target
m=7	December 17	260	413	1.59	Missed the Target
m=8	January 18	207	464	2.24	Missed the Target
m=9	February 18	193	473	2.45	Missed the Target
m=10	March 18	177	436	2.46	Missed the Target
m=11	April 18	198	309	1.56	Missed the Target
m=12	May 18	208	311	1.50	Missed the Target
m=13	June 18	167	298	1.78	Missed the Target
m=14	July 18	132	286	2.17	Missed the Target
m=15	August 18	145	242	1.67	Missed the Target
m=16	September 18	160	162	1.01	Missed the Target
m=17	October 18	171	101	0.59	Missed the Target
Total months		3,193	6,153	1.93	

Table 43: Average Bets ($KPI_{NB2,t,m}$)

t \ m	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Gesamt-ergebnis
0	2.11	4.95	3.40	1.40	2.22	0.63	0.63	2.48	1.40	0.89	1.65	1.25	2.14	8.00	2.00	0.44	1.00	1.71
1		1.69	9.67	8.20	1.83	3.12	0.89	0.29	2.67	2.12	0.63	2.69	1.06	1.71	7.00	1.20	0.50	1.91
2			2.89	6.63	3.83	2.53	1.75	1.13	0.53	2.13	1.73	0.00	3.00	0.87	1.00	5.00	0.25	2.23
3				2.91	4.89	2.00	2.14	1.07	2.09	0.07	1.40	0.77	0.00	2.71	0.31	1.00	3.50	2.01
4					2.78	4.56	0.00	3.60	1.75	1.82	0.38	2.24	0.00	0.00	3.40	0.00	0.33	2.22
5						2.08	1.43	2.00	3.57	1.67	1.12	0.38	2.20	0.10	0.00	0.00	0.07	1.80
6							2.28	5.33	2.00	3.97	1.70	0.76	0.22	2.67	0.30	0.00	0.00	2.22
7								2.68	5.43	0.00	2.37	1.56	1.12	0.13	3.10	0.33	0.00	2.16
8									2.54	5.33	0.50	2.34	0.67	1.81	0.33	1.00	0.27	1.94
9										2.74	3.17	0.00	3.58	1.75	1.35	0.00	0.64	2.22
10											1.41	2.33	0.00	4.10	0.63	1.00	0.00	1.68
11												1.33	6.67		3.29	0.00	1.00	1.81
12													1.83	8.00		2.52	0.00	2.04
13														2.32	3.80	0.00	1.00	1.69
14															1.00	5.67	0.00	1.45
15																0.83	1.50	0.91
16																	0.50	0.50
Gesamt-ergebnis	2.11	2.08	3.66	2.20	2.36	1.84	1.59	2.24	2.45	2.46	1.56	1.50	1.78	2.17	1.67	1.01	0.59	1.93

Explanation for reading the table by an example: In month m =3 and t =1 the average bets were 9.67. This means that those who have downloaded the app just a month before (t=1) are made in August 2017 (m=3) in average 9.67 bets. For m=3 independent of t, the month when the app download accrued, the average bets are 3.66.. For the t=1, the average bets are 1.91. The underlying colours visualizes the success indication based on t, green = success, yellow = promising and red = missed the target

4.1.4 Number of downloads ($KPI_{DOW,m}$)

The number of downloads indicates the popularity of the app. A large number of downloads shows high popularity for the app but it does not give information about the usage of the app. Therefore the number of downloads should be combined with the other *KPIs* which have been defined before to get a clearer view about customer satisfaction with the app.

The $KPI_{DOW,m}$ shows the number of downloads compared to the number of customers to whom the app was offered.

Table 44: Variables for the calculation of Number of downloads key performance indicator

Variable	Symbol	Units	Description
Total Target Group	*N*	# of people	Number of customers of the energy supplier to whom the app was offered
Number of users in month m	D_m	# of users	Number of all users which downloaded the app until month m.

$$KPI_{DOW,m} = \frac{D_{m2}}{N} \qquad \text{Eq. 7}$$

During the field test period the amount of households data was collected from, increased at different dates (see Table 45). In June 2017 (m=1) 671 households were participating in the field test, the amount increased by 610 households in September 2017 (m=4) and 292 in November 2017 (m=6). The relevant number for calculating the $KPI_{DOW,m}$ are those housholds whom the app was offered to. Hence, N consists of the members which belongs to Group A and Group B.

Table 45: Tranches of participants joining PEAKapp fieldstudy

Tranche	Starting date	Group A (Tariff group)	Group B (App group)	Group C (Control group)	∑ Households
1	11. June 2017	290	207	174	671
2	19. September 2017	157	226	227	610
3	20. November 2017	81	93	118	292

To answer the question what is a good number of downloads is difficult because it is depending on the target of a project. Because in this project a field experiment is started with special circumstances following range for the $KPI_{DOW,m}$ after 12 months is suggested to check whether the project is a success, promising or missed the target:

Table 46: Success indication for the $KPI_{DOW,m}$

Month m after release	Success	Promising	Missed the Target
$KPI_{DOW,m}$	> 80%	80 % to 60 %	< 60 %

Table 47 shows the $KPI_{DOW,m}$. It can be seen that depending on the tranche participants joining PEAKapp field study 44.4% to 84.5% downloaded the app. In overall 55.1% households downloaded the app. This number refer those households, which downloaded the app at least once (only the first download is counted). Looking at D_{m1} compared to D_{m2} can be seen that there were various households which multiple downloaded the app.

The success indication for the $KPI_{DOW,m}$. which is calculated by D_{m2} (only one download counts per household) is visualized by different colours at. Green indicates a success, yellow a promising result and red that the set target is missed. For tranche 3 the $KPI_{DOW,m}$ indicates a success, while at tranche 1 and 2 the target was missed.

Table 47: *$KPI_{DOW,m}$*

Month		D_{m1} (All downloads of housholds)	D_{m2} (Only 1st download per household)	N	$KPI_{DOW,m}$	$KPI_{DOW,m}$
m=1	June 17	254	252		50.7%	53.1%
m=2	July 17	185	11	497	2.2%	
m=3	August 17	122	1		0.2%	
m=4	September 17	254	153	new 383	39.9%	44.4%
m=5	October 17	241	17	∑ 880	4.4%	
m=6	November 17	276	110		63.2%	84.5%
m=7	December 17	294	0		0.0%	
m=8	January 18	234	10		5.7%	
m=9	February 18	219	7		4.0%	
m=10	March 18	198	2		1.1%	
m=11	April 18	221	7	new 174	4.0%	
m=12	May 18	235	5	∑1,054	2.9%	
m=13	June 18	180	1		0.6%	
m=14	July 18	142	4		2.3%	
m=15	August 18	159	0		0.0%	
m=16	September 18	176	1		0.6%	
m=17	October 18	195	0		0.0%	
Total months		3,585	581	1,054	55.1%	55.1%

4.1.5 Call-Center Calls (*KPI_{CCC}*)

KPI_{CCC} depicts the total number of call-center calls and gives also an overview about the topics which have been discussed with the customers.

On the one hand it is important for the energy supplier to know how intensive the call-center is used by the customers, to be able to react with additional personal if necessary. On the other hand the customers are giving feedback about the app through call-center calls. Problems can be detected which have not been clear before by the support of the customers which are calling the call-center. Many complaints are a strong sign for problems which have to be repaired. The *KPI_{CCC}* can be measured in two ways:

Quantitative: total number of call-center calls

Qualitative: reasons for calling. Following list is a suggestion for the division of reasons for calling:

- Questions
- Complaints
- Improvement suggestions

Over the time, there were 384 calls to the call-center. The reason for most calls were requests to get general information (294) about PEAKapp and information regarding the access (68) to PEAKapp. 22 calls had the purpose to cancel the PEAKapp account. There were no call center calls with complaints or suggestions for improvement as the main reason.

5 Conclusion

In this deliverable a set of KPIs related to PEAKapp energy and monetary savings as well as environmental are analysed. In this deliverable we used 2 scenarios to calculate the respective KPIs scenario which takes into account only the users who downloaded PEAKapp on their smartphones or tablets, the second scenarios also includes households that used PEAKapp desktop version without downloading the app. For the majority of KPIs the results of PEAKapp field tests in Austria are either promising or meeting the target. At the same time a strong variation between different months especially winter summer months as well as significant difference in results of the KPIs in the beginning and towards the end of the field tests. Depending on the scenario, the treatment group saved on average 12.49 kWh (scenario 1) or 61 kWh (scenario 2) in total on period compared to the control group. The total average energy savings per user over the whole field test period are 0,23 % to 1,12 % ($eKPI_{ES1,m}$) suggesting that household that used PEAKapp increased their household energy efficiency and decreased their electricity consumption. Comparing this results with the active treatment group results, which 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*, shows similar results with slightly higher decrease average decrease in consumption compared to control group.

The related to the increased household energy efficiency monetary savings and a GHG reduction are also analyzed in this deliverable and follow the same pattern as the reduction in electricity consumption of the treatment group. Monthly monetary savings vary from -6.42 € to 4.32 € in scenario 1 and from -4.85 € to 4.11 € at scenario 2. The average monthly monetary saving for the treatment group compared to the control group is 2.50 € in scenario 1 which is a promising result and 12.32 € for scenario 2, which indicates a success.

The monthly average GHG emissions of the treatment group compared to the control group are in the range of -16.06 kg $CO_{2\text{-eq}}$ per kWh to 10.78 kg $CO_{2\text{-eq}}$ per kWh in scenario 1 resp. -12.13 kg $CO_{2\text{-eq}}$ per kWh to 10.28 kg $CO_{2\text{-eq}}$ per kWh in scenario 2. The average monthly *GHG* emission reduction is 6.25 kg $CO_{2\text{-eq.}}$ in scenario 1 resp. 30.81 kg $CO_{2\text{-eq}}$ in scenario 2. Looking at the differences in the KPI in the 17 months of the field tests we find that higher monetary and energy savings occurred in the very first month and in the second half of the field tests. We interpret this as potential learning and awareness effect suggesting that PEAKapp users accumulated knowledge on how to increase household energy efficiency and reached better results towards the end of the field tests. PEAKapp project demonstrate unique in this regard constituent behavioural effect and knowledge base accumulation. This result is especially relevant for further implementation of PEAKapp and similar application on a wider market. In many cases such programs are tested only over a relatively short period of time and thus do not demonstrate the highest possible energy savings which could be achieved if the app is tested over a longer period of time, enough to accommodate the required knowledge. In the long-term PEAKapp showed a persistent energy saving behaviour

Based on the values of the different KPIs we find a very high acceptance of the app. In average over the whole field test period more than the half of the target group members who had downloaded the app were active users, which used the app at least once per month. Even the last months of the field tests the indicator for active usage of the app was still indicating a success. Not only the active usage of the app was high, but also the results regarding the time spent in the app exceeded our estimation. The average session duration per month over the whole field test period was 19 minutes. Looking at the individual months, the results regarding the average session duration are promising in six month and in eleven months the session duration indicates a success. The game functionality although regularly used did not achieve the required targets, which could be explained by either the specific age group of PEAKapp users which is a rather difficult group to interest in any type of online game, but also might be due to a learning effect of the game which was reached through tweaking function way faster than we predicted, so further interest from the household side to play the game was lost. Looking at the KPI on the number of downloads, we find that 581 out of 1,054 and consequently 55 % of the household the app was offered to, downloaded it.

Further on, it is important to mention that roughly 53% PEAKapp users used a desktop version and never downloaded the app. This effect can be also possibly explained by the age of PEAKapp users, the group can be more comfortable using computer than smartphones however it can also be a simple matter of comfort.

Summing app, the KPIs on the usage of the app exceed all of over expectations showing a persistent long-term interest and interaction with the main features of PEAKapp.

6 Annex

6.1 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.
Session Duration of users in month m	SD_m	Minutes	# of users	This variable contains the session duration of the app users in month m.
Session Duration of users in month t after the month of the download	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.