The pro-economical behaviour of households and their knowledge about changes in the energy market

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Abstract. The behaviour of energy and heat consumers is an important and interesting topic. For a long time the energy market was the classical example of a monopoly. In general, households are weak partners for energy companies, but energy markets are changing all over the world. This trend is noticeable in Poland too, but it is not as strong as in Germany or other countries where renewable energy sources (RES) are very popular and widely used. So, here we investigate why the development of RES in Poland is so weak. The main aim of the paper is to highlight the key factors, especially ecological and economic ones, determining households' decisions about installing RES in Poland. An additional aim is to present the level of energy awareness of households. We conducted a survey of Lower Silesia's households in November and December 2015. Economic factors are the best motivators for households to install RES. Among the economic aspects, the respondents indicated potential savings and potential profits.

1 Introduction – Polish context

Nowadays, the energy sector is developing on two levels in parallel. The first of them is the energy system at national level. It consists of, inter alia, a large number of conventional energy plants with big blocks. In Poland, most electricity (more than 80%) and heat are produced from coal and lignite. The second level is composed of dispersed energy systems, which are located near or at energy consumers' homes. Of course, this is typical for heating systems. In Poland, most heat comes from conventional fuels. Dispersed RES (renewable energy sources) intended for installation in households could be developed in Poland, but this process began later than in Germany and is progressing too slowly.

Statistical data are available about the capacity installed in Poland and the production of electricity and heat coming from bigger plants. However, the parameters of individual RES located in dispersed households are not identified. The most comprehensive source of information about RES is a periodical publication entitled "Energy from renewable sources" prepared by the Central Statistical Office (called GUS in Polish). Data are available for 2003-2015. The structure of RES in Poland is different from the EU-28. For example, in 2014 [1, pp. 26]:

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- the proportion of energy obtained from bio-fuel totalled 43.8% in the EU and 76.6% in Poland,
- the proportion of energy obtained from liquid bio-fuel equalled 7.1% in the EU and 9.2% in Poland,
- wind energy accounted for 11.1% of energy production in the EU and 8.02% in Poland,
- solar energy is 6.1% of total energy production in the EU and 0.4% in Poland.

From an ecological point of view, it is important to reduce CO₂ emissions by reducing the consumption of energy (by the end-user). In Poland, the high level of such pollution is the result of using outdated heating systems based on conventional fuels. This is an important issue in villages and some cities (e.g. Cracow), where most citizens burn conventional fuel in individual heating systems, which causes smog. UE guidelines and legislation (e.g.: [2], [3]) impose an obligation to reduce pollution. In 2005, the share of RES in energy consumption in Poland totalled 7.2% and it should increase to 15% by 2020. In 2009, Polish households accounted for 20% of total energy consumption [4, p. 122], as did German households. However, only 7% of the energy consumed by Polish households was from renewable energy sources, while in Germany this figure was 17% [4, p. 124]. In 2011, these values were lower. Polish households used 19% of total energy consumption and renewable energy accounted for 7% of this, while German households used 17% of total energy consumption and renewable energy accounted for 18% of this, [5, p. 142] and [4, p. 144]. Authors often account for this by stating that Germany is a leading proponent of RES and its energy policy is effective and efficient. We should remember that Germany is the largest energy market in Europe. Since 2010 the share of RES in primary energy has dramatically increased in Germany, and recently the introduction the ‘*Energiewende*’ programme has even strengthened this process, e.g. “from 1990 to 2012 the gross national product of Germany increased by 37%, while primary energy consumption overall decreased 7.7%” [6, p.230]. Recent publications have taken into consideration macroeconomic aspects of the ‘*Energiewende*’ and its potential results related to Public Choice Theory and Interest Group Theory [6. 7].

Table 1. Consumption of energy from RES by households in Poland [TJ].

Kinds of energy	Category (class)	2008	2009	2010	2011	2011	2013	2014
Solid bio-fuel	Total final consumption	160630	162085	179138	187187	186927	198427	185807
	Including households	102500	102500	112746	115000	116850	116850	105450
Solar energy	Total final consumption	54	283	350	434	544	639	720
	Including households	-	200	250	300	380	460	520
Geothermal energy	Total final consumption	531	600	563	531	661	778	847
	Including households	402	460	440	430	510	561	608

Source: [1, pp. 52-53, 63], [8, pp. 31-32, 42]

Table 1 presents statistical data about the use of RES by households in Poland. There are no statistics showing how much electricity used by Polish households comes from wind

and water, because these primary energy sources are used mainly to produce electricity. The energy balance sheet presents only primary energy sources with a division into kinds of users, e.g. households, transport, industry. We should remember that electricity is a derivative of energy production.

The development of RES at the consumer-end seems to be a key aim, so national and regional authorities should be interested in the factors influencing “ecologically friendly” behaviour in households. These observations are the background to asking about the main reasons for this situation. Therefore, our considerations focus on variables which describe households and could change their behaviour in a more ecological direction. So, the main aim of the paper is to highlight the key factors determining the decisions of Polish households about installing RES and ecologically friendly behaviour. From this point of view, we would like to answer the following important questions:

- do Polish households act pro-ecologically?
- do they possess basic knowledge about changes in the energy market which create favourable conditions for installing RES?
- are Polish households energy-aware consumers, especially in terms of electricity?
- is there any correlation between a household possessing RES and economic factors (e.g.: income, floor area) or demographic and social factors (e.g.: age, sex, number of persons in household).

Our research is conducted according to a microeconomics approach and we try to identify not only typical demographic and economic factors influencing households’ behaviour, but social factors and, related psychological factors. It is not a popular and widely used approach to explore the behaviour of individual energy consumers, i.e. households, but recently some researchers have studied e.g. households’ behaviour, their willingness-to-pay for RES micro-installations [9], green energy [10] or the factors determining prosumer behaviour [11] and they have taken into account the psychological features of individual energy consumers.

R. Scarpa and K. Willis dealt with similar aspects using a *choice experiment* related to *consumer theory*. Based on a sample of households in the UK, they identified the barriers to installing micro-generation technologies, such as solar photovoltaic cells, micro-wind turbines, solar thermal cells, heat pumps, biomass boilers and pellet stoves. The vast majority of British households had not installed these technologies, due to high capital costs. We should remember that the UK is richer than Poland [9], so we can imagine that Polish households are not interested in using these technologies

Admittedly, the Polish Statistical Office has been conducting research among households since 2006, every 2 years, including information on their energy and heat installations etc. However, these data do not enable us to make our analysis. However, based on it we can estimate the number of households who have RES installations (Table 2).

Table 2. The share of Polish households possessing solar collectors and heat pumps in 2009 and 2012.

The kind of RES installation	2009	2012
solar collectors	0.31%	0.41%
heat pumps	0.03%	0.05%

Source: [4, p. 116], [5, p. 120]

We can compare the results of our research to the outcomes of the Consumer Federation’s survey conducted in 2015. This institution divided respondents into four

segments: (1) prosumers, (2) energy-aware consumers, (3) consumers interested in RES and (4) consumers who do not know what renewable energy sources are. The results of this survey say that the most important barrier to installing RES is high cost (70%). Other obstacles are: the long period required for investment to become economically beneficial, lack of financial support (grants) and problems with finding appropriate advice and information [8].

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2 The research results – installing RES

We conducted a survey of households in Lower Silesia in November and December 2015. The sample was made up of 2000 households, but the number of correctly completed questionnaires was 949. Stratified random sampling was applied and the research was conducted by telephone. The stratification of the sample was based on the set of households in Lower Silesia according to the following strata: age, sex and place of residence according to poviats (local government units).

Based on respondents' answers, we identified the three following groups of respondents:

- prosumers – 45 households,
- potential prosumers – 281 households,
- unwilling to have RES (called 'not desiring RES') – 623 households.

In this paper, a prosumer is defined to be a household who has installed RES[†]. The second group of respondents did not have RES, but declared that they would like to install it in the future. The remainder of the respondents did not have RES and would not like to install it in the future. They are called 'unwilling to have RES'. Potential prosumers and those unwilling to have RES are together referred to as 'not possessing RES'.

We see that only 4.76% of the respondents have installed RES, but 31% of the households 'not having RES' would like to install it. Two interesting questions are why most households have not installed any RES and what causes the negative state of (lack of interest in) RES development in Polish households. We aimed to answer these issues through our research by asking the respondents about the barriers to installing RES (considered in this section) and we make conclusions based on statistical analysis (presented in section 2.2).

Only 41 of 45 prosumers answered a closed question linked to the reasons for installing RES. 68.3% of prosumers (28 households) stated that the reason for installing RES was long-term savings. Only a small number of households stated other reasons for installing RES: 'I am an ecologist' (17.1%), 'a professional persuaded me' (9.8%), 'neighbours or friends persuaded me' (4.9%).

Among economic aspects, the respondents indicated potential savings and potential profits from having RES[‡]. The most important advantage was 'smaller fees, savings'. This option was chosen by 39.6% of those in the groups of prosumers and potential prosumers[§]. 8.8% of these respondents answered 'own needs, free energy'. This answer is similar to 'smaller fees, savings' and so we can group them together. 'Financial profit' was another important issue, as mentioned by 18.7% of the respondents. Other answers connected with

[†] Here, our definition of prosumer is the same as in research by the Federation of Consumers [12].

[‡] This was an open question addressed to prosumers and potential prosumers. We asked about the advantages of being a prosumer.

[§] Not all prosumers and potential prosumers answered this question. We obtained 91 answers.

financial profit are: 'it is possible to sell surplus energy' - 3.3% of prosumers and potential prosumers chose this option; 13.2% chose the 'ecology and clean air' option; 8.8% selected 'financial and environmental benefits'; and 4.4% chose 'energy independence as a benefit from being a prosumer'. Therefore, saving and financial profit are the main advantages from having RES. Ecological aspects and independence are not such important benefits.

On the other hand, the respondents 'not possessing RES' specified the most important factors that influenced their reluctance to install RES. The most significant barriers to installing RES are: (1) high installation costs (27.0%)^{**}, (2) the technical impossibility of installation (21.7%), (3) lack of interest in installing RES (15.98%), (4) unclear regulations (10.04%), (5) complicated process of connecting to the grid (9.3%), (6) lack of knowledge (9.2%).

Among the less important factors, the respondents also indicated the following opinions: unprofitable, no need to install RES, neighbours or friends dissuaded me, lack of time, lack of financial assets, long period required for the investment to become financially beneficial.

2.1 Economic and social behaviour of households

According to our research, the basic ecological knowledge of households and the associated behaviour are relatively advanced, but some ecologically friendly behaviour depends on the level of income. The psychological literature shows that human behaviour depends on, inter alia, emotional feelings, economic situation, education, knowledge and experience, see e.g. the model of pro-environmental behaviour according to Kollmus and Agyeman [13]. The marketing literature talks about ecological (green) consumers, e.g. in 1992 Meffert and Kirchgeorg made a typology of consumers according to their relation to the environment [14]. A similar approach was presented by Simmon, who divided American consumers into five groups [15, p.148].

Generally, the results obtained show that the average household does not know its tariff group or the meaning of word 'prosumer'. They do not even know what kind of electricity meter they have. We assume that these facts reflect the awareness of our respondents^{††}. Only 12.3% of households know their electricity tariff group, but some of them (in the following question) gave the incorrect tariff group or made other mistakes, e.g. they did not give the electricity tariff group, but a gas tariff group, or they wrote the name of an electricity provider. 89.4% of respondents do not know what a prosumer is. Moreover, some respondents who declared that they knew what this word means, do not understand it completely. This understanding was checked by other questions. 27.8% of households have a smart meter.

In our research, we took three groups of respondents into consideration: (1) prosumers, (2) potential prosumers and (3) those unwilling to install RES. In all our statistical tests, we assumed a significance level of 5%, i.e. the p-value should be less than 0.05 to accept any hypothesis about the dependence between a given variable and a household's decision about installing RES. We divided potential factors that could influence a household's decision about installing RES into two groups: (1) demographic and social factors and (2) economic factors.

^{**} The number in brackets indicates the percentage of households without RES who chose the given option. 807 households answered this question. This question was multiple choice.

^{††} The public awareness of solar water heaters has been investigated e.g. by Chinese researchers [16] and British researchers [17].

2.2 Identification of significant factors

2.2.1 The influence of demographic and social factors

In the first group of factors, we analysed the influence of such factors as: age, sex, number of people in the family. The most active group of prosumers are respondents in the age range of 30-49, and the second most active are respondents in the age range of 50-65. The group most reluctant to install renewable energy systems are respondents of age 65 or more. The result of the chi-square test of independence ($\text{Chi-square}(6) = 19.799$ with $p\text{-value} = 0.003$) clearly indicates a significant relationship between age and willingness to install RES. Additionally, we carried out Spearman's test of correlation, which also indicates that younger individuals are more willing to install RES ($\rho = 0.08$, $n=949$ $p\text{-value} = 0.014$). Note that the lower the group number, the greater the willingness to install RES (those who have installed RES are in group 1, those who do not want to install RES are in group 3). Hence, a positive correlation between age and group number indicates a negative correlation between age and willingness to install RES.

We observed a significant association between sex and the three groups of respondents. Women more often do not have or want to install RES in the future (57.6%). Among prosumers, most are male (62.2%), as well as among potential prosumers (58.4%). The result of the corresponding test of independence ($\text{Chi-square}(2) = 23.63$ with $p\text{-value} < 0.001$) indicates a very significant relationship between sex and willingness to install RES. Additionally, we carried out Spearman's test of correlation which also indicated that males are more willing to install RES ($\rho = -0.158$, $n=949$ $p\text{-value} < 0.001$).

Table 3. Influence of the number of people in a family on a household's decision about installing RES.

Number of people in a family	Prosumer	Potential prosumer	Unwilling to have RES	Total
1	0.8%	18%	81.2%	100%
2	2.4%	21.3%	76.3%	100%
3	6.7%	26.2%	67.1%	100%
4	7.3%	38.9%	53.8%	100%
5 or 6	6.6%	45.5%	47.9%	100%
7 and more	7.7%	57.7%	34.6%	100%

We now analyse the association between the number of people in a family and the three groups of respondents. The results are shown in Table 3. We can observe that households which consist of one or two people more often do not want to install RES (81% and 76%, respectively). There is a positive correlation between the number of individuals in a family and the willingness to install RES. One- and two-person households very rarely have installed RES (0.8% and 2.4%, respectively). Around 7% of larger households had installed RES (independently of the number of people in the household). On the other hand, the proportion of households wishing to install RES increases steadily as household size increases. The result of the chi-square test of independence ($\text{Chi-square}(10) = 71.884$ with $p\text{-value} < 0.001$) indicates a clear association between the number of individuals in a household and the willingness to install RES. Additionally, we carried out Spearman's test of correlation, which clearly indicates a positive association between the number of individuals in a household and willingness to install RES ($\rho = -0.263$, $n=949$ $p\text{-value} < 0.001$).

2.2.2 The influence of economic factors

We analysed the relationship between installing RES and a number of factors, such as: income, expenditure on electricity, and floor or building area. For the purposes of presenting the results, we classified each economic factor into several categories. Table 4 presents the structure of all these categories in relation to the type of household (prosumer, potential prosumer or ‘not desiring RES’).

Table 4 The association between economic factors and willingness to install RES [%].

Economic factor	Category	Prosumer	Potential prosumer	Not desiring RES
income ^{††}	< 3,000 PLN	2.0%	26.7%	71.3%
	3,001 – 4,000 PLN	4.9%	37.4%	57.7%
	4,001 – 5,000 PLN	3.6%	40.0%	56.4%
	5,001 – 6,000 PLN	11.1%	29.6%	59.3%
	6,001 – 8,000 PLN	35.3%	11.8%	52.9%
	8,001 – 10,000 PLN	25.0%	12.5%	62.5%
	> 10,000 PLN	16.7%	25.0%	58.3%
expenditure on electricity	< 50 PLN	2.8%	9.7%	87.5%
	51-100 PLN	1.9%	18.8%	79.3%
	101-200 PLN	5.5%	35.0%	59.6%
	201-300 PLN	8.5%	44.1%	47.5%
	>300 PLN	8.9%	44.3%	46.8%
floor or building area	< 40 m ²	0.0%	0.0%	100.0%
	40-79 m ²	0.0%	13.5%	86.5%
	80-149 m ²	6.7%	40.2%	53.0%
	>150 m ²	13.9%	57.6%	28.5%

Table 5. Results of statistical tests for an association between chosen economic factors and willingness to install RES.

Economic factor	Chi-square statistic	df	p-value	rho
income	68.414	12	0.000	-0.159
expenditure on electricity	78.690	8	0.000	-0.284
floor or building area	240.773	6	0.000	-0.499

Table 5 presents the results of statistical analysis related to each of the above mentioned variables. We tested the three following hypotheses:

- H1: household income is associated with the decision to install RES,
- H2: household expenditure on electricity is associated with the decision to install RES,
- H3: floor or building area is associated with the decision to install RES.

^{††} This question asked respondents to give their household’s monthly net income. About 30% of the respondents did not answer this question. The number of households answering this question was 643 out of 949.

In each category of income, the majority of households belong to the 'not desiring RES' group. When household income is bigger than 5,000 PLN, then a relatively large proportion of respondents are prosumers and a smaller proportion of households are potential prosumers. We can hence see that as household income increases, potential prosumers become real prosumers. Statistical analysis (see Table 5) confirms that hypothesis H1 can be accepted ($\text{Chi-square}(12) = 68.414$ with $p\text{-value} < 0.001$).

We can also observe a tendency that households which have higher expenditure on electricity more often install RES or state that they would like to install it.

Looking at the association between willingness to install RES and 'floor or building area', we see that all the households possessing less than 40 m² floor area belong to the group 'not desiring RES'. This result should not seem surprising, because small apartments are located in cities, where the conditions for installing RES are unfavourable. Such households need a relatively small amount of energy mainly for heating and electricity. All the households which have installed RES possess a floor area of more than 80 m². When the floor or building area totals 80-149 m², 53% of households belong to the 'not desiring RES' group. We observed that when the floor or building area becomes larger, then the frequency of both prosumers and potential prosumers increases, e.g. for floor areas of 40-79 m², 13.5% of respondents are potential prosumers and for floor areas of 80-149 m², 40.2% of respondents are potential prosumers.

All of the selected factors are significantly associated with the decision to install RES, since the p -value is less than 0.05 in each case. Hence, we can reject the null hypotheses of independence and accept each of the hypotheses H1, H2 and H3. According to Spearman's correlation coefficient (Table 5 - ρ), we see that 'the floor or building area' is most strongly associated with the willingness to install RES. The larger a property, the more likely it is that the household has installed RES or wishes to install RES. Expenditure on electricity and household income also have an important influence on the decision to install RES.

3 The research results – ecologically friendly behaviour of households

In this section we present factors related to ecologically friendly behaviour that are associated with households' decisions to install RES. We specified some examples of ecologically friendly behaviour that we called *factors*. Moreover, we noticed that the possession of certain home devices could be related to installing RES. Besides the factors presented in Table 6, we proposed the following factors: unplugging devices that are on standby, using eco-options on a washing machine, such as low water consumption or low energy options, measuring the amount of water to be boiled.

The respondents indicated the frequency of such behaviour on a six-level scale or on a four-level scale. We analysed the relation between each factor specified above and a household's decision to install RES. In this analysis we grouped respondents who have installed RES and those declaring that they wish to install RES in the future and compared them with those not desiring RES. In all our statistical tests, we assumed a significance level of 5%, i.e. the p -value should be less than 0.05 to accept any hypothesis about the dependence between a given variable and a household's decision about installing RES.

In the case of the factor described as 'unplugging devices that are on standby', the result of the test of association was ($\text{Chi-square}(3) = 0.516$ with $p\text{-value} = 0.915$). Hence, there is no evidence of an association between this factor and the willingness to install RES. Below we present the results of our research regarding key behaviour factors in the groups of respondents who have installed RES or wish to install RES.

In our research we specified eight key behavioural factors, each having a slightly different association with a household’s decision to install RES (described below). The differences between the groups of ‘prosumers’ and ‘potential prosumers’ according to these factors were negligible, therefore, for the purposes of our analysis, we combined these two groups into one called ‘pro-RES’, and compared this combined group to the group called ‘not desiring RES’.

In the case of the factor ‘using eco-options in a washing machine’, the answers were on a six-level scale, which had the following categories: never, very rarely, rarely, often, very often and always. The result obtained ($\text{Chi-square}(5) = 12.113$ with $p\text{-value} = 0.033$) allows us to reject the null hypothesis that willingness to install RES is independent of this factor. Spearman's test of correlation was also carried out to assess whether this relationship was monotonic (e.g. as the frequency of using eco-options increased, the willingness to install RES always tended to increase). There was no significant monotonic association between the frequency of using eco-options and the willingness to install RES ($\rho = -0.062$, $p\text{-value} = 0.101$).

In the case of the other factors, the answers were on a four-level scale that had the following categories: never, rarely, often, and always. The results of the statistical analysis linked to these behavioural factors are shown in Table 6. We tested the seven following hypotheses:

- H4: using energy-saving lights (LED) is associated with the decision to install RES,
- H5: the utilization of electro-rubbish is associated with the decision to install RES,
- H6: installing energy-saving household equipment is associated with the decision to install RES,
- H7: sorting rubbish (garbage) is associated with the decision to install RES,
- H8: battery utilization is associated with the decision to install RES,
- H9: switching off the lights is associated with the decision to install RES,
- H10: washing or ironing at particular times is associated with the decision to install RES.

Table 6. The results of tests for the association of behavioural factors with the willingness to install RES.

Factor	Chi-square(3)	p-value
the utilization of electro-rubbish	15.687	0.001
using energy-saving lights (LED)	27.47	<0.001
installing energy-saving household equipment	13.881	0.003
sorting rubbish (garbage)	10.345	0.016
battery utilization	9.962	0.019
switching off the lights	8.819	0.032
washing or ironing at particular times	7.828	0.05

Six of these factors are significantly associated with the decision to install RES (we can accept hypotheses H4-H9 at a significance level of 5%). It is only unclear in the case of H10 whether this association is significant (the p-value is equal to 0.05). Three factors are significant at the 1% level: ‘using energy-saving lights (LED)’ – H4, ‘the utilization of electro-rubbish’ – H5, ‘installing energy-saving household equipment’ – H6. These relations are described below.

In the case of the ‘utilization of electro-rubbish’ factor, among pro-RES respondents 10.7% had never utilized electro-rubbish, whereas among respondents ‘not desiring RES’, this value is greater (equal to 18.9%). Among pro-RES respondents, 71.5% always utilized electro-rubbish, whereas among respondents ‘not desiring RES’, this value is smaller (equal to 60.7%). In the case of the ‘installing energy-saving lights (LED)’ factor, only 21.5% of the respondents from the pro-RES group did not have LED lights at all, whereas among the respondents ‘not desiring RES’, this number is equal to 36.5%. Among those ‘not desiring RES’, 16.4% of households have only such lights, whereas among the ‘pro-RES’ group, this percentage is 22.4%. In the case of the ‘installing energy-saving household equipment’ factor, 31.0% of the ‘pro-RES’ respondents do not have such devices at all, whereas among respondents ‘not desiring RES’, this proportion is greater (equal to 41.1%). Among those ‘not desiring RES’, 13.4% of households have only such devices, whereas among the ‘pro-RES’ this proportion is 20.6%. Statistical analysis (see Table 6) confirms that the hypotheses H4-H6 can be accepted at the 1% level.

4 Conclusions

The majority of households are not willing to install RES. The key economic reason is the excessive cost of installation. The next most important causes are the technical impossibility of installing RES and a lack of interest from respondents. The size of a house/flat is the main factor associated with the decision to install RES. Other significant factors are the expenditure on electricity and household income. Prosumers and potential prosumers emphasized savings and financial profit as the main advantages from installing RES. The same factors motivate them to install RES. The following are less important motivators: ecological aspects, neighbours and friends and energy independence (which means energy safety). Among demographic factors, the ones most significantly associated with willingness to install RES are: the number of people in a household and sex. In Poland, economic benefits give the strongest motivation to install RES, but we observed that some ecological friendly behaviours are positively associated with willingness to install RES. Three of these factors: installing energy-saving lights (LED), utilization of electro-rubbish, installing energy-saving household equipment, were significantly associated with the willingness to install RES at the 1% significance level.

Given these conclusions, we recommend the following:

- more intensive distribution of information, which should improve the awareness of society regarding energy,
- using economic tools in energy policy,
- organizing marketing action appropriate to the size of a household and the sex of the decision-maker.

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