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Determinants of household energy use in the Fergana Valley

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ABSTRACT

In July-August, 2023, CAREC Institute, Public Opinion Research Institute, and Asian Development Bank Institute conducted a sociological survey on household energy use in the Fergana Valley spanning over the Kyrgyz Republic, Tajikistan, and Uzbekistan. The following article uses the data from that survey for investigating what determines the choice of different energy types for heating. The article concludes that high household expenditures for coal and high awareness of the harm fossil fuels can inflict on the environment and family health are insufficient to trigger a large-scale shift towards cleaner energy. To motivate households for such a shift a substantial increase in fossil fuel prices compared to electricity and other clean energy is required. This might call for a sales tax on coal. However, energy expenditure already accounts for up to one-third of household income. Low- and middle-income households would need to be compensated for increased energy spending to avoid social hardship and a backlash against such a tax.

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1. Introduction[1]

The following article examines one of the aspects of energy transition – households' access to energy and energy use habits. To know these habits is crucial for designing policies and incentives promoting the adoption of sustainable heating technologies, as well as for accelerating the transition to a low-carbon heating, cooling, and cooking environment.

The project region was the Fergana Valley, which spans over parts of the Kyrgyz Republic, Tajikistan and Uzbekistan. Geographically, it is a relatively compact area shared by three different countries. It thus provides a good opportunity to study the differences and similarities of energy use by households living under three different legislations and three different power supply systems.

The main survey topics were related to the ones generally mentioned in the literature, i.e. energy poverty, affordability and reliability of energy supply, etc. The impacts of various energy sources on health were likewise investigated during the research. Numerous studies have documented the health risks associated with traditional cooking fuels such as biomass and coal, including respiratory illnesses, cardiovascular diseases, and indoor air pollution related deaths.

Household energy access is not least determined by socio-economic characteristics such as income level, education, gender, and employment. In turn, improved energy access can enhance productivity, enable income-generating activities, and alleviate poverty. At the same time, demographic characteristics influence the readiness to transit to new ways of energy use.

A considerable body of literature focuses on technological interventions to improve household energy access. This includes better access to electricity distributed via the grid, off-grid electrification solutions such as solar home systems, microgrids etc., and the adoption of cleaner cooking technologies, including improved cook stoves, biogas digesters, solar cookers and the like. A range of studies evaluates the effectiveness, scalability, and sustainability of these technologies in different contexts. To an extent, the survey also intended to cover these aspects.

Due to the growing concern about climate change and the need to reduce greenhouse gas (GHG) emissions, environmentally friendly heating solutions have become a subject of height-ened interest. Electrifying heating systems and powering them with renewable energy (RE) like wind or solar can drastically reduce GHG emissions associated with heating. However, this approach relies on

[1] This article is based on the data from a project initiated by the Central Asia Regional Economic Cooperation (CAREC) Institute in partnership with the Asian Development Bank Institute (ADBI). The CAREC Institute is an intergovernmental organization of 11 countries, namely Afghanistan, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, the People's Republic of China, Tajikistan, Turkmenistan, and Uzbekistan. The survey was organized by the Public Opinion Research Institute, Republic of Kazakhstan (PORI). The project was funded by the Asian Development Bank. The general project report is published at the CAREC Institute's website (https://www.carecinstitute.org/publications/new-research-report-reveals-insights-on-household-access-to-energy-in-the-fergana-valley/).

the decarbonization of the electricity supply to ensure electric heating remains environmentally friendly. The literature now often mentions heat pumps which are still costly but can be highly efficient, particularly in moderate climates, and can utilize RE such as geothermal or air-source heat.

The literature also emphasizes the importance of energy-efficient building design to reduce heating demand. Strategies such as proper insulation, air sealing, and passive solar design can significantly lower heating requirements and improve the total energy performance.

Overall, the literature suggests that a combination of environmentally friendly solutions tailored to local conditions and resources is necessary to achieve significant reductions in GHG emissions while ensuring energy security and affordability.

Another topic in the literature is rural vs. urban dynamics. While rural areas typically face challenges related to infrastructure and poverty, urban ones may struggle with energy affordability, reliability, and pollution.

Examination of the effectiveness of various policy instruments, regulatory frameworks, incentives, etc. in promoting energy access represents a highly important research track. The questionnaire for the Fergana Valley study was developed considering most of the above-mentioned topics discussed in the literature.

1.1. Other recent studies

The findings of the survey on household energy use in the Fergana Valley are very much in line with the results of other recent reported studies.

The factors influencing heating choices include income level, education, and awareness of environmental issues (Bai et al., 2023). Factors influencing energy-related decision-making also include financial considerations, and access to information (Brown et al., 2023). House-hold carbon footprints are influenced by a combination of socio-economic, demographic, and environmental factors (Gao et al., 2024). Demographic characteristics such as household size, type (urban or rural), etc. play a role as well. Cultural norms cannot be neglected either (Mbaka et al., 2019). Consumer attitudes and behavior towards energy consumption play a crucial role in shaping energy demand (Brown et al., 2023). Consumption patterns significantly influence household carbon footprints (Huang et al., 2024).

Another major issue is the availability of energy-efficient technologies (Guo et al., 2023). Access to reliable and affordable energy services is essential for enhancing households' resilience to climate-related challenges (Deng et al., 2023). Energy affordability plays a critical role in households' decision-making regarding clean energy adoption, according to some research results (Li et al., 2023). Rural households are particularly vulnerable to energy price increases due to lower income levels and limited access to alternative energy sources (Nie et al., 2024).

At the same time, environmental awareness and climate change policies matter and have led to changes in energy consumption patterns and reduced CO2 emissions

in Lithuanian house-holds (Jakučionytė-Skodienė et al., 2023). Rural households in China showed willingness to pay more for clean heating options (Bai et al., 2023).

Most of the literature is quite optimistic about the potential of policy interventions to change households' energy behavior, at least in the longer term, and if properly designed. Many articles indicate that policy interventions targeting clean heating adoption in rural areas could be effective in reducing pollution and improving public health (Bai et al., 2023). They also express the opinion that policy measures promoting energy efficiency and RE adoption can contribute to mitigating climate change at the household level (Jakučionytė-Skodienė et al., 2023). Integrated policies that target both energy access and environmental sustainability goals are seen to be able to maximize societal benefits and foster sustainable development (Xin et al., 2024).

Recommendations put forward that policy interventions should aim to influence consumer behavior by providing incentives and promoting awareness of sustainable energy practices (Brown et al., 2023). They should focus on incentivizing low-carbon behaviors and transitioning to renewable energy sources to achieve sustainability goals (Huang et al., 2024). Policies should leverage behavioral insights to design effective incentives and nudges that motivate households to adopt sustainable practices (Caballero et al., 2024).

A substantial role is given to financial incentives to change consumer behavior. Incentives are seen to play a crucial role in motivating household action towards energy efficiency and sustainability (Caballero et al., 2024). Policy interventions should focus on improving energy affordability through targeted subsidies, financing mechanisms, and income generation opportunities (Li et al., 2023).

Tailoring interventions to address the diverse needs and preferences of households according to different demographic and other characteristics is essential for promoting clean energy and sustainability (Mbaka et al., 2019).

Other approaches more strongly emphasize technological preconditions. Policies should focus on promoting energy efficiency and technological solutions (Lingyan Li et al., 2023), address disparities in carbon footprints between urban and rural areas by promoting equitable access to clean energy technologies (Gao et al., 2024). Localized approaches that account for the specific needs are necessary for effective energy planning and resource allocation (Guozhu Li et al., 2016).

1.2. Research question

Based on the survey on household energy access and use in the Fergana Valley, the article strives to answer the question of what determines the choice of energy source in the target region, and what policy recommendations can be derived from this research.

2. Methods and data

The following paragraphs describe the sampling, interviewing methods, and respondent profile.

2.1. Sample

The survey was conducted among the settlement residents in the Kyrgyz Republic (Jalal-Abad, Osh and Batken Regions, and the city of Osh), Tajikistan (Sughd Region) and Uzbekistan (Fergana, Namangan, Andijan Regions) located in or near the Fergana Valley. The respondents were citizens of the countries sharing the Fergana Valley, over 18 years old, heads of households or family members making decisions on financial and household matters. The total of 1,522 interviewees from three countries partook in the survey, among them 763 male and 759 female household heads. In the Kyrgyz Republic, 262 male and 260 female heads of house-holds; in Tajikistan – 245 male and 255 female heads of households; in Uzbekistan – 256 male and 244 female heads of households participated in the survey.

The survey used a special quota of 50:50 for male and female household heads to understand the difference in answers in the gender context. The household members themselves determined the status of the "head" or "member" of the household responsible for making decision on financial and other household issues (buying food, paying for utilities, buying fuel, etc.). Previous studies of households conducted by national and international organizations pointed to a difference in the behavior of men and women in matters regarding financial costs, fuel costs, etc. This study has also revealed gender differences.

Table I. shows the basic survey parameters for the three countries.

Table I. Basic sociological research parameters

Country/ Parameters	Kyrgyz Republic	Tajikistan	Uzbekistan
Survey geography	3 regions and 1 city - Jalal-Abad, Osh, Batke, City of Osh	1 region – Sughd	3 regions - Fergana, Namangan Andijan
Number of respondents	522	500	500
Age of respondents	18 and older	18 and older	18 and older

Table I. Cont.

Number of questions in the questionnaire	62	62	62
Number of socio-demographic parameters	12	12	12
Survey method	face-to-face CAPI	face-to-face CAPI	face-to-face PAPI
Survey language	Kyrgyz, Russian	Tajik, Russian	Uzbek, Russian
Sampling error	+/-4.38 at 95% confidence interval	+/-4.38 at 95% confidence interval	+/-4.38 at 95% confidence interval
Refusal rate	561	44	607

2.2. Interview method

The interviews in all three countries were executed using a single method – face-to-face. In the Kyrgyz Republic and Tajikistan, the interviews were conducted with the help of tablets (Computer-assisted personal interviews, CAPI), and in Uzbekistan a paper questionnaire (Pen and paper personal interviews, PAPI) was used.

2.2. Field work

The survey was held in July-August, 2023, using a single questionnaire that consisted of the main part and a socio-demographic (age, gender, level of education, social status, employment) block.

2.3. Respondent profile

The survey respondents were the heads of households or other family members that were the decision-makers related to energy supply, heating or cooling. The selection of the respondents was carried out according to quotas that made it possible obtaining opinions of men and women in equal proportion, and of respondents of different ages, ethnicity, education, and forms of employment. The questionnaire was answered by 130 urban and 392 rural residents in the Kyrgyz Republic, 137 urban and 363 rural residents in Tajikistan, 290 urban and 210 rural residents in Uzbekistan. Approximately an equal proportion of male and female household heads participated in the survey.

The survey was conducted using interviews with respondents – heads of households or family members who decide on matters related to energy supply, heating or cooling of the house. A total of 1,522 respondents were interviewed:

522 in the Kyrgyz Republic (262 men, 260 women), 500 in Tajikistan (245 men, 255 women), and 500 in Uzbekistan (256 men, 244 women). The survey was conducted in July-August 2023.

Table II. Respondent gender

Answer options	Kyrgyz Republic		Tajikistan		Uzbekistan	
	Q-ty	%	Q-ty	%	Q-ty	%
Men	262	50.2	245	49.0	256	51.2
Women	260	49.8	255	51.0	244	48.8
Total	522	100.0	500	100.0	500	100.0

2.4. Family

The majority of the survey participants had family experience, only 5% of Uzbekistan is, 11.6% of Tajikistanis, and 13.4% residents of the Kyrgyz Republic indicated that they had never been married. 81% of respondents from Uzbekistan, 78.7% of respondents from the Kyrgyz Republic and 72% of respondents from Tajikistan are married. The majority of respondents from the Kyrgyz Republic and Uzbekistan lived in families of 4 to 7 people, including themselves. The majority of respondents from Tajikistan lived in families of 3 to 7 people. On average, the families that took part in the survey in the Kyrgyz Republic had 6 members, in Tajikistan and Uzbekistan – 5 members.

2.5. Employment

The largest share of respondents were housewives (and some housemen) – 149 women and 6 men, i.e. 155 respondents (29.7%) in the Kyrgyz Republic, 109 women (21.8%) in Uzbekistan, and 66 women and 18 men, i.e. 84 respondents (16.8%) in Tajikistan (Table III.). Other relatively large groups that participated in the survey were pensioners (retired), farmers, civil servants, individual entrepreneurs, and private and public sector employees.

Table III. Responses to the question "What is your current employment?"

Answer options	Kyrgyz Republic		Tajikistan		Uzbekistan	
	Q-ty	%	Q-ty	%	Q-ty	%
I work for myself - individual activity (sole proprietorship without hired employees)	32	6.1	61	12.2	23	4.6
I work for myself - an entrepreneur (with hired employees)	9	1.7	40	8.0	21	4.2
Self-employed/do not have an official/ permanent place of work	33	6.3	48	9.6	40	8.0
Private sector employee	47	9.0	53	10.6	18	3.6
Public sector employee	9	1.7	39	7.8	49	9.8
Civil servant	56	10.7	53	10.6	64	12.8
Student	22	4.2	28	5.6	6	1.2
Pensioner (retired)	74	14.2	46	9.2	126	25.2
Housewife/householder	155	29.7	84	16.8	109	21.8
Unemployed	18	3.5	29	5.8	42	8.4
Farmer	67	12.9	10	2.0	2	0.4
Refuse to answer	-	-	9	1.8	-	-
Total	522	100.0	500	100.0	500	100.0

3. Results

3.1. Energy use for heating by type of energy

The main source of energy used by households for heating in the Fergana Valley strongly differed between the target countries. Whereas over 70% of the surveyed households with off-grid heating systems in Tajikistan used electricity, only 13% of households in Uzbekistan and only 6.7% in the Kyrgyz Republic did so (Table IV.).

Table IV. Responses to the question "If you have an off-grid heating system, what energy source do you use to heat your house during the winter season?"

Response options	Kyrgyz Republic		Tajikistan		Uzbekistan	
	N=466		N=500		N=500	
	Q-ty	%	Q-ty	%	Q-ty	%
Hard coal	413	**88.6**	68	13.6	273	**54.6**
Fuel oil/diesel	-	-	2	0.4	3	0.6
Natural gas from underground pipes	2	0.4	-	-	76	15.2
Propane (bottled gas)	-	-	03	0.6	43	8.6
Electricity	31	6.7	351	**70.2**	65	13.0
Biofuel (pressed dung)	5	1.1	10	2.0	1	0.2
Kerosene	-	-	-	-	-	-
Firewood	15	3.2	64	12.8	39	7.8
Solar panels	-	-	-	-	-	-
Waste and garbage (rubber, plastic, paper, etc.)	-	-	2	0.4	-	-
Total	466	100.0	500	100.0	500	100.0

Note: Only respondents with off-grid or mixed heating answered this question.

At the same time almost 55% of households in Uzbekistan and almost 89% of households in the Kyrgyz Republic used coal for heating. In Uzbekistan, gas also played a significant role; and firewood to some extent in all three countries.

An obvious candidate for the explanation of what determines such a choice of energy sources is the relative price of different sources of energy and the resulting household spending for them. Preferences related to different demographic characteristics or different degrees of awareness of the harm fossil fuels can inflict on the environment or family health could also explain the choice of energy type.

When asked directly about their motives for choosing a specific energy source, about one-third of respondents across the three countries of the Fergana Valley indicated the "least financial burden" (Table V.). In the Kyrgyz Republic and Uzbekistan, the reliability of supply and the presence of the existing heating systems were frequent responses as well. In Tajikistan, environmental and health consideration played a larger role than in the other two countries – an explanation could be that "greener" statements are easier to make when already more heating by electricity is in place.

The following parts of the article trace down to what extent the answers to the direct question are in line with the data generated by the survey on current energy use and on plans for change.

Table V. Responses to the question "What guides you in choosing your main heating source?"

Response options	Kyrgyz Republic		Tajikistan		Uzbekistan	
	N=466		N=500		N=500	
	Q-ty	%	Q-ty	%	Q-ty	%
I choose based on the least harm to the environment	2	0.4	158	**31.6**	80	16.0
I choose based on the least harm to the health of my family	51	10.9	130	**26.0**	5	1.0
I choose based on the least financial burden	144	**30.9**	143	**28.6**	175	**35.0**
I choose based on the considerations of uninterruptedness/reliability of energy supply	192	**41.2**	33	6.6	140	**28.0**
Due to the presence of an existing heating system	77	**16.6**	-	-	100	**20.0**
Difficult to answer	-	-	34	6.8	2	0.4
Responses recorded based on respondent statements						
I'm trying to prepare for winter	-	-	1	0.2	-	-
Every year there are electricity issues	-	-	1	0.2	-	-
Total	466	100.0	500	100.0	500	100.0

Note: Only respondents with off-grid or mixed heating answered this question.

3.1. Spending on energy by income

To get a first impression of spending patterns, Fig. 1. gives an overview of the distribution of spending by income brackets. The vertical lines in the histograms represent the mean for the total sample population of each country. A normal-density plot is added for reference. As to be expected, poorer households generally spend less on energy than the more affluent ones; the bulk of the distributions of the lower-income brackets lie left of the mean in all three countries.

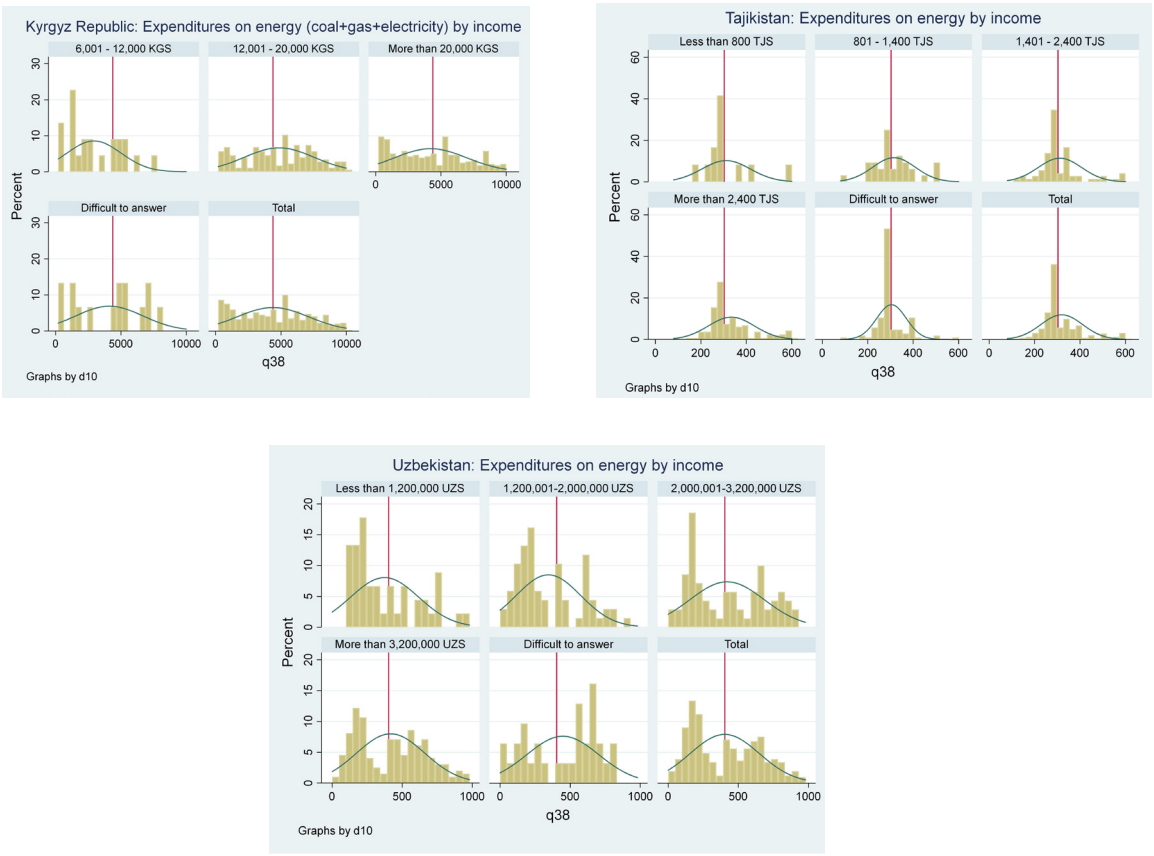

Figure 1. Expenditure on energy by income brackets.

Table VI. shows that a common feature for all three countries of the Fergana Valley is that households spend a substantial part of their income on energy. Looking at the two income brackets in the middle – where midpoints can be assumed to roughly represent the average income in these brackets – delivers the following results: in the Kyrgyz Republic, the median expenditure amounts to KGS 2,325 for the lower of the middle income-brackets. This is as much as 26% of the income bracket's mid-point. The respondents of the next higher income bracket indicated that they spent even 33% (median) of the income bracket's mid-point on energy. In Tajikistan, the respective numbers are 27% and 15.5%, respectively, and in Uzbekistan it is 17% in both income brackets.

Table VI. also confirms that in general more affluent households tend to spend more on energy than poorer ones. In the Kyrgyz Republic and Tajikistan there is a significant difference by household income of how much households spend on energy – with an 0.48% and 5.36% error probability, respectively. However, in the former the "more than 20,000 KGS" bracket spends less than the "12,001 - 20,000 KGS" bracket. The result for Uzbekistan is that more affluent households spend more – but the result is significant only at the error probability of 17%.

Table VI. Expenditure on energy per month - by income brackets.

Household income per month		Spending per month on coal, gas, and electricity				
	Frequency	Median	Mean	Std. Err.	[95% Conf. Interval]	
Kyrgyz Republic (Analysis of Variance: Adj R-squared = 0.0203; **Pr > F = 0.0048**)						
Less than 6,000 KGS	0 (0.0%)	-	-	-	-	-
6,001 - 12,000 KGS	22 (4.5%)	**2,325**	**2,938**	442	2,069	3,808
12,001 - 20,000 KGS	175 (35.9%)	**5,150**	**4,863**	202	4,466	5,260
More than 20,000 KGS	276 (56.6%)	**4,100**	**4,208**	167	3,880	4,536
Difficult to answer	15 (3.1%)	**4,900**	**4,114**	668	2,802	5,426
Total	488 (100.0%)	**4,450**	**4,382**	124	4,139	4,626
Tajikistan (Analysis of Variance: Adj R-squared = 0.0119; **Pr > F = 0.0536**)						
Less than 800 TJS	15 (3.3%)	**295**	**307**	24	259	355
801 - 1,400 TJS	38 (8.5%)	**297**	**311**	15	282	340
1,401 - 2,400 TJS	90 (20.0%)	**294**	**308**	10	289	328
More than 2,400 TJS	186 (41.4%)	**297**	**333**	7	319	347
Difficult to answer	120 (26.7%)	**296**	**304**	6	292	317
Total	449 (100.0%)	**296**	**318**	4	309	326
Uzbekistan* (Analysis of Variance: Adj R-squared = 0.0059; Pr > F = 0.1708)						
Less than 1,200 thUZS	45 (10.9%)	**250**	**375**	36	303	446
1,200-2,000 th UZS	68 (16.5%)	**265**	**345**	28	290	399
2,000-3,200 th UZS	70 (17.0%)	**413**	**420**	32	358	483
More than 3,200 th UZS	197 (47.9%)	**430**	**418**	17	383	452
Difficult to answer	31 (7.5%)	**550**	**447**	46	356	538
Total	411 (100.0%)	**400**	**404**	12	380	428

KG: Expenditure limited to below or equal to 10,000 KGS per month to cut off outliers;

TJ: Expenditure limited to below or equal to 600 TJS per month to cut off outliers;

*UZ: *Expenditure in thousand UZS; expenditure limited to between 100th and 1,000th UZS per month to cut off outliers.*

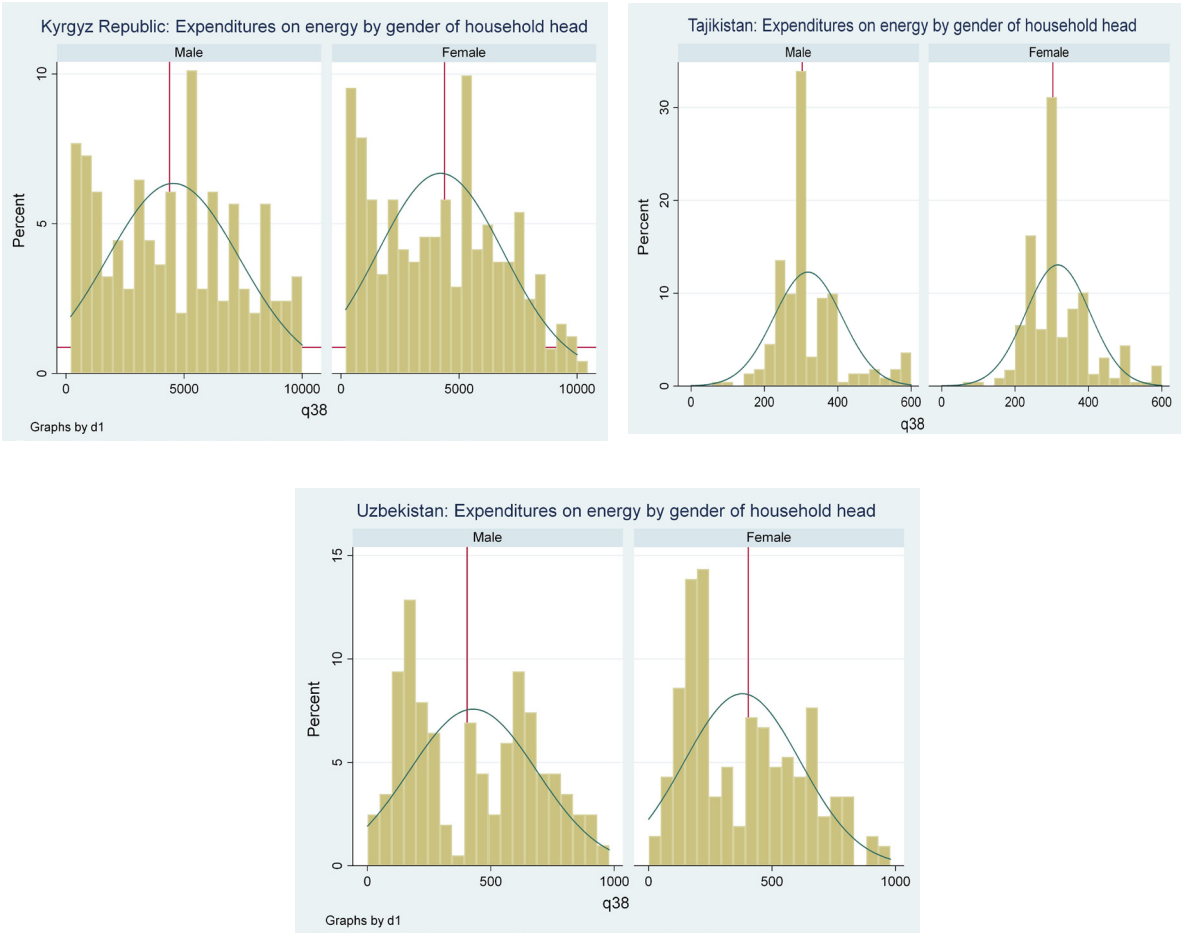

Figure 2. Expenditure on energy by gender.

Fig. 2. and Table VII. indicate that in the Kyrgyz Republic and Uzbekistan households with female heads spend somewhat less on energy than households with male heads. This is in line with the survey finding that significantly fewer households of female respondents are in the higher income brackets than households with male heads (10% error probability). For Tajikistan, the picture is less clear both regarding the energy spending and the household head income by gender.

Table VII. Expenditure on energy by gender.

	Kyrgyz Republic			Tajikistan			Uzbekistan		
	Frequency	Median	Mean	Frequency	Median	Mean	Frequency	Median	Mean
Male	247 (50.6%)	4,500	4,545	221 (49.2%)	295	319	202 (49.1%)	430	428
Female	241 (49.4%)	4,250	4,216	228 (50.8%)	296	317	209 (50.9%)	330	380
Total	488 (100.0%)	4,450	4,382	449 (100.0%)	296	318	411 (100.0%)	400	404

Households with more members spend generally more than smaller households (Fig. 3 and Table VIII.). In all three countries households with more than 6 members spend the most, households with 1-3 people – the least.

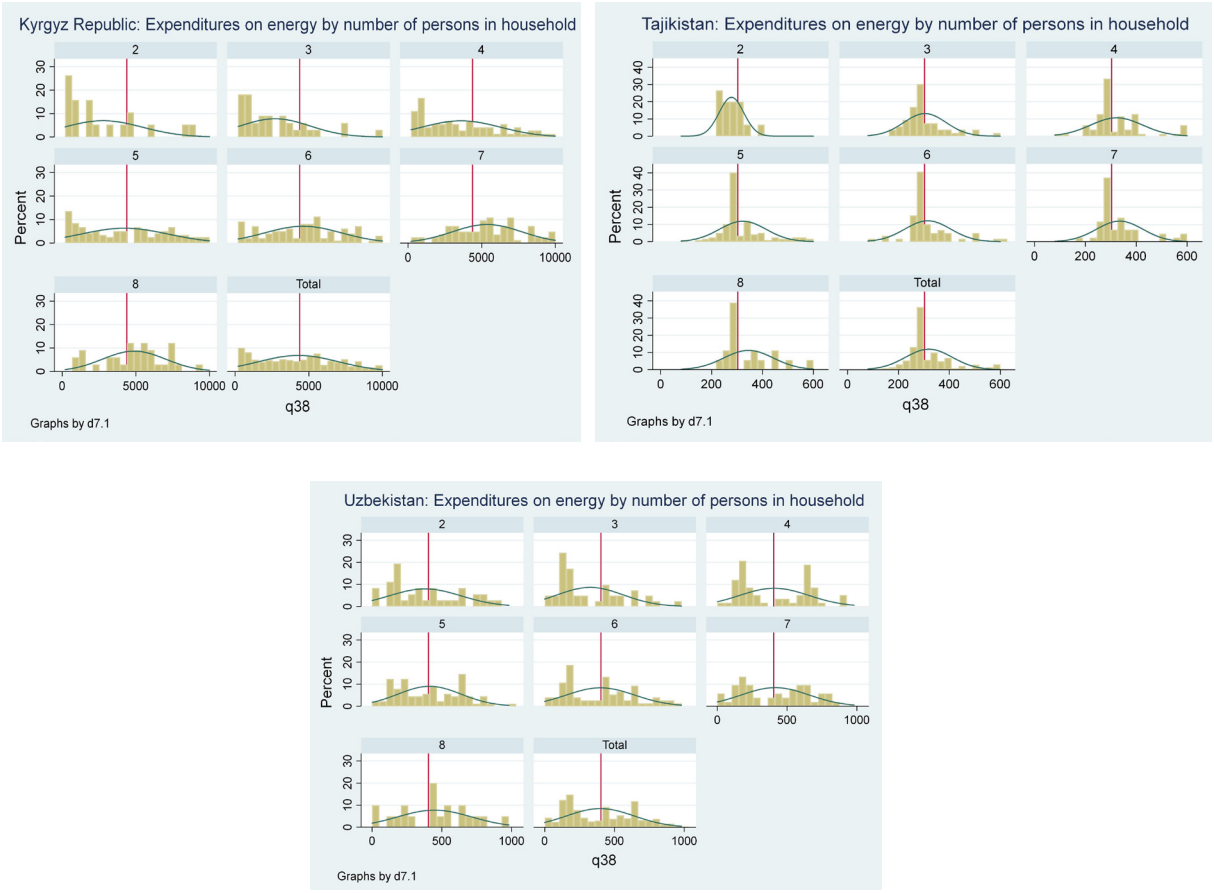

Figure 3. Expenditure on energy by the number of persons in household.

Table VIII. Expenditure on energy by the number of persons in household.

	Kyrgyz Republic			Tajikistan			Uzbekistan		
	Frequency	Median	Mean	Frequency	Median	Mean	Frequency	Median	Mean
1	1*	8,250	8,250	41 (9.1%)	293	302	6 (1.5%)	225	292
2	19 (3.9%)	1,700	2,775	15 (3.3%)	274	278	36 (8.8%)	318	380
3	33 (6.8%)	1,750	2,711	53 (11.8%)	295	304	41 (10.0%)	200	326
4	72 (14.8%)	2,950	3,604	78 (17.4%)	296	323	58 (14.1%)	326	408
5	118 (24.2%)	4,075	4,231	117 (26.1%)	296	322	89 (21.7%)	400	412
6	98 (20.1%)	4,750	4,615	59 (13.1%)	294	315	75 (18.2%)	425	399
7	83 (17.0%)	5,500	5,370	43 (9.6%)	298	335	52 (12.7%)	438	415
8	33 (6.8%)	5,280	4,879	18 (4.0%)	297	345	20 (4.9%)	450	447
>8	31 (6.4%)	5,500	5,502	25 (5.6%)	294	316	34 (8.3%)	582	481
Total	488 (100%)	4,450	4,382	449 (100%)	296	318	411 (100%)	400	404

* Seems to be an outlier.

While the survey reveals differences in energy spending by income brackets, gender, and household size, only a small portion of the variance is explained by these factors; in Table VI., less than 2% of the expenditure variance is explained by income brackets for all three countries. This leads to the conclusion that the amount the households in the Fergana Valley spend on energy is not hugely influenced by the amount of money they can dispose of, even though spending on energy eats up a substantial part of household income, and some differences exist.

3.2. Spending on energy by the main source of energy used for heating

All three countries of the Fergana Valley demonstrate statistically significant differences of household energy spending depending on the main source of energy for heating, as the analysis of variance shows (Table IX.). However, the somewhat surprising result of comparing the expenditures on different energy sources is that the average (mean) spending of households that use electricity as their main energy source is lower than the spending by households that use coal – in all three countries, notwithstanding that in the Kyrgyz Republic and Uzbekistan coal is the dominant source for heating. Except for the Kyrgyz Republic this is also the case for the median.

Table IX. Expenditure on energy per month - by main energy source for heating

Main energy source for heating		Spending per month on coal, gas, and electricity				
	Frequency	Median	Mean	Std. Err.	[95% Conf. Interval]	
Kyrgyz Republic (Analysis of Variance: Adj R-squared = 0.0895; **Pr > F = 0.0000***)						
Coal	382 (88.4%)	**4,581**	**5,137**	120	4,901	5,373
Natural gas from underground pipes	2 (0.5%)	3,988	5,200	4,400	-3,448	13,848
Electricity	29 (6.7%)	**5,720**	**2,324**	460	1,420	3,229
Biofuels (pressed dung)	5 (1.2%)	4,236	2,766	1,066	671	4,861
Firewood	14 (3.2%)	**4,955**	**3,318**	957	1,437	5,198
Tajikistan (Analysis of Variance: Adj R-squared = 0.0161; **Pr > F = 0.0110***)						
Coal	54 (12.0%)	**302**	**340**	13	314	367
Fuel oil/diesel	2 (0.4%)	336	336	43	251	421
Propane (gas in cylinders)	2 (0.4%)	331	331	246	-152	814
Electricity	319 (71.0%)	**295**	**318**	5	308	328
Biofuels (pressed dung)	8 (1.8%)	398	364	28	309	419
Firewood	62 (13.8%)	**297**	**291**	9	274	309
Waste and garbage	2 (0.4%)	280	280	71	141	418

Table IX. Cont.

Uzbekistan* (Analysis of Variance: Adj R-squared = 0.2160; **Pr = 0.0000****)						
Coal	203 (49.4%)	**575**	**531**	17	498	563
Fuel oil/diesel	3 (0.7%)	195	275	88	103	447
Natural gas from underground pipes	69 (16.8%)	**200**	**283**	23	239	327
Propane (gas in cylinders)	40 (9.7%)	**188**	**224**	20	184	264
Electricity	58 (14.1%)	**210**	**313**	27	259	367
Biofuels (pressed dung)	1 (0.2%)	250	250	-	-	-
Firewood	37 (9.0%)	**190**	**280**	34	213	348

KG: Natural gas and biofuels omitted from Anova due to low count; expenditure limited to below or equal to 10,000 KGS per month to cut off outliers;

*TJ: *Oil/diesel, propane, biofuels, and waste omitted from Anova due to low count; expenditure limited to below or equal to 600 TJS per month to cut off outliers;*

*UZ: *Thousand UZS; **Oil/diesel and biofuel omitted from Anova due to low count; expenditure limited to between 100 and 1,000 UZS per month to cut off outliers.*

Fig. 4. depicts energy spending by households that use coal as their main source of energy for heating versus the spending by households that use electricity as their main source. The t-test for these two energy sources shows that for the Kyrgyz Republic the zero-hypothesis that there is no difference can be rejected with an error probability of 0.00% – with a mean spending of KGS 5,137 on coal and KGS 2,324 on electricity.

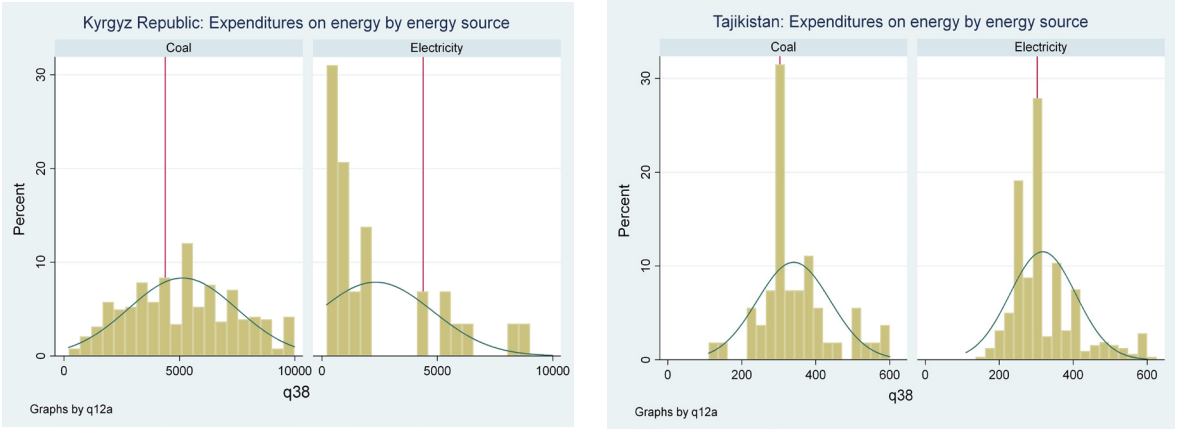

Figure 4. Cont.

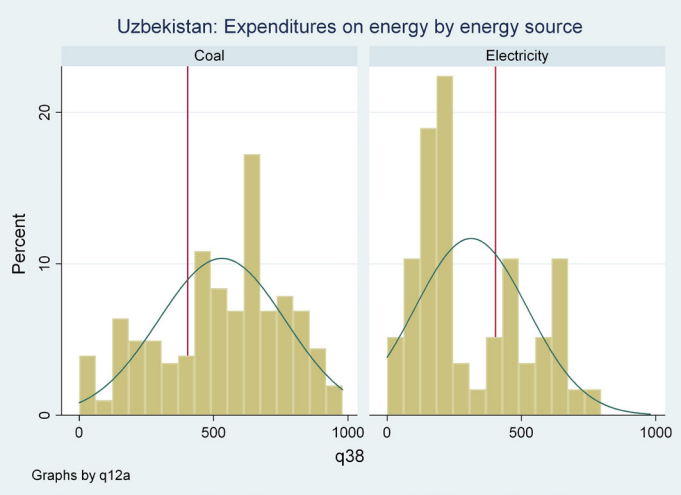

Figure 4. Expenditure on energy by main energy source for heating

In Tajikistan the mean spending is TJS 340 on coal and TJS 318 on electricity, respectively, the error probability that there is a difference is 4.7%, and in Uzbekistan the mean spending is UZS 531,000 on coal and UZS 313,000 on electricity, and the error probability is 0.00%. Thus, households that use coal clearly tend to spend more in the Kyrgyz Republic and Uzbekistan. This leads to the conclusion that notwithstanding the rather high emphasis of financial issues in the direct responses on the motives of energy choice, the relative spending is currently not the decisive determinant for households' choice of energy.

3.2. Plans and motives for changing households' heating systems

Another way of looking at the determinants for the choice of energy is to investigate plans and motives for changing heating systems. While one could assume that wealthier house-holds are more likely to change their energy systems than the lower-income ones because of more financial opportunities, there is no clear evidence for that. The chi-quadrat test shows little significance for any of the three countries, and both in Tajikistan and in Uzbekistan even a lower percentage in higher income brackets have plans to change their heating systems than in lower income brackets (Table X.).

Table X. Planning to change the autonomous heating system in the next 5 years - by income brackets

Frequency	Plan to change	Don't plan to change	Total	Plan to change, % of total
Kyrgyz Republic (Pearson chi2(4) = 1.3009; Pr = 0.729)				
Less than 6,000 KGS	-	-	-	-
6,001 - 12,000 KGS	**5**	15	**20**	25.0
12,001 - 20,000 KGS	**53**	115	**168**	31.5
More than 20,000 KGS	**73**	191	**264**	27.7
Difficult to answer	**3**	11	**14**	21.4
Total	**134**	332	**466**	28.8
Tajikistan (Pearson chi2(4) = 3.4099; Pr = 0.492)				
Less than 800 TJS	**4**	14	*18*	22.2
801 - 1,400 TJS	**4**	36	*40*	10.0
1,401 - 2,400 TJS	**13**	84	*97*	13.4
More than 2,400 TJS	**21**	201	*222*	9.5
Difficult to answer	**14**	109	*123*	11.4
Total	**56**	444	*500*	11.2
Uzbekistan (Pearson chi2(4) = 0.3039; Pr = 0.990)				
Less than 1,200,000 UZS	**8**	39	**47**	17.0
1,200,001 - 2,000,000 UZS	**12**	62	**74**	16.2
2,000,001 - 3,200,000 UZS	**14**	70	**84**	16.7
More than 3,200,000 UZS	**41**	213	**254**	16.1
Difficult to answer	**8**	33	**41**	19.5
Total	**83**	417	**500**	16.6

While the large majority of respondents in all three countries were aware of the harm that fossil fuels can inflict on the environment and on family health, there is little evidence that this awareness leads them to plan a change in their heating systems. The same 28.7% aware and not-aware plan a change in their heating systems in the Kyrgyz Republic; and in Uzbekistan the percentage is also almost the same – at 20% in both groups (Table XI.). In Tajikistan, where most of heating is already based on electricity, 11.5% of the ones aware plan to change versus 8.6% of the non-aware; however, also in Tajikistan the difference is not significant.

Table XI. Planning to change the autonomous heating system in the next 5 years - by awareness of potential harm to environment and health

Frequency	Plan to change	Don't plan to change	Total	Plan to change, % of total
Kyrgyz Republic (Pearson chi2(1) = 0.0623; Pr = 0.969)				
Aware	107	266	373	28.7
Not aware	25	62	87	28.7
Difficult to answer	2	4	6	33.3
Total	134	332	466	28.8
Tajikistan (Pearson chi2(1) = 0.4451; Pr = 0.800)				
Aware	46	354	400	11.5
Not aware	5	53	58	8.6
Difficult to answer	5	37	42	11.9
Total	56	444	500	11.2
Uzbekistan (Pearson chi2(1) = 0.0277; Pr = 0.986)				
Aware	54	271	325	19.9
Not aware	28	140	168	20.0
Difficult to answer	1	6	7	16.7
Total	83	417	500	19.9

Among the households that are inclined to change their heating systems, it is not coal from which households intend to move away most frequently. In the Kyrgyz Republic this is electricity, and in Tajikistan and Uzbekistan – firewood (Table XII.).

Table XII. Planning to change the autonomous heating system in the next 5 years - by main energy source for heating

Frequency	Plan to change	Don't plan to change	Total	Plan to change, % of total
Kyrgyz Republic (Pearson chi2(1) = 5.5383; Pr = **0.063***)				
Coal	**112**	**301**	**413**	**27.1**
Natural gas from underground pipes	0	2	2	0.0
Electricity	**14**	**17**	**31**	**45.2**
Biofuels (pressed dung)	2	3	5	40.0
Firewood	**6**	**9**	**15**	**40.0**

Table XII. Cont.

Tajikistan (Pearson chi2(2) = 9.4894; Pr = **0.009***)				
Coal	**10**	**50**	**60**	**16.7**
Fuel oil/diesel	1	1	2	50.0
Propane (gas in cylinders)	0	3	3	0.0
Electricity	**27**	**313**	**340**	**7.9**
Biofuels (pressed dung)	1	9	10	10.0
Firewood	**11**	**46**	**57**	**19.3**
Waste and garbage	0	1	1	0.0
Total	50	423	473	10.6
Uzbekistan (Pearson chi2(4) = 20.1766; Pr = **0.000***)				
Coal	**45**	**228**	**273**	**16.5**
Fuel oil/diesel	1	2	3	33.3
Natural gas from underground pipes	**11**	**65**	**76**	**14.5**
Propane (gas in cylinders)	1	42	43	2.3
Electricity	**10**	**55**	**65**	**15.4**
Biofuels (pressed dung)	0	1	1	0.0
Firewood	**15**	**24**	**39**	**38.5**
Total	83	417	500	16.6

*KG: *Natural gas and biofuel omitted due to low count;*
*TJ: *Oil/diesel, propane, and biofuel omitted due to low count;*
*UZ: *Oil/diesel and biofuel omitted due to low count.*

There is some difference in the readiness to change heating systems by the level of education. In the Kyrgyz Republic and Tajikistan, higher education households show the highest propensity for change (Table XIII.). However, this is not the case for Uzbekistan, and for all three countries the outcome is not significant.

Table XIII. Planning to change the autonomous heating system in the next 5 years - by the level of education

Frequency	Plan to change	Don't plan to change	Total	Plan to change, % of total
Kyrgyz Republic (Pearson chi2(1) = 2.6644; Pr = 0.446)				
Incomplete secondary (9 classes)	**11**	27	**38**	**28.9**
Secondary (11 classes)	**69**	180	**249**	**27.7**
Secondary specialized and vocational education (college, technical school)	**21**	64	**85**	**24.7**
Higher education (specialist, bachelor, master, candidate of science, doctor of science, PhD)	**33**	61	**94**	**35.1**
Total	134	332	466	28.8

Table XIII. Cont.

Tajikistan (Pearson chi2(2) = 1.3226; Pr = 0.516*)				
Incomplete secondary (9 classes)	4	47	51	7.8
Secondary (11 classes)	**17**	120	**137**	**12.4**
Secondary specialized and vocational education (college, technical school)	**11**	114	**125**	**8.8**
Higher education (specialist, bachelor, master, candidate of science, doctor of science, PhD)	**24**	163	**187**	**12.8**
Total	56	444	500	11.2
Uzbekistan (Pearson chi2(2) = 0.7969; Pr = 0.671*)				
Incomplete secondary (9 classes)	2	12	14	14.3
Secondary (11 classes)	**35**	158	**193**	**18.1**
Secondary specialized and vocational education (college, technical school)	**28**	161	**189**	**14.8**
Higher education (specialist, bachelor, master, candidate of science, doctor of science, PhD)	**18**	86	**104**	**17.3**
Total	83	417	500	16.6

*TJ: *Incomplete secondary omitted due to low count;*
*UZ: *Incomplete secondary omitted due to low count.*

The readiness to change heating systems is almost the same in all three countries between urban and rural areas: about 26-29% in the Kyrgyz Republic both in urban and rural areas, 16-17% in Uzbekistan, and 11-12% in Tajikistan. The Chi-square tests are highly insignificant (Table XIV.).

Table XIV. Planning to change the autonomous heating system in the next 5 years - by urban/rural households.

Frequency	Plan to change	Don't plan to change	Total	Plan to change, % of total
Kyrgyz Republic (Pearson chi2(1) = 0.4073; Pr = 0.523)				
Urban	**19**	55	**74**	25.7
Rural	**115**	277	**392**	29.3
Total	**134**	332	**466**	28.8
Tajikistan (Pearson chi2(1) = 0.0435; Pr = 0.835)				
Urban	**16**	121	**137**	11.7
Rural	**40**	323	**363**	11.0
Total	**56**	444	**500**	11.2
Uzbekistan (Pearson chi2(1) = 0.0439; Pr = 0.834)				
Urban	**49**	241	**290**	16.9
Rural	**34**	176	**210**	16.2
Total	**83**	417	**500**	16.6

The results about the plans for changing the heating system are somewhat more significant for gender than for income, harm awareness or level of education, and the urban-rural divide – however, with a lower than 10% error probability only for the Kyrgyz Republic (Table XV.). Male household heads are slightly more likely to have plans for changing the heating system than female ones: the percentage of male respondents indicating such plans were between 2.9 percentage points in Tajikistan and 7.4 percentage points in the Kyrgyz Republic higher than for their female counterparts. Given that this result is not well explained by any of the other demographic indicators, it should probably be attributed to some upbringing-based higher male propensity to "technical plans".

Table XV. Planning to change the autonomous heating system in the next 5 years - by gender

Frequency	Plan to change	Don't plan to change	Total	Plan to change, % of total
Kyrgyz Republic (Pearson chi2(1) = 3.0731; Pr = **0.080**)				
Male	**77**	161	**238**	**32.4**
Female	**57**	171	**228**	**25.0**
Total	**134**	332	**466**	28.8
Tajikistan (Pearson chi2(1) = 1.0198; Pr = 0.313)				
Male	**31**	214	**245**	**12.7**
Female	**25**	230	**255**	**9.8**
Total	**56**	444	**500**	11.2
Uzbekistan (Pearson chi2(1) = 2.4458; Pr = 0.118)				
Male	**49**	207	**256**	**19.1**
Female	**34**	210	**244**	**13.9**
Total	**83**	417	**500**	16.6

There is also some higher tendency among the young population to change heating systems than among the older one, significant at roughly 10% error probability only in the Kyrgyz Republic though (Table XVI.).

Table XVI. Planning to change the autonomous heating system in the next 5 years - by age

Frequency	Plan to change	Don't plan to change	Total	Plan to change, % of total
Kyrgyz Republic (Pearson chi2(1) = 2.5640; Pr = 0.109)				
Age 19-45	**99**	220	**319**	**31.0**
Age 45+	**35**	112	**147**	**23.8**
Total	**134**	332	**466**	28.8
Tajikistan (Pearson chi2(1) = 0.0323; Pr = 0.857)				
Age 19-45	**41**	320	**361**	**11.4**
Age 45+	**15**	124	**139**	**10.8**
Total	**56**	444	**500**	11.2
Uzbekistan (Pearson chi2(1) = 0.7786; Pr = 0.378)				
Age 19-45	**46**	209	**255**	**18.0**
Age 45+	**37**	208	**245**	**15.1**
Total	**83**	417	**500**	16.6

When asking household heads directly about the reasons households plan to change the heating system, the most frequent answer was “problems with the existing system”, followed by “con-venience”, colder winters, and financial issues (Fig. 5.). New technical possibilities also played a role. The environment and health got a count of only 11% in Tajikistan, 7.5% in the Kyrgyz Republic, and mere 2.1% in Uzbekistan.

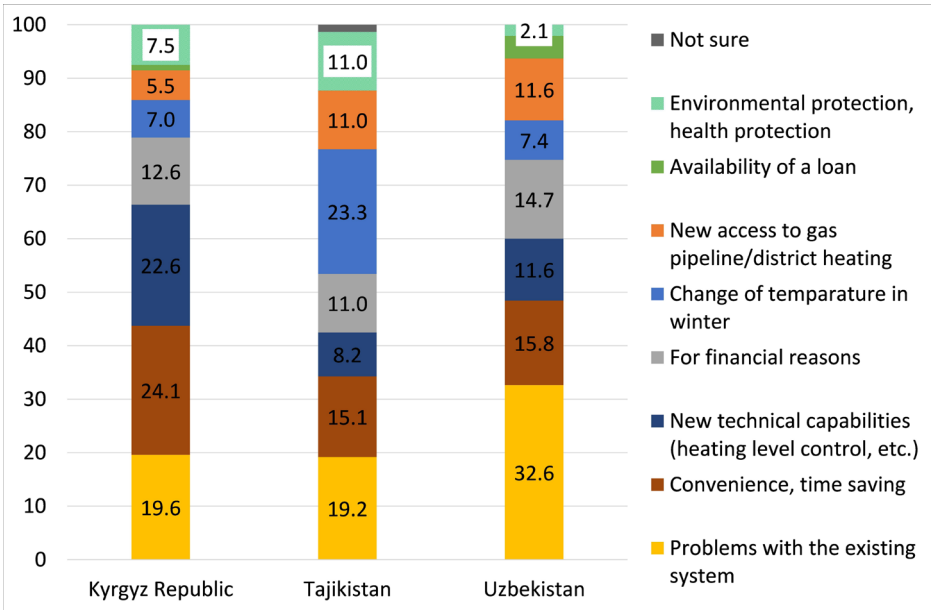

Figure 5. Answers to the question “What is the reason you are planning to change your heating system?” (%)

This outcome is roughly in line with the answers to the question "What guides you in choosing your main heating source?" shown in Table 5. However, when asked about future plans, even encountered issues with energy supply in the past seem not sufficient to induce households to change their heating systems. In the Kyrgyz Republic, 33.5% of those with problems in the past stated their readiness for change, significantly more than the 21.6% for the ones not affected (Table XVII.). For Tajikistan the respective figures are 12.5% and 8.6%, respectively, which is significant only on the 20% level, however. In Uzbekistan, of the 90% of the respondents who mentioned encountering challenges with energy in winter only 15.6% intend to change versus 25% of the households without issues (though the number of 13 of households without problems is small, which might have affected the outcome).

Table XVII. Planning to change the autonomous heating system in the next 5 years - by past problems

Frequency	Plan to change	Don't plan to change	Total	Plan to change, % of total
Kyrgyz Republic (Pearson chi2(1) = 7.6211; Pr = **0.006**)				
Problems in winter	**94**	187	**281**	**33.5**
No problems in winter	**40**	145	**185**	**21.6**
Total	**134**	332	**466**	28.8
Tajikistan (Pearson chi2(1) = 1.6578; Pr = 0.198)				
Problems in winter	**42**	295	**337**	**12.5**
No problems in winter	**14**	149	**163**	**8.6**
Total	**56**	444	**500**	11.2
Uzbekistan (Pearson chi2(1) = 2.9579; Pr = **0.085**)				
Problems in winter	**70**	378	**448**	**15.6**
No problems in winter	**13**	39	**52**	**25.0**
Total	**83**	417	**500**	16.6

4. Conclusions and policy recommendations

As many as 80.5% respondents in the Kyrgyz Republic, 80.0% in Tajikistan, and 65.0% in Uzbekistan indicated their awareness of the potential harm fossil fuels can inflict on the environment and on health. Yet, the dominant type of energy for heating in the Kyrgyz Republic and Uzbekistan is coal, notwithstanding higher energy expenses by households that use coal as the main source of energy for heating than by households that use electricity.

A large-scale move towards clean energy use by households will thus require profound policy interventions.

The relative price between clean energy such as electricity and coal should be sharply adjusted in favor of clean energy. This calls for taxes on coal, for example a sales tax and removal of subsidies for coal and/or administrative setting of price limits. At the same time, households in the Fergana Valley already spent up to one-third of their income on energy. In order not to further increase their financial burden, to cause social hardship, and to trigger a backlash against reforms such as taxes on coal, households need to be compensated for their higher energy bills by money transfers to them.

An increasing part of literature – for example Feng et al. (2018) for Latin America – shows that recycling a relatively small part of fiscal revenues from removing energy subsidies or from energy taxation could be sufficient to shield vulnerable households from the effects of energy price hikes. At the same time, the literature on the impact of energy taxes on residential final energy consumption (RFEC) in the context of developing countries and "within the integrated framework which takes into account socio-economic and contextual factors" (Borozan, 2019) is still relatively limited. This is even more the case regarding sales taxes on coal. However, Parry et al. (2017) found that ramping up India's special additional tax (cess) on coal would "significantly reduce local outdoor air pollution deaths, raise revenue… and is about the most efficient policy for reducing CO2 emissions". And Sumarno and Laan (2021) recommended to the Government of Indonesia: "Simply increase taxes on coal as a de facto form of carbon taxation". Further studies on the potential impact of coal sales taxes in the Central Asian region would be helpful as guidance for the authorities on what measures should be taken.

Borozan (2019) concludes for the EU that in less energy-consuming countries, high energy taxes have a stronger impact on residential energy consumption than in more energy-consuming ones. To an extent, this might also be the case for "higher-coal-consuming" house-holds, simply because there are fewer actual choices available due to the lack of appropriate technical solutions, which are also affordable.

Therefore, a new wave of (green) electrification is required to be able to satisfy the potentially higher demand for electricity from households and other sectors of the economy such as e- ve-hicles and the production of hydrogen. In fact, it is already underway in the three countries of the Fergana Valley – in Uzbekistan with a focus on solar and wind, and on hydropower in Tajikistan and the Kyrgyz Republic on hydropower. Azhgaliyeva et al. (2021) also found for Kazakhstan and the Kyrgyz Republic that "access to cleaner and more modern energy infrastructure such as natural gas pipelines and district heating reduces solid fuel consumption, especially in rural areas".

For utilizing each country's comparative advantages in the generation of electricity and for facilitating the balancing of supply and demand during different

seasons and times of the day, closer cross-country cooperation, upgraded grid connectivity and intensified electricity trading are desirable.

"Gradual and well-publicized reforms are also recommended to give firms and house-holds time to adjust in anticipation of higher energy prices and to allow time for strengthening social safety nets" (Parry, 2017). Along with these reforms, timely information campaigns via the internet, social networks, and other communication channels about opportunities for using clean and renewable energy sources are necessary to trigger a broad-based movement towards cleaner household energy use.

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