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Assessment of Alternative Rural Energy Sources and Technologies in South-Eastern Oromia Region, Ethiopia

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Abstract
8 a9ority of world o ulation (:#; of total world! is li<ing in rural area 0ut consu . es only a0out 3#; of glo0al co . . ercial energy. In rural de<elo ing nations the energy sources for coo7ing and lighting are traditional sources with . ore re<alence in rural areas. S ecially in Ethio ia- literatures indicated that . ore than ,4; of the energy sources are fro . traditional sources. Po<erty- lac7 of a<aila0ility of . odern energy and lac7 of education are the . ain causes of this heno . enon. 40undance use of 0io . ass fuel with inefficient sto<es caused scarcity of 0io . ass resources in Ethio ia. =owe<er- in the study areas- na . ely 4rsi and west 4rsi- 0io . ass energy sources and other energy sources and technologies under utili>ation were not characteri>ed for research and de<elo . ent inter<ention. Therefore- this research ro osal was initiated with o0 9ecti<es of characteri>ing energy resources and technologies under utili>ation and related constraints in the study areas. ?our districts fro . 4rsi and three districts fro . w*4rsi >ones were selected and data was collected through ? / &- @II and household le<el sur<ey. The result re<ealed that . a9ority of rural households are using 0io . ass fuel (wood- ani . al dung and cro residues! s ecially for coo7ing ur oses and there is e5 ansion of solar cells for lighting ur oses. The 0iogas lant use was under de . onstration stages and it was also constrained with high ca ital in<est . ent and its accessory technology (in9era sto<e!.de<elo . ent of energy lants li7e 9athro ha is also underway in lowlands of 4rsi >one.
Keywords: Arural energy- 0io . ass fuel- ure energy- i . ro<ed coo7 sto<es- 4rsi >oneB
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Introduction

8 ore than half of world o ulation- which is a0out three 0illion- has no access to . odern sources of energy. These eo les are oor and their redo . inant energy sources are traditional 0io . asses (&awit &. / uta- 2#(2!. 4ccess to efficient and . odern energy is e5tre . ely crucial for the de<elo ing nations to counter the econo . ic and health issues and at the sa . e ti . e with the roducti<e use of energy increase the econo . ic growth and life standard of the oor eo le. &e<elo ing countries ha<e :#; of the worldCs o ulation 0ut consu . e only 3#; of glo0al co . . ercial energy (Eric 8 artinot et.al- 2##2!. 4 well erfor . ing energy syste . can ro<ide these eo le with inco . e generating o ortunities as well as to esca e the . fro . the awful i . acts of o<erty. Dnfortunately this has not 0een . ade ossi0le due to financial issues- lac7 of resources- ineffecti<e energy olicies and energy syste . s in the de<elo ing nations.

&e endency of the eo le on traditional energy for catering their coo7ing and lighting energy de . ands in the de<elo ing nations still re<ails es ecially in rural areas. Po<erty- lac7 of a<aila0ility of . odern energy and lac7 of education are the . ain causes of this heno . enon. 40undant use of 0io . ass for . eeting the de . ands also 0rings the scarcity of these resources li7e fuel wood. =owe<er- due to gradual increase in awareness of the eo le de . and for electrification in Ethio ia is increasing to around 2# ercent er annu . (Sa . son T.- 2#()!.
Ethio iaCs energy consu . tion as one of de<elo ing countries is redo . inantly 0ased on 0io . ass energy sources. 4n o<erwhel . ing ro ortion (,4; ! of the countryCs energy de . and is . et 0y traditional energy sources such as fuel wood- charcoal- 0ranches- dung ca7es and agricultural residues and nearly 2 ercent of the o ulation of Ethio ia has an access to grid electricity. The 0alance is . et 0y co . . ercial energy sources such as electricity and etroleu . . The . ost i . ortant issue in the energy sector is the su ly of household fuels- which is associated with . assi<e deforestation and the resultant land degradation. The increasing scarcity of fuel wood is co . ounded 0y Ethio iaCs high o ulation growth rate.

4nother detri . ent side of utili>ing energy in inefficient way is higher consu . tion of energy than usually reFuired with disastrous health effects due to s . o7e. S . ith *et al.,* 2### in their study indicated that fuel wood- roots- agricultural residues and ani . al dung are all roducing high e . issions of car0on . ono5ide- hydrocar0ons

and articulate . atter. 4ccess to . odern and clean energy li7e electricity and efficient coo7ing technologies to the rural areas in de<elo ing world not only ro<ide i . ro<ed and healthy life style 0ut would also hel in reducing har . ful en<iron . ental effects. Efforts on the all le<els are reFuired to counter this situation with effecti<e ro9ects and olicies on go<ern . ent le<el as well as awareness of the uneducated . asses in the rural de<elo ing world. In general this acti<ity is initiated to conduct a situation analysis for characteri>ing the sources of energy and technologies used in rural areas for research and e5tension inter<ention.

The . ain o09ecti<e of this study was to assess and analy>e the e5isting energy resources in the area while the s ecific o09ecti<es of the study were' to characteri>e and analy>e the e5isting energy resources- to identify and rioriti>e challenges and constraints of the energy resources- to identify and rioriti>e otential o ortunities of the energy resources and to identify and rioriti>e otential research inter<ention areas to connecting the e5isting o ortunities of the energy resource of the study area

Methodology

Description of the study areas

The research was carried out in south-east areas of %ro . ia regional state. This area of the region is one of the . ost roducti<e clusters of the region. Two >ones na . ely 4rsi and w*4rsi were selected ur osi<ely 0ased on accessi0ility. Each >one was clustered into three 0ased on . a9or agro-ecologies as lowland- . idland and highland and sa . le districts were selected fro . each cluster.

4rsi >one is di<ided into twenty-fi<e ad . inistrati<e districts and one ad . inistrati<e town (4sella!. It is located in 3$N """(33.#,$))$:3 :")),2.23:)22)3 DT 8 coordinates. The >one has four agro-cli . atic >ones and altitude is the . ain source of difference. These di<erse agro-cli . atic conditions create wider o ortunities of ha<ing different <egetation which are sources of 0io . ass energy.

Gest 4rsi >one is also di<ided into ele<en ad . inistrati<e districts and one ad . inistrati<e town (Shasha . ane which is the ca ital town of the >one. Gest-4rsi >one has land area of a0out (-($$-44# hectares or (2-,3: 7 . 2. 1ro -li<estoc7 . i5ed far . ing and astoral and agro- astoralis . are co . . only racticed in all highlands- and . id and lowlands. 4ccording to data fro . >onal agricultural de<elo . ent office and discussion held with agriculture and rural de<elo . ent office e5 erts- ty ical highlands of so . e districts li7e &odola and 4da0a and lowlands ha<e 0oth astoral and agro- astoral far . ing syste . .

Sample and Sampling Methods

%n the 0asis of agro-ecology di<ersity- re resentati<e districts- easant associations (P4s! and artici ant far . ers were selected using syste . atic sa . ling techniFue. Then- fro . the identified P4s*<illages- re resentati<e far . ers were rando . ly selected for grou discussion and inter<iews using syste . atic sa . ling rocedure. &uring sa . ling for focus grou discussion and household le<el inter<iew- ageHse5 co . osition- educational status- roles and res onsi0ilities in the co . . unity were ta7en into consideration. 4 . ulti-disci linary tea . was esta0lished to conduct the sur<ey using different P34 tools.

Data types and methods of data collection and analysis methods

6oth ri . ary and secondary data were collected fro . different sources at different le<els. Pri . ary data were generated through focus grou discussion- indi<idual inter<iews- and for . al and infor . al discussions with far . ers- &4s and e5 erts. ?ocus grou discussions- 7ey infor . ant inter<iew and infor . al discussion were a . ong the e . loyed tools to collect ri . ary data using chec7list and se . i-structured Fuestionnaire.

&ifferent P34 tools were e . loyed to collect infor . ation on different as ects of e5isting 0io . ass fuel resource of the study area including se . i-structured inter<iews- focus grou discussions and ersonal o0ser<ations were e . loyed to generate ri . ary data ertaining to the e5isting 0io . ass fuel resource in the study area. ?ocus grou discussion was e . loyed to get a0out the e5isting 0io . ass fuel resource- re<ailing o ortunities and constraints- with 7ey infor . ants (far . ers- &4s- co . . unity leaders!. In general a total of 32, households were sa . led fro . se<en districts of which three were fro . west 4rsi and the rest four were fro . 4rsi >one. 4round 4" ercent and "" ercent of the res ondents were fro . 4rsi and west 4rsi >one res ecti<ely. The collected data was analy>ed using a ro riate statistical tools to fulfill the o09ecti<es of the study. The Fuantitati<e data was analy>ed using descri ti<e statistics li7e . ean- standard de<iations freFuency and t-test using statistical ac7age for social sciences (SPSS! for analysis.

Result and Discussion

Demographic and Socioeconomic Characteristics of the Respondents

8 ean age of res ondents was 4"."# years which within wor7ing age grou . 4round " ercent of the households were fe . ale headed and the rest ," ercent were . ale headed. 8 ore than ,: ercent of the res ondents were . arried while only around one ercent of the res ondents were widowed. The o<erall a<erage fa . ily si>e of the households was $.,2 ersons er a household while the . ean . ale fa . ily . e . 0ers and fe . ale fa . ily . e . 0ers

were 4.2$ and 3.)4 ersons er household res ecti<ely (ta0le (!.

Table 1: Demographic and Socioeconomic Variables of the Respondents

Variable	N	Mean	Std. Deviation	Min.	Max.
4ge	32,	4"."#	((.,,	22	$:
Education	32,	4.(#	3.4:	#	((
Total . ale fa . ily	32,	4.2$	2.2"	(.##	(4.##
Total fe . ale fa . ily	32,	3.)4	2.(2	#.##	(3.##
Total ?a . ily	32,	$.,2	3."3	#	22

	N	Percent	Cumulative percent
8 ale headed	3(3	,".(#	,".(#
?e . ale headed	()	4.,	(##
8 arried	324	,:."	,:."#
Single	(	#.3	,:.:#
G idowed	4	(.2#	(##.##

Source- own sur<ey result- 2#($

It was tried to 0alance the sa . le fro . each agro-ecological >ones. 4ccordingly- 43.2# ercent of the res ondents were fro . highland areas while around 3

Table 4: Household facility holding of respondents in Arsi and W/Arsi zones

	?acility ty e	?reFuency	ercent
(.	=a<e electricity	22	).$#;
2.	=a<e tele hone	22)	):.$#;

Major Energy Sources and Energy saving Technology Use patterns in Arsi and West Arsi

Gater- .ine and energy office is esta0lished at each >one and district le<el with the .a9or o0%ecti<es of (! i. ro<ing the li<elihood and Fuality of life of rural households through the e5 loitation of .ar7et and non-.ar7et oriented 0iogas sector- 2! to aware and introduce 0iogas technologies to 0uild ca acity of disse .inators through training and enhancing s7ill and 7nowledge of artici ants- 3! to de<elo a co. .ercially <ia0le do .estic 0io-digester and disse .ination of technologies- 4! to create access to grid electric light to rural co. .unity in colla0oration with Ethio ian electric ower coo eration (EEP1%!.

4ll res ondent households are using .ulti le sources of 0io .ass and other energy sources. The household le<el sur<ey result re<ealed that the .ost widely used 0io .ass energy sources were round wood- ani .al dung-cro residues and 0ranch leaf and twigs (6IT! and each of the . were selected 0y "#.2-4)." ;-4(.3; and 3".3; of the res ondents res ecti<ely. 4round 33; of the res ondents 0uy su le .entary energy sources while the rest are using fro . their own forest trees (.ostly eucaly tus tree! far .- cro residues and ani .al dung. 1onsidera0le households are using co. .unity forest (around "#.: ercent! for household energy sources. 8a9ority of the households- .ore than ,(ercent of the res ondents- fetch 0io .ass energy sources and wi<es and daughters (the fe .ale grou s! are the .a9or res onsi0le fa .ily .e .0ers to fetch fire wood and other energy sources each accounting for :2.4; and ",.#; of total res ondents (ta0le "!.

Table 5: Energy Sources, technology use and household responsibility

No.	Energy sources	Frequency	percent
(.	3ound wood	()"	"#.2
2.	4ni .al dung	("3	4)."
3.	1ro residues	(:2	"".3
4.	Dse forest as household energy sources	()$	"#.:
".	=us0and is res onsi0le to fetch firewood	(:3	"".)
).	Gife is res onsi0le to fetch firewood	2$(	:2.4
$.	&aughters are res onsi0le to fetch firewood	(,4	",.#
:.	6oys res onsi0le	("$	4$.$
,.	=a<e i. ro<ed coo7ing sto<e	3:	((.)#
(#.	Dse 3-stone o en coo7ing sto<e	2$4	:3.3#
((.	Dse enclosed clay sto<e	4	(.2#
(2.	=a<e se arate coo7ing roo. (7itchen!	2(2	)4.4#
(3.	Dse any technology that i. ro<e efficiency of 0io .ass	$(	2(.)#

Source' own sur<ey result- 2#(:

Trend in use of 0io .ass energy sources was assessed through household indi<idual inter<iew. Since the last fi<e years wood (s ecially the round ones! was the .ost co. .only and e5tensi<ely used energy source that was ran7ed as first and followed 0y ani .al dung and cro residues with a .ount of ").2;-42.); and 3".); res ecti<ely (ta0le "!.

Table 6: Energy use patterns across major agro-ecologies

	=ighland	8id-highland	Iow-land		
Energy source	**Yes**	**Yes**	**Yes**	χ^2	**Total**
?irewood	(3$(,)."![a]	,:(,3.3!	$#(:".4!	,.)222	
1harcoal	3:(2).:!	",(").2!	,(((!	4)."(222	3#"(,2.$;!
4ni .al dung	(("(:(!	$3(),."!	4:(":."!	(3.3222	(#)(32.2;!
IiFuid etroleu. gas	2:((,.$!	33(3(.4!	4,(",.:!	3$.$222	((#(33.4;!
6iogas	4(2.:!	(((.#!	#(#!	3	"((."#;!
1ro residue	2"(($.)!	$,($".2!	$:(,".(!	("2222	(:2("".3;!
Electricity	$(4.,!	((((#."!	3(3.$!	4.4$2	2(().4;!
Solar cell	",(4(."!	4#(3:.(!	$(:."!	2:222	(#)(32.2;!

[a]nu .0ers in arenthesis are ercent of articular energy source users fro. o ulation in the articular agro-ecology

2- 222 chi-sFuare is significant at ,#; and ,,; le<el of significance

The use of firewood is high in all agro-ecologies with .ini .u. great <alue in lowland areas. The result fro. ta0le) re<ealed that around ,$; of highland res ondents are using firewood while in lowland area it is little lower to :";. The use of cro residue as household energy source is also highest in low land where it is the .ain energy

source for ," ; of the households. The use of liFuid etroleu . gas for house lightening is co . . on all areas 0ut it is highly racticed in lowland areas (around)# ; !. In highland areas- the culture of using solar cell for lightening is increasing through ti . e (42 ; ! and su0stituting liFuid etroleu . gas.

Table 7: energy sources and technologies used for household lighting

Tech used for light		?reFuency	Percent	1u . ulati<e
(.	Electric	2(	).4	).4
2.	Solar	,(	2$.$	34.(
3.	Torch	4)	(4.#	4:.(
4.	6iogas	(	.3	4:.4
".	@erosene	($#	"(.)$	(##.#
	Total	32,	(##.#	(##.#

Source' own sur<ey result- 2#($

4s it is re<ealed in ta0le $- . a9ority of the households are using 7erosene for lighting ur ose which is around "2 ercent of total households. The use of s . all scale solar cell was also . uch considera0le- which is a0out 2: ercent of the total households.

Households' kitchen use characteristics

8ore than)4 ercent of the res ondent households ha<e se arate coo7ing roo . s (7itchens! facilities while the rest ha<e no se arate roo . s for coo7ing ur oses and the use of i . ro<ed technologies (i . ro<ed coo7 sto<es! are <ery li . ited and only ((.) ercent of the households are using i . ro<ed coo7 sto<es called *mirt/gonzie* for *injera* 0a7ing which are ro<en to sa<e 0io . ass energy. &uring focus grou discussion res ondents e5 lained that they e<en can coo7 outside ho . e in o en air during the winter eriod. In general only around 22 ercent of the res ondents are using i . ro<ed coo7 technologies li7e *mirt* (for in9era 0a7ing! and charcoal sa<ing sto<es for stew and coffee . a7ing (ta0le "!. The result fro . 4rsi >one©s office of energy also shows that the ercent of households using i . ro<ed coo7 sto<e are only (# ; and it is al . ost the sa . e with that of sur<ey result.

Household Energy Consumption and their determinant factors in Study Area

Esti . ate of household©s daily and annual energy consu . tion was assessed during sur<ey and resented in ta0le :. 4s e5 ected the . a9or sources of 0io . ass fuel were fuel round wood- cro residue and ani . al dung. The annual consu . tion of 0io . ass fuel er a household was $",.2#@g (which is 2.#:@g er day er household! of wet fuel wood-)2#."#@g of dry fuel wood ((.$#@g er day!- and 43#.$#@g of dry cro residue ((.(:@g*day!. Nearly a liter of 7erosene is 0eing consu . ed er . onth er each household . ainly for house lightening ur ose.

Table 8: Annual Household Energy Consumption

Energy sources	&aily 1onsu . tion	4nnual 1onsu . tion
(. 3ound fuel wood (@g!	(.:,	):,.:"
2. 6ranch Ieaf and Twigs	#.:3	3#(.(3
3. 1ro residue	#.:3	3#(.(3
4. 4ni . al dung	#.::	3(,.3:
". 1harcoal	#.24	:$.)
). @erosene (lit.!	#.#3	(#.,"
$. Electricity (@Gh!	#.#,	32.:"

The a . ount and ty e of energy sources and use of i . ro<ed coo7 sto<e technologies are deter . ined 0y different socioecono . ic factors. The use of i . ro<ed coo7 sto<es li7e i . ro<ed 0io . ass sa<ing Ainjera 0a7ingB sto<es- solar anels and electricity were highly deter . ined 0y household©s inco . e a . ount. The . ean inco . e for I1S- solar energy anel and electricity users were 3#"2(.::- 3(2#:.:3 and 3(-)(".## while they were (:#(4.4- (2$,4.2(and (:)##.:" for non-users with t-<alue significant at ,"- ,, and ,# ercent of ro0a0ility res ecti<ely (ta0le ,!.

Table 9: Income and choice of energy technologies

+aria0le		I . ro<ed coo7 sto<e	Solar anel	Electricity
Inco . e for'	Dsers	3#"2(.::	3(2#:.:3	3()(".##
	Non-users	(:#(4.4#	(2$,4.2(	(:)##.:"
	t-<alue	2.4,22	).(:222	2.(#2

The choice of coo7ing or lightening energy sources was influenced 0y other factors li7e fa . ily si>e- age land holding and li<estoc7 ossession. 4s an indicator- household©s daily fuel wood and ani . al dung consu . tion were regressed against different socioecono . ic <aria0les li7e natural logarith . transfor . ed inco . e- fa . ily si>e- . an-eFui<alent fa . ily la0or- li<estoc7 ossession in TID- age of res ondent and landholding si>e of the households. The a . ount of fuel wood consu . tion was significantly and ositi<ely influenced 0y fa . ily si>e and

li<estoc7 ossession (TID! while it was negati<ely influenced 0y natural logarith . of inco . e and . an-eFui<alent of fa . ily la0or. The a . ount of ani . al dung used was also ositi<ely and significantly influenced 0y landholding and negati<ely 0y fa . ily la0or.

The results fro . ta0le , and (# re<eal that as household inco . e increases- there is a shift fro . traditional energy sources and co . 0ustion technologies to . odern and i . ro<ed and efficient technologies. The a . ount of daily fuel wood consu . tion was negati<ely affected 0y the a . ount of household inco . e which shows that there is a shift fro . traditional energy sources to . odern ones li7e electricity and solar. This result is si . ilar with 6ansal et al. (2#(3! in rural India- 1haudhuri and Pfaff (2##3! in Pa7istan- =elt0erg (2##"! in /uate . ala and Nlo . and @ari . o< (2#(4! in northern 1a . eroon which shows that household inco . e is one of the . ain factors in choosing fuels for coo7ing. %uedraogo (2##)! in his findings while analy>ing ur0an households coo7ing fuel choice in %uagadougou- 6ur7ina ?aso- he re orted that the fuel wood utili>ation rate decreases with increasing household inco . e. Si . ilarly- research findings 0y 4rthur *et al.* (2#(#!- shows that households' wealth deter . ines the transition fro . 0io . ass to electricity in 8 o>a . 0iFue. The a . ount of daily ani . al dung use was also affected negati<ely 0y a . ount of inco . e and it was ositi<ely affected 0y si>e of li<estoc7 o ulation.

Table 10: OLS result for fuelwood and animal dung use in Arsi and w/Arsi zones

&e endent Jdaily fuel wood (@g!			&e endent <aria0le Jdaily ani . al dung (@g!		
+aria0les	6	t-<alue	+aria0les	6	t-<alue
1onstant	".)2	3.4(22	1onstant	2.3$	2.4(2
?a . ily si>e	#.(,	2.332	InInco . e	-#.#:	-(.3#
?a . ily la0or	#.()	2.#(2	4ge	#.#:	(.3"
Ii<estoc7 (TID!	#.#$	(.(#	Iandholding	#.(2	2.#2
InInco . e	-#.((	-(.$42	fa . ily la0or	-#.("	-2.4(22
4ge	-#.2#	3.)"	TID	#.:,	3.)4222
?-<alue 2.3:(			?-<alue J2.2$		
4d9usted 3^2 J #.#($			4d9usted 3^2 J#.#("		

22- 2significant at " and (# ; ro0a0ility le<el

Constraints and opportunities of existing energy resources in Arsi and W/Arsi zones

The . a9or energy ty es under use are co . . only 0io . ass sources fro . different sources . a9orly woods- ani . al dung cro residue and others. ?ro . result of focus grou discussion with all sta7eholders at different stages- the rate of deforestation due to use of 0io . ass as a source of household 0io-fuel is higher than rate of reforestation in Ethio ia (there is un0alanced utili>ation of forest!. The e5 ansion of agricultural land is also one of the . ost i . ortant causes of deforestation and as a result in . ost districts where this sur<ey was conducted- e<ery . arginal land was distri0uted as a far . land and deforested. %ther studies done 0y different authors also re<ealed the sa . e result. ?or instance the research 0y /essesse and 1hristiansson (2##:! in South-central 3ift +alley and 6edru (2##)! in central and southern 3ift +alley of Ethio ia show the i . act of far . land e5 ansion on deforestation. ?urther . ore- as it is 7now in a . i5ed far . ing syste . the li<estoc7 and cro roduction are su le . entary and 0y roducts fro . one enter rises is an in ut for the other and <ice-<ersa. 6ut due to the lac7 of fuel-wood fro . forest e<erything fro . li<estoc7 or cro roduction goes to fire and the fertility of soil is highly affected.

%nly few households are using solar cells for lighting 0ut co . ared to its starting ti . e- the o<erall 32 ercent of res ondents is not insignificant nu . 0er (ta0le)!. The o<erall use of electricity use is only) ercent which insignificant and li . ited to <illages which are so . ehow condensed. /rid rural electrification is difficult due to high cost of initial in<est . ent since the o ulation is scattered. 8oreo<er- the atte . t to i . ro<e the efficiency of the 0io . ass through use of i . ro<ed technologies li7e i . ro<ed coo7 sto<e is not effecti<e.

/ood energy utili>ation o ortunities in study areas are that there is gradual increase in rural households' awareness on i . ortance of clear energy and health related ro0le . s of using 0io . ass energy sources with o en inefficient technologies which is creating de . and for i . ro<ed technologies. This will in turn . a7e the duty of de . onstrating technologies easier for 0oth research centers and de<elo . ent ractitioners. 8oreo<er- the rural households understand the effects of using 0io . ass in unsafe ways and deforestation and there is good start in 0iological conser<ation (afforesting the degraded land! and this will reha0ilitate the stoc7 of 0io . ass in general. ?or instance the res ondents were as7ed whether they 7now the corres onding effects of using firewood*other 0io . asses in o en sto<es or o<er utili>ation of forest in unsafe and i . ro er ways for coo7ing on health- en<iron . ent (deforestation- rain attern- ti . e of raining- a . ount of rain we recei<e- etc and al . ost $# ercent of the res ondents answered that they 7now it 0ut they don't ha<e an alternati<es to i . ro<e their ways of li<ing.

4n attention gi<en 0y ?ederal /o<ern . ent of Ethio ia for energy de<elo . ent and distri0ution is which is su orted 0y good energy olicy and in<ol<e . ent of different N/%s such as solar energy foundation (/er . an N/%!- =unde wor7ing in %ro . ia on 0iogas installation and other wor7ing on <aries energy alternati<es are also another o ortunities. 8inistry of Gater Irrigation and Electricity is also in<esting on energy lant lantation li7e 9atro ha in otential areas li7e 8erti- Je9u and /ololcha districts of 4rsi >one which is an additional o ortunity

for de<elo . ent of clean energy in the study area.

Limitations in Use of Improved Technologies: Key Challenges

E<en though there is an atte . t to de . onstrate and disse . inate i . ro<ed coo7ing sto<es li7e . irt- gon>ie and others- it is not as er the lan due to 0udget shortage- continuous structural changes in de<elo . ent offices and . andates of rural de<elo . ent agents. Pre<iously- natural resource conser<ation e5 erts at <illage le<el were res onsi0le for conser<ation of forest and disse . ination of i . ro<ed coo7 sto<es at <illage le<el 0ut currently since the disse . ination of i . ro<ed coo7 sto<es res onsi0ility is shifted to . ineral- water and energy offices at different le<el- and they donCt ha<e re resentati<e de<elo . ent agents down le<el (<illage!- it 0eco . es a forgotten 0usiness at P4 le<el.

The lower use of i . ro<ed coo7 sto<es is associated to . any socioecono . ic and institutional issues. The first critical reason was lac7 of awareness on effects of traditional energy using on health a . ount of 0io . ass to 0e consu . ed and natural resource degradation (s ecially 0oth 0ac7yard and natural forest!. The second reason for low use of I1S was technology su ly shortage. E<en though there an atte . t to organi>e I1S roducing . icroenter rises in . ost districts- the roduction and distri0ution are li . ited to ur0an and eri-ur0an areas where there is alternati<e energy sources and this is due to oor access to infrastructure and logistics.

The third reason for lower ado tion (disse . ination! of I1S was low urchasing ower of the users due to low inco . e. The other reasons for low disse . ination of the technologies re orted 0y rural energy offices at >onal and district le<el were lac7 of logistics and 0udget shortage.

The use of 0iogas is still at de . onstration stage 0y different N / %s and go<ern . ent ro9ects and the nu . 0er of lants constructed so far is still insignificant. %ro . ia 6iogas 1onstruction Dnit is constructing 0iogas for far . ers in cost sharing . ode and there are also so . e N / %s li7e =unde %ro . o which are funding full cost of the ro9ect. 4ccording to re orts fro . >onal offices of energy only :4, and 32, 0io-gases were constructed in 4rsi and w*4rsi >ones res ecti<ely. 8 a9or constraints in 0iogas disse . ination are afforda0ility (e5 ensi<eness of the technology!- lac7 of technical ga fro . constructors (due to this it was re orted that . ost 0iogas lants are not functional and this goes to 2"-3# ; !- and lac7 of awareness fro . users side on ad<antages of 0iogasCs 0i- roduct (slurry!- and inco . leteness of the technology (there is no *mitad* which widely used for 0a7ing of *injera* and other food and it is only used for stew and coffee . a7ing and lightening ur ose!. 6ut currently there is solar cell for lightening ur ose as an o tion and a0sence of this sto<e is a critical ro0le . to 0e sol<ed 0y research.

Iiteratures re<ealed that- 0eing a thirteen- . onth shine country- the otential solar energy in Ethio ia is "." @w* 8 2 and less than (ercent was e5 loited so far (&ere9e &.- 2#(3!. 6ut the use of solar energy for lightening ur ose is constrained 0y technical ga of users and forged roduct of (fraudulently re roduced fa7e*co ied roducts! solar cells which are i . orted illegally. The su ly fro . go<ern . ent side with colla0oration of Ethio ian &e<elo . ent 6an7 has no consistency and not accessi0le when far . ers de . and. In . ost cases there is no or too li . ited after sales ser<ices. ?ro . the result of @II and ? / & it was understood that there is no trained technicians to train users e<en how to install and there is no . aintenance ser<ice in case of any da . ages. The re ort fro . assess . ent done 0y solar energy foundation in 2##) also re<ealed that these a0o<e . entioned constraints were . ain challenges in solar cell use 0usiness (Sa . son T.- 2#( )!. The assess . ent . ade at national le<el descri0ed the . ain challenge in the sector as shortage of hard currency for i . ort- shortage of finance 0oth at local and a0road- 0ad roduct Fuality in the . ar7et and ina ro riate co . etition- and fa7e and co ed roduct i . ort due to lac7 of national standard and control.

Conclusion and Potential Research and Development Intervention Recommendation Areas in areas of rural energy

To enhance efficiency and sustaina0ility of the e5isting energy resources of the area- different research acti<ities has to 0e conducted and in . eanti . e- inter<ention with e5isting at hand technologies that can enhance efficiency of the energy sources is also a crucial.

Gith at hand e5isting technologies 0oth research and de<elo . ent 0odies can wor7 on de . onstration and re-scaling u of the i . ro<ed coo7 sto<es- organi>ing technical and o erational trainings for users and local technicians on solar energy a aratus and 0iogas utili>ations. This will increase the awareness of the households on i . ortance of using clean energy and how to use*o erate the i . ro<ed energy source technologies at their ho . e. Iocal technicians eFui ed with s7ill and 7nowledge of these technologies can also 0oost the confidence of rural households to in<est on such technologies. The study area s ecially the lowland areas of 4rsi are ideal sources of solar energy. ?or e5a . le &era district was one of the nationally reco . . ended sites for solar P+ de<elo . ent in Ethio ia. In addition- districts li7e 8erti- / ololcha- Je9u and >uway-dugda fro . 4rsi >one and Shalla and 4rsi Negelle fro . w*4rsi >one are e5a . les of districts with higher otential for solar energy. Therefore- de . onstration of e5isting ones and researching on different solar coo7ing technologies is crucial wor7 of research centers to . a7e use of this large renewa0le energy resource. &e<elo ing A*injera mitad*B*Sto<e for 0iogas which was started 0y 4sella agricultural engineering research center- de<elo . ent of energy lant li7e

9atro ha rocessing technologies and efficient technology for 9atro ha oil co.0ustion are areas which need research inter<ention in near future. There are also otential s.all scale hydro ower generation units in the study area. ?or e5a. le in 4rsi >one currently it was re orted that there are se<en water .ills that can 0e used for electrical energy generation ur ose. Therefore- designing and de<elo ing a ro riate water tur0ine for these s.all scale hydro ower should 0e also one of the research area.

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Appendix

4 endi5 I' 1on<ersion factors used to esti.ate TID

Ty es of ani.als	TID
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4 endi5 II' 1on<ersion factors used to esti . ate adult eFui<alent

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