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Determinants of Households' Adoption of Improved Cook Stoves in Kilimanjaro Region, Tanzania

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Abstract: ***Despite being used in inefficient and unsustainable ways, traditional biomass remains the largest source of cooking energy in Tanzania. Improved Cook Stoves (ICS) have been proved to be among the best ways of efficient utilization of biomass, nonetheless, their adoption has been low. Limited empirical evidence exists on the reasons for low ICS adoption in Tanzania. This paper analyses factors which determine household adoption of ICS in Kilimanjaro region, Tanzania. A total of 294 households from six villages were randomly selected for the household survey, and qualitative data were collected through focus group discussions and key informant interviews. Results from a binary logistic regression revealed that awareness campaigns about ICS, quality of living house and kitchen room, awareness on the village environmental regulations and by-laws, sources of firewood and household Socio-Economic Status (SES) to be among the factors influencing the adoption of ICS. The study concludes that low adoption is attributed to limited awareness on the benefits of the stoves and a negative myth attached to the quality attributes of the household that can adopt ICS. The study recommends the organization dealing with ICS promotion to continue with comprehensive awareness campaigns and targeted intervention to households perceived to have to limit adoption characteristics***.

Keywords: Adoption, improved cook stoves, Traditional Biomass, Socio-Economic Status, Kilimanjaro,

1. Introduction

Traditional biomass has continued to be a major source of cooking energy for the majority of people living in many parts of developing countries (Rehfuess *et al*., 2014; Franco *et al.,* 2017). Despite biomass being a renewable source of energy, heavy dependence on it and use of low efficiency end-use technologies like traditional cooking stoves make it to be s a major source of indoor air pollution that lead into serious health effects (Saatkamp *et al*., 2000; Foell *et al*., 2011). Given this background, it is evident that there is a need to promote interventions that will increase efficient and sustainable utilization of traditional biomass (Maes and Verbist, 2012) that will allow the same amount of energy to be produced with less fuel and emission exposure reduction (Larson and Rosen, 2002).

The improved biomass cookstove (ICS) programme is one among old intervention aimed at addressing the world energy crises (Bailis *et al.,* 2009) by improving efficient utilization of biomass. The most current initiative is Global Alliance for Clean Cookstoves that aim at adding 100 million homes with clean and efficient stoves and fuels by 2020 through promoting large-scale adoption of clean and safe household cooking solutions. The ICS reduce the negative impacts of cooking with traditional open fires (Ruiz-Mercado *et al*., 2011) and improving the environmental quality through reducing deforestation and emission while meeting the socio-economic benefit by reducing fuel consumption, health and social drudgery associated with traditional biomass use (Rouse, 1999, Masera *et al*., 2005; Legros *et al*., 2009).

Shifting to improved cook stoves can bring significant health and environmental benefits, but only with proper and consistent use (Jürisoo *et al*., 2018). Given the current number of people who are still using traditional biomass energy and stoves it is logical to say that the global target to replace traditional cooking energy and stoves is far to be reached. It is argued that, if the current trajectory continues it is likely that 2.3 billion people will continue to use traditional cooking methods in 2030 (Global Alliance Clean Cook Stoves, 2018.). Regardless of worldwide concerted efforts to promote and disseminate ICS and multiple benefits associated with the use of ICS, the adoption rate in developing countries is still low (Global Alliance Clean Cook Stoves, 2012). Despite the limited adoption of ICS in most developing countries, the existing studies on ICS adoption and its driving factors are skewed to Asia and more specifically to India and China while few studies have been directed to Africa (Lewis and Pattanayak, 2012) and specifically Tanzania. In Tanzania, data for ICS adoption rate and its associated factors varies from one place to another. For example a study by Lusambo (2009)) reported that only 25% of households in Morogoro and Ruvuma Regions were using improved cooking stoves while Kulindwa *et al*., (2018) reported an adoption rate of between 30% and 48% in Eastern part of Tanzania. Therefore, given the continued global efforts to expand promotion for ICS there is a need to conduct empirical studies to examine set of contextualised variables to improve successful implementation of ICS program (Smeets *et al.*, 2012; Lewis and Pattanayak, 2012). This paper therefore analyses factors which determine adoption of ICS in Kilimanjaro region, Tanzania. The study provides context specific empirical information and scientific recommendations to policy makers and other stakeholders working in energy sector in Tanzania on the best way of promoting and disseminating ICS for successful results.

2. Theoretical/Conceptual Framework

Rogers Diffusion of Innovation (DOI) Theory (2003) has been extensively applied in studying adoption of innovations nevertheless the theory has received a number of criticisms. Straub, (2009) criticized the theory for being too broad and depth while Düvel, (1991) argued the theory to be weak in sense that it is missing the direct or indirect provision of all causes of behaviour change. The argument by Düvel (1991) is based on the fact that adoption and sustained use of any new idea or practices like ICS requires user's behaviour change. The users should change in terms of moving away from traditional cooking practices and social norm, and adopt alternative, modern energy practices. Therefore, Herington *et al.,* (2017) call for integration of human behavioural change determinants in studying adoption of ICS. As shown in Fig. 1, this study therefore, adopted Düvel's Model of behaviour analysis and change (1991) that focus on behavioural related factors (needs, perception and knowledge) which are refereed as intervening variables. The Düvel model (1991) focuses on an argument that low or high adoption of innovation can be traced through two major causes which are termed as willingness to adopt and ability to pay or buy an innovation. Willingness is more of an individual behavioural aspect which according to Düvel can be traced through intervening variables (need, knowledge and perception). Düvel (1991) further argues that, intervening variables are psychological constructs and are devoted intervening since they are regarded as; mediating or transmitting the effects of personal and environmental to the variable behavioural outcome, and having a causal effect on behaviour outcome.

While the Düvel model insists on behavioural related factors to be key determinants in adoption of innovation decision Abrahamse, (2007) on the other is arguing that behaviour in terms of adoption decision can be intervened through structural and psychological interventions. While structural factor address more of contextual variables which are refereed as personal and environmental factors on the other hand psychological factors addresses more of individual level variables like knowledge, perception, attitude, norms, and values. In the same line Egmond and Bruel, (2007) argued behaviour to be a product of the individual and his or her context thus proposing two approaches that are refereed to internal and external perspective in studying determinants of consumers or adopter's behaviour. While others scholars (Düvel, 1991; Annor-Frempong and Düvel, 2009; Abrahamse, 2007) are arguing the external factors to influence behaviour through internal factors (intervening variables) Egmond and Bruel, (2007) argued the external factors (personal and environmental factors) to work independently in determining consumers or adopter's behaviour. This implies that the external factors can influence adoption decision directly.

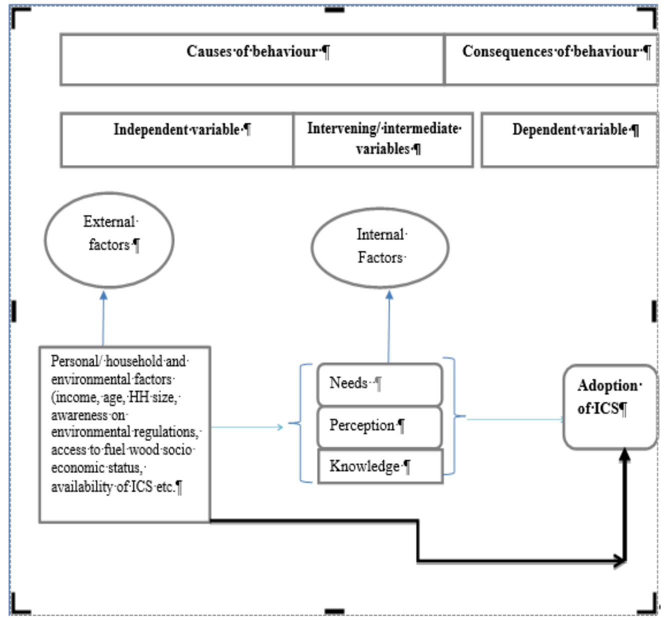

Figure 1: Conceptual framework adopted and modified from Düvel's model of behaviour analysis and change (1991)

The assumption behind the scholars who argued external factors (personal and environmental factors) to influence adoption decision indirectly through intervening variables is based on the perspective of looking at consumers as atomistic agents autonomous of social structure (Egmond and Bruel, 2007) while in reality consumers are influenced by external forces beyond their comprehension or control. Therefore, this study modified the Düvel's model of behaviour analysis and change (1991) to capture external and internal determinants of adoption behaviour. External factors which in this paper are referred to personal and environmental factors covers a wide range of variables that are beyond consumer's control. Broadly the factors can be grouped into household's specific characteristics, innovation characteristics and institutional related factors.

A number of stoves related characteristics have been reported to have influence on ICS adoption in various parts of the world. For example, stoves that decreased cooking frequencies and time spent on wood collection due to fuel consumption reduction (Gebreegziabher *et al.,* 2011), stove design that fit local cooking preferences (Bailis *et al.*, 2009; Sinton *et al*., 2004), reduce indoor pollution (Arif *et al*., 2011), stove having secondary chamber that can be used for low power cooking tasks, such as keeping food warm or heating water provides incentive for ICS adoption (Masera *et al*., 2005).

Factors like educational level of the housewife and the average educational level of the female household's members (Muneer, 2003), income, household size, (Jan *et al*., 2012); (Pine *et al*., 2011), wealthy status of household, adult women in household, involvement in communal activities (Adrianzén and Miguel, 2011), women age

(Gebreegziabher *et al.*, 2011) to be among the factors that influence adoption of ICS.

Institutions are set of behavioural rules that are responsible in governing rights to resource access, prices and accessibility (Erenstcin, 1999). According to Simon, (2006) the institutional environment provides an important set of external conditioning for the consumer's adoption decisions. Factors like information campaign were potential adopters access information about the ICS and ICS supply chain were found to significantly influencing household choice to ICS and cleaner fuel (Pattanayak and Pfaff, 2009). Some factors like stove design, quality assurance and quality control, marketing channels, financing and monitoring and evaluation are part of successful aspects for wide scale adoption (Bailis *et al.*, 2009). Remoteness of the village (Gebreegziabher *et al.*, 2011), acceptance of the stove by opinion leaders (Arif *et al.*, 2011), user participation in the cookstoves program and broader national policy context are identified as one among success factors for ICS adoption (Masera *et al.*, 2005; Pohekar *et al*., 2005). This varying list of factors influencing adoption of ICS leads to conclusion that there is no single factor which can determine adoption of ICS. Therefore, this paper, presents factors which determines adoption of ICS in Kilimanjaro region, Tanzania.

3. Methodology

3.1 Study area and data collection

The study was conducted in Rombo and Hai, Districts, Kilimanjaro Region, Tanzania. The region is among the regions where there are initiatives to promote and disseminate fuelwood efficient stoves. Kilimanjaro is among the most densely populated region in Tanzania with population density of 124 people per square kilometre. This accelerates the problem of fuelwood scarcity since people have inadequate land on which to plant trees. The region is characterised by mountains where the highest mountain Kilimanjaro is located. The percentage of households using firewood for cooking increased from 79.5 in a year 2012 to 83.8% in a year 2016 (The United Republic of Tanzania, 2017).

A total of 6 villages were involved in the study namely Shimbikati, Manda Juu, and Mamsera Juu in Rombo District while Foo, Nkuu Sinde and Nshara villages represented Hai District. The selection of the villages was based on availability of initiatives to promote and disseminated different designs of ICS. Simple random sampling technique was used to select a total of 294 households that were included in the interview. The study collected primary data through quantitative and qualitative approaches. Qualitative data were collected through 6 Focus Group Discussions (FGDs) and key informant interviews (KIIs). Group formulation was based on age category whereby in each category female and male groups were separated. The groups comprised youth, middle age and old age discussants. The aim to separate the discussants was based on the subject of study whereby views on cooking stoves were expected to differ between different age and sex categories. The FGDs were useful to trigger discussion and hence give explanations to answer some questions which could not be captured in household survey.

3.2 Data analysis

Qualitative data were organised and categorized into various themes based on each specific objective. Then the interpretation was made and used for discussion to back up quantitative results. Descriptive statistics specifically frequencies and percentages were used to show the distribution of some selected households characteristics. To establish which factors influenced adoption of ICS, binary logistic regression was employed. Binary Logistic regression was used to predict a response usually a dummy variable, using a set of predictor variables. The predicted dependent variable is a function of the probability that a particular subject will be in one of the categories. Several personal and household characteristics were involved as predictor variables to determine the likelihood of the household to adopt or not to adopt an ICS. The model and the predicators used were as follows:

Regression equation

$$\text{Ln}\,[Pi / (1\text{-}Pi)] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots\ldots\ldots + \beta_k X_k i + e \quad (1)$$

Where the subscript i means the ith observation in the sample. P is the probability that a household adopts the ICS and (1-P) is the probability that a household does not adopt an ICS

β_0 = intercept term
$\beta 1$ ------------- β_k = are the coefficients of the independent variables
e_i = error term
X_1= Attended awareness campaign on improved stoves (1= attended 0=never attended)
X_2 = Household size (total Number of people living in the household)
X_3 = Sex of household head (1 = Male headed household 0 =female headed household)
X_4 = Awareness about the village environmental regulations and by-laws (1=aware, 0 = not aware)
X_5 = Household Socio Economic Status (SES) (1= least poor, 0 = poor)
X_6 = Housing Quality (1 = Improved house, 0 = Otherwise)
X_7 = Quality of kitchen (1 = Improved kitchen room, 0= Otherwise)
X_8 = Proportion of educated people above primary school in the household
X_9 = Sources of firewood (1 = Buying, 0 = otherwise)

4 Findings and Discussion

4.1 Socio -Demographic Characteristics of Study Population

The study highlighted the distribution of some household level social and economic characteristics. As shown in Table 1, 78% had primary education and few had secondary and college education. On headship of the households, the results show that female headed households were only 19.4% while the rest were male headed households. This high percentage of male headed household can be associated with low level of adoption of ICS as men have typically control over household budget (Rehfuess *et al.*, 2014) and women are less involved in household decision making (Ringo *et al*., 2018).

As indicated in Table 1, the majority of households had between 4 and 7 members while the average size of the household was 4 members. The minimum number of household members was 1 and the maximum was 14 members. Hafner *et al.*, (2018) argued that household size has significant impact on the cooking time and fuel wood consumption regardless of the type of stoves used for cooking. Hence it is expected that households with large size will adopt ICS to reduce fuel consumption and time spent on fuel collection and cooking. Access to fuel wood resources is diminishing in the study area where only 31% of household would access firewood by collecting from their own sources or any other area while the rest were either buying or combining collection and buying. Increasing fuel wood scarcity is expected to increase ICS adoption (Barnes *et al.*, 1994) to reduce fuel wood consumption and cost to the households.

Table 1: Socio-Demographic Characteristics of respondents

Characteristics	Frequency	Percentage
Sex of households' head		
Female	57	19.4
Male	237	80.6
Household size		
1-3	124	42.1
4-7	154	52.4
>8	16	5.4
Education level		
Primary	230	78.2
Secondary	27	9.2
College	12	4.1
Adult education	1	0.3
No education	24	8.2
Main sources of cooking fuels		
Collecting	91	31.0
Buying	101	34.3
Both (Collecting and Buying)	102	34.7

Findings in Table 2, show that on housing characteristics, majority had good houses with concrete/ block wall material (70.7%) and covered with iron sheet roofs (95.9%), but with limited concrete floor.

Quality of kitchen room was identified as one of the factors that influence adoption of ICS in FGDs. The community members in the study area perceive quality or good kitchen to be the one that has concrete wall and covered with iron sheet. This was common perception for adoption and installation of improved stoves with chimneys which are made of concrete cement and fixed in the kitchen. This design of the ICS was considered to be of high quality hence needed to be installed in permanent kitchen. The findings show that most of the kitchen rooms had iron sheet covers (88.4%) but with low quality wall and floor. This was also reported by Rwiza, (2009) that the respondents would expect to have a better kitchen before installation of the stove.

Table 2. Housing and kitchen characteristics

Characteristics	Frequency	Percentage
Main House condition		
Floor material		
Earth floor	196	66.7
Concrete	72	24.4
Wooden	26	88
Roof materials		
Thatch	12	4.1
Iron sheet roof	282	95.9
Wall material		
Poles	49	16.7
Wooden	37	12.5
Block/Concrete	208	70.7
Connection to grid electricity		
Yes	119	40.5
No	175	59.5
Quality of the kitchen room		
Roof materials		
Iron sheet	260	88.4
Thatch	29	9.9
Timber	3	1.0
Open	2	0.7
Wall materials		
Mud and poles	101	34.4
Burnt/bloc bricks	84	28.5
Wooden	71	24.1
Others	38	13.0
Floor materials		
Earth	215	73.1
Concrete	79	26.9

4.2 Determinants of adoption of improved cook stoves

Binary logistic regression was performed to examine the impact of various factors on the chances of ICS adoption. The model contained 9 independent variables (Table 3). The full model containing all the predictors were statistically significant, χ^2 (9, n = 291) = 126.35, $p < 0.001$, indicating that the model was able to distinguish between respondents who reported to have adopted and those who reported not to have adopted ICS. The model as a whole explained between 35.2% (Cox and Snell R^2) and 51.4% (Nagelkerke R^2) of the variance in adoption status, and correctly classified 73.5% of cases. As shown in Table 2, six of independent variables had statistically significant impact on the chances of ICS adoption.

The strongest predictor was attendance to awareness campaigns about efficient stoves. The variable had a Wald value of 50.782 and an odds ratio of 26.07 implying that households reported to have chances to attend awareness campaigns from organization dealing with ICS promotion were more than 26 times likely to adopt an ICS. This implies that attendance to awareness campaigns improve potential consumer's awareness and knowledge about the ICS in general. Therefore, people will be able to make informed decision to adopt or not to adopt an ICS. The study by Massawe *et al.*, (2015) found most of non ICS adopters to have limited knowledge on ICS benefits and various technical aspects associated with ICS proper use. Therefore, there is a need to create more awareness on the benefits of ICS to increase its adoption.

Sources of firewood for household cooking and heating needs were the second predictor variable influencing adoption of ICS. The variable had a Wald value of 15.612 and an odds ratio of 4.336 implying that the households which reported to exclusively depend on buying firewood were more than 4 times likely to adopt ICS than those collecting or combing collection and buying. The implication is that the cost paid for firewood triggers the household to be innovative and look for alternative technology which can reduce fuel consumption. This was also report by Jan (2012) in a study which was conducted in Northwest Sudan where it was found that households which were not collecting biomass were more likely to adopt improved stoves.

Table 3: Determinants of adoption of ICS (n = 294)

Factors	B	S.E.	Wald	Sig.	Exp (B)
Attended awareness campaign on efficient stoves	3.261	.458	50.782	.000	26.068
Household size	.028	.094	.091	.763	1.029
Quality living house	-1.372	.443	9.590	.002	.254
Sex household head	-.265	.435	.373	.541	.767
Quality kitchen room	.980	.385	6.491	.011	2.664
Awareness on environmental bylaws	.885	.411	4.644	.031	2.424
Household socio Economic status	.886	.416	4.525	.033	2.425
Ratio of educated people above primary school in the household	.189	.596	.101	.751	1.209
Sources of firewood	1.467	.371	15.612	.000	4.336
Constant	-3.095	.821	14.225	.000	.045

The results further show that the quality housing in terms of its construction material was the third predictor and negatively influencing adoption of ICS with Wald value of 9.6 and odds ratio of 0.254. The implication is that the household perceived themselves to have poor living houses were less than 0.26 likely to report having adopted an ICS than their counterparts. This is attributed to the fact that ICS has been classified as a high status quo asset, which implies that owning it is associated with higher socio economic status. It is reported by (Massawe and Bengesi, 2017) that ICS is adopted by households with a minimum level of ownership of valuable assets and owners of high standard houses. Similar finding is reported by Masera *et al.*, (2005) that once an household adopts improved cook stoves it is seen as household ‘‘assets’’ and prompt new positive changes within households.

During FGD in most of villages, it was reported that it is shameful for someone to have an executive stove while not having a good house or kitchen. This finding was supported by FGD participants in Nshara village where, when they were asked on what are the limiting factors for installation of ICS or Okoa stove as known by the majority.

> *Many people in our village have a plan to construct OKOA stove, but there are several challenges facing the majority of us. ....one is the types of living houses and kitchens we are owning. It is shame to have such a good stove in a very poor house or a very poor kitchen.*
> *….. it is possible for other stoves like OKOA without chimney (Dr. Mwasha stove) which are movable, but not for the fixed stove with a chimney.*
> (Male and female FGD- Nshara Village)

The response from FGD is in line with the findings from binary logistic regression which revealed that quality of kitchen to be among the statistically significant variables for ICS adoption as indicated in Table 3; the variable had a (Wald = 6.491and B (Exp) value = 2.664). The result implies that the household that perceived their kitchen to be of good quality were more than 2 times likely to adopt an ICS compared to their counterparts. This was common for the improved stove with chimney that demand use of cement and permanently fixed in the kitchen. The ICS with chimney was considered to be a high quality asset, which implies that household perceiving their kitchens to be of good quality would prefer having ICS installed in their kitchen rooms. In addition, the model of stove does not allow the household to transfer it in case of shifting of the cooking place. This is attributed to the fact that the stove is not portable; hence it makes the household to be sure that the kitchen they had were of satisfactory quality and could serve the families for some years.

Other studies reported that many households prefer to build new kitchen or modified the existing one before installation of the stove (Barnes *et al*., 1994; Rwiza, 2009). This was attributed to the lack of awareness, knowledge and negative perception about ICS as some adopters were found to have stoves constructed outside the main kitchen room with a simple shade. Similar findings have been documented by Ramirez *et al.,* (2012); Massawe *et al*., (2014) on the negative perception about ICS being associated with low adoption decision behaviour. Obviously, there is a need for more awareness and knowledge creation to the potential adopters on possibility to construct a stove in open spaces even in old kitchens perceived to be poor. This can be well done by stove technicians who are located in different villages.

Awareness of various village environmental regulations and by-laws had recorded a Wald value of 4.64 and an odds ratio of 0.031 indicating that the households which were not aware were less than 0.031 times likely to adopt an ICS than the ones who were aware. The villages were found to be guided by various bylaws and regulations regarding access and use of environmental goods and services. For example, individuals are not allowed to cut trees from their own farm or wood lots without having a prior permit from the village government. This has been claimed to be one among the bylaws affecting availability and access to firewood. This increases the scarcity of fuel wood and more specifically firewood which is the major source of cooking energy in the study area. In the past people were free to cut down their own trees and use them in whatever ways they wanted which was acknowledged to ensure access to firewood but negatively affected resources availability and sustainability. In addition, the restrictions by conservation authorities have now limited access to forestry resources including regular collection of firewood. In some way the bylaws influence people to look for more energy efficient cooking stoves to minimize firewood consumption. This calls for more awareness on future scarcity of fuel wood and the benefits of ICS in reducing stress on fuel wood consumption and general environmental conservation. This can easily be done through village environmental committees and other stakeholders within the villages.

Household's Socio Economic Status (SES) was found to be among determinants of ICS adoption. The variable had an odds ratio of 2.425 implying that the household which were categorized as least poor were 2 times more likely to report having adopted an ICS than poor households. The finding is similar with what was reported by Silk *et al*., (2012) in Kenya that two-thirds of ICS famously known as *upesi jiko* installations were concentrated among households with two highest quintiles of socioeconomic status (i.e. least poor). Since in this assets owned were regarded as a proxy indicator for socio economic status the results imply that ICS is classified to be among the household assets than just being an energy efficient device. This corroborate findings on quality of kitchen and living house since the potential consumers consider moving up the socio economic status ladder by acquiring basic assets before making decision to install ICS.

5.0 Conclusions and Recommendations

The study revealed both institutional and households related factors to influence ICS adoption. The institutional factors can easily be manipulated while the households related factors provide room for the targeted intervention. To increase ICS adoption, awareness campaign about the stoves should continue. In addition, there is a need to increase community awareness about by-laws that govern access and use of environmental services and their implications for future access to environmental services and goods. On household specific characteristics like living house conditions, quality of kitchen creates room for more targeted intervention to the households with those specific characteristics. These are more of perceived quality attributes attached to the stove which in one way or another delay the pace of ICS diffusion. Together with target intervention to these households there is a need to increase awareness and knowledge to potential adopters on the importance of ICS and its flexibility to be installed in any house without taking much concern of the quality. This will remove the myth that ICS fits the household with good houses, good kitchens and higher SES hence increase a mass of adopters and ultimately reviving the adoption. The study recommends more comprehensive awareness creation on benefits of stoves from organization dealing with promotion of ICS.

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