Status and Prospect of Clean Cookstoves in Terai Region of Nepal

Hari Bahadur Darlami, Suvita Jha, Bishnu Kumari Budha

***Abstract*— Energy for cooking is the basic requirement for human society. Type of fuel and its technology keeps importance socially, economically and environmentally. In Terai region of Nepal, diversified fuel is used and most of people are using biomass based fuel in traditional cookstove. In Terai Disticts, Traditional cookstove (TCS), Improved Cookstove (ICS), Rocket stove, Biogas stove, Kerosene stove, LPG stove and induction stove user households have been found 1,600,000; 37,000, 6,000, 90,000; 17,000; 1,107,000 and 12,000 respectively. Grid connection, biogas potential and fuelwood available households have been found 89.6%, 44% and 45% respectively. Total potential ICS, biogas and induction stove promotion potential have been found 679,8400; 249,750 and 536,390 respectively. Most of people are using biomass based cookstove in traditional cooking device which can be replaced by as per their capacity and plan and policies of government sector.**

Keywords: Traditional cookstove, Improved cookstove, biogas, induction cookstove

I. INTRODUCTION

It is estimated from the historical evidences that fire has been used for cooking of meals for about 100,000 years [1]. About 2.6 billion people do not have access to clean cooking facilities; and if predictions are believed the approximately same number will still be so in 2030 [2]. Pollutants emitted from cookstoves cause serious indoor air pollution and have a negative impact on health of people. [3]. About half the people across the world use different types of biomass fuels, to cook a large number of dishes in diverse ways. [4]. The heavy dependency on traditional biomass technology has caused the social burden on majority women and children [5]. About 1.6 million people have premature death per year from indoor air pollution [6]. Venkataraman et al. found that solid biofuel combustion is the dominant source of global black carbon emissions [7]. Linkages between household energy technology, indoor air pollution, and greenhouse gas (GHG) emissions have become increasingly important in understanding the local and global environmental and health effects of domestic energy use [8].

Biomass is a renewable source of energy, traditional biomass stoves cause significant greenhouse gas (GHG) emissions due to formation of products of incomplete combustion; also, exposure to smoke and causes serious health problems [9]. The national policies should be in the favor of cheap and efficient cookstove availability to biomass using families [10]. Sheela Pradhan, (2006) has studied on impact of improved cooking stove on rural livelihood and found that two pot hole improved cookstove is highly accepted in the rural area where fuelwood is available [11]. Multiple cooking fuels are used in nearly all households, although wood is the dominant fuel source. [12].

More than 50% population of Nepal are staying in Terai region, southern part of Nepal [13]. With the low availability of firewood mostly direct burning of animal dung cakes (dried cattle dung: Guintha) and/or burning of agricultural residues and remains (leaves, stems and foliage) of trees and shrubs as fuel for cooking are using by low income people [14]. “Animal Dung Cake” is considered to be the most polluting fuel for cooking and it is the cause of destruction of high quality fertilizer. Usually, it is used by the poorest of the poor people. The dung cakes are produced at the household level and burnt in traditional open fires or mud stoves, resulting emission of hundreds of health hazards pollutants to which women and young children are exposed on a daily basis [15] . In Nepal, traditional energy sources have the highest share accounting 299.7 million GJ in the national energy demand and into this fuel-wood has the major contribution [16].

The share of rural population in Nepal is 87% [17]. More than 431 thousands household biogas plants, above 1,434 thousands Improved Cook Stoves and more than 2 thousand solar cookers/dryers across the country have been installed [14]. About 77% of energy consumption of Nepal is supplied by traditional biomass energy technologies and most of energy consumed in the domestic sector for cooking purpose [18]. Alternative Energy Promotion Center (AEPC) has policies for supporting to buy clean cooking device and developed the delivery mechanism [19].

There are several options to improve this precarious situation, like use of induction electric cook stoves where there is sufficient electricity availability with suitable infrastructure, biogas technology, replacement of direct burning of dung with biomass briquettes, use of stoves that aid in better fuel combustion, etc. However, acceptance of any particular stove or energy technology for that matter depends on various aspects like availability and price of fuel, socio-cultural and ethnic values and practices, geographic and climatic conditions, cooking behaviors and practices, kitchen design and management, economic status

Hari Bahadur Darlami, Department of Mechanical Engineering, Institute of Engineering, Pulchowk Campus, Tribhuvan University, Lalitpur, Nepal.

Suvita Jha, Kathfort International College of Engineering, Tribhuvan University, Lalitpur, Nepal.

Bishnu Kumari Budha, National Basic School, Kathmandu, Nepal

etc. Thus, the developing nations have to think about different strategies and method to meet their requirement by utilizing the renewable energy sources available in their geographical area [20].

Hierarchy of cooking device starts form use of traditional cookstove using biofuel and use of induction stove at highest level of clean cooking solution shown in Figure 1.

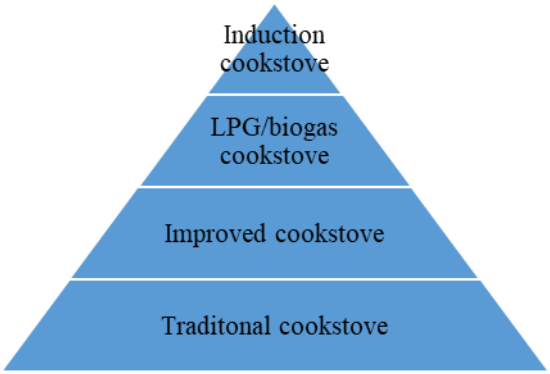

Figure 1: Hierchy of cookstove

The main purpose of this study is to prepare in-detail baseline status of local levels so as to promote higher hierarchy of cooking fuel and technology in Terai Districts of Nepal with integrating life style, living standard of people, local level and government plan and policies.

II. METHODOLOGY

The secondary data have been collected for all the 284 Local Levels of 22 Terai districts through various sources. Then, each and every local levels were contacted through phone and email to inform them about the basic concept of the study. The field visit was conducted in each local levels for data collection and organized focal group meeting. During the focal group meeting, cooking technology, available resources, technologies and institutions working in clean cooking sector, suitability of tier-3 and above clean cooking solutions, gap between demand & supply, annual physical targets of clean cooking solutions for the district were discussed. The filled up questionnaire with collected data was mailed to the local level for the cross checking. The final data obtained from the local levels were validated using secondary information from various sources like Central Bureau of Statistics, Nepal Electricity Authority, and Alternative Energy Promotion Center etc. The shift towards clean cooking has been planned based on data and focal group discussion with respective local levels. Finally, plan for local level has made with the consideration of available resource and discussion with local levels during the field visit.

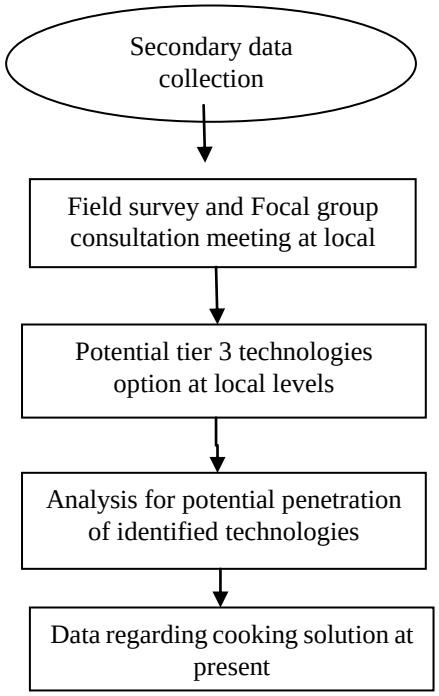

Figure 2: Field visit plan

Following assumptions and limitations has been taken for the analysis are as follows

- This study is based on information from focus group discussions and data provided by local levels.
- Case study and sampling has not taken
- Due to multiple fuel user, total cooking technology user household is more than actual household.

III. RESULTS AND DISCUSSIONS

Assessment of energy resources and current status of cooking device has been taken. Then based on current status, potential resources and plan of local and government level, promotion plan has been developed.

A. Assessment of energy resources

Assessment of availability of energy resources is one of the important factor for the promotion of technology. In the Terai region, main potential energy resource for cooking are grid electricity, fuelwood and biogas. Now most of the people are using imported LPG for cooking purpose.

Table 1: Availability of energy resources

(In '000)

S.N.	District	Households			
		Nos.	Grid cone-cted	Biogas potential	Fuel wood potential
1.	Jhapa	205	198	123	99
2.	Morang	218	208	96	78
3.	Sunsari	168	165	73	44

S.N.	District	Households			
		Nos.	Grid cone-cted	Biogas potential	Fuel wood potential
4.	Udaypur	69	46	51	32
5.	Siraha	126	115	54	67
6.	Saptari	128	124	63	61
7.	Dhanusha	138	125	58	62
8.	Bara	112	99	35	50
9.	Parsa	326	289	94	143
10.	Rautahat	117	103	48	46
11.	Sarlahi	142	126	82	54
12.	Mahottari	114	103	58	42
13.	Chitwan	136	123	46	52
14.	Banke	102	81	35	56
15.	Bardiya	96	84	47	66
16.	Dang	123	97	66	72
17.	Kapilvastu	94	81	45	60
18.	Rupandehi	180	169	59	43
19.	Nawalpur	73	62	29	45
20.	Parasi	67	63	19	23
21.	Kanchanpur	89	73	53	55
22.	Kailali	158	132	76	96
Total		2,979	2,667	1,310	1,346

Table 1 shows that grid connected households in the Tarai Districts has been found lowest 67% in Udayapur district to highest 98% in Sunsari District. Average grid connected households in Terai Districts has been found 90%. Similarly, biogas potential has been found lowest in Parasi District 28% and highest in Jhapa Distircts 60%. Average biogas potential household has been found 44%. Similarly, Rupandehi has lowest fuelwood resources 24% and highest 68% in Bardiya District. Average fuelwood potential has been found 45% in the Terai districts. On the basis of resource point of view, improved cookstove technology can be promoted, biogas plants can be installed, and induction stove can be promoted with supporting by local level.

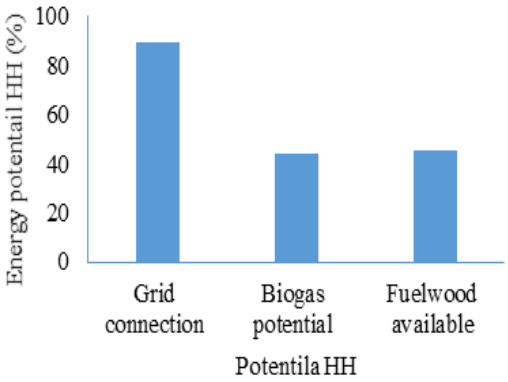

Figure 1: Energy potential households

While looking cooking energy resoruces, most of people have grid connection. Grid electricity is used lighting and domestic applications. But still people are lagging to use elctricity for cooking purpose. There are few reasons behind it (a) low econimic status of user (b) low size of the meter and conductor (c) low voltage, unreliability of electricity (d) practice, lack of awareness and unavailable of induction stove and accessories. Specially, very poor people are using loose biomass and dung cake. Biogas has great potential in Terai Districts. Most of family have small land, involving for farming and cultivation. Climatic condition for biogas production also but biogas is not promoting in Terai because of (a) lack of biogas companies in the Terai region (b) lack of awareness (c) low focal by local bodies and government institutions. Poor people have potential but they don't have capacity to construct biogas plant and the other hand higher level family are using LPG. Middle family are installing biogas plants. Very few people are using induction stove and now it is growing trend.

B. Status of Cooking Solution

Status of fuel used for cooking purpose and installed cooking technology keeps importance to access the social status, use of local resources and to develop the plan and policies for renewable energy technology development in the local level. Current status of cooking fuel and technology in Terai region has been accessed by collecting data from local level and other secondary sources of information.

Table 2: Current status of cooking solution in Terai Districts

(In '000)

S. N.	District	TCS	ICS	Rocket stove	Biogas plant	Kerosene	LPG	Induction stove	other
1.	Jhapa	100.82	3.43	0.77	13.21	0.03	103.57	1.41	
2.	Morang	103.77	0.62	1.76	7.97	0.46	08.73	0.12	
3.	Sunsari	74.09	0.75	1.33	2.39	0.27	91.24	6.53	
4.	Udaypur	42.89	1.99	0.04	1.82		23.11		

5.	Siraha	79.46	4.04	0.04	1.63	0.15	56.55	0.50	
6.	Saptari	89.47	1.13	-	1.85	0.26	39.65	0.82	
7.	Dhanusha	96.20			0.14	0.16	42.29	0.12	
8.	Bara	80.49	2.41	0.20	0.77	1.39	24.77	0.20	2.03
9.	Parsa	69.54	0.91	0.04	0.29	0.59	36.72	0.45	0.28
10.	Rautahat	90.77	0.10		1.44	0.81	24.94	0.05	1.39
11.	Sarlahi	101.42	1.29	0.51	1.03	2.28	40.34	0.05	0.31
12.	Mahottari	77.51	0.53	0.06	0.33	0.30	32.82	0.03	2.84
13	Chitwan	27.24	1.22	0.30	9.25	0.73	104.90	0.19	0.05
14.	Banke	57			1.77	0.23	42.37	0.24	0.18
15.	Bardiya	69.46	1.51		8.26	0.16	18.80	0.15	0.02
16.	Dang	75.69	2.63		4.75	3.42	41.29	0.23	0.20
17.	Kapilvastu	68.93	0.33		3.21	0.49	20.94	0.02	0.20
18.	Rupandehi	66.71	4.30	0.47	4.81	5.00	106.70	0.23	
19.	Nawalpur	34.64	3.16	0.23	3.47	0.12	36.06	0.04	
20.	Parasi	36.17	1.08	0.09	1.73	0.14	28.25		
21.	Kanchanpur	53.82	3.50		8.01	0.07	37.79	0.05	
22.	Kailali	104.06	2.42		11.86	0.18	45.19	0.21	
Total		1,600	37	6	90	17	1,107	12	8

Overall 1,600,000 households still use TCS as their primary source of cooking in 284 local levels of 22 districts of Terai region of Nepal. The maximum TCS users has been found in Kailai District (104,000) and minimum in Chitwan District (27,200). Similarly, maximum and minimum LPG user have been found in Morang (108,700) and Bardiya (18,800) respectively. The cleaner cookstove such as ICS, Rocket and biogas which are cleaner technology is generally available in the northern part of Terai. ICS and Rocket stove user has been found 37,000 and 6,000 respectively. Total biogas plant user has been found 90,000 in Terai Districts. They are heavy dependent in imported fuel such as Kerosene and LPG by using 17,000 and 1,157,000 households respectively. Very few people are using induction stove in Terai Districts and now in increasing trend. Overall, 1,600,000 households still use TCS as their primary source of cooking in 284 local levels of 22 districts of Terai region of Nepal. The maximum TCS users has been found in Kailai District (104,000) and minimum in Chitwan District (27,200). Similarly, maximum and minimum LPG user have been found in Morang (108,700) and Bardiya (18,800) respectively. The cleaner cookstove such as ICS, Rocket and biogas which are cleaner technology is generally available in the northern part of Terai. ICS and Rocket stove user has been found 37,000 and 6,000 respectively. Total biogas plant user has been found 90,000 in Terai Districts. They are heavy dependent in imported fuel such as Kerosene and LPG by using 17,000 and 1,157,000 households respectively.

Very few people are using induction stove in Terai Districts and now in increasing trend. Looking at the specific cookstoves within Terai districs, LPG stove is the most commonly used modern cooking solution. As for the traditional cooking solutions, traditional self-built stoves with a variety of basic fuels, namely fuelwood, dry dung and crop residue is still very common in Morang District.

Considering the very high share of households currently using traditional cookstoves, a transition towards ICS could result in great potential benefits. Most of the people are using biomass based fuelwood for cooking. In Terai Districts, about 74% people are using biomass based fuel and while seeing its resources only 45% people have access to fuelwood so most of family are using loose biomass and dung cake for cooking purpose.

The penetration potential of clean cooking solutions appears to be large in Terai Districts. Increasing the use of improved cookstoves and biogas plants as the primary cooking solution among households that currently use self-built traditional stoves, in particular, appears to be the most feasible and reasonable target in the nearer term.

Households owning at least one cattle and having sufficient space to install biogas plants can benefit largely from the biogas plants. Analyzing the current cooking status along with available resources, the awareness level of people, lifestyle, willingness to pay and the interest of the concerned Local Levels, a plan to shift to tier-3 and above has been developed and presented in Table 3.

Table 3: Plan to shift to teir-3 and above technologies of local levels of Terai Distrcts

(In '000)

S.N.	District	To ICS	To biogas	Induction	
		From TCS	ICS/ ICS	ICS/ ICS	From LPG
1.	Jhapa	48.19	27.23	9.17	42.26
2.	Morang	37.08	26.24	7.02	57.07
3.	Sunsari	39.79	9.26	8.01	49.89
4.	Udaypur	26.24	11.70	1.47	8.04
5	Siraha	35.94	8.90	5.88	15.76
6.	Saptari	25.34	16.45	3.51	10.41
7.	Dhanusha	33.57	18.07	4.44	13.65
8.	Bara	29.26	7.00	5.10	5.57
9.	Parsa	28.36	5.12	5.69	10.45
10.	Rautahat	40.55	14.34	7.42	8.16
11.	Sarlahi	36.71	15.65	10.05	12.88
12.	Mahottari	25.81	11.35	6.64	10.36
13.	Chitwan	6.66	3.57	3.53	21.31
14.	Banke	30.58	6.63	4.10	21.40
15.	Bardiya	42.36	12.33	5.95	6.12
16.	Dang	39.46	10.65	9.69	20.99
17.	Kapilvastu	26.41	9.88	9.88	6.15
18.	Rupandehi	24.79	7.73	11.95	29.71
19.	Nawalpur	12.12	3.08	8.04	10.77
20.	Parasi	10.42	3.74	3.39	8.61
21.	Kanchanpur	23.54	6.23	4.22	14.52
22.	Kailali	56.64	14.63	4.50	12.52
Total		679.84	249.75	139.67	396.62

On the basis of availabe resources, and plan of the local level plan, Chitwan has lowest potential of 6,500 to replace TCS by ICS and Parasa has highest potential of 86,000. The potential shift from traditional cookstove toward improved cookstove in Terai has been found 738,000.

Biogas is more cleaner fuel. Middle level can afford for biogas technology. It costs around NPR 70,000 and there is government subsidy for biogs construction. In Chitawan, Nawalpur and Parasi there is 3,000 biogas installation possibility in each disrtics from TCS to biogas. Jhapa and Morang have around 25000 biogas can be installed by replacing biomass based cookstove which is highest among the Terai. The potential shift from biomass cookstove toward biogas has been found 263,760 in Terai.

The shift of TCS/ICS towards induction in higher range disrtics of Parsa, Sarlahi and Rupandehi can be promoted above 10,000. In most of the disrtics, transiton possibility from TCS/ICS to induction stove is very low. This is due to poor economic status of people. on the other hand, most of the Terai peole use LPG. There is high possibility towards the shift of induction stove from LPG. Udaypur, Bara, Rautahat, Bardiya, Kapilvastu, Parasi have lower potential district to shift towards induction stove from LPG. These disrtict less then 10,000 induction cookstove can be promoted by replacing LPG. In morang more than 50,000 LPG can be replaced by induction. About 407,000 induction stove can be used by replacing LPG in toral Terai.

IV. CONCLUSIONS

- In Terai Districts, grid connected, biogas potential and fuelwood available households have been found 89.6% , 44% and 45% respectively.
- Maximum national grid connected household is 98% in Sunsari District and minimum 67% in Udayapur District
- Biogas potential has been found maximum in Udayapur District and minimum in Parsa District with 74% and 24% respectively.
- Current status of TCS, ICS, Rocket stove, Biogas stove, Kerosene stove, LPG stove and induction stove have been found 1,600,000; 37,000, 6,000, 90,000; 17,000; 1,107,000 and 12,000 households respectively.
- Total potential ICS promotion by replacing TCS has been found 679,8400.

- Biogas promotion potential by replacing ICS/TCS has been found 249,750.
- Similarly, Induction promotion potential by replacing ICS/TCS and LPG have been found 139,670 and 396,620 respectively.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support from Alternative Energy Promotion Center, Mid Baneshwor, Kathamdnu for their continuous support. Finally, we would like to thank the editor and all reviewers for their helpful and incisive comments.

REFERENCES

[1] J. Bronowski, *The Ascent of Man*. Little, Brown & Company, 1973.

[2] IEA, "International Energy Agency. World Energy Outlook 2012-Executive Summary. France, November 2012. ⟨ http://www.iea.org/publications/freepublications/publication/English.pdf⟩ ," 2012.

[3] A. Warwick, H. and Doig, "Smoke: the Killer in the Kitchen, Indoor Air Pollution in Developing Countries, ITDG Publishing, London.," 2004.

[4] M. P. Kshirsagar and V. R. Kalamkar, "A comprehensive review on biomass cookstoves and a systematic approach for modern cookstove design," *Renew. Sustain. Energy Rev.*, vol. 30, pp. 580–603, 2014, doi: 10.1016/j.rser.2013.10.039.

[5] S. Joshi, "ocio-economic impact of solar home system on the rural people of Nepal:A case study of Dhading District. An Unpublished Dissertation on Central Department of Rural Development.," *S*, 2010.

[6] M. A. Haines A, McMichael AJ, Smith KR, Roberts I, Woodcock J, "Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. Lancet 2009;374(9707): 2104–14, http://dx.doi.org/10.1016/S0140-6736(09)61759-1," 2014.

[7] F. S. Venkataraman C, Habib G, Eiguren-Fernandez A, Miguel AH, "Residential biofuels in south Asia: carbonaceous aerosol emissions and climate impacts. Science 2005;307(5714):1454–6, http://dx.doi.org/10.1126/ science.1104359.," 2005.

[8] D. M. Kammen, R. Bailis, and E. Kituyi, "Greenhouse Gas and Particulate Emissions and Impacts from Cooking Technologies in Africa Greenhouse Gas Implications of Household Energy Technology in Kenya," no. December, 2003.

[9] S. C. Bhattacharya and P. Abdul Salam, "Low greenhouse gas biomass options for cooking in the developing countries," *Biomass and Bioenergy*, vol. 22, no. 4, pp. 305–317, 2002, doi: 10.1016/S0961-9534(02)00008-9.

[10] Manoj Kumar, Sachin Kumar, and S. K. Tyagi, "Design, development and technological advancement in the biomass cookstoves: A review," *Renew. Sustain. Energy Rev.*, vol. 26, pp. 265–285, 2013, doi: 10.1016/j.rser.2013.05.010.

[11] S. Pradhan, "No Title," *Impact ICS Rural livelihood A case study Siwalik Area Chulachuli VDC Ilam Dist.*, 2006.

[12] M. A. Johnson *et al.*, "Impacts on household fuel consumption from biomass stove programs in India, Nepal, and Peru," *Energy Sustain. Dev.*, vol. 17, no. 5, pp. 403–411, 2013, doi: 10.1016/j.esd.2013.04.004.

[13] CBS, "Central Bureo of Statistics," 2011.

[14] AEPC, "No Title," 2019, [Online]. Available: https://www.aepc.gov.np/improved-cooking-stoves.

[15] P. G. R. Dralami, Hari Bahadur; Ale, Bhakta Bahadur, "Assessment and optimization of thermal efficiency of two pot raised mud improved cookstove with variation of different parameters," *J. Eng. Appl. Sci.*, 2018.

[16] WECS, "Energy Situation and Supply Conditon of Nepal," *Water Energy Comm. Secreteriate*, 2014.

[17] WECS, *Energy sector synopsis report, Water and Energy Commission Secreteriate, Governmnet Nepal, Simhadarbar, Kathmandu, Nepal*. 2012.

[18] N. Bhattarai and S. Risal, "Barrier for Implementation of Improved Cook Stove Program in Nepal," *J. Inst. Eng.*, vol. 7, no. 1, pp. 116–120, 1970, doi: 10.3126/jie.v7i1.2069.

[19] AEPC, "Renewable energy hand book. Lalitpur: Alternative Energy Promotion Center.," 2010.

[20] WECS, "Energy Sector Synopsis Report; Perspective Energy Plan," 1994.

Hari Bahadur Darlami works at Tribhuvan University Institute of Engineering, Pulchowk Campus, Lalitpur. He has involvement in energy sector since 15 years. He is working in mechanization of agriculture sector. He has more than 20 publications.

Suvita Jha works at Kathford International College of Engineering and Management, Tribhuvan University, Nepal since 10 years. She is doing reaserach and development in economic analysis. She has more than 20 publications.

Bhishnu Kumari Budha woks at National Basic School, Kathmandu, Nepal. She is involving for socio economic analysis. She has more than 10 publications.