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How Can the Rural Energy Poor Obtain Appropriate Sustainable Energy Technologies?

Michael Waggoner*

ABSTRACT

Solutions to a current serious problem for the rural energy poor might best be found at least in part in older practices.

The problem comes from cooking over open fires, impairing the health of the cook and of others in her family, using fuel so inefficiently as to threaten forests, and releasing soot that contributes to global warming. Small, cheap, reliable cooking stoves could address these issues, improving health by reducing smoke and exhausting it through a chimney and thus away from the cook, using fuel more efficiently so that less needs to be gathered, and more completely burning the fuel so that less soot is released.

Older practices may most effectively put such stoves into the hands of the rural energy poor: Traveling merchants once sold small tools in rural areas. More recently they have sold cellular phones, and now they can sell the stoves. They might also sell water filters and other small appliances, reducing costs by spreading them over more products. A problem here is that many developing nation governments are bureaucratic, unfriendly to business, or even corrupt, and these barriers to commerce hurt the energy poor. Reforming markets and politics, while of course important to people in business, is also important to those needing better access to energy.

The U.S. has a long tradition of county agricultural extension agents serving as a bridge between farms and ranches, on the one hand, and agricultural universities on the other. The agricultural universities are in

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touch with industries serving agriculture such as those selling fertilizer, pesticides, seed, and tractors. The agent transmits information both ways, telling the colleges and thus industry of problems on the farms and telling the farmers of new solutions. This model would be useful in transmitting the new technology of the efficient stoves, providing a neutral alternative to the self-interested traveling merchants. These agents might be hired from among the well-educated people in the developing nations who at present are finding it difficult to obtain suitable employment.

INTRODUCTION

One should separate urban areas from rural areas when addressing the problem of getting appropriate sustainable energy technologies ("ASETs") to the energy poor. Rural as well as urban areas need to develop and to deploy ASETs, both to provide the energy needed for improved standards of living and to minimize greenhouse gas emissions. For urban areas, large-scale projects such as wind or solar farms, biomass- or nuclear-fueled thermal electric generators, or geothermal may be most appropriate. These technologies are being developed.¹ They may be deployed because the dense populations of urban areas make such projects practical, and current low interest rates, when added to subsidies and tax credits, make constructing such projects affordable. Governments and large corporations may be required to raise the capital and to provide the organization needed for such projects. For rural areas, however, it may be appropriate to develop different technologies and to deploy them in different ways, using social and economic institutions different from those used in urban areas.

The article examines two traditional institutions appropriate for the deployment of the new technologies of ASETs in rural areas, institutions that should also help with the improvement of the ASETs technologies. The first institution is the peddler or traveling salesperson; the second is the local agricultural extension agent. The ASET in focus will be primarily the cooking stove, although the analysis will also apply to similar small-scale and inexpensive ASETs such as water filters, irrigation pumps, etc. Some of these ASETs may also be appropriate in energy-poor urban areas, where cooking may be done over small fires and where the water may be unsafe to drink, but the focus will be on the rural energy poor.

1. See, e.g., Larry Greenemeier, *Winds of Change Blow Renewable Energy Across Latin America*, SCI. AM., July 2, 2010, available at <http://www.scientificamerican.com/article.cfm?id=wind-power-colombia-guajira>.

COOKING PROBLEMS

Let us begin with a major problem of the rural energy poor: cooking. Most of the rural energy poor cook with biomass such as wood or dried animal dung. So long as new biomass grows as fast as old biomass is burned—and unfortunately, this too often is not the case—such cooking contributes nothing to the excess of carbon dioxide (“CO₂”) that threatens our planet with climate change or global warming. Biomass cooking nonetheless imposes very great costs. Cooking over an open fire exposes the cook to inhalation of the products of incomplete combustion. Breathing this harmful air is a leading cause of premature death among the rural energy poor, ranking only slightly behind bad water² and HIV/AIDS.³ Furthermore, the cook, often a wife and mother, may carry her children or keep them close as part of her mothering duties, thus also exposing them to the unhealthy air.

Open-air cooking imposes additional costs beyond its harm to the health of those doing the cooking and others nearby. Open fires use fuel inefficiently, so they require large quantities of fuel,⁴ which means that the rural poor must gather more wood. This gathering risks destruction of nearby forests, which are important to the local community. Forests provide wood, fiber, and food and are important parts of the ecosystem. They also protect against soil erosion and help to average out the water resources by storing rain and snowmelt in the root systems so water will be available in drier seasons.⁵ As nearby forests are cut, fuel gatherers must go farther in search of fuel, distracting them from education and other economically productive activities, and sometimes exposing them to risks from human and animal predators.

Cooking with biomass fuels need not contribute to net CO₂

2. Sabaleel Nandy, Gen. Manager, Water Purifier Bus., Tata Chem. Ltd., Story of the Swach Water Filter, Presentation at the University of Colorado Law School Energy Justice Conference (Nov. 5, 2010), available at <http://lawweb.colorado.edu/events/mediaDetails.jsp?id=3000>.

3. Lupita Motoya & Christian L’Orange, Cooking, Presentation at the University of Colorado Law School Energy Justice Conference (Nov. 5, 2010), available at <http://lawweb.colorado.edu/events/mediaDetails.jsp?id=3000>.

4. See, e.g., *Energy Savers, Your Home, Wood and Pellet Heating*, U.S. DEP’T OF ENERGY, ENERGY EFFICIENCY AND RENEWABLE ENERGY, http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12570 (last updated Feb. 9, 2011) (under the section titled “Types of Wood- and Pellet-Burning Appliances, High-efficiency Fireplaces and Fireplace Inserts”) (“[T]raditional open masonry fireplaces should not be considered heating devices” because they are so energy inefficient).

5. Gordon W. Stuart & Pamela J. Edwards, *Concepts About Forests and Water*, 23 NAT’L J. APPLIED FORESTRY 11 (2006), available at http://www.fs.fed.us/ne/newtown_square/publications/other_publishers/OCR/ne_2006_stuart001.pdf.

emissions, so long as the forests are maintained, so that the CO₂ emitted in cooking is counterbalanced by the CO₂ taken up by growing forests and other plants. However, in many areas, gathering fuel for biomass cooking contributes to the net reduction in forests and other vegetation.⁶ If the forests and other biomass sources are not replaced as fast as they are consumed, biomass cooking will contribute to net CO₂ emissions and thus to climate change.

Perhaps a more serious contribution to global warming from biomass cooking is the emission of soot. The tiny black carbon particles in the smoke of incomplete biomass combustion—in addition to being very dangerous when inhaled—absorb heat from solar radiation when released into the environment, thus contributing to global warming generally.⁷ Because black-colored objects absorb energy and white-colored objects reflect energy, black carbon deposited into the air generally absorbs the energy that white clouds would reflect, and black carbon deposited onto the landscape in colder areas absorbs the energy that white snowfields and white glacial ice would normally reflect. Thus, carbon soot deposits on glaciers may add to the destruction of glaciers, not only indirectly by increasing global temperatures, but also directly by making a glacier absorb more heat from the sun.⁸ The retreat of glaciers, in addition to being a symptom of global warming, reduces a glacier's ability to even out seasonal stream flow by storing water in the form of ice and releasing it slowly into streams as it melts.⁹

Thus, open-air biomass cooking creates problems by harming the health of the cook and people nearby. It also leads to deforestation,

6. Fuel wood gathering and non-timber forest products usage by subsistence farmers are estimated to cause six percent of net deforestation. U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, INVESTMENT AND FINANCIAL FLOWS TO ADDRESS CLIMATE CHANGE 81 (Oct. 2007) (see Table IV-35), available at http://unfccc.int/resource/docs/publications/financial_flows.pdf.

7. David E. Steitz, Rob Gutro, Krishna Ramanujan & Mary Tobin, *Black Soot and Snow: A Warmer Combination*, NASA, (Dec. 22, 2003), http://www.nasa.gov/home/hqnews/2003/dec/HQ_03420_black_soot.html.

8. Adam Volland, *Black Carbon Deposits on Himalayan Ice Threaten Earth's "Third Pole"*, NASA, (Dec. 14, 2009), <http://www.nasa.gov/topics/earth/features/carbon-pole.html>.

9. Press Release, Univ. of Cal., Santa Barbara, Scientists Find That Debris on Certain Himalayan Glaciers May Prevent Melting (Jan. 24, 2011), available at <http://www.ia.ucsb.edu/pa/display.aspx?pkey=2406>, citing Dirk Scherler, Bodo Bookhagen & Manfred R. Strecker, *Spatially Variable Response of Himalayan Glaciers to Climate Change Affected by Debris Cover*, 4 NATURE GEOSCI. 156 (Jan. 23, 2011), available at <http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo1068.html> ("Retreating glaciers, and thus a reduction of seasonal water storage in this region, have a large impact on hundreds of millions of people living in the downstream section of these rivers").

which contributes to global warming.

COOKING SOLUTIONS

A possible solution to these problems is to increase the use of enclosed cookstoves. Enclosing the fire increases cooking efficiency and reduces pollutants in smoke—heat retained close to the fire cooks food more quickly, and smoke held near the flames combusts more thoroughly. Cookstoves therefore improve the efficiency of biomass combustion, protecting the cook's health, the forests nearby, and the planet and its glaciers. Benjamin Franklin recognized the increased efficiency of stoves compared to open fires over 300 years ago.¹⁰

It is possible to increase cooking efficiency by replacing an open fire with a stove made from brick, cement, clay, stone, etc. Many of the energy poor may already be taking these approaches.¹¹ However, various outreach and educational efforts may be able to help more people use these materials. It may be possible to increase employment in rural areas as those trained to work with these materials are paid to build stoves for their friends and neighbors. But these materials may not be readily available to many of the energy poor, and even if they are, they may not be the best materials for making cook-friendly stoves. These materials may be most efficient for building ovens, with the stove's thermal mass retaining the heat for baking or roasting after the fire has burned out. They would not be efficient, however, for frying or boiling because they cannot quickly transfer energy.

An alternative could be durable and inexpensive cook stoves that could be mass-produced and sold to the rural energy poor. They would have to be small and light so that they could be easily transported in areas with less developed road or river transportation. The history of similar selling success is both recent and old.

BRINGING TECHNOLOGY TO THE PEOPLE

In older times, simple tools and farm implements were sold by traveling salespeople and later in small stores.¹² As time went on, similar

10. I. BERNARD COHEN, *BENJAMIN FRANKLIN'S SCIENCE* 200-11 (2nd prtg. 1996).

11. See the discussion of building and selling more efficient cookstoves in Guatemala in Tina Rosenberg, *When Microcredit Won't Do*, N.Y. TIMES, Jan. 31, 2011, available at <http://opinionator.blogs.nytimes.com/2011/01/31/when-microcredit-wont-do/>.

12. James W. Baker, *The Yankee Peddler*, JABEZ CORNER, <http://www.jabezcorner.com/jbz/jbz-peddlers.html> (last updated July 28, 2010).

sales techniques were used for more sophisticated and expensive equipment. Starting with the recent successes, cellular phones have been broadly sold in energy poor areas.¹³ Once the needed electromagnetic spectrum was allocated to cellular phones, sales increased even in quite rural areas.¹⁴ In fact, much of the world may never see substantial hard-wired phone networks because of the success of cellular phones. While the manufacture of cellular phones and the creation and operation of networks require large organizations (public or private), the selling of the phones themselves has been largely decentralized.

The techniques that sold axes and sewing machines in older times and cellular phones more recently could be used to sell cookstoves. These techniques might also be used to sell inexpensive and reliable products such as water filters¹⁵ or irrigation pumps for which the energy poor have needs similar to the need for safe and efficient stoves. Later, these techniques might be used for more sophisticated products such as photovoltaics or wind generators. Indeed, traveling vendors could use their time more efficiently and increase revenue if they had a broad array of products that could be brought to the rural poor at one time.

In the developed world and even in developing urban areas, the consumer often goes to a commercial area or a store with a broad spectrum of products, but the rural energy poor often lack the transportation and roads needed to get to such stores. The traveling seller could, during each trip, deliver what would take many trips by individual rural villagers. Repeat visits to the village allow the traveling seller to sell parts, new applications, and different products and also to keep in touch with prior customers who may have repair issues or may need guidance on proper use of older products. Networks of such traveling sellers might be operated by new small-scale entrepreneurs, by retail businesses already operating in the energy poor country, by

13. See, e.g., Nicholas Kristof, *Buying Rice—With Your Cell Phone*, N.Y. TIMES, Dec. 4, 2010, available at <http://kristof.blogs.nytimes.com/2010/12/04/buying-rice-with-your-cell-phone/>; see also *M-PESA Mobile Money*, CONSULTATIVE GROUP TO ASSIST THE POOR, <http://www.cgap.org/p/site/c/media/?play=1.9.45741> (last visited Feb. 2, 2011) (a video on use of cell phones for money transactions).

14. See *A Special Report on Telecoms in Emerging Markets, Eureka Moments*, ECONOMIST, Sept. 24, 2009, available at <http://www.economist.com/node/14483872>; *The Mother of Invention*, ECONOMIST, Sept. 24, 2009, available at <http://www.economist.com/node/14483880>. The process of allocating spectrum in the U.S. (presumably somewhat similar to that in other nations) is described in Dylan Loeb McClain, *Directing Traffic in the Radio Spectrum's Crowded Neighborhood*, N.Y. TIMES, Feb. 24, 2000, available at <http://www.nytimes.com/2000/02/24/technology/directing-traffic-in-the-radio-spectrum-s-crowded-neighborhood.html?scp=3&sq=electromagnetic%20spectrum&st=Search>.

15. Nandy, *supra* note 2.

nongovernmental organizations, or by international commercial companies.

The important point is that many of the needs of the rural energy poor might best be served through market activities—this has been the case from the age of new axes to the age of cellular phones. Although such market forces as carbon taxes and cap-and-trade are major tools for those concerned about the environment and climate change, perhaps reformers should turn their focus to the operation of traditional markets for goods and services, rather than the more exotic and abstract markets that operate under cap-and-trade. Perhaps Adam Smith and private enterprise deserve a larger place in environmental reform.¹⁶ Meetings on environmental reform are heavily attended by experts from the social sciences and hard sciences, including economists, political scientists, physicists, biochemists, and engineers. How many attendees are from business schools, people who can talk about design, marketing, finance, and warranties? How many are from mass merchants such as Coca-Cola and Wal-Mart?¹⁷ How many are from extenders of credit, whether micro lending or bankcards? There is something crass and rough about markets, and few would seriously doubt that markets need such infrastructure as courts, regulations, and laws of contracts, property, creditors' remedies, and bankruptcy. But markets are great at making technology available, at bridging the gap between what technology can do, and what end users want and need.

Despite the substantial benefits that markets produce, in much of the world—particularly in the energy poor nations—there are many barriers to the creation and operation of small- and medium-sized businesses.¹⁸ One may speculate as to why these barriers exist.¹⁹ Some governments may follow the mercantilist beliefs that dominated thought about public finance before Adam Smith.²⁰ Authoritarian regimes desiring to control all power may fear economic power centers as much as they fear political or religious rivals. Some nations may operate under systems of crony capitalism, under which a few large enterprises friendly

16. Adam Smith's *THE WEALTH OF NATIONS* (1776) is regarded by many as the foundation of modern market economics.

17. The representative from Tata, the conglomerate founded in India that has grown to be a major worldwide economic force, contributed significantly to this conference.

18. See, e.g., INT'L FIN. CORP. & WORLD BANK, *DOING BUSINESS 2011, MAKING A DIFFERENCE FOR ENTREPRENEURS* 4 (Nov. 4, 2010), available at <http://www.doingbusiness.org/reports/doing-business/doing-business-2011> (the Executive Summary provides the ranking of nations for their ease of doing business, a list where many of the energy poor are ranked as less hospitable).

19. *Id.*

20. See note 16, *supra*.

to the regime dominate the economy and are protected by the regime from competition.²¹ Various nations may have serious corruption problems that delay and increase the cost of starting and operating businesses. Whatever the causes of the hostile business conditions in many of the energy poor nations, that hostility is imposing serious costs on the people and the environment of that nation.

ANOTHER LINK BETWEEN TECHNOLOGY AND THE END-USER

United States history includes another powerful influence on the process of getting technology to end-users: the cooperation between land-grant universities and local Cooperative Extension System Offices for the purpose of improving farming and ranching.²² We are well aware of the technological progress in cars, computers, planes, and telecommunications. Perhaps further back in our consciousness are the revolutions in applying technology to agriculture.

The agricultural revolution has many components that together have allowed much less labor to produce much more food, fiber, etc. Chemical analysis allows better determination of what fertilizer or other soil enhancement may be appropriate.²³ Water use has been extensively studied and is increasingly well-understood,²⁴ even though the relatively water-rich United States lags behind such drier areas as Israel in the efficient use of water.²⁵ Crops have been improved by careful selection,²⁶

21. See, e.g., Kareem Fahim, Michael Slackman & David Rohde, *Egypt's Ire Turns to Confidant of Mubarak's Son*, N.Y. TIMES, Feb. 7, 2011, at A1, available at <http://www.nytimes.com/2011/02/07/world/middleeast/07corruption.html?scp=1&sq=%20crony%20capitalism%22&st=cse> ("While hard facts are difficult to come by, Egyptians watching the rise of a moneyed class widely believe that self-dealing, crony capitalism and corruption are endemic."); Thomas L. Friedman, *The \$110 Billion Question*, N.Y. TIMES, Mar. 6, 2011, at WK12, available at http://www.nytimes.com/2011/03/06/opinion/06friedman.html?_r=2&scp=21&sq=corruption,%20development&st=cse ("[O]ne reason for the rebellion in Egypt and protests in Jordan was the in-your-face corruption and crony capitalism that everyone in the public knew about.").

22. See *Cooperative Extension System Offices*, NAT'L INST. OF FOOD AND AGRIC., U.S. DEP'T OF AGRIC., <http://www.csrees.usda.gov/Extension/index.html> (last updated Dec. 14, 2010).

23. See generally VACLAV SMIL, ENRICHING THE EARTH: FRITZ HABER, CARL BOSCH, AND THE TRANSFORMATION OF WORLD FOOD PRODUCTION (2004).

24. *Irrigation Techniques*, U.S. GEOLOGICAL SERVICE, WATER SCIENCE FOR SCHOOLS, available at <http://ga.water.usgs.gov/edu/irmethods.html> (last modified Mar. 30, 2011).

25. Andrew Martin, *Can Israel Find the Water It Needs?*, N.Y. TIMES, Aug. 10, 2008, at BU7, available at <http://www.nytimes.com/2008/08/10/business/worldbusiness/>

later by hybridization,²⁷ and more recently by genetic modification.²⁸ Methods to control pests and weeds have been improved.²⁹ Contour plowing became the norm, and in many areas no-till farming is practiced.³⁰ Harvesting techniques seek to better preserve freshness and to protect against contamination and decay.³¹

These techniques have been developed, improved, and implemented through extensive collaboration among the agricultural colleges, farmers, and ranchers via the extension offices.³² Agents who staff the extension offices are local residents who know the community and are known by the community. These agents transmit information from the farmers such as new problems, new solutions, or difficulties with old solutions. Going the other direction, these agents transmit information from the agricultural colleges to the farmers. The developers of better equipment, fertilizers, herbicides, pesticides, seeds, etc., use this communication system in both directions.

The new technologies for the rural energy poor might benefit from a communications system similar to that developed in the United

10feed.html?ref=irrigation (“Israel has always been considered to be at the forefront of water efficiency in agriculture.”).

26. Paul Voosen, *Molecular Breeding Makes Crops Hardier and More Nutritious*, SCI. AM., Dec. 21, 2009, available at <http://www.scientificamerican.com/article.cfm?id=molecular-breeding-crops-genetics-rice-soy-corn-wheat>.

27. Keith Schneider, *Science Debates Using Tools To Redesign Life*, N.Y. TIMES, June 8, 1987, at A17, available at <http://www.nytimes.com/1987/06/08/us/science-debates-using-tools-to-redesign-life.html?scp=7&sq=crop%20hybridization&st=cse> (“The genetic traits of plants and animals have been manipulated for centuries. But until now animal breeding and the hybridization of crop plants have been slow, cumbersome and difficult.”).

28. See David Biello, *Can Genetically Modified Crops Feed the World?*, SCI. AM., April 16, 2009, available at <http://www.scientificamerican.com/podcast/episode.cfm?id=can-genetically-modified-crops-feed-09-04-16>.

29. Emily Laber-Warren, *Green Chemistry: Scientists Devise New ‘Benign by Design’ Drugs, Paints, Pesticides and More*, SCI. AM., May 28, 2010, available at <http://www.scientificamerican.com/article.cfm?id=green-chemistry-benign-by-design>.

30. John R. Huggins & John P. Reganold, *No-Till: How Farmers Are Saving the Soil by Parking Their Plows*, SCI. AM., June 30, 2008, available at <http://www.scientificamerican.com/article.cfm?id=no-till>.

31. Jan Ellen Spiegel, *An Enduring Summer Treat, Improved by Science*, N.Y. TIMES, July 30, 2010, available at <http://www.nytimes.com/2010/08/01/nyregion/01dinet.html?scp=8&sq=improved%20harvesting&st=cse> (“Using plastic on the ground and covers on rows of selected fields, he is widely credited with harvesting the earliest corn in New England.”).

32. See the website for the National Institute of Food and Agriculture (the former Cooperative State Research, Education, and Extension Service (“CSREES”)), U.S. DEPARTMENT OF AGRICULTURE, <http://www.csrees.usda.gov/qlinks/extension.html>, on which the following discussion is based.

States, linking colleges with extension offices with those living in remote, small villages. A cookstove must be designed for its fuel, with different equipment required in stoves that burn animal dung, charcoal, coal, dried grass or twigs, hardwood, softwood, etc. The cookstove must be designed for the kind of cooking its users want, whether it be baking or boiling, frying or roasting, etc. The users of the stove must know how to use it and for what, to avoid the risk of carbon monoxide poisoning or accidental fires. If the climate permits, outdoor cooking reduces the risks of fire to the dwelling and of carbon monoxide poisoning. In harsher climates, a chimney may be required for safety, and in general chimneys increase the efficiency of stoves.³³ But chimneys must be well-designed and maintained.

Sustainable technologies that appear simple might actually require users to have continued contact with people who are familiar with the technology. A water filter might be effective at removing organic materials, but ineffective with ionic salts, or vice versa, and the filtering element is likely to need cleaning or changing. A water pump may need cleaning or replacement of seals, and if it is powered by an electric motor or internal combustion engine still more maintenance will be required. More sophisticated equipment for solar- or wind-generated electricity is likely to require periodic upkeep. Improvements are expected in these technologies, leading to the need to replace machines made with the old technology before their useful lives are over. While these issues should also be covered by the traveling salespeople discussed above under "Cooking Solutions," it will be valuable to have back-up from neutral agricultural extension agents.

In many energy-poor parts of the world, educated people are unable to find employment that suits their training.³⁴ This may be due to the fact that energy-poor countries lack the jobs or niches in which educated people can use their skills. Every professor and student may want to become an Oxford don, but the world demands relatively few purveyors of such services. Having those people use their skills to help transmit knowledge back and forth between universities and the energy poor might be the most gainful use of their education, and it might beneficially encourage the universities to employ more useful problem solving as opposed to some of the very abstract academic issues upon

33. Because the air inside the chimney is warmer and thus lighter than the outside air, the air in the chimney rises. The rising air in the chimney draws more fresh air into the fire, aiding the combustion process, much as blowing on a campfire makes the campfire burn more intensely.

34. See, e.g., Josh Chin, *Value of a Chinese College Degree: \$44?*, CHINA REAL TIME REPORT, Nov. 22, 2010, available at <http://blogs.wsj.com/chinarealtime/2010/11/22/value-of-a-chinese-college-degree-44/#>.

which higher education too often fixates with great redundancy. Of course there is a need for and utility in pure research, but there is also a need for practical applications of theory to bridge the gap between the theory-rich and the energy-poor.

CONCLUSION

Getting appropriate sustainable energy technologies into the hands of the rural energy poor might best be done through the activities of traveling salespeople—they have brought cellular phones and plows to the rural poor. Alternatively or in addition, colleges might work with extension offices located in rural energy poor areas, much as they have long provided practical information transfer in U.S. agriculture. Colleges can provide appropriate sustainable energy technologies, skills, and knowledge to the rural energy poor, and the energy poor can return feedback about the success of these technologies. Supplementary benefits of this approach would be to orient the colleges away from pure theory and toward more practical activities, and to provide a more useful and reasonably compensated outlet for the abilities of their students.

