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Public Health Effects of Wood Fuel in Africa: Bioenergy from Tree Commodities as a Sustainable Remedy

Serge Mandiefe Piabuo and Janice Tieguhong Puatwoe

Abstract

Globally, about 2.8 million people depend on solid wood fuel for energy, developing countries account for more than 90% of this population. About 70% of households in Sub-Saharan depend on wood fuel for energy. The combustion of solid wood fuel indoors and outdoors emits smoke with particles that have adverse effects on the health of users. This chapter investigates the health effects of wood fuel combustion on the users and evaluates the potential of bioenergy from tree commodities as a sustainable remedy. Through a literature review of literature on health effects of wood fuel, this chapter shows that acute respiratory infections, lung problems, cataract, cardiovascular diseases and bronchitis are common public health issues that wood fuel users suffer from. Bioenergy provides a clean and healthier alternative energy for rural households; tree commodities provide a more sustainable option for millions of Africans who depend on tree commodities for their livelihoods. Estimates show that between $4.26\text{E}+06$ and $1.14\text{E}+07$ MW of bioelectricity can be generated from tree commodities, while $6.26\text{E}+08$ to $1.71\text{E}+09$ litres of bioethanol and $4.27\text{E}+08$ to $1.14\text{E}+09$ litres of biodiesel can potentially be generated from tree commodities. Significant government support, financial investment, public-private partnerships and community sensitisation are required for tree commodities to sustainably provide clean and healthy bioenergy to rural Africa.

Keywords: solid wood fuel, respiratory infections, bioenergy, tree commodities

1. Introduction

Renewable energy remains the most dominant energy source in Africa with wood sources accounting for a large share of biomass energy. Although wood energy accounts for only 10% of global primary energy, about 2.8 million people depend on wood fuel for cooking and heating [1, 2]. The extraction and use of wood for energy is prominent in developing countries with more than 70% of households in Sub-Saharan Africa depending on wood energy. Access to modern energy remains a major problem in developing countries; however, poorer countries suffer more from energy access problems [3]. Poor access to modern energy rates in less developed countries (LDCs) and Sub-Saharan (SSA) countries remain high at 91

and 83%, respectively. In SSA, the access to electricity and modern energy remains a major constraint with 560 and 625 people deprived, respectively. Poor access to modern energy equally varies between urban and rural areas in Africa; in SSA, 66% of the population use solid fuels for heating and cooking, 13% use charcoal while kerosene, electricity and LPG follow with 7, 6, and 5%, respectively [4].

The global use of wood fuel for cooking and heating has devastating negative health effects with 2 million deaths annually from pneumonia, cancer and chronic lung diseases due to exposure to pollution from biomass combustion. Women and children are most affected by these diseases with about 44% of these deaths being children and 60% of adult death being women [3]. More than 50% of deaths from pneumonia, cancer and chronic lung diseases in LDCs and SSA is due to combustion of solid fuels, while only 38% for developing countries in general [3]. Household air pollution (HAP) is a major driver of global health emergencies with about 4.3 million premature deaths; non-communicable diseases (NCDs) account for 3.8 million deaths (WHO, 2016). HAP accounts for more than 33% deaths related to chronic obstructive pulmonary in both low- and middle-income countries, 17% of deaths related to cancer, 15% of ischaemic heart disease and 25% stroke-related deaths (WHO, 2016). This chapter seeks to review the different diseases caused by incomplete combustion of biomass for energy and how bioenergy from tree commodities can be a sustainable remedy.

2. Solid fuelwood combustion and health effects in rural Africa

Several scientific publications have reported significant health effects of wood fuel combustion for cooking especially through open fire in rural areas [5, 6]. Childhood respiratory infections such as pneumonia and otitis media have been highly associated with fuel wood combustion [5]. Among women, there is a high association between fuelwood combustion and high risk of chronic bronchitis and chronic obstructive pulmonary disease, especially asthma and cataract. Indoor combustion of fuelwood has been called the ‘kitchen killer’ because about 1.6 million deaths have been registered as a result, accounting for 2.7% of global disease burden (WHO, 2007).

The combustion process generates smoke; this smoke contains a complex mixture of numerous particles and substances composed of varied organic and inorganic compounds [7, 8]. These compounds are toxic and dangerous to the health system of human beings; they contain carbon monoxide (CO), nitrogen and sulphur oxide (NO₂, CO₂), aldehydes, particulate matter PM (PM₁₀), volatile organic compounds, chlorinated dioxins, free radicals and polycyclic aromatic hydrocarbons [8]. The health effects on children less than 5 years and women are not homogenous. Respiratory infections such as pneumonia are common in young children less than 5 years, while chronic obstructive pulmonary disease (COPD) and lung cancer are common in women. Other health effects such as adverse pregnancy and eye diseases are equally common [9, 10].

To better appreciate the health effects of fuelwood combustion, a review of literature for over 17 papers was done. The objective was to capture the most prevalent health outcomes as a result of indoor and outdoor fuelwood combustion. The table below (**Table 1**) shows the results of the reviewed papers in a summary form [11].

The exposure to smoke due to cooking fuel accelerates respiratory-related illnesses such as dry cough and nose irritation; further analysis equally underscores high association with headache, dry cough and hypertension [25]. The review above shows significant health effects related to respiratory-related diseases, of the 17

Author(s)	Study carried out	Country/region	Methodology	Major findings	Discovered health outcomes
Bruce et al. [12]	Indoor biofuel air pollution and respiratory health: the role of confounding factors among women in highland Guatemala	Guatemala	Cross-sectional analysis	The prevalence of reported cough and phlegm was significantly high among women using open fire	Cough and phlegm
Vinod et al.	Biomass cooking fuels and prevalence of tuberculosis in India	India	Logistic regression	Substantial prevalence of active tuberculosis in person living in households using biomass cooking fuels (wood or dung)	Tuberculosis
Neelam et al. [13]	Indoor air pollution from biomass combustion and its adverse health effects in central India: an exposure response study	India	Qualitative analysis with the use of peak expiratory rate flow	Exposure to biomass smoke causes health related problems	Eye irritation, headache, bronchitis, cataract and respiratory problems
Rajiv [14]	Disease burden of fuelwood combustion pollutants in rural households of the Himalayas	India	Qualitative analysis	The use of fuelwood has an impact on health	Acute lower respiratory infection, chronic obstructive pulmonary disease and lung cancer
Zschauer [15]	Households' energy supply and the use of fuelwood	Kenya (case of Taita Hills)	A qualitative analysis	The use of fuelwood has a negative impact on health	Eye problem, respiratory problems (coughing irritation of the lungs and sniffles), tuberculosis
Silwal and McKay [16]	The impact of cooking with firewood on respiratory health	Indonesia	A unique Indonesian household survey	Individuals living in households that cook with firewood have lower lung capacity than those that cook with cleaner fuels; impact being larger on women and children	Lower lung capacity
Agrawal and Yamamoto [17]	Effect of indoor air pollution from biomass and solid fuel combustion on symptoms of preeclampsia/eclampsia in Indian women	India	Logistic regression	Women living in households using biomass and solid fuels have two times higher likelihood of reporting preeclampsia/eclampsia symptoms than those living in households using cleaner fuels	Preeclampsia/eclampsia
Sharma et al. [18]	Types of cooking stove and risk of acute lower respiratory infection among under five children: a cross sectional study in Rasuwa, Nepal	Nepal	Cross-sectional survey	The presence of acute lower respiratory infection among users of biomass fuels	Lower respiratory infections
Zoë et al.	Residential heating with wood and coal: health impacts and policy options in Europe and North America	Europe and North America	Qualitative analysis	Evidence links emissions from wood and coal heating to serious health effects	Respiratory and cardiovascular mortality and morbidity

Author(s)	Study carried out	Country/region	Methodology	Major findings	Discovered health outcomes
Tao et al. [19]	Residential solid fuel combustion and impacts on air quality and human health	Mainland China	A qualitative analysis	Evidence showed that household air pollution in china causes a range of health outcomes	Respiratory diseases; asthma, lung cancer, cardiovascular diseases; heart diseases, stroke and immune system impairment
Zidago & Wang [20]	Charcoal and fuelwood consumption and its impacts on environment	Cote d'Ivoire (Case Study of Yopougon Area)	A qualitative analysis through the households was used	The production and consumption of charcoal have a negative impact on the health of its producers and consumers	Burns, chronic cough
Das et al. [21]	Biomass cooking fuels (firewood, Charcoal) and health outcomes for women in Malawi	Malawi	Cross-sectional sample analysis	The use of firewood and charcoal for cooking is associated with five categories of health outcomes.	cardiopulmonary, respiratory, neurologic, eye health and burns
Kadafa et al. [22]	The health impact of fuelwood Utilisation on users	Nigeria (case study of Yelwa Village)	A qualitative analysis	It was discovered that fuelwood has health implications on its users	Eye problem, respiratory problem and heart diseases
Mbanya and Sridhar [23]	PM10 emissions from cooking fuels in Nigerian households and their impact on women and children	Ibadan, Nigeria	Qualitative analysis	Majority of the respondents complained of health-related issues during and after cooking with cough, breathing problems, skin and eyes irritation being the most common	Cough, breathing problems, skin and eyes irritation
Badamassi et al. [24]	The effects of particulate matter (PM2.5) from household combustion on life expectancy in SSA	43 SSA countries	GMM and panel cointegration model	Household particulate matter (PM2.5) is significantly and negatively associated with higher life expectancy in the long run especially with females	Lower life expectancy
Mohapatra et al. [25]	Health impact on women using solid cooking fuels in rural area of Cuttack District, Odisha	Cuttack District, Odisha	Cross-sectional study with the use of Chi-square test	Exposure to smoke from cooking fuel is significantly associated with the prevalence symptoms of headache, dry cough and hypertension	Headache, dry cough and hypertension

Table 1.
Review of health effects of fuelwood combustion on users.

studies, 13 underscore respiratory tract infections as major outcome of fuelwood combustion. The most common forms of the respiratory tract infections are dry cough, breathing problems, neurologic problems, cardiopulmonary, cardiovascular diseases, asthma and lung cancer [20, 23, 25].

Lower life expectancy has equally been reported by Badamassi et al. [24]; they underscore that combustion of particulate matter (PM_{2.5}) has adverse effect on life expectancy in the long run, with a greater negative effect on female life expectancy. Their study equally shows higher life expectancy for exposed households in urban areas and countries with higher GDP per capita; this can be explained by the fact that these groups can have better access to health care. Cardiovascular diseases have equally been reported to be associated with fuelwood combustion [19]. Other diseases such as asthma, stroke and immune system impairment have equally been attributed to indoor and outdoor pollution as a result of fuelwood combustion [19].

3. Bioenergy as a sustainable and health energy source

The precedent section underscores that about 700 million (82%) of Africans are at high risk of household air pollution due to the use of solid-fuel for cooking with an average 581,000 deaths annually [26]. Globally, the demand for solid-fuel for cooking has reduced considerably, average 50–40%; however, Africa stagnates at 80% over the decades. Escalating fuel cost, population growth and supply interruptions have accounted for reduced demand in modern fuel demand. Even when households use modern fuel for cooking, they often combine with solid-fuel cooking stoves [27, 28]. The production of energy from biological waste using modern production techniques has been promoted as a way out of this public health crisis. Significant efforts have been made through different cross-country projects aimed at producing clean and modern bioenergy such as liquid and gel biofuels. Efforts to promote more clean energy sources such as ethanol stoves and clean cooking stoves have not met required objectives due to poor market penetration and high subsidisation cost [26]. However, in West Africa, ethanol businesses have registered steady growth with over 200,000 stoves reported in different countries over 3 years.

Biogas projects in East Africa played an important role in changing mindsets and providing a cleaner alternative for households. In Kenya, three biogas operating units have been constructed by the Taita Taveta Wildlife Forum (TTWF) as part of a pilot project aimed at improving access to clean energy. This is promoted because biogas produces clean energy, with less indoor and outdoor pollution, thus reduced chances of respiratory tract infections and heart infections. The biogas production process equally generates nitrogen and liquids rich in nutrients that can serve as fertilizers.

The use of bioenergy as an alternative to solid-fuels is encouraged because through the different conversion techniques, energy is generated which enhances good combustion with limited emission of air pollutants. This form of energy is good both for indoor and outdoor use at urban and rural areas. The promotion of this form of energy is equally backed by the constant availability of biomass for bioenergy conversion, with by-products that are equally good for crop cultivation.

4. Bioenergy from tree commodities as a sustainable remedy

Tree commodities commonly referred to as ‘money trees’ are trees grown principally for cash by many African countries. These trees are often the principal

source of income for most farmers in Sub-Saharan Africa. In Africa, cocoa, coffee, oil palm, industrial round wood, cashew, almonds and walnuts are the principal tree commodities. These tree commodities are a source of income to millions of Africans and accounts for tons of agricultural biomass produced annually. Agricultural biomass after extraction of the fruit of these products is often left to rot in the farms while farmers suffer from energy shortages. Residue from tree commodities such as husk of cocoa and coffee, empty fruit bunch of oil palm, forest thinning from timber exploitation and shell of almonds are potential sustainable feedstock for bioenergy generation.

With the appropriate technology and adoption by community members, tree commodities can serve as a pathway for sustainable bioenergy generation without changing land use and without extra efforts from the farmer to find feedstock. The potential of using bioenergy for reducing health effects of traditional biomass for combustion is backed by the fact that tree commodities are often found in rural areas, with serious energy deficiencies, high prevalence of respiratory tract infections as a result of solid wood fuel combustion.

The potential of using bioenergy from tree commodities as a clean energy source is evaporated in this chapter by looking at two aspects: (1) by evaluating the potential in terms of quantity of bioenergy that can be generated by tree commodities and (2) operational framework for bioenergy from tree commodities to effectively serve rural population as a renewable and healthy energy source.

4.1 Evaluating the potential quantity of bioenergy from tree commodities in Africa

To evaluate the potential of bioenergy from tree commodities, seven tree commodities were chosen for analysis based on the number of farmers or population affected by the different tree commodities. The chosen tree commodities are coffee (*Coffea arabica* and *Coffea canephora*), cocoa (*Theobroma cacao*), oil palm (*Arecaceae*), walnuts (*Juglans*), cashew (*Anacardium occidentale*), almonds (*Prunus dulcis*) and industrial round wood. When evaluating bioenergy potential from tree commodities, provisions are taken for the use of residue for other uses, such as soil nutrient. The extraction equally considers other aspects such as weather, soil types, crop yields, harvesting technique and wind patterns [29, 30]. Researchers have evaluated different soil systems and uses of residue from biomass and conclude that 44–64% of biomass residue can sustainably be used for biomass generation [29–31]. Using a more conservative approach, this chapter uses a 20% extraction rate to estimate bioenergy production from tree commodities. Data from the FAO (2018) database serve as a basis for estimation in this chapter. Sustainable extraction rates were gotten from literature review from a variety of sources; residue to product ratio and moisture content was extracted from OECD/IEA [32]. Moisture content for coffee and cocoa was obtained from NREL [33], oil palm from Husain et al. [34], walnuts from Uzan and Yaman [35], cashew from Mohod et al. [36], industrial round wood from FAO [37] and almonds from [38]. **Table 2** below shows the results of bioenergy potential from tree commodities for bioelectricity, biochemical ethanol and diesel.

Bioenergy generation from tree commodities in Africa can potentially generate between 4.26E+06 and 1.14E+07 MW of bioelectricity from the seven-tree commodities while 6.26E+08 and 1.71E+09 L of bioethanol can potentially be generated from tree commodities. Tree commodities equally can equally serve as an important potential source for diesel, estimates from tree commodities show that 4.27E+08–1.14E+09 L can be generated from tree commodities.

Tree commodity	Average	Type of residue	Residue to product ratio	Moisture content	Lower heating value	Residue (wet tons)	Residue (Bone dry tons)	Residue. 30% Sustainable Extraction (bone dry tons)	Energy potential (bone dry x MK/kg) GJ	bioelectricity		Biochemical ethanol		Thermochemical syngas to Fischer Tropsch diesel	
										15% efficiency MW h (low)	40% efficiency MW h (high)	(low) litres	(high) litres	Low (litres)	High (litres)
Coffee	1,149,511	Husk	2.10	0.15	12.56	2.41E+06	2.05E+06	6.16E+05	7.73E+06	3.25E+05	8.66E+05	6.77E+07	1.85E+08	4.62E+07	1.23E+08
cocoa	3,398,572	Pods, Husk	1.00	0.15	15.48	3.40E+06	2.89E+06	8.67E+05	1.34E+07	5.63E+05	1.50E+06	9.53E+07	2.60E+08	6.50E+07	1.73E+08
oil palm	19,402,457	empty fruit bunch (EFB)	0.25	0.60	15.51	4.85E+06	1.94E+06	5.82E+05	9.03E+06	3.79E+05	1.01E+06	6.40E+07	1.75E+08	4.37E+07	1.16E+08
Walnuts, with shell	37,471	shell	2.00	0.15	16.70	7.49E+04	6.37E+04	1.91E+04	3.19E+05	1.34E+04	3.57E+04	2.10E+06	5.73E+06	1.43E+06	3.82E+06
Cashew	1,713,285	Shell	2	0.15	23.98	3.43E+06	2.91E+06	8.74E+05	2.10E+07	8.80E+05	2.35E+06	9.61E+07	2.62E+08	6.55E+07	1.75E+08
Industrial round wood	28,764,846	forest thinning	0.5	0.4	18.3	1.44E+07	8.63E+06	2.59E+06	4.74E+07	1.99E+06	5.31E+06	2.85E+08	7.77E+08	1.94E+08	5.18E+08
Almonds, with Shell	281,549	shell	2	0.15	18.86	5.63E+05	4.79E+05	1.44E+05	2.71E+06	1.14E+05	3.03E+05	1.58E+07	4.31E+07	1.08E+07	2.87E+07
Total									1.02E+08	4.26E+06	1.14E+07	6.26E+08	1.71E+09	4.27E+08	1.14E+09

Table 2.
Tree commodities as a source of bioenergy, bioelectricity, biochemical ethanol and diesel.

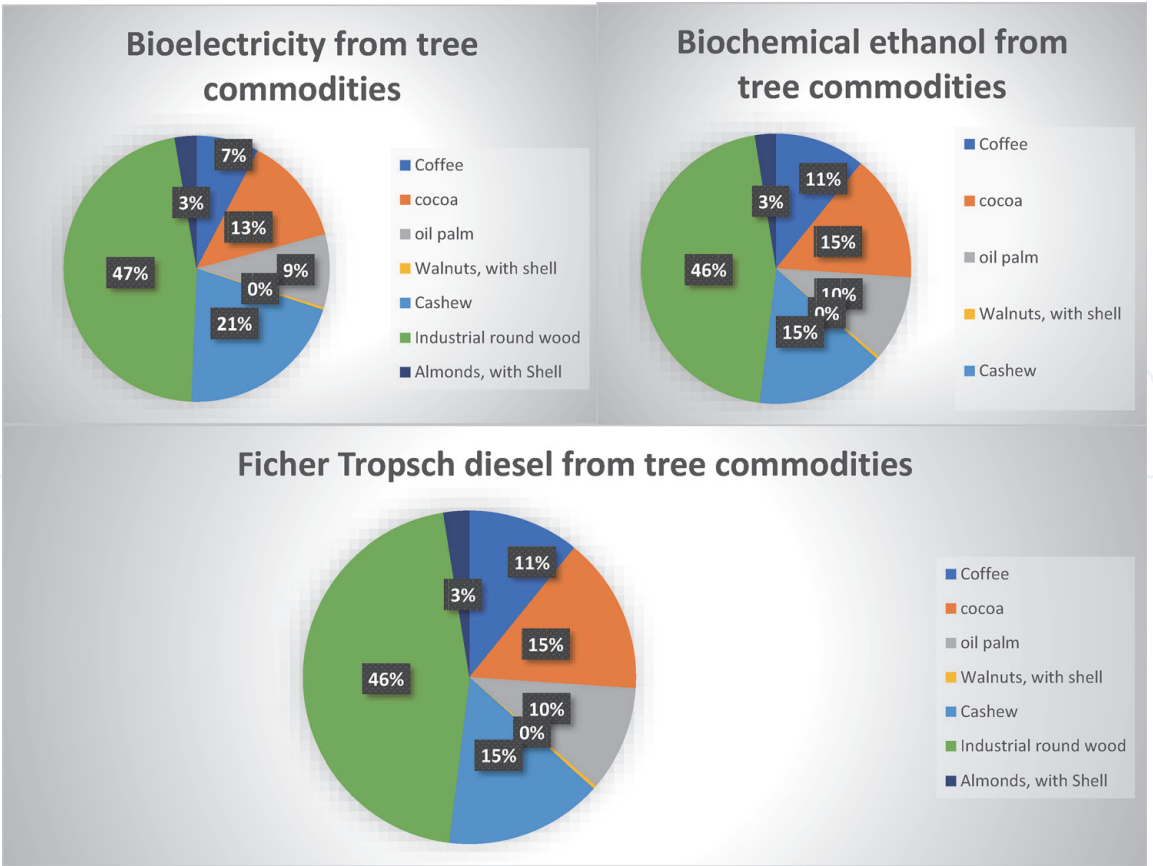


Figure 1.
Percentage of bioenergy generated from different tree commodities.

The figure above (**Figure 1**) shows that bioenergy generation from industrial round wood is the highest averaging 46% for the bioelectricity (47%), bioethanol (46%) and Fischer-Tropsch diesel (46%). Cashew shell can equally contribute significantly bioenergy production accounting for 15% of diesel and bioethanol and 21% of electricity. Cocoa comes third as the highest contributor, accounting for 13% of bioelectricity and 15% of bioethanol and diesel. Coffee follows representing 7% of bioelectricity production and 11% of bioethanol and diesel. Oil palm equally contributes significantly to this potential, with 9% of total potential of bioelectricity and 10% of bioethanol and diesel potential production. These percentages underscore the significant potential contribution of tree commodities in generation clean, modern bioenergy than can potentially reduce public health diseases associated with the combustion of solid-fuel biomass. However, for this to be a reality, a lot of policy and operational tools must be put in place and readily available at local level.

4.2 Operational framework for bioenergy from tree commodities to effectively serve rural population as a renewable and healthy energy source

For modern bioenergy to serve as a potential clean energy source for rural African communities and millions of Africans at risk of respiratory tract infections and cardio-vascular diseases, several important pre-requisites are required.

- i. **Government support:** For modern bioenergy to be a mainstay in rural Africa and reduce incidences of deaths through solid-fuel combustion, government authorities must support the development of modern bioenergy infrastructure. This requires significant shift in policy and investment from the government and different multi-lateral partners. The understanding of policy makers of the health advantages of developing modern bioenergy

systems coupled with sustainable management practices is key to pushing a policy reform agenda for modern bioenergy generation in Africa.

- ii. **Significant financial investment:** Developing modern bioenergy generation systems for tree commodities requires significant financial investment. Multi-lateral development agencies aimed at reducing carbon emissions and promoting healthy living of populations can shift their funding streams to bioenergy generation. For this to happen, they must understand that modern bioenergy does not only reduce carbon emission, deforestation but can equally save the lives of millions of people potentially at high risk of respiratory tract infections as a result of solid-fuel combustion. This financing should go along way in investing not only in infrastructure for bioenergy development but equally in community adapted distribution mechanisms that will enhance adoption of new form of energy. These new energy sources should be cheaper and more efficient for adoption to be faster.

4.3 Sensitization and training on modern bioenergy generation from tree commodities

The acceptance and adoption of new bioenergy as an improved energy source required that users understand the key advantages. Thus, sensitisation at different levels with a clear distinction of advantages over traditional solid-fuel combustion should be made. Adoption can equally be facilitated by developing simple modern bioenergy generation systems that are adapted to rural context with minimal investment. This will enhance adoption especially when the cost of generation is relatively low and accrued advantages and multi-scaled.

- i. **Public-private partnerships and cooperation:** The developments of sustainable modern bioenergy systems stakeholder buy-in at different levels and scales. Thus, a public-private partnership scheme is very important. The private sector with similar objectives can collaborate with government agencies in developing the bioenergy agenda as financial partners, technical support agents, or for policy advocacy. International cooperation is equally important for broad-based decision-making with local impacts coupled with strategic deployment frameworks adapted to different contexts. Understanding different stakeholders from different countries is paramount to advancing bioenergy generation.

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Author details

Serge Mandiefe Piabuo^{1*} and Janice Tieguhong Puatwoe²

1 World Agroforestry Centre (ICRAF), Yaounde, Cameroon

2 Technical Training Research Centre for Development (TTRECED), Yaounde, Cameroon

*Address all correspondence to: p.mandiefe@cgiar.org

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