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Original article

Cooking in refugee camps and informal settlements: A review of available technologies and impacts on the socio-economic and environmental perspective

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ABSTRACT

In the world, the number of forcibly displaced people is arising. These people have several needs, especially in terms of food security. The humanitarian response usually focuses on food availability and access, while food processing is often neglected. In this framework, cooking technologies play an essential role. Many scientific studies and international reports address the issue of clean cooking technologies dissemination in developing countries. Less information is instead available in the literature for the specific case of humanitarian contexts, such as refugee and Internally Displaced Persons (IDP) camps, or informal humanitarian settlements. Unsustainable and inefficient cooking technologies or practices can have direct impact on food preparation, and indirect effects on local biomass resources overexploitation, health of local people, and social conflicts between hosted and hosting communities. This study aims at presenting a systematic review of both scientific and grey literature on cooking technologies and related practices, including a selection of experiences from the implementation of cooking devices in humanitarian projects and programmes. The Authors conclude that the attention to the problem is arising, but still very few information is available, in terms of scientific research.

Introduction

Natural disasters, population growth, social conflicts, political or structural crises often are a cause of forced migrations, which can lead to humanitarian emergencies. The number of forcibly displaced people in the World at the beginning of 2015 was more than 55 million, the highest in the last decades. The United Nations High Commission for Refugees (UNHCR) reports that about 15 million are refugees, while about 34 million are internally displaced persons (IDPs). Moreover, about 2 million are considered as asylum-seekers. Numbers have been particularly increasing for the last 4 years [1]. Such people have several needs and one of the most relevant for preserving a decent standard of living is food security. Humanitarian actors usually try to address them focusing on food availability and access, while food utilization – a fundamental pillar of food security – is often neglected [2]. The lack in technologies for appropriate and safe food utilization leads to malnutrition and weak health, enhances causes of mortality, and creates a status of permanent emergency.

Humanitarian emergency response deals, in first place, with food safety and security, but most of the food provided by humanitarian agencies has to be cooked before eating. The way food is prepared has an important impact on nutrition: in the case of Niger, for example, the distributed food had to be prepared with boiled water (and this happened 3 or 4 times a day). Since traditional cooking generally requires a great quantity of fuels, and takes time, it was found that rations were consumed dry (limiting the nutritional value) or prepared using non-boiled water (raising the risk of infections) in the vast majority of cases [2].

In this framework, sustainable energy technologies can play a key role to provide efficient, reliable and equitable access to basic services, such as cooking and food preservation. Furthermore, the issue of access to cooking energy in humanitarian contexts is also at the core of other challenges, such as protection, relations between hosts and displaced people, environmental damage, overexploitation of natural resources, etc. [3]. As a matter of facts, in many cases, women and children must cover long distances to find firewood and have to carry heavy loads back to the camps. This puts them at risk for physical and sexual attack, physical injuries, and other problems. Women and children are also exposed to health risks, especially asthma, pneumonia, or other respiratory infections due to the smoke produced by inefficient cooking

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Acronyms

CO	Carbon monoxide
CO_2	Carbon dioxide
DALY	Disability Adjusted Life Year
DME	Dimethyl ether
DRC	Democratic Republic of Congo
EA	Environmental Audit
EIA	Environmental Impact Assessments
FAO	Food and Agriculture Organization
FNC	Forest National Corporation
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GBV	Gender Based Violence
IAP	Indoor Air Pollution
ICS	Improved Cooking Stove
IDP	Internally Displaced Person
IEA	International Energy Agency
LPG	Liquefied Petroleum Gas
NGO	Non-Governmental Organization
PM	Particulate Matter
SAFE	Safe Access to Fuel and Energy
TLUD	Top-Lit Up-Draft
UNHCR	United Nations High Commissioner for Refugees
USAID	United States Agency for International Development
UXO	Unexploded Ordnance
WHO	World Health Organization

systems [4–6]. In addition to this, refugees often sell or exchange a portion of their food rations in order to procure the firewood needed to cook the remaining food. Moreover, in situations where firewood is the main resource, such as in sub-Saharan Africa, the competition for the access to fuel is a trigger for tensions between refugees and host communities. The collection of firewood by refugees can cause deforestation or degradation of green areas, which can have a permanent impact on the local environment [5,7].

At the international level, the Safe Access to Fuel and Energy (SAFE) initiative is trying to draw the attention on the issue of energy in the case of crisis-affected populations, in particular refugees and IDPs [8]. On the other hand, the level of attention of academic and scientific research in the field is still weak, despite several gaps are evident, in particular regarding rigorous and independent impact assessments of programmes [9].

Aim and structure of the work

In the light of all the factors concurring to the situation previously depicted, this study aims at presenting the results from a systematic review of available scientific and grey literature on cooking technologies and related practices in humanitarian contexts. The analysis includes a selection of experiences and findings from the implementation of improved technologies in humanitarian projects and programmes developed up to now.

The work is organized in two main parts: in the first one, we present a review of the main typologies of Improved Cooking Stoves (ICSs) and other cooking technologies, with a specific focus on humanitarian contexts. In the second part, we carry out a review of scientific and grey documentation on the experiences and impacts from different humanitarian projects focusing on the specific issue of cooking; we identified four main areas of study and research, namely: (i) *Environmental impact*; (ii) *Health*; (iii) *Safety*; (iv) *Education, livelihood, and social issues*. We searched for peer-reviewed papers by Science Direct editorial platform and Scopus database, and reports within the grey-literature produced by international organizations and institutions within the Union of International Associations – IGO Search engine [10] and PubMed, using the following key-words and combinations: Improved Cook Stoves, biomass fuel, biomass stove, solar cooker, fireless cooker, firewood, internally displaced, refugee, humanitarian. Among all the papers matching our key-words, a selection has been carried out, based on the following rules:

i. reference context of the documents must be related to humanitarian settings: refugee camps, IDPs camps, informal settings.
ii. documents must deal with experiences related to the use of ICSs and biomass cooking technologies within the abovementioned context. Works that merely cite or touch upon campaigns of stove dissemination, without providing any detail on the technology and/or mention to the impact on people, have been discarded.
iii. publications date must be in the years ranging 1995–2016.

Cooking stoves taxonomy and their utilization in humanitarian contexts

According to the World Energy Outlook 2015, 2.7 billion people in the world rely on such stoves, and in particular on traditional ones [11]. In fact, in developing and emergency contexts, such traditional biomass cooking stoves are generally used for water and space heating, lighting, smoking and cooking food.

In general terms M. P. Kshirsagar and V.R. Kalamkar define a "Biomass cookstove" as "a physical structure that contains air-fuel combustion for heat release, and subsequently, directs the heat of combustion towards a cooking target (pot/pan/griddle)" ([12], p. 582).

Traditional cooking stoves

A univocal definition of traditional cooking stoves does not exist, since the term refers to devices, which differ according to the specific context. Usually, the term identifies very cheap or no cost models of stove, whose use is well established within people's traditional habits. In most cases, they are characterized by very low efficiency and high Carbon monoxide (CO) and Particulate Matter (PM) emissions. The literature commonly identifies four models of traditional stoves: *three-stone fire stoves*, *mud stoves, metal stoves* and *fired clay* (*viz.* ceramic) *stoves*. The former, often named "open-fire stoves", are simple and zero cost fires built directly on the ground where three stones work as the pot support. The main drawbacks of such devices are the large amount of radiative thermal losses toward the environment, the huge amount of PM produced during the combustion, and the exposure to open burning flames. On the other side, the fact the flames surround directly the pot makes them sometimes more efficient than other cooking devices [13,14].

Mud stoves are structures made of sun-dried mud dried by heat from the fire with a hole for placing the pot on the top and three sides that enclose the fire (Fig. 1left side). They are semi-permanent stoves and they are usually built on site, with no-cost or at least very low. They are supposed to be more efficient than three-stone fire stoves since the enclosed fire caused a reduction

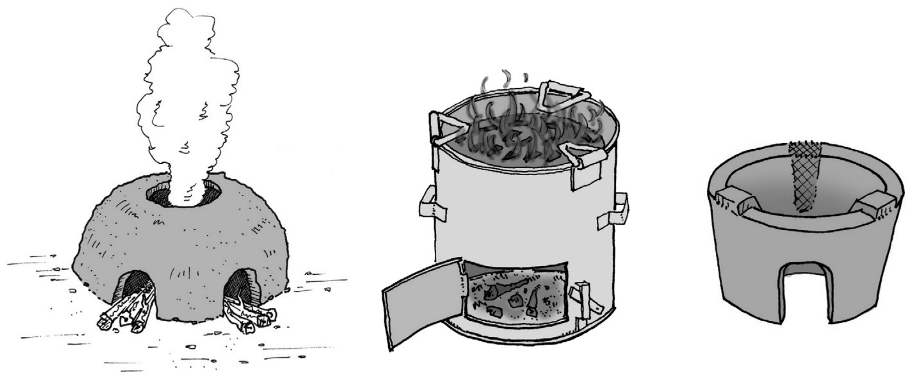

Fig. 1. Sketches of mud, metal and fired clay stoves (adapted from [25]).

in radiative losses [13], but it depends on the models and how they perform on the field, since sometimes they show higher fuel consumption rates [15]. Mud stoves are suited to be home-made. According to M. P. Kshirsagar and V.R. Kalamkar [12], examples of traditional models include *Chullah*, *Angithi*, and *Haroo* in India [16], *Mogogo* and *Jiko* models in Africa and *Plancha* in central and south America [17–20]. Mercy Corps and S. Abdelnour report the use of mud stoves respectively in Mugungu and Goma camps in the Democratic Republic of Congo (DRC) and Darfur [21]. Y. De Mol in [22] reports the adoption of improved mud stoves in Darfur and South Sudan within the context of Food and Agriculture Organization (FAO)'s Dimitra Project, where women experience both cash savings on wood and charcoal collection and a reduction in the required time for fuel collection. The UNHCR reports that in 2002, training on the construction and use of energy-saving mud stoves benefited 1400 households within camps and villages in Sudan, resulting in a 40–60% saving in fuel consumption [23]. In 2005, refugees in Gihembe camp (Rwanda) were trained in the construction of stoves and fuel-saving practices [24]. Nevertheless, user-constructed stoves could result in low efficiency and durability when appropriate design principles are not applied in a rigorous manner [25]. As a matter of fact, an inappropriate primary air supply may result in incomplete combustion, leading to increase the CO and PM emissions and the Indoor Air Pollution (IAP).

Uninsulated metal stoves are cooking stoves made of steel, metal sheet, or cast iron (Fig. 1centred side). They can be easily built using scrap metal such as cooking oil containers or old oil drums, with no or at least very low cost. A stencil should be used to guide the cutting of the components that can be coupled together by semi-skilled artisans. For this reason, the stoves can be built by local people, but they should be specifically trained. One of the most widespread model is the *VITA* stove developed by S. F. Baldwin, who provided detailed instructions on how to build the stove in [26]. They are very perishable, and a low-maintenance exposes them to brief lifespan due to corrosion and rust [25]. M. P. Kshirsagar and V.R. Kalamkar report some examples of this kind of stoves [12]: *Jumla* stove in Nepal and *Bukhari*, *MA-II* and *I* in South-Asian regions [27], and *metallic Jiko*, suitable for charcoal, in Africa [14]. More recent and commercial models exist as well, like *Vikram*, *Harsha*and *Magh* stove in India [28,29]. ProAct Network no-profit Organization states that mud stoves and metal stoves were the most widespread models used among IDPs, refugees and local residents in West Darfur until 2008 [30].

Fired clay stoves, also known as ceramic stoves, are made of sand, clay, straw, mica, sawdust and grass, mixed with binding materials, as mud stove (Fig. 1right side). The major difference is the possibility of baking the clay in an appropriate kiln that increases the durability and reliability of the material. In this case the specific skills of potters are required as well as stencils/moulds and tools for kneading the material, which make the costs higher even until 10–20$ [25]. Detailed guides on their construction are provided for example in [31–33]. Groups of refugees or local artisans might need up to several months in training in clay stove making [25]. Traditional models promoted by international programmes are the *Upesi* (also known as *Maendeleo*) stove in Kenya [34,35] and the *Chitetezo Mbaula* in Malawi [34–36], with applications in refugee camps, as described by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) [37] and United States Agency for International Development (USAID) [38]. The use of clay stoves in refugee camps as substitutes of the more traditional 3-stone fires has been reported by S. Dick in [39] and by UNHCR in a refugee camp in Kenya, within the GTZ-RESCUE and the Somali Refugee Programme in Kenya [40]. A. Thulstrup and W.J. Henry note that two model of stoves were selected by the communities of IDPs in Yei County, South Sudan: a portable ceramic charcoal stove and a stationary mud/brick stove which uses both fuelwood and charcoal. According to M. P. Kshirsagar and V.R. Kalamkar [12], recent models of fired clay stoves have a metal cladding to increase durability by protecting the ceramic and clay structure from possible accidental blows and natural crumbling away process, like the Ethiopian *Lakech charcoal stove* [41], the Cambodian *New Lao Stove,* the Kenyan *Gyapa*, *Uhai* and *Ceramic Jiko.*

Improved and modern-fuel cooking stoves

Improved cooking stoves (ICSs)

The literature lacks of a clear and univocal definition of ICSs. The term has been historically referred to cooking stoves installed in "legacy" programmes, usually equipped with close combustion chamber and a chimney, but without common standards regarding their performances [42]. Some sources define a cooking stove as improved with reference to a traditional model. For example, GIZ HERA [43] refers that cooking stoves can be defined as "improved" if they show higher efficiencies than the traditional ones, while O. Freeman and H. Zerriffi [44] consider that all the stoves that reveal some improvements respect to the replacing technologies (as the *three-stone fire stoves*) are ICSs. More often, the term improved refers to some specific energy requirements and design features of a stove: the World Bank [42] refers that "cookstoves with chimneys and closed combustion chambers were usually considered *improved*" (p. 4), while T. Urme and S. Gyamfi [45] report that the ICSs are designed to achieve higher thermal and fuel efficiencies, as well as to reduce the harmful pollutant emissions and increase the safety of operation. A number of cooking stoves are classified as "improved" based on their design, as well as on indicators of performance evaluated through laboratory-based tests. Based on the definitions of ICS, sometimes also traditional mud, metal and clay stoves may result as improved if compared to a tra-

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ditional three-stone fire. In particular, the UNHCR promotes such traditional devices as improved, since they could potentially achieve energy savings of about 20–30% over three-stone fires, usually the most wide-spread adopted cooking method in humanitarian contexts [46]. As an example, the UNHCR [46] reports that some Bangladeshis refugees constructed semi-submerged stoves made of mud so that the fuel entrance remains underground and the pot is placed at floor level in order to maximize the thermal efficiency.

In order to give a detailed picture of ICSs in humanitarian contexts, in the next sections we describe the most common models and their utilization on the field.

Rocket stoves. Among all the existing cooking devices, the rocket stove is the most widespread model of ICS [12]. The term refers to a designed model of stoves with a combustion chamber made up of two orthogonal parts: an insulated upright chimney (with a height of two or three times the diameter) and a horizontal zone where wood sticks are placed. Different models exist, from domestic to institutional use, insulated or not, with and without skirt, fuelled with wood or charcoal (Fig. 2).

Commercial models are usually expensive, up to 100–150 $, and not so common in refugee camps, where people could build their own models with local waste materials such as cans and sands [25]. The Non-Governmental Organization (NGO) TChad Solaire reports the use of the homemade *Save 75* metal rocket stove in Touloum Refugee Camp, Chad [47]. A project proposal [48] presented by GTZ (now GIZ), Divisional Environmental Committee, UNHCR and Government of Kenya in 2008, within the "Strengthening Protection Capacity Project" programme of UNHCR, considered the expansion of the availability of the fuel-efficient "rocket stove" by training refugees of Kakuma and Dadaab camps in Kenya. The stove, made of bricks arranged in a narrow, tall circle, was supposed to save 60% of fuel compared to a 3-stone fire, and 30% compared to the local Maendeleo clay stove. USAID reports a pilot test made in the Dadaab refugee settlements on two "Rocket" type direct combustion stoves of the "Envirofit International's Family of Rocket Stoves" and "StoveTec family". The models resulted to be most closely resemble locally produced stoves already used in the camp in terms of design, operation, and fuel size, and almost immediately familiar to the women [38]. Pilots of different commercial models of rocket stoves have been carried on in Darfur with *Save80* and *Berkeley Tara* models [49]. Uses of *Stove80* are reported by UNHCR among Sudanese refugees living in Touloum camp, Chad [50].

Some models called forced air rockets have a blower injecting air above the fire. Forced air should improve the combustion process and increase the energy performance [12,51]. Other models can be provided with thermoelectric generator (TEG) modules which can produce small amounts of electricity [52,53]. Y. Kazerooni et al. [54] report the use of BioLite *CamStoves* for cooking and generating electricity by many hurricane Sandy survivors.

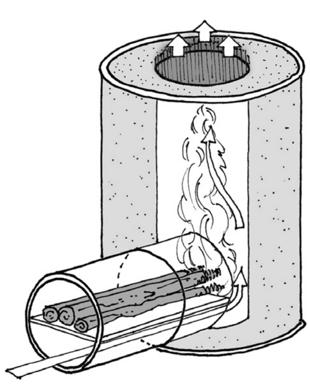

Fig. 2. L-shape combustion chamber of a rocket cooking stove model [25].

Micro-gasifier. Gasifier (*or* wood-gas) stoves are another famous category of ICSs. The term refers to a model of stove which works via multistage combustion. This particular device makes it possible to separate the stages of drying, pyrolysis, char-gasification and final gascombustion that in a common solid biomass stove are overlapped, with a great decrease in combustion efficiency. A common and easier-to-build gasifier, where the stage of char gasifation is suppressed, is called a micro-gasifier. In this case, the process can be schematized though two stages of combustion in which the biomass fuel is first burned in the lower part of the combustion chamber, causing a decomposition of the biomass into volatile gases and vapours, while a solid char remains behind (Pyrolysis) [25,55]. Through a second flux of air towards the top of the stove, the gases that are released in the first stage are mixed and burned (Gas-combustion). A scheme of a micro-gasifier and gasification process is given in Fig. 3. The gasifier stoves can be equipped with fan – like *Philips* stove developed by Royal Philips Electronics of the Netherlands [12,56] – or they can operate through natural draft – like *Vesto* model developed by the New Dawn Engineering (Swaziland) [57], *Champion*, *Karve* and *Sampada* from India [27,56]. These stoves usually cost in the range of 20–50$, but their cost increases if fixed devices with a chimney are considered (up to 100$). Dissemination of micro-gasifiers in humanitarian contexts has been experienced by WorldStove [58], which, after the Haitian earthquake, stress the need to supply displaced people and disaster victims with affordable and reliable cooking devices. COOPI – Cooperazione Internazionale and Politecnico di Milano proposed an adapted version of the *Elsa* micro-gasifier for a pilot-project in a Lebanese informal settlement [25], but local surveys confirmed that such technology did not became familiar to people because they find it is too hard to light it. C. Birzer et al. [59] investigate the potential use of dung-burning top-lit up-draft (TLUD) micro-gasifier cooking stoves for humanitarian purposes. In addition to this, a study of Berkeley Air Monitoring Group, prepared for USAID in 2010, evaluates the performance of *Vesto – The Variable Energy Stove* micro-gasifier, along with other different four models of commercial rocket stoves, for application in Dadaab Refugee Camp in Kenya [38]. Lastly, C. Roth reports an application of the *PekoPe* model in a refugee camp in Uganda in 1994 [55].

Modern-fuels cooking stoves

Liquid and gas fuelled stoves include stoves that utilize modern fuels like Liquefied Petroleum Gas (LPG), biogas, ethanol gel, vegetable oils, dimethyl ether (DME) and electricity [60] (Fig. 4). Generally, lab tests suggest that their thermal efficiency is high (up to 55%) and the level of pollutant emissions is very low or null. However, emissions may be higher in the event of improper use of some of these fuels, for example the improper use of vegetable oils such as jatropha oil. There are also hybrid stoves fuelled by more than one fuel, for example kerosene and vegetable oil, or paraffin and ethanol gel [25].

Due to the frequent unavailability and the high cost of these fuels and the stoves themselves (they can be bought in local markets at between a price range of 10 – 50$ or even more), these stoves are not very common in developing countries. In humanitarian settings, application can be found in Ethiopian refugee camps, where stoves fuelled by ethanol have been successfully disseminated by "Gaia Association" in place of kerosene stoves, which was considered smoky, dangerous and too expensive [61]. The UNHCR and the Forest National Corporation (FNC) provided 4256 households in Eastern Sudan refugee camps with LPG units as a means for the promotion of clean domestic energy for cooking

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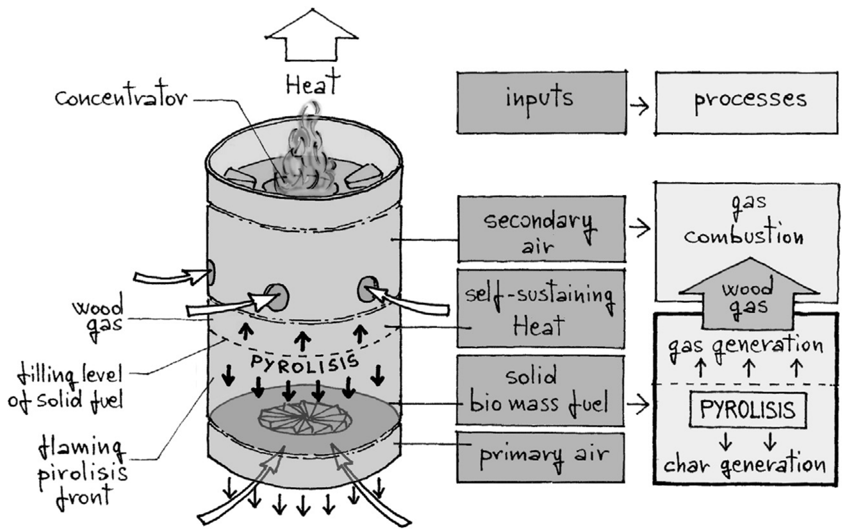

Fig. 3. Scheme of the gasification process [25] (adapted from [55]).

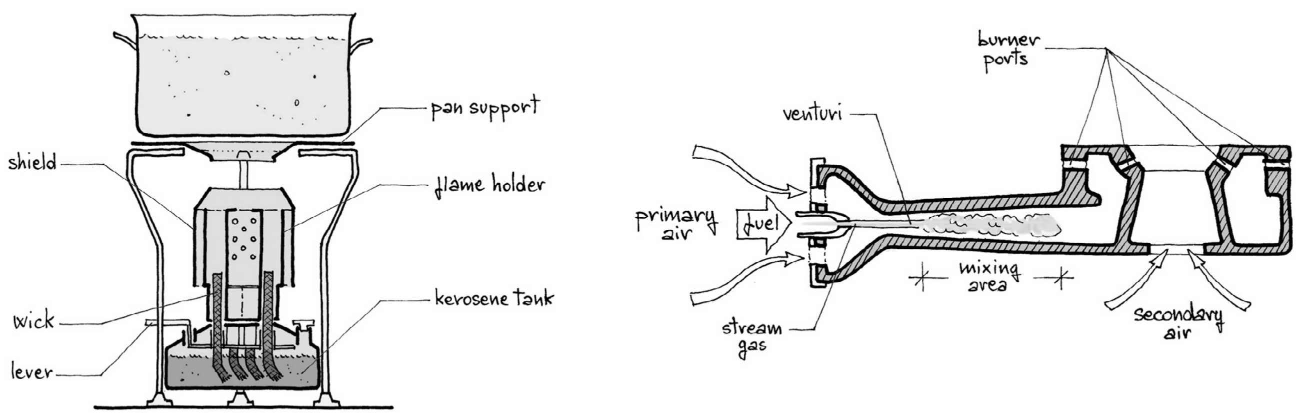

Fig. 4. Sketch of a liquid *range wick* burner (left-side), and a Gas stoves/Burners (right-side) [25].

[62]. G. Lahn and O. Grafham describe the experience of Practical Action in facilitating the development of a local LPG market in El Fasher in North Darfur, an area with *peri*-urban and rural villages and IDP camps [63]. M. Ahmed reports the use of LPG stoves and mud stoves among IDPs at El Genaina Locality, West Darfur State – Sudan [64]. GIZ [65] carried out a pilot project in the Kakuma Refugee Camp in Northern Kenya with ethanol stoves: the refugees appreciated the stoves, but the lack of stable and sustainable LPG provision prevents their widespread adoption. Pennise et al. [66], C. O'Brien [67] and E. Hassen [68] report the use of the ethanol stove *CleanCook* among the inhabitants of Kebribeyah Refugee Camps in Ethiopia. C. Rogers [69] states that Gaia has distributed almost 4000 ethanol combusting stoves throughout refugee camps in Addis Abeba, Ethiopia, within the Gaia Project. An application of electric stoves for baking injera is reported by M. Bizzarri in Mai Aini refugees camp in Ethiopia [70].

Additional cooking technologies

With the term *Additional cooking technology*, we refer to the category of devices that can be worth using only as supplementary or additional cooking devices, adopted at family level. The introduction of such technologies in the household economy may allow a decrease in the use of fuels and consequently the related costs and emissions with respect to using only solid, liquid, gas and electric fuel stoves. On the other hand, they increase the time of cooking but they would be useful where the cost of fuel is high, the performance of the stoves is very low and fuel collection entails social problems (e.g. women who expose themselves to Gender Based Violence (GBV) or the time lost for undertaking this activity) [25]. In this work, we introduce main categories of additional clean cooking technologies for application in humanitarian contexts: *hay boxes* and *solar cookers*.

Solar cookers

Cooking with the sun is a potentially viable supplementary cooking option to fuelwood in food preparation [68] through particular devices called Solar Cookers. A solar cooker is a device that uses the energy of sun radiation for heating, cooking or pasteurizing food or drink. Different types of solar cookers have been developed all over the world and they can be categorized in a schematic way that identifies three main models [71]: panel (a), box (b) and parabolic (c) cookers (Fig. 5).

Panel Cookers consist in simple surfaces – made of corrugated papers or plastic – that reflect sunrays on a black pot. To enhance the greenhouse effect and reduce the convective heat losses, the pot is often covered with a transparent bag. This model is quite ineffective under cloudy conditions, since its performance highly depends on reflected direct irradiance [72]. Thanks to its low cost and ease of construction it has a widespread distribution [71]. Doz-

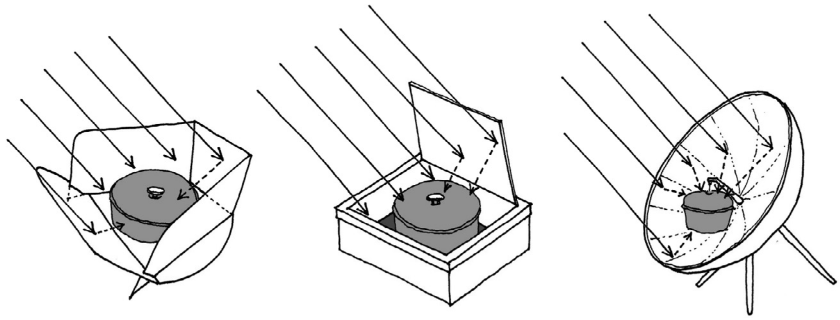

Fig. 5. Categories of solar cookers: (a) panel, (b) box and (c) parabolic cooker.

ens of models exist [73], and the *CooKit* and *Funnel* types are the most popular models, even if commercial models are more expensive, up to 40–50$ [74]. In 2005, 15 thousand *CooKits* were introduced in the Iridimi camp through the Solar Cooker Project carried on by TchadSolaire, Cord NGO, KoZon Foundation, Jewish World Watch, and Stichting Vluchteling. The project aimed at reducing refugee's reliance on firewood, as well as improving the safety of the refugee women [75,76]. Indeed, women's outings from the camp to collect firewood have been reduced by 86%. In January 1995, Solar Cookers International started a dissemination programme of solar panels in the Kakuma refugee camp, which was formed in 1972 when Sudanese refugees first arrived in Kakuma, Kenya. The project served over 15,000 families and it was one of the earliest to use the *CooKit* solar panel cooker to introduce solar cooking [77]. Thanks to a project started in 2006 and run by Tchad Solaire and by the British NGO CORD, more than 50,000 people in four Darfur refugee camps in Eastern Chad are using locally made *CooKits*. They stated that the project has improved the safety and survival of the women in the refugee camps, while previously they were faced with dangerous and arduous trips outside the camps to collect scarce firewood. In the end of nineties, In Ethiopia, a project carried on by Solar Cooker International concerning the dissemination of *CooKit* stoves made of reflective cardboard with a plastic bag to contain the food and pot was piloted within the Aisha Refugee Camp in Ethiopia. It was found that almost 95% of households used the *CooKit* for some of their cooking activities, achieving up to 44% firewood savings and 78% charcoal savings [78].

Box Cookers consist in an insulated box with reflective surfaces, a transparent top face and a black painted bottom, where a black pot is located [79]. They heat up slowly, because the sunrays are not concentrated on the pot. Thanks to their good insulation, they work satisfactorily in the presence of wind, intermittent cloud cover and low air temperature [80]. If built with local scrap materials like corrugated paper, the cost is in order of few dollars, while commercial models can cost up to 200$ [81]. Trans World Radio pioneered solar cooking in the Kenyan Kakuma Refugee Camp in the early 1990s, promoting homemade box cookers among refugees [82]. In 2010, Trust in Education no profit organization, under the leadership of Jack Howell, started distributing solar panel and box cookers in refugee camps in Kabul, Afghanistan [83].

Parabolic Cooker consists in parabolic reflectors supported by a wood or metal structure, with a cooking pot located in the focus point of the cooker. The Solar Parabolic Cooker reaches very high temperatures quicker than the two models described previously: therefore, there is no need of special cooking vessel or transparent covers for the pot [71]. On the other hand, since the irradiance is concentrated on the focus point, Parabolic Cooker requires a frequent manual azimuthal tracking – less than 5 min [84,85]. Commercial devices are the most expensive solar cooker models, up to 300–400$. The Vajra Foundation Holland has worked in the Bhutanese refugee camps in Nepal since 1995 to bring solar cooking and heat-retention cooking to the refugees there. By 2013, 85,000 refugees were cooking their meals using these methods [86]. The use of parabolic devices has been registered also in Kakuma Refugee Camp in Kenya [77]. Regattieri et al. [87] developed a portable parabolic solar cooker that can be used in refugee settlements, by recycling the card board box used for the packaging of humanitarian supplies and Al-laminated kitchen-set.

New and innovative models of cookers are emerging, increasing the potentiality of solar cookers to be used also as a primary device for cooking. No application in humanitarian contexts have been found so far, mainly due to their complexity and economic reasons. University of Iowa [88] developed the *iHawk* Cooker in villages in Rajasthan: a half-pipe parabolic reflector concentrates solar rays onto a second V-shaped mirror in the centre, which reflects the radiation on an absorber plate inside a plywood box, filled with sand and aluminium cans, that works as a storage for cooking during the day and night. Joshi and Jan [89] developed a small scale box type hybrid solar cooker connected with PV panels, in order to increase efficiency, maximum temperature and to enhance the possibility to cook at night by storing electrical power in a battery. Harmim et al. [90] presented a new box-type solar cooker equipped with an asymmetric parabolic concentrator, which allows to cook without the need to track the device towards the sun during its operation. Esen [91] fabricated a solar cooking device composed by a box connected with vacuum-tube collectors containing a refrigerant as working fluid; the device, if compared to traditional parabolic and box cookers, results as more expensive and complex, but it allows to cook different types of food in a range of 27–70 min, and to reduce the risk of being harmed by concentrated irradiation.

Hay boxes

A hay box (or fireless cooker/straw box/insulation cookers/retained-heat cookers) is an insulated container where a partially cooked food can be stored in order to continue cooking with no need to consume further fuel or external heat (Fig. 6) [25,92]. In such contexts with limited access to fuels, particularly for food requiring a long cooking time (*i.e.* legumes and rice), food can be initially brought to a boil with a traditional stove and then placed in a hay box to complete the cooking without burning any further fuel [25]. Therefore, instead of simmering it over fire, the food continues to cook over a longer period inside the fireless cooker, using its own stored energy and reducing the fuel use by even 40% [92]. As main drawbacks, the length of cooking time required in a hay box is higher compared with a traditional stove – food prepared in a hay box normally requires more than one to two times the normal cooking time [93], and there is risk of bacteria growth if food remain too long at temperatures dropped below 60 °C.

They can be easily built starting from a basket, cloths and pillows, at zero or very low cost. Within humanitarian settings, The

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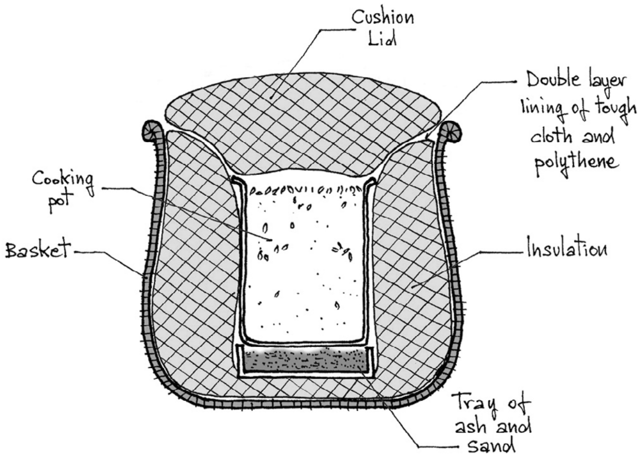

Fig. 6. A diagram of a hay box.

Vajra Foundation Holland [86] has been active in the Bhutanese refugee camps in Nepal since 1995 to bring both hay boxes and solar cookers to the refugees there. From 2001 to 2003 hundreds of hay boxes were distributed, covering the main sectors of Beldangi-I camp. After 2006, the Vajra Foundation Holland received nearly $1 million for their programme, and they disseminated 6300 solar cookers and 12,000 hay boxes to families in the camps as well as an extensive use and maintenance training. The UNHCR[94] reports that a total of 3500 units of *Save80* stoves and fireless cookers were distributed in 2010 in refugee camps in Chad, Djibouti, Ethiopia, Kenya, Rwanda, Sudan, Togo and Uganda.

Comparative table of cooking stoves

A comparative analysis of all the cooking technologies analysed in the previous paragraphs is given in Table 1.

Review of the impact of ICSs and traditional cooking stoves in humanitarian context

In the following sections, we present the review of the results of available scientific and grey literature on the impact of cooking technologies on people and related practices in humanitarian contexts. The review includes more than 100 documents, published from 1995 to 2016 within international peer-reviewed journals and grey literature. The selected papers have been organized and grouped according to four main areas of study and research: (i) *Environmental impact*; (ii) *Health*; (iii) *Safety*; (iv) *Education, livelihood, and social issues*. We defined the categories based on the main issues and research themes arising from the analysis of the literature.

Environmental impact

When disasters occur, increased dependence on local resources such as wood fuels increases the vulnerability of populations and sets back remediation. In general, the influx of refugees can constitute a shock to the ecological system of the host area due to the sudden increase in the human population. The presence of refugees or IDPs can cause severe additional environmental impact not only in the place where camps or informal settlements take place, but also in the surrounding areas, due to an unsustainable demand for natural resources. One of the most relevant issues is deforestation or degradation of forests and other green areas. In turn, deforestation worsens and concurs to the environmental degradation caused by erosion, sedimentation, floods, decline in ground water availability, loss of wildlife, desertification and loss of well-being and livelihood security among communities living near the affected area. To give an example, for the case of Darfur, M. Bizzarri [95] directly reports a number of different impacts: (i) depletion of soil and declining of yields due to the over cultivation and overgrazing in reachable areas, with no use in other areas that are not reachable, and (ii) eradication of traditional seasonal harvesting, livestock migration and resolution of disputes. In North Darfur, the problem of massive deforestation is exacerbated by the no-longer-sustainable demand of environmental resources and the increased reliance on "fuelwood intensive livelihoods" like the manufacturing of bricks, the production of charcoal and the collection of firewood [95].

Huge and irreversible damage often threatens the livelihood base of hosting communities. In other cases, the placement of camps close to a national park or other area of ecological importance can threaten wildlife resources and destroy natural heritages. While the use of timber and poles for construction of refugee huts typically occurs in the short-term, after the arrival, in the medium- to long-term the collection of firewood for cooking and heating is the most environmentally damaging activity in refugee situations. For this reason, firewood supply tends to be the most serious cause of environmental impact associated with refugee camps [21,96].

At the global level, it is estimated that more than 64,000 acres of forest are burned each year by forcibly displaced families living in camps [63]. On the other hand, when looking at the situation in specific countries and areas, a number of documents report cases of deforestation or forest/woodland degradation due to firewood needs in humanitarian crises. A selection quantitative information about relevant cases is given in Table 2, based on a review by M. van Dorp [49].

In addition, qualitative evaluation of impact on forests and woodlands is given also by other studies in different places, such as Ethiopia, Kenya, Rwanda, Sierra Leone, Nepal, Sri Lanka [3,39,49,69,70,95,97,98]. In many cases, the overexploitation of woodlands is so huge, that refugees are forced to sell or barter some food to get some firewood. For example, this situation was observed in refugee camps in Kenya (Kakuma and Dadaab camps), where it is estimated that an average of 25% of food was bartered to supplement cooking energy [99]. In Malawi, S. C. Babu and R. Hassan report that fuelwood crisis was so bad that the butter fat distributed to the refugees for cooking was used as a source of fuel [100].

The specific demand for firewood or charcoal depends on the kind of cooking technology in use, but also on other factors such as the type of food that is prepared, as well as climatic conditions, which determines the eventual need for heating [101]. In most cases, refugees or IDPs heavily rely on traditional stoves such as 3-stones fires, mud stoves, or metal sheet stoves for cooking and other purposes. These kind of technologies have very low efficiency, and cause the consumption of great quantities of energy. The choice of type of foods distributed to the refugees also influences the need for fuelwood resources. For example, according to S. C. Babu and R. Hassan [100], pigeon peas that have been distributed to refugees in Malawi, require at least 50% more fuel for cooking than other foods, such as maize flour.

As regards impact at the global level, carbon dioxide (CO_2) emissions from displaced people are a small amount in terms of share of total world's emissions, but, on the other hand, the estimated emission of 13 million tons of CO_2 per year appears to be disproportionately high in absolute terms [63]. Moreover, traditional cooking devices emit huge quantities of black carbon. The contribution of such element to climate change is at the moment unclear, however some scientists have estimated that black carbon warming is in the range 27–55% that of CO_2 [102,103].

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Table 1
Comparative table of cooking technologies.

	Traditional				ICS		Modern			Additional	
	Three-stones	Mud	Metal	Fired clay	Rocket	Micro-gasifier	Electric	Liquid fuel	Gas fuel	Solar cooker	Hay box
Fuel	Wood	Wood	Wood/charcoal	wood/charcoal	Wood/charcoal	Wood	electricity	Kerosene/ vegetable oil/ ethanol	LPG	–	–
Materials	Stones	Sun-dried mud	Steel/metal sheet/cast iron	Mix of clay, straw, mica, sawdust and grass	Steel/metal sheet/cast iron/clay/bricks	Steel/metal sheet/cast iron	Metal	Metal	Metal	Wood/ metal/cardboard	Any insulating material
Cost (commercial models)	Null	Very low	Very low	10–20$	100–150$	20–50$ (up to 100$ with chimney)	Depends on model	Depends on model	Depends on model	40–50$ (panel) 150–200$ (box) 300–400$ (parabolic)	–
Efficiency	Very low	Low	Low	Low	Medium	Medium to high	Very high	Very high	Very high	–	–
Examples of models	–	Chullah, Mgogo, Plancha	VITA, Jumla, Bukhari, metallic Jiko	Upesi, ChitetezoMbaula	Save 75,Save 80, Berkeley Tara	Philips, Vesto, Champion	–	CleanCook	–	CooKit, iHawk	
Examples of contexts	Any	DRC, Darfur, South Sudan	Darfur, Nepal	Malawi, Kenya, South Sudan	Chad, Kenya	Haiti, Lebanon, Kenya, Uganda	Ethiopia	Ethiopia, Kenya	Sudan, Darfur	Kenya, Darfur, Ethiopia, Chad, Afghanistan, Nepal	Nepal, Chad, Djibouti, Ethiopia, Kenya, Rwanda, Sudan, Togo, Uganda

Main issues for mitigation

From the previous analysis, the extreme complexity of facing and mitigating the impact of refugees and IDPs on the environment, with particular reference to the issue of deforestation and forest degradation, is evident. As a consequence, mitigation actions which do not face this complexity, neither take into account the multiple concurring elements, cannot be fully effective. In this framework, a list of the main social or technical considerations comes from a couple of key documents published by UNCHR [40,96]:

1. Energy-efficient cooking technologies play a fundamental role, but their potential should not be over-estimated;
2. Centralized systems, as well as pooling of cooking between groups of families, improve the efficiency of cooking operations and limit fuel consumptions;
3. Energy sources other than firewood or charcoal should be examined;
4. Right cooking techniques can save substantial amounts of energy;
5. Afforestation and environmental policies should be put in place.

As regards efficient cooking technologies, ICSs may have the potential to save energy and fuels, compared to traditional open fire systems. By reducing firewood demand, clean cooking technologies can reduce as a consequence environmental impact on forests and green areas [63,96,104]. Studies from the field report some promising results achieved by such technologies. For example, T. Bodson and C. Kavira [105] report that in Goma (DRC), the utilization of the locally-produced *Jiko Nguvu Nyeusi* stove permitted to save up to 50% of charcoal compared to traditional devices. The distribution of the stove to many households permitted to estimate the reduction in the overall charcoal consumption of the city of Goma by over 22.3% in 2012. According to the authors, this means that more than 3000 hectares of natural forest may have been saved thanks to this action. Significant firewood savings, in the range 30–70% have been reported also in Darfur region [30].

Centralized cooking can lead to even greater savings: according to [40], institutional stoves can achieve up to 80% savings in daily per capita wood consumption. This can be particularly appropriate in situations such as transit camps, or community centres like hospitals and schools. On the other hand, centralized cooking can result in negative social consequences at family level. For this reason, pooling of cooking technologies and operations between groups of families is referred to as a good compromise in most cases.

Interesting findings on efficient cooking technology also came from the experience of the Gaia project in Kebribeyah and Shimelba camps (Ethiopia) [69,106]. In these cases, efficient cooking technology was introduced, coupled with shift to cleaner fuel: the introduction of the *CleanCook* ethanol stove partially substituted the utilization of traditional biomass fuel. Ethanol was produced from waste molasses locally available. In Shimelba camp, the results of a local survey showed a 42% reduction in the amount of firewood used by the households. A pilot phase of the project in Kebribeyah camp characterized by a very high penetration of the technology, showed even better results: the provision of 1 L of ethanol per day to the refugee families replaced between 95 and 100% of their firewood use. According to M. Debebe, based on an average household consumption of about 3.7 tons/year of firewood, this would suggest savings of about 6600 tons/year, and of about 6.2 tons/year of CO_2 equivalent per each household [107].

The approach adopted in the latter cases is particularly interesting. As a matter of facts, many authors underline that the potential of improved stoves should not be over-estimated. For this reason, an integrated approach including other considerations and actions (points 2–5 of the previous list) has higher probability for a signif-

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Table 2
Documented environmental impacts (deforestation or forest degradation) due to firewood needs in humanitarian crises (Source: [49]).

Place	Origin of refugees/IDPs	Number of refugees	Reference period	Reported impact
Malawi	Mozambique	>1 million	1985–1995	Consumption rate of firewood estimated in between 500,000 and 700,000 m^3 per year. Evidence of extensive deforestation around the camps
Zimbabwe	Mozambique		1985–1994	58% reduction in woodland cover around the camps
Tanzania (North-Western)	Rwanda	524,000	1994–1996	Consumption rate of firewood estimated at 585,000 m^3 per year in Ngara district Overall, 570 km^2 of forest in Tanzania affected, of which 167 km^2 severely deforested
DRC (Virunga region)	Rwanda	≈730,000	1994–1996	Consumption rate of firewood estimated at 1000 tons per day. 105 km^2 of forestland impacted by deforestation, of which 35 km^2 totally denuded
Sudan (Darfur)	Sudan	2 million	2003–2008	Consumption rate of firewood estimated at 1500 tons per day. Distance for firewood collection have increased from 15 km to up to 75 km or more from Kalma Camp

icant mitigation. The opportunity of a shift to cleaner fuels, such as LPG, and/or fuels produced from waste biomass, such as briquettes or ethanol, is underlined also in other cases, such as in [3,21,64,95].

However, in many situations fuel shift is not feasible, due to different constraints. For this reason, other approaches are suggested, such as: (i) regulation of firewood collection, through organized wood supply. In this case, harvesting and distribution are locally conducted by an agency, while displaced people can participate in the process at various levels; (ii) fuel from other regions is purchased from an agency, and distributed to the people [3].

Another important element that should come together with efficient technology and fuel shift is the familiarity the user needs to acquire with the introduced innovations. As a matter of facts, right utilization of the devices, as well as complementary energy-saving practices, are fundamental in order to achieve the best results[1]. In this context, capacity building plays a fundamental role, as well as environmental education [3,39]. Moreover, Ahmed [64] reports a case in Darfur, where displaced people received a ICS, but only few people received training on how to use and maintain it. As a consequence, most of the people where not using the ICS regularly.

Lastly, many authors underline the importance of putting in place afforestation and/or environment conservation policies. M. Bizzarri, for the case of Darfur, states that environmental protection and recovery can be achieved by reducing soil degradation and deforestation associated with unsustainable collection of firewood, as well as by "investing in the regeneration of the forest base through interventions such as woodlots, community forests and tree-planting" ([95], p. 33). Moreover, other best practices are suggested in [99], such as: (i) the provision of tree seedlings for planting in institutional, as well as residential compounds; (ii) monitoring of firewood harvesting zones, and (iii) conducting Environmental Impact Assessments (EIAs) and Environmental Audits (EA) in compliance with Government. Moreover, S. C. Babu and R. Hassan [100] report that user-pay-based measures for regulating environment protection are no-longer sustainable in refugee contexts, while additional measures should be carried on by the host government and international relief agencies to decrease deforestation. General consensus is given on the importance of a direct involvement of refugees in the operations in order to ensure the long-term sustainability of such activities (see, in particular, [96]).

Health

The huge negative impact on health due to air pollution is widely recognised by the scientific community and international agencies. According to the latest Global Tracking Framework report of the International Energy Agency (IEA) and the World Bank [108], about 7 million people die every year due to outdoor and indoor air pollution. A large share of this picture occurs in low- and middle-income countries, and is related to the combustion of biomass with traditional stoves or three-stone fires [6]. Comprehensive reviews also addressing this issue are available in the literature, such as [5,109].

The specific case of displaced people is just a subset of the global picture. Based on World Health Organization (WHO) global data, Chatham House reports as a broad estimate that about 20,000 forcibly displaced people die prematurely every year due IAP caused by the utilization of traditional cooking methods [63]. When focusing on literature reporting the situation in specific areas, on the one hand few full quantitative information is available. On the other, a number studies report qualitative or mixed evaluation of health problems due to smoke inhalation. For example, in Shimelba camp (Ethiopia), most of the people declares that biomass fuel consumption has a negative impact on their health [106]. In particular, according to the study, 74% of the cooks interviewed report a cough, 64% suffer from headaches, 50% experience eye irritation, 31% of them suffer from shortness of breath, and 21% have constant phlegm. All these symptoms can be linked to cooking operations. Other studies in refugee camps show similar results, such as reported in [110] and [69]. In particular, in the latter the authors show that cooking with traditional stoves can result in CO levels enough to contribute to mild headaches, fatigue, nausea, and other diseases as well.

At the local scale, it is worth noting that different conditions heavily influence the impact of outdoor and indoor air pollution due to biomass burning. In this framework, a couple of papers report the results of an interesting analysis on the different impacts of IAP on two different sub-groups of refugees in Bangladesh, i.e. climate and non-climate refugee children under 5 years of age (according to the authors' definition, a climate refugee is someone who is displaced by climate change induced environmental disasters). Disability Adjusted Life Years (DALYs) lost due to asthma is used as reference indicator. The results show that, compared with the non-climate refugee's community, climate refugees are substantially more affected by asthma (DALYs loss of 70% in the latter case, compared to 45% in the other case). The difference is due to different characteristics of households and habits, and include cooking location, structure of the households, ventilation (present or absent), hours of cooking, etc. [111,112]. The research clearly shows how different local conditions and contexts heavily influence the impact of air pollution on health. Moreover, it is worth underlining that in the same context, different groups of people are influenced in a different way: in general, women and children are particularly vulnerable to health and respiratory problems, since they often reside in poorly ventilated dwellings, and are in charge for food preparation [69,113].

[1] Some examples are: firewood cutting and drying, careful control of the fire and air supply, accurate simmering, pre-soaking of foods, and the use of lids [40].

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Actions regarding the improvement of combustion efficiency through the adoption of cleaner technologies and/or shift to fuels other than solid biomass can give significant improvements in terms of emissions, and consequently health. D. Pennise et al. [66] describe the results of field testing of two different supposed improved stoves in different locations, also including refugee camps: the ethanol fuelled *CleanCook* stove (in the framework of the Gaia project), and the *Gyapa* wood-burning improved stove. Kitchen concentrations of PM2.5 and CO, were monitored before and after the introduction of the new stoves, referring to a baseline where traditional stove or open fire were used. The authors found significant improvements associated with both of the stoves, with a reduction of average 24-h PM2.5 concentrations in between 52% and 84%, and of average 24-h CO concentrations in between 40% and 76%. On the other hand, they underline that further changes in stove or fuel type or household fuel mixing patterns would be required to meet WHO air quality guidelines as per PM concentrations.

The results reported within Gaia project are endorsed also by qualitative evaluations carried out in [68] and [114]: beneficiaries declared significant reductions in the smell, eye irritation, headache, and other "body pains", including cough alleviation while cooking. The introduction in Iridimi camp (Chad) of a different technology, i.e. solar cookers, gave similar findings [75]. Lastly, for the case of South Sudan, A. Thulstrup and W J. Henry [104] also introduce another aspect: according to them, beneficiaries of ICS have also witnessed nutritional and health benefits due to the fact that the new devices reduced the risk of undercooking food to save firewood.

Safety

A number of risks other than health problems from air pollution are associated with the utilization of traditional biomass and traditional cooking devices. Protection-related issues, such as sexual violence, and attacks from armed people or rebels, are the most frequent problems associated to the collection of firewood or other combustible biomass. Sexual harassment and GBV, in particular rape, stay in the spotlight. According to selected literature, harassment or GBV occur with particular frequency in the African context. Selected reports and studies refer to the problem in camp assessments in Ethiopia [69,70,107,115], Uganda [102], Kenya [116,117], Sudan [75,95], South Sudan [118], Namibia [3], Chad [3,118], Tanzania [118]. The situation is particularly critical in some areas, such as in Darfur region (Sudan) and Doro (South Sudan), where respectively 43% and 54% of interviewed women indicated rape as the most common type of violence occurring during wood collection outside the camps [95,118].

However, risk of sexual harassment and rape is also mentioned out of the African context, such as in the case of Bhutanese refugee women and girls in Nepal [3], and many other developing countries [49,119]. In some cases, such as Shimelba camp (Ethiopia), women and girls indicated that the risk is significantly reduced by the fact that they go to collect firewood in groups [70,115].

In addition to this, many authors report also the risk of being intimidated or violently attacked by militia, rebels, or even local population which is worried from the idea to share their scarce wood resources with thousands of refugees [75,116,120].

In a review which dates back to 2005, S. Ziebell [117] identified the following main gaps in the literature regarding the link between fuel provision and GBV: (i) literature on fuel provision mainly focuses on environmental impact and not on security; (ii) the causes of and vulnerabilities to GBV in humanitarian context are poorly understood; (iii) experience of direct fuel provision has revealed unsustainable; and (iv) there has been lack of coordination in the provision of fuel alternatives.

Despite the quite wide number of studies cited above, these considerations still appear to stay at least partially valid, since, based on our more recent investigation, there is still a clear need for further and more punctual research in this ambit. In particular, in many cases ICSs and/or modern-fuels stoves have been provided to refugees as the main tool in order to lower dependence from firewood, with the objective of decreasing violence episodes and sexual assaults. The idea at the basis is that reducing the need to leave camp directly improves the personal security of refugees. One of the first large programmes regarding sexual violence reduction through ICS distribution was developed in the Darfur region. The same idea was applied in other contexts later on. However, in most cases, only qualitative and general data are available regarding the fulfilment of the objective regarding the reduction of violence episodes (see, for example, [67,75,115,117]), and the efficacy of ICS programmes on GBV reduction is debated. According to S. Abdelnour and A.M. Saeed [121], starting from the experience in Darfur, efficient stoves were indicated as a "universal technical panacea for sexual violence in any conflict or refugee camp context" (p. 145), even if their effectiveness remain questionable. Nevertheless, although the dissemination of stoves seemed to have very little impact on GBV reduction, the Authors state that "the language of sexual violence continues to be associated with efficient stoves for Darfuris" ([122], p. 8).

Apart from violence, other hazards are related to the collection of firewood out of the camps and its utilization in traditional devices: on the one hand, fuel collection often exposes refugees to the danger of gas holes, insects, wild animals, and, in certain contexts, landmines and unexploded ordnances (UXOs) [98,120]. Dehydration, back injuries, scrapes, broken limbs, and exhaustion are common consequences from the arduous work necessary to carry several kilos of firewood on long distances [67,69,107,115,119]. Regarding these issues, the effectiveness of an approach based on the utilization of ICS to reduce the firewood needs, and/or the substitution of traditional biomass with other fuels, seems more evident. For example, in the framework of the Gaia project, the switch to ethanol stoves decreased the need for women to travel out of the camp to gather firewood [115].

On the other hand, the utilization of three-stone fires or traditional cooking stoves, as well as kerosene lamps, is frequent cause of injuries, such as burns and scalds, and of accidental fires [123]. For example, G. Lahn and O. Grafham report the following testimony of an UNHCR camp official in South Sudan: "House fires, kids' burns and hospitalization of individuals with severe burns are common, especially during the dry season when the country is dry and there are strong winds" ([63], p. 12) Moreover, they describe the case of three huge fires in Thai refugee camps in 2013, which led to a number of deaths (the causes have not been established with certainty, but very likely are related with the use of cooking stoves or similar devices). Other references to the above mentioned risks, are available in [49,54,75].

Despite the high frequency of accidents reported in the literature, in the latter study Y. Kazerooni et al. underline how only few leading humanitarian agencies provide recommendations, in particular regarding fire prevention/control strategies in refugee and IDPs settlements. Based on this, they suggest the introduction of some innovations, including: (i) utilization of safer stoves and fire retardant shelter materials; (ii) promotion of energy-efficient cooking practices, including the use of fuel-efficient stoves, firewood preparation, fire management, food preparation; (iii) utilization centralized cooking facilities where possible; (iv) ensure chimneys projects through a solid wall or through a fireproof plate. The promotion of communal or centralized cooking and heating facilities as a good practice in order to minimize fire risks (in addition to reducing firewood consumption and emission of pollutants) is also cited in [49].

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Focusing mainly on the first points, positive experience comes from the utilization of solar cookers (e.g. in Iridimi camp, people stated that solar cookers appear to be safer than wood stoves, which put children and women at risk of being burned [75]), or ethanol stoves (e.g. in the framework of Gaia project, many refugees expressed a sense of safety and improved well-being during their cooking practices [106]).

However, B. F. Nielsen also warns regarding possible risks related to the introduction of new technologies, referring to cases where refugees were injured from explosions while cooking with gas. In fact, it should not be forgotten that the challenge of introducing innovative technologies is larger in the humanitarian context than in others, as training is often unsatisfactory and experience with using the products is limited [124].

Education, livelihood, and social issues

Cooking technologies both are influenced by, and have direct or indirect influence on social issues, in particular education and livelihood. On the one hand, it is worth to consider that the social and cultural context strongly affects the appropriateness of a given technology. Many projects aiming at the introduction of more efficient and modern cooking systems have failed due to cultural and/or social issues. G. Lahn and O. Grafham [63] report interesting examples, such as: (i) the case of biogas for cooking, that was introduced as an innovative technology in Somalia, but was rejected due to the fact that beneficiaries were not feeling comfortable using energy produced from human waste; (ii) the case of solar parabolic cookers in Nepal, that in some areas has led to problems, with families which were not provided with the technologies asking to share food even if uninvited; and (iii) the case of fuel briquettes from waste biomass, that are often rejected due to an unusual smell and to a different taste of the food, compared to cooking with wood or charcoal.

On the other hand, when adequate consideration is given to the factors underlined in the first part of this paragraph, programmes on efficient and/or modern cooking stoves could improve the condition of refugees and IDPs regarding many aspects of both education and livelihood. Traditional cooking devices require high quantities of firewood to be collected or purchased. Since children and women are mainly in charge for firewood collection in many humanitarian settings, this duty takes time away from their education [125]. The relevance of this issue seems to emerge by the findings from many projects. More time available for education for both children and adults (in particular women) is confirmed as one of the most important social progress associated with the introduction of more efficient stoves and/or a shift in the type of fuel [68,69,114]. Moreover, in some cases to provide schools with fuel efficient stoves is reported as another important step, when the objective is to ensure that the cost of fuel is not an obstacle to school attendance, as well as to spread the knowledge about new technologies and the advantages that can come thanks to their utilization [99].

As per livelihood and other related issues, there are some advantages that can be expected to come with efficient stoves programmes. According to [30], they can be summarized in five main categories: (i) cash savings, in cases where firewood or charcoal are purchased from the market; (ii) time savings, in cases where firewood is collected, which not only implies more possibilities in education, but also in livelihood activities, and time with friends and families; (iii) sale of stoves, when refugees (in particular women) produce stoves and sell these to others; and/or (iv) payments per stove produced, in projects where refugees are trained in order to make stoves, and are then contracted for supply of the devices.

Findings from most of the documents can easily fit into these four categories, even if most documents mainly report findings regarding categories (i) and (ii), such as in [67,69,75,106,114]. In the case of category (ii), it is worth bringing some specific examples concerning the different activities that are more often given relevance. In Sudan, Ethiopia and Chad, interviewed women stated that they had more time for activities such as to grow and collect vegetables and for other small farming activities, for laundering and bathing of their children, and to stay with their neighbors [69,75,114]. In this framework, sustainable energy programmes themselves can further incentivize these activities as a further mean to reduce uncontrolled firewood gathering. Within actions promoted by the SAFE initiative, for example, communities are specifically trained on sustainable agriculture practices, tree nurseries and community forests, in order to help families to become more self-sufficient and resilient [125].

Conclusion

In this paper we proposed a review of more than 100 documents published from 1995 to 2016 within international peer-reviewed journals and grey literature addressing the topic of biomass cooking technologies uses in humanitarian settings: refugee camps, IDPs camps, informal settings.

In the first part of the work, we included a foreword on the issue related to the use of traditional cooking devices in humanitarian contexts and a state of the art of the main models and types of the existing traditional, improved and modern technologies. Their use and adoption in humanitarian settings have been documented as well, by reporting examples of their application on the field. Mud stoves and fired clay (*viz.* ceramic) stoves appear to be the most widespread models of cooking stoves promoted as substitutes of the inefficient and polluting three-stone fire stove in the case of humanitarian contexts. People are usually trained to build, reproduce and use such devices, in order to achieve the most beneficial impact on local hosted communities. Among the so-called improved cooking stoves and modern cooking stoves, commercial models of Rocket stoves and LPG stoves emerge to be the most common ones, respectively.

The literature reports as well the widespread promotion of additional clean cooking technologies within refugee/IDPs/informal camps: solar cookers and hay boxes. Among all the existing models, *CooKit* panel cookers emerged as the most diffused, allowing people to decrease the use of fuel for cooking.

The second part of the review concerned the analysis of the impacts of such cooking technologies, focusing on the following main issues: *Environmental impact*; *Health*; *Safety*; *Education, livelihood, and social issues*. As per the environmental dimension, the reliance on fuelwood intensive livelihoods such as firewood collection, charcoal-production and brick-making in humanitarian settings shows a rapid and irreversible bad impact on the surrounding environmental resources, which often threats the livelihood base of hosting communities. In these contexts, the promotion of more sustainable cooking technologies and cooking practices (*e.g.* communitarian cooking systems and diversification of fuels) may reduce the intensive negative pressure on local environmental resources. The relying on polluting biomass technologies negatively impacts on people's health, especially on women and children, while the promotion of cleaner technologies, especially those fuelled by LPG and ethanol, are reported to drastically reduce the harmful emission and related diseases. Regarding safety, protection-related issues, such as sexual violence, and attacks from armed people or rebels, are the most frequent problems associated to the collection of firewood or other combustible biomass within refugee and informal camps. ICSs and/or modern stoves are usually provided as the main tool in order to lower dependence from firewood, with the objective of decreasing vio-

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lence episodes and sexual assaults, even if their effectiveness remains questionable since very few qualitative and quantitative results have been published in support of this thesis. In the end, cooking technologies both are influenced and have direct or indirect influence on social issues, in particular education and livelihood. Cash savings, in cases where firewood or charcoal are purchased from the market, and time savings, in cases where firewood is collected, appear to be the most direct and recurrent effects on the social dimension, which people experienced.

Although in most cases we found that the substitution of traditional devices by ICSs and modern-fuels cooking stoves are reported as an effective strategy in order to mitigate the negative impacts of cooking operations on the different dimensions we considered in our analysis, it is important to underline that in most cases the results are not clearly supported by scientific evidence. For example, as regards firewood-based ICSs, some recent studies suggest and report some doubts concerning their benefits in terms of reduction in fuelwood consumption on the field [126–128]. Moreover, the efficacy of ICSs and modern-fuels programmes as regards the mitigation of protection-related issues is another controversial point. For these reasons, the authors wish this work would encourage a more in-depth scientific research on the issue of impact of cooking technologies programmes among communities living in humanitarian contexts. As a matter of facts, a number of information only comes in a qualitative form from grey literature, while a lack of quantitative and scientifically verified data is clearly evidenced. This is the reason why the review does not allow to robustly assert which are the best improved cooking technologies to be adopted in the humanitarian contexts, but rather it shows how the choice of appropriate ICSs in such contexts is highly dependent on economic, social and environment local conditions; the attempt to create a generally-accepted ranking of appropriate technologies may be therefore misleading. Nevertheless, when the supply of modern fuels is reliable and affordable, modern-fuels cooking stoves guarantee the most positive health impact on local forest resources, while the additional use of solar cookers and hay boxes along with traditional cooking methods contributes to reduce the use of fuel and the related pollutant emissions.

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