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A model for partnering with the informal e-waste industry: Rationale, principles and a case study

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ABSTRACT

Various forms of informal activity have long played an under-recognized yet substantial role in solid waste management, especially in developing countries. In particular, informal activity is prominent in the electronic waste (e-waste) sector, whose volume and impacts have grown rapidly over recent decades. While the worrying aspects of informal e-waste recycling have been widely discussed, less attention has been given to its positive potential and to its relation to formal e-waste actors and policies. These topics have direct implication for pathways for transitioning from informality, and, in particular, ways in which informal recyclers can build on their strengths while beginning to operate in cleaner ways that retain livelihoods while reducing ill effects.

In this paper, we draw upon extensive field work as well as secondary literatures to offer a taxonomy of management stances towards informal e-waste practices. These range from hostility through disconnection to interaction and, finally, synergy. Our recommendation is for the latter since the informal sector has important strengths and merits, as well as its harmful aspects, while formal approaches that ignore or attempt to squelch the informal sector do not yield constructive outcomes. Specifically, we suggest an incremental ratcheting synergistic model that draws on the respective strengths of both sectors to forge a genuine partnership between them. We describe six key elements of this model, and illustrate it through application to the Israeli–Palestinian context we have studied in depth. In particular, we show how the treatment of copper cables, now one of this industry's largest and most harmful segments, can be improved through an incremental series of synergetic solutions that preserve or even improve livelihoods of informal recyclers while greatly reducing their health and environmental impacts.

1. Introduction

While electronic and electrical waste (e-waste) is increasingly processed by formal and regulated institutions, much – and in many places, the majority – is processed in less formal channels. Historically, informal scrap networks have generated income by collecting, extracting and selling recyclable materials, thereby playing an important role in solid waste management, especially in developing countries (Medina, 1997; Wilson et al., 2006). In the past 10–20 years, increased electronic waste has become an important and profitable component of the 'scrap system' at domestic and international scales. The e-waste fraction of this informal scrap trade is of exceptional environmental and health concern as the high inherent value and complex composition, including highly toxic materials, and lack of regulation or oversight make harmful dismantling, extraction, and disposal practices prevalent in the informal e-waste industry (Grant et al., 2013; Sepúlveda et al., 2010). For these reasons, and because of economic competition and underlying social cleavages, formal and informal e-waste sectors often have an uneasy relation. It is only recently that studies such as that of Estrada-Ayub and Kahhat (2014) are beginning to give us detailed accounts of the scope, complexity of stakeholders and decision-making, and frequently cross-border dynamics of the informal e-waste sector, and of its seamless interfaces with more formal channels.

While informal e-waste flows and processing are a global phenomenon, in this paper, we discuss an almost unknown local instance of this, the Israeli–Palestinian e-waste system. For over 15 years, Palestinians have been entering Israel to informally collect e-waste among other used items that can be sold, refurbished or recycled. This is brought to an extensive informal industry concentrated in three Palestinian villages in south-west Hebron (Idhna,

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Deir Samet, and Beit Awwa) where about 80% of the population is directly or indirectly dependent on this economy (Davis, 2013). This transboundary economy has created a longstanding and important source of livelihood in the West Bank, while developing a massive and efficient e-waste collection network in Israel. However, certain dangerous e-waste processing methods have had considerable environmental and health costs, with the tension between livelihoods and impacts now reaching a breaking point. At the same time, Israel has recently begun an attempt at regularizing its e-waste management, with a set of regulation and organizational structures, which are increasingly being enforced. This case, in which the conjunction of waste exporter and importer, formal and informal, are particularly close and stark, offers a useful window into the interfaces and dynamics of formal and informal industries in a critical point in time. While the distinctive geo-political context makes the case idiosyncratic in its details, we suggest that many of the dynamics and dilemmas (and, thus, the policy approach we suggest) are of global relevance.

The need for adequate management of e-waste is pressing. E-waste contains over 1000 substances, many of which can be directly toxic upon release or else create toxic chemicals through secondary emissions from open burning (Chan et al., 2007; Wen et al., 2009; Widmer et al., 2005). In particular, heavy metals and organic compounds such as dioxins, furans, and brominated flame retardants can negatively affect the environment and human health if they are not disposed of properly (Brigden et al., 2005; Gullett et al., 2007; Li et al., 2006; Wu et al., 2008), entering the food chain and creating long-lasting effects even after initial exposures have subsided (Bellinger et al., 1992, 1994; Ciesielski et al., 2012). Labourers working in this profession are often part of a marginalized community that are poor, uneducated, lacking basic knowledge of occupational and health risks associated with informal dismantling and have no alternatives to this risky form of employment (Wath et al., 2011). Income from informal e-waste recycling can benefit poor communities, over time, but the resultant disease and environmental degradation can worsen their situation greatly in the longer term.

Beyond the health and environmental consequences of informal e-waste processing, the industry is also often accompanied by the negative employment, spatial, and economic correlates of informality. While earnings can be relatively good in developing country contexts, especially for individuals without formal qualifications (hence the lure of working in a hazardous and often precarious industry), workplaces typically have poor health and safety conditions, job stability and social security benefits, and child labour is prevalent (Prakash et al., 2010; Umair et al., 2015). Regions that host informal recycling hubs often have uncontrolled dismantling and disposal sites, with noise, emissions, and rubbish marring the landscape and causing tensions within communities. The industry is often predicated on criminal and corrupt activities to assure the supply, transport, and sale of materials, and the operation of dubious facilities (Interpol, 2011), while tax avoidance means that revenues are not fed into systems intended to provide broader infrastructures, services, and investments.

While these numerous and worrying aspects of informal e-waste recycling have been widely studied and emphasized its positive aspects and potentials have received far less attention. Similarly under-examined are the pathways for transitioning from informality, and, in particular, the ways in which informal recyclers can build on their strengths while beginning to operate in cleaner ways that retain livelihoods while reducing ill effects.

Thus, e-waste recycling has been able to provide a much needed source of income to populations unable to find formal employment. For example, Duan and Eugster (2007) estimated that in 2005 5 million people were employed in the e-waste re-use industry in China, and in 2007 an additional 0.7 million in the e-waste recycling industry. Strikingly, 98% of these worked in informal businesses. For many, and especially the more vulnerable populations, this source of income provides the basic necessities of life, improving quality of life overall, despite exposure to harmful substances. And, without sidestepping the negative aspects of an unregulated industry, despite (and, partly, because of) their operation outside of formal frameworks, informal scrap workers offer some distinct advantages over their formal counterparts in many phases of solid waste management systems.

On the collection side, informal recyclers have built up extensive and street-tested knowledge of the industry including disposal patterns, current prices for metals, the metal content/value of piles of scrap, etc. and a bottom-up set of collection practices of very fine grained spatial and temporal resolution and responsiveness. In most countries, even ones with developed formal facilities, the informal sector collects an impressively large portion of the e-waste stream, despite operating outside of the formal infrastructures, and, in some cases, against pressures levelled at their “illegal” practices. On the extraction side, low labour costs make manual disassembly feasible, allowing separation of e-waste into purer fractions, with greater recycling efficiency than possible with mechanical separation. When coupled to state-of-the-art refineries, this efficient extraction can yield a high recycling efficiency that lowers demand for mining and extraction of primary materials (Li et al., 2007; Wang et al., 2012), drastically reduces e-waste entering landfills, and eases the costs of municipal waste collection. These benefits are, often, independently viable on the basis of waste sources that cannot be processed by formal systems, at least not in the absence of subsidies.

The challenge we tackle in this paper is how to harness these strengths while reducing negative environmental and health consequences, and, specifically, how to manage the increased and potentially fraught contact between formal and informal sectors that such a hybrid approach would require. On one side, such an arrangement would allow the e-waste management system to drastically increase collection and recycling rates (or, more accurately, increasingly bring existing informal collection under the umbrella of regulation). On the other, such an arrangement can provide a platform for informal recyclers to continue to derive much needed income from their trade at the same time that their contact with the formal sector spurs critically overdue health and environmental improvements. While policies that incorporate the strengths of the informal recycling sector into national and binational e-waste management plans are beginning to be discussed and developed (Chi et al., 2011; Rochat et al., 2008; Wang et al., 2012), the pathways, priorities, and processes through which such partnerships would occur are still far from clear. The goal of this paper is to begin fleshing these out, and offer a roadmap of incremental steps combining top-down and bottom-up approaches. Our work, thus, contributes to an emerging dialogue engaging informal recyclers with formal e-waste management (Chatterjee and Kumar, 2009; Chi et al., 2011; Gunsilius, 2010; Rochat et al., 2008; Wang et al., 2012; Yu et al., 2010).

For the sake of clarity, our description and model refer to e-waste processing businesses as either “formal” or “informal,” though, in fact, there can be a range of intermediary and blended situations. One end point would be completely formal businesses which are registered and monitored by the government, adhering to a set of e-waste processing standards and paying taxes, while at the other would be completely informal businesses which adhere to none of these formal arrangements. Less clear-cut cases are businesses that are registered and pay taxes, to some extent, but obtain inputs from undocumented sources on a cash basis. Or a well-regarded formal recycling company may rely on informal partners to take and process certain fractions of the waste stream that are marginally profitable within the formal system. In the Israeli/Palestinian case study presented in this article, the informal sector in the West

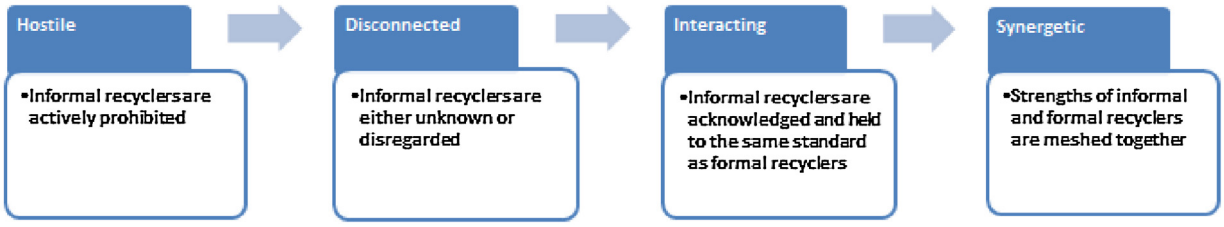

Fig. 1. An integration continuum of management strategies addressing the informal e-waste industry.

Bank, by and large, operates in a completely informal manner, outside the radar of governmental regulation and taxation, while the Israeli e-waste sector, which is only recently being impelled towards formalization, has businesses across the entire range of the formalization spectrum.

The structure of this paper is as follows. First, we review the treatment of the informal sector in the literature on e-waste management, the range of stances embodied in these, and the outcomes of such policies and interventions. This review is the basis for our claim for the need and superiority of strategies with a synergetic partnership orientation, which we offer in the following section. Drawing on the literature and our own field work, we suggest six core principles that should inform such partnership strategies, and illustrate this approach through a case study of an informal sector we have studied in recent years. Specifically, we describe our proposal for an alternative to open-burning of copper cables as the linchpin of a shift towards cleaner operation of the informal scrap recycling industry in the West Bank.

2. Methodology

This study is based on field observations and engagement with the informal e-waste industry in the West Bank and Israel over several years as part of a larger research project, grounded in an extensive review of the literatures on informal e-waste recycling and its interface with formal waste management systems internationally. The field work involved exploratory, semi-structured interviews over three years (June–November, 2012; June–August, 2013; and May–August, 2014) with stakeholders who are involved with or impacted by the informal e-waste industry in south-west Hebron, West Bank. To date, over 200 different stakeholders were interviewed, many of whom were interviewed multiple times in both formal and informal settings. Interviewees in the West Bank included employees and owners of small and large scrap yards, e-waste collectors, officials in local municipalities, the police, the Ministries of Agriculture and Health, and members of local NGOs advocating against unregulated e-waste recycling, as well as many local residents. In Israel, a lesser number of informational interviews were held with representatives from the Ministry for Environmental Protection, the Tarqumiya border crossing, a variety of e-waste recycling business owners, and some of the key players in the emerging formal industry.

Due to the informal and sometimes sensitive nature of the issues touched on in interviews (e.g. business models, buying and selling prices, quantities, tax evasion, bribery, illegal extraction and burning practices, etc.), all interviewees were assured confidentiality and anonymization of any insights derived from them, and information sources were triangulated and cross-verified in order to ensure the accuracy of interview responses.

Our literature review on e-waste management examined government initiatives and regulations, academic writing, and private initiatives, and in particular the ways in which these offered implicit or explicit strategies for managing informal e-waste recycling. From these, we attempted to determine the outcomes as well as the characteristics of what seemed to be effective management strategies.

3. The continuum of management stances towards informal e-waste recyclers—A review

The literatures relating to the informal e-waste industry can be conveniently arrayed along a continuum of the degree of integration of the informal sector they posit (see Fig. 1). This ranges from those advocating a prohibition of informal recycling, through those ignoring their existence, to those where the sector is recognized but pressed to conform to and compete with the formal sector, to those, such as our own approach, attempting to integrate the strengths of the informal sector with those of the formal. In what follows, we elaborate and evaluate in turn the stances along this spectrum, and the rationale for our own emerging endorsement of strategies located farther to the right of the "integration continuum," which, we argue, have the potential to produce superior outcomes.

3.1. Hostile stances

On the far left of the integration continuum are approaches that view the "unfair competition" of the informal market as preventing or undermining Extended Producer Responsibility (EPR) policies (Nnorom and Osibanjo, 2008) or more actively call for its prohibition. Many developing countries hosting informal e-waste recycling industries have implemented a variety of importation bans to restrict the flow of incoming e-waste, with little success (SBC, 2011). In general, these laws have not reduced the quantity of imported e-waste, only altered the way it is shipped. For instance, instead of shipping a container under the label 'electronic scrap', containers will be shipped under the guise of 're-usable electronics'—incorrectly designating it as suitable for refurbishment and re-use.

Beyond bans on the importation of e-waste, there have been attempts to craft formal recycling policies in ways that will undermine the economic basis of the informal sector, or to act more directly to ban the informal e-waste treatment itself, enforced by strict government interventions (i.e. fines and imprisonment). The former, for example, would require producers and importers to buy back end-of-life products at prices that would exceed those offered by the thriving informal collection networks (Dwivedy et al., 2015). These, too, have also had limited success because they underestimate the multiple financial and transaction benefits of informal operation (Hu and Wen, 2015), and because of the flexibility of informal recyclers in adapting to newly imposed measures. This was clearly evidenced, for example, in measures instituted in Guiyu, China, after the release of the Basel Action Network (BAN) report 'Exporting Harm,' which put international pressure on the Chinese government to close down all informal dismantling shops (Puckett et al., 2002). Soon, dismantling shifted from larger facilities to households and small workshops, making recycling operations more difficult to identify and shut-down (Chi et al., 2011), and, perhaps, increasing their damage. Similarly, working habits adjusted

so as to elude government punishments: hours of operation shifted from day to night and obvious polluting activities re-located to more remote sites. Because informal recyclers have few options for work and are desperate for any source of income, they are motivated and adept at finding such adaptations that allow them to work around government imposed bans on e-waste importation and recycling.

3.2. Disconnected stances

Disconnected management approaches underestimate or even fail entirely to recognize the existence and capacity of informal e-waste recycling. For instance, many countries have implemented EPR management schemes, which put the onus on producers to collect and treat a certain percentage of e-waste that they generate, but do so in a way that ignores the operation of a large existing informal sector. This might be because of its invisibility (their activity is not accounted for in national statistics, for example), or due to some unfounded sense that the informal sector will evaporate. Because these informal recyclers are often not considered in advance, their significance is not incorporated in formal models and management schemes, whose efficacy suffers as a result. Thus, in many developing countries, the schemes fail because the informal sector efficiently collects (and often pays for) a significant percentage of domestic e-waste, limiting the amount of e-waste available for formal collection (Ciocoiu and Tartiu, 2012; Manomaivibool and Vassanadumrongdee, 2011; Ylä-Mella et al., 2014).

3.3. Limited or non-cooperative interaction

The third category of management approaches acknowledges the significance of informal recyclers and actively interacts with them, but in a loose and ineffectual manner. As a result, the two sectors operate largely in parallel, and in ways that compete with one another to varying degrees, whether explicit or not. That is, whether as a stated goal or simply a by-product of parallel operation, the formal sector's success, if achieved, would curtail or undermine the informal sector's operation. The point here is that this interaction does not attempt to cooperate with or transform this sector, nor to harness its unique strengths. There is little attempt to incentivise reform in the informal sector, draw on its strong entrepreneurial spirit and widespread and thorough collection system, nor to tap the informal sector's low labour costs and extensive experience.

The following are two examples of this stance, where government management strategies recognized the importance of the informal e-waste sector, but focused on formal measures, limiting its engagement with the informal sector to measures that reduce its environmental damage.

The first example is the Indian government's attempt to regulate informal e-waste recyclers by simply legislating uniform work conditions and environmental standards requirements for all e-waste recycling facilities (Spies and Wucke, 2004). This was done without incentivising informal businesses to adhere to these new regulations, or considering the underlying reasons why these recycling facilities are informal to begin with. This placed informal recyclers in direct competition with formal ones, with little reason for them to change their recycling practices to meet expensive environmental standards, thus limiting their participation in the e-waste management strategy.

A second example of this stance is represented at a transnational scale by the StEP (Solving the E-waste Problem) initiative, attempted by a coalition of government agencies, NGOS and UN organizations working towards developing solutions to e-waste. StEP adopted a philosophy termed 'The Best-of-2-Worlds' (Bo2W), whose aim was to develop an alternative recycling path for domestic e-waste in developing countries by combining the respective strengths of the recycling systems in developed and developing countries (Gmünder, 2007; Wang et al., 2012). Some of the mixed achievements of the initiative stem from the lack of a deeply cooperative stance towards the informal sector.

In China for example, a StEP pilot project was established in 2008 with the creation of a large scale dismantling centre, employing former informal e-waste recyclers on the one hand, and supplying global state-of-the-art end-processing facilities on the other. However, as was the case with other dismantling centre pilot projects in China, sufficient e-waste could not be collected at reasonable prices, and the large scale infrastructure of the StEP facility was never fully utilized (Wang et al., 2012; Yang et al., 2008; Yu et al., 2010). Because they operated in the absence of overall national e-waste legislation and enforcement, informal recyclers operating in parallel to such facilities had an economic advantage compared to the formal system, because they could capture the refurbishment value of functioning electronics, for example, or avoid the cost penalties of environmentally sound treatment (Wang et al., 2012).

In India, the Bo2W philosophy was applied in 2008 with two trial containers of motherboards collected, separated and shipped to precious metals refineries in Europe for end-processing, thereby avoiding the damaging practices of wet chemical extraction commonly used by local informal recyclers (Rochat et al., 2008). Thus, electronics containing valuable motherboards were dismantled from computers in India, but shipped to the state-of-the-art facilities of Umicore Precious Metals Refining in Belgium for extraction. Though operating under much more stringent environmental and health standards, Umicore's advanced recycling technology was still able to offer a superior economic alternative because its precious metal extraction rate of 95% far exceeded the 25% rate prevailing with informal extraction methods (Rochat et al., 2008). While this arrangement appeared to offer a win-win partnering of formal and informal sector, it encountered limitations that underscore the need for deeper and broader kinds of synergy, operating not only across a geographic developed/developing country divide, but binding together all aspects and components of both formal and informal value chains.

First, because the informal sector is typically dominated by smaller and, often, unregistered businesses, it has less ability to tap into institutionalized sources of capital. Thus, the cash flow timing of the Umicore model presented a major barrier to informal buyers/suppliers in India. These pay cash-in-hand for motherboards they purchase from even smaller operators, while Umicore only makes payments after shipments have arrived and the metal content of the motherboards has been systematically assayed, which can take approximately four months. Since the informal buyers and sellers rely on this immediate cash flow in order to continue purchasing more electronics to dismantle or resell, this delay constituted a crippling barrier. Conceivably an intermediate organization could provide this fiscal buffering, but this was not available to informal recyclers.

Second, this alternative business model only targeted one high value slice of the value chain, and did not adequately consider the remainder. The arrangement was economically advantageous for motherboards with high precious metal content, but the precious metal content of lower quality motherboards did not justify shipment costs to the distant Umicore facility (Rochat et al., 2008), so that the entire market of low grade motherboards continued to be processed with wet chemical extraction. Similarly, even in equipment containing high quality motherboards, it is only the small valuable fraction of the motherboard itself that is shipped to superior facilities overseas; the remaining waste fractions, which constitute the overwhelming majority of the equipment, remained in the informal contexts and a geographic setting that almost guaranteed that it would be improperly disposed of (landfilled, burned,

buried, etc.). Thus, while the Bo2W framework seems to offer a promising approach in principle, in order to achieve its admirable goals a broader understanding and front of cooperative interaction with informal recyclers is needed. This kind of broadening is what we propose in the following section.

3.4. Broadly synergetic interaction

The final stance, which is the one we propose, is situated at the far end of the "integration continuum" of Fig. 1. It represents a deeper form of partnership between the informal and the formal recycling sectors, one that makes the most of the strengths of each sector, and operates across as much of the value chain as possible. We find elements of this approach scattered across the literature, sometimes as a brief recognition of the virtues and call for governments to absorb them into formal systems and improve their conditions (Asim et al., 2012; Sasaki et al., 2014), and less often as more elaborated proposals for doing so, such as that of Williams et al. (2013). This focuses on providing incentives for informal recyclers to abandon harmful e-waste recycling practices by fixing market prices for those e-waste components that cause the most environmental and health damage when improperly dismantled or discarded. For example, municipal collection centres offering a higher buying price for Cathode Ray Tube (CRT) screens than could be earned from dismantling them manually would economically motivate informal recyclers to return collected CRTs to formal collection centres. In this way, concrete incentives would link informal recyclers to central collection sites in a way that encouraged them to deliver the more worrying fractions of the value chain rather than partially processing these on their own (typically, removing the copper coils and discarding the plastic and lead-impregnated glass). This, therefore, would be one example of how to harness the informal recycler's main strengths of intensive collection in a way that reduces some of the more important health and environmental impacts of e-waste, while allowing these businesses to remain informal if they choose to. In our own work, described below, we show how to further build on such a mechanism in financially sustainable ways by tapping into and optimizing the high value parts of the value chain in ways that will cross-subsidize low value and harmful ones.

We suggest that the model of broad synergy between formal and informal sectors occupying the right edge of the integration spectrum of Fig. 1, is necessary for effective e-waste management in contexts in which both these sectors operate—which is most of them. In the following sections we further develop this fourth stance, elaborating how rather than expending their efforts on very partially effective measures to stamp out informal operators, governments can use their regulative and enforcement capacities to create paths that invite formalization partnerships.

These must be thought through in a systemic way, balancing different factors. For example, a proposed license scheme that would incentivize informal recyclers to operate formally (Shinkuma and Managi, 2010) should reward environmentally sound recycling but in a way that does not allow gaming of the system, does not disadvantage smaller businesses or household-generated waste (a far larger but less valuable component of the e-waste stream), and which maintains the right price differentials to attract material from the informal to formal channels but within a sustainable business model. Failure to do so will undermine their effectiveness. Thus, such license schemes were introduced in both China and India, but a lack of participation limited their success, with only 12 recycling firms applying for a license in the Indian case, of which only 6 were granted (Shinkuma and Managi, 2010).

4. A model for partnering with the informal e-waste industry

In previous sections we have seen that stances that fall short of full partnership with the informal e-waste sector across various facets of the value chain are unlikely to yield adequate policies and results, and gave an initial illustration of the kinds of measures that would begin to achieve this kind of partnership. This section develops the principles, strategies, and measures we have found to be important for achieving this kind of effective and transformative partnership of the informal and formal e-waste industries. Our account is structured by a series of prescriptive headings, which organize the insights of the relevant literature and findings from our own research and advocacy over recent years.

4.1. Understand both sectors

This may seem obvious, but it is far from it. Unless one surveys the players, dynamics, constraints (actual and perceived), prices, and quantities in both formal and informal sectors, one is likely to overlook key parts of the value chain, misjudge the price differentials needed to incentivise desired actions, and implement policies with unintended consequences.

Within the context of our Israel-West Bank case study, Israel has recently formulated an EPR policy without extensive knowledge of the existence and extent of the Palestinian informal sector. This policy uses funds collected from electronics and electrical equipment importers to pay certified organizations to collect waste that is then transmitted to certified recycling companies. Yet, in many instances, this newly legislated formal collection, which is dependent on external payment in order to collect waste from actors that receive nothing (or even pay a nominal fee), cannot compete with an existing informal sector, which is willing to pay and pick-up e-waste. Given that the informal sector is already "managing" almost half of all e-waste generated in Israel, a management scheme unaware of its dynamics is likely to fail, or resort to police enforcement, rather than price advantage, to eliminate its informal competition. This oversight of the informal sector in a formal EPR management policy is not unique to Israel, but has been the norm in many other countries (Kojima et al., 2009). On the other side of the equation, the Palestinian e-waste industry – people whose livelihood has depended on Israeli e-waste for a decade – know almost nothing of the new Israeli e-waste legislation and intended arrangements. Thus, they are less able to manoeuvre, prepare, and negotiate their relation to the formal sector in a pro-active way.

4.2. Recognize integration as an incremental and continual process

Many e-waste management schemes targeting the inclusion of informal recyclers have operated in linear processes from problem definition to management action. The institution of sweeping single-shot measures, however, can be a setup for polarized understandings of success versus failure, overwhelm actors with change on too many simultaneous fronts, and prematurely lock in measures that should be gradually tested or that rely on a maturation of trust and coordination. For example, India's initiative to require informal recyclers to obtain licenses and adhere to specific work conditions and environmental standards may have overwhelmed informal recyclers who were suddenly met with a full formalization regime of obtaining a license, paying taxes, changing operational practices and potentially buying and selling e-waste from different sources (Shinkuma and Managi, 2010). In the Israeli case, the legislation came into legal force in a full blown manner well before the details (prices, bodies, etc.) had been determined, and over a year later significant portions are still not operative. Warnings regarding

the scale and significance of the informal sector were barely heard, and not heeded, so that the stance is rapidly deteriorating from one of disconnection to one of hostility, with calls for police action and a law suit against the Israeli Ministry of Environmental Protection for not enforcing laws that prohibit activities that are now illegal.

A balancing act is needed, therefore, between the kind of full-system perspective essential for durable change, and the incremental and continual progress towards its achievement; and between the need of those investing in upgraded or new procedures to do so on the basis of reliable long term commitments (to supply sources, prices, and regulation), on the one hand, and the impossibility of being able to correctly stipulate all such commitments *a priori*. The challenge for decision-makers, then, is not to map out the whole thing in advance, but to find the right size chunks that provide enough stability and the opportunity for visible wins, while still allowing course correction in the face of uncertainty.

4.3. Engage relevant stakeholders, and design policies co-operatively

There are few, if any, sustained examples of e-waste management policies that emerged from active and continued consultation with informal e-waste recyclers to develop mutually beneficial management policies. This despite the fact that active stakeholder participation, emphasizing empowerment, equity, trust and learning, can enhance the quality of environmental management decisions by considering more comprehensive inputs (Reed, 2008)—especially the case in managing e-waste and its associated environmental problems, which requires flexible and transparent decision-making reflecting a diversity of knowledge and values.

Despite the fact that the informal sector is often responsible for the majority of e-waste processing, especially in developing countries, efforts to incorporate a range of stakeholders in developing and implementing solutions usually includes representatives from a familiar set of stakeholders (national agencies, solid waste management professionals, NGOs, academia, and formal businesses), but not the informal stakeholders in the industry. These could include collectors, dismantlers, and the ornate "feeding chain" of specialized niche markets, as well as those upstream who illicitly or unwittingly provide inputs to it, and those downstream, such as the local residents whose health and landscapes are directly affected by the informal recycling industry. Each of these can shape and be affected by the trajectory through which the informal and formal sectors are brought into contact, and they must be at the table in all phases. Since many informal actors operate at the edge of survival and legality, this inclusion requires considerable sensitivity and forbearance.

In the Israeli–Palestinian case the usual divide between formal and informal was further heightened by the fact that the Palestinians deeply active within Israel in a geographic sense have no standing in a legal and social sense: they are not Israeli citizens or even residents, and they operate through proxies or through entry for collection on a daily basis. The number of Palestinians able to enter Israel is very small, as is the number of Israelis who would feel comfortable entering the locations in which most Palestinian e-waste activity occurs. Thus, despite the physical proximity that has allowed Palestinian entrepreneurs to establish a broad and effective e-waste collection network within Israel, the veil of ignorance separating the formal and informal sectors and the lack of civil representation of the informal sector is almost as marked as the more familiar instances where e-waste is shipped to remote locations.

4.4. Focus on minimizing key risks and supporting key strengths of the informal sector

While there are myriad interfaces between formal and informal systems, a Pareto-like principle can help prioritize the entry point for integrating these two spheres, namely focusing first and foremost on the few spheres in which the informal sector has greatest and undeniable advantage, and on those practices where it causes greatest and undeniable harm. Typically, the informal sector has evolved a creative and resilient value chain able to operate without subsidy; has a highly developed, extended and efficient collection network, ranging from the smallest capillary level of households and individual scrap pickers to larger businesses; operates with low operational costs and can utilize detailed and economic methods of manual dismantling; and possesses a sound practical knowledge of scrap values and market cycles (Bangasser, 2000; Lund and Srinivas, 2000). On the other hand, informality leads to difficulties in scaling and access to capital; a tendency to operate with minimal regard for environmental consequences of processes, freely externalizing undesirable by-products of production; and operation outside of the regulations of working conditions and worker safety (Chen et al., 2011). While not always in a position to alter these, informal operators are knowledgeable about these relative strengths and weaknesses—one more reason to incorporate them in planning from the earliest phases (see above).

Focusing on the weak points of the informal sector has the potential to lead to quick and impressive gains, as illustrated in our cable burning case study (see below). Similarly, harnessing the strengths of the informal sector can also allow rapid and visible benefits from partnership (for example, allowing formal Israeli recyclers to achieve recycling goals far more rapidly than anticipated). Conversely, by explicitly and pro-actively playing to the strengths of the informal sector, policy-makers can avoid policies that are likely to fail because they pit the formal sector against the informal one in arenas such as collection, where it is at a clear disadvantage (Wang et al., 2012).

4.5. Create change by incentivising rather than punishing the informal sector

The informal sector is driven directly by income, without the niceties of providing broader economic or civic benefits. Informal workers are willing to override health and environment to make a living: clearly the economic dimension is paramount. It is a realistic consideration of this orientation that drives both sides of our dictum: "incentivise rather than punish." On the one hand, punitive measures will be far less effective against a sector hardened by operating in challenging settings, which operates routinely outside of formal systems, and has survived over time by virtue of its agility and adaptability. Various studies and our own field work demonstrate the informal sectors ingenuity in finding ways to work around legislation and penalties, which can sometimes simply drive activities into less visible modes of operation. On the other hand, because it is so profit-driven and nimble, the informal sector can respond very rapidly to a realignment of incentives, including incentives to "do the right thing." For example, Blackman (2000) identified "green subsidies" and/or "machinery for cleaner production" as the most successful policy options to address informal brick kiln businesses in Mexico as they provide economic incentives for informal workers to improve environmentally harmful processes, allowing informal businesses to adopt them voluntarily.

The government often wield considerable added value in creating such incentives. Due to their monopoly of, or, at least, dominant position within governance systems, governments can often create incentives without investing "hard" resources. For example, they can give considerable competitive advantages to formalizing

businesses simply through providing selective authorizations and certifications or allowing favoured access or information. Thus, the government can create interventions that steer businesses into desirable trajectories without capital expenditures or forfeiting incomes. At the same time, in the context of many developing countries, volatile government regulations, power struggles, and even conflicts of interest make national e-waste legislation and its enforcement unlikely or unpredictable at best. In such contexts, integrative initiatives should look towards ways of allowing innovative business models that favour cleaner trajectories without relying on government allowances or regulations. These can begin to attract the informal sector even in advance of the kinds of interventions possible in more mature governance contexts. The case study of a proposed copper grinding facility which we describe in this paper, provides an example of a means to economically incentivize methods of cleaner production that cross subsidize low value components of the value chain with high value ones, independent of continual government intervention.

4.6. Integrate bottom-up and top-down management approaches

A natural extension of the forgoing points is the importance of integrating bottom-up and top-down efforts. The modern environmental management literature stresses the need for community involvement to identify indicators to monitor progress towards sustainable development and environmental management tools (Fraser et al., 2006). The adoption of bottom-up community involvement has been driven by past failings of exclusive top down approaches. One of the most successful examples of combining bottom-up and top-down approaches to environmental management comes from the Marine Protection Areas (MPA) literature, specifically in California and the Mediterranean, which have traditionally been centralized and not effective towards reversing declining fisheries resources. However, emerging management schemes which integrate bottom-up stakeholder participation through knowledge, participation, economic and legal incentives have produced more successful outcomes (Arceo et al., 2013; Mauerhofer, 2011). Thus, use of top-down and bottom-up approaches within complex environmental management schemes are often critical for successful outcomes.

At the same time, governmental top-down regulation can enhance bottom-up processes by creating structures that channel the workings of the informal sector. For example, the increased costs entailed by adhering to environmental standards make the comprehensive recycling of certain e-waste items unprofitable, creating a strong incentive for the inappropriate disposal of the fractions remaining after valuable metals are extracted. For example, the costs of proper recycling of the plastic casing and lead-impregnated glass remaining of CRT monitors outweighs the value of the copper that can be extracted from the CRT deflector coils, so that this material is often improperly burned, buried, or dumped by the informal sector. In cases such as this, authorities can use their ability to reshape the landscape of incentives in a way that makes proper treatment advantageous even to informal actors. On the stick side, of course, are targeted regulations that set penalties for the more harmful dismantling or disposal practices. But, at the same time, these will be more effective when coupled with the carrots, such as realistically available environmentally-friendly alternatives as well as bundling e-waste items and entities in a way that cross-subsidizes lucrative aspects of operation with burdensome ones.

Thus, our experience with the Palestinian case has yielded a series of policy recommendations that would allow authorities to orchestrate carrots and sticks in a way that encourage a transition to clean and more formal operation. Thus, enforcement (and, even, community-enforcement) of measures against burning or dumping are more likely to yield adherence, rather than evasion, when a free or affordable landfill is located close to the informal e-waste industry or when favourable terms are available for the purchase or operation of alternative methods of extraction and recycling. Authorities can also reshape the landscape of incentives by conditioning favourable terms for operation (access to producers of e-waste, the ability to transport e-waste materials and extracted metals, financing of facilities and technologies, etc.) to businesses that have obtained some kind of certification for their operation, or, less sweepingly, approval of a given shipment or supply chain link when it can be demonstrated that its less desirable fractions are being properly handled in volumes corresponding to the more valuable ones to which preferential access is granted. These kinds of arrangements are discussed more fully in the following sections.

5. Case study background: Informal Israeli–Palestinian e-waste sector and cable burning

In this and the following section we describe the context and emerging partnership solutions embodying the six integration principles in a particularly complex and largely unknown informal e-waste system that has operated for more than a decade between Israel and the occupied West Bank. While this context carries its idiosyncratic circumstances, it is, also, a microcosm of global e-waste problematics, and of the relation between formal and informal sectors.

Israel's prolonged occupation of the Palestinian areas and the truncation of Palestinian sovereignty processes that were begun in the abortive Oslo process, have resulted in an impoverished dependent economy as well as fragmentation and semi-paralysis of governance in the West Bank. As we describe in a paper now in preparation (Garb and Davis, in preparation-a), unemployment rates, poverty, and a dearth of income opportunities combined with high transaction costs, corruption, and a constrained or selective governance have given rise to a flourishing e-waste industry among the marginalized and poor populations of south-west Hebron. Here, a series of Palestinian villages have developed an extensive system that collects, transports, and processes a large amount of e-waste from Israel to the West Bank. This is delivered to over 150 scrap yards (mainly in the villages of Beit Awa, Deir Samit and Idhna) where workers pick through piles of e-waste, item-by-item, dismantling products into critical fractions (e.g. copper, aluminium, iron, etc.) using "smash and separate" tactics.

This processing method releases harmful chemicals into the soil and air such as lead in CRT screens and Freon gas in air conditioners and refrigerators. Other worrying processes occur during the disposal of "non-valuable" waste, which are either burnt, disposed of haphazardly along the country side, or informally landfilled. Interestingly, the phenomenon of using hazardous leaching processes to manually extract precious metals from motherboards does not occur in the West Bank as essential chemicals required to conduct this operation are not easily available[1]. Environmental standards and strict monitoring are not enforced allowing informal e-waste dismantling to cause great harm to the health and environment of the surrounding area, as documented in a series of papers and reports by the authors (Garb and Davis, in preparation-b; Davis, 2013).

The most strikingly obvious environmental and health hazard of this informal industry is open-burning of e-waste as both an extraction and disposal method. The most common burning is of

[1] This is likely because these chemicals are possible precursors in the production of improvised explosive devices (IEDs) (i.e. nitric acid). These chemicals would be extremely difficult to obtain as Israeli checkpoints on all sides of the West Bank have a strict ban on these chemicals due to ongoing troubled relationships with Palestine.

copper cables to extract valuable copper from plastic insulated wire. This burning produces a witch's brew of Polychlorinated Bidenzo-*p*-Dioxins and Dibenzofurans (PCCD/Fs), Polycyclic Aromatic Hydrocarbons (PAHs), and Polybrominated Diphenyl Ethers (PBDEs), which are released into the air (Sepúlveda et al., 2010; Zhang et al., 2011) and deposited in ash residues. The scientific literature (Brigden et al., 2005; Gullett et al., 2007; Hicks et al., 2005) as well as our own preliminary findings indicates that such residues also contain heavy metals, such as cadmium, lead and hexavalent chromium among others, which can be transported by wind and water and taken up in the food chain.

Our estimates of the volume of cables burnt in south-west Hebron, derived from a variety of convergent sources working in the industry (large scrap yards, copper cable burners, large traders, etc.), range from 7 to 35 t every day operating at this scale for over ten years. The bulk of burnt cables are done by "professional burners," who are young men that are contracted by scrap yard owners to burn their cables. Professional burners often allow young teenagers to assist them in burning the cables, in exchange for access to pick through the ashes to collect copper remains after the burn is complete. Many health complaints in south-west Hebron are attributed to the burning of cables ranging from increases in respiratory problems, kidney failure, birth defects, miscarriages, and several forms of cancer.

Our work also indicates that the kinds of health, environmental, and ecological dislocations that have been observed in similar settings world-wide are also present in the setting under discussion. These potentially harmful environmental and health effects from cable and waste burning are increasingly understood by residents in the e-waste recycling villages, but the industry generates income in a context where there are few alternatives. Some informal recyclers have sought an alternative to open-burning, which is currently the preferred method to separate copper from its plastic insulation. Mostly, these have been small scale cable stripping machines, costing $1000–$2000 (3800–7600 NIS), which have been purchased by over twenty of the larger scrap yards. While these can effectively strip the plastic from thick cables, they have a small capacity (taking 185 min to strip vs. 10 min to burn 18 kg of cable), are inconvenient to operate, and cannot separate plastic from thin cables. These machines, therefore, cannot really compete with open burning.

More technologically advanced grinding machines overcome these limitations, but they require a large initial investment and considerable sophistication to choose, import, and operate. Until now, this has constituted an insurmountable barrier, though in the last couple of years two separate attempts to import and operate such a machine have been made. One innovative scrap yard owner invested $40,000 (151,600 NIS) in a 'low-capacity' copper grinding machine from China, which has the capacity to grind 200–400 kg of cables daily. However, after purchasing the machine the owner quickly discovered that he was not able to receive enough electricity from the municipality to operate the machine, and the extension of direct electrical supply from Israel (Palestine's electricity supplier) to his scrap yard would have cost him approximately $60,000 (227,400 NIS)—more than the machine itself. Thus, he was forced to power his grinding machine with a generator, and after a month, the high cost of fuel made burning cables a more economically advantageous practice.

This abortive attempt with a larger machine contained an important lesson. While the grinding machine was in operation, scrap yards from Beit Awa, Deir Samit and Idhna were bringing cables to his machine and offering to pay for its use. Given the small capacity of his machine, the owner had to turn away other scrap yards as he barely had enough capacity to grind his own cables. A high-capacity copper grinding facility with adequate electricity could be a solution to open-burning of cables for the entire informal e-waste industry in this region. This approach was subsequently adopted by a second Palestinian businessman recently returned from abroad, who invested in such a machine, operated in a location with adequate electrical supply. However, shortly following the establishment of his facility Israel, prompted by growing awareness and complaints regarding burning, began clamping down on the conveyance of cables from Israel. Since these restrictions did not differentiate between cables intended for grinding and those intended for burning, the flow of inputs to his facility has been greatly reduced, with the mostly idle machine barely recovering its expenses. This second thwarted attempt signified the importance of government support for the success of formalization initiatives. This is the context for the formalization intervention we propose in the following section.

6. Case study: A proposed copper grinding facility

Against the foregoing background, it is clear that an important candidate for formalization would be a copper grinding facility as an alternative to open-burning. In our advocacy and coalition-building work together with the local community, this was chosen as a practical way to achieve the broadest reduction in pollution, relatively unencumbered by political hazards and constraints, and, it turns out, one that will allow a considerable and robust revenue stream over and above operating expenses. This surplus has the potential of leveraging the grinding facility for broader improvements in the system, as it can be invested in the shift away from other damaging e-waste dismantling practices and addressing some of the past environmental and health impacts of the value chain.

In exploring a viable business model in some detail with informal recyclers, we identified three potential motivations for paying for the service of grinding cables rather than open burning. First, ground cables produce a copper of a higher grade than burnt copper, and can be sold for a higher price. Whereas burnt 'dirty copper,' classified as 'B' grade, is sold at 85% of the current commodity price of copper, ground 'clean copper,' classified as 'A' or 'AA' grade, is sold for between 90% to 95% of the current price of copper—a difference that currently amounts to an excess of $265 (1000 NIS) per ton. Second, many large scrap yards already now pay $105 (400 NIS) a ton for two of their employees to burn cables at a 'regulated' burn site, so that a grinding facility charging this rate would have an advantage. Third, quite apart from any economic benefits, cable burners are increasingly concerned about the health impact of their occupation, and are eager to transition to less risky methods, and public pressure of exposed residents is large and mounting.

Given these substantial motivators, we drew further on interviews and observations to flesh out estimates of the key elements of a business model for a shared regional copper grinding facility. The following factors were on the revenue side: the volume of copper currently processed in the south-west Hebron, how much informal recyclers are willing to pay for grinding, and the potential for the sale of extracted plastic to refineries. On the cost side are primarily the start-up costs (site preparation and machine purchase) and the ongoing operational costs for the facility. These parameters are given in more detail in the table and text described in this section, which indicate that revenues would exceed operational costs in the most optimistic and expected estimates, but could produce a financially inviable business in the worst case scenario (see Table 1).

More specifically, revenues of the copper grinding facility stem from two sources: charging clients for the use of grinding services and, possibly, revenues derived from retaining and selling the insulation plastic. Our "willingness to pay" figures were derived in consultation with people in the industry (especially cable burners and large scrap yard owners), and they suggest an anticipated fee at

Table 1
Comparing possible scenarios estimating the market, cost and revenue of a copper grinding facility in the West Bank.

	Best-case scenario[a]	Worst-case scenario[b]	Expected scenario[c]
Daily cables burnt	35 t	7 t	10 t
Willingness to pay[d]	$265/t	$55/t	$105/t
Grinding revenue[e]	$2142,525/year	$88,935/year	$242,550/year
Plastic revenue[f]	$646,800/year	$−3557/year	$0/year
Total expected revenue[g]	$2789,325/year	$85,378/year	$242,550/year
Establishment costs[h]	$200,000/year	$355,000/year	$330,000/year
Operational costs[i]	$110,000/year	$160,000/year	$140,000/year
Expected profit[j]	$2679,325/year	$−74,622/year	$102,550/year
Start-up capital required[k]	$310,000/year	$525,000/year	$470,000/year

[a] Highlighting the most favourable estimates that would maximize profits.
[b] Highlighting the least favourable estimates that would minimize profits.
[c] Expected estimates based on most realistic averages and projections from interviews coupled with direct observation.
[d] Original values were determined in Israeli Shekels (NIS) and were converted to US Dollars (USD) at a rate of: 1 USD = 0.265 NIS.
[e] Annual grinding revenue = 10 t × $105/t × 231 work days (11 working months × 21 work days in a month).
[f] Annual plastic revenue = 50% (sellable cables to plastic recycling plant) × t/day × 40% (percentage of cable, on average, that is plastic) × 231 work days × $400 (estimated price of plastic/t).
[g] Total expected revenue = grinding revenue + plastic revenue.
[h] Establishment costs include: copper grinding machine, purchasing land, preparing land, scale, increasing electricity subscription, legal costs, tools, office, and office supplies. Main variations in estimates are based on the costs of different copper grinding machines.
[i] Operational costs include: employee salaries, electricity, water, office supplies, transportation, maintenance, and insurance.
[j] Expected profits = total expected revenue − operational costs.
[k] Amount of capital required to cover establishment costs and operational costs for one year.

the same level as large scrap yards currently pay for the labour and use of land to burn. The higher potential "best case" figure reflects increased revenue through producing higher quality copper from grinding opposed to burning, and the value of avoiding unhealthy burning practices. The pessimistic value reflects the lowest value people in the industry would be willing to pay for use of the facility (these lower values often reflected perceived added costs of transportation based on the single location of the grinding facility versus the more dispersed location of burn sites).

Our estimates of revenues from the stripped plastic insulation are derived from an initial exploration of the market for this kind of plastic. The expected value is $0, under the currently prevailing scenario in which no market has yet formed for this non-standard form of plastic, although several Israeli recycling companies have offered to take the material for the cost of delivery. The worst case scenario reflects a situation in which landfill fees must be paid for its disposal, and the optimistic value reflects the price plastic recycling factories are currently willing to pay for ordinary plastic pellets, $395–475 (1500–1800 NIS) per ton. One ton of cables yields 350–800 kg of plastic (depending on the thickness of the cable), which would yield between $140 and 380 (525–1440 NIS) per ton under the optimistic scenario. These price and cost estimates combined with the estimates of cable volumes yield our overall estimates under the worst, best, and expected scenarios.

Our deliberations also considered the institutional model under which such a facility might operate. A registered NGO would be the most appropriate fiscal and institutional vehicle of the project, under close managerial oversight of an external management party and a Board of Directors to ensure proper allocation of funding. The NGO would be dedicated to maintaining and broadening the basis of livelihoods in the region affected by the informal e-waste industry while safeguarding health and environment, and remediating damages. Ideally, this NGO would be an entity registered specifically for the purpose of implementing the copper-grinding facility, then operating it as a self-sustaining business, with utilization of revenues for purposes and projects aligned with these goals. Over time, and with a proven track record, this NGO could include other projects and broaden its geographic reach and policy engagement. Ideally, the Board of Directors would adopt an adaptive management approach to continually understand and further integrate the informal e-waste industry through the copper grinding business and any additional projects that were funded through its surplus revenues.

7. Conclusions

While this proposed formalization initiative is in early stages, as of May 2015 it had won broad support by the community, the industry, the mayors of the affected villages, the Israeli authorities administering the area, and portions of the Israelis affected by the burning. While the ultimate outcome hinges on the volatile vagaries of Israeli–Palestinian geo-political developments, the fact that the project was seen as sensible by such a broad coalition of stakeholders is remarkable, and we believe it reflects the degree to which the six integration principles were embedded in its design.

Thus, in shaping this proposal, we worked to deeply understand the informal sector and, also, the emerging Israeli e-waste policies and dynamics as these formed over the last year or two. The proposed intervention tackles a significant but not overwhelming piece of the puzzle, and is incremental in that it targeted one component (copper cables) in the e-waste stream, which would leverage upstream and downstream changes at a pace that would be matched to the capacities and business dynamics of a formalizing sector, allowing other components in the e-waste stream to be addressed in the future. This management strategy was evolved by us in co-operation with informal recyclers. Their estimates of the industry's willingness to use and pay for cable grinding services provided the foundation for the proposed business model, while their inputs on costs and barriers produced a management strategy that is acceptable to informal recyclers, and also assured local buy-in. The approach draws on the strengths of the informal sector's proven ability to economically collect and dismantle e-waste, while harmful extraction processes are shifted to formal treatment using advanced machinery for cleaner production. Economic incentives for informal recyclers to earn a higher profit from grinding cables opposed to burning encourages informal e-waste workers to transition to cable grinding on the basis of the financial benefits of cleaner production.

The intervention combines these bottom-up aspects, as well as top-down ones. The willingness of Israeli authorities to selectively allow passage for inputs only to facilities that can demonstrate clean operation is another considerable incentive. If implemented and assured on a stable operating horizon, we know it will encourage other businesses to attempt reforms that would give them such advantage. Similarly, once a viable clean alternative to burning is in place, future top-down regulations setting high penalties for burning cables should be implemented to further motivate informal

recyclers to transition to grinding cables. In addition, we know that there will be a greater willingness of community members to censure and report on facilities that burn: the excuse of "we need to make a living and there is no alternative" will no longer hold.

Of course, informal industries in different regions will have their own distinctive characteristics, and we should be hesitant of blanket management strategies; in each case, a deep understanding of the specific industry to be addressed is required. The political-geographic configuration of Israel/Palestine is unique, but most places will have similar idiosyncratic inflections to some degree. The details might be different, but the key features of the model copper grinding facility described above could potentially be replicated in other contexts: high quantities of cables in one concentrated area, open-burning as the main extraction method, a market for extracted plastic pellets, and community "buy-in" to support such a facility. And, more broadly, we believe the broad formalization principles embodied in the project and in the process by which it was developed have broader reach. They were derived from a survey of the international literatures on e-waste formalization, honed in the Israeli-Palestinian context, and can, in turn, serve as key guidelines – a kind of "conceptual checklist" – that could be usefully applied to similar efforts globally.

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