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by Travis Blackmer, Brienne Berry, Michael Haedicke, Cindy Isenhour, Susanne Lee, Jean D. MacRae, Deborah Saber, and Erin Victor

Abstract

Maine's materials management system is stuck in a disposal mode of waste governance. Despite significant investments in programs and policies designed to reduce the amount of waste the state buries each year, recent shocks and uncertainties have resulted in increased waste generation and disposal. This paper analyzes specific ways through which materials management in Maine has become locked in to a disposal mode of waste governance. We build a framework to help understand various forms of lock-in and how they might be unlocked. This framework is applied to the extended producer responsibility packaging law that is presently under the rule-making process in Maine, the first state to adopt such a policy in the United States.

While this incident was related to incineration, *feeding the beast* is a common necessity among waste management organizations of all types. Recent efforts to ban out-of-state waste in Maine (38 MRSA §1303-C) are the result of growing frustration about the movement of waste from other states into Maine's infrastructure of waste processors and landfills, as a means of keeping them running. Processors and disposal entities depend on various sources of input materials and insist

that keeping a consistent feedstock is necessary for their operations to remain functional and economically solvent.

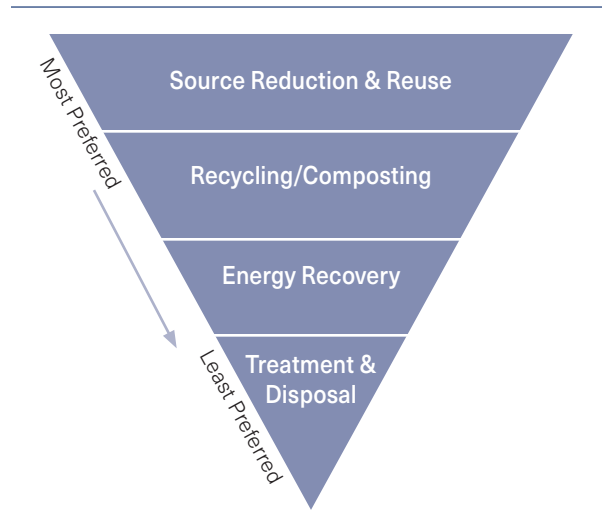
As scholars interested in sustainable materials management in Maine and beyond, we see a problem. While waste disposal is certainly necessary—since not all materials can currently be avoided or recycled—efforts to reduce overall waste generation, disposal, and pollution have largely failed. Maine has implemented strong policies designed to reduce waste and is objectively leading the country on many materials management issues with policies such as extended producer responsibility for packaging and a statewide plastic bag ban. Despite the state's leadership, however, Maine continues to generate and dispose of more waste each year. It seems that the state's system for waste governance is stuck in a disposal mode (Pollans 2017). In other words, Maine, like most states, governs the overwhelming majority of wasted materials by burying or burning them.

Disposal-based waste management options are environmentally least preferred according to the waste management hierarchy (see Figure 1), a decision-making tool for solid waste managers and policymakers.¹ The concepts behind the hierarchy date to the 1970s—first appearing in the European Union's 1975 Waste Framework Directive, which reflected a growing concern with unsustainable waste generation as well

INTRODUCTION

In late 2020, a large shipment of solid-recovered fuel (SRF) traveled by boat from Ireland to the coast of Maine. The shredded, dried, and baled plastic waste was intended to be burned as fuel in a local waste-to-energy facility, but a problem at the receiving dock resulted in two bales of SRF being dropped into Penobscot Bay. Approximately 5,000 pounds of shredded plastic were released into the coastal environment (Carpenter 2020). The story made news globally, prompting questions about why materials should travel so far simply to be processed as waste. The explanation is relatively simple: it was far cheaper to export the waste to Maine than to dispose of it in the United Kingdom. Further, the Maine facility needed the waste as a backup feedstock that could be stored for times when local waste inputs were low. Waste-processing infrastructures (recycling plants, landfills, composters, incinerators) depend on a steady stream of waste to function. Periods of drought—or low materials throughput—raise costs, endanger jobs, and reduce the efficiency of pollution controls. In other words, those bales of waste were considered necessary to fuel the fire of the proverbial beast.

FIGURE 1: US EPA's Waste Management Hierarchy



as insights emerging from systems and life-cycle-based thinking during that period (Lansink 2018). Based on an analysis of the life-cycle costs and benefits of various waste management options, the hierarchy established preferred forms of waste governance (waste reduction and materials reuse) and least preferred options (disposal), based on the prioritization of sustainability, resource efficiency, and environmental health. Nearly 50 years later, the waste hierarchy has become the dominant frame shaping waste policy. It forms the basis of the US Environmental Protection Agency's guidance on waste and is institutionalized in the legislation of many states, including Maine. Yet despite rhetorical and policy frameworks that prioritize source reduction and reuse, the overwhelming majority of the waste stream in the United States continues to be buried or burned.

In this paper we explore why materials management professionals and decision-makers in Maine perceive that the state is stuck in a disposal mode of governance. We first describe the history of materials management in Maine and draw upon interviews with a wide range of materials management professionals to explore why Maine seems stuck in a disposal mode of waste governance. We analyze the information shared with us by stakeholders relative to four forms of lock-in observed in previous research. Finally, we draw upon these insights about lock-in to explore how Maine might break free from its dependence on disposal.

Historical Influences on Materials Management in Maine

Until roughly the last century, waste management was seen largely as a private matter and left to households. As changes in settlement patterns brought larger numbers of people into smaller spaces and trade made our materials more varied, waste management became a matter of public concern and was increasingly seen as a public utility, necessary to ensure sanitation and protect public health (Strasser 1999). These conditions have produced a system of waste management that went from ignoring the problem to dumping wastes in unlined landfills (Vasarhelyi 2021) or the ocean (Galka 2016). Eventually, environmental concerns and pollution forced more careful disposal in managed landfills and closely regulated incinerators.

In 1976, the federal Resource Conservation and Recovery Act (PL 94-580) was passed. The Act set a deadline for the closure of inadequate and unsanitary landfills and put in place strict engineering requirements for all new facilities.² The resulting wave of activity in Maine included construction of sanitary landfills designed to meet EPA requirements, the construction of several waste-to-energy (WTE) facilities, and the start of recycling programs. Two years later the 1978 Public Utility Regulatory Policies Act subsidized waste-to-energy (WTE) facilities with favorable energy purchasing arrangements commonly referred to as power purchasing agreements or PPAs (APPA 2020). In response, the Mid-Maine Waste Action Corporation (MMWAC) was formed in 1986 in Auburn, the Maine Energy Recovery Company (MERC) built a WTE plant in Biddeford in 1987, ecomaine (originally Regional Waste Systems) built a WTE plant in Portland in 1988, and the Penobscot Energy Recovery Company (PERC) was constructed in Orrington in the same year.

In 1989, Maine created the Maine Waste Management Agency and charged it with creating a solid waste management plan, assisting municipalities and businesses in waste reduction and recycling efforts, and developing criteria for the selection of new landfills. Perhaps most importantly, the state established a recycling goal of 50 percent (38 MRS § 2132(1)), developed various assistance programs including an infrastructure grant program and educational efforts, and officially adopted a waste management hierarchy (38 MRSA § 2101).

This framework legislation—along with relatively low per capita waste-generation rates and more progressive legislation like the bottle bill, requirements for electronic waste

recycling, and some of the nation's first product stewardship requirements for mercury and batteries—helped Maine to gain a reputation as a national leader in materials management in the first decade of the 21st century (Blackmer et al. 2015). While these efforts certainly yielded significant improvements, the state has continued to struggle to meet its waste reduction and recycling goals. In fact, the latest Municipal Solid Waste (MSW) Generation and Disposal Capacity report issued by the Maine Department of Environmental Protection states (Maine DEP 2023: 2),

Maine is not currently meeting its MSW reduction and recycling goals. Overall, solid waste disposal tonnage decreased slightly by 0.4% in Maine over the reporting period from 2020 to 2021 although disposal tonnage has generally been trending upward over the past decade. In contrast, recycling tonnage decreased by 10.6% from 2020 to 2021.

This slide in recycling rates can be attributed to a *perfect storm* of recent disruptions in Maine's materials management landscape (Berry et al. 2022), which included China's prohibition of recycling imports (National Sword Policy), increased costs and uncertainty about the safety of recycling due to COVID, and significant controversy surrounding the end of power purchase agreements for incinerators. A detailed analysis of the Municipal Review Committee's decision to transition from the PERC waste-to-energy plant to a startup waste-processing company, Coastal Resource of Maine, is warranted. Regardless of the cause for the facility's still not being operational, this transition is an example of Maine continuing to lock in to a disposal-centric facility with a long-term contract.³

But despite disruptions, Maine has continued its national leadership in materials management over the last five years with a statewide plastic bag ban (38 MSRA § 1611), the nation's first extended producer responsibility (EPR) for packaging (38 MRSA §2146), and legislation to reduce out-of-state waste (38 MRSA §1303-C, sub-§40-A). These progressive materials management policies seem incompatible with a disposal mode and raise interesting questions about why a state with such a progressive history of materials management policy remains stuck in a disposal mode of governance.

Literature Review

The problem of waste governance lock-in has attracted considerable attention from the international research community. It has been observed that, despite significant

awareness of the problems associated with waste production and management, materials management systems are frequently stuck in an unsustainable mode of waste management.

As a whole, the United States remains locked into what Pollans (2017) describes as “the disposal mode” of waste governance. For example, in 2018 the United States produced 292.4 million tons of waste, the equivalent of nearly 5 pounds of waste per person per day. Of this, more than 146 million tons were landfilled and 35.5 million tons were incinerated, meaning that more than 60 percent of US waste is still handled through a disposal mode of governance, nearly 50 years after the waste hierarchy was adopted (US EPA 2023).

The disposal mode is “characterized by governmental rationalities of economic efficiencies” (Pollans 2017: 2302), where materials are managed at the end of life rather than higher up the hierarchy or in the supply chains. This *weak* mode of governance not only fails to address larger issues of consumption levels and waste, but also reinforces existing practices, as “the more mature a system...the more difficult it is to change” (Pollans 2017: 2307). Unfortunately, without accompanying reductions in consumption, the disposal mode reinitiates the process of virgin resource extraction, processing, production, distribution, and consumption to replace materials that were buried or burned. This linear system unnecessarily depletes resources; initiates processes that contribute to biodiversity loss and climate change; and wastes all the human labor and care that went into the production, distribution, and use of wasted goods.

Pollans and many other scholars have researched what it might take to transition to alternative governance approaches. Pollans (2017) identifies several alternative modes of waste governance and the forms of change that will be required for a successful transition (Table 1). Some might argue that Maine has moved into a diversion mode of governance since the waste hierarchy is encoded in regulation and there are some regulatory and infrastructural provisions in place to support improved recycling and recovery rates. The state's disposal numbers, however, tell a different story.

So why has the disposal mode of governance persisted? Many studies focus on the barriers that prevent the adoption of more sustainable practices.⁴ While recognizing that barriers are often inextricably linked, most studies propose a classification system to identify barriers in different fields, typically social/behavioral, political, economic, and technical. A complimentary approach to

TABLE 1: Alternatives to the Disposal Mode of Waste Governance

Alternative governance modes	Focus	Current status	Change required
Diversion (weak sustainability)	Improving recycling and composting to reduce impact of landfills and incineration.	Encoded in regulation and has some infrastructural and regulatory support	Incremental: does not challenge the current order
Eco-efficiency (strong sustainability)	Waste reduction through material reuse	Encoded in policy but with no supportive infrastructure or regulations	Visionary: requires some rethinking of current systems of valuation
Waste as resource (strong sustainability)	Social, economic and environmental benefit through material reuse	No current policy, regulatory or infrastructural support.	Aspirational: requires reframing to see materials governance as social and ecological stewardship

Source: adapted from Pollans (2017)

understanding why we remain stuck in a disposal mode of governance comes from research on socio-technical transitions, path dependencies, and lock-in, which recognizes that waste infrastructures, institutions, and behaviors coevolve and are the products of history. These elements evolve together such that change in one element requires change across the system, often making shifts complicated and difficult. Lock-in mechanisms thus foster the status quo (Simoens et al. 2022) and “develop inertial resistance to large-scale systematic shifts” (Seto et al. 2016: 426). This approach implies that to foster a socio-technical transition toward more sustainable modes of waste governance, we must first understand the mechanisms that must be unlocked to enable change (Foxon 2014).

While the literature on lock-in has traditionally focused on technical-material systems, based on more recent research Simoens and colleagues (2022) propose four categories of lock-in: material, institutional, behavioral, and discursive.

- **Material lock-in** refers to the entrenchment of the existing waste management infrastructure. Existing systems represent significant historical investments of time, labor, learning, and money. All these sunk costs make it difficult to rationalize additional expenditures to replace existing infrastructure, even when alternatives might have favorable returns on investment in both the short and long term (Seto et al. 2016).
- **Institutional lock-in** refers to systems of social and political organization that are designed to be stable. Institutions can be informal or formal, but once established, these institutions are typically defended by those most likely to benefit from the current arrangement.

- **Behavioral lock-in** refers to ingrained patterns of behavior, among various actors from the private citizen to policy makers and corporate executives. Habits, practices formed by institutions and infrastructure, conventions of managing waste, and convenience all shape waste behaviors on multiple scales.
- **Discursive lock-in** can be found in dominant ideas and interpretations of the waste problem. Incumbent and powerful agents often have the ability to shape common understandings of waste-related problems as well as possible solutions potentially limiting the collective imagination.

It is important to note that these four forms of lock-in are deeply interconnected. For example, the behavioral lock-ins are certainly more than the product of individualized habits. They reflect deeply ingrained social practices that developed alongside existing waste infrastructure and institutions (Shove 2014). Likewise, institutional formations are often linked to the values and assumptions of dominant discourses about waste efficiencies and technological solutions (Simoens et al. 2022).

METHODS

In early 2021 our interdisciplinary team of researchers conducted semistructured interviews with 14 professionals deeply engaged in Maine’s materials management system (see Table 2).⁵ Our interviewees—selected from our existing network of nearly 200 stakeholders across the state for their depth of expertise—represented a range of professional and geographical identities, including waste haulers, brokers, and processors, as well as municipal and

TABLE 2: Interviewees, Sectors Represented, and Date of Interview

Sector	Interviewee*	Date
Municipal government	Louis	3/10/21
	Stephanie	4/14/21
	Jada	3/10/21
	Alicia	3/22/21
	John	4/22/21
	Dianne	4/21/21
Waste managers	Monica	4/23/21
	Mitch	5/27/21
	Jesse	5/27/21
	Mark	3/17/21
	Tamara	3/9/21
State government	Larry	4/9/21
	Jack	3/18/21
	Lynn	3/11/21

*Interviewees were assigned pseudonyms to protect confidentiality.

regional officials responsible for making decisions about issues of waste and recycling across the state. All have considerable experience with Maine's materials management system, some having worked in multiple roles over time (e.g., municipal managers, landfill operators, regulators, legislators). While the sample is small, our intention was to provide a representative snapshot of challenges faced by various facets of the materials management system. An open call for interviewees was not solicited and therefore these results cannot be construed as a fully comprehensive account of all stakeholders' understandings of lock-ins. However, we can use these results to understand how key figures and decision-makers in Maine understand the challenges faced by the state as well as potential solutions for moving forward.

Our focus on materials management professionals and decision-makers was motivated by their capacity to both shape and manage local and state waste issues. Pollans (2021) notes the outsized role of municipal managers in defining garbage arguing that these definitional matters shape waste governance practices. Yet we recognize that our participants are not the only voices seeking to define waste in Maine. Scholars have emphasized how activists, NGOs, and informal waste workers redefine and resist dominant waste regimes (see, for example, Liboiron and Lepawsky 2022;

MacBride 2011). Our work here represents the barriers to change as described by a select group of insiders with the power and authority to make decisions about waste issues in Maine. Despite their power within the system, many of our participants described feeling stuck.

We conducted paired interviews to allow for our team to become close to the data and to provide multiple interpretations and opportunities for follow-up questions based on our diverse disciplinary perspectives. Interviews were conducted remotely via Zoom (n=13) or in-person (n=1) based on the preferences of our interviewees. All interviews were recorded with the permission of participants and lasted between 30 and 60 minutes. Members of our research team were assigned to transcribe interviews that we did not participate in to maximize our exposure to interview data and to help us develop an analysis protocol based on emergent themes.

Our goal was to understand the challenges faced by Maine's materials management system and how these experts conceptualize solutions to build resilience. We were interested both in the effects of more recent challenges (COVID-19, National Sword, and infrastructure issues) and in the longstanding issues that emerged through our past engagement with materials managers in Maine. Interviews were semistructured, allowing us the flexibility to follow up on important topics while retaining a common core of questions for all participants.

Our collaborative analysis process involved three iterative cycles of coding and discussion to refine codes, analyses, and ideas. In our first round of coding, interdisciplinary teams of three coded sets of transcripts for key themes. Next, we worked individually within the themes to identify areas of tension or agreement. We discussed how our coding aligned with a range of theoretical frameworks and concluded that theories of lock-in were a strong fit for our data. The final round of coding explored how forms of lock-in were represented in our interviews. Our research process allowed all team members to contribute to the work. This approach drew on insights from our diverse disciplinary training and helped us see the problems and solutions from multiple perspectives.

RESULTS

Our discussions with waste management experts throughout the state suggest that all forms of lock-in are apparent. While we recognize that the different forms of

lock-in are highly interrelated, we outline the forms of lock-in our participants alluded to during interviews.

Material Lock-in

Interviewees identified four material lock-ins that prevent Maine from developing a sustainable, resilient materials management system: the necessity of landfills, the need for centralized recovery facilities to achieve economic scale, the character of materials in the waste stream, and the uncertainty about the return on infrastructure investments.

Landfills

There are many materials produced and circulating in contemporary markets that cannot be recovered for recycling or incinerated to produce energy, which means that as long as those materials are sold, landfills must be available for them and other process residuals. One participant put it succinctly: “landfills are a necessity. There are some things that we just can’t dispose of any other way” (Monica). Because landfills generally require less infrastructure and investment than other approaches to materials management, however, they may be used for materials that are potentially recoverable but at a greater cost. In nearly all circumstances at the same scale, landfilling materials is cheaper, with volume primarily being the driving factor at how cheap. As one participant said, “the cheapest alternative is to just throw everything in a hole in the ground and bury it for the next generation to deal with” (Tamara). Although from a sustainability perspective landfills are the least desirable way to manage trash, their presence and economic efficiency make them the default option.

Centralized recovery facilities

Recovering materials from mixed waste is complex and costly. The economics of recycling favor large facilities that achieve economies of scale to make them more competitive with landfills. These large recycling facilities tend to be located in near population centers, which are able to provide the consistent feedstock necessary for efficient operation and pollution control. Sparsely populated states like Maine create a more challenging environment for recycling facilities. An operator of one facility noted, “we have run out times where we haven’t had enough material and we haven’t had material in the quantities that were at the prices needed to support this operation” (Mitch). These facilities also face the risk of changing market prices obtained for recovered

materials, which occurred when China stopped importing baled recycled materials (Resource Recycling 2018, 2022).

In Maine’s rural areas, materials diverted from landfills to recycling are often transported long distances to recovery facilities. This distance increases the cost of recovery for communities even if per-unit material handling cost is low in the far-off facility. As one participant explained, “one of the big barriers in any rural area...they just don’t have anywhere close enough to be able to transport these materials to make it economically feasible, whether there’s markets or not” (Stephanie). The wide array of materials used in products and packaging makes recovery of most low-value commodities infeasible. As a result, many Maine communities have simply stopped recycling some or all materials.

Other communities that continue to recycle struggle to store materials (at a cost) for long enough to accumulate enough for a load. Additionally, they may lack the resources to invest in collecting materials and supervising storage containers. In the words of one participant, “there are some municipalities that are so far behind in terms of the resources that they can allocate to collection, aggregating—really being able to ensure that what is going into various streams as the appropriate material, when it’s just a bunch of dumpsters” (Alicia). More contamination of stored materials increases the cost of processing and often reduces the value (or acceptance) of the materials. Remote rural communities and cooperatives thus face higher costs for material storage, transportation, and recovery.

Character of the materials

Most products currently available are not designed to maximize product lifetimes, or for the ease of end-of-life management, or to ensure reuse. So although materials and waste management systems are held responsible for sustainably managing materials and waste, they often have little influence on the types of waste materials generated. Instead, materials managers must respond to the constantly changing nature of the waste stream. When new materials enter the waste stream, waste managers often struggle to respond given relatively rigid management infrastructures. More than one stakeholder complained that many packaging innovations are not recyclable and items are not designed for longevity: “there’s just so much stuff that people blow through. Everything’s disposable....You know, it’s terrible. It’s just really horrible” (Dianne).

Similarly, new materials, such as composites, and materials treated with additives that are not reported or evident create challenges for recovery operations. One of our participants noted:

We need to get the hazardous components out of our packaging...you can't have combustibles with PFAS. You can't have plastics with phthalates and brominated flame retardants and what not because you don't want to recycle those into something (Lynn).

While innovative recovery methods to control these risks are possible in theory, such methods have not been demonstrated to work at scale, and the costs to test and refine them can be prohibitive. These factors impose considerable risk to communities that invest in such facilities in the early stages of development. One interviewee commented that “you might be able to do something in...a science lab that says we could do this with that product, but to try to do it on a grander scale...is just not realistic” (Mark). With changing materials, limited ability to identify and find dangerous additives, and rapidly evolving technologies, attempting new material recovery is risky. Again, this pushes communities to avoid the cost of recovery in favor of the landfill option, which is cheaper and less risky in the short term.

Infrastructural investments

The fourth material lock-in mechanism is related to the previous two and contrasts the risk and reward tradeoffs for comprehensive facilities to divert materials from landfills. The large capital investment required for material and energy recovery, combined with uncertainty in the feedstock and volatile markets for materials, introduces a level of risk that some communities are unable or unwilling to accept. Regionalization can spread the risk of investment in infrastructure, but it exacerbates the transportation cost issues for the more remote communities. Having one or two large and geographically distant facilities vs several small options also limits redundancy in the system and can produce power imbalances that limit future choices. One stakeholder said, “but the closer you can keep the material, turn it back into the goods you need, of course, that would be better. But then again, we're back to the old issue of, can we generate enough volume to run that next plant?” (Jesse). The volatility and uncertainty are likewise difficult to mitigate. “If we put like a real big effort into getting a lot more plastic, we don't have the infrastructure to handle it. So that would drive the price way down if we had a lot more places that could take it” (Mark). The relatively small amount of feed material and

high investment generates fierce competition among the facilities that process those feedstocks. “All of these different methods of disposal are often pitted against each other” (Monica), and they are left in a situation where they compete for feedstock to feed their independent facilities.

Institutional Lock-in

A second set of lock-ins is produced by the social organizations that make up the materials management system and by the formal and informal rules that govern practices within it. Our stakeholders helped us to identify three institutional lock-ins that prevent movement towards a more sustainable and resilient system: the absence of comprehensive institutional planning at the state level, lack of institutions to coordinate policy across different levels of government, and market institutions that create barriers for behavioral modification. These institutional lock-ins make processes difficult to change because of their roots in the expectations, processes, and organization of institutional power.

Absence of comprehensive planning

Maine is considered a strong home-rule state, meaning that the state delegates broad home rule to cities and towns. As such, state-level mandates are difficult to justify and pass, particularly if they add additional costs for municipalities. The state must fund municipalities to carry out any state-mandated requirements. Due to this system, Maine's waste management landscape is a patchwork of institutions. Without strong coordination, municipalities make decisions based on local institutional norms, often centered on cost or risk avoidance. Many municipalities have formed public-private partnerships with processors or have joined with surrounding communities to set up institutions for collaboration.

With little centralized planning and the absence of institutions for state-level waste management, processes are often driven by the economy as well as localized or regional contracts that municipalities sign with waste management providers. This patchwork of stakeholders is often unable to gather the market power necessary to design more sustainable institutions for waste management. Towns, in particular, tend to get locked into long-term contracts that lack the flexibility to allow local governments to respond to shifts in the recycling (or other material) markets.

Further, without centralized planning to reduce the impact of uncertainty in markets, communities are also differentially affected by disruptions including new

waste-related bills, facilities closing, recycling changes, and changes to the waste stream and workforce caused by the pandemic. One participant explained their overall views of the system, commenting that “right now, it’s pretty piecemeal, so I think that’s a barrier...we’re basically going product by product right now...and I suspect funding, of course, is probably an issue” (Dianne). Another noted that “there’s no overall plan anywhere. Not nationally and not statewide” (Jada).

Some interviewees also expressed an interest in the information that disbanded state-level institutions formerly had the capacity to provide for waste management. One, for example, said:

So, we probably have an opportunity to think about planning and zoning. And I wish we had the State Planning Office back.... But we have an opportunity to plan ahead and think about smart growth as our population grows because I anticipate that that will continue happening (Lynn).

The remaining tasks of the state’s waste activities that were already not assigned to the Department of Environmental Protection (DEP) have been placed with that organization. Agencies such as the Maine Waste Management Agency (created in 1989 and disbanded in 1995) and the State Planning Office (created in 1968 and disbanded in 2012) were responsible for planning and goal setting for the state, disentangling the regulatory, policy-making, rule-making, and visionary roles for materials management in Maine that exist for the DEP today.

Another set of interviewees were focused on the markets for the end products. Both identified a need for policy support at the state or local level. Monica noted that “the conversation should be let’s figure out how to create a market demand, how to build the infrastructure, how to recover these materials, and using legislation for recycled content.” Another said, “I think the state should be doing a lot more. The legislature should be doing a lot more. We need the government to step in a little bit more, I believe” (Louis).

Uncoordinated policy

The choices available to participants in Maine’s materials management system are shaped by policy decisions at different levels of government. In the United States, policymakers guide regulatory agencies at the local, regional, state, and federal levels to mandate and recommend processes for waste management. However, policies designed to encourage sustainable practices within the jurisdiction of one

government entity may unintentionally push other areas towards disposability. One participant described how this dynamic appeared in state-level policy in New England:

You see what happen[ed] in Massachusetts and how they just legislated things that just couldn’t be deposited in their state. Well, all they did was push things...to different places’ processing facilities. So it’s great for legislators to say, ‘no you can’t do this.’ But they didn’t open up new disposal markets and they... actually closed a lot of the disposal markets that existed (Mark).

As this participant explained, the failure of New England states to coordinate policy with one another resulted in a failure to advance sustainability at a regional level. Rather, states are locked into a zero-sum relationship where one state’s progress towards sustainable materials management increased burdens on recovery and disposal facilities in neighboring states.

Lack of coordination is also apparent at the global level, as policy decisions in one country may disrupt recovery practices in other countries. For instance, one participant spoke about the National Sword policy in China:

You just even look at before and after the Chinese National Sword policy that went into effect in 2018, what that did to even just the value of one commodity and how that disrupted all of the recycling markets and all the articles out there saying recycling is dead and your stuff is just going to a landfill (Tamara).

Landfilling becomes a frequently used fallback for divertible materials during these recurring disruptions. Materials are diverted to landfills because they are readily available and their use lets the municipality maintain safety and sanitation.

Barriers to behavioral modification

Finally, several participants noted that the organization of the market creates institutions that make it difficult to modify the waste governance structure. Several participants lamented that a reliance on market institutions limits their choices for waste management. The booms and busts of recycling prices lead many to feel they were beholden to the whims of the market rather than any sort of best practices. As one stakeholder identified, “we don’t have a solid waste management system, we have a marketplace. We don’t direct where trash can go, it basically is going to flow to the cheapest option. And so far, the cheapest option has been landfills” (Larry). For town managers who may be required

to choose the cheapest option and will be held responsible if they invest in a more expensive system that fails to meet diversion goals, there is little incentive to maximize material recovery in this changing environment.

Other participants shared a sense that our institutions, both public and private, are not designed for anything but disposal. One said, “pay the repair guy two hundred and something dollars to come here or go buy a new one for four hundred bucks? I’m going to buy a new one so I don’t have to pay the repair guy twice...we’re very much a disposable society and that’s a cultural thing” (Mark).

Cultural institutions, while often intangible, certainly shape human behavior, yet these cultural systems are often reproduced without much thought. Some waste managers have been thinking about them for years, however, and lament how durable our cultural institutions are. One said in an interview, “we should [take] back the sense of ownership over the things that we own and [care] for them as if they really matter instead of their being disposable” (Lynn).

Behavioral Lock-in

Deeply rooted human behaviors also keep our communities locked in to the disposal mode of waste governance. We identified three behavioral lock-ins based on our interviews that prevent movements toward a sustainable and resilient system: habituation, risk avoidance, and obstacles to public understanding.

Habituation

Habits and routines unconsciously reinforce established practices. Our stakeholders explained that one of the problems they faced was the mindset of “it’s always worked this way. Why would it be different now?” (Alicia). All our research participants had opinions on the mindset of the end disposer. One of the ascribed traits to individuals was laziness:

I hate to say laziness, but people don’t want to—they don’t want to do it anymore. They won’t sort....They want to just back in, dump it, and leave. They want it to just go away (Jesse).

A common thread in discussions of habituation was the idea that materials are disposed of without much thought. One stakeholder lamented that many people “have managed their solid waste by not thinking about it. But just everything goes into a dumpster. And what we know is that’s not going to work” (Alicia).

These automatic habits and routines commonly form around cheap and convenient solutions. Interviewees also identified that “the perspective from the general population is that [materials management] should be free. It shouldn’t cost anything, and we don’t really care about what the implications are” (Mark). The seamless provision of waste collection services has, according to some stakeholders, given individuals the impression that municipalities “already have free garbage collection...when I say free, what I mean is it’s on the tax rolls so they don’t notice it. It’s paid for in their property taxes. That doesn’t give people much incentive to recycle” (Stephanie). Waste experts connected to large urban centers in Maine noted that about residents: “[if] you have no concept of where [trash] goes, it doesn’t really teach you that there needs to be another alternative” (Tamara). This lack of understanding leads to a mindset of “don’t know, don’t care, put it at the curb, put it in my dumpster, and it’s gone” (Mark). Habituated to the convenience and low cost of disposal, more hands-on materials management options can appear intrusive and burdensome.

Risk avoidance

The second behavioral lock-in mechanism is risk avoidance, which leads people to avoid new practices because of perceived risks and unclear outcomes. This behavior will manifest in the administration of any institution as well as at the individual level. At least one stakeholder made explicit reference to this behavioral mechanism when explaining obstacles to change in Maine’s materials management system: “Municipalities in the state—we are risk averse. We don’t like that....We need to be willing to take risks and we need to be more willing to accept that when things don’t work, we need to pivot and try something different” (Alicia). A town manager or public works director would need intrinsic motivation to take a risk that could enhance the sustainability of their materials management if it could possibly create a negative outcome, increase costs, or inconvenience constituents. A second stakeholder echoed this concern, highlighting the tendency of municipal leaders to focus on the potential negative consequences of innovations rather than their potentially transformative benefits. Describing the reasoning of a hypothetical municipal waste manager, this individual explained, “Yeah, I want to recycle, but how much is that going to cost? Oh, man, I’ve got to put a second dumpster out there? That’s going to take up a parking spot. I can’t take up a parking spot” (Mark).

Other stakeholders described how risk avoidance contributes to financial and regulatory barriers to innovative waste management practices. One interviewee asserted, “somebody has got to be willing to take a chance and to invest in new technologies and new ways of doing things. And we can’t just keep waiting for somebody else to do it. You know, we’ve got to step up” (Monica). Risk avoidance is particularly strong if a new solution was tried and failed. The risk avoidance lock-in will be difficult to overcome in the future. Several stakeholders expressed concerns about difficulty in undertaking innovative, unproven, or expensive management solutions.

Obstacles to public understanding

Interview participants also noted that waste producers, particularly at the household level, generally had little understanding of recovery and disposal processes within Maine’s materials management system. One participant explained:

I bet if I asked one hundred people in Bangor, do you know where your trash goes? Nope!....I think the majority of people don’t know and they’re not really interested to learn more. And then when you do talk to them about it, it’s like, holy cow I had no idea that all that was going on! (Mark).

The lack of public understanding translates into an absence of pressure to develop alternatives in Maine’s materials management system. In explaining this lack of understanding, one participant emphasized institutional arrangements, in particular municipal control of waste management, and the resulting diversity of practices between municipalities that exists within the state. This individual noted:

I think that the way that the system is set up with local control and each municipality having to decide what they can do creates a spider web of just logistics and issues that cause a lot of uncertainty.... And that makes education, outreach around waste management and recycling issues very difficult sometimes because depending on where you live, there could be five different answers to the same question (Monica).

Discursive Lock-in

Discursive lock-in refers to the ways in which dominant ideas and interpretations of waste management reinforce unsustainable practices by concealing the problems created by these practices and making reuse-focused alternatives more difficult to contemplate. Our stakeholders identified

three discursive lock-ins that in their experience contributed to a resistance to change Maine’s approach to materials management: difficulty producing effective public messaging, the focus of the waste hierarchy on postconsumer aspects of the system, and an isolated success focus that overlooks challenges.

Public messaging

Interviewees recognized the challenge of crafting compelling public relations messages to promote recycling, reuse, or other alternatives to the disposal of materials in landfills. Several interviewees attributed these challenges to the dominant role that manufacturers of disposable goods play in public conversations about materials management. For instance, one interviewee drew attention to the discursive power of the resin identification codes (which resemble recycling symbols) printed on plastic containers:

I think part of it as a recycling facility, you see contamination and we see some real hazards coming into our facility from lack of education and product labeling that’s misleading. If there’s a recycling symbol on something that doesn’t always mean that that should go into a recycling bin. We’re having to be reactive... rather than being a part of that conversation in the designing and planning stages of a product (Tamara).

Similarly, a second interviewee highlighted the legacy of industry advertising campaigns that linked convenience with disposability and influenced consumers’ practices:

There is a huge concentrated effort by the plastics industry and the chemical companies to promote this lifestyle of disposable and easy convenience. You can look online and there’s all these old advertising campaigns showing people happily throwing stuff in the trash can. But it took decades of marketing to get us where we are now (Lynn).

Another interviewee emphasized the role and power of industry-funded quasi-scientific studies on the environmental impact of plastics, which, in this person’s view, designed life cycle assessments (LCAs) to produce a largely positive view of the environmental burdens of disposable plastics. These views shape public discourse and make it challenging to advocate for increased use of recyclable or reusable materials:

There’s a lot of industry-funded LCAs—life cycle assessments—that look at plastics and they often come out on top in terms of packaging because they’re lighter, but they leave out a lot....There aren’t as many

studies that look at kind of these critical things that we should be thinking about. There's how do you factor in the health cost of the people who live near plastics production facilities? We don't have ways to measure a lot of this stuff. We don't have ways to measure health impacts of microplastics (Lynn).

Waste hierarchy

Interviewees identified the waste hierarchy model promoted by environmental groups and public authorities as a discursive lock-in. While interviewees acknowledged that the model was well intentioned, they also noted that it focuses conversation on the postconsumer phase of the material's life cycle. As a result, this model can make it more difficult to discuss upstream strategies focused on product and packaging design, which have the potential to alter the magnitude and composition of the waste stream. For instance, one interviewee noted:

We want to talk about how this disposal option or that disposal option is bad or worse or better...maybe we should just try to figure out a way to stop making the stuff in the first place....Let's go upstream a little bit... and try to get some of this consumer packaging out, try to figure out ways to develop markets and demand for some of the waste...and infrastructure to manage it (Monica).

Another interviewee remarked, “the conversation isn't really about generating less material. It's all about the disposal sites and what's better” (Mark).

Isolated success focus

Interviewees identified the tendency for public authorities and the media to focus attention on isolated recycling and reuse success stories as a discursive lock-in. These successes are often located in the more populous regions of the state, where there are more options available, and largely unavailable to the rest of the state due to lack of infrastructure and high transportation costs. Another interviewee voiced concern that this focus on isolated successes might obscure the fact that disposal is still the dominant approach to materials management in Maine. One individual offered the following perspective about construction and demolition debris (CDD). While celebrated for diversion and beneficial reuse, it also results in loss of landfill capacity:

We get construction and demolition debris from Massachusetts because Massachusetts has a ban on the disposal....So there's [company x]...and the majority of waste that they take is from Massachusetts for their

CDD, and then they process it. The residual goes into the landfill at Juniper Ridge and then the wood chips and some of the other materials they use for alternative daily cover as a beneficial use. It's about 250,000 tons of out-of-state waste...a year; 910,000 of CDD are generated in the state of Maine over a two-year period [went unprocessed]...if we're really concerned about landfill capacity and about that air space and recycling this material—then why isn't the conversation about the 910,000 tons that we generate in the state of Maine over the course of two years? (Monica).

Moving from the bottom to the top of the waste hierarchy is often difficult to achieve. CDD, food waste, and other diversion activities at the municipal or service provider level are most often found in southern Maine with its higher population density and material volumes. Rural and urban planners alike have commonly referred to the “two Maines” concept at planning meetings organized by the DEP and the Mitchell Center. One stakeholder discussed this mindset from the middle ground—not a rural county (Aroostook, Franklin, Piscataquis, or Washington) nor a highly urban county (Androscoggin, Cumberland, or York):

If I was to be looking at getting into that business I would have to think twice because so many operations have failed for a number of different reasons...it seems to be a real kind of roll of the dice if you're going to be able to make it succeed or not....I feel like we're probably in a better position than...a lot of the other towns in Maine, we've got things a lot closer, so. But still, even here, we don't have a facility here, so we're all having to go outside to get that done (Stephanie).

DISCUSSION: UNLOCKING SOLUTIONS

So how might Maine unlock solutions to our materials management issues? Our stakeholders outlined material dimensions of lock-in that suggest the need for new infrastructure designed with an eye to the future and the forms of waste governance the state aspires to. Complementary institutional initiatives could help facilitate a transition to a system focused higher on the waste hierarchy, such as centralized state-level planning and coordination across scales to reduce uncertainty and vulnerability to market booms and busts. Stronger incentives to shift behavior in support of the waste hierarchy are also important. Similarly, there is a need for clear and reliable information about waste management options and outcomes and data to counter the confusing and often contradictory claims of those who

LOCK-IN SUMMARY

- **Material lock-in** includes economic and technical aspects that act as barriers to change and improvement in the system.
 - The necessity of landfills
 - Large, centralized recovery facilities
 - Character of materials in the waste stream
 - Uncertainty in infrastructural investments
- **Institutional lock-ins** are elements that can be experienced in the work setting that make processes difficult to change because of their root in expectations, processes, and institutional power.
 - Absence of comprehensive planning at the state level
 - Uncoordinated policy at different levels of government
 - Market institutions that prevent behavioral modification
- **Behavioral lock-in** refers to the dominant and deeply rooted human behavioral rules or paradigms that reinforce the status quo.
 - Habituation
 - Risk avoidance
 - Obstacles to public understanding
- **Discursive lock-in** refers to the dominant ideas and cultural messages that impede social and institutional change.
 - Public messaging
 - The waste hierarchy
 - Isolated success focus

benefit from sales of disposable products and packaging. Shifts in discourse can also help shift our attention away from managing waste at the end of useful life and toward preventing waste in the first place through a focus on more sustainable design.

The multiple dimensions of lock-in (material, institutional, behavioral, and discursive) often overlap and intertwine in ways that make it difficult to address one dimension without working to unlock the others. However, if we better understand their relationship to one another, we might use this understanding to evaluate existing and potential policies—that is, to see how a policy might address ways in which we have become stuck.

We outline this process through a brief analysis of extended producer responsibility (EPR) legislation in Maine. Our focus on EPR is motivated by its relative recency, as well as by its transformative potential (Berry et al. 2022). Further, EPR policy is not yet settled in Maine. An extensive rulemaking process with substantial public engagement is underway, during which time many important facets of the policy will be determined. This present malleability offers a unique moment where we can both evaluate proposals and offer actionable alternatives to address some of the present challenges for materials management in Maine.

In 2021, Maine became the first state in the country to pass EPR for packaging legislation. Maine’s policy creates a nonprofit stewardship organization to oversee the program and collect statewide data. Producers are required to pay an annual fee to the stewardship organization based on the amount and type of packaging materials sold in the state. To be reimbursed by the stewardship organization for the costs of managing packaging materials, municipalities must accept a minimum list of recyclables (38 MRSA §2146).

EPR offers opportunities to unlock specific aspects of Maine’s materials management system from a disposal mode. For example, the policy not only offers reimbursement to municipalities for recycling costs, but also intends to change product design and manufacture so items are less wasteful and potentially less hazardous (Lifset et al. 2013). Such a policy, if effective, would address material lock-ins related to a lack of communication between producers and materials managers. EPR also has the potential to address a dimension of institutional lock-in. By ensuring that municipalities across the state have a common list of recyclables, EPR provides a level of coordination and harmonization across previously diverse practices and processes. Overcoming the home-rule requirement for mandatory funding is also a key lock-in for comprehensive planning that EPR is designed to achieve.

EPR in Maine, however, does not yet address dimensions of behavioral lock-in related to cultural norms and habituation. Yet there is potential to unlock this dimension. Oregon, the second state in the country to pass EPR for packaging, has written public education into its policy, which could help overcome some behavioral lock-ins. Maine’s legislation also does not address some discursive forms of lock-in, specifically around public messaging. If there are remaining funds after reimbursing municipalities, the Maine EPR for packaging law indicates funds will be

used to improve infrastructure and education. In Oregon, there is more explicit attention to public education and messaging with producer responsibility organizations required to design educational resources for local government use. Additionally, the Oregon legislation required the establishment of a Truth in Labeling Task Force to evaluate the use of the chasing arrows recycling logo on plastics and recyclability claims on packaging. This requirement will address a discursive lock-in related to public messaging around what is recyclable and how producers make claims about recyclability on their products (2021 Oregon SB 582).

It is clear when analyzing EPR against the conceptual lens of lock-in that the policy is not a panacea. Much depends on how the policy is defined in the rulemaking process, where, for example, it might be possible to allocate funds toward public education or messaging. What we find most useful about this exercise is its ability to show the potential of materials management policies. If we understand lock-ins as obstacles to more sustainable materials management, then the use of a lock-in framework to evaluate policy can help us unlock solutions.

CONCLUSION

Although we have argued that Maine is stuck in a disposal mode of waste governance, which might come across as hopeless, this article also offers hope to its readers. We cannot experience a breakthrough if we do not understand the factors that are holding us back. Our brief analysis of EPR for packaging policy provides an example of how the concept of lock-in can show the potential for materials management policies to address some of the dimensions of lock-in. Importantly, no one policy can solve all Maine's current challenges. But if future policies are oriented around solutions to our material, institutional, behavioral, and discursive lock-ins, we see enormous potential for more sustainable materials management in Maine and beyond.

NOTES

- 1 <https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy>
- 2 <https://www.epa.gov/rcra>
- 3 To illustrate the effect of the ingrained disposal mode of waste governance, consider the controversial transition and subsequent disruptions following the Municipal Review Committee's (MRC) shift from Penobscot Energy Recovery Corp's (PERC)

in Maine. These two organizations established a contract to incinerate MSW tethered to a power purchasing agreement at a waste-to-energy facility located in Orrington. When that contract expired in 2018, rather than continuing to invest in older infrastructure with PERC, the MRC partnered with Fiberright/Coastal Resource Management (CRM) to shift to a new technology. The technology was unproven at scale, and there were significant delays in permitting, construction, and financing of the facility intermingled with legal challenges exacerbating each barrier. These issues led to a later opening than anticipated and the closure of the facility by early 2020 (Staub 2020). Although the new contract would change from a disposal system that generates electricity from waste processing (PERC) to one that generates methane from anaerobic digestion (CRM), both are linear materials systems. Both reduce waste volume and get additional use out of some materials being processed, but neither creates a circularized organics management system, such as, for example, processing food waste into compost that helps grow the next crop of food. CRM's benefit was that the historically unmanaged organics stream, which includes diapers and pet waste in addition to clean food scraps, could be converted to usable energy.

Despite its brief tenure in Maine, CRM had an outsized impact on the state's materials management system. The CRM process made it appear plausible for some communities to adopt a "one-bin-all-in" process, which did not require separating materials (though many towns did choose to continue to separate recycling). Additionally, there was a bypass agreement that if there were any plant disruptions or delays, towns would send their materials to Crossroads Landfill in Norridgewock. CRM's initial delays, and now longer-term closure, has caused a great deal of waste that was formerly recycled or processed for energy by PERC to be sent to landfills instead. The 115 communities that had signed with CRM could not develop composting programs due to language in their contracts because organic materials were a vital part of CRM's intended process. This occurred against a backdrop of the community food waste reduction movement that is expanding today but was not present when these agreements were signed between 2015 and 2017.

- 4 See Blackmer et al. (2015), Graham-Rowe et al. (2014), Isenhour et al. (2016), Stanislaus (2018).
- 5 This paper is rooted in our interdisciplinary research team's history of stakeholder-engaged work in collaboration with materials managers in Maine (and across New England). Our work began in 2015 through a series of workshops to understand the issues materials managers faced across the state (Mitchell Center 2015). Through engagement with a diverse range of partners, we have been encouraged and supported to conduct research on the history of waste management in Maine (Berry 2022; Blackmer et al. 2015), waste reduction policies (Isenhour et al. 2016), reuse economies (Isenhour et al. 2017), food waste policy (Isenhour 2018), and circularizing the food system (Isenhour et al. 2022; MacRae et al. 2020; Thakali et al. 2022) to explore opportunities to build more sustainable materials management systems. Our work has indicated a materials management system—or systems—that are both ever-changing, but have not, as a whole, been able to move beyond the disposal mode of governance.

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