Local Sustainability Policies and Programs

A Handbook for Deliberation Support

Editor: Steven O. Kimbrough

Institute: University of Pennsylvania

Date: July 6, 2021

Version: 0.00001

GitHub link for local and academic workbooks:

https://github.com/stevenokimbrough/sokpapers/blob/master/ClimateDecisionsLab/Climate_Decisions_Lab_Workbook_Local.pdf

https://github.com/stevenokimbrough/sokpapers/blob/master/ClimateDecisionsLab/Climate_Decisions_Lab_Handbook_Academic.pdf

This is a draft, very much a work in progress. Comments and suggestions welcome. kimbrough@wharton.upenn.edu

Contents

Preface

This handbook is, as its subtitle proclaims, meant to serve as a tool to support deliberation with regard to climate change-related programs and policies ("programs" for short). Our focus is on programs that may be implemented at state and local levels of government and administration. The needs of such deliberation are open-ended and in consequence the handbook can never truly be completed. Our plan is to begin by producing something that has some immediate utility and then grow it to become ever more valuable.

Policy making is fraught, vexing, and contentious, especially so in the case of climate policy. The purpose of this handbook is to assist those who would seek to establish effective climate and sustainability policies in the face of great ranges of interests and views by stakeholders. The assistance is in the form of policy and program information, as well as pertinent methodologies, tools, instruction, and results. We appreciate that the methodologies will be unfamiliar to many and their relevance and use not apparent. Indeed, there is no imperative to select everything on the menu this handbook presents. We encourage picking and choosing and we counsel patience and communication with the authors.

We envision several kinds of supports for policy deliberation on sustainability. In brief:

1. A curated repository of information about policies and programs appropriate for state and local adoption. This information constitutes the core of the project, upon which all else builds.
2. Tools, instruction, and eventually results on decision processes for group decision making for climate change policies.
3. Tools, instruction, and eventually results on decision analysis modeling pertaining to climate change policies.
4. Role-play simulations for climate change policy design.

Part I presents a succinct overview for each of these elements.

There are two overarching and distinctive presumptions to this project. (1) There is much to be gained in considering the program alternatives as a group. (2) The analysis will be permanently incomplete, with imprecise and incomplete data present. The trick is to make the most of what we have.

—Steven O. Kimbrough, April 4, 2021, `kimbrough@wharton.upenn.edu`

Part I

Preliminaries

Chapter 1 Overview

By: Steven O. Kimbrough

1.1 Introduction

Transitioning to a sustainable, resilient society is necessary and urgent. It is also dauntingly complex. This great transition requires putting into place a large number of programs and policies. These programs will be selected from a much larger set of possibilities. They will often interact, with vexing consequences that are challenging to foresee.

Organizations of all sizes–civic organizations, state and local governments, small, medium and large commercial firms, national governments, and international treaty organizations—have to grapple with decisions of which programs and policies to implement, and how. They are doing so today and will continue to need to do so at scale.

Focusing on programs and policies apt for selection by municipalities and other local governments, the purpose of this handbook is to facilitate the discussions, the deliberations, and the decisions, that are undertaken to effect the great transition. We are especially concerned with how policies interact with each other and with the preferences and interests of stakeholders. The present chapter overviews concepts for facilitating and supporting these deliberations. It is an introduction to—a brochure for—the larger report that follows and that will be permanently under development.

Throughout and especially in this chapter, we proceed concretely, with examples. We begin with examples of programs and policies that constitute the basis of any deliberation. The deliberations are, after all, about which policies and programs to put into effect and how. It is best, then, to put examples of the objects of deliberation, the policy options, clearly in view and to keep them there.

1.2 A High-Priority Discussion Pool of Sub-National Programs and Policies

This section presents several **kinds** of programs and policies; each has multiple specific variants. Subsequent chapters will expand the scope and specificity of policies in play. Our focus in this chapter is on examples that illustrate the overall approach.

1.2.1 The Short List

The purpose of this section is to present and maintain one or more short lists of policies, suitable to be candidate policies in role play and group discussion exercises. Unless otherwise noted, the presumed context is a county or municipal government.

1. Low embodied carbon concrete
2. Composting
3. Sustainable living and brokering

   Includes green financing, perhaps in a brokering role, as well as green living information, such as on building electrification. Rather like a form of extension agent.
4. Building electrification mandates and subventions
5. Mandate to electrify lawn care equipment
6. Conversion of buses and utility vehicles to all electric
7. Food rescue programs

   From restaurants and grocery stores mainly
8. Fund EV charging stations
9. Expand non-motorized (pedestrian and bicycle) thoroughfares.

   Possible co-benefit: reduction of traffic and congestion on motorized thoroughfares.
10. Revision of municipal work rules (e.g., 4-day week; work at home encouragement) to reduced GHG emissions
11. Purchase green electricity

1.2.2 Low Embodied Carbon Concrete

Making cement for concrete is a major GHG emissions source, perhaps seven percent to total global emissions (https://www.iea.org/reports/cement).[1] Fortunately, commercial products are now available at a modest cost premium that provide *low embodied carbon concrete*. In consequence many organizations, both commercial and governmental, have developed policies and practices to encourage or even require the use of low embodied carbon concrete in new construction, including buildings, roads, and sidewalks. The additional cost is a very small percentage of the total cost of the associated projects.

Research the calculation of what it costs to reduce a tonne of CO2 emissions by using low carbon concrete.

Administrative costs (rules and verification procedures) are small for the governing entity and quite incremental to the funder of a project.

The Concrete Center is a good online source, https://www.concretecentre.com/ and especially https://www.concretecentre.com/Publications-Software/Concrete-Compass/Low-Carbon-Concrete.aspx. See chapter 12 for further discussion.

[1] For a news report: https://theconversation.com/bendable-concrete-and-other-co2-infused-cement-mixes-could-dramatically-cut-global-emissions-152544 https://theconversation.com/bendable-concrete-and-other-co2-infused-cement-mixes-could-dramatically-cut-global-emissions-

1.2.3 Composting

Composting is the process of turning organic, carbon-based materials into nutrient-rich fertilizer for soil. It enhances the porosity, stability, water retention, and tillage of soil and improves its resistance to erosion and parasites. As an aerobic process, it decomposes waste materials from yards, kitchens, homes, and other sources in order to manage waste. This diverts the waste from going into a landfill and provides a variety of benefits. There is some benefit from GHG emissions reduction, as the composted materials sequester carbon in the soil.

We need to nail this down more specifically.

Composting programs come in several varieties. The most relevant form for municipalities is *curbside composting*, in which buckets of compostable materials are collected from households much as garbage and recyclables are collected. When run as a typical commercial service, customers are given a fresh five-gallon bucket with each pick up and are changed \$12 (\$18) per month for bi-weekly (weekly) pick up and bucket replacement.

Curbside composting programs may be run in a variety of ways. They may be done in-house or outsourced to a commercial vendor; they may be charged directly to participants or funded as part of general waste collection.

Municipally-sponsored curbside composting programs are common and have existed for several years.

What can be composted is an important issue that arises with all composting programs. Plastics substitute products (table ware, bottles, etc.) on the market are often promoted as compostable but must be treated with high-end industrial composting processes that local vendors often to do provide. Local vendors typically dismiss these compostable claims as greenwashing.

Composting programs require initial and perhaps ongoing educational programs to assure their proper use and flourishing.

See chapter 8 for further information.

1.2.4 Green Financing

Green financing is often instituted through a *green bank* of one kind or another. A green bank is an institution that is created to provide opportunities and funding for green initiatives.

Contrary to the name, a green bank is typically not actually a bank; the institution is often a nonprofit that acts more as an investment vehicle and works to broker deals between investors (clients) and funders. Rather than competing with existing financial institutions, a green bank provides financing with the goal of creating environmental impact, not maximizing profit. The value proposition is that the green bank reduces the cost of capital for green projects, thus incentivizing the change towards a more sustainable future. Some green banks take on many smaller, conventionally unprofitable loans and securitize them for larger banks; this allows the green bank to pursue smaller projects and enables larger banks to partake in financing green projects.

In addition to simple financing, green banks may implement creative or non-traditional methods of allocating capital to customers unable to dedicate sufficient money to green projects. For example, a green bank may choose to co-invest in a project that does not have sufficient funds or resort to on-bill financing (allowing customers to include repayment as a part of their utility bill). However, the function of a green bank does not stop with financing; green banks typically provide ancillary services to customers, ranging from standardized contracts to project-specific consultation.

There are a few dozen stably operating green banks in the U.S. The one for Montgomery County, MD, is notable as a successful green bank operating at the county level (https://mcgreenbank.org).

See chapter 9 for more information.

1.2.5 Electrification of Transit Buses and Utility Vehicles

Policies to replace internal combustion engine (ICE) transit buses and utility vehicles with battery electric-powered vehicles (BEVs) have been put into operation by a number of municipalities. A handful of vendors now supply the market. Many new entrants are anticipated during the next few years.

The basic economic properties of the BEVs are clear: BEVs presently cost much more than ICE vehicles and must also be supported with charging stations. After acquisition, operation and maintenance costs are much lower than with ICE vehicles. It is generally agreed that life-cycle costs of BEVs are now often competitive with ICE vehicles of this class. Further, cost reductions are anticipated in the near future due to competition and falling prices of batteries.

A number of financing and service arrangements are available, including state and federal subsidy programs, and vendors that offer leasing programs.

Reduced air pollution is a significant co-benefit of BEVs, in addition to meaningful reduction in GHG emissions.

We need more numbers here on costs, etc. Just a little.

See chapter 11 for more information.

1.2.6 Internal Carbon Pricing

Internal carbon pricing occurs when an organization—whether public, private or third sector—imposes on itself a price for greenhouse gas (GHG) emissions. The price is normally expressed in dollars per metric tonne of CO_2e (carbon dioxide equivalent) emissions. This can be done in various ways. For present purposes, we focus on pricing by *carbon fee* because it is likely the most important option for local governments and institutions. It works along the following lines:

1. The institution identifies activities to be subject to the fees and quantifies CO_2e emissions for them.

For example, an institution might designate a standard CO_2e emissions rate in tonnes per passenger mile traveled by airplane.

2. The institution sets the internal carbon price in dollars per tonne of CO_2e emitted.
3. When institutional funds are expended for a covered activity a carbon pricing fee is assessed for the activity. Typically, this would be internal carbon price times the standard rate for the activity times the amount of activity, e.g., carbon price $\times$ emissions per mile $\times$ miles traveled.
4. The funds collected are subsequently allocated for broadly "green" purposes, such as purchasing carbon offsets and funding green investments in the organization.

The potential benefit of internal pricing programs is that at small cost to the organization they gently and effectively encourage reduction in GHG emissions and encourage productive investment in that direction. It is also likely that there are positive effects on organizational culture.

See chapter 13 for more information.

1.2.7 Sustainable Living Information and Advice

This family of programs is both informational and educational. As such it belongs in a long tradition of government-sponsored information and advisory programs, such as extension agents and health advisories. This form collates and circulates information about saving money on energy and about living more efficiently, more sustainably, and more healthfuly. Pertinent topics include advice (regarding supporting programs, contractors, etc.) for home energy improvements, information on composting, information on healthy lifestyles, information on indoor air quality, information on carbon footprinting and building thermal efficiency, and so on.

Budget costs can be kept minimal by organizing volunteers or working with NGOs. Co-benefits may include a positive response from the community and gratitude for a service economically rendered.

See chapter 19 for more information.

1.2.8 Building Electrification

Electrification of buildings, especially replacing fossil fuel-based residential heating and cooling systems with electric alternatives, is perhaps the most substantial policy available to municipalities in terms of reduction of GHG emissions.

Building electrification is also perhaps the most fraught and contentious of the available policy options. See https://podcasts.apple.com/us/podcast/the-clash-over-gas-bans-in-b id663379413?i=1000513548635 (https://podcasts.apple.com/us/podcast/the-clash-over-gas-bans-in-buildings/id663379413?i=1000513548635) for a podcast discussion of recent developments (March 18, 2021). See also https://www.motherjones.com/environment/2021/02/how-the-fossil-fuel-industry-convinced-americans-to-love-gas-stoves/

(https://www.motherjones.com/environment/2021/02/how-the-fossil-fuel-industry-convinced-americans-to-love-gas-stoves/) (February 11, 2021).

A number of municipalities have enacted requirements that new building construction after a certain date provide natural gas hookups, thereby in effect requiring electrification of heating and cooling. Alternative policies offer subsidies for electrification.

Vehement opposition from the oil and gas industry is likely.

See chapter 10 for more information.

1.2.9 Behavioral Interventions

There are any number of ideas popping up for gently encouraging people to take beneficial action with regard to climate and sustainability. The very existence of parks and trails encourages outdoor recreation and exercise. Libraries encourage reading. Opt-out instead of opt-in defaults on employment savings plans encourage savings. The ideas are legion.

What might encourage pro-climate action? A recent proposal by Howard Kunreuther and colleagues is for a polity or organization to hold a lottery into which all members of the community are entered. If the winning ticket is drawn by a member who has committed to the preferred action, that member gets a prize. If the member has not previously committed, the prize is not handed out.

To illustrate, a lottery with winning prize of say $500,000 might be instituted with the prize being given out only if the owner of the winning ticket has an operating 10 kilowatt or larger solar installation on their home. The theory is that advance knowledge of the lottery would encourage solar PV. Of course, there are equity considerations present and any such lottery program would need to be carefully designed, but the concept is intriguing.

See chapter 14 for more information.

Chapter 2 Introduction to first-cut analysis

This chapter uses a simple example to introduce first-cut analysis for comparing decision alternatives, in particular the alternatives in the pool described in chapter 1. First-cut analysis is in turn simple and intuitive method for taking an initial towards evaluating a collection alternatives.

We begin with a discussion of the evaluation criteria to be used in the example and how they are to be scored. Then, in §2.2 we discuss and score each program in the pool laid out in chapter 1. The last section, §2.3, discusses the pool of alternatives in light of the scoring in §2.2 and draws out some insights for further deliberation.

2.1 Criteria and Their Scoring

The programs and policies under consideration are to be evaluated by comparing how they perform on the evaluation criteria that are important to the relevant stakeholders and decision makers. In our first-cut analysis we use a maximally simple scale with three points (-1, 0, 1) where a 1 indicates a definite and discernible positive value, -1 a definite and discernible negative value, and 0 an intermediate value, which may be slightly positive or slightly negative. These assessments are, of course, merely a first cut.

We work with a simplified list of evaluation criteria. (Remember, the chapters in part I are not only tutorial in nature, they are introductory. We are giving an overview of the approach.) Our criteria for now are:

BCO Budget expense (cost) to the local government or other organization net of outside grants and program funding such as federal programs. A 1 indicates that the organization actually profits in a meaningful way. A 0 indicates a small profit (rare) or expense, say on the order of funding one employee for a year. A -1 indicates substantial expense to the organization, paid out of its own funds net of outside grants and other funding programs; roughly, these are general revenue dollars raised from the tax payers.

SCO Social expense (cost) to the pertinent body of stakeholders. A -1 indicates a substantial expense. This may occur, for example, due to mandated behavior, such as building improvement, that is not compensated. A 0 indicates a small expense or payment. A 1 indicates a meaningful payment to members of the stakeholders.

GHG Greenhouse gas emission reduction, also called climate mitigation. 1: indicates a definite and discernible positive value. 0: intermediate value, which may be slightly positive or slightly negative. -1: definite and discernible negative value.

HnS Health and safety effects.

CoB Co-benefits, positive consequences other than cost and GHG emissions. Example: a program that creates or improves a recreational area as a side-effect.

DiB Disbenefits, positive consequences other than cost and GHG emissions. Example: a program that destroys or degrades a recreational area as a side-effect.

TRA Transition effects. Are we moving in the right direction? Does it favor something that has to be done eventually? Does it help with adaptation or resilience?

Scores on these criteria can be recorded in tables with the following columns:

BCO	SCO	GHG	HnS	CoB	DiB	TRA

2.2 First-cut scoring

2.2.1 LECC: Low Embodied Carbon Concrete

A policy of requiring use of only low embodied carbon concrete on publicly funded projects has a very modest cost, and so is scored a 0 on BCO, yet would yield a definite benefit in foregone GHG emissions and so is scored a 1 on GHG. The remaining attributes are scores as 0s because any effects are rather minor, expect transition because presumably low carbon concrete in some form or another will be required in the future.

The following, then, is a reasonable first-cut scoring for low carbon concrete.

	BCO	SCO	GHG	HnS	CoB	DiB	TRA
LECC	0	0	1	0	0	0	1

2.2.2 CSCom: Curb Side Composting

A policy of curb side composting, funded as garbage pickup and disposal is funded is here scored as a 0 on BCO because it is expected to be only marginally more expensive than the status quo, net of landfill savings. It is scored a 1 on CoB, co-benefits, because the soil created is environmentally friendly and useful. It is scored a 1 on GHG because it sequesters or reduces some GHG (CO2 and methane) compared to the alternative of landfill disposal. It also scores a 1 on TRA, transition, because it is likely to be required in a highly sustainable society. The remaining criteria come in as 0s.

The following, then, is a reasonable first-cut scoring for curb side composting.

	BCO	SCO	GHG	HnS	CoB	DiB	TRA
CSCom	0	0	1	0	1	0	1

2.2.3 GreF: Green Financing

A successful green financing program, whether or not in the form of a green bank of some kind, would lead to significant GHG emissions reduction by leading to completion of projects that would otherwise not have been undertaken soon, or even at all. Examples include investments in solar PV, replacement of gas with electric appliances, building energy efficiency, and so on. Health and safety benefits (e.g., clearer inside air) and transition benefits would normally ensue. In many cases co-benefits may be realized.

The following, then, is a reasonable first-cut scoring for green financing.

	BCO	SCO	GHG	HnS	CoB	DiB	TRA
GreF	0	0	1	1	1	0	1

2.2.4 EBus: Electrification of Transit Buses and Utility Vehicles

The following is a reasonable first-cut scoring for electrification of transit buses and utility vehicles. HnS scores a 1 on air pollution reduction. CoB = 1 because of noise reduction and comfort improvement. TRA = 1 because ICE vehicles will eventually have to be eliminated. BCO = -1 on the assumption that the life-cycle costs of the vehicles remain a bit higher than for ICE vehicles (but the difference is small and will go the other way, it is believed, within a few years).

	BCO	SCO	GHG	HnS	CoB	DiB	TRA
EBus	-1	0	1	1	1	0	1

2.2.5 InCP: Internal Carbon Pricing

In principle, internal carbon pricing is cost neutral and serves to increase efficiency in the organization. It does assume, however, a prior commitment by the organization to make expenditures in service of climate change mitigation. The positive scores on GHG and other attributes assume that accompanying investments are made that achieve these goals.

The following, then, is a reasonable first-cut scoring for internal carbon pricing.

	BCO	SCO	GHG	HnS	CoB	DiB	TRA
InCP	-1	0	1	1	1	0	1

2.2.6 SusL: Sustainable Living Information and Advice

An effective ongoing informational campaign, funded at minimal cost with volunteer and NGO participation, may foster behavior and community values leading to higher levels of climate and environmentally friendly activity. Mechanisms include reducing barriers to action and encouraging action by imitation of others. This latter impetus is a form of behavioral intervention, §2.2.8.

	BCO	SCO	GHG	HnS	CoB	DiB	TRA
SusL	0	0	1	1	1	0	1

2.2.7 GasB: Building Electrification

A growing number of cities have imposed prohibitions of gas hook ups for new construction. The budget cost of this is low, while the social cost is scored a -1 because it is borne by individuals. The disbenefit score is likewise a -1 because many individuals may prefer gas heating, etc., regardless of cost. On the other hand, banning gas from buildings has a hugely positive effect on GHG emissions, especially as the secular greening of the electric power system advances. Building electrification has positive health and safety aspects as well as co-benefits.

	BCO	SCO	GHG	HnS	CoB	DiB	TRA
GasB	0	-1	1	1	1	-1	1

2.2.8 BHav: Behavioral Interventions

Behavioral interventions constitute a grab bag of policies of great variety, making it problematic to characterize them collectively. We saw one example in §2.2.6: encouraging people to undertake pro-climate and environment actions by informing them of similar actions taken by their neighbors. There is good evidence for this effect.

Many behavioral interventions are informational in nature and can be classed as cases covered by §2.2.6, e.g., for overcoming myopia bias and herding bias. Programs to overcome inertia bias often work by setting up favorable defaults and allowing stakeholders to opt out. There is much evidence supporting the effectiveness of the opt out design.

As an example program, new construction permits might be denied gas hook ups without paying a fee and making a presentation at a public hearing or otherwise making this decision public.

Depending on how onerous the opt out provision is, behavioral interventions can be effective at very small cost, in part because the social cost is judged small because the actor is acting voluntarily, whether opting in or out.

	BCO	SCO	GHG	HnS	CoB	DiB	TRA
Bhav	0	0	1	1	1	0	1

2.3 Discussion of the Scored Pool

Combining these scoring results into one table yields table 2.1.

Program	BCO	SCO	GHG	HnS	CoB	DiB	TRA
LECC	0	0	1	0	0	0	1
CSCom	0	0	1	0	1	0	1
GreF	0	0	1	1	1	0	1
EBus	-1	0	1	1	1	0	1
InCP	-1	0	1	1	1	0	1
SusL	0	0	1	1	1	0	1
GasB	0	-1	1	1	1	-1	1
Bhav	0	0	1	1	1	0	1

Table 2.1: Example First-Cut ACS (alternatives, criteria, scores) table. Alernatives: LECC: Low Embodied Carbon Concrete, CSCom: Curb Side Composting, GreF: Green Financing, EBus: Electrification of Transit Buses and Utility Vehicles, InCP: Internal Carbon Pricing, SusL: Sustainable Living Information and Advice, GasB: Building Electrification, BHav: Behavioral Interventions. Evaluation Criteria: BCO: Budget expense (cost), SCO: Social expense (cost), GHG: Greenhouse gas emission reduction, HnS: Health and safety effects, CoB: Co-benefits, DiB: Disbenefits, TRA: Transition effects.

Table 2.1 is instructive, but hardly dispositive. It constitutes information useful for subsequent deliberation, rather than a decision tool itself. Its main virtues lie in identifying especially strong or weak alternatives and in identifying where more study and finer scoring might be especially rewarding.

On identifying especially strong or weak alternatives:

1. Green financing (GreF), sustainable living advice (SusL) and behavioral interventions (Bhav) have identical scoring signatures and weakly dominate all other policies under the scores and scoring regime in place. That is to say, each of these alternatives is at least as good on all criteria and better on some than each of the other five alternatives.
2. Banning gas in new construction, GasB, is flagged as problematic if only because it is the only alternative with two negative scores.

On identifying were more student and finer scoring might be especially rewarding:

- Curb side composting (CSCom) dominates low embodied carbon concrete (LECC). Both get a 1 on GHG emissions, but are they actually close in this regard and which is better? If LECC reduces GHG emissions very much more than does CSCom, it may well be judged preferable to give LECC a higher priority than CSCom. The point here is that the first-cut ACS table directs us where to look for more information.

Discussion and reflection on a first-cut ACS table, such as table 2.1, are likely to reveal need for two kinds of improvements. The first is improvement in measurement. The table is potentially useful for advising our efforts better to nail down costs, emission levels, and so on. It can do this by identifying where better information is likely to matter and where not.

The second kind of improvement likely to be identified is in the criteria, the columns in the ACS table. Are these the right attributes? What should be added or removed from consideration?

The first-cut ACS table supports deliberation by being modified in response to deliberation with new scores and new kinds of scores, and with new criteria. But this is just a beginning. We turn next to a deeper look at program and policy evaluation criteria, extending the discussion beyond the introductory example of this chapter.

Chapter 3 Evaluation Criteria, Costs and Benefits

The "shopping list"[1] (consideration set) of program alternatives in the rows of the ACS table, table 2.1 page 12, is obviously incomplete. Any realistic situation will have many more programs on the list and up for consideration. See chapter 6 for a more comprehensive list of program alternatives. What should be clear, however, is that no list as in chapter 6 can be complete. Comprehensive, yes; complete, impossible. New ideas are constantly arising and there is no reason at all to think this will end anytime soon. We have to proceed accepting that the situation, and the stock of program ideas, is and will remain in flux.

The same is true of the evaluation criteria, in the columns of table table 2.1 page 12, and for pretty much the same reasons. Making a comprehensive list is possible; making a complete list is not.

For alternatives in the shopping list as well as their evaluation criteria, it is ultimately up to the decision makers to decide which alternatives and which evaluation criteria to consider. The job of handbook such as this is to supply useful information, not to make the decision. Our purpose in the present chapter is to provide useful information about evaluation criteria. Chapter 6 provides a reasonably comprehensive inventory of program and policy alternatives. We take a different tack when it comes to evaluation criteria. This is because evaluation criteria will often be particularized to places and circumstances. While just about every local government can have a curb-side composting program, only Lower Merion Township in Montgomery County, Pennsylvania, can sensibly have an evaluation criterion that takes into account the Cynwyd Heritage Trail (`http://www.cynwydtrail.org/`).

In consequence, discussion of evaluation criteria needs to proceed at a more general level if it is to be useful. That is what we essay to do in this chapter. We begin with discussion of certain fundamental principles that haunt and suffuse climate change policy making.

3.1 Externalities

"Greenhouse gas (GHG) emissions are externalities and represent the biggest market failure the world has seen." Thus begins, famously and correctly, Nicholas Stern's 2008 Richard T. Ely lecture "The Economics of Climate Change" [33].[2] Stern's point is central to climate change policy at all levels of decision making, from international agreements to local program development. Therefore, we dwell on it briefly in order to communicate the core of the concept and then we explore the ramifications for our context, policy making at the local level.

---

[1] Thanks to Michael McElfresh for the term, which we hope communicates effectively.

[2] The lecture summarizes and reflects on the authoritative and highly influential *Stern Review* [32], which was commissioned by the British government for the purpose of providing advice on climate change policy.

Externality is a term of art in economics (jargon in other words). The associated concept lies at the core of climate change policy and may be characterized as follows. In a transaction between a buyer and a seller, an externality is said to be present if there is a cost or benefit to a third party not participating in the transaction. Environmental pollution is a standard example. A factory manufactures widgets, dumps waste chemicals into a stream, and sells the widgets to a buyer. The damage done by the waste chemicals is said to be an externality because its cost is not reflected in the price of the widgets. Buyer and seller save money by imposing a cost on a third party, in this case users of the stream.

Greenhouse gas emissions in particular are said to be externalities because when fossil fuels are burned and GHGs are emitted costs are imposed on third parties. Neither the buyer nor the seller of the fossil fuel pays for the damage done by the resulting GHG emissions. In consequence, neither buyer nor seller has, absent policy interventions, any incentive to expend money to reduce their GHG emissions.

Economists generally agree that the case for a market-based economy rests on markets that succeed and in consequence are efficient mechanisms of allocating value. They further agree that significant externalities constitute market failures and lead to inefficient markets, and that such failures should be redeemed by policy interventions, typically by imposing a price on transactions with externalities and using the resulting revenues to compensate for damages. We are safe in making these assumptions and will do so. The idea of imposing compensating costs on GHG emissions shows up in ongoing discussions of putting a price on GHG emissions, thereby encouraging green alternatives and better functioning markets. Imposing a price on GHG emissions, it is agreed, will reduce them and ameliorate the onslaught of global warming. How much it would do so, and whether it would be fast enough to present catastrophe, is another matter, one that not detain us for present purposes.

GHG emissions are an especially vexing externality because in addition to market failure GHG emissions also constitute what is called a *tragedy of the commons* [15]. An example will make the notion clear. In a typical policy case, a particular group of tax payers pays to reduce GHG emissions, but everyone in the world benefits more or less equally and very slightly at that. Put bluntly, why should the citizens of Our Town spend real money to reduce GHG emissions when the overall effect is minuscule and is enjoyed by the entire world? Whatever the cost is, the benefits are less to those who pay. The atmosphere is owned by no one and can be owned by no one, yet is used by everyone. Any individual or business that pays to reduce its GHG emissions is at a comparative cost disadvantage to other individuals and business that forego the payments. In consequence, we can expect ongoing damage from GHG emissions. It pays no single government or other organization to invest in GHG reductions because the benefits will always be less than the costs.

That is the standard story. Of course we do see governments, corporations, individuals, and others paying real money to reduce GHG emissions and it is instructive to inquire why. For the present, the point is that the tragedy of the commons story teaches us that proposals to spend money to save the commons, in this case to reduced GHG emissions, will in all likelihood face serious headwinds from some quarters. That these headwinds might disrupt an election and lead to reversal of a policy is hardly beyond the realm of possibility. In these very politicized times we see people who prefer to spend money to degrade the atmosphere.

As a practical matter, we note that faced with an ACS table as in table 2.1 page 12, many stakeholders will place little if any value on the GHG reduction criterion (column), especially if the associated program has significant costs associated with it. In a nutshell, this is a big part of why programs to ban natural gas in new construction arouse resistance.

The upshot for policy making at the local level (and indeed at all levels) is that effective climate change programs and policies need to find ways to circumvent the tragedy of the commons aspect of GHG emissions. Relying on "doing what is right" is unlikely to garner sustained and overwhelming political support.

What, if anything, can be done in response to this problem? At an abstract level the solution is plain, keeping ACS tables in mind (e.g., table 2.1 page 12). The challenge is to find additional criteria for a program that reduces GHG emissions (or whatever else is in contention) such that the program scores well enough on the additional criteria to overwhelm the costs of GHG reduction from the program.

There are two distinct but related kinds of criteria for doing this: externalities not subject to the tragedy of the commons, and co-benefits.

There are important externalities associated with climate change other than GHG emissions. Among them are the following, all of which involve local effects and so are less exposed than GHG emissions to the tragedy of the commons.

1. Noise

   ICE (internal combustion engine) vehicle traffic and two-cycle lawn care equipment, for example, can disperse significant amounts of noise to third parties, for which they are not compensated. Costs imposed on the buyer and sellers of this equipment for the sake of converting to quieter machines may be justified at least in part by noise reduction to third parties.

2. Health effects

   Air pollution from ICE traffic and from fossil fuel (mainly gas) combustion in residences degrades air quality with multiple health-related effects.

3. Habitat loss

   Habitat loss from new construction, including roads may diminish environmental services, including simple enjoyment, in many ways.

4. Risk imposition or shifting

   Long term commitment to use of natural gas (as in the case of new power plants), shifts the risk of price increases to the customers.

These and other negative externalities of fossil fuel use (no doubt others can be found) can potentially be leveraged to support programs that reduce fossil fuel usage and GHG emisssions.

To be sure, there are negative externalities associated with some climate solutions. Wind turbines for example have often elicited complaints on grounds of noise and esthetics.

3.1.1 Examples

Health effects are perhaps the most salient and documented externalities associated with fossil fuels. They are also much less vulnerable to tragedy of the commons problems than GHG emissions. The following article presents a strong public case in this regard.

"One small idea in Biden's infrastructure plan with big benefits: Electric school buses" (April 6, 2021) https://www.vox.com/future-perfect/2021/4/6/22364385/ one-small-idea-in-bidens-infrastructure-plan-with-big-benefits-electric-schoo (https://www.vox.com/future-perfect/2021/4/6/22364385/one-small-idea-in-bidens-infrastructure-plan-with-big-benefits-electric-school-buses)

3.2 Co-Benefits

The material in this section is drawn from https://riskcenter.wharton.upenn.edu/climate-risk-solutions/recruiting-values [16].

And needs further editing to get the references in.

Action on climate change is often presented—accurately—as costly and difficult, but necessary. The following passage is typical:

> Devising ways to sustain the earth's ability to support diverse life, including a reasonable quality of life for humans, involves making tough decisions under uncertainty, complexity, and substantial biophysical constraints as well as conflicting human values and interests [8]. https://science.sciencemag.org/content/302/5652/1907

This "tough decisions" message, truthful as it is, is in fact a message that many people will not be receptive to, simply because it is tough. Lamentable as this may be, the brute fact is that change will happen faster the more people there are who see an immediate and direct benefit to themselves.

There are things that can be done, including behavioral interventions that circumvent biases and irrationality, effective framing, and research aimed at understanding human decision making. All of this is well and good, and should be vigorously pursued. My purpose here is to draw attention to different approach, one that is entirely complementary.

Consider the following passage appearing in a recent op-ed piece in the Philadelphia Inquirer. The author is discussing a proposal for handling storm water, which proposal she claims:

. . . creates community green space, revitalizes vacant lots, enhances recreational use, and even reduces illegal drug use in public spaces. It can reduce heat stress and energy use while improving air quality and contributing to climate change resiliency. And . . . can stabilize property values and reduce poverty through job creation.

In all, as we can see, she recruits ten values (create community green space; . . . ; reduce poverty through job creation) that she adduces in favor of her proposed policy.

The proposal advocated by Jacquelyn Bonomo in the Inquirer piece is presumably not the cheapest—not the best on direct, immediate costs—of the proposals under consideration. Were it otherwise, she would have argued directly for it on the basis of cost. Instead, she appeals to other values to compensate for comparative weakness on the cost value.

Bonomo's strategy is entirely legitimate, and in fact is routinely and widely used. We may describe it as recruiting values beyond the narrowly economic to support a policy position. Much of what makes complex problems complex is that multiple values are in play. Climate change is a case in point. Here and in general, normatively proper decision making requires that all pertinent values associated with a decision be identified and considered in the deliberation for decision making.

The observation I would to make, the impetus for this blog post, is that recruitment of values beyond the narrowly economic has not been done thoroughly and systematically enough on matters pertaining to the necessary transitions mandated by climate change. There is opportunity for the climate change community to do better. Proposers (Bonomo is an apt example) today must, on a case by case basis, identify and assess the wide range of values associated with policy initiatives.

Imagine instead that an organized, curated, maintained, and accessible body of information on recruitable values were available to help every Jacquelyn Bonomo making a policy proposal for climate change transitions. We might call this tool a climate change values repository.

Note that many, perhaps all, of the ten values Bonomo cites as favoring her proposal (above) are relevant to other transition issues. Knowledge assembled about one value—its benefits, its costs, its main characteristics—can be leveraged in multiple ways and on multiple issues.

Such a tool would bid fair to speed the development of transition policy proposals, and strengthen them in the process. It would also speed the identification of weaker ideas, serving to focus attention on more promising ideas. It could help to assemble policy bundles that would be broadly attractive. Log rolling is an essential, legitimate feature of compromise and accommodation of diverse interests. Also, because the values in play for climate change are wide-ranging, assembling a climate change values repository will serve to draw in and involve a correspondingly wide-ranging collection of people, skills, and interests.

Most important of all, the values recruitment approach, and any tool to support it, would afford ways of reaching people for whom the tough decisions messaging fails to convince. By systematically and thoroughly recruiting values beyond the narrowly economic and beyond a narrow focus on the primary targets of climate change transitions (for example, reducing GHG emissions), we can hope to find values and benefits that make tough decisions easier and even attractive for a wider circle of people.

* * *

Our sense is that in actual deliberations a creative and thorough search for co-benefits will often yield surprising and influential sources of value, favoring climate friendly programs.

3.3 Risk

ACS (alternatives, criteria, scores) tables and the like, such as discussed in chapter 2 and shown in table 2.1 on page 12, are essential and foundational tools for deliberation support. They do not, however, address risk straightforwardly.

There are many types of program risks, including:

1. Efficacy. Will it deliver the promised benefits?
2. Execution. Do we have reliable capability to implement a successful program?
3. Budget overruns. Will its costs balloon unacceptably?
4. Unintended consequences or developments. What is the chance that a favored policy will be undone by new technology or other developments, including policy, regulatory and legal developments? How resilient, how immune to regret is the program in the face of foreseeable developments?
5. Opposition and blow back. Will implementation of the program provoke strong reaction against it?

Classical decision analysis has techniques for modeling and decision making in the face of identifiable risks and they can be useful. The recommendation here, where we focus on practicality above all, is to begin by holding discussions that identify and articulate the risks of concern and then to incorporate them as criteria in expanded ACS tables.

Chapter 4 Interactions

We have noted that the evaluation criteria (the columns) in the ACS table may, and often should, be altered during deliberation. Our purpose in this chapter is to discuss an important source of evaluation criteria in deliberation: interactions among alternatives under consideration and goals and values present in the deliberation. We discuss two kinds of interactions: interactions with goals and objectives and interactions with external considerations.

4.1 Goals and Objectives

As usual, we proceed by example. Figure 4.1 graphs supporting interactions between and among programs and goals.

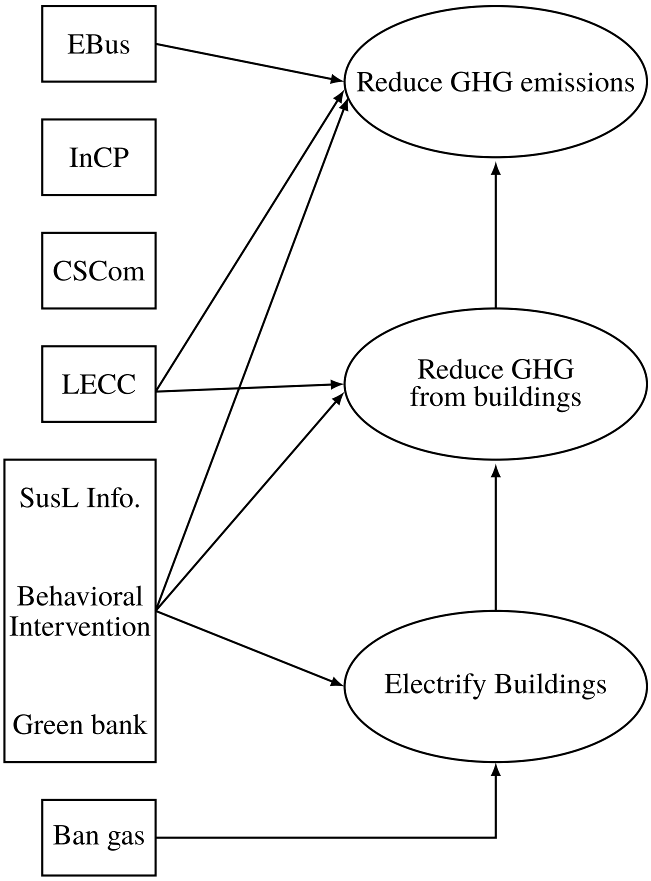

Figure 4.1: Supporting interactions between programs and goals.

Programs are within rectangles; goals and objectives are within ellipses. The diagram states that the overall goal of reducing GHG emissions is supported by the objective of reducing GHG associated with buildings. This objective is in turn supported by the objective of electrifying buildings.

Banning gas hook ups in new construction, “Ban gas,” directly affects the objective of electrifying buildings, and indirectly the other two goals and objectives. Electrifying buses and utility vehicles, “EBus,” directly affects the goal of reducing GHG emissions, but does nothing for buildings. Green banks, behavioral interventions, and sustainable living information potentially can directly affect all three objectives. Curb side composting and internal carbon pricing are depicted as isolated, without interactions with the objectives because their affects are deemed slight. This is, of course revisable upon receipt of new information.

Not depicted are supporting interactions among the programs, again only because their magnitudes are judged to be small. Sustainable living information, for example, may well motivate someone to make a green investment, perhaps first seeking green financing. Also not depicted is the important goal of reducing fossil fuel consumption, especial petroleum products. This captured through the depicted support by the EBus programs for reducing GHG emissions. Were it desirable to include other displacements of petroleum products (say by electrifying police cruisers) a separate goal for this could be added to the diagram.

The supporting interactions diagram helps reveal important aspects of the candidate programs that are not easily captured by listing evaluation criteria, as in the ACS table, table 2.1. This is because supporting interactions are inherently relational—like “x is longer than y”—rather than monadic—like “x is red”—as are the criteria in table 2.1.

Temporal sequencing is another important aspect of program selection that is relational and not well suited to be represented as one or more criteria in an ACS table.

We will in the sequel discuss methods for deliberating with relational factors arising in pools of alternatives. The reader can go far, however, simply being aware of the matter and exercising good judgment while deliberating.

4.2 External Factors: Logrolling

> Logrolling is the trading of favors, or *quid pro quo,* such as vote trading by legislative members to obtain passage of actions of interest to each legislative member. . . . In organizational analysis, it refers to a practice in which different organizations promote each other’s agendas, each in the expectation that the other will reciprocate.
>
> https://en.wikipedia.org/wiki/Logrolling

People who cannot agree on a given collection of options often can and agree when the collection is expanded. In terms of our ACS table, this largely amounts to modifying alternatives (rows) and adding features or conditions to the alternatives that bring additional evaluation criteria. This sort of thing is simply the normal way of doing business, even when the modifications to an alternative have little to do with it, as when a curb-side composting alternative is expanded to include paving a certain street, thereby garnering a key vote.

Logrolling is a normal part of policy making, present more often than not. This has long be understood and is amply documented by political scientists [30]. It is fundamentally why it is not possible to give a comprehensive, let alone complete list of evaluation criteria. Relevant criteria may be just about anything at all, anything that gets the crucial votes.

Creative and diligent search for logrolling opportunities is a central feature of deliberation about climate programs and policies.

Chapter 5 Proceeding

This is the concluding chapter of our quick introduction to deliberation for climate programs. We hope that those who made it this far will find some material of interest and use. We imagine that many groups will be content to survey the chapters in part II, select a consideration set of policies and programs, and then proceed in their wonted fashion to decide what to do. To those in this category, we say "Go for it! Proceed."

To those who would consider additional methods and techniques to support deliberation, what we have to say begins in part III with chapter 20, "Overview of Deliberation Support Methods." There we discuss five deliberation supporting methods that are available and may be useful, depending on circumstances. Briefly:

1. Information about policies and programs.

   This is about communicating to the relevant publics the programs and policies under consideration, and inviting their feedback and participation.
2. Group discussion processes.

   There is good social science behind a number of processes for conducting group policy discussions. The aim is to conduct discussions that are actually informative and rewarding to the participants.
3. Decision processes for group decision making.

   Activists, analysts, and social scientists have devised a number of processes for group decision making. These group decision processes aim to facilitate choice by groups in a way that is judged by the participants to be fair and appropriate. Such processes might be used to make recommendations to decision making bodies, including official committees with responsibility to recommend actions.

   These processes are widely used for such purposes as natural resources management, especially water management. They are under continuing development and often benefit from computational support.
4. Decision analysis modeling.

   Decision analysis modeling produces mathematical models for decision making. Expert participation is necessary, but participants need not be experts. Decision analysis covers a wide range of modeling techniques, which methods have often produced models that yield useful insights for decision makers.
5. Role-play simulations for policy design.

   Role-play simulations have their origin in military war games, which have proved valuable to top military organizations for 200 years.

   A main use of role-play simulations for policy making is as a prelude to negotiation. Much may learned about possibilities and conditions for agreement by having players undertake key roles in practice negotiations.

See chapter 20 for examples and further discussion of role-play simulations for policy making.

5.1 Overriding Principles for Deliberation Support

Must:

1. Maintain flexibility, especially wrt evaluation criteria, which may need to be added at any point, requiring additional scoring to go with them.
   [30].
2. Recognize and be prepared to work with very imprecise quantification, especially scores in ACS tables.

5.2 Meta-Policies

Needs editing, translation into prose. Perhaps, change "policies and programs" to simply "programs" and use "policies" as I have used "meta-policies" here.

1. Identify and implement, ceteris paribus, programs that pay for themselves (in time).
   Example: Conversion to LED lighting.
2. Budget for experimental programs with apparently good cost-benefit characteristics, even if full analysis is not available.
   Example: Information brochures on building electrification.
3. Promote a culture of sustainability.
   Examples: Sponsored walking tours. Bicycle and pedestrian access to recreation and shopping/commercial centers.
4. Be assiduous in identifying and evaluating co-benefits of programs under consideration, with a view to conducting a sufficiently broad cost-benefit analysis.
   Example: Health benefits of building electrification.

Part II

Programs and Policies

Chapter 6 Union Pool of Programs and Policies

6.1 Union List of Policies and Programs

These are **kinds** of programs and policies. Each has multiple specific variants. Combinations and consolidations among programs are options as well as implementing parts of individual programs and policies.

1. **Green banks: financing for rooftop solar, for building weatherization, for building electrification**

   A green bank is a program or office that facilitates green financing, e.g., for rooftop solar, building weatherization, building electrification. Green banks typically are not genuine banks. Instead they partner with banks and credit unions to facilitate and reduce the cost of financing green projects. Montgomery County, MD has a successful program.

   Householders then have the prospect near term of saving money on energy bills and, at least during daylight hours, being resilient to power outages.

   See chapter 9.
2. **Curb-side composting**

   See chapter 8.
3. **A climate corps**

   Akin to the CCC and WPA. Participants are trained and deployed for work on broadly environmental projects, improving parks and watersheds, etc. Can work at multiple levels, from national to local.

   Can be as small as a summer jobs and educational program for high school students.
4. **Electrification of lawn care equipment**

   Example: Ban on two-cycle engines for powering lawn care equipment.

   In favor of battery-driven equipment.
5. **Distributed demand response programs**

   Demand response participants are paid to curtail their electricity use during periods of peak demand. Residential participants typically work through an aggregator who holds the primary contract with the utility.

   In principle, municipalities could also be participants in such programs.
6. **Policy support for V2G**

   V2G = vehicle to grid, power: A form of DER (distributed energy resources) that permits EV owners to be compensated for providing electricity to the grid during high demand times.
7. **Policy support for community solar PV**

This allows renters and homeowners with poor solar prospects to participate in and benefit from renewable energy. Typically a government or NGO organizes the project. Requires state-level authorization and is not yet permitted in Pennsylvania.

8. **Policy support for DER aggregators**
   This is likely the preferred mechanism for effecting DER, demand response, V2G, etc. It's a financial opportunity for households.
9. **Training and education incentives for trades in the energy and sustainability transition**
   Leads to jobs for young people and for mid-career people in sunset industries. Work with NGOs to leverage their assets, e.g., ECA (the Energy Coordinating Agency, https://www.ecasavesenergy.org).
10. **Support for converting to electric buses (and other utility vehicles) by local governments and school districts**
    The economic case is now strong with health and pollution benefits extra. Synergy with own solar panels for cheaper, behind the meter, charging.
11. **Sustainable living information**
    Health and safety information programs serve as precedent. Can be done "in the small" by encouraging volunteer groups and NGOs, or "in the large" through extension agents, item (12.), below.
    One form: **Public awareness programs for electrification and energy efficiency**.
12. **Extension agents**
    Akin to agricultural extension agents for helping businesses and governments run the numbers, etc. to make the energy and sustainability transition.
13. **Building electrification mandates and encouragement**
    Such as require new construction to be fully electrified, require electrification upon sale of an existing building, provide technical and other information to facilitate electrification, and so on.
    Could be combined with green financing, (1.).
    The Energy Gang podcast of April 15, 2021, "Unlocking Home Electrification With Heat Pumps"
    Excellent discussion of operating characteristics and policy.
    `https://podcasts.apple.com/us/podcast/unlocking-home-electrification-with`
    `id663379413?i=1000517299281`
    https://podcasts.apple.com/us/podcast/unlocking-home-electrification-with-heat-pumps/id663379413?i=10005
14. **Food rescue programs**
    Feed the hungry with what would otherwise be wasted food from restaurants and grocery stores. Many examples exist of successful programs. Typically they are run by volunteers and NGOs.

See chapter 18.

15. **EV charging stations**

    Construction of; mandates for; "right to charge" laws.

16. **Transition municipal buildings to high-grade efficiency standards**

17. **Expand public transit**

    Study and assess the costs and benefits of increasing frequency and of adding new routes.

18. **Expand bicycle and pedestrian thoroughfares**

    Often described as "low stress" bike routes and "last mile design." Study and assess the costs and benefits of adding and improving routes and connectors.

    See chapter 16.

19. **Amenities for public transit and bicycles**

    Study and assess the opportunities costs and benefits of making making public transit and bicycle commuting more attractive to use. Look at parking near transit hubs.

    See chapter 16.

20. **Support for compostable food utensils and containers**

    Including water/liquid bottles. The issue here is that in many cases bottles and tableware advertised as compostable require industrial processing (to grind them up) cannot be handled by local outfits as they are presently configured.

    Were a municipality to arrange for this extension to acceptable compost, the range of composting programs and benefits to landfill would be greatly extended.

    See chapter 8.

21. Waste regulation, including ban on single-use plastics, bottle deposits, etc.
22. EV incentives, including charging stations, HOV lane access, parking benefits, etc.
23. Soil management for carbon capture, etc.
24. Transitioning municipal buildings to sustainable standards (weatherization, efficiency; net-zero buildings?)
25. research on green building codes
26. **Low Embodied Carbon Concrete**

    See chapter 12.

27. Internal Carbon Pricing
28. **Behavioral Interventions**

    See chapter 14.

29. **Municipal Vehicle Electrification**

    See chapter 11.

30. **Municipal building electrification**

    See chapter 10.

31. **Municipal work rules reform**

    Aimed at reduction of GHG emissions. One proposal being tried is for a 4-day (32 hour)

work week
(https://www.treehugger.com/spain-to-try-4-day-workweek-5120478).
Other ideas include mixing on-site and distal work, extending practices from the Covid-19 pandemic.

32. Environmental and Sustainability Dashboard
In part a form of behavioral intervention. In part an opportunity for citizen science. Valuable contributions can be had from students, as well as citizen hobbyists. Has educational and cultural value for the entire community. Moves towards the higher levels of environmental monitoring and management that will be needed with climate changes.

33. TOD: Transit-oriented development

> TOD, or transit-oriented development, means integrated urban places designed to bring people, activities, buildings, and public space together, with easy walking and cycling connection between them and near-excellent transit service to the rest of the city. It means inclusive access for all to local and citywide opportunities and resources by the most efficient and healthful combination of mobility modes, at the lowest financial and environmental cost, and with the highest resilience to disruptive events. Inclusive TOD is a necessary foundation for long-term sustainability, equity, shared prosperity, and civil peace in cities.
>
> https://www.itdp.org/library/standards-and-guides/tod3-0/what-is-tod/ (https://www.itdp.org/library/standards-and-guides/tod3-0/what-is-tod/)

There is a good discussion in [27].

34. Promote a culture of walking
And bicycling, and being out and about as a pedestrian. Orient the built environment as much as is practicable towards pedestrians (bicycles, etc.). Create new walkways and upgrade existing walkways to make them more useful (e.g., connected with car parks, with public transit) and more pleasant (greenery, sound barriers.)
Contributions: Reduced vehicle miles traveled (VMT) reduces GHG emissions. Walking promotes health and well-being. Greenery and sound barriers are pleasant and reduce stress. Greenery is beautiful.

35. Green walls, living walls
Green walls, aka living walls, e.g., https://architizer.com/blog/product-guides/product-guide/eantka-green-walls/.
Green Engine Coffee in Haverford, PA:
http://www.greenenginecoffee.com/
https://www.yelp.com/biz/green-engine-coffee-haverford-2
Contributions: Encourages walking (which reduces VMT and promotes health), cleans the air, reduces stress. Greenery is beautiful.

Figure 6.1: Green wall on administrative building of the Musée du Quai Branly in Paris.

See figure 6.1.

American vendor, Nedlaw Living Walls, http://nedlawlivingwalls.com/.

36. Sound barriers

Contributions: Encourages walking (which reduces VMT and promotes health), reduces stress. See figure 6.2.

37. Green, planted areas for storm and flood buffering

Convert areas prone to flooding to marshland and parkland that can quickly recover from flooding. Landscape for use for parks and recreation.

Contributions: Mitigation of storm damage, expected to increase with climate change. Promotes health and well-being, beauty, and stress reduction.

38. Biochar

An important form of carbon dioxide removal (CDR).

Good discussion and references in https://cdrprimer.org.

39. Build and support solar PV

Just do it.

https://foreignpolicy.com/2021/04/13/solar-community-owned-projects-green

https://foreignpolicy.com/2021/04/13/solar-community-owned-projects-green-transition/

40. **Commit the governmental unit to 24/7 carbon-free energy**

This is a much stronger commitment than net-zero energy. Under 24/7 carbon-free energy, **all** energy used is green or from carbon-free sources of generation (marginally carbon-free).

https://blog.google/outreach-initiatives/sustainability/our-third-decade-

Figure 6.2: Glass wall facing street in the garden of the Musée du Quai Branly in Paris.

https://blog.google/outreach-initiatives/sustainability/our-third-decade-climate-action-realizing-carbon-free-future

41. Community microgrids

    Come in many forms. A good search term.
42. Buy only green electricity
43. A transition fund to cover projects that come close to paying for themselves, but do not and that reduce GHG emissions effectively.
44. A green brokerage agency, generalizing the notion of a green bank and modeling itself on extension agencies.

    Information and know-how (e.g., about state and federal support programs) directed at businesses, contractors, designers, who can use the information and possibly support to encourage electrification.
45. Tree planing and maintenance

    Resilience and quality of life; cooling.
46. Infrastructure for living with challenging weather conditions

    Heat waves, heavy rains, etc.

6.2 Links

- United States Climate Alliance `http://www.usclimatealliance.org/`
  `http://www.usclimatealliance.org/state-climate-energy-policies`

Chapter 7 School Bus Electrification

By: Jae Kwak

7.1 Faqs

1. What is the name of the policy or program type?

   School bus electrification

2. What is school bus electrification?

   The program intends to reduce carbon emissions by replacing diesel school buses with electric buses. Optimally, the excess capacity of the electric buses will be used for vehicle-to-grid (V2G) operations to provide electricity to the grid during peak times.

3. What are some examples in practice?

   In March 2020, Highland Electric Transportation made a deal with the city of Beverly, MA to receive an annual fixed fee to provide, fuel, and maintain electric buses for the school district.

   As a pilot program, Dominion Energy, a Virginia utility company, will sell 50 electric buses with bidirectional charging capabilities to a school for the price of typical diesel buses; in exchange, Dominion Energy will own and operate the charging equipment, using the electric bus batteries to help balance the grid.

   In 2018, Lion Electric Company, an electric school bus manufacturer; Nuvve, a V2G tech company; National Express, a British public transport company; and the White Plains School District of New York partnered to deploy five electric buses equipped with V2G technology.

   Since 2016, the Lion Electric Company has delivered 40 all-electric school buses to the Twin Rivers Unified School District in Sacramento, California. The program is part of the California Climate Investments, a state-wide initiative that uses cap-and-trade dollars for projects that improve the environment.

   In 2019, the California Energy Commission allocated $94MM to its School Bus Replacement Program to replace old diesel buses with electric buses. The California Climate Investment Grant has also been funding electric buses at the local level, as in the case of the $7.5MM grant to the Twin Rivers School District. In 2020 August, the state legislature passed a bill that would spend approximately $1BB on green infrastructure for schools, which would also contribute to the efforts of replacing diesel school buses.

4. What does school bus electrification cost and who pays?

   Diesel school buses cost around $100,000, and electric school buses cost around $300,000 to $400,000. In the case of California, there has been a number of local and state-level funding to cover the upfront costs of replacing diesel buses, but without funding they are too large for school districts to cover. In other cases, a utility company like Dominion Energy or a transportation company like Highland Electric Transportation will charge an annual fixed fee or a lump sum cost equivalent to the typical cost of purchasing or operating diesel buses. These companies plan to cover the difference through lower fuel and maintenance costs, and possibly through V2G operations by discharging power to the grid in peak times when electricity prices are high.

According to a US PIRG Fund Report, an electric school bus costs upfront on average $120,000 more than their diesel equivalent, but can save about $170,000 to $240,000 in lifetime fuel and maintenance costs. Therefore it is highly likely that the upfront costs can be covered within a couple years.

5. What are the climate-related benefits of school bus electrification?

   According to Dominion Energy, replacing one diesel bus can drive down greenhouse gas emissions by 54,000 pounds per year, which translates to 3.75 pounds of CO_2 per middle driven.

6. What are some additional benefits, co-benefits?

   Improved air quality inside and outside: By replacing diesel buses, this program can eliminate the diesel exhaust from traditional school buses. The diesel exhaust from diesel school buses are designated by the IARC to be carcinogenic and are linked to premature death, aggravated asthma, and decreased lung function; it can be even more harmful to children. The diesel exhaust affects the air in and around the bus and can potentially enter school buildings. These pollutants also contribute to acid rain and ozone pollution.

   Seat belt installation: Traditional diesel school buses often do not have seat belts equipped, but in the case of Dominion Energy's electric bus contract with the Virginia school districts, seat belts will be installed in the new electric buses. Although buses are generally considered to be very safe, seat belts provide additional protection in the case of serious crashes.

   Lower Maintenance and Fuel Costs: According to Thomas Built Buses, electric school buses can save nearly $2000 per year in lower fuel costs and $4400 per year in maintenance costs.

   Grid Balancing: If V2G operations are possible, the electric school bus batteries can be used as energy storage for the grid by charging them when prices are cheap and discharging power back to the grid at peak times. School buses are especially promising for V2G because of large capacity sizes, predictable operation schedules, and long idle times. Battery life reduction is a potential concern for V2G operations, but the Becker et al.(2019) case study shows that as long as proper thermal management is conducted, battery degradation can be minimized.

7. What are the dis-benefits?

Range: Electric school buses on average have a range of 100-135 miles. While typical bus routes are 30-40 miles in the morning and 30-40 miles in the afternoon, for some rural areas and for long-distance transportation, e.g. field trips, the range may not be enough. Route optimization and the expansion of local charging infrastructure may be able to mitigate this issue.

Charging Infrastructure: Installing, maintaining, and operating charging infrastructure for electric buses are costly tasks and school districts may not be equipped for the task. As a result, companies like Highland Electric Transportation and utilities like Dominion Energy are offering to install and operate the charging infrastructure for the school districts.

Training: Additional training of staff may be required because electric buses are operated and maintained differently from diesel buses.

8. How difficult is it to implement and maintain school bus electrification?

The two major barriers for replacing diesel school buses with electric buses are the higher upfront costs of electric buses and the costs involved in installing and operating charging infrastructure. In order to facilitate implementation, state government grants and funding like in the case of the Twin Rivers school district or contracts with companies like Highland Electric Transportation or Dominion Energy that would cover the difference in upfront costs are necessary. Attention has been slowly building up for this program, marked by increased media coverage. Emphasizing co-benefits like improved air quality for children would be helpful for gaining public support. V2G operations may face more challenges as not all utilities allow them, but it is expected that more and more utilities will be favorable to V2G in the future.

In terms of maintenance, electric buses have fewer parts that require maintenance compared to diesel buses, so they pose less challenges. Operating and maintaining charging infrastructure may be outside the expertise of existing staff employed by school districts, so the service of third parties may be necessary. Complexity will be further increased if V2G operations are employed, but V2G platforms like Nuvve or utility companies may be able to handle them more efficiently.

9. What are the leading vendors pertaining to P?

Bus Manufacturers:

- Proterra
- Yutong
- BYD Motors
- NFI Group
- Lion Electric Company
- Thomas Built Vehicles

V2G Technology: NUUVE

Utility: Dominion Energy

Transportation Company: Highland Electric Transportation, National Express

7.2 Useful Links

"Highland Electric Raises $235M, Lands Biggest Electric School Bus Contract in the US" (2021-02-25), Greentechmedia.com. (https://www.greentechmedia.com/articles/read/on-heels-of-253m-raise-highland-electric-lands-biggest-electric-school-bus-contract-in-the-u.s) https://www.greentechmedia.com/articles/read/on-heels-of-253m-raise-highl
s

"One small idea in Biden's infrastructure plan with big benefits: Electric school buses" (April 6, 2021) https://www.vox.com/future-perfect/2021/4/6/22364385/
one-small-idea-in-bidens-infrastructure-plan-with-big-benefits-electric-s
(https://www.vox.com/future-perfect/2021/4/6/22364385/one-small-idea-in-bidens-infrastructure-plan-with-big-benefits-electric-school-buses)

Chapter 8 Composting

By: Shan Shan (Christine) Liang

8.1 FAQs

1. What is composting?

   Composting is the process of turning organic, carbon-based materials into a nutrient-rich fertilizer for soil. It enhances the porosity, stability, water retention, and tillage of soil and improves its resistance to erosion and parasites. As an aerobic process, it decomposes trash from your yard, kitchen, home, or community in order to manage waste. This diverts the waste from going into a landfill and provides a variety of benefits.

2. What can be composted?

   The best compost includes a variety of materials in order to get a richer result with more micro-nutrients and diverse, beneficial microbial life. Generally, compost should have approximately 25–30 parts of carbon to 1 part of nitrogen. If there is too much carbon, decomposition slows down. If there's not enough carbon and too much nitrogen, the compost will give off an odor.

   Many random things from yards and kitchens can actually be composted because they are organic and carbon-based. Some materials like paper, cloth, wood, and string can also be composed but take more time because they need to be decomposed further. However, animal products and synthetic materials generally cannot be composted.

Yes	No
Leaves	Raspberry & blackberry brambles
Grass clippings	Long twigs or big branches
Brush trimmings	Pet droppings, especially dogs & cats
Manure (preferably organic) & Animal products—meat, bones, dairy, fish skins, fat	Coal ash
Any non-animal food scraps: fruits, vegetables, peelings, bread, cereal, coffee grounds and filters, tea leaves and tea bags	Colored paper
Old wine	Diseased plants
Pet bedding from herbivores ONLY—rabbits, hamsters, etc.	Inorganic materials
Dry cat or dog food	Synthetic chemicals
Dust from sweeping and vacuuming	
Dryer lint	
Old herbs and spices	

Table 8.1: Examples of compostable and non-compostable materials.

3. What is compost used for?
   - Agriculture: crops and sod farms
   - Landscapers: industrial and commercial properties, golf courses, athletic fields, landfill covers, and damaged soils
   - Plant Nurseries: seedling crops and reforestation projects
   - Public Agencies: highway median strips, parks, recreational areas, other public property
   - Residents: home landscaping and gardening
4. What are the benefits of composting?
   Without composting, most of this waste would go into a landfill. This is detrimental to our health and environment because of the toxic methane emissions released there. Instead, composing turns waste into a rich nutrient that improves soil health by preventing soil erosion and adding more nutrients. Since waste is diverted from landfills, cities and governments can also save money by reducing landfill capacity and avoiding landfill tipping costs. Moreover, composting improves plant growth and carbon sequestration and reduces soil contamination. This also creates opportunity to strengthen communities and boost local employment as people come together to protect their environment.
5. What are composting programs that can be implemented?

Curbside Collection	Drop-off Collection	Compost Bin Distribution
• Food waste is picked up by waste haulers every week and sent to a composting site • Different bins are provided to people to encourage waste separation	• Individuals store and drop off food waste at designated locations • Waste is transported to another location to be composted	• People receive their own compost bins at a subsidized cost • Composting happens at residents' own homes • Requires thorough education to teach residents about composting techniques

Table 8.2: Composting program types.

6. What composting services are on the market and who does them?
   - residential composting (food scraps and yard waste)
   - commercial composting (compostables from schools, businesses, restaurants and markets)

8.1.1 Vendors in the Philadelphia, PA region

(a). Kitchen Harvest, Inc.
Drexel Hill, PA 19026, Chris@MyKitchenHarvest.com, https://www.mykitchenharvest.com/

(b). Circle Compost https://www.circlecompost.com/.

Local community composter. Reported that claims of compostable bottles and tableware is mostly incorrect.

Feedstocks Accepted: Leaves,Grass,Brush,Tree Trimmings,Clean wood waste,Wood Chips,Garden Waste Yard Trimmings, Source Separated Food Scraps (Vegetative Only), Compostable paper, packaging and serviceware, Certified compostable bio-plastic packaging and serviceware Pre-consumer only (including food processing waste) Food Scraps Certified Compostable Bioplastic Bags, Clear Cups, Paper cups with bioplastic lining, Utensils, Plates and carryout containers Compostable Paper Kraft Bags,Soiled paper (e.g., napkins, towels, certified paper plates), Corrugated boxes (including pizza boxes), Wooden-only utensils, Crop/garden residuals.

Focuses on Center City, Philadelphia. There, $18/month for weekly pickup, $12 for bi-weekly.

(c). Philly Compost Inc. Philadelphia, Pennsylvania

Category: Community Composter, Organics Collection Service No website. Phone: (215) 880-0465.

Feedstocks Accepted: Leaves, Food Scraps, Bags, Clear cups, Paper cups with bioplastic lining, Utensils, plates and carryout containers.

(d). Organic Diversion LLC

http://www.organicdiversion.com/, Address: 46 South Maple Avenue, Marlton, NJ 08053. Phone: (609) 841-1326.

Commercial composter, focusing on supermarkets, restaurants, colleges.

Strictly food waste and a few other items.

Pricing depends on: location/distance, how it's collected, how much material is collected.

(e). County Conservation Co. LLC

https://www.countyconservation.com/, Address: 212 Blackwood-Bransboro Rd. Sewell, NJ 08080. Phone: T: 856.227.6900, F: 856.228.9600.

Category: Full Scale Composter. Feedstocks Accepted: Leaves, Grass, Brush, Clean wood waste.

(f). Laurel Valley Soils

https://laurelvalleysoils.com/, Address: 705 Penn Green Rd Landenberg, PA 19350-9204. Phone: 1-866-LV-SOILS (1-866-587-6457), Local 610-268-5555. Category: Full Scale Composter.

(g). Borough Of Phoenixville

https://www.phoenixville.org/212/Composting, Address: 351 Bridge Street Phoenixville, PA 19460. Phone: 610-933-8801. Category: Full Scale Composter.

(h). WeCare Denali Burlington County Co-Composting Facility
http://www.wecarecompost.com/ Address: not given. Phone: (888) 325-1522. Category: Full Scale Composter Feedstocks Accepted: Brush, Tree Trimmings, Wood Chips.

(i). Fairmount Park Organic Recycling Center Philadelphia, Pennsylvania
Category: Full Scale Composter. Feedstocks Accepted: Horse manure.

(j). Bennett Compost
https://www.bennettcompost.com/. Address: 5650 Rising Sun Ave, Philadelphia, PA 19120. Phone: (215) 520-2406.

7. What are some examples of successful, ongoing municipal composting programs?
Describe the programs and try to assess how successful they are, including on costs.

8. What are some examples of successful, ongoing composting programs at academic institutions?
Describe the programs and try to assess how successful they are, including on costs.

8.1.2 Expanding Scope through Grinding

Materials such as “compostable” bottles and tableware cannot be composted by ordinary composters. They require industrial grinding up first and there are no commercial vendors of this near Philadelphia.
An intriguing possibility is that an institution, such as Penn, might undertake to grind its own compost, thereby allowing various “compostable” plastics substitutes (food wrappers, plates, etc.) to be composted, either directly or by a third party. This needs to be looked into and its costs estimated.

8.2 Links

1. National locator for composters: www.findacomposter.com Useful site: http://www.findacomposter.com/.
2. “Municipal Composting Programs in Massachusetts: What Works, Where, Why and How,” a nice report, undergrad thesis: [25]
3. U.S. Composting Council
4. “Austin, Texas, pitches customer cost savings as curbside composting reaches over 200K homes” from Wastedive.com,
https://www.wastedive.com/news/austin-residential-curbside-composting-exp 594499/. (https://www.wastedive.com/news/austin-residential-curbside-composting-expansion/594499/)
Interesting story and has several useful links as well.
5. U.S. Composting Council https://www.compostingcouncil.org/?. Trade and promotion organization for the composting industry.

6. Local full scale composting company, MyKitchenHarvest. https://www.mykitchenharvest.com/
7. Local community composter, Dave Bloovman, good guy: Circle Compost https://www.circlecompost.com/
8. Local composter: Bennett Compost
https://www.bennettcompost.com/
9. See San Francisco's successful mandatory composting program: https://sfenvironment.org/recycling-composting-faqs.

Chapter 9 Green Financing

By Saahil Kamulkar

9.1 Green Bank Overview

9.1.1 What is a Green Bank?

- Institutions, not programs
- Provide financing not grants
- Prime objectives are modest profit, environmental impact
- The value proposition or mission is to reduce the cost of capital required for these projects, thus increasing the transition to renewables and sustainable living.

9.1.2 What problems do green banks solve?

- Provide customers with necessary information
- On-Bill financing allows customers with limited credit to take action
- Co-investment for areas with limited capital
- Standardized contract to streamline the underwriting process
- Securitization of smaller loans to then incentivize larger banks to participate (scale of larger banks prohibits them from taking such loans)

9.1.3 What are things to be cautious of?

- Crowding out

  The goal is not to compete with private equity, but rather serve projects that would not be able to get off the ground.

9.2 Green Banks: FAQs

We should say a little about costs, how this gets set up and the practicalities of keeping it going. Talk with someone from Montgomery Co. MD?

9.2.1 What is a Green Bank?

A green bank is an institution that is created to provide opportunities and funding for green initiatives. It is important to note that, contrary to the name, a green bank is not actually a bank; the institution is often a nonprofit that acts more as an investment vehicle. Rather than competing with existing financial institutions, a green bank provides financing with the goal of creating environmental impact, not maximizing profit. The green bank reduces the cost of capital for green projects, thus incentivizing the change towards a more sustainable future. Some green banks take on many smaller, conventionally unprofitable loans and securitize them for larger banks; this allows the green bank to pursue smaller projects and enables larger banks to partake in financing green projects. In addition to simple financing, green banks may implement creative or non-traditional methods of allocating capital to customers unable to dedicate sufficient money to green projects. For example, a green bank may choose to co-invest in a project that does not have sufficient funds or resort to On-Bill financing(allowing customers to include repayment as a part of their utility bill). However, the function of a green bank does not stop with financing; green banks provide ancillary services to customers, ranging from standardized contracts to project-specific consultation.

9.2.2 Where do Green Banks Invest?

Traditionally, a green bank primarily focuses on low-income areas. These areas are often too risky for traditional banks and are unable to secure enough funding to make the transition to more environmentally friendly projects. Many green banks declare their primary focus to be serving low- and moderate-income consumers, LMI. For the aforementioned reasons, these communities are often underserved; however, in order to create meaningful change, everyone must strive towards sustainability. Many community green banks have focused their attention on allocating capital to community solar projects, enabling low-income areas to switch to renewable power generation and saving money in the future. In terms of the actual projects that green banks commonly fund, there are seven primary categories:

1. Renewable power generation: solar, wind, geothermal, hydropower, ocean and hydrokinetic, and fuel cells
2. building efficiency, fuel-switching and electrification
3. clean transportation: electric vehicles, hydrogen vehicles, and associated charging or fueling infrastructure
4. industrial decarbonization
5. grid infrastructure including transmission, distribution, and storage;
6. sustainable agriculture: reforestation, afforestation, and regenerative agriculture climate-resilient infrastructure

9.2.3 How do Green Banks Invest?

As mentioned before, Green Banks play a key role in enabling small, underserved communities to transition towards sustainability. In order to do this, the Green Bank must provide low-cost capital to places where traditional banks and traditional investments do not service; it is important to note that these investors do not necessarily pass on these investments because of the risk involved, but rather because of the projects' size. The smaller transactions still have the same fixed and due diligence costs, making them less attractive compared to larger projects.

This is where Green Banks have a critical role. Green Banks work to take on and aggregate many small and medium-sized loans until the aggregate size is something that is sufficient for larger institutions. Then, the Green Banks works to securitize the loans or projects so that other, larger investors may invest. Green Banks utilize standardized contracts to create economies of scale that dilute the fixed cost relative to the total benefit. In essence, the Green Bank works to bundle the smaller projects into a singular larger project. Since institutional investors, like Penn, have a lower cost of capital and risk tolerance, a Green Bank would facilitate more investment into sustainability.

9.2.4 The Effects of the Green Bank Movement

Since 2011, green banks have caused over $5 billion in investments. This considerable funding was made possible by the partnership between publicly allocated money and investment from private organizations. Although the green banks themselves only invested $1.8 billion, they were able to actively attract further private investment of $3.8 billion. Over the past few years, cumulative investment caused by green banks has grown considerably. Moreover, many people consider green banks to be unsustainable long-term because green banks do not prioritize profits. However, this is not accurate. Over the last few years, many green banks have been able to grow operating income significantly. "Green banks in the United States collected $55.9 million in earned revenue to support their operations in 2019, a 22% increase over 2018's $46.0 million in earned revenue and a 141% increase from 2017's $23.2 million in earned revenue."

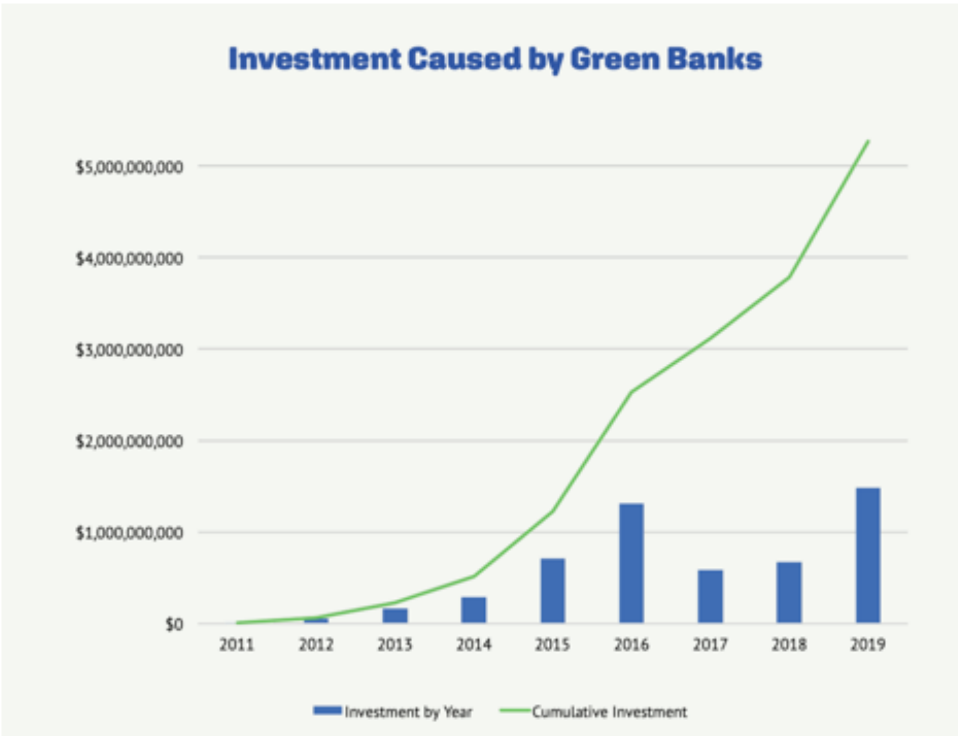

Figure 9.1: Green bank investment.

Do we have a source for this figure or its information?

9.2.5 Connecticut Green Bank Case Study

The Connecticut Green Bank had the goal of bringing solar energy and energy efficiency to LMI homeowners (these homeowners stand to benefit the most from this kind of project, because energy is a large cost relative to their annual income). The Connecticut Green Bank accomplished this using the following steps:

- Initiated a Request-for-Proposal Process: a general outline of the project that outlined the following features
- The project offered solar to single-family households.
- Incentivized LMI households through elevated performance based incentives (paying a certain amount ($/kWh) based on the energy production of the solar energy production)
- Offers Photovoltaic Systems that are leased to owners, so homeowners don't have to pay up-front. The lease has a 20-year term with fixed lease payments, allows the homeowner to purchase at the end of the term, and has a production guarantee (reimbursement if the system fails to provide enough energy).
- Bundled with a basic energy efficiency package from the local utility's Home Energy Solutions, with an EE installment option (ESA).
- Established Financing Logistics

  The project requires many people to participate: PosiGen(PV installer), tax equity investors, private-sector lenders, and CT Greenbank.
- Created a Special Purpose Entity which is owned by tax equity investors.

  This entity would own the project and thus benefit from the tax credit, benefits, and depreciation (these benefits replace the need for substantial cash flow from the project). PosiGen also invests in these SPEs utilizing senior third-party debt and subordinated CT Green Bank debt ("back leverage").
- Assisting with Deployment

  The Green Bank then helps by co-branded marketing This may include canvassing and troubleshooting market barriers In doing so, the Green Bank lowers the customer acquisition costs to PosiGen while raising awareness.
- Incentivizing Continued Operation

  The Green Bank continues to provide PBI's to the SPE, which incentivizes the LLC to continue to operate the solar panels efficiently (as they are paid per kWh)[PBIs end at a certain date, or kWh amount, if earlier]

  Homeowners benefit from lower cash payments, as tax equity investors are harvesting the benefit of the Tax Credits that would otherwise be largely unused by individual homeowners; LMI homeowners also benefit from the increased availability of credit, since the creditworthiness is not necessarily based on FICO(it may be based on other things like utility bill payment).

9.3 Implementing a Green Bank at Penn

sok, 3/30/21: This is a good start. Here are some suggestions.

1. Talk with the Penn Credit Union people and see if they just might possibly be interested. If so, let's set up a meeting to explore further.
2. Regarding:

   > The most effective way to implement a Green Bank at Penn would probably be to use a combination of the Bank and broker method. Rather than simply being an intermediary for green projects, Penn can start a green Bank that has some financial autonomy and power of its own.

   Don't start off with this. Instead make your recommendation after discussing alternatives, and painting the best picture you can of each. In particular, I suggest you consider these alternatives: (i) the broker model (teamed with? perhaps the credit union, perhaps some other institution. (ii) a fund-based model that does not require creating an actual bank that is chartered, regulated, etc. (iii) the hybrid model in which funds are raised and put in trust with a bank for lending and brokering activities accompany via Penn. I think this latter hybrid model is what you have in mind. This all needs to be spelled out very clearly.

The most effective way to implement a Green Bank at Penn would probably be to use a combination of the Bank and broker method. Rather than simply being an intermediary for green projects, Penn can start a green Bank that has some financial autonomy and power of its own. As opposed to simply raising awareness, these funds would be able to catalyze development by putting some teeth into the action (without independent funds of its own, this process might be more tedious, as it would require more stakeholders). In terms of marketing and legal operations, a hybrid method would certainly necessitate more personnel. However, along with this personnel, Penn would be better able to utilize the carbon credits cost-effectively and allocate the ancillary benefits(like tax credits) in the way it sees best. Nevertheless, the critical benefits to Penn will not be financial. Since the bank would be a non-profit, the green bank's primary aim would be to benefit the community– much like the purpose of most other green banks; this goal aligns well with Penn's philosophy and many of the outreach projects that Penn undertakes. The advantage of having a Green Bank is that it could be closely intertwined with some existing initiatives that Penn already funds; one such program is the Penn CURF Projects of Progress Prizes. A similar layout could help with funding projects that specifically address environmentally-conscious community improvements.

Expanding a little more on the ancillary benefits, including the Carbon benefits and the tax benefits. Both of these will be highly related to the project at hand; some projects may be more tax-advantaged than others, based on state tax laws. Similarly, the carbon offsets that Penn could use from the project will also depend on the logistics of the individual projects; certain projects will obviously be more impactful in terms of the environment. Going over the logistics of the Carbon Offsets, Penn has a few options. The first option is to undertake calculations of the offset independently. Under this method, Penn as an institution might be able to calculate and establish the carbon offsets of every project that it undertakes. One concern with this method might be the veracity of claims made by Penn, as there is a small conflict of interest: Penn stands to benefit from inflating the carbon offset number. An alternative method is to use a third-party verification service. Some of the services I found included American Carbon Registry, Verra, and Climate Action Reserve. These organizations are often the ones recognized by states like California, and thus are likely to be generally acceptable. Although using these reputable companies may be slightly more expensive, it is something that the Penn faculty would have to consider.

The following is incomplete. Good notes for further development.

Penn green bank lend to faculty and staff + landlords in Philadelphia

Maybe we can use payroll deductions

Externally funded greenbank

Projects for progress

9.4 Useful Links

For more information:

1. https://www.forest-trends.org/wp-content/uploads/2018/07/Factsheet_Producing-a-Voluntary-Carbon-Offset.pdf
2. https://coalitionforgreencapital.com/what-is-a-green-bank/
3. https://mcgreenbank.org/
4. https://michigansaves.org/about-us/
5. https://static1.squarespace.com/static/59bc05f0c534a543a9f96b0d/t/5edf9fbd8285f063f6c13bbe/1591713732
   Saahil says read this. See page 7.
6. https://greenbanknetwork.org/reports-white-papers/
7. Mechanics of a transaction: https://greenbanknetwork.org/wp-content/uploads/2018/07/GB-TT-Connecticut-18-07-A_05-1.pdf
8. Agg. and sec.: https://greenbanknetwork.org/wp-content/uploads/2019/04/Green-Bank-Aggregation-and-Securitization-Coalition-for-Green-Cap
   pdf
9. https://cgs.umd.edu/sites/default/files/2020-12/CGS_Public-Private%20Partnership%20%26%20Clean%20Energy%20FInance_Green%20Bank_

Final%20Report_ENG.pdf

https://coalitionforgreencapital.com/what-is-a-green-bank/

(https://coalitionforgreencapital.com/what-is-a-green-bank/)

https://mcgreenbank.org/

https://michigansaves.org/about-us/

https://static1.squarespace.com/static/59bc05f0c534a543a9f96b0d/t/5edf9fbd8285f063f6c13bbe/1591713732941/2020+Annual+Industry+Report+Final.pdf

https://greenbanknetwork.org/reports-white-papers/

Mechanics of a transaction:

https://greenbanknetwork.org/wp-content/uploads/2018/07/GB-TT-Connecticut-05-1.pdf

Agg. and sec.:

https://greenbanknetwork.org/wp-content/uploads/2019/04/Green-Bank-Aggrega pdf

* * *

Montgomery County Maryland https://mcgreenbank.org/ Has a video

Green Bank Network https://greenbanknetwork.org/

Coalition for Green Capital https://coalitionforgreencapital.com/what-is-a-green-ban

New York Green Bank https://greenbank.ny.gov/

American Green Bank Consortium https://greenbankconsortium.org/

Chapter 10 Building Electrification

By: Anvit Rao

10.1 FAQs

1. What is the name of the policy program?
   Building Electrification
2. What is building electrification?
   Building electrification is the process of using electricity to power buildings and appliances as opposed to fossil fuels. This will comprise of both upgrading buildings themselves as well as using renewable sources such as solar, wind, and others to power them. This is an important task because buildings proportionally consume a significant amount of energy in the US and other countries as well.
3. What are some examples in practice?
   The most popular form of building electrification in practice is the replacements of gas furnaces and air conditions with heat pumps. Heat pumps rely on transferring air from outside a home to inside to heat and cool. Electricity is used to send heat where it is needed and remove it from where it is not. Other forms of electric heating in buildings is geothermal heating, which functions similarly to a heat pump except it uses heat from the earth. Additionally, there are also systems that rely on water to heat and cool buildings, sending it back and forth from a central location. The most significant for the future, however, will be heat pumps opposed to electric space heaters. There are many electric heating programs that have been implemented across the country. The most notable ones are:
   - Many states such as Maine and California mandated that all new construction must incorporate heat pumps. Maine specifically has a goal set for 100,000 new heat pumps by 2025. States like Vermont and New York are also implementing heat pump rebate programs.
   - In a case study done by the Sacramento Municipal Utility District, heat pumps were very economically advantageous for new residential buildings and for existing units that housed multiple families. Heat pumps were slightly more expensive for existing single family homes, as well as more expensive for small to medium sized office buildings.
   - There was a case study in Austin Texas that showed that adjusting building codes in addition to making electrification updates resulted in a 37% greater savings that having a system that only makes electrification updates.

- Stanford University fully converted its campus heating and cooling systems to a water-based system, and has cut emissions by 65 %

In addition to the area of heating, there is also potential to navigate away from the use of gas ovens and stove tops through the use of electric induction stoves. Currently, this write up focuses on heating and cooling, but there is more research to be done on electric appliances like inductions stove-tops

4. Important policy areas and considerations:
    - Incentivize use of electric heating and cooling
    - Manage increased demand on the grid

      There is potential for the involvement of smart grid technology, and there are multiple ways through which local governments can do this:
        - The incorporate of customer feedback on energy use. This is effective in both allowing customers to understand the impact they are having, as well as making a behavioral chance. BCG reports that utilities boosted their gross margin by more than 20% after incorporating more customer feedback methods.
        - Implementing a demand-response grid system. This would adjust utility service prices based on peaks in energy usage as well as allow for customers to sell electricity back to the grid for credit. Measures like these will incentivize off-peak electricity usage and have the positive impact of decreasing grid stress to accommodate for greater use of electricity in buildings
    - Improve technology to benefit building efficiency
5. What do heat pumps cost and who pays?

   On the residential side, heat pumps for a whole house can cost between $2,500 and $7,500 depending on the size of the home. These fees will generally come out of the pocket of the homeowner unless there is a government rebate. For larger buildings like universities or commercial buildings, the cost would follow a similar rate but depend on the size of the building

   More research to be done on the cost and varying pricing
6. What are the climate-related benefits of building electrification?

   By relying on electricity instead of natural gas or fossil fuels, building electrification reduces greenhouse gas emissions. Additionally, it caters better to renewable energy because that energy can now be used directly to heat and cool buildings. This is particularly impactful because homes and businesses burning natural gas, oil, or propane account for 560 million tons of CO_2 each year, which is 10% of the total US emissions. Looking at universities specifically, on average, 53% of their energy usage comes from heating and cooling buildings. Making a dent in these highly energy-consuming processes has the potential for big climate impacts through reducing emissions as a result of less reliance on fossil fuels.

7. What are some additional benefits, co-benefits?

   One of the first benefits is in terms of cost. For new buildings being made, it is clearly more cost-efficient for them to rely on electric methods such as heat pumps. This is because, in the long run, electric heating methods can some roughly 30 to 40% on utility bills. On the other hand, the decision to renovate old buildings is a little bit more difficult, but once again, in the long run, switching to electric heating will lead to emissions savings. Additionally, electric systems such as heat pumps offer benefits in terms of health and safety. Studies have linked the presence of gas furnaces in homes to developing conditions such as asthma. Additionally, electric systems remove the risk of gas explosions and carbon monoxide leaks.

   More data on safety and health related risk still needs to be found
8. What are the dis-benefits?

   There are negative effects for natural gas and oil companies that rely on building heating and cooling systems to sell a lot of their product, as well as utilities that send these products to customers.

   This section still needs to be flushed out
9. How difficult is it to implement and maintain building electrification

   The biggest struggle with implementing large-scale heat pumps is the installation process, but states are already starting to develop groups that are trained for this installation. One note on the maintenance of this switch to electricity is the stress that it could potentially put on the electricity grid.
10. Additional notes on building electrification

    Something very interesting about building electrification is the possibility for it to work in tandem with other sustainability policies. First, because building electrification marks the transition away from natural gas, decoupling could be a potential solution to managing the effect on utilities. Second, because there will be more stress on the grid, smart grid and storage advancements could become even more important in managing the nation's electricity usage. Finally, green financing could play a significant role in funding building construction and retrofitting.

    There is more research still to be done on these policies and how they could work together with building electrification

10.2 Links

- "A Furious Industry Backlash Greets Moves by California Cities to Ban Natural Gas in New Construction"
  https://insideclimatenews.org/news/05032021/gas-industry-fights-bans-in-homes-businesses/
  `https://insideclimatenews.org/news/05032021/gas-industry-fights-bans-in-h`

- https://www.huffpost.com/entry/climate-green-building-codes_n_60381e23c5b60d98bec8dc7d
- “How Dangerous is Natural Gas?” (August 8, 2017) https://safer-america.com/dangerous-natural-gas/

Chapter 11 Electrification of Transit Buses and Utility Vehicles

By: Jae Kwak

11.1 FAQs

1. What is the name of the policy or program type?

   Transit Bus Electrification

2. What is transit bus electrification?

   Local policies that will replace diesel transit buses with electric battery-powered transit buses.

3. What are some examples in practice?

   Seneca, SC: In 2014, Seneca, SC became the first city in the world to launch an all-electric bus fleet. The policy is considered successful so far, as the new fleet has outperformed diesel equivalents in terms of fuel and maintenance costs and have beat expectations regarding range and charging times.

   Chicago, IL: The Chicago Transit Authority(CTA) launched 2 electric buses in 2014 as a test pilot, and found that they saved more than $24,000 each in fuel costs and $30,000 each in maintenance costs. Most importantly, the vehicles performed well without much difficulty in extreme cold weather. CTA is planning to fully electrify the bus fleet by 2040.

   King County, WA: Since 2016, the King County Metro Transit has been testing electric buses, and found them to perform well in a variety of weather conditions. However, there were some issues regarding battery life, range, and higher (than diesel) per-mile fuel costs due to high electricity demand charges. However, the King County Metro Transit considers the ROI to be reasonable if emissions reductions and other co-benefits are considered and is planning to expand the rollout.

   Albuquerque, NM: Albuquerque tested electric buses in 2018, but eventually cancelled the contract due to issues such as subpar battery life, inadequate range, and sensitivity to extreme heat. However, in August 2019, the city announced it would purchase five new 40-foot electric buses.

4. What does transit bus electrification cost and who pays?

   There are two main components of costs in providing public transportation service: operating costs and capital expenditures. On average, 25.4% of the total costs are funded by fares, 37.4% from Local governments, 20.5% from State governments, and 16.8% by the Federal Government. Operating costs are funded mostly with fares and local government funds, and capital expenditures are mostly funded by the local governments and the federal government.

As of 2019, according to PIRG, on average diesel transit buses cost $500,000 while electric buses cost $750,000. Most of the difference in upfront costs will likely have to be borne by local governments through municipal bonds and local option transportation taxes. State grant programs and subsidies like in the case of California, if possible, will help cover the difference in upfront costs. The Federal Transit Administration's (FTA) Low or No Emissions Program, which funds state and local government agencies for low-emissions transit buses and related infrastructures, can also lower the cost burden for local government.

As long as electricity prices are stable, electric buses can produce substantial savings in terms of lower fuel and maintenance costs relative to diesel buses despite higher upfront costs. Proterra, one of the leading electric bus manufacturers, says its electric buses can save up to $50,000 a year relative to fossil fuel powered buses, indicating a 5 year payback period. However, as seen in the case from King County, WA, the cost savings of electric buses depend on electricity rate structures.

There is potential for even more cost savings if Vehicle-to-Grid (V2G) operations are implemented. Under V2G operations, the electric bus batteries are charged at times when electricity prices are cheap, while discharging power back to the grid at peak demand times. Partnerships with utilities are crucial for V2G to be viable.

5. What are the climate-related benefits of transit bus electrification?

   Electric buses emit substantially less carbon than diesel counterparts, even when the electric grid is carbon intensive. If an electric bus is charged with the national electricity mix, it produces less than half of carbon emissions per mile produced by diesel-hybrid or natural gas buses, which are considered to be "cleaner" than diesel buses. The reduction in carbon emissions will increase even more as the percentage of electricity generated by renewables and other clean energy sources increases.

   According to a 2019 PIRG report, replacing all of US diesel transit buses could eliminate more than 2 million tons of greenhouse gas emissions per year. On the local level, the Chicago Transit Authority can save approximately 55,000 tons of greenhouse gas per year if they electrify its entire fleet. Similarly, the Southeastern Pennsylvania Transportation Authority can reduce 2,000 tons of greenhouse gas emissions per year if they electrify all of its transit buses. These figures will further improve as US grids move towards more clean, renewable energy.

6. What are some additional benefits?

   Improved air quality: By replacing diesel buses, this program can reduce harmful emissions from diesel exhaust that pollute the air, thereby reducing health care costs. Pollutants that are expected to be reduced are ozone, lead, diesel particulate matter, carbon monoxide, sulfur oxides, and nitrogen oxides, which are all harmful for the human health and the environment. Exhaust from diesel buses are designated by the IARC to be carcinogenic and are linked to premature death, aggravated asthma, and decreased lung function. The exhausts are also linked to ozone pollution and acid rain. Air pollution tends to be more severe in low-income and minority communities, so municipalities like King County, WA are considering to first electrify buses in such communities to address social equity concerns.

Grid Balancing: If V2G operations are possible, the electric bus batteries can be used as energy storage for the grid by charging them when prices are cheap and discharging power back to the grid at peak times. Electric transit buses have potential for V2G because of large capacity sizes and predictable operation schedules. Battery life reduction is a potential concern for V2G operations, but the Becker et al.(2019) case study shows that as long as proper thermal management is conducted, battery degradation can be minimized.

Noise Reduction: Traditional diesel buses contribute to noise pollution, which can be harmful in some instances. A Toronto study found that 12% of transit bus noise exposure exceeded the EPA threshold for hearing damage risk. Electric buses can reduce the risk substantially because they are mostly quiet.

Lower Maintenance and Fuel Costs: As mentioned earlier, electric buses can save more in lifetime costs due to lower maintenance and fuel costs.

7. What are the dis-benefits?

Range: Range has often been cited as an issue for electric vehicles in general, especially during the early stages of development. Local municipalities need to test thoroughly before mass deployment to ensure that the original routes would not be disrupted, especially during extreme weather conditions. In King County Metro's electric bus pilot programs, there were some instances when the batteries were depleted faster than usual, especially in cold temperatures. The case was more severe for Albuquerque, as the average 177 mile range failed to meet the contractually-stipulated 275 mile per charge range, especially in hot temperatures. However, this doesn't mean that electric buses always fail to provide enough range. In the case of Seneca, the new electric buses were expected to provide a range of 30 miles, but the buses exceeded ranges of 40 miles. Similarly, the Chicago Transit Authority found its new electric buses to maintain its range through extreme cold temperatures. Overall, we recommend that local governments test the vehicles thoroughly in different conditions before committing to a contract.

Infrastructure: Building out the charging infrastructure will likely be a costly expenditure. The costs will be higher if on-route charging infrastructure is needed. However, as fleet sizes become larger, there is greater potential of economies of scale, which would bring down the infrastructure cost per vehicle. Furthermore, partnering with a local utility may bring opportunities to bring down the cost of installing charging infrastructure.

Operational Complexity: In the transition period where traditional buses and electric buses coexist, the complexity of managing the vehicles and organizing routes may sharply increase. Additional staff training will also be necessary. However, as we see more successful cases of adoption, it may be possible for more guidelines to be established that will help local transit authorities adjust to the changes.

Potential stress on the Electric Grid: If the transition to electric buses happens in a short period, it may potentially cause strain on the local electric grid. If electricity prices increase sharply due to strain, lifetime costs of electric buses may increase. One potential solution to mitigate this is to partner with utilities to coordinate charging and V2G operations.

8. How difficult is it to implement and maintain transit bus electrification?

   As mentioned above, the biggest obstacles for implementing would be the difference in upfront costs and the installment of charging infrastructure. For these financial obstacles, local governments should actively seek out federal and state grants or even pursue partnerships with local utilities.

   In terms of maintenance, the largest challenges would come from changes in operational complexity. However, we believe that these operational challenges would become easier to overcome as more and more transit authorities experiment with potential solutions.

9. What are the leading vendors pertaining to transit bus electrification?

11.2 Electric Bus Manufacturers

Yutong

BYD Motors

Proterra

AB Volvo

11.3 References and Links

2019 PIRG Report: https://uspirg.org/sites/pirg/files/reports/ElectricBusesInAm
US_Electric_bus_scrn.pdf

EPA on air pollution: https://www.epa.gov/dera/school-bus-idle-reduction#:~:text=Not%20only%20can%20diesel%20exhaust,acid%20rain%2C%20and%20climate%20change.

Public Transportation Funding: https://fas.org/sgp/crs/misc/R42706.pdf

Becker et al. (2019): https://www.nrel.gov/docs/fy20osti/74187.pdf

Yao et al. (2017): https://journalotohns.biomedcentral.com/articles/10.1186/s40463-017-0239-6

King County Metro Report (2017): https://kingcounty.gov/~/media/elected/executive/constantine/news/documents/Zero_Emission_Fleet.ashx

Holland et al. (2021): https://www.sciencedirect.com/science/article/pii/S0301421520306327

Xylia et al. (2018): https://www.sciencedirect.com/science/article/abs/pii/S0959652618330993

Blynn and Attanucci (2019): https://journals.sagepub.com/doi/abs/10.1177/0361198119842117

Greentech Media (2020): https://www.greentechmedia.com/articles/read/should-e-bus-fleets-be-paired-with-microgrids

https://www.greentechmedia.com/articles/read/on-heels-of-253m-raise-highla
s

Chapter 12 Low Embodied Carbon Concrete

Gabriela Gerity

12.1 FAQs

12.1.1 What is Low Embodied Carbon Concrete?

Low embodied carbon concrete (LECC) generates less carbon emissions in its production than conventional concrete. Cement, the "glue" that holds concrete together, comprises only 7-15% of concrete's volume, but is responsible for 95% of the emissions. Cement is made by roasting limestone at 2,600° F. Approximately half the emissions come from the fuel used to heat the ovens, and the other half is released in a chemical reaction in which carbonaceous limestone becomes calcium oxide. Therefore, reducing overall embodied carbon in concrete can be achieved through three primary strategies: reducing the amount of cement in concrete mixes, using renewable energy for cement production, and and storing CO2 within cement.

12.1.2 Reducing Cement Use in Concrete

Using less cement is the most effective way to reduce the carbon footprint of concrete. Portland cement, the most common type of cement, can be replaced with other materials, called Supplementary Cementing Materials (SCMs). Fly ash from coal-fired power plants and slag from steel-blast furnaces are industrial wastes, often called geopolymers, that are typically used as SCMs. However, as these industries decarbonize, the supply of their byproducts is expected to decrease. Non-fossil fuel based SCMs include glass pozzolan, made from post-consumer recycled glass, as well as rice husk ash, made from the agricultural byproducts of rice production. Limestone can also be added to mixes to reduce the amount of cement in concrete. A variety of other lab-based and naturally occurring SCMs are currently being researched and published. Some examples of companies bringing lower-carbon SCMs to market are introduced below.

12.1.3 Geopolymer Solutions

Geopolymer Solutions combines recycled industrial wastes of fly ash and ground granulated blast-furnace slag as well as other naturally occurring minerals to create a heat-free cement with a carbon footprint approximately 10% that of Portland cement. It also offers added benefits including a higher quality, more durable, acid-resistant, longer lasting product that requires less water to produce. It can easily replace Portland cement at standard ready-mix concrete facilities. However, the initial material cost of geopolymer concrete is approximately 32% higher than conventional concrete. Builders who choose geopolymer concrete primarily do so for its environmental benefits.

12.1.4 Pozzotive

Pozzotive processes recycled glass into pozzolan that improves concrete performance. By increasing compressive strength and avoiding a chemical reaction that causes cracking, glass pozzolan reduces the amount of cement needed in concrete mixtures and saves maintenance costs. It is also more workable, pumpable and longer lasting. According to Pozzotive, their product reduces the embodied carbon in concrete by up to 50%. As environmental regulations are forcing the closure of coal-fired plants, fly ash, a once abundant source of pozzolan for concrete making, is becoming more and more scarce. This has allowed recycled glass to compete better in the pozzolan market. Concrete made with Pozzotive has been used for high-visibility projects in New York City including the United Nations Plaza, City Point, and the Second Avenue Subway station. According to Pozzotive, the price of concrete made with their products is on par with normal concrete. In addition, salvaging recycled glass saves governments money by sending less glass to landfills, which are costly. The greatest barrier to widespread adoption of this SCM is lack of awareness. Changing industry standards will require engineers, contractors, subcontractors, and ready-mix suppliers to understand and implement the replacement. The recently published ASTM Standard Specification for Recycled Ground-Glass Pozzolan for Use in Concrete will make it easier for building teams to specify this material.

Lafarge Holcim's OneCem® Portland Limestone Cement Portland-limestone cement (PLC) is the most widely used SCM today, already beginning to be accepted by the construction community and readily available through existing supply chains. This blended cement is made of 5-15% limestone, reducing the amount of cement required in concrete and reducing its carbon footprint by approximately 10%. Lafarge Holcim, the largest cement manufacturer in the United States, is one of the many suppliers promoting this SCM with their OneCem® Portland Limestone Cement. The OneCem® branding is intended to represent that this is the "one cement" that can be used for nearly all applications, serving as an equivalent or better replacement for standard Portland cement. The price of PLC is equal to or in some cases cheaper than regular Portland cement. Lafarge Holcim says that limestone is still an underutilized carbon solution for the construction industry and that it is working to accelerate its adoption.

Renewable Energy in Cement Production The energy required to heat cement ovens constitutes about 40% of emissions from concrete production. Fossil fuels are currently the primary energy source since they are the cheapest option, but they can be can be replaced with renewable sources such as solar power, biomass, municipal waste, and green hydrogen. The European Cement Association says it already gets 44% of its energy from non-coal sources including industrial waste, mineral oil and used tires. A California-based startup called Heliogen is developing a way to cost-effectively use solar energy to power cement ovens using arrays of mirrors connected to advanced computer vision software. Capturing sunlight to produce a consistent stream of energy concentrated enough to power enormous cement kilns has been an ongoing challenge, and it will be up to Heliogen to demonstrate an economically-competitive way to do so. Hanson, a subsidiary of the global building materials giant HeidelbergCement, is collaborating with researchers to use green hydrogen produced through on-site solar- and wind-powered electrolysis to partially power their cement plant. LaFarge Holcim, another building materials giant, currently gets 45% of fuel used to heat cement kilns from waste, biomass, and other low carbon sources, and it seeks to increase that to 65% by 2022. LaFarge Holcim expects that stricter building regulations and carbon taxes, especially in the EU, will increase customers' willingness to pay a premium for low-carbon concrete. However, until renewable energy becomes competitive with fossil fuels worldwide, this method of reducing the carbon footprint of concrete is likely to be the least popular.

Carbon Capture in Cement Production Carbon emissions themselves can be captured and reused in the cement making process to generate value-added cement products. CarbonCure and Solidia are companies that seek to store greenhouse gases in the pores of concrete by using CO2 instead of water to cure it. By retrofitting existing concrete plants, these companies expect to commercialize their technologies quickly. Although products like carbon-cured concrete could earn a "green premium" among environmentally-conscious buyers, both CarbonCure and Solidia claim that the costs of concrete made using their technologies are on par with conventional concrete. Carboncure claims that CO2 delivery and equipment costs are offset with a stronger product, which means lower quantities of concrete required as compared to conventional concrete. Solidia claims that their products use the same equipment and raw materials, cost less to produce, and cure in 24 hours rather than the conventional 28 days. As carbon policies become more stringent, carbon storage technologies like these can present additional economic advantages for the construction industry.

Software tools

https://newbuildings.org/embodied-carbon-conundrum-solving-for-all-emissio

> While designers can use energy modeling software to estimate the carbon emissions of building operations, the industry has lacked a standardized system to track the carbon embedded in construction materials. The development of open-source tools such as Athena Impact Estimator, the Bath Inventory of Carbon and Energy (ICE), Tally, One Click LCA, and most recently the Embodied Carbon in Construction Calculator (EC3), is making it easier. These tools help design teams and owners better understand the levels of carbon locked in the structures they create.

https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete-0/3-overcoming-barriers "Digital tools will play a key role in building the market for novel cement and concrete products. Such tools can address knowledge gaps and 'democratize' access to relevant information at different points along the value chain."

12.2 Low Embodied-Carbon Concrete Options in the Greater Philadelphia Area

Conewago Ready Mix

Conewago Ready Mix is a locally owned and operated concrete supplier serving the South-Central Philadelphia region that has partnered with CarbonCure to incorporate CO2 injection technology into their concrete production facilities. Conewago is also one of the first concrete suppliers to launch a concrete reclamation program that turns unused concrete back into usable stone, sand and recycled water.

Delaware Valley Recycling

https://www.hkgroup.com/companies/delaware-valley-recycling-inc

https://www.bdcnetwork.com/lf-driscoll-and-balfour-beatty-recently-wrapped-largest-concrete-pour-philadelphiahttps://structuretone.com/making-history-penn-medicines-newest-hospital-sets-philadelphia-record/ Already using fly ash

12.3 Barriers to adoption

`https://www.bloomberg.com/news/articles/2019-06-23/green-cement-struggles-`

(https://www.bloomberg.com/news/articles/2019-06-23/green-cement-struggles-to-expand-market-as-pollution-focus-grows)

expensive

What's less certain is the desire of developers and construction companies to buy greener products. Without action from policymakers, green cement may remain a low priority for the builders, said Tiffany Vass, who assesses energy technology and policy on the IEA's industry team. "I don't believe the pressing need for decarbonization has broadly reached the construction industry in many parts of the world," Vass said. https://www.marsh.com/vn/en/insights/research/risks-of-using-low-carbon-cement.html Insurance costs - uncertain product Need to incldue testing regime in timeline Philadelphia options

12.3.1 Further research required

Current Municipal LECC Requirements: When it comes to implementing LECC in construction, science is not the problem. With a wide variety of solutions already being developed in labs around the world, the greatest barrier will be getting the construction industry to adopt them. State and local governments have already begun to implement LECC requirements of their own, with considerable success. . . . For example. . .

`http://go.carboncure.com/rs/328-NGP-286/images/CarbonCure%27s%20Path%20to%20the%20Decarbonization%20of%20Concrete%20eBook.pdf` Page 13 municipal experiments https://www.enr.com/articles/50910-low-embodied-carbon-concrete-options-se

Research the new york law more

Policy options

https://www.oecd.org/greengrowth/GGSD2019_IssuePaper_CementSteel.pdf p 27

Buy clean california act

https://grist.org/politics/cement-has-a-carbon-problem-here-are-some-conc

Potential challenges

https://www.oecd.org/greengrowth/GGSD2019_IssuePaper_CementSteel.pdf p 24-25

Note any opposition to these policies

For nongovernmental organizations (like a university) specifying low carbon concrete during new construction design is key

Quantifying the impact of using LECC in terms of carbon emissions Construction = 39% of global GHGs, and over 25% of these come from embodied carbon Between now and 2050, embodied carbon will be responsible for almost half of all new construction emissions (carboncure) Concrete is responsible for 8% of all global greenhouse gas emissions every ton of cement creates 900 kg of CO2 emissions (asme) Green cement can reduce the carbon footprint by 40% (kapre) https://grist.org/politics/cement-has-a-carbon-problem-here-are-some-concrete-solutions/ More on the additional cost of using LECC Note that concrete is not too costly - small percentage of total building costs Question: there are so many LECC options - which to focus on? Big questions: What could be done? What would it cost? What would the impact be at an institution like Penn or Lower Merion Township (or other municipality)? steel

12.4 Model Resolution/Recommendation

Try drafting a model resolution that might be adopted by an advisory committee or activist group, to be implemented in detail by the appropriate legislative council. One thought is to require bids to include LECC with a price, and optionally without LECC. Announce a policy of going with LECC if it is not excessively expensive (and say what that is).

12.5 Notes

sok: I think this might be a winner, both for Penn and for Lower Merion (i.e., for academic institutions and for local governments). Needs following up.

https://theconversation.com/bendable-concrete-and-other-co2-infused-cement

> Local governments are taking the first steps. "Low embodied carbon concrete" rules and projects to reduce the amount of cement in concrete have cropped up around the country, including in Marin County, California; Hastings-on-Hudson, New York; and a sidewalk pilot in Portland, Oregon.

It would be good to compute a cost of carbon offset for low carbon concrete. What does the additional cost of the concrete buy us in terms of reduced GHG emissions? This is a good source: https://www.concretecentre.com/Publications-Software/Concrete-Compass/Low-Carbon-Concrete.aspx. Depending on application and type of concrete, seems that saving 100 kg/m^3 is realistic.

https://www.carboncure.com/about/

The Interchange podcast on April 29, 2021.

Chapter 13 Internal Carbon Pricing

By Steven O. Kimbrough

State of the draft: This is a work in progress. The first section, on FAQs, is reasonably mature and can be circulated for comment.

Are there any studies of these programs?

13.1 FAQs

1. What is internal carbon pricing?

   Internal carbon pricing occurs when an organization—whether public, private or third sector—imposes on itself a price for greenhouse gas (GHG) emissions. The price is normally expressed in dollars per metric tonne of CO_2e (carbon dioxide equivalent) emissions. See `https://www.c2es.org/content/internal-carbon-pricing` for a standard description, aimed at the private sector but applicable generally.

2. Are there different ways of doing internal carbon pricing? If so, what are they?

   Yes, and they are not mutually exclusive and may be used in combination. See Figure 13.1 for a summary.

   For present purposes, we focus on pricing by *carbon fee* because it is likely the most important option for local governments and academic institutions. The *shadow price* method is mainly apt as a planning tool, to ascertain robustness of investments in a future in which external carbon pricing might be imposed.

3. How does a carbon fee work?

   (a). The institution identifies activities to be subject to the fees and quantifies CO_2e emissions for them.

   For example, an institution might designate a standard CO_2e emissions rate in tonnes per passenger mile traveled by airplane.

   (b). The institution sets the internal carbon price in dollars per tonne of CO_2e emitted.

   (c). When institutional funds are expended for a covered activity a carbon pricing fee is assessed for the activity. Typically, this would be internal carbon price times the standard rate for the activity times the amount of activity, e.g., carbon price $\times$ emissions per mile $\times$ miles traveled.

4. How much is the carbon fee?

   The level of carbon fee varies and is typically adjusted dynamically during an internal carbon pricing program. Figure 13.1 reports a range of \$5–\$20 per metric tonne of CO_2e. The Yale experiment set the price at \$40. Microsoft's current price is \$15.

5. What happens to the money collected by imposing the fee?

   The money is put into a special fund. Let us call it the Sustainability Fund. The institution then decides what to do with the money in the Fund. Common uses of the monies include:

   (a). Purchase carbon offsets.

   (b). Invest in greening the institution, that is in further reducing GHG emissions.

6. What are some examples in practice?

   There are many. In the private sector Microsoft and Disney, among others, have long had carbon fees.

   Among academic institutions, Yale University has experimented with a carbon fee. See https://carbon.yale.edu/project-overview, https://carbon.yale.edu/ and: (https://shopcases.som.yale.edu/products/putting-a-price-on-emissions-yale-universitys-internal-carbon-charge-experiment).

7. How is it working out?

   In the private sector it appears that a number of firms have carbon fees that have been in place for several years, perhaps most notably Microsoft:

   > In July 2020, we will start phasing in our current internal carbon tax to cover our scope 3 emissions. Currently this fee is $15/metric ton and covers all scope 1 and 2 emissions, plus scope 3 travel emissions. Unlike some other companies, our internal carbon tax isn't a "shadow fee" that is calculated but not charged. Our fee is paid by each division in our business based on its carbon emissions, and the funds are used to pay for sustainability improvements.
   >
   > https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/, 2020-01-16, accessed 2021-03-05.

   Examples of municipal and academic carbon pricing, especially carbon fees, are thin. Yale did an experiment that was considered successful. The following is from [10].

   > Yale University's carbon-charge pilot was launched as part of the university's broader sustainability initiative and ran from December 2015 to May 2016. The charges covered direct and indirect emissions from consuming energy sources such as electricity, gas, steam and chilled water. The price was set at $40 per tonne of CO2, which was close to the US government's estimated social cost.
   >
   > . . . By the end of the trial, buildings that had faced carbon charges had used less energy than those that had not (see 'Energy savings'). Reasons for this included increased awareness of energy use, competition between buildings and the higher price of energy.
   >
   > . . . At the end of the pilot, the university selected the revenue-neutral pricing structure to implement campus-wide, because of its financial stability. The

structure is not subject to potentially large outflows of funds if buildings exceed a target, saving energy because of an unusually mild winter, for example, or if energy needs rise unexpectedly owing to a cold snap or other reasons.

Yale implemented a carbon charging program in 2017, which continues today https://carbon.yale.edu/implementation.

Regarding municipal carbon pricing, the following is an interesting and well-researched proposal: "An Internal Carbon Price for the City of Ann Arbor" by Adam Freed, Lauren Jones, Yu-Ting (Eileen) Lo, Rosanna Ren.

https://deepblue.lib.umich.edu/bitstream/handle/2027.42/155014/354%20internal%20carbon%20price%20for%20city%20of%20ann%20arbor.pdf?sequence=1&isAllowed=y

8. Pros?
   (a). Promotes environmental awareness in stakeholders.
   (b). Encourages reduction in GHG emisssions, and efficiently so.
   (c). Prepares the institution for external carbon pricing.
9. Actual or Potential Barriers and Impediments?
   (a). Charging a fee for an expenditure that is funded by outside grants or donations. Is it permitted?
   (b). Administrative mechanics.
   (c). Setting the fee basis and maintaining it.
10. Bottom line?

    It's a contender. Careful follow up needed to ascertain feasibility and workability. Potentially an efficient way for an organization to reduce GHG emissions, by encouraging individual behavior.

13.2 Assessment of the Yale program and experience

13.3 Assessment of the Ann Arbor proposal

13.4 Model program for academic institutions

13.5 Model program for municipalities

13.6 Resources on Municipal Carbon Pricing

White paper on municipal carbon pricing: "IMPLEMENTING CARBON PRICING AT THE MUNICIPAL LEVEL".

https://climate-xchange.org/wp-content/uploads/2018/08/Implementing-a-Carbon-Price-at-

	CARBON FEE	SHADOW PRICE	IMPLICIT CARBON PRICE
Definition	A monetary value attached to each metric ton of emissions charged to business units for their emissions.	A theoretical internal cost of carbon applied in project planning processes to test the feasibility of capital expenditure and R&D investment decisions.	The value of past measures and initiatives implemented to reduce a company's greenhouse gas emissions and/or comply with climate policies and regulations.
Key Objectives	To create a dedicated revenue or investment stream that can fund projects to help meet a company's greenhouse gas reduction targets, and establish a common business "language" internally to address climate change.	To screen potential business risks of future carbon regulations, build a business case to shift investments to low-carbon options.	Identify marginal abatement costs of mitigating greenhouse gas emissions and complying with climate policies and regulations.
Calculation	Commonly calculated as the amount of funding or level of investment needed to meet the company's greenhouse gas reduction targets.	Commonly calculated as the current or expected future price of carbon regulations along with other market, technology, and policy factors (including indirect carbon pricing policies).	Can be calculated as the marginal abatement cost of reducing a company's greenhouse gas emissions and/or the cost of complying with regulations. Some companies calculate an implicit price as the costs associated with buying and generating renewable energy divided by the number of tons of emissions saved.
Observed Price Range[123]	\$5–\$20 per metric ton of CO_2e.	\$2–\$893 per metric ton of CO_2e.	No revealed prices or price ranges.[124]
Investment and Revenue Allocation	Revenues used to fund sustainability projects, realized as an actual monetary transaction between business unit(s) and the department collecting the fee.	A theoretical price that is not collected, but which guides future investments and research and development activities toward low-carbon alternatives.	There is no reinvestment or revenue allocation since the price is derived retroactively.
Key Benefits	Sends a direct price signal to business units to justify investments in low-carbon options and raise awareness among employees that carbon reductions are valuable. May help reduce greenhouse gas emissions and drive cultural change and accountability.	Can help prioritize investments in low-carbon options and prepare a company for future carbon pricing regulations. Easier to gain buy-in from C-suite executives. Often viewed a part of a risk management strategy, rather than a cost imposed across business units.	Helps understanding of a company's carbon footprint and the costs of abatement or compliance. It can serve as a benchmark before launching an explicit internal carbon pricing program.
Key Challenges	May pose upfront challenges for implementing, administering, and gaining internal buy-in because it is an actual financial cost imposed throughout the organization. Requires an administrative structure to collect revenues, evaluate revenue/investment allocation, and distribute funds to projects across business units.	As the theoretical price is not reflected in a company's or a business unit's budget, it may not shift investments to low-carbon options, may not provide a strong near-term signal or incentive to reduce emissions. It will also likely not motivate changes to employee behavior. Because it is part of a risk strategy, employees may not be engaged or aware of the price.	Retroactively calculated after measures have been implemented, therefore may not have same incentivizing effect as a carbon fee (and in some cases a shadow price) to mitigate greenhouse gas emissions and shift investments to low-carbon options.

Figure 13.1: From "The Business of Pricing Carbon: How Companies are Pricing Carbon to Mitigate Risks and Prepare for a Low-Carbon Future," Center for Climate and Energy Solutions, (http://www.c2es.org/document/the-business-of-pricing-carbon-how-companies-are-pricing-carbon-to-mitigate-risks-and-prepare-for-a-low-carbon-future/)

the-Municipal-Level-Climate-XChange-compressed.pdf

https://climate-xchange.org/wp-content/uploads/2018/08/Implementing-a-Carb
pdf

“Designing an European municipal Carbon pricing model: A collaborative project between Klimaatverbond Nederlandand Climate Alliance”

https://www.climatealliance.org/fileadmin/Inhalte/4_Activities/Projects/Carbon_pricing_working_group.pdf

13.7 Resources on Academic Carbon Pricing

The University of Illinois discussed it only, it seems: https://icap.sustainability.illinois.edu/project/internal-price-carbon

Swarthmore https://www.swarthmore.edu/sustainability/carbon-pricing-policy-br
and Vassar appear to have instituted shadow pricing of carbon. (This is principally a planning tool. See Figure 13.1).

13.8 Useful Links

1. The Work Bank maintains a useful collection of links on carbon pricing:
   https://carbonpricingdashboard.worldbank.org/resources
   https://carbonpricingdashboard.worldbank.org/resources
2. “The Business of Pricing Carbon: How Companies are Pricing Carbon to Mitigate Risks and Prepare for a Low-Carbon Future,” Center for Climate and Energy Solutions, (http://www.c2es.org/document/the-business-of-pricing-carbon-how-companies-are-pricing-carbon-to-mitigate-risks-and-prepare-for-a-low-carbon-future/)
3. “The State of Internal Carbon Pricing” McKinsey & Company, February 10, 2021
   https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/the-state-of-internal-carbon-pricing
   https://www.mckinsey.com/business-functions/strategy-and-corporate-financ
   our-insights/the-state-of-internal-carbon-pricing

Chapter 14 Behavioral Interventions

1. Past programs and policies have thrived on using competition to motivate behavior. Take, for example, the company OPower. It showed a household's energy usage compared to others with the same house size and background. By creating a competitive environment, OPower successfully influenced peoples' actions.
2. Following the same line, something that OPower and other companies do that is very effective is making sure that
3. Toyota Prius Dashboard
   (a). Real-time and continuous feedback is important; people respond more to what they can directly see
   (b). Shows drivers real time how much energy their car is using and how much they are saving
4. Price base approaches have seen limited success and can be financially challenging
5. A more involved smartphone ap could be successful in making change
   (a). Visualizing behavior goals
   (b). Create a displace that is continually present on the lock screen, giving the effect of continuous feedback
6. Certain behaviors are easy to chnage by educating people when there are few disincentives to act
   (a). Recycling, turning off the lights
   (b). But it is not as successful when there are major disincentives to act like using public transportation of changing ones diet
7. It is important to make people feel that they have the ability to have a significant impact; if their self-efficacy is low, they are less likely to change their behavior in a positive way
   (a). Show people that they are having a significant positive impact
   (b). This relates to giving them reasonable outcome expectations
   (c). Help them estimate the impact of their actions
   (d). Compare actions in order to help consumers visualize the effect of their actions
8. There are a variety of views on being able to affect actions
   (a). People should be made aware of the negative impact of their actions
   (b). People should recognize their responsibility to act in a positive way
   (c). Behaviors should be related to one's personal values; if they believe their values are under threat and that they have the ability to protect their personal values
9. It is is important that set goals are both realistic and measurable
10. It is important to consider contextual factors; everyone will respond differently

    (a). Take note of what population you are trying to affect
    (b). People have difference mindsets when it comes to sustainable behavior: alarmed, concerned, cautious, disengaged, doubtful. Each of these groups represent different approaches and should be treated differently when it comes to trying to create change

11. Just information isn't enough to make change; emphasis needs to be placed on how and when information is delivered
    (a). People need to be aware of opportunities
    (b). People need to be provided with guidance and technical assistance
12. Everyone has the intent to act in a pro-environmental way, but they are not always able to do so
13. Changing the way people make decisions: choice architecture, is a way to adjust how they make decisions while still preserving their freedom to decide
14. Making the default the "green" setting
    (a). People are less likely to change from the default setting, so this will increase the likelihood that they will participate in green behavior
    (b). Make it an opt-out rather than an opt-in
15. Quotas can be very effective because they create an "either this or that" mindset
16. It is important to make people feel personally connected
    (a). Make people feel close and related to the issues they are trying to prevent Don't focus on the "future" or "over there", focus on "right here, and "right now"
17. It is important to reward people for their behavior, this keeps them engaged and motivated
18. Sustainable actions should be made the norm, so people do them without thinking and it becomes a habit
19. Small changes add up
20. Individual changes lead to large group changes
21. Frame your information in a way that makes it more likely for people to respond
22. Provide many opportunities for people to act sustainably
    (a). Give them more than one way to help make change
23. Create support networks; create a sense of community. This helps keep people more engaged in sustainable behavior
24. Foster mindfulness, get people thinking about sustainable behavior
    (a). This keeps them more engaged
25. Changing a physical environment can make it easier for people to act sustainabily

14.1

Chapter 15 Municipal Vehicle Electrification

By: Jae Kwak

15.1 FAQs

1. What is the name of the policy or program type?
   Municipal Service Vehicle Electrification. For this FAQ, the focus will primarily be on police patrol car electrification.
2. What is municipal service vehicle electrification?
   These are efforts in the local municipal level to replace fossil-fueled vehicles operated by municipal service departments with electric-powered vehicles. There are various types of vehicles operated by municipal governments, ranging from fire trucks and garbage trucks to police cars. The focus of this FAQ will be on electrifying police patrol cars, which has had more pilot experiments conducted on.
3. What are some examples in practice?
   In 2019, Bargersville, Indiana became the first police department in the nation to deploy a Tesla Model 3. (https://www.indystar.com/story/news/crime/2020/01/03/bargersville-chief-turns-heads-in-indianas-first-tesla-police-car/2606866001/, https://www.indystar.com/story/news/crime/2020/01/03/bargersville-chief-turns-heads-in-indianas-first-tesla-police-car/2606866001/) At a price tag of $39,500, the Model 3 cost about $14,500 more than its non-EV counterpart, the Dodge Charger, but over 6 years it is expected to save about $21,000 in fuel and maintenance costs. The department is planning on incrementally expanding its EV fleet.
   In 2019, the Fremont, CA police department deployed a 2014 Tesla S 85 as a patrol car. (https://www.governing.com/next/Fremont-Looks-to-Expand-All-Electric-Poli html, https://www.governing.com/next/Fremont-Looks-to-Expand-All-Electric-Police-Car-Fleet.html) After a highly publicized incident in which this vehicle ran out of battery in the middle of a high-speed pursuit, the department has made some improvements in how it operates the vehicle. Despite the incident, overall, the department evaluated the pilot to be successful in terms of emissions, costs, range, and service life. It acquired an additional 2020 Tesla Model Y at $57,000 and a 2021 Ford Utility Hybrid PPV for $48,000, with plans for further expansion.
   In 2019, the Westport, CT Police Department paid $52,900 to purchase a Tesla Model 3, compared to the $37,000 Ford Explorer which makes the majority of the fleet. (https://westfaironline.com/119360/westport-police-department-adds-tesla-model-3-t https://westfaironline.com/119360/westport-police-department-adds-tesla-model-3-to-its-

fleet/) The police chief believes that the fuel and maintenance savings over the life of the vehicle will compensate for the higher purchase price.

In 2015, the LAPD announced that it is leasing 288 electric vehicles, including 160 fully-electric vehicles, which were mostly BMW i3s. (https://electrek.co/2018/01/18/lapd-bmw-i3-fleet-barely-used/, https://electrek.co/2018/01/18/lapd-bmw-i3-fleet-barely-used/) However, it was later found that the all-electric vehicles were barely being used, with those with the most mileage having only a few thousand miles and most cars having only a few hundred miles on the odometer. It is speculated that they were rarely used because of range anxiety stemming from the fact that the vehicles can only go 80-100 miles on a charge. Eventually, the i-3 vehicles were sold by dealerships at cheap prices after the lease ended (https://www.businessinsider.com/lapd-selling-fleet-bmw-i3-cheap-ev-electric-vehicle-california-2020-9, https://www.businessinsider.com/lapd-selling-fleet-bmw-i3-cheap-ev-electric-vehicle-california-2020-9).

The LA fire department plans to introduce the first electric-powered fire truck in North America (https://www.govtech.com/transportation/Los-Angeles-Buys-in-to-the-html, https://www.govtech.com/transportation/Los-Angeles-Buys-in-to-the-Promise-of-the-Electric-Fire-Truck.html). By 2035, the LA Sanitation and Environment department plans to transition its garbage truck fleet to EVs.

4. What does municipal service vehicle cost and who pays?

   In the case of mid-size patrol cars, the Tesla Model 3 costs around \$39,500, while the non-EV counterpart Dodge Charger costs around \$25,000 (https://www.indystar.com/story/news/crime/2020/01/03/bargersville-chief-turns-heads-in-indiana 2606866001/, https://www.indystar.com/story/news/crime/2020/01/03/bargersville-chief-turns-heads-in-indianas-first-tesla-police-car/2606866001/). For police patrol SUVs, the Tesla Model Y costs \$57,000 while the non-EV counterpart Ford Explorer costs \$37,500 (https://electrek.co/2020/12/16/tesla-model-y-help-electrify-two-us-polic https://electrek.co/2020/12/16/tesla-model-y-help-electrify-two-us-police-departments/).

   In terms of fuels and maintenance costs, the Tesla Model 3 is expected to save \$21,000 relative to its non-EV counterpart, while the Tesla Model Y is expected to save \$30,000 relative to its non-EV counterpart.

   Vehicle purchases are financed by the municipal budget. State and federal grants and subsidies, if applicable, can help overcome the differences in upfront costs.

5. What are the climate-related benefits of municipal service vehicle electrification?

   Relative to petrol cars, average lifetime emissions from electric cars are up to 70% lower in places where most of the electricity is generated from clean sources, and is at worst 30% lower for areas where the grid is carbon intensive (https://www.bbc.com/news/science-environment-51977625, https://www.bbc.com/news/science-environment-

51977625).

6. What are some additional benefits?

   Decreased Air Pollution: Because of its zero direct emissions, all-electric vehicles can improve air quality in urban areas. The improved air quality will also lead to decreased health-related costs.

   Lower fuel and Maintenance Costs: As mentioned earlier, electric vehicles can reduce maintenance and fuel costs over its lifetime relative to non-EV counterparts.

   Virtually quiet: For police officers, the fact that a Tesla can go to zero to 60 mph in 3.2 seconds without making a sound may be beneficial to their operations.

7. What are the dis-benefits?

   Range: Range is the biggest concern for using EV as police patrol cars, as officers usually travel 70-90 miles in a 11-hour shift. Most EV models that police departments are considering using have ranges over 200 miles, so technically it wouldn't be an issue if the cars are always charged before shifts. However, as in the Fremont case where a Tesla had to drop out of a high-speed pursuit due to battery issues, the batteries aren't always fully charged before shifts. This is more of a compliance/logistics issue as police officers aren't used to charging the vehicles after shifts. There needs to be clear guidelines and routines in place to ensure that the batteries are sufficiently charged before shifts.

Chapter 16 Bicycle and Pedestrian Routes

By: ????

16.1 FAQs

1. What is the policy?

   Expand bicycle and pedestrian thoroughfares This is often described as "low stress" bike routes and "last mile design." Study and assess the costs and benefits of adding and improving routes and connectors.

   - Adding paths defined primarily as bicycling lanes physically protected from motorized traffic on busy streets to produce an experience similar to riding on an off-street trail
   - "Low stress" to incentivize more bike travel; distance from motor vehicles and busy roads
   - Emphasis on higher quality bike lanes and pathways; protected lanes with clear pathways
   - Can also look into increasing bike-share services

2. What are the benefits?

   These, among others:

   - Biking and walking do not create any additional pollution or greenhouse gas emissions: Increased bicycling and walking will help to slow the pace at which GHG emissions are increasing.
   - Low interference/demand for public resources and space.

3. Attributes?

   Costs:

   - Budget cost: MEDIUM-HIGH

     Can cost anywhere from 15k-400k a mile depending on the level of protection added to create a lane (ex. Posts, planters, buffers)
   - Social cost: LOW

     Does not create many negative externalities.

     Minimal use of public space and resources outside of construction; bike racks may be needed, but requires less than other transportation

     Does not burden public spaces immensely

     Main cost comes in adding the bike lanes (shutting down roads)
   - Time and attention: SIGNIFICANT

     Can be very time-intensive to see projects to completion; may require roads to be shut down temporarily.

Can be expedited in certain cases depending on how its prioritized with other local policies.

- Political capital: MEDIUM

  May be hard to gain traction with local/county governments.

  Need approval of certain number of bike lanes; also needs to fall within local budgeting.

Climate Benefits:

- Mitigation: MEDIUM

  Only would succeed in reducing if policy was more widely adopted (primarily in the US and Canada where bike travel rates are lower)

  "The IPCC's report classifies cycling and walking as 'non-motorised transport' and says that 'viability rests on linkages with public transport, cultural factors, climate and geography.' "

  Depends on ability to adopt multiple policies:

  - Offering more multimodal options for travel (bike some distance, public transportation the rest)
  - Funding bike lanes bike parking
  - Lowering speed limits in certain areas to make biking safer
  - Increase regulatory policies to protect cyclists Improving city layouts to connect neighborhoods with work spaces, schools, shopping centers, etc.

  Statistics:

  Bicycling could help cut carbon emissions from urban transportation 11% assuming 14% of world travel is done by bike by 2050; currently at 6%

  More than half of bicycling miles currently come from a select few countries (ex. Netherlands, China, Japan, Denmark)

- Adaptation: HIGH

  Easily adaptable in the current climate; may be even more suitable given peoples' increased desire for outdoor activity and local travel/commuting Less of a need for long-distance travel

- Transition: MEDIUM

  May encourage more widespread adoption of alternative forms of transportation

  May be again less adoptable in a post-COVID era

Co-Benefits:

- Environmental: HIGH

  Encourage greater plant life and less concrete in roadways; more lively spaces in communities

  Decrease need for cars and other public transportation infrastructure which may intervene with community spaces or add lots of noise

- Health: HIGH

  Physical health benefits

  Longer life expectancy (Netherlands as example)

- Other

  Economic: Support local bike businesses, ride-share economy is growing (job creation and local business stimulation)

  Social: More social and recreational than traditional transportation (could be used to promote bicycle usage)

Dis-Benefits:

- Aesthetics: LOW (cost on aesthetics)

  Adds to the aesthetics of local communities and neighborhoods through greenery (more expensive bike thoroughfares)

- Land use disruption: Significant

  Requires initial construction which may disturb local residents

  Requires shutting down potentially crowded roads

Chapter 17 Climate Corps

Nice article at
https://e360.yale.edu/features/how-a-climate-corps-could-put-youth-to-work-ir
(https://e360.yale.edu/features/how-a-climate-corps-could-put-youth-to-work-in-greening-america), "How a Climate Corps Could Put Youth to Work in Greening America." I don't agree with everything, but this is a fine start. A related point is made in The Energy Gang podcast, on December 11,
https://www.greentechmedia.com/articles/read/revisiting-pandemic-predictions-
(https://www.greentechmedia.com/articles/read/revisiting-pandemic-predictions-for-energy). See (hear) the discussion on the "Youth Climate Corps" beginning just after 21 minutes from the end, about 45 minutes from the start. Jigar Shah makes a really interesting point that this sort of thing should not be just for youth. There are, he observes, lots of people who would like to "give back", participate in a non-commercial enterprise, "who don't believe in the capitalist system," etc. We should leverage this impulse and all the NGOs out there who have been working in this space. The comments by all three participants in the podcast are terrific. This idea is redolent with promise.

Chapter 18 Food Rescue

The material here originated in sok's lecture notes for a class meeting of OIDD 525 in fall 2020. The notes should be accessible to the general reader, at least wrt to what a food rescue program is and why it can be successful. The paper by Mittal et al. can be downloaded from https://ieeexplore.ieee.org/document/9004732. One of my students asserted that there are very impressive food rescue programs operating in India. Also, The Robin Hood Army is an international organization that does this. https://robinhoodarmy.com/

18.1 Mittal et al., Food Rescue

18.1.1 QuickDoc

Stepping through a QuickDoc summary of the model in [26].

18.1.1.1 Title/Name

- *A small thing, but needed.*
- *Name the model and name the project.*
- *Can be the same name.*
- *Can be code name for development, e.g. H5.*

"AN AGENT-BASED MODEL OF SURPLUS FOOD RESCUE USING CROWD-SHIPPING" by Anuj Mittal et al., WSC 2019, [26].

The model is written in NetLogo and Dr. Mittal has graciously sent the implementation for use in teaching and research. The file is Mittal_NetLogo_WSC19.zip and is posted on Canvas.

18.1.1.2 Background and Motivation

The U.S. wastes a whole lot of food. This increases GHG emissions, municipal waste, which is expensive, and it deprives people in need. The problem is to find a way to make the situation better.

Problem statement from the paper:

> The Food and Agriculture Organization of the United Nations estimates that 1.3 billion tons (approximately one-third) of all food produced for human consumption worldwide is lost or wasted (Gustavsson et al. 2011). In developing countries, much of this waste occurs in the post-harvest and processing stages of the food

> supply chain, due to inadequate transportation and storage infrastructure. However, in industrialized countries, most food waste occurs at the consumption stage of the food supply chain, meaning that it is discarded even if it is still suitable for human consumption (Gustavsson et al. 2011). The U.S. Department of Agriculture estimates that 31% of the 430 billion pounds of available food supply at retail and consumer levels in the U.S. goes uneaten each year (Buzby et al. 2014).
>
> Because agriculture and food production are resource-intensive activities, producing surplus food is an unnecessary strain on the environment. Hall et al. (2009) estimate that more than 25% of total freshwater use in the U.S. is used to produce food that is finally wasted. The energy embedded in wasted food represents approximately 2% of total annual energy consumption in the U.S. (Cuéllar and Webber 2010). Furthermore, the production of food that is wasted at the retail/consumer level in the U.S. generates greenhouse gas emissions equivalent to the emissions of 33 million passenger vehicles annually (Heller and Keoleian 2015). The disposal of food waste also has severe environmental consequences. The U.S. Environmental Protection Agency (EPA) estimates that 15.1% of all municipal solid waste (MSW) in the U.S. is food, which translates to 246.8 pounds of food waste generated per capita annually (U.S. EPA 2018). Only 5.3% of this food waste is recovered, leaving 30.3 million tons to be sent to landfills. As a result, food waste is the largest component of all landfilled MSW in the U.S., comprising a total of 22%. MSW landfills account for nearly 18% percent of anthropogenic methane emissions in the U.S. (U.S. EPA 2017a). With a global warming potential that is 28 times greater than carbon dioxide (Myhre et al. 2013), methane from food waste is, therefore, a major contributor to climate change. [26]

18.1.1.3 Purpose

- *Purpose: Why are we doing this (building a model)? What do we hope to investigate with its help?*

To model and investigate how food that would otherwise go to waste might be "rescued" and gotten to those in need and benefit them. The study models a novel delivery system by which restaurant food waste that is still consumable is delivered to homeless shelters. The study explores use of "crowd-shipping":

> *Crowd-shipping* is defined as "an information connectivity enabled marketplace concept that matches supply and demand for logistics services with an undefined and external crowd that has free capacity with regards to time and/or space, participates on a voluntary basis, and is compensated accordingly" (Rai et al. 2017). Examples of commercial crowd-shipping schemes include Uber Eats and DoorDash, in which food vendors use an online platform to find an available driver from a pool of drivers

(i.e., the crowd-shippers) who is willing to pick up and deliver a customer's order (typically using his/her personal vehicle) for a predetermined price. The appeal of crowd-shipping lies in its ability to provide low-cost delivery service with greater flexibility and shorter lead times than conventional transportation service providers.

18.1.1.4 Basic Story

- *Recommended: A short paragraph, easily understood by your Aunt Martha or your boss.*
- *Clear and succinct on what the main action consists of.*
- *Focus on the main items, neglecting small details.*
- *In more recent versions of NetLogo the default Info tab begins with the categories What Is It? And How It Works?.*

  You might consider the basic story as aiming to answer these questions.

Restaurants sign up to participate in the surplus food-to-homeless shelters program. Three times a week food is pick up at the restaurant by a crowd-shipper agent (if available) and delivered to a homeless shelter. Operation of the system is monitored for reliability of pickup (are crowd-shipper agents ready and willing when called upon? how often does donated food not get picked up and delivered? What are the costs? etc.)

18.1.1.5 Basic Census

- *What do we have here?*
- *Main agents, or types of agents?*
- *Main (non-agent) entities?*
- *Main data (or parameter values) required?*
- *Main Measure(s) of Performance (MoPs)?*

  MoPs: Output of the model having diagnostic value; ultimately what we want to get in building the model.

- Agents: restaurants, crowd-shippers
- Non-agent entities: homeless shelters and crowd-shipper homes, both located spatially
- Data: driving time and distances from homes to restaurants, from restaurants to homeless shelters; cost of shipping
- MoPs:

  > **The three key performance metrics of interest are the number of successful and failed deliveries over time and the number of restaurant donation requests.** A failure corresponds to a situation in which a restaurant is willing to donate food in a particular time-step, but none of the crowd shippers chooses to fulfill its request. A success corresponds to a donation that is picked up by a crowd shipper and delivered to the assigned shelter. The total number of

restaurant donation requests is, therefore, the sum of the number of successful and failed deliveries. Upon experiencing a failed delivery, a restaurant?s willingness to participate in the food rescue program in future time-steps decreases. Maintaining and increasing restaurant do- nations, therefore, requires consistent active participation by a sufficient number of crowd shippers.

18.1.1.6 Major Components

- *What are the principal procedures (command procedures and/or reporters in NetLogo) and briefly what are they for, what do they do? Emphasize: principal.*
- *What, if there are interesting (non-agent) entities, are their important aspects? What makes these important for the model?*
- Sub-Model 1: Restaurant Agent Decision-Making
- Sub-Model 2: Shelter Assignment
- Sub-Model 3: Crowd-Shipper Agent Decision-Making

18.1.1.7 Basic Procedures

- *For the principal procedures (command procedures and/or reporters in NetLogo) how to they work?*
  Emphasize: principal.
- *Main ways of answering:*
  - *Structured, terse natural language.*
  - *Flow chart.*
  - *Pseudocode.*
  - *Use case.*

There is a control procedure that drives the simulation in ticks of a day for a year. As indicated above, when the clock ticks, each restaurant decides if it has good to donate that day. Then the crowd-shipping agents are probed to see determine whether they will volunteer to make deliveries for the several restaurants. Each restaurant may or may not be assigned a volunteer, depending on availability. Volunteers show up at the restaurants at the arranged times and wait a random length of time. Once given food they deliver it to their assigned homeless shelter. Comment: The paper would be improved by presenting a detailed flow chart of this control procedure.

The individual decision making procedures are described in the paper in a series of 6 equations.

18.1.1.8 Approach to Validation

- *A HUGE topic, of course.*
  Here, just some high-level pointers.

- *Beyond these remarks, look for introductory material to the larger QuickDoc decks and, especially, to Rand and Wilensky, IABM Textbook, Chapter 7 [34].*
- *Commonly: verification versus validation.*
  Did we built the system right? versus Did we build the right system?
- *At the end of the day, there are no guarantees.*
  Only reasonable procedures that can be pursued assiduously. To a proper degree?
- *Foundationalism (demonstrating from first principles) is a non-starter.*
  Don't even think of going there. Software is like a written document (think: literate programming). Keep reviewing it and testing its behavior (assertions), and eventually it will be apparent you can stop.

The paper several times describes the study and model as "conceptual." This is an apt term, corresponding well to what we have called "insight". The aim of this exercise is to gain insight into a concept—crowd-shipping for food rescue—by building an approximate of one such system.

Validation (the term and its cognates do not appear in the paper) was principally undertaken by studying and emulating existing food rescue programs. The paper notes that 17 such programs are presently in operation in the U.S. Also, the model is calibrated to real-world data in several ways:

1. A several studies are cited to support the sub-model for determining whether a potential crowd-shipper will be willing to do particular jobs.
2. The model is placed in the context of Arlington, Texas, and focuses on several block groups in a census block, using census demographic data to ascertain properties of the potential crowd-shippers.
3. Being tied to a specific geography, the model uses estimated travel times using the Google Maps API.

18.1.1.9 Nagging Worries

- *Not that we should be Hamlet, but it's a good thing to write down potential problems.*
- *What has been assumed or implemented that really hasn't been checked out properly and may very well be quite mistaken, and significantly so?*

The paper explicitly asserts that this is a "conceptual" model and expresses the hope that it can transition to a decision support system (DSS) for managing a food rescue program. The concluding paragraph does well at summarizing and identifying some limitations in this regard.

> The model described in this paper serves as a starting point for the development of a system, in which the restaurant surplus food is diverted from landfill and provided to people in need. . . . To further capture the capabilities of this ABM, a larger sample of population needs to be modeled. Incorporating an estimated amount of food per donation into the model will help track the positive environmental impact

> of this volunteer-based crowd-shipping system for rescuing the surplus food from restaurants. This is a conceptual model incorporating motivation of participants that determines their utility based on factors that could be of primary importance to them and thus captures their decision-making process. The model could be used to further investigate specific motivations of these participants by collecting empirical survey data from them and thus strengthen the factors determining their utility for the specific application.

Although the authors do not make this suggestion, transition to a DSS for managing such a program could be furthered by running the model in parallel to an operating problem and using discrepancies to refine and tune the model.

File: Mittal-ABM-food-rescue-WSC-2019.tex

Chapter 19 ***Sustainable Living Information***

Liken to health and safety info.

Figure 19.1: Representative Dean's constituent services brochure.

Part III

Deliberation Support

Chapter 20 Overview of Deliberation Support Methods

Deliberation proper can begin once a pool of policies and programs, serving as a consideration set of alternative, is to hand and available for discussion. The previous section presented a small example of such a pool. How, then, should deliberation proceed once a pool is available?

A healthy process will be inclusive and iterative, seeking information and comment by the broadest possible range of stakeholders and iteratively revising and refining the consideration set and the policies in it. An exemplary deliberation may surely occur under the usual norms and procedures of committees, civic organizations, and legislative bodies. Deliberation is familiar, something done in the usual course of events. The important question is, then, what else, if anything, might assist deliberation about policies and programs for sustainability. Far from wishing to prescribe deliberation processes to those already immersed in them professionally, our aim in this handbook is additive. We offer concepts, tools, and methods that may prove to be useful, and that we are prepared to support.

We envision several kinds of optional supports for policy deliberation on sustainability. In brief:

1. Information about policies and programs.
2. Group discussion processes.
3. Decision processes for group decision making.
4. Decision analysis modeling.
5. Role-play simulations for policy design.

20.1 Information about Policies and Programs

In discussing example sustainability policies, §1.2 gave brief descriptions of the example policies. Deeper background on them is presented in the chapters of part II, chapters 7–19. Our aspiration is for this *Handbook* to evolve to encompass a comprehensive repository of information about sustainability programs and policies, amenable to implementation at the state and local levels of government and administration.

We note that there are collections of information about these policies, for example the Inventory of Climate and Clean Energy Policies from the U.S. Climate Alliance, `http://www.usclimatealliance.org/state-climate-energy-policies`. The policies in the lists we are acquainted with require more elaboration and description than is normally present. We see these lists as starting points for the repository we envision.

See also town hall meetings in §20.2.

20.2 Group Discussion Processes

There are any number of informal methodologies used successfully in practice that aim to facilitate civic engagement, discussion, and deliberation with members of the general public. There follows below a sample list of more prominent and promising methods.

1. Town hall meeting

   These are generally open-ended as to subject matter and not intended to constitute deliberation. Instead, they are seen as useful preliminaries to further discussion. Potentially valuable for surfacing issues and worries, and for addressing immediate concerns.

   Town hall meetings are perhaps best seen as a way to communicate information about policies and programs, §20.1.

2. Public debate

   Perhaps followed by moderated open discussion and voting. A traditional form, perhaps not well suited for these times and their hyper-contested issues. Instead of focusing on a win-lose contest, perhaps better to frame discussion around finding good, widely attractive solutions, unless of course it precedes an election or referendum.

3. Focus group

   A mainstay of product marketing and politics. Used to discover reactions to ideas and to see what is on people's minds. Useful for framing a marketing pitch.

4. Nominal group technique

   Nominal groups are more structured than a focus group. They are oriented towards choice and group decision making, normally without much in the way of more formal decision analysis methods. See [7] for how to conduct them. The technique has gained good empirical support and has shown real staying power.[1]

5. World Café method

   http://www.theworldcafe.com/key-concepts-resources/world-cafe-method/

6. "Business plan" competition

   Groups form, develop ideas, present plans to a panel which judges them and awards funding.

7. Design charrette

   Established practice in the architecture and landscape design fields. Has shown success in community engagement and in reaching consensus.

8. Participatory budgeting

   > Participatory Budgeting (PB) is a democratic process in which community members directly decide how to spend part of a public budget. The process began in Porto Alegre, Brazil in 1989. Today, there are more than 3,000

[1] A favorite technique of SOK's. Appropriate for gaining a group decision or judgement when formal methods and modeling are not appropriate or not available.

participatory budgeting processes around the world, most at the municipal level. (https://council.nyc.gov/pb/)

And it has been done with success on a small scale in Philadelphia.

- Excellent source: https://www.participatorybudgeting.org/
- New York City's program https://council.nyc.gov/pb/.
- Inevitably, but not bad: https://en.wikipedia.org/wiki/Participatory_budgeting

20.2.1 A Straw Man Process: Participatory Design & Budgeting

Here is a straw man process, meant for feedback and discussion. It and this document are intended as evolving entities. Most assuredly, the number of valuable variations is indefinitely large, and many details remain to be worked out.

The Participatory Design & Budgeting process I have in mind draws upon and recombines many if not all of the processes listed above. It perhaps most closely resembles participatory budgeting, augmented by design charrette. In a nutshell, the workflow for participatory budgeting is:

(i) Generate ideas.

(ii) Work with experts to refine ideas and transit them to specific proposals.

(iii) Discuss and vote on the resulting proposals. Fund and implement as decided, as resources permit.

Points arising:

(a) Step ((i)) might be preceded by information sessions and/or materials that guided participants about possibilities and resources. Also, basic background on the energy transition (see below). This might be done with a teach-in process.

(b) Step ((i)) might be facilitated (in part, but we would always want an open submission process, as in the 2019 Your Big Idea contest) by nominal group sessions held with various community organizations, for example.

(c) Step ((ii)) might be facilitated by Penn's Academically Based Community Service (ABCS) courses or other similar initiatives, including Senior Design Projects in SEAS, and much else. There is ample scope for participation from those beyond the immediately Penn community.

(d) Step ((iii)) might be articulated into multiple steps, including presentation by teams, facilitated discussion as in a civic engagement forum, and much else.

(e) In parallel, there needs to be a process that identifies and characterizes evaluation attributes, such as cost, feasibility, amount of GHG saved, disruption, preservation of communities, promotion of broader values, and so on.

20.3 Decision processes for group decision making

There is a substantial literature and body of experience on *group decision making* (GDM) and on *multiple criteria decision making* (MCDM).[2] Both of which are highly pertinent. We can be assisted, at least conceptually, by this extensive body of knowledge.

These methods are used widely in practice, especially for natural resources planning and policy making, and are designed to administered by facilitators working with groups of stakeholders, who do not need to have technical knowledge of, or exposure to, the methods, some of which rely on mathematical underpinnings that are not broadly accessible. Figure 20.1 on page 89 shows the workflow of a GDM methodology developed and used for securing energy supplies for Fairbanks, Alaska.

In a typical case, after planning and preparation by a team of facilitators, a group of stakeholders will meet for a day-long session to undertake the decision process with the facilitators, and arrive at a consensus decision, e.g., selection of one or more policies. The results—whether in the form of recommendations or a report on lessons learned—may then be implemented or forwarded as advice to decision makers. Participants often aver that insights gleaned from the exercise constitute ample justification for the effort.

20.4 Decision analysis modeling

Decision analysis is a body of theory and practice, widely used, that constructs mathematical models of decision makers' preferences in order to gain insights for choosing among alternatives. Construction of the models needs to be facilitated by experts, who know how to assure the models are valid. As in the case of group decision making, §20.3, which is a form of decision analysis, it is part of the job of the expert facilitators to shield the participants from exposure to the underlying mathematics (unless they want to see it!). Models of this kind are sometimes used to determine choices, for example, in scoring multiple work proposals solicited from vendors. More often, the models are probed for their behavior under varying assumptions and their answers are taken into account in a governing but a less formal deliberation process.

Table 20.1 contains a schema that illustrates a common form of MCDM decision analysis model, one that may be well suited for selection of a policy from a consideration set of policies (and programs). In the table, the alternatives, $a_1, \ldots, a_m$, correspond to the programs and policies in the pool of policies (consideration set), an example of which was developed in §1.2.

The columns headed by the weights, $w_1, \ldots, w_n$ represent multiple evaluation criteria for the alternatives in the policy pool. Examples of evaluation criteria include: budget cost, social cost,

[2]See `https://en.wikipedia.org/wiki/Group_decision-making` for a very high level account. See [9, 13, 21] among others for textbook treatments of standard decision-making methods in environmental policy, which is a close cousin of policy for the great transition. See [28] for a relatively rare GDM and MCDM study of energy policy.

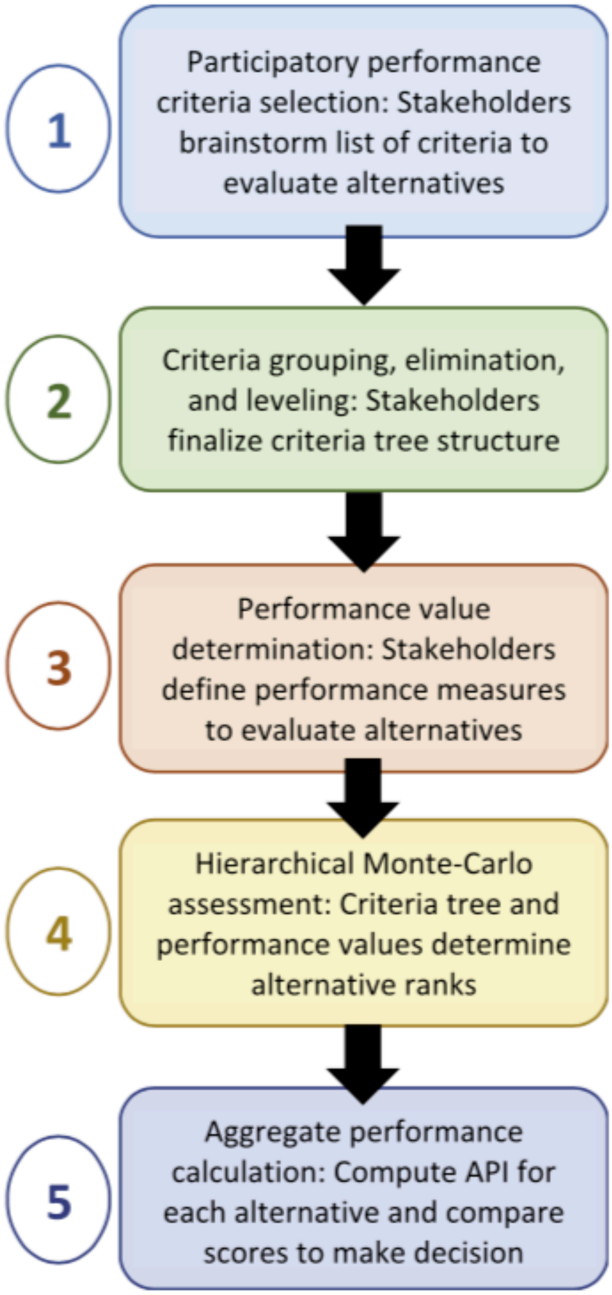

Figure 20.1: Workflow of GDM methodology from [28].

Alternatives	Criteria Weights w_1	w_2	$\ldots$	w_n	Alternatives Utilities
a_1	$u_1(s_{1,1})$		$\ldots$	$u_n(s_{1,n})$	$U(a_1) = \sum_{j=1}^{n} w_i u_i(s_{1,j})$
$\vdots$	$\vdots$			$\vdots$	$\vdots$
a_m	$u_1(s_{m,1})$		$\ldots$	$u_n(s_{m,n})$	$U(a_m) = \sum_{j=1}^{n} w_i u_i(s_{m,j})$

Table 20.1: Alternatives, Weights, and Utilities table for a single stakeholder or decision maker.

time and attention, political capital, mitigation, adaptation, transition, environmental, health, job creation, local business stimulation, aesthetics, and land use disruption. Ascertaining what the evaluation criteria should be is a key and crucial step in any decision analysis exercise. It is facilitated by an expert, whose job is to ferret out the values from the stakeholder participants. The $w_1, \ldots, w_n$ values themselves are weights on the corresponding criteria. If a criterion, such as social cost, is judged to be comparatively more important, it will have a correspondingly higher weight.

The $u_i(s_{i,j})$ values within the table represent normalized scores: $u_i(s_{i,j})$ is the score of alternative i on evaluation criterion j. Finally, the $U(a_1), \ldots, U(a_m)$ values in the Alternatives Utilities column represent overall assessment values (higher is better) for the alternatives, taking into account how they score on the multiple evaluation criteria.

The upshot of such a model, prepared under the leadership of an expert facilitator, is to give each alternative an overall evaluation score, thereby providing a preference ranking of the alternatives, and serving to serve to provide additional insights based on, for example, how close various alternatives are to each other. Again, it is to be emphasized that the expert and technical work is lead by a specialist, but the method is designed to work with non-specialist stakeholders.

The core of Table 20.1 is called the *alternatives-criteria-scores* (ACS) table. It is foundational for the other decision analysis exercises.

20.5 Role-play simulations

Role-play simulations originate in military war games and have much in common with certain, but not all, types of them. The term *war gaming* is often used in non-military as well as military contexts, as no alternative terminology has emerged as a generally accepted standard. "Role-play simulation," however, is standard terminology in teaching negotiation and we retain it here because our concept is that of a kind of negotiation and not at all that of a kind of military exercise.

A prototypical role-play simulation begins by characterizing a negotiation context, associated rules of play, and representative roles for players. The players in their assigned roles then negotiate and otherwise act in accordance with the rules. The ensuing outcomes and behaviors are recorded and examined for insight and understanding.

Role-play simulations may to a degree resemble and take on the functions of group decision making (GDM) exercises. Role-plays, however, tend to be more free form, open, and exploratory than GDM exercises, which unlike role-plays aim at the outset to settle on an alternative. Role-plays are more expansive and may be used to discover alternatives to the given consideration set.

Our concept revolves around developing *realistic* role-play simulations to model policy deliberations pertaining to climate change, based in part on a well-developed pool of policies and programs and the problem of deciding which, if any, to implement. Further, we would hope to engage representative stakeholders as players in the exercises. We believe that both participants and observers stand to benefit by coming to better understandings of which policies can be implemented and accepted, and why.

Two recent examples of role-play simulations with high-end production values are:

- Event 201 (`https://www.centerforhealthsecurity.org/event201/`) which was about responding to a viral pandemic.
- The Transition Integrity Project (TIP, `http://transitionintegrityproject.net`) which was about dealing with anticipated attempts to undermine the 2020 election.

Each is in retrospect remarkably prescient and insightful.

The Harborco role-play `https://www.pon.harvard.edu/freemium/harborco-role-play-si` (https://www.pon.harvard.edu/freemium/harborco-role-play-simulation-2/) is a popular case for teaching negotiation. Although it is fictional, it nicely illustrates a valuable exercise developed with a minimal budget and level of effort.

An interesting and valuable climate-related role-play simulation has been developed at MIT by John Sterman and the Systems Dynamics group:

- `https://mitsloan.mit.edu/teaching-resources-library/world-energy-a-climat` (https://mitsloan.mit.edu/teaching-resources-library/world-energy-a-climate-and-energy-policy-negotiation-game)
- `https://www.climateinteractive.org/tools/world-climate-simulation/` (https://www.climateinteractive.org/tools/world-climate-simulation/)

It has a global rather than local outlook and is not focused on policies and programs per se, nor is it focused on negotiation.

If a role-play along the lines indicated is rich enough and realistic enough it will have a recurring value. The exercise could be played multiple times, presumably with revisions, and reported.

20.6 From the slides

- Necessary and underway; fraught and contentious
    - Difficult tradeoffs
- Requires decision making over *large numbers of policies and programs*

- Interacting with each other; Interacting with stakeholders and special interests

Mission The mission of the Deliberation Modeling project of the Climate Decisions Lab is to investigate the policy and program alternatives in this space, for the sake of facilitating good decision making for the energy and sustainability transition.

Premises (1) There is much to be gained in considering the alternatives in bundles. (2) The analysis will be permanently incomplete, with imprecise data present. The trick is to make the most of what we have. (3) Above all, there is much value in undertaking group deliberations.

20.6.1 Purpose of this presentation: Focus on (3)

Introduce, motivate, advocate, and sketch an idea:

Group deliberation on portfolios of climate and sustainability policies.

Elements of the Context

A. Alternatives

B. Criteria

C. Participants

Stakeholders, decision makers, students, experimental subjects

D. Deliberation processes

Purposes ranging from education to decision making.

Forms ranging from discussion to decision, from informal to form.

20.6.2 To illustrate. . . A. Alternatives.

Focusing on state and local programs and policies ("programs"). Some programs:

LECC Low embodied carbon concrete

CSCom Curb side composting

GreF Green financing

EBus Electric buses and utility vehicles

InCP Internal carbon pricing

SusL Sustainable living information

GasB Ban natural gas in new construction

Bhav Behavioral interventions

We could go on at length. See for more:

https://github.com/stevenokimbrough/sokpapers/blob/master/ClimateDecisions Climate_Decisions_Lab_Workbook_Local.pdf

https://github.com/stevenokimbrough/sokpapers/blob/master/ClimateDecisions Climate_Decisions_Lab_Handbook_Academic.pdf

20.6.3 To illustrate. . . B. Evaluation Criteria.

BCO Budget expense (cost) to the local government or other organization net of outside grants and program funding such as federal programs. A 1 indicates that the organization actually profits in a meaningful way. A 0 indicates a small profit (rare) or expense, say on the order of funding one employee for a year. A -1 indicates substantial expense to the organization, paid out of its own funds net of outside grants and other funding programs; roughly, these are general revenue dollars raised from the tax payers.

SCO Social expense (cost) to the pertinent body of stakeholders. A -1 indicates a substantial expense. This may occur, for example, due to mandated behavior, such as building improvement, that is not compensated. A 0 indicates a small expense or payment. A 1 indicates a meaningful payment to members of the stakeholders.

GHG Greenhouse gas emission reduction, also called climate mitigation. 1: indicates a definite and discernible positive value. 0: intermediate value, which may be slightly positive or slightly negative. -1: definite and discernible negative value.

HnS Health and safety effects.

CoB Co-benefits, positive consequences other than cost and GHG emissions. Example: a program that creates or improves a recreational area as a side-effect.

DiB Disbenefits, positive consequences other than cost and GHG emissions. Example: a program that destroys or degrades a recreational area as a side-effect.

TRA Transition effects. Are we moving in the right direction? Does it favor something that has to be done eventually? Does it help with adaptation or resilience?

20.6.4 First-cut ACS (alternatives, criteria, scores) table

Program	BCO	SCO	GHG	HnS	CoB	DiB	TRA
LECC	0	0	1	0	0	0	1
CSCom	0	0	1	0	1	0	1
GreF	0	0	1	1	1	0	1
EBus	-1	0	1	1	1	0	1
InCP	-1	0	1	1	1	0	1
SusL	0	0	1	1	1	0	1
GasB	0	-1	1	1	1	-1	1
Bhav	0	0	1	1	1	0	1

Table 20.2: Example First-Cut ACS (alternatives, criteria, scores) table.

This is a very rough cut indeed, but it is apt as an early step in deliberation. We can learn much from it.

20.6.5 To illustrate. . . C. Participants

- High school students

- College students
- Decision makers and influencers

  Township commissioners, administrators; business executives and other representatives, policy makers at all levels (local, state, national, international); stakeholders and general public (NGOs, faith organizations, civic organizations, etc.)

20.6.6 frame

To illustrate. . . D. Group processes

1. Focus groups
2. Nominal groups

   More structured than a focus group. Oriented towards choice and group decision making.
3. World Café method

   http://www.theworldcafe.com/key-concepts-resources/world-cafe-method/
4. "Business plan" competition

   Groups form, develop ideas, present plans to a panel.
5. Design charrette

   Established practice in the architecture and landscape design fields. Has shown success in community engagement and in reaching consensus.
6. Participatory budgeting

   https://www.participatorybudgeting.org/
7. Role-play simulations
8. Various MCDM methods
9. Enterprise crowdfunding

20.6.7 Now what?

- Identify participants (α customer)
- Settle on an initial group process

  Design and evaluation plan. (Funding in place for starting on role-play simulations.)
- Develop supporting materials
  - Expand the consideration set of programs
  - Develop and curate background information on each of the program areas
  - Consider further evaluation criteria
  - Undertake a much deeper scoring effort
  - Develop support tools (computational)
  - . . .

  (Some of these may become part of the deliberation process itself.)
- Hold group process session(s)
- Assess results

- Revise and extend
- Rinse and repeat

Discuss voting systems. Range voting, ranked choice voting. Etc.

20.7 Related Literature

Multicriteria Analysis for Environmental Decision-Making [5]

Multiple Criteria Decision Making: State of the Art Surveys [11]

"Stakeholder-driven multi-attribute analysis for energy project selection under uncertainty" [28]

Portfolio Decision Analysis: Improved Methods for Resources Allocation [29]

Decision Making Under Deep Uncertainty [23]

Chapter 21 PROMETHEE

Ishaan to take the lead on this. Organized into phases:

I. Pre-processing
II. Core processing
III. Group decision making
IV. Portfolio decision making

For starters, work on II, core processing. That is, assume you have an ACS table in good order numerically. Some scores are ordinal, some cardinal (either ratio or interval scales). Do not assume the numbers are all on the same scale, so the first step is to deal with this if necessary.

Then step through what has to be done, explaining the calculations etc., including asking for human judgments. Be explicit with examples.

And in going along, show how your code gets used to actually make the calculations.

The purpose here is to document everything very clearly. Also we will draw upon this for instructional purposes.

Put the code in the Google Docs folder I will set up.

You might want to set up a Jupyter Notebook for demonstration purposes. (Hint: recommended!)

Actually, as we think of it, do first a nice Jupyter Notebook implementation, possibly importing the basic code and stepping through the steps in the notebook, with comments and documentation. Once this is working, we can use it as the primary documentation vehicle and draw from it for instructional material, which can be put here.

21.1 Introduction

The "Preference Ranking Organization Method for Enrichment of Evaluations" (PROMETHEE) is multi-criteria decision analysis (MCDM) method in the class of outranking methods. It relies on comparing pairs of alternatives.

An authoritative reference on all facets of PROMETHEE is [11, chapter 6]. See the file `Greco et al. - 2016 - Multiple Criteria Decision Making State of the Ar.pdf` in the Climate Decisions Lab public Dropbox folder: `https://www.dropbox.com/sh/05x02cn5lrvpkyf/AAAaJROZhjmhressHC2uoM_pa?dl=0`.

A very good YouTube presentation on how to make the PROMETHEE II calculations can be found at [24]. Also good is [22], which presents PROMETHETHEE I calculations as well.

Neither presentation says much about assumptions, proper uses, etc. Both assume cardinal input data and neither have much to say about where criteria weights come from. For use of ordinal data see [12]. This is important material but I propose to eschew ordinal scores in favor of linguistic ratings (see below). We can return to this if need be.

Now, following [24] as much as possible for the sake of tracking we will lay out the basic PROMETHEE II procedure and calculations. In doing so, we introduce two phases of the calculation procedure.

21.1.1 Phase 1: Preparing the ACS or Evaluation Table

ACS = alternatives, criteria, scores table, known as the evaluation table and the decision matrix in PROMETHEE.

21.1.1.1 Swag Table

A swag table is meant to be a precursor to a proper ACS or evaluation table with which we start the PROMETHEE calculations. The swag table, again, is meant as an open-ended scratch table, from which extractions are made to create a single ACS table for PROMETHEE calculations (and indeed for calculations for other MCDM methods). Constructions pointers:

- Rows: distinct programs/policies (these are alternatives). In the swag table, freely add or remove or reorder alternatives, even if they are duplicative. Keep a record of links to information (such as chapters in this workbook) about the individual policies and programs, the alternatives. **These records and records subsequently described for the swag table should be place in a Swag Table Records document and kept organized.**
- Columns: evaluation criteria (these are criteria). As in the case of alternatives, freely add or remove or reorder evaluation criteria. Keep a record of links to information (such as chapters in this workbook) about the individual evaluation criteria.
- Table entries: evaluation information for the associated program (row) and criterion (column) (these are or become scores). Feel free to use either cardinal numbers or linguistic descriptors that can be put on a scale (e.g., high, medium, low). Do not record rankings. The sense of the scores can be either direction: higher is better (GHG reductions) or lower is better (costs). Keep a record of the sense of the scores for each evaluation criterion. The several criteria should at this point be seen as having its own unique scaling. So, on one criterion the scores may range from -6 to 17, while on another they may range from 0 to 100.
- Evaluation information (scores) may be specified specified loosely (as falling in a range), and locally in the sense that the meaning is conditioned by the intended context. For example, what is high cost will vary by funding source. Keep a record of this score metadata. For the present the record can be informal, textual. If possible, provide confidence levels for the scores. The UN IPCC practice is a good model.

Complete this prepatory step by creating an initial ACS table. Do this by extracting rows and column (and their associated scores) from the swag table. For any column of scores with phrase (linguistic) scoring, develop and record a numerical score for the several phases, e.g., high = 5, medium = 3, low = 1. Develop and substitute into the ACS table a *phrase-anchored scale*. Likert scales are good models for this, e.g., https://www.extension.iastate.edu/Documents/ANR/LikertScaleExamplesforSurveys.pdf.

Having thus extracted an ACS table (with m rows and n columns) we will have completed

Step 1: Determine the criteria $(j = 1, \ldots, n)$

of the PROMETHEE II procecess as described by Martin in her YouTube video [24], but as you can see much more is involved than she describes.

To be emphasized: In extracting the ACS table from the swag table we are provisionally deciding which alternatives to consider and which criteria we are to use to evaluate them. This decision can of course be revisited in the sequel.

21.1.1.2 Calculations with the ACS Table

The first thing to be done is to address the weighting of the criteria. In terms of Martin's video, [24], this is

Step 2: Determine weight w_j of each criterion, such that

$$\sum_{j=1}^{n} w_j = 1$$

and

$$w_j \geq 0, \quad \forall j$$

(Here we are modifying Martin's formulation in the direction of full specification.)

How is this to be done? The simplest place to start is to set the weights to be equal to each other

$$w_j = \frac{1}{n}$$

With this assignment, all criteria a judged to be equally important. This is fine for testing purposes, and may even be a good starting point for analysis, once the ACS table has been normalized (see below) and the scores places on a common scale. There are methods, from expected utility theory, for validating weight assignments, but for now we'll proceed without them.

Perhaps the second simplest way of assigning weights to criteria is to first rank the criteria by importance (be sure this is done after normalization!) and then use the formula for assigning weights that is given in [17, chapter 16].

Will fill this in later.

A third way is perhaps the one to recommend. Begin by subjectively assigning nominal weights to the criteria. For example, find the least important criterion, assign it a value of 10, then assign the others relative to the 10 value. Once this is done, normalize the assigned weights by dividing the individual nominal values by the sum of the nominal values. This is easily done with a spreadsheet program and affords explorations with weightings.

Finally, the underlying assumption here that is begin made by PROMETHEE is that weights are appropriate because they are the parameters we need for a weighted average. But there is no necessity that our aggregated preference function should have the form of a (linear) weighted average. This is, as we just said above, something that can be tested.

The assumption of a linear preference function is *prima facie* reasonable. See [6] on "improper" linear models and how they tend to perform well. So, we should proceed, but keep this all in mind and be prepared to revisit assumptions. There is one way especially that the linear model can be mistaken and we should be on guard for this. The linear model is said to be a *compensatory* decision model (or preference model) because no matter how badly an alternative does on one criterion it is possible to make up for the deficit on another criterion, which compensates for the shortcoming. Decision makers, however, often reveal non-compensatory preferences. Great guy, but he killed your brother, so don't marry him. Hot and powerful woman, would make you king, but after all she's your mother, so don't make her your wife, too. (See `https://www.hospitalitynet.org/opinion/4056066.html`, the best short description I could find on the Web on short notice.)

Once we create the criteria weights, normalized to 1, we normalize the ACS table ("decision matrix" in [24]). This is step 3.

Step 3: Normalize the ACS table.

Martin [24] gets the formulas wrong, but they are almost right. Corrected, the key formulas are:

$$S^B_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}, \quad \forall j = 1, \ldots n \tag{21.1}$$

$$S^C_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}, \quad \forall j = 1, \ldots n \tag{21.2}$$

(Here we are modifying Martin's formulation in the direction of full specification.) S^B_{ij} signifies the x_{ij} score in the ACS table in the case that the jth criterion is a "benefit" criterion in which, crucially, higher values for x_{ij} are better. Similarly, S^C_{ij} signifies the x_{ij} score in the ACS table in the case that the jth criterion is a "cost" criterion in which, crucially, lower values for x_{ij} are better. The key thing is that the formulas are applied on individual columns—you fix the j value first—and S^B_{ij} or S^C_{ij} are calculated and written into the ACS table according to whether the column in question is a benefit or a cost column. Thus, for example, $\max(x_{ij}$ fixes j and the maximum is taken over all values of i, i.e., $i = 1, \ldots, m$. The effect is to scale everything from 0 to 1 such that 1 is best and 0 is worst. This step in PROMETHEE does not accommodate the case in which the best or the worst value in a column lies between the extreme values. If this occurs a different transformation is required, one which we'll skip over for the present.

Let's put an example before us. We'll begin with the normalized evaluation/ACS table example from Manoj [22]. You can see the interpretation in the original video. Here we'll abstract the table to a matrix, E, representing a normalized evaluation.

$$E = \begin{pmatrix} 0.5 & 0 & 0.5 & 1 \\ 1 & 0 & 0 & 0.3333 \\ 0 & 1 & 1 & 0.6667 \\ 0.25 & 1 & 0 & 0 \end{pmatrix} \tag{21.3}$$

Martin's next step [24] is

Step 4: Determination of deviation by pairwise comparison
$d_j(a, b) = g_j(a) - g_j(b)$

This is not as clear as it could be, although the video makes it clear later when the spreadsheet calculations are demonstrated. Mathematical notation is helpful here, perhaps.

Let e_{ij} be the element at row i and column j of E. Then $e_{i\bullet}$ is the ith row of E, a vector. Continuing, $e_{i\bullet} - e_{h\bullet} = d(i, h)$ is the vector obtained by subtracting row h of E from row i of E. For this step of PROMETHEE, we obtain *all* $d(i, h)$ values for which $i \neq h$. For the example before us, we calculate $d(1, 2), d(1, 3), d(1, 4), d(2, 1), d(2, 3), d(2, 4), \ldots, d(4, 3)$, for a total of $m(m - 1)$ in all and here $4(4 - 1) = 12$. To illustrate,

$$\begin{aligned} d(1, 2) &= \begin{pmatrix} 0.5 & 0 & 0.5 & 1 \end{pmatrix} - \begin{pmatrix} 1 & 0 & 0 & 0.3333 \end{pmatrix} && (21.4) \\ &= \begin{pmatrix} -0.5 & 0 & 0.5 & 0.6667 \end{pmatrix} && (21.5) \end{aligned}$$

Martin's next step [24] is even more unclear.

Step 5: Define the preference function
$P_j(a, b) = F_j(d_j(a, b))$
$P_j(a, b)$ represents the function of the difference between the evaluations of alternative a regarding alternative b on each criterion into a degree ranging from 0 to 1.

But the underlying PROMETHEE idea is straightforward. For every $m(m - 1)$ of the $d(i, h)$ (our notation) values we replace negative values by zeros. Thus for example

$$P(a, b) = F(d(a, b)) = \begin{cases} d(a, b) & \text{if } d(a, b) > 0 \\ 0 & \text{otherwise} \end{cases} \tag{21.6}$$

So really the notation $F(d(a, b))$ does no work. Calling $P(a, b)$ profit is a bit odd, but there you have it. Maybe positive surplus. From our previous example,

$$P(1, 2) = \begin{pmatrix} 0 & 0 & 0.5 & 0.6667 \end{pmatrix} \tag{21.7}$$

Step 6: Determine the multi-criteria preference index

$$\pi(a,b) = \sum_{j=1}^{n} P(a,b)w_j$$

This is again incorrect. Instead, let

$$P = \begin{pmatrix} P(1,2) \\ P(1,3) \\ \vdots \\ P(m,m-1) \end{pmatrix} \tag{21.8}$$

So, P is a matrix (or array) with dimensions $m(m-1) \times n$ where n is the number of criteria. Let

$$W = \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} \tag{21.9}$$

be the vector (or array) of criteria weights, w_j. It has dimensions $n \times 1$. Then

$$\pi(P) = P \times W \tag{21.10}$$

and $\pi(P)$ has dimensions $m(m-1) \times 1$. Let $\pi(P(a,b))$ be that element of $\pi(P)$ corresponding to $d(a,b)$.

Note that

$$\pi(P(a,b)) = \pi(p_i) \;\text{ where }\; i = (m-1)(a-1) + \begin{cases} b & \text{if } b < a \\ b-1 & \text{if } b > a \end{cases} \tag{21.11}$$

and p_i is the ith element of P (assuming P was constructed along the same lines).

21.2 In detail

In the following document, we outline the first and second version of the PROMETHEE outranking method by utilizing PROMETHEE calculations on a dataframe consisting of multiple alternatives and criteria.

As per usual, begin by importing the important python packages. Python offers a "pymcdm" library which can do PROMETHEE calculations. We can either use this pymcdm library, or do our own calculations by hand.

```
# python library used for reading and modifying dataframes
import pandas as pd
#python library used for mathematical calculations with matrices/dataframes
import numpy as np
# python library for data visualization
import seaborn as sns
import math
```

```
# python library for data visualization
import networkx as nx

# pre-made python library for multicriteria decision making
from pymcdm import methods as mcdm\textunderscore methods
from pymcdm import weights as mcdm\textunderscore weights
from pymcdm import normalizations as norm
from pymcdm import correlations as corr
from pymcdm.helpers import rankdata, rrankdata
import inspect

# python library for data visualization
import matplotlib.pyplot as plt
#from pymcdm.methods import PROMETHEE
#from pymcdm.helpers import rrankdata
```

PROMETHEE requires two pieces of data. First is an $n \times m$ matrix of alternatives and criteria with each entry of the matrix being the corresponding 'score' for the alternative on the criterion. Secondly, if applicable, PROMETHEE needs an $1 \times m$ matrix of weights corresponding to each criterion where the sum of the weights equals 1.

The first step of PROMETHEE is to pre-process the data into dataframes that are useable for calculations. Data can be read using the pd.read function. For example, if data is located in an Excel sheet called 'data.xlsx', then we would the read the data by using pd.read_excel('data.xlsx'). The data for weights, if present, can be read in a similar fashion. Below is an example of reading the data from an excel sheet and storing it in dataframes:

```
acsdf = pd.read_excel('TestACS1.xlsx', header=1, index_col=0, nrows=20)
acsdf = acsdf.drop(axis=1, columns=['Unnamed: 11'])
acsdf2 = acsdf.copy(deep = True)
acsdf.head()

weights=pd.read_excel('TestACS1.xlsx',header=1,index_col=0,nrows=1,skiprows=2
# Drop the extra column
weights=weights.drop(axis=1,columns=['Unnamed: 11'])
# Set the column names
weights.columns = acsdf.columns
weights2 = weights.copy(deep = True)
weights
```

Now, for a brief interlude on notation. We denote a_i to be the ith alternative such that

$1 \leq i \leq n$ and n is the amount of alternatives. Additionally, we denote $g_j(.)$ to be the jth criteria such that $1 \leq j \leq k$ and k is the amount of criteria. Lastly, $g_j(a_i)$ is the evaluation for the jth criteria for the ith alternative. This value of $g_j(a_i)$ corresponds to the value in the ith row and jth column of the dataframe.

As stated before, PROMETHEE is an outranking method that relies on pairwise comparisons. Consider the following example with two alternatives and two criteria (equally weighted):

X	Crit 1	Crit 2
Alt 1	5	5
Alt 2	3	1

Suppose we wish to maximize the values for all criteria. In this example, it is evident that Alternative 1 is the better choice because it outperforms Alternative 2 for both Criteria.

Now, consider this next example:

x	Crit 1	Crit 2	Crit 3
Alt 1	3	7	4
Alt 2	6	5	2

For this example, it may not be immediately obvious which alternative is the better choice. We could claim that Alternative 1 is better because the sum of its scores is greater than the sum of scores for Alternative 2. But on the other hand, Alternative 2 might be better because its performance on criteria 1 & 2 are decent with only criterion 3 being bad, but Alternative 1 has two bad scores.

With a larger dataframe with more alternatives and more criteria, it is very challenging to determine the best choices for alternatives. Additionally, when considering the weights for each criterion, the problem becomes more challenging

The way PROMETHEE handles the difficulty of choosing between two alternatives is by considering the deviations between each criteria for two specific alternatives. Utilizing our notation, the deviation between a_i and a_j is a list $[d_1, d_2, ..., d_k]$ of size k (the number of criteria) such that $d(a_i, a_j)_m = g_m(a_i) - g_m(a_j)$.

Utilizing the second example from above, the deviation between alternatives 1 and 2 is the list $[-3, 2, 2]$.

The following cell of code establishes a method called 'get _deviation' which takes in two integer parameters – 'alt1' and 'alt2'. The method returns a list of the deviations between the two alternatives specified.

For example, get _deviation(2, 4) would return the list of deviations between the 2nd and 4th alternatives of the dataframe.

```
def get_deviation(alt1, alt2):
# obtain the two rows of the dataframe corresponding to parameters
```

```
    alternative1 = acsdf.iloc[alt1]
    alternative2 = acsdf.iloc[alt2]
    deviations = []
    #loop through every entry of each row and append their deviation to a list
    for i in range(len(alternative1)):
        deviations.append(alternative1[i] - alternative2[i])
    return deviations
```

Obtaining deviations for each criterion between two alternatives is the first step of PROMETHEE, but the next step is to develop a 'preference function'. A preference function, denoted as $P_j(a,b)$ returns a value between 0 and 1 inclusive which indicates how preferable alternative a is to alternative b for the jth criterion.

In fact, the preference function is a function of the deviation between two alternatives: $P_j(a,b) = F_j[d_j(a,b)], \quad \forall a,b \in A$ where A is the set of alternatives

$P_j(a,b) = 1$ indicates that alternative a is strongly preferred to alternative b for the jth criterion.

$P_j(a,b) = 0$ indicates that alternative b is strongly preferred to alternative a for the jth criterion.

The Preference Function can be mathematically computed using predetermined functions, or it may be possible to use user input to generate a new preference function. For the remainder of the code, we will use predetermined preference functions.

Some of these function require parameters. These parameters are described as follows: q - The threshold of indifference. This parameter indicates the largest deviation for which the decision maker deems negligible. p - the threshold of strict preference. This parameter indicates the smallest deviation for which the decision maker has a strict preference. s - an intermediate value in between q and p.

It is of utmost importance to recognize the type of data included in the dataframe. Thus far, we have assumed the data to be of cardinal values where a higher number indicates that an alternative exceeds at a particular criteria, and a lower number indicates failure.

Under the condition that the dataframe contains purely ordinal values, different parameter values should be used. For example, an alternative that has an ordinal ranking of 1 may be strongly preferred to an alternative with an ordinal ranking of 5.

In the case of mixed data, meaning that there is both cardinal and ordinal values, it may be necessary to include two sets of parameters and use the appropriate set of parameters for cardinal data and the other set for ordinal data. An example of defining parameters is seen below:

```
param_q = 2
param_p = 5
param_s = 3
```

```
# Parameters for ordinal criteria
# NOTE: FOR ORDINAL CRITERIA, WE ASSUME THE HIGHEST VALUE IS THE BEST AND THE
# For example, an alternative with a ranking of 2 for a ordinal criteria woul
# an alternative with a ranking of 15 out of 20 total alternatives would be c

param_q_ord = 1
param_p_ord = 3
param_s_ord = 2

# A list indicating which columns in the dataframe contain ordinal values
ord_cols = [0, 2, 4]
```

To understand the meanings of the parameters more thoroughly, let's investigate an example brought up previously.

x	Crit 1	Crit 2	Crit 3
Alt 1	3	7	4
Alt 2	6	5	2

And suppose we introduce parameters q = 2, p = 3, s = 2.5. From this, we can gather that for criteria 1, Alternative 2 is fully preferred to Alternative 1 because $(6-3) \geq p$. For criteria 2 and 3, the absolute value of the deviation is 2, which is exactly equal to the parameter of q which means that this deviation is considered as negligible.

Therefore, with these parameters, Alternative 2 would be the best choice.

One common preference function that can be used with PROMETHEE is the Gaussian function. The Gaussian function, which we will denote as $P(d)$ uses two parameters, d and s, where d is a single deviation, and s the parameter s specified above.

If $d \leq 0$, then $P(d) = 0$.

If $d > 0$, then $P(d) = 1 - e^{-\frac{-d^2}{2s^2}}$

Graphically, the Gaussian function remains increasing and has no discontinuities or corners (which makes it differentiable). The parameter s determines the inflection point of the distribution.

In the following cell of code, we create a method called get_gaussian_value, which takes in two parameters, and returns the appropriate Gaussian value.

```
def get_gaussian_value(deviation, s_param):
# By definition, if deviation <=0, then the preference value will be 0
# because the second alternative is clearly better
if (deviation <= 0):
```

```
        return 0
    else:
        # computes the gaussian value using the exponential equation from abov
        exponent = - ((math.pow(deviation, 2))/(2*math.pow(s_param, 2)))
        return (1 - math.exp(exponent))
```

Note for Ishaan: Perhaps revisit the next few paragraphs if you decide to switch from adjaceny list to dictionary

Next, we define the tuple $\{g_j(.), P_j(a,b)\}$ to be the "generalized criterion" associated to criterion $g_j(.)$

Suppose we have a alternatives and c criteria. Then this would mean that each of the c criteria would have $\binom{a}{2}$ preference values associated with it for the "generalized criterion". This is because $P_j(a,b)$ is the preference value between ANY two alternatives a, b.

In the following cell of code, we create these generalized criteria in the form of an adjaceny list. Calling the following method get_adj_list will return a list of lists.

The specific generalized criterion of $\{g_j(.), P_j(a,b)\}$ is located in the adjacency list at:

```
adj_list[j][num_alternatives*a + b]
```

```
    # considers cardinal values and ordinal values
def get_adj_list_v2():
    adj_list = []
    for i in range (num_criteria):
        preferences = []
        # for each criterion, loop through every pair of alternatives
        if i in ord_cols:
            for j in range(num_alternatives):
                for k in range(num_alternatives):
                    preferences.append(round(get_gaussian_value(get_deviation
        else:
            for j in range(num_alternatives):
                for k in range(num_alternatives):
                    # appen the preference value to a sub-list by getting the
                    # the preference value is rounded to 3 decimal places
                    preferences.append(round(get_gaussian_value(get_deviation
            #append the sublist to the larger adjaceny list
        adj_list.append(preferences)
    return adj_list
```

While the adjacency list is quite helpful to obtain the preference value for specific alternatives for a specific criterion, it is equally important to create an aggregate preference index.

We define $\pi(a, b)$ to be an "Aggregate Preference Index" which specifies with which degrees alternative a is preferred to alternative b.

Mathematically, the Aggregate Preference Index is defined as:

$\pi(a, b) = \sum_{j=1}^{k} P_j(a, b) \cdot w_j$ where k is the number of criteria.

Since $0 \leq P_j(a, b) \leq 1$ and $0 \leq w_j \leq 1$, this implies that $0 \leq \pi(a, b) \leq 1$

A value of $\pi(a, b)$ close to 0 indicates that there is a weak global preference of alternative a over b.

A value of $\pi(a, b)$ close to 1 indicates that there is a strong global preference of alternative a over b.

The code below runs through all pairs of alternatives and compares the Aggregate Preference Index between them. The method returns a list of size *num _alternatives*^{2}. To obtain the value of $\pi(a, b)$, we dereference the list in the following way:

```
list[num_alternatives*a + b]
```

The method takes two parameters. First is the adjacency list from the code above, and second is the list of weights. Originally when we read the weights from the csv file in the pre-processing stage, the data was stored in a pandas dataframe. For this method to work, the weights dataframe should be converted into an array. This can be done using the function .to_numpy()

```
def get_pi(adj_list, weights):
    pi_sum_list = []
    # loop through every pair of alternatives
    for a in range(num_alternatives):
        for b in range(num_alternatives):
            pi_sum = 0
            # next, obtain the aggregate preference index
            for j in range(num_criteria):
                # Pj(a,b) * wj
                temp_sum = adj_list[j][20*a + b] * weights[j]
                pi_sum += temp_sum
            # append this aggregate index to a list (rounded to 3 decimal plac
            pi_sum_list.append(round(pi_sum, 3))
    return pi_sum_list
```

Finally, we reach the outranking section of PROMETHEE. To do this, we compute "Outranking Flows". First, let's introduce some terms and their definitions.

The Positive Outranking Flow, denoted $\phi^+(a)$, for alternative a expresses the outranking power of alternative a. A better alternative will have a higher value for ϕ^+.

The Negative Outranking Flow, denoted $\phi^{-}(a)$, for alternative a expresses how that alternative is outranked by all other alternatives. While ϕ^{+} shows an alternative's power, ϕ^{-} indicates the alternative's weakness. A better alternative will have a lower value for ϕ^{-}.

We will next define these terms mathematically. Suppose A is the set of all alternatives and n is the amount of alternatives (this means that $|A| = n$). Then the Positive Outranking Flow and Negative Outranking Flow are defined as follows:

$\phi^{+}(a) = \frac{1}{n-1}\sum_{x \in A} \pi(a, x)$

$\phi^{-}(a) = \frac{1}{n-1}\sum_{x \in A} \pi(x, a)$

Below, we define four methods: get_pos_flow, get_neg_flow, get_all_pos_flow, and get_all_neg_flow. The first two methods are helper methods for the last two methods.

get_pos_flow and get_neg_flow both take in two parameters. The first parameter is the aggregate list of all values of $\pi(a, b)$ that was previously computed. The second parameter is an integer value indicating which alternative to analyze. get_pos_flow returns a float value which is equivalent to $\phi^{+}(a)$, and similarly, get_neg_flow returns a float equivalent to $\phi^{-}(a)$.

The methods get_all_pos_flow and get_all_neg_flow compute the outranking flow for all alternatives and compile them into one list. These methods return said list. For example, for get_all_pos_flow, list[i] would return $\phi^{+}(i)$ and for get_all_neg_flow, list[i] would return $\phi^{-}(i)$

```
def get_pos_flow(list_pi, a):
    flow_sum = 0
    for x in range(num_alternatives):
        # flow_sum(a) = sum(pi(a, x))
        flow_sum += list_pi[num_alternatives*a + x]
    # phi_pos(a) = 1/(n-1) * flow_sum(a)
    return (1/(num_alternatives - 1))*(flow_sum)



def get_neg_flow(list_pi, a):
    neg_flow_sum = 0
    for x in range(num_alternatives):
        # neg_flow_sum(a) = sum(pi(x, ))
        neg_flow_sum += list_pi[num_alternatives*x + a]
    # phi_neg(a) = 1/(n-1) * neg_flow_sum(a)
    return (1/(num_alternatives -1))*(neg_flow_sum)

def get_all_pos_flows(pl):
    all_pos_flows = []
    for a in range(num_alternatives):
        # loops through all alternatives and appends their pos_flow to a list
```

```
        all_pos_flows.append(get_pos_flow(pl, a))
    return all_pos_flows


def get_all_neg_flows(pl):
    all_neg_flows = []
    for a in range(num_alternatives):
        # loops through all alternatives and appends their neg_flow to a list
        all_neg_flows.append(get_neg_flow(pl, a))
    return all_neg_flows
```

While PROMETHEE I relies solely on the positive and negative outranking flows for all alternatives, PROMETHEE II requires a last calculation which computes the net outranking flow (ϕ_{net}) for all alternatives.

$\phi_{net}(a) = \phi^{+}(a) - \phi^{-}(a)$

The method get_net_flow defined below computes the net outranking flows for all alternatives and compiles them into a list where list[i] returns $\phi_{net}(i)$

```
# PROMETHEE II Complete Ranking
def get_net_flow(pl):
    pos_flows = get_all_pos_flows(pl)
    neg_flows = get_all_neg_flows(pl)
    net_flows = []
    for a in range(num_alternatives):
        #net flow(a) = pos_flow(a) - neg_flow(a)
        # append net flow for each alternative to a list
        net_flows.append(pos_flows[a] - neg_flows[a])
    return net_flows
```

Up to this point, we have computed all PROMETHEE calculations from scratch. Now, we will spend some time exploring the pymcdm library. This library does very similar calculations to what we have done thus far. However, the PROMETHEE method in pymcdm only has five different preference functions, these being 'usual', 'vshape', 'ushape', 'level', and 'vshape_2'. So while using pymcdm saves a lot of code, it limits creativity due to the very few preference functions. With the code written thus far, we can define other preference functions (not just gaussian), and make minimal adjustments such that the PROMETHEE calculations will still work for customized preference functions.

```
preference_functions = ['usual', 'vshape', 'ushape', 'level', 'vshape_2']
promethee_methods = {
    f'{pref}' : mcdm_methods.PROMETHEE_II(preference_function = pref)
```

```
    for pref in preference_functions
}
```

PROMETHEE from pymcdm also requires a new parameter that we have not yet explored. The new parameter is a "types" array. The size of this array is equivalent to the amount of criteria. Within this array, the value "1" indicates that a higher score for the criteria is better, whereas a value of "-1" indicates that a lower score is better for the criteria.

```
types = np.array([1, 1, 1, 1, 1, 1, 1, 1, 1, 1])
acsdf_np = acsdf2.to_numpy()
acsdf_np_f = acsdf_np.astype(float)
weights_np = weights.to_numpy()[0]
p = np.random.rand(acsdf.shape[1]) / 2
q = np.random.rand(acsdf.shape[1]) / 2 + 0.5

results = {}
for name, function in promethee_methods.items():
    results[name] = function(acsdf_np_f, weights_np, types, p=p, q=q)
```

Lastly, we do some data visualization. Below are some methods to visualize PROMETHEE I and II data.

```
# graphs the data from PROMETHEE 1. A coordinate closer to the top right is c
def specialized_visual(pos_outflows, neg_outflows, x_low_lim, x_lim, y_low_li
    plt.figure(1)
    fig, ax = plt.subplots()
    ax.set_xlim(x_low_lim, x_lim)
    ax.set_ylim(y_low_lim, y_lim)
    for i in np.arange(x_low_lim, x_lim+0.01, 0.1):
        ax.plot([0, 0.01], [i,i], 'k')
    for i in np.arange(y_low_lim, y_lim+0.01, 0.1):
        ax.plot([i,i], [0, 0.01], 'k')
    x_coor = [0,x_lim]
    y_coor = [0,y_lim]
    plt.plot(x_coor, y_coor, linewidth = 3)

    ax.text(-0.08, y_low_lim + 0.2, 'Phi-', fontsize='large')
    ax.text(0.2,y_low_lim-0.08, 'Phi+', fontsize='large')
    ax.axis('on')
```

```
for i in range(len(pos_outflows)):
    phi_pos = pos_outflows[i]
    phi_neg = neg_outflows[i]
    plt.scatter(phi_pos, 1-phi_neg, label = f'A{i}')
    ax.text(phi_pos, 1-phi_neg+0.01, f'A{i}')
    start_coors = [phi_pos, phi_pos]
    end_coors = [0, phi_neg]
    #plt.plot(start_coors, end_coors, linewidth = 1, linestyle = '--', co
    start_coors = [0, phi_pos]
    end_coors = [phi_neg, phi_neg]
    #plt.plot(start_coors, end_coors, linewidth = 1, linestyle = '--', co
plt.legend()
```

For visualization, we have to define two arrays for parameters p and q. The meaning of these parameters is the same as before, but now we are defining the parameter values for each criterion.

```
q_vals = [3, 3, 3, 3, 3, 3, 3, 3, 3, 3]
p_vals = [5, 5, 5, 5, 5, 5, 5, 5, 5, 5]
```

An example of using the visual is seen here:

```
prom_usual = mcdm_methods.PROMETHEE_II('usual')
Fp_usual, Fm_usual = prom_usual(acsdf_np_f, weights_np, types, p = p_vals, q =
specialized_visual(Fp_usual, Fm_usual, 0.1, 0.8, 0.1, 0.8)
plt.title('usual')
```

Similarly, we can graph the net flows into a nice visual by utilizing the barplot feature of the python library "seaborn". Below is an example implementation:

```
plt.figure(1)
plt.title('usual')
prom_usual = mcdm_methods.PROMETHEE_II('usual')
Fp_usual, Fm_usual = prom_usual(acsdf_np_f, weights_np, types, p = p_vals,
Fi_usual = prom_usual(acsdf_np_f, weights_np, types, p=p_vals, q=q_vals)
#barplot_x is essentially an array = [0, 1, 2, ..., (num_alternatives - 1
sns.barplot(x = barplot_x, y = Fi_usual)
```

21.3 Links

1. PYMCDM [31]

Part IV

Phase II: Policy Analysis and Configuration

Until this point we have been concerned with Phase I of the Climate Decision Lab's activities, focusing on collecting and documenting a comprehensive set of sub-national policies and on evaluating them comparatively using a MCDM approach (PROMETHEE). In Phase II we focus on analyzing, configuring and assessing individual policies or policy types (again with MCDM methods and taking into account co-benefits).

Chapter 22 Challenge Categories for Energy and Sustainability Modeling

Challenge areas for energy modeling:

1. Cost and consumption models (e.g., EROI calculations); energy and materials accounting models

   Generally, these are "bean counting" models.

   Urban energy use modeling, e.g.,

   > An integrated urban energy model that enables modeling components of urban operational and embodied energy can provide a more holistic image of urban energy use and help understand the interrelation between various components and the trade-offs between the different planning and design strategies to achieve more sustainable cities. [1]

   More generally, system energy use models, urban energy use models being a special, albeit important, case.

   Apt approaches include: life cycle assessment modeling https://www.nakedcapitalism.com/2021/07/whats-the-carbon-footprint-of-a-wind-turbine.html

2. Accommodating VRE (variable renewable energy)

   Ümit: district modeling at IIP. Country, district, household.

   Modeling (ultimately individual) behavior and investment in the face of VRE, along with possibilities of storage in various forms.

   Apt approaches include: microsimulation ABMs with simulation optimization, activity based modeling, synthetic data to model behavior.

3. Assessing neighborhoods, amenities, quality of life while going green and having to deal with climate change (e.g., heat waves).

   Access to grocery stores, pharmacies, restaurants, barbershops and beauty salons, cafés and coffee shops, . . . Access by mixed mode of transport, walking, biking, bus, trolley, automobile. Look to develop indexes of neighborhood quality, neighborhood in a broad sense.

   Activity-based modeling: Castiglione, J. (2015). Activity-based travel demand models: A primer. Transportation Research Board. [3] and http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_C46.pdf

   Apt approaches: microsimulation ABMs; activity based modeling, synthetic data to model behavior; DEA for comparing neighborhoods (e.g., census tracts) on multiple criteria.

4. Deep decarbonization. And energy systems design.

This can cover many topics, including decarbonizing the electric power grid, but also, e.g., agriculture, cement and steel production. For electric power, apt approaches include capacity planning models, which a constrained optimization models. Note: brownfield versus greenfield models. Also, finding optimal paths (brownfield).

5. Risk assessment and management
   (a). Discovering and estimating risks (climate science, systems analysis for system risks)
   (b). Design in the face of risk.
   Apt approaches include: DMDU, model analysis with synthetic data, and much else.
6. Choice/decision models
   For selecting policies, configuration options, designs, etc. In its core, an MCDM problem. Look to PROMETHEE (and other outranking methods), also MAUT.
7. Opinion management. For lack of a better term. Creating and maintaining mindsets and cultural norms. "Tithing for transition" idea.
   With MM, key idea: public accounting of this. Better called budgeting (investing?) for mitigation of global warming.
   Apt modeling approaches include: microsimulation ABMs with identity models.
8. Synthetic data
   Especially time series data and data for activity based models. Thus relevant to most of the above.
   Time series data: [18] and `https://ieeexplore.ieee.org/document/9453485`.
   Activity based modeling data: [19], and `https://www.climatechange.ai/papers/neurips2020/33.html`.

File: energy-sustainability-modeling.tex

Chapter 23 Microsimulations for Energy and Sustainability Policies

The policy development and design process for major energy and sustainability policies may usefully be considered as having a characteristic workflow. This workflow has three prominent components. They are pursued flexibly.

a. Configuration. A full design is specified, constituting a version under consideration of the policy in question.

   Example: A proposed food rescue program is comprehensively described, including rules for participation, expected volumes, numbers of delivery vehicles, sources, and destinations, and so forth.

b. Performance modeling and observation.

   Operation and performance of the program is modeled, formally and/or informally, and pertinent observations recorded.

   Example: An agent-based model of a proposed food rescue program is executed to estimate performance characteristics (cost, timing, amount of food rescued, etc.). Optionally, simulation optimizations are used to suggest configuration improvements.

c. Assessment. The configuration is assessed based on the results of the performance modeling and observation and on the envisioned goals for the policy. Normally, multiple criteria will be relevant, putting this into the category of multiple criteria decision making (MCDM) and making its tools and concepts available.[1] Specifying the most important evaluation criteria (including co-benefits) is a key step in the overall assessment process.

Typically upon completion of the assessment step, revisions to the policy are proposed, new configurations specified, and the workflow is repeated.

The Microsimulations for Energy and Sustainability Policies project has several main goals

i. To produce open-source tools and concepts with which the preceding workflow may be, and eventually is, conducted.

ii. To focus development of the tools and concepts on policy and modeling contexts for which, broadly speaking, microsimulation agent-based models are suitable.

iii. To conduct a series of policy studies on the basis of computational tools that are usable, open, public, transparent, and that support all three phases of the policy design workflow.

iv. In doing so to advance the state of the art in modeling and analysis, particularly in areas known as microsimulation and activity-based behavioral modeling.

Examples of policies that can be studied with micro-agent-based simulation and would

[1] And in particular the tools for the PROMETHEE MCDM method developed in previously in the Climate Decisions Lab.

benefit thereby from detailed modeling of agent behavior include the following:

1. Food rescue programs. (Discussed above.)
2. Curbside composting. Study participation rates and compliance based on costs, emulation of others, etc.
3. Funding of EV charging stations. Study optimal location of stations, effects on commerce, GHG emissions reduction effects, etc.
4. Expansion of non-motorized thoroughfares. Study costs, traffic reduction, GHG emissions reduction, optimal placement, etc.
5. Revision of municipal work rules such as 4-day work week, working at home, etc.) Study costs, traffic reduction, GHG emissions reduction, etc.
6. Transit Oriented Development (TOD). Study how transit infrastructure can be developed to meet community goals of reducing traffic and GHG emissions, of saving money, or providing improved access to shopping and other amenities.
7. Adoption of building electrification measures. Study how information, behavioral interventions, incentives, social emulation, etc. can speed replacement of fossil fuel heating and cooking devices with electric ones.

Comments: By microsimulation and microsimulation agent-based models we mean, broadly, the employment of detailed computational models of individual behavior. Detailed modeling of individuals for policy analysis was pioneered in transportation studies, where it goes by the name of activity modeling. In that field it has achieved an advanced state of development and has produced demonstrable successes [3]. The underlying ideas are having uptake in related areas, including energy policy modeling [4] and building design [14]. The field is undergoing rapid development.

Beyond purely transportation and movement topics, modeling social emulation is an important subject, which is also undergoing rapid development [4, 20].

Data acquisition is an ongoing challenge in activity modeling and related methods, not the least because a main purpose of these models is to investigate counterfactual situations. This is a large topic, ranging well beyond the scope of this overview. We assert, however, that in many particular cases the data challenges can be adequately met. Judgments in this regard should be reserved for a case-by-case basis.

There has been a tendency to use “microsimulation” as something of an umbrella term, including techniques specific to transportation (e.g., trip modeling, activity modeling), microsimulation in the original formulation (`https://microsimulation.pub/articles/00002`), agent-based modeling, as well as other forms of computational modeling. The key idea is that of a simulation model specifying in some detail the actions and behaviors of individuals. We employ the term in this broader sense. See also [2].

File: microsimulation-brochure.tex

Chapter 24 Modeling Studies: Starters and Building Blocks

The purpose of this chapter is to describe a series of modeling studies that exemplify in the small what we hope to achieve in the large. The models and exercises we describe are suitable for teaching purposes and as conceptual building blocks for larger models.

A key, very common feature of the agents in our microsimulation models is that they somehow acquire plans, representations of what they aim to do. For example, an agent with the goal of traveling to point P and returning will have a representation that can be interpreted by the agent as effective instructions for undertaking the tour, much as human travelers consulting route planners are given a sequence of instructions. In either case, the representations may be given exogenously or with more difficulty constructed by the agent itself. Both of these as well as other possibilities will need to be explored in the research project.

Try implementing in NetLogo. If that proves too awkward, use Python instead (with objects). In any case, document your design and your code. For every model, suggest interesting enhancements to it and sketch how they could be implemented.

24.1 Basic travel script

A map of the environment is presented to the agent. An agent is given a goal location to travel to from its present location, both on the map. The agent is given a script to follow, which is sufficient for transiting from start to finish. The agent when set in motion follows the script, arrives at the destination, and halts.

After implementing the above narrative,

1. Discuss and assess various design alternatives for the agent. How is the script implemented and why? Alternatives?
2. Specify a number of interesting additional features or wrinkles. Implement them and discuss how they were implemented and why that design was chosen? Alternatives?

24.2 Basic travel plan construction

A map of the environment is presented to the agent. An agent is given a goal location to travel to from its present location, both on the map. The agent constructs an efficient plan, which is sufficient for transiting from start to finish. The agent when set in motion follows the plan, arrives at the destination, and halts.

After implementing the above narrative,

1. What are the pros and cons of the two approaches, exogenously given scripts versus self-constructed plans?
2. Discuss and assess various design alternatives for the agent. How is the script implemented and why? Alternatives?
3. Specify a number of interesting additional features or wrinkles. Implement them and discuss how they were implemented and why that design was chosen? Alternatives?

24.3 Local park visits

El Farol++

24.4 Geographic SIR

As in the SIR (susceptible, infectious, recovered) epidemiological model, agents may be in one of these three states. Model the halls of an office building (or the layout of a dormitory). Agents travel through them, entering at various points and walking to various destinations. If an infected agent passes within a certain distance of a susceptible agent, then with a given probability the susceptible agent becomes infected and later infectious. Model the spread of disease under various conditions, especially crowding/level of traffic in the halls.

24.5 Coffee room; office canteen

Model the halls of an office building with a coffee room on the floor. Spread of ideas as well as infections. Crowding.

Riffing on El Farol, add learning by the agents, either to seek or avoid crowding.

24.6 Contagion models with explicit space

As in an office or dorm or department store. Model the pathways and locations and have contagion occur there.

Chapter 25 ABM Energy Models

Two grand challenge areas for microsimulation ABM energy modeling:

1. Accommodating VRE (variable renewable energy)
   Modeling (ultimately individual) behavior and investment in the face of VRE, along with possibilities of storage in various forms.
2. Assessing neighborhoods, amenities, quality of life while going green and having to deal with climate change (e.g., heat waves).
   Access to grocery stores, pharmacies, restaurants, barbershops and beauty salons, cafés and coffee shops, . . . Access by mixed mode of transport, walking, biking, bus, trolley, automobile.

25.1 Living on solar

Obtain hourly production values for solar PV for at least one year. (e.g., PJM). Scale the values so that the maximum value corresponds to a reasonable maximum value for a residence, say 2–4 kilowatts. Add battery storage with a 90% round trip efficiency. Add a control system that turns off sources of load as solar energy becomes unavailable. Model foregoing or postponing the service versus drawing on battery storage, which was created when the sun was shining. Describe life at various levels of solar PV and battery storage.

25.2 Composting

curb-side, routing, etc.

25.3 Food rescue program

25.4 EV charging stations

Much to be modeled here. Look especially to spillover effects such as placing the stations at commercial or recreational centers.

25.5 Expanded non-motorized thoroughfares

Pedestrian and bicycle.

Much to be modeled here. Look especially to spillover effects such as placing the stations at commercial or recreational centers.

25.6 BRT: Bus rapid transit

Similar modeling issues and opportunities to expanded non-motorized thoroughfares.

25.7 Revision of work rules

4-day week; work at home. Model effects on GHG emissions, on traffic and conjestion, on local businesses, etc. Notice that not everything is transit-centric. Some involves changes of attitudes.

25.8 Alternative provision of electricity

Time of day pricing. Real time pricing. Time of day absolute limits. Model how households, other establishments might work with these alternative regimes.

25.9 Delivery versus pickup

See 525 notes, fall 2020.

25.10 Demand response

Residential, commercial, etc.

25.11 Neighborhood modeling

Intriguing topic, but not yet sure how to approach it. Perhaps use microABMs to locate desirable/undesirable residential locations? On the plus side, there are lots of urban data available, e.g. InforGroup on WRDS. Also, consider local services provisioning.

25.12 Accommodating VRE

Huge theme. Needs specific modeling ideas.

File: microABM-models.tex

Bibliography

[1] Abbasabadi, N. and Ashayeri, M. (2019). Urban energy use modeling methods and tools: A review and an outlook. *Building and Environment*, 161:106270.

[2] Association, I. M. (2021). International Microsimulation Association. https://www.microsimulation.org/.

[3] Castiglione, J. (2015). *Activity-based travel demand models: a primer*. Transportation Research Board, Washington, DC. http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_C46.pdf.

[4] Castro, J., Drews, S., Exadaktylos, F., Foramitti, J., Klein, F., Konc, T., Savin, I., and Bergh, J. v. d. (2020). A review of agent-based modeling of climate-energy policy. *WIREs Climate Change*, n/a(n/a):e647. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/wcc.647.

[5] Davide, G. (2019). *Multicriteria Analysis for Environmental Decision-Making*. Anthem Press, London.

[6] Dawes, R. M. (1979). The robust beauty of improper linear models in decision making. *American Psychologist*, 34(7):571–582.

[7] Delbecq, A. L., Van de Ven, A. H., and Gustafson, D. H. (1975). *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes*. Scott, Foresman, and Company.

[8] Dietz, T., Ostrom, E., and Stern, P. C. (2003). The Struggle to Govern the Commons. *Science*, 302(5652):1907–1912.

[9] Geneletti, D. (2019). *Muticriteria Analysis for Environmental Decision-Making*. Anthem Press, London.

[10] Gillingham, K., Carattini, S., and Esty, D. (2017). Lessons from first campus carbon-pricing scheme. *Nature News*, 551(7678):27. Section: Comment.

[11] Greco, S., Ehrgott, M., and Figueira, J. R., editors (2016). *Multiple Criteria Decision Making: State of the Art Surveys*. Springer, 2nd edition.

[12] Greco, S., Ishizaka, A., Tasiou, M., and Torrisi, G. (2021). The ordinal input for cardinal output approach of non-compensatory composite indicators: the PROMETHEE scoring method. *European Journal of Operational Research*, 288(1):225–246.

[13] Gregory, R., Failing, L., Harstone, M., McDaniels, T., and Ohlson, D. (2012). *Structured Decision Making: A Practical Guide to Environmental Management Choices*. Wiley.

[14] Happle, G., Fonseca, J. A., and Schlueter, A. (2018). A review on occupant behavior in urban building energy models. *Energy and Buildings*, 174:276–292.

[15] Hardin, G. (1968). The tragedy of the commons. *Science*, 162(3859):1243–1248.

[16] Kimbrough, S. O. (2019). Recruiting values for tough decisions on climate change. https://riskcenter.wharton.upenn.edu/climate-risk-solutions/recruiting-values-for-tough-decisions-on-climate-change/. https://riskcenter.wharton.upenn.edu/climate-risk-solutions/.

[17] Kimbrough, S. O. and Lau, H. C. (2016). *Business Analytics for Decision Making*. CRC Press, Boca Ratan, FL.

[18] Kimbrough, S. O. and Yilmaz, U. (2021). A symmetric block resampling method to generate energy time series data. In *Proceedings of the International Conference on Industrial Technology (ICIT)*. IEEE, IEEE. https://ieeexplore.ieee.org/document/9453485,https://github.com/stevenokimbrough/sokpapers/blob/master/2020/Resampling_to_Generate_Time_Series.pdf.

[19] Kleinebraham, M. (2020). Climate Change AI - NeurIPS 2020 Accepted Work. https://www.climatechange.ai/papers/neurips2020/33.html.

[20] Kverndokk, S., Figenbaum, E., and Hovi, J. (2020). Would my driving pattern change if my neighbor were to buy an emission-free car? *Resource and Energy Economics*, 60:101153.

[21] Lovett, A. and Appleton, K., editors (2007). *GIS for Environmental Decision-Making*. Taylor & Francis.

[22] Manoj Mathew (2019). PROMETHEE- I & II (Preference Ranking Organization Method for Enrichment Evaluation). https://www.youtube.com/watch?v=xe2XgGrI0Sg.

[23] Marchau, V., Walker, W. E., Bloemen, P. J., and Popper, S. W., editors (2019). *Decision Making Under Deep Uncertainty*. Springer. https://doi.org/10.1007/978-3-030-05252-2_1.

[24] Martin, N. (2020). PROMETHEE Method. https://www.youtube.com/watch?v=dPQgOX45I_I.

[25] Min, K. C. Y. (2018). Municipal Composting Programs in Massachusetts: What Works, Where, Why and How? | Wellesley College Digital Collections. Technical report, Wellesley College. https://repository.wellesley.edu/object/ir893.

[26] Mittal, A., Gibson, N. O., and Krejci, C. C. (2019). An Agent-based Model of Surplus Food Rescue Using Crowd-shipping. In *2019 Winter Simulation Conference (WSC)*, pages 854–865, National Harbor, MD, USA. IEEE.

[27] Randolph, J. and Masters, G. M. (2018). *Energy for Sustainability: Foundations for Technology, Planning, and Policy*. Island Press, Washington, D.C., second edition.

[28] Read, L., Madani, K., Mokhtari, S., and Hanks, C. (2017). Stakeholder-driven multi-attribute analysis for energy project selection under uncertainty. *Energy*, 119:744 – 753.

[29] Salo, A., Keisler, J., and Morton, A., editors (2011). *Portfolio Decision Analysis: Improved Methods for Resources Allocation*, volume 162 of *International Series in Operations Research and Management Science*. Springer, New York.

[30] Schattschneider, E. (1960). *The Semisovereign People: A Realist's View of Democracy in American*. Wadsworth Cengage Learning, Boston, MA.

[31] Shekhovtsov, A. (2021). pymcdm 1.0.3.post2 : Python library for Multi-Criteria Decision-Making.

[32] Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge, UK.

[33] Stern, N. (2008). The Economics of Climate Change. *American Economic Review*, 98(2):1–37. https://www.aeaweb.org/articles?id=10.1257/aer.98.2.1.

[34] Wilensky, U. and Rand, W. (2015). *An Introduction to Agent-Based Modeling*. The MIT Press, Cambridge, MA.

Index