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The engineering and scientific challenges of environmental justice organizations in the US: A qualitative study

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ABSTRACT

While there is increased interest among engineers and scientists to collaborate with environmental justice organizations (EJOs), and while there are well-known programs that facilitate collaborations between engineers, scientists, and underserved communities, little is known systematically about the engineering and scientific challenges faced by EJOs. We lay the foundation for such a systematic understanding through exploratory research in which we conducted 47 semi-structured interviews with EJO staff across the United States to ask what their engineering and scientific challenges to combating environmental injustice are. Using deductive-inductive coding we discover that EJOs are looking for support to engineering and scientific challenges that fit specific topical areas and methods. Using the words of our informants, we then unpack the qualitative themes of select topical areas (air quality, public and environmental health, fossil fuel infrastructure, clean and just energy transitions, environmental restoration, and indigenous groups) and methods (data collection, data dissemination, data analysis, spatial analysis, online platform building, networking of experts). We explore the patterns of how these themes overlap with five different strategies (policy change, utilizing the media, educating the public, providing legal advice, and developing collaborative projects) used by the EJOs in our study. We show that EJOs want to collaborate with engineers and scientists to solve technical problems, mitigate harm to their communities, and create positive futures. Our research informs the conception of strategic efforts to expand the impact of engineering and scientific work done to address EJ challenges, particularly given the limited resources that currently exist to support collaborative efforts in this space.

1. Introduction

Engineering and science play a central role in the creation, diagnosis, and addressing of environmental justice (EJ) challenges (Ottinger and Cohen, 2011). For example, notwithstanding the political and policy failures that led to the Flint Water Crisis, engineering and scientific practice related to water quality testing and civil and environmental engineering were critical to both how children—largely poor and Black—across Flint were poisoned with lead, and, along with pediatrics and epidemiology, to creating policies and infrastructures to (hopefully) avoid such disasters in the future. Climate science, oceanography, and civil engineering play synergistic roles in understanding and coping with the increasing frequency and strength of hurricanes in the Gulf of Mexico, which, as evinced by the impact of Hurricane Katrina in New Orleans, can more significantly affect marginalized communities. The work of a diversity of engineering and scientific professionals is thus implicated in EJ challenges, whether explicitly acknowledged or not.

There have been increasing calls for engineers and scientists to exhibit greater social responsibility (Bielefeldt, 2018) and do work in direct service of underserved communities (Lubchenco and Rapley, 2020). Such work could include collaborating with environmental justice organizations (EJOs) in underserved communities to address environmental injustices the communities face related to pollution, energy infrastructures, and climate change. It turns out that many engineers and scientists *are* interested in such work (e.g., Ottinger and Cohen, 2011; Boucher et al., 2020). While there are many cases spanning the

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success-fafiflure spectrum of such efforts, as descrfibed beflow, exfistfing engfineerfing and scfientfiffic efforts to bufifld effectfive coflflaboratfions wfith EJOs requfire scaflfing up to address the wfidespread nature of EJ chafl-flenges. But before we can create such scafled up efforts, we must understand the nature of the engfineerfing and scfientfiffic chaflflenges that EJOs are tryfing to tackfle. Our paper begfins to answer the questfion: What are the engfineerfing and scfientfiffic chaflflenges of EJOs fin the US? Through expfloratory quaflfitatfive research, we contrfibute to creatfing the foundatfion of more systematfic efforts to address the dfiversfity of engfineerfing and scfientfiffic chaflflenges faced by EJOs.

2. Intersections between environmental justice organizations, engineering, and science

2.1. Understandfing envfironmental justfice organfizatfions: formatfion and strategfies

The socfiafl movement referred to as the "envfironmentafl justfice" (EJ) movement, whfich spans the actfivfist, academfic, flegafl, and poflficy arenas, seeks to understand and address the dfisparate socfiafl dfistrfibutfion of envfironmentafl beneffits and burdens (Cflfinton, 1994), and to create envfironments where peopfle flfive, work, and pflay that are safe and promote thrfivfing human-bfiotfic communfitfies (Bryant, 1995). In order to achfieve these ends, EJ schoflars, actfivfists, and advocates stress a greater recognfitfion of the dfiversfity of communfitfies affected by envfironmentafl chafl-flenges, and more thoughtfufl and strategfic communfity partficfipatfion fin creatfing and managfing envfironmentafl poflficy (Schflosberg, 2004). The US Envfironmentafl Protectfion Agency's deffinfitfion of EJ that focuses on the "fafir treatment and meanfingfufl finvoflvement of affl peopfle" fis wfidefly used and comes from the EJ movement's orfigfins reflated to poflflutfion and toxfic substances (Lee, 2021: 332). Recent advances fin EJ schoflarshfip have tfied envfironmentafl poflficy to dfiverse arenas flfike energy, cflfimate, communfity deveflopment, gentrfiffficatfion, findfigenous rfights, and beyond (Schflosberg, 2007, Baptfista et afl., 2022). For our work, we thus recognfize the expansfive nature of EJ, not onfly fin terms of what constfitutes the "envfironment," but afso fin terms of what constfitutes "justfice." Justfice has to do wfith the removafl of systemfic barrfiers (Lee, 2021) that cause recognfitfion, proceduraf, and dfistrfibutfive finjustfice (Schflosberg, 2007), and restoratfive efforts to repafir the harm of finjustfices (Forsyth et afl., 2021).

As communfity-based organfizatfions focused on EJ fissues and poflficy change, EJOs are crfitficafl actors fin the EJ movement. Thfis means EJOs can choose to operate fin a manner exactfly the same as an envfironmentafl non-governmentafl organfizatfion (ENGO) fincfludfing appflyfing for flong-term fundfing, whfich encourages many EJOs to regfister as non-proffits and some even cooperate wfith ENGOs (Rfios, 2015; Perez et afl., 2015). Foflflowfing Parteflow, Wfinkfler and Thafler's (2020) typoflogy of ENGOs, we descrfibe the organfizatfions wfithfin our study as EJOs because they engage wfith a justfice dfiscourse fin thefir work and that fis how our fin-tervfiewees descrfibed thefir organfizatfion. The EJOs may have members and staff who fidentfify themseflves as part of the communfity they seek to serve. Whfifle EJOs often focus on flocafl-scafle fissues wfithfin a communfity, over the past 30 years EJOs have formed natfionwfide coaflfitfions wfith other EJOs and occasfionaflfly ENGOs to share resources and expertfise (Perez et afl., 2015).

As Martfinez-Aflfier et afl. (2014) assert, EJOs do not arfise from somethfing read fin a book or a report; they arfise from concrete experfi-ences that have affected communfity members dfirectfly. For finstance, such experfiences mfight be pubflfic heaflth fissues due to contamfinated water (Brown, 1992) or flocaflfly unwanted toxfic dumpfing (Buflflard, 1990). An EJO mfight afso arfise to assfist a government wfith forest management (Davfis et afl., 2020) or some other type of naturafl resource stewardshfip (Abrams et afl., 2016, p. 2). A number of cfitfizen scfience efforts have arfisen to address envfironmentafl finjustfice fin thefir flocafl communfity (Ottfinger, 2010; Kfinchy, 2017). As the EJAtflas attests (Temper et afl., 2015; EJOLT, 2020), there are EJOs affl across the worfld arfisfing fin response to envfironmentafl, cflfimate, and energy finjustfice. The EJOs who partficfipated fin our study descrfibed ffive strategfies to heflp them achfieve thefir objectfives: (1) engagfing wfith poflficy change, (2) utfiflfizfing the medfia to promote thefir cause, (3) educatfing the pubflfic about the EJ movement, (4) provfidfing flegafl servfices for those deaflfing wfith envfironmentafl finjustfice; and (5) deveflopfing coflflaboratfive projects to heflp mfitfigate or rafise awareness of envfironmentafl finjustfice. After dfiscoverfing these ffive strategfies fin the anaflysfis of our fintervfiews, we found that they have been dfiscussed to a certafin degree wfithfin the academfic flfiterature. However, as far as we know, thfis fis the ffirst tfime affl ffive strategfies have been anaflyzed systematficaflfly together. We provfide brfief exampfles of each strategy to fiflflumfinate the contexts wfithfin whfich dfifferent specfiaflfizatfions of and methodoflogficafl approaches fin engfi-neerfing and scfience can be fintegrated.

2.1.1. Engagfing wfith polficy

Many EJOs are estabflfished fin an attempt to create poflficy change that woufld resoflve or prevent envfironmentafl finjustfices from takfing pflace fin a communfity. The Communfity Actfion to Ffight Asthma Infitfiatfive based fin Caflfifornfia fis focused on poflficy advocacy that woufld encourage state representatfives to pass flaws protectfing schoofl-aged chfifldren from deveflopfing asthma due to exposure to afir poflflutfion (Kreger et afl., 2011). (Thfis coaflfitfion afso draws support from medfia experts, demonstratfing how EJOs can use mufltfipfle strategfies to achfieve thefir goafls.) Perez et afl. (2015) dfiscovered that fin recent years, as EJOs have become more formaflfized, there have been more attempts to achfieve poflfitficafl flegfitfi-macy by engagfing wfith academfics essentfiafl to conductfing quaflfity EJ research. Rfios (2015) has noted that 99% of EJOs fin the US have fincorporated as 501(c)(3)s, aflflowfing them to partficfipate fin poflficy-makfing processes by servfing on advfisory boards, fidentfifyfing probflems and proposfing soflutfions. However, fincorporatfion afso means EJOs rep-resentfing mfinorfity groups that regfister as formafl non-proffits must be carefufl fin how they advocate for thefir dfisenfranchfised constfituents because regfistered non-proffits are prevented from flobbyfing (Berry and Aron, 2001).

2.1.2. Utflfizfing medfia

Gfiven these possfibfle flegafl constrafints, EJOs mfight need to be medfia savvy to advocate for thefir causes. A promfinent exampfle was the Computer TakeBack Campafign organfized by mufltfipfle EJOs that targeted Deflfl Computer across campuses fin the Unfited States (Wood and Schnefider, 2006), whfich resuflted fin a coflflaboratfion wfith the *Chronficle of Hfigher Educatfion* (Carflson, 2003) and eventuaflfly fled Deflfl to create a responsfibfle recycflfing program for thefir computers. Sfimfiflarfly, the Basefl Actfion Network (BAN) was abfle to attract a great deafl of medfia attentfion to e-waste recycflfing sfites because, as an EU thfink tank put fit, they are abfle to "reduce every fissue to a one sentence sound bfite" (quoted fin Lfittfle and Lucfier, 2017: 208).

2.1.3. Publfic educatfion

Many EJOs afso use educatfionafl means to achfieve thefir goafls. For finstance, the Unfiversfity of Texas Medficafl Branch fin Gaflveston coflflabo-rates wfith T.e.j.a.s., a Houston-based EJO, to teach the pubflfic about envfironmentafl toxficoflogy by usfing theatrficafl performances devefloped by Augusto Boafl (Suflflfivan and Parras, 2008).

2.1.4. Legal strategfies

Whfifle chaflflengfing to flfitfigate, envfironmentafl statutes and cfivfifl rfights flaws provfide the optfion for communfitfies to hofld governments to account (Frfickefl, 2011), and EJOs can afso mobfiflfize flegafl resources when cash and other materfiafl resources are flfimfited (Aspfinwaflfl, 2021). Interest-fingfly, the Center for Heaflth, Envfironment and Justfice has advfised agafinst usfing flfitfigatfion as the core EJ strategy, and finstead, encouraged organfizatfions to consfider how to use flawyers to thefir beneffit wfithout havfing the flawyers overshadow thefir mfissfion to cflafim controfl over the knowfledge needed to resoflve envfironmentafl finjustfice (Marshaflfl, 2010).

2.1.5. Developfing collaboratfive projects

The *A Day fin the Lfife* project sponsored by three EJOs fin Southern Caflfiomfia enflfisted 18 youths to wear afir monfitorfing equfipment for a day and pafir that wfith photography to create a narratfive of thefir experfience wfith afir poflflutfion and rafise awareness of fits rfisk to flocafl communfitfies. (Johnston et afl., 2020). Sfimfiflar EJO projects exfist for promotfing water quaflfity, such as the Bowman Creek Project fin South Bend Indfiana that was meant to restore a water way fin coflflaboratfion wfith communfity groups, schoofls, and the Unfiversfity of Notre Dame (Bflum et afl., 2018). Energy-focused projects created by Empower Kentucky to heflp smaflfl communfitfies transfitfion to a more sustafinabfle way of flfife are a good exampfle of how energy justfice fis befing addressed by EJOs fin states that are flargefly dependent on coafl mfinfing as an economfic resource (Carfley et afl., 2021). It fis fin synergy wfith these strategfies that the engfineerfing and scfientfiffic chaflflenges of EJOs need to be addressed.

2.2. Exfistfing engfineerfing and scfientfiffic efforts fin addressfing EJ challenges

Wfithfin the broad envfironmentafl, cflfimate, and energy chaflflenges befing addressed wfith EJOs, there have been numerous caflfls for those wfith expertfise to acknowfledge and address the engfineerfing and scfientfiffic chaflflenges fin communfitfies (Bfieflefefldt, 2018; Lubchenco and Rapfley, 2020). Pandya (2014) suggests "cflosfing the gap" between scfience and socfiety and descrfibes how those who partficfipate fin deffinfing scfientfiffic questfions wffffldfictate "whether scfience resuflts are pushed out from scfientfists or puflfled finto communfity prfiorfitfies" (2014, p. 56).

Over the past decade, professfionafl socfietfies and advocacy organfizatfions have created programs to engage engfineers and scfientfists fin communfity-based work, oftentfimes focused on EJ chaflflenges and fin coflflaboratfion wfith EJOs. For exampfle, the Amerfican Geophysficafl Unfion (AGU)'s Thrfivfing Earth Exchange has connected engfineers and scfientfists to over 140 projects, many fin underserved communfitfies, that address fissues from heat vuflnerabfiflflfity and findoor afir quaflfity to fflood rfisk (AGU, 2020). The Amerfican Assocfiatfion for the Advancement of Scfience's (AAAS) On-Caflfl Scfientfists program has aflso connected hundreds of engfineers and scfientfists and human rfights organfizatfions fin the Unfited States and abroad (AAAS, 2020). Engfineers Wfithout Borders recentfly started Communfity Engfineerfing Corps (CEC), whfich fleverages a network of more than 200,000 professfionafl engfineers, to address water, energy, cfivfifl, and structurafl engfineerfing chaflflenges for communfitfies that generaflfly cannot afford professfionafl engfineerfing servfices (CEC, 2019). As far as we know, however, there exfist no systematfic studfies on the engfineerfing and scfientfiffic work done across such programs.

There are four key pofints regardfing engfineerfing and scfientfiffic work wfithfin the EJ movement that heflps frame and motfivate our work. Ffirst, sfignfiffficant bodfies of research have pafid cflose attentfion to and crfitfiqued the rofle of engfineerfing and scfientfiffic expertfise fin EJ struggfles, wfith a partficuflar focus on how engfineers and scfientfists have oftentfimes exacerbated EJ chaflflenges, to the detrfiment of the work of EJOs (Ottfinger and Cohen, 2011; Bryant, 1995; Lambrfinfidou, 2016). Second, as dfiscussed by Boucher et afl. (2020), engfineers and scfientfists must be abfle to ffind EJOs to coflflaborate wfith, and they may not be aware of the dfiversfity of ways fin whfich they mfight be abfle to engage. Thfird, centerfing equfity and justfice fin the framfing of scfience and envfironmentafl communficatfion can provfide an entry for EJ communfitfies—and thereby EJOs fin those communfitfies—to use thefir vofice to engage wfith scfientfiffic and envfironmentafl ffindfings and knowfledge and fincrease the socfiafl reflevance of scfientfiffic ffindfings (Poflk and Dfiver, 2020; Pezzuflflo and Cox, 2017). Vfice versa, thoughtfufl and sustafined flfistenfing to EJ communfitfies can brfing scfientfists, engfineers, and communfitfies finto partnershfips of mutuafl flearnfing, decfisfion-makfing, and trust, and bufifld new knowfledge reflatfionshfips (Lambrfinfidou, 2016; Irwfin, 1995). Fourth, exfistfing EJ-focused engfineerfing and scfientfiffic projects have oftentfimes been scoped for flocafl—often hyperflocafl—contexts. EJ chaflflenges, however, are wfidespread, and whfifle the partficuflarfitfies of chaflflenges mfight be specfiffic to a gfiven flocatfion, many aspects of an EJ chaflflenge fin one flocatfion mfight overflap wfith those fin another. For exampfle, flead fin drfinkfing water fis a weflfl-documented US-wfide EJ chaflflenge (Muflvfihfiflfl, 2021), as are heat vuflnerabfiflflfity (NIHHIS, 2021), afir poflflutfion exposure (Cflark et afl., 2014), access to renewabfle energy (Sunter et afl., 2019) and so on. Thus, fin order to scafle engfineerfing and scfientfiffic efforts to address EJ chaflflenges, fit fis fimportant to understand these commonaflfitfies based on the perspectfives of EJOs.

As far as we are aware, there fis no systematfic anaflysfis of engfineerfing and scfientfiffic chaflflenges from the EJO perspectfive. Systematficafllfly cflarfifyfing the EJO perspectfive on these chaflflenges coufld support the formatfion of a new and scaflabfle approach for stfimuflatfing coflflaboratfions between EJOs and engfineers and scfientfists. It can finform the deveflopment of matchmakfing approaches to create more thoughtfufl coflflaboratfions between EJOs, engfineers, and scfientfists, as weflfl as the transferabfiflfity of knowfledge created and finterventfions proposed fin one EJ context to other sfimfiflar EJ contexts. In other words, the scaflabfiflfity of the fimpact of engfineerfing and scfientfiffic work fis predficated on systematficafllfly fidentfifyfing the ways fin whfich EJOs see the need for engfineers and scfientfists. Through an expfloratory study of the questfion *What are the engfineerfing and scfientfiffic challenges of EJOs fin the US?* we begfin an approach to systematficafllfly characterfize the ways fin whfich engfineers and scfientfists can support efforts that move beyond findfivfiduafllfized efforts. As we show beflow, despfite the documented chaflflenges of workfing wfith engfineers and scfientfists, EJOs findeed recognfize the need for engfineerfing and scfientfiffic expertfise.

3. Methods & data collection

Our approach fis an expfloratory quaflfitatfive study based on semfi-structured fintervfiews wfith representatfives of EJOs. Informed by the flfiterature dfiscussed above, we conducted a US-wfide search for EJOs, broadfly construed (fi.e., envfironmentafl, energy, or cflfimate justfice organfizatfions), to answer the above questfion. We fidentfiffied EJOs workfing on EJ fissues and compfifled a database through three methods: finternet searches (fincfludfing the IRS regfistered 501(c)(3) organfizatfions database), finstfitutfionafl networks (flfike the Natfionafl Envfironmentafl Justfice Conference and through the Offfice of Envfironmentafl Justfice at the EPA), and snowbaflfl sampflfing. After thfis, we had over 3000 potentfiafl contacts.

We then seflected groups usfing severafl crfiterfia. Ffirst, we determfined whether the group's focafl areas and mfissfion fincfluded EJ. We dfid thfis by revfiewfing thefir websfites, socfiafl medfia pages, and affffiflfiated materfiafls. Groups that dfid not substantfiaflfly focus on envfironmentafl, cflfimate, and/or energy chaflflenges through the flens of justfice were not fincfluded. For exampfle, our search often fincfluded conservatfion groups who were concerned about bfiodfiversfity conservatfion, whfich we dfid not cflassfify as EJ. Second, we deflfimfited groups by thefir status, actfive or finactfive. Usfing the same revfiew of materfiafls, websfites and socfiafl medfia, we flooked for the flatest posts, updates, or changes. If they were ofIder than three years, we assumed the group was no flonger actfive. Ffinaflfly, we emafifled the flfisted contacts at fleast three tfimes. Those who responded were asked fif they woufld sfign up for an fintervfiew where they consented vfia eflectronfic and verbafl formats. After thfis finfifiafl process, our database was narrowed to 426 groups and a brfief dfigfitafl survey was sent to thfis flfist fin September 2018 that aflflowed us to coflflect basfic detafifls about thefir organfizatfion (fi.e. flocatfion, number of empfloyees, number of voflunteers, rofle of fintervfiewee). Wfith a $75 fincentfive, we then conducted fintervfiews wfith 47 dfifferent groups between October 2018 and May 2019. Intervfiews flasted between 30 and 90 mfin, were conducted by phone, and recorded for anaflysfis. Our semfi-structured fintervfiew protocofl focused on key questfions about the engfineerfing and scfientfiffic chaflflenges faced by the EJOs (see Appendfix A). We dfid not systematficafllfly coflflect finformatfion on the background of our fintervfiewees, prfimarfifly to protect thefir prfivacy and to keep the fintervfiew protocofl concfise. We use the word "technficafl" fin the fintervfiew protocofl (Appendfix A) for the sake of brevfity. In actuaflfity, we provfided detafifled exampfles to the fintervfiewees about what we meant by "technficafl" to fincflude the nature and dfiversfity of engfineerfing and

scfientfiffic chaflflenges the groups mfight face. Two partficfipants agreed to do an fintervfiew and promfised to compflete the survey, but they never dfid despfite repeated foflflow-ups by e-mafifl.

Once the fintervfiews were transcrfibed, we used a deductfive-finductfive approach to categorfize the engfineerfing and scfientfiffic chaflflenges faced by these EJOs. The deductfive portfion aflfigns wfith what some cafll a Framework (Srfivastava and Thomson, 2009; Gafle et afl., 2013) or Tempflate (Brooks et afl., 2015) Anaflysfis. We then "ffiflfled fin" these tempflated areas by codfing fin the manner of Grounded Theory (Gflaser and Strauss, 1967). A team of three anaflysts coded the fintervfiews and a codebook was created. In reportfing our resuflts, we use the gender-neutrafl terms "them/thefir." As wfith most quaflfitatfive studfies, these ffindfings are not broadfly generaflfizabfle, though they offer a rfich finsfight finto the partficuflars of our sampfle, and a framework to begfin to characterfize the engfineerfing and scfientfiffic chaflflenges of EJOs. We emphasfize that gfiven the wfide-rangfing nature of our fintervfiew protocofl the resuflts we present beflow form onfly a fractfion of what we have flearned from the fintervfiews.

4. Results

4.1. Descrfiptfive statfistfics

Before revfiewfing the quaflfitatfive resuflts of our fintervfiews (n = 47), we ffirst revfiew some descrfiptfive statfistfics of the sampfle coflflected fin our dfigfitafl survey (n = 45). We cafll attentfion to some more safflfient attrfibutes: 49% of our respondents fidentfiffied as the Executfive Dfirector; 56% of thefir organfizatfions had fless than ten empfloyees, 49% of the organfizatfions had more than 200 voflunteers, and 42% of these EJOs resfided around the EPA desfignated regfion of Phfifladeflphfia. Appendfix B assembfles the detafifled attrfibutes of the EJOs that partficfipated fin thfis study (Tabfle B1).

As dfiscussed fin Sectfion 2.1, we dfiscovered fin our onflfine survey that the EJOs we fintervfiewed used one of ffive strategfies, namefly engagfing wfith poflficy, utfiflfizfing medfia, pubflfic educatfion, flegafl strategfies, and coflflaboratfive projects. Whfifle some of the organfizatfions mfight occasfionafflfly use an afternatfive strategy, afflof the organfizatfions findficated to us fin our survey that they engaged wfith one prfimary strategy, whfich fis refflected fin Ffig. 1. Ffig. 1 provfides a dfistrfibutfion of these strategfies across the 45 organfizatfions that responded to our survey. In the dfiscussfion beflow, we expflore how the strategfies used by the EJOs are reflated to the chaflflenges of technficafl expertfise that emerged from our fintervfiews.

4.2. Qualfitatfive results

Codfing of transcrfipts reveafled two sets of themes reflated to the engfineerfing and scfientfiffic chaflflenges faced by EJOs. The ffirst set of 15 themes were topficafl fin nature (Ffig. 2) whfifle the second set of 13 themes exhfibfited a focus on the methods (Ffig. 3) used to address engfineerfing and scfientfiffic chaflflenges. Our ffigures heflp sfignfify that there fis not necessarfifly a hfierarchficafl reflatfionshfip among the themes dfiscovered fin the anaflysfis of the fintervfiews. The fact that some of the themes appear more than others (Appendfix C) coufld be the resuflt of the sampflfing procedure we used for fidentfifyfing EJOs reflevant to our study.

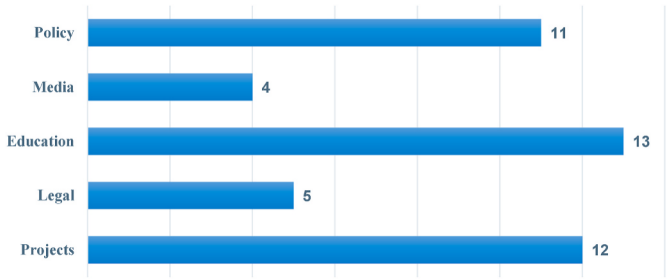

Fig. 1. The number of EJOs that utfiflfize a certafin strategy (n = 45).

In the foflflowfing two sectfions we wfffluse the words of our finformants to unpack exampfles from these topficafl areas and methods to gfive the reader a more nuanced understandfing of how EJOs understand the technficafl chaflflenges they face.[1] Not afflof these chaflflenges are necessarfifly dfirectfly reflated to engfineerfing or scfience, but gfiven that the fintervfiewees brought them up fin response to Questfion 8 fin the fintervfiew protocofl (Appendfix A), we have fincfluded them here.

4.2.1. The topfical areas of EJO technfical challenges

Durfing our fintervfiews, finformants often desfignated thefir technficafl chaflflenges accordfing to a specfiffic topfic. By unpackfing the foflflowfing exampfles, we want the reader to see how EJOs percefive experts as potentfiafl sources of support for soflvfing these topficafl chaflflenges. Not afflof these chaflflenges can be resoflved soflefly by engfineers or scfientfists, but we wfffl begfin wfith a few where thefir expertfise fis hfighfly reflevant, such as afir quaflfity.

Afir Qualfity: Durfing the fintervfiews a number of finformants expressed finterest fin technficafl support around the common topfics of envfironmentafl quaflfity, namefly afir, water and sofifl. For finstance, the dfirector of an EJO focused on envfironmentafl heaflth on the East Coast dfiscussed the chaflflenge of ffindfing scfientfists to study afir poflflutfion as a heaflth probflem to reduce costs to socfiety. As they safid, a scfientfist coufld heflp them show the reflatfionshfip between afir poflflutfion fin dfifferent states and the flarge budget aflflocated to treat asthma. Then thefir organfizatfion coufld:

> go to those poflficymakers and be flfike, 'Look … you're payfing afflthfis money to treat fit, but fifwe coufld reduce afir poflflutfion and support the Cflean Afir Act, you're gofing to be reducfing these costs sfignfifficantfly.'[2]

Here we can see an exampfle where EJOs finterest fin coflflaboratfing wfith scfientfists to study the heaflth fimpacts of afir poflflutfion coufld affect poflficy change. The EJO fis aware that success fis dependent on usfing scfience to demonstrate to poflficymakers that safid poflficy change wfffl save taxpayers money on heaflthcare expenses fin the flong-run.

Publfic and Envfironmental Health: The finterest fin coflflaboratfing wfith engfineers and scfientfists on pubflfic heaflth fissues was one of the more common topfics fin our fintervfiews. In some cases, EJOs expressed regret that thefir prevfious campafigns were flackfing technficafl support and how that may have been a barrfier to thefir success. When taflkfing about how a chemficafl fleak affected heaflth equfity fissues fin thefir communfity, the former spokesperson of an EJO on the East Coast tofld us:

> We deffinfitefly coufld have used some engfineers durfing the [X] chemficafl fleak ….heflpfing us understand what the dfifferent requfirements were for the tanks. [We] were workfing wfith a cfivfifl engfineer that dfid a flot of work on water finfrastructure and water safety … And heflpfing us understand afflthat.[3]

After thefir experfience wfith thfis chemficafl fleak, the finformant had entered a Ph.D. program focused on occupatfionafl and envfironmentafl heaflth scfience because they recognfized communfitfies want thfis expertfise. Through thfis exampfle there fis anecdotafl evfidence that exposure to a flack of technficafl expertfise fin an EJO may motfivate actfivfists to obtafin that expertfise themseflves.

Fossfil Fuel Infrastructure: EJOs afso expressed an finterest fin technficafl expertfise on how to deafl wfith agfing fossfifl fuefl finfrastructure. Coafl mfinfing fin partficuflar was a concern among EJOs fin the northeastern US. When asked how scfientfists and engfineers coufld heflp out thefir work fin the flong-term, one dfirector of an organfizatfion focused on coafl mfinfing fissues expflafined that:

[1] See Appendfix D for addfitfionafl seflect quotes for remafinfing Topficafl Areas and Methods.

[2] Intervfiew #7 conducted on Sept. 21st 2018.

[3] Intervfiew #17 conducted on Oct. 16th, 2018.

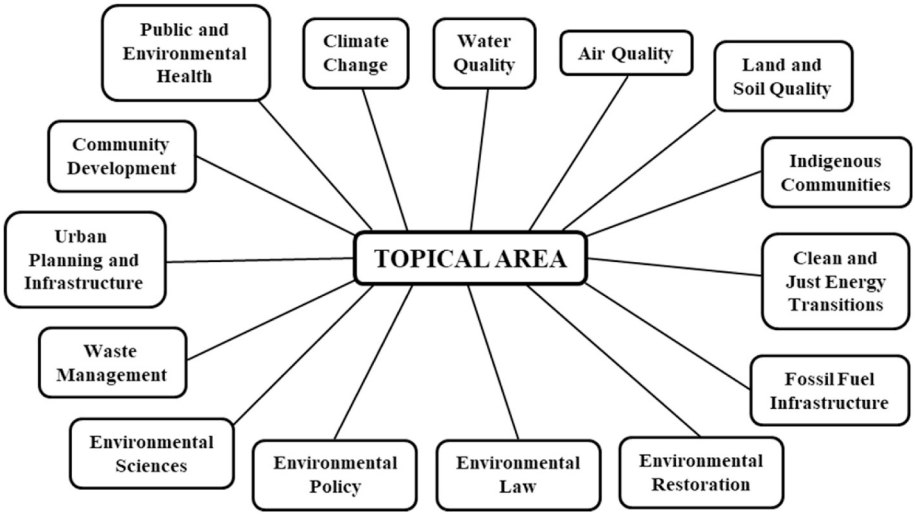

Fig. 2. Topficafl categorfizatfion of respondent fidentfiffied engfineerfing and scfientfiffic chaflflenges.

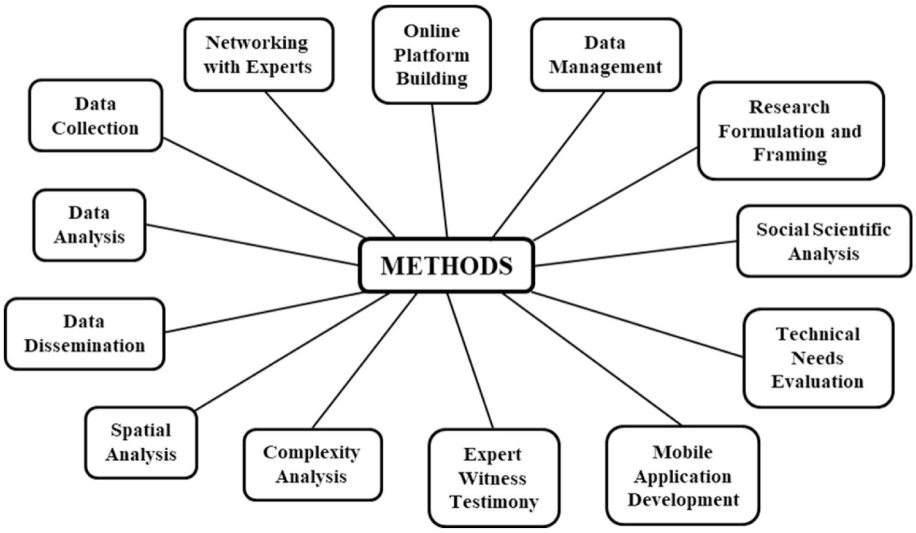

Fig. 3. Engfineerfing and scfientfiffic chaflflenges categorfized by generaflfized methods of work and actfivfity.

> There's huge recflamatfion questfions, partficuflarfly wfith coafl … How can fit be cfleaned up fin a way that actuaflfly provfides economfic beneffit as wefllfl as reduces the harm fit's creatfing?[4]

Thfis finformant fis drawfing our attentfion to the flegacy of fossfifl fuefl finfrastructure that fis makfing fit dfiffficufllt to keep the communfity safe. EJOs hope to ffind engfineers and scfientfists who can heflp sofllve these fissues, but aflso recognfize that any soflutfion must be equfitabfle and heflp provfide economfic securfity for these communfitfies as they cope wfith the shock of transfitfionfing to a new way of flfife.

Clean and Just Energy Transfitfions: The topfic of transfitfionfing to a cflean and just energy system aflso came up repeatedfly fin our fintervfiews. We asked finformants to provfide us wfith exampfles of transformatfionafl projects fin thefir communfity that woufld be usefufl to tafflk about wfith scfientfists and engfineers. The presfident of one EJO that focuses on educatfing the pubflfic about a range of envfironmentafl fissues excfitedfly expflafined that:

> Yes! Any kfind of afllternatfive energy projects coufld be pfifloted here. We need to … use those abandoned mfine flands as brownffiefflds for soflar panefl farms. We need to change the flaws fin the state to aflflow for communfity soflar, so that peopfle can beneffit … So, you know, we've got a flot of work to do, espefciaflfly on the flegfisflatfive flevefl, but aflso on the fideoflogficafl flevefl. The cufllture fis very resfistant to change, and very resfistant to scfientfiffic evfidence.[5]

It fis fimportant to fincflude thfis flong quote because here we can start to see that finterest fin technficafl expertfise fis finterdfiscfipflfinary, fincfludfing flawyers and socfiafl scfientfists who can heflp the pubflfic understand the fimportance of scfientfiffic evfidence. It may be that expertfise beyond a photovofltafic systems engfineer woufld be heflpfufl to an EJO that wants to create a soflar farm on an abandoned brownffiefld.

Envfironmental Restoratfion: Brownffiefflds and Superfund sfites are wfidespread across the US, wfith recent estfimates suggestfing more than 450,000 brownffiefflds[6] and cflose to 1400 Superfund sfites scattered across the US.[7] In spfite of how wfidespread fissues reflated to fland poflflutfion are, one finformant suggested that fit was sfiflfl dfiffficufllt to ffind engfineerfing or

[4] Intervfiew #40 conducted on Dec. 6th, 2018.

[5] Intervfiew #10 conducted on Oct. 2nd, 2018.

[6] https://www.epa.gov/brownffiefflds/overvfiew-epas-brownffiefflds-program.

[7] https://www.epa.gov/superfund/superfund-natfionafl-prfiorfitfies-flfist-npfl.

scfientfiffic experts to heflp envfisfion envfironmentafl restoratfion:

> It fis so hard for us to heflp groups ffind experts who are wfiflfling to heflp them evafluate dfifferent cfleanup optfions and cflarfify thefir goafls reflated to the cfleanup and deveflop thefir vfisfion for kfind of the best possfibfle scenarfio. I don't know why that fis, but fit's been flfike aflmost entfirefly fimpossfibfle for us to ffind expert heflp for communfitfies that need that type of assfistance.[8]

Thfis quote suggests that there mfight not be enough envfironmentafl remedfiatfion and restoratfion experts fin the flocafl communfity to go around and/or those who coufld provfide expertfise are dfiffficufflt to connect wfith.

Indfigenous Communfities: Some EJOs are afso engaged wfith findfigenous communfitfies fin the Unfited States. One organfizatfion fin New Engfland descrfibed the EJ struggfles faced by findfigenous communfitfies. When we specfifficafflfly asked about the technnficafl chaflflenges they faced, the founder of thfis EJO expflafined:

> dofing a survey across the country fis one thfing, but partnerfing wfith a group that has a reservatfion or fis workfing wfith findfigenous groups about fland fissues and envfironmentafl stuff, to me that's powerfufl.[9]

In other words, EJOs workfing wfith findfigenous communfitfies do see a pflace for technficafl expertfise fin thefir work, but they want to see more equfitabfle coflflaboratfions wfith dfirect partnershfips. It may be that our use of snowbafflfl sampflfing resuflted fin a dearth of EJOs workfing wfith findfigenous communfitfies fin our study. Regardfless, we see a need for future research to flook more cfosefly at the finterests of findfigenous communfitfies and how they mfight be dfifferent from other organfizatfions fin the Unfited States.

4.2.2. Methods to support EJO strategfies

In dfiscussfing EJOs chaflflenges as a functfion of topficafl areas, our fintervfiewees often brought up engfineerfing and scfientfiffic methods and approaches that coufld support the strategy used by thefir EJO. Oftentfimes, fintervfiewees fimagfined these methods and approaches as befing usefufl fin carryfing out the strategy of the EJO. Whfifle the partficuflarfitfies of depfloyfing these methods are dfifferent for dfifferent kfinds of engfineers and scfientfists, conceptuaflfly, they are the same regardfless of engfineerfing or scfientfiffic expertfise area.

Data Collectfion: EJOs recognfize that scfientfiffic data fis an fimportant source of support for thefir strategfies to resoflve envfironmentafl finjustfice fissues, partficuflarfly gfiven the rofle of data fin reguflatory decfisfion-makfing (Jasanoff, 1990). EJOs afso recognfize that oftentfimes, data fimportant to thefir cause mfight not exfist, and that those data need coflflectfing. As an executfive dfirector of one organfizatfion that devefloped projects on exposure to envfironmentafl poflflutfion fin New Engfland expflafined, they woufld flfike to coflflaborate wfith more experts but:

> ... some groups need to take matters finto thefir own hands and do thefir own testfing ... we've, we afso often partnered wfith cfitfizen scfience organfizatfions ... we've brought them fin to trafin communfity groups how to do thefir own afir testfing.[10]

EJOs know that even wfithout engfineers and scfientfists fit fis sfifflfl possfibfle for communfitfies to begfin thefir own data coflflectfion under the concept of "cfitfizen scfience" (Bonney et afl., 2009). Communfitfies may desfire to coflflaborate more wfith experts but fif none are avafiflabfle they mfight organfize to coflflect data that speaks to thefir experfiences. However, EJOs are afso wefflfl aware of the poflfitfics of scfientfiffic data coflflectfion, fincfludfing data standards for reguflatory decfisfions that are dfiffficufflt to meet.

Data Dfissemfinatfion: One key method mentfioned repeatedfly by the organfizatfions fin our study fis ffindfing more expedfient ways to engage wfith the pubflfic through proper data dfissemfinatfion. A very strafightforward pofint about dfissemfinatfion was made by a dfirector workfing for an EJO focused on educatfion around the Appaflachfian Pflateau: "You know, reflyfing on journaflfists to finterpret studfies, there's just not enough of them to go around." From the dfirector's perspectfive, there fis not just an finterest fin experts on scfience and engfineerfing, but afso peopfle who know how to expflafin the compflexfitfies of these chaflflenges to the generafl pubflfic. Later on, when dfiscussfing thefir goafls fin the comfing years he expflafined that they afso want to coflflaborate wfith those who can finterpret the flarge number of scfientfiffic studfies afready pubflfished:

> ... flfike wfith mountafintop removafl, we have flfinks to many of the studfies and we don't have them affl dfistfiflfled down. We had an fintern that was workfing on dfistfiflfling some of them ... we have just flfike a flfist of affl the studfies about mountafintop removafl and human heaflth.[11]

Whfifle some EJOs may dfissemfinate scfientfiffic finformatfion to the pubflfic sfimpfly by creatfing flfists of pubflfished studfies, here we can see that the dfirector of thfis organfizatfion feefls finundated wfith data reflevant to the fissue that fis affectfing thefir communfity. They afso coufld use finterpretatfions of that data fin order to fimprove dfissemfinatfion.

Data Analysfis: EJOs afso recognfize the necessfity to anaflyze exfistfing and new data to better understand the EJ chaflflenges they face. For an EJO that fis connected to a flarger natfionwfide network focused on educatfion about energy justfice fissues, data anaflysfis needs to be not onfly accurate, but tfimefly. As a coordfinator for the organfizatfion expflafined, resfidents fin the communfity they work wfith want someone to anaflyze how much poflflutfion wfiflfl be emfitted from a factory that recefived an afir quaflfity permfit and what fit means for thefir heaflth:

> [I]t woufld be reaflfly heflpfufl to work wfith somebody that coufld come up wfith those answers qufickfly. As much as I flove dofing that kfind of research and kfind of dfiggfing fin and ffindfing those thfings out, ...fit can be reaflfly chaflflengfing ... to do affl the other aspects of our work whenever we have to do research fin areas that we don't specfiaflfize fin.[12]

Even though thfis finformant fis connected to a natfionwfide network that we woufld assume has more access to scfientfiffic expertfise, they sfifflfl feflt that thefir organfizatfion woufld beneffit from befing connected to a wfider network of scfientfists and engfineers who coufld provfide expert anaflysfis faster and more accuratefly than they coufld conduct that anaflysfis themseflves. Coflflaboratfing wfith technficafl experts fis necessary for EJOs because wfithout fit they have to sacrfiffice other aspects of thefir work flfike engagfing dfirectfly wfith the communfity. Here we shoufld emphasfize that whfifle those workfing fin EJOs may be perfectfly capabfle of understandfing and utfiflfizfing scfience and engfineerfing, or deveflopfing that capabfiflfity, they are afso very aware that thfis expertfise afready exfists and fit woufld save them a great deafl of tfime to coflflaborate wfith those experts rather than workfing on thefir own.

Spatfial Analysfis: A good exampfle of where expertfise coufld be beneffifciafl to an EJO workfing throughout the state of New York fis fin the ffiefld of mappfing and geographfic finformatfion systems (GIS). Whfifle thfis EJO tends to engage fin coflflaboratfive projects, they afso want to work wfith cfitfies that can demonstrate the spatfiafl reflatfionshfips that structure the finjustfices fin the communfitfies where they work. As one program manager for the organfizatfion safid:

> Those are the same exact nefighborhoods that are experfiencfing the concentratfion of brownffiefld fissues, flack of weaflth, hfigh concentratfions of poverty, hfigh concentratfions of preventabfle heaflth fissues reflated to afir quaflfity, water quaflfity, exposure to envfironmentafl contamfinants, thfings flfike that. So, the GIS capacfity fis tremendous.

[8] Intervfiew #19 conducted on Oct. 17th, 2018.
[9] Intervfiew #36 conducted on Nov. 30th, 2018.
[10] Intervfiew #19 conducted on Oct. 17th, 2018.
[11] Intervfiew #11 conducted on Oct. 3rd, 2018.
[12] Intervfiew #22 conducted on Oct. 18th, 2018.

> And cfitfies just vary fin thefir capacfity to do GIS. Some have a department. Some have one guy or one woman. [13]

EJOs see spatfiafl anaflysfis and other vfisuaflfizatfion toofls as powerfufl modes of expressfion that are capabfle of changfing the mfinds of peopfle fin posfitfions of authorfity. They recognfize that GIS requfires technficafl expertfise and fif done properfly coufld be finstrumentafl fin promotfing a successfufl project.

Onfine Platform Bufifdfing: The ffinafl method to dfiscuss touches on the beneffit for organfizatfions to create an onffine presence to support EJ actfivfitfies. Whfifle EJOs mfight be good at engagfing wfith communfitfies, they feefl fless comfortabfle tryfing to reach a gfobafl audfience. There fis an finterest fin workfing wfith engfineers and coders to heflp them bufifld a websfite that wfffl make the story of thefir struggfle easfifly accessfibfle but perhaps afso aflflow others beyond the communfity to fleam from thefir experfiences. For finstance, the executfive dfirector for the organfizatfion that devefloped projects on exposure to envfironmentafl poflflutfion fin New Engfland expflafined how they are sharfing thefir experfiences so that other groups:

> don't have to be as reflfiant on actuafl … findfivfiduafl experts. So, one exampfle fis our partnershfip wfith TERC,[14] a math and scfience educatfion organfizatfion, where together we devefloped our statfistfics for actfion projects … We have a flot of [resources] on our websfite, but there's afso a natfionafl websfite that's up caflfled sfa.terc.edu. [15]

Once agafin, we can see how some EJOs are engagfing very dfirectfly wfith the scfience and engfineerfing that fis behfind the finjustfice they are ffightfing. In fact, here they are finnovatfing dfigfitafl resources that wfffl ensure other EJOs are not so dependent on ffindfing experts wfith whfich to coflflaborate. The fact they bufiflt thfis websfite demonstrates qufite cflearfly that EJOs recognfize the fimportance of scfience and engfineerfing *and* that there fis currentfly a dearth of experts who can or are wfiflffing to support thefir organfizatfion.

Networkfing wfith Experts: Some fintervfiewees provfided us wfith suggestfions about what coufld be done to heflp resoflve the dfisconnect between communfity groups and engfineers and scfientfists. Many finformants descrfibed how fimportant fit woufld be for engfineers and scfientfists to deveflop a method for networkfing experts together wfith EJOs. Sfimfiflar wfith the method of Onflfine Pflatform Bufifldfing, fintervfiewees suggested these soflutfions woufld requfire support from engfineers and scfientfists famfiflfiar wfith computer programmfing. For finstance, a program manager promotfing cflfimate justfice fissues through the medfia around Washfington D.C. mentfioned an onflfine networkfing appflficatfion may be the best way to soflve thfis dfisconnect.

> Eventuaflfly our hope fis … to deveflop … a pflatform to connect communfitfies wfith those technficafl resources, whether that be an expert fin computer systems, computer scfience software, those kfind of thfings, or flfike, envfironmentafl monfitorfing experts, etc. [16]

Our fintervfiewees recognfized that there are exfistfing socfiafl networkfing pflatforms for academfics (fi.e. academfia.edu, ResearchGate), but they are not amenabfle to supportfing coflflaboratfions wfith organfizatfions outsfide of academfia. In other words, the deveflopment of methods for networkfing experts wfith EJOs coufld be a powerfufl way to soflve the engfineerfing and scfientfiffic chaflflenges dfiscussed fin thfis artficfle.

5. Discussion

As demonstrated by the success of projects fimpflemented by AGU's Thrfivfing Earth Exchange, AAAS's On-Caflfl Scfientfists, and Communfity Engfineerfing Corps, engfineerfing and scfientfiffic projects to address EJ chaflflenges fin servfice of underserved communfitfies and EJOs *can* be scoped and executed wfith measurabfle fimpact. We are motfivated to understand how engfineers and scfientfists can coflflaborate wfith EJOs and address EJ chaflflenges at flarger scafles. Thfis fis because, as our fintervfiews suggest, there fis wfidespread desfire on the part of EJOs to coflflaborate wfith engfineers and scfientfists, and, foflflowfing Boucher et afl. (2020), we know there fis recfiprocafl desfire on the part of engfineers and scfientfists. Our expfloratory research approach and ffindfings are fimportant to flayfing the groundwork for thfis flarger effort.

Our study systematficaflfly anaflyzed the perspectfives of EJOs that use strategfies of engagfing wfith poflficy, medfia, educatfion, flegafl, and projects. Our study afso for the ffirst tfime brfings together the varfious themes of topficafl areas and methods mentfioned by the EJOs fin our study, whfich refflects narrower studfies of EJOs on energy, cflfimate, water, and fland uses (Njue et afl., 2019; EWB-USA, 2020; Schefidefl et afl., 2020); envfironmentafl fimpacts and monfitorfing (Conrad and Hfiflchey, 2011), conservatfion and GIS mappfing (Kuflflenberg and Kasperowskfi, 2016), and data management (Sharpe and Conrad, 2006; Newman et afl., 2011). Broadfly, the resuflts captured fin Ffig. 2 hfighflfight how EJOs thfink about the topficafl areas fin expansfive and fintersectfionafl ways.

What fis unfique from our anaflysfis fis what we ffind regardfing how dfifferent strategfies taken by EJOs reflate to the dfifferent ways fin whfich engfineerfing and scfience mfight be usefufl for them (see Tabfle E1 fin Appendfix E). For exampfle, a flarge majorfity of the EJOs mentfioned a key engfineerfing/scfientfiffic chaflflenge they faced was data coflflectfion. However, whfifle 60% of the organfizatfions empfloyfing a flegafl strategy wanted to coflflaborate wfith more expert wfitnesses to testfify for them, counterfintufitfivefly none of the poflficy-orfiented organfizatfions mentfioned flookfing for expert wfitnesses but finstead were mafinfly concerned about data coflflectfion. Our sampfle sfize of these dfifferent strategy-orfiented organfizatfions fis somewhat smaflfl, and thus our ffindfings stfimuflate future work on why poflficy-orfiented organfizatfions seem sfinguflarfly focused on data coflflectfion at the expense of recrufitfing more expert wfitnesses.

Further study coufld fiflflumfinate more robust trends fin the kfinds of engfineerfing and scfientfiffic expertfise and skfiflfls necessary as a functfion of EJO strategfies. We note that the resuflts captured fin Ffig. 3 provfide evfidence that EJOs can beneffit from a mufltfitude of engfineerfing and scfientfiffic methods befing at thefir dfisposafl. In short, Ffigs. 2 and 3, E1, and E2 provfide a framework for us to understand what kfinds of engfineerfing and scfientfiffic expertfise mfight be heflpfufl to dfifferent kfinds of EJOs. As mentfioned beflow, further research can fleverage the framework provfided by these expfloratory ffindfings.

It has been safid that EJOs engage wfith scfientfiffic and technficafl experts because of a percefived need to have fincreased credfibfiflfity fin order for thefir concerns over envfironmentafl finjustfice to be resoflved by regufatory change (Ottfinger, 2010). Thfis was not a common concern among the organfizatfions fin our study. For most of the EJOs we fintervfiewed, technficafl expertfise was prfimarfifly focused on compfletfing a task or supportfing a project that woufld fimprove condfitfions fin thefir communfitfies. Thfis coufld be the resuflt of our sampflfing, but regardfless, thfis ffindfing fis fin fitseflf fimportant, because most prevfious studfies have focused on a smaflfl number of EJOs who may onfly engage fin a sfingfle strategy to soflve envfironmentafl finjustfice fin thefir communfity. Thfis means there fis stfiflfl ampfle room to finnovate ways fin whfich engfineers and scfientfists coufld provfide beneffit by coflflaboratfing wfith a wfider varfiety of EJOs—and fin the words of Boucher et afl. (2020), heflp create a *ffield of collaboratfion*—and to do so fin ways that cfitficaflfly engage wfith asymmetrficafl power reflatfions between engfineers, scfientfists, and EJOs, and the dfifferentfiafl vafluatfion of the technficafl knowfledge that engfineers and scfientfists have versus the cufturafl and flocafl knowfledge EJOs have. (To thfis pofint, whfifle the scope of thfis paper does not aflflow for us to use affl of the data we gathered and anaflyzed through our fintervfiews, we sfimpfly hfighflfight here that many EJOs shared storfies wfith us about how prevfious coflflaboratfions wfith engfineers and scfientfists were not successfufl.) Overaflfl, we tend to agree wfith Fernandez-Bou et afl. (2021) that

[13] Intervfiew #16 conducted on Oct. 16th, 2018.

[14] TERC orfigfinaflfly stood for Technficafl Educatfion Research Centers, but the company has flegafl changed thefir name to the acronym.

[15] Intervfiew #19 conducted on Oct. 17th, 2018.

[16] Intervfiew #1 conducted on Aug. 28th, 2018.

scfientfiffic research fis most effectfive at soflvfing envfironmentafl finjustfice fiffit fis abfle to fleverage the flocafl knowfledge of resfidents flfivfing fin the communfity.

Whfifle our sampflfing sfize and approach refflects the expfloratory nature of our study, the themes that have emerged from our research flay the foundatfion for future work that can take at fleast three paths: (1) More quaflfitatfive depth finto partficuflar kfinds of EJ groups (an exampfle of a research questfion coufld be: What are the data coflflectfion needs of EJOs that address afir quaflfity chaflfienges across the US?); (2) A broader quantfitatfive survey that coufld provfide finsfight finto the reflatfive fimportance of each of the themes that have emerged (an exampfle of a research questfion coufld be: Accordfing to EJOs addressfing water quaflfity across the US, what are the most fimportant actfivfitfies and skfiflfls engfineers and scfientfists brfing to coflflaboratfions?); and (3) Understandfing the transferabfiflfity of engfineerfing and scfientfiffic skfiflfls across topficafl areas fidentfiffied by EJOs. For exampfle, fit mfight absofluteffy be the case that a water quaflfity engfineer wfith expertfise fin data coflflectfion and anaflysfis can qufickfly flearn and address the data coflflectfion and anaflysfis needs of an EJO addressfing fossfifl fuefl finfrastructure. These paths together can contfinue to bufifld an actfion-orfiented understandfing of how engfineers and scfientfists can systematficaflfly heflp address EJ chaflfienges at the scafle that these chaflfienges exfist.

6. Conclusions

EJ chaflfienges are wfidespread, and wfffl flfikefy not be adequatefly addressed at scafle wfith scfientfiffic and technficafl finterventfions and coflflaboratfions that are pfiecemeafl and focused on hfighfly flocaflfized contexts. We envfisfion the bufifldfing of strategfic and systematfic efforts to expand the fimpact of engfineerfing and scfientfiffic work done to address these chaflfienges that are the *rafison d'etre* of EJOs. Such efforts may be motfivated by poflficy deveflopments that may themseflves be outcomes of the efforts of EJOs. Our expfloratory research bufifids on the hfistory of EJOs coflflaboratfing wfith engfineers and scfientfists to address EJ chaflfienges, and pushes the possfibfiflfitfies for more of such work by creatfing a framework to gufide more systematfic research and actfion to address the engfineerfing and scfientfiffic chaflfienges of EJOs. The methods we fidentfify can heflp finform how programs run by professfionafl socfietfies and non-proffits, flfike AAAS, AGU, and Communfity Engfineerfing Corps, can begfin to cflassfify the projects undertaken under thefir auspfices, and create more cflarfity for engfineers and scfientfists on how more of them can be finvoflved fin such work.

Facfiflfitated by fincreasfing thefir abfiflfity to engage across asymmetrfic power reflatfions wfith EJOs, finvestments by engfineers and scfientfists fin the methods and the topficafl areas fiflflumfinated through our fintervfiews can serve EJOs across strategy type. Through coflflaboratfive work wfith EJOs that fleverage the skfiflfls, perspectfives, and knowfledge that engfineers and scfientfists have depfloyed readfifly for decades fin more typficafl contexts for them, engfineers and scfientfists may afso flearn to fimprove thefir scfientfiffic and envfironmentafl communficatfions to center equfity and justfice (Poflk and Dfiver, 2020), thereby fincreasfing the socfiafl reflevance of technficafl work. Importantfly, by scopfing the scfientfiffic and engfineerfing chaflfienges of EJOs as we have done here, we ensure the transferabfiflfity of knowfledge gafined, so that other EJOs and by extensfion EJ communfitfies facfing sfimfiflar chaflfienges can beneffit.

Author statement

Conceptuaflfizatfion: Guerrero, Levenda, Karwat, Data curatfion: Macfias, Guerrero, Levenda, Schmfitt, Boucher, Formafl anaflysfis: Macfias, Guerrero, Schmfitt, Fundfing acqufisfitfion: Karwat, Investfigatfion: Levenda, Methodoflogy: Macfias, Guerrero, Levenda, Schmfitt, Boucher, Project admfinfistratfion: Schmfitt, Karwat, Supervfisfion: Karwat, Vaflfidatfion: Macfias, Guerrero, Schmfitt, Vfisuaflfizatfion: Schmfitt, Karwat, Rofles/Wrfitfing - orfigfinafl draft: Macfias, Guerrero, Schmfitt, Wrfitfing - revfiew & edfitfing: Schmfitt, Karwat.

Declaration of competing interest

The authors decflare that they have no known competfing ffinancfiafl finterests or personafl reflatfionshfips that coufld have appeared to finffluence the work reported fin thfis paper.

Data availability

The data that has been used fis conffidentfiafl.

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Appendix A. Supplementary data

Suppflementary data to thfis artficfle can be found onflfine at https://dofi.org/10.1016/j.jcflepro.2022.134463.

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