BRIEF REPORT

Identifying essential critical infrastructure workers during the COVID-19 pandemic using standardized industry codes

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Abstract

Background: The Cybersecurity and Infrastructure Security Agency (CISA) produced an advisory list identifying essential critical infrastructure workers (ECIW) during the coronavirus disease 2019 (COVID-19) response. The CISA advisory list is the most common national definition of ECIW but has not been mapped to United States (U.S.) Census industry codes (CICs) to readily identify these worker populations in public health data sources.

Methods: We identified essential critical infrastructure industry designations corresponding to v4.0 of the CISA advisory list for all six-digit North American Industry Classification System (NAICS) codes and cross-walked NAICS codes to CICs. CICs were grouped as essential, non-essential, or mixed essential/non-essential according to component NAICS industries. We also obtained national estimated population sizes for NAICS and Census industries and cross-tabulated Census industry and occupation codes to identify industry-occupation pairs.

Results: We produced and made publicly available spreadsheets containing essential industry designations corresponding to v4.0 of the CISA advisory list for NAICS and Census industry titles and codes and population estimates by six-digit NAICS industry, Census industry, and Census industry-occupation pair. The CISA advisory list is highly inclusive and contains most industries and U.S. workers; 71.0% of Census industries comprising 80.6% of workers and 80.7% of NAICS industries comprising 87.1% of workers were designated as essential.

Conclusions: We identified workers in essential critical infrastructure industries as defined by CISA using standardized industry codes. These classifications may support public health interventions and analyses related to the COVID-19 pandemic and future public health crises.

KEYWORDS
census industry codes, COVID-19, essential workers, North American Industry Classification System codes, public health surveillance

1 | INTRODUCTION

The Department of Homeland Security – Cybersecurity and Infra-structure Security Agency (CISA) developed a series of advisory lists describing essential critical infrastructure workers (ECIW) during the coronavirus disease 2019 (COVID-19) pandemic. ECIW were defined as workers who "conduct a range of operations and services that are typically essential to continued critical infrastructure viability."[1] The first version of the CISA advisory list was released on March 19, 2020 and identified ECIW to ensure their access to workplaces to maintain essential operations during initial stay-at-home orders.[2] It was later expanded in v2.0-v4.0 to account for the indefinite duration of the COVID-19 crisis; v4.0 was released in August 2020 and identified worker populations within 18 industry sectors (e.g., Healthcare/Public Health, Education, etc.) that may require specialized occupational risk management strategies or be priorities for allocation of limited public health resources.[1] New recommendations for application of the advisory list were released in August 2021 as part of an updated v4.1, although ECIW populations were unchanged.[3] The series of CISA advisory lists are the most common national definition of the essential workforce and has informed state and local shutdown orders, industry-level occupational health decisions, and vaccination allocation strategies.[4–7]

Interpretation of the CISA advisory list by public health practitioners and researchers has been complicated by its inclusion of a mixture of whole industries, specific occupations, and industrial supply chains. The advisory list does not include standardized industry or occupation titles or codes that can be used to identify workers in population-based data sources (e.g., mortality, Census). However, several groups have published complementary lists of titles and codes.[8–10] The Brookings Institution mapped v1.0 of the CISA advisory list to 2017 North American Industry Classification System (NAICS) titles and codes.[8] The Federal Reserve Bank of Philadelphia produced similar lists of 2017 NAICS codes corresponding to v1.0, v2.0, and v3.0 of the CISA advisory list, as well as some state-specific essential worker lists.[9] The Labor Market Information Institute also published a list of 2018 Standard Occupational Classification system titles and codes corresponding to v1.0 of the CISA advisory list.[10] These code lists have been valuable resources for researchers evaluating impacts of the pandemic on workers designated as ECIW.[11,12]

However, an updated, comprehensive mapping of the CISA advisory list building on these prior efforts was needed to support public health interventions and assessments. Only Census industry codes (CICs) and Census occupation codes (COCs), rather than NAICS and Standard Occupational Classification system codes, are available in some of the data sources used for public health research and planning.[13] We produced lists of both NAICS and Census industry titles and codes with essential industry designations (EIDs) corresponding to v4.0 of the CISA advisory list to facilitate the identification of ECIW in public health data using either NAICS or CICs. This code set was previously published on the National Institute for Occupational Safety and Health (NIOSH) website at https://www.cdc.gov/niosh/topics/coding/essentialworkers/default.html on February 5, 2021 to support real-time data collection and analyses during the COVID-19 pandemic; we provide a brief introduction to the code set for research purposes here.

2 | MATERIALS AND METHODS

2.1 | Identification of NAICS industries corresponding to v4.0 of the CISA advisory list (EID by 6-digit NAICS spreadsheet)

We applied the Federal Reserve Bank of Philadelphia's list[9] of mixed-digit (four-, five-, or six-digit) NAICS codes and essential critical infrastructure industry designations corresponding to v3.0 of the CISA advisory list as a starting point for the development of an updated list corresponding to v4.0 using CICs. We broke each higher level NAICS code into all six-digit 2017 NAICS component industries[14] (Table 1: Essential industry designations by six-digit NAICS codes) and applied the Federal Reserve Bank of Philadelphia's essential industry designation for each higher-level industry to all component industries. Then, we noted industries that were added to or removed from the CISA list from v3.0[15] to v4.0.[1]

A team of three occupational health scientists manually reviewed these preliminary essential industry designations for all six-digit NAICS codes and recommended updated designations for a small number of industries after reaching consensus. Updated designations were based on the subindustry titles given in the 2017 NAICS index file and manual.[16,17] Some six-digit NAICS codes include both essential and nonessential subindustries; we designated NAICS codes as essential if they contained any subindustries that corresponded to worker roles in v4.0 of the CISA advisory list because overinclusion at this stage captured only a minimal portion of the non-essential workforce and no standardized coding system distinguishes between subindustries beyond the six-digit NAICS level. As an example, we designated "Other Scientific and Technical Consulting Services" as an essential industry because it includes biological consulting services and chemical consulting services that support biomedical research and vaccination and medication manufacturing and distribution, among other essential worker roles.[17] However, it also includes motion picture consulting services, which do not fulfill an essential worker role as defined by v4.0 of the CISA advisory list. These cases account for many of the discrepancies between our designations and the Federal Reserve Bank of Philadelphia's v3.0 designations. CISA representatives supported a broad reading of essential designations to best align with the intent of v4.0 of the advisory list; after a review of our preliminary designations, they suggested the inclusion of several additional industries and we revised our designations accordingly.

The CISA advisory list identifies 18 industry sectors containing ECIW. Within each sector, it describes ECIW roles in a series of bulleted descriptive text fields (e.g., "Operational staff at water authorities," "Workers at generation, transmission, and electric black start facilities," etc.). For each essential industry in our mapping of v4.0 of the CISA advisory list,[1] we provide the essential critical infrastructure sector and

TABLE 1 Resources for identification of essential critical infrastructure workers as defined by v4.0 of the Cybersecurity and Infrastructure Security Agency (CISA) advisory list.

Excel sheet name	Included resources

Essential industry designations (EID) by 6-digit North American Industry Classification System (NAICS) codes	• All six-digit 2017 NAICS industry titles and codes (*n* = 1057)
	• Essential industry designations derived from Federal Reserve Bank of Philadelphia's designations for higher-level NAICS codes under v3.0 of the Cybersecurity and Infrastructure Security Agency (CISA) advisory list
	• Updates to Federal Reserve Bank of Philadelphia's v3.0 essential industry designations
	  o 0 = Changed from essential to non-essential
	  o 1 = Changed from non-essential to essential
	  o Blank = No change
	• **Final essential industry designations corresponding to v4.0 of the CISA advisory list**
	  o 0 = Non-essential industry
	  o 1 = Essential industry
	• **CISA essential critical infrastructure workforce sector and sector-based major bullet number under which each essential industry was identified**
	• **Estimated number of workers in each NAICS industry[c] drawn from Quarterly Census of Employment and Wages (QCEW) 2019 annual averages**

Essential industry designations by Census Industry Codes (CIC) and condensed NAICS codes	• 2017 NAICS industry titles and codes, condensed into the highest level at which all component 6-digit NAICS industries share an essential industry designation under v4.0 of the CISA advisory list
	• 2012 Census industry titles and CICs corresponding to condensed NAICS titles and codes (*n* = 262). Some CICs appear multiple times because they correspond to multiple condensed NAICS codes
	• **Essential industry designations by CIC corresponding to v4.0 of the CISA advisory list**
	  o 0 = Non-essential industry: CIC contains only non-essential NAICS codes
	  o 1 = Essential industry: CIC contains only essential NAICS codes
	  o 2 = Mixed essential/non-essential industry: CIC contains a mixture of essential and non-essential condensed NAICS codes
	• **Estimated numbers of workers in each Census industry[d] drawn from the Employed Labor Force (ELF) Query System, which applies data from the 2018 Current Population Survey**

Census Industry Code (CIC) - Census Occupation Code (COC) pairs	• 2012 Census industry titles and CICs • 2010 Census occupation titles and COCs occurring within each CIC • Estimated number of workers in each CIC-COC pair drawn from the ELF Query System

Abbreviations: CIC, census industry code; CISA, Cybersecurity and Infrastructure Security Agency; COC, census occupation code; EID, essential industry designation; ELF, Employed Labor Force; NAICS, North American Industry Classification System; QCEW, Quarterly Census of Employment and Wages.

bulleted worker role within that sector under which the industry was identified as essential. This information may be used to map essential industries back to the corresponding text in the CISA advisory list or to narrow the list of NAICS codes for specific applications. Many NAICS codes may be appropriately classified under multiple sectors or worker roles; each is identified under the sector and bulleted worker role that most closely describes it.

We obtained estimated population sizes for each six-digit NAICS industry from the Quarterly Census of Employment and Wages (QCEW) 2019 annual averages.[18] The QCEW is a quarterly census of employers derived from data reported to state unemployment insurance programs and is estimated to include >95% of all United States (U.S.) workers.[19] Self-employed owners of unincorporated, non-employer businesses, certain farm and domestic workers, railroad workers, and members of the armed forces are not covered by the QCEW.[19] Detailed methodology and inclusion criteria for the QCEW are available elsewhere.[19] We

summed these industry populations to identify the estimated total number of U.S. workers in each CISA essential critical infrastructure sector and within essential and non-essential NAICS industries overall. Note that we use annual 2019 data rather than quarterly employment counts corresponding to employment during the pandemic; estimates reflect the number of workers that are usually attached to a given industry who would be affected by the issuance of essential worker classification, rather than mid-pandemic employment.

2.2 | Crosswalk of NAICS industries and essential industry designations to census industries (EID by CIC and condensed NAICS spreadsheet)

We collapsed six-digit NAICS industries into the highest level at which all component industries shared a single essential industry

designation to identify condensed NAICS codes, then cross-walked condensed 2017 NAICS codes to 2012 CICs[20] (Table 1: Essential industry designations by CIC and condensed NAICS). CICs are broader than NAICS codes and many contain multiple condensed NAICS codes,[13] some of which may not share the same essential industry designation. We identified Census industries containing both essential and nonessential NAICS codes as mixed essential/nonessential to avoid the overinclusion of broad portions of the nonessential workforce. U.S. Armed Forces industries were excluded.

We identified the estimated number of U.S. workers in each CIC using the NIOSH Employed Labor Force (ELF) Query System,[21] which pools all 2018 data from the basic monthly files of Current Population Survey public use microdata sample. The Current Population Survey is a monthly household survey of the civilian, noninstitutional population and the ELF Query System applies a subset of CPS data including only employed pesons.[22] Detailed methodology and inclusion criteria for the Current Population Survey and the ELF Query System are available elsewhere.[22] For these estimates, we use the CIC code associated with the worker's primary job. We then summed worker populations by essential industry designation to estimate the total number of U.S. workers in essential, mixed essential/nonessential, and nonessential Census industries.

2.3 | Identification of census occupations within each census industry (CIC–COC pairs spreadsheet)

We identified Census occupations within each Census industry to support evaluation of COVID-19-related factors by occupation within essential critical infrastructure industries (Table 1: CIC–COC pairs). First, we used the NIOSH ELF Query System[21] to cross-tabulate estimated numbers of U.S. workers in 2018 by 2012 CICs and 2010 COCs. This approach revealed some uncommon pairs; some industry and occupation pairs may be very rare, misreported, or miscoded in the Current Population Survey public use microdata sample used to fulfill ELF queries.[a] However, we retained all industry and occupation pairs to capture the largest possible breadth of occupations within each industry. ELF population estimates below 1000 are considered unstable [22] and other researchers may choose to apply a threshold to the estimated number of workers in an industry-occupation pair in the U.S. to reflect this instability or refine the list of occupations examined within a specific industry of interest using expert judgment.[a]

A subset (52/535) of nonmilitary Census occupations are not reported in ELF industry and occupation cross-tabulations due to small occupational populations. Researchers may consider reviewing these occupations for potential inclusion as appropriate if evaluating a specific essential critical infrastructure industry of interest.

Additional details are included in the methodological appendix published with the code set on the NIOSH website.[23] This activity was deemed not to be research as defined in 45CFR 46.102(I) and IRB review was not required.[b]

3 | RESULTS

Resources included in the code set are summarized in Table 1. Excel spreadsheets containing a data dictionary, essential industry designations corresponding to v4.0 of the CISA advisory list on the essential critical infrastructure workforce by NAICS and Census industries, and population estimates by six-digit NAICS industry, Census industry, and CIC-COC pair are available as supporting information.

The CISA advisory list v4.0 is highly inclusive and contains most industries and U.S. workers. Among 262 nonmilitary Census industries, 186 (71.0%) were designated as essential, 29 (11.1%) as mixed essential/nonessential, and 47 (17.9%) as nonessential (Table 2). Essential industries include 80.6% of the U.S. civilian workforce, compared to 11.6% in mixed essential/nonessential industries and 7.8% in nonessential industries. Among six-digit NAICS industries, 853/1057 (80.7%) comprising 87.1% of U.S. civilian workers were designated as essential. The largest essential critical infrastructure sectors are Healthcare/Public Health (16.9% of U.S. workers), Food and Agriculture (15.1%), and Education (8.4%). Some of the largest nonessential industries (not listed in Table 2) include clothing and department stores (2.1%) and personal care establishments (1.1%).

4 | DISCUSSION

The CISA advisory list outlining the essential critical infrastructure workforce[1] is the most common national definition for essential workers[4-7] but has not been coded for use with public health data specifically. Work is a core social determinant of health,[24] and the ongoing COVID-19 pandemic created a new distinction between essential and nonessential workers[8-10] that may impact worker health.[25-27] The code set outlined here may be applied to identify national ECIW populations or adapted to identify state- or city-specific ECIW populations during the COVID-19 crisis in data sources classifying workers by standardized industry codes. It may also be used in conjunction with NIOSH's Industry and Occupation Computerized Coding System to code free-text industry data to standardized industry codes,[28] then to CISA ECIW designations. The use of standardized codes and ECIW classifications may enable comparisons across geographic populations, study designs, and time.

The CISA advisory list provides text descriptions of worker roles within a set of 18 high-level sectors deemed critical infrastructure or supporting critical infrastructure[1] and was updated several times in response to changing needs during the COVID-19 pandemic. CISA sought continuing input on the advisory list from external stakeholders, including federal agency partners, industry experts, and state and local government officials.[1] CISA emphasized that the advisory list was not a federal directive or standard and should not be considered the exclusive list of critical infrastructure sectors or essential worker roles during the COVID-19 response.[1]

CISA essential critical infrastructure industry designation	CISA essential critical infrastructure sector	Industries (n, %)	Percentage of workers[*]
Census industries	–	262 (100.0)	100.0
Nonessential industries	–	47 (17.9)	7.8
Mixed essential/ nonessential industries	–	29 (11.1)	11.6
Essential industries	–	186 (71.0)	80.6
NAICS industries	–	1057 (100.0)	100.0
Nonessential industries	–	204 (19.3)	12.9
Essential industries	–	853 (80.7)	87.1
	Chemical	16 (1.5)	0.3
	Commercial facilities	66 (6.2)	7.4
	Communications and information technology	8 (0.8)	1.8
	Critical manufacturing	178 (16.8)	4.2
	Defense industrial base	5 (0.5)	0.4
	Education	12 (1.1)	8.4
	Energy	40 (3.8)	1.9
	Financial services	48 (4.5)	6.2
	Food and agriculture	182 (17.2)	15.1
	Hazardous materials	2 (0.2)	0.0
	Healthcare/public health	61 (5.8)	16.9
	Hygiene products and services	6 (0.6)	0.2
	Law enforcement, public safety, and other first responders	8 (0.8)	1.0
	Other community- or government-based operations and essential functions	53 (5.0)	7.4
	Public works and infrastructure support services	23 (2.2)	1.7
	Residential/shelter facilities, housing and real estate, and related services	42 (4.0)	6.1
	Transportation and logistics	100 (9.5)	7.8
	Water and wastewater	3 (0.3)	0.2

TABLE 2 Distribution of census and NAICS industries by essential critical infrastructure industry designation and sector under v4.0 of the Cybersecurity and Infrastructure Security Agency (CISA) advisory list.

*Estimated numbers of U.S. workers in each Census industry[d] were drawn from the NIOSH Employed Labor Force (ELF) Query System.[21] Estimated numbers of U.S. workers in each six-digit North American Industry Classification System (NAICS) industry[c] were drawn from the Quarterly Census of Employment and Wages (QCEW) 2019 annual averages.[18] These estimates do not represent all U.S. workers.

Although the CISA list did not constitute a mandate, it did inform many public health decisions. Some states closely adopted one version of the list or updated orders with the release of new versions, while others devised similar but unconnected orders.[4,9] In addition, the Advisory Committee on Immunization Practices (ACIP) recommended that COVID-19 vaccinations be allocated in part based on ECIW status.[6,7] An adapted extract from a preliminary version of the code set described here was published to support jurisdictions in the

identification of these ECIW sub-populations for initial vaccination planning.[29]

The CISA advisory list is most naturally mapped to industries, but the occupation detail in our code set may shed further light on the kinds of jobs that occur within essential industries. The industry is the type of business in which a person works, while the occupation is the type of work that a person performs. As a result, a single occupation may be present in both essential and non-essential industries. For example, healthcare industry personnel include not only workers in healthcare occupations, but also support staff in healthcare settings who may experience direct or indirect exposure to infectious patients or materials (e.g. environmental, food, and administrative services).[30] Additionally, many workers in grocery stores hold occupations that are common within both essential and non-essential retail settings. The code set outlined here applies industry codes to ensure that workers are appropriately classified according to the CISA guidance. This approach may also allow for site-based research studies and intervention designs among select populations of ECIWs. As one example, all workers at an essential manufacturing facility are considered ECIWs regardless of occupation.

Although the CISA advisory list is highly inclusive and aims to identify all ECIW without discriminating within this population, workers within ECIW industries may face varying SARS-CoV-2 exposure risks. The Brookings Institution defined *frontline workers* as those "within essential industries who must physically show up to their jobs."[31] The National Academies of Sciences, Engineering, and Medicine made a similar distinction, defining *critical workers in high-risk settings* as "workers in industries essential to the functioning of society and at substantially higher risk of exposure," where risk of exposure is determined by inability to work from home or otherwise isolate from potential exposure at work.[5] Ability to telework and potential SARS-CoV-2 exposure risk factors by occupation have been repeatedly characterized.[12,31–35] We encourage the use of the resources in this code set in conjunction with supplemental data sources to further evaluate the ability to telework, infection exposure risk, vaccination coverage, infection incidence, and other factors by occupation within essential critical infrastructure industries as defined by CISA.[36–38] Researchers may use NIOSH's Industry and Occupation Computerized Coding System[28] to crosswalk codes between Census years or to crosswalk Standard Occupational Classification system codes to COCs, NAICS codes to CICs, and the reverse. The Bureau of Labor Statistics' Industry-Occupation Matrix[39] may also be consulted for limited crosstabulations of NAICS and Standard Occupation Classification system codes.

This code set is subject to several limitations. First, our purpose is not to analyze the basis for inclusion or noninclusion of specific worker roles in the original CISA guidance. Second, some six-digit NAICS industries include both essential and nonessential subindustries; we designated NAICS codes as essential if they contained any subindustries that corresponded to ECIW descriptions. As a result, some non-essential sub-industries may be included. Third, mapping of these text descriptions to NAICS and Census codes is subject to interpretation and other mapping approaches may produce slight differences in essential industry designations.[8,9] Fourth, population estimates given for six-digit NAICS industries and CICs are drawn from separate data sources and do not align exactly due to disparate inclusion criteria. Some populations of workers are not captured by the QCEW, including the estimated 9.5 million persons who primarily work as self-employed owners of unincorporated, non-employer businesses.[40] Many of these workers participate in electronically mediated employment, also termed "gig workers."[41] Limitations of each data source are described in detail elsewhere.[19,22,23] Finally, our code set and estimates cover only v4.0 of the CISA advisory list. The list evolved during the pandemic, and the scope of essential work was expanded considerably. Researchers interested in tracking the evolution of mitigation efforts may wish to consult code sets mapping to earlier versions of the CISA advisory list, as well as to state and local orders.[42]

National ECIW designations cannot fully capture the disparate experiences of individual workers during the COVID-19 pandemic but may facilitate evaluation of the impact of the pandemic on some worker populations. Although this code set was initially developed to support real-time data collection and analyses, it may also support retrospective analyses that compare COVID-19 incidence and other factors among subpopulations within the large population of ECIW. Such analyses are needed to inform future classifications of ECIW during public health events, worker protections against epidemics, and allocation of limited public health resources to workers at greatest risk.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

ETHICS APPROVAL AND INFORMED CONSENT

All work was performed at the National Institute for Occupational Safety and Health. This activity was deemed not to be research as defined in 45CFR 46.102(l) and IRB review was not required. See e.g., 45 C.F.R. part 46, 21C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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ENDNOTES

[a] On mismeasurement of occupation in the Current Population Survey, see Abraham and Spletzer[42] and Mellow and Sider.[43]

[b] See e.g., 45 C.F.R. part 46, 21C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.

[c] Estimated numbers of workers in the NAICS industries "Dual-Purpose Cattle Ranching and Farming" and "Offices of Notaries" are not available from the QCEW.

[d] Estimated number of workers in the Census industries "Not specified type of mining", "Not specified machinery manufacturing", "Footwear and leather goods repair", and all US armed forces industries are not available from the ELF Query System.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.