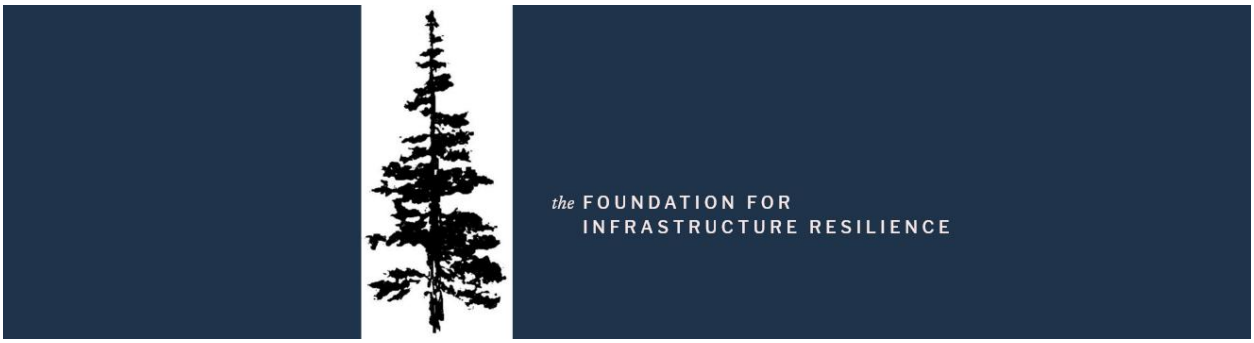

Assessment of Critical Infrastructure with No Grid Power

Stephen Chill

Foundation for Infrastructure Resilience

Introduction

> ***"There is a lack of understanding of the cascading, cross-sector interdependencies between infrastructure and what that means for prioritizing backup generation and other limited resources to maintain services and functions during a long-term, widespread outage."*- The President's National Infrastructure Council**

The purpose of this paper is to assess the Critical Infrastructure (CI) Sectors' "timeframe to failure" in a Black Sky Event (BSE-nationwide or near nationwide grid power outage lasting 30 days) to assist in the understanding of cascading and cross-sector interdependencies in a BSE. This paper demonstrates the fundamental need for a resilient electric grid as none of the fifteen other critical infrastructures can continue to fully function without electricity from the grid. Most fail completely. A small number of CI elements (not the majority of any CI) may continue to function at an insufficient level using on-site natural gas generation, solar, wind, or other sources. This paper demonstrates that all CI rely on the grid.

This paper benefits leaders and planners involved with resilience and continuity of operations for each CI sector or CI element. The Energy Sector is not analyzed as this paper focuses on the impact to the other fifteen sectors by the loss of the grid. Elements of the Energy Sector not contained in the grid are addressed in specific CI (e.g. gas for automobiles is in the Transportation CI).

"Critical infrastructures are those infrastructure systems and assets that are so vital that their incapacitation or destruction would have a debilitating effect on security, the economy, public health, public safety, or any combination thereof." (DHS, CISA).

"CI in a BSE" has been poorly analyzed which contributes to current plans and organizations being "overmatched" by a BSE.[1] There are occasionally "bright spots" of planning and preparation in each CI; however, most plans are dated or insufficient.[2] [3]

The analysis of CI "time to failure" in a BSE has largely been ignored despite the key role time plays in a disaster. Every CI fails without power, the question addressed is "When?". For example, most of the IT Sector likely fails immediately without electricity but the Dams Sector will likely continue to function.

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[1] The Presidents National Infrastructure Advisory Council, Surviving a Catastrophic Power Outage; How to Strengthen the capabilities of the Nation, Dec 2018

[2] Ibid

[3] DHS/CISA, Critical Infrastructure Sectors (plans are located in each sector), https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/critical-infrastructure-sectors

The need for each CI is also based on time. For example, a healthy human can live for weeks without food, but only for days without water[4] thereby making the Water/Wastewater Sector more BSE time-critical than the Food/Agriculture Sector. Every CI is needed, but an analysis focused on time is required to conduct resilience planning.

> ***"Current planning frameworks focus on sector-by-sector preparedness and response, but in a catastrophic power outage, U.S. infrastructure and services will fail as a system. We need to take a systems approach—from the federal level down to the local level—to plan, design, and respond to these never-before-experienced events. This approach must move beyond existing planning and response frameworks and provide the guidance needed for an integrated cross-sector, cross-government strategy."*** **- The President's National Infrastructure Council**

Sector Analysis

In order to analyze CI timeframes, one must define the CI, deconstruct each CI into its elements (subsectors), and determine supporting infrastructures. This paper therefore defines/describes each CI with their sub and supporting elements. "Time to failure" is then portrayed and assessed. Understanding the timelines of CI failure in a BSE will assist in BSE (and other disaster) planning.

Failure means the majority of that sector or subsector is unable to perform the majority of its function. Consideration is given to the capability of sector specific backup power.

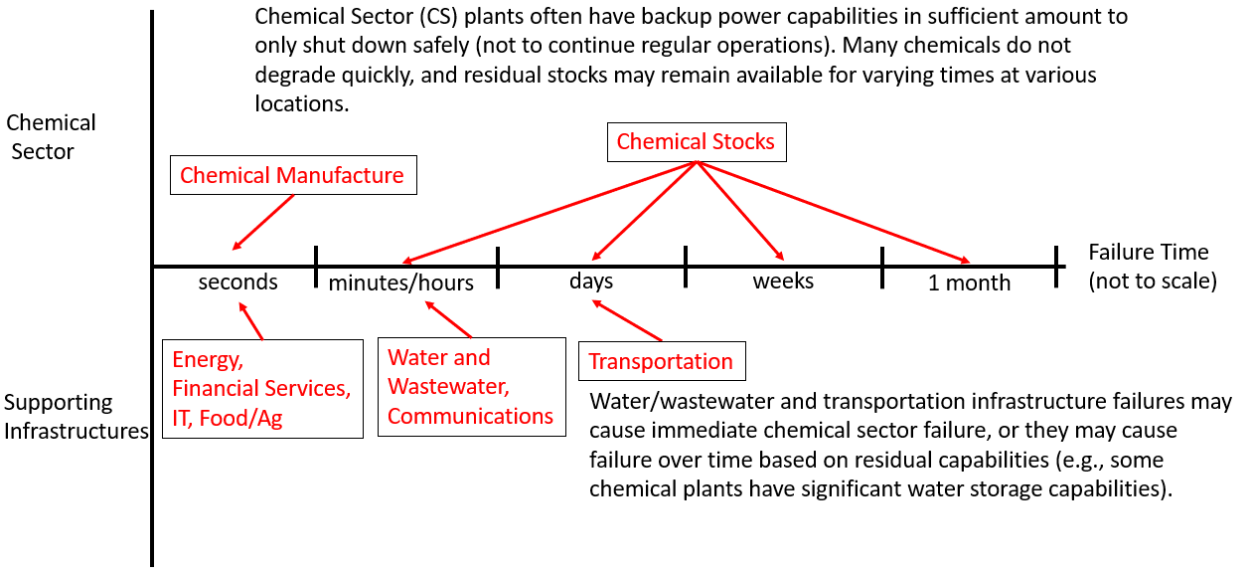
Subsectors are the main elements of the CI that, if failing, would cause the CI to fail. Assessed subsector timelines to failure are at the top of each timeline diagram (see below). Subsector elements assessed failure timelines may be used to plan sector resilience/continuity. If there is no plan to address CI subsectors, the sector will likely fail in a BSE.

Supporting CI (the bottom half of each diagram) shows the assessed failure times of supporting CI. Supporting CI are required for a given CI to function. The impact of the loss of supporting CI is not necessarily felt right away. For example, most water treatment systems have stocks of chemicals on-hand, so the immediate failure of the Chemical Sector will impact water treatment only when stored stocks are depleted and no more chemicals are coming from factories. If unaddressed, supporting CI will cause the given CI to fail anywhere from seconds to weeks (not depicted).

Diagram Example: The Chemical Sector Diagram is depicted below. The Chemical Sector subsectors are chemical plants and chemical stocks (located on the top with arrows depicting assessed BSE failure timelines). The Chemical Sector supporting CI are located on the bottom

[4] FEMA, FEMA NATIONAL US&R RESPONSE SYSTEM STRUCTURAL COLLAPSE TECHNICIAN , https://www.fema.gov/pdf/emergency/usr/appen_b.pdf

with their own assessed failure timelines (note that supporting CI will not necessarily cause the Chemical CI to fail in the same "failure time").



Communications, Energy, Financial Services, and IT are required for the administration of most CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. These CI are important for CI survival while other CI (e.g., Water) are more important for human survival. As humans are a required element of each CI, food and water become Supporting CI for all other CI.

Sectors are identified as local, regional, or national to assist in assigning planning responsibility. For example, if a CI is national, national planning should occur as well as regional and local planning. If it is local, then local planning is required. For example, wastewater treatment plants require local planning as there is no national wastewater system while the Finance CI requires a national plan.

A brief impact statement for the failure of each CI is included as is a brief recommendation for each CI based on the failure timeline.

Additional Considerations

In addition, the following entities are important in analyzing the impact timelines of BSE in the US (these are not official Critical Infrastructures):

- People: People are an element of all CI, and their survival needs to be considered within each CI. For example, a water treatment plant may want to have its personnel and families live at the treatment plant in a BSE (some have planned for this). Much of

"power out" planning focuses on human survival vs CI survival. Humans can generally survive for 3 days without water or 3 weeks without food.[5] As people are an element of each CI, there is a first order need for food and water in each CI. Family concerns and widespread societal panic that could lead to desperate behavior, to include looting, rioting and violence, may keep people away from their CI posts (exacerbating CI failure). CI personnel may have old, sick (to include medicated), and very young dependents that have more pressing needs earlier in a BSE. Shelter may be a necessity. Many books and recommendations for family preparedness have been published (to include by FEMA[6]) but it is improbable that preparedness of CI individuals and families can be accurately determined (until an actual emergency occurs). In addition, it is unclear how many CI workers will show up to work without some form of compensation (finance).

- Fuel: Fuel is not a CI, but elements of the fuel system are included in several CI. Transportation includes rail, barge/ship, and truck transportation for fuels. Many CI and individuals have backup generation, but the lack of fuel will restrict their usage. If gas stations and bulk fuel distributors are not functioning, then all CI that depends on backup generation will not have (or run out of) the fuel required to function (Commercial facilities, communications (for credit cards) and finance generally are required for the normal function of gas stations.[7]). Previous power outages have shown that gas for automobiles/trucks and generators is generally unavailable.[8] This problem remains.[9] Superstorm Sandy demonstrated the need for backup power, especially for the fuel industry.
- Backup generation: Many CI have elements that have backup generation. If CI have backup generation, then their "time to failure" is extended. If CI have fuel storage for their backup generation, then their "time to failure" is further extended. There are no CI that have full backup generation for all elements. Some CI have sufficient backup power to last hours and days, but no CI has sufficient backup power to last weeks (due to lack of on hand fuel). A CI plan that relies on continuous fuel resupply for backup generation is assessed as unlikely (due to the failure of CI that are required for continuous

[5] FEMA, FEMA NATIONAL US&R RESPONSE SYSTEM STRUCTURAL COLLAPSE TECHNICIAN , https://www.fema.gov/pdf/emergency/usr/appen_b.pdf

[6] FEMA, Build a Kit, https://www.ready.gov/kit

[7] FEMA, Power Outage, Keep Vehicles Fueled, https://community.fema.gov/ProtectiveActions/s/article/Power-Outage-Keep-Vehicles-Fueled#:~:text=%E2%80%9CKeep%20your%20car%20fuel%20tank,Several%20Minutes%20or%20Several%20Days

[8] FEMA, Power Outage, https://community.fema.gov/ProtectiveActions/s/article/Power-Outage-Keep-Vehicles-Fueled

[9] The Presidents National Infrastructure Advisory Council, Surviving a Catastrophic Power Outage; How to Strengthen the capabilities of the Nation, Dec 2018, page 30 https://www.cisa.gov/sites/default/files/publications/NIAC%2520Catastrophic%2520Power%2520Outage%2520Study_FINAL.pdf

resupply). In addition, Superstorm Sandy showed that backup generators require significant maintenance when in constant use.[10]

- Military: The Military role in a BSE is governed by the same processes and procedures that apply to hurricanes and other natural disasters.[11] In sum, the US Military relies on other local/state/federal organizations for the welfare of its personnel and families that live off-installation (approximately 70 percent[12] of its force). In modern times, the military has not responded to community needs until a DSCA (Defense Support of Civilian Authorities) request is approved.[13] Certain commanders do have the ability to respond to emergencies without DSCA approvals.[14] There is currently no published military plan that addresses a BSE despite the severe impact it would have on military personnel and the infrastructure required to support military bases.
- Governance: As with the Military, continuity plans that address governance are inadequate for a BSE. Some agencies will have a skeletal capability to function, but the ability to support the population with required governance in a BSE is deficient.[15] [16]

Recommendations

Plan for a BSE. Subsector elements and supporting CI may be used to organize planning for sector resilience (see Food/Ag Sector for example). If there is no plan to address subsector elements or supporting CI, the sector will fail in a BSE.

There is a lack of redundancy throughout CI (e.g., each household taps into one water system and if that system fails to produce, there is no alternate system). Increasing sector redundancy while eliminating single points of failure will increase CI resilience.

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[10]P CISA, Resilient Power Best Practices for Critical Facilities and Sites with Guidelines, Analysis, Background Material, and References 61, ttps://www.cisa.gov/sites/default/files/2023-03/CISA_Resilient_Power_Best_Practices_for_Critical_Facilities_and_Sites_508c.pdf

[11] Congressional Research Service, Defense Primer: Defense Support of Civil Authorities, https://crsreports.congress.gov/product/pdf/IF/IF11324#:~:text=Courts%20have%20generally%20construed%20this,and%20criteria%20for%20handling%20requests.

[12] US Dept of Housing and Urban Development, Community Housing Impacts of the Military Housing Privatization Initiative, p 1, https://www.huduser.gov/portal/sites/default/files/pdf/insight_3.pdf

[13] DODD 3025.18, Defense Support to Civil Authorities, https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/302518p.pdf

[14] Congressional Research Service, Defense Primer: Defense Support of Civil Authorities, https://crsreports.congress.gov/product/pdf/IF/IF11324#:~:text=Courts%20have%20generally%20construed%20this,and%20criteria%20for%20handling%20requests.

[15] The Presidents National Infrastructure Advisory Council, Surviving a Catastrophic Power Outage; How to Strengthen the capabilities of the Nation, Dec 2018, page 10 https://www.cisa.gov/sites/default/files/publications/NIAC%2520Catastrophic%2520Power%2520Outage%2520Study_FINAL.pdf

[16] DHS/CISA, Critical Infrastructure Sectors (plans are located in each sector), https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/critical-infrastructure-sectors

CI are most often considered individually instead of as "strands" of mutually supporting CI. National, state, and local planning should prepare using a "mutually supporting CI" approach.

Explore increasing natural gas generation and solar generation that does not rely on the grid or grid power (based on CI requirements).

Summary Table

The following table summarizes the assessed general failure times for each CI without power. The United States Government published an Energy Sector Specific Plan (SSP) that includes wording stating that each sector is reliant on energy/electricity.[17] While the reliance on electricity was clearly stated, the timeline to failure was not. This table summarizes the assessed "times to failure" based on the more detailed CI analysis contained herein. These failure summaries are assessed for the majority of the CI (every sector will have some well-prepared entities).

Critical Infrastructure (CI)	Failure Within Seconds	Failure Within Minutes/hours	Failure Within Days	Limited Failure
Chemical				
Commercial Facilities				
Communications				
Critical Manufacturing				
Dams				
Defense Industrial Base				
Emergency Services				
Energy				
Financial Services				
Food and Agriculture				
Government Facilities				
Healthcare				
Information Technology				
Nuclear				
Transportation				
Water and Wastewater				

[17] FEMA, DHS, Energy Sector Specific Plan, p 19, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-energy-2015-508.pdf

Notes:

"The NIPP [National Infrastructure Protection Plan] 2013 identifies lifeline functions— water, transportation systems, communications, and energy—as services and resources that are essential to the operations of most critical infrastructure partners and communities."[18]

Most Sector Strategic Plans contain a section describing sector dependencies. These provide the bulk of the sector interdependencies discussed in this paper.

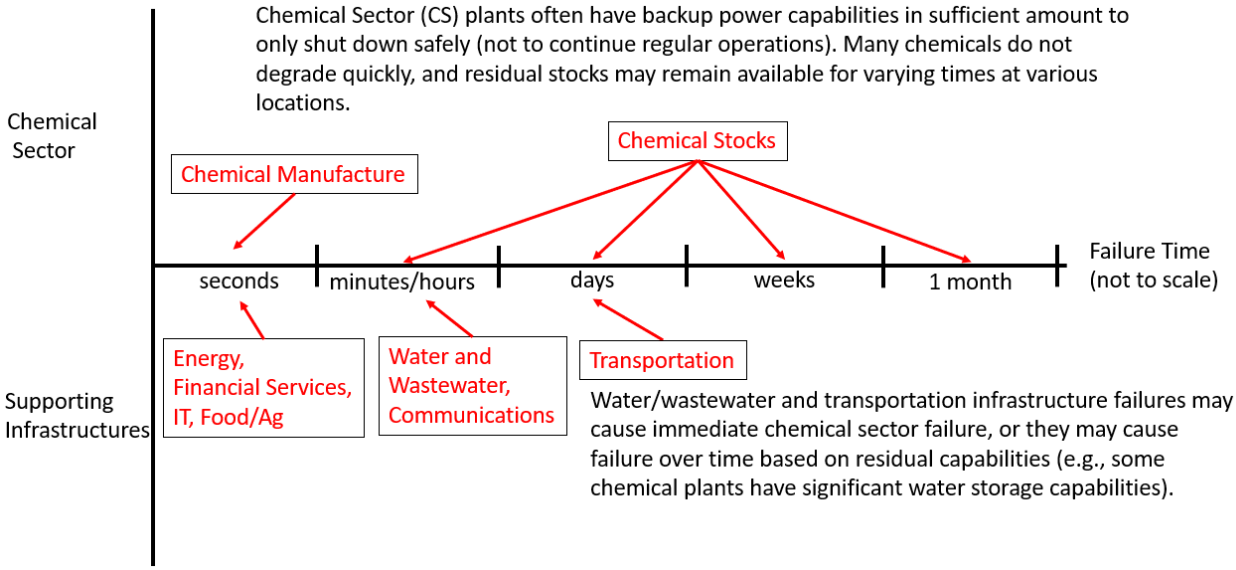
The Financial Services Sector is normally ignored in most Sectors. This paper includes Financial Services in each CI as a "Supporting CI" (except Emergency Services). All CI include personnel who require paychecks (Assumption: Most ES personnel will report for duty without pay…for a period of time). All CI require the ability to pay bills, invoices and conduct other purchase/sell transactions. Required payments don't become free in a power outage.

No backup effort is considered effective unless it has been planned for and at least partially rehearsed. For example, a food warehouse that relies on IT to receive invoices is not considered functional by simply stating that warehouses can use paper invoices and manual accounting; they have to plan and rehearse this option for it to be viable.

[18] DHS, Chemical Sector Specific Plan, 2015, p 5, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-chemical-2015-508.pdf

Chemical Sector

Define/Describe CI: "The Chemical Sector converts raw materials into more than 70,000 diverse products and is a major component of the U.S. economy, contributing approximately 25 percent of the Nation's gross domestic product (GDP). The Chemical Sector employs nearly 800,000 workers who manufacture, store, and transport chemicals to customers in multiple critical infrastructure sectors. About 96 percent of U.S. goods in 2013 were manufactured using Chemical Sector products, making uninterrupted chemical production and transportation essential for national and economic security."[19] "A chemical plant may include such equipment as reactor vessels, filters, compressors, pumps, valves, furnaces, fractionating columns, generators, centrifuges, stripping units, blenders, mixers, evaporators, distillation columns, heat exchangers, storage tanks, pipelines and other similar equipment."[20] The chemical sector is one of the top energy consuming CIs. The chemical sector includes pharmaceuticals, agricultural pesticides, fertilizer, and everyday household products.[21] Many chemical plants (less than 50%) use a direct supply of natural gas to run their own power generation. Some also generate electricity by using waste heat from their own chemical processes (called CHP or "Combined Heat and Power").



[19] DHS, Chemical Sector Specific Plan, 2015, p v, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-chemical-2015-508.pdf

[20] James LeBlanc, Chemical, in "Powering Through; Building Critical Infrastructure Resilience", editor Mary Lasky, (NDRC, 2021), p 273

[21] DHS, Introduction to Chemical SSA, https://www.cisa.gov/sites/default/files/publications/chemical-ssa-fact-sheet-2017-508.pdf

Failure timeline: (subsectors sourced from Chemical SSP[22], chemical transportation included in Transportation section) Chemical plants will generally fail in their primary mission (producing chemicals) within seconds of a power outage.[23] "Most chemical facility operators have developed sound contingency plans for responding to various types of plant utility interruptions, including electric power outages."[24] Those plants that use natural gas for power generation may last longer as natural gas will be able to continue to flow (based on non-electric compressor stations and residual natural gas pressure in pipelines). These procedures are not always tested and sometimes they fail, causing harmful toxic chemical release.[25] Most chemicals have a lengthy shelf life and can last months. Other CI failure times due to chemical sector failure will vary based on the chemical and the CI need.

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the chemical sector to fail)

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Chemical: Chemicals are required as both elements of other chemicals as well as parts of a chemical development process (e.g., lubricants for machines). On-hand stocks will shape chemical plant failure times due to lack of chemicals.
- Energy: Energy is required to operate chemical plants and the chemical distribution system.
- Information Technology (IT): IT is required in many chemical factories (e.g., SCADA data systems).
- Transportation: Transportation is required to move chemical products. Natural gas is required to manufacture many chemical products, either as feed stock or fuel.
- Water and Wastewater (WW): Water is required to process many chemicals and is an element of many chemicals.

[22] DHS, Chemical Sector Specific Plan, 2015, p v, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-chemical-2015-508.pdf

[23] EPA, Chemical Accidents from Electric Power Outages, Sept 2001 (updated 2023), p 2, https://www.epa.gov/sites/default/files/2013-11/documents/power.pdf

[24] EPA, Chemical Accidents from Electric Power Outages, Sept 2001 (updated 2023), p 3, https://www.epa.gov/sites/default/files/2013-11/documents/power.pdf

[25] EPA, Chemical Accidents from Electric Power Outages, Sept 2001 (updated 2023), p 1-2, https://www.epa.gov/sites/default/files/2013-11/documents/power.pdf

Sort into local or regional or National entities. Most chemical plants require raw materials and other chemicals from all over the country if not overseas.[26] From 2018 to 2019 "U.S. general imports of chemicals and related products increased by $9.7 billion (3.1 percent) to $320.1 billion."[27] Chemicals are used locally but the supply chain may be local to national.

Impact of this CI with no power. (to CI and to society) The chemical sector with no power is often an underappreciated problem. For example, most drinking water requires chlorine.[28] Most food contains chemicals.[29] Without power the chemical sector fails causing the "lifeline" CIs (and the Chemical CI) to rely on "on-hand" stocks. Chemical plants that do not execute their shutdown procedures correctly may discharge toxic chemicals causing widespread illness/death.[30] Nearby or adjacent water ways could become contaminated. A no-power scenario would have a gradual impact on the availability of chemicals as on-hand stocks are depleted.

Conclusion

- **Summary**: Assessment: The chemical sector will fail in seconds. Several of the interdependencies that the chemical sector relies upon will fail within seconds. The lack of chemicals will cause an ever-increasing impact on other CI as stocks dwindle. Some chemicals are understood to be more important than others (e.g., chlorine), but the analysis of chemical requirements during a BSE has not been done.
- **Point towards broad solutions:** Analysis (including exercises) is required to determine the type and amounts of chemicals that critical infrastructures need to keep on-hand for a BSE. Alternatives to these required chemicals should be identified. On-hand stocks should be increased to allow continued CI functionality in a BSE. Critical chemical plants should be identified and plans for continued production should be established. A corresponding effort for the entire chemical sector supply chain should be undertaken.

[26] DHS, Chemical Sector Specific Plan, 2015, p 2 and 5, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-chemical-2015-508.pdf

[27] US International Trade Commission, Chemicals and Related Products, https://www.usitc.gov/research_and_analysis/trade_shifts_2019/chemicals.htm

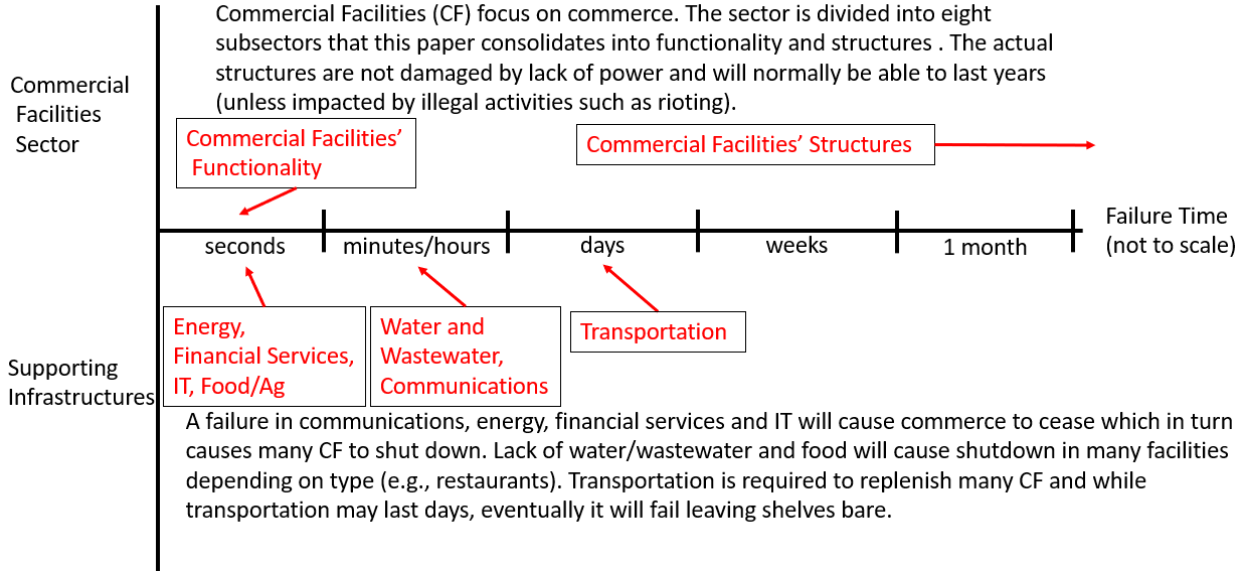
[28] CDC, Drinking Water, 2024, https://www.cdc.gov/drinking-water/about/about-water-disinfection-with-chlorine-and-chloramine.html?CDC_AAref_Val=https://www.cdc.gov/healthywater/drinking/public/water_disinfection.html

[29] Academy of Nutrition and Dietetics, Buyer Beware: 60% of Foods Purchased by Americans Contain Technical Food Additives — a 10% Increase Since 2001, Mar 2023, https://www.eatrightpro.org/about-us/for-media/press-releases/60-percent-of-foods-purchased-by-americans-contain-technical-food-additives

[30] EPA, Chemical Accidents from Electric Power Outages, Sept 2001 (updated 2023), p 1-2, https://www.epa.gov/sites/default/files/2013-11/documents/power.pdf

Commercial Facilities (CF) Sector

Define/Describe CI: "The Commercial Facilities (CF) Sector is made up of an extremely diverse range of sites and assets where large numbers of people congregate daily to conduct business, purchase retail products, and enjoy recreational events and accommodations…. The sector is divided into eight subsectors—Entertainment and Media, Gaming, Lodging, Outdoor Events, Public Assembly, Real Estate, Retail, and Sports Leagues—to facilitate coordination among facilities with similar functions, operations, and security issues."[31]



Failure timeline: (subsectors consolidated from CF SSP) CF will generally fail in their primary mission (commerce) within seconds of a power outage. "Without power, many facilities could not function for an extended period of time, as access to backup power is often limited in scope."[32] The structures will generally remain unaffected unless impacted by illegal activities such as rioting.

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the CF sector to fail). CF facilities often overlap with other CI (e.g., a food warehouse is part of the Food/Agriculture sector but also part of the CF sector).

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.

[31] DHS, Commercial Facilities Sector Specific Plan, 2015, page v, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-commercial-facilities-2015-508.pdf

[32] DHS, Commercial Facilities Sector Specific Plan, 2015, page 13, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-commercial-facilities-2015-508.pdf

- Food and Agriculture: Many CF focus on food and many others have food as an element. However, many do not require food as part of their operations.
- Transportation: Transportation is required to move products to and from CF.
- Water and Wastewater (WW): Fresh water and wastewater support is required at many CF for humans as well as for product development.

Sort into local or regional or National entities CF are most often locally focused. Major CF (e.g., major warehouses, or large corporate headquarters) may service regions or even the entire nation.

Impact of this CI with no power (to CI and to society) Commerce is how a capitalist society distributes goods. Without functioning commercial facilities an alternate commerce structure will be required to deliver the same goods. While the sports/entertainment CF may not be critical, the lodging, real estate and retail CFs provide shelter, medicine, and food for tens of millions.[33] Media facilities, such as those in the Emergency Alert System, provide critical information during crises.[34] These services would not be available without functional facilities.

Conclusion

- **Summary**: Assessment: The Commercial Facilities sector will fail within seconds without power. The residual products in these facilities may prove to be very beneficial in a BSE. Many products (medications, food items, etc.) will last for days/weeks with no power, but they will degrade over time. The buildings, cooking facilities, hardware (and other non-perishables) can last for years. Looting that often accompanies power outages would impact CF in a BSE.
- **Point towards broad solutions:** Critical commercial facilities should be identified and prioritized for power/fuel (e.g., radio stations or commercial urgent care facilities). Critical products within commercial facilities should be identified (e.g., drug stores for pharmaceuticals or hardware stores for generators). Planning should support these critical facilities.

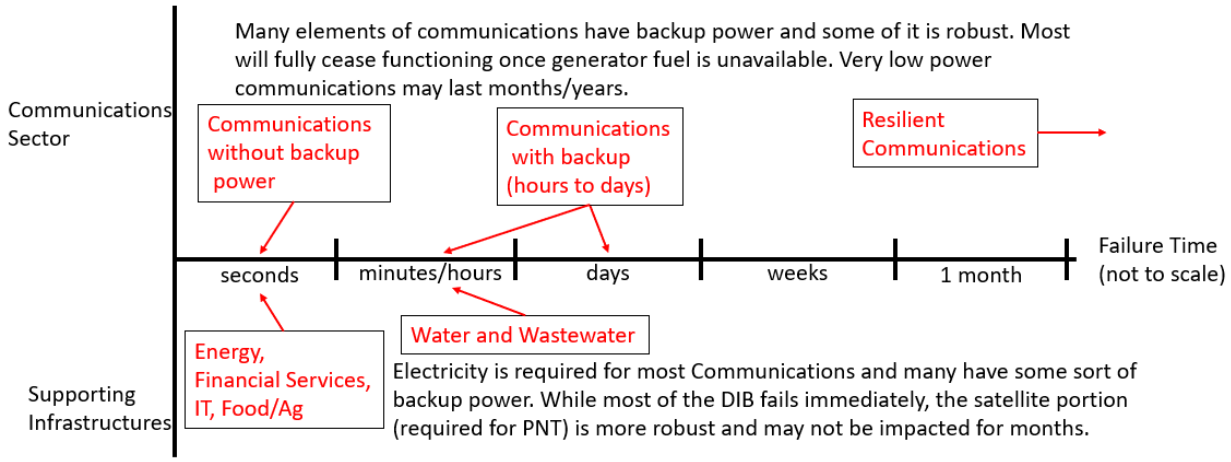
[33] DHS, Commercial Facilities Sector Specific Plan, 2015, page 3, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-commercial-facilities-2015-508.pdf

[34] FCC, The Emergency Alert System, 2024, https://www.fcc.gov/emergency-alert-system

Communications (Comm) Sector

Define/Describe CI: "The national communications architecture is a complex collection of networks that are owned and operated by individual service providers, consisting of three main functional areas: Services and Applications, Core Network, and the five segments' Access Networks."[35] The IT Sector overlaps Communications Services and Applications. The core network can be defined as "the high-functioning communication facilities that interlink the primary nodes."[36] "The five segments of the Communications sector are: broadcasting, cable, satellite, wireless, and wireline."[37] The five segments below[38] are generally described as:

- Broadcast: over-the-air radio and TV
- Cable: digital video programming services, digital telephone service, and high-speed broadband services.
- Satellite: a platform launched into orbit to relay voice, video, or data signals as part of a telecommunications network. Satellites provide Position, Navigation and Timing (PNT) capability.
- Wireless: telecommunication in which electromagnetic waves (rather than some form of wire) carry the signal over part of or the entire communication path (e.g., cell phones).
- Wireline: circuit- and packet-switched networks via copper, fiber, and coaxial transport media (e.g., most of the internet).



Failure timeline: (subsectors consolidated from Comm SSP) The Comms SSP is one of the few CIs that addresses loss of electricity: "On a national level, a geomagnetic solar super storm,

[35] DHS, Communications SSP, 2015, p 4, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-communications-2015-508.pdf
[36] Tata Communications, What is a Core Network and How Does It Work, 2023, https://www.tatacommunications.com/knowledge-base/network-core-network-explained/
[37] DHS, Communications SSP, 2015, p 3, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-communications-2015-508.pdf
[38] DHS, Communications SSP, 2015, p 6-7, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-communications-2015-508.pdf

such as the one in July 2012, could cause an electromagnetic pulse that collapses electric power grids and triggers a long-term outage (LTO) in national communications."[39] The communications sector will have elements fail immediately and other elements with backup generators will last until generator fuel runs out: "While backup generation provides power needed to operate in the short term or safely shutdown a facility, an LTO would significantly disrupt operations."[40]

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the Comms sector to fail)

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Communications: The communications sector requires other comms to carry out communications for the Nation (e.g., PNT from satellites).
- IT: Not only do comms provide IT, but comms also requires IT for system functions. Undersea cable communications are heavily reliant on electricity.

Sort into local or regional or National entities Communications have National (e.g., satellite), regional (e.g., regional cable), and local capabilities (e.g., local broadcast).

Impact of this CI with no power (to CI and to society) The resilience to a BSE of comms nodes differs significantly. For example, satellites do not require electricity so satellite phones could contact satellites as long as they had battery power. Satellite ground stations that receive satellite signals, however, require generator power during a power outage. Many communications assets have some sort of backup power, but that backup often requires fuel: "The Communications Sector generally relies on diesel fuel to power its backup generators and the Transportation Sector to deliver those fuels."[41] Once the fuel runs out, most comms will fail. Once communications fail, most other CI fail. One often overlooked element of communications is the comms required for every credit card transaction.[42] Without these comms, credit cards are rendered useless.

Conclusion

- **Summary**: Assessment: The Communications sector will have elements that fail immediately without electricity. Robust generator capability in this sector will allow for many elements to continue operations for hours/days. The lack of fuel and the inability

[39] DHS, Communications SSP, 2015, p 7, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-communications-2015-508.pdf

[40] DHS, Communications SSP, 2015, p 9, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-communications-2015-508.pdf

[41] DHS, Communications SSP, 2015, p 9, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-communications-2015-508.pdf

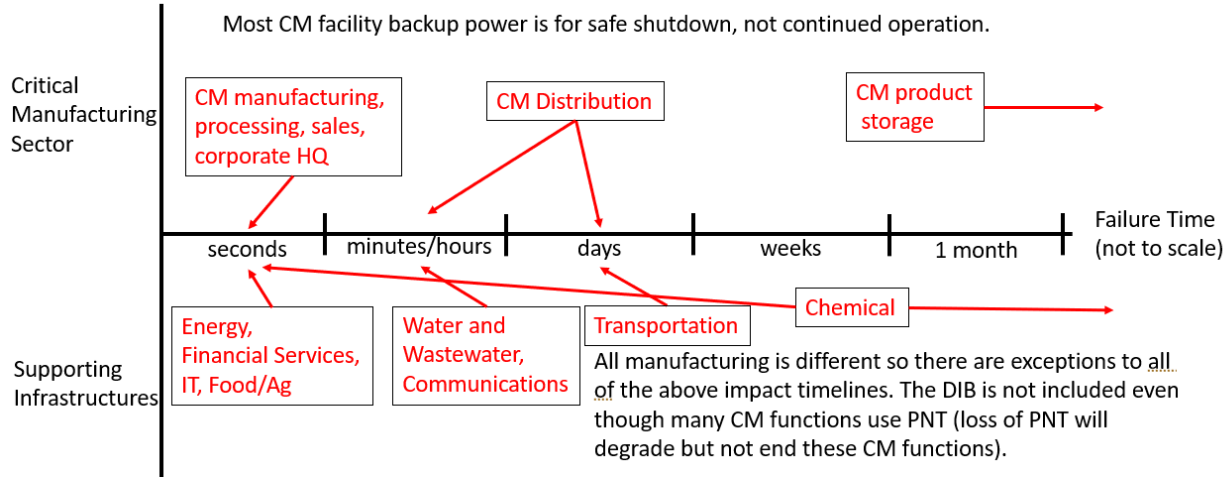
[42] Kagan, J., Investopedia, Credit Card Authentication: What It Is and How It Works, 2023, https://www.investopedia.com/terms/c/credit-card-authentication.asp#:~:text=Every%20credit%20card%20transaction%20is,who%20they%20say%20they%20are.

to rely on constant generation usage will degrade this CI over a period of days leaving only some residual capability (e.g., HAM radio or Satellite phones).

- **Point towards broad solutions:** Communications nodes are ubiquitous. Key nodes should be identified for power based on a larger survivability and recovery plan. Emergency communications nodes and procedures exist for broad messaging, and these should be maintained (e.g., keeping AM radio requirements in commercial vehicles). A BSE should prompt immediate communications actions that provide guidance before the Communications CI severely degrades.

Critical Manufacturing (CM) Sector

Define/Describe CI: "The Critical Manufacturing Sector…includes the manufacturing industries that are the most crucial for the continuity of the other critical sectors and have significant national economic implications. Manufacturers in the sector process raw materials and primary metals; produce engines, turbines, and power transmission equipment; produce electrical equipment and components; and manufacture cars, trucks, commercial ships, aircraft, rail cars, and their supporting components."[43] CM assets "include manufacturing facilities, processing and distribution facilities, sales offices, corporate headquarters, and product storage."[44]



Failure timeline: (subsectors sourced from CM SSP) The CM Sector will start to fail immediately. "Shut down procedures" for manufacturing facilities may often be conducted by on-site generation, but full operational capability does not exist without grid electricity: "Manufacturers require large amounts of uninterrupted power for operations. Although backup generation provides power needed to operate during short-term disruptions to safely shutdown a facility, a long-term outage would significantly disrupt operations."[45] Those facilities that use natural gas for power generation may last longer as natural gas will be able to continue to flow (based on non-electric compressor stations and residual natural gas pressure in pipelines). On-hand stocks and products in the supply chain will mitigate some of the effects of an immediate shutdown. Processing, sales, and corporate HQs will cease functioning immediately as they require IT, comms and finance. Distribution continuity will depend on other CI such as transportation. Most CM products in storage can remain in storage for well over 30 days. Manufacturing that relies upon very high pressures, extreme temperatures, or large volumes of pressurized liquids or gases may not safely shut down and could cause uncontrolled releases of feed stock or product into the nearby area, to include water ways and atmosphere.

[43] DHS, CISA, Critical Manufacturing Sector Specific Plan, p 1, https://www.cisa.gov/sites/default/files/publications/critical-manufacturing-ssp-2015-fact-sheet-v2-508.pdf
[44] Ibid, p iv
[45] DHS, CISA, Critical Manufacturing Sector Specific Plan, p 6, https://www.cisa.gov/sites/default/files/publications/critical-manufacturing-ssp-2015-fact-sheet-v2-508.pdf

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the CM sector to fail)

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Chemical: Chemicals are critical for many CM manufacturing efforts but are often stored in bulk at manufacturing facilities. On-hand stocks will determine failure times.
- Energy: Energy is required to operate facilities. This includes the energy required in ports for mass onload/offload of CM products.
- Transportation: Transportation is required to move CM products. Natural gas is required to manufacture many products, either as feed stock or fuel.
- Water and Wastewater (WW): Water is required in most CM manufacturing and processing.

Sort into local or regional or National entities. Most CM plants require materials from all over the country if not overseas: "The Transportation Systems Sector—also a lifeline function—enables the global movement of large and specialized materials and products on strict timelines. Manufacturers depend on multiple modes of transportation (aviation, freight rail, highway, and maritime) for the secure movement of raw materials and finished products—key components of their operations."[46] Manufacturing, processing, and storage tend to be local affairs. Sales, finance, and distribution tend to be national.

Impact of this CI with no power. (to CI and to society) The CM sector is critical in the Energy, Transportation and Defense Industrial Base Sectors. The international impact would be significant (both export and import). Short-term recovery (less than 30 days) from a BSE may not depend on the CM sector, but longer-term recovery does as many CI are dependent on CM.[47]

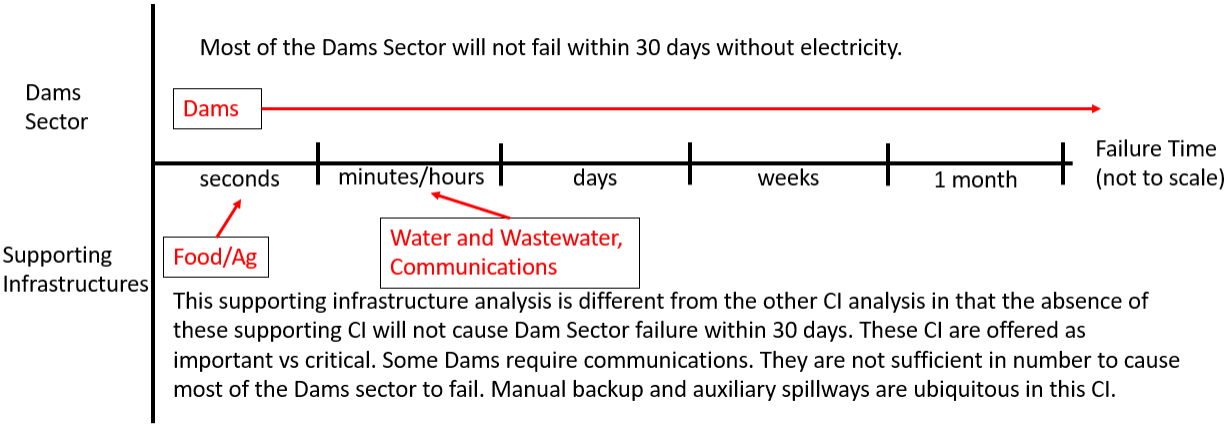
Conclusion

- **Summary**: Assessment: The CM sector is a critical sector that will fail in seconds. The lack of a functioning CM sector will be more significant over time as CM products fail (e.g., new engines to replace unrepairable engines). Existing products in the CM supply chain will mitigate many aspects of the loss of the rest of the CM sector.
- **Point towards broad solutions:** CM uses large amounts of power. Most CM will not be required immediately in a BSE. The CM that is required should be identified for recovery priorities. For example, a BSE would cause transformer problems so transformer manufacturing should be a priority. Local CM storage facilities and their products should be identified for local/regional BSE recovery efforts.

[46] Ibid, p 7
[47] Ibid, p iv

Dams Sector

Define/Describe CI: The Dams Sector "delivers critical water retention and control services in the United States, including hydroelectric power generation, municipal and industrial water supplies, agricultural irrigation, sediment and flood control, river navigation for inland bulk shipping, industrial waste management, and recreation… Dams Sector assets irrigate at least 10 percent of U.S. cropland, help protect more than 43 percent of the U.S. population from flooding, and generate about 60 percent of electricity in the Pacific Northwest."[48] "There is a large diversity of Dams Sector operations and controls. Some Dams Sector facilities use manual controls, electromechnical controls, and/or onsite or remote industrial control systems to monitor and control key operations."[49]



Failure timeline. Most dams will not fail due to a lack of electricity. Dam failure is defined as: "Catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water or the likelihood of such an uncontrolled release. It is recognized that there are lesser degrees of failure and that any malfunction or abnormality outside the design assumptions and parameters that adversely affect a dam's primary function of impounding water is properly considered a failure. These lesser degrees of failure can progressively lead to or heighten the risk of a catastrophic failure. They are, however, normally amenable to corrective action."[50] Dams primary function is to impound water, and there is a robust emergency action effort in the dam sector that mitigates harmful flooding.[51] "31% of dams have a high or significant hazard potential if they fail or misoperate."[52] Even the dams that "misoperate" have emergency procedures that allow for continued operation. Dam resilience is beneficial as Dams are considered a valuable asset to help "Black Start" the grid.

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[48] DHS, CISA, Dams SSP Fact Sheet, p 1, https://www.cisa.gov/sites/default/files/publications/dams-ssp-fact-sheet-2015-508.pdf

[49] DHS, CISA, Dams SSP, p 2, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-dams-2015-508.pdf

[50] [50] FEMA, Emergency Operations Planning: Dam Incident Planning Guide, Nov 2019, p 50, https://www.fema.gov/sites/default/files/2020-08/dam_incident_planning_guide_2019.pdf

[51] FEMA, Federal Guidelines for Dam Safety, Dec 2023, https://damtoolbox.org/images/f/f6/FEMA_P-93_2023_Document.pdf

[52] DHS, CISA, Dams SSP, p 3, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-dams-2015-508.pdf

Describe CI Interdependencies: (first order interdependencies that, if failing, will cause the Dams sector to fail). The Dams Sector has significant variations in assets and these varying assets are governed by various authorities including States, FERC, federal entities, and municipalities.[53] The Dams sector writ large will not fail due to CI failures that impact other CI. Manual backup procedures mitigate many automated procedures. However, some individual dams will experience difficulties and may fail. Food/Ag and Water are required to maintain the human element of each CI.

Sort into local or regional or National entities: Dams are local/regional and should be incorporated into planning at those levels.

Impact of this CI with no power: Dams will not fail within 30 days. A failure in the rest of the energy sector will not allow generation from dams to reach consumers.

Conclusion

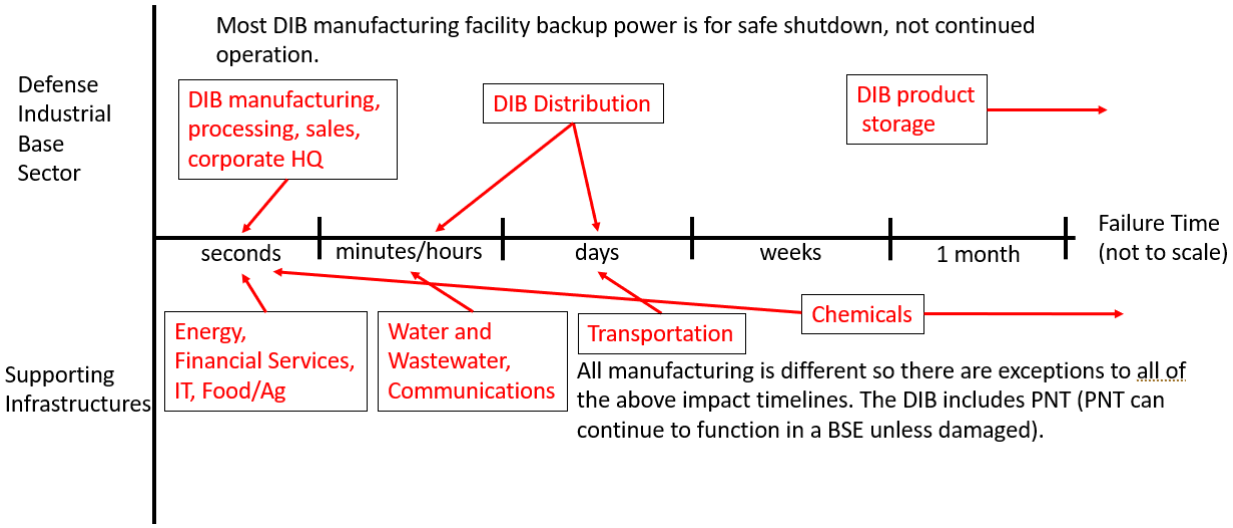
- **Summary**: Dams are the most resilient CI as they are solid structures often constructed to operate independently. Assessment: Manual controls and spillways prevent Dam Sector failure in a BSE. The retention of water occurs based on the existence of dams, not the interaction of dams with other CI. Emergency planning for dams has yielded procedures and construction (e.g., auxiliary spillways) that mitigate dam lack of electricity.[54] Dams are often providers of electricity and if damaged will not be able to continue providing power.
- **Point towards broad solutions:** Dams should be established as black start assets wherever possible.

[53] DHS, CISA, Dams SSP, p 2, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-dams-2015-508.pdf

[54] FEMA, Emergency Operations Planning: Dam Incident Planning Guide, Nov 2019, https://www.fema.gov/sites/default/files/2020-08/dam_incident_planning_guide_2019.pdf

Defense Industrial Base (DIB) Sector

Define/Describe CI "The DIB Sector is the worldwide industrial complex that enables research and development (R&D), as well as design, production, delivery, and maintenance of military weapons systems, subsystems, and components or parts, to meet U.S. military requirements. The DIB partnership consists of the DoD components and DIB companies which prioritize and coordinate protection of DIB Critical Infrastructure and Key Resources (CIKR). The private sector component of the DIB consists of hundreds of thousands of independent and competing domestic and foreign companies…"[55] The DIB CIKR extends outside the United States.



Failure timeline. (DIB subsectors are similar to CM subsectors). The DIB Sector will start to fail immediately. The US DIB overlaps the Critical Manufacturing Sector therefore the comments here are similar. "Shut down procedures" for manufacturing facilities may often be conducted by on-site generation, but full operational capability does not exist without grid electricity. "Manufacturers require large amounts of uninterrupted power for operations. Although backup generation provides power needed to operate during short-term disruptions to safely shutdown a facility, a long-term outage would significantly disrupt operations."[56] Those plants that use natural gas for power generation may last longer as natural gas will be able to continue to flow (based on non-electric compressor stations and residual natural gas pressure in pipelines). On-hand stocks and products in the supply chain will mitigate some of the effects of an immediate shutdown. Processing, sales, and corporate HQs will cease functioning immediately (see Commercial Facilities CI). The continuance of distribution will depend on other CI such as transportation. Most DIB products in storage can remain in storage for well over 30 days. Manufacturing that relies upon very high pressures, extreme temperatures, or large volumes of pressurized liquids or gases may not safely shut down and could cause uncontrolled releases of feed stock or product into the nearby area, to include water ways.

[55] DHS, DOD, Defense Industrial Base Sector Specific Plan, p 2, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-defense-industrial-base-2010-508.pdf

[56] DHS, CISA, Critical Manufacturing Sector Specific Plan, p 6, https://www.cisa.gov/sites/default/files/publications/critical-manufacturing-ssp-2015-fact-sheet-v2-508.pdf

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the DIB to fail). DIB contracts may require more resilience than CM contracts, but the DIB will still fail in a BSE.

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Chemical: Chemicals are critical for many DIB manufacturing efforts but are often stored in bulk at manufacturing facilities. On-hand stocks will determine failure times.
- Energy: Energy is required to operate facilities. This includes the energy required in ports for mass onload/offload at DIB facilities.
- Transportation: Transportation is required to move DIB products. Natural gas is required to manufacture many products, either as feed stock or fuel.
- Water and Wastewater (WW): Water is required in most DIB manufacturing and processing.

Sort into local or regional or National entities. Most DIB plants require materials from all over the country if not overseas.[57] Manufacturing, processing, and storage tend to be localized unless an overseas DIB effort is established. Sales, finance, and distribution tend to be national (DOD).

Impact of this CI with no power (to CI and to society) The DIB end user is the DOD, therefore, most of the DIB does not service other CI. PNT is supported by the DIB so all organizations that depend on PNT depend, in part, on the DIB. Overseas contracts and support can mitigate portions of the DIB in a BSE.

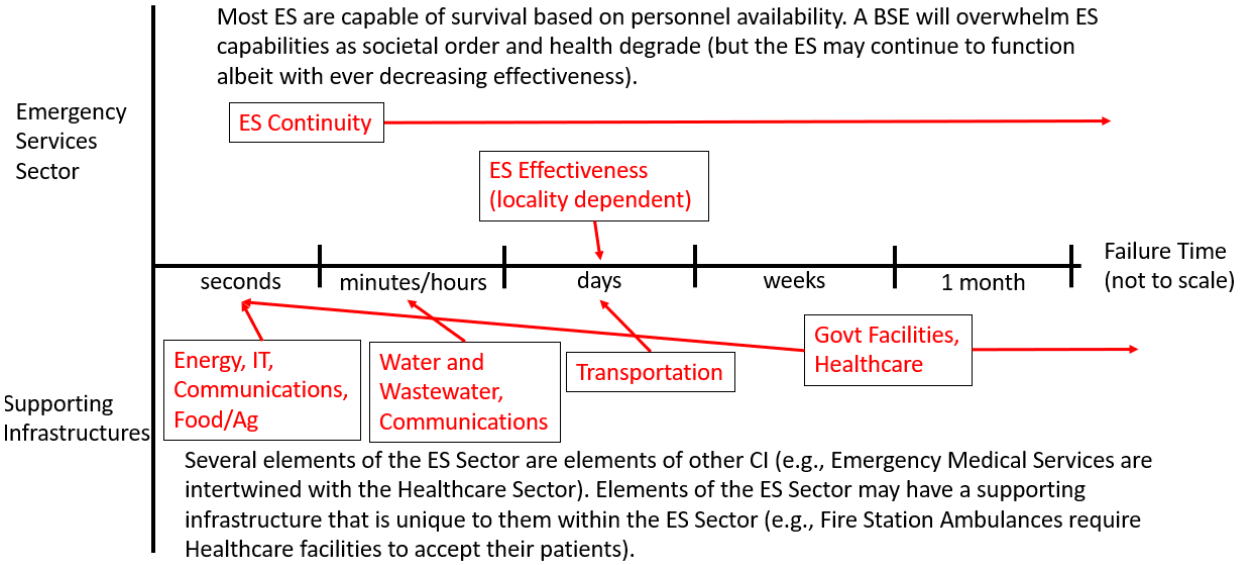
Conclusion

- **Summary**: Assessment: The US DIB will, for the most part, fail within seconds in a BSE. The DIB directly supports the DOD; therefore, the impact is focused on the DOD and not society writ large. The DOD maintains stocks and equipment backup so the loss of the DIB may not be as significant to society as the loss of other CI. It is not known if the DOD has classified plans for BSE survival, although the viability of classified plans is in doubt as few CI personnel hold clearances that would allow viewing of said plans.
- **Point towards broad solutions:** DOD policy should be developed to include the possibility of a BSE. On-hand stocks, over-reliance on just-in-time logistics, and operations conducted in severe scarcity should be topics for DOD planning.

[57] DHS, DOD, Defense Industrial Base Sector Specific Plan, p 69, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-defense-industrial-base-2010-508.pdf

Emergency Services (ES) Sector

Define/Describe CI: The ES Sector consists of Law Enforcement, Fire and Emergency Services, Emergency Management, Emergency Medical Services, and Public Works (the ES Sector also has several lesser specialized capabilities).[58] "The sector focuses primarily on the protection of other sectors and people, rather than protecting the sector itself"[59] Mutual-Aid agreements are often used to increase the size of response efforts.[60] Mutual aid, however, is conditioned on the support not being committed to its own emergency in its own area. A BSE that hits the entire country simultaneously will pose problems for any ES that expects aid from anywhere. Public Works (an ES function) overlaps other CI (e.g., a ruptured public water pipeline is both a public works issue and water issue).[61]



Failure timeline: (subsectors primarily sourced from ES SSP) ES may continue to function in a BSE, but capabilities will continue to degrade over time (an assumption was made that ES personnel will continue to perform their missions without pay for a period of time in a BSE). Most ES use the number of emergencies as a factor to determine the size of the day-to-day ES.[62] The number of emergencies (e.g., fires or criminal incidents) can be forecasted and normally do not unexpectedly change rapidly. When large, unexpected threats occur, ES limited

[58] DHS, Emergency Services SSP, p 1, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf
[59] Ibid, p 2
[60] DHS, Emergency Services SSP, p 20, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf
[61] DHS, Emergency Services SSP, p 15, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf
[62] DHS, Emergency Services SSP, p 2, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf

resources may be challenged and unable to protect against the threat.[63] A BSE presents an unexpected change, therefore while ES may continue to survive for over a month, their effectiveness degrades rapidly.

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the Emergency Services sector to fail)

- Communications, Energy, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Assumption: ES personnel will continue to work for a period even if the financial system is down and they can't be paid. Food/Ag and Water are required to maintain the human element of each CI.
- Communications: Law Enforcement, Fire and Emergency, Emergency Medical Services and to a lesser extent Emergency Management and Public Works all rely on communications from the public. Internal comms is required for dispatching/managing assets.
- Energy: Fuel reserves/storage will determine the availability of most ES. Many ES functions have special government-only fueling stations.[64]
- Government Facilities: Facilities require energy (may not have an immediate direct impact).
- Healthcare: EMS require a Healthcare destination for their patients.
- Transportation: Transportation is required for all ES Services.
- Water and Wastewater (WW): Water is required for Fire and Emergency Services.

Sort into local or regional or National entities ES are largely local functions, so local readiness for a BSE will dictate survivability and effectiveness. Mutual assistance agreements may broaden ES capabilities from local to regional.

Impact of this CI with no power (to CI and to society) ES is more energy independent than most CI as it is a human-centric CI. ES hold society together. Lawlessness, sickness, and general chaos can be anticipated without adequate ES.

Conclusion

- **Summary**: Assessment: The ES Sector is capable of some continued functionality during a BSE, but that functionality depends on the amount of local preparation that has been conducted. The lawlessness anticipated during a BSE will impact all other CI personnel. The "duty focus" nature of CI personnel may keep ES personnel available (perhaps for the entire 30 days). Their continued availability in a BSE should not be assumed.
- **Point towards broad solutions:** Few ES plans exist for a BSE. They should be created and rehearsed. Civilian support for law enforcement will be required.

[63] DHS, Emergency Services SSP, p 4, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf

[64] Philadelphia Police Department, Directive 4.4, https://www.phillypolice.com/assets/directives/D4.4-ObtainingFuelFromCityRefuelingStations.pdf

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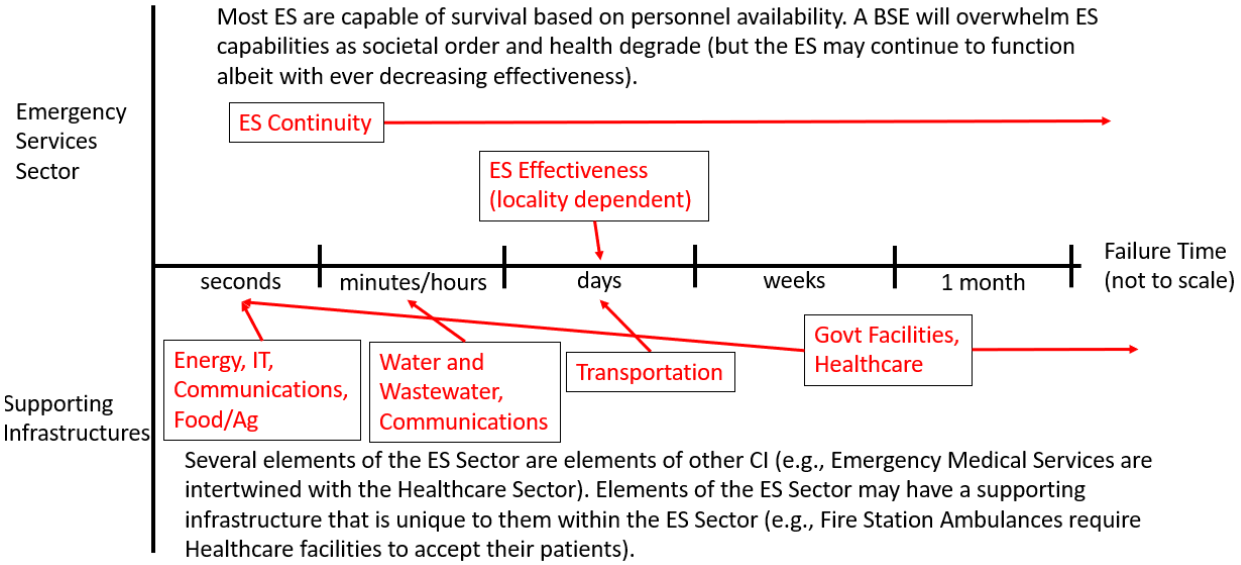

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[65] DHS, Emergency Services SSP, p 1, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf
[66] Ibid, p 2
[67] DHS, Emergency Services SSP, p 20, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf
[68] DHS, Emergency Services SSP, p 15, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf
[69] DHS, Emergency Services SSP, p 2, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf

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Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the Emergency Services sector to fail)

- Communications, Energy, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Assumption: ES personnel will continue to work for a period even if the financial system is down and they can't be paid. Food/Ag and Water are required to maintain the human element of each CI.
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- Energy: Fuel reserves/storage will determine the availability of most ES. Many ES functions have special government-only fueling stations.[71]
- Government Facilities: Facilities require energy (may not have an immediate direct impact).
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Sort into local or regional or National entities ES are largely local functions, so local readiness for a BSE will dictate survivability and effectiveness. Mutual assistance agreements may broaden ES capabilities from local to regional.

Impact of this CI with no power (to CI and to society) ES is more energy independent than most CI as it is a human-centric CI. ES hold society together. Lawlessness, sickness, and general chaos can be anticipated without adequate ES.

Conclusion

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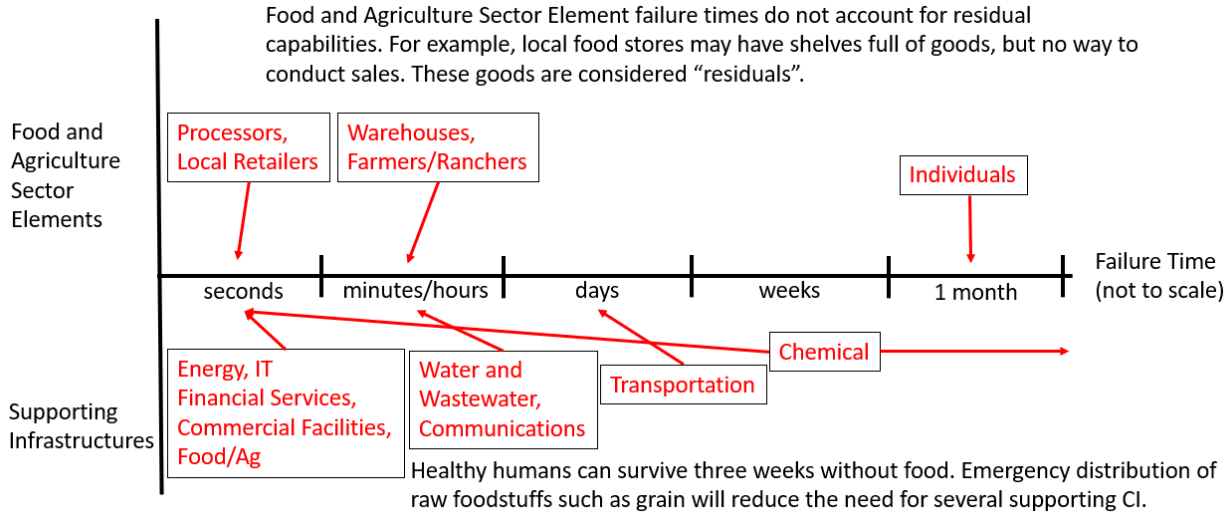
[70] DHS, Emergency Services SSP, p 4, https://www.cisa.gov/sites/default/files/publications/emergency-services-sector-specific-plan-112015-508.pdf

[71] Philadelphia Police Department, Directive 4.4, https://www.phillypolice.com/assets/directives/D4.4-ObtainingFuelFromCityRefuelingStations.pdf

Food and Agriculture Sector

Define/Describe CI "The food sector generally extends from farmers/ranchers to processors/distributers, to warehouses, through retailers (local stores and restaurants), and finally to the individual consumer."[72] Some capability exists even if all of these elements are not fully functional (e.g., a pig farmer may butcher his own pigs for food). Each element also will have residual food that may be charitably donated in a BSE. Charitable donations and residuals will ensure elements of the food sector remain viable for a period of time (see failure timeline below). The food structure in the United States eventually fails without any of the following elements:

- Farmers/Ranchers grow and raise unprocessed agriculture/meat/fish products.
- Processors take raw agriculture/meat/fish, combine them with other raw and finished products (e.g., salt, chemicals, wrapping) to form a shelf-ready product
- Warehouses store food products from processors prior to retail.
- Local Retailers sell foodstuffs to consumers and may process some foods (e.g., store bakery or butcher). Restaurants are also retailers.
- Individuals consume foodstuffs. Many family households have larders and refrigerators with sufficient food to avert starvation for weeks. Others don't. The average individual can last weeks without food, but most equate food with survival and food violence must be anticipated in a BSE.



Failure timeline. (subsectors sourced from Powering Through, Building Critical Infrastructure) Healthy adults can live 21 days without food.[73] The sick, elderly, and young cannot live as

[72] Chill S et al, Food and Ag, in "Powering Through; Building Critical Infrastructure Resilience", editor Mary Lasky, (NDRC, 2021), p 143

[73] Kottusch, Tillmann, Puschel. 2009. Survival Time Without Food and Drink. NIH, National Library of Medicine. https://pubmed.ncbi.nlm.nih.gov/20069776/

long.[74] Even though most people in the US will be able to survive one month with minimal food, many will die within that month (there are over 13 million Americans over 80 years old[75] and approximately 7 million under the age of 2[76]). The Food CI degrades immediately upon losing power due to immediate cessation of communications, energy, financial services, and IT. Processing plants are a form of manufacturing (see Critical Manufacturing section). Food warehouses are commercial facilities (see CF section) and may be able to ship and receive goods for a short period of time if they are already administratively processed (farmers and ranchers may similarly be able to ship for a short period of time). Residual food in all elements of the food system will create a slow vs immediate degradation of the individual ability to survive. A more detailed analysis of the food sector is discussed below.

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the food sector to fail)

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Chemical: Chemicals are required in feed and agriculture and are required for processing/packaging foodstuffs.
- Commercial Facilities(CF): CF are required to warehouse and sell foodstuffs.
- Communications: Communications are required between every element of the food sector to coordinate onward movement of products but also to enable electronic transactions (including financial) to take place.
- Energy: Energy is required to operate every element of the food sector except individuals (individual's frozen foods will spoil without refrigeration).
- Financial Services(FS): FS are required to conduct transactions between every food sector element. Charity is the alternative.
- Food and Agriculture (FA): It takes food and agriculture to make all but the most basic foodstuffs (e.g., meat or rice).
- Transportation: Transportation is required to move products between every element of the food sector.
- Water and Wastewater (WW): Water is required as an ingredient of most foodstuffs but is also required for processing.

Sort into local or regional or National entities Interstate shipping and rail has made the food sector a national sector. There are regional/local aspects (warehousing, local retailers, and individuals). Most regions of the Country have the capability to source from local farms/ranches.

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[74] Brink, S, NPR, What Happens To The Body And Mind When Starvation Sets In?, 20 Jan 2016, https://www.npr.org/sections/goatsandsoda/2016/01/20/463710330/what-happens-to-the-body-and-mind-when-starvation-sets-in

[75] Statista, Resident population of the United States by sex and age as of July 1, 2023, https://www.statista.com/statistics/241488/population-of-the-us-by-sex-and-age/

[76] Stobbe, M, AP News, US Births Fell Last Year, Marking an End to the Late Pandemic Rebound, Experts Say, https://apnews.com/article/how-many-babies-are-born-us-25d99f438645908e5ed6ae29d3914b89

Impact of this CI with no power (to CI and to society) The lack of a functioning food sector will cause starvation. All US residents require food and only a very small portion of residents are involved in food production. The rest rely on the output of the food sector. It is logical to estimate millions of deaths would occur without a functioning food sector. The weak (old and very young) are the most vulnerable. Violence is to be expected as hunger sets in.[77] Residual food in the various food elements may hold off this expected violence. Even the strong will weaken without food.

Conclusion

- **Summary**: The food sector will start failing in seconds in a BSE. Several of the CIs that the food sector relies upon will fail immediately, but the impact of food sector failure (starvation) will not be immediately felt. Each element of the food sector has some resilience and humans have a natural ability to survive without food for weeks. Food will become more important over time. Violence should be anticipated.
- **Point towards broad solutions:** A "survival" level food sector is very different from the "luxury" level food sector Americans currently experience. Planning is required to achieve a survival level food sector. Emergency stocks should be redeveloped (done in the past). Local produce should feed local populations (e.g., cattle feeds Texans, fruits and vegetable feed southern Californians, fish feeds coastal communities). Plans should be developed for a local/regional/national level "skeleton structure" of survival level elements of the food sector (from farm/ranch to distribution). Coastal cities should plan/organize for emergency food imports.

More Detailed Analysis

The list below contains basic planning considerations for each of the Food/Ag subsectors. The list was created by templating each subsector against key supporting infrastructures (sourced from previous sections). The resultant list contains Food/Ag planning considerations required to function in a BSE. Many considerations are critical for continuity of operations and therefore, if not planned for, will cause subsector or entire Food/Ag CI failure. Planners should conduct a similar identification process for each CI.

The red highlighted items below indicate the elements of the Food and Agriculture CI that will cease immediately without electricity. If there are no plans that take effect immediately, then the subsector or CI ceases to function. For example, checkout counters in food stores require electricity to determine prices and process payments (credit card, debit card, digital wallet). If there is no plan for checkout counters (point of sale systems and payment processing), then food stores cease to adequately function severely impacting the viability of the entire Food/Ag CI.

[77] Sova, C. and Zembilci, E., CSIS, Dangerously Hungry: The Link between Food Insecurity and Conflict, https://www.csis.org/analysis/dangerously-hungry-link-between-food-insecurity-and-conflict

Farmers/Ranchers

- IT-farming management tools (e.g., soil tracking, automated equipment), supply chain management, market access/e-commerce, climate weather prediction, regulatory compliance
- Financial Services-access to credit, insurance, loan payment, banking services (accept and make payments including payroll and supplier payments), globalized export exchange
- Commercial Facilities-some storge and warehousing before sale
- Food/Ag-seed, feed, some fertilizer
- Water/Wastewater-crops, livestock, cleaning, aquaculture, wastewater management
- Communications-large farm/ranch coordination, IT and financials support
- Transportation-inputs (seed, feed, fertilizer), harvest (use and movement of machinery), movement to market/processors, worker movement
- Chemical-pesticides, herbicides, fertilizers, cleaning/sterilization products

Processors (Energy for machinery for processing, cooking, cleaning)

- IT-production control, quality control, supply chain management, factory automation, security
- Financial Services- access to credit, insurance, loan payment, banking services (accept and make payments including payroll and supplier payments)
- Commercial Facilities-manufactured products inputs (e.g., packaging for finished food products), testing facilities
- Food/Ag-farmer/rancher inputs, semi-finished food products (e.g., flour for noodles)
- Water/Wastewater-product ingredient, cleaning (W&WW), cooking (W&WW), processing (W&WW), on-site wastewater treatment
- Communications-internal employee and safety coordination, supply chain coordination, automation and control systems, IT and financials support
- Transportation-raw material supply, semi-finished product supply, in-plant movement, product distribution, waste management
- Chemical-food additives (e.g., preservatives), cleaning and sanitation, packaging

Warehouses

- IT-warehouse management systems, automation, temperature control, inventory management, security
- Financial Services-access to credit, insurance, loan payment, banking services (accept and make payments including payroll and supplier payments), leasing and asset finance
- Commercial Facilities-food warehouses may act as fulfillment centers
- Food/Ag-Many foodstuffs may bypass processing and go directly to warehouses (e.g., fresh fruits)

- Water/Wastewater-cleaning
- Communications- internal employee and safety coordination, supply chain coordination, automation and control systems, IT and financials support
- Transportation-reception and distribution of products
- Chemical-cleaning, pest control

Retailers

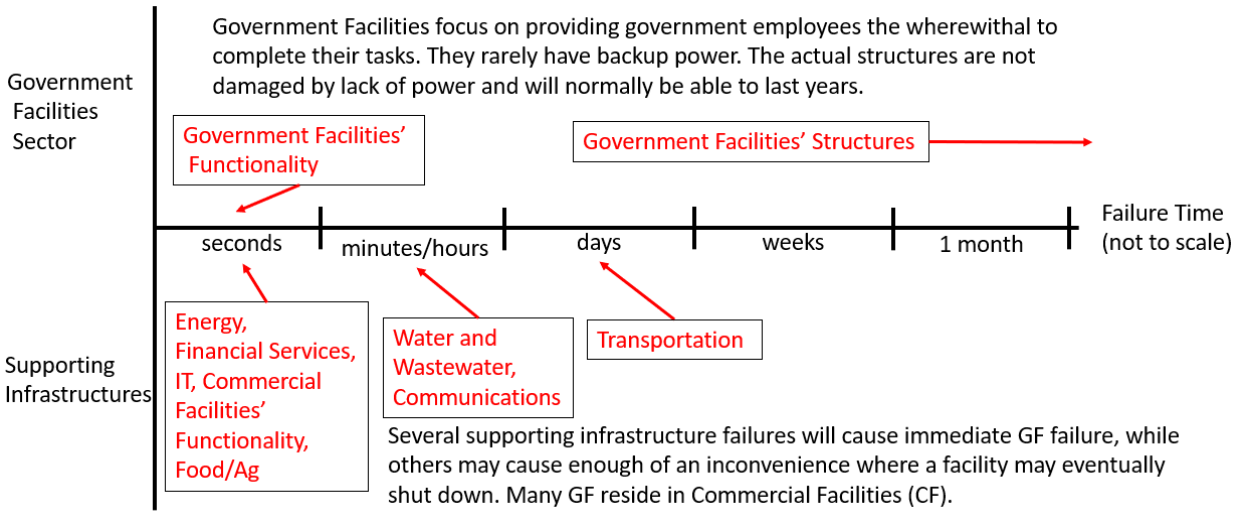
- IT-inventory management, point of sale systems, online shopping and delivery, security
- Financial Services-payment processing, insurance, banking services (accept and make payments including payroll and supplier payments)
- Commercial Facilities- cold storage, food processing, sales
- Food/Ag-fresh produce, processed goods
- Water/Wastewater-cleaning (equipment, produce, floors) (W&WW), baking/prepared foods, cooling
- Communications-employee coordination, supplier and vendor coordination, IT and financials support
- Transportation-product reception, online and call-in delivery
- Chemical-cleaning, pest control

Individuals

- IT-remote purchasing
- Financial Services-payment processing, banking services (make payments, accept payroll)
- Commercial Facilities-n/a
- Food/Ag-home gardening
- Water/Wastewater-cleaning/preparing food
- Communications-remote purchasing
- Transportation-product reception, product transport
- Chemical-n/a

Government Facilities (GF) Sector

Define/Describe CI: "The Government Facilities Sector (GFS) includes more than 900,000 constructed assets owned or operated by the Federal Government alone. The assets owned or operated by the 56 States and territories, 3,031 counties, 85,973 local governments, and 566 federally recognized tribal nations also fall in the purview of the GFS. In addition, the GFS comprises two subsectors: Education Facilities (EF) and National Monuments and Icons (NMI)."[78] Many Government Facilities are also (or also have) elements of other Critical Infrastructure Sectors (e.g., a health clinic within a government facility continues its ties to the Healthcare CI).



Failure timeline: (subsectors consolidated from GF SSP and mirror CF subsectors) GF will generally fail in their primary mission (generally described as housing and enabling government functions) within seconds of a power outage. GF (as with CF) are mandated to maintain emergency power capabilities according to National Fire Protection Association Code 70 (National Electric Code, Article 700). "The purpose of an emergency system isn't to provide power for normal business operations — it's to provide lighting and controls essential for human life."[79] GF structures will generally remain unaffected unless directly damaged.
Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the GF sector to fail). GF facilities often overlap with other CI (e.g., a food store is part of the Food/Agriculture sector but may also be a government store located in a GF).

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.

[78] DHS, CISA, Government Facilities SSP, 2015, p 1. https://www.cisa.gov/sites/default/files/2023-03/nipp-ssp-government-facilities-2015-508.pdf
[79] Holt, M, Article 700: Emergency Systems, 2006, https://www.ecmweb.com/national-electrical-code/code-basics/article/20891942/article-700-emergency-systems

- Financial Services: Most GF rely on civilian infrastructures for support (requiring financial transactions).
- Transportation: Transportation is required to move personnel to and from GF.
- Water and Wastewater (WW): Fresh water and wastewater support is required at many GF. Limited functionality will continue without water.

Sort into local or regional or National entities Federal GF are administered nationally. State GF are administered by State. Local GF are administered locally.

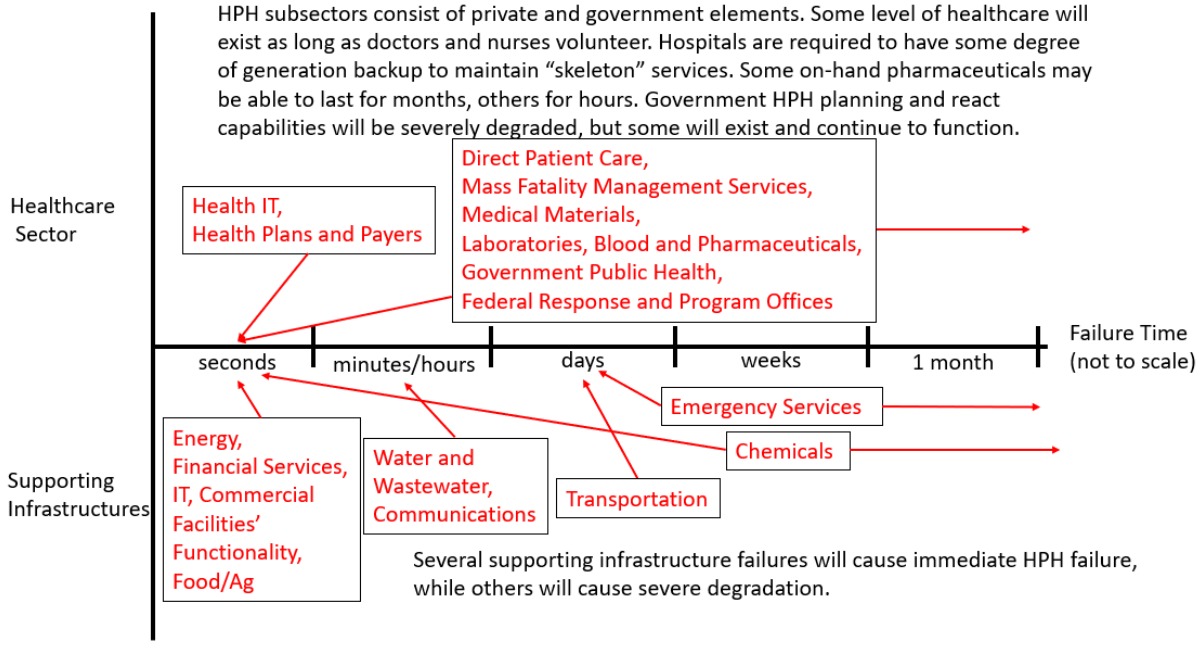
Impact of this CI with no power (to CI and to society) GF house not only the people who make government work, but also the functions of government. Those functions degrade/cease without GF. Many colleges host millions of students that would have no way home in a BSE. Functionality of prisons/jails becomes extremely difficult without power.

Conclusion

- **Summary**: Assessment: The GF Sector will continue to physically exist without power, but functionality will degrade and/or cease in in seconds during a BSE. The GF Sector is ubiquitous throughout society and the different GFs will have different levels of functionality without power.
- **Point towards broad solutions:** GFs have the potential to be the backbone of BSE response planning. Many GFs can host their employees and families in a BSE. Some cannot (e.g., The Pentagon). Planning and preparation for each GF (as well as the Government) should occur. Governments should determine government functions that may be done manually and prepare accordingly.

Healthcare (sometimes referred to as Healthcare and Public Health (HPH)) Sector

Define/Describe CI: "The HPH Sector provides goods and services integral to maintaining local, national, and global health security."[80] "The HPH Sector is large, diverse, and open, spanning both the public and private sectors. It includes publicly accessible healthcare facilities, research centers, suppliers, manufacturers, and other physical assets and vast, complex public-private information technology systems required for care delivery and to support the rapid, secure transmission and storage of large amounts of HPH data. Access to healthcare is critical in maintaining national health security…"[81] The HPH SSP is one of the few that discusses EMP impact: "In particular, the Nation's power grid is at risk of being damaged or rendered ineffective by the effects of an EMP—a sudden burst of electromagnetic radiation (pulse) resulting from a natural or manmade event…Depending on the impact area, an EMP event could be catastrophic for healthcare facilities, causing long-term power outages that may overwhelm the Sector's backup power sources."[82]



Failure timeline: (subsectors sourced from HPH SSP) Many aspects of the HPH sector will fail in seconds in a BSE. Other aspects of HPH will have a robust capability for hours as services are gradually curtailed.[83] Facilities will remain, but without power they will become less useful. Doctors and nurses can perform their duties "manually", but without modern facilities and equipment, their capability will be vastly reduced (if they continue to work at all). It is unclear

[80] DHS/CISA, Healthcare SSP, 2016, p 3, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-healthcare-public-health-2015-508.pdf
[81] Ibid, p 4
[82] Ibid, p 10
[83] DHS/CISA, Healthcare SSP, 2016, p 12, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-healthcare-public-health-2015-508.pdf

how many hospitals have planned to function for 30 days or more without electricity. Many standards reference a need for up to 96 hours of backup power.[84] Pharmaceuticals will run out over time as supply chains are disrupted (adding more patients).[85] A lack of clean drinking water for the entire population will cause mass casualties, adding to healthcare burdens.
Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the HPH sector to fail). HPH facilities often reside in Commercial Facilities. HPH, as a whole, have better procedures for power outages than most CI.

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Electronic patient records may be unavailable. Food/Ag and Water are required to maintain the human element of each CI.
- Emergency Services: ES is a personnel heavy infrastructure. Without pay (financial services) personnel will have to work voluntarily. Voluntary ES (similar to voluntary HPH) personnel may maintain some ES functionality.
- Transportation: Transportation is required to move personnel to and from HPH.
- Water and Wastewater (WW): Fresh water and wastewater support is required at HPH facilities as well as for the entire population. Bad drinking water will cause mass casualties, overwhelming an already taxed BSE HPH sector.

Sort into local or regional or National entities Most of the HPH sector is local. Access to supplies (e.g., medications, medical supplies) may be regionally or nationally sourced.
Impact of this CI with no power (to CI and to society) "About 60% of adults aged 18 and over reported taking at least one prescription medication in 2021, with 36% reporting taking three or more."[86] Without a functioning HPH sector, these medications will run out (some faster than others). "Every year in the United States, there are about 36 million hospital stays."[87] This equates to approximately ten percent of the US population. The lack of medications and hospital care will cause mass deaths, even without considering disease, lack of clean water, food, and violence (all of which will tax the HPH Sector in a BSE).
Conclusion

- **Summary**: Assessment: The HPH sector has a robust short-term capability in a BSE (hours) but as time passes, generator fuel and other support will run out. The healthcare sector is massive and impacts much of the US society on a regular basis. Voluntary healthcare efforts may succeed in the short term, but mass casualties should be

[84] Mackey, P, Hospital Emergency Power Supply Systems, 2022 https://www.csemag.com/articles/hospital-emergency-power-supply-systems/
[85] DHS/CISA, Healthcare SSP, 2016, p 9, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-healthcare-public-health-2015-508.pdf
[86] Mykyta and Cohen, NCHS, Characteristics of Adults Aged 18–64 Who Did Not Take Medication as Prescribed to Reduce Costs: United States, 2021, June 2023, https://www.cdc.gov/nchs/data/databriefs/db470.pdf
[87] OASH, HHS, Hospital and Emergency Services, https://health.gov/healthypeople/objectives-and-data/browse-objectives/hospital-and-emergency-services#:~:text=Every%20year%20in%20the%20United,about%2036%20million%20hospital%20stays.

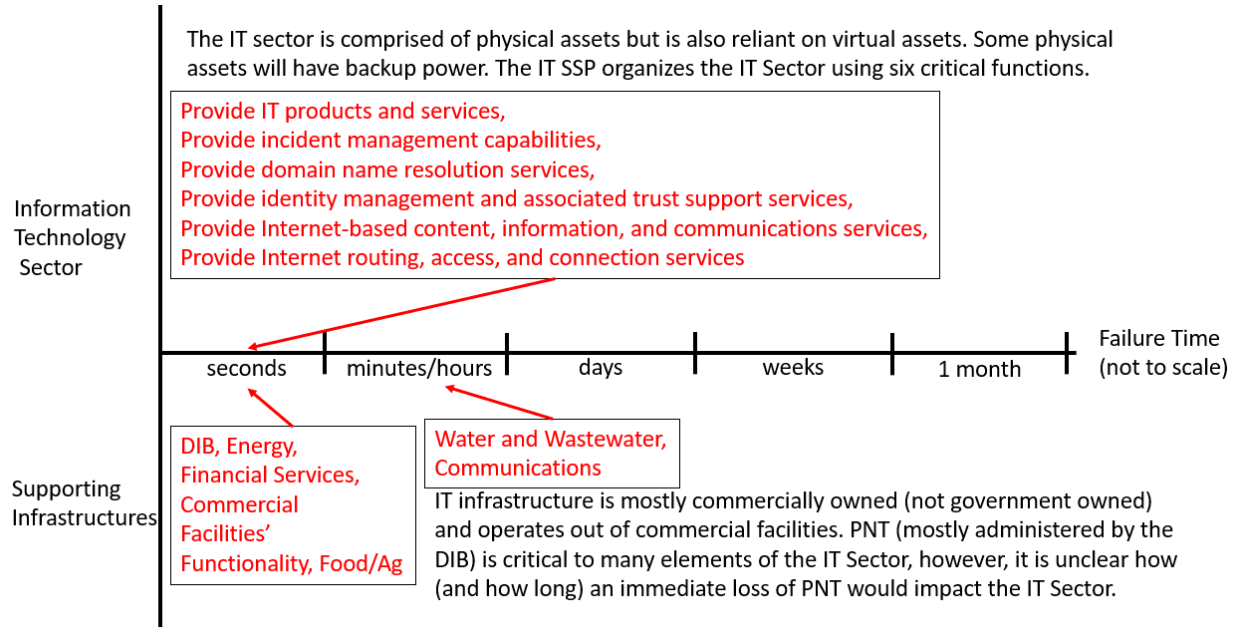
anticipated after weeks in a BSE. The HPH sector will not be able to adequately support a BSE.

- **Point towards broad solutions:** The HPH sector has accomplished some level of BSE planning as power outages have been a threat to HPH for decades. The plans are simply not robust enough to deal with a BSE. HPH should increase capability to a BSE level. The Bipartisan Commission on Biodefense produced an analysis of CI response to a biological attack that can be useful in HPH planning for BSE.[88]

[88] Bipartisan Commission on Biodefense. (2021). Insidious Scourge: Critical Infrastructure at Biological Risk, https://biodefensecommission.org/reports/insidious-scourge-critical-infrastructure-at-biological-risk/

Information Technology (IT) Sector

Define/Describe CI: "The Information Technology (IT) Sector produces and provides high-assurance IT products and services for governments, critical infrastructure sectors, commercial businesses, and private citizens around the globe."[89] "Unlike many critical infrastructure Sectors composed of finite and easily identifiable physical assets, the IT Sector is a functions-based Sector that comprises not only physical assets but also virtual systems and networks that enable key capabilities and services in both the public and private sectors."[90] Both the physical and virtual elements require power.[91]



Failure timeline: (subsectors sourced from the IT SSP) The IT sector will fail in seconds in a BSE. None of the six IT critical functions (see top of diagram)[92] will continue to function without power. "These functions are required to maintain or reconstitute networks (e.g., the Internet, local networks, and wide area networks) and their associated services."[93] The amount of time and effort spent on cyber security capabilities has not been matched by the effort to protect the power sources required to operate IT.

[89] DHS, CISA, IT SSP, 2016, https://www.cisa.gov/sites/default/files/2023-01/nipp-ssp-information-technology-2016-508%20%281%29.pdf

[90] DHS, CISA, IT SSP, 2016, p 2, https://www.cisa.gov/sites/default/files/2023-01/nipp-ssp-information-technology-2016-508%20%281%29.pdf

[91] Cailloce, L., CNRS News, New Technologies' Wasted Energies, 23 May 2018, https://news.cnrs.fr/articles/new-technologies-wasted-energies

[92] DHS, CISA, IT SSP, 2016, p 3, https://www.cisa.gov/sites/default/files/2023-01/nipp-ssp-information-technology-2016-508%20%281%29.pdf

[93] DHS, CISA, IT SSP, 2016, p iii, https://www.cisa.gov/sites/default/files/2023-01/nipp-ssp-information-technology-2016-508%20%281%29.pdf

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the IT sector to fail).

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Commercial Facilities: IT facilities most often reside in Commercial Facilities.
- Communications: IT depends on robust communications to interact with other IT (including user IT).
- Energy: Many IT companies have facilities that have some level of backup power, but most IT users do not. Destroying energy is a fast way to destroy the IT Sector.
- Water: The vast majority of datacenters require large volumes of water for cooling. Without water, they will rapidly overheat and be forced to shut down even if there is adequate backup power.

Sort into local or regional or National entities The IT Sector is not only National, but also International. Many foreign countries rely on and participate in the US IT Sector. Many elements of the IT sector are also local and regional.

Impact of this CI with no power (to CI and to society) IT depends on energy. Every CI depends on IT.[94] Several are severely impacted within seconds; the rest are severely impacted over hours or days. The IT CI is the most vulnerable CI to a BSE.

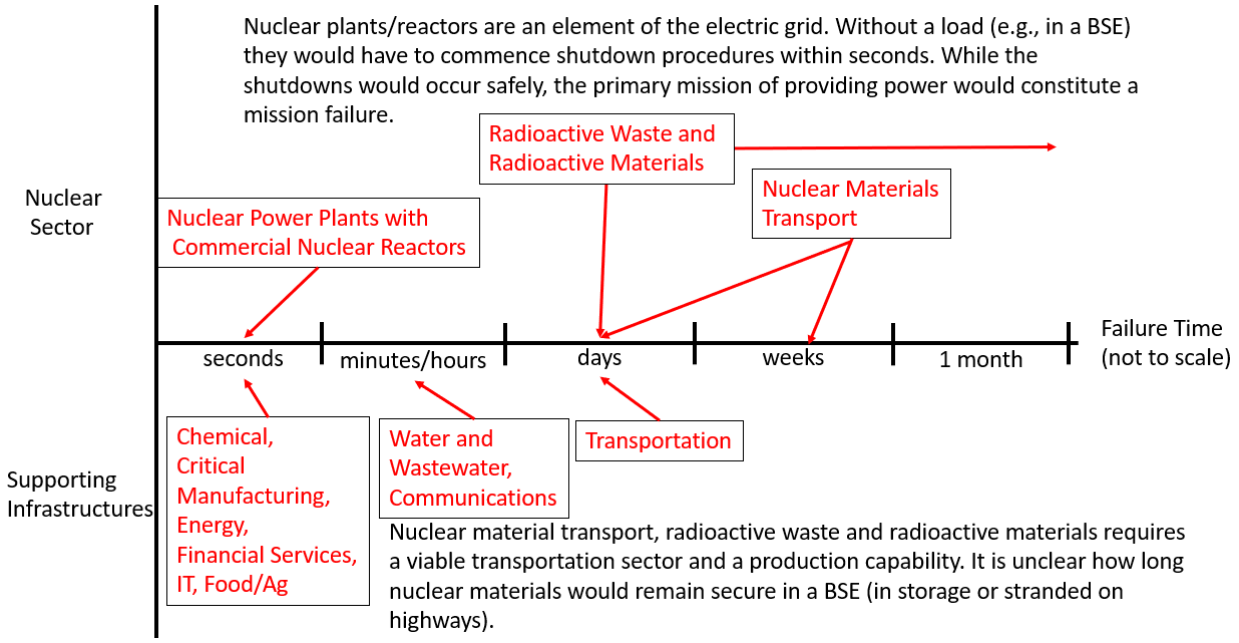
Conclusion

- **Summary**: Assessment: The IT sector will fail in seconds in a BSE. The IT Sector is critical to all other Critical Infrastructures and its failure in seconds will cause many other CI to fail in seconds. The US is dependent on IT, and that dependency is growing.
- **Point towards broad solutions:** The IT Sector has grown exponentially over the past two decades. The ability to operate without IT (as it was 20 years ago) should be a core competency for every institution. The growing dependence on data centers prompts the need for incorporating them into BSE planning.

[94] San Antonio Electromagnetic Defense, DEMSO Resiliency Guide, p 19, https://www.jbsa.mil/Portals/102/Documents/DEMSO%20Resiliency%20Guide%20(CAO%208%20June%202022).pdf?ver=XFSaIcKg27Y8nJkm8-iFtQ%3D%3D

Nuclear Sector

Define/Describe CI: "Nuclear power reactors generate 20 percent of U.S. electricity, while more than 20,000 licensees use nuclear materials in diagnosis and medical therapy—an estimated 20 million medical procedures each year in science and biomedical research—for irradiation of food and medical products, and during construction and oil exploration. Accidents, failures, or disruptions in the Nuclear Sector could have severe human health and safety consequences and cascading effects on critical infrastructure sectors that rely on nuclear power or nuclear medicine and industrial uses. Uniquely hazardous characteristics make Nuclear Sector assets the most highly regulated and heavily guarded of all civilian infrastructure."[95] "The Nuclear Reactors, Materials, and Waste Sector (or Nuclear Sector) includes the Nation's 99 commercial nuclear power plants; 31 research, training, and test reactors (RTTRs); 8 active fuel cycle facilities; waste management; and 18 power reactors and 6 fuel cycle facilities that are decommissioning or inactive. It also includes the transport, storage, use, and safe disposal of more than 3 million packages of radioactive or nuclear materials and waste annually."[96] "The private sector primarily owns and operates all civilian nuclear assets under a large framework of regulations…"[97] The most important element of the Nuclear Sector is nuclear reactors amongst which are Research, Training and Test Reactors (RTTR). "Most RTTRs require cooling for only short periods after a shutdown and do not generate enough heat to cause concern in a loss-of-coolant accident. Others have auxiliary features to add water from a tank or city water supply to provide core cooling."[98]



[95] DHS, CISA, Nuclear Reactors, Materials, and Waste Sector-Specific Plan, p v, http://www.dhs.gov/publication/nipp-ssp-nuclear-2015
[96] Ibid, p vi
[97] Ibid, p vi
[98] Ibid, p 6

Failure timeline: (subsectors sourced from Nuclear SSP) A BSE would cause nuclear plants to immediately shut down (thereby ceasing the Nuclear Sector's primary mission of providing power: "Nuclear facilities both supply electricity to the grid and depend heavily on uninterrupted power for continuous safe operation. Nuclear power plants employ multiple backup generation systems and adhere to detailed regulations governing safe shutdown in the event of long-term local grid failure and loss of offsite power."[99] Nuclear power plants are required to maintain the capability (including fuel) to operate for seven days (and up to 30 days with fuel resupply) without grid power.[100] This resilient capability is wasted if there is no load to service. Hospitals may store radioactive materials, however, once transportation is unavailable, radioactive waste will have to remain in place. Supplies of radioactive material are often stored at production facilities, but they require transportation to get to users.[101] Nuclear materials transport also require special transportation assets. While the lack of transportation will start mission failure, the detailed safety procedures and high priority of nuclear materials may allow transportation needs of the Nuclear Sector to continue for days and perhaps weeks (assessed).[102] Onsite storage of waste fuel rods in cooling pools will require ongoing electrical power to keep the pumps running. Once backup generation fails, cooling pools will evaporate and rods may overheat and ignite, creating large plumes of radioactive smoke and fallout similar to the Fukushima event.[103]

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the Nuclear Sector to fail)

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Chemical: Nuclear plants/reactors, radioactive material production and nuclear material production all require chemicals
- Communications: Nuclear electricity generation requires constant communications with grid control centers. Communications are also required amongst the elements of the Nuclear Sector.
- Critical Manufacturing: Radioactive and nuclear materials are produced by CM
- Energy: Nuclear plants/reactors use electricity from the grid (not from their reactors).
- Transportation: Radioactive and nuclear materials need transportation to and from use sites.

[99] DHS, CISA, Nuclear Reactors, Materials, and Waste Sector-Specific Plan, p 11, http://www.dhs.gov/publication/nipp-ssp-nuclear-2015

[100] U.S. Nuclear Regulatory Commission, Regulatory Guide 1.137, pp 4-5, https://www.nrc.gov/docs/ml1230/ml12300a122.pdf

[101] DHS, CISA, Nuclear Reactors, Materials, and Waste Sector-Specific Plan, p 11, http://www.dhs.gov/publication/nipp-ssp-nuclear-2015

[102] DHS, CISA, Nuclear Reactors, Materials, and Waste Sector-Specific Plan, p 7, http://www.dhs.gov/publication/nipp-ssp-nuclear-2015

[103] Powering Through, From Fragile Infrastructure to Community Resilience, Appendix 3

- Water and Wastewater: Nuclear reactors require a constant supply of water for cooling.

Sort into local or regional or National entities The Nuclear Sector operates locally and regionally with heavy regulation and oversight at a national level.[104]

Impact of this CI with no power (to CI and to society) The Nuclear sector will shut down its energy production in a BSE. Shutdown procedures present risk and are therefore a focus of the Nuclear Sector.[105] Shutdown of production of radioactive and nuclear materials would eventually present problems for plants/reactors. Fuel rods stored in cooling pools/systems without power are at higher risk for uncontrolled ignition.

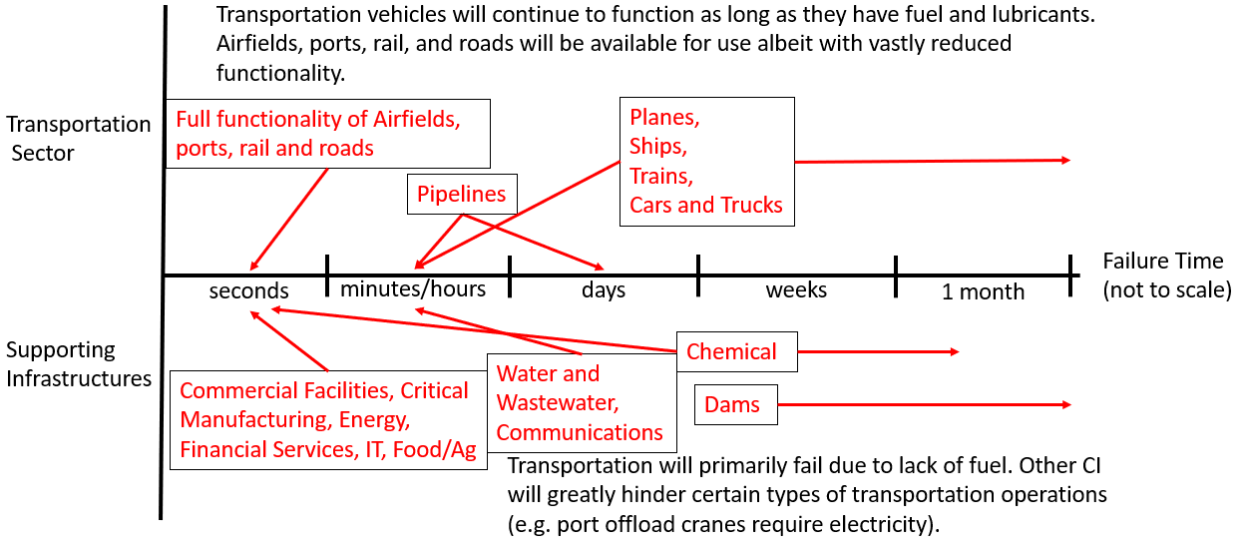
Conclusion

- **Summary**: The Nuclear Sector is well regulated and has well thought out shutdown procedures (including transportation segments). Assessment: In a BSE, nuclear reactors will start shutdown procedures within seconds as their load would cease to exist. Nuclear Sector shutdown removes approximately twenty percent of the Nation's electricity generation.
- **Point towards broad solutions:** The Nuclear Sector should be required to establish procedures and capabilities to operate during a BSE (not simply shut down). This may require a designated load or the ability to "island" nuclear plants and their loads. Increase storage of required BSE materials to reduce movement requirements. Fuel rod cooling pools require long term solutions that mitigate the no-power ignition risk.

[104] Ibid, Appendix D, p 45
[105] Ibid, p 11

Transportation Sector

Define/Describe CI: The Transportation Sector "consists of physical infrastructure, control systems, vehicles and people that operate and control aviation, maritime, highway, public transportation, rail, pipelines, and the combinations of these that constitute supply chain logistics"[106]



Failure timeline: (subsectors sourced from Transportation SSP) The transportation sector is comprised of many physical assets that can continue to function in a BSE with residual fuels. Airplanes carry enough fuel to get to their destination as do ships. Trains carry enough fuel to get to their next refueling point. Some vehicles will start to run out of fuel within minutes causing a cascade of other vehicles to be stuck in traffic and run out of fuel which continues and cascades until major roads are blocked. Vehicles not in use retain their ability to function based on fuel load. Approximately 10% of natural gas pipelines rely on electric pumps.[107] Transportation control systems require electricity.[108] While Transportation physical assets will continue to exist, their ability to operate is in question due to lack of fuel, maintenance, and transportation infrastructure functionality. Gas stations pumps rely on electricity and immediately lose functionality in a BSE.[109]

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the Transportation Sector to fail)

[106] Churchill B, Transportation, in "Powering Through; Building Critical Infrastructure Resilience", editor Mary Lasky, (NDRC, 2021), p 179

[107] Smillie S., Morgan G., Apt J., The Electricity Journal, mar 2023, How vulnerable are US natural gas pipelines to electric outages?, https://www.sciencedirect.com/science/article/pii/S1040619023000180

[108] DHS, CISA, Transportation SSP, p 15, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-Transportation:systems-2015-508.pdf

[109] FEMA, Power Outage, Keep Vehicles Fueled, https://community.fema.gov/ProtectiveActions/s/article/Power-Outage-Keep-Vehicles-Fueled#:~:text=Gas%20stations%20rely%20on%20electricity,in%20vehicles%20for%20essential%20use.

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Commercial Facilities: Commercial facilities create and maintain Transportation assets. Gas stations are critical commercial facilities for transportation/other CI.
- Chemical: Refineries, fuels and lubricants require chemicals.
- Critical Manufacturing: CM creates transportation systems and spare parts.
- Dams: Dams create navigable waterways in some areas of the Country.
- Financial Services: Travel and freight operations rely on financial contracts. Fuel is purchased by electronic means (credit/debit cards) and most gas stations will shut down without a functioning financial process.
- IT: "Cyber technologies upon which transportation services rely include positioning, navigation, tracking, shipment routing, industrial system controls, access controls, signaling, communications, and data and business management."[110]

Sort into local or regional or National entities Transportation has local, regional, and national aspects. Local, regional and national transportation capabilities are needed in a BSE.

Impact of this CI with no power (to CI and to society) "The Chemical, Commercial Facilities, Critical Manufacturing, Defense Industrial Base, and Energy Sectors rely on transportation for the movement of raw materials, feed stocks, and products. The Emergency Services Sector depends on resilient transportation networks to respond effectively to emergencies. The Food and Agriculture Sector depends on the security of truck, rail, and maritime shipments to protect the Nation's food supply chain. The Healthcare and Public Health Sector depends on transportation, particularly postal and shipping services, for delivery of medical supplies, medicines, and organs, often in urgent circumstances."[111]

Conclusion

- **Summary**: While transportation assets can continue to exist for a long time, they may not be able to operate for a long time. Assessment: The lack of fuel will cause this CI to fail in a BSE (days), and the failure of traffic control devices will lead to immediate gridlock in urbanized areas. The transportation sector directly supports most critical infrastructures and indirectly supports the rest. This sector can be very resilient as many assets are able to function long term with the only need being fuel.
- **Point towards broad solutions:** The local nature of much of the transportation required for food/water points towards local solutions in a BSE. Fuel is an over-riding concern and fuel reserves should be established for a BSE. Shipping could provide support from unaffected countries as long as they have ports with offload capability and a

[110] DHS, CISA, Transportation SSP, p 11, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-Transportation:systems-2015-508.pdf

[111] Ibid, p 15

transportation system for distribution. Planning and coordination for external shipping and aviation support should occur with other Nations.

Water and Wastewater Sector

Define/Describe CI: "Safe drinking water is a prerequisite for protecting public health and all human activity, and properly treated wastewater is vital for preventing disease and protecting the environment. Ensuring continuity of drinking water and wastewater treatment and service is essential to modern life and the Nation's economy."[112] "The Water and Wastewater Sector is a complex sector composed of drinking water and wastewater infrastructure of varying sizes and ownership types. Multiple governing authorities pertaining to the Water and Wastewater Sector provide for public health, environmental protection, and security measures, among others."[113] "There are over 148,000 public water systems in the United States. EPA classifies these water systems according to the number of people they serve, the source of their water, and whether they serve the same customers year-round or on an occasional basis."[114]

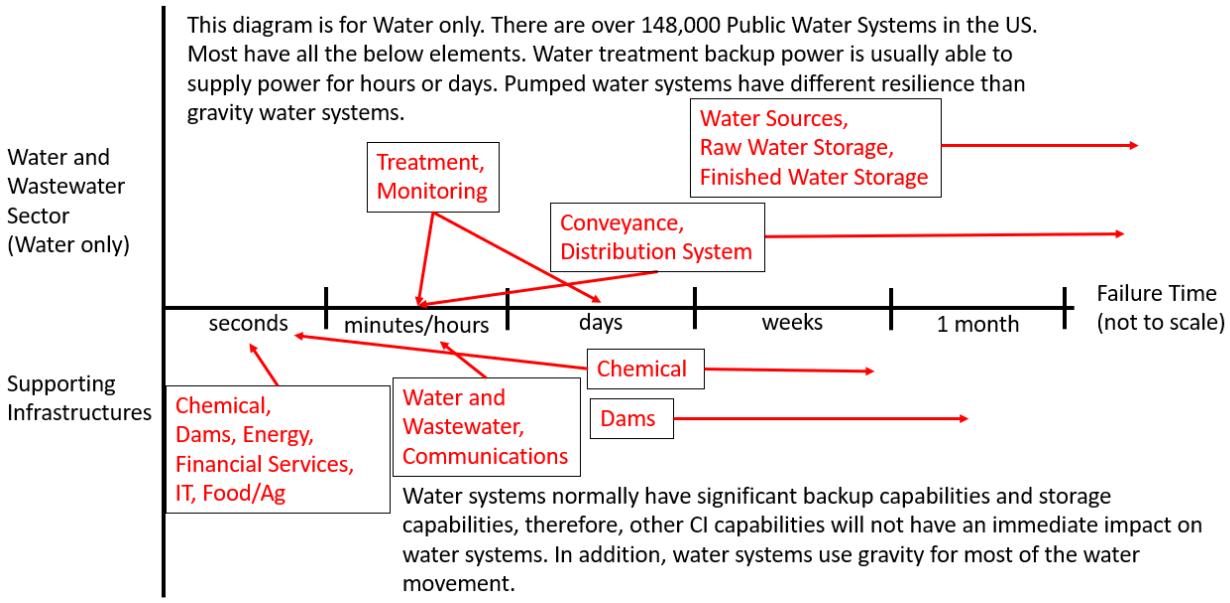
- "Physical Elements (of a water system)
  - Water source. This may be ground water, surface water, or a combination of the two. The vast majority of CWSs serving fewer than 10,000 people use ground water as their source. Large CWSs obtain most of their water from surface sources.
  - Conveyance. To bring water from a remote source to the treatment plant, CWSs may use pipes or open canals; the water may be pumped or gravity-fed.
  - Raw water storage. Reservoirs or lakes hold water from the source before it is treated; these reservoirs may be in remote or urban areas.
  - Treatment. A variety of physical and chemical treatments are applied, depending on the contaminants detected in the raw water.
  - Finished water storage. Treated water is stored before being distributed to customers. In a limited number of cases, treated water is stored in large, uncovered reservoirs that may be vulnerable to attack and contamination.
  - Distribution system. This network of pipes, tanks, pumps, and valves conveys water to customers. The flow is adjusted so that the proper volume and pressure is delivered when and where needed.
  - Monitoring system. Most monitoring is conducted for conventional regulated and unregulated contaminants. Some utilities have sensors installed at critical points to monitor a range of physical properties, such as water pressure and water quality."[115]

[112] DHS, CISA, Water and Wastewater SSP, p 1, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf

[113] Ibid, p 2

[114] EPA, Information About Public Water Systems, https://www.epa.gov/dwreginfo/information-about-public-water-systems#:~:text=There%20are%20over%20148%2C000%20public,or%20on%20an%20occasional%20basis.

[115] DHS, CISA, Water and Wastewater SSP, p 4, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf



Failure timeline: (subsectors sourced from Water/Wastewater SSP) Water systems are built relying on the natural resource of water (other CI require mostly manmade resources). Those resources do not cease in a BSE and make many water systems very resilient. Water sources, raw water storage and finished water storage are often controlled by gravity and can easily last for over 30 days. Many conveyance and distribution systems are also gravity powered. Pumped water systems, however, require power and backup fuel.[116] Pumped systems will rapidly fail without backup power. Treatment requires power and will last as long as the backup generation continues (if chemicals remain available). Monitoring using electronics will also depend on backup generation.[117] Water treatment systems are high energy users.[118] Systems that require pumps also require energy. Many water sources will rapidly become too contaminated (in a BSE) for the remaining inoperable water treatment plants to process, due to untreated sewage discharge from municipal and industrial sources, as well as catastrophic releases from rapidly de-energized chemical and manufacturing plants.

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varied times) the Water and Wastewater (water only) Sector to fail)

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the

[116] DHS, CISA, Water and Wastewater SSP, p 40-41, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf

[117] DHS, CISA, Water and Wastewater SSP, p 4, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf

[118] Daw, Hallet, Dewolfe and Venner, NREL, Energy Efficiency Strategies for Municipal Wastewater Treatment Facilities, p vi, https://www.nrel.gov/docs/fy12osti/53341.pdf

ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
    - Chemical: Water treatment for most systems requires chemicals. Some use natural filtrations.
    - Dams: Dams, in several locations, create/control required water sources.

Sort into local or regional or National entities Water is a local CI with State and National regulation.

Impact of this CI with no power (to CI and to society) Generally, humans may live up to 3 days without water.[119] Humans forced to consume untreated contaminated water may rapidly develop life-threatening diseases. Most CI require water.

(Wastewater) Define/Describe CI: "Wastewater is predominantly treated by publicly owned treatment works (POTWs), although there is a small number of private facilities such as industrial plants. The POTWs and privately owned wastewater treatment works that discharge treated effluent into the waters of the United States are subject to regulation under the Clean Water Act (CWA) National Pollutant Discharge Elimination System (NPDES) program…. There are more than 16,500 POTWs in the United States that collectively provide wastewater service and treatment to more than 227 million people and are generally designed to treat domestic sewage. However, POTWs also receive wastewater from industrial (non-domestic) users; these industrial users discharge effluent into a collection system for subsequent treatment at a POTW and are subject to the national pretreatment program."[120]

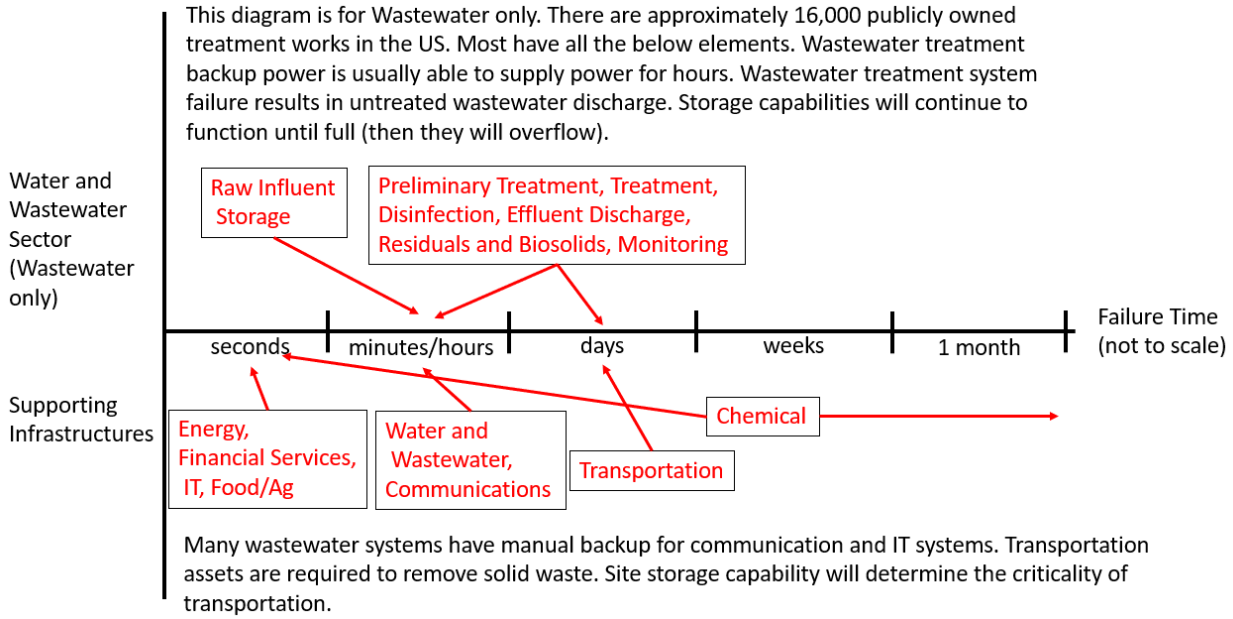
- "Physical Elements (of a wastewater system)
    - Collection. A network of pipes, conduits, tunnels, lift stations, equipment, and appurtenances convey and pump wastewater from the source to the treatment plant. There are three principal types of municipal sewers: sanitary sewers, storm sewers, and combined sewers. Treatment plant operations can profoundly differ based on the type of collection.
    - Raw influent storage. Raw sewage and industrial effluent can be stored in tanks or impoundments, generally for the purposes of flow equalization prior to treatment.
    - Preliminary treatment. This includes removal of materials (rags, wood, plastic, grit, etc.) that could damage a plant's headworks or impair operations. Means for removal can include chemical addition, pre-aeration, bar racks, screens, shredding equipment, and/or grit chambers. Pretreatment can include coagulation, flocculation, and flotation for particle and solids removal.
    - Treatment. Primary treatment involves suspended and floating material removal. Secondary treatment provides for the reduction of dissolved and colloidal organic substances and suspended matter. Many secondary treatment processes involve biological treatment. The use of settling

[119] Johnson, J., MedicalNewsToday, https://www.medicalnewstoday.com/articles/325174

[120] DHS, CISA, Water and Wastewater SSP, p 5, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf

tanks to separate the solids from the liquid is common; however, flotation and other methods might be used. Physical and chemical treatment processes are used for oil, grease, heavy metals, solids, and nutrient removal. Advanced wastewater treatment processes (that can include physical, chemical, biological or a combination) are utilized for nutrient and soluble organics reduction and resource recovery.

- Disinfection. Disinfection inactivates or destroys pathogenic bacteria, viruses, and protozoan cysts. Chemical disinfection (such as chlorine), ozonation, and ultraviolet irradiation are among the types of processes used.
- Effluent/discharge. Treatment plant effluent can be discharged to a body of water or wetlands, to ground water aquifers via percolation (via deep-well injection), land-applied, or re-used for other purposes….
- Residuals and biosolids. These treatment processes can encompass the costliest part of wastewater treatment. Some of the solids treatment processes include thickening, stabilization, digestion, chemical, composting, dewatering, incineration, and heat drying equipment….
- Monitoring system. Sensors can be installed at critical points to monitor a range of physical properties, such as flow rates and water quality indicators, and to detect levels of contaminants before, during, and after treatment."[121]



Failure timeline: Wastewater systems rely on gravity as sewage flows downhill. Pumps elevate sewage so that it may have a downhill flow for the next leg of its journey. If not pumped,

[121] DHS, CISA, Water and Wastewater SSP, p 7, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf

sewage will simply backup and may overflow. "If it is not contained within a short amount of time, this sewage will flow over land and may eventually enter a drainage system or a local stream or lake."[122] Wastewater pumping stations left idle for several days may not be able to restart due to settling and solidification of the fibrous matter in the sewage. Wastewater treatment requires a lot of power.[123] Generators may function for hours, but once they fail, most wastewater functions will fail causing backup and sewage spills.

Describe CI Interdependencies (first order interdependencies that, if failing, will cause (at varying times) the Water and Wastewater (wastewater only) Sector to fail).

- Communications, Energy, Financial Services, and IT are required for the administration of all CI. This includes (and is not limited to) financial transactions for supplies/raw materials, pay for employees, supply chain efforts, and the ability to effectively coordinate and execute operations. Food/Ag and Water are required to maintain the human element of each CI.
- Chemical: Most wastewater treatment is dependent on chemicals. Most treatment plants have stored chemicals.
- Financial Services: Plants require constant replenishment/purchase of chemicals and constant removal (paid haulers) of solid wastes.

Sort into local or regional or National entities Wastewater is a local CI with State and National regulation.

Impact of this CI with no power (to CI and to society) Wastewater systems use gravity in several stages of the treatment process and may use pumping stations along collection paths.[124] If the flow of wastewater is interrupted pipes will continue to back up and eventually overflow.[125] Wastewater treatment facilities also use pumps without which sewage will also backup/overflow and the pumps may become permanently damaged. Wastewater discharge is clean water that most often flows to natural waters (e.g., rivers). Without treatment, wastewater overflow will contaminate freshwater sources. The health impacts would be significant and widespread. Solid waste is usually binned at wastewater treatment plants, but those storage facilities are limited, and solid waste may cause contamination if there is too much.

Conclusion

- **Summary**: Assessment: "The Water and Wastewater Sector is dependent on sectors such as Chemical or Energy for continuity of its operations."[126], therefore, the Water and Wastewater Sector will fail in a BSE (failure time depending on backup generator

[122] City of Durham, Sanitary Sewage Spill Prevention and Best Management Practices, https://www.durhamnc.gov/DocumentCenter/View/2904/Sanitary-Sewer-Spill-Prevention-PDF?bidId=#:~:text=A%20sewage%20spill%20occurs%20when,lids%2C%20cleanouts%2C%20or%20outside%20drains

[123] Daw, Hallet, Dewolfe and Venner, NREL, Energy Efficiency Strategies for Municipal Wastewater Treatment Facilities, p vi, https://www.nrel.gov/docs/fy12osti/53341.pdf

[124] Enviroline Co, The ins and outs of a lift station, https://enviro-line.com/2021/08/the-ins-and-outs-of-a-lift-station/

[125] Ibid

[126] DHS, CISA, Water and Wastewater SSP, p 18, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf

capability). Water and Wastewater are mutually supporting. Water treatment is based on the cleanliness of water sources that often can be contaminated by wastewater. Wastewater conveyance and treatment requires water. Both are dependent on gravity, but they also require power. Water/wastewater systems are local.

- **Point towards broad solutions:** Prioritization of water usage in a BSE is required. People require drinking water. Many other uses of water can be reduced/eliminated in an emergency (eliminating the need for a lot of wastewater treatment). Rainwater collection is a viable option in many localities. Wastewater volume may be controlled by water allocation plans. On site chemical and fuel storage will determine the amount of time Water and Wastewater facilities are able to function in a BSE.