



Assessment of Critical Infrastructure with No Grid Power: Food and Agriculture

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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

“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

There is a general lack of understanding of Critical Infrastructure (CI) in a Black Sky Event (BSE- nationwide or near nationwide grid power outage lasting 30 days) and a corresponding lack of published research. **The purpose of this paper is to portray all Critical Infrastructure (CI) Sectors’ “timeframe to failure” and their cross-sector interdependencies in a Black Sky Event to assist in the understanding of and planning for BSE.** “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} Many of the BSE interdependencies and timelines portrayed in this paper were validated by the Iberian power outage of 2025 (see Appendix B).

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.

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 is “When?”. For example, most of the IT Sector likely fails immediately without electricity but much of the Transportation Sector can continue to function for minutes, hours or days. 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 water⁴ thereby making the Water/Wastewater Sector more BSE time-critical than the Food/Agriculture

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>

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

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

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 fully analyzed as this paper focuses on the impact to the other fifteen sectors by the loss of the grid. Many 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). An Oil and Natural Gas Appendix is included at the end of the paper.

Sector Analysis

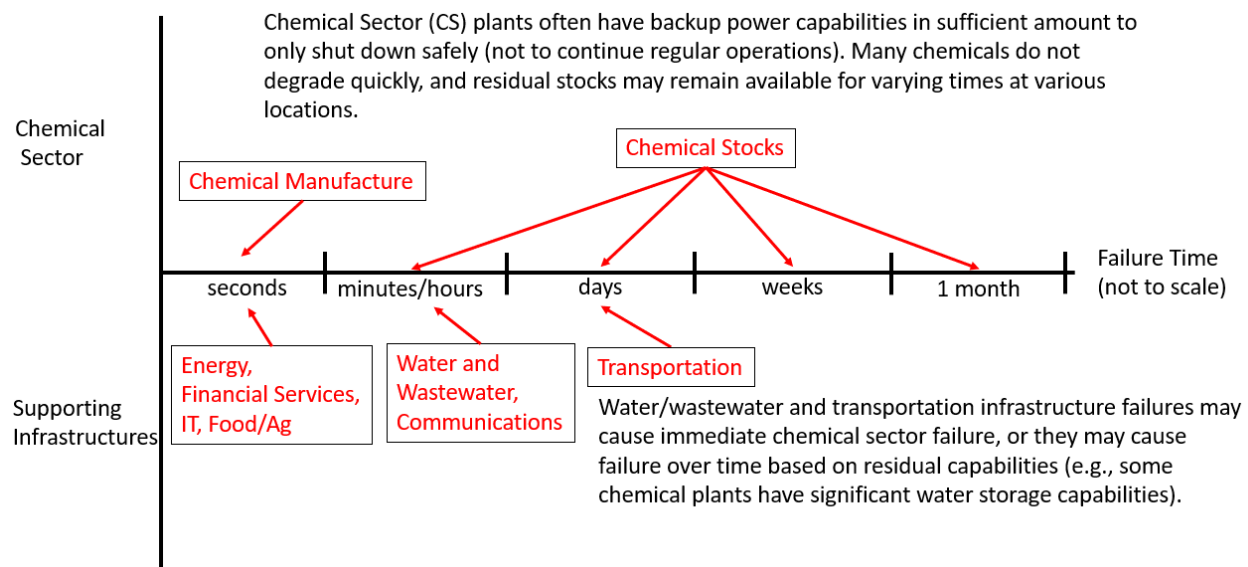
In order to analyze CI timeframes, one must define the CI, deconstruct each CI into its elements (subsectors), and determine supporting infrastructures. This paper therefore defines/describes each CI with their sub and supporting elements. “Time to failure” is then portrayed and assessed. Understanding 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 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, including 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 FEMA⁶) 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

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

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 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 percent¹² 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.

¹⁰P CISA, Resilient Power Best Practices

for Critical Facilities and Sites with Guidelines, Analysis, Background Material, and References 61,
https://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>

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.

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.

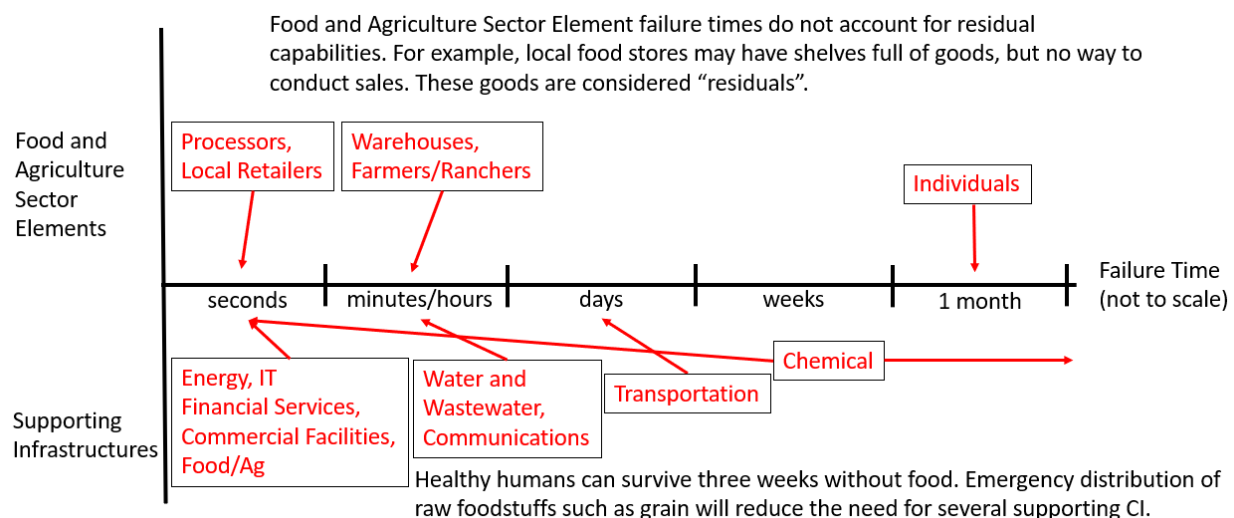
No backup effort is considered effective unless it has been planned for and at least partially rehearsed. For example, a food warehouse that relies on IT to receive invoices is not considered functional by simply stating that warehouses can use paper invoices and manual accounting; they have to plan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

Food and Agriculture Sector

Define/Describe CI “The food sector generally extends from farmers/ranchers to processors/distributors, to warehouses, through retailers (local stores and restaurants), and finally to the individual consumer.”¹⁹ 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.²⁰ The sick, elderly, and young cannot live as

¹⁹ Chill S et al, Food and Ag, in “Powering Through; Building Critical Infrastructure Resilience”, editor Mary Lasky, (NDRC, 2021), p 143

²⁰ Kottusch, Tillmann, Puschel. 2009. Survival Time Without Food and Drink. NIH, National Library of Medicine. <https://pubmed.ncbi.nlm.nih.gov/20069776/>

long.²¹ 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 old²² and approximately 7 million under the age of 2²³). 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.

²¹ 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>

²² 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/>

²³ 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.²⁴ 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.

²⁴ 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 storage 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