

This document contains student handout files associated with the following case study:

Sustainable Development: It's as easy as F-E-W¹

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¹ We are interested in improving this case and in tracking its use. Please contact Dr. Thushara Gunda at [tgunda \[at\] sandia \[dot\] gov](mailto:tgunda@sandia.gov) with comments on the use of this case and any suggestions to improve it.

Case Study Overview

You and your fellow countrymen and women have arrived in a new land that is rich in fertile soil, water, and minerals. However, within this land there is no single area that is well endowed with all three of these important resources.

- *Scouts report that the Northwest region is a beautiful landscape of snowcapped peaks and lush green hills woven together by an intricate network of gleaming strands of silvery water. However, they have not detected any significant sources of fertile land or minerals.*
- *Scouts describe the Central region of the land as a sea of endless plains and rolling grasslands covered in rich loamy soil and cut across by large rivers. They note, however, that most of the land is untouched by natural waterways and that few mineral sources were discovered.*
- *Finally, the scouts investigating the Southwest region report that, in the rough wilderness and mountains of sand, they found numerous sites where gleaming minerals could be harvested to generate energy. However, they note that the rocky terrain is not amenable to farming nor is there much water in the region.*

Your fellow settlers could not come to an agreement about where to establish your home base. So by unanimous decision, you decide to split up into 3 communities, one in each of the 3 regions. Your goal is to settle this land and develop a prosperous and long-lived society at your community's location.

However, upon arriving at your assigned destination, you have come to the realization that you don't know the first thing about managing the natural resources in your area in order to sustainably develop your community. The success of your community depends on your ability to develop sound strategies for natural resource development and utilization. Therefore, you task your three most trusted advisors with studying the intricacies of three products that you feel are critical to maintaining and developing your community: drinking water, food, and electricity. Armed with this knowledge, you plan to craft robust policies that will allow your community to prosper and thrive through good times and bad for countless generations.

However, you wonder if this will be enough. Only time will tell, as this sustainable development adventure starts now!

Homework 1: Individual Product Concept Map

Due date: Class 1

Assigned product: _____

As a trusted advisor for your community, you have been tasked with understanding the various factors influencing one of the critical products your community needs. For this product, develop a concept map that captures the social and natural factors influencing its availability, accessibility, and utilization by your community. Recall that a concept map is essentially a flowchart that connects key concepts (nodes) with each other using directional arrows that identify the interactions.

Some like to focus on the problem associated with the issue globally while others focus on local manifestations. In both cases, your analysis will depend on doing significant research into the problem and answering the following broad question: What social, biological, technological and ecological factors influence the interaction between the community and your product? Draw on the information presented in previous classes (including lectures, discussion, and readings) to map out how these factors interact with each other. Your concept map should address the following elements to some extent:

- Source, treatment/processing, distribution, and waste phases of the product
- Connections (if any) to other two products (if any) that could occur
- Interactions with natural resources

Developing this product-specific concept map will help set the stage for the integrated FEW concept map you will be developing for an assigned community in the next class. These concept maps are intended to make you think critically about how you can leverage your community's resources to grow sustainably and have resiliency against future shocks. If done correctly, the concept maps will provide the basis for a large segment of your final exercise.

In-Class Activity 1: Group Product Concept Map

Within product-specific groups, discuss each other's concept maps. What concepts were addressed in all concept maps? What concepts were overlooked in some maps? Work together to develop a cohesive product concept map for your group. You will need to work together to come to a consensus on the key concepts as well as how they are connected. You will turn in both the group concept map and your individual concept maps for grading. The group concept map will be graded following Rubric #1.

Rubric #1: Product Concept Map

| Grading Criteria | Excellent - A (5 points) | Adequate - C (3 points) | Fail - F (1 point) | Points awarded |
|---------------------------------|---|---|---|-----------------------|
| 1. Natural and Social Concepts | Addresses multiple natural and social factors influencing various phases of human-product interactions | Addresses some natural and social factors influencing some phases of human-product interactions | Overlooks most natural and social factors of human-product interactions | |
| 2. Resilience | Map demonstrates many factor interactions that could enable or hinder community resilience | Map demonstrates few factor interactions that could enable or hinder community resilience | Resilience considerations in map are not obvious | |
| 3. Structure | Non-linear structure of map indicates complex thinking about the meaningful relationships between natural factors, social factors, and resilience | Map shows definite thinking about relationships between natural factors, social factors, and resilience | Thinking process is not clear and presents to be cluttered; inappropriate structure | |
| 4. Communication | Information is presented clearly and allows for a high level of understanding | Information is presented clearly and allows for a basic level of understanding | Information is not clear, very difficult to understand | |
| Total Points (out of 20) | | | | |

In-Class Activity 2: FEW Concept Map

Within your community group, briefly share your individual concept maps and discuss how they could be connected to each other. Similarly to the previous class, you will need to negotiate with your community members to develop a consensus on what aspects from the individual maps you would like to retain or delete for the overall community's FEW map. As you develop your map, consider your specific community's location and what challenges it might face given its nearby natural resource base.

You will eventually present your community's map with the class as a whole. Sharing the FEW maps with other communities will provide an opportunity to share your ideas in class and obtain feedback on both your concept map and your presentation style. Both the map and your oral presentation will be graded following Rubric #2. So as you develop your map, consider the following grading cheat sheet:

| Grading Cheat Sheet | Food | Energy | Water |
|---------------------|-------|--------|-------|
| Food | Black | Green | Green |
| Energy | Green | Black | Green |
| Water | Green | Green | Black |

Maps within the green zone qualify for a higher grade (A or B) because they contain concepts and relationships that connect across resources. Maps in the black zone, on the other hand, only contain limited connection across FEW systems in their diagrams.

After sharing your community's FEW concept map with the class, work with your community members to develop a strategy that will guide your community's development strategy during gameplay in the next class. In addition to the directions in which you would develop your infrastructure, consider how extreme events could affect your progress and how you would interact with your neighbors as you develop your strategy. You will not turn in your strategy before the game. However, you will need to reflect on your strategy's effectiveness as part of your final written assignment for this case, don't forget to record your strategy somewhere. You will need to finish developing your strategy as part of your homework if you run out of time in class.

Rubric #2: Integrated FEW Concept Map²

| | 5 | 3 | 1 | Points Awarded |
|--|---|--|--|----------------|
| 1. FEW Integrated CM: Does your concept map (CM) address social and natural factors for all three products? Does it consider their interactions in multiple ways? Does it consider challenges faced by your particular community? | CM addresses interactions across all three resources (i.e., covers all of the green zone) and includes challenges a specific community might face | Some interactions between resources are considered and it is unclear how a community's challenges might interact with CM | Resource interactions are very limited (i.e., mostly in the black zone). No community challenges are apparent in the CM. | |
| 2. Group/Team: Does your team include the diversity of expertise necessary to accomplish your goals? Has your team engaged a strong team of advisors and/or engaged with peer reviewed literature? | Team demonstrates a solid base of expertise and has clearly consulted an array of resources. | Team demonstrates some experience and some resources. | Team has not connected with potential resources and it does not display much experience. | |
| 3. Presentation and Other Strengths: Was your presentation professional and well-practiced? Is there anything else that your team has done exceptionally well? | Team demonstrates exceptional, participatory presentation skills that integrate all team members' strengths and abilities. Team is professional in appearance, and is strong in its overall cohesion and related skills | Team demonstrates moderate presentation and team cohesion/related skills, but would benefit from further guidance and practice | Team is not comfortable or is ineffective in presentation skills and/or team cohesion and related skills | |
| 4. Demonstration of progress through the challenge: What has your team learned in the process of working on integrated FEW CM? | Team demonstrates significant learning around FEW nexus, collaboration and the competencies to bring them all together. | Team demonstrates some learning but still has significant gaps that could be barriers to understanding FEW nexus. | Team has not demonstrated significant learning about FEW nexus | |
| Total Score (out of 20) | | | | |

² The green and black colors in the rubric refer to the grading cheat sheet provided in the assignment description.

Homework 2: Pro-Con Grid & Game Rules

Due Date: Class 3

In addition to finishing your community strategy, you will also need to do a pro-con grid and read the game rules before next class.

The pro-con grid is a reflection exercise. Compare the individual product concept map with the community integrated FEW concept map. What are the advantages of optimizing a single product in the context of the resiliency that changed when you had to consider the other two products? In other words, relative to the individual product concept map, what were the benefits (i.e., pros) and drawbacks (i.e., cons) associated with the community-level, FEW planning? For example, were there certain concepts on the individual product maps that did not make it into the community map? In addition, consider how the benefits and challenges you've identified vary in their level of impact to the community. Do they affect the community a little (i.e., "Least Affected"), a great deal ("Most Affected"), or somewhere in the middle ("Moderately Affected")? Feel free to brainstorm using the grid below.

| | Least Affected | Moderately Affected | Most Affected |
|------------|-----------------------|----------------------------|----------------------|
| Pro | | | |
| Con | | | |

You will turn in a brief write-up (approximately half a page) summarizing your pro-con reflections at the beginning of next class. In addition to listing the specific pros and cons (minimum two of each), the reflection needs to address potential impacts to community resiliency stemming from these items and needs to be well-written. See the next page for the associated assessment rubric for this assignment.

Rubric #3: Pro-Con Grid

| Criteria | 5 | 3 | 1 | Points Awarded |
|---|---|--|---|----------------|
| <p>1. Pros: Does the assignment capture benefits of a product-specific concept map? Does it address more than one product? Does it identify benefits of an integrated FEW concept map?</p> | <p>Has articulated more than two benefits of a product-specific concept map, addressing more than one product’s perspective, and identified at least one benefit of an integrated concept map</p> | <p>Has articulated two benefits of a product-specific concept map, does not address more than one product’s perspective or the benefits of an integrated concept map</p> | <p>No benefits of a product-specific or integrated concept map were articulated</p> | |
| <p>2. Cons: Does the assignment capture challenges associated with developing an integrated FEW concept map? Does it identify potential pitfalls in product-oriented planning?</p> | <p>Has articulated more than two challenges of FEW concept map, and at least one potential issues with product-oriented planning</p> | <p>Has articulated two challenges of FEW concept map, does not identify potential issues around product-oriented planning</p> | <p>No challenges of FEW concept map development or issues with product-oriented planning were articulated</p> | |
| <p>3. Resilience: Are the associated social impacts of the pro-cons discussed? How is community resilience enhanced or hindered by the pro-cons?</p> | <p>Displays a solid potential to make the community sustainable. Has clearly defined the potential for exceptional impact.</p> | <p>Has thought about how to make the community sustainable, but still has significant gaps in its viability.</p> | <p>Does not have a viable plan for how to sustain the community.</p> | |
| <p>4. Communication: Is the writing easy to follow and understand? Does the style and organization enhance reader comprehension?</p> | <p>Writing style is clear and well-organized, thus facilitating reader comprehension</p> | <p>Main points are there but writing style is only somewhat clear and organized</p> | <p>Unclear what the sentences mean or how they relate to each other</p> | |
| <p>Total points (out of 20)</p> | | | | |

Game Overview

1. You and your fellow countrymen and women have arrived in a new land that is rich in fertile soil, water, and minerals³. However, within this land there is no single area that is well endowed with all three of these important resources. Your goal is to settle this land and develop a prosperous and long-lived society.
2. In order to develop your community you will need to convert natural resources into products which can sustain your population. The general development flow in the game is summarized in Figure 1.

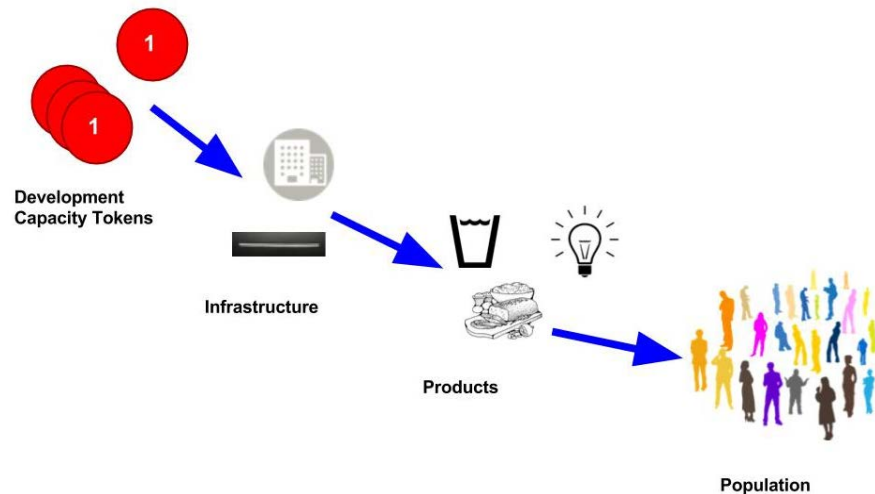


Figure 1. Development flow in game.

3. There are three types of landscape patches in this new land, each of which represents a natural resource. These resources are: water, fertile land, and minerals.
 - a. Each resource represents the raw materials used to create the products needed to develop and maintain your community: drinking water, food, and electricity.
 - b. The availability of these products determines the population that your community can support. One of each type of product (food, drinking water, and electricity) is needed to sustain one population unit.
 - c. Each product card is worth one point and each population card is worth five points. **The community with the most points at the end of the game wins.**
4. At the beginning of the game, each player is assigned a community in a pre-specified location and five “development capacity” tokens. The “development capacity” tokens represent social, technological, and economic capabilities of your community to develop infrastructure; these tokens must be traded-in in order to build infrastructure. To develop products and increase your population you must use the tokens to develop infrastructure that transform the raw materials on the natural resource landscape patches into products and transport these products to your community location.
5. How do you acquire “development capacity” tokens?

³ For simplicity, “minerals” denote a wide range of natural resources that could be used to generate electricity.

- a. Development capacity is determined, in part, by the size of your community. Large communities have a greater workforce and economic system that can support more infrastructure projects. Therefore, at the beginning of every turn, each community receives one token per population card.
 - b. In addition, as prosperity is also dependent on outside random forces, at the beginning of every turn, each community will roll a die. If the number on the die face is odd, the community collects that number of tokens. However, if a community rolls an even number, they must draw a chance card instead.
6. How do you convert resources to products?
- a. There are several prerequisites that must be met before a resource can be used to create a product for your community.
 - i. Your community must be physically connected to the resource in some way. If your community touches the landscape patch on which the resource is found you are considered to be physically connected. If not, transportation infrastructure (i.e., roads) must be built along the edges of the landscape patches in order to connect your community to the resource. The roads are half the length of a resource patch.
 - ii. If the product requires more than one resource to be created, the landscape patches on which the resources are located must be physically connected. *For example, if no water source is found adjacent to the fertile land, water must be transported to fertile land via irrigation infrastructure in order to grow food crops.*
 - iii. Note that the availability of your resources is limited. Mineral and fertile land resource patches provide three units of the resource and water patches can provide up to five units. *For example, if you use a water landscape patch as input for a drinking water product card and as input for a food product card, then you can still use that same patch as input three more times.* Each unit represents the flow of resources for an indefinite period. In other words, a unit of land sufficiently supplies the nutrients needed to support 1 unit of food for 1 unit of population throughout their lives.
 - iv. Once the physical connections between resources and your community have been made, facilities that transform the resources into the desired product must be built. *For example, before water can be used as drinking water it must be processed at a water treatment plant where it is transformed to remove bacterial and other contaminants into the relatively clean and sterile water that comes out of our faucets.* Each facility is capable of transforming one unit of a resource into one unit of the desired product.
 - v. The cost of building facilities used to transform resources into products is 1 token for each unit developed on a patch.
 - vi. Your development card summarizes the resources, infrastructure, and associated tokens needed to develop products.
7. How do you utilize products to increase your population?

- a. A set of one food, one drinking water, and one electricity card can be traded in for one population card during any round of game play.
 - b. If, for any reason, you do not have enough products to sustain your current population, any unsupported population cards must be turned over (rendered inactive) until your product supply is replenished. *For example, if a chance card requires you to turn in 1 drinking water card but you do not have any in your hand, then you need to turn over one of your population cards until you are able to turn in a drinking water card.*
 - c. You may decide during any round to turn back in a population card for a set of product cards.
8. What if I don't have all the resources I need to grow my population?
- a. You can trade and negotiate with other communities so long as your communities are connected by infrastructure. You may trade resources, products, tokens, or favors. There are no specific rules limiting possible trades and negotiations. Use your imagination!
9. Carefully consider how to balance your population growth with your development. Chance cards may produce unexpected results!

Game Rules

These pages include all the information you need to play the game. For specifics on developing your resources during game play, you may refer to the Development Card.

1. Landscape patches are considered naturally connected if they share an edge (no diagonal connections) and communities are considered connected to all landscape patches they touch.
2. In order to collect a product card, the necessary resources must be connected (either directly or through infrastructure) and transformed. The development card lists the resources and infrastructure needed to develop each of the products.
 - a. In order to produce 1 unit of drinking water, a community must be connected to a water resource patch containing both 1 available resource unit and 1 facility.
 - b. In order to produce 1 unit of food, a community must be connected to a fertile land patch and a water patch that both have at least 1 available resource unit as well as a facility on the fertile land patch. The associated water patch must be connected (either directly or through infrastructure) to the fertile land patch on which the food is being produced. Note that the patch with the production facility must also be physically connected to your community.
 - c. In order to produce electricity, a community must be connected to a mineral patch and a water patch that both have at least 1 available resource unit as well as a facility on the mineral patch. Again, the associated water patch must be connected (either directly or through infrastructure) to the mineral patch on which the electricity is being produced, and the patch with the production facility must be physically connected to your community.
3. There are 3 resource units per mineral and fertile land patches and 5 resource units per water patch. The quantity of resources used by communities should be indicated on each landscape patch using hash marks.

4. Roads can be used to connect communities with resources. Roads are half the length of a landscape patch edge and extend along edges of landscape patches connecting at midpoints (see board example in Figure 2). Roads must be connected to your community or to other road segments (i.e., no free-floating roads). Communities are able to utilize resources at patches touching the sides of a road. Each road segment costs 1 token.
5. Facilities should be placed on the associated primary resource landscape patch: a drinking water facility is on a water patch, a food facility on a land patch, and an electricity facility on a mineral patch. One facility is needed to per one unit of product. Multiple facilities may reside on the same patch. Each facility costs 1 token.
6. A set consisting one of each product card (i.e., 1 drinking water, 1 food, and 1 electricity card) is required to obtain 1 population card.
7. Trades and negotiations may be conducted between any players during any round of the game after setup has been completed.
8. Chance cards may benefit or injure a community's development. Once drawn, the community cannot make any development decisions (including building infrastructure) unless it is directly related to meeting the criteria on the Chance Card. If an immediate resolution is not available to the community, they have the following options:
 - a. Turn over a population card (i.e., render it "inactive") to continue making development decisions. The population card can become active again once the criterion on the Chance Card has been satisfied.
 - b. Turn back in a population card for each of the individual product cards.
 - c. Enlist assistance from one of their neighbors for assistance.
 - d. Hold onto the Chance Card until the next turn and hope they gain some tokens that will help get them out of their rut.



Figure 2. Example of a game board layout. Community locations (teal pentagons), marked road segments (pink highlighter), resource unit utilized (hash marks), and facilities developed (stars).

Materials (provided by teacher)

- Game board with 3 resource patches (water, fertile land, minerals) marked
- Community markers
- Product cards (3 types)
- Development cards (“W” - water, “L” - fertile land, “M” - minerals)
- Population cards
- Chance cards
- Infrastructure pieces (roads and facilities)
- Tokens
- Dice
- Sharpie

Setup

1. Setup the game board with resources and community markers.
2. Assign each player a community to act on behalf of.
3. Assign each player a role.
4. Each community collects 5 tokens to start.
5. Determine order of play: Each community takes a turn rolling the die. The community with the largest value begins, with the game play continuing to the left.
6. Establish communities: Following the established order of play, each community makes their initial development decisions, following Game Rules 1-7. Be sure to mark the quantity of resource units used and infrastructure developed as well as collect any associated product and population cards.

Game Play

Game play begins immediately after setup has been completed. Each round of game play is turn-based, following the established order of play. During their turn in each round a community will undertake the following steps:

1. Community collects 1 token for each active population card
2. Community rolls the die
 - a. If an odd number is rolled, the community collects the associated number of tokens
 - b. If an even number is rolled, they draw a Chance Card and follow the directions printed on the card.
 - i. Remember if you do not have enough cards or tokens in your hands, or enough product facilities in play, to follow the Chance directions, then you must turn over (render inactive) as many population cards as necessary to address the product deficit. If that option isn’t available, you can ask your neighbors for aid or hope that your next turn/die roll brings you tokens.
 - ii. A community can decide at this point to turn in an existing product card in order to free up a utilized resource unit for another purpose or to turn in a population card for a set of product cards.

- iii. Once the chance card has been fulfilled, it should be returned to the bottom of the chance card deck.
3. Community makes development decisions, following Game Rules 1-7.
 - a. Be sure to mark the quantity of resources used and infrastructure developed, collect any associated product cards, and trade in product cards for the desired number of population cards.
 - b. During this time, the community may negotiate agreements with other communities and trade for resources, products, or tokens.
4. Repeat steps 1-3 for each community
5. Repeat steps 1-4 until the end of the game
6. End of Game
 - a. When time is up, each community tallies their points. The community with the most points wins!
 - b. Remember
 - i. Each product card is worth 1 point
 - ii. Each active population card is worth 5 points

Homework 3: Policy Brief

Due Date: _____

The final assignment associated with this case involves a written policy brief (2-3 pages long), in which you delve more deeply into your post-game class reflections. Your overall aim is to increase your community's resilience with regards to FEW systems. Specifically, you will be reviewing your community's initial development strategy and suggesting ways it could be improved. Questions to reflect on include:

- How effective was your overall strategy? What factors "out of your control" (e.g., weather, neighbors) influenced the strategy's effectiveness?
- How robust was your overall strategy? Was your strategy's level of detail helpful or a hindrance?
- How did you mitigate adverse conditions (e.g., drought) during game play? Could you have predicted any of the adverse conditions?
- Were there any unintended consequences (favorable or otherwise) that arose from your strategy?
- Did you modify your strategy during game play?
- Having played the game, would you modify your overall strategy? If so, how?
- How well do you think your strategy might work for a real community? Why? What other factors might you want to take into consideration for a real community?

You are encouraged to re-review all of the materials associated with the case, including your product-specific and integrated FEW concept maps as well as your pro-con grid, to help develop your responses to the above questions. This is intended to be a challenging assignment that engages both your critical and systems thinking skills. The associated rubric for this assignment is provided on the next page.

Rubric #4: Policy Brief

| Criteria | 5 | 3 | 1 | Points Awarded |
|--|---|--|--|----------------|
| <p>1. Initial Strategy Evaluation: Were the strategy's strengths and weaknesses discussed in the context of community resiliency? Were insights from the game drawn to inform these considerations?</p> | Both strengths and weaknesses were discussed in the context of community resilience. Insights from game play are obvious. | Some strengths and weaknesses discussed; unclear about connection to community resilience and game play. | Unclear how points connect to strategy assessment or game play. | |
| <p>2. External factors: Were "out of control" factors discussed in the brief? Were unintended consequences of community's strategy mentioned?</p> | Both "out of control" factors and unintended consequences were addressed | Only one set ("out of factors" or unintended consequences) addressed | Neither set was addressed | |
| <p>3. Modifications: Were strategy modifications proposed? If no, was there a justification provided?</p> | Proposed modifications reflect initial strategy evaluation and external factors | Proposed modifications exist but unclear how they reflect game play | No proposed modifications | |
| <p>4. Critical and Systems Thinking: Does student demonstrate evidence of critical thinking skills and systems thinking skills?</p> | Student demonstrates excellent ability to connect FEW concepts and factors related to community resilience strategies | Student demonstrates good ability to connect FEW concepts and factors related to community resilience strategies | Student demonstrates poor ability to connect FEW concepts and factors related to community resilience strategies | |
| <p>5. Communication: Is the writing easy to follow and understand? Does the style and organization enhance reader comprehension?</p> | Writing style is clear and well-organized, thus facilitating reader comprehension | Main points are there but writing style is only somewhat clear and organized | Unclear what the sentences mean or how they relate to each other | |
| Total points (out of 25) | | | | |