

## ABSTRACT

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ENVRIZ: A METHODOLOGY FOR  
RESOLVING CONFLICTS BETWEEN  
PRODUCT FUNCTIONALITY AND  
ENVIRONMENTAL IMPACT

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Product development organizations are facing more pressure now than ever before to become sustainable. However, organizations are reluctant to compromise product functionality in order to create products that have less environmental impact than that required by regulations. Thus, engineers may face a conflict between improving product functionality and reducing environmental impact.

The design for environment (DfE) tools currently available are inadequate with respect to helping engineers determine how to resolve this conflict during the conceptual design phase. The Theory of Inventive Problem Solving (TRIZ) which is based on Design by Analogy provides a promising conceptual design approach for

this problem. Examples of products that simultaneously reduce environmental impact and improve product functionality can inspire engineers to do likewise.

This research consists of 1.) Finding products and patents that overcome a contradiction between product functionality and environmental impact; 2.) Analyzing and determining the functionality parameter, environmental parameter, and TRIZ principle demonstrated by each example; 3.) Organizing this knowledge into an accessible DfE tool (matrices); and 4.) Developing a methodology for using the tool. The combination of the tool and methodology is named ENVRIZ, a merge of environment and TRIZ.

After ENVRIZ was complete, an effectiveness study was completed to understand whether the new tool provided better solutions than TRIZ. Results of the study support that utilizing specific product examples from ENVRIZ provides better solutions compared to utilizing engineering principles from either ENVRIZ and TRIZ.

Although the use of the tool on its own does not guarantee a reduction in a product's overall sustainability, the ENVRIZ methodology provides design engineers with a useful conceptual design tool to help overcome contradictions between improving product functionality and reducing environmental impact. Moreover, despite the limited number of examples identified to date, this research provides a framework and prototype that can be extended to incorporate new solutions to these contradictions.

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PRODUCT FUNCTIONALITY AND ENVIRONMENTAL IMPACT

By

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## Preface

This work came to be through merging two topics that intrigued me. First was my interest in how engineers innovate. In college courses we are taught the fundamentals of engineering, but given little opportunity or instruction on creating good ideas. Brainstorming seemed to be the common method used and naturally some students were better at coming up with good ideas than others. Were these students born with engineering intuition or was it something that could somehow be learned? In a graduate course, I was exposed to Theory of Inventive Problem Solving (TRIZ) and it really stuck with me because it was the first time I had seen a systematic process for innovation.

The second area that interested me through my graduate work was Design for Environment (DfE). A lot of work has been completed in this area and there are many tools available yet companies still struggle with adoption. One problem is that companies have a mission to make money and it is a tough sell if being environmentally friendly means being less profitable. Furthermore, while engineers understand the basic concepts of design for environment and its benefits, they do not have much support when it comes to *how* to design an environmentally friendly product after the simple fixes such as material substitution are implemented.

This research combines these two areas of interest to provide engineers with a systematic methodology for developing innovative environmentally friendly products.

## **Dedication**

To my loving wife and unborn son's mother Staci for her support, motivation and patience along the way. Also, to my parents Patrick and Sandra who instilled the importance of education and hard work in me.

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## **List of Abbreviations**

ARIZ – Algorithm of Inventive Problem Solving

CFCs – Chlorofluorocarbons

DDT – Dichloro-diphenyl-trichloro-ethane

DfA – Design for Assembly

DfE – Design for Environment

DfM – Design for Manufacturing

ENVRIZ – The name given to the methodology developed in this Dissertation. It is a combination of Environment and TRIZ.

LCA – Life Cycle Assessment

TRIZ – The Theory of Inventive Problem Solving

QFD – Quality Function Deployment

QFDE – Quality Function Deployment for the Environment

## Chapter 1: Introduction

Today, product development organizations are facing pressures to become sustainable. The most widely accepted definition of sustainable, which comes from the “Brundtland Report,” is meeting the needs of the present without compromising the ability of future generations to meet their own needs [1]. According to WM Adams’ analysis of the report, “This definition...cleverly captured two fundamental issues, the problem of the environmental degradation that so commonly accompanies economic growth, and yet the need for such growth to alleviate poverty [2].”

While the idea of sustainability has gained popular notoriety, there are complications with practical implementation because of the widely varying interpretations of what sustainable is. The broad definition helped spread the concept but hinders measureable progress since many efforts already being undertaken can now be relabeled as sustainable efforts (i.e. complying with regulations). Businesses are responding to the notoriety of the term by including sustainability sections in their annual reports [3]. Wall Street is responding by developing sustainable indexes to cater to sustainable investors [4]. While businesses may have genuine aspirations to become sustainable, the fact remains that many decisions rely heavily on economic implications in order to create value for the owners and remain viable.

Current thinking on sustainability focuses on three pillars: environmental, social and economic sustainability. Figure 1 below demonstrates how these pillars should interact in theory, our current status, and what changes are needed to get where we need to be. Clearly, a large focus needs to be on the environment to make substantial progress.



The three pillars of sustainable development, from left to right, the theory, the reality and the change needed to better balance the model

**Figure 1: Pillars of Sustainability [2]**

Issues such as “the fossil fuel supply, global warming, depletion of the ozone layer, misdistribution of water use, and the loss of forest have been described by some as ‘extinction-level’ crises” [5]. Most organizations track typical “manufacturing” metrics such as total air emissions, total water emission, and total landfilled waste. Instead, engineers should be designing environmentally benign products and processes whose manufacturing or operation naturally reduces air emissions.

Environmentally benign products are products that comply with environmental regulations and may have significant features that reduce environmental impact. The ideal environmentally benign product is one that would not only be environmentally neutral to make and use but also actually reverse whatever substandard conditions exist in its use environment. It would also end its life cycle by becoming a useful input for another product instead of creating waste.

When the benefits of being environmentally responsible are not enough to shape behavior, countries impose restrictions on materials and processes to limit the amount of environmental damage an organization can commit. The current regulatory situation reflects the need to influence manufacturers through penalties. Developing the next

generation of products contributing to a sustainable world requires identifying a new set of business strategies and design and manufacturing tactics. Products for a sustainable way of life may be an unrealistic objective for green engineering practice today, but many benefits exist for moving in this direction. Studies demonstrate the greatest opportunity for environmentally responsible product development occurs during the product design phases, specifically the early design phases [6,7,8,9,10]. The greatest impact engineers can have on the environment is to learn a new set of Design for Environment (DfE) practices and principles that will lead us to products for global sustainability.

Many researchers are working on conceptual design tools to help engineers develop more environmentally benign products. Bohm *et al.* show that a streamlined life-cycle assessment (LCA) can be conducted at the conceptual design phase if information about the components in the design is already contained within a Design Repository [11]. By providing engineers with the ability to understand the environmental impact of their conceptual designs, they can make better decisions before the design is locked in. Telenko and Seepersad present a methodology for uncovering environmentally conscious principles and guidelines through the use of reverse engineering and LCA [12]. Appropriate principles and guidelines are important during conceptual design because they assist the engineer in arriving at solutions quicker.

The next section will review the Environmental Movement which helps to explain why the engineering community is interested in DfE.

## 1.1: The Environmental Movement

The environmental movement has evolved fairly quickly over its short life. In its infancy, it meant putting a filter on a smokestack, avoiding dumping in the river, and placing recycling marks on items that could be recycled. Much of the work to improve these end-of-the-production-line metrics were “patch jobs” which is like inspecting quality into a product, an inefficient strategy that produces favorable results in the short-term but does not discover and fix root causes that compromise product quality. Then, the environmental movement became more product focused and consisted of removing harmful materials from products, such as lead, and substituting them with materials that had less environmental impact. Today, we are entering a phase where products are being designed with specific environmental goals that are just as important as the product’s functionality. Companies are beginning to realize that functionality can be maintained or improved while reducing harmful environmental effects and thus creating a more ideal product. This section will explore the drivers of the three generations of the environmental movement.

### **1.1.1 The First Generation**

The beginning of the environmental movement in the United States can be traced back to Rachel Carson’s book *Silent Spring*, which was published in 1962. In her book, she argued that the overuse of pesticides, specifically DDT (dichloro-diphenyl-trichloro-ethane), could eventually destroy all life on earth. She described a world where the “songbird would be silenced and the spring barren” and used references to an atomic fallout to reach her readers [13]. Carson passed away just eighteen months after her book was published, but her writing eventually led to the ban of DDT in 1972 and



sparked “an awakening of public environmental consciousness [13].” As a result, a host of environmental legislation and milestones soon followed, including:

- **U.S. Clean Air Act (1963)** – Legislation aimed at reducing air pollution.
- **National Environmental Policy Act (1970)** – U.S. national policy established to promote the enhancement of the environment.
- **Environmental Protection Agency Established in 1970.**
- **U.S. Clean Water Act (1972)** – Legislation aimed at reducing water pollution.
- **United Nations Conference on the Human Environment** – First meeting in 1972 of global representatives to discuss the environment.
- **U.S. Endangered Species Act (1973)** – Legislation to protect species whose population had been compromised due to a lack of conservation.
- **Resource Conservation and Recovery Act (1976)** – Legislation requiring tracking of hazardous wastes from cradle to grave.
- **U.S. Comprehensive Environmental Response, Compensation, and Liability Act (1980)** – Legislation that holds polluters accountable for environmental damage.

Consequently, the first generation of the environmental movement was focused on the manufacturing stage of the product development process. Companies were focused on issues such as reducing the emissions of their factories and ensuring that hazardous wastes were disposed of properly. During this generation, the design of the product was rarely focused on with respect to improving environmental impact.

### **1.1.2 The Second Generation**

In 1974, Frank Rowland and Mario Molina published an article in *Nature* that suggested chlorofluorocarbons (CFCs) were causing the depletion of the ozone layer [14]. Shortly thereafter, the U.S. National Academy of Sciences published a report that supported the hypothesis of Rowland and Molina [15]; however, it was believed that this report overestimated the effects of CFCs on the ozone layer and there was still doubt in the general population. Then, in 1985 an ozone hole was discovered in the arctic that confirmed the theory for the majority and ignited another generation of environmental awareness where people became interested in what was in the products they were using. It should be noted that ill effects of lead poisoning had been discovered before ozone depletion and the use of lead in paint was restricted in 1971. However, it did not have the same global implications as the ozone depletion discovery and did not incite a new type of thinking.

The second generation of environmental movement was focused on the detailed design stage and end of life stage of the product lifecycle while maintaining focus on the manufacturing stage from the first generation. Companies were attentive to issues such as substituting harmful materials in their products with materials that had less of an environmental impact and informing consumers of recycling opportunities with products and packaging. During this generation, the conceptual design of a product did not include consideration of environmental impact. However, there was consideration during the execution of the design which is an improvement from the first generation where the product was rarely the focus. The legislation during this generation provides

some insight to the reasons behind these detailed design initiatives [16]. Legislation included:

- **CFCs Banned in Aerosol Cans by US, Canada, Sweden and Norway (1978)**
- **Montreal Protocol (1987)** – Phases out ozone depleting compounds.
- **European Commission Directive 94/62 on Packaging and Packaging Waste (1994)** - Set packaging take-back standards for every member country to meet.
- **European Restriction on Hazardous Substances (RoHS) Directive (2003):** Restricts the use of Lead, Cadmium, Hexavalent Chromium, Mercury and two Brominated Flame Retardants.
- **Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Directive (2006):** A massive directive that requires analysis of the use of all chemicals entering the European Union.
- **European Battery Directive (2006):** Hazardous substances such as Cadmium are banned in batteries for most applications.

### 1.1.3 The Third Generation

Al Gore's 2006 movie, *An Inconvenient Truth*, won him the Nobel Peace Prize and more importantly raised the public's overall environmental awareness through the global warming issue. Scientists believe that greenhouse gases are a possible cause of global warming. Greenhouse gases are most predominately generated through energy use, so companies are searching for ways to develop and manufacture products using less energy and to inform consumers about their efforts to do so through eco-labels.

Companies are not stopping with just global warming though; most are looking for any

type of innovation that can provide an environmental benefit compared to a similar product. Driving this are major retailers, such as Home Depot, which has developed their own eco-labeling program. Another example is Wal-Mart which is driving suppliers to meet more stringent environmental requirements for the opportunity to sell their product.

This is the beginning of the third generation of the environmental movement which incorporates conceptual design, detailed design, manufacturing and end-of-life: the complete product life-cycle for product development organizations. The design of the product should be such that it performs its intended function while causing the least amount of harm to the environment. One influential piece of legislation that is directing companies towards this generation is the European Commission Directive 2005/32/EC on the Eco-design of Energy-Using Products (EuP). It mandates the environmentally responsible design of products that consume electricity and providing information to users about environmentally responsible use [16]. While this directive was passed in 2005, the writers of the directive are still having trouble defining environmental design requirements that exceed basic energy usage limits.

### 1.2: Problem Statement

Product development organizations are constantly redesigning their products to keep up with changes in technology, regulations, consumer preferences and to get ahead of market competition. During redesigns, organizations are interested in increasing the functionality of their products. Functionality includes all valuable results of a product's behavior in its use environment, such as specific features, ergonomics, and capacity. During a redesign it is also desirable to reduce the product's environmental impact

(among other harmful effects) to satisfy consumer demand and existing and pending environmental regulations.

Design engineers understand the social benefits of a DfE program, but they are unsure of how to reduce the environmental impact of their products once the obvious changes in materials and processes are implemented. DfE programs begin with statements about the corporation's responsibility to preserve the environment and adhere to applicable environmental regulations. DfE programs may also include enterprise-wide energy conservation and recycling goals. For product development teams, typical DfE implementation plans disseminate documents such as checklists, guidelines, and scorecards that provide the engineer information on what needs to be done, that is, which environmental metrics need to be improved.

Unfortunately, broad DfE guidelines do not provide any ideas on how to conceptualize a solution. In some product redesign cases there are management sponsored brainstorming sessions that can provide intellectual stimulation, but these sessions are limited to the experience of the attendees and are not a systematic way to realize a solution. Furthermore, design solutions that arise from DfE practices may not increase the functionality of a product. For instance, biodegradable materials may be less durable than the synthetic materials that need to be replaced. As a result, companies have been reluctant to prioritize DfE objectives with as much fervor as they do other key objectives like product functionality, unit cost, and time to market [17].

In general, engineers may face a contradiction or conflict between improving product functionality and reducing environmental impact. Automobile manufacturers, in particular, face the challenge of redesigning their vehicles, including performance and

luxury models, to reduce their environmental impact without affecting their performance [18]. Engineers need tools to resolve this conflict, especially in the conceptual design phase, when a small number of design decisions have a large impact on product functionality and environmental impact. Innovations and improvements beyond material substitutions are needed.

Given the number of possible conflicts and the vast number of problem domains in which such conflicts can occur, it is unreasonable to create a predetermined set of solutions that can completely resolve all possible contradictions. To overcome this obstacle other design methodologies, such as the Theory of Inventive Problem Solving (TRIZ), have utilized design by analogy. Design by analogy consists of mapping knowledge from one situation to another through a supporting system of relations or representations between situations and is well recognized for its innovative power [19].

The specific problem to be solved is determining a way to provide engineers with information that helps them resolve contradictions between aspects of functionality and environmental impact during conceptual design. That is, helping them find a solution when improving a functionality aspect seems to degrade an environmental aspect or vice versa. When improving either a functionality or environmental aspect and there is improvement or no change in the other aspect, a contradiction does not exist. Improvements made to products that do not overcome a contradiction are still beneficial to society; however, this research is focused on overcoming contradictions because they tend to be more difficult problems to solve.

### 1.3 Research Goals

This research proposes a new conceptual design tool that, like design by analogy, provides engineers with relevant knowledge about solutions that have been implemented in the past. This research has two goals: (1) to increase our understanding of product design by uncovering and organizing design principles that are shown to overcome contradictions between product functionality and environmental impact and (2) to develop a systematic methodology that engineers can use to access this knowledge. It is important to note that the proposed design tool does not attempt to address the entire problem of reducing a product's complete eco-footprint or overall sustainability. Instead, it focuses on the specific, practical, and critical task of resolving a conflict between an aspect of product functionality and an environmental impact.

## Chapter 2: Literature Review

This chapter reviews the major concepts that are important in order to explain the research, namely: Design for Environment (DfE); Design by Analogy; The Theory of Inventive Problem Solving (TRIZ); and combining TRIZ and DfE.

### 2.1: Design for Environment (DfE)

Environmental objectives are increasingly important as companies seek to satisfy environmental regulations, to attract consumers who value environmentally benign products, and to be good citizens. Design for Environment (DfE) is the systematic consideration of design performance with respect to environmental, health and safety objectives over the full product life cycle [6-10]. Implementing DfE requires not only using DfE analysis tools but also changes to the product development process such as adding environmental criteria to the product specification to be effective [20,21].

Design for “X” programs and practices, including Design for Manufacturing (DfM) and Design for Assembly (DfA), have developed over time as a natural response to improving profitability. These methodologies were first used by Ford and Chrysler to help with the design of wartime necessities during World War II [22]. The drivers for DfM and DfA are reducing the time to bring a product to market, reducing a product’s cost and improving a product’s quality. Since DfM and DfA practices have obvious benefits to profitability, guidelines such as reducing the number of total parts and exploiting part symmetry are now embedded in the engineering culture.

DfE, on the other hand, is driven by regulations and social responsibility and does not always increase profitability. DfE practices such as designing for recyclability and



using renewable resources are historically not part of most company's engineering culture. Thus, a barrier to the effective incorporation of DfE programs is the low priority that organizations often assign to environmental issues. Most organizations are not willing to compromise functionality, unit cost, or time to market in order to create products that have less environmental impact than required by regulations [23,24]. The exceptions are those organizations, like Interface, Inc., that court environmentally conscious consumers.

Moreover, "even when motivated to design for the environment, product designers are unsure exactly how to proceed. They face an open-ended problem about which information is scarce [24]." Consequently, manufacturing companies and academia have spent a great deal of effort developing tools to help designers create more environmentally benign products. There are a few problems associated with the DfE tools currently available [25] that prevent designers from realizing innovative solutions. First, most of the tools focus on determining which environmental aspect needs to be improved rather than how a designer can improve that aspect. Second, most tools require too much information to be useful during conceptual design. A tool that can be used earlier in the product development process will have more influence on the design. Finally, most DfE tools are focused solely on reducing the environmental impact of a product and neglect other important aspects such as product functionality.

The two major classes of tools are LCA and decision support tools [7]. LCA provides a fundamental methodology that evaluates the environmental impact associated with a product during its complete life cycle. Decision support tools, such as checklists, guidelines, and scorecards, help an engineer reduce these impacts by improving the

product design. The decision support tools incorporate the consideration of topics such as national regulations, human health and safety, hazardous material minimization, disassembly, recovery, recycling, and disposal into the design process. When implemented, tools and guidelines become part of the long list of items an engineer must consider when designing a new product. Environmental concerns must be balanced against other design considerations to optimize a design.

Unfortunately, serious obstacles exist to the effective use of LCA and decision support tools. Two of the most significant obstacles are the difficulties acquiring the needed data and the challenges developing realistic, appropriate metrics of environmental impact. In addition, these tools are ineffective because “they [are] far too time consuming to be useful to designers and often too specific for general design use [24].” Consequently, LCA and decision support tools are generally not integrated with the other activities and tools used in the product development process. That is, the information flow and decision-making required in order for existing LCA and decision support tools to be effective is inconsistent with what is currently present in product development organizations. The result is often a post-design, standalone, environmental review of a product.

Devanathan et al. [26] emphasized the importance of considering environmental issues during conceptual design. They proposed a novel tool called the function impact matrix, which combines tools for Eco-Design such as life cycle assessment and tools for functional/customer requirements such as Quality Function Deployment. Their approach confirms that environmental improvements can be made without negatively affecting

functional performance. Their function impact matrix identifies which aspect of the product needs to be improved but not how to improve that aspect.

Other design tools that come close to overcoming the aforementioned problems are the House of Environmental Quality and the Product Ideas Tree. The House of Environmental Quality highlights potential conflicts between functional and environmental criteria but does not provide the designer with any information on how to overcome the contradiction [25]. The Products Idea Tree is a “diagram [that] provides a record and organization strategy for ideas to incorporate into a product concept generated during design brainstorming sessions where ideas are recorded by the most relevant design process stage and environmental impact category affected [25].” The tool provides a structure for brainstorming but these sessions are limited to the experience of the attendees and are not a systematic way to realize a solution. Also, the tool considers only the environmental aspects of the product.

Ramani *et al.* provide a review of the current state of research on sustainability across the life-cycle of product development including design, manufacturing, supply chain and end of life [27]. A key conclusion of the paper is that the integration of downstream information into early eco-design tools is essential to achieving true sustainable product development.

## 2.2: Design by Analogy

In design by analogy, the engineer applies his own experience and relevant examples to the new problem. “In the past 25 years, analogy has assumed a central role in theories of problem solving and scientific discovery...Used in conjunction with domain-specific knowledge, analogy may enable the search process to be greatly

abridged when patterns are noticed in the current problem state. Pre-stored knowledge can be evoked and used to plan the next steps toward solution of the problem, provide macros to replace whole segments of step-by-step search, or even suggest an immediate problem solution. The recognition mechanism (with its associated store of knowledge) is a key weapon in the arsenal of experts and a principle factor in distinguishing their performance in the domain of expertise from that of novices” [28].

Analogical thinking is one of the cognitive processes that engineers use when searching for solutions to technical challenges, such as imagining design improvements that also improve environmental impact. Research is underway to test the impact of providing seed ideas or cues to engineers during the process of ideation that is critical to conceptual design. One group in the United Kingdom tested the value of providing idea stimulus to design teams in industry. They found that introducing stimuli in the form of TRIZ innovative principles supported the rate of ideation generation during brainstorming sessions and lead to less obvious ideas [29]. Work with student groups concluded that the nature of the provided stimulus was important on its ideation impact. This study found that the more disparate the stimulus is, the more difficult it seems to be for engineers to use it; thus, the context within which the cues are provided is important for success [30].

Another study with engineering students focused on the impact of lexical stimuli (words) on design generation and found that students tended to use the words as verbs, especially when the stimulus was seemingly unconnected to the design task [31]. The same lexical study found that the dichotomous stimulus, like that presented in the TRIZ method, led to concepts that were judged by raters to be more novel than other concepts.

A final study examined the effect of analogical example properties on conceptual ideation [32]. The study found that when compared to near-field examples, using far-field examples (examples from a different problem domain) increased the novelty of concepts, increased the variability in quality of concepts and decreased the quantity of concepts due to moving the engineer into one or two novel regions of the design space which they explored in more depth. Additionally, the study found that when compared to more-common examples, using less-common examples (designs not commonly found in the engineer's world) also increased the novelty of concepts and increased the variability in quality of concepts but appeared to do so via broadening the search space which increased the quantity of concepts.

This research on ideation suggests that engineers who consider cueing examples after determining some initial problem solving parameters may improve the quantity and quality of the concepts they generate. Furthermore, a design by analogy style conceptual design tool requires identifying examples that embody good solution characteristics. Once collected, examples must be organized for retrieval based on objectives relevant to the design challenge rather than presented in some more natural means of coding (e.g., application area and key mechanical principle). Finally, the tool must be able to extract the examples that embody the key solution objectives even if the example is very different from the original problem.

### 2.3: The Theory of Inventive Problem Solving (TRIZ)

The Theory of Inventive Problem Solving (known by the Russian acronym TRIZ) [33,34,35,36,37] defines inventive principles and processes used within different

industries and provides tools for solving technical problems of varying complexities. These tools provide engineers with an incredible knowledge base [38].

TRIZ was developed by Genrich Altshuller, a Russian-born patent examiner [37]. During his experience in the Soviet Navy, he not only helped many inventors apply for patents, but also to solve problems as well. His line of work lead to him to question the accepted fact that inventing was a random act and ideas just came easier to some people. Altshuller believed there had to be a systematic process for inventing that could be documented and taught to inventors. Instead of randomly searching the design space for a solution to a problem, a methodology that directed inventers to the solution was needed.

Altshuller and his associates studied over 1.5 million patents and determined that over ninety percent of engineering problems they addressed had been previously solved. By studying the patents that represented original solutions to problems, Altshuller's team was able to define inventive principles and processes used within different industries. The results of their study yielded foundations and tools for solving technical problems of varying complexities, which is known as TRIZ. The next sections will provide: an overview of an important tool within TRIZ, the contradiction matrix; an overview of the concept of Ideality; and a discussion on the validity of TRIZ as a design methodology.

### **2.3.1: The Contradiction Table**

The contradiction table, one of the most recognizable tools within TRIZ, consists of two sets in matrix form: engineering parameters and principles. An engineering parameter is a feature of a problem that can worsen or improve such as weight of a moving object, temperature, or reliability. The engineering parameters form the headings on the left and top side of the matrix with the left side corresponding to an improving

parameter and the top side corresponding to a worsening parameter. A principle is a technique that has been used for solving a contradiction between certain parameters. Examples of principles are segmentation, preliminary anti-action, and periodic action.

Within TRIZ there is a complete list of the forty principles, along with explanations of each principle, and examples of how the principle is implemented [35]. Principles that have been found to help resolve a particular conflict between two engineering parameters are located in the box of the matrix where the two engineering parameters intersect. For example, the intersection of an improvement in the weight of an object and a reduction in the strength of an object lists four design principles: #28 Replacement of Mechanical System; #27 Dispose (replacing an expensive object with a cheap one); #18 Mechanical Vibration; and #40 Composite Materials. A list of the TRIZ principles along with their definitions can be found in Appendix A.

The contradiction matrix only provides the principle and the engineer has to interpret how to apply the principle to their problem. Since many people have difficulty with applying the principles, most commercial TRIZ software provides product examples that embody the principle to help with application of the principle.

### **2.3.2: Ideality**

A major goal of many organizations is increasing their market share of a particular product or family of products. In order to achieve this goal, organizations are constantly redesigning their products to keep up with their competitors. During the redesigns organizations are interested in increasing the “usefulness” of their products. The term usefulness includes all valuable results of the product’s function such as specific features, ergonomics, and capacity. Within these redesigns it is also desirable to

reduce the harmful effects of a product. Examples of harmful effects include cost, energy use, safety hazards, and pollution. Within TRIZ, the idea of increasing useful effects and decreasing harmful effects is captured within the law of ideality. The law of ideality states that “technical systems evolve toward increasing degrees of ideality, where ideality is defined as the quotient of the sum of the system’s useful effects,  $U_i$ , divided by the sum of its harmful effects,  $H_j$ ” [33]:

$$Ideality = \frac{\sum U_i}{\sum H_j}$$

Typically an improvement in the usefulness of a product results in an increase in the harmful effects and the design team is forced to make a trade-off. When a trade-off is made the ideality does not increase and the technical system does not evolve. Using techniques found in TRIZ helps increase the ideality of a technical system by resolving design contradictions. The ideal final result would be a product that provides the useful benefit but does not exist itself.

Some organizations have also adopted the concept of ideality as a way of measuring environmental improvements in their products. Matsushita and Toshiba have adopted versions of Factor X, which was developed using terms coined by both the Wuppertal Institute for Climate, Environment and Energy (Factor) and The World Business Council for Sustainable Development (Eco-Efficiency) [39,40]. Factor X was first advocated in the late 1990s as a technique for evaluating both the functional and environmental aspects of products and services.

Matsushita measures Factor X using the ratio of the improvement in “Quality of Life” to the reduction in “Environmental Impact.” Toshiba calculates the eco-efficiency of a product as its value divided by its environmental impact and then calculates a



product's Factor T as its eco-efficiency divided by the eco-efficiency of the benchmark product. While the specific values they use for calculations are different, both firms have adopted the idea that a product can be made more environmentally benign by increasing its functionality, decreasing its harmful effects, or both. Since most decisions to redesign a product are based on increasing the usefulness of a product, it would be beneficial for engineers to have a tool to help them reduce the environmental impact at the same time.

### **2.3.3: Validity of TRIZ**

TRIZ is a popular design methodology amongst the engineering community and one that has been successfully commercialized. This is evidenced in the creation of TRIZ software such as TRIZSoft and CreaTRIZ, the formation of TRIZ consulting firms such as Innovation TRIZ and Ideation International, the teaching of TRIZ at Universities (ENME808T & ENME601 at the University of Maryland-College Park), textbooks [41], The TRIZ Journal [42], and the use of the methodology at major corporations such as Proctor & Gamble, Ford Motor Company, and Boeing. The use of TRIZ has also been proposed and utilized in hybrid design methodologies [43,44,45].

Opponents of TRIZ argue that the contradiction matrix is outdated, the methodology is not based on mathematics, and the methodology is not a panacea to all design problems. However, the contradiction matrix is an excellent tool used for creativity enhancement. The matrix is based on mechanical engineering problems and as we move into newer technologies with more focus on electronics, the matrix will need to be updated to address new challenges. One of the steps of this dissertation is creating a new contradiction matrix with environmental parameters based on products that have overcome recent environmental design challenges.

TRIZ, like other accepted design methodologies such as synectics and brainstorming, is not based on mathematics. It consists of a systematic process (ARIZ) which breaks down a solution into a core contradiction and then utilizes a knowledgebase (the previous work done by other engineers in the form of the contradiction matrix) to generate a new concept.

No design methodology will solve all problems. Many factors are involved, including the structure of the design methodology, the organizational support of the design methodology, and the engineer's personal preference, training and ingenuity. "The strength of [TRIZ] comes [from] the analysis tools [contradiction matrix] developed from the patent research" which provide engineers with an incredible knowledgebase [38]. TRIZ is a concept generation tool and will not help with detailed design like other methodologies, such as Design for Manufacturing. While TRIZ should not be the only design methodology used, it is an integral part of an engineer's toolbox [41].

#### 2.4: Combining TRIZ and DfE

Many researchers acknowledge the strengths of the TRIZ approach to improving design and have experimented with adaptations of TRIZ [46,47,48,49,50,51,52]. Liu and Chen [46] developed a green innovation design method by analyzing the TRIZ contradiction matrix. The authors mapped TRIZ parameters to environmental goals and through frequency analysis of the contradiction matrix concluded that certain inventive principles are more likely to achieve specific environmental goals. This approach does not address conflicts between functionality and environmental impact, and the parameters in TRIZ do not thoroughly address all of the environmental parameters as discussed later in Section 3.1. Chang and Chen [47] present an eco-innovative example product for each

of the forty TRIZ inventive principles to highlight that the inventive principles can be used for eco-innovation. Low *et al.* [48] explore the applicability and adaptation of TRIZ to an eco-centered service solution. The authors conclude that TRIZ is better suited to generate product focused solutions rather than service oriented solutions because of its inability to handle multifaceted, multihierarchical situations. Jones and Harrison [49] investigated how TRIZ might be used and modified for eco-innovation through examination of environmentally innovative compact florescent lamps within Philips Lighting. To adapt TRIZ for use in eco-innovation, Jones and Harrison suggested extracting generic principles for solving environmental contradictions through the study of environmental patents and including more parameters within the contradiction matrix that address environmental issues and resource conservation. Kobayshi and Aoyama [50] proposed an expanded contradiction matrix that includes functionality parameters and environmental parameters on both the top and left sides of the matrix. They provide only a framework and one entry to the table based on an example provided in the paper. Morgan [51] explored expanding TRIZ to include environmentally benign products and utilizing functional models to identify environmental innovations. He only explored certain products that demonstrated an improvement in energy efficiency but determined that expanding TRIZ to include environmental products would be worthwhile. Sakao [52] proposed a methodology for environmentally conscious design that combines the use of life-cycle assessment (LCA), quality function deployment for the environment (QFDE), and TRIZ. This paper suggests that the current TRIZ contradiction matrix can easily handle functionality and environmental contradictions. However, the hair dryer example provided by Sakao resolves a contradiction between two functionality

requirements rather than a contradiction between a functionality and environmental requirement. Overall, however, this methodology is a very useful framework because it covers a wide range of the development process, from product planning to concept selection.

The previous work, while an inspiration to this work, lacks the detailed research required to provide engineers with a systematic way to access design principles that have been used previously to resolve contradictions between functionality and environmental impact.

## Chapter 3: Research Methodology and Results

The methodology [53] used to develop this conceptual design tool proceeded through the following steps:

1. A broad set of functionality and environmental parameters that are useful to engineers during conceptual design were selected. This step is described in Section 3.1
2. Patents and products that demonstrated a reduction in environmental impact were found. This step is described in Sections 3.2.1 and Section 3.2.2.
3. The patents and products found in Step 2 were analyzed to determine if a functionality improvement accompanied the reduction in environmental impact. If so, the product or patent was selected for the design tool and the improving functionality parameter, improving environmental parameter and TRIZ principle demonstrated were defined. This step is described in Section 3.2.3 and examples of products and patents that were used in the research are provided in Section 3.3.
4. The information was organized into two ENVRIZ matrices: one that contains TRIZ principles and one that contains references to patent and product examples. This step is described in Section 3.4.
5. A process for using the ENVRIZ matrices was developed. This step is described in Section 3.5.
6. An online collaborative version of the tool was developed to provide an example of how the matrices could be continually improved. This step is described in Section 3.6.

### 3.1: Selection of Environmental and Functionality Parameters

Before beginning the search for products that demonstrate a reduction in environmental impact and an improvement in functionality, the environmental and functionality parameters needed to be defined. For the environmental parameters, six of the seven eco-efficiency dimensions developed by the World Business Council for Sustainable Development were used [54]. This approach was also used by Chang and Chen [47] as a suitable standardized set of critical objectives for improving products. Listed below are the seven dimensions of eco-efficiency and their product level definitions:

1. *Reduce the material intensity of goods and services*: Reduce the amount of material used in the product and by the product (e.g., packaging, consumable accessories).
2. *Reduce the energy intensity of goods and services*: Reduce the energy consumed by the product.
3. *Reduce toxic dispersion*: Reduce the use of toxic chemicals or prevent toxic chemicals used from being emitted into the environment.
4. *Enhance material recyclability*: Increase the amount of material that can be reused or recycled.
5. *Maximize sustainable use of renewable resources*: Increase the use of resources that can be replaced naturally at a rate that is greater than or equal to the rate of consumption.
6. *Extend product durability*: Increase the useful life of the product and include serviceability of the product.

7. *Increase the service intensity of goods and services*: Increase the focus on providing a service to satisfy customer needs rather than a product for individual purchase. Examples include shared use, multi-functionality, and upgradeability.

The Service Intensity dimension was excluded from this study because it depends on infrastructure decisions that are made prior to an engineer working on a product. However, the decision to provide a service rather than sell a product for individual use could lead to different product requirements and contradictions. For instance, a product used in a service application would probably require a greater focus on product durability.

The set of engineering parameters used in the TRIZ contradiction matrix was a natural starting point for selecting the functionality parameters because of the link of this methodology to the TRIZ approach. Domb's list of definitions were used for the TRIZ engineering parameters [55]. Many, but not all, of the 39 TRIZ engineering parameters were selected. Parameters that overlapped or directly related to environmental parameters were excluded. For instance, "speed" was excluded because it is very similar to "productivity" and "loss of time," and "ease of repair" was excluded because it is related to the "product durability" environmental parameter. Additionally, when two parameters were used to cover both stationary and moving objects they were consolidated them into one parameter. For example, the "weight of moving object" and "weight of stationary object" parameters were combined. Appendix B lists the thirty-nine TRIZ engineering parameters, the resulting twenty-one functionality parameters used in this research, a definition for each parameter [55], and an explanation of why certain

parameters were not used. Table 1 below shows examples of information contained within Appendix B.

**Table 1: Examples from Appendix B**

<b>TRIZ Parameter</b>	<b>Functionality Parameter</b>	<b>Definition</b>	<b>Explanation</b>
1 - Weight of moving object	1 - Weight	The force that the body exerts on its support or suspension	Consolidated into one parameter for simplicity.
2 - Weight of stationary object			
9 - Speed	Not Used	The velocity of an object; the rate of a process or action in time.	Similar to Productivity and Loss of Time
25 - Loss of Time	11 - Loss of Time	Reducing the time taken for the activity	Used
34 - Ease of repair	Not Used	Quality characteristics such as convenience, comfort, simplicity, and time to repair faults, failures, or defects in a system.	Similar to Environmental Parameter Product Durability
39 - Productivity	21 - Productivity	1.) The number of functions or operations performed by a system per unit time. 2.) The time for a unit function or operation. 3.) The output per unit time or cost per output	Used

### 3.2: Patent and Product Search and Analysis

The goal of the patent and product search and analysis was to identify existing products that improve functionality and reduce environmental impact compared with the previous generation of that product. Because the term “improvement” is a comparative term, the product search sought products that could be compared with a prior embodiment (instead of “first of its kind” products).



Two separate searches were conducted and the results of those searches have been labeled “patents” and “products.” “Patents” are products that were specifically found in the United States patent database. “Products” are those that were found outside of the patent database in sources such as journal articles, online stores, and manufacturer’s websites. In order to quickly narrow the search space, the search began with finding environmental improvements since there are fewer patents and products with environmental improvements than those with functionality improvements. Then each candidate identified by these searches was analyzed to determine if it had a functionality improvement. If the candidate had both an environmental improvement and a functionality improvement then the candidate was selected for the design tool. Section 3.2.1 provides details about the patent search, Section 3.2.2 provides details about the product search and Section 3.2.3 provides details regarding the analysis of the searches

### **3.2.1 Patent Search**

Patents were searched for in the United States patent database, which contains three different types of patents: utility patents, design patents, and plant patents. Utility patents are issued for the invention of a new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof. Design patents are issued for new, original, and ornamental designs for articles of manufacture. Plant patents are issued for new and distinct, invented or discovered asexually reproduced plants [56]. This research considered only utility patents because these patents must have a functional improvement.

Within the large set of utility patents, patents that provided environmental improvements were searched. The NexisLexis Academic Database was used to search

for environmental terms in the patent titles and abstracts, which describe the most important aspects of the patents. For each of the environmental parameters listed in Section 3.1, equivalent search terms (shown in Table 2) were developed that were likely to appear in the text of patents.

**Table 2: Search terms used for environmental parameters**

<b>Environmental Parameter</b>	<b>Search Terms</b>
Material Intensity	Material Reduction, Light Weight
Energy Intensity	Energy Efficient, Less Energy
Dispersion of Toxic Materials	Toxic, Hazardous
Recyclability	Recycle, Reuse
Renewable Resource Use	Renewable, Biodegradable, Sustainable
Product Durability	Durability

Patents that were issued within a one year period (June 14, 2008, to June 14, 2009) were searched for by Marion Bizouarn, a study-abroad student hosted by Dr. Linda Schmidt. The complete list of patents resulting from the search are included in Appendix C and sorted by environmental parameter. The patent number, device name, and description columns were provided by Bizouarn and the analysis column, which explains why certain patents were not used in design tool, was added by the author and is further explained in Section 3.2.3.

### **3.2.2 Product Search**

The search for “Products” involved examining sources highlighting products with environmental innovations. Although lists of “green” products are widely available, finding useful information about innovative products that are appropriate for the design tool was a more difficult task. For example, the Energy Star certified products list could not be used blindly because Energy Star only focuses on energy reduction and does not consider functionality improvement or decrement. Sources utilized for the product search

included journal articles, online stores specializing in selling environmental products, manufacturer's websites and other various sources found through web searches. Examples of sources include an article by Chang and Chen [47] which provided environmental product examples for all forty TRIZ principles and Nigel's Eco Store [57] which specializes in selling environmentally benign products. A complete list of all of the products examined is not available because as products were being searched, the first step of the analysis described in Section 3.2.3 below was concurrently conducted and products that did not also improve functionality were immediately rejected and not noted.

### **3.2.3 Analysis of Patent and Product Search**

The analysis of the patent and product searches consisted of two steps. First, was determining whether or not the candidate patent or product had an improvement in functionality because the searches focused only on finding examples of environmental improvement. If there was no functionality improvement, the patent or product was rejected for the design tool and no further analysis was completed. If there was a functionality improvement, then the patent or product was selected for the design tool and the improving functionality parameter, improving environmental parameter and TRIZ principle demonstrated were defined.

The patent search conducted by Bizouarn yielded one hundred thirty four candidate patents. After conducting the first step of the analysis, eighty patents were identified that provided an improvement in functionality. Those eighty patents were further analyzed to define the functionality parameter, the environmental parameter, and the TRIZ principle demonstrated to overcome the contradiction. The first step of the patent analysis is documented in Appendix C which was previously described in Section

3.2.1. The second step of the patent analysis for the eighty patents that were included in the design tool is provided in Appendix D. For each patent, Appendix D lists the patent number, the description of the patent, a summary of its innovation, the previous generation of products upon which it improves, the functionality parameter that is improving, the environmental parameter that is improving, the relevant TRIZ principle, and the search terms used to find the patent.

The analysis of the product search is not as neatly documented as the patent search. The reason for this is the product search was conducted by the author and the first step of the analysis was concurrently conducted with the product search. In the absence of a product candidate list to specifically demonstrate the first step of the analysis, two general analysis examples are provided. First, Chang and Chen [47] provided environmental product examples for all forty TRIZ principles, however, only twenty four of the forty products in the article were selected for the design tool. The products excluded either did not resolve a functional-environmental contradiction or were not thoroughly explained. Second, many of the products on Nigel's Eco Store website [57], including items such as organic clothing, were simple substitutions of materials and did not provide any functionality improvement.

Products that showed improvement in functionality were further analyzed to define the functionality parameter, the environmental parameter, and the TRIZ principle demonstrated to overcome the contradiction. The second step of the product analysis for the fifty products that were selected for the design tool is provided in Appendix E. For each product, Appendix E lists the product number, the name of the product, a summary of its innovation, the previous generation of products upon which it improves, the

functionality parameter that is improving, the environmental parameter that is improving, the relevant TRIZ principle, and a reference to where the product was found.

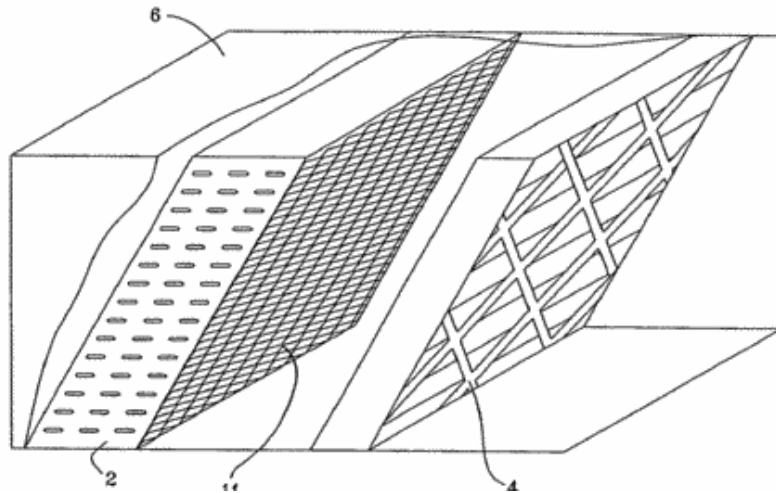
After completely analyzing one hundred and thirty patents and products, the search and analysis phase had to end in order to develop and evaluate the design tool.

### 3.3: Patent and Product Examples

This section lists some examples of the patents and products that were found in the search. Each example describes the functionality improvement, the environmental impact reduction, and the TRIZ principle demonstrated to overcome the contradiction. The examples are being presented to provide insight into the analysis process. The numbers refer to the patent and product lists in Appendix D and Appendix E.

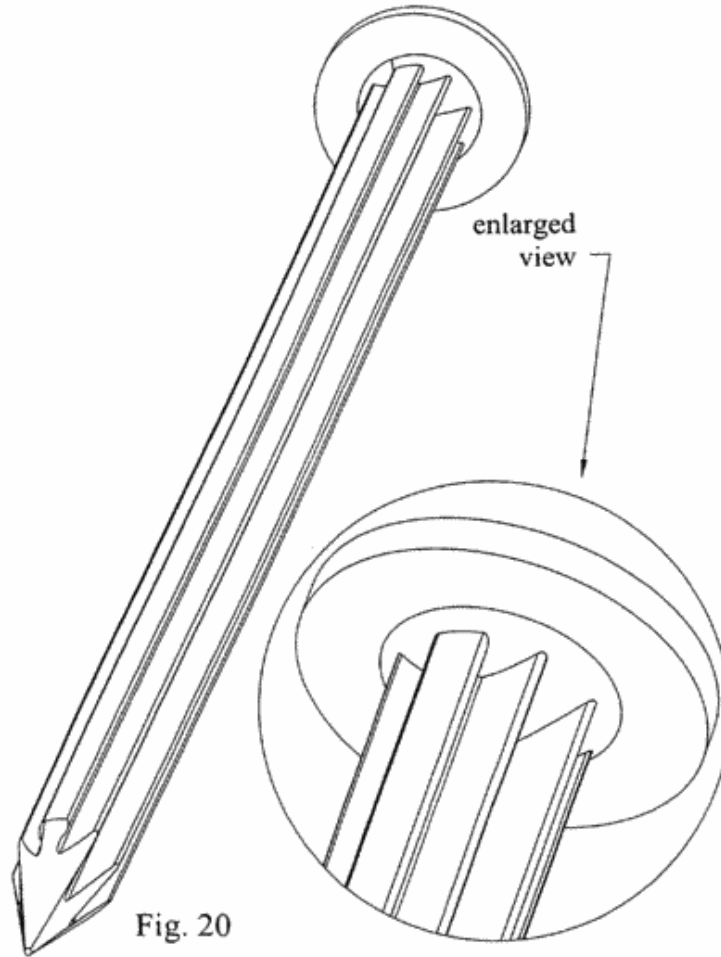
**Patent #2: High-Efficiency Air Conditioning Apparatus.** This invention relates to an improved air conditioning filter and cooling/heating coil that can easily be applied to new and existing air handling systems. The slant design of the components allows a more efficient heat transfer and particle entrapment than their conventional counterparts. By residing at an angle rather than ninety degrees in their air handling enclosures, and by virtue of their oblique prismatic construction, more filter media can be used and more heat transfer surface area can be incorporated without offering any substantial additional impediments to the flow of air. At angles of forty-five degrees, air friction of the coil and filter are reduced by forty to fifty-five percent. Figure 2 below shows a drawing of the apparatus provided in the patent. The functionality improvement is object generated harmful factors. In this case, dispersion of dust would be the harmful factor being improved. The environmental improvement is a reduction in energy intensity due to the more efficient heat transfer. The TRIZ principle demonstrated in this

solution is Transition into a New Dimension as the orientation of the coils was shifted from ninety to forty five degrees.



**Figure 2:** High-Efficiency Air Conditioning Apparatus (Patent #7540320)

**Patent #5: Reduced Material Fastener.** This invention comprises a shank cross section for a reduced material fastener that is selected to provide a parting line. Having a parting line means that the fastener may be made using two opposing dies to cold form the cross section. In spite of some inventive effort, over many years, nails with noncircular cross section shanks are not in widespread use. Part of the problem is the difficulty in manufacturing. Therefore, this invention provides a nail shank design that, compared with a round one, provides reduced weight but has the same or increased holding power and can be manufactured using practical forming apparatus. Figure 3 below shows a drawing of the fastener provided in the patent. The improved functionality parameter is ease of manufacture and the environmental improvement is a reduction in material intensity. The TRIZ principle demonstrated in this solution is Segmentation because the fastener is specifically designed to provide a parting line so that two dies instead of one can be used for manufacturing.



**Figure 3:** Reduced Material Fastener (Patent #7513728)

**Product #7: Self-Cleaning Exhaust Hood.** This product actively deploys water vapors to intercept oil and dust before they reach the hood, whereas a traditional hood is equipped with a filter that needs to be regularly cleaned or else damage to the system may occur [47]. Figure 4 below shows a drawing of the hood. The functionality improvement is external harm affects product. In this case, the external harm is the oil and dust. The environmental improvement is an extension of product durability through the removal of a service task that could lead to product failure. The TRIZ principle demonstrated in this solution is Cushion in Advance because the water vapors proactively prevent oil and dust from reaching the filter to improve reliability.



**Figure 4:** Self-Cleaning Exhaust Hood [47]

**Product #31: Eco Toaster.** A toaster that uses thirty-four percent less energy than standard toasters, thanks to its rather clever auto-close lid that keeps the heat around the toast and prevents it from escaping through the top. It also toasts the bread quicker [57]. Figure 5 below shows a picture of the toaster. The functionality improvement is a loss of time (that is, the new design reduces the time required for an activity) and the environmental improvement is a reduction in energy intensity. The TRIZ principle demonstrated is Dynamicity because the toaster was modified to temporarily cover the entry slot to provide optimal performance during toasting.



**Figure 5:** Eco Toaster (<http://ecotoaster.com/the-tru-eco-2-slice-toaster.html>)



**Product #35 Eco Kettle.** This innovative kettle has a double chamber that directs a user to measure out exactly how much water they want to boil. By boiling only the water that is needed, users get their hot water quicker and use thirty-one percent less energy [57]. Figure 6 below shows a picture of the kettle. The functionality improvement is a loss of time and the environmental improvement is a reduction in energy intensity. The TRIZ principle demonstrated is Dynamicity because the kettle was modified to heat only the water needed which provides optimal performance during heating.



Figure 6: Eco Kettle (<http://www.ohgizmo.com/2007/05/29/eco-kettle-boils-only-what-you-need/>)

### 3.4 The ENVRIZ Matrices

The ENVRIZ matrices that will be presented in this section were inspired by the TRIZ contradiction matrix. The format of the TRIZ contradiction matrix is a convenient way to disseminate an abundance of knowledge. Furthermore, the format provides an easy way to access the specific knowledge an engineer needs to solve his specific problem. The two ENVRIZ matrices have the same headings across the top and down the left-hand side. The top of the matrices contains the environmental parameters and the left hand side contains the functionality parameters which are described in Section 3.1.

The only difference is what is contained within the boxes that form the intersection of the parameters. The first matrix, the ENVRIZ Principle Matrix, contains numerical references to the TRIZ principles demonstrated to overcome the contradiction. The second matrix, the ENVRIZ Example Matrix, contains numerical references to the specific products and patents. Since the raw data for the ENVRIZ matrix was developed in this work, there is an added benefit in being able to provide engineers with an option as to whether they prefer working with principles or specific product examples and designing by analogy. While Altshuller must have utilized a similar research methodology to create his matrix, the records of the patents he researched are not publically available and we are only left with a principle matrix.

The ENVRIZ Principle Matrix is shown in Figure 7 below. Within the matrix, the numbers refer the TRIZ principle listed in Appendix A. For example, the cell at the intersection of the Energy Intensity column and the Weight row has two TRIZ principles: #19 Periodic Action and #33 Homogeneity. These principles could be used to resolve contradictions between weight and energy intensity. In its current form, the matrix identifies if a conflict has been resolved more than once by the same principle because the sample size is limited. As the matrix expands with new additions, a frequency analysis must be conducted and the principles most often used to solve the contradiction would remain while others would drop out of the matrix. The goal would be to provide engineers with the principles most likely to help them solve their contradictions.

		Improving Environmental Parameter					
		Material Intensity	Energy Intensity	Dispersion of Toxic Materials	Recyclability	Renewable Resource Use	Product durability
<b>Improving Functionality Parameter</b>	Weight		19, 33	24			14, 17, 17, 17
	Area	7					
	Volume	5,18,26, 36					
	Stress or Pressure	1	13				3
	Shape						7, 7
	Strength	11, 31	3				40
	Temperature		3, 15, 35, 35		33		11
	Illumination Intensity		1, 2			17	40
	Loss of Substance					22	19
	Loss of information	26					
	Loss of Time		15, 15, 15, 19, 24, 28	3, 20			3, 35
	Quantity of Substance		18				
	Reliability	6	19, 20	10, 10		31	11
	External Harm Affects Product			15	38	10, 35	11
	Object Generated Harmful Factors	9, 23	17	11	24	2, 14, 25, 33	2, 3, 3, 3, 3, 17, 35
	Ease of Manufacture	1, 5			33	16	6, 11, 34
	Adaptability or versatility	1, 1, 1, 6	5, 15, 15, 15, 19, 23			3, 23, 25	1, 4, 7, 15,17, 29
	Device Complexity	6	2, 19	2		5	
	Difficulty of detecting and measuring	3	23			23	
	Extent of automation	25	23, 23, 23	19, 25, 28		20, 25, 31, 36	
Productivity	3	2, 3, 5, 9, 10, 22, 24, 25, 27		1, 1, 1	15		

**Figure 7: ENVRIZ Principle Matrix (Numbers refer to TRIZ Principles in Appendix A)**

The ENVRIZ Example Matrix is shown in Figure 8 below. Within the matrix, a number in parentheses (e.g., “(1)” or “(41)”) refers to a patent in Appendix D, and a number with a leading pound sign (e.g., “#15” or “#23”) is a product in Appendix E. In its current form, the matrix identifies all of the products and patents that have been shown

to resolve the contradiction. As the matrix expands with new additions, the way the examples are presented may need to change due to overcrowding. It is imagined that a web based version, with a link in each contradiction box that takes the user to the list of examples that have resolved the contradiction, would be ideal.

Looking at the matrices, one may notice that some of the specific contradictions have many examples such as improving productivity and reducing energy intensity, while others have no examples. This results from the finite scope of the search and some aspects of the search. First, the search was focused on finding products that improved environmental impacts. Products that satisfied particular functionality improvements or specific functional-environmental contradictions were not directly sought out. Second, some of the functionality parameters (e.g., productivity and adaptability or versatility) are broader than others. In general, fewer products were found for more specific functionality parameters such as illumination intensity and temperature.

		Improving Environmental Parameter					
		Reduce Material Intensity	Reduce Energy Intensity	Reduce Dispersion of Toxic Materials	Increase Recyclability	Increase Renewable Resource Use	Product durability
Improving Functionality Parameter	Weight		#12, (48)	#16			(68), (71), (73), (74)
	Area	#4					
	Volume	#3, #11, #18, (27)					
	Stress or Pressure	(46)	(32)				(15)
	Shape						(20), (78)
	Strength	(22), (26)	(1)				#23
	Temperature		#24, (35), (38), (65)		(57)		(70)
	Illumination Intensity		#41, (41)			#40	(11)
	Loss of Substance					#49	#30
	Loss of Information	#42					
	Loss of Time		#25, #31, #32, #35, #48, (3),	#13, (12)			#37, (69)
	Quantity of Substance		(4)				
	Reliability	#27	(34), (37)	#6, #26		#22	#5
	External Harm Affects Product			(52)	(53)	(54)	#7
	Object Generated Harmful Factors	#15, (24)	(2)	(47)	(50)	#8, #46, (10), (59)	#2, (14), (18), (72), (75), (79), (80)
	Ease of Manufacture	(5), (29)			(55)	(49)	(17), (19), (77)
	Adaptability or versatility	#50, (21), (23), (25)	#9, #10, #21, (33), (40), (43)			#39, (33), (61)	#1, #20, #43, (16), (67), (76)
	Device Complexity	(28)	(31), (42)	(45)		(60)	
	Difficulty of detecting and measuring	(30)	#38			#36	
	Extent of automation	(7)	#29, #34, (36)	#28, #45, (44)		#17, #44, (9), (66)	
Productivity	(6)	#14, #19, #33, #47, (8), (13), (39), (63), (64)		(51), (56), (58)	(62)		

**Figure 8: ENVRIZ Example Matrix (a number in parentheses (e.g., “(1)” or “(41)”) refers to a patent in Appendix D, and a number with a leading pound sign (e.g., “#15” or “#23”) is a product in Appendix E)**

### 3.5 Process for Using the ENVRIZ Matrices

The ENVRIZ matrices are resources that provide engineers with engineering principles or examples of products that overcome contradictions between functionality and environmental performance. The following steps suggest how to use the ENVRIZ matrices:

1. Identify and prioritize the functional and environmental parameters to be improved. Functionality parameters are identified through market research and given priority scores based on customer feedback, competitive market conditions, etc. Environmental parameters are identified through either market research where consumers may be focused on a mainstream environmental issue, such as energy efficiency, or through an environmental impact analysis (i.e., life-cycle assessment). Because of this, setting the priority scores of environmental parameters becomes an interesting decision for companies. The customers may really care about a certain environmental impact but quantitatively that environmental impact may be low when compared with another impact. It is up to the company to decide whether they focus more on a “perceived” environmental impact or a true environmental impact. The conceptual design tool is able to handle either decision.
2. Identify and prioritize conflicts between parameters. The list of parameters from Step 1 needs to be examined to identify all instances where improving a parameter causes another parameter to get worse. Once all conflicts have been identified, they need to be prioritized. This can be done by multiplying the priority score of the two parameters that are part of the conflict. The process

described is a manual method and alternatively, a more advanced design tool such as the House of Quality could be used.

3. Use the ENVRIZ matrices to find principles and product examples that have shown to overcome conflicts between functionality and environmental impact. The ENVRIZ matrix should be used if the conflict to be resolved is between a functionality and environmental parameter. If the conflict to be resolved is between two functionality parameters, then the TRIZ contradiction matrix can be utilized.
4. Use the engineering principles or the product examples and design by analogy to develop conceptual designs that resolve the conflict. The TRIZ contradiction matrix will only provide principles to help resolve a conflict between two functionality parameters. The ENVRIZ matrices provide the option to either utilize principles or specific product examples that embody those principles to help resolve a conflict between a functionality and environmental parameter.
5. Repeat steps 3 and 4 as necessary to resolve other conflicts. Once a conceptual design is found that resolves the highest priority contradiction, the other contradictions in the list need to be re-evaluated based on the new concept to see if they still exist or if any new contradictions have appeared. If a new contradiction appears with a higher priority than the contradiction resolved, then the new concept should not be used. If lower priority contradictions still exist, then the contradictions can be evaluated iteratively based on priority using the conceptual design tool to see if they can be resolved without introducing higher priority contradictions. It may not be possible to resolve all of the remaining

contradictions but by addressing the higher priority contradictions first, the final concept will better address the most important requirements.

The procedure described above is similar to the methodology proposed by Sakao [52], which has the following steps: (1) Utilize LCA to determine scientifically based environmental impacts that may not be captured through traditional market research, (2) utilize a QFD style approach to capture and prioritize functional and environmental requirements and determine contradictions, and (3) utilize a TRIZ based tool for concept generation and evaluate the concept. For resolving functionality-environmental contradictions identified with Sakao's methodology, the conceptual design tool presented in this research should be more effective than the contradiction matrix found within TRIZ because the parameters in TRIZ do not thoroughly address all of the environmental parameters. For example, one might argue that the TRIZ parameter "weight" could be used instead of "reducing material intensity" but weight would not encompass the amount of material used by a product during its useful life, which is part of "reducing material intensity."

### 3.6 Example Use of ENVRIZ Matrices

This section will provide an example of how to utilize the ENVRIZ matrices. Suppose you are engineer on a product development team in General Electric's oven division. You are beginning a new project and the marketing team has provided your engineering team with the following requirements along with priority rankings (a larger number means the requirement is more important) for the new oven based on market research and life cycle assessments of comparable ovens:

- quicker preheating (5)



- stylish design (stainless steel) (3)
- larger cooking capacity (3)
- reduce energy use (5)
- reduce the amount of material used (3)

You notice that the first three items on the list are functionality parameters and the last two items on the list are environmental parameters. Furthermore, you recognize that trying to improve some of the parameters results in a conflict with improving another parameter. For instance, providing a larger cooking capacity and reducing energy use is a conflict because a bigger oven requires more energy to heat. You note these conflicts in Table 3 and also calculate the priority score of each conflict by multiplying the requirement priority scores.

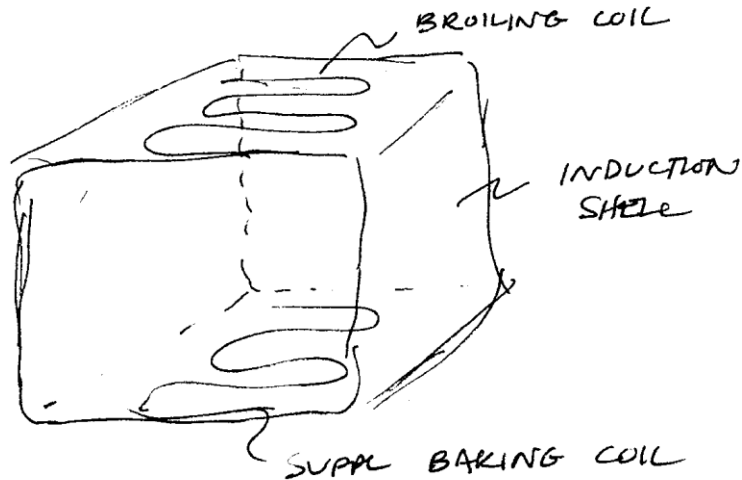
Before you can look to the ENVRIZ and TRIZ matrices for help with resolving the contradictions, the parameters need to be translated into the parameters used in the matrices. You check Appendix B for the definitions of the parameters and determine that Quicker Preheating translates to Loss of Time and Larger Cooking Capacity translates to Volume. These translations are shown in parentheses in Table 3.

**Table 3: Conflict Priorities**

<b>Improving Functionality Parameter</b>	<b>Improving Environmental Parameter</b>	<b>Priority Score</b>
Quicker Preheating (Loss of Time)	Reducing Energy Use	25
Quicker Preheating (Loss of Time) & Larger Cooking Capacity (Volume)	None	15
Larger Cooking Capacity (Volume)	Reducing Energy Use	15
Larger Cooking Capacity (Volume)	Material Intensity	9

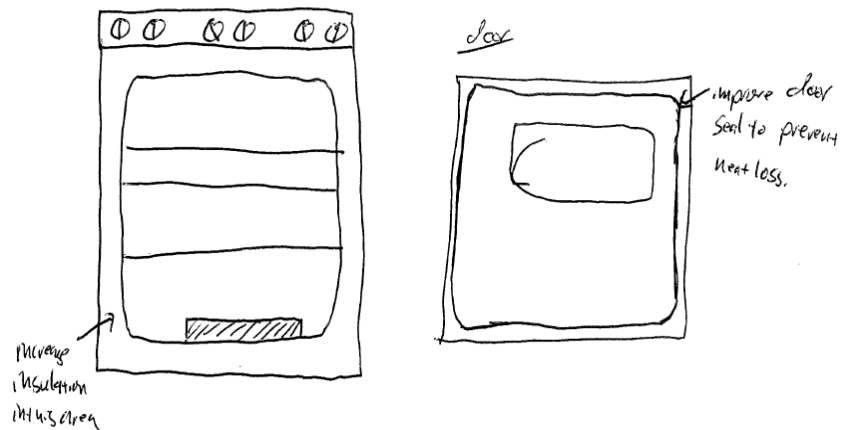
The conflict with the highest priority score is quicker preheating (loss of time) and reducing energy use, so this should be addressed first. This is a conflict because the easy solution would be to apply more energy to preheat the oven quicker. Thus, you are interested in improving both loss of time and energy intensity. Since the contradiction is between a functionality and environmental parameter, you should use one of the two ENVRIZ matrices: The Principle Matrix or The Example Matrix. Suppose you choose to use the Example Matrix in Figure 8. Looking at the intersection between Loss of Time and Reduce energy intensity you find six examples that overcome the contradiction. You decide to explore three of the examples in greater detail: the Induction Rice Cooker, the Eco Toaster, and the Eco Kettle.

The Induction Rice Cooker makes use of induction heating which reduces energy use and allows the unit to heat quicker compared to conductive heating. From this example, you develop an oven concept that utilizes an induction heated shell as shown in Figure 9. If you would have chosen to use the Principle Matrix, the principle you would find in the matrix that is demonstrated by this product is Replacement of Mechanical System.



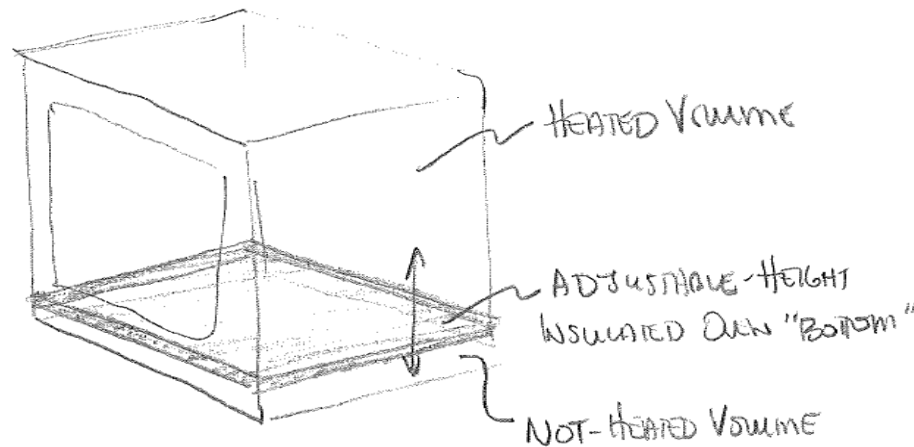
**Figure 9: Oven Concept from Induction Rice Cooker Example**

Next, you examine the Eco Toaster which utilizes a cover that retains heat when closed. Ovens already have a door that closes to retain heat but this example leads you to look into improving heat retention by improving the door and window seals. You come up with the concept shown in Figure 10 below. If you would have chosen to use the Principle Matrix, the principle you would find in the matrix that is demonstrated by this product is Dynamicity.



**Figure 10: Oven Concept from Eco Toaster Example**

Finally, you examine the Eco Kettle which contains a feature that allows a user to heat only the amount of water that the user needs. Applying this to your oven leads you to consider preheating only the volume within the oven that is needed for the task at hand. A solution that allows the cook to adjust the heated volume, based on the size of the food being cooked, would reduce the preheating time and reduce the amount of energy used. You develop the concept shown in Figure 11. If you would have chosen to use the Principle Matrix, the principle you would find in the matrix that is demonstrated by this product is Dynamicity.



**Figure 11: Oven Concept from Eco Kettle Example**

After evaluating and selecting the best concept developed, this process can be repeated to address other conflicts that may remain in the design.

### 3.7 Continual Development of the Design Tool

The ENVRIZ methodology provides a way to consider and resolve contradictions between functionality and environmental parameters and currently has some principles and examples that can be useful. However, the ENVRIZ matrices become more useful as

the number of examples within them increases. More examples will provide insight into which principles are most likely to solve certain contradictions and this will help engineers solve problems quicker. For engineers that prefer the example matrix, more examples means more chances to utilize design by analogy. The tool in its current form is intended to include a sufficient number of examples to provide a starting point for future collaborative use and enhancement.

A web-based version of the design tool was developed during this research to test the idea of collaborative use. This prototype design tool was posted on a wiki that could be accessed online. Unfortunately, by the time this dissertation was published, the company hosting the wiki must have gone out of business and the website is no longer available. The wiki contained an introduction describing the tool and how to use it, both matrices, the product and patent list, and the list of inventive principles and parameters along with definitions. Figure 12 below shows a screenshot of the wiki.

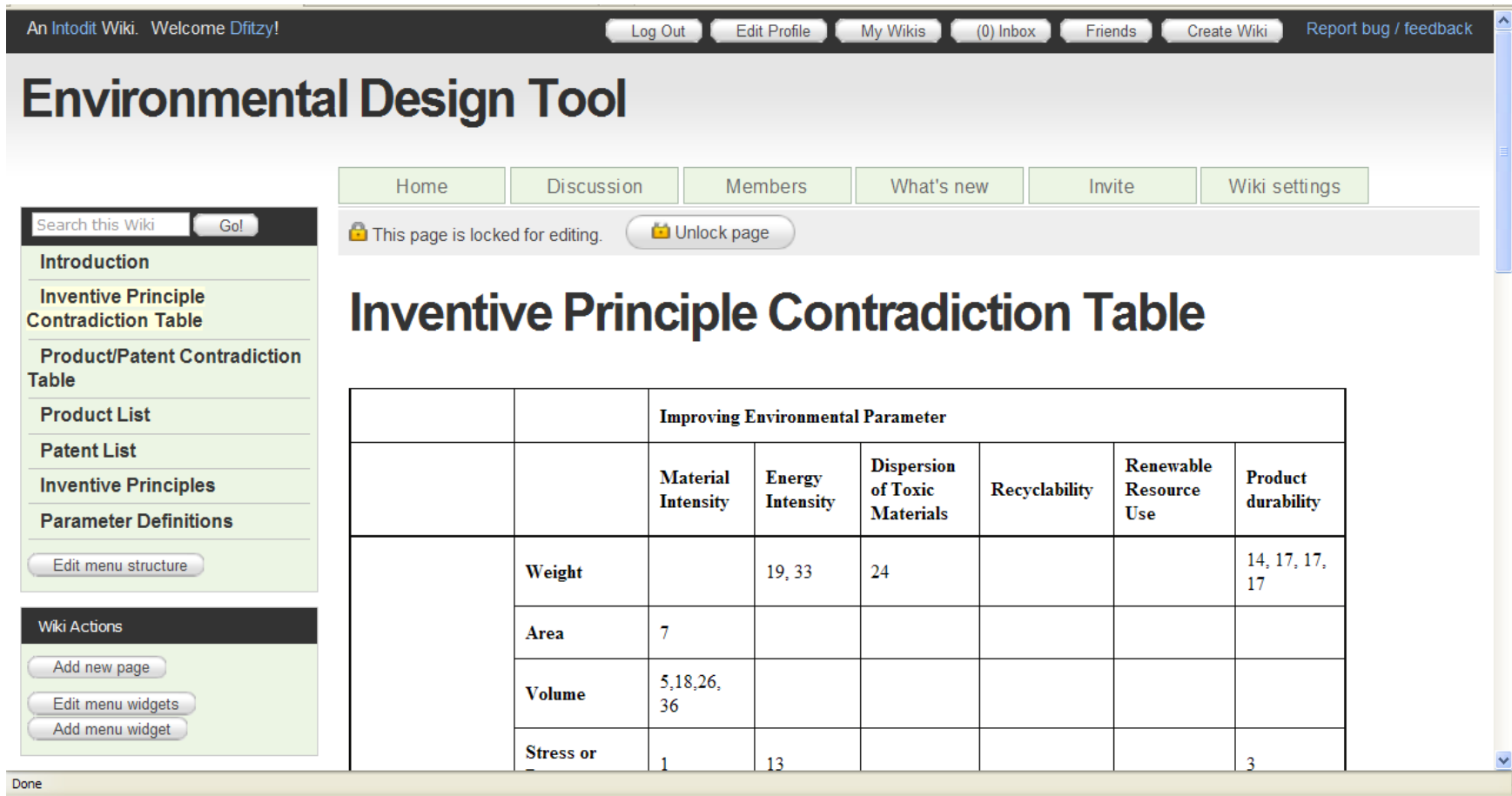


Figure 12: Screenshot of prototype collaborative tool

After the wiki was developed, an article [58] was published explaining the prototype tool and inviting members of the TRIZ community to join the wiki and use the tool. The wiki was setup so members could edit many of the items on the page. Below is a list of the items that were editable along with an explanation extracted from the aforementioned article as to why editing the items would improve the tool.

- Adding New Products – Genrich Altshuller’s life gave him a unique opportunity to devote a tremendous amount of time to a solitary effort to create a contradiction table. While we do not have the same amount of time, we have the benefit of greater information accessibility so that many can contribute a little to create something just as great. The tool becomes more useful as the number of contributors and products increases.
- Editing Existing Products – Based on their different experiences and perspectives, users may disagree with how a product or patent is categorized within the tool. If there is disagreement with the functionality parameter, environmental parameter or inventive principle selected, the wiki page provides a forum for discussion and creating a consensus about a product’s categorization.
- Proposing New Functionality Parameters – The set of engineering parameters used in the TRIZ contradiction matrix was a natural starting point for selecting the functionality parameters for this tool. We relied on Domb’s helpful list of definitions for the TRIZ engineering parameters [55]. We selected many, but not all, of the thirty nine TRIZ engineering parameters and excluded the parameters that overlapped or directly related to environmental parameters. Additionally, when two parameters were used to cover both stationary and moving objects, we

consolidated them into one parameter. Some of the parameters (such as productivity) are broad and could be decomposed into more specific parameters.

There could also be new parameters that were not considered by Altshuller.

- Proposing New Environmental Parameters - For the environmental parameters, we used six of the seven Eco-Efficiency dimensions developed by the World Business Council for Sustainable Development [54]. The Eco-Efficiency dimensions were used by Chang and Chen [47] as a standardized set of critical objectives for improving products. The Service Intensity dimension was excluded because it depends upon infrastructure decisions that are made prior to an engineer working on a product. Once it is decided that a product is needed to provide a service to satisfy a customer need, the engineer will need to focus on the other six dimensions to improve the environmental impact of the product. There exist openings for new environmental parameters or decomposing existing parameters into more specific parameters.
- Proposing New Inventive Principles – The 40 inventive principles developed by Altshuller were used for describing the solution method utilized for the products. New inventive principles may remain undiscovered, or some of the current principles (such as Dynamicity) that seem broad could be decomposed into more specific principles. Telenko and Seepersad provide examples of specific Design for Environment principles being developed [12].
- Examples of How the Tool has Inspired New Products – Examples of new products or ideas inspired by the tools provide credibility to its usefulness and will attract more people to use and contribute to the tool.



- Upgrade to Current Online Format – The current online format of the tool was created using a simple and free wiki creator. Anyone wishing to volunteer to create a better wiki or online format should contact the authors.

The results of the collaborative prototype tool were less than optimal. The last time the wiki was checked, only four people had signed up to use the tool. There were no edits to the wiki and the author was only contacted once via e-mail with questions about the tool. Since the format of the wiki was very primitive and the journal used to promote the tool was directed towards a specific, small audience (TRIZ enthusiasts), it was not expected to be a huge success. However, it was anticipated that a few more members would join and some edits to the tool. Hopefully, another researcher with more expertise in collaborative design will be able to take the foundation provided in this research and expand on it.

## Chapter 4: Effectiveness Study

After ENVRIZ was completed, an effectiveness study was developed to determine whether this new tool provided better solutions than a comparable conceptual design tool; namely TRIZ. This chapter will: 1.) describe the development of the effectiveness study, 2.) explain the tasks the participants were asked to complete, 3.) explain the scoring method used to judge the results of the study, 4.) present the results of the study and 5.) discuss the results of the study.

### 4.1: Development of the Effectiveness Study

In order to determine if ENVRIZ provides better solutions than TRIZ, conceptual designs realized through the use of each tool needed to be compared. To accomplish this, an example design problem was developed for participants in the study to solve using cueing examples from both ENVRIZ and TRIZ. The problem requires improving the preheating time of an oven while at the same time reducing the oven's energy use. The intent of the problem was to encourage an innovative solution and not simply adding more power to the oven during preheating which would result in reduction of time but no decrease in energy use. Participants were asked to create three conceptual design solutions using a different set of cueing examples each time. The cueing examples were provided directly to eliminate any mistakes that could occur with selecting the correct parameters from the ENVRIZ or TRIZ tables. Furthermore, participants were not informed of where the cueing examples came from to avoid any bias towards the new conceptual design tool. Following the completion of the conceptual designs, participants were asked to answer follow-up questions about the designs they developed and to

provide some personal background information. This effectiveness study received approval from the University of Maryland Institutional Review Board.

#### 4.2 Participant Tasks

The participants were provided with a booklet that contained the following items: 1.) An overview of the purpose of the exercise, 2.) Details on the specific problem they were to solve, 3.) General instructions for completing the exercise, 4.) Specific task instructions and cueing examples for all tasks, 5.) Photographs for task three, 6.) Six follow-up questions, 7.) Seven background questions and 8.) Either a student or professional Institutional Review Board Consent Form. Copies of these materials can be found in Appendix F.

The first task participants were asked to complete involved developing a conceptual design using cueing principles from TRIZ. From the TRIZ matrix, the contradiction that most closely aligns with this problem is Loss of Time vs. Energy Use by a Stationary Object. For this contradiction there is only one principle provided in the TRIZ matrix and it is Segmentation. An assumption was made that if Segmentation did not work for someone using TRIZ, the user would look to another similar contradiction for more principles. A similar contradiction that provides four more principles (Consolidation, Prior Action, Mechanical Vibration and Changing the Color) is Loss of Time vs. Loss of Energy. Therefore, for this task, these five principles were provided as cueing examples.

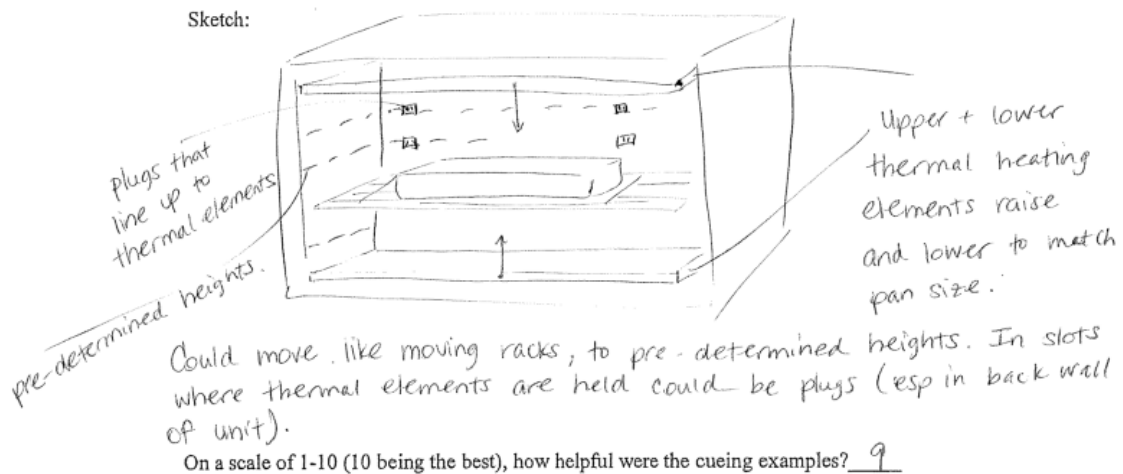
The second task participants were asked to complete involved developing a conceptual design using cueing principles from ENVRIZ. From the ENVRIZ matrix, the contradiction that most closely aligns with this problem is Loss of Time vs. Reduce

Energy Intensity. For this contradiction, four principles were provided: Dynamicity, Periodic Action, Mediator and Replacement of Mechanical System. These four principles were provided as cueing examples for Task #2.

The third and final task participants were asked to complete involved developing a conceptual design using the specific products and patents from ENVRIZ as cueing examples rather than the principles demonstrated by those products and patents from Task #2. The five example products and patents provided with the principle in parenthesis were: Induction Heat Rice Cooker (Replacement of Mechanical System), Eco Toaster (Dynamicity), Energy Saving Gas Net (Mediator), Eco Kettle (Dynamicity), and an Ice Making Machine (Periodic Action). One product in the ENVRIZ table, Dryer Balls, was accidentally not included in the study as an example. The Dryer Balls exhibit the Dynamicity principle like the Eco Toaster and Eco Kettle. The word “product” will be used throughout the remainder of this chapter to convey either a patent or product.

For each of the tasks, the participants were asked to provide a written description of the conceptual design solution along with a sketch. They were also asked to explain which cueing example helped inspire the solution, how that cueing example inspired the solution and how helpful they thought the cueing examples provided were. An example of one participant’s sketch and explanation is provided in Figure 13 below. After completing the tasks, the participants were asked to answer follow-up questions such as whether they preferred principles or product examples, whether they noticed similarities between the principles and product examples and whether they thought they could come up with a better design without the cueing examples.

Description: Adjust oven size to match pan being cooked.  
Eco Toaster. Energy saving + less area to heat.



On a scale of 1-10 (10 being the best), how helpful were the cueing examples? 9

**Figure 13: Example of Participant Response from Effectiveness Study**

The main goal of the study was to determine whether the cueing examples provided by Task #2 and Task #3 lead engineers to find better solutions than the cueing examples from Task #1 because ENVRIZ was developed by specifically finding products that have overcome functional and environmental contradictions. An additional secondary question this experiment will help answer is whether abstract principles or concrete examples are more helpful for participants.

#### 4.3: Scoring Methodology used for the Research Study

To determine whether a solution provided by the participant was considered a good solution, it was evaluated against the following criteria:

- 1.) Will the solution reduce the preheat time and the amount of energy used by the oven?

- 2.) Did the participant utilize the cueing example they selected to solve the problem?
- 3.) Will the solution avoid reducing the functionality of a currently available oven?

A good solution would receive an answer of “yes” to all three criteria. The following paragraphs will describe these criteria in more detail.

The first criterion is important because it determines whether or not the objective of the problem was attained. Obtaining this objective comes down to the engineering problem of reducing the amount of energy needed to preheat the oven while maintaining the rate at which the energy is converted (power).

Let  $Q$  be the energy used by the oven,  $Q_{Loss}$  be the energy lost by the oven,  $m$  be the mass of the substance being heated,  $\Delta T$  be the change in temperature, and  $c_p$  be the specific heat of the substance being heated. These are related as follows:

$$Q - Q_{Loss} = m\Delta T c_p$$

From the equation, it is clear that reducing the energy used by the oven can be accomplished in the following ways:

- 1.) Reducing  $Q_{Loss}$ : Methods of reducing the energy lost by the oven include improving insulation.
- 2.) Reducing  $m$ : Reducing the mass of the substance being heating can be achieved by reducing the volume of the substance (typically air) in the oven.
- 3.) Reducing  $\Delta T$ : Since the problem implies that the old and new oven will preheat to the same temperature, this variable will remain constant.

- 4.) Reducing  $c_p$ : The specific heat can be reduced if a substance other than air with a lower specific heat is used for baking.

The second criterion is important because it is a measure of whether or not the cueing examples provided contributed to the solution developed by the participant. The cueing principles provided in Task #1 and Task #2 were judged by whether or not the participant's concept utilized the principle they selected. The product examples provided in Task #3 were judged by whether or not the participant utilized the principles exemplified in the product or if the thought process from product to solution was thoroughly explained. If no principle or product example was selected for a task, then the participant received an answer of "no" for this criterion.

The third criterion is important because as products evolve consumers expect them to keep getting better. If a solution provided achieves the objective of the problem but in doing so other functionality that consumers have become accustomed to is reduced or eliminated, the concept will probably not be viable. Participants were not specifically asked in the problem statement to avoid reducing other functionalities of the oven.

The three criteria outlined above define what is considered a good solution to help determine whether the cueing examples from ENVRIZ provide more good solutions than the cueing examples from TRIZ. Besides determination of good solutions, the analysis will include categorizing the solutions for further analysis and highlighting the innovative solutions. Based on the author's experience and research of the heat transfer characteristics of ovens, the expected solution to the problem was an adjustable area oven

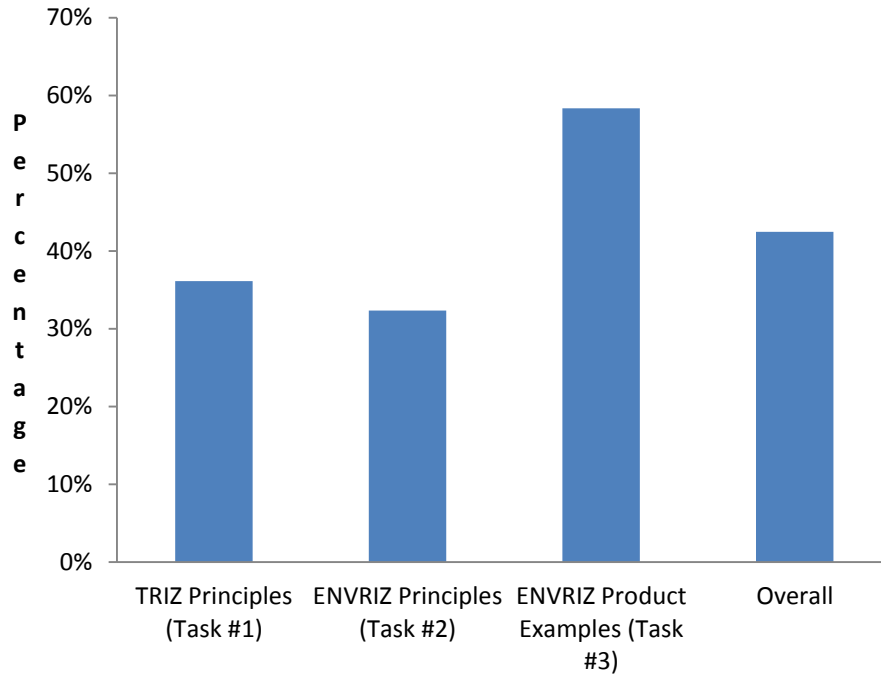
that adapts to the size of the food so less air needs to be heated. This concept was based off the Eco-Kettle which demonstrates the Dynamicity principle.

#### 4.4: Results of Study

The study was completed by thirty four participants resulting in a total of one hundred and six design concepts evaluated, as a few participants provided more than one concept per task. Almost all participants had an engineering degree or were pursuing a degree in engineering. Experience of the participants ranged from zero to thirty-six years of design experience. Fifteen of the participants were students in a graduate course on engineering design methodologies and the other nineteen participants were professional contacts of the author. Since the purpose of the study was to determine whether ENVRIZ provided better solutions than TRIZ regardless of the participant, the results of the study are presented for the entire group. The complete results of the study can be found in Appendix G. For each participant, Appendix G provides the answers to the background questions, the details of the conceptual designs and cueing examples used, the rankings of the cueing examples, the author's ranking of the conceptual designs, and the answers to the follow-up questions.

The main goal of the study was to determine whether the ENVRIZ cueing examples provided better solutions than the TRIZ cueing examples. It should be noted that throughout the results section, the term "ENVRIZ principles" refers to TRIZ inventive principles found looking up the functionality-environmental contradiction in the ENVRIZ Principle Matrix. The number of good solutions from each task was tabulated and analyzed. Figure 14 shows the percentage of good solutions by task and overall.





**Figure 14: Percentage of Good Solutions from Effectiveness Study by Task and Overall**

While the percentages show that ENVRIZ product examples had the highest number of good solutions, TRIZ principles had the second highest number of good solutions and ENVRIZ principles had the lowest number of good solutions, an analysis as to whether these differences are statistically significant needed to be conducted. A test of statistical hypothesis for two proportions was utilized for this analysis. The null hypothesis is that the two proportions are equal, and the alternative is that the first is larger. For a significance level of  $\alpha$ , the test statistic  $z$  and the rejection criteria can be expressed as follows:

$$z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\hat{p}(1 - \hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \geq z_\alpha$$

For this analysis, a significance level of  $\alpha = 0.05$  is used which results in  $z_{0.05} = 1.645$ . Table 4 shows the values used for each test.

**Table 4: Values used for the statistical test**

Test	$\hat{p}_1$	$\hat{p}_2$	$\hat{p}$	$n_1$	$n_2$
TRIZ principles > ENVRIZ principles	0.3611	0.3235	0.3429	36	34
ENVRIZ product examples > TRIZ principles	0.5833	0.3611	0.4722	36	36
ENVRIZ product examples > ENVRIZ principles	0.5833	0.3235	0.4571	36	34

The first test seeks to determine whether the difference in good solutions between TRIZ principles and ENVRIZ principles is significant enough to suggest that TRIZ principles provide better solutions than ENVRIZ principles. The result of the calculation is a  $z$  value of 0.3311 which is less  $z_{0.05}$  therefore the null hypothesis is accepted. We can conclude that the greater number of good solutions provided by TRIZ principles when compared to ENVRIZ principles is not statistically significant.

The second test seeks to determine whether the difference in good solutions between ENVRIZ product examples and TRIZ principles is significant enough to suggest that ENVRIZ product examples provide better solutions than TRIZ principles. The result of the calculation is a  $z$  value of 1.8885 which is greater than  $z_{0.05}$  therefore the null hypothesis is rejected. We can conclude that the greater number of good solutions provided by ENVRIZ product examples when compared to TRIZ principles is statistically significant.

Since the greater number of good solutions provided by ENVRIZ product examples was statistically significant when compared to TRIZ principles, we know that that ENVRIZ product examples will be significant when compared to ENVRIZ principles

since the difference in good solutions is greater. However, the numbers were run and a  $z$  value of 2.1808 was calculated which is greater than  $z_{0.05}$  therefore the null hypothesis is rejected. We can conclude that the greater number of good solutions provided by ENVRIZ product examples when compared to ENVRIZ principles is statistically significant.

Another goal of the study was to determine whether abstract principles or concrete examples were more helpful for participants. The data regarding the number of good solutions per task indicates that product examples generally led to more good solutions than principles. However, additional data was acquired during the experiment to determine how helpful the participants thought the cueing examples were. The three sets of data were:

1. A score from one to ten (with ten being the best) of the cueing examples for each task as the participant was completing the study.
2. A final ranking from one to three (with one being the best) of the cueing examples after all of the tasks have been completed.
3. A specific follow-up question asking if the participant felt it was easier to develop a solution using engineering principles or specific product examples.

For the first set of data, a count was taken for each task to determine the number of times the score of the cueing examples fell within a specific range. The three ranges are one to three, four to seven, and eight to ten. The TRIZ principles had the most scores from one to three with seven responses. The ENVRIZ principles had the most four to seven scores with nineteen responses followed closely by the TRIZ principles with sixteen responses. The ENVRIZ product examples had the most eight to ten scores by far

with twenty responses. The complete results are shown in Figure 15. Note that there are only thirty two total responses because two participants did not complete the scoring question.

For the second set of data, a count was taken for each task to determine the number of times the cueing examples were ranked one, two or three which corresponds to best, second best, or worst. The TRIZ principles had the most worst rankings with sixteen responses. The ENVRIZ principles had the most second best rankings with twenty responses. The ENVRIZ product examples had the most best rankings with twenty three responses. The complete results are shown in Figure 16.

For the third set of data, a count was taken to determine the number of times a participant responded that either engineering principles or specific product examples were more helpful. Some participants responded that they had no preference so that became a third category. Seventy-three percent of participants responded that specific product examples were more helpful, eighteen percent of participants responded that engineering principles were more helpful and nine percent of participants responded that they had no preference. Figure 17 shows the results of the question.

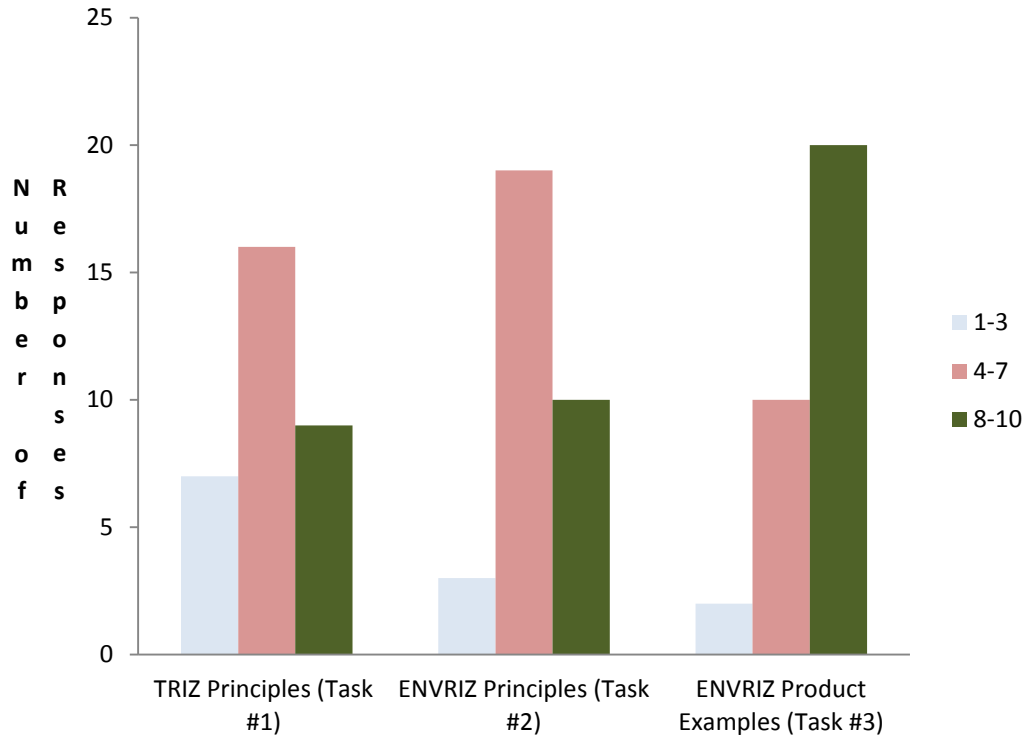


Figure 15: Number of Responses by Scoring Range for Each Task (ten being best)

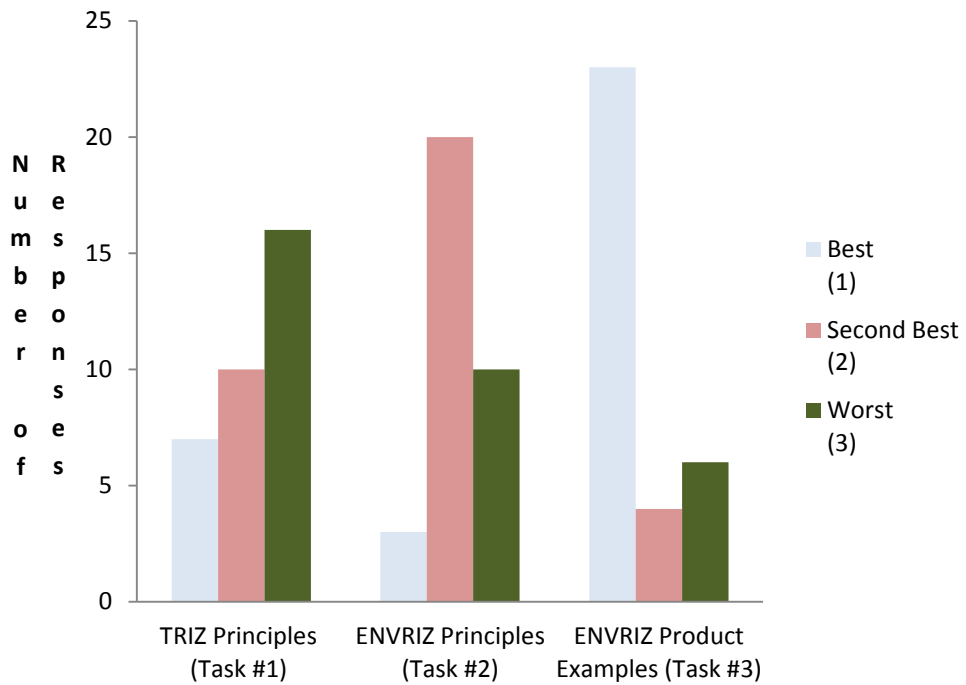
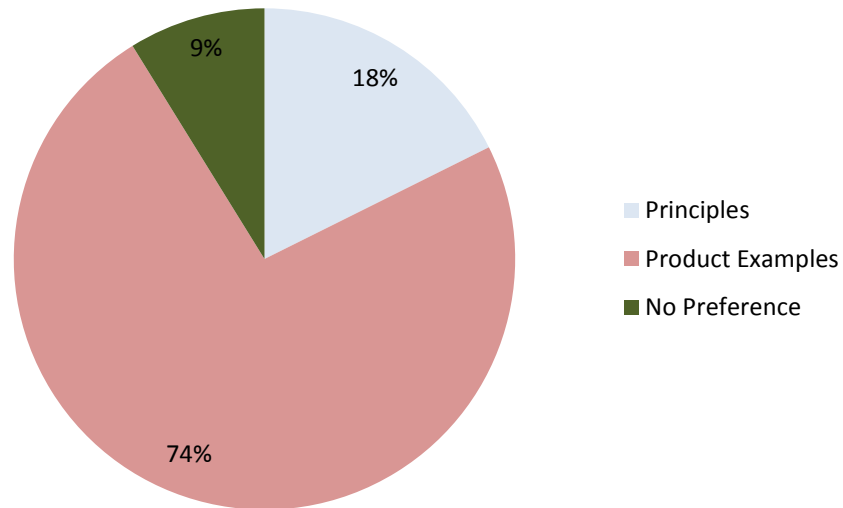


Figure 16: Number of Responses by Rank for Each Task (one being the best)



**Figure 17: Percentage of participants who preferred engineering principles, who preferred product examples, and who had no preference.**

While reviewing the results of the study, the concepts were categorized to give another view of the results. An attempt was made to ensure that the categories developed were at a similar level of abstraction. Below is a list of the concept categories along with a brief explanation of each.

1. **Adjustable Heating Area.** These concepts propose reducing the size of the oven to more appropriately fit the item being cooked. The reduction in size results in less air being heated which speeds up preheat time and reduces energy use. This was the expected solution to the problem.
2. **Increasing the Oven's Power.** These concepts involved a variety of ways to add power to the oven during preheating. The concepts solve the problem of reducing preheat time but not reducing energy usage.
3. **Using more Efficient Heating Methods.** These concepts involved introducing more efficient heating methods such as induction heating and

microwaving. Whether or not these concepts were considered good depended on the specific concept.

4. **Improving Distribution of Heat.** These concepts included ideas such as dividing the heating elements but maintaining original power, moving the heating element around the oven and forced convection. These concepts do not preheat the oven quicker or reduce energy usage.
5. **Preventing Heat Loss.** These concepts focus on preventing heat from escaping the oven. Example concepts are improving general insulation in the oven and reducing heat losses associated with the window. Again, whether or not these concepts were considered good depended on the specific concept.
6. **Saving Energy while Cooking.** These concepts help save energy during cooking and do not focus on preheating. Because the concepts did not address the problem, they are not considered good solutions.
7. **Solution Not Explained Clearly Enough.** These concepts could not be categorized because they did not provide enough explanation.
8. **Using a Preheated Substance.** These concepts involve using preheated air or water to help the oven preheat quickly. These concepts typically require more energy use. One interesting concept was ducting excess heat from the burner (if being used) to help preheat the oven which was considered a good solution because it takes advantage of heat that would otherwise be wasted.

9. **Changing the Color of Oven Walls.** These concepts involve changing the color of the oven's walls. A darker color wall absorbs more of the radiant energy produced by the element, which helps heat the air in the oven quicker.
10. **Substitute Cooking Medium.** This concept involved using steam instead of air to cook the food. While an interesting idea, the use of steam does not reduce the energy use of the oven because energy is needed to convert water to steam.

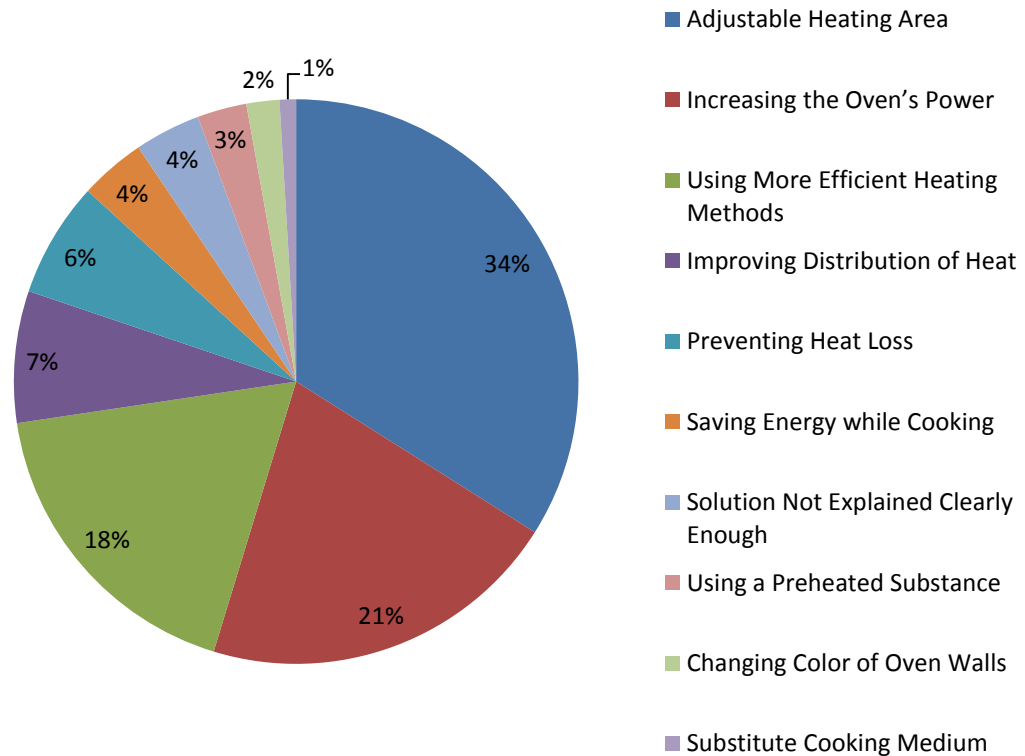
Table 5 shows the different concept categories along with how many concepts fell into each category and a list of the specific concepts that contributed to the total number. In the List of Specific Concepts column, P stands for participant and T stands for task so P3T2 means participant three, task two. Figure 18 shows the percentage of concepts in each category.

**Table 5: Design Concepts by Category**

<b>Concept Category</b>	<b>Number of Concepts</b>	<b>List of Specific Concepts</b>
Adjustable Heating Area	36	P1T1, P1T3, P2T3, P3T3, P6T2, P7T1, P7T3, P9T1, P10T1, P11T1, P13T2, P13T3, P15T1, P16T3, P17T1, P17T3, P18T1, P19T2, P19T3c, P20T3, P23T3, P24T1, P24T2, P24T3, P25T1, P25T2, P25T3, P26T3, P28T1, P28T2, P28T3, P29T3, P32T3, P33T1, P33T2, P34T1
Increasing the Oven's Power	22	P1T2, P2T2, P5T1, P5T2, P7T2, P8T1, P10T2, P11T2, P12T2, P13T1, P14T1, P15T2, P17T2, P18T2, P19T1, P21T1, P21T2, P22T1, P27T1, P27T2, P29T2, P31T1
Using More Efficient Heating Methods	19	P6T1c, P6T3, P8T2, P8T3, P9T3, P12T3, P15T3, P16T2, P18T3, P19T3b, P21T3, P22T3, P23T2, P27T3, P31T2, P31T3, P32T1, P32T2, P33T3
Improving	8	P4T1, P4T2, P6T1a, P9T2, P11T3, P16T1, P23T1,



Distribution of Heat		P34T2
Preventing Heat Loss	7	P2T1, P3T2, P4T3, P5T3, P6T1b, P10T3, P20T2
Saving Energy while Cooking	4	P19T3a, P20T1, P26T2, P34T3
Solution Not Explained Clearly Enough	4	P12T1, P30T1, P30T2, P30T3
Using a Preheated Substance	3	P3T1, P14T2, P22T2
Changing Color of Oven Walls	2	P26T1, P29T1
Substitute Cooking Medium	1	P14T3



**Figure 18: Percentage of Concepts by Category**

Finally, the study produced interesting behaviors and innovative concepts. Below is a list of these behaviors and concepts.

- Some participants simply utilized the method in the product example without thinking about how the method would apply to the oven. For example, one participant (6) wrote “Induction heating method should be introduced into the design of a traditional oven to replace its conventional conductive heating method. Since it works for [a] rice cooker, it works for ovens.” The concept does not explain what part of the oven would be subjected to the induction heating. Introducing induction cooking with a magnetic pan would cause the food to cook as if it were being cooked on a stove top rather than baked. Other induction cooking solutions went into further detail and explained that they intended to heat the shell of the oven which is plausible.
- Many participants utilized the segmentation principle in Task #1 to come up with the adjustable heating area solution. The solutions using segmentation focused on fixed chamber sizes though rather than an adjustable area.
- A few participants (13 and 24) recognized the link between Dynamicity and the Eco-Kettle.
- One participant (7) came up with the adjustable heating area solution from the Eco-Toaster. Typically, solutions utilizing the Eco-Toaster revolved around improved insulation but this participant wrote: “The Eco-Toaster inspired this design as it led me to think about a design that would keep the heat around the food and not let it escape to heat unnecessary space.”
- One participant (8) proposed turning the oven into a microwave through the use of the Replacement of Mechanical System principle: “This is a typical conventional oven, however, it operates as a microwave. Like a microwave, is

able to quickly heat food, this oven is able to quickly preheat by utilizing the same method as the microwave. Once the oven reaches its preheated temperature, a constant heat wave is transferred back and forth to sustain the temperature of the oven.”

- Participant 24 felt constrained by the cueing examples and offered an electronic solution that can calculate appropriate time from a cold oven start based on typical cooking instructions as an input.
- Innovative Concepts (regardless of whether they are considered good solutions):
  - Having pre-heated air always available. (P3T1)
  - Using a microwave to heat water to steam which gets you to 212 degrees more efficiently. (P6T1c, P16T2)
  - Covering the window to prevent losses during pre-heating. The coverage does not reduce functionality because you do not need to see the food during pre-heating. (P10T3)
  - Utilizing a concept from a baby bottle warmer where steam is used to transfer heat to the bottle. (P14T3)
  - Using heat from burners to help preheat oven. Requires the burner being used for other cooking processes and capturing heat that would otherwise be wasted. (P22T2)
  - Using infrared cooking which has no preheating time and more efficient than natural convection (P31T2)

#### 4.5: Discussion of Results

The main goal of the study was to determine whether the cueing examples from ENVRIZ would provide better solutions than the TRIZ cueing examples. To support this statement, the number of good solutions resulting from ENVRIZ principles and ENVRIZ product examples would need to be higher than the number of good solution resulting from TRIZ principles with an appropriate level statistical significance. The results showed that ENVRIZ principles did not show a significant difference to TRIZ principles therefore the claim that ENVRIZ generally provides better solutions than TRIZ cannot be supported. However, most participants found the ENVRIZ principles to be better than the TRIZ principles in both the one to ten scoring and one to three ranking. ENVRIZ product examples had a statistically significant higher number of good solutions compared to both TRIZ principles and ENVRIZ principles. The data supports the suggestion that utilizing specific product examples from ENVRIZ results in better solutions compared to utilizing engineering principles from either ENVRIZ and TRIZ. It would have been ideal to compare ENVRIZ product examples to TRIZ product examples, but again, TRIZ product examples for specific contradictions are not publically available.

A secondary question of the exercise was to determine whether abstract principles or concrete examples were more helpful for participants. Based on the number of good solutions, one could surmise that product examples were more helpful. However, the question was also asked to participants more directly in a variety of ways throughout the exercise: 1.) Score from one to ten during the exercise 2.) Ranking from one to three after the exercise and 3.) Specific follow up question. The results of these questions clearly

point to a strong preference for product examples over engineering principles. This strong preference was seen in both groups of participants (students and professionals).

While there were many different concepts developed by participants in the exercise, three quarters of the concepts fell into three categories: Adjustable Heating Area, Increasing the Oven's Power, and Using More Efficient Heating Methods. The adjustable heating area solution was the most proposed concept, and in fact the one imagined when creating this problem. The author relied on the Eco Kettle cue and the concept of only heating what is needed. Others came up with the solution through various cueing examples such as Segmentation, Dynamicity, the Eco Kettle and the Eco Toaster. The second most proposed concept was increasing the oven's power during preheating. It was surprising that this was the second most proposed solution because it was exactly the solution the author was hoping to avoid through the problem statement. While increasing the power theoretically does not increase the energy use, it does not reduce energy use either. This is the kind of solution one would expect if there was no contradiction and the problem was simply reducing preheat time. The third most proposed concept was utilizing more efficient heating methods and the results were hit and miss with respect to whether the concepts were good solutions. Some participants fell into the pitfall of simply using a concept provided by a product example without understanding the concept or providing detail on how it would be utilized in this particular example. The concept of inductive heating for the rice cooker was a prime example of this. Other concepts provided under this category were good solutions and pretty innovative such as using a microwave to turn water into steam.

The results of this experiment support the hypothesis that product examples provide more good solutions than engineering principles, and that most people prefer using product examples as cueing examples. It appears that starting with a concrete example and applying the engineering principle that it embodies to a problem is easier than starting from the engineering principle itself. In fact, the engineer may not even be aware they applied an engineering principle. The reason for this is that engineering principles are often too abstract on their own and thus harder to implement. Having specific product examples provides immediate context for the engineers and it has been shown that the context within which the cues are provided is important for success [30].

The contradiction matrix within TRIZ provides only engineering principles to help solve certain contradictions. Although there are books and papers [35,47] that provide examples of applying TRIZ principles, the examples are not associated with specific contradictions. Furthermore, the contradictions currently provided in the TRIZ matrix do not account for the contradictions between functionality and environmental concerns that engineers are encountering today. The ENVRIZ matrix does provide product examples for specific, relevant contradictions between functionality and environmental concerns. Therefore, further development of the ENVRIZ matrix would provide a useful tool for design engineers.

While this exercise provides support for further development of ENVRIZ, there are limitations of the study. First, only thirty-four participants completed the study and the amount of time required to complete the study led to the less than ideal number of responses. The thirty-four responses were acquired over the course of ten months and time limitations required an end to the data collection. Furthermore, the sample does not

represent the entire target population of design engineers around the world. Second, the design of the study could have led to biased results. While every effort was taken to reduce any bias, one could argue, for example, that the order of tasks could affect the results. To help address this, the determination of a good solution requires that the participant use a cueing example within the particular task. A future effectiveness study could randomly assign the task order to help overcome this limitation. Additionally, it could be argued that the specific example chosen for the study, the oven, could have had an impact on the results. Since there was only time to complete one survey, an example was chosen that most people were familiar with. Finally, the concepts are subject to the author's bias of judgment and limitations of knowledge, and there is the possibility that some concepts were misjudged from a technical perspective.

## **Chapter 5: Conclusion**

This chapter summarizes the results presented in this dissertation, explains the contributions of the work, describes the limitations of the study, and identifies areas for future work.

### 5.1 Summary of Results

During the course of this research, hundreds of products and patents were examined while looking for examples of improved product functionality and reduced environmental impact. Those examples were then analyzed to determine which contradiction was overcome and which TRIZ engineering principle was used to overcome the contradiction. The results of the research were incorporated into an easily accessible ENVRIZ matrix, and a methodology for utilizing the matrix was provided.

An unexpected finding of this research was that design engineers preferred, and tended to develop better solutions, using specific product examples over engineering principles. Given the inspiration provided by the TRIZ matrix, which contains only principles, it was anticipated that the final design tool would be the ENVRIZ matrix with principles only. After searching and analyzing the products and patents, it became clear that there were two sets of data that could be used as cueing examples and the decision was made to include both in the effectiveness study. The results showed that the differences in the principles resulting from TRIZ and ENVRIZ did not lead to a significant difference in good solutions. This was surprising because one would think that principles derived from products that were specifically sought out for their functionality and environmental improvements would be more precise than the TRIZ



matrix, which does not account for the contradictions between functionality and environmental concerns that engineers are encountering today. The specific product examples from which the principles were derived showed a significant increase in good solutions. This result suggests that it may be easier for an engineer to see a concrete solution to their contradiction, abstract the principle without realizing or categorizing it, and apply it to their problem. The difficulty with engineering principles, or any abstraction for that matter, is that they can be too vague to be useful because they are defined by someone else. For example, with regards to the oven problem in the effectiveness study, it is easier to look at the Eco-Kettle and take away “Heat only what you need” compared to being given the principle Dynamicity and “Characteristics of an object, or outside environment, must be altered to provide optimal performance at each stage of an operation.” The ENVRIZ methodology and matrix can provide engineers with a database of example products that solve their specific contradiction, whereas the TRIZ matrix can provide only a principle even if the engineers are able to find an appropriate contradiction for their problem.

## 5.2 Contributions

The goals of this research were to extend our understanding of product design by uncovering and organizing design principles that are shown to overcome contradictions between product functionality and environmental impact and to improve product design by developing a systematic methodology that engineers can use to access this knowledge.

The identification of contradictions, engineering principles, and examples of solutions yielded a body of knowledge that is a contribution to the field of design engineering. Furthermore, ENVRIZ was validated through the effectiveness study which

demonstrated the tool's usefulness and supports further development of the ENVRIZ matrix.

While inspired by the TRIZ contradiction matrix, the ENVRIZ matrices are new and different because they were designed to solve a new problem that the TRIZ matrix cannot solve; overcoming functionality and environmental contradictions. The ENVRIZ matrices introduce new environmental parameters that were not considered within the TRIZ matrix. They are populated based on examples that specifically overcome functionality-environmental contradictions. And finally, they provide the option to utilize principles or specific examples to help overcome a contradiction being faced.

The ENVRIZ methodology provides design engineers with a useful conceptual design tool to help overcome contradictions between improving product functionality and reducing environmental impact. ENVRIZ is novel because other DfE tools currently available do not assist engineers in developing innovative solutions for one or more of the following reasons: (1) the tool was designed to determine *which* environmental aspect needs improvement rather than *how* to improve the aspect, (2) the tool requires too much information for the conceptual design phase, or (3) the tool considers only reducing environmental impact. ENVRIZ integrates downstream information (examples of other successful solutions) into an early eco-design tool (ENVRIZ matrices) to support the goal of achieving true sustainable product development [27].

Without a methodology like ENVRIZ, engineers would not have an efficient way to overcome the contradictions they face while designing and reducing environmental impact would be sacrificed at the expense of product functionality more often. The pace at which products became more environmentally benign would slow and the future would

look much bleaker for our grandchildren. Fortunately, many innovative solutions are already out there and ENVRIZ provides an efficient way organize and disseminate those solutions to the engineers that can make a difference.

### 5.3. Limitations

There are some limitations of the research that need to be discussed. First, the matrices are limited based on the number of examples they currently contain. To put it in perspective, Altshuller examined over 40,000 inventions to create the TRIZ contradiction matrix [37]. The current ENVRIZ matrix contains 130 examples. Practically, the patent and product search and analysis stage had to end to begin creating the matrix and conducting the effectiveness study. The tool presented is intended to include a sufficient number of examples to provide a starting point for future collaborative use and enhancement.

Second, the Effectiveness Study has some limitations. They were the number and sample of participants, the design of the survey, and the author's bias of judgment and limitations of knowledge. These limitations are thoroughly explained in Section 4.5.

Finally, it is important to understand that this design tool does not attempt to address the problem of reducing a product's complete eco-footprint or overall sustainability on its own. It is up to the user of the tool to decide whether they focus more on a "perceived" environmental impact or a true environmental impact. If an LCA is conducted and a user decides to address the biggest environmental impact that resulted from the LCA, then the tool can help with reducing a product's eco-footprint. If the user decides to address smallest environmental impact resulting from the LCA because the customer perceives it to be most important, then the tool will not help with reducing a

product's eco-footprint. The tool focuses on the specific, practical, and critical task of resolving a conflict between an aspect of product functionality and an environmental impact and is able to handle either decision.

#### 5.4 Future Work

For the ENVRIZ matrix to be widely adopted, the number of examples within the matrix needs to be increased, which will make the tool more useful. For instance, more examples could be found by searching a larger time frame within the patent database. Furthermore, adoption of the tool will result in new designs being realized from the tool, which also adds to the number of examples, creating a virtuous circle. It is the author's hope that the results of this research will encourage someone to take advantage of the current technological state of information accessibility and develop a method, like the wiki presented in Section 3.7, to further populate this tool.

Also, another effectiveness study could also be conducted to address some of the limitations of the previous study and to examine other aspects of the conceptual designs. The study could be revamped so that it could be administered online to capture a more representative sample of the engineering population. It could include a design innovativeness metric to further analyze the quality of the solutions being developed. Most ideal for business would be a way to determine the estimated profitability of a concept. If it can be shown that ENVRIZ generates profitable solutions while overcoming functionality-environmental contradictions, then its chances for adoption by business increases.

## Appendices

### *Appendix A: TRIZ Principles and Definitions*

#	Principle	Definition
1	Segmentation	Divide an object into independent parts
		Make an object sectional
		Increase the degree of an object's segmentation
2	Extraction	Extract the disturbing part or property from an object
		Extract only the necessary part or property from an object
3	Local Quality	Transition from homogeneous to heterogeneous structure of an object or outside environment
		Different parts of an object should carry out different functions
		Each part of an object should be placed in conditions that are most favorable for its operation
4	Asymmetry	Replace symmetrical forms with asymmetrical forms
		If an object is already asymmetrical, increase its degree of asymmetry
5	Consolidation	Consolidate in space homogeneous objects or objects destined for contiguous operations
		Consolidate in time homogeneous or contiguous operations
6	Universality	An object can perform several different functions; therefore, other elements can be removed
7	Nesting	One object is placed inside another. That object is placed inside a third one. And so on...
		One object passes through a cavity in another object
8	Counterweight	Compensate for the weight of an object by combining it with another object that provides a lifting force
		Compensate for the weight of an object with aerodynamic or hydrodynamic forces influenced by the outside environment
9	Prior Counteraction	Preload countertension to an object to compensate excessive and undesirable stress
10	Prior Action	Perform required changes to an object completely or partially in advance
		Place objects in advance so that they can go into action immediately from the most convenient location
11	Cushion in Advance	Compensate for the relatively low reliability of an object with emergency measures prepared in advance

#	Principle	Definition
12	Equipotentiality	Change the conditions of the work in such a way that it will not require lifting or lowering an object
13	Do It in Reverse	Instead of the direct action dictated by a problem, implement an opposite action
		Make the moveable part of an object or outside environment stationary and the stationary part moveable
		Turn an object upside-down
14	Spheroidality	Replace linear parts with curved parts, flat surfaces with spherical surfaces, and cube shapes with ball shapes
		Use rollers, balls, and spirals
		Preplace linear motion with rotational motion; utilize centrifugal force.
15	Dynamicity	Characteristics of an object, or outside environment, must be altered to provide optimal performance at each stage of an operation
		If an object is immobile, make it mobile. Make it interchangeable
		Divide an object into elements capable of changing their position relative to each other
16	Partial or Excessive Action	If it is difficult to obtain 100% of a desired effect, achieve more or less of the desired effect.
17	Transition Into a New Dimension	Transition one-dimensional movement or placement of objects into two-dimensional; two-dimensional to three-dimensional, etc.
		Utilize multi-level composition of objects
		Incline an object or place on its side
		Utilize the opposite side of a given surface
		Project optical lines onto neighboring area, or onto the reverse side of an object
18	Mechanical Vibration	Utilize oscillation
		If oscillation exists, increase its frequency to ultrasonic
		Use the frequency of resonance
		Replace mechanical vibrations with piezo-vibrations
		Use ultrasonic vibrations in conjunction with an electromagnetic field
19	Periodic Action	Replace a continuous action with a periodic one (impulse)
		If the action is already periodic, change its frequency
		Use pauses between impulses to provide additional action
20	Continuity of Useful Action	Carry out an action without a break. All parts of the object should constantly operate at full capacity

#	Principle	Definition
		Remove idle and intermediate motion
		Replace back and forth motion with a rotating one
21	Rushing Through	Perform harmful and hazardous operations at a very high speed
		Utilize harmful factors to obtain a positive effect
		Remove one harmful factor by combining it with another harmful factor
22	Convert Harm into Benefit	Increase the degree of harmful action to such an extent that it ceases to be harmful
		Introduce feedback
23	Feedback	If feedback already exists, change it
		Use an intermediary object to transfer or carry-out an action
		Temporarily connect the original object to one that is easily removed
24	Mediator	
		An object must service itself and carry-out supplementary and repair operations
25	Self Service	Make use of waste material and energy
		A simplified and inexpensive copy should be used in place of a fragile original or an object that is inconvenient to operate
		If a visible optical copy is used, replace it with an infrared or ultraviolet copy
26	Copying	Replace an object (or system of objects) with their optical image. The image can then be reduced or enlarged.
		Replace an expensive object with a cheap one, compromising other properties
27	Dispose	
		Replace a mechanical system with an optical, acoustical, thermal or olfactory system
		Use an electric, magnetic or electromagnetic field to interact with an object
	Replacement of Mechanical System	Replace fields that are stationary with mobile, fixed with changing in time and random with structured
28		Use fields in conjunctions with ferromagnetic particles
	Pneumatic or Hydraulic Construction	Replace solid parts of an object with a gas or liquid. These parts can now use air or water for inflation or use pneumatic or hydrostatic cushions.
29		
	Flexible Membranes or Thin Films	Replace customary constructions with flexible membranes or thin film
30		Isolate an object from its outside environment with flexible membranes or thin films

#	Principle	Definition
31	Porous Material	Make an object porous, or use supplementary porous elements (inserts, covers, etc.)
		If an object is already porous, fill pores in advance with some substance
32	Changing the Color	Change the color of an object or its environment
		Change the degree of translucency of an object or its environment
		Use color additives to observe an object or process which is difficult to see
		If such additives are already used, employ luminescent traces or trace atoms
33	Homogeneity	Objects interacting with the main object should be made out of the same material (or material with similar properties) as the main object
34	Rejecting and Regenerating Parts	After completing its function, or becoming useless, an element of an object is rejected (discarded, dissolved, evaporated, etc.) or modified during its work process
		Used-up parts of an object should be restored during its work
35	Transformation of properties	Change the physical state of the system
		Change the concentration or density
		Change the degree of flexibility
		Change the temperature or volume
36	Phase Transition	Use the phenomena of phase change (i.e., a change in volume, the liberation or absorption of heat, etc.)
37	Thermal Expansion	Use expansion or contraction of material by changing its temperature
		Use various materials with different coefficients of thermal expansion
38	Accelerated Oxidation	Make transition from one level of oxidation to next higher level: Ambient air to oxygenated to oxygen to ionized oxygen to ozoned oxygen to ozone to singlet oxygen
39	Inert Environment	Replace a normal environment with an inert one
		Introduce a neutral substance or additives into an object
		Carry out a process in a vacuum
40	Composite Materials	Replace homogeneous materials with composite ones.



*Appendix B: Parameter Analysis*

<b>TRIZ Parameter</b>	<b>Functionality Parameter</b>	<b>Definition</b>	<b>Explanation</b>
1 - Weight of moving object	1 - Weight	The force that the body exerts on its support or suspension	Consolidated into one parameter for simplicity.
2 - Weight of stationary object			
3 - Length of moving object	Not Used	Any one linear dimension, not necessarily the longest, is considered a length	Products and Patents are analyzed at a system level and length is too detail oriented.
4 - Length of stationary object			
5 - Area of moving object	2 - Area	The part of a surface occupied by the object	Consolidated into one parameter for simplicity
6 - Area of stationary object			
7 - Volume of moving object	3 - Volume	The cubic measure of space occupied by the object	Consolidated into one parameter for simplicity
8 - Volume of stationary object			
9 - Speed	Not Used	The velocity of an object; the rate of a process or action in time.	Similar to Productivity and Loss of Time
10 - Force	Not Used	Force is any interaction that is intended to change an object's condition.	Similar to Stress or Pressure
11 - Stress or Pressure	4 - Stress or Pressure	Force per unit area. Also, tension.	Used
12 - Shape	5 - Shape	The external contours, appearance of the system	Used

<b>TRIZ Parameter</b>	<b>Functionality Parameter</b>	<b>Definition</b>	<b>Explanation</b>
13 - Stability of the object's composition	Not Used	The wholeness or integrity of the system; the relationship of the system's constituent elements. Wear, chemical decomposition, and disassembly are all decreases in stability. Increasing entropy is decreasing stability.	Similar to Environmental Parameter Product Durability
14 - Strength	6 - Strength	The extent to which the object is able to resist changing in response to force. Resistance to breaking.	Used
15 - Duration of action by a moving object	Not Used	The time that the object can perform the action. Service life. Mean time between failure is a measure of the duration of action. Also, durability.	Similar to Environmental Parameter Product Durability
16 - Duration of action by a stationary object			
17 - Temperature	7 - Temperature	The thermal condition of the object or system.	Used
18 - Illumination Intensity	8 - Illumination Intensity	Light flux per unit area, also any other illumination characteristics of the system such as brightness, light quality, etc.	Used
19 - Use of Energy by moving object	Not Used	The measure of the object's capacity for doing work. Energy required to do a particular job.	Similar to Environmental Parameter Energy Intensity
20 - Use of Energy by stationary object			
21 - Power	Not Used	The time rate at which work is performed. The rate of use of energy.	Similar to Productivity, Loss of Time and Energy Intensity
22 - Loss of Energy	Not Used	Use of energy that does not contribute to the job being done.	Similar to Environmental Parameter Energy Intensity
23 - Loss of Substance	9 - Loss of Substance	Partial or complete, permanent or temporary, loss of some of a system's materials, substances, parts, or subsystems.	Used

<b>TRIZ Parameter</b>	<b>Functionality Parameter</b>	<b>Definition</b>	<b>Explanation</b>
24 - Loss of Information	10 - Loss of Information	Partial or complete, permanent or temporary, loss of data or access to data in or by a system.	Used
25 - Loss of Time	11 - Loss of Time	Reducing the time taken for the activity	Used
26 - Quantity of substance	12 - Quantity of Substance	The number or amount of a system's materials, substances, parts or subsystems which might be changed fully or partially, permanently or temporarily.	Used
27 - Reliability	13 - Reliability	A system's ability to perform it's intended functions in predictable ways and conditions. [Note: Definition includes Availability.]	Used
28 - Measurement Accuracy	Not Used	The closeness of the measured value to the actual value of a property of a system. Reducing the error in a measurement increases the accuracy of the measurement.	Did not find any product examples that improved this parameter. Could be used.
29 - Manufacturing Precision	Not Used	The extent to which the actual characteristics of the system or object match the specified or required characteristics.	Similar to Ease of Manufacture
30 - External Harm affects the object	14 - External Harm Affects Product	Susceptibility of a system to externally generated harmful effects	Used
31 - Object Generated Harmful Factors	15 - Object Generated Harmful Factors	A harmful effect generated by the product that reduces efficiency or quality of the functioning object or system	Used but this parameter cannot be associated with environmental harm
32 - Ease of Manufacture	16 - Ease of Manufacture	The degree of facility, comfort or effortlessness in manufacturing or fabrication the object/system.	Used
33 - Ease of operation	Not Used	Simplicity: The process is NOT easy if it requires a large number of people, large number of steps in the operation, needs special tools, etc. "Hard" processes have low yield and "easy" process have high yield; they are easy to do right.	Similar to Device Complexity

<b>TRIZ Parameter</b>	<b>Functionality Parameter</b>	<b>Definition</b>	<b>Explanation</b>
34 - Ease of repair	Not Used	Quality characteristics such as convenience, comfort, simplicity, and time to repair faults, failures, or defects in a system.	Similar to Environmental Parameter Product Durability
35 - Adaptability or Versatility	17 - Adaptability or Versatility	1.) The extent to which a system/object positively responds to external changes 2.) A system that can be used in multiple ways for a variety of circumstances.	Used
36 - Device Complexity	18 - Device Complexity	The number and diversity of elements and element interrelationships within a system. The user may be an element of the system that increases the complexity. The difficulty of mastering the system is a measure of its complexity.	Used
37 - Difficulty of Detecting or Measuring	19 - Difficulty of Detecting or Measuring	Measuring or monitoring systems that are complex, costly , require much time and labor to set up and use, or have complex relationships between components or components that interfere with each other	Used
38 - Extent of Automation	20 - Extent of Automation	The extent to which a system or object performs its functions without human interface	Used
39 - Productivity	21 - Productivity	1.) The number of functions or operations performed by a system per unit time. 2.) The time for a unit function or operation. 3.) The output per unit time or cost per output	Used

*Appendix C: Patents on the Candidate List*

**Environmental Parameter: Material Intensity**

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7524249	Golf Club	Golf club head with concave insert	Not included, functionality improvements vague
7543892	Seat back	Seat back of automotive seat with back board	Not included, no functionality improvement
7543842	Trailer	Portable and adjustable trailer assembly	Use in research
7540518	Seat tube	The present invention relates to a bicycle and more particularly to such a seat tube having strong structure with light weight.	Not included, no environmental improvement
7537290	Extruded vehicle axle	Light weight, stiffened, twist resistant, extruded vehicle axle	Use in research
7503546	Strap winder	A light weight strap winder assembly is provided which is made of plastic material preferably through injection molding	Not used, less functionality than previous generation, substituting metal with plastic
7494196	Demountable stations	System of ultra light-weight demountable stations, for exhibiting articles and attending customers	Use in research
7493961	Gun connector	[No description provided]	Do not understand patent
7481147	External, underside positioned aircraft object mounting system	Light weight honeycombed metal support plank structure, a specially designed light weight object mounting system	No Environmental Improvement...previous generation was also light-weight
7478478	Method of providing reinforcing members	A means for providing structural reinforcement	Use in research
7467502	Interlocking box system	Infrastructures	Use in research

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7460337	Disk drive suspension for high resonance frequency applications	Low density, high rigidity disk drive suspension for high resonance frequency applications,	Use in research
7458429	Pneumatic hand tool	The primary objective of the present invention is to provide a compact pneumatic hand tool	Not used, functionality and environmental goals are the same: Weight and material reduction
7451719	High temperature superconducting degaussing system	The invention involves the use of a light-weight reduced-size degaussing system that comprises a plurality of degaussing coils arranged in a plurality of axes.	Use in research
7449818	Actuator	An object of the present invention is to provide a thin and light-weight actuator module structure	Not used, no functionality improvement
7448292	Transmission	A simple structure and mechanism, and is light-weight and compact.	Use in research
7441359	Circular frame for inserting a picture	Convenient hanging, easy replacement, stability, esthetic shape and light weight.	Not used, no functionality improvement
7438432	Linear fixture assembly	an extrusion of aluminum thereby reducing the weight of the housing, one-piece plastic material, which reduces the weight of the fixture	Not used, no functionality improvement
7429114	Mirror blank assembly	Having at least one sheet of corrugated material; and at least one face sheet in intimate contact with a surface of the sheet of corrugated material forming the light-weight mirror blank assembly.	Use in research
7424832	Cable tensiometer for aircraft,	The invention is extremely light-weight. The invention is a cable tensiometer that can be used on aircraft for real-time, in-flight cable tension measurements.	Use in research

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7424765	Remote control windshield wiper	Remotely control the operation of a windshield wiper this device will be made of lightweight material.	No environmental improvement over regular wiper
7420587	small mobile vehicles	A light weight vehicle adapted to conduct and assist cleaning and video inspections of sewer lines. Be made of any lightweight material.	No environmental improvement, this vehicle is in addition to bigger vehicles
7404601	chair	Light-weight foldable chair for leisure	No Environmental Improvement

### Environmental Parameter: Energy Intensity

Patent Number	Name of Device	Description	Analysis
7539601	Energy efficient air handling system for clean rooms	A refrigeration based air handling system design process for significant energy and cost savings in clean room and other applications requiring large air change rates is presented	Use in research
7527679	Polluting gas desulfurization apparatus,	To provide a polluting gas desulfurization apparatus of simple structure able to effectively remove sulfur from a polluting gas, reduce gas flow pressure loss, and significantly reduce the consumption of electrical power	Use in research
7524380	Energy efficient dishwashing,	A method for controlling a dishwasher	Use in research
7520072	Exit signs with and without emergency lighting	Emergency signs and combination emergency signs and emergency lights wherein the combination signs are compact for shipment and are energy efficient using first interior light emitting diodes.	Shift from Resistive lighting to LEDs...major improvement not meant to be solved by contradiction matrix
7514879	A plasma-based light source	Method and system for driving a plasma-based light source	Use in research
7494071	Water sprinkler	The total line pressure and total water volume to operate a rotating spray header to provide a distribution pattern of water. Energy efficient water sprinkler,	No environmental improvement...quicker time to water lawn only.
7490480	Variable speed refrigeration system	Various temperature sensors are provided to sense system parameters which are used by a controller to regulate each of the variable components	Use in research
7481546	Low-voltage lighting apparatus	The lighting apparatus also includes a circuit board comprising a plurality of light-emitting diodes	Shift from fluorescent lighting to LEDs...major improvement not meant to be solved by contradiction matrix



<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7480544	Fluid transporting machineries	Operation method of energy-saving fluid transporting machineries in parallel array with constant pressure,	Use in research
7479902	Universal mobile keyboard,	An energy efficient keyboard scanning method utilizes higher-valued pull-up resistors for energy conservation.	Use in research
7475965	Inkjet printer	Smaller movements of the actuator are more energy efficient	Use in research
7466074	Organic light-emitting device	An organic light-emitting device that emits light by applying an electric field to a thin film composed of an organic compound.	Do not understand patent
7454918	Refrigeration and defrost control system	A system and method for refrigeration timer control having an energy efficient defrost cycle are provided.	Use in research
7445663	Energy efficient oxygen concentrator	The higher cycle speed reduces the maximum compressor pressure to reduce energy consumption.	Use in research
7438447	Improved illumination area fill	Reflector for a light source	Use in research
7434955	Flashlight system	The flashlight illuminates via the use of a plurality of light emitting diodes (LEDs)	Shift from Resistive lighting to LEDs...major improvement not meant to be solved by contradiction matrix
7402028	Pressurization system	A pressurization device is described mobilizing gravity to mobilize seawater and to employ a weight ( 56 ) for gravitationally	Use in research
7398642	Gas turbine system	A gas turbine cycle that utilizes the vaporization of liquefied natural gas as an intercooler in an open loop gas turbine system.	Use in research

### Environmental Parameter: Dispersion of Toxic Materials

Patent Number	Name of Device	Description	Analysis
7544253	Method and apparatus for flushing asphalt feeding devices	A vehicle mounted patching system for patching potholes and the like and incorporating method and apparatus for removing and flushing asphalt emulsion from the feed lines of the patcher	Used in research
7543577	Combustion system for supplying vehicle engine	Low-fuel consumption and low pollution combustion system for supplying vehicle engine with mixture of fuel and oxygen	Used in research
7534399	Gas abatement system	Gas abatement system decontaminates an exit gas stream containing global warming gases using an electrical heater and a water scrubber	Used in research
7533530	Engine	Engine for the efficient production of an energized fluid	Do not understand patent
7514015	Method for surface cleaning	The system utilizes a solid-state laser having wavelengths in the near-visible and visible portions of the electromagnetic spectrum to remove photoresist without requiring hazardous gases or wet solutions	Used in research
7493974	Solar powered engineless vehicle	The vehicle is capable of running without practical driving distance limitations under all weather conditions, day or night, without use of fossil or alternative fuels	Used in research
7469540	Energy recovery from waste heat sources	[No Description provided]	Do not understand patent
7465332	Filter for air filtration system	Disposable grease filter for air filtration system and method of manufacturing same	Used in research

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7456418	RF-enablement of auditable storage for hazardous materials	The container is used for storage of hazardous waste are disclosed having an inner layer of substantially unhydrated cement in contact with the hazardous waste and an outer layer of hydrated cement.	No reduction in toxicity, just information improvement
7448397	Apparatus for applying disparate etching solutions to interior and exterior surfaces	A method in accordance with one embodiment cleans articles with differently contaminated interior and exterior surfaces by using those articles to separate a cleaning vessel	Used in research
7438869	Emission control system	[No Description provided]	No Environmental improvement, previous generation products do just as well
7434753	Simplistic approach to design of a reusable nozzle hub	A novel hub design that enables removal of nozzle core for disposal while the hub is retained for reuse.	Used in research, but environmental parameter is material intensity
7430865	Miniaturized waste heat engine	[No Description provided]	Used in research
7428911	Spill containment system	The system comprises a containment rail system to define a perimeter to accommodate the at least one industrial battery	Used in research
7409753	Method for producing spunlace non-woven cloth	[No Description provided]	Do not understand patent
7389627	Method of shipping container with expanding bag	The shipping container includes a rigid gas permeable exterior enclosure and an interior positioned substantially gas impermeable flexible bag.	No environmental improvement, shipping container for hazardous materials

### Environmental Parameter: Recyclability

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7544253	Flushing asphalt feeding devices	A vehicle mounted patching system for patching potholes and the like and incorporating method and apparatus for removing and flushing asphalt emulsion from the feed lines of the patcher	Used in research
7540346	Automotive vehicle employing kinetic energy storage/reuse capability	[No Description provided]	Used in research but environmental parameter is energy intensity
7527736	Method for generating fracturing water,	Systems and methods have been developed for reclaiming water contaminated with the expected range of contaminants typically associated with produced water in order to produce a treated water having a quality adequate for reuse as a fracturing water.	Used in research but environmental parameter is renewable resource use
7520959	Method for manufacturing light barrier packaging material	A method of manufacturing a light barrier paper packaging material and the light barrier paper package container with low cost, no need of an ink removing apparatus at reproduction step and easily recycle are provided.	Used in research
7520455	Device for reuse of plastic materials and paper fibers	A device reuses several plastic materials and paper fibers rejected in previous recycling performed by paper industries, by compacting the fragments of the plastic materials inside of a conventional container.	Used in research
7520371	Materials and processes for reducing combustion by-products in a lubrication system	A new engine lubrication paradigm for a gasoline or diesel internal combustion engine wherein the lubrication system,	Used in research but environmental parameter is dispersion of toxic materials

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7488416	Bathing pool assembly	A bathing pool assembly with water full of nano-scale ozone bulbs for rehabilitation has a bath, a reservoir and two circulating systems.	Used in research
7470172	Water reuse in food processing,	Methods and systems enable reuse of water in processing of animals into food.	Used in research but environmental parameter is renewable resource use
7467909	Arresting systems and methods	Systems and methods for arresting vehicles or other moving objects are detailed	No environmental improvement
7467495	Vehicle seal	Vehicle seal with discontinuous alternating soft and rigid u-shaped segments and method of forming same	Used in research
7459138	Process and apparatus for producing single-walled carbon nanotubes	Catalytic particles are exposed to different process conditions at successive stages	Used in research
7445084	Soundproof thermal shield	The invention relates to a soundproof thermal shield, particularly for motor vehicles, comprising a support made from aluminum, a noise-absorbing layer, and a thermal covering made from aluminum.	Used in research
7416137	Thermodynamic cycles	A thermodynamic system that produces mechanical, electrical power, and/or fluid streams for heating or cooling.	Do not understand patent
7410573	Waste water purification apparatus	Waste water purification apparatus and waste water purification method including the regeneration of used coagulant	Used in research

**Environmental Parameter: Renewable Resource Use**

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7544192	Sinus delivery of sustained release therapeutics	The invention provides biodegradable implants for treating sinusitis.	No environmental benefit compared to previous generation (pills and nose sprays)
7543772	Fishing line spool	Provide a fishing line spool which is capable of securely holding a fishing line wound around the fishing line spool and reduced in cost.	Simple material substitution
7534422	Universal fishing bait	The current invention involves a universal fishing bait fundamentally comprised of a matrix of fibrous collagen made up into any shape or design capable of attracting fish, that is 100% biodegradable	No functionality improvement
7530138	Toilet bowl cleaning tool with disposable swab	A toilet bowl cleaning tool comprising a hollow curved elongated outer member with a handle at the proximal end and a head at the distal end, an inner member and a disposable swab that attaches to the head	Functional improvement not related to environmental improvement
7517821	Automobile interior board	An automobile interior board and more particularly to an automobile interior board obtained by complexing bamboo fiber, natural material-derived fiber and biodegradable fiber with each other.	Simple material substitution
7506615	Animal waste collection and disposal system	An animal waste collection and disposal system having a portable carrying housing with a plurality of separately sealable compartments, an integral ergonomic handle and integral apparatus to mount a leash	No environmental improvement of the product
7501133	Light-activated adhesive composite,	The present invention provides a light-activated adhesive composite suitable for medical and surgical applications.	Used referenced patent 6391049 in research

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7491458	Active metal fuel cells	active metal (e.g., lithium) fuel cells made possible by active metal electrode structures having ionically conductive membranes for protection of the active metal from deleterious reaction with air,	No environmental benefit
7476987	Stand-alone wind turbine system	a wind turbine with battery storage to create a stand-alone system	Used in research
7467523	Autonomous water source	An autonomous water source (AWS) for extracting water from ambient air and delivering it to a plant to support growth.	Used in research
7453164	Wind power system	A system for capturing and converting and/or storing wind energy includes a vessel adapted to receive at least one wind machine for capturing wind and a device for converting wind energy to storable energy	Used in research
7444189	An energy optimization method and control apparatus	An intelligent distributed generation system for optimizing utility-supplied electricity, natural gas, and hydrogen production and storage to minimize a total energy cost.	Used in research but environmental parameter is energy intensity
7425269	Method to increase lateral oxygen transfer in waste water,	An improved apparatus and method which eliminates rotating impellers and air plates.	Used in research
7422780	Environmentally friendly plastic container	Environmentally friendly plastic container intended to stably maintain the quality of the contents and capable of being subjected to waste disposal with ease after use without adversely affecting the natural environment.	Not used, material substitution
7404651	Renewable energy flashlight	A renewable energy flashlight includes a flashlight housing, a light emitter carried by the housing, and a power source carried by the housing and powering the light emitter	Same as flashlight found in the product list

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7401241	Controlling standby power	Systems and methods of managing power provide for applying a voltage from a voltage regulator to a component of a computing system and reducing the voltage based on a power saving parameter	Used in research
7397142	Renewable energy electric power generating system	The present invention is a concept for meeting America's growing energy demand through the use of non-polluting electric generating technology utilizing renewable energy	Do not understand patent
7392765	Biodegradable pet mat	biodegradable pet mat for absorbing moisture and containing debris from the feet of pets	Used in research



**Environmental Parameter: Product Durability**

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7544174	Quiet flexion/extension stop for orthopedic brace	Apparatus and methods for decelerating an orthosis to prevent hyperextension and/or hyperflexion.	Used in research
7537035	Pneumatic tire	A pneumatic tire which enables durability thereof to be improved by preventing oxidation degradation of the belt layers.	No Functionality Improvement
7531145	Honeycomb structure	Honeycomb structure which hardly generates cracks during the use and which is superior in durability.	No Functionality Improvement
7531056	Run-flat tire support and manufacturing method for the same	An annular run-flat tire support which is disposed in the inside of a tire such that, when it gets punctured, it can run a significant distance as punctured	Used in research, Found before in product list
7530718	Lamp for vehicle	A vehicle lamp includes a reflective member having a silver vapor deposition reflective surface with good durability to prevent cracking or peeling of a protective film and capable of maintaining a high reflectance	Used in research
7530585	Rear suspension structure for large vehicles	A rear suspension structure for large vehicles which is provided with an air spring having an improved structure, thus further increasing the durability of the air spring,	Used in research
7527252	Spring spacer for a spring	A spring spacer is provided to improve the durability of a spring,	Used in research
7523774	Pneumatic tire with high turnup	Pneumatic tires designed for heavier loads and characterized by a reduced weight, high durability bead area.	Used in research
7520480	Stand for flat-panel display	A stand for a display device, such as a flat-panel display, selectively accommodates mounting surfaces having disparate orientations	No Environmental Improvement

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7520307	Pneumatic radial tire	A safety tire capable of safely and continuously running a vehicle	Do not understand patent
7514163	Magnetic recording medium	The protective layer of the magnetic recording medium is composed of two layers, that is, a lower layer contacting with the magnetic layer and an upper layer on the lower layer.	Used in research
7510755	Honeycomb structure	Honeycomb structured body having improved durability in a honeycomb structure body obtained by unitarily bonding a plurality of honeycomb segments	Not used, similar to 7531145
7510284	Projection-type display devices	Display devices that provide projection-type video output and use redundant sets of lasers to generate light.	Used in research
7506608	Hinge mechanism	A hinge component which is used in folding or rotating mechanisms for electronic devices such as portable phones, laptop computers, electronic notebooks (PDA), DVD monitors, and remote controls.	Can't determine functional improvement, complicated
7500660	Vehicle stabilizer for high stress	A vehicle stabilizer for high stress in which fatigue life of a bending portion can be prolonged and which can exhibit excellent durability	No Functionality Improvement
7500493	Tuning slide valve for intake manifold	A tuning valve and more particularly to a planar slide valve for use in an intake manifold.	Used in research
7498724	Piezoelectric element	A piezoelectric element including a lower electrode, a piezoelectric layer and an upper electrode	No functionality improvement
7497509	Exterior component	An exterior component attached to a lower part of a vehicle body, such as a fender liner and an under protector that are attached to the lower part of the exterior of vehicle body.	Used in research

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7490945	Wear-proof detente for folding mirrors,	A folding assembly for a vehicle side mirror that employs specialized ramped détentes.	No Functionality Improvement
7490668	Method for designing and constructing a well with enhanced durability	Methods for cementing in a wellbore, designing a well, constructing a well, and wells constructed according to such methods.	No Functionality Improvement
7485054	Two piece sports equipment stick	Sporting goods, namely sticks, shafts and bats for sports such as hockey, lacrosse, field hockey, golf, baseball, softball, polo and fishing.	Used in research
7484492	Four-cycle internal combustion engine and vehicle,	A four-cycle internal combustion engine and, more particularly, relates to a high-revolution type four-cycle internal combustion engine mounted on a vehicle such as a sport type motorcycle.	No Functionality Improvement
7481721	Multi-piece solid golf ball	a multi-piece solid golf ball composed of a core, an envelope layer, an intermediate layer and a cover that have been formed as successive layers.	No Environmental Improvement
7478577	Quick adjust ratcheting wrench with cam actuated clamping	This invention is directed to a wrench tool with jaws adjusted by a cam mechanism, and a ratchet mechanism for providing a free return stroke of the handle.	Used in research
7476051	Laterally stable vertical panel system	A vertical panel system comprises a vertical panel having a panel with opposing first and second panel surfaces and a base edge	Not used, but provides tradeoff of use of recyclable materials and durability (Local Quality)
7475861	Seat rail for vehicles,	A seat rail for vehicles, which sufficiently bears the load of a passenger, allows an upper track to smoothly slide along a lower track	Used in research
7467485	Inserted knife fortified snowplow blade	Snowplow with articulated blades, provided with fortified knives inserted and maintained in place into the blades to offer a greater durability during passages over altered roads in frequent uses	No functionality improvement

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7464586	Tire designing method and program	[No description provided]	Not a product
7461679	Heavy duty tire	A heavy duty tire having a bead structure capable of reducing the tire weight without deteriorating the bead durability.	Do not understand patent
7452136	Bearing apparatus for a wheel of vehicle	A vehicle wheel bearing apparatus, such as an automobile, and, more particularly, to a bearing apparatus with a wheel hub having improved strength and durability under rotary bending conditions.	Do not understand patent
7449818	Actuator and method of manufacturing actuator module	The structure of a flexible sheet-like bent actuator constituted by a multi-layer structure such as a bimorph or unimorph structure capable of being fabricated easily and permitting complicated and large movements, as well as a method of manufacturing the same.	Do not understand patent
7443047	Multiphased and multidimensional wave converter	A wave-powered generator, also termed a wave converter, which converts and exploits most of the energy in the waves	Used in research
7441811	Casement window lock	A casement window locking device having improved function, including improved strength, security, and durability.	Used in research
7434528	Self draining boat plug	A boat plug which does not need to be repetitively inserted and removed.	No Environmental Improvement
7431669	Low compression golf ball	A golf ball has a core ( 22 ) with a low compression, but has at least two additional layers ( 24, 26 ) that provide for increased durability and control	Not used, material substitution

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7430111	Mounting structure for display unit in refrigerator	A mounting structure for a display unit in a refrigerator which is mounted to a front surface of a refrigerator door to display a variety of information to the outside and to receive operating signals.	Used in research
7427248	Continuously variable transmission	A continuously variable transmission to be mounted on a vehicle and, specifically, to a technique effectively applied to a continuously variable transmission having a rubber drive belt.	No Functionality Improvement
7421965	Flexible buoy	A flexible buoy configured to enhance workability of placing and removing mooring rope and the like of a rig in water.	Used in research
7416625	Rubber strip	Electrical power is generated by using piezoelectric technology to convert mechanical strain, due to tire flexure during rolling, to electric charge, that is stored in an energy storage device, and is thus made available to an electronic device disposed within the tire.	No Functionality Improvement
7415776	Magnetic scale	A magnetic scale for use for position detection.	No Functionality Improvement
7414352	Piezoelectric/electrostrictive body,	A piezoelectric/electrostrictive body, a piezoelectric/electrostrictive laminate, and a piezoelectric/electrostrictive film type actuator.	No Functionality Improvement
7411339	Manufacturing method of actuator device and liquid jet apparatus	A manufacturing method of an actuator device, in which a vibration plate is provided on a surface of a passage-forming substrate including pressure generating chambers and in which piezoelectric elements are formed on the vibration plate, and relates to a liquid jet apparatus, in which droplets such as ink are ejected by displacement of the actuator device formed by the manufacturing method.	No Functionality Improvement

<b>Patent Number</b>	<b>Name of Device</b>	<b>Description</b>	<b>Analysis</b>
7398604	Tape rule with resilient lock	Tape rule assemblies	No Functionality Improvement
7396301	Golf ball	A golf ball, more particularly to a technique which improves the intermediate layer of the golf ball.	Not used, material substitution
7395941	Artificial nipple	An artificial nipple, which has durability enough not to be torn with fatigue load resulting from teeth contact since fiber nets are embedded within the thickness of the artificial nipple, eliminates a difficulty in breathing by facilitating the flow of air, and prevents obstruction of the airway of an infant by distributing milk suction pressure when the infant sucks milk	Used in research

*Appendix D: Patent Analysis*

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
1	7540402	Method for controlling weld metal microstructure using localized controlled cooling of seam-welded joints	This invention is directed to methods for manufacturing seam welds with reduced weld-zone hardness and improved weld-zone ductility and toughness. The first and second surfaces of hardenable ferrous alloys are welded together by applying a heat source, preferably in the form of a traditional welding apparatus so as to bring the first and second surfaces to sufficiently high temperatures so as to melt and form a weld. A second heat source is provided to immediately apply heat to the weld zone prior to the weld cooling below the martensitic finish temperature (MF) for the hardenable ferrous alloys. The second heat source preferably provides "localized" heat in the form of a propane or oxyacetylene torch, resistance, electric arc, lasers, conductive, radiative, convective or high-frequency induction so as to provide heat to the weld zone. However, the second heat source does not provide heat to the entire component such as would be provided by traditional furnaces or ovens typically used for heat treating operations such as annealing. The second heat source provides sufficient heat at a sufficiently high temperature and for a sufficiently long period of time so as to reduce the hardness of the weld.	Using a traditional furnace for heat treating	Strength	Energy Intensity	Local Quality	Energy Efficient (All Fields), Time frame 1 week (LexisNexis Academic) Accessed June 2, 2009
2	7540320	High efficiency conditioning air apparatus	The present invention relates to an improved air conditioning filter and cooling/heating coil that can easily be applied to new and existing air handling systems. The slant design of these components allows a more efficient heat transfer and particle entrapment than their conventional counterparts. By residing at an angle in their air handling enclosures, and by virtue of their oblique prismatic construction, more filter media can be used and more heat transfer surface area can be incorporated without offering any substantial additional impediments to the flow of air. At angles of 45 degrees air friction of the coil and filter are reduced by 40 to 55 percent.	Air filter inserted at 90 degrees	Object Generated Harmful Factors (Dust)	Energy Intensity	Transition into New Dimension	Energy Efficient (All Fields), Time frame 1 week (LexisNexis Academic) Accessed June 2, 2009
3	7540161	Ice making machine, method and evaporator assemblies	An ice making machine of the present invention comprises a water supply, a cooling system, an electrical energy source and an evaporator assembly. The evaporator assembly comprises at least one thermally conductive surface disposed in thermal transfer with an electrically conductive and thermally conductive layer, which is connected in circuit with the electrical energy source. A controller during a freeze mode operates the water supply and the cooling system to form ice on the electrically conductive and thermally conductive layer and during a harvest mode operates the electrical energy source to apply electrical pulse energy to the electrically conductive and thermally conductive layer to melt an interfacial layer of the ice such that it is freed from the layer. This prior art method of harvesting the ice represents a loss in ice making efficiency due to: (a.) the amount of ice that is melted during the harvesting operation caused by the excess heat provided by both the hot gas in the evaporator and the warm water introduced, (b) the time it takes to perform the harvest operation--such time not being available to make ice, and (c) the excess heating of the evaporator--such heat having to be removed from the evaporator during the subsequent ice making mode.	Traditional ice harvesting method (passing warm refrigerant through line)	Loss of Time	Energy Intensity	Periodic Action	Energy Efficient (All Fields), Time frame 1 week (LexisNexis Academic) Accessed June 2, 2009

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
4	7534358	Horizontal vibratory centrifuge apparatus	Method of imparting vibration to a slurry in the separation component by a single low energy vibrating motor which operates in resonance with the torsion springs to achieve maximum vibration and thus maximum separation between the solid and liquid components of the slurry.	Traditional centrifuge or vibratory centrifuge that doesn't utilize resonance.	Quantity of Substance	Energy Intensity	Mechanical Vibration	Energy Efficient (All Fields), Time frame 1 month (LexisNexis Academic) Accessed June 2, 2009
5	7513728	Reduced material fastener	The invention comprises a shank cross-section for a reduced material fastener that is selected to provide a parting line. Having a parting line means that the fastener may be made using two opposing dies to cold form the cross-section. The cross-sections do not have to be symmetrical with respect to the parting line as long as hypothetical dies can be separated. Typical fasteners include common nails. In spite of some inventive effort over many years, nails with non-circular cross-section shanks (or non-square ones in the case of rail spikes) are not in widespread use. Part of the problem is probably the difficulty in manufacturing. Therefore, what is needed is a nail shank design that, compared to a round one, provides reduced weight but has the same or increased holding power and can be manufactured using practical forming apparatus.	Traditional round nail	Ease of Manufacture	Material Intensity	Segmentation	Material Reduction (All Fields), Time frame previous year (LexisNexis Academic) Accessed June 3, 2009
6	7208051	Underbody car wash for home-use	An underbody car wash sprayer for home-use, which can be hooked up solely to a garden hose or in combination with a pressure washer. The device utilizes a three nozzled "I" design, supported by four swiveling casters. In addition, it is connected to an ergonomically effective wand system to allow easy maneuverability under the vehicle. Finally, in some embodiments a trigger spray gun acts as a handle and pressure regulator. The compactness of the specific design allows for significant material reduction and hence a reduction in production costs, providing the consumer with a more economical choice. Additionally, the concentrated pressure and spray pattern of the "I" design along with its precision maneuverability allows the consumer to easily access and forcefully remove sediment adhesions to the vehicle underbody while controlling water flow at all times with a trigger spray gun.	Previous generation underbody cleaning devices	Productivity	Material Intensity	Local Quality	Material Reduction (All Fields), Time frame all (LexisNexis Academic) Accessed June 3, 2009
7	7544253	Method and apparatus for flushing asphalt feeding devices	A vehicle mounted patching system for patching potholes and the like and incorporating method and apparatus for removing and flushing asphalt emulsion from the feed lines of the patcher which completely recycles the cleaning agent used to flush the feed lines, as well as eliminating any external discharge of potentially toxic materials.	Dispensing asphalt and clean agent each time lines were cleaned	Extent of Automation	Material Intensity	Self-Service	Toxic (Title & Abstract), Time frame 1 year (LexisNexis Academic) Accessed June 14, 2009
8	7543577	Low-fuel consumption and low pollution combustion system for supplying vehicle engine with mixture of fuel and oxygen	A low-fuel consumption and low-pollution combustion system supplies an engine with a mixture, in which oxygen contained in air is separated from nitrogen through a PSA (pressure swing adsorption) whereby oxygen having purity above 95% and a fuel mixture is fed into and burned in the combustion chamber obtaining a desired engine output with low-fuel consumption. Nitrogen is previously removed so that nitride oxide can be minimized during combustion procedure and CO and toxic gas derived from incomplete combustion can be minimized. The system obtains high engine output and low-fuel consumption by reducing toxic gas derived from incomplete combustion. The system includes an oxygen separator for separating oxygen from nitrogen by introducing external air into adsorption towers with predetermined pressure while storing the oxygen separated from the nitrogen in an oxygen storage tank and exhausting the nitrogen.	Traditional Combustion Engine	Productivity	Energy Intensity	Extraction	Toxic (Title & Abstract), Time frame 1 year (LexisNexis Academic) Accessed June 14, 2009



#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
9	7493974	Solar powered engineless vehicle	A solar powered thermoelectric vehicle lacking an internal combustion engine. The vehicle may include a fiber optics bundle heat collector/conductor, a heating element embedded within a heat sink, a plurality of thermoelectric chips mounted around the outer surface of the heat sink, a hollow body surrounding the heat sink with a space present between the heat sink and the hollow body, a power converter, a plurality of thermoelectric power generators, an extended heat motor/apparatus, and at least one DC motor mounted to a wheel of the vehicle. The vehicle is capable of running without practical driving distance limitations under all weather conditions, day or night, without use of fossil or alternative fuels, and without generating and introducing toxic emissions into the environment.	Traditional Combustion Vehicle	Extent of Automation	Renewable Resource Use	Phase Transition	Toxic (Title & Abstract), Time frame 1 year (LexisNexis Academic) Accessed June 14, 2009
10	7465332	Disposable grease filter for air filtration system and method of manufacturing same	An all natural filter assembly without toxic materials for use in an air filtration unit is provided. The disposable grease filter is formed of wool fiber coated with a bonding agent comprising a natural soy, whey and/or linseed solution. Also provided is a disposable grease filter blanket, which includes a wool fiber woven, non-woven or needle punched blanket coated with a bonding agent of a natural soy, whey and/or linseed solution. Current air filtration units can include various unnatural fibers and chemicals that may be toxic if ingested or inhaled. U.S. Pat. No. 6,293,983 discloses the use of a wool pre-filter for removing grease from the air, that is used in front of a filter. In order to maintain structural integrity of the pre-filter, the wool is homogenously blended with a synthetic polyester mix, which is melted by application of heat to the coated pre-filter so that the polyester coats the fibers of the pre-filter. The use of a synthetic chemical on the pre-filter is a cause for concern, and a potential hazard.	Synthetic Filter	Object Generated Harmful Factors	Renewable Resource Use	Extraction	Toxic (Title & Abstract), Time frame 1 year (LexisNexis Academic) Accessed June 14, 2009
11	7530718	Lamp for vehicle	A vehicle lamp includes a reflective member having a silver vapor deposition reflective surface with good durability to prevent cracking or peeling of a protective film and capable of maintaining a high reflectance. The reflective member includes a topcoat layer which serves as a protective film on a silver vapor deposition film which is a silver alloy including Nd on a surface of a base material made of synthetic resin inside a lamp chamber S. The topcoat layer includes a transparent modified silicone series resin using a silicone resin and an acrylic resin as resin components.	Previous generation vehicle lamp	Luminosity	Durability	Composite Materials	Durability (Title & Abstract) Time frame 1 year (LexisNexis Academic) Accessed June 14th
12	7448397	Apparatus for applying disparate etching solutions to interior and exterior surfaces	Described are methods, systems, and chemistries for cleaning various components of semiconductor process equipment. A method in accordance with one embodiment cleans articles with differently contaminated interior and exterior surfaces by using those articles to separate a cleaning vessel into separate chambers, one chamber for the interior surface and one for the exterior surface. Different chemistries are then applied to the differently contaminated surfaces. This embodiment reduces the required volume of etchant, and consequently saves the cost, treatment, and disposal of toxic chemicals. One embodiment further reduces the requisite etchant volume using one or more volume-displacement elements that displace some of the etchant volume.	Using single chemical to clean all surfaces and fully submerging components	Loss of Substance	Dispersion of Toxic Materials	Local Quality	Toxic (Title & Abstract), Time frame 1 year (LexisNexis Academic) Accessed June 23, 2009

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
13	7430865 (Claudio Filippone)	Miniaturized waste heat engine	A closed loop vapor cycle generated by a special device formed by heat transfer and a vapor expander it is utilized to convert waste heat from conventional power systems into additional thermodynamic work, thereby improving the overall power system efficiency. When the power system under consideration is an internal combustion engine the energy contained in the exhaust gases (waste heat) is transferred back to the engine through one or more expanders directly or indirectly coupled with the engine load. The energy extracted from the waste heat can also be added back to the engine by an apparatus able to enhance the availability of oxygen (oxygenators) during the combustion. In this case, the engine also improves its dynamic response and reduces its production of toxic emissions. If the engine utilizes heavy fuels (i.e. diesel engines), this device completely eliminates the formation of the highly toxic particulate (black smoke), while significantly improving engine performance. The cost of the energy required to operate the device proposed in this invention is zero since it only recuperates and utilizes energy in the form of heat that is normally discharged into the environment.	Traditional car where exhaust is wasted	Productivity	Energy Intensity	Convert Harm to Benefit	Toxic (Title & Abstract), Time frame 1 year (LexisNexis Academic) Accessed July 1, 2009
14	7544673	Coating compositions for bioactive agents	A coating composition and related method for use in applying a bioactive agent to a surface in a manner that will permit the bioactive agent to be released from the coating in vivo. The composition is particularly well suited for coating the surface of implantable medical device, such as a stent or catheter, in order to permit the device to release bioactive agent to the surrounding tissue over time. The composition includes a plurality of compatible polymers having different properties that can permit them to be combined together to provide an optimal combination of such properties as durability, biocompatibility, and release kinetics.	Medical device without coating	Object Generated Harmful Factors (infection)	Durability	Local Quality	Durability (Title & Abstract) Time frame 1 year (LexisNexis Academic) Accessed July 19th
15	7544174	Quiet flexion/extension stop for orthopedic brace and orthopedic brace incorporating a quiet flexion/extension stop	The present flexion and/or extension stop includes a body portion constructed of a hard and durable material and at least one bumper portion constructed of a soft and resilient material. The stop provides quiet operation and non-jarring motion termination for the wearer. The stop also provides positive range of motion control, strength and durability. Also disclosed is an orthopedic brace incorporating the present flexion and/or extension stop.	Brace made of solid material with good durability and bad stress OR brace made of resilient material with good stress and bad durability	Stress or Pressure	Durability	Local Quality	Durability (Title & Abstract) Time frame 1 year (LexisNexis Academic) Accessed July 21st
16	7540555	Mobile truck tent of adjustable height	A portable, highway legal truck tent made of steel tubing, having a durable cover, and containing two built-in bench seats is disclosed. The truck tent assembles within thirty minutes and once on a truck, it requires no disassembly/reassembly. Because of its durability, the cover will not flutter when driving at fast speeds. The construction/design of the metal tubing frame allows campers to drive to their destinations with the tent already assembled. The mobile tent can remain on the truck bed or be placed on the ground. The frame has poles that extend into the truck bed and lock on the truck tie downs, which are in the form of clamps that hook under the lip of the truck bed. Interlocking pins in the frame of the bench seat allow for enlargement of the bench seat to adjust to varying lengths and widths of different trucks.	Truck tent limited to truck bed only	Adaptability/Versatility	Durability	Asymmetry (to improve Aerodynamics)	Durability (Title & Abstract) Time frame 1 year (LexisNexis Academic) Accessed August 9th

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
17	7531584	Providing freezing and thawing resistance to cementitious compositions	An improved freeze-thaw durability cementitious composition is provided that uses at least partially degradable polymeric particles that are blended directly into the cementitious composition mixture. The degradable polymeric particles provide void spaces in the cementitious material matrix, and such void spaces act to increase freeze-thaw durability of the cementitious material. The method used in the prior art for artificially producing such voids in concrete has been by means of air-entraining agents, which stabilize tiny bubbles of air that are entrapped in the concrete during mixing. These air voids are typically stabilized by use of surfactants during the mixing process of concrete. Unfortunately, this approach of entraining air voids in concrete is plagued by a number of production and placement issues,	Cement created by placing air voids	Ease of Manufacture	Durability	Rejecting and Regenerating Parts	Durability (Title & Abstract) Time frame 1 year (LexisNexis Academic) Accessed August 9th
18	7527644	Stent with geometry determined functionality and method of making the same	The present invention provides a stent, which combines many of the excellent characteristics of both silicone and metal stents while eliminating the undesirable ones. In particular, a principal objective in accordance with the present invention is to provide a family of stents where the relative hardness/softness of regions of the stent can differ from other regions of the stent to provide additional patient comfort and resistance to radial forces. An exemplary embodiment also provides a family of stents with novel interstice configurations that facilitate flexibility, durability and/or proper installation. Historically, in order to provide a stent with varying characteristics, the stent had to be manufactured from multiple materials, at least one for each characteristic desired. As a result, many of these stents are woven from two or more metals having differing shape-memories for example. Unfortunately, braided stents are vulnerable to premature obsolescence. Moreover, providing multiple material types in a single stent may lead to inconsistent characteristics along the surface area of the stent. The stent needs to be stiffer in some regions while more flexible in others.	Composite Stents	Object Generated Harmful Factors (Patient Comfort)	Durability	Local Quality	Durability (Title & Abstract) Time frame 1 year (LexisNexis Academic) Accessed August 9th
19	7527252	Spring spacer for a spring	A spring spacer is provided to improve the durability of a spring, which is made of Ti or the like and low in surface hardness, by preventing abrasion. With the spring spacer placed between a first turn and a second turn of a Ti spring, the spring spacer prevents an end of the first turn from contacting the second turn. The spring spacer improves the durability of the spring and is easily mounted to the spring so as to improve productivity.	Low surface hardness spring without spacer	Ease of Manufacture	Durability	Cushion in Advance	Durability (Title & Abstract) Time frame 1 year (LexisNexis Academic) Accessed August 16th
20	7510244	Event chair construction	A chair construction includes a back member having back legs, a front member having front legs, and side members, all constructed of a synthetic polymeric material molded about a reinforcing metal core, the metal cores being constructed for securement together to establish an integral reinforcing metal core structure enveloped within unitary sheaths of synthetic polymeric material corresponding to each of the back member, the front member and the side members, subsequent to constructing each of the back member, the front member and the side members, so as to erect a chair having the durability, aesthetic appearance and feel provided by the synthetic polymeric material, and the strength and rigidity provided by the integral reinforcing metal core structure.	Chair constructed of either plastic or metal	Shape	Durability	Nesting	Durability (Title & Abstract) Time frame 1 year (LexisNexis Academic) Accessed August 16th
21	7543842	Portable and adjustable trailer assembly and method of use thereof	Disclosed is a portable and adjustable trailer assembly that allows for easy assembling and de-assembling, foldability, portability, requiring small storage space, multi-functional utility, retrofittable to various vehicles, and at the same time light weight and cost effective.	One piece trailers and foldable trailers that aren't as versatile	Adaptability or Versatility	Material Intensity	Segmentation	Light weight, Marion's Research, Accessed August 31st

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
22	7537290	Light weight, stiffened, twist resistant, extruded vehicle axle	An extruded, tubular vehicle axle for front and rear wheel applications, is formed with integral, radially outwardly extending ribs, at the radial top and bottom dead centers of the axle, and continuously extending longitudinally along substantially the entire length of the axle parallel to the axis of the axle. The invention herein is primarily concerned with providing a lighter-weight axle, which is accomplished by using thin, cross-sectional wall thicknesses where feasible for handling normal loads, while simultaneously rigidifying or stiffening the axle wall along its top dead center and bottom dead center to preclude bending or flexing under sudden extreme loads. This also interlocks the axle ends within their connecting sockets and resists twisting of an axle or rotation of an axle relative to its sockets.	Axels with varying internal wall thicknesses	Strength	Material Intensity	Cushion in Advance	Light weight, Marion's Research, Accessed August 31st
23	7494196	System of ultra light-weight demountable stations	The invention is related to a dismountable ultra light stations system to exhibit commercial items and attend customers, according to which finished station structure to exhibit is supplied so that no interlocking mechanical elements participate during its construction, so that parts of each station may be assembled and dismounted manually, without the need to use special tools. Exhibitors usually in commercial use have been constituted by a structure, generally metallic, suitable to support horizontally on it a flat board to satisfy basically functions of a table. Although it can be said that among such designs from the previous art, there are some ones which offer decorative structures, their mechanical characteristics, such as those related to their weight, and specially related to their properties regarding handling operations as those related with their assembling and dismounting, and with their feasibility to be stored and transported, do not result satisfactory at all, mainly because to carry out said operations, it is necessary to keep in mind weight of the structure and also the use of tools.	Tables with metallic folding legs	Adaptability or Versatility	Material Intensity	Segmentation	Light weight, Marion's Research, Accessed August 31st
24	7478478	Method of providing reinforcing members	Parts are provided which combine structural reinforcement of hollow profiles and light weight means of attachment. Optionally, the part may also provide an acoustic baffle. The parts consists of a core coated with expandable structural reinforcing foam on at least part of its surface the core being provided with means for receipt of a nut and means to prevent rotation of the nut. A shorter bolt is used that connects with a nut in a cavity located in the hollow section of the structure. This is possible because the expandable foam in the hollow provides the structural support. Previous generation used a longer bolt that extended across the hollow portion of the frame.	Long bolts that extend across hollow portion of frame	Object Generated Harmful Factors (Noise)	Material Intensity	Prior Counteraction	Light weight, Marion's Research, Accessed September 5th
25	7467502	Interlocking box system	Walls and other structures can be made from blocks assembled from relatively light-weight standard panels that fit together like a puzzle. The blocks are held together without the use of mortar. Each block is formed of six rectangular panels fitted together by sliding capturable elements into cooperating receiving grooves. Conventional masonry construction commonly requires transport of heavy components, such as cinder blocks, to a building site where they are stacked and mortared together by skilled laborers. The overall construction process could thus benefit if one were to avoid transporting heavy material and, instead, use of on-site materials (e.g., sand or dirt) in making the structure. Moreover, it would be advantageous to provide a means by which a wall could be built by relatively unskilled labor and without the use of mortar.	Cinder Blocks	Adaptability or Versatility	Material Intensity	Segmentation	Light weight, Marion's Research, Accessed September 5th

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
26	7460337	Low density, high rigidity disk drive suspension for high resonance frequency applications	A disk drive suspension component for carrying a slider at a disk is formed of a laminate of at least three metal layers of like mechanical and chemical formability, including a first outer layer, a second outer layer, and an intermediate layer, at least one of the layers having a void-containing interior and a surface area having an undivided series of local regions distributed across substantially the width and length thereof with each local region equaling less than 10% of the surface area. Each suspension application has a vertical stiffness requirement for the load beam component that requires a particular stiffness or rigidity in the load beam. The required stiffness or rigidity can be achieved by beam thickness increases but this typically undesirably increases unsprung mass in the suspension, by use of side rails which are flanges at an angle to the general plane of the load beam, and use of relatively thin and lightweight materials shaped and combined to provide a greater apparent thickness without adding a comparable amount of mass, e.g. monocoque structures.	Suspension component made with layers that do not contain voids	Strength	Material Intensity	Porous Materials	Light weight, Marion's Research, Accessed September 7th
27	7451719	High temperature superconducting degaussing system	Superconducting cable technology is used to reduce the negative impacts of the Advanced Degaussing System to ship design and construction while maintaining or increasing its performance. Superconductivity is a phenomenon whereby a material will transition from a resistive state to a perfect conductor of electricity. This transition will occur suddenly and is governed by the materials' temperature, current density, and magnetic flux density. A High Temperature Superconductor is a conductor that is typically a mixed state superconductor composed of material having no resistance linked by material having electrical resistivity. Electric fields and, therefore, voltage drops exist in HTS wires/cables when they are operated at useful currents. But these voltages, and the resistances that cause them, are very small compared to copper, aluminum, silver or any other conducting material operating at the same current, fields, and temperatures. HTS wires/cables cooled to cryogenic temperatures can be operated at current densities that are a factor of 100 to 200 higher than that of room temperature conductors. This allows magnets to be fabricated with HTS wire that are a fraction of the weight of room temperature magnets producing the same magnetomotive force (MMF) and magnetic flux.	Traditional conductors that take up a lot of space	Volume	Material Intensity	Phase Transition	Light weight, Marion's Research, Accessed September 7th
28	7448292	Transmission	A transmission with a simple structure and mechanism, light-weight and compact is realized. In the transmission, a first rotation shaft coaxially fixed to a first turning transmission wheel and a second rotation shaft coaxially fixed to a second turning transmission wheel are arranged in parallel with each other. A support shaft is arranged to extend between the first turning transmission wheel and the second turning transmission wheel. An intermediary transfer wheel is provided on the support shaft rotatably and movably along the longitudinal direction of the support shaft. The intermediary transfer wheel contacts with a side peripheral surface of the first turning transmission wheel and the side peripheral surface of the second turning transmission wheel and moves longitudinally along the support shaft while maintaining the contact.	Hydraulically driven pulleys	Device Complexity	Material Intensity	Universality	Light weight, Marion's Research, Accessed September 7th
29	7429114	Mirror blank assembly	A light-weight mirror blank assembly, having at least one sheet of corrugated material; and at least one face sheet in intimate contact with a surface of the sheet of corrugated material forming the light-weight mirror blank assembly. In the provided prior art, a supplier requires custom tooling and significant time to build the mirror blank to specification. The costs for tooling, material, and process steps can be prohibitive. Therefore, there exists a need for a method of construction for precise mirror blanks that does not incur such drawbacks and adequately supports the precise optical surface 650. The present invention reduces the fabrication time from tens of months to tens of hours. The areal densities from this process are less than what current technology has recently produced. The mirror blank is created from using a mold that creates a corrugated structure. Through using the mold, some support structures that previously required adhesion are integrated into the corrugated support.	Blanks that are reduced in mass by special tools	Ease of manufacture	Material Intensity	Consolidation	Light weight, Marion's Research, Accessed September 7th

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
30	7424832	Cable tensiometer for aircraft	The invention is a cable tensiometer that can be used on aircraft for real-time, in-flight cable tension measurements. The invention is extremely light-weight, hangs on the cable being tested and uses a dual bending beam design with a high mill-volt output to determine tension. U.S. Pat. Nos. 5,728,953 and 6,343,515 disclose cable tensiometers that use a bending beam configuration. However, the U.S. Pat. No. 6,343,515 patent employs a separate tubular structure to hold the cable and deflection blocks to create the angle in the cable and the U.S. Pat. No. 5,728,953 patent employs a spacer block to create the angle in the cable, which increases the weight of the devices to a point where they could not be used in a flight environment. Further, the U.S. Pat. No. 6,343,515 patent clamps the cable to the tubular body and the U.S. Pat. No. 5,728,953 clamps the cable to the fixed structure. Such clamping creates significant friction on the cable and dramatically decreases the precision of the devices. This invention is designed as a dual bending beam tensiometer that employs pulleys to minimize cable friction and uses the physical design to create the cable angle, rather than spacer blocks or similar extraneous components, in order to reduce the device weight.	Pats. 6,343,515 and 5,728,952	Difficulty of detecting and measuring	Material Intensity	Local Quality	Light weight, Marion's Research, Accessed September 7th
31	7539601	Energy efficient air handling system for cleanrooms	A refrigeration based air handling system design process for significant energy and cost savings in cleanroom and other applications requiring large air change rates is presented. The process utilizes a by pass around the air conditioning system, the ratio of bypass to air conditioning flow being such that minimal or no reheat of the air is required for applications having relative humidity (RH) control requirements and with RH control being achieved via cooling. In air handling systems applicable to cleanrooms and other applications requiring large air exchange rates, the air is cooled to meet the sensible heat load of the cleanroom. If the cleanroom or other enclosed environment is to have relative humidity (RH) control in addition to a large air exchange rate, and if dehumidification is achieved by cooling, then the air is cooled to a dew point corresponding to the required moisture content level by allowing the excess moisture to condense on the cooling coils of the air conditioning system. Typically, this means that the air leaving the cooling coil would be too cold for the cleanroom environment. Therefore, the air leaving the cooling coil must be re-heated to the required temperature.	Systems that send all air to be cooled and re-heated the air	Device Complexity	Energy Intensity	Extraction	Energy Efficient, Marion's Research, Accessed September 7th
32	7527679	Polluting gas desulfurization apparatus,	A compact and energy-efficient polluting gas desulfurization apparatus which reduces gas flow pressure loss and the consumption of electrical power. Slurry, which is pumped upward by a circulation system, is discharged onto the top of the circumferential surface of the drum at a point offset from the horizontal shaft along the radial axis, thus forming a mechanism able to rotate the drum from the weight of the slurry only and thus eliminating the need for an electric motor. In the previous embodiment the path through which the gas to be treated flows is extremely narrow, thus resulting in a significant loss in gas flow pressure which adversely affects the efficiency of the desulfurization process. Also, the overall size of the previous embodiment is quite large due to the power required to rotate the drum and carry the slurry upward, and the need to use a relatively large mechanism to rotate the drum.	System that uses motor to rotate drum dipped in slurry with narrow passageway	Stress or Pressure	Energy Intensity	Do it in reverse (instead of motor driving drum through slurry, slurry drives drum)	Energy Efficient, Marion's Research, Accessed September 20th

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
33	7524380	Energy efficient dishwashing	Disclosed is a method for controlling a dishwasher, including sensing weight, volume, and location of items disposed in dishwasher compartments, communicating sensed data to a controller, calculating duration of a washing and drying cycle and an amount of cleaning solution to be used based on the sensed data, implementing the washing and drying cycle for the length of time, wherein a smaller sensing of the weight and volume results in a shorter amount of time than would be spent based on a larger sensing of weight and volume, directing cleaning solution to each compartment, wherein any of the compartments including fewer or none of the items will receive less cleaning solution than any of the compartments including more items, transmitting efficiency data based on the calculating, implementing, commanding, and sensing to a viewable medium, and minimizing usage of electrical energy and water via the implementing, commanding, and transmitting.	Standard Dishwasher	Adaptability/Versatility	Energy Intensity, Renewable Resource Use	Feedback	Energy Efficient, Marion's Research, Accessed September 20th
34	7514879	Method and system for driving a plasma-based light source	A gas discharge lamp is driven with a constant current square wave from a current transformer where the number of volt-microseconds are designed such that at the start of each square wave, the voltage rises to the required ionization potential for the lamp, while the plasma has not yet started to conduct. As soon as the lamp ionizes the gas within the lamp and current flows, the voltage drops and current flows at the desired level. The current level is set to prevent the input of excessive power pulses into the lamp, to reduce the creation of infrared photons. In addition, the plasma is driven at this current level almost continuously (with reversing polarity), which does not allow the plasma time to cool down. Consequently, the lamp becomes a more efficient light emitter, thereby requiring less energy to achieve the same light output. The wasted power of the previous embodiment causes excessive heat in the ballast and lamp(s); which shortens the lifetime of both the ballast and lamp(s).	Gas discharge lamp with standard transformer	Reliability	Energy Intensity	Continuity of Useful Action	Energy Efficient, Marion's Research, Accessed September 20th
35	7490480	Variable speed refrigeration system	A refrigerator incorporates a variable speed refrigeration system including a variable speed compressor, a variable speed evaporator fan, a variable speed fresh food compartment stirring fan and a variable position damper. When the internal temperature exceeds a predetermined limit, sensors send a signal representing the temperature change to the electronic control system. Based upon the magnitude of the temperature change, the electronic control system determines not only which component(s) require activation, but also the optimum speed at which the component(s) should be operated. However, the operation of the components are interdependent such that temperature control is performed in a synergistic manner. For instance, the operational speed of the compressor is established based on a sensed temperature in the freezer compartment. The operational speed of the evaporator fan is optimized based on sensed temperatures of the evaporator and the condenser, while being reduced in dependence upon the established speed for the compressor. A refrigerator constructed in accordance with the present invention is energy efficient, having a reduced noise output and minimal thermal stratification.	Single Speed Refrigerator, partially variable refrigerators	Temperature	Energy Intensity	Dynamicity	Energy Efficient, Marion's Research, Accessed September 20th
36	7480544	Operation method of energy-saving fluid transporting machineries in parallel array with constant pressure	The invention discloses a system of energy-efficient and constant-pressure fluid-transport machines coupled in parallel, which can flexibly and massively provide gas and water to every fabrication unit. The performance curves of the abovementioned system of fluid-transport machines coupled in parallel and the system impedance curves of the loads are analyzed theoretically and built in the controllers together with the equal-efficiency curves provided by the manufacturer. When the system is operating, the data detected by the pressure gauges, power meters, and flow meters are compared with the built-in data to obtain the optimal energy-efficient conditions as the operational criteria of the system of the present invention.	Operators set controls for machines based on experience (Approximation)	Extent of Automation	Energy Intensity	Feedback	Energy Efficient, Marion's Research, Accessed October 12th

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
37	7479902	Universal mobile keyboard	A versatile and mobile keyboard and a highly energy efficient keyboard scanning method are provided. An energy efficient keyboard scanning method utilizes higher-valued pull-up resistors for energy conservation. The keyboard scanning method includes a charging step to charge stray capacitance associated with the keys. The keyboard scanning method can also be operated at a variable scanning frequency. In the prior art, such pull-up resistors are usually in the tens of kilo-ohms range, so that a few tenths milliamperes of current flow through the pull-up resistor when a connected output pin is driven to a "low" level. The firmware of prior art keyboards scan the keyboard at fixed time intervals (e.g., once every 10 to 40 milliseconds). Because of the low resistance in the pull-up resistors, each scan consumes a considerable amount of energy.	Keyboards with lower value resistors and constant scanning interval	Reliability	Energy Intensity	Periodic Action	Energy Efficient, Marion's Research, Accessed October 12th
38	7475965	Inkjet printer with low droplet to chamber volume ratio	An inkjet drop ejection apparatus having a chamber with a nozzle; and, an actuator for ejecting drops of ink through the nozzle; wherein, the area defined by the nozzle is less than half a cross sectional area of the chamber. A chamber with a relatively large internal cross section will accommodate a large actuating surface. As the nozzle area is relatively small, the actuator need only move a small amount to force a drop out of the nozzle with sufficient kinetic energy. Smaller movements of the actuator are more energy efficient. Some designs can use the relatively large volume of ink in the chamber to cool the actuator and eventually remove the heat via the ejected drops.	Cartridges with smaller chambers that require more energy for actuation	Temperature	Energy Intensity	Transformation of Properties	Energy Efficient, Marion's Research, Accessed October 13th
39	7454918	Refrigeration and defrost control system	A system and method for refrigeration timer control having an energy efficient defrost cycle are provided. The system and method provide a delay time after the refrigeration cycle and prior to the defrost cycle. During this delay period the evaporator fan may run. The fan circulation and the heat from the fan coil provide a pre-warm cycle to the evaporator prior to the defrost cycle. To further enhance energy efficiency, the system and method may also provide a pre-refrigeration cycle after the defrost cycle. During this pre-refrigeration cycle only the compressor is energized. This prevents warm moist air from being circulated until the evaporator coils are cooled.	Defrost operation begins immediately after compressor turns off	Productivity	Energy Intensity	Prior Action	Energy Efficient, Marion's Research, Accessed October 14th
40	7445663	Energy efficient oxygen concentrator	An energy efficient oxygen concentrator in which a compressor applies pressurized air to at least two gas separating elements which will pass a flow of oxygen while blocking a flow of nitrogen. The gas separating elements are alternately cycled between a gas separating mode for producing oxygen enriched gas and a purge mode for purging nitrogen from the elements. According to the invention, the speed of the cycle time is increased as the oxygen enriched gas flow requirement is decreased below the maximum concentrator output. The higher cycle speed reduces the maximum compressor pressure to reduce energy consumption. The oxygen concentrator controller is programmed to operate the rotary valve to produce the desired oxygen enriched product gas flow for the patient.	Oxygen concentrators that only pump max flow rate of oxygen	Adaptability/Versatility	Energy Intensity	Periodic Action	Energy Efficient, Marion's Research, Accessed October 14th
41	7438447	Apparatus and method for improved illumination area fill	A reflector for a light source, such as an LED, is provided with a shape which efficiently collects and directs energy to an illuminated surface whereby almost 100% of the light is collected and distributed into a designer composite beam. The shape in one embodiment is comprised of three zones beginning with a parabolic surface of revolution at the base of the reflector, followed by a transition or straight conic zone and ending with an elliptical zone. In another embodiment the reflector shape is determined according to a transfer function which allows for arbitrary designer control of the reflected rays at each point on the reflector, which when combined with direct radiation from the source, results in a designer controlled composite beam or illumination. The device is more than 90% energy efficient and allows replacement of higher power, less energy efficient light sources with no loss in illumination intensity.	Single Pattern Reflector	Illumination Intensity	Energy Intensity	Segmentation	Less Energy, Marion's Research, Accessed October 18th



#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
42	7402028	Pressurization system	A pressurization device is described mobilizing gravity to mobilize seawater and to employ a weight for gravitationally applying a force to and thereby pressurizing an enclosed pocket of seawater, resulting in low energy utilization. High pressure pumps, for example displacement pumps, are conventionally used for drawing the seawater from the water source, pressurizing the drawn seawater by compressing the seawater within a volume and supplying the pressurized seawater to the desalination system. However, the energy consumption of each of these pumps is high which results in high operating costs. Systems using these high pressure pumps require a variation of components to reduce water supply pulsation and prevent over-pressurization of downstream pipes for conveying pressurized seawater.	High Pressure Pump	Device Complexity	Energy Intensity	Periodic Action (Pressure stages vs. continuous pressure)	Low Energy Utilization, Marion's Research, Accessed October 18th
43	7398642	Gas turbine system including vaporization of liquefied natural gas	A gas turbine cycle that utilizes the vaporization of liquefied natural gas as an intercooler in an open loop gas turbine system. The system provides an increase in gas turbine cycle efficiencies while providing a convenient system for vaporizing liquefied natural gas. The systems and methods of the present invention permit the vaporization of liquefied natural gas using air that has been compressed in a first compressor, with the resulting cooled air being easier to compress and/or having fewer contaminants therein for compression in a second compressor. As the air is easier to compress, less energy is needed to operate the second compressor, thereby increasing the efficiency of the system. Additionally, unlike prior art systems that use water as an intercooler, no additional equipment is needed to cool the vaporized natural gas, such as cooling towers.	Systems that use water as an intercooler	Adaptability/Versatility	Energy Intensity	Consolidation	Less Energy, Marion's Research, Accessed October 18th
44	7534399	Hazardous gas abatement system using electrical heater and water scrubber	A hazardous gas abatement system decontaminates an exit gas stream containing global warming gases using an electrical heater and a water scrubber. A cleaning ring mounted on an eccentric rod cleans particles from the outside of the internal heater, and the inside of the external heater. An air cylinder drives the eccentric rod and cleaning ring down and up between the heaters and stores the ring above the gas inlets. In existing gas cleaning systems heaters are used. However, the heaters insufficiently heat all of the gases, and the heaters become fouled and unable to efficiently transfer heat. They also become so burdened with particulate contaminants or reaction products as to interfere with free flow of gases through the cleaning systems. Periodic cleaning of the heaters and the chambers becomes necessary, which requires shutting down of the systems or taking the treatment apparatus off line, resulting in duplicate systems and greater expense. If the systems are not cleaned contaminated gases will be released.	Systems without self-cleaning heaters	Extent of Automation	Dispersion of Toxic Materials	Self-Service	Toxic, Marion's Research, Accessed October 28th
45	7514015	Method for surface cleaning	A system for removing photoresist from semiconductor wafers is disclosed. The system utilizes a solid-state laser having wavelengths in the near-visible and visible portions of the electromagnetic spectrum to remove photoresist without requiring hazardous gases or wet solutions. In addition, the system does not damage the substrate being cleaned, nor leave a carbon residue requiring further processing to remove. The system uses photon energy, oxygen, water vapor and ozone to interact with contaminants on a surface, forming a gas reaction zone (GRZ). The GRZ reacts and completely removes the photoresist or other unwanted contamination. Some dry techniques use fluorine which is a hazardous gas and requires complicated equipment to collect the gas.	Wet removal methods using harmful chemicals and dry removal methods using harmful gasses	Device Complexity	Dispersion of Toxic Materials	Extraction	Toxic, Marion's Research, Accessed October 28th

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
46	7434753	Simplistic approach to design of a reusable nozzle hub	A novel hub design that enables removal of nozzle core for disposal while the hub is retained for reuse. The reusable hub provides a cost advantage over a one-piece metal design, enabling the use of a dispensing system that is of high quality and low cost to proliferate the use of the technology in the industry. Using this method, a nozzle hub dispensing system has a very favorable impact on the environment, 90% less hazardous waste with a reusable hub system, as only the lightweight cores are disposed. This nozzle hub provides a positive locking, tool-less mechanical connection of nozzle core to hub, which offers a financial advantage over competitive products. Modified hypodermic needles have a constant diameter throughout the length. This causes a very high-pressure drop across the needle and restricts liquid flow. The fluid path is not contiguous and usually constrictive at the connection point, hub and fluid path are permanently connected together. Transition points of the flow channel through the nozzle using this manufacturing technique are abrupt and inconsistent.	hypodermic needle nozzle	Stress or Pressure	Material Intensity	Segmentation	Hazardous Waste, Marion's Research, Accessed October 28th
47	7428911	Spill containment system and method	A battery spill containment system and method are provided for containing a hazardous spilled substance from at least one industrial battery in service as a back-up power supply. The system comprises a containment rail system to define a perimeter to accommodate the at least one industrial battery; a flexible liner for placement within the perimeter defined by the containment rail system, the flexible liner having a base and an edge, wherein the edge rises at least about four inches above the base, the flexible liner being resistant to damage from the spilled substance; and a material for placement within the perimeter defined by the containment rail system, the material to absorb and chemically neutralize the spilled substance from the at least one industrial battery so that the hazardous nature of the spilled substance to humans or material structures is reduced, wherein the containment rail system is mounted to the floor whereby battery lifting equipment can be used to access the at least one industrial battery for servicing or replacement.	Battery on standard storage shelf	Object Generated Harmful Factors (Health & Property Damage)	Dispersion of Toxic Materials	Cushion in Advance	Hazardous Material, Marion's Research, Accessed October 28th
48	7540346	Automotive vehicle employing kinetic energy storage/reuse capability	When the automotive vehicle decelerates, the electronic control device connects the flywheel to the power transmission system through the continuously variable transmission, and transfers energy of the power transmission system to the flywheel. When the automotive vehicle accelerates and the electronic control device connects the flywheel to the power transmission system through the continuously variable transmission, energy of the flywheel is transferred to the power transmission system. Disadvantages of previous system are: 1.) efficiency in converting kinetic energy through the motor/generator into electric energy in the batteries is low and 2.) the motor/generator and batteries occupy a significant space, the overall automobile size is correspondingly increased, which not only runs counter the efforts at manufacturing small-sized automobiles, but also, due to the corresponding increases in the body weight of the automobile, an engine with a larger displacement is required for providing sufficient driving power.	Traditional Hybrid Vehicles	Weight	Energy Intensity	Homogeneity (all kinetic energy rather than kinetic and chemical)	No search term provided, Marion's Research
49	7527736	Method for generating fracturing water	Systems and methods have been developed for reclaiming water contaminated with the expected range of contaminants typically associated with produced water in order to produce a treated water having a quality adequate for reuse as a fracturing water. The system includes anaerobically digesting the contaminated water, followed by aerating the water to enhance biological digestion. After aeration, the water is separated using a flotation operation that effectively removes the spent friction reducing agents and allows the treated water to be reclaimed and reused as fracturing water, even though it retains levels of contaminants, including boron and methanol, that would prevent its discharge to the environment under existing standards. The treated water has had a sufficient amount of the gellation-inhibiting contaminants, such as acrylamide friction reducing compounds, removed to allow the treated water to be an economically viable fracturing water.	Completely treating water to meet environmental standards	Ease of manufacture	Renewable Resource Use	Partial or Excessive Action	Reuse, Marion's Research

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
50	7520959	Method for manufacturing light barrier packaging material, light barrier packaging material, semi paper packaging material and light barrier paper packaging container	A method of manufacturing a light barrier paper packaging material and the light barrier paper package container with low cost, no need of an ink removing apparatus at reproduction step and easily recycle are provided. A light barrier paper packaging material which comprises the paper substrate and the laminate layers on the paper substrate comprises: the paper substrate having a clay coat layer applied to the paper substrate; a light barrier layer printed with black ink on the clay coat layer; cover-up layers printed with white color ink to the light barrier layer a plurality of times; an outside laminate layer of thermoplastic resin formed on the cover-up layer, and design printed to the outside laminate layer. Some previous concepts provide the light barrier layer in the inside of the paper substrate. When the food such as cow's milk being sensitive to chemical is filled up, from viewpoint of legal regulation and effect to taste, it is unfavorable to provide the light barrier layer in the food side. Also, some print the black ink directly on the paper and an ink removing apparatus is necessary for reproduction in the recycle.	Light barrier on inside of paper substrate or printing directly on the paper	Object Generate Harmful Factors (Chemicals in Milk)	Recyclability	Mediator (clay substrate)	Recycle, Marion's Research
51	7520455	Device for reuse of plastic materials and paper fibers rejected in previous recycling	This device is a novel method for separating paper fiber, plastic and other impurities to improve recycling efficiency. Currently, paper industries, in the operation of paper recycling, come across with the problem of the existence of plastic materials in the volume under recycling, being observed the inefficiencies aforementioned which means loss of approximately 20% of the volume put in recycling and consequently becoming environmental waste. That occurs under automation technical conditions, being elementarily used in operations of paper recycling a big-sized hydraulic device, equipped with a rotor responsible for the dissolution of the papers into fibers. However, at the moment of the dissolution of the papers into fibers, said hydraulic device does not present enough technique to prepare the plastic material contained in the volume, aiming its later use.	Hydraulic device	Productivity	Recyclability	Segmentation	Recycle, Reuse, Marion's research
52	7520371	Materials and processes for reducing combustion by-products in a lubrication system for an internal combustion engine	A lubrication system having an oil filter modified to replace or supplement the performance of lubricant additives that may be used within an internal combustion engine to increase the performance of a lubricant. The formulation of the lubricant is changed in accordance with the chemicals placed in the oil filter. For example, when the oil filter contains a strong base, the lubricant concentration of detergent will decrease, in some cases to zero, while the dispersant concentration in the lubricant will increase. The dispersant is the ideal weak base to neutralize combustion acid at the piston ring zone, carry the resultant weak base-combustion acid complex to the strong base in the oil filter, undergo ion exchange with the strong base, immobilize the acid in the oil filter and recycle back to the piston ring zone for reuse as an acid neutralization agent. The reduction or elimination of detergent from the lubricant will reduce the fouling of the emission filter and of deposit formation on engine parts such as the piston. The oil filter may also contain an additive which is slowly released into the lubricant. The rate of release is limited by the equilibrium concentration of the additive in the lubricant. As a result, a relatively constant concentration of the additive may be maintained in the lubricant. The resultant closed system allows the oil drain intervals to be significantly extended.	Oil with a specific amount of pre-added lubricants	External Harm Affects Product	Dispersion of Toxic Materials	Dynamicity	Recycle, Marion's Research
53	7488416	Bathing pool assembly with water full of nano-scale ozone bubbles for rehabilitation	A bathing pool assembly with water full of nano-scale ozone bubbles for rehabilitation has a bath, a reservoir and two circulating systems. The bath and the reservoir both have a main inlet and a main outlet. The reservoir further has a tap to allow water to flow out of the reservoir, which is provided for people to drink or gargle. The circulating systems are connected respectively to and communicate respectively with the bath and the reservoir to recycle water. The circulating systems are further connected to a gas generator assembly having an oxygen generator and an ozone generator to provide water full of oxygen and ozone to release free radicals and anions.	Traditional Baths where fresh water is used	External Harm Affects Product (Germs)	Recyclability	Accelerated Oxidation	Recycle, Marion's Research

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
54	7470172	Water reuse in food processing	In contrast to conventional food processing system in which a carcass is cooled only at the end of a processing line, the present invention cools an animal carcass as soon as it is practical and as much as possible during processing to maximize shelf life and reduce microbial growth. In particular, the food processing system preferably cools the animal carcass immediately after it is slaughtered and drained of blood, because blood drainage may be hindered by reduced temperatures. Preferably, the food processing system continues this cooling up to and including the time when the carcass is processed further and packaged. Because the ozone and water mixture and gases, such as ozone, carbon dioxide, and nitrogen, are used for cooling, rather than pure water, the present invention requires less water than conventional food processing systems. The preferred embodiment of the invention uses a reduced amount of fresh water and produces a reduced amount of waste water by purifying and recycling water used by the system.	Processing animals at room temp. and washing machines with water	External Harm Affects Product (Germs)	Renewable Resource Use	Transformation of Properties and Prior Action	Reuse, Marion's Research
55	7467495	Vehicle seal with discontinuous alternating soft and rigid u-shaped segments and method of forming same	A strand-form vehicle seal is equipped with a flexible reinforcement with a substantially U-cross section. The flexible reinforcement includes at least two different substances formed of individual sections of a nonmetallic, soft-elastic material together with individual sections of another nonmetallic, however dimensionally stable and hard or rigid material. The individual sections in the reinforcement are interrupted and disposed intermittently each alternating one after the other along the direction of the reinforcement. The rigid sections form the clamping portions of the reinforcement. The soft elastic sections disposed between them lend flexibility to the reinforcement. In this manner, the vehicle seal is easier to process, dispose of and recycle. A method is also disclosed for making the seal.	Seals made of metal and plastic	Ease of manufacture	Recyclability	Homogeneity (composite plastics rather than plastic and metal)	No search term provided, Marion's Research
56	7459138	Process and apparatus for producing single-walled carbon nanotubes	The process contemplates methods and apparatus which recycle and reuse the gases and catalytic particulate materials, thereby maximizing cost efficiency, reducing wastes, reducing the need for additional raw materials, and producing the carbon nanotubes, especially single walled carbon nanotubes, in greater quantities and for lower costs. During several step of the process, substances are separated. In one step, the support is separated from the catalyst and nano-tube. In the next step, the catalyst is separated from the nano-tube. The support and catalyst then separately have fresh support and fresh catalyst added to them and are impregnated for the next round of nano-tube production.	Discarding waste support and catalyst material	Productivity	Recyclability	Segmentation	Recycle, Reuse, Marion's research
57	7445084	Soundproof thermal shield	Since all the elements of the thermal shield according to the invention are made entirely of aluminum, the resulting material being made from a single substance is readily recyclable. The mat-like noise-absorbing layer made from multiple plies of knitted aluminum fabric lends high noise absorbing qualities to the thermal shield. The sound waves striking the mat penetrate the narrow pores of the mat and cause the air in the pores to vibrate back and forth, so that the sound energy is converted to heat under the effects of friction. The thermal shield, which is made from aluminum, provides good thermal insulation, although the perforated aluminum support and the noise absorption layer also enhance the thermal shielding. Conventional thermal shields include a supporting aluminum sheet, an inner noise-absorbing layer made of mineral fibres, for example glass fibre, rock fibre, or ceramic fibre, and a closing aluminum foil. Because different materials are used in the noise-absorbing layer and the support layers, disassembling conventional thermal shields into their component materials for recycling is relatively expensive.	Aluminum thermal shield with mineral fibres for noise absorption	Temperature	Recyclability	Homogeneity	Recycle, Marion's Research

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
58	7410573	Waste water purification apparatus and waste water purification method including the regeneration of used coagulant	A waste water purification system for purifying polluted salt water including oil and the like by coagulating and separating pollutant matter in the polluted salt water can regenerate and reuse a coagulant in the system while scarcely resupplying the coagulant, an acid solution and an alkaline solution. The acid and alkaline solutions are required for disintegrating coagulated flocs from the polluted salt water and regenerating the coagulant from sludge. Alkaline water enriched in sodium hydroxide and an acidic aqueous solution containing hydrochloric acid and the like are generated by electrolyzing the purified salt water. The flocs in the separated sludge are disintegrated by use of the alkaline water, pollutant matter is removed from the disintegrated aqueous solution, and the strong acidic containing the hydrochloric acid is added to the aqueous solution removed of the pollutant matter to have the coagulant. The coagulant can be thus regenerated from the recovered sludge. Conventional purification apparatuses and operation methods require continuous addition of coagulants as expendables in every operation.	Discarding coagulant which requires continual addition of coagulant	Productivity	Recyclability	Segmentation	Reuse, Marion's Research
59	6391049	Solid biodegradable device for use in tissue repair	A composition and method for a light activated composition for improved wound closure, is disclosed. The composition includes a biodegradable polymer that is impregnated with a solder that is biologically compatible and a chromophoric dye. The chromophoric dye enhances the amount of light energy that the composition absorbs. The solder, the polymer scaffolds and the chromophoric dye are all bio-compatible. Foreign body reaction is expected to be minimal using the new device as the degradation products of the scaffolds, including lactic acid and glycolic acid for the example of PLGA scaffolds, are naturally occurring substances inside the body [Wake 1996]. Altering the macromolecular structure of the scaffold may also control the degradation rate of the scaffolds. For example, the degradation rate of the scaffolds may be altered from days to years by varying the ratio of polylactic acid (PLA) to polyglycolic acid (PGA) and may be varied from 0 to 100% in PLGA scaffolds.	Scaffold made of non biodegradable material	Object Generated Harmful Factors	Renewable Resource Use	Homogeneity	Biodegradable, Marion's Research
60	7476987	Stand-alone , , wind turbine system, apparatus, and method suitable for operating the same,	This invention provides a wind turbine-battery-dump load stand-alone renewable energy system and an optimal control of the same. The system may include both power conversion and control units. In one embodiment, the power conversion unit features a wind-turbine-driven three-phase induction generator, a diode rectifier, a battery charger, a boost dc/dc converter, a battery bank (48V), and a dc/ac inverter. A dump load is also used to dissipate excess power that is not required for either the battery charging or for the load. The integrated control unit may use the TMS320LF2407A DSP microcontroller from Texas Instruments, which allows operations of the wind power system and the battery storage system to be merged into a single package under a master controller. An embodiment of the control system features battery-charging control, battery voltage-boost control, dump load control, PWM inverter control, and system protection. It enables the use of renewable energy resources, while at the same time facilitating an efficient management of energy dispatch. This integrated control system offers remote villages the potential to fully supply their electrical power needs.	Wind-Turbines that aren't "stand-alone" (have to purchase separate components and assemble)	Device Complexity	Renewable Resource Use	Consolidation	Renewable, Marion's Research

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
61	7467523	Autonomous water source	An autonomous water source (AWS) for extracting water from ambient air and delivering it to a plant to support growth. The system is based on an adsorption-desorption-condensation (ADC) cycle using a sorption material to extract moisture from ambient air and condensing the water vapor driven off from the sorption material by subsequent heating and followed by condensation. Liquid condensate produced in this process on the condenser is collected and delivered by gravity to a plant to reduce thermal stress and to support growth. The invention provides a sustainable source of irrigation water for agriculture and forestry, including areas where no water resources exist or are not economically viable. It can be tailored in size, and therefore, output capacity, reflecting the desired water requirements of a particular application, and can be used to replace most agricultural situations now reliant on surface water drip feed systems. The device is simple, rugged, invulnerable to rain, snow, and freezing conditions, and can be designed to last for many years without service as there are few moving parts and power required for operation is provided by sunlight.	Drip Irrigation	Adaptability/Versatility	Renewable Resource Use	Self-Service	Sustainable, Marion's Research
62	7453164	Wind power system	A system for capturing and converting and/or storing wind energy includes a vessel adapted to receive at least one wind machine for capturing wind and a device for converting wind energy to storable energy. A method of adapting a vessel, such as a surplus cargo ship or an oil tanker, for use as a offshore power generating system comprises equipping a vessel with devices for capturing a renewable energy source, positioning the vessel at sea to capture the renewable energy source, converting the renewable energy to a storable energy source, and storing the converted energy, and repositioning the vessel to capture further renewable energy or transport the stored, converted energy.	Stationary Wind Turbines	Productivity	Renewable Resource Use	Dynamicity	Renewable, Marion's Research
63	7444189	Method and apparatus for simultaneous optimization of distributed generation and hydrogen production	In one embodiment, the energy management system receives electricity and natural gas from traditional sources such as electric and natural gas utilities. It can also produce electricity and thermal energy onsite from renewable sources, and can use the energy inputs from either traditional or renewable sources, or both, to produce hydrogen. The hydrogen can be used during peak consumption periods to produce electricity and natural gas as well as provide a volume of transportation fuel for a vehicle powered by a hydrogen fuel cell. The production of hydrogen can be a type of energy arbitrage method because it can be produced at times when the relative cost of source energy is low, and consumed as a replacement for traditional sources of energy when their relative cost is high. This method of energy arbitrage might use an optimization method to optimize the relative mix of hydrogen created and source energy consumed.	Using independent energy sources (electricity, natural gas, and gasoline)	Productivity	Energy Intensity	Mediator (hydrogen)	Renewable, Marion's Research
64	7425269	Apparatus for aeration without significant agitation to deplete and biodegrade sludge	An improved apparatus and method which eliminates rotating impellers and air plates from aerators substituting a specially designed disc. And, as a result, less horse power per unit can be used to achieve smaller entrained air bubbles resulting in increased residence time for entrained air and enhanced lateral oxygen transfer to replace oxygen consumed by aerobic bacteria during the biodegradation process. It may be used on industrial waste water of all types and from all sources that are biodegradable by aerobic bacteria. It can be seen in comparison with the old unit that less energy is used, the louvered disc is easier to control, takes less horsepower, provides entrained air level bubble size that is smaller, evacuates the chamber faster, runs quieter and in general provides significant improvement in operation and resulting test data efficiency, all with less mechanical parts. It therefore can be seen that the invention accomplishes at least its primary objective.	Similar device using air plates and impellers	Productivity	Energy Intensity	Consolidation	Biodegradable, Marion's Research

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
65	7401241	Controlling standby power of low power devices	Systems and methods of managing power provide for applying a voltage from a voltage regulator to a component of a computing system and reducing the voltage based on a power saving parameter that is dedicated to the component. Manufactured components tend to exhibit slightly different characteristics from one part to the next. For example, two CPU parts resulting from the same manufacturing process may have different minimum sustainable voltages. Conventional power management approaches, however, select a worst case minimum sustainable voltage for all CPUs of a given type and use this value to program the voltage regulator. Thus, a non-optimal minimum sustainable voltage is shared among all instances of a given computing system component. The same is true for other power saving parameters such as the minimum operating voltage. As a result, the majority of parts use non-optimal power saving parameters, which often results in missed power saving opportunities. Furthermore, conventional approaches do not permit the CPU to change the preset minimum value and therefore have limited ability to tailor the voltage regulator to individual components rather than a group of components.	Only using one minimum voltage value for all components	Temperature	Energy Intensity	Local Quality	Sustainable, Marion's Research
66	7392765	Biodegradable pet mat	A biodegradable absorbent mat for absorbing and containing moisture including debris from pet feet, consisting of a bottom layer formed of an organic absorbent mesh composite, a top layer affixed and overlying said bottom layer, having an alternating combination of stitched paper ruffles and helically intertwined brush fibers. The configuration of the stitched paper ruffles, provide maximum exposure of the cut linear edges of the ruffles to a pet's feet. The cut linear edges wick away moisture increasing the rate of absorbency. The stitched paper ruffles provide increased capacity for absorbency and debris containment. The helically intertwined brush fibers primarily remove debris from pet feet, and also provide a secondary function of containment of debris. Another device designed to maintain litter box areas is a hard plastic, rubber, commercial grade carpet or combination thereof, that is placed next to the litter box. This device does not absorb pet waste moisture, the device only holds the litter and body waste, requiring the pet owner to manually clean and sterilize regularly.	Rubber Mat	Extent of Automation	Renewable Resource Use	Porous Materials	Biodegradable, Marion's Research
67	7530585	Rear suspension structure for large vehicles,	A rear suspension structure for large vehicles increases durability of a bump stopper and an air spring, thus markedly enhancing the riding comfort and handling ability of a vehicle. Furthermore, the amount of air to be drawn into and discharged from the air spring is increased thanks to a changed installation position of a leveling valve, so that stable handling ability of the vehicle is ensured, thus markedly enhancing traveling stability of the vehicle. As well, the present invention is provided with a lower radius rod having an improved shape and installation structure, so that lateral rigidity of a rear axle is increased, and a process of correcting misalignment of the rear axle can be performed more conveniently, thus preventing deflection of the vehicle when traveling,	Previous suspension without enhancements	Adaptability/Versatility	Durability	Transition into a new dimension	Durability, Marion's Research
68	7523774	Pneumatic tire with high turnup locked bead construction,	A pneumatic radial ply tire for heavier load conditions having a reduced weight, high durability bead area. The pneumatic tire includes a tire bead and a carcass ply folded about the bead to define a main body portion and a turnup portion. The turnup portion is folded around the bead and located adjacent the main body portion radially outward of the bead. The turnup portion has a turnup height of approximately 35-45% of the total section height. A thin rubber strip associated with the bead is disposed between the main body portion and the turnup portion and has an insert height of approximately 25% of the total section height. The pneumatic tire further includes a chafer having a maximum chafer gauge of not more than approximately 1.5 times the thickness of the tire side wall.	Previous tires that include additional elements, such as chafers, chippers, toe guards, and clamping members, all designed to improve the durability of the bead area.	Weight	Durability	Transition into a new dimension	Durability, Marion's Research

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
69	7514163	Magnetic recording medium and magnetic recording device	A magnetic recording medium having excellent durability and corrosion resistance. The protective layer of the magnetic recording medium is composed of two layers, that is, a lower layer contacting with the magnetic layer and an upper layer on the lower layer. The internal stress of the lower layer is made smaller than that of the upper layer, and the surface free energy of the lower layer is made smaller than that of the upper layer. In the current information-intensive society, the amount of information to be handled shows a tendency to increase in every application. In order to meet the requirement for a higher recording density, it is indispensable to shorten the distance between the magnetic layer and the information recording/reading part of the head, that is, so-called magnetic spacing, and therefore, it is believed necessary to make thinner the protective layer itself. As the protective layer reduces in thickness, the durability tends to decrease.	Filtered Cathodic Arc method provides thin layer with good mechanical strength but bad corrosion resistance	Loss of Time (Recording Density affects access time and transfer rate)	Durability	Local Quality	Durability, Marion's Research
70	7510284	Projection-type display devices including redundant laser sets	Described herein are display devices that provide projection-type video output and use redundant sets of lasers to generate light. The laser set produces a desired amount of light, e.g., for a primary color. A redundant laser set includes more lasers than that needed to produce the desired amount of light. For example, a set of six lasers may only need five lasers to generate and emit a desired amount of light. The sixth laser allows failure of one laser in the set to not compromise operability of the entire set--and the display device. In addition, extra lasers in a laser set also allows the lasers to be cycled for heat purposes and to extend longevity of individual lasers in the set.	Using only the number of lasers necessary	Temperature	Durability	Cushion in Advance	Longevity, Marion's Research
71	7500493	Tuning slide valve for intake manifold	A slide valve for use in an air intake manifold is disclosed, wherein a durability of the valve and a quality of a seal created while the valve is in a closed position are maximized, and a cost and a weight of the valve are minimized. Prior art tuning valves, typically butterfly valves, may be prone to leakage or permitting undesirable communication to occur across the valve. More specifically, when the butterfly valve is in a closed position, the pressure pulsations exerted on the valve can cause the valve to open slightly or otherwise impinge on existing gaps in the closed valve, wherein a small amount of fluid, such as air, is permitted to communicate therethrough. To overcome this problem, some butterfly valves are produced with elastomeric seals around their periphery in combination with stronger springs to maintain valve position while under load. These additions tend to increase the costs of the assembly with additional materials and the need for more powerful actuation devices. While these sealed tuning valves have resulted in reduced leakage of pressure pulsations and fluid past the valve while in a closed position, there is a continued desire to maximize the robustness of the seal and minimize the cost, weight, and complexity of the valves.	Butterfly Valve	Weight	Durability	Transition into a new dimension	Durability, Marion's Research
72	7497509	Exterior component	A fender liner includes a surface layer serving as the outermost layer and an inner layer located between the surface layer and the outer surface of a wheel well. The surface layer and the inner layer are formed of nonwoven fabric. The nonwoven fabric forming the inner layer has a higher tensile strength than that of the nonwoven fabric forming the surface layer. Accordingly, the fender liner has a favorable noise reduction capability, and has a sufficient rigidity to bear a weight increase due to water absorption. Alternatively, the nonwoven fabric forming the surface layer may have a higher bulk specific gravity and a smaller fiber diameter than those of the nonwoven fabric forming the inner layer. In this case, the noise reduction capability and the durability are both improved.	Fenders liners that are durable but bad noise reduction or fenders that have good noise reduction but bad durability due to absorption of water	Object Generated Harmful Factors (Noise)	Durability	Local Quality	Durability, Marion's Research



#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
73	7485054	Two piece sports equipment stick with internal truss construction and vented handle	A two-piece sports stick exhibiting a superior strength to weight ratio. A two-piece sports stick comprising two identical sections, each comprising a substantially smooth external portion and an internal portion possessing at least one cutaway; and a multiplicity of construction pegs. The sports stick design allows for decreased flexure, increased rigidity and increased durability, which lead to greater generation of force, accuracy, reliability and longer life expectancy. Prior to the introduction of the present invention, the major focus has lied mainly in matters concerning materials to be utilized to minimize weight, as opposed to structural and aerodynamic considerations. The instant invention combines the material breakthroughs developed over recent shaft design with the obvious advantages of aerodynamic research. The instant design features internal trusses and curved cutaway surfaces to add strength and reduce weight in conjunction with small through slots in a substantially smooth external profile to provide aerodynamic airflow.	Sticks that only focus on material changes	Weight	Durability	Spheroidality	Durability, Marion's Research
74	7478577	Quick adjust ratcheting wrench with cam actuated clamping	It will be appreciated that the present invention provides for cam surfaces satisfies an object of the invention in that the cantilever torque present in prior art designs is significantly reduced permitting light weight material construction, reduced wear and improved durability and reliability. The present invention transfers torque directly from the control disc to the cam followers of the jaws. Because the cam follower is positioned in direct line with the V-shaped grip surface of the jaw there is no cantilevered torque applied to the element. The work piece is thusly in a direct line relative to the handle, pawl, control disc and jaws further improving control and efficient transfer of load to the work piece as there is no vertical force vector as present in the prior art. Another object of the invention further reducing manufacturing cost is the absence of a ratcheting mechanism fixing the control and adjusting discs during a return stroke. Of particular noteworthiness is the load transfer through the control disc wherein application of torque to the handle causes a high level of cantilever load on both the control and adjustment discs therefore necessitating hard or harden materials for their construction thereby increasing weight and manufacturing costs over lighter materials.	Design with cantilevered torque	Weight	Durability	Transition into a new dimension	Durability, Marion's Research
75	7475861	Seat Rail for Vehicles	The seat rail of this invention eliminates gaps between a lower track and an upper track in horizontal and vertical directions, and distributes a load transmitted through the upper track, thus improving overall durability. The load transmitted through the upper track is force acting in a vertical direction. Most of the force is exerted on the roller members. However, according to the present invention, a ball bearings are installed in the left and right bearing seats to have contact points in an inclination direction so that the load transmitted through the upper track 20 is distributed and supported by the ball bearings as well as by the roller members. Thereby, the load concentrated on the roller members is distributed, so that overall durability is increased. The construction minimizes a frictional area when the upper track slides, thus improving operational performance, reducing operational noise, and improving operating sensation.	Design with gaps between upper and lower tracks	Object Generated Harmful Factors (Friction)	Durability	Transition into a new dimension	Durability, Marion's Research

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
76	7443047	Multiphased and multidimensional wave converter	The special feature of this multiphase and multidimensional wave converter is that it exploits, in an efficient and enduring manner, substantially all of the energy in all waves of the sea, also side waves, and hence is capable of producing large amounts of cheap power. The wave converter comprises at least two buoyant elements connected in a chain of rods and joints. Each single buoyant element is in a different phase of the wave than that of the others. They will therefore absorb the energy from the relative motion and forces between each set of buoyant elements. Each of the elements is capable of moving and pivoting in three dimensions whilst the energy from all these motions is exploited. The energy-producing devices may be comprised of fluid-driving pumps responding to the pivoting of the joints and the motion of the rods. The wave converter absorbs energy from a varying wave spectrum and from all directions. The forces affecting the wave converter are balanced by the various buoyant elements, thus avoiding transmitting these forces via mooring. The wave converter provides appreciable economic advantages and durability. It may also operate at any place in the sea and the ocean, at shallow depths as well as at the large depths of the ocean.	Designs that fixed and subjected to force. Also, designs that only convert energy based on specific wave movement.	Adaptability/Versatility	Durability	Dynamicity	Durability, Marion's Research
77	7441811	Casement window lock	The present invention relates to a casement window locking device having improved function, including improved strength, security, and durability. The invention provides a simple, elegant casement window lock having an extended operating range, is economical to manufacture, and uses few parts. Casement windows have utilized various mechanisms to secure closure, primarily for safety, security, and energy efficiency. Many casement window locks include a complex set of levers, gears, and pins. These locks are difficult and expensive to make, repair, and replace.	Complicated designs described in description	Ease of manufacture	Durability	Universality	Durability, Marion's Research
78	7430111	Mounting structure for display unit in refrigerator	Accordingly, an object of the present invention is to provide a mounting structure for a display unit in a refrigerator, which is configured such that components for supplying electric power to or transmitting a plurality of electric signals to the display unit can be prevented from being exposed to the outside. With such an arrangement the external appearance of the refrigerator can be improved, the durability and operational reliability of the refrigerator can be ensured, and the usability can also be enhanced.	Designs where the wires are exposed	Shape	Durability	Nesting	Durability, Marion's Research
79	7421965	Flexible buoy	The flexible buoy for achieving the above object is characterized in that an airtight hollow structure is formed of a flexible membrane made of rubber or resin, in which a reinforcement layer is buried, that a flange opening includes a gas inlet fixed to at least one position of the hollow structure, and that buoyancy thereof is controllable by using an internal pressure of a gas injected in the hollow structure. Since the buoy is flexible, when the buoy is collided with another object on the water, the buoy will not be recessed or damaged, and additionally will not damage a counterpart object, such as a boat, colliding with the buoy	Steel Buoys	Object Generated Harmful Factors	Durability	Transformation of Properties	Durability, Marion's Research

#	Pat number	Description	Summary	Previous Generation	Functionality	Environmental	Triz Principle	Search Info
80	7395941	Artificial nipple with reinforcement	<p>The present invention relates to an artificial nipple, which has durability enough not to be torn with fatigue load resulting from teeth contact since fiber nets are embedded within the thickness of the artificial nipple, eliminates a difficulty in breathing by facilitating the flow of air, and prevents obstruction of the airway of an infant by distributing milk suction pressure when the infant sucks milk. The air inflow groove in the present invention causes outside air to be introduced into the mouth of an infant so that the pressure in the mouth can become the atmospheric pressure, thereby ensuring the smoothness of milk suction. Considering that the nipple body in the present invention becomes thin at a portion corresponding to the air inlet groove due to the formation of the air inflow groove a reinforcement thickening is formed at a portion of an inner surface of the nipple body that is at the back of the air inflow groove. Further, a reinforcement thickening is also formed around the feeding hole in the inner surface of the nipple body so as to prevent premature breakage of the nipple due to stress concentration around the feeding hole.</p>	Thumb type and roman type artificial nipples	Object Generated Harmful Factors (Choking)	Durability	Local Quality	Durability, Marion's Research

*Appendix E: Product Analysis*

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
1	Sectional Sofa	A sofa that divided into pieces so it can be placed in many locations providing greater functionality and extended use.	Non-Sectional Sofa	Adaptability or Versatility	Product Durability	Segmentation	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
2	Dual-Layer Tread Tires	Makes use of a hybrid tread structure (2 types of rubber) that exposes rubber with higher grip as the tire wears down, reduces noise associated with wear	Regular Car Tires (1 Type of Rubber)	Object Generated Harmful Factors (Noise)	Product Durability	Local Quality	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
3	High Efficiency Cooling Device for Notebook Computer	The radiator for the CPU, auxiliary CPU, Intel 845 chip and display chip are connected to a single heat extraction pipe which is cooled by a single fan.	Either fans attached to each component or heat sinks with fins that take up more volume	Volume	Material Intensity	Consolidation	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
4	Stacked Chip Scale Packages	Provides double the memory capacity while taking up the same footprint on the motherboard	Non-Stacked Chip Scale Packages	Area	Material Intensity	Nesting	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
5	Run-Flat Tire System (Found patent 7531056)	A lightweight metal ring is attached to the car rim that can carry the load of the car for a certain distance in case of a flat tire	Tires that cannot be driven on when flat	Reliability	Product Durability	Cushion in Advance	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
6	Flashlight without Batteries and Bulbs	Utilizes Faraday Principle, shake 15-30 seconds for 5 minutes of light. Reduces instances where one is left in the dark due to a dead battery.	Battery Operated Flashlights	Reliability	Dispersion of Toxic Materials	Prior Action	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
7	Self-Cleaning Exhaust Hood	Actively deploys water vapors to intercept oil and dust before they reach the hood	Exhaust hood with fan and filter	External Harm affects product (oil and dust)	Product Durability	Cushion in Advance	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
8	Washing Machine using centrifugal force	Tub is spun quickly to push the water through the clothing forcing out stains and dirt. Less water used and quiet.	Standard Washing Machine with agitator	Object Generated Harmful Factors (Noise)	Renewable Resource Use	Spheroidality	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
9	Temperature Controlled Containers in Low-Temperature Logistics	By storing smaller cargo containers inside of a larger one and separating them with eutectic materials, products that need to be shipped at different temperatures can be shipped on the same truck	Truck with 1 container at a specific temperature	Adaptability or Versatility	Energy Intensity	Dynamicity	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
10	BMW's Valvetronic Engine	System provides more control of air entering the combustion chamber which reduces pumping losses, increases fuel efficiency and improves responsiveness	Butterfly Throttle Engines	Adaptability/Versatility	Energy Intensity	Dynamicity	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
11	Washing Machine for Single Person	Small washing machine that can be folded for easy storage. Tub is able to be folded because agitator is replaced with ultrasonic wave generator.	Standard Washing Machine with agitator	Volume	Material Intensity	Mechanical Vibration	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
12	Inverter Welder	Used variable frequency technique to reduce power consumption and weight	Constant frequency welder	Weight	Energy Intensity	Periodic Action	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
13	Correction Tape Device	No waiting for drying, more environmentally benign materials, can be reused	White Out	Loss of Time	Dispersion of Toxic Materials	Continuity of Useful Action	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
14	Gasoline Direct Engine	Gasoline direct injections pump gas directly in to the cylinder allowing a more controlled air to fuel mixture and more complete combustion	Conventional indirect fuel injection system where air and gas are mixed in the intake manifold	Productivity	Energy Intensity	Local Quality	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
15	Active Noise Control	Speakers located within a car that produces sound waves in the opposite phase of the disturbing noise to cancel the noise through interference. A feedback device measures the disturbing noise and provides an input for the speakers.	Noise Insulation Material	Object Generated Harmful Factors (Noise)	Material Intensity	Feedback	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
16	Small-Scale, High Performance Fuel Cells for Portable Devices	Cells turn methanol to hydrogen gas in the presence of a catalyst. A generating cell turns hydrogen gas into electric energy. Half the weight and 4 times battery life.	Li-Ion Batteries	Weight	Dispersion of Toxic Materials	Mediator	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> <a href="http://world.casio.com/info/fuelcell.html">http://world.casio.com/info/fuelcell.html</a> Accessed May 18th, 2009
17	Automatic Faucet	Faucet turns on when hands are brought near and hydro powered turbine recharges the battery in the unit	Hand operated Faucet	Extent of Automation	Renewable Resource Use	Self-Service	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
18	Virtual Keyboard	Projection of a keyboard on a flat surface from a hand-held device	Standard Keyboard	Volume	Material Intensity	Copying	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
19	Vehicle Hybrid System	Car with a combination of a gasoline engine and AC motor powered by an on-board battery which is recharged by an on-board generator. One neat feature is the motor acts as a generator when braking to capture typically lost energy. Results in more mileage on a tank of gas.	Standard Gasoline Engine	Productivity	Energy Intensity	Replacement of Mechanical System	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
20	Air Suspension System for Cargo Trucks	Compressed air is used for suspension at each wheel providing a smoother ride and less wear on the tires.	Steel Springs	Adaptability/Versatility	Product Durability	Use a Pneumatic or Hydraulic Construction	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
21	Saab Variable Compression Engine	Saab designed an engine that separated the engine block into two parts, the cylinders in the top portion and the crankshaft in the lower portion. The two parts are connected by rubber bellows and the cylinder portion is adjustable to allow the cylinder to have a different volume depending on the Compression Ratio necessary for the driving condition.	Standard engine with fixed cylinder volume and compression ratio	Adaptability or Versatility	Energy Intensity	Dynamicity	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
22	Eco-Drive Watch	The watch's dial is porous which allows light to pass through to a solar panel which recharges the battery.	Battery Operated Watches	Reliability	Renewable Resource Use	Porous Material	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
23	M-Wood	Conifer is crushed to powder and then resin is added to create "wood-like" building materials with greater strength and durability	Wood	Strength	Durability	Composite Materials	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009



#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
24	Induction Heat Variable Pressure Boiling Rice Cooker	Rice cooker increases and decreases pressure from 1 to 1.2 atm which stirs the rice and allows heat to be evenly applied.	Constant pressure rice cooker	Temperature	Energy Intensity	Transformation of Properties	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
25	Induction Heat Variable Pressure Boiling Rice Cooker	The Induction heat source reduces energy use and allows the unit to heat quicker.	Rice cooker utilizing electric resistance heating	Loss of Time	Energy Intensity	Replacement of Mechanical System	<a href="http://www.triz-journal.com/archives/2003/08/a/01.pdf">http://www.triz-journal.com/archives/2003/08/a/01.pdf</a> Accessed May 18th, 2009
26	Wind Up Radio	Radio powered by a hand crank	Battery Operated Radio	Reliability	Dispersion of Toxic Materials	Prior Action	<a href="http://www.nigelsecostore.com/acatalog/Wind_Up_Radios.html">http://www.nigelsecostore.com/acatalog/Wind_Up_Radios.html</a> Accessed May 18th, 2009
27	Staple Free Stapler	This innovative and very cool Staple Free Stapler cuts out tiny strips of paper and uses the strips to stitch up to 5 pieces of paper together.	Standard Stapler with Metal Staples	Reliability	Material Intensity	Universality	<a href="http://www.greenhome.com/products/office/office_supplies/107970/">http://www.greenhome.com/products/office/office_supplies/107970/</a> Accessed May 18th, 2009
28	Solar Vent	Solar powered vent that maintains comfortable interior conditions	Battery powered fan	Extent of Automation	Dispersion of Toxic Materials	Periodic Action	<a href="http://store.sundancesolar.com/ststsove.html">http://store.sundancesolar.com/ststsove.html</a> Accessed May 18th, 2009
29	Intellipanel - Power Strip with Stand-by Power Reduction	Plug your computer (or TV) into the main socket and when you turn it off, the peripherals will turn off as well	Regular Power Strip	Extent of Automation	Energy Intensity	Feedback	<a href="http://www.nigelsecostore.com/acatalog/One_Click_Power-panel.html">http://www.nigelsecostore.com/acatalog/One_Click_Power-panel.html</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
30	Battery Wizard	The Battery Wizard uses a patented pulse charging system to refresh and recharge most batteries.	Throw away alkaline batteries after use	Loss of substance	Durability	Periodic Action	<a href="http://www.nigelsecostore.com/acatalog/Battery_Wizard.html">http://www.nigelsecostore.com/acatalog/Battery_Wizard.html</a> Accessed May 18th, 2009
31	Eco Toaster	This new eco-lectric toaster uses 34% less energy than other toasters, thanks to its rather clever auto-close lid that keeps the heat around the toast and prevents it escaping through the top.	Toaster with opening in top	Loss of time	Energy Intensity	Dynamicity	<a href="http://www.nigelsecostore.com/acatalog/Eco_Toaster2.html">http://www.nigelsecostore.com/acatalog/Eco_Toaster2.html</a> Accessed May 18th, 2009
32	Energy Saving Gas Net	The special catalytic alloy disc fits neatly over one burner converting all the unburnt gas to heat and energy.	Using gas burner by itself	Loss of time	Energy Intensity	Mediator	<a href="http://www.nigelsecostore.com/acatalog/Gas_Energy_Saver.html">http://www.nigelsecostore.com/acatalog/Gas_Energy_Saver.html</a> Accessed May 18th, 2009
33	Radiator Booster	Uses a small fan to capture the heat that comes out the back of your radiator, circulating it better into your room.	Radiator by itself	Productivity	Energy Intensity	Self-Service	<a href="http://www.nigelsecostore.com/acatalog/Radiator_Booster.html">http://www.nigelsecostore.com/acatalog/Radiator_Booster.html</a> Accessed May 18th, 2009
34	Radiator Booster	In-built automatic thermostat - the fan only operates when the radiator reaches 32 degrees Celsius, eliminating the need to turn the unit on and off manually, making it very energy efficient.	Manually turning fan on and off	Extent of Automation	Energy Intensity	Feedback	<a href="http://www.nigelsecostore.com/acatalog/Radiator_Booster.html">http://www.nigelsecostore.com/acatalog/Radiator_Booster.html</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
35	Eco Kettle	The innovative Eco Kettle has a unique double chamber that gets you to measure out exactly how much water you want to boil	Heating full kettle	Loss of Time	Energy Intensity	Dynamicity	<a href="http://www.nigelsecostore.com/acatalog/Eco_Kettle3.html">http://www.nigelsecostore.com/acatalog/Eco_Kettle3.html</a> Accessed May 18th, 2009
36	Shower Coach Shower Timer	The Shower Coach shower timer times exactly 5 minutes, showing you when it's time to turn the shower off.	Showering without monitoring time	Difficulty of detecting and measuring	Renewable Resource Use	Feedback	<a href="http://www.nigelsecostore.com/acatalog/Show er_Coach.html#aSHWRCOACH01">http://www.nigelsecostore.com/acatalog/Show er_Coach.html#aSHWRCOACH01</a> Accessed May 18th, 2009
37	Moon Cup	The Mooncup is a unique reusable feminine hygiene product that is bell shaped, around two inches long and made from soft silicone rubber. Need to empty your Mooncup less frequently than you currently replace towels or tampons.	Tampons or pads	Loss of time	Durability	Transformation of Properties	<a href="http://www.nigelsecostore.com/acatalog/mooncup.html">http://www.nigelsecostore.com/acatalog/mooncup.html</a> Accessed May 18th, 2009
38	Efergy Elite Wireless Smart Meter	Efergy Elite enables you to monitor and calculate the cost of running your home or office lights and appliances, to help you work out your energy costs, so you can reduce them, and cut your carbon footprint.	Using power without monitoring energy use	Difficulty of detecting and measuring	Energy Intensity	Feedback	<a href="http://www.nigelsecostore.com/acatalog/Efergy_Elite.html#aEFERY_2dEF_2d05">http://www.nigelsecostore.com/acatalog/Efergy_Elite.html#aEFERY_2dEF_2d05</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
39	Sloan Valve Company Uppercut(TM) Flushometer	Lifting handle up initiates reduced flush (1.1 gpf), eliminating liquid and paper waste, saving a 1/2-gallon of water. Pushing handle down initiates full flush (1.6 gpf), eliminating solid waste and paper.	Handle flushed same amount up and down	Adaptability or Versatility	Renewable Resource Use	Local Quality	<a href="http://www.mbdc.com/c2c/itemDetails.php?item=156">http://www.mbdc.com/c2c/itemDetails.php?item=156</a> Accessed May 18th, 2009
40	Alcoa, Inc. Kawneer InLighten® Light Shelf	InLighten® Light Shelf is a series of standard design elements that are assembled to passively channel natural day lighting into an occupied space.	Windows with no light shelf and artificial lighting	Illumination Intensity (light quality)	Renewable Resource Use	Transition Into a New Dimension	<a href="http://www.mbdc.com/c2c/itemDetails.php?item=245">http://www.mbdc.com/c2c/itemDetails.php?item=245</a> Accessed May 18th, 2009
41	Moonlight - low energy night light	The Moonlight is a low energy night light (LED) that fits into a normal wall socket and uses NASA space-age technology, developed to illuminate cockpit panels, to give a restful, soft blue/green light, making rooms feel safer at night. The electro-luminescent bulb-free panel is cool to touch.	Nightlight with incandescent bulb	Illumination Intensity (light quality)	Energy Intensity	Extraction (blue/green light but not heat)	<a href="http://www.nigelsecostore.com/acatalog/Moonlight-lo-energy-nightlight.html">http://www.nigelsecostore.com/acatalog/Moonlight-lo-energy-nightlight.html</a> Accessed May 18th, 2009
42	Digital Camera	Allows users to see if a picture is good before developing (if they decide to develop)	Film Camera	Loss of information (bad photos)	Material Intensity	Copying	<a href="http://www.mnn.com/technology/research-innovations/stories/top-ten-eco-innovations-for-a-better-planet?page=1">http://www.mnn.com/technology/research-innovations/stories/top-ten-eco-innovations-for-a-better-planet?page=1</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
43	USB rechargeable batteries	AA batteries with built in USB rechargeable port	Standard Rechargeable Batteries	Adaptability/Versatility	Product Durability	Nesting	<a href="http://www.usbcell.com/">http://www.usbcell.com/</a> Accessed May 18th, 2009
44	Solar Breeze Pool Cleaner	The Solar Breeze is a pool skimmer with two solar panels on its top, allowing the skimmer to run off 100% free energy. It even stores extra energy in its onboard batteries, allowing it to run at night or on a cloudy day.	Using only Pool Pump to clean pool	Extent of Automation	Renewable Resource Use	Continuity of Useful Action	<a href="http://ecogadget.net/2007/12/24/the-solar-breeze-robot-vacuum-for-your-pool/">http://ecogadget.net/2007/12/24/the-solar-breeze-robot-vacuum-for-your-pool/</a> Accessed May 18th, 2009
45	Hg Ionic Toothbrush	Uses ionic power to clean teeth without toothpaste. Temporarily reverses tooth polarity from negative to positive to reject the positive plaque. 60% of hyG users said that their teeth felt cleaner, smoother and more polished.	Regular toothbrush that uses bristle friction	Extent of Automation	Dispersion of Toxic Materials	Replacement of Mechanical System	<a href="http://www.nigelsecostore.com/acatalog/Ionic_Toothbrush.html">http://www.nigelsecostore.com/acatalog/Ionic_Toothbrush.html</a> Accessed May 18th, 2009
46	Bamboo Socks	Not only are they super soft and breathable, but these socks, made from bamboo, are naturally antibacterial, so they just don't smell.	Cotton Socks	Object Generated Harmful Factors (Smell)	Renewable Resource Use	Self-Service	<a href="http://www.nigelsecostore.com/acatalog/Bamboo_Sock-s.html">http://www.nigelsecostore.com/acatalog/Bamboo_Sock-s.html</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
47	Heatkeeper Radiator Panels	Without them, some of the heat from a radiator is wasted on heating the wall behind it. This heat seeps through the wall and goes outside. When you fit the panels, the wall behind the radiator is insulated and the heat from the back of the radiator is directed back into the room.	Radiator by itself	Productivity	Energy Intensity	Prior Counteraction	<a href="http://www.nigelsecostore.com/acatalog/Radiator_Panels.html#aHEATKEEP">http://www.nigelsecostore.com/acatalog/Radiator_Panels.html#aHEATKEEP</a> Accessed May 18th, 2009
48	Dryer Balls	Reduce drying time by separating clothing during tumbling	No Dryer Balls	Loss of Time	Energy Intensity	Dynamicity	<a href="http://www.nigelsecostore.com/acatalog/dryer-balls.html#aDRYERBALLS01">http://www.nigelsecostore.com/acatalog/dryer-balls.html#aDRYERBALLS01</a> Accessed May 18th, 2009
49	Briquette Maker	Make use of old newspapers with this natural and very effective alternative to burning charcoal, coal or wood. The Briquette Maker compresses your old newspapers into solid, high-energy briquettes, ideal for lighting fires, BBQ's, stoves etc.	Buying or using Charcoal, coal or wood	Loss of substance (paper would be discarded)	Renewable Resource Use	Convert Harm into Benefit	<a href="http://www.nigelsecostore.com/acatalog/Briquette_Maker.html">http://www.nigelsecostore.com/acatalog/Briquette_Maker.html</a> Accessed May 18th, 2009

#	Product	Product Description	Previous Generation	Improving Functionality Feature	Environmental Parameter	TRIZ Principle	Reference
50	Sharpie Twin Tip Pen	Pen that has a tip on each end for different styles of writing with 1 pen (e.g. fine and ultra fine)	2 Sharpies with one tip each	Adaptability/Versatility	Material Intensity	Universality	<a href="http://www.sharpie.com/enUS/Product/Sharpie_Twin_Tip_Permanent_Marker.html">http://www.sharpie.com/enUS/Product/Sharpie_Twin_Tip_Permanent_Marker.html</a> Accessed June 28th, 2009, saw television commercial

*Appendix F: Resolving Conflicts between Product Functionality and  
Environmental Impact Study*

**Overview:** Research on ideation suggests that designers who consider cueing examples after determining some initial problem solving parameters may improve the quantity and quality of the concepts that they generate. This exercise will consist of solving the problem below using three sets of cueing examples in order to determine which cueing examples provide the best conceptual designs.

**Problem:** You work as a project engineer for GE's oven division. Market research has shown that consumers are dissatisfied with the amount of time they have to wait when preheating current oven models. Furthermore, one of GE's overall corporate goals is to reduce the amount of energy used by its products. Your job is to develop a conceptual design for the oven that accomplishes both goals. The design you are trying to improve is a standard free-standing electric oven like the one shown below. Your focus should be on improving the oven portion of the unit (not the top burners) and assume that this model already has features common to today's oven designs (e.g. a convection fan).



**Instructions:** Complete the following tasks starting on the next page in order. Do not skip ahead and read the cueing examples for the future tasks because it could influence your thinking on the current task you are working on. Also, do not go back and modify your rating for each task based on your experience with the following tasks. Each task should take you about 20 minutes to complete. It is okay if the cueing examples in different tasks happen to lead you to the same conceptual design. When you are finished completing the tasks, please answer the follow-up and background questions. If you need more room for your description or sketch, you can use the back of the paper. Please use pen for all responses and sketches because your results will be scanned into digital form.



**Task 1** - Solve the problem using one of the five principles provided below. Provide a written description of the conceptual design solution and explain which principle helped inspire the solution and how. Also, provide a sketch of the solution.

<b>Principle</b>	<b>Definition</b>
Segmentation	Divide an object into independent parts
	Make an object sectional
	Increase the degree of an object's segmentation
Consolidation	Consolidate in space homogeneous objects or objects destined for contiguous operations
	Consolidate in time homogeneous or contiguous operations
Prior Action	Perform required changes to an object completely or partially in advance
	Place objects in advance so that they can go into action immediately from the most convenient location
Mechanical Vibration	Utilize oscillation
	If oscillation exists, increase its frequency to ultrasonic
	Use the frequency of resonance
	Replace mechanical vibrations with piezo-vibrations
Changing the Color	Use ultrasonic vibrations in conjunction with an electromagnetic field
	Change the color of an object or its environment
	Change the degree of translucency of an object or its environment
	Use color additives to observe an object or process which is difficult to see
	If such additives are already used, employ luminescent traces or trace atoms

Description:

Sketch:

On a scale of 1-10 (10 being the best), how helpful were the cueing examples? \_\_\_\_\_

**STOP – Do not proceed to the next page until this task is completed**

**Task 2:** Solve the problem using one of the four principles provided below. Provide a written description of the conceptual design solution and explain which principle helped inspire the solution and how. Also, provide a sketch of the solution.

Principle	Definition
Dynamicity	Characteristics of an object, or outside environment, must be altered to provide optimal performance at each stage of an operation
	If an object is immobile, make it mobile. Make it interchangeable
	Divide an object into elements capable of changing their position relative to each other
Periodic Action	Replace a continuous action with a periodic one (impulse)
	If the action is already periodic, change its frequency
	Use pauses between impulses to provide additional action
Mediator	Use an intermediary object to transfer or carry-out an action
	Temporarily connect the original object to one that is easily removed
Replacement of Mechanical System	Replace a mechanical system with an optical, acoustical, thermal or olfactory system
	Use an electric, magnetic or electromagnetic field to interact with an object
	Replace fields that are stationary with mobile, fixed with changing in time and random with structured
	Use fields in conjunctions with ferromagnetic particles

Description:

Sketch:

On a scale of 1-10 (10 being the best), how helpful were the cueing examples? \_\_\_\_\_

**STOP – Do not proceed to the next page until this task is completed**

**Task 3:** Solve the problem by applying a design technique utilized by one of the products described below. Visuals of these products are provided on the next page. Provide a written description of the conceptual design solution and explain which product helped inspire the solution and how. Also, provide a sketch of the solution.

<b>Product</b>	<b>Product Description</b>
Induction Heat Rice Cooker	Induction heating reduces energy use and allows the unit to heat quicker compared to conductive heating.
Eco Toaster	This toaster uses 34% less energy than other toasters, thanks to its rather clever auto-close lid that keeps the heat around the toast and prevents it escaping through the top.
Energy Saving Gas Net	The special catalytic alloy disc fits neatly over one burner converting all the unburnt gas to heat and energy.
Eco Kettle	The innovative Eco Kettle has a unique double chamber that gets you to measure out exactly how much water you want to boil.
Ice making machine, method and evaporator assemblies	Ice is formed on an electrically conductive and thermally conductive layer and during the harvest mode an electrical pulse is applied to the electrically conductive and thermally conductive layer to melt an interfacial layer of the ice such that it is freed from the layer. The prior art would reverse the cooling system and pump heat through the cooling line to harvest the ice. The new design speeds up the ice making process and reduces the energy that was required to constantly switch between heating and cooling.

Description:

Sketch:

On a scale of 1-10 (10 being the best), how helpful were the cueing examples? \_\_\_\_\_



Induction Rice Cooker



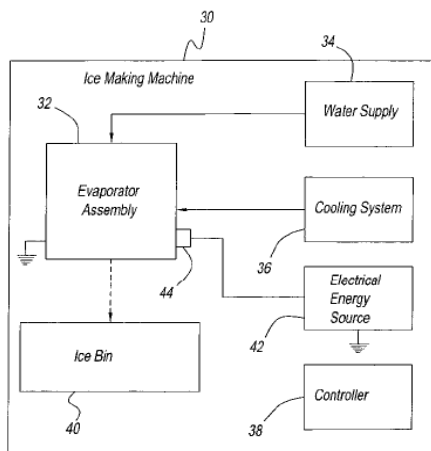
Eco-Toaster



Energy Saving Gas Net



Eco-Kettle



Ice Making Machine

### Follow-Up Questions

- 1.) Which of the three conceptual designs do you believe is the best solution to this problem? Why?
  
- 2.) Do you feel that it was easier to develop solution using engineering principles (Tasks #1 and #2) or reviewing specific product examples (Task #3)? Why?
  
- 3.) Rank the three tasks (1-3, 1 being the best) with respect to how helpful you thought the principles or product examples were in developing a good solution.
  - a. Task #1 \_\_\_\_\_
  - b. Task #2 \_\_\_\_\_
  - c. Task #3 \_\_\_\_\_
  
- 4.) Do you believe that the conceptual designs developed in the earlier tasks affected your design on the later tasks? Please explain.
  
- 5.) If you came up with the same conceptual design more than once, please explain the similarities between the cueing examples that caused you to come up with the same design.
  
- 6.) Do you think you could've come up with a better design if you didn't have to use the cueing examples provided?

## Background Information

- 1.) Are you Male or Female? \_\_\_\_\_
- 2.) What is your age? \_\_\_\_\_
- 3.) What is the highest level of education you have completed?
  - a. High School/GED \_\_\_\_\_
  - b. Associates Degree \_\_\_\_\_
  - c. Bachelors Degree \_\_\_\_\_
  - d. Masters Degree \_\_\_\_\_
  - e. Doctorate Degree \_\_\_\_\_
  - f. Professional Degree (MD, JD) \_\_\_\_\_

Please indicate the specific field(s) of study for the degree(s) selected above.

- 4.) Are you currently pursuing a degree? \_\_\_\_\_

If so, please indicate the degree being pursued below along with the anticipated completion date and the specific field of study.

- 5.) How many years of engineering experience do you have (include only jobs/internships, do not include years of schooling) and what percentage of your time was spent on design?
  - a. Number of years \_\_\_\_\_
  - b. Percentage of Time spent on design \_\_\_\_\_

- 6.) Briefly describe your employment experience in engineering design (if applicable)?

Have you ever heard of TRIZ? If so, please explain you experience with TRIZ.

**PROFESSIONAL CONSENT FORM**

<b>Project Title</b>	<b>RESOLVING CONFLICTS BETWEEN PRODUCT FUNCTIONALITY AND ENVIRONMENTAL IMPACT</b>	
<b>Why is this research being done?</b>	<i>This is a research project being conducted by Dr. Linda Schmidt, Dr. Jeffrey Herrmann and Daniel Fitzgerald at the University of Maryland, College Park. We are inviting you to participate in this research project because you are an engineering professional. The purpose of this research project is to investigate the usefulness of a new conceptual design tool.</i>	
<b>What will I be asked to do?</b>	<i>The procedure involves completing a given design problem using different methods.</i>	
<b>What about confidentiality?</b>	<i>We will do our best to keep your personal information confidential. To help protect your confidentiality, the completed assignments will be stored in a secure location. In reporting results of this study, the data will be grouped together and your identity will be protected to the maximum extent possible. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law.</i>	
<b>What are the risks of this research?</b>	<i>There are no known risks associated with participating in this research project.</i>	
<b>What are the benefits of this research?</b>	<i>This research is exposing you to a new design methodology that is in its formative stages. Study results will be used to judge the effectiveness of the design methodology.</i>	
<b>Do I have to be in this research? May I stop participating at any time?</b>	<i>Your participation in this research is completely voluntary and you may stop participating at any time.</i>	
<b>What if I have questions?</b>	<p><i>This research is being conducted by Dr. Linda Schmidt, Dr. Jeffrey Herrmann and Daniel Fitzgerald at the University of Maryland, College Park. If you have any questions about the research study itself, please contact Dr. Linda Schmidt at: The University of Maryland, 2181 Glenn L. Martin Hall, Room 0162, 301-405-0417 or <a href="mailto:lschmidt@umd.edu">lschmidt@umd.edu</a>.</i></p> <p><i>If you have questions about your rights as a research subject or wish to report a research-related injury, please contact: <b>Institutional Review Board Office, University of Maryland, College Park, Maryland, 20742; (e-mail) <a href="mailto:irb@umd.edu">irb@umd.edu</a>; (telephone) 301-405-0678</b></i></p> <p><i>This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.</i></p>	
<b>Statement of Age of Subject and Consent</b>	<p><i>Your signature indicates that:</i></p> <p><i>you are at least 18 years of age,;</i></p> <p><i>the research has been explained to you;</i></p> <p><i>your questions have been answered;</i></p> <p><i>you freely and voluntarily choose to participate in this research project; and</i></p> <p><i>you give permission to use your sketches and comments in publications without attribution.</i></p>	
<b>Signature and Date</b>	<b>NAME OF SUBJECT</b>	
	<b>SIGNATURE OF SUBJECT</b>	
	<b>DATE</b>	



**STUDENT CONSENT FORM**

<b>Project Title</b>	<b>RESOLVING CONFLICTS BETWEEN PRODUCT FUNCTIONALITY AND ENVIRONMENTAL IMPACT</b>	
<b>Why is this research being done?</b>	<i>This is a research project being conducted by Dr. Linda Schmidt, Dr. Jeffrey Herrmann and Daniel Fitzgerald at the University of Maryland, College Park. We are inviting you to participate in this research project because you are currently enrolled in ENME600/ENRE 648E: Engineering Design Methods or ENME472. The purpose of this research project is to investigate the usefulness of a new conceptual design tool.</i>	
<b>What will I be asked to do?</b>	<i>The procedure involves completing a given design problem using different methods.</i>	
<b>What about confidentiality?</b>	<i>We will do our best to keep your personal information confidential. To help protect your confidentiality, the completed assignments will be stored in a secure location. In reporting results of this study, the data will be grouped together and your identity will be protected to the maximum extent possible. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law.</i>	
<b>What are the risks of this research?</b>	<i>There are no known risks associated with participating in this research project.</i>	
<b>What are the benefits of this research?</b>	<i>This research is exposing you to a new design methodology that is in its formative stages. Study results will be used to judge the effectiveness of the design methodology.</i>	
<b>Do I have to be in this research? May I stop participating at any time?</b>	<i><u>Your participation in this research is completely voluntary, not a course requirement.</u> If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify. If you choose not to participate in the study you will be required to complete the same homework assignment but your results will not be used in the research study.</i>	
<b>What if I have questions?</b>	<i>This research is being conducted by Dr. Linda Schmidt, Dr. Jeffrey Herrmann and Daniel Fitzgerald at the University of Maryland, College Park. If you have any questions about the research study itself, please contact Dr. Linda Schmidt at: The University of Maryland, 2181 Glenn L. Martin Hall, Room 0162, 301-405-0417 or <a href="mailto:lschmidt@umd.edu">lschmidt@umd.edu</a>. <i>If you have questions about your rights as a research subject or wish to report a research-related injury, please contact: <b>Institutional Review Board Office, University of Maryland, College Park, Maryland, 20742; (e-mail) <a href="mailto:irb@umd.edu">irb@umd.edu</a>; (telephone) 301-405-0678</b></i> <i>This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.</i></i>	
<b>Statement of Age of Subject and Consent</b>	<i>Your signature indicates that: you are at least 18 years of age; the research has been explained to you; your questions have been answered; you freely and voluntarily choose to participate in this research project; and you give permission to use your sketches and comments in publications without attribution.</i>	
<b>Signature and Date</b>	<b>NAME OF SUBJECT</b>	
	<b>SIGNATURE OF SUBJECT</b>	
	<b>DATE</b>	

IRB APPROVED  
EXPIRES ON  
**NOV 08 2013**  
UNIVERSITY OF MARYLAND  
COLLEGE PARK



*Appendix G: Detailed Results of Study*

**Background Information**

Participant Number	Gender	Age	Highest Degree	Which Degree	Enrolled?	Degree Being Pursued	Years of Experience	% Time Designing	Employment Experience	TRIZ Experience
1	Male	23	Bachelors	Mechanical Engineering	Yes	Master of Science Mechanical Engineering (expected May 2011)	2	5	Developing test fixtures to test non-standard materials on an existing machine.	Only experience is ENME600
2	Female	22	Bachelors	Mechanical Engineering	Yes	Master of Science Mechanical Engineering (expected May 2010)	0	0	N/A	Yes, one lesson in class with homework assigned - some practice w/application of method from homework
3	Female	28	Bachelors	Naval Architecture, Mechanical Engineering	Yes	Master of Science Fluid Mechanics (Expected May 2010)	<1 year	10	2 months yacht design firm, 2 months Navy Research Center	Yes, my experiences with TRIZ have all been associated with the UMD class ENME600
4	Male	25	Bachelors	Mechanical Engineering	Yes	Master of Science Mechanical Engineering (Expected Summer 2012)	5	50	Flight test aero structures engineer designing and analyzing modifications for electronic test aircraft	Yes, never used in my job, just in classroom exercises
5	Male	22	Bachelors	Mechanical Engineering	Yes	Master of Science Mechanical Engineering (Expected 2012)	1	30	Design came into play when considering the method of resolution for the problem. The design process could best be described as educated guessing.	Yes, I worked out a 2 hour example for ENME600
6	Male	25	Bachelors	Mechanical Engineering	Yes	Master of Science Mechanical Engineering (Expected 2011)	0	0	N/A	Yes, In ENME600
7	Male	28	Bachelors	Mechanical Engineering	Yes	Engineering Management (Expected 2011)	1	95	Designing heavy machinery and gas turbine flexible disc/diaphragm couplings	Yes, only used TRIZ in engineering design demos

Participant Number	Gender	Age	Highest Degree	Which Degree	Enrolled?	Degree Being Pursued	Years of Experience	% Time Designing	Employment Experience	TRIZ Experience
8	Female	23	Bachelors	Electrical Engineer	Yes	Master of Science Systems Engineering (Expected 2012)	0 (put 5 but misread question)	0	None	Only in class
9	Male	27	Bachelors	Applied Physics	Yes	Master of Science, Systems Engineering (expected 2012)	0	0	None	Learned about TRIZ in ENME600. Used it in a HW assignment. I thought it was interesting but at times forced me away from ideas that I had in order to try and fit the method
10	Male	34	Masters	Nuclear Engineering	Yes	PhD, Mechanical Engineering, Fall 2011 or Spring 2012	0	0	None	Yes, in ENME600. I am a novice user: only recently introduced to it.
11	Male	26	Masters	Mechanical Engineering	Yes	PhD, Mechanical Engineering, Spring 2012	1	0	None	Yes, I appreciate the homework but it puts limits on my ideas
12	Male	28	Masters	Computer Science, Systems Security	Yes	PhD, Reliability Engineering	2	10	I used software engineering design methods to model software before development.	Yes, in ENME600 class
13	Male	26	Bachelors	Computer Science, Japanese Language	Yes	Masters, Mechanical Engineering May 2013	1.5	30	I designed software for web applications. Much of the time was spent designing my data structures, databases, and user interfaces.	Yes, Dr. Schmidt showed it to me. It's pretty nifty although I think the engineering principles could be considered without the need for a contradiction matrix
14	Male	34	Bachelors, MBA	Mechanical Engineering	Yes	Mechanical Engineering	10	0	None	Yes, my only experience has been in class
15	Female	27	Bachelors	Bio Engineering	Yes	Masters, Mechanical Engineering Fall 2012	0	0	N/A - have been a chemist and a biologist since graduating. Am currently trying to break into engineering design field with this degree	Yes, ENME600 coursework.
16	Male	54	Bachelors	Chemistry, Electrical Engineering	No	N/A	22	7	Power electronics and digital controls in UPS's, power supplies, chargers. Also some 8 bit systems design.	Yes, through Dan Fitzgerald and Internet

Participant Number	Gender	Age	Highest Degree	Which Degree	Enrolled?	Degree Being Pursued	Years of Experience	% Time Designing	Employment Experience	TRIZ Experience
17	Male	37	Associates	Electronics	Yes	Electrical Engineering	0	0	N/A	No
18	Male	38	Bachelors	Electrical Engineering	No	N/A	7	60%	You always come across a problem that you have never seen before. It is a rewarding experience to find a solution to that problem.	No
19	Male	35	Masters	International Economics	No	N/A	0	0	N/A	No, I have not heard of TRIZ
20	Female	33	Bachelors	Environmental Engineering	No	N/A	4	20%	Designing wastewater treatment plants. Improving the hydraulics of a UV-disinfection system	No
21	Male	61	Ph.D.	Business and Management, MS in Engineering	No	N/A	22	30%	Materials Design, Engineering Analysis	Yes but no real world experience using TRIZ
22	Male	29	Masters	Electrical and Computer Engineering	No	N/A	7	20%	Mostly focused on electrical systems for robotics: i.e. power distribution and computer systems	Have not
23	Male	53	Bachelors	Chemical Engineering	No	N/A	31	15%	Designing, developing and testing reformers to convert various fuels to hydrogen	Heard of it; no experience with it
24	Male	58	Bachelors	Mechanical Engineering	No	N/A	36	80%	Designed custom large equipment. Also, designed high volume throwaway products. Vast majority design of power tools.	Yes. Had one session learning and applying TRIZ
25	Male	49	Masters	Mechanical Engineering	No	N/A	23	75%	Various internships with GM in product design and manufacturing. Process control for major US paper company. Design, product development, project engineering, technical manager @ B&D.	Yes, no experience

Participant Number	Gender	Age	Highest Degree	Which Degree	Enrolled?	Degree Being Pursued	Years of Experience	% Time Designing	Employment Experience	TRIZ Experience
26	Female	36	Masters	MBA, Engineering	No	N/A	13	50%	Design and develop power tools. Design phase is about half of the cycle. Rest is implementing in production and changing design to fix test issues.	No
27	Male	59	Doctorate	BS - Forestry/Wood Science MS - Wood Science MS - Civil Engineering/Structures PHD - Forest Products	No	N/A	25	0	N/A	No
28	Male	36	Bachelors	Civil Engineering	No	N/A	10	20%	Structural design of commercial and residential buildings	No
29	Male	30	Masters	Mechanical Engineering - Materials Option	No	N/A	3	20%	Consumer Product Development	Yes, I've heard of it but have no experience using/applying it.
30	Male	49	Bachelors	Mechanical Engineering	No	N/A	21	100%	Power tool and lawn and garden product design and development	No
31	Male	38	Bachelors	Metallurgical Engineering	No	N/A	15	75%	In reality it is design support in helping the design engineers problem solve to improve designs. Primarily in power tools, but also in high temperature pressure vessels.	No
32	Male	26	Bachelors	Electrical Engineering	Yes	Engineering Management	5	70%	Design and get to production PMDC Motors, power tool switch assemblies, wire harnesses, LED assemblies and other related electrical components for DeWalt cordless power tools	No

Participant Number	Gender	Age	Highest Degree	Which Degree	Enrolled?	Degree Being Pursued	Years of Experience	% Time Designing	Employment Experience	TRIZ Experience
33	Male	35	Masters	BS- Mechanical, MS - Mfg. Systems Eng.	Yes	Ph.D. Automotive Engineering	11	35%	Cordless nailer design and process development	No
34	Male	27	Bachelors	Mechanical Engineering	No	N/A	3.5	70%	Worked in accessory power tool design for 1 year and innovation design for 2.5 years.	No

**Conceptual Design Details**

<b>Participant Number</b>	<b>Design #1 Description</b>	<b>Cue Used for Design #1</b>	<b>Design #2 Description</b>	<b>Cue Used for Design #2</b>	<b>Design #3 Description</b>	<b>Cue Used for Design #3</b>
1	Assuming that the oven only has a heating element in one location (top or bottom), an oven rack could be designed such that it seals off unused portions of the oven. Most items cooked do not take up the full space and a smaller space would both preheat faster and use less energy. The rack could be moved to different positions so that larger items could still be accommodated.	Segmentation	Additional heating elements could be added and only used during the preheating cycle. This should not drastically increase energy use since there are more heating elements running, but it should take significantly less time to preheat.	None given, Assuming Dynamicity or Mediator	The Eco Kettle product description leads me to basically the same solution as in Task 1. Like the kettle selecting exactly how much water needed to boil, the oven user would select exactly how much space they need to heat. For example, you do not need to heat an entire 2 ft. tall oven chamber for baking cookies that take up maybe 3-4 inches of that space at most. Unlike the other design, this one will have the heating element height adjustable.	Eco Kettle
2	Reduce the size of the viewing window and cover it with a translucent insulating coating; add a layer of insulating material around the entire inside of the oven	Changing the color	Install removable heating rods throughout the oven to better disperse the heat throughout the oven in faster time. (Removable is necessary so larger pots/pans/turkeys/hams etc. can still fit in oven. 1.) Speeds heating time. 2.) Better distribution of heat reduces losses as air moves = more efficient object	Dynamicity and Mediator	Build a chamber inside the oven that can adjust in size based on the size of the object in the oven. 1.) Incremental side inserts for top, left, and right sides. 2.) Adjustable rack inserts. 3.) Moveable heat coils with height adjustors to create bottom side	Eco Kettle
3	Utilize a volume of insulated air that is kept at some high temperature and is directed into the oven when the user begins to preheat. Could be very well insulated so it wouldn't require much energy to maintain high temperature in this reservoir	Prior Action	Using the first definition of dynamicity, one option could be simply to alter the insulation of the existing oven. Improving this feature would reduce heat loss to the outside-oven environment and likely increase preheat speed	Dynamicity	Make the oven's heated volume adjustable. By decreasing the volume of air that must be heated to the minimum required for a given task, you could reduce the total energy used and probably decrease the preheat time.	Eco Kettle
4	Redistribute the heating elements from the bottom of the oven to the top, bottom and right. These elements can be smaller than the original to conserve power while more effectively distributing heat. Combine this with a reflective substance coating that will help reflect and radiate the heat in the oven.	Segmentation	Make the heating element move on a track around the oven. Allows heat to be evenly distributed inside the oven. Make element flexible so it can go around the corners in the oven.	Dynamicity	Increase the insulation around the oven, especially in the area of the door to prevent heat loss and improve overall efficiency.	Eco Toaster
5	Introduce a sliding vertical heating element to increase the amount of heating pieces in the oven. The presence of more heating is beneficial to the preheat speed.	Segmentation	Place heating elements inside the oven rack itself or on the oven rack. This shortens the required distance for the heat to travel. These can be tied in with the main elements as a sort of intermediary.	Mediator	Employ a more easily sealed and insulated oven chamber. The lack of external heat loss in the system will allow the chamber to reach the target value faster and maintain the target value more effectively.	Eco Toaster

Participant Number	Design #1 Description	Cue Used for Design #1	Design #2 Description	Cue Used for Design #2	Design #3 Description	Cue Used for Design #3
6	a.) Divide the main heating coil into many ones that distributes averagely in the oven, which may help heat the oven quickly and uniformly b.) Make the oven insulated as possible to prevent the heat to dissipate during and after use. The heat preserved may help the next use. c.) Make a hybrid oven by adding a microwave heating part into traditional oven. The microwave portion can efficiently and quickly heat water to steam which can be utilized to heat the oven as an aid.	a.) Segmentation b.) Prior Action c.) Mechanical Vibration	Alter the shape of the oven chamber and the position of heating coils to optimize the heating efficiency	Dynamicity	Induction heating method should be introduced into the design of a traditional oven to replace its conventional conductive heating method. Since it works for rice cooker, it works for ovens	Rice Cooker
7	This design involves changing the 2 (upper and lower) heating elements into 8 (4 upper and lower) and the provision of reflective plates that segment/partition off part of the oven for smaller objects to be cooked. This reduces the energy used as the space to be heated is smaller, the time required to heat the space is reduced. Burners can be individually switched on for partitioned spaces or can all be turned on for conventional use. Reflective partitions can be inserted to make heated space smaller (for smaller portions) or can be removed to transform space into a large conventional oven.	Segmentation	This design involves heating elements in the sides of the oven as well that reduce the time required to heat it. Once at operating temperature, the side heating elements switch off and the conventional heating elements do their job. Although not really an intermediary object, they are having the responsibility for heating the space shared with them. I think of a mediator as sharing the responsibility for figuring out a problem between 2 parties.	Mediator	This design involves an enclosed chamber inside the oven that is open only to the heating elements. This small space heats faster and use less energy as a result. The Eco toaster inspired this design as it led me to think about a design that would keep the heat around the food and not let it escape to heat unnecessary space.	Eco Toaster
8	This is a typical conventional oven however, in order to increase the amount of time to preheat and further conserve energy, an individual will light the holders located at the bottom of the oven which will bring the oven to its designated temperature quickly. In parallel, the metal will warm up to the designated temperatures as well, but not as quickly as the holders. Once the holders sense that the metal has reaches its temperature, the holders will autonomously turn off and the metal will control the heat of the oven.	Prior Action	This is a typical conventional oven, however, it operates as a microwave. Like a microwave, is able to quickly heat food, this oven is able to quickly preheat by utilizing the same method as the microwave. Once the oven reaches its preheated temperature, a constant heat wave is transferred back and forth to sustain the temperature of the oven.	Replacement of Mechanical System	This oven has a seal door which traps the heat exchange within the oven. The heat within the oven is induction heating similar to a rice cooker. The door is sealed and like a rice cooker, the oven is quickly preheated through induction heating.	Induction Heat Rice Cooker
9	Insert a removable barrier which can be used when cooking smaller items. The oven would heat a smaller area and still have the capability to cook large items	Segmentation	Have the heating element move to the center of the oven to heat in all directions.	Dynamicity	Use induction cooking with metal pans in oven...if that would even work.	Induction Heat Rice Cooker

Participant Number	Design #1 Description	Cue Used for Design #1	Design #2 Description	Cue Used for Design #2	Design #3 Description	Cue Used for Design #3
10	Make the oven compartment capable of being smaller based on the size of the food needed to be cooked. Cookies require short but long space. Turkey requires large space. Making the compartment smaller could reduce warm-up time and energy required to maintain temperature (under the proper engineering conditions: insulation, etc.)	Segmentation	If the oven is gas operated, use extra gas at the beginning. If electric, use extra coils. User could set oven to 350 degrees F and with proper systems the oven could detect that it is well below at start of heat up. Extra coils would be turned on without the operator even being aware and turn off when the temperature differential is smaller. When extra coils are off, main coil could still be on.	Periodic Action	Auto-doors that seal off glass window during heat-up. Latching mechanism that prevents user from opening during heat-up.	Eco Toaster
11	Divide the oven into 2 partitions by adding a plate with low thermal conductivity in the middle. Can use half of the oven when we do not need the whole space	None selected	Replace the rack in the middle of the oven by an electrical resistance that will heat the oven faster. Rack will be disconnected from power when door is open	None selected	Circulate a very small stream of air from the outside inside the oven in order to increase heating by convection as opposed to radiation.	None selected
12	The idea is to divide the object into independent parts and to modify each component in order to get the maximum energy conservation	Segmentation	Idea to use a halogen lamp to accelerate the pre-heating process	Mediator	Use the induction to quickly heat the oven and reduce energy use.	Induction Heat Rice Cooker
13	The new oven has a separate preheat coil which is only active during the preheat stage. Once preheating is complete, this coil turns off and a coil which heats more slowly and uses less energy kicks in.	Segmentation/Prior Action	The oven's size can be adjusted to decrease the volume when a larger chamber is unneeded, so the volume heats faster and consumes less energy.	Dynamicity	The Eco-Kettle calls to mind my solution for Task 2	Eco Kettle
14	Add side heating elements that turn on only during pre-heating.	Segmentation	Instead of just normal insulation, use a layer of heated water to help initially heat, maintain heat, and reduce electricity use.	Replacement of Mechanical System	The descriptions of the 3 tasks made me think about a baby bottle warmer, which is similar to the Eco-Kettle. Basically, a miniscule amount of water is poured into a chamber with an electric heat plate. The bottle is inserted in the chamber with the top sticking out and a small space is available for steam to escape. The water turns to steam and transfers heat to the bottle. Using this concept, I think the steam could be used to quickly heat the oven and keep energy use to a minimum.	Eco Kettle
15	Divide the larger oven space into 2 smaller spaces to allow less energy to be required to heat the oven up for common uses. Top Space - Larger to allow for larger items. Bottom Space - smaller, heats quickly for day to day tasks.	Segmentation	Use a system that disperses more heat in a periodic fashion	Periodic Action	Could use a modified version to cover the bottom of a gas oven and speed heating.	Energy Saving Gas Net



<b>Participant Number</b>	<b>Design #1 Description</b>	<b>Cue Used for Design #1</b>	<b>Design #2 Description</b>	<b>Cue Used for Design #2</b>	<b>Design #3 Description</b>	<b>Cue Used for Design #3</b>
16	In theory, the total amount of energy required to pre-heat the oven to a set temperature should remain the same regardless of the time it takes. Energy loss occurs due to high temperature gradients which might be reduced by adding smaller heating elements combined with high speed circulating fans to diffuse the heat faster. Heating elements could be designed with heat sinks to improve the transfer to air.	Segmentation	Preheat air in oven by using steam generated in a microwave chamber and blowing into the oven volume. The steam condenses and the water is drained off and reused. This brings the oven temp up to 200 degrees F. The remaining rise is provided convective heating elements (w/forced convection) acting in parallel.	Replacement of Mechanical System	Select oven volume that is needed for baking task. With conventional ovens there is little need for a large oven volume to maintain constant temperature. In most cases, most of the oven volume is wasted along with the energy consumed with heating the air. The solution is an oven with selectable volumes.	Eco Kettle
17	Develop quadrants within the oven that A.) can be individually activated by the user. B.) Have removable barriers allowing the user to select the amount and type of cooking space needed.	Segmentation	Add a secondary heating system that can be user activated to decrease preheating time. Suggest infrared secondary system.	Mediator	Design quadrants within the oven allowing the user to control the size of the cooking space needed by removing barriers and also allowing the customer to control the temperature of each individual quadrant as needed.	Eco Kettle
18	Since cost is not a factor, I would create a dual space oven. One door would be approximately 1/4 to 1/3 the size of the other door. This would allow quicker heating for smaller meals and use less energy to cook it. An example would be a pizza as opposed to a pot roast or turkey.	Segmentation	I modified the design by adding booster coils (since this is an electric oven) that heats the oven section up even quicker yet are switched off when the temperature is reached and then use smaller current pulling coils to cook the food. This reduces energy further.	Mediator	I used the induction heat rice cooker. This changed the design from dual coil design to high frequency preheating, which switches to lower frequency cooking. This also reduces cost of additional coils	Induction Heat Rice Cooker

Participant Number	Design #1 Description	Cue Used for Design #1	Design #2 Description	Cue Used for Design #2	Design #3 Description	Cue Used for Design #3
19	Faster heating could be achieved by having both the top and bottom burners activated during the heat up phase with the bottom burner maintaining temperature during maintenance phase. This is similar to a hybrid car using its gas engine to get up to speed and then the electric motor for maintenance. Another important addition would be improving the display to include a "Time to Desired Temperature" indicator. This would reduce the amount of time people give to heat up the oven and maximize its function by limiting the time it sits heated but empty.	Consolidation	Allow a separate bottom plate carrying the burner to be raised from the bottom of the oven (allowing enough space for a turkey or large dish) to a mid-level (allowing enough space for a lasagna pan, cake, etc.). To ensure that this didn't lead to a less efficient oven overall, it would require keeping the oven casing intact and having a separate insulated base plate which can move up and down within. This along with the dual burner approach to heating, insulation and 'Time to desired' feedback would be beneficial.	Dynamicity	a.) From the eco-kettle the concept of making it easier for people to be more efficient with their energy choices (e.g. only heating up as much water as they need). I would have the 'time to desired temperature' feature but also add a probe or mechanism to test the temperature of the food being cooked. This would need to be removable to be washed but could always be used to ensure accurate cooking of meats, dishes, cakes, etc. In theory, this would reduce the number of times the oven is opened and the contents checked. This would help to ensure that the energy they are using is being directed in a way that they want - similar to heating up only as much water as they want to use and not heating an empty oven or overcooking its contents. b.) From the induction cooker - comes a technological solution with the induction heating (I'm not very familiar with the technology so am not sure its appropriateness for general baking). However, the combination of either induction cooking or the dual burner heat up strategy (which came from the hybrid car model) may be a beneficial strategy to accelerate the time to desired temperature and reduce the amount of time users preheat their ovens. c.) From the eco-toaster - the ability to adjust the oven size and cut off some unused space to focus the heat on the product to be heated. This could be done in the manner described in Task 2.	a.) Eco Kettle b.) Induction Rice Cooker c.) Eco Toaster
20	Split Door - decrease the size of the oven door such that less heat will escape when the food is being placed into the oven	Segmentation	Line the oven with material that retains heat, such as condensed sand (like a pizza stone).	None Selected	Eco-Kettle inspired solution: double-chamber oven that allows user to choose whether he/she would like to heat half the oven or the whole oven at one time. Would also allow two different temperature settings at one time. Oven shelf can be raised or lowered depending on the user's need.	Eco Kettle
21	Embedded elements in refractory sidewalls used for rapid preheat cycle	Consolidation	Oven racks contain preheating elements. More thermal mass in rack - integral heating element for pre-heating cycle.	Replacement of Mechanical System	Induction heated shell to quickly preheat and reduce energy consumption	Induction Heat Rice Cooker
22	Expand heating element to cover sides/rear of oven to increase surface area being heated during preheat. Once preheat finishes, oven elements that are on can be reduced. Principle used here is segmentation.	Segmentation	During preheat, capture excess heat from outside environment (i.e. stove, burner usage). Duct heat into oven, then once oven is hotter than outside, mechanically replace insulated cover to maintain oven temperature.	Dynamicity	Replace conductive heating elements with induction system. Rice cooker is closest to desired system in that it is attempting to quickly heat an enclosed and insulated space. Convection would still be required to transfer heat from induction coils areas. Induction coil is in contact with metal which is heated. Convection then used to transfer heat throughout oven.	Induction Heat Rice Cooker
23	Reduce thermal mass of heating element and distribute it around the oven increasing heat transfer area.	Segmentation	Use induction heating. Electromagnet with FE plate	Replacement of Mechanical System	Use moveable insulated layer to reduce heated volume and heat loss. Moveable lid on track to adjust position higher and lower.	Eco Toaster

Participant Number	Design #1 Description	Cue Used for Design #1	Design #2 Description	Cue Used for Design #2	Design #3 Description	Cue Used for Design #3
24	Segmentation to make oven correct size for the food. 2 walls in oven to create 3 zones for cooking. Utilize the smallest zone = faster preheat.	Segmentation	Using the principle of dynamicity, make the walls of the oven moveable to minimize the effective oven size.	Dynamicity	The Eco Kettle has the idea of right sizing to the cooking task. Stay with idea #2 - moveable ceiling and walls	Eco Kettle
25	Most ovens have to accommodate a turkey. For turkey, all coils are energized and oven floor and walls are in lower position. Most cooking in oven done in smaller portions. For most smaller jobs, the floor and walls are moved to upper position enclosing a small volume and using 1/3 of the heating coils.	None selected	Same solution as Task 1. Dynamicity may help to inspire a solution to this problem. It's hard to say after the solution has been selected/developed in Task 1.	Dynamicity	Oven with a movable ceiling. When small items need to be cooked, the ceiling adjusts to minimum required height thus reducing volume to be heated.	Eco Toaster
26	Coat the inside of the oven with a thicker insulating material; explore dark/other colors to help hold heat; explore materials on inner surfaces that conduct heat faster and back up with a thermal barrier that's more efficient.	Changing the color	Improve efficiency by cycling heat on and off. Maintain temp range within a window, but allow electricity to turn off (or cycle) during baking cycle. Must combine with improved thermal walls.	Periodic Action	Adjust oven size to match pan being cooked. Energy Saving and less area to heat.	Eco Toaster
27	The oven is a volume that has to be warmed through some delta T before baking (broil is ignored). Adding supplemental heating units that shut off prior to reaching set temp will reduce time to potentially energy. A fan to implement forced convection will also speed heating and facilitate baking at lower temps and shorter periods. Supplemental heating units would be added to all interior surfaces of the oven space. I think segmentation facilitates this design solution by the addition of pre-heat only elements on four sides of the oven while baking is accomplished by traditional radiant (top/bottom) elements supplemented by convection fan.	Segmentation	The initial solution relied on supplemental pre-heat units that were on continuously during the pre-heat phase. The supplemental preheat units could be programmed for periodic heating during warm up. The periodicity could be devised to facilitate natural convection as a supplement to the fan. Also, the supplemental pre-heat units might be programmed to work in unison and have longer on-periods while the delta T is large. Then, as delta T approached 0, supplementation heat units would power on and off to minimize heat-up duration and prevent over-heated condition that would require cooling or adversely affect cooking.	Periodic Action	The final solution uses induction heating where the oven racks are induction heating units. In initial baking would use these elements while radiant elements heated to target temp as needed for baking and browning. One alternative is to use the oven racks as induction pre-heaters that shut off completed once the set temperature is reached or the oven door is opened to place the food object in the oven. The design cues are dedicated to very limited applications - toasting, broiling, heating, burning. The baking process is more complex and involves multiple essential processes depending on the subject in order to generate visual appearance, texture, and flavors.	Induction Heat Rice Cooker
28	Oven Chamber reduces in size based on size of food	None Selected	Multiple Chamber Oven, thermostat for each chamber	None Selected	4-Door multi-chamber with thermostat for each chamber	Eco Toaster
29	Change the color of the inside of the oven to reflect heat. Less heat loss decreases preheat time and improves efficiency	Changing the color	Add an additional smaller heating element. The extra element can help preheat the oven quickly and use less energy to maintain heat by using the small element.	Mediator	Design a moving shelf that seals heat to one compartment of the oven. Based on the size of the object being put in the oven, the shelf can be adjusted. For smaller item, the area can be reduced - decreasing preheat time and increasing efficiency.	Eco Toaster
30	Change number, shape, locations, material etc. of oven heating elements to optimize speed of pre-heat while minimizing energy consumption	Prior Action	Move heating elements of optimal size to the optimum position/location to minimize pre-heat time and energy	None Selected	Combine Conduction with convection	None Selected

<b>Participant Number</b>	<b>Design #1 Description</b>	<b>Cue Used for Design #1</b>	<b>Design #2 Description</b>	<b>Cue Used for Design #2</b>	<b>Design #3 Description</b>	<b>Cue Used for Design #3</b>
31	Have a "quick preheat" button. Hitting button would utilize all oven and broiler burners to get oven to 400 degrees F. User can change temp setting from 400 at any time. The prior action principle inspired this.	Prior Action	Replace at least one set of heating elements with a high efficiency, high power infrared burner capable of heating very quickly to a high temperature. This idea uses the "replacement of mechanical system" principle.	Replacement of Mechanical System	Utilize the heating element similar to that in the induction heat rice cooker, replacing at least on of the existing elements.	Induction Heat Rice Cooker
32	Reducing the time required to pre-heat will also reduce heat losses out of the oven, so a solution which pre-heats faster also saves energy. Install a microwave generator and energy absorbing/releasing racks in the oven to quickly transfer energy into the "space". The rack is made of a material with resonance near the frequency of the microwave energy.	Mechanical Vibration	Turn the walls and racks into heating elements. Like an inductive heat cooktop, have both the "pot" or plate of metal and the "Burner" built into the walls and racks.	Replacement of Mechanical System	Allow for a moveable size oven chamber for smaller items. Allow the user to reduce the size of the oven chamber.	Eco Kettle
33	Divide the oven area into sections that are removable if large space is needed. Increase coil length by increasing the nesting (coil area) within the same given space. The division/segmentation would improve total pre-heating time and reduce energy required due to reduced space to be heated.	Segmentation	Using dynamicity, the coils can be moved to a section of the oven that needs to be heated. Isolate a section depending on object/food being baked.	Dynamicity	Large Inductive system rather than conventional coils used in ovens.	Induction Heat Rice Cooker
34	Individually controlled heating elements with insulated removable tray which reduces size of oven in half.	Segmentation	Moving heating elements to desired position within close proximity to food. Dynamicity gave me the idea to move the heating elements. My first thought was to move them up and down to increase heat transfer during preheat but the last suggestion of making parts replaceable gave me the idea to put the heating elements closer to the food.	Dynamicity	Oven door with multiple openings for each slot. The Eco Toaster helped inspire this idea by showing the importance of not letting heat escape through the opening.	Eco Toaster

## Participant Rankings

<b>Participant Number</b>	<b>Cueing Rank Task #1 (0-10)</b>	<b>Cueing Rank Task #2 (0-10)</b>	<b>Cueing Rank Task #3 (0-10)</b>	<b>Follow Up Rank Task #1 (1-3)</b>	<b>Follow Up Rank Task #2 (1-3)</b>	<b>Follow Up Rank Task #3 (1-3)</b>
1	6	7	8	3	2	1
2	6	8	9	2	3	1
3	9	9	8	3	2	1
4	6	5	8	1	3	2
5	6	7	8	2	3	1
6	7	3	9	2	3	1
7	8	7	8	2	3	1
8	No Ranking	No Ranking	No Ranking	3	2	1
9	4	4	5	1	2	3
10	8	8	8	3	1	2
11	No Ranking	No Ranking	No Ranking	1	2	3
12	1	8	10	3	2	1
13	8	6	3	1	2	3
14	4	5	7	3	2	1
15	8	1	6	1	3	2
16	5	5	8	2	3	1
17	8	5	8	No Ranking	No Ranking	No Ranking
18	5	7	9	1	2	3
19	7	8	9	3	2	1
20	6	6	7	2	2	1
21	7	9	7	2	3	1
22	3	6	8	2	3	1
23	1	7	9	3	2	1
24	1	1	1	2	1	3
25	1	5	7	3	2	1
26	8	8	9	3	2	1
27	4	6	7	3	1	2
28	6	6	8	3	2	1
29	2	5	7	3	2	1
30	3	5	7	3	2	1
31	7	8	8	2	3	1
32	4	8	10	3	2	1
33	8	7	7	3	2	1
34	8	8	9	1	2	3

**Reviewer Rankings**

Participant Number	Task #1 Criteria #1	Task #1 Criteria #2	Task #1 Criteria #3	Task #2 Criteria #1	Task #2 Criteria #2	Task #2 Criteria #3	Task #3 Criteria #1	Task #3 Criteria #2	Task #3 Criteria #3	Design #1 Good?	Design #2 Good?	Design #3 Good?	Reviewer Comments
1	Yes	Yes	Yes	No	No (None Selected)	Yes	Yes	Yes	No	Yes	No	Yes	1.) Participant came up with the expected solution in design #1 (adjustable heating area). 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) Participant came with the solution the reviewer came up with in design #3 (adjustable heating area). Additional: The link between segmentation and the Eco Kettle is different than what the reviewer thought (Dynamicity) but could see how segmentation could also be used.
2	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	1.) Changing the color of the window to a translucent coating could reduce radiant heat loss but it removes the functionality of the window. Also additional insulation for oven door doesn't match color change cue. 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) Participant came with the solution the reviewer came up with in design #3 (adjustable heating area). Additional: The link between the eco-toaster and the first design is not based on the cueing example changing color.
3	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	1.) It would use more energy to keep the air constantly heated but interesting idea. 2.) Improving the insulation throughout the oven modifies the object at all stages of operation, not just preheating so Dynamicity wasn't used. 3.) Participant came with the solution the reviewer came up with in design #3 (adjustable heating area)
4	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	1.) Splitting the element into smaller elements and placing them around the oven does not reduce the time necessary to preheat or reduce the energy use. 2.) Moving the element around the oven does not reduce the time to preheat or energy used. 3.) Design 3 would work but it's not too innovative.
5	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	1.) This solution adds more power to improve preheating and does not reduce energy usage. Also, it would be impossible to cook food with a moving vertical heating element. 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) Design 3 would work but it's not too innovative.
6	a.) No b.) No c.) Yes	a.) Yes b.) No c.) Yes	a.) Yes b.) Yes c.) Yes	Yes	Yes	Yes	No	Yes	Yes	a.) No b.) No c.) Yes	Yes	No	1a.) Splitting the element into smaller elements and placing them around the oven does not reduce the time necessary to preheat or reduce the energy use. 1b.) Providing more doors provides more areas for energy loss. Heat is almost never present from last use. 1c.) Reduces energy loss by using a more efficient heat source (microwave) to create steam. 2.) Participant came with the solution the reviewer came up with (adjustable heating area) 3.) Using induction heating is a potential solution but the idea is not explained specifically enough to determine whether it meets the goal of the problem.
7	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	1.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). Additional - Eco-Toaster was used as cue for design #3 rather than Eco-Kettle.

Participant Number	Task #1 Criteria #1	Task #1 Criteria #2	Task #1 Criteria #3	Task #2 Criteria #1	Task #2 Criteria #2	Task #2 Criteria #3	Task #3 Criteria #1	Task #3 Criteria #2	Task #3 Criteria #3	Design #1 Good?	Design #2 Good?	Design #3 Good?	Reviewer Comments
8	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	1.) This solution adds more power to improve preheating and does not reduce energy usage. 2.) Design #2 just changes the oven to a microwave which doesn't provide the functionality the user is looking for. 3.) The seal on the oven has nothing to do with the rice cooker. Using induction heating is a potential solution but the idea is not explained specifically enough to determine whether it meets the goal of the problem.
9	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	No	No	1.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). 2.) Design number 2 does not reduce the amount of energy used or the time to heat the oven. The design is also not feasible as it would interfere with the food in the oven. 3.) The induction cooking method would cook the food in the magnetic pan similar to a stove top which is not the kind of cooking an oven is designed for.
10	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	1.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) By reducing losses associated with the window only during preheating, it improves time and energy and still allows the window to be functional.
11	Yes	No	Yes	No	Maybe	Yes	Yes	No	Yes	No	No	No	1.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) Design 3 did not utilize a cueing example and proposed a solution that was already stated as being included in the design in the problem section.
12	No	Yes	Unsure	No	Yes	Yes	No	Yes	Yes	No	No	No	1.) The idea is not explained clearly. 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) Using induction heating is a potential solution but the idea is not explained specifically enough to determine whether it meets the goal of the problem.
13	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	1.) This solution adds more power to improve preheating and does not reduce energy usage. 2.) Participant came up with the solution the review came up with in design #2 (adjustable heating area). 3.) Participant came up with the solution the review came up with in design #3 (adjustable heating area). Additional Comments: Participants recognized link between Eco-Kettle and Dynamicity.
14	No	Yes	Yes	No	No	Yes	No	Yes	Yes	No	No	No	1.) This solution adds more power to improve preheating and does not reduce energy usage. 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) While an interesting idea, the use of steam does not reduce the energy use of the oven because energy is needed to convert water to steam.
15	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	1.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) This solution is not feasible for the current problem since it specifically states the oven is electric.

Participant Number	Task #1 Criteria #1	Task #1 Criteria #2	Task #1 Criteria #3	Task #2 Criteria #1	Task #2 Criteria #2	Task #2 Criteria #3	Task #3 Criteria #1	Task #3 Criteria #2	Task #3 Criteria #3	Design #1 Good?	Design #2 Good?	Design #3 Good?	Reviewer Comments
16	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	1.) Splitting the element into smaller elements and placing them around the oven does not reduce the time necessary to preheat or reduce the energy use. The fins and circulating fans do not relate to segmentation. 2.) Reduces energy loss by using a more efficient heat source (microwave) to create steam. 3.) Participant came with the solution the reviewer came up with in design #3 (adjustable heating area).
17	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	1.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). Additional: The link between segmentation and the Eco Kettle is different than what the reviewer thought (Dynamicity) but could see how segmentation could also be used.
18	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	1.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) The induction cooking method would cook the food in the magnetic pan similar to a stove top which is not the kind of cooking an oven is designed for.
19	No	No	Yes	Yes	Yes	Yes	a.) No b.) Yes c.) Yes	a.) Yes b.) Yes c.) Yes	a.) Yes b.) No c.) Yes	No	Yes	a.) No b.) No c.) Yes	1.) This solution adds more power to improve preheating and does not reduce energy usage. 2.) Participant came up with the expected solution in design #2 (adjustable heating area). 3a.) The probe solution focuses on cooking the food and not preheating. 3b.) The induction cooking method would cook the food in the magnetic pan similar to a stove top which is not the kind of cooking an oven is designed for. 3c.) Participant came with the solution the reviewer came up with in design #1 (adjustable heating area). Additional - Eco-Toaster was used as cue for design #3 rather than Eco-Kettle.
20	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	1.) Design 1 is focused on saving energy when the food is cooking, not during preheating. 2.) The intent of design #2 is to improve the oven's insulation to retain the heat in the oven which reduces energy losses. 3.) Participant came with the solution the reviewer came up with in design #3 (adjustable heating area).
21	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	1) This solution adds more power to improve preheating and does not reduce energy usage. 2.) This solution adds more power to improve preheating and does not reduce energy usage. 3.) Utilizing induction heating with respect to the shell of the oven baking area is a feasible solution.
22	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	1) This solution adds more power to improve preheating and does not reduce energy usage. 2.) This solution could work if someone was using the burner to cook something else while using the oven (capturing heat that would otherwise be wasted). 3.) Utilizing induction heating with respect to the shell of the oven baking area is a feasible solution.



Participant Number	Task #1 Criteria #1	Task #1 Criteria #2	Task #1 Criteria #3	Task #2 Criteria #1	Task #2 Criteria #2	Task #2 Criteria #3	Task #3 Criteria #1	Task #3 Criteria #2	Task #3 Criteria #3	Design #1 Good?	Design #2 Good?	Design #3 Good?	Reviewer Comments
23	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	1.) Splitting the element into smaller elements and placing them around the oven does not reduce the time necessary to preheat or reduce the energy use. 2.) Utilizing induction heating with respect to the shell of the oven baking area is a feasible solution. 3.) Participant came with the solution the reviewer came up with in design #3 (adjustable heating area).
24	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1.) Participant came with the solution the reviewer came up with in design (adjustable heating area). 2.) Participant came with the solution the reviewer came up with in design (adjustable heating area). 3.) Participant came with the solution the reviewer came up with in design (adjustable heating area).
25	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	1.) Participant came up with and adjustable heating area solution in design #1 that combines segmented areas of the oven and a moving floor but no cueing example selected. 2.) Participant came up with the same solution as #1 for design #2 using dynamicity. 3.) Participant came up with an adjustable heating area solution in design #3 by utilizing a moving ceiling.
26	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	1.) A darker color wall absorbs more of the radiant energy produced by the element which helps heat the air in the oven quicker. Adding insulation doesn't relate to changing the color. 2.) The solution for task #2 does not address the preheating phase. 3.) Participant came up with an adjustable heating area solution in design #3 by utilizing moving ceiling and floor.
27	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	1.) The solution adds more heating elements (energy) to quicken pre-heating. The cueing principle selected also does not clearly align to the solution provided. 2.) This solution is a modification to solution #1 which the additional heating elements being periodically cycled. 3.) This solution introduces the concept of induction heating but doesn't describe the surface that will be heated inductively.
28	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	1.) Design #1 uses the concept of an adjustable heating area by moving the floor and ceiling but no cueing example selected. 2.) Design #2 uses the concept of an adjustable heating area through multiple chambers but no cueing example selected. 3.) Design #3 uses the concept of adjustable heating areas with separate doors.
29	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	1.) A more emissive coating rather than reflective coating is better for ovens. 2.) Adding additional heating elements does not reduce energy usage. 3.) Design #3 uses the concept of an adjustable heating area with a moveable floor.
30	No	Yes	Yes	No	No	Yes	No	No	Yes	No	No	No	1.) The solution isn't specific enough to determine whether it meets the goal of the problem. 2.) The solution isn't specific enough to determine whether it meets the goal of the problem. Also, no cueing principle selected. 3.) The solution isn't specific enough to determine whether it meets the goal of the problem. Also, no product example selected.

Participant Number	Task #1 Criteria #1	Task #1 Criteria #2	Task #1 Criteria #3	Task #2 Criteria #1	Task #2 Criteria #2	Task #2 Criteria #3	Task #3 Criteria #1	Task #3 Criteria #2	Task #3 Criteria #3	Design #1 Good?	Design #2 Good?	Design #3 Good?	Reviewer Comments
31	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	1.) The solution adds more heating elements (energy) to quicken preheating. 2.) This solution is feasible as infrared cooking requires no preheating time and is more energy efficient than traditional natural convection. 3.) Using induction heating is a potential solution but the idea is not explained specifically enough to determine whether it meets the goal of the problem.
32	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1.) The design concept involves microwaving a material that can absorb and release the energy which is more efficient and quicker than natural convection. 2.) Design solution uses induction heating to heat oven walls and rack which is more efficient and quicker than natural convection. 3.) Design #3 uses the concept of an adjustable heating area with a moveable ceiling.
33	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	1.) Design #1 uses the concept of an adjustable heating area through multiple chambers. 2.) Design #1 uses the concept of an adjustable heating area by moving the floor and ceiling. 3.) Using induction heating is a potential solution but the idea is not explained specifically enough to determine whether it meets the goal of the problem.
34	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No	1.) Design #1 uses the concept of an adjustable heating area through 2 smaller chambers with a removable insulated tray. 2.) Design 2 has movable coils but the concept doesn't reduce the volume. It also focuses on cooking rather than preheating. 3.) The concept has multiple doors to prevent heat loss when opening the oven. It doesn't focus on preheating.

## Follow Up Responses

Participant Number	Best Solution to Problem	Principles or Examples	Earlier Tasks Affected Design in Later Tasks	Similarity Between Cueing Examples	Better design without cueing examples?
1	I think that solutions 1 & 3 are the best because they should effectively solve the problem without complicating the system as much as adding two more heating elements would, especially since they would have to be controlled separately from the main element.	I found it easier to develop solutions using specific product examples because they presented possible solutions that could just be adapted to this problem rather than having to generate them on your own.	Yes, as seen in Task #3, my design was a slightly modified version of my task 1 design	In task 1, one of the cues was segmentation which is essentially what the eco kettle uses by having two separate chambers to limit the amount of water being boiled to the minimum necessary	I am not sure. The cueing examples were good to get my train of thought started. Different cues or no cues at all may result in both better and worse solutions.
2	The third because it could be applied to existing and new models while the other 2 solutions require completely new ovens to be manufactured.	Specific product examples: having an idea of a method that works and applying it through modification to a new design was easier for me based on this task	Yes, my first design could have been used based on the eco-toaster so I chose a different design	N/A	No
3	Equally, designs 2 & 3. Ideally, I would combine both solutions in one final design. These seem the most simple and relatively easy to develop further.	Task 3 was the easiest - probably because the exemplified engineering options were easy to picture being utilized for the given problem	Yes - I felt that I did not want to develop the same idea twice, so I looked for specifically different solutions in later tasks	N/A	No - my unfamiliarity with the existing design made me initially unsure of how to begin the redesign. The cues were very helpful in getting started with idea generation.
4	I believe task 1 represents the best solution because it allows for more even heat distribution in the simplest manner available	Easier by reviewing product examples. Shows completed design used to solve similar problem. Easier to adapt than create new solutions	No, treated them separately	N/A	Possibly, but I didn't spend much time thinking about that.
5	The third because it more effectively addresses the energy problem	Specific examples because the implementation was more obvious	Not particularly, the concepts used weren't amazingly similar except between 1 and 2	Mediator is the conclusion I arrived at with segmentation essentially	No idea, probably not
6	The third one will be the most practical since it utilizes existing technology that has been proven to be feasible in engineering	Reviewing specific example would be easier, the reason is provided in question 1	Yes, developed ideas can be integrated into later ones.	N/A	No
7	The third one. It uses an oven that is essentially unchanged from the current design.	I was comfortable with all 3 tasks. I do not feel any one was harder than another.	Yes, I refined by first "enclosed/smaller space" design	No Response	No Response
8	Task #2 because the provided principles inspired more ideas. The principle of replacement of mechanical systems was helpful.	Task #3 because it channeled my ideas into a particular direction	Yes because they help me build upon the next design.	No response	No
9	Compartmentalizing - it's similar to heating a smaller oven without the need for a second appliance	Using principles. It let me use a goal to create an idea instead of converting a design that was analogous.	I was less likely to use a similar design idea in later tasks because I had already used ideas and wanted something else.	N/A	It's possible, but I would need more time to work on it

Participant Number	Best Solution to Problem	Principles or Examples	Earlier Tasks Affected Design in Later Tasks	Similarity Between Cueing Examples	Better design without cueing examples?
10	#3: easiest to implement. Design is proven and could probably be easily adapted from toaster	Specific examples seems like it is cheating a little. If there is a rush, money for R&D is limited and examples are available, use them. If not, use principles to develop a potentially better solution. Prefer principles is time/budget allow.	Absolutely. As more information becomes available, you absorb it and use it regardless. Your sub-conscience is working with previous information whether you realize it or not. This information is bound to manifest itself or influence all that comes after.	I purposely avoided the same design even though it could have been done for #1 and #2.	Given enough time, perhaps. The cueing examples aided in getting started.
11	The first one, I can relate to the physical device immediately	Task 1 and 2 are easier. My suggestion included some of the methods used in 3.	Yes, the first one seemed fundamental and a starting point for 2 and 3	N/A	Maybe
12	The task 3 solution is best, the first and second principles were too broad	It was easier to use examples. It didn't require creating a new way to heat/save energy.	Yes I do. In task #2 I used the concept of mediator. I added a component to help the oven to heat up and save energy. Between concept #2 and #3, the method to heat changed but the modification is the same, add something to solve the problems	N/A	No, not immediately, maybe after a few attempts
13	The adjustable volume oven is probably the easiest to implement with existing designs - it could possibly even be sold as a separate unit (the insulated rack) for existing ovens	The engineering principles helped because I didn't have to try to make analogies from products designed for completely different applications (a natural gas burner to an electric oven for example)	I saw my design for task 2 indicated by the product in task 3	"Dynamicity" was reflected by the Eco-Kettle	Probably not. The real problem is in the design requirements. Electricity is a terrible inefficient way to product heat.
14	Task 3's solution because it combines the best aspects of Task 1 and Task 2, with new ideas specific to task 3	Produced examples because you can incorporate engineering principles or see how they are applied and re-apply them to your specific problem.	Yes, once I had developed what I thought was an adequate solution, it is hard to divorce myself from that solution to develop other solutions.	I tried not to come up with the same design, but applied aspects of previous designs to my Task 3 design. The eco toaster led me to include my idea about the doors from Task 1 to Task 3.	Possibly, for task 2 the mechanical vibration and color cues didn't help me. The prior action was marginal. That left segmentation and consolidation. Task 2 were slightly more helpful. One of the aspects that limits the designs for this problem are the space constraints regarding a conventional oven in an existing home - it must have certain inner and outer dimensions.
15	Task 1 because it address both issues - less energy consumption and faster heating.	Engineering principles, but only if they are the correct ones. I found task 2's principles almost irrelevant to the problem.	Yes, because I was trying to come up with something new each time.	N/A	Not necessarily, I thought Task 1's cues were pretty good.

Participant Number	Best Solution to Problem	Principles or Examples	Earlier Tasks Affected Design in Later Tasks	Similarity Between Cueing Examples	Better design without cueing examples?
16	#3 - probably yields highest overall energy efficiency. Easy to understand by purchasers and users	Allied products - cooking appliances - must deal with similar issues and constraints. Easier to relate to the problem at hand.	Designs were not so clearly linked with principles that the design couldn't have been generated from another set of principles. That said, I didn't use an earlier design with a later set of principles.	N/A	Cueing examples are good in that they generate a chain of thought that leads to the design. It might be difficult to relate the final design to the principle that started it all. Therefore, the cues did not act as constraints, rather as seeds of thought. With that in mind, there should be less supposition onto the appropriate cue for a particular problem and provide a multitude of cues and examples to spur the process.
17	1 and 3 because the designs seem simple, realistic and potentially low cost while meeting both requirements	Reviewing specific product examples; because you have a visual of the engineering principles that you can study and apply to your product	Yes, particularly task 3 because it was similar to the design developed for Task 1	Segmenting seemed to be a design practice used to develop the Eco-Kettle	Possibly, cueing examples could restrict the thought process by focusing only on the types of cueing examples available rather than thinking outside the box.
18	The last because it went through all stages of development	Both. It is good to use engineering principles so you look "outside the box". But you don't want to reinvent the wheel. Do your research and see what technologies exist and how they may be integrated into your project.	Yes, I wouldn't have thought of the dual door design if I started on task 3	N/A	No
19	The design in Task 3 built on those from one and two with the addition of the probe as the potential key differentiator. Thinking through the objective of the use of the oven this addition, along with the improved display (i.e. time to desired temperature) may lead to a substantially more efficient use of the energy going into the product during the cooking phase. In terms of accelerating the heat up phase, the dual burner approach may help to address the customer need of faster heat up time.	I found the specific product examples easier to help with the conceptual design. I found even with the engineering principles I was applying them to other existing products I was familiar with to understand and apply them.	Definitely. I wasn't sure if it was the different approaches which made the following designs better or if it was simply looking at the same problem from different perspectives/trying to come up with new solutions based on additional constraints (e.g. task 2 and 3)	I found that the designs tended to build on each other. The design constraints led me to think about the problem in different ways - in particular in Task 2. Thinking through how the design principle could apply to the challenge helped me to identify a new approach which had not been apparent to me in Task 1.	No the cueing examples helped me to think through the problem. I would assume that there would have to be a phase in the design process to validate if these were the best cueing examples to lead to the best design, but the additional constraint help me to think through the issues and how best to address them.
20	The third design addresses both goals whereas the first two designs only address energy efficiency	Product Examples: I wasn't always able to visualize the engineering principles being applied, whereas the examples were easier to visualize.	Yes, as I had already spent some time thinking about and evaluating the previous conceptual designs.	The third design incorporates the first design in it. The words "segmentation" and "double chamber" contributed to the iteration of the final third conceptual design.	No

Participant Number	Best Solution to Problem	Principles or Examples	Earlier Tasks Affected Design in Later Tasks	Similarity Between Cueing Examples	Better design without cueing examples?
21	Induction heating would seem to be the best - speed and energy efficiency	Specific Product examples: easier to envision (although examples outside of my area of expertise and may have made it more difficult to apply principles). However my preference is to use induction rather than deduction.	Applied some principles from 1st example in 2nd example. Thought about induction principle but picture of rice cooker helpful	I would attribute to anchoring and adjustment heuristic. Tendency to lock into idea and then tweak using additional principles	No, cueing helpful to stimulate thinking
22	Three. Known to be more efficient than conductive systems, which were used in 1 and 2.	Product Examples	Yes, after designing a conduction solution in the first task, it seemed to lead me towards attempting to improve using similar concepts in the second task.	N/A	No
23	Number 3 is likely the best combination of cost and effectiveness	Specific Product examples provided practical ideas. Principles were sometimes too conceptual to apply.	Yes, Since my approach in task #2 used induction heating, I looked for other concepts from the examples in task #3.	N/A	I felt the examples in Task #1 were restricting and there weren't many applicable in Task #2
24	Moveable walls - This is completely flexible to any size of container & also allows for single very large turkey or such	Engineering principles were better. Difficult to transfer product ideas to the new concept. Maybe they were not close enough to a solution.	Limiting which principles & which product examples also limits ideas. Ideas were there before principles were presented.	Product examples didn't help in any way so task #2 was brought forward and connected to a product example.	Yes, cueing examples forced me into limited thinking with boundaries. Can I add an electronic control which negates preheating altogether? Knowing container size, food type and usually time & constant oven temperature, the physics should be able to be calculated to start cooking immediately.
25	#3. Minimal number of moving parts. Uses proven technology	Product Examples - engineering principles were a bit esoteric.	Yes, the problem remained the same. Each subsequent task only provided additional information. Other thoughts came up, but none offered a better solution to the problem	The cueing examples did not cause me to come up with the same design, but the product may have spurred me to improve/evolve the design.	Yes/No. The cueing example in Task #1 were useless to me. The cueing example "dynamicity" in Task #2 only served to give a name to what I had done for the solution in Task #1. The product example in Task #3 somehow served to help me evolve my original concept.
26	#3. It meets both goals (heat up time and reduced energy) the best.	Task 3. I could visualize the product better once a related example was presented. I think it did help to review the engineering principles first though. It got me thinking about alternatives.	Yes. Even though I didn't use all of the principles. I thought about each of them in working on subsequent tasks.	N/A	Not at all.

Participant Number	Best Solution to Problem	Principles or Examples	Earlier Tasks Affected Design in Later Tasks	Similarity Between Cueing Examples	Better design without cueing examples?
27	Third solution. The solution is the most advanced in that it incorporates the existing oven racks into the design solutions	I think it is preferable to start with engineering principles because #1 and #2 could actually be satisfactory solutions that can be realized at minimum cost.	Yes, the earlier tasks provided simple models that were made more sophisticated with further work.	The fundamental design was unchanged but each iteration was more advanced	I think the design at #2 would have been conceptualized. However I would not have thought to use induction heating without a cue.
28	#1 because it's simple. Reducing the chamber volume will help lower the pre-heat time. Also, the adjustability of the chamber is ideal for broiler use.	Product examples led to my multi door design, the rest of my ideas were self-created. I tend to get more ideas from visuals.	Yes, I stuck with my idea of reducing the oven chamber size because I believe it's a common problem. Most meals don't require such a large oven chamber but are a little too big for a toaster oven.	I used similar designs because I believe it's an effective way to reduce preheat time and reduce energy use.	My ideas were mostly self-created so I would say doesn't apply.
29	Final Design - other designs would only offer minor improvements.	Task 3 - It's easier to generate ideas from specific examples rather than creating new unique ideas from engineering principles	No, they were separate ideas. I did not expand from the original idea. However, the three designs could be combined into one.	N/A	Ideas may not have been better but they would have been different. Cueing narrows your focus.
30	The third. Cueing examples were most closely applicable to the problem to be solved.	Task #3 - starting from principles left too many ineffective solution paths still in consideration. One specific product example was close to the stated problem.	Yes - #1 affected design choice for Task #2. However, they did not affect Task #3. Different basic principle used, not applicable to later task.	N/A	Yes
31	The induction heat rice cooker because it is proven, similar application	It was easier (not necessarily better) using the specific product examples. By looking at similar products, it gives the impression that they are efficient and cost-effective.	My design concept in task #2 involved a replacement burner/element. Since this was an option in Task #3, I was drawn to it.	In task 2, the replacement of a system was related to the induction heating element in task #3.	I may have come up with a better design but it would have taken significantly more time.
32	#3 is much more practical and might actually save energy. The other ideas were more crazy "maybe we save energy if we heat up quicker"	#3 - it's much easier to modify or adopt concepts which have already been applied rather than try to modify and apply at once	#1 sort of influence #2 in that I was already thinking electromagnetics. #3 wasn't influenced by #1 or #2.	N/A	I actually tried to think of something else before responding to #1. All I could think about was using a jet engine type combustion to quickly heat the air. So no, I don't think I could have had a better idea.
33	Inductive system would be the best as it eliminates the need to section off the oven and it would automatically save energy without user intervention in adjusting partitions or coils.	Seeing specific, relevant examples makes the brain get channeled and prevents the need to think about abstract ideas. However, it slightly limits innovation.	I think they definitely did. Your thoughts get channeled when conceptual design is shown	Segmentation and Dynamicity led me to the same conceptual design	Would have made me think a bit more but cues definitely helped

Participant Number	Best Solution to Problem	Principles or Examples	Earlier Tasks Affected Design in Later Tasks	Similarity Between Cueing Examples	Better design without cueing examples?
34	I believe the first solution is best based upon cost to produce vs. effectiveness	I believe it was easier to create a solution by reviewing specific examples because the solution is already there, however I don't think the outcome is as good	Yes, I think that having worked out a couple of solutions made it easier to keep going	N/A	No, I think the first 2 cueing examples definitely helped me with my designs (both quality and time to create). I do think being limited to use the final designs might have limited creativity but the examples helped with the speed to produce ideas.



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