

# Defining a New Business Model for Sustainable Biomass Production from Forestry Residues in Türkiye by Using TRIZ

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## ABSTRACT

Global Energy demand is growing steadily. However, the world's primary energy resources are fossil fuel based, and they are finite. Furthermore, it causes irreparable damage to the precious environment. Therefore, energy resources need to shift towards renewables, which can deliver sustainable growth and a climate-neutral outcome. While Türkiye has been quickly adopting renewable energy sources for power generation, it has yet to see opportunities for biomass generated from forestry residues readily available in abundant supply with an estimated quantity of about 5 million tons. However, most of this residue is left untouched in the forest due to a perceived lack of demand for this resource. This study aims to define a new business model for sustainable biomass production from forestry residues that will overcome this false perception. The new model was defined by using a creative problem-solving method, known as the Theoria Resheneyva Isobretatelskehuh Zadach (TRIZ). Through the semi-structured interviews with open-ended questions, the authors analyzed the responses by qualitative data content analysis (QDCA) to serve the rules of TRIZ. The new business model requires employing a small business unit (SBU) approach. It contains the involvement of forest villagers (FVs) engaged in a self-employment structure under the coordination of authorities.

**Keywords:** Sustainability, Biomass Production, Forestry Residues, Business Model, TRIZ

**JEL Classifications:** D2, O3, O15, Q2

## 1. INTRODUCTION

Without energy, no life on Earth would be possible; nothing could exist, from microorganisms to great civilizations (Jankowski, 2020; Caineng et al., 2022). However, most ever-growing energy demands resources from finite and polluting fossil fuels (Yue et al., 2021). The World's extensive fuel companies are getting rewards when accessing more fossil reserves (Brown and Spiegel, 2017; Bebbington et al., 2020) even though the World's fossil fuel bank is finite (BP, 2021). Moreover, the damage to ecosystems and climate systems caused by fossil fuel burning has reached a tipping point (Ucal and Xydis, 2020). As such, it is of utmost importance to shift Türkiye's energy dependence away from fossil fuels to renewable and non-polluting sources (Kotagodahetti et al., 2021). Türkiye underutilizes biomass, one clean and renewable energy

resource (Ozdil and Caliskan, 2022). There are 292 biomass-fired power stations registered within the Renewable Energy Support Mechanism (EPDK, 2022). However, only 190 of them are active (BEPA, 2022). As of June 2022, the installed capacity of biomass-fired power stations is 2.172 MW, representing only 2.12% of the total installed energy generation capacity in Türkiye (Republic of Türkiye Ministry of Energy and Natural Resources, 2022). On the other hand, the allowable annual cut declared by The Regional Directorates of Forestry is summing to 30,625,000 m<sup>3</sup> for the year 2021 (General Directorate of Forestry (GDF), 2021). PwC Türkiye (2021) reported that the producers utilize only 50% of the biomass volume after harvesting forest products. The remaining 50% is left uncollected as residue in the forest. However, Saracoglu (2010), more conservatively and realistically, considered that branches, barks, and leaves, as a source of biomass, constitute 25% of the

whole volume of a tree. Using this matrix, based on the realized cut for the year 2021 declared by GDF, the uncollected annual biomass resource potential of forest residue in Türkiye is as high as 5 to 7.5 million m<sup>3</sup>. However, biomass collectors leave them in the forest due to a perceived lack of demand. In other words, there is an idle potential for resources, and therefore, there is a need to introduce a new business model to attract sustainable biomass production from forestry residues. The study aims to certain the reasons behind the lack of desire and to introduce a new business model for sustainable biomass production from forestry residues using TRIZ methodology.

## 2. CONSTRUCTING A NEW BUSINESS MODEL AND USE OF TRIZ

A business model (BM) defines how business is done (Donner et al., 2021). Further, BM innovation (BMI) has become an interesting topic in recent management research (Wang et al., 2022). Although creating an innovative or new business model can be equally important in terms of value creation for society, capturing the hidden value of the business is only possible unless the capacity exists to create innovative BMs (Tece, 2010).

There is significant interest in searching for different sustainable approaches from the business community, policymakers, and academia after reaching the physical limits of natural resources under the present economic system and urgent climate change pressure (Bocken et al., 2021; Tura et al., 2019). There is also a rising focus on establishing business models that are more suitable for providing more sustainable outcomes in terms of the environment and society and still maintaining development (Bocken and Short, 2021). The transformation of existing production and consumption business models aims to reduce environmental harm and social inequality (Droste et al., 2016). While studying complex relations between stakeholder pressure and barriers within circular business models, Jabbour et al. (2020) found that firms face barriers during their transition to sustainable business model practices. They further commented that these barriers are related to a lack of skilled people, administrative processes, regulations, technical solutions and capabilities, and financial resources. Therefore, stakeholder interaction becomes essential to sustainable business models (Fobbe and Hilletoft, 2021). Ghosh (2016), in his research, reviewed the biomass supply chain and investigated the cause of the main challenges in India. He described poor awareness of the stakeholders as one of the main constraints of sustainability and proposed community participation as a solution. Developing a sustainable business model adds a systemic approach to a business-as-usual practice. It enhances the integration of sustainability into value creation through proactive involvement to overcome barriers and solve problems (Ziolo et al., 2020).

By the way, business process management (BPM) aims to improve business efficiency (Chalupa et al., 2021). In comparison, total quality management (TQM) aims to maximize competitiveness (Fawzy and Olson, 2018). There are different methodological approaches for business process improvements. For example, business process reengineering (BPR), one of the widely used techniques for organizational improvement (Featis et al., 2022), aims to increase

the organization's efficiency. On the other hand, innovation plays different roles in TQM and BPM, providing better flexibility than applying one alone (Judi and Beach, 2010). Moreover, in some cases, business process improvement efforts need innovative support to achieve better results (Sojka and Lepšik, 2020). Therefore, in this research, a creative problem-solving method, TRIZ, and its tools are applied to define the obstacles and possible solutions in the biomass production business model in Türkiye. Starting in 1946, the former USSR engineer Genrich Altshuller, accredited as the father of TRIZ, and his colleagues analyzed more than two million patents and asserted that inventiveness and creativity could be learned (Maia et al., 2015). Altshuller, after analyzing many patents, concluded that creative innovation is based on universal principles and defined 39-Technical parameters causing contradictions and 40-Principles to overcome those contradictions.

TRIZ contains the resolution of a technical contradiction, which occurs when improving one technical system's characteristic or parameter worsens another system's characteristic (Technical Innovation Center (TIC), Inc., 2022). TRIZ tools direct the problem solver to reach successful solutions proven before (Chai et al., 2005). Although the theory was applied initially to solve technical engineering problems, researchers have used it in different areas. For example, Spreafico (2021) identified promising results in his study of all the TRIZ strategies for almost all the environmental impact categories and provided quantitative evidence on the validity of the individual TRIZ strategies in eco-design. Kou et al. (2022) used TRIZ in their research to identify the most critical factors to consider to increase the effectiveness of solar energy projects. Researchers used TRIZ; for the designing of a new lighting unit (Kiraz et al., 2020), in an assessment of the sustainability of mega projects (Chen et al., 2021), to increase the safety of a device by describing the concern of insufficiency to resolve technical discrepancy (Galik et al., 2021), to solve the problem of increase in electricity consumption at home (Ang et al., 2015), to identify innovative strategies for green energy investment projects (Meng et al., 2021).

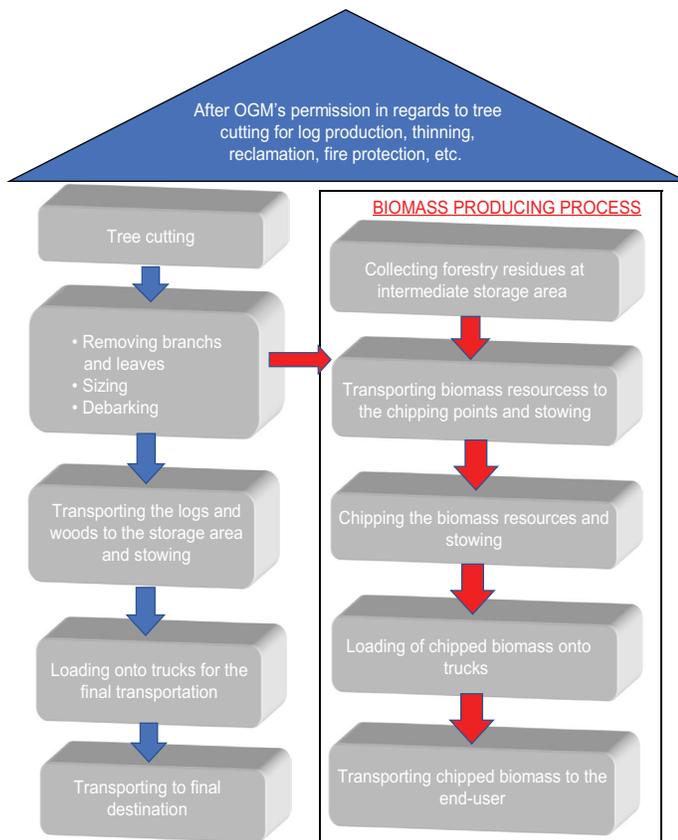
As per observations of the authors, in the traditional business model in Türkiye, the forestry residues, primarily roots, are chipped at the terminal, whereas some recent attempts to chip the remaining/unused forestry residues at the site where it is to reduce the size/stowage factor of the residues and transport them to the plants for further process and stowing. It is an interlinked process between tree-cutting and end-use of biomass resources (Figure 1) (Biyoenjerji, 2014).

## 3. METHODOLOGY

### 3.1. Applying TRIZ Methodology to Determine a New Business Model

TRIZ is a structured problem-solving process integrated to define the problems and their resolutions that have been proven successful based on patent analysis (Ekmekci and Nebati, 2019; Sheu et al., 2020; Alvarez et al., 2022; Guarino et al., 2022; Spreafico, 2022; Munje et al., 2023). A typical TRIZ problem-solving process consists of three stages: problem definition, problem resolution, and solution evaluation (Technical Innovation Center (TIC), Inc., 2022).

**Figure 1:** The general outline of the forestry production functions in Türkiye



### 3.1.1. Stage 1: Problem definition

It starts with separating prior opinions and side issues by breaking down the problem into main components so that the main problem is defined clearly (Ekmekci and Nebati, 2019). This stage consists of four steps: situation analysis, problem modeling, problem formulation, and result analysis.

#### 3.1.1.1. Situation analysis

For this purpose, a semi-structured interview, defined as a gold standard approach by Barbour (2008), is a widely used technique to collect data based on the experiences of the participants (Galletta, 2013) and to learn about the impacts of specific policies and events on the business conducted or taken part by them (Hopkins et al., 2019). In this respect, the Innovative Situation Questionnaire (ISQ) (Chai et al., 2015) serves TRIZ to understand the main problem of the situation. As a problem solver, the researcher records any idea while compiling the questionnaire responses. The contents of the questionnaires become a database for different TRIZ tools in further stages, and the answers to the questionnaire illustrate the concepts of possible solutions to the problem (Terninko et al., 1998). In this research, the semi-structured open-ended interview questions derived from the ISQ structure serve the situation analysis of TRIZ. The responses to questionnaires are collected in written form to avoid language barriers (Kunkel et al., 2022), Covid-19 restrictions, and time constraints (Knoth et al., 2022) via email (Svartvatten et al., 2015) to six experts based on purposive sampling techniques (Silverman, 2010). Unfortunately, only three of them are responded to and considered enough for evaluation due to the nature of the subject research (Li et al., 2021). Saldana (2013)

recommended that for small-scale studies coding on hard copies provides more control over and belonging to the work. In this study, due to the nature of the research and the number of respondents, the responses are evaluated by using computer-assisted QDCA to make inferences from a text in the context of their use (Harding, 2019; Hsieh and Shannon, 2005; Krippendorff, 2013) and follows a common approach for content analysis (Schilling, 2006; Erlingsson and Brysiewicz, 2017). The answers of all responders serve to construct the content matrixes. They are rectified and evaluated in such a way as to provide a more convenient base for inferences and categorizations (Svartvatten et al., 2015). Using table templates, the “find” function in word processing programs such as Microsoft Word to facilitate locating and counting the meaning units and codes in the responses to interview questions can also serve the purpose of analysis (Erlingsson and Brysiewicz, 2017). The authors use the below sequences (Figure 2) in content analysis which is adopted from Krippendorff (2013, p. 36) where the analytically constructed texts guide coding and provide a base to analyze by creating a quantitative description of the contents of the text. The value of qualitative research conducted by computer application is more dependent on the interpretation of researchers as they undertake the analysis (Harding, 2019, p. 109).

#### 3.1.1.2. Problem modeling and formulation

At this stage, the information obtained from the situation analysis constructs the functions diagram (Figure 3). It is a problem definitions tools used in the context of TRIZ to identify system problems or weak points (Daniilidis et al., 2011). The process starts with identifying the primary functional components, and later the relationships among the functions are specified as cause-and-effect relationships. Next, problem formulation defines the functions either harmful or useful functions. Finally, it formulates preventive statements for harmful and alternative statements for useful functions. However, as the organizational processes are strongly interconnected, improving a process can alter the other interrelated processes. To avoid the unexpected worsening of interrelated processes, TRIZ has been practiced alone or as a part of different methodologies. This approach usually leads to a locally mature solution that strongly depends on the researchers' background (Brad et al., 2015).

#### 3.1.1.3. Problem statements and result analyses

The problem statements use the functional diagram to separate the complex problem into more minor issues. Consequently, eight problem statements and some indications for possible solutions are obtained mainly by analyzing problem statements (Table 1).

#### 3.1.2. Stage 2: Problem resolution

Contradiction analysis and elimination are the two main activities followed in this stage. But, correctly identifying the contradiction relies on the user's capabilities and knowledge (Montecchi and Russo, 2015). Contradiction analysis uses 39-Technical parameters of TRIZ (Table 2). It identifies a few fundamental contradictions causing many other problems within the system (Table 3). On the other hand, elimination enhanced by using the 40-Principals of TRIZ (Table 4) usually lead to the resolution of the problems stated in the previous stage. After formulating the contradictions, elimination applies to the contradiction matrix (Table 5).

It consists of 39-Technical parameters as contradiction problems placed in columns and rows as worsening and improving features, with the 40-Principles proposed as solutions at cross-sections of each contradiction (Kiraz et al., 2020). Dave (2017) investigated which of the 40-Principles is more important and significant according to the frequency of appearance in the contradiction

matrix and found that only 20 principles can address more than 75% of the contradiction. The analysis result of problem statements constitutes the shortlist of the TRIZ contradiction matrix (Table 6).

**Table 1: Problem statements and result analyses**

Serial number	Problem statements and indications for possible solutions
1	Find a way to avoid HF1 required to obtain UF1
2	Find a way to reduce/eliminate HF2 caused by HF1 and UF1 influencing UF2
3	Find a way to reduce HF3 caused by UF2-1 influencing UF2
4	Find a way to reduce/avoid HF4 caused by UF2-2 influencing UF2
5	Find a way to reduce HF5 caused by UF2-3 influencing UF2
6	Find a way to reduce HF6 caused by UF2-4 influencing UF2
7	Find a way to reduce HF7 caused by UF2-5 influencing UF2
8	Find a way to enhance the effectiveness of UF2-1 to UF2-5 required to obtain UF2

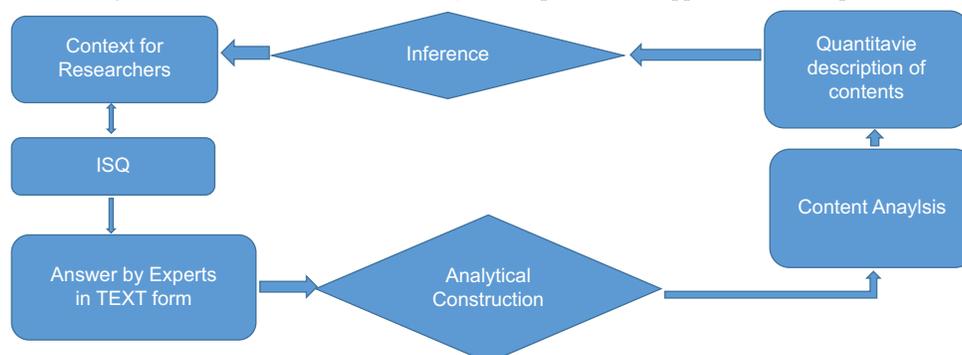
The highest frequency appearances of the most probable inventive principles (Mansoor et al., 2013) are shown in Figure 4. The authors suggest that the shortlist includes the most probable candidates to enhance sustainable biomass production. The 40-Principles of TRIZ include suggestions adopted over the years for acting to overcome contradictions. However, implementing the principles individually or in combination, or the concepts within the suggested principles, remains the researcher’s work (Technical Innovation Center (TIC), Inc., 2022).

Table 7 shows the implementations of suggestions for the top ten principals. They are only illustrative and based on the authors’ experiences (The TRIZ Journal, 1997; Retseptor, 2003; Chai et al., 2005; Nikolić et al., 2016; Kiraz et al., 2020).

**Table 2: The 39-technical parameters of Theoria Resheneyva Isobretatelskehuh Zadach**

Serial number	Parameter	Serial number	Parameter	Serial number	Parameter
1	Weight of the moving object	14	Strength	27	Reliability
2	Weight of the stationary object	15	Duration of action of the moving object	28	Measurement accuracy
3	Length of the moving object	16	Duration of action by the stationary object	29	Manufacturing precision
4	Length of the stationary object	17	Temperature	30	Object-affected harmful factors
5	Area of the moving object	18	Illumination intensity	31	Object-generated harmful factors
6	Area of the stationary object	19	Use of energy by the moving object	32	Ease of manufacture
7	The volume of the moving object	20	Use of energy by the stationary object	33	Ease of operation
8	The volume of the stationary object	21	Power	34	Ease of repair
9	Speed	22	Loss of energy	35	Adaptability or versatility
10	Force (intensity)	23	Loss of substance	36	Device complexity
11	Stress or pressure	24	Loss of information	37	The difficulty of detecting and measuring
12	Shape	25	Loss of Time	38	Extent of automation
13	Stability of the object’s composition	26	Quantity of substance/the matter	39	Productivity

**Figure 2: Framework for content analysis (adopted from Krippendorff (2013, p. 38))**



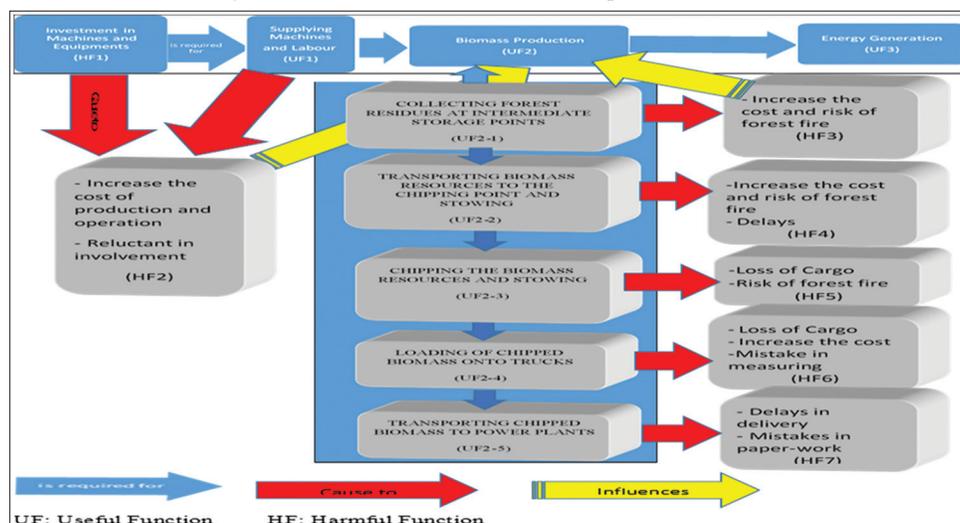
**Table 3: Contradictions of possible solutions to problem statements**

Serial number	Problem statements	Possible solution	39-technical parameters	
			Improving	Worsening
1	Find a way to avoid HF1 required to obtain UF1	Produce without or with less investment in machine/equipment	32	27, 29
2	Find a way to reduce/eliminate HF2 caused by HF1 and UF1 influencing UF2	Supply machine/personnel with low cost and high motivation	19, 31, 33, 34, 35, 36	26, 27
3	Find a way to reduce HF3 caused by UF2-1 influencing UF2	Collecting residues with lower cost and risk	33, 31	26, 27
4	Find a way to reduce/avoid HF4 caused by UF2-2 influencing UF2	Transport the residues to chipping points and stow them at a lower cost and risk	22, 23, 31, 33	26, 27
5	Find a way to reduce HF5 caused by UF2-3 influencing UF2	Chip the residues and stow them with no or less loss and low risk	23, 30,31,33	35, 36
6	Find a way to reduce HF6 caused by UF2-4 influencing UF2	Load chips onto trucks with less/no loss and lower cost	23, 31, 33, 37	35, 36
7	Find a way to reduce HF7 caused by UF2-5 influencing UF2	Deliver the chips to the final destination in time and in a more adequate way	23, 28, 33, 37	26, 31, 36
8	Find a way to enhance the effectiveness of UF2-1 to UF2-5 required to obtain UF2	Increase the efficiency and reduce adverse effects of obstacles during production of biomass	1, 7, 19, 23, 28, 31, 33, 34, 35, 37	30, 36

**Table 4: The 40-Principals of Theoria Resheneyva Isobretatelskehu Zadach**

Principal number	Name	Principal number	Name
1	Segmentation	21	Skipping
2	Taking out	22	“Blessing in disguise” or “Turn Lemons into Lemonade”
3	Local quality	23	Feedback
4	Asymmetry	24	“Intermediary”
5	Merging	25	Self-service
6	Universality	26	Copying
7	“Nested doll”	27	Cheap short-living objects
8	Anti-weight	28	Mechanics substitution
9	Preliminary anti-action	29	Pneumatics and hydraulics
10	Preliminary action	30	Flexible shells and thin films
11	Beforehand cushioning	31	Porous materials
12	Equipotentiality	32	Color changes
13	‘The other way round’	33	Homogeneity
14	Spheroidality-curvature	34	Discarding and recovering
15	Dynamics	35	Parameter changes
16	Partial or excessive actions	36	Phase transitions
17	Another dimension	37	Thermal expansion
18	Mechanical vibration	38	Strong oxidants
19	Periodic action	39	Inert atmosphere
20	Continuity of useful action	40	Composite materials

**Figure 2: Functional model of a biomass production at site**



**Table 5: Contradiction matrix of sustainable biomass production**

Serial number	Worsening Feature	Improving Feature	Quantity of substance (4)	Reliability (4)	Object-affected harmful factors (1)	Object-generated harmful factors (1)	Adaptability or versatility (2)	Device complexity (4)
			26	27	30	31	35	36
1	Weight of moving object (1*)		3, 26, 18, 31	1, 3, 11, 27	22, 21, 18, 27	22, 35, 31, 39	29, 5, 15, 8	26, 30, 36, 34
7	Volume of moving object (1)		29, 30, 7	14, 1, 40, 11	22, 21, 27, 35	17, 2, 40, 1	15, 29	26, 1
19	Use of energy by moving object (2)		34, 23, 16, 18	19, 21, 11, 27	1, 35, 6, 27	2, 35, 6	15, 17, 13, 16	2, 29, 27, 28
22	Loss of energy (1)		7, 18, 25	11, 10, 35	21, 22, 35, 2	21, 35, 2, 22		7, 23
23	Loss of substance (5)		6, 3, 10, 24	10, 29, 39, 35	33, 22, 30, 40	10, 1, 34, 29	15, 10, 2	35, 10, 28, 24
27	Reliability (1)		21, 28, 40, 3	+	27, 35, 2, 40	35, 2, 40, 26	13, 35, 8, 24	13, 35, 1
28	Measurement accuracy (2)		2, 6, 32	5, 11, 1, 23	28, 24, 22, 26	3, 33, 39, 10	13, 35, 2	27, 35, 10, 34
30	Object-affected harmful factors (1)		35, 33, 29, 31	27, 24, 2, 40	+	+	35, 11, 22, 31	22, 19, 29, 40
31	Object-generated harmful factors (6)		3, 24, 39, 1	24, 2, 40, 39				19, 1, 31
32	Ease of manufacture (1)		35, 23, 1, 24					27, 26, 1
33	Ease of operation (7)		12, 35	17, 27, 8, 40	24, 2		2, 13, 15	
34	Ease of repair (2)		2, 28, 10, 25	11, 10, 1, 16	2, 25, 28, 39		15, 34, 1, 16	32, 26, 12, 17
35	Adaptability or versatility (2)		3, 35, 15	35, 13, 8, 24	35, 10, 2, 16		7, 1, 4, 16	35, 1, 13, 11
36	Device complexity (1)		13, 3, 27, 10	13, 35, 1	22, 19, 29, 40		+	15, 29, 37, 28
37	The difficulty of detecting and measuring (3)		3, 27, 29, 18	27, 40, 28, 8	22, 19, 29, 28	19, 1	29, 15, 28, 37	+
						2, 21	1, 15	15, 10, 37, 28

\*Number of appearances of each 39-technical parameter

**Table 6: The list of top ten appearances of 40-principals**

Short List of 40-principals of TRIZ		
Serial number	Name	Frequency
35	Parameter changes	25
1	Segmentation	19
2	Taking out	18
27	Cheap short-living objects	14
10	Preliminary action	13
29	Pneumatics and hydraulics	13
15	Dynamics	11
28	Mechanics substitution	11
40	Composite materials	11
22	“Blessing in disguise” or “Turn Lemons into Lemonade”	10

TRIZ: Theoria Resheneyva Isobretatelskekh Zadach

**Table 7: Implementations of suggestion (s) for top ten principals**

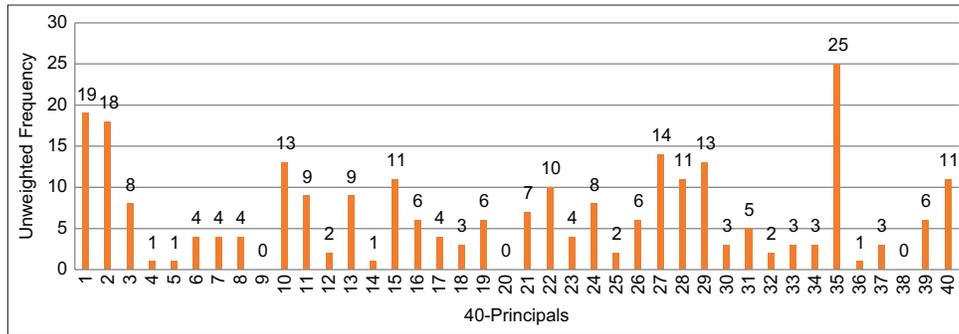
Serial number	Principles	Implementations of suggestion (s)
35	Transformation of properties	Provide a self-employment atmosphere to increase the willingness of the laborers Change the required machines into modular units to increase flexibility and ease the transport when needed
1	Segmentation	Divide machine supply and labor supply Design the work so that the machines are able to serve independently
2	Extraction	Supply labor locally from FVs and machines from the authorities Minimize the need for complex machines. Simplify the working units
27	Dispose	Use SBUs rather than a complex and expensive one Use big-bags to avoid the need for a bigger machine (loader, crane) to load chips
10	Prior action	Use FVs to avoid delays in reaching the operation area Keep the chipped biomass ready to transport at a convenient time by stowing them in big-bags
29	Pneumatic or hydraulic construction	Consider the social side of labor supply by involving FVs instead of considering the economical side only
15	Dynamicity	Use modular/mobile machines instead of stationary ones to increase mobility Use FVs as labor who are familiar with and closer to the operation area
28	Replacement of the mechanical system	Use equipped FVs to shorten the physical traveling of labor and machines
40	Composite materials	Use big-bags to stow chips
22	Convert harm into benefit	Use big-bags which will increase the overall cost of operation but will minimize forest fire risk and loss of cargo Combine stowing/loading of big-bags with stowing/loading of logs/wood

FVs: Forest villagers

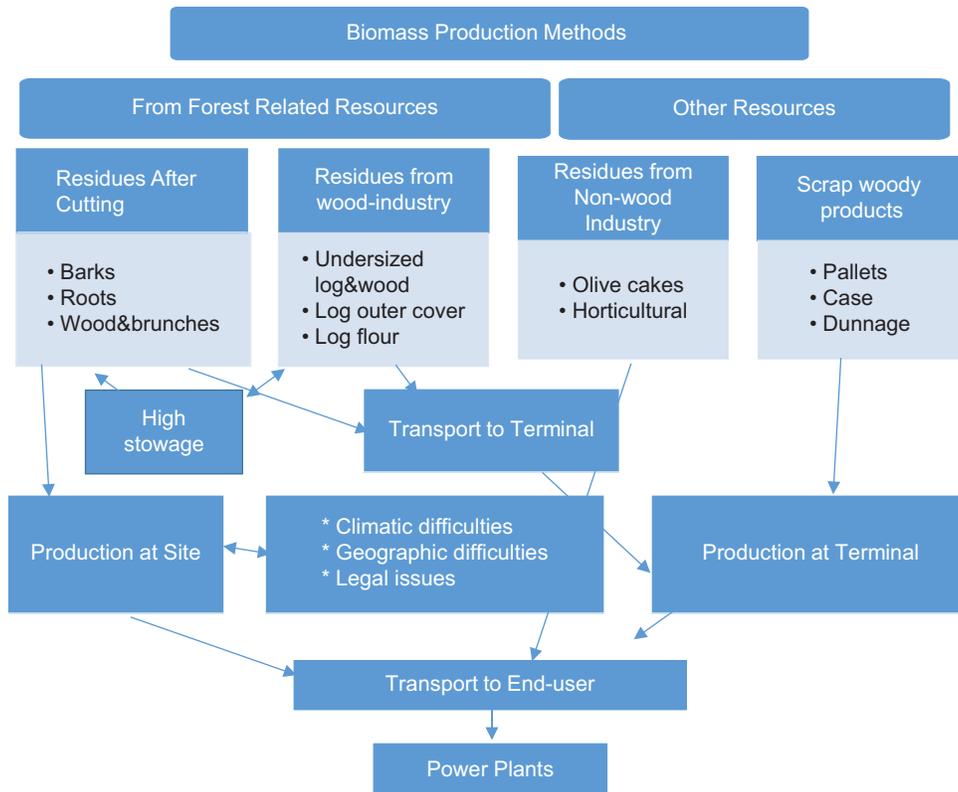
**3.1.3. Stage 3: Solutions evaluation**

This latest stage evaluates the implementations of suggestions constructed by TRIZ’s principals based on the law of ideality. It

**Figure 4:** Frequency of appearances of principals in shortlisted TRIZ contradiction matrix



**Figure 5:** Present biomass production/supply methods in Türkiye



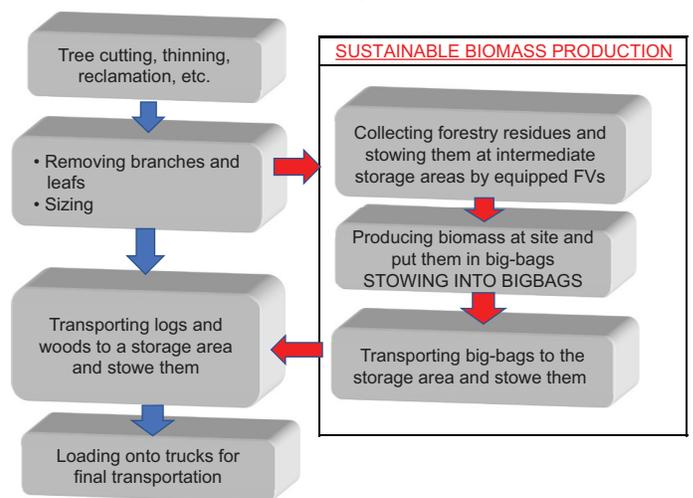
reflects maximum utilization as the system tends to become more reliable, simple, and effective through its lifetime and costs less, requires less space, and wastes less energy (Technical Innovation Center (TIC), Inc., 2022).

#### 4. RESULTS

Inferences obtained from the content analyses of each question are modeled in Figure 5. Content analyses show that biomass producers concentrate more on roots and undersized logs/woods rather than brunch/leaves as biomass resources due to their difficulties during production.

Content analyses also show that the crucial difficulties are operational and financial. Challenges of quantifying, pricing, and strict forestry rules are also other difficulties to consider. All experts agree that government should lower biomass resource prices and supports stakeholders in a better manner. The involvement of FVs seems

**Figure 6:** The new business model for sustainable biomass production from forestry residues



less productive in the present situation and more dependent on the location of villages and their machines and equipment ownership level. Hence, the ideal solution for sustainable biomass production, which enhances all desired benefits without any harm or injuring any cost to improve the traditional way of production, can be achieved by;

- Involvement of FVs in the self-employment structure
- Using SBUs
- Stowing the chipped biomass in big-bags
- Government intervention provides direct and indirect incentives, regulating and coordinating the operation at the site and the market price.

The above results construct a new business model, as below (Figure 6). SBU consists of two truck drivers and three workers to run two trucks (one of them is a trailer with a crane) and one chipper.

## 5. DISCUSSION

Despite obstacles in production, 64% of biomass energy uses forestry resources in Türkiye (Karayilmazlar et al., 2011). Therefore, it is paramount to ensure eco-friendly harvesting and removal of forestry residues to sustain social acceptance (Titus et al., 2021). Mustalahti (2018) focused on citizen participation in the bio-economy and commented that it has yet to get as much attention as it deserves within today's concept of efforts to mitigate climate change effects. Being close to cutting areas and strong interrelation with forest and forestry-related businesses make the FVs the most appropriate candidate as a stakeholder to involve in this process. As per Forestry Law 6831 in Türkiye (Official Gazette, 2022), FVs have privileges in obtaining low-cost wood and having employment priority in forestry-related jobs. Although transition in bio-economy creates new products and services, they will only be attractive with the authority's appropriate intervention, such as subsidies (Devaney and Henchion, 2018). Despite this fact, only a small portion of FVs believe the rights granted by the forestry law are sufficient (Alkan and Kilic, 2014). Moreover, due to the fact that the prices of primary products are higher than those of by-products (Sahibinden, 2022), producing main forestry products, logs, and wood, for example, has more intention than co-products, biomass, for example. Moreover, biomass produced from logging residues costs less when integrated into log harvesting due to cost sharing between timber harvest and biomass production (Wood Energy, 2019). Kwasniewski et al. (2021) studied the costs of biomass production from selected energy crops on ten farms in Poland's Małopolska region. They found that biomass production cost depends on the type of machines used. Employing SBUs provides not only operational easiness but also cost advantage (Table 8). But in any case, the investment and the operation cost of the machines need governmental intervention

**Table 8: Comparison of small and big business units**

Definition of unit	Weight	Size (m)	Price (€)	Output (m <sup>3</sup> /h)
Big chipper	22 ton	1.5×0.9×4.25	540,000	150
Small chipper	2 ton	3.35×1.29×1.68	30,000	5–10
Tractor	2 ton		35,000	-
Romork with crane	1 ton		50,000	-

both from finance and regulation aspects and to be coordinated appropriately to achieve the desired result.

The supplied biomass quantity mainly varies depending on the climate and geographical conditions, the desire for forest-related industry, and the allocated budget by the authority in forestry activities (Biyoenerji, 2014). But, although FVs have priority to collect those residues by law (Official Gazette, 2022), they are reluctant to involve in forestry-related business, primarily due to economic reasons (Atmis, 2022). However, the forestry residues remaining in the forest are considered a peril that is causing forest fires (P'erez et al., 2020) and the Department of Forestry should concentrate on disposing of them with an environmental approach and use them economically (Tolay, 2017). On the other hand, biomass power plants want to ensure a sufficient and uninterrupted supply of biomass resources as they need to be continuously operative throughout the year (Duc et al., 2021). Durmaz and Bilgen (2020), constructed a model in their research and assessed the impact of the distance between the facility and the source of biomass. In their optimal model, the results show that total profit increases at a 60 km distance. Therefore, considering the irregularity in the supply and demand and the cost of transport being only economical up from 60 km to 100 km (Biyoenerji, 2014), biomass resources may require storage either in chipped or unchipped form (Anerud et al., 2021). Covering can also avoid rewetting and increase the energy available within the biomass resource. Anerud et al. (2021) examined the effects of covering. They found that the accessible energy of piles covered with waterproof or light semi-permeable cover materials is higher than the uncovered piles. Therefore, putting the chipped biomass into big-bags can both covers the product and provides easy operation as suggested in this research. Despite the advantages, the covering materials have material and operation costs. Therefore, there is a need to discuss finding the most efficient way to mitigate the disadvantages of covering.

## 6. CONCLUSION

As per the traditional business model in Türkiye, forestry residues, mostly the roots of trees, are chipped at the terminal, whereas some recent attempts to chip the remaining/unused forest residues at the site/forest interlinked to the tree-cutting processes. The new business model requires employing an SBU approach to achieve the desired result of ideality in sustainable biomass production: reliable, low-cost, and socially accepted production with utmost care to protect the environment. Even though the chipped biomass market price as a by-product is well below the prices of timber and firewood as primary products, the involvement of FVs in self-employment structure within the new business model increases the motivation of the people involved due to the attractiveness of direct income. SBUs in the new business model not only ease the operation but also reduce overall operation and investment needs and lesser running costs. Putting the chipped biomass in big bags as a part of the new business model provides more efficient operation by reducing loss of product and easier handling on top of the advantage of avoiding forest fires. In summary, sustainable biomass production from forestry residue requires employing a new business model employing SBUs and the involvement of FVs in a self-employment structure with governmental support under GDF coordination as the regulating authority.

## REFERENCES

- Alkan, H., Kilic, M. (2014), Forests and forestry organizations from the forest villagers' perspective: A case study from Türkiye. *Biogeosciences and Forestry*, 7(4), 240-247.
- Alvarez, J.C., Hatakeyama, K., Carvalho, M., Marçal, R.C., Inche, J., Melo, N.D. (2022), A model for renewable energy-based product innovation based on TRIZ methodology, exergy analysis and knowledge management: Case study. *Energy Reports*, 8, 1107-1114.
- Anerud, E., Bergström, D., Routa, J., Eliasson, L. (2021), Fuel quality and dry matter losses of stored wood chips - Influence of cover material. *Biomass and Bioenergy*, 150, 106-109.
- Ang, M.C., Ahmad, S.A., Ng, K.W., Wahab, A. (2015), Reducing home energy usage based on TRIZ concept. *Advances in Environmental Biology*, 9(1), 6-11.
- Atmis, E. (2020), Orman köyleriyle orman mahalleleri arasındaki sosyo-ekonomik farklılaşmanın yarattığı fırsatlar. *Journal of Bartın Faculty of Forestry*, 22(3), 1004-1013.
- Barbour, R. (2008), *Introducing Qualitative Research: A Student's Guide to the Craft of Doing Qualitative Research*. Ohio: Sage. Available from: <https://methods.sagepub.com/book/introducing-qualitative-research-2e/i288.xml> [Last accessed on 2022 May 01].
- Bebbington, J., Schneider, T., Stevenson, L., Fox, A. (2020), Fossil fuel reserves and resources reporting and unburnable carbon: Investigating conflicting accounts. *Critical Perspectives on Accounting*, 66, 102083.
- BEPA. (2022), *Türkiye Potansiyel Biomass Energy Atlas*. D. G. Affairs. Ankara, Türkiye. Available from: <https://bepa.enerji.gov.tr> [Last accessed on 2022 Nov 30].
- Biyoenjerji. (2014), *Biyokütle Potansiyeli Olarak Orman Atıkları*. İstanbul, Türkiye. Available from: <https://biyoder.org.tr/biyoenjerji/biyokutle/orman-atiklari> [Last accessed on 2022 Apr 13].
- Bocken, N.M., Short, S.W. (2021), Unsustainable business models- Recognising and resolving institutionalised social and environmental harm. *Journal of Cleaner Production*, 312, 127828.
- Bocken, N., Weissbrod, I., Antikainen, M. (2021), Business experimentation for sustainability: Emerging perspectives. *Journal of Cleaner Production*, 281, 124904.
- BP. (2021), *Statistical Review of World Energy 2021*. 70<sup>th</sup> ed. London: BP. Available from: <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf> [Last accessed on 2021 Nov 26].
- Brad, S., Mocan, B., Brad, E., Fulea, M. (2015), Leading innovation to improve complex process performances by systematic problem analysis with TRIZ. *World Conference: Triz Future*, 131, 1121-1129.
- Brown, B., Spiegel, S.J. (2017), Resisting coal: Hydrocarbon politics and assemblages of protest in the UK and Indonesia. *Geoforum*, 85, 101-111.
- Caineng, Z., Feng, M., Songqi, P., Minjie, L., Guosheng, Z., Bo, X., Zhi, Y. (2022), Earth energy evolution, human development and carbon neutral strategy. *Petroleum Exploration and Development*, 49(2), 468-488.
- Chai, K.H., Zhang, J., Tan, K.C. (2005), A TRIZ-based method for new service design. *Journal of Service Research*, 8(1), 48-66.
- Chalupa, S., Petricek, M., Ulrych, Z. (2021), The use of business process management in hotel direct sales improvement. *TEM Journal*, 10(1), 215-220.
- Chen, Z., Agapious, A., Li, H., Xu, Q. (2021), A TRIZ approach to reliable megaproject sustainability. *Froniers in Built Environment*, 7, 650699.
- Daniilidis, C., Eben, K., Lindemann, U. (2011), A functional analysis approach for product reengineering. *Procedia Engineering*, 9, 270-280.
- Dave, H.P. (2017), *TRIZ: 40 Principles and their Ranking by Contradiction Matrix*. 2017 2<sup>nd</sup> International Conference for Convergence in Technology (I2CT) Mumbai, India: IEEE. p1258-1261.
- Devaney, L., Henchion, M. (2018), Consensus, caveats and conditions: International learnings for bioeconomy development. *Journal of Cleaner Production*, 174, 1400-1411.
- Donner, M., Verniquet, A., Broeze, J., Kayser, K., Vries, H.D. (2021), Critical success and risk factors for circular business models valorising agricultural waste and by-products. *Resources, Conservation and Recycling*, 165, 105236.
- Droste, N., Hansjurgens, B., Kuikman, P., Otter, N., Antikainen, R., Leskinen, P., Thomsen, M. (2016), Steering innovations towards a green economy: Understanding government intervention. *Journal of Cleaner Production*, 135, 426-434.
- Duc, D.N., Meejaroen, P., Nananukul, N. (2021), Multi-objective models for biomass supply chain planning with economic and carbon footprint consideration. *Energy Report*, 7, 6833-6843.
- Durmaz, Y.G., Bilgen, B. (2020), Multi-objective optimization of sustainable biomass supply chain network design. *Applied Energy*, 272, 115259.
- Ekmekci, I., Nebati, E.E. (2019), *Triz Methodology and Applications*. *Procedia Computer Science*, 158, 303-315.
- EPDK. (2022), *YEKDEM. Elektrik Piyasası YEKDEM Listesi*. Available from: <https://www.epdk.gov.tr/Detay/Icerik/3-0-72/elektrikyekdem> [Last accessed on 2022 Dec 17].
- Erlingsson, C., Brysiewicz, P. (2017), A hands-on guide to doing content analysis. *African Journal of Emergency Medicine*, 7, 93-99.
- Fawzy, M.F., Olson, E.W. (2018), *Total Quality Management & Apple Success*. In: *The American Society for Engineering Management 2018 International Annual*. Coeur d'Alene, Idaho: ResearchGate. p1-7.
- Featis, A., Abdella, G.M., Al-khalifa, K.N., Hamouda, A.M. (2022), Modeling the relationship between business process reengineering and organizational culture. *Applied System Innovation*, 5(4), 5040066.
- Fobbe, L., Hilletoft, P. (2021), The role of stakeholder interaction in sustainable business models. A systematic literature review. *Journal of Cleaner Production*, 327, 129510.
- Galik, J., Kohar, R., Brumercik, F., Hudec, J., Patin, B. (2021), Increasing the safety of a device using the TRIZ Methodology. *Scientific Journal of Silesian University of Technology. Series Transport*, 111, 43-56.
- Galletta, A. (2013), *Mastering the Semi-Structured Interview and Beyond*. New York: New York University Press. Available from: <https://books.google.com.tr> [Last accessed on 2022 May 01].
- General Directorate of Forestry (GDF). (2021), *Turkish Forest Assets - 2020. Türkiye'de Ormanlık Alan*. Ankara: General Directorate of Forestry (GDF). Available from: <https://www.ogm.gov.tr/tr/ormanlarimiz>
- Ghosh, S.K. (2016), Biomass & bio-waste supply chain sustainability for bio-energy and bio-fuel production. *Procedia Environmental Sciences*, 31, 31-39.
- Guarino, G., Samet, A., Cavallucci, D. (2022), PaTRIZ: A framework for mining TRIZ contradictions in patents. *Expert Systems With Applications*, 207, 117942.
- Harding, J. (2019), *Qualitative Data Analysis from Start to Finish*. 2<sup>nd</sup> ed. London: Sage. Available from: <https://books.google.com.tr> [Last accessed on 2022 Apr 30].
- Hopkins, A., Narayan, S., Raworth, K., Rowlands, J., Sweetman, C. (2019), *Conducting Semi-Structured Interview*. Oxford, UK: Oxfam GB. Available from: <https://www.oxfam.org.uk/policyandpractice> [Last accessed on 2022 May 01].
- Hsieh, H.F., Shannon, S.E. (2005), Three approaches to qualitative content analysis. *Qualitative Health Research*, 15(9), 1277-1288.
- Jabbour, C.J., Seuring, S., Jabbour, A.B., Jugend, D., Fiorini, P.D., Latan, H., Izeppi, W.C. (2020), Stakeholders, innovative business models for the circular economy and sustainable performance of firms in an emerging economy facing institutional voids. *Journal of Environmental Management*, 264, 110416.
- Jankowski, R. (2020), Viruses and viral epidemics in the metabolic theory of evolution. *European Annals of Otorhinolaryngology, Head and*

- Neck Diseases, 137(4), 297-301.
- Judi, M.H., Beach, R. (2010), Achieving manufacturing flexibility: The role of people, technology, innovation and continuous improvement. *International Journal of Innovation and Technology Management*, 7(2), 161-181.
- Karayilmazlar, S., Saracoglu, N., Cabuk, Y., Kurt, R. (2011), Utilizations of biomass as an energy source in Türkiye. *Bartın Orman Fakültesi Dergisi*, 13(19), 63-75.
- Kiraz, C., Basak, H., Neslihan Top, I.S. (2020), Design of a new lighting unit using TRIZ approach. *Gazi University Journal of Science, Part C*, 8(1), 109-120.
- Knoth, K., Fufa, S.M., Seilskjaer, E. (2022), Barriers, success factors, and perspectives for the reuse of construction products in Norway. *Journal of Cleaner Production*, 337, 130494.
- Kotagodahetti, R., Hewage, K., Karunathilake, H., Sadiq, R. (2021), Evaluating carbon capturing strategies for emissions reduction in community energy systems: A life cycle thinking approach. *Energy*, 232, 121012.
- Kou, G., Yuksel, S., Dincer, H. (2022), Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy*, 311, 118680.
- Krippendorff, K. (2013), *Content Analyses: An introduction to Its Methodology*. 4<sup>th</sup> ed. London: Sage Publications. Available from: <https://books.google.com.tr> [Last accessed on 2022 Apr 28].
- Kunkel, S., Matthess, M., Xue, B., Beier, G. (2022), Industry 4.0 in sustainable supply chain collaboration: Insights from an interview study with international buying firms and Chinese suppliers in the electronics industry. *Resources, Conservation and Recycling*, 182, 106274.
- Kwasniewski, D., Plonka, A., Mickiewicz, P. (2021), Harvesting technologies and costs of biomass production from energy crops cultivated on farms in the Małopolska region. *Energies*, 15(1), 131.
- Li, Y.X., Wu, Z.X., Dinçer, H., Kalkavan, H., Yüksel, S. (2021), Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval Type-2 fuzzy modeling. *Energy Reports*, 7, 95-108.
- Maia, L.C., Alves, A.C., Leão, C.P. (2015), How could the TRIZ tool help continuous improvement efforts of the companies? *Procedia Engineering*, 131, 343-351.
- Mansoor, M., Mariun, N., Ismail, N., Wahab, N.I. (2013), A guidance chart for most probable solution directions in sustainable energy developments. *Renewable and Sustainable Energy Reviews*, 24, 306-313.
- Meng, Y., Dincer, H., Yuksel, S. (2021), TRIZ-based green energy project evaluation using innovation life cycle and fuzzy modeling. *IEEE Access*, 9, 69609-69625.
- Montecchi, T., Russo, D. (2015), Knowledge based approach for formulating TRIZ contradictions. *Procedia Engineering*, 131, 451-463.
- Munje, S., Kulkarni, S., Vedant Vatsal, A.A., Pankade, S. (2023), A Study on Product Development using the TRIZ and Additive Manufacturing. In: *Materials Today: Proceedings*.
- Mustalahti, I. (2018), The responsive bioeconomy: The need for inclusion of citizens and environmental capability in the forest based bioeconomy. *Journal of Cleaner Production*, 172, 3781-3790.
- Nikolić, V., Sajjadi, S., Petković, D., Shamshirband, S., Čojbašić, Ž., Por, L.Y. (2016), Design and state of art of innovative wind turbine systems. *Renewable and Sustainable Energy Reviews*, 61, 258-265.
- Official Gazette. (2022), Forestry Law. Law No: 6831. Ankara, Türkiye. Available from: <https://www.mevzuat.gov.tr/MevzuatMetin/1.3.6831.pdf> [Last accessed on 2022 Apr 8].
- Ozdil, N.F.T., Caliskan, M. (2022), Energy potential from biomass from agricultural crops: Development prospects of the Turkish bioeconomy. *Energy*, 249, 123770.
- Pérez, S., Renedo, C., Ortiz, A., Ortiz, F. (2020), Residual biomass in Eucalyptus globulus plantations according to stand quality. *Biomass and Bioenergy*, 141, 105699.
- PwC Türkiye. (2021). *Biyokütle ve Biyoenerji Sektörlerine Genel Bakış*. Istanbul: PwC. Available from: <https://www.pwc.com.tr/tr/sectorler/enerji/biyokutle-ve-biyoenerji-sektorlerine-genel-bakis-web.pdf> [Last accessed on 2022 Apr 13].
- Republic of Türkiye Ministry of Energy and Natural Resources. (2022), *Energy. Biomass*. Ankara, Türkiye. Available from: <https://enerji.gov.tr/bilgi-merkezi-enerji-biyokutle> [Last accessed on 2022 Nov 30].
- Retseptor, G. (2003), *40 Inventive Principles in Quality Management*. Available from: <https://www.metodolog.ru/triz-journal/archives/2003/03/a/01.pdf> [Last accessed on 2022 May 11].
- Sahibinden, (2022), *Forestry Products*. Türkiye. Available from: <https://www.sahibinden.com/orman-urunleri>
- Saldana, J. (2013), *The Coding Manual for Qualitative Researchers*. London: Sage. Available from: <https://books.google.com.tr> [Last accessed on 2022 Apr 30].
- Saracoglu, N. (2010), The biomass potential of türkiye for energy production: Part I. *Eenergy Sources*, Part B: Economics, Planning and Policy, 5(3), 272-278.
- Schilling, J. (2006), On the pragmatics of qualitative assessment. *European Journal of Psychological Assessment*, 22(1), 28-37.
- Sheu, D.D., Chiu, M.C., Cayard, D. (2020), The 7 pillars of TRIZ philosophies. *Computers and Industrial Engineering*, 146, 106572.
- Silverman, D. (2010), *Doing Qualitative Research- A Practical Handbook*. London: Sage. Available from: <https://books.google.com.tr> [Last accessed on 2022 Apr 30].
- Sojka, V., Lepšik, P. (2020), Use of TRIZ, and TRIZ with other tools for process improvement: A literature review. *Emerging Science Journal*, 4(5), 319-335.
- Spreafico, C. (2021), Quantifying the advantages of TRIZ in sustainability through life cycle assessment. *Journal of Cleaner Production*, 303, 126955.
- Spreafico, C. (2022), Can TRIZ (Theory of Inventive Problem Solving) strategies improve material substitution in eco-design? *Sustainable Production and Consumption*, 30, 889-915.
- Svartvatten, N., Segerlund, M., Denhag, I., Andersson, G., Carlbring, P. (2015), A content analysis of client e-mails in guided internet-based cognitive behavior therapy for depression. *Internet Interventions*, 2, 121-127.
- Technical Innovation Center(TIC), Inc. (2022), *Levels of Innovation. TRIZ*. USA. Available from: <https://triz.org/levels> [Last accessed on 2022 May 27].
- Teece, D.J. (2010), Business models, business strategy and innovation. *Long Range Planning*, 43, 172-194.
- Terninko, J., Zusman, A., Zlotin, B. (1998), *Systematic Innovation: An Introduction to TRIZ*. Boca Raton, Florida: St. Lucie Press. Available from: <https://books.google.com.tr> [Last accessed on 2022 Apr 26].
- The TRIZ Journal. (1997), *Contradictions: Air Bag Applications*. USA: The TRIZ Journal. Available from: <http://www.xtriz.com/publications/40Principles.pdf> [Last accessed on 2022 May 30].
- Titus, B.D., Brown, K., Helmisaari, H.S., Vanguelova, E., Stupak, I., Evans, A. (2021), Sustainable forest biomass: A review of current residue harvesting guidelines. *Energy, Sustainability and Society*, 11, 10.
- Tolay, M. (2017), *Steam Power Plants in Türkiye*. Ankara: The Union of Chamber of Turkish Engineers and Architects. Available from: <https://www.mmo.org.tr/sites/default/files> [Last accessed on 2022 Apr 18].
- Tura, N., Hanski, J., Ahola, T., Stahle, M., Piiparinen, S., Valkokari, P. (2019), Unlocking circular business: A framework of barriers and drivers. *Journal of Cleaner Production*, 212, 90-98.
- Ucal, M., Xydis, G. (2020), Multidirectional relationship between energy resources, climate changes and sustainable development: Technoeconomic analysis. *Sustainable Cities and Society*, 60, 102210.

- Wang, C., Fang, Y., Zhang, C. (2022), Mechanism and countermeasures of “The Innovator’s Dilemma” in business model. *Journal of Innovation and Knowledge*, 7(2), 100169.
- Wood Energy. (2019), The Economics of Forest Biomass Production and Use. *Wood Energy*. Available from: <https://wood-energy.extension.org/the-economics-of-forest-biomass-production-and-use> [Last accessed on 2022 Sep 29].
- Yue, H., Worrell, E., Crijns-Graus, W., Zhang, S. (2021), The potential of industrial electricity savings to reduce air pollution from coal-fired power generation in China. *Journal of Cleaner Production*, 301, 126978.
- Ziolo, M., Bak, I., Cheba, K., Spoz, A. (2020), Sustainable business models of enterprises - actual and declared activities for ensuring corporate sustainability. *Procedia Computer Science*, 176, 1497-1506.