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**Article**

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# 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 m³ 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 m³. 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 (Teece, 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 Hilletofth, 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 Lepšík, 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).

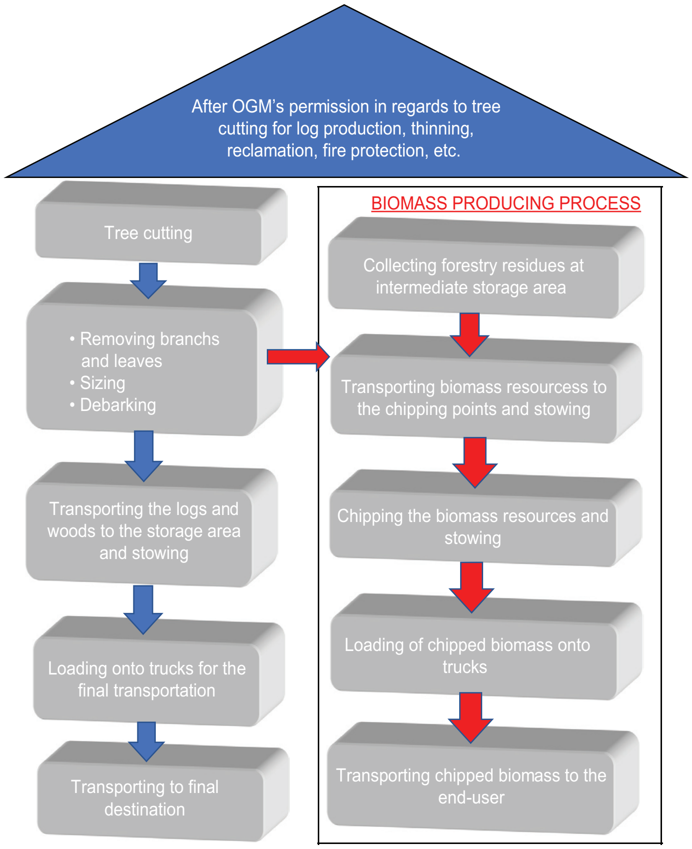
As per observations of the authors, in the traditional business model in Türkiye, the forestry residues, primarily roots, are chipped at the terminal, whereas some recent attempts to chip the remaining/unused forestry residues at the site where it is to reduce the size/stowage factor of the residues 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) (Biyoenerji, 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)

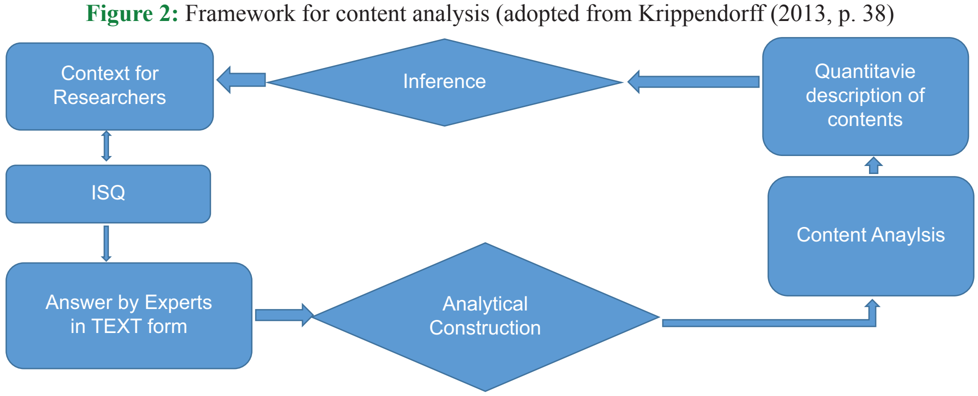


**Table 3: Contradictions of possible solutions to problem statements**

| 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 Isobretatelskehuh 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

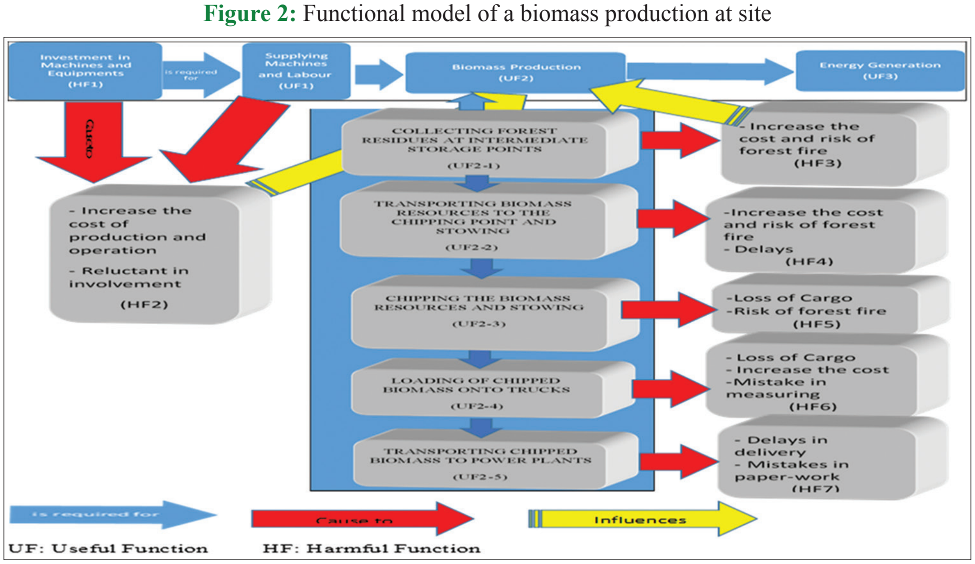


**Table 5: Contradiction matrix of sustainable biomass production**

| Serial number | Worsening Feature → / Improving Feature ↓ | Quantity of substance (4) 26 | Reliability (4) 27 | Object-affected harmful factors (1) 30 | Object-generated harmful factors (1) 31 | Adaptability or versatility (2) 35 | Device complexity (4) 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 | | 24, 2 | | 2, 13, 15 | 27, 26, 1 |
| 33 | Ease of operation (7) | 12, 35 | 17, 27, 8, 40 | 2, 25, 28, 39 | | 15, 34, 1, 16 | 32, 26, 12, 17 |
| 34 | Ease of repair (2) | 2, 28, 10, 25 | 11, 10, 1, 16 | 35, 10, 2, 16 | | 7, 1, 4, 16 | 35, 1, 13, 11 |
| 35 | Adaptability or versatility (2) | 3, 35, 15 | 35, 13, 8, 24 | 35, 11, 32, 31 | | + | 15, 29, 37, 28 |
| 36 | Device complexity (1) | 13, 3, 27, 10 | 13, 35, 1 | 22, 19, 29, 40 | 19, 1 | 29, 15, 28, 37 | + |
| 37 | The difficulty of detecting and measuring (3) | 3, 27, 29, 18 | 27, 40, 28, 8 | 22, 19, 29, 28 | 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 Isobretatelskehuh 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<br>Change the required machines into modular units to increase flexibility and ease the transport when needed |
| 1 | Segmentation | Divide machine supply and labor supply<br>Design the work so that the machines are able to serve independently |
| 2 | Extraction | Supply labor locally from FVs and machines from the authorities<br>Minimize the need for complex machines. Simplify the working units |
| 27 | Dispose | Use SBUs rather than a complex and expensive one<br>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<br>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<br>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<br>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

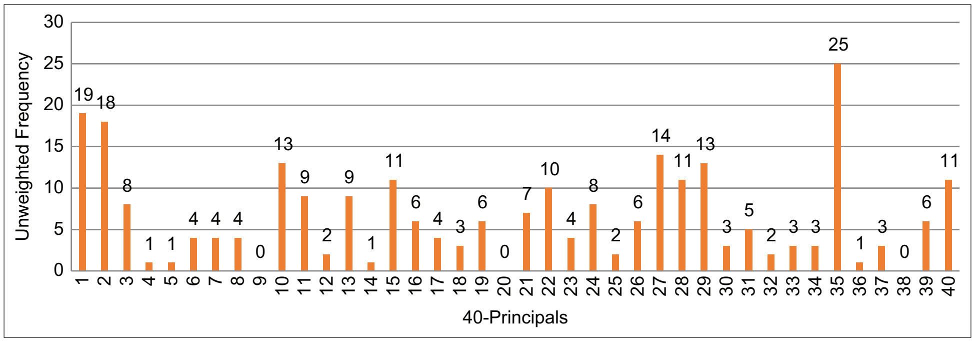
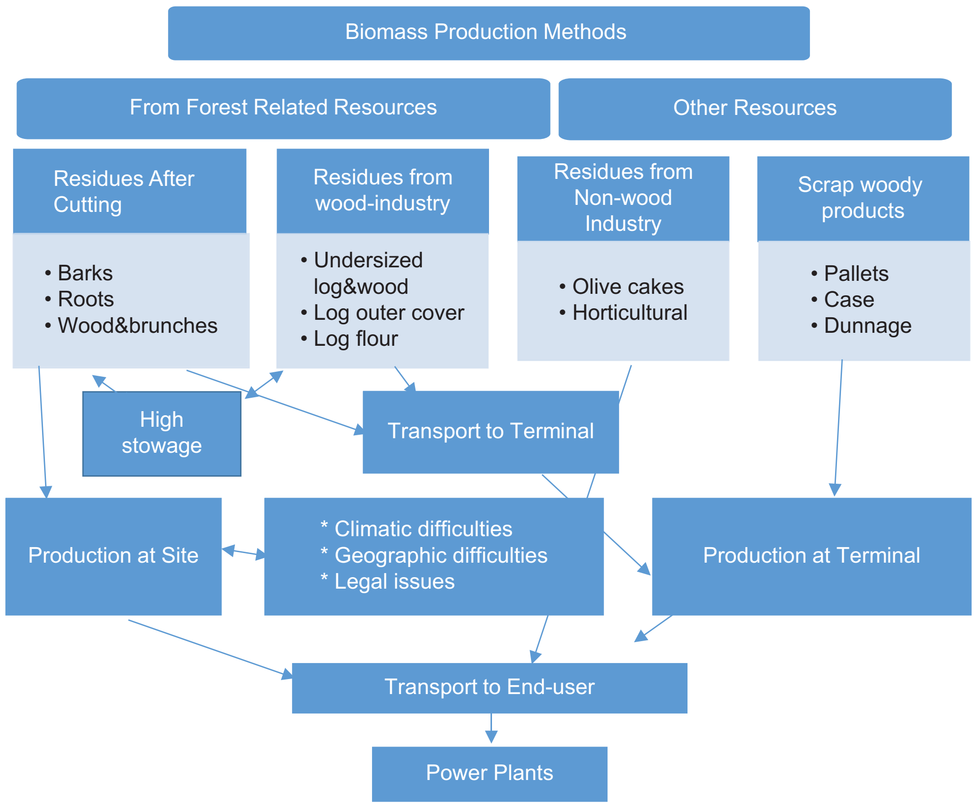



**Figure 5:** Present biomass production/supply methods in Türkiye



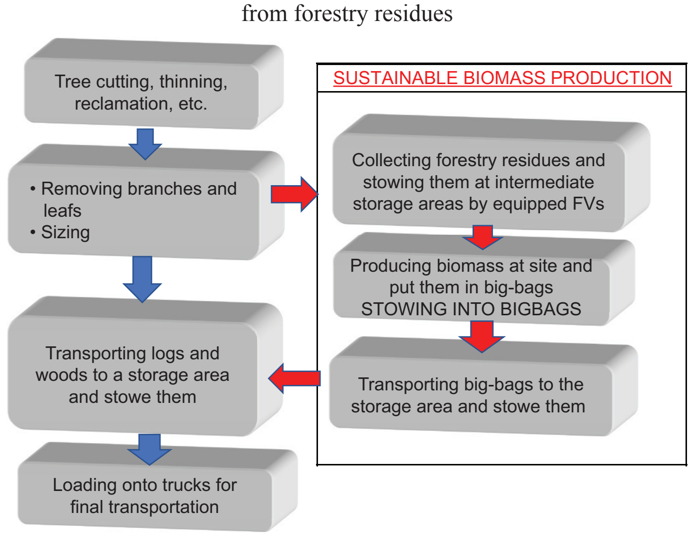

reflects maximum utilization as the system tends to become more reliable, simple, and effective through its lifetime and costs less, requires less space, and wastes less energy (Technical Innovation Center (TIC), Inc., 2022).

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

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

| Definition of unit | Weight | Size (m) | Price (€) | Output ($m^3$/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 | - |

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.

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